TRANSACTIONS

OF

THE ACADEMY OF SCIENCE OF ST. LOUIS.

VOL. XXI.

JANUARY, 1912, TO DECEMBER, 1912.

PUBLISHED UNDER DIRECTION OF THE COUNCIL.

ST. LOUIS.
NIXON-JONES PRINTING CO.

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MEMBERS.

1. Patrons.

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ABSTRACT OF HISTORY.

ORGANIZATION.

The Academy of Science of St. Louis was organized on the 10th of March, 1856, in the hall of the Board of Public Schools. Dr. George Engelmann was the first President.

CHARTER.

On the 17th of January following, a charter incorporating the Academy was signed and approved, and this was accepted by a vote of the Academy on the 9th of February, 1857.

OBJECTS.

The act of incorporation declares the object of the Academy to be the advancement of science and the establishment in St. Louis of a museum and library for the illustration and study of its various branches, and provides that the members shall acquire no individual property in the real estate, cabinets, library, or other of its effects, their interest being merely usufructuary.

The constitution as adopted at the organization meeting and amended at various times subsequently, provides for holding meetings for the consideration and discussion of scientific subjects; taking measures to procure original papers upon such subjects; the publication of transactions; the establishment and maintenance of a cabinet of objects illustrative of the several departments of science and a library of works relating to the same; and the establishment of relations with other scientific institutions. To encourage and promote special investigation in any branch of science, the formation of special sections under the charter is provided for.

MEMBERSHIP.

Members are classified as active members, corresponding members, honorary members and patrons. Active membership is limited to persons interested in science, though they need not of necessity be engaged in scientific work, and they alone conduct the affairs of the Academy, under its constitution. Persons not living in the city or county of St. Louis who are disposed to further the objects of the Academy, by original researches, contributions of specimens, or otherwise, are eligible as corresponding members. Persons not living in the city or county of St. Louis are eligible as honorary members by virtue of their attainments in science. Any person conveying to the Academy the sum of one thousand dollars or its equivalent becomes eligible as a patron.

Under the By-Laws, resident active members pay an initiation fee of five dollars and annual dues of six dollars. Non-resident active members pay the same initiation fee, but annual dues of three dollars only. Patrons and honorary and corresponding members are exempt from the payment of dues. Each patron and active member not in arrears is entitled to one copy of each publication of the Academy issued after his election.

Since the organization of the Academy, 1,314 persons have been elected to active membership, of whom, on December 31, 1912, 378 were carried on the list. Six patrons, Mr. Edwin Harrison, Mrs. Eliza McMillan, Mr. William Northrop McMillan, Mr. Henry W. Eliot, Mr. William Keeney Bixby and Mr. Edward Mallinckrodt, have been elected. Elections to honorary membership number 19 (page vi), and 226 persons (Vol. X., p. xii) have been elected to corresponding membership.

OFFICERS AND MANAGEMENT.

The officers, who are chosen from the active members, consist of a President, two Vice-Presidents, Recording and Corresponding Secretaries, Treasurer, Librarian, three Curators and two Directors. The general business management of the Academy is vested in a Council composed of the officers.

The office of President has been filled by the following well-known citizens of St. Louis, nearly all of whom have been eminent in some line of scientific work: George Engelmann, Benjamin F. Shumard, Adolphus Wislizenus, Hiram A. Prout, John B. Johnson, James B. Eads, William T. Harris, Charles V. Riley, Francis E. Nipher, Henry S. Pritchett, John Green, Melvin L. Gray, Edmund A. Engler, Robert Moore, Henry W. Eliot, Edwin Harrison, Adolf Alt, Calvin M. Woodward, and William Trelease.

MEETINGS.

The regular meetings of the Academy are held at its building, 3817 Olive Street, at 8 o'clock, on the first and third Monday evenings of each month, a recess being taken between the meeting on the first Monday in June and the meeting on the third Monday in October. These meetings, to which interested persons are always welcome, are devoted in part to the reading of technical papers designed for publication in the Academy's Transactions, and in part to the presentation of more popular abstracts of recent investigation or progress. From time to time public lectures, calculated to interest a larger audience, are provided for in some suitable hall.

The following dates for regular meetings for the year 1913 have been fixed by the Council:

Jan	Feb	Mar	April	May	June	Oct	Nov	Dec
6	3	3	7	5	2		3	1
20	17	17	21	19		20	17	15

LIBRARY.

After its organization, the Academy met in Pope's Medical College, where a creditable beginning had been made toward the formation of a museum and library, until May, 1869, when the building and museum were destroyed by fire, the library being saved. The library now contains about 18,500 books and 16,000 pamphlets, and is open during certain hours of the day for consultation by members and persons engaged in scientific work.

PUBLICATIONS AND EXCHANGES.

Twenty-one octavo volumes of Transactions have been published since the organization of the Academy, and widely distributed. Two quarto publications have also been issued: one from the Archaeological Section, being a contribution to the archaeology of Missouri, and the other a report of the observations made by the Washington University Eclipse Party of 1889. The Academy now stands in exchange relations with 422 institutions or organizations of aims similar to its own.

MUSEUM.

After the loss of its first museum, in 1869, the Academy lacked adequate room for the arrangement of a public museum, and, although small museum accessions were received and cared for, its main effort, of necessity, was concentrated on the holding of meetings, the formation of a library, the publication of worthy scientific matter, and the maintenance of relations with other scientific bodies.

The Museum is at present located on the third floor of the Academy Building and has in it a number of specimens illustrating the various branches of natural science, among which may be mentioned the Yandell Collection of fossils, a collection of some 600 exotic butterflies, a collection of Mound Builder pottery and skulls from near New Madrid, Mo., and a collection of 25 meteorites. Our material forms but a nucleus of a museum which the Academy hopes to establish—a museum which we trust will be of benefit to the public and to the educational institutions of the city.

RECORD.

From January 1 to December 31, 1912.

The following list of papers were presented at the meetings during this period:

January 2, 1912:
- A. S. Langsdorf.—Graphical Methods for Constructing the Characteristic Curves of Electric Motors.

January 15, 1912:
- A. E. Ewing.—Sanninoidea exitiosa (Say) and Sanninoidea opalescens (Hy. Edw.). Borers which infest the peach tree root; examples of the insects from the egg to the imago; description of the life history and the resulting tree destruction.

February 5, 1912:
- G. O. James.—Mechanical Flight.

February 19, 1912:
- C. H. Turner.—Experimental Study of Color Vision and Pattern Vision of Bees.
  (Published in Biological Bulletin, Vols. XIX and XXI.)
- H. M. Whelpley.—Miniature Indian Baskets.

March 4, 1912:
- C. A. Todd.—A Problematical Geological Phenomenon in Colorado.
- H. T. A. Hus.—Inheritance in Capsella.
- F. E. Nipher.—Effect of a Sudden Draining of Negative Corpuscles from Matter.

March 18, 1912:
- R. J. Terry.—A Grove of Deformed Trees.
- C. A. Waldo.—The Problem of Coal Exhaustion.
- H. M. Whelpley.—Miniature Flint Arrows.

April 1, 1912:

J. L. Van Ornum.—The Permeability of Concrete and Methods of Securing Impermeability.

G. O. James.—The Application of the Relativity Law of Gravitation to the Motion of the Perihelion of Mercury.

(Published in Astronomical Journal, Vol. XXVII, 1912.)

F. E. Nipher.—Effect of a Disruptive Discharge Through a Fine Wire.

C. A. Waldo.—Multiplication Tables of Russian Peasants.

April 15, 1912:

A. S. Langsdorf.—Transient Electrical Phenomena.

C. H. Turner.—Results of Recent Experiments on the Homing of Ants.

A. E. Bostwick.—Atomic Theories of Energy.

(Published in The Monist, October, 1912.)

Wm. H. Roever.—A Mechanism for Illustrating Lines of Force.

May 6, 1912:

J. F. Abbott.—The Water Boatmen, an Unexplored Corner of the Insect World.

C. M. Gill.—Recreation Studies in Estes Park, Colorado.

Fred Hecker.—Microscopic Studies of Living Organisms and Their Growth Rate.

May 20, 1912:

A. S. Pearse.—Fiddler Crabs.

(Published in Philippine Journal of Science, Vol. 7, No. 3, 1912.)

Phil Rau.—The Life History of the Devil Horse (*Stagmomantis carolina*).

(Published in Transactions of The Academy of Science of St. Louis, Vol. XXII, No. 1, 1913.)

June 3, 1912:

F. E. Nipher.—Electric Waves in Solid Conductors.

R. J. Terry.—The Development of the Cranium in Mammals.

J. L. Van Ornum.—The Effect of Fatigue Tests and of Moisture Upon the Elasticity of Concrete.

October 21, 1912:

G. O. James.—On the Contingence of the Physical Theory and the Problem of the Geologic Past.

G. O. James.—Notice of the Death of Poincaré.

November 4, 1912:

F. E. Nipher.—Geissler Tube Effects in Solid Conductors.

(Published in Transactions of The Academy of Science of St. Louis, Vol. XXI, No. 3, 1912.)

M. E. Hard.—Mushrooms Found in the Vicinity of St. Louis.

November 18, 1912:

J. F. Abbott.—Permeability of Animal Membranes.

(Published in Biological Bulletin, February, 1913.)

C. H. Turner.—The History of an Orphan Colony of the Paper-Making Wasp, Polistes pallipes.

(Published in Psyche, December, 1912.)

H. M. Whelpley.—Indian Miniature Axes and Celts.

December 2, 1912:

Wm. H. Roever.—The Design and Theory of a Mechanism for Illustrating Certain Systems of Lines of Force and Stream Lines.

(Published in Zeitschrift für Mathematik und Physik, 1913.)

D. L. Harris.—Experimental Work on the Etiology of Rabies and the Mechanism of Anti-Rabio Immunity.

(Published in Series of Articles in Journal of Infectious Diseases, Vols. V, VIII, X, XI, 1908-12.)

December 16, 1912:

LeRoy McMaster.—A Review of the Address of Dr. E. A. Schaefer, on the Chemical Origin of Life, before the British Association for the Advancement of Science.

(Published in Chemical News, London, Vol. CVI, Nos. 2754 and 2755.)

A. E. Ewing.—The Plum Curculio; its Food, Ability to Stand Cold, Inability to Stand Drought, Longevity.

Meeting of January 2, 1912.

The Academy of Science of St. Louis met in the Academy Building, 3817 Olive Street, at 8 p. m., January 2, 1912; President Trelease in the chair; attendance 18.

The President delivered his address as President of the Academy for the year 1911.[3]

The Treasurer's report for the year 1911 was submitted.[4]

The report of the Curators for 1911 was read.[5]

The report of the Librarian for 1911 was presented.[6]

The report of the Entomological Section was submitted.[7]

The Nominating Committee reported the results of the election of officers for 1912, as follows:

President	E. A. Engler
First Vice-President	F. E. Nipher
Second Vice-President	A. E. Ewing
Recording Secretary	M. E. Hard
Corresponding Secretary	Geo. T. Moore
Treasurer	H. E. Wiedemann
Librarian	Wm. L. R. Gifford
Curators	Julius Hurter
	Joseph Grindon
	Philip Rau
Directors	Otto Widmann
	Adolf Alt

Professor A. S. Langsdorf explained graphical methods for constructing the characteristic curves of electric motors. These methods involve only straight lines and circles.

January 15, 1912.

President Engler in the chair; attendance 18.

Dr. A. E. Ewing presented an illustrated account of "*Sanninoidea exitiosa* (Say) and *Sanninoidea opalescens* (Hy. Edw.). Borers which infest the peach tree

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[3] Transactions, Vol. XX, page xxxi.

[4] Transactions, Vol. XX, page xxxiii.

[5] Transactions, Vol. XX, page xxxiv.

[6] Transactions, Vol. XX, page xxxiv.

[7] Transactions, Vol. XX, page xxxiv.

root; examples of the insects from the egg to the imago; description of the life history and the resulting tree destruction."

After describing the varieties of the *S. exitiosa* and the difference between them and the *S. opalescens*, giving the history of the insects and Beutenmueller's classification, examples were exhibited of the eggs on the bark of the tree, on the gum from the base of the tree, on leaves from the lower limbs of trees, and one on a trumpet vine leaf that grew a foot from the base of a tree, all of which were observed as they were laid and immediately collected, the collection having been made at the Mountainboro orchard, Mountainboro, Alabama, and at Gadsden, Alabama, between the first and the fifth of September, 1911. The exit of the larvae from these eggs was observed to be from seven to nine days, the time of the one laid on the trumpet vine was eight days.

For four successive seasons the life period of the insect had been carefully noted at Mountainboro, and it was found to confirm for northern Alabama the observations of Porter, Starnes and Sherman for Georgia and North Carolina, and shows that in the Southern Alleghany peach belt pupation begins about the first of August and the moth appears the last week in the same month. In 1908, August 4th, as many full grown borers were captured in this orchard of 15,000 trees as there were cocoons, the total number being 1,100. August 7th, 300 cocoons were captured and as many borers destroyed. In this same orchard 8,500 cocoons were taken from the trees between the 20th and 24th of August, in 1910. Two hundred of these cocoons were placed in a wire cage on a southern covered porch. From these 25 moths emerged previous to September 5th, 46 between the 5th and the 8th, inclusive, 29 between the 9th and the 13th, and after this only two, one male the 16th, and another the 21st. The remainder failed to develop.

Observations on the moths in the cage were that their activity depends greatly upon the temperature; with it below 70° F. they are very quiet, and very active when it is above 80° F. At night they sleep with their antennae spread rather wide, some with the wings moderately spread, usually, however, with the wings near the body as when at rest, and the male with the tip of the abdomen strongly turned upward. When awake and alert the antennae were erect and near together as if indicating the facial expression of the insect. At night they took no notice of an electric light right above them when it was turned on and off. Thus caged they lived only three or four days.

The 28th of August, 1911, fifty infested trees were examined. From the half of the cocoons the moths had escaped. During the examination only one borer was found which had not yet begun its cocoon. Throughout the orchard the moths were numerous, and in greater numbers from the first to the fifth of September. On September 13th only one moth was found, although a careful outlook was kept during the middle of the day, the time when the imago is most active.

An exhibition was made of the larvae at numerous ages, from the emergence from the egg to the time of spinning the cocoon, together with an example of their destructive work on the tree, and numerous mounted examples of the male and female moth of the *S. exitiosa* type.

Also a cocoon was shown filled with the larvae of *Bracon mellitor* (Say), and others filled with the cocoons of this ichneumon, the parasite having been found in from one to two per cent of the *S. exitiosa* cocoons examined.

Particular stress was laid upon the fact that only black and white drawings of the insects were given in the various state and national bulletins which were distributed throughout the country for the instruction of the orchardist, and lantern slides were shown from the plates of Beutenmueller in which there were at least 75 other examples of *Sesia*, which in black and white would readily be confused with this one by the laity. To be of any real value to the people all government bulletins dealing with insects should contain exact colored plates of the insects described in order to be intelligible to those not familiar with entomology. As an example, the owners and the foreman of the Mountainboro orchard did not know the *S. exitiosa* until they saw it emerge from the cocoon, although all of them had carefully read all the important government bulletins on the subject, particularly those of Slingerland, Marlatt, and Starnes, and they had owned and cared for the orchard for more than ten years. As the moth flies only in mid-day it was unquestionably often seen by them without being recognized.

The death of Mr. Samuel Cupples was reported.

February 5, 1912.

President Engler in the chair; attendance 25.

Dr. G. O. James addressed the Academy on the subject of "Mechanical Flight."

Dr. James divided the history of mechanical flight into four periods: the legendary, leading up to the Renaissance; the heroic, ending with the XVIII century; the scientific, extending through the XIX century, and finally the industrial, beginning with the present century.

Passing over the first two divisions, the scientific period began in 1809, when Sir Geo. Cayley published the first complete mechanical theory of the aeroplane, in which he put clearly in evidence the fundamental principle of sustention obtained by velocity. This memoir, published in Nicholson's Journal, passed almost unnoticed until unearthed some sixty years later by Pénaud. Following Cayley there was a long period of unfruitfulness. At the close of the Franco-Prussian War interest in heavier than air flying machines was revived. Pénaud constructed the first toy aeroplane with the propeller in the rear and driven by a rubber band. This apparatus flew for an appreciable time, utilizing motive energy which it carried with it, and this property differentiates very sharply the experiment of Pénaud from those of his predecessors in which was realized only a fall more or less retarded by the resistance of the air.

The German Lilienthal followed Pénaud, and from 1891 to 1896 studied the equilibrium, manoeuvering and landing of gliders, falling to his death on his two thousandth flight, August 9, 1896. In this country the French engineer Chanute and the American Langley had meanwhile been experimenting and developing the laws of aerodynamics, Langley's work going as far back as 1887 and continuing to his unsuccessful attempts at flight in 1903. In 1891 he published the results of his researches and definitely stated that it was possible to construct machines which would give such velocity to inclined surfaces that bodies indefinitely heavier than air could be sustained upon it, and moved through it with great speed. For sixteen years, Langley continued his efforts to attain mechanical flight, and this long period of fruitful scientific achievement closed with failure due primarily to lack of funds. Langley died February 27, 1906, about two years before the Wright brothers astonished the world by their feats in sustained flying in 1908.

Turning then to the mechanical principles underlying flying, Dr. James discussed the distribution and action of forces on an aeroplane in uniform horizontal flight in still air. If a uniform horizontal wind is blowing, whatever be its velocity, the machine behaves exactly as in still air except that its velocity relative to the ground is the resultant of its velocity in still air and the velocity of the wind. The effect is exactly as if the machine flew in a volume of still air enclosed in a great spherical envelope while at the same time this envelope is carried along by the wind.

If the velocity of the aeroplane in still air is greater than that of the wind the machine may move in any desired direction relative to the ground, while if it is less it will be forcibly carried in the direction of the wind.

The mechanical theory of the behavior of the aeroplane in flight is built on the hypothesis that "the normal thrust on the sustaining plane is proportional to its area, the square of its velocity and to the sine of the angle of attack." By mathematical deductions follows the interesting result that the power expended is inversely proportional to the velocity and directly proportional to the angle of attack, and the advantages of a small angle of attack are evident. In this discussion the passive resistances have been neglected and the power necessary to drive the machine against these increases with the velocity so that there is a minimum angle of attack and a maximum speed for a given machine and motor.

Passing now to the question of stability, there are three types of oscillations of an aeroplane which must be guarded against; rolling, pitching and gyration. After discussing these phases the speaker passed to the future of the aeroplane.

That mechanical flight is possible is evident, but it is equally evident that the aeroplane even yet is at the mercy of the wind and one of the most important advances of the future is some method of realizing certain stability of flight so that inequalities in air conditions and variations in skill on the part of the aviator shall have but negligible effect. It is desirable that the stability may be rendered automatic while at the same time the machine is not deprived of all sensitiveness but remains easy to manoeuver. Stabilization must be attained by mechanical methods which call into play the stabilizing devices at will by a mechanism of transmission. Theoretically either pendular or gyroscopic masses may be used and brought into effective play by the transmitting device.

It has already been pointed out that the speed required for sustention depends on the angle of attack and increases as this angle decreases, while the power required to drive the sustaining plane against the air resistance decreases with this angle. Theoretically then at least, a given motor might drive an aeroplane at any desired speed however high by flying it "close to the wind." Practically this is not the case because of the passive resistances developed by moving the accessory parts of the machine through the air at high velocity. The resistance to flight offered by the sustaining planes is for high velocities only a small fraction of the total resistance, and it is very difficult to get even an approximate idea of the value of the passive resistances. They are very considerable even for trains and automobiles and for the greatest velocities actually attained by these they absorb nearly all the driving energy. The problem of velocity is then much the same for high speed machines whether they are designed to move on the ground or through the air. Their principal parts are the motor and its accessories, including the full reservoirs, and the problem is essentially one of building a motor which will develop sufficient power to drive itself, including the full tanks and the rigid frame which carries it, against its own resistance.

The power of a motor is roughly proportional to its weight and a motor of 100 horse power is capable of moving at 100 kilometers per hour. A motor of 800 horse power, homothetic to the first and making the same number of strokes per second will have a volume eight times as great and hence a surface four times as great. The power required to move this at the same velocity as before is then quadrupled, but since the power is now eight times as great as formerly the velocity may be increased. How much? The passive resistances are proportional to the square of the velocity and hence the power required to overcome them is proportional to the cube of the velocity and also to the resisting surface. But this resisting surface has been quadrupled and hence the new velocity is only the cube root of two times the old and cannot exceed 126 kilometers per hour. To raise it to 200 kilometers per hour would require—on the same theory—a 50,000 horse power motor. Very little is to be gained by increasing the power of the motor once its weight is such that the weight of the pilot and its accessories is small in comparison, and large machines cannot expect to make greater speed than moderate sized ones.

The architecture of the aeroplane is then seen to be the important point for future investigation and machines with bodies so constructed as to offer a minimum resistance for a given weight are the racing planes of the future.

The death of Mr. Ernest R. Buckley was reported.

February 19, 1912.

President Engler in the chair; attendance 36.

Dr. Chas. H. Turner addressed the Academy on "Experimental Study of Color Vision and Pattern Vision of Bees."

To those whose interest in the interrelations of insects and flowers has been stimulated by the work of Spengel, Darwin, Mueller, Robertson and others, the most logical theory that has yet been proposed to account for the colors and color patterns of flowers is the one which asserts that colored flowers are for the purpose of causing the cross-fertilization of plants.

This theory was held by practically all serious students until a short time ago, when a reaction set in and a number of men came to feel that, although the theory is plausible, there is not sufficient experimental evidence to establish it. This change of view was brought about by two things: first, the advent of the tropism theory of the physiologists, and second, deductions based on morphological studies of the insect eye.

After a discussion of these two conceptions, Dr. Turner described a series of experiments which he had made. Dr. Turner argued that if bees can distinguish colors and color patterns it should be possible, first, to train bees to collect from artifacts of a certain color, if such artifacts contain something of value to the insect; second, once having learned to collect from such artifacts, the bees should be able to select artifacts of that color under each of the following conditions; when the artifacts of that color pattern contain the thing of value and none of the others do, when the artifacts of that color pattern and some of the others contain the thing of value, when none of the artifacts contain the thing of value.

Dr. Turner conducted two sets of experiments; one, to determine if bees can distinguish between plain colors and the other to test the ability of bees to distinguish between color patterns.

In the experiments of the first summer Dr. Turner found that without a doubt bees can discriminate between solid colors, and his experiments the second year proved conclusively that, after a bee had learned, by experience, that artifacts bearing a certain color pattern contained a more copious supply of easily obtained honey than ordinary flowers, it would select artifacts bearing that color pattern from those marked in a different way. This was true: first, when several of the artifacts to be selected were scattered among a number of plain artifacts of the colors used in making the color pattern; second, when the artifact to be selected was scattered among several other artifacts, some of which were plain and some of which were marked with patterns unlike that of the artifact to be chosen; third, when the only difference between the artifacts was that one was marked with transverse and the other with longitudinal stripes; fourth, when the artifacts to be selected contained the honey and the others did not; fifth, when honey was to be found not only in the artifact to be selected, but in some of the other artifacts also; sixth, when none of the artifacts contained honey.

Dr. H. M. Whelpley spoke on "Miniature Indian Baskets."

Dr. Whelpley exhibited two specimens made by the Pomo Indians, which were viewed by means of simple microscopes. The foundation of the baskets is from the white leaf willow (*Salix argyrophylla*) and is sewed with California sedge (*Carex barbarae*). The baskets are made in pattern black and white, the black being from the root of the California sedge.

The larger basket is .18x.10 inches, with the opening .06 inches across and weighs ¼ grain. The smaller basket is .10x.04 inches, with an opening .04 of an inch across, and weighs 1/20 grain. Both baskets are woven in the same manner as large baskets and carefully patterned.

The Pomo Indians, located in northern central California, are noted for their basketry which is unrivaled in North America, for workmanship, beauty and variety of design. The women are the weavers but the smaller basket was made by a man, who is one of the few men weavers among the Pomo Indians.

Dr. Geo. O. James was elected to membership.

The death of Dr. Enno Sander, an honorary member of the Academy, and for forty-eight years its Treasurer, was reported.

MARCH 4, 1912.

President Engler in the chair; attendance 48.

Dr. Chas. A. Todd addressed the Academy on "A Problematical Geological Phenomenon in Colorado."

The remarkable arrangement of rocks, which Dr. Todd discussed, is found in the northeastern mountainous district of Colorado, in the region known as Estes Park, near Fern Lake.

After describing the topography of the region, Dr. Todd described the particular locality. It is a conical pit, the sides of which slope at an angle of about 45°. Its length is roughly 600 feet, its width 200, and its depth about 50. Adjoining and blended with this oblong pit at its eastern end is a circular pit of the same general character.

The walls are of distinct masses of broken granite rock, chiefly cubical, the largest near the top of the wall, the smallest at the bottom. The edges of these rocks are as sharp as though freshly broken out of a quarry.

What was the origin of these pits? Two theories have been advanced. One, that it is a great "blow out," i. e., volcanic in nature; the other, that it is simply a glacial deposit.

As to the theory of volcanic origin, the fact that the fragments tend to be cubical, are sharp angled, the largest lying in the highest places, and the whole structure of the pit being so regular in plan, would strongly suggest a violent local upheaval, due, say, to superheated steam, since there is nothing in the immediate neighborhood to imply volcanic action accompanied by eruption of lava or ash. Still, close to the Park is Specimen Mountain, which is said to abound in pumice. In the canyon four miles distant huge blocks of rock encumber the valley, having the appearance of having been thrown down from the bordering mountains all at the same time. If by an earthquake, it may have opened a crevice close to Fern Lake, letting water into the depths to be suddenly converted into steam that burst through the granite crust and left these pits to mark the site of the explosion.

As to the second theory, that of glacial deposit, there is much in its favor. The pits are directly over the course of a glacial stream, at its lower end is the beginning of a great moraine.

At first glance the pits will call to mind the so-called "kettle holes," so common on the site of moraines. But if the theory of the origin of kettle holes is correct, then our Estes Park cavities can hardly be so classified. For it is supposed that the ice carrying upon its surface the debris that is to form the moraine melts in such a fashion as to cause the transported rock, sand, etc., to slide off and down, gradually forming a ring or oblong with the unmelted ice in the center as a core. This core finally melting, a hollow is left—the kettle. The sides fall in under the wash of rains or from the weight of the loose material, so as to form slopes that may meet to make hollow cones or troughs.

Now, in the Estes Park pits we have these configurations, but instead of a loose, movable material, the walls are of angular rock masses firmly jammed together and altogether incapable of any such sliding movement.

So far the only solution of this mystery seems to be through a stout derrick and some dynamite, backed by a good working squad, but in the wilderness such aids to research are not readily at hand.

Dr. H. T. A. Hus spoke on "Inheritance in *Capsella*."[8]

[8] When Dr. Hus read this paper he left it an open question whether new forms of *Capsella* were to be looked upon as hybrids or as mutations *sensu de Vries*. Subsequent observations have enabled Dr. Hus to explain new forms as the result of hybridization.

Professor F. E. Nipher discussed his recent work on the effect of a sudden drainage of negative corpuscles from matter.

March 18, 1912.

President Engler in the chair; attendance 32.

The following donations to the Museum were reported:

J. A. Drushell...5 species of Ordovician Brachiopods,
2 species of Ordovician Bryozoa.

Mary J. Klem..A section of a fossil tree trunk from Veedersburg, Indiana.

The following report of the committee, appointed by the President to write a memorial to the late Dr. Enno Sander, was read and ordered spread on the records of the Academy.

The Academy of Science of St. Louis wishes to place upon record its great appreciation of the valuable service which has been rendered to it by Dr. Enno Sander.

He became a member during the first year of its history, fifty-five years ago. For nearly fifty years he served as its Treasurer. Much of its success is due to the attention which he gave to its financial affairs. In his death the Academy loses a valued supporter.

(Signed) FRANCIS E. NIPHER,
WM. TRELEASE,
ADOLF ALT.

Dr. Robert J. Terry spoke on "A Grove of Deformed Trees."

A grove of four or five hundred small persimmon trees in St. Louis County has suffered from the ravages of a beetle which has been identified as *Oncideres cingulata.* Limbs varying in diameter from 5 to 15 mm. are girdled and the ends fall to the ground. All the trees, old and young, have been attacked. The girdling is done in the fall, mainly in September and October. During this time the larger trees present scores of branches bearing dead leaves and the ground is strewn with fallen branches often laden with fruit. Small trees have, in some instances, lost several or all of their main limbs in one season, in others been divided so near the ground that only a short stump of the tree remains. The work is indeed a most complete pruning; but the operation evidently does not consider the future symmetry of the persimmon tree. Buds on the truncated limbs develop an excess of branches the following spring, some of which in turn are cut away at some future time. The highest latent buds of the seedling stump, which at first grow out at an angle, later assume a more or less vertical direction and are adapted to the supporting functions of the trunk. Many of these secondary trunks were found girdled. There is no tree in the grove that does not present crooked trunk and limbs. The deformities in some cases are extreme. Most of the trees are as a consequence dwarfed, although able to make some advance in growth. Some trees only a meter and a half tall bore fruit in 1911.

A few beetles have been observed working. The girdling was begun on the upper side of the branch and was made ¾ mm. wide and about 3 mm. deep. Most of the limbs fall, within a few days after the girdling. A small proportion remain throughout the following winter. On every severed branch, near the distal ends of the twigs, one or more small deep excoriations of the bark were found. That the beetle makes similar abrasions of the bark of twigs of the honey locust is known from observations on *Oncideres* in captivity. Limbs recovered from the ground in winter in some cases presented no evidence of the propagation of the beetle, whereas in others more or less of the wood has been destroyed under the bark along one side of the branch, extending from the distal end proximally. The cavity never quite reached the proximal severed end. Larvae which are now being studied were discovered in some of the tunnels.

Professor C. A. Waldo then addressed the Academy on "The Problem of Coal Exhaustion."

"Miniature Flint Arrows" was the subject of a short paper by Dr. H. M. Whelpley.

