LIFE HISTORY, NON-SPECIFICITY AND REVISION OF THE GENUS *CHORIOPTES*, A PARASITIC MITE OF HERBIVORES

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A Thesis

submitted to the Faculty of Graduate Studies

and Research of McGill University

in partial fulfilment of the requirements

for the degree of

Doctor of Philosophy

April, 1957

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GENERAL INTRODUCTION

Mange, scabies or acariasis is a dermatitis associated with various species of mites on domestic herbivores and other animals. One species on cattle is Chorioptes bovis (Héring, 1845) Gervais and Van Beneden, 1859. This mite has been incriminated as the cause of most clinical cases of mange reported in Canada during the past 20 years, although a few outbreaks of psoroptic, sarcoptic and demodectic acariasis were noted also. The last three kinds of mange are often severe and sometimes generalized, but chorioptic mange is generally mild and frequently restricted to small patches on the hind quarters. It only infrequently irritates the host to an extent that interferes with milk or meat production.

Canada rejects the importation of cattle from Great Britain and elsewhere when the animals are affected with chorioptic mange, and infested Canadian cattle are rejected for exportation to the United States. The disease is, therefore, a barrier to international trade, even though the mites appear to be as prevalent in one country as the other. The condition in Canada is listed under the Contagious Disease Act, and as a consequence is a reportable disease. Once located, infested animals are placed under quarantine and treated by officials of the Health of Animals

Division of the Canada Department of Agriculture.

Although chorioptic mange is of considerable importance in world agriculture, remarkable little is known about either the occurrence of the mite on the host, or the biology of the mite itself. Consequently, the purpose of this investigation was to study the life history of the mite, and to gain a better understanding of the relationship between the mite and its host in the presence or absence of lesions. These are then discussed in relation to the current measures of control, together with the effect of lindane on the mite, the acaricide generally employed for the treatment of infested animals.

HISTORICAL SETTING

The relationship between the mite and mange in human sarcoptic acariasis possesses a unique position in medical history. According to Friedman (1942), Aristotle, or possible Zau-yun-fang of the seventh century, but more likely At-Tabarī of the tenth century, made the discovery of the mite on man. If any of these authors did really see the mite, they noted no association between the mite and scabies. In the seventeenth century, two Italians, Diacinto Cestoni, a biologist, and Giovan Cosimo Bonomo, a physician, described the mite and were finally convinced of its relation with human scabies. On June 20, 1687, they communicated their findings to Francesco Redi, poet and naturalist, and early opponent of the theory of spontaneous generation. Redi published their observations as the first scientific proof of the parasitic nature of scabies. Some have hailed this as the most important contribution of the seventeenth century for it demonstrated that a microscopic organism can cause a definite disease (Woglom, 1949).

Mange on domestic animals has also been recognized since antiquity. Hastings (1919) interprets the Biblical reference of Leviticus (XXII:22) as mange where Moses excluded "animals ... having ... an itch or scabs ..." from being offered as sacrifices. Bovine scabies is mentioned in the first century writings of the Spaniard Lucius Columella, and also in the treatise on the diseases of mules and cattle

written by the militarist Flavius Vegetius in the fourth century (Neumann, 1906; Harvey, 1937). Centuries passed before an animalcule was associated with the disease, and according to Gerlach (1857), it was Kegelaar in 1835 who first associated the chorioptic mite with the malady. Subsequent knowledge of the genus Chorioptes will be incorporated in more appropriate sections of the current study.

MATERIALS AND METHODS

Animals were examined for natural infestations by scraping a prescribed site with a sharp scalpel, using that kind of instrument with a permanently attached blade. Epidermic debris and hair were placed on paper or more frequently directly into a wide-mouthed jar. The collected material and jar were examined for mites under a stereoscopic microscope. Mites preserved for further study were either fixed in 70% alcohol with added glycerine, or were mounted directly in Hoyer's Medium. Morphological studies were carried out under the oil immersion of a Zeiss Phase-Contrast microscope. Measurements were made with an ocular micrometer, and the bodies of the mounted specimens, when measured, were slightly enlarged by compression of the cover glass.

In Vitro Culture Method

All previous attempts to rear mange mites off the host have failed. As a consequence, little knowledge has been forthcoming on the biology of the mites themselves. A technique has been developed in the current study for rearing reproducing populations of C. bovis for periods of 3 to 8 months, although it seemed impossible to maintain them indefinitely. The best source for beginning cultures was a foot scraping of a cow, or for that matter, from almost any part of an animal with a heavy general infestation.

Mites together with epidermic debris and hair in the scraping were placed in a series of vials that, in turn, were maintained in a jar with a capacity of about a gallon (Fig. 1). The lid of the jar was large enough to permit freedom of the hand and wrist within it. Paraffin in the bottom of the jar was at least a centimeter deep, and contained appropriate excavations for holding about 10 vials. A solution of sulphuric acid on the paraffin maintained the relative humidity at 80% according to the data of Buxton (1931). The relative humidity was checked from determination of the specific gravity of the solution, and by use of a dew-point apparatus. It was necessary to circumvallate the lip of each vial with lead in order to keep the vial upright in the paraffin when the solution was present. The solution also served as a moat preventing the exchange of mites between vials. Vials were of a height (five cm.) that permitted them to be used directly under a stereoscopic microscope (Spencer). Both paraffin and lead were suitable to use with sulphuric acid, since the former, and the product of the latter (lead sulphate), are inert. Bolting silk, held in place with elastic bands, was used to retain mites within the vials, but even with it, it was impossible to prevent loss of some individuals. This problem, however, was aided somewhat by the mites themselves. After being in the vials three or four days, many mites displayed a kind of "homing instinct" and apparently became content with their artificial environment. It was then possible to remove the bolting

silk without fear of losing the mites. The jar was sealed with petroleum jelly and placed in an incubator at 35°C.. This simple technique was suitable for rearing mites through sequential generations for some months. By transferring mites to vials with unused epidermic debris it was possible to perpetuate them longer. It was possible also to start a culture with a single individual, for example a bred ovigerous female, and anticipate an increase in the number of individuals in subsequent generations.

The maintenance of the mites under high humidity and temperature encouraged the growth of remarkably few fungi, but fungi did sometimes occur and not infrequently used dead mites as focal points of growth. Even when present, they appeared of little significance in the survival of mites in the cultures.

Isolation Unit #1

Some in vivo observations were made in two kinds of isolation units (#1 and #2) which facilitated transfer of the mites to a small area on an otherwise negative cow. The cows on experiment were maintained indoors in stanchions. The isolation units were used primarily for testing the effects of lindane on various stages of the mites, and most particularly on the hatchability of the eggs. Fig. 2 shows unit #1. It consisted of a rubber column that was about two cm. high and one cm. wide with a bottom flange

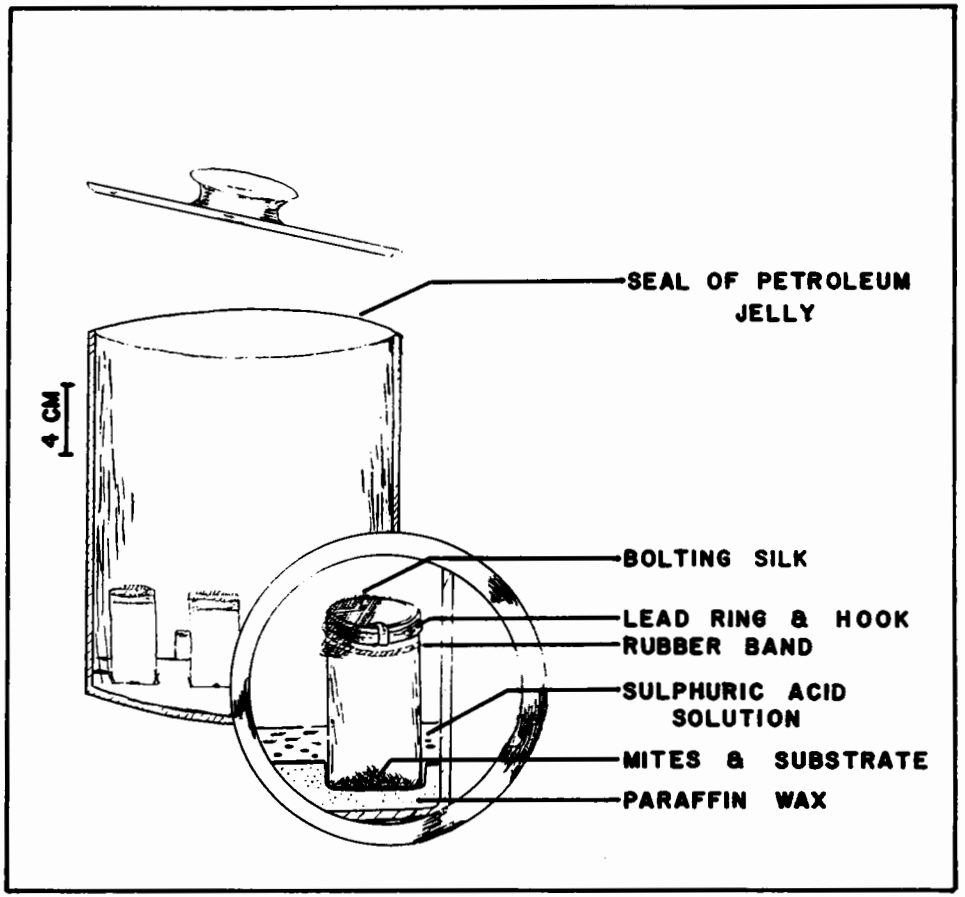


Fig. 1. In Vitro culture technique.

Fig. 2. Isolation unit #1.

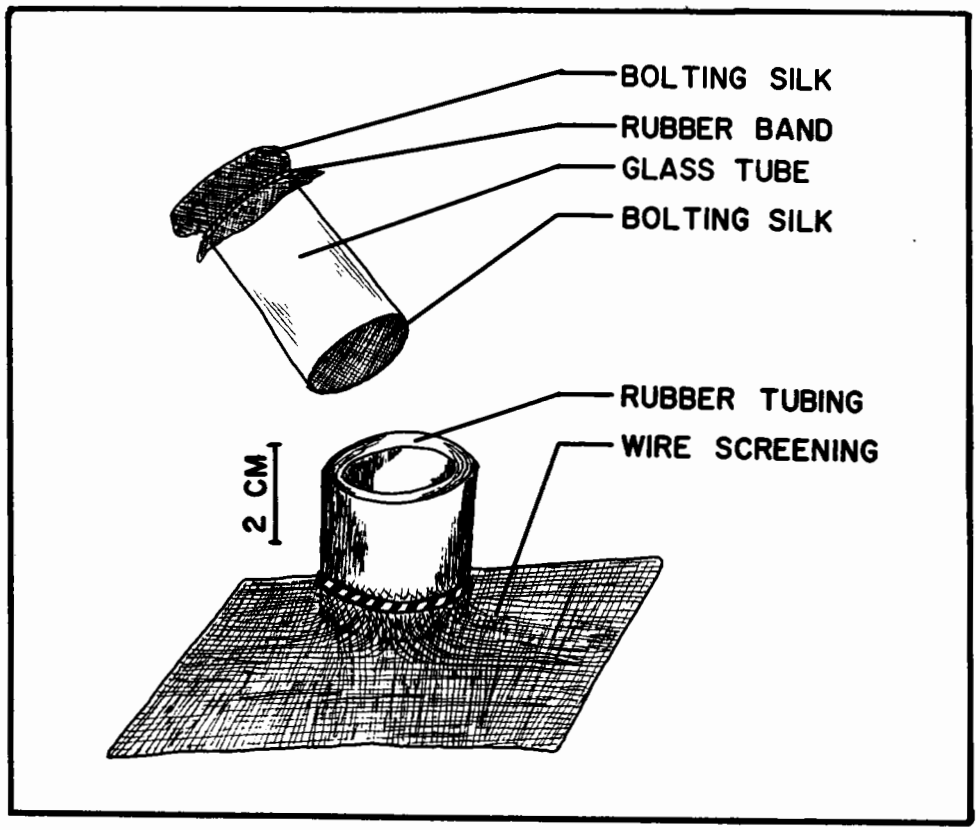


Fig. 3. Isolation unit #2.

(made from a serum bottle top) held in place with wire screening which was stuck with collodion to the clipped (not shaved) hide of a cow. A number of mites of a particular stage were collected from the in vitro culture vials or from a scraping taken from a positive host and placed directly on the cow's hide within the confines of the unit by use of a pointed wooden probe. The opening of the rubber column was then covered with bolting silk held in place by a rubber band. (Not shown in Fig. 2.) After a period of time, the unit was carefully town off, and the epidermal material below and around the rubber column was shaved off and examined microscopically.

With this unit, mites were restricted to a small area in direct contact with the host, but even so, the percentage recovery of the minute mites was low. This necessitated the development of isolation unit #2.

Isolation Unit #2

This unit, as shown in Fig. 3, consisted of a glass column (five cm. high) with bolting silk attached to the bottom edge with Pliobond*. Under a stereoscopic microscope, a number of quiescent mites or eggs were placed on the bottom bolting silk. None of the stages used necessitated the inclusion of epidermal material as feed.

*Good-Year Adhesive.

The latter would only have obscured the recovery of the mites at subsequent examinations. The top of the glass tube was itself covered with bolting silk held in place by an elastic band. The glass tube was then placed snugly within a column of rubber tubing held to the cow by wire screening stuck with collodion. Mites in this unit, unlike those in unit #1, were not in direct contact with the host, but were exposed to almost the same physical environment. This unit had the advantage that it could be removed and examined as frequently as necessary with virtually a complete recovery of the quiescent mites or eggs originally placed in it. The percentage efficacy of the drug was then readily determined.

I. NATURAL INFESTATIONS AND PATHOLOGY OF THE MITE ON CATTLE

INTRODUCTION

In 1835, Kegelaar first associated the chorioptic mite with mange. Chorioptes bovis (Héring, 1845) Gervais and Van Beneden, 1859 was found restricted to the base of the tail of cattle by Gerlach (1857), and Neumann (1906) stated that symptoms began almost exclusively at that site, extending occasionally to the back and neck in one direction, and to the perineum, udder and inner surface of the thighs in the other direction. Johne observed in 1877 that mites sometimes infested the posterior pasterns without manifesting lesions, but these areas were included as sites of mange by Hirst in 1922. Ewing (1929), either from his own observations or perhaps from other writers, stated that the mite, rather than the lesion, appeared about the base of the tail and then spread to other parts of the body. Some of these reports apparently confused the occurrence of the pathological condition with simply the presence of mites, making little or uncertain reference to the habits of the parasite.

It is well known that lesions attributed to C. bovis occur mainly during winter with an abeyance, if not a complete disappearance, in summer only to recur during the following winter. Gerlach (1857) believed that the mites, like the lesions, disappeared in summer, but Mégnin (1872a,

1872b, 1874, 1880) found them at that season living on the skin causing little damage. Mégnin suggested that the mites bite into the skin producing lesions in winter, but feed only on exuded material from the skin in summer. Direct mechanical injury of this sort has been assumed by many workers up to the present day.

It became clear from the above as well as other reports (Baker, 1942, 1946, 1947a, 1947b; Schwardt, 1949; Baker and Howe, 1950; Goodwin and Schwardt, 1952; McEnerney, 1953) that there was need for a systematic search for C. bovis at different seasons. Since little heed had been given to the possibility that most mites may occur at a site not manifesting lesions, it would be desirable also to clarify whether a direct relationship exists between the presence of mites and the occurrence of disease. Consequently, monthly observations were made for a year on a herd of cattle to ascertain seasonal variations in the incidence and sites of infestation of C. bovis, and to determine their relationship with the manifestation of lesions.

RESULTS

Incidence and Sites of Infestation

Seasonal variations in the incidence and sites of infestation of C. bovis were determined from 4,946 examinations of 38 members of a Holstein herd during each

month from November 1954 to October 1955. Various sites were generally examined once, and if negative more frequently. Fig. 4 shows a gradual increment in detectable incidence from three animals in November to 23 in March, with the number remaining similar during April and May. The cattle were on pasture (except for the daily milking routine) during most of May and the following summer months*. A concurrent drop in the incidence of infestation occurred in June and July, and only three animals were positive from August to October. Two of these were the same individuals that had been positive the previous November, indicating that they were significant in the maintenance of the parasite over the pasture period in one and possibly two summers. Even though no more than 23 of the 38 animals were ever found positive simultaneously, mites were located at least once on all but four of them. In fact, only 12 animals were consistently positive from January to May inclusive, while nine other cattle were found lightly infested only once in a small localized area. Infestations like the latter were either too light to be found repeatedly, or were only temporary. Grooming might explain temporary transfer of parasites, since viable mites were found on a currycomb on three of five occasions following the currying of a known infested area.

Mites were observed more consistently on the pasterns, particularly those of the hind legs, than at any other site. Fig. 5 shows that the number of animals with

*"Summer" and "winter" are used throughout in the colloquial sense extending from May to October and November to April respectively, rather than in the precise calendar sense.

at least one positive hind pastern reached a peak in March with 14 positive, followed by a decline in subsequent months. When all feet were considered, the total was much greater with 34 infested pasterns in March. Indications were that the number of mites varied between wide limits even in consecutive months.

In the peak months, a single infested pastern did not account for the entire incidence shown in Fig. 4, but in late summer each of the three positive animals had at least an infested hind foot. This demonstrated that examination of heels alone was not always enough for the diagnosis of C. bovis. Presence of infestations at sites other than the pasterns, however, was variable. Probably this was influenced by grooming carried out by the herdsmen. Table I shows that most of the infested sites other than the pasterns were on the hind quarters, and, like the pasterns, occurred most frequently from January to May inclusive.

From March to May, the escutcheon (where the udder joins the posterior thighs) and crotch were positive nearly as frequently as a single hind heel, but were less important than the latter at other times of the year. Regions of the hocks, posterior thighs, base of the tail, udder, abdomen, upper front legs, and areas of the lateral and dorsal torso were infested occasionally during winter, but appeared to be of limited significance in the maintenance of C. bovis.

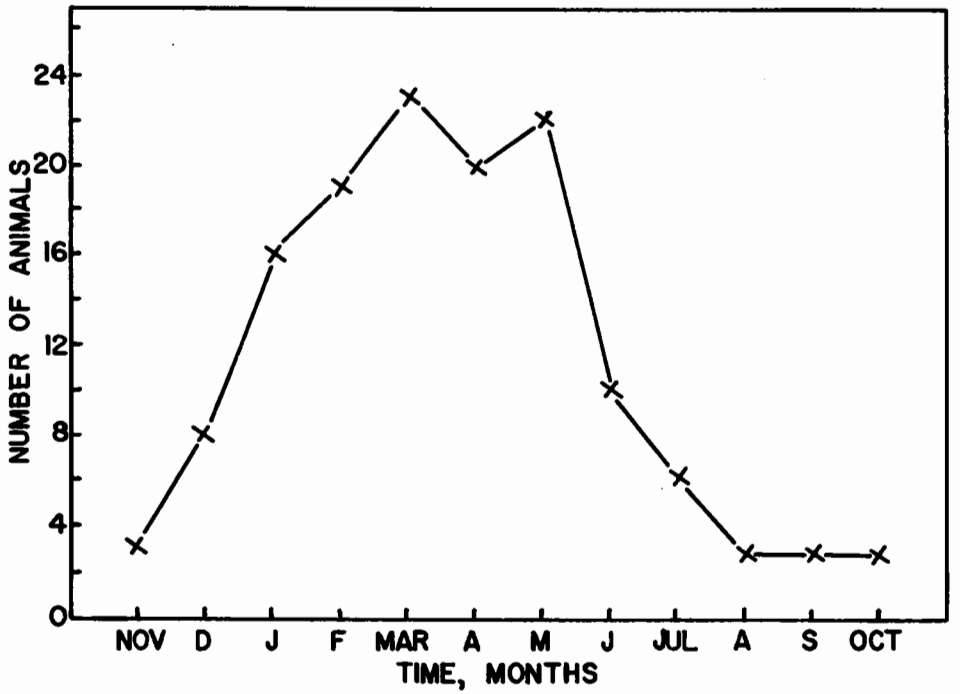


Fig. 4. Monthly variations in the incidence of C. bovis in a herd of 38 animals.

