Helen Abbott Michael

STUDIES IN
PLANT AND ORGANIC CHEMISTRY
AND
LITERARY PAPERS

BY

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(HELEN C. DE S. ABBOTT)

WITH
BIOGRAPHICAL SKETCH

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THE arc of Helen Abbott Michael's life swept through several fields of human activity, in each of which she showed remarkable ability and achieved unusual success. Versatility, however brilliant, is often a dangerous gift, leading to a scattering of energies and to practical failure; but she had great power of concentration, and realized, as few have, the necessity of systematic application. She was not led by her manifold talents into desultory or spasmodic expenditure of energy, but having deliberately chosen a path which seemed to offer her opportunities of usefulness, she was not content to abandon it until she had followed it to a profitable ending. Nor, even after she had proceeded to another department of work, did she lose her interest in that from which she had passed. She assimilated all that was best in every branch of knowledge that she took up, and her symmetrically developed character proved that her attainments were not made for selfish ends. Her altruism was ever apparent.

Certain marked qualities of hers deserve commemoration. Lovely in person, graceful in figure, she preserved a charming simplicity and modesty. She was wholly lacking in self-consciousness. Her association with men of science and her own keen zest in subjects of scientific import gave to her conversation a note of deep seriousness; but she had a natural play of wit, and she was quick to see the ludicrous aspect of any question. Broad and liberal in her ideas, she displayed a genuine sympathy with all phases of thought, scientific and religious. She had made a special study of the plastic arts, and her diaries are full of brief and always pointed criticisms and appreciations of the paintings, sculptures, and beautiful buildings that she studied, even while making her specialty of chemical or medical investigations.

Through her zeal for study she met with an accident which affected her health for many years, but this unfortunate depletion of physical power never stood in the way of her ambition; she fought against suffering with Spartan heroism.

Another of the great lessons of her life emphasizes the value of thoroughness. She was not satisfied to be a smatterer. After she had won an enviable reputation as an original investigator in plant chemistry, she made a pilgrimage to Europe, with a view of perfecting herself in the use of methods and appliances; and she records with sweet humility her consciousness of what she lacks in training, — with humility, but with no sense of discouragement, rather with quickened zeal and enthusiasm. Even at that time it could have been said of her, as was said later of what she had already accomplished, "Her studies in tracing the relations existing between chemical composition and botanical species are of the highest interest from the view-point of research."

Women have ever been leaders in great popular movements. History is studded with the names of queens. Mythology, which is in a sense crystallized history, gives equal honor to goddesses and gods. It seemed to the Greeks perfectly in accordance with the order of Nature that a whole tribe of women should have had a comity and state by themselves, with Hippolita their mistress. Sappho held rank with the greatest poets of antiquity. Yet in modern days, when the tendency of the Church, based on a chance remark or possibly a set principle of Saint Paul, has been to condemn women to silence and to subordination, the occasional woman who has had the genius and the courage to break a path for her sex into the more active life of the world, has compelled recognition.

Such a woman was Helen Abbott Michael. She did in chemistry what Maria Mitchell did in astronomy, and others before and since have done in other branches. It seems almost incredible that within so short a time she accomplished so much. Woman has in the last decade made such tremendous strides in all professions that it sounds strange to state that she was a pioneer. Only twenty years ago she made her first investigations, and it is perfectly true that, in the words of Dr. H. W.

Wiley of the United States Department of Agriculture, her "papers on plant analysis were not only valuable when they were written, but will continue to be so for an indefinite time."

She had something worth saying in regard to art and literature as well as science. Toward the end of her life she found herself drawn to express her deeper feelings in verse, and there is little doubt that if she had been spared she would have contributed valuable thoughts in this beautiful medium. Her numerous friends and all who are interested in the work accomplished by so daring and fertile a mind, all who admire the splendid progress that women have made of recent years in emancipating themselves from the shackles of conservatism, all who are devoted to science, whether in its stricter analyses or in its popular presentations of great facts, will be glad to possess in valid and tangible form the outcome of Dr. Michael's scientific and literary labors. They are a veritable contribution to the growing collection of books that glorify the age.

It is a privilege to be allowed to introduce the volume with a brief sketch of its author's career, and to add a few words of appreciation of her lovely nature, her admirable character, her astonishing ability, and her epoch-making work, as well as to express the universal regret that her career was so prematurely cut off, when she seemed to be entering upon a new phase that promised to be of great benefit to her fellow-men. She was a rare and radiant spirit, no less womanly that she chose to vie with men in an active and laborious occupation.

Helen Cecilia De Silver Abbott, youngest child of James Abbott and Caroline Montelius, was born in Philadelphia, December 23, 1857. After a careful home education under governesses and private teachers, who without exception were delighted with her affectionate and studious disposition and her extraordinary quickness of mind, she was inclined to make a specialty of music, a genius for which she early manifested.

She had excellent training. Among her instructors was Miss Mary F. Howell, a talented pianist, a musician of the highest ability, and a remarkable personality. Her father's house became the centre of a musical circle, and solo and ensemble playing used to delight such audiences as were favored with its entrée. In her renderings of the works of the great masters, she was notable for her union of strength and delicacy of touch with sympathetic appreciation. She read at sight with extraordinary fluency and correctness. She speedily secured a reputation as being one of the ablest amateur pianists of her native city.

This reputation she carried abroad with her in 1878, and at the concert given at Ventnor in the Isle of Wight in aid of the "Distress Fund," — after the training-ship *Eurydice*, on its way home from Bermuda, foundered off Dunnose Headland with a loss of three hundred lives, — she played three selections, and was characterized by a local newspaper as "a performer of great finish and artistic appreciation of her subject." Another newspaper said her performance "was marvelously clever and testified to a most thorough acquaintance with the pianoforte."

She spent that winter in Paris, and how well she improved her opportunities and what an impression she made are well shown by a recent letter from M. Alphonse Duvernoy of the Conservatoire. He says: —

"She had a superior mind open to everything. Her eagerness for instruction recognized no obstacles, and under a frail exterior she concealed an energy and will power of which many men might have been envious. In a word, by her nature she was one of the elect, and I was happy to appreciate her at her real value. . . . She worked under my direction from July, 1878, until the end of April, 1879. Remarkably gifted for music, she made very rapid progress, and her execution was sufficiently advanced to allow her to grapple with the works of the great masters, for whom she felt a passionate admiration. In May, 1879, she returned to America, and was back in Paris in 1880. At this time she devoted herself to chamber music, into which she was initiated by two eminent artists — MM. Armingaud the violinist and Jacquard the violoncellist. In 1881 she ceased to work with these gentlemen, whom she entirely won by the quickness of her intelligence and by her musical feeling."

Madame Arabella Goddard, the eminent pianist, who made her last public appearances in connection with Sir Arthur

Sullivan's concerts at the Paris Exposition of 1878, had advised her to take up music professionally and had offered to be sponsor for her success on the stage; but even at this time wider and more satisfying vistas were opening before her eager ambition. She was beginning to think for herself on many matters of philosophy and religion. Perhaps the turning-point of her career was reached when, in company with a pleasant party of relatives and friends, she visited Spain. A glimpse of her in this enjoyable tour is afforded by the late George Parsons Lathrop's "Spanish Vistas," in which she is frequently mentioned under the appellation of "The Novice."

She returned to Philadelphia in 1881, and with characteristic thoroughness attended a course of musical composition with Professor Hugh A. Clarke of the University of Pennsylvania. Her interest in music never waned; many years afterwards she took a course of lessons in singing, and entered into the subject with much enthusiasm. She was also in the habit of going with a Boston friend to the Burrage Rooms, where through the generous provisions of a music-loving young lady who died at an early age, opportunity is provided for practice with two or more pianos and the use of a valuable library of pianoforte compositions.

An intimate friend of hers, writing of her abandonment of music as a specialty, comments on the power that she possessed "of taking up almost any study and carrying it forward to completion; as soon as this point was reached," says this friend, "her agile mind turned to another theme, with the same result."

The impulse that led her to put the practice of music behind her, and to enter into a far more laborious occupation, is clearly explained in a fragment of autobiography which she began in February, 1900. This writing also throws some light upon her mental development, and is so interesting one could wish that it had been more inclusive, that she had deemed it worth while to relate her experiences during the time when she was devoting herself to music and meeting many of the eminent virtuosi with whom she was privileged to associate, and also that she had brought it down to the attainment of her medical degree. But even as a fragment it is worthy of insertion in this place. A few verbal changes, never in any way affecting the sense, have been made here and there. Also a few paragraphs have been omitted. She entitled it: —

A BRIEF OUTLINE OF TEN YEARS OF SCIENTIFIC LIFE

On my return from Europe, early in the eighties, after six years spent in the study of music there and in America, I began my education. My first introduction to scientific thought was Helmholtz's great work on Optics. This book I had purchased at one of the second-hand bookstalls on the quais along the Seine in one of the old quarters of Paris. This book was treasured and brought with me back to America. I may note that when I was only eight years old, I found a small book of human anatomy belonging to my brother at home.

My governess, a highly instructed, conscientious Catholic, saw me reading this book and studying the plates representing the human skeleton. She remonstrated with me for my interest in the subject, and said that Catholic teaching did not favor such studies for youth. There never had been, as far as I know, any one in my family who had been devoted to a scientific life, although my father's father had shown an interest in botany, and at one time followed in New Jersey the calling of pharmacist.

My father was of an active, inquiring mind, but he had never devoted himself to any special scientific studies. I had been told that some generations back ancestors on my mother's side had been scholars, graduates from foreign universities, but I always inferred that their interest ran more in literary lines.

A first cousin on my father's side is known as a veritable Nimrod among the scientific collectors of the day. This is Dr. William Louis Abbott, whose marvelous collections of animals, skins, birds, plants, and ethnological specimens fill or contribute to fill some of the leading museums of our country. I think this is all that I need to say about the scientific tendencies in the family.

I am especially indebted to Dr. William Thomson of Philadelphia for being the first to explain to me the laws of physics, especially of light and refraction; and in the many hours of his brilliant conversations I learned to appreciate the meaning of a scientific life and the possibility that would open up to humanity through the scientific spirit. From Optics my interest ran to Zoölogy and to the dissection of animals for closer anatomical study than the plates or specimens offered. The horror of my friends and acquaintances at this sudden change in my tastes from Art may be readily imagined, but I persevered, and in June of 1882 Mrs. Matilda M. Cohen, the mother of one of my dearest friends, accompanied me to the Woman's Medical College of Philadelphia and introduced me to the Dean. I had determined to study medicine in order to get a broader education. This channel seemed the easiest way, as I had not had the special preliminary training for entrance to one or two of the colleges then open to women, and I did not care to spend the time to secure this entrance knowledge. I looked to the Woman's Medical College as the open sesame to the undiscovered lands.

Upon my introduction to the college I was brought into association with Dr. Emelie B. DuBois, who was the demonstrator of anatomy. I went to her house several times each week during the summer months, studying with her and reciting to her Gray's Anatomy. This study had always a most vivid interest for me, and I awaited with impatience the opening of the dissecting-room in the autumn. I felt that in the demonstrating and lecturing on anatomy I should find my main interest for life, but I was turned aside from this intention, as I shall show later on.

During the first year at college I devoted myself mainly to becoming acquainted with the requirements in anatomy, chemistry, physiology, materia medica, and with practical anatomy by constant dissections. The cadaver had no terrors for me, and the marvelous construction of the human frame was an endless source of interest. There were a number of women then studying at the college who have since become eminent in their profession. I may mention Dr. Grace Wolcott and Dr. Lena Ingraham.

I formed a warm friendship at that time with a student who entered the college with myself. She was Eda Wilhelmi of New Philadelphia, Ohio. She later married Dr. McLane, and took her degree in Cleveland, Ohio. She practiced medicine in New Philadelphia with her husband, but subsequently gave up medicine for literature, for which she had always a strong bent.

We were inseparable companions and pursued our studies together. The lectures which troubled us the most to understand were those given by Dr. Frances Emily White on Physiology. She followed the plan to introduce her class to a general review of Biology and Morphology based on the principles of evolution and a great deal of Herbert Spencer. To one who had been from childhood associated with thoughts of Art, the languages, and literature, shrouded in a mantle of Catholic orthodoxy and mysticism, these lectures were puzzling in the extreme. I found myself, out of college hours, devouring all the works I could find on subjects to elucidate Dr. White's lectures.

I was no different from the rest of the beginners, who found these lectures difficult to grasp, but I was assured that on reaching my second year what then seemed obscure would become very plain. I owe an eternal debt of gratitude to Dr. White for the difficulties she had me encounter during these first weeks at college. Her lectures and the private teaching which I had from her later were most stimulating and full of enlightenment. I passed the first year's examinations in chemistry, anatomy, and physiology with a record of one hundred in each branch.

The summer following my first year at the Medical College was full of interest. I spent a great portion of the time in chemistry, geological expeditions, and delving more deeply into books on biological subjects. I made the acquaintance, at this time, of Professor Edward D. Cope. The versatility of his mind attracted me, and his interest in all general subjects, such as music, the stage, literature, metaphysics, and philosophical speculation, was the basis of a congenial friendship that then sprang up and lasted for some years. His mental alertness and responsiveness to all the humorous sides of life made him a delightful companion.

Of French and Quaker descent, with the stolid characteristics of the Quaker, he had inherited from the French the art of living a happy life. Notwithstanding Professor Cope's mental broadness in general, he did not believe in woman's equality with man. This rested mainly upon the fact that men do the policing of the world, the hard labor, and the fighting. He also based her more infantile traits upon the fact that certain embryonic characteristics are more persistent in her than in man. Still he did grant woman some reason for her existence, as being essential to man's comfort and the perpetuation of the race. He was generous to woman to this extent, though he would deny her suffrage. He claimed that because she was man's intellectual and physical inferior, she needed all the more the higher education in order to help her overcome her natural disabilities, and on every occasion, in public lectures or in private, he was woman's warm aider in forwarding her scientific work or opportunities. Later when I had taken up the study of plant chemistry, Cope helped me secure specimens of unstudied plants of Mexico and Central America; he urged me to pursue research, publish my investigations, speak before societies, attend scientific meetings, collect specimens of fishes, batrachia, reptiles, plants, and in innumerable ways gave me the weight of his experience, encouragement, and hours of his time to acquaint me with the subjects in which he especially worked. I have still by me the summary of his instruction in comparative osteology. I consider his influence in my life of inexpressible importance.

It was mainly owing to his presentations of the life of research that I afterwards discontinued my medical studies and because of ill health decided to take up other lines.

Among the many pleasant scientific excursions we enjoyed together I may mention one in 1885. After the meeting of the American Association at Ann Arbor, which I attended accompanied by my father, he, Professor Cope, and myself started on a trip across the continent to the Yellowstone National

Park. I was daily enjoying the instructive companionship of Cope during the month of our stay and, the company having been augmented by several State geologists, we formed parties for exploring some of the less frequented parts of the Park. Some of us pushed on from the Yellowstone Cañon across the Mt. Washburn trail to Yancey's, the petrified forest, and amethyst mountain. That expedition was full of adventure, including an encounter with a bear, a snowstorm on top of Mt. Washburn, one of the ponies sliding three hundred feet down the trail, and a runaway. Our journey later continued across the plains of Idaho to Utah. Cope had left us for a few days to visit the Green River region for specimens. He brought me back a perfect specimen of a fossilized fish-skeleton. He said it was a most unusual find.

Our experiences in Salt Lake City were somewhat unique. We met quite a number of women who were living in plural marriage. Those with whom we spoke seemed generally content. On the Sunday of our stay we attended services at the temple. They included reading from the Old Testament, the singing of hymns, preaching, and the participation in a sort of a communion, bread being handed around among the congregation. My father had preserved a most reverent attitude towards the services, and when the dish of bread was handed to him, he took a piece, bowed his head, and proceeded to eat it as all the good Mormons were doing.

Afterwards when we taxed my father with the query if he intended to become one of the elders, he did not vigorously affirm that he would not. He said, "Well, you would n't have me refuse the hospitality they had extended to a stranger."

The second year I spent at the Medical College, I devoted extra time to the dissecting-room, and in order to have an abundance of material, I made arrangements, in addition to my dissecting at the Woman's College, for the evening use of a dissecting-table in the Dental College then at Twelfth and Filbert streets. The dissecting-room was very thoroughly equipped, and from eight until ten o'clock I worked there nightly. This institution was so much more accessible to my home that I was saved a long, lonely walk which I should otherwise have had from the Woman's College had I attended the night classes.

The previous spring, Dr. William H. Parrish became my private preceptor in medical studies, and three evenings during the week I spent at his office in recitation and in explanations of medical subjects. Dr. Parrish was at that time the professor of anatomy in the Woman's Medical College. He offered me opportunities for seeing operations and special cases. I saw him perform the Porro-Mueller operation, which had at that time not been so often done. During January of my second year at the Medical College, I had an accident to which may be attributed the ill health which has more or less attended me all the years up to the present time. I had driven with Dr. Parrish on one cold day in January from his office on Pine Street to the old Blockley Hospital. I was much fatigued by my work, and probably more susceptible in consequence to the evil odors of the ward, which we visited together to see a patient whom I had seen him operate on a few days before for fibroid tumor. Without any warning, I fainted, and falling backward down a step, struck the side of my head on a marble hearthstone. The result of the accident was serious, for the articulation of the jaw was crushed and the bony ring of the ear injured; concussion of the brain followed, and internal displacement of the pelvic organs.

It was some hours after my return to consciousness before I was able to be taken home. Dr. Parrish spent the day by my side, and I was confined to my bed for three or four weeks before I was able to lose the constant dizziness which followed the fall. Even years afterwards, suddenly turning the head on the pillow towards the injured side would bring on dizziness. Three attacks of peritonitis in following years were the outcome of my Blockley expedition. The disturbance to the nervous system which also attended the fall, forced me to give up such close application to my work as I had previously given. I decided to spend four years over my medical course instead of the three I intended to follow, but owing to continued ill health I gave up the attendance at lectures and clinics for the less exacting scientific work where I could control my time. However, I came up for my final examinations after the accident at the end of the second year's course, and passed in chemistry, anatomy, and physiology, with the same record as my examinations of the year before.

The autumn following my second year at college, that is, in August of 1884, I read my first scientific paper before the American Association for the Advancement of Science, which was meeting that year in Philadelphia. I had worked during the late spring and early summer in the laboratory of Henry Leffman, but I was dissatisfied with the opportunities for the class of work I was doing, for I had become interested in the chemical analyses of plants, and through the advice of scientific friends I was introduced to Professor Sadtler, lecturer on chemistry at the Philadelphia College of Pharmacy. He offered me whatever help he could in the class of work I was then interested in, and placed me as a private student with Professor Henry Trimble, who was in charge of the chemical laboratory at the College of Pharmacy and had made a special study of plant analysis.

About this time there was published, in English, Dragendorff's scheme for the chemical analysis of plants, which was the best systematic method for plant analysis published up to that time. Previously to the appearance of this book, plants had been analyzed in a haphazard sort of way, and simply special methods had been used for the isolation of certain compounds that were suspected to exist in the plants under analysis.

I was especially interested in the study of Mexican and Central American plants, not only on account of their not having been much studied up to that time, but because they contained substances of interest both scientific and medicinal.

The facilities for this study were very good in Professor Trimble's laboratory, and the College library was most complete in works of reference and journals containing the literature on the subject. My first piece of work at the laboratory was the analysis of the bark of the Mexican candle-tree, botanically known as *Fouquieria splendens*. This tree is mentioned in the Mexican Boundary Survey reports. An interesting wax was isolated from this bark which was also known locally by its Mexican name *ocotilla.*

This paper was afterwards published in the "American Journal of Pharmacy" and in the American Philosophical Society's "Proceedings."

Following the meeting of the American Association for the Advancement of Science, I went on a geological expedition in September, 1884, into the coal regions for the study of plant fossils. Later, on my way to the Susquehanna Valley, I was taken ill with peritonitis, and not until the month of February, 1885, was I able to return to the laboratory. I spent the following months until July in the study of the Mexican plant *Yucca angustifolia.* A paper on the subject was read at Ann Arbor at the American Association for the Advancement of Science meeting in August, 1885. It was published in the American Philosophical Society's "Transactions;" also a synopsis of it appeared in other journals and in the "Proceedings of the American Association for the Advancement of Science."

My attention had been especially directed to plant chemistry at one of the weekly meetings of the Academy of Natural Sciences. Some one had sent from Danville in Pennsylvania, specimens of what were supposed to be *Daucus carota.* A party of children in the woods had found roots that were supposed to be these, and had eaten of them with disastrous results, as one death had occurred. It was probably roots of wild parsnip, which greatly resembles those sent as specimens. Presumably death resulted, if the children had eaten wild carrot, from conium, the volatile alkaloid contained in roots belonging to this botanical group.

About that time, I was working in Dr. Leffmann's laboratory at the Polyclinic Hospital, and I made some experiments on some of the roots sent to me from Danville to determine the presence of this alkaloid. The species sent were not the noxious wild carrot, but Mr. Thomas A. Meehan informed me that it was very difficult from the roots alone to identify the species, and that the only way to ascertain the fact was to plant some of the roots and await the foliage. The chemical work in the study of identification fascinated me, and from that time my interest in chemistry centred around the chemical constitution of plants and the chemical life-processes at work in living tissues.

Some of my later views on the chemical evolution of plant forms were the outcome of my studies begun with the little incident I have related.

Early in the year 1886, I renewed a friendship dating from childhood, but somewhat interrupted by my long residence in Europe previous to the eighties, and later by my close application to study. This friendship was with Dr. Daniel G. Brinton, and for many reasons I regard it as the most important influence of my life.

Dr. Brinton directed my thoughts to the higher intellectual, spiritual, scientific, and artistic regions, and the year 1886 was one of the most formative periods of my mental growth. With few exceptions, our tastes and attractions for philosophic speculation and literature were the same. In flights of the intellectual imagination, I have never met any one who was capable of soaring so boldly as he.

We seldom discussed the details of his scientific work, at least in its more special phases, and I think I never heard him speak of linguistic subjects or of the characteristics of the Indian tribes and races, but we often conversed on subjects appertaining to the general domain of anthropology, and we most frequently found ourselves going over the broad outlines and theories of science, especially its generalizations.

Dr. Brinton encouraged me to print some of the views I had reached in my scientific work. These were afterwards collected in two lectures published under the titles, "Chemical Basis of Plant Forms" and "Comparative Chemistry of Higher and Lower Plants."

I also wrote out my impressions from the study of a collection of pictures, exhibited at the rooms of the American Art Association, during the spring of 1886. This was about the first time any collection of the works of a school of French painters called the "Impressionists" had been exhibited in New York. The paintings of Monet, Renoir, Sisley, Manet, and Pisaro were among the canvases displayed. This pamphlet I wrote after spending a week or more in New York studying these paintings. It was published under the pen name of Celen Sabbrin. Copies were sent to the various art journals, and to the New York Art Exhibition, and many were sold at the door of the gallery as supplementary to the catalogues. This article was afterwards translated into French by the editor of "La Vogue."

Some of the Impressionist paintings especially emphasized the pitilessness of natural forces or of Nature where all human interests were lost to view. It was as if the universe were a huge scientific demonstration, with feeling, mental response, and all that goes to form religion eliminated. It was the inevitable onward march of the physical life of the world, as each æon brought it nearer and nearer to cold, death, and annihilation.

Such thoughts may have been due to an overwrought, sensitive mental organization, but it was all very real, and even the sunlight shining on the green trees and grass brought with it a suggestion of the steel-blue light that astronomers tell us prevails beyond this earth's atmosphere. To break the spell of this mood, I gave up the study of the Impressionist paintings at the time, and even the study of the physical sciences became so painful to me that I felt obliged to discontinue it and find relief in literature, poetry, and whatever else suggested sentiency.

It happened to be Holy Week, and often in the late afternoon, I would drive to some church and sit there in meditation in the deepening twilight under the spell of the solitary altar-lamp, symbolical of everlasting light, and the slowly-fading colors of the stained-glass windows, as one by one they settled into the common tone of the early evening dusk.

Especially in the domain of poetry were many hours at this season spent. The works of Goethe received due share of attention. Alfred de Musset, Murger, Béranger, Shelley, and later, Browning, all contributed their delightful companionship. Spinosa and Novalis were constantly referred to and read.

Dr. Brinton had a happy way of selecting passages from his favorite authors and copying them in his own handwriting for use at some special time or season, and frequently these would be the text on which we discoursed, ranging from these to wider and more spontaneous themes. Wilhelm von Humboldt furnished many passages which were stimulating and enjoyable. George Sand was another of our favorite writers, and "Indiana," which so beautifully portrays human devotion, we found well worth reading more than once.

Dr. Brinton used to say that writers from whom he could derive no thought leading to the higher life were valueless to him. Balzac contained no message for him.

The autobiography ends abruptly, and requires a little supplementary filling in.

In 1883–84, Miss Abbott acted as assistant in the chemical laboratory of the Philadelphia Polyclinic, and published her first scientific paper under the title, "Some Observations on the Nutritive Value of Condiments."

Her paper on the analysis of the bark of the *Fouquieria splendens* was published in the Proceedings of the American Association for the Advancement of Science and in the "American Journal of Pharmacy." Her studies into the chemistry of drugs attracted the attention of the trustees of the College of Pharmacy, and they not only asked her to lecture before the students, — the first time that a woman had ever been thus honored, — but went so far as to expend the sum of five thousand dollars in purchasing some small houses at the rear of the college building adjoining the main laboratory and fitting up a portion of the space thus acquired as a research laboratory for the use of such women as wished to go into higher work. Miss Abbott had here her own special apparatus, which she imported from abroad, and the trustees furnished her with all facilities necessary to carry out the line of her investigations.

Dr. William Thomson, the eminent oculist of Philadelphia, to whose stimulus Miss Abbott was indebted for much of her success in scientific work, did not approve of her digressions into the field of art and literature, and urged her not to dissipate her energies, but concentrate them on her chemical labors. In reference to this she says, in one of her "Scientific Notes:"

"I returned with renewed energy to my laboratory work, which I had omitted for some months.

"After I discontinued my medical studies, I had the thought to work at the University of Pennsylvania for a Ph. D. degree, and during some portions of the years 1885 and 1886, I studied with close application, mathematics, with a Mr. Howard Lukens. He undertook in coaching me to prepare for passing the preliminary examinations which would allow me to enter the University as a student of the Junior year. The Dean of the University had arranged to allow me to pursue my studies in chemistry and botany with a view to the degree, if I should satisfactorily pass some preliminary examinations in mathematics, German, French, and English literature. The requirements in mathematics were considerable, and Mr. Lukens worked conscientiously with me in that branch. Mr. Nathan Haskell Dole, the writer and translator, was then living in Philadelphia, and he was introduced to me by Mr. Henry Hobart Brown, the principal of a boys' school in the city, as the most competent person to fit me for the examinations in the other branches, and we spent the winter in as serious work as my health permitted. I do not wish to forget mentioning Dr. Frederick P. Henry, a well-known practitioner in Philadelphia, and at the time when I met him, a professor of Histology and Microscopy at the Polyclinic College.

"He was a warm advocate of the higher education for women, and later on became a professor of the Practice of Medicine in the Woman's Medical College. I took one private course of his instruction in his branches at the Polyclinic. Dr. Henry was interested in my scientific work, and after our lessons, he would often keep me in his laboratory discussing subjects relating to science and literature. He was a fine classical scholar. . . .

"Dr. Henry had heard me speak of a Mr. Thompson, the keeper of the snake-house at the Zoölogical Garden. I had, on several occasions, assisted him in feeding the rattlesnakes according to Dr. S. Weir Mitchell's method of forced feeding of reptiles in confinement. He was desirous of seeing the process, and I arranged to take him to the Zoo with me one day to witness the performance. When it came to the point, our excursion ended merely in a visit to the gardens, as Mr. Thompson was not willing longer to undergo the risk.

"This Thompson was an unusual character; he had had few opportunities for education, but he was a keen, natural observer of the habits of animals, and he had made a close study of the habits of snakes in the wild state. His interest in the snakes that he had under his care had resulted in his observing closely their habits in confinement, and Professor Cope, who often visited the gardens, enjoyed discussing with him the ways of his pets. Thompson was an artist. He had taught himself to work in oil colors, and some of his canvases were quite creditable."

Another brief extract from Dr. Michael's "Scientific Notes" gives fuller details of her experiment in trying to overcome the natural feminine antipathy to snakes, and shows how zealous she was to help along the cause of science. Dr. S. Weir Mitchell, the distinguished neurologist and poet, was at this time engaged in analyzing the venom of poisonous reptiles, and his discoveries of the deadly alkaloids were exciting much interest in the learned world. She says: —

"Thompson's arrangements for snake-feeding were somewhat more primitive possibly than those used in the Mitchell laboratory, but they were quite as effective. A stout piece of leather nailed on to the end of a wooden stick and, with a loop for the strap to pass through, made a solid noose to hold the snake's throat securely. Two persons were required to carry out the feeding. The snakes in the cage were disturbed by touching them with a stick, and as the head was raised the noose was quickly slipped over and drawn sufficiently tight to allow the snake to be pulled out of the cage to the opening. A small porcelain dish, like the evaporating dishes used in the chemical laboratories, was forced between the snake's jaws. The enraged reptile bit the edge of the dish savagely, and the poison from a sack above the fangs would then flow through a hole in the fang into the dish. This not only proved a safeguard for those engaged in the feeding, but also served to use in the investigations on rattlesnake poison which were still being continued under Dr. Mitchell's direction.

"The next step in the process was by all means the most difficult. A smooth glass tube from one quarter to one half inch in diameter was thrust down the snake's throat. The assistant who was holding the snake by the noose was obliged to loosen the strap sufficiently to permit the tube to be inserted. Finely chopped beef was then rammed down the glass tube with a small stick until some ounces of beef had been used in this way. This was the only means to keep rattlesnakes, copperheads, or the poisonous Mexican lizards in captivity, for they would refuse even live food. Rattlesnakes would live many months without food, but would eventually die of starvation unless this method was resorted to.

"They were fed every two weeks or later according to circumstances. On one occasion, Mr. Thompson took out of the cage eight or nine rattlesnakes, and let them crawl over the floor of the room where we were. They made no effort to molest us, but the sensation was rather strange, feeling that so many poisonous snakes were close at hand.

"In order to overcome a natural repugnance I had for snakes, at Thompson's suggestion I used to pick up and handle the king snakes of Carolina. They were really beautiful creatures, but their cold slippery surface and constricting propensities, for they would twist themselves around my arms, and only by striking them along the back by the percussion of my hand could I loosen them, only intensified my repugnance."

Two further isolated "Scientific Notes" which she left in manuscript may be pieced together and afford a glimpse of her activities during that memorable year. She says: —

"A portion of 1886 was spent by me working in the laboratory over an interesting bark called *Chichipate.* This plant contained a class of compounds which I had not found before in any plant. On analysis they were proved to be solid hydrocarbons, also from the same plant was isolated a yellow dye substance which gave a good and permanent color on wool and cotton fabrics.

"A short vacation in July I passed with my aunt, Mrs. Ellen Abbott, at the Delaware Water Gap. There she introduced me to one of the resident clergymen, a man who was immensely interested in scientific work, and who had brought up his children to be familiar with natural history and botany, and although his means were extremely limited, he had spared no opportunities that he was able to command to train them in scientific methods. My aunt knew my tastes and of Professor Cope's encouraging me to collect specimens. He had purchased her home in Haddonfield and, to her despair, had allowed her beautifully cultivated garden to become a perfect wilderness and headquarters for all the small game and rodents of the country around. I desired very much to obtain a collection of the geological specimens of the country around and of the numerous fossils in which the neighborhood abounded. My Aunt Ellen entrusted me to the escort of her clergyman friend, and with the assistance of my colored maid, Fannie, a 'stone-breaker,' as she called herself, we started out bright and early of mornings with basket and hammer in hand. These excursions were amply rewarded by the interesting finds that we made.

"Fannie and I had been warned by our friend to look out for copperhead snakes, as the ridges where the fossils abounded were the favorite haunts of these snakes. The color of the stones and ground were so nearly like the color of the snake that some care was necessary not to pick one up. It was the season when snakes were plentiful. Rattlesnakes were at times encountered in the region, and often when we would be seated resting, an odor from the woods would be wafted to us, and then Fannie would say, 'Come on, Miss Helen, there's rattlesnakes about here. Don't you smell the watermelon odor?' As she had come from the South and had lived long in a locality where rattlesnakes were plentiful, I did not dispute her knowledge, and I invariably 'moved on.'

"The autumn of '86 I attended the American Association meeting held in Buffalo, and I read before the chemical section two papers, one on the classification of plants on a chemical basis, and the other on an analysis of the Honduras plant *Chi-*

chipate in which I had discovered the interesting yellow dye that compared favorably with fustic.

"At this meeting I made the acquaintance of quite a number of scientific men and renewed the acquaintance of others whom I had met at former meetings.

"Professor Edward S. Morse of Salem was the president, and his delightful geniality never showed to better advantage than at this meeting. Professor S. P. Langley, whose laboratory I had visited near Pittsburg in '85, also attended the meeting. I saw a good deal, too, of Dr. Wiley, the chemist of the Agricultural Bureau. He was president that year of the chemical section, and he had me preside in his place on one or two occasions when he read papers before the section.

"I saw a great deal of Dr. Wiley the following winter, and we talked over many subjects relating to my chemical theory of plant classification. He was himself interested in plant analysis, as it was a part of the work of the Agricultural Department, and his private researches were almost exclusively in that field. In my public lectures, given during the winter of '86 and '87, Dr. Wiley came from Washington especially to attend them, and assisted me in arranging the diagrams and experiments in the hall before the lectures.

"That season I gave two lectures before the Franklin Institute, and I lectured at the Academy of Natural Sciences and at the Philadelphia College of Pharmacy to large audiences. In the spring of '87, I gave, in Washington, one of the Saturday lectures under the auspices of the Philosophical and Anthropological and Biological Societies, in the United States National Museum. The subject chosen was the chemistry of the higher and lower plants, and owing to the courtesy of Dr. Wiley, the government greenhouses were placed at my disposal, and a living exhibition of plants, from the highest to the lowest, illustrated my lecture. Most of the Washington science coterie were present, and after the lecture we met at an informal reception."

The Philadelphia "Ledger," in a long and appreciative notice of her Monday night lecture on plant chemistry before the Franklin Institute, called it "an entertainment altogether unique," and remarked: —

"The spectacle of a graceful young girl, surrounded by a battery of chemical appliances, and explaining, with the familiarity of an elderly savant, the valuable results of laboratory researches among plants strictly as related to commercial uses, was interesting from more than one point of view. All the other girl-students — and Philadelphia has a number — who are engaged in original research in various departments of science must take courage from Miss Abbott's success and her enthusiasm. When she tells us that we shall some day have bottled up for purchase as perfumes, the delicate aroma of the buckwheat cake, the delicious fragrance of birch, hickory, and other trees, and the elusive scents that now fill the spring air in woodland, meadow, and the farmer's fields, it will be seen how fascinating is the subject, and how it may be expanded from the rose and violet culture of the south of France, and beyond the orange and lemon laboratories that give us now such rich fragrance and flavors.

"When Miss Abbott prophesies that the wax in the sugar-canes, now only an impediment in sugar processes, will one day be made an article of commercial supply, when she points to the paper made from sorghum canes, and to the pretty pink specimens obtained from the familiar yucca plant, as witness of the great magazine in the cellulose of plants, her hearers are charmed by the practical vision.

"In a range of tall glasses, like organ tubes, on one table were shown the various tints of the familiar logwood and madder dyes, and in other tubes the new hæmatoxylon, — the discovery made by the lecturer of the same coloring principle in another plant hitherto held innocent of this mercantile importance. The new gum, which can be made to replace the now lessening supplies of gum arabic, was shown among the glass jars of the exhibit. A variety of sugars was also exhibited, and some of the processes of making beet and sorghum sugars illustrated by the camera on the screen.

"But a greater charm than was in the subject even, was in the clue all these demonstrations and the elaborate preparations for illustrating the lecture, gave to the energy, the command of resources, and the skilled industry of this young lady.

The laboratory, the prolonged and absorbing study into the secrets of plant life, compelling it to yield up its foods, its fuels, its fabrics, its flavors, its essences, its hues, its tonics; adding from hitherto useless plants, or developing additional resources from those already partly known,— what more dainty, more beautiful, more useful work to set before the girl-student? What a good and brilliant development of woman's work this is!

"It is, perhaps, permitted to say of Miss Abbott, that her inclination first led her into the study of medicine, but discovering in one of its auxiliary sciences the unharvested field, she promptly accepted the line of special research as one which fully satisfied her ambition and her talents. She has made her own way therein, and not only a distinguished position, but, what is even better, she furnishes one more example of what a girl may do who wishes to fill her life with occupation formerly held to be only possible to the young man."

A Washington newspaper, a few months later, commenting on her lecture there on the Chemistry of the Higher and Lower Plants remarked that she had "evolved a theory by which the flora of past ages can be demonstrated. This theory is original with her and is attracting the attention of scientific men."

This theory would seem to have a prophetic bearing on the recent experiments made by an American scientist, with a view to follow back the steps of creation by an empirical collocation of certain chemical elements, and resulting, microscopically at least, in startling imitations of vegetable, mineral, and animal forms.

The same April, Miss Abbott gave a lecture on Plant Chemistry in a course offered by the Philadelphia Academy of Natural Sciences. It was remarked at the time and afterward that she had an extraordinary faculty of "bringing the results of her investigations within the scope of lay readers and hearers."

In the summer of this year, she went abroad carrying with her an unsolicited letter of introduction from Mr. S. P. Langley, secretary of the Smithsonian Institute, to its foreign correspondents, and commending her as one "who visits Europe for study and advancement of knowledge." The writer in a private letter accompanying it called attention to the fact that it was "intended to be more than an ordinary letter of introduction to an individual or individuals would be." In the notes that she made of her experiences in various educational centres, at universities, museums, and laboratories, she usually found, to her surprise, that she had no need of any introduction. The magic of her name was an open sesame to all doors. Her researches had made her known to the learned world of England and the Continent.

These notes were jotted down, as she went from place to place, and were afterwards, as she found time amid all the distractions of travel and assiduous work, copied into a book. Many of them are accompanied by quick pencil-drawings of such chemical or scientific apparatus as attracted her attention by their usefulness, originality, or peculiarities. Occasionally, also, the autographs of famous foreign chemists, German or Swedish, are attached to the manuscript. With the aid of these notes, we are enabled to follow her pilgrimage — for a strictly scientific pilgrimage it was — from place to place, almost from day to day. One cannot fail on reading them carefully to be impressed by her keenness of observation, her enthusiasm for knowledge, her readiness to adapt and adopt every improvement brought to her notice, the breadth of her views, and the wonderful dignity and charm of her attitude as a representative of American science in the person of a young woman asking admittance to conservative institutions on equal terms with men, and yet never in any way transcending the proprieties of womanliness. She was accompanied by her colored maid, who served as a sort of bodyguard and symbol of station, and everywhere attracted much attention, which she endured with imperturbable good nature.

She went directly to Manchester, England, where the British Association for the Advancement of Science met in the early days of September, during the great Exhibition of 1887. Of the evening meeting, which was addressed by Professor Sir Henry Roscoe, she says: —

"The hall was crowded. We had seats in front row of gallery, left hand, facing and near stage. A few green plants were arranged in front of the platform, and above rose a mass of heads of the most distinguished scientists of our day. The ladies were in evening dress, low necks, and many æsthetic costumes were in the hall. The audience present seemed of a higher social caste than our own scientific assemblies."

The weather grew unpropitious; Miss Abbott was confined to her room by a bad attack of bronchitis and found no other amusement on the 2d of September, than "a wiry upright piano, Chopin nocturnes, and the Schumann Carnival." She records a call from Joseph S. Ames, of the Johns Hopkins University, who had been for eight months at Helmholtz's laboratory at Berlin, and complained bitterly of the primitive methods, the disregard of the value of time, and the boorishness of the students that distinguished that university. As she was informed that it was idle to go there without one's own apparatus and with work already planned out, she notes that her plan is "to get a number of products ready and to take them to some one laboratory to work under advice." She was told that the celebrated chemist, Sir William Crookes, and other distinguished men desired to meet her, and that when she should once get out she would find herself "quite a lion." She says: "I am gathering experience from my trip. It was just the thing to do; by the time it is over I shall have a clearer idea of how to follow up my work. The meeting with *men* is the greatest educator for me. A wide or limited experience makes the difference between people."

On the 4th of September, she was able to go to Dr. Edward Schunck's, where she was delighted with his beautiful house, grounds, and laboratory. She told her host, when she saw the yellow brick exterior, the stone staircases, and the walls painted robin's egg blue with fine gold bordering, the opal glass window-panes with soft, mellow, creamy light, that it suggested to her mind "celestial chemistry."

She remarked the exquisite crystalline products that Dr. Schunck had isolated from plants, his specimens of substances dyed with chlorophyll and various organic products in a glass case with pomegranate-red glass doors. She was delighted with his library and its rare books, its walls beautifully tinted, its frieze with the Aristotelian elements — air, earth, fire, and water — represented in it, and in each corner the arms of the doctor and his wife; the ceiling in blue and gold, a large sun in the centre and around in squares the alchemistic symbols, the inlaid floor, beautifully polished, and the motto on the wall end of the room, so suitable for a chemist: "Thou hast ordered all things in measure and number and weight."

She chronicles meeting Sir William Crookes, who remarked that her Yucca essay "was a model of a good scientific paper." Professor Leech, of Owens College, who had written a notice of her Yucca paper for the Manchester "Chronicle," "was admirably polite" and showed her over the college, the museum where were "glass cases fitted with drugs in jars labeled," and the laboratories with their convenient arrangements for students. She was particularly interested in Professor Leech's method of showing the effect of drugs in destroying nerve-fibres and the "immense effects of impurities in drugs on tissue."

At a reception at the college, she met a number of distinguished scientists, Springer, Newcomb, Dewar, Professor Armstrong, of London, as well as Ladenburg and Lothar Meyer of Germany. At the luncheon of sandwiches and champagne that was served, she had some chance to talk with the Germans. She asked their advice about studying in Germany, but was informed that there was no chance of her gaining admission as a private student in Kiel or Tübingen, and perhaps not in Germany. She says: —

"They gave me cards of introduction to Dorpat and Leipsic. Ladenburg is accomplishing syntheses of alkaloids. He said he would never come to America. His wife would not let him go without her and she had to rest with the children."

After a few weeks in England, the record of which seems to have disappeared, Miss Abbott sailed first to Christiania and then to Sweden, and one of her first experiences in Stockholm brought her into acquaintance with the famous Norwegian poet and dramatist, Henrik Ibsen. Her description of the reception where she met him deserves to be preserved: —

"September 24, at Grand Hôtel, there was an evening reception to Henrik Ibsen, the distinguished Norwegian poet, whom I was introduced to and shook hands with. He was of rather short stature, ruddy face, wiry, brown hair, and side whiskers. He wore decorations and a wide red ribbon across his breast. The reception was held in a suite of rooms of the Grand Hôtel. About nine o'clock, the guests passed into the large dining-room set with long table in middle on which the supper was placed: cold fish dressed with delicious sauce and cold peas, carrots cut fine, small cabbage, vegetable something like pods of beans, cold potatoes, delicate cutlets with peas, the Norwegian game, white meat like a partridge, the berry like cranberry only smaller, and salad cut fine. The waiter passed, after serving the game, a tray on which was a sauce and little dishes holding other articles. After that came a kind of charlotte russe surrounded with ice cream.

"Before sitting down, the guests go first to smaller tables covered with small round plates like soup plates with the food arranged very artistically, — cold beef in thin, small slices, raw fish, sardines left in boxes. The middle of the table has two piles of plates, which, however, the Swede never uses when eating this *hors d'œuvre.* First one helps one's self to a thin slice of bread or a piece of the Swedish knäkkebråd, a rye bread which is like Jewish bread in appearance, a coarse kind of passover bread. The knife is then brought into use, and butter is taken from a large butter dish; then with a fork some kind of cold meat or fish is chosen and eaten. I noticed also a small kind of fried sausage, and a decanter and glass for the strong, white, Swedish whiskey.

"There was an absence of obsequious serving on the part of servants, each person helping himself, and no servants were seen helping at the beginning of the supper. Wine, claret and sherry, also beer and seltzer water, were opened and standing about for each to help himself.

"Before drinking, the glasses are always touched with the word *skåld*, meaning "health.' In saluting, the ladies give a little courtesy, bending the knee, which it is considered very polite to do though not obligatory. The men bow quite low, nodding the head twice or thrice. I noticed an absence of earrings; only half a dozen men in the room wore them, though many of the ladies had their ears bored and doubtlessly wear earrings at balls and the like. The dresses were generally woolen, of dark colors, tastefully made though plain, very little jewelry, clean, neat-fitting gants de Suède. . . .

"The reception was noted for the distinguished men and women present: professors and their wives, a young man of Stanley's corps who had walked across East Africa, Nordenskjöld, who went in the Vega by the northwest passage around from Sweden to Japan. He shook hands cordially. A famous actress of Sweden, Lenke, zoölogist, Leffler, mathematician, Hildebrandt, and Montelius.

"Miss Topelius of Finland spoke in French. Her father is a distinguished writer [1] of Finland. She was charming in manner, a painter, and was most warm in her manner, patting me on the shoulder and arms. This is quite a national trait since Professor Löven and the chambermaid did the same. There is much kindliness in their manner. After supper we went back to the reception room. Miss Inez C. Rundström from Kansas was a charming girl of Swedish parentage. She graduated from one of the Western colleges, having begun the study of mathematics when a child. She is here studying mathematics in the High School (the beginning of the University) with Leffler and Professor Sophia Kovalevskaya. The teaching is entirely by means of lectures, and those of Kovalevskaya are regarded as very profound. The atmosphere of great men was about the room. The tremendous and gigantic strength of their mental qualities very apparent. Many, if not all the ladies, speak excellent French, and they seem more thoroughly educated and trained than our own women. They met me with such a delightful spirit of welcome.

"Within a brief hour after the supper, we returned to the dining-room. The long table was spread with a row of glasses all around the table, filled with punch — alternating color of red and white — opened bottles of seltzer water and glasses.

"At the end of the room near the head of the table sat Ibsen,

[1] Professor Zakris Topelius, author of *The Surgeon's Stories*, etc.

his wife by him. The other guests sat in two or three rows of chairs around the room, all faces turned towards the poet. Sven Hedin, a member recently reëlected to Parliament, made a long speech in honor of Ibsen, and then it was responded to by the poet, but first each person rose, at a word, from their chairs, approached the table, and took a glass of punch to drink the poet's health; he had also a glass. Friends, guests, and ladies hurried up to touch his glass and drink his health. Other speeches and responses followed, — one by the actress in which she read from a slip of paper. A singer from the opera, Miss Oka, sang several Scandinavian songs beautifully. She is from the royal opera.

"The same spirit of solid intelligence I feel here in distinction to the brilliancy of home intellect. About midnight ladies were leaving, — the reception continued, as far as the men were concerned, until late. Sounds of laughter and drinking came to me.

"The memory of the reception was one of warmth, intelligence, solidity, and of the highest culture.

"Governesses to high families, literary and artistic persons, all belonging to the upper middle class, were represented."

One day in company with the famous Professor Hildebrandt, whom she thought "the most magnificent intellectual giant" she had as yet met, she visited a private school for girls where she was impressed by "the seriousness with which the girls followed the class, and the marked interest on the part of the teacher." She says: —

"The first class or reading lesson was very instructive. The little girls in turn were reading from 'Robinson Crusoe' in Swedish. The two little pupils on the front benches reminded me of little birds in a nest reaching out their heads for food, with such eagerness did they correct the mistakes in pronunciation of the other readers."

With a letter of introduction from Sven Löven of the Svenska Vetenskaps Akademien, a kindly old man of seventy-nine who had patted her on the back and inquired into her work, she visited the chemical laboratory of the "high technical school" which was under the direction of Professor F. L. Ekman, and her notes are full of drawings which she hastily jotted down as she found anything in the way of apparatus or convenience to interest her. She discovered that Ekman had worked considerably in physical chemistry, and that he had studied botany with the view of making researches into plant chemistry. At the Pharmaceutical Laboratory Library she was shown, among other treasures, copies of her own *ocotilla* paper and her lecture on sugar. She also visited the "Medical Institute which is identified with the name of the celebrated Doctor Retzius" (whose wife and son she had met at the Ibsen reception), and was much pleased with the chemist Jolin, who was at the time "engaged in research on the acids in the bile of pigs — a very bright and intelligent man."

At Upsala where she remarks on the fine University buildings and particularly the Grand Hall for commencements, "said to be the finest in Europe," she found an instructive cicerone in Dr. Bovallius, the famous geologist. She met Professor Cleve, the discoverer of scandium, and was delighted with the immense activity displayed in his laboratories, especially in original research. Professor Cleve advised her to go to the Charlottenburg Technical School. She says: —

"I was impressed by the fact that all of these chemists had studied for more or less time under distinguished chemists in France or Germany, and that they are continuously going to those countries to renew their knowledge or to acquire more.

"The plain interior of many of the laboratories is in direct proportion to the magnitude of the work accomplished by the men. A foundation of most accurate and solid information and study is why they are so eminently ahead of some of us. Cleve seemed thoroughly acquainted with the literature of all departments of chemistry. His collection of chemical preparations was complete. Specimens of many of the rarest metals, — a specimen belonging to Berzelius and one of the first double chlorides of platinum made. His collection of organic compounds was equally fine. The cases containing the specimens were of the poorest and meanest, of painted wood, dirty white. The cases containing the inorganic classified specimens were jammed into a small miserable portion of the room immediately back of the lecture-table — thrust upon the shelves in a way disregarding their value. In public display of museums, we are ahead."

She was amazed at the libraries, both at the Royal Academy and at the University of Upsala, and she found the arrangements of the botanical division of the Academy, as conducted by Professor Willrock, excellent. She says: —

"The flora of Europe and of other countries was kept in portfolios behind locked doors. I never saw such beautiful preservation of leaves and color of flowers. He said the colors were only preserved by careful drying, it being necessary to change the paper frequently during the drying and pressing. He had series of dried plants showing the different stages of growth and development from first to last. This same idea was carried out with the plants in alcohol (about 50% alcoholic solutions). This means of keeping plants is new to me and most excellent.

"The fungi and algæ were prepared by taking very thin sections, drying and gumming them on paper. The spores were allowed to drop from the fungi upon paper, which preserved absolutely the arrangement of the spores as they are on the fungi.

"The collection of alcoholic specimens of all fruits and fleshy plants was very large and superb in value of specimens.

"Such collections and the ready access of other collections in near towns cannot fail to make students. Study from objects, collections, and by observation seems to be the method of study generally followed.

"The ethnographical collection, under the direction of Professor Smitt, was very instructive. The specimens were outside of cases and exposed for close examination.

"Smitt is working up the fishes and has made some comparative measurements of value.

"The Laboratorrein for the preparation of specimens for the museum is outside of the city on a stretch of the Baltic. Smitt took us in a yacht belonging to the museum; his wife accompanied us. The cold was intense. The water was covered with little boats. The maceration, as the Laboratorrein is called, contains an enormous tank where the flesh can be boiled from whales and other large animals. Other smaller tanks are also in the building. Within a few feet of the door rise up a wilderness of rocks showing glacier action, pine forests, and a dense impenetrable wilderness of green growth."

Professor Hildebrandt showed her the ethnographical and archæological treasures of the museum, and she was much interested in his description of the evolution of the modern safety-pin, where gradually useless parts of the pin were dropped "to forms of mere decoration," until the "ornamentation had so far progressed as to be almost unrecognizable as the original type."

She remarks: "The idea of studying evolution by means of stone and bronze implements and other archæological records was new to me, and my interest in all these studies received a new impulse."

Hildebrandt talked to her learnedly of dolmens, and the stone implements found in them, and gave her an impromptu sketch of one. She discovered that the assistant curator of the museum, "who had written ably on antiquarian subjects," bore her mother's name of Montelius, and had not long previously received a letter from a W. W. Montelius of Colorado, inquiring if he could furnish any information regarding his family. She remarks: "It seems the name may be common enough here, since during the past hundred years it has been the fashion to latinize every name. Persons living near the mountains may have been called Borg-hjem, which would give the name Montelius, from *mons*."

Professor Hildebrandt also took her to his own home, which she describes as "a story in itself," its study facing the north, its walls lined to the ceiling with histories, Oriental works, and books on his specialty. She noticed that there were no carpets on the floor of white boards, only rugs under the tables. She says: —

"Hildebrandt spoke much of the different Swedish customs, and the matter of dropping titles. The younger of two acquaintances would never suggest addressing the older without the title Doctor, Professor, or Herre. When the proposition to call each other by the surname alone is made, it is always done with ceremony over a glass of wine, saying, 'Let us drink to drop all titles.' The King and Queen and Crown Prince would address Hildebrandt as 'thou' and call him Hildebrandt without title. The younger members of the royal family could not.

"In rare exceptions, a gentleman may address a lady with 'thou.' The case given was where a very intimate friend of the gentleman married a lady who was an intimate friend of the wife."

Taken all in all she was much pleased with Stockholm and with Swedish people and customs; she says in her penciled notes: —

"The first impressions of Stockholm are lasting. It is one of the most attractive and beautiful of European cities. Its canals, handsome buildings, its sweet pure air, its dignified inhabitants render it a place of growing interest. The politeness of even the most menial is phenomenal. No servant ever addresses you without first taking off his cap in salutation.

"The pavements are of Belgium block as well as the streets. Before the large hotels and cafés are little tables and chairs. Large trees or screens of growing ivy shut off one table from another, giving seclusion.

"The people seem to be under the care of a wise and careful government. Along the quays are life preservers to be thrown at once into the water in case of an accident. In winter, ropes, lanterns, and hooks are along the water's edge for accidents on the ice. . . .

"A market day in Stockholm on a clear day is as bright as an Italian scene. The products are offered for sale from little white-awninged stalls. White and black bread, flowers, fruits, and vegetables are for sale. The square measures, Morse said, were like Japanese measures. I noticed that all the baskets and larger boxes were never oval, always square. The fishing-nets along the banks were also like Japanese ones, only round instead of square. Several resemblances to Japan occur: the shop signs over the doorways.

"The market-places are near the water's edge, and all the products seem to be brought by steamer. I watched them unloading. Wood is also brought in large open sailboats.

"The fish-market offered the same features as the market in Christiania. The lobsters' claws were tied. The politeness of the market-people would have caused a shudder of dismay in the minds of the coarse English marketwomen. As one approached the stalls, the men kindly raised their hats.

"The Swedish language when spoken is beautiful; the sounds are soft and musical, flowing from the lips like Italian words.

"There is a refinement among the people which has been prompted by their surroundings, their great institutes of learning, and their pride and dignity are well warranted when the country has given them such men as Gustavus Adolphus, Linnæus, Berzelius, Charles XII, and Hildebrandt. . . .

"Honesty in its highest expression marks the character of the people of Scandinavia. They seem often slow to grasp an idea, it being long before the transference reaches the brain. It may be possible that other languages do not so readily convey ideas as our own, and the people have developed a slow habit."

From Stockholm, Miss Abbott proceeded to Copenhagen, where she was everywhere welcomed and given encouragement to come to the laboratories of the various institutions of learning. Professor Steenstrup himself, "a dear old man seventy-nine years of age, and very lame," conducted her over the Zoölogical Museum of the Royal University which was housed in the former palace of the princes, built in 1744, and nothing escaped her inquisitive notice from the catches of the windows to the arrangement of the fossils. She could not find herself supporting the inartistic effect of ornamentation which she says, "were birds of prey coming down upon the dead animals, as Steenstrup observed, and above this, and as a frieze, were windows painted and trailing vines of a bright green." She found Steenstrup witty and of artistic feeling, but was surprised to discover that he, like Professor Löven, was not an evolutionist, and clung to the "old systems of classification."

She enjoyed "a lovely drive through the country to the

Agricultural School, which fully repaid the effort." "The buildings," she says, "are over very extensive grounds, where all subjects relating to agriculture are taught. In asking the usual question, if ladies would be admitted, the reply was, 'Of course, but they must study general agriculture, and could not come for only one branch.' The gentlemen in the laboratory, also the servants, were extremely courteous and gave me a warm welcome, at the same time showing me over the rooms."

Through the kindness of Professor Steenstrup, she was permitted to visit the University Laboratory, where he thought ladies "had even more opportunities than in Sweden." She found many of the students working on elementary chemistry, qualitative analysis, and the preparation of organic compounds, while for quantitative work they went to the Polytechnic School. "Lady-students are admitted on equal terms with the men, and the examinations are open to them. They receive their diplomas. Only in law and theology they cannot receive a diploma, for they cannot practice those professions, but they study both branches if they desire to do so." She found that lady-students were also admitted at the Polytechnical Laboratory under the direction of Dr. S. M. Jörgensen, and that several had studied there though "not with a view to practical application of their knowledge." She was delighted with the Carlsberg Laboratory, which had been founded by a Herre Jacobsen, but after his death, in 1878, had come under the special patronage of the King. Professor Hansen, the director, "a noble specimen of a gentleman, thoroughly courteous," welcomed her "as the first lady who had ever visited his laboratory on a scientific mission, and he expressed his admiration and gratification." He told her that "his laboratory was first for the acquisition of scientific truths, secondly for imparting knowledge, and that students sufficiently advanced were free to come, but they must be acquainted with some chemistry and botany, since those subjects were not taught elementarily."

Dr. Hansen had been cultivating many specimens of yeast-ferments, and had determined which species of yeast gave the best beers. Although he had not then found time to publish any account of his methods, she learned that they were carried out in a Chicago brewery.

"Hansen said it would be necessary for one to come and work by his methods to understand his work. Many of his yeast-cultures have been living many years. He said that when he was an old man he would perhaps give into the hands of his successors culture-cells that were started years ago! He keeps alive these cells in solutions of sucrose. He has experimented widely in making different species of these organisms, and he hopes to work out experimentally the chapter of Darwin on the variation of species.

"Hansen has promised to send me his publications. He gave us to drink some of his scientific beer."

Early in October, Miss Abbott left Copenhagen, taking "a remarkably shallow and long boat from Korsör to Kiel. On arriving in the dark of the early morning of the 5th, she and her maid went to the Hotel Germania, were "shown into a large cold room where they shivered in beds covered with down pillows until eight," when she despatched a note to Professor Ladenburg asking if he would receive her, and on receiving his courteous reply, started out for his laboratory, the peculiarities of which she describes with the usual accompaniment of illustrative drawings. Of this visit she says: —

"His rooms are in the university, beautifully furnished, indicating a love of art and refinement. Ladenburg was charming in his manner, so courteous, and giving me the fullest information in regard to the apparatus. What a pleasure it would be to study under such a man, and in such conditions! But it is impossible since no lady can enter as a student within the university walls.

"Ladenburg showed me his specimens of synthetically prepared coniin. He has obtained two, one which turns the plane of polarized light to the right, and this one, physiologically and in every way resembles coniin obtained from the plant. The one which turns the plane of polarized light to the left is not like the natural product. He has been many years obtaining this synthetical product.

"My visit to Ladenburg was wonderfully delightful. I should have been glad to question him as to the course for students and methods pursued in investigation, but the time was limited. He had previously arranged to go with Mrs. Ladenburg to Hamburg to the theatre, and it was impossible to undo the arrangement. Mrs. Ladenburg invited me cordially to visit her on my ever coming again to Kiel. She served me to chocolate she had learned to prepare in Holland. The service was of very costly silver; a kind of cake curled, and tasting like lady cake with cinnamon,was eaten with it.

"A visit to the Museum of Antiquities, where an Anglo-Saxon boat built 1500 years ago, and other Wydham Moor relics well repay study. The Zoölogical Museum and Botanical Garden closed one of the eventful days of my trip." She spent two days in Hamburg where she visited the famous Technical School for Girls. It may be all told in her own words which were written down later in Nuremburg.

"October 6, 1887, was spent at Hamburg — Hotel Kronprinz. Sent my card to Dr. Wiebel, but failed to find him during my two days' stay. Early on the 6th, I sent my card of introduction by a *commissionnaire*, who spoke only German, and from a lack of teeth and other obstacles in his way, I found it difficult to comprehend if my letter had been delivered and received. No answer ever came. It may be Professor Wiebel was absent.

"I hunted out his laboratory, which opened back of his dwelling upon a very old street. The houses were extremely old, and two were built at an angle so close together that passage between was quite impossible, and even the light was impeded from entering some of the windows. I had difficulty in making the *commissionnaire* go to the laboratory door with my card. I remained waiting in a garden outside of the laboratory building. Ten pairs of eyes watched Fannie and me, for some time, no doubt, wondering why we came and what we wanted. During the delay, I could see through a window that energetic conversation was taking place between three men, evidently assistants. I noticed that the windows were utilized for carrying on chemical operations. The sides were of glass slats which, by an iron rod, could be opened at will. It is a very marked feature of European laboratories to utilize their windows for chemical operations, and in botanical laboratories for little hothouses.

"After a few minutes an assistant appeared, who most affably took me over the Institute.

"Dr. Wiebel's laboratory is a private one, and his students are from the University, especially during the summer months. I believe one or two ladies have studied here. The only condition exacted is that they should know German. There seems to be no obstruction to ladies studying anywhere in the private institutes; the regulation preventing their working in the laboratories applies only to government schools. The Minister of Instruction himself holds the right to grant permission even here, but I am told that permission is rarely if ever given by him. The rooms though small seemed to be conveniently fitted up, but there were none of the great conveniences of the newer and larger laboratories."

Dr. J. Brinckmann, Direktor des Museums für Kunst und Gewerbe in Hamburg, gave her a card to Frau Rée, the head of the Woman's Art Industrial School, and on the following day she made her a visit, finding her "a lady perhaps over fifty, with hair brushed smoothly down each side, and a quick blue eye." She says: —

"The Gewerbeschule für Mädchen was started from a very humble origin by Frau Rée. She took almost from the streets young and ignorant girls who had no training or education, and in a few small rooms had them taught the rudiments of education, such as writing, arithemetic, and grammar. The money for the present building was raised by subscription. At present the institution is supported by the school fees, and the payment by the public for work done. There is very little capital from which to draw money. The highest school fee for one year is 180 marks. The average is 150.

"The time of the course is about two years. The girls are expected to work about thirty-six hours a week, six hours a day, from nine to three o'clock. The present number of students is three hundred, varying from fifteen to twenty-five, though women of thirty years have come. There is no distinction made as to rank, all classes must meet upon a common footing. Many are the daughters of very wealthy men, merchants, landed proprietors, and others; one of the teachers was the daughter of a landed proprietor. Even some of the teachers now in the school were former pupils, well-to-do, and would have no need to work but do so from preference. Even now in Germany it is quite common for girls of good families to secure positions as governesses or to help in the domestic work.

"The girls' schools of Hamburg give an ordinary good school education, but there is no 'higher education' of the women here, no colleges, and the universities are closed to them. Frau Rée considered that it was purely for a monetary reason, as it is scarcely possible for a man of education to get a living since there are so many educated men and few openings. They fear if the intellectual avenues are open to women that they will have even fewer opportunities than at present. Frau Rée said Germany was a century or so behind in this respect. She described the North German, the Prussian, as the representative of centuries of culture, very able and conscious of his thoroughness in education, a little overbearing, but really of good stock.

"She described the people of South Germany as lazy and of less active temperament. She thought that Wiebel would have helped me very little, and that there was nothing of special interest to me chemically at Hamburg. She described Ladenburg and his wife (she is a daughter of the botanist Pringsheim) as being extremely delightful and advanced people.

"In speaking of the woman's suffrage movement in America, she said it had done harm, and that those women who were advanced could afford to wait, but that women were not as a rule prepared for it, nor fitted generally for the positions they claimed by suffrage.

"The new building where the school is now was entered in 1874. One feature I noticed about the school is the fact that very capable students are frequently paid to do the very finest art work. They were engaged in embroidering samples of the kind of work that can be done in the school. These samples are sent to museums, etc. They are at present preparing a set for the Museum in Stockholm. The character of the art work is general, embracing embroidery on linen or satin of every description, copies of Japanese patterns, on crèpe, and the long embroidery Japanese stitch in colors, beadwork, finest of laces, etc. These samples are expensive because they are the finest of needlework. Two hunderd and forty marks was asked for one sample of linen which contained about nine different kinds of embroidery.

"Frau Rée thought that it would be necessary to have samples of work in a museum, or in a school, showing the development from the more simple to the more elaborate. She said in case it was desired to have these samples, that if she were informed of the amount of money that could be spent in this way, she would do her best to select typical and good specimens.

"The teachers were formerly obtained from Vienna, which also has a famous industrial school, but she found the teachers less anxious to work than the North Germans, and they now train their own teachers. She said the drawing was the most expensive; the teachers required higher salaries, doubtless, than the others. The South Kensington Museum Frau Rée felt was too limited. The work done there is exquisite, but it is usually done by ladies in reduced circumstances. Frau Rée thought that such a school was much needed in London.

"She has various departments of industrial work in the building, French, German, and book-keeping classes. The latter idea was introduced from Munich and Nuremberg. However, there are few opportunities for girls getting situations for book-keeping in Hamburg. The idea of women taking care of accounts, etc., has worked so well in France that Frau Rée saw no reason why it would not work well in Hamburg. Typewriting is not much done, nor is there much call for stenography. Formerly the school had a class of stenography, but not at present, since there seemed to be no demand for it. The Hamburg merchants are very particular about the handwriting, and one of the first questions asked is, 'Does she write a good hand?' Samples of the different kinds of writing done was shown by the teacher in charge. It was absolutely perfect in every kind of writing and figuring. Drawing as a foundation for forming good seamstresses and dressmakers was accentuated very strongly by Frau Rée.

"Many of the pupils were occupied in designing original patterns. These patterns are afterwards worked out in bead or silk embroidery in the art-room. The patterns were all cut in the underclothing-room on scientific principles. They were first drawn on paper according to measure, then cut. They were also taught the rules of enlarging or making smaller. The sewing on white goods was exquisite. Every kind of stitch known was made on pattern-slips of linen two or three feet or less long. The seams sewed on the bias were marked, 'Felled seams on the *bias*.' To pass the board of examiners, it is necessary to have made a shirt or chemise by hand, as well as other articles. The board of examiners is composed of men. On being asked what they knew of sewing, Frau Rée laughed, and said that she was trying to have women appointed on the board.

"On account of having no special printing-establishments in Hamburg, there are few opportunities for a girl to get a situation as a designer.

"In speaking of the little regard for educated women, she said those lady-doctors in Hamburg, who had studied dentistry in America, were not allowed to put out their signs as American dentists. Also I believe that one of the professors in the dental department was not permitted to use his American title.

"All the girls who study underclothes-making (they are here trained for going into large white-clothes establishments) must learn to sew on the machine. Frau Rée said that the American sewing machines were the best in the world, but that Americans could not sew the best on them; when Singer, or Wheeler, or others wish to exhibit samples of what their machines could do, they would send to Hamburg to hire the work done. The pupils made entire garments out of white tissue paper, sewed with the same care and skill as if it were in linen. Carefully feather-stitched around the neck and sleeves, the little chemises looked very dainty.

"Frau Rée said the pupils delighted to make them, and she encouraged it, since it gave lightness of hand.

"Orders for underclothing, art work, millinery, washing and ironing, lace renovating, etc., are taken from the public, and the pay goes to help support the institution. Frau Rée said that any industrial school, starting, should always take in work from the public; it made the pupils more careful. Fine work would only be done by those who were no longer pupils, but who had been engaged by the Institution to do this work. Room after room is filled with classes.

"In the basement is the laundry. Young girls come and wash for three or four hours once in ten days or so. They all learn. Frau Rée said that as soon as a girl became betrothed, she came to the school to learn washing, etc., in order that she might tell her servant how it should be done, or in case of her going to remote country districts and out of reach of servants from any cause. It was quite a pretty picture to see two young girls of fifteen or sixteen starching collars. In the laundry-room the laces were done up equal to new. It was impossible to tell the difference. She said that many ladies brought their finest laces, knowing that they would not be injured. The charges in the laundry were not above the laundries outside nor lower. For very fine work, the charges were proportional to what was done. They are taught to clear up their shop after washing. Frau Rée said that often when some proud girl would not condescend to wipe up the floor, she would stoop down and clean up her place. The young girl would color, but the second time would not leave a wet place.

"I noticed that strict discipline seemed to be exerted, and the pupils were addressed with much firmness. We had a little talk on servants, etc. Frau Rée said that the prejudice in Germany against women earning money was still very strong, and that her own husband would not have permitted her to take a cent for the work she was doing at the school, though she remained there from eight to five. Having no children at home, and her husband being engaged in his work, she was free to give her life entirely to her work. She agreed with me that the servant was often the product of the mistress, and when a servant saw that the lady herself did not work, she was apt to impose. It is the spirit of the age, said Frau Rée, that the public are above work. Work is looked upon as a disgrace. Only by years of patience can things be better.

"Frau Rée would have liked to combine a kitchen with the school, but she said the building was too far out of town, and pupils would not come so far for the food. Her idea, the leading one, was always to do for the public.

"This lady has erected a monument to herself. It has been a colossal undertaking, — now a success and running fairly alone. The excellence of the work done in every department requires much time, and in this respect Americans are superficial, — they do not take the time to work properly.

"I could not help feeling that the two years spent almost entirely upon practical work was at the expense of intellectual training. Even supposing that the pupils had not the intelligence to become scientists or literary women, yet absolute handicraft is narrowing to what intellect they have. To introduce good, substantial work and art work into homes of the middle classes certainly is a good scheme, since it helps to refine and cultivate the lower. To what extent practical and intellectual work can be run side by side is a question. Also to what extent is intellect involved in so-called practical work. Many of the parents only allow their children to stay part of the course. This is the same old story everywhere. Many of the young girls are only learning in order to make their own and families' clothing.

"A half hour is given the girls for lunch during the day. Some of the pupils come several miles from the country to attend their classes.

"We talked over the difficulty to train servants in schools, when they had no means of support during their learning. In some cases, their families would be willing to help daughters to get a good training, especially when higher wages could be demanded for skilled work. Frau Rée believed that the public should, from the first, be called in to add to the support of any school of this kind, and on this account she took in immediately sewing, washing and ironing, and art work."

Here the account of the visit comes abruptly to a close, the remaining sheets having been lost or mislaid. From Hamburg, Miss Abbott went directly to Berlin, where she spent nearly a week.

She was pleasantly welcomed by the distinguished chemist Liebermann, whose "immense collection of organic preparations were most interesting. Case after case was filled with every variety of chemical compounds. It was certainly a startling sight to see so much of value collected together. During the lectures, specimens, as wanted, are exhibited. These large chemical collections are parallel to the zoölogical and ethnological collections in the big museum. It is in a great measure owing to such collections that the excellence of European work comes in." She adds: —

"I have found in all cases the utmost willingness on the part of scientific men to give me all the information possible in the limited time at our disposal. Never once have I seen the slightest sign of impatience or desire to hurry me away on their part. They seem only too desirous of imparting, without ostentation, information resulting from their own work. Here I want again to say that from naturalists (botanists included) I have had more sympathy and help than from chemists."

She gives an interesting description of Hofmann's famous laboratory: —

"October 12, 1887.

"About Hofmann. A silver-haired man, handsome. One who shows the result of high school associations, amiable, even charming in his manner. Speaks English very well. The places in the laboratory are so much sought for, that application must be made far in advance. I am to write and apply for a place in his laboratory, to avail myself of the opportunities of extending my knowledge. The question of attending his lectures would have to be done in secret, since women are not permitted in the auditorium, nor to work in the rooms with the men-students.

"I did not meet or see the members of Hofmann's family. His house, 10 Dorotheenstrasse, has always been the abode of chemists. Margraff, who first got sugar from beets, was the first to occupy it. Various busts and pictures of chemists adorn the laboratory walls.

"A new name to me was the Loggia. These are rooms which are open on the side to the fresh air where dangerous operations may be carried on or reactions which give off deleterious gases. There were several of these rooms. The space allotted for each student is small, and necessarily requires that only one operation be carried on at once. The number of water-baths, drying-ovens, combination-furnaces, is extremely limited, and it would seem that the students must wait their turns, a slow and time-wasting process, but impossible to be avoided. Closed tubes are used for combustions.

"The laboratory looked like a place, a home, which had not the personal supervision of a head. I see where my weak points are, and what is necessary for me to do to fortify myself by study. The beginners are made to work on some inorganic compound first for qualitative study; then they are hurried to organic chemistry. It is the worship of the benzole ring. The assistant told me that it was all he cared for. Tiemann, the one who has synthetically made vanillin, was absent.

"Hofmann's study in his house is quite a large room containing family portraits. Over his desk is a marble female bust. The furniture is black and gold, sofas and chairs covered with green. The carpet looks like chinchilla, a velvet one. The chemical lecture-room of the university (Hofmann's) is where the chemical society usually meets. I was present on the opening night, October 10. . . .

"Hofmann must be a most brilliant lecturer. I cannot help feeling that the centuries of cultivation, and the early university training, have established these men on a plane which we cannot yet quite approach. The absolute familiarity and recognized mastery of the subject on the part of these men is what the student would most profit by."

She gives a brief account of an evening spent at the Session of the Berlin Chemical Society, which she thought most interesting: —

"Liebermann took me. It was not a very large attendance. Hofmann presided. On his left sat Pinner; on the right Liebermann. A notice of a defunct member was read, then Hofmann introduced me to the members present by a very pleasant little speech. I believe I am the first lady who ever attended one of these meetings. There were some original communications. Then a little discussion followed. Pinner read extracts or gave abstracts of the papers sent in to the society containing new discoveries, etc. In some cases, he wrote formulas on the blackboard.

"Hofmann thanked him for his able presentation of the papers, and the meeting adjourned to supper, to which I did not go, though Liebermann asked me. The ladies at the Liebermann dinner thought I did well in declining the supper, and that I should have laid myself open to talk if I had gone. There was no temptation on my part to go. I met Witt. He speaks English almost perfectly, indeed with no accent. He is a large man (young), light mustache, and wears a diamond and gold rings on one hand, a seal ring on the other.

"He is especially interested in how the diatomaceæ dissolve the silica which they contain in their cells. He had by no means any explanation to give, except that the amounts found in them was greater than could be expected from the silica dissolved in salt water. In speaking of the amorphous condition of starch, he said he doubted that any amorphous substance could polarize light, and that all starch granules must be crystalline, although the crystalline character was not made out. Liebermann's communication before the society was an exhibition of dramatic gymnastics on the blackboard. It was given with an agility really phenomenal. Liebermann's eye is as quick as lightning. A rosy face, Jewish countenance, dark beard and hair, rather short stature and slender, make up his personality. He was most anxious to examine the chemical compounds in fresh plants, and spoke of obtaining indigo plants from Mexico. He thought that I should rather work on some well-known substance, which was not yet studied chemically, and which was of practical use. He was very nice about my work, apologizing in regard to suggesting, but doing it all so nicely that he could never have been objectionable. He questioned me with interest about my plant-compounds, and said it was an especially interesting field, and one that chemists had not much touched upon."

After her visit to the Hofmann laboratory and to Frau Liebermann's, she went to the Industrial School Museum, a building adjoining the Ethnological Museum, where there was an exhibition of students' industrial art work. Mr. Ewald, the director, conducted her over the room. She says: "All that has an industrial feature is taught in the building. Those departments which teach a trade where it is impossible for a woman to get employment are of course not attended by women-students. Both sexes work together. Professor Ewald told me he was the one to push forward the idea of admitting women, and to allow them to work freely in the classes with men. There is an exception in the life-classes, where women are not allowed. They study from the living model in the preparatory school, but in divided classes from the men. The other classes in the preparatory school are also divided, not from prejudice, Professor Ewald answered me, but because the classes of both sexes were sufficiently large to admit of separate classes, and that the women preferred to be alone. They only joined the classes in the higher school because the women were very few in number. The girls working in the few rooms which were occupied at the time I came, were timid and unaggressive, and seemed as if they were unable to resist any masculine pressure, and seeing the character of these girls, I did not wonder at the impossibility of their working with men in the laboratories. Yet Ewald told me they had never any trouble, and all went on peaceably. There were drawings from casts, the flat, and from life. One room was devoted to modeling. The models for beginners are first modeled in wax, part yellow and part white wax, colored. The vases are modeled in sections, then joined. All the fine modeling is done likewise in wax. There are classes of anatomy but given with the skeleton and few plaster casts. The etchings were very interesting. . . .

"The Lette-Verein is a large house, more like an apartment house, utilized to serve the purposes of the school. They take some boarders. The girls eat on a long table in the middle of the restaurant, whilst persons from the street eat on small side tables. The rooms are small, and the classes come in different numbers for several hours each day. The lady who conducted me over the house explained that in Berlin the girls had not the time to come all day, and some had even other occupations which made an all-day attendance impossible. On an average, three hours was all that was expected of them. The classes held two sessions per day. The second began about four o'clock P. M., but with different scholars. The attendant told me they took all girls of respectability who applied, but as some pay was required, the very poorest could not come. She said they did not care much for the lower classes.

"The institution had none of the earnest atmosphere of the Hamburg school, and the spirit of Frau Rée was absent. The art work was quite beautifully done. I saw none so beautifully done as the Hamburg samples. In the Kunst-Gewerbe Museum one thing pleased me, and that was the photographs of the different pieces of work. Professor Ewald thought that it was very important to get a general idea of the effect of any work. The cooking department of the Lette-Verein smelt of grease and fat. I was there after hours, and the kitchen had not yet been cleaned up. The washing-rooms were steamy and presided over by two very rough washerwomen.

"The scholars themselves very seldom do the washing, but learn from observation. The ironing is done especially well, and the Institution takes it in. The charges are high, the lady said, in accordance with the good work done. The house is under the especial patronage of the crown princess. Contributions have been given, and the scholars pay. But the lady complained of every one in Prussia being poor."

Her experiences in Berlin led her to make the following observations: —

"The position of German women, I think, is unenviable. The broader avenues are shut to even the few who could claim them. The domestic training of the women to become good housekeepers and economical is excellent, and might well be copied more by us. The thoroughness, too, of what education they have is also where they seem ahead of our women, but in comparing only the more highly cultivated here and our own highly cultivated, the American of to-day is doubly ahead in many ways. We do things, perhaps, too quickly, and it may seem to foreigners superficial. There is probably no woman in America capable of holding such a position through her ability as Madame Kovalevskaya. There is very much to be learned from the Europeans. Their tenacity and patience might here be imitated by us."

In Berlin, she was invited to a dinner at the Liebermanns, — "the table elegantly set and the food deliciously cooked in the French mode," — and she found it most interesting.

"We discussed many points of woman's position in Germany. The young ladies, after leaving school at sixteen, take conversation lessons in different languages. They do not study from grammars, but acquire superficially for drawing-room use several languages. They paint, do art work, and sing and play. Mrs. Liebermann thought that it was because the language lessons were fashionable that they were so generally followed. Mrs. Liebermann designed patterns for artistic work; many of her designs were given to the Lette-Verein. Her old mother executed them in work. One screen nearly six feet high was most beautifully done. Table-covers and other embroideries wherever art work could be used had been placed. This is very attractive and gives to nimble fingers employment which is preferable to the waste of time at home. Mrs. Liebermann told me that comparatively little time was spent in visiting — I suppose she spoke of her circle — and in this way much time was spent over lessons. Mrs. Liebermann took the lessons with her daughter, and I noticed the same elsewhere. The mothers take an active part in their daughters' and children's education, and if they do not become renowned women, at least they keep where they were when leaving school and do not retrograde. There is very much for us to learn from these mothers. . . .

"The ladies complained very much of their restrictions of liberty, and how Mr. Liebermann objected to their doing this thing or that. It is a question of the man keeping the control by imposing this discipline. Liebermann has a Jewish face, red cheeks, dark hair and beard."

She was also entertained at dinner at the house of Professor Pringsheim to whom she had brought a letter of introduction. Here also her notes give a pleasant picture of herself: —

"The Pringsheims were charming. The old professor especially was kind, giving me cards of introduction to those for whom I asked, also to others. The wife spoke only German and French, but the daughters spoke very good English. I cannot speak enough of the genuine kindness shown me. Mrs. Pringsheim invited me to come to her home and stay with her. My letter from Ladenburg must have been especially introductory from the reception I received. Mrs. Pringsheim thought that of course it was strange for a lady to come over for such a purpose as I had, also that Fannie would cause attention, but she said nothing of an objectionable nature could come from it as the object of my visit was so apparent, and Fannie held her place so thoroughly as a servant. Her quiet dressing and respectful manner gave at once a dignity to my position.

"At the dinner were Professor, Mrs. and Miss Pringsheim, also Miss Du Bois Raymond. The table was set with autumn leaves as decoration. They blended beautifully with the fruit on the table. Professor Pringsheim rather showed signs of slight displeasure with the decoration. Mrs. Pringsheim responded that Professor Pringsheim cared only for chlorophyll. I replied that I did not like chlorophyll, it was too difficult a subject. Professor Pringsheim in his list of botanists of all the world (it was a printed volume) had written down my name in ink as one of the botanists of Philadelphia. The dear old man showed it to me. He has a laboratory of his own, where he works when he feels like it. His home is large, and has a garden attached. Some figs on the table had grown in it."

She also describes interestingly an hour spent with Kny in his laboratory at the Agricultural School. "I went to him on Thursday, Oct. 13, after my visit to Landolt's laboratory. Kny has a good library attached to his rooms. The 'Botanischer Jahresbericht' contains extracts of all the botanical publications, and Kny said I should send to Dr. E. Koehne (Friedenau bei Berlin) my papers for notice. He has, in connection with his rooms, a hothouse for the cultivation of the necessary plants required for use in teaching. Both Schwendener and Kny are principally occupied with the mechanical rule of plant-physiology. Schwendener told me there was just now wanting in Germany a man who would devote himself to chemical physiology.

"Water-culture experiments are carried on here sometimes. He had a table on wheels which ran on a rail to an outside balcony where the jars could have access to the air and light. The wheels were controlled to go very slowly by a kind of crank. The hothouse was built quite on the top of the house so that there was no obstruction to light and air. Kny has displayed much originality in his methods of arranging his plants. He has injected many by mixing with the soil colors that have been taken up and followed along the tracks of certain vessels. In drying, the lines of these vessels can be most distinctly seen.

"He has his dried specimens between sheets of heavy paper and then placed in pasteboard boxes about the dimensions of a music portfolio, and four to six inches deep. His fungi are classified according to morphological points, or rather all morphological points which can be brought out as particularly characteristic are noted on the covers as features. The morphological characters of fungi are so strongly marked that they offer great chances for this means of identification. The phænogams and even the cryptogams had their various physiological or chemical characters given on the portfolios when they were especially notable. I think Kny had one portfolio devoted to plants especially characterized by containing iodine.

"The paper describing all this Kny presented to me. He is still a young man of perhaps forty or more, and he was most desirous of having me write him and meet his family on Sunday. I could not go, however, as I left too early to undertake it. He had many specimens of Brendel's botanical models, and praised them highly for the purposes they are intended to meet. Kny is also the author of botanical charts which I first saw in Copenhagen. They are drawn large and from the specimens. . . . He said it might be possible for me to work with him, but I might have to be in his dark room. This was indeed a funereal chamber, painted black. Formerly it was used for conducting spectroscopic experiments."

She goes on to describe a visit to Professor Schwendener to whom she brought a card of introduction given her by Professor Pringsheim. He received her pleasantly on Sunday at his home, and made an appointment for her to inspect his laboratories in the Botanical Institution on Dorotheenstrasse near Hoffmann's house.

"Schwendener," she says, "was rather afraid to say he would admit a lady-student. He was very firm in his opinion that the Minister of Instruction was so much opposed to ladies being admitted that it would be exceedingly rare to have the permission, and to do so without permission, was to lay one's self open to a severe reprimand. It is quite opposed to the regulations to have any women present in the lecture auditoriums, and when women attend lectures, they must do so under cover, behind a screen, or back of a window or door. Schwendener said he had been much reprehended for having Miss Gregory as a student, but as he had her in his private room, no one had a right to complain. My conversation with Schwendener was interesting in the extreme. My idea of chemical constituents was new to him. His only speaking German and French was a disadvantage as I was unable to do myself full justice. Both he and Kny offered to do anything for me which lay in their power. Kny especially offered his services."

She remarks on the tremendous advantage that European students had over American in the opportunities afforded by the universities, museums, and gardens. She was amazed at the great Botanical Garden of Berlin, with its 20,000 specimens, its stupendous palm-house, and its facilities for studying different species "classified according to order and all fully labeled." But she thought that the trees "seemed rather miniature and poorly nourished, especially those from other countries, and our American trees." She adds: "The more I go, the more I see the absolute necessity of knowing the art of drawing sufficiently to reproduce what one observes;" and this leads by a natural transition to a brief comment on her enjoyment of the National Museum, the Kaulbach frescoes, the splendid ancient statues and the fine paintings of the old masters.

Indeed she found so much to interest her in Berlin "with its colossal advantages that her stay of but a week, when months of residence was required, seemed "only an aggravation." She did not have time even to present all her letters of introduction. Thus she refrained from seeking out the famous Virchow, or Koch, the great experimenter, and several others; but she consoled herself by remarking modestly, —

"Perhaps, too, an idea that I had no claim to intrude upon these men, helped to keep me away."

Under the impetus of her art enthusiasm, so rekindled in Berlin, she went, directly on her arrival at Dresden, on the 16th of October, to the Gallery and to the room containing the Sistine Madonna, the effect of which she chronicles as overpowering. She immediately entered into an elaborate study of the colors, with the thought that a comparison of the predominant tones used by different painters would be interesting, and the suggestion "that the colors obtained by one master may be owing to certain impurities," non-existent in other localities, with the possibility that "our chemically pure colors of to-day are perhaps the artist's worst enemies." She would have been glad to spend months of study over the collection of pictures, many of which were to her "dreams of beauty," but she had only two days to spend in Dresden, "the charming old place of her childhood," and there was much else for her to accomplish. One thing she did not neglect to do, and that was to visit her former music teacher, whom she found still unmarried, and living with her old mother and sister in rooms "filled with artistic souvenirs." Before making any investigation of the chemical facilities of Dresden she visited the wonderful glass-works of the celebrated Blaschkas, and an extract from her account of them, well merits insertion here, —

"The father (who formerly made glass eyes) had been in America many years ago. He spoke Polish, Bohemian, Italian, and German. They have recently begun to model flowers after nature. They are artistic productions and accurate, after life. It would be a stupendous addition as a botanical collection of flowers for a museum. It has occurred to me that by beginning on a small scale I could collect the plants or these models and also have the chemical compounds contained in these plants, at least those compounds of sufficient importance. Blaschka has offered for $1000 to make Professor Goodale, of Harvard, a unique collection. He has as yet not replied, and I asked him to write me in case Goodale should not be able to accomplish it.[1]

"They said it would be necessary to deposit a certain amount, perhaps the sum that I wished to expend for the collection, and they would furnish by degrees, the flowers. They preferred to make the flowers directly from the growing plants and not from drawings. The matter was left in such a way that I was to write him what I wanted and the amount I was willing to expend on the plants. It is difficult yet to decide upon what I would order, whether flowers to illustrate an evolutionary order, or those which apply directly to my work. It will be later decided. I have an idea of forming a collection to become an embryo museum where the chemical compounds contained in any plant would be exhibited, and all else in connection with the plant also shown. But the chemical side made the most conspicuous.

