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BY

WILLIAM RUSSEL DUDLEY

AND

APPRECIATIONS AND CONTRIBUTIONS

IN HIS MEMORY

BY

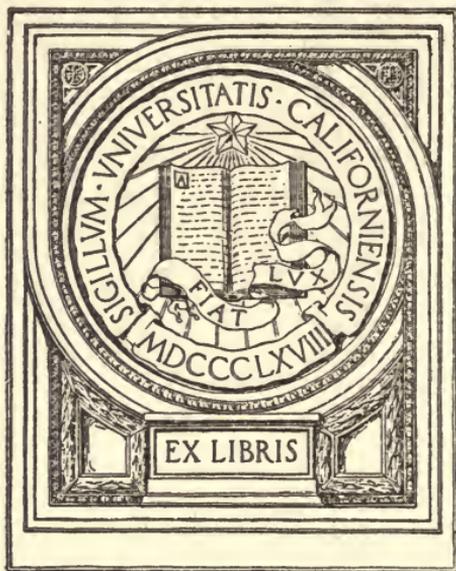
FRIENDS AND COLLEAGUES

(WITH PORTRAIT)

STANFORD UNIVERSITY, CALIFORNIA
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WILLIAM RUSSEL DUDLEY was born at Guilford, Connecticut, March 1, 1849, and died at Los Altos, California, June 4, 1911. He was educated at Cornell University, graduating with the class of 1874, and taking his master's degree at the same institution in 1876. He was instructor in botany in Cornell University from 1873 to 1876, and assistant professor of botany from 1876 to 1892. On leave of absence from Cornell he was acting professor of biology in the University of Indiana in 1880, and he spent the year 1886-1887 studying at Strasburg and Berlin. He was appointed professor of systematic botany at Stanford University in 1893, a position which he held from that time until December, 1910, when, on account of ill health, he voluntarily retired and became professor emeritus.

University Chapel

September 10, 1911



In Memoriam

William Russel Dudley

Emeritus Professor of Botany



Born March 1, 1849 Died June 4, 1911

WILLIAM RUSSEL DUDLEY

[An address delivered at the services held in the University Chapel of
Stanford University, September 10, 1911.]

By JOHN CASPER BRANNER, Vice-President

I DOUBT if there is any time in men's lives when they come to know each other as well as they do in their college days, especially when they happen to have the same studies, to be in the same classes, and to be much thrown together by any circumstances whatever.

Professor Dudley and I belonged to the class of 1874 in Cornell, we had some of the same studies, we belonged to the same fraternity, and as students we had about the same ups and downs. Aside from these mutual interests we were thrown together still more by the fact that Dudley, being a student in the scientific course, had botany in the early part of his studies, while I in the course in Greek and Latin took botany near the end of my college work, and so it came about that in our senior year he was instructor in botany and I was his pupil.

As enthusiastic students and as intimate friends we tramped together every hill, explored every gorge and penetrated every swamp for many miles around Ithaca. Under his guidance I came to have a personal acquaintance with and affection for every flowering plant of the region about Cayuga Lake, and for Dudley always a deeper love and a greater esteem.

The first piece of scientific work I ever did—a study of the fibrovascular bundles in the palms—was undertaken and carried through under his guidance.

On the slopes of the hills west of Ithaca it was he who pointed out to me for the first time the deep marks cut in the hard rocks by the ice of the glacial epoch. Thus Dudley was not only my first and principal instructor in botany, but he was also, in a way, my first effective instructor in geology.

We college professors are more or less given to the discussion of methods of instruction, and it is no uncommon thing to hear this or that man's methods found fault with. I dare say such criticisms are well enough in their way, but after all is said and done there remains one supreme test of a teacher that is often lost sight of in these discussions, and that is his results. I do not speak with a knowledge of the precise number of his students who stand to-day in the front rank of our botanists, but my general impression is that, judged by this standard—by results with his

students—Professor Dudley was one of the most successful teachers of botany this country has ever produced. And I am confident that that success is to be attributed to a great extent to the human and personal rather than to the technical part of his methods as a teacher.

He was always at the service of his students. No hour of the day or the night was inopportune when a student wanted his advice or direction.

His personal influence during his early manhood was the finest and most wholesome that I have ever found among men, whether old or young. Professor W. R. Lazenby of the University of Ohio, who was a classmate, writes of him: "I may say for myself that I owe Dudley a great deal. I roomed with him my first year at Cornell, and he had a great influence for good over my life. I think, all in all, he was one of the best men I ever knew—pure gold."

Dudley was a warm hearted, genuine lover of nature in all her forms and in all her moods, and this gave him that enthusiasm without which a teacher is not a teacher. No man could have fitted more perfectly into the sentimental side of botany—if botany has any such side. The colors, the beauty, and delicacy of flowers and plants, their lives, their kinships, their histories—all appealed to the artistic side of his nature.

This love for and appreciation of nature, however, was his despair as well as his constant delight. His soul overflowed with affection for it all, but he was so sensitive to the defects of language and of other methods of representation that he rarely undertook to give expression to his love for it.

But I would not have you imagine that he was a botanist and nothing but a botanist, neither was he a scientific man to the exclusion of other interests. Indeed he was deeply and generally interested in everything human and spiritual.

At heart he was a poet. I shall never forget the glow of enthusiasm with which he read to me, when it first appeared, Longfellow's *Morituri Salutamus*. He always had about him the works of the best poets and a few pictures and other works of art of the first quality.

His was

"The love of learning, the sequestered nooks,
And all the sweet serenity of books."

To be rather than to appear was the steadfast principle of his life. Modesty, gentleness, unobtrusiveness, decorum, and purity of life were his most prominent characteristics. He never did anything for the sake of display; he never courted popularity. His whole life, within and without, was one long, living protest against vulgarity in all its forms.

He was a man of the finest possible fiber, so fine indeed that the very delicacy of his nature unfitted him for some of the pioneer work he was called upon to do in his lifetime.

When Dr. Jordan was President of the University of Indiana, he tried for some time to induce Dudley to go to that institution as professor of botany. And I recall in this connection that Dr. Jordan said to me on one occasion: "Quite aside from his ability as a teacher of botany we need him here on account of his personal influence."

But Dudley declined the proffered position largely because he felt that he was not altogether fitted for the pioneer work required there at that time.

With the idea that poverty helps rather than hinders a young man, Dudley did not altogether agree; in fact he entirely disagreed with it in so far as it related to himself. He felt keenly the inconveniences of having to earn his living while carrying on his studies.

The necessity of devoting so much time to his teaching and the strictness of the standards he set for himself explain why he was not a writer of books or the publisher of a very long list of scientific papers.

Lest some who did not know him well should imagine that so much self-effacement indicated a man with but little force of character I hasten to say that such was very far from being the case. With all his gentleness and sweetness I have never known a man of more decision of character, stronger will power, or of more determination, firmness, and unswerving purpose.

In the summer of 1882, I think it was, when Dudley was thirty-three years old, the baccalaureate sermon at Cornell was preached by the Rev. Dr. Heber Newton, who was for a while chaplain here at Stanford University.

Dudley and I went to chapel together. We found it so crowded that we could not find seats together, and I sat in the row of seats just behind him. Dr. Newton's address was a eulogy upon the life, character, and influence of Ralph Waldo Emerson. You can imagine the tribute he paid to that distinguished writer and lecturer. I recall that when Dr. Newton had finished his eloquent address I said to myself: "Yes, but right here living in our own midst and within the reach of my hand is a man who has every one of the finest traits of character of Emerson."

In the latter part of his life certain of his traits became more prominent than during his younger manhood. He was always, and of necessity, a purist in every sense in which that word can be used. But as he grew older I imagine that his sensitiveness brought him more pain than pleasure,

and to this I attribute the rather lonely life he led after coming to California.

Unfortunately there are those who knew Professor Dudley only as a name in the university register. I am sure my friend would not thank me to apologize for the modest part he played in this or in any other community, but in closing I am constrained to say a word in behalf of him and of all such men: It behooves us not to lose sight of this blessed truth, that there are fine men and women in this world of ours—and plenty of them, too—who keep out of the limelights, whose names we never see in the headlines of the newspapers, but who lead quiet, sane, and wholesome lives. Such people always suggest to me the foundations of a great structure. These foundations lie deep beneath the surface of the ground; we never see them; we seldom think of them; they are not decorated with flying flags or written across with gaudy colors or blazing electric lights. But they stand fast and firm, and the stability and the real worth of the entire superstructure depends upon them.

• One of these foundation-men was William Russel Dudley.

WILLIAM RUSSEL DUDLEY

[An address delivered at the services held in the University Chapel of
Stanford University, September 10, 1911.]

By PROFESSOR DOUGLAS HOUGHTON CAMPBELL

WILLIAM RUSSEL DUDLEY was born in Guilford, Connecticut, in 1849 and was one of the earlier students of Cornell University, from which he graduated with the degree of Bachelor of Science in 1874. At that time Cornell University had only been opened for a short time, and I fancy the conditions there were in many respects very much like those of Stanford twenty years ago. The new university at Ithaca had broken away from the traditions of the earlier eastern colleges, and science received far more attention than in most of the other institutions. The opening of the new university with its facilities for scientific work attracted a group of young men who have since attained pre-eminence in their various departments. Among those who are on our own faculty were Dr. Jordan and Professor Branner, with whom Professor Dudley was associated on intimate terms. Of Professor Dudley's life as spent at Cornell, Professor Branner has just given us a most sympathetic account. In Dr. Jordan's recent sketch of Professor Dudley in Science, he tells us that for a time he was himself instructor in botany, and that Professor Dudley during the early part of his stay at Cornell came under his instruction. However, it was not long before Dudley himself was acting as instructor even in his undergraduate days, and later became attached to the staff of the university.

It is hard for us to realize in these days when every college or university of any pretensions whatever has its department of botany well-equipped and well-manned, that during the '70s the number of professorships of botany in the whole United States probably did not exceed half a dozen. Cornell was one of the first of the universities to establish a distinct chair of botany, and at the time that Professor Dudley entered Cornell the chair was held by Professor Albert Prentiss. While a student at Cornell, Dudley attended the summer session of the famous school at Penikese where Agassiz for the first time instituted a seaside summer school, the model of which has since been repeated in so many places. At Penikese Dudley was associated not only with his fellow students of Cornell but also with a number of other men who laid the foundation of the biological studies which have had such a tremendous influence in the development of science since that time.

Professor Dudley very early became interested in the problem of plant distribution. The region about Ithaca is a peculiarly interesting one botanically, offering an unusual variety of conditions with a correspondingly varied and interesting flora. Dudley soon became intimately acquainted with the flora of this whole region and the results of his studies were later published under the name "The Cayuga Flora." This was soon supplemented by a second similar work on "The Lackawanna and Wyoming Flora." While at Cornell, Professor Dudley also published in collaboration with Professor M. B. Thomas a "Manual of Histology." He also published a number of other shorter papers dealing mainly with the flora of the same region.

During the latter part of his stay at Cornell Professor Dudley had charge of the work on the lower plants, especially the fungi, to which he devoted much attention. In connection with this work upon the fungi Professor Dudley made a trip to Europe in 1887, and it was upon this trip that I had the first opportunity of making his acquaintance. I was myself at the time a student at the University of Berlin.

My first meeting with Professor Dudley was at Strasburg, where he had gone to study under the famous botanist, De Bary. Somewhat later Professor Dudley went to Berlin, where I was a student, and I had an opportunity of renewing the acquaintance so pleasantly begun at Strasburg. It is seldom that I have had the good fortune to meet a man who has made upon me a deeper impression. The extraordinarily fine quality of Professor Dudley's personality it is not necessary to describe to those who knew him. In every sense of the word he was a gentleman of the finest type. We little thought then that it was not going to be many years before we should be colleagues in a new university in far-away California, for to us then California seemed very far away indeed.

Just twenty years ago a little band of pioneers, to which I had the great good fortune to belong, started our University on its career. Everything looked most promising and we were all full of enthusiasm and hope for the future. Two years later Mr. Stanford died, and the university entered upon a period of anxiety and privation, which was only tided over by the noble and self-sacrificing devotion of Mrs. Stanford.

Professor Dudley was called to Stanford as professor of systematic botany in 1892, but did not come to California until the fall of 1893, just at the time when the outlook was most discouraging. He naturally had expected to have all the necessary equipment for establishing his department, and of course nobody could have foreseen the unfortunate condition of things which prevailed at the time he took up his duties in the autumn

of 1893. Although it must have been a great disappointment to him, he nevertheless vigorously set to work to make the best of the situation and for several years before the outer quadrangle was built and the present botanical quarters provided, he carried on the work of his department under most discouraging conditions. His laboratories, if such they may have been called, occupied the attic of one of the shop buildings back of the quadrangle, and were very far from satisfactory either for laboratory or herbarium purposes. However, he began collecting assiduously and before long the nucleus of the fine herbarium which he has left to the university was brought together.

The flora of California is a peculiarly rich and interesting one and offers exceptional opportunities to the student of the problems of plant distribution. To Professor Dudley, whose work had been especially along these lines, the opportunities for work in his chosen field must have been very enticing, and doubtless compensated in great measure for some of the drawbacks in other respects which he must have felt keenly when he came to Stanford. From the time of his arrival, almost until his death, he made many trips to all parts of the state, collecting zealously and accumulating an invaluable herbarium which remains to remind future students of our flora of his tireless interest in his work.

Professor Dudley paid especial attention to the flora of the Sierras, and was a recognized authority upon it. California is pre-eminent in its coniferous forests, which are unrivaled in all the world, and Professor Dudley soon became deeply absorbed in a study of the distribution of these magnificent trees. A considerable number of these are peculiar to California and often of very restricted range, like the familiar Monterey cypress. Professor Dudley studied with especial care the habits and distribution of a beautiful fir (*Abies venusta*) which is only known to grow in the Santa Lucia range. He made a number of trips to this remote region for the purpose of studying this rarest of the Californian firs. His acquaintance however with all of the coniferous trees was most intimate, and he soon became a recognized authority on the distribution of the Californian conifers.

Professor Dudley's interest in the study of the distribution of the forest trees naturally led him to a study of the problems of forestry, which for the past twenty years or so have been arousing so much interest in the United States, and which so deeply concern the welfare of the country. As might be expected, his sympathies were entirely with those who would protect what is left of our magnificent western forests from the reckless exploitation of ignorant or unscrupulous men who have so devastated the

forests of the eastern states, and are now threatening the great forests of the Pacific Coast. An intimate friend of Gifford Pinchot, who has been an effective champion of the rights of all the people in our splendid forests, which have been so wantonly devastated, he always stood for the most enlightened views of forest conservation. The state has never had a more devoted advocate of sound and modern methods in forestry than Professor Dudley.

His teaching work in the university, especially in his later years, was to a great extent strongly influenced by his interest in forestry problems, and the students who were intending to devote themselves to forestry as a profession found in his teaching a sound preparation for their future vocation.

Professor Dudley's interest in forestry was evinced in a very practical way through his participation in the movement to reserve as a state park the fine body of redwood timber in the Santa Cruz Mountains known as the Big Basin. Largely through his instrumentality this magnificent body of virgin redwood forest was bought by the State as a permanent public park. Until compelled by illness to give up his position, he served as one of the commissioners of the park, in which to the last he took the keenest interest.

For many years also Professor Dudley was an active and interested member of the Sierra Club, and accompanied the club in its outings in the Sierras on several occasions. Those who were fortunate enough to be members of the party and thus came to know Professor Dudley in his most congenial surroundings, will always remember with the keenest pleasure their associations with him on those excursions.

As a teacher Professor Dudley was devoted to the welfare of his students, who will bear witness to his constant interest in their work and the unfailing assistance always rendered them. Many students both at Cornell and Stanford came under his influence, and the long roll of those who have achieved success in their work after leaving college bears witness to the success of his labors as a teacher. At Cornell, Professor Atkinson, the present head of the department of botany, was one of his students. Professor Trelease, the distinguished director of the Missouri Botanical Gardens, which position he recently resigned, was also a student at Cornell; and Dr. Coville, head of the National Herbarium at Washington, also claims Professor Dudley as his teacher. Many others, successful both as teachers and investigators, look back with pleasure and gratitude to their student days in his laboratory. On our own faculty Professor Abrams and Mr. McMurphy were both associated with him as students and colleagues, and are carrying on the work which he so well began.

Undoubtedly Professor Dudley's most important scientific work was the collection of the extensive herbarium to which he devoted so much time and labor during all the years that he spent in California. It is doubtful whether any botanist had a more intimate knowledge of the flora of California than he, and the great number of specimens collected by him on his many botanical trips are now the property of the university. And the Dudley Herbarium will remain as a monument to his devoted labors as a student of California plants.

A characteristic California genus, *Dudleya*, has been named in his honor, and will always recall to botanists the name of one of the most devoted students of the flora of our state.

WILLIAM RUSSEL DUDLEY *

By PRESIDENT DAVID STARR JORDAN

THE fact that the writer has been intimately associated with Professor Dudley since the day he entered the freshman class at Cornell University, in September, 1870, will perhaps excuse the personal element in this little sketch.

The word "instructor" as a technical term, describing a minor assistant to a professor, had just then been invented, and the present writer had just been appointed "instructor in botany" under Professor Albert N. Prentiss.

One day Professor Henry T. Eddy, now of Minnesota, brought to me a tall, well-built, handsome and refined young man, older and more mature than most freshmen, and with more serious and definite purposes. Young Dudley had an intense delight in outdoor things and especially in flowers and birds. He wanted to be a botanist, and had turned from old Yale, to which as a descendant of Chittendens, Griswolds and Dudleys he would naturally have gone, to new Cornell, because Cornell offered special advantages in science. For the rest of my stay at Cornell, Dudley was my roommate, living in a cottage on the hill, built by students and termed "University Grove." In this cottage was established the boarding-club, known later and appropriately as "The Struggle for Existence," and in later and more economical times as the "Strug."

In time he was made botanical collector, and this congenial work he kept up until he became my successor as instructor in botany. In college Dudley was a member of the Delta Upsilon fraternity, and took an active part in holding this society to the high ideals (*Δίκαια γροθίκη*) on which it was originally based. He was also a charter member in the honorary scientific society of Sigma Xi (*Σπουδῶν Ἐυνῶνες*).

From 1872 to 1876 he was instructor in botany at Cornell, his eminent knowledge of the eastern flora overbalancing the fact that at first he had not yet received a degree. From 1876 to 1892 he was assistant professor of botany at Cornell, with a year's absence in 1880, in which he served as acting professor of biology in the University of Indiana, in the absence of the present writer, who then held that chair.

In 1892, Professor Dudley became professor of systematic botany at Stanford University, which position he held until, in January, 1911, failing

* *Science*, N. S., Vol. XXXIV, 142-145, August 4, 1911.

health caused his retirement on the Carnegie Foundation, as professor emeritus, his work being then taken by one of his students, Associate Professor LeRoy Abrams.

Many of the leading bōtanists of the country have been students of Professor Dudley. H. E. Copeland, Kellerman, Lazenby, Branner were among his associates at Cornell. Atkinson became his successor at Cornell. Abrams, Cook, Elmer, Olssen-Seffer, Cannon, Wight, E. B. Copeland, E. G. Dudley, Greeley, Herre, McMurphy and many others were under his tutelage at Stanford.

In Stanford University, Dudley was one of the most respected as well as best beloved members of the faculty. No one could come near to him without recognizing the extreme refinement of his nature; a keen intellect, an untiring joy in his chosen work, and the Puritan conscience at its best, with clear perceptions of his own duties to himself and a generous recognition of the rights and the aspirations of others.

Dudley entered with great joy into the study of the California flora. He became especially interested in the study of trees, the evolutionary relations of forms and especially the problems of geographical distribution. The conifers of California were his special delight, and he made many field trips with his students to all parts of the state, notably to the Sierra Nevada and the Sierra Santa Lucia. His extended collections were presented to Stanford University, where with the collections of Dr. Abrams they form the major part of the large "Dudley Herbarium."

A genus of stone-crops, of many species, abounding on the cliffs of California and especially on those which overhang the sea, was named *Dudleya* by Britton and Rose. *Dudleya pulverulenta*, is one of the most conspicuous plants in California wherever "sea and mountain meet."

Dudley was instrumental in inducing the State of California to purchase a forest of redwoods (*Sequoia sempervirens*), that this, the second of California's giant trees, might be preserved in a state of nature. Two thousand five hundred acres in the "Big Basin" of Santa Cruz county were thus bought and established as the "Sempervirens Park." For several years Dudley served on the board of control of this park.

Of the Sierra Club of California, Dudley was a leading member and for some years a director.

As an investigator, Professor Dudley was persistent and accurate, doing his work for the love of it. A partial list of his papers is given below. A large work on the conifers of the west was long projected, but still exists only in uncompleted manuscript.

Dudley was master of a quiet and refined but effective English style. He was one of those scientific men, too few I fear, who have real love for literature, and who understand what poetry is and what it is about. In his early days he wrote graceful verse. Three of his poems are in print, "The Kaaterskills as seen from the Taconics," "Sunrise on the Kaaterskill" and "A Legend of the Lehigh Valley." The last is the story of the Moravian settlements of "Friedenhütten, Tents of Peace, and Gnadenhütten, Tents of Grace."

From the first of these, I quote:

'Twas reached at last, with toiling long and weary
 Taconic's loftiest hill;
 Then, visions of all visions, stood uncovered
 The domes of Kaaterskill!

They rose above the lesser hills as sovereigns
 Above the common herd;
 They gathered then in conclave grand and solemn;
 They breathed no spoken word.

But full as anthemed voices of the ocean
 A soundless song was borne
 Up from those lips that changeless through the ages
 Sang on Creation's morn.

A mighty calm sits on these silent summits,
 Time fades, as breath away,
 O'er all in solemn oceanic pulsings
 Deep flows—Eternity.

From "A Legend of the Lehigh Valley" I quote the last verses:

Full six score years have passed away.
 Still on the silent summer morn,
 At noon's repose, or evening's gray,
 O'er Lehigh's vale this dirge is borne.
 The reaper hears, on far-off hills,
 And the traveler by the mountain rills,
 And the fisher in the evening's chills;

They hear and feel some echo wake
Of sorrow slumbering long. A tear
Is shed for some sweet lost one's sake,
A tear that leaves life's stream more clear.
They bless the song and them who sing;
They feel the sympathy upspring
That's born of human suffering.

The air is full of sad-toned bells
That never cease their brazen toll;
With circling suns their pulsing swells,
And in one tireless world-wave roll.
But grateful unto sorrow's ear
From the Lehigh, far or near,
Comes this dirge so sweet and clear—
Come these human voices dear.

Professor Dudley's health was good until about three years ago, when he set out to study the trees of Persia. In Egypt he was attacked by a severe cold or bronchitis which ended in tuberculosis.

He never married.

PROFESSOR DUDLEY'S WORK FOR STANFORD *

By PROFESSOR LEROY ABRAMS

PROFESSOR William Russel Dudley, who became professor emeritus of botany at the opening of the present semester, although born in an old New England town that has been the home of the Dudley family since early colonial times, is essentially a pioneer. Entering Cornell University with its second freshman class, he remained in that young institution after graduation, first as instructor and later as assistant professor of botany, until the foundation of our own university, when at the urgent request of President Jordan, his college mate and intimate friend, he came to Stanford as one of the pioneer professors at the opening of its second year.

Of Professor Dudley's experience at the very beginning of work in his new field, and of the arduous times during the dark days that engulfed the university soon afterward, I have no personal knowledge, for it was some four or five years after his arrival that I came to know him. Upon entering the university I sought out the department of systematic botany with the intention of carrying on some studies in flowering plants. At that time the twelve small buildings which form the inner quadrangle, and three small shop buildings in the rear of them, were the only buildings available for university work. In my search for the department I was directed to the farthest of the shop buildings, the one situated just back of the new geology building, where I was told that I would find Professor Dudley on the second floor. And here I did find him, tucked away in one end of a loft, in a single room, one corner of which had been partitioned off as an office. In a quiet, reserved manner he talked over my work; then he took me into the main room to select a table and material for study. It was a curious room, this "laboratory," perched high amid the rafters. Three huge beams ran lengthwise of it a good hurdling distance apart, but about five feet and a half from the floor. With an apologetic smile, he warned me of these as he calmly ducked under the first. The table was soon selected and my initial study outlined. Day by day, throughout the course, as he went from student to student directing their studies, he patiently dodged those formidable beams.

For ten years this man, one of America's foremost teachers of botany, conducted his classes under such handicaps. Yet with these great obstacles constantly checking the normal growth and development of his cherished plans, he labored on incessantly; his quiet, dignified, courteous manner,

* From the *Stanford Alumnus*, Vol. XII, No. 6, pp. 165-166, February, 1911.

his thoroughness and enthusiasm in his work, his broad interests and scholarly attainments moulding the lives of his students. For none can come under his influence without, at least unconsciously, acquiring higher ideals and more serious purposes.

During the summer vacations the pursuit of his botanical studies took him into the mountains and forested areas of the state, where he was constantly confronted with the great and shameless waste of our forest resources. He thus became one of the pioneers in the movement toward conservation, and rendered valuable service to the state and nation through suggestions and advice to the Forest Service and other authorities. The establishment of the California Redwood Park, a beautiful tract of forested land in our neighboring mountains, set aside by the state primarily for the purpose of preserving a forest of the coast redwood in its primitive conditions, was accomplished largely through his efforts. And as secretary of the first park commission he labored for its betterment and the establishment of a permanent policy in its management.

But Professor Dudley saw that if the conserving of our forests was to be placed on an intelligent and permanent basis it was essential that young men be trained for the work, and that the people of the states where the forests abound be educated to the necessity of scientific forestry; he saw that fully nine-tenths of the nation's forests lay west of the continental divide, yet in all this region not one of the educational institutions was training men for the scientific management of this vast wealth. He therefore directed his energies toward the establishment of courses in forestry at Stanford. For a number of years he planned toward this end, and finally, just as success seemed probable, the fateful April 18th wiped out every promising hope of immediate realization. Soon afterward he contracted a serious illness which left him physically weakened. This hampered his work, but not his enthusiasm, and he is now retiring from the regular routine departmental duties in the hope that he may regain his health sufficiently to complete his research studies on the western flora.

Professor Dudley's students and his many other friends who have known and followed his courageous and uncomplaining struggle against disheartening obstacles hope that he may not only live to complete his own studies, but that he may yet see young men trained at Stanford for the scientific management of the vast forests of the West.

PROFESSOR WILLIAM RUSSEL DUDLEY *

By PROFESSOR GEORGE JAMES PEIRCE

WILLIAM RUSSEL DUDLEY, professor of systematic botany in Leland Stanford Junior University from 1892 to 1911, died on June 4, 1911, at the age of sixty-two. By ancestry and place of birth a New Englander, a graduate and for twenty years a member of the botanical staff of Cornell University, a student of De Bary's for a time in Strasburg, he brought to California the mature powers of an enthusiastic student and sympathetic lover of nature, the ripe scholarship and the winning personality of the inspiring teacher. At home in the laboratory, he was still more strikingly the gracious host when he was with students and other friends out of doors, in the fields and woods and mountain forests.

He knew the forests of middle California as no one else; his acquaintance was with individual trees, as his collection of tree portraits testifies. And his studies of their geographical distribution, following and amplifying the earlier studies of Asa Gray and others, gave his knowledge a degree of accuracy and detail, as well as breadth, which was very precious. It is to be hoped that his notes and other manuscripts are in such condition that his associates and successor can give them to the world.

Professor Dudley's nature was so sensitive, his perceptions so fine, and his ideals so high, that he could but rarely bring himself to publish what he knew. He wished always to add to and improve what he had learned and written. Thus the botanical world had little opportunity to know his accomplishments and achievements.

Besides the young men and women whose lives he has enriched, and the Forest Service which he long assisted in various ways, he contributed to the great gift to California and the nation which the state and national forests of California constitute. The "Big Basin Park," the property of the state, will preserve to all time a part of the natural redwood forest of the Santa Cruz mountains. Professor Dudley assisted in securing and preserving as a state park this part of the virgin forest of *Sequoia sempervirens*. It was his interest too which stimulated and directed the federal authorities in the selection of others of the mountain forests of California as national forests.

Of courtly manner, cultivated as well as educated, of ripe scholarship and rich in the knowledge of nature, he was a lovable and elevating associate, an inspiring teacher, a devoted man of science, an honor to Stanford University of which he was an honored member.

* From *The Plant World*, Vol. XIV, No. 8, pp. 200-202, August, 1911.

PROFESSOR WILLIAM RUSSEL DUDLEY *

By JARED TREMAN NEWMAN

ONE of the purest and noblest souls—such as one is fortunate to come close to even once or twice in a lifetime—passed to the life beyond yesterday afternoon.

Professor Dudley was a prominent scientist, "one of America's foremost teachers of botany, one of the pioneers in the movement toward conservation," largely instrumental in the establishment of the California Redwood Park, and the secretary of the park commission; yet, it is not of these, nor of his other scientific attainments or accomplishments, that we think chiefly at this time.

Of fine New England stock, cultured, with a refinement that was genuine all the way thorough, doing splendid work in his chosen profession and capable of making a great name for himself, his best service to the world was in imparting to other men higher aspirations and nobler ideals.

Far back in the early days at Cornell, there was a little coterie of men gathered in close association. It included Jordan and Branner and Nichols and Gage and Fairchild and Kellerman and many others who have deservedly come to high position. Among them all there was none of finer instincts or more lovable character than Dudley.

For many years after his graduation at Cornell, and while he remained a teacher there, he was the guiding and inspiring genius of successive groups of young men. Some were taking his work. Others were attracted to him by his rare personality. Still others he sought out. What he imparted to them, and to all who came close to him, was something of priceless value. It was the very soul of the man. He withheld nothing. Absolutely uncalculating in his unselfishness, so pure that impurity could not be thought of in his presence, a lover of nature and nature's God, his influence was constantly ennobling. Like many noble souls, he was peculiarly sensitive. He was hurt often when no hurt was intended. He was often melancholy, sometimes almost morbid. It has always seemed so strange that one who gave so much and so constantly should not be always happy. Perhaps he made up for it in the intensity of his joys. While he was often misunderstood and while the number of persons who came close to him was not relatively large, yet few men have merited, or have known, in so large a degree, the love of their fellows.

* From *The Palo Alto Times*, June 5, 1911.

A lover of truth and imbued with the scientific spirit, he might have become more famous had he spent more time in research and in publishing the results; but his principal work is of the kind that lives in the hearts of living men, and goes on, and will continue to go on, in a generation of workers who owe to him the touch that makes their work worth while.

WILLIAM RUSSEL DUDLEY

[Read before the Stanford Alumni Association at Washington, D. C.,
November 11, 1911.]

By WILLIAM FRANKLIN WIGHT

DURING the early summer one of Stanford's most lovable teachers closed his life's work and found that last long rest which must come to us all. I wish therefore to-night to pay a brief tribute to the memory of Professor William Russel Dudley. His kindly feeling and interest in his students made him loved by them all, and he possessed that indescribable quality in a teacher that without thought and without effort instantly arouses enthusiasm in the laboratory and in the classroom. He was an unusual teacher, and it is a sad thought to realize that years before the allotted time of life his voice will be heard no more in the classroom and his charming manner will be unknown to the students who shall fill the halls of Stanford.

It was my fortune to be with him on the last day. I had visited him a few weeks earlier, and then he was hopeful that there might still be left to him a few years in which to complete the botanical work that he had begun almost immediately on coming to California. Nevertheless, those who saw him knew that it was even then too late—that the end must soon come. It was therefore with a sad heart that I went on the morning of June 4th to pay a last visit to my friend and teacher.

From the balcony where he lay in the cottage at Los Altos one could look across the valley to the Mount Hamilton range bathed in sunlight, and view the glory of a California landscape. The air was crisp and full of life to the strong. It was indeed a beautiful day in which to live, but there with the vision of nature he loved so well before him, now too far away for his eyes to see, in the midst of a few friends, he calmly awaited the end.

It is however of other days that we would keep the memories fresh. We would rather remember him strong and enjoying the activities of a busy life. And I think he took keen pleasure in all his work, for he appeared to go through each year at the university with an enthusiasm equal to that we should expect if the studies and discoveries of the laboratory were as new to him as to the student. But it was on long tramps in the mountains, in the solitude and grandeur of the redwood forest, that one really began to appreciate the fineness of the man, to know how much he saw in mountain and forest, and how much he loved nature in sunshine and in storm. At

fifty years there was the freshness and joy of youth in botanical exploration. It was when on such walks too that one came to know the fullness of his knowledge and how perfect was his memory, as every species was recognized and its distribution or other fact of interest was related.

In many ways his life at Stanford was a disappointment. He felt the burden of the years of financial stress through which the university passed more than was his share, and very often supplied from his own purse the necessary materials for the laboratory. The hopes and ideals he had for the development of botanical science he could not live to see realized. But whatever was lacking in appropriate rooms and equipment was more than compensated for in the ability and spirit of the teacher. He lived in his work and for his students. His time and energy were so very largely occupied in their interest that he published little, and this is the regret of all who realize the high scientific ideal which guided him in his work, and who appreciate the charm of his literary style. His *Flora of Ithaca* and of the Wyoming Valley will be regarded as classics and as models of their kind for many years to come. For some it is not given to publish much—it is theirs to write in the hearts and minds of men and women, an influence as enduring perhaps as that of printed books.

I never heard him speak ill of any person but once, and then he did it deliberately, reluctantly, and as though he felt it a painful duty. It was his habit to see the good qualities in mankind and he did it naturally and without effort.

I trust that so long as modesty, thoughtfulness, and a kindly spirit are regarded as evidences of a fine character, that so long the memory of Professor William Russel Dudley will live at Stanford University.

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SCIENTIFIC PAPERS

THE VITALITY OF THE SEQUOIA GIGANTEA *

By WILLIAM RUSSEL DUDLEY

EXISTING along the western slopes of the Sierra Nevada range in California, in isolated groves from Placer County to Tulare, *Sequoia gigantea* is a relict of another age and time. In these trees we have—with the *Sequoia sempervirens*, the redwood of the Coast Ranges—the remnants of a great genus that once spread over all the Northern hemisphere, as evidenced by fossil specimens of a considerable number of species found from France and Hungary to Spitzbergen, and from Greenland to Oregon and Nebraska. These fossils are found from the Cretaceous, through the Tertiary, down to recent times. How the species have disappeared and the individuals of the Big Trees have shrunk to the few thousands perched among the high salubrious valleys of our Sierra, cannot be easily answered. The unknown complex of causes which brought about the great ice age, brought *Sequoia* as a race near to extinction; and conditions surrounding life were so profoundly changed, that their former distribution could never be again restored. Whatever the cause of the present restriction of this species, its comparative rarity, its inaccessibility, its great size, its majesty and the beauty of its coloring have all served to enhance the interest which we all feel in the California Big Tree.

Indeed it is so noble, that it has been the subject of a considerable amount of exaggeration and mistaken comment. The statements that its age reaches 4,000 to 6,000 years, and its height exceeds 400 feet do not seem to be based on any actual observation. Nevertheless it is crowned with many titles to greatness, and the most remarkable of all is its relative approach to immortality. The evidence that all living things are finite is so overwhelming that the mind is chastened with the thought of it. But the life of a single great tree of *Sequoia gigantea*, when known clearly, stirs the imagination again to thoughts of what might be attained, if disease and the crushing weight of physical injury, as factors controlling life, could be eliminated. Certainly the oldest of the Big Trees, such as we see in the Calaveras groves and the forests of the Kings and Kaweah rivers, have the distinction of being the oldest, the longest enduring upon the face of the earth, of any living organism; and this is largely because of their freedom from disease and inherited weakness and, as I propose to show a little later, from their marvelous recuperative power in the face of injury.