Dr. Whelpley illustrated his remarks with over two thousand specimens, varying in length from .06 to 1 inch. In form they represent all of the common types of ordinary arrows and were evidently made by the same process of pressure chipping. Specimens have been found in England, Spain, Belgium, India, Palestine, Egypt and the United States. These artifacts belong to the Neolithic age. It has been suggested, but without evidence, that they were made by a pygmy race of human beings. It is also claimed that they were barbs for harpoons, tattooing instruments, fish snags or drills for skin and shell work.

Dr. Whelpley concluded that the medium size and larger miniature arrows, such as are very plentiful along portions of the Missouri and Meramec Rivers, were used as arrow heads. The most minute ones he considers examples of skill in flint chipping, the same as the miniature baskets made by the Pomo Indians today are merely examples of skill in basketry.

April 1, 1912.

President Engler in the chair; attendance 25.

The Corresponding Secretary reported that he had attended the celebration of the one hundredth anniversary of the founding of the Philadelphia Academy of Natural Science as the representative of the Academy.

Professor J. L. Van Ornum spoke on "The Permeability of Concrete and Methods of Securing Impermeability."

Professor Van Ornum reviewed the methods practicably applicable to prevent dampness in rubble masonry foundation walls; that is, by drainage or by an impervious coating of their exterior, or by both. He then referred to the general use at present of concrete foundation walls for important structures and the necessities for securing their impermeability. This may be attained by constructing an impervious diaphragm of a bituminous material; by an efficient surface coating, preferably on the outside; by carefully securing a maximum density by properly proportioning the components of the concrete; or by mixing with the concrete certain colloidal (or other) substances to secure this result. The latter two methods have been experimentally investigated in successive years as thesis work by H. F. McFarland, P. C. Grace, S. Johnson, and W. K. Begeman. Their results agree in general with those of others in concluding that, for any usual conditions, the patented mixtures sold for this purpose vary in effectiveness from very poor to very good; and that proper proportioning of the constituents of the concrete to attain a maximum density, such as is desirable to secure a maximum strength, will also effect practical impermeability; but they differ from the conclusions of some others in the fact that they found no advantage to result from the incorporation of such a material as hydrated lime in the richer mixtures.

The apparatus designed by the students for these experiments, which gave pressure up to forty pounds per square inch, was planned to eliminate certain features of the experimental devices of other tests which seemed objectionable to them; particularly in eliminating tensile stresses from the specimens tested, with the resulting tendency to form cracks. It is such development of the student's initiative and his responsibility in adapting his methods to conditions so as to secure the desired results which constitute the most valuable experience in the work of graduation theses.

Dr. Geo. O. James then addressed the Academy on "The Application of the Relativity Law of Gravitation to the Motion of the Perihelion of Mercury."

Professor F. E. Nipher gave a preliminary account of work he has been doing on the effect of a disruptive discharge through a fine wire.

Planté discovered that the wire buckles. He ascribed the phenomenon to rapid vibrations of more or less elastic matter, brought about by the propagation of the "electric movement."

Professor Nipher is experimenting on a very delicately suspended wire, with a view of determining whether the longitudinal thrusts are balanced under all circumstances. He suggests that the forces which cause positive and negative ions in discharge through gases and liquids to move in opposite directions are active in a metal conductor.

Professor C. A. Waldo gave an interesting demonstration of how the Russian peasants can multiply any two numbers, provided they know how to multiply and divide by two.

For example, it is desirable to multiply 69 by 49. Divide 69 by 2 and multiply 49 by 2. Continue this process as indicated:

69	49
34	98
17	196
8	392
4	784
2	1568
1	3136

Then cancel in the second column all numbers opposite even quantities in the first. Add the remaining figures, which will give 3381. Multiply 69 by 49 according to the regular method and the result will be the same, 3381.

Mr. Albert Briggs Lawver was elected to membership.

April 15, 1912.

President Engler in the chair; attendance 65.

Professor A. S. Langsdorf addressed the Academy on "Transient Electrical Phenomena."

The speaker showed that in most mechanical systems there is stored a certain amount of energy, this energy being potential in the case of stationary systems and kinetic in the case of moving systems. When such a system changes from one condition to another, the amount of the energy stored in it also undergoes a change in magnitude, and this increase or decrease of energy must take place in a finite time. The period during which the change of energy occurs is the transient period. In some cases the energy is stored in only one form, as for instance, kinetic energy (a moving train being an example), and this energy must be gradually dissipated in bringing the train to rest. In other systems the energy may exist in two forms, potential and kinetic, as for instance, in a pendulum, and in such a case the dissipation of the stored energy may take place by an oscillation of the system.

Electrical circuits are in many respects analogous to the above forms of mechanical systems. Energy may be stored in one form only, such as magnetic energy only, or electrical energy only, or it may be stored in both forms simultaneously. In the first case, that is, single energy circuits, the dissipation of energy is gradual; in the second case the dissipation of energy takes place by means of an oscillating current.

There was then discussed the question of the oscillating currents that may be produced in a transmission line, and it was shown that the oscillation may give rise to excessive and dangerous voltages and currents which must be guarded against to prevent a breakdown. Following this, the speaker discussed the conditions obtained in a transformer at the moment of switching such a device on to a live circuit, and it was shown that a transient condition existed for a short period during which very excessive currents might be produced in the transformer windings.

Finally, the short circuit conditions in large alternating current generators were described, showing that dangerous rises of voltage accompanied by a rush of current could occur, and the measures employed to prevent this condition were explained.

Dr. Chas. H. Turner gave an illustrated account of "Results of Recent Experiments on the Homing of Ants."

On account of the remarkable complexity of their behavior ants have been studied by many investigators. For convenience these students may be divided into four groups.

The first school, of which Bethe is the most noted member, claims that ants are mere machines that respond to certain stimuli, always with the fixed actions or set of actions. The most complex activities of ants are but unconscious mechanical responses to diverse stimuli. In other words the life of these creatures is a round of mechanical responses to tropisms. For them there is no content of consciousness. Heliotropism, galvanotropism, stereotropism, polarized trails, etc., explain all of their behavior. They do not learn. All reflexes may not be possible at birth, because the physical mechanism is not yet perfected; but, once the mechanism has responded, thereafter under the same conditions, it always responds to the same stimulus in the same manner.

The second school, to which may be assigned Pieron, admits that reflex actions, some of which are connate and some of which are deferred, do not fully explain the habits of ants. According to it, the so-called instincts of these creatures are decidedly plastic. They profit by experience; but not by associating present sensations with revived sensations, nor by inference, nor by any of the higher forms of rational thought, but by what Morgan, Thorndike and others have called the method of trial and error.

The third school, to which belong Emery, Forel, Lubbock, Wasmann and others, holds that ants have elementary feelings, elementary ideas, and even what the English have called association of ideas, but that they do not have rational thoughts and emotions.

The fourth school, which includes L. Buchner, Huber, MacCook, Romanes and others, insists that the difference between human consciousness and that of ants is one of degree and not of kind.

About ten years ago Dr. Turner began a series of experiments on the behavior of ants, the aim of which was to see which of these sets of men was right. Some of the results of these studies were published in 1907. The purpose of this evening's paper was to discuss the bearing of those experiments on the homing of ants and compare with them the published results of experiments on the same subject conducted by two independent workers, Cornetz of Algeria and Santsci of Tunis. The experiments of these two men were performed during the years 1909-1911.

From a series of experiments Dr. Turner came to the following conclusions:

1. The movements of ants are not tropisms and ants are not guided by a homing instinct.
2. In their wanderings, ants are influenced by olfactory, topochemical, optic, auditory, kinesthetic and tactile stimuli.
3. Ants have fairly definite impressions of direction in both horizontal and vertical planes, and also impressions of distance.
4. Ants have associative memory and in their home-goings they display marked individual variations.

Cornetz's experiments made in the field on ants in Algeria lead him to the following conclusions:

1. There is no homing instinct, for ants that are carried away from home cannot find the way back.
2. Ants are not lead home by the odor trail, because an ant never returns to the nest along the path by which it left it.
3. Ants have memory of location and persistent sensory ideas of direction and these have been acquired independently of vision, touch or smell.

From field observations and field experiments on ants of Tunis Dr. Santschi arrived at the following conclusions:

1. Among ants we find two kinds of trails; in one kind the ants are guided largely by odors and topochemical sensations, in the other they are guided by perceptions that are based largely upon visual sensations.
2. Among the Tapinomas and, perhaps, other harvesting ants, the trails are started by odors secreted intentionally by a single worker.
3. Such an intentionally scented trail is utilized by workers that do not slavishly follow it, to teach other workers the way to the food.
4. This trace of odor is not sufficient to fully explain the behavior of the ants guided by it.
5. As a rule orientation among ants is a complex phenomenon based upon a variety of sense stimuli; the predominant stimulus depending upon the species and the condition under which it is operating.

6. Odors, topochemical sensations, visual sensations, direction of the rays of light, tactile sensations, auditory sensations form an idea which serves as a flexible guide to behavior.

The final conclusion of all these experiments Dr. Turner summed up as follows:

Ants are much more than mere reflex machines; they are self-acting creatures guided by memories of past individual experience. These associative memories are usually complexes of sensations contributed by several different kinds of sense organs and include an awareness of distances and of direction.

Dr. Arthur E. Bostwick read a paper on "Atomic Theories of Energy."

A theory involving some sort of a discrete or discontinuous structure of energy has been put forward by Prof. Max Planck of the University of Berlin. The various aspects of this theory are discussed and elaborated by M. Henri Poincaré in a paper entitled "L'Hypothese des Quanta," published in the Revue Scientifique (Paris, Feb. 21st).

A paper in which a discontinuous or "atomic" structure of energy was suggested was prepared by the speaker some fifteen years ago, but not published. In the light of present radical developments in physical theory this paper has historical interest. Planck's theory was suggested by thermodynamical considerations, while in this paper the matter was approached from the standpoint of a criterion for determining the identity of two portions of matter or of energy. A brief abstract of the paper is as follows:

"Physicists are divided into two opposing schools, according to the way in which they view the subject of energy, some regarding it as a mere mathematical abstraction and others looking upon it as a physical entity, filling space and continuously migrating by definite paths from one place to another.

"While we now believe that a material body can by no possibility increase continuously in mass, but must do so step by step, the minimum mass of matter that can be added being the molecule, we believe on the contrary that the energy possessed by the same body can and may increase with absolutely perfect continuity, being hampered by no such restriction.

"At first sight both matter and energy appear non-molecular in structure. But we have been forced to look upon the gradual growth of a crystal as a step-by-step process, and we may some day, by equally cogent considerations, be forced to regard the gradual increase of energy of an accelerating body as also a step process, although the discontinuity is as invisible to the eye in the latter case as in the former.

"Modern views of the identity of matter seem closely connected with modern views of its structure, and the same connection will doubtless hold good for energy."

The speaker read a letter addressed to him in criticism of this paper by J. Willard Gibbs, in which the writer adduced certain general objections to any atomic theory of energy.

In conclusion, after commenting on Prof. Gibbs's views in the light of later developments, Dr. Bostwick presented in abstract Poincaré's discussion of Planck's theory, which is that a physical system is susceptible only of a finite number of distinct states; it leaps from one of these to the next without passing through any continuous series of intermediate states. The universe leaps suddenly from one state to another; but in the interval it must remain immovable, and the divers instants during which it keeps in the same state can no longer be discriminated from one another; we thus reach a conception of the discontinuous variations of time—the *atom of time*.

Professor Wm. H. Roever exhibited and explained "A Mechanism for Illustrating Lines of Force."

The mechanism consisted essentially of two wheels with radial spokes (about 8 inches in diameter) which could be made to rotate in nearly coincident planes and thus render visible the loci of the intersections of the spokes. In the Transactions of the Academy, Vol. VII, No. 9, p. 201, Professor Roever has shown for what fields of force the systems of curves exhibited by this mechanism are the lines of force.

May 6, 1912.

President Engler in the chair; attendance 45.

The gift of a volume of "Globus" and one of "Naturwissenschaftliche Rundschau" from Dr. Edward Evers was announced.

Professor James F. Abbott gave an interesting account of "The Water Boatmen, an Unexplored Corner of the Insect World."

Mr. Chas. M. Gill gave an illustrated lecture on "Recreation Studies in Estes Park, Colorado."

Mr. Frederick Hecker read a paper on "Microscopic Studies of Living Organisms and Their Growth Rate."

Dr. William Trelease was unanimously elected an Honorary Member of the Academy.

May 20, 1913.

President Engler in the chair; attendance 62.

The following gifts to the museum were announced:

Dr. Joseph Grindon—Three Colubris from Guadeloupe, West Indies.

Dr. Wm. Trelease—Four rosaries made from seeds by the Alaska Indians. Two pouches of sealskin (the hair seal or blubber seal), made by the Alaskan Coast Indians. An Aleutian waterproof jacket and belt, made of seal intestine. Relaxed by wetting these are worn, the belt tightened about the waist and about the rim of the bidarka or kayak—a skin boat.

Dr. A. S. Pearse gave an illustrated talk on "Fiddler Crabs."

Mr. Phil Rau read a paper on "The Life History of the Devil Horse (*Stagmomantis carolina*)."

The death of Mr. J. J. Cole was announced.

June 3, 1912.

President Engler in the chair; attendance 25.

Dr. Wm. Trelease presented to the Academy a paper weight—the original punch for the Engelmann medal on the occasion of the semi-centenary of the Academy.

Professor F. E. Nipher addressed the Academy on "Electric Waves in Solid Conductors."

Dr. Robert J. Terry presented some results of his work on "The Development of the Cranium in Mammals."

Professor J. L. Van Ornum spoke on "The Effect of Fatigue Tests and of Moisture Upon the Elasticity of Concrete."

Six years ago the Civil Engineering Department of Washington University made an extensive investigation of the effects upon concrete of repeated loadings, the number of repetitions generally running well into the thousands. Pertinent to the discussion of this evening, that of "The Effect of Fatigue Tests, and Moisture Upon the Elastic Properties of Concrete," are conclusions then reached that, if the intensity of the repeated load exceeded about half the ultimate strength of the concrete, the Modulus of Elasticity continually decreased after the first repetition until it became exceedingly small just before failure; and if the repeated load was less than the intensity just mentioned, the modulus decreased at first but rapidly approached a constant value of about two-thirds the maximum, and the failure of such specimen did not occur. These experiments were of service in enabling a satisfactory fixing of the equivalent elastic limit or yield point of concrete and so arrive at safe working stresses in design.

The particular experimental investigations now reported by Professor Van Ornum, as abstracted from a graduation thesis of a year ago, all involved loads below the yield point of the concrete, which had an age of seven years, instead of a month, which is the usual age at which tests have been made. Repetition on the dry specimens not only verified the previous conclusion as to its capacity to safely endure an indefinite number of repetitions, but unexpectedly indicate that repeated loadings did not lower the Modulus of Elasticity materially below its early high value, which was perhaps ten per cent greater than at an age of one month. When saturated for a few days preceding the experiments, the Modulus had a value of about sixty per cent of the value when dry, and repetition of loading in this case also did not materially change its first value.

Mr. Herbert A. Smith was elected to membership.

OCTOBER 21, 1912.

President Engler in the chair; attendance 32.

Dr. Geo. O. James addressed the Academy "On the Contingence of the Physical Theory and the Problem of the Geologic Past."

After reviewing the theories of Helmholtz, Mach and Enriques on the Principle of Causality, Dr. James stated that so far as descriptive representation of the present is concerned, it makes no difference whether or not we admit that pushing precision of measurement further and further we shall ultimately come to a point where there ceases to be accord between observation and theory, and beyond which it cannot be again established. Even adhering to this conception of the contingent nature of the world of experience, we may still assert that the results of observation agree with those of theory to within errors which can be assigned. Experience alone, however, does not justify us in concluding that successive approximations will make these outstanding errors as small as we please, although this has long been the scientific conception. Admissible or not, this conception must be referred to some postulate of knowledge—the causal postulate as formulated by Enriques, for instance—and becomes a metaphysical question.

On the other hand, we may ask ourselves what we lose by denying this exactness to the laws of nature, and reasoning on the basis of the existence of an approximate physical theory only, which need never become rigorously exact no matter how large be the circle of phenomena taken into consideration, nor how precise the observations.

Painlevé's assumptions are:

1st. It is possible to adopt for all time and for all phenomena such a measure of length and such a measure of time that the principle of causality will be true always and everywhere.

2nd. It is possible to adopt for all time and for all measurements of the universe, such a system of reference that the laws of mechanics will be true always and everywhere.

This is the admission of a rigorous solution for the general problem of celestial mechanics, of which Anding's statement: "The problem of celestial mechanics is the representation of the motions of the heavenly bodies by means of the Newtonian Law of Gravitation, while at the same time the constants entering that representation, and the system of reference and the time are so determined as to give the best possible representation," is too narrow in that he assigns the law of attraction, and so fixes the form of the equations of motion.

The existence postulate of the planetary problem may be written: "It is possible to choose for the Solar system measures of length and time, a set of masses, a system of reference and a law of force, such that the behavior of the system is representated."

Does such a choice exist? The question may be stated in two essentially different ways:

A. Does a choice exist such that the resulting equations represent the behavior of the system to within errors less than the probable errors of observation in the neighborhood of a given epoch?

B. Does a choice exist such that the resulting equations rigorously represent the behavior of the system for all time?

An affirmation of B may be termed the Postulate of Causality, and a denial of B, but an affirmation of A, the Postulate of Contingence. It will be of interest to inquire into the answer to A by examining the degree of approximation attained in the representation of the motions of the solar system.

Using mean solar time, the masses of theoretical astronomy, the trihedron of the fundamental catalogue, and the Newtonian law of attraction, we find that the outstanding differences for the following are:

1. Mercury: A secular perturbation in the longitude of the perihelion of 41″ a century.
2. Venus: A secular perturbation in the longitude of the node of 10″ a century.
3. Mars: A secular perturbation in the longitude of the perihelion of 8″ a century.
4. Moon: A difference of about 5″ a century between the theoretical and observed values of the acceleration of the longitude.
5. Encke's Comet: A shortening of about 2½ hours in its 3.3 year period at each revolution.

Various attempts at modifying the planetary theory proving unsatisfactory, Seeliger in 1906 so modified the solar system itself as to remove the difference in the motions of Mercury, Venus and Mars.

So far as Encke's Comet is concerned, it is now recognized that the presence of a resisting medium in the neighborhood of the sun, as first assumed by Encke himself, is not an adequate explanation of the variation in its period and it remains one of the outstanding problems.

The disagreement in the observed and theoretical motion of the Moon has led to an attempted modification of the measure of time, and to the substitution of an inertial time gaining nine seconds a century on the mean solar time. This would remove the difference in the Moon's longitude.

The truth of A is established through experience quite independently of B, and so far as a representation of the behavior of the solar system throughout historic time is concerned, the Postulate of Contingence is sufficient. What then is the positive content of the postulate of causality which makes its retention essential to the existence of science? It is this:

The Postulate of Causality builds the program according to which we must envisage the geologic past, and prescribes the confines within which expectation places the future.

Without it neither would exist for us. Affirming B is equivalent to postulating the existence of a geologic past and a future accessible to us through a physical theory satisfying the requirements of A. The present planetary theory adequately represents the behavior of the solar system throughout historic time, but extended into the geologic past, it pictures a system without observational control. The past is constructed on the assumption of a permanent planetary theory, and if this theory does not possess permanence the past certainly furnished no means of detecting it.

Once the Postulate of Causality is replaced by a mere contingent coherence of phenomena, the past ceases to be and the mental horizon lies entirely in the world of experience. The data of that world may be ordered in any way that fits it, and the complex of relations connecting such data is controlled solely by the resulting errors. The problem is to make these as small as possible by continuous adjustment, and experience itself furnished no ground for belief that these outstanding errors themselves constitute an ordered group. They stand always, a chaotic totality, between the physical theory and the world of experience, preventing us from regarding that world as subject to law in the sense that relations are rigorously satisfied by its phenomena. Suppose then that we replace this world of experience by a fictitious world governed by a causal principle and osculating the world of experience during the present. This fictitious world will possess both a past and a future rigorously reducible from its present, and the postulate of causality identifies the past and the future of this fictitious world with the past and future of the world of experience, and so creates both for the world of experience.

Does a past or future created in accordance with the Postulate of Causality possess reality? The older point of view, which regarded empirical verification as a proof of reality, which nevertheless did not cease to exist even when all connection between the external world and its representation was broken, has given way to a modern conception of reality of which invariance is the criterion, but regards this invariance as relative and approximate.

Notice of the Death of Poincaré.

Dr. James then read the following:

Mr. President and Members—It seems fitting that on this, the first meeting of the Academy since Spring, we should express our recognition of the loss which science has suffered in the death of M. Jules Henri Poincaré, Member of the Institute of France and Professor of Celestial Mechanics in the Sorbonne.

M. Poincaré died in Paris on July 17 of an embolism after a two weeks' illness, and on July 19 after the religious ceremonies at the Church of Saint-Jacques-du-Haut-Pas, the funeral procession passed to the cemetery of Montparnasse, where lie also his friends Tisserand and Callandreau, who preceded him by but a few years.

Eulogies were delivered by M. Claretie, Director of the French Academy; by M. Lippmann, President of the Academy of Science; by M. Plainlevé, of the Institute; by M. Appell, Dean of the Faculty of Science, and by M. Bigourdan, President of the Bureau of Longitudes.

M. Poincaré was born at Nancy, April 29, 1854, received the degree of Doctor of Science from the University of Paris in 1879, and in 1881, at the age of 27, was offered the chair of Mécanique Physique by the Faculty of Science. In a period of 30 years he occupied successively the chairs of Mechanics, Mathematical Physics, Mathematical Astronomy and Celestial Mechanics.

In 1887, at the age of 33, he was elected to the Academy of Science, and in 1908 to the French Academy. He became a member of all the National Academies of Science of the world of the first class before he was 40, the only scholar ever accorded that honor.

In 1885 he was awarded the Poncelet prize, and in 1896 the Regnaud prize, both by the French Academy of Science. In 1889 he received the King Oscar II prize, in 1900 the gold medal of the Royal Astronomical Society, in 1901 the Sylvester medal, in 1904 the Lobachevsky prize, in 1905 the first award of the Boylai prize, and in 1909 the gold medal of the French Association for the Advancement of Science.

His memoirs and papers exceed fifteen hundred, and his published volumes cover almost the entire field of mathematical physics and astronomy.

In celestial mechanics alone his work would suffice for his glory. In 1887 King Oscar of Sweden established an International Congress of Mathematics, and it was the great medal of gold which was adjudged to Poincaré in 1889 for his study of the mechanical stability of our universe.

Year after year this intellectual giant attacked new problems and opened up new solutions for those that had long baffled the ablest minds. Whatever he touched yielded to the marvelous power of that great thinker, until all France knew that there lived among them a man capable of comprehending and adding to the accumulated knowledge of all time, *un "cerveau consultant,"* of human science. The scientific world envied France his possession, and nations with no reason to love her bowed down before the genius of her son, and accorded her respect because of him.

His was a life of profound and uninterrupted meditation—meditation despotic and pitiless, which stoops the shoulders and furrows the brow. Too soon he exhausted the body which he inhabited.

Toward the end of this magnificent intellectual career, which was the admiration and envy of the world, he turned the power of his mind to certain philosophic questions, profoundly conscious that nature was at last about to break him who had wrested so many secrets from her. The foundations of science trembled under his hands, but his was ever a constructive criticism, and he labored for truth, the high goddess whose servant he was.

A great thinker is dead, one of the greatest of all time. For him life was but a short episode between two eternities of death, thought but a gleam in the midst of a long night, but through the centuries science will bear the impress of the mighty mind of Henri Poincaré.

A motion was carried that the Academy record in its minutes the death of M. Poincaré and that Dr. James' paper be included in full in the record.

The Corresponding Secretary was requested to convey to Mrs. Russell Sage the appreciation of the Academy for her gift of $250,000 for the purchase of Marsh Island to be used as a reservation for the protection of bird life.

The death of Dr. W. J. McGee, a Corresponding Member, was reported.

NOVEMBER 4, 1912.

President Engler in the chair; attendance 35.

Professor F. E. Nipher addressed the Academy on "Geissler Tube Effects in Solid Conductors."

Professor Nipher gave a verbal account of work supplemental to that published in his last paper (Transactions Academy of Science of St. Louis, Vol. XXI, No. 3). This work has reference to the longitudinal creeping of a copper wire through which spark discharges are passed.

Mr. M. E. Hard gave a brief talk on "Mushrooms Found in the Vicinity of St. Louis," illustrating his remarks with fresh specimens.

Messrs. Robert A. Hall and W. H. Schlueter were elected to membership.

NOVEMBER 18, 1912.

President Engler in the chair; attendance 31.

Professor James F. Abbott addressed the Academy on "Permeability of Animal Membranes."

The "Fiddler Crabs" of the genus *Uca* accommodate themselves readily to immersion either in fresh or salt water, or to life in the open air.

This is due to a special mechanism for storing water in a capacious gill-chamber. When the gill-chamber is opened and rinsed out, they do not live longer than four hours in pure distilled water. Under such circumstances they gain in weight by the absorption of water, and lose salts to the surrounding medium by diffusion. They will live indefinitely in a mixture of NaCl and KCl of much lower concentration than that of sea water, although either salt is toxic by itself in the same concentration.

Dr. C. H. Turner gave a short talk on "The History of an Orphan Colony of the Paper-Making Wasp, *Polistes pallipes.*"

A colony of this wasp, consisting of nine capped cells containing pupae and fifteen open cells containing larvae, had been deprived of its "widow mother" and transferred to an insectary. This paper was a discussion of some incidents in the life of the wasps that emerged from the cells of that nest. The following conclusions were reached:

1. These wasps, which had never seen their mother nor associated with other wasps, performed all of the ordinary activities of such wasps except egg-laying and paper-making.

2. Large larvae that had nearly completed their larval, after fasting for eight days, then feeding on honey for two days and on their normal diet for the remainder of their larval life, spun normal cocoons and emerged normal wasps. Young larvae when submitted to this treatment died. Two large larvae after fasting for eight days and feeding on honey for two days, wove normal cocoons and emerged normal wasps. This result was a surprise, for Fabre's experiments on several different wasps (not of this species) has caused the belief that hymenopterous larvae that feed on insect food will die if fed honey.

3. After being restricted to a honey diet for several days, these wasps became cannibals, upcapping a pupal cell and feeding on the contents of the pupa.

4. From the first the wasps were so tame that they would accept honey or insect food when offered them on glass rods, steel spatulas or the fingers.

5. Lepidopterous larvae captured for food are not stung. Grasping the caterpillar with her forelegs, the wasp rotates it on its longitudinal axis and gradually elevates the insect while she malaxates the posterior end until her jaws are filled with a ball of pulpy

matter. The remainder of the insect is then dropped. This is quite unlike what Belt found to be the case in *Polistes carnifax*.

6. Several of the small larvae died. The wasp that was acting as nurse would enter the cells and attempt to feed these dead wasps.

7. The behavior of these wasps indicated that, in finding their way home, they were guided in part by associative memory.

"Indian Miniature Axes and Celts" was the subject of a talk, illustrated with lantern slides and specimens by Dr. H. M. Whelpley.

Stone axes of utility range from four to six pounds and those of hematite from one-half to four pounds. Ordinary axes occur not weighing more than three ounces. Miniature axes form a class by themselves in weight below one-half ounce. The usual miniature ax weighs about one hundred grains. They are similar in shape to ordinary axes. The workmanship is usually very good. They are generally made of granite or hematite and are found where axes of utility occur. The purpose for which they were made is problematical. It has been suggested that they were toys for children, ornaments, amulets for medicine men or examples of expert workmanship. They are usually found on village sites or picked up in the field. Fraudulent miniature axes are more plentiful than genuine. They are usually made from material which is readily worked and seldom equal the genuine article in finish.

Of four hundred stone celts in Dr. Whelpley's collection, 74 per cent weigh between four ounces and two pounds. Three hundred and fifty hematite celts in the same collection average about two ounces each. Miniature celts, like miniature axes, are separated from those of normal size by a wide line of demarcation in weight and size. Scarcely any normal celts occur below three ounces or hematite celts below one-half ounce in weight. Miniature celts weigh about one hundred grains each. They are not faked to the same extent as are miniature axes. The comments on shape, workmanship, material, distribution, use and conditions of finding miniature axes also apply to miniature celts.

It has not been suggested that miniature axes and celts were made by a race of dwarfs. Such claim has been made to explain miniature flint arrows. The speaker estimated that miniature axes and celts occur in about the proportion of 1 to 5000 of those of normal size.

Messrs Benjamin M. Duggar and LeRoy McMaster were elected to membership.

December 2, 1912.

President Engler in the chair; attendance 25.

Professor Wm. H. Roever read a paper entitled "The Design and Theory of a Mechanism for Illustrating Certain Systems of Lines of Force and Stream Lines."

In this paper, which includes the theory of the mechanism exhibited at the meeting of April 15, 1912, it is shown that not only for radial spokes, but also for spokes in the form of logarithmic spirals, the mechanism illustrates lines of force. By having several pairs of wheels with different systems of logarithmic spirals (in particular, of radial lines) it is possible, in virtue of the device for obtaining different angular velocity ratios, to obtain a great number of different systems of curves, each of which may be regarded as lines of force or stream lines in five or six different branches of mathematical physics. It is possible, by making time exposures, to obtain well-defined photographs of these systems of curves. This possibility adds to the usefulness of the mechanism. The mechanism and photographs of some of the systems of curves were exhibited.

Dr. D. L. Harris read a paper on "Experimental Work on the Etiology of Rabies and the Mechanism of Anti-Rabio Immunity."

Professor W. H. Roever, Mr. Frank Schwarz and Dr. R. J. Terry were elected a committee to nominate officers for the year 1913.

December 16, 1912.

President Engler in the chair; attendance 32.

The following report of the Nominating Committee was read:

St Louis, Mo., Dec. 16, 1912.

The Academy of Science,
St. Louis, Mo.

Gentlemen: The nominating committee, appointed at the meeting of December 2, 1912, begs to submit the following nominees for offices for the year 1913:

For President........................... Edmund A. Engler.
For First Vice-President................. Francis E. Nipher.
For Second Vice-President................ Arthur E. Ewing.
For Recording Secretary.................. J. A. Drushel.
For Corresponding Secretary.............. Geo. O. James.
For Treasurer............................ H. E. Wiedemann.
For Librarian............................ Wm. L. R. Gifford.
For Curators............................. Julius Hurter, Philip Rau, Hermann von Schrenk.
For Directors............................ Adolf Alt, H. M. Whelpley.