"It would be a stupendous work to carry out such a plan as I have conceived. But with a great fixed purpose, there would be little time left for outside matters to come along as interruptions. I know of no place where the two ideas of botany and chemistry could be combined.

"The workshop of these men was a very small room. The flame was furnished by a paraffine lamp. It is not only glass blowing, but they called it modeling. Various colors of glass are used, and the flowers are also painted."

Her time being so limited, she determined to concentrate it on the Polytechnic which she learned ranked almost with a university for the grade of studies followed, though the students rarely studied for the love of study, but generally because they wished to follow some profession or business. Women

[1] The arrangement was subsequently made, and Harvard University has a unique collection of the Blaschka glass flowers, which are the admiration of every visitor.

were not admitted, "because there were no places for them in the professions, and it never seemed to occur to the director that they might wish to study for the study's sake."

Professor Walter Hempel, who had married an American wife and spoke English, received her "with the greatest kindness," and made an appointment with her to visit the laboratories, where he afterwards showed her many interesting pieces of apparatus which he had invented, particularly for his specialty of gas investigation. She says: —

"The atmosphere for study was most promising, and I was very much delighted with all I saw. Hempel impressed me as a very able man, and one whose methods of gas-analysis were both simple and good. . . . Hempel went over each room describing to me the methods and uses of his apparatus. Nothing could be more charming than his manner, and he is one of the exceptionally pleasant chemists I have yet met. It seems to be a sad fact that the farther removed the man is from the study of life, just so far is his nature blunt. The botanists have been by far the most agreeable and willing to aid me. My visit to this laboratory is one of the bright days of this journey."

Dr. Hempel gave her an introduction to his colleague, Drude, and she was most enthusiastic over his kindness to her. She thus describes it: —

"What can I begin to say of my visit to Drude! For he treated me like a prince. When I called at his home, I found the number, an old two-story long building, up one flight of stairs. I was shown into a very pleasant room. The servant made the mistake of taking my cards to Mrs. Drude. She is a bright-faced woman and, though she kept me waiting to change her dress, she welcomed me heartily. I explained my reason for calling, and then she went for her husband who soon came. He is associated with Prantl and Engler in bringing out the botanical encyclopedia. He is still quite young and enthusiastic over his work. He has made a special study of palms . . . and has given also much attention to the geographical distribution of plants, and showed me a map of the world which was divided into floras of a few districts, which is very convenient for general classification. Mrs. Drude has herself made some studies in botany, and many of the beautiful drawings in her husband's book were made by her. The collection in the museum is excellent, though the room is small. . . .

"His idea of having some of the plant's constituents exhibited with the plant was a particularly good one. The plan of the garden is given in the little guide which the author presented. But he will have in his new garden a slightly different arrangement. He had in front of his palm trees a small plot of ground with one bed given to each country of the world's flora. A little rise in the garden was called by Drude the Alps. We had much amusement clambering up the little wandering path. His rooms and library at the Polytechnic were full of interest. The library is particularly fine.

"The books are arranged according to the botany of each country. The collection seemed very complete and contained many rare and costly works. There is a set of plates, painted by hand, of all flowers. Two former kings of Saxony were great lovers of botany, and one had ordered this book to be made. Each painting is absolutely perfect of the flowers, and on the margins are paintings of the different flower parts. The books number ten volumes and were lined within the binding with pink satin. As the work is in manuscript, it has no other title than '*Plantae Selectae.* Centurin.' Most of the students in the Polytechnic are interested in botany only for its practical side, but those who wish to carry on investigations have the right to the libraries. The herbarium was not new, and under Drude's orders is undergoing renovation. The laboratory was small but fitted with all essential apparatus. An apparatus for measuring and recording the hourly growth of a plant was very delicate. The tracings of one plant showed that the greatest growth occurred during the night, especially between 2 and 4 A. M. The plant at night probably absorbs for its growth what it makes during the day. Outside of a window a glass case was built with opening doors for water-culture experiments. . . .

"Drude was simply lovely. He talked with me about my studies and about my chemical idea. He said if chemistry and morphology went hand in hand that it would be a great thing to have discovered it, and he seemed immensely pleased at the idea, saying that those who favored chemistry could employ this means for classification, etc."

Miss Abbott promised to send Drude various specimens of American plants, particularly the ocotilla and other Mexican flora which she had studied, and they parted on the friendliest terms.

From Dresden she went to Leipsic. She presented to Professor Johannes Wislecenus a letter of introduction with which she had been provided by Professor Ladenburg. She found him "a large, tall man with silver-gray hair." He received her at once in his study, and informed her that it would be impossible to offer her a place in his laboratory, as it was already very much crowded with men-students, and it was altogether against the rules to admit women. She was rather disgusted at the way in which he advised her to go to Zurich: "the way all women are shoved to Zurich," seemed to her "like the last stage of investigation which only pushes the problem of life so far back without removing the veil." He told her that it might be possible for her to attend the lectures, but that that "depended entirely upon the wishes of each professor and the exercise of individual right." However, he gave her a card of introduction to Dr. Ernest von Meyer, who he thought might be willing to take her into his private laboratory. Then without offering to show her his private laboratory, he turned her over to the tender mercies of an assistant who had general charge of his fifty students, to show her around the institution. Professor Wislecenus, when a young man, had been chemical assistant at Yale. She was impressed with "the great scale on which the laboratories were run," but she found comparatively few new or original pieces of apparatus; and her experience led her to the conclusion, that though the accommodation for the training of chemical graduates is immense, there was not much chance of obtaining the best education rapidly in these large universities. She says: —

"The heads, of course, are such eminent men that they are too busily engaged in their own researches to devote time especially to students. The latter are then given to the care of an assistant. The assistants even show the most minute manipulation, and it is a quite easy matter to become thoroughly conversant with chemical technique. In looking over the university calendar for each semester, one will notice the many different minor courses in schematic analysis, in spectroscopic work, etc., and each small branch has its professor and separate lectures. In this way it is possible to obtain an immense amount of facts quickly."

She had an interesting visit at the Botanical Garden.

"After a trial in German speaking, I made the servant understand that I would speak with Professor Pfeffer. He was out, and the servant could not name the hour for his return. As I was leaving the building, Pfeffer appeared, and I handed him Drude's card of introduction. He welcomed me kindly and said that the laboratory was not as yet installed. He had just come from Tübingen, where he said he had left a very beautiful Botanical Institute. He hoped in about a year to have a fine school here. He thought that it would be difficult to have permission to admit a lady-student. He had just come to Leipsic and knew nothing of the rules and regulations. . . .

"He thought that the most difficult problems in plant physiology were the mechanical ones involving mathematical explanation and treatment."

Professor Ernest von Meyer, to whom she presented her card of introduction from Wislecenus, and Professor Strohmann, an authority on plant-chemistry, showed great interest in her work, and made her feel that she might spend some months in Leipsic with great profit, since in addition there were good bookstores, fine music, excellent sources of chemical supplies, and admirable educational facilities including Pfeffer's botanical garden and Dr. Gruber's chemical physiological laboratory. Her diary has this interesting entry: —

"Oct. 20. Visited Prof. Ernest von Meyer's private laboratory. It is a private one, though Prof. Meyer is one of the professors at the University. Wislecenus thought he might admit me, and Von Meyer said that if he had sufficient notice in advance, he would make a place for me. He said he only took very advanced students, those who were preparing their dissertation, or who were pursuing researches. The laboratory is particularly a research laboratory.

"The rooms are few and small, but such a place as one would be willing to study in. He said that Strohmann, professor of agricultural chemistry and physiology, was my man, and gave me a card to him, which I presented at once. Von Meyer is an elegant gentleman, and the writer of a 'Handbuch der Chemie,'—I believe a new edition of Kolbe, but I am not sure of this. His reference library was small, but contained the best. I noticed very few, if any, American publications, and it just occurred to me how inconvenient it would be not to have access to English publications as well in investigation. This is where we have the advantage in our libraries, since we buy all the foreign and have our own, too.

"Strohman looks like an intelligent but more affable copy of Von Bülow, with gray hair, bright eye, and a very penetrating glance. He spoke and understood English so well that I was able to talk very freely with him about work and the future lines in which to pursue my studies. He was of the opinion that saponin and the study of the saponin plants was where I ought to stop and work up the matter thoroughly.

"In regard to the study of the chemistry of growing plants in different stages, he agreed to have anything planted and started in a plot of ground belonging to the Agricultural Station for my investigations. In order to save time, I should have my plants all ready to bring over, in order that there should be no delay, and that I should get to work at once. I might have some plants cultivated at home during this next summer, and at different stages of growth have them taken up, dried, and ready to study during the winter. It seems absolutely necessary to concentrate energies upon one group, or a limited number, for studying generally results in accomplishing little. Strohmann said he would take me into his own private laboratory as a special student. He seemed most anxious to have me return and to assist me with all his ability. He urged me to send him my scientific papers very promptly."

From Leipsic our eager pilgrim hastened to Weimar, with which she was favorably impressed.

"There is an air of homelike refinement in the homes and streets. The town seems to have been for all time to come influenced by the wonderful coterie of Goethe, Schiller, Wieland, Herder, and the hosts of others."

She found it "a relief for once not to have any educational institutions to visit," and she gave herself up "to the poetry of her surroundings.

"The weather was very uncertain. Sunshine, pouring rain, and hail alternated during the day. The low hills that surround Weimar, the park and delightful bits of old architecture, are all fitting for the residence of Goethe. The veneration in which that literary set was, and still is, held is shown by the liberal monuments raised to them.

"Goethe and Schiller, Wieland and Herder each have a fine statue raised in their honor. Many of the streets bear the names of these illustrious men. Their houses of residence are shown and preserved as the most precious relics. The house of the painter Cranach is also preserved, and the house which Liszt occupied during several years is also pointed out. Well may the inhabitants of this city be proud of its intellect, for the public good which Goethe rendered to the people is everywhere apparent.

"His house, a fine roomy dwelling, now belongs to the town. It was given by the last member of Goethe's family, now dead. No descendant of that wonderful genius is now living. Goethe's home is preserved very much as it was. It is now a museum of the scientific collections of minerals, painting, sculpture, and of books and engineering illustrating so plainly the wide culture of the man and his power of appreciating the good in all art, science, and literature. His workroom was impressive. Plain, modern desk, bookcases, cabinets containing specimens, table, and chair, all stand as used by him. Opening into his study was his bedroom with his bed, the chair on which he died. The table and cup, saucer, and medicine bottle last used. Each room recalled the man so vividly, that I expected each moment to see him stand before me. The greatest simplicity and refined taste were prevalent. The bedroom was very small and devoid of lavish decoration. Some of the paintings were a trifle coarse, but these were exceptions to the general tone. The reception room held many interesting paintings and a grand piano upon which Mendelssohn played. I touched the keys. Portraits of members of Goethe's family, of himself, and of his friends, Charlotte von Stein and Bettina, adorned the walls. Presents from famous artists of all objects were exhibited, rare medals, and rich golden objects. The handiwork of different members of his family were still in their accustomed places. His traveling-bed, and so many things mentioned in Eckermann's conversations, were right before me, so that any interest I had ever had in Goethe returned a thousand fold.

"The way through the room to the balcony leading to the garden is as dear to the art and Goethe lover as Gethsemane is to the pious Christian. To look upon the garden where Goethe used to walk and talk was like a dream. The rain was pouring, and as I looked upon the very trees the good man had planted, I remembered the curious phenomenon that occurred during the earthquake of Lisbon when Goethe mentioned at the time that some great terrestrial convulsion was taking place and still not a leaf could be seen stirring in quiet Weimar.

"The Bibliothek was formerly a residence, and the room where Goethe danced as a young man, when he first came to Weimar, is now the main library room. Goethe was the director of the library, and began the foundation of a museum.

"Here are collected heads of the distinguished men and women who once lived in Weimar. A colossal bust of Goethe, also Schiller. Goethe said of the bust that the forehead was that of Mephisto. A lovely head of Novalis held me spellbound. I tried to obtain a photograph of it, but could not. The upper part of the head was very full, with large eyes, and the face tapered to a pointed chin. A portrait by Vandyke of himself was hung unframed against a bookcase. The Schröder, also painted by herself from a glass, occupied a good position. Bettina, as a young girl and an old woman, showed a lovely face with pathetic eyes. In age, the face was sorrowful. The library contains a large number of books and many objects of interest: Goethe's court suit; his dressing-gown (light blue Japanese silk); the monastic gown of Luther, etc. An ivory walking-stick with a snuff-box in the handle, of Frederick the Great, is preserved in an upper room. It was in the possession of Liszt and given by him to the Museum. A belt of Gustavus Adolphus is shown. Portraits, miniatures, collections, many of them having been collected by Goethe or relating to him, give great interest to the room. A very original staircase occupies the tower: sixty-four steps cut from one oak tree, arranged in a spiral around the centre of the trunk which has been carved in a turritine manner. It is said to have been the work of a prisoner.

"The castle contains what are called the poet's rooms. The Grand Dukes have collected pictures or other objects of interest relating to Goethe, Schiller, and Herder, and frescoes on the walls illustrate scenes from the writings of each.

"To have missed Weimar would have been indeed an immense loss. For all time will my readings of Goethe recall this visit, and the sights that once influenced the poet will come to me and vivify each of the poet's thoughts."

Leaving her colored maid, who was ill, at Weimar, she went alone the hour's ride in a slow train to Jena with its four hundred-year-old university, famous as the place of the great naturalist, Ernst Haeckel. She was interested to see "the men along the road at the gates stand with their sticks in hand in military style," and the "women trudging along, carrying immensely heavy baskets on their backs." She noticed that the oxen at the plow were covered with bright-colored blankets, but a horse attached to a plow was not protected, and she explained the discrepancy by the supposition that "perhaps his actions are more lively and he is kept warm." The approach to Jena reminded her of Spain.

"The great antiquity of the town calls up such an unusual train of emotions. The high hills back give a grandeur to the place. A few quaint towers outline the town distinctly, as it nestles among soft, green trees.

"It was market day, and a band played folk-lore tunes from a high tower. This reminded me of the Moravian trombone playing."

She had no special letters of introduction, but, from the university directory, found who were the professors of chemistry and botany, and sent in her card, together with "her dear Smithsonian letter," which served her, as always, by opening to her at once all doors.

"The building where the chemical laboratory is situated was originally a house, and not designed for the purpose, but the rooms, though small and old, were more attractive to me than the larger and more attractive rooms of the great laboratory. Dr. Geuther, the chemist, was an old man who spoke some English, and welcomed me so heartily that I at once felt at home. He took me to see his collection of specimens. All are made by himself, or students in the laboratory. . . .

"The kind old chemist took me into his auditorium. The benches were primitive, as were also the appointments, and I felt almost pity for him as he apologized for his unattractive entourage. He doubtlessly thought that I had seen so much grander rooms that I would look down upon his. But the interesting lecture, illustrated by experiments, repaid for any lack of show. . . .

"We passed from room to room. I found an assistant working in one of the fatty acids. I noticed such neatness in the arrangement of apparatus, cleanliness, and all absence of smut or dirt. They rarely have more than one or two operations on hand at once, and seem to concentrate upon them their entire attention. . . .

"Another assistant was distilling some plant extract. The old gentleman shook my hand most warmly on parting, and asked me to visit him again, should I ever return to Jena. He was very lovely in manner and most courteous. I have found it so often to be the case, where I have had no letter of introduction, there I have had the most attention and kindness on the part of the professors. It may be that the letters of introduction which I take may prejudice them against me, in some cases, because the men may be rivals or have bitter feelings against each other.

"Another interesting fact is this: that in the small laboratories, the professors have been much more affable, and would give me personally their time, whereas in the larger universities, I should be handed over to assistants. This is an element to be remembered in case of returning for study. The selection of a place where I could have the personal attention of the director would be eminently preferable. The directors, in many cases, are too great men to be easily and familiarly approached, and are occupied very fully with their own investigations.

"Ladies are not admitted at Jena, and I could not help feeling that it was a wise decision on the part of the Minister of Instruction to prohibit it, since the German students, as a rule, are a rough, brutal set. Dueling in Jena is very common, and the faces of many of the students were badly slashed and showed the signs, too, in one case, of a very recent contest.

"I drove from Geuther's to the Botanical Gardens where I had hoped to meet Detmar. However, Professor Stahl, the associate professor, was in his laboratory, and after I had given a few words of explanation for the reason of my visit, he at once welcomed me and gave me an opportunity to talk over the botanical ground of Europe, and spoke highly of Strohmann — my Leipsic friend. The laboratories and lecture-room were very well lighted. The auditorium was hung with many botanical charts like Kny's. The alcoholic specimens were very beautifully preserved.

"Stahl said that up to this time no fluid had been found which would preserve both the specimen and its color. The herbarium was not new. I did not examine it. But a very novel and beautiful feature of the museum was the imitations of books. The front and sides were of wood, and the back was the bark of the same species with its characteristic lichens or other growths. The title of the book above was the Latin name of the plant. The book opened in half, and within were contained the cover, seeds, leaves, flowers, or any interesting or instructive object in connection with the plant. Stahl did not know who had made them, but he had seen them nowhere else. The university was established 400 years ago. With such a line of ancestry, the professors and students may well feel a pride in their surroundings.

"The botanical museums are far below the zoölogical and other collections, both in cases, arrangements, and in exhibits. Willrock's in Stockholm is far ahead. There would be a magnificent opportunity to form a botanical museum that might compare with museums in other departments. There seems to be often a lack among botanists of the virility that influences zoölogists and the other naturalists. . . .

"It occurred to me, from what I had seen in Kny's laboratory of injecting with colors, that flowers might be colored by this means before placing in alcohol. It might be possible to use insoluble colors, or colors that would not be dislodged from the cells. I got one very excellent idea from Stahl. He has a large tin box, made with double sides and tops and back containing water which can be heated from below with a gas-jet. It is a very large water-oven. Above can be inserted a thermometer to gauge the temperature. There are double doors and no means of admission of light. In winter time, by this means plants are germinated very rapidly. The temperature is kept quite constant.

"It is a great invention and would supply a need in germinating seeds for lecture-illustrations, etc., and would also answer for obtaining plantlets for chemical study. A glass case, in addition to this, which could also be heated by hot water from underneath, would enable a student to carry out, in his own room, important investigations. This is where my trip has been of such infinite service in giving me an insight into methods and ideas for my own study on a small scale. The botanical gardens in connection with all botanical schools are of great importance to the student. The hothouses supply the plants from tropical climates. The temperate and cold houses those from other climes, and the out-door beds contain the hardy plants and annuals.". . .

She learned that the evolutionary theory was not held in favor by the Emperor, who had grown very pious in his old age, and that consequently the professors were wary about promulgating it. Even the great Haeckel had been pretty severely handled on account of his advanced ideas, and would probably have been called to Berlin had it not been for his outspoken defense of evolution.

She found time for a hasty trip to the city museum, and was fortunate enough to meet the art-director, with whom she had a pleasant talk.

She left Weimar on the morning of the 23d, but for an hour before the train started, she strolled through the old town, passing by Herder's house, which she found larger and more pleasing in appearance than the one which she the day before had supposed to be his. Hearing the strains of music, she hastened down to an old street with tumble-down houses in it, and was surprised to find a band of about fifty brass pieces playing the Brünhilde "Sleep Theme" from *The Walkyrie*, and she thought how in America such a concert would have brought two or three dollars. It was Sunday morning, and she noted the children going to Sunday-school or church "two by twos."

She found the slow, deliberate ride from Weimar to Würzburg very beautiful, as it passed through the Thuringian Mountains, clothed in autumn coloring, and here and there guarded by old ruined castles.

At Würzburg she presented a letter to the famous Emil Fischer, a young man, with brown beard and hair, and bright eyes. He at once received her and conducted her over the laboratory, and through the students' rooms, which she found "much more homelike and suggestive of comfort than in the larger laboratories." Dr. Fischer showed her many of his preparations, particularly the substance from which he had synthetically formed glucose. She says: —

"Synthetical chemistry is the specialty of the institute, and it reigns in supreme power. I put the usual question to Professor Fischer, — if he would allow a lady-student to study in his laboratory. He stated that it was not permitted, but he promised to write and let me know. He is very agreeable, and we spoke together in French, since he spoke little English and I understood little German."

She had caught a bad cold, so that in spending some time in seeking for a Russian bath, she missed seeing the Botanical Garden, Museum, and Laboratory which she greatly regretted. She says, "The effort ought to have been made."

At the quaint old city of Nuremburg, in spite of her sore throat and chest, and the intensely disagreeable weather which greeted her with hail and snow, she found great pleasure in all the curiosities there displayed, — the Roman tower, the Castle, and the instruments of punishment used during the Middle Ages; the fascinating houses and churches. Some of these "infernal means of torture," with their brutal humorous names, she depicted with her pencil. A sketch of St. Lawrence's church spire adorns her manuscript. She was amazed at the wretched taste displayed in restoring some of the rooms in the Schloss, and their furnishings of "common dark paper and mean furniture," but the wonderful views across the country delighted her. She spent some time in Albrecht Dürer's house. One little glimpse of the interior which she gives might have been painted by Dürer himself:—

"An old man, the janitor's father, lives at the top of the house. He is a distinguished glass painter. He is nearly eighty years old. His room was scrupulously clean though very simply furnished. His windows were adorned with bits of painted glass, — copies from Albrecht Dürer's paintings. In the corner, between the stove and a window, were the easel, stool, painting brushes, the old clock hung on the wall, a set of pipes. The colors were in a little chest of drawers. The old man must have been a lover of art, for a copy of the Sistine Madonna hung on the wall. Two soft, lovely cats kept the old man company. He had placed a sheet of paper on a chair for one cat, but the other cat had to be satisfied with a stool before the fire."

She also visited the old Rathhaus, the courtyard of which dates from 1340. The building, with its wooden ceiling and quaint chandeliers, and its enormous paintings by Dürer, is now used for concerts. At the Church of Our Lady, a wedding was taking place. She was impressed by the superb stained-glass windows, especially the reddish-violet color, which she had never seen except in old Chinese porcelain. She also gives a rather elaborate account of some of the curiosities in the immense German Museum.

One of the great treats of Nuremburg was a late afternoon visit to the Albrecht Dürer restaurant, so called because the great painter himself used to go there to drink his beer. She notes that "the little, low room has been frequented by crowned heads and the greatest celebrities of Europe." On one of the age-and-smoke-darkened walls hung a framed poem composed by Carmen Silva, Queen of Roumania. She was much amused by the sausage factory connected with the tavern, and thus describes it:—

"The house is famous for these as the dish is made on the spot. Two fat, live pigs were in a clean pig-pen in a corner of the little house, waiting to be killed. The flesh is at once boiled, chopped, and made into sausage meat. This is put into a kind of mill like a coffee-mill, and comes out of the pipe the size of a sausage, and is then pressed into the skins. Everything about the working was so clean and interesting, that the further evolution to the kitchen, and the final sausage consumption followed, of course. The sausages were broiled upon an iron, very close over a coal fire. They were browned almost immediately. Cabbage is served, too. The little kitchen was filled up with old appliances, and took the visitor back quite to olden times."

At Nuremburg there seems to have been no chemical attraction, but in company of a quaint old character, whom she called her "guide Napoleon," she visited the Industrial School of which she has this to say:—

"It was very poor in comparison with Hamburg. The rooms, as well as their inmates, were very dirty. But one of the head teachers very kindly explained about the school, and lent me later a book with the drawings of the shape of the garments and descriptions. The ages of the pupils vary from fifteen to twenty years. The average school-term is for ten months.

"The first months are spent in needlework, the second in muslin work, and the last in dressmaking. They do little, if any, art work, but they hope to carry this on later. Book-keeping will also be taught later. The idea of this school is that it shall be a continuation of the elementary ordinary school, for here the studies taught in the schools may be carried on to a more advanced stage. French and English are taught as well as German. The school expenses are met by the fees paid by the students; also the State contributes per annum 500 marks. At present the school has four women-teachers and two men-teachers. As in Hamburg, the candidates for examination are examined by a gentleman appointed by the State, and if the candidates are successful, they may be engaged, by right of their certificates, as teachers in the school.

"The teacher, Miss Winter, who kindly made the copy of the cutting-book, studied in Munich. These schools do great good, and meet a certain demand, although I am impressed with the thought that there is a great dearth of intellectual stimulus. The German women, however, are trained very equally, and, as I was later told by Mrs. Smith of Freiburg, one observes less distinction among the women than in our country. Each one, as far as she goes, is taught very thoroughly. The higher studies are not especially encouraged. It is not the custom of the country for women to turn their attention away from domestic matters, and it is particularly unfashionable as well. . . .

"The girls buy their own materials, and what they make they keep for themselves. The principles are quite different from Hamburg and Berlin, where all is done for the public and for sale."

From Nuremburg she went to Munich, where she arrived on the evening of the twenty-sixth. The weather was cold, and the buildings were so large that they gave the city a cheerless aspect. The next morning she visited the new pictures at the National Museum, which as usual she criticises with intelligence.

Unfortunately her accounts of a visit to Baeyer's great laboratory, as well as the Botanical Institute under the guidance of Professor Löw, are missing. From Munich she proceeded to Zurich, where Lunge, the director of the chemical laboratory, assured her that it was quite unnecessary for her to present any letters to him, since she was very well known to him, some of her work having been described in the "Berichte."

He explained the situation very fully to her: —

"The Polytechnicum is quite distinct from the University, and cannot confer degrees; but after a very severe course of study, and a hard examination in several branches, they give a diploma which entitles the student to go, with this diploma and a dissertation, to the University, and after a very light examination from that faculty, to have the degree of Ph.D. conferred. Or it is possible to pursue two or three branches and then to go up to the University faculty and be examined by them. This examination, of course, would be difficult, since the professors who examine have not taught. This is frequently done, however, by students. The chemical courses are so extreme that five semesters are required to cover the entire ground. Lunge advised my returning preferably for a summer semester for the start. This begins in May, but the student should arrive early — not later than the middle of April. The chemistry is divided into so many departments that a student may select almost any line for study. Lunge said the chemical school was almost unsurpassed for its advantages." He gave her other advice, in regard to a thorough grounding in German, for example, and to come to hear lectures in all departments of chemistry and botany, and then be free to avail herself of all advantages. This very much appealed to her.

Lunge invited her to dine at his house and presented her to his wife and children. At the dinner, she met a Japanese and a Pole. At table "Lunge discussed the comparative merits of the chemists of other countries. He thought the French to be immensely behindhand in not recognizing the studies of other nations. . . . Some of the French chemists have not yet given up the old nomenclature. He described the laboratories as old and generally poor." He thought that the inferiority of English and American chemists, when compared with the Germans, was due to a less thorough training and the lack of those long years of preparatory study which Germany required.

It seemed to Miss Abbott that it might be well to combine, if possible, the quick, progressive, and original character which Lunge attributed to the Americans with the solidity and carefulness of the Germans. "It occurs to me," she says, "as I have thought before, that the only guide to one's investigations must be the standard of the German publications." Lunge spoke to her of the few who were pursuing physiological chemistry, and of its great needs in research.

She was greatly struck with the mixture of nationalities in Zurich, and by the intelligence of the young Japanese whom she met at dinner. He had come there without knowing a word of German, and within a few days was already able to use the language.

Of course women-students abounded in Zurich, but Lunge remarked that their conduct was sometimes objectionable. She was overwhelmed at the magnificence of the laboratories, though she thought Lunge's department was deficient in apparatus for extracting the constituents of plants, and doing plant-work on a large scale, — a lack which their abundance of means would easily correct. The rooms seemed to her lighted and heated admirably, and everything was "so clean and bright that a student would enjoy working under such auspices." The general impression was so favorable that she was inclined to return there, especially when Lunge told her that she would be received as an advanced student and allowed to follow whatever courses she pleased.

From Zurich she went to Berne, which she found "of wonderful interest," with its splendid views of the Bernese Alps covered with freshly fallen snow. The lower part of the town was swarming with children, and she was struck with the beauty of many of them; she wondered that some of them were not drowned, for "a rapid current runs in the street near the river's bank." Of course, she, like every one else, was drawn to the bear-pit, and she was interested in the ingenious way in which the bears were fed. At the astonishingly fine Museum of Natural History, the mineral collection suggested to her the advisability of studying the carbonates occurring in minerals, as including amorphous conditions, and determining if all minerals tending to organic forms are carbonates.

She spent the afternoon of November 1 in an excursion to Thun and Interlaken. The weather had cleared and the Alps stood out most sharply defined. She says: "The water of Lake Thun is perfectly clear, and the bottom can be seen many feet under water a long distance from shore. The old town of Thun is perched most attractively on the side of a hill overlooking the lake and facing the mountains. What more heavenly spot to select than this? The grandeur of the Bernese Oberland cannot be more felt than under these conditions under which I saw them. The total absence of clouds and the soft, turquoise blue sky recalled the land of Italy beyond, but the intense cold recalled the many tragedies which have occurred among those heights of snow. It was indeed the best view I had ever had of the Alps, and I felt my heart leaving me with the intense longing to stay among them. The autumnal sun, of course, added to the charm. The pine trees were lightly touched with a snowy mantle. Many of the rocky prominences where the pines grow scattered were also sprinkled. It reminded me of a grisly-haired old man.

"As the landing was approached, the Jungfrau and her companions rose in all majesty. The sky was of the tenderest blue. At the mountains' base, this color took on a deeper tone. The snow-fields interrupted this color symphony, and by contrast added new grace and beauty to the color gradation."

A short ride by rail took her to Interlaken, where she was fortunate enough in having a full moon. "As I opened the window, I believe I shall never again see such a sight. Not a cloud was to be seen. The Jungfrau was a field of silver. The red and blue stars showered smiles of admiration and light upon these snow-mounds."

The next day she went to Grindelwald, and saw the mountains absolutely free from clouds or mist. She was struck with the beautiful and artistic carvings on the exteriors of the many châlets that she saw, in contrast to the dirt and squalor that prevailed within, and the pale and pinched faces of women and children, testifying to the poor food, hard work, and miserable surroundings. She learned that the guides had a hard time to make both ends of the year meet, the season being short, and their families often large. She felt sorry for the expressionless faces of the people whom she saw. "The little children look like old people, as if even at birth the age of the mountains had reflected itself upon them." She was amused at the absurd cut of their clothes; the men wearing homespun of snuff-brown color. "Some of the older men, when dressed in their best, have the tail of the coat cut very short like an abbreviated dress-coat. Their boots are of the clumsiest make with wooden soles and leather tops. . . . A story is told of how one of the mountaineers thus dressed went to camp, and the officer who made the inspection to see if his uniform and boots were right, looked with his one eyeglass at such a pair of nailed, solid boots which the poor fellow had brought, and asked him how he could fight in such boots. The mountaineer replied, 'Your boots are to run in, mine are to stand in.' With this he stamped his foot on the ground, and looked with contempt on the thin shoes of the exquisite."

At the Hôtel de l'Ours, at Grindelwald, she was delighted not only with the homelike food and accommodations, but also with the whole family of the proprietress, which consisted of a lovely, refined girl, speaking very good English, and seven sons. One of these sons, an alert, intelligent youth, beaming all over with the daring and manliness that come from an open-air, adventurous life, had been out chamois hunting in the mountains for two days, and, more fortunate than the famous Tartarin of Tarascon, had bagged one of those rare deer. He had spent the night before camping out in the deep snow, with the cold so intense that it had frozen his bread, wine, and cheese. She says: —

"He was a Protestant, and spoke of the two Swiss parties being powerfully divided on religious grounds, the Catholics being the conservative body, and the Protestants going in for radical measures. The President over all, is elected every four years, and may remain in office indefinitely. It occurs to me that it would be a very interesting study to collect the systems of governments and parties, and methods of election of all countries, and publish in a summarized form. Such information is probably scattered in geographies and other books; but in lieu of any such publication, I believe it would be of general interest."

She gives an interesting account of a Russian countess who had been spending the season at Grindelwald, making all the excursions of the neighborhood: "She ascended the Wetterhorn, and was obliged to stay two days upon the mountain, for a severe snowstorm came up. The proprietor said to look at her when she was dressed for the evening, one would say she could not walk a mile — 'not even to the glacier.'

"The day was so clear that I concluded to visit the upper glacier, and at once engaged a guide. The horse had to be caught and saddled. He was pretty lively after his week's rest since the last tourists had been up the valley. The shadow side of the valley was covered with a deep snow in contrast with the green hills where the sun shone. As we approached the glacier, the snow deepened. I had to leave the horse, and, the guide leading, I waded through snow to my knees; each step the guide tested before I advanced. I had one fall, as the ice under the softly fallen snow made the walking very unsafe.

"At the glacier, the snow concealed many crevasses, and it was with great difficulty that the entrance to the grotto was found. At last I entered and walked for some distance along the delicately blue tunnel. The imprisoned air-bubbles assumed the most fantastic shapes, and several curious features in the ice-formations indicated that glaciers would offer a fruitful subject for study. I believe that very much is yet to be done to explain the attendant phenomena.

"The proprietor said that twenty-seven deaths had occurred this year from mountain accidents. The most distressing was the Jungfrau accident, when six gentlemen fell 8,000 feet from the summit. They were walking along what is called a cornice, when it broke, and they were hurled to death. The proprietor, though accustomed to mountaineering, said that only the experienced and expert guides knew from certain signs the conditions of the ice and snow, and no one should ever undertake any excursion without a guide. These men who tried the Jungfrau ascent refused to allow any guide to accompany them, though several offered their services free. They made the ascent by a new route, from the Lauterbrunnen side called the Rotthal. . . . Miss Boss said they were quite in pieces when found, and were brought down the mountain in racks. Several other fatal accidents have occurred in the same neighborhood. The proprietor said that nothing, however, deterred an Englishman from making the ascent, though a hundred had been killed the same day.

"A party of Americans were at 'The Bear' on my return. Their vulgar talk and actions repelled me, and I gladly took the carriage to return. . . .

"It is advisable to travel out of the season, and the quietness of the surroundings with the magnificent scenery helped to restore my head to a better state than when I left Zurich. A life near these mountains would be the medicine for the nerve wear and tear of city anxieties and worry. I thought of a home near one of these lovely lakes where existence could be made absolutely blissful.

"At the return to the 'White Cross,' Interlaken, a supper awaited me; then bed. From my window, the moon poured a flood of light over the Jungfrau, and the snowy chain and a few brilliant stars looked like lamps before some sacred shrine."

On her return to Berne, she had several hours to wait, and spent them on the terrace by the old Cathedral where she obtained another fine view of the snowy Alps. At a garden dating from the fourteenth century, she bought a few flowers of the old gardener, and gave them to the three pretty children that were playing near the water's edge at the foot of the hill, at the base of the terrace. They "smiled at me and reminded me of the 'little maids from school.'"

At Bâle she slept at the "Three Kings," her room overlooking the river. Her mood of enthusiasm had somehow changed.

"It is dark and unsympathetic. The thought that this river will flow on undisturbed by the changes in the lives of men oppressed me, so that I gladly closed the curtains and sought comfort from the candle-light and fire. It is very strange to look on scenes that once were seen under different circumstances, and with others who may now be dead. It was in 1869, I visited here with my mother. This old river with its current and retarding whirlpools reminds me of Philadelphians, who with their progress must take it conservatively like the retarding action of the whirlpool on the molecules. What a contrast to the sparkling and quick intellect of other localities — just as marked as this big Rhine is different from the Alpine torrent."

At Bâle she felt "too tired and miserable to hunt up the university authorities," and so devoted herself to sight-seeing, though about all that rewarded her was the mediæval collection adjoining the Cathedral, and here all that she deemed worthy of chronicling was "two wooden statues of a man and a woman coquetting — a good example illustrating unrefined gallantry." After a three hours' ride from Bâle to Freiburg, she notes that she "feels quite at home returning to Germany." The next morning, which was the fifth of November, she went to the chemical laboratory of Professor Claus, who received her amicably and himself conducted her over the extensive rooms where there seemed to be great activity. "He is a tall, wiry man, with blond mustache and hair. He might be any age, dressed in a gray felt gown faced with green, and wearing a smoking cap on his head." She was pleased with the open yard around which the buildings ran, allowing excellent ventilation, and minimizing the dangers of explosion.

In the rooms adjoining those occupied by Professor Claus worked Professor Baumann, whom Lunge had told her to be sure to visit.

"I sent in my card and very soon was welcomed. He is still a young man, of full habit, with a yellow beard. He spoke little English, and our conversation followed slowly. He begged to be excused for a moment, and then returned with a gentleman whom he introduced as Dr. W. J. Smith, working in his laboratory. He reminded me very much of Dr. Brinton. He is an Englishman, a physician, who has left practice and is occupied with investigation at present on the changes occurring in seeds during germination. I found him very broad and intelligent.

"He conducted me over the rooms, and from him I found that Baumann was a wise and able master, to be absolutely relied upon as to his knowledge and power of aiding his students. I saw the basement-room where Dr. Smith is studying. On his table were three dishes of glass, such as we use for crystallizing. The bottom was covered with moistened filter paper, and on it many seeds were germinating. He covered these with a glass plate, and a dark cover over the whole to exclude light. The seedlings, as they grew upon their own resources, lived perhaps three weeks. The roots were of the most dazzling whiteness, and gave the appearance of the finest tufted spun-glass. Dr. Smith said they were studying a glucoside and later would attempt the synthesis of a ferment. He offered to ask if I might become a private student of Baumann, and to the astonishment of us both, he said 'Yes.' He even showed us the room in which I might work. It was a private room of his assistant.

"Dr. Smith invited me to his apartment, and the same evening Mrs. Smith called. I was unfortunately absent, having gone to a performance of *The Huguenots*. It was not of a very high order, but presented an interesting picture of provincial life. The theatre and its occupants reminded me of a great family party. The Grand Duke and some ladies of the party were present, and sat in one of the upper stage-boxes. Upon the Duke's entrance, a crier proclaimed in a loud voice that His Royal Highness had arrived. Immediately every one rose; then the orchestra began the overture of the opera. If a fire had started, every one would surely have been burned, as there seemed no means of ready exit. After the performance, a crowd was seen some distance down the street before the Duke's home, waiting for his carriage to drive up. It was too cold to stop, so I hastened back to the hotel. . . .

"The cathedral square offers one of the prettiest sights to be seen anywhere in Germany. The spire of the cathedral is openwork of stone of a rich brown color; old houses border the open place, and peasants with their Black Forest wares crowd all around the space. The country is quite hilly all around. The people seem kindly and sympathetic. One good woman on a side street has a large store of the Black Forest ware, and she allowed me to come into her house, and see where the pottery was made. It is very coarse, but the decoration and baking, as well as the moulding, are done under the roof. The military band plays at noon, and though I hired a carriage and waited through the program, my ears were not repaid for my pains. The event of the day was my visit to Mrs. Smith. . . .

"The lady was intelligent and well-read, and was taking an especial interest in woman's work generally. She said that the finest needlework she had ever seen was made in Spain, and one shirt in particular that had been made for the examination, was the most exquisite sewing she had seen. She spoke about the German woman's education, and said it had this general advantage, that all were evenly educated, and as far as it went, this was very well, for no one noticed the deficiencies of the other, and when one appeared with superior attainments, she was in such a minority as to be forced to hold herself in very much. She talked about temperance and other American ideas. The hour passed in the most agreeable conversation.

"A charming boy, their son, assisted in the delightful interchange of ideas. At the station, as I was dragging a heavy bag, a delicate little voice said, 'Give me your bag, please.' It was the child, and a few steps back were the father and mother. They waited until my train started off and wished me good speed."

November seventh found her at Heidelberg, renewing the memories of a visit made there six years before, but she missed "the dear presence of former companions and also the warm summer sun." She had a rather unique experience at the chemical laboratory presided over by the famous chemist, Robert Wilhelm Bunsen. She had no letter to him, but relying on her previous fortune, she drove to his residence, adjoining his laboratory, and sent up her visiting-card.

"After a wait, I was asked upstairs by Bunsen himself to his private room. I explained that I hoped to see his laboratory, and I was politely refused. He said that there was a law against admitting women to the university. I explained I had not come to study, but to visit. To this he replied that the laboratory rooms were now filled with young men, but if I would wait until Sunday — seven days — I could have the privilege of going through — probably. I explained that I was leaving Heidelberg that day. This seemed in no way to shake him, and so I departed, wondering what kind of young men were in his rooms, different from those I had already seen elsewhere in German laboratories."

From Cologne, where she renewed her earlier impression of what she calls the "monarch of cathedrals," with its mind-satisfying interior, she went to Bonn, where she was fortunate enough to find all the prominent chemists. Of Professor Friedrich August Kekulé, who had done so much to develop the theory of carbon-compounds, she says: "He is a very charming-looking person, gray-haired and bearded. He asked me why in the world I wanted to study chemistry, why I did not do something else! This was a very difficult question to answer. He had had a very poor experience with his lady-students. Two Russian ladies had applied and been admitted into his private laboratory. One killed herself, by taking poison intentionally in his laboratory. The other lady was always making combustions and reading romances, so as Kekulé said, he never got results. I may say here that generally, in Germany, the right to admit ladies into the professor's laboratory rests with him. It is his castle, no one has the right to inquire what he does there, and if the professor so pleases, he can admit the woman-student."

She had a letter of introduction to Professor Rein, who presented her to his wife, who spoke English with some fluency, and as she had a little time to spare, he took her to the Beer House, where they sat at the professors' table. It was so called because a number of the university instructors, lawyers, doctors, and scientists met there for an hour or so each evening and discussed all sorts of subjects, special or general.

After a long, tedious ride to Paris, the weather being stormy, she was ill for more than a fortnight, and unable to "record events in chronological order." Then she fell in with "a distinctly artistic set," and so did not push forward her scientific opportunities as she would have desired. But she visited the School of Pharmacy and got there some new ideas and learned that there were lectures at the Jardin des Plantes.

She visited the wonderful picture collection of M. Théodore Duret. Among them were seventeen Monets, which he had bought some time before when they still brought small prices. Duret informed her that, having his pictures, he wished for no wife. He slept on a low couch, which he called his bed, in order that he might give some turkeys, by Monet, a good position and light. She noticed on his table a new work on Spinoza, and asked him if he was an admirer. He seemed pleased to find her enthusiastic. He asked her if she liked Wagner, and when she replied in the affirmative, he said those things all went together. He then gave her his book and a letter of introduction to Whistler.

She was delighted with the magnificent collection of Japanese engravings and pictures which M. Bing had gathered together. She spent an afternoon and evening at his house looking over his treasures. She was amazed at the immense variety in Japanese combs, many with exquisite crystal tips. She also was fascinated with a "kind of jade green enamel quite elaborately ornamented with gold tracings." At his house, she met M. Gonze, the editor of "Les Beaux Arts," a great authority on Japanese painting.

By the twenty-second of November, Miss Abbott was in London again, full of zeal for her future work, and making arrangements for an ample supply of seeds, plants, and drugs which she found she could secure through Christy. This learned importer informed her that Huxley believed that no ill existed which some drug could not be found to cure. She was warmly welcomed by the junior member of Cross and Bevan's Laboratory, with whom she "discussed the field." He gave her some very interesting analyses and compounds and the results of his experiments with cellulose, telling her that each plant had its own kind of cellulose, that in the lower plants being less complex than in the higher. He listened with pleasure to her idea of the chemical evolution in plants.

One of her most interesting experiences in London was her interview with Professor, now Sir, William Crookes.

"His house is large and elegant. An open fireplace in his library insured a warmth, and he said to me that he could always think better in a warm room. Bookcases lined the walls. The chair before his desk was wooden, with two depressions where the thighs would come. The back was toward the fire, and the desk stood parallel to the fireplace, the side almost against the window.

"He is a curious-looking man, gray-bearded, and his hair also shows signs of snow. His mustache was waxed out several inches, and this gave him quite a unique look. He was handsomely dressed in dark cutaway coat and waistcoat, light trousers, and a brilliant red necktie with long ends. This color seems to be, just at present, the style, as I saw later several of them at the Royal Society meeting. I asked him to show me the photograph of his laboratory as I had seen it. This surprised him very much. He said, 'You must be a clairvoyant.' I described some of the laboratory to him, and he declared it was indeed like his room, but as the photographs were only recently taken, and he had not given them away, it was quite impossible for me to have seen them.

"We soon passed to his laboratory which was adjoining the library. He has in his first room the physical laboratory. There is a tool-room, also used for glass-blowing. Then the chemical laboratory. There is an entry which he can close into a dark room for photography. He told me that he amused himself a great deal with photography, and during vacations and on trips he always took his camera and brought back views. He showed me quite a number of recent ones.

"The physical laboratory contains a treasure: in fact many! A large stand on which rests his spectroscope, a most ingenious yet simple arrangement, where he obtains the most extended spectra. The reading is effected by an arc marked. This is *illuminated by the light being carried along a curved glass rod from the gas-burner to a little looking-glass* which is over the figures and magnifies them perfectly. I was enthusiastic over the glass rod. It seemed quite weird, and Crookes said: 'Can you not carry water along a glass tube? Then why not light along a glass rod? Indeed I can turn corners and carry the light wherever I have a mind to.'"

Professor Crookes showed her his induction-coil, — then the largest in the world, — and his various tubes, which she greatly amused him by calling "spooky." He explained to her how he tested the genuineness of gems by the use of his little pocket spectroscope, — "when by direct vision under ordinary conditions, by simply holding up the stone before a window, the most positive opinion may be had as to a stone's worth." A large diamond placed in a tube and subjected to the electric current gave forth the most beautiful phosphorescence. Others from South Africa gave a pale-blue light, those from India being harder gave a yellowish-green; others a yellow light. One tube containing a number of small diamonds of different qualities "were beautiful in their play of color when subjected to the electricity." He showed her a crystal of some lead salt which remained phosphorescent for some time after the current had been turned off. It gave the most brilliant apple-green color. She thought that, without exception, this exhibition was the most remarkable and interesting of her whole trip. She spent three hours in that "most wonderful room." When she went away he presented her with two or three of these tubes, one containing a large ruby.

She says: "I have not begun to do justice to my stay in his laboratory. Nothing could surpass his courtesy, amiability, and humor. He took me into his room containing his rare earths. They were kept in a glass case. He had the various rare earths from many sources of minerals and in many cases these were different in color from the earth source. I thought what an interesting thing it would be to find out if any one of the ash-constituents from different plant sources would present also differences. He showed me the first radiometer, and a series of electric bulb-lights from the smallest in the world to the usual size.

"Mrs. Crookes told the story. Professor Crookes said when he discovered his radiometer he rushed in where Mrs. Crookes was and cried, 'It moves.' She answered, 'Six oysters.' It seems that she was engaged in going over the fishmonger's book and found the account out six oysters. Crookes said he could never forgive her for this! This was all amiable. Mrs. Crookes is extremely agreeable and bright; both she and her daughter were most hospitable. I had been invited in to lunch, so we soon went into the dining-room. It is on the ground floor front — a very handsomely furnished room, rather dark, but at night illuminated, as are all the rooms, by electricity. A blessing was asked by Mrs. Crookes before beginning the meal. Miss Alice Crookes, Mrs. Crookes's mother, and a visitor made up the party. Mrs. Crookes regretted not knowing that I would remain longer, for she had gathered from my note that I should sail on that day, and they had no other free time. Professor Crookes said he would like to have given me a dinner and to have invited some of the chemists to meet me. I had expected to leave this week, and so had to endure the disappointment of missing this opportunity. After lunch, we went to the drawing-room and talked with the ladies. Crookes absented himself a short time to correct a proof but he soon rejoined us, and we went again to his laboratory and saw more marvels.

"It was suggested that I should go with him to the Royal Society meeting in Burlington House, and be taken from there to Dr. Armstrong, whom I was to meet, to go from Charing Cross to his house, half an hour out. Crookes said ladies did not attend, but he proposed to take me; so off we drove in a hansom to Burlington House, chatting on the way about many subjects, novels, art, etc. Many members had already assembled in the anteroom. A large table where tea, coffee, etc., were served was surrounded by members. Crookes introduced me to McCleod, Austen, Frankland, and several others; then we passed into the meeting-room. The papers were principally on palæontology (Seely). Professor Flower and Whittaker were present, and many others whose names I do not remember. It was very interesting to see the formal manner in which the meeting was carried on. At 5.30 we adjourned to the Chemical Society rooms, and soon Dr. Armstrong came, and off we went to the station."

She cites some of Armstrong's recollections of Germany and the German chemists and ends her account of that evening with these characteristic words: —

"I came back to London at 10 P. M. alone and reached the hotel independently. What a delight to be free! Armstrong said that abroad it was now quite generally recognized that women could go about in the most independent way and still be respected."

She had a long and "most instructive conversation" with Professor Holmes, curator of the museum, and lecturer on *Materia Medica* at the Pharmaceutical Institute, whom she found a man of immense knowledge of his specialty. He showed her a great variety of specimens of plants and of chemical compounds, many of them having the most delicate perfumes. She was interested to learn that great strides had recently been made in determining the genus and species of any bark or plant by its microscopical character. She questioned him very closely on points touching her own theory, but found that he had no answer ready; as in the case of others, "it is so eminently a subject foreign to their minds that they are unable to grasp the thought." He expounded to her an ingenious theory as the reason for the sap mounting in the spring: "He believes that the warmth of the spring sun shining on the trunks causes the vessels to expand and thus allow the sap to mount. I asked if the sap flowed more rapidly on sunny days than at night or on cloudy days, and he said he believed so. He had never been able to investigate this point and had never published his idea."

On the twenty-sixth of November, she presented a note of introduction given to her by Mr. Christy to Dr. Murie, Librarian of the Linnæan Society. She says: "The old man placed every book in the library at my disposal. I spent nearly four hours in taking notes and shall return on Monday. He allowed me to bring home with me some books from the library. One is in manuscript. I think women have every opportunity for advancement if they will only persevere. It will require very little effort to throw over the last barriers."

Professor Armstrong had criticised Miss Abbott's Yucca paper as showing evidences of hunting out methods and means for herself, and he discouraged this as a waste of time, and thought that she ought to be near some one who could teach her rapidly the very newest methods, and really help her in arriving at a successful termination of any research work. He thought that before going to Germany, it would be well for her to stop in England and have a good deal of personal supervision, since in Germany "one is left to carry out one's own fate a good deal."

On her return to America, she went to Boston, where she studied for a time under the direction of Professor Arthur Michael, of Tufts College, to whom she was married in June, 1888. In the summer of the same year Professor and Mrs. Michael started on a trip around the world.

It is unfortunate that we do not possess even brief and hasty notes of this memorable journey, which lasted about a year and a half. With her keen powers of observation, her unusual interest in art, science, and life, she would have chronicled a host of varied experiences, especially in Japan and in India, where the prevailing phases of religious thought would naturally appeal to her ever-widening sympathies.

In Japan she added materially to her unique collection of art objects, — rich silken embroideries, keramics, and kakemonos, especially those portraying "the harmless necessary cat." She had a host of bronze and porcelain effigies of her favorite pet animal, and among her treasures was one painted by a Chinese emperor hundreds of years ago. When she was in

Egypt, Brugsch Bey presented her with a graceful little bronze cat that had been dug up from a recently excavated tomb.

On their return to America, Professor Michael accepted the position of Director of the Chemical Laboratory of the newly established Clark University at Worcester. He resigned shortly afterwards, and the following year (1891) he and Mrs. Michael took up their residence at Bonchurch, Isle of Wight, England, where they equipped a private laboratory and continued their research work. After a residence of four years, they returned to Boston, Professor Michael resuming his connection with Tufts College.

For a time, while living in a charming home on Beacon Hill in Boston, Mrs. Michael resumed her chemical researches at the Tufts College Laboratory, but her interests were becoming enlisted in wider fields.

She was identified with many public organizations in Boston. She was an associate member of the American Branch of the Society for Psychical Research, the New England Woman's Club, the Walt Whitman Fellowship, of which she was at one time secretary, and the Boston Browning Society. She was one of the original members of the New Century Club of Philadelphia on its foundation in 1887; she was also an early member of the Twentieth Century Club of Boston. She was one of the original members of the Boston Authors' Club.

In November, 1895, she read before the Browning Society a paper on The Conception of Truth among the Greeks and in Browning. That same year she read before the Franklin Institute of Philadelphia, of which she had been elected a member, a "Review of Recent Synthetic Work in the Class of Carbohydrates." She also contributed several articles to "Poet-Lore," a valuable magazine edited by personal friends of hers.

In 1896, she went abroad again, and there are one or two passages from scattered notes which merit reproduction as showing how quick she was to respond to the beckonings of humanity. Thus in June she was at Linthal in Switzerland. She says: —

"On Sunday, June 28, at the Linthal church, all the singing societies from the upper Linthal villages assembled in a singing festival. The choruses were admirably sung, notably by the societies from the village of Diesbach; the men taking part were from all the village classes. Their faces were earnest; many looked intelligent; but a serious expression hardened by toil had sapped the life of inspiration. It was as if the soul's spontaneity had been crushed by labor. It was an affecting sight to see this number (400) from all these little far-away mountain villages, giving themselves up to the influences of music. I felt my heart going out to humanity in sympathy and with ardor. The thought again returned, when all the promises or creeds are found void, and humanity is left alone without perhaps even the possibility of attaining religion's ideals, what utter misery and despair! Cannot those who have already passed through religious and many other silenced ideals do something to lessen the anguish of their poor, bleeding hearts? Yes, it is a noble ideal to do something to assist this coming pang. The inscriptions on the village tomb tablets, assuring the toilers on earth that the poor soul is safe in heaven's peace, stand like mocking forms."

Two days later she went up the Sernfthal to Elms. She says: "A beautiful, clear day; drive romantic; village inn (Elmer's) very clean and so situated as to get a good view of Martin's Loch — a round hole in the Tschingelhörner, through which the sun shines only twice a year on the village church spire. It is a wild region, hemmed in by snow mountains, with their saw-edged rugged piles of stone. The spirit of the terrible landslide of 1881 hung around the spot. Under some circumstances, how profitable would the spot and scenery have proved for inspiration, the valley of approach passing through Engi and Matt, sombre at times, again opening out to the sunshine, with green fields spreading before the eyes, all inviting to meditation; but alas — the soul-communion with nature was disturbed by inharmonic influences. The breeze blew strong from the west, and brought messages, interrupted, but none the less real, from those that never fail to inspire. The excursion, from the negative thoughts, longings for more complete companionship, and the reflections on the disaster of '81, was still a profitable one."

About a month later, she was at Cortena in Austria, and here again the scenery leads her thoughts to religious expression: "The view from the Hotel Faloria is wide and grand. The evening lights give architectural reality to the summits. I thought I was looking upon an Indian rock city with mosques, minarets, and palaces. The red and purple coloring with tawny yellow shades gives already a superb background for the play of direct and reflected light. The groves of larch trees remind me of delicate, fringed ferns; the sunlight effects on these limbs, and the vistas through the pendant branches, give food for long meditation; the scene is one of great beauty. The rocky, huge amphitheatre surrounding this plateau vies with the clouds in taking fantastic forms. The air is dry and invigorating.

"A feeling of absolute peace and calm pervades me. This scene is a fitting cathedral for the services of the real religion of humanity. This calm completes existence. Nothing more is needed. Perhaps nowhere else could such absolutely restful elements be found. Sweet pine air — almost silence, no turbulent streams, a long way off a pale Nile-green stream murmurs — just enough sound to give movement to the scene. The mountains do not oppress — all gayly colored, not over 9,000 or 10,000 feet in height. They seem simply to exclude too much of the world."

After her return to America she contributed to a paper published in Portland, Oregon, a letter descriptive of her experiences in the Austrian Alps. It was signed Alfred Karson, the initials of which pseudonym she was accustomed, during that year and the next, to affix to the poems which she liked to send to her niece and one or two friends. This letter is sufficiently interesting and characteristic to cite *in extenso.*

A PAGE FROM A SUMMER DIARY

If I were asked to give of all the impressions of the past few months spent abroad those which were then and still are in memory the most vivid, they would not be of the streets and sights of a gay capital, nor of a much-talked-of artiste and a new opera, nor the pages of any recent literary success, nor yet a woodland scene of exquisite grandeur, but they would be the impressions of the daily life of a people in remote valleys of Austria. This peasantry leads a life of toil incessant, unfruitful, and hopeless, with no other outlook beyond the life their fathers led before them, with no other promise than the promise held out by the wide-stretching arms of Rome to her faithful children, in lieu of their allegiance. Not an unusual picture outside of Austria.

A people bound by an iron band of authority, forged by church and state, from whose clasp there is no escape. A happy people withal, the discontented possibly the exception; but happy only through an enforced ignorance of the truth; the awful reality of their own helplessness and hopelessness. Any day the disillusion may come. How unprepared are these people for disclosures! Can their condition be imagined at the awakening?

A people whose lands are taxed and mortgaged, only the strenuous exertion of united family labor, and that is barely enough, to meet their obligations. The money from this labor goes for the sustainment and support of the nobility, and the leisure classes. What are their lives? Very little beyond a round of useless charities, pleasures, and idleness in the cities. There is no need to enumerate in detail. Their lives are well enough known to all. They do not want for bread. Whilst the blood of the worn, scantily fed, meanly housed, poorly clothed workers is shed, literally drop by drop, for beings calling themselves human but — in fact incarnations of aimlessness. This contrast, so unjust, so inhuman, opposed to the teachings of the Nazarene whom all in that land profess to revere — cannot be portrayed by words. The condition must be seen to be felt.

In conversing with men and women belonging to the titled classes in Austria, I gathered that the desire on the part of the majority of these persons was only an echo of a common feeling to discourage the education of the poorer classes beyond a very limited standard. Others went so far as to pronounce all education for these classes baneful, as leading to discontent and final rupture from the limits of their narrow lives.

Again, many among the nobility are themselves simplifying their own lives, especially those faithful Catholics who may be classed as holding socialistic tendencies, their object being to lessen the space between the very high and the very lowly born. The simplicity of the home-life of these titled families of Austria, compared with the reckless extravagance of our own property-holding classes, would bring the blush of shame to the reflective American, who believes himself inferior to none. I do not accept this remedy, good in its intent, as sufficient to relieve this cancerous growth sapping the progress of humanity.

Not the architecturally favored gem of a Tyrolese town, nor the Ampezzo mountains with their natural rock-summit cities, all outlined as really against a blank blue sky as the purple coloring and tawny shades of their steep and precipitous foundations, nor yet the valley of Heiligenblut with its marvel of a church overshadowed by the snow-heights of the Glocknerwand; all of these, beautiful, pure and inspiring, fail to move the heart so strongly as the scene of a sordidly laid table for the toilers in and about the village inn.

The sounds of the evening Ave rang through the valley as these tireless toilers assembled for their repast, a break in the monotony of their hours. The table stood beyond the kitchen door in the open air, in full view of my window. Amidst this wondrous natural setting, these men and women had gathered to sup. One small tureen of some meagre soup, scarcely sufficient to fill the plates of the twelve or fourteen workers who had come to the table, comprised the menu; neither bread, drink, nor a second course supplemented the soup. I shall never forget the hungry-eyed glance of a woman, herself the expression of what her life had been, as she looked into the unreplenished tureen, and then to the tables in the dining-room, at whose boards sat those who scarce had known in their lives what hunger meant.

I will not detain you by repeating the gist of many conversations with the people that dwell in those valleys. Your sympathies would be moved to hear of these heartbursts,—the scanty and bare existence, the nominal wages and rewards of toil, the longing in some hearts for a wider life, the glimpse that some few had that all was not well in the world, the waiting of others for a helping hand and leadership where alone they would be powerless to go, the refuge of others in thoughts of a reunion through their faith with loved ones now afar, who have succumbed, alas! after years of anguish. The hope and aspiration of these souls, starving for sympathy, are engraved in words on stones and tablets of their dead,—to those dead, asleep under the guardianship of fir-covered slopes and distant snows, whose step will no longer resound within the walls of the green-spired church, around whose base their graves cluster.

I carried away with me the sense of a great oppression, an oppression the outcome and realization of what the causes of this burden to my senses might mean. The horror of these sharp social contrasts in life, whether brought to us by painter or observation, is as great as other horrors — indeed greater — because the source of the misery besetting our path. The errors of all systems fostering and harboring such motives of light and joy cannot be dismissed with a careless thought.

If I have brought these impressions for you to weigh, it is with the knowledge that human suffering is not peculiar to Europe, nor to any quarter of the globe; also I know by earnest effort a light will arise to dispel from humanity these shadows.

A passage from a letter written in October of the following year deepens the impression of the serious and increasingly religious trend of her mind. She says: —

"I have returned, if I may say 'return,' although I do not imply a retrogression, if the word carries with it that idea, to a state of mind I at one time approached; but, with the accumulated wealth of experience and knowledge, this state is not comparable with the old. The present condition is one divested of all externality or desire to give expression by external forms, where before Church rites and rules were the outward manifestation. Not that the state is one absolutely devoid of externality, inasmuch as my outward bearing and actions may not be identical with those of the past. Where more light shines the path is necessarily more distinct and the lay of the land clearer. But I referred to 'externalities' as direct modes of expression.

"The state is a deep sense of religious being and oneness with the spirit of Buddha, Christ, and the Prophets. It is inspirational with all religions, one with all philosophies, cults, or creeds. In brief: The unity of the world lies before me, I am one with all knowledge and experience. This sudden opening of the spiritual founts has quenched all other fires. My state is beyond will-power itself, which is identified with humanized divinity, or God. I am afloat upon a limitless sea of refined spirituality; my soul bathes in these waters; I am refreshed and strengthened; I ask for nothing more than this complete absorption with what I understand by God. It is the highest mode of love.

"In a degree you will now understand why I seek solitude. I need silence to question this translation to more ethereal spheres than I ever traversed. Logic and so-called reason here avail not. I shall try to get back to work before long; with this farther sight I ought to obtain clearer results than ever. I speak of the sudden opening of the spiritual founts; but of course the waters had been the result of accumulations of stored-up rays of light from early years to the present. There is nothing miraculous in this.

"The October balm caught in your letter was not gone when your letter reached me. It pleased me to read that you felt in that 'September Day,' the influence of freedom and security and a more universal flow than you had noticed before in my writings. I felt the lines and they meant a great deal to me, much more than I could find language to express."

The poem to which she refers, entitled "One September Day," depicts a walk at "high noon along the turgid stream."

"Alone I went, but by my side were you,
Enclasped in thought intent and feeling too.

From looming crags straight hemlocks skyward went;
Along their shafts upcarried the eye sent
Its glance to plains of constant deepest blue,
By bough enhanced and leaf of greenest hue.

"On hilltop tall above a flowery field
There sat aloft the sylvan spires to shield,
When rays of sun ashoot from median sky
In throbs of heat restrain the bird's shrill cry.
Woodlands rise on and on, and murmuring sounds
Of rush and splash rise out from dense tree-mounds,
And song of winds entranced around me play,
Whence life and forceful vigor crown the day. . . .

"Hush! Night at last reigns over all supreme,
And sense and mind blend one in trance or dream.
The mood of noon with form of thine still clings,
Tho midnight's note gives voice that truly rings
Of greater depths of ardor than e'er first
When yearning youth paused but to quench its thirst.
Then folded for one brief respite by thee,
Earth's feeling, true with thine eternity;
In thought like this what care for life or death,
What staying bond hath power this force to wrest?"

Not far from the same time she wrote, in a poem which was probably a sort of metrical letter to a friend, these significant lines, pointing to this vital change or deepening of her religious consciousness: —

"I stand imbued
With light laid up from youth's first early store,
For hours of penitential act and psalm
May not from faith, but intent fervid come.
You smile that penance such as these trite ways
Could turn the spirit into wake of dawn?
Yes, smile you may, for very fact remains,
Not prayer, the guiding mind alert and free
From doctrines, litanies, and forms of Church,
But meanings born of stress and strain
Uplead the toilsome path of growth's full self,
Where Science, Art, and all of Beauty's wiles

Their use do yield, but fail to grasp or thwart.
Let's stop awhile and rest in memory's chain!
And then came light of truth with swiftest dart,
So swift and sure it came that all grew bright,
As night by firefly's torch or floating star.
And love enwove with touch sublime and strong,
Where freedom's voice arose for wrongs of kind;
Such wrongs are felt, scarce sung in rhythmic line.
Then wide the world of human form expands,
And tribes and nations to one vast compound
Of common interest and impulse rise,
Not bound by ties of artificial end.

. . . .

I'd haste this news, with greeting, all chords tune,
And sound aloft 'mid haunts and marts of men!
'Comrade, there stand you, brave, with all man's poise
To breast the storm, to ride the gale of life,
To bring new hopes to minds of starving men,
To meet, though meeting may but parting prove,
In moments rare of sympathetic hours;
To me has come this zest, to know again
Upon life's hurried track ere journey's end
That valiant hearts untouched by dross or coin,
With ardent beat of pulse and throbbing brain,
Live true, undaunted, yea, in spirit one
To spurn all false, to scorn all gain
Save Freedom's goal — though to reach that were vain!"

In 1897 she spent some weeks at Chestnut Hill, at the residence of her sister, and toward the end of April she wrote the following descriptive poem.

SUNSHINE ON THE DELAWARE.

A sun-flashed wave,
An oar's quick stroke,
A sail of whitest sheen;
A cloudless blue,
A freshening breeze,
And banks aglow with spring.

A shore astir with 'longshoremen
A-hauling-in the seine;

A loiterer from the city's whirl
Stands viewing scene and men.
A flowing tide with rushing flood
And lapping swish and swirl,
A swinging barge, a fisher's craft
Drives in with reef unfurled.

Afar, the busy smoke-born haze,
Outshoot from factory depths,
The ferry, town, and dusky wharfs
The terraced tower o'erlooks.
Afar, the haunts of toil-worn forms,
Afar, the shimmering sea,
Afar, speed thoughts from sun-lit crests —
To thoughts illumed by thee.

Interesting also is "A Fragment," which is found in her notes in several variants; this is the second: —

"I stood and looked into the night —
A fir tree sombre rose to sight,
A full-limbed evergreen tree.
I stood and looked beyond the night
Upon a distant star,
Whose emerald light
Shone dim from heaven's vault afar.
What thoughts of earth or sky hold you,
Sole watchers of night's sleep —
Are life problems veiled to you
As the night in leaden mist?
What know yon star and tree
Of passion, death, or bliss?
What use were science' teachings
To answer dreams like this!"

In a criticism occasioned by reading Thomas Davidson's "Prolegomena to *In Memoriam*" she says: —

"As I look backward I see the spark of faith or religious feeling early developed — perhaps at nine years. I can recall hours spent in meditation and silent prayer at afternoon service. This mood deepened until all the joys from a firm belief in Catholic doctrine and practice were mine. At last came a time when knowledge brought doubts of the rights of Church or of system to hold back the craving of the soul for development; for soul-development, it seems to me, may in some natures where the love for knowledge is strong, be retarded by the withholding of facts or the control through Church laws to the detriment of the free action of the individual. To bind myself entirely to scientific thought and its teachings, to the exclusion of Literature and Art, brought me to a solid blank wall, to a full stop. This state of being was most unfruitful, as interest, through weak health, flagged in objective studies. The veil of night enveloped me. A severe illness at the end of ten years of soul-suppression — the last five, of almost total repression — came, and with it a clearing away of the mist and low heavy clouds. A curious vision brought to my soul's eye the realization of God, the Universe, and my place in it. . . . After this, clearer conception of objective things came; and the voice, though indistinct at first, that I must encourage the plan of declaring my individuality and throw off the shackles of custom — habit, through early education or conventionality, holding me down — became clearer."

In a letter to the late Dr. Bucke, one of the literary executors of Walt Whitman, she seems to refer more explicitly to this "ecstatic vision." She says: —

"A long period before last spring had been a season of what might be called spiritual dryness. My spiritual nature was in a condition of tension, from which once liberated it sprang into space with a force likened to an arrow released from a taut bowstring.

"I will mention here, subsequent minor experiences have been initiated in a similar manner; the soul seemed for a time before mute, as if preparing by a recoil to dart forward with greater velocity. Returning to my experience — I am unable to picture, verbally, the exaltation accompanying this liberation. My soul was moistened by a dew of bliss and contentment I had never before felt; a happiness pervaded my being. I seemed to have acquired a new strength.

"I stood alone in the Universe, powerful to comprehend in its entirety the *whole*, I knew my place as a personality in this great Universe. I felt I was one element in a huge mosaic system. A mosaic, essential to the whole. For one brief second, alas! too brief, I seemed to comprehend Divinity. Everywhere, around, above and below me, the Universe was bathed in a soft, gray, pearly light; symbolically the Universe appeared as an immense gray shining sphere; smaller orbs represented personality, distinct, yet a part of the grand whole. A composite flower also illustrates the feeling. The centre of the flower and its numerous divisions are all separate flowers; still they grow, jointly contributing to the glory of one unity — in complexity.

"With the rapidity of a flash of light I felt the reality of the eternal, undying, inner core of personality, and of the immortal place in the Universe, of self.

"Briefly these are the facts as I have stated. The months following revealed to me the results of the reconstruction of my being dating from then. I have never lost the vivid vitality of the experience. The impressions of those spring days are easily recalled; to them I turn for support and consolation. On that March day was forged the anchor of my soul; firmly it grapples as it ever will the infinite currents of the absolute."

Apparently the same sense of religious rehabilitation is embodied in the following mystic poem, which, in spite of Emersonian license of rhyme and rhythm, has decided merit. It is entitled "My Star."

"A star with flashing light and power,
My soul a-flaming woke,
A vivid flare midst luring loom,
A burning stream my senses smote.

"This star in radiancy sublime,
With speeding worlds was borne,
And shedding thence its varied light,
In waning left me wan and lorn.

"Oh, how I longed and waited
For my star to come again!
I scanned the azure heavens,
Scarce knowing if I watched in vain.

"Though other stars arose and set,
For me they flashed no light,
I waited for the emerald fire,
The beacon of my lonesome night.

"The years they passing came and went,
Fate weaving life and death,
With visions fair most sweet were spent
The hours, for which alone I 've wept.

"Then when all hope seemed ebbing fast,
My star arose again,
I saw it span the jeweled sky,
I knew that longing proved not pain.

"Ah! then I learned what light of star
To me must ever bring:
A mystic throb of Nature's heart,
The magic glow of Spring.

"My Star" seems a complete answer to one entitled "Separation," written the year previous, just after Christmas, 1896: —

"What grief is this — that o'er my senses comes?
All tears are stilled,
My heart's beat lulled.
Oh! separation from all that vivifies,
The soul's throb now silenced,
  Music's note is mute.

"Is ne'er comprehension and full expression to be mine?
Oh! soul, cease with cross-purpose and meanings bewildering,
With sentences fraught with half-weighted words.
Leave words, forward sense!
Seek in clasp of hand and eye-glance else denied thee
The shining forth of thy soul's true light,
And illumination extending to that other soul,
More loved than thine."

This spiritual awakening was accompanied by the gradual blossoming of a new purpose in life. All these years her mind had been broadening and becoming more universal in its interests, and yet she felt that her early plan of becoming a physician was the logical outcome of her career. She had felt naturally dissatisfied with her incomplete excursion into the fascinating field of medicine, interrupted as it had been by ill health, family reasons, and the claim of chemical research. She now began to hear the renewed call to go further into its luring mysteries.

Many honorary distinctions had been conferred on Mrs. Michael. In 1887 she was elected a member of the American Philosophical Society, one of the eight women who, in more than a century, had received that mark of high consideration. In 1893 she became a corresponding member of the Philadelphia College of Pharmacy. Eight years later she was made an honorary member in recognition of her valuable scientific work in connection with plant chemistry. She was also a fellow of the American Association for the Advancement of Science, a member of the Academy of Natural Sciences, of the Franklin Institute of Philadelphia, and of the Deutsche Chemische Gesellschaft of Berlin.

In spite of serious ill health, which had culminated in a severe surgical operation, which she resolutely and philosophically faced and bore, with no fear as to its outcome, she entered the Medical School of Tufts College in the autumn of 1900, and after passing all of her examinations with very high marks, and winning the admiration of her instructors, she was graduated with her title of Doctor on the seventeenth of June, 1903.

Even before she had received her license to practice she had transformed a private house into a beautifully arranged free hospital, which bore an inscription dedicating it to the memory of her Mother, and, in association with another woman physician in regular standing, she spent a good part of her spare time in caring for the poor patients who flocked to it for advice and relief. With the same sincerity of purpose she had spent the summer of 1902 in Europe, and visited the most prominent hospitals and clinics in London.

Amid her maturing plans for an ever-widening activity she was stricken with an attack of the *grippe*, superinduced by too great assiduity in caring for her poor patients. She herself realized that her case was very critical, and prepared for the worst. After a long and trying illness which was vainly ameliorated by a summer spent in Dublin, New Hampshire, she passed away in Boston on the twenty-ninth of November, 1904. The funeral took place in Philadelphia on the 2d of December, and she was laid to rest in Laurel Hill Cemetery. At the funeral service, one who had been for some years a friend of her family spoke a few heartfelt words which may be echoed here: —

"We cannot help recalling the universality of her personality and its many-formed expression, of her wide sympathies and appreciations. We must realize that as, after all, humanity is the essence of religion, she was deeply religious. We must mention the many polished facets of her jewel-like mind, and how she won distinction in music, languages, expression, both prose and poetic, in scientific research, and finally, even in the few months of her active practice, in medicine. We are certain that medicine, being both subjective and objective, and bringing her into ever closer touch with humanity and its needs, spiritual and physical, was her final and most fitting expression."

He remembered her loving kindness to all who came into contact with her, in whatever capacity, and her respect for their individuality.

A paraphrase of her own brief "memorial paper" to the memory of Dr. Brinton, published in the "Conservator" of September, 1899, might fittingly characterize Dr. Michael's relations to others: —

"Her influence in stimulating the younger minds of her acquaintance to more active growth was one of her pronounced characteristics. An hour spent in her presence enabled those so favored to carry away the germs of many a fresh thought and inspiration. To the few who possessed the key to unlock the inner storehouse of Dr. Michael's mentality was revealed a treasure-house of richness not to be forgotten."

These words will be appreciated by the circle of those who used to gather at her house or elsewhere and discuss every imaginable topic of religion, philosophy, poetry, art, science, politics in its wider sense. But in all discussions, though she always took a foremost part, she was a courteous and gentle opponent if ever she felt called upon to combat any theory or challenge any fact. She demanded freedom of thought and utterance for herself; she was ready to grant every one else the same privilege. A fragment dated July 16, 1900, and consisting of only three or four paragraphs, gives, in brief, expression to much of her philosophy of life. She here says: —

"To live is only worth while in order to build character.

"In the East, character is called Karma. It is built from blocks of truth. It is only that which lasts through eons. This is the tower for each to build.

"Only the strong are tried and they alone can reach everlasting life; for in strength rests peace, solidarity, unity, infinity."

Still another phase is found in the form of a bit of rhythmical prose: —

"The epilogue of Love is death.

"For he who has truly loved only finds fulfillment in death.

"The quest of life is love, its finding the signal for death.

"Love knows neither consciousness nor volition. It is, in its fullest expression, oblivion; in its fullest activity, quiescence."

But what perhaps strikes one most powerfully in studying her life is her passionate desire for independence, for complete liberty of thought and action. She was an individualist of the most pronounced type. She so insistently felt the need of unhampered fields of activity for women that she may sometimes have shocked the ultra-conservative in her pleas. She could never see the reason why men should have all the prerogatives and women all the restrictions. Instructive in this connection is her prose hymn to Liberty, which was printed in emphatic italics in the "Conservator" for April, 1897: —

"*Freedom is the end which revolution and revolt through truth have in view. It is a liberation from all the chains which are holding back the human being from greater expansions of mind and soul. By Freedom is meant a state wherein all the shackles from preconceived ideas of the rights and wrongs of a question are cast aside; where the being stands unhampered to view* *each question on its own merits, to let each concept to which the human mind is open work out through a sequence to its logical conclusion; where the individual's action need not necessarily be one with the full possibilities of the conceptional outgrowth, but where the individual may partake of equal actional with theoretical liberty if so he or she desires. In Freedom each being must stand alone and the conduct of another cannot be prescribed by you or by me. Freedom is also a state wherein we are surely not free to give ourselves up to unbridled passions, license, and vices. For once we have resigned our leadership into their lawless hands, we can call ourselves free no longer; we become enslaved men and women. Perhaps the man and woman ruled by even the noblest themes lose in their devotion to any one absorbing idea something of the essence of liberty.*"

Again, in a few paragraphs written to a young woman considerably younger than herself, she gives interesting glimpses of her individuality. They are extracted from several letters but are so characteristic that they find an appropriate place here. She says in a letter written in 1896: —

"I have been speaking on several occasions these past eight days, — for the time being I have seemed to run into these public utterances. . . . Don't make any resolutions of what you will or will not do during the coming winter. As you grow older you will find your place in the great world of thought, art, or action. Keep yourself free, until at least your thirtieth year, from matrimony. You want these intervening years to fill your being with knowledge which may later in your life bring fruition.

"Above all accept some *idea* as your *ideal*. I have found mine in the theme of 'freedom' and 'liberty.' You must find yours in what most appeals to you. But remember that all thoughts of temporizing, or reform or philanthropy — good enough as expedients — are not good enough as *an ideal* ultimate aim. . . . But look to literature as one of the best means of expressing yourself. . . . The topics gold and silver are interesting enough, but there is a vast power at work now in the world at destruction of all old systems of economics and other social ones. . . . You will listen to all these arguments and form your own opinions. Opinions, I need not say, are always alive and changing. . . .

"In reply to what you need, I can give you this from my own experience, — that life is only bearable when lived depending upon one's own resources for passing the time, and upon the few spiritually congenial persons with whom I have formed lasting friendships. Your literary tastes above all means cultivate; and *write, and write, and write,* no matter how poorly it reads. You will be improving your powers of expression; also seek to employ new words to increase your vocabulary. Literature is worth living for when made a means to give expression to the development of the writer's character and soul. As mere ornamentation, or to pander to the conventionalisms of the day, literature, as a life, is very unsatisfactory when devoted to such false ends.

"You may rest assured that even if you do not find congenial sympathy for your tastes and occupations, that is no reason to feel discouraged over their pursuit.

'Loving! what claim to love has work of mine? . . .
I looked beyond the world for truth and beauty:
Sought, found, and did my duty.'

You know the poet? No need to say who said these words.

"I have found some beautiful passages in Walt Whitman's prose volume to read you. . . . I feel as if I had lost all my thoughts and, until this indigestion stops, I feel I shall be unable to think. I have not read lately; to pass the time I mended some stockings for want of something else to do. I read what George Sand said on this subject only a few days ago: 'Sewing is the work of female captivity.' I had come to the same conclusion before reading the passage — when my mind was too weak for anything else, I took to sewing, and I think this the state of the great mass of female minds."

In spite of her intense love of independence and her advanced thought Mrs. Michael was always essentially and delightfully feminine. Her love for nature and all beautiful things found expression in many of her essays in verse, notably in a little prose poem which describes a field bounded by "stately groves of trees." It thus concludes: —

"A cedar for many a year had stood along this path which tallied with the course of my vision across the enclosure.

"The moon shone clear through leafy fringes of chestnut limbs.

"Hopefully, I waited for some whispered message from Nature, to be transmitted to my ear.

"No sound, a blank echoed in my soul,

"Only when I turned and looked upon a face I loved, framed as square in miniature as these trees, then a flood of gladness suffused my soul. That image stood for more than tree, — to me it meant a sentient thing."

Still another, in the free form which she liked so much, has a mystic pensiveness and pathos and a remarkable weirdness of imagery. It is entitled "Full Moon."

The Moon shone bright and cold,
The Moon's bright course had run,
And o'er the rim of yon dark hill
Had spilt in flood of light
Her orb's excess.

Hot the earth; Nature pants for breath,
Looking upward to this bounteous guest
Who spills thus her treasure-cup's need,
Drinks feverishly, lapping with Summer's parched tongue
Of her cool rays,
Delusive draught, not life-giving,
Bringing no living repose or rest.
All leaf or tracery of limb and trunk was lost,
Was lost in the transforming flood.
The willows wept hot tears of living green;
For, under branch and bough sprung one grand arch,
And from it hung in showers of stone,
Not as before, streams of living leaves,
But heavy pendants unmoved by breeze; the very air was fixt.
My fancy's flight carried me to such a sight
I once had seen, far under earth's surface,
Where drop by drop water rich in saline substance
Had done for that place what moonlight did for this tree.

The moon shone bright and cold,
Cold, cold, its light did enter my soul,

My soul did fold,
And froze each heart's drop to ice,
Drop by drop
That heart was changed to one great stalactite.

Thoughts for words too deep,
Eyes too dim to weep,
Heart too sad to break —
Yet in breaking only will come rest!

It was, after all, the demand of her nature to give and to share affection. This is shown in a brief sentence in one of her note-books, where she says: "Especial kindness and sympathy on the part of my family and friends. I have never known of such evidences of affection."

She was deeply interested in Philosophy; her reading of Lotze and Rosmini, of Ferrier and Maurice, of Spinoza and Hegel was wide and thorough. She was always ready to discuss the deepest questions, and a sympathetic interlocutor always caused her mind to work with lucid activity. She was equally fond of poetry, especially of Browning and Whitman, but also of Dante and Shelley — such was her breadth of range.

It seems one of the strange and inexplicable measures of the Power that rules this world that such a woman, just on the threshold of a most beneficent activity, where her work would have been of inestimable value, should be snatched away. One cannot call her life wasted, for what she had already accomplished must forever be an inspiration to all who knew her or knew what she had done and was doing. Her utterances in behalf of freedom for woman, her union of many accomplishments with a strict scientific spirit, her pioneer work in securing for her sex many advantages which, had it not been for her, might have been much longer delayed, her sweetness of disposition and charm of personality, make her life a power that will never cease to be felt in the world.

NATHAN HASKELL DOLE.

STUDIES IN PLANT AND ORGANIC CHEMISTRY

WITH AN INTRODUCTION BY DR. H. W. WILEY, CHIEF OF THE BUREAU OF CHEMISTRY, UNITED STATES DEPARTMENT OF AGRICULTURE

INTRODUCTION

The work of Miss Helen C. De S. Abbott is prominent in the annals of American chemistry. She was among the very first investigators of this country who began in a systematic way to study the relations of chemical composition to species of plants and to plant growth.

The work which she did is the more remarkable when it is considered that it was mostly finished before the modern science of physical chemistry was placed upon its present firm foundation. In those days it was not acknowledged by all, and was recognized by few, that chemistry was the basic science of all forms of life. Investigators had not realized that the so-called vital processes were nothing more nor less than chemical reactions of greater or less complexity. With our present understanding of the domain of physical chemistry, it seems strange that the studies which Miss Abbott really inaugurated on this subject had not been begun at an earlier period. This delay, however, detracts nothing from the credit due her in being a pioneer in the work.

The most important result of her investigations pointed out in a clear way the regular existence of certain classes of chemical bodies in certain species of plants. The results of her investigations were to point out the existence as a predominant factor of some one substance, or of associated compounds, in classes of plants related by certain evolutionary common features. The fact that occasional bodies of the same kind are found in the most widely separated species and genera is no indication of the futility of such an investigation.

Miss Abbott studied particularly the occurrence and relation of glucosides in plants, and especially the remarkable similarity in composition in certain plants related as above mentioned. She established the fact [1] that the "Glucosides

[1] See paper on "Comparative Chemistry of Higher and Lower Plants."

are more especially the compounds of the middle plane of plant development, and are found in the higher monocotyledons of this stage, in the lower and some of the higher dicotyledons, and less frequently in the highest of all plants." Her work in tracing the process of development of glucosides was of the highest possible character, as well as of scientific interest.

She discovered, among other things, that saponin is a glucoside which serves to unite all of what are known as the "saponin groups," and these facts were brought out most strikingly in her paper on "The Chemical Basis of Plant Forms." Even in the constituents of plants which are almost universal, it is found that they grow in greater or less quantities according to the evolutionary stage of the plant. For instance, she pointed out, I believe, the first of all chemists, that although alkaloids are very widely distributed, they are not found in the very lowest nor the very highest forms of life. They do, however, occur sometimes in fungi.

She again pointed out the fact that one class of bodies was very apt to occur with another and to lead up in the development of one species of plants to another. Thus, the tannins and sugars are apt to be co-related, and coumarin, which is the odorous principle of the tonka-bean, is found only in plants containing oils. In her work in this direction Miss Abbott bound together more intimately than ever before the correlated sciences of chemistry and botany. In fact, as we view her work, we are forced to the conclusion that botany, even in its morphological aspects, is more nearly a chemical science than has ever been supposed. For instance, if we consider, as we must in such investigations, the physiology of plant growth or what is known as economic botany, we find it impossible to separate the two sciences. No one can study plant physiology except from the chemical standpoint, and economic botany involves the application of the principles of chemical technology at almost every step.

The good of such investigations is apparent. It helps to bring together branches of science which sometimes, without such a bond, would tend to become antagonistic.

I recall one of the most striking illustrations of the data collected in the chemical work which Miss Abbott accomplished in the arrangement of series of plants to illustrate the development of certain particular compounds by genera and species, and this arrangement of genera and species showed in a most marked manner the development of the chemical compounds forming important constituents of the plants exhibited.

The study of the principles of evolution during the last fifty years has shown the dominating influence of environment on the development of animals and plants. The investigations conducted by Miss Abbott also show the dominating influence of environment upon the particular composition of the plant. Thus were laid the first stones of the foundation on which the important study of securing variations in plants which change their environment is based. In the careful breeding of plants there are two important things which are to be kept in view. First, the development of new forms or kinds of plants; and second, the development of a more abundant content of valuable constituents of plants and the elimination of the undesirable constituents. All of these ideas were outlined in Miss Abbott's work, and from the starting-point of these investigations most of the more important contributions to plant chemistry in this country in relation to environment have been made.

H. W. Wiley.

Washington, D. C., October 1st, 1906.

SOME OBSERVATIONS ON THE NUTRITIVE VALUE OF CONDIMENTS[1]

THE prevailing opinion respecting the substances known as condiments is that they possess essentially stimulating qualities, rendering them peculiarly fitted for inducing, by reflex action, the secretion of the alimentary juices. Letheby gives, as the functions of condiments, such as pepper, mustard, spices, pot-herbs, etc., that besides their stimulating properties, they give flavor to food; and by them indifferent food is made palatable, and its digestion accelerated. He enumerates as aids to digestion: proper selection of food, according to taste of the individual; proper treatment of it as regards cooking; and proper variation of it, both as to its nature and its treatment.

While it is difficult to give an entirely satisfactory definition as to what constitutes food, the following extracts from standard works will serve as guides. L. Hermann in his "Elements of Human Physiology," translated by Gamgee, published in 1883, says: "The compound must be fit for absorption into the blood or chyle, either directly or after preparation by the processes of digestion, *i. e.*, it must be digestible. It must replace directly some inorganic or organic constituent of the body; or it must undergo conversion into such a constituent while in the body; or it must serve as an ingredient in the construction of such a constituent." He further says that water, chlorides, and phosphates are the most indispensable articles of diet. Watts[2] states that "whatever is commonly absorbed in a state of health is, perhaps, the best, or rather the truest, definition of food."