* Read by invitation before the California Alumni Association of Columbia University, January, 1905.

The forests of the Sierra Nevada in October are not dissimilar in aspect to those of the Appalachian mountain ranges. Yellowing oaks lighten the somber conifers, and crimson dogwoods lend an aspect of brilliancy to the forest, unknown to the camper beneath its shade in summer. Even Sequoia exhibits a warm golden tint, due to a thousand small yellow branchlets which are maturing preparatory to the annual natural pruning of the species. It was a pleasure to incidentally note these forest charms when in October, 1900, I made my way into the lumber camp belonging to the Sanger Lumber Company in the Converse Basin near the Kings River. This mill is probably the largest in capacity of any along the forested slopes of the Sierra Nevada. During the previous month of August it cut 200,000 feet of lumber a day, or considerably above 5,000,000 feet for that month. The records for the other working months of 1900 fell somewhat short of this amount, but an enormous quantity was flumed for forty miles down to the railroad at Sanger, in the San Joaquin Valley, 6,000 feet below the mill. While some of this was pine and fir, the greater proportion was made from the giant trunks of the California Big Tree. Had a measurably large amount of these trunks been utilized for lumber the cutting might have been justified from the lumberman's point of view; but frequently one-half to even three-fourths or seven-eighths of the great trunks were broken and rent beyond use in falling. Not anywhere in the world is there such wasteful lumbering, and this is a species that above all trees, should be saved from the lumberman!

The Converse Basin, before its deforestation—for its forests have now been entirely leveled—presented for observation and study the best development of this rare coniferous species that existed. The trees were large and continuous in area, and this high mountain "basin," like all others on the slopes of the Sierras containing Sequoias, is watered by small brooks of sparkling spring water. Here, too, the streams soon plunge by cataracts into the profound gorge of the Kings River, thus ensuring excellent drainage and good conditions for growth; and here a brief visit in the summer before had shown me the great number of cut trees with logs and stumps remaining, which gave an unrivaled opportunity to continue certain observations already begun. My object, while determining the age of the trees by means of the number of their annular layers of wood, was to observe their record year by year, century by century, of their behavior toward nutrition, injury or disease.

The age of a tree can only be told by counting the concentric rings of growth on the cross-section of the felled trunk. The question may be asked: Does each ring represent a year's growth? A considerable

number of observations on several species of conifers and oaks enables us to answer that it does, approximately, in those observed on the Pacific Coast. If exceptional seasons cause variations from this rule, the variations would be small in number and not greatly affect the totals. During my examination of the felled trees of the Kings River, it was a part of my task to carefully traverse these records of growth; but I will here give you briefly only the results. Of the various trunks of *Sequoia gigantea* examined ranging from 900 years upward, the oldest possessed 2,425 rings, or had begun its existence 525 years before the Christian era. Extended scrutiny undoubtedly would bring to light trees even older than this, but I do not expect any to exceed 3,000 years of age.

It has often been inferred that the size of a Big Tree bears an approximately exact relation to its age. If a tree exists eighty feet in circumference five feet above the base, it was inferred, it would be twice as old as one forty feet in circumference. This was found to be very far from true. The favorite situation of the larger trees is near some hollow, where a tiny perennial spring brook is always flowing. The soil should be good and deep, but with a large amount of mineral matter in it; and above all, I think well drained, though always moist.

One tree occupying such a situation and at the confluence of two small Sierra Brooks, was over eighty feet in circumference ten feet from the ground, but was only 1,510 years old, all the rings being measurably thick and uniform. It felt the effects neither of drouth nor of unusual precipitation, and it had never been burned beneath its bark.

On the other hand, the tree which a little later I shall use as the chief illustration of this paper, was a small tree for one of its age. It stood on a hillside not near a stream; the influence of years of abundant rains and nutrition were shown by rings of fair degree of thickness; the effects of years of scarcity were seen in rings so thin that fifty of them would not cover an inch of the tree's radius. Moreover, from its unprotected situation it had been seriously attacked by forest fires, each burning away portions of its sap-wood and thus assailing the vitality of the plant. This tree was only thirty-nine feet in circumference ten feet from the ground, but had attained the age of 2,171 years and a height approaching 300 feet, although injury and failing strength had resulted in a dead and broken top and reduced the tree to 270 feet at the time of its destruction in 1900.

Observations of the greatest interest, however, concerned the Big Tree's behavior toward severe injury; evidences of a remarkable recuperative power being found after examination of the Sequoias of the Converse Basin. The effects of certain tremendous forest fires were registered in the trunks of

these trees, but the record was completely concealed by subsequent healthy growth.

Among a number of similar cases the most instructive record of these ancient fires was observed in the tree of moderate size—the one of 2,171 years of age above mentioned. This tree, when felled, had an enormous surface burn on one side, occupying eighteen feet of the circumference and with a height estimated at thirty feet. The fire had eaten through the sap-wood and deeply into the heart. It was an immense black scar and an apparently irreparable wound upon a tree already advanced in age, even for a Sequoia. Yet this was not the only similar injury it had suffered, and before we describe the remarkable life of this tree as registered within, let us see how a Sequoia goes about the repair of such appalling wounds.

A burn on the bole of a giant Sequoia occurs usually on one side only—the side toward the forest fire. It may be a foot wide or even, as in this case, occupying an enormous area of the trunk surface; it may be of great height, it may decrease the tree's vitality and yet not fatally injure the individual thus attacked. While there is life there is growth. After the wound comes the healing; and there is nothing more insistent (if we may use the word) in the processes of plant life than the attempt of a strong tree to cover a wound on its surface.

We have two words in our language in which the pronunciation and even the correct orthography is the same, but each has a different meaning, together with a very distinct, ancient and highly respectable ancestry; I mean the word *heal*. It is a curious fact, moreover, that one of these words is properly applied to the process of healing seen in animal life, the other describes the process of covering a wound, such as that adopted by the tree. The first and frequently used word *heal* means to make sound, and implies that, after a wound, new tissue organically connected with the old has been formed, that the muscular, the circulatory and the nervous systems have been extended in a normal way from the old to the new, and conditions in the once injured part have been restored to complete and harmonious working order. The latter word *heal* means to cover or conceal. It is chiefly observed in the gardener's art in the expression "to heal in" (less correctly "heel") as applied to nursery seedlings. It is a much rarer word than the former, but good old English, and we are told that it may be traced back through the German, the Gothic and even the Latin. We remark, by the way, that so far as we know, not only the English word, but its whole family-tree clear back to the Latin root, is no older than single individuals of *Sequoia gigantea* to-day standing in the full vigor of life in the groves of Calaveras and Kaweah.

It is the latter word we use in this paper. The effort of an injured tree is not one to re-establish organic connection of the new tissue with the old, injured surface below, but wholly one to complete and re-establish, by extension, the broken circle of growth—the broken annual rings—to round out the tree again to its full circumference, to establish roots below, supporting and sap-conducting tissue above. Fortunately for the tree, it has no nervous system connected with delicately organized “nerve centers”; no circulatory system extending to every point of its surface and connected with and controlled by a small uncertain organ deep within the body. The heart-wood of a Big Tree is imperishable while the tree stands and long after it falls, unless attacked by fire. In the words of the foreman of the logging camp, “nothing hurts the heart of a redwood—*nothing*; it’s always sound.” Moreover, it is completely independent of the living zones outside of it, although joined cell by cell with the living tissue. Its cells have ceased to grow or change, and the living juices of the plant have ceased to flow in them. From the point of view of life, whatever tissue in a tree has ceased to grow in every sense, has ceased to be vitally useful. Only that tissue which is in the process of building is living, is a vital part of the great organism, and this life must exist in a complete cylinder forming the outer tissues of the trunk; a circle constantly, and in the case of a Big Tree, indefinitely widening. If the circle is broken, apparently all the energies of life and growth are directed toward closing it again, not toward any useless vivification of the dead cells of the wound below. The burned surface is dead tissue, not differing essentially from that of the tree’s heart-wood, and the healing of the latter is only incidental to the tree’s supreme effort at the extension of its living tissue over the wound in order to reunite the margins of the zone that should have remained inviolate and unbroken.

The increase of the tree is rhythmical, as we have seen, accompanying the sun and the seasons. The Spring after a wound has occurred, the tree begins its effort toward healing by the formation of a layer of wood and bark along all margins of the burned area. This is repeated the second year, a layer of new wood tissue being superimposed upon that of the previous year along the burned margins. These layers next the wound are much thicker than the ordinary ones, the ring for the same year on the side of the tree opposite the burn being often correspondingly thinner and more attenuated. This process continues with each returning season, and the new tissue reaching inwards from all margins of the injury takes on the form of solid folds of wood growing uniformly broader on each side, the black char narrower, year by year. There is no organic union, however,

between the new wood of the folds and the wood of the charred surface underneath them, no healing at this point of contact, in the ordinary sense of the word; but there is effectual *covering*, or healing in the rarer sense, according to the tree trunk's way. Sometimes, from the attack of insects on the rapidly formed wood of the folds, these folds die. There is no surgeon present to cut away this dead tissue, but the tree patiently begins to form a new fold to cover the dead one. In a species with the ordinary span of life the delay, this waste of effort, might be fatal to the final closing of the wound. Not so with the Big Tree, to whom a score of years is as one. The first fold is overtaken and passed—in one case it took just fifty years to do it—and sooner or later the two folds from opposite sides touch one another; a few years more and the bark is pinched out, the charred surface is entirely covered, and finally the annular layers become continuous around the entire circumference, each resuming a normal thickness throughout. The process, which has drawn on all the resources of the plant, it may be for scores of years, it may be for centuries, is completed. The wound is healed! This is a momentous event, yet only the spectacle of a perfected cylinder with the splendid circumference of forty or sixty or ninety feet, of living tissue through which the sap of the tree can pass, to a considerable extent laterally as well as vertically, is the result; only continuous healthful growth and unbroken increase, the most inspiring of all spectacles.

In the life history of a Big Tree such injury, such prolonged but complete and thorough repair may occur not only once but several times, and yet all evidence of the various catastrophes be entirely obliterated except for the thin cavities, each with one charred surface, and the peculiar structure of the repair layers deep within the undecayed heart of the tree. When the tree of 2,171 years of age was cut, in addition to the great burn on its trunk eighteen feet in width, the record of three other fires was revealed. The history of the tree was as follows:

It began its existence 271 B. C.

At the beginning of the Christian era it was estimated to be already about twelve feet in circumference just above the base.

At 516 years of age (A. D. 245) occurred a burning three feet in width on the trunk.

One hundred and five years were occupied in healing this wound.

One thousand, one hundred and ninety-six years without injury followed.

At 1,712 years of age (A. D. 1441) occurred a second burning, making two wounds of one and two feet each in width. Each had its own system of healing.

One hundred and thirty-nine years of growth followed, including the time occupied by the covering of the two wounds.

At 1,851 years of age (A. D. 1580) occurred another fire, causing a burn on the trunk two feet wide, which took fifty-six years to heal.

Two hundred and seventeen years of growth followed the fire.

When the tree was 2,068 years old (in 1797) a tremendously aggressive fire attacked the trunk (perhaps aided by the burning stem of a neighboring pine or fir) and burned the great scar eighteen feet wide with a height estimated at thirty feet. The 103 years which had elapsed since 1797 had reduced this to fourteen feet in width. If the same rate of growth continued without interruption—a hazardous estimate—and the tree had been in possession of the United States and under its protection, the wound might have been closed in three and one-half centuries more, or about the year 2250. Four centuries and a half to repair in one tree the results of one forest fire! If the tree had been a younger tree, less the victim of previous fires, we are convinced that such a healing would be possible. In any case *Sequoia gigantea* practically stands alone, sublime among living objects in its ability to withstand an injury of this magnitude, and to endure a sufficient length of time for its complete recovery.

It is to be noted that in the trunk next to each of the three older burns described, there is a thin cavity chiefly occupied by the charcoal of the burned surface (some of that formed in 245 was brought away), and that this produced a pathologically protective covering, no doubt calculated as well as any to prevent decay during the long period consumed in covering the wound with healthy tissue. But this will not account for all this superb resistance to the attack of insect, fungus, ferment or microbe. Burned areas of other trees have the same charred surface, but no oak or sycamore, pine or Douglas spruce under similar conditions would remain so long without being attacked in this region by some cause of decay. There is something in the sap of the Big Tree that is an elixir of life, something deposited in the lignified cells of the normally formed layers of wood that resists in an unexampled way the dreaded "tooth of time." The wound is finally covered—not healed, in the surgeon's sense—the new tissue formed above it is thickened, the tree is rounded to its original fullness, bark and wood become continuous about the whole circumference, the latter forming in rings of normal uniformity, the old healthful symmetry of life is re-established, and no outward sign of distortion exists, or even a scar from the old injury. Nevertheless, well within, and as the centuries pass, deeper and deeper within the heart of the tree the wound exists unchanged and therefore no source of decay.

Again, it is to be observed from the notes of the tree's yearly growth, that after it was out of its first youth, the periods of most vigorous increase were after the successive burnings and during the periods of healing. In part this accounted for the lessened area of the tree's live circumference; but as this thickening of the rings appears to continue after complete healing has taken place, when the tree is again forming tissue over its entire circumference, and as this phenomenon was seen in other trees similarly injured, one is led to believe that an increased activity in the tree's life had been occasioned not by the burn, but from the effort at healing and recovering from what threatened to be a vital wound; and that this activity led to more vigorous growth. It is a curious fact, moreover, that in the middle of the long period of freedom from fire, from 245 to 1441, a period of nearly twelve centuries, the tree made its least relative increase in diameter. Peace and apparent prosperity had been coincident with a sluggish growth if they had not been the cause of it.

About three and one-half inches was the most frequent amount of radial growth during one century, a total increase of about seven inches in the diameter of the stem; but during the first six hundred years its average was five inches (a total increase of ten inches in diameter each century) and during the first and fourth centuries of this tree's existence its radial increase was six inches in each case. During the seventh, eighth, ninth, tenth and eleventh centuries the increase in the radius of the stem was between two and three inches only per century. It was during this period, from the seventh to the twelfth century of its existence—the period of greatest depression in the apparent vitality of the tree—that the rings or annular layers became so thin that it was impossible to count them without the aid of a lens: over forty layers were frequently found in one inch of radial line, and in two cases apparently there were fifty-two and fifty-four layers in each inch.

I cannot help thinking we are here in the presence of one of the most remarkable products of the globe, not excepting those of human civilization. Almost no structure erected by human hands has come down to us intact through the lifetime of a Sequoia; and the few we can admire are hewn from inanimate marble or granite and cannot be compared to a living organism, vast in life and complete in the records of every year of its existence. An empire or republic may be compared to the life of these great trees. But what empire or republic has lived for twenty-five centuries? None worthy of the name, and certainly none among those of the Aryan civilization. Then in the building of a Sequoia, no blood has been shed through all its twenty-five hundred years, no injustice or oppression has secured the means necessary for its construction, no hate or strife has been engendered,

no accident occasioning pain or suffering or the extinction of human life has left a stain on the history of its growth. Tragedies and great passions, as we have seen, have crossed its silent life, but they have been the elemental passions of fire and storm, clean and wholesome, and the tree has been stimulated by them to a greater and more vigorous growth. Indeed, there is something sublime in the patience of the task and the completeness of its execution when, after centuries of slow rebuilding, we see every outward trace of its injuries eliminated and a robust and uninterrupted life again attained.

Mr. James Bryce, in his sketch of the life of the late Lord Acton, Professor of History at the University of Cambridge, says: "Twenty years ago, at midnight in his library at Cannes he expounded to me how a history of Liberty might be written and in what way it might be made the central thread of all history. He spoke like a man inspired, seeming as if from some mountain summit high in air he saw beneath him the far winding path of human progress, from dim Cimmerian shores of prehistoric shadow, into the fuller, yet broken and fitful light of the modern time. * * * It was as if the whole landscape of history had been suddenly lit up by a burst of sunlight. I had never heard from any other lips any discourse like this, nor from his did I hear the like again."

The impression made was not dissimilar, on that cloudless October afternoon with the crimson leaves of the dogwood and the yellow oak falling silently in the Sierra forests, as one patiently wrought out with lens, measure, pencil and camera the great history of the Sequoia above named, year by year, century by century; centuries of peace, years of tragedy, and again centuries of stimulated growth. It was as if the whole landscape of life, from the dim prehistoric forests until now, "had been suddenly lit up by a burst of sunlight." I had never heard from any other lips any discourse like this, nor from this fallen seer and patriarch could I hear the like again.

During the past ten years hardly a season has passed but I have camped among the Sequoias. I am glad to say I have visited nearly all the groves, but I regret to say that a considerable proportion of them is in private hands; some have been leveled already and the mills are busy in not less than four others, notwithstanding there is little profit in the lumbering. These groves of Sequoias form a question apart from the ordinary questions of forestry. In the heart of the Sierra forests they are, it is true, an important part of the protective forest cover of the headwaters of California rivers; but I believe you will now join me in the assertion that they have an interest for the citizens of California, for the cultivated traveler and the

scientific man, far beyond that of the other trees of the forest. The United States should own and properly protect every one of them. Senator Hoar, of Massachusetts, once said if the Calaveras Groves were in Massachusetts, she would herself buy them and not ask the National government to purchase them. There are some things, however, that are the natural heritage of a nation, and the *Sequoia gigantea* is one of them. We would rather see the Yellowstone National Park and the Grand Canyon of the Colorado under the protection of the United States than that of any state, not excepting California or Massachusetts. If the Sequoias are among the most remarkable objects on the globe, if they are the best calculated, as we can show, of any living organism to throw light on certain problems of scientific inquiry, then a nation should own them and their preservation should be a matter of national pride.

We make every effort to preserve the manuscript of our great Anglo-Saxon and American charters; nevertheless the ink fades, the parchment crumbles and they disappear, except from the lives of just men. We house the archives of our wars in buildings of great cost, maintained with great care, yet all these are on paper that is more perishable than the parchment of our charters. In these great trees, however, we have, deep in their annual rings, records which extend far beyond the beginnings of Anglo-Saxon peoples, beyond even the earliest struggles for liberty and democracy among the Greeks, the first of the Indo-Europeans to crystallize into national life through the pressure of this struggle. The records are those of forest conflagrations, of the vicissitudes of seasons, of periods of drouth and periods of abundant and favoring rains, and we might find next to the charcoal of some trunk scar, centuries old, the stone implements belonging to the ancient aboriginal inhabitants of Western America. Practically none of these records have yet been studied. Let the nation purchase these trees of the Calaveras groves—among the largest of all those still remaining alive—let it take them as a right and a duty, not parleying with the cupidity of an owner who has done nothing to increase their value; let it gradually gather under its protection all the groves of *Sequoia*, now in alien hands, and care for them all intelligently. When the oldest of trees succumb and die, as from past injuries they must do in time, then let them be felled; and instead of being sold or burned with criminal indifference to their real value, as at the present day, may their records be read and recorded by skilled hands and interpreted by the best intelligence; and finally may their massive timbers, of wonderful fineness, uniformity, luster, color and beauty, be used only in the interior of a nation's buildings, in places which shall the longest endure.

THE MORPHOLOGY AND SYSTEMATIC POSITION OF
CALYCULARIA RADICULOSA (Steph.)

By DOUGLAS HOUGHTON CAMPBELL, Professor of Botany

THE classification of the so-called anacrogynous Jungermanniales, an important group of liverworts, is at present in a very unsatisfactory condition, and much remains to be done before the true relationships of the members of this group can be satisfactorily settled. A recent attempt has been made toward a better classification of the liverworts by Cavers¹ and this is a distinct advance upon the classifications which have heretofore been accepted. There are, however, a number of forms whose relationships are still by no means clear, and among these is a rare liverwort from Java originally described as *Calycularia radiculosa*. Schiffner² speaks of the plant as an extremely rare one, but during a stay in Tjibodas where the plant had been collected before, the writer succeeded in finding it a number of times. The plants did not grow in large masses but were associated with various other liverworts growing on the trunks of trees. The general aspect of the plant (see Figs. 1 and 2) is very much like that of the creeping forms of the genus *Blyttia*. *Pallavicinia* (*Blyttia*) *Levieri*, a common species

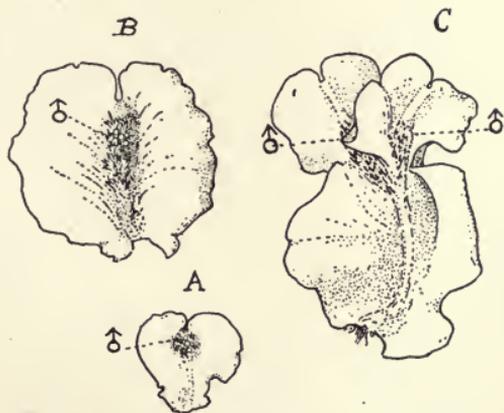


Fig. 1. Three male plants of *Calycularia radiculosa*. Steph. $\times 3$. ♂, antheridial receptacle.

¹ The inter-relationships of the Bryophyta. New Phytologist Reprint, No. 4, 1911.

² Die Hepaticæ der Flora Von Buitenzorg, 1900.

of the same region, much resembles the plant in question, but the latter is readily distinguishable on account of the numerous dark reddish purple rhizoids.

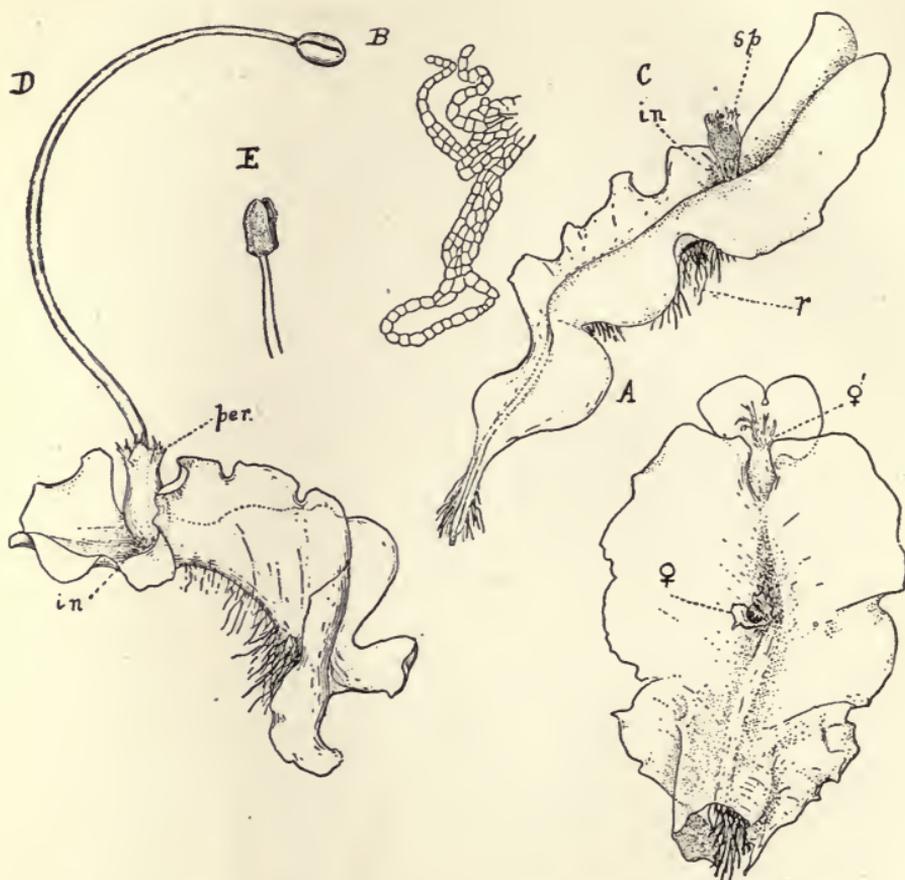


Fig. 2. *A*, female plant 1×3 ; the thallus has begun active growth again and developed a second archegonial receptacle, ♀², in the new portion. *B*, part of one of the involucre scales, slightly magnified. *C*, female plant bearing a young sporophyte, *sp*. *D*, plant with mature sporophyte. *E*, open capsule with the valves entirely separated at the apex. *In*, involucre; *per*, perianth.

The material collected by the writer was sufficient to make possible a pretty complete study of the structure and development of the plant, except the earlier stages of the sporophyte which were wanting in the specimens collected.

The genus *Calycularia* as generally understood comprises four species of thallose liverworts of rather unusual distribution. One of these, *C. laxa*, occurs in arctic Siberia, two, *C. crispula* and *C. Birmensis*, are found in India and Burmah, while the other, *C. radiculosa*, occurs in Java. The question has been raised whether the latter species really should be united with the others. Schiffner³ after an examination of the plant, concluded that it should be placed in the genus *Mörkia*, a genus sometimes regarded as a section simply of the larger genus *Pallavicinia*. The material upon which the present account is based was collected by the writer in Java in 1906 while staying at Tjibodas, one of the stations where the plant had originally been collected.

GENERAL MORPHOLOGY

The plants are dioecious, the male plants (Fig. 1) being decidedly smaller than the females (Fig. 2). Antheridia may be developed while the plants are not more than 5 mm. in length, but the male plants may reach a length of 12-15 mm. The female plants are two or three times as long as the males and may reach a length of about 30 mm., with a breadth of about 14 mm.

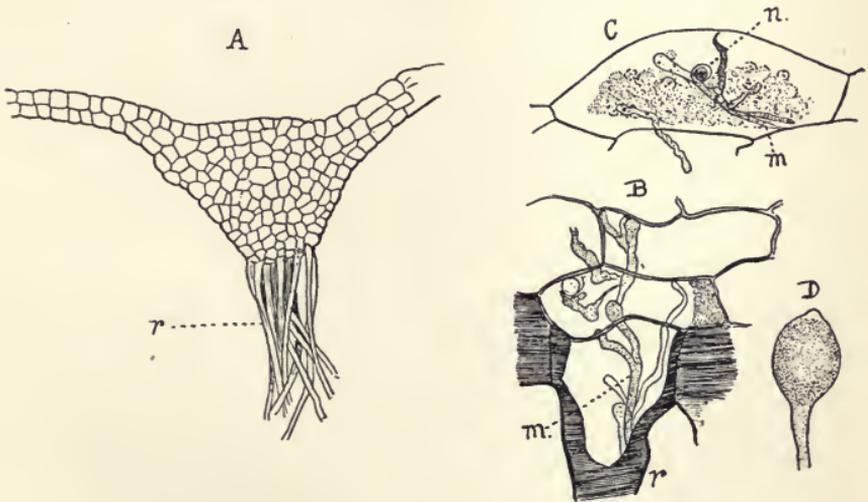


Fig. 3. *A*, cross-section of the thallus, showing the thickened mid-rib and rhizoids, *r*, \times about 30. *B*, cells from the ventral side of the thallus, showing the mycorrhiza, *m*, extending from the rhizoid, *r*, into the inner cells of the thallus, \times about 400. *C*, an inner cell of the thallus invaded by the mycorrhiza; the nucleus of the cell is still intact. *D*, oögonium-like enlargement of a mycorrhizal filament.

³ Österreichische Botanische Zeitschrift, Feb., 1901.

They are usually not branched but may be forked once (Fig. 1, C). There is a deep sinus in front within which lies the growing point of the thallus. A thick midrib is developed strongly, projecting on the lower side where its ventral surface is covered with numerous deep purple-red rhizoids. The margin of the thallus is more or less strongly undulate and folded, but these undulations are hardly distinct enough to be called leaves. The whole aspect of the plant is very much like certain species of *Pallavicinia*, and also suggests the Japanese genus *Makinoa*.⁴ A section of the thallus (Fig. 3, A) shows that the midrib comprises about a dozen cells in thickness, but there is no trace of the conducting strands of tissue which are a constant character in *Pallavicinia*. In *Eupallavicinia* (*Blyttia*) there is a single very conspicuous axial strand, while in *Mörkia*, according to Cavers, there are developed two strands which are however much less strongly developed than in *Blyttia*. In the character of the midrib, therefore, *Mörkia* seems to be somewhat intermediate in character between *Calycularia radiculosa* and *Blyttia*.

The wings of the thallus are composed of a single layer of cells in the marginal region, but toward the midrib the wings are composed of two or

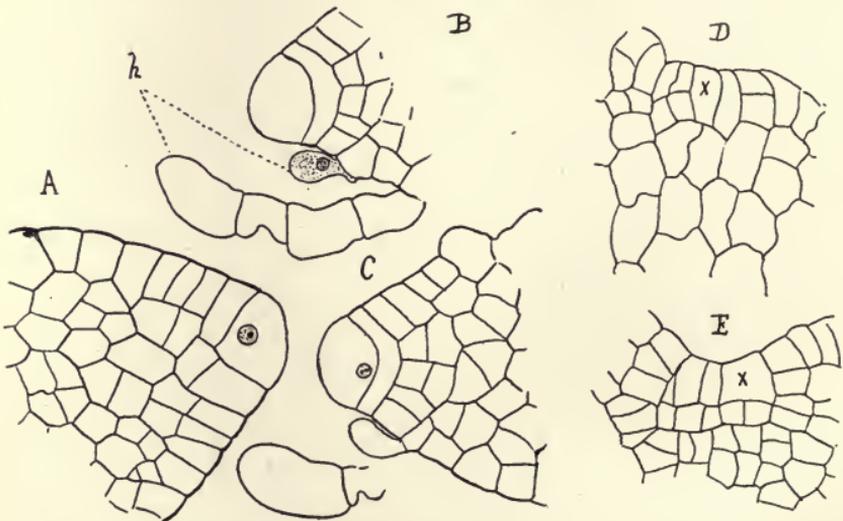


Fig. 4. A, vertical section of the thallus apex, in which there are dorsal and ventral segments cut off from the apical cell. B, C, two consecutive sections from a thallus apex, in which a single basal segment is cut off. D, E, two nearly horizontal sections, showing the appearance of the apical cell, *x*, when seen from above, $\times 225$, *h*, ventral glandular hairs.

⁴ Miyake, K.; *Makinoa*, A New Genus of Hepaticæ. Bot. Mag., Vol. 13, 1899.

sometimes even of three layers of cells. In this respect *Calycularia radiculosa* perhaps more nearly resembles *Makinoa* than it does *Pallavicinia*.

A characteristic feature of the thallus is the presence in the older portions of an endophytic fungus or mycorrhiza, very much like that found in the subterranean prothallia of various pteridophytes. A similar mycorrhiza, however, has been found also by the writer in various green fern prothallia, and it is also known to occur in various other liverworts.

The fungus both in its structure and manner of growth resembles more closely the mycorrhiza described by the writer⁵ in *Ophioglossaceæ*. As in the *Ophioglossaceæ* there were occasionally found oögonium-like enlargements (Fig. 3, D) which may have been perhaps special reproductive bodies, but this could not be positively demonstrated. The genus *Calycularia* is

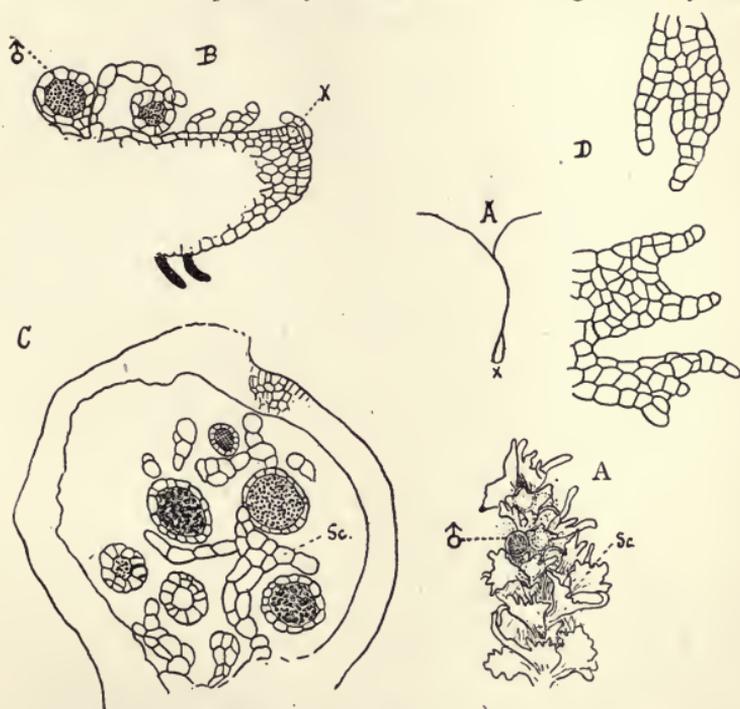


Fig. 5. *A*, upper surface of a male plant, *x*, apex of the thallus. *A*¹, under surface, showing the antheridia, ♂, surrounded by the lacinate scales, *sc*. × 15. *B*, median section of the thallus, showing the apex, *x*, and the antheridia, ♂, × 40. *C*, a horizontal section of the antheridial receptacle, *sc*, scales. *D*, scales showing the lacinate margins.

⁵ Campbell, D. H. *The Eusporangiata*. Pub. 140. Carnegie Institution of Washington. 1911.

described as having upon the ventral surface leaf-like scales or amphigastria, but Schiffner found that these were not present in *Calycularia radiculosa*, and the writer's investigations confirm this. These leaf-like scales are replaced by multi-cellular hairs (Fig. 4, Bh), such as are common on many other thallose Jungermanniales. The terminal cell is enlarged and probably secretes mucilage for the protection of the thallus apex.

The latter is turned strongly upward (Figs. 5, B; 8, A) and it is almost impossible to make satisfactory sections parallel with the surface of the thallus. Figures 4, D and 5, B show sections which are approximately parallel; but as these are somewhat oblique, the apical cell appears somewhat shorter than it really is. In this view it appears somewhat oblong in outline, and it is evident that segments are cut off both from the lateral and from the basal portions. In vertical horizontal sections the apical cell shows certain variations, resembling in this respect the genus *Pellia*. While *Pellia epiphylla* has an apical cell with a single basal segment extending the whole length of the thallus, in *P. calycina* a vertical section shows two sets of segments, dorsal and ventral, such as occur in certain species of *Pallavicinia*, as well as in the *Marchantiales* and in *Anthocros*. In *Calycularia radiculosa* both of these types were found. The type found in *Pellia epiphylla* (See Fig. 4, B, C) were common in the smaller plants, but it was not at all clear whether there really is any definite relation between the thickness of the thallus and the form of the apical cell. The second type is shown in Figure 4, A.

Where branching takes place it seems to be a true dichotomy, but whether one of the branches retains the original apical cell or whether two new apical cells are developed, was not investigated.

THE MALE PLANT.

The male plants (Fig. 1) are usually quite short, often being scarcely longer than broad, and as we have already stated, antheridia are sometimes found upon plants which are not more than 5 mm. in length. The antheridia are in small groups, seldom more than ten together, and are much less numerous than is the case in either *Mörkia* or *Blyttia*. In the restriction of the antheridia to such a limited region the plants suggest *Makinoa*, but the whole antheridial group is not subtended by a common envelope as in *Makinoa*, though the antheridia occupy a more or less well-marked depression or cavity upon the dorsal surface of the midrib. Each antheridium is subtended by a much lacinated scale. The scales are often more or less confluent, so that imperfect chambers are formed (Fig. 5, C) about each antheridium. As a rule, only one receptacle occurs upon the plant, but in a few of the larger

ones, where old groups of antheridia were present, a second younger group was occasionally found near the apex; and in the rare instances where the thallus forks, each branch may bear an antheridial receptacle. (Fig. 1, C.)

The antheridia (Figs. 5 and 6) are short-stalked nearly globular bodies and closely resemble those of *Pallavicinia*, and as usual they are formed in acropetal succession alternately right and left of the apex of the thallus.