Respectfully submitted,

(Signed) Wm. H. Roever,
Frank Schwarz,
Robert J. Terry.

Professor LeRoy McMaster gave a review of the address of Dr. E. A. Schaefer, on the "Chemical Origin of Life," before the British Association for the Advancement of Science.

Dr. A. E. Ewing gave some of the results of his investigations on the plum curculio: its food, ability to stand cold, inability to stand drought, longevity.

A series of experiments with the plum curculio, conducted during the summers and the winter of 1908 and 1909, showed that the fruit of the plum or of the peach tree is not essential to the life of the adult being, 45% of the insects that survived the winter living until the last of May, 20% until the middle of June, 10% until the first of July and 3% until the first of August, although in captivity and fed only on fresh plum and fresh peach leaves. While they always showed a strong preference for plum and peach leaves, they also ate apple leaves, celery, cabbage and bits of Irish potato vines. Quince, willow and rose vine leaves were eaten sparingly. Attempts were made to eat the pear leaf, but the epidermis seemed to be too tough. The leaves of the maple, black and white mulberry, haw, wild and cultivated cherry, wild plum, raspberry, grape vine and honeysuckle were not touched. Fresh slices from winter apples and also dried peaches were readily eaten, and dried peach and cultivated plum leaves after having been moistened in water.

For a single, apparently thoroughly satisfying meal a curculio was observed to cut a hole 1.5x4.5 mm. in size in a fresh, green plum leaf in two and one-half hours. The action of the snout, as seen under a hand-glass, was similar to that of the head of a sheep or a cow while grazing. The accompanying halftone (Fig. 1) shows the peach leaves eaten by 18 curculio from September 20 to 26, 1909, while in captivity in a Mason jar. The companion halftone (Fig. 2) shows the control leaves which were in an adjoining jar.

During the winter a number of curculio were kept in jars covered with tarlatan, near a window in the celler, where the temperature was never below 50° F. They continuously fed on moistened dried peach and plum leaves and slices from fresh winter apples and bits from dried peaches, though not with the avidity as in the case of the fresh leaves of the spring and summer.

The ability to stand cold was evidenced by the following experiment: A tin can, five inches in diameter and eight inches deep, capped with fine copper wire mesh, was filled to five inches with earth and sunk five inches in the ground in the back yard, numerous fine holes having been punched in the sides and bottom to admit moisture and to prevent the entrance of ants. In this can twenty-five curculio were placed November 1st, 1908, together with a handful of dried plum leaves and several slices of dried peaches. On the 7th of the following March, which was a bright warm spring day, ten of the curculio were found alive among the leaves. These were removed from the can. On the

4th of April, 1909, a further very careful examination was made and fourteen others were found alive, in all twenty-four out of twenty-five that had survived the winter. The weather report shows that in January, 1909, the temperature ranged as follows: Sixth, 2 degrees; 7th, 1 degree; 10th, 9 degrees; 11th, 5 degrees, 12th, 3 degrees, 29th, 7 degrees; 30th, zero; 31st, 1 degree below zero, which would have frozen the ground to a depth greater than five inches. This refutes the idea, which obtains in our Southern states, that the insects are killed by the cold. What really takes place is that the fruit is killed by the cold and this destroys the nesting place for the insect, the result of which is one or two years of sound fruit. It is of further interest that the plum leaves in the can were full of holes, as if they had been fed upon during the warm days of the winter and spring when the curculio were not torpid.

One of the jars in the cellar was permitted to become dry as the winter progressed. The curculio in the jar all died, although it was the hibernating season. This lack of ability to stand drought is the probable explanation of why the fruits from the Pacific Coast are free from the pest.

It is shown above that a considerable percentage of the curculio that have successfully passed the winter will live till June or July. In this series of experiments one lived until September 12th, and in another series, conducted during the summer of 1910, one survived until August 21st, an evidence that the curculio of the preceding year are in the orchard until after the usual season for gathering the peach crop.

REPORTS OF OFFICERS.

Treasurer's Report.

Receipts.

Balance from 1911	$ 26.84
Dues from members	2,002.00
Rent from tenant societies	610.00
Telephone (Engineers' Club)	10.00
Academy's Transactions sold	50.50
Interest on balance	.71
H. E. Ewing (toward printing paper)	33.06
Income from endowment fund	788.76
Total receipts for the year	$3,521.87

Expenditures.

Salaries	$1,380.00
Water license	24.61
Gas, electric light and power	118.11
Fuel	324.93
Telephone	54.25
Printing	822.12
Current expenses	329.78
Fire Insurance (5 years)	120.00
Total expenditures for the year	3,173.80
Balance December 31, 1912	348.07
	$3,521.87

Respectfully submitted,
(Signed) H. E. Wiedemann,
Treasurer.

Librarian's Report.

The Librarian reported that the accessions to the library for the year 1912 by exchange with 114 home and 308 foreign societies amounted to 589 volumes and 263 pamphlets, by donation 71 volumes and 110 pamphlets, and by purchase 4 volumes.

The Transactions for the year were sent to 114 home and 308 foreign societies.

Curators' Report.

The Curators reported that during the year donations were received from:

J. A. Drushel.—Five species of Ordovician Brachiopods and two species of Ordovician Bryzoa.

Joseph Grindon.—Three Colubris from Guadeloupe, West Indies.

Mary J. Klem.—Fossil tree trunk from Veedersburg, Indiana.

Wm. Trelease.—Four rosaries made of seeds by Alaska Indians. Two pouches made of sealskin by Alaska Indians. Aleutian waterproof jacket and belt made of seal intestine. Paper weight of the original punch for the Engelmann medal of the fiftieth anniversary

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Transactions of The Academy of Science of St. Louis.

VOL. XXI. No. 1.

THE ORIGIN AND SIGNIFICANCE OF PARASITISM IN THE ACARINA.

HENRY ELLSWORTH EWING.

Issued June 18, 1912.

PUBLICATIONS.

The following publications of the Academy are offered for sale at the net prices indicated. Applications should be addressed to The Librarian, The Academy of Science of St. Louis, 3817 Olive St., St. Louis, Mo.

TRANSACTIONS (in octavo).

Vol.	Number.	Price per number.	Price per vol.	Price in set.
1	1* 2† 3, 4	.... $4.00 2.00 each.	$7.50 (Nos. 2-4 only.)	$7.00 (Nos. 2-4 only.)
2	1 to 3	2.00 each.	5.50	5.00
3	1 to 4	2.00 each.	7.50	7.00
4	1 to 4	2.00 each.	7.50	7.00
5	1-2, 3-4	4.00 each. (double numbers)	7.50	7.00
6‡	1, 2, 6, 8, 10, 11, 16, 17 4, 5, 7, 13, 14, 15, 18 3, 9 12	25 cts. each. 50 cts. each. 75 cts. each. $1.00	7.50	7.00
7‡	2, 3, 4, 6, 7, 8, 13, 15, 16, 18, 19 5, 9 to 12, 14, 20 17 1	25 cts. each. 50 cts. each. 75 cts. $1.00	7.50	7.00
8‡	1, 3 to 6 8, 10, 12 2, 7, 9, 11	25 cts. each. 50 cts. each.	3.75	3.50
9‡	1, 3, 4, 7, 9 2, 5, 8 6	25 cts. each. 50 cts. each. $1.25	3.75	3.50

Continued on page 3 of Cover.

THE ORIGIN AND SIGNIFICANCE OF PARASITISM IN THE ACARINA.*

HENRY ELLSWORTH EWING.

In the study of the origin and significance of parasitism in the Acarina one is confronted by conditions extremely complex, on account of the great variety in the forms met with and the complicated symbiotic relations involved. In the preparation of the present paper the writer made many and extended field observations of these minute creatures, covering a period of several years; and these have been supplemented by laboratory experiments.

In my treatment of the subject of parasitism in the Acarina special attention will be given to three aspects of the question:

The causes leading to the origin of the parasitic habits, and the subsequent development of these habits.

The analysis and classification of the various aspects of parasitism.

The significance of distribution according to host species.

In regard to the first of these aspects, altogether too little has been done by the way of scientific research, and scarcely nothing in the Acarina. In this country Professor H. Osborn has studied the origin and development of the parasitic habit in epizoic insects.

In regard to the second aspect it appears that as yet we are without a very complete and analytical classifica-

* Presented by title to The Academy of Science of St. Louis, February 19, 1912. Presented to the faculty of the Graduate School of Cornell University for the degree of Doctor of Philosophy, June, 1911.

tion of the various kinds of parasitism, notwithstanding the fact that the various symbiotic and other relationships involved in the habits of parasites have received the serious attention of parasitologists for years. It might be mentioned, however, that a few years ago Stiles compiled a list of the various kinds of parasites,[1] as recognized by different workers, and tabulated them according to the basis upon which they were made.

In regard to the third point, the significance of distribution according to host species, much more has been done, but scarcely anything in the Acarina; although here there is perhaps, one of the very best groups in which to study it. Professor Kellogg of Stanford University has made an extensive study of the distribution according to host species in the Mallophaga.

The chief work upon this paper was done in the Entomological Laboratory of Cornell University, and in its preparation I have become indebted to several persons, but especially to Professor Comstock, and to Dr. W. A. Riley, who has made an extensive study of parasitism. Professor V. L. Kellogg has also made suggestions which have been especially valuable, since he has made a thorough study of somewhat similar problems in the Mallophaga, and Dr. R. H. Wolcott of the University of Nebraska has supplied me with valuable data in regard to the habits of the "Water Mites."

Definition of Parasitism.

But few terms exist in the biological literature of such common usage as the term parasitism, yet few are so difficult of definition or so incapable of proper limitations. Many attempts have been made to define parasitism; but as our knowledge has been extended we have been compelled to recognize more and more its complexity; until today perhaps no two naturalists could agree upon the

[1] Stiles, C. W. Parasitism. Proc. Ent. Soc. Wash. **3** : 6.

same limits of its definition. Used in the broader sense Mégnin has described as parasites[2] those which live at the expense of others which are living. Simple as this definition is, the scope of its interpretation is so great that it appears almost useless, for it might well be said that nearly all organisms live at the expense, directly or indirectly, of other living organisms. Leuckart would include as parasites[3] all those creatures that inhabit a living organism, and obtain nourishment from its body. This definition, which is perhaps as good as any, is objected to by many who claim that a parasite need not necessarily "inhabit a living organism"; or in other words a definite host relationship is not necessary in order to establish parasitism; for example, many parasites only visit the forms subject to their attacks at feeding times, and certainly do not inhabit them. Another objection may be raised to this definition because the statement of obtaining "nourishment from its body" is hardly clear or sufficient. Some epizoa live upon the excretions, or the secretions, or the food taken into their hosts, yet I do not see how it could be said that they obtained their nourishment from the body of the forms they attack. So with equal impunity every definition offered in the past may be criticised and rejected.

I cannot hope, therefore, to give a definition of parasitism that will meet with general acceptance. But I believe that the special forms of parasitism can be satisfactorily defined.

It is only in recent years that the varied nature and complexity of the factors involved in parasitism have been realized. Prominent parasitologists as Leuckart, Küchenmeister, Cobbold, Mégnin, and Neumann, did great and extensive work on the life histories of parasites. Many specialists in the various groups of parasitic

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[2] Mégnin, P. Les Parasites et les Maladies Parasitaires. Paris, 1880.

[3] Leuckart, K. G. F. R. The Parasites of Man. Translated from the German by W. E. Hoyle. Edinburgh, 1886.

organisms have studied the aspects of parasitism and helped settle many questions in regard to their nature, significance and ecological relations. From the results of these various workers and from my own observations, I have been able to obtain a large amount of data in regard to the various biological aspects presented in the different states of symbiosis which have been included under the term parasitism.

Although numerous and various kinds of symbiosis have been considered under parasitism by others, for the purposes of this paper the writer has decided to limit the use of the term as follows:

It must predicate the actual subsistence of one form upon the bodily tissues or the physiological products of the bodily tissues of another living organism.

A host relationship will not be necessary in order to establish parasitism.

The organism affected by the parasite is not necessarily injured by the same.

Limiting the term in this way, the following classification of parasites can be made. This classification is in a nature theoretical to the extent that in a few phases of parasitism given, examples appear to be as yet wanting, but no doubt that more extended observation in the plant and animal kingdom will reveal all or most of them.

A Classification of Parasites.[4]

Taking into account the nature and habits of the parasites themselves.

Depending upon whether the parasite is a plant or an animal.

Phytoparasites.

Zooparasites.

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[4] In giving this classification of the different kinds of parasites many of the kinds are not designated by special names; the writer preferring to define the kind of parasite given rather than inflict upon the general student of biology any new technical terms, thus overloading a terminology already rather unwieldy.

Depending upon the nature of the food eaten.
- Those living upon the bodily tissues.
  - Those living upon live tissues.
  - Those living upon dead tissues.
- Those feeding upon partially digested food.
- Those living upon blood of the species affected.
- Forms feeding on secretions.
- Forms feeding on excretory products.
- Forms living upon the eggs of the species affected.
- Forms living on spermatozoa.

Depending upon adaptation to the parasitic life.
- Facultative parasites.
- Obligatory parasites.

Depending upon the stage of degeneration of the locomotor organs.
- With wings.
- Without wings.
- Capable of walking when off the host.
- Incapable of walking when detached from host.
- Without legs.

Taking into account the nature and habits of the organisms attacked.

Depending upon whether the organism attacked is a plant or an animal.
- Photophagous parasites.
- Zoophagous parasites.

Depending upon the free state, or the stage of parasitism of the organism affected.
- Primary parasites.
- Secondary parasites.
- Tertiary parasites.

Depending upon the conditions imposed by the life of the host.
- Hydroxenous parasites (with an aquatic host).
- Geoxenous parasites (with a terrestrial host).
- Aeroxenous parasites (with an aerial host).

Depending upon the number of hosts.
- Monoxenous parasites.
- Heteroxenous parasites.
  - Bixenous.
  - Trixenous.
  - Tetraxenous.
    - etc.

Taking into account the interrelations of the parasites and organisms affected.

Depending upon the position of the parasites in relation to their hosts.

Endoparasites.

Living in the passages or cavities of the body where there is a direct communication with the outer world.

Living free inside of the body cavity but not in connection with the outer world.

Imbedded in the tissues of the host.

Ectoparasites.

Cuticolata, living on the skin.

Villicolata, living on hairs.

Plumicolata, living on feathers.

Depending upon the duration or time of parasitism.

Erratic parasites.

Periodical parasites.

Nocturnal.

Diurnal.

During a definite stage or stages in the life cycle of the species attacked.

During the egg stage.

During the fetal stage.

During immature stage or stages.

During the adult stage.

Permanent parasites.

Depending upon symbiotic relationship.

Mutualists (where the relationship is beneficial to both parasites and host).

Commensals (where the relationship is beneficial to the parasite, and neither beneficial nor injurious to the host).

True parasites (where the relationship is beneficial to the parasite and injurious to the host).

Depending upon the blood relationship of the parasite to the host.

Host or organism affected not related to the parasite.

Host or organism affected closely related to the parasite, perhaps belonging to the same family, but not of the same species.

Organism affected of the same species as the parasite itself.

Host the opposite sex.

Host the male.

Host the female, parasite the male.

Host one of the parents, but parasite not fed by special secreting glands or nourished in the uterus of the female.

The father the host.

The mother the host.

Host one of the voung of the parents.

The Zoological Position of the Acarina.

The Acarina consist of a more or less natural group of the class Arachnida. The saclike form of the body, the absence of a distinct head, the possession of four pairs of legs, the usually very incomplete metamorphosis, as well as the structure and relationships of the internal organs, are only a few points which demonstrate their undoubted position in this class. The absence or incomplete development of many of the special senses, the loss of many specialized structures found in a high grade of development in some of the other groups of Arachnida, as well as the frequent assumption of a parasitic life, all point toward a line of degenerate descent from the ancestral stock of the class to which they belong. It must be remembered, however, that in some respects they show a development of specialization that is perhaps not excelled by any of the various groups of the arachnids.

The nearest affinity of the order appears to be with the Phalangidea, yet in some respects they are more nearly related to the Solpugida. This relationship of the Acarina to the Phalangidea has been most clearly shown by the discovery and study of some of the smaller tropical phalangids. Some of these phalangids are exceedingly mitelike in general appearance, and a careful study of them brings out other points of relationship. Among these characters might be mentioned their smallness, the shortness of the legs and their reduced number of segments, the more nearly saclike shape of the body, the length of the palpi, and the form of the body. But many of the characters of the Acarina may be used to demonstrate their affinity with the more common of the Phalangidea. These may be listed as below:—

A general similarity in the shape of the body, especially in the breadth and frequently depressed condition of the abdomen.

The possession of a segmented abdomen by several forms of the Acarina, showing probably a homologous state to that of the Phalangidea.

The possession of median eyes in some of the mites, suggesting the condition found in the Phalangidea.

The close similarity of the typical chelate chelicera of the mites to those of the Phalangidea.

The possession by the two groups of very similar internal organs, especially those of reproduction, and digestion.

The similarity of habits existing between many of the free-living Acarina and the Phalangidea.

The relation of the Acarina to the Solpugida is best brought out by the study of the species of the genus *Rhagida,* belonging to the family Eupodidae. There is a remarkable resemblance of these mites to solpugids. This is shown in the general shape of the body, the form and shape of the legs and the palpi, but more especially in the size and shape of the chelicerae. These are of enormous size as in the solpugids, being equal to a fourth or fifth of the total length of the body. They are greatly swollen, and the movable digit works vertically as in the solpugids. An investigation of their internal anatomy has shown that it is among the most primitive of the Trombidoidean type.

Of the various groups of the Acarina which have been suggested as being most nearly related to the primitive stock, the genus *Opilioacarus*[5] has attracted most attention of late. The genus is represented by four species found in the following countries: Algeria, Italy, Arabia, and South America. These mites have a segmented abdomen, leg-like palpi, chelate chelicerae, two pairs of eyes; while the tracheae open by means of four dorsal stigmata. The possession of a segmented body is certainly a marked primitive character, but it must be remembered that some of the well-known groups possess a more or less segmented body, for example the Tarsonemidae and some of the Tetranychidae. The possession of leglike palpi as well as chelate chelicerae are even

[5] For a figure of one of these species and a short discussion of the systematic characters see: Oudemans, A. C. A Short Survey of the More Important Families of Acari. Bull. Ent. Research. 1 :105. 1910.

typical of several of the well-known groups of mites, the chelate chelicerae being the most common type in the Acarina. The most curious fact in regard to this genus, the phylogenetic significance of which is much in doubt, is the possession of four dorsal stigmata. This character is so different from that of any of the other known Acarina that the genus has been raised to the rank of a suborder by some acarologists.

The Range of Parasitism in the Acarina.

In order to determine the origin and significance of parasitism in the Acarina it is necessary to study the range of parasitism within the order, to determine the relationships between the parasitic and the free-living forms.

This study can only be tentative at this time; for only a small proportion of the acarid fauna of the world is known. The results of such a study are shown in tabular form below, and in the further notes regarding separate families that follow the table.

TABLE I.

Table of Habits of Mites.

Family	Free	Semi-parasitic	Parasitic	Only larvae parasitic
Eupodidae	All genera			
Bdellidae	All genera			
Cheyletidae	Cheyletus	Cheyletiella	Myobia Harpyrhynchus Psorergates Picobia Syringophilus	
Caeculidae	Caeculus only genus			
Tetranychidae	 Caligonus	Bryobia Raphignathus Neophyllobius Tenuipalpus	Tetranychus Stigmaeodes Stigmaeus	
Erythraeidae	Erythraeus Anystis		Gekobia	
Rhyncholophidae				All genera
Trombidiidae				All genera
Hydrachnidae			Atax	All genera except Atax
Halacaridae	Some of the genera			Most of the family
Ixodidae			All genera	
Argasidae			All genera	
Dermanyssidae			All genera	
Gamasidae	Iphiopis Epicrius Greeniella Macrocheles (mostly) Celaenopsis Megisthanus Antennophorus	 Laelaps	Haemogamasus Raillietia	

TABLE I.—*Continued.*

TABLE OF HABITS OF MITES.

FAMILY	FREE	SEMI-PARASITIC	PARASITIC	ONLY LARVAE PARASITIC
GAMASIDAE	Podocinum Liroaspis Zercon Seiodes Seius Gamasus			
URODODIDAE	Glyphopsis Polyaspis Uroseius Dinychus	Uropoda	Cilliba (some species)	
ORIBATIDAE	All genera			
NOTHRIDAE	All genera			
HOPLODERMIDAE	All genera			
PEDICULOIDIDAE	Pediculoides (mostly) Siteroptes	 Pigmeophorus	Pediculoides (in part) Podapolipus	
TARSONEMIDAE	Tarsonemus (in part) Disparipes	Tarsonemus (in part)	Tarsonemus (in part)	
TYROGLYPHIDAE	Most of the genera	Histiostoma (in part)	Histiostoma berghi	
LISTROPHORIDAE			All genera	
ANALGESIDAE			All genera	
CANESTRINIDAE		Hemisarcoptes	Most of the family	
SARCOPTIDAE			All genera	
CYTOLEICHIDAE			All genera	
DEMODECIDAE			All of family	
ERIOPHYIDAE			All genera	
Unplaced				
OPILIOACARIDAE				

Further Notes Regarding the Separate Families.

Eupodidae.—This is a small family of mites which live in dark, damp places. They are predaceous and of very agile movements.

Bdellidae.—A small family of mites of medium size. They live among dead leaves and rubbish, but may be found on trees under bark. All are predaceous. The mouth-parts are very large, the palpi may be raptorial.

Cheyletidae.—The genus *Cheyletus* is free and predaceous, and its members are found under dead vegetation and under dead bark, etc. *Cheyletiella* is found upon furred animals, but it is doubtful if it lives at all from their tissues, but rather, simply preys upon other parasites present. The parasitic genera are found upon both birds and mammals.

Caeculidae.—Only a few forms are included in this family, and little or nothing is known of their habits. They are found in moss and rubbish where there is plenty of moisture.

Tetranychidae.—All the members of this group are plant feeders. Where the attacks of a single individual or several generations of the same species are confined to a single food plant (hence host plant) the species is called parasitic. In several cases there is a strong tendency for individuals to attack a single plant, yet they may leave the same; these species may be called semi-parasitic.

Erythraeidae.—The two free genera include predaceous forms which run about plants. The parasitic genus includes forms parasitic on reptiles.

Rhyncholophidae.—Rather large acarids, the adults of which are found running over the leaves of various plants and the bark of trees. The adults are predaceous.

Trombidiidae.—Some of the mature forms of this group constitute the largest known free-living Acarina. Although the larvae are parasitic, the mature forms are predaceous.

Hydrachnidae.—The largest family of the order. They are aquatic, and with but few exceptions, are free in the adult state. The larvae are parasitic on aquatic insects.

Halacaridae.—Includes marine forms. All the adults are free and feed upon minute vegetation. Some of the larvae are free and some are parasitic.

Ixodidae.—Includes most of the ticks. All are parasitic, but usually leave their hosts in order to molt. They are haematophagous, and do not show nearly as great a stage of degeneration as some of the other parasitic groups.

Argasidae.—A very small family, including some forms of ticks which have not degenerated as much as the true ticks. They are nocturnal, haematophagous parasites.

DERMANYSSIDAE.—Parasitic mites, but the habit of parasitism is evidently not of very long standing, since some of the members are yet facultative parasites, and few species show any noted symptoms of degeneration.

GAMASIDAE.—As far as habits are concerned this group is very heterogeneous. Most of the species are free and predaceous; however, many species live in various degrees of symbiotic relationships with certain insects, especially the ants. Some of these are pure scavengers, others live upon the salivary secretions with which the ants cover their eggs, while others feed upon food regurgitated by the ants. At least two genera are true parasites, while semiparasitic species are found in the genera composed mostly of free species.

UROPODIDAE.—Most of the members of this group are predaceous in their adult state. In the nymphal state they are frequently found attached to various arthropods for the purpose of transportation. A few forms are parasitic when mature.

ORIBATIDAE.—Free-living forms. They are found in dark, moist places, where they live upon fungi or small bits of decaying matter.

NOTHRIDAE.—A large family. They are especially characterized for their hard, chitinous integument. They live under bark and under logs where it is moist and feed upon small vegetable organisms and rotten wood.

HOPLODERMIDAE.—A very small group of vegetable feeders of similar habits to the preceding family.

PEDICULOIDIDAE.—The members of this family are very small and constitute a very heterogeneous group. Some of the members are plant feeders, others will make sporadic attacks upon animals, and a few are real parasites.

TARSONEMIDAE.—Contains two well represented genera, one of which is plant feeding and one which has free as well as parasitic forms and intermediate stages.

TYROGLYPHIDAE.—This is a small family in species, but large in number of individuals. They are atracheate creatures, blind and live as scavengers. Individuals of the genus *Histiostoma* are taking up parasitic habits.

LISTROPHORIDAE.—This is probably not a natural group, but the forms included in it have been so placed because of a similarity of habit. They are parasitic upon small mammals.

ANALGESIDAE.—A very large family. They live in the plumage of birds, feeding upon epidermal scales, excreted matter, etc. About 400 species are known.

CANESTRINIDAE.—Only a few species represented and these are parasitic on insects. *Hemisarcoptes* is hardly a true parasite as yet.

SARCOPTIDAE.—A very important family composed of the itch mites. They live in the skin, and in a few cases in the internal organs of other animals. Here degeneration reaches its limit.

CYTOLEICHIDAE.—Only two species known. They live in or upon the skins of fowls, or in the air passages of the same.

DEMODECIDAE.—Includes but one genus, *Demodex*, which occurs in the hair follicles of mammals. The body is vermiform and the legs are reduced to stumps.

ERIOPHYIDAE.—Consists of several genera of vermiform Acarina which live upon plants. Most of them produce galls or other malformations of leaves.

OPILIOACARIDAE.—Habits unknown and systematic position uncertain.

PATHS OF EVOLUTION FROM THE FREE-LIVING TO THE PARASITIC FORMS.

In our study of the origin of parasitic forms from free-living types two facts appear pre-eminently important; first, no great or sudden change in the nature of the food must be encountered; and, second, there should be but a gradual change in the environmental conditions.

A study of the way in which parasitism has arisen in many of the larger natural groups of the animal kingdom, has shown us that it has followed at least several well defined courses. Of these several lines of descent, as we may call them, the first of which I will treat, and which is the simplest of all, is the origin of parasitism in predaceous groups of animals. In such cases it is evident that often there would be little and frequently no change whatever in the nature of the food, in the transition from the predaceous to the parasitic life. What is yet more significant of the gradual transition from the predaceous habit, is that forms now exist that are actually on the border line between the two and might equally well be called predaceous or parasitic, according as to whether they attack forms smaller or larger than themselves. This point might be illustrated in the case of some of the leeches, which may attack forms larger than themselves and thus be parasitic, or attack forms smaller than themselves, in which case they might be called predaceous. The same might be said of some of the blood-sucking members of the family Pentatomidae in the insects. In these cases all that is necessary to establish the parasitic habit is that the preying form shall more frequently attack larger animals than itself and in such a way as not to overpower these or hold them captive while feeding from their substances.

Another road over which we find the parasitic habit developing is in groups which are scavengers. In these groups the free individuals frequently live upon small bits of dead plant or animal tissues and when they first begin to take on parasitic tendencies they generally confine their attention to essentially the same kind of food material, which is found in the dead cutaneous or excretous products of the organism to be parasitized. In these cases, as in most cases of parasitism, the parasites themselves are small and likewise descended from small forms. A good illustration of this method of the origin of the parasitic habit is shown in the origin of parasitism in the Mallophaga. The Mallophaga are small, flat, apterous insects that live chiefly on the barbules of feathers and on dead cutaneous cells. A study of their development and structure[6] has established a very close relationship between them and the Corrodentia, or book-lice. These free-living insects live on small bits of organic matter which they find under logs, bark, etc. That parasitic forms have been evolved from these or from forms of similar habits appears to be evident. Here again we find the change of the kind of food is but slight and also the environmental conditions are entirely satisfactory for those forms which should, perhaps at first by accident, find themselves transferred to the plumage of birds.

Yet a third way in which zoophagous parasitism may have originated is in forms which live on plant juices. The structure of their mouth-parts is such as to be al-

[6] Kellogg, V. L. New Mallophaga, II. Proc. Cal. Acad. Sci. II. 6: 431-471. 1896.

most as well adapted for sucking the blood of animals as the juices of plants. Mr. Tucker[7] has recently made some careful observations on several species of plant-bugs in regard to their attacks on man. He found that several of these, particularly some of the Jassidae, or leafhoppers, would at times attack human beings and cause them much annoyance. In doing so they really did feed on the blood of the individuals bitten. In regard to the attacks of *Empoasca mali* Le B. he states: "From the time my attention was first attracted by feeling the bite until the insect desisted, a trifle over four minutes elapsed according to my watch. The first insect was then captured, and after being crushed on a white sheet of paper a faint bloody streak was produced, which proved beyond any doubt that the specimen had actually engorged itself with blood."

In the Acarina we find the parasitic habit developed independently from several groups of free-living forms, but in each case I think that its method of development has been over one of the three roads indicated above. By a study of Table I the following classification of the free-living Acarina can be made, all of them falling into one of three classes. These classes are as follows:

I. Free-living predaceous forms: usually provided with eyes and prehensile organs; possessing a delicate sense of touch and being very agile in movements. To this class belong:

The Eupodidae and Bdellidae.
Caeculidae (Habits doubtful but probably predaceous).
Of the Cheyletidae, the genus *Cheyletus*.
Some of the Halacaridae.
Most of the Gamasidae.
Many of the Uropodidae.

II. The free-living scavengers. These forms, as a rule, are less highly specialized than the predaceous forms (a correlation with their mode of life). They

[7] Tucker, E. S. Random Notes on Entomological Field Work. Can. Ent. 43: 29-31. 1911.

usually are blind, without prehensile organs, atracheate, and are more or less sluggish. To this class belong:

A few of the Gamasidae.

The Oribatidae, Nothridae and Hoplodermidae. (Many of the species of these families live partially on small vegetable organisms, as fungi, but on the whole they are to be regarded as scavengers.)