Chemical analysis shows that the most important and widely applicable foods contain carbon, hydrogen, oxygen, nitrogen,

[1] Originally printed in *The Polyclinic*, Philadelphia, 1883.

[2] *Dictionary of Chemistry*, vol. iv, pp. 147, 148.

and mineral matter, the latter containing phosphates and chlorides. Other things being equal, it may be considered that the comparative nutrient value of two articles is in proportion to the amounts of carbon, nitrogen, and phosphoric acid they contain.

"The food of man also contains certain substances known under the name of condiments. Since these bodies perform their functions outside the real body, though within the alimentary canal, they have no better reason to be considered as food than has hunger, *optimum condimentum*."[1] Such is the positively expressed opinion of Foster, the author of the article on Nutrition, in Watts's "Dictionary of Chemistry." With a view of determining how far the common condiments deserve this summary dismissal, a number of analyses have been made in the laboratory of the Philadelphia Polyclinic. My examinations were especially directed to the mineral matter, phosphoric acid and nitrogen. The following table shows the result of the analyses:—

	Per cent. of Ash.	*Per cent. of P_2O_5.*		*Per cent. of Ash.*	*Per cent. of P_2O_5.*
Fennel	9.00	.103	Allspice	5.54	.017
Marjoram	8.84	.050	Mustard	3.90	.134
Peppermint	8.80	.016	Black Pepper	3.60	.011
Thyme	8.34	.122	Jamaica Ginger	3.16	.052
Poppy	7.74	.024	Cinnamon	3.02	.009
Sage	7.58	.033	Mace	2.44	.230
Caraway	7.08	.118	Nutmeg	2.24	.092
Spearmint	7.06	.017	Celery	1.29	.082
Coriander	6.10	.097	White Pepper	1.16	.017
Cloves	5.84	.563	Aniseed	1.05	.113

The articles were examined in the condition in which they were obtained in the market, without any preliminary drying, selecting, or preparation. The ash was obtained by burning in a platinum crucible, at as low a temperature as possible, dissolving in hydrochloric acid the phosphoric acid separated

[1] *Dictionary of Chemistry*, vol. iv, p. 149.

as ammonium molybdo-phosphate, and determined in the usual manner.

Qualitative tests made for nitrogen indicated its presence in each one of the condiments examined.

It is of importance to observe that the majority of these condiments are fruits, ripe, or nearly so. The seed appropriates to itself the nitrogen and the greatest nutritive properties for the development of the future plant. All nutritive substances fall into two classes; the one serves for the repair of the unoxidizable constituents of the body, the other is destined to replace the oxidizable. Condiments fulfill both of these requirements, as is shown by a study of their composition; the phosphoric acid and nitrogen are taken up by the tissues, as from other substances used in diet. Some articles affect the character of the excretions; this is often due to essential oils; the presence of these in the excretions cannot be said to diminish the value of the substances in supplying to the tissues the necessary elements. The same holds true for condiments; the essential oils conspicuous in them are accorded only stimulating properties; however, it may be observed that the essential oils in tea and coffee are accredited with a portion of the dietetic value of these beverages. It appears that when condiments are used in food, especially for the sick, they may serve the double purpose of rendering the food more appetizing and of adding to its nutritive value. The value of food as a purely therapeutic agent is attracting some attention at present, and in its study we must not neglect those substances which combine stimulant and nutritive qualities.

PRELIMINARY ANALYSIS OF THE BARK OF FOUQUIERIA SPLENDENS [1]

In the published proceedings of the Mexican Boundary Survey of 1859, conducted by General William H. Emory, are found numerous references to *Fouquieria splendens.* No region of equal extent presents more marked illustrations of the relations of the vegetation of a country to its topography and geology than that lying along the Mexican boundary line. The traveler traversing the desert table-lands will not fail to unite in his recollections of these tracts the dull foliage of the creosote bush, the palm-like Yucca, and the long thorny wands of the *Fouquieria splendens.* The vegetation of the El Paso basin and the Upper Rio Grande valley is described as strikingly different from that of the immediately adjoining country: new and strange plants are seen on every side. Upon the table-lands many plants grow not to be found in the more fertile valleys; among these is *Fouquieria,* a tree locally known by its Mexican name ocotilla. A full description of the appearance of the plant is given in the Mexican Boundary Survey; also one in an article by Edward Lee Green.[2] The latter author describes *Fouquieria splendens* in these terms:—

"It is a splendid oddity, and not more odd than beautiful, flourishing in great abundance in many places. It grows to the height of from eight to twelve feet, and in outline is quite precisely fan-shaped. The proper trunk, usually ten to twelve inches in diameter, is not more than a foot and a half high. A few inches above the surface of the sands this trunk abruptly separates into a dozen or more distinct and almost branchless stems. These simple stems, rising to the height of eight

[1] Paper read before the Chemical Section of the American Association for the Advancement of Science, at Philadelphia, 1884; also before the American Philosophical Society, November 7, 1884.

[2] "Botanizing on the Colorado Desert," *American Naturalist,* 1880.

or ten feet, gradually diverge from one another, giving to the whole shrub the outline of a spread fan. Each separate stem is clothed throughout with short gray thorns and small dark green leaves, and terminates in a spike, a foot long, of bright scarlet trumpet-shaped flowers. The stems are not so thickly armed with thorns but that they can be handled if grasped circumspectly, and being very hard and durable, as well as of a convenient size, they are much employed for fencing purposes about the stage stations and upon the ranches adjoining the desert." The author states: "Give a skillful Mexican ocotilla poles and plenty of rawhide thongs and he requires neither nail nor hammer to construct a line of fence, which for combined strength, neatness, and durability fairly rivals the best work of that kind done in our land of saw mills and nail factories."

The plant is botanically described under order *Tamariscineæ*, tribe III, *Fouquiereæ*, new genus and species.[1] For other sources of information see "A Tour in New Mexico;"[2] and in "Plantæ Wrightianæ[3] Texano-Mexicanæ." The writer has not been able to find any notice of chemical studies made upon it.

The specimens of ocotilla, at the writer's request, were collected and transmitted from Lake valley, Southwest New Mexico, through the kindness of Professor E. D. Cope. The portions of the stem, similar to those used in the analysis, vary in diameter from an inch to an inch and a half. The bark shows a thickness of over an eighth of an inch, and is of a sage color generally. The exterior surface is made rough by an interlacement of hard projecting material; some of the smaller stems are encircled with the gray thorns described, arising in regular series from the projecting portions of the bark. Between the interlacements are oblong and diamond-shaped intervals, which are filled with superimposed layers of a yellowish color and looking as if coated with a wax. They appear to be cemented together by a glistening substance which,

[1] Bentham and Hooker, *Genera Plantarum*.

[2] By Dr. N. Wislizenus.

[3] Gray, *Smithsonian Contributions to Knowledge*, vol. iii, part i, p. 85, and part ii, p. 63.

on warming the bark, exudes and possesses a resinous or gum-like consistency.

In the present investigation, the scheme proposed by Dragendorff [1] has been followed out, with the exception of the maceration at the ordinary temperature; an apparatus similar to the one last devised by Tollens [2] has been used for the extraction. The air-dried material reduced to a very fine powder was again dried at 100° C., giving 9.4 % moisture, since the great importance of powdering the material for the various estimations as insisted upon by Dragendorff,[3] was fully confirmed in these examinations. Quantitative determinations with ocotilla bark reduced to fine pieces gave 2 % and 3.5 % less than the percentage obtained from the estimations with the powdered substance. Determination of total ash gave 10.26 %; a qualitative ash analysis showed the presence of calcium, magnesium, aluminum, potassium, sodium, and a trace of iron; sulphates, phosphates, and chlorides.

Ten grams of the air-dried powder treated with petroleum spirit of boiling point 46° C. extracted a substance without aromatic odor, communicating to the liquid a light color. From 100 c. c. a measured portion was evaporated for determination of total amount of substances brought into solution. The residue dried at 100° C. gave 9 %; at 110° C. 8.87 %; at 120° C. 8.875 % and a loss of .125 % showing scarcely appreciable trace of volatile oil. The remainder of the petroleum spirit extract, on evaporation at the ordinary temperature, left a solid yellowish-green wax substance of specific gravity .984, melting from 84° C. to 85° C., insoluble in water, slowly soluble in boiling 95 % alcohol, readily in absolute alcohol, in cold ether, chloroform, amyl alcohol, benzole, carbon disulphide, oil of turpentine, and linseed oil; slightly dissolved in aqueous alkalies, but not saponifying with them. It is colored yellow by nitric acid; acted upon by concentrated sulphuric acid, and not by hydrochloric acid or aqua regia.

[1] *Plant Analysis, Qualitative and Quantitative,* G. Dragendorff, Ph. D. Translated from the German by H. G. Greenish. London, 1884.

[2] *Zeitschrift f. anal. Chemie,* xiv, 82, 1875, and xvii, 320, 1878.

[3] *Loc. cit.*

By means of combining sulphuric acid and solvents, I was able to obtain several color reactions that may prove upon further investigation of value in identification of the different vegetable waxes. With Japanese wax, the only specimen of vegetable wax I could obtain, the color reactions differed in each test from the substance under consideration. The following color reactions were obtained with the petroleum spirit residue. When small fragments were stirred on a watch crystal with two or three drops of concentrated sulphuric acid of 1.84 sp. gr., the substance at once changed color to a clear garnet red and was slowly dissolved by the acid, the liquid remaining colored; with different portions of the red acid liquid stirred on a watch crystal with various solvents used in excess, it was noted as follows: with absolute alcohol the color was instantly dissipated, leaving a white precipitate; petroleum spirit discolored the acid solution, leaving no precipitate; ether discolored it with gray precipitate; chloroform changed the red acid liquid to yellow, no precipitate; with benzole the red color was changed to snuff-brown, gradually passing to red-brown; amyl alcohol gave a rose-pink, slowly passing through varying tints to a fine purple. So-called pure amyl alcohol was used, and when tested did not give a color reaction alone with sulphuric acid. The petroleum spirit residue on boiling with absolute alcohol and, when warm, thrown into several times its volume of cold water, separated out as a white cloud.

Under a method by which melissyl alcohol has been obtained from carnaüba wax,[1] the petroleum spirit residue was submitted to a like treatment. It was boiled with alcoholic potash and saponified, the alcohol distilled off and lead acetate added; a heavy light yellow-colored precipitate formed, and on boiling, yellow masses separated out. They were washed, dried, and boiled with absolute ether. The filtered liquid on cooling deposited a yellow crystalline substance, which, on heating on platinum foil, turned black and disappeared. Beyond ascertaining the fusing-point, solubilities, and color reactions, the substance was not further examined. It was

[1] Liebig, *Annalen*, 183, p. 344, *teste* Watts's *Dict. Chem.*

found to fuse between 43° C. and 60° C., the greatest change occurring between 57° C. and 60° C.; to be soluble in chloroform and ether; scarcely soluble in cold absolute alcohol; very slightly soluble in boiling 95 % alcohol; not acted upon by nitric acid or aqua regia. Sulphuric acid dissolved the substance and gave an orange color reaction discolored on adding alcohol, ether, chloroform, and ammonia to the acid liquid, with no precipitate; with amyl alcohol a pale rose pink, quickly fading, and with benzole a brown color were obtained. The color tests differed from those obtained with the substance before saponification and treating with boiling ether, indicating that the petroleum spirit residue can be separated into at least two substances, and possibly more, which remain to be determined by a future study.

The powder exhausted by petroleum spirit was dried and similarly treated with absolute ether, as in the previous extraction. The ethereal extract of a greenish color gave an acid reaction with litmus, and on addition of alcohol the liquid became turbid. Spectroscopic examination failed to detect the characteristic chlorophyll bands. The ethereal residue on evaporation presented differences in color and solidity from the petroleum spirit residue. It was quite brittle, and was not appreciably softened at 120° C. It gave, when dried at 100° C. 4.52 % of solids extracted; at 110° C. 4.44 %; and at 120° C. 4.42 %. The residue when evaporated at ordinary temperature was insoluble in petroleum spirit, slightly soluble in 95 % alcohol and carbon di-sulphide, quite soluble in cold absolute alcohol, amyl alcohol, chloroform, benzole, and oil of turpentine. Nitric acid gave no reaction. With sulphuric acid and small portions of the ethereal residue, I obtained a dark mahogany color. This solution on adding absolute alcohol was partially discolored, no precipitate. With ether the sulphuric acid solution gave a greenish precipitate; with amyl alcohol the acid solution was discolored, changing to pale red, then green. These tests showing in each case a wide difference in color reactions from those obtained with the petroleum spirit residue. The amount of solids taken up on treating the ethereal residue with water was .36 %. The aqueous liquid was neutral to litmus, portions tested for alkaloids gave negative results; on warming and addition of dilute sulphuric acid, Fehling's solution was reduced, indicating possibly glucosides.

The portion insoluble in water was then treated with absolute alcohol. The liquid gave an acid reaction with test paper. A measured part of the liquid was evaporated and the weighed residue showed 1.6 % of solids dissolved. The residue from the evaporated alcoholic liquid was partially dissolved by aqueous alkalies. It readily saponified with alcoholic soda, forming a soft brown soap, which on boiling with lead acetate yielded a yellow precipitate. This was collected on a filter and washed. When the precipitate was boiled with absolute ether and the filtrate allowed to evaporate slowly, a white organic crystalline substance separated out. Under the microscope, particles of coloring matter were found to be interspersed among the crystalline structures.

The indications would show an acid resin to have been extracted by the ether.

The ten grams of powdered bark, after exhaustion with petroleum spirit followed by absolute ether, were treated with absolute alcohol. A measured quantity of the alcoholic extract was evaporated in a weighed platinum dish, dried, until weight noted was constant. After incineration the amount of ash was found to be .15 % of the original material. The alcoholic extract, for determination of total amount of organic solids dissolved, was evaporated in a current of carbonic acid, when the residue dried gave 8.6 % and 7.98 % of solids respectively. A cloudiness formed on the addition of water to the residue, which cleared up on addition of alkalies. It was restored by acid. The aqueous liquid gave precipitates with calcium and lead salts. It reduced Fehling's solution on adding dilute acid, and warming. Negative results followed tests for alkaloids. Treating with two volumes of absolute alcohol, according to Dragendorff, for detection of gum, vegetable mucilage was separated. Tests failed to detect the presence of tannin.

The residue of the powdered bark, after exhaustion with absolute alcohol, was treated with cold water. A deep-red mucilaginous liquid, which became frothy on shaking, was extracted. The amount of solids in this solution, on evaporating the liquid and weighing the residue, was found to be 19.11 %. In absence of acid or boiling, glucose was identified by Fehling's solution, also by Mulder's test. A gum, separated by absolute alcohol and quantitatively estimated, showed 4.8 % of the amount of substances dissolved in water. The powdered residue, after treatment with water, was macerated with dilute acid, and gave negative tests for alkaloids. The extraction with caustic soda for identification of albuminous substances, followed by chlorine water for the estimation of lignin and cellulose, have not as yet been determined.

The results of the proximate analysis as so far completed may be stated as follows: —

Moisture	9.4	per cent.
Petroleum spirit residue	9.	"
Ethereal residue	4.52	"
Alcholic residue	8.6	"
Water residue	19.11	"
Total ash	10.26	"
Alcholic extract ash	00.15	"
	61.04	"

The difference of 38.96 % would include pectose, coloring matter, and cellulose or woody fibre.

A qualitative ash determination showed the presence of calcium, magnesium, aluminum, potassium, sodium, a trace of iron, sulphates, phosphates, and chlorides.

Petroleum spirit extracted a solid substance, yellowish-green in color, of sp. gravity .984, melting from 84° C. to 85° C., insoluble in water, slightly soluble in boiling 95 % alcohol, soluble in absolute alcohol, cold ether, chloroform, amyl alcohol, benzole, carbon di-sulphide, oil of turpentine, and linseed oil. It was slightly acted upon by aqueous alkalies, but readily saponified with alcoholic soda. Treating the soap with lead acetate and boiling the precipitate with ether, a yellow crystalline substance was obtained, melting from 43° C. to 60° C.

Sulphuric acid combined with solvents gave characteristic and distinct reactions with the yellowish-green petroleum spirit residue, and with the crystalline substance separated from it.

A scheme has been proposed for the identification of various waxes, based upon quantitative experiments.[1] The examination rendered division into two groups possible, according to the solubilities of the waxes with chloroform. Again, their action with ether, and acetate of lead solution added to the alcoholic solutions, allows the several varieties of waxes to be distinguished from one another.

The petroleum spirit residue was submitted to the tests proposed in Hirschsohn's scheme. It was boiled with ten times its volume of chloroform, and when cool the liquid became cloudy. By this test, the petroleum spirit residue was placed in the group with carnaüba and Bahia wax. An ethereal solution of the petroleum spirit residue, on adding an equal volume of alcohol, remained clear. According to Hirschsohn's scheme,[2] an ethereal solution of Bahia wax similarly treated remains clear, and by this means the wax is distinguished from carnaüba wax, which it is said to resemble in most of its properties. The wax from *Copernicia cerifera*, the carnaüba tree of Brazil, and carnaüba wax obtained from the leaves of *Corypha cerifera*, are related very closely by their chemical properties, and possibly are identical.[3]

Carnaüba wax is described as a clear yellow wax with a greenish tinge, and harder than beeswax. It contains a notable percentage of free melissyl alcohol and other alcohols very difficult to separate. Insoluble in water, it is dissolved with difficulty by alcohol and ether, though readily soluble in carbon di-sulphide and oil of turpentine. It is not acted upon by linseed oil; it is changed yellow by nitric acid; with sulphuric acid no appreciable effect is produced. The melting-point is variously stated from 82° to 85° C. The specific gravity from .998 to .999.

[1] "Contributions to the Chemistry of Several Varieties of Wax," by E. Hirschsohn, *Pharmaceutical Journal and Transactions*, vol. x, March, 1880.

[2] *Loc. cit.*

[3] Gmelin, *Handbook of Chemistry*, vol. xviii. Translated by H. Watts, London.

A table of the specific gravity of the different kinds of waxes, prepared by Dietrich,[1] shows the density of animal wax to be notably low, compared with vegetable waxes. Allen[2] states that the presence of vegetable wax in adulterations of beeswax is positively established if the density of the sample exceed .970.

By the method followed out in this analysis, petroleum spirit extracted from the powdered bark a substance of constant melting-point, which is identified as a wax. It resembles, in its ethereal solution not clouding on addition of alcohol, Bahia wax; in melting-point and specific gravity, carnaüba wax; also the latter wax by its insolubility in water and action with nitric acid. It differs from carnaüba wax in its greater degree of solubility in absolute alcohol, ether, and aqueous alkalies. Linseed oil is an active solvent for it, but does not dissolve carnaüba wax. The color reactions of the petroleum spirit residue with sulphuric acid have been described above. It is stated that sulphuric acid produces no effect with carnaüba wax.[3]

The wax obtained from the bark of *Fouquieria splendens* differs generally in its properties from known vegetable waxes, and is evidently a new wax peculiar to this plant. I propose that it be called ocotilla wax.

In the ether, absolute alcohol, and water extracts, the presence of an acid resin, a white crystalline substance, gum resin, glucose, possibly glucosides, gum, and a red coloring matter were indicated.

The investigations described in the preceding pages were conducted in the chemical laboratory of the Philadelphia College of Pharmacy, August and September, 1884.

[1] E. Dietrich, "Specific Gravity of Wax." *Journal* of Chemical Society, 1882, vol. xlii, p. 1139.

[2] A. H. Allen, *Commercial Organic Analysis*. (Also see in same work tables of sp. gr., Waxes.)

[3] A. B. Prescott, *Outlines of Proximate Organic Analysis*.

A CHEMICAL STUDY OF YUCCA ANGUSTIFOLIA[1]

THIS plant is well known in the West as the "soapweed." It grows very abundantly in most of the Western States and territories. It has attracted the attention of botanists, and is a plant of interest on account of the many uses to which it has been put in the countries where it is found.

The results noted in this paper are based upon a first and introductory chemical analysis of the *Yucca*. Previously, little has been studied of its chemistry. It is briefly mentioned in the work of a French writer, Dr. Georges Pennetier;[2] also, in a paper on the study of manganese found in the ash of plants, in which M. Maumené states that the ash of the *Yucca* contains manganese.[3] He does not name what species of *Yucca* was examined. The former writer gives the micro-chemical characters of the action of iodine and sulphuric acid, dilute chromic acid, and cuprammonia on the fibres of the *Yucca angustifolia*.

The specimens of *Yucca* used in these analyses were of large growth and in good condition. The entire plant was examined, and a separate study made of the bark and wood of the root, and of the green leaf and the yellow basal part. The roots were air-dried, freed from adherent dust, reduced to a very fine powder, and passed through a No. 80 sieve. The leaves were less finely powdered.

Dragendorff's scheme for plant analysis[4] has been gener-

[1] Read before the American Philosophical Society, December 18, 1885. An abstract of this paper was read before the Chemical Section of the American Association for the Advancement of Science, at Ann Arbor, Michigan, August 28, 1885.

[2] *Leçons sur les Matières Premières Organiques*, Paris, 1881, p. 446.

[3] M. E. J. Maumené, *Bul. de la Société Chimique de Paris*, tome xlii, p. 305.

[4] *Plant Analysis, Qualitative and Quantitative*, by G. Dragendorff. Translated from the German by Henry Greenish, London, 1884.

ally followed. Ten grams of the air-dried powder were used for the preliminary examination of soluble substances. For every gram of the powder, ten c. c. of the solvents were employed. An additional quantity of the powder was prepared for special purposes. Five grams of the air-dried powder were dried, in a hot-air oven, at a temperature between 100° C. and 110° C., until the weight remained constant, for the estimation of moisture. This powder was incinerated in a covered porcelain crucible at a dull red heat until the carbon was entirely consumed. The per cent. of total ash was determined from it.

QUALITATIVE ASH ANALYSES

Calcium, magnesium, potassium, sodium, iron, manganese, chlorides, phosphates, and sulphates were found in every part of the plant.

Determination of { I. MOISTURE / II. TOTAL ASH } on the powder.

	I. Per cent.	*II. Per cent.*	*Color of Ash.*
1. The bark of the root	6.78	17.38	reddish
2. " wood "	11.67	15.75	" gray
3. " green leaf	8.11	5.75	gray
4. " yellow base of leaf	37.00	10.63	white

PETROLEUM SPIRIT EXTRACTS

Extract (1) *Bark of Root.*

The maceration was conducted in an apparatus similar to one described in Dragendorff's "Plant Analysis."[1] A light petroleum spirit was used which boiled between 25° C. and 45° C. The *extract* was filtered from the powder-residue. It was a clear pale yellow-colored liquid, and slightly acid in reaction. A drop of the *extract* on evaporating left a uniform

[1] Page 99, Tollen's apparatus.

spot on blue paper. The *extract* was evaporated at the ordinary temperature. The *residue* was a solid, and it had the odor and characteristic crystalline structure of fatty acids, suggesting the presence of a fixed oil. Its melting-point was taken. The substance melted at 60° C., and on cooling solidified amorphous. To determine the total amount of solids extracted, a definite volume of the *extract* was evaporated, dried, and weighed.

TOTAL SOLIDS.

Petroleum spirit residue dried at 100° C	1.24	per cent.	of	solids.
" " " 110° C	1.20	"	"	"
	0.04	"	"	loss.

The *residue* was identified as a fixed oil. It was soluble in petroleum spirit, ether, benzole, chloroform, amyl alcohol, carbon di-sulphide, and cold aqueous alkalies; incompletely soluble in cold or boiling 86 per cent. alcohol, 95 per cent. alcohol, absolute alcohol, acetic ether, and ammonium hydrate. No change of color was observed on treating the fixed oil with concentrated sulphuric acid, nor on the addition of syrupy phosphoric acid, though it was partially soluble in these acids. Phosphoric acid colored it yellow; it was colered yellowish by concentrated hydrochloric acid and nitric acid of 1.22 specific gravity. A mixture of concentrated sulphuric acid and nitric acid of 1.22 specific gravity changed the color of the fixed oil to a reddish-brown; it was colored pale green by sulphuric acid of 1.634 sp. gr. and of 1.53 sp. gr. Calcium di-sulphide gave a bright green color reaction with the fixed oil, but did not form an emulsion with it; aqueous solutions of gold and platinum chlorides were reduced by it. The fixed oil was saponified with difficulty by alcoholic soda; but readily by boiling aqueous soda; a white fragile soap was separated and filtered from the liquid. The soap was decomposed by hydrochloric acid and the fatty acids separated. The filtrate from the soap was examined for glycerin. By the method[1] used, an oily liquid was ob-

[1] *Plant Analysis*, G. Dragendorff, p. 12.

tained; it was heated with anhydrous borax on platinum foil, and gave the usual green-colored flame test for glycerin. The alcoholic solution of the *petroleum spirit residue* was fractionally precipitated with an alcoholic solution of magnesium acetate, and traces of an amorphous residue were recovered.[1]

The *petroleum spirit residue* was digested with water containing sulphuric acid, and examined for alkaloids which are sometimes brought down with fixed oils. The usual reagents failed to detect traces of alkaloids.

Extract (2), *Wood of the Root.*

The maceration was carried out under the same conditions as in *extract* (1).

The *extract* was a clear, colorless solution, neutral in reaction. A drop of the liquid left no uniform spot on blue paper. The *extract* was evaporated at the ordinary temperature. The *residue* was light yellow-colored, of a semi-solid consistency and melted at 36° C. A definite volume of the *extract* was evaporated, dried, and weighed.

TOTAL SOLIDS.

Petroleum spirit residue dried at 100° C..........	0.55	per cent. of solids.	
" " " 110° C..........	0.35	" " "	
	0.20	" " loss.	

The *residue* was identified as a fixed oil, associated with volatile fatty acids. The latter were indicated by the 0.2 per cent. of loss, and the disagreeable odor of the *residue* which was dissipated on heating at 110° C.

The *petroleum spirit residue* from the *extract* was evaporated at the ordinary temperature, dissolved with difficulty in cold 95 per cent. alcohol, and in boiling weaker alcohol; absolute alcohol hardened and discolored it. Concentrated sulphuric acid, nitric acid, and hydrochloric acid did not appreciably act on the *residue*. It was not saponified, but slowly dissolved by boiling aqueous and alcoholic soda. The alco-

[1] *Loc. cit.*, p. 16.

holic solution of the *petroleum spirit residue* was submitted to a fractional precipitation with an alcoholic solution of magnesium acetate. The first precipitation obtained was purified by boiling alcohol; it was an opaque scaly crystalline solid which melted at 85° C. The second precipitation yielded traces of a white amorphous substance. The third precipitation resulted from adding strong ammonia water to the magnesium acetate solution, and the purified residue melted at 60° C.

Negative tests for alkaloids followed an examination of the aqueous treatment of the *petroleum spirit residue.*

Extract (3), *Green Part of the Leaf.*

The method of extraction was the same as that used in the previous extractions. The *extract* was clear, pale green in color, and non-fluorescent. It was colored by a small quantity of chlorophyll, which the petroleum spirit dissolved. The liquid was acid in reaction. A drop of it left a permanent stain on blue paper, when evaporating. The *extract* was evaporated at the ordinary temperature, and the *residue* was a dark greenish-yellow semi-fluid substance. The solidifying point was taken. It was found to be about 15° C. A definite volume of the *petroleum spirit extract* was evaporated, dried, and weighed.

TOTAL SOLIDS.

Petroleum spirit residue dried at 100° C.	2.20	per cent. of solids.
" " " 110° C.	2.01	" " "
	0.19	" " loss.

The *petroleum spirit residue* was identified as a fixed oil with a small amount of chlorophyll that had been brought into solution by it. It was soluble in cold 83 per cent. alcohol, 95 per cent. alcohol, absolute alcohol, amyl alcohol, ether, acetic ether, chloroform, benzole, carbon di-sulphide and glycerin. It was also soluble in oil of turpentine, almond oil, ammonium hydrate, mercuric chloride, and slowly soluble in acetic acid. Concentrated nitric acid, and hydrochloric acid slowly dissolved the fixed oil; the former colored it dark green, and on stirring the mixture the color was changed to a brown. Concentrated sulphuric acid dissolved and changed it to a very dark brown color; on adding concentrated nitric acid, the liquid was changed to a reddish-brown color.

The following reactions were noted: The fixed oil changed to a hard greenish-yellow substance on heating it with anhydrous borax on platinum foil. When rubbed on a crucible lid with powdered rosaniline, it was colored red, showing the presence of free fatty acids. It did not emulsify with calcium di-sulphide nor with syrupy antimony chloride, but it was colored dark-green by the latter. It was imperfectly dissolved by phosphoric acid, and slowly soluble in equal parts of cane sugar and concentrated hydrochloric acid; more rapidly soluble in equal parts of cane sugar and nitric acid. An aqueous solution of picric acid made alkaline by sodium carbonate colored the fixed oil a light reddish-brown color; cane sugar added to the solution facilitated dissolving it. It was instantly dissolved by equal parts of picric acid and acid ammonium phosphate, and on warming with stannous chloride, leaving a turbid yellow-colored liquid. It was insoluble in aqueous barium hydrate; soluble in alcoholic ammonia with no coloration, and in sulphurous acid. It was colored brown when mixed with sulphuric acid of 1.634 specific gravity, and incompletely dissolved; it was also colored brown by ferric chloride. On adding to the fixed oil sulphuric acid of 1.475 specific gravity, and a small quantity of zinc, hydrogen was generated, and the solubility of the oil in the acid liquid was accompanied by a rosy tint given to the solution.

Extract (4), *Yellow Part of the Leaf.*

The *extract* was obtained by a similar process to that used for the other petroleum spirit *extracts*. The *extract* was a pale yellow-colored liquid. The reaction was slightly acid. A uniform spot was left on blue paper as the drop evaporated. The petroleum spirit was evaporated at the ordinary temperature, and a yellow-colored *residue* recovered, of a semi-solid consistency and crystalline in structure. It solidified at 12° C. From a definite volume of the *petroleum spirit extract*, the amount of total solids was determined.

TOTAL SOLIDS.

Petroleum spirit residue dried at	100° C.	1.1	per cent. of solids.
" " "	110° C.	1.1	" " "
		0.00	" " loss.

The *residue* was identified as a fixed oil. It was soluble in warm absolute alcohol, incompletely soluble in weaker alcohol; soluble in cold acetic ether, chloroform, benzole, amyl alcohol, ether, carbon di-sulphide, and glycerin. It was saponified with aqueous soda and a white soap separated. No reaction was observed with picric acid and ammonium phosphate, nor with nitric acid of 1.32 specific gravity and 1.18 specific gravity. The fixed oil was soluble in potassio-mercuric iodide solution; and colored dark brown by alcoholic ammonia. A mixture of ferric chloride solution and powdered rosaniline gave a fine violet-colored reaction with the fixed oil.

An examination of the aqueous treatment of the *petroleum spirit residues* (3) and (4), for alkaloids, gave negative results. A portion of the original powder, from each of the four parts of the plant, was mixed with an aqueous solution of caustic soda, and the distillate examined for volatile alkaloids with negative results.

SUMMARY I. PETROLEUM SPIRIT EXTRACTS

	Solids extracted.	*Character of residue.*	*Reaction with litmus.*	*Melting point.*	*Solidifying point.*
1. Bark of the root....	1.24 %	fixed oil	slightly acid	60° C.	solid at ordinary temperature
2. Wood of the root...	0.55 %	fixed oil	neutral	36° C.	
3. Green leaf..........	2.20 %	fixed oil, chlorophyll	acid	semi-fluid at ordinary temperature	15° C.
4. Yellow base of leaf	1.10 %	fixed oil	faintly acid		12° C.

The solids extracted by petroleum spirit from the four parts of the plant are identified as fixed oils;[1] associated with a vola-

[1] "Fixed Oils," *Science*, September 11, 1885.

tile principle (0.2 per cent.) in *extract* (2), and with traces of chlorophyll in *extract* (3).

Fixed oil (1) was crystalline in structure. It was soluble in ether, chloroform, benzole, carbon di-sulphide, and amyl alcohol; incompletely soluble in cold or boiling alcohol, acetic ether, and ammonium hydrate. It was colored pale green by sulphuric acid of 1.634 specific gravity, and changed to a bright-green color by calcium di-sulphide, but formed no emulsion with it. Phosphoric acid colored it yellow. The fixed oil was saponified, and a white soap separated. This was decomposed, and the fatty acids recovered. Glycerin was separated from the soap filtrate.

Fixed oil (2) was dissolved with difficulty in boiling 95 per cent. alcohol, and hardened and discolored by absolute alcohol. It was not saponified. Crystalline solids were separated by precipitating the alcoholic solution with magnesium acetate. They melted at 85° C. and at 60° C., respectively.

Fixed oil (3) was soluble in alcohol, ether, chloroform, benzole, carbon di-sulphide, oil of turpentine, almond oil, glycerin, and slowly soluble in acetic ether. The presence of free fatty acids was demonstrated. The fixed oil was colored dark-green by syrupy antimony chloride; on adding to it sulphuric acid of 1.475 specific gravity, and a small quantity of zinc, hydrogen was generated, and the solubility of the oil in the acid liquid was accompanied by a rosy tint given to the solution.

Fixed oil (4) was crystalline in structure. It was soluble in warm absolute alcohol, in cold acetic ether, chloroform, benzole, amyl alcohol, ether, carbon di-sulphide, and glycerin. It was saponified, and a white soap separated. The fixed oil was colored dark-brown by alcoholic ammonia, and a mixture of ferric chloride solution and powdered rosaniline gave a violet-colored reaction with it.

These fixed oils differed in their physical characters and chemical reactions. This difference may be due to the presence of free fatty acids and glycerides in varying proportions in the four parts of the plant. It is of interest to note that in the subterranean part of the *Yucca*, the oil extracted from the bark was solid at the ordinary temperature; from the wood it was of a less solid consistency; while the yellow base of the leaf contained an oil quite soft, and in the green leaf the oil was almost fluid.

Extract (2) contained an oil of low melting-point. It melted at 36° C. An alcoholic solution was fractionally precipitated with magnesium acetate, and three members of the fatty acid series were isolated. The quantities obtained were small, and it was impossible to do more than to take the melting-point of two of the purified crystalline residues. They melted at 85° C. and at 60° C., respectively. It is a well-known fact that a mixture of fat acids in certain proportions has a lower melting-point than those of its constituents.

Alkaloids and volatile-alkaloids were not detected in the *petroleum spirit extracts.*

ETHER EXTRACTS

Extract (1), *Bark of the Root.*

The residual powder from the petroleum spirit extraction was dried until thoroughly freed from petroleum spirit. It was then macerated with Squibb's stronger ether in the apparatus already described. The *ethereal extract* was filtered from the powder. It was a clear crimson-colored liquid, tinted by some red coloring matter dissolved; and acid in reaction. The *extract* was slowly evaporated at the ordinary temperature; white needle-shaped crystals were seen as the liquid concentrated. The *ethereal residue* was of a resinous character. It was ruby-colored, transparent, and of a softer consistency than ordinary resin. Microscopically, the *residue* was identified as a resin by its color reaction with Hanstein's aniline violet solution.[1] The *ethereal residue* was treated with petroleum spirit to remove any traces of fat that may have been extracted with it. It was heated in a small tube; at 50° C. it experienced a slight change, and melted at 70° C. For a determination of the total solids, a definite volume of the *ethereal extract* was evaporated, dried, and weighed.

[1] *Botanical Micro-Chemistry*, Poulsen-Trelease, Boston, 1884, p. 59.

TOTAL SOLIDS.

Ethereal residue dried at 100° C.	3.16	per cent. of solids.
" " " 110° C.	3.16	" " "
	0.00	" " loss.

The resin was incompletely soluble in 95 per cent. alcohol, absolute alcohol, and amyl alcohol; readily soluble in ether, not appreciably soluble in chloroform, benzole, and carbon disulphide. It was dissolved by sulphuric acid to a colorless solution, which, on warming, turned to a yellow color, and gradually darkened to a dull brown color, fading to a pale yellow.

An attempt was made to separate the white needle-shaped crystals mentioned above. The *ethereal residue* was agitated with acetic ether. The liquid was filtered from the insoluble matter and evaporated. Traces of a resinous substance were separated. The insoluble matter was treated with boiling ether, filtered hot, and the filtrate concentrated. On cooling, the white needle-shaped crystals reappeared. They were insoluble in water and in acetic ether.

A separate portion of the *ethereal extract* was evaporated, and treated with warm distilled water. The aqueous extract was made up to a definite volume, and a known quantity evaporated, dried, and weighed. The amount of total solids was almost inappreciable by weight. The aqueous extract was not colored by iron salts, and it did not form a precipitate with alum and gelatine solution, lead acetate, potassio-mercuric iodide, nor gold chloride solutions; showing absence of tannin, gallic acid, and alkaloids. The *ethereal extract* was directly tested for these compounds, and with negative results. A portion of the aqueous extract was evaporated to dryness, and treated with potassa solution, and the residue dissolved with no coloration. Another portion of the aqueous extract was agitated with acetic ether, and the liquids were separated; on evaporating the acetic ether solution, traces of a residue were obtained which sulphuric acid acted upon. A resinous substance separated from the greenish-colored acid liquid; the former was partially disintegrated by cold water.

The specific gravity of the resin was 1.091.

Extract (2), *the Wood of the Root.*

The residual powder from the petroleum spirit extraction was macerated in stronger ether. The *ethereal extract* was of a reddish-yellow color, slightly acid in reaction. It was slowly evaporated at the ordinary temperature, and as the liquid concentrated, white needle-shaped crystals appeared, and presented the same physical structure as the crystals found in the *ether extract* (1).

The *ethereal residue* was identified as a resin. It was a transparent, ruby-colored substance, and acid in reaction. It was heated to 50° C., at that temperature its color deepened, and at 70° C. it melted. The specific gravity of the resin was 1.091. A definite volume of the *ether extract* was evaporated, dried, and weighed to determine the amount of total solids.

TOTAL SOLIDS.

Ethereal residue dried at 100° C.	1.70	per cent. of solids.
" " " 110° C.	1.45	" " "
	0.25	" " loss.

The resin was examined by Hirschsohn's scheme [1] with a view to classify it with known resins. It was imperfectly soluble in 95 per cent. alcohol and chloroform, soluble in ether. The alcoholic solution gave a turbidity with lead acetate, not cleared upon boiling, and with ferric chloride formed a clear mixture. Concentrated sulphuric acid dissolved the resin, leaving a dark yellow-brown liquid which faded to a dull yellow color. The sulphuric acid solution, when mixed with alcohol, changed to a pale gray color. On addition of water to the acid solution, there was no coloration nor separation of the resin. Alcohol containing hydrochloric acid gave no color reaction with the resin. Bromine solution added to the chloroform-resin extract, and iodine solution to the ether-petroleum-resin extract, gave no reactions. Sodium carbonate at the ordinary temperature had no effect on the resin, but, on boiling, the liquid was colored yellow.

[1] E. Hirschsohn, Watts's *Chem. Dict.*, vol. viii, pt. ii, p. 1743.

By the above examination, this resin was thrown out of the numerous classes of described resins. It is proposed to name it yuccal.[1]

Yuccal was soluble in boiling absolute alcohol and acetic ether; incompletely soluble in benzole, carbon di-sulphide, alcoholic ammonia, and cold acetic ether. The red color of the resin was removed by cold acetic ether, a transparent substance remaining, soluble in hot acetic ether.[2] Yuccal was dissolved by potassio-mercuric iodide. It reduced aqueous solutions of gold and platinum chlorides. A blood-red color reaction was obtained by warming a small quantity of the resin on a crucible lid with a crystal of ammonium molybdate and a few drops of nitric acid. On adding to the resin mixture a few drops of strong sulphuric acid, and again warming, it was dissolved. Warm dilute nitric acid dissolved the resin, colorless; cold nitric acid gave a brownish-green color reaction.[3] Yuccal was heated on platinum foil, and as it decomposed the fumes that were given off were pleasant and aromatic. Tests failed to show the presence of benzoic or cinnamic acids.

[1] I suggest that in future all resins be distinguished by the terminal syllable *al*, for uniformity of resin nomenclature. "Yuccal," *Science*, September 11, 1885, p. 210.

[2] I have examined the action of acetic ether as a solvent for resins. Cold acetic ether dissolved ordinary resin, turpentine, styrax, tolu-balsam, mastic, elemi, Canada-balsam, Peru-balsam, copaiba-balsam, Venice-turpentine, and, incompletely, spruce-gum and yuccal. In hot acetic ether, spruce-gum and yuccal were soluble. The following resins were insoluble in hot or cold acetic ether: guiacum, sandarac, shellac, benzoin, olibanum, ammoniac, myrrh, galbanum, and asafœtida.

[3] A reddish-yellow decomposition product resulted from the action of nitric acid on many resins which followed generally quite soon after adding the acid to a small quantity of the resin (0.1 gram of the resin and 5 c. c. of nitric acid, 1.4 sp. gr.). But the reaction which took place varied according to the conditions, *i. e.*, strength of acid used, the application of heat to the resin acid mixture, or the addition of solvents to the mixture. The more concentrated the acid the more rapid was the reaction. The application of heat also hastened the change, especially if a more dilute acid was used in the mixture. Some solvents acted like heat by increasing the energy of the reactions. Alcohol and ether were active solvents, and the reaction was attended by the escape of nitrous fumes from the combination of alcohol or ether and nitric acid. Chloroform and benzole were indifferent. Amyl alcohol acted feebly.

The *ethereal residue* was treated with warm water, and on cooling, the liquid was agitated with acetic ether, which was separated, and when evaporated yielded a small quantity of resinous substance. The *ethereal residue* insoluble in water was treated with boiling ether, and as the liquid concentrated, the white needle-shaped crystals were seen floating in it, but on further concentration they could not be seen, and a yellow greasy-looking mass settled in the bottom of the beaker. On driving off the ether, a transparent and ruby-colored resinous substance remained. The aqueous extract obtained in the way described above gave no coloration with iron salts, and no precipitate with gelatine and alum solution, potassio-mercuric iodide, or gold chloride solutions. Fehling's solution was not reduced by boiling, though the aqueous extract was boiled with acid, then rendered alkaline before adding the copper test. The preceding tests gave negative results for gallic acid, tannin, alkaloids, and glucosides. A portion of the aqueous extract was acidified and agitated successively with different solvents, for glucosides, bitter principles, and alkaloids which may be removed from solution by this means. The acid liquid was then rendered alkaline with ammonia, and agitated successively with the same order of solvents that were used with the acidified liquid. No solids were separated by these methods. The *ethereal residue* insoluble in water was treated with alcohol, and yielded traces of a resinous substance. The residue, insoluble in water and alcohol, was not dissolved by ether, acids, or alkalies.

Yuccal, or the *ethereal residue* soluble in ether and alcohol, was saponified, and the soap boiled with lead acetate. The yellow masses were collected on a filter and treated with boiling ether, and the filtrate was slowly evaporated. The residue was a granular solid. This substance was imperfectly purified by repeated boiling with ether, and a solid of crystalline structure obtained. It gave an acid reaction with litmus, and a red color with concentrated sulphuric acid. The acid dissolved a substance enclosing the crystals, leaving the structure of the latter uninjured and colored. Strong nitric acid dissolved the crystals with no coloration. They were soluble in absolute alcohol, amyl alcohol, benzole, chloroform, glycerin, and a solution of alcoholic soda; soluble in potassium iodide, potassium chromate, mercurous nitrate, cobalt nitrate, potassium ferro- and ferri- cyanide solutions; insoluble in ammonia and aqueous alkalies.

Yuccal was treated with spirit of different strengths, as a means of separating resin acids if any were present. It was treated with 85 per cent. spirit; an opaque brown substance was left undissolved, which was soluble in absolute alcohol; insoluble in ether, and colored brown by concentrated sulphuric acid. The color was not discharged by alcohol or ether. The 85 per cent. spirit solution was evaporated, and the residue treated with 50 per cent. spirit, and a small quantity of a brown residue was insoluble. The 50 per cent. spirit solution, on evaporating, left a non-crystalline, transparent, reddish-colored solid, acid to litmus. It was colored cherry-red by concentrated sulphuric acid, and slowly dissolved to a yellowish-red liquid.

Extract (3), *the Green Part of the Leaf.*

The residual powder from the petroleum spirit maceration was thoroughly dried, and again placed in the percolator. It was treated with Squibb's stronger ether. The *extract* was a deep green-colored liquid and fluorescent. The reaction was slightly acid. Alcohol, benzole, and petroleum spirit added to the *ethereal extract* did not cause a precipitation. An amorphous and green-colored residue was obtained on evaporating the *extract*. The amount of total solids was estimated from a definite volume of the *extract*, which was evaporated, dried, and weighed.

TOTAL SOLIDS.

Ethereal residue dried at 100° C.	1.25	per cent. of solids.
" " " 110° C.	1.14	" " "
	0.11	" " loss.

The *ethereal residue* was brought into a state of fine division and treated with water. The amount of total solids soluble in ether and water was 0.34 per cent. The aqueous extract was neutral in reaction. It was faintly colored and slightly bitter to the taste. It was not colored by iron salts or precipitated with alum and gelatine solution, showing absence of gallic acid or tannin. Copper solutions were not reduced, indicating absence of glucosides, though the precaution was observed of boiling the aqueous extract with acid, and rendering alkaline before adding the copper solution. The aqueous extract was agitated with acetic ether and a distinctly crystalline residue separated. Under the miscroscope these crystals were white, needle-shaped, and arranged in bundles. They did not respond to tests for gallic acid. Potash solution formed a yellow mixture with the crystals. The color was discharged by a drop of hydrochloric acid. Chloroform did not dissolve any substance from the *ethereal residue.* The *ethereal residue* was treated with acidulated water and tested negatively for alkaloids.

The *ethereal residue* insoluble in water was treated with alcohol. The amount of substances insoluble in water, and soluble in ether and alcohol, was 0.15 per cent. The alcoholic solution was evaporated, and the residue was crystalline in structure. Concentrated sulphuric acid imperfectly dissolved it, and gave a reddish-yellow color reaction; acetic ether discolored the solution. The alcoholic residue was insoluble in acetic ether, cold and boiling aqueous alkalies; soluble in chloroform. It saponified with alcoholic soda.

The amount of the *ethereal residue* insoluble in water and alcohol was 0.65 per cent. It was not soluble in alcoholic or aqueous soda. This would indicate a resin anhydride. Concentrated sulphuric acid gave no color reaction with it; and a mixture of sulphuric acid and cane sugar dissolved the residue.

The *ethereal residue*, on treating with cold ether, was not entirely soluble in it. It was soluble in chloroform, benzole, and carbon di-sulphide; incompletely soluble in cold alcohol, and insoluble in amyl alcohol. The *ethereal residue* was treated with 95 per cent. alcohol, in which it was slightly soluble. A turbidity formed in the alcoholic solution on adding lead acetate, ferric chloride, ammonium hydrate, and sulphuric acid;

it did not clear up on warming. Hydrochloric acid made a muddy mixture with the alcoholic solution. The *ethereal residue* was not entirely soluble in acetic ether; the latter separated coloring matter from it. The *ethereal residue* insoluble in acetic ether and freed from coloring matter (chlorophyll) was a resinous substance. It melted at 80° C. The resin was boiled with absolute alcohol, and on throwing the alcoholic solution into cold water it was precipitated as a white cloud. It was not saponified.

Extract (4), *Yellow Base of Leaf.*

The residual powder from the petroleum spirit maceration was dried and extracted with stronger ether. The *ether extract* was a turbid yellow liquid, slightly acid in reaction. On evaporating the *ethereal extract* at the ordinary temperature a reddish-yellow granular solid remained. It melted at 79° C. For the determination of total solids extracted, a definite volume of the *extract* was evaporated, dried, and weighed.

I.

TOTAL SOLIDS.

Ethereal residue dried at 100° C.	1.7	per cent. of solids.
" " " 110° C.	1.7	" " "
	0.0	" " loss.

The *ethereal residue* was treated successively with distilled water, alcohol, and ether.

II.

Substances soluble in ether and water	0.8	per cent.
" " " ether and alcohol	0.4	"
" " " water and alcohol	0.5	"
Total solids	1.7	"

The aqueous extract gave a neutral reaction with litmus. Negative results followed examination for tannin, gallic acid, glucosides, alkaloids, and any compounds containing nitrogen.

The *ethereal residue* (the *residue* insoluble in water) was an opaque, reddish-yellow colored substance, and was identified as a resin. It melted at 79° C. It was insoluble in ether, benzole, chloroform, and acetic ether; incompletely soluble in cold absolute alcohol, amyl alcohol, carbon di-sulphide, and oil of turpentine. It was soluble in aqueous and alcoholic soda. On boiling with them, it was saponified. Concentrated sulphuric acid dissolved the resin and colored it a yellowish brown. Chloroform formed a turbid mixture with the acid solution. The action of strong nitric acid on the resin was slow. The resin was incompletely soluble in 95 per cent. alcohol. Lead acetate gave a cloudliness with the alcoholic solution which increased on boiling. Ferric chloride thickened the alcoholic solution, and on boiling it gave a yellow precipitate which was insoluble in acids, alkalies, absolute alcohol, and acetic ether. The chloroform extract gave no coloration with bromine solution.

SUMMARY II. ETHEREAL EXTRACTS

	Solids extracted.	*Character of residue.*	*Reaction with litmus.*	*Melting-point.*	*Specific gravity.*	*Substances soluble in ether and water.*	*Substances soluble in alcohol and water.*	*Substances soluble only in ether.*
1. Bark of the root....	3.16%	resin	acid	70° C.	1.091	traces	traces	....
2. Wood of the root	1.70%	resin	slightly acid	70° C.	1.091	traces	traces	....
3. Green leaf	1.25%	resin, chlorophyll	slightly acid	80° C.	......	0.34%	0.15%	0.65%
4. Yellow base of leaf	1.70%	resin	slightly acid	79° C.	......	0.80%	0.40%	0.50%

The residues from the *ether extracts* (1) and (2) of the bark and of the wood of the root contained resins which were identified as the same compound. They correspond in color, melting-point, specific gravity, solubilities, and reactions. The resin is a transparent, ruby-colored substance, crystalline in structure, and of a softer consistency than ordinary resin. It was examined by Hirschsohn's scheme.[1] It differed from all described resins in its reactions with the reagents used to identify them. It is proposed to name it yuccal.[2]

[1] *Loc. cit.*

[2] See foot-note, *ether extract* (2).

Yuccal is imperfectly soluble in 95 per cent. alcohol; soluble in boiling absolute alcohol, in cold ether, and amyl alcohol; not appreciably soluble in chloroform, benzole, carbon di-sulphide, or alcoholic ammonia. Cold acetic ether dissolved the coloring matter from the resin, leaving a colorless solid. Hot acetic ether dissolved it perfectly. Yuccal when heated on platinum foil gave off as it burned a pleasant and aromatic odor. Tests failed to show the presence of benzoic or cinnamic acids. A blood-red color reaction was obtained by warming yuccal with a crystal of ammonium molybdate and a few drops of strong nitric acid. Warm dilute nitric acid dissolved the resin, colorless; cold nitric acid gave a brownish-green color reaction. Yuccal was mixed with concentrated nitric acid and heated. After some time had passed, an energetic reaction occurred and nitrous fumes were given off. A yellowish-brown residue was one of the products of the reaction. This residue was almost insoluble in water or acids. It was soluble in alcohol and potassium hydrate.[1]

As the *ether extracts* (1) and (2) were concentrated, white needle-shaped crystals appeared floating in the liquids, whose physical structure, and insolubility in water and acetic ether, suggested identical substances. The crystals separated from yuccal by the lead acetate method, already described, have not been sufficiently studied to identify them with the white needle-shaped crystals in the *ether extracts* nor with any class of chemical compounds. However, the absence of gallic acid, glucosides, and alkaloids in the aqueous extracts from *ethereal residues*, would show that the crystals separated from yuccal are a constituent part of the resin.

The experiments with spirit of different strengths are only of value, as far as they were carried out, in showing the possibility of separating the resin into distinct parts.[2]

Tannin was not present in these *ethereal extracts*.

Ethereal extract (3) was green-colored and fluorescent from

[1] See foot-note 3, *ether extract* (2).

[2] The amount of material on which these experiments, as well as others described in this paper, were tried, was too small in quantity for me to obtain more conclusive results. The facts which have been ascertained will serve as a guide in future investigations.

the chlorophyll of the leaves. On evaporating, the *ethereal residue* was amorphous and of a green color. The aqueous extract obtained from treating this *ethereal residue* was neutral in reaction and bitter to the taste. It contained no gallic acid, tannin, or glucosides. It was agitated with acetic ether, and the solvent removed a solid, which under the microscope proved to be white-needled shape crystals arranged in bundles. Potash solution formed a yellow-colored mixture with the crystals ; hydrochloric acid discharged the color. The subject has been too little studied to state definitely if these crystals are or are not identical with the crystals found in the *ethereal extracts* (1) and (2). But it should be noted, that unless the crystals from *ethereal extract* (3) are brought into aqueous solution mechanically by some compound not present in *ethereal extracts* (1) and (2), the indications are in favor of the crystals from (3) not being identical with them; for the crystals from (1) and (2) were insoluble in water and not removed by acetic ether.

The *ethereal residue* was treated with acidulated water and tested negatively for alkaloids.

The *ethereal residue* insoluble in water was a mixture of two resins (1) and (2). The one (1) was dissolved by absolute alcohol, the other (2) was mostly soluble in ether. The alcoholic residue was crystalline. It was insoluble in acetic ether, but was saponified with alcoholic soda. The ether residue was a resin anhydride; it was insoluble in alcohol, and in alcoholic or aqueous alkalies.

The amorphous and green-colored *ethereal residue* was not entirely redissolved by cold ether. It was soluble in chloroform, benzole, and carbon di-sulphide; incompletely soluble in cold alcohol, and insoluble in amyl alcohol. It was slightly soluble in 95 per cent. alcohol and in acetic ether. The latter separated the green coloring matter from it. The resinous mass insoluble in acetic ether melted at 80° C. It was not saponified. This resinous mass insoluble in acetic ether is a mixture of the two resins just described (1) and (2). It was noticeable that the resinous mass was not saponified. Resin

(1) was saponified. Resin (2) did not saponify, and as this resin exceeded in amount by 0.5 per cent. resin (1), it would show that a certain percentage of resin anhydride in a mixture of two resins forbids the saponification of the mixture.

It was not determined if the crystals dissolved by water and separated by acetic ether were a part of resin (1) or resin (2) or an independent compound.

Ethereal extract (4) was a turbid yellow liquid. On evaporating, a reddish-yellow granular solid remained. The extract from the aqueous treatment was tested with negative results for tannin, gallic acid, glucosides, and alkaloids. The *ethereal residue* insoluble in water was identified as a resin. It was soluble in ether, benzole, chloroform, and acetic ether; incompletely soluble in cold absolute alcohol, amyl alcohol, carbon di-sulphide, and oil of turpentine. It was saponified. A resin was extracted by boiling absolute alcohol from the residual powder of the leaves (the yellow base) which was identified as the same resin, and the name of pyrophæal[1] was proposed for it.

I. Resins (1) and (2) are identical substances (yuccal).

II. *Ethereal residue* (3) is a mixture of two resins, and a crystalline principle soluble in water.

III. Resin (4), pyrophæal, is identical with a resin found in *alcoholic extract* (4).

ALCOHOLIC EXTRACTS

Extract (1), *Bark of the Root.*

The residual powder from the ether extraction was dried, and replaced in the percolator. The maceration was conducted at the boiling temperature of alcohol. Squibb's stronger alcohol was used. A dark red-colored liquid was extracted. It was neutral in reaction with litmus. The *alcoholic extract* was evaporated in a current of carbonic acid. The residue was non-crystalline and of a red color. A definite volume of the *alcoholic extract* was evaporated, dried until the weight

[1] "Pyrophæal," *Science*, September 11, 1885.

remained constant, and the *residue* incinerated in a weighed platinum dish and the ash estimated.

I.

TOTAL SOLIDS.

Alcoholic residue dried at 100° C.	9.25	per cent.
" " " 110° C.	9.25	"
" " ash	0.2	"

The *alcoholic residue* was treated with distilled water, and a definite volume of the extract was evaporated, dried, and weighed. The *alcoholic residue* insoluble in water was treated with water containing ammonia (one part in fifty). This ammoniacal extract was evaporated with excess of acetic acid, and the residue rinsed with a little water on a filter, dried, and weighed. The dried aqueous extract insoluble in ammonia was then estimated.

II.

Distilled water residue	3.22	per cent.
Ammonia " "	5.43	"
Insoluble " "	0.60	"
Total solids	9.25	"

The aqueous extract from *alcoholic residue* was studied as follows: It was not colored by a ferroso-ferric salt nor precipitated by gelatine and alum solutions, showing absence of gallic acid and tannin. A portion of the aqueous extract was acidified with sulphuric acid and agitated successively with petroleum spirit, benzole, chloroform, and amyl alcohol. The acidified liquid was rendered alkaline by ammonia and agitated with the solvents in the same order. Petroleum spirit removed from the acidified solution traces of an amorphous residue, soluble in sulphuric acid and caustic soda. Benzole and chloroform separated no substances from the solution. As the amyl alcohol solution was evaporating, white needle-shaped crystals were seen floating in the liquid. On drying the residue they were decomposed and melted, leaving a dark-colored liquid. Several attempts were made to dry these crystals, without success. A few of the crystals were recovered from the solution, and tested for alkaloids; no reactions were obtained with the usual reagents for them.

Glucose was estimated from the aqueous extract. The liquid was heated over a water bath with Fehling's solution, and the precipitated red cuprous oxide was thrown upon a weighed filter, dried, and incinerated. The glucose was estimated gravimetrically by calculating the amount of cupric oxide. It yielded 0.619 per cent. A portion of the aqueous extract was boiled with acid, neutralized, and heated over a water bath with Fehling's solution to calculate, by difference, saccharose or other reducible compounds, and by this method 0.18 per cent. was obtained.

The *alcoholic extract* was described as being deeply colored. This coloring principle[1] was completely precipitated by subacetate of lead. The lead precipitate was collected on a filter, suspended in water, and decomposed by sulphuretted hydrogen, filtered, and the filtrate freed from all odor. It was allowed to evaporate slowly over sulphuric acid. The residue was a brownish-gray mass, interspersed with fine crystals which radiated from a nucleus. The mass was weighed and gave 3.27 per cent. of solids. Another portion of the *alcoholic extract* was agitated with water and acetic ether. The coloring matter was taken up by the acetic ether, and on evaporating a red-colored substance was recovered. It was dried and weighed, yielding 2.2 per cent. This red-colored residue was perfectly soluble in cold water. This solution was tested with the following reagents: It gave with potassium bichromate a creamy-colored precipitate; ferric chloride, a yellowish-green precipitate; ferrous sulphate, a reddish-brown precipitate; stannous chloride, no precipitate, a yellow cloudy liquid; alum, a cloudy solution; neutral acetate of lead, a slight precipitate. The red color of the coloring matter was brought out on addition of alkalies. It was destroyed by acids.

[1] "A Red Crystalline Coloring Matter," *Science*, September 11, 1885.

Extract (2), *Wood of the Root.*

The residual powder from the ether treatment was dried and macerated with Squibb's stronger alcohol. The *alcoholic extract* was neutral in reaction; when warm it was a clear reddish-golden colored liquid. On cooling, a creamy-white solid settled at the bottom of the flask. This substance was soluble in water, and was identified as saponin by the usual tests for it. A definite volume of the *alcoholic extract* was evaporated in a current of carbonic acid, dried, and weighed. The residue was incinerated in a weighed platinum crucible for the ash determination.

TOTAL SOLIDS.

Alcoholic residue dried at 100° C.	14.3	per cent.
" " " 110° C.	14.3	"
" " ash	00.1	"

The *alcoholic residue* was treated with cold water in which it was soluble. A cloudy solution was formed, and on shaking, it became frothy, and presented the appearance of an emulsion. It was allowed to stand for several days to see if the resinous matter separated, but the emulsion was permanent, as no separation had taken place. The emulsified liquid was agitated with acetic ether, and this solvent readily separated most of the resin from the aqueous portion. The water extract was then evaporated to dryness and redissolved in water. Gelatine and alum solution did not precipitate the extract, showing absence of tannin; no coloration with iron salts, absence of gallic acid; negative results followed tests for alkaloids; the aqueous extract was boiled with potash and no ammonia fumes were formed; adding gold chloride and potassio-mercuric iodide solutions to the extract gave no precipitate. A measured portion of the aqueous extract was acidified with sulphuric acid, and agitated successively with petroleum spirit, benzole, and chloroform. The solvents were evaporated; petroleum spirit removed 0.01 per cent. of a resinous substance, imperfectly soluble in cold and boiling aqueous alkalies, dissolved by sulphuric acid with a red coloration; chloroform left a brownish residue which, on weighing, yielded 0.4 per cent. This residue was moistened with a few drops of concentrated sulphuric acid, and changed to a red-violet color characteristic of saponin.

A certain portion of the aqueous extract was rendered alkaline, and heated over a water bath with Fehling's solution. The precipitated copper was collected on a weighed filter, dried, and incinerated, and the glucose estimated gravimetrically from it. It yielded 1.592 per cent. Another portion of the aqueous extract was acidified, boiled, and potash added until the solution was alkaline to litmus paper; then the liquid was mixed with Fehling's solution and heated over a water bath. The percentage of saccharose or other substances which reduced the copper was calculated by difference. It amounted to 0.929 per cent.

The resin separated by acetic ether was an opaque substance, greenish-yellow in color, and insoluble in ether. The resin was dissolved in water and frothed on shaking. The emulsion in this case was not quite so permanent, as a slight resinous sediment settled after a time, possibly due to changes in the resin through oxidation.

Extract (3), *the Green part of the Leaf.*

The dried residual powder was macerated by the aid of heat with Squibb's stronger alcohol. When warm the *alcoholic extract* was clear, but on cooling the solution became cloudy, and a creamy-white fine precipitate settled. The *alcoholic extract* was neutral in reaction. It was evaporated in a current of carbonic acid, dried, and weighed. A certain part of the residue was incinerated and the ash determined.

TOTAL SOLIDS.

Alcoholic residue dried at 100° C.	3.80 per cent.
" " " 110° C.	3.80 "
" " ash	0.15 "

The *alcoholic residue* was treated with cold distilled water.

It had a slightly acid reaction with litmus. An emulsion was formed on the addition of water to the *alcoholic residue.* A measured quantity of it was evaporated, dried, and weighed. It amounted to 3.4 per cent., 0.4 per cent. of the *alcoholic residue* was insoluble in water. Tannin, gallic acid, and alkaloids were tested for and with negative results.

The liquid from the aqueous treatment of the *alcoholic residue* was rendered alkaline, and boiled with Fehling's solution, and there was no reduction. Boettger's bismuth test was also tried and with negative results. The aqueous portion was boiled with acid and examined in the usual way for glucosides; the results were negative.

One volume of the aqueous solution was mixed with three volumes of stronger alcohol. It was placed on ice, and after some time a white precipitate formed. The precipitate was collected and dissolved in water. It frothed on shaking. On addition of a concentrated solution of caustic baryta, a creamy-white precipitate of saponin-baryta was obtained. Sulphuric acid gave the usual red-violet color reaction with the precipitate from the alcoholic aqueous solution.

The method of successive agitation of an aqueous extract with solvents already described was followed. Petroleum spirit on evaporating left a resinous substance. The residue separated by chloroform from an acidified solution was a brownish-colored substance. It was soluble in water, and frothed on shaking. It was colored red-violet by sulphuric acid, and the aqueous solution was precipitated by barium hydrate. Chloroform separated a brownish solid from an alkaline aqueous solution. It was precipitated by barium, colored red-violet by sulphuric acid, and its aqueous solution frothed on shaking. This brownish residue was identified as saponin.

Extract (4), *the Yellow Base of the Leaf.*

The residual powder, dried from all traces of ether, was macerated with hot alcohol. The *alcoholic extract* was a currant-colored liquid, and slightly acid in reaction. The liquid became clear on standing, and a creamy-white solid, identified as saponin, separated from it. The *alcoholic extract* was evaporated, dried and weighed, and the ash of the residue was estimated.

TOTAL SOLIDS.

Alcoholic residue dried at 100° C.	4.30	per cent.
" " " 110° C.	4.30	"
" " ash	0.05	"

The *alcoholic residue* was treated with cold distilled water. The solution was slightly colored, and faintly acid in reaction. The absence of gallic acid, tannin, and alkaloids was determined by negative results with iron salts, gelatine, and alum solution, gold chloride, and potassio-mercuric solutions. Acetate of lead caused no precipitation. Fehling's solution detected a trace of glucose.

An imperfect emulsion formed on adding water to the *alcoholic residue.* Upon standing, the resin settled; the liquid was filtered several times, and the greater part of the resin collected. It was an opaque reddish-yellow-colored substance. It had the same melting-point (79° C.), solubilities, and physical appearance as the resin of *ether extract* (4). The resin was examined by Hirschsohn's scheme. It differed in character from the many resins described by that author, and it is proposed to name it pyrophæal.[1]

Pyrophæal was slightly soluble in ether, and 95 per cent. alcohol; soluble in benzole, chloroform, and acetic ether; incompletely soluble in cold absolute alcohol, amyl alcohol, carbon di-sulphide, and oil of turpentine. It was saponified with aqueous and alcoholic soda. The ethereal resin solution was cloudy. The alcoholic resin solution gave a precipitate with lead acetate which did not disappear on boiling; ferric chloride and aqueous ammonia formed turbid mixtures with it. The chloroform resin solution was not affected by bromine solution. The petroleum-ether-resin solution turned to a turbid mixture on adding iodine solution. Alcohol containing hydrochloric acid was not colored by the resin. Sulphuric acid and alcohol gave a turbid brown mixture with it, and

[1] "Pyrophæal," *Science*, September 11, 1885.

sodium carbonate solution was colored pale brown when cold or on warming.

SUMMARY III. ALCOHOLIC EXTRACTS

	Solids extracted.	*Character of residue.*	*Reaction with litmus.*	*Quantitative estimation of glucose.*	*Quantitative estimation of saccharose or other reducible compounds.*
1. Bark of the root...	9.25 % 0.20% ash	red coloring matter crystalline	neutral	0.619%	0.180%
2. Wood of the root..	14.30 % 0.10 % "	resin, saponin	neutral	1.592%	0.929%
3. Green leaf........	3.80 % 0.15 % "	resins, "	neutral	none	none
4. Yellow base of leaf	4.30 % 0.05 % "	resin, "	slightly acid	traces	traces

Extracts (1).

My attention was not directed to the presence of saponin in *extract* (1), for the characteristic properties which it imparted to *extracts* (2), (3), and (4) were absent; but it was evident that saponin was present in the bark, for on boiling the latter in distilled water, the presence of the compound was indicated. The solution frothed on shaking, and by adding a concentrated solution of caustic baryta, saponin-baryta was precipitated.[1]

A coloring matter[2] contained in the bark was extracted, and imparted to the *alcoholic extract* a brilliant red color. It was precipitated by sub-acetate of lead, and the lead precipitate suspended in water and decomposed by sulphuretted hydrogen. The lead sulphide filtrate was evaporated over a water bath until the odor of sulphuretted hydrogen was expelled, and the concentrated liquid was placed over sulphuric acid to evaporate slowly. A crystalline residue was obtained. On addition of alkalies to the colorless lead sulphide filtrate the red color of the original solution was developed. Acid disdischarged the color. Acetic ether took up the red colored substance. The acetic ether residue was a red uniform solid,

[1] "Saponin in the Bark of *Yucca Angustifolia*," *Science*, September 11, 1885.

[2] "A Red Crystalline Coloring Matter," *Science*, September 11, 1885.

and soluble in water. It was precipitated from the aqueous solution by sub-acetate of lead, potassium bichromate, ferric chloride, ferrous sulphate, and it was clouded by alum, and stannous chloride solutions.

Tannin, gallic acid, and alkaloids were absent.

Amyl alcohol separated from the acidified aqueous extract white needle-shaped crystals. It was not determined if these crystals were the same as those of the coloring matter.

Extracts (2), (3), *and* (4).

Extracts (2) and (3) when warm were clear, and on cooling a creamy-white solid separated. Extract (4), if warmed, was turbid, and as the liquid cooled, a creamy-white substance remained at the bottom of the flask, and the supernatant fluid became clear. This creamy-white substance was identified in each of the *extracts* as saponin.[1]

The results following an aqueous treatment of *alcoholic residues* (2) and (3), were noticeable. The *residues* were dissolved, and by shaking the mixtures, emulsified. This emulsion was permanent, as no resinous matter separated on standing several days. The emulsion was agitated with acetic ether, and by this means most of the resin and saponin were separated from the aqueous portion. The saponin was removed mechanically with the resin, as it is almost insoluble in acetic ether. The resin-saponin mass was insoluble in ether, soluble in water. The solution frothed on shaking and emulsified, but the emulsion was not so permanent as in the first case, for a resinous sediment settled after a time. Chloroform separated saponin from an acidified aqueous solution, and also from an alkaline aqueous solution of the *residues*; and the red-violet saponin reaction with concentrated sulphuric acid was obtained.

The solubility in water of the *alcoholic residues* (2), (3), and (4), and the resulting emulsion were unusual, and explicable

[1] "Saponin in the Wood of the Root and Leaves," *Science*, September 11, 1885.

by the facts collected from a series of experiments with resins and saponin, since I had successfully emulsified resins with aqueous and alcoholic saponin solutions.[1]

By hot alcoholic treatment the *yucca* yielded a residue of saponin and resin which became emulsified on the addition of water, giving results identical with those of the resins above described.[2]

Extract (4) contained a resin. It was an opaque reddish-yellow colored substance, and it differed, by its reactions, from the many resin classes given in Hirschsohn's scheme. It is proposed to name it pyrophæal.[3] A resin having the same melting-point, solubilities, physical appearance, and chemical reactions was discovered in the *ethereal extract* (4). It was identified as the same compound for which the name pyrophæal is proposed.

Tannin, gallic acid, and alkaloids were not detected in *extracts* (2), (3), and (4). In *extract* (3) glucose was not found.

The Solids of the Alcoholic Extracts.

I. A red coloring matter (crystalline).
II. A new resin (yuccal).[4]
III. A second new resin (pyrophæal).[4]
IV. A mixture of a crystalline resin and a resin anhydride.
V. Saponin.[4]
VI. Glucose, and saccharose or other reducible compounds.
VII. Ash.

[1] The same kinds of resins were used in these experiments as in those with which I determined the solubility of resins in acetic ether. See foot-note 2, *ethereal extract* (2).

[2] It was not until a later date following the time of these experiments that I found a reference to saponin-resin emulsion in *L'Officine ou Répertoire Général de Pharmacie Pratique*, par Dorvault, huitième édition, Paris, 1872, p. 816. Also refer to examination of the *Yucca angustifolia*, by H. C. De S. Abbott, published in the *Medical and Surgical Reporter*, Philadelphia, September 12, 1885, p. 301.

[3] "Pyrophæal," *loc. cit.*

[4] *Science*, September 11, 1885, p. 210, extract of a paper on "The Chemical Study of *Yucca Angustifolia*," by H. C. De S. Abbott.

AQUEOUS EXTRACTS

Extract (1), *Bark of the Root.*

The residual powder was thoroughly dried from alcohol. It was returned to the percolator, and cold distilled water added until a definite amount had been used. The *aqueous extract* was dark colored, and of a faintly acid reaction. A certain quantity of the *extract* was evaporated, dried, and weighed. From a known weight of the *aqueous residue*, the ash was calculated. The incineration was conducted in a covered porcelain crucible of known weight.

TOTAL SOLIDS.

Aqueous residue dried between 100° C and 110° C	4.00	per cent.
" " ash	2.65	"

Gum.

One volume of the *aqueous extract* was mixed with two volumes of Squibb's stronger alcohol. The mixture was kept in a cool place for twenty-four hours, and the precipitate which had formed was collected on a weighed filter, washed with 66 per cent. alcohol, dried, and weighed. The precipitate and filter were incinerated in a weighed porcelain crucible, and the weight of the filter being deducted, the percentage of ash was determined.

Weight of precipitate by stronger alcohol yielded	2.0	per cent.
" " ash yielded	0.2	"

Another portion of the *aqueous extract* was precipitated by stronger alcohol, and the precipitate consisted of gum and albuminous substances. It was incompletely soluble in water. The soluble matter was gum; it was recovered from solution by evaporating the liquid to dryness. The gummy residue was almost completely soluble in cold water. It was precipitated from a concentrated aqueous solution by stronger alcohol; basic acetate of lead precipitated it as a flocculent precipitate. Borax did not thicken the gum solution, and ferric chloride and sodium chloride solutions did not precipitate it. The gum was boiled with dilute acid, and heated over a water bath with Fehling's solution, which it reduced. A few drops of hydrochloric acid and stronger alcohol were mixed with the concentrated gum solution for the separation of arabin. It was not separated.

Carbhydrates.

The filtrate and wash alcohol from the gum precipitate were mixed, and evaporated to a syrupy consistency at a temperature of 70° to 80° C. The concentrated solution was treated with four volumes of stronger alcohol, and the resulting precipitate of *carbhydrates* rapidly filtered off. It was soluble in water. It was not precipitated from aqueous solution by basic acetate of lead, and by this means it was distinguished from vegetable mucilage. The *carbhydrates* were boiled with dilute acid, and the solution was rendered alkaline, and heated over a water bath with Fehling's solution. The latter was reduced. The percentage of *carbhydrates* as estimated, amounted to 0.2 per cent. An aqueous *carbhydrate* solution was mixed with a solution of barium in 40 per cent. alcohol. It yielded no precipitate.

Carbhydrate Filtrate.

The *carbhydrate filtrate* was concentrated at a low temperature in a current of carbonic acid until the alcohol was dissipated. The *residue* was examined for glucose, organic acids, saponin, and tannin. Traces of glucose were detected qualitatively by Fehling's test; the amount of cuprous oxide present was too small to estimate gravimetrically. A part of the *carbhydrate filtrate residue* was boiled with 83 per cent. alcohol, and filtered while hot. On cooling, a precipitate formed. This precipitate was identified as saponin. It was almost insoluble in stronger alcohol. Baryta-water precipitated it from aqueous solution. Its aqueous solutions frothed on shaking. When agitated with chloroform and on evaporating the chloroform solution, a light-colored residue was obtained. A few drops of concentrated sulphuric acid mixed with it gave a reddish-violet-color reaction. Another portion of the *carbhydrate filtrate residue* was precipitated with neutral acetate of lead and filtered. The precipitate was suspended in water, decomposed by sulphuretted hydrogen, and the lead sulphide filtrate evaporated over a water-bath to expel all odor of sulphuretted hydrogen. The liquid was cooled and lime-water added until the reaction was alkaline to litmus. A turbidity formed when the lime-water was added to the filtrate, and was not entirely cleared on the addition of dilute acetic acid. A neutralized portion of the lead sulphide filtrate gave a yellow precipitate with a ferrous salt. Oxalic acid by these tests was indicated, and possibly other vegetable acids were present in the filtrate. The *carbhydrate filtrate residue* was examined for tannin, and with a negative result. Calcium oxalate was separated.

Extract (2), *the Wood of the Root.*

The powder used in the alcoholic maceration was thoroughly dried, and replaced in the percolator. A measured quantity of cold distilled water was allowed to percolate slowly through the powder. The *extract* was colored, and slightly acid in reaction. A definite volume of the *extract* was evaporated, dried, and weighed. A known weight of the *residue* was incinerated in a weighed covered porcelain crucible, and the ash determined. The ash was white and incompletely soluble in water.

TOTAL SOLIDS.

Aqueous residue dried between 100° C. and 110° C.	12.10	per cent.
" " ash	1.74	"

Gum.

A certain quantity of the *aqueous extract* was mixed with two volumes of stronger alcohol (Squibb's). The mixture was allowed to stand for twenty-four hours, and the precipitate which formed was collected on a weighed filter. It was dried, and weighed. The precipitate and filter were incinerated in a weighed porcelain-covered crucible, and the percentage of ash calculated.

Weight of precipitate by stronger alcohol yielded ....1.70 per cent.
" " ash yielded.......................0.34 "

Carbhydrates.

The filtrate and wash-alcohol from the gum precipitate were concentrated at a low temperature, and the residue was mixed with four volumes of stronger alcohol. The precipitate was rapidly filtered off, and the percentage of *carbhydrates* calculated gravimetrically in the usual way, from the amount of cupric oxide reduced from Fehling's solution. It yielded 2.75 per cent.

Carbhydrate Filtrate.

A portion, representing a certain volume of the *aqueous extract*, of the *carbhydrate filtrate* was evaporated, dried, and weighed. It yielded 7.65 per cent. of the total solids of the *aqueous extract residue.* A known weight of the *carbhydrate filtrate residue* was dissolved in water and heated over a water bath with Fehling's solution, and the amount of glucose present estimated gravimetrically from the weight of the cupric oxide. It was estimated as 4.47 per cent. Another portion of the *carbhydrate filtrate residue* was boiled with 83 per cent. alcohol. A precipitate formed on cooling, which was collected on a weighed filter, dried, and weighed. It yielded 1.98 per cent. The 83 per cent. alcohol precipitate was identified as saponin by the usual tests. The *carbhydrate filtrate residue* was precipitated by acetate of lead and the precipitate examined qualitatively for organic acids. The lead precipitate was decomposed by sulphuretted hydrogen and filtered, and the filtrate concentrated over a water bath, and mixed with lime-water until turbid. The turbidity did not clear on adding dilute acetic acid.

The *aqueous extract* was examined for tannin, and with negative results. Calcium oxalate was present.

Extract (3), *the Green Part of the Leaf.*

The residual powder was dried from all traces of alcohol, and cold distilled water was allowed to slowly percolate through the powder. The *extract* was colored, and slightly acid in reaction. A definite volume of the *extract* was evaporated, dried, and weighed, and the ash calculated from incinerating a known weight of the *residue.*

TOTAL SOLIDS.

Aqueous residue dried between 100° C. and 110° C.	4.35	per cent.
" " ash	0.40	"

Gum.

One volume of the *aqueous extract* was mixed with two volumes of stronger alcohol. The precipitate was collected after twenty-four hours, washed with 66 per cent. alcohol, dried, and weighed. The precipitate and filter were incinerated, and the ash estimated.

Weight of precipitate by stronger alcohol yielded	0.775	per cent.
" " ash yielded	0.125	"

Carbhydrates.

The gum filtrate and wash alcohol were concentrated at a low temperature, and the residual liquid mixed with four volumes of stronger alcohol. The resulting precipitate was rapidly filtered and collected. The percentage of *carbhydrates* was estimated gravimetrically from a copper solution in the usual way. It amounted to 0.525 per cent.

Carbhydrate Filtrate.

The *filtrate* was evaporated to dryness. A part of the *residue* was boiled with 83 per cent. alcohol. On cooling, a precipitate formed. It was identified by the usual tests as saponin. Another portion of the *residue* was precipitated with basic acetate of lead. The lead precipitate was decomposed by sulphuretted hydrogen, the solution filtered, and the filtrate evaporated over a water-bath until all odor of sulphuretted hydrogen was dissipated. A part of the lead sulphide filtrate was mixed with lime-water, and a precipitate formed not completely dissolved by acetic acid. The remainder of the lead sulphide filtrate was allowed to evaporate over sulphuric acid. The residue consisted of a mass of fine crystals radiating from a centre.[1]

The crystals gave a very acid reaction when placed on moistened blue litmus paper. They turned black and left a residue when heated on platinum foil, and the residue was slowly dissolved by nitric or hydrochloric acid. The quantity of residue was very small, and no effervescence was observed. The melting-point of the crystals was taken. A small quantity was placed in a tube with thin walls, and gradually heated; at 150° C. the substance sublimed, leaving a white, cloudy stain on the inner surface of the tube; at 190° C., this cloudy stain changed to a pale green spot, and with increasing temperature to 210° C., no further change was noted. Dry sodium carbonate was added to an aqueous solution of the crystals, and a slight effervescence was observed. Some iron was separated which possibly was in combination with the crystalline principle. Negative results followed tests for formates, acetates, malates, tartrates, citrates, phosphates, oxalates, alkaloids, and glucosides.

The amount of glucose present in the *aqueous extract* was too small to determine quantitatively. Negative results for tannin.

Extract (4), *the Yellow Base of the Leaf.*

The residual powder from the alcoholic maceration was dried and replaced in the percolator. Cold distilled water was allowed to percolate slowly through the powder. The *aqueous extract* was slightly acid in reaction. A known measure

[1] The material used in this analysis of the green part of the leaf was quite dry and powdered readily. A previous examination of the *fresh leaves* gave more satisfactory quantitative results. A gum was extracted which promises to be of interest for a future study, and the crystals separated from the lead sulphide filtrate are to be further investigated.

of it was evaporated, dried, and weighed. The ash was determined from a part of the *aqueous extract residue.*

TOTAL SOLIDS.

Aqueous residue dried between 100° C. and 110° C.......11.35 per cent.
" " ash.................................. 3.10 "

Gum.

One volume of the *aqueous extract* was mixed with two volumes of stronger alcohol. The precipitate was collected, washed with 66 per cent. alcohol, dried, and weighed. The ash was calculated from incinerating the precipitate, and deducting the filter.

Weight of precipitate by stronger alcohol yielded........3.850 per cent.
" " ash yielded.......................0.676 "

Carbhydrates.

The filtrate and wash alcohol from the gum precipitate were concentrated at a low temperature. The residual liquid was mixed with four volumes of stronger alcohol, when a precipitate formed, and was rapidly filtered off. The *carbhydrates* were dissolved in water boiled with dilute acid, and the liquid rendered alkaline and heated over a water-bath with Fehling's solution. The amount of carbhydrates was estimated gravimetrically in the usual way. It gave 2.95 per cent.

Carbhydrate Filtrate.

The *filtrate residue* was examined for glucose, and traces of it were present. The *filtrate residue* was precipitated with acetate of lead, and the lead precipitate was dissolved in water and decomposed by sulphuretted hydrogen. The lead sulphide filtrate was tested qualititatively for organic acids, and a turbidity formed on adding to the filtrate lime-water. It was not completely cleared by acetic acid.

Negative results followed tests with alcoholic methyl-violet solution for mineral acids. The *aqueous extract* contained no tannin. Calcium oxalate was determined in it.

AQUEOUS MACERATION AT A TEMPERATURE OF 50° C. TO 60° C.

The Bark of the Root (1), *the Wood of the Root* (2).

The powder (1) used in the cold water extraction was macerated with distilled water heated between 50° and 60° C. The *warm aqueous extract* (1) was cooled and mixed with three volumes of stronger alcohol. A precipitate formed; it was dried, weighed, and the percentage estimated. It yielded 0.03 per cent.[1] The precipitate was dissolved in warm water. On evaporating the filtrate a white residue was obtained. It was stained yellow by iodine.

The powder (2) from the cold-water treatment was macerated in the warm water. The *warm aqueous extract* (2) was a dark-colored liquid, indicating a coloring-matter. A certain measure of the *extract* was evaporated, and the solids estimated. It amounted to 4 per cent. The percentage of solids precipitated from the *extract* by stronger alcohol was 0.25 per cent.

QUANTITATIVE ESTIMATION OF SAPONIN[2]

The two methods of Christophsohn and Otten for the quantitative estimation of saponin were adopted. The wood of the root was examined.

A. Ten grams of the original powder were boiled with distilled water. The saponin was precipitated by baryta-water. After weighing, it was ignited, and the baryta estimated as carbonate, calculated into oxide and deducted from the weight of the saponin-baryta, the difference being the weight of saponin.

B. The saponin-baryta was decomposed by acid and the weight of the sapogenin was ascertained and calculated to saponin.

[1] *Examination for Inulin*, page 87, "Plant Analysis," G. Dragendorff. English translation.

[2] *Loc. cit.*, p. 68.

Several estimations were made on two specimens of the Yucca, collected at different times of the year.

Mean percentage, A .... 8.95 per cent.
" " B .... 10.40[1] "

SUMMARY IV. AQUEOUS EXTRACTS

	Solids extracted.	*Ash.*	*Gum.*	*Ash.*	*Glucose.*	*Saponin.*	
						A.	*B.*
1. Bark of the root....	4.00 %	2.65 %	2.00 %	0.20 %	traces		
2. Wood of the root...	12.10 %	1.74 %	1.70 %	0.34 %	4.47 %	8.95 %	10.40 %
3. Green leaf.........	4.35 %	0.40 %	0.77 %	0.12 %	traces	....	....
4. Yellow base of the leaf.	11.35 %	3.10 %	3.85 %	0.67 %	traces	....	....

The *aqueous extracts* contained gum, albuminous substances, carbhydrates, glucose, saponin, organic acids, calcium oxalate, and no tannin, mineral acids, nor alkaloids. Arabin was not separated from gum (1). Calcium oxalate was brought into aqueous solution possibly by means of the organic acids or saponin. Needle-shaped crystals were found in *extract* (3). They did not respond to tests for formates, acetates, malates, citrates, tartrates, phosphates, oxalates, glucosides, and alkaloids.

Aqueous extracts of 50° C. to 60° C. from the bark and wood of the root contained Inulin.

DILUTE CAUSTIC SODA EXTRACTS

Extract (1), *the Bark of the Root.*

The residual powder insoluble in water was suspended whilst moist in a dilute soda solution (0.1 to 0.2 per cent). After twenty-four hours the mixture was filtered. One volume of the filtrate was acidified with acetic acid and mixed with three volumes of 90 per cent. alcohol, and allowed to stand in the cool. The precipitate was collected, washed with 75 per

[1] "Examination of the *Yucca angustifolia*," by H. C. De S. Abbott, *The Medical and Surgical Reporter*, September 12, 1885, p. 301.

cent. alcohol, dried, and weighed, deducting ash. It consisted of mucilaginous substances and albuminoids.

Weight of precipitate by 90 per cent. alcohol yielded......	0.85	per cent.
" " ash yielded......................	0.25	"

Lassaigne's test showed the presence of albuminous substances.

The filtrate and wash alcohol from the 90 per cent. alcohol precipitate was evaporated to dryness, and weighed, deducting the amount of soda acetate. It gave 0.24 per cent. The residue soluble in water was mixed with acetate of copper solution. A very small quantity of albuminous substances was precipitated by the reagent.

The albuminoids of the bark were estimated from the total nitrogen in one gram of the original powder. It yielded 4.75 per cent. of albuminoids.

The powder insoluble in dilute soda solution was washed with distilled water. The liquid was deeply colored. It was evaporated, and the amount of solids estimated. It gave 1.3 per cent.

Extract (2), *the Wood of the Root.*

The powder insoluble in water was treated in the same way as in *extract* (1). The filtered solution was mixed with 90 per cent. alcohol in the manner described. The precipitate was estimated, deducting ash.

Weight of precipitate by 90 per cent. alcohol yielded.....	2.170	per cent.
" " ash yielded.....................	0.256	"

The filtrate from the 90 per cent. alcohol precipitate was treated with water, and the soluble matter precipitated by copper acetate. The precipitate was collected, dried, weighed, and ignited, the resulting oxide of copper being deducted. It yielded 0.104 per cent. of albuminoids. A current of washed carbonic acid was passed through the *dilute soda extract* to determine the presence of globulin (vitellin, myosin), and with negative results. The albuminoids were determined from the total nitrogen in the powdered wood. It amounted to 4.75 per cent. The total albuminoids in the leaves gave 9.62 per cent.

DILUTE HYDROCHLORIC ACID EXTRACTS

Extract (1), *the Bark of the Root*

The powder insoluble in dilute soda was washed with water and suspended in water containing 1 per cent. of hydrochloric acid. The absence of the blue color which the starch granules assume when treated with iodine solution was determined by examining the bark under the microscope; and consequently it was not looked for in the *extract*. A qualitative test showed the presence of calcium phosphate and calcium oxalate. A measured quantity of the *filtrate* was neutralized with ammonia and mixed with three volumes of 90 per cent. alcohol. The precipitate was collected on a weighed filter, washed with 60 per cent. alcohol, dried, and weighed. It was incinerated, and the ash deducted from the precipitate.

The precipitate yielded	5.20	per cent.
" " " of ash	0.98	"
Organic substance	4.22	"

The filtrate from the 90 per cent. alcohol precipitate was evaporated. The residue was composed of ammonium chloride from the reagents employed, and an organic substance having an odor like gum benzoin. It was agitated with ether, and on evaporating the solvent a white residue with an odor like benzoin was obtained. Sulphuric acid gave a red color with it. The amount of this substance was calculated. It gave 0.45 per cent.

Extract (2), *the Wood of the Root.*

The insoluble powder from the dilute soda maceration was washed with distilled water, and suspended in water containing 1 per cent. of hydrochloric acid. The same means were used as in *extract* (1) to determine the absence of starch in the wood of the root. Parabin was also absent. Calcium oxalate was detected by qualitative tests. A similar method, employed for its estimation in extract (1), was used to determine it quantitatively.

The precipitate yielded	0.305	per cent.
" " " of ash	0.155	"
Organic substance	0.150	"

Extract (3), *the Green Part of Leaf.*

The powder used in the dilute soda maceration was washed with distilled water and suspended in water containing 1 per cent. of hydrochloric acid. Iron and calcium phosphate were detected in the extract. The leaves were examined under the microscope, and a blue color was developed by an aqueous solution of iodine, indicative of starch granules. Starch was also present in the yellow base of the leaves.

TOTAL QUANTITATIVE RESULTS.

	(1) *The bark of the root.*	(2) *The wood of the root.*	(3) *Green part of leaf.*	(4) *Yellow base of leaf.*
	Per cent.	Per cent.	Per cent.	Per cent.
1. Moisture	6.78	11.67	8.11	37.00
2. Total ash	17.38	15.75	5.75	10.63
3. Petroleum spirit extract	1.24	.55	2.20	1.10
4. Ethereal extract	3.16	1.70	1.25	1.70
5. Alcoholic extract	9.25	14.30	3.80	4.30
6. Aqueous extract	4.03	16.10	4.35	11.35
7. Dilute soda extract	1.09	2.41	....	....
8. Wash residue	1.30	....	....	....
9. Dilute acid extract	5.65	.30	....	....
Total percentage	49.88	62.78	25.46	66.08
Total albuminoids estimated on powder	4.75	4.74	9.62	....
Quantitative saponin determination on powder by *A* and *B*	....	*A* 8.95 *B* 10.40	....	....

In my paper on "The Chemical Study of *Yucca angustifolia,*" read at Ann Arbor, Mich., I stated what methods I had employed to separate saponin, and the properties of the compound as observed in that plant. Since that time a further study of it has induced me to withhold the notes used at Ann Arbor, from this, and to offer them, with those collected later, in a separate and more complete publication.

I am indebted to Dr. F. M. Endlich for his courteous consideration and kindness in selecting and forwarding the fine specimens of *Yucca* which were used in these analyses, and which were grown in the neighborhood of Lake Valley, New Mexico. Within a few weeks I have received, in addition, several hundred pounds of the plant from Dr. Endlich.

The investigations described in the preceding pages were conducted in the chemical laboratory of the Philadelphia College of Pharmacy, from February to August, 1885.

CERTAIN CHEMICAL CONSTITUENTS OF PLANTS CONSIDERED IN RELATION TO THEIR MORPHOLOGY AND EVOLUTION.[1]

THE writer has been engaged for some time upon the study of plants by means of proximate qualitative and quantitative chemical analysis, in which the latest methods advanced by Dragendorff were followed. The facts obtained from these studies tend to show a chemical progression in plants, and a mutual dependence between chemical constituents and change of vegetable form.

All plants that were known to contain *saponin* were examined to determine the correlation between this constituent and the accompanying morphological forms. It was found that these saponin plants occupied the great middle plane of M. Édouard Heckel's scheme of plant evolution.[2] M. Heckel arranges all plants within three divisions: 1, Simplicity of floral elements, 2, Multiplicity of floral elements, 3, Condensation of floral elements; and in addition he bases his theories upon three characters: filiation, adaptation, and progression. These laws, as well as the three divisions of development, are not only elements of test for the great divisions, but are to be found in orders, sub-orders, and classes. It is a significant fact that all the saponin groups belong to this middle division, or multiplicity of floral elements. Saponin is thus a constructive element in developing the plant from the multiplicity of floral elements to the cephalization of those organs. It is an indispensable principle in the progression of certain lines of plants

[1] Abstract, by the author, of a paper read before the Chemical Section of the A. A. A. S., at Buffalo, 1886: "Evolution used in the Sense of Progression." Published in the *Botanical Gazette*, vol. xi, October, 1886.

[2] "Les Plantes et la Théorie de l'Évolution," *Revue Scientifique*, 13 Mars, 1886.

passing from their lower to their higher stages. Saponin is invariably absent where the floral elements are simple; it is invariably absent where the floral elements are condensed to their greatest extent. Its position is plainly that of a factor in the great middle realm of plant life when the elements of the individual are striving to condense and thus increase their physiological action and the economy of parts. All the great groups that contain saponin are closely allied and possess other properties in common, as fibrous or bulbous roots, root-stocks, tubular character of some part of the flower, and a climbing tendency in *Smilaceæ* and some of the *Sapotaceæ*.

Numerous analogous examples of a correspondence between morphology and chemical constituents were advanced, and the following conclusions reached:

1. A similarity of one or more chemical constituents is to be found in all plants that are equally developed, and on the same evolutionary plane.

2. The evolution of chemical constituents in which they follow parallel lines with the evolutionary course of plant forms, the one being intimately connected with the other, and consequently that chemical constituents are indicative of the height of the scale of progression, and are essentially appropriate for a basis of botanical classification. In other words, that the theory of evolution in plant life is best illustrated by the chemical constituents of vegetable form.

The reasons offered in favor of a chemical basis of classification are:—

1. The disagreement among botanists themselves, depending upon the insufficiency of the present methods of classification.

2. Chemical constituents, or the constructive elements of form are intimately associated with the origin and progression of plant life, and are consequently better adapted for classification than organs and tissues, because, as component parts, less complex.

3. By the invariable composition and structure of given determinate chemical constituents.

4. The percentage of any given compound in a plant would

gauge the progression or retrogression of a plant, species, or genus, and would accentuate the characters of progression, adaptation, and filiation.

5. Variations in chemical constituents would be detected by analysis earlier than consequent variations of organs or tissues.

6. It is a law of internal influences controlling function and modifying forms rather than of external forces, hence a study of the elements of the innermost structure of plant life is a study of that law and of life itself.

Not all chemical constituents will answer as means of classification for the same great evolutionary plane, though any compound might be found to furnish a basis for the division of plants into classes, orders, sub-orders, genera, and species.

Albuminous compounds and chlorophyll are less likely to be serviceable as compounds of classification. They are intimately associated with the manifestation and continuance of the conditions of life, though they are not regarded as the essential factors in development.

The chemical study of plants is meant to include microchemistry in its application to histology and physiology, in determining the position in the cell of any chemical compound, and qualitative and quantitative analysis to be practiced in accordance with the schemes of Dragendorff and others. I should suggest that analysis be made of each part of the plant, as of the root, stem, bark, wood, leaf, flower, and seeds; also of the separate organs of plants, *i.e.*, in the flower, of the stamens, pistils, petals, calyxes, and of various plants under various conditions of age, climate, soil, and seasons. Under these conditions a comparison of chemical constituents with plant structure would lead to a comprehension of the correlation between morphology and chemistry.

ON HÆMATOXYLIN IN THE BARK OF SARACA INDICA.[1]

MISS HELEN C. DE S. ABBOTT stated that De Candolle[2] and Linnæus describe *Saraca Indica* as a member of the family Leguminosæ. According to De Candolle it belongs to the genus *Jonesia*, *Saraca* Linn., and is separated by five genera from the genus *Hæmatoxylon*, or the logwood.

In an article on certain drugs indigenous to India, Dr. Waring[3] gives an account of the medicinal uses of the bark of *Saraca Indica*. The attention of Messrs. Parke, Davis & Co., Detroit, Michigan, was called to this drug, and through their correspondents in India they secured a supply, samples of which have been submitted to the speaker for a chemical analysis. The full results of this analysis will appear elsewhere, but it is now desired to announce a discovery of practical and scientific interest in this connection.

A coloring principle, identical with logwood dye, has been isolated by her from the bark of *Saraca Indica*, where it existed in two conditions, as hæmatoxylin and an oxidized product. The former was separated as yellow crystals, analogous in form to hæmatoxylin crystals from the true logwood, *Hæmatoxylon campechianum*. The alcoholic extract of the bark contained about 18 per cent. of a red-colored substance, which agreed in color and dye tests with a like constituent found in logwood. Mordanted cotton fabric was dyed with hæmatoxylin, extracted by ether from the *Saraca* bark, and presented the characteristic logwood dye colors.

[1] From the Proceedings of the Academy of Natural Science of Philadelphia, November 30, 1886.

[2] *Pro. Sys. Nat. Reg. Vegetabilis*, vol. ii, p. 487.

[3] *British Med. Jour.*, June 6, 1885, p. 1145.

The following is a table of dyewood colors with reagents, yielded by Brazil wood and logwood:[1]—

Reagents.	*Brasilin.*	*Hæmatoxylin.*
Alkalies	Claret-red sol.	Reddish purple sol.
Acids (dilute)	Orange ppt.	Pink sol.
Acids (strong)	Yellow ppt.	Pink sol.
Alum sol.	Crimson-red ppt.	Yellow, then violet sol.
Lime-water	Crimson-red ppt.	Bluish purple ppt.
Ferrous salts	Purplish-bl'k ppt.	Bluish black ppt.
Ferric salts	Brownish-red ppt.	Black ppt.
Copper salts	Brownish-red ppt.	Purple sol.
Lead salts	Crimson-red ppt.	Violet sol.
Mercuric salts	Yellow ppt.	Yellow sol.
Silver salts	Yellow ppt.	Gray ppt.
Tartar emetic	Rose-colored ppt.	Purple sol.
Stannous chloride	Red ppt.	Purple ppt.
Sodium aluminate	Claret-red ppt.	Purple ppt.

The extracts of *Saraca Indica* bark, containing the coloring principle, were tested with these reagents, and it was observed that the reactions agreed with the hæmatoxylin colors, and in no case with those of brasilin. However, the colors produced by different alkalies varied in tints as she had found in both the logwood and *Saraca* extracts, but the general term "reddish-purple solution" is comprehensive. A rose-violet precipitate was yielded by stannous chloride solution with the neutralized acidified extracts of the barks.

The bark of the logwood-tree is not used for making the commercial logwood extracts, the wood of the tree being employed for this purpose. The presence of a small quantity of hæmatoxylin was determined in the specimens of logwood-bark which she examined, and with the bark extracts the same reactions with reagents were obtained as with the logwood extracts, but owing to the smaller percentage of dye in the bark the colors were less intense. In the case of the *Saraca Indica* bark the colors were very brilliant and indicated the

[1] S. P. Sadtler and Wm. L. Rowland, *Am. Jour. of Phar.*, February, 1881.

presence of a larger proportion of the coloring-matter than in the logwood bark. These results should encourage investigators to secure specimens of the *wood* of the *Saraca*, in order to determine if it contains the coloring principle, and should this be ascertained affirmatively, whether it exists in sufficiently large quantities to warrant its introduction as a new source of this commercial product.

To exhibit the colors produced by alkalies upon the dye from logwood bark and *Saraca Indica* bark, the powdered material was macerated over the water-bath with distilled or filtered river water acidulated with dilute sulphuric acid (1 part to 50), the extract was filtered and the process repeated until no more color was removed. This extract was treated directly with the reagents. Excess of reagents produced darker tints, and after a time the solutions were decolorized.

Reagents.	*Saraca Indica.* / *Hæmatoxylon Campechianum.* } Bark. Acidified Extract.
Sodium Carbonate	Pale purple to reddish violet solution
Sodium Hydrate	Blue violet ppt. and solution
Potassium Hydrate	Red-colored solution
Ammonia	Pinkish-purple solution

Among other constituents contained in the *Saraca* bark, catechin and saponin were determined. Their presence along with hæmatoxylin is significant as showing the chemical position of *Saraca* in relation to the genera *Acacia* and *Hæmatoxylon*, catechin and saponin being found, as is well known, in *Acacia*. The evolutionary position of the order Leguminosæ, to which these genera belong, was pointed out in a former paper,[1] and it was stated that all orders containing saponin came under the middle division of M. Heckel's botanical scheme,[2] or multiplicity of floral elements. The facts

[1] "Certain Chemical Constituents of Plants considered in Relation to their Morphology and Evolution," by H. C. De S. Abbott. *Botanical Gazette*, vol. xi, 1886, p. 270.

[2] "Les Plantes et la Théorie de l'Évolution," *Revue Scientifique*, 13 Mars, 1886.

accumulated from recent researches, since the publication of her article in the "Botanical Gazette," and the discovery of saponin in many plants of widely different genera and family, seem to justify and confirm what was stated in the article referred to above, "saponin is invariably absent where the floral elements are simple; it is invariably absent where the floral elements are condensed to their greatest extent. Its position is plainly that of a factor in the great middle realm of plant life when the elements of the individual are striving to condense, and thus increase their physiological action and the economy of parts." [1]

[1] *Loc. cit.*, *Botanical Gazette.*

PLANT ANALYSIS AS AN APPLIED SCIENCE[1]

SCHLEIDEN,[2] in his "Principles of Botany," states: "Botany is an indispensable branch of knowledge for the chemist and physiologist." I think he might have said, with equal truth, chemistry and physiology are indispensable branches of knowledge to the botanist. An acquaintance with these three branches of knowledge is indispensable to the plant chemist. If we consider that our food, fabrics, dyestuffs, perfumes, drugs, and beverages are all derived from plants, we can scarcely fail to inquire into the functions and intimate structure of vegetable life. The application of chemical knowledge to the study of plant life under all conditions is the first step toward a practical solution of the problems of agriculture, materia medica, and the industries derived from plant sources.

As long ago as 1795,[3] a learned Scotch nobleman said, "Indeed there is no operation or process in agriculture, not merely mechanical, that does not depend on chemistry." Fifteen years later than Earl Dundonald's treatise, the first vegetable substance was accurately analyzed. Another period passed before the analyses of Liebig. Since that day investigators have been busily engaged in plant analysis.

Plant analysis to-day rests on a sure foundation as a distinct subdivision of general chemistry. Chemistry teaches us what vegetation needs for its growth, and points out the sources whence the materials for crops can be derived. Intense cultivation of the plant is the agricultural motto. The contrary is true for pharmacy. Plants which are to be used for medicinal

[1] Delivered before the Franklin Institute, Philadelphia, January 17, 1887. Printed in the *Journal* of the Franklin Institute; also in pamphlet form, 1887.

[2] *Principles of Scientific Botany*, by Dr. J. M. Schleiden. London, 1849.

[3] *How Crops Grow*, by S. W. Johnson. London, 1869, p. 4.

purposes should grow under natural conditions. Cultivation of plants tends to diminish in quantity or to eradicate their noxious or medicinal principles. According to Professor Vogel, hemlock does not yield coniin in Scotland; cinchona plants are nearly free from quinine when grown in hothouses; and tannin is also found in the greatest quantity in trees which have a direct supply of sunlight. Wild belladonna plants [1] contain more alkaloids than the cultivated.

Until within a comparatively very recent date, there were no schemes for vegetable analyses equivalent to Fresenius's "Manual for Inorganic Substances." The irregularities of the methods of individual investigators in plant chemistry made it extremely difficult for students to follow this kind of analysis. The deficiency has been filled by the admirable book on "Plant Analysis," by Professor Dragendorff, of Dorpat, Russia. This book has appeared in a French translation,[2] and the first edition of an English translation [3] was published a year before. Professor Dragendorff does not claim to have written a perfect book. He offers a scheme, which, if followed, supplemented by well-known or original methods in the study of special or new compounds, will give the student a knowledge of the chemical constituents of a plant which he could not well obtain by a non-systematic scheme.

Dragendorff's scheme has been criticised as encouraging a mechanical method of work on the part of the analyst, but I think any student, on working for the first time on a new drug, by this method will find that he will be thrown very much on his own resources, and that the scheme serves him merely as a chain and anchor in a sea of novelty and uncertainty. It is indeed the most complete scheme for plant analysis which we have.

The scope of plant analysis is well outlined by Dragendorff in his introduction, and if my time permitted me I could not

[1] "The Alkaloidal Value of Cultivated and Wild Belladonna," by Girrard. *Pharm. Jour. and Trans.*, vol. xv, p. 153.

[2] *Encyclopédie Chimique*, tome x, "Analyse chimique des Végétaux." Traduit de l'allemand et annoté, par F. Schlagdenhauffen. Paris, 1885.

[3] *Plant Analysis*, by G. Dragendorff. Translated from the German by H. G. Greenish. London, 1884.

do better than read it. The attention of the reader is directed to the great number of species of plants which occur in nature, to the great abundance and variety of their chemical constituents, and to the circumstance that almost every skillful analysis of a plant that has not been examined yields new hitherto unknown products. The difficulties of plant analysis are pointed out, but it should be the effort of future investigators to endeavor to overcome these difficulties, when the importance of plant chemistry is considered in relation to scientific botany and chemistry, medicine, pharmacy, dietetics, agriculture, etc. The author says that the analysis of plants in one respect possesses an advantage over the analysis of minerals,[1] and in that respect can often be made more complete than that of a mineral.

It would not be possible within the space of an hour to give an accurate description of how to analyze a plant, and the many methods which may be followed. I can give an idea of how to follow the scheme of which I have spoken as being the most complete, and the practical application of some facts derived from plant analysis.

The specimens which are presented for analysis should be in good condition and well selected as typical of the genus or species. In case of comparative studies the time of year of the gathering should be noted. All foreign substances and dust should be removed, and care taken not to displace parts of the specimens.

All plants are chemically composed of two classes of substances, and on incineration one class is decomposed into gases and the other class forms the ash constituents. These two divisions of the plant's constituents are known as the volatile and fixed parts. The manner of proceeding with an analysis of a plant is somewhat different in the case of fresh plants and those which are air-dried. Fruits and succulent plants and fleshy roots may sometimes be examined with advantage in the fresh condition, especially if they contain much saccharine material or volatile products. Generally the parts of plants to be used for analysis are dried at a temperature under 30° C., or air-

[1] *Plant Analysis*, English translation, p. 2.

dried until in a state of powder; for all vegetable substances must be brought into fine subdivision before extraction, in order that the solvents may penetrate the cells.

The fine powdering of the material is of the utmost importance; a drug mill is usually used for this purpose. An agate or iron mortar may be used sometimes to advantage, or the material may be grated upon a fine grater, and then submitted to the same process of powdering and sifting, until it can be passed through a No. 80 sieve.

The Mexican ocotilla bark[1] is resinous and contains a wax, and it is very difficult to powder. From this fine powder the analysis yielded, by cold maceration, thirteen per cent. of waxy substance. Hot maceration gave nine per cent. An analysis from portions less finely powdered gave three per cent. less of wax. To estimate the amount of moisture retained in the air-dried plant, a small quantity of the powder, from two to five grams, may be weighed and dried until constant weight at a temperature from 100° C. to 105° C. By means of this determination the results of all other estimations of the analysis can be calculated to the dry substance. Even in the case of fresh plants, it will be necessary for a quantitative examination of the entire plant, at least to dry the portions which are to be treated with petroleum-ether, ether, and alcohol.

The powder which has served for the moisture determination is carefully burned at a dull red heat, and the ash residue weighed. This gives the total ash constituents of the plant. In many cases it is desirable to estimate the amount of soluble and insoluble ash, and to determine, quantitatively, one or more of the ash constituents, especially sulphuric and phosphoric acids and potash. In the ash may be found phosphorus, sulphur, silicon, chlorine, potassium, sodium, calcium, magnesium, iron, and manganese, as well as oxygen, carbon, and nitrogen; rarely lithium, rubidium, iodine, bromine, fluorine, barium, copper, zinc, and titanium. The carbon, hydrogen, nitrogen, sulphur, and phosphorus are derived more especially from the organized parts of the plant, as the protoplasm and

[1] "Preliminary Analysis of the Bark of *Fouquieria Splendens*," by Helen C. De S. Abbott. See p. 117.

cell wall, and from carbonaceous substances, such as sugar, fats, and acids. It was stated that the volatile part of plants on incineration is gaseous, consisting principally of carbon dioxide, watery vapor, and nitrogen, — the inference being that the combustible portion of the plant contains the elements carbon, hydrogen, and nitrogen.

The fact that various mineral constituents are essential to the growth and development of plants is of practical value in agriculture. The soil must contain the various constituents in such quantity and form as to be available to the plant. The ash analysis of any plant indicates in a great measure the character of its surrounding soil, though the chemical composition in which the ash is contained in the plant is not necessarily the same as in the soil.

In investigating a new plant for the first time, all rational means for discovering its component parts should be resorted to. Before beginning the systematic analytical scheme, a microchemical investigation of thin sections of the plant, and even of the powdered plant, may be followed. I have found it an excellent aid in the work, after knowing what constituents were present from chemical analysis, to determine in what tissues and cells these various substances are found. A drop of the extracts evaporated on a glass slide frequently indicates the character of the substances contained in them.

It is of importance to determine if volatile oils or acids, alkaloids, and other substances are present, which can be separated by distillation, and for this purpose a sufficient quantity of the powdered plant may be mixed in a convenient vessel with water, acidulated water, or milk of lime, and the mixture heated, preferably by steam. The distillate is condensed and may be examined as to its reaction, odor, and physical appearance. If the aqueous distillate is agitated with a light pretroleum-ether,[1] volatile products may be readily obtained.

Many volatile oils diffuse in moist air and pass off with the petroleum-ether, if precautions are not taken to prevent it;

[1] Manufactured by Dr. H. W. Jayne, Frankford, Pa.

but a system by Osse[1] has been devised to evaporate the petroleum-ether and save the volatile oil.

Distillation of volatile principles may be sometimes substituted by other methods, such as "infusion" and "enfleurage," of which I shall speak later.

The following is the general plan I usually follow, based upon Dragendorff's scheme, in order to determine the constituents of any plant. Twenty, fifty, or a hundred grams of the dried powdered plant are weighed and macerated with successive solvents. The solvent is added in the proportion of ten c. c. to one gram of powder. This is allowed to stand, with frequent shaking, for eight days, when the liquid is removed with a pipette or filtered from the powder. The residual powder is then rinsed with more of the solvent, which, added to the extract first obtained, is made to a known volume. The powder is dried at the ordinary temperature, and is then ready for maceration with a second solvent, and so on, until the sequence of solvents has removed all soluble matter from the powder. The residual insoluble portions are cellulose, lignin, and other allied substances, which form the firm framework of the plant.

The solvents used must be chemically pure. The order of solvents recommended by Dragendorff, and the classes of compounds which may be extracted by them are given in the table.

PETROLEUM-ETHER EXTRACT

Ethereal oils; volatile fat acids; glycerides; waxes; camphors; cholesterin or allied substances; chlorophyll and alkaloids with fixed oils; aldehydes; ethereal salts; alcohols; aromatic acids; resins.

ETHER EXTRACT

Resins; waxes; fats; chlorophyll; coloring-matters; organic acids; glucosides; alkaloids (caoutchouc, chloroform, or bisulphide extracts).

[1] *Archiv. d. Pharm.* (3), vii, 104 (1875). (*Year-Book Pharm.*, 1876, 362.)

ALCOHOL EXTRACT

Tannic acids; bitter principles; organic acids; alkaloids; glucosides; glucose; saccharose; coloring-matters; resins.

WATER EXTRACT

Mucilaginous and albuminous substances; dextrin and other carbohydrates; saponin and allied compounds; glucoses; saccharoses; organic and mineral acids.

DILUTE SODA EXTRACT

Metarabic acid; albuminous substances; phlobaphenes, etc.

DILUTE HYDROCHLORIC ACID EXTRACT

Parabin; oxalate of calcium, etc.; starch.

DETERMINATION OF LIGNIN AND ALLIED SUBSTANCES AND OF CELLULOSE

Benzole, chloroform, amyl alcohol, and acetic ether are frequently valuable solvents for certain extractions, although they are not included in the general scheme.

Dragendorff recommends the maceration to be conducted at the ordinary temperature, but a fixed oil, if present, may be extracted more readily by exhaustion at an elevated temperature. Such substances as caoutchouc may be readily extracted by boiling chloroform or bisulphide of carbon. If a known volume of the extract is evaporated, the residue will yield an approximate result of the amount of definite substances obtained in the plant.

In my own work, I have usually found it convenient to take about twenty grams of the powdered plant and exhaust them in a displacement apparatus. There are some advantages for this method, in a preliminary study of the plant. The time necessary for the exhaustion is very much lessened; from ten to twelve hours at the most is ample time to allow the apparatus to run with each solvent, if the solvents are kept at a boiling heat during this period. It is a rapid way to determine qualitatively what constituents are to be found in any plant, and this may be followed by a careful quantitative study on larger amounts. The general insight which can be obtained of the chemistry of a plant from this small quantity of material serves as a valuable guide for the future study on a larger scale.

The extracts obtained by heat show more proneness to oxidation than those from cold maceration, and there are some slight differences in the character of the extracts. The tendency of the higher temperature is to increase the number of constituents in the first extracts; *i. e.*, hot petroleum-ether will remove a considerable quantity of chorophyll; hot ether will extract tannin, and hot alcohol extracts contain sugar, saponin, etc. After the hot alcoholic maceration, the water, dilute soda, and acid extractions are conducted at the ordinary temperature.

It will depend somewhat upon the object in view on the part of the analyst what course to follow in the study of a plant. If only one compound is to be isolated and examined, disregarding the other constituents, suitable methods of study will be employed for this end. Even when Dragendorff's systematic scheme is followed, a fresh portion of powder should be extracted with water for an accurate estimation of soluble albuminoids, amides, and other classes of nitrogenous compounds. These subjects are very clearly stated in the volume of "Plant Analysis," to which I have referred.

I wish to bring forward some well-known statements, which may serve to illustrate the practical application of facts discovered by plant analysis. One of the more recent applications of new processes to industrial chemistry is the manufacture of hop-resin extract [1] on a large scale. The use which is made of this extract is in the manufacture of beers, and it is being used to a large extent in Philadelphia and New York, fully supplying the place of the ordinary hop. The process is somewhat as follows: The hops are loosely placed

[1] "Hop Extract," by W. B. Bissell, *Am. Jour. Pharm.*, April, 1885, p. 166.

in large wire cages, and then are run into an immense boiler or "extractor." A heavy door is shut securely, and about 300 barrels of light petroleum are pumped in by an engine, and heat is applied by means of a steam coil, until a pressure of 100 pounds to the square inch has been obtained.

The object of this high pressure is to break or crush the glands, which contain the valuable principle called lupulin, this being taken up by the hot petroleum. The process is so managed that there is very little waste of menstruum, and the hop extract is readily separated; the petroleum-ether being used over and over again. One pound of this extract represents about twelve pounds of choice hops, and it has a great advantage over the hop itself, as it will keep for an indefinite time; whereas at the end of two years the hop is useless.

Hop-resin,[1] or bitter, was discovered from the chemical analysis of a plant, and it illustrates to what practical ends a fact derived from this source may be applied. The solubility of hop-resin in petroleum-ether is availed of also in the examination of beer.[2]

Vegetable wax is found on the surfaces of leaves, on the stem, and the berries of plants, and is obtained from many sources. The commercial supply comes from certain species of the palm-tree family in considerable quantities. Carnaüba wax is from a large Brazilian palm. *Myrica*, or myrtle wax, comes from the berries of an American and Mexican plant, *Myrica recifera* of the *Myricaceæ* family, and Japan wax is obtained from *Rhus succedaneum.*

Vegetable wax[3] is principally used in the manufacture of candles, but on account of its greater dryness, it breaks much more readily than animal wax; hence, if animal wax is mixed in small proportions with vegetable wax, it answers very well.

[1] Lermer, *Vierteljahresschr. f. prakt. Pharm.*, xii, 504, 1863; Bissell, *Amer. Jour. Pharm.*, xlix, 582, 1877; Griessmayer, *Ber. d. d. Chem. Ges.*, xi, 292, 1878; Isleib, *Archiv. d. Pharm.* (3), xvi, 345, 1880; Cech, *Zeitschr. f. Anal. Chem.*, xx, 180, 1881.

[2] Griessmayer.

[3] *Matières Premières Organiques.* Par Pennetier, p. 771.

It is also used in adulteration of beeswax. Cerosin,[1] a wax from sugar-cane, is said to melt at 82° C. It has been proposed, on account of its high melting-point, to use it in the manufacture of candles. Five hundred plants can furnish, it is claimed, one kilogram of wax.

The bark of *Fouquieria splendens*,[2] or the ocotilla tree of Mexico, also yields a wax. The native Indians use this stem for illuminating purposes; it burns with a red, smoky flame, and is called the candle tree.

The vegetable waxes are mixtures of resinous substances and the higher fatty acids, and differ from the fixed oils in containing, in place of glycerin, cetyl and myricyl alcohols; properly they contain ethers of higher alcohols of the ethylic series and free acids. The wax obtained from the *Gramineæ*, or grasses, to which class sugar-cane belongs, has been studied by König.[3] He found that it contained no glycerine but chloresterin, cerotic, palmitic, and oleic acids.

The importation of vegetable and mineral wax[4] for 1884 was 617,992 pounds ($69,026); 1885, 1,056,438 pounds ($123,976).

The oils of vegetable origin used in commerce[5] are usually derived from grains; a few only are extracted from the fleshy parts of fruits. The oil is found in the form of minute drops in the rinds of fruits; the orange contains four different oils, and in many seeds the place of starch is supplied by oil, and serves the future seedling for nutrition. The oil is usually obtained on a large scale by pressure; however, oils are soluble in petroleum-ether, and may be extracted by it. In France,[6] the cultivation of oil-yielding plants occupied 445,000 hectares, the product of which represented a value of 105,000,000 francs. Olive oil[7] is obtained from several species of the olive tree.

[1] *Matières Premières Organiques.* Par Pennetier, p. 771. *Annales de Chimie et de Physique*, lxxv, 218. *Annal d. Chem. und Pharm.*, xxxvii, 170, 1841. *Ibid.*, (new series), xiii, 451.

[2] *Proc. A. A. A. S.*, vol. xxxiii. *Amer. Jour. Phar.*, February, 1885. The analysis of this plant is among the first published accounts of plants treated by Dragendorff's scheme in this country.

[3] *Landw. Versuchsstat*, xiii, 241.

[4] Bureau of Statistics, Treasury Department, 1885.

[5] *Loc. cit.*, Pennetier, p. 706.

[6] *Ibid.*, p. 709.

[7] *Ibid.*, p. 709.

It serves for many purposes, and enters into the food of some nations. In Spain, a kind of soup, made of oil, garlic, and bread soaked in water, is eaten by the poorer classes.

The nuts[1] of *Corylus avellana* give an excellent table oil; it is also used in perfumery. The residue from the extract is used for almond confection, and is preferable to that made of ordinary almonds. A commerce is made in China of "Chou-lah"[2] obtained from one of the *Euphorbiaceæ*. This tallow is made into candles, which burn with a brilliant and white flame. There is an enormous demand for them. Many other plants of the same family furnish this oil. The genus *Bassia*, of the *Sapotaceæ* family, yields several important fats, among which is one known as Galam butter. This vegetable butter can replace animal fats, and is largely used in soap-making. The annual report of the manufacturers of linseed oil alone for one year was figured at high rates, but the manufacture and uses of this oil are too well known to need more than a mention.

Olive oil in the *American Pharmacopœia* is replaced by cotton-seed oil.[3]

The supply of cotton seed — *Gossypium* — is obtained from several countries, and may be said to be inexhaustible. The Southern States of North America contribute the largest quantity by millions of tons. A large proportion is not worth the expense of transit, and is burned for fuel and given to stock for litter. A considerable quantity is used in the manufacture of decorticated cotton cake and oil. Egypt is said to grow a superior quality of seed, and England derives her principal supply from there. Improvements in the method of irrigation are said to have increased the annual quantity, but the average of past years has been about 250,000 tons.

The seeds yield some twelve to twenty per cent. of oil. The oil in appearance, taste, and smell resembles fresh olive oil.

The fixed oils are chemically glycerides and are principally composed of glycerin, in combination with oleic, palmitic,

[1] Pennetier, p. 750. [2] *Ibid.*, p. 752.

[3] "Notes on Cotton-Seed Oil," by W. Gilmour. *Am. Jour. Pharm.*, November, 1885, p. 565.

and stearic acids. They are frequently solid at ordinary temperature, and their consistency depends upon the proportion of oleic acid present.

Commercial oils [1] frequently contain free acids; thus in palm oil the free acid calculated as palmitic acid usually varies from twelve to eighty per cent. The presence of free acid in an oil is doubtless the principal if not the only cause of its tendency to act on metals, and therefore seriously affects the suitability of an oil for use as a lubricant.

Before leaving the subject of vegetable oils, I wish to call attention to the essential-oil industry in Grasse.[2] The world-wide fame of this locality depends upon the essential oils of plants which grow wild or are cultivated in the neighborhood. The oil of lavender, rosemary, the garden thyme, of the *Labiatæ* family afford an important export industry of Grasse.

The following quantities of oil are produced in Grasse every year: From the lavender, 80,000 to 100,000 kilograms; from thyme 40,000, and from rosemary, 20,000 to 25,000 kilograms. The quantity sent out from Grasse probably meets the requirements of the whole world. Dalmatia only furnishes the oil of rosemary and sends about 20,000 kilos of this essential oil into the market; Grasse also sends forth each year oil from the citrus species, especially oil of neroli, which is much esteemed. Orris butter is distinguished above many other perfumes by an agreeable softness and great permanence. One of the houses in Grasse prepares four to ten kilograms yearly. Its value in Grasse is 1,500 to 1,800 francs the kilo. Besides the wholesale distillation of orange flowers and roses, some other aromatic plants are occasionally worked up when needed, though not to any great extent.

The processes used for extracting these perfumes by the methods of "infusion" and "enfleurage" are extremely interesting and may deserve a passing notice. The fat used as the basis of the "pommade" is selected from the best pig's lard or beef suet. The melting, its mechanical purification,

[1] *Commercial Organic Analysis*, by A. H. Allen, Philadelphia, 1887, vol. i, p. 28.

[2] F. A. Fluckiger, *Amer. Jour. Phar.*, March, 1885, p. 131.

and washing are conducted with great care. The stability of the fat is increased by its digestion with benzoin. The "infusion" is effected in large jacketed boilers, in which the fat is warmed by steam heat and the flowers are added. In the month of May over 10,000 kilos of rose or bigarade flowers pass daily for many successive days into the boilers of the factory of one house alone. The fat is diligently stirred by female workers; the expression by means of hydraulic presses is done by men. After the clearing of the fat, the finished "pommade" is at once weighed and stored in tin boxes.

In the case of the more delicate perfumes, the above method of "infusion à chaud" is replaced by "enfleurage." For this purpose light square wooden frames, about eighteen inches each way, in which a plate of glass can be placed, are used. Upon each glass is spread a quantity of fat in a thin layer, and this is strewn thickly with flowers. Sometimes contact with the fat is avoided, and the layer of fat is confined to the other glass wall of each compartment. When a perfumed oil is desired, cloths saturated with oil for the "enfleurage" may be used. The flowers are shut up in these glass compartments for a longer or shorter time, and are repeatedly renewed and replaced by fresh ones. The perfumed fat is mixed with alcohol by means of powerful stirrers. The alcohol takes up scarcely any of the fat, but the greater part of the odorous substances.

From several trials, I think these processes of extraction may be applied to extract the delicate odors of barks and other substances which would be destroyed by distillation, and have escaped detection up to this time.

Among the chemical substances recently introduced into the field of chemical industry [1] may be mentioned cholesterin, or lanolin, $C_{26}H_{44}O + H_2O$. Commercially, this substance is obtained from animal sources; but its wide distribution through the vegetable kingdom warrants its mention in this place. The singular property of this substance and its prom-

[1] "Notes on Chemical Substances Recently introduced into the Field of Chemical Industry," by J. Levinstein. *Jour. Soc. Chem. Industry*, Nov. 29, 1886.

ising commercial future deserve more than a passing notice. Liebrich observed that cholesterin fat possesses the peculiar property of being able to absorb more than 100 per cent. of water, and this singular property was denominated by the great pharmacologist, lanosation, while the cholesterin, mixed with water, was termed by him, lanolin. He also first called attention to the great therapeutical value of lanolin, and shortly afterwards the industrial production of pure lanolin was commenced by a Berlin firm,[1] and its manufacture has been of late steadily increasing.

Lanolin is already taking the place of vaseline, paraffine, and lard. Its efficacy has already been established beyond doubt, and its superiority is due to the extraordinary readiness with which it is absorbed by the skin. This property is not known to belong in a similar degree to any other fatty substance. Besides the medicinal use, it has also been already introduced into various branches of industry, such as perfumery, soaps, and pomades, also for greasing leather belting and for improving the pliability of leather.

The history of the wholesale drug trade for the year 1886 is one of the most remarkable on record, since 1879–80. In a late number of the "Druggist's Circular,"[2] a summary is given of the year, from which I have taken some statements, from the table of prices, as follows: —

	January 1.	*December* 15.	*July* 1.
Alcohol	$2.10	$2.17	$2.09
Camphor	.23	22.25	.23
Gum arabic	.70	.95	.82½
Morphine	2.25	2.10	1.90
Vanilla bean	10.00	18.00	12.00
Copaiba balsam	.34	.36	.34
Cubebs	.90	1.35	.95
Tragacanth	.45	.42	.37½
Senna leaves	.15	.27½	.30
Golden-seal	.14	.18	.13
Pink-root	.35	.47½	.60

[1] Messrs. Jaffé & Darmstadter.

[2] *The Druggist's Circular and Chemical Gazette*, January, 1887.

The advance in alcohol is said to be the result of a combination amongst the distillers. Balsam copaiba has for a long time been very scarce; but the arrival of new stocks will make it freer. "Cubebs, vanilla beans, gum arabic, tragacanth, senna, golden-seal, serpentaria, and pink-root have been and are still very scarce and are likely to be higher." . . . "The largest movement in cocoa leaves ever known, took place early in the month." . . . "A short crop of senna coming at a time when all markets were poorly supplied, and during an unusually active period, is responsible for the upward movement of the drug." . . . "The position of quinine just now is an interesting one, and the future of the market depends upon the source of barks, and that at present is expected to be upward, owing to reduced visible and prospective supplies."

The commercial value of these drugs depends upon certain chemical compounds which they contain. The scarcity of some of these drugs in itself is a sufficient inducement to push forward investigation in plant chemistry, and to endeavor to discover the same valuable constituents or their equivalents in new plants.

The preparation of fine prescriptions has been advanced by the perfection in chemical methods of isolating plant constituents. The medicinal value of many drugs is due to one or more principles, and to be able to administer these principles, apart from the accompanying compounds of the plant, is a triumph of analytical skill.

A new and convenient form to prescribe the more important alkaloids, glucosides, and other active plant principles, is offered by Frederick Stearns & Co., Detroit, Mich. This firm manufactures alkametric granules and alkadermic pellets. These granules contain carefully prepared medicines representing the pure alkaloid or active principle.

The enormous quantity of drugs used to furnish alkaloids or other medicinal principles may be seen from the import [1] of cinchona bark or other barks used in the manufacture of quinine.

[1] Bureau of Statistics, Treas. Dept.

	Pounds.	Value.
1884	2,588,307	$718,035
1885	3,559,691	913,189
Of sulphate of quinia:	*Ounces.*	*Value.*
1884	1,263,732	$1,610,163
1885	1,390,126	1,292,794
Other salts of quinia:	*Ounces.*	*Value.*
1884	712	$1,038
1885	5,435	1,868
Cinchonidia:	*Ounces.*	*Value.*
1884	381,885	$206,405
1885	478,747	220,846

A New York firm [1] has recently introduced upon the market quintessential oils; the odorous principle of these oils is due to the stearoptens or camphors, which readily separate from the more volatile portions.

It has been suggested, owing to the scarcity of gum arabic, to introduce upon the market a gum [2] from a Mexican tree, called the mesquite. This gum exudes from the stem and branches during the summer months. The analysis of this gum offers several interesting features: amongst others its solutions can be combined with basic lead acetate and ferric salts, without being precipitated, and, it is suggested, for this reason, as more applicable in medicine than gum arabic. It is probable that, in time, gum mesquite will become a commercial article of importance.

We are indebted to plants for our tea, coffee, and chocolate supply, and these articles may be reckoned among our foods; for one or all are used by every people.

In Spain, chocolate is looked upon as a necessity. The Spaniard may be seen making his early breakfast with a slice of bread spread with a thick paste of chocolate. The smiling-faced "cocinero" told me how he prepared it, by carefully

[1] Fritzsche Brothers.

[2] "Products of the Mesquite," by H. J. Schuchard. *Amer. Jour. Pharm.*, November, 1885, p. 542.

melting the solid chocolate cake to the desired consistency. A cup of steaming hot goat's milk is offered to the traveler to mix with this chocolate, if he is unable to take it straight.

"When Cortez and the Spaniards entered the vast empire of Montezuma, they found the use of cocoa or chocolate, as a beverage, common. The emperor alone drank it flavored with vanilla from a golden cup."[1] The Spaniards very jealously guarded as a secret the mode of chocolate manufacture, and were able to retain the monopoly of the trade for many years.

Theobromine, caffeine, and theine are the alkaloids which give cocoa, coffee, and tea their exhilarating properties. They owe their aroma to certain volatile oils, which in the case of cocoa is probably developed by roasting.

Tea[2] is of the utmost importance as an article of consumption, and far exceeds in demand cocoa or coffee. Tea can be grown in a wide range of climate; in Pekin, with winters of Russian severity, to Canton and Macao. Any country having a long and hot summer and a cold winter can grow tea. The proportion per head of consumption for Great Britain and Ireland during 1875 was 4.44 pounds.

The very best workers in gathering the tea leaves rarely earn as much as sixpence a day, and until other nations can raise tea for six cents a pound, they cannot compete with China in its production.

Guarana, a product allied to cocoa, and maté, or Paraguay tea, are also used. The same or allied alkaloids prevail in all the principal substances employed for these beverages in different parts of the world. After tea, there is scarcely any other staple of commerce used for dietetic beverages more generally acceptable with all classes than coffee.

The statistics of cocoa, tea, and coffee:[3]—

IMPORTED INTO THE UNITED STATES.

Tea:	*Pounds.*	*Value.*
1884	65,774,234	$13,504,798.56
1885	69,820,172	13,725,380.75

[1] *Tropical Agriculture*, by P. L. Simmonds, London, 1877, p. 2.

[2] *Ibid.*, p. 79.

[3] Bureau of Statistics, Treasury Department.

Coffee:	*Pounds.*	*Value.*
1884	532,514,850	$49,685,689.30
1885	572,222,841	46,723,290.16

Leaves and shells of crude cocoa:	*Pounds.*	*Value.*
1884	12,263,948	$1,673,088.00
1885	10,300,078	1,332,375.00

The above facts, including the tables of statistics, show the extent of our dependence on the presence of chemical compounds in the various plant sources from which we derive many of our supplies.

The consideration of the cereal products of the United States and our domestic sugar supply in relation to this subject, seems of sufficient importance to detain us for a few minutes.

"The total production[1] of the six principal cereal grains of the United States for the census year amounts to 2,697,962,456 bushels, an average of 58.8 bushels per head for the whole population. The total breadth of cultivation and the amount of product of each of the grains is as follows: —

Grain.	*Acres.*	*Production, Bushels.*
Corn	62,368,869	1,754,861,535
Wheat	35,430,052	459,479,505
Oats	16,144,593	407,858,999
Barley	1,997,717	44,113,495
Rye	1,842,303	19,831,595
Buckwheat	848,389	11,817,327
Total	118,631,923	2,697,962,456

"Whether considered in respect to breadth of cultivation, total product, or average production per head of the whole population, these figures place the United States at the head of the grain-producing countries of the world." . . . "The tables of cereal production, taken in connection with the tables of other production, and these compared with the returns of previous census years, show that agriculture con-

[1] *Report on the Cereal Production of the United States*, Dept. of the Interior, Census Office, 1884, p. 381.

tinues to be the leading productive industry of the country, and cereal production the most prominent feature of this industry. . . .

"The increase in grain production, since the previous census enumeration, is in part due to the cultivation of new lands in the West and in the Northwest, but more largely due to gain in farming regions already occupied in 1870. The popular belief that the chief increase in production and the rapid growth of the grain exports is due to the cropping of new and cheap lands, is not sustained by the census enumeration. The tables of production show that the most of the grain is in regions some time in cultivation, and on lands ranging in value from $30 per acre upwards. . . .

"The actual production of 58.8 bushels per head of total population shows that the United States must be a grain-exporting country, notwithstanding the enormously large consumption by its population. The grain and flour exports[1] for the five years ending June 30, 1880, amount as follows: —

Wheat and corn	833,692,207	bushels
Flour and corn meal	24,850,316	"
Total value	$892,788,117	

"The profitable cultivation[2] of cereals on a large scale is more dependent upon climate than upon soil. Rocks of various geological ages underlie the different portions of the chief grain-producing regions. The immediate influence of the underlying rocks is, however, greater in the southern and western portions of the United States than in the northern and eastern." The production and distribution of grain in the United States is influenced largely by the physical character of the soil. "The portions producing the bulk of the grain have soils of reasonable fertility, but are also those which are easily tilled, and upon which the best machinery and labor-saving appliances can be most readily used."

"The acreage and crop[3] of wheat, in 1879, amounted to 35,430,052 acres, 459,579,505 bushels; the acreage being 29.7

[1] *Cereal Report*, p. 383.
[2] *Ibid.*, p. 396.
[3] *Ibid.*, pp. 440–442.

per cent. of all the land and cereals, and the product about 9.2 bushels per head of total population. . . .

"There is but little wheat land east of the Hudson River, and although New York and Pennsylvania produce considerable wheat, the great bulk of the wheat country lies west of those states, beyond the seventy-seventh meridian and the Appalachian chain of mountains, and north of the Ohio River. . . .

"The successful cultivation of wheat, in a commercial sense, is determined by a complicated set of conditions." In an agricultural sense, "the yield and quality of the crop practically depend upon but five conditions, — the climate, the soil, the variety cultivated, the mode of cultivation, and the liability to destruction by insects." Chemistry has to do, however, with only the soil and the variety of grain related. The chemical composition of the grain and its value as a bread plant not only vary greatly in the different varieties, but also in the same variety, from year to year, and on different soils.

Indian corn [1] stands first in amount of the cereal productions of the country. This cereal is more generally distributed over the country than any other; the place of its greatest production is on the fertile prairies and river bottoms of the West, and north of the thirty-sixth parallel of latitude. A comparatively few states [2] produce the bulk of the crop, the four states of Illinois, Iowa, Missouri, and Indiana producing upward of fifty-two per cent.

"The chemical composition [3] of Indian corn varies more than wheat, as might be expected from the vast number and great difference of its varieties. As a whole, it is not quite so rich in albuminoids." It varies also much more in the amount of fibre. The average proportion of starch is less than in wheat, but the most noticeable difference is in the amount of oil. Indian corn when in the "milk" is a most nutritious and excellent food. "The chemical analysis of green corn shows respectively fourteen to fifteen per cent. albuminoids, . . . an amount equal to that in the very best wheat flour." [4]

[1] *Cereal Report*, p. 470.
[2] *Ibid.*, p. 471.
[3] *Ibid.*, p. 482.
[4] *Ibid.*, p. 484.

Oats [1] stand the third cereal of importance in the United States. Maine, Vermont, New York, and Wyoming raise more oats than any other cereal. The muscle-producing value of oats depends upon the amount of their albuminoids. The average composition of some American oats on analysis showed a higher percentage of albuminoids than the richest wheat flours. The amount of fat in oats ranges from four to nearly six per cent.

Barley [2] is successfully cultivated in a wider range of climate than any other cereal. It is the most hardy of all the cereals, and it grows in the north nearly to the point where all cultivation ceases. On the other hand, barley flourishes well in semi-tropical countries, and in this country the region of its greatest production is California. In Arizona and Nevada, more of barley than any other cereal was grown in the census year.

Rye [3] has become of very minor importance in the United States, in comparison with other cereals. It can be grown upon very poor soils. In Europe, for many ages, it was the principal bread-stuff of the people, for it could be cultivated on soils too poor to grow wheat. Pennsylvania has, at each census return, been the leading state in total production; it is now followed by New York.

From analyses, rye in the kernel is less nutritious than wheat, and the deficiencies in their respective flours is still greater. Wheat flours average about eleven per cent. of albuminoids, while rye flours average at about six per cent. On the other hand, rye bran is richer in albuminoids than wheat bran.

The popular belief that buckwheat [4] is less strengthening and more fattening than wheat, is founded on a chemical reason; for the percentage of albuminoids is low, ranging from four to eight per cent. The starch is in larger amount than in wheat, the percentage of oil being about the same. The peculiar aroma of buckwheat cakes is probably derived from the presence of an essential oil decomposed by heat.

Chemistry plays an important part in the cereal production

[1] *Cereal Report*, p. 491. [2] *Ibid.*, p. 497.
[3] *Ibid.*, p. 502. [4] *Ibid.*, p. 508.

of our country. The United States Agricultural Department furnishes several reports on this subject.[1] The analyses have been conducted to show the effect of environment on the grain. The albuminoids, fat, and ash composition of American grain are given and compared with foreign crops, and the average composition of flour from different sections of the country has been studied.

The importance of chemical analyses in this connection is evident, for the relative chemical composition of a cereal decides its nutritive value, and this information is essential to the farmer in the selection of the kinds of grain for sowing. The percentage of chemical composition of grains varies in crops grown in different sections of the country, and furnishes a scientific basis for careful selection of climate and soil.

Agricultural chemical analysis is usually conducted to show the aggregate percentages of groups of substances. All the nitrogenous compounds are determined together and classed as the albuminoids; starch, gum, sugar, and similar substances, as carbohydrates. Oils, waxes, and allied compounds are classed as fats. Special compounds existing in minute quantities, but belonging to one of these classes, would fail to be detected in such a general plan of analysis; such compounds might have great economic interest. Careful and detailed plant analysis can be the only means to discover and isolate these principles.

The sources of sugar supply to the world are from a few plants; the beet, maple, sugar-cane, and sorghum. In our country, during 1883–84, beet-sugar was all made at Alvarado,[2] California. Sugar manufactured from the beet on the Pacific Coast is an assured success. The climate and soil of northern California, Oregon, and Washington Territory are especially suitable to this plant. A vast range of territory in our Northern States would be adapted for the cultivation of the sugar beet. The causes of past failures to establish a beet-sugar industry

[1] *Buls. No. 1, No. 4, No. 9, Chem. Div. Dept. of Agr.*, by Clifford Richardson.

[2] "Our Sugar Supply," by H. W. Wiley. From *Bul. No. 2, Chem. Soc. of Washington*, January, 1887.

may be remedied, depending upon more scientific methods of agriculture and chemical methods. Maple sugar is costly; the trees yielding this product are of slow growth, and their territory of cultivation limited. An adequate supply cannot be expected from this source, nor from the sugar-cane of the South during the present stage of this industry.

If it is admitted that the prosperity of a country is shown by its advance in agriculture, then the onward march should be encouraged by every means in our power. We should look to our own acres for our sugar supply, since this can become practicable, and not abroad. The encouragement of a sugar industry in this country is of importance, when it is considered that over $100,000,000 is sent out of the country for raw sugar, annually.

The problem of how to reduce our revenue does not apply to this industry; in a recent letter on a plan of tariff revision, Mr. E. H. Ammidown says: "Legislation to reduce the duty on sugar should be deferred until the conditions and prospects of the whole sugar industry have been more carefully investigated and are better understood. An industry which, if established, would produce $150,000,000 in value of a staple article of food required in every American household, and save $100,000,000 now or in the immediate future, annually paid to foreign producers, — such an industry, with the example of France and Germany to encourage us, is of too serious importance to this nation to be treated by the national legislature otherwise than with the utmost caution and most cautious deliberation."

The following statistics will show the sugar and molasses importation: —

For the year ending June 30, 1886,[1] free of duty from the Hawaiian Islands: —

	Amount.	*Value.*
Molasses	61,171 gallons.	$7,786.00
Sugar	191,623,175 pounds.	$9,174,612.00
Total		$9,166,826.00

[1] Bureau of Statistics, Treas. Dept. 1886.

Dutiable.	*Amount.*	*Value.*
Molasses	39,018,637 gallons	$5,587,884.00
Sugar	2,498,258,590 pounds	71,606,918.00
Sugar candy, etc.		23,333.00
Total		$77,218,135.00

Value of all imported sugars and molasses	$86,392,747.00
The value of all imported sugars and molasses, for the year ending June 30, 1885	76,738,719.00
For the year ending June 30, 1884	103,884,275.00
The total value[1] of domestic sugars and molasses amounted to	43,037,409.03
The amount of money sent out of the country during the last year to meet the demands of sugar consumption was	135,000,000.00[2]

The above figures show the amount of sugar and molasses consumed in the United States annually. If we are to obtain all of these products from our own lands, it is a reasonable question to ask, how is this to be accomplished?

Former analyses show that the yield of sugar from Louisiana cane is less than from cane grown in the tropics. The future prosperity of Louisiana growers need not suffer from this poorer juice. The recent experiments at Fort Scott[3] demonstrated that a given weight of cane, without notably increasing the cost of manufacture, yielded thirty per cent. more sugar than had ever been made before. The Southern sugar industry will thrive with the encouragement of a greater sugar yield, and by the introduction of more scientific methods of growing and manufacture.

Of late years the manufacture of sugar from *Sorghum saccharatum* has attracted attention. So far, as a business project, it has proved a financial failure. From the recent chemical reports of the Agricultural Bureau, under proper conditions of cultivation, this cereal promises to become a profitable source of sugar supply.

I give a few of the chemical results of the late Fort Scott

[1] *Bul. No. 5, Chem. Div. Dept. of Agr.*, pp. 7, 8.

[2] From *Bul. No. 2, Chem. Soc. of Washington*, p. 16.

[3] *Bul. No. 14, Chem. Div. Dept. of Agr.*, 1886. H. W. Wiley, Chemist.

experiments.[1] Up to October 1st, the mean composition of the chips entering the diffusion battery was: —

	Per cent.
Sucrose	8.76
Glucose	3.28
Soluble solids	14.88
Available sugar	2.64

Following that date: —

	Per cent.
Sucrose	7.02
Glucose	4.16
Soluble solids	14.89
Available sugar minus	0.85

With such raw material it was found to be impossible to manufacture sugar successfully.

It must not be inferred from these discouraging analyses that sorghum is not capable of becoming a good sugar-producing plant. Many samples of cane brought fresh from the fields or from protected parts of piles of cane cut for a day, showed a remarkably high percentage of sugar.

On September 30th, a sample of cane from the carrier showed: —

	Per cent.
Sucrose	12.39
Glucose	3.76
Total solids	17.8
Available sugar	6.98

Such cane would yield 140 pounds of sugar per ton.

An October cane cut one day gave an average of 176.6 pounds of sugar per ton.

Dozens of samples of cane during the season would have given over 100 pounds of sugar per ton. When it is remembered that sorghum cane can be grown and delivered at the factory for $2 a ton, the importance of these figures cannot be overestimated. If sorghum can be produced which will

[1] *Bul. No. 14.*

contain five per cent. available sugar from the whole crop, the future of the industry is a most promising one.

Until the variations of the percentage of sucrose in the juice can be controlled, sorghum cannot be considered a profitable crop for sugar production.

It is purely a question of more scientific agriculture. As far as the processes are concerned, the problem of extracting the sugar from the cane has been solved.

To insure the financial success it will be important to select a suitable situation of climate and soil. Before embarking upon a large money outlay, the scientific representative of a company should experimentally grow, under trial conditions, sorghum cane in the localities where it is proposed to start the industry.

On a broad scale the northern and southern limits have been already defined. Seventy degrees Fahrenheit is the isotherm [1] for the best sorghum sugar production for June, July, and August; but cane for syrup will grow north of that line.

At a comparatively small expenditure the question of climate for special localities and other conditions could be tested by a chemical analysis of the plant, whose juices respond as quickly to favorable or adverse conditions as the mercury to heat and cold.

Dr. Wiley [2] recently, in his annual address as President of the Washington Chemical Society, said: "The hope of sorghum is not in new methods and new machinery, it is in the skill and patience of the agronomist. Wise selection of seed, intensive culture, judicious fertilization — these are the factors that can make the sorghum sufficiently saccharifacient."

It seems to me that the refinements of plant analysis are destined to play an important part in this connection. Chemical analysis of chosen seed would ensure a wise selection for planting. Analysis of the cane and juice would show the results of experimental culture. For experiment, the proportional constituents of the soil may be varied, to determine if the proportion of chemical constituents of the cane, detrimental

[1] *Bul. No. 3, Chem. Div. Dept. of Agr.*
[2] "Our Sugar Supply."

or favorable to the production of richer juice, may be controlled.

Analyses would show what external chemical conditions are requisite to insure a vigorous growth, and if upon these depends a larger sugar yield. Series of experiments at different stages of growth undertaken to discover the chemical processes attending growth, maturing, and ripening of the canes, under trial conditions, are necessary to be known by the chemical representative of the producer.

Plant chemistry, in applying this knowledge to practical agricultural ends, will fulfill a high aim. It may be suggested as a worthy object of agricultural experiment to discover what parts of the residual sorghum, juice, and cane, after the sugar extraction, may serve a practical end. A profitable utilization of these products would assist the improved machinery and new chemical processes in lessening the cost of sugar production. Paper [1] has been manufactured from the cellulose of the sorghum cane. Future experiments will determine the separation and economic interest of other constituents.

Very many dye substances of vegetable origin are used industrially. It would detain us too long to enumerate the list, and I shall select a few of the well-known ones for illustration: —

The dye-woods imported in a crude state are as follows: [2]

	Tons.	Value.
Camwood:		
1884	659.82	$65,461.00
1885	730.00	68,721.00
Fustic:	*Tons.*	*Value.*
1884	11,811	$177,830.00
1885	8,090	119,689.00
Logwood:	*Tons.*	*Value.*
1884	55,921.59	$875,291.00
1885	56,507.80	904,205.25

[1] "Sorghum Saccharatum," by C. A. Goessmann. From *Trans. N. Y. State Agr. Soc.*, 1861. *Bul.* XLI, *N. J. Agr. Experimental Station*, 1887, p. 23. *Bul. No. 14, Chem. Div. Dept. of Agr.*, p. 56.

[2] Bureau of Statistics, Treas. Dept., 1885.

The madder plant was formerly grown to a large extent in many countries, and in France [1] large tracts of land were given up to its cultivation. "Madder [2] owes its importance to the beauty and fastness of the tints it yields, and to the fact that by a variation of the mordant used, it produces rose pink, black, violet, lilac, and puce colors." The character of the soil where the madder grows affects the color of the dye. The roots grown in a rich clay soil exhibit a rose-pink color; under other conditions, a deep red coloration.

Alizarin, the chief coloring-matter of madder, is now produced artificially from coal tar in large quantities, though the madder is especially in request for woolen dyeing. This plant, which yielded such large revenues to the growers, is replaced by a cheaper manufactured product. Very likely we should not have discovered the synthesis of its valuable dye, if our attention had not first been directed to it in the plant.

When it is remembered that coal tar is undoubtedly of vegetable origin, the many brilliant dyes derived from this source are only evidences of what plant chemistry could have found in the carboniferous ages.

The following statistics show: —

The amount [3] of imported madder:

	Pounds.	*Value.*
1884	253,385	$13,521.00

Ground or prepared madder:

	Pounds.	*Value.*
1884	1,458,313	$111,456.00
1885	1,211,370	80,628.00

The natural or artificial alizarin:

	Pounds.	*Value.*
1884	778,660	$296,123.00
1885	1,470,864	404,002.00

[1] *Tropical Agriculture*, by P. L. Simmonds. London, 1877, p. 369.

[2] *Hand-Book of Dyeing and Calico Printing*, by W. Crookes. London, 1874, p. 228.

[3] Bureau of Statistics, 1885.

Total value madder and alizarin:

1884	$421,100.00
1885	484,630.00

Many species of plants grown in different parts of the world, but especially the *Indigofera*, yield a glucoside called indican, which, under the influence of dilute mineral acids and certain ferments, breaks up, yielding indigo blue and a substance resembling glucose.

"Indigo [1] has undoubtedly been known in Asia from a very remote period of antiquity, since there exist, in very ancient records written in the Sanskrit language, descriptions of its mode of preparation mainly not different from the methods yet in use." The manner of cutting the plant and extracting the indigo is not the same in all countries. In India, the plants are grown from seeds which are sown in the fall and spring, according to the kind of plant. As soon as the young plants are sufficiently forward they are replanted in regular rows. The flower buds are pulled off before they are fully developed, experience having taught that by so doing the leaves of the shrub become larger and yield more indigo, the coloring-matter being chiefly present in the leaves.

The indigo of commerce is a blue dyestuff extracted by fermentation. Other plants [2] used occasionally for the extraction of indigo are more frequently employed directly in dyeing; they belong to the *Polygonaceæ* family. These plants are from India, China, Central Africa, and South America, and they can be acclimated in all warm countries. In the mode of indigo manufacture [3] two processes are employed. In the one the dry leaves are used, in the other the green leaves. This is the one in most common use. When the plant begins to flower it is cut down at about six inches from the ground and carried to the steeping vats with as little delay as possible, strewn horizontally in the vats, and pressed down by means

[1] *Hand-Book of Dyeing and Calico Printing*, by W. Crookes, p. 447.

[2] *Matières Premières Organiques*, par Pennetier, p. 513.

[3] *Ibid.*, p. 516. *Bul. de la Société Industrielle de Mulhouse*, vol. xxviii, p. 307.

of beams fixed into side posts, bamboo being placed under the beams. Water is immediately run in, just sufficient to cover the plant. The pure water from the Ganges is especially sought for in these manufactories, and many indigo factories line the river banks. The time for steeping depends much on the temperature of the atmosphere, and can only be learned by experience and careful watching of the vats, but in close, sultry weather, with the thermometer at 96° in the shade, eleven or twelve hours are sufficient. In cooler weather more time is requisite.

When fermentation is established, the surface of the vat is covered with a violet scum. The liquid is drawn off through plug holes in the wall of the vat. The fecula at the bottom is then removed to the boiler. It is brought to the boiling point as quickly as possible, and kept there for five or six hours. While boiling it is stirred to keep the indigo from burning, and skimmed with a perforated ladle. When sufficiently boiled it is run off to the straining table,where it remains twelve or fifteen hours draining. It is then taken to the presses and gradually pressed. This process takes twelve hours. It is then ready to be taken out, cut, stamped, and laid in the drying house to dry.

In the manufacture of indigo the ordinary processes of fermentation, drawing-off the liquor, beating, and collecting the fecula, are generally well known and are followed with but trifling variation in different provinces and manufactories in India. The main points appear to be the watching and the soaking of the plant so as to be able to tap off the infused liquid at exactly the right point of fermentation, and next to beat the liquid in the second vat long enough.

Indigotin as it is contained in the vegetable tissues is colorless, but it becomes blue on contact with air. If it is desired to change indigo blue to indigo white, it is only necessary to place it in the presence of a deoxidizing and alkaline liquid, but as soon as air is admitted its blue color is resumed.

The dyeing of fabrics is based upon the transformation of indigo blue into soluble indigo white. The colorless matter is placed on the stuff, which becomes blue by exposure. The solubility of indigo in sulphuric acid is utilized for blue dyeing of wools.

Indigo has been made artificially by several methods, though the process so far is too expensive to allow the manufactured compound to replace the commercial supply from plants.

The table of statistics is as follows: —

Amount of indigo[1] *imported:*	*Pounds.*	*Value.*
1884	2,674,062	$2,267,048.00
1885	3,035,934	2,007,066.00

Artificial indigo:	*Pounds.*	*Value.*
1884	None.	———
1885	3,300	$3,600.00

The dye commonly known as logwood has been cultivated in Jamaica[2] since 1715, and has been known and used in Europe from a short period after the discovery of America. The commercial supply of the dye is from *Hæmatoxylin campechianum*, a tree belonging to the natural order *Leguminosæ*. It is the wood of the tree which is used, and is met in commerce in the shape of large, irregular blocks.

The only other tree besides logwood in which hæmatoxylin so far has been discovered is the *Saraca indica*, of the same natural order.

I stated[3] before the Academy of Natural Sciences, in November, the discovery of this principle in my analysis of the bark of the *Saraca indica*.

The *Saraca indica*[4] is called in India the asok or asoka tree, and it is said when this tree is in full blossom, there is nothing in the vegetable kingdom which affords a more beautiful sight. Frequent mention is made of the plant in Hindoo mythology, and the bark is much used by native physicians in some diseases.

[1] Bureau of Statistics, 1885. [2] *Crookes*, p. 342.

[3] "On Hæmatoxylin in the Bark of *Saraca Indica*," by Helen C. De S. Abbott. *Proc. Acad. Nat. Sciences*, Philadelphia, November 30, 1886. See p. 171.

[4] *The Materia Medica of the Hindus*, by Udoy Chaud Dutt. Calcutta, 1877.

I undertook the analysis of this bark at the request of Messrs. Parke, Davis & Co., of Detroit, Michigan, who furnished me with a liberal supply of the drug. The coloring principle exists in the bark in two or more conditions, as hæmatoxylin and as oxidized products. The former was separated as yellow crystals, analogous in form to hæmatoxylin crystals from the true logwood. The alcoholic extract of the bark contained about eighteen per cent. of a red-colored substance which agreed in color and dye tests with like constituents found in logwood. Mordanted cotton fabric was dyed with hæmatoxylin from *Saraca* bark, and presented the characteristic logwood dye colors.

The extracts of *Saraca indica* bark containing its coloring principle were tested with various reagents,[1] and it was observed that the reactions agreed with hæmatoxylin colors, and in no case with those of brazilin.

The bark of the commercial logwood tree is not used for extracting the dye, the wood of the tree being employed for this purpose. I determined the presence of a small quantity of hæmatoxylin in the logwood bark, and obtained with its extracts the same reaction without alkalies and other reagents as with the other wood extracts. But owing to the smaller percentage of dye in the bark of the specimens examined, the colors were less intense. In the case of the *Saraca indica* bark, the colors were very brilliant, and certainly indicated the presence of a large proportion of coloring-matter in it. It would be of interest to secure specimens of the wood of *Saraca*, in order to determine if it contains the coloring principle, and should this be so, if it exists in sufficiently large quantities to warrant its introduction as a new source of this commercial product.

Last summer [2] I extracted from a Honduras plant, called "chichipate," a yellow dye. It yielded with mordanted wool fabrics, colors somewhat resembling those yielded by fustic

[1] S. P. Sadtler and W. L. Rowland, *Amer. Jour. Pharm.*, February, 1881.

[2] "Preliminary Analysis of a Honduras Plant, named 'Chichipate.'" Paper read before the A. A. A. S , at Buffalo, August, 1886.

wood. A plant [1] was analyzed in the laboratory of Parke, Davis & Co., named *Cascara amarga*, from which a new alkaloid, picramnine, was separated. This alkaloid is like berberin in its properties. Specimens of this plant were lately forwarded to me, and there is every indication of the relationship of identity of "chichipate" and *Cascara amarga*. This incident is significant as deciding by means of chemical analysis the identity of plants under distinct names from different regions. No analysis under the name of "chichipate" had ever been published until my own report. The dyeing property of the substance, chichipatin, separated from "chichipate," I think is quite independent of the alkaloid, though berberin, it is well known, yields yellow colors with wool. I also separated a new camphor from this plant. It is crystalline, and under polarized light gives a beautiful play of colors.

During the year 1886, Professor Trimble [2] separated a new crystalline camphor, phloxol, from the underground portion of *Phlox carolina*. This substance resembles the camphor found in chichipate. It is soluble in petroleum-ether, and this solvent is suggested as a means of distinguishing powdered *Phlox carolina* from *Spigelia*. The latter contains no camphor. *Phlox* is frequently put on the market for *Spigelia*. The two drugs in the normal condition can be readily identified.

An estimate of the profitable ends of the chemical analysis of plants may be gathered from the above statements.

Plant analysis covers a wide field, for it includes the chemistry of the living and the dead plant. Its application to various industries is far-reaching.

Plant analysis in this country has been called an "infant industry." There are probably differences of opinion about the infant needing protection. It certainly needs encouragement and support, when its importance as a citizen is recognized.

Plant chemistry should not only be directed towards the

[1] "Cascara Amarga," by F. A. Thompson. *Ther. Gazette.*, January 15, 1884, p. 8.

[2] "An Analysis of the Underground Portion of *Phlox Carolina*," by Henry Trimble, *Amer. Jour. Phar.*, October, 1886, p. 479.

study of new plants, but in the study of old plants it is to be encouraged; for each new investigation of many well-known plants has revealed new chemical principles, and given additional knowledge of the old ones. We can never know to what practical uses the constituents of any plants may be brought, and the money value of this information should be considered.

Many chemical compounds which are of the most practical use, now made by synthesis, were first discovered in plants, products of living matter.

Synthetical chemistry has derived its knowledge from the results of analytical study. Researches in plant analysis have revealed many facts, though the exploration field is still wide.

In our present state of knowledge, plant chemistry is a safe political ground for either the Protectionist or Free-Trader. The vegetable cell has placed the tariff of human penetration so high, and protected so well its industry, that the plant enjoys the monopoly of proteids and a magazine of other substances. The Free-Trader may console himself, for if he is intelligent enough he can find out the processes, and start his own factory, duty free.

Professor Cohn, of Breslau, tells us that it is only a question of time when we may hope for the chemist to succeed in doing what the simplest Algæ and mosses are able to do, namely, to produce starch from carbonic acid and water. On that day the bread problem, which is in fact the greatest of all social problems, will be solved.

It is indeed true that those organic compounds which are of the most importance in the life of the plant, the hydrocarbons and the albuminoids, are those which as yet have not permitted the secrets of their production to be discovered.

In the future, when synthesis has accomplished this prophecy, and the synthetical chemist reigns supreme, our coming race, to my imagination, will be chemists, and our farmers will manufacture our food supply of proteids, sugars, and starch. The surface of the land will be one huge teeming laboratory. The plants, the analytical chemist, and others of his race, asphyxiated by their environment, will have long ago passed away into a suffocating forgetfulness.

But for the present we must be satisfied to depend upon our humble colleagues, the plants, for our food and beverages, our fabrics, perfumes, and dyestuffs, our medicines, and other things too numerous to mention.

PLANT CHEMISTRY, AS ILLUSTRATED IN THE PRODUCTION OF SUGAR FROM SORGHUM[1]

In its broadest sense, a knowledge of plant chemistry comprises, at least, a general understanding of botany and physiology, as well as of chemistry. It may be compared to a plane bounded by three lines. This simple geometrical figure stands for a triple theorem, from which the life-problem of the plant is to be solved.

Tables of analytical data are worthless as facts unless they serve for purposes of generalization, or to interpret the physiological changes incident to growth and decay.

All parts of plants are composed of chemical bodies, and are, at some period of the plant's growth, engaged in certain physiological functions. Chemical processes accompany the different stages of development. Daily analyses of the plant, from its seed to maturity, cannot fail to acquaint the student with the order of chemical succession. "Such information is of equal importance to agriculture, *materia medica*, and scientific botany." [2]

I shall not attempt to discuss the chemical analysis of plants in all its bearings. Its application to many of our great industries may be shown; but I have selected the subject of sugar, from the number, for illustration.

The sugar interests of our country concern all. Pharmacy needs its quota of sugar, as well for the manufacture of its *placebo* as for disguising the taste of its bitterest drug; and the sources of this supply are of special interest to the scien-

[1] A lecture delivered before the Alumni Association of the Philadelphia College of Pharmacy, February 8th, 1887. Printed in *Proceedings* of the Alumni Association; also in pamphlet form, under imprint of Burk and McFetridge, 1887.

[2] "Plant Analysis as an Applied Science," see p. 175.

tist as well as to the people. I am venturing upon a field that has grown more crops of dissension and contest than acres of the juicy reed. I refer to the possibility of an indigenous sugar supply from sorghum cane.

It may be of interest to note that almost the earliest impulses given to the consideration of the manufacture of sugar from the beet root and sorghum cane were from Philadelphia. As early as the year 1836, the sugar beet was first introduced into the United States by a society in this city;[1] and Dr. Goessmann called the attention of the agricultural institutes of his native country, Germany, to his own observations concerning the nature of the juice of sorghum, made during the summer season of 1857, while here.[2]

Nearly three quarters of a century have been spent to develop the chemical processes of the beet-sugar industry, and improvements are even now being introduced. The working of sorghum juices will be found as difficult as those of beet, and true success cannot be hoped for until the processes used for the one are as complete and scientific as for the other. It is not meant by this that the processes and machinery are to be identical.

Sorghum will have to develop a chemistry of its own. This will not be the work of a day or a year, but it will be accomplished sooner or later.[3]

The pronounced success of the beet-sugar industries of France and Germany should serve as a beacon-light to the struggling and distressed manufacturers of other countries.

I wish to sketch briefly what chemistry, particularly plant analysis, has done for sorghum.

Before taking up this subject in detail, it may be well to state that the sources of sugar supply to the world are from a few plants [4] — the sugar beet, maple, sugar cane, and sorghum.

[1] *Observations on the Sugar Beet and its Cultivation.* Philadelphia, 1840.

[2] "Sugar Cane, Sorghum Saccharatum," by Dr. C. A. Goessmann. From *Transactions, N. Y. State Agricultural Society*, 1861.

[3] *Bul. No. 14, Chem. Div. U. S. Dept. Agr.*, page 43, by H. W. Wiley.

[4] A fifth source of sugar supply is threatened by introducing upon the

It will be unnecessary in this connection to give the history of beet culture from its introduction into this country up to the present time. But during 1883 and 1884 all the beet-sugar in our country was made at a factory located at Alvarado, California.[1] The juice of beets raised on the estate of this corporation contained 14.38 per cent. sugar, and last August reached 20.5 per cent. at one time, with the "purity coefficient" of 82, the usual average per cent. in Germany being from 12 to 13, with but one factory reaching as high as 15.6 per cent.[2] The quantity of sugar produced per acre by the factory has averaged about 3000 pounds.

Sugar manufactured from the beet on the Pacific coast is an assured success. The climate and soil of northern California, Oregon, and Washington Territory are especially suitable to this plant. A vast range of territory in our Northern States would be adapted to the cultivation of the sugar beet. Scientific methods of horticulture and agriculture should be resorted to, to increase the supply, for an insufficiency of beets in the past, and not the defects of machinery, has been the cause of failures.

An adequate supply of sugar cannot be expected from the maple, nor from the sugar-cane of the South during the present state of this industry.

The maple is a tree of slow growth. Only after twenty-five years can it be used for sugar-making. It yields the best harvest after a severe winter, and, therefore, the North is the proper field for the planting of this tree. "Even if forestry is successful in securing a wide increase of maple orchard, it will be many years before it can affect our sugar supply." [3]

The annual production of maple sugar is now about 20,000 tons,[4] and of molasses, 2,000,000 gallons.

market saccharine-glucose — a combination of two parts of the coal-tar derivative product and one thousand parts glucose, which, it is claimed, will be elevated to the dignity of a genuine competitor with cane sugar.

[1] "Our Sugar Supply," by H. W. Wiley. From *Bul. No.* 2, *Chem. Soc. of Washington*, January, 1887.

[2] *Overland Monthly*, December, 1886. E. W. Hilgard.

[3] From *Bul. No.* 2, *Chem. Soc. of Washington.*

[4] *Bul. No.* 5, *Chem. Div. Dept. Agr.*, p. 7.

The yield of sugar per tree varies from 2.5 to 5 pounds, according to the season. A single tree has been known to yield as much as 40 pounds of sugar. It will be seen that the average yield of sugar may easily reach 200 pounds per acre.[1]

The period is remote when we may hope to obtain our sugar supply from the maple. This sugar will doubtlessly always remain a luxury rather than an article of general consumption.[2]

Former analyses show that the yield from Louisiana cane is less than from cane grown in the tropics. The future prosperity of Louisiana growers need not suffer from the poorer juice, since the recent experiments at Fort Scott[3] demonstrated that a given weight of cane, without noticeably increasing the cost of manufacture, yielded thirty per cent. more by the diffusion process than has ever been made before. The Southern sugar industry will thrive with the encouragement of a greater sugar yield, and by the introduction of more scientific methods of growing and manufacture.

The following statistics will show the sugar and molasses importations for the year ending June 30, 1886,[4] free of duty, from the Hawaiian islands: —

Free of Duty.	*Amount.*	*Value.*
Molasses	61,171 gallons	$7,786.00
Sugar	191,623,175 pounds	9,166,826.00
Total, ...		$9,174,612.00
Dutiable.	*Amount.*	*Value.*
Molasses	39,018,637 gallons	$5,587,884.00
Sugar	2,498,258,590 pounds	71,606,918.00
Sugar candy, etc., ...		23,333.00
Total		$77,218,135.00
Value of all imported sugar and molasses		$86,392,747.00

[1] *Our Sugar Supply*, by H. W. Wiley, p. 20.
[2] *Ibid.*, p. 21.
[3] *Bul. No.* 14, *Chem. Div. Dept. Agr.*, 1886.
[4] *Bureau of Statistics, Treas. Dept.*, 1886.

The value of all imported sugars and molasses for the year ending June 30, 1885	$76,738,719.00
For the year ending June 30, 1884, ...	103,884,275.00
The total value[1] of domestic sugars and molasses amounted to	43,037,409.03
The amount of money sent out of the country during the last year to meet the demands of sugar consumption, was	[2] 135,000,000.00

If it is admitted that the prosperity of a country is shown by its advance in agriculture, the onward march should be encouraged by every means in our power.[3] To establish an indigenous sugar industry would add to this prosperity. An idea may be obtained, from the above statistics, to what magnitude the industry must reach before it can supply to the people this necessary article of food.

The President of the Chemical Society of Washington, in his annual address,[4] presented, under four headings, the possible solution of the sugar problem. The general conclusions reached were in favor of the establishment of a domestic industry.

The wide range of territory and the varied climate of our country render it particularly fitted for sugar production. The maple and sugar beet can be grown on our lands in the North. The best range of latitude for the beet in America is from 38° to 44°.[5] The sugar-cane plantations of the South will contribute their share, and the great middle belt of our vast country may be given to sorghum crops. On a broad scale the northern and southern limits of this belt have been already defined.

The isotherm[6] is 70° Fahrenheit for the best sorghum sugar production for June, July, and August; but cane for syrup

[1] *Bul. No.* 5, *Chem. Div. Dept. of Agr.*

[2] *Bul. No.* 2, *Chem. Soc. of Washington*, p. 16.

[3] "Plant Analysis as an Applied Science." *Franklin Institute Journal.*

[4] "Our Sugar Supply," by H. W. Wiley. From *Bul. No.* 2, *Chem. Soc. of Washington*, 1887.

[5] *Observations on the Beet Root Sugar and Sugar Beet Culture, as adapted to the United States*, Chicago, 1863, p. 13.

[6] *Bul. No.* 3, *Chem. Div. Dept. of Agr.*

will grow north of that line. It is probable that the area of successful sorghum culture is not nearly so extensive as a few years ago it was thought to be;[1] but at a comparatively small expenditure the question of climate for special localities, the best varieties of sorghum for planting, and other conditions, could be tested by a chemical analysis of the plant, whose juices respond as quickly to favorable or adverse conditions as the mercury to heat and cold.

The history of the introduction of sorghum into America would fill several volumes. "All the evidence goes to show that China was the first country that cultivated it, and manufactured sugar; and not only were the Chinese the first, but there is good reason to believe that they enjoyed its use many centuries before it was generally known and used in Europe. When first known it went by the name of Indian salt, and under that name it was sent abroad from China to India and Arabia, and thence to Rome and Greece among the costly spices, and was considered a rare luxury. The cultivation of the plant gradually extended over the different countries of Europe.

"For some time after the introduction of sugar into Europe, it was used only on great occasions, such as feasts, and for medicines; and in a different form from what it is now commonly used — more like our candy. The sugar cane was first brought to this country and cultivated to some extent in Louisiana, on the very place where the city of New Orleans now stands."[2]

It is said that sugar marks the progress of civilization. "The consumption of sugar may be taken as the index to the prosperity and refinement of the people. Those nations holding first rank in wealth, intelligence, and enterprise are the greatest sugar-eaters."[3] We must contest with England to hold the first place in this respect. The immensely large quantities of table syrup used in this country, in addition to the 56 lbs.

[1] *Bul. No.* 14, *Chem. Div. Dept. Agr.*, p. 43.

[2] *The Chinese Sugar Cane, its History, Mode of Cultivation, etc.*, by James F. C. Hyde, N. Y., 1857.

[3] "Our Sugar Supply," from *Bul. No.* 2, *Chem. Soc. of Washington*, p. 32.

of sugar per capita, doubtless rival England with her 67 lbs. per capita, and her marmalade and jelly consumption.

Sorghum saccharatum belongs, botanically, to the *Gramineæ*, or grasses, a class of plants characterized chemically by their large percentage of sugars, wax, and silica. The quantity of silica in sorghum is small; according to Dr. Goessmann, is .0015 per cent.

The principal end for the cultivation of sorghum is for sugar and molasses manufacture. Uses are still to be found for many of the by-products. The profitable utilization of these products would assist in lessening the cost of sugar manufacture.

The disposition of the bagasse is a question of great economic importance. "Three uses appear to be possible, —No. 1 for paper stock; No. 2 for manure; No. 3 for fuel." [1]

"The great object sought in France in the cultivation of this plant is the juice contained in its stalks, which furnishes three important products — namely, sugar, which is identical with that of cane; alcohol; and a fermented drink analogous to cider or champagne. The chaff or pellicles which cover the seeds is used for dyeing silk various permanent shades of red." [2]

The bagasse is a valuable fodder, being sweeter than ordinary grasses and sufficiently nutritious. The leaves of the plant, removed in stripping the stalks, are much relished by stock. The leaves of the sorghum have a higher nutritive ratio than our grain or hay, on account of the large percentages of sugar and albumen they contain.[3] The seeds furnish good food for farm animals. Proximate analyses show that this seed differs but little in composition from the other cereals, and closely resembles corn. It has been reported that sorghum seeds contain considerable tannin, which makes them less valuable as food. It is probable that the tannin is not present in the seeds themselves, at least of many varieties, but in the hulls which inclose these seeds.

[1] *Bul. No.* 14, *Div. of Chem. Dept. of Agr.*, p. 56.

[2] *Chinese Sugar Cane and Sugar Making*, by Charles F. Stansbury. N. Y., 1857.

[3] *Investigation of Sorghum*, by Collier. Dept. of Agr., 1883.

These hulls may be readily separated from some varieties of sorghum seeds and with more difficulty from others.[1]

Comparative analyses of the sorghum seeds with other cereals show the place which the sorghum holds among the more prominent cereals. The seeds contain starch, albuminoids, oil, sugar, and fibre in such proportions as to render them suitable for animal food.[2] These seeds are ground to flour, and are used extensively for food by the people over large tracts of India.

In the experiments of Dr. Goessmann[3] upon the bagasse with various chemicals, he obtained a colorless pulp suitable for making a superior quality of paper without injuring the fibre. From his analyses he obtained 8.2 per cent. of very pure cellulose or fibre. The manufacturer would probably obtain more, as he could not afford to purify it as completely as was done in the analysis. The increased consumption of paper has for years obliged the manufacturer to seek new sources of vegetable fibre supply. Sorghum promises to furnish this supply.

The pulp from the mill bagasse of the Rio Grande Sugar Company, by experiment, was shown to rank next to that from linen rags.[4]

Several organic acids probably occur in the sorghum juice. The presence of these acids may interfere seriously with the successful manufacture of sugar and of clear free syrup. Among them aconitic acid has been found, and also malic acid. The free acids vary in amount from .1 to .2 per cent. There is also acid present combined with potash and other bases found in the ash.[5] The acidity of the sorghum juice is often a serious cause of failure, by inverting the sucrose. After the close of the season at Fort Scott, a comparative study was made of the amount of the inversion which takes place in the diffusion-cells. It was clearly shown "that the

[1] *Special Report, No.* 33, *Dept. of Agr.*, by Peter Collier, p. 99.

[2] *Bul. No.* 3, *Chem. Div. Dept. of Agr.*, p. 114.

[3] "Sugar Cane," by Dr. C. A. Goessmann. From *Transactions N. Y. State Agr. Soc.*, 1881, p. 25.

[4] *Bul. XLI, N. J. Agr. Experimental Station*, 1887, p. 23.

[5] *Bul. No.* 3, *Dept. of Agr.*, by H. W. Wiley, p. 16.

trouble is due to acids of the cane, chiefly to those formed by the partial fermentation which has produced the inversion of the sugar, or else in the increased susceptibility of the sucrose remaining to the inverting action of the organic acids." [1]

The soluble solids, not sugar, are soluble starch and gum, the acids, coloring-matters, wax, resin, and mineral substances. In every case where sorghum juice was tested for starch it was found to be present.[2] Several coloring-matters have been obtained from sorghum, sorgothine and sorghine from the covering of the fruit, and also a red dye from the cane itself.[3]

Since the ash constituents of a sugar-producing plant interfere with its highest yield of sugar, we find that sorghum is superior in this respect to the sugar beet, for its average total ash amounts to .62132 per cent.; and the sugar beet reaches 1.3 per cent.[4]

From these analyses it is seen that the sugar beet contains nearly twice as much ash as the stalk of sorghum.[5]

The presence of large quantities of the alkalies in sugar juice is also unfavorable to the production of sugar. Hence, in selecting localities for growing crops, it is very important to obtain a soil free from such substances.

The character and composition of the soil best adapted to the cultivation of sorghum for sugar production are obviously matters of fundamental importance.

A sandy loam appears to be the most favorable soil for cane.[6]

Comparative analyses were made on the sorghum to show the effects of fertilizers on the sucrose, glucose, and solids in the juice. In these experiments it was found that the soil must have contained sufficient food for the proper development of the sorghum plant, and that the addition of these special fertilizers was unnecessary, and resulted in no marked change in the composition of the sorghum juices.[7] These results

[1] *Bul. No.* 14, p. 27. [2] *Bul. No.* 3, p. 16.
[3] *Matières Premières Organiques*, par Pennetier, pp. 480–509.
[4] *Bul. No.* 3, p. 17. [5] *Ibid.*
[6] *Ibid.*, p. 44.
[7] *Dept. of Agr.*, *Special Rep. No.* 33, by Peter Collier, Chemist.

do not prove that on certain soils, which are deficient in one or more essential constituents of plant-food, that the addition of proper fertilizers will not be of great value.

"The analysis of the ash, taken with that of the soil, is a good guide for the application of mineral fertilizers. Sorghum is a very much less rapacious potash and phosphoric acid consumer than the sugar beet." [1]

The importance of this statement about potash is obvious, when it is remembered that alkalies seriously interfere with the successful manufacture of sugar.

Many interesting facts about sorghum may be culled from the earlier reports of the Agricultural Department.

From comparative analyses of different parts of the stalk of the sorghum, it appears that the amount of juice present in the upper and lower halves does not vary widely. Hence, the practice of cutting the stalk several inches above the ground involves a large waste of sugar.[2]

Analyses of the stalk and leaves show that the stripping of the cane diminished the quantity of the juice, but increased its quality, although there is no available sugar in the juice of the leaves, owing to the larger percentage of other solids than glucose.[3]

Experiments at the Rio Grande Station were conducted: —

"No. 1. To compare mill juice from unstripped cane with diffusion juice from thoroughly cleaned stalks.

"No. 2. To compare the diffusion juice from stripped and unstripped sorghum.

"The results were as follows: —

"No. 1. Eighty-nine per cent. of the total sugar in the cane was secured by diffusion. Forty-eight per cent. of the total sugar in the cane was secured by milling. Milled products, therefore, must be increased by eighty-four per cent. in order to equal diffusion products.

"No. 2. Diffusion juices from stripped cane excelled mill juices in concentration, color, taste, and purity. Diffusion

[1] *Dept. of Agr., Chem. Div. Bul. No.* 3, p. 19.

[2] *Chem. Div. Dept. of Agr., Report,* 1883, Collier, p. 30.

[3] *Report,* 1883, Collier, p. 30.

juices from unstripped cane are inferior to mill juice in all of these respects.

"As a result of these experiments, it was claimed that leaves, leaf-sheaths, and seed were the chief obstacles to the introduction of diffusion. This claim was admitted by Mr. Potts, and Mr. Hughes was directed to construct his stripping machine." [1]

"A further fact, which is illustrated by the analyses of the diffusion juices from uninjured canes is, that the diminished purity is produced solely by the extraction of gum and chlorophyll, chiefly from the blades and sheaths, and that this injury can be avoided by a proper cleaning of the canes." [2]

From tables of comparative analyses, showing the average composition for each variety of sorghum in every stage of its growth, it is seen that "in the earlier stages in the growth of each plant, the amount of crystallizable sugar is small, but as the plants mature, the sucrose rapidly increases, until it equals from twelve to sixteen per cent. of juice. The solids, not sugar, in the juice also increase from the first, but very much less rapidly than does the crystallizable sugar; at the same time, the glucose steadily diminishes." [3]

The habits of some varieties of sorghum and their demands upon climate and soil are almost identical with those of the several varieties of maize, and yet there appears to be, in certain respects, marked differences. The sorghums, as a class, are capable of sustaining a period of drought which would prove fatal to maize.[4]

The root system of sorghum renders it peculiarly adapted to growing upon poorer lands than other kinds of crops, especially if the subsoil is sufficiently rich in nutritive matter to give to the plant its needed food supply.

The chemical analyses of the sorghum may be made from the expressed juice or directly from the cane. Numerous investigations have been conducted in both ways.

[1] *Bul. XLI*, 1887, p. 4. [2] *Bul.* 14, p. 40.

[3] *Spec. Rep. No.* 33, *Dept. of Agr.*, 1881, p. 11.

[4] *Investigation of Sorghum as a Sugar-producing Plant, Dept. of Agr.* Peter Collier.

The relative value of the juice of any sugar-producing plant depends upon the ratio of crystallizable sugar or sucrose to the other sugars or solids which it contains. The great inferiority of sorghum, as a sucrose-producing plant, as compared with the sugar beet, is in the fact that it contains sugars which are not sucrose. These sugars are not crystallizable in the ordinary way. The general term glucose has been applied to them.

The chief one of these "other sugars" present does not affect the plane of polarized light. Dr. Wiley proposes to call it *anoptose*, a term which signifies a sugar without influence on the polarized ray.[1]

In normal ripe sorghum cane, sucrose and anoptose are probably the only sugars present. If the cane is abnormal or exposed for a time after cutting, or frost-bitten, the sucrose undergoes a transformation. It is converted into invert sugar, which is non-crystallizable.[2]

The expression of available sugar means "the proportion of sugar which can be obtained in a dry crystallized form from the canes. Its amount depends on the percentage of juice extracted from the canes, and the ratio of sucrose to the other bodies in the juice." [3]

The "coefficient of purity" [4] is the ratio per cent. of the total sucrose in a juice to the total solids. Juices having an average "purity coefficient" less than sixty will scarcely prove profitable for sugar manufacture. They will, however, make good syrup.

Sorghum has proved to be the most capricious of crops. In the late experiments at Fort Scott, analyses of different canes presented the widest differences, and with such raw material it was found to be impossible, successfully, to manufacture sugar.

However, it must not be inferred, from these discouraging analyses, that sorghum is not capable of becoming a good sugar-producing plant. Many samples of cane brought fresh

[1] *Bul. No.* 3, *Chem. Div. Dept. of Agr.*, p. 15.
[2] *Ibid.*, p. 15. [3] *Ibid.*, p. 20.
[4] *Ibid.*, p. 21.

from the fields, or from protected parts of piles of cane kept for a day, showed a remarkably high percentage of sugar.

On September 30th,[1] a sample of cane from the carrier showed: —

Sucrose	12.39	per cent.
Glucose	3.76	"
Total solids	17.80	"
Available sugar	6.98	"

Such cane would yield 140 lbs. of sugar per ton.

An October cane gave an average of 176.6 lbs. of sugar per ton. Dozens of samples of cane during the season would have given over 100 lbs. of sugar per ton. When it is remembered that sorghum cane can be grown and delivered at the factory for $2.00 a ton, the importance of these figures cannot be overestimated. If sorghum can be produced which will contain 5 per cent. of available sugar from the whole crop, the future of the industry is a most promising one.

Until the variations of the percentage of sucrose in the juice can be controlled, sorghum cannot be considered a profitable crop for sugar production.

The tendency of sorghum cane is to undergo rapid change. This changeable disposition of the sorghum, as compared to the sugar beet, and even to the tropical cane, is a serious fault. To overcome this characteristic of sorghum will require the most scientific agriculture and the researches of chemistry. Special experiments should be undertaken, which have in view the increase of the ratio of the sucrose to the other substances of the juice. "The great trouble is in the remarkable variation of the quantity of sugar in a field of sorghum plants. No estimate of the total yield can be gathered from the examination of one plant, as others in its immediate neighborhood might be found to be radically different. The obtaining of a uniform standard of high sucrose production by the sorghum cane will possibly take scientists years to accomplish." [2]

[1] *Bul. No.* 14, p. 15.

[2] H. W. Wiley, *The Eighth Annual Meeting of the National Sugar Growers' Association.* St. Louis, Feb. 8th, 1887.

In the report for 1884, on the Northern Sugar Industry,[1] the chemist in charge summed up the necessary conditions for a future success of the sorghum industry.

1. A careful selection and improvement of the seed with a view of increasing the proportions of sucrose.

2. A definition of geographical limits of successful culture and manufacture.

3. A better method of purifying juices.

4. A more complete separation of the sugar from the canes.

5. A more complete separation of the sugar from the molasses.

6. A systematic utilization of by-products.

7. A careful nutrition and improvement of the soil.

Sorghum juice is specially fitted for the manufacture of an excellent grade of syrup. There is no danger, should this indigenous sugar industry grow to the proportions necessary to supply the people with sugar, that our land would be overloaded with an excess of molasses production. By suitable methods this molasses might be used for distilling alcohol. This would constitute an important part of the profit of the sugar house. In France, distilleries are connected with the beet-sugar factories. In the case of the alcohol from beets, it is not fitted for the manufacture of beverages; and such alcohol may be used in the arts. It has been suggested, that a similar use be made of the alcohol from sorghum, and that it be distilled and sold free of taxation.[2]

It is well known that sorghum has been successfully and profitably grown for the production of an excellent syrup. But the problem which is now placed before us is to obtain a crystallizable sugar from the juice which will compete successfully with other sugars in the market.

The solution of this question will probably depend upon advances to be made in plant chemistry. The following lines of investigation are suggested: —

1. To secure the increase and constancy of the percentage

[1] *Bul. No.* 3, *Chem. Div. Dept. of Agr.*, p. 107.

[2] *Ibid.*, p. 118.

of sugar or sucrose would need a happy choice of location, successful cultivation, and wise selection of the best seeds.

2. After cutting the cane, to counteract the instability which inverts the sucrose into non-crystallizable sugar before it is subjected to any process of extraction.

3. To determine the most favorable mechanical and chemical processes for obtaining the largest production of dry sugar from this juice.

4. To utilize profitably the by-products.

I stated a few weeks since:[1] "It seems to me that the refinements of plant analysis are destined to play an important part in this connection. Chemical analysis of chosen seeds would insure a wise selection for planting. Analysis of the cane and juice would show the results of experimental culture. For experiment, the proportional constituents of the soil may be varied, to determine if the proportion of chemical constituents of the cane, detrimental or favorable to the production of a richer juice, may be controlled.

"Analysis would show what external chemical conditions are requisite to insure a vigorous growth; and if upon this depends a larger sugar yield, series of experiments, at different stages of growth, undertaken to discover the chemical processes attending growth, maturing, and ripening of the canes, under experimental conditions, are necessary to be known by the chemical representative of the producer.

"Plant chemistry, in applying this knowledge to practical agricultural ends, will fulfill a high aim. It may be suggested, as a worthy object of agricultural experiment, to discover what parts of the residual sorghum and cane, after the sugar extraction, may serve a practical end."

Among the most successful experiments on sorghum, have been those conducted in Italy, a report of which is made by the Italian Minister of Agriculture.[2] The sorghum plants seem to thrive there better than in this country, and the percentage of sugar from the canes reached as high as twenty-

[1] "Plant Analysis as an Applied Science." Lecture before the Franklin Institute, Philadelphia, Jan. 17th, 1887. See p. 175.

[2] *Annali di Agricultura.*

six, a month after cutting, which might be partly due to the concentration by evaporation.

No statement is made as to how the canes were preserved so long, but they were probably placed underground.

Experiments at the station in Washington[1] were conducted by the chemist in charge, to preserve cane in the same manner as beets are kept. The sorghum canes were placed in a shallow ditch, and covered with earth. In January, when the ground was frozen, the silo was opened, the cane, from analysis, yielding 8.39 per cent. sucrose. The next analysis of the cane was made after the winter was practically over. There was a small loss of sucrose, and the yield showed 7 per cent. Sorghum is preserved in silos in Japan.[2]

The crude juice of the sugar beet is a very unpromising product, but the processes are so perfected that nearly all the juice is worked up into crystallizable sugar. Mr. Hilgard states that "the juice of the sugar beet is in the same cases the least pure of sugar-producing plants. To obtain pure sugars from such a raw material requires the confidence of a chemist in the resources of his science, and the solution of the problem stands as one of the most striking instances of the utility of apparently recondite research in developing latent resources for industrial uses."[3]

The cells of the sorghum cane are grouped together like a honeycomb. The sugar, which is held in a state of solution, is contained within the cellular tissue. Dr. Wiley states,[4] "The idea that sugar exists in the cane in a crystalline form is contrary to all rules of chemical physics and accurate observation."

A process of extracting the sugar from sugar-producing plants is based upon taking advantage of the natural condition of things as they exist in the plants, and the application of the theory of osmose.

This process, known as *diffusion*, is the "spontaneous mixing

[1] *Bul. No.* 3, p. 78, by H. W. Wiley.

[2] From a Report of Consul-General Van Buren.

[3] *The Beet Sugar Industry in California*, by E. W. Hilgard, Dec. 1886.

[4] *Bul. No.* 2, *Chem. Div. Dept. of Agr.*, p. 5.

of two liquids of different nature, density, or temperature, independent of chemical action upon one another."[1] More exactly it is a molecular force.[2]

Practically, diffusion is the means by which all solid contents are extracted from the cells. The water used for the diffusion enters the cells of the cane and leaves it charged with soluble solids. The end of the operation obtains when the fluid within these cells is of the same density as the surrounding medium.

The advantages of diffusion over the older methods of milling, to extract the juice of sugar-producing plants, will be seen from the statement that 95 per cent. of the sugar present can be secured by the new method,[3] whilst the old processes gave only 50.

The method of diffusion is used in the beet-sugar factories of Europe with marked success. The late experiments at Fort Scott, applying this process to sorghum cane, resulted in a marked success for extracting the juice. From the diffusion experiments with sugar-cane, it was found that the yield of sugar was the highest ever obtained from sugar-cane.[4] By this same process a larger percentage of sugar was yielded than that from the richer tropical cane with the old methods.

The marked cellular character of the sorghum adapts it to the process of diffusion more readily than is the case with the sugar beet.

It may be of interest briefly to describe the process of diffusion, and the subsequent methods of defecation and carbonatation employed in these experiments.[5]

The cane is cut and transported from the field to the factory, where, by means of carriers, it is conveyed to the cutters.

In the case of sorghum, it should be cleaned of its blades

[1] *Manuel Pratique de Diffusion*, par Fleury et Lemaine.

[2] Dubrunfault.

[3] *Bul. No.* 8, *Chem. Div. Dept. of Agr.*, p. 15. From *Bul. No.* 2, *Chem. Soc. of Washington*, p. 29, by H. W. Wiley.

[4] *Bul. No.* 14, p. 51.

[5] The machinery used in the manufacture of sugar from the beet-root and sorghum was shown by lantern projections.

and sheath before being submitted to the cutting machine. The cane leaves the cutters in small chips ready to fill the diffusion battery, which is composed of vessels technically called cells, of various sizes; those at Fort Scott[1] held 1900 pounds of chips, and had a capacity of 75 cubic feet each.

These cells may be disposed in a row or in a circular arrangement as is usual in the beet-sugar factories abroad. The cells are connected by means of pipes for the passage of water from tanks to the cells of the battery, and for the flow of water from cell to cell. Calorisators for heating are connected with the cells, and an apparatus for compressed air to drive the water from the chips when the process is over. The best temperature for sorghum diffusion is about 70° Centigrade,[2] and for sugar-cane 90° Centigrade.[3]

The cells are filled with the chips from above by an opening in the top, and when the diffusion is over they are removed by opening a discharge gate of the diameter of the cell at its bottom. This door is held firmly in place, during the extraction, by an hydraulic joint of circular rubber tubing, the pressure within the tube being greater than within the cell.

The flow of water through the cell is controlled by pressure, and passes from the cell first filled to the last one of the battery. The water enters the first cell by means of a valve from below, and is turned off, when it overflows, from an air valve above. The pipes are reversed, and fresh water driven in from above cell 1, to displace its contents of saccharine liquid, which then flows below into cell 2, as the fresh water originally passed into cell 1 from the bottom upwards. This process is continual, making a complete system of displacement, the water as it passes from cell to cell becoming more dense. Whilst the last cell is filling, cell 1 is emptied of the chips and refilled with a fresh charge.

Thus it will be seen that in a battery of 14 cells all in operation, 12 cells would be under pressure and one filling and the other emptying.

[1] *Bul. No.* 14, *Chem. Div. Dept. of Agr.*, by H. W. Wiley, p. 9.

[2] *Ibid.*, p. 40.

[3] *Ibid.*, p. 45.

The fluid from the diffusion cell is placed in tanks for defecation with lime, which is added in the amount of 1.5 per cent. for sorghum;[1] though .75 per cent. has been found ample in the case of juice from the sugar-cane.[2]

Much of the albuminoid and non-sugar organic substances are carried down, and the sugar forms a soluble lime sucrate. Carbonic acid is then pumped in, and the lime is precipitated, and with it further impurities. This process of single carbonatation was found to work better with sorghum juice than double carbonatation.[3]

The contents of the tanks are then carried to filter presses, and the clear juice recovered from the lime cake. This juice is partially evaporated, and then whilst hot put through bone-black filters. The final evaporation of juice is conducted in vacuum pans and its crystallization ends the process.

Among the difficulties to be overcome in this process is the acidity of the chips in the diffusion cells. This will cause a loss from inversion of the sucrose and a greatly diminished yield of crystallizable sugar. The high temperature needed for the diffusion will aid in bringing about a like result when the canes are not in proper condition.[4]

Various means were tried to prevent this inversion. It is probable that fine carbonate of lime, if sprinkled over the chips before they enter the battery, may obviate the difficulty.[5]

The addition of lime to the water tanks which supply the diffusion cells was not favorable for the full extraction of the sugar. Analysis showed 2 per cent. less of sugar in this juice. The loss was probably induced by the coagulation of the albumin of the cane cells.[6]

The addition of milk of lime and sulphurous acid [7] to the juice has a preservative effect, and juice so treated may be kept unchanged for months.

Among the reasons advanced for the process of carbonatation may be mentioned that it does away with skimming the juices.

[1] *Bul. No.* 14, *Chem. Div. Dept. of Agr.*, p. 54. [2] *Ibid.*, p. 54.
[3] *Ibid.*, p. 25. [4] *Ibid.*, p. 28. [5] *Ibid.*, p. 32.
[6] *Ibid.*, p. 20. [7] *Bul. No.* 3, pp. 96, 97.

From analysis of the scum the quantity of the sugar in it was found to be equal to that of the juice.[1] Thus a source of waste is prevented.

The maximum yield of sugar can be obtained from carbonization, but it is fatal to the manufacture of molasses, as it darkens too much the juice. But Dr. Wiley has suggested a modification of the process, which, he believes, will prevent this difficulty.[2]

From the last "Chemical Bulletin of the Agricultural Department,"[3] published since the Fort Scott experiments, the chemist in charge, in a general review of the work, points to the "absolute failure of the experiments to demonstrate the commercial practicability of manufacturing sorghum sugar." Among the causes of this failure he mentions: —

"1. Defective machinery for cutting the cane and for elevating and cleaning the chips and for removing exhausted chips.

"2. The deterioration of the cane, due to much of it becoming over ripe, but chiefly to the fact that time would generally elapse after the canes were cut before they reached the diffusion batteries.

"3. The deteriorated cane caused a considerable inversion of the sucrose in the battery — an inversion which was increased by the delay in furnishing chips, owing to the defects of machinery."

The chemist in charge of these experiments states that he should be glad to "leave this industry in a more promising condition. All admit that the process of diffusion has been successfully worked out." And to this opinion Dr. Wiley subscribed, "with the reservation that a proper mechanical method for distributing over the chips a substance to prevent inversion of the sucrose has not yet been discovered."

There is a difference of opinion as to the best method of treating the diffusion juices. Some method of purification by carbonatation or other means, may easily be decided on. But

[1] *Bul. No.* 5, *Chem. Div. Dept. of Agr.*, p. 57.

[2] *Bul. No.* 14, *Chem. Div. Dept. of Agr.*, p. 40.

[3] *Ibid.*

it was shown at Rio Grande that the juice from clean cane can be worked without purification.

"Last of all, the chief thing to be accomplished is the production of a sorghum plant containing a reasonably constant percentage of crystallizable sugar."[1]

The above statement appears to be where the sorghum industry rests for a solution of the problem.

"The universal experience of practical manufacturers shows that the average constitution of the sorghum cane is far inferior to that indicated in many of the tables of analyses."[2]

"Taking the means of several seasons as a sure basis of computation, it can now be said that the juices of the sorghum as they come from the mill do not contain over 10 per cent. of sucrose; whilst the percentage of other solids in solution is at least 4. It is needless to say to a practical sugar-maker that the working of such a juice is one of extreme difficulty, and the output of sugar is necessarily small.[3]

"It is true the present outlook is discouraging; but discouragement is not defeat. The time has now come for solid, energetic work. Science and practice must join improved agriculture, and all together can accomplish what neither alone would ever be able to achieve."[4]

The beet-sugar factory at Alvarado makes money with a competition of free cane sugar imported from the Hawaiian Islands under the one-sided reciprocity treaty now in force.

As this is so, there seems to be no reason why sorghum should not compete with other sugars when its physiology and chemistry have become better known.

Compelled now to accept the fact that there is no sound scientific expectation for the immediate success financially of the production of sugar from sorghum, we are only the more compelled to mark the present difficulties, and point out, as I have done, the lines of research that will finally enable the problem of an indigenous sugar supply to be safely solved.

[1] *Bul. No.* 14, *Chem. Div. Dept. of Agr.*,, p. 42.
[2] *Bul. No.* 5, *Chem. Div. Dept. of Agr.*, 1885.
[3] *Ibid.*, p. 185.
[4] *Ibid.*, p. 187.

Years of struggle preceded the final success of the best sugar production, made possible only by the persevering investigations of chemists supported by the determination of the French Government to prevent the admission of foreign sugars. The full profitable employment of the beet-sugar factories of Europe and the financial success of the one enterprise in California, all warrant the hope of our establishing an indigenous sugar industry from sorghum as well. By means of scientific discovery carried on if requisite at experimental stations supported by Government aid, or if undertaken commercially by private enterprises aided by full protection or an adequate system of bounties, the final result will be reached, and we shall save the millions now sent abroad for sugar, and establish our independence in this particular of the rest of the world.

It is not meant that the sorghum growers should profit at the expense of other sugar growers. It has been indicated that our great country can grow several kinds of sugar crops. Each is to contribute its share. "There should be no enmity between the grower of sorghum, the sugar beet, and the sugar-cane, but all should work in harmony for the general good."[1]

It will be observed that I have not attempted to give a history of the sorghum enterprise, nor to dwell upon the evolution of the mechanical or chemical methods which have cost so much time and money with so little success. The very latest series of experiments of diffusion and its chemistry as conducted under the direction of the chemist of the Agricultural Bureau himself, at Fort Scott, is placed at your service, and the failure to solve the sugar problem but increases the duties of students of plant chemistry, whose researches and faithful studies will alone make it possible to surmount many of these difficulties, we trust in the near future.

[1] *Bul. No.* 5, p. 187.

THE CHEMICAL BASIS OF PLANT FORMS [1]

THE boundary between the mineral and vegetable kingdom is not a definite line. The individual of the one encroaches upon the dominion of the other. The terms "non-living" and "living matter" are only relatively accurate. "Nature in all its manifestations constitutes a unity," . . . and "all matter is in a sense living." [2]

Through chemical evolution a condition of matter obtains favorable for functional activity or life. This state may be described [3] "as a colloidal albuminoid united with more or less water." Its simplest expression is found in the low forms of plants, slime-mould for example. This colloidal basis of life is protoplasm, a chemical compound of complex constitution, very unstable, and manifesting when alive certain properties called vital, or "biotic." [4]

Active chemical changes are inseparably associated with both living and dead protoplasm. Synthetical or progressive processes prevail in life, analytical or retrogressive in death.

Absorption, metabolism, excretion, reproduction, contractility, automatism, and irritability are the properties of living matter; disorganization and dissociation those of dead matter.

Chemists have to discover the subtle differences between the chemical equation of living and dead protoplasm.

I wish to speak of some of the chemical compounds of plants, or more properly the chemical forms, since the structure of all plants is built up of chemical constituents. This subject is as extensive as the genera and species of the vegetable kingdom.

Last August, I read a paper on "Certain Chemical Con-

[1] A lecture delivered before the Franklin Institute, January 24, 1887. Printed in the *Journal* of the Franklin Institute, September, 1887; also reprinted in pamphlet form, Philadelphia, 1887.

[2] *Mineral Physiology and Physiography*, by T. Sterry Hunt. Boston, 1886, p. 18. [3] *Ibid.* [4] Dr. T. Sterry Hunt.

stituents of Plants considered in Relation to their Morphology and Evolution."[1] The facts cited tended to show a chemical progression in plants, and a mutual dependence between chemical constituents and change of form.

Among the conclusions reached were the following: —

1. A similarity of one or more chemical constituents is to be found in all plants which are equally developed, and on the same evolutionary plane.

2. The evolution of chemical constituents follows parallel lines with the evolutionary course of plant forms, the one being intimately connected with the other, and consequently chemical constituents are indicative of the height of the scale of progression, and are essentially appropriate for a basis of botanical classification; in other words, the theory of evolution in plant life is best illustrated by the chemical constituents of vegetable forms.

Chemistry will aid us to comprehend the laws of evolution controlling plant forms. Evolution should also apply to chemical compounds as well as to morphology, since the latter can be shown to depend upon chemistry in general.

We have no certain knowledge of the precise chemical changes which take place in transforming carbon, hydrogen, oxygen, nitrogen, sulphur and other elements into the starches and proteids. We know, however, certainly the necessary conditions for many of these changes. The law controlling the absolute relation, or the connective link, between the form of a plant and its chemical composition is undetermined. But investigations in plant chemistry have not been conducted with this end in view. The facts which I have to offer, to sustain the theory of a possible relation between plant forms and chemical compounds, may seem to some inadequate, but no other explanation than the one offered to account for these statements has been suggested.

The chemical composition of the cell-contents and wall has been determined in many plants; also of their roots, leaves, flowers, and fruits.

[1] Chem. Section A. A. A. Science, Buffalo, 1886. Abstract, *Botanical Gazette*, xi, No. 10, October, 1886. See p. 168.

Most of the ash-constituents essential or injurious to the growth and development of plants are known, and also the variations in growth caused by the presence or absence of certain inorganic compounds.

The chemical changes through which many plants pass from the germination of their seed to maturity and decay are also known, each separate stage of growth showing a distinct chemical composition or a predominance of some one chemical compound.

It should be especially noted that some chemical compounds occur in certain species of plants and do not occur in others. Certain classes of compounds are found widely distributed through the plant kingdom, accompanied by correlated morphological characters. Some one compound, as saponin, will be found with similar botanical characters in plants of distinct genera and families, on the same plane of evolution or development.

It cannot be the result of accident that cinchona and related plants contain quinine; and other plants, distributed through the vegetable kingdom, their own typical compounds. Nor can it be the result of accident, or changes produced by climate or other causes, that an absence of some one or more compounds is accompanied by a modification of the exterior of the plant.

Before taking up the consideration of the above statements in detail, it may be well to study briefly two properties [1] of living protoplasm, namely, absorption and metabolism.

The seeds of plants are the storehouses of a certain amount of latent energy or life, elaborated by the parent plant and stored up in the form of complex chemical compounds. Under suitable conditions of warmth and moisture, certain chemical changes take place within the seed. The latent energy becomes active, and the seedling grows, feeding upon its food supply until it has exhausted its store.

At this stage the little plant must seek its food from without, from the atmosphere and the soil. The soil is of varying and complex composition, containing, between its particles, gases

[1] *Lectures on the Physiology of Plants*, by S. H. Vines. Cambridge, 1886.

and moisture. The air which surrounds the leaves of land plants is a mixture of nitrogen and oxygen with small quantities of carbon-dioxide, ammonia, varying quantities of aqueous vapor, and occasionally traces of nitric acid.

The elements from these media are absorbed by different parts of the plant, and there is a difference in the manner of absorption by fungi, parasites, air plants, and green plants. However, the elements which are absolutely essential for the nutrition and maintenance of the life of all plants are carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, potassium, calcium, magnesium, iron, in the case of green plants, and, in certain cases, chlorine.

It is characteristic of plants that they must absorb their food in the fluid form. The absorbent organs of plants are the roots, for water and salts in solution, and the leaves, for gases. In the lower plants, where there are no roots or leaves, water or substances in solution and gases are absorbed either directly by the cells of the thallus, or by root hairs. Among the higher plants, the root hairs and the uncuticularized epidermal cells of the younger roots are active in absorbing material from the soil. Any part of the plant, if immersed in water, will absorb a smaller or a larger quantity of it; as, for instance, cut flowers placed with their cut ends in water will absorb, for a time, sufficient to prevent withering. The absorption of gases in higher plants is by means of the leaves, for it has been found that carbon-dioxide is absorbed from the air by those organs which are green and contain chlorophyll; and in experiments where the carbon-dioxide of the air was cut off from the leaves, though it was supplied to the roots, it was found that the plant could not live long. It has also been found that the presence of carbon-dioxide in another part of the plant does not contribute to the formation of starch in the leaves.

Green plants obtain their carbon from the carbon-dioxide of the air. Plants which do not contain chlorophyll obtain their carbon by the absorption of complex organic substances. Green plants can absorb complex carbon compounds, and it has been proved by direct experiment that they can take up these complex substances when supplied to their roots.

Darwin[1] has shown that the insectivorous plants, by means of their modified leaves, absorb complex compounds, and that these are of importance in their nutrition. Flies and other small insects may often be found clasped in the tentacles of the *Drosera*, and in those experiments small pieces of meat, when placed on the leaves, were dissolved after a time by the secretions of the leaf glands and absorbed.

Hydrogen is absorbed by all plants in combination in the form of water or ammonia and its compounds, or in the complex substances mentioned above.

Oxygen is taken up by plants, free or in combination in water or in salts. The free oxygen is especially concerned in destructive metabolic processes. The large quantities of this gas absorbed by plants, and especially by fungi, show conclusively its consumption in metabolic processes.

The process known as the respiration of plants is the absorption of oxygen and the exhalation of carbon-dioxide.

The researches of Garreau[2] show that two distinct processes are in operation when leaves are exposed to the light: in the one oxygen is absorbed and carbon-dioxide is exhaled; in the other, carbon-dioxide is absorbed and oxygen is exhaled. When the leaves are exposed to a very bright sunlight, carbon-dioxide is absorbed and oxygen is exhaled, and the activity of these processes is so much greater than the absorption of oxygen and the exhalation of carbon-dioxide, that it appears as if the former only were in operation.

Gases, like solids, can be assimilated only in solution, and as they are soluble in water, the cell walls of submerged plants may absorb them, and the sap near the surface of land plants will dissolve the gases from the atmosphere. The sap of plants contains, in solution, carbon-dioxide, oxygen, and also a certain amount of free nitrogen. That this nitrogen does not enter into the metabolism of the plant seems completely decided by the experiments[3] of Lawes, Gilbert, and Pugh; but the more recent experiments of Atwater[4] and Hellriegel[5] should be compared

[1] *Insectivorous Plants.*
[2] *Ann. d. Sci. Nat.*, ser. 3, t. xv.
[3] *Phil. Trans.*, 1860.
[4] *Amer. Chem. Jour.*, viii, Nos. 5 and 6.
[5] *Zeit. d. Ver. f. d. Rübenzucker Industrie*, Nov., 1886.

in this connection, and the matter cannot be said to be definitely settled.

I can only enumerate in this connection, without going into the subject, the possible sources[1] of the nitrogen supply: —

1. Organic, nitrogenous matter.
2. The ammonia of the air, and of the ocean.
3. The nitrous and nitric compounds formed by combustion and by electric discharges.
4. Nitrogen fixed in the soil by microbes.
5. The free nitrogen of the atmosphere.
6. Mineral nitrates.

The sap which is continually flowing through living plants is a watery fluid, holding in solution mineral matters, gases, and organic substances. The root hairs of plants penetrate the particles of soil and absorb the moisture from a film which surrounds each particle: this is known as hygroscopic water. In thallophytes, the absorption is effected by the cells of the thallus, and in epiphytes a membrane invests the air roots especially adapted for the purpose. The distribution of water takes place — at least to some extent — by the same process as its absorption. It passes by osmosis from cell to cell, as it passes originally from without into the superficial cells of the plant. The direction of this movement is not necessarily constant. The proportion of water in each cell varies and the tendency to establish a fluid equilibrium will cause a current towards those tissues which are deficient. These statements apply equally to gases and other substances held in solution, which are needed for the continuance of the chemical and physical changes going on in the living cells of different parts of the plant.

The changes are more active for different substances in different parts of the plant. The mineral substances absorbed by the roots pass up to the leaves, where they are concerned in the constructive metabolism going on in those organs. The products of these processes pass from the leaves to parts of the plant which are actively growing, and where plastic material is re-

[1] "The Economical Aspect of Agr. Chemistry." By H. W. Wiley. *Proc. A. A. A. S.*, xxxv, 1886.

quired, or to the seeds or other organs in which organic stores are being laid up.

If the stems or plants are cut in the spring, a flow of sap proceeds from the cut surface of that portion of the stem which is connected with the roots. This fact was investigated by Hales.[1] He concluded that there is "a considerable energy in the root to push up sap in the bleeding season." This force is termed the root pressure, and is the measure of the absorbent activity of the root hairs. The root pressure is not only manifested by causing the flow of sap; it also may cause the exudation of drops of sap on the surface. There is a marked periodicity in the flow of sap, which is not due to the immediate result of variations in external conditions, but is inherent in the absorbent cells themselves.

The current travels from the roots to the leaves through the lignified cell walls of the wood of the plant. The activity of the exhalation of watery vapor from the plant is not the same from its surfaces. The refreshing effect of a shower on withered leaves is due to the moisture penetrating the soil and being absorbed by the root hairs. From experiments [2] it has been shown that if the air is very moist, and the leaves dry, the leaf surfaces may absorb a little water.

The cuticle offers a certain amount of resistance to the passage through it of vapor; this is due to resinous or waxy substances contained in it. The Mexican ocotilla [3] offers a striking example. It grows in very dry and exposed parts of the country, where rainfalls are infrequent. The bark is chiefly composed of wax and resinous substances.

Other substances, as well as water, can be absorbed by leaves,[4] experiments having shown that if a drop of calcium sulphate solution be placed on a leaf, it will have disappeared in the course of a few hours. This is more rapid when placed on the under surface. Though it seems that leaves may absorb water and substances in solution under certain circumstances,

[1] *Statical Essays*, 1, 1769 (4th edition).

[2] Detmer and Boussingault.

[3] H. C. De S. Abbott, *Proc. A. A. A. S.*, xxxiii. See p. 117.

[4] Boussingault, *Ann. Chem. et Phys.*, sér. V, xiii; also *Agronomie*, VI, 1878. Mayer, *Landwirthschaftl. Versuchs-Stat.*, xvii, 1874.

the especial absorptive function of leaves is the absorption of gases, as has been already explained.

The subject of the ash-constituents of plants is a very important one in this connection. The essential mineral constituents of plants have already been mentioned; silicon, fluorine, manganese, sodium, lithium, rubidium, cæsium, barium, aluminium, zinc, copper, titanium, iodine, and bromine have also been found among the ash ingredients of certain plants.

The method of absorption of soluble mineral salts has already been described. A solution of insoluble salts is brought about in a different way. A soil rich in organic matter is always charged with carbon-dioxide, and this gas is also given off by the roots of living plants. Water containing this gas is able to dissolve calcium carbonate and some silicates that are insoluble in pure water. The presence of certain soluble salts in the soil brings about a decomposition and renders the insoluble salts more readily soluble. Finally, the insoluble salts are brought into solution by means of the acid sap which saturates the cell wall of the root hair. This acid is not carbonic acid, for its reddening of litmus paper is permanent.

It has been shown by experiment that the chemical elements are not universally absorbed by roots in their combinations in the soil.

The wide differences in the composition of the ashes of plants show that each plant is endowed with a specific absorbent capacity. It is upon this fact that the "rotation of crops" in farming depends. A gramineous plant [1] is able to withdraw relatively larger quantities of silica from the soil than a leguminous plant. The latter can only do so to a very slight extent.

The absorbent capacities of nearly allied species are very different; again, individuals of the same species yield different ash compositions, depending upon their vigor; and the absorbent capacity of the plant varies at different periods of its life. It has been stated that "similar kinds of plants, and especially the same parts of similar plants, exhibit a close general agreement in the composition of their ashes, while plants which are unlike in their botanical characters are also unlike in the proportions

[1] Wolff, *Aschenanalysen*, 1871.

of their fixed ingredients."[1] If an ash-constituent can pass through a cell wall, its absorption will take place independently of its use or harmfulness to the plant, but the absorption of essential inorganic constituents will depend upon its relation to the metabolism of the plant.

The ash-constituents of a plant increase from the roots upwards to the leaves, a fact showing that the leaves are the organs in which more especially active chemical changes take place.

The ash ingredients are usually present in each plant cell; in the cell wall, imbedded in the cellulose, and partly in the contents of the cell. The salts of the alkaline metals and of the sulphates and the chlorides of magnesium and calcium occur in the solution of the sap. Silica and phosphates of calcium and magnesium are mostly insoluble and exist in the tissues of the plant.

Water-culture experiments[2] have shown the essential ash-ingredients. Potassium, like phosphorus, is always found in relation with living protoplasm. If[3] the plant was not supplied with potassium, it grew very little, and very little starch was formed in the chlorophyll corpuscles of the leaves. On the addition of potassium chloride, the starch grains became more numerous in the leaves, and made their appearance in other parts of the plants. Potassium, doubtless, plays an important rôle in the formation and the storing up of carbohydrates, for the organs in which these processes are active, as the leaves, seeds, and tubers, are found to be the richest in this element.

It has been observed that cæsium[4] and rubidium can replace potassium in the food of certain fungi (mould, yeast, and bacteria).

Salm-Horstmar describes[5] some experiments, from which he infers that minute traces of lithium and fluorine are indispensable to the fruiting of barley. The same investigator has concluded that a trace of titanic acid is a necessary ingredient of plants.

[1] *How Crops Grow*, by S. W. Johnson, London, p. 145.

[2] Nobbe, Siegert, Wolff, Stohmann, Sachs, and others.

[3] Nobbe, *Die organische Leistung des Kaliums*, 1871.

[4] Naegeli, *Sitzber. d. Akad. d. Wiss. zu München*, 1880.

[5] *Jour. für Prakt. Chem.*, 1884, p. 140.

Zinc[1] is also a frequent constituent of plants growing about zinc mines. Certain marked varieties of plants are peculiar to, and appear to have been developed by such soils, as the violet, *var. calaminaris*, and penny-cress. In the leaves of the latter plants, thirteen per cent. of zinc oxide was found; in other plants from .3 per cent. to 3.3 per cent.

From the investigations of Baumann,[2] insoluble zinc salts in the soil are harmless to plants. All plants excepting the Coniferæ speedily die in a solution containing 10 mg. zinc to the litre, though traces of zinc in solution are harmless.

The specific action of zinc on the vegetable organism consists in a destruction of the chlorophyl coloring-matter and a consequent stoppage of the whole process of assimilation.

Experiments[3] on maize, oats, buckwheat show that arsenic attacks the protoplasm of the cell and destroys the power of osmose by the roots.

Sulphates occur in the cell sap of organs where chemical changes are rapidly taking place, and are doubtless formed in connection with the decomposition of proteids. Phosphorus occurs in actively growing cells in the most various plants. It has been found present in the green coloring-matter of the leaves and is always found in relation with living protoplasm. Schumacher[4] holds that the chief work of the alkaline phosphates is the acceleration of the diffusion of these difficultly diffusible albuminoids.

Calcium is especially abundant in the leaves of green trees, and it cannot be replaced in the food of green leaves by any other metal. It can be replaced by strontium,[5] barium, or magnesium in the food of certain fungi. Magnesium[6] resembles lime in many points, but is present in larger quantity in the stem and grain, and not in the leaves of the maize plant.

[1] A. Braun and Risse (Sachs, *Exp. Physiologie*, 153).

[2] *Landw. Versuchs-Stat.*, xxxi, 1–53 (*Jour. Chem. Soc.*, 1884, p. 1408).

[3] F. Nobbe and others. *Landw. Versuchs-Stat.*, xxx, 381–422 (*Jour. Chem. Soc.*, 1884, p. 1409).

[4] *Physik der Pflanze*, p. 128.

[5] Naegeli.

[6] R. Hornberger and E. V. Raumer, *Bied. Centr. Bl.*, 1882, 837–844 (*Jour. Chem. Soc.*, 1883, p. 491).

Iron is found to be essential to green plants only. If a seedling be cultivated by water culture in a fluid containing no iron, the leaves will become pale until at length they are nearly white, but on the addition of a small quantity of iron to the solution, or if the white leaves are painted with a dilute iron solution, they will very shortly become green. It plays an important part in the formation of the green coloring-matter, though it does not enter into its chemical composition.

"Buckwheat,[1] barley, and oats do not flourish when grown in solutions containing no chlorides, and as in these plants the chlorophyll corpuscles become overfilled with starch grains, it was thought that this element was of importance in connection with the translocation of carbohydrates."

Sodium [2] has been used in water culture to replace potassium, but the plants deprived of potash did not develop.

Manganese is abundant in the ash of *Trapa natans*. I also found it in the different portions of *Yucca angustifolia*.[3]

Iodine and bromine are found in marine *Algæ* and in minute quantity in some plants grown far from the sea.

Silica is found in the form of soluble or insoluble silicic acid. It occurs principally in the cell wall, but it has been found in the cell sap of a plant (*Equisetum hiemale* [4]), and certain cells in the pseudo-bulbs of epiphytic orchids [5] contain each a plate of silica.

Experiments have shown that the absorption of silicic [6] acid greatly assists the assimilation of other plant foods, and that plants to which it is supplied show a decidedly more healthy development of grain and straw than others not so treated. Silica is doubtless of mechanical use, giving firmness and rigidity to plant tissues; though the real cause of "laying" of crops

[1] Vines, Cambridge edition, p. 136. Also, Beyer, *Landw. Versuchs-Stat.*, xi. Leydhecker, *ibid.*, viii.

[2] Salm-Horstmar, Knop and Schreber.

[3] "Yucca Angustifolia," Helen C. De S. Abbott, *Trans. Am. Philos. Soc.*, Dec. 18, 1885, also *ante*, p. 126.

[4] Lange, *Ber. d. Deutsch. Chem. Ges.*, xi.

[5] Pfitzer, *Flora*, 1877.

[6] C. Kreuzhage and E. Wolff, *Landw. Versuchs-Stat.*, xxx, 161–198 (*Jour. Chem. Soc.*, 1884, p. 1112).

has been found to be due to the imperfect development of the tissue and not to an insufficient supply of silica.

The percentage of ash-constituents in plants varies, but the quantity is sufficient to be a very important factor in the consideration of chemical forms of plants.

I have already said that the albuminous cell contents, called protoplasm, are always present in the living cells of plants. The introduction into the cell of the gases, water, and inorganic substances goes to the direct formation of this colloidal body, or assists in it.

It has been stated that the soil, water, and atmosphere supply the food of all plants. It would be of interest to dwell upon the processes of assimilation and the chemical changes that go on within the living plant, if our time would allow. It may be mentioned that nowhere in any department of chemistry have our former views been more modified than in the physiological chemistry of the vegetable cell during the last three years.

For example, I may say that, at least in some plants, nascent starch passes in a soluble form from cell to cell by osmosis without conversion into sugar, as was formerly held.

Sugar in some plants may be regarded as a waste product, resulting from the breaking down of more complex substances, of no further service in the development of the plant.

Sorghum [1] cane, at the time of the maturing of the seed and the full growth of the plant, contains the largest percentage of sugar, and this sugar appears to be really a waste product.

The classification *of Plastic and Waste Products*, in Vines's late *Physiology*,[2] cannot be accepted as final, since many changes in plant chemistry have resulted since 1882 — the date of his chemical bibliography.

It may be generally said that the proteids or albuminoid substances are formed in the cell from a simple carbohydrate and some nitrogenous body, probably an amide.

The inorganic acids supply sulphur and other substances necessary to enter into combination with the proteid, or act mechanically by removing waste material.

[1] H. W. Wiley, *Botanical Gazette*, 1887.

[2] Cambridge edition, 1886.

The function of chlorophyll may be briefly stated: [1] It absorbs certain rays of light, and thus enables the protoplasm of the cell to avail itself of the radiant energy of the sun's rays for the construction of organic substances from carbon-dioxide and water.

Plants which are grown in the dark, or at low temperature, are usually of a yellow color. Such plants are said to be etiolated. There is reason to think that this yellow substance, etiolin, is an intermediate substance in the formation of chlorophyll, for if it is exposed to light it is converted into a green color; these complex coloring-matters are probably derivatives of protoplasm.

The autumnal change of leaves is owing to a third coloring-matter, called xanthophyll; in many cases, the leaves also contain a red coloring-matter, erythrophyll.

The importance of chlorophyll in the plant will be admitted when it is said that the absorption of carbon-dioxide, the evolution of oxygen, and the formation of many organic substances are effected solely by chlorophyll corpuscles.

The organic acids occur in plants free and also in combination with bases. It is to the presence of these bodies that the acid reaction of plant tissues is due. Some organic acids are assimilated by plants; the turgidity of cells is to be ascribed to their presence, and the acid sap in root hairs renders possible the solution and absorption of mineral substances insoluble in water.

The primary function of the resins [2] of Coniferæ and analogous juices of other plants is to render service in cases of injury, and, by covering the wound with a protecting coating, to favor its healing.

During my studies on the *Yucca*,[3] resins and saponin were separated from each part of the plant. Experiments were made to determine the emulsive power of saponin on resins. It was found that aqueous solutions of saponin were able to emulsify

[1] Cambridge edition, p. 157.

[2] H. De Vries, *Chem. Centr. Bl.*, III, xiii, 565 (*Jour. Chem. Soc.*, 1883, p. 365).

[3] *Trans. Am. Phil. Soc.*, Dec. 1885. See *ante*, p. 126.

many classes of resins, and in my paper it was pointed out that saponin may serve mechanical purposes in the plant as well as those of nutrition.

The succession of plants from the lower to the higher forms will be reviewed superficially, and chemical compounds noted where they appear.

When the germinating spores of the fungi, *Myxomycetes*, rupture their walls and become masses of naked protoplasm, they are known as plasmodia. The plasmodium *Æthalium septicum* occurs in moist places, on heaps of tan or decaying barks. It is a soft, gelatinous mass of yellowish color, sometimes measuring several inches in length.

The plasmodium [1] has been chemically analyzed, though not in a state of absolute purity. The table of Reinke and Rodewold gives an idea of its proximate constitution.

Many of the constituents given are always present in the living cells of higher plants. It cannnot be too emphatically stated that where "biotic" force is manifested, these colloidal or albuminous compounds are found.

The simplest form of plant life is an undifferentiated individual, all of its functions being performed indifferently by all parts of its protoplasm.

The chemical basis of plasmodium is almost entirely composed of complex albuminous substances, and correlated with this structureless body are other compounds derived from them. Aside from the chemical substances which are always present in living matter, and are essential properties of protoplasm, we find no other compounds. In the higher organisms, where these functions are not performed indifferently, specialization of tissues is accompanied by many other kinds of bodies.

The algæ are a stage higher in the evolutionary scale than the undifferentiated non-cellular plasmodium. The simple *Alga protococcus* [2] may be regarded as a simple cell. All higher plants are masses of cells, varying in form, function, and chemical composition.

[1] *Studien über das Protoplasm*, 1881.

[2] Vines, p. 1. Rostafinski, *Mem. de la Soc. des Sc. Nat. de Cherbourg*, 1875. Strasburger, *Zeitschr.*, XII, 1878.

A typical living cell may be described as composed of a cell wall and contents. The cell wall is a firm, elastic membrane, closed on all sides, and consists mainly of cellulose, water, and inorganic constituents. The contents consist of a semi-fluid colloidal substance, lying in contact with the inner surface of the membrane, and like it, closed on all sides. This always is composed of albuminous substances. In the higher plants, at least, a nucleus occurs embedded in it. A watery liquid holding salts and saccharine substances in solution, fills the space called the vacuole enclosed by the protoplasm.

These simple plants may be seen as actively moving cells or as non-motile cells. The former consist of a minute mass of protoplasm, granular and mostly colored green, but clear and colorless at the more pointed end, and where it is prolonged into two delicate filaments called cilia. After moving actively for a time they come to rest, acquire a spherical form, and invest themselves with a firm membrane of cellulose. This firm, outer membrane of the *Protococcus* accompanies a higher differentiation of tissue and localization of function than is found in the plasmodium.

Hœatococcus and plasmodium come under the classes Algæ and Fungi of the Thallophyta group. The division [1] of this group into two classes is based upon the presence of chlorophyll in Algæ and its absence in Fungi. Gelatinous starch is found in the Algæ; the Fungi contain a starchy substance called glycogen, which also occurs in the liver and muscles of animals. Structureless bodies, as *æthalium*, contain no true sugar. Stratified starch [2] first appears in the Phanerogams. Alkaloids have been found in Fungi, and owe their presence doubtless to the richness of these plants in nitrogenous bodies.

In addition to the green coloring-matter in Algæ are found other coloring-matters.[3] The nature [4] of these coloring-mat-

[1] *Botany*, Prantl and Vines, London, 1886, p. 110.

[2] For the literature of starch, see p. 115, *Die Pflanzenstoffe*, von Hilger and Husemann.

[3] *Kützing*, *Arch. Pharm.* xli, 38. Kraus and Millardet, *Bul. Soc. Sciences Nat.*, Strasbourg, 1868, 22. Sorby, *Jour. Lin. Soc.* xv, 34. J. Reinke, *Jahrb. Wissenscht. Botan.*, x, B. 399. Phipson, *Phar. Jour. Trans.*, clxii, 479.

[4] Prantl and Vines, p. 111.

ters is usually the same through whole families, which also resemble one another in their modes of reproduction.

In form, the Algæ differ greatly from filaments or masses of cells; they live in the water and cover damp surfaces of rocks and wood. In these they are remarkable for their ramifications and colors and grow to a gigantic size.

The physiological functions of Algæ and Fungi depend upon their chemical differences.

These facts have been offered, simple though they are, as striking examples of chemical and structural opposition.

The Fungi include very simple organisms, as well as others of tolerably high development, of most varied form, from the simple bacillus and yeast to the truffle, lichens, and mushrooms.

The cell membrane of this class contains no pure cellulose, but a modification called fungus cellulose. The membrane also contains an amyloid substance, amylomycin.[1] Many of the chemical constituents found in the entire class are given in *Die Pflanzenstoffe*.[2]

Under the *Schizomycetes*, to which the *Micrococcus* and *Bacterium*[3] belong, are found minute organisms differing much in form and in the coloring[4] matters they produce, as that causing the red color of mouldy bread.

The class of lichens[5] contains a number of different coloring substances, whose chemical composition has been examined. These substances are found separately in individuals differing in form. In the *Polyporus*[6] an acid has been found peculiar to it, as in many plants special compounds are found. In the Agaricaceæ the different kinds of vellum distinguish between species, and the color of the conidia is also of differential

[1] L. Crie, *Compt. Rend.*, lxxxviii, 759, 985. J. de Seynes, 820, 1043.

[2] Page 279.

[3] M. Nencki and F. Schaffer. N. Sieher, *Jour. Pract. Chem.*, xxiii, 412.

[4] E. Klein, *Quar. Jour. Micros. Science*, 1875, 381. O. Helm, *Arch. Pharm.*, 1875, 19–24. G. Gugini, *Gaz. Chem.*, 7, 4. W. Thörner, *Bul. Ber.*, xi, 533.

[5] *Handbook of Dyeing*, by W. Crookes, London, 1874, p. 367. Schunck, *Ann. Chem. Pharm.*, xli, 157; liv, 261; lxi, 72; lxi, 64; lxi, 78. Rochelder and Heldt, *ibid.*, xlviii, 2; xlviii, 9. Stenhouse, *ibid.*, lxviii, 57; lxviii, 72; lxviii, 97, 104; cxxv, 353. See also researches of Strecker, O. Hesse, Reymann, Liebermann, Lamparter, Knop and Schnedermann.

[6] Stahlschmidt.

importance. In all cases of distinct characteristic habits of reproduction and form, one or more different chemical compounds is found.

In the next group of the Musiceæ, or mosses, is an absence of some chemical compounds that were characteristic of the classes just described. Many of the albuminous substances are present. Starch [1] is found, often in large quantities, and also oily fats, which are contained in the oil bodies of the liverworts; wax,[2] organic acids, including aconitic acid, and tannin, which is found for the first time at this evolutionary stage of the plant kingdom.

The vascular Cryptogams are especially characterized by their mineral composition.[3] The ash is extraordinarily rich in silicic acid and alumina.

Equisetum [4]	silicic acid	60 per cent.
Aspidium..............	" "	13 " "
Asplenium.............	" "	35 " "
Osmunda..............	" "	53 " "
Lycopodium [5]	" "	14 " "
"	alumina	26 to 27 " "
"	manganese	2 to 2.5 " "

These various plants contain acids and compounds peculiar to themselves.

As we ascend in the plant scale, we reach the Phanerogams. These plants are characterized by the production of true seeds, and many chemical compounds not found in lower plants.

It will be convenient, in speaking of these higher groups, to follow M. Heckel's [6] scheme of plant evolution. All these plants are grouped upder three main divisions: apetalous, monocotyledonous, and dicotyledonous, and these main divisions are further subdivided.

It will be observed that these three main parallel columns are divided into three general horizontal planes.

[1] E. Treffner, *Inaugur. Diss. Dorpat*, 1880. [2] W. Pfeffer, *Flora*, 1874.

[3] *Die Pflanzenstoffe*, p. 323. W. Lange, *Bul. Ber.*, xi, 822.

[4] *Ann. Chim. Phys.*, xli, 62, 208; *Ann. Chim. Pharm.*, lxxvii, 295.

[5] Flückiger, *Pharmakognosie*. Kamp, *Ann. Chim. Pharm.*, c, 300.

[6] *Revue Scientifique*, March 13, 1886.

On plane 1 are all plants of simplicity of floral elements, or parts; for example, the black walnut with the simple flower contained in a catkin.

On plane 2, plants which have a multiplicity of floral elements, as the many petals and stamens of the rose; and finally, the higher plants, the orchids among the monocotyledons, and the Compositæ among the dicotyledonous plants, come under the third division of condensation of floral elements.

It will be impossible to take up in order for chemical consideration all these groups, and I shall restrict myself to pointing out the occurrence of certain constituents.

I desire now to call attention to chemical groups under the apetalous plants having simplicity of floral elements.

Cassuarina equisetifolia [1] possibly contains tannin, since it is used for curing hides. The bark contains a dye. It is said to resemble *Equisetum* [2] in appearance, and in this latter plant a yellow dye is found.

The *Myrica* [3] contains ethereal oil, wax, resin, balsam, in all parts of the plant. The root contains, in addition, fats, tannin and starch, also myricinic acid.

In the willow and poplar,[4] a crystalline, bitter substance, salicin or populin, is found. This may be considered as the first appearance of a real glucoside, if tannin be excluded from the list.

The oak, walnut, beech, alder, and birch contain tannin in large quantities; in the case of the oak ten to twelve per cent. Oak galls yield as much as seventy per cent.[5]

The numerous genera of pine and fir trees are remarkable for ethereal oil, resin, and camphor.

The plane [6] trees contain caoutchouc and gum; peppers,[7]

[1] *Dictionary of Economic Plants*, by J. Smith, London, 1882, p. 294.

[2] *Ibid.*, p. 160. *Pharmakognosie des Pflanzenreichs*, Wittstein, p. 736. *Ann. Chem. Pharm.*, LXXVII, 295.

[3] Rabenhorst, *Repert. Pharm.*, lx, 214. Moore, *Chem. Centralbl.*, 1862, 779, Dana.

[4] Johansen, *Arch. Pharm.*, III, ix, 210. *Ibid.*, III, ix, 103. Bente, *Berl. Ber.*, viii, 476. Braconnot, *Ann. Chim. Phys.*, II, xliv, 206.

[5] Wittstein, *Pharm. des Pflanzenreichs*, p. 249.

[6] John, *ibid.*, p. 651.

[7] Dulong, Oersted, Lucas, Poutet, *ibid.*, p. 640.

ethereal oils, alkaloids, piperin, white resin, and malic acid. *Datisca cannabina*[1] contains a coloring-matter and another substance peculiar to itself, datiscin, a kind of starch, or allied to the glucosides.

Upon the same evolutionary plane among the monocotyledons, the dates and palms[2] contain in large quantities special starches, and this is in harmony with the principles of the theory. Alkaloids and glucosides have not as yet been discovered in them.

Other monocotyledonous groups with simplicity of floral elements, such as the Typhaceæ, contain large quantities of starch; in the case of *Typha latifolia*,[3] 12.5 per cent., and 1.5 per cent gum. In the pollen of this same plant, 2.08 per cent starch has been found.

Under the dicotyledonous groups there are no plants with simplicity of floral elements.

Returning, now, to apetalous plants of multiplicity and simplification of floral elements, we find that the Urticaceæ[4] contain free formic acid; the hemp[5] contains alkaloids; the hop,[6] ethereal oil and resin; the rhubarb,[7] crysophonic acid; and the begonias,[8] chicarin and lapacho dyes. The highest apetalous plants contain camphors and oils. The highest of the monocotyledons contain a mucilage and oils; and the highest dicotyledons contain oils and special acids.

The trees yielding common camphor and Borneol are from genera of the Lauraceæ family; also sassafras camphor is from the same family. Small quantities of Stereoptenes are widely distributed through the plant kingdom.

The Gramineæ, or grasses, are especially characterized by

[1] Braconnot, *Ann. Chim. Phys.*, II, iii, 277. Stenhouse, *Ann. Chim. Pharm.*, CXCVIII, 166.

[2] *Pflanzenstoffe*, p. 412.

[3] Lecocq, Braconnot, *Pharmacog. Pflan.*, p. 693.

[4] Gorup-Besanez.

[5] Siebold and Brodbury, *Phar. Jour. Trans.*, III, 590, 1881, 326.

[6] Wagner, *Jour. Prakt. Chem.*, lviii, 352. E. Peters, v. Gohren, *Jahresb. Agric.*, viii, 114; ix, 105; v, 58. *Am. Jour. Pharm*, IV, 49.

[7] Dragendorff, *Pharm. Zeitschr. Russ.*, xvii, 65–97.

[8] Boussingault, *Ann. Chim. Phys.* II, xxvii, 315. Erdmann, *Jour. Pract. Chem.* lxxi, 198.

the large quantities of sugar and silica they contain. The ash of the rice hull, for example, contains ninety-eight per cent. silica.

The Ranunculaceæ contain many plants which yield alkaloids, as *Hydrastis canadensis*, *Helleborus*, *Delphinum*, *Aconitum*, and the alkaloid berberin has been obtained from genera of this family.

The alkaloid [1] furnishing families belong, with few exceptions, to the dicotyledons. The Liliaceæ, from which is obtained veratrine, form an exception among the monocotyledons. The alkaloids of the fungus have already been noted.

[2] Among the greater number of plant families, no alkaloids have been found. In the Labiatæ none has been discovered, nor in the Compositæ among the highest plants.

One alkaloid is found in many genera of the Loganiaceæ, in genera of the Berberidaceæ, Ranunculaceæ, Menispermaceæ, Rutaceæ, Papaveraceæ, Anonaceæ.

Waxes are widely distributed in plants. They occur in quantities in some closely related families.

Ethereal oils occur in many families, in the bark, root, wood, leaf, flower and fruit, — particularly in Myrtaceæ, Laurineæ, Cyperaceæ, Cruciferæ, Aurantiaceæ, Labiatæ, and Umbelliferæ.

Resins are found in most of the higher plants. Tropical plants are richer in resins than those of cold climates.

Chemical resemblance between groups, as indicating morphological relations, has been well shown. For example: the similarity [3] of the viscid juices, and a like taste and smell among Cactaceæ and Portulaceæ, indicate a closer relationship between these two orders than botanical classification would perhaps allow. This fact was corroborated by the discovery of irritable stamens in *Portulaca* and *Opuntia*, and other genera of Cactaceæ.

Darwin [4] states that in the Compositæ the ray florets are more poisonous than the disc florets in the ratio of about 3 to 2.

[1] *Die Pflanzenstoffe*, p. 21. [2] *Ibid.*

[3] Meehan, *Proc. Acad. Nat. Sciences.*

[4] "Different Forms of Flowers on Plants of the Same Species," Introduction.

Comparing the Cycadeæ and Palmæ, the former are differently placed by different botanists, but the general resemblance is remarkable, and they both yield sago.

Chemical constituents of plants are found in varying quantities during stated periods of the year. Certain compounds present at one stage of growth are absent at another. Many facts could be brought forward to show the different chemical composition of plants in different stages of growth. The *Thuja occidentalis*,[1] in the juvenescent and adult form, offers an example where morphological and chemical differences go hand in hand. Analyses of this plant under both conditions show a striking difference.

Different parts of plants may contain distinct chemical compounds, and the comparative chemical study of plant orders comprises the analysis of all parts of plants of different species.

For example: four portions of the *Yucca angustifolia* [2] were examined chemically—the bark and wood of the root and the base and blades of the leaves. Fixed oils were separated from each part. These were not identical, — two were fluid at ordinary temperature, and two were solid. Their melting and solidifying points were not the same.

This difference in the physical character and chemical reaction of these fixed oils may be due to the presence of free fatty acid and glycerides in varying proportions in the four parts of the plants. It is of interest to note that, in the subterranean part of the *Yucca*, the oil extracted from the bark is solid at the ordinary temperature; from the wood it was of a less solid consistency; while the yellow base of the leaf contained an oil quite soft, and in the green leaf the oil is almost fluid.

Two new resins were extracted from the yellow and green parts of the leaf. It was proposed to name them *yuccal* and *pyrophœal*. An examination of the contents of each extract showed a different quantitative and qualitative result.

Saponin was found in all parts of the plant.

Many of the above facts have been collected from the in-

[1] Meehan, *Proc. Acad. Nat. Sciences.*

[2] H. C. De S. Abbott, *Trans. Amer. Philos. Soc.*, 1886. See p. 126.

vestigations of others. I have introduced these statements, selected from a mass of material, as evidences in favor of the view stated at the beginning of this paper.[1] My own study has been directed towards the discovery of saponin in those plants where it was presumably to be found. The practical use of this theory in plant analysis will lead the chemist at once to a search for those compounds which morphology shows are probably present.

I have discovered saponin in all parts of the *Yucca angustifolia*, in the *Y. filimentosa*, and *Y. gloriosa*; in several species of Agavæ, and in plants belonging to the Leguminosæ family.

The list[2] of plants in which saponin has been discovered is given in the note. All these plants are contained in the middle plane of Heckel's scheme. No plants containing saponin have been found among apetalous groups. No plants have been found containing saponin among the lower monocotyledons.

The plane of saponin passes from the Liliaceæ and allied groups to the rosales and higher dicotyledons.

Saponin belongs to a class of substances called glucosides. Under the action of dilute acids, it is split up into two substances, glucose and sapogenin. The chemical nature of this substance is not thoroughly understood. The commercial[3] product is probably a mixture of several substances.

This complexity of chemical composition of saponin is admirably adapted for the nutrition of the plant, and it is associated with the corresponding complexity of the morphological elements of the plant's organs. According to M. Perrey,[4] it seems that the power of a plant to direct the distribution of its carbon, hydrogen, and oxygen to form complex glucosides is indicative of its higher functions and developments.

The solvent action of saponin on resins has been already

[1] For further facts confirming this theory, see "Comparative Chemistry of Higher and Lower Plants," by H. C. De S. Abbott, *Amer. Naturalist*, August, 1887. See p. 257.

[2] Different genera and species of the following: Ranunculaceæ, Berberidaceæ, Carophyllaceæ, Polygalaceæ, Bromeliaceæ, Liliaceæ, Smilaceæ, Yuccas, Amaryllideæ, Leguminosæ, Primulaceæ, Rosaceæ, Sapindaceæ, Sapotaceæ.

[3] Kobert, *Chem. Ztg.*

[4] *Compt. Rend.*, xciv, p. 1124.

discussed. Saponin likewise acts as a solvent upon barium [1] sulphate and calcium [2] oxalate, and as a solvent of insoluble or slightly soluble salts would assist the plant in obtaining food otherwise difficult of access.

Saponin is found in endogens and exogens. The line dividing these two groups is not always clearly defined. Statements pointing to this are found in the works of Heckel, Bentham, and others.

Smilax belongs to a transition class, partaking somewhat of the nature of endogen and of exogen. It is worthy of note that this intermediate group of the sarsaparillas should contain saponin.

It is a significant fact that all the groups above named containing saponin belong to Heckel's middle division.

It may be suggested that saponin is thus a constructive element in developing the plant from the multiplicity of floral elements to the cephalization of those organs.

It has been observed that the composite occurs where the materials for growth are supplied in greatest abundance, and the more simple forms arise where sources of nutrition are remote. We may gather from this fact that the simpler organs of plants low in the evolutionary scale contain simpler non-nitrogenous chemical compounds for their nutrition.

The presence of saponin seems essential to the life of the plant where it is found, and it is an indispensable principle in the progression of certain lines of plants, passing from their lower to their higher stages.

Saponin is invariably absent where the floral elements are simple; it is invariably absent where the floral elements are condensed to their greatest extent. Its position is plainly that of a factor in the great middle realm of vegetable life, where the elements of the individual are striving to condense, and thus increase their physiological action and the economy of parts.

It may be suggested as a line of research to study what are the conditions which control the synthesis and gradual forma-

[1] *Bul. de la Soc. Chim.*

[2] "Yucca Angustifolia," *Trans. Am. Philos. Soc.*, December, 1885. See p. 126.

tion of saponin in plants. The simpler compounds of which this complex substance is built up, if located as compounds of lower plants, would indicate the lines of progression from the lower to the saponin groups.

In my paper,[1] read in Buffalo at the last meeting of the American Association for the Advancement of Science, various suggestions were offered why chemical compounds should be used as a means of botanical classification.

The botanical classifications based upon morphology are so frequently unsatisfactory, that efforts in some directions have been made to introduce other methods.[2]

There has been comparatively little study of the chemical principles of plants from a purely botanical view. It promises to become a new field of research.

The Leguminosæ are conspicuous as furnishing us with important dyes, *e. g.*, indigo, logwood, catechin. The former is obtained principally from different species of the genus *Indigofera*, and logwood from the *Hæmatoxylon* and *Saraca indica.*

The discovery [3] of hæmatoxylin in the *Saraca indica* illustrates very well how this plant, in its chemical as well as botanical character, is related to the *Hæmatoxylon campechianum;* also, I found a substance like catechin in the *Saraca.* This compound is found in the *Acacias*, to which class *Saraca* is related by its chemical position as well as botanically. Saponin is found in both of these plants as well as in many other plants of the Leguminosæ. The Leguminosæ come under the middle plane or multiplicity of floral elements, and the presence of saponin in these plants was to be expected.

From many of the facts above stated, it may be inferred that the chemical compounds of plants do not occur at random. Each stage of growth and development has its own particular chemistry.

It is said that many of the constituents found in plants are the result of destructive metabolism, and are of no further use

[1] *Botanical Gazette*, October, 1886. See *ante*, p. 168.

[2] Borodin, *Pharm. Jour. Trans.*, xvi, 369. Pax. Firemy, *Ann. Sci. Nat.*, xiii.

[3] H. C. De S. Abbott, *Proc. Acad. Nat. Sciences*, Nov. 30, 1886. See *ante*, p. 171.

in the plant's economy. This subject is by no means settled, and even should we be forced to accept that ground, it is a significant fact that certain cells, tissues, or organs peculiar to a plant secrete or excrete chemical compounds peculiar to them, which are to be found in one family, or in species closely allied to it.

It is a fact that the chemical compounds are there, no matter why or whence they came. They will serve our purposes of study and classification.

The result of experiment shows that the presence of certain compounds is essential to the vigor and development of all plants, and particular compounds to the development of certain plants. Plant chemistry and morphology are related. Future investigations will demonstrate this relation.

In general terms, we may say that amides and carbohydrates are utilized in the manufacture of proteids. Organic acids cause a turgescence of cells. Glucosides may be a form of reserve food material.

Resins and waxes may serve only as protection to the surfaces of plants; coloring-matters, as screens to shut off or admit certain of the sun's rays; but we are still far from penetrating the mystery of life.

A simple plant does what animals more highly endowed cannot do. From simplest substances they manufacture the most complex. We owe our existence to plants, as they do theirs to the air and soil.

The elements carbon, oxygen, hydrogen, and nitrogen pass through a cycle of changes from simple inorganic substances to the complex compounds of the living cell. Upon the decomposition of these bodies the elements return to their original state. During this transition those properties of protoplasm which were mentioned at the beginning, in turn, follow their path. From germination to death this course appears like a crescent, the other half of the circle closed from view. Where chemistry begins and ends it is difficult to say.

COMPARATIVE CHEMISTRY OF HIGHER AND LOWER PLANTS [1]

On coming before a popular audience to present a special subject like plant chemistry, I do so in hopes, perhaps, of showing some of the less familiar sides of plant life. The chief idea of the remarks I am about to make is one that has not occupied to any great extent the minds of botanists and chemists, and if it be not true, at least no other hypothesis has been suggested than the one I shall indicate to account for the chemical compounds of the vegetable kingdom.

On past occasions [2] I have spoken of certain chemical compounds in relation to plant morphology and evolution. The facts then advanced tended to show a chemical progression in plants, and a mutual dependence between chemical constituents and change of vegetable form, and in the following pages I shall keep this idea prominently before you.

Certain condensations of force on our planet are known as chemical bodies. By usual methods they cannot be split up into component parts, hence are denominated elements. However, we have reason to believe that these so-called elements are in reality themselves compounds, formed in the cosmic laboratory from still simpler aggregations of matter.

In mineralogy the series of chemical formations are doubt-

[1] Lecture delivered in the course given under the auspices of the Philosophical, Anthropological, and Biological Societies in the United States National Museum, Washington, April 23, 1887. Printed in the *American Naturalist*, August, September, 1887; also in pamphlet form, Philadelphia, 1887.

[2] "Certain Chemical Constituents of Plants considered in Relation to their Morphology and Evolution." Read before the Chemical Section of the A. A. A. S. at Buffalo, 1886. Abstract published in the *Botanical Gazette*, vol. xi, October, 1886. "The Chemical Basis of Plant Forms." Lecture delivered before the Franklin Institute, Philadelphia, 1887. *Franklin Institute Journal*. See *ante*, p. 168.

less the result of evolution from the more simple elements to the complex structure of the crystalline rocks.[1]

The plant kingdom may be considered as a third and higher stage; it contains in its structure combinations of the elements carbon, hydrogen, nitrogen, oxygen, sulphur, phosphorus, and compounds derived from the mineral world.

The essence which underlies all force and life may be traced through these three planes as a law of progression, little varying in its general course, though ever giving more involved problems for solution, according to the increasing complexity, from elements and minerals to plants, and even to animals.

The line separating each of these conditions of matter is indistinct, "the individual of the one encroaches upon the dominion of the other;" [2] as a spiral coil is of a single thread, so "nature in all her manifestations constitutes a unity," [3] and the rounds of the spiral present each stage parallel, but in reality a continuation.

Analogies should not be given too much weight, but from numerous facts the above statements seem theoretically reasonable and may be provisionally accepted. The possibility of chemical evolution of the elements, in itself, is not only one of the most absorbing questions of the moment for investigation, but the evolution of compounds from these elements and their possible influence upon the external forms of plants is of equal interest.

That directive force which controls the different groupings of atoms in a molecule under the solid, liquid, or gaseous forms of matter, manifests itself in still more complicated conditions in each grade of the chemical compounds of living cells, and thus, from the single cell to the highest of plants, is ever active.

It is not my wish to claim for plant chemistry more than the facts at my disposal will allow; though in the past, — and this should not be overlooked, — without the aid of the imagination to penetrate the avenues of the unknown, many of

[1] *Mineral Physiology and Physiography*, by T. Sterry Hunt, Boston, 1886.

[2] *The Chemical Basis of Plant Forms*, p. 232.

[3] T. Sterry Hunt, p. 18.

our well-established scientific facts would still be buried from sight.

The chemical analysis of the dead plant and the study of the chemical changes occurring in the living plant are among our means for some of these investigations; and much of all the knowledge derived from each field of chemical research may be utilized in aiding to unravel the mystery of these changes in the vegetable cell.

In the mineral kingdom certain elements are invariably associated with others, as nickel with cobalt; and in plants not only do we find two or more compounds invariably present together, — *i. e.*, tannin and starch in the tannin groups, lime and saponin in the pink family (*Caryophyllaceæ*),[1] resins and saponin in all of the saponin-containing groups, and sugar and silica in the grasses (*Gramineæ*), — but also in certain plant groups we notice the predominance of special compounds, and their absence in other groups. The grouping of these compounds in definite association must bear some relation to their respective sequence and formation, and cannot be the result of accident. That the cinchona plant does not manufacture the alkaloids of the poppy, but each its own particular series of compounds, illustrates this.

I have said, elsewhere,[2] "The chemical compounds of plants do not occur at random. Each stage of growth and development has its own particular chemistry. . . . The result of experiment shows that the presence of certain compounds is essential to the vigor and development of all plants, and particular compounds to the development of certain plants." It may be inferred that "plant chemistry and morphology are related. Future investigation will demonstrate this relation."

The theory of evolution, which underlies all mineral and organic forms, comprises the evolution of the component parts of the whole, and since the structural bases of minerals and plants are chemical compounds, their evolution must neces-

[1] *Die Pflanzenstoffe*, by Hilger and Husemann, p. 542; E. v. Wolff, *J. pr Chem.*, li, 24; lii, 86; Wolff, *Aschenanalysen*, 1881, pp. 144, 145.

[2] "The Chemical Basis of Plant Forms," p. 232, *ante*.

sarily be included in a study of plant life. Whether this life reveals itself in the perfume of sweet flowers, or in the manifold forms of vegetation, from the simple mass of plant-jelly to the majestic forest-tree, its dependence upon matter invokes the most eager desire to acquaint ourselves with its various manifestations.

When matter, through chemical change, exhibits properties of absorption, metabolism, excretion, reproduction, contractility, automatism, and irritability, it is said to be living. In this condition it is called protoplasm. This substance is very complex and of undetermined composition, though its proximate constitution is known.[1] It is always present where life, as defined, is found, apparently the same in the lower as in the higher plants.

The lowest forms of plants, plasmodia, are irregular-shaped masses of jelly, undifferentiated in form, function, and chemical composition. This living jelly is described "as a colloidal albuminoid united with more or less water." [2]

Plant cells, when alive, are composed of a semi-fluid albuminous substance very like plasmodia, closed on all sides, with a watery liquid holding salts and saccharine substances in solution, and lying in contact with a firm elastic membrane called the cell wall; also, like it, closed on all sides, and consisting of cellulose, water, and inorganic matter. Some of the Algæ and all higher plants are congregations of these cells grouped as tissues and organs, and their albuminoid contents are undergoing continual change; in life it is a building-up process, the food being supplied from the gases, water, and inorganic substances of the surroundings, and elaborated in the plant's own laboratory to meet its needs.

The vegetable kingdom does not usually claim our attention for its intellectual attainments, although its members would certainly seem to possess greater chemical skill than a higher race of beings exhibit in their laboratories. Some few of this higher race are "going to take lessons" how to

[1] Reinke and Rodewald, Berlin, 1881; *Physiological Botany*, by G. L. Goodale, 1885, p. 197.

[2] T. Sterry Hunt, *Min. Phys. and Physiography*.

construct proteids and carbohydrates as we are told our now automatic cousins were once taught to do; though man fails to consider that it may be a lost art, and the secret has died with the plants in a "catagenetic" decline.

All plants and their products are composed of two general classes of compounds, — volatile and fixed. The former, on incineration of the plant, are transformed into gases, leaving the last as so-called ash-constituents.

I will very briefly refer to the sources of the substances which go to the building of the plant structure. Green plants derive their carbon from the carbon dioxide of the atmosphere, and even from complex organic compounds, since Darwin [1] has shown that insectivorous plants, by means of their modified leaves, are able to absorb flies and other small insects.

Plants that do not contain chlorophyll, as fungi, take their carbon from complex compounds of decaying organic matter. Not only do all the so-called organic compounds of plants contain carbon, but it is found also in the form of carbonates.[2]

Hydrogen is absorbed by all plants in the form of water, or ammonia and its compounds, or in complex substances, as mentioned above. Oxygen is taken up by plants free or in combination, in water or in salts, and there are six possible sources of nitrogen supply; but I will not delay by going into this subject.[3]

Sulphur and phosphorus are constituents of proteids, and are derived from inorganic compounds. In addition to these the elements essential to the nutrition and maintenance of the life of all plants are potassium, calcium, magnesium, iron in the case of green plants, its absence producing the condition of etiolation; and, in certain cases, chlorine. Silicon, fluorine, manganese, sodium, lithium, rubidium, cæsium, barium, strontium, aluminium, zinc, copper, arsenic, titanium, iodine, and bromine have also been found among the ash-ingredients of certain plants.

[1] *Insectivorous Plants.* [2] *Ann. Phys. et Chim.*, Berthelot.

[3] "The Economical Aspect of Agr. Chem.," by H. W. Wiley, *Proc. A. A. A. S.*, vol. xxxv, 1886.

These ash-ingredients are usually present in each plant cell, in the cell wall, imbedded in the cellulose and partly in the contents of the cell. The salts of the alkaline metals, sulphates, chlorides of magnesium and calcium, also soluble silicic acid, as in *Equisetum hiemale*,[1] occur in solution in the cell-sap, and insoluble salts exist in the tissues of plants.

The differences in the composition of the ash of plants show that each plant is endowed with a specific absorbent capacity; thus a gramineous plant [2] is able to withdraw relatively larger quantities of silica from the soil than a leguminous plant. The latter can only do so to a very slight extent.

The absorbent capacities of allied species are very different. Again, individuals of the same species yield different ash-constituents, depending upon their vigor, and at different periods of growth the ash-composition varies. In a summary of experimental results it has been stated that [3] "similar kinds of plants, and especially the same parts of similar plants, exhibit a close general agreement in the composition of their ashes, while plants which are unlike in their botanical characters are also unlike in the proportions of their fixed ingredients."

Certain marked varieties of plants appear to be peculiar to and developed by certain soils, as the violet, *var. calaminaris*, and the penny cress, in zinc soils.[4] In the leaves of the latter plant thirteen per cent. of zinc oxide was found, and I have found manganese in the different portions of *Yucca angustifolia* [5] grown near Lake Valley, New Mexico.

Plants may absorb from the soil mineral matters independently of their use or harmfulness to the plant, but the absorption of essential inorganic constituents will depend upon their relation to the changes in the vegetable cell.

The ash-constituents of a plant increase from the roots upward to the leaves, the largest percentage being found in the younger portions of the growing plant, and I have observed this same principle on a more general scale running

[1] Lange, *Ber. d. Deut. Chem. Ges.*, xi.
[2] Wolff, *Aschenanalysen*, 1871.
[3] *How Crops Grow*, by S. W. Johnson, London, p. 145.
[4] A. Braum and Risse, Sachs, *Exp. Physiologie*, p. 153.
[5] *Amer. Phil. Soc. Trans.*, H. C. De S. Abbott. See *ante*, p. 126.

through the entire plant kingdom, for the largest ash-percentages are found among those plants lower in the evolutionary scale, which would correspond to the larger ash-percentage of younger, or formative, parts of the growing plants. Some of these lower groups, as the diatoms of the Algæ and the vascular cryptogams,[1] contain enormously large ash-percentages; in the Horse-Tail, *Equisetum*,[2] 60 per cent. alone of silicic acid. The *Lycopodium*,[3] in addition to 14 per cent. of silicic acid, contains 27 per cent. of alumina and 2.5 per cent. of manganese. Among comparatively lower plants the willow and poplar[4] are rich in ash-constituents; the former[5] contains 1.53 per cent. of manganese. Members of the sedge order and grasses contain large quantities of silica; the rice-hull, 98 per cent. Various species of apetalous plants on the same evolutionary plane with these groups also contain a large percentage of ash-constituents, as the *Salicornia*, *Salsola*, *Chenopodium*, and *Atriplex*, also the sugar beet.

I have stated what chemical elements are essential for the life of the lower as well as the higher plants; also those which may occur in certain plants; and I have spoken of the two general classes of compounds of which plants are built as the volatile and ash constituents. The four elements, carbon, hydrogen, oxygen, and nitrogen, enter into the composition of the first class of compounds, and the grouping of these elements with each other and with the ash-elements, constitutes what is called plant chemistry.

As certain chemical elements are always present in plants, so certain changes occur, and compounds are found generally, more especially among the albuminous constituents. However, even this statement should be restricted to saying that the first chemical reactions between these elements are probably identical at the start, the subsequent compounds formed depending upon the evolutionary stage.

The infinite variety of these compounds is only equalled by

[1] *Die Pflanzensenstoffe*, p. 323; W. Lange, *Bil. Ver.*, xi. 822.

[2] *Ann. Chim. Phys.*, xi, 62, 208; *Ann. Chim. Pharm.*, 77, 295.

[3] Flückiger, *Pharmacognosie;* Kamp, *Ann. Chim. Pharm.*, 100, 300.

[4] Durocher and Lalaguti, Liebig's *Agric. Chemie*, 8. Aufl., 371.

[5] E. Riechardt, *Chem. pharm. Centralbl.*, 268, 567.

the numerous genera and species of the vegetable kingdom; though certain compounds frequently occur, as starch, sugar, tannin, and other bodies, correlated in special groups of plants with special and distinct properties. For example, the true starch of the cryptogams will be found gelatinous in Algæ, replaced in Fungi as glycogen, and only in the lowest of the flowering plants does it occur in the simplest stratified form; from this stage to the highest of plants, the Compositæ, in which it occurs as a crystalline substance called inulin, it may be traced from plane to plane of plant-group development in a succession of stratification until it reaches its highest point in our most evolved plants. So strongly marked are these varieties of starch-forms that some investigators, notably Nägeli, have proposed this means for the identification of many plant families.

The many kinds of vegetable sugars known to chemists also have their locations, not only during different stages of the individual plant-growth and in different parts of the plant, as synanthrose,[1] the especial sugar of the unripe grain of rye and wheat, but also in certain families, some one kind of sugar will predominate in many of the individuals. The tannins of the oak, beech, and poplar are not those of the higher plants.

At a certain stage of plant evolution, glucosides, substances capable of splitting up and yielding, among other products, sugar, appear. I have observed in those plants where large percentages of such substances are found, a diminished proportion of starch and sugar,[2] or their absence, notably in soap-bark and species of the *Yucca*.

The waxes, oils, camphors, resins, acids, and other classes of vegetable compounds might be similarly cited as offering characteristic properties in various plants in which they appear, but the examples given are ample to illustrate my point, that the chemical compounds of plants should be considered from three sides, viz.: —

1. In their own development through many plant groups,

[1] "Ripening of Seeds," by A. Muntz, *Ann. Agronom.*, xii, 399–400; *Jour. Chem. Soc.*, February, 1887, p. 173.

[2] *Trans. Amer. Phil. Soc.*, "Yucca Angustifolia." See *ante*, p. 126.

from a gelatinous or undifferentiated compound to a polymer, or a substance of the same chemical formula, having a solid or crystalline form.

2. In their succession of changes, which may be observed during the different stages of the individual plant's growth, and the relation of these chemical changes to other compounds present in the plant.

3. The location as predominant of some one or associated compounds only in certain plants on similar evolutionary planes.

These three conditions correspond to what was stated at the beginning, that a law of universal progression may be traced wherever matter or force exists.

There is no absolutely certain knowledge of the precise character of the chemical changes which these plant compounds undergo, though we have some information about them. Investigations are being vigorously pushed in this department of plant life, and it may be reasonably inferred that definite facts will be obtained on many of these subjects.

It would seem from the latest researches that the albuminous or proteid compounds to which life is essentially linked are formed from a compound containing nitrogen, called an amide, and some carbohydrate; its sulphur and phosphorus supply being derived from inorganic sources. This amide is probably asparagine or a related body. Various suggestions have been offered to explain its formation in the plant, from the breaking down of protoplasm to its construction from simple nitrogenous and carbon compounds, and among the latest investigations [1] the results show that the formation of asparagine is independent of carbohydrates, and that the amide formed is not a by-product of the interchange of matter within the plant. The author of these experiments considers that asparagine is formed by the union of inorganic nitrogen compounds and malic acid within the plant, the acid being derived from the carbohydrates.

Other nitrogenous compounds, as the alkaloids, for example,

[1] O. Müller, "Landw. Versuch. Stat.," 1886, 326–335; *Jour. Chem. Soc.*, p. 70, January, 1887.

are probably formed from the complex albuminoids, and in fungus plants, which are especially rich in nitrogenous compounds, alkaloids are common.

It has been generally held that alkaloids, with resins and some other compounds occurring in plants, are waste products, but this cannot be accepted as final. The researches [1] of Selmi, Gautier, Etard, Brieger, and others have broken down an imaginary distinction between plants and animals, which is of interest in this connection. They show that the production of alkaloids is a general function common to all living cells, whether they be bacteria or the cells of living animals.

In the animals, with their excretory functions, these poisonous substances would be readily eliminated from the system; but it seems to me that in the absence of homologous organs in plants these compounds might be used again for the building up of tissue and prevent the accumulation of products detrimental to plants, and the recent investigations of Kellner [2] on the composition of tea-leaves show that this view is not unlikely, for he states that the non-albuminoid nitrogen is almost wholly absent during the latter stages of growth, being found as theine; in the seeds the albumen has increased, but no theine is found; thus the author believes that positive proof is afforded that the alkaloids are a decomposition product of albumen, and capable of again forming albumen-like asparagine and glutamine.

It will not be possible in this place to enter more fully into the details of the chemical changes going on within the plant. My time will not allow a discussion of the changes of starch into sugar, and conversely, nor a review of the many steps in the transformation of protoplasm into the simpler products of cellulose, chlorophyll, and other substances; and it may be well to say that the ideas of physiologists in regard to these changes are unstable, since the acquisition of new facts seems to unsettle former opinions. But, to illustrate the revolution within the last few years from former views held in plant

[1] "Les Alcaloides d'Origine Animale," par Dr. L. Huhouneng, Paris. *Chem. News*, December 10, 1886.

[2] "Landw. Versuch. Stat.," 1886, 370, 380; *Jour. Chem. Soc.*, January, 1887, p. 73.

chemistry, I will mention that sugar is not, in all plants, a reserve or plastic body, and in some few (for example, the sorghum cane [1]) it must be regarded rather as a waste product, and its advent in larger percentage after the maturity of growth marks the decay of the plant and attends its euthanasia.

I have desired, by entering into all of the above particulars, to prepare for a consideration of the compounds which are formed by these chemical successions and occur through the plant kingdom. In treating of this subject I shall have so frequent occasion to speak of the different plant families that, for convenience, I shall use the order of evolution for flowering plants proposed by M. Édouard Heckel,[2] and which is represented in the table.

The author classes all these plants under three main parallel divisions, from the lowest of the apetalous,[3] mono- and di-cotyledonous groups to their respective highest plants. These three main columns are divided at the same point into three general planes. On plane 1 are all plants of simplicity of floral elements or parts; for example, the black walnut with the simple flower contained in a catkin. On plane 2 are plants of multiplicity of floral elements, as the many petals and stamens of the rose; and, finally, the higher plants, as the orchids among the monocotyledons, and the Compositæ among the dicotyledonous plants, come upon the third plane, or the division of condensation of floral parts.

These three characteristics, simplicity, multiplicity, and condensation of floral elements, are correspondingly repeated in

[1] "On the Variations of Sucrose in *Sorghum Saccharatum*," by H. W. Wiley, *Botanical Gazette*, vol. xii, March, 1887.

[2] *Revue Scientifique*, March 13, 1886.

[3] Heckel's division of apetalous plants from mono- and di-cotyledonous groups has been criticised by some botanists as an artificial method of classification. Since all botanical classifications have been declared, on botanical authority, in a measure artificial, the author does not feel called upon to apologize for introducing M. Heckel. She has found his scheme to answer her purposes, provisionally, more fully than other classifications, and she is indebted to him for a means of presenting her subject which would be otherwise impracticable. Further than this she is not responsible for advocating the classification. M. Heckel's table is published with his paper, "Les Plantes et la Théorie de l'Évolution," in the *Revue Scientifique*, March 13, 1886.

SCHEME OF PLANT EVOLUTION

By M. Édouard Heckel

Processes.		*Apetalous.*		*Monocotyledons.*	*Dicotyledons.* *Cupuliflores.*		*Thalamiflores.*
Simplicity of Floral Elements.	Amentales.	Casuarineæ, Myriceæ, Juglandeæ, Salicineæ, Corylaceæ, Cupuliferæ, Betulaceæ, Balsamifluæ, Plantaneæ.	Fluviales.	Lemnaceæ, Naiadaceæ, Potameæ.			
	Spadiciflores.	Piperaceæ, Ceratophyllaceæ, Chloranthaceæ, Saurureæ, Datisceæ, Nepentheæ.	Spadiceæ.	Jugcagineæ, Aroideæ, Pandaneæ, Cyclantheæ, Palmæ, Typhaceæ.			
Metamerization. Multiplicity of Floral Elements.	Monimo-Urtico, Polygonales.	Monimiaceæ, Urticeæ, Cynocrambeæ, Cannabineæ, Ulmaceæ, Celtideæ, Moreæ, Polygoneæ, Amarantaceæ, Baselleæ, Chenopodeæ, Artocarpeæ.	Glumoideæ.	Cyperaceæ, Gramineæ, Restiaceæ, Eriocaulonaceæ, Xyrideæ, Junceæ, Commelyneæ.	Rosales, Ficoids.	Ranales.	Polycarpels, Hydropeltideæ.
	Daphnales.	Phytolacceæ, Laurineæ, Myristicaceæ, Santalaceæ, Loranthaceæ, Cytineæ, Balanophoraceæ, Begoniaceæ, Elæagneæ, Proteaceæ, Thymeleæ, Nyctagineæ.	Liroideæ.	Liliaceæ, Irideæ, Alismaceæ, Butomeæ, Hydrocharideæ, Pontederaceæ, Taccaceæ, Bromeliaceæ, Tillandsiaceæ, Musaceæ, Zinziberaceæ, Cannaceæ.	Saxifrages.		Cruciforms-Euphorbiales, Parietales, Tilio-Malvales, Rutales, Gamopetalous-Isogyns.
					Leguminous plants, Rhamnales, Bicarpels.		Gamopetalous-Anisogyns, Labiatiflores.
Cephalization. Simplification of Floral Elements.	Serpentaria.	Asarineæ, Aristolochiaceæ.	Gynandres.	Apostasiaceæ, Orchideæ.	Apocyneæ, Asclepiadeæ.		
					Epicorolliflores. 1. Corysantheria.		Caprifoliaceæ, Campanulaceæ, Lobeliaceæ, Valerianeæ, Dipsaceæ.
					Epicorolliflores. 2. Synantheria.		Goodeniaceæ, Brunoniaceæ, Stylideæ, Compositæ.

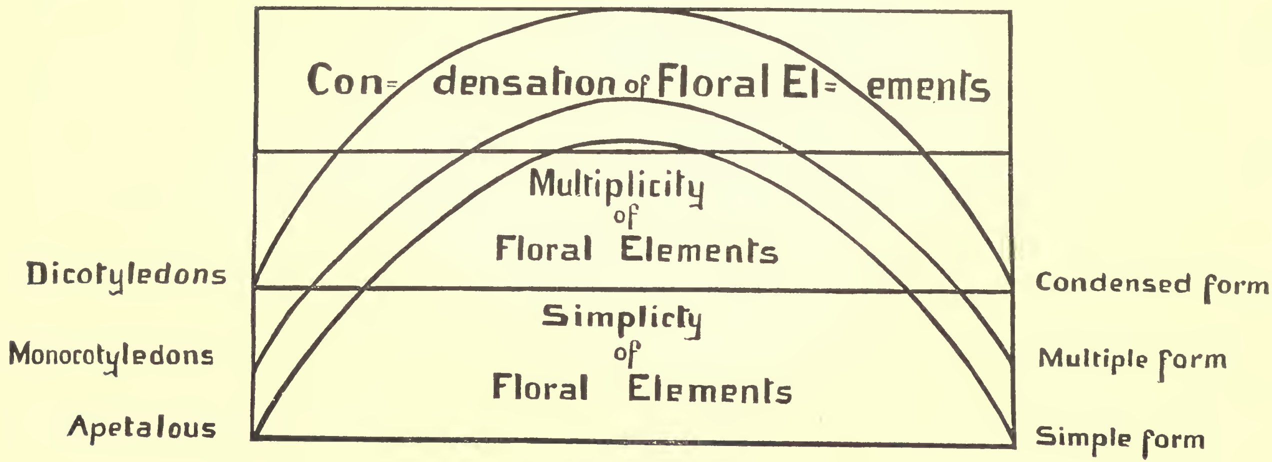

Con= densation of Floral El= ements
Multiplicity
of
Floral Elements
Simplicty
of
Floral Elements
Dicotyledons
Monocotyledons
Apetalous
Condensed form
Multiple form
Simple form

PLATE I

each of the three horizontal planes, and even in individual orders, in their lowest and highest plants.[1] To facilitate the comprehension of this classification I have assembled a sufficient number of the plants themselves, so arranged as to place before you a living representation of this complicated diagram.

The laws controlling the chemical evolution of plant-constituents are too little comprehended to formulate, but before reaching a position ever to do this, it will be necessary to study carefully the facts from extended researches, to ascertain how these chemical constituents occur, under what conditions, and if these conditions are constant or variable, and to what may be ascribed the variability.

In speaking of chemical compounds I will describe them as occurring according to the botanical disposition of Heckel's table, which I use provisionally, since it is not probable that this presentation will be the ultimate or best way to introduce the subject. But I am not prepared as yet to offer any other arrangement on a purely chemical basis; since the application of the chemical side of plant life as one more evidence in favor of the hypothesis of evolution is still too new to possess a literature of its own.

I have already referred to the protoplasm and starch, also to the large ash-percentages of some of the lower groups, and among the compounds commonly found in many plants, tannin appears first, according to the evolutionary order, in liverworts.

Chlorophyll is one of the earliest compounds to appear, and its presence in Algæ and its absence in Fungi is a distinction between the two divisions of the Thallophyta group. Besides this green coloring-matter, which is, with few exceptions, common to all plants, other brilliant coloring-matters occur in some of these lower plant forms which are peculiar to whole families and correlated with special physiological functions.

The general distribution of chlorophyll, with few exceptions, in all plant groups is only second to the proteid compounds; however, the color of this compound is not the same tint in all plants, and the evergreens and many other plants when com-

[1] Plate I illustrates this principle for the three horizontal planes, which is also applicable to the orders.

pared will be found in this respect distinct. The gradual change from the bright greens of the early spring foliage to the duller greens of late summer illustrates the transmutation of color which may be observed in plants, and I would suggest that this same gradation may be seen on the large evolutionary planes of all plant groups, chlorophyll, like the plants, being at different evolutionary stages; for example, in many Algæ and lower plants it appears as light bright greens, and finally in the darker greens of the higher plants.

Considering in general the chemical compounds of flowering plants among the apetals and monocotyledons on the first evolutionary plane, where the plant elements are simple, tannin, wax, starch, aromatic or acrid principles, and the oils and sugar of the palm are the most conspicuous substances. These compounds are found in the same or in neighboring plants, and their association is doubtless of evolutionary significance. Glucosides or alkaloids, though occurring in some few of these plants, are not characteristic of this stage of evolution.

Tannin is a general name for a class of substances which presents many aspects in different plants. It first appears, as was stated, in the liverworts, combined with large quantities of starch and wax; then in ferns. Among the amental apetalous groups it is one of the conspicuous compounds, also associated with starch; the casuarina, willow, poplar, hazel, oak, beech, chestnut, alder, and birch containing large quantities. Tannin is widely distributed, though especially in the leaves, barks,[1] seeds, and rinds of fruits, and in other plants in considerable quantities, as the maple, sumach, tea, in many berries, the holly, and the seeds and stalks of the grape-vine.

Tormentilla erecta,[2] Rosaceæ, yields from six to twenty per cent. tannin, and, although this compound is present in mono- and di-cotyledonous plants, it seems to be more prominent in the apetalous on the first evolutionary plane, and to occur less, if at all, in the highest plants. When it is remembered that tannin is found in greater abundance in lower plants, which I

[1] "Répartition du Tannin dans les Diverses Régions du Bois de Chêne," *Ann. de la Science Agr.*

[2] Fraas, *Ergebnisse, Landw. Versuche,* München, 1861.

have compared as formative to the formed or higher evolutionary groups, it is a still further illustration of what was stated about the higher percentage of ash-constituents in lower plants.

Physiologists differ as to the tannin functions in plants. It probably serves several purposes; according to Schell, as a plastic material for the building up of tissues, especially where starch or fats are absent; or it exists as a subordinate product. It is certainly true that some tannins play a distinct rôle as the source of many vegetable colors, — the reds and blues of flowers, the brown of tree-barks, and the colors of changing leaves owing their origin to this source.

The large quantity of starch in most tannin plants is remarkable; and Sachs believes it, or a fixed oil, to be the mother-substance of tannin.

Datiscin,[1] a kind of starch, is found in the *Datisca* order, and, among the monocotyledons, the palms occur on the same plane, and in most of their genera contain large quantities of starch, eight hundred pounds of sago having been obtained from one plant of *Metroxylon*, or the sago-palm species. The *Arum pandanus* (screw-pine) and bulrush orders yield much starch; of the latter plants, 12.5 per cent from *Typha latifolia* (Lecoq).

Large quantities of wax are found in species of the myrtle, and also of the palm.

On the second plane, or multiplicity of floral parts, the chemical constituents become much more numerous at this stage. Under the apetalous and monocotyledonous groups, volatile, pungent, and aromatic principles, alkaloids, sugars, coloring-matters, camphors, resins, starch, and glucosides appear prominently. The lower dicotyledonous plants reproduce many of the compounds of the other two classes, for the Rosaceæ contain the tannins of the lower apetalous plants and parallel groups, and the glucosides of the higher monocotyledons.

Cane sugar is a prominent compound here. If a horizontal line be drawn from a given point of Heckel's scheme it passes through the apetalous, mono- and di-cotyledonous groups, which contain this substance most abundantly, — namely, the sugar

[1] According to Stenhouse, datiscin is a crystalline glucosidal bitter substance.

beet, sugar-cane, sorghum, the fruit groups of the Rosaceæ, and the sugar maple.

The sugar of the palms, among the highest of plants with simplicity of floral elements, is very like that of the cane. Since the grasses are the lower of monocotyledons with multiplicity of parts, it is notable that at the meeting-ground between these groups, or at the transition-stage into multiplicity, sugar should occur. The sugar of the palm is very little above the sugar line; it may be considered, in an evolutionary sense, as passing to the cane sugar of these other groups, and as forming the apex of a low triangle, the base being the sugar line already described. The large percentage of grape-sugar in the fig, *Ficus carica*, occurs in a class very nearly on a line with these cane-sugar plants.

Glucosides are more especially the compounds of the middle plane of plant development, and are found in the higher monocotyledons of this stage, in the lower and some of the higher dicotyledons, and less frequently in the highest of all plants, or under cephalization. The first appearance of a glucoside occurs in the apetalous groups of flowering plants, as quercitrin in *Carya tomentosa*, Juglandaceæ, or in other hickory varieties; then in the next following orders, as salicin and populin, of the willow and poplar; antiarin, of the Antsjar, or Upas-tree (*Antiaris toxicaria*); acorin, of the *Arum*, and coniferin, of the Coniferæ. Among the Lirioideæ groups many glucosides occur, especially saponin, and I have found this compound in species of the yucca, agave, and among dicotyledons in leguminous plants; besides, it is found in Rosaceæ and other parallel groups.

Saponin is also found in *Smilax*, a genus partaking somewhat of the nature of endogens and exogens, and serves to unite all the saponin groups;[1] and although this compound is widely distributed in plants, it is a significant fact that all the groups containing it belong to this middle evolutionary division.

Rosoll [2] has found saponin in the cell-sap of living roots of *Saponaria* and *Gysophila*, and I have elsewhere called attention

[1] "Chemical Basis of Plant Forms." See p. 232.

[2] *Monats. Chem.*, v, 94; *Jahresb. d. Chem.*, 1884.

to the solvent action of saponin on resins,[1] also on calcium oxalate. This property is of value to the plant not only by acting as a solvent of insoluble or slightly soluble compounds, and thus assisting it in obtaining food otherwise difficult of access, but also resins are found in nearly all the Lirioideæ, and the presence of this chemical class associated with saponin shows a physiological adaptation of importance to the plant. It may be recalled that the pink family is remarkable for its proportion of lime, and this element is frequently found in large quantities, as well as resins, in other saponin orders. Saponin may thus be called a constructive element in developing the plant from the multiplicity of floral elements to cephalization of these organs.

Among the members of the higher groups of plants many of the preceding stages of chemical evolution are represented up to a certain point, when the plants acquire other chemical characteristics, — *i.e.*, indigo, hæmatoxylin, and other coloring-matters of the leguminous groups, and the dyes of the madder plant, give way to the alkaloids of the cinchona, the coffee, the atropa, and the strychnos orders, and to the organic acids of the valerian order, and the aromatic and volatile compounds of the Compositæ.

Alkaloids, though so widely distributed, are not found in the very lowest or the highest plants. Their occurrence in fungi has been already noted. In flowering plants, among the lower apetals, piperin, the alkaloid of Piperaceæ, occurs; also, alkaloids are found in the monimia, hemp, laurel, and amaryllis orders, and in colchicum; but they are exceptional in these lower groups, and belong properly to dicotyledons, where they are found in many orders.

Besides the occurrence of compounds peculiar to distinct plants, or whole plant groups, another class is found, and the substances of this class may be scattered quite generally through the plant kingdom, but always associated with some other compound.

Coumarin, the odorous principle of tonka-bean and vernal grass, is one illustration; its occurrence is limited to those plants

[1] "Yucca Angustifolia," *Trans. Amer. Phil. Soc.*, see p. 126; "Chemical Basis of Plant Forms," *Journal* Franklin Institute. See p. 232.

containing oils, and since, in many genera in which this substance has been found, certain fixed or ethereal oils also occur, it may be inferred that this constancy relates to their chemical evolution. The palms are the lowest plants which contain coumarin; then it occurs in the grass and rose families on the same evolutionary plane, also among the leguminous, madder, rue, and portulaca orders, and in orchids and Compositæ. These plants are characterized by their aromatic and volatile oily products; and vanillin, the fragrant principle of vanilla, also occurs among orchids. It may be noted that oils are formed abundantly in the highest plants.

A knowledge of the chemical compounds, as they are found grouped in plants, is a first step towards the study of their evolution, and acquaintance with the conditions which control their synthesis and gradual formation in the plant can only be had by patient research. The simpler compounds of which any complex substance is built, if located as compounds of lower plants, would indicate the lines of progression from the lower to the higher groups.

It has been already said that every plant contains compounds peculiar to it, but certain compounds seem to play a special part in plant evolution, since the wax and tannin of the vascular cryptogams lead to the tannin and wax groups of the apetalous plants, and the starch of these lower plants to the great starch groups of the monocotyledonous. It will not be out of place to note here that the greatest accumulations of starch occur in plant orders just before they pass on to a higher plane of evolution. This is seen, for example, in the palm and neighboring orders of the first plane, and among the Lirioideæ of the second plane, since these plants are the richest in starch constituents, and it seems as if they were preparing by large reserve of food-supply for their higher position, represented by more evolved groups, where the demands for nutrition are greater. Again, the line of cane sugar indicates that sugar occurs prominently in plants passing from simplicity to multiplicity of floral elements, and the glucosides in their turn are found in the middle stage of plant development, assisting the plants to the highest plane of cephalization.

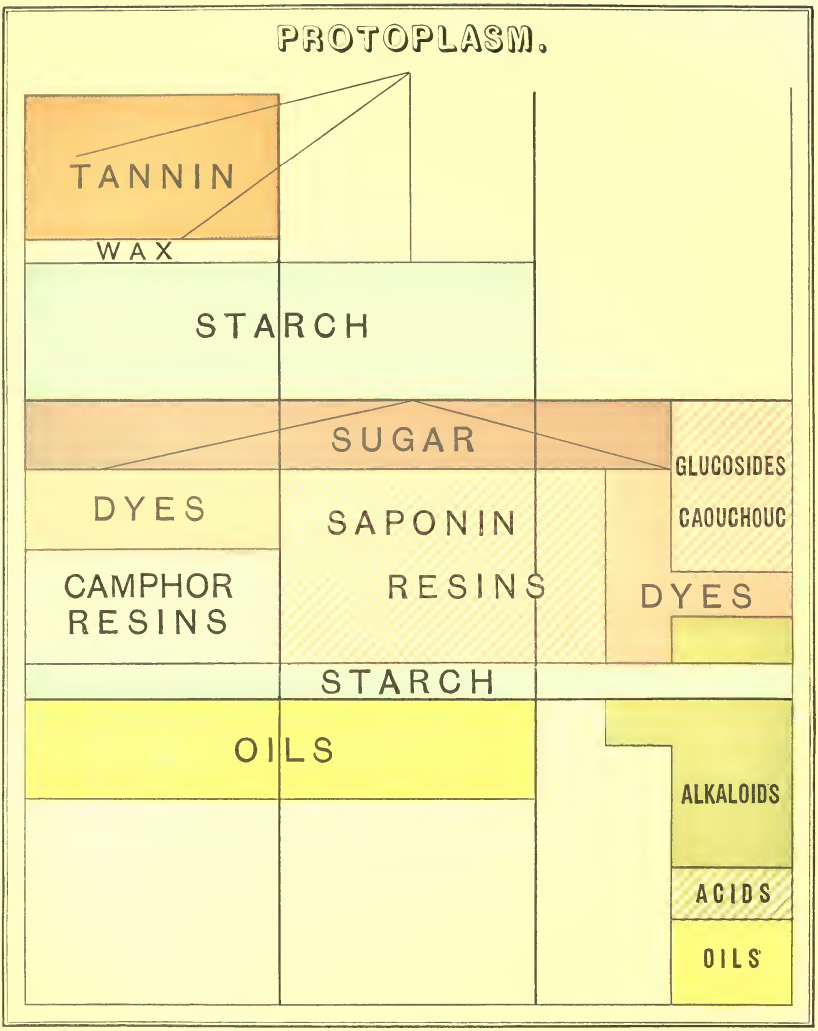

PROTOPLASM.
TANNIN
WAX
STARCH
SUGAR
GLUCOSIDES
CAOUCHOUC
DYES
SAPONIN
CAMPHOR
RESINS
RESINS
DYES
STARCH
OILS
ALKALOIDS
ACIDS
OILS

PLATE II

Plate II is a chemical representation, drawn after Heckel's botanical table, and, from what has preceded it, will be easily comprehended. It is not to be inferred that all classes of chemical compounds found in plants are represented, since only a few have been used for illustration, nor that all of these given compounds occur only in the designated plant groups, since they may occur in traces, or varying quantities, elsewhere. However, these compounds are conspicuous as being especially typical of the plant groups which correspond to their location, and where their presence is doubtless associated with the plant's evolution.

The chemical compounds which may be said to be typical of an order, species, or an individual member of a series would be out of place in this general presentation.

Some plant groups, as the Proteaceæ, orchids, and Compositæ, develop in æsthetic beauty at the expense of their chemical constituents,—all resources go to develop the perfection of the flower, and the absence of numerous compounds in these plants is a strong point in favor of chemical evolution favoring plant development. These beautiful plants being among the highest of their series, may well be called the aristocrats of the vegetable kingdom.

It is still impossible to demonstrate the full significance of this chemical theory in plant development, but it will be evident to any one who examines botanical and chemical facts that the presence of certain chemical compounds is associated with certain botanical conditions, and where these conditions are variable, is found a like variability of chemical composition. If it can be proved that chemical and botanical morphology are not one and the same, at least the two are very intimately correlated.

It has been said that many of the constituents found in plants are the result of destructive metabolism, and are of no further use in the plant's economy, but our knowledge of what constitute plastic and waste products is by no means settled, and even should we be forced to accept the conclusion that some products are of no use to the plant, yet it is a significant fact that certain cell-tissues or organs secrete or excrete chemical compounds peculiar to them, and found in only one family, or in species closely allied to it.

Broadly speaking, the study of plant life cannot be confined within the limits of the vegetable cells, since its radiations reach to the domains of mineralogy and animal life. From a chemical point alone it would be difficult to discriminate in every case between the plant and animal cell. The series of animal gums, carbohydrates, alkaloids, and coloring-matters find their analogous series in plants. By the study of embryology it is found that alantoin occurs in animal and plant life, also glycogen and inosite are found in both kingdoms, and the secretion of some plant-leaves is a fluid chemically like the animal gastric juice.

M. Leo Errera,[1] in a recent paper on a fundamental condition of equilibrium of living cells, calls attention to the thin and plastic condition of plant as well as animal cells at the moment of their formation, and their tendency to assume a form which, under the same conditions, an imponderable lamina of liquid would take, and he attributes to this fact their adaptability and the facility with which they change. He believes that we can trace to this cause the great number of organic forms, and for the first time unite the architecture of the cell to molecular physics. Only with age the cell-membrane becomes thick and offers a considerable resistance.

It may be suggested that this fact is further exhibited when applied to the conditions obtained when plants pass from their younger to older stages; again, it is seen on comparing the lower plastic protoplasmic plants with the rigidity and firmness of the tissues of the higher plants, and in the change from the semifluid to the formed and fixed states of chemical compounds.

The law of progression is one that regards the general good to the disregard of the individual; since in the death or fixation and crystallization of individuals the vegetable kingdom, on the whole, has ascended to its highest present living form, and many of its constituent chemical parts had long ago reached their pinnacle in the cycle of evolution. This concerns equally the changes in the vegetable-cell, and its complex molecule of pro-

[1] *Comp. Rend.*, t. xiii, 1886, p. 822.

teid is built from simple substances, which in turn break down into less complex bodies, and are again reconstructed into proteids, or, as cellulose and other compounds, remain as the component parts of tissue in higher plants, thus serving the mechanical and physiological needs of the organism.

Aside from the practical application of plant products to dietetics, pharmacy, and the industries, it is eminently for purposes of scientific investigation that the field of plant chemistry is most promising.

It has been suggested to me, from botanical sources, that time will be unwisely expended over a detailed study of the chemical compounds of plants; in this, as in mineralogy, its use as a means of classification will depend upon the convictions of the investigator, although it seems to me that many of the vexed questions of plant development can be solved only by a full comprehension of vegetable chemistry.

It is not to be inferred that "botanists," the knights of morphology and systematic classification, will thereby be deprived, by chemists, from tilting over the floral tournament courts. Perhaps in such pleasant pastimes of contest for disputed plant groups this veteran army of knights-errant may at least become weary, and willingly exchange the lance for the balance.

The vegetable kingdom is so vast that the botanico-chemical facts at our disposal are meagre in comparison to the data required, and in consequence many of the explanatory statements advanced can only be considered in the light of speculation. Vistas have opened most promisingly but to be cut off suddenly by a limitation of these details, and I cannot urge too strongly the very great importance of minute chemical research at least in certain typical members of botanical groups. Without such investigation a great deal of our present knowledge is worthless. The changes of the chemical compounds within the cell, the simultaneous appearance of two or more compounds always in association, and the predominance of some one compound in certain plant groups, should be seriously considered before the evolution of plant chemistry be definitely approved or condemned. These facts suggest questions which must be answered before a further advance can be made in plant biology.

The practical application of a theory which advocates that the morphology of a plant is the outcome of its chemistry, will be used by the chemist to direct him to certain plant groups for any compound which experience proves to be present with similar morphological characters in other groups.

It has been recently suggested [1] that many of the chemical compounds may serve the plant as means of defense against animals, and when we camphorize our furniture and poison our flower-beds, we are only imitating and reinventing what the plants practiced before the existence of man; and I may add that the cinchona-trees of malarial countries proclaimed long since their subtle therapeutical skill in securing for themselves a corner in quinine manufacture, independent of contemporary sources.

A full acquaintance with the chemical compounds of living plant orders may even lead to a chemistry of paleo-botany, and where the fossil forms resemble modern groups, as in some of the well-preserved remains lately discovered in France,[2] the same chemical compounds might have existed as are now found in similar groups. From the knowledge which will one day be ours, of the morphology and evolution of chemical substances, a flora may be reconstructed reaching far back into the recesses of time.

In minerals, plants, and animals the same principles recur, though, at each higher plane, under more complicated conditions; and any one who, on visiting the Hot Springs of the Yellowstone National Park, has seen the non-carboniferous gelatinous masses assuming the forms of organized life, will ask himself if silica, under some conditions, may not replace carbon and become living matter. Since Confervæ do live in these springs at high temperature, perhaps some such locality as the Yellowstone may have been the birthplace of "a protoplasmic primordial atomic globule."

The impulse which directs minerals to masquerade as living plants and animals often manifests itself, for example, in the ferns called stag-horns; and orchids, disguised like insects, pre-

[1] M. Leo Errera, Royal Bot. Soc. of Belgium, *Revue Scien.*, 29th Jan., 1887,

[2] M. Louis Crié, *Comp. Rend.*, t. ciii, p. 1143.

tend to be what they are not. When will all of these intricacies of nature's secrets belong to commonplace facts? The day is distant. And in the meantime my hour is drawing to a close; and, to return to my first statement of the evolution of the chemical elements, I would say that the studies[1] of Lecoq de Boisbaudron, Auer, Demarçay, and Crookes on didymium, and the latter's researches on yttria, and more recently on the crimson line of phosphorescent alumina,[2] go to show that the molecules of these so-called elements are compound, and if I have dwelt at all upon this subject, in connection with plant life, it is on account of the indisputably serious nature of the investigations in this field. The following concluding remarks of Professor Crookes's address[3] show that the theory of the chemical evolution of plant compounds has an able ally. He says, "We cannot venture to assert positively that our so-called elements have been evolved from one primordial matter, but we may contend that the balance of evidence . . . fairly weighs in favor of this speculation. . . . The doctrine of evolution, as you well know, has thrown a new light upon and given a new impulse to every department of biology, leading us, may we not hope, to anticipate a corresponding wakening light in the domain of chemistry. I would ask investigators not necessarily either to accept or reject the hypothesis of chemical evolution, but to treat it as a provisional hypothesis; to keep it in view in their researches, to inquire how far it lends itself to the interpretation of the phenomena observed, and to test experimentally every line of thought which points in this direction."

From the above sketch I have attempted to show that the hypothesis of evolution may also apply to the chemistry of plant compounds, and that plant chemistry will be found, like any special study, to include many others. It is, however, exceptional in its broad range, and the variety of its topics, like the variations of flower-species, may be cultivated to suit the taste of the investigator.

[1] *Comp. Rend.*, t. civ, 1887, p. 165, M. Henri Besquerel.
[2] *Chem. News*, Jan. 21, 1887.
[3] Delivered before the British A. A. S., 1886.

ON THE OCCURRENCE OF SOLID HYDROCARBONS IN PLANTS[1]

A CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE PHILADELPHIA COLLEGE OF PHARMACY

[At a stated meeting of the American Philosophical Society, Philadelphia, March 16, 1888, Miss Helen C. De S. Abbott made the following remarks on the Occurrence of a Series of New Crystalline Compounds in Higher Plants.

"In many plants, especially those which belong to the natural orders Simarubaceæ, Polemoniaceæ, Rubiaceæ, Ebenaceæ, Rhodoraceæ, and Compositæ occur, respectively, a class of compounds which present definite crystalline forms. They are extracted from the plants most readily by a light petroleum-ether. Boiling absolute alcohol was used to purify these compounds from fats, wax, and coloring-matter, and by fractional crystallization three distinct forms of crystals were obtained which in ultimate analysis represented compounds of different chemical constitution.

"These bodies are characterized by containing a high percentage of carbon. They are indifferent to alkalies and have high melting-points. The discovery of one of these compounds in *Cascara amarga* was made by me in 1884, and announced at the Buffalo Meeting of the American Association for the Advancement of Science. Since that time my investigations are continuing, and from those studies I am able to announce, as derived from plant sources, compounds which until now have not been observed. Lately, from independent investigations, Professor Henry Trimble has also discovered similar com-

[1] Printed in the *American Journal of Chemistry*, Philadelphia, July, 1888. Noticed in *American Chemical Journal*, vol. x, p. 439; also in *Berichte d. Deutschen Chem. Ges.*, vol. xx, p. 202. In this investigation and report Mr. Trimble was associated with Miss Abbott.

pounds in various plants. Our eventual results will form the substance of a future communication."

The results of the investigations referred to in the above preliminary announcement appear in the following paper, entitled "On the Occurrence of Solid Hydrocarbons in Plants," by Helen C. De S. Abbott and Henry Trimble.]

WHEN many plants of the higher botanical orders are exhausted with petroleum-ether, crystalline compounds may be separated from the extracts which have not been noticed previously to these investigations. These compounds are also obtained when alcohol or ether is used as a solvent; but it is preferable, on account of the greater number of constituents extracted by these menstrua, to employ petroleum-ether, and thus avoid certain difficulties of separation. Among the plants in which up to this time these compounds have been discovered may be mentioned *Cascara amarga*, *Phlox carolina*, and the *Phlox* species, *Anthemis nobilis*, and in different species of the following natural orders: Rubiaceæ, Rhodoraceæ, Eupatoriaceæ, and others among the Compositæ.

The crystals from these petroleum-ether extracts first attracted attention in the winter of 1884. Samples of "chichipate" bark which yielded, on powdering, about two hundred grams, were then obtained and submitted to chemical examination. This bark was subsequently, from chemical analysis, identified as *Cascara amarga*.[1]

Other investigations prevented the announcement of this work until some time later, under the title of "Preliminary Analysis of a Honduras Plant named 'Chichipate.'"[2] In this paper a new crystalline compound was described and identified by its physical and chemical properties as a "camphor-like body." Its analysis gave the following results: —

	I.	II.
C.	80.84	80.90
H.	10.13	10.11

[1] *Journal* Franklin Institute, vol. cxxiv, p. 1, Abbott.

[2] By Helen C. De S. Abbott. Amer. Assoc. Adv. of Science, Buffalo, Aug., 1886.

A compound resembling the one from *chichipate* was also discovered later in *Phlox carolina*,[1] and the account of it was read before a meeting of the American Pharmaceutical Association at Providence, R. I., September, 1886. The combustions of this camphor-like substance gave the following:—

	I.	II.
C.	82.49	82.57
H.	11.11	11.23

From subsequent study, we were led to believe that the above results were based upon a mixture of compounds. Because of the small amounts of crude material then at our disposal we were not able to overcome the difficulties inherent in purifying and separating these substances. However, from the preliminary investigations we were induced to think that these compounds presented features of unusual interest and novelty.

Recently we began anew our studies upon twenty-five and twenty kilos of *Cascara amarga*[2] and *Phlox carolina* respectively.

The drugs were very thoroughly exhausted with a light petroleum-ether, boiling-point under 45° C. The total solids extracted from *Cascara amarga* were 2.015 per cent.; of this about 0.1 per cent. were fats. The yield from *Phlox carolina* was 1.00 per cent., including traces of coloring-matter. On heating to 110° C., there was no appreciable loss of weight in *Cascara*. The *Phlox* contained small quantities of volatile oil.

The extracts, on evaporating spontaneously, deposited upon the sides of a dish or beaker glittering, white, feather-like crystals, often several centimeters in length. At the bottom of the glass were stellate groups of brilliant acicular crystals. Fats, wax, and in *Phlox* a red coloring-matter accompanied the crystalline principle, and rendered the subsequent purification tedious and difficult.

The method finally adopted to purify, upon freeing the petroleum-ether residue from fats and coloring-matter, was to

[1] "On the Underground Portion of *Phlox carolina*." By Henry Trimble. *Amer. Jour. Pharm.*, vol. lviii, p. 479.

[2] By Helen C. De S. Abbott, New York, August, 1887.

treat it with boiling absolute alcohol, filter out the wax, which separated on cooling, and allow the filtrate to evaporate at the ordinary temperature. By fractional crystallization at least three substances of different and definite crystalline forms have been separated. We have, at present, examined only one of these constituent compounds; whether the others are the result of oxidation during the separating and purifying processes or exist as such in the plants, we are now unable to state.

The subject of our communication is the compound the least soluble in alcohol of the three obtained by fractionation. It formed silky, acicular crystals, often two to four centimeters in length, which, under polarized light, gave a play of colors. It also exhibited decidedly electrical properties. To determine the melting-point, about 0.5 of a gram of the crystals were placed directly in the inner tube of an apparatus devised by Roth, for the determination of melting-points. The substance melted at 196.2° C. to 196.4° C., leaving a clear, amber-colored mass. On heating to a higher temperature, the substance decomposed and vapor was driven off in dense clouds. It had an odor very like sandal wood; when condensed upon a cool surface, the sublimate consisted of fluffy crystals of a lower melting-point.

The silky, acicular crystals were soluble in petroleum-ether, ethylic and acetic ethers, benzole, chloroform, hot alcohol, glacial acetic acid, acetic anhydride, and linseed oil. The addition of water to the acetic anhydride reprecipitated the substance, in white, flaky masses. The crystals were insoluble in hot, cold, or acidulated water, or in the alkalies or other hydrate solutions; insoluble in amyl alcohol and alcoholic soda. Nitric and sulphuric acids dissolved the crystals; sulphuric acid gave a reddish-brown coloration.

The first ultimate analyses of this purified product from *Cascara amarga* gave the following results:—

	I.	II.	III.
C.	86.30	86.29	86.33
H.	12.96	12.96	12.83

While the mean percentage obtained from these combustions indicated oxidation or the presence of adherent impurities, they also pointed strongly to the conclusion that the compound was a solid hydrocarbon.

The announcement of this discovery was reserved until it should be confirmed by further study. But a paper describing generally the occurrence of crystalline compounds rich in carbon was read, by title, last summer before the American Association for the Advancement of Science.[1] This inference has been put beyond doubt by the further study of the compound.

Twenty-five kilos of *Cascara amarga* were extracted and the residue purified by often repeated fractional crystallizations, from which the following results were obtained: —

0.1058 grms. gave 0.3413 CO_2 and 0.1133 H_2O.
0.1113 grms. gave 0.3588 CO_2 and 0.1193 H_2O.

	I.	II.
C.	87.97	87.89
H.	11.89	11.90
	99.86	99.79

From the plants mentioned at the beginning of this paper in which this crystalline principle exists, the *Phlox carolina* was also selected as the one to confirm still further the presence and identity of this principle and its chemical composition.

Recently about 15 kilos of this drug were exhausted and the compound separated and repeatedly purified. Its ultimate analyses gave the following: —

0.1117 grms. gave 0.3600 CO_2 and 0.1208 H_2O.
0.1314 grms. gave 0.4228 CO_2 and 0.1421 H_2O.

	I.	II.	Theory for $(C_{11}H_{18})^x$
C.	87.90	87.76	88.00
H.	12.02	12.02	12.00
	99.92	99.78	100.00

The above results indicate that this compound is an unsaturated hydrocarbon, and we intend to make it the subject of

[1] By Helen C. De S. Abbott, New York, August, 1887.

a thorough chemical investigation with a view of ascertaining its chemical constitution.

Whilst the discovery of the hydrocarbon resulted from independent investigations on different plants, we are agreed that the identity of the compounds justifies us in publishing together these results of our studies.

ÜBER EINE NEUE BILDUNGSWEISE VON AROMATISCHEN NITRILEN[1]

Bekanntlich ist die Condensation von Aldehyden und Ketonsäuren mit aromatischen Kohlenwasserstoffen als das Endresultat zweier Vorgänge aufgefasst worden, indem das erste Stadium dieser Reaction eine der Aldolbildung entsprechende Polymerisation darstellt, wobei ein secundäres Carbinol entsteht, und nun das Condensationsmittel auf die entstandene Verbindung und den Kohlenwasserstoff unter Wasserentziehung einwirkt. Diese Auffassung ist durch die schon von V. Baeyer[2] beobachtete Wasserentziehung aus Gemischen von Carbinolen und aromatischen Kohlenwasserstoffen unterstützt worden, sowie dadurch, dass später V. Meyer und Wurster[3] aus Benzylalkohol und Benzol das Diphenylmethan, und Hemilian[4] aus Diphenylcarbinol und Benzol das Triphenylmethan darstellten, und namentlich dass man in gewissen Fällen die Bildung von solchen intermediären Zwischenproducten constatirt hat. Es schien uns möglich auch die durch Addition von Blausäure auf Aldehyde und Ketone entstehende Hydroxynitrile, welche als Carbinolderivate aufgefasst werden können, mit aromatischen Kohlenwasserstoffen zu condensiren, wodurch man zu einer neuen Synthese von aromatischen Nitrilen gelangen würde. Die folgenden Versuche mit Mandelsäurenitril und verschiedenen aromatischen Kohlenwasserstoffen zeigen, dass in der That diese Synthese mit Leichtigkeit ausführbar ist.

Es wurde zuerst versucht, das Diphenylacetonitril darzu-

[1] Printed in the Berichte der deutschen chemischen Gesellschaft, XXV, 1615; also in pamphlet form, Berlin, 1892. With Mrs. Michael was associated John Jeanprêtre.

[2] Diese Berichte VI, 221.

[3] Diese Berichte VI, 963.

[4] Diese Berichte VII, 1203.

stellen und zu diesem Zwecke haben wir zu einem Gemisch von einer Lösung von einem Theile Mandelsäurenitril und zwei Theilen Benzol etwa ein Theil Phosphorpentoxyd zugesetzt; und, nachdem in der Kälte keine Einwirkung stattfand, auf dem Wasserbade während fünf Stunden erwärmt. Die Reactionsmasse wurde mit Wasser gewaschen, behufs Entfernung der Phosphorsäure, und mehrmals mit Benzol ausgezogen. Eine bedeutende Menge, durch Einwirkung von Phosphorpentoxyd auf Mandelsäurenitril allein entstandener Verbindungen blieben als in Benzol unlösliche stark gefärbte Harze zurück, während der Destillationsrückstand der filtrirten Benzollösung durch Destillation im Vacuum etwa ein Drittheil der angewandten Menge Mandelsäurenitrils an einem gelblichen Öle lieferte, das bald nachher erstarrte. Unter 45 mm ging die Verbindung gegen 200° über und schmolz nach einigen Krystallisationen aus Ligroïn bei 72°. Anschütz und Romig[1] haben durch Erhitzen von Cyanquecksilber mit Diphenylbromäthan ebenfalls das Diphenylessigsäurenitril dargestellt und denselben Schmelzpunkt beobachtet.

Unter ganz ähnlichen Bedingungen wurde der Versuch mit einem Gemisch von Mandelsäurenitril und Toluol ausgeführt und er nahm auch einen entsprechenden Verlauf. Nach Entfernung des Toluols destillirte bei 40 mm Druck gegen 240° eine gelbliche Flüssigkeit die ebenfalls bald erstarrte und durch Krystallisation aus verdünntem Alkohol seidenglänzende Nadeln vom Schmelzpunkt 61° lieferte, die in absolutem Alkohol und Äther sehr leicht löslich sind.

Eine Verbrennung ergab folgende für Tolylphenylacetonitril stimmende Zahlen.

I. 0.2096 g gab 0.6697 g Kohlensäure und 0.1294 g Wasser.
II. 0.2819 g Substanz lieferte 16.5 cc Stickstoff bei 12° und 754 mm Druck.

Ber. für $C_6H_5 . < {CN \atop C_6H_4 . CH_3}$		Gefunden I.	Gefunden II.	
C	86.95	86.90	—	pCt.
H	6.28	6.84	—	"
N	6.77	—	6.90	"

[1] Ann. Chem. Pharm. **233**, 349.

Dieselbe Verbindung ist schon von Neure[1] auf eine umständliche Weise gewonnen worden, indem er Chlorphosphor auf Paraphenyltolylessigsäureamid einwirken liess, mit dem Unterschied, dass der Schmelzpunkt derselben von ihm zu 59° angegeben wurde.

Um die bedeutende Verharzung, die sich bei den beschriebenen Condensationen zeigt zu verringern, haben wir als wasserentziehendes Mittel Zinntetrachlorid benutzt, und auf diese Weise kann man in der That eine bedeutend bessere Ausbeute erzielen. Zu einer Lösung von Mandelsäurenitril in Toluol, in molecularen Verhältnissen, wurde die Hälfte am Gewichte von Zinntetrachlorid zugesetzt und das Gemisch färbte sich schon bei gewöhnlicher Temperatur stark dunkel; die Reaction wurde aber durch zweistündiges Erwärmen auf dem Wasserbade beendigt, wobei sich nur eine ganz geringe Entwicklung von Blausäure bemerkbar machte. Das Ganze wurde in Wasser gegossen und nach Zusatz von etwas Äther getrennt. Durch Destillation des Ätherrückstandes im Vacuum wurden neben unverändertem Toluol und etwas Benzaldehyd etwa 30 pCt. der theoretischen Ausbeute von Tolylphenylacetonitril als schwach gefärbtes, bald erstarrendes Öl gewonnen.

Zur Bereitung der Säure haben wir das Nitril mit concentrirter Salzsäure im Rohr auf 100° erhitzt, wobei aber nach 12 Stunden noch keine Verseifung stattgefunden hatte. Letztere Operation gelingt, wenn das Nitril während sechs Stunden mit einer concentrirten alkoholischen Kalilösung am Rückflusskühler erwärmt wird. Nach Entfernung des Alkohols und Zusatz von Wasser fällt beim Ansäuern ein roth gefärbtes Öl aus, welches wir zur Reinigung in Ammoniak lösten und durch Zusatz von Chlorbaryum in das fast unlösliche Baryumsalz per Tolylphenylessigsäure verwandelten. Durch Krystallisation aus Alkohol kann es, wie Zincke[2] beschreibt, leicht gereinigt werden; eine Krystallwasserbestimmung, die 2 Mol. Krystallwasser ergab, stimmt mit den Angaben von Zincke überein.

[1] Ann. Chem. Pharm. **250**, 149.

[2] Diese Berichte X, 997.

0.2203 g Substanz gaben 0.0145 g Wasser.

Ber. für $C_{28}H_{24}O_4Ca\ 2H_2O$		Gefunden
H_2O	6.84	6.59 pCt.

Durch Zersetzen dieses Salzes mit verdünnter Salzusäre gewinnt man die entsprechende Säure von Neuem als Öl, das in kurzer Zeit fast vollständig fest wird. Nach einigen Krystallisationen aus Alkohol erhielten wir die Verbindung rein mit dem schon von Zincke gefundenen Schmelzpunkt 115°.

Wir versuchten ferner Mandelsäurenitril mit Mesitylen zu condensiren und zwar so, dass auf 3 Theile Nitril 2 Theile Mesitylen und ein Theil Zinntetrachlorid, während sechs Stundun auf Wasserbadtemperatur erhitzt wurden. Durch Behandeln der Reactionsmasse mit Wasserdampf wurde unverändertes Mesitylen entfernt, das aus dem Rückstand gewonnene Öl, etwa 40 pCt. der theoretischen Menge, wurde bei 40 mm Druck zwischen 220° und 230° destillat. Das Destillat erstarrt sogleich und wurde durch wiederholte Krystallisation aus Ligroïn und verdünntem Alkohol in schwach gelblichen Prismen erhalten, die constant bei 91° schmolzen.

Die folgende Verbrennung stimmt mit Phenyltrimethylphenylacetonitril überein.

Ber. für $C_6H_5 - CH <\begin{matrix} CN \\ C_6H_2.\ (CH_3)_3 \end{matrix}$		Gefunden
C	86.80	86.57 pCt.
H	7.23	7.48 pCt.

Mit Naphtalin und Mandelsäurenitril geht die Condensation viel leichter vor sich als mit Benzol oder Toluol. Um das Phenylnaphtylacetonitril darzustellen, haben wir zuerst Phosphorpentoxyd auf das blosse Gemisch der beiden Körper einwirken lassen, aber es fand eine starke Blausäure-Entwickelung unter tiefgehender Verharzung statt. Wirh aben daher das Nitril wie das Naphtalin in Chloroform gelöst und nach Zusatz des Phosphorpentoxyds während sechs Stunden auf dem Wasserbade erwärmt. Die sehr dunkel gefärbte Flüssigkeit wurde alsdann mit Wasser behandelt und zur Trennung von den harzigen Nebenproducten mit Äther ausgeschüttelt;

der Rückstand, der nach dem Abdestilliren des Äthers hinterblieb, wurde im Vacuum rectificirt, wo, nachdem unverändertes Naphtalin übergegangen war, unter 45 mm Druck ein gelbes dickflüssiges Öl bei 280° ohne Zersetzung destillirte. Im Exsiccator erstarrte das ganze Destillat nach kurzer Zeit und die Masse wurde zur Reingewinnung aus Alkohol umkrystallisirt. Wir erhielten das neue Nitril auf diese Weise in schönen farblosen Prismen, die bei 97° schmolzen. Sie sind ziemlich löslich in Alkohol und Chloroform, weniger löslich in Äther und fast unlöslich in Ligroïn und Wasser. Durch folgende Verbrennung wird die Zusammensetzung als Naphtylphenylacetonitril bestätigt.

0.2295 g gaben 0.7481 g Kohlensäure und 0.1175 g Wasser.

	Ber. für $C_6H_5 . CH < {CN \atop C_{10}H_6}$	Gefunden
C	88.88	89.33 pCt.
H	5.76	5.69 pCt.

Selbst unter diesen Bedingungen ist die Ausbeute immer noch gering und geht nicht über 10 bis 12 pCt. der Theorie. Wurde dagegen Zinntetrachlorid als Condensationsmittel in Anwendung gebracht, so gelangten wir zu weit günstigeren Resultaten. Das Naphtalin wurde in Chloroform gelöst, dieselbe Menge Mandelsäurenitril zugefügt und mit der Hälfte des Gewichtes Zinntetrachlorid versetzt. Das Ganze erwärmte man während zehn Stunden auf dem Wasserbade, behandelte dann behufs Entfernung unveränderten Naphtalins und etwas gebildeten Benzaldehyds mit Wasserdampf und zog den Rückstand mit Äther aus. Wir gewannen auf diesem Wege 40 bis 45 pCt. der Theorie eines rothbraunen sehr dicken Öles, das unter 38 mm Druck fast vollständig zwischen 271° bis 274° als gelbliche, schön grünfluorescirende Flüssigkeit überging; sobald alles fest geworden war, reinigten wir das Product wie oben angegeben, durch Krystallisation aus Alkohol.

Die Verseifung dieses Naphtylphenylacetonitrils gelingt durch zweistündiges Erhitzen mit alkoholischem Kali, und zwar kamen auf einen Theil Nitril zwei Theile Kalihydrat in Anwendung. Versetzt man die noch heisse Lösung mit dem gleichen Volumen Wasser, so krystallisirt beim Erkalten das Kaliumsalz der Säure in perlmutterglänzenden Blättchen aus. Aus der wässrigen Lösung des Salzes fällt beim Ansäuern rein weisse Naphtylphenylessigsäure nieder, die nach Krystallisation aus Alkohol constant bei 141° schmilzt. Die Verbrennung dieser Säure gab folgende Zahlen:

0.1605 g Substanz gaben 0.4830 g Kohlensäure und 0.0770 g Wasser.

Ber. fur $C_6H_5 . CH<\begin{matrix}COOH\\C_{10}H_7\end{matrix}$		Gefunden
C	82.44	82.05 pCt.
H	5.33	5.34 "

Diese Säure bildet prismatische Säulen, welche in Alkohol, Ather, Chloroform und Schwefelkohlenstoff löslich sind, weniger leicht in Benzol und gar nicht in Wasser.

Die hier mitgetheilte Synthese von aromatischen Nitrilen besitzt ein zweifaches Interesse, da sie gestattet, sonst sehr schwierig darstellbare Körper leicht in jeder Quantität zu erhalten und sie ermöglicht deshalb das Verhalten solcher Nitrile [1] gegen Natrium leichter zu studiren.

Wir beabsichtigen die neuen Nitrile in dieser Beziehung zu untersuchen, sowie Versuche über die Condensation von anderen aromatischen, sowie auch fetten Hydroxynitrilen mit aromatischen Kohlenwasserstoffen anzustellen, und möchten uns die weitere Ausarbeitung dieses Themas vorbehalten.

[1] V. Meyer, Ann. Chem. Pharm. 250, 118.

ZUR KENNTNISS DER MANDELSÄURE UND IHRES NITRILS [1]

NACHDEM VON MEYER [2] gezeigt hat, dass Phenylacetonitril ein Natriumderivat lieferte, welches zur Darstellung von homologen Nitrilen benutzt werden kann, war es wahrscheinlich dass Phenyläthoxyacetonitril gegen Natrium in ähnlicher Weise sich verhalten würde. Die Ausbildung einer solchen Methode wäre insofern von Interesse, da man durch Einwirkung von Alkyljodiden und Erhitzen der alkylirten Verbindungen mit Salzsäure zur Synthese von der Atropasäure und Homologen derselben gelangen könnte.

Leider sind wir bei der Darstellung von Phenyläthoxyacetonitril auf unerwartete Schwierigkeiten gestossen, und es ist uns bis jetzt nicht gelungen, dessen habhaft zu werden, aber die dahin zielenden Versuche haben einige interessante Thatsachen kennen gelehrt, die wir hier mittheilen möchten, sowie auch einige Versuche über das Amid und den Äthyläther der Mandelsäure. In Betreff der letztgenannten Verbindungen existiren Angaben in der Literatur, wonach beide Verbindungen in zweifachen Formen existiren sollen und es schien von Wichtigkeit diesen Gegenstand näher zu untersuchen.

Wir haben zuerst das Natriumderivat des Mandelsäurenitrils darzustellen versucht, um darauf durch Einwirkung von Äthyljodid das gesuchte Phenyläthoxyacetonitril darzustellen.

Die Auflösung des Natriums in absolutem Alkohol wurde langsam mit der entsprechenden Menge des Nitrils versetzt, wobei nur eine leichte Trübung entstand. Sodann wurde die äquivalente Menge Jodäthyl hinzugefügt und auf dem Was-

[1] Printed in Berichte der deutschen chemischen Gesellschaft, XXV, 1678; also in pamphlet form, Berlin, 1892. With Mrs. Michael was associated John Jeanprêtre.

[2] Ann. Chem. Pharm. 250, 123.

serbade während einiger Stunden erwärmt. Wir haben aber nur Benzöin und Benzaldehyd aus dem Reactionsproduct gewinnen können. Es wurde nun die Einwirkung von Natrium allein auf Mandelsäurenitril in ätherischer Lösung untersucht. Es fand eine Einwirkung unter Wasserstoffentwicklung statt, aber das zuerst entstandene Natriumderivat hatte sich in Cyannatrium und Benzaldehyd zersetzt.

Wir haben nun das Phenyläthoxyacetonitril durch Darstellung des Phenylchloracetonitrils und Behandlung derselben mit Natriumäthylat darzustellen gesucht. Es wurde das Mandelsäurenitril tropfenweise zu einer Mischung von Phosphorpentachlorid mit dem dreifachen Gewichte Benzol gefügt, unter guter Abkühlung von aussen. Sobald die anfangs ziemlich heftige Reaction nachliess, wurde langsam auf dem Wasserbade erwärmt, bis alles Chlorid verschwunden ist. Nach Abkühlung wurde das Einwirkungsproduct vorsichtig auf zerkleinertes Eis gegossen, und nach vollständiger Zersetzung des Phosphoroxychlorids die Benzolschicht abgehoben.

Beim Abdestilliren des Benzols hinterblieb ein starkgefärbtes Öl, das im luftverdünnten Raume rectificirt wurde, und nach wiederholter Destillation ging die Hauptmenge zwischen 131° und 133° über:

0.1957 g Substanz gaben nach Carius 0.1856 g Chlorsilber.
0.1998 g Substanz lieferten 15.2 ccm Stickstoff bei 754 mm Druck und 7°.

	Berechnet für C_8H_6NCl	Gefunden
Cl	23.43	23.45 pCt.
N	9.24	9.16 "

Das Phenylchloracetonitril bildet eine farblose, stark lichtbrechende Flüssigkeit, deren Dämpfe auf Augen und Respirationsorgane einen ausserordentlich heftigen Reiz ausüben.

Wird dieses Nitril mit einem Überschuss von concentrirter Salzsäure im Rohr auf 100° erhitzt, so findet vollständige Verseifung statt. Die gebildete farblose Krystallmasse wurde abgesaugt und mit einer concentrirten Lösung von Natriumcarbonat behandelt. Die filtrirte alkalische Lösung schied beim Ansäuern ein gelbliches Öl aus, das beim Stehen bald erstarrte. Durch Krystallisation aus Alkohol erhielten wir die Säure in farblosen Nadeln vom Schmelzpunkt 78°, in Übereinstimmung mit den Angaben von R. Meyer[1] für die Phenylchloressigsäure, was durch die folgende Chlorbestimmung noch bestätigt wurde.

0.1804 g lieferten nach Carius 0.1478 g Chlorsilber.

Berechnet für $C_8H_7O_2Cl$	Gefunden
Cl 20.50	20.30 pCt.

Den in Natriumcarbonat unlöslichen Theil krystallisirten wir mehrere Male aus heissem Benzol um. Die farblosen, in Alkohol und Äther leicht löslichen Nadeln schmolzen ohne Zersetzung bei 116°.

Diese Substanz ist das Amid der Phenylchloressigsäure:

0.1404 g gaben 10.6 ccm Stickstoff bei 13° und 755 mm Druck.

Ber. für C_8H_8ONCl	Gefunden
N 8.86	8.26 pCt.

Die Einwirkung von Natriumäthylat auf das Chlornitril ergab ein unerwartetes Resultat. Bringt man das Nitril in eine alkoholische Lösung von Natriumäthylat, so entsteht augenblicklich ein Niederschlag, während die Lösung eine blaugrüne, dann gelbliche Färbung annimmt. Nach mehrstündigem Stehen wurde filtrirt und der Niederschlag mit Chloroform extrahirt, und von unlöslichem Salz abfiltrirt. Das Filtrat wurde verdunstet und der schwach gefärbte Rückstand, einmal aus Alkohol krystallisirt, schmolz bei 158°. Die aus einer Stickstoffbestimmung, sowie dem Schmelzpunkt gezogene Annahme dass der Körper Dicyanstilben sei, wurde durch Überführen in das Anhydrid der entsprechenden Säure vollkommen bestätigt.

Die Reaction wäre demnach folgendermaasen vor sich gegangen:

$$2\ \begin{array}{l} C_6H_5-CH\,Cl \\ \qquad\ \ | \\ \qquad\ CN \end{array} + 2NaOC_2H_5$$

$$= 2\ NaCl + 2C_2H_5OH + \begin{array}{c} C_5H_5-C-CN \\ \| \\ C_6H_5-C-CN \end{array}$$

[1] Ann. Chem. Pharm. **220**, 43.

Zu einem ganz gleichen Resultate gelangten wir, als trocknes in Benzol suspendirtes Natriumalkoholat angewandt wurde.

Um die Bildung des Dicyanstilbens zu erklären, kann man annehmen, dass zuerst ein unstabiles Natriumderivat des Phenylchloracetonitrils sich bildet, welches zugleich, unter Abspaltung von Salz, unter Polymerisation, oder auch dass zwei Moleküle desselben auf einander einwirken, um Dicyanstilben zu bilden.

Die beschriebenen Reactionen bieten eine vorzügliche Methode zur Darstellung vom Dicyanstilben, da das Chloronitril leicht in jeder Quantität darzustellen ist und die Ausbeute an Dicyanstilben bedeutend günstiger ist, als bei Anwendung des Verfahrens von Reimer.[1]

Fügt man zu einer ätherischen Lösung von Phenylchloracetonitril das Doppelte der äquivalenten Menge Anilin und erwärmt langsam auf dem Wasserbade, so scheidet sich salzsaures Anilin aus. Der Ätherrückstand wurde mit Wasser behandelt und sodann wiederholt aus Alkohol umkrystallisirt, wobei farblose Nadeln vom Schmelzpunkt 85° erhalten wurden, was, wie das Ergebniss folgender Stickstoffbestimmung mit den Angaben für Phenylanilidoessigsäurenitril von C. O. Cech.[2] und Tiemann und Piest[3] vollkommen übereinstimmt.

0.1572 g Substanz lieferten 19 ccm Stickstoff bei 13° und 753 mm Druck.

Ber. für $C_{14}H_{12}N_3$	Gefunden
N 14.19	14.15 pCt.

Wird Mandelsäurenitril mit Essigsäureanhydrid in molecularer Menge während 3 Stunden am Rückflusskühler zum Sieden erwärmt, so bildet sich fast quantitativ die Acetylverbindung. Durch Destillation im Vacuum wurde sie als farbloses dickflüssiges Öl erhalten, das unter 25 mm Druck bei 152° (Bad 170°) siedet.

Die Verbrennung dieser Verbindung lieferte entsprechende Zahlen:

[1] Diese Berichte XIV, 1798.
[2] Diese Berichte XI, 246.
[3] Diese Berichte XV, 2028.

0.1998 g Substanz gaben 0.4995 g Kohlensäure und 0.0988 g Wasser.

Ber. für $C_{10}H_{10}O_3N$	Gefunden
C 68.57	68.37 pCt.
H 5.15	5.48 "

Das Acetylmandelsäurenitril, das man mit dem gleichen Volumen Äther verdünnt hat, wurde langsam zu einem Überschusse von in Äther suspendirtem Natrium gefügt, worauf sich unter nur spärlicher Wasserstoffentwickelung ein gelblicher Niederschlag bildet. Zur Vollendung der Reaction wurde auf dem Wasserbade während zwei Stunden erwärmt. Der Niederschlag besteht theilweise aus einer natriumhaltigen Verbindung und wurde mit verdünnter Schwefelsäure behandelt. Der unlösliche Rückstand liefert, aus Alkohol krystallisirt, prismatische Nadeln von constantem Schmelzpunkt bei 134°. Das saure Filtrat enthielt Blausäure und Essigsäure und setzte nach einiger Zeit sehr wenige tafelförmige Krystalle vom Schmelzpunkt 115° ab, deren Zusammensetzung aber nicht ermittelt werden konnte.

Als Hauptproduct wurde die bei 134° schmelzende Verbindung gewonnen. Die bei der Verbrennung erhaltenen Zahlen stimmen annähernd auf Benzoïn, obgleich durch wiederholte Krystallisation der Schmelzpunkt nicht erhöht werden konnte.

	Gefunden		
Ber. für $C_{14}H_{12}O_2$	I.	II.	III.
C 79.2	78.55	78.76	79.34 pCt.
H 5.66	5.93	6.04	6.14 "

Wie Fischer[1] für das Benzoïn angiebt, reducirt auch dieses Product Fehling'sche Lösung in der Kälte, und es mag die Differenz in dem Schmelzpunkt wie auch den Verbrennungen von einer nicht zu entfernenden Verunreinigung herrühren.

Über die Amide der Mandelsäure existiren folgende Angaben:

Zinin[2] hat zuerst durch Einwirkung starker Säuren auf blausäurehaltiges Bittermandelöl eine krystallisirende, stickstoffhaltige, bei 194° schmelzende Verbindung erhalten, der er

[1] Ann. Chem. Pharm. **211**, 215. [2] Jahresber. 1868, 626.

die Zusammensetzung $2(C_6H_5 . COH)HCN$ zuschrieb. Als er diesen Körper mit Wasser auf 180° erhitzte, gewann er das von ihm zum ersten Male beschriebene Amid der Mandelsäure vom Schmelzpunkt 132°. Später liessen Tiemann und Friedländer[1] rauchende Salzsäure auf reines Mandelsäurenitril einwirken und gelangten zu einem Producte, das sie bei 190° schmelzend beschrieben. Eine beigegebene Verbrennung wies in vollkommener Übereinstimmung auf das Mandelsäureamid hin.

C. Beyer[2] stellte dann durch Erhitzen von salzsaurem Phenyloxyacetimidoäther ein Mandelsäureamid dar, das bei 132° schmolz. Indem er auf die Arbeit von Tiemann und Friedländer[3] zurückkommt, vermuthet er in dieser Abweichung einen Fall von Polymerie.

In letzter Zeit ist von J. Biedermann[4] eine Mittheilung erschienen, wo das angebliche *a*-Lacton der Mandelsäure mit Ammoniak behandelt wird und auf diese Weise, wie die Analysen zeigten, das Amid der Mandelsäure erhalten wurde, welches aber bei 190° schmolz.

Um diese Abweichungen etwas eingehender zu studiren, haben wir die angeführten Versuche theilweise wiederholt.

Als wir nach den Angaben von Tiemann und Friedländer Mandelsäurenitril mit rauchender Salzsäure stehen liessen, fanden wir den gebildeten Kuchen aus zwei verschiedenen, krystallisirten Verbindungen bestehend. Durch Krystallisation aus Alkohol gewinnt man sogleich farblose Nadeln vom Schmelzpunkt 194°, während aus der Mutterlauge eine bedeutend leichter lösliche Verbindung in rhombischen Tafeln erhalten wurde, die nach mehrmaliger Reinigung aus Alkohol constant bei 132° schmolzen und deren Menge mit der Stärke der Salzsäure zunahm.

Die höher schmelzende Verbindung ist in kaltem wie in heissem Wasser, Äther und kaltem Alkohol fast unlöslich, leicht löslich in heissem Alkohol. Eine Verbrennung ergab folgende Resultate, die für die von Zinin gegebene Zusammensetzung sprachen.

[1] Diese Berichte XIV, 1967.
[2] Journ. für prakt. Chem. 1885, 385.
[3] *Loc. cit.*
[4] Diese Berichte XXIV, 4083.

0.2394 g Substanz gaben 0.6595 g Kohlensäure und 0.1273 g Wasser.
0.4095 g Substanz gaben 22 ccm Stickstoff bei 763 mm Druck.

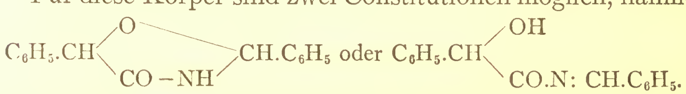
Berechnet für

	$C_{15}H_{13}O_2N$	$C_6H_5.CHOH$ | $CO.NH_2$	Gefunden
C	75.31	63.57	75.13 pCt.
H	5.40	5.96	5.90 "
N	5.90	9.47	6.18 "

Wir haben nun das bei 190° schmelzende Amid nach den Angaben von Biedermann darzustellen versucht. Der schwach gefärbte Krystallbrei wurde in kochendem Alkohol gelöst, woraus sich beim Erkalten als einzelnes Product kleine rhombische Tafeln ausschieden, deren Schmelzpunkt zu 132° statt, wie Biedermann angiebt, zu 190° gefunden wurde.

Um die Zusammensetzung des dei 194° schmelzenden Körpers zu beweisen, haben wir denselben auf folgendem indirekten Wege dargestellt. Das Mandelsäureamid wurde mit einer molecularen Menge von Benzaldehyd während zwei Stunden auf 130° erwärmt. Nach dem Erkalten wurde durch Waschen mit Äther etwas unveränderter Benzaldehyd entfernt, und die farblose Masse aus heissem Alkohol mehrmals umkrystallisirt. und erwies sich als identisch mit dem vom Zinin erhaltenen Körper.

Für diese Körper sind zwei Constitutionen möglich, nämlich:



Kommt ihm erstere Structur zu, so sollte er ein Nitrosoderivat liefern, während eine Verbindung mit der letzten Constitution leicht ein Acetylderivat bilden sollte. Die folgenden Versuche sprechen entschieden für die zweite Auffassung.

Die pulverisirte Verbindung wurde in Eisessig suspendirt und mit salpetriger Säure behandelt, es gelang jedoch in keinem Falle die Bildung einer Nitrosoverbindung zu konstatiren Wurde sie dagegen mit Essigsäureanhydrid am Rückflusskühler während einiger Zeit erhitzt, so entstand eine aus Alkohol in schöngebildeten Prismen krystallisirende Verbindung, die bei 123° schmilzt:

0.2580 g Substanz gaben 0.6842 g Kohlensäure und 0.1315 g Wasser.

Ber. für $C_{17}H_{15}O_3N$		Gefunden
C	72.59	72.32 pCt.
H	5.33	5.66 "

In der Literatur über Mandelsäure findet sich noch ein weiterer Punkt, den wir in Folgendem aufzuklären gesucht haben.

Naquet und Louguinine[1] haben den Mandelsäureäthylester durch Einwirkung von Jodäthylr auf das Silbersalz dargestellt und als einen krystallinischen Körper vom Schmelzpunkte 79° beschrieben. C. Beyer[2] hat denselben Äther durch Spaltung von Phenoxyacetimidoäther beim Erhitzen mit Wasser erhalten und als eine farblose, in Kältemischung erstarrende Flüssigkeit beschrieben, die bei 250° unzersetzt destillirt. Vor Allem handelte es sich darum, nach den Angaben von Naquet und Louguinine die bei 79° schmelzende Verbindung zu bereiten. Das im Vacuum getrocknete Silbersalz erhitzten wir im geschlossenen Rohre bei 100° während 12 Stunden mit einem geringen Ueberschuss von Jodäthyl. Das Reactionsproduct wurde mit Äther ausgezogen und der nach dem Verdampfen des Äthers bleibende gefärbte Rückstand destillirt. Schon nach der zweiten Destillation erhielten wir ein vollkommen farbloses, stark lichtbrechendes, Öl, in Übereinstimmung mit den Angaben von Beyer.

Nach einiger Zeit aber erstarrte die ganze Masse krystallinisch. Durch Umkrystallisiren aus Petroläther wurden sehr feine seidenglänzende Nädelchen erhalten, die bei 34° constant schmolzen und deren Zusammensetzung durch folgende Verbrennung bestätigt wurde.

Ber. für $C_6H_5CH\,OH$ | $COO\,C_2H_5$		Gefunden
C	66.67	66.50 pCt.
H	6.67	6.73 "

Es gelang uns nich eine Verbindung vom Schmelzpunkt 79° darzustellen, sodass es scheint, als ob Naquet und Louguinine nicht den Mandelsäureäther, sondern wohl ein anderes Derivat der Säure in Händen gehabt haben.

[1] Bull. Soc. Chim. 1866, **5**, 255.

[2] J. prakt. Chem. 1885, 389.

ZUR KENNTNISS DER ADDITION VON BROM UND CHLOR ZU FESTER CROTONSÄURE[1]

NACHDEM J. WISLICENUS[2] die Configuration der α-Brom und Chlorcrotonsäure vermittelst seiner Hypothese entwickelt hatte, wurde von A. Michael[3] darauf hingewiesen, dass bei der consequenten Anwendung dieser Annahme auf bekannte Thatsachen nicht weniger als drei verschiedene Configurationen für jede dieser Säuren gleich berechtigt waren. In seiner speciellen Arbeit über die Crotonsäuren[4] und seiner „Antikritik"[5] kommt Wislicenus auf die discutirte Frage zurück, und sucht auf Grund ausgedehnter Versuchsreihen über die Addition von Brom und Chlor zu fester Crotonsäure unter verschiedenen Bedingungen und unter Aufstellung der neuen, für diesen Zweck ersonnenen Annahme der „unfertigen" Moleküle[6] seine früheren Erklärungen aufrecht zu halten. Wollte man aber auch der neuen Hypothese zustimmen, und die angeführten experimentellen Versuche als zutreffend ansehen, so wären die Configurationen von Wislicenus selbst dann nicht durchführbar, denn er hat bei seinen Betrachtungen übersehen, dass es sich bei den betreffenden Reactionen nicht um freie Säuren, sondern um Salze derselben handelt, und seine Annahmen standen direct im Widerspruch mit sehr einfachen und bekannten Auffassungen analoger Reactionen.[7]

Nach Wislicenus sind die α-Brom- und die α-Chlorcrotonsäure „abnorme" Zersetzungsprodukte der $\alpha\beta$-Dibrom-, resp. Dichlorbuttersäure, und verdanken ihre Entstehung

[1] Printed in the Journal für praktische Chemie, neue Folge, Band 46, 273; also in pamphlet, Leipzig, Johann Ambrosius Barth (n. d.).

[2] Räuml. Anord. S. 41–45.

[3] Dies. Journ. [2] **38**, 7–11.

[4] Ann. Chem. **248**, 281.

[5] Das. S. 344.

[6] Das. S. 328.

[7] A. Michael, dies. Journ. [2] **40**, 30–34.

dem Einfluss der Wärme, und er behauptete, dass rein $\alpha\beta$-Dichlorbuttersäure in der Kälte „keine Spur" von α-Chlorcrotonsäure liefert. Es ist aber oben bewiesen worden, dass diese Dichlorbuttersäure eine beträchliche Menge von α-Chlorcrotonsäure in der Kälte liefert, und dass das relative Bildungsverhältniss derselben auch in der Wärme das gleiche ist. Es war kein Grund vorhanden, die W i s l i c e n u s' schen Versuche über die Addition bei erhöhter Temperatur zu wiederholen, weil seinen, unter einander nicht übereinstimmenden, Resultaten eigentlich keine Beweiskraft zukommt, und schon die bedeutend grössere Chlorwasserstoffentwicklung, die unter solchen Bedingungen vor sich geht, mahnte gegen das Heranziehen solcher Versuche für theoretische Schlüsse. In Betreff des vereinzelten Versuchs der Bromaddition ohne Abkühlen wird unten nachgewiesen, dass demselben kein Wert beizulegen ist. Dagegen war es von Interesse, auf die W i s l i c e n u s' schen Versuche über den Einfluss des mehr oder weniger schnellen Zusatzes des Halogens auf die relative Mengen der gebildeten alloisomerischen $\alpha\beta$-Dihalogenbuttersäuren näher einzugehen.

Es wurden zuerst qualitative Versuche angestellt über die Rolle welche das Licht bei der Bromaddition spielt, und inwiefern das ölige Nebenprodukt, welches W i s l i c e n u s für allo-$\alpha\beta$-Dibrombuttersäure gehalten hat, hiermit in Verbindung steht. 10 Grm. reine feste Crotonsäure wurden in zwanzigfacher Menge gereinigten Schwefelkohlenstoffs gelöst, das Gefäss an einen dunkeln Ort gestellt, und tropfenweise die theoretische Menge mit CS_2 verdünnten Broms (18,6 Grm.) zugesetzt. Gewöhnlich, selbst im schwach zerstreuten Licht, bemerkt man, dass ein nicht unbedeutender Antheil des Broms sogleich beim Eintritt in die Lösung sich entfärbt, aber bei diesem Versuch war von einer Entfärbung nichts zu sehen; nach Zusatz von wenigen Tropfen der Bromlösung hatte die Crotonsäurelösung die Farbe des Broms angenommen. Nachdem alles Brom zugesetzt war, blieb die Lösung mehrere Tage an demselben Ort, und da beim Stehen die Farbe der Lösung nicht abnahm, so wurde das Lösungsmittel verjagt und die nach längerem Stehen abgeschiedenen Krystalle von dem dicken Öl getrennt. Sehr bemerkbar war die Bildung von Bromwasserstoff, und zwar in bedeutender Menge, was auf eine Substitutionswirkung des Halogens hindeutete. Die Krystalle wogen 17 Grm. und bestanden aus bei 87° schmelzender $\alpha\beta$-Dibrombuttersäure. Das Öl hatte einen sehr üblen, an Chlorschwefel erinnernden Geruch, und enthielt noch $\alpha\beta$-Dibrombuttersäure, da durch Behandeln desselben mit überschüssigem Kali α-Bromcrotonsäure gewonnen werden konnte. Die Addition von Brom zu Crotonsäure im halb dunkeln Licht wurde mehrfach unter etwas abgeänderten Bedingungen wiederholt, und stets ein ähnliches Resultat erhalten. Es wurden nun 5 Grm. Säure in CS_2 gelöst und 1,9 Grm. Brom (etwa ein Fünftel der Theorie) auf einmal zugesetzt, und die Flasche in halb dunkles Licht gestellt. Nach zehnstündigem Stehen besass die Lösung noch die Farbe des Broms, und sie wurde nun in helles zerstreutes Licht gestellt, wobei sogleich bemerkt wurde, dass eine Entfärbung der Lösung, und zwar zuerst am Boden der Flasche, anfing. Nach kurzer Zeit war die Lösung ganz entfärbt, und es wurde nun jedesmal ein neues Fünftel Brom erst nach Entfärbung der Lösung zugesetzt. Bromwasserstoff hatte sich auch bei diesem Versuch gebildet, aber in weit geringerer Menge, als bei den vorangehenden Versuchen. Das Additionsprodukt wog 14,1 Grm. (Theorie 14,3 Grm.) und bestand zum weitaus grössten Theil aus harten Krystallen neben sehr wenig Öl. Bei einem anderen Versuch wurde die Lösung auf — 17° abgekühlt, dem hellen zerstreuten Licht ausgesetzt und nun auf einmal die nöthige Menge mit CS_2 verdünnten und ebenfalls abgekühlten Broms hinzugefügt. Bei diesem Versuch wurden 14 Grm. einer harten Krystallmasse erhalten, ohne dass selbst eine Spur des Öls gebildet worden war. Ein weiterer Versuch wurde nun unter Anwendung von reinem Tetrachlorkohlenstoff als Lösungsmittel im hellen Licht und unter Abkühlung ausgeführt, und die theoretische Menge des Additionsprodukts, ohne Bildung einer Spur des Öls, und nur von sehr wenig Bromwasserstoff, erhalten.

Nachdem nun die Bedingungen zu einer glatten Addition ermittelt waren, konnte ich zur quantitativen Untersuchung des Vorganges übergehen. Die käufliche Crotonsäure ist stets etwas verunreinigt, und wird am leichtesten gereinigt durch Umkrystallisiren aus heissem Ligroin und durch Destillation der Krystalle, indem man die zwischen 180°—181° siedende Fraction besonders auffängt. Dieser Antheil schmilzt bei 72°, obwohl er schon etwa ein Grad niedriger zu erweichen anfängt. Um überhaupt vergleichbare Resultate über den Einfluss des schnellen oder langsamen Zutritts des Broms zu erhalten, muss man vor Allem dafür sorgen, dass die zu vergleichenden Produkte zur gleichen Zeit und unter ganz gleichen Bedingungen aufgearbeitet werden. Es wurde daher bei jeder der fünf Versuchsreihen der Versuch, wobei die ganze Menge des Halogens auf einmal zugesetzt wurde, erst angestellt, nachdem das letzte Fünftel des Broms bei dem Versuch mit langsamem Bromzusatz zugefügt war, und nach Entfärbung die Produkte der beiden Versuche gleichzeitig und unter absolut gleichen Bedingungen aufgearbeitet. Die Verhältnisse der ersten Versuchsreihe werden eingehender beschrieben, und zu den anderen nur dann Bemerkungen gemacht, wenn abweichende Resultate bemerkt worden sind.

I. 3 Grm. Crotonsäure wurden in 45 Grm. reinem CCl_4 gelöst, die Lösung in Eis abgekühlt, und auf einmal 5,6 Grm. Brom (Theorie 5,58 Grm.) zugesetzt. Die Lösung wurde nun den directen Sonnenstrahlen ausgesetzt, wobei fast sogleich die Bildung einer weissen Wolke von Bromwasserstoff im obern Theil der Flasche zu bemerken war, die nach kurzem Stehen verschwand. Die stets abgekühlte Lösung war in weniger als einer Stunde ganz entfärbt, und beim Öffnen der Flasche konnte man erst beim Ausgiessen der Flüssigkeit eine Spur Bromwasserstoff bemerken. Der Tetrachlorkohlenstoff wurde unter etwa 15 Mm. Druck zuerst bei gewöhnlicher Temperatur abdestillirt, zuletzt kurze Zeit auf 35° erwärmt, und die rückstandige, g a n z f e s t e sowie weisse, krystallinische Masse mit reinem Äther in eine tarirte Krystallisirschale gespült. Die Schale wurde im Vacuum über geschmolzenem $CaCl_2$ und Paraffin unter beständigem Absaugen gelinde auf und nieder bewegt, wobei der Äther in kurzer Zeit vertrieben wurde, und die Krystallmasse über $CaCl_2$ und Paraffin, nicht über H_2SO_4, da dadurch ein nicht unbebeutender Verlust an Dibromsäure stattfindet, so lange in einem partiellen Vacuum gelassen, bis nach zwölfstündigem Stehen ein Verlust von nur etwa 0,005 Grm. zu bemerken war. Das Produkt, eine ganz harte Krystallmasse, wurde mit 10 Grm. Wasser übergossen, in Eiswasser gestellt und allmählich so viel einer normalen Kalilösung zugetropft, dass auf 1 Mol. der Säure $2\frac{1}{2}$ Mol. KOH kamen. Nach zwölfstündigem Stehen in der Kälte wurde mit 20 procent. H_2SO_4 stark angesäuert, und fünfmal mit reinem Äther ausgezogen. Da Wislicenus nicht anführt, ob er bei seinen Versuchen den ätherischen Auszug getrocknet hat, so wurden bei dieser Versuchsreihe derselbe ohne Weiteres gelinde erwärmt, bis der grösste Theil des Äthers abdestillirt war, der abdestillirte Äther aus einem anderen Siedekolben nochmals überdestillirt, da sehr wenig Bromcrotonsäure bei dem ersten Abdestilliren mit übergeht, und die ätherische Lösung, wie schon oben beschrieben worden ist, in das Vacuum gestellt. Das feste Gemisch der α-Bromcrotonsäuren wurde in 100 Ccm. absoluten Alkohols gelöst, und die Lösung sofort mit einer alkoholischen Lösung von Kalihydrat neutralisirt. Nach zwölfstündigem Stehen wurde von dem abgeschiedenen, von Wislicenus als rein angenommenen α-bromcrotonsauren Kalium abfiltrirt, der Niederschlag bei 100° getrocknet, und das alkoholische Filtrat zur Trockne eingedampft und ebenfalls bei 100° getrocknet.

Bei dem zweiten Versuch in dieser Reihe wurde das gleiche Verhältniss von Säure und Lösungsmittel angewandt, die Lösung auf ungefähr 10°—12° gehalten und nach jedem Tage ein Fünftel der Brommenge auf einmal zugesetzt. Die Flasche wurde in so zerstreutes Licht gestellt, dass die Addition nur langsam vor sich ging. Bis zur letzten Addition hat sich jedesmal die Lösung ganz entfärbt, und eine fast farblose Lösung wurde auch zuletzt erhalten, als die Lösung unter Abkühlung $\frac{1}{2}$ Stunde dem Sonnenlicht ausgesetzt wurde. Es wurde die Bildung einer sehr kleinen Menge eines unlöslichen Öls bemerkt, dessen Entstehung beim ersten Versuch ausblieb; auch hatte sich bedeutend mehr, obwohl nicht sehr viel, Bromwasserstoff gebildet.

II. Bei der zweiten Versuchsreihe wiederholten sich dieselben Erscheinungen, und der einzige Unterschied in der Bearbeitung der Additionsprodukte bestand darin, dass die ätherischen Lösungen der Säuren, wie auch in den folgenden Reihen, mit wasserfreiem Natriumsulfat getrocknet waren, wobei zu bemerken ist, dass man das Salz mehrmals mit Äther auswaschen muss, da kleine Mengen der Säure leicht zurückgehalten werden.

III. Die dritte Reihe wurde bei sehr nebeligem Wetter ausgeführt, und obwohl die Lösung beim ersten Versuche direct vor dem Fenster stand, und zwar bei etwa 10°—12°, vergingen vier Tage, bevor die sonst in weniger als einer Stunde stattfindende Entfärbung erfolgte. Dieselbe Erscheinung wurde beim zweiten Versuch beobachtet; es war z. B. am dritten Tag die Lösung noch sehr stark von freiem Brom gefärbt, aber als dann blauer Himmel sich zeigte, fand die Entfärbung in kurzer Zeit statt. Bei diesen Versuchen schieden sich aus dem alkoholischen, allo-bromcrotonsaures Natrium enthaltenden Filtrate würfelförmige Krystalle aus, die aus Bromkalium bestanden, eine Erscheinung, die ich in keiner anderen Reihe beobachtete; wohl aber ist zu bemerken, dass das Gemisch der Bromcrotonsäuren vor der Neutralisation durch einen Zufall vier Stunden lang in alkoholischer Lösung blieb.

IV. und V. Die vierte und die fünfte Reihe verliefen ganz wie schon beschrieben worden ist, es wurde stets ein ganz festes Additionsprodukt erhalten. Bei allen diesen Versuchen zeigte sich, dass die Addition am glattesten vor sich ging, wenn man die stark abgekühlte Lösung direct in das Sonnenlicht stellte, und sie bestätigten die frühere Beobachtung, dass, je schneller dieselbe stattfand, desto weniger Bromwasserstoff gebildet wird.

TABELLE I. RESULTATE DER FÜNF VERSUCHSREIHEN

Versuchsreihen.	*Art des Bromzusatzes.*	*Dibrombuttersäuren.*	*Monobromcrotonsäuren.*	*a-bromcrotonsaures Kalium.*	*allo-a-bromcrotonsaures Kalium.*	*Gesammtmenge d. Kaliumsalze.*
		Grm.	Grm.	Grm.	Grm.	Grm.
Theorie	—	8,5814	5,7556	—	—	7,0814
I.	auf einmal	8,4036	5,6274	0,6377	6,1847	6,8224
	portionsweise	8,3555	5,5029	0,6741	5,9277	6,6018
II.	auf einmal	8,5218	5,5591	0,4616	6,3863	6,9479
	portionsweise	8,4072	5,4448	0,4951	5,8176	6,3122
III.	auf einmal	8,4878	5,7518	0,4160	6,6301	7,0347
	portionsweise	8,4139	5,5498	0,4486	6,0180	6,4666
IV.	auf einmal	8,4483	5,6439	0,6660	6,0875	6,7538
	portionsweise	8,3815	5,5016	0,4855	6,0072	6,4927
V.	auf einmal	8,5408	5,6086	0,4983	6,4186	6,9169
	portionsweise	8,3110	5,5418	0,5131	6,3878	6,9009

TABELLE II. BERECHNETE WERTE AUS OBIGEN RESULTATEN

Versuchsreihen.	*Art des Bromzusatzes.*	*Relative Verhältnisse des erhaltenen.*		*Verhältnisse des a-bromcrotons. Kalium auf 100 Thle. theoret. Ausbeute.*
		a-bromcrotons. Kalium.	*allo-a-bromcrotons. Kalium.*	
I.	auf einmal	9,34	90,66	9,00
	portionsweise	10,21	89,79	9,51
II.	auf einmal	6,64	93,36	6,52
	portionsweise	7,84	92,16	6,99
III.	auf einmal	5,91	94,09	5,08
	portionsweise	6,93	93,17	6,32
IV.	auf einmal	9,86	90,14	9,40
	portionsweise	7,47	92,53	6,85
V.	auf einmal	7,20	92,80	7,03
	portionsweise	7,43	92,57	7,24

TABELLE III. ANALYTISCHE RESULTATE

Veruschs-reihen.	*Art des Bromzusatzes.*	*Angew. Menge α-bromcrotons. Kalium.*	*Erhalt. Menge K_2SO_4.*	*Angew. Menge allo-α-bromcrotonsaures Kalium.*	*Erhalt. Menge K_2SO_4.*	*Kaliumgehalt.* *α-bromcrotons. Kalium.*	*Kaliumgehalt.* *allo-α-bromcrotons. Kalium.*
		Grm.	Grm.	Grm.	Grm.	Proc.	Proc.
Theorie	—	—	—	—	—	19,20	19,20
I.	auf einmal	0,2157	0,1060	0,2810	0,1273	22,06	20,32
	portionweise	0,3501	0,1881	0,4311	0,1984	24,12	20,63
II.	auf einmal	0,1575	0,0693	0,4897	0,2109	19,75	19,34
	portionweise	0,1385	0,0605	0,2205	0,0965	19,61	19,64
III.	auf einmal	0,0827	0,0362	0,6318	0,2795	19,65	19,85
	portionweise	0,0915	0,0405	0,7025	0,3235	19,86	20,67
IV.	auf einmal	0,1385	0,0660	0,9101	0,4052	21,39	19,98
	portionweise	0,1010	0,0445	0,3295	0,1480	19,78	20,16
V.	auf einmal	0,2142	0,0939	0,2758	0,1215	19,68	19,76
	portionweise	0,2713	0,1191	0,1849	0,0837	19,73	20,32

Zu diesen analytischen Resultaten ist zu bemerken, dass sämmtliche Kaliumsalze Spuren von Kaliumbromid enthielten, indessen war fast stets etwas mehr in den *α*-bromcrotonsauren als in den allo-bromcrotonsauren Salzen; in verhältnissmässig namhaften Spuren kommt es in den beiden *α*-Salzen von Versuchsreihe I und in nicht unbedeutender Menge im Salz von dem ersten Versuch der Reihe IV vor. In Betreff dieser letzten Versuche ist hervorzuheben, dass durch ein Versehen die alkoholische Lösung des Gemisches von den *α*-Bromcrotonsäuren etwa 2 Stunden vor der Neutralisation mit Kali sich überlassen wurde und man schon mit blossem Auge die würfelförmigen Krystalle von Kaliumbromid im Niederschlag erkennen konnte. Wahrscheinlich ist ein kleiner Theil der Säuren verestert worden, so dass dieser Versuch eigentlich von keinem grossen Wert ist. Auch konnten Spuren von kohlensaurem Kalium in einigen der Niederschläge nachgewiesen werden, scheinbar mehr in den allo-*α*-, als in den *α*-Brom-salzen; vielleicht rührt dies zum Theil von dem unvermeidlichen geringen Ueberschuss von Kali her, das man zur Neutralisation benutzt. Merkwürdiger Weise war aber viel mehr Kohlensäure nachweisbar in allen Salzen der ersten Versuchsreihe als in den Salzen der anderen Reihe, womit wohl der hohe Kaliumgehalt dieser Salze in Verbindung steht.

Wir sind nun im Stande zu erklären, in welcher Weise W i s l i c e n u s in Betreff der Bildung von „abnormen" Produkten bei der Addition von Brom zu Crotonsäure sich täuschte, und weshalb seine hierauf bezüglichen Versuche fehlerhaft sind. Er hat zuerst Versuche mit einander verglichen, die nicht unter absolut gleichen Bedingungen ausgeführt waren, und namentlich ist in seinen Arbeiten kein Anzeichen vorhanden, dass er den Einfluss des Lichtes auf den Additionsvorgang irgendwie erkannt, ober bei seinen Versuchen in Betracht gezogen hat. Er hat ferner Schwefelkohlenstoff angewandt, ein Lösungsmittel, das meistens zu quantitativen Versuchen mit Brom wenig empfehlenswerth ist; denn, wie oben gezeigt wurde, bildet sich im schwachen Licht stets ein schwefelhaltiges Öl, das namentlich entsteht, wenn man das Reagens nicht sehr sorgfältig reinigt, und die Addition sehr langsam vor sich gehen lässt. Die Verhältnisse bei der Bromaddition waren gerade geeignet, um solche Täuschungen als wahrscheinliche Beweise erscheinen zu lassen, denn die relative Menge der entstehenden α-Bromcrotonsäure ist nur gering, so dass eine kleine Gewichtsvermehrung der Niederschläge als beweisend für die Annahme von „abnormen" Produkten und „unfertigen Molekülen" angesehen werden konnte. Es ist sicherlich aber schwer zu verstehen, wie W i s l i c e n u s sich begnügen konnte, eine an sich so unwahrscheinliche Hypothese aufzustellen ohne zu versuchen, die hypothetischen „hochmolekularen" Produkte zu isoliren, oder wenigstens zu ermitteln, ob die geringe scheinbare Zunahme der α-Bromcrotonsäurebildung nicht andersartigen Verunreinigungen zuzuschreiben ist. Hätte er dies versucht, so würde er gefunden haben, dass man bei richtig angestellten Versuchen nur die bei 106° schmelzende α-Bromcrotonsäure daraus isoliren konnte.

Überblickt man die in den obigen Tabellen zusammengefassten Resultate, so wird man sofort erkennen, dass absolut kein Grund vorhanden ist, die Bildung von „abnormen" Produkten oder „unfertigen" und „hochmolekularen" Molekülen bei der Addition von Brom zu Crotonsäure anzunehmen. Die geringfügigen Differenzen in den procentigen Verhältnissen der gebildeten *α*-Bromcrotonsäure bei schnellem oder langsamem Bromzutritt liegen ganz innerhalb der Grenzen von den bei solchen Versuchen unvermeidlichen experimentellen Fehlern, wie aus den bei verschiedenen Versuchsreihen erhaltenen Zahlen klar hervorgeht. Bei solchen Versuchen, wie in Versuchsreihe I, wo eine abnorme Menge von *α*-Bromcrotonsäure scheinbar gebildet wurde, ist das Verhältniss zu gross, unabhängig von der Art des Bromzusatzes, und es handelt sich hier, wie die Analysen zeigten, nicht um eine grössere Menge von Säure, sondern um Verunreinigungen, die wohl grösstentheils aus Mineralsalzen bestehen. Der oben angeführte Beweis, dass bei der Zersetzung von reiner *αβ*-Dibrombuttersäure schon etwa 4% an *α*-Bromcrotonsäure gebildet werden, verbunden mit meinen Resultaten, wonach etwa 7% dieser Säure bei der Zersetzung des rohen Additionsproduktes entstehen, machen es wahrscheinlich, dass ungefähr 3% allo-*αβ*-Dibromcrotonsäure als normales Produkt der Addition von Brom zu Crotonsäure gebildet werden. Es schien mir unnöthig, den vereinzelten Versuch, den Wislicenus durch Vermischen bedeutender Mengen Brom und Crotonsäure in Schwefelkohlenstofflösung, wobei die Flüssigkeit 20 Minuten lang kochte, zu wiederholen, denn ein solcher Versuch konnte unmöglich regelrecht sein, wie man schon an der relativ grossen Menge von Öl, welches Wislicenus erhalten hat, erkennt.

Merkwürdiger Weise hat Wislicenus bei allen seinen Versuchen übersehen, dass immer Bromwasserstoff entsteht, und zwar, wenn man wie bei einem solchen Versuch verfährt, in nicht unbedeutender Menge; obwohl er so entschienen gegen verschiedene Forscher, die bei anderen Untersuchungen die Bildung desselben nicht hervorgehoben haben, aufgetreten ist.

Die Versuche von Wislicenus über die schnelle oder verlangsamte Addition von Chlor zu Crotonsäure ergaben Resultate, die unter einander so differirten, dass denselben schon damals eigentlich keine Beweiskraft zugemessen werden konnte; ich habe trotzdem einige Versuche über diese Reaction angestellt, woraus hervorgeht, dass es bei richtig angestellten Versuchen, beim Chlor wie beim Brom, nicht darauf ankommt, in welcher Weise der Zusatz geschieht.

Vorläufige Versuche zeigten, dass die Addition meistens besser vor sich geht in Gegenwart von wenig gereinigtem Schwefelkohlenstoff, unter Abkülung, in hellem diffusem Licht. Die Addition von Chlor ist ein so leicht vor sich gehender Process, dass es nicht nöthig ist im Sonnenlicht zu arbeiten.

I. 3 Grm. pulverisirte Crotonsäure wurde mit etwas Schwefelkohlenstoff übergossen, auf —17° abgekühlt, und die berechnete Menge, ebenfalls abgekühltes Chlor, in Tetrachlorkohlenstoff gelöst, zugesetzt, indem die Flasche im hellem diffusem Licht stand. Die Addition ging sehr schnell vor sich, und war nach einigen Minuten vollendet. Obwohl eine geringe Menge Chlorlösung noch zugesetzt wurde, zeigte die Lösung, selbst nach $\frac{1}{2}$ Stunde, die Anwesenheit einer Spur freien Halogens und nur Spuren Chlorwasserstoffsäure. Die Bearbeitung des Additionsproduktes geschah ganz wie schon bei den Versuchen mit Brom beschrieben ist. Die gebildete, rein weisse Dichlorbuttersäure war, bis auf eine Spur Öl, ganz fest.

II. Vorangehender Versuch wurde zur gleichen Zeit angestellt, als die letzte Portion Chlorlösung bei diesem Versuch zugesetzt worden war. Der Unterschied bestand darin, dass bei diesem Versuch die Chlormenge in Portionen von je $\frac{1}{5}$ in 5 Tagen zugesetzt wurde, und die abgekühlte Flasche in bedeutend schwächeres Licht gestellt wurde, damit die Addition nicht so schnell vor sich gehe. Auch hier bekam man, bis auf eine sehr geringe Menge, ein festes Additionsprodukt, obwohl die gebildete Salzsäure etwas bedeutender war, als bei dem vorigen Versuch.

III. Wei bei II das Chlor schnell, und IV. in 5 Portionen wie bei II zugesetzt. Die Bearbeitung dieser Versuche geschah nicht zu gleicher Zeit, wie dies bei I und II der Fall war, sonst sind keine Unterschiede in Betreff derselben hervorzuheben.[1]

TABELLE I. GEFUNDENE RESULTATE

Versuch.	*Art des Chlorzusatzes.*	*Dichlorbuttersäure.*	*Monochlorcrotonsäuren.*	*α-chlorcrotonsaures Kalium.*	*allo-α-chlorcrotonsaures Kalium.*	*Gesammtmenge der Kaliumsalze.*
		Grm.	Grm.	Grm.	Grm.	Grm.
Theorie	—	5,476	—	—	—	—
I.	auf einmal	5,383	3,834	1,264	3,463	4,727
II.	portionsweise	5,400	3,818	1,306	3,596	4,912
III.	auf einmal	5,358	3,847	1,374	3,895	5,269
IV.	portionsweise	5,359	3,695	1,163	3,391	4,554

Theorie für Kalium im chlorcrotonsauren Kalium sind 24,60%

I. 0,1864 Grm. α-chlorcrotonsaures Salz gaben 0,1025 Grm. K_2SO_4 = 24,67% Kalium.

0,5843 Grm. allo-α-chlorcrotonsaures Salz gaben 0,3228 Grm. K_2SO_4 = 24,79% Kalium.

II. 0,1683 Grm. α-chlorcrotonsaures Salz gaben 0,0925 Grm. K_2SO = 24,67% Kalium.

0,1888 Grm. allo-α-chlorcrotonsaures Salz gaben 0,1046 Grm. K_2SO_4 = 24,83% Kalium.

III. 0,1125 Grm. α-chlorcrotonsaures Salz gaben 0,0618 Grm. K_2SO_4 = 24,66% Kalium.

0,2297 Grm. allo-α-chlorcrotonsaures Salz gaben 0,1242 Grm. K_2SO_4 = 24,13% Kalium.

IV. 0,2370 Grm. α-chlorcrotonsaures Salz gaben 0,1283 Grm. K_2SO_4 = 24,26% Kalium.

0,1242 Grm. allo-α-chlorcrotonsaures Salz gaben 0,0685 Grm. K_2SO_4 = 24,76% Kalium.

[1] Da die α-Monochlorcrotonsäuren sich noch leichter im Vacuum verflüchtigen, als die entsprechenden Bromsäuren, so ist es ganz unmöglich, ein selbst annähernd constantes Gewicht zu erhalten. Die Versuche I und II sind unter absolut gleichen Bedingungen ausgeführt wurden, und es kann daher dieser Umstand keinen wesentlichen Einfluss auf das Endresultat ausgeübt haben, obwohl aus dem theoretischen Gewicht der Chlorcrotonsäuren hervorgeht, dass eine kleine Menge der Chlorsäuren sich verflüchtigt haben muss. Beim Versuch IV verblieben, in der Hoffnung, ein mehr constantes Gewicht zu erhalten, die Säuren länger im Vacuum, als beim III., wodurch die noch geringere Ausbeute erklärt wird.

TABELLE II. BERECHNETE WERTE AUS OBIGEN VERSUCHEN

Versuch.	*Art des Chlorzusatzes.*	*Relatives Verhältniss des erhaltenen.*	
		α-chlorcrotonsauren Kalium.	*allo-α-chlorcrotons. Kal.*
I.	auf einmal	26,7	73,3
II.	portionsweise	26,6	73,4
III.	auf einmal	26,1	73,9
V.	portionsweise	25,5	74,5

Es ist aus obigen Resultaten ersichtlich, dass, ebenso wenig wie mit Brom, die Wislicenus'schen Annahmen und Erklärungen betreffend den Einfluss von schnellen und verlangsamten Additionen von Chlor zu fester Crotonsäure richtig und stichhaltig sind. Bemerkenswerth ist, dass man bei der Chloraddition anscheinend ein Gemisch reinerer Chlorcrotonsäuren nach der Zersetzung der Dichlorbuttersäure gewinnt, wie dies aus den sehr genau stimmenden Zahlen der Kaliumbestimmungen hervorgeht, als bei den entsprechenden Versuchen mit Brom. Zieht man in Betracht, dass bei der Kalizersetzung von reiner $\alpha\beta$-Dichlorbuttersäure schon etwa 16% β-Chlorcrotonsäure gebildet werden, so ist man berechtigt anzunehmen, dass etwa 10% allo-$\alpha\beta$-Dichlorbuttersäure als normales Additionsprodukt bei der Einwirkung von Chlor auf Crotonsäure gebildet werden; daher in beträchtlich grösserem Verhältniss, als die allo-$\alpha\beta$-Dibromsäure, von der nur etwa 3% bei der Addition von Brom zu Crotonsäure entsteht.

ZUR CONSTITUTION DES PHLORETINS[1]

Die Feststellung der Constitution des Phloridzins und des Phloretins beruht auf einer Untersuchung von Hugo Schiff,[2] welcher durch Acetylirung die Gegenwart von fünf Hydroxylen in der ersten und von zwei solcher Gruppen in der letzten Verbindung bewiesen hat. Von diesem Resultat ausgehend hat Schiff das Phloretin als einen Äther der Phloretinsäure und des Phloroglucins aufgefasst, welcher, da er nach dieser Auffassung ein Carboxyl enthält, eine Säure darstellen solle. Diese Vorstellung der Constitution steht aber im Widerspruch mit den lediglich phenolartigen Eigenschaften des Phloretins und es schien mir daher von Interesse, das Studium des Phloretins wieder aufzunehmen.

Zur Acetylirung des Phloretins wurde ein Stückchen wasserfreien Zinkchlorids in 20 g Essigsäureanhydrid in der Hitze aufgelöst und zu der heissen Lösung, nach und nach und nur in kleinen Mengen, 5 g bei 100° getrocknetes Phloretin zugefügt. Der Kolben wurde mit einem Luftkühler verbunden und die Lösung auf ganz kurze Zeit zum Kochen gebracht; der Inhalt desselben wurde in eine Porzellanschale gegossen und nach dem Erkalten die krystallinisch erstarrte Masse mit kaltem Wasser übergossen. Das Wasser wurde von Zeit zu Zeit erneuert; nach zwei bis drei Tagen blieb eine schwach gefärbte, feste Masse zurück, die im Vacuum getrocknet wurde. Nach vollständigem Trocknen wurde sie mit wenig wasserfreiem Äther ausgezogen, der Rückstand abfiltrirt und mit Äther nachgewaschen, wodurch eine amorphe Masse entfernt wurde, und der nun fast farblos gewordene Rückstand drei bis fünf Mal aus heissem, absolutem Alkohol

[1] Printed in the Berichte der deutschen chemischen Gesellschaft, XXVII, 2686; also in pamphlet form, Berlin, 1894.

[2] Ann. d. Chem. 156, 1.

krystallisirt. Die gleiche Substanz ist auch durch Anwendung von wasserfreiem Natriumacetat als Wasserentziehungsmittel dargestellt worden; in diesem Fall wurden auf 1 g Phloretin 0.5 g des Natriumsalzes und etwa 4 g Anhydrid angewendet und das Gemisch fünfzehn Minuten in einem Kochsalzbade erhitzt. Nach dem Ausziehen des Reactionsproducts mit Wasser erhält man den Körper in fast weissem Zustand, dessen weitere Reinigung wie oben angegeben vorgenommen wurde. Auch durch Gebrauch von Zinntetrachlorid, ein Reagenz, das, meines Wissens, man bisher nicht zur Acetylirung angewandt hat, kann man das gleiche Acetylproduct erhalten. Aus 10 g Phloretin wurde nach der Acetatmethode etwa 9 g Rohproduct, aber daraus wurden nur 3 g reines Product gewonnen. Zur Analyse wurde die Substanz im Vacuum getrocknet.

Analyse: Ber. für $C_{15}H_{12}O_5(C_2H_3O)_2$.
Procente: C 63.7, H 5.0.
Analyse: Ber. für $C_{15}H_{11}O_5(C_2H_3O)_3$.
Procente: C 63.00, H 5.00,
Gef. " " 62.65, 62.70 62,70, " 5.49, 5.32, 5.32.

Der Körper bildet schöne, farblose Nadeln, die bei 93.5—94.5° schmelzen und in kaltem Eisessig, Aceton, Benzol, Essigäther und Chloroform löslich, in Ligroïn und kaltem Äther unlöslich sind. Um zu ermitteln, ob Phloretin aus dem Acetylderivat zurückgewonnen werden konnte, wurde das Acetylproduct mit 3 procentigem, wässrigem Kali übergossen und das Gemisch bei gewöhnlicher Temperatur so lange sich selbst überlassen, bis gänzliche Lösung erfolgt war. Beim Ansäuern der Lösung fiel ein Körper aus, der in Betreff seiner Eigenschaften und Aussehen mit denen des Phloretins übereinstimmte. Das rohe Product schmolz bei etwa 220° und es kann daher wohl kein Zweifel obwalten, dass Phloretin wirklich vorlag. Obwohl die Verbrennungsresultate viel besser mit den theoretischen Zahlen eines Tri- als mit denen eines Diacetylphoretins übereinstimmten, so wurde wegen der verhältnissmässig kleinen Differenz zwischen den beiden Zahlenreihen die Anzahl der Actylgruppen direct bestimmt und zwar nach der von H e r z i g[1] angegebenen Methode. Eine gewogene Menge der Substanz wurde mit einem Überschuss 10 procentiger Kalilauge im zugeschmolzenen Rohr 10 Stunden auf 100° erhitzt, der Inhalt des Rohres in einen Kolben gebracht, mit Phosphorsäure angesäuert und zuerst längere Zeit mit Dampf behandelt, zuletzt im Vacuum zur Trockne abdestillirt. Die Bestimmung der Essigsäure im Destillate geschah wie H e r z i g angegeben hat; es ist hervorzuheben, dass bei der Behandlung von Phloretin auf gleiche Weise kein saures Destillat gewonnen wurde.

Analyse: Ber. für $C_{15}H_{12}O_5(C_2H_3O)_2$.
Procente Acetyl: 22.05,
Analyse: Ber. für $C_{15}H_{11}O_5(C_2H_3O)_3$.
Procente Acetyl: 32.20,
Gef. " " 33.39, 33.68.

Nach diesem Resultat kann man nicht zweifeln, dass Phloretin nicht zwei, sondern mindestens drei Hydroxylgruppen enthält, wie es S c h i f f aus seinen Versuchen gefolgert hat. Um zu erfahren, ob das amorphe S c h i f f 'sche Product wirklich von dem oben beschriebenen Körper verschieden ist, wurden die Angaben von S c h i f f zur Darstellung des Acetylderivats vermittelst Essigsäureanhydrid ohne Anwendung eines Wasserentziehungsmittels genau wiederholt; beim Einengen der alkoholischen Lösung des Rohproducts wurde aber eine nicht unbeträchtliche Menge der bei 94° schmelzenden Verbindung zunächst abgeschieden. Bei einer zweiten Probe wurde das mit Wasser behandelte und im Vacuum getrocknete Rohproduct direct mit Äther ausgezogen, wodurch etwa ein Dritteil einer harzigen Masse entfernt wurde, und der Rückstand mehrmals aus Alkohol krystallisirt. Der Körper schmolz bei 94° und hatte alle Eigenschaften des Triacetylphloretins, dessen Bildung durch eine Analyse bestätigt wurde.

Analyse: Ber. für $C_{15}H_{11}O_5(C_2H_3O)_3$.
Procente: C 63.00, H 5.00,
Gef. " " 62.59, " 5.20.

[1] Monatshefte 1884, 90.

Das harzige Nebenproduct der Einwirkung von Essigsäureanhydrid auf Phloretin repräsentirt vielleicht ein weniger acetylirtes Derivat und wird weiter untersucht.

Die Zeitdauer der Einwirkung von Essizsäureanhydrid auf Glucoside spielt bekanntlich eine bedeutende Rolle, indem meistens nach kurzem Verlauf nur teilweise Acetylirung stattfindet; auch mit Phloretin entsteht bei längerem Erhitzen ein zweites, höher schmelzendes Acetylderivat. Das Gemisch von Phloretin, Natriumacetat und Essiganhydrid in den angegebenen Verhältnissen wurde 2—3 Stunden in einer kochenden Salzlösung gehalten und das Reactionsproduct wie oben für das Triacetylderivat weiter behandelt. Zur Reinigung des Products wurde es bis zum constanten Schmelzpunkt aus Alkohol krystallisirt, wozu mehrmalige Krystallisation notwendig ist, da das Rohproduct aus einem Gemisch besteht. Die Verbrennungen wurden mit Bleichromat ausgeführt.

Gef. Procente: C 63.52, 63.10; H 5.33.

Der Körper bildet lange, weisse Nadeln, die bei 166—167° schmelzen. In Eisessig, Benzol, Aceton und Essigäther ist er löslich, dagegen wird er sehr schwer von kaltem und auch schwierig von heissem Alkohol sowie von Äther aufgenommen. Die analytischen Zahlen passen nicht auf ein enifaches Derivat des Phloretins, und es ist höchst wahrscheinlich, dass der Körper ein Condensationsproduct des Triacetylphloretins darstellt. Hervorzuheben ist, dass man das gleiche Product, obwohl in geringerer Ausbeute, mittels Zinnchlorids erhält und dass das Triacetylphloretin, wieder mit Anhydrid und Natriumacetat erhitzt, ebenfalls den höher schmelzenden Körper liefert. Ich gedenke denselben weiter zu untersuchen. Nachdem diese Versuche vollendet waren, erschien eine Arbeit von Ciamician und Silber,[1] die aus Phloretin ein Acetylproduct vom Schmp. 170—171° gewannen und demselben die Constitution $C_{23}H_{20}O_8$ zuschreiben. Da dieser Körper als leicht löslich in Äther angegeben ist, so ist es zweifelhaft, ob wir mit der gleichen Verhindung zu thun haben.

[1] Diese Berichte 27, 1630.

Die Constitution des Phloretins scheint mir aus meinen Resultaten mit ziemlicher Sicherheit hervorzugehen. Dasselbe ist kein oxydartiger Körper, wie Schiff annahm, sondern der Phloroglucinester der Phloretinsäure von der Constitution $C_6H_3<^{(OH)_2}_{O\,.\,OC\,.\,C_2H_4.C_6H_4OH}$,

eine Auffassung, die mit der Bildung des Triacetylderivats und den Eigenschaften des Phloretins übereinstimmt.

A REVIEW OF RECENT SYNTHETIC WORK IN THE CLASS OF CARBOHYDRATES [1]

EVOLUTION is so universal, whether as exhibited in the unfolding of human conceptions or in the making of worlds, that in all reason it may be accepted as a cosmic principle. The factors of evolution are essentially constructive and destructive ones, since growth and decay, progress and retardation, synthesis and decomposition, accompany the rhythmic pulsations of this general condition of change. Likewise, the chain of chemical causality may be conceived of as closely correlated with this presentation of evolution. The notion advanced in this consideration precludes the thought of permanence. In chemical activity the atoms are ever shifting their position in space, and this unrest is indicative of the fundamental law of advance. Howsoever stable and fixed may seem the individual links of this chain, in reality the seeming stability is a condition of variation and rearrangement of the atoms and molecules. The molecule, that smallest portion of matter self-existing, when considered as the resultant of chemical reaction, is but a state of force equilibrium between the becoming and the vanishing.

In this evening's review of recent synthetic work, in the sugar group, these constructive and destructive processes are well exemplified; also, the unfolding changes so apparent in other manifestations of universal phenomena are likewise observable in the realm of chemistry. This underlying unity and dominant principle unites all aspects of the cosmos, and connects the parts into a living universe of the whole.

Evolution, when applied to chemistry, as elsewhere, com-

[1] A lecture delivered before the Franklin Institute, March 8, 1895. Printed in the *Journal* of the Franklin Institute, September, 1896; also in pamphlet form, Philadelphia, 1896.

prises the notion that the conceptions of the science advance with the unfolding of its parts.

The evolution of chemical compounds is theoretically illustrated by the building of more complex compounds from simple compounds, themselves formed from the elements, which, no doubt, in turn come from still simpler sources. The complex bodies of the same type, as, for instance, the hydrocarbons of the fatty series, show development on their own lines. Passing from the fatty hydrocarbons to those of the aromatic series is another example and indication of progress to syntheses beyond. In the laboratory these processes no doubt oftentimes are carried out by circuitous methods, as Nature's sequences in these particulars are unknown. In the natural changes that rocks, plants and animals undergo, a self-directive chemical consciousness, adequate to the needs of the respective conditions, doubtless obtains.

There was a time, not so long ago, when many of the chemical compounds resulting from the chain of existence were isolated from animal and plant life. The key of chemical change was looked for in the study of plants, and to these sources, from life, chemists turned for new research fields.

A little later, chemical synthesis, or the production of compounds by artificial means, had its beginning. From time to time, at longer or shorter intervals, appeared the announcement of the synthesis of some compound hitherto derived from plant or animal life. But the later years of this century, from the chemical point of view, may be regarded specially as synthetic years, ever nearing the zenith of greater attainment.

The subject of sugars early attracted the attention of chemists, not only because of the industrial aspects, but also, being one of the main divisions of the classification of compounds, the study of its varieties and composition has been untiringly pursued. The vision arose in the long past of its possible synthesis. Liebig first conceived the idea of making sugar artificially. But the synthesis of this important group of compounds defied all efforts until comparatively recent times. The first mixture of synthetical sugars was obtained by Butlerow,[1] by the action of lime-water on oxymethylene, in the form of a syrupy liquid which he named methylenitan. In 1863, Van Deen, by the oxidation of glycerine, discovered a compound which reduced salts of copper in alkaline solution, and showed other properties indicative of a sugar, although of a simpler kind than those found in nature. The discoveries of Löw, Tollens, and Fischer have brought the investigations of sugars to our own times.

The researches of Nägeli, from a botanical standpoint, led him to advance a theory that starch was the origin of sugar in plants.

A later purely chemical hypothesis of the synthesis of sugars from simple compounds in the living cell, which, in turn, yield more complicated compounds, is thought by many to be a more satisfactory theory, for it coincides with our ideas derived from other branches of scientific investigation, in support of the notion that from simple integrals arise intricate structures. But it is quite probable that both processes of construction and destruction are carried on simultaneously in the plant. In the laboratory it is possible, starting with the elements carbon, hydrogen, and oxygen, to form, from these elements, compounds which are found in vegetable life. From the simple bodies thus derived are the means ready at hand to proceed to compounds of a sugar type.

The carbon dioxide in the plant is derived from the external environment of the air and soil, or the gas is generated within the plant cells. Under the influence of sunlight, carbon dioxide and water yield formaldehyde, a compound containing the group (CHO); *i. e.*, one atom respectively of carbon, hydrogen, and oxygen, known as the aldehyde group, united to hydrogen by the residual affinity of carbon. According to Baeyer, formaldehyde is the source of the plant's sugar.

In the chlorophyll grains of the green part of the leaf, it is supposed that the formation of glucose takes place.

The aldehyde group enters into the constitution, and is characteristic, of many of the sugars. One of the divisions in the classification of sugars containing this group is known as

[1] *Ann.*, cxx, 295.

the aldehyde sugars. As a comprehensive name for the class, the word *aldose* has been adopted. The other class of sugars is known as the *ketose* sugars, so called from the ketone group (CO), or carbonyl, contained in their molecules.

The ease with which formaldehyde polymerizes, under favorable conditions, qualifies this compound eminently for its function in sugar-formation.

Polymerization is the amalgamating, so to speak, of two or more aldehyde groups, forming a carbon compound containing a greater number of carbon atoms.

In considering the polymers of formaldehyde, Baeyer suggested that, under the influence of the contents of the plant cells, 6 molecules of formaldehyde polymerize to form 1 molecule of glucose, $6HCHO = C_6H_{12}O_6$.

It has been claimed that formaldehyde occurs in plants, and has been found in very small quantities in plant cells; but in any great proportion it acts as a poison to the living plant, and Fischer has suggested, in consequence, that there can be no doubt that other intermediary compounds occur in the formation of sugars. Bokorny[1] has made an interesting observation on the assimilation by the green cells of Algæ of a double compound of formaldehyde and sodium bisulphite. He has shown that, if plants are deprived of starch and placed in an atmosphere free from carbonic acid, they are capable of forming considerable quantities of starch under the influence of sunlight, if fed upon this compound. In the dark the conversion of formaldehyde into starch does not take place.

Löw, by treating formaldehyde with lime, obtained a sugar which he called formose. Fischer has shown that this product contains sugar compounds of the composition $C_6H_{12}O_6$, and among these, one named acrose, which stands in very close relation to natural glucose.

It may be well to state here that the term sugar includes a variety of substances. It includes fruit sugar, glucose, and chemically allied sugar groups, some of which contain more and some less carbon atoms than glucose. These compounds are not to be confounded with the food material derived from

[1] *Landw. Jahrbuch*, xxi, 445.

the sugar-cane or beet-root, and milk sugar. Starches and gums, though conveying little idea of sugar, are chemically to be considered as sugars.

The characteristics of these different compounds are very unlike. They vary from very soluble to insoluble compounds, and from crystalline to non-crystalline bodies. But the insoluble compounds, like starch and cellulose, may be converted into the soluble sugars by the action of heat and dilute acids, and by certain ferments, as diastase. The reaction which accompanies this conversion involves the taking up of water, and at the same time the complicated molecule splits into several simpler ones. This reaction is called hydrolosis:

$$x(C_6H_{10}O_5) + xH_2O = xC_6H_{12}O_6.$$

As will be observed, the sugar group — collectively designated as "carbohydrates" — comprehends a vast widening-out vista of compounds, from a simple compound derived directly from the elements, to complex bodies with numerous isomers.

The sugars of physiological consequence are widely spread in animals and plants, and, as carbohydrates, constitute one of the three great classes of natural organic compounds, the fats and albuminoids constituting the other two classes. Lavoisier discovered that the materials of which carbohydrates are composed were carbon, hydrogen, and oxygen; but the objection to the use of the term carbohydrate, which is defined as a compound containing carbon and hydrogen and oxygen in the proportion of 2 to 1, is its non-universality. The sugar called rhamnose, $C_6H_{12}O_5$, may be mentioned as an exception to the definition, but for purposes of classification the name carbohydrate has been retained by writers.

The carbohydrates have been divided for convenience into three groups:

(1) Simple sugars, or monosaccharides, as grape or fruit sugars.

(2) Decomposable sugars, or polysaccharides, as cane or milk sugar and raffinose.

(3) Polysaccharides unlike sugar, as starch, cellulose, and dextrine.

The polysaccharides are bodies made up from several simple sugar molecules, uniting with elimination of water. Thus cane sugar may be converted into grape and fruit sugar by hydrolytic reaction, as shown by the equation:—

$$C_{12}H_{22}O_{11} + H_2O = C_6H_{12}O_6 + C_6H_{12}O_6;$$

consequently, the simple sugars, like glucose, appear as the basis of the entire group.

In nature, the simple sugars, or monosaccharides, are found not only as carbohydrates, but they occur also in combination with phenols as glucosides.

From the widely spread distribution of glucose, its uses as a food product, and considered chemically as the basis of more complicated carbohydrates, it deserves careful consideration.

The name hexose, which is the general name for the glucose group, as the word implies, shows that 6 carbon atoms enter into the composition of the individuals of the group. These carbon atoms are united in an open chain, each carbon atom, except one at one end of the chain, being united to a hydroxyl (OH) group. This end carbon atom is united with hydrogen and oxygen, forming an aldehyde group which is peculiar to these sugars. Glucose and sugars of its class are represented by the constitution which expresses an aldose or aldehyde sugar, $CH_2OH \cdot (CHOH)_n \cdot CHO$.

Fruit sugar, or ketose, is expressed by the formula:—

$$CH_2OH \cdot (CHOH)_n \cdot CO \cdot CH_2OH.$$

The reason for accepting this atomic arrangement to express the constitution of the glucose and fructose groups is based upon several considerations. Grape and fruit sugar, on reduction with hydrogen, yield the alcohol mannite. Galactose, which is also an aldehyde sugar, under the same conditions gives the alcohol dulcite. The 6 hydrogen atoms of the hydroxyl groups of these alcohols are replaced by acetyl groups on treating them with acetic anhydride, so they must be considered as the hexavalent alcohols of the above sugars.

The aldehyde character of glucose and galactose is also shown by their behavior towards oxidizing agents. On partial oxidation, by chlorine or bromine water, they yield respectively gluconic and galactonic acids. By complete oxidation they both give saccharic acid.[1]

Conversely to the aldehyde sugars, fruit sugar is slowly attacked by bromine water. By the action of a more powerful oxidizing reagent it is decomposed into products containing fewer carbon atoms.

The aldehyde and ketone character of these compounds is shown by the readiness with which the sugars form hydrazone and osazone compounds. This reaction with phenylhydrazine is characteristic of all compounds containing aldehyde and ketone groups.[2]

The sugar varieties which to-day go to make up a magnificent display of synthetic skill include many isomers, depending upon the different arrangement of the atoms in space. In order to have a clear view over this field, it is important to ascertain the spacial relations or configuration of each member of the sugar groups.[3]

The latest publications by Emil Fischer on the stereomers of the sugar groups show an admirable agreement between the conflicting facts pertaining to the sugars which have poured in from isolated researches during past years, when these are considered in the light of Le Bel and Van't Hoff's theory. The names of these investigators are especially identified with stereo-chemistry, although others have followed in the same lines.

Among the writings of the past, the geometrical forms of matter were suggested by the Greeks, and later by Swedenborg as a possibility; but it was Pasteur, in 1860, who gave the underlying idea of grouping of atoms in space.

[1] When a solution of the alcohol mannite is heated for some hours to 42° C. with nitric acid, it is oxidized to mannose; if the reaction is continued with increased heat, the oxidation is carried on to the acid formation.

[2] $CH_2OH(CHOH)_4CHO + C_6H_5HN_2H_2 = CH_2OH(CHOH)_4CH(N_2HC_6H_5) + H_2O$

$CH_2OH(CHOH)_3CO \cdot CH_2OH + C_6H_5HN_2H_2 = CH_2OH(CHOH)_3C(N_2HC_6H_5) \cdot CH_2OH + H_2O$

[3] The configuration of a compound is the relative position of its atoms in space. The portion of chemistry treating on this subject is called stereochemistry.

This theory explains the existence of two or more compounds of like chemical composition, by assuming different dispositions of the atoms entering into the compound.

The simplest hydrocarbon, methane, is conceived as being a tetrahedron with a carbon atom in its centre and one hydrogen atom joined at each of its four angles. The carbon atom of this compound is symmetrical, inasmuch as all the atoms to which it is united are of a like kind. In such a case stereomers are impossible.

But in order to have the conditions for stereosomerism, it is necessary for a compound to contain one or more atoms of asymmetrical carbon; that is, a carbon atom united by all of its four bonds to atoms or groups of atoms of different kinds.

Methane may be represented, for illustration, by a pasteboard tetrahedron model,[1] the angles being painted red to distinguish the points of carbon's union with hydrogen atoms. If this model be placed angle to angle with a second methane tetrahedron, the hydrogen atoms will coincide, and if one of the models be superimposed upon the other, the hydrogen atoms at each of the angles will touch, showing the symmetrical grouping. The symmetry of the molecule is not disturbed when two or three different kinds of atoms replace the hydrogen atoms of methane. But when all of the hydrogen atoms are replaced by different kinds of atoms, it will be found, on bringing the angles of like color of two models together and superimposing the one model upon the second model, that the angles of like colors cannot be made to coincide.

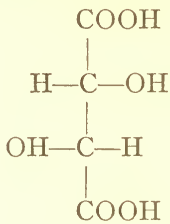
Lactic acid is an illustration of a compound containing an asymmetrical carbon. This compound, represented by the constitution $CH_3 . CHOH . COOH$, contains two symmetrical carbon atoms, one at either end; the carbon atom which occupies the middle position is the asymmetrical carbon, since this atom is united by its four bonds with different atoms or groups. The presence of this middle carbon atom induces the conditions which cause lactic acid to appear under two *acid* modifications. By the action of these compounds on the

[1] The subject here and what follows was explained by means of models and charts.

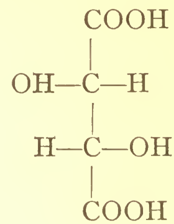
rays of polarized light, which are turned to the right or left, depending upon the isomer, the acids are known as the right and left lactic acids. In uniting they give an inactive form.

In connection herewith, it may be well to mention the tartaric acid experiments of Pasteur. On working with certain of the salts of that form of tartaric acid called racemic acid, he noticed that he could separate them into two crystalline forms, which in aqueous solution behaved differently towards polarized light. According to the direction that the solutions of the crystals turn the plane of polarized light, they are known as the salts of the right and left tartaric acids. The corresponding acids contain two symmetrical and two asymmetrical carbons. They may be represented in this manner: —

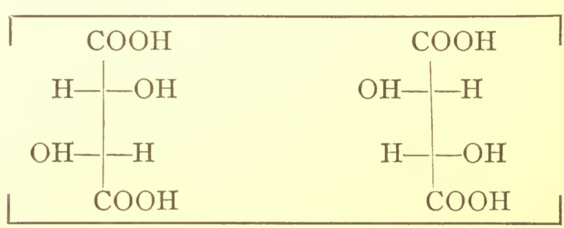
Right Tartaric Acid.



Left Tartaric Acid.



The two active modifications may he brought together, and when united, give the inactive form, or racemic acid.



The inactive acid may be separated into its active components by chemical means, or by the action of certain ferments. These ferments have the effect of destroying either the right or the left modification.

There is another inactive form of the acid, known as the anti-tartaric acid. This is the result of synthesis, and is not decomposable into active parts.

Anti-tartaric Acid.

```
      COOH
       |
OH—   —H
       |
OH—   —H
       |
      COOH
```

From what has been said it will be easy to understand the parallelism of Pasteur's classical experiments with the sugars and the application of this theory to other classes of compounds.

With the simple sugar molecules the conditions are not so complex as in the higher sugar series, and the number of stereomers is less. With an increasing number of carbon atoms the conditions of asymmetry increase and stereomers are more numerous.

In the case of glucose the number of asymmetrical carbons is four. The possible number of stereomers is sixteen, of which eleven are known. Among these, five are optical pairs. That is, each member of these optical pairs turns the plane of polarized light in an opposite direction, and one of the pair may be described as the reflected or "mirror image" of the other.

When it is remembered that glucose refers to a compound which appears under two forms in respect of its action on polarized light, the explanation, from what has gone before, of this quality is seen to rest on the space position of its atoms. The position of the hydrogen and hydroxyl groups, with respect to the asymmetrical carbons in the molecule of the active glucose, which turns the plane of polarized light to the right, is diametrically opposite to the position in space of these same atoms and groups in the other modification of glucose, which turns the plane of polarized light to the left.[1]

The right glucose may be spoken of as the "mirror image"

[1] This was represented on a diagram.

TABLE I.—PENTOSE, PENTONIC ACID,

1	2	3	4
(Mirror Images.) COH HO — | — H HO — | — H HO — | — H CH_2OH *l* Ribose. *l* Ribonic acid.	COH H — | — OH H — | — OH H — | — OH CH_2OH	COH H — | — OH HO — | — H H — | — OH CH_2OH *l* Xylose. *l* Xylonic acid.	COH HO — | — H H — | — OH HO — | — H CH_2OH

9	10
COOH H — | — OH H — | — OH H — | — OH COOH Ribo-trioxyglutaric acid. Adonite (inactive).	COOH H — | — OH HO — | — H H — | — OH COOH Xylo-trioxyglutaric acid. Xylite (inactive).

HEXOSE, HEXONIC ACIDS, HEXITE AND

13	14	15	16
COH H — | — OH H — | — OH HO — | — H HO — | — H CH_2OH *l* Mannose. *l* Mannic acid.	COH HO — | — H HO — | — H H — | — OH H — | — OH CH_2OH *d* Mannose. *d* Mannic acid.	COH HO — | — H H — | — OH HO — | — H H — | — OH CH_2OH *l* Idose. *l* Idonic acid.	COH H — | — OH HO — | — H H — | — OH HO — | — H CH_2OH *d* Idose. *d* Idonic acid.

The configurations of the acids correspond-

b. DULCITE

27	28	29	30
COH HO — | — H H — | — OH H — | — OH HO — | — H CH_2OH *l* Galactose. *l* Galactonic acid.	COH H — | — OH HO — | — H HO — | — H H — | — OH CH_2OH *d* Galactose. *d* Galactonic acid.	COH HO — | — H HO — | — H HO — | — H HO — | — H CH_2OH	COH H — | — OH H — | — OH H — | — OH H — | — OH CH_2OH

PENTITE AND TRIOXYGLUTARIC ACIDS.

5	6	7	8
COH H — | — OH HO — | — H HO — | — H CH_2OH *l* Arabinose. *l* Arabonic acid.	COH H — | — OH H — | — OH HO — | — H CH_2OH	COH HO — | — H H — | — OH H — | — OH CH_2OH *d* Arabinose.	COH HO — | — H HO — | — H H — | — OH CH_2OH

11	12
COOH H — | — OH HO — | — H HO — | — H COOH *l* Trioxyglutaric acid. *l* Arabite.	COOH HO — | — H H — | — OH H — | — OH COOH

SACCHARIC ACIDS. — *a*. MANNITE GROUP.

17	18	19	20
COH HO — | — H H — | — OH HO — | — H HO — | — H CH_2OH *l* Glucose. *l* Gluconic acid.	COH H — | — OH H — | — OH HO — | — H H — | — OH CH_2OH *l* Gulose. *l* Gulonic acid.	COH H — | — OH HO — | — H H — | — OH H — | — OH CH_2OH *d* Glucose. *d* Gluconic acid.	COH HO — | — H HO — | — H H — | — OH HO — | — H CH_2OH *d* Gulose. *d* Gulonic acid.

ing to the above have been omitted.

GROUP.

31	32	33	34
COH H — | — OH H — | — OH H — | — OH HO — | — H CH_2OH	COH H — | — OH HO — | — H HO — | — H HO — | — H CH_2OH	COH HO — | — H H — | — OH H — | — OH H — | — OH CH_2OH	COH HO — | — H HO — | — H HO — | — H H — | — OH CH_2OH *d* Talose. *d* Talonic acid.

of the left one, for by no possible turning can the configuration of the one be superimposed upon the other. Thus they are called enantiomorphic; but united, they give the modification towards polarized light. The inactive glucose may be again decomposed into the two active forms.

The question naturally arises, Why are these configurations represented as they are on the diagram? [1] It would carry us beyond the time allotted for this occasion to go into the reasonings for each case. I will only take one or two examples. But it may be stated generally that the observations made on these sugars from experimental facts are in accord with theory.

On the chart, beginning at the top of the diagram, are the two *triose* sugars, each with one asymmetrical carbon. On the next lines are the four *tetroses*, which have been made synthetically. There are eight *pentose* sugars having three asymmetrical carbons; and below these are represented the sixteen *hexose* sugars, to which glucose belongs. I have not considered it necessary to continue the representation of the higher sugars on the chart.

But suppose that I should change the aldehyde group of these sugars into a corresponding alcohol group, it would become apparent that the conditions for asymmetry were changed. Each of the end carbon atoms, in its atomic relations, is alike, and these alcohols contain only two asymmetrical carbons. The configurations for the pentose sugars, one and two, here given, are unlike. They are the mirror images of each other. When reduced, however, to their alcohols, the identity of the alcohols arising from these two sugars becomes apparent on turning the end group of one of the compounds in the plane of the diagram, and bringing this group to the top of the other configurations. Also, if these alcohols are imagined to be the acids of the group, the tri-oxyglutaric acids, the (COOH) groups standing at each end of the carbon chain when the acid is turned in the same plane on the diagram as the alcohols, it will be seen that one acid configuration results from two sugar ones, as in the former case of the alcohols.

[1] See Table I.

There are only four alcohol and acid isomers for the eight sugar isomers in this group. In the other higher sugar groups the conditions are somewhat changed. But by studying the results of oxidation or reduction on sugars, it may be shown that the compounds so obtained point to the probable configuration of a given sugar; and in this way, these formulæ express the conclusions of actual experiment.

These active asymmetrical compounds are obtained directly from natural products, or are derived from optically active compounds. If compounds are formed from inactive ones, and inactive modifications arise, these inactive forms must be decomposed in order that the active form may appear.

Although these active compounds are the resultants of accompanying life processes, they are not regarded by the chemical thinkers of the day as essentially due to a life force. Fischer believes that these active compounds will all be made synthetically. This is by no means assuming that the knowledge to fabricate these active substances will give into the hands of the chemist the secret touch to set these molecules into a life mechanism.

The example of the glorious period of the highest achievements in Greek art remains as a reminder that neither the skill of a Phidias nor of a Praxiteles could give to their creations the breath of life. The analogous height and limit of relative perfection in attainment is seen in other developments of human conception. Each later development may reach a higher round of the ladder than its predecessors, and the standpoint of vision may be a line nearer that goal which seems to recede as the effort of advance reaches forward.

An Arabian alchemist, it is said, first obtained grape sugar, or glucose, in a solid form, by concentrating grape sap. It was obtained pure by the chemist Marggraf, in the middle of the last century. The conversion of starch into grape sugar by boiling with dilute acids was discovered by Kirchhoff, in 1811. No less interesting is the recent work of Rohmann, wherein he shows that blood serum converts potato starch into dextro-glucose, and that finally, at the end of the reaction, maltose, likewise soluble starch and dextrine, remain.

TABLE II.

	Aldose.	*Mono-basic acid.*
Biose	Glycolaldehyde.	Glycolic acid.
Triose	Glycerose. (*Mixture of aldose and ketose.*)	*d-i* Glyceric acid.
Tetrose	Erythrose.	Erythritic acid.
Pentose	*d-l-i* Arabinose. Xylose. *l* Ribose.	*l* Arabic acid. Xylonic acid. *l* Ribonic acid.
Methyl Pentose	Rhamnose. Chinovose. Fucose.	Rhamnic acid.
Hexose – Mannite Group	*d-l-i* Glucose. *d-l-i* Gulose. *d-l-i* Mannose. *d-l-i* Idose.	*d-l-i* Gluconic acid. *d-l-i* Gulonic acid. *d-l-i* Mannic acid. *d-l-i* Idonic acid.
Hexose – Dulcite Group	*d-l-i* Galactose. *d* Talose.	*d-l-i* Galactonic acid. *d* Talonic acid.
Methyl-hexose	*α* Rhamno-hexose.	*α* Rhamno-hexonic acid. *β* Rhamno-hexonic acid.
Heptose	*d-l-i* Manno-heptose. *α* Gluco-heptose. *β* Gluco-heptose. *α* Gala-heptose. *β* Gala-heptose.	*d-l-i* Manno-heptonic acid. *α* Gluco-heptonic acid. *β* Gluco-heptonic acid. *α* Gala-heptonic acid. *β* Gala-heptonic acid.
Methyl-heptose	Rhamno-heptose.	Rhamno-heptonic acid.
Octose	Manno-octose. *α* Gluco-octose. Gala-octose.	Manno-octonic acid. *α* Gluco-octonic acid. *β* Gluco-octonic acid. Gala-octonic acid.
Nonose	Manno-nonose. Gluco-nonose.	Manno-nononic acid. Gluco-nononic acid.
Aromatic Series	Phenyltetrose.	Phenyltetronic acid.
	Ketose.	*Structure Unknown.*
Triose	Dioxyacetone (contained in glycerose).	
Hexose	*d-l-i* Fructose. Sorbose.	Formose. *β* Acrose.

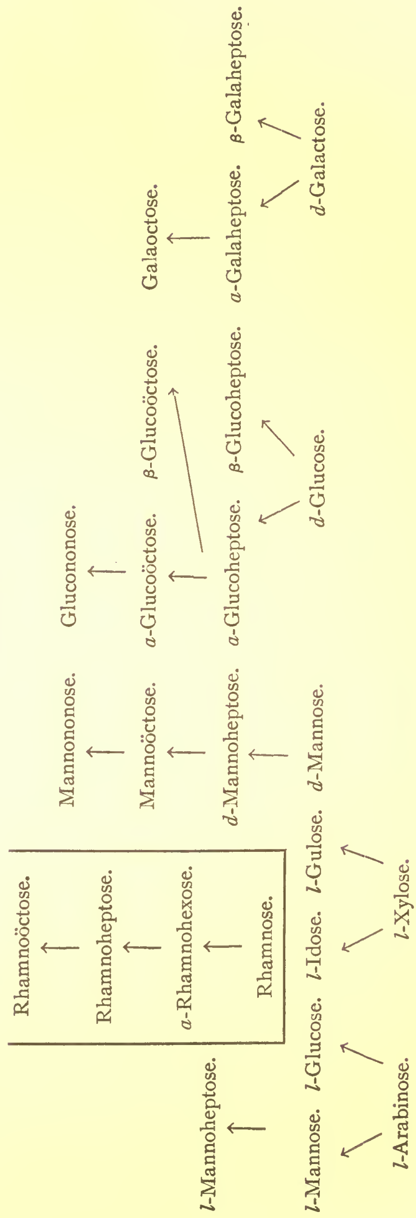
TABLE II.

Di-basic acid.	*Polyvalent alcohol.*
Oxalic acid.	Glycol.
Tartronic acid.	Glycerine.
4 Tartaric acids.	2 Erythrite.
l Trioxyglutaric acid.	*l* Arabite.
Xylo-trioxyglutaric acid (inactive).	Xylite (*inactive*).
Ribo-trioxyglutaric acid (inactive).	Adonite (*inactive*).
	Rhamnite.
{ *d-l-i* Saccharic acid.	*d-l*-Sarbite.
{ *d-l-i* Manno-saccharic acid.	*d-l-i* Mannite.
{ *d-l-i* Ido-saccharic acid.	*d-l* Idite (1).
Mucic acid (inactive).	Dulcite (inactive).
{ *d-l* Talo-mucid acid. / Allo-mucic acid. }	*d-i* Talite.
	a Rhamnohexite.
d Manno-heptanpentoldic acid.	*d-l-i* Mannoheptite (Perseit).
a Gluco-heptanpentoldic acid (inactive).	*a* Glucoheptite (inactive).
β Gluco-heptanpentoldic acid.	
a Gala-heptanpentoldic acid.	
β Gala-heptanpentoldic acid.	*a* Galaheptite.
	Manno-octite.
	a Gluco-octite.
	Gluco-nonite.
	(1) Ber. 28, 1975.

Aldehyde Acids.

$(CHOH)_4 < {COOH \atop COH}$	Glucuronic acid. Oxygluconic acid.
$(CHOH)_5 < {COOH \atop COH}$	Aldehydgalactonic acid.

TABLE III.



l-Mannoheptose.
l-Mannose.
l-Glucose.
l-Idose.
l-Gulose.
l-Arabinose.
l-Xylose.
Rhamnoöctose.
Rhamnoheptose.
a-Rhamnohexose.
Rhamnose.
Mannononose.
Mannoöctose.
d-Mannoheptose.
d-Mannose.
Glucononose.
a-Glucoöctose.
β-Glucoöctose.
a-Glucoheptose.
β-Glucoheptose.
d-Glucose.
Galaoctose.
a-Galaheptose.
β-Galaheptose.
d-Galactose.

From all sources the number of simple sugars, from the beginning of the century to less than ten years ago, numbered not over 6. Now, by means of synthetical research, not less than 30 simple sugars are known, and 7 of them are natural products. Among the 7 carbon-atom sugars, by calculating the possible number of isomers, 32 are possible, of which only 6 have thus far been obtained. Of the 128 possible nonose sugars, as yet but 2 have been made.[1]

To carry out the thought of the sugar-group development it will be necessary to give rapidly an outline of these sugars before summing up the methods which led to their synthesis.

Under the mannite group are included grape sugar and sugars possessing the same chemical composition as grape sugar. The mannose sugars also come under this group, with their corresponding alcohols and acids. The right, left, and inactive mannose correspond to the *d-l* and *i* glucose. The right mannose is formed at the same time as the right fructose, by the careful oxidation of the alcohol mannite. It was first obtained in this way. It may be mentioned that mannite is found in manna. Mannose may also be obtained from the natural carbohydrates by hydrolytic reaction. It is also found in the fruit of many palms. A very cheap source of supply is from the shavings of vegetable ivory in the manufacture of buttons. In separating the right mannose from its solutions, its phenylhydrazone compound is used. This compound is very insoluble, and affords a characteristic test for this substance.

The left mannose is obtained from the left arabinose.[2] The arabinose compounds contain 5 atoms of carbon. The cyanhydrine reaction in the sugar series, or Kiliani's reaction, is the one employed in its formation. This method has opened the field to some of the most important discoveries in sugar synthesis. In this reaction prussic acid unites directly with sugar,[3] and in this way the number of carbon atoms in the

[1] The table shows the present sugar status.

[2] By right, left, and inactive acids, of course, is meant the effect of these compounds on polarized light.

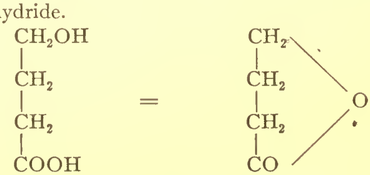
[3] $C_2HOH(CHOH)_4CHO + HCN = CH_2OH(CHOH)_4CHOH \cdot CN + H_2O$.

sugar chain may be increased and a higher synthetic compound formed. Upon the addition of prussic acid to sugar compounds, the further processes of saponification and reduction are necessary before obtaining a higher sugar. By this method it is possible to pass from sugars containing a few carbon atoms to sugars representing a higher synthetical series. However, this method can only be used with sugar compounds containing not less than 3 carbon atoms. Such compounds have the power of forming lactones, and sugars of a higher carbon percentage are obtained by reducing these lactones.[1] By the use of this method Fischer has obtained some of his most brilliant achievements.

The right, left, and inactive glucose and idose, which are stereomers of glucose, have been obtained synthetically from their corresponding acids. Idose is named from the symmetrical form of its molecules, and is among the latest discovered compounds of this group. The acids of these last two sugars are isomeric with the sugar acids obtained by oxidizing glucose and mannose.

Two other sugars, which may be mentioned as belonging to the hexoses, are galactose and talose. The right, left, and inactive galactose have been obtained. The *d*-galactose as well as the *d*-glucose may be derived from milk sugar by hydrolysis. The latter may also be obtained by the same means from other carbohydrates. Galactose yields, on reduction, an alcohol called dulcite. These sugars belong to the second division of the hexose group, known as the dulcite group, and by oxidation yield mucic acid; whereas the sugars of the mannite division yield, on oxidation, saccharic acid. All these sugars may be separated from their solutions, in a solid form, by

[1] The lactones are gamma hydroxy compounds, which, by the loss of water, give an anhydride.



Counting from the one above the bottom group, the carbons are known as the alpha, beta, gamma, delta carbons, etc.

means of their hydrazones and osazones.[1]" However, with the exception of mannose, the hydrazones of other sugars are mostly soluble in water. Hence, the reaction with phenylhydrazine is carried on to a further state, which results in the formation of the insoluble osazones. These compounds differ decidedly in color and system of crystallization. They have sharp melting-points, which lead to their easy identification.

Another class of substances, which are called mercaptals, and are compounds of sugar with sulphur, of the composition $CH_2OH(CHOH)_4CH(S_2C_5H)_2$, furnishes a means of separating and distinguishing the aldehyde sugar compounds.

The synthetical sugars containing 7, 8, and 9 carbon atoms, derived from the groups containing less carbon atoms, may be made by Kiliani's method.

It is an interesting fact that the sugars containing 3, 6, and 9 atoms of carbon are fermentable; while those containing 4, 5, and 7 atoms of carbon cannot be fermented.

Fischer has suggested wherein the interest of these massive sugar molecules lies. It is in physiological research. He has proposed, as worthy of attention, that these higher synthetical sugars be experimented with as to their full physiological value. Possibly the tissues of animals nourished with these higher sugars may yield other chemical products; the liver may give a new glycogen, and a new acid may be found in the milk secretions from the mammary glands. Here may possibly be opened a new research ground for the biologist.

The pentosans are compounds belonging to the sugars containing 5 carbon atoms. These pentosans occur in various parts of plants of different age and development. The amount increases during the development of the plants. The wood of dicotyledonous plants is richer in pentosans than that of the Coniferæ. It is thought by De Chalmot that these substances are reserve materials. But they seem of importance in the formation of wood, for they are developed at *this* stage.

Arabinose is one of the important members of the pentose series. It was discovered by Scheibler on boiling the gum of the cherry tree with sulphuric acid. This compound was con-

[1] The reaction and products of some of these sugars were demonstrated.

sidered by him an isomer of grape sugar; but it was shown by Kiliani to possess the formula $C_5H_{10}O_5$. Although the natural arabinose turns the plane of polarized light to the right, on account of its relation to *l*-glucose, it should be considered as a left compound. Artificially, the right-turning arabinose may be made from glucose by a *building-down* process, as it were, discovered by Wohl. This process consists in passing from a sugar richer in carbon atoms to one containing fewer carbon atoms.

On boiling bran, wood, jute, straw and like substances, with acids, pentosan compounds are obtained. In some cases they may be isolated, or their presence may be proved by the furfurol reaction. This is a well-known test for their identification. If compounds belonging to the hexose groups be heated with acids, they yield lævulinic acid ($CH_3COCH_2CH_2CO_2H$). On the contrary, pentose compounds, by distillation with strong acids, yield furfurol compounds, which easily pass over with steam.

The portions of the coffee berry insoluble in water, when distilled with dilute hydrochloric acid, yield furfurol aldehyde, which demonstrates the presence in the coffee of a compound belonging to the pentosans.

By warming with phloroglucin and hydrochloric acid, the pentosans, as also all compounds which, by decomposition, yield sugar compounds containing 5 carbon atoms, give a cherry-red color reaction.

Ribose, a colorless syrup, and xylose, wood sugar, are isomeric with arabinose.

Rhamnose, formerly erroneously called "isodulcite," is a methylpentose. It is obtained from datiscin by hydrolytic reaction, and by the same method from different glucosides.

Fucose, obtained from the sea-tangle or grass wrack, is isomeric with rhamnose, also chinovose, which is derived from chinovite. The alcohols, xylite and adonite, belonging to the sugars xylose and ribose, correspond to arabite, the alcohol of the sugar arabinose, and are inactive.

The remaining series of compounds, which chemically belong to the same class as the sugars, are designated as biose, triose, and tetrose sugars. These compounds contain, respectively, as their names indicate, 2, 3, and 4 carbon atoms. The latest addition to this list is the number containing the smallest number of carbon atoms. This is a compound with two atoms of carbon, chemically known as glycol-aldehyde, and may be obtained from brom-acetaldehyde, by means of barium hydrate in the cold. This compound possesses all the properties to be expected from a simple sugar. Of these, the property of being converted by phenylhydrazine into the gloxalosazone may be mentioned. It has not been possible to obtain the glycol-aldehyde *from admixture* with the brom-aldehyde from which it is derived; consequently, the behavior of this simple sugar with ferments has not been proven. Since brom-compounds act as a poison towards yeast, the mixture will probably be found not to ferment.

Triose or glycerose is considered to be a mixture of glycerine aldehyde (CHOH . CHOH . CHO) and dioxyacetone (CHOH . CO . CHOH). This compound is a syrup, and reduces Fehling's solution, and actively ferments with yeast.

The chemical sugar next higher in the scale is the tetrose sugar, which is formed by the oxidation of erythrit, and is named therefrom erythrose. This is likewise a mixture of aldehyde and ketone compounds. The regeneration of this sugar from its osazone has not as yet been accomplished. The synthetical tetrose probably arises by a kind of aldol condensation. It has been isolated in form of its osazone only, which is identical with the erythrosazone.

It may be mentioned in reference to aldol condensation, that it is of two kinds. The condensation may be accompanied either by the loss of a molecule of water or by no loss of water. The former is known as aldehyde condensation, when, for example, two molecules of ethylaldehyde are heated with zinc chloride, and a molecule of water is lost. In the latter case, the aldehyde must stand for a longer time with dilute hydrochloric acid; thence arises a condensation product known as aldol condensation.

The distinctions between the sugars characterized as the aldose and ketose sugars disappear when these sugars are converted into the osazones; for each sugar gives identically the same osazone, and this compound affords a means of passing from a sugar of one class to a sugar of the other class.

The other division of natural sugars, or the ketone sugars, of which fructose is the type, includes, up to the present time, three representatives only. Of these three sugars, only the dextro-fructose combines with prussic acid; consequently, the synthesis in this division by Kiliani's method is limited. It has not gone beyond the fructo-heptose, or a ketone sugar containing 7 atoms of carbon.

Fructose is the fruit sugar to which the sweetness of fruits is chiefly due. This sugar crystallizes from alcohol in crystals belonging to the rhombic system, whilst the crystals of glucose are obtained as fine needles. Fructose occurs in three modifications. The inactive modification is of historical interest, since it was the first synthetic sugar made out of materials obtained by synthetical means.

Of the methods which serve for the direct synthesis of sugar may be mentioned: (1) the polymerizing of formylaldehyde by bases; (2) a valuable synthetical means is, likewise, the reaction which corresponds to aldol condensation; and (3) Kiliani's method has been of untold value in this field; (4) the artificially made sugars may be separated from solution in form of their osazone compounds, and, in most cases, the sugars can be regenerated from these compounds.

In all cases a mixture of these osazones arises. The inactive phenyl-glucosazone is the direct source of the inactive fructose; for, by reducing the osone derived from the osazone, a ketose arises which agrees in all respects with the inactive form of fructose. It possesses all the properties of the natural fruit sugar.

By the reduction of this inactive fructose, obtained synthetically, arises the inactive mannite. The synthesis of the active glucose and fructose (the natural sugars) may be made from the inactive mannite in the following way: By treating the inactive mannite with the suitable oxidizing agent, it will be oxidized to the inactive mannose and the inactive mannonic acid; the inactive mannonic acid can be split into its active constituents, the right and the left acids. The right mannonic acid yields, by reduction, the right mannose on the one hand, while on the other, by heating with chinolin or pyridin, a molecular change takes place, and the *d*-gluconic acid is obtained, which yields the active glucose. Finally, the active glucose and mannose, through their phenyl-glucosazones, may be converted into the active fructose. Thus the problem of the synthesis of the most important natural sugars has been accomplished.

Sugar, as a class, is thus derived not only from sources pertaining to the land and sea, but also, from the brief sketch just drawn, from no less a source than man's intelligence.

According to the earliest records, the sugar-cane, the main source of the supply of saccharose, or cane sugar, was cultivated in India for food supply. The beet-sugar industry dates from our own time.

Cane sugar is found in many plant species, and occurs in grain during germination at the expense of starch, as it was observed in the barley. Cane sugar has not as yet been made synthetically. It stands as one of the atomic peaks still to be scaled. The discovery, by Biot, of the power of cane sugar solutions to turn the plane of polarized light led Dubrunfaut, in 1847, on decomposing cane sugar, to discover fructose, the second sugar constituent of cane sugar. In the same way, we may read any day the announcement of the discovery of a chemical spyglass, which will reveal the pathway to the synthesis of this member of the chemical chain.

Maltose, a sugar of the same composition as cane sugar, was discovered by Dubrunfaut. Maltose, a polysaccharide, has been made synthetically.

Milk sugar, which also belongs to this same division, was separated from milk as early as the year 1619, by Bartoletti, of Bologna. Demole claims to have made it synthetically.

Starches, gums, cellulose, and mucous compounds are of great physiological interest in their bearing on plant life, and the recent thorough investigations of the sugar groups will not be unavailing to bring forward a clearer knowledge of these bodies. There are many sources of starch, and some peculiarities among the different kinds. Lichenin, from Ice-land moss, and inulin, from many composital plants, act the *rôle* of starch in the plants wherein they occur.

A brief reference may be given here to compounds like dextrin and lævulin, which stand intermediary between the starches and sugars. Dextrin is formed from starch by treating with dilute acids, or by diastase. According to the conditions, several dextrin kinds may be separated. A crystalline form, produced by the action of dilute mineral acids on starch for months, has been isolated. Dextrin gives with iodine a red coloration.

Glucosides are compounds of grape sugar or glucose with another substance, and naturally find place in a study of carbohydrates. Grape sugar, on account of its containing an aldehyde group, is capable of uniting with different kinds of chemical bodies to form these compounds. The compound which results on decomposing a glucoside is frequently of a complex nature. Glucosides are very widely spread in nature. In many cases the chemical constitution of glucosides is well known, and some of these compounds have been made synthetically.

Recently, Fischer has described a method of obtaining glucosides synthetically. By the action of hydrochloric acid on sugars, alcohols, oxyacids, and phenols, he obtained condensation products of the nature of glucosides. These compounds, like other glucosides, do not react with Fehling's solution or with phenyl-hydrazine. But they are decomposed by acids.[1]

[1] Also ketones, by warming and treating with hydrochloric acid, are changed into glucosides. Ketones combine with sugar; rhamnose with one molecule; arabinose, fructose, and glucose unite with two molecules of acetone; sarbose, with a ketosane, yields a beautiful crystalline compound. By employing a very weak solution to work with, in contradistinction to the former work with strong hydrochloric acid, α-and β-stereomers were obtained, also a third product, an acetal compound, analogous to the glucose mercaptans. In the beginning these are in excess, then they go over into glucosides.

The ketose sugars react with alcohol, in presence of HCl, more quickly than aldosans.

Fischer has also discovered, as a between-product, glucose-acetone, which is separated in fine, colorless needles. This compound is distinguishable from the glucose di-acetone.

A new glucoside, similar to amygdalin, but of a simpler formula, named amygdonitril glucoside, has been recently described by Fischer.

These simple compounds are analogous to the more complex ones, and are of interest for their bearing on the natural glucosides. There is no essential difference between the simple synthetical glucosides and the more complicated carbohydrates like cane sugar. Indeed, the latter should be considered as the glucosides of sugar.

The list of natural glucosides is a long one. A summary of their particular occurrence and properties is unnecessary here. But a glucoside, for example, like either saponin or phlorizin, illustrates the fact that compounds of a like composition are found in closely related botanical families. Plants in which saponin occurs are nearly related in regard to their stage of evolution, and so with phlorizin-containing plants. Phlorizin, when isolated from the bark of the apple, cherry, or plum tree, or from other plants belonging to the order Pomaceæ, is a crystalline substance of a white color when quite pure. Like all glucosides, it is decomposed by dilute acid into glucose and a second product. In this case the second product is phloretin.

From experiments on animals, phlorizin, when taken into the body, produces a condition which results in diabetes. The amount of sugar excreted from the system after ingestion is far in excess of what could be produced from the glycogen of the liver, nor would the amount of glucose in the glucosides explain the large quantity of sugar excreted. But, in fact, according to Cremer, the phlorizin passes through the system unchanged, and the sugar which arises is from the proteids of the body.

The very latest trend of investigation is to show that the configuration of a compound has its place in the explanation of the functions of an organism. Also, the reasons for the fermentation of certain compounds are to be found in stereochemical considerations.

It is stated in a recent publication that the most ordinary functions of a living being depend more upon the molecular geometry than upon the composition of the food material. It is well known that the fermentation processes are brought about by minute organisms, and it is supposed that the geometrical configuration of the ferment coincides with that of the compound which it attacks. The most important chemical agents of the living cell are the optically active ones of the albuminoids, and these possess, consequently, an asymmetrically constructed molecule. Since the simple albuminoids result from the sugars, the fact is given in proof of the same geometrical structure for these two classes of bodies. On this reasoning it has been claimed that, when sugar comes into contact with the albumen of the yeast cells, fermentation takes place only if the geometrical form of the sugar molecule does not differ too widely from that of the yeast substance.

In some recent experiments, Fischer found that the ferments invertin and emulsin attack only the glucosides of grape sugar, whilst they leave those of other sugars — likewise starch, salicin, phlorizin, and other synthetical phenol-glucosides — unacted on.

However, the *a*-methyl glucoside is decomposed by invertin and not by emulsin; but with the methyl-glucoside the reverse occurs. These facts are given to show that a different molecule structure alters the condition.

The influence of the bacilli on chemical changes in the body is recognized. That these changes do occur is evident. Many experiments on plant tissues show this. The transformation of starch into sugar by the *Bacillus anthracis* has been shown lately by cultivating the bacillus on a potato. After a short time, the surface of the potato gave, not the blue color of starch with iodine, but the red color of dextrin. Portions of the potato were then placed in sterilized water, and, after some days, on testing the liquid, it reduced Fehling's solution. The explanation of these changes is supposed to rest on the configuration of the molecule.

From the survey of the chart, on which are summarized the synthesis and work on the sugars, the attention of the least interested observer will be called to this fact,— that a vast amount of work has been accomplished in this field, and the harmony in these groups between facts and theories is significant. That chemical compounds are *solids* and occupy space is not to be gainsaid, but there must be an adjustment between scientific facts and hypotheses. To pervert or carelessly to observe facts in order to make them, at all hazards, fit into theoretical moulds, is the highest act of treason of which the scientist can be guilty. Chemistry, studied from a geometrical basis, is of comparatively recent date. It is purely arbitrary to settle upon any particular figure to express the grouping of the atoms in space. However, the tetrahedron is the simplest expression that explains the fact.

The entire subject of the chemistry of sugars would be the chaos it was before, without the aid of geometrical speculations. These at once bring order and system to a confusion of facts.

Hegel names time and space the accidents of true existence. In the consideration of the space relations of these compounds a step is taken to the reality which lies beyond time and space and the imperfection of knowledge. These configurations represent crudely the ideal basis of what is called matter.

The next query that will occur to those who are not daily working in scientific matters is this: Is the subject of sugars, just reviewed, settled for all times? In science there is no fixed ground. The true object of scientific research is to seek truth regardless of the consequences, and on our plane, truth is evolving. To embrace, when found, that truth which seems the more evolved, even though the pet hypotheses and results of a lifetime's personal effort are laid aside, is the true aim of endeavor. This is the true scientific spirit. The magnetic needle oscillates until it finds its resting-place pointing northward, and the chemist, too, should oscillate within the arc of his science until he finds the currents flowing towards light and higher truth.

It has been said that "every man who would do anything well must come to it from a higher plane. A philosopher must be more than a philosopher." Plato was clothed with the powers of the poet, though he chose to use his poetic powers to an ulterior purpose. In the love for facts, the other side of the subject, the "mirror image," so to speak, must not be forgotten. The true insight will come from the employment of the imagination and the cultivation of the higher reasoning faculties. This insight will reveal the meaning of all these phenomena, and the oneness underlying all things will become apparent. To cleanse the eye from seeing only the grosser phenomena, and to gain the perfect faultless eye of wisdom, compensated Kunala, the king's son, for the loss of his eye, which, by a cruel order, was torn from its socket.

The more apparent phenomena of a science have their true place when studied in harmony with the bold outlines of the universe. Call these outlines philosophical principles, cosmic laws, or what you will, but the facts of science, culled from many fields, only confirm the words of long ago: "Our whole existence depends on our thought; thought is its noblest factor; in thought its state consists."

Chemical facts, or the facts of any science when regarded, not as the end of endeavor, but as the means to an end, take their true place in the intellectual universe.

The facts of a science being more or less relative, in the search of truth these relative facts are useful, inasmuch as they indicate the principle which underlies the manifestations.

The ceaseless change and interchange; the impermanence of all things in nature, whether pertaining to the so-called inorganic or organic life phenomena, is expressed by the mutations and transformations of chemical reaction.

The recurrent properties and the chemical laws, exhibited in all syntheses, as well as in breaking-down processes of compounds, are in unison with the rhythmic system of evolution from which nothing in this universe can escape.

LITERARY PAPERS

SCIENCE AND PHILOSOPHY IN ART [1]

Wer gegenwärtig über Kunst schreiben will, der sollte einige Ahnung haben von dem, was die Philosophie geleistet hat, und zu leisten fortfährt. — *Goethe.*

SUMMARY: Art as one of the highest forms of scientific and philosophic expression — This illustrated by the Impressionist school — Elements of their method — Triangulation — Examples — Motion and force — Theory of lines — Theory of dissymmetry — Dissymmetry in mind and thought — Technique and coloring — Psychological effect of colors — Focal visual point and perspective — Examples — Water effects — Tone *motifs* — Philosophic analysis of two landscapes — Comments on Renoir and Sisley — Conclusion.

THE mainspring of happiness to the philosophic mind is to penetrate into the internal structure of things, and to analyze the complex to its ultimate elements. This principle has been accepted consciously or unconsciously, and underlies the works of the best representatives of the impressionist school of painting. The truths of geometry and the laws of force have been also recognized by them, whether consciously or unconsciously, as the only correct basis upon which to proceed, in order to produce on the mind of the observer those subjective effects which are the highest expression of Art, and of which this school, *par excellence*, is the most able exponent. The pictures of Claude Monet come first as the latest art expressions of scientific and philosophic thought.

This is clearly shown both by the treatment and the subject. The simplest elements are introduced and managed

[1] A review of the work of the Impressionists of Paris exhibited at the American Art Association Rooms, New York, during the spring of 1886. By "Celen Sabbrin." Printed in pamphlet form. Philadelphia, Wm. F. Fell & Co., 1220–24 Sansom St., 1886.

with such consummate skill as to form a combination in the highest degree complex. These pictures are the work of a genius, of a master thinker, who feels the power of the infinite, and can reflect it to others. This familiar association with the eternal problems, is where the master spirit of Claude Monet manifests itself. None in art before him has ever approached so near the domain of the philosopher. The inflexible principles of geometry give the form to his charming color harmonies. The line between the æsthetic and the intellectual is so lightly traced in his creations, that the slightest touch effaces it, and thus almost proclaims their identity. Nature is rendered more lovely by this revelation of her mechanism and the sources of her activity, which are clearly brought out by study of his pictures; though to those minds unprepared for and incapable of grasping the laws of the universe, these pictures will offer little of interest. But to the thinker, the canvases of Claude Monet are records of what the sensitive mind sees in nature. It is not the pitiless laws of growth and decay which present themselves, but humanity with its hopes and fears shining forth, with which the true soul alone can sympathize.

The compositions of Claude Monet are animated evidences of what some one has said, that the true source of knowledge can be derived alone from the subjective. He does not paint what nature is, or as she presents herself to the ordinary mind through the medium of the imperfect senses, but he paints those thoughts which she impresses upon him by means of subtle forces to which only the sensitive mind responds.

The idea of *triangulation* is clearly expressed in the works of most of the followers of the Impressionist school. It would be difficult for one unacquainted with this school's teachings to say if this is purely unconscious or by design. It is not accidental. Of this there can be no doubt; for in each picture of Monet's, as well as of those other painters whose pictures have been studied, the same theory is expressed. The attention of the observer is, as a rule, directed along the hypotenuse of the right-angled triangle. This line is used as a framework upon which to construct the picture. The lights and shadows and objects, when introduced for the main effect, are always along this line. Nor is there only one line, but a parallel series, always running at the same angle. So with shadows, trees, elevations, depressions, or with whatever objects the picture is composed. Numerous examples can be brought forward from his pictures. One may refer to No. 250, "Le Jardin de Monet à Vetheuil."

It represents a garden rising from the foreground. This is occupied by an open space a little to the left of a right line drawn from the median line of the canvas. This space is a very high light, with deep shadows of dark blue. On each side are blue figured vases filled with flowering plants, the shadows on the space and vases being along the diagonal line. A staircase, which is interrupted by a narrow terrace, leads from the space upward to the right, to a second terrace, on which are the houses. Nearly the entire canvas is occupied, and the narrow space above is a deep blue sky. On either side of the staircase are numerous tall plants, their yellow flowers rising one higher than the other, like a flight of steps. This is ended by a lattice work running along the second terrace. The light falls along the hypotenuse line through the flowers to the left, across the stone steps, and vanishes beyond to the right-hand lower corner. The same is true of the shadows. The lattices of the little fence around the terrace are distinctly seen only where the slats are arranged in the direction of the hypotenuse. The left-hand corner, which corresponds to the right angle of the triangle, is where the objects are most clearly represented, and the coloring is richer in tone. As the right-hand upper corner of the picture is examined, it will be seen that the objects are less distinctly painted, but the lines that correspond to the direction of the hypotenuse are more distinct, and the color of the picture seems to fade away, and only the geometrical basis remains.

The sky is cloudless, but a vapor-like effect can be detected by close observation, draped over the sky's form, in directions corresponding to the hypotenuse. This light drapery is a most appropriate clothing for the heated sky. The coloring of the sky is remarkable; the appearance is one familiar to those who have seen it in southern France and Spain. The rich colored vault is apparently brought almost within reach. On gazing at it steadily, the eye becomes fatigued, and the sky is no longer blue, but of a leaden color. This can also be seen on examining the picture by gaslight; the sky, by artificial light, loses its blue tone and assumes the dull, leaden hue. It may be noted that the skies of Monet are the most carefully painted of any parts of his pictures.

Two little children stand on the flight of steps leading to the dwelling, in a diagonal line. The immediate impression conveyed by this scene is one of warmth and vitality. Rich tones of green, blue, red, and orange are used with wondrous skill. It is a midsummer scene; the vegetation is at its highest, the air sultry and heavy with heat. It is a picture of the present moment, and the only pause to check the joy which such a surrounding offers is the sky, by its depth suggestive of the impenetrability to human understanding of the termini of life.

Everywhere is seen this theory of *triangulation*. It is the painter's guide for composition. In these color idyls, drawing is scarcely present. The artist's mind rests upon this simple geometrical foundation, and his thoughts are turned into a perfect form, because true to nature. Frequently the pictures can be divided into several triangles; these triangles are formed by shadows, lights, clouds, fields, the sea, houses, or lines of trees, and are always significant of the underlying truths of life, which these painters have felt. In 123, "Mail Post at Étretat," the roll of the waves, the dip of the rock, and the direction in which the clouds are flying, are all expressed in lines corresponding to the hypotenuse. The oblique parallelism of the picture is indicative of movement. Motion is suggested by every stroke of the knife. The sunlight is coming from the same direction as the lines run; and the shadow of the great rock upon the water is in motion. As the observer moves from one to the other side of the picture, the shadow seems to change its position. The effect is strange. The sea is shimmering in the sunlight and seems to be many fathoms deep. Its lovely transparency, which is finally lost in depth, reminds us of how we are lured on in our search after truth — simplicity and clearness at the start, ever-increasing dimness following. The high swells of the sea are coming on in a stately procession, each bending before the mighty rocky arch, and then rushing upon it as if to reach to its summit. These great billows are composed of small waves, and upon them rise smaller ones still, until the little ripples come, as a bright smile upon a loved face. The prevailing color-tones of greens, blues, and pinks offer a harmony of incomparable composition. One can sniff the fresh salt breezes, and hear the heavy thud of the waters coming against the rock. On viewing such a scene, we cannot but feel that we are looking upon more than nature has to offer in her cold way. We see and feel, in addition to the sea, rock, and waves, the thoughts which the artist had on painting this picture.

The theory of *triangulation* should be considered at this stage. It was stated above that in No. 123 movement is forcibly expressed by all the objects in the picture being painted along parallel diagonal lines. Motion can be represented only by ideas of force. Force is always exerted in straight lines, whether as initial or deflected force. The triangle is selected as the simplest figure enclosing space, and thus represents the lines of force in their simplest elements.

The hypotenuse offers the opportunity of introducing the idea of *dissymmetry.* We owe to M. Pasteur the acknowledgment of presenting molecular dissymmetry in its widest bearing. Dissymmetry is essential to the conditions of life. The results of synthesis in the laboratory of the chemist are always symmetrical, because the forces employed are non-dissymmetrical. On the contrary, all chemical products made in the plant cell are dissymmetrical, for they are formed by forces of dissymmetry. How should the chemist break away from his methods, which are, from this point of view, obsolete and imperfect? He should have recourse to the action of solenoids, of magnetism, of the dissymmetrical movement of light, and the reactions of substances themselves dissymmetrical. A vast field opens here for future investigations into the origin of life. Dissymmetry is not only the basis of organic life, but of the universe, for the cosmic forces are dissymmetrical.

Some bodies which are not symmetrical on the right and the left are constructed on a general plane of symmetry. A chair has a plane of symmetry; it is the vertical plane passing through the middle of the back and of the seat. But the two halves of the chair, separated by this plane, are not symmetrical; the right is not superposable upon the left.

There is a marked separation between the organic kingdom and the mineral kingdom. Dissymmetry and symmetry, or function and crystallization, are the modes of cosmic forces. The nearer the approach to the symmetrical, so much the nearer to a condition of crystallization and cessation of so-called vital functions. The transition from the dissymmetrical to the symmetrical is at the expense of force, consequently involves motion. Symmetry is equalized force, dissymmetry is unequalized force. When force is in a state of equilibrium it is symmetrical, and conversely.

The striving of the human mind to attain the symmetrical or ideal also carries with it the idea of movement. A deeper meaning underlies this. In the human struggle after perfection, or symmetry geometrically expressed, should such a state be reached, every further progress would end — human effort would be changed to a stable condition or one of crystallization. Perfection would be fixation. Absolute truth, if achieved, would terminate all thought, as the crystal terminates all directive motion. A geometrical formula expressing all life, would be also expressive of all death. Relative truth is dissymmetrical; absolute truth symmetrical.

That this conclusion seems to be where scientific thought will eventually drive the world is imminent, and the thought crops out from many of the canvases of Monet. Many of the tricks which painters of other schools employ to give motion to their pictures, are disregarded by the impressionists. They have penetrated to the source of motion, and they recognize force as the cause. This fact that force manifests itself in straight lines is not only expressed in generality, but in the details or technique of their pictures. On close inspection, their pictures are masses of short, straight lines, and all their effects are produced in this way. Curved lines are only employed when it is desired to express the idea of retardation, and when curves are used, they are formed of short, straight lines, much as in modern geometrical teachings, a circle is held to be formed of innumerable straight lines.

The right angle of the triangle, which includes all the elements of the picture, falls sometimes outside the canvas. The hypotenuse, however, is never absent. Without it, there could be no basis for the composition. Sometimes the right angle of the triangle is occupied with the most prominent objects of the painting, and to these the focal point of vision is directed. No. 184, "The Setting Sun," by Monet, is a conspicuous example of this. The focal point of vision is thrown entirely to the left, where are seen the coast line and the setting sun; to the right is a vast expanse of sea. A mistiness pervades the picture; the sky and sea blend to shut off forever from the soul the knowledge of what lies beyond.

Another extraordinary picture is No. 198, "Fog Effect near Dieppe." The sandy bank and trees are to the right. The technique and coloring of these trees are startling; straight lines mark the canvas, reproducing this mood of nature with a masterly insight. The sea dashes with violence against the coast. A faint light shines through the waves, and the foam rests on their proud, crested heads, like a bridal wreath. On just such a coast-line might life have originated, as the sport of accident, by the cruel sea, indifferent to the origin, progress, and destiny of this life to which she had given birth. The color-tints of pinks and grays delineate the outlines.

Monet's pictures are noticeable for the psychological effect they produce by their coloring. His colors are like an orchestra of instruments in perfect tune, and the pitch of his scale is given by the foundation tone of his pictures.

On close examination, it would be reasonable to conclude that the canvases were first coated by a uniform tint of paint; this is the pitch to which all the other colors are tuned, and the different effects in his pictures are produced by heavy straight lines of suitable colors, according with the pitch.

For Monet's pictures are essentially harmonies of color-tones, in distinction to Renoir's pictures, which are color discords.

The color-scale of Monet's pictures is original, and essentially calculated to produce upon the observer an intense psychological impression. As the pitch is high or low, so his colors vary in strength. Some of his most beautiful water and sea effects are reached by combinations of pale Nile green, blue and violet tints, of varying shades.

Some of his views are bathed in an atmosphere of magic grace and purity. The tone pitch is often taken from the visual forms. In No. 131, "Cap D'Antifer," the prevailing tones are violet and lilac colors. It is a late afternoon scene; the cliff stands out with wonderful distinctness; along its rugged edge runs the road, twisting and turning, but always true to a parallelism with the coast-line, our line of dissymmetry. The light through the picture follows the same line, though the light is symmetrical with regard to the oblique line, for it is equal in intensity on both sides, and it fades away equally towards the right of the picture.

To obtain their full effect, the pictures of the Impressionists should be studied in the light in which the scene was painted; and this is a very important point to be remembered in judging the works of these artists. A noticeable example of this was a picture by Besnard, "By Candle Light." The light of day detracts a great deal from the beauty of this painting.

Not only does Monet excel in painting water in motion, but also in representing it when at rest. No. 28, "Breaking of Ice on the Seine," is an example. The middle distance is the point to which the eye is attracted. We feel how cold the water must be. Its marvelous transparency and depth are startling, and in contrast with the opacity of the blocks of ice floating on its surface. It is like a silvered mirror, with here and there the coating effaced. The foreground is rough, and in blue, green, and gray tints. The picture is constructed on the principle of dissymmetry, and the effects of distance, depression, and rising ground are well portrayed. The valley, between the lines of trees which follow the bend of the river and the distant hills, is observable only after long study.

"The Low Tide at Pourville," by Claude Monet, shows the facility of this artist. The cloudy sky is reflected in the moist sands, and the eye is carried along the beach to the distant blue sea, which is painted with much distinctness.

In many of Monet's pictures, the middle or far distances are brought out with great force. It is a natural inclination of the mind, on viewing a scene, to gaze beyond the immediate foreground. Consequently, Monet's foregrounds are usually indistinct, and especially in his highest psychological studies, where this indistinctness of foreground has a philosophical bearing.

In point of fact, it is impossible to see clearly more than one object at a time; all surroundings are less distinct, or reflect the color of the focal visual object. Monet's "Cabin at Pourville," No. 169, illustrates this statement. The central object of interest is a little shrimp-colored house. The atmospheric conditions doubtless influence the mind of the observer, but the tone most deeply impressed on the house is reflected on the entire scene, on the hill beyond, and even in the sky. The same idea is brought out in Renoir's pictures, where the background, though often very indistinct, echoes the prevailing rich colors of the figure which occupy the foreground.

Monet's No. 168, "The Seine at Giverny," is a picture which at once attracts attention. The view suggests calmness and purity. A delicious fragrance steals over the senses, and the delicate perfume of lilacs permeates the mind. The transparency and depth of the water are finely represented. The shadows of the trees growing along the banks are reflected in the water, and again carry out the theory of dissymmetry. For clearness and crispness of coloring, this picture is excelled by none in the collection.

No. 108, "Scene at Port Villers," carries out several of the originalities of Monet's style. The canvas is covered by a thin layer of a pale-gray tint. In places there is apparently an absence of all color, and the canvas itself shows. The prevailing tones are pinkish grays. The last layers of color are laid on very heavily, and thus the scene is admirably represented. The theory of triangulation and dissymmetry is clearly expressed by the lines of trees to the right, forming the hypotenuse. The edge of the bank is a transverse line, prominently shown, and the ground rises above it in ragged outline against the sky, broken, dissymmetrical. The hill is reproduced in the river by reflection. This general effect is one of the best illustrations of symmetry in any of Monet's works. The subjective side of this picture is produced by adherence to simple and exact principles. The ground-plan is triangular, and the tints are in those colors which subjectively produce the sensations of chilliness.

Monet's "Morning at Pourville," No. 216, is an interesting study of shadow effects. The rock that boldly rises in the foreground is reflected in the rolling sea as a triangle. Here let us note how frequently any distinct object in the foreground of Monet's pictures is sure to be inorganic, inanimate, massive, stable, recalling the blind, immutable forces of unsympathetic nature. The extraordinary sheen of the water is most noticeable; straight lines of light aid the mind to realize that it is real water upon which the observer looks. The delusion is complete. The gallery and all surroundings vanish, and the sea spreads before you, with its restlessness. Innocence is depicted upon the siren's countenance. In the past, how many adventurous mariners she has lured on to repose upon her trustful bosom, only to drag them to her distant abode, the dwelling of death!

When Monet obtains his best water effects for depth and transparency, he employs thin, delicate colors. Pale green and blue exert a marked psychological influence upon the æsthetic emotions, reviving peaceful or agitating thoughts in the soul, as the conditions of the picture exact. For late evening effects, salmon pinks and dark greens are used with telling results, as in No. 219, "Evening on the Seine."

The "Wheat Field," of Monet, No. 158, will instantly attract the observer, as more than a landscape; in fact, in the ordinary sense, none of Monet's pictures are landscapes, but mental studies.

The middle distance is the field of wheat, ripe, and awaiting the labor of man, to be applied to its greatest usefulness.

The rich salmon coloring of the wheat inspires the feeling of hope in the human breast, and encourages the struggle of toil. The sky above echoes this happy thought of effort being rewarded. The few red poppies at the sides of the immediate foreground add to the brilliant scene of the present, and it seems as if for the minute nature had relented, and given promise to the weary worker of a haven of eternal joy. The strong red hues of the foreground, tinged with this most potent of colors, are suggestive of the vigor of life, the plentitude of the powers; and soon they fade into the uncertain shades, the feebler tones of the farther distance.

The eye travels beyond the wheat, past trees and green fields, to the distant blue hills, and just beyond the salmon-pink color is discernible, also suggesting the thought of toil. The pinkish haziness of the far distance suggests a town and busy industries, they in turn some day to be silenced and dead, even as the wheat-field after the harvest will leave only stubble and straw. The wheat will relieve the immediate hunger of man, and the industry that of his soul's longing, but only as a temporary aliment. This picture, a color poem, is a step in advance of art; it is the cry of humanity.

Wagner, in his operas, has used with telling effect his tone *motifs*. Our ear always tells us what our eye should see on the stage; the *motif* is indicative of the personality of his characters, or forewarns us what we have to expect. So with these creations of Monet, his tone *motifs* are his combinations of colors. He has certain color-scales which he uses, and to which the mind responds. This is too well marked to be passed over, and in so many of his pictures, which are eminently philosophical studies, his use of reds and peculiar greens is constant.

"A Farm," No. 135 of the catalogue, is a study in red-orange tones. The axes of dissymmetry are the lines, lights and shadows of the picture, and are so used as to be suggestive of motion. The key-note of the scene is force. In the foreground is a marshy pond, on which are floating some ducks; a roadway limits the extent of the water, and the row of piles which support the side of the road is one of the diagonal lines. The fence back of the road, the trunks of the trees, the lights and shadows, the rising ground, the outline of the roofs against the sky, and the clouds, all follow the direction of the hypotenuse. The visual focus is, as usual, dissymmetrical, and in the diagonal. It is to the left of the centre of the scene. The strong sunlight pouring down upon the side of the farm-house, and the intense shadows of the trees upon it, all indicate energy, the very power of the cosmic forces themselves. The reddish-orange color of the roof contrasted with the sky gives to the latter a greenish tinge, which adds to the color harmony of the whole. The two sides of the picture differ as to intensity of coloring and distinctness of form, and in these respects further illustrate the dissymmetrical principles which underlie.

Monet's Nos. 270, "Poppies in Bloom," and 212, "Landscape at Giverny," are companion pictures, inasmuch as one is the continuation of the other, and an expression of philosophical thought. The prevailing color-tones of the two pictures are brilliant reds and peculiar bluish-greens. Attention was called above to this color rule, as being used in what are most properly the highest philosophical studies of this artist. As art expressions of scientific and philosophical thought, these two pictures occupy the most prominent place of any in the collection.

No. 270 is the best illustration of the theory of triangulation to be found in Monet's pictures. From the foreground and running diagonally from left to right is the poppy-field, and the ground rising above it forms a green, grassy amphitheatre, closing out from sight all objects beyond the foreground, thus inviting to progress. The narrow expanse of sky is seen above the hilly bank. Its depth is interminable, and a sense of solemnity steals over the observer. He is brought most terribly near the source and origin of things. The sky is in marked contrast to the poppy-field and hill, where it is the present that offers. Here is the beginning of life's course. Unconscious of what is back of the hill, the soul is absorbed by the immediate; though she may step forward, through the gay-flowered field, onward to her future, the past is locked in mystery. Nature throws no obstacle to her progress; there is no warning hand to hold the soul from running to her own destruction; and the indifference of nature to suffering or happiness is terrible to contemplate. The grassy bank is covered with many colored grasses, the different colors giving the effect of light and shadow. These different patches are formed like triangles. The entire picture can be looked upon as the interior of a geometrical solid. The poppy-field is a parallelogram; diagonal lines run across it from one to the opposite corner, and these large triangles can in turn be divided into smaller ones. The effect of triangulation can be well seen at a distance, but is very much plainer by a near inspection of the canvas. It is significant that in one of Monet's highest expressions of thought the unbending principles of geometrical form are the most clearly discernible. It may be claiming too much to say that mathematical principles are the basis of all truth, but that the two are nearly related must be acknowledged.

No. 212, "A Landscape at Giverny," is an expression of hopelessness, of the unattainableness of absolute truth, and a confirmation of science's teachings, in the ultimate uselessness of human effort. To the appreciative such a picture would be unbearable as a constant companion; though it is the crowning effort of Monet's genius, and proclaims him the philosopher of the Impressionist school.

The mathematical principles are fully expressed in this picture, and vivify the thought that geometry is soulless, and that natural forces are relentless and pitiless. In the immediate foreground runs a gay poppy-field, which might well be the poppy-field of No. 270 continued, and we may accept it as the continuation of the soul's history. Bounding this field, along a diagonal line, are some deserted houses; beyond, and to the right, are a series of fields and lines of trees alternating. A bright light strikes one of these fields, and gives the effect of water. On and on the eye travels to the right corner of the background, where the deep blue of the hill range looms up. Above all lowers a heavy gray sky, blank and cheerless. Speculation can go no further; what is beyond these hills may never be known. The heart weakens and the soul is faint at what she sees. It is the end of the struggle of the human race; all work and thought have been of no avail; the fight is over and inorganic forces proclaim their victory. The scene is a striking reality. Nature is indifferent, and her aspects are meaningless, for what indications of the unavoidable end come from seeing that gay-flowered field? It is a mockery, and that mind which has once felt the depth of the thoughts expressed in this painting, can only seek safety in forgetfulness.

Monet does not offer any solution to the result to which his pictures lead. He is occupied in giving expression to the most serious truths of our life. He is recording the chronicles of modern thought.

The pictures of Renoir and Sisley are of great interest, as offering solutions to the ideas that run through Monet's pictures; or, if not solutions, at least those painters may be considered in the light of physicians, who are engaged in alleviating human suffering, so that the patient may forget the incurableness of his malady.

Renoir offers a course which so many of our day gladly follow. "The Breakfast at Bougival" and his studies of the nude clearly show the direction of his thought. The latter are void of expression. The idea of the immediate present in its sensual aspects is expressed by subject and treatment. The figures are prominently in the foreground. The coloring is rich and intense, and the backgrounds are indistinct, and echo the coloring of the objects of the foreground. He would teach us not to look into the distant, for all there is indifferent; we can never outline the forms of the future. Life is impenetrable, and why should we trouble ourselves with what will only result in failure and disappointment? Renoir has presented this side of the situation with a masterly hand, but the dangers of his teaching are great, and the character who hopes to forget, by these means, is utterly lost to himself and to others.

Sisley's pictures offer scenes of industry, home life, and the peace that results from leading an honorable and pure career. He sings the song of work. His pictures are beautiful, and if examined in this spirit, are powerful lessons.

In the Eternal City built on Seven Hills there is a piazza from which three streets lead into different districts of the city. This great piazza, with its open gate and plashing fountain, is the expression of the reality forced upon us by scientific thought, and the wearied pedestrian, who cannot rest here, must decide which of the three streets he will follow. Who can say by what accident his steps may be turned to the way which Renoir has depicted, or to the flower-strewn path of Sisley, or to the embrace of dogma? Each one of these three vias leads across Rome, and at a life's close, when standing on the walls of that city, and the hour for the fatal plunge into the moat has come, who can say, but the soul alone, if the choice has been well?

THE DRAMA IN RELATION TO TRUTH[1]

The patriotic spirit, or love of country, as an incidental sentiment leading upward to a wider love embracing all countries and races, has its place in the individual's and nation's development.

The fond striving of the patriot should be a means, not the end of endeavor. Lotze, in his last work, which is a summary of his comprehensive system, opposes strenuously "the deification of the state, a manifestation of which he sees in the fact that the state is conceived of as an end in itself."

A patriotism limited exclusively to any particular land is not desirable in itself, since this kind of patriotism is a species of selfish love, and must tend to contract certain sides of the human character which are very important sides to expand. But the love of country, or a localized patriotism so strongly innate in the hearts of many, is a divine germ which will grow, if nurtured, into a perfected bloom of universal love.

The advance of peoples is correlated with rightly directed individual effort. The progressive unfolding of the state and nation depends upon the earnestness of the effort and the highest possible development of the individual. To find out the paths leading to truth, love, and charity, and to reverence the high endeavor of others, whether at home or abroad, is a goal for individual effort. This effort of the individual is the first step toward a free and noble life. Once to have attained these vistas, is to realize the inseparableness of the development of the multitude from that of the individual.

In the cause of truth, the drama and stage may be used as strong levers in overturning false idols.

[1] Paper read before the New England Women's Club, December 10, 1894. The subject given to be treated was, "The Relation the Drama has to Patriotism." Printed in *Poet-Lore*, pp. 149–154, March, 1895.

The history of the drama shows that dramatic art has been a means used to depict events in the religious and historic development of nations. The stage may serve as a reflector for the customs and manners of the times. It is a chronicle of action. A writer regards the stage as an "agency of civilization," and indeed it may not inappropriately be called the school-house of the world.

The drama has also been a favorable mode of popular diversion and instruction, by strongly appealing to the emotions as well as to the finer faculties of human perception. Numerous are the play-writers of the past who dwell upon the records of deeds of heroism and conquest, and who, by recitals of the horrors of bloodshed and crime in the name of patriotism, have more often pictured the greed of gain.

The drama of Greece was intimately blended with the religious and patriotic sentiments of the nation. No less were these sentiments present in the *Nô* plays of Japan. The origin of the drama in Japan is attributed, early in eleven hundred, to Iso-no-Zenji, called the "mother of the Japanese drama," although these so-called dramatic performances were, doubtless, exhibitions of dancing. True dramatic representations may be said to have begun at a later date. Learning in those days was in the hands of men and women who composed the court circles; women were prominent as writers, and many beautiful fragments of their literary skill have come down to us. Originally the nobles took part in the performances of the *Nô* plays. The imperial theatre was attached to the court, and the ladies of the household attended. The brocaded costumes of the actors, even to the present day, are historical monuments of the past, and keep alive the traditions of those ideal heroes so dear to the Japanese patriot. Likewise in China, the drama, theoretically, was elevated in tone, and the penal code threatened those who misused their talents with punishment in purgatory after death. Among the masterpieces of Chinese dramatic art, is one, "The Sorrows of Han," which appeals to patriotism.

Along the gamut of dramatic writings might be cited numerous plays written especially with the purpose of noting some patriotic event. It must suffice here to take for granted the existence of a large dramatic literature bearing on the subject. National drama occupies a conspicuous place in a nation's literature; but to be truly great, dramatic creation needs to treat of noble subjects which shall stand as truths for all races and times, irrespective of party feeling or creeds.

An old writer has said, "You will do the greatest service to the State if you shall raise, not the roofs of the houses, but the souls of the citizens; for it is better that great souls should dwell in small houses, than for mean slaves to lurk in great houses." Again, the same writer says: "Truth is a thing immortal and perpetual, and it gives to us a beauty which fades not away in time nor does it take away the freedom of speech which proceeds from justice."

Among later dramatic writers, to Browning may be given the appellation of the apostle of truth. Of truth he says, —

> "Truth is the proper policy: from truth —
> Whate'er the force wherewith you fling your speech, —
> Be sure that speech will lift you by rebound,
> Somewhere above the lowness of a lie!"

And elsewhere he writes, "Love bids touch truth, endure truth, and embrace truth; though, embracing truth, love crush itself."

In many passages of his dramatic writings, he insists upon the full play of truth in word and action; and if truth be veiled, or perverted from its direct course, the results are fatal. In the long range of Browning's writings is the obligation insisted upon again and again that he who would be a neophyte of the noble way, must learn to pick out truth from the tangled meshes of the life around him. Truth is the first, the middle, the last of things.

In the dramatic poem of "In a Balcony," at the final scene, where Norbert, Constance, and the Queen meet, and the Queen hears Norbert's words to Constance, "Now you know that body and soul have each one life, but one: And here 's my love, here, living at your feet," Constance is terrified at the thought of the climax in affairs which this disclosure to the

Queen will produce. As she cries, "See the Queen!" Norbert notices that the Queen is grasping the balcony. He addresses her: "Madam — why grasp you thus the balcony? Have I done ill? Have I not spoken truth? How could I other?" At the end he says, "I am love and cannot change: love's self is at your feet!" As death is nearing, he reassures Constance, "Sweet, never fear what she can do! We are past harm now. . . . Men have died trying to find this place, which we have found."

Here was the mutual recognition of the high abstractions of love and truth: indestructible ideals which even death could not shatter.

Many quotations might be made from the dramas of Browning in illustration of the necessity to be through and through a seeker of truth. One more illustration will suffice. The scene is after the murder of Henry Mertoun. Mildred asks, —

"You let him try to give
The story of our love and ignorance,
And the brief madness and the long despair —
You let him plead all this, because your code
Of honor bids you hear before you strike."

And Tresham answers,—

"No! No!
Had I but heard him — had I let him speak
Half the truth — less — had I looked long on him —
I had desisted! Why, as he lay there,
The moon on his flushed cheek, I gathered all
The story ere he told it: I saw through
The troubled surface of his crime and yours
A depth of purity immovable;
Had I but glanced, where all seemed turbidest
Had gleamed some inlet to the calm beneath;
I would not glance: my punishment 's at hand —
There, Mildred, is the truth!"

There are probably few things society at large is less willing to do than to hear and accept the truth. Public opinion and conventionality more often than not serve as veneering to right and direct vision. This state of affairs is taken up by

Ibsen in "An Enemy of the People," a play eminently adapted for study and representation in any community. From the beginning to the end, the action of the play is a crusade in the cause of truth.

The situation is drawn with an unsparing hand. The indifference of the many and the cowardliness of others in not openly living up to their convictions are equally delineated. Refreshingly contrasting is the picture of Dr. Stockmann and his daughter Petra, who would willingly sacrifice all self-interests to stand on the rock of truth and freedom. Pathetic is the utterance of the doctor, when, in answer to his wife's solicitude for the materialities of life, he replies, "That 's my least concern. Now, what *does* trouble me is, that I don't see any man with enough independence and nobility of character to dare to take up my work after me." To this Petra hopefully suggests that others will come, and tells her father he is not to "bother about that."

In "The Doll's House" is shown that woman has duties to herself as well as to others. In fact, duty to self is first. Only by a knowledge of self and by developing her own character may she hope with a stronger personality to live for some permanent good. The obligation that evolution imposes on her to think out for herself her own problems is a text Ibsen often reads from. In the last scene between Nora and Helmer, where she tells him she has other duties equally sacred with those of wife and mother, the duties to herself, Helmer reiterates, "Before all else you are a wife and a mother." She replies, "That I no longer believe. I think that before all else I am a human being just as much as you are — or, at least, I will try to become one. I know that most people agree with you, Torvald, and that they say so in books, but henceforth I can't be satisfied with what most people say, and what is in books. I must think them out for myself and try to get clear about them."

Many critics, as well as a not deep-thinking public, have cavilled and reviled Ibsen's plays, and this because he dares to raise the curtain on true situations not uncommonly met with in life. Truly these situations may be unpleasant ones for some persons among his audience to face. But the truth should be "greeted with a cheer," no matter in what shape it comes. The sooner this is realized and the remedy applied, then the sooner will the necessity to think on many of these unpleasant situations be over.

This occasion will not permit of a fuller treatment of the subject. The purport of this brief sketch is to suggest that the drama may be used as a medium to elevate women and men, and to educate them equally to a knowledge of truth. From truth will all of the noblest sentiments radiate. Action in the name of patriotism, which includes love of self, State, or land, exclusive of other selves, states, or lands, partakes of an attribute not truly noble. The patriot who would be truly noble must work for the world.

Ibsen, in a paragraph to which my attention has been called lately by a friend, remarks, "The State is the curse of the individual. How has the national strength of Prussia been purchased? By the sinking of the individual in a political and geographical formula. The State must go. That will be a revolution which will find me on its side. Undermine the idea of the State, set up in its place spontaneous action and the idea that spiritual relationship is the only thing that makes for unity, and you will start the elements of a liberty which will be something worth possessing."

The spiritual relationship is the thing.

WOMAN AND FREEDOM IN WHITMAN[1]

FROM the many rich utterances of Whitman on Woman and Freedom, the reader naturally feels himself at a loss when called upon to repeat selections to others. At best, within the limits of a paper, the merest sketch or outline of Whitman's conception of these subjects can be drawn.

During his early childhood and youth Whitman spent many of his days in roaming along Paumanok's shores, where his vision and soul were enthralled by the vistas of sands and sea stretching outward. And, if the sea winds blowing along the coast-line and the shining stars or the sunlit-crested waves had not as yet taught him fully to know their voices, still he had begun to think "a thought of the clef of the universe and of the future." And he was not unmoved by the tirelessly tossing white arms when from the sea they beckoned him to launch his craft upon "the wild unrest," the limitless waters of "eternal progress" and freedom.

His early impression of woman was gathered from his own family circle, whose women-folk were strong in character and purpose. The halo of motherhood illumined his homely abode And the fact, too, that he was the outcome of a vigorous woman ancestry had not failed to leave an indelible mark upon the poet.

He begins his songs in recognition of self and personality as first, "One's self I sing, a simple separate person;" then, placing his voice where the resonance is most clear and beautiful, he sings, removing all obstructions, that his tones may be distinct and pure: —

[1] Read before the Walt Whitman Fellowship, Boston, November 19, 1896. Printed in *Poet-Lore*, April-June, 1897; also in pamphlet form, Boston Poet-Lore Company, 1897.

"The Female equally with the Male I sing.

Of Life immense in passion, pulse, and power,
Cheerful, for freest action form'd under the laws divine,
The Modern Man I sing."

Whitman's passages on woman convey the embodiment of her under practical aspects; also ideally as the typification of some of his noblest forms, as in the "Santa Spirita" and "Victress on the Peaks." Comprehensively he addresses woman, "You womanhood divine, mistress and source of all, whence life and love and aught that comes from life and love." The mother, wife, sister, daughter, nurse, comforter, the administrator in sickness and health, the *artiste*, the working woman or the woman of wealth and power, in all these capacities is she described. Even as the lowest prostitute she is not slurred by; in her, Whitman sees "the divine woman." He tells women, "Be not ashamed — your privilege encloses the rest, and is the exit of the rest."

Following the words, "A woman's body at auction," are these lines: —

"She too is not only herself, she is the teeming mother of mothers,
She is the bearer of them that shall grow and be mates to the mothers.
Have you ever loved the body of a woman?"

Whitman's universal love for humanity did not permit him to withhold his heed and sympathy from one or all of these woman-types.

The personal touch of woman's presence is very dear to him; he relates that, starting betimes for a day's outing at the seashore, fortified by a good breakfast, cooked by hands he loved, his "dear sister Lou's," how much better it made "the victuals taste and then assimilate," — the whole day's comfort afterwards resting upon this little service.

In the hospital wards, too, the magnetic touch of hands, the expressive features of the mother, the silent soothing of her presence, her words, her knowledge and privileges, arrived at only through having had children, are the precious and final qualifications. It is a natural faculty that is required, it is not merely having "a genteel young woman at a table in a ward."

He tells of "Girls, mothers, housekeepers in all their performances. The group of laborers seated at noon-time with their open dinner kettles, and their wives waiting;" of the prison visitor leading her children by each hand, who brings, with the rustling folds of her silken gown, balm to heal the convict's woe. Whether as the woman containing all, nothing lacking, in the one who "waits for me," or in those lines relating to a city where all is forgotten but the woman who detained him for love of him; or women old and young; or the sleeping mother, — Whitman studies them "each and all, long and long."

Thus in labors and charity, abroad or in the home, Whitman sees "male and female everywhere." But Whitman describes woman, too, standing alone; she it is, the dusky woman from Ethiopia who salutes the flag, who recognizes the banner, the colors assuring freedom. The one-time slave, who, knowing the lament of servitude, welcomes liberty "and courtesies to the regiments," though through men's strife freedom comes. Whitman also does not forget the "young American woman," one of a large family of daughters, who has gone out from her own home to gain her own support; who, unstained, preserved her own independence, and by her own efforts sustains herself and helps her parents and sisters. Nor is he silent as to the woman who "from taste and necessity conjoined, has gone into practical affairs, carries on a mechanical business, partly works at it herself, dashes out more and more into real hardy life, is not abash'd by the coarseness of the contact — and will compare any day, with superior carpenters, farmers, and even boatmen and drivers. For all that, she has not lost the charm of the womanly nature." Then there is the woman "physiologically sweet and sound, loving work, practical. She yet knows that there are intervals, however few, devoted to recreation, music, leisure, hospitality — and affords such intervals. Whatever she does, and wherever she is, that charm, that indescribable perfume of genuine womanhood, attends her, goes with her, exhales from her, which belongs of right to all the sex, and is, or ought to be, the invariable atmosphere and common aureola of old as well as young."

Then there is the Peacemaker, "the resplendent person" his dear mother once described to him, "the neighborly, sensible, and discreet woman, an invariable and welcomed favorite." Whitman admits that these three last portraits are "frightfully out of line" from the models, "the stock feminine characters of the current novelist, or of the foreign court poems, . . . which fill the envying dreams of so many poor girls and are accepted by our men, too, as supreme ideals of feminine excellence to be sought after." Whitman says of his ideals, "But I present mine just for a change."

But above all, Whitman lingers with most affectionate touch at motherhood: "O the mother's joys! The watching, the endurance, the precious love, the anguish, the patiently yielded life," — to him the womanly attribute, at once the most potent and divine, to him the consummation of the early promise in the eons of the past when the structures of organic life, emerging from cosmic forces, bore characters of femininity. The sweet and joyous recollections of his own mother tinged with a sacred flame all relationships of mother and child, and in no other of her rôles is woman more warmly described by him than as mother. "O ripened joy of womanhood! O happiness at last!"

The mother stands as symbol and seal of immortality.

In his glowing tribute to his mother's memory, Whitman graves a monumental line: "To her, the ideal woman, practical, spiritual, of all of earth, life, love, to (him) the best."

A truly beautiful attribute is that of mother and child, to Whitman, and when extended to broader horizons on the planes beyond the bodily motherhood, the thought grows to noble proportions. Woman considered as the mother of great intellectual and spiritual progeny. The giver out of the fluid of true life. A mother for humanity verily; in this sense the human motherhood of Whitman is impressive, she exists for the race at large, she is the impersonification of the democratic idea, a thought of fullest possibility. The human mother receptive of all noblest traits, she, freed from systems and rules, gives forth offspring of body and thought, noble as she is, permeated as she is through and through with noblest aspirations. She is alive to the requirements of others for sympathy and comprehension. What she absorbs from the cosmos, she gives out in generous plentifulness. Whitman enumerates the women who are the theme of writers from the earliest time to the present, then he says, "Yet woman portrayed or outlined at her best or as perfect human mother does not hitherto, it seems to me, fully appear in literature."

But there is one aspect of motherhood which does not seem to have been touched on by Whitman perceptibly, that is, the mother who might be named the impersonal mother, she who, whether for her own offspring or another's, holds out to the tender being her care and love because she is actuated by the highest motives of kindliness based upon universal brotherhood. These motives are not akin to the motives due to the mother's instinct. Their roots are centred in currents deeper by far, if less turbulent, than the mother's instinct; in steady flowing currents destined to speed towards seas of promise. This impersonal motherhood obtains irrespective of any special claims of ownership because the child is of one's own flesh and blood. This child has, as have all other children, the claims to its own being, its own rights; it stands independent, and towards such the impersonal mother stands independent. Ibsen has brought out this point in the closing scenes of his drama, "Little Eyolf." The husband and wife meet on a plane of sympathy and action, to bring joy and happiness to the hearts of the innumerable homeless children of the poor, who are now to occupy with them their home. The wife, in contrast to the mother's exclusive love, of the early scenes of the play, opens her heart to these other children of the poor. They are to use the belongings of little Eyolf, their own child, who was enticed so mysteriously into a watery grave. It needed the shock of this child's death to develop the characters of Alfred and Rita Allmers to this impersonal parental feeling.

Ibsen has also made an attack on the modern family, centring around the mother's instinctive love, in the "Doll's House," where, in the development of the plot, and for motives displayed, Nora leaves her children.

Turning our thoughts towards Jerusalem and the events of that memorable day on Mount Calvary, at the moment when Jesus from the cross saw his mother and the disciple whom he loved standing by, and whom he addressed in these words: "Woman, behold thy son!" and to the disciple, "Behold thy mother!" we bring to ourselves from this scene an imprint beyond the mere interpretation of the words, which are that Mary and John should cling to each other in mutual sustainment and comfort. Much more is meant by these words of Jesus. They stand as the utterance of one who, out of the depth of agony and love for humanity, foresaw in spiritual relationship the horizon of a richer and more glowing dawn.

If Whitman tacitly accords to woman, in the vigorous outlines of many of his poems, the rights to freedom, self-emancipation, and the individual life, he does so more generally by including her under the impersonal cognomen of man. In the verses where her sex is especially spoken of, the poet seems to have restricted her spheres, with few exceptions (among these "Mediums" may be noted), to those capacities serving the ends of practical life.

Whitman pauses less upon his touches of woman leading an individual life apart from sexuality, maternity, domesticity, and toil. All of these activities being by no means meant by me to be excluded, one and all, from her individual life; they may form a part of it, but not one and all are consequently essential to woman's individual development. The exercise of the woman's special functions just enumerated are, indeed, accidental and quite separate from her real life, just as much as the claims of paternity and laboring for the support of a family are apart from man's. The real life of man or woman may be conceived of as being the mental and emotional life, which may or may not inclose for woman aspects of maternity, domesticity, and toil. In other words, the individual life is the life of self, denuded of all externalities.

Whitman is not insensible to woman's needs, nor to her possibilities as a future power in the greater development of the race, apart from her maternal qualities; everywhere is claimed for her equality and equal share in the freedom she is to be the co-worker with man to gain. In comparatively few parts of the poet's works are the concrete affairs of life in the lines just mentioned discussed; but when Whitman is moved to give expression to his aspiring opinion, he does so forcibly, with the least weight on the material properties, which he indeed considers insignificant before the higher gains of character and personality.

He tells us that —

"The place where a great city stands is not the place of stretch'd wharves, docks, manufactures, deposits of produce merely,
Nor the place of the tallest and costliest buildings or shops selling goods from the rest of the earth,
Nor the place of the best libraries, and schools, nor the place where money is plentiest;"

but where "common words and deeds" exist as monuments to heroes, there thrift and prudence are in their places, —

"Where the men and women think lightly of the laws,
Where the slave and the master of slaves ceases,
Where the populace rise at once against the never-ending audacity of elected persons,
Where outside authority enters always after the precedence of inside authority,
Where the citizen is always the head and ideal, and President, Mayor, Governor, and what not, are agents for pay,
Where children are taught to be laws to themselves, and to depend on themselves,
Where equanimity is illustrated in affairs,
Where speculations on the soul are encouraged,
Where women walk in public processions in the streets the same as the men,
Where they enter the public assembly and take places the same as the men."

And as a blow against making gods of all the relative acquisitions on the material plane, he adds, "and nothing endures but personal qualities." And does he not say, too, "A great city is that which has the greatest men and women?" If it be a "few ragged huts it is still the greatest city in the whole world." Whitman, in accord with the sages of past times, brings his message into relation with our day and existence; and though we are divested and stripped in our strife, and go out naked and alone into the world, we are yet the possessor of all riches and all gain in the possession of the freedom of soul which is Whitman's everlasting theme.

It cannot be disputed that Whitman allows for women all constitutional rights in state and country; and if stress on my part is laid on this point, it is out of deference to those who believe woman's complete emancipation will come through suffrage.

Whitman more than once refers to the subject: but, speaking on general suffrage, elections, etc., he expresses himself as doubtful whether these will ever secure officially the best results. "Officers, candidacy for them, caucusing money, the favoritism, the interest of rings, the superior manipulation of the ins over the outs," are indeed at best the mere business agencies of the people, are useful as "formulating neither the best and highest, but the average of the public judgment (or sometimes want of judgment)." But he says, "as to the general suffrage, after all, since we have gone so far, the more general it is the better. I favor the widest opening of the doors. Let the ventilation and area be wide enough, and all is safe."

In Whitman's plea for equality, and in all due consideration of material rights, which to him are only substrata to increase man's and woman's height towards spirituality, and in his greetings to worldly prosperity and material comforts and progress, he declares that "the soul of man will not with such only — nay, not with such at all — be finally satisfied; but needs what (standing on these and on all things, as the feet stand on the ground) is address'd to the loftiest, to itself alone."

The basis of Whitman's plea for equality is his belief in immortality. He leaves the earth and its belongings below him. Immortality is the flux which resolves all inequalities into equalities.

"Why, what have you thought of yourself?
Is it you, then, that thought yourself less?
Is it you that thought the President greater than you?
Or the rich better off than you? or the educated wiser than you?
Because you are greasy or pimpled, or were once drunk, or a thief,
Or that you are diseas'd, or rheumatic, or a prostitute,
Or from frivolity or impotence, or that you are no scholar and never saw
your name in print,
Do you give in that you are any less immortal?"

This unity with that undying principle unites us all in this life and beyond, wherein we are equals. Whitman asks: "What is it, then, between us? What is the count of the scores or hundreds of years between us? Whatever it is, it avails not, — distance avails not, and place avails not."

In woman's equality as a political or economic being, Whitman seems less concerned; his eye is directed towards the opening future; woman's equality with man's lies in her spiritual aspirations, aim, and purpose. But he believes whatever is done in life counts towards immortality.

"I believe of all those men and women that fill'd the un-named lands,
every one exists this hour here or elsewhere, invisible to us.
In exact proportion to what he or she grew from in life, and out of what
he or she did, felt, became, loved, sinned, in life."

But Whitman tells of mutterings — of which he says, "We will not now stop to heed them here, but they must be heeded" — of something more revolutionary. "The day is coming when the deep questions of woman's entrance amid the arenas of practical life, politics, the suffrage, etc., will not only be argued all round us, but may be put to decision and real experiment." Then, as if heeding the insufficiency of our present state of affairs and conditions, he projects the "types of highest personality . . . entirely recast . . . from what the oriental, feudal, ecclesiastical worlds bequeath us. Of course, the old, undying elements remain. The task is, to successfully adjust them to new combinations, our own days." He describes the community he conceives of, a possibility for to-day, where "perfect personalities without noise meet;" where "best men and women of ordinary worldly status have by luck been drawn together, with nothing extra of genius or wealth, but virtuous, chaste, industrious, cheerful, resolute, friendly, and devout." He conceives "such a community organized in running order, powers judiciously delegated, farming, building, trade, courts, mails, schools, elections all attended to, and then the rest of life, the main thing freely branching and blossoming in each individual;" and he sees there in "every young and old man — and in every woman — a true personality developed, exercised proportionally in body and mind and spirit;" and this case he imagines "in buoyant accordance with the municipal and general requirements of our times."

It is not possible to pass over in silence the practical side of woman's life on matters of equality, which our poet asks for her, though, in view of present-day systems, Whitman is silent in directing her how she is to obtain this equality. He says, "I seek less to state or display any scheme or thought, and more to bring you, reader, into the atmosphere of the theme or thought, there to pursue your own flight."

To discuss the rhythmic rise and fall in woman's development through the times is beyond these bounds, nor can these limits include a review of woman's history from any point of view. It conceded, as a wise biologist has said, that man is the result of what woman has made him; likewise is it true that man has not been entirely inactive in woman's construction. We must take woman, in any consideration of the subject, as we find her to-day, in the light of a modern civilization, as the resultant of a long series of conditions, as more or less the creature of her environment, — physically, mentally, and spiritually.

I have to omit, for want of space, the discussion in any detail of woman's inequalities, and I will merely mention those upon which Whitman dwells. However, it would scarcely be fair to my subject to leave out mentioning one other inequality; this is the inequality of duties, which is sorely felt by many women. The loading of all domestic cares upon the woman, to the exclusion of other duties to herself. The arbitrarily established customs of society that men should labor for the support of families and women should devote themselves to the domestic work of the households, is an unequal position from the point of view that either sex is lowered from its sphere if assuming the scope of the other. A writer has said that this fact of forcing household duties upon woman as a specialty "is alone a proof of the inferiority which society ascribes to woman, since it assigns her duties which it confesses are beneath the dignity of male labor."

One other inequality is the inequality in the making of the laws. Men make the laws, and, by voting, select the rulers and representatives of women as well as themselves. If happiness depends upon enlarged sources of activity, then truth rests in these words: "It is quite certain that in all distribution of happiness, the stronger sex has seized the lion's share."

The words just quoted are worth remembering when studied in company with the utterances of one party among writers, who maintain that masculine force has had no share in woman's subjection, and who believe that woman alone has put herself into bondage.

Perhaps nowhere is woman's inequality more marked than in her limited opportunities for experiences in the life surrounding her. Whitman has given expression to woman's longings for wider experience when he presents, in the "Song of the Broad Axe," the shape of her who is to know all, pass through all, untouched and spotless, a law to herself. It may be said in general terms that, from the cradle to the grave, woman is debarred by social restrictions from taking her share either as observer or actor in the activities of the community in which she resides. The freedom of men to go and come as they please, and liberty in all their relations with their fellow beings, is a factor, and a large one, in man's present vantage ground. When woman attempts to step aside from her narrowing spheres, she exposes herself not only to other inconveniences, but also to the anomalous criticisms of a binary system of moral standards which is at work in the world in judgment on man and woman.

The suffrage already referred to is a cause Whitman champions for the attainment of woman's rights in civil and political affairs.[1]

The persistent withholding of these rights is one of the crying disgraces of the day. If the political system of representation by suffrage is the chosen form of a country's government, then withholding these rights from even one woman, if she wants them, clearly shows that she is not regarded worthy of citizenship, and "woman's position has reached the lowest and most dependent state."

It is unnecessary to enter here into a discussion of the rights and wrongs of universal suffrage, and the majority rule, or of those systems with divergent paths leading on one side to Authority, and on the other side to Freedom. It is enough to recall to memory those ancient systems where women at certain periods rose to places of eminence before the law, and then to ask: If universal suffrage is admitted to be such a dangerous weapon as the opposers to woman suffrage contend it is, why do not those who oppose woman's claims on the ground that her ignorant vote will help to bring about general destruction, wage war against the entire system of suffrage? If it contains such germs of terror, why bring these arguments to eliminate woman simply because she is a woman, when the voting list is being yearly increased by foreign, ignorant voters, controlled by bosses and demagogues? Point out to me where freedom is to be found in this state of affairs.

I cannot pass over just here the words of John Stuart Mill, — words in harmony with Whitman's words, which I shall repeat later. Mill, in reference to the United States, calls

[1] To the movement for the eligibility and entrance of women amid new spheres of business, politics, and the suffrage, the current prurient, conventional treatment of sex is the main formidable obstacle. The rising tide of 'Woman's rights,' swelling, and every year advancing farther and farther, recoils from it with dismay. There will, in my opinion, be no general progress in such eligibility till a sensible, philosophic, democratic method is substituted. — Whitman's *Prose*, p. 304.

attention to our "democratic institutions" resting avowedly on the "inherent right of every one to have a voice in the government." He points to the statement with which our Declaration of Independence commences, "that all men are created equal; that they are endowed by their Creator with certain inalienable rights; that among these are life, liberty, and the pursuit of happiness; that to secure these rights, governments are instituted among men, deriving their just powers from the consent of the governed." And he does not imagine that any "American democrat will evade the force of these expressions by the dishonest or ignorant subterfuge that men, in the memorable document, does not stand for human beings, but for one sex only — and that 'the governed' whose consent is affirmed to be the only source of just power is meant for that half of mankind only, who in relation to the others, have hitherto assumed the character of governors."

It is unnecessary to go into the arguments for and against woman's intellectual equality here. They have been discussed during past years threadbare. I will quote only a few words more from Mill on this theme; he has been speaking of the deleterious effects of forcing women into careers which are devoted to trivial details, to the exclusion of combining with them other activities or professions; he adds: —

"Not to be misunderstood, it is necessary that we should distinctly disclaim the belief that women are even now inferior in intellect to men. There are women who are the equals in intellect of any men who ever lived; and, comparing ordinary women with ordinary men, the varied though petty details which compose the occupation of women call forth probably as much of mental ability as the uniform routine of the pursuits which are the habitual occupations of a large majority of men."

Whitman's words, to which I referred in this connection, are these (he is speaking of democracy and its ideals of women): —

"The idea of the women of America (extricated from this daze, this fossil and unhealthy air which hangs about the word lady), develop'd, raised to become the robust equals, workers and it may be even practical and political deciders with the men — greater than man, we may admit, through their divine maternity, always their towering emblematical attribute — but great, at any rate, as man, in all departments; or rather capable of being so, as soon as they realize it, and can bring themselves to give up toys and fiction, and launch forth, as men do, amid real, independent stormy life."

The physical inequality of woman is one that Whitman would wipe out. His lines repeat themselves again and again, urging women on to robustness. He deprecates dyspeptic womanly amours. He calls for the "athletic American matron speaking in public to crowds of listeners." In jubilant song he announces the "horsewoman's joys." He encourages woman to fill her being with the great world ideas, "events and revolutions," sweeping in waves of immense passion across the earth.

Something of this spirit has filtered its way to-day into France. Woman's physical inequality is to be met by especial attention to the culture of her physique, and as a part of the solution of the sex problem, as well as the problem of society, the indispensableness of woman standing with man as physical peer is recognized.

Whitman urges both women and men to action; he tells them: "As for you, I advise you to enter more strongly into politics — always inform yourself; always do the best you can; always vote. Disengage yourself from parties." Whitman exults in independence. "What is independence? Freedom from all laws or bonds except those of one's own being, controll'd by the universal ones. To lands, to man, to woman, what is there at last to each but the inherent soul, nativity, idiosyncrasy, highest poised, soaring its own flight, following out itself?"

Whitman is not blind to the fact that these States are not true to what he believes the real spirit of their constitution to be, "for all this hectic glow and these melodramatic screamings." He sounds the alarm, and cautions political and business readers "against the prevailing delusion that the establishment of free political institutions and plentiful intellectual smartness, with general good order, physical plenty, industry, etc. (desirable and precious advantages as they all are), do of themselves determine and yield to our experiment of democracy the fruitage of success. Society in these States is canker'd, crude, superstitious, and rotten. Political, or law-made society is, and private, or voluntary society is also. . . . The spectacle is appalling. We live in an atmosphere of hypocrisy throughout. The men believe not in the women, nor the women in the men. The aim of all the *littérateurs* is to find something to make fun of. A lot of churches, sects, etc., the most dismal phantoms I know, usurp the name of religions."

He tells of the business depravity of our country: that it "is not less than has been supposed, but infinitely greater." He speaks of all official services and departments as "tainted" and saturated in "corruption" and "falsehood." These are the sins that men have to answer for. Woman's share of all this putrification is her part in "fashionable life, flippancy, tepid amours, weak infidelism, small aims or no aims at all." These things are all untruth, soul-unsatisfying. All these excrescences are to be cut away, and in their stead arise "charity and personal force — the only investments worth anything."

Whitman would favor the financial independence of woman as part of his scheme. He says, "my theory includes riches and the getting of riches," and he maintains that, after the rights of property have been listened to and acquiesced in, the liberalism of these United States asks "for men and women well off, owners of houses and acres, and with cash in the bank." Thus he would extend wealth to all, giving to men and women money, products, and power as a base upon which to raise the edifice of personal liberty. He does not suggest how these riches are individually to accrue, although he condemns modern business methods and despises materiality as the aim of all effort; still he is not in sympathy with the idea that "property is theft," for in other passages than those just quoted he perceives "clearly that the extreme business energy, and this almost maniacal appetite for wealth prevalent in the United States, are parts of amelioration and progress indispensably needed to prepare the very results" he demands.

Whitman's idea is one of endless material and spiritual progress. We are constantly being told by students of social matters that we are developing, and slowly approaching a better state of human affairs. In a few of our States some of the inequalities of woman which we have been reciting are met by reform measures. Woman has been granted suffrage in these exceptional States; in one or more States the married woman stands as owner of herself. Acceptable as all reforms are, they are not enough singly, or isolated here and there throughout the land. The field of the world at large is too wide to be protected by one piece of reform artillery. And those of us who are happy in living in the more enlightened community of our own ideas, or actually in these exceptional spots on the earth's surface alluded to a few moments ago, must not disregard the fact, in thinking of woman the world over, that to-day she stands far below the knoll where Whitman would carry her.

Whitman speaks of this land as "the great women's land, the feminine, the experienced sisters and the inexperienced sisters." He salutes woman and invites her to a place of equality with man, and he bids one and the other to be free. The situation takes on an awe-inspiring aspect as well as a gruesome one when we consider the conventional idols across the pathway which must be cast aside in this search for equality and freedom.

By some writers it has been stated that from evolution to revolution is only a hurried step in the process of human affairs. Indeed, revolution has been named a hurried evolution. In our present consideration, revolution more particularly applies to bringing the woman question to an issue. But woman's deliverance may be more intimately blended with a social reconstructive scheme than has seemed evident to woman's warmest adherents.

Whether this general revolution is to be accomplished by violent or pacific means, rests upon the vigor of individual convictions. If either man or woman is convinced that the existing state of human affairs is so utterly wrong as to be righted only by destroying it and starting anew, then comes the personal justification of a revolutionist.

Certain passages in Whitman's prose writings point to his expressions of revolution being meant in a symbolic sense. Possibly his poetic expressions of revolt may be likewise meant.

"Pale, silent, stern, what could I say to that long-accrued retribution?
Could I wish humanity different?
Could I wish the people made of wood and stone?
Or that there be no justice in destiny or time?

O Liberty! O mate for me!
Here too the blaze, the grape-shot and the axe, in reserve, to fetch them out in case of need,
Here too, though long represt, can never be destroy'd,
Here too could rise at last murdering and ecstatic,
Here too demanding full arrears of vengeance."

"Courage yet my brother or my sister!
Keep on — Liberty is to be subserv'd whatever occurs;

. . . .

(Not songs of loyalty alone are these,
But songs of insurrection also,
For I am the sworn poet of every dauntless rebel the world over,
And he going with me leaves peace and routine behind him,
And stakes his life to be lost at any moment)."

Again Whitman tells us:—

"What we believe in waits latent forever through all the continents,
Invites no one, promises nothing, sits in calmness and light, is positive and composed, knows no discouragement,
Waiting patiently, waiting its time."

And Whitman extends his sympathy to those who, abiding the truths that rest in all things, "neither hasten their own delivery nor resist it." Whitman stands for each in warm sympathy. He looks to the time when the "People themselves are lifted, illumined, bathed in peace — elate, secure in peace," and he would do "away with themes of war! away with war itself! . . . And in its stead speed industry's campaigns," and in the work to be done, "For every man to see to it that he really do something, for every woman too."

A writer has said, if ever any class on earth has had cause to revolt, it is woman, be the causes of her limitations from many factors, or what you please. In simplest terms, it may be asked, what is to be gained by this revolution? The answer is Freedom. Freedom is the end which revolution and revolt through truth have in view. It is a liberation from all the chains which are holding back the human being from greater expansions of mind and soul. By Freedom is meant a state wherein all the shackles from preconceived ideas of the rights and wrongs of a question, are cast aside; when the being stands unhampered to view each question on its own merits, to let each concept to which the human mind is open work out through a sequence to its logical conclusion; where the individual's action need not necessarily be one with the full possibilities of the conceptional outgrowth, but where the individual may partake of equal actional with theoretical liberty if so he or she desires. In Freedom each being must stand alone, and the conduct of another cannot be prescribed by you or by me.

Freedom is also a state wherein we are surely not free to give ourselves up to unbridled passions, license, and vices. For once we have resigned our own leadership into their lawless hands, we can call ourselves free no longer; but we become enslaved men and women. Perhaps the man and woman ruled by even the noblest themes, lose in their devotion to any one absorbing idea something of the essence of liberty. Any enslavement thus becomes incompatible with Freedom. Freedom also does not mean restrictions which condemn and kill the energies and activities from and to the higher nature. To be free means a just use of all functions and all powers leading to a fine and unfolding future of individuality and race. In one sense perhaps we can never obtain perfect freedom, but the freest man or woman is the one who maintains an equilibrium amidst the contending storms of desires.

But to "the self that knows" truths take on in this knowing self an effulgence incomparably bright with former states. To truth's justification in each soul and guidance to its own freedom, must self look to self alone, and be its own guide to that point which makes each particular individual free.

How incompatible is this state with the social world around us! From reading Whitman, especially those portions of his works bidding us bow in obedience to law, I have understood him to be speaking of universal spiritual laws. To these, when recognized, we owe allegiance and obedience. In conforming and bringing our spiritual nature into touch with our psychical environment we become freest men and women. These thoughts, which are found scattered through Whitman's writings, as it were like jewelled stars in the vast sky, are presented concisely in his prose under the title "Freedom." He says: —

"It is not only true that most people entirely misunderstand Freedom, but I sometimes think I have not yet met one person who rightly understands it. The whole Universe is absolute Law. Freedom only opens entire activity and license *under the law.* To the degraded or undeveloped — and even to too many others — the thought of freedom is a thought of escaping from law, — which, of course, is impossible. More precious than all worldly riches is Freedom — freedom from the painful constipation and poor narrowness of ecclesiasticism — freedom in manners, habiliments, furniture, from the silliness and tyranny of local fashions — entire freedom from party rings and mere conventions in Politics — and better than all, a general freedom of One's-Self from the tyrannic dominations of vices, habits, appetites, under which nearly every man of us (often the greatest bawler for freedom) is enslaved. Can we attain such enfranchisement — the true Democracy, and the height of it? While we are from birth to death the subjects of irresistible law, enclosing every movement and minute, we yet escape, by a paradox, into true free will. Strange as it may seem, we only attain to freedom by a knowledge of, and implicit obedience to Law. Great —

unspeakably great—is the Will! the free Soul of man! At its greatest, understanding and obeying the laws, it can then, and then only, maintain true liberty. For there is to the highest that law as absolute as any — more absolute than any — the Law of Liberty. The shallow, as intimated, consider liberty a release from all law, from every constraint. The wise see in it, on the contrary, the potent Law of Laws, namely, the fusion and combination of the conscious will, or partial individual law, with those universal, eternal, unconscious ones which run through all Time, pervade history, prove immortality, give moral purpose to the entire objective world, and the last dignity to human life."

Walt Whitman charges us here, and elsewhere in his writings, to see to it that we seek this freedom. He gives, too, so beautifully the progress of souls as the means of gaining immortality. But the soul with its germs of unfolding possibilities can only bud and blossom in free fields.

This thought finds expression by Whitman in these words: —

"O sight of pity, shame and dole!
O fearful thought — a convict soul!"

I think I shall not only express my own but the thoughts of others when I say that after all Whitman has said on woman there remains a feeling of dissatisfaction. Woman in many characters accompanies the poet, but there comes a moment in the life of his poems when his path seems to diverge from hers. He goes on his way to heights and out-reaching vistas alone. Nature becomes more and more a source of his inspiration. In his spiritual growth and aspirations woman is not found, in his poems, by his side. Later and later she is more and more out-distanced, till in "Sands of Seventy," with the exception of the lines in tribute to "My science friend, my noblest woman friend," woman's influence seems nigh dead.

Nowhere among his writings do I find woman standing out in bold relief as the embodiment of great emotions, — nowhere does she rise up as a form *inspiratrice*. Nor has Whitman embodied woman's thought, passion, and power in such frames as Ibsen and Browning have here and there placed their womanly creations in.

Of a spiritual womanly ideal, Whitman has reached in these words his highest one: "Prophetic joys of better, loftier love's ideals, the divine wife, the sweet, eternal, perfect comrade." In the passages cited, however, where he treats of woman in the lower planes of life, he has been full and clear in his utterance.

Woman divested of her corporeal attributes as a reality in comradeship, has not become a part of the poet's theme. And the vast areas of the regions of the super-sensuous he has not explored with her. Whitman has not met woman on a plane of reciprocity where truth, liberty, and love re-echo from soul to soul here on earth or in thoughts of death, and where the soul of man and woman are entwined and live as one enfolding form. Nor has Whitman been touched by the quivering light from that unseen and far-away realm where thoughts on life and immortality pass from hand to heart, from lips to soul, to that blessed unity awaiting man and woman, which is eternity's own!

But this silence of Whitman's mind is not inharmonious with his plan. In his writings he distinctly says that he is describing his own personality, the personality of its own time and place. And there are chords of harmony in these relations of the sexes which Whitman never touched or heard.[1]

To me, Whitman's idea of comradeship even does not clearly stand for the mutual development of man towards woman or woman towards man, which may exist and be the outcome of a state resting on perfect freedom and liberty. It may be that woman herself alone is capable of giving the truest utterances about herself; and in turning to the pages

[1] Man and woman are parts of one and the same humanity, "the human integral," — each brings something which is specially pertinent to individual sex. Hope for humanity in the future would seem to rest on the coöperation of the sexes. This coöperation may or may not be based on unity in aspiration and reciprocal sympathy, but when these elements arise, they do not interfere, on the contrary they aid the force of coöperation for the good of others. Whitman's position towards love in this broadest sense is a negative one.

of George Sand, exquisite passages — living entities from woman's heart and soul — strengthen such a belief.

But to return to Freedom. Whitman, on this point, is found firm, strong, and imperative, and as the harbinger of contest for liberty he goes forth and cries out to the cities and to the States, "Resist much, obey little." He sings of war, — "a longer and greater one than any," with "victory deferr'd and wavering," but the cause as certain as if won, "the field the world, for life and death, for the Body and for the eternal Soul." Lo, he comes, and chants "the chant of battles"!

In Paris, last summer, as I stood before the large canvas of Rochegrosse, where the artist tells the story of human anguish, of the struggling pyramid of humanity on the crags of suffering and misery, my imagination was filled with the smoke-laden air of the factory-strown lowlands, — material contest, competition, mistaken aims, beauty slain, all being portrayed as futile, leading nowhere, the only realities being the aspirations toward the ideal, which few ever gain foothold on the tapering rock-summit to view from afar, — then occurred to me Whitman's words, "I have no chair, no church, no philosophy. I lead no man to a dinner-table, library, exchange. But each man and each woman of you I lead upon a knoll." Upon this "knoll," — Whitman's outlook towards a promised land, — each man and each woman of us meet to gaze upon vistas of equality and freedom.

Cast aside fear, there is no danger that all may not reach the goal. Whitman tells us that he has in mind all through his book the average man and woman, "the working man and the working woman." [1]

It is for them and ourselves, when we have reached the knoll, to take up the staff and scrip and journey farther, be-

[1] Curious as it may seem, it is in what are call'd the poorest, lowest characters, you will sometimes, nay generally, find glints of the most sublime virtues, eligibilities, heroism. Then it is doubtful whether the State is to be saved, either in the monotonous long run, or in tremendous special crises, by its good people only. When the storm is deadliest, and the disease most imminent, help often comes from strange quarters, — (the homeopathic motto, you remember, *cure the bite with a hair of the same dog*). — Whitman's *Prose:* "The Tramp and Strike Question."

yond the hillock where Whitman carries us. He tells us, "Not I, not any one else, can travel that road for you, you must travel it for yourself." He brings the man or woman into the atmosphere of individualism, — into a state where the words of the writer of the "Chung Yung," who spoke them long ago, live as the true fabric and foundation of government. These words are: "When one cultivates to the utmost the principles of his nature and exercises them on the principles of reciprocity, he is not far from the path. What you do not like when done to yourself, do not do to others."

THE CONCEPTION OF TRUTH AMONG THE GREEKS AND IN BROWNING.[1]

THE poem of "Ixion" suggests the aspirations of a soul racked on the fiery wheel of life's troubles and despair, but a soul that looks beyond the torments of time into the region of purity, hope, and truth far away; for in all conditions this life's journey is crowded with anxieties, griefs, and care.

It is impossible to escape from under suffering's yoke. But in reality, these so-considered barriers to happiness may be made the means to elevate the soul to higher planes; and the burden of the yoke, through truth and hope, is changed to a silken scarf, if the eye be but fixedly turned upward. All sorrow melts to joy when the realization comes to the toiler that true happiness is reached through pain. Grief may be termed an essential factor in the evolution of character. Suffering is the seasoning of life, the necessary condiment of existence. There is no tinge of pessimism or despair in the candid heart that acknowledges woe as the common heritage. But in recognition of poison one must also recognize that an antidote is to be applied. From the world's healers many formulæ have descended to us to save the human heart from utter annihilation.

The Blessed One spoke at Benares: "He who recognizes the existence of suffering, its cause, its remedy, and its cessations has fathomed the four noble Truths:—

"The Truth of suffering.

"The Truth of the cause of suffering.

"The Truth of the cessation of suffering.

"The Truth of the path which leads to the cessation of suffering."

[1] Read before the Boston Browning Society November 17, 1895. Preceded by the reading of "Ixion."

Again he spoke: "The world is full of sin and sorrow, because it is full of error. Men go astray because they think the delusion is better than truth. Rather than truth they follow error, which is pleasant to look at in the beginning, but causes anxiety, tribulation, and misery. . . . The truth is the end and aim of all existence, and the worlds originate so that the truth may come and dwell therein. . . . Those who fail to aspire to the truth have missed the purpose of life." "Truth is the essence of life. Truth cannot be fashioned. Truth is one and the same; it is immutable. Truth is above the power of death; it is omnipresent, eternal, and most glorious." Numerous passages of the "Dharma" are of the same purport. "And again I would say, Truth sweeps the world of error; its breath scorches the false and untrue. It is the great Agni, — the fire god, — whose emblematic flames point heavenward."

The religious writers denounce the liar and the lying life: "A false balance is abomination to the Lord; but a just weight is his delight."

The teachings of Christ and his apostles battle against falsehood in the relations of man to man; and in the account of Ananias and Sapphira, his wife, for an illustration, the lie and fraud which stand for lying and perjury against our own higher nature and the God within us are justly punished by death, — the figurative total extinction of all progressive powers.

The lode-star of philosophy is Truth: Truth the unified principle through all and in all. From Truth our being emanates and returns by Truth to its source. Truth is thus glorified by its transitions, defeats, and victories. At each tone of Truth's gamut rests Browning, who emphasizes as no one else its beauty and power.

A rapid mental survey seems to show that the writings of the past lead in a direct line to Robert Browning; in none of these writings, epics though they be in Truth's cause, does the Truth obtain in such a marked degree, under so many aspects and varieties of conditions, as in our poet's works. In every state and degree Truth is studied from its earliest manifestation "deep down in a lie . . . and every lie quick with the germ of Truth," to its highest query, —

"Friend, did you need an optic glass,
 Which were your choice? a lens to drape
In ruby, emerald, chrysopras,
 Each object — or reveal its shape
Clear outlined, past escape,

"The naked very thing? — So clear
 That, when you had the chance to gaze,
You found its inmost self appear
 Through outer seeming — truth ablaze,
Not falsehood's fancy-haze?"

Not only once or in any limited number of his poems, but again and again, with a persistent effort born of the firmest conviction and intuition, Browning whispers, pleads, nay thunders the truth of Truth, the religion of Truth, salvation by Truth; Truth in all worldly relations, and the infinite and absolute Truth, that deepest of all Truth which Shelley calls imageless. Browning makes no compromise with diplomacy and social usage. Our poet's admiration for Shelley does not cease with approving words. Browning carries onward the torch of Truth from him he calls "Sun-treader," who teaches, "There is one road to peace, and that is Truth." And the flame grows brighter with the onward march, for our poet tells us that —

"the troubled life
Of genius, seen so gay when working forth
Some trusted end, grows sad when all proves vain.
How sad when men have parted with truth's peace
For falsest fancy's sake!"

It seems almost needless to mention the fact, well recognized by all Browning readers and portrayed in his poems, of the deep impression made upon Browning's mind by his wide and careful reading of Greek literature. Browning not only made transcriptions from the Greek drama, but he also selected Greek topics as subjects for several of his poems. The pearls of Greek philosophy and higher thought he set in verse and made his very own. The ethical life of the Greeks, their Gods, religion, belief in immortality, and thoughts on life and death he brought before us with remarkable clearness.

In the earlier Greek writings, Homer, for example, the notion of Truth is not so exalted as in later Greek writings. Its applications are more generally to concrete objects, and Truth is used more in our sense of verity in relation to some particular situation, as when Sarpedon addresses Glaucus, "But now, for a truth ten thousand fates of death press upon us;" or in another passage, "Thine of a truth will shame and disgrace now be, O Menelaus, if the swift dogs tear the faithful companion of illustrious Hercules beneath the walls of the Trojans." Hector interrogates the maids of the palace thus, "I pray you, maids, tell me truly whither went white-armed Andromache from the palace?" Him then the active housewife in turn addressed, "Hector, since thou biddest me to tell the truth, she has not gone to any of her husband's sisters — but she went to the lofty tower of Ilium."

Very frequently similar passages occur in the Iliad and other Homeric writings. When the Gerenian Knight says, "Shall I speak falsely or say the truth?" doubtless his hesitation arose from fears lest his forebodings should dampen the courage of his companions. Nestor well comprehended the imperfections of our senses and the relativity of Truth depending upon the senses as its source, and the need of coöperation when resorting to such experience. He says, "Truly, my friend, thou hast spoken all these things aright, — for when two go together, the one perceives before the other how the advantage may be. But if one being alone should observe anything, his perception is more tardy and his judgment weak."

It was a Greek principle in warfare that stratagem, deceit, and cunning were legitimate means to employ in overcoming an enemy, although treaties with the enemy were concluded and ratified upon oath and were binding. Ulysses is openly addressed as "Jove-sprung son of Laertes, much-scheming Ulysses," "Ulysses of many wiles," "Cunning Ulysses," and again he is "the divine Ulysses," who although divine unhesitatingly promises to save the life of the weeping Trojan, Dolon, if he but tells correctly why he comes alone from the camp towards the fleet. The reply given, Dolon is speedily dispatched; promises avail naught, falsehood is in conformity with custom.

The gods held similar principles, for Agamemnon complains how Zeus, the son of Chronos, entangled him in a grievous calamity. He calls him "cruel" for his "plottings" and evil "fraud." Asius, who was slain by Idomeneus, groaned, smiting both his thighs and exclaiming indignantly, "Father Zeus, now at least thou hast become utterly deceitful."

That Zeus was quite capable of appreciating the inconveniences arising from deception is fully depicted by Homer in a little scene where Here figures prominently. No doubt some such thoughts as these were in the mind of Zeus on that occasion.

"Womanhood, — 'the cat-like nature,
False and fickle, vain and weak,' —
What of this sad nomenclature
Suits my tongue if I must speak."

The Truth ideal evolves and announces itself with bolder outline as the centuries roll on. But here and there in the old Greek literature occur passages suggestive of the coming cumulative height of Truth which found full expression in Plato and later writers. Hesiod extols the man who is sincere with his friend. The eye of Apollo is described as "piercing beyond all other eyes." The sun-god is "the guardian of moral life and the expression of moral purity and exaltation." He thus stands for light, enlightenment, the coming of Truth, as Orestes says, "For night is the time for thieves, the light for Truth."

In the early courts of justice the necessity for Truth in political and legal life was recognized, and the Heliastic oath concluded with these words, "May much good befall me if I keep my oath, but if I prove false to it may destruction fall upon me and my family." However, the system of the Heliæa, we read, led to much uncertainty in the administration of justice, and a crop of sycophants at Athens made their living by levying blackmail, which their victims were afraid to refuse.

From the dramatic writers passages bearing on Truth in its relations with practical life may be culled. Many of these passages refer specifically to Truth. In the words of Polynices, "The speech of Truth is simple and those things which are just need not wily interpretation; for they have energy themselves; but the unjust speech, unsound in itself, requires cunning preparation to gloze it." The writings of the dramatists besides are replete with passages containing the truths of Truth in sympathy with much present-day thought. Imperfect though words be to express the full purport of the idea, nevertheless, in the mouth of Eteocles Euripides shows what power he thought they might possess uttered in Truth's cause. Eteocles addressed his mother Jocasta thus: "But he ought to effect a reconciliation not by arms, for speech does everything which even the sword of the enemy could do."

Many other passages might be pointed out in which occur beautiful eulogies to Truth, showing the dawn in the Greek mind of the idea of universal Truth.

But too often a feeling that truth is inexpedient is manifested, where revenge, hostility, or the relations of the sexes are concerned. Falsehood and deception have full play to gain some other end considered good in itself. Again, some truths were not considered decorous to tell. Electra pleads with Orestes that it is not becoming a virgin to tell why her most unholy mother slew her husband Agamemnon.

Deception and falsehood are often practiced in Greek drama in connection with the preservation of the life or the prestige of an individual; apparently untruthfulness in such a cause was not opposed to the ethics of the time. Iphigenia by the arts of Ulysses, under pretense of being wedded to Achilles, was drawn to Aulis. Later on, her escape from Tauris was effected by a plot against her preserver. Even Pylades in the Greek play concealed the identity of himself and companion. It is interesting to note just here what an advance Goethe has made in the treatment of the same situation. In Goethe's drama Iphigenia could not be false to her own ideals or untruthful to Thoas, her king and preserver. Also in Goethe's version Orestes cannot deceive by uttering a false word. He exclaims to Iphigenia, "Between us let there be Truth!"

The proposal of Electra to the two friends Orestes and Pylades, to entrap Hermione by falsehood, murder Helen, and hold the virgin for hostage as a means of saving their own lives, is not only considered a laudable stratagem worthy of applause, but it brings down upon Electra the weighty mantle of Orestes' words, "O thou that hast indeed the mind of a man, but a form among women beautiful, to what a degree art thou more worthy of life and death?"

Stratagem was the keynote of the situation, and a moral standard where cunning and lying were tolerated was also accompanied by a lower estimate of woman. The chorus laments, "Women were born always to be in the way of what may happen to men to the making of things unfortunate." That woman was made to feel this of herself, is mentioned more than once by the old tragedians. In Ion, Creusa laments, "For women's condition is a difficult one among men, and the good being mixed up with the evil, we are objects of hatred. So unhappy are we by nature."

Inasmuch as the Greek notion of Truth up to this point includes belief in the ethical necessity of true speaking and the binding qualities of an oath and true living where the conditions of life-motives are not complex, it also includes the setting aside of Truth when circumstances according to the Greek method of justice demand vengeance or revenge, in warfare, and for other reasons, where Truth is not considered expedient. Also hospitality, so strong a Greek characteristic, would take precedence to Truth, as illustrated in the situation between Admetus and Hercules in Euripides' "Alkestis."

Browning nowhere approvingly considers setting Truth aside for expediency. As a seeker after Truth he starts on the quest with the clear understanding that he will carefully and conscientiously give to the world the details of his search and his conclusions on the problems concerning life and death, and his forecast of what is to be. Oft with him it is "the pain of Truth's deliverance troubling all within me." But with courage from knowing and loving he speaks. And even at the last he would face Truth whate'er presents. Those words of his in "Prospice" spur on the soul to pass "Arch Fear" for the Truth, "for Light," and for the "Soul of his soul."

"I was ever a fighter, so — one fight more,
The best and the last!
I would hate that death bandaged my eyes, and forebore,
And bade me creep past.
No! let me taste the whole of it, fare like my peers
The heroes of old,
Bear the brunt, in a minute pay glad life's arrears
Of pain, darkness, and cold.
For sudden the worst turns the best to the brave,
The black minute 's at end,
And the elements' rage, the fiend-voices that rave,
Shall dwindle, shall blend,
Shall change, shall become first a peace out of pain,
Then a light, then thy breast,
O thou soul of my soul! I shall clasp thee again,
And with God be the rest!"

Browning is all patience with the weak, even with the false and untruthful; but the lying soul is hateful to him. His far sight helps him to see that in the distance all will become true and truthful. With his penetrating vision he discerns all evils blending into the good. He says, "So may a glory from defect arise." But he urges action as essential to the real regeneration. Action towards the relatively true were better than stagnation in the absolute. And all evils are as the waters of the ocean whose waves in turn and time will surge over the shores of Goodness and Truth. Yes, through the evil the good is found, through the false the true, and in "Fifine at the Fair" he tells us—

"We must endure the false, no particle of which
Do we acquaint us with, but up we mount a pitch
Above it, find our head reach truth, while hands explore
The false below."

So it is in the consideration of phases of life which may be classified among those opposed to the customs of society, convention, or morals. Under all these conditions the poet teaches, be true to ourselves, no matter if this trueness is in conflict with all outside. This truthfulness to ourselves may not be rightful action as we may some day see when we have journeyed farther on; but it is the right course for us if in all conscience we cannot see anything better and truer at the moment. And such a thought should inspire in all hearts toleration, pity, and love towards our fellow beings slower than ourselves in the upward climb.

Perhaps it is not well to hurry the climber too rapidly in his climb. The head must be steady and the pulse-beats strong. Browning gives this warning: —

> "Are you adventurous and climb yourself?
> Plant the foot warily, accept a staff,
> Stamp only where you probe the standing-point,
> Move forward, well assured that move you may.
> Where you mistrust advance, stop short, there stick!
> This makes advancing slow and difficult?"

He also tells us, —

> "Weakness never needs be falseness: truth is truth in each degree,
> Thunder pealed by God to Nature whispered by my soul to me."

> "It was not strange I saw no good in man,
> To overbalance all the wear and waste
> Of faculties, displayed in vain, but born
> To prosper in some better sphere; and why?
> In my own heart love had not been made wise
> To trace love's faint beginnings in mankind,
> To know even hate is but a mask of love's,
> To see a good in evil, and a hope
> In ill-success; to sympathize, be proud
> Of their half-reasons, faint aspirings, dim
> Struggles for truth, their poorest fallacies,
> Their prejudice and fears and cares and doubts;
> All with a touch of nobleness, despite
> Their error, upward tending all though weak,
> Like plants in mines which never saw the sun,

But dream of him, and guess where he may be,
And do their best to climb and get to him.
All this I knew not, and I failed."

Effort in any direction is better than the greatest of evils — inaction.

Take the situation in "The Statue and the Bust," where the poet tells that the lady, resolving on her course, though it be to break her vow, —

"Turned on her side and slept. Just so!
So we resolve on a thing and sleep:
So did the lady ages ago."

By flight, she thought, —

"'I save my soul — but not to-morrow' —
(She checked herself and her eye grew dim)
'My father tarries to bless my state;
I must keep it one day more for him.'"

Thus how often consideration for the sensitiveness of others defeats prompt action!

Later in the poem listen to the poet's own words,

"I hear you reproach, 'But delay was best,
For their end was a crime.' — Oh, a crime will do,
As well, I reply, to serve for a test,
As a virtue golden through and through,
Sufficient to vindicate itself,
And prove its worth at a moment's view!"

Browning insists upon the wrong there is in the silence which makes the lie. A procrastinating soul sounds its own death warrant. He exclaimed, —

"If you choose to play,
Let a man contend to the uttermost
For his life's set prize, be it what it will!"

The sin he imputes —

"To each frustrate ghost
Is — the unlit lamp and the ungirt loin,
Though the end in sight was a vice, I say."

In this poem Browning carries out the idea of Truth to self to the extreme verge of its limit. He does not place the given incident of the poem as a model of virtue nor one that the highest living would contain; but he shows the hatefulness of subterfuge and indecision, and the soul-perjury of this woman who could take an unmeaning nuptial vow. Even if death followed her words, she had not courage to speak and be true to herself. Browning does not advocate vice instead of virtue; but the greater of the evils is the life wasted in *unliving* resolutions.

> "Aspire, break bounds! I say,
> Endeavor to be good, and better still,
> And best! Success is naught, endeavor 's all."

Sin, punishment, and the recognition of past sins and evils which it is the lot of innumerable beings during their evolutionary passage to experience, are the prelude to hope and the eternal progressive translations of the soul.

> " Strive, mankind, though strife endure through endless obstruction
> Stage after stage, each rise marred by as certain a fall!"

but out of the wreck "to rise" where light is in aspiration and hope. Thus it is in the long outlook when the false resolves itself into the true. Falsehood, deceit, duplicity, and lies are the weights and hindrances to character and soul building; while open avowal, sincerity, and truthful action and speaking under all circumstances to the degree of individual knowledge are the props to the higher planes.

What may often be considered defects and the reverse of virtue may indeed be but the accidents of character and tolerable when combined with truthful action. The poet's meaning in the preceding words is not distorted, for in his schedule of true living, duty's place and share are fully expressed over and over again. In "Saint Martin's Summer" he says —

> "Give my frank word pardon!
> What if I — somehow, somewhere
> Pledged my soul to endless duty
> Many a time and oft?"

In "Bifurcation" he says: —

> "Duty and love, one broad way, were the best —
> Who doubts? But one or other was to choose,
> I chose the darkling half."

Where duty and sentiment conflict and duty is chosen, love should not be simulated. Life's "worn causeway" should not be walked "arm in arm with friend," while caressing the ear with words of "truth turned falsehood." "How I loathe a flower, how prize the pavement!" It is right that the one for whom we choose duty should know how few of heart's flowers we have to offer. Dead fruit as well as sacrifices are not always acceptable gifts: this should not be forgotten by altruists.

The Truth is often painful to tell; it is painful to hear.

Truth in whatsoever way it comes, even if it brings a shock, is better than a lie. Browning speaks of the —

> "rough but wholesome shock,
> And accident which comes to kill or cure.
> A jerk which means a dislocated joint!
> Such happy chance, at cost of twinge, no doubt,
> Into the socket back again put truth,
> And stopped the limb from longer dragging lie."

And for those who have grown indolent with "maws out of sorts" he prescribes a healthful cure.

> "Don't nettles make a broth —
> Wholesome for blood grown lazy and thick?"

Very few pages of Browning's works do not contain some reference to Truth. It is always to the same purport; death were better than untrue life; for death will bring the truth of many a thing to the surface. This is reasoned over in the poem "Before and After." Willingness to die for the truth is brought out with telling power in "Ned Bratts" and "In the Balcony."

To give up worldly honors for Truth is beautifully and simply expressed by Colombe. "I take him, — give up Juliers and the world." And in "Daniel Bartoli" the wife of but an hour, to save her husband's "honor" and her "soul," gives up the duke, and wealth. How little are the materialities of life, in comparison with right action, prompted by Truth! Even words which poorly express our thoughts and are susceptible of misunderstanding, when Truth is back of them, fire nearer the bull's eye.

> "From truth
> Whate'er the force wherewith you fling your speech,
> Be sure that speech will lift you, by rebound
> Somewhere above the lowness of a lie!"

In those forcible lines in Francis Furini to the "Bounteous God, deviser and dispenser of all gifts" the poet exclaims, —

> "True — true — all too true —
> No gift but, in the very plenitude
> Of its perfection, goes maimed, misconstrued
> By wickedness or weakness : still, some few
> Have grace to see thy purpose, strength to mar
> Thy work by no admixture of their own,
> — Limn truth not falsehood, bid us love alone,
> The type untampered with, the naked star!"

Browning is for Justice too. He is neither arrogant nor falsely modest. He is Aristotelian in considering the aim of man to be happiness, in its highest and purest sense, and he believes that this aim can be reached only through virtue, man being born with a natural capacity for virtue. He will have nothing to do with those worldly philosophers who would call Truth "the lancet of the heart" and say "not all truths can be spoken and 't is dangerous, yet a good man cannot avoid speaking the truth."

He tells us of the liar being so from habit, lies being a part of his stock in trade, and in harmony with a lying character which can reason itself into believing its own lies; Browning expresses a thought akin to Plato's of the romancing *métier* of poets, "who sing how Greeks that never were, in Troy which never was, did this or the other impossible thing!" nor does he countenance good conduct and truthfulness when these arise for the reward or praise of fellow men.

Browning is in accord with Aristotle in denouncing abstract falsehood as bad and blamable and in declaring truth as honorable and praiseworthy. He shows if the character is thoroughly impregnated with truth the outward expressions are truthful, and the man "who is cautious of falsehood for its own sake will surely be cautious of it as being disgraceful." Aristotle advises to decline "from the truth rather on the side of defect; for this appears to be in better taste because excesses are hateful." This means that it is not truthful to volunteer true statements regarding persons or affairs for the sake of talking, as this tends towards arrogance, unless by withholding information through false modesty harm should befall our neighbor.

The individual conscience alone can be the guide to the middle path of Truth. To give one's own conscience into the keeping of another must in the end prove baneful. A close study of Browning's poems and the application of their ethics to every-day life will prove useful in aiding the growth of the individual conscience. Many conditions of woman's social state have seemed to justify her in resorting to deceit and falsehood, the weapons of the weaker, for these alone were her means to sustain and defend herself. Indirectness is the necessary outcome of inequality. If women had once seen this and combined for equality and truth, no matter what the results, Browning need not have remarked upon man's truth subduing —

> "for sake of chivalry and ruth
> Its rapier edge to suit
> The bulrush-spear womanly falsehood fights with!"

Just here scientific training is of value in strengthening the character and in guiding the senses to a nicer perception of the Truth. Any one may prove this to himself by going for the first time into a physical laboratory and attempting to carry out even the simplest experiments requiring the perfect adjustment of muscular action with vision. The inability of the novice will be proven in almost every case. Likewise such training, while aiding the cultivation of more exact touch and sight, is of value as bringing the will into concentrated action and coördination with muscular movement. Scientific research is the effort to reach a new point of view. The investigator requires a preliminary training of the senses, and he needs an endowment of well-developed mental qualities, especially judgment.

Above all the worker must give his allegiance to Truth. He works to find the absolute Truth. Many times failure rewards his pains, even the slightest grasp at Truth eludes him, and the reality is never reached. But the scientist in dedicating his life to the search for the Truth stands in the relation of one who would bring his world of relativities into touch with the world of the ideal, into the actual world of living Truth. Thus he unifies his outer and inner life. He becomes not only one who says, "I still must hoard and heap and class all truths with one ulterior purpose; I must know!" but also his truth teaches him to know that Truth, God, and Love are one.

That one whose brow the kiss of the higher imagination and intuition has sealed its own, be he poet, scientist, or artist, is one with a noble race of bards.

Truth pertaining to phenomena must be in a measure relative. The relativity of Truth is ever shifting its angle of refraction as the number of its facets increases through experience. In personal experience what may seem Truth in early years may not remain wholly Truth in later years. All grades of knowledge from a fixed point of view may be Truth in their relation to other objects on the same level. But in the advancing process the point of view will not be the same for those who have watched the Truth's unfolding. Other scenes rise in the vista, truths for the nonce, but the old truths remain on their levels just as much Truth as before.

They are the foothills on which we once stood and from which we have climbed to the higher lands. Our horizon widens. Our vision embraces the plains as well as the towering peaks ahead with their bold traceries screening the farthest distance. Looking onward from the halfway heights of Truth across the mountain ranges, rising one higher than the other, until the most distant, and last to be traversed, the impenetrable great Himalayan snow fortresses, loom against the sky of eternity, — then the wise explorer knows full well that the every-day mountain shoe and axe of these lower ranges will not carry him on to those walls of everlasting whiteness. To scale these summits requires new devices. The would-be pioneer must start on a journey where experience and knowledge from without are of little avail. These adjuncts have brought him far, but they cannot help him now.

With Browning's attempt to ascend these altitudes he never loses sight of the lowlands, and from time to time he returns to the level to gain new force in order to advance a step higher. He does not forget the heights from which he has descended, but he reminds his readers of the "resting-place, the C major of this life," and the obligation to use this life's materialities for climbing and the soul's growth. He gathers happiness, too, from earth's favors, as well as from earth's bitters.

> "Through wholesome hard, sharp soft, your tooth must bite
> Ere reach the birdling."

He says, —

> " Man I am and man would be . . . merest man and nothing more,"

and in the same poem he exclaims, —

> "Now on earth, to stand suffices."

The poet teaches that although he and a chosen few may advance farther on the snows, still those in the valleys who desire to climb must be fed and nourished by the exertions of their stronger fellow men.

> "God thus admonished: 'Hast thou marked my deed?
> Which part assigned by providence dost judge
> Was meant for man's example? Should he play
> The helpless weakling, or the helpful strength
> That captures prey and saves the perishing?
> Sluggard, arise; work, eat, then feed who lack!'
> Waking, 'I have arisen, work I will,
> Eat, and so following. Which lacks food the more,
> Body or soul in me? I starve in soul;
> So may mankind; and since men congregate
> In towns, not woods, — to Ispahan forthwith.'"

Browning in his earlier and later poems insists that although work we must, the motives should be Truth and Duty, never gain. The soft voice whispered, "Wilt thou adventure for my sake and man's apart from all reward?"

> "'Why from the world,' Ferishtah smiled, 'should thanks
> Go to this work of mine? . . . Justice says:
> Be just to fact, or blaming or approving:
> But — generous? No, nor loving!
>
> "Loving! what claim to love has work of mine?
> Concede my life were emptied of its gains
> To furnish forth and fill work's strict confine,
> Who works so for the world's sake — he complains
> With cause when hate, not love, rewards his pains.
> I looked beyond the world for truth and beauty:
> Sought, found, and did my duty."

The impress of Platonic thought concerning truth and ideality are apparent in passages of "Pauline" and "Paracelsus." Indeed the impression is not lost in other poems running with the poet's advancing years, and such thoughts are sprinkled as gems through "Asolando."

Plato tells us that the kind of rhetoric a wise man should concern himself with is truthful speaking and the cautious defining of words. Words are misleading, and the utmost care must be observed in the rightful appropriation of names.

Flimsy word architecture of gaudy structure is not for Browning's ideal city. He warns us that "words are but words and wind, why let the wind sing in your ear, bite sounding to your brain?" Not from names but from their essences we must really learn of things. Phædrus is bid to go and tell Lysias and other composers of speeches — Homer, and other writers of poems, Solon and others who compose political discourses called laws — he is bid to say to all of them if their compositions are based on knowledge of the Truth, and they can defend or prove them, then they are to be called not only poets, orators, legislators, but they are worthy of a higher name: they are lovers of wisdom or philosophers. This worthy name of lover of wisdom and philosopher is Robert Browning's, as any one may prove by testing and proving in daily life the poet's far-reaching conclusions. Now what is the meaning of all this externality of true speaking, true living, true searching? Absolutely meaningless nothings, as external expressions pure and simple; but pregnant, all meaning and powerful as forms in which our thoughts live and breathe. These thoughts to be vital must be centred in the inner shrine of being with God; they must be firmly anchored by intent in the stream of Truth. Then, and not until then, will the outward forms of our speech and activity become vitalized entities, and not prove worthless husks.

At the moment of death or great danger the veil is oftentimes raised and delusions vanish.

> "At the word, the woman's eyes, slow wandering till they neared
> The blue eyes o'er the bush of honey-colored beard,
> Took in full light and sense and—tore to rags some dream
> Which hid the naked truth — O loud and long the scream
> She gave, as if all power of voice within her throat
> Poured itself wild away to waste in one dread note!"

The thought of death brings another thought that beyond death higher Truth abides. When Alkestis in "Balaustion's Adventure" was borne to take her last look at the sun, and the living to look their last at Alkestis, Balaustion says, —

> "We grew to see in that severe regard, . . .
> What Death meant when he called her consecrate
> Henceforth to Hades. I believe, the sword —
> Its office was to cut the soul at once
> From life, — from something in this world which hides
> Truth, and hides falsehood, and so lets us live
> Somehow."

Often the realization of our true purpose of living becomes known to us by ways and means insignificant in themselves but great as their influences turn us to broader living and knowledge of good and evil. The flight of the Duchess is an incident where this thought finds expression. Events in our past lives may in years after, through memory, be powerful movers in freeing us from the fetters of Ignorance. Then, again, in liberating the desires from worldly strivings and seeking refuge in the domain of thought, the soul becomes strong in distinguishing good from evil, truth from error: —

"And, as in moments when the past
Gave partially enfranchisement, he [Sordello] cast
Himself quite through mere secondary states
Of his soul's essence, little loves and hates,
Into the mid-deep yearnings overlaid
By these; as who should pierce hill, plain, grove, glade,
And on into the very nucleus probe
That first determined there exists a globe.
As that were easiest, half the globe dissolved,
So seemed Sordello's closing truth evolved
By his flesh-half's break up; the sudden swell
Of his expanding soul showed Ill and Well,
Sorrow and Joy, Beauty and Ugliness,
Virtue and Vice, the Larger and the Less."

Browning's standpoint, besides embracing the use of this world's means, includes also the comprehension of the living death of the philosopher, the living beyond the dominion of bodily pleasures and of the senses. And with Plato he would rid himself of eyes and ears and with the light of the mind only behold the light of Truth. For truthfulness is the quality a *philosopher* should possess and falsehood should be held in detestation.

There are the two kinds of knowledge, one derived from without, the other from within, the two halves of the perfect whole.

"Thus: I possess
Two sorts of knowledge, — one vast, shadowy,
Hints of the unbounded aim I once pursued;
The other consists of many secrets, caught
While bent on noble prize, perhaps a few
Prime principles which may conduct to much. . . .
And I betake myself to study
Till patient searchings after hidden lore
Half wring truth from its prison."

Frequent passages in Browning's works uphold the belief that the inner knowledge is the unerring. He writes, —

"Alack, one lies oneself
Even in the stating that one's end was truth,
Truth only, if one states as much in words!
Give me the inner chamber of the soul
For obvious easy argument; 't is there
One pits the silent truth against a lie."

Browning would not have the training of the senses and the knowledge of outer things neglected. For training will help to perfect what is so imperfect in the crude. But this outer knowledge can never take the place of its higher, purer type. There is no conflict between the two kinds of knowledge. They are each distinct and parts of the immense scheme of the universe all tending to unity. And he who from the realm of phenomena can gather strength to look and hear where neither body's eye nor ear serve, is he "who hears the poem, therefore sees the play."

Although Browning has drunk deeply of the philosophic well, and in "Pauline" describes such a personality as one —

"full of bliss, who lived
With Plato and who had the key to life;
And I had dimly shaped my first attempt,
And many a thought did I build up on thought,
As the wild bee hangs cell to cell; in vain,
For I must still advance, no rest for mind."

Yet he carries his thought beyond the pale of philosophic systems onward where his soul's eye dimly perceives, yet perceives the outer violet border of the infinite dawn. He yearns to stand on the perfect sphere of the universe to look on God, —

"As though naught else existed, we alone!"
"Do I not pant when I read of thy consummate power,
And burn to see thy calm pure truths out-flash
The brightest gleams of earth's philosophy?"

To this Truth, the full-orbed Truth of the creative, actual, living universe, all effort tends. The aim of life's journey is the qualification of ourselves through good and evil to unite with the throbbing currents of the Absolute. And life is worth living for the experiences happy or sad which we gather from this world's plane for help of soul's growth and progress.

But great as these are they are not alone enough; there is yet another power, and this is to bring out and express the Truth within ourselves which lives in greater or less degree and finds expression from intuition in highly wrought results of Science, Poetry, or Art.

> "Truth is within ourselves; it takes no rise
> From outward things, whate'er you may believe.
> There is an inmost centre in us all,
> Where Truth abides in fulness; and around,
> Wall upon wall, the gross flesh hems it in,
> This perfect, clear perception — which is truth,
> A baffling and perverting carnal mesh
> Binds it, and makes all error; and to know
> Rather consists in opening out a way
> Whence the imprisoned splendor may escape,
> Than in effecting entry for a light
> Supposed to be without. Watch narrowly
> The demonstration of a truth, its birth,
> And you trace back the effluence to its spring
> And source within us; where broods radiance vast,
> To be elicited ray by ray, as chance
> Shall favor."

This is a stage we have reached when the eye discerns "truer truths."

This inner enlightenment and guidance emanating from the very core of the man or woman does not, to me, exclude the thought of the striking in from outward of subtle powers, once the passage is effected by Truth's exit from within. These outer influences react on the hidden forces which they strengthen and reinforce. A similar interplay of powers and intuitions goes on in the plane of the world's knowledge: "A pinch of powder," and "harmless dewdrops," "mixed nothings make somethings," and the "lip's mere tremble," and "cheek's just change of color" effect heart's earthquake.

Likewise, —

> "You let your eyes meet mine, touch what you term
> Quietude, — that 's an universe in germ —
> The dormant passion needing but a look
> To burst into immense life!"

Many examples will occur to one, not only in Browning's life and soul studies of those out and in soul flashes, but in the lives of real men and women where this sudden and deliberate self-dedication of the person to a fixed and noble course quite opposite to the one before led denotes the apprehensiveness and readiness of the individual to respond to an inspiring voice. It is the voice of God, whether sounding within or without us. It speaks in a language all may learn, and needs no interpreter beyond the individual self. The sinner or saint alike may be spoken to, but the ear which has once heard will be deaf no more.

Perhaps nowhere is this responsiveness to reaction more markedly portrayed than in the scene between Ottima and Sebald. In that situation the voice of God, by the simple instrument of a young girl's song, penetrates above the words and storms of passion, and the Truth, bursting forth over that scene in all its horror and bareness, strikes, destroys, and creates the man and woman anew. They now possess the knowledge, by Truth, of passion and of the higher Love beyond the material which their own love so dimly foreshadowed. Instantly was effected the transmutation of earthly love to hatred and the passing over from earthly to heavenly Love and unity with God.

The sudden flashing and forcible emanation of Truth inspires as the creative God-principle held by every woman and man in common with others, worlds, and universes. Man the creation is also as a spark one with the Creator.

Browning says, "Truth remains true, the fault's in the prover." Perhaps it may be the fault of our methods of searching, if Truth's light is withheld for a time. But with a clear intent and as faithful workers, great or small, all ranking the same before God, with God's lamp pressed close to breast, striving to be truthful in life and thought, seekers after ever-growing truth and light, we shall become worthy of a wider philosophy and religion including all men and women in ties of loving and truthful sympathy. Truth will not lead us wrong, though for a moment we are plunged "into a dark tremendous sea of cloud. It is but for a time." We shall arise.

I, for one, do not fear the dangers that many claim will fall if the discrimination of good and evil be left to the individual. But these conditions contain an active, quickly moving, truthful, progressive ethics. The man or woman sunk in lowest degradation, sin, or crime is the laggard, and when pathological conditions do not explain the status, then poverty, a deplorable social state, love of luxury, the delights from money possession do. Seekers of vice for its own sake and for its supposed gains are not those seeking Truth for Truth's sake and God's.

The greatest necessity of life, far beyond any other sort of prosperity, a necessity of our soul and body, is the struggle for the Good, and by research it is our duty to find out what is evil. With the diversity of men's and women's minds, there will be a corresponding diversity of what is good and what is evil. Never mind, let us have all diversities; out of the confusion of many tongues we shall find the middle way paved with blocks of truth leading towards the ultimate good. Every working hour of our lives should be devoted to the pursuit of the Good. When the relative good found has passed over into evil, because we have gained in knowledge and know that what seemed good in ignorance is so no more, then must this former good be spurned as lesser good and the soul must aspire again to dig through error's crust. At last the sparkling transparent stream is found, the soul drinks of the inspiring waters, and pauses never again to define and distinguish the good from the evil.

It has occurred to some that there is no purer motive than the pursuit of the higher Truth, the ideal Truth; and to express these quests in the thoughts and deeds of every-day life is not only a duty, but an inspiration. Call such motives a religion if you will, but it is a religion so broad and untrammeled as to include all points of view.

If the composite impression from Browning's poems has led me to gather support from them for these views, be it understood that they are not uttered except as an individual expression, not as criticism other than Browning's own, and these suggestions alone are of interest as the outcome of a soul's experience. I do not deny the need of assistance to the weaker from the stronger, and the weight of greater learning, greater knowledge, should not be lightly thrust aside.

Browning says all this. But the day comes when the spirit, like the little child who learns to stand and walk alone, rises up and says, "I go to prove my soul; I see my way as birds their trackless way. I shall arrive in God's good time." Who will presume to deny to this soul its power?

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