The earliest stages were not found, so that it is impossible to say whether the early divisions correspond to those observed in other genera, but as the young antheridia resemble so closely those of *Pallavicinia*, it is to be

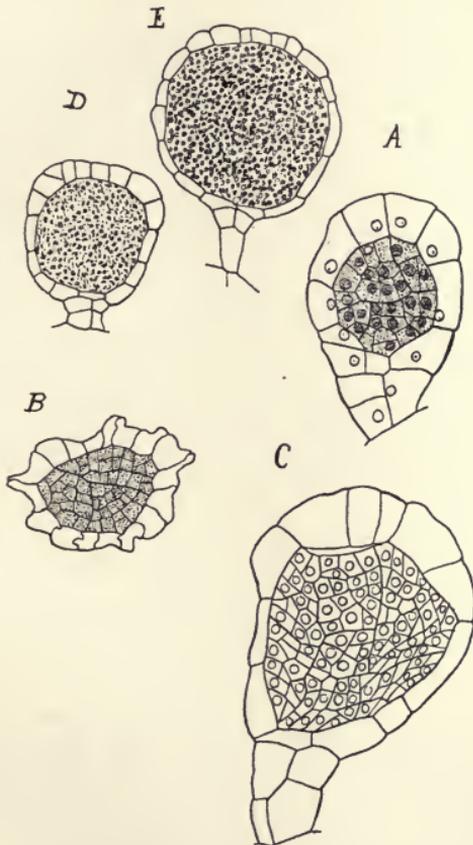


Fig. 6. Development of the Antheridium. *A*, median section of young antheridium, \times about 225. *B*, cross-section of the antheridium of about the same age. *C*, an older antheridium. *D*, *E*, two nearly ripe antheridia, \times about 90.

expected that the early stages would conform to the usual type found in the Jungermanniales.

In his description of the genus *Calycularia* given in Engler and Prantl's *Natürliche Pflanzenfamilien*, Schiffner states that the antheridium has a single celled stalk, but in his later description of *C. radiculosa*, given in his work on the Liverworts of Buitenzorg he says that he did not see the male plants, so that this description would not apply to that species, and as we shall see, the stalk is multicellular, very much like that of *Pallavicinia*.

Figure 6, A shows a longitudinal section of the youngest perfect antheridium that was found. The short stalk shows in sections two rows of cells and the upper portion shows a mass of young spermatogenous cells surrounded by a single layer of sterile cells. Figure 6 B shows a cross-section of an antheridium of about the same age. Sometimes the stem of the antheridium is more slender and may have a single basal cell (Fig. 6 E) which often becomes very much elongated.

Before the final division of the spermatogenous cells they are polygonal in outline, with dense contents usually more or less contracted, but how far this is normal and how far it is due to artificial shrinkage could not be determined. The cell walls are clearly defined. The nucleus is conspicuous and stains strongly. The contents appear somewhat finely granular, the

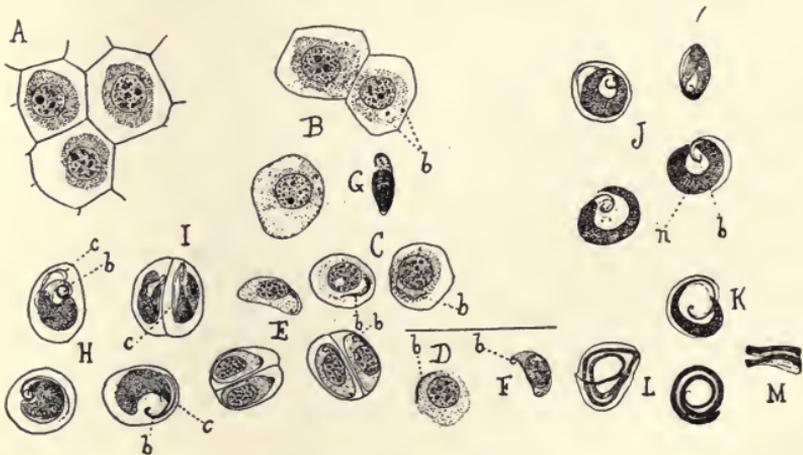


Fig. 7. Spermatogenesis. All figures magnified about 750. A, B, spermatogenic cells, just before the final mitosis; in B can be seen two small bodies, b, which are probably the young blepharoplasts. C, D, stages in the development of the spermatozoid. E, I, M, show the pair of spermatocytes seen from the side, the others are mostly single spermatocytes seen from above; b, blepharoplast; c, cilia; n, nucleus of the young spermatozoid. Figs. L, M, show the mature spermatozoa.

nuclear reticulum not being clearly visible, and there are a number of bodies, one of which is probably the nucleus, although it is possible that there may be more than one nucleus (Figs. 7 A, B). In a number of cases shortly before the division to form the spermatocytes, there could be seen two minute granules (Figs. 7 B, b), sometimes surrounded by a colorless area and perhaps representing the young blepharoplasts, but the small size of these, and the presence of other granular bodies in the cytoplasm makes one hesitate to assert positively that these really were blepharoplasts, especially as no division stages were found, and the relation of these bodies to the nuclear spindle could not be determined.

The further development of the spermatozoids, which are unusually large in this species and therefore favorable for study, is on the whole much like that of *Pellia*. After the final nuclear division a definite cell wall is formed between the spermatozoids, the division not running diagonally, as described by Ikeno for *Marchantia*, but dividing the cell into two approximately hemispherical ones. (Fig. 7 E, I.)

In the youngest stages met with (Figs. 7 C, D) the nucleus, which now appears somewhat coarsely granular, was still unchanged in form. The cytoplasm was often contracted but not always so, and in the cytoplasm, sometimes at the periphery, but quite as often near the nucleus, could be seen the blepharoplast (Fig. 7, C, D, b), which was already extended into a delicate band. No cases were found where the blepharoplast showed its original round form. A careful examination of the nucleus at this time shows that it is decidedly flattened in the plane of the division wall between the two spermatocytes, so that it appears oval when seen from the side but circular when viewed from above.

No signs of any body equivalent to the so-called "Nebenkörper," or the "accessory body" described by Wilson⁶ for *Pellia* could be seen, and such a body is probably quite wanting in *Calycularia radiculosa*. In a slightly later stage, however (Figs. E, F, G), there could often be seen what appeared like cytoplasm extending beyond the nucleus and connecting with the blepharoplast. Strassburger refers to such a structure in his somewhat brief account of *Pellia*.

The nucleus now begins to elongate and to increase notably in size, having the form of an almost homogenous crescent-shaped body when seen from the side. The forward end of the crescent is somewhat more prominent than the posterior end and extends into the cytoplasmic prominence, connecting with the blepharoplast, the exact limits of which are very difficult

⁶ Wilson, M. Spermatogenesis in the Bryophyta. *Ann. Bot.*, 25, 1911.

to determine. The cytoplasm surrounding the nucleus becomes less and less evident as the nucleus increases in size and it can no longer be clearly recognized in the later stages of development, although there probably persists a thin envelope of cytoplasm surrounding the posterior coils of the spermatozoid.

The blepharoplast at this time forms a short hooped prominence at the forward part of the spermatozoid and merging insensibly into the delicate cytoplasmic prominence which extends beyond the nucleus. The latter continues to elongate and become curved over in the plane of the division wall, so that the older spermatozoid has the form of a flat coil. (Fig. 7, M.)

When fully developed the sperm is a slender thread composed of two complete coils and part of a third. In these later stages the double stain of safranin and gentian violet failed to clearly differentiate the different parts, the spermatozoid appearing almost uniformly stained. The two spermatozooids of a pair are very closely approximated (Fig. 7, M) and present a very characteristic appearance.

The cilia could be made out in a number of the older stages (Fig. 7, H), but their exact origin and position could not be determined as accurately as might have been wished. It is probable, however, that as in some other cases which have been investigated, they begin to double up at an early stage and arise somewhat back of the apex. Woodburn⁷ in a recent paper states that in *Porella* the anterior end of the spermatozoid shows a slight enlargement, which he interprets as the blepharoplast. The cilia in this case arise a short distance back of this enlarged part of the blepharoplast. No trace of it was observed in *Calycularia*.

ARCHEGONIUM.

The female plants, as we have already seen, are decidedly larger than the males, and are usually 20-30 mm. in length, with a breadth of from 10-12 mm. Like the male plants, they are usually unbranched, but it is not uncommon to find them forked once. The position of the archegonia is much like that of the antheridia, these being grouped on a sort of receptacle. (Fig. 2, A.) As a rule, only one archegonial receptacle is formed, but sometimes the thallus will resume its growth and a second one may be formed near the apex. The archegonium appears to agree in all respects with that of other *Jungermanniales* that have been investigated. (Figs. 8 and 9.) After a short stalk has been formed, the archegonium mother cell divides by the usual three intersecting vertical walls into an axial cell and

⁷ Woodburn, W. L. Spermatogenesis in Certain Hepaticæ. *Ann. Bot.*, 25, 1911.

three peripheral ones. From the axial cell is cut off the cover cell (Fig. 8, B and C) and then follows a series of transverse walls separating the lower part or venter from the upper region or the neck. From the lower of the two primary axial cells the egg and ventral canal cells arise, and from the

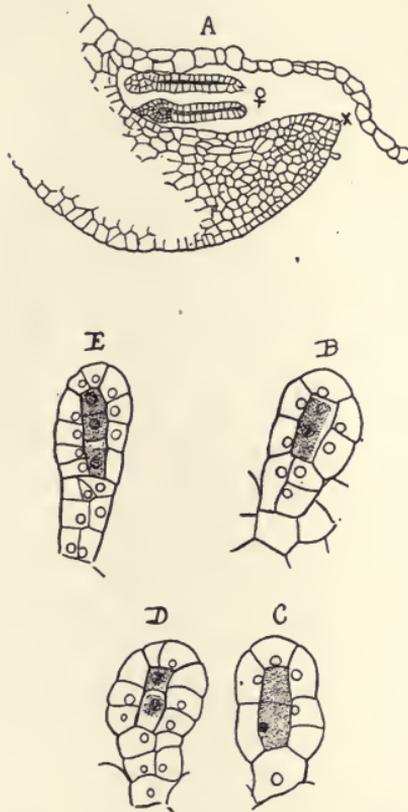


Fig. 8. *A*, apex of female plant, showing the position of the archegonia, \times about 40. *B-E*, young archegonia in median section, \times about 225.

upper ones the series of neck canal cells and the outer cells of the neck. The number of neck canal cells is variable, but to judge from the few that were examined, there are first formed four of these neck cells, some or all of which divide again, so that there may be as many as eight. The division, however, is very often not complete but confined to the nucleus (Fig. 9, C and D). As usual in the Jungermanniales, the neck of the archegonium has but five peripheral rows of cells (Fig. 9, F).

In the ventral region peripheral walls occur in the outer cells, so that at maturity the venter is more or less completely two layered (Fig. 9, D and E).

Figure 9, G, shows an abnormal archegonium from a receptacle in which one of the archegonia had been fertilized. In this archegonium there were four axial cells, all of which were a good deal alike and all except one much enlarged, so that they resembled the egg of the normal archegonium more than they did the neck canal cells.

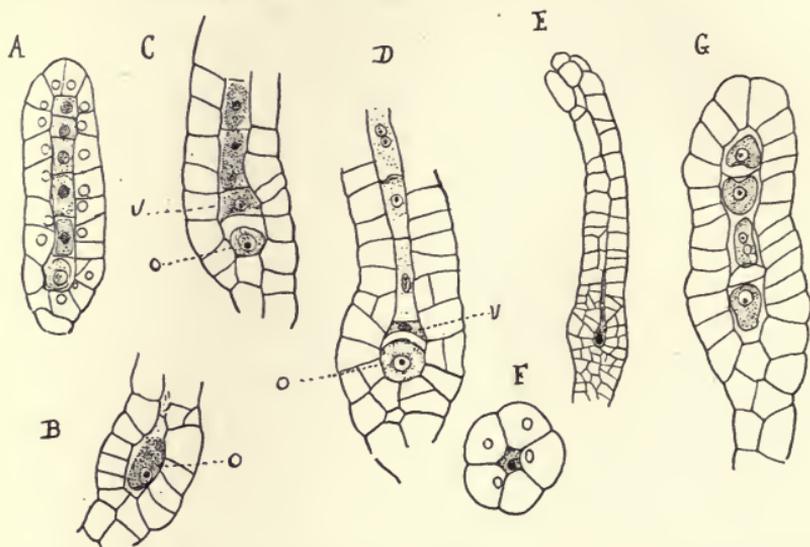


Fig. 9. *A, B*, two sections of a young archegonium with five neck canal cells; the ventral canal cell is not yet formed, \times about 225. *C*, a somewhat older stage, showing the egg, *o*, and the ventral canal cell, *v*. *D*, lower part of a nearly ripe archegonium. *E*, full grown archegonium which has failed to be fertilized, \times about 90. *F*, cross-section of the neck of archegonium. *G*, an abnormal archegonium with unusually large axial cells.

After fertilization there arises about the group of archegonia a tubular envelope, the perianth, which finally forms a very conspicuous vase-shaped sheath around the sporogonium, inside the involucre, which, like that of the antheridial receptacle, is made up of very much lacinated scales. (Fig. 1, C. D, per.)

THE SPOROPHYTE.

Only a few very young embryos were found and these were not well fixed, so that it was impossible to make a satisfactory study of the development of the embryo. The youngest sporogonia of which successful prepara-

tions were made were already far advanced and were differentiated into the various parts.

Even before the first division takes place in the young embryo, the venter of the archegonium becomes much enlarged, and a calyptra is developed, enclosing the sporogonium until it is far advanced. This attains a thickness of 5 or 6 layers of cells at the base, but is much thinner toward the apex. As the sporogonium develops, the upper portion or capsule becomes oval in form, and below consists of a thick seta, which terminates in a large heart-shaped foot very much like that which Cavers describes for *Mörkia Flowtowiana*. (Cavers *Loc. cit.* Fig. 37). A similar foot has been observed in various other Jungermanniales.

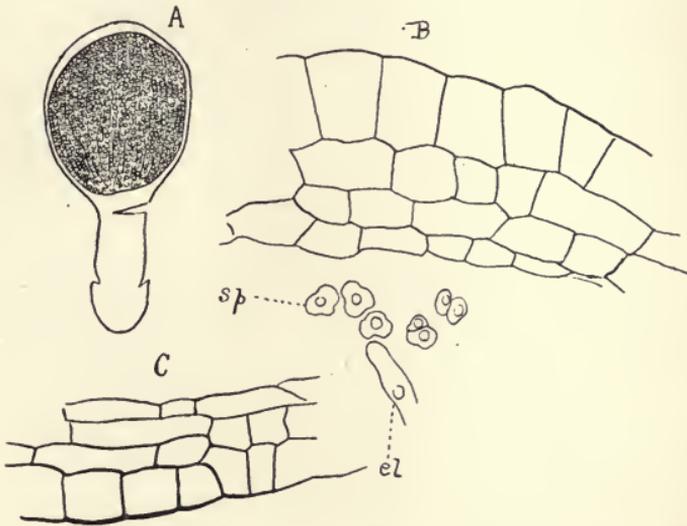


Fig. 10. *A*, median section of a sporogonium at the time of the mitosis of the spore mother cells, $\times 15$. *B*, apical region of a younger sporogonium, *sp.* spore mother cells, *el.* young elator, $\times 225$. *C*, part of the lateral wall of the sporogonium.

The capsule (Fig. 10) has a relatively thick wall which is better developed at the apex than at the sides, this difference becoming still more marked in the later stages. The inner tissue now shows a separation into the roundish spore mother cells and the elongated young elaters. Long before the division of the spore mother cells begins, they show the first indications of the lobing which later becomes so conspicuous. At this stage the walls of both the spore mother cells and the elaters are very delicate, but can be readily demonstrated by suitable stains, e. g. Bismarck brown.

The seta at this stage has about the same length as the capsule, and in longitudinal section (Fig. 12, H) shows the cells to be arranged in pretty regular rows. Probably the great elongation of the seta at the time the spores are shed is due to simple elongation of the cells without any cell divisions, as has been shown to be the case in other liverworts. The large heart-shaped foot (f) is composed of somewhat irregular cells showing no definite arrangement.

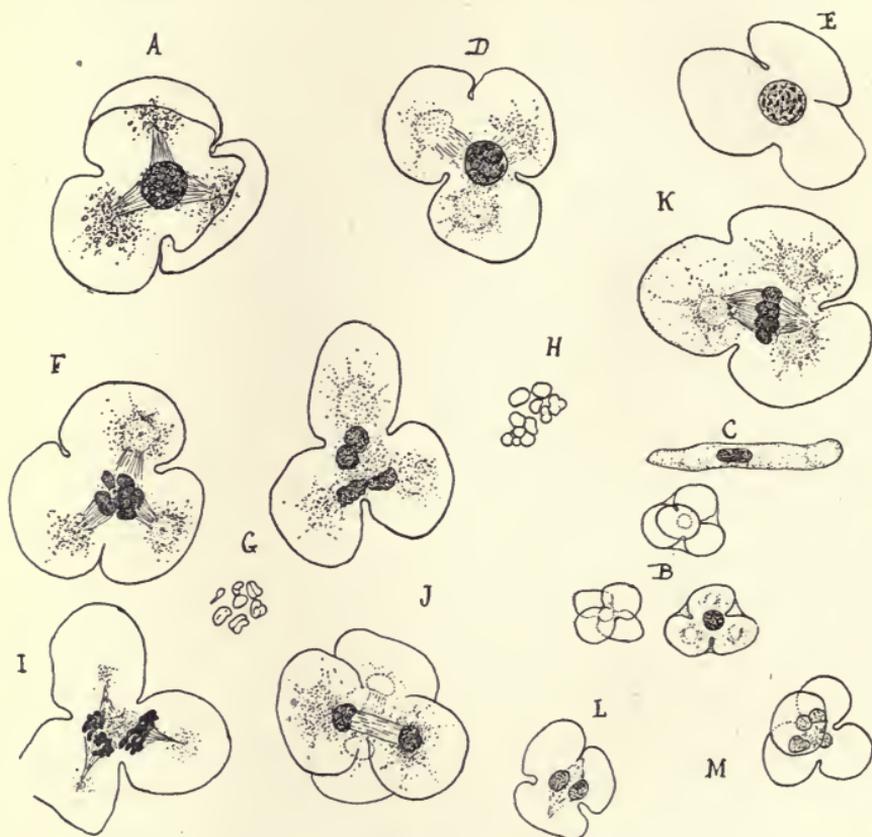


Fig. 11. Spore division. *A*, spore mother cell, showing the quadripolar spindle, $\times 750$. *B*, three spore mother cells of about the same age, showing the different arrangement of the lobes of the cell, \times about 350. *C*, young elater. *D*, spore mother cell, showing the chromosomes. *E*, a somewhat earlier stage. *F-I*, successive stages of mitosis with quadripolar spindle. In *G* and *H* the chromosomes only are shown. *J*, mother cell with the lobes in pairs; there are two nuclear spindles at right angles to each other. *K*, mother cell, showing a bi-polar spindle at the first mitosis. *L*, first mitosis, showing two nuclei separated by a distinct cell-plate, \times about 400. *M*, mother cell just before the final separation of the spores, $\times 400$.

THE SPORE DIVISION.

(Figure 11.)

One sporogonium showed the spore mother cells in process of division, all stages occurring in the same sporogonium. The preparation was somewhat overstained with hæmatoxylin, but nevertheless showed pretty well the details of division, which exhibited a considerable amount of variation.

The spore mother cells before the first nuclear division are deeply four-lobed, the lobes being usually arranged tetrahedrally, but occasionally placed in pairs at right angles to each other (Fig. 11, J). The nucleus is large, but in this over-stained material the structure was not usually very clear, the nucleus appearing almost homogenous. A few specimens, however, (Fig. 11, E) showed a more or less granular structure, but the reticulum was not clearly evident nor could the nucleolus be seen.

A striking feature was noticed in most of the cells, viz.: the extension from the nucleus into each of the four lobes of the cell of a body which was apparently the same as the "quadripolar" spindle described by Farmer for *Pallavicinia decipiens*⁸. Often the center of each lobe was occupied by a roundish body which perhaps marked the position of a centrosome, but it cannot be stated positively that centrosomes are present. However, as centrosomes occur in *Pellia*, which in some other respects suggest a relationship with *Calycularia*, it is possible that centrosomes may have been present in this case also.

In the later stages of nuclear division some differences were found to occur. Usually the process seems to agree very closely with that described by Farmer for *Pallavicinia decipiens*. The nuclear membrane disappears and the separate chromosomes, thick oval bodies, can be made out. (Fig. 11, F.) There are eight of these in *Calycularia radiculosa* instead of the four found in *Pallavicinia decipiens*; but it was found that in *Pallavicinia radiculosa* there were also eight, as there are in *Pellia*.

The eight chromosomes next divide longitudinally (Fig 11, G), and the resulting sixteen chromosomes separate into two groups (H). Usually the chromosomes do not arrange themselves into a new reticulum, but immediately undergo a second division, so that there are two groups of 16 chromosomes (Fig. 11, I), each of which separates into two secondary groups of eight chromosomes which finally assume the form of resting nuclei. One

⁸ Farmer, J. B. Studies in Hepaticæ *Pallavicinia decipiens* Mitten. Ann. of Botany, 8, 35-52, 1894.

of these nuclei moves to each lobe of the mother cell, but generally remains near the center of the cell, so that the four resulting nuclei are quite close together (Fig. 11, M).

Not all of the spore mother cells, however, behave in this fashion, but sometimes after the first division of the chromosomes a conspicuous bi-polar spindle of the usual form was observed. (Fig. 11, K). Later two resting nuclei were seen with a cell-plate between them. (Fig. 11, L). These secondary nuclei then divided again, each developing another bi-polar spindle, these secondary spindles sometimes lying at right angles to each other. (Fig. 11, J).

After the nuclei have assumed the resting condition cell walls are formed, simultaneously extending inward from the indentations between the lobes and completely dividing the mother cell into its four component parts, the young spores.

The ripe spores (Fig. 12, F, G) possess a thick membrane, which in sections shows two well-marked parts, an inner uniform layer and a thick outer one provided with rounded knobs, which give it a very characteristic appearance. The color of the spore is dark purple-brown, like the thickenings upon the cells of the capsule wall. It is probable that immediately adjacent to the spore cavity is a thin membrane (intine) of cellulose, but this was not specially investigated and did not show clearly in the sections that were examined. The nucleus of the spore is rather small but fairly conspicuous.

The elaters (Fig. 12, C, D and E) show a good deal of variation. They are sometimes very much attenuated, with the spiral bands almost obliterated at the ends, suggesting the elaters of *Makinoa*, where the spirals are present only in the mid-region of the elaters. More commonly, however, they taper more gradually and the double spiral extends to the end. Considerable difference in size may be noted (Fig. 12, E). While no basal elaterophore is present, occasionally some of the elaters at the base of the capsule seem to be attached at one end and suggest a rudiment of such an elaterophore, as is said to occur in the other species of *Calycularia*.

The surface markings of the spore in *Calycularia radiculosa* are strikingly different from those of *Pallavicinia* whether of the section *Mörkia* or *Blyttia*. In *Pallavicinia* (See Fig. 12, K, L) the surface markings have the form of a network of delicate ridges, such as also occur in *Fossombronia*. This marked difference in the character of the spores, together with certain other differences, might be considered to be an objection to uniting *Calycularia radiculosa* with the genus *Mörkia*.

The structure of the capsule wall of *Calycularia radiculosa*, according

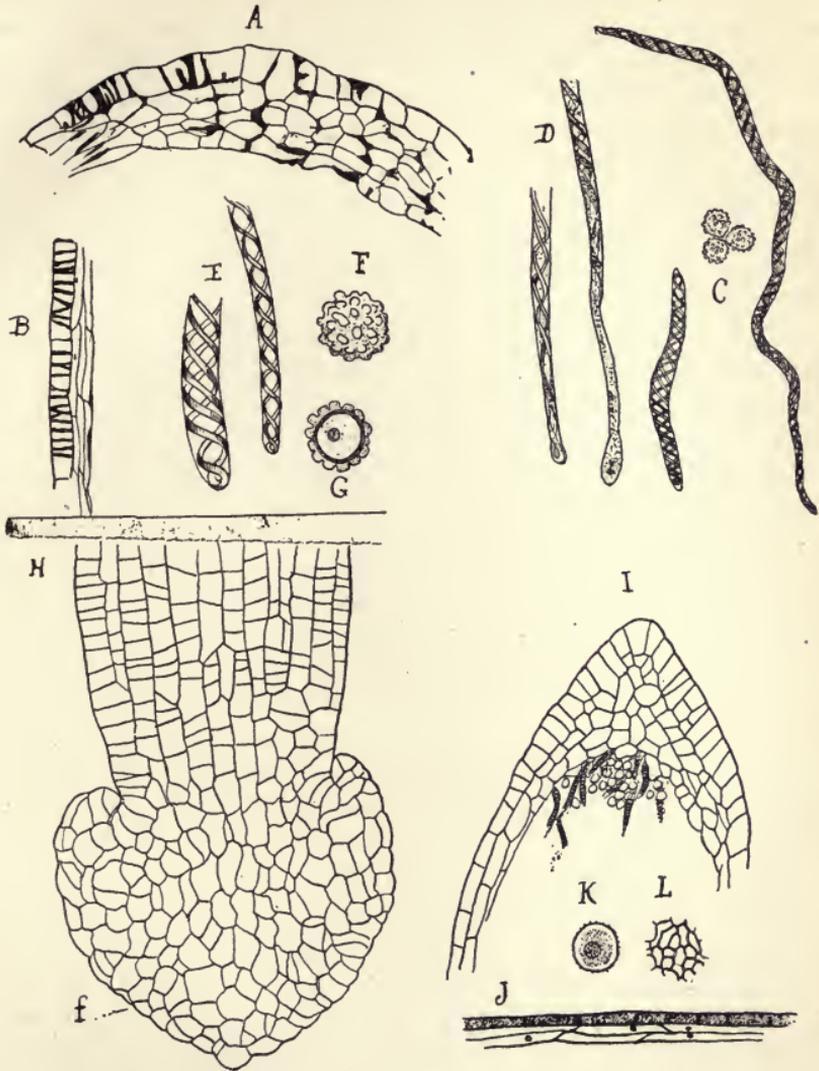


Fig. 12. *A*, apical region of the sporogonium of *Calycularia radiculosa*, showing the thickenings on the cell walls, $\times 90$. *B*, lateral wall of the same sporogonium. *C*, ripe spores and elaters, \times about 200. *D*, very much attenuated elaters, $\times 350$. *E*, typical elaters, $\times 350$. *F*, ripe spore, $\times 350$. *G*, section of spore. *H*, lower part of seta and foot, *f*, $\times 90$. *I*, apex of sporogonium of *Pallavicinia (Blyttia) radiculosa*, $\times 90$. *J*, lateral wall of the same, $\times 90$. *K*, section of ripe spore, $\times 350$. *L*, markings on the surface of spore, $\times 750$.

to Schiffner, is very different from that of the other species of *Calycularia*. He examined *C. crispula* and found that the capsule is much smaller than in *C. radiculosa*, and was perfectly round instead of being oval. The wall showed quite a different structure, being composed of two layers of cells with somewhat different markings from those found in *Calycularia radiculosa*.

In the ripe sporogonium in the latter species (See Fig. 12, A, B) the wall is much thicker at the apex, where there are five or six layers of cells which form a sort of apical cap, while at the sides there are usually about four layers of which the outer one is composed of much larger cells, the inner layers being made up of much compressed thin walled cells. The radial walls of the outermost layer of cells are marked by conspicuous thickened bands, which are sometimes more or less confluent, giving the cells much the appearance of reticulate tracheary tissue. The inner cells have slight thickenings, but these are very irregularly disposed, and are almost wanting upon the inner cells of the lateral walls of the sporogonium.

At maturity there may be recognized four valves of equal size, but usually these do not separate completely, but remain together in pairs, the capsule opening by two slits. (Fig. 1, D). There may be seen between these two slits, however, a delicate line marking the junction between the two coherent valves. Schiffner states that the valves never separate at the apex but are held together by the apical cap of cells. While this is no doubt often the case (See Fig. 2, D), it may happen that the two pairs of valves separate completely. (Fig. E). In its dehiscence, therefore, *Calycularia radiculosa* is more like *Blyttia* than it is like *Mörkia*. In the other species of *Calycularia* Schiffner states that the capsule at maturity breaks into several (5-6) irregular parts which may break up still further, thus resembling *Fossombronia*.

The seta finally becomes very long (Fig. 2, D) and its base is surrounded by the very conspicuous vase-shaped perianth, whose opening is deeply lobed and fringed. Material of *Mörkia* was not available for comparison of the structures of the sporogonium with that of *Calycularia radiculosa*, but sections of the sporogonium of *Pallavicinia (Blyttia) radiculosa* were made. In this species the capsule is extremely long, cylindrical and very little thicker than the seta. The foot is pointed and not clearly delimited from the seta.

The apex of the capsule is pointed and much more conspicuous than in *Calycularia* (Fig. 12, I). The capsule wall also differs in the character of the cells. There are about three layers of cells instead of four and the outer cells have the walls uniformly thickened instead of showing the thickened bands so conspicuous in *Calycularia radiculosa*. (Fig. 12, J.)

The spores are very different in their markings, as we have already noted, and this seems to be true also for *Mörkia*.

THE AFFINITIES OF CALYCVLARIA RADICULOSA.

Schiffner, from his study of *Calycularia radiculosa* concluded that it should be removed from its present association with *C. crispula*, *C. Birmensis* and *C. laxa* and united with *Mörkia*. While there seems to be reason to remove the species from the genus *Calycularia*, it may be questioned whether its association with *Mörkia* is justified. While Schiffner states that *Mörkia* is without conducting tissue in the mid-rib, Cavers has shown that in *M. Flo-towiana* there are two strands of conducting tissue, but in *Calycularia radiculosa* these are entirely wanting. Moreover, the structure of the sporogonium, *i. e.*, the character of the thickenings of the wall and the markings of the spores are quite different, and more like *Makinoa*, or some of the forms usually referred to the *Codoniaceæ*. It would probably be better to consider this plant as the type of a new genus intermediate in some respects between *Mörkia* and some of the less specialized forms like *Makinoa* or *Pellia*. It is hardly likely that the line between the *Codoniaceæ* and *Lep-tothceæ* (or *Blyttiaceæ*, as Cavers has called them) is very well defined, and it is probable that further study of the thallose *Jungermanniales* will result in decided changes in the accepted arrangement of the genera.

STUDIES OF IRRITABILITY IN PLANTS.

By GEORGE JAMES PEIRCE, Professor of Botany and Plant Physiology.

III.

THE FORMATIVE INFLUENCE OF LIGHT.

Introduction.

IN 1906¹ I published a paper, under the above title, recording the results of a series of experiments on the influence of the direction of illumination upon the shape of certain plants. The most striking result reported was that *Anthoceros* plants grown from the spore on a disc revolving in a horizontal plane, and therefore receiving fairly equal amounts of light on all sides successively, showed no trace of the usual dorsi-ventral form and structure of the thallus but were radial in structure, cylindrical or conical in form. *Anthoceros fusiformis*, Aust. and *A. Pearsoni*, M. A. Howe, both native here and growing within a short distance of this laboratory, gave the same results; but the spores of the Marchantiaceous liverwort *Fimbriaria (Asterella) Californica* and of the fern *Gymnogramme triangularis* did not, under the same conditions, give rise to plants round in section. To this extent their dorsi-ventrality failed to show itself—rhizoids grew equally in all directions from their thalli or prothalli, respectively—but the plants were thin plates, though curiously crumpled, as the figures showed. I did not understand this difference in result and have tried in various ways to ascertain the reason for it. I have not yet reached a satisfying explanation, but some of the results of these succeeding experiments are interesting enough to record now.

THE APPARATUS: A MULTIPLE CLINOSTAT.

The apparatus used in the experiments of Czapek², which suggested mine, consisted essentially of the expensive form of clinostat, the only one generally known and used in botanical laboratories. My experiments were carried on with cheap clocks, modified as described by Ganong³. Such apparatus is, however, unreliable. Indeed, cheap apparatus may be the most expensive. Although cheap apparatus may perhaps be well enough for an

¹ *Annals of Botany*, XX, 449-465, 1906.

² Czapek, F. *Weitere Beiträge zur Kenntniss der geotropischen Reizbewegungen*. *Jahrb. f. w. Bot.*, XXII, 261, 1898.

³ Ganong, W. F. *A laboratory course in Plant Physiology*, pp. 120-1, New York, 1901.

experiment lasting only a few minutes or at the most an hour or two, it ought not to be trusted longer. An experiment which lasts a week or even months increases in value as it lasts, if it had any value at the start; and the failure of the apparatus at the end of six months entails a loss much greater than more serious mechanical difficulty within a day or two of the beginning. The cost, unreliability and the wearisomeness of winding a suitable number of separate instruments drove me to consider other apparatus. And by devising new apparatus I tried to ascertain the dominating reason for the persistent dorsi-ventrality of the thalli of *Fimbriaria* and of the prothalli of *Gymnogramme*.

To Professor W. F. Durand, head of the Department of Mechanical Engineering, is due all the credit for structural details and for supervising the construction and the successive modifications of the apparatus in the Mechanician's Shop of this University. And I take this opportunity to express my most grateful appreciation of his skill in divining what I wanted and his untiring help and unflagging patience in securing it. As a detailed description of the apparatus would be more appropriate elsewhere, I may here content myself with a statement of its essential features.

The apparatus may be called a multiple clinostat. As my experiments involved the turning of cultures in a horizontal plane upon a vertical axis, the apparatus began with a set of twenty-five turn-tables on five shelves built into the embrasures of each of three windows, the turn-tables in each window revolving at different speeds, but all the turn-tables in one window turning at the same rate. The actuating mechanism consisted of a clock-work driven by a heavy weight and controlled by a fan governor. This actuating mechanism was connected by a series of belts and shafts with the batteries of turn-tables. Experience, however, has led to the gradual and final elimination of all belts. Chains and sprockets were first substituted for belts. Finally these were replaced by direct gears. This made possible the consolidation of the cultures into one window, there being five rows of ten turn-tables each on a set of shelves in the window nearest the clock-work and connected with it by a shaft with bevel gears. This shaft is horizontal and runs from the clock-work, bolted to a table, which is itself bolted to the floor, to a vertical shaft at one side of the window. At each shelf this vertical shaft carries a gear which engages a corresponding gear carried on the axle of the nearest turn-table. The margin of this turn-table, and of all the others in the row, is toothed, and the turn-tables are so set that the movement of one of them sets all the others into similar motion. All the turn-tables in a row move at the same rate, but the rate of each row is determined by the ratio of the gear on the vertical shaft to that of the first turn-table in the row. It is possible,

therefore, to revolve fifty or more cultures simultaneously, but at five different rates. The apparatus runs continuously, day and night, and requires to be wound only once in thirty hours.

After experience and reflection, I concluded that the only constant and uniform force at my disposal for driving my clock-work was gravity. This is represented by discs of cast iron and of lead, amounting to a weight of two hundred and fifty (250) pounds—approximately 113.4 Kilos—which is hung from a pulley running on a wire cable, the end of which is fastened to a beam in the ceiling of the room. The clock is wound by pulling up the weight nearly to the ceiling, the wire winding upon a drum revolved by a crank.