Practically all the Tyroglyphidae.

III. The free-living phytophaga. The phytophaga, as a rule, have piercing mouth-parts. They possess the special senses developed to a moderate degree, while the palpi have become reduced. In their movements they are not as agile as the predaceous forms. To this class belong:

Some of the Tetranychidae.

A few of the Oribatidae and Nothridae.

Some of the Pediculoididae and Tarsonemidae.

From these three classes of free-living forms, or from their ancestral types of very similar habits and of somewhat similar structure, there arose the various groups of our present day, living, parasitic Acarina. To show how this process probably took place, and how many and what kind of lines of descent there are in the parasitic forms, will be the next object for our consideration.

Standing in close relation to the free-living forms of the first class, either as genera of the same families or as closely related families, or groups of genera or families, we have the following apparently natural groups:

The parasitic Cheyletidae.

Families of the trombidoidean type with parasitic larvae (Rhyncholophidae, Trombidiidae, Hydrachnidae, Halacaridae [mostly]).

Ixodidae, Argasidae, Dermanyssidae and some genera of the Gamasidae.

A few parasitic forms of Uropodidae.

In a similar manner the following groups of parasitic Acarina are allied to the free-living forms of the second group, the scavengers:

Some of the Gamasidae (?).

Canestrinidae and Sarcoptidae.

Listrophoridae (in part).

Analgesidae.

One zoophagous parasitic group, showing affinity to the plant feeding free forms, is known:

The parasitic Pediculoididae.

Very many facts could be brought together, showing that each of the four phylogenetically separate subgroups of parasitic forms included in the first group of parasites indicated above has been evolved from predaceous ancestors; but, owing to the limits of space, only two of the subgroups will be considered here, the parasitic Cheyletidae and the parasitic Peritremata, excluding those few forms found in the Uropodidae, which evidently had a separate origin.

The parasitic Cheyletidae both in habits and in their superficial external characters appear to be related to the Sarcoptidae and the Analgesidae, and have been placed with such forms by some authors; but the following structural characters will, I think, show that their affinity with the Cheyletidae should not be disputed:

They possess tracheae, hence these must have been either evolved from tracheate ancestors, or the tracheal system must have been evolved independently in forms of parasitic habits. The latter alternative is something almost entirely beyond our belief, since it is in contradiction to the common influence of parasitism; and if so, would represent a process so exceptional in the history of arthropod evolution as to be only duplicated in an extremely few instances, covering vast periods of geological time.

The absence of anal suckers and tarsal suckers, and the possession of almost normal tarsal claws allies them with the Cheyletidae rather than the Analgesidae.

In the case of the genus *Harpyrhynchus* the enormous size of the palpi, so similar to those of the free Cheyletidae certainly establishes the affinity of these forms with the Cheyletidae.

Passing to a study of the habits of the Cheyletidae, the steps in the origin of parasitism in this family become more clear.

The free-living Cheyletidae are very small creatures, many of them being not more than half a millimeter in length. Their palpi are enormously developed (Pl. III, Fig. 8), and instead of working vertically, as is true of practically all the other free-living Acarina, they move horizontally. Thus it can be seen how these organs alone are excellently adapted for clinging to a host; as a matter of fact they are perfectly typical of the adhering forms of palpi as we find them in the parasitic trombidoidean larvae (Pl. V, Fig. 20). Next, we actually know of some species of the genus *Cheyletiella* which live upon the backs of fur bearing animals. Here they apparently feed only upon the other parasites present, but the conditions are perfect for the development of the parasitic habit. All that is necessary is that the normal food supply be cut short; then, according to the law of the survival of the fittest, only those individuals will live that are able to sustain themselves for a while, at least, upon another diet. Since they are already accustomed to the animal juices of smaller forms, it is but a slight step for them to take in order to be able to digest the juices of mammals. Perhaps those individuals which first partook of these juices only did so for a very short time and perhaps from some wound upon the animal.

In the case of the parasitic Peritremata (the poultry mite, blood-sucking bird mites, ticks, etc.), not only can we trace the anatomical homologies of the different groups step by step as we pass from the free-living to the parasitic groups, but we can also trace in a parallel manner the development of the parasitic habit.

Among the free-living Gamasidae it is a frequent occurrence to find species which live in association with other animals. Mention here will only be made of a few cases. Some of these forms use their pseudohost only for the purpose of transportation. Many species, as *Macrocheles moestus* Banks, live in association with other animals, acting somewhat as scavengers. I have frequently observed such cases in the rearing of insects and also in my experiments upon inoculations with parasites upon some of the higher animals. In some cases, as with species of *Antennophorus*, the mites come in as symbia for a share of the food of the host; again, as in *Oölaelaps oöphilus,* they feed on the saliva with which ants coat their eggs or their young. As a very gradual step from these symbiotic relationships, we find several facultative or semiparasitic forms, which may be parasitic for a while, but which can yet maintain themselves without a host. An excellent example of this class is the common chicken mite, *Dermanyssus gallinae* (Redi) (Pl. I, Fig. 2). In favorable circumstances, as in the moist droppings from the roost, they can maintain themselves almost indefinitely. In the Argasidae we find species which are very similar to the Dermanyssidae both in habits and structure. They are nocturnal, but may be regarded as obligatory parasites. However, here the parasitic habit has not developed to the extent that it has in the Ixodidae, as has been well established by Nuttall.[8] In the true ticks, Ixodidae, the parasite is firmly attached to a single place on its host, hence is a stationary or fixed parasite. However, in most cases it leaves the host to molt. For a sketch of the degenerative processes accompanying this progress in the development of the parasitic habit see the explanation for Plate I.

In considering the second groups of parasitic Acarina, those most nearly related to the free-living scavengers, we must regard them as representing at least four different and phylogenetically distinct lines of descent. The ways in which each separate line arose from scavenger ancestors is practically the same, so only one line will be considered.

The small family Canestrinidae and many, if not all of the Sarcoptidae, may be regarded as descending from an ancestral type very similar to some of our living Tyroglyphidae, as the species, *Monicziella entomophagus* (Laboulbène). This form (see Pl. II, Fig. 4), as well as most of the members of the family, is a true scav-

[8] Nuttall, G. H. F. On the adaptation of ticks to the habits of their hosts. Parasitology. 4:46-67.

enger. The members of the Tyroglyphidae live on refuse matter of various sorts, but especially on decaying animal matter and upon sores of animals, etc. The species just mentioned differs from most the members of the family in that it is always associated with a certain species of insect, in this case the Oyster Shell Scale. Here it feeds, not on the live scale insects, as was once supposed, but only on the dead insects and the old egg shells. However, there is a form present in association with the same scale insect, and which has been much confused with the mite just mentioned, which does live on the fresh eggs of the scale, and I have observed it occasionally attacking the scale insects themselves. This is *Hemisarcoptes malus* (Shimer), (Pl. III, Fig. 5); which, as the name indicates, may be regarded as the connecting link between the true Sarcoptidae and the scavenger free forms.

Among the scavenger types the first steps toward parasitism are perhaps the constant association of the mite with some other particular species of animal, as is the case of *Monieziella entomophagus* Laboulbène. The next step in the case of the origin of parasitism among the Canestrinidae and Sarcoptidae was perhaps the change of diet from dead tissues to that of live tissues as found in fresh eggs. Then began a partial life on some fresh animal food and finally a complete parasitic form was evolved.

In the Analgesidae, of course, the change of diet by forms taking up the parasitic habit would be very slight. Here the ancestral type was probably the same as that of the Canestrinidae, that is, was similar to our present day Tyroglyphidae. In this connection, I may mention that I have discovered a species of Tyroglyphidae that is repeatedly found upon the plumage of birds. Mr. W. R. Thompson, a specialist in the group, has also confirmed my observations. In the case of this species, *Glycyphagus spinipes* Koch, there is but little doubt that these mites get on the birds while they are roosting or sitting upon the nest and, finding plenty to eat, remain for long periods of time with the same bird. This might be called accidental parasitism, but since it is so frequently met with I would be inclined to call it semi-parasitism. After several generations, through the action of natural selection, we would have evolved forms that would feed upon little else except the excretious material or dead epidermal scales of the birds; and finally a form would appear that would be wholly parasitic.

The parasites of the third class, those that have arisen from plant feeding ancestors, all belong to a single group, the parasitic Pediculoididae. One of our most common parasitic species is *Pediculoides ventricosus* Newp. This species is remarkably similar to the plant feeding species of the same genus, so much so that it has been frequently confused with them even by well trained entomologists. This species has recently been extensively studied by Webster[9] who has shown that it is changing its habits of feeding upon insects and now is a serious parasite of man himself.

But it is among the plant feeding forms themselves that we have seen the beginnings of the development of the parasitic habits.

Some of these, as *Tarsonemus intectus,* frequently have attacked man among other animals and have caused him very serious trouble. Here the step in the change of diet is much greater than is usually the case, but the mouthparts are extremely well adapted for the new life as a parasite.

The Significance of Distribution According to Host Species.

Two methods of attack have been employed in studying the significance of the distribution of the parasitic Acarina according to host species. The first of these

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[9] Webster, F. M. A predaceous and supposedly beneficial mite, Pediculoides, becomes noxious to man. Ann. Ent. Soc. Amer. 3: 15-39. 1910.

is by means of the statistical method, lists of the parasites with more than one host species having been prepared. In some groups a complete list of all the known parasites with the host or hosts of each is given. The second method is by experimentation by means of which data were obtained; in regard to the ability of the parasites to move about when detached from their hosts, in regard to the length of time a parasite can live when detached from its host when either with food or without food, the habits of the parasites themselves, and lastly and most important of all, transfers of the various parasites from their normal hosts to various other hosts.

In the following pages of this chapter the different groups of the parasitic forms will be taken up separately; the list of species with their hosts being given first, after which follow the deductions obtained from a study of these lists, together with what experimental evidence I have secured.

The first group with which we will occupy our attention is that of the parasitic Cheyletidae, a list of them being given with the hosts of each.

A List of the Parasitic Cheyletidae and Their Hosts.

MYOBIA Hey.

M. lemnina (Koch)—Arvicola arvalis Pall.
M. caudata Banks—Little brown bat.
M. musculi Schrank—Mus musculus, M. silvaticus L., M. rattus.
M. brevihamata Haller—Mustela vulgaris.
M. pantopus Troues.—Synotus barbastellus.
M. heteronycha Berl. & Troues.—Phyllorhina tridens.
M. poppei Troues.—Vesperugo abramus.
M. chiropteralis Michael—Rhinolophus hipposideros. Vesperngo pipistrellus.

PICOBIA.

P. heeri Guzzoni.

SYRINGOPHILUS Hel.

S. bipectinatus Heller—Phœnopepla nitus Sev.

PSORERGATES Sty.

P. simplex Tyrrell—Mus musculus, Arvicola agrestis.
P. simplex var. *musculinis*.

HARPYRHYNCHUS Még.

H. longipilus Banks—Loxia curvirostra minor (Brehm.).
H. nidulans Mégnin—Alauda arvensis Linn., also on grosbeak sp. (?)
H. brevis Ewing—Coccothraustes vespertina (Coop.).

The parasitic members of the Cheyletidae form a very small and probably heterogeneous group. The five different genera are morphologically rather widely separated and each is markedly specialized. These genera are certainly not in the least allied to the atracheate parasitic forms which in all probability arose from atracheate free-living types. For the present, on account of convenience, we will consider them taken together as a group.

Two of the genera *Myobia* and *Psorergates* are found on mammals, the former attached by their highly specialized clasper-legs to the bases of the hairs, the latter in little cavities or cells just beneath the skin. Two of the other genera, *Picobia* and *Syringophilus,* live inside of the quills of the feathers of birds; while the genus *Harpyrhynchus* is found forming tumors in the skins of birds.

Of the thirteen species known in this group all are confined either to a single host species or to very closely related host species. These extremely narrow limits in their distribution are due chiefly to one of two things; either the development of a highly specialized clinging apparatus or to semi-endocolous habits. Thus the members of *Myobia* have the highly specialized claspers for grasping a single hair; and it would be impossible for them to hold on to a hair very much smaller or very much larger than those of their host.

Of course the members of the genera *Picobia* and *Syringophilus,* living inside the quills of birds, would have only rare chances for their transference from one host to another. Likewise the members of *Psorergates* and *Harpyrhynchus* which are almost endocolous would not be easily transferred from one host to another.

I made an attempt to inoculate our common striped ground squirrel, *Spermophilus 13—lineatus* with *Myobia musculi* from a mouse. The parasites took hold at first and caused the ground squirrel much annoyance, but could not establish themselves and soon disappeared.

A List of Some Trombidium Larvae and Their Hosts.

In considering the larvae of the Rhyncholophidae, Trombidiidae, Hydrachnidae and Halacaridae, it seemed that the data in regard to all of them and their distribution were so inadequate that it was decided to give lists of species and hosts for only two of the best known genera. These records are taken chiefly from Oudemans.

ALLOTHROMBIDIUM Berlese.

A. fuliginosum (Herm.)—Aphis tiliae L., A. sambuci L., A. jaceae L., A. evonymi F., A. rosae L., A. fabae, A. ribis.
A. poriceps Oudms.—Specimens have been taken upon Homo, but the true host or hosts are unknown.
A. inexspectatum Oudms.—Host unknown.
A. italicum Oudms.—Acridium, Mantis, Gryllotalpa.
A. tectocervix (Oudms.)—Host unknown.
A. striaticeps Oudms.—Found on Homo as an accidental host. Its true host unknown.

TROMBIDIUM Fabricius.

T. granulatum Oudms.—Host unknown.
T. muscae Oudms.—Musca domestica, Vesperugo pipistrellus, V. serotinus, Plecotus auritus.
T. Wichmanni Oudms.—Found upon Goura sp.
T. russicum Oudms.—Upon a bat; host probably accidental.
T. inopinatum Oudms.—Crossopus fodiens (Pall.). Talpa europaea L.
T. meridionale Oudms.—True host unknown.
T. berlesei Oudms.—Hirundo riparia.
T. vandersandei Oudms.—Found on the legs of Homo in New Guinea.

Although the list of species of these *Trombidium* larvae is not large, and doubtless a more careful search would add several more hosts for each species, yet from these data I think we can draw the conclusions; that they are not as a rule restricted to a single host species, also that their normal hosts are always closely related forms, usually species of the same genus or of closely related genera.

In regard to the fuller biological significance of the distribution of the *Trombidium* larvae and the parasitic larvae of related forms, Rhyncholophidae, Hydrachnidae, and Halacaridae, several interesting facts were brought to light. First, some of these larvae may sustain themselves for long periods of time when detached from a host. Thus I found that the larvae of one of our common hydrachnids remained alive for sixty-four days in a watch glass without any hosts. In this case I believe that these small creatures lived partially upon minute organisms found in the water, but no doubt these various larvae can live for several days without food. This I found to be the case with the larvae of *Microtrombidium muscarum* Riley, the larvae of our common house-fly mite, which lived for five days in confinement without food.

I made several attempts to inoculate other forms than the normal hosts with the larvae of *Microtrombidium muscarum* (Riley) and *M. locustarum* Walsh, but was unsuccessful. The larvae soon fell from the forms on which they were placed and apparently never did firmly fasten the beak into their integument. I was somewhat surprised at this for in some cases the alien species used was very closely related to the normal host. I thought that it might have been because of mechanical reasons, or because that once having a square meal the appetite no longer acted as a sufficient incentive for obtaining a second attachment. However, I found this was not true, at least with *Microtrombidium muscarium* Riley, as I got this species to change its attachment from one individual of its host species (the house fly) to another very easily.

In regard to the experiments made in attempts to get a suitable host for two hydrachnid larvae, I will state that after trying many insects, mostly aquatic forms from the same pool from which the mothers of the larvae were obtained, I was unable to get any of them to attach. In some cases the aquatic insects were confined in a small jar in the water of which hundreds of larvae swarmed, yet after days of confinement not a single larva was attached. These results are similar to many others obtained by different workers.

The reason why these larvae will thrive only upon a single host species or upon a few closely related host species appears to be physiological differences in the nature of the two diets met with. That they will frequently attack many different kinds of animals, vertebrates as well as invertebrates, is well known. Thus man himself is attacked by probably several species. Yet in all these cases the mites do not thrive but soon perish.

It may be suggested that it is because the larvae do not have a chance to meet with a larger range of host species that they are so limited in their distribution, but I have carefully investigated the habitats and surroundings of several of our American species, and find that such is not the case. Grass sweepings made in the vicinity of Ames, Iowa, where there were thousands of the larvae of *Microtrombidium locustarium* Walsh present, contained representatives of many orders of insects, but these larvae were only found on a few closely related species of grasshoppers.

A List of the North American Ixodoidea and Their Hosts.

Argasidae.

Argas Latreille.

A. brevipes Banks—Cereus giganteus.

A. miniatus Koch—Chickens, cattle, quail.

A. reflexus Fabricius—Pigeon.

A. persicus (Oken)—Fowls, ducks, geese, turkeys, ostriches, quail, wild doves, canaries, man, cattle.

ORNITHODOROS Koch.

O. coriaceus Koch—Cattle, man.
O. megnini Dugès—Cattle, horses, man, ass.
O. marginatus Banks—West Indian bat.
O. talaje Guérin—Man.
O. turicata Dugès—Hogs, man, cattle, llama, horse, tortoise, gopher.

IXODIDAE.

CERATIXODES Neumann.

C. putus Cambridge—On several migratory sea birds.
C. signatus Birula—Cormorant.

IXODES Latreille.

I. angustus Neumann—Neotoma occidentalis, Sciurus hudsonius douglasi, Tamias townsendi, Lepus dalli, "Mouse."
I. arcticus Osborn—Seal.
I. brunneus Koch—Tufted titmouse, hermit thrush, "Chipping bird," Californian birds.
I. californicus Banks—Gray fox, black-tail deer.
I. cookei Packard—Lutra, Mustela vison, Spermophilus, weasel, porcupine, marmot, pocket gopher, dog, cat, sheep, robin.
I. dentatus Neumann—Rabbit.
I. diversifossus Neumann—Raccoon.
I. hexagonus Leach—Erinaceus europaeus, Mustela erminea, M. vulgaris, M. putorius, M. furo, Lutra vulgaris, Meles taxus, Lepus cuniculus, Myopotamus coypu, Sciurus sp., Canis vulpes, C. familiaris, Ovis aries, Sus scrofa, Homo sapiens.
I. marxi Banks—Red squirrel, fox.
I. pratti Banks—Prairie dog, skunk (?), rock squirrel (?).
I. ricinus Linnaeus—Bos taurus, Ovis aries, Canis familiaris, Cervus elaphus, C. capreolus, C. dama, Capra hircus, Equus caballus, Homo sapiens, Felis concolor, Genetta sp., Lepus europaeus, Erinaceus europaeus, Mustela putorius, M. erminea, Meles taxus, Mus decumanus, "Mouse," Myoxus sp., Talpa europaea, ground squirrel.
I. scapularis Say—Dogs, man, cattle, sheep, deer.
I. sculptus Neumann—Rock squirrel.
I. aequalis Banks—California ground squirrel.
I. uriae White (?)
I. canisuga—Canis familiaris, C. vulpes, Cotile riparia, Mustela furo, Meles taxus, Sciurus, Talpa europaea, Equus caballus, Ovis aries.

I. rubidus—Bassaris astuta.
I. bicornis—Felis concolor, F. onca, Homo sapiens.
I. texanus—Grey squirrel, Procyon lotor.

HAEMAPHYSALIS Koch.

H. chordeilis Packard—Nighthawk, turkey, killdeer (?).
H. leporis-palustris Packard—Rabbits, quail, lark.

RHIPICEPHALUS Koch.

R. texanus Banks—Dogs, horses.

MARGAROPUS Karsch.

M. annulatus Say—Cattle, rabbit, porcupine, man (?), moose (?), sheep, horses.

AMBLYOMMA Koch.

A. americanum Linnæus—Cattle, man, horses, hogs, dogs, goats, panther, wolf, some of the small mammals.
A. cajennense Fabricius—Cattle, horses.
A. maculatum Koch—Cattle, horses, dogs, fox, man.
A. tuberculatun Marx—Gopher, tortoise.

DERMACENTOR Koch.

D. albipictus Packard—Moose, wapiti, beaver.
D. bifurcatus Neumann—Wild cat.
D. nigrolineatus Packard—Deer.
D. nitens Neumann—Horses.
D. occidentalis Neumann—Deer, California ground squirrel.
D. parumapertus Neumann—Man, chicken (?), jack-rabbit.
D. variabilis Say—Man, dogs, cattle, various smaller animals.
D. venustus Banks—Man, horse, and several small mammals.

Of all the groups of the parasitic Acarina the Ixodoidea, or ticks, have the widest distribution among host species. Single species of the ticks have been reported from hosts not only belonging to different families, but to different orders and even classes. For example, *Ixodes ricinus* Linn. has been found upon sheep, goats, cattle, horses, deer, dogs, cats, fox ferrets, hedgehogs, hares, rabbits, bats, birds, man and ground-squirrels.

Such a wide spread distribution of the different species as is presented in the ticks is unique in the Acarina. It is true that in the Analgesidae we may have a single species found on hosts belonging to different families, or even in a few cases to different orders, but never are these forms found on other hosts than birds. That a single species like *Ixodes ricinus* Linn. has been found on such widely separated hosts as bats, birds, hedgehogs and man shows that they possess most of the characters necessary for a wide host distribution. Perhaps the most important point in this regard is their peculiar adhering apparatus. This consists of a strong, dartlike hypostoma with prominent recurved teeth. This structure, as can easily be seen, is capable of being inserted with about equal ease into the skin of a mammal, a bird, or a reptile; this is in marked contrast with the clinging apparatus of *Myobia,* which can only be used upon a single mammalian hair, and that of a definite size. Then the ticks possess good walking legs, have a very tough skin, are resistant to temperature changes when off a host. Being blood suckers, they can engorge themselves with blood, drop to the ground and live for months upon this meal. Again the females are enormously prolific, laying in some cases as high as 10,000 eggs. These eggs usually hatch upon the ground and the young are given opportunities to find various hosts, each for himself. In closing my remarks about this group it might be safe to say that almost every condition necessary for a great range in distribution among host species has been fulfilled in regard to it.

A List of the Species of Listrophoridae Which Have Been Recorded from More than One Host Species, Together with Their Hosts.

LISTROPHORUS Pgst.

L. gibbus Pgst.—Lepus cuniculus, L. timidus L.

L. mustelae Mégn.—Mustela valgaris Erxl., M. erminea L., M. putorius L., also on pole cat.

L. leuckarti Pgst.—Paludicola terrestris (L.), P. amphibius (L.), Arvicola arvalis (Pall.), Mus sylvaticus L.

MYCOPTES Clap.

M. tenax Michael—Arvicola arvalis (Pall.), Mus sylvaticus L.

TRICHOECIUS Can.

T. brevipes (Can. & Trt.)—Arvicola arvalis (Pall.). Also on rats.

SCHIZOCARPUS Trt.

S. mingaudi Trt.—Castor fiber L., C. canadensis Kuhl.

This little group of mammal-infesting parasites is of particular interest to us because of its extremely narrow limits of host distribution, and the factors which cause the same. Up to the present, eighteen species have been described and of these only four are found upon hosts belonging to different genera, twelve are known from only a single host species, and none is found upon hosts belonging to different families.

They are very small forms and are all unique in one respect, *i. e.,* in the possession of some specialized apparatus for clinging to the hairs of mammals (Pl. V, Fig. 19). They feed, as do the Analgesidae, upon the oily secretions of the skin and on old epidermal cells.

What are the factors which cause such very limited host distribution? It can not be on account of their diet for it is the same as that of the Analgesidae, the members of which may have a very wide distribution among host species. It can not be on account of the habits of the hosts, for they are frequently more or less gregareous, and besides have other habits, as that of burrowing and nesting in close proximity to other species, which would offer splendid opportunities for a very wide distribution of the parasites. This point is proved by the fact that these same hosts have other external parasites that do have a wide host distribution.

As a solution of the question I think that there can be little doubt but that these forms have such very narrow host limits because of mechanical reasons pertaining to their attachment to a hair. The special apparatuses which have been developed consist, of either a high specialization of the front pairs of legs into chitinous claspers shown on Pl. V, Fig. 19, in the development of the maxillary lip so as to form two curved, shovellike claspers, or in the special modification of the hind group of legs into clasping structures. A careful examination of these clasping organs shows that they can only be used upon a hair of almost a definite diameter and even of a definite shape. A hair much larger than those of the accustomed host would frequently be too large even to permit the presentation of the claspers, while a hair much smaller could not be held tightly at all.

A List of the Analgesidae Found upon More than One Host Species, Together with the Names of Their Hosts.[10]

Pterolicheae.

freyana Haller.

F. gracilipes Trt. & Mégn.—Grus antigone (L.), Ephippiorhynchus senegalensis (G. Shaw).

F. pelargica Trt. & Mégn.—Ciconia ciconia (L.), C. nigra (L.), Euxenura maguari (Gm.).

F. anserina Trt. & Mégn.—Anser anser (L.), Cygnus olor (Gm.), Chen hyperboreus (Pall.).

F. anatina (C. L. Koch)—Anas acuta L., A. crecca L., A. querquedula L., Mergus serrator L., Fuligula fuligula (L.), Nettapus auritus (Bodd.). Other water birds.

F. leclerci Trt.—Lobivanellus senegalus (L.), L. indicus (Bodd.).

F. caput-medusae Trt.—Sula bassana (L.), and other species of the genus.

F. gigas Trt.—Diomedea nigripes Audub., and on related species.

pterolichus Robin.

P. lunulatus (Haller)—On species of Strigidae.

P. denticulatus Mégn. & Trt.—Pyrrhula cruentata (Wied), and American parrots.

P. canestrinii Trt.—Ara macao (L.), A. canga, A. severa (L.).

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[10] The following list has been compiled chiefly from Canestrini's monograph of the family published in 1899. Des Tierreich, Lieferung 7.

P. venustissimus Trt.—Conurus canicularis (L.), and other species of Conurus.

P. squatarolae (Can.)—Charadrius squatarola (L.), C. pluvialis L.

P. charadrii (Can.)—Charadrius hiaticula L., C. alexandrinus L., C. curonicus Gm., Totanus hypoleucus (L.), and other marsh birds.

P. obtusus Robin—Caccabis rufa (L.), C. saxatilis (Meyer), Perdix species.

P. ornatus Mégn. & Trt.—Upon parrots.

P. ardeae (Can.)—Botaurus stellaris (L.). Other species of fam. Ardeidae.

P. gracilis Trt.—Megapodius forsteni Temm., M. freycineti Temm., Aepypodius bruijni (Oust.).

P. delibatus Robin—Corvus corone L., C. cornix L., C. corax L., C. frugilegus L., C. scapulatus Daud., Corvultur albicollis (Lath.). Other related species of Corvidae, and species in Vulturidae.

P. musophagi Trt.—Schizoris africana (Lath.). Tauracus buffoni (Vieill.).

P. uncinatus Mégn.—Steganura paradisea (L.). Other Fringillidae.

P. nisi (Can.)—Accipiter nisus (L.), Circaetus gallicus (Gm.), Buteo buteo (L.), Pernis apivorus (L.), Circus pygarus (L.).

P. intermedius Mégn. & Trt.—Upon diurnal birds of prey.

P. bicaudatus (Gerv.)—Struthio camelus L., Rhea americana (L.).

P. cuculi Mégn. & Trt.—Cuculus canorus L., and upon related genera in Europe and America.

P. biemarginatus Mégn. & Trt.—Capito auratus Dumont, and on other species of Capitonidae.

P. rhamphastinus Mégn. & Trt.—Pteroglossus aracari (L.), Rhamphastus dicolorus L. Other species of Rhamphastidae.

P. circiniger Mégn. & Trt.—Rhytidoceros plicatus (Forst.), Cranorrhinus leucocephalus (Vieill.). Other species of Bucerotidae.

P. attenuatus Mégn. & Trt.—On species of Bucerotidae.

P. ninnii (Can.)—Numenius arquatus (L.), N. tenuirostris Vieill.

P. limosae (Buchh.)—Species of Limosa. Totanus fuscus (L.).

P. limosae var. *selenura* Mégn. & Trt.—Symphemia semipalmata (Gm.), Limosa lapponica (L.).

P. totani (Can.)—Totanus calidris (L.), T. pugnax (L.), Tringa alpina L.

P. proctogamus Trt.—Fulica atra L., Porphyrio caeruleus (Vand.).

P. buchholzi (Can.)—Limosa limosa (L.), Charadrius squatarola (L.).

P. buchholzi var. *hastigera* Mégn. & Trt.—Tringa alpina L., Microsarcops cinereus (Blyth).

P. buchholzi var. *fascigera* Mégn. & Trt.—Totanus calidris (L.), Tringa canutus L., Arenaria interpres (L.).

P. colymbi var. *major* Mégn. & Trt.—Colymbus cristatus L., Urinator septentrionalis (L.).

P. vexillarius Mégn. & Trt.—On Buceros species.

P. vexillarius var. *homophylla* Mégn. & Trt.—Upon Buceros species.

P. vexillarius var. *minuta* Mégn. & Trt.—Lophoceros melanoleucus (Lcht.), L. erythrorhynchus (Temm.).

P. cultrifer Robin—Apus apus (L.), A. melba (L.).

P. onychophorus var. *fauna* Trt.—Brachypteracias pittoides Lafr., B. crossleyi (Sharpe).

P. brachiatus Trt.—Lorius domicella (L.), Loriculus sclateri Wall., Trichoglossus haematodes (L.).

P. brachiatus var. *crassior* Trt.—Trichoglossus novaehollandiae (Gm.), Glossopsittacus concinnus (G. Shaw), Loriculus sclateri Wall.

P. chiragricus Mégn. & Trt.—Pezoporus formosus (Lath.), Platycercus flaveolus J. Gd., P. elegans (Gm.).

P. velifer Trt.—Nymphicus cornutus (Gm.), Pyrrhulopsis personata (G. R. Gray), Platycercus flaveolus J. Gd.

P. flavettei Trt.—Nestor notabilis J. Gd., N. meridionalis (Gm.), Psephotus xanthorrhous Bp., Microglossus aterrimus (Gm.).

P. casuarinus Trt.—Calcopsitta atra (Scop.), Eos rubiginosa (Bp.).

P. eurycnemis Trt.—Ara macao (L.), Pyrrhula ferruginea (St. Müll.).

P. bisubulatus Robin—Caccabis rufa (L.), Perdix perdix (L.).

P. bimucronatus Trt.—Upon Lagopus species.

P. aquilinus Trt.—Aquila chrysaëtus (L.), A. pomarina Brehm., Haliaëtus species.

P. aquilinus var. *milvulina* Trt.—Milvus milvus (L.), Haliastur indus girrenera (Vieill.).

P. calcaratus Trt.—On many species of Bucerotidae.

P. curtus Trt.—Megapodius freycineti Temm., Aepypodius bruijni (Oust.).

P. quadratus Trt.—Aepypodius bruijni (Oust.), Talegallus cuvieri Less.

P. tritiventris Trt.—Upon Ara and Conurus species.

P. panoplites Trt.—Poeocephalus gulielmi (Jard.) and related species.

P. fissiventris Trt.—Penelopides manillae (Bodd.), Rhytidoceros plicatus (Forst.), Anthracoceros malabaricus (Gm.) and related species.

P. fürstenbergi (Buchh.)—Buceros rhinoceros L., Ortholophus leucolophus (Sharpe), Anthracoceros malabaricus (Gm.), Hydrocorax hydrocorax (L.).

P. pterocolurus Trt.—Anthracoceros convexus (Temm.), Penelopides manillae (Bodd.).

P. pegasus Trt.—Anorrhirus galeritus (Temm.), Rhytidoceros plicatus (Forst.), Hydrocorax hydrocorax (L.). Various species of Bucerotidae.

P. pegasus var. *retusa* Trt.—Anthracoceros malabaricus (Gm.), Anorrhinus galeritus (Temm.).

XOLOPTES Can.

X. claudicans (Robin)—Coturnix coturnix (L.), Perdix perdix (L.), Caccabis rufa (L.).

FALCULIFER Raill.

F. rostratus (Buchh.)—Lophophaps plumifera (J. Gd.), Goura coronata (L.). On European species of Columbidae.

F. cornutus (Trt.)—Cyanocorax violaceus Du Bus.

CHILOCERAS Trt.

C. cervus Trt.—Caloenas necobarica (L.), Eutrygon terrestris (G. R. Gray).

C. taurus Trt.—Carpophaga pinon (Q. & G.), C. goliath G. R. Gray.

BDELLORHYNCHUS Trt.

B. polymorphus Trt.—Anas crecca L., A. clypeata L., Erismatura leucocephala (Scop.), and other water birds.

DERMOGLYPHEAE.

THECARTHRA Trt.

T. longitarsa (Mégn. & Trt.)—Charadrius squatarola (L.), C. pluvialis L.

T. theca (Mégn. & Trt.)—Sterna caspia Pall. and related species.

DERMOGLYPHUS Mégn.

D. minor (Nörn.)—Gallus domesticus, Meleagris gallopavo L., Numida meleagris L.

D. elongatus (Mégn.)—Gallus domesticus, Serinus canarius (L.), and Ploceidae.

D. major (Trt.)—Eutoxeres aquila (Bourc.), Phaethornis longirostris (Less. & Delattre).

D. pachycnemis (Trt.)—Struthio camelus L., Rhea americana (L.).

D. pteronyssoides (Trt.)—Gallinago nigripennis Bp., Aulacorhamphus caeruleicinctus (Orb.).

D. paradoxus Trt.—Pyrrhula leucotis (Lcht.), Conurus aeruginosus (L.), Chrysotis farinosa (Bodd.).

SPHAEROGASTRA Trt.

S. thylacodes Trt.—Totanus littoreus (L.), Tringa subarquata (Güld.).
S. monstrosa (Trt.)—Eclectus pectoralis (St. Müll.), Trichoglossus cyanogrammus Wagl.

ANALGEAE.

PTERONYSSUS Robin.

P. gracilis (Nitzsch)—Upon species of Picus.
P. chiasma Trt.—Pteroglossus aracari (L.) and other Rhamphastidae.
P. obscurus Berl.—Chelidonaria urbica (L.), Clivicola riparia (L.).
P. truncatus Trt.—Sturnus vulgaris L., Lamprotornis sp.
P. truncatus var. *subtruncata* Trt.—Mainatus javanensis (Osb.), Calornis panayensis (Scop.).
P. integer Trt. & Neum.—Muscicapa grisola L., Parus cristatus L.
P. conurus Trt.—Pogonorhynchus bidentatus (G. Shaw), Barbatula leucolaema Verr.
P. quadratus Haller—Picus viridicanus Wolf, Sylvia atricapilla (L.).
P. puffini (Buchh.)—Dromas ardeola Payk., Sterna sp., Larus sp., Puffinus sp., Procellaria sp.
P. abbreviatus (Buchh.)—Buceros rhinoceros L. and related species.
P. lyrurus Trt. & Neum.—Rhytidoceros plicatus (Forst.), Anorrhinus galeritus (Temm.). Other Bucerotidae.
P. elephantopus Trt. & Neum.—Rhytidoceros plicatus (Forst.), Anorrhinus galeritus (Temm.). Other Bucerotidae.
P. spinosus Trt. & Neum.—Upon Bucerotidae.

ANALGES Nitzsch.

A. chelopus (Herm.)—Corvus sp., Parus sp., Motacilla sp.
A. bidentatus Gieb.—Accentor modularis (L.), Acrocephalus arundinaceus, Anthus sp.
A. passerinus (L.)—Passer sp. and related genera.
A. corvinus Mégn.—Corvus corone L. and other Corvidae.
A. mucronatus (Buchh.)—Panurus biarmicus (L.). Other Paridae.
A. pachycnemis Gieb.—Accentor modularis (L.), Picus species.

PROTALGES Trt.

P. affinis Trt.—Pterophanes temmincki (Boiss.), Aglaeactis cupripennis (Bourc. & Muls.).
P. longitarsus Trt. & Neum.—Petasophora iolata J. Gd., Eulampis jugularis (L.).
P. attenuatus (Buchh.)—Asio otus (L.), Fam. Strigidae.

P. accipitrinus Trt.—Falco tinnunculus L. and other diurnal birds of prey.

P. curtus Trt.—Platycercus elegans (Gm.) and related species.

P. lorinus Trt.—Lorius garrulus (L.), L. domicella (L.) and related species.

P. larva Trt.—Species of Psittacidae.

MÉGNINIA Berl.

M. cubitalis (Mégn.)—Meleagris gallopavo L., species of Phasianidae.

M. cubitalis var. *ginglymura* (Mégn.)—Upon Phasianidae, Anatidae, Corvidae.

M. columbae (Buchh.)—Columba domestica and other Columbidae, Serinus canarius (L.).

M. picimajoris (Buchh.)—Picus viridis L., Dendrocopus major (L.), other Picidae.

M. hirsuta Trt.—Conurus solstitialis (L.), C. canicularis (L.), C. nenday (Vieill.), Caica melanocephala (L.), Pyrrhura picta (St. Müll.), P. leucotis (Lcht.), Brotogerys chirii (Vieill.).

M. velata (Mégn.)—Upon Anatidae.

M. aequinoctialis Trt.—Phaëthon aethereus L., P. rubricaudus Bodd.

M. gallinulae (Buchh.)—Gallinula chloropus (L.), Ortygometra porzana (L.), Rallus aquaticus L., Vanellus vanellus (L.), Coturnix coturnix (L.).

M. aestivalis var. *subintegra* Berl.—Chelidonaria urbica (L.), Clivicola riparia (L.).

M. psoroptopus Trt.—Dichoceros bicornis (L.), Anthracoceros malabaricus (Gm.).

M. magnifica Trt.—Upon Paradiseidae.

PTERALLOPTES Trt. & Mégn.

P. mégnini var. *falcinelli* (Trt.)—Plegadis falcinellus (L.), Platalea leucorodia L.

P. bipartitus (Trt.)—Anthracoceros convexus (Temm.), A. malayanus (Raffl.) and other Bucerotidae.

P. corrugatus (Trt.)—Ortholophus leucolophus (Sharpe), Anthracoceros malayanus (Raffl.), Cranorrhinus corrugatus (Temm.).

P. elythrura (Trt.)—Upon species of Bucerotidae.

XOLALGES Trt.

X. analginus Trt.—Dendroecia aestiva (Gm.), Elainea martinica (L.), other Rhamphastidae.

PROCTOPHYLLODEAE.

ALLOPTES Can.

A. nörneri Trt.—Cyanolesbia mocoa (Del. & Bourc.) and other Trochilidae.

A. aviculocaulis Trt.—Eutoxeres aquila (Bourc.), Phaëthornis longirostris (Less. & Delattre), other Trochilidae.

A. intermedius (Trt. & Neum.)—Elainea martinica (L.), Loxigilla noctis (L.).

A. trogontis (Trt.)—Trogon collaris (Vieill.), Harpactes orrhophaeus (Cab. & Heine), other Trogonidae.

A. hemiphyllus (Robin)—Fringilla coelebs L., F. montifringilla L., Emberiza calandra L., other Fringillidae.

A. pteronyssoides Trt.—Pipra aureola L., P. erythrocephala L., other Tyrannidae.

A. dielytra Trt.—Pipra erythrocephala L., P. aureola L.

A. minutus Trt.—Phaëthon æthereus L., P. rubricaudus Bodd.

A. phaethontis (Gm.)—Phaethon rubricaudus Bodd., P. aethereus L., Fratercula arctica (L.).

A. crassipes (Can.)—Limosa limosa (L.), Totanus pugnax (L.), Tringa alpina L., Sterna minuta L. and other Scolopacidae and Laridae.

A. crassipes var. *curtipes* Trt.—Haematopus ostralegus L., Totanus macularius (L.).

A. crassipes var. *minor* Trt.—Alca torda L., Fratercula arctica (L.), Uria grylle (L.), Larus ridibundus L.

A. bisetatus (Haller)—Sterna hirundo L., S. cantiaca Gm., Stercorarius parasiticus (L.), Tringa alpina L.

ALLANALGES Trt.

A. gracilipes (Trt.)—Lanius excubitor L. etc.

PROCTOPHYLLODES Robin.

P. glandarinus (C. L. Koch)—On Fringillidae.

P. armatus (Banks)—On Fringillidae, Turdidae, Mniotiltidae.

P. ampelidis (Buchh.)—Bombycilla garrula (L.), Accentor modularis (L.), Anthus, Fringillidae, Laniidae, Corvidae, etc.

P. truncatus Robin—Passer domesticus (L.), P. montanus (L.).

P. arcuaticaulis Trt.—Acanthis sp.

P. stylifer (Buchh.)—Upon Paridae.

TROUESSARTIA Can.

T. corvina (C. L. Koch)—On Corvidae.

T. appendiculata (Berl.)—Clivicola riparia (L.), Apus apus (L.).

T. bifurcata (Trt.)—Upon Sylviidae.

PTERODECTES Robin.

P. orthygometrae (Can.)—Orthygometra pusilla (Pall.), O. porzana (L.).

P. actitidis (Can.)—Totanus hypoleucus (L.), Tringa sp.

P. edwardsi (Trt.)—Acrocephalus arundinaceus (L.), Sylvia galactodes Temm.

P. rutilus Robin—Chelidonaria urbica (L.) and related species.

P. muticus Banks—Poocætes gramineus (Gmel.), Sayornis phœbe (Lath.).

P. bilobatus Robin—Anthus trivialis (L.), Alauda arvensis L.

P. gracilis Trt.—Ostinops decumanus (Pall.), Xanthura yncas (Bodd.), Cyanocorax chrysops (Vieill.).

P. paradisiacus Trt.—Paradisea minor G. Shaw, Sericulus melinus (Lath.).

P. gracilior Trt.—Topaza pella (L.), Chrysolampis mosquitus (L.), Lophornis ornatus (Bodd.) and other Trochilidae.

P. mainati var. *aculeata* Can.—Eurylaemus ochromelas Raffl., Lamprocolius glaucovirens Ell.

P. trochilidarum Trt.—Upon Trochilidae, Chrysolampis mosquitus (L.), Topaza pella (L.), Lophornis ornatus (Bodd.), Cyanolesbia mocoa (Del. & Bourc.).

P. gladiger Trt.—Upon Trochilidae, Chrysolampis mosquitus (L.), Eulampis jugularis (L.).

P. selenurus Trt.—Cyanolesbia mocoa (Del. & Bourc.), Topaza pella (L.).

PTEROPHAGUS Mégn.

P. strictus Mégn.—Upon Columbidae.

EPIDERMOPTEAE.

HETEROPSORUS Trt. & Neum.

H. pteroptopus Trt. & Neum.—Acrocephalus streperus (Vieill.), Erithacus cyaneculus (Wolf.), Emberiza cirlus L., E. schoeniclus (L.).

PACHYLICHUS Can.

P. crassus Can.—Erithacus phoenicurus (L.), Dendrocopus medius (L.).

MICROLICHUS Trt. & Neum.

M. avus (Trt.)—Gallinago major (Gm.), G. nigripennis Bp., Dendrocopus medius (L.), Garrulus glandarius (L.), Eulampis holosericeus (L.), Passer domesticus (L.).

The list of the mites recorded from more than one host species in this group is in itself extremely long, while the total number of all the species is over 400. The various genera and species differ greatly in their external morphology and considerably in their internal structure, yet their food habits are practically the same.

In their distribution according to host species most of the forms fall into two classes; those confined to a single host and those found on several closely related host species. Although over half of the known forms are at present reported from only a single host, this does not indicate in the least that most of these have such a restricted host distribution; the reason they have not been reported from other hosts being that no search has been made for them on other hosts, or at least no careful and thorough search for them.

In regard to the Analgesid species it will be noticed that frequently there is a greater range of hosts than is usually found in the mite species of other groups excepting the Ixodoidea. No case, however, is known of one of these forms being reported from other than a bird host, hence it is probable that they could not survive upon such forms as mammals. In the absence of direct inoculation experiments upon mammals it is hard to tell just why this is. In the Mallophaga, a group of more unity of structure and of comparatively few individuals, a few bird-inhabiting forms are found also on mammals. Since the Mallophaga of the birds live upon the barbules of feathers it is easy to see that one of them would find insufficient food when transferred to a mammal; but this would not be true of the Analgesidae, for they live upon old epidermal scales and oily secretions. As far as the diet is concerned I can not see why these mites could not live upon mammals. It is my opinion that the reasons are mechanical. In the flattening of the form of the analgesid body, it has become *depressed,* not *compressed,* hence when turned edgeways between the hairs of a mammal the mite would lose its footing and either fall off or would be incapable of locomotion.

Among the birds themselves it is by far the more usual thing to find a species of Analgesidae upon closely related forms, but such is not always the case. For example *Proctophyllodes ampelidis* (Buchh.) is found on members of five different families, four of which are not closely related; they are the Ampelidae, Mniotiltidae, Fringillidae, Laniidae, Corvidae. *Megninia cubitalis* (Mégn.) is found on three different families, Phasianidae, Anatidae and Corvidae, each of which belongs to a different order. Other cases of the same kind exist so that we are forced to the conclusions that under favorable conditions a species may have a very wide range of hosts.

Since quite a number of these species, representing most of the important genera, are found on widely separated host species, it may be regarded as an indication that the reason why other species have not as great a distribution is simply because they have not had the chance to be transferred to other hosts. However, of the two attempts which I made at transference of these mites from their normal to a foreign host, neither was successful.

When the members of this family are detached from their hosts they walk freely about and at a moderate rate. I tested their vitality under these conditions and found that frequently they would live for three days. These two facts make the transference from one host to another much easier and more probable and doubtless are great factors in the explanation of the distribution of many of the species.

Of special interest in regard to their host distribution are the forms which are found upon the raptorial birds. Of the ten species of Analgesidae found on the Falconidae, four are known to occur on more than one host species. Although these four species are distributed among several hosts none of them are on any birds outside of the Falconidae. Thus *Pterolichus nisi* (Can.) is found on six host species, but all of them belong to the Falconidae and are closely related.

If these forms are able to adapt themselves to lives upon rather widely separated hosts, why have they not done so as have many of the other forms? Since the hosts are preying birds there would be a good chance for them to get the mite parasites from the species preyed upon, but such does not seem to have happened.

Since the members of the Falconidae are non-gregarious and solitary in habits, thus making the transfer of the parasites from one host to another improbable, it is interesting to see how they became distributed among several hosts belonging to this family. Doubtless it is to be explained in the same manner as Kellogg has explained the host distribution of similar cases in the Mallophaga, "that the parasitic species have persisted unchanged from the common ancestor of the two or more now distinct but closely allied bird-species."

A List of the Sarcoptidae Known to Occur upon More than One Host Species, Together with Their Hosts.

NOTOEDRES Raill.

N. notoedres (Mégn.)—Mus rattus L., M. decumanus Pall., Paludicola amphibius (L.).

PROSOPODECTES Can.

P. chiropteralis (Trt.)—Rhinolophus ferrumequinum (Schreb.), Vesperugo serotinus (Schreb.).

SARCOPTES Latr.

S. caprae Fürstb.—Capra hircus, Ovis aries, Equus caballus, Bos taurus, Homo.

S. dromedarii Gerv.—Camelus dromedarius L., C. bactrianus L., Lama glama (L.), Giraffa camelopardalis (L.), Antilope bubalis (sp.?).

CNEMIDOCOPTES Fürstb.

C. mutans (Robin)—Gallus domesticus and other birds.

PSOROPTES Gerv.

P. equi (Hering)—Equus caballus, E. asinus, E. caballus♂X E. asinus♀.

PSORALGES Trt.

P. libertus Trt.—Tamandua tetradactyla (L.) and other species of the same genus.

OTODECTES Can.

O. cynotis (Hering)—Canis familiaris, Felis domestica.

In this family over forty species have been described. Only eight of them have been recorded from more than one host species, and they are found in seven of the nine genera comprising the family.

The study of the distribution according to host species in these itch mites presents a puzzle indeed. Perhaps no group of the parasitic Acarina has such a large percentage of forms restricted to a single host and yet, strange to say, a few of the species have a distribution among host species not closely related, for example *Sarcoptes caprae* Fürstb. is found on man, the horse, and several of the Bovidae.

Several attempts at inoculation have been made by other workers with various forms of itch mites, and with results just as perplexing as the distribution of the species themselves.

I made a very careful attempt at inoculation with *Notoedres notoedres* (Mégn.) taken from rats, upon our common striped ground squirrel, *Spermophilus 13-lineatus,* but the attempt was a failure. Mégnin was unable to get any successful inoculations with the Sarcoptidae when placed on other than their normal hosts, hence he called several of the forms, morphologically identical, separate physiological species. Yet against these experiments, it is established that the itch mite of the dog, *Sarcoptes canis,* is transferable to man.

In regard to the factors bearing upon the possibility of transportation it might be mentioned that these forms are practically helpless in regard to their locomotion, yet in regard to duration of life when off a host, I found that forms would live easily for four days in minute scrapings. Doubtless under favorable circumstances they would live much longer. What then are the conditions which cause such a contradictory distribution of the species? Some forms have been able to adapt themselves to hosts not closely related; others can not live except upon a single host. I can not give any very satisfactory answer to this question, but merely suggest that it is because some species have either a much more delicate taste or more delicate digestive systems than other forms, and for this reason have remained upon a single host species.

A List of the Eriophyidae Known to Occur upon More than One Host Species, Together with Their Hosts.

Eriophyinae.

eriophyes Sieb.

E. tenuis (Nal.)—Avena pratensis L., Bromus arvensis L., B. erectus Huds., B. mollis L., Dactylis glomerata L.

E. laevis (Nal.)—Alnus glutinosa Gärt., A. incana D. C., A. viridis D. C.

E. brevitarsus (Focken)—Alnus glutinosa Gärt., A. incana D. C., A. viridis D. C.

E. rudis (typicus) (Can.)—Betula verrucosa Ehrh., B. pubescens Ehrh.

E. rudis longisetosus (Nal.)—Betula verrucosa Ehrh., B. pubescens Ehrh.

E. lionotus (Nal.)—Betula verrucosa Ehrh., B. pubescens Ehrh.

E. ilicis (Can.)—Quercus ilex L., Q. ithaburensis Decne.

E. populi (Nal.)—Populus tremula L., P. nigra L.

E. tetanothrix (Nal.)—Salix fragilis L., S. aurita L.

E. drabae (Nal.)—Alyssum calycinum L., A. hirsutum M. B., Berteroa incana D. C., Camelina sativa Crantz, Capsella bursa-pastoris L., Erysimum canescens Rth., Lepidium draba L., Sisymbrium sophia L.

E. rosalia (Nal.)—Helianthemum fumana Mill., H. hirsutum Th., H. oelandicum Wahlb.

E. tiliae (typicus) (Pgst.) Nal.—Tilia platyphyllos Scop., T. ulmifolia Scop.
E. tetratrichus (Nal.)—Tilia platyphyllos Scop., T. ulmifolia Scop.
E. geranii (Can.)—Geranium sanguineum L., Malva alcea L.
E. heteronyx (Nal.)—Acer campestre L., A. platanoides L.
E. macrorhynchus (Nal.)—Acer campestre L., A. platanoides L.
E. macrochelus (Nal.)—Acer campestre L., A. platanoides L., A. pseudoplatamus L.
E. brevirostris (Nal.)—Polygala amara L., P. depressa Wend.
E. peucedani (typicus) (Can.)—Orlava grandiflora Hoffm., Peucedanum venetum Koch, Seseli glaucum L., S. hippomarathrum L., Torilis infesta Koch, Trinia vulgaris D. C.
E. ribis (Nal.)—Ribes rubrum L., R. alpinum L., R. nigrum L.
E. kochi (Nal. & F. Thom.)—Saxifraga aizoides L., S. mutata L.
E. piri (Pgst.), Nal.—Pirus communis L., P. malus L., Amelanchier vulgaris Mönch., Cotoneaster vulgaris Lindl., C. tomentosa (Rech.), Sorbus aria Crantz, S. aucuparia L., S. torminalis Crantz, S. mongeoti (Rech.).
E. piri var. *variolata* (Nal.)—Sorbus aria Crantz, S. aucuparia L., S. torminalis Crantz.
E. calycobius (Nal.)—Crataegus oxyacantha L., Amelanchier vulgaris Mönch.
E. parvulus (Nal.)—Potentilla argentea L., P. reptans L., P. verna L.
E. similis (Nal.)—Prunus domestica L., P. spinosa L.
E. padi (Nal.)—Prunus padus L., P. domestica L., P. spinosus L.
E. genistae (Nal.)—Genista pilosa L., Sarothamnus scoparius Koch.
E. euaspis (Nal.)—Lotus corniculatus L., Dorycnium pentaphyllum Scop.
E. plicator (typicus) (Nal.)—Medicago falcata L., M. lupulina L.
E. plicator trifolii (Nal.)—Trifolium arvense L., Ervum hirsutum L.
E. ononidis (Can.)—Ononis repens L., O. spinosa L.
E. anthonomus (Nal.)—Thesium intermedium Schrad., Th. divaricatum Jan.
E. alpestris (Nal.)—Rhododendron hirsutum L., Rh. ferrugineum L.
E. laticinctus (Nal.)—Lysimachia vulgaris L., L. nummularia L.
E. fraxini (Karp.)—Fraxinus excelsior L., F. viridis Bosc.
E. eucricotes (Nal.)—Lycium europaeum L., L. mediterraneum Dun.
E. anceps (Nal.)—Veronica chamaedrys L., V. officinalis L.
E. ajugae (Nal.)—Ajuga reptans L., A. genevensis L.
E. salviae (Nal.)—Salvia pratensis L., S. silvestris L., S. verbenaca L.
E. schmardae (Nal.)—Campanula rapunculoides L., C. glomerata L., C. trachelium L., C. rotundifolia L.
E. galii (Karp.), Nal.—Galium aparine L., G. mollugo L., G. silvaticum L., G. verum L.

E. galiobius (Can.)—Galium verum L., G. lucidum All.
E. artemisiae var. *subtilis* (Nal.)—Artemisia campestris L., A. vulgaris L.
E. centaureae (Nal.)—Centaurea amara L., C. maculosa Lam., C. scabiosa L.
E. oleivorus Ashmead—On orange and lemon.

PHYLLOCOPTINAE.

PHYLLOCOPTES Nal.

Ph. dubius (Nal.)—Avena pratensis L., Bromus arvensis L., B. errectus Huds., B. mollis L., B. sterilis L., Dactylis glomerata L.
Ph. comatus (typicus) Nal.—Corylus avellana L., C. a. var. fol. lasc.
Ph. reticulatus Nal.—Populus alba L., P. tremula L.
Ph. magnirostris Nal.—Salix fragilis L., S. purpurea L., S. alba L.
Ph. parvus Nal.—Salix alba L., S. purpurea L., S. sp.
Ph. eurynotus Nal.—Torilis infesta Curt., T. anthriscus (L.).
Ph. schlechtendali Nal.—Pirus malus, P. communis L.
Ph. fockeui Nal. & Trt.—Prunus cerasus L., P. domestica L., P. mahaleb L.
Ph. cytisicola Can.—Cytisus nigricans L., C. laburnum L.
Ph. anthobius Nal.—Galium silvaticum L., G. uliginosum L., G. verum L.

EPITRIMERUS Nal.

E. salicobius (Nal.)—Salix alba L., S. fragilis L.
E. heterogaster (Nal.)—Clematis recta L., C. cirrhosa, C. alpina (L.).
E. trilobus (Nal.)—Sambucus nigra L., S. racemosa L.

OXYPLEURITES Nal.

O. carinatus (Nal.)—Aesculus hippocastanum L., A. rubicunda Lois.

Of about 250 known species of the Eriophyidae I have listed 59 that have been recorded from more than one host species. Of these 59, 50 are found only upon species of the same genus and the remaining 9 are found only upon closely related genera. Thus *Eriophyes tenuis* (Nal.) is found only on members of the grass family, *E. drabae* (Nal.) only on members of the mustard family, and *E. piri* (Pgst.) Nal. only on related genera of the rose family.

When one species is found upon more than one host it is interesting to note that the malformations produced may be quite different on the different host species, although frequently they may be very similar.

Since the species of mites in this group have such narrow limits in their host distribution it is interesting to study the causes of it. In the first place is there a ready means of transference from one kind of a host to another? I think that there can be no doubt but that these species are easily transferred from the leaves of one kind of a plant to those of another. In many forests we find the branches of one tree mingled with those of another or superimposed over those of another, so that during a high wind they would be frequently rubbed together.

Again a tree or bough when falling frequently would lodge in another, and the mites which it carried would be transferred to the latter. Since the gall inhabiting forms always inhabit open galls and since all of the Eriophyidae travel very well, though they have but four legs, they would thus be enabled to pass easily from one host to another when these hosts are in actual contact.

I am inclined to attribute this very limited distribution of the different species of this group to physiological reasons. The forms are very small and have a simple and somewhat degenerate digestive system, hence too great a change in the nature of the diet could not be endured. In this regard it may be interesting to note that some of the members of the phytophagous Tetranychidae are well nigh omnivorous. They are hardy forms and do not have a delicate digestive system.

Experiments Upon the Length of Life of Parasites When Detached From Their Hosts.

No. of Experiment	Name of Parasite	With or Without Food	Maximum Length of Life	Remarks
1	*Pediculidae* sp.	without	29 hours	
2	*Nirmus vulgatus* Kel.	without	5 days	Individuals used taken from a robin
3	*Nirmus vulgatus* Kel.	with	6 days	
4	*Nirmus* sp.	without	2 days	
5	*Docophorus* sp.	with	3 days	
6	*Mallophaga* sp.	with	23 days	Many individuals kept on a bunch of feathers in a glass jar
7	*Siphonaptera* sp.	without	2 days	Individuals used taken from a rat
8	*Gamasid* sp.	without	22 hours	
9	*Gamasid* sp.	without	1 day	
10	*Dermanyssus avium* De Geer	without	4 days	
11	*Proctophyllodes* sp.	without	3 days	
12	*Proctophyllodes* sp.	with	2 days+	Nine individuals used and all alive after 2 days
13	*Notoedres notoedres* (Mégn.)	with	4 days	Many specimens kept in scrapings from the skin of a rat
14	*Notoedres notoedres* (Mégn.)	with	4 days	Scrapings with mites kept moist and after putrifaction the mites continued to live
15	*Hydrachnid* larvae	without (?)	25 days	
16	*Hydrachnid* larvae	without	33 days	
17	*Hydrachnid* larvae	without	64 days	Many larvae alive after 64 days. They may have fed upon microorganisms (?)
18	*Microtrombidium muscarium* (Riley) (larvae)	without	5 days+	No observations after fifth day

INOCULATION EXPERIMENTS.

No. of Experiment	Name of Parasite	Host Taken from	Animal Inoculated	Results
1	*Nirmus vulgatus* Kel.	Robin	Chimney swift	Six individuals used. Unsuccessful
2	*Pediculidae*	Mus rattus	Spermophilus 13—lineatus (striped ground squirrel)	They at once crawled down to the roots of the hairs and began to feed. Later they disappeared
3	*Pediculidae*	Mus rattus	Spermophilus 13—lineatus	Unsuccessful
4	*Pediculidae*	Spermophilus 13—lineatus	Mus musculus	Unsuccessful
5	*Dermanyssus avium* De Geer	Robin	Domestic fowl	Fifty individuals taken. Five days later none found on the chicken
6	*Dermanyssus gallinae* (Redi)	From nest of English sparrow	Domestic fowl	Very successful. Immediately the mites began to thrive and reproduced rapidly for over a month
7	*Dermanyssus gallinae* (Redi)	Domestic fowl	English sparrow	Inoculation very successful
8	*Gamasus* sp.	Spermophilus 13—lineatus	Mus musculus	Unsuccessful
9	*Gamasus* sp.	Musca domestica	Another individual of musca domestica	Unsuccessful
10	*Gamasus* sp.	Musca domestica	Syrphus-fly	Unsuccessful
11	*Gamasus* sp.	Musca domestica	Blue-bottle-fly	Unsuccessful
12	*Proctophyllodes* sp.	Red-headed woodpecker	Mourning dove	Twenty-five individuals used. Examinations 5 and 29 days later revealed no mites present
13	*Proctophyllodes* sp.	Blue jay	Domestic fowl	After four days none found
14	*Myobia musculi*	Mus musculus	Spermophilus 13—lineatus	They crawled down the hairs and soon began to feed, causing the ground squirrel much irritation. Later they disappeared

INOCULATION EXPERIMENTS.—*Contiuued.*

No. of Experiment	Name of Parasite	Host Taken from	Animal Inoculated	Results
15	*Notoedres notocdres* (Mégn.)	Mus rattus	Spermophilus 13—lineatus	Unsuccessful
16	*Trombidium* larvae	Melanoplus bivittatus	Musca domestica	Unsuccessful
17	*Trombidium* larvae		Man	Unsuccessful
18	*Microtrombidium muscarum* (Riley)	Musca domestica	Another individual of musca domestica	Very successful. It at once attached itself and fed for a long while
19	*Microtrombidium muscarum* (Riley)	Musca domestica	Another individual of musca domestica	Very successful. Larva remained attached for several days and increased in size
20	*Microtrombidium locustarium* (Walsh)	Melanoplus sp.	Grasshopper of a different species	Unsuccessful
21	*Microtrombidium locustarium* (Walsh)	Melanoplus sp.	Disosteira carolina L.	Unsuccessful
22	*Microtrombidium locustarium* (Walsh)	Melanoplus sp.	Arphia carinata Scudder	Five larvae were folded under the wings. None adhered
23	*Hydrachnid* larvae	Reared from eggs	Various aquatic insects including Zaitha	Scores of larvae were hatched and kept for several days, but none became attached
24	*Hydrachnid* larvae	Reared from eggs	Water beetle	Unsuccessful
25	*Hydrachnid* larvae	Reared from eggs	Water beetle	Unsuccessful
26	*Hydrachnid* larvae	Reared from eggs	Man	Unsuccessful

Adaptive Convergence.

Although the Parasitic Acarina have descended from many widely separated free-living groups, yet when examined many of these forms show a remarkable superficial resemblance which at first sight suggests a very close phylogenetic relationship (See Pl. III, Figs. 10 and 11). This superficial resemblance is a direct response of these originally widely separated groups to the same environmental conditions.

The flattened form of the body has been assumed by many of the Acarina of parasitic habits, and it is interesting to note that we find a duplication of the same process in some of the parasitic insects. It is obvious that a compressed form of the body is an advantage to those parasites that inhabit fur-bearing animals, as it enables the parasite to pass easily between the hairs of its host. Examples of such parasites possessing this form of body are the fleas, among insects, and the fur-inhabiting Listrophoridae among the mites.

On the other hand a depressed form of body is an advantage to those parasites that live upon birds and need to crawl between the superimposed feathers; this form offering less resistance to movements and affording better footing for the locomotor organs. Familiar examples of parasites having this form of body are the Mallophaga among insects and the Analgesidae among mites.

We find the need and the development of the locomotor organs becoming less and less as we pass from the free to the occasional, to the semiparasitic, and finally to the permanent parasitic epizoa; likewise we find a gradual development of clinging organs. These organs may be of several kinds, but of special importance are the hooks or claws. Many of the parasitic groups have these structures developed for adhering to their hosts. These may be developed on any or all of the legs as is the case in the Ixodidae, Argasidae, Analgesidae, Listrophoridae and several other groups; or they may be developed upon the palpi as in the case of the parasitic Cheyletidae (Pl. III, Fig. 10), or the larval parasites of the families, Trombidiidae, Hydrachnidae or Halacaridae (Pl. V, Figs. 18 and 20, and Pl. VII, Fig. 28); or again they may be developed upon some other structure of the mouth-parts as the hypostoma in the case of the ticks.

The possession of stout, backwardly directed spines or bristles is a characteristic almost universally found in external parasites inhabiting fur or feather bearing animals. The fleas, Mallophaga and Pediculidae have them, and in the Acarina we find them well developed in members belonging to the Dermanyssidae, Cheyletidae (Pl. III, Fig. 10), Analgesidae (Pl. IV, Figs. 15 and 16, and Pl. VI, Figs. 24 and 25), Sarcoptidae (Pl. II, Fig. 6, and Pl. III, Fig. 11), and Listrophoridae (Pl. V, Fig. 19).

In order to establish the significance of the possession of these backwardly directed spines, I have made a number of observations and experiments and from these have decided that they fulfill chiefly two functions. First, because they are very stiff and are directed toward the rear, they aid the possessor of them very materially in its forward movements. Frequently I have watched fleas advance themselves very successfully through a mass of hairs simply by a backward and forward movement of the body and legs, the spines permitting a free forward movement of the parts, but blocking a backward thrust of the legs and thus compelling an advance of the body. Another advantage of these spines and bristles is in retarding any effort which is made by the host to rid itself of its tormentors. Dogs, cats, chickens, and almost all other infested animals, being much irritated by the parasites, will make repeated efforts to get free from them. They do this by scratching themselves with beak or claw, or by rubbing against some object, or wallowing in the dust. In these efforts frequently the parasites are dislodged either from their hold on the skin or the hairs or feathers only to be caught by other hairs or feathers on account of these long spines and thus are saved from a complete loss of a host. This fact, I think, would suggest itself immediately to any one who had ever endeavored to pick off these live parasites from their hosts, or who has watched domestic animals trying to rid themselves of them.

The degeneration of the special senses, an almost universal accompaniment of parasitism, is fully illustrated in the Acarina. Of the special senses found in the free-living mites that of touch is undoubtedly the highest developed; sight is present in some cases, but many of the free forms are without eyes. It appears to be established that many free forms have the faculty of smell and also that of taste. The possession of the sense of hearing has never been satisfactorily proved, I believe, for any of the Arachnida, not even in the spiders, where stridulating organs are found; so, of course, it is supposed to be wanting in the mites.

All of the special senses which are found in the free forms show successive stages of degeneration in accordance with the progressive stages of parasitism. In practically all of the free forms we find special tactile structures present, in the form of long specially adapted palpi or front legs, the possession of tactile bristles, or even special organs developed for this purpose. In the Sarcoptidae, some of the Cheyletidae, in the Listrophoridae, and in other groups all these tactile organs have atrophied. Although many of the free forms, closely resembling the types from which parasitic forms evidently arose, have well-developed eyes, these structures appear to be universally absent in parasitic forms. Here the degenerative process has been complete. No evidence appears to be obtained that the sense of smell has been lost or has become weakened in the parasitic forms. But since the development of this sense in the free forms is slight, it would be difficult to get reliable data upon its decline, if present, in the parasitic forms.

The degeneration of the locomotor appendages is also as complete as that of the special senses. We get all degrees of degeneration from the type of legs found in the free forms; consisting of from five to seven distinct segments, clothed with bristles and ending in special adaptive tarsal appendages, as claws, caruncles, and pulvilli; to even entirely limbless sarcoptids.[11] Bridging the space between these two extremes, two common types of legs might be mentioned, that of the Eriophyidae and that of the Demodecidae. In the former family the legs are reduced to four in number; and although they consist of five segments each, they are weak and unable to sustain the weight of the body (See Pl. VII, Fig. 29). In the latter family the legs are of the normal number, yet are greatly reduced, consisting of only three short, stumpy segments and scarcely extending beyond the margins of the body (Pl. IV, Fig. 14).

All of these changes thus far mentioned, the assumption of a flattened form of body, the possession of backwardly directed spines and bristles, of hooks and claws for adherence, and the degenerative process affecting the special senses and the locomotor organs, can only be fully accounted for by the action of natural selection working in response to similar environmental conditions. It has resulted in bringing forms descended from widely different groups to the assumption of a variety of similar characters, so that now they appear to be closely related forms. It illustrates excellently adaptive convergence (Note the similarity of Figs. 10 and 11 on Pl. III, and compare with illustrations of living forms, Figs. 8 and 9, probably very similar to the ancestral types of each).

Divergence and Special Adaptations.

While the assumption of similar parasitic habits has in many cases resulted in similar adaptations so that primitively widely divergent forms now are structurally

[11] Trägardh, in 1902, discovered some sarcoptids under the elytra of a species of *Pimelia* in which the extremities were entirely suppressed. See Zool. Anzeig. 25: 617-8 (3 figs.).

very similar, on the other hand some forms which phylogenetically were closely related, are now structurally very diverse, because their habits, at least in some particular aspects, lead to peculiar environmental conditions. This response, which has resulted in such peculiar specializations, has often brought about some very highly evolved types.

Prominent among those forms which exist under peculiar environmental conditions might be mentioned the gall mites, Eriophyidae (Pl. VII, Fig. 29). These mites live by sucking juices from various plants, but especially from leaves of trees. Here their attacks have resulted in the development of various malformations of the leaves and in many cases in the formation of definite galls. Not all species, however, cause galls and some form only a distorted area in the leaf which is densely covered with small hairs. The ancestors of these forms evidently were simple plant feeders and probably were closely related to the "Red Spiders." Certainly there are many things which indicate their phylogenetic relationship to this group. As to just what kind of galls were originally formed by these mites, probably we can never know; yet there is the significant fact about the galls now formed by them, that they all have openings to the exterior through which the mites can pass. The life in any of these galls with such small openings, or in those of a pinlike formation, or even among the hairs on the erineum, requires that the body must be very narrow in order that the mite may be able to move about. In response to these conditions we find that these gall-inhabiting mites have the body enormously lengthened (Pl. VII, Fig. 29), so much so as to suggest a superficial resemblance to the worms.

Again in other groups we find this same enormous lengthening of the body in response to very different conditions but each requiring this vermiform structure of the body. This is true in the case of the Demodecidae, the "hair-follicle mites." These mites live in the hair follicles of man and other mammals. Here evidently the form of body best adapted is that which these mites have assumed, the vermiform type (Pl. IV, Fig. 14). Perhaps the most beautiful adaptation of this vermiform body is shown in those mites which inhabit the quills of bird's feathers. We find it well illustrated in the genera *Picobia* and *Syringophilus* which have this habit (See Pl. V, Fig. 17).

As is true of most external parasites specialization in the form of clinging or clasping organs may become highly developed. Besides the claws or hooks, which have been mentioned, we have several other structures of considerable interest. In the Analgesidae there are developed upon tarsal pedicels partial-vacuum suckers (See Pl. IV, Figs. 15 and 16), which are very effective as adhering organs. These forms when placed on a smooth glass surface adhere so tightly that it is very hard to lift them off with a sable-hair brush.

The well known development of the hypostoma in the ticks is also a good example of specialization. Here the hypostoma becomes greatly developed into the form of a dart and is provided with many strong recurved teeth. When this structure is thrust into the skin of the host the recurved teeth act like the barbs on a fish-hook against its being withdrawn.

The most varied and interesting cases of specialization in the form of clinging organs are found in the Villicolata. In the family Listrophoridae we have several genera represented, all of which have some specialized apparatus developed for clasping hairs.

In the case of the genus *Listrophorus* the underlip is modified into a large, curved, flexible plate, which can be brought around a hair so as to clasp it very effectively. In the genus *Labidocarpus* the front two pairs of legs have been entirely changed from their primitive shape, and each consists of a single, strongly curved chitinous plate entirely without appendages (See Pl. V, Fig. 19). These appendages when opposed to each other act like a vise upon the partially encircled hair. In *Myocoptes* it is the posterior group of legs which is modified into clasping organs. Here the apical joints, which are broad and flat, can fold upon the basilar ones like the blade of a knife into its handle.

Perhaps one of the most significant things that appears in connection with the evolution of the parasitic Acarina is the development of marked sexual dimorphism. In the free forms from which the parasitic ones arose there was evidently little or no sexual dimorphism, yet in some of the Analgesidae, for example, it is very marked as will be seen by looking at Pl. IV, Figs. 15 and 16, and Pl. VI, Figs. 24 and 25. In most of these cases the dimorphism consists of an increased size of the male over the female, and in his possession of special organs for holding her during pairing. In the genus *Analges* these modifications for clasping reach such an enormous size as to cause some conjecture as to the factors influencing their development. They consist simply of an enormous enlargement of the third pair of legs, but to such an extent that the two legs taken together may be equal to the total size of the body of the mite (See Pl. VI, Fig. 25). How such enormous structures if used alone for holding the female during coition could have been developed through natural selection is a puzzle. It may be that the members of this genus are the descendents of a primitive ancestor which was a mutant. If this is true this initial variation was out of all reasonable limits in its magnitude. Again it may happen that these organs are used by rival males in striving with each other for the possession of the females, but their structure hardly suggests it, and besides I am not aware that in the Acarina any one has ever noticed any rivalry between the males over the females. I am inclined to think that these structures have an important, and perhaps their chief function, as organs for holding on to the feathers of the host. As the male is the one that hunts out the female, and is thus much the more active, his liability of becoming detached from the host is much greater than hers. In this regard it is interesting to note that he has many more enormous bristles than the female which is in harmony with the suggestion just given (since I have already shown that such long bristles in the epizoa frequently keep them from becoming detached from their hosts).

Generalizations Regarding Various Aspects of Parasitism in the Acarina.

As a whole, the order Acarina has not been very extensively studied in the different parts of the world, but this statement can hardly hold true in considering the parasitic forms, for it is concerning these that we know the most, at least in regard to geographical distribution. Our knowledge of the ticks and the "Bird Mites" includes forms from almost every part of the globe. However, much is yet to be learned in connection with the distribution and life histories of most of the smaller groups.

In our study of parasitism in the Acarina it is interesting to note the tremendous range of its various aspects. The parasitic forms have originated independently from several rather distantly separated free ancestors. The process of evolution in each separate group has been going on for vast periods of time, upon hosts which belong to different classes and even subkingdoms. These hosts in turn have become evolved, they have assumed different habits and environments. The processes of degeneration and specialization have wrought great structural changes, and with them vast differences in their relation to each other and their hosts. When we consider all of these things it is not so much to be wondered at that in this group we probably find a larger variation in the different aspects of parasitism than is presented by any other group of the Arthropoda.

The following classification of the parasitic Acarina is given, based upon an analytical study of their structure, habits, food relations, etc. This is simply an application of the general classification given for all parasites in the introductory chapter.

A Classification of the Parasitic Acarina Based Upon the Different Aspects of Parasitism Presented.

Taking into account the nature and habits of the parasites themselves.

- Depending upon the nature of the food eaten.
  - Living upon the bodily tissues.
    - Living upon live tissues.
      - Gen. *Harpyrhynchus.*
      - Sarcoptidae (itch mites).
      - Gen. *Laminosioptes* of the Cheyletidae.
    - Living upon dead tissues.
      - Analgesidae (bird mites).
      - Listrophoridae.
      - Canestrinidae (?). These forms doubtless live upon live tissues also.
  - Feeding upon partially digested food.
    - *Antennophorus.*
    - *Echinomegistus wheeleri* (?).
  - Living upon blood.
    - Parasitic larvae of Rhyncholophidae, Trombidiidae, Hydrachnidae and Halacaridae.
    - The ticks, Ixodidae and Argasidae.
    - Dermanyssidae.
    - *Haemogamasus* and *Raillietia* of the Gamasids; *Cillibano* (?).
    - Some species of *Pediculoides.*
    - Some species of *Cilliba,* a genus of the Uropodidae.
  - Feeding upon secretions.
    - *Cytoleichus* (?). It probably feeds both upon mucous secretions and the cellular fluids of its host.
    - *Demodex.* The species of this genus live largely upon the oil secreted in the hair follicles.
    - *Myobia.* Species of this genus feed at the bases of hairs of mammals upon cutaneous excretions.
    - *Oölaelaps oöphilus.* (Lives upon the salivary secretion with which some ants coat their eggs.)
  - Living upon eggs.
    - Genus *Hemisarcoptes.* It lives upon eggs of scale insects (predaceous?).
    - *Histiostoma berghi,* lives in egg capsule of a horse-leech.
    - Larvae of some of the Halacaridae.

- Depending upon adaptation to the parasitic life.
  - Facultative parasites.
    - *Cheyleticlla* (?). The species of this genus may not be parasitic at all, but there is evidence that during their immature stages they are real parasites.
    - Some of the Dermanyssidae.
    - *Uropoda* (Some species).
    - *Hemisarcoptes.*
  - Obligatory parasites.
    - All of the other parasitic Acarina not mentioned under facultative parasites.
- Depending upon the state of degeneration of the locomotor organs.
  - Capable of walking when off the host.
    - Parasitic Cheyletidae.
    - *Gekobia.*
    - Larvae of Rhyncholophidae, Thombidiidae, Hydrachnidae and Halacaridae.
    - Ixodidae, Argasidae, Dermanyssidae and the parasitic Gamasidae.
    - *Uropoda* (some species), *Cilliba.*
    - Parasitic Tarsonemidae.
    - Analgesidae.
    - Canestrinidae.
    - Cytoleichidae.
    - Some of the Sarcoptidae.
    - Eriophyidae.
  - Incapable of walking when detached from host.
    - Many of the Listrophoridae.
    - Most of the Sarcoptidae.
  - Without legs.
    - *Pimelobia apoda.*

Taking into account the nature and habits of the organisms attacked.

- Depending upon whether the organism attacked is a plant or an animal.
  - Phytophaga.
    - Most of the Tetranychidae.
    - Tarsonemidae (in part).
    - Eriophyidae.
  - Zoophaga.
    - Parasitic Cheyletidae.
    - *Gekobia.*
    - Larvae of Rhyncholophidae, Trombidiidae, Hydrachnidae, Halacaridae.
    - Ixodidae, Argasidae, Dermanyssidae and parasitic Gamasidae.
    - Parasitic Uropodidae.

Zoophaga.
- Tarsonemidae (in part).
- Listrophoridae.
- Analgesidae, Canestrinidae, Sarcoptidae, Cytoleichidae.
- Demodecidae.

Depending upon the conditions imposed by the life of the host.

Hydroxenous.
- Larvae of Hydrachnidae and Halacaridae.
- Gen. *Atax.*

Geoxenous.
- *Myobia* and *Psorergates.*
- *Gekobia.*
- Ixodidae, Dermanyssidae (in part), parasitic Gamasidae.
- *Cilliba.*
- Parasitic Tarsonemidae.
- Listrophoridae (in part).
- Canestrinidae.
- Sarcoptidae (mostly).
- Cytoleichidae.
- Demodecidae.

Aeroxenous.
- *Harpyrhynchus, Picobia* and *Syringophilus.*
- Larvae of Rhyncholophidae and Trombidiidae.
- Argasidae, Dermanyssidae (in part).
- Listrophoridae (in part).
- Analgesidae, some of the Sarcoptidae.

Depending upon the number of host species.

With a single host species.
- Parasitic Cheyletidae (in part).
- *Gekobia* (?).
- *Cilliba* (?).
- Listrophoridae (in general).
- Analgesidae (in part).
- Canestrinidae.
- Sarcoptidae (in general).
- Cytoleichidae (?).
- Eriophyidae (in part).

With more than one host species.
- Parasitic Tetranychidae.
- Larvae of Rhyncholophidae, Trombidiidae, Hydrachnidae and Halacaridae (in general).
- Ixodidae, Argasidae, Dermanyssidae and parasitic Gamasidae.
- Parasitic Tarsonemidae.
- Analgesidae (in general).
- Sarcoptidae (a few species).
- Demodecidae (?).
- Eriophyidae (in part).

Taking into account the interrelations of the parasites and organisms affected.

- Depending upon the position of the parasites in relation to their hosts.
  - Endoparasites.
    - Sarcoptidae (in part).
    - Cytoleichidae (?).
    - Demodecidae (?).
  - Ectoparasites.
    - Cuticolata.
      - *Harpyrhynchus*, *Psorergates*.
      - *Gekobia*.
      - Larvae of Rhyncholophidae, Trombidiidae, Hydrachnidae, Halacaridae.
      - Ixodidae.
      - Parasitic Tarsonemidae.
      - Sarcoptidae (mostly).
      - Cytoleichidae (?).
      - Demodecidae.
    - Villicolata.
      - *Myobia*.
      - Listrophoridae.
    - Plumicolata.
      - *Picobia*, *Syringophilus*.
      - Analgesidae.
- Depending upon the duration or time of parasitism.
  - Erratic parasites.
    - Semiparasitic Tetranychidae.
    - *Atax* (?).
    - Some of the Gamasidae and some of the Uropodidae.
    - Some of the Tarsonemidae.
    - *Hemisarcoptes*.
  - Periodical parasites.
    - Nocturnal.
      - Argasidae.
      - Dermanyssidae (in part).
    - Diurnal.
      - (Data upon habits in this regard wanting.)
      - During a definite stage or stages in the life cycle of the species attacked.
        - During the egg stage.
          - *Histiostoma berghi*.
          - *Hemisarcoptes*.
        - During the fetal stage.
        - During the immature stage.
          - *Pediculoides ventricosus*.
        - During adult stage.

- Permanent parasites.
    - *Gekobia* (?).
    - Parasitic Cheyletidae.
    - Ixodidae.
    - Listrophoridae.
    - Analgesidae.
    - Sarcoptidae.
    - Cytoleichidae.
    - Demodecidae.
    - Eriophyidae.

Depending upon symbiotic relationship.

- Mutualists.
    - Some of the Gamasidae.
    - Many of the Analgesidae.
- Commensals.
    - *Picobia, Syringophilus.*
    - Many of the parasitic Gamasidae.
    - Listrophoridae (in part).
    - Most of the Analgesidae.
- True parasites.
    - Parasitic Tetranychidae.
    - *Gekobia.*
    - Trombidoidean larvae.
    - *Myobia, Harpyrhynchus, Psorergates.*
    - Ixodidae, Argasidae, Dermanyssidae.
    - Cilliba (some species).
    - Parasitic Tarsonemidae.
    - Some of the Listrophoridae.
    - Canestrinidae.
    - Sarcoptidae.
    - Cytoleichidae.
    - Demodecidae.
    - Eriophyidae.

Depending upon the blood relationship of the parasite to the host.

- Host of organism affected not related to parasite.
    - Nearly all of the parasitic Acarina.
- Host or organism affected closely related to parasite.
    - Larva of *Smaris longilinealis* on *Oribata latincisa.*
- Organisms affected of the same species as the parasite itself.
    - Host one of the parents.
        - *Rhyncholophus parvisetosus* (?).

SUMMARY.

As to the Origin of Parasitism in the Acarina.

We have very strong evidence indicating that the parasitic habit has originated independently at least eleven times in the phylogeny of the Acarina.

Among the zoophagous parasites the parasitic habit has been developed from three different types of free-living Acarina; (a) predaceous forms, (b) scavengers, (c) forms living upon the juices of plants.

The chief reason for so frequent occurrence of parasitism in the Acarina is because of their minute size; and the predaceous, scavenger, or plant-sucking habits of the free-living forms.

Among our living forms we can to-day trace out all the stages of advancing parasitism including the occasional or erratic parasitism, semiparasitism, facultative parasitism, even to the fixed and permanent type, and finally to endoparasitism.

As is usually the case with other parasites, we generally find here a gradual increase in the state of degeneration as we follow the advancing stages of parasitism from its origin among free types. In the Analgesidae however this is not true as they are in several respects highly specialized and have undergone little or no degeneration.

We find in the Acarina a process of degeneration which in its completeness is seldom obtained in the animal kingdom. We must remember that the Arachnida are in many ways a highly evolved group, certainly much more so than the Crustacea, yet here we find degeneration almost equal to that of the classical example of *Sacculina*.

As to the Distribution According to Host Species and its Significance.

The parasitic Acarina may be arranged into three classes depending upon their distribution according to host species:—

Those which are confined or limited to a single host species.

Those which may be found upon only closely related host species, usually species of the same genus or of very closely related genera.

Those which are found upon host species which are very widely separated from each other, belonging to distantly related families or even to different classes.

Our present distribution of the parasitic Acarina according to host species is dependent upon many factors, some of the more important being:

The nature of the food of the parasite, whether it be blood, living tissues, cast epidermal cells, etc.

The means by which the parasite attaches itself to its host.

The ability of the parasite to withstand fasting when detached from its normal host.

The degree of locomotor ability possessed by the parasite when detached from its normal host.

The ability of the parasite to sustain or partially sustain itself when detached from its host upon the diet of a free-living species; in other words a facultative or partially facultative parasite.

The life history of the parasite especially in regard to the number and methods of its transformations.

The shedding or molting habits of the host or hosts.

The wandering or migration habits of the host or hosts.

The surroundings and the materials of the home or nest for the young of the host or hosts.

The feeding habits of the host especially in regard to preying or scavenger habits.

The limits and nature of the geographical distribution of the host or hosts.

General climatic conditions of the country, especially in regard to temperature.

Some of the conditions actually found to favor the greatest distribution among the most widely separated hosts are:

A blood diet (This enables the parasite to engorge itself with an enormous amount of food in a short time and then become detached and live for long periods until a new host is found).

The possession of ambulatory legs.

The possession of a clinging apparatus designed to adhere to the flesh itself (Special apparatuses for clinging to either hairs, or feathers, etc., disqualifying their possessors from adhering to hosts which do not have these).

Oviparous reproduction with a large number of eggs laid when away from any host.

The ability to withstand great changes in temperature and moisture.

The ticks most completely fulfill these conditions, and are actually found to have the greatest distribution among the most diversified hosts.

Any one of the following conditions appears to cause a very restricted host distribution, and in many cases a restriction to a single host species or even to a single host individual:

Endocolous habits.

The possession of highly specialized clinging apparatus for holding on to external growths of the host or hosts.

A delicate and degenerate digestive system (This condition often gives rise to physiological species in forms which are anatomically identical).

The inability of the parasite to live off its host because of climatic conditions.

The inability of the parasite to walk when detached from a host.

The host being one of solitary and monogamous habits.

As to the Analysis and Classification of the Various Types and Aspects of Parasitism.

Although various classifications of the parasites have been made, and many more will doubtless follow, all of them may be included in three groups:

Those which take into account the nature and habits of the parasites themselves.

Those which take into account the nature and habits of the organisms attacked.

Those which take into account the inter-relations of the parasites and the organisms attacked.

Under each of these three general groups several classifications may be made having for a basis either habits, morphological characters, or ecological relations; and these classifications may each in turn be subdivided into others of a more restricted meaning, having for their bases these same factors.

EXPLANATION OF PHYLOGENETIC TREE.

In the diagram, or phylogenetic tree, given on the opposite page the writer has shown by the use of a series of symbols (squares, circles, dashes, etc.) much more than is generally done in such trees. This is in order to give the habits of these arachnids as they have been traced in this phylogeny. Thus, although according to this diagram we have living mites with eight different kinds of feeding habits, they all have descended from predaceous forms.

As we pass in position from the top of the page to the bottom, we get a regular decline in the state of evolution. Forms with many specialized parts or organs and with highly developed functions are considered highly evolved; those with many similar parts and with these parts not highly specialized, or those with few parts and with functions poorly developed are considered as being less highly evolved.

EXPLANATION OF ILLUSTRATIONS.

Plate I.—Steps in the Origin of Parasitism from Predaceous Types. —Fig. 1. *Gamasus dentatus* Ewing, dorsal view. This species is typical of the free living forms of Gamasidae. They are predaceous in habit and evidently are very similar to the ancestral predaceous type or types from which the Dermanyssidae, as well as the Argasidae and Ixodidae, arose.—Fig. 2. *Dermanyssus gallinae* (Redi), female, dorsal view. This is the notorious chicken mite of domestic poultry. As yet it may be considered a facultative parasite as it can maintain itself indefinitely away from its host if suitable conditions are at hand. In this stage of parasitism, which is only a step toward the final one, degeneration and adaptation are well exhibited as may be seen by comparing this figure with Fig. 1. The legs have become somewhat shortened, the palpi are much smaller and the body is much depressed in form, while the chelicerae are modified into long piercing organs.—Fig. 3. *Boophilus annulatus* Say. The well known Texas Fever Tick. In the Ixodidae the parasitic habit has become permanent, the parasite, however, leaves its host in most cases in order to molt. Degeneration and specialization has continued as is seen in the great reduction of the size of the legs and mouth-parts, in the flattened form of the body, and in the enormous development of the hypostoma which is provided with recurved teeth for the purpose of clinging to a host.

Plate II.—Steps in the Origin of Parasitism from Scavenger Types. —Fig. 4. *Monieziella entomophagus* (Laboulbène). This mite belongs to a small family of scavenger mites. It does not live upon live insects, as the name suggests, and as has been long supposed by most entomologists, but only chews and sucks the juices of dead insects and other decaying organic materials. It evidently is very similar to the ancestral type from which a very large group of our most important mite parasites arose. It is found generally associated with scale insects.—Fig. 5. *Hemisarcoptes malus* (Shimer). This is the most efficient of all the natural enemies of the Oyster Shell Scale. It is hardly a real parasite as yet, but has taken to feeding upon live eggs of the scale insects and will occasionally attack the mature insects themselves. The diet upon decaying organic matter has been entirely forsaken. Degeneration is noticed in the shortening of the legs and in the reduction of the mouth-parts. Specialization is shown in the development of suckers situated each on a tarsal pedicel. The homologues of these suckers can be seen in Fig. 4, where they are present as a flat padlike tarsal appendage.—Fig. 6. *Notoedres notoedres* (Mégn.). The itch mite of the rat. Here parasitism is firmly established. Degeneration has continued in the shortening of the legs, and the shortening or loss of their tarsal suckers, the reduction of the mouth-parts and a change of the original bodily form.—Fig. 7. *Cnemidocoptes mutans* (Robin), dorsal view. The itch mite causing "Scaly Leg" among chickens; a true parasite. Here the individual has become so degenerate that only stumps of legs are left which bear no tarsal appendages. The mouth-parts are very simple while the body is only a round fleshy mass entirely devoid of hairs except for a single posterior pair.