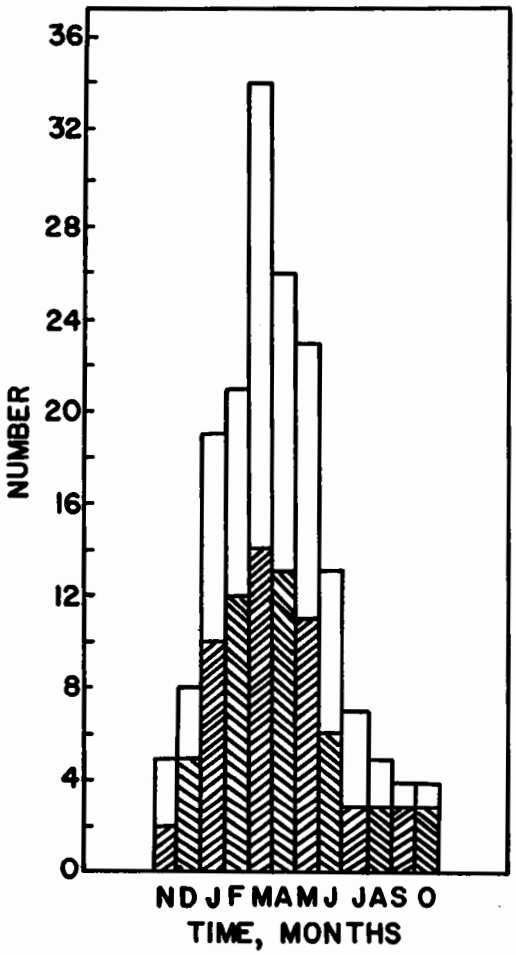


Fig. 5. Monthly incidence of pastern infestation in a herd of 38 animals.

Hatched -- Number of animals infested on one and generally both hind pasterns.
Hatched + Unhatched -- Total number of infested pasterns in the herd.

TABLE I

SEASONAL VARIATIONS IN THE INCIDENCE OF INFESTED SITES
EXCLUSIVE OF THE PASTERNS

SITE	PEAK MONTH	NUMBER POSITIVE AT PEAK MONTH	MONTHLY AVERAGE JANUARY TO MAY INCLUSIVE	MONTHLY AVERAGE OTHER MONTHS	TOTAL EXAMINATIONS
Below Hock	April	6	3	2	364
Hock	March	7	6	2	352
Crotch	March	12	9	3	426
Escutcheon	March	13	10	3	396
Mid-Post. Thigh	April	4	3	-	390
Base of Tail	April	5	2	-	368
Lateral Regions					
1) Posterior	February	4	2	-	292
2) Middle	March	2	1	-	246
3) Anterior	March	1	-	-	241
Udder	January	9	5	2	316
Abdomen	April	3	2	-	250
Below Carpal	March	3	1	-	243
Above Carpal	December	2	-	-	241
Elbow	January	2	-	-	130

Two of the three infested animals observed on pasture in late summer had infested feet, and some mites also occurred at their hocks, escutcheons, crotches, and bases of the tails. One of these cows had a moderate number of mites at the base of the tail in August, but they had disappeared in September. The above observations showed that the pasterns were important reservoirs of C. bovis, with other infested sites occurring most frequently during winter concomitant with the stanchioning of the herd. This was followed in summer by a decline in the number of mites as well as a decrease in the incidence and sites of infestation.

The susceptibility of calves may differ from that of adults. To determine this, 739 examinations were made on 16 Holstein calves from dams of the above herd together with seven Ayrshire calves housed in the same open pens as those of the other breed. Calves received no grooming during the period of study, and were maintained in a different wing of the barn, and hence partially isolated from other members of the herd except for a 24 hour period immediately following birth when they remained with their dams.

Calves were found infested initially only after they reached an age of two to five months, when 15 of the 23 animals were positive. Seven were from dams that were positive at parturition, but the source of the calves' infestations is unknown. In all cases, mites were first

observed on one or more pasterns, occasionally (four times) with other infested areas on the hind legs as high as the escutcheon. Mites displayed a marked numerical increment on the pasterns of five calves between one and four months following the initial findings, but in no case were mites located on the torso. These results indicate that calves are highly susceptible to C. bovis, and that the important sites of infestation are the same as for adult animals.

Results indicated no differences in susceptibility or sites of infestation referable to the sex of the host. Two of the above calves were males (uncastrated), but observations were similar to those of the female calves and hence the results are grouped together above. The three-year-old herd sire was found infested consistently on the four heels, and mites were observed occasionally on the abdomen and on the hind legs as high as the mid-perineal region.

Effect of Pasture Conditions

It was established previously that the number of mites on cattle becomes markedly reduced in summer. This could result from the pasturing of cattle, or be simply coincident with it when the real cause is some intrinsic factor, such as an immune reaction. To determine this, two of four heavily infested Holstein heifers were pastured by themselves. As controls, the two other heifers remained

stanchioned indoors. Large numbers of mites persisted and possibly increased numerically over the entire bodies of the controls. Contrariwise, examinations on alternate days on the pastured animals indicated a rapid reduction in the mite population. During the third week, no mites were observed on the backs and sides of these heifers, and by the sixth week mites had virtually disappeared from all sites except the pasterns. Pasture conditions were necessary, therefore, for the decrease in numbers of mites on these animals.

Spread of Mites on Ungroomed Hosts

The two heifers, now only lightly infested, were re-stanchioned in September in isolated, unheated and previously unused quarters. These animals received localized grooming only when absolutely necessary. Observations were conducted to determine whether an animal can become heavily infested for a second time, and, if so, whether the mites become detectable in a helter-skelter fashion over the surface of the host or originate from one or more reservoir sites. During the following 11 months, 598 scrapings were examined from various surface areas, using, on the lateral aspects, a five inch square grid for purposes of orientation. Fig. 6 shows that seven months (April) passed before mites were located on the animals at sites other than the lower legs. Four additional months

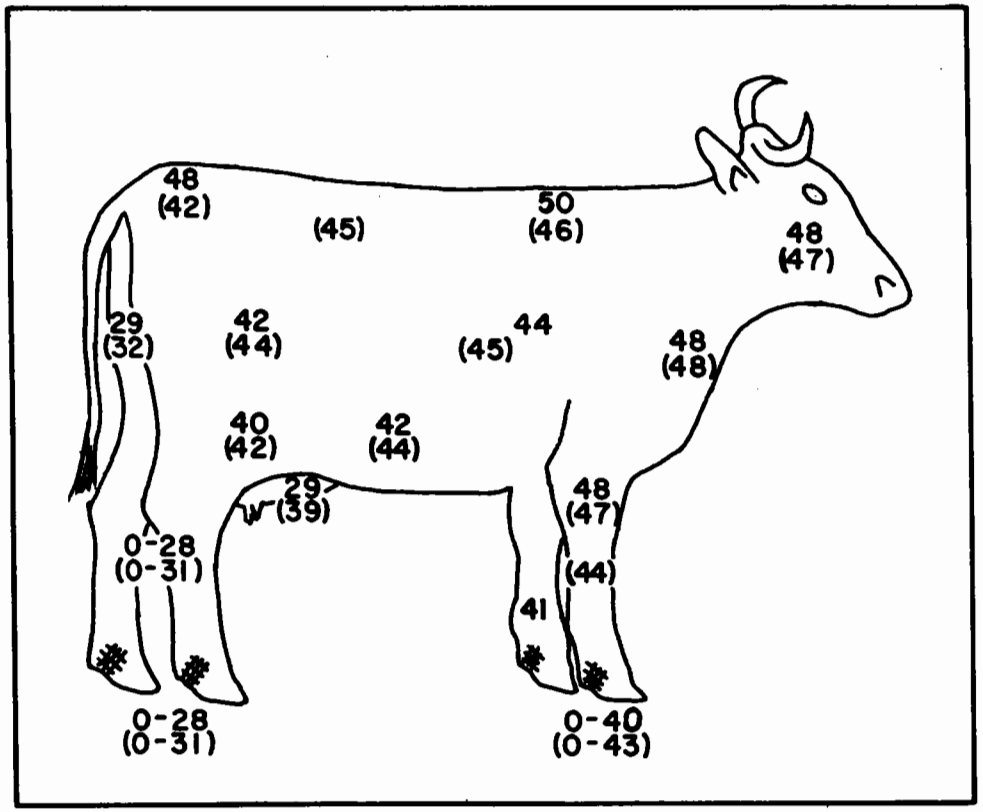


Fig. 6. Locations of C. bovis.

Arabic Figures -- number of weeks after stanchioning that mites were located at various sites. Unbracketed -- results on one heifer. Bracketed -- results on another heifer.

were necessary before mites were located on their cheeks. It is likely that mites spread by direct bodily contact from the feet and lower legs to areas like the udder, abdomen and shoulders, and that they became detected eventually. Since the animals were in stanchions, those mites about the base of the tail, along the back and on the cheeks must have emigrated from other infested areas. There was no apparent residual immunity from the previous heavy infestations, and the pasterns of both hind and forelegs, but particularly the former, served as important reservoirs of infestation for other regions.

Noxography

It is stated generally that C. bovis causes a benign acariasis. A lesion attributed to the mites is manifested in a localized area by increased amounts of scurf followed by a small irregularly outlined patch of coalesced papuliferous nodules with exuding serum. These patches frequently occur rather suddenly. There is subsequent scab formation like that shown in Fig. 7. Table II shows that most lesions in the herd under study occurred in the regions of the escutcheon and mid-posterior thighs with an occasional lesion in other areas on the hind quarters and elsewhere. Most were unimportant clinically being only mildly pruriginous and occasionally depilatory, but a single advanced lesion with confluent serous exudations extended from the pasterns

to the base of the tail of an animal and remained unabated from February to April even though the cow received treatments that removed the mites.

Mites frequently lived in large numbers without producing lesions. Animals with lesions at one or more localized sites were generally infested with C. bovis at other locations and occasionally over the whole body. Frequently, areas with lesions harboured no more mites than contiguous areas without lesions.

Calves and the herd sire displayed no lesions. Table III shows that most lesions on 21 of the 38 Holstein cows persisted for no longer than a month or two, but many symptomatic animals had recurrences. Lesions were observed throughout the year, with most occurring in winter. Some lesions in Table III contained numerous mites, others contained few mites, while no mites were observed in other lesions. Three animals (Table III: no. 19-21) with sporadic lesions were never found infested with mites. Mites in small numbers may have been overlooked, but the above findings suggest no direct relationship between the lesions and C. bovis.

Additional data on lesions were obtained from two heifers that were maintained continuously indoors for two years beginning in January, 1954. Mites occurred over their entire bodies by the following May. Lesions, extending from the hocks to the feet, first appeared rather suddenly on

Fig. 7. Nodular scab associated with C. bovis at a cow's hock.

TABLE II

INCIDENCE OF SITES WITH TOPICAL PUSTULOUS SKIN ERUPTIONS

SITE	NUMBER
Pastern	2
Below hock	5
Hock	4
Escutcheon	21
Crotch(es)	4
Mid-posterior thigh(s)	11
Base of tail	3
Udder	2
Shoulder	1

TABLE III

RELATION BETWEEN LESIONS AND THE PRESENCE OF MITES

NUMBER	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
	1[a] 2[b] 3[c]	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3
1	+	+	+	+	+	+	+	+	+	L - +	+	+
2	-	-	+	+	+	+	+	+	+	+	L + +	+
3	-	-	L + +	L + +	L + +	L + +	-	-	-	-	-	-
4	-	-	L + +	-	-	-	-	-	-	-	-	-
5	-	+	+	L + +	+	+	-	-	-	-	-	-
6	+	+	+	L + +	+	+	+	+	+	-	-	-
7	-	L + +	L + +	L[d]								
8	-	-	-	+	+	-	L + -	-	-	-	-	-
9	-	L - -	-	L + +	L + +	-	L - +	L - -	-	-	-	-
10	-	-	+	L - +	+	L + +	L - +	+	-	-	-	L - -
11	-	-	-	L - +	-	L + +	-	-	-	-	-	-
12	-	-	-	L - -	-	L - -	L - +	-	-	-	-	-
13	-	-	-	- -	+	L - +	-	-	-	L - -	-	-
14	-	L + +	-	L - -	-	-	-	-	-	-	-	-
15	-	-	-	L - -	+	-	L - -	-	-	-	-	-
16	-	-	+	L - -	-	-	-	-	-	-	-	-
17	-	-	-	L - -	-	-	+	-	-	L - -	L - -	-
18	-	-	-	-	-	L + -	L + -	L - -	-	L - -	-	-
19	-	L - -	L - -	-	-	L - -	L - -	-	-	-	L - -	L - -
20	L - -	-	-	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	L - -	-	-	-	-	-	-

[a] Column 1 - lesion present (L) or absent.

[b] Column 2 - lesion positive (+) or negative (-) for C. bovis.

[c] Column 3 - mites present (+) or absent (-) elsewhere on animal, but not associated with lesions.

[d] Received treatments.

Fig. 8. Lesions on the upper hind legs and sides of a heifer.

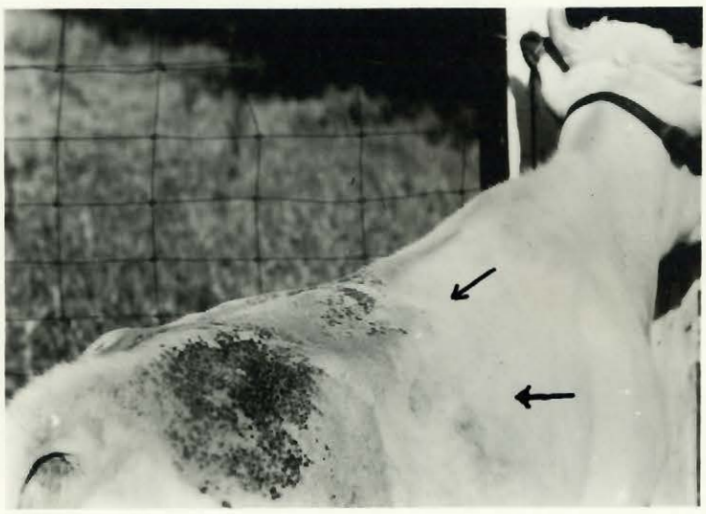


Fig. 9. Scabs on the posterior dorsal region of a heifer. Arrows indicate former extension of lesions.

both animals in July, and within two weeks had extended to the escutcheons and posterior thighs. Marked scabbing occurred subsequently, as shown in Fig. 8. This condition persisted, and additional lesions appeared on the sides (Fig. 8) and backs of these animals by September, becoming gradually more extensive up to December as indicated by arrows in Fig. 9. Large numbers of C. bovis were associated with these advanced cases. Within two to three months, the mite population became considerably reduced although some still occurred associated with the scabs that continued without abeyance. By May of the second year, however, one animal had lost its scabs on the dorsal and lateral aspects even though some mites were still present. Lesions on the other animal regressed more slowly; some dorsal patches still persisting at the end of the second year as shown in Fig. 9.

Two other heifers were maintained under similar conditions except that they were on pasture during the first summer. These animals developed lesions initially on the lower hind legs in December of the second year. This was 15 months after they had been placed indoors, and three months after mites had migrated over their entire bodies. Mange at various sites on the hind quarters of the above animals only occurred subsequently to an intensive and general mite infestation. Since lesions of clinical significance occur only rarely on cattle maintained seasonally

on pasture, it seemed likely from the above results that continuous stanchioning. favoured the formation of extensive lesions in the same way as it had facilitated an increase in the number of mites present.

DISCUSSION

Observations demonstrated that the pasterns, particularly those of the hind feet, were important sites of infestation. Other sites over the surface of the body were sometimes infested, but these appeared to be of less significance in the maintenance of the parasite. From the time of Gerlach in 1857, writers have emphasized the base of the tail as the significant site of infestation in cattle even though the lower leg regions were the accepted sites of chorioptic mites on horses, sheep and goats. Cows in the present experimental herd had mites at the base of the tail far less frequently than on the feet, and on fewer occasions than other sites including the escutcheon, udder and hocks. Goodwin and Schwardt (1952) and Pullin (1956) indicated that the escutcheon was an important site of infestation, but did not state whether they examined other sites. Some observers, like Johne in 1877, referred to infested feet, but these are frequently emphasized as unusual situations. In 1941, for example, Derivaux made special note of an infestation on the lower legs of a bull. It was a lesion that brought this site to his attention. Indeed, areas without lesions generally have received little

or no attention. The rarity of mange on the lower legs of cattle that are pastured seasonally, as shown in the present report, may be of general occurrence, and could explain infrequent examination of the feet and environs for C. bovis. Some bulls are seldom on pasture, and that of Derivaux may have been kept continuously indoors. If so, the occurrence of lesions on this animal would then be comparable to those on the hind legs of the heifers reported herein that were stanchioned in summer as well as in winter.

Lesions occurred mainly in winter, and only at some sites infested with mites. Nearly all lesions were on the hind quarters of cows in the experimental herd, with many skin eruptions at the escutcheon and mid-posterior thighs. (Use of the word escutcheon by Pullin (1956) included both of these sites). Localized lesions frequently occurred with only small numbers of mites, and mites were often unobserved at the time of examination. If, as Mégnin (1872a, 1872b, 1874, 1880) and others have assumed, rasping of the skin by the chewing chelicerae of the acarine produced the lesions, then one would expect to have observed many more mites in them than was the case. In fact it seems unlikely that C. bovis must damage the skin in order to live. Evidence for this is the in vitro technique of the current study in which mites were maintained on epidermic debris and hair from cattle under satisfactory physical conditions for as long as eight months. Mites completed sequentially a number of life cycles during this period. Pulverized

scab in addition to the above substrate proved equally satisfactory. These data indicate that some explanation other than direct mechanical injury must be advanced as the cause of lesions.

Two heifers in the present study manifested widespread lesions only after seven to nine months of continuous stanchioning indoors; a longer period than that usually spent by animals in barns in winter. The lesions began on the lower legs and eventually extended the length of the hind legs and over the dorsal and lateral posterior regions. This differs from the statements of Neumann (1906) and some later observers who indicated that lesions began at the base of the tail and extended forwards and downwards from that site. Scabs on the backs and sides of the present heifers were preceded by a general mite infestation. A subsequent reduction occurred in the number of mites, followed by a regression of the amount of scab. This logical sequence made it difficult to suggest that something other than C. bovis was responsible for these lesions, even though the mechanism remained unknown.

As McEnerney (1953) pointed out, proponents of an allergic reaction suggest the significance of (a) lesions with only a few mites, and (b) their sudden appearance, sometimes spreading over a wide area. Here, consideration of the possible effect of acarine excretions or of tarsal

claws and caruncles on the skin is necessary. This suggestion, however, is inadequate also. Some cows in this study manifested more extensive lesions on the hind legs during non-lactation. Lesions on one cow persisted after the mites were killed, and McEnerney (1953) reported the opposite situation where local treatment cured the lesions while mites persisted elsewhere on the host. A practitioner indicated to the writer that he has successfully combatted chorioptic mange by transferring diseased animals from stanchions to box-stalls where the animals rubbed and licked themselves as well as one another. McEnerney (1953) also had some evidence suggesting the value of auto-grooming. This differs from psoroptic and sarcoptic mange that occur in winter on cattle on the western plains of Canada, and from ovine psoroptic mange in various other countries that persist when animals have an opportunity to groom themselves. McEnerney (1953) observed also that exchange of a stanchioned animal in winter from one herd to another, even with an attempt to simulate management, was associated with a reduction in the number of C. bovis. These observations indicate the complexity of the disease mechanism, but its true nature remains unknown.

Pasture conditions are lethal to many mites, but some persist on the feet of cattle and elsewhere. Treatment of herds that experience recurrent or chronic chorioptic mange would be best instituted, therefore, in summer to effect eradication of the mites even though the lesions would be

small or non-existent at this time of year. Complacency may have to be overcome. The pasterns are important sites for purposes of diagnosis. Fore-feet are frequently more sensitive to a scalpel blade, and hence less suitable for diagnosis, than hind feet. Observations indicated that examination of other sites should supplement that of the feet when the latter are negative. Wet faeces on the feet, or excitable animals, may also interfere with an examination of the pasterns when it will be desirable to examine other sites.

The presence of mites on the feet of ungroomed calves suggests that C. bovis has a predilection for that site. The feet of two heifers, following stanchioning in autumn, also served as reservoirs from which mites spread to other regions, eventually covering their entire bodies. Ovigerous females frequently lay their eggs at the margin of culture vials, and if eggs are laid peripherally to the main population of mites on the host as well, this would contribute to the spread of C. bovis to the back and other places on the host. All surface areas may harbour C. bovis, while the feet are of particular importance in the maintenance of the parasite at all seasons.

II. MORPHOLOGY AND LIFE CYCLE

INTRODUCTION

Virtually nothing has been written on the structure of Chorioptes bovis. In 1857, Gerlach stated that C. bovis was morphologically identical (he examined only the adult stages) with C. equi from the horse, but maintained that each was host specific. C. equi has received a little more attention than C. bovis, but the only reasonably adequate description of any species in the genus is that of C. caprae from a goat made by Oudemans in 1926. In the present study, therefore, there is included a morphological description of the various stages in the life cycle of C. bovis.

The biology of any of the described mites in the genus has received even less attention than the morphology. Most writers have simply made notes on the dermatitis associated occasionally with the mite. This has been sometimes done in conjunction with the results of treatment with various drugs. Two main technical obstacles have confronted researchers. Firstly, the annual summer reduction in the number of mites that made mites essentially unavailable at that season; and secondly, the minute size of the mite compared with its host, indicating the need for a suitable technique to rear or even maintain one or few mites at a time for study. The first obstacle has been overcome by simply keeping cattle indoors in summer as well as during the previous winter. This facilitated a build up

of the mite population to phenomenal numbers, making mites available at all times. The problem of the contrasting size of the parasite and its host was conquered by designing a suitable *in vitro* technique for rearing *C. bovis*. These methods made it possible to study the biology of the organism.