The material and methods of culture have undergone nearly as many changes since I began as the method of revolving the cultures. With the exception to be noted below, I still use small crystallizing dishes. These are about 7 cm. diameter and 3 cm. depth. I have had small square tiles of porous flower-pot clay especially made. These fit into the bottom of the dishes, and, as their upper surface is smooth, the least possible shadow is cast by one part upon another. These porous tile are first boiled in distilled water, to extract, as completely as may be, the soluble matter which they may contain. To this end I boil the tile in distilled water for hours, using three or four waters for this washing and leaching process. The tiles are then allowed to drain and dry. Meanwhile Knopp's Solution is made as follows:

SOLUTION A		SOLUTION B	
KNO ₃	2 grs	Ca (NO ₃) ₂	8 grs
MgSO ₄	2 "	Aq. dist.....	3000 cc
K ₂ HPO ₄	2 "		
Aq. dist.....	1000 cc		

To 1 part of A 3 parts of B are added and the mixture boiled for fifteen minutes in a cotton-plugged flask. The resulting precipitate is either filtered off or allowed to settle in the bottom of the flask. At all events, the clear liquid is poured into the culture dishes to about three-quarters the depth of the porous tiles. The dishes are covered with the lids or bottoms of Petri dishes of suitable size. They are now steam sterilized for an hour or more and are allowed to cool over night in the sterilizer. As it is necessary to prevent light from falling otherwise than from the side upon the plants to be cultivated, the lids of the dishes are given, after cooling, a smooth continuous coat of dull black "Japalac," an inexpensive and quickly drying varnish easily applied.

It may be wondered why I did not use Plaster of Paris poured into the crystallizing dishes and allowed to set in them as molds. These would have

furnished a fairly smooth substratum of convenient extent. Two considerations prevented, namely: the solubility of Plaster of Paris, and its color. The latter could have been modified by lamp-black or any other insoluble pigment, but the constant presence of an undue amount of calcium sulphate in the water which the plants were to absorb seemed to me unnecessary and possibly confusing. Flower-pot tile is certainly more nearly like soil in color and composition than is Plaster of Paris, more convenient to handle, and readily enough obtained in any desired size, if a reasonable number of tiles be ordered at any one time.

The spores are sowed as uniformly as possible on the now damp tile, which is standing in sterilized Knopp's Solution in the dishes. The spores are sowed from stiff smooth writing paper by tapping the paper with a pencil or paper knife in such a way as to discharge a fairly even shower of spores upon the tiles. The culture dishes are then marked and put in place on the turn-tables, and on the shelf beside them as controls, respectively.

The speed of the turn-tables is a matter of considerable importance. The greater the speed, the greater the amount of power required. In no case, however, have I used a speed at which the centrifugal force, even at the edge of a culture, could have had any part in the result; and at the center of revolution, which is also the point of most nearly equal illumination, there would be no centrifugal force. The speeds which I have so far used, in addition to those previously reported⁴, are the following:

10	turn-tables	making	four	revolutions	a	minute.
20	"	"	two	"	"	"
10	"	"	one	"	"	"

I have also arranged to have a fifth row of ten turn-tables, so geared as to make a complete revolution in *two* minutes. I may add that, although I have so far used the turn-tables only on vertical axes, I have, nevertheless, had the shelves so attached to the frame of the shelving in the window that they may be set at any desired angle between the vertical and the horizontal. The positions and structures of the gears of the vertical distributing shafts and of the first turn-tables in each row must be and may be modified accordingly. Obviously, if the turn-tables are to be used in a position in which their axes would point obliquely downward, it would be necessary to use cups, into which the axes could be locked; but for my experiments so far, no modification of the cups has been necessary. The cups carrying the axes of the turn-tables are cast steel with a steel ball of suitable size in the bottom of

⁴ Annals of Botany, XX, 1906.

each cup, and screwed to the shelves. So long as the diameter of the bore of the cups remains uniform and the wear of the axis corresponds, the motion of the turn-tables should be uniform. The turn-tables themselves are made of a light alloy, Alzine, which sometimes appears to be too brittle; but if not, teeth of great uniformity may be cut in the edges of the turn-tables. When the regular teeth of adjacent turn-tables are so set that they do not bind or allow too much play, with the inevitable contraction and expansion of the shelves and frame in the changing temperatures and humidities of a laboratory, the clock-work drives them with great regularity. Indeed, next to the very desirable feature of carrying many cultures at once on this multiple clinostat, the regularity of revolution is its most valuable feature.

It may not be necessary to add that the multiple clinostat now in my laboratory, and thus briefly described, is the product of the experiments, failures and successes, of the last six years. Each improvement has been the fruit of failure. Some of these failures have been very disheartening, for one does not like to lose or to vitiate the accumulated result of six or eight months of work by the clock-work or any set of turn-tables coming to a stand-still for an hour.

EXPERIMENTAL WORK.

Only one or two of the questions suggested by my previous work and left unanswered in that paper will be considered in this. The plants which I have experimented upon have been the prothalli of *Pteris aquilina* and *Gymnogramme triangularis*, grown from the spore on tile; plants of *Porella Bolanderi*, a foliose liverwort which I brought into the laboratory from rocks and tree-trunks near by and cultivated on the tile in crystallizing dishes; plants of *Fimbriaria (Asterella) Californica*, also grown from the spore; *Anthoceros fusiformis*, grown from the spore and used simply as a check, for the results on turn-table and shelf were the same as previously reported; and plants of white mustard and of wheat, raised in two-inch flower pots in good soil from the seed. The results are in the main similar, and I shall discuss them all together after separately describing the experiments on the different sorts of plants.

Porella Bolanderi (Aust.) Pearson.

On November 14, 1907, I collected plants of *Porella Bolanderi* growing on rocks and tree-trunks about a half mile from this University. The plants were dry and dormant. I sorted these, after moistening with sterilized water, and selecting clean branches about a centimeter long, placed these upon

sterilized tiles in crystallizing dishes, containing sterilized Knopp's Solution of 0.35% concentration and covered with blackened lids. These dishes I set on the turn-tables and on the shelf beside the turn-tables. I took all possible pains to select branches clean and healthy-looking, but as no sterilization of the material was possible, it was inevitable that a certain amount of moulding should take place. All of the cultures succumbed to infections sooner or later, but enough of them grew well to justify a record of the experiment, although I do not by any means regard it as concluded.

The general characteristics of this plant are well known. Detailed descriptions may be found in Campbell's "Mosses and Ferns"⁵ and elsewhere. For our purpose it is sufficient to say that the plant is dorsiventral to the extent of having two sets of leaves: foliage leaves, which are green and closely arranged, forming the upper side of the plant, and the so-called amphigastria, leaves or scales not green, and overlapping along the under side of the stem. The plant grows more or less closely appressed to the sub-stratum, whether this is vertical, oblique, or horizontal; that is, the plant grows at right angles to the direction from which most of the light comes. If, therefore, the plant be put on a horizontal surface and the light be made to fall more or less horizontally upon it, the plant or its leaves should so turn that its foliage leaves would stand mainly at right angles to the incident rays, and the amphigastria should be on the side away from the light. This happens with the plants growing on the shelf, receiving light always in one and the same direction, just as it would happen in the case of a *Porella* plant growing from a horizontal to a more or less vertical sub-stratum out of doors. The case of the plants on the turn-tables, on the other hand, is quite different, for they have no darker side. The position of all the leaves and of the amphigastria on the older parts of these plants changes; they flare more from the stem. On the younger, as well as on the older parts, the amphigastria become less scale-like and grow more and more leaf-like. I have no doubt that this experiment, continued with greater freedom from infections than I secured in 1907, would yield results entirely similar to those of Němec⁶, but I have not yet been able to repeat it and carry it through. I would suggest here only that experiment seems likely to confirm the opinion of morphologists that amphigastria are modified leaves, and to show that they develop as they do partly because they are on the shaded parts of these plants.

⁵ Campbell, D. H. The Structure and Development of Mosses and Ferns. 2d Edition, New York, 1905.

⁶ Němec, B. Die Induktion der Dorsiventralität bei einigen Moosen. Bull. int. de l'Acad. Sci. de Bohême, 1904, 1906.

Fimbriaria (Asterella) Californica, Hampe.

Spores of this plant were collected at the beginning of the dry season, late in April or in May, according to the time of ripening, from plants growing on a sandy-loam bank, not far from the laboratory. The spores were kept in envelopes and pasteboard boxes in a case in the laboratory and were, therefore, air-dry and well ventilated. As the humidity of the air runs low during the summer dormant period, both in the laboratory and out of doors, the spores were necessarily inactive for months. With greater humidity or—what would produce this—inferior ventilation, their respiratory activities⁷ would be greater and there would be danger that their germinating and other powers might be impaired. For this reason I avoid keeping spores or seeds which are to be used for germination in tightly-closed jars or bottles. If it be necessary to protect them against mice, I use tins, the lids of which close them loosely enough to permit more or less circulation of air. In this way spore and seed deterioration is delayed and normal dormancy is maintained.

The spores were sowed, as above described, on sterilized tile in black-covered crystallizing dishes, on October 11, 1911. Of these, five were put on turn-tables making two complete revolutions per minute, and three were set on the shelf beside them. The crystallizing dishes standing on the shelf were marked on the side away from the window, so that one might always know the original exposure and the more easily maintain it.

As previously shown⁸, the direction of the plane of division in the germinating spores, and of growth in the germ-tube, is determined by the direction from which the light falls upon the spores. On the clocks, therefore, the spores germinate in every direction, and the plantlets are *erect from the start*. Germination actually begins almost at once, no doubt, but the evidences of it are plainly visible within ten days after sowing the spores. In the shelf cultures the plantlets are prostrate, growing toward the light as single chains of chlorophyll-containing cells. In these latter cultures, as in nature, the light falls upon the plantlets mainly from one direction, and the plantlets react accordingly. After the plantlet has become a single chain of several cells, the end cell repeatedly divides in such planes as to change the plantlet to a conical shape. These little cones, with their apices pointing away from the light and obliquely downward, grow both in length and in diameter fairly symmetrical for a few weeks. After a time, however, they

⁷ Babcock, S. B. Metabolic water; its production and role in vital phenomena. Research Bull. 22, Univ. Wis. Agric. Exp. Sta., March, 1912.

⁸ Peirce, G. J. Annals of Botany, XX, p. 453+, 1906.

cease to be symmetrical, the side of the cone *away* from the light growing out in a form more or less shelf-like. This is the beginning of the thallus of the more or less mature form.

In cultures I have never carried the plants beyond this beginning—six months or thereabouts after sowing the spores—for although plants of the same species normally survive the summer out of doors⁹, they do not withstand the much more complete drying in a culture dish, or, if an attempt is made to keep them moist over summer, they succumb to fungus enemies. I do not know what would happen if the cultures were kept continuously on the shelves and on the revolving turn-tables, for it has never been possible for me to stay in my laboratory throughout the long summer vacation, and I have so far been unable to arrange to have my clock-work regularly wound, *i. e.*, daily throughout my absences. It is usually easier, in a laboratory as well as elsewhere, to provide apparatus than to secure assistants. Hence, at the end of the college year, in May, I am obliged to take my cultures from their places on shelf and turn-table and set them away in a dark cupboard. They remain there till September. During these months they have succumbed to mould or drought. Some day, however, I shall be able to carry them along continuously from the spore to the production of spores again.

Turning now once more to the plantlets subjected, on the turn-tables, to light from all directions successively, we find that they maintain the erect position which they assume immediately on germination. They thicken at the ends away from the spores, and, since they are revolved in a horizontal plane and receive light mainly horizontally, they become vertical. I do not think the force of gravity, or the presence of water below them, or any other influence than light has much to do with the erect position of these plantlets. They become erect cones standing on their apices, and, uniformly on all sides, they develop rhizoids, which attach them to the tiles. The little plants are thus stayed and kept from toppling over. They keep pace in their growth with the plants receiving light from one side only, on the shelf, and after a time exceed them considerably in size. On account of the difficulties previously enumerated, however, I have never been able to carry these plants through the summer or continue the experiment for more than seven months. Though the plants on the shelf are at first and for some weeks radial in structure, they sooner or later go over to the dorsi-ventral form under the influence of light falling upon them from one direction only. This form they maintain throughout all but the very early stages of their existence. The plants revolving on the turn-tables, on the other hand, remain radial in

⁹ Campbell, D. H. Resistance of drought by liverworts. *Torreya*, IV, 1904.

structure, conical in form, for a much longer time, and in so doing resemble *Anthoceros*¹⁰. For the reasons given above I cannot say that they would always maintain this radial structure, though experience with these plants and with *Anthoceros* leads me to believe that dorsi-ventrality, in these two genera at least, is not alone inherited, but that it is a product of circumstances as well as of substance, the continuity of substance and the continuity of influence (direction of illumination) from generation to generation insuring the repetition of this quality in successive generations.

It may be suggested that the dorsi-ventrality does not develop in the plants revolving on the turn-tables, not because it is not inherited, but because it is prevented from appearing because one of the conditions for its developing is lacking. I do not care to contribute to a revival of the profitless discussion, wisely dropped, involving a conceivable if unnecessary distinction between condition (Bedingung) and stimulus (Reiz), for, as will more plainly appear in the next section (pp. 70-74), the influence of the direction of illumination is active rather than passive. When one compares, at the end of an experiment which has lasted for months, the sizes of the plants on the turn-tables with those on the shelf, one realizes the greater size of those more uniformly illuminated, symmetry and size going together.

The result of growing *Fimbriaria Californica* from the spore under conditions of equal and of unequal illumination from all directions successively, is the same, so far as the experiments could be continued, as with the two species of *Anthoceros* previously reported upon, but the longer life-cycle of *Fimbriaria* makes it necessary to continue the experiment for a longer time than has so far been possible, in order to reach a definitive result and to justify a final conclusion. *Fimbriaria* grown from the spore does not fruit, at least in my cultures, within the time limits of one natural growing season—that is, between the first rains, say early in November, and the beginning of the dry season, in May. On the other hand, *Anthoceros* does, but its spores are not equally fertile in successive seasons, and since the wonderful crop of 1905 I have been unable to secure spores of such vigor that I cared to continue experimenting upon the plantlets beyond confirming previous results. Nor is it necessary, as the results reported in the next section will show.

- *Pteris aquilina* and *Gymnogramme triangularis*.

Spores of *Pteris* collected in southern California in June, and of *Gymnogramme* collected near the laboratory in September, were sowed on October 11, 1911, under the conditions previously described. Six of the cultures of *Pteris* were set on turn-tables revolving four times a minute, two on the shelf

¹⁰ Peirce. Ann. Bot., 1906.

by them. A second sowing in other dishes was made on November 13, 1911. About the same number of cultures of *Gymnogramme* were started on October 11 and November 13. The results were similar to those obtained with *Pteris* but less striking, because of the smaller size of the prothalli. Furthermore, the *Pteris* material was so much freer from contaminating blue-green algæ that the cultures were correspondingly more satisfactory. Since sterilizing the spores is impossible, it is not usually possible to make a pure culture of fern prothalli directly from the spore.

The spores of both ferns germinated well, behaving during the earlier stages on the turn-tables and on the shelf as before described¹¹. In the experiments previously reported, the spores of *Gymnogramme* germinating on turn-tables developed into thin prothalli, crumpled or waved instead of flat, heart-shaped instead of conical or cylindrical, but with rhizoids, antheridia and archegonia in equal numbers on both sides, and with the prothalli standing erect, but at all possible angles on the tiles. In the shelf cultures, on the other hand, the prothalli were normal in shape and almost linearly placed, in ranks surprisingly regular, at right angles to the incoming light from the window. These results I thought might be due to the slow revolution of my turn-tables and I hoped by using quicker ones I might obtain cylindrical or conical prothalli. I have not yet. Why, I do not know. It may be that the turn-tables, revolving four times a minute instead of once in fifteen as before, are still too slow, or it may be that continuous as well as uniform illumination is necessary.

The results of five months' growth on turn-tables are shown in Figures 1 and 2. Figures 3 and 4 show shelf cultures. These two sets of photographs of *Pteris* cultures sowed on October 11, 1911, were kindly taken for me by Mr. James McMurphy, Instructor in Botany in this University. The culture dishes were uncovered and placed on the horizontal stand of a vertically working camera, so focused as to give a picture double natural size.* The magnification was the same for all five photographs. This was made possible by the uniform thickness of the tiles and of the glass of the dishes. The four figures are, therefore, perfectly comparable.

Figure 1 shows, within the circular line which indicates the bottom of the crystallizing dish, and upon a square porous tile, the corners of which have been knocked off to fit the glass dish, a large number of fern prothalli of two very different sizes. These prothalli are erect or nearly so. Those nearest the center of the tile (the center of revolution) are most nearly erect and most plainly show the copious growth of rhizoids on both sides. The

¹¹ Annals of Botany, XX, p. 454+, 1906.

* Reduced to natural size in the figures.

larger prothalli bear archegonia, the smaller prothalli are antheridial. Toward the upper right hand corner is a young sporophyte, showing that conditions in the culture were sufficiently favorable to permit fertilization and subsequent development. Microscopic examination shows that the reproductive organs are borne on both sides of the prothallus, as uniformly as the rhizoids. The prothallus has the usual cushion, which bears the rhizoids, archegonia and antheridia.

Near the lower edge of the figure is a large archegonial prothallus, irregular in outline but plainly dorsi-ventral in structure. This has rhizoids only on the side toward the middle of the tile. Comparing this prothallus with the two nearest the center of the culture, one sees that the more uniform illumination of the plants in the middle is accompanied by a more uniform growth of rhizoids. The distance between the prothallus at the edge and those in the middle of the tile is about 2 centimeters, but this slight difference in position is accompanied by enough difference in illumination to permit the plantlet near the edge to complete its usual dorsi-ventral development, while the plants at the center form rhizoids and reproductive organs equally on both sides.

From this one may infer either that the fern prothallus is very sensitive to light, since slight differences in illumination cause such evident differences in behavior, or that it is only slightly sensitive, since exactly uniform illumination is necessary to overcome the usual dorsi-ventrality in any degree. Whether the plant is sensitive or not sensitive can be proved only by experiment. One of these experiments would involve constant illumination, and this I hope to try shortly.

In Figure 2 the number is larger, the distribution more regular, and the results striking.

Figure 3 is that of a shelf culture, the direction of illumination of which is indicated by the arrow. The size, position, form and appendages of the largest archegonial prothalli are quite as usual and normal. Rhizoids and archegonia develop only on the side away from the light, the prothalli are erect in response to the nearly horizontal plane along which the light is received, but they are nearly flat and extend at right angles to the light and they are of the usual size. The much (and normally) smaller antheridial prothalli correspond in all these respects with the much more striking archegonial.

I do not know what may be said to be the normal ratio between archegonial and antheridial prothalli in *Pteris*, and I think most botanists would doubt there being any "normal" apart from the conditions or circumstances in nature or in an experimental culture, but the ratio of archegonial prothalli to antheridial in the two turn-table cultures figured is certainly larger than

in the shelf culture shown in Figure 3. Figure 4 shows another shelf culture, but this was robbed from time to time of some of its prothalli, both archeogonial and antheridial, for purposes of examination. Pains were taken, however, to remove such numbers of male and female prothalli as to maintain the ratio. We see that this ratio is quite different in the shelf and in the turn-table cultures, there being a larger proportion of female prothalli in the turn-table cultures.

Measurements of typical archeogonial prothalli from turn-table and shelf cultures were very kindly made for me by a student in my laboratory, Miss Viola F. Nichols, whom I wish to thank for her help. The data follow:

PTERIS sowed X, 11, '11. measured IV, 15, '12.	SHELF	TURN-TABLE
	8 x 4 mm.	10 x 5 mm.
	6 x 4	11 x 5
	5 x 3.5	9 x 5
	5 x 3	10 x 4
	2.5 x 1	10 x 5
	4 x 2.5	8 x 4
	4 x 3	8 x 4.5
average'	4.85 x 2.85 mm.	9.42 x 4.64 mm.
measured IV, 15, '12.	5 x 3	10 x 6
		10 x 4
		10 x 4
		9 x 4
		8 x 4
		7 x 4
average	5 x 3 mm.	9.00 x 4.33 mm.
mean of 2 averages	4.91 x 2.91	9.21 x 4.48
" area	14.28 sq. mm.	41.26 sq. mm.
ratio of areas	1	to 2.8

The difference in size, so apparent to the eye, is thus confirmed by measurements. Accompanying this difference in size is a more than corresponding difference in the number of archeogonia and antheridia on the turn-table prothalli as compared with those in the shelf cultures. This ratio is nearer four or five to one. For this figure I am also indebted to Miss Nichols, but my own observations correspond.

These figures, together with an inspection of the photographs, furnish the evidence of differences between *Pteris* prothalli grown on turn-tables in approximately uniform illumination on all sides successively, and others grown on the shelf with the light always from one side. These differences are of three main sorts: *1st*, in size of the vegetative parts, the prothalli; *2nd*, the numbers of reproductive organs; *3rd*, the proportions of male and

female prothalli. These are very surprising, but what I have recorded above for *Pteris aquilina* sowed X, 11, 1911, is equally true of those started on XI, 13, 1911, allowing for the slight and decreasing differences due to age, and of both sets of cultures of *Gymnogramme triangularis*. How can one account for these differences? The cultures were sowed all together, the culture solution, the tiles and the dishes had all been treated exactly alike and together; no selections were made at any time. Some of the cultures were put on the turn-tables at once after sowing and the remainder were placed on the shelf by them. They were thereupon marked. Almost from the moment when the dry spores touched the moist tile they began, either to remain still, or to turn, with the tile on which they had fallen. And so they remained night and day, the diffused sunlight from the window falling through a white Holland shade nearly horizontally upon them by day, darkness enveloping them at night (for I very seldom use artificial light in the room where the multiple clinostat is), turning night and day or staying motionless, according to their position; watered from time to time with fresh Knopp's solution when necessary, equally warmed and similarly treated in every respect, so far as I can see, except that in one respect they are not similarly lighted. The light is the same in composition, intensity and duration, not in direction. This difference alone is accompanied by the differences in the vegetative and the reproductive parts above described.

It may be easier to gain some insight into this problem, into the reasons or causes of these differences, if we consider the vegetative and the reproductive parts separately. Acting on this principle, I proceeded to experiment upon young flowering plants grown from the seed.

SEEDLINGS OF MUSTARD AND OF WHEAT.

Seedlings of white mustard (*Sinapis alba*) and of wheat were sowed on sterilized greenhouse soil in 2-inch porous flower pots. I selected these plants because of the promptness with which they germinate and the vigor with which they grow, for a time at least, under laboratory conditions, and because the early growth of the one (mustard) is mainly hypocotyledonary and at the expense of food made by the seedling as well as drawn from the seed, whereas the growth of the other (wheat) is mainly epicotyledonary and the seedling, though well fed, is not self-nourishing for some time. Recalling the well known phototropism of these two seedlings, I thought that by exposing the two sets, one on the shelf and one on the turn-tables, to the same light, I could ascertain whether there were any greater stimulus to growth for the one set of plants or the other, whether if an adjustment as to position between light and darkness—that is, between more and less light—cannot be attained, growth will be more rapid than where a plant is able to attain a

position of such adjustment. A geranium, for example, growing on a window sill, turns toward the light. If, after it has accomplished a bend toward the window, it be turned around, it will reverse the bend or make a new one, again carrying the tip over toward the light. And this process may be repeated indefinitely, with the same result so long as the plant can grow. Such a plant is likely to become longer in the same length of time than one beside it which has not been changed in position. If this is the effect on stems, the position of which is reversed only at long intervals—say every other day or two—would this also be the case if the intervals were short? The result of an experiment on mustard will throw some light on this question.

Seeds of *Sinapis alba* were sowed on II, 22, 1912, on greenhouse soil in 2-inch flower pots, six of which were put on turn-tables making four revolutions a minute, seven on turn-tables making two revolutions each minute, and seven on the shelf, and therefore getting light mainly from one side. These were allowed to grow until the first leaves in the plumule began to show and were thereupon measured, that is, on III, 12, 1912, nineteen days after sowing. The length taken for measurement was that from the surface of the soil to the tip of the plant. The data follow:

Average length of 29 seedlings in Pot I on $\frac{1}{4}$ -minute turn-table.				4.08 cm.
16	"	"	II	3.88
13	"	"	III	4.13
9	"	"	IV	4.53
29	"	"	V	4.96
5	"	"	VI	4.38
<hr/>				
"	"	101	"	4.32 "

Average length of 24 seedlings in Pot I on $\frac{1}{2}$ -minute turn-table.				3.90 cm.
24	"	"	II	4.25
19	"	"	III	3.92
10	"	"	IV	3.20
25	"	"	V	4.78
23	"	"	VI	4.01
6	"	"	VII	4.09
<hr/>				
"	"	131	"	4.02 "

Average length of 6 seedlings in Pot I on the shelf.				4.27 cm.
15	"	"	II	4.80
20	"	"	III	3.80
12	"	"	IV	3.99
15	"	"	V	4.89
19	"	"	VI	4.33
14	"	"	VII	3.91
<hr/>				
"	"	101	"	4.28 "

From these three averages of the lengths of mustard seedlings—4.32 cm., 4.02 cm. and 4.28 cm.—it is clear that, so far as the growth of the hypocotyledonary stem is concerned, it makes no material difference whether the plant is illuminated mainly from one side or on all sides successively. So far as I could see, the seedlings all presented a normal appearance, both in stems and cotyledons, as to size, color and form.

This experiment having failed to throw any light on the question, I sowed wheat similarly on III, 15, 1912, and put five pots on the quarter-minute turn-tables, five pots on the half-minute turn-tables and five on the shelf beside them. Four weeks after sowing I measured them, from the surface of the soil to the tip of the unopened leaf, with the following results:

Average length of 10 seedlings in Pot I on $\frac{1}{4}$ -minute turn-table. 13.2 cm.

7	"	"	II	11.6
7	"	"	III	15.2
3	"	"	IV	16.2
7	"	"	V	17.3

" " 34 " 14.7 "

Average length of 9 seedlings in Pot I on $\frac{1}{2}$ -minute turn-table. 17.1 cm.

10	"	"	II	16.3
12	"	"	III	9.6
11	"	"	IV	12.9
4	"	"	V	14.0

" " 46 " 13.98 "

Average length of 6 seedlings in Pot I on the shelf. 9.68 cm.

9	"	"	II	18.63
10	"	"	III	13.45
6	"	"	IV	12.7
10	"	"	V	15.3

" " 41 " 13.95 "

This experiment also, so far as the growth of the stem is concerned, throws no light on our question, for there is no material difference in these averages, of 14.7 cm., 13.98 cm. and 13.95 cm. There was, however, a difference in the length of the leaves, which unfortunately I did not realize in time to measure. But the leaves of the seedlings on the turn-tables were in many instances as long again as those of seedlings on the shelf. Here, then, we do have a resemblance to the behavior of the fern-prothallus and the liverworts. In both instances we have chlorophyll-containing photosyntheti-

cally food-manufacturing organs, dependent for their efficiency upon the amounts of light and of carbon dioxide which can penetrate to the deeper as well as more superficial cells. I cannot see that the revolution of a culture in a covered crystallizing dish at no greater speed than four times a minute could promote diffusion or otherwise increase the supply of carbon dioxide sufficiently to account for the larger size of the prothalli and of the liverworts on the turn-tables, as compared with those motionless on the shelf. The supply of carbon dioxide to the leaves of wheat seedlings revolving on turn-tables may be greater than for the plants stationary on the shelf. But the supply of light is certainly increased in the same way that the supply of heat is increased for the man who first turns his face and afterwards his back to a fire until he is comfortably warmed.

DISCUSSION AND SUMMARY.

1. An analysis of the influence of light upon growth in plants shows that it affects the direction, kind, rate and amount of growth¹². Phototropic bending of plants and plant-organs is of common and long-established knowledge. That the kind of growth is influenced by light has been shown mainly by the earlier ecologists, such as Stahl¹³, and by the experimental morphologists and physiologists like Goebel¹⁴, Klebs¹⁵, and Vöchting¹⁶. It has long been supposed that the rate of growth, and also the amount, are greatly influenced by light, that, as Sachs¹⁷ would have it, light depresses the rate of growth, other things being equal. Common experience shows that plants grown in darkness or in insufficient light are long, slender, spindling, or at least "drawn," as compared with plants growing for the same length of time, and under otherwise identical conditions, in the light. But that the cause of this difference can be expressed in the usual

¹² Peirce, G. J. Text book of Plant Physiology, p. 210. 1903.

¹³ Stahl, F. Ueber den Einfluss des sonnigen oder schattigen Standortes auf die Ausbildung der Laubblätter. Zeitschr. f. Naturwissenschaft, XVI. Review in Botanische Zeitung, 41, 1883.

¹⁴ Goebel, K. Einleitung in die experimentelle Morphologie der Pflanzen. 1908. And the literature there cited.

¹⁵ Klebs, G. Willkürliche Entwicklungsänderungen bei Pflanzen. 1903. And the literature there cited.

¹⁶ Vöchting, H. Ueber den Einfluss des Lichtes auf die Gestaltung und Anlage der Blüten. Jahrb. f. wiss. Bot. XXV. 1893.

¹⁷ Sachs, J. Lectures on the Physiology of Plants. Oxford, 1887. Etc.

simple terms I believe the experiments which are described in the preceding pages show is not the case. Light does not always check growth, other things being equal. Instead, it promotes it, also, other things being equal.

When plants are grown in darkness, their leaves are small and may even be misshapen; it is their stems which are long, and they lack thickness. The organs devoted to food manufacture require light for their normal development. This, too, has long been known and it has been explained on the supposition that use (activity) and food are necessary for the development of leaves and their tissues. Given a certain amount of light, growth (and development) should take place at a certain rate and to a certain amount, other things being equal. By a certain amount of light is meant that quantity which the plant or organ can use or which so penetrates its living cells as to affect them. We conceive that, under usual conditions, a plant and its organs grow in direction, rate and amount into such positions as afford what may be called the optimum, all its activities contributing to this resultant. If this be true, the position and size of a plant represent the influence of circumstances upon its substance. By modifying the circumstances in any way, we may also influence the resultant. Without increasing the quantity of light available or changing the quality, and without, so far as I can see, affecting the supply of carbon dioxide and of other food materials, the plants used in the experiments here described exhibit remarkable differences according to their different exposures to light. The usual position occupied in the light by chlorophyll-containing organs is that which presents the greatest possible contrast between the amounts of light available on the two sides of these organs. The positions of ordinary leaves show this, and I am not sure that even such vertical and two-faced leaves as those of *Eucalyptus* do not also show this more or less. But in darkness and on turn-table there is no such position of contrast. There is no contrast. In darkness—that is, under conditions free from the alleged depressing influence of light upon growth—growth does not take place to the usual extent in chlorophyll-containing organs, even when food is supplied in adequate quantities and in suitable form. Under these conditions growth should be greater. But one may attribute this lesser growth to lack of use of the chlorophyll apparatus. This hypothesis may usually be correct without necessarily being complete. For light may conceivably stimulate, apart from its effect on food manufacture and the apparatus concerned. The manufacture of food depends upon many factors, of which sufficient water, light, carbon dioxide and chlorophyll are the most

obvious. The available amounts of these decrease in the order named, the supply of chlorophyll pigments being always very small but also very effective. The supply of carbon dioxide, because of its great dilution, rarely reaches the optimum proportion, whereas the amounts of chlorophyll, light and water, in proportion to carbon dioxide, often exceed it. Increasing the supply of light beyond the usual amount without a corresponding increase in the supply of carbon dioxide does not necessarily increase the products of photosynthesis. But the foregoing experiments show that increased exposure of chlorophyll-containing organs of liverworts, ferns and one grass to the usual quantity of light results in increased growth. This increased growth necessarily implies increased use of food, perhaps there may also be increased food manufacture, but I do not yet know this to be the case. From this, one is forced, so far as I can see, to conclude that light, up to a certain intensity at least, stimulates growth rather than depresses it.

2. We have seen, also, that a more uniform illumination increases symmetry in development. In certain instances this symmetry appears to be complete, a dorsi-ventral giving place to radial structure, the stimulating effect of light showing itself, not merely in change (increase) in size, but also in change in form.

3. The foregoing experiments on the ferns, *Pteris aquilina* and *Gymnogramme triangularis*, show that, although the archegonia and antheridia ordinarily form on the shaded side of the prothallus, they form on both sides when the illumination is equal, and in greater numbers on the two sides than is usual on either. Increased illumination is followed and accompanied by increased numbers of the organs of sexual reproduction, the fertility of which is evident from the development of sporophytes whenever there is sufficient water for the sperms to swim. I am not aware that such experiments have been made on ferns, but the experiments of Klebs¹⁸, Vöchting¹⁹ and their followers on algæ, fungi and the flowering plants, demonstrate the intimate connection between illumination and the development of reproductive organs, light being for many plants the indispensable stimulus thereto. The behavior of ferns is, therefore, consistent with the behavior of the other plants already experimentally investigated.

¹⁸ Klebs, G. Die Bedingungen der Fortpflanzung bei einigen Algen und Pilzen. Jena. 1896.

¹⁹ Vöchting, H. Ueber den Einfluss des Lichtes auf die Gestaltung und Anlage der Blüten. Jahrb. f. wiss. Bott. XXV. 1893.

4. As to the possible influence of light on the ratio of male and female prothalli, I wish merely to record the observation that, in my cultures, illumination, increased by revolving the prothalli, seemed to be followed by an increased proportion of female prothalli. I do not care at this time to discuss this observation or to hazard an opinion as to the extent of this possible effect of light on plants.

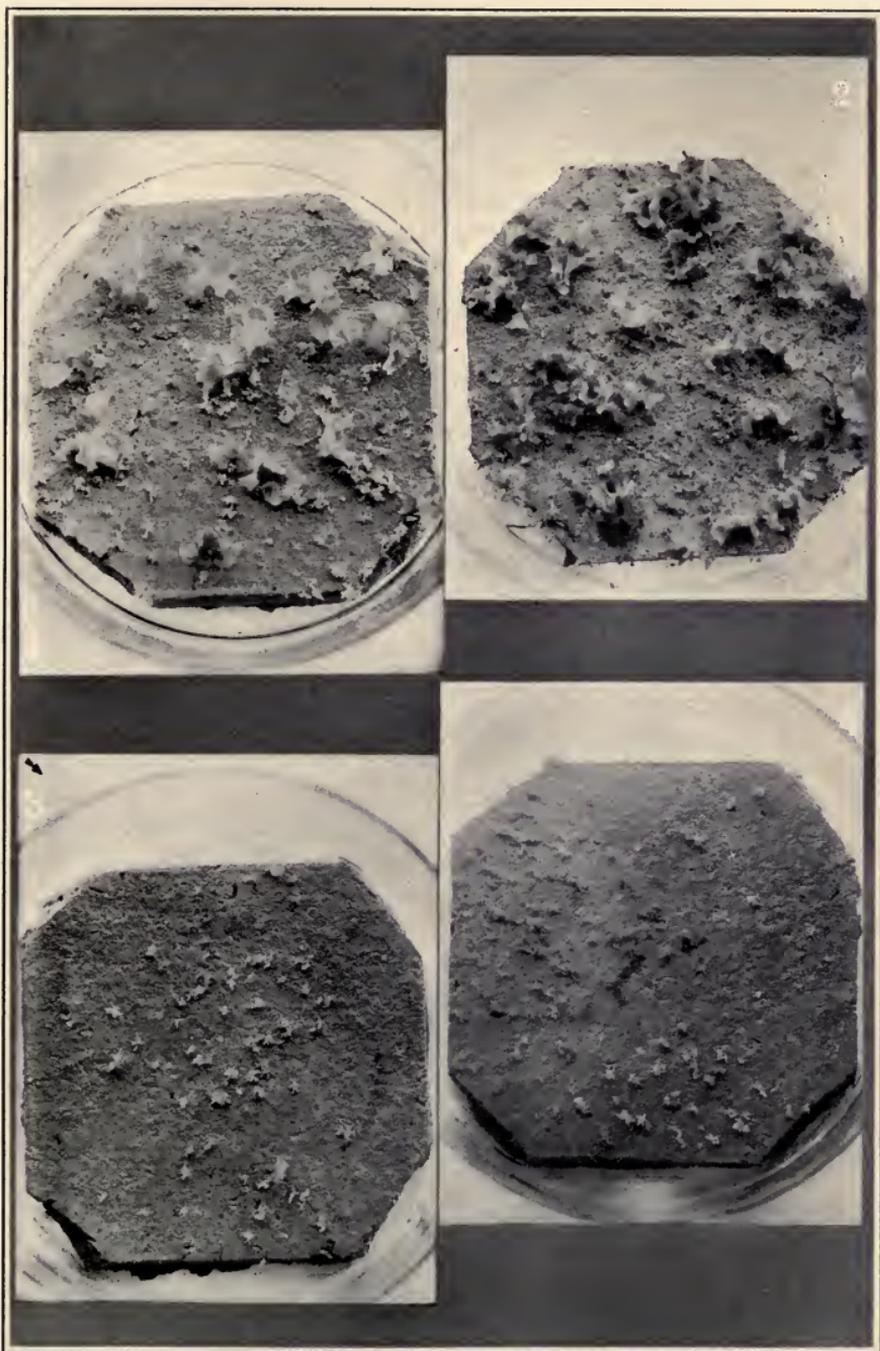


Fig. 1. Fern prothalli five months old, grown from spores on a turn-table revolving four times a minute.

Fig. 3. Fern prothalli of same age, from same lot of spores, receiving light from one side only.

Fig. 2. Fern prothalli five months old, grown from spores on a turn-table revolving four times a minute.

Fig. 4. Fern prothalli of same age, from same lot of spores, receiving light from one side only.

THE GYMNOSPERMS GROWING ON THE GROUNDS OF LELAND STANFORD JR. UNIVERSITY.

LEROY ABRAMS, Associate Professor of Botany.

THE GYMNOSPERMS are biologically more primitive than the Angiosperms. The flowers are always unisexual and without perianth (except *Gnetales*). The staminate flowers resemble those of the club-mosses and are short or elongated shoots bearing a number of spiral or verticillate stamens. The ovulate flowers are of a more varied structure, but the ovules are not enclosed in an ovary as in the Angiosperms.

The Gymnosperms comprise only trees and shrubs, and are represented by four living and two extinct orders. Representatives of two of the orders, *Ginkgoales* and *Coniferæ*, are cultivated on the University grounds.*

GINKGOALES.

A single species, *Ginkgo biloba*, is the sole survivor of this ancient order of Gymnosperms.

1. *Ginkgo biloba* L. Ginkgo or Maidenhair Tree.

Leaves deciduous, clustered on short stubby twigs, fan-shaped, thickened on the margin and usually divided, parallel-veined; flowers diœcious; staminate in slender aments; ovulate in pairs on long stalks; fruit drupe-like, with an ill-scented, fleshy coat surrounding a smooth oval stone.

Native of China and Japan. Handsome staminate trees are on the grounds of the Stanford Residence, and a few young trees are planted on the Campus.

CONIFERÆ.

Trees or shrubs with more or less resinous wood and usually narrowly linear or needle-like evergreen or rarely deciduous leaves. Flowers monœcious or diœcious. Fruit a woody cone or fleshy and drupe-like.

* In the spring of 1909 Professor Dudley prepared a key to the *Coniferæ* growing on the Campus for the use of the students of Forest Botany. As only a few carbon copies were made the present paper was undertaken in order that Professor Dudley's work might be embodied in permanent form. Although the key has been the basis of this paper the writer has gone over the field with considerable thoroughness, verifying the identifications, and has added the following species not credited to the Campus by Professor Dudley: *Agathis loranthifolia*, *Cephalotaxus pedunculata*, *Picea Parryana*, *P. sitchensis*, *Pinus Cembra*, *P. edulis*, *P. excelsa*, *P. Jeffreyi*, *P. Lambertiana*, *P. monticola*, *P. nigra*, *P. Pinea*, *Sciadopitys verticillata* (probably added to our collections since the key was prepared), *Taxodium mucronatum*, *Thuyopsis dolabrata*.

The Coniferæ are the prevailing Gymnosperms of the present geological age. They are represented by two families and about forty genera.

Fruit composed of a solitary stone surrounded by a fleshy, greenish or bright red aril.

1. *Taxaceæ*.

Fruit a woody cone made up of scales, each of which bears 1-several seeds in its axil (scales coalescent and fleshy in *Juniperus*).

2. *Pinaceæ*.

1. TAXACEÆ. Yew Family.

Trees or shrubs with durable close-grained wood. Leaves flat, linear or broader, usually 2-ranked by a twist of the compressed petioles, decurrent on the branchlets. Flowers diœcious, axillary; staminate composed of many stamens; ovulate of a single erect ovule. Fruit a stone more or less enclosed by a fleshy aril-like disk.

Fruit drupe-like; aril completely enclosing stone.

Leaves broadly lanceolate; pollen-sacs 2.

1. *Podocarpus*.

Leaves linear or nearly so; pollen-sacs 3-4.

Flowers pedunculate, clustered in heads; pollen-sacs 3.

2. *Cephalotaxus*.

Flowers axillary; pollen-sacs 4.

3. *Torreya*.

Fruit with a bright red cup-shaped aril partly enclosing the stone.

4. *Taxus*.

1. Podocarpus.

Trees or sometimes shrubs with linear or lanceolate alternate or opposite evergreen leaves. Fruit drupe-like, borne on a thickened foot-stalk; seeds inverted.

A genus of over 40 species, chiefly in the tropics and subtropics of the southern hemisphere. Many species are valuable timber trees.

1. Podocarpus macrophylla Don.

Leaves alternate, lanceolate, sometimes falcate, 2-5 inch long, about $\frac{1}{2}$ inch wide, bright green and lustrous above, pale beneath; fruit greenish, on a thickened purplish foot stalk.

One specimen, planted by Professor Dudley, is on the lawn at 8 Alvarado Row.

2. Cephalotaxus.

Leaves linear, acute and often sharp-pointed, spirally arranged but usually appearing 2-ranked. Flowers diœcious, pedunculate, clustered in small heads. Fruit drupe-like; endosperm uniform.

A small genus containing but 4 species, all of which are native of Japan and China.

Leaves appearing 2-ranked by a twist in the petiole.

Leaves $\frac{1}{2}$ - $\frac{3}{4}$ inch long, abruptly acute. 1. *C. drupacea*.

Leaves about 2 inches long, gradually tapering from near base.

2. *C. Fortunei*.

Leaves spreading from all sides, at least on the principal shoots, spiny-tipped.

3. *C. pedunculata*.

1. *Cephalotaxus drupacea* Siebold.

Leaves appearing 2-ranked and opposite, $\frac{1}{2}$ - $\frac{3}{4}$ inch long, scarcely $\frac{1}{8}$ inch wide, abruptly acute, margins not revolute; fruit elliptic, about $\frac{3}{4}$ inch long; stone smooth.

Native of northern China and Japan, where it attains a height of 30-40 feet. One ovulate shrub is at the west end of Encina Garden and a couple of small staminate specimens are in the nursery.

2. *Cephalotaxus Fortunei* Hook.

Leaves 2-ranked, margins thin, slightly revolute, gradually tapering to the sharp-pointed apex, about 2 inches long, over $\frac{1}{8}$ inch wide.

Tree 40-60 feet high with long, slender, drooping branches. Native of northern China. One small staminate tree is north of the live oak on the Mausoleum lawn.

3. *Cephalotaxus pedunculata* Siebold.

Leaves on leading shoots and principal branches scattered on all sides of the stem, $1\frac{1}{2}$ inches long, sharply acute, margins distinctly revolute.

A small Japanese tree, 20-25 feet high, with the spreading branches in whorls.

One small sterile shrub in very poor condition is in the eastern part of the Cactus Garden.

3. *Torreya*.

Leaves flat and linear, appearing 2-ranked, spiny-tipped. Flowers diœcious, axillary; pollen sacs 4, arranged in a semi-circle; fruit drupe-like, the greenish aril completely enclosing the stone; endosperm nutmeg-like.

A genus of four species, widely separated geographically and of very local distribution. One is in Florida, one in California, and the other two are in China and Japan.

1. *Torreya californica* Torrey. California Nutmeg.

Leaves $1\frac{1}{2}$ -2 inches long, $\frac{1}{8}$ inch wide, tapering slightly to the sharp-pointed apex, dark glossy green above, pale beneath; fruit 1- $1\frac{1}{2}$ inches long.

Tree sometimes 80 feet high, with spreading or drooping branches and smooth, scaly bark. Native of central and northern California in the Coast Ranges and the Sierra Nevada.

4. *Taxus*. Yew.

Trees or shrubs with spreading or erect branches and scaly bark. Leaves flat, linear, 2-ranked. Flowers diœcious, axillary; pollen-sacs 6-8, arranged in a circle. Fruit with a bright red fleshy viscid open cup partly enclosing the erect stone.

A genus of approximately 8 closely related species, distributed through the north temperate regions.

1. *Taxus baccata* L. English Yew.

Leaves linear, 2-ranked, usually falcate, shortly acuminate, dark green above, pale beneath, $\frac{1}{4}$ - $\frac{3}{4}$ inch long; fruit $\frac{1}{3}$ - $\frac{1}{2}$ inch broad, with almost globose aril.

The English Yew is a native of Europe, western Asia and northern Africa. It has long been cultivated and many garden forms exist. Several shrubs are in the neighborhood of the Cactus Garden, especially near the entrance.

1a. *Taxus baccata fastigiata* Loud. Irish Yew.

Leaves linear, as in the typical form, but spreading from all sides of the erect fastigate branches.

Specimens are on the borders of the Cactus Garden.

1b. *Taxus baccata adpressa* Carr.

This variety is distinguished by its broader and shorter, oblong obtuse leaves.

Our specimens are the compact erect form. They are on the east and west sides of the Cactus Garden.

2. PINACEÆ. Pine Family.

Trees or shrubs with resinous wood. Leaves linear, needle-like or scale-like, spirally arranged or decussately opposite, evergreen or in a few genera deciduous. Flowers diœcious; staminate in ament-like deciduous clusters; pollen-sacs 2-several. Fruit, a woody cone, made up of several scales, each with or without a subtending bract, bearing 1 or more seeds at

base on the upper surface (scales coalescent and fleshy in *Juniperus*); seeds often winged.

Leaves and cone-scales spirally arranged.

Leaves usually broad at base and tapering to a sharp point; ovules and seed 1 to each scale. Tribe 1. *Araucareæ*.

Leaves linear or needle-like.

Leaf-bases not decurrent on twigs; ovules and seeds 2 to each scale, pendent. Tribe 2. *Abietæ*.

Leaf-bases decurrent on twigs; ovules and seeds several to each scale, erect. Tribe 3. *Taxodeæ*.

Leaves and cone-scales opposite, the former often scale-like.

Tribe 4. *Cupresseæ*

Tribe 1. *Araucareæ*.

A very distinct tribe composed of the two genera *Agathis* and *Araucaria*. These are almost wholly restricted in their distribution to the tropical or extra-tropical realms.

Scales persistent; seeds free.

1. *Agathis*.

Scales deciduous; seeds adherent.

2. *Araucaria*.

1. *Agathis*.

Leaves opposite or alternate, ovate-lanceolate, attenuate, parallel-veined and of a firm leathery texture. Flowers diœcious, solitary, the staminate elongated. Cones ovate to globose, axillary; scales persistent; seeds winged only on one side, free.

1. *Agathis loranthifolia* Salisbury. Amboyna Pine.

Leaves opposite or sometimes alternate, 1½-4 inches long, ovate-lanceolate, glaucous green; staminate flowers 2 inches long; cones globose or turbinate, 3-4 inches long.

A large forest tree, often 8 to 10 feet in diameter and 100 feet or more high. Native of the mountains of the Malay Archipelago. One young specimen, which seems perfectly hardy in this climate, is in Professor Durand's garden.

2. *Araucaria*.

Leaves evergreen, flattened, lanceolate or short-ovate to awl-shaped, usually sharp-pointed. Flowers normally diœcious; cones erect, their scales deciduous; ovules and seeds 1 to each scale, pendent; anthers with several elongated pendent pollen-sacs.

Araucaria is represented by 10 species, all of which are restricted to the southern hemisphere.

Leaves lanceolate to ovate.

Leaves lanceolate; spiny tip of scale about $\frac{1}{2}$ inch long.

Leaves 2-ranked, dark green; scales nearly as broad as long, bract and scale distinct toward the apex. 1. *A. Bidwillii*.

Leaves spreading from all sides of the branches; scales over twice as long as broad, bract and scale completely united.

2. *A. brasiliana*.

Leaves broadly ovate, concave, stiff and very spiny-tipped; spiny tip of scale $1\frac{1}{2}$ inches long. 3. *A. imbricata*.

Leaves awl-shaped; bark exfoliating.

4. *A. Cunninghamii*.

1. *Araucaria Bidwillii* Hooker.

Leaves narrowly ovate-lanceolate, flat, rigid, sharp-pointed, dark green and shiny, those on the branches twisted and 2-ranked, 1-2 inches long; cones ovate-globose, 8-10 inches long; scale and bract distinct above the middle, free part of scale $\frac{3}{4}$ inch broad; bract 2 inches long, nearly as wide, thin, sharply and very prominently keeled at apex, terminated by a reflexed linear-lanceolate spine, $\frac{3}{4}$ inch long.

A forest tree 100 to 150 feet high. Native of the Brisbane Mountains, Australia, where it is known as the Bunya-Bunya. A large tree is on the grounds of the Stanford Residence, and smaller specimens are near the Mausoleum Avenue and in Encina Garden.

2. *Araucaria brasiliana* Rich.

Leaves linear-lanceolate, tapering to a spiny tip, flat, straight, spreading from all sides of the branches, rather pale glaucous green, 1-2 inches long; cones globose, 6-8 inches long; bracts and scales completely united and indistinguishable, wedge-shaped and somewhat 4-sided, 2 inches long, $\frac{3}{4}$ inch broad, terminated by a linear-lanceolate spine, $\frac{1}{2}$ inch long.

A tree 75 to 100 feet high. Native of southern Brazil. Two small trees are between the Cactus Garden and the Mausoleum.

3. *Araucaria imbricata* Pavon. Monkey Puzzle.

Leaves broadly ovate, closely set and spreading from all sides of the branches, straight, concave, rigid, very sharp-pointed, $\frac{3}{4}$ -1 inch long; cones globose, 6-8 inches long; scales wedge-shaped, 2 inches long, about 1 inch broad, terminated by a slender subulate spine $1\frac{1}{2}$ inches long.

A forest tree, often 100 feet high, forming extensive forests in the Andes of southern Chili. A good specimen is on the Mausoleum lawn, and other smaller trees are on the Campus.

4. *Araucaria Cunninghamii* Ait.

Leaves awl-shaped, enlarged at base, $\frac{1}{2}$ inch long, spreading from all sides of the branches, rigid; cones ovate-globose, 3-4 inches long; scales wedge-shaped, $\frac{1}{2}$ inch broad, terminated by an awl-shaped awn $\frac{1}{3}$ its length.

A large tree, 100 to 150 feet high, with exfoliating bark. An Australian species forming extensive forests in New South Wales and Queensland. One tree is at the east end of Roble Garden and another is on the southwest border of the Cactus Garden.

Araucaria excelsa R. Br. The Norfolk Island Pine resembles *A. Cunninghamii*, but the branches are in very symmetrical and rather distant whorls. This species is not cultivated on the grounds, but is planted in gardens at San Jose and San Francisco.

Tribe 2. Abietæ.

Leaves and floral parts spirally arranged; ovulate scales subtended by bracts, becoming woody and forming a cone in fruit; ovules 2, adnate to the upper surface of scale near the base, pendent; seeds usually with a conspicuous membranous wing; cotyledones 3 or more.

Leaves in 1-5-leaved clusters, surrounded at base by membranous sheaths; cones maturing the second year.

1. *Pinus*.

Leaves without basal sheaths, scattered or clustered on short, stubby branchlets; cones maturing the first year. •

Leaves clustered on short, stubby branchlets; cones erect.

2. *Cedrus*.

Leaves single, spirally arranged or appearing 2-ranked.

Cones pendent; scales persistent.

Branchlets rough with the persistent, woody leaf-bases; bracts not exerted.

3. *Picea*.

Branchlets smooth; leaf-bases sessile; bracts 3-parted, well exerted.

4. *Pseudotsuga*.

Cones erect; scales deciduous; branchlets smooth.

5. *Abies*.1. *Pinus*. Pines.

Trees or a few shrubs. Leaves evergreen, needle-shaped, in clusters of 2-5 (solitary in one species) from the axils of scale-like primary leaves, each cluster surrounded at base by a persistent or deciduous sheath of membranous scales; cones maturing the second year, their scales persistent, woody, often thickened or awned with a prickle at apex. Seeds usually winged.

The pines with approximately eighty living species constitute the largest genus of the Gymnosperms. They are restricted to the northern hemisphere and chiefly to the temperate regions.

Sheaths deciduous; leaves with 1 vascular bundle, in 5s (except No. 6, 7); wood light-colored and soft.

Cones cylindric; scales thin; wings elongated; leaves in 5s, serrulate.

White Pines.

Leaves not sharp-pointed; resin ducts not surrounded by strengthening cells.

Leaves grayish green, soft, recurved or drooping; branchlets glabrous.

Leaves 5-8 inches long, drooping; cones 6-10 inches long; scales abruptly pointed at apex. 1. *P. excelsa*.

Leaves 2-4 (rarely 5) inches long; cones 2-4 inches long; scales rounded at apex. 2. *P. Strobus*.

Leaves bluish green, stiff and erect; branchlets puberulent; cones 4-11 inches long; scales pointed. 3. *P. monticola*.

Leaves sharp-pointed and stiff, 2-4 inches long, dark bluish green; resin ducts surrounded by strengthening cells; cones 12-20 inches long.

4. *P. Lambertiana*.

Cones not cylindric; scales thickened; wings reduced to a ring; leaves not serrulate. Stone Pines.

Leaves in 5s; cones $2\frac{1}{2}$ -3 inches long. 5. *P. Cembra*.

Leaves in 2s or 4s; cones $\frac{3}{4}$ -2 inches long.

Leaves in 4s. 6. *P. quadrifolia*.

Leaves in 2s. 7. *P. edulis*.

Sheaths persistent; leaves with 2 vascular bundles, in 2s or 3s (except Torreyana); wood resinous. Pitch Pines.

Leaves in 5s, about 10 inches long. 8. *P. Torreyana*.

Leaves in 2s or 3s.

Leaves in 3s.

Cones with the umbo ending in a stout, hooked projection; leaves 8 or more inches long.

Leaves grayish green, drooping; cones chocolate-colored, ovate.

9. *P. Sabiniana*.

Leaves dull green, spreading; cones light brown, cylindric-ovate.

10. *P. Coulteri*.

Cones with rounded or flattened apophysis; umbo with or without a slender prickle.

Umbo with a prominent prickle; apophysis but little thickened.

Branchlets glaucous; leaves bluish green.

11. *P. Jeffreyi*.

Branchlets not glaucous; leaves bright yellowish green.

12. *P. ponderosa*.

Umbo without or with a rudimentary prickle.

Leaves slender, drooping, 8-10 inches long; cones cylindric, 4-8 inches long; apophysis low-pyramidal.

13. *P. canariensis*.

Leaves not drooping, 4-6 inches long, dark green; cones ovate and unsymmetrical; apophysis on the outside rounded.

14. *P. radiata*.

Leaves in 2s.

Cones unsymmetrical; scales much enlarged on the outside; armed with prominent prickles.

15. *P. muricata*.

Cones nearly symmetrical; prickles none or inconspicuous.

Leaves slender and flexible, 2-4 inches long; apophysis flattened, deep, lustrous brown.

16. *P. halepensis*.

Leaves stout and rigid.

Cones and leaves 4 inches long or more.

Seeds $\frac{3}{4}$ inch long, with a very short wing; apophysis low, somewhat 6-sided.

17. *P. Pinea*.

Seeds scarcely $\frac{1}{2}$ inch long, much shorter than the wings; apophysis pyramidal and sharply keeled.

18. *P. Pinaster*.

Cones and leaves $1\frac{1}{2}$ -3 inches long.

Trees of good size.

Leaves flattened; cone-scales with a flattened apex projecting beyond the dorsal umbo.

19. *P. sylvestris*

Leaves rounded on the back, grooved beneath, 2-3 inches long; apex of scale not projecting.

20. *P. nigra*.

Low dwarf shrub with dense foliage of dull green leaves.

21. *P. montana*.

1. *Pinus excelsa* Wall.

Branchlets greenish brown, glabrous, glaucous; leaves very slender, flaccid, drooping, grayish green, 6-8 inches long; cones on stalks 1-2 inches long, cylindric, 6-10 inches long; scales sharp-pointed; seeds $\frac{1}{3}$ inch long; wings 1 inch long, acute.

A native of the Himalaya Mountains, where it attains a height of 150 feet. One tree is in the Arboretum northeast of the Cactus Garden.

2. *Pinus Strobus* L. White Pine.

Branchlets glabrous, green or greenish brown; leaves soft and very flexible, 2-5 inches long, light bluish green; cones on stalks $\frac{1}{2}$ -1 inch long,

cylindric, 2-4 inches long; scales oblong-obovate, flexible; seed reddish brown, mottled with black, $\frac{1}{4}$ inch long; wings 4 times as long, acutish.

A native of eastern America, extending from Newfoundland to Manitoba, south to Georgia and Iowa. Specimens are along Pine Avenue, between University Avenue and the automobile road and in the nursery south of the lath-house.

3. *Pinus monticola* Don. Mountain White Pine.

Branchlets puberulent, yellowish or reddish brown; leaves stiff, bluish green and glaucous, $1\frac{1}{2}$ -4 inches long; cones short-stalked, cylindric, 5-11 inches long, yellowish brown; scales pointed by the slightly thickened umbo; seeds $\frac{1}{3}$ inch long, reddish brown, mottled with black; wings 3 times as long, acute.

A native of western America, extending from British Columbia to Idaho and the high mountains of California. One tree east of Cactus Garden, a few others are scattered through the Arboretum.

4. *Pinus Lambertiana* Dougl. Sugar Pine.

Branchlets pubescent, brown; leaves $\frac{3}{4}$ inch long, stout, sharp-pointed, dark bluish green with conspicuous white lines on back; cones on stalks, 2-3 $\frac{1}{2}$ inches long, cylindric, light brown, shiny, 10-20 inches long; seed $\frac{1}{2}$ inch long, dark brown or nearly black; wing rounded at apex.

A Pacific Coast species, extending from southern Oregon to northern Lower California. The largest and most magnificent of all the pines. Several trees are north of the Angel of Grief, and one or two fairly large trees are north of the Stanford Residence.

5. *Pinus Cembra* L. Swiss Stone Pine.

Branchlets with yellowish brown tomentum; leaves straight, dark green on back, bluish white inside, 2-3 $\frac{1}{2}$ inches long; cones short-peduncled, ovate, light brown, 2 $\frac{1}{2}$ -3 $\frac{1}{2}$ inches long; scales rounded at apex; apophysis much broader than high; seed $\frac{1}{2}$ inch long.

Native of the Alps and extending northward to Russia and northern Asia, where it attains 70 or occasionally 120 feet. One small tree which has not fruited is at the entrance of the Cactus Garden.

6. *Pinus quadrifolia* Parl. Parry's Piñon.

Branchlets puberulous, light grayish brown; leaves 3-5 (usually 4), rigid, incurved, light green on back, whitish inside, $1\frac{1}{2}$ -2 inches long; cones subglobose, $1\frac{1}{2}$ -2 inches long, chestnut brown; apophysis thick, pyramidal, conspicuously keeled: umbo with minute recurved prickle; seed $\frac{1}{2}$ inch long.

Tree attaining 40 feet, with spreading branches forming a rounded top; bark dark brown tinged with red, shallowly fissured. Native of the extreme southern part of California and extending into the mountains of northern Lower California. There are no specimens of this tree in the Arboretum, but one tree which fruited in 1911 is at 17 Salvatierra Street, and another small specimen is at 8 Alvarado Row.

7. *Pinus edulis* Engelm. Piñon.

Leaves in 2s or rarely 3s, stout, rigid, incurved, dark green on the back, marked within by several rows of stomata, $\frac{3}{4}$ -1 $\frac{1}{2}$ inches long, persistent for 3 or 4 years or sometimes longer; staminate flowers dark red; cones $\frac{3}{4}$ -1 $\frac{1}{2}$ inches long and nearly as broad; seeds ovate, dark red-brown below, orange-yellow above, $\frac{1}{2}$ inch long; wings $\frac{1}{8}$ inch wide.

A small tree with a divided trunk, 30 to 40 feet high. Native of the southern Rocky Mountains, extending from eastern Utah and southwestern Wyoming southward to the mountains of northern Mexico. One young tree is in Professor Durand's garden.

8. *Pinus Torreyana* Parry. Torrey Pine.

Branchlets greenish or purplish, glabrous; leaves rigid, dark green, 8-12 inches long; cones broadly ovate, 4-6 inches long, chocolate-brown; apophysis low-pyramidal; umbo elongated, reflexed, with a short spiny tip; seed $\frac{3}{4}$ inch long; short-winged.

Tree 40 or occasionally 60 feet high, with spreading branches and dark brown bark. Perhaps the rarest pine, known only in two small groves: one is at Del Mar, San Diego County, the other is on Santa Rosa Island off the coast of southern California. Good-sized trees are near the middle of the Arboretum just west of University Avenue.

9. *Pinus Sabiniana* Dougl. Digger Pine.

Leaves slender, drooping, grayish green, 8-12 inches long; cones pendent on stalks 2 inches long, light red-brown, 6-10 inches long; apophysis pyramidal, sharply keeled, flattened at the straight or incurved apex; seeds $\frac{3}{4}$ inch long; short-winged.

Tree 50 to 80 feet high with the trunk usually divided into several stems, forming a round-topped head. Native of the inner Coast Ranges and the foothills of the Sierra Nevada, California. Specimens are in the Roble Garden, near the Museum, and in the Nursery.

10. *Pinus Coulteri* Don. Coulter Pine.

Leaves stout, acuminate, dark bluish green, not drooping, 6-12 inches long; cones short-stalked, cylindrical-ovate, yellowish brown, 9-14 inches long;

apophysis elongated-pyramidal, gradually narrowed into straight or incurved umbo; seed $\frac{1}{2}$ inch long.

Tree 80 feet high, forming a loose pyramidal head. Native of the Coast Ranges of California. Trees are planted in the Roble Garden near the Museum and elsewhere.

11. *Pinus Jeffreyi* Murry. Jeffrey's Pine.

Leaves stout, 5-8 inches long, pale bluish green; cones conic-ovate, light brown, 6-12 inches long; apophysis depressed, keeled; umbo elongated into a slender recurved spine; seed about $\frac{1}{2}$ inch long.

Forest tree attaining a height of nearly 200 feet, with short spreading branches forming an open pyramidal head. Native of the mountains of Oregon and California. Specimens are in the Nursery south of the lath-house.

12. *Pinus ponderosa* Dougl. Western Yellow Pine.

Branchlets reddish brown; leaves dark yellowish green, 5-10 inches long; cones ovate-oblong, light reddish brown, $3\frac{1}{2}$ -5 inches long; apophysis flattened, keeled; umbo triangular, ending in a stout, straight or incurved prickle; seed $\frac{1}{4}$ inch long; wing 1 inch long.

Tree 150 or occasionally 230 feet, forming a spire-like head. Native of western America, extending from British Columbia to Mexico, and from western Nebraska and Texas to California. A row of trees is west of the Nursery lath-house, others are between University Avenue and the Mausoleum, and a few large trees are north of the Stanford Residence.

13. *Pinus canariensis* C. Sm. Canary Island Pine.

Branchlets yellowish; leaves slender, 8-11 inches long, light green, flexible, usually drooping, flattened; cones ovoid, 4-7 inches long, light brown, lustrous; apophysis low-pyramidal, umbo obtuse or sometimes depressed; seed $\frac{1}{2}$ inch long.

Tree 80 feet high with slender branches forming a round-topped head. Native of the Canary Islands and Teneriffe. Several trees are west of the Nursery and one near Mausoleum Avenue. Some of the trees west of the nursery which were severely burned three or four years ago are sending out new shoots from the burned branches and trunks. The primary leaves on these shoots are silvery glaucous.

14. *Pinus radiata* Gord. Monterey Pine.

Leaves bright green, 3-6 inches long; cones light brown, lustrous, conic-ovate, unsymmetrical, 3-5 inches long, 2-4 inches broad; scales on upper sur-

face with rounded apophysis, those on the lower surface with nearly flat apophysis; prickles very minute; seeds black, $\frac{1}{4}$ inch long, half the length of the wing.

Tree 80 to 100 feet, broadly pyramidal or with round-topped head. Native of the coast of California and abundant at Monterey. Commonly cultivated on the University grounds.

15. *Pinus muricata* Don. Prickle-cone Pine.

Leaves bright green, rather stout, 4-6 inches long, strongly serrate; cones 2-2½ inches long, very unsymmetrical by the enlargement of scales on outside; prickles prominent; seeds $\frac{1}{3}$ inch long; wings $\frac{1}{2}$ inch long.

A compact pyramidal or branching tree 50 to 90 feet high, with dense foliage. Native of the California coast. Specimens are among the pines between the Post Office and the Quadrangle. Others were formerly back of the Chemistry Building.

16. *Pinus halepensis* Ait. Aleppo Pine.

Leaves dull green, very slender for the group, 2½-3 inches long, tufted at the end of the branches; cones conical, smooth, 2½-3 inches long, deep lustrous brown; scales flattened, $\frac{3}{4}$ inch broad; apophysis but slightly thickened, flat and smooth, except for a rather faint transverse ridge.

A low spreading tree with an open, thin and straggling aspect, 20-40 feet high. Native of the Mediterranean region, extending from Portugal to Asia Minor. Several trees are planted in the Arboretum; one especially fine specimen is between the Mausoleum and the Museum.

16a. *Pinus halepensis* Pityusa Stevens.

Larger tree than the typical form, with leaves 4-5 inches long and cones 3-5 inches long.

Native of the eastern Mediterranean region. Specimens are south of the Nursery.

17. *Pinus Pinea* L. Italian Stone Pine.

Leaves stout, straight, deep shiny green, 5-8 inches long; cones 5-6 inches long, broadly ovate, lustrous brown; scales thick and heavy, 1 inch broad; apophysis but slightly elevated, often 6-sided; umbo with a short blunt prickle; seeds $\frac{3}{4}$ inch long, with broad but very short wings.

Tree 25-60 feet, with a broad, rounded head. Common on the sandy shore of Tuscany. One tree is north of the Nursery lath-house.

18. *Pinus Pinaster* Ait. Cluster Pine.

Leaves glossy green, very stout, stiff and twisted, acute, 5-9 inches long, appearing in definite and somewhat remote bands; cones, in the older trees,

clustered, conic-oblong, 4-7 inches long; apophysis nearly $\frac{3}{4}$ inch broad, low-pyramidal, conspicuously keeled with a prominent triangular umbo; seed $\frac{1}{3}$ inch long; wing about 1 inch long.

Tree 100 feet high with regular pyramidal habit and rapid growth. Native of the coastal region of southern Europe. A variety has been extensively used in Europe to reclaim wastes of maritime sands. Several trees are in the row of pines between the Post Office and the Quadrangle. A handsome specimen is in the rear of Madrone Hall, and a few trees are south of the Nursery.

19. *Pinus nigra* Arnold. Austrian Pine.

Leaves stout and very rigid, $1\frac{1}{2}$ - $2\frac{1}{2}$ inches long, abruptly sharp-pointed, rounded on the back, deeply grooved beneath, dark green; cones $2\frac{1}{2}$ inches long, light brown; scales about 1 inch long, $\frac{3}{8}$ inch broad; apophysis low-pyramidal, slightly keeled and with a minute prickle.

This species is more generally known under the name *Pinus Austriaca*. It is a native of southeastern Europe. A small tree is southwest of the Nursery lath-house.

20. *Pinus sylvestris* L. Scotch Pine.

Leaves light green, flattened and twisted, stiff. $1-1\frac{1}{2}$ inches long; cones $2-2\frac{1}{2}$ inches long, light brown; scales $\frac{1}{2}$ inch broad; apophysis, at least of the middle scales, with a dorsal knob-like, keeled and truncated thickening, and a thin, somewhat recurved apex; seed $\frac{1}{4}$ inch long; wing narrow, acute.

A forest tree 70-100 feet high, with pyramidal head and scattered foliage. The Scotch Pine is one of the important timber trees of Europe. Several trees are in the Nursery north of the lath-house, and one is in about the middle of the Arboretum near University Avenue.

21. *Pinus montana* Mill. Swiss Mountain Pine.

Leaves stout and crowded, $\frac{3}{4}$ -2 inches long, bright green, acutish; cones $\frac{3}{4}$ - $2\frac{1}{4}$ inches long, light grayish brown; apophysis low-pyramidal, with a black band surrounding the umbo.

A variable species, often a low dwarf shrub, or sometimes a pyramidal tree 40 feet high. Native of the mountains of central and southwestern Europe. One dwarf specimen is on the west side of the Cactus Garden.

2. *Cedrus*. Cedars.

Large forest trees, with stiff 4-sided, more or less sharply-pointed leaves in clusters at the ends of short, stubby lateral branchlets. Flowers monœcious, erect; cones ovate, 3-5 inches long, with broad, thin, closely imbricated scales.

A genus of three closely allied species, confined to northern Africa, Asia Minor and the Himalaya Mountains. These are the true cedars, although the name is applied to a number of totally different genera, such as *Libocedrus*, *Juniperus*, *Thuja* and *Chamaecyparis*.

Branches stiff horizontal or ascending, not pendulous; cones truncate and often concave at apex.

Branches mostly ascending; leading shoots not nodding; leaves mostly less than 1 inch long, thicker than broad. 1. *C. atlantica*.

Branches horizontal; leading shoots nodding; leaves 1-1¼ inches long, broader than thick. 2. *C. Libani*.

Branches and leading shoots pendulous; cones obtuse; leaves often 2 inches long. 3. *C. Deodara*.

1. *Cedrus atlantica* Manetti. Mt. Atlas Cedar.

Leaves mostly less than 1 inch long, rigid, dark or glaucous green, thicker than broad; cones 2-3 inches long, light brown.

A pyramidal tree 120 feet high, with ascending branches and erect, or at least not drooping, leading shoots. A horticultural variety, *glauca*, has leaves very glaucous with a silvery hue. Native of the mountains of northern Africa. Frequently planted on the University grounds. A handsome specimen of the variety is east of the Cactus Garden.

2. *Cedrus Libani* Barr. Cedar of Lebanon.

Leaves 1 inch long or more, dark green or in some forms bluish green or even silvery, broader than thick; cones 3-4 inches long, brown.

Large forest tree, with wide-spreading, horizontal branches and nodding leading shoots. Native of the mountains of Syria and Asia Minor. Two trees are east of the Cactus Garden, near the silver-leaved Mt. Atlas Cedar, and another is in the western part of the Nursery, surrounded by a cluster of the Mt. Atlas Cedar.

3. *Cedrus Deodara* Loud. Deodar.

Leaves 1-2 inches long, dark bluish green, rigid, as thick as broad; cones 3½-5 inches long, reddish brown.

Large forest tree, often 150 feet high, with branches and leading shoots pendulous. Several horticultural varieties are in cultivation: one, *argentea*, has silvery leaves. Native of the Himalaya Mountains. Specimens are in Encina and Roble Gardens, and the variety, *argentea*, is in the Arboretum north of the Mausoleum.

3. *Picea*. Spruce.

Trees with spreading or sometimes pendulous branches. Leaves linear, flat or 4-sided, spirally arranged, sometimes appearing 2-ranked, not narrowed into a leaf-stalk; leaf-scars raised on prominent woody pedicels, which give the twigs a decided roughness after the leaves have fallen. Cones pendulous, their scales persistent, completely concealing the very short bracts.

The eighteen known species are confined in their distribution to the north temperate and subarctic regions.

Leaves quadrangular with stomata on all 4 sides.

Cone-scales rounded at apex.

Leaves $\frac{1}{3}$ - $\frac{2}{3}$ inch long, obtuse; branchlets not long-pendulous.

Young twigs glabrous; cones $1\frac{1}{2}$ -2 inches long.

1. *P. canadensis*.

Young twigs pubescent; cones 3-5 inches long.

2. *P. orientalis*.

Leaves $1\frac{1}{4}$ -2 inches long, sharp-pointed.

3. *P. Smithiana*.

Cone-scales not rounded at apex; leaves acute or sharp-pointed.

Leaves dark green, abruptly acute; cone-scales firm on the margins, truncate at apex.

4. *P. excelsa*.

Leaves blue green, acuminate and callous-tipped; cone-scales rhomboidal, their margins flexuose.

5. *P. Parryana*.

Leaves flattened, with 2 silvery bands of stomata above.

6. *P. sitchensis*.

1. *Picea canadensis* (Mill.) B. S. P. White Spruce.

Leaves spreading from all sides of glabrous twigs, $\frac{1}{2}$ - $\frac{2}{3}$ inch long, $\frac{1}{24}$ inch wide, sharp-pointed, dull glaucous green; flowers pale red or yellowish; cones $1\frac{1}{4}$ -2 inches long, about 1 inch broad; scales rounded at apex, $\frac{1}{3}$ inch wide.

A tree 50-150 feet high, with a symmetrical pyramidal head. Native of north temperate and subarctic America, extending from Alaska to Labrador and from Montana to New England. One tree is near the center of the Cactus Garden.

2. *Picea orientalis* (L.) Carr. Caucasian Spruce.

Leaves spreading from all sides of the pubescent twigs, $\frac{1}{3}$ - $\frac{1}{2}$ inch long, $\frac{1}{12}$ inch wide, 4-sided, blunt at apex, dark lustrous green; flowers carmine; cones 3-5 inches long, about $1\frac{1}{2}$ inches broad; scales rounded at apex, $\frac{2}{3}$ inch wide.

Native of the Caucasus and Asia Minor. Two trees are near the center of the Cactus Garden.

3. *Picea Smithiana* (Wall) Bois. Himalaya Spruce.

Leaves spreading from all sides of the long pendulous branches, $1\frac{1}{4}$ -2 inches long, $\frac{1}{20}$ inch wide, sharp-pointed, light green; cones 5-7 inches long, about 2 inches broad; scales firm and shiny, about $\frac{3}{4}$ inch wide, crowded into close spirals, rounded at apex.

A common tree in the coniferous forests of the Himalaya Mountains. One tree is on the west side of the Cactus Garden and two others are near the Angel of Grief.

4. *Picea excelsa* Link. Norway Spruce.

Leaves spreading from all sides of the sparsely pubescent light brown twigs, $\frac{1}{2}$ - $\frac{2}{3}$ inches long, $\frac{1}{24}$ inch wide, 4-sided, sharp-pointed, bright green; cones $2\frac{3}{4}$ -5 inches long, about half as broad; scales $\frac{2}{3}$ inch wide, their exposed tips 3-sided, the 2 lateral margins oblique from a truncate and erose apex.

Native of the mountains of central and northern Europe. One tree is on the west side of the Cactus Garden, and others are planted elsewhere on the Campus.

5. *Picea Parryana* Sargent. Blue Spruce.

Branchlets glabrous; leaves stout, rigid, acuminate and sharp-pointed with a callous tip, $\frac{3}{4}$ - $1\frac{1}{8}$ inches long, or less on fertile branches, bluish green, or sometimes silvery, marked on both sides with 4-7 rows of stomata; staminate flowers yellow tinged with red; cones oblong-cylindric, about 3 inches long, pale chestnut brown and glossy; scales rhomboidal, flexuose on the margins, erose at the summit; seeds $\frac{1}{8}$ inch long; wings twice as long.

Forest tree, 80 to 150 feet high, with a trunk sometimes 3 feet in diameter. Native of the mountains of Colorado, eastern Utah and Wyoming. A young tree is in Professor Durand's garden.

6. *Picea sitchensis* Carr. Tideland Spruce.

Leaves spreading from all sides of the light brownish yellow glabrous twigs, green and rounded below, flat, slightly keeled and with 2 broad silvery bands above, sharply acute, $\frac{1}{2}$ -1 inch long; cones cylindric-oval, $2\frac{1}{2}$ -4 inches long; scales rounded and erose at apex.

Tree 100 to 200 feet high, with slender horizontal branches. Native of the northwest coast, extending from Alaska to northern California. One tree is in the Arboretum between the the Automobile road and the carline near the old *Sempervirens* avenue. This tree was apparently identified as *Picea Parryana* in Dudley's key.

4. *Pseudotsuga*.

Large evergreen forest trees, with flat, indistinctly 2-ranked leaves, narrowed at base into short petiole; leaf-scars sessile. Cones pendent, their 3-pronged bracts much exserted; seeds prominently winged.

A genus of three species; two in western America, and one in Japan.

1. *Pseudotsuga taxifolia* Britton. Douglas Fir.

Leaves $\frac{3}{4}$ - $1\frac{1}{2}$ inches long, obtuse, dark green above, paler beneath; cones oblong-ovate, 2-4 inches long, light reddish brown, with broad, rounded scales and well exserted 3-parted bracts.

The Douglas Fir is the most important timber tree of western America. It often attains a height of 200 feet or even more, and a trunk 12 feet in diameter. Frequently planted in the Arboretum. Native trees are growing on the Palo Alto estate at the north end of Jasper Ridge.

5. *Abies*. Firs.

Trees generally pyramidal in outline, with their branches in whorls. Leaves solitary, scattered along the twigs in definite spirals, but often appearing 2-ranked by a twist near the base, linear, flat or slightly 4-sided, sometimes narrowed at base but not into a distinct leaf-stalk; leaf-scars sessile on the smooth twigs. Cones erect on the branches, their scales deciduous, and bracts exserted beyond scales or concealed by them.

A genus of 24 known species, which inhabit the northern or mountainous parts of the northern hemisphere.

Leaves stomatiferous and alike in color on both surfaces.

Leaves rigid, spreading from all sides, $\frac{1}{3}$ - $\frac{1}{2}$ inch long, closely crowded on the twigs, their much enlarged bases nearly contiguous.

Leaves $\frac{1}{3}$ - $\frac{1}{2}$ inch long, steel green, $\frac{1}{12}$ inch wide, somewhat 4-angled.

1. *A. pinsapo*.

Leaves $\frac{1}{2}$ - $\frac{2}{3}$ inch long, dark green, $\frac{1}{8}$ inch wide.

2. *A. barborensis*.

Leaves curved upward on twigs, more or less 2-ranked, pale glaucous green, 1-2 inches long.

3. *A. concolor*.

Leaves stomatiferous only on lower surface.

Leaves bright green on lower surface, distinctly 2-ranked.

4. *A. Momi*.

Leaves silvery on lower surface with 2 broad bands of stomata.

Leaves not pungently acute.

Leaves obtuse.

Leaves distinctly 2-ranked, forming flat sprays; twigs ill-scented when bruised.

5. *A. grandis*.

Leaves mostly curved upward; twigs not ill-scented.

Cones 6 inches long or less; bracts projecting beyond scales; leaves $\frac{2}{3}$ -1 inch long, bright green on upper surface.

6. *A. nordmanniana*.

Cones 8 inches long; bracts concealed by scales; leaves 1-1 $\frac{1}{4}$ inches long, dark green on upper surface.

7. *A. cilicia*.

Leaves acute.

8. *A. cephalonica*.

Leaves pungently acute; bracts long-exserted.

9. *A. venusta*.

1. *Abies pinsapo* Boiss. Spanish Fir.

Leaves dark steely green on both surfaces, rigidly spreading from all sides of the twig, crowded, their much enlarged bases nearly contiguous, $\frac{1}{3}$ - $\frac{1}{2}$ inch long, $\frac{1}{12}$ inch wide, slightly keeled on both surfaces, stomatiferous on both surfaces, with inconspicuous gray bands, obtuse but curved upward at tip and appearing acute; cones about 8 inches long, 1 $\frac{1}{2}$ -1 $\frac{3}{4}$ inches broad; scales wedge-shaped, 1 inch wide; bracts short, rounded, not stalked.

The Spanish Fir is a native of central and southern Spain, where it forms extensive forests on the mountains at altitudes of 4,000-6,000 feet. Excellent specimens of this species are at the southeastern border of the Cactus Garden.

2. *Abies barborensis* M'Nab. Algerian Fir.

Leaves dark lustrous green on both surfaces, rigidly spreading from all sides of twig, enlarged at base, less crowded than in the preceding; $\frac{1}{2}$ - $\frac{1}{4}$ inch long, $\frac{1}{8}$ inch wide, rounded at apex, flat but keeled on both surfaces, stomatiferous bands inconspicuous on both surfaces; cones 10 inches long, dull grayish brown; scales rounded at apex, tapering to base, 1-1 $\frac{1}{2}$ inches wide; bracts short, rounded.

Native of Mt. Barbor and Mt. Tababor, Algeria, where it is found with the Mt. Atlas cedar. It is a forest tree, often 60 feet high, with compact branches forming symmetrical pyramidal heads. Two trees are along the eastern border of the Cactus Garden near *Abies grandis*.

3. *Abies concolor* (Gord.) Parry. White Fir.

Leaves ascending or indistinctly 2-ranked, glaucous green and stomatiferous on both surfaces, 1-2 inches long, $\frac{1}{12}$ inch wide, obtuse or acutish, faintly grooved above, keeled below, with 2 lateral shallow grooves; cones 6-10 inches long, 1-1 $\frac{1}{4}$ inches broad; scales broader than long, rounded at apex, gradually tapering to the base; bracts half the length of scales, oblong,

denticulate and mucronate at the emarginate or truncate apex; seeds $3/12-4/12$ inch long, dark dull brown; wings rose-colored, widest near the middle.

A large forest tree, sometimes 200 feet or more high, with a trunk 6 feet in diameter, dull grayish brown bark and short stout horizontal branches in remote whorls. Native of western America, extending from southern Oregon to the high mountains of northern Lower California and eastward to New Mexico. A number of young trees are scattered along Mausoleum Avenue, and others are planted elsewhere on the Campus.

4. *Abies Momi* Siebold. Momis Fir.

Leaves appearing 2-ranked, flat, $3/4-1\frac{1}{4}$ inches long, $1/12-1/8$ inch wide, grooved and bright green above, faintly keeled and bright yellowish green beneath, inconspicuously emarginate; cones 2-3 inches long; scales transversely oval or reniform, $1\frac{1}{2}$ inches wide, $3/4$ inch long, lateral margins dentate; bracts stalked, $2/3$ as long as scales; spatulate, mucronately pointed.

The Momis Fir is a Japanese species and is often cultivated in Japanese gardens and about the temples, where trees over 100 feet high and 6 feet in diameter are to be found. One small tree is north of the Cactus Garden and another is just back of the Angel of Grief.

5. *Abies grandis* (Dougl.) Lindl. Lowland Fir.

Leaves appearing 2-ranked, forming a flat spray, $2/3-1\frac{1}{3}$ inches long, thin and flexible, deeply grooved and dark lustrous green above, silvery white below, with 2 broad bands of stomata, emarginate; cones cylindrical, slightly narrowed at rounded apex, $2-3\frac{1}{2}$ inches long, $1-1\frac{1}{2}$ inches broad; scales broader than long, rounded at apex, abruptly or gradually narrowed to the stalk-like base; bracts about $1/4$ the length of scales, obcordate, irregularly serrate, mucronate; seeds $1/2$ inch long, light brown; wings $1/2-3/4$ inch long.

A large forest tree, sometimes attaining a height of 250 feet and a diameter of 4 to 5 feet, clothed with long downward sweeping branches. The wood is ill-scented and is known among lumbermen as Stinking Fir. Native of northwestern America, ranging from Vancouver Island southward along the lowlands of the coast to Mendocino County, California, and eastward to the Bitterroot Mountains of western Montana and the Blue Mountains of eastern Oregon. One tree is situated on the western border of the Cactus Garden and a number of young trees are planted elsewhere in the Arboretum.

6. *Abies Nordmanniana* (Stevens) Spach. Caucasian Fir.

Leaves curved upward, $3/4-1\frac{3}{4}$ inches long, $1/12$ inch wide, obtuse, slightly grooved and dark shiny green above, keeled, and with 2 broad silvery bands of stomata below; cones about 8 inches long, $1\frac{3}{4}$ inches broad;

scales $1\frac{1}{2}$ inches wide, lateral margins lobed near the apex, serrate, tapering to a short slender stalk; bracts $1\frac{1}{4}$ inches long, their recurved, mucronate apex exerted beyond scales.

The Caucasian or Nordmann Fir is a native of Crimea and the Caucasus, where it inhabits the mountains at about 2,000 feet. It is a large forest tree, sometimes attaining 150 feet in height and 6 feet in diameter. Two handsome trees are in the Cactus Garden, and other smaller trees are planted on the University grounds.

7. *Abies cilicia* (Kotsch.) Carr. Cilician Fir.

Leaves curved upward, closely resembling those of the preceding, but darker green above and usually longer, $1-1\frac{3}{4}$ inches; cones about 10 inches long, $1\frac{3}{4}$ inches broad; bracts not exerted.

The Cilician Fir with the Cedar of Lebanon forms extensive forests in the Cilician Taurus at elevations of 4,000-6,000 feet. Two large trees are near the center of the Cactus Garden.

8. *Abies cephalonica* Loud. Cephalonian Fir.

Leaves spreading at right angles from all sides of the twig, dark shiny green above, with 2 silvery bands beneath, tapering from base to the sharp-pointed apex, their bases dilated lengthwise; cones cylindric, 5-6 inches long; scales rounded above and entire, wedge-shaped toward base; bracts projecting beyond scales, linear-oblong, unequally toothed at apex.

Native of the island of Cephalonia, Greece. One specimen is on the southwest border of the Cactus Garden.

9. *Abies venusta* (Dougl.) Koch. Santa Lucia Fir.

Leaves appearing 2-ranked, $1-1\frac{1}{4}$ inches long, $\frac{1}{8}$ inch wide, tapering at both ends and ending in a sharp spiny tip at apex, bright green above, grayish beneath with 2 broad bands of stomata; cones ovate, 3-4 inches long; bracts much exceeding the scales.

Native of the Santa Lucia Mountains. Tree often 100 to 150 feet high, narrowed toward the top into a spire-like head. A young tree is on the left hand side of the Palo Alto entrance to the Campus, another is in Encina Garden.

Tribe 3. Taxodeæ.

Leaves and floral parts spirally arranged, or the leaves whorled in *Sciadopitys*; ovuliferous scales bractless, forming woody cones; ovules usually several to each scale and erect; seeds small, sharply and irregularly angled.

Leaves in whorls, elongated.

6. *Sciadopitys*.

Leaves spirally arranged or appearing 2-ranked.

Leaves persistent for more than one season; seeds several to a scale.

Cone-scales with several sharp projections. 7. *Sequoia*.

Cone-scales without sharp points. 8. *Cryptomeria*.

Leaves deciduous with the slender twigs, or sometimes persistent for a year; seeds 2 to a scale.

9. *Taxodium*.

6. *Sciadopitys*.

Evergreen pyramidal tree, with long needle-like leaves in whorls. Flowers monœcious; staminate with spirally arranged 2-celled anthers. Cones ovate-oblong, with broadly orbicular scales.

1. *Sciadopitys verticillata* Sieb. & Zucc. Umbrella Pine.

Leaves in whorls of 15-30, 3-6 inches long, grooved on both surfaces, dark green above, and with white band beneath; cones 3-4 inches long.

This species, which is the only member of the genus, is a native of Japan. One young specimen is temporarily placed in the Nursery lath-house.

7. *Sequoia*.

Tall massive forest trees with trunks usually heavily buttressed at base, covered with thick fibrous bark. Leaves evergreen, linear or scale-like, decurrent on the twigs. Flowers terminating the branchlets, monœcious; pollen-sacs several on the lower half of the connective. Cones maturing the first year, with spirally arranged, peltate scales; seeds several to each scale, reddish brown.

Once a genus of several species widely distributed over North America, Europe and Asia, but now reduced to two and restricted to the Coast Ranges and the Sierra Nevada of California.

Leaves of 2 kinds, ordinarily flat, linear and 2-ranked, but on leading shoots often scale-like and spreading from all sides of the branchlets.

1. *S. sempervirens*.

Leaves all scale-like and scattered on all sides of the branchlets.

2. *S. Washingtoniana*.

1. *Sequoia sempervirens* Endl. Redwood.

Leaves distichously spreading, about $\frac{3}{4}$ inch long, or those on leading shoots smaller and scale-like; cone oblong, $\frac{3}{4}$ -1 inch long.

Tall, magnificent forest trees often 200-300 feet high. The tallest tree authentically measured is 340 feet. Native of the fog belt of the California Coast Ranges, extending from southwestern Oregon to the Santa Lucia Mountains in Monterey County, and inland not more than 20 to 30 miles.

Frequently planted on the University grounds but enduring badly in the dry soil. Native trees are on the estate along San Francisquito Creek. A notable individual is the "Palo Alto" at the railway bridge between Palo Alto and Menlo Park.

2. *Sequoia Washingtoniana* Sudw. Giant Sequoia.

Leaves scale-like, arising from all sides of the branchlets, $\frac{1}{8}$ - $\frac{1}{4}$ inch long, glaucous green; cone ovate-oblong, 2-3 $\frac{1}{2}$ inches long.

The Giant Sequoia is the largest and probably the oldest of trees. It is 200-325 feet high and attains a diameter of 30 feet. Native of the western slopes of the Sierra Nevada, where it usually occurs in small, isolated groves, but it forms rather extensive forests in the basins of the Tulare, Kings and Kaweah rivers. Frequently planted on the University grounds, and apparently better adapted to our local climate and soil than the Redwood.

8. *Cryptomeria*.

Pyramidal tree with reddish brown bark. Leaves linear-subulate, arising from all sides of the twigs, decurrent. Flowers small, monœcious; staminate oblong; pistillate globose. Cones globose, with thick, wedge-shaped scales furnished with a recurved projection on the back and pointed lobes at the apex.

A monotypic Japanese genus.

1. *Cryptomeria japonica* Don.

Leaves compressed, somewhat incurved, $\frac{1}{2}$ -1 inch long; cones reddish brown.

A handsome evergreen tree extensively planted in Japan, especially about temples. A few trees are planted on the University grounds, but it does not thrive in our dry soil. An excellent specimen is at 9 Lasuen St.

1a. *Cryptomeria japonica elegans* Beissn.

Low dense tree or shrub, with horizontal branches and pendulous branchlets; leaves linear, flattened, soft, bright green changing to bronze in winter.

A garden form. Good specimens are on the grounds of the Stanford Residence.

9. *Taxodium*.

Tall, deciduous or evergreen trees, with cinnamon brown, flaky bark. Leaves linear, 2-ranked, falling off in the autumn or the second year with the short slender lateral twigs; flowers monœcious, the staminate with 4-5 pollen-sacs to each anther, the pistillate solitary or in pairs at the ends of the branch-

lets of the previous year; cones globose or nearly so, maturing the first year, their scales spirally arranged, thickened at apex and mucronate; seeds 2 to each scale, triangular, winged.

Leaves deciduous; flowers appearing in the spring.

1. *T. distichum*.

Leaves persistent; flowers appearing in the autumn.

2. *T. mucronatum*.

1. *Taxodium distichum* Rich. Bald Cypress.

Leaves deciduous in the autumn, narrowly linear, light green, $\frac{1}{2}$ - $\frac{3}{4}$ inch long; staminate flowers purplish, in panicles 4-5 inches long; cones 1 inch long, without mucros at maturity.

Tall tree becoming 150 feet high, with a buttressed trunk, sometimes 12 feet in diameter. Native of the southeastern United States. A handsome specimen of this very ornamental tree is near the Angel of Grief, and another young tree is at 23 Salvatierra.

2. *Taxodium mucronatum* Tenore. Mexican Bald Cypress.

Similar to the last but leaves persistent through the winter; flowers appearing in the autumn instead of the spring; pollen-sacs 7-9 instead of 4-5.

Native of eastern and southern Mexico. Several notably large trees are known; one of these, the Cypress of Montezuma, was a noted tree four centuries ago. A young specimen that is withstanding our winters badly, is in Professor Durand's garden. This specimen has now passed through three winters, and although the tips of the young shoots have been killed by frost, the leaves have retained their persistent character.

Tribe 4. Cupresseæ.

Leaves and floral parts decussately opposite or ternate, the former scale-like or sometimes subulate. Ovuliferous scales woody or coalescent and fleshy; ovules 2-many to each scale.

Cones woody.

Scales flat or wedge-shaped, imbricate.

Seeds 4-5 to each scale; branchlets frond-like; leaves with broad scales.

10. *Thuyopsis*.

Seeds usually 2 (1-3) to each scale.

Leaves appearing in whorls of 4, flat.

11. *Libocedrus*.

Leaves decussately opposite.

12. *Thuya*.

Scales peltate.

Cones maturing the second year; seeds many to each scale.

13. *Cupressus*.

Cones maturing the first year; seeds few to each scale.

14. *Chamaecyparis*.

Cones becoming fleshy and berry-like.

15. *Juniperus*.

10. *Thuycopsis*.

Evergreen forest tree with a pyramidal head. Leaves decussately opposite, convex above and somewhat sac-like. Flowers monœcious, solitary and terminal; staminate cylindrical; cone subglobose, with 8-10 wedge-shaped scales; seeds 5 to each scale, compressed.

A monotypic Japanese genus.

1. *Thuycopsis dolabrata* Sieb. & Zucc. Hatchet-leaved Arborvitæ.

Leaves glossy green above, silvery white beneath, rounded at apex, the upper and lower appressed, the lateral spreading, hatchet-shaped; cones $\frac{1}{2}$ inch long; scales reflexed at apex.

A native of canyons and moist slopes of Japan. Two young trees are at 9 Lasuen St.

11. *Libocedrus*.

Evergreen aromatic trees, with fibrous bark and flattened spray-like branchlets. Leaves scale-like, imbricate in 4 rows. Flowers monœcious; staminate with 12-16 stamens; pollen-sacs 4. Cones oblong, with 6 scales, the lower pair much reduced, only the middle pair fertile; seeds 2 to each scale, winged.

A genus of about 8 species; one is a Californian species, the others are in western South America, New Zealand, New Caledonia, New Guinea, Formosa and southwestern China.

1. *Libocedrus decurrens* Torr. Incense Cedar.

Leaves yellowish green, appearing in whorls of 4, the lateral nearly covering the obscurely pitted inner ones; cones $\frac{4}{5}$ inch long, about $\frac{1}{3}$ inch thick; scales with a short recurved mucro.

Tree sometimes 150 feet high, with an irregularly lobed trunk tapering from a broad base, and a reddish brown, fibrous bark. Native of the Sierra Nevada and the inner Coast Ranges, extending from southern Oregon to northern Lower California. The row of trees back of the Engineering Buildings is of this species. Other trees are planted elsewhere on the University grounds.

12. *Thuya*.

Evergreen trees with thin, scaly bark and decussate scale-like leaves. Flowers monœcious; staminate ovoid, with 4-6 pollen-sacs. Cones ovoid-

oblong, erect or drooping, maturing in one season; scales 8-12, the middle 2 or 3 pairs fertile.

Four species are recognized in this genus, two in North America and two in Asia.

Cones pendulous; scales thin, with a minute mucro.

1. *T. plicata*.

Cones erect; scales angled on the back, with a stout, recurved dorsal hook.

2. *T. orientalis*.

1. *Thuja plicata* Don. Western Red Cedar.

Leaves bright green and glossy above, dark green beneath, with whitish triangular markings; cones cylindrical-ovoid, scarcely over $\frac{1}{2}$ inch long; scales 8-10, elliptic-oblong, usually the 3 middle pairs fertile; seeds compressed, notched at the apex, with 2 narrow wings.

A large forest tree, 200 feet high, with short horizontal branches often with pendulous tips. Native of northwestern America, extending from Alaska to northern California. A specimen is in the eastern part of Encina Garden and another is near Mausoleum Avenue.

2. *Thuja orientalis* L. Arborvitæ.

Leaves acute, bright green, with a small dorsal gland; cones erect, globose-ovate, $\frac{3}{4}$ inch long; scales usually 6, oval; angled on the back, and with a dorsal horn-like process, the uppermost pair sterile; seeds wingless.

Pyramidal trees 25 feet high or bushy. Native of Persia and extending to eastern Asia. There are many garden forms of this extensively cultivated species. Abundantly planted on the University grounds.

12. *Cupressus*.

Evergreen trees or rarely shrubs. Leaves decussately opposite, appressed, small, scale-like. Flowers monœcious, very small, terminating short branchlets. Cones globose or nearly so, consisting of 3-7 pairs of peltate woody scales, each bearing many seeds, maturing the second year.

Branchlets terete or quadrangular, not forming flat spays.

Leaves glandless or with an obscure dorsal gland.

Branchlets erect or spreading, the ultimate rather short and stout.

Ultimate branchlets terete or nearly so; cones usually $1\frac{1}{4}$ inch long or more.

1. *C. sempervirens*.

Ultimate branchlets 4-sided; cones globose, 1 inch or less broad.

Staminate cones subglobose, with 2 lateral anthers in each row; seeds dull grayish or blackish brown.

2. *C. macrocarpa*.

Staminate cones oblong-ovoid, with 3 anthers to each row; seeds reddish brown.

3. *C. Goveniana*.

Branchlets usually pendulous, the ultimate terete, slender, elongated; cones globose, $\frac{1}{2}$ inch broad.

4. *C. torulosa*.

Leaves conspicuously glandular and very fragrant.

5. *C. Macnabiana*.

Branchlets flattened, forming frond-like sprays on long, pendulous branches.

6. *C. funebris*.

1. *Cupressus sempervirens* L. Italian Cypress.

Tree attaining 80 feet, the typical form with erect branches forming a narrow columnar head; leaves closely appressed, ovate, glandless or with inconspicuous dark pits; staminate flowers cylindrical, with 4 lateral anthers in each row; cones oblong or subglobose, $1\frac{1}{4}$ inches long or more, glossy; seeds nearly $\frac{1}{4}$ inch long, reddish brown, with light-colored hilum.

The columnar form is the classical Cypress of the Greeks and Romans, and is much cultivated in southern Europe. It is the type of the species, but is not now known in the wild state. Commonly planted on the University grounds.

1a. *Cupressus sempervirens horizontalis* Gord.

Branches horizontal, forming a broad pyramidal head, otherwise like the typical form.

This form is also common on the Campus.

2. *Cupressus macrocarpa* Hartw. Monterey Cypress.

Branchlets short and stout, arising from all 4 sides of the twig; leaves dark green, glandless or glands marked by a dark pit; rhombic-ovate, acute; staminate flowers subglobose, with 2 lateral anthers in each row; cones globose to oblong, $\frac{3}{4}$ - $1\frac{1}{2}$ inches long; scales 8-12, with a short obtuse umbo; seeds sharply angled, $\frac{3}{16}$ inch long, chestnut brown, with a conspicuous light-colored hilum.

Tree attaining 40 feet or occasionally 70 feet, broadly oval in outline, with spreading branches or, especially in its native habitat, with horizontal branches forming a broad flat-topped head. The Monterey Cypress, which is the most abundantly planted tree on the University grounds, is restricted in its wild state to two small groves occupying the two promontories, Point Lobos and Cypress Point, that mark the boundary of Carmel Bay.

3. *Cupressus Goveniana* Gord.

Branchlets arising from all 4 sides of the twigs, quadrangular; leaves ovate, acute, glandless or with an inconspicuous dark pit; staminate flowers

oblong, with 3 lateral anthers; cones subglobose or oblong, $\frac{1}{2}$ - $\frac{3}{4}$ inch broad; seeds reddish brown with hilum of similar color.

Tree attaining 50 feet, with slender spreading or erect branches, forming a broad, open, or pyramidal head. Native of the coastal region of northern and central California. Two trees are on either side of the first cross street between the Library and the Gymnasium.

4. *Cupressus torulosa* Don. Himalayan Cypress.

Ultimate branchlets usually arising from only 2 sides of the twig, terete, slender; leaves ovate, acute, bluish green; staminate flowers cylindric, with 3-4 lateral anthers in each row; cones globose, $\frac{1}{2}$ inch broad; scales 8-10 with a small, sharp umbo; seeds light brown, glossy, flattened and broadly winged.

Tall, slender tree, attaining 150 feet, with short horizontal branches and slender pendulous branchlets. Native of the Himalaya Mountains. Several trees are around the Cactus Garden.

5. *Cupressus Macnabiana* Murr. MacNab Cypress.

Leaves ovate, obtuse, thickened at apex, conspicuously glandular and very fragrant; staminate flowers very small, globose, with 1-2 lateral anthers in each row; cones subglobose, $\frac{1}{2}$ - $\frac{3}{4}$ inch broad; scales usually 6, with a prominent conical umbo; seeds reddish brown, with a broad light-colored hilum.

Low spreading tree or shrub, or sometimes forming a pyramidal tree 20 feet high or more. Native of northern California, extending from Lake County to the vicinity of Mt. Shasta, and also in Lassen County. Several trees are between the Library and University Avenue. Flowers are produced abundantly almost the year round.

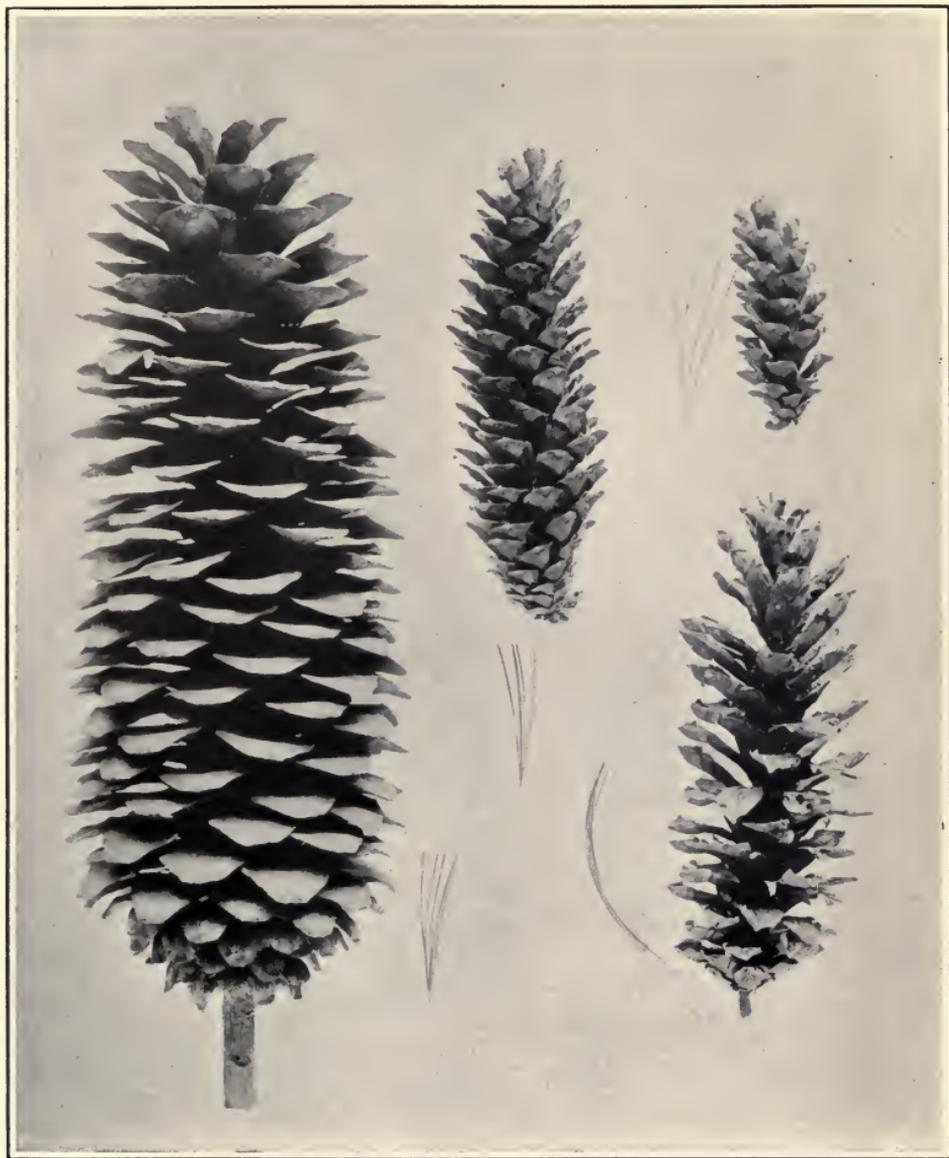
6. *Cupressus funebris* Endl. Funeral Cypress.

Branchlets somewhat flattened; leaves deltoid-ovate, light green; cones short-peduncled, globose, $\frac{1}{3}$ inch broad; scales 8, with a short mucro.

Tree often 60 feet, with wide-spreading branches curved upwards and bearing long slender pendulous branchlets. Native of China. Several trees are near the Cactus Garden and others are on the west side of University Avenue near the center of the Arboretum.

13. *Chamæcyparis*.

Evergreen trees with flattened branchlets densely clothed with opposite scale-like leaves in 4 rows. Flowers monœcious on separate branchlets; staminate oblong, pistillate subglobose. Cones globose, maturing the first



GROUP OF FIVE-LEAVED PINES.

Pinus Lambertiana

Pinus monticola

Pinus Strobus

Pinus excelsa

(Reduced to one-third natural size.)



GROUP OF THREE-LEAVED PINES.

Pinus radiata

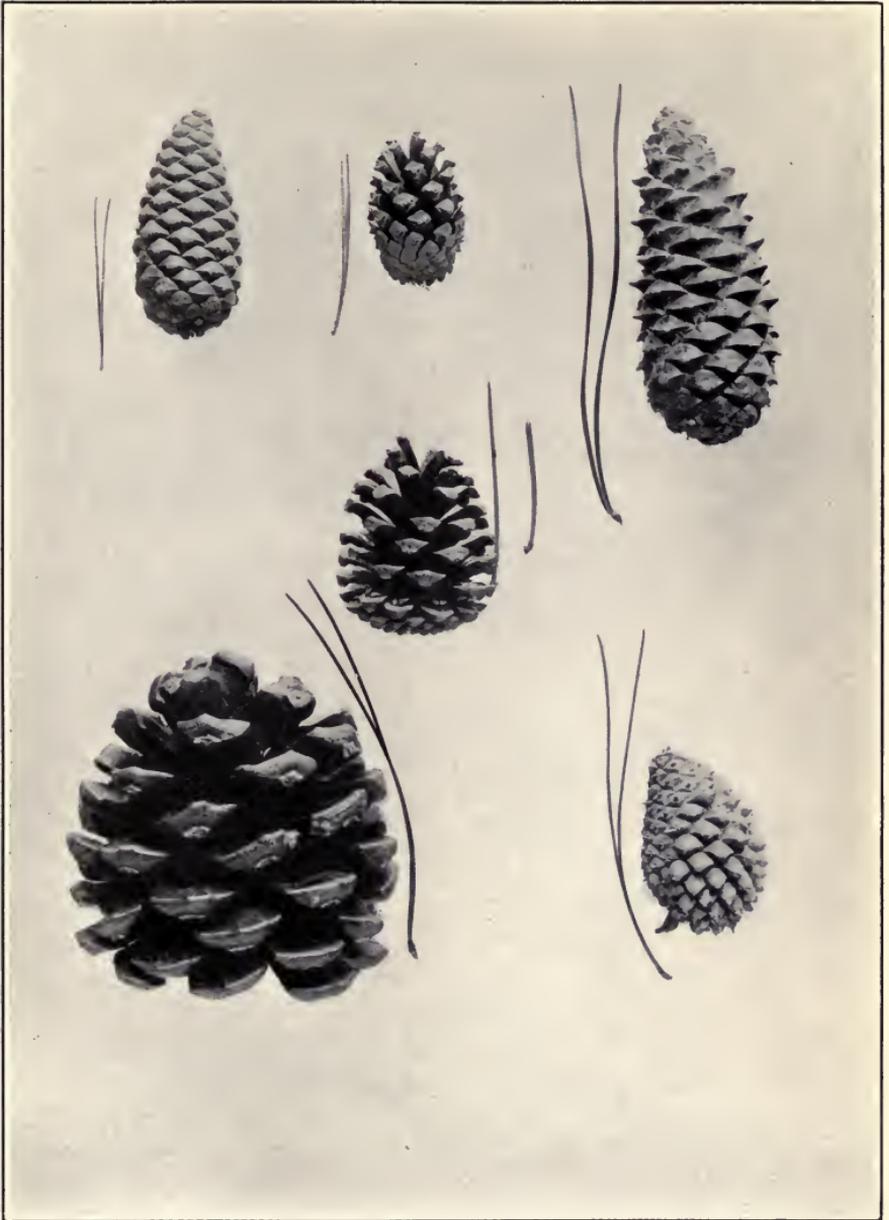
Pinus ponderosa

Pinus canariensis

Pinus Coulteri

Pinus Sabiniana

(Reduced to one-third natural size.)



GROUP OF TWO-LEAVED PINES.

Pinus halepensis
Pinus Pinea

Pinus sylvestris
Pinus nigra

Pinus Pinaster
Pinus muricata

(Reduced to two-fifths natural size.)



GROUP OF THE ABIETACE.

Abies cephalonica
Cedrus Libani

Picea excelsa
Pseudotsuga taxifolia

(Reduced to one-half natural size.)



GROUP OF THE TAXODIACEÆ.

Sequoia sempervirens
Cryptomeria japonica

Sequoia Washingtoniana
Taxodium distichum

(Reduced to one-half natural size.)



GROUP OF THE CUPRESSEÆ.

Cupressus macrocarpa
Chamæcyparis Lawsoniana

Thuja orientalis
Libocedrus decurrens

(Reduced to one-half natural size.)

year; scales abruptly dilated and flattened at apex, with short, prominent points; seeds 1-5 to each scale, slightly compressed.

Six species are known. They are confined to the Atlantic and Pacific Coast regions of North America and to Japan and Formosa.

1. *Chamæcyparis Lawsoniana* Parl. Lawson Cypress.

Leaves closely appressed to the flattened frond-like branchlets, bright green and with a gland on the back, paler beneath with whitish markings; staminate flowers red; cone about $\frac{1}{3}$ inch broad, red brown.

Tree sometimes 200 feet high, with horizontal spreading and usually pendulous. Native of the coastal region of Oregon and northern California. A variable species with over 60 garden forms. Young trees are along Alvarado Row, others are in the Arboretum but they endure our dry season badly. A handsome specimen is in the lawn at the Stanford Residence and another is at 9 Lasuen Street.

14. *Juniperus*.

Evergreen trees with opposite or ternate, scale-like or needle-shaped leaves. Flowers are diœcious or monœcious, minute; staminate oblong-ovate; anthers with 4-8 pollen-sacs. Cones globose or oblong, with 2-3 series of fleshy coalescent scales, berry-like, maturing the second year; seeds 1-several, ovate, terete or angled.

A genus of about 30 species widely scattered over the northern hemisphere from the Arctic Circle to the mountains of the subtropical regions. Flowers monœcious, axillary; leaves jointed at base, spreading and needle-shaped.

1. *J. communis*.

Flowers diœcious, terminal; leaves not jointed at base, often scale-like.

Leaves all alike, in 3s, slightly spreading; prostrate shrub.

2. *J. recurva squamata*.

Leaves often of 2 kinds, those on vigorous shoots in 3s, acicular, those on foliage branches in 2s, minute and scale-like.

Trees; fruit erect.

3. *J. virginiana*.

Low shrub with procumbent branches; fruit pendulous on recurved peduncles.

4. *J. Sabina*.

1. *Juniperus communis* L.

Leaves widely spreading, jointed at the base, narrowly linear-lanceolate, sharp-pointed, $\frac{1}{2}$ inch long or less, concave and with a broad white band above; fruit sub-sessile, dark blue and glaucous, $\frac{1}{4}$ - $\frac{1}{3}$ inch broad.

A small tree or erect shrub. Widely scattered over the northern hemisphere. A variable species with many geographical varieties and garden forms. One specimen is west of the Cactus Garden.

1a. *Juniperus communis hemispherica* Parl.

A low dense shrub; leaves $\frac{1}{3}$ inch long or less, stouter and stiffer than those of the typical form.

A geographical variety found in the mountains of southern Europe and northern Africa. One bush on the west side of the Cactus Garden near the typical form.

1b. *Juniperus communis oblonga* Loud.

Erect shrub with widely spreading branches and pendulous branchlets; leaves strongly concave, the longest $\frac{3}{4}$ inch long.

A geographical variety, native of Transcaucasia. One specimen is west of the Cactus Garden.

2. *Juniperus recurva squamata* Parl.

Leaves in 3s, straight, slightly spreading, linear-lanceolate, $\frac{1}{4}$ inch long, sharp-pointed; fruit $\frac{1}{3}$ inch broad, 1-seeded.

Prostrate shrub with long trailing branches. Native of the Himalaya Mountains. One specimen is on the southwest border of the Cactus Garden.

3. *Juniperus virginiana* L. Red Cedar.

Leaves of leading shoots acicular, in 3s, those of the foliage branches in 2s, small and scale-like, acute or acutish; fruit erect on short peduncles, globose or ovoid, $\frac{1}{3}$ inch broad, 1-seeded.

Tree with a maximum height of about 100 feet, with spreading branches and often pendulous branchlets. A variable species with many garden forms. Native of eastern North America. One tree with wide spreading branches and pendulous branchlets is east of the Cactus Garden, and another smaller and more compact specimen is west of the Cactus Garden, near *J. communis*.

4. *Juniperus Sabina* L.

Leaves of leading shoots often in 3s and acicular, those of the foliage branches scale-like, in 2s, obtusish; fruit pendulous, on elongated curved peduncles, globose, 1-3-seeded.

A variable species with many garden forms. Native of eastern North America, Europe and Asia. There are several staminate specimens along the border of the Cactus Garden.

THE SYNCHYTRIA IN THE VICINITY OF STANFORD UNIVERSITY.

By JAMES MCMURPHY, Instructor in Botany.

THE GENUS *Synchytrium* belongs to the *Chytridiales*, the lowest order of true fungi. The majority of the simple forms making up this order are parasitic upon protozoa, algæ and other fungi, but the *Synchytria* and some others are parasitic upon higher plants. All forms yet found here belong to the sub-genus *Eusynchytrium*, in which both resting spores and summer sori are present. And it is the so-called summer sorus that is meant in this paper when the word sorus is used, and not that formed directly by the germination of the resting spore. There are no sori formed here in summer.

Most of the parasitic fungi are supposed to attack only one species of host or to be limited to plants nearly related botanically, but the *Synchytria* are not supposed to be so limited. The hosts given for *S. globosum* of Europe are "Violaceæ, Rosaceæ, Compositæ, Rubiaceæ, etc.," plants of widely different botanical orders. I have seen no account of any *Synchytrium* having been transferred from one host to another under laboratory conditions. Since the species of *Synchytrium* are distinguished by the presence or absence of sori, the shape and general appearance of the galls produced, and the shape and size of the resting spores, it may be asked if these characters would be so modified by a change of host as to make the fungus unrecognizable.

In April, 1910, I found near Stanford University what appeared to be a *Synchytrium* growing on *Amsinckia intermedia* and took a small quantity to the laboratory, where I found the material to contain both sori and resting spores. Some days later I gathered more material and found that only resting spores were present, sori not having been formed during the clear, warm days preceding. At the same time I found growing with the *Amsinckia*, *Erodium cicutarium* bearing *S. papillatum* with only resting spores. Now *S. papillatum* is known only from California and is supposed to be indigenous here, though it is found only on the above named host, which is a weed introduced from Europe.

As there were no more long periods of wet weather, I was unable to get any zoospores for cross infections, but in March of the following year I had an abundance of zoospores from both forms. I was unable to infect *Amsinckia* with zoospores from *Erodium* or to infect *Erodium* with those from

Amsinckia. In March of this year, I placed an inch or so of the ends of the leaves of a few potted *Erodiums* and *Amsinckias* into a vessel of water containing zoospores of the *Synchytrium* on *Amsinckia*. After about two hours the plants were removed to a damp place. Some of the leaves of *Amsinckia* developed an abundance of *Synchytrium* on the ends that had been immersed in the water, but there was none on the *Erodium*. I have had no zoospores for further experiment.

In the hills I have found *Erodium cicutarium* growing with *Erodium botrys*, nearly every plant of the former more or less discolored by *Synchytrium papillatum*, but the latter entirely free of the parasite. Near the Museum and the Nursery, I found *Erodium cicutarium* growing with *Erodium moschatum*, the one often discolored with *Synchytrium*, the other with none. These two species of *Erodium* are so similar in appearance that beginners in botany often find it difficult to distinguish them, but the *Synchytrium* zoospores seem to have no such difficulty.

If *Synchytrium papillatum* is really endemic on some native California plant, then, since we have no native *Erodiums*, it must have passed to *E. cicutarium* from some host much farther removed botanically than either of the two mentioned above.

The following species of *Synchytrium* have been found in the vicinity of Stanford University:

SYNCHYTRIUM PAPILLATUM Farlow.

Synchytrium papillatum Farlow. Bull. Bussey Inst. 2:239. Bot. Gaz. 10:239, 1885.

"Spots dark purple, galls glandular, formed of papillate, pyriformly swollen epidermal cells, resting spores elliptical, .06-.07 mm. by .04-.05 mm., epispore brown, somewhat roughened. Sori superficial, spherical, .10-.12 mm. in diameter."

"On leaves of *Erodium cicutarium* L'Her. California."

In late winter and early spring this species may be found on the slopes of the hills as well as in the valley, and often there are places where it is difficult to find plants of the Red-stemmed Filaree that are entirely free of the deep red (dark purple when dried) discolorations caused by the parasite.

The galls vary considerably in size and may be nearly regular in outline or irregular and strongly papillate. Usually there are only one or two resting spores in a gall, but there are sometimes four or five. The sori are spherical, flattened or elongated and contain about 45-70 zoosporangia 15-21 x 15-26 μ in diameter. In material taken after a week or two of rainy weather I have found sori more abundant, but after a few days of sunshine only resting spores.

SYNCHYTRium AMSINCKIÆ *n. sp.*

Spots light yellow when immature, reddish brown at maturity; galls formed of swollen, externally projecting epidermal cells, which collapse when mature; resting spores one or two in a cell, elliptical or globose, 70-100 x 90-115 μ , epispore brown, smooth; sorus yellow, elliptical or globose, in galls similar to those of the resting spores, 65-90 x 100-120 μ ; zoosporangia in a sorus, 7-20, angular from mutual pressure, or globose to elliptical, 25-40 x 25-45 μ in diameter.

On leaves and stems of *Amsinckia intermedia* F. & M. Stanford University, California, in fields and waysides.

This is closely related to the European species *S. Myosotides* Kuhn, but that species, so far as I know, has never been known to produce sori, and belongs to the sub-genus *Pycnochytrium*, while in this form sori are common and the galls, which are often 200-265 μ in diameter before collapsing at maturity, are brown rather than deep red, as in that species.

The type was collected near Stanford University March 24, 1911, and is deposited in the Dudley Herbarium.

SYNCHYTRium INNOMINATUM Farlow.

Synchytrium innominatum Farlow. Bot. Gaz. 10:240, 1885.

"Spots dark red, resting spores globose or slightly elliptical, .07-.10 mm. in diameter, epispore thin and smooth, in oval host cells, which do not project beyond the surface of the leaves. Sori yellow, about .12-.15 mm. in diameter, sunk in the leaves."

"On leaves of *Malacothrix*. Santa Cruz, Cal."

On leaves of *Agoseris grandiflora* Greene, Page Mill Road, altitude about 1,000 feet.

My specimens are referred to the above species, though the resting spores, of which there are one or two in a cell, are more often elliptical than globose and vary more in size, 40-80 x 60-90 μ . The sori are also smaller, 70-117 x 78-117 μ . As Dr. Farlow says, l. c., "the species is certainly closely related to *S. Taraxici* D. By. & Wor." But the sori in my material are larger on the average and the discolorations on the leaves, when fresh, were dark red rather than golden red or blood red.

It is very desirable that cultures be made on the dandelion and related plants, that the limits of the species may be determined.

SYNCHYTRium ANDINUM Lagh.

Synchytrium andinum Lagh. Bull. Boiss. 1895, p. 61.

Galls multicellular, reddish brown, often confluent; sori globose or

elliptical, 60-110 in diameter; zoosporangia numerous, irregular, angular from mutual pressure, 40-60 in diameter, contents golden yellow; resting spores solitary, 80-120 in diameter, epispore thick, smooth, dark brown.

On leaves of *Ranunculus*, Quito, Ecuador.

On stems, leaves and floral parts of *Ranunculus californicus* Benth, wet ground between Stanford University and Mayfield.

In the spring of 1911, many of the buttercups were badly deformed by this fungus, the ovaries, stamens and petals being sometimes attacked as well as the leaves and stems, but this spring, presumably on account of the very light rainfall, I was unable to find more than half a dozen leaves attacked by the parasite.

My specimens, while agreeing very well with the above description taken from Saccardo, show somewhat greater variation in size of resting spores and sori, and the zoosporangia are considerably smaller, 26-34 x 26-48, usually 15-30 in a sorus. The galls, when solitary, are hemispherical or subglobose and 150-250 in height.

UROPHLYCTIS PLURIANNULATUS Farlow.

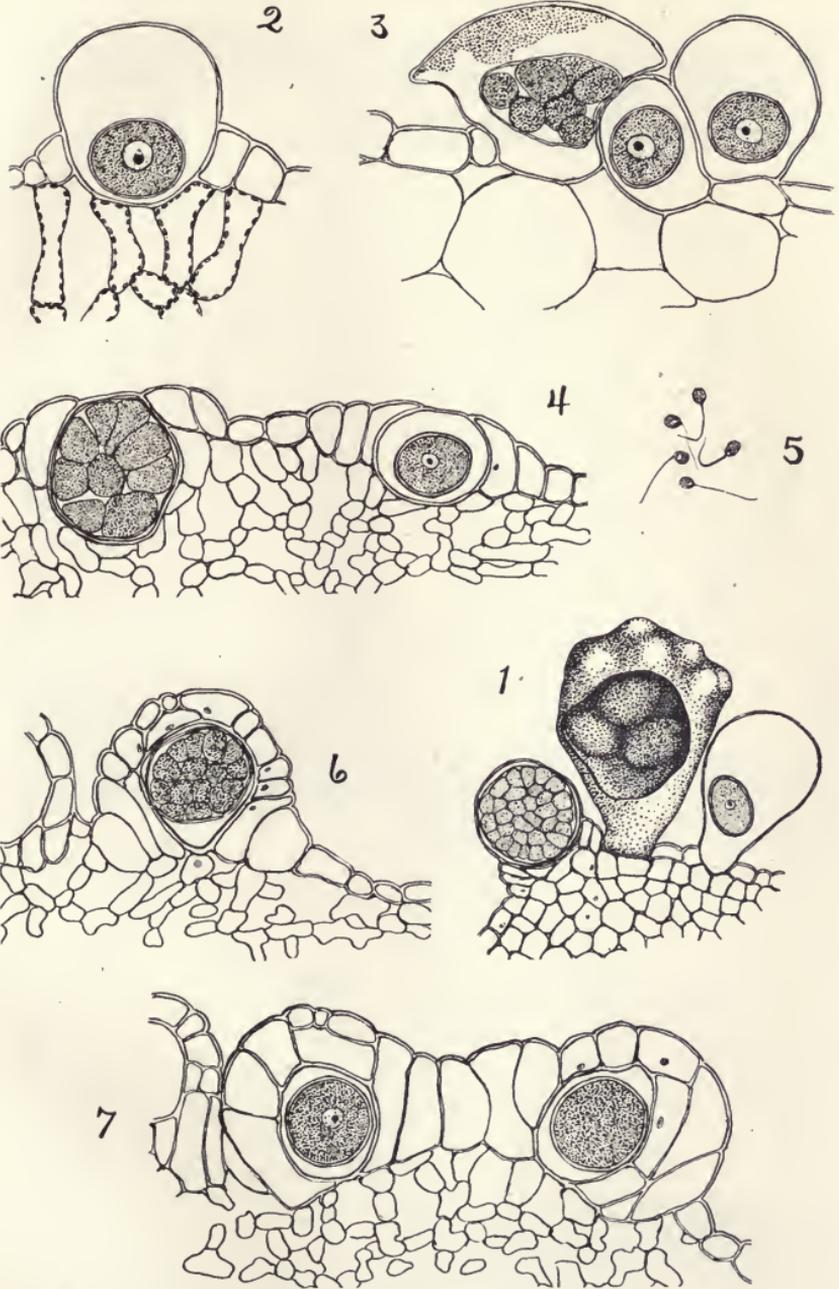
Urophlyctis pluriannulatus Farlow, *Rhodora* 10:13. 1908.

Uromyces pluriannulatus B. & C., *Grevillia* 3:57. 1874.

Synchytrium pluriannulatum Farlow, *Bot. Gaz.* 10:243. 1885.

This fungus was found growing on *Saniclua Menziesii* H. & A. along the creek below Searsville Lake.

PLATE I.



EXPLANATION OF PLATE.

- Fig. 1. *Synchytrium papillatum*, sorus and two galls with resting spores, about 125 diameters.
 Fig. 2-3. *S. Amsinckiae*, sections through sorus and three galls with resting spores, about 140 diameters.
 Fig. 4. *S. Amsinckiae*, zoospores, from stained preparation, 500 diameters.
 Fig. 5. *S. innominatum*, section through sorus and resting spore, about 150 diameters
 Fig. 6-7. *S. Andinum*, sections through sorus and two resting spores, about 120 diameters.



Fig. 1. *Agoseris grandiflora*, with very light attack of *Synchytrium innominatum*.

Fig. 2. *Ranunculus californicus* with *Synchytrium andinum*. The leaves and floral parts of the plant at the right are much deformed.

Fig. 3. *Amsinckia intermedia*, deformed by *Synchytrium Amsinckiae*.

Fig. 4. *Erodium cicutarium*, with parts of the leaves and petioles darkened by *Synchytrium papillatum*.

THE LAW OF GEMINATE SPECIES.*

By DAVID STARR JORDAN, President of Stanford University.

IN "Evolution and Animal Life," by Jordan and Kellogg (page 120), the following words are used:

"Given any species, in any region, the nearest related species is not to be found in the same region nor in a remote region, but in a neighboring district separated from the first by a barrier of some sort or at least by a belt of country, the breadth of which gives the effect of a barrier."

Substituting the word "kind" for species in the above sentence, thus including geographical subspecies, or nascent species, as well as species clearly definable as such, Dr. J. A. Allen accepts this proposition as representing a general fact in the relations of the higher animals. To this generalization Dr. Allen, in *Science*, has given the name of "Jordan's Law." The present writer makes no claim to the discovery of this law. The language above quoted is his, but the idea is familiar to all students of geographical distribution and goes back to the master in that field, Moritz Wagner. Dr. Wagner was one of the most clear-sighted and long-headed men of the early evolutionists. In recognizing the potency of isolation in species-forming he made the mistake, however, of not recognizing selection as the basis of adaptation.

This law rests on the fact that the minor differences which separate species and subspecies among animals are due to some form of segregation or isolation. Selection produces adaptation, but the distinctive characters of species are in general non-adaptive. They find their origin in the different currents of life which isolation makes possible. By some barrier or other the members of one group are prevented from interbreeding with those of another minor group or with the mass of the species. As a result, local peculiarities arise. "Migration holds species true, localization lets them slip," or rather leaves them behind in the process of modification. The peculiarities of the parents in an isolated group become intensified by in and in breeding. They become modified in a continuous direction by the selection induced by the local environment. They are possibly changed in one way or another by germinal reactions from impact of environment. At last a new form is recognizable. And this new form is never coincident in its range with the parent species, or with any other closely cognate form, neither is it likely to be located in some remote part of the earth. Whenever the range of two such forms overlaps in any degree, the fact seems to find an

* Most of this paper was published in the *American Naturalist*, vol. 42, pp. 73-80, February, 1908, under the same title.

explanation in reinvasion on the part of one or both of the forms. The obvious immediate element in the formation of species is, therefore, isolation, and behind this are the factors of heredity, of variation, of selection, and others as yet more or less hypothetical. The formation, through segregation, of different breeds of sheep in the different countries of England, as noted by Jordan and Kellogg (p. 82), seems exactly parallel with the formation of species in nature. In like manner, the occasional development of breeds arising from the peculiarities of individuals is possibly parallel with the "mutations" of the evening primrose. It seems to me probable, however, that these mutations are phenomena of hybridism. Such breeds are the Ancon sheep in Connecticut and the blue-cap Wensleydale sheep in Australia. The hornless Hereford cattle lately established in Kansas is a case in point. The "ontogenetic species"—groups in which many individuals are simultaneously modified in the same way by like conditions of food or climate—show no permanence in heredity. Such forms, however strongly marked, should, therefore, have no permanent place in taxonomy. The recent studies of Mr. Beebe on the effects of moist air in giving dusky colors to birds serve to illustrate the impermanence of the groups or subspecies characterized by dark shades of color developed in regions of heavy rainfall. These dark shades are not inherited and are not constant in the same individual if it is brought under new conditions.

It may also be noted in passing that one cause of the potency of artificial selection among domesticated animals or cultivated plants is that such selection is always accompanied by segregation. The latter is taken for granted in discussions of this topic and hence its existence as a factor is usually overlooked. While poultry or pigeons can be rapidly and radically changed by artificial selection, in isolation, no process of selection without isolation can have any permanent result. For example, we know no way of improving the breed of salmon, because the salmon we have selected for reproduction must be turned loose in the sea, where they are at once lost in the mass.

New forms of gold fish, carp and other domesticated fishes can be made easily by selection, because these fishes can be kept in aquaria or in little ponds, but new forms of mackerel or herring are beyond the control of man and the species actually existing have been of the slowest creation, their origin lost in geologic times.

One of the most interesting features of "Jordan's law" is the existence of what I have termed *geminate* species—twin species—each one representing the other on opposite sides of some form of barrier. In a general way, these geminate species agree with each other in all the respects which usually distinguish species within the same genus. In all matters of selection and adap-

tation they are absolutely identical. They are usually identical in habits. They differ in minor regards, characters which we may safely suppose to be of later origin than the ordinary specific characters in their group. Illustrations of geminate species of birds, of mammals, of fishes, of reptiles, of snails, or of insects, are well known to all students of these groups, and illustrations may be found at every hand.

Each island of the West Indies, which is well separated from its neighbors, has its own form (species or subspecies) of golden warbler (*Dendroica aestiva*). Each island in the South Seas has its geminate forms of reptiles or fishes. Each island of the Hawaiian group has its own representative of each one of the types or genera of *Drepanidæ*. Each of the three groups of rookeries in Bering Sea has its own species of fur seal. *Callorhinus alascanus* on the Pribilof Islands, *C. ursinus* on the Commander Islands, and *C. curilensis* of the Kuriles and Robben Islands, these species most clearly related but showing no intergradations, because no intercrossing is possible, each having its own distinct line of migrations.

Similar conditions exist among species of fresh water fishes, the world over. Dr. Ortmann has described the conditions of species forming through isolation in the river cray fish (*Cambarus*); Dr. Gulick in the land snails (*Helix*) and various writers in the river mussels (*Unionidæ*).

Most clearly marked cases of geminate species occur among the fishes on the two sides of the isthmus of Panama. Living under essentially the same conditions, but separated since the end of the Miocene Period by the rise of the isthmus, we find species after species which has been thus split into two. These geminate species, a hundred or more pairs in number, were at first regarded as identical on the two shores of the isthmus. Later one pair after another was split into recognizable species. The latest authority on the subject, Mr. C. T. Regan, seems to doubt if any species of shore fishes are actually identical on the two sides of the isthmus.

To make this clear, though at the risk of being tedious, I give below a partial list of these genuine species about the isthmus of Panama:

Atlantic Coast	Pacific Coast
<i>Harengula humeralis</i>	<i>Harengula thrissina</i>
<i>Clupanodon oglinus</i>	<i>Clupanodon libertatis</i>
<i>Centropomus undecimalis</i>	<i>Centropomus viridis</i>
<i>Centropomus pedimacula</i>	<i>Centropomus medius</i>
<i>Centropomus affinis</i>	<i>Centropomus ensiferus</i>
<i>Epinephelus adscensionis</i>	<i>Epinephelus analogus</i>
<i>Alphestes afer</i>	<i>Alphestes multiguttatus</i>
<i>Dermatolepis inermis</i>	<i>Dermatolepis punctatus</i>
<i>Hypoplectrus unicolor</i>	<i>Hypoplectrus lamprurus</i>

Atlantic Coast	Pacific Coast
<i>Lutianus cyanopterus</i>	<i>Lutianus novemfasciatus</i>
<i>Lutianus apodus</i>	<i>Lutianus argentiventris</i>
<i>Lutianus analis</i>	<i>Lutianus colorado</i>
<i>Lutianus synagris</i>	<i>Lutianus guttatus</i>
<i>Hæmulon album</i>	<i>Hæmulon sexfasciatum</i>
<i>Hæmulon parra</i>	<i>Hæmulon scudderi</i>
<i>Hæmulon schrancki</i>	<i>Hæmulon steindachneri</i>
<i>Anisotremus surinamensis</i>	<i>Anisotremus interruptus</i>
<i>Anisotremus virginicus</i>	<i>Anisotremus taniatus</i>
<i>Conodon nobilis</i>	<i>Conodon serrifer</i>
<i>Pomadasis croco</i>	<i>Pomadasis branicki</i>
<i>Calamus macrops</i>	<i>Calamus taurinus</i>
<i>Xystæma cinereum</i>	<i>Xystæma simillimum</i>
<i>Eucinostomus pseudogula</i>	<i>Eucinostomus dowi</i>
<i>Kyphosus incisor</i>	<i>Kyphosus analogus</i>
<i>Isopisthus parvipinnis</i>	<i>Isopisthus remifer</i>
<i>Nebris microps</i>	<i>Nebris zestus</i>
<i>Larimus fasciatus</i>	<i>Larimus pacificus</i>
<i>Odontoscion dentex</i>	<i>Odontoscion xanthops</i>
<i>Corvula sialis</i>	<i>Corvula macrops</i>
<i>Bairdiella veræ-crucis</i>	<i>Bairdiella armata</i>
<i>Micropogon furnieri</i>	<i>Micropogon ectenes</i>
<i>Umbrina broussoneti</i>	<i>Umbrina xanti</i>
<i>Menticirrhus littoralis</i>	<i>Menticirrhus elongatus</i>
<i>Eques acuminatus</i>	<i>Eques viola</i>

This list may be greatly extended, but the series noted will illustrate the point in question. Whenever a distinct and sharply defined barrier exists, geminate or twin species may be found on the two sides of it, unless, as sometimes happens, the species has failed to maintain itself on one side or the other of the barrier. So far as Panama is concerned, we have evidence that the barrier was raised near the end of Miocene time with no trace of subsequent depression. We can thus form some estimate of the age of separation in at least a small number of closely related species. In this and similar cases it is not possible to conceive of the formation of these species by sudden mutation, or that they would retain their separate existence were the element of segregation removed. While segregation or isolation is not a force, and perhaps not strictly a cause in species formation, it is a factor which apparently can never be absent, if the species retains its independent existence.

There is no doubt that the distribution of higher animals in general is in accord with "Jordan's law." Examples by the thousand come up from every hand. If we had a hundredth part of the amount of available evidence in support of mutation theories, these theories would pass from the realm of

hypothesis into that of fact. But the application of this law or rule to plants and to one-celled animals has been questioned. So far as rhizopods are concerned, Dr. Kofoed finds that the species are in general sharply defined and of the widest distribution in the sea, so that we can hardly state laws as defining their geographical distribution. To these minute floating animals, the sea scarcely offers barriers at all, and the recognized species do not seem to be products of geographical isolation. Doubtless these species in duration and in nature correspond more nearly to genera or families of higher animals than to actual species. Perhaps minor specific differences such as we note among arthropods or vertebrates are intangible or non-existent. The effects of isolation may be tangible only among forms which possess more varied relations with their environment.

The application of this law to plants has also been denied. But geminate species are just as common in botany as in zoology, and the effects of isolation in species-forming are just as distinct. The law is just as patent in the one case as in the other. It is merely obscured by other laws or conditions which obtain among plants.

In the nature of things, most physical barriers are more easily crossed by plants than by animals. The possibilities of reinvasion are thus doubtless much increased. The plant is limited by climate, rainfall, nature of soil, and the same species is likely to occupy all suitable locations within a large area. Animals are more mobile than plants within their range, a fact which tends to keep the interbreeding masses more uniform. In the struggle for existence, the plant is pitted against its environment. Whether the plant survives or not depends not much on the nature of the seed, but mainly on its relation to the spot on which it falls. There is little selection within the species due to the choice of one individual as against another. Selection can only happen where plants are overcrowded, and there the survival is mainly that of the seed whose roots run deepest. There is little room for struggle between closely related species. Each individual grows—if it can—on the spot where it falls. The variations among plants are great, but these variations are mostly lost unless reinforced by segregation. There is no likelihood of the survival of DeVries' mutants (or hybrids) of the evening primrose if these forms are left free to mix in the same field.

Among plants we often notice the fact—rare, though not unknown among animals—of numerous species of the same genus occupying the same area. In some cases these species are closely related, suggesting mutants, and in other cases the relation indicates the existence of hybrids. In California, for example, there are in the same general region many species of *Lupinus*, of *Calochortus*, of *Ceanothus*, of *Arctostaphylos*, of *Eschscholtzia*, of

Godetia, of *Cenothera*, and *Opuntia*. *Eucalyptus*, *Acacia* and *Epacris* in Australia are examples even more striking. But I have never seen very closely related or geminate forms in any of these genera actually growing together. I suspect that they do so sometimes and that the explanation is found in reinvasion. Dr. G. H. Shull of the Carnegie Station for Experimental Evolution tells me that most of these plants are self-fertilized, a condition unfavorable to Panmixia or the loss of the individual or local variation in the mass. Self-fertilized plants may be neighbors without really "growing together." But "growing together" is an indefinite statement as applied to plants. The elder, the alder and the madroño (*Arbutus*) abound in the Santa Clara Valley. But no one ever saw any two of these trees standing side by side. Each has its limitations, as to soil and moisture, and its own choice of locations.

Setting aside these genera which are represented by many species in a limited area, and among which mutation, hybridism and self-fertilization may be conceivable factors in species-forming, we find the law of geminate species applying to plants as well as to animals. Crossing the temperate zone anywhere on east and west lines, we find species after species replaced across the barriers by closely related forms. Illustrations may be taken anywhere among the higher plants—equally well, no doubt, among lower ones. Many genera are local in their distribution, monotypic—with a single species, the origin of which cannot be traced. Such species spread far and wide without visible change within the species. But many other genera belt the earth or come very near doing so, each form or species being geminate as related to its next neighbor. This fact is illustrated in *Rubus*, *Alnus*, *Sambucus*, *Platanus*, *Fagus*, *Veratrum*, *Symplocarpus*, *Symphoricarpus*, *Castanea*, *Quercus*, *Pinus*, *Tsuga*, *Acer*, *Rhus*, *Pyrus*, *Prunus*, *Lonicera*, *Ranunculus*, *Trientalis*, *Lilium*, *Trillium*, *Veronica*, *Aquilegia*, *Gentiana*, *Viola*, *Epilobium*, *Pteris*, *Mimulus*, *Trifolium*, *Solidago*, *Aster*, *Helianthemum*, *Triosteum*, *Geranium*, *Ribes*, *Asarum*, *Habenaria*, *Saxifraga*, *Clintonia*, *Calycanthus*, *Fraxinus*, *Philadelphus*, *Cratægus*, *Azalea*, *Erythronium*, *Rhododendron*, *Viburnum*, *Cornus*, *Cercis*, *Eupatorium*. All these genera and many others furnish an abundance of examples. It would be hard to find a widely-distributed genus which did not.

Taking a single example, the pink-flowering raspberry of the eastern United States, *Rubus odoratus*, becomes on the Pacific Slope the white-flowered *Rubus parviflorus*, ("nutkanus"). On the California sea coast, *Rubus velutinus*, with tasteless fruit, again takes the place of the latter. The black raspberry, *Rubus occidentalis*, is replaced westward by its double, *Rubus leucodermis*. The common blackberry, *Rubus villosus*, is replaced in the eastern

hills by *Rubus alleghaniensis* and in the far west by *Rubus vitifolius*, while still other species surround the world, taking its place in Europe and in Asia.

We may, therefore, say that with plants as well as animals geminate species as above defined owe their distinctness to some form of isolation or segregation, and that, broadly speaking, with occasional exceptions, given any form of animal or plant in any region, the nearest related form is not to be found in the same region nor in a remote region, but in a neighboring region, separated from the first by a barrier of some sort, not freely traversable.

A law, that is, an observed relation of cause and effect, is not invalidated by the presence of other effects due to other causes in the same environment. The actual conditions in nature are everywhere not products of single and simple forces, but resultants of many causative influences, often operative through the long course of ages. As a rule, also, related species in almost every group are connected by a fringe of intergradations we call subspecies. If barriers are sharply defined geminate species are sharply defined, also. If barriers are diffuse, we find geographical subspecies connecting them, either wholly or in part. There is no difference between a subspecies and a true species except that which is involved in sharpness of definition. If the barrier cannot be crossed, the species dependent on the barrier is well defined and therefore unquestionable, however small the elements of difference. A subspecies, if real, is always based on some matter in geographical distribution.

It may be urged that these geminate groups or forms are not true species because they often intergrade one into another, and they would probably be lost by intermingling if the barriers were removed. It is sometimes claimed that only physiological tests of species can be trusted, as true species will not blend and their hybrids, if formed, will be sterile. All this is purely hypothetical and impracticable to the systematic zoologist, and not of much value to the botanist. Interbreeding is no test of species. Closely related species in almost any group of plants or animals can usually be readily crossed. As the relation becomes less close, partial sterility of all grades and then total sterility appear.

If the term species has any meaning at all, those species we find in nature are real *species*. Nothing can be more real than that which actually exists. And real species have, as a rule, indefinite boundaries, shading off into subspecies, geminate species, ontogenetic forms and the like. In these eccentricities we must humor them. As Darwin observed, these peculiarities are fascinating to us "as speculatists" however "odious" they are to us "as systematists." And if we are to understand the significance of nature, we have

to describe these facts and relations as they actually are. Then we have to find out what changes we can work in individuals and species by such alterations of conditions as experiment can give.

We do not know actually any species of animal or plant until we know all changes that would or could take place in its individuals under all conditions of environment.

P. S.—Since this was written I have received the charming sketch of Linnæus by Professor Edward Lee Greene. In a discussion of Linnæus as an evolutionist Mr. Greene shows very clearly that the great botanist had in mind the same fact as to the relation of species which I have indicated in this paper. In a note on *Thalictrum lucidum* referring to the geminate form, he says, "This plant is possibly not very distinct from *T. flavum*. It seems to me to be the product of its environment." Of these species of meadow rue, *flavum* belongs to the cool moist meadows of northern Europe, and *lucidum* to southern France and Spain.

Referring again to the seaside Virgin's Bower, *Clematis maritima*, he says, "Magnol and also Ray have adjudged this to be a variety of *C. flammula*. I should rather think it is derived from *C. recta* under altered conditions."

As to the Siberian yarrow, as compared to the common yarrow of Europe, he says, "May not the Siberian mountain soil and climate have moulded this out of *A. ptarmica*?"

Comparing two species of *Kosteletzkya (Hibiscus)*, one from the Adriatic region, the other from the salt marshes of our southern states, he asks, "May not the Venetian species have sprung from the Virginian?"

Dr. Greene mentions other cases of a similar sort, but these will show that the idea of geminate species split off from the parent by separation and changed conditions was present with the great botanist.

SOME RELATIONS BETWEEN SALT PLANTS AND SALT-SPOTS.

By WILLIAM AUSTIN CANNON, Desert Laboratory, Tucson, Arizona.

ONE of the characteristic environmental factors which desert plants must successfully meet is the high salt content of the soils. This is especially true of such areas as have poor surface drainage and where water is removed only by evaporation, leaving the salts behind and forming the highly saline areas commonly known as salt-spots. In the salt-spots the most important salts are those of sodium. From these conditions it appears that such perennials as live in areas where the salt content of the substratum is relatively high must not only be able to extract water from a relatively highly concentrated soil solution, but must be able to endure the salts of whatever kind as such. In addition to these conditions the salt plants live in a climate otherwise very arid. The physiological activities of halophytes are accordingly of great interest in that they appear to include an especially high osmotic efficiency as well as immunity to the salts of sodium. Their divergence in these regards from many desert plants, and especially from mesophytes, is thus very great.

VEGETATION OF A SALT-SPOT NEAR TUCSON.

A salt-spot of considerable extent lies on the edge of the flood-plain of the Santa Cruz river along the old Fort Yuma road about four miles northwest of the city of Tucson. The area is more or less sharply set off from the surrounding bottom land by the surface depression, but especially by the high salt content of the soil and by the halophytic character of its perennial plant covering. The vegetation of the non-salt lands adjoining the salt-spot is made largely of *Prosopis velutina* (the mesquite), two or three Acacias, *Atriplex canescens*, *Bigelovia hartwegii*, *Koerberlinia spinosa*, *Suaeda suffrutescens* and *Zizyphus lycioides*. Of these plants *Prosopis* and *Bigelovia* occur also along the washes which traverse the salt-spot. Among the plants which are typical of the salt-spot proper are at least four species of *Atriplex*, namely, *canescens*, *elegans*, *nuttallii* and *polycarpa*. In addition to these there may be found species of *Lycium* and small specimens of *Suaeda* (*Dondia*).

Generally speaking, the salt plants have a well-marked zonal distribution. As one enters the spot he encounters *Atriplex canescens* and no other salt bush. But associated with *A. canescens* are small specimens of *Prosopis* and *Bigelovia* in abundance. This zone is referred to in this paper as the *canescens* zone. As one passes through this zone on his way to the more cen-

tral portion of the salt-spot he enters the *polycarpa* zone, where such non-salt loving plants as are found there are along the washes only. Still nearer the center of the spot *A. nuttalli* is met and with it *A. elegans* and dwarfed specimens of *Suaeda suffrutescens*. In places where there are evidently less salts, species of *Lycium* and *Prosopis* occur along the washes. The inner area is called here the *nuttalii* zone. At the very center of the spot there are no plants and the surface of the ground usually shows white incrustations of salts.

CHARACTER OF THE SOIL.

The soil of the Santa Cruz river bottoms is largely "adobe," but that of the salt-spot is a fine sandy loam. Mechanical and chemical analyses made by the Bureau of Soils, U. S. Department of Agriculture, of samples of soil taken from the center of the spot are, for the upper 12 inches, as follows: Clay, 33.3% ; silt, 21.5% ; very fine sand, 17.0% ; fine sand, 23.5% ; medium sand, 2.6% ; coarse sand, 2.0% ; fine gravel 0.1%.

Table 1. Analysis of soil from salt-spot.¹

CONSTITUENTS		CALCULATED COMBINATIONS	
Ca	trace	MgSO ₄	3.38%
Mg	.70%	Na ₂ SO ₄	70.78
Na	29.45	KCl	4.42
K	2.33	NaCl	5.94
So ₄	50.53	NaHCO ₃	15.48
Cl	5.70		
HCO ₃	11.29		

The salts are not uniformly distributed in the soil. The total soluble salts in the first foot, as determined by resistance tests made by the Bureau of Soils, is 1.72% ; in the second foot, 1.0%, and in the third foot, 1.3%. The salt content was not observed at a greater depth than three feet. Observations on the resistance of the soil solutions, which the writer made with an electric bridge of the type used by the Bureau of Soils², showed that the

¹ Analysis furnished by the Bureau of Soils, U. S. Dept. of Agriculture. The soil was from 1-12 inches deep taken from the center of the salt-spot, Tucson.

² The instrument employed in these tests was kindly loaned me by Prof. R. H. Forbes, Arizona Experiment Station.

salts are likewise unequally distributed horizontally. Following is presented the typical resistance of soil solutions for different portions of the salt-spot; the results have not been reduced to percentages:

Table 2. Resistance in ohms of soil solutions of salt-spot near Tucson.

	1ST FOOT	2D FOOT	3D FOOT
<i>Canescens</i> zone	1100 ohms	1350 ohms	850 ohms
<i>Polycarpa</i> zone	160 ohms	350 ohms	225 ohms
<i>Nuttallii</i> zone	320 ³ ohms	31 ohms	34 ohms

The field tests show, then, that the salts are most abundant in the *nuttallii* zone, and least abundant in the *canescens* zone, and in the zone between the two they are intermediate in amount. A detailed study of the salt-spot would show a secondary variation in the quantities of salts in the soil, as where the washes, which are flooded with each heavy rain, run into and through the spot. In such places the soil is leached and, as above stated, makes possible the invasion of less resistant salt plants and even of non-salt plants.

CHEMICAL ANALYSES OF SALT PLANTS.

The observed zonal distribution of the salt plants taken in connection with the marked vertical and horizontal distribution of the salts in the soil, suggested the desirability of conducting an inquiry into the character of the constituents of the plants themselves. This was done along two lines, namely, by chemical analysis⁴, and electric resistance.

³ This anomalous condition is not explained in the notes. In dry seasons the ground at this place is covered with an incrustation of salts.

⁴ The chemical analyses were made by Mr. William H. Walker, Laboratory of Physiological Chemistry, Columbia University, and through the kindness of Professor Wm. J. Gies.

Table 3. Summary of analytic results in percentages.
(Analysis of William H. Walker.)⁵

	<i>Atriplex polycarpa</i>		<i>Atriplex nuttallii</i>		<i>Atriplex canescens</i>	
	FOUND	CALCULATED FOR WATER FREE ASH	FOUND	CALCULATED FOR WATER FREE ASH	FOUND	CALCULATED FOR WATER FREE ASH
Si O ₂	1.93%	2.00%	4.69%	4.72%	1.68%	1.71%
Fe ₂ O ₃ , P ₂ O ₅ , Al ₂ O ₃	1.44	1.50	2.63	2.65	2.87	2.92
Fe ₂ O ₃	0.31	.32	0.44	0.44	0.61	0.62
P ₂ O ₅	1.10	1.15	0.87	0.88	1.89	1.92
Al ₂ O ₃	0.03	.03	1.32	1.33	0.37	0.38
CaO	15.93	16.54	8.27	8.33	17.31	17.59
MgO	7.00	7.26	3.66	3.69	10.35	10.51
SO ₃	3.70	3.84	5.17	5.21	8.40	8.56
Cl	9.11	9.43	24.56	24.74	9.15	9.30
CO ₂	19.82	20.57	11.67	11.76	15.00	15.24
Na ₂ O	18.88	19.60	26.58	26.77	1.74	1.80
K ₂ O	18.56	19.26	12.04	12.13	31.85	32.37
H ₂ O (by difference)	3.63	0.73	1.65

The following supplemental report was sent later by Prof. Gies (April 22, 1907) :

Table 4. Results obtained by washing the ashes free from chloride.

	INSOLUBLE MATTER	SOLUBLE MATTER
<i>Atriplex nuttallii</i>	20.80%	79.20%
<i>Atriplex polycarpa</i>	33.01%	66.99%
<i>Atriplex canescens</i>	37.725%	62.275%

SUMMARY OF TESTS OF ELECTRIC RESISTANCE OF PLANT SOLUTIONS.

The electric resistances of the plant solutions were determined by the use of the same apparatus as was employed in testing soil solutions. Several methods were used in preparing the material for testing, as follows: *Air dry* leaves and young twigs were boiled in water for five minutes, and the solution expressed by the use of a small press. *Fresh leaves* and young twigs were

⁵ The figures in the first of each pair of columns are averages of closely agreeing results in duplicate. The second column of each pair gives the figures for corresponding percentage contents in water-free material.

treated in a similar manner. As a control, a portion of air-dry material, which had been boiled, was left one-half hour in cool water, after which the solution was expressed as usual. The method usually followed was to bring the plant to the laboratory and allow it to become air-dry. A 10% solution was then prepared, which was boiled five minutes. The fluid was expressed and allowed to cool.

Very many tests were made mainly on the salt plants named, and also on other non-salt forms. The results were so consistent that it will not be necessary to give more than a single representative experiment.

Table 5. Electric resistance of plant solutions.

Canescens Zone.

	OHMS	TEMPERATURE OF SOLUTION
<i>Atriplex canescens</i>	65	30° 0 C.
<i>Bigelovia hartwegii</i> ⊙	115	28° 5 C.
<i>Prosopis velutina</i> ⊙	400	28° 0 C.

Polycarpa Zone.

<i>Atriplex polycarpa</i>	35	28.0° C.
<i>Suaeda suffrutescens</i>	25	id
<i>Bigelovia hartwegii</i> ⊙	110	id
<i>Atriplex canescens</i> ⊙	70	id
<i>Lycium</i>	67	id

Nuttallii Zone.

<i>Atriplex nuttallii</i>	25	28.0° C.
<i>Suaeda suffrutescens</i>	42	id
<i>Prosopis velutina</i> ⊙	280	id

The averages of five resistance tests of solutions of salt plants, made at various times during the summer, are as follows: *Atriplex canescens*, 41 ohms; *Atriplex polycarpa*, 23.9 ohms; *Atriplex nuttallii*, 18.2 ohms⁷.

⁶ These plants were situated in some of the small washes which traversed the salt-spot.

⁷ A verification of the relative results obtained by the use of the bridge was obtained by freezing plant solutions previously tested electrically. The following were some of the results:

	ELECTRIC RESISTANCE	FREEZING POINT
<i>Atriplex canescens</i>	70.0 ohms	-0.2° C.
<i>Atriplex polycarpa</i>	29.0 ohms	-0.3° C.
<i>Atriplex nuttallii</i>	16.5 ohms	-0.4° C.

SOME INFERENCES AND CONCLUSIONS, AND SUMMARY.

The most important findings of the present study, together with suggestions as to their possible significance, may be briefly presented.

Chemical analyses of three species of halophytes, which occur naturally in a certain salt-spot, or area, where there is a large amount of "white alkali," near Tucson, show, among other features, that the amount of salts, as well as the kind, is unlike and is characteristic for the species. It is found also that certain elements, especially sodium and calcium, are present in unlike amounts in the ash of these plants. The relation of sodium and calcium in the salt plants, and in mesophytes, based on data already presented, is given in the following table:

Table 6. Calcium and sodium in plants, in per cent, with the

ratio $\frac{\text{Ca}}{\text{Na}}$

	Ca	Na	$\frac{\text{Ca}}{\text{Na}}$
Cultivated plants.....	7.9	3.1	2.5
Fresh water plants.....	43.75	8.58	5.1
<i>Atriplex canescens</i>	17.31	1.74	9.8
<i>Atriplex polycarpa</i>	15.93	18.88	.84
<i>Atriplex nuttallii</i>	8.27	26.58	.31
Saltwater plants.....	12.88	24.81	.31

Electric resistance tests were carried out on the same species of halophytes as were subjected to analysis. These showed in general that the resistances were characteristic for any given species. *Atriplex canescens* had the highest and *A. nuttallii* had the lowest resistance.

Physical and chemical studies of the alkali soil were also made. Sodium salts were found especially abundant and calcium salts were present as a trace only. The salts were found to be most abundant at the center of the salt-spot and to become less gradually as the periphery of the spot was approached.

Combining the observations on both plants and soil we find, therefore, that the center of the salt-spot, where the soil solution is most dense and

carries the most sodium salts, is inhabited by the species, *A. nuttallii*, which contains the largest amount of soluble salts and also the largest proportion of sodium. It has also the least amount of calcium. The species which occupy the outer portion of the salt-spot, where the salts are least in amount, are those which contain the least amount of sodium and the largest of calcium. From these facts it is inferred that there is probably an increase in the osmotic pressure in the different species as one goes from the periphery of the salt-spot to the center, and that among the substances which contribute to this effect the salts of sodium may find an important place. Whether there is also an increase in such osmotically active organic substances as are not electrolytes, the inference necessarily leaves out of consideration.

It has already been stated that the relative amounts of sodium and calcium in the different species of salt plants are unlike, Na being most abundant in such species as contain the lowest proportion of Ca and *vice versa*. These facts are so striking that they may have a special bearing beyond the well known facility of plants of storing up in insoluble form certain salts. There may be some relation, also, with the occurrence of salts in the soil solution. It is known⁸ that lime, when applied to certain alkali soils, serves as a correction, making such soils more tolerable for mesophytes. It should be noted that in such conditions the soil solution is probably made more dense. Osterhout⁹ has shown that calcium holds an antagonistic relation to sodium by which the latter may be prevented from entering the protoplast. Applying these findings to the case in hand, it may be concluded that the salt-spot in question, if treated with a proper amount of calcium salts, might support an entirely different type of vegetation, or that the kinds of salt plants inhabiting it would be different than at present, owing probably to the absence of the more intensely halophytic species. In such a case, the density of the soil solution would play a minor rôle. The findings of the present study also indicate that the most intense halophytes absorb salts of sodium in large amounts without injury, and that it is due to this that such species can survive where such salts constitute the leading features of the substratum.

⁸ Some mutual relations between alkali soils and vegetation. Kearney and Cameron. U. S. Dept. Agric. Rep. No. 71, 1902.

⁹ The permeability of protoplasm to ions and the theory of antagonism, Science, N. S., Vol. 35, page 112, 1912. The permeability of living cells to salts in pure and balanced solutions, Science, N. S., Vol. 34, page 187, 1911.

NORTH AMERICAN SPECIES OF THE GENUS AMYGDALUS.¹

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THE SPECIES which form the subject of the present paper have been referred to both *Prunus* and *Amygdalus* by various authors who have had occasion to consider them. They are, however, so distinct from all other species of *Prunus* in America as at once to suggest the propriety of constituting a new genus. This in fact was done by Torrey² for one species of the group, he having published the genus *Emplectocladus* in 1854. Notes on a few specimens in the herbarium of the Muséum d'Histoire Naturelle at Paris indicate that Spach who studied the *Amygdalaceæ* as thoroughly as any one of his time, also had under consideration the recognition of the genus *Emplectocladus*. A study of the material preserved in some of the European herbaria, however, shows conclusively that they cannot be separated from certain Asiatic species which are referred to *Amygdalus* by authors, who recognize the latter as a genus distinct from *Prunus*. In fact, the Asiatic species apparently show a gradual but complete transition from this North American group to the species of *Amygdalus* common in cultivation. Again, while the groups *Padus* and *Laurocerasus* appear to be separable from true *Prunus* by well-defined characters, it must be admitted that when all the species are considered, the groups *Prunus* and *Amygdalus* show no such well-marked diagnostic characters, even though their extremes are different enough. Nevertheless, unless these two groups are recognized as separate genera, to speak or write of a given species as belonging to *Prunus* conveys little conception of its true character, or to what economic species it may be most closely related. Since nomenclature cannot well be made to express accurately the relationship of species, but is, first of all, a matter of convenience, the present author would retain the name *Amygdalus* for the peach and almond-like species. And while this group may not be readily

¹ In the preparation of this paper the author has consulted the material in the following herbaria: the Gray Herbarium, Arnold Arboretum, New York Botanical Garden, United States National Herbarium, Missouri Botanical Garden, Field Museum, University of California, Leland Stanford Jr. University, Kew Gardens, and the Muséum d'Histoire Naturelle of Paris. The curators of these collections have kindly made available the material in their charge and for this the writer wishes to express his appreciation.

² Torrey, John, *Smithsonian Contributions VI.* (*Plantae Fremontianæ* 10. t. 5. 1854.)

separated by prominent diagnostic characters, the species do form a fairly natural group and the name *Amygdalus* at once conveys to the mind characters very different from those associated with true *Prunus*.

AMYGDALUS TEXANA (Dietr.) W. F. Wight.

Amygdalus glandulosa Hook. Ic. Pl. 3:t. 288. 1840.

Prunus glandulosa Torr. & Gray, Fl. N. Am. 1: 408. 1840.

Prunus texana D. Dietr. Syn. Pl. 3: 45. 1843.

Prunus hookeri Schneider, Hanb. Launholz. 1: 597. 1905.

Leaves oval to oblong-oval, mostly 14 to 25 mm. or sometimes 30 mm. long on young succulent shoots, 6 to 15 mm. broad, slightly narrowed toward the base, mostly obtuse at the apex, green and pubescent above, grayish to mentose below, the margins conspicuously glandular-serrate; petioles 1 to 4 mm. long, pubescent; stipules linear and glandular. Flowers appearing in March with or slightly before the leaves, solitary or in twos, 10 to 12 mm. broad; pedicels 3 to 4 mm. long, grayish pubescent; calyx pubescent, the tube about 2 mm. long, the oblong-ovate lobes as long and glandular-serrate; petals apparently white, oblong, 4.5 to 6 mm. long, obtuse at the apex and abruptly narrowed to a very short claw. Fruit rather densely velvety-hairy, apparently maturing in June; stone ovoid 13 to 15 mm. long, 11 mm. broad and 9 mm. thick, usually rounded at the base, pointed at the apex and slightly flattened toward the ventral edge but rounded on the dorsal side, the surface smooth.

A dwarf bushy shrub with very irregular branches and grayish bark, that of the young branchlets light-gray and strongly pubescent. It occurs only in Texas, where it is found in granitic soils from between Laredo and Bejar, the type locality of Hooker's material preserved in the Kew Herbarium, to Llano and Mason Counties and eastward to Hampstead.

The specific name *glandulosa* was used earlier for a different species by Thunberg and the name *hookeri* was published by Schneider for this reason. There appears, however, to be nothing to prevent the use of Dietrich's name *texana*, which was doubtless overlooked by Schneider. The original description by Dietrich was based on a specimen collected by Drummond but for which the locality is not given.

Specimens examined: Texas; Stevens Bend, Colorado River, Lampasas Co., C. S. Mason, 1910. Hoover's Hill, near Kingston, C. S. Mason, Mar. 26, 1910. Llano Co., Reverchon, May, 1885. Big Branch, Gillespie Co., G. Jermy. Sandy Plains, Hampstead, Elihu Hall, No. 189, June 4, 1872, San Antonio Wells on the Prairie road between Ringgold Banks and Laredo, G. H. Thomas, Feb., 1857. Kimble Co., I. Reverchon, No. 53, May, 1885.

Sandy region of Llano and Mason Co., I. Reverchon, May, 1885. Between Laredo and Bejar, Berlandier.

Without locality, Lindheimer, No. 236, 1844, Drummond. Hall, No. 189, 1872. Chas. Wright, 1848.

AMYGDALUS MICROPHYLLA H. B. & K.

Amygdalus microphylla H. B. & K. Nov. Gen. & Sp. Pl. 6: 243. t. 564. 1823.

Prunus microphylla Hemsl. Biol. Centr. Am. Bot. 1: 368. 1879-88.

Leaves with petioles about 1 mm. long, oblong-oval to oblong-oblongate, 10 to 15 mm. long, 3 to 6 mm. broad, glabrous on both surfaces at maturity but when immature often sparingly pubescent, narrowed toward the base, obtuse at the apex, the margins crenate-dentate and glandular when young, the glands in age remaining as callous mucronate-like points. Flowers appearing with or before the leaves on very short lateral spurs, one to three on each spur, the pedicels pubescent and 1 mm. or less long; calyx turbinate, about 3 mm. long, glabrous, the lobes 1 mm. long, obtuse and furnished with a few marginal glands; petals oval or obovate, obtuse, 1.5 mm. long and 1 mm. broad. Fruit in dried specimens about 12 mm. long, 9 mm. in diameter, oblong-ovoid, rounded at the base, terminated at the apex by a slight mucronate-like point; the exocarp dry and pubescent, dehiscent along the ventral side; stone about 10 mm. long, 8 mm. broad, slightly winged on the ventral side and with an indistinct groove along the dorsal edge, the surface smooth.

A small shrub with rather rigid branches and more or less spinescent branchlets, the bark of the young growth light gray and pubescent but becoming dark gray with age. The species was originally described from Mexico on dry hills between Pachuca and Moran at 7,800 feet altitude. It seems to have been rarely collected, as very little material is to be found in herbaria, either in Europe or America.

Specimens examined: Mexico; chiefly in the region of San Luis Potosi, 6,000 to 8,000 ft. alt., C. C. Parry and E. Palmer, No. 221, 1878. Prope El Gigante, Hartweg, No. 1602.

AMYGDALUS MINUTIFLORA (Engelm.) W. F. Wight.

Prunus minutiflora Engelm.; Gray, Bost. Journ. Nat. Hist. 6: 185. 1850.

Cerasus minutiflora Gray, Pl. Wright. pt. 1. 68. 1852.

Leaves oblong-oval, narrowed toward the 2 to 3 mm. long petiole and rounded at the apex, 7 to 20 mm. long, 5 to 8 mm. broad, pale below and glabrous on both surfaces, the margins sometimes slightly revolute, entire or occasionally irregularly toothed, glandless. Flowers appearing with the leaves in February or March on short lateral spurs, sessile or very nearly so,

one to four on each spur; calyx-tube campanulate with broadly ovate lobes about 1 mm. long; petals white, obovate, about 3.5 mm. long. Fruit maturing in June, globose, about 12 mm. long, 11 mm. broad and 10 mm. thick when dry, the exocarp thin and dehiscent along the ventral edge; stone turgid and with a smooth surface, grooved along the dorsal edge, the ventral edge rather thick with an inconspicuous groove a short distance from the margin.

A low shrub with irregular, often zigzag, scarcely spinescent branches, and grayish bark. It sometimes forms dense masses and occurs in Texas from the vicinity of New Braunfels westward to Devils River and the Rio Grande. It was originally described from "Hills and dry slopes between San Antonio and New Braunfels."

Specimens examined: Texas; Comanche Spring, New Braunfels, Lindheimer, No. 789, Mar., 1850. San Antonio, Mackensen, Feb. 20, and June, 1910. Valvada Co., C. S. Mason, May 10, 1910. Between New Braunfels and San Antonio, Lindheimer, No. 401, Mar., 1850. San Antonio, Geo. Thurber, Mar., 1853. San Felipe Creek, C. Wright, 1851. Without locality, Lindheimer, No. 388.

AMYGDALUS HARVARDII, W. F. Wight, sp. nov.

Leaves obovate to oblong-obovate or sometimes fan-shaped on young growth, 7 to 20 mm. long, 3 to 10 mm. broad, glabrous or sometimes finely pubescent on both surfaces, usually somewhat pale below and under a lens rather prominently reticulate veined, the margin conspicuously dentate toward the apex, very rarely toothed below the middle, the teeth usually acute and apparently glandless. Flowers appearing with the leaves and sessile; calyx slightly pubescent, the tube about 2.5 mm. long, the lobes scarcely more than 1 mm. long, entire and obtuse; petals not seen. Fruit sessile, nearly globular, the pubescent exocarp dehiscent along one edge, when dry about 9 mm. long, 7 mm. broad and 7.5 mm. thick; stone about 8 mm. long, 6.5 mm. broad and 7 mm. thick, rounded at the base and slightly pointed toward the apex, the surface smooth except for indistinct grooves near the ventral edge.

A shrub with rather rigid branches, stout spinescent branchlets and light gray bark. The type specimen in the United States National Herbarium was collected in fruit by V. Havard in July, 1883, in western Texas, east of the Chisas Mountains, near Bone Springs. It was also collected by C. C. Parry, J. M. Bigelow, Charles Wright and A. Schott on the Mexican Boundary Survey under the direction of Major W. H. Emery, this specimen being labeled "chiefly in the valley of the Rio Grande, below Doñana." The species is most closely related to *Amygdalus microphylla* H. B. & K. of Mexico, but is easily distinguished by its broader, more obovate leaves as well as by their reticulate venation and eglandular margins.

AMYGDALUS FASCICULATA (Torr.) Greene.

Amygdalus fasciculata Greene, Fl. Franciscana 49. 1891.

Emplectocladus fasciculata Torr. Smith. Contr. VI, (Pl. Fremont. 10. t. 5. 1854.)

Prunus fasciculata Gray, Proc. Am. Acad. 10: 70. 1874.

Leaves oblanceolate-spatulate, 6 to 12 mm. long, 1.5 to 2 mm. broad, gradually narrowed toward the base to an indistinct petiole, obtuse or sometimes acute at the apex, rather pale green and hirsute pubescent on both surfaces or sometimes very sparingly pubescent, only the midvein apparent, the margin entire or very rarely somewhat dentate and the teeth either glandular or eglandular. Flowers about 6 mm. in diameter, 1 to 3 on short spurs and sessile; the calyx glabrous without but hairy within, the tube about 2 mm. long, the lobes 1.5 mm. long; petals apparently white, oblanceolate. Fruit ovoid, when dry 8 to 10 mm. long, 7.5 mm. broad and 7 mm. thick borne on a pedicel 1.5 mm. long, the dry exocarp pubescent and dehiscent along one edge; stone about 8.5 mm. long, 6.5 mm. broad and 6 mm. thick, rounded at the base, pointed at the apex, somewhat winged and with a shallow groove on the ventral edge, the surface smooth.

A shrub with grayish or often whitish bark, numerous straight, scarcely spinescent branches, and sometimes pubescent young growth. The specimens from which this species was originally described were collected by Colonel Fremont, but their labels had been lost and the locality from which they were obtained is therefore unknown, though the author of the species says "Sierra Nevada of California; probably in the southern part of the range." The species is known to occur from southern Utah through southern Nevada and northern Arizona to the slopes of the southern Sierra Nevada, and the San Bernardino Mountains of California. A specimen has also been seen labeled "Santa Maria, Santa Barbara County, California."

Specimens examined: Utah; southern Utah, C. C. Parry, 1874. St. George, at 2000 ft. alt., M. E. Jones No. 1630, April 5, 1880. Southern Utah, Dr. Palmer No. 135, 1877. Valley of the Virgin, C. C. Parry No. 56, 1874. St. George, Dr. Palmer, 1871. Silver Reef, M. E. Jones, 1894.

Nevada; Mormon Mts., Lincoln Co., at 6000 ft. alt., Kennedy and Gooding No. 140, July, 1906. Rocky hillsides, Calientes, L. N. Gooding No. 609, April 26, 1902. Kernon, L. N. Gooding No. 652, April 28, 1902. Washes in the Palmetto Range at 6-7000 ft. alt., C. A. Purpus No. 5852, May-Oct., 1898.

Arizona; On trip to Castle Rock, near Tucson, D. Griffiths No. 2119, Nov. 17, 1900. Without locality, Dr. Palmer, 1876. Choride, at 4500 ft. alt., M. E. Jones, April 14, 1903.

New Mexico; "Western New Mexico," Dr. Bigelow on the Whipple Expedition.

California; Panamint Mts., Inyo Co., Coville & Funston No. 555, April 4, 1891. Mill Creek Canyon, Panamint Mts., at about 4200 ft. alt., Coville & Funston No. 801, May 20, 1891. Lone Pine Canyon, desert slopes of the San Gabriel Mts. at 4500 ft. alt., Abrams and MacGregor No. 668, July 5, 1908. Morongo Mts., Colorado Desert, S. B. & W. F. Parish, April, 1882. Mountains, Mojave Desert, S. B. & W. F. Parish, May, 1882. Sandy places, south fork of Kern River, at 2-3000 ft. alt., C. A. Purpus No. 5022, 1897. Santa Maria, Santa Barbara Co., L. Jared, 1882. Summit of Providence Mts., at 5000 ft. alt., J. G. Cooper, May 29, 1861. San Bernardino Mts., Pipe Canyon, S. B. Parish, June 16, 1894. Pleasant Canyon, Panamint Mts., 5500 ft. alt., M. E. Jones, May 6, 1897. Summit Cajon Pass, San Bernardino Co., at 4200 ft. alt., H. M. Hall and H. P. Chandler No. 6755, April 27, 1906. San Gabriel Mts., Los Angeles Co., L. R. Abrams and E. A. McGregor No. 525, July 3, 1908.

AMYGDALUS ANDERSONII (Gray) W. F. Wight.

Prunus andersonii Gray, Proc. Am. Acad. 7: 337. 1868.

Leaves sessile, oblong-oval to lanceolate, sometimes varying to oblanceolate on flowering shoots, 10 to 20 mm. long, mostly 3 to 6 mm. broad, cuneate toward the base and furnished with one to three glands or eglandular, acute at the apex or sometimes obtuse, light green and glabrous on both surfaces or slightly paler below, the margins with indistinct acute and eglandular serrations or entire. Flowers appearing in March and April, about 18 mm. broad in dried specimens, apparently solitary in pedicels 3 to 4 mm. long; the calyx glabrous, the tube broadly campanulate, about 2 mm. long, the lobes 1.5 mm. long, obtuse, pubescent within, the margins sparingly glandular or eglandular; petals pinkish, obovate or oblong and cuneate toward the base, 6 to 8 mm. long, 3 to 4 mm. broad; ovary hirsute. Fruiting pedicels rather stout, 6 to 10 mm. long; the fruit with a dry exocarp and pubescent but not densely so, slightly flattened and narrowed toward the base, usually rounded at the apex but furnished with a mucronate point, when dry 12 to 17 mm. long, 10 to 14 mm. broad; stone 11 to 13 mm. long, 9 to 11 mm. broad and 6 to 7 mm. thick, narrowed toward the base, obtuse at the apex, within a rather well-marked ventral wing and a shallow groove along the dorsal edge, the surface reticulate.

A shrub about 1 m. high with rather rigid, strict branches and more or less spinescent branchlets, the young growth greenish or sometimes with a

glaucous appearance turning reddish gray with age. Originally described from the "Foothills of the eastern side of the Sierra Nevada, near Carson." It appears to be rather common in the eastern Sierra Nevada and the foothills of both California and Nevada from the vicinity of Reno in Nevada southward to Owens Valley in California.

Specimens examined: Nevada; Hawthorne, at 6000 ft. alt., M. E. Jones, April 15, 1907. Verdi, Washoe Co., C. F. Sonne, May, 1895. Foothills northwest of the University Reno, P. B. Kennedy, April 22, 1901. Near Carson City, C. L. Anderson, 1866. Near Empire City, J. Torrey No. 136, 1865. Carson City, at 5000 ft. alt., S. Watson No. 299, April, 1868. King's Canyon, Ormsby Co., Nev., at about 6000 ft. alt., C. F. Baker No. 907, June 1 and July 1, 1902. Empire City, Nevada, M. E. Jones No. 3856, May 19, 1882. Candelaria, W. H. Shockley, 1890. Carson Valley, J. C. Phillips and C. S. Sargent, Sept.-Oct., 1878. Reno, F. H. Hillman, Oct., 1893. Miller Mts., at 7500 ft. alt., W. H. Shockley No. 1216, May 18, 1882. Near Carson City, C. L. Anderson No. 217, 1864 and Mar., 1865. Near Woodford, border of Nevada, J. Ball, July, 1884. Carson Flats, J. D. Hooker and Asa Gray, 1877. Reno, J. D. Hooker and Asa Gray, 1877.

California; White Mts., at 5-6000 ft. alt., C. A. Purpus No. 5805, May-Oct., 1898. Lone Pine, at 7000 ft. alt., M. E. Jones, May 14, 1897. Base of White Mts. east of Laws, Inyo Co., A. A. Heller No. 8186, May 5, 1906. Beckwith Pass, H. N. Bolander. Camp Bidwell, D. W. Mathews, 1879. Owens Valley desert, Dr. W. Matthews, April, 1877.

AMYGDALUS FREMONTI (S. Wats.) Abrams.

Amygdalus fremonti Abrams, Bull. N. Y. Bot. Gard. 6: 384. 1911.

Prunus fremonti S. Wats. Bot. Calif. 2: 442. 1880.

Leaves with petioles 3 to 4 mm. long, ovate to nearly orbicular, rounded or sometimes subcordate at the base, obtuse or acute at the apex, 12 to 25 mm. long, 10 to 18 mm. broad, pale green above, grayish or sometimes even somewhat silvery below and marked with reddish brown veins, glabrous on both surfaces, the margins strongly crenate-dentate and the teeth glandular. Flowers appearing in March with the leaves, solitary or in fascicles of two or more on pedicels 8 to 12 mm. long; calyx with ciliate lobes; the corolla about 12 or 15 mm. broad; the ovary densely pubescent. Fruit pedunculate, about 12 mm. in diameter, the exocarp apparently dry and dehiscent along the ventral side; stone oblong and turgid, about 12 mm. long, 10 mm. broad, and 8 mm. thick, rounded on the dorsal side and with a thick wing on the ventral side.

A shrub or small tree 5 m. high with irregular more or less spinescent branches and reddish bark, originally described from "Coast Ranges of Southern California; Oriflamme Cañon, San Diego County (D. Cleveland); San Bernardino, Parry and Lemmon, n. 108, 1876. Also collected by Fremont in 1846, locality uncertain." The species occurs in southern California from the Chuckawalla Mountains southward to northern Lower California.

The type sheet of this species in the Gray Herbarium at Cambridge contains with other specimens a fragmentary one collected by Fremont probably in 1846, but this is *Prunus subcordata* and was evidently taken by Watson to be identical with the other material and Fremont's name was accordingly given to the species, though it is doubtful if he ever collected it.

Specimens examined: California; Palm Springs, C. S. Mason, Mar., 1908. Agua Caliente Canyon, C. C. Parry, April, 1881. Mountains on the edge of the desert, San Diego County, Parish, Mar., 1881. San Felipe, C. C. Parry, June, 1850. Colorado Desert, W. G. Wright No. 198, Mar., 1881. Oriflamme Canyon, San Diego Co., D. Cleveland, 1877. Without locality, Dr. A. Davidson, 1893. Parry and Lemmon No. 108, 1876.

Lower California; Northern Lower California, C. R. Orcutt, April 12, 1886. Santo Thomas, C. R. Orcutt, Sept. 29, 1884. El Rancho Vego, T. S. Brandegee, April 29, 1889.

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