Plate III.—Converging Adaptation.—The two small parasitic mites figured at the bottom of this plate have a very great superficial resemblance to each other, and for a long time were supposed to be closely related forms. The one represented by Fig. 10, is now known to be closely related to the predaceous Cheyletidae, forms that are very highly developed; the other, represented by Fig. 11, is on the contrary most nearly related to the simplest of the free-living Acarina, the Tyroglyphidae.—Fig. 8. *Cheyletus seminivorus* Packard. A member of the family Cheyletidae. The Cheyletidae possess highly developed and specialized mouth-parts, an elaborate tracheal system, have the sense of touch highly developed, and usually possess eyes.—Fig. 9. *Tyroglyphus lintneri* Osborn, one of the "Cheese Mites." The members of the family Tyroglyphidae, the "Cheese Mites," are probably the most degenerate and the simplest of all the free-living mites. The mouth-parts while rather prominent are very simple; no tracheae are present, the sense of touch is poorly developed, and they are all blind.—Fig. 10. *Harpyrhynchus brevis* Ewing. The members of the genus Harpyrhynchus differ from their predaceous free ancestral types in the great shortening of the legs, the degeneration of the mouth-parts, the loss of the eyes, etc. Internally they still have left a tracheal system, but it is very vestigial.—Fig. 11. *Sarcoptes scabiei* De Geer, the itch mite of man. Superficially it resembles the species of Harpyrhynchus just mentioned. Since its free type was very simple the degenerative process has been less.

Plate IV.—Diverging Adaptation.—The different types of parasitic Acarina here figured, though very diverse in their appearance and structure, apparently have descended from a common scavenger ancestor which was very similar to our present day cheese mites, a member of which is represented by Fig. 12.—Fig. 12. *Rhizoglyphus phylloxerae* Riley, dorsal view. A good representative of the family Tyroplyphidae "Cheese Mites." This species is found in this country upon old decaying grain, etc.—Fig. 13. *Sarcoptes scabiei* De Geer, male from below. This is the itch mite of man. In the assumption of a small round form of body, of long stout spines on the legs, and the rudimentary mouth-parts, it has adapted itself to a life within the skin of man.—Fig. 14. *Demodex folliculorum* Simon, ventral view. This species is taken from the hair follicles of man. Several closely related forms are found in similar situations in other animals. Apparently it has little resemblance to the itch mite of Fig. 13, yet we have very strong evidence that the two are closely related. The extreme reduction of the legs and mouth-parts, and the very long drawn out, wormlike body are all beautiful adaptations for the life in hair follicles.—Fig. 15 and 16. *Megninia magna* Ewing, male and female respectively as seen from below. This species, as well as the other members of the Analgesidae has adapted itself to a life among the feathers of birds. Scarcely any degeneration is noticed, but on the contrary it shows a higher state of evolution than the ancestral type in the development of very efficient partial-vacuum suckers on the tarsi, and in the marked sexual dimorphism shown. Phylogenetically this species is closely related to the two preceding.

Plate V.—Special Adaptations.—Fig. 17. *Syringophilus elongatus* Ewing. The very elongate form of body, found in this and a few other allied species, is a curious adaptation for living in the quills of bird's feathers. The affinity of this species with the Cheyletidae, a family the free-living members of which are highly evolved forms, appears to be established.—Fig. 18. A Hydrachnid larva. These larval parasites of the Hydrachnidae, show the palpi modified into adhering organs, being provided with stout claws and working horizontally. In some species, as in this one, the presence of long hairs on the legs show an adaptation for locomotion in the water.—Fig. 19. *Labidocarpus compressus* Ewing. The members of this genus exhibit a remarkable adaptation in the form of the anterior group of legs, which do not look at all like legs and which as locomotor organs are useless. These legs have become reduced to a single segment which is much flattened, strongly curved, and strongly chitinized. The two pairs oppose each other and when contracted strongly grip a single hair to which the parasite is attached.—Fig. 20. A Hydrachnid larva. The last segment of the palpus has been transformed into a strong hook by means of which the mite clings tenaciously to its host. The species is chiefly a wader, as is shown by the absence of long hairs on the legs, in this respect it has not become perfectly adapted to the aquatic life.—Fig. 21. A dipterous insect with a larva of *Rhyncholophus* attached. Shows the exposed position assumed by many of these parasitic larvae and the great necessity of having good adhering organs.

Plate VI.—A Symbion and Commensals.—Fig. 22. *Macrocheles moestus* Banks. One of the several species of Gamasidae which live in symbiotic relationship with ants. This species has been studied by Prof. S. A. Forbes, who found that the ants paid much attention to it and would carry these mites about as if they were their own young. The mite probably lives as a scavenger of the domicile. In many cases these gamasids will attach themselves to the bodies of the ants and live upon food regurgitated by their hosts.—Fig. 23. *Pterodectes muticus* Banks. One of the commensals belonging to the Analgesidae. The members of this genus live among the feathers of birds where they eat cast epidermal cells and oily secretions.—Fig. 24 and 25. Female and male respectively of *Analges passerinus* Linnaeus. Like the preceding species this species lives among the feathers of birds upon excretory products and dead cells.

Plate VII.—Some types of True Parasites.—Fig. 26. *Psoroptes cuniculi* (Delaf.). Male and female in copulation. The species of this genus infest the skin of mammals where they cause great sloughing of the same. They live on the cellular tissues.—Fig. 27. *Microtrombidium muscarum* (Riley). It is a larval parasite of one of the harvest mites. The common house fly is its true host from which it sucks the blood. At times these larvae attack man himself and cause intense itching.—Fig. 28. Larva of *Rhyncholophus*. It lives as a haematophagus parasite upon species of *Empoasca*.—Fig. 29. *Eriophyes ulmi* (Garman). One of the gall mites. The gall mites live upon the juices of plants. Often their attacks cause various malformations to appear upon the leaves, some of which are called galls. The vermiform shape of the body is an adaptation similar to that of the hair follicle mites.

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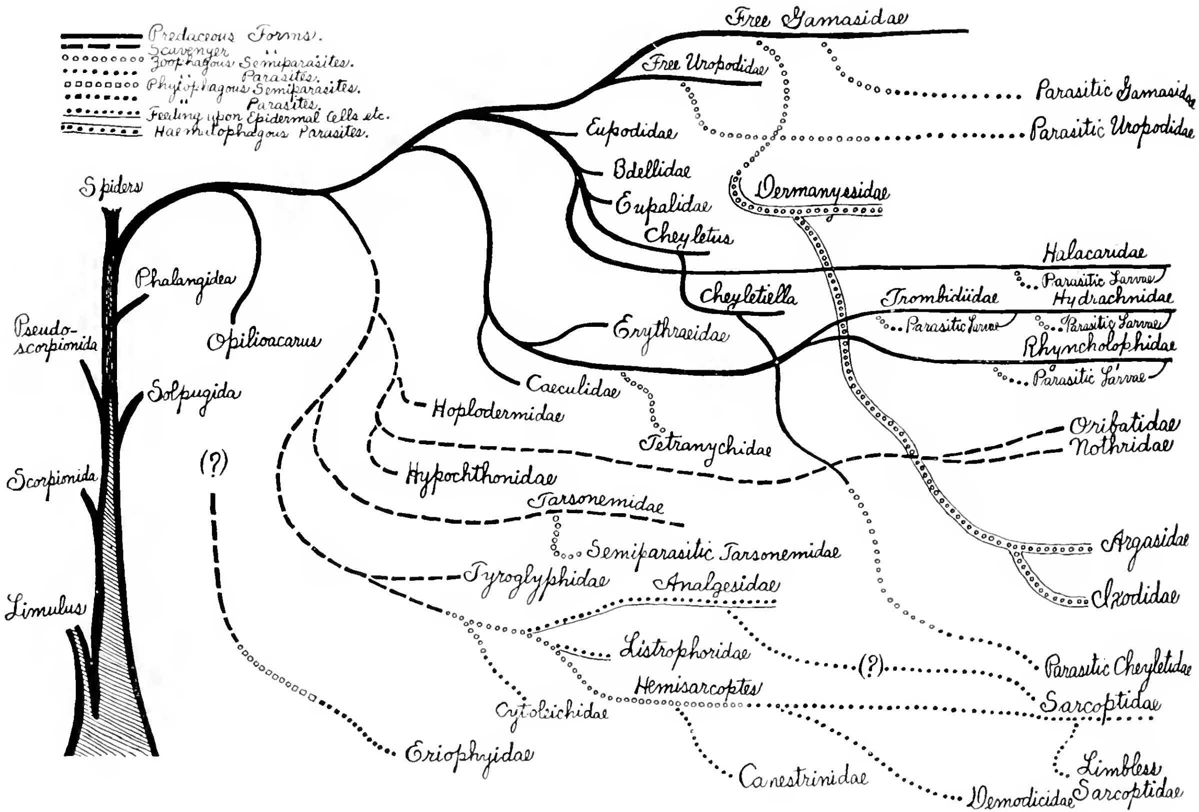
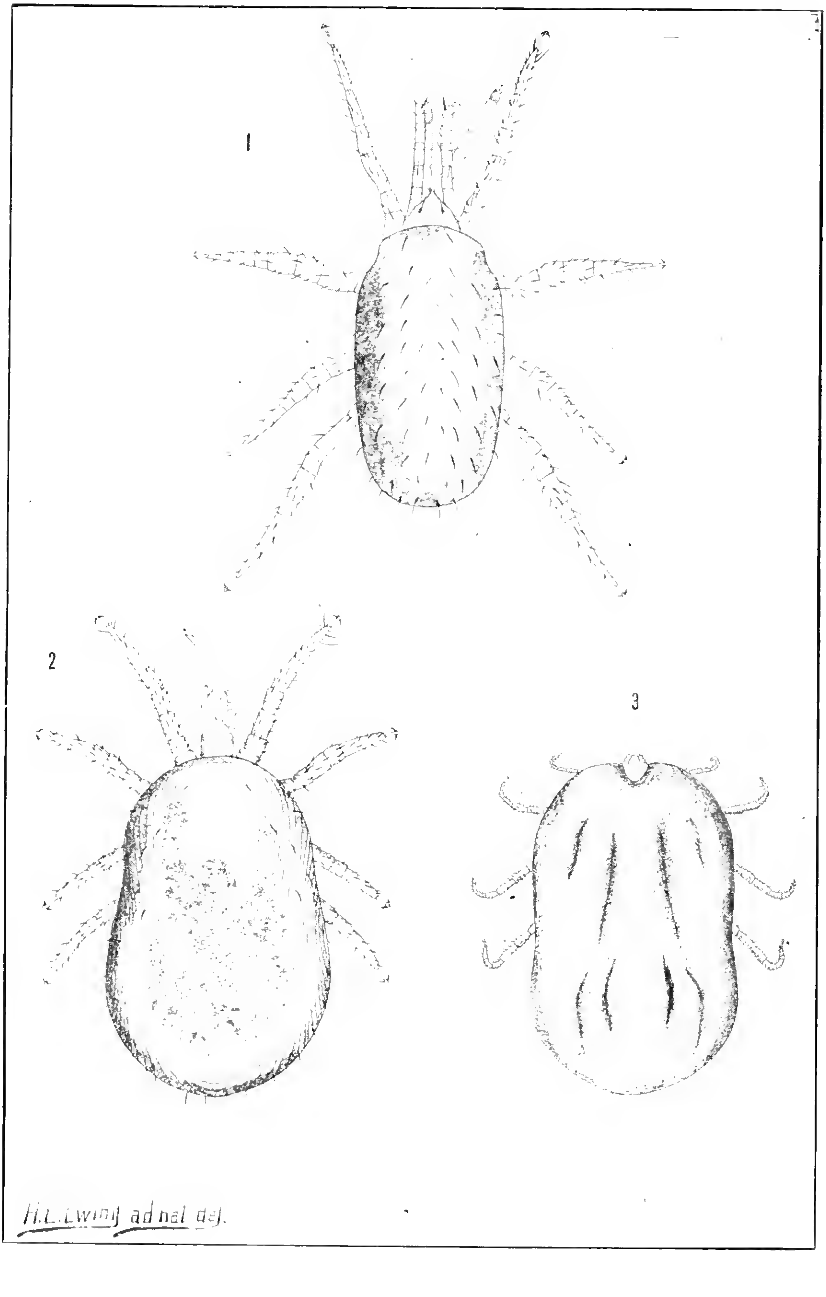


PHYLOGENETIC TREE.



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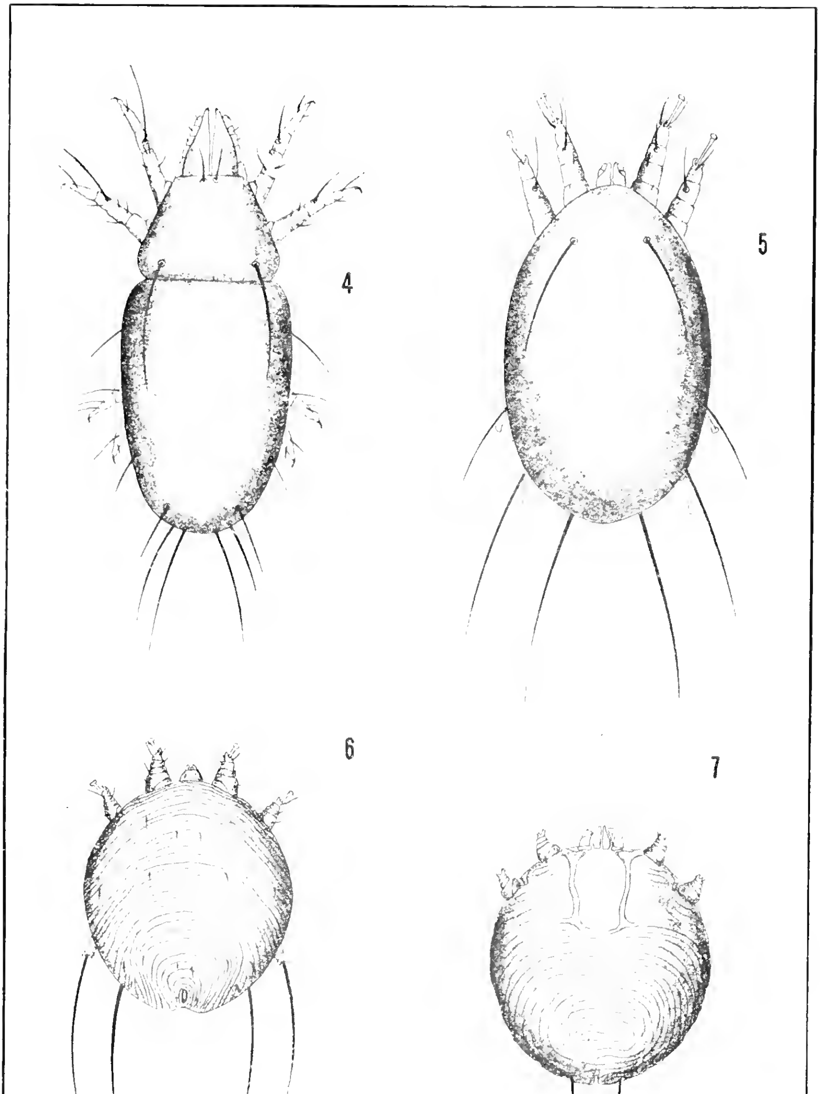
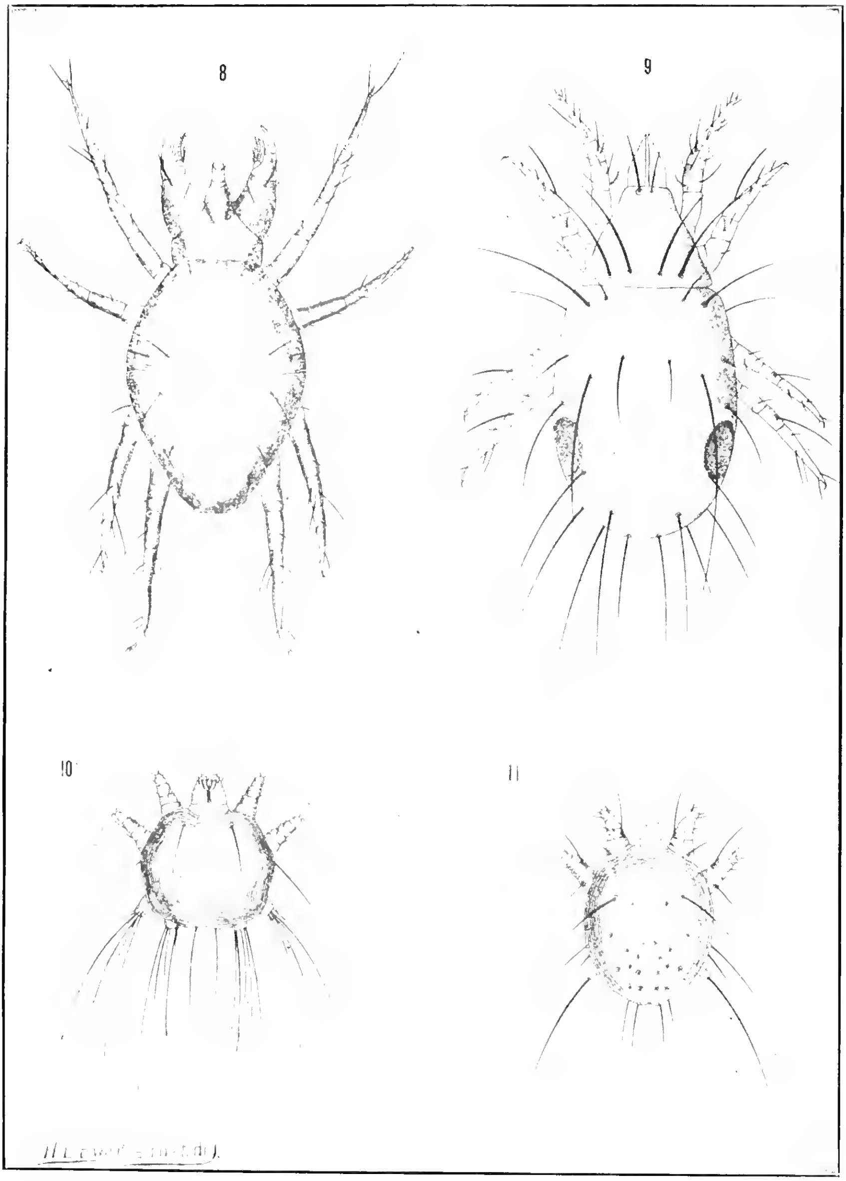


PARASITISM FROM SCAVENGER TYPES.



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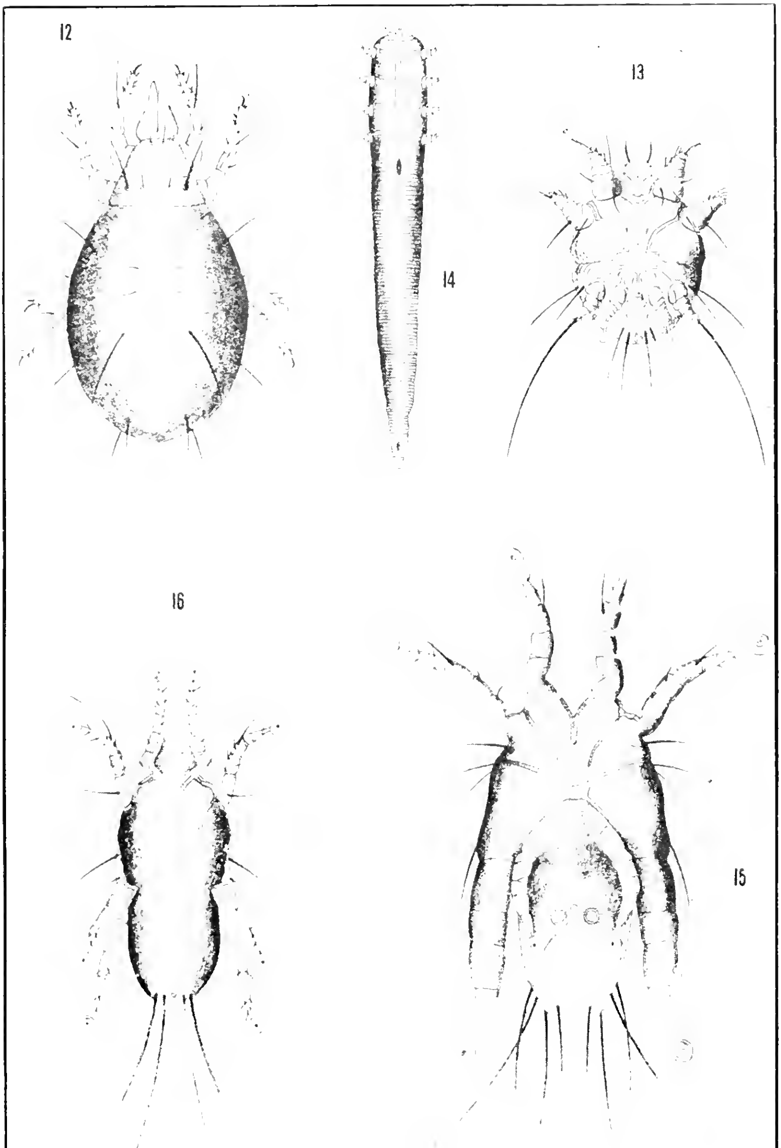

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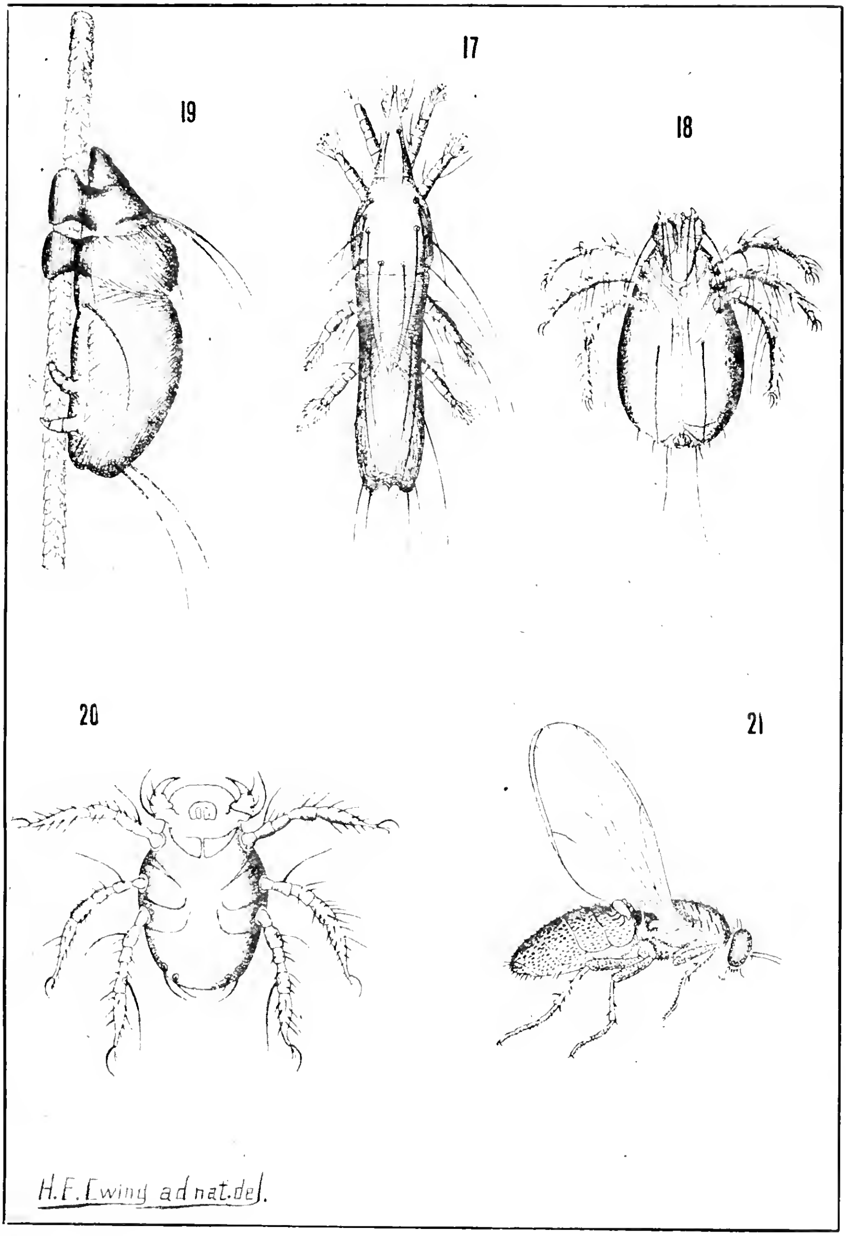

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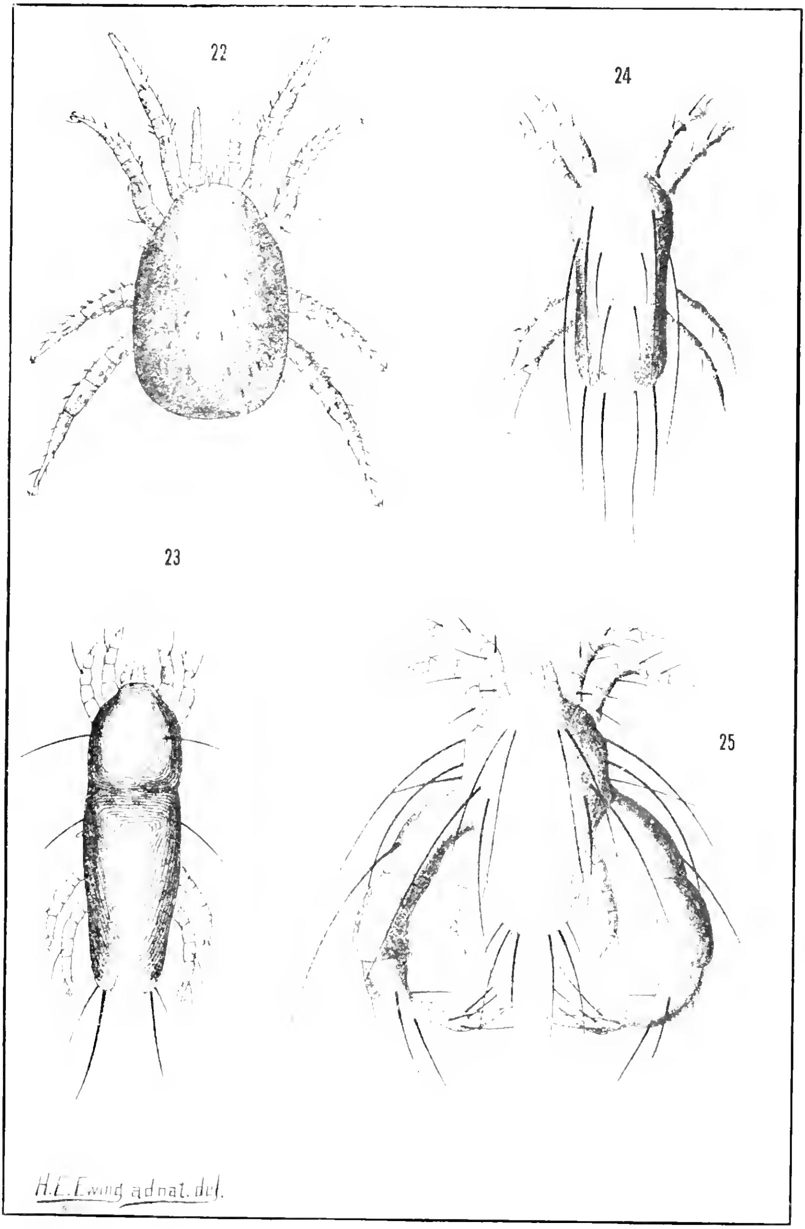
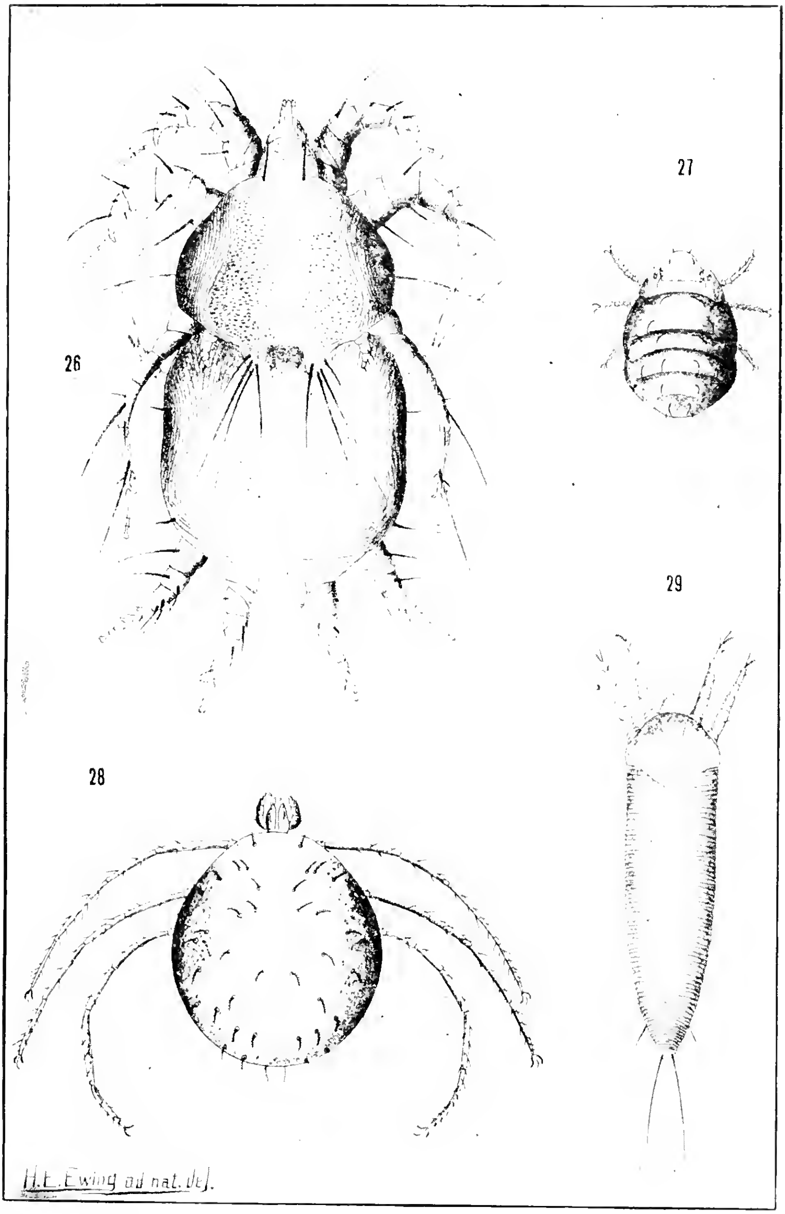


A SYMBION AND COMMENSALS.