A. DESCRIPTION OF STAGES

Chorioptes bovis is an obligatory, non-burrowing mite that passes all stages on the host. In a single cycle, the mite passes through five stages -- the egg, larva, protonymph, deutonymph and adult (Fig. 10). These terms will be used for the sequential development of the male, but in keeping with previous authors the female deutonymph and adult female will be called the pubescent female and ovigerous female respectively.

Larva

Figs. 12-22, 24-25, 27, 31-33.

(Measurements in microns with the mean in the first bracket and the standard deviation of individuals (measured 15) in the second bracket. The parts referred to in the text are labelled in Fig. 11).

An elongate oval mite with distinct shoulders and rather short legs. It is soft-bodied. No sexual dimorphism was noted. Translucent white immediately after hatching, but soon becomes a brownish-grey colour.

Dorsum. Length 131-236 (191) (24) and width 82-175 (146) (21). Sclerotized propodosomal plate in the general shape of an isosceles triangle, but variable in detail (Figs. 13 to 20), with a pair of setae near, or sometimes attached to the posterior corners. Plate elevated medially (Fig. 14). Remainder of integument finely striated.

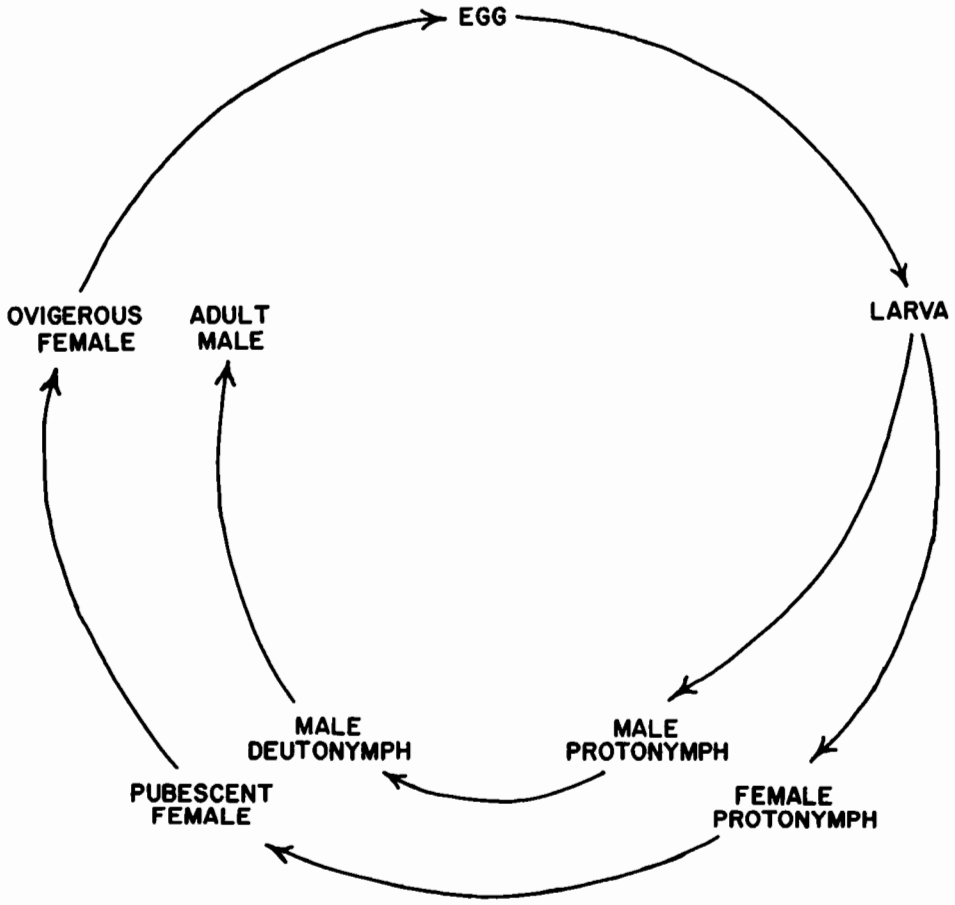


Fig. 10. Life cycle of C. bovis.

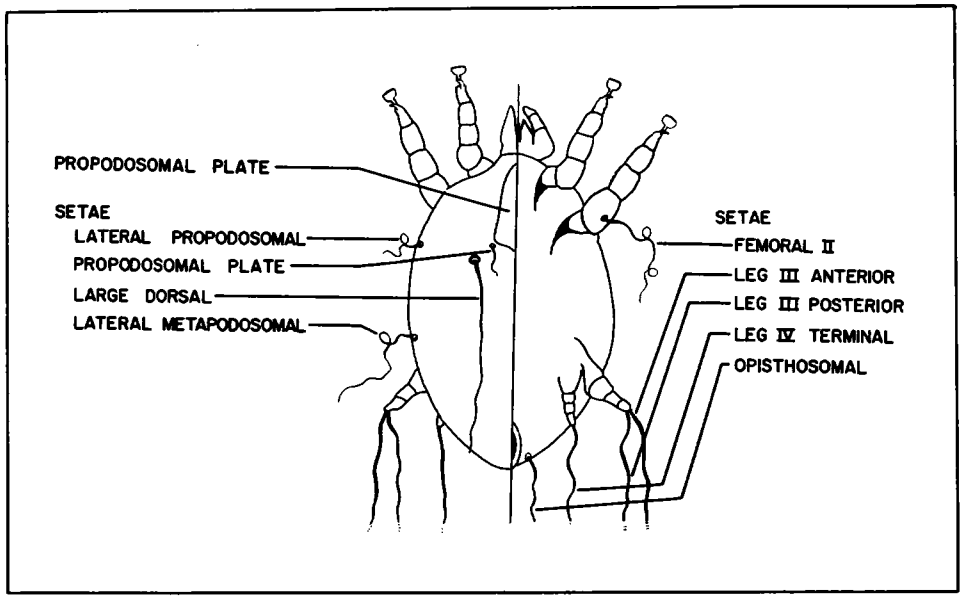


Fig. 11. Important structures on mites referred to in text.

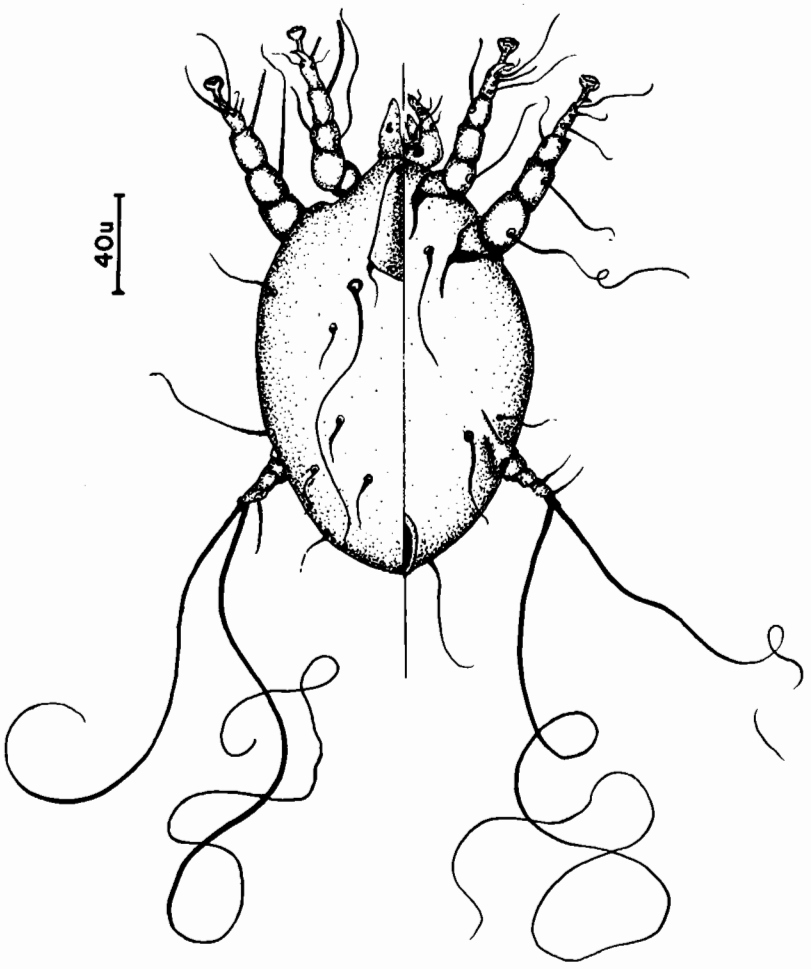


Fig. 12. Dorso-ventral view of larva.

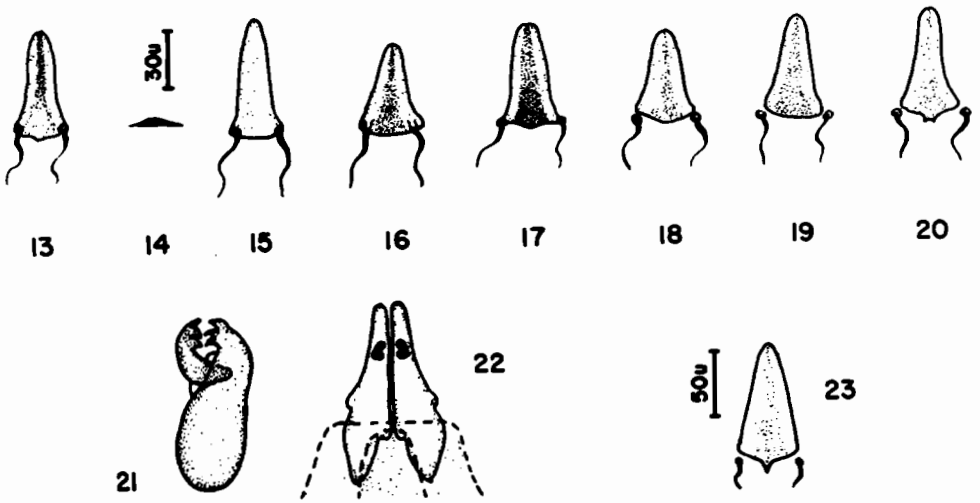


Fig. 13, 15-20. Variations in shape of the propodosomal plate and positions of the propodosomal plate setae.

Fig. 14. Cross-section of a propodosomal plate.

Fig. 21. Lateral view of chelicera.

Fig. 22. Dorsal view of chelicerae.

Fig. 23. Propodosomal plate of adult male or ovigerous female.

One pair of quite long dorsal setae arise postero-laterally to the plate and measure 87-112 (105) (7). Two pairs of dorso-lateral setae occur, the propodosomal being 20-38 (34) (3) and the metapodosomal 58-81 (71) (9). Also, five other pairs of short idiosomal setae are present. These infrequently vary in relative position as in Figs. 31 to 33. The pair that is marginal, however, is invariably more terminal than the corresponding pair on subsequent stages.

Venter. Integument finely striated except for a clear, non-sclerotized area around the posterior anus. Only four pairs of setae present -- one pair of propodosomal 34-60 (42) (8), two pairs of metapodosomal and one long pair, 71-118 (101) (13), arising terminally from the opisthosoma.

Legs. Leg I and II with six articles each, ambulatory, and approximately the same length, being 74-101 (88) (10) and 77-101 (87) (10) respectively*. Leg III with only four, small, weak articles, mainly tactile and measuring 37-54 (45) (4)**. Coxae of all legs specialized as apodemata. Setae of legs I and II both long and moderately short, and increase numerically on distal articles -- absent on trochanters; femurs I and II each with a single seta; genu with two setae each; tibia I and II with one seta and one fairly stiff rod (no setal base) each, the latter situated antero-dorsally. Tarsus I (Figs. 24 and 25) with a special

* Measured from the coxa along the antero-dorsal border. Does not include caruncle.

** Measurement of only the articulating part of the leg along the outer surface.

pit, possibly a sensory structure, in the proximal dorsal position; seven setae, two of which occur anteriorly and are short and inconspicuous; one moderately long rod in the distal dorsal position. This pattern persists through the male and female protonymphs. Tarsus II (Fig. 27) with five long and one short setae, the latter occurring just anterior to a moderately short rod in the proximal dorsal position. This pattern persists through all female, but none of the male stages. Tarsi I and II with a single claw and an unjointed pedunculated caruncle. Pretarsi I and II arise as an anterior "thumb" from the tarsi (Figs. 24 and 27).

Leg III, the last article of which has three short setae and also two extremely long whiplike setae situated distally. Of the two, the posterior is longer, 462-654 (558) (64), than the anterior, 200-312 (261) (38).

Gnathosoma. Chelicerae dorsal (Fig. 22) measuring 32-40 (36) long; wide, tapering apically; chelate, powerful chewing apparatus (Fig. 21); movable digit articulates by its posterior extremity in a cleft of the fixed digit; each possesses three hooked teeth on different planes. Pedipalpi located at the latero-ventral surface of gnathosoma. Possess three strong articles which gradually shorten and taper distally. Pedipalpi curve medially giving the gnathosoma a blunt appearance. They reach to the distal margin of the genu of leg I. Palpal base without setae. First palpal article with a single seta while the middle and terminal articles have two setae each. One of these, on the anterior

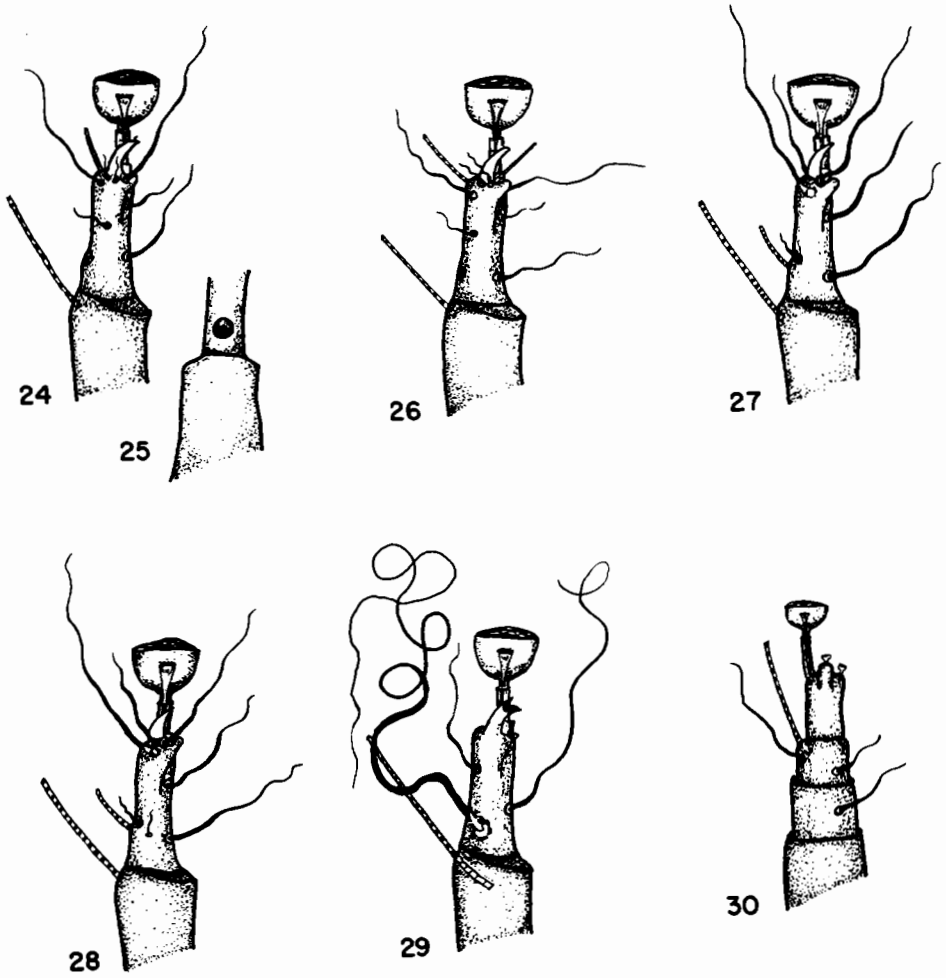
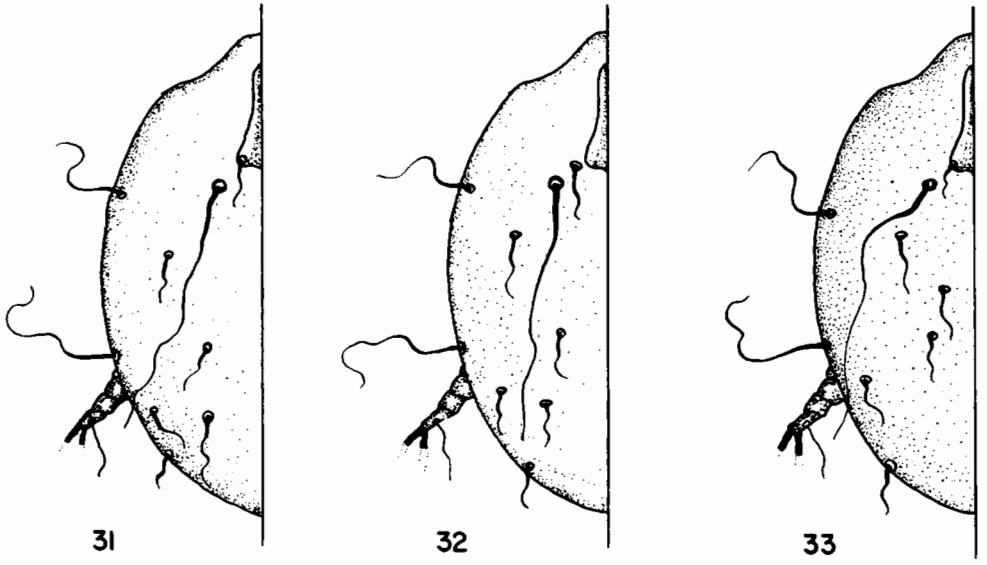


Fig. 24. Lateral view of tarsus I and pretarsus I of larva, male protonymph, and female protonymph.
Fig. 25. Dorsal view of proximal part of tarsus I.
Fig. 26. Lateral view of tarsus I and pretarsus I of male deutonymph, pubescent female, and adult male.
Fig. 27. Lateral view of tarsus II and pretarsus II of larva, female protonymph, pubescent female, and ovigerous female.
Fig. 28. Lateral view of tarsus II and pretarsus II of male protonymph, male deutonymph, and adult male.
Fig. 29. Lateral view of tibia III, tarsus III, and pretarsus III of adult male.
Fig. 30. Terminal end of leg IV of acult male.



Figs. 31-33. Irregular positions of idiosomal setae on larvae.

article, is located terminally and is short and inconspicuous. The hypostome, which forms the ventro-medial wall of the gnathosoma, has one pair of moderately long, centrally located setae. The gnathosoma is essentially the same in all stages, except for an increase in relative size.

Male Protonymph

Figs. 38, 21-22, 24-25, 28, 34.

(Measurements presented as for larva.)

Idiosoma and gnathosoma essentially the same as in larva, except that the protonymph is larger and possesses the fourth pair of legs. The mite is soft-bodied, and the colour persists as brownish-grey.

Dorsum. Length 188-280 (240) (29) and width 140-209 (178) (23). Additional sclerotization occurs as a platelet over trochanter I. Length of propodosomal plate 55-71 (64) (5) and the accompanying setae 24-40 (33) (5). The long dorsal setae measure 110-171 (146) (17), while the lateral propodosomal measure 36-56 (42) (6) and the lateral metapodosomal 79-132 (106) (18). Six pairs of other idiosomal setae, the additional pair beyond the five pairs on the larva being in the medio-terminal position.

Venter. The four pairs of setae in the larva occur in this stage, together with an additional five pairs of short setae in the hysterosomal region. The ventral propodosomal measure 37-61 (50) (10). One of the additional pairs of setae occurs near coxa IV, one pair is anal, another

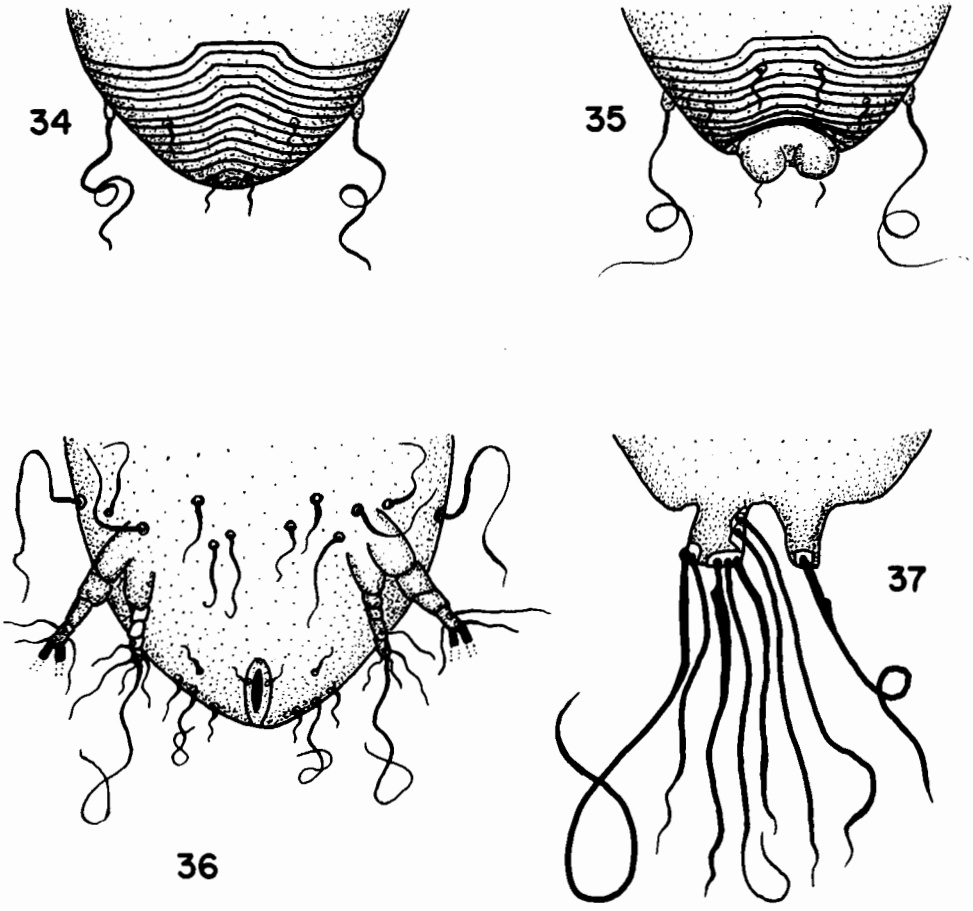


Fig. 34. Striated opisthosomal region of dorsum of male protonymph.

Fig. 35. Unstriated opisthosomal region of dorsum of female protonymph with pair of posterior suckers.

Fig. 36. Ventral hysterosomal asymmetry on a male deutonymph.

Fig. 37. Malformation of opisthosomal lobes of an adult male.

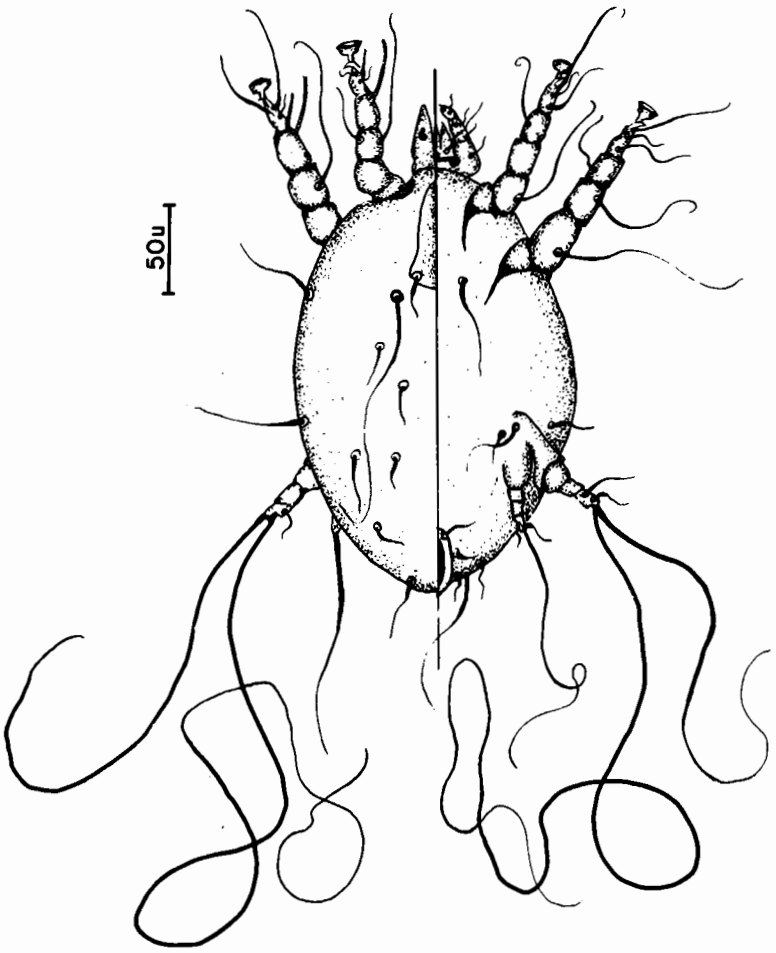


Fig. 38. Dorso-ventral view of male protonymph.

adanal, and two pairs flank the terminal opisthosomal setae. This last pair measures 82-150 (119) (26).

Legs. Leg I 90-126 (107) (12) long; leg II 95-128 (110) (12) long; and leg III 44-61 (52) (5) long. Terminal setae on leg III measure 258-341 (307) (26) and 575-678 (637) (41) for the anterior and posterior respectively. These legs are structurally identical with the larval legs, with the exception of tarsus II which has an additional inconspicuous seta located proximally in the latero-dorsal position (Fig. 28). This new tarsal pattern persists through all male stages. Leg IV measures 21-31 (25) (3)***. Composed of four articles that decrease in size apically. The final article has two short setae and one long terminal seta that measures 180-246 (212) (25).

Gnathosoma. Essentially as in the larva, except for increase in size. Chelicerae 47-52 (50).

Female Protonymph

Figs. 39, 35, 21-22, 24-25, 27.

(Measurements presented as for larva.)

This stage is much the same morphologically as the male protonymph, with the additional feature of a pair of posterior dorsal suckers. Tarsus II, however, unlike that of the male protonymph, remains identical with tarsus II of the larva.

*** Measurement of the articulating leg along the inner surface.

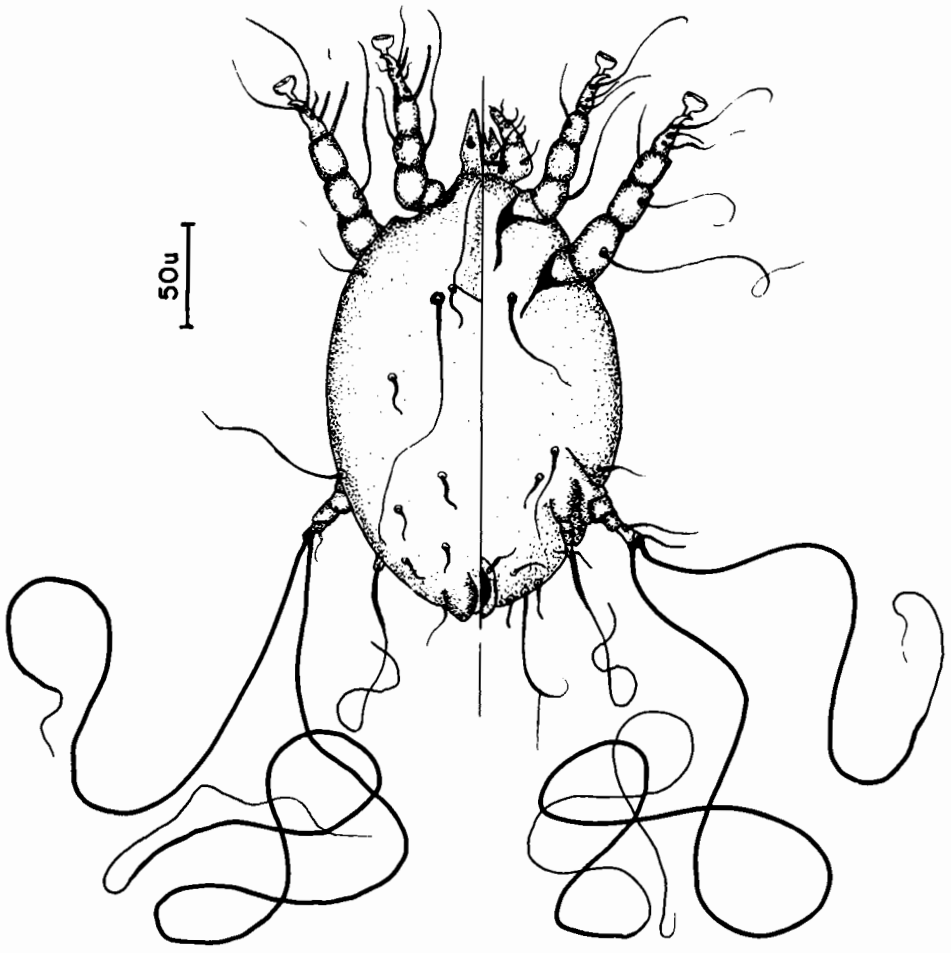


Fig. 39. Dorso-ventral view of female protonymph.

Dorsum. Length 176-285 (214) (30) and width 145-238 (184) (28). Length of propodosomal plate 57-76 (63) (5) and the accompanying setae 24-35 (30) (4). The large propodosomal setae measure 103-142 (125) (13) while the lateral propodosomal measure 36-49 (42) (4), and the lateral metapodosomal 72-97 (81) (8). The remaining idiosomal setae are identical with those on the male protonymph. A pair of suckers occurs at the tip of the opisthosoma surrounded by a clear unstriated area (Fig. 35) that may be compared with the striated area in the same region of the male protonymph (Fig. 34).

Venter. Identical with that of the male protonymph. The ventral propodosomal setae measure 34-67 (50) (10), and the long opisthosomal setae measure 74-109 (94) (11).

Legs. Leg I 94-111 (104) (5) long; leg II 95-116 (104) (7) long; and leg III 37-55 (48) (6) long. Terminal setae on leg III measure 253-325 (285) (28) and 501-683 (611) (60) for the anterior and posterior respectively. These legs are otherwise identical with the larval legs. Leg IV measures 19-34 (25) (4) long. It is identical with leg IV of the male protonymph. The terminal setae measure 140-240 (198) (35).

Gnathosoma. As for preceding stages. Chelicerae 47-53 (49).

Male Deutonymph

Figs. 40, 21-22, 26, 28, 36.

(Measurements presented as for larva.)

This stage still displays immature characters, adding only the occasional seta and an additional article to leg IV.

Dorsum. Except for size differences and the occurrence of a second sclerotized platelet over trochanter II, the dorsum is identical with that of the male protonymph. Length 230-336 (275) (28) and width 165-250 (203) (28). Length of propodosomal plate 58-80 (74) (7) and the accompanying setae 35-48 (40) (4). These setae in this stage, the pubescent female and both adults are never attached directly to the propodosomal plate, as is sometimes true in more immature stages. The dorsal propodosomal setae measure 153-192 (166) (12) while the lateral propodosomal measure 50-68 (57) (5) and the lateral metapodosomal 104-157 (122) (14).

Venter. Five metapodosomal setae on this mite compared with three on the protonymph readily distinguish the two stages. Other setae identical for both stages except in size. The ventral propodosomal setae measure 48-72 (62) (8), and the long opisthosomal setae measure 138-198 (164) (18).

Asymmetry is a not uncommon abnormality among invertebrates. Fig. 36 shows an example of a male deutonymph where the ventral metapodosomal setae varied in relative position on the two sides of the animal.

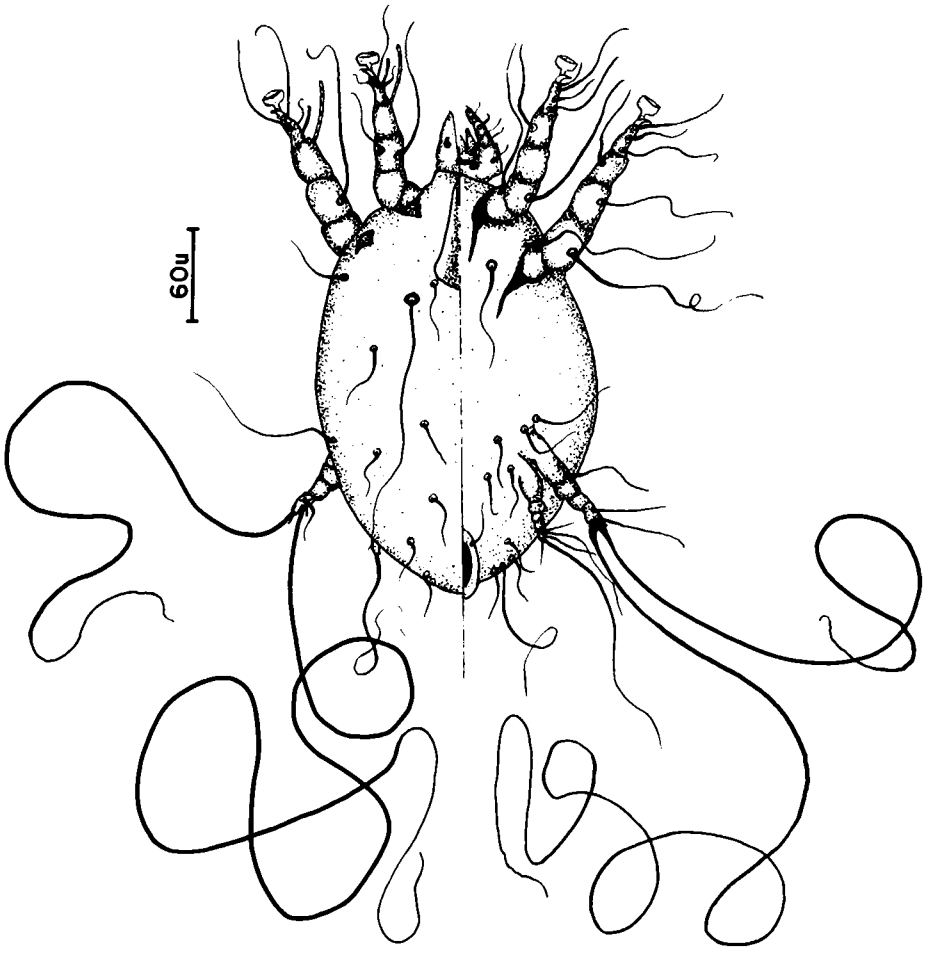


Fig. 40. Dorso-ventral view of male deutonymph.

Legs. Leg I and II 101-134 (122) (10) and 100-136 (124) (10) long respectively. Trochanter I and II have developed one long seta each. Femur, genu and tibia identical with preceding stages. Tarsus I has an anterior rod (Fig. 26) in addition to the structures on the protonymph. Tarsus II, however, remains unchanged. Leg III 58-77 (67) (6) long. The proximal article has acquired a seta, but the terminal article setae remain unchanged. The long terminal setae measure 304-420 (351) (36) and 690-865 (786) (57) for the anterior and posterior respectively. Leg IV measures 30-40 (36) (3). Now composed of five articles that decrease in size apically. The fourth article has one seta, and the apical article four setae, of which the terminal measures 293-364 (331) (23).

Gnathosoma. As for preceding stages. Chelicerae 52-58 (55).

Pubescent Female

Figs. 41, 21-22, 26-27, 47.

(Measurements presented as for larva.)

General appearance of the female protonymph dorsally and the male deutonymph ventrally.

Dorsum. Identical with that of the female protonymph. Like this, but unlike the male deutonymph, there is no platelet over trochanter II. Length dorsum 258-361 (288) (30) and width 180-246 (222) (31). Length of propodosomal plate 61-84 (73) (7) and the accompanying setae

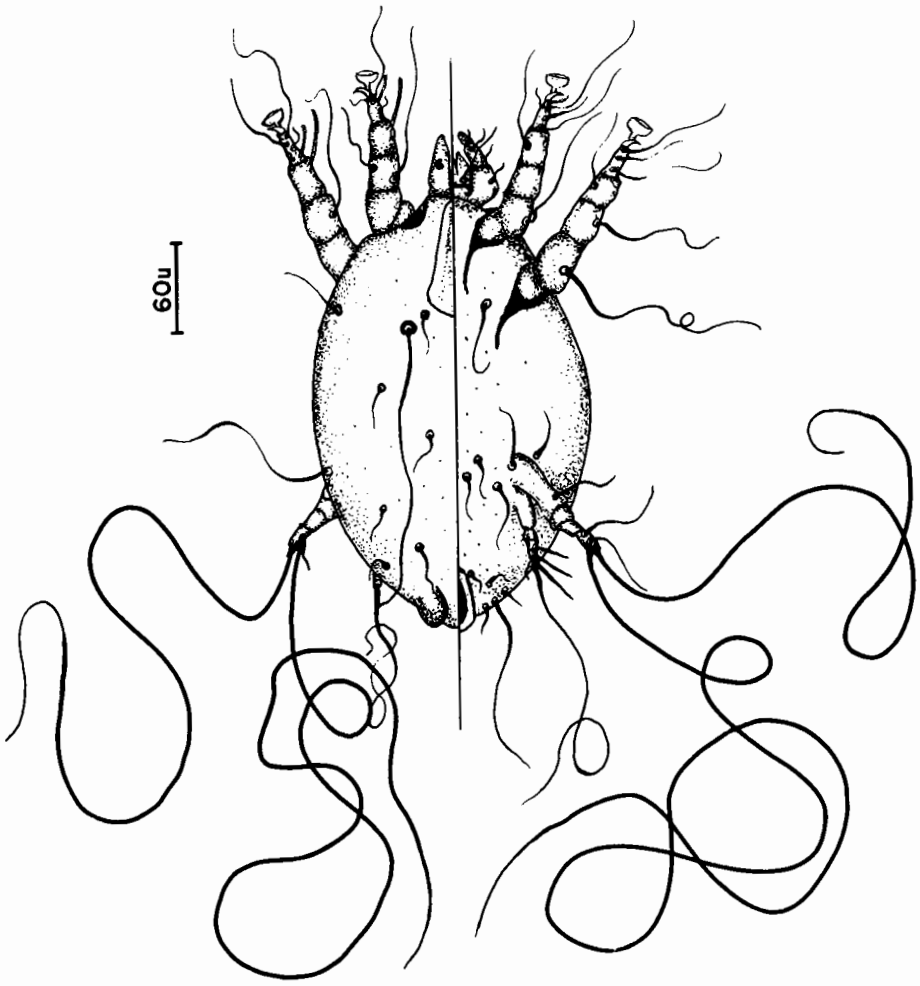


Fig. 41. Dorso-ventral view of pubescent female.

27-34 (31) (3). The dorsal propodosomal setae measure 130-314 (220) (45) while the lateral propodosomal measure 30-45 (38) (5) and the lateral metapodosomal 66-81 (75) (5).

Venter. Identical with that of the male deutonymph. The ventral propodosomal setae measure 32-61 (46) (10), and the long opisthosomal 106-248 (178) (43).

Legs. Four legs much like those of male deutonymph; only exception is tarsus II which is identical with that of the female protonymph. Leg I measures 97-119 (103) (10); leg II 95-115 (101) (6); leg III 36-53 (42) (5); and leg IV 27-32 (30) (2). The whiplike setae of leg III measure 233-327 (293) (27) and 534-669 (593) (53) for the anterior and posterior respectively. The terminal seta of leg IV measures 151-195 (175) (15).

Gnathosoma. As for other stages. Chelicerae 47-56 (53).

Adult Male

Figs. 42, 21-23, 26, 28-30, 37, 47.

(Measurements presented as for larva.)

Marked morphological changes exist between the male deutonymph and adult. Additional sclerotization occurs on the dorsum, venter and legs. All legs have caruncles.

Dorsum. Length 272-325 (294) (16) including opisthosomal lobes. Width 208-238 (228) (9). The propodosomal plate is often pointed posteriorly (Fig. 23)

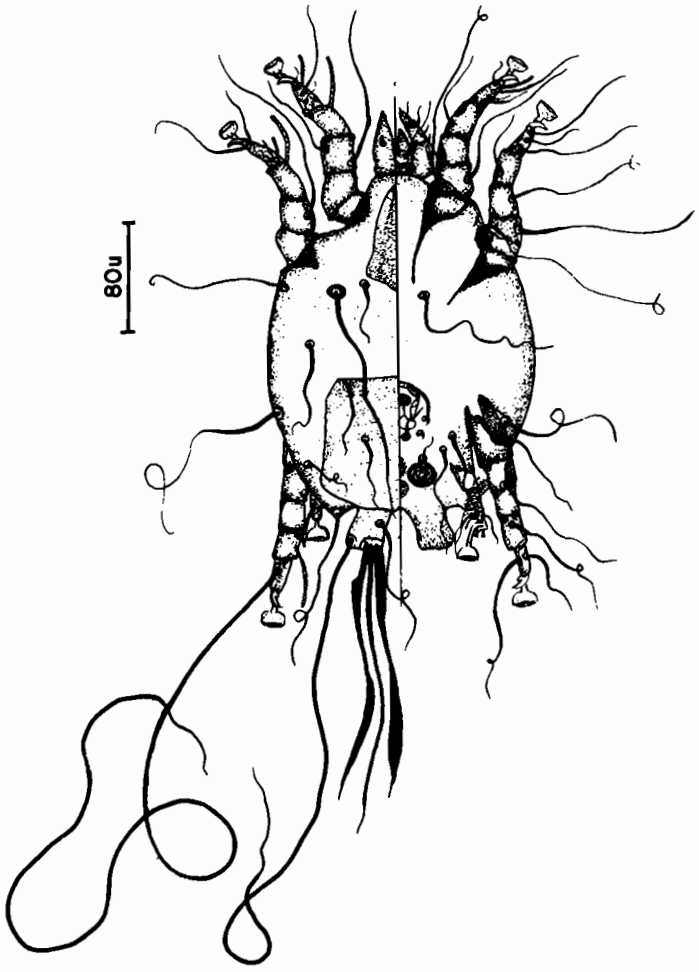


Fig. 42. Dorso-ventral view of adult male.

and measures 72-85 (79) (4). Many of the setae that occur on the immature stages are present. The two most posterior pair of setae on the deutonymph, however, are replaced in the adult by a moderately long pair of opisthosomal setae and two opisthosomal lobes which also support setae. The pair of setae near the propodosomal plate measures 43-53 (50) (3), and the dorsal pair of propodosomal measures 172-217 (194) (16). The lateral propodosomal measures 71-87 (80) (5) and the lateral metapodosomal 198-253 (229) (20). Additional sclerotization is present in the form of a large septagonal plate over much of the hysterosoma, while the platelets over trochanters I and II persist as on the deutonymph. A pair of large opisthosomal lobes occurs which support five pairs of setae. Three of these arise from the postero-medial corner of the lobe from a common setal base. The middle seta of the three is thick basally but gradually tapers distally; the other two are also thick basally, and towards the distal end, change to a membranous ensiform or lanceolate shape. The outer of the three also has a conspicuous hook towards the proximal end. Another thick seta arises from a large setal base at the outer corner of the lobe. A more typical seta also arises from an antero-medial position of the lobe.

Malformations, like the asymmetry noted previously, sometimes occur among lower animals. Fig. 37 shows an anomaly in the opisthosomal lobes of an adult male that was apparently in normal attachment with a female. The male

appeared otherwise normal. One opisthosomal lobe supports only a single seta, while the other supports the usual complement of five with the addition of two others, each of which arises from a setal base supporting a normal seta. All the setae, unlike those on normal mites, taper gradually to a point.

Venter. Like the dorsum, the hysterosomal region of normal adult males has changed markedly between the deutonymph and adult. Just anterior and lateral to the anus, a pair of adanal copulatory suckers occurs with an associated pair of short setae. In the center of the metapodosomal region the reproductive apparatus is now present together with a pair of setae and two pairs of hooks. The deutonymphal pair of anal and adanal setae, as well as one pair of metapodosomal setae, do not occur on the adult. The ventral propodosomal setae measure 81-103 (88) (7).

Legs. Apodemata heavier and more extensive than on immature stages and coxae II and III with some additional sclerotization. Legs I and II 143-162 (157) (8) and 145-177 (160) (9) long respectively. Identical with those of the deutonymph with the addition of some sclerotization on genu I and tibia I. Leg III 150-166 (160) (5) long and now has five articles. The long whiplike setae of the deutonymph do not occur, but instead there is a tarsus with three setae, a caruncle, a hook with two teeth, and a third

ventral hook in the same relative position as pretarsi I and II. The tibia supports a rod and seta (Fig. 29). Leg IV 61-74 (69) (4) long and now with five articles. The long terminal deutonymphal seta is absent, but there is now a tarsus with three small distal lobes (Fig. 30), two of which support a minute caruncle each, while the third gives rise to a larger caruncle. The latter, however, is only about half the size of those on tarsi I, II and III. The tibia supports a rod and two setae.

Gnathosoma. As for other stages. Chelicerae 40-58 (53).

Ovigerous Female

Figs. 43, 21-23, 26-27, 48.

(Measurements presented as for larva.)

Morphologically, the ovigerous female does not change so drastically from the immature stages as the adult male. The genital suckers do not occur dorsally, but the vulva is present ventrally. Leg III, unlike the adult male, retains the terminal whiplike setae that occur on immature stages.

Dorsum. Much like that of the pubescent female -- same setae, but without the posterior genital suckers. With sclerotized platelets over trochanter II and around the setal base of the dorsal pair of propodosomal setae. Dorsum 306-415 (358) (30) long and 229-287 (248) (18) wide. Length

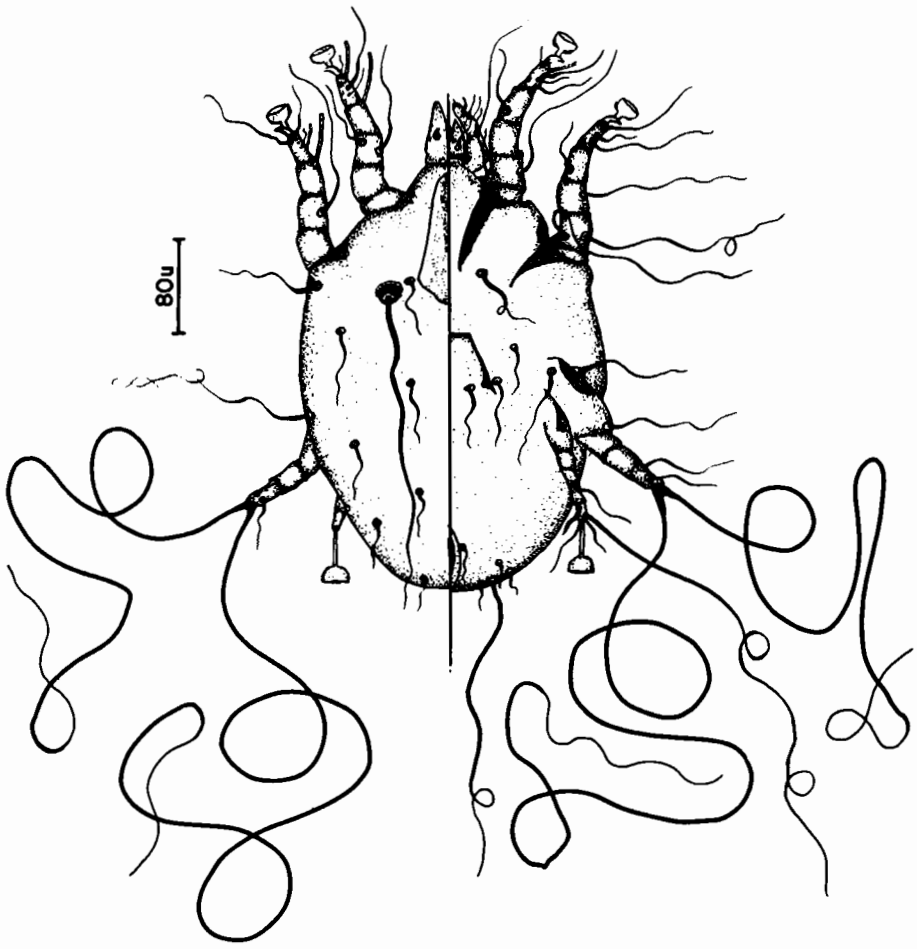


Fig. 43. Dorso-ventral view of ovigerous female.

of the propodosomal plate (many are pointed posteriorly as in adult male) 92-107 (98) (5) and the accompanying setae 37-47 (42) (3). The dorsal propodosomal setae measure 185-229 (203) (15) while the lateral propodosomal measure 43-64 (56) (6) and the lateral metapodosomal 129-158 (140) (8).

Venter. Vulva present in central podosomal region; consists of transverse and diagonally posterior slits, and hinges posteriorly. Venter with one less pair of metapodosomal setae than pubescent female. The ventral propodosomal setae measure 56-71 (65) (5), and the long opisthosomal 194-257 (223) (22).

Legs. Apodemata heavy and extensive and with some associated sclerotization on all legs. Darker colour than those of pubescent female. Leg I and II 138-164 (154) (9) and 125-167 (155) (12) long respectively. Identical with those of pubescent female. Leg III 87-106 (100) (6) long and of four articles like the pubescent female, but unlike the adult male. The whiplike setae measure 377-542 (449) (45) and 744-886 (835) (37) for the anterior and posterior respectively. Leg IV 100-129 (118) (11) long; terminal article with a caruncle and also one quite long and three moderately short setae.

Gnathosoma. As for other stages. Chelicerae 58-72 (65).

Egg

Fig. 55.

(Measurements presented as for larva.)

The eggs are elliptical and have white, shiny surfaces. Length 139-181 (164). Shell has two bosses (Fig. 55) on the same side and towards one end of the egg which, during embryonation, is the capital end of the egg.

B. LIFE CYCLE

Since chorioptic mites live on the skin, it would be desirable to learn the mode and kind of their general nutrition. Fig. 21 shows that these mites have chewing chelicerae. Material that they eat is excreted in the form of pellets, some of which accumulate about the anus. Food in the digestive tract is passed from one active stage to the next via the intermediary quiescent stage; and the new stage, when starved, will excrete pellets from the former stage. In culture, mites were maintained as successfully on epidermal debris and hair kept four months before use, and on material sterilized by heat, as on freshly obtained material. Therefore, the mites can, and on the host probably do, feed on dead tissue. Washed hair from cattle was unsuitable, whereas epidermal material and hair obtained from an Indian water buffalo, which had hair resembling wire that was presumably unpalatable, was highly satisfactory. These results showed that it was the epidermic debris, and not the hair, on which the mites fed. This verified Fürstenberg's belief of 1861 that the mites lived on sloughed epidermis; a suggestion found unacceptable in 1872 by Mégnin who was responsible for influencing some later observers.

In the life cycle, it is the larval stage that follows the egg, but it will be understood that the larva is actually formed before the egg hatches. Larva is defined

here as that period from the hatching of the egg up to its ecdysis into the protonymph. It includes, therefore, the quiescent period immediately preceding ecdysis during which internal transformation takes place from the larval state *per se* to the protonymphal state. Terms for the subsequent stages will be used for the period from one ecdysis to the next.

To observe a stage in the life cycle, eggs or quiescent mites were transferred directly from the host or from a culture vial to an unused vial. Only one or a few eggs or quiescent stages were used at a time. Epidermic debris and hair from a positive area on the hind legs of a grade Holstein-Freisian cow were then added to the vial, but only after the material had been heated to 400°F.. This killed the mites that were collected with the epidermal material. Observations were made on the biology and longevity of the stages that emerged.

The larva is an active feeding stage. If starved, it will not live more than a day. A feeding larva gradually increases in size from the time it hatches until it enters quiescence. The actual amount of increase was determined by comparing the length and width of recently hatched and unfed larvae with the same measurements for quiescent larvae. Both length and width increased by approximately a quarter (Fig. 44). Under the *in vitro* conditions of 35°C. and 80% R.H., the larva generally remained motile for 3 to 5 days, but sometimes for as long as 12 days (Table IV) after

hatching from the egg. Since the eggs took four days to incubate, this was 7 to 16 days following oviposition. The mite then enters quiescence. Some larvae lived longer than 12 days, but these failed to become quiescent and died as larvae. Healthy larvae spent 22 to 30 hours in the quiescent state. This wide variation under such constant conditions may be related to the time required by the protonymph to split the larval integument, rather than on the period required for the complete transformation process. Only the occasional quiescent mite failed to moult. The new stage is formed during quiescence when histolysis of the internal tissues occurs. The tissue within the legs is resorbed into the body of the larva, leaving the latter's legs as hollow exoskeletons. The mite, therefore, loses its motility completely. It maintains its position on the host or on the glass of the vial, however, by the suction of the caruncles and to a lesser extent by the claws on the tarsi which remain with the old exuvium. Nevertheless this attachment is not firm. Oftentimes the quiescent mite was observed on its back or in other unoriented positions, but this did not seem to interfere with the transformation process. Quiescent mites of various stages were frequently clustered together on the underside of a piece of scab or with a group of eggs or elsewhere. This suggests that some mites secure a common, and sometimes protected, location

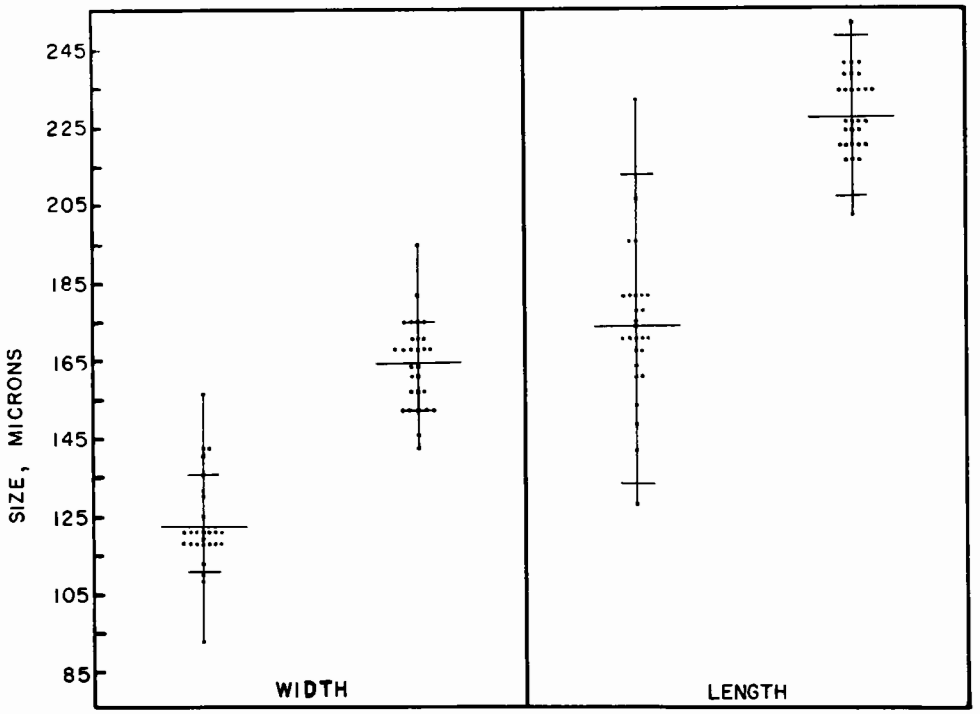


Fig. 44. Width and length of larvae at the time of hatching and at quiescence. Each point is an observation, and the vertical line marks the range. The long horizontal bar represents the mean, and the short horizontal bar represents twice the standard deviation of individuals.

TABLE IV

Longevity of Immature Stages

PERIOD (DAYS)	MOTILE PERIOD				PERIOD OF ATTACHMENT PAIR
	LARVA (NUMBER)	MALE PROTONYMPH (NUMBER)	MALE DEUTONYMPH (NUMBER)	FEMALE PROTONYMPH (NUMBER)	
2	--	--	--	--	2
3	22	19	24	14	6
4	32	21	16	11	12
5	12	8	5	2	10
6	2	3	2	1	15
7	1	1	1	--	14
8	1	--	--	--	9
9	2	1	--	--	--
10	4	--	--	--	--
11	1	--	--	--	--
12	1	--	--	--	--

TABLE V

Hatching Time of Eggs after Oviposition

TIME (HOURS)	NUMBER EGGS
72-77	6
78-83	8
84-89	10
90-95	102
96-101	46
102-107	4

just prior to the transformation period. It seems likely that at least some immotile mites on cows, particularly those without scabby lesions, must be brushed off the host during quiescence.

Immediately preceding ecdysis, it is possible to discern the protonymphal characters. Fig. 45 demonstrates this. A space is apparent between the larval integument and that of the protonymph. The protonymphal gnathosoma and pedipalpi develop immediately behind the larval gnathosoma, and like the legs, within the exoskeleton of the larval body. Legs I and II are folded posteriorly over the venter of the protonymph, while legs III and IV with their long setae project over the venter anteriorly. Moulting is a relatively simple process. The new stage ruptures the larval integument transversely across the mid-dorsal hysterosoma. This is followed by a medio-dorsal longitudinal rupture extending from the transverse slit forward to the propodosomal plate. The integument then rolls laterally in both directions along the posterior edge of the propodosomal plate. The new stage emerges by backing out of the exuvium between the slits. The complete exoskeleton with the setae and propodosomal plate is discarded. The pattern is the same for all stages, and the positions of the slits on a more advanced stage are shown in Fig. 46.

Two morphologically distinct protonymphs representing each sex (Figs. 38 and 39) emerge from the larval stage. Both are active feeding stages which

gradually increased to a maximum size and most entered quiescence after 3 to 5 days. Many protonymphs that lived longer than that period died as protonymphs, although a few did enter quiescence and did eventually moult (Table IV). The protonymphal quiescent period, like that of the larva, lasted 22 to 30 hours. The method of emergence of the male deutonymph or the pubescent female was also identical with that of the previous stage. Like both preceding stages, the male deutonymph was an active creature and generally remained motile for 3 to 5 days, then entered quiescence and moulted into the adult male in the same manner as the other stages. Upon emergence, the adult male moved rapidly through the hair and epidermic debris until it found a pubescent female with which it became immediately attached, primarily by means of its copulatory anal suckers (Fig. 47). This is the attachment pair, or what previous authors referred to as the copulation pair. Only a few adult males failed to become attached to pubescent females when the latter were available. The attachment period generally persists through both the motile and quiescent periods of the pubescent female. Table IV shows that this might be two days, but is generally at least four days and frequently 7 or 8 days. The pubescent female, therefore, generally lives twice as long as the other immature stages. During the attachment period, the male drags the female wherever it goes. It is rare for the mites

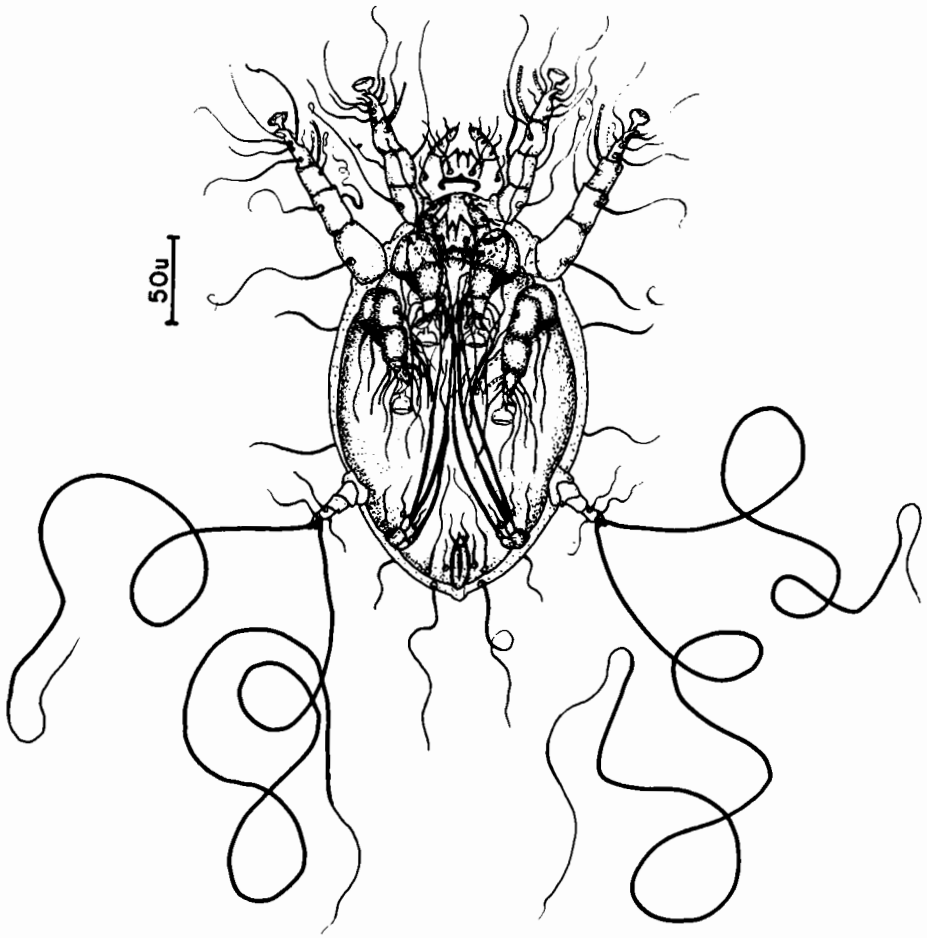


Fig. 45. Quiescent larva containing a developed male protonymph.

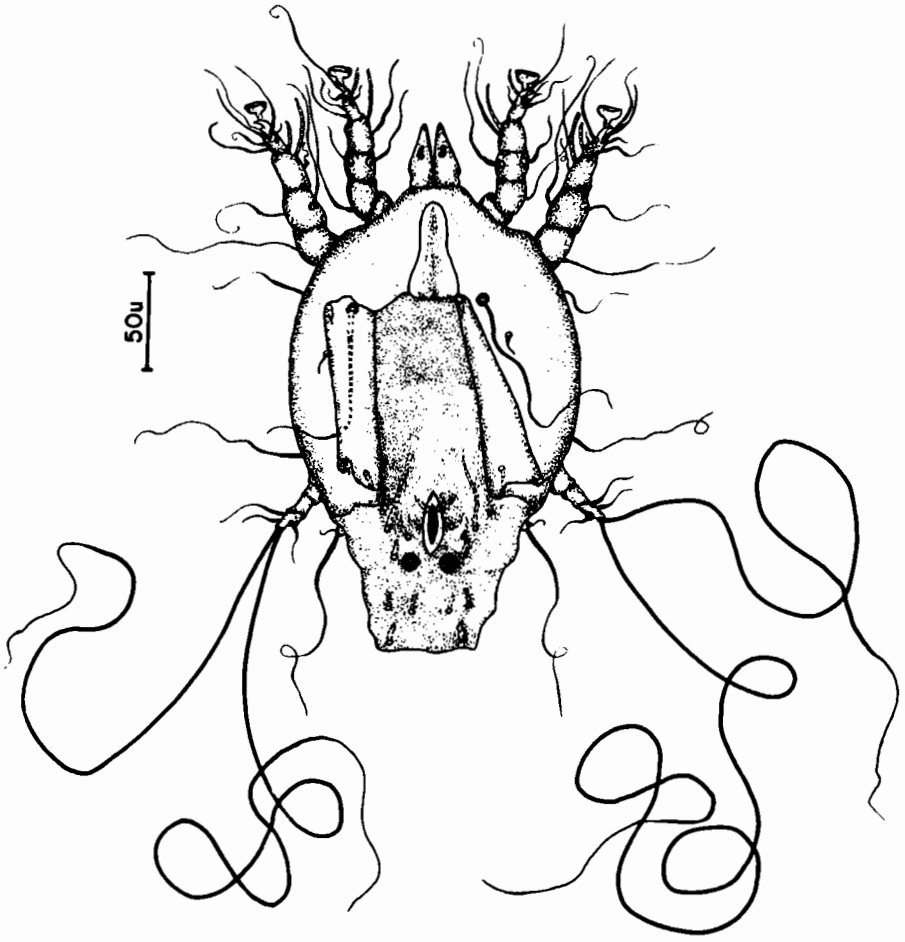


Fig. 46. Moult skin of a female protonymph.

to terminate their attachment spontaneously either permanently or temporarily. Pairs separated mechanically seldom reunited. Normal attachment is so firm that it often continues after one member of the union has died; and the male is frequently left, following the female's moult, pulling an empty exuvium. The adult male, which is blind, sometimes attaches itself to various stages including the female protonymph (which has posterior attachment suckers), the ovigerous female or even another adult male. Unattached pubescent females, either in the presence of single adult males or that were reared separately from protonymphs, never entered quiescence or made the final moult, but persisted in the motile condition frequently for two to three weeks and on two occasions for 30 days. A continuance in the motile state would assure a greater chance of attachment. Once in attachment with males and the pubescent females have undergone quiescence, it is then possible to pinch off the males without interfering with the final moult of the females. These females, however, do not lay eggs. Nor will these females commence laying after being exposed in their final stage to adult males. These observations demonstrate that the act of copulation, however accomplished, takes place with the ovigerous female at a precise moment during the final moult of the female, and that the long period of attachment simply makes certain that the male is available at the appropriate moment for copulation. It

demonstrates also that eggs are not laid parthenogenetically.

Unlike the preceding stages for which the longevity was determined by starting with either eggs (for the larva) or quiescent stages (for the nymphs), the total period required for the development of adult males, ovigerous females and the laying of the first egg were determined (frequently independently) by starting with large numbers (30 to 200) of eggs 0 to 24 hours old. Ovigerous females were first seen between the wide limits of 16 to 26 days following oviposition, but most occurred after 19 to 23 days (Table VI). The females increased in size to a maximum during a pre-oviposition period of two, but sometimes 3 or 4, days. They then commenced to lay a series of eggs without additional intervention by a male. The first egg to be laid, concomitant with the first appearance of the ovigerous females, varied widely between 18 and 28 days after the original oviposition. Table VI shows that many took 21 to 26 days. This three week period was, therefore, that usually required for a complete life cycle under the in vitro conditions.

It will have been noted from Table IV that a summation of the minimum periods of survival for the larva and two male nymphs plus the incubation time of the egg (four days, but sometimes three) and three quiescent phases (one day each) comes to 15 to 16 days. This was observed to be true in vials started with numerous eggs, although most adult males emerged from 17 to 20 days after oviposition

TABLE VI

Period for Adult Mites and Next Generation

FROM OVIPOSITION (DAYS)	ADULT MALES (NUMBER)	OVIGEROUS* FEMALES (NUMBER)	FIRST EGG (NUMBER)
15	4	---	--
16	7	4	--
17	20	6	--
18	19	3	2
19	13	14	4
20	16	8	6
21	9	19	8
22	6	10	6
23	2	11	10
24	--	4	10
25	--	2	7
26	--	3	15
27	--	--	6
28	--	--	2

* The ovigerous females are not necessarily the same individuals that produced the eggs listed in the final column.

TABLE VII

Egg Production of Ovigerous Females Raised Individually

PRE-OVIPOSITION PERIOD (days)	NUMBER OF FEMALES	OVIPOSITION PERIOD (days)	NUMBER OF FEMALES	TOTAL EGGS LAID BY A SINGLE FEMALE	NUMBER OF FEMALES	NUMBER OF EGG GROUPS*	NUMBER OF FEMALES	SENESCENCE PERIOD (days)	NUMBER OF FEMALES
2	33	3	3	3	3	3	6	1	5
3	18	4	4	4	3	4	7	2	12
4	15	5	4	5	5	5	17	3	38
		6	3	6	5	6	10	4	8
		7	6	7	6	7	6	5	3
		8	8	--	--	8	3		
		9	7	9	8	all laid singly	17		
		10	6	10	9				
		11	6	11	10				
		12	4	12	6				
		13	3	13	4				
		14	8	--	--				
		15	2	15	2				
		16	2	16	3				
				17	2				

* Number of eggs in each group ranged from one to five

(Table VI). Many pubescent females took 13 to 14 days to appear. Since this is at least one and generally two, three or more days before adult males occurred, and since the latter generally became attached to pubescent females immediately after emergence from their previous stage, it is most probable, that on the host, members composing an attachment pair are from eggs laid at different times.

Ovigerous females demonstrated oviposition periods of 3 to 16 days (Table VII). Each female laid eggs at the rate of about one a day. The occasional female laid two eggs, and an odd female three eggs, in a 24 hour period. This rapid reproduction, when it occurred at all, was invariably at the beginning of the oviposition period. Following oviposition, there was a period of senescence that generally lasted three days, but ranged from one to five days (Table VII). Non-productive adult females outlived their egg-laying counterparts. While the latter lived up to three weeks, most of the former lived up to a month and few as long as 49 and 55 days. The longevity of adult males, whether they had been in attachment with females or not, corresponded to that of the non-laying females by living up to 49 days.

Females laid their eggs singly. The act of laying takes but a minute or two. With the egg's expulsion, there is a simultaneous secretion of a fluid that lubricates the egg in its passage, and which also, upon solidification,

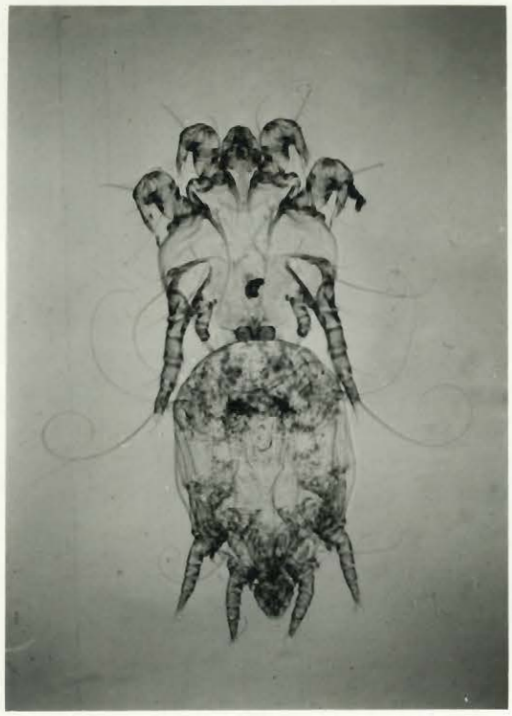


Fig. 47. Photomicrograph of an attachment pair. Adult male above and pubescent female below.

Fig. 48. Photomicrograph of an ovigerous female containing an egg.

firmly attached the egg to the substrate by its end or along one edge. On the host, the substrate is a flake of skin scurf contiguous with the animal's body, or the outer layer of skin, and in the culture vials it is the surface of the glass (Figs. 49 and 50). One female, though blind, tends to return to a few places to oviposit, although no female ever lays all its eggs in only one or even two groups. Table VII shows that some females, raised individually, used from three to eight sites to deposit 3 to 17 eggs with up to five eggs in a group, but many, under these isolated conditions, chose a different location for each egg. A few females deposit some of their eggs in an apparently haphazard fashion amongst the hair and debris in the culture vials. The exact number was determined by subtracting the number of eggs attached to the substrate from the total number of larvae recovered following incubation. The difference indicated the number of eggs laid in the hair, which for each of 10 culture vials, ranged between 22% and 36% of the 9 to 11 eggs laid.

In vials with numerous mites, the presence of eggs from one female attracted other females to lay their eggs at the same site, resulting in communal groups. Groups of eggs often began at the peripheral margin of the bottom of the vials, and spread gradually inwards towards the center, or up the sides of the vial (Fig. 49). Less frequently, groups of eggs were produced in more central positions of the bottom

of the vial (Fig. 50). When numerous females were present, the number of eggs in a group usually ranged from three or four to a few hundred, but one group contained 2,961 eggs which spread over an area of 3.7 sq. cm.. All eggs were spread out singly in close proximity over the surface of the substrate and were only rarely laid in cumulo. Because of this, each egg was exposed to virtually the same microclimate. Hence, following incubation, eggs hatched in the same sequence as they had been laid.

Some observations were possible on the development of the egg during both pre- and post-oviposition. Pre-ovipositional development consisted of the formation of the yolk mass in the hysterosomal region of the ovigerous female. A small mass in irregular outline was first apparent on either the left or right side of the mite. This enlarged irregularly (Fig. 51), but eventually acquired a regular oval outline (Fig. 52). It may be enclosed by a membrane. With further enlargement, the yolk mass assumes an elliptical shape, typical of the egg, and is enveloped by a membrane. The shell, however, has not yet formed (Figs. 53 and 48). When this stage is reached in some, but not all, mites, a second yolk mass becomes apparent on the opposite side of the female. The latter increases into an irregular yolk mass about the same time that the original egg acquires its shell and moves medially to a position posterior to the vulva (Fig. 54). From these observations, it seems likely that

Fig. 49. Communal group of eggs at bottom edge of culture vial.

Fig. 50. Communal group of eggs at center of bottom of culture vial.

eggs develop in an alternating bilateral fashion. This would partly explain why some mites could lay two or even three eggs in a day while most laid only a single egg in that period.

Many eggs, like the one behind the vulva in Fig. 54, had been laid by some females (Fig. 56). Post-ovipositional development was observed in eggs collected within two to three hours following oviposition. The eggs were partially cleared and examined in glycerine in a depression slide. Within the first two hours, the yolk mass had partly receded from the capital pole, displaying a translucent egg white area (Fig. 57). After about five hours, the latter had extended to about a quarter of the length of the egg (Fig. 58). The yolk mass occupied less than half the postero-ventral part of the egg about 10 hours after oviposition when there also appeared three indentations in the egg white at the capital end (Figs. 59 and 60). The primordial mouth parts are first to appear in the form of a pair of anterior projections, still enveloped within a membrane (Fig. 61). This occurs after approximately 16 hours. After about 48 hours, legs I and II appear as partially differentiated projections (Fig. 62) arising from distinct shoulders (Fig. 63), and are directed posteriorly over the venter. (Leg III may be present and concealed by the yolk mass). Near the end of the incubation period, all the yolk mass is apparently absorbed, and complete differentiation of the larva has

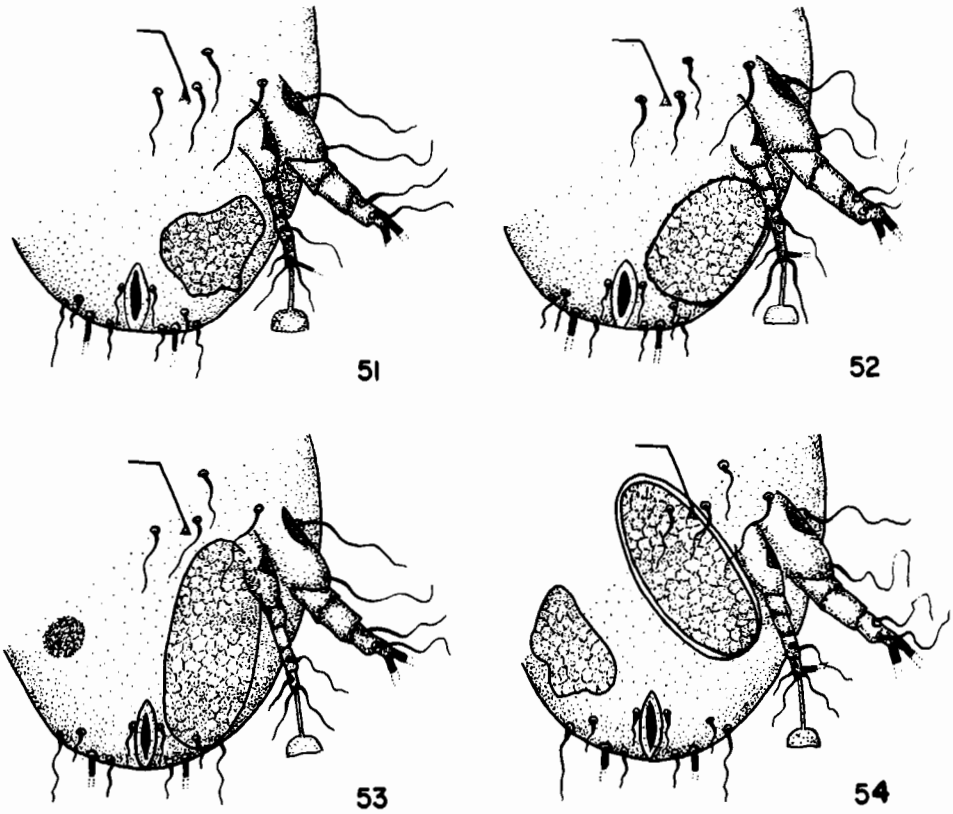


Fig. 51. Hysterosomal region of an ovigerous female with an egg yolk mass of irregular outline.

Fig. 52. The same region with an egg yolk mass of an oval shape.

Fig. 53. The same region with an egg yolk mass of an elliptical shape. Another small egg yolk mass appears on the opposite side of the female.

Fig. 54. The same region with a shelled egg just posterior to the vulva, together with another enlarged egg yolk mass.

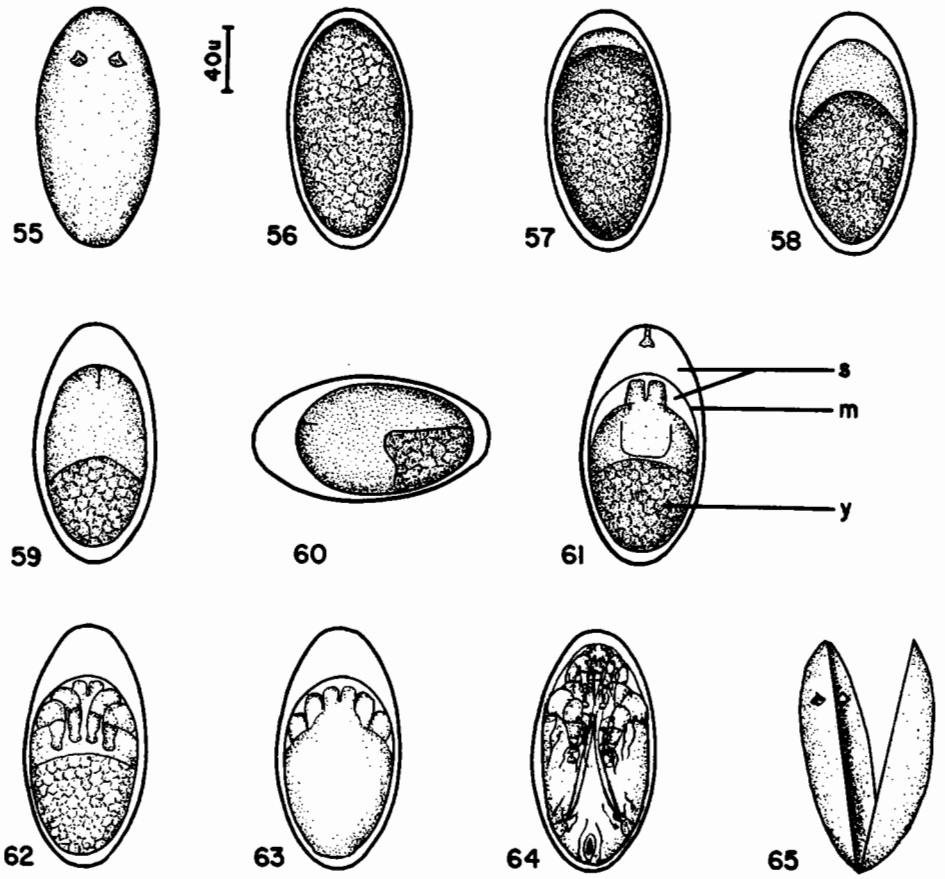


Fig. 55. Egg shell with two bosses.
Fig. 56. State of egg at time of laying.
Figs. 57-59, 61-62. Degree of embryonation after about 2, 5, 10, 16 and 48 hours respectively. s -- space; m -- membrane; y -- yolk mass.
Fig. 60. Lateral view of Fig. 59.
Fig. 63. Dorsal view of Fig. 62.
Fig. 64. Complete development of larva within egg.
Fig. 65. Discarded egg shell.

occurred within the egg. A space occurs between the larval integument and the egg-shell. The larval gnathosoma and pedipalpi are pointed antero-ventrally, and the legs, like those within quiescent mites, lie over the venter of the larva with the anterior legs directed posteriorly and the hind legs are directed anteriorly with their setae extending to the tip of the gnathosoma.. Because of their length, the setae must then turn posteriorly, but this could not be traced (Fig. 64). Each larva emerged through a cleavage of the shell that encircled the egg along its longitudinal axis. Both bosses on the egg shell were on the same side of the cleavage (Fig. 65). Sometimes the two halves of the egg remained unseparated at the posterior end or along the edge attached to the substrate, but this did not interfere with the emergence of the larva.

Under the in vitro conditions, the post-oviposition period required before the eggs hatched varied from 72 to 107 hours, but most eggs took 90 to 95 hours (four days) to hatch (Table V). Larvae emerged anterior end first. Only three eggs among thousands failed to hatch. Two of these did not differentiate, while the third contained a complete larva that failed to split the shell. Why some eggs took longer to hatch than the majority may not be related to the degree of embryonation but to the time required to split the shell. This, in turn, would probably depend in part on the degree of attachment of the egg with the substrate. At the other extreme, the fact that some eggs took only three days to hatch might be explained by previous prolonged retainment

within the female. A few of the eggs examined in glycerine immediately after laying had developed to the extent where some of the yolk mass had receded posteriorly. An abnormal situation occurred where a freshly killed ovigerous female contained an egg that had fully embryonated. If this egg had been laid, it would have been only a matter of a few hours before it would have hatched. (The end of this egg that pointed towards the vulva was the posterior end of the mite, but it is unknown whether all eggs are laid in that direction). Much of the variation in the post-ovipositional time of hatching, therefore, may be attributable to pre-ovipositional retainment. This would also explain some of the variation in the two to four days required for pre-ovipositional periods (Table VII).

Leg structure appears to be closely related with the reproductive activities of the mite. The ratio of the length of the mite to its width varies from 1.16 for the female protonymph to 1.44 for the ovigerous female. The value for the male deutonymph is 1.36 and for the four remaining stages remains a constant 1.30. Because of this fairly consistent relationship between length and width, one of these -- length -- was used as the abscissa in Fig. 66, and against it were plotted the length of the various legs in each stage. For the male stages, leg I shows an expected increase in length with an increase in body size. The length of leg I of the female stages, however, increases from the

larva to the female protonymph, but maintains the same size in the pubescent female stage, even though the body has increased in size by a little less than a third. This loss is regained by the ovigerous female where leg I is of a comparatively "normal" length. Results for leg II are virtually the same as for leg I. Leg III of the female stages shows the same graphic pattern as legs I and II. It seems possible that the comparative decrease in the length of the three anterior legs in the pubescent female reflects their limited usefulness, since most pubescent females spend this entire phase being dragged around by the adult males. Leg III of the adult male also shows a relation to what has happened in the pubescent female stage. It has an additional article and obviously greater strength than that of the preceding male stages, and has replaced the two whiplike terminal setae with a caruncle and hooks (Fig. 29). In general, the leg has transformed from one that is essentially sensory to one that is mainly ambulatory. It is the third leg that would support much of the weight of the attached female. Concomitant changes take place in leg IV. On all four of the first and second male and female nymphs, this leg is short, weak and perhaps a little more sensory than ambulatory. Leg IV of the adult male increases considerably in length beyond that on immature stages, and is equipped with three caruncles. It seems, therefore, to be suited mainly for traction. The importance of this in support of, and making proper attachment with, the pubescent

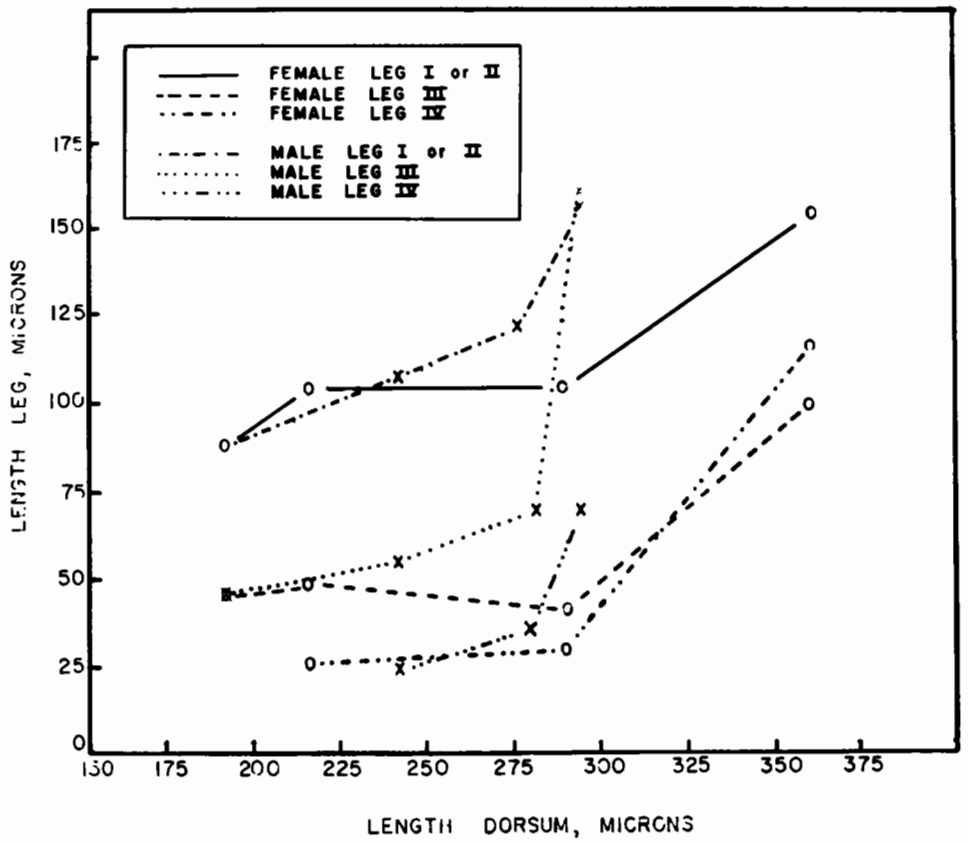


Fig. 66. Comparative increase in leg length from one stage to the next.

From left to right, the first series of vertical points represent the larva; the second the female protonymph; the third the male protonymph; the fourth the male deutonymph; the fifth the pubescent female; the sixth the adult male; and the seventh the ovigerous female.

female is obvious. In the ovigerous female (where leg III persists essentially as a sensory structure), leg IV appears to support most of the weight. Such would be most important to a female in the process of egg-laying.

The foregoing observations on the life cycle have demonstrated that the structure and activities of each of the seven active stages are similar to one another, and that the wide variations in their longevity suggest that a constant temperature and humidity, as influential as they probably are, may be less significant than some unknown factors. Feeding may have an appreciable effect on the survival of each stage. This will become apparent in the following sections of this communication.

The physical environment on the hide of a cow or other ungulate may vary at different sites and between wide limits. Such would influence the period necessary for completion of a mite's life cycle. Direct measurements were made of one physical factor -- temperature. By means of a contact pyrometer*, skin temperatures were taken on members of a Holstein-Freisian herd in winter when the animals were maintained in a warm, well-ventilated barn. The temperature of most body areas, including the feet where most mites generally occur, varied irregularly between 31° and 35°C.. The temperature of the side of the udder, where there is considerable blood supply, was somewhat higher (36° to 37°C.), and the crotch between the udder and thigh of a high production animal was generally 37° to 38°C..

* Manufactured by Light Laboratories, Brighton, Sussex, England. Ser. No. 163.

The pasterns of a Jersey cow in a different barn, however, had a temperature of only 30°C.. This probably reflected the colder floor temperature and smaller leg and foot size of this breed. Hosts of other species of Chorioptes were examined. The body temperature of goats, the host of C. caprae, varied between 33° and 38°C., while the feet -- where most mites were found -- of members of the herd in question were so cold that no temperature would record on the pyrometer which registers a minimum temperature of 25°C.. Two Belgian horses, naturally infested with C. equi, had pastern temperatures of 35° to 36°C.. The environment of a chorioptic mite varies, therefore, with the environment of the barn or stable, the locus of the mite on the host, and, when infesting the leg of the host, on the mass and probable blood supply of that extremity. Additionally, eggs laid in vitro within a period of 24 hours were placed in isolation unit #2. These took 5 to 6 days to hatch on the back (33° to 34°C.) of a grade Holstein cow, whereas those eggs under in vitro conditions generally took four days. It seems likely from the above observations that the period required for a life cycle on the host varies greatly with the conditions, and that it is generally somewhat longer than that observed under the in vitro conditions.

III. NON-SPECIFICITY AND REVISION OF THE GENUS CHORIOPTES

INTRODUCTION

During the past 100 years, eight species or subspecies of Chorioptes have been described from almost as many hosts. Most were on farm stock, but some were from animals in zoological gardens. In the present study, a wide variety of mammalian species and breeds were examined for chorioptic mites. Five host species were found. Studies followed on the in vitro culture of the mites from the different hosts, a morphological comparison of the mites, and on the validity of the species in the genus Chorioptes. Before describing the experimental results, it is imperative to clarity exactly what has been written by others on natural infestations on all hosts, and the criteria used by them for the creation of the different species in the genus.

RESULTS

Natural Infestations on All Hosts

Natural infestations on all hosts that have been noted throughout the world are summarized, irrespective of the specific names applied by the author, together with those infestations observed in the present study to ascertain any detectable difference in mite behaviour on different hosts, as well as comparative data on the incidence of infestation. The literature survey showed that published

reports for the most part referred to mites only because the observer was confronted with a dermatitis requiring an etiological explanation. Observations on mites in the absence of a pathological condition have been scant indeed.

(a) Domestic Cattle and Horses

A review of the papers in various agricultural and veterinary bulletins suggests that chorioptic mites have a cosmopolitan distribution on cattle and horses. It is recognized generally that the dermatitis sometimes associated with the mites usually remains localized and appears for the most part in winter. Rose (1940), however, stated that the condition was more apparent on horses in summer in the warm, moist atmosphere of New South Wales. Horse breeds of purebred stock found naturally infested in the present study were the Clydesdale, Belgian and Percheron, with some members of the first two breeds displaying typical lesions on the posterior pasterns, sometimes referred to colloquially as "Clyde Itch" or "Foot Mange". For cattle, observations made monthly for a year on a herd of one breed (Holstein-Freisian) were noted previously. Various other positive cattle breeds (Ayrshire, Dual-Purpose Shorthorn, Shorthorn, Hereford, Aberdeen Angus, Scotch Highland) were examined in which few of the infested individuals displayed mild skin eruptions.

(b) Domestic Sheep and Goats

Reports of infested sheep and goats have appeared less frequently than those of cattle and horses. In the last century, a Negretti ram in Germany displayed chorioptic mange on the legs and scrotum (Zürn, 1874). More recently, McKenna and Pulsford (1947) listed only two reports of chorioptic mites on sheep in Australia, one of which included lesions on the scrota of Corriedale rams. Foot and scrotal mange associated with chorioptic mites on Corriedale and other sheep breeds may be more prevalent in New Zealand than in Australia (Helson, 1956; Murray and Thomas, 1956). Interestingly, both breeds mentioned above (Negretti, Corriedale) were bred from a merino foundation. In 1909, Cave summarized four reports of infested flocks in England, one associated with foot-rot, and another in Kent (Romney Marsh) lambs with lameness. In the present study, 8 of 38 Suffolk sheep in two flocks were found with mites, but not mange, in Quebec; and chorioptic mange occurred on the muzzle and lower legs of some members of one flock of grade sheep in Nova Scotia*. Reports of chorioptic mites on goats are about as sparse as those on sheep. In 1854, Delafond and Bourguignon (1857-58) found chorioptic mange on a number of Angora goats in the Jardin des Plantes de Paris, and in 1889, Mollereau reported chorioptic mange on common goats in

* Kindly submitted by J. F. Frank, Animal Pathology Division, Canada Department of Agriculture, Eastern Section Branch Laboratory, Mount Allison University.

rural France. Kemper et al. (1952) observed chorioptic mange on about five percent of more than 2000 Angora goats in three herds in the western United States. The lesions on the animals sometimes extended beyong the legs to include the abdomen and thorax. Hirst (1924) reported the condition from Texas; Gerlach (1857) noted it from Germany; and Oudemans (1926) recorded it on the legs and muzzle of goats in Sumatra. Four Quebec goat herds were examined in the current study. None had lesions, but chorioptic mites occurred on the feet of individuals in three of the herds. One herd, examined more carefully than the others, had six of its 13 animals positive, and three kids born subsequently became infested within a month of freshening. From the results in this study it seems possible that chorioptic mites may be more prevalent on goats than is generally maintained, and that mange is an infrequent complication.

(c) Other Hosts*

Chorioptic mites have occurred on mammals other than farm stock. Gerlach (1857) stated that Gurlt figured a symbiotic (chorioptic) mite from an elephant, but that no details were available. In 1874, Zürn may have observed chorioptic mites in the ears of a rabbit. These reports

* According to Brumpt (1936), chorioptic mites were observed by Zürn on the head of a man with alopecia; and Moniez observed them in the nose of another person. These were probably incidental parasites. The present writer has had chorioptic mites crawling repeatedly on his hands and arms for over two years with no suggestion of sensitization.

are discussed later in this communication. Railliet and Mouquet (1919) reported chorioptic mange on the legs, abdomen and thorax of one of four Barbary sheep (Ammotragus lervia) in the London Zoological Gardens. In the same gardens, Hirst (1922) noted this malady on the feet of a guanaco (Lama huanacus). In the present study, mites -- not associated with mange -- were collected from both hind and fore-feet of two yearling llamas (Lama huanacus glama) in the Société Zoologique de Granby (Québec). The observations summarized above indicate that the important sites of infestation of chorioptic mites on both farm and zoo animals are the feet and lower hind legs with occasional involvement elsewhere. The mites, therefore, display no apparent behaviouristic differences on different hosts.

Present Taxonomic Status

Confusion in the literature regarding the scientific names of chorioptic mites persisted until, and sometimes after, the work of Vitzthum in 1943. Vitzthum's comprehensive volume was remarkably complete, but he did overlook recognized species of Chorioptes. He also, as well as previous authors (Railliet, 1893; Neveu-Lemaire, 1938), erred in some authority citations that were augmented or perpetuated by Radford (1950), Baker and Wharton (1952), and Sweatman (1956). This has necessitated a summary and re-examination of the genus before suggesting its revision.

The chorioptic mite from the cow was first described by Héring in 1845 and named Sarcoptes bovis. It had been observed ten years earlier on that host by Kegelaar (in Gerlach, 1857), but he did not describe it. Gerlach coined Symbiotes in 1857 for the genus of these mites on cattle (S. bovis) and horses (S. equi), and referred a mite from an elephant figured by Gurlt to the same genus (S. elephi). In 1857-58, Delafond and Bourguignon gave the name Sarcoptes caprae to what we now recognize as a chorioptic mite from goats. Realizing that this mite had features of both Sarcoptes and Dermatodectes (Psoroptes), these same authors re-named it Sarco-Dermatodectes in 1862. In 1859, however, Gervais and Van Beneden had already adopted Chorioptes for this same mite of Delafond and Bourguignon, removing it from Sarcoptes in which it had been placed incorrectly, and also rejecting Gerlach's Symbiotes as a homonym. The generic name with priority is therefore Chorioptes, and the type species is C. caprae. At the time of Gervais and Van Beneden, four species were referable to the genus -- C. caprae, C. bovis, C. equi and C. elephi. New hosts have been observed subsequently. Morphological differences between the mites from the different hosts were absent or slight. Chorioptes, however, like Sarcoptes, Psoroptes, Otodectes, and Demodex, was thought to be host specific and different physiologically. Therefore, convention

dictated adoption of a new specific (or sometimes subspecific) name for the mite as it occurred on each host. There was one exception; and that was Hirst's (1922) collection of chorioptic mites from the guanaco. He refrained from creating a new species, or even attempting to refer the mites to a recognized species. Two years later, however, Hirst (1924) described a second caprine species of Chorioptes taken on a domestic goat in Texas. A summary of the species of Chorioptes, with their synonyms, is shown below:

Chorioptes Gervais and Van Beneden, 1859.

Type: Sarcoptes caprae Delafond and Bourguignon, 1857-58.

Syn.: Symbiotes Gerlach, 1857; Dermatophagus Fürstenburg, 1861; Sarco-Dermatodectes Delafond and Bourguignon, 1862; Dermatophagus symbiotes Verheyen, 1862; Chorioptes symbiotes Railliet, 1893; Symbiotes communis Cave, 1909; Chorioptes bovis Railliet and Mouquet, 1919; Chorioptes communis McKenna and Pulsford, 1947.

Domestic Goat

Chorioptes caprae (Delafond and Bourguignon, 1857-58) Gervais and Van Beneden, 1859.

Syn.: Sarcoptes caprae Delafond and Bourguignon, 1857-58; Chorioptes symbiotes var. caprae Railliet, 1893; Chorioptes bovis var. caprae Neveu-Lemaire, 1938.

Domestic Goat

Chorioptes texanus Hirst, 1924.

Domestic Cow

Chorioptes bovis (Héring, 1845) Gervais and Van Beneden, 1859.

Syn.: *Sarcoptes bovis* Héring, 1845; *Symbiotes bovis* Gerlach, 1857; *Dermatophagus symbiotes* var. *bovis* Verheyen, 1862; *Chorioptes symbiotes* var. *bovis* Railliet, 1893; *Chorioptes bovis* var. *bovis* Neveu-Lemaire, 1938.

Horse

Chorioptes equi (Gerlach, 1857) Gervais and Van Beneden, 1859.

Syn.: *Symbiotes equi* Gerlach, 1857; *Symbiotes spathiferus* Mégnin, 1872; *Chorioptes symbiotes* var. *equi* Railliet, 1893; *Chorioptes bovis* var. *equi* Neveu-Lemaire, 1938.

Domestic Sheep

Chorioptes ovis (Zürn, 1874) Baker and Wharton, 1952.

Syn.: *Dermatophagus ovis* Zürn, 1874; *Chorioptes symbiotes* var. *ovis* Railliet, 1893; *Symbiotes communis* var. *ovis* Cave, 1909; *Chorioptes bovis* var. *ovis* Neveu-Lemaire, 1938; *Chorioptes communis* var. *ovis* McKenna and Pulsford, 1947.

Elephant

Symbiotes elephi Gerlach, 1857.

Barbary Sheep

Chorioptes bovis var. ammotragi Railliet and Mouquet, 1919.

Domestic Rabbit

Chorioptes symbiotes var. cuniculi Railliet, 1893.

Syn.: Chorioptes bovis var. cuniculi Neveu-Lemaire, 1938; Chorioptes cuniculi Vitzthum, 1943.

Comparative Biology and Morphology

Since it was convention, rather than good experimental evidence, that persuaded most observers to name each chorioptic mite differently as it was discovered on a new host, it was essential in the current study to ascertain the validity of the accepted species and their host specificity. This problem has been approached using six different methods, each summarized below under its own subheading. Mites for the experiments were from five different hosts -- cow, horse, goat, sheep and llama -- and, for the first four, presumably represented the species of Chorioptes (C. bovis, C. equi, C. caprae, and C. ovis) associated with that host. The hosts were from Quebec, but came from widely separated premises.

1. Life History and *In Vitro* Survival

It has been shown already that the feet and lower hind legs are the important sites of infestation on all hosts. The life cycle with seven motile stages and the habits of the mites from each of five hosts have been observed *in vitro* to be identical for each. The period required for completion of the cycle was also similar, and varied within the range (18 to 28 days) established previously for *C. bovis* from cattle. Not only was it possible to culture the mites on epidermic debris from their own host, but also on material from the feet of each of the other four hosts. Table VIII shows that all cycles in repeated trials were completed in the standard period, and there was no apparent loss of vigour or any indication of sterility in the second and third generations. These observations proved that epidermal material from each host contained the necessary nutrients for culturing mites taken from each of the other hosts.

2. Cross-Breeding

The ultimate criterion of a species is usually its reproductive isolation from other species. Hence, experiments were conducted to permit cross-breeding of mites from the different hosts. The viability of any progeny would indicate success since it was demonstrated in the life cycle that eggs are not laid parthenogenetically. About a dozen motile pubescent females or quiescent female protonymphs from one

host were placed in a vial with adult males from a different host. In all instances, the epidermal material in the vial was from either cattle or horses, and had been sterilized previously by heat to kill any mites or eggs that might have been present. Table IX shows that males and females from each of the five hosts (18 of a possible 20 combinations used) did copulate and the females laid eggs which in turn produced fertile progeny and eggs in the second generation. Mites from the five sources, therefore, were compatible reproductively.

3. Comparative Survival on Foreign Epidermal Material

The hosts found naturally infested with chorioptic mites are from three families of hoofed mammals -- Bovidae, Equidae and Camelidae. If the mites from the different hosts are truly different, then it is conceivable that mites from one member of a family might respond differently on epidermal material from another member of that same family than would mites from members of each of the other two families. To determine this, eggs from the cattle, horse and llama cultures were transferred to vials containing epidermic debris from other members of their families. Table X shows that the results were similar on three species of oxen, two equids and three camelids regardless of the original host of the mites. This emphasizes further the similarity of the mites from the different hosts.

TABLE VIII

Period (in Days) for Life Cycle on Epidermic Debris from Each of Five Hosts

Egg Source \ Debris Source	Cow	Horse**	Goat	Sheep†	Llama
Cow		21-25	19-25	22-27	25-27
Horse**	18-26		18-23	25-27	26
Goat	18-21	23		26	27
Sheep*	19	21	20		26
Llama	21	23	19	26	

** Clydesdale or Belgian.
* Suffolk.
† Suffolk, Leicester, North Country Cheviot, or Hampshire Down.

TABLE IX

Cross-Breeding of Mites from Different Hosts

Male \ Female	Cow	Horse	Goat	Sheep	Llama
Cow		+	+	+	+
Horse	+		+	+	+
Goat	+	+		+	N.D.*
Sheep	+	+	+		N.D.*
Llama	+	+	+	+	

* Not Done.

4. Comparative Survival within the Family Bovidae

The next approach to the problem of host specificity was similar to the last one. It was to use epidermic debris from antelopes, since these in the family Bovidae, link the oxen on the one hand to the sheep and goats on the other. Eggs from cow cultures as well as the goat or sheep cultures were placed in vials with epidermal material from the eland (Taurotragus oryx), Bohor reedbuck (Cervicapra bohor) and White-bearded gnu (Connochaetes albojubatus). The results were similar regardless of the source. The life cycle was completed on material from the eland, but reached only the nymphal stages on material from the two other antelopes. No differences, therefore, were detected between the mites from cattle and those from goats or sheep.

5. Induced Natural Transmission

The preceding laboratory studies indicated the non-specificity of chorioptic mites, but this required confirmation by transmission of the mites from one host species to another. Four individual experiments were conducted. Two uninfested goats were placed with a heifer having a general infestation; one calf, raised on milk and never in association with its dam or other cattle, was maintained with a positive goat herd; and a similar calf was corraled with three positive Suffolk sheep. Two protonymphal mites were located on the muzzle of one of the two goats with the positive heifer one week following their

TABLE X

Comparative Survival of Mites on Epidermic Debris from Close Relatives

Egg Source / Debris Source	Cow	Horse	Llama
Zebu	C	C	C
Indian Water Buffalo	C	C	C
American Bison	P	P	P
Grant's Zebra	C	C	C
Donkey # 1	C	C	C
Donkey # 2	P	P	P
Arabian Camel	D	D	D
Bactrian Camel	D	D	D
Guanaco	D	D	D

Key: C Life cycle completed in the usual three week period.

P Prolongation of early developmental stages with only the occasional, if any, mite reaching maturity.

D Death from apparent starvation in the larval stage following the hatching of the eggs.

first association. This goat had a habit of rubbing its head against the heifer, suggesting that the mites were transferred by direct bodily contact. Within three weeks of the initiation of the experiments, both goats and the two calves had reproducing mite populations on at least two of their feet. This proves that the mites are capable of transfer between, and reproduction on, different host species of hoofed mammals.

6. Morphological Comparisons

Regardless of the preceding data, it is theoretically possible that more than one species was involved in the experiments, both, or all of which showed non-specificity and which might interbreed and produce fertile progeny under unnatural conditions as do Black and Mallard ducks or the gayal and zebu. It is possible also that the mites might be genetically the same, but respond differently in different environments (hosts), thus displaying ecophenotypic variation. It was necessary therefore to make morphological comparisons of the mites on the same and different hosts, as well as with descriptions of previous workers. A summary of the latter will be used to introduce this section. Gerlach (1857) made rather imperfect drawings of the adult chorioptic mites, declaring the mite on the horse and that on the cow to be host specific and therefore distinct (C. equi and C. bovis), although morphologically indistinguishable. In 1872,

Mégnin redescribed the mite from the horse, and made more detailed drawings than Gerlach of the adult mites. Additionally, he pointed out some discrepancies between Gerlach's figures and what he saw. Mégnin also recognized the presence of some immature stages, although only a meager attempt was made to describe them. On the differences noted on the adult mites, Mégnin created a new species, (C.) spathiferus, but stated that he would not be surprised if it were really the same as C. equi. Five years later (1877), he did reduce the original C. equi to a synonym with his new name. With this arrangement, he was willing, apparently, to overlook the slight morphological differences he had noted originally. About 50 years later, Oudemans (1926) recognized the inadequacies in the original drawings of C. caprae by Delafond and Bourguignon (1857-58), so he redescribed this species from material sent him from a goat in Sumatra. Oudemans described and figured both the immature and adult stages. He then noted the differences between his specimens and the drawings and notes on C. equi by Mégnin (1872). In 1947, Palimpsestov recognized the presence of the immature and quiescent stages of C. equi from horses in Russia. The number of stages seen by him for C. equi were the same as those noted by Oudemans for C. caprae. All previous authors had relied on the drawings of their predecessors for purposes of comparison, rather than

examining actual specimens. They were obliged, therefore, to accept any descriptive differences as specific differences. The present writer was unable to obtain the actual specimens used by others, and in lieu of this collected chorioptic mites from as many hosts as possible and accepted each as being representative of the species generally attributed to that host. Suffice it to say that all morphological characters, including the positions of the setae etc., were identical on each of the seven motile stages from each of five hosts (cow, horse, goat, sheep, and llama). A series of critical measurements were also made to ascertain the presence or absence of any ecophenotypic variation. These included a comparison of the lengths of each leg and seven setae as well as for the body per se. Tables XI to XVII summarize the data. Measurements given by previous authors are included in a column of each table. An examination of the data shows that variations occur for the same structure on different individuals from each host, but all fall within the same approximate range. (A statistical analysis was deemed superfluous.) No differences were therefore apparent.

A comparison will now be made with some of the figures and comments of previous authors. The setae on the opisthosomal lobes of the adult male on C. equi are from independent setal bases in the drawings of Gerlach (1857). Mégnin first showed the correct groupings of the setae in common bases as shown here in Fig. 42. Oudemans (1926) also showed this arrangement for C. caprae. Oudemans

pointed out differences in the shape of the propodosomal plate of Mégnin's drawing of C. equi and his own C. caprae. These differences are, however, referable to individual variation as shown here in Figs. 13 to 20. As Oudemans stated, the long dorsal propodosomal setae as drawn by Mégnin appear directly behind the short setae near the posterior corners of the propodosomal plate, whereas on Oudemans' specimens they were postero-lateral to the plate. The actual positions of setae in general do vary considerably, and it is not impossible that Mégnin actually saw what he drew, although neither Oudemans nor the present writer have seen the pattern Mégnin described. Oudemans indicated that the sides of the vulva in C. caprae are straight, and not in the artistic shape of an inverted lyre as shown for C. equi by Mégnin. This author agrees with Oudemans. Mégnin shows the three pairs of setae at the posterior end of the vulva all lateral to the opening of the vulva. Oudemans, for C. caprae, and the present writer for all species, show only two pairs of the setae lateral to the slit of the vulva, and the third pair medial to the vulva opening. On the same ovigerous female, Oudemans shows two pairs of anal setae. The present writer has found one pair of these to be adanal rather than anal, and this is frequently displaced some distance laterally. Judging from his drawings, Oudemans overlooked dorsal setae on all stages. He shows, for example, eight pairs of idiosomal setae on the pubescent female, whereas the present writer has 10 pairs; the male

TABLE XI

Comparative Measurements (in Microns) of Larvae from Different Hosts*

PART	CATTLE MEAN	CATTLE RANGE	GOAT MEAN	GOAT RANGE	HORSE MEAN	HORSE RANGE	SHEEP MEAN	SHEEP RANGE	LLAMA MEAN	LLAMA RANGE	OTHER REPORTS
Dorsum											
Length	191	131-236	187	145-222	194	163-217	205	158-258	179	143-209	GOAT
Width	146	82-175	137	97-175	144	122-161	153	116-195	136	97-164	REF. 46.
Propodosomal Plate	59	56-67	56	52-61	59	50-63	58	50-66	54	47-58	L 136
											W 95
Legs											HORSE
I	88	74-101	91	84-100	89	78-101	98	87-113	81	64-92	REF. 38.
II	87	77-101	90	84-98	88	77-103	98	87-110	81	66-87	L 160-200
III	45	37-54	44	39-48	44	40-50	48	42-60	41	37-47	W 100-120
Caruncle I or II	15	12-18	16	13-18	16	14-18	15	13-18	14	13-16	BARBARY SHEEP
											REF. 54.
Setae											L 175-225
Lateral Propodosomal	34	20-38	38	31-44	34	29-39	36	32-68	43	29-44	W 92-130
Large Dorsal	105	87-112	111	97-121	98	87-108	113	97-135	103	93-109	
Propodosomal Plate	23	19-25	25	19-35	23	21-26	24	21-27	25	23-27	
Lateral Metapodosomal	71	58-81	75	61-89	65	60-71	81	69-97	73	64-77	
Opisthosomal	101	71-118	116	90-150	100	71-118	120	101-137	102	82-134	
Ventral Propodosomal	42	34-60	44	37-53	39	32-47	43	35-63	44	29-50	
Femoral II	66	60-73	69	53-79	63	55-71	74	60-87	64	53-93	

* Ten to 15 measurements were made on each item for each host.

TABLE XII

Comparative Measurements (in Microns) of Male Protonymphs from Different Hosts*

PART	CATTLE MEAN	CATTLE RANGE	GOAT MEAN	GOAT RANGE	HORSE MEAN	HORSE RANGE	SHEEP MEAN	SHEEP RANGE	LLAMA MEAN	LLAMA RANGE	OTHER REPORTS
Dorsum											
Length	240	188-280	227	195-280	224	187-274	226	185-279	234	188-283	GOAT
Width	178	140-209	172	137-208	175	147-204	176	145-219	179	153-211	REF. 46.
Propodosomal Plate	64	55-71	63	55-69	63	55-72	65	55-71	65	55-72	L 220
											W 153
Legs											
I	107	90-126	104	95-108	100	87-113	115	100-130	110	93-130	
II	110	95-128	104	93-111	100	89-114	116	98-132	112	100-130	
III	52	44-61	53	47-61	55	47-61	55	45-61	53	42-61	
IV	25	21-31	25	23-29	24	21-27	26	21-29	26	21-35	
Caruncle I or II	18	14-23	18	14-21	18	14-23	19	16-21	18	14-21	—
Setae											
Lateral Propodosomal	42	36-56	48	39-58	44	39-50	46	39-56	47	34-58	
Large Dorsal	146	110-171	137	126-150	126	114-140	140	121-151	136	106-204	
Propodosomal Plate	33	24-40	33	27-40	29	24-37	29	24-41	34	29-45	
Lateral Metapodosomal	106	79-132	101	85-113	88	77-101	97	77-130	98	76-140	
Opisthosomal	119	82-150	122	95-150	103	81-119	102	82-152	116	79-158	
Ventral Propodosomal	50	37-61	47	32-64	49	40-55	56	40-64	51	40-64	
Femoral II	79	64-103	81	76-89	74	64-84	77	66-103	82	64-105	

* See footnote to Table XI

TABLE XIII

Comparative Measurements (in Microns) of Female Protonymphs from Different Hosts*

PART	CATTLE MEAN	CATTLE RANGE	GOAT MEAN	GOAT RANGE	HORSE MEAN	HORSE RANGE	SHEEP MEAN	SHEEP RANGE	LLAMA MEAN	LLAMA RANGE	OTHER REPORTS
Dorsum											
Length	214	176-285	214	161-245	229	201-248	219	180-290	221	195-288	GOAT
Width	184	145-238	171	134-206	186	161-206	181	145-253	180	158-243	REF. 46.
Propodosomal Plate	63	57-76	61	58-64	66	61-72	63	60-74	62	55-79	L 180 W 132
Legs											
I	104	94-111	104	97-111	102	92-111	103	94-113	101	93-106	
II	104	95-116	102	95-109	102	93-114	104	94-116	105	97-119	
III	48	37-55	49	44-55	50	45-56	49	39-54	49	35-56	
IV	25	19-34	25	21-32	24	21-26	24	19-39	23	18-26	
Caruncle I or II	18	14-21	17	14-21	17	14-19	17	13-21	17	14-21	
Setae											
Lateral Propodosomal	42	36-49	42	29-50	40	35-45	42	32-49	41	37-27	
Large Dorsal	125	103-142	133	124-145	126	109-142	128	111-142	119	100-137	
Propodosomal Plate	30	24-35	32	26-37	28	26-31	31	24-37	29	24-32	
Lateral Metapodosomal	81	72-97	85	72-103	78	66-92	80	71-100	83	72-95	
Opisthosomal	94	74-109	104	81-130	89	74-108	91	76-113	89	72-109	
Ventral Propodosomal	50	34-67	46	34-63	45	39-52	47	36-65	49	32-71	
Femoral II	75	66-87	77	64-93	77	66-87	76	64-89	75	63-84	

* See footnote to Table XI

TABLE XIV

Comparative Measurements (in Microns) of Male Deutonymphs from Different Hosts*

PART	CATTLE		GOAT		HORSE		SHEEP		LLAMA		OTHER
	MEAN	RANGE	MEAN	RANGE	MEAN	RANGE	MEAN	RANGE	MEAN	RANGE	REPORTS
Dorsum											
Length	275	230-336	253	225-282	263	227-338	290	233-341	285	258-324	GOAT
Width	203	165-250	198	161-214	199	168-242	214	161-258	218	193-248	REF. 46.
Propodosomal Plate	74	58-80	72	55-79	74	61-79	74	56-80	75	66-82	L 227
											W 150
Legs											
I	122	101-134	118	98-126	115	10?-132	123	114-130	129	121-139	
II	124	100-136	119	97-127	115	111-136	124	110-133	128	122-134	
III	67	58-77	66	58-72	68	60-80	68	58-81	69	64-72	
IV	36	30-40	37	31-40	38	32-40	37	30-43	36	29-42	
Caruncle I or II	20	18-24	20	18-24	21	20-24	20	19-24	20	18-24	
Setae											
Lateral Propodosomal	57	50-68	60	50-72	56	47-68	58	42-70	56	50-61	
Large Dorsal	166	153-192	163	151-175	164	160-188	165	156-196	168	153-174	
Propodosomal Plate	40	35-48	41	35-50	41	35-49	40	32-48	41	39-48	
Lateral Metapodosomal	122	104-157	123	101-167	124	105-160	124	104-156	127	109-145	
Opisthosomal	164	138-198	164	134-211	148	138-206	161	134-200	165	142-177	
Ventral Propodosomal	62	48-72	62	50-74	58	47-70	59	48-72	57	45-68	
Femoral II	93	81-117	90	77-101	96	80-119	94	82-120	97	81-122	

* See footnote to Table XI

TABLE XV

Comparative Measurements (in Microns) of Pubescent Females from Different Hosts*

PART	CATTLE MEAN	CATTLE RANGE	GOAT MEAN	GOAT RANGE	HORSE MEAN	HORSE RANGE	SHEEP MEAN	SHEEP RANGE	LLAMA MEAN	LLAMA RANGE	OTHER REPORTS
Dorsum											
Length	288	258-361	273	246-314	282	240-340	286	267-361	280	219-322	GOAT
Width	222	180-246	210	166-245	226	174-270	241	188-309	230	196-258	REF. 46.
Propodosomal Plate	73	61-84	66	55-74	70	61-81	78	67-84	69	61-81	L 270
											W 160
Legs											HORSE
I	103	97-119	99	95-100	105	95-114	111	104-119	100	95-105	REF. 38.
II	101	95-115	96	87-101	105	91-113	112	105-121	99	89-103	L 270
III	42	36-53	44	35-53	42	34-51	43	38-48	38	34-43	W 180
IV	30	27-32	27	21-32	29	27-34	32	30-35	30	24-35	BARBARY
Caruncle I or II	19	16-23	17	14-23	18	16-23	21	18-23	17	14-19	SHEEP
											REF. 54.
Setae											L 298
Lateral Propodosomal	38	30-45	41	35-45	38	32-42	--	--	38	34-42	W 210
Large Dorsal	220	130-314	162	127-224	232	198-321	--	--	272	240-349	
Propodosomal Plate	31	27-34	33	29-37	30	26-34	29	26-34	30	26-34	
Lateral Metapodosomal	75	66-81	81	72-103	77	66-97	73	66-82	79	56-97	
Opisthosomal	173	106-248	169	140-206	--	--	--	--	--	--	
Ventral Propodosomal	46	32-61	47	32-53	45	32-60	44	39-51	45	35-60	
Femoral II	74	64-82	80	71-97	--	--	81	68-92	66	61-77	

* See footnote to Table XI

TABLE XVI

Comparative Measurements (in Microns) of Adult Males from Different Hosts*

PART	CATTLE MEAN	CATTLE RANGE	GOAT MEAN	GOAT RANGE	HORSE MEAN	HORSE RANGE	SHEEP MEAN	SHEEP RANGE	LLAMA MEAN	LLAMA RANGE	OTHER REPORTS
Dorsum											CATTLE
Length	294	272-325	284	254-299	296	274-319	301	272-327	292	274-314	REF. 53.
Width	228	208-238	223	208-235	231	208-251	239	209-261	231	211-254	L 270-300
Propodosomal Plate	79	72-85	75	72-81	77	72-85	80	74-87	77	69-85	W 210-220
											GOAT
Legs											REF. 53.
I	157	143-162	--	--	156	143-168	160	143-175	154	145-161	L 290-300
II	160	145-177	--	--	158	145-173	161	145-177	158	153-163	W 180-210
III	160	150-166	155	148-163	157	146-164	160	154-166	157	143-167	GOAT
IV	69	61-74	69	61-76	70	61-76	71	63-77	64	56-72	REF. 46.
Caruncle I or II	30	27-32	31	27-32	30	27-32	30	23-32	29	26-32	L 240+lobes
											W 193
Setae											HORSE
Lateral Propodosomal	80	71-87	87	68-97	--	--	74	68-81	80	72-87	REF. 53.
Large Dorsal	194	172-217	197	172-219	--	--	205	190-229	207	182-242	L 280-330
Propodosomal Plate	50	43-53	51	42-58	49	42-54	45	40-53	47	42-52	W 190-230
Lateral Metapodosomal	229	198-253	244	201-275	230	203-261	229	198-248	228	213-251	HORSE
Ventral Propodosomal	88	81-103	90	76-116	86	72-101	85	74-97	75	68-85	REF. 38.
Femoral II	148	119-161	159	145-182	--	--	--	--	150	142-161	L 280
											W 180
											SHEEP
											REF. 63.
											L 310
											W 250
											BARBARY SHEEP
											REF. 54.
											L 300-348
											W 200-235

* See footnote to Table XI

TABLE XVII

Comparative Measurements (in Microns) of Ovigerous Females from Different Hosts*

PART	CATTLE MEAN	CATTLE RANGE	GOAT MEAN	GOAT RANGE	HORSE MEAN	HORSE RANGE	SHEEP MEAN	SHEEP RANGE	LLAMA MEAN	LLAMA RANGE	OTHER REPORTS
Dorsum											CATTLE
Length	358	306-415	361	306-386	367	346-383	383	350-409	357	314-415	REF. 53.
Width	248	229-287	252	230-285	258	237-271	267	225-290	259	229-293	L 380-390
											W 230-250
Propodosomal Plate	98	92-107	98	90-108	105	98-111	104	101-109	98	90-109	GOAT
Legs											REF. 53.
I	154	138-164	144	121-158	--	--	159	140-172	146	137-156	L 310-360
II	155	125-167	148	122-159	--	--	160	141-175	146	140-158	W 210-230
III	100	87-106	102	97-113	105	97-111	106	93-116	94	81-106	GOAT
IV	118	100-129	118	100-129	124	112-131	123	111-135	114	100-129	REF. 46.
Caruncle I or II	30	27-34	29	27-34	30	27-32	31	28-32	28	24-31	L 362
											W 230
Setae											HORSE
Lateral Propodosomal	56	43-64	62	56-69	56	48-61	53	42-63	58	47-69	REF. 38.
Large Dorsal	203	185-229	204	188-217	--	--	208	190-232	193	184-214	L 400
Propodosomal Plate	42	37-47	43	39-47	41	36-48	39	35-43	42	37-48	W 250
Lateral Metapodosomal	140	129-158	146	129-177	143	135-151	149	127-179	140	130-151	HORSE
Opisthosomal	223	194-257	233	201-259	220	196-242	226	193-248	217	198-243	REF. 53.
Ventral Propodosomal	65	56-71	69	61-81	67	61-69	68	61-77	61	56-66	L 360-390
Femoral II	108	101-118	107	89-119	112	100-121	110	98-126	104	93-116	W 225-250
											SHEEP
											REF. 63.
											L 370-400
											W 260
											BARBARY SHEEP
											REF. 54.
											L 348-400
											W 230-280

* See footnote to Table XI

deutonymph of Oudemans has four pairs of ventral metapodosomal setae, but this author has five pairs. A number of other examples are possible, but seem unnecessary. These, as well as the drawings of Mégnin and earlier writers, suggest that during the past 100 years there has been a gradual increase in the detail on the drawings of the mites concomitant with improved microscopic equipment. The present writer is of the opinion, therefore, that differences between drawings of the mites of the various authors are not real.

Zürn, when he described C. ovis from a sheep, simply stated that it resembled exactly the chorioptic mite from the horse, except for a possible difference in size. The size differences he observed (in Tables XVI and XVII) fall within the range of measurements noted in this study for a number of individuals.

In summary, there are no morphological differences between the four species of Chorioptes from domestic hosts (C. bovis, C. equi, C. caprae and C. ovis), as well as those mites from a llama. This fact, together with their identical life cycles, capacity to interbreed and transmit to at least some other hosts, and their in vitro survival on epidermal material from each other and some foreign material, demonstrate to this writer that perpetuation of the four species is untenable. It is believed that only one of the above species exists, which infests each of the hosts, and the name with priority is C. caprae. The four remaining specific or

subspecific names in the genus will be discussed following the next section of this report.

Mite Survival on Epidemic Debris from Various Animals

The synonymy of chorioptic mites that occur naturally on a variety of domestic hosts suggested that some measure be made of their degree of potential ubiquitousness. The experiment was conducted by obtaining hair with epidermic debris from various ungulates within the families Camelidae, Bovidae and Equidae, in which natural hosts occur, together with epidermal material from members of the propinquent family Cervidae.

Approximately 200 eggs were collected from the cattle culture vials and placed in an unused vial with epidermal material from the mammal to be tested. Determination was made of the time required for the development of the various stages in the life cycle of the mite. The vials were examined every second or third day. Table XVIII summarizes the results. Observations were generally made in duplicate, but results that were virtually the same (as they often were) are not repeated in the table. Members of Bovidae are arranged in the table according to the recent classification of Pilgrim (1939). The pronghorn is now included in this family rather than in Antilocapridae, and the saiga is in the goat and sheep subfamily (Caprinae) rather than with the "antelopes". It will be noted also that the musk-ox is in a subfamily more closely related to the sheep and goats than

to the oxen. Hair was obtained from at least one representative in 10 of the 12 subfamilies within Bovidae, as well as from three species of Camelidae, six of Cervidae, and three species of Equidae, one of which has two subspecies.

The results show that C. caprae can survive in vitro to at least some extent on epidermal material from many ungulates. The life cycle was completed in the usual three week period on hair from some, but not all, individuals of reindeer, wