More interesting still was an attack made by Argentine workers upon the giant *Camponotus herculeanus* L., subspecies *pennsylvanicus* De G.^e While watching a heavy stream of *I. humilis* workers passing up and down the bark of a large water oak tree one afternoon, three or four workers of the former species made their appearance, seeking food here and there on the same tree. Presently one of these giants crossed the line of *humilis* workers and was immediately attacked, the small ants fastening themselves to tibiae, tarsi and antennae and hanging on with bull-dog tenacity. With marvelous rapidity the large worker caught from one to three of her small adversaries at a time, crushed them between her jaws and threw them aside. She would reach from side to side and twist about to crush the little enemies clinging to her tarsi, but as fast as she could dispose of them others took their places. The extreme hatred which the little workers displayed towards this giant that had crossed their path was indicated by an Argentine worker which crossed the bark a couple of inches back of the *herculeanus* worker. Immediately the small worker changed its course and ran at full speed after the large one, catching up after traveling four or five inches, and at once attached itself to a hind tarsus. After watching this interesting battle for a considerable time the large worker was captured and placed in a cyanide bottle.

There are many other points to be mentioned in connection with this introduced pest, such as its probable future distribution, its natural enemies, measures of control, and the manner in which it is likely to affect various agricultural and commercial interests, were space to permit. The problem presented by this species is a large and complicated one and much tedious work of investigation will have to be done before the economic entomologist can claim a victory over this small but formidable foe.

This paper was listened to with much interest by the members present. Mr. H. E. Weed stated that workers of this species will carry food to their nests for a distance of three quarters of a mile. He said that people who did not live in the infested district utterly failed to appreciate the havoc that these insects were causing.

Three closely related papers were next presented, as follows:

LIFE HISTORY, HABITS AND METHODS OF STUDY OF OF THE IXODOIDEA.

BY W. A. HOOKER, *Bureau of Entomology, U. S. Department of Agriculture.*

The intention in presenting this paper upon the life history and

^eDetermined by Prof. W. M. Wheeler.

habits of the ticks is to give a brief resumé of our present knowledge of the group. The species found in this country, according to Banks' latest list, number no less than thirty-four, and aside from the North American Fever Tick *Margaropus* (*Boophilus*) *annulatus*, but comparatively little is recorded relating to their biology. In looking through the records for information as to the habits of exotic species, we find but little beside the valuable work of Prof. C. P. Lounsbury, the Entomologist of Cape Colony. Realizing their importance, particularly in relation to the dairy industry, he began an investigation of them in 1898. His studies present two results: first, the remarkable discoveries that several dreaded diseases of domestic animals in South Africa are transmitted through the agency of ticks; and second, the elucidation of the life history and habits of a number of species, including that of *Amblyomma hebraeum*, *Haemaphysalis leachi*, *Rhipicephalus appendiculatus*, *Argas persicus*, and more or less completely that of others. Wheler, in England, has given valuable information on the biology of the old world Linnaean species *Ixodes ricinus*, also found in this country, as has Prof. H. A. Morgan upon several species and Dr. H. T. Ricketts on *Dermacentor occidentalis*.

In connection with the study of the biology of the North American fever tick, the writer (under the direction of Mr. W. D. Hunter) has taken up the study of other species also, because of their importance as external parasites and because of their possible agency in disease transmission. In this work frequent reference has been made to the publications of the before-mentioned investigators. In addition the writer received valuable information and suggestions from Professor Lounsbury during his visit to this country the past summer. As a result nearly the complete life cycles of eight species represented in this country have been followed in addition to that of the North American Fever Tick *Margaropus* (*Boophilus*) *annulatus*, so that granting the life history and habits of the European Castor-bean Tick *Ixodes ricinus*, to be the same in this country as found by Wheler, in England, we are now acquainted with that of ten native species, and have data on two additional species.

The ticks are of primary importance in their transmission of disease. At least ten distinct diseases of man and the domestic animals are known to be thus transmitted, no less than sixteen species of ticks being implicated. Again they are of great importance as external parasites because they irritate and drain the system of the animal attacked and are followed in some hosts by the screw-worm fly (*Chrysomya macellaria*), which deposits her eggs at these points of entrance, with resultant injury.

It is well known that in order to develop, it is necessary for the ticks to attach to and suck blood from some animal and that unless such host is found within a certain period, which varies mainly with the temperature and precipitation, that it will starve. Upon this knowledge as related to *Margaropus* (*Boophilus*) *annulatus* is based the method of freeing pastures by the so-called rotation system as first worked out by Prof. H. A. Morgan.

All ticks pass through four distinct life stages: the egg, the larva or seed-tick, the nymph or yearling-tick, and the adult or sexually mature stage. The female, following the engorgement of blood, becomes greatly distended and drops to the ground, crawls to some protective covering, and soon commences the deposition of large numbers of eggs. In the course of a few weeks these hatch into the six-legged larvæ or seed-ticks, which await the coming of, or in some species crawl to, the host. Having found a host they attach and soon engorge with blood, after which they either molt while attached or drop and pass a short period of quiescence during the metamorphosis, then appear in the eight-legged nymph stage.

A second engorgement takes place and the ticks either molt attached or drop as before, pass a period of quiescence, then molt and appear in the adult stage. Another, the third engorgement, is followed by dropping and oviposition, and the generation is completed. In the Spinose Ear Tick, *Ornithodoros megnini*, we find a variation from this. It drops as a nymph and, following the molt, without engorging as an adult, commences oviposition. In the genus *Argas* a second nymphal engorgement and molt takes place. In the family *Ixodidae* death follows the completion of oviposition, but in the genus *Argas* of the family *Argasidae* repeated engorgement takes place, followed each time in the female by the deposition of eggs.

The appearance of the active stages of the ticks varies greatly from the unengorged to the gorged, excepting in the male, which does not engorge with blood, but seems to exist upon serum. Because of this variation in appearance, individuals of the same species have been described as different species. The nymphal stage can be separated from the adult by the absence of the genital pore. The sexes can only be distinguished after the final molt, except in a few species in which the high color markings can be seen through the nymphal skin a day or two prior to molting. As adults they are separated readily in the *Ixodidae* by the shield or scutum, which in the female covers but a small part of the dorsum, but in the male completely covers it. In the *Argasidae* the sex can only be distinguished by the shape of the genital pore, which in the male is crescent shaped, while in the female it is merely a transverse slit.

The position of the genital pore varies from midway between the front coxæ to midway between the posterior pair.

The ticks are naturally separated into three classes according to their habits of molting as suggested by Ransom: first, those which pass both molts upon the host, represented by members of the genus *Margaropus* and by *Dermacentor nitens*; second, those in which the first molt is passed upon but the second off the host, represented by *Ornithodoros megnini* of this country and *Rhipicephalus bursa* and *evertsi*, two South African species; third, those in which both molts are passed off the host, as is the case with most of the ticks found in this country.

A fourth class might be recognized to include those which drop to pass the first molt, but which remain upon the host for the second; as yet, however, no representative of this class has been found.

Of importance in connection with the transmission of disease is the fact that while the first class pass the entire parasitic period of a generation upon a single host, yet the second may attach to two and the third class to three separate hosts.

It will be seen that in the first class, where the ticks molt upon the host and instead of having to wait long periods to find a host, they merely continue sucking blood from the same animal. As a result these ticks reproduce very much the faster and become of greater importance as external parasites, where numbers and the removal of blood are considered. This is the case with our fever tick. In the class where both molts are passed off the host and a host found three separate times for each generation their chances of reaching maturity are lessened as compared with the first class by the proportion of three to one. They have overcome this great disadvantage it would seem by having become more resistant to heat and cold and by having gained the power to withstand much longer periods of fasting, as well as by having acquired adaptation of habits. This will be discussed under the heading of host relationship.

While the representatives of the first class, all belonging to the sub-family *Rhipicephalinae*, are more numerous, yet their greater importance as external parasites is to some extent surpassed by the third class, particularly by the members of the sub-family *Ixodinae*, owing to the fact that the much greater lengths of the hypostome permit of several times deeper penetration. As the result of this deep penetration by the *Ixodinae*, an inflammation is produced oftentimes resulting in suppuration. Frequently in the attempt to remove ticks belonging to this latter class from the body of the host, the capitulum is separated from the body of the tick and remains embedded in the host. Lounsbury reports that in some sections of South Africa dairy

farming is becoming well nigh impossible in consequence of this deep penetration by *Amblyomma hebraeum*. Their attachment is followed by suppuration and sloughing of the teats; dairy herds in that country are often found in which one at least of the teats of each cow of nearly the entire herd is missing or injured so as to be useless.

With many species it is the habit shortly after hatching or molting to crawl upon nearby herbage, as grass, weeds and shrubs, or temporary structures, as fences and posts, and there await the approach of the host. When closely observed, the front pair of legs will be seen waving in the air, ready to attach to the host as it comes in contact, while with the other legs it holds to its support. In other species, as is the case with *Amblyomma hebraeum*, recorded by Lounsbury, the ticks are not satisfied with waiting, but start in search whenever a host comes near. In some species the waiting seems to be upon the ground.

Host Relationship.—Most species of ticks have certain hosts or group of hosts upon which they are largely dependent for existence. From this fact have arisen many of our common tick names, as the cattle tick, the dog tick, the fowl tick, the rabbit tick and many others. Many of these, however, more or less frequently attach to other hosts. The former may be termed the usual host or hosts and the latter the accidental or temporary host or hosts. There seems to be a rather close analogy between ticks and fleas as regards hosts. In his revision of the Siphonaptera, p. 268, Baker mentions rabbit fleas as remaining on a human being for some little time, biting frequently while there, still not frequenting that host nor its clothing or bed. He considers it very probable that many of the records of fleas refer merely to the temporary host, since the cases of temporary hosts are quite common. To illustrate how fleas would find these temporary hosts he mentions the possibility of the rabbit running into a badger hole, or the mouse into a mole burrow; that an owl's eating a mouse or a cat's devouring a rat would be favorable conditions for this temporary transference. Similar instances will account for many of our accidental hosts of ticks. Experiments conducted during the past summer by the writer have shown that when confined in a bag in close proximity to the scrotum of a bovine, nearly all of the Ixodids will attach. As a result of these accidental or temporary attachments for some species we have large host lists, including hosts upon which the ticks could only occasionally or never reach maturity. Lounsbury has found a peculiar habit in *Hyalomma aegyptium*; as a larva it will not feed on any mammalia, but attaches to fowls upon which the first molt is passed. Following the second molt, which takes place off the host,

with the exception of the dog, it attaches to almost all domesticated mammalia.

Mammals serve as the principal hosts of the ticks. Fowls are largely the hosts of the genera *Argas* and *Ceratixodes*, and of one or two species of the genus *Haemaphysalis*. Several species of the genera *Ixodes*, *Amblyomma* and *Hyalomma* are also parasitic upon fowls. The reptiles are not immune, several species attaching to them.

Adaptations as factors in Host Relationship.—It cannot be doubted that a great evolutionary process has taken place in the adaptation both of structure and of habits as related to reattachment and protection. It is not the intention of the writer at this time to enter deeply into a discussion of this matter but merely to mention the result of this great natural process as he sees it. This evolutionary process or survival of the fittest has resulted in the special adaptation, first of function and structure, and second of the habits of ticks.

All ticks must find hosts and attach at least once, some as many as four times. This necessity has resulted in *Special adaptation of function and structure for attachment*. An illustration of this adaptation of function is found in the way the Ixodids use the front pair of legs. As one approaches the free tick these legs can be seen waving in the air, while with the others it holds to its support. When a host comes in contact with them they cling to it most tenaciously with these legs. To determine the fact one has but to pass a finger rapidly over a cluster of the seed-ticks. The *adaptation of structure for protection* is represented by the engorged larvæ of *Argas miniatus* or *persicus*. Up to within a few hours of dropping these larvæ are globular in shape, but at this time they flatten and assume the typical *Argas* shape; this flattened form, natural to all of the other stages, permits the ticks to crawl rapidly and to secrete themselves in cracks and crevices protected from the wily fowl. In the *Ixodinae* we find what may be considered specially adapted mouth parts, which being unusually long, penetrate deeply and prevent their being easily removed.

In the *adaptation of habits favorable to attachment and protection* we find most striking illustrations of the great process of natural selection. The adaptation of habits favorable to attachment may be placed in four classes: first, in molting; second, in attachment to any host; third, of habits to habits of host; and fourth, in acquired greater vitality. There is a great disadvantage in dropping to molt, for it necessitates long periods of waiting, and results in a high percentage of mortality from not finding the host. This disadvantage seems to have been overcome by some species which have acquired the habit of

molting on the host, for example, by the various species of *Margaropus* and by *Dermacentor nitens*. To this class belong several other species which have partially overcome this disadvantage in their passing the first molt upon the host. Two representatives of this class are the South African species, *Rhipicephalus bursa* and *evertsi*. A species of *Haemaphysalis*, which has recently been discovered by the writer to occur frequently upon the heads of birds in the southern part of the United States, also seems to have acquired this habit, at least partially, for it has been determined by the molted larval skins that the first molt is so passed. It has been overcome entirely by *Ornithodoros megnini*, the Spinose Ear Tick, in a somewhat different way, that is, by passing the first molt upon the host, then feeding sufficiently as a nymph, so that following the second molt, which takes place off the host, engorgement as an adult is unnecessary for oviposition and probably never occurs.

Even in species most diverse in their tastes there are some hosts especially favored; this in some cases may be accounted for by the great numbers of that host.

In the class which has adapted its habits to the habits of the host, the ticks are confined largely to a host or group of hosts with similar habits. In the studies of the ticks made by the writer, these adapted habits have been found most interesting. The species *Haemaphysalis leporis palustris*, commonly known as the Rabbit Tick, has adapted itself to the habits of the Leporidae, the hares and rabbits, and only accidentally attaches to other hosts. It is the habit of the hares and rabbits to remain more or less inactive during the day in their "forms" or resting places, protected by a clump of grass or bushes from enemies such as birds of prey, their activity being largely at night. The writer has found that this tick following engorgement drops largely during the day, in other words when the hares and rabbits are in their forms or resting places, to which places they or others return to pass the day. Thus, when the ticks have hatched or molted and are ready to attach, they have little trouble in finding the host. This same habit has been acquired by the Fowl Tick, *Argas miniatus*, which in the engorged larval stage, the writer finds drops only at night (except accidentally) when its host, the fowl, is upon the roost. Thus when ready to re-attach it is near and readily finds the host, whereas had it dropped during the day when the fowl was on the "run" the chances of its finding a host would be greatly lessened. A habit apparently acquired by *Ornithodoros megnini* is that of crawling to a height of several feet from the ground as a nymph before molting and depositing its eggs; thus when the seed-ticks appear ready to attach they will be rubbed off by the horse, cow or other host and readily find

ADAPTATIONS AS FACTORS IN HOST RELATIONSHIP.

access to the ear. These species furnish what evidence we now have of the adaptation of habits to the habits of the host, but I have no doubt that similar habits will be discovered in other species when they have been given sufficient study.

It seems probable that in the species which drop to pass their molts greater resistance to high and low temperatures and the power to withstand long periods of fasting have been acquired. Again the species which have acquired the habit of molting on the host has probably lost in this power of resistance.

As related to protection, the *adaptation of habits* may be considered under accelerated engorgement, attachment to favorable part of body, and nocturnal habits. Of *accelerated engorgement* we have several instances among the ticks. This is best illustrated by *Argas persicus* and *miniatus* in their engorging within a few hours at the most. Lounsbury argues that they are descendants from forms which remained for days at a time on the host. That this is the case is shown by the larva, which still remains upon the host for days to engorge. In the Cattle Tick, *Margaropus annulatus*, after it has become about one third engorged, which requires a number of days, complete engorgement takes place and the ticks drop within a comparatively few hours. In this way the chances of destruction due to the removal by enemies such as birds and the attack by parasites have been reduced to the minimum.

Again we find species which have adapted their habits for protection in attaching to favorable parts of the body as have *Ornithodoros megnini* and *Dermacentor nitens* in attaching to the inside of the ears. The species of *Haemaphysalis* found upon quail, field larks (and other ground-feeding birds) in Texas, Louisiana and Florida, appear to attach only to the head, a place from which they are not easily removed by the fowl. Perhaps the most highly developed habit acquired by ticks for protection is that found in the nocturnal habits of the genus *Argas*. Through this habit of resting during the day time, they escape detection by the fowls, which, upon discovery, devour them with great avidity. At night the fowls come to their roost near by and the ticks have little trouble in finding the host and engorging at a time when the fowl is inactive, and thus largely escape detection and destruction.

Mating.—In the *Argasidæ* mating takes place after the final engorgement has occurred and the tick has left the host, but few observations having been recorded. In *Ornithodoros megnini* the nymph leaves the host, molts, and without further feeding is fertilized and commences oviposition.

In the *Ixodidæ* the mating appears normally to take place upon the

host, but some species have been observed in copulation off the host. In most of the species which pass their molts off the host (the genus *Ixodes* possibly excepted) it seems to be necessary that the male at least attach and take food before the sexual instinct is developed. In *Margaropus annulatus*, which molts upon the host, the male detaches as soon as the nymphal skin is shed and goes in search of the female, which it embraces when found and with which it remains in copulation until the replete female drops. The Brown Dog Tick, a species of *Rhipicephalus*, has similar habits, females often being found each with several males attempting to embrace them. Apparently *Derma-centor nitens* also has the same habit of remaining in copulation on the host. While the two sexes are usually nearly equal in numbers, yet by the dropping of the female and remaining of the male on the host, the latter are usually found present on the host in greater numbers. Lounsbury has made extensive observations upon the mating of *Amblyomma hebraeum*, the habits of which species are very remarkable. He has found that the female goes in search of the male, the latter accepting the female only after having attached and fed for several days. Considerable difficulty has been experienced by the writer in getting the sexes of the three species of *Amblyomma* and *Derma-centor variabilis* to copulate, and there remains much to be learned in relation to this habit. Mr. J. D. Mitchell has observed *Amblyomma americanum* apparently in copulation on shrubbery. Wheler mentions observing *Ixodes ricinus* as apparently in copulation off the host; this act he describes as taking place through the introduction of the mouth parts of the male into the genital pore of the female. The writer has observed this same habit in *Ixodes scapularis*, both upon and off the host. An unengorged, unattached female taken in the field from a hunting dog and placed in a pill box with unattached males taken from the same dog was shortly after found in copulation with one of the males. From this it would appear that it is unnecessary, for the female of this species at least, to take food prior to fertilization. The habit of fertilization through the introduction of the male mouth parts into the genital opening of the female thus appears to be typical of the genus *Ixodes*.

Geographical Distribution.—While ticks are found which have adapted themselves to colder climates, it is in the tropics that they are found in the greatest numbers. That the distribution of species is controlled by cold is well illustrated by the original quarantine line against the cattle tick in this country. Humidity and precipitation also appear to be factors in control of the distribution, as in the case of the Gulf Coast Tick, *Amblyomma maculatum*, a species found in the immediate vicinity of the Gulf Coast from Cameron Parish, Louisiana, to the Rio Grande River in Texas.

Life History and Habits of the Genera and Species.—The life history and habits of the *Argasidae* are quite different from those of the *Ixodidae*. The Argasids are represented by the two genera *Argas* and *Ornithodoros*, the species being comparatively few in number. Some of these, known as man-attacking ticks, have had the reputation from the effect of their bites of producing critical conditions. Livingstone, in the account of his travels in Africa, speaks of the oftentimes serious symptoms and occasional fatal result following their attack. Lounsbury in the investigation of this effect permitted specimens of *Argas persicus* and *Ornithodoros savignyi* (the Tampan Tick), two species implicated, to feed upon his arm, and concludes that while they may be productive of considerable irritation and their penetration serve as entering point for some of the abscess-forming bacteria, as *Streptococcus pyogenes*, etc., yet otherwise their direct effect is harmless. They may, however, transmit disease in both man and the lower animals. Dutton and Todd have shown *Ornithodoros savignyi var caecus (moubata)* Neum. to be the agent in the transmission of a spirillum which produces a disease of man known as human tick fever. This may account for the reputation that they have borne in Africa.

In the genus *Argas* the nocturnal habit is developed. They remain hid away by day, coming out from their places of hiding by night to find the fowl host and engorge with blood. The genus is represented in this country by two species, *sanchezi* and *miniatus*. Of the former species, known as the Adobe Tick from its habit of frequenting adobe houses, little or nothing is known as relating to its life history. *Argas miniatus*, commonly known as the Fowl Tick, is a species very similar in structure, life history and habits to that of the old world *Argas persicus*, and is probably at most but a variety of that species. The life history and habits have been carefully worked out by Lounsbury in South Africa and the similarity of our species in life history and habits has been determined by the writer. *Argas miniatus* is of importance because of its attack upon poultry; in sections of Southwestern Texas it has made profitable poultry raising impossible. As a larva, this tick attaches to a fowl, preferably beneath the wings, remains attached for five or six days, becomes engorged, and, a few hours before dropping, flattens out and assumes the typical Argas shape. As mentioned in the discussion of host relationship, it has been found that the larvæ drop only at night, at a time when the fowl host is upon the roost and where it will be near the host when ready to engorge again. In summer a period of four or more days passes before molting of the engorged larvæ takes place and the eight-legged nymphs appear. The second engorgement, always at night, lasts but a few hours at the

most and is followed in summer by five days before the second molt and the appearance of the second stage nymph. A third engorgement occurs at night (in the latter part of August) and twenty-six days pass before any of the ticks molt and appear as adults. A fourth engorgement then takes place, the sexes copulate and eggs are soon deposited. Unlike the ticks of all other genera, so far as known, these ticks re-engorge a number of times as adults, and the re-engorgement is followed each time by oviposition. The eggs hatch in summer in about fifteen days. The longevity of these ticks and their resistance to insecticides is remarkable.

The genus *Ornithodoros* is represented in this country by the two more common species *turicata* and *megnini* and two but little known species, *coriaceus* and *talaje*. But little is known of the life history of *turicata*, which Lounsbury suggests as being identical with the African species *savignyi*. *Ornithodoros megnini*, known as the Spinose Ear Tick, from spines of the nymph and its habit of infesting the ear, is a species found frequently in some parts of the South in the ears of cattle, horses, sheep, and a few other animals. The life cycle, which has been followed by the writer, is found to be this: Seed ticks, having gained entrance to the ear, attach deep down in the folds, engorge, and in about five days molt; as nymphs with their spinose body they appear entirely unlike the larvae. As nymphs they continue feeding sometimes for months. In experiments made by the writer the first nymph to leave had remained in the ear thirty-five days from the time it entered as a seed tick; others still remain in the ears at the time of writing (December 7th), a period of ninety-eight days having passed since they entered as seed ticks. After leaving the ears as nymphs, these ticks usually crawl up several feet from the ground and secrete themselves in cracks and crevices, where, in about seven days in September, after leaving the ear, they shed a membranous skin and appear as adults without the spines. Fertilization then takes place and oviposition commences, the female dying with its completion. Unless fertilization takes place, eggs are not deposited and the ticks live for a long period. The incubation period in summer is as short as eleven days. Owing to their habit of remaining for long periods in the ears, they can be carried great distances. This fact may account for their being reported from some of the northern states.

The second family, the *Ixodidae* or typical ticks, is represented in this country by nine genera, including thirty recognized and described, and several undescribed, species. The life cycle of species of the genera *Margaropus*, *Rhipicephalus*, *Dermacentor*, *Haemaphysalis*, *Ixodes* and *Amblyomma* has been followed. The greater number of these drop to pass both molts off the host. Of the species found in

this country *Margaropus annulatus* and *Dermacentor nitens* pass both molts on the host and a species of *Haemaphysalis*, found in Texas, Louisiana and Florida upon birds, has been determined by the attached molted skins to pass at least the first molt upon the host. In the species which molt upon the host, molting closely follows engorgement, but in the species which drop to molt there follows a quiescent period of two weeks or more.

All species of the genus *Margaropus*, so far as known, pass both molts upon the host. The single species of the genus found in this country, *annulatus*, attaches to cattle, horses, mules, donkeys, deer, and occasionally to sheep, goats and dogs. The larvae following attachment engorge to repletion and molt in six or seven days; then follows a similar period of engorgement as a nymph and another molt. Appearing as an adult, the male searches out the female, and copulation continues until the engorged female drops, which may be as soon as five days after molting. In summer deposition commences in three days after dropping and an incubation period of twenty-one to twenty-five days follows.

Most species of the genus *Rhipicephalus* pass their molts off the host, as is the case with the species found in this country. Lounsbery, however, has found that a South African species, *Rhipicephalus evertsi*, passes the first molt upon the host. The Brown Dog Tick, an undescribed species near *sanguineus* and the sole representative found in this country, engorges as a larva and drops in from three to seven days following attachment. A quiescent period of twenty days as the minimum was found to be passed at Dallas in October before molting commenced. As nymphs a period of engorgement of four days or more is passed before dropping occurs; this is followed by a quiescent period of fourteen days in October, when molting commences. As in *Margaropus* the male searches out the female and remains in copula until she drops, engorgement of the adult female taking about a week. Deposition of eggs commences in three or four days after dropping. At Dallas eggs deposited May 17th commenced hatching in twenty-five days. The usual host of this species is the dog, so far as is known, no records of other hosts having been made.

In the genus *Dermacentor* we find species of the two classes, i. e., those which drop for both molts and those which pass both molts on the host, the first represented by *occidentalis* and *variabilis* and the latter by *nitens*. Doctor Ricketts has determined this habit in *occidentalis* from material collected in Montana and has furnished some additional data on their habits.* He reports horses and cattle as hosts in Montana. It has been determined by the writer at the

*Journ. Amer. Med. Ass'n, p. 1069 (Oct., 1907).

Dallas laboratory that *Dermacentor variabilis* in the larva stage, attach, engorge and commence dropping in four days; a quiescent period of seven days or more passes before the molt takes place. The nymphs then engorge in about five days and pass a quiescent period of seventeen days (in September at Dallas) before molting. Considerable difficulty has been experienced in getting adults to attach and engorge, owing probably to a failure to understand what Lounsbury calls the courtship. A male that had previously fed and a female unfed were confined upon the scrotum of a bovine on November 1st; these attached and reattached a number of times, but up to November 14th had not been found in coito, though examined twice daily. On November 14th the female, having nearly fed to repletion, was found in copulation with the male, remaining in this relation for about twenty-four hours, but separating a number of hours before dropping. Dropping took place on the 15th, a period of over two weeks from attachment. Professor Morgan, however, reports that he has found the female to engorge in from five to eight days. The incubation period of eggs deposited the latter part of June was twenty-seven days. This species usually chooses the dog as its host, although it has been found upon a number of other mammals. *Dermacentor nitens*, the Tropical Horse Tick, a species found in Texas from Brownsville to Corpus Christi, has been determined as passing both molts upon the host. It is found largely in the ears, although from lack of room it sometimes attaches in the mane of the horse. The horse is the common host, although a few specimens have been taken from the ear of the goat.

Two species of the genus *Haemaphysalis*, *leporis palustris*, the Rabbit Tick of this country, and *leachi*, the Dog Tick of South Africa, pass both molts off the host. There is a species of *Haemaphysalis* found throughout the South, upon quail and other birds that feed upon the ground, which, although its life cycle has not as yet been followed, has been determined by the writer as passing (at least occasionally) the first molt upon the host. This species may prove to be *leporis palustris*, which is found so commonly upon the rabbits (with a somewhat changed habit of molting) or it may be *chordeilis*. This will soon be determined, but as yet the adults have not been obtained. The life cycle of *Haemaphysalis leporis palustris* has been partially followed by the writer at Dallas and the part remaining will soon be completed. The larvae engorge and commence dropping on the fifth day from attachment; in October they were found to remain quiescent eighteen days before molting. Nymphs attached and engorged in six days, those dropping November 4th not having molted at the time of writing (December 7th). It has been determined by large numbers of larvae

and lesser numbers of nymphs to be the habit of the engorged stages to drop during the day time. As mentioned under host relationship, this appears to be a remarkable adaptation to the habits of the host on the part of the tick. It is the habit of the hares and rabbits to remain during the day time in their resting places, which are commonly known as "forms." These forms are made by scratching in the grass beneath weeds or brush and furnish protection from the sun and enemies, such as the birds of prey. At night they become active, being protected from enemies by the darkness. Thus it is seen that the ticks by dropping during the day time in or near these forms readily find the host after hatching or molting.

In the genus *Ixodes* the life cycle of but a single species has been followed, that of *Ixodes ricinus* by Wheler in England. While there are fourteen species reported from this country, but few have been collected by agents of the Bureau, and these only occasionally. In Florida the writer has found *Ixodes scapularis* to be quite common on dogs, but because he was not acquainted with the fact that the members of this genus require more moisture than most other ticks, these died without development. Wheler finds *Ixodes ricinus* to drop for both molts, as is probably the case with the other species of the genus. He reports the larvae to engorge and drop in two days; that in winter (February to April) eleven weeks pass before they molt. Of the periods of engorgement of the nymph and adult we are not informed. Engorged nymphs removed May 29 molted three weeks later and an engorged female removed April 15 commenced oviposition on the 27th day following. While this species occurs in this country, it has been taken but once in Texas by agents of the Bureau, although extensive collections of ticks have been made. Immature stages of an undetermined species have been taken from the heads of birds by the writer.

The species of the genus *Amblyomma*, the life cycles of three of which (*americanum*, *cajennense* and *maculatum*) have been followed by the writer and that of the South African species *hebraeum* by Lounsbury, all appear to drop to molt. The genus is represented in this country by four species, the three mentioned and *tuberculatum*. Aside from *tuberculatum*, which has been found only on the land turtle in Florida, the species are not closely restricted in their host relations. The Lone Star Tick, *Amblyomma americanum*, as larvae engorge in three days, drop and commence molting eight days later; as nymphs similar periods are necessary for engorgement and molting; as adults eleven days was the quickest period in which engorgement and dropping took place. After dropping, at least eight days were found to pass before oviposition commenced. The minimum incubation period recorded is for eggs deposited June 25, when 27 days

were necessary. The Gulf Coast Tick, *Amblyomma maculatum*, as a larva engorges and drops as soon as the third day from attachment, and in the latter part of September, eleven days were necessary for molting. As nymphs, five days were necessary for engorgement, ticks that dropped November 3d not having molted at the time of writing (December 7). This species is the largest found in the United States. When fully engorged it measures two thirds of an inch in length. It also deposits the largest number of eggs, those from one specimen recorded numbering 11,265. The Cayenna Tick, *Amblyomma cajennense*, as a larva engorges and drops on the third day, following which eleven days are necessary before molting takes place. As a nymph, three days as in the larva were necessary for engorgement, and fifteen passed before they molted. The adult was found to engorge and drop in seven days. The incubation period of this species seems to be much longer than that of the other two native species studied, eggs deposited the latter part of May requiring five weeks before hatching commenced.

The species of the genus *Ceratixodes* are apparently all parasites of marine birds, little or nothing being known as to their life history and habits. *Ceratixodes signatus* Birula was described from specimens taken from Alaska. It has since been taken from cormorants in California. *Ceratixodes putus* Camb. has also been recorded from Alaska. Banks now considers *Ceratixodes borealis* K and N, a synonym of *putus*.

The Methods Used in Breeding Ticks.—So far as possible the usual host should be used in determining the parasitic periods in order to eliminate any possible variation from the normal condition.

In the ticks which pass both molts upon the host, as does *Margaropus* (*Boophilus*) *annulatus*, it is a comparatively easy matter to follow the life cycles, but in the species which drop from the host to molt, as do most of our North American species, it is much more of a task. In these species we must succeed in getting the same individuals to attach to the host and catch them as they drop, three separate times. After dropping each time they must be confined under favorable conditions and frequent examinations made to determine the normal periods of molting and oviposition and the variations therefrom. These periods as well as the incubation period vary with the temperature. In order to present satisfactory information upon these periods, they should all be recorded in connection with the thermometric readings. Thus the following data should be recorded: locality bred, date of dropping or oviposition, date of molting or hatching, total period and total effective temperature. With such data at hand, information from studies in the South can be applied in the North.

The methods found the most satisfactory for the species attaching

to cattle is that suggested by Professor Lounsbury, of attaching a bag to the scrotum of a bovine. In this way the various stages of the ticks can be applied, examinations made and the ticks removed as they drop. All of the Ixodids thus applied by the writer have attached. Some species, however, *Dermacentor variabilis* in particular, attach with considerable reluctance. In this way by removing the bag and with it the unattached ticks at the end of a given period and then making examinations twice daily and removing the engorged ticks from the bag (which has been re-attached), the exact periods of engorgement can be determined. In order to prevent the removal of the bag from the scrotum, a harness has been arranged and will be found necessary.

In determining the life cycle of ticks that attach to small animals, such as dogs, rabbits, squirrels, fowls and others, the only satisfactory arrangement found has been a cage made of wire of about one fourth inch mesh, permitting the ticks to drop through into a pan beneath. This cage made of a wooden frame should have the joints set in white lead or putty in order to eliminate all possible hiding places, into which the ticks might crawl for protection. Nails inserted in the frame serve as good posts, preventing the ticks from crawling again to the cage. In the pan or tray under the cage may be placed strips of paper beneath which the ticks will crawl. It has been the practice to place a ring of white axle grease about the rim of the pan or tray to prevent the escape of any of the ticks which have dropped. Another way of preventing their escape is by setting this pan or tray in a larger one filled with water. When the examinations are made the tray can be removed, the ticks collected and the cage cleaned with little difficulty. The plan of this tray was first suggested to the writer by Professor Lounsbury and is similar to that which he has used.

Many ticks will molt when but a small amount of moisture is supplied, whereas others, as the species of the genus *Ixodes*, require much more. As the engorged ticks are removed from the bag or tray, it has been found that favorable conditions are furnished by placing them in pill boxes upon moist sand. These pill boxes are prepared by puncturing the tops and bottoms, or better yet, furnished with gauze tops, to permit of free circulation. Still more favorable conditions are furnished by inserting in sand test tubes from which the bottoms have been removed. As stoppers for the tubes, absorbent cotton will largely prevent too humid an atmosphere, if protected from rains. A large tray has been used filled with sand into which the tubes have been inserted and on which the pill boxes have been kept. By sub-irrigation the amount of moisture furnished can be kept nearly constant without interfering with the pill boxes. This sub-irrigation is best furnished by use of a large cylinder tube extending to the bottom of the

sand; water poured into this will gradually percolate through and moisten the sand.

For longevity experiments ticks are best kept in this way, observations being readily made through the glass without disturbing the ticks. These tubes may be kept outside inserted in the soil and the longevity of the stages determined under the prevailing or normal climatical conditions which, however, are not always the most favorable to longevity. In determining the longevity of ticks on grass and weeds, a screen cage is necessary to assure protection from accidental intrusion.

The life history of the Spinose Ear Tick, *Ornithodoros megnini*, has been determined by attaching to the ears of animals bags held in place and prevented from being rubbed off by tying to a cord about the horns.

SOME LIFE HISTORY NOTES ON THE SOUTHERN CATTLE TICK

(Illustrated with Lantern Slides.)

By E. C. COTTON, *Knoxville, Tenn.*

(Withdrawn for publication elsewhere.)

A TENTATIVE LAW RELATING TO THE INCUBATION OF THE EGGS OF MARGAROPUS ANNULATUS

By W. D. HUNTER, *Bureau of Entomology, U. S. Department of Agriculture.*

Studies of the effects of temperatures upon insects have always held great interest and have frequently led to results of practical value. In this country the principal work has been done by Dr. L. O. Howard, who in 1896 in a paper read before this Association, "Some Temperature Effects on Household Insects,"^a pointed out exactly how cold storage practice could be utilized in the control of certain species. A year before, the same entomologist had shown the probabilities of the restriction of imported injurious species to certain life zones which, of course, are predetermined by temperatures.^b Later Doctor Howard in his paper on the geographical distribution of the yellow fever mosquito made much the most interesting and important contribution to the subject.^c He showed how the range of *Stegomyia calopus* was determined by temperature and how the exact limitations of the regions in which this mosquito, if accidentally introduced, might be expected to become perfectly established, could be determined by computing the accumulated effective temperature.

^aBul. Bur. Ent. 6, p. 13-17.

^bProc. Ent. Soc. Wash. 3: 219-226.

^cPublic Health Rep'ts, 18, No. 46.

Hooker, W. A. 1908. "Life history, habits and methods of study of the Ixodoidea." *Journal of economic entomology* 1(1), 34–51.

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