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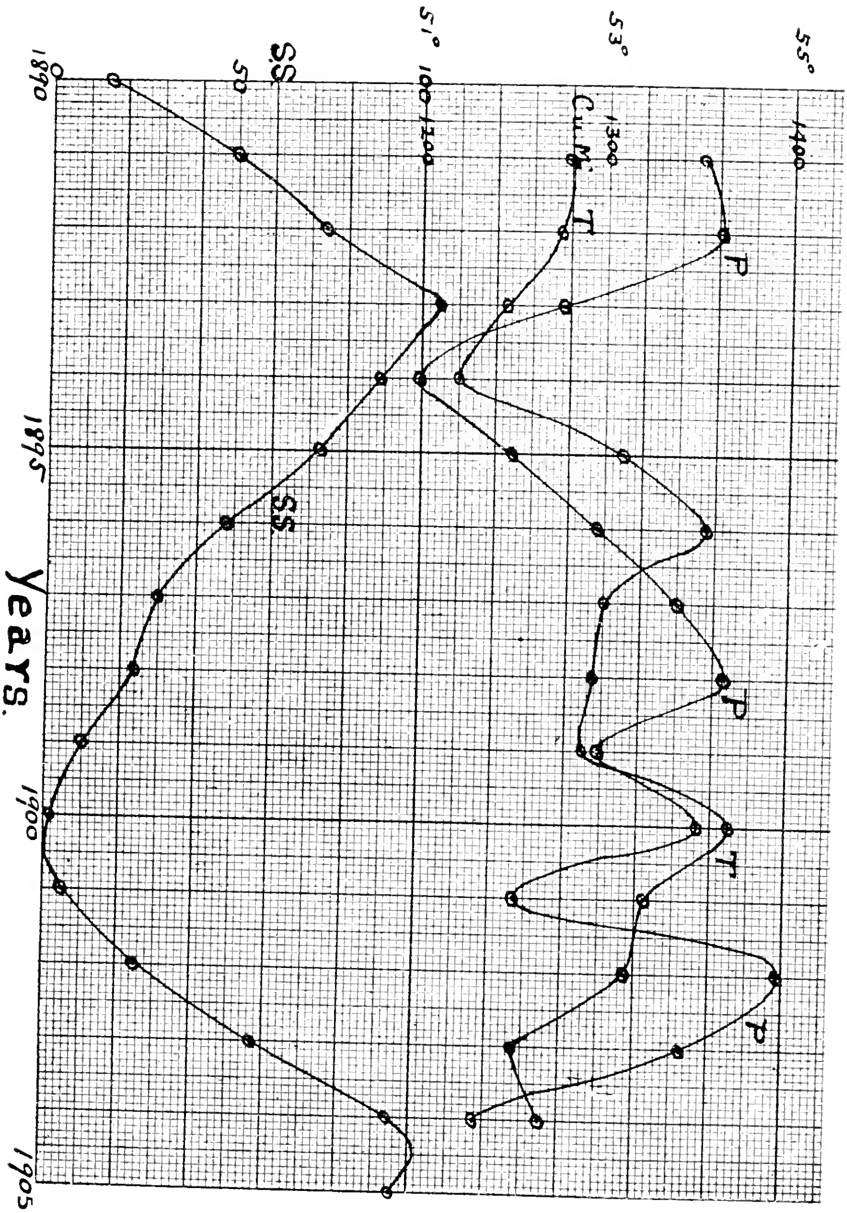
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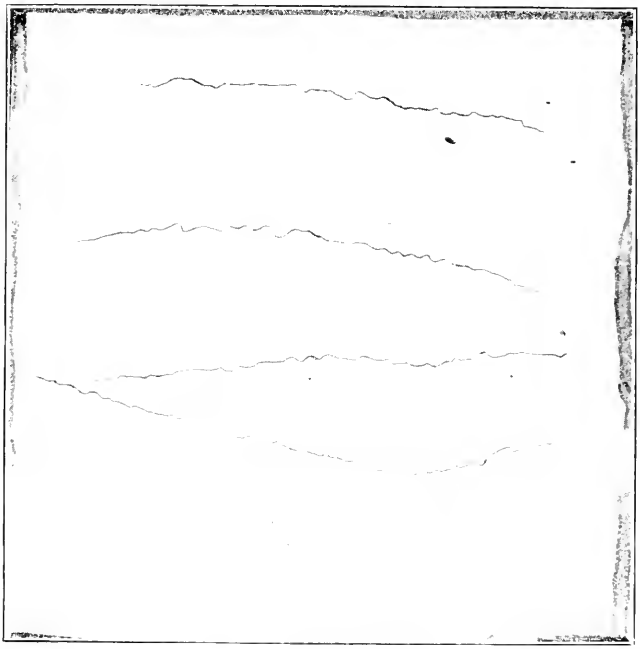

PLATES A AND B.

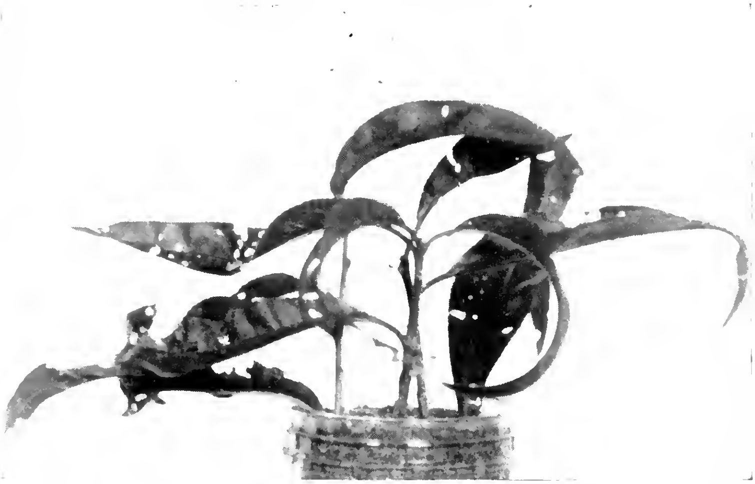

FIG. 1. PEACH LEAVES EATEN BY 18 CURCULIO FROM SEPT. 20TH TO 26TH, 1909, WHILE IN CAPTIVITY IN A MASON JAR.

FIG. 2. CONTROL PEACH LEAVES WHICH WERE IN AN ADJOINING JAR FOR THE SAME LENGTH OF TIME AS THOSE IN FIG. 1.

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Transactions of The Academy of Science of St. Louis.

VOL. XXI. No. 2.

THE ANNUAL RAINFALL AND TEMPERATURE OF THE UNITED STATES.

GEO. A. LINDSAY.

Issued June 19, 1912.

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Continued on page 3 of Cover.

THE ANNUAL RAINFALL AND TEMPERATURE OF THE UNITED STATES.*

Geo. A. Lindsay.

A record of the annual temperature and rainfall of various stations scattered over a large territory, having wide variations of climate cannot give a very accurate idea of the mean annual temperature of the whole region, or of the total volume of precipitation upon its surface.

In "A Report on Missouri Rainfall"[1] for the years 1878-1887 inclusive, Professor Nipher has shown the average number of cubic feet per second of water in the various forms of precipitation which fell upon the surface of the state during those years.

In the following work, which was also begun by Professor Nipher, and completed by the writer, an attempt has been made to compute the total precipitation on the main body of the United States, exclusive of Alaska, and the outlying possessions; and also to find the average annual temperature of the same region as a whole. It would seem that this, or some similar method, is the proper way of expressing the climate of an entire country, such as the United States.

Twenty-eight manuscript maps, covering the fourteen years 1891-1904, were obtained from the office of the Weather Bureau at Washington. Half of these indicated the precipitation in inches per year, and the other fourteen the mean annual temperature. The figures for these had been marked on the maps at the points of observation, and lines passing through points having equal precipitation, and lines of equal temperature had also been drawn upon the maps by the weather officials. These

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* Read before The Academy of Science of St. Louis, June 5, 1911.

[1] Trans. Acad. Sci. St. Louis. 5:383.

lines divided the maps into zones or sections, one zone comprising, let us say, the territory whose mean annual temperature lay between 50° and 55°, the next 55° to 60°, etc.

It was intended at first to find the areas included in these several zones by the planimeter. Then, knowing the area over which the mean temperature was 50°, another over which it was 55°, etc., the average of the whole might easily be computed.

This integration by means of the planimeter was abandoned, however, for it was found by Professor Nipher that the areas of different sections of the map as shown by the instrument were not proportional to the actual areas of those sections. It was also difficult to properly weight the values with respect to areas, unless the areas between the lines of equal value were subdivided into smaller areas.

The method actually adopted by Professor Nipher was to take each state by itself, and for each year average all the observations recorded, also filling in values by interpolation methods, where the reports were thinly scattered in some portions of the state as compared with other portions, so as to make the observations as evenly distributed as possible. These interpolated values were estimated by means of the values on each side of the deficient areas.

As an illustration, Minnesota has naturally a great many more stations to report from the southern and southeastern parts of the state than from the northern; perhaps the lower half of the state would have three-fourths of the observations. It would be manifestly unfair to give the northern half of the state only one-third the weight of the southern half in determining the rainfall or average temperature. In some states no interpolation was necessary, in others a great many were added. Enough observations were on the maps originally, however, so that these interpolations could be made with a tolerable degree of accuracy.

In Missouri in the year 1896 the number of observations of rainfall, including those interpolated, was 44. The average of these 44, or the average for the whole state, was 40.1 inches. If we multiply this 40.1 by the number of square miles in the state and divide by 63,360 which is the number of inches in a mile, we have the number of cubic miles of water which fell in the state during the year; that is, if τ is the precipitation in inches and A the area of the state $\frac{\tau A}{63360}$ is the number of cubic miles of water. This for Missouri in the year 1896, just mentioned, was 43.9 cubic miles. The total number of cubic miles of water falling in Missouri in the fourteen years was 609.3, giving a mean of 43.5 cubic miles per year. This is at the rate of 203,000 cubic feet per second as compared with 195,800 cubic feet per second found by Professor Nipher between 1877 and 1887. The maximum was in 1898, 60.9 cubic miles, 40% above the average; the minimum was in 1901, 28.2 cubic miles, 35% below the average. These two years, however, were very abnormal, the highest outside of 1898 being 49.1 cubic miles, and the lowest, excepting 1901, 34.6 cubic miles.

The 43.9 cubic miles which fell in Missouri in 1896 are alone enough to make a layer over the whole city of St. Louis (which has an area of 62½ square miles) 0.7 of a mile deep. If it could all be utilized it would make a river ½ mile wide, 16 feet deep, and 29,000 miles in length. If this flowed at the rate of 3 miles per hour, it would take over a year to pass a given point, so that enough water falls in Missouri to fill and keep flowing continuously a river of this crossection, and of the whole length of the Mississippi, and then enough would be left over each year to fill a canal of the same section from New York to San Francisco.

Professor Nipher showed in his paper before referred to that the total rainfall in cubic miles falling upon the State of Missouri during the ten years, was within two per cent equal to the discharge of the Mississippi river at St. Louis during that interval.

It may thus be seen that most of the water which falls as rain or snow never reaches the sea through the medium of drainage, but is evaporated from the land. If all of the precipitation were led into the rivers and conducted back to the sea we should have mighty streams of water which would make our present ones seem as little brooks.

The discharge of the whole Mississippi system, however, is considerably greater than the river we have imagined. To make it more definite, the discharge of the Mississippi river at Carrollton, La., was computed for the fourteen years. A discharge curve of the river at that station was constructed from simultaneous gauge readings and discharge observations taken from the reports of the Mississippi River Commission. From this curve a discharge curve for each year was constructed, and by mechanically integrating the areas under these curves, the discharge of the river at Carrollton was found for each year. These yearly discharges ranged from 76.3 cubic miles in 1895 to 154.7 cubic miles in 1903. The average was 117.0 cubic miles per year, or 545,800 cubic feet per second. This is less than three times the precipitation on the state of Missouri. It would be interesting to see what part this discharge is of the whole amount falling upon the area which drains into the Mississippi above its mouth.

After the precipitation for each state had been computed, they were summed up in five districts; the Northeast, the Southeast, the North Central, the South Central, and the Western. The Northeast division comprised the New England States, New York, New Jersey, and Pennsylvania. The Southeast division, Delaware, Maryland, West Virginia, and the South Atlantic States. The North Central, Ohio, Indiana, Illinois, Wisconsin, Michigan, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska and Kansas. The South Central, Kentucky, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Texas and Oklahoma. The Western division comprised the remaining states to the west.

In the year 1896 the total rainfall on the Northeast section was 98.9 cubic miles; on the Southeast, 199.7; on the North Central, 363.0; on the South Central, 308.8, and on the Western, 326.0, making a total for the United States of 1,296.4 cubic miles. This is about thirty times as much as falls in Missouri in one year. The greatest annual volume of precipitation during the years considered was in 1902 when 1,396.9 cubic miles fell. In 1894, the year of minimum fall, there was only 1,199.1, a difference of about 200 cubic miles.

The curve P shows the variation of precipitation from year to year. The average for these fourteen years is 1,308.0 cubic miles. One cubic mile of water weighs 4.58 $x10^9$ tons. This great volume of 1,308 cubic miles appears more gigantic when we think of its weight—6.00x 10^{12} tons for the year. A tremendous amount of work would be required to lift this mass from the surface of the earth to the height from which it falls again as rain. Taking the average height of the raincloud as ½ mile, it would require $317x10^{17}$ foot-lbs. of work. 18,270,000 engines of 100 h. p. each would be kept in operation day and night to elevate the water to the clouds as rapidly as it falls on the surface of the United States. If we consider the heat required to vaporize it we find it would require the combustion of $5x10^{11}$ tons of anthracite per annum to furnish enough to change the water into vapor at a temperature of 68° F.

The average yearly temperature for the whole country was obtained as follows: The average for each state was found, just as in the case of the rainfall, by averaging the values of the several station reports, together with interpolated values, multiplying the average by the area of the state, adding these products for all the states, and dividing the sum by the area of the whole United States.

This gives for the average temperature of the United

States for successive years, the values shown in a table at the close of this paper and represented by the curve T. It will be seen that the values are remarkably constant, the highest in the fourteen years being 54°.4 in 1900 and the lowest 51°.4 in 1894, a difference of only 3°. The mean for the period being 52°.9, the greatest variation was only 1°.5 above or below this.

We may say then, that taking the fourteen years as a basis, the average annual temperature of the United States, excluding the outlying parts, is 52°.9 F., and the annual precipitation is 1,308 cubic miles.

The state having the lowest amount of precipitation in any year was Arizona in 1894, 5.8 inches; the greatest, Alabama in 1900, 71.6 inches. The state having the lowest average temperature was North Dakota in 1893, 35°.5; the highest, Florida in 1897, 71°.8. These of course are far from representing the extremes for small areas. The maximum rainfall for single stations is not in Alabama at all, but on the North Pacific coast, where in Washington and Oregon the rainfall is very often more than 100 inches per year, while some areas are of course practically rainless.

Many attempts have been made to show a periodic variation of the temperature and rainfall, and to connect this period with some celestial phenomenon, as sunspots. The chart shows both temperature and precipitation curves together, and also the curve of Wolff's sunspot numbers. While there seems to be a tendency, especially in the first part of the fourteen years, for a minimum temperature and rainfall to occur at a maximum of sunspots, the latter part of the period covered is erratic in both temperature and precipitation curves. The fluctuation is a large fraction of the general periodic change which coincides fairly well with the sunspot period. A continuation of this work through the next sunspot period may yield more conclusive results.

Brückner has constructed a table of world temperatures and precipitation from about 1731 to 1885, which he finds, apparently, indicates a period for both of about thirty-five years. The interval, however, between maxima and minima varies from four to thirty years. The maxima for temperature and rainfall sometimes fall together and sometimes a maximum of temperature coincides with a minimum of rainfall.

It may be considered then that the most that may be said is that there are not yet enough data, or perhaps, better, not enough work has been done on the vast amount of data already accumulated, to show with any certainty, or even probability, that any celestial phenomena govern the variation of temperature and precipitation from year to year. The remarkable thing is that the yearly variation is so small, considering the great storms and great variations of temperature extending over short periods. This very uniformity is perhaps more wonderful than the discovery of some celestial cause for the variation.

The integrated values for the entire country evidently furnish a much more reliable basis for a study of climatic conditions upon the earth than could ever be obtained by observations at isolated stations.

EXPLANATION OF PLATES.

Plate VIII.—With the time interval 1891-1904 are plotted: (P) The precipitation, in cubic miles per year, on the entire United States. (T) The annual temperature of the United States. (S.S.) Wolff's sunspot numbers.

Issued, June 19, 1912.

Year.	Average Temp. ° F.	Precipitation Cubic miles.
1891	52.6	1352.0
1892	52.5	1362.1
1893	51.9	1277.5
1894	51.4	1199.1
1895	53.2	1249.8
1896	54.1	1296.4
1897	53.0	1340.3
1898	52.9	1366.2
1899	52.8	1298.2
1900	54.4	1352.9
1901	53.5	1254.3
1902	53.3	1396.9
1903	52.1	1345.4
1904	52.4	1235.0

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Transactions of The Academy of Science of St. Louis.

VOL. XXI. No. 3.

THE NATURE OF ELECTRICAL DISCHARGE—POSITIVE COLUMN EFFECTS IN A METAL CONDUCTOR.

FRANCIS E. NIPHER.

Issued July 3, 1912.

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Continued on page 3 of Cover.

THE NATURE OF ELECTRICAL DISCHARGE—POSITIVE COLUMN EFFECTS IN A METAL CONDUCTOR. *

FRANCIS E. NIPHER.

In former papers in these Transactions (Vols. XIX No. 1; XIX No. 4; XX No. 1) experimental evidence has been obtained, which seems to indicate that the positive column or the positive streamers in electrical discharge through gases, is a negative inflow to the exhaust or positive terminal. The molecules of matter in such a drainage channel are moving in the opposite direction from that in which the negative fluid is flowing.

The result of recent experiments with solid conductors seems to justify the conclusion that such a conductor carrying a discharge, is an aggregation of positive ions, and that a copper wire under such conditions is urged in the opposite direction from that of the corpuscular flow.

A wire 50 centimeters in length and having a diameter of 0.23 mm. was placed in a glass tube supported at its middle point in a horizontal position. Tubes of various internal diameters between one and five mm. have been used, and all give similar results. The length of the tube is such that the wire protrudes from it at each end a distance of about a centimeter.

Two discharge knobs forming the terminals of rods 2.5 meters in length were placed with their centers over the ends of the glass tube. The rods were supported near the glass tube by silk cords. The other ends rested on the discharge rods of an eight-plate influence machine, driven by an electric motor. The glass tube containing the wire was parallel to the discharge rods of the machine, and at right angles to the rods leading from the

*Presented June 3, 1912.

machine. It is necessary that the knobs be placed above the ends of the tube. The protruding ends of the wire are slightly lifted just before the sparks occur. This prevents bending of the wire around the edge of the glass at the end of the tube, from interfering with the longitudinal creeping of the wire.

The discharge gaps at the ends of the glass tube were made equal. The discharge knobs had equal diameter. The gaps usually had a length of four or five cm. each, so that discharges could be freely produced, at intervals varying from half a second to three seconds.

The machine was in a glass case containing a supply of calcium chloride, and warmed inside by a one-kilowatt heater. The wire was observed by means of a telescope magnifying about 27 diameters. No longitudinal motion of the wire due to a single spark, can be detected by observation with this telescope, but the summation effects of three or four sparks is plainly to be seen. The wire gradually creeps along within the tube in the opposite direction from that in which the negative discharge passes through it. In one case the wire was placed symmetrically in the tube so that each end projected 1.2 cm. The sparks were passed into the side of the wire at the end of the glass tube. A condenser of sheet glass having on each side a metal plate of about 1,000 sq. cm. was used. Sparks were passed into the wire for about three hours, during which time the displacement of the wire was 1.2 cm. due to about 3,500 discharges. As the wire was gradually displaced from the position of symmetry, sparks at the positive end occasionally entered the wire at its end. At the close of the operation when the end of the wire was at the end of the tube, all of the sparks at this end, entered the wire at its end. It may be that an end effect due to interaction between the wire and the air is thus increased. At each end of the wire there is a point discharge, but these opposing effects on the wire seem to be greatest when no spark is passing, and to cease when the spark has passed.

No creeping of the wire occurs except at the instant when the sparks occur. The gaps may be made so long that no sparks can pass. Electrostatic attractions are then greatest and point effects at the ends of the wire can be observed in a dark room. The wire does not then move. The arrangement of the apparatus is shown in the annexed figure.

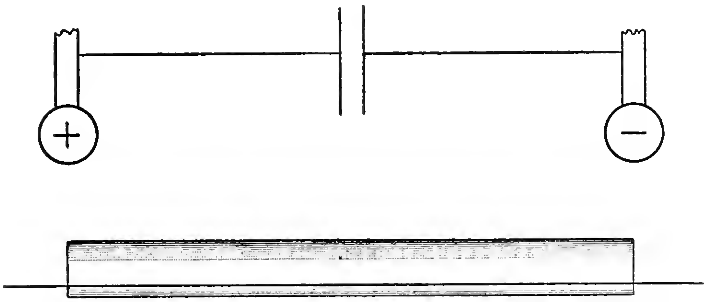

FIG. 1. Apparatus showing the gradual creeping of a wire in a direction opposite to that of the corpuscular discharge.

It is found that the wire creeps to the right as shown in the figure, when it is unsymmetrically placed with the end on the right hand even with the end of the glass tube. It then projected from the left end of the tube a distance of 2.4 cm. It would require over 7,000 discharges with the apparatus used to displace the wire 2.4 cm. into the position formerly described. The amount of displacement per spark does not seem to depend upon the position of the wire between such limits, although no precise measurements have been made.

The question arises whether the observed creeping of the wire is due to a differential action between the ends of the wire and the air which surrounds these ends, at the instant when the spark occurs.

This was examined by means of a differential electric whirl constructed as follows:

Two small hollow spheres of metal were mounted upon the ends of a thin metal tube about 50 cm. in length.

Curved and pointed wires having a length of 18 cm.

were mounted around the two spheres in their equatorial planes. The ends of the wires were 14 cm. from the axis of the tube, which was along the polar diameters of the spheres. The wires on the two spheres curved in opposite directions, so that each group would produce whirling in an opposite direction. The device was hung in a vertical position on a bundle of fibers of unspun silk. From the lower sphere a small weight was hung on a similar bundle of silk.

One object to be secured was a symmetrical arrangement of matter at the upper and lower ends of the whirling device.

Vertical discharge rods were placed above and below the whirl, so that sparks could be sent along the silk fibres to the two balls. The tube was gently clamped in a friction brake of hard rubber, the force being applied by means of a flexible rubber band. This was necessary by reason of the fact that local clouds of ionized air in the room produced rotations of the whirl which were sometimes in one direction and sometimes in the opposite direction. This device was much more sensitive to differential point effects than the wire lying in the glass tube. The air in the room has occasionally been in such a condition that the frictional contacts could be wholly removed, and the device would be in perfect equilibrium while sparks were passing. Reversing the discharge gave the same result.

Such stability has been maintained for intervals of several minutes, and would only be disturbed by movement of the observer, or other causes producing a movement of the air, such for example as gusts of wind.

The apparatus shown in Fig. 1, has been varied in length from 20 to 50 cm. The ends of the wire have been tipped with small spheres of solder, in order to diminish point discharges from the two ends into the surrounding air. So far as could be observed, the creeping of the wire was not affected by such changes.

There have been conditions when no creeping of the wire was observed. If the wire protrudes too far from the tube at the positive end, it is likely to cause frictional contact with the glass tube. This is particularly the case when the wire has been long in use so that its surface has become irregular from the effects of the discharge. It is also necessary that the terminal potentials shall be high, and that the condenser shall be of capacity not much less than that described.

Apparently the effect here observed in the creeping of the wire, is what might have been expected, as a logical sequence of Rowland's experiment. His results showed that a wire having upon its outer surface a thin film of negative supercharge, when given a longitudinal motion, produced an external magnetic field. When a thin film of the wire surface is drained of the negative fluid, and the wire is moved in the opposite direction the same external field is produced. In both cases the external field is electro-magnetic in character.

The phenomenon here described appears to indicate that when the external field is imposed upon the wire from an external source, the negative fluid and the solid aggregation of positive ions, namely, the copper wire, are urged in opposite directions.

The ends of the wire were bent at right angles and dipped into mercury cups. By means of a snap key, the wire was momentarily connected with terminals of a separately excited dynamo. The potential difference thus imposed was 175 volts. In this case very appreciable expansions could be observed with the unaided eye. The wire was not appreciably distorted in form, as was the case in smaller wires through which spark discharges were sent. Some deceptive results were at one time observed which appeared to be a creeping of the wire along the tube. They were later traced to contraction effects. The two ends of the wire were found to be unequally free to contract after expansion had taken place. There was no creeping of the wire as a whole under the conditions last described.

The field thus impressed upon the wire was deficient in its electrostatic component, necessary to produce an apparent recoil of the wire.

Under the conditions in which the creeping of the wire occurs, we must consider the simultaneous discharge at the two ends of the wire to be compression and rarefaction waves traveling in opposite directions through the wire. There was no visible expansion when the wire was observed through the telescope. The phenomena of the cathode discharge discovered by Crookes, and the fact that the plates of the influence machine are in continuous motion, give standing evidence of sudden displacements at each spark discharge. The corpuscular displacements in the compression and in the rarefaction waves are in the same direction, namely, in the opposite direction from that in which the wire creeps. It would seem that such waves impressed upon the two ends of a wire might result in the formation of a series of waves throughout the entire wire. The corpuscular nebula within an insulated sphere of metal is displaced when a charged sphere is brought near it. It seems evident that the conditions which exist on the two halves of such a spherical surface may exist along a metal wire. They would somewhat resemble longitudinal waves which might be produced in a column of water contained in a flexible rubber tube. The two halves of such an electric wave would attract each other.

A result which appears to give evidence of the existence of such waves was obtained as follows:

A piece of ¼ ampere fuse wire, having a diameter of 0.115 mm. and a length of about 50 cm. was placed in a glass tube containing coal-oil. The ends of the fuse wire were soldered to copper wire of about 0.2 mm. diameter which protruded through sealing wax with which the ends of the tube were closed. A single discharge from the machine to which was connected a condenser of about 4,000 sq. cm. area, gave various results depending upon the spark-length. In two cases the wire reached the condition bordering closely on fusion. Some parts were fused. Fragments of the wire are shown in Plate IX, Fig. A. At fairly regular intervals of 0.05 cm., the wire was longitudinally compressed into nodules, shown in the figure. This result may be due to electrical striae within the wire. The wire cooled down to a rigid condition at the instant when it had assumed this form. The nodules would then represent nodes of compression, and the points midway between the nodules would be rarefaction nodes in the electrical waves. Adjoining semi-waves have alternately a surface super charge and a deficiency of negative corpuscles. These semi-waves attract each other, and the metal yields for the moment.

In one case the discharge was slightly greater, so that the nodules separated, and further change in form was arrested at the instant when they had an almost perfectly spherical form. There were about 1,000 of these minute spheres distributed over a length of 50 cm. Those at the ends of the tube were somewhat larger than those along the main body of the tube, and were slightly distorted. In cases where the discharge was greater, the fragments of the wire were distorted into irregular forms.

A sample of the fuse wire which is in its natural form is also shown in Fig. A. The effect shown by the other fragments in this figure were due to a single discharge.

In Fig. B is shown a few cuttings from a copper wire having a diameter of 0.09 mm., through which about 50 discharges were sent. This wire gradually buckles into irregular wave forms, as was first observed by Planté. Two wires, three meters in length were suspended in a horizontal position on thirty-one fine silk threads at regular intervals. The threads were about two meters in length. The wires terminated in somewhat larger wires which show no such effects, which were bent downwards into metal vessels containing a salt solution. A slight expansion of the wire could be observed at each end when a spark was sent through the wire. No recoil of the wire as a whole could be observed, and summation effects were not obtained, such as were obtained by the arrangement first described, and which was used later.

One end of each wire was then fixed to a glass tube by means of sealing wax. Switching connections were so made that alternate and equal discharges from either terminal could be sent into one wire at the free, and the other wire at the fixed end, and thence to ground. The other terminal of the machine was grounded on a separate earth connection.

Precisely the same buckling effects were obtained as in the former arrangement. These effects were alike from end to end of each wire. The last half-centimeter at the fixed end showed the same effects as the last half-centimeter at the free end. This also points to balanced longitudinal stresses within the wire as the cause of this buckling effect. The irregularity in form may be due to variations in structure and form of the drawn wire. In a previous paper, such waves in a fine platinum wire were described, and their form was much more nearly uniform. That some differences in the length and form of striae in a vacuum tube are observed, is well known.

Added June 17, 1912.

After this paper was in type, a simple method suggested itself, of practically eliminating opposing end thrusts due to point discharges from the ends of the wire in the device of Fig. 1. About 1 cm. of the wire at each end was bent downwards at right angles to the wire. This results in applying these end thrusts at right angles to the direction in which the wire creeps. This effect is thus also utilized in diminishing frictional contact between the wire and the edge of the glass at the ends of the tube. The ends of the wire rise slightly as the conditions for the disruptive discharge are approached. The effect of thus directing the ends of the wire downwards, is to slightly increase this upward lifting of the wire at its ends. It does not appear to materially increase the creeping effect, if the wire is not in contact with the edge of the tube. In all cases the ends of the wire drop slightly, at the instant when the discharge passes.

The fact that the creeping of the wire occurs under these conditions, shows very conclusively that this result is not due to a differential end thrust resulting from point discharges from the ends of the wire into the air.

The only rational explanation which suggests itself is, that it is a reversal of the Rowland effect referred to in the body of this paper. This also involves the assumption that a wire having a positive charge is one from which negative corpuscles have been drained. The creeping wire is a solid aggregation of positive ions. It is a positive column. Like the positive column of the Geissler tube it may have in it striations. Here, however, these striations are waves in the corpuscular nebula which pervades the conducting column.

EXPLANATION OF THE PLATE.

Plate IX.—Fig. A. Nodules in a fuse wire, giving evidence of striations in the corpuscular nebula within the wire.

Fig. B. Buckling of a fine wire due to balanced forces in electric waves.

Issued July 3, 1912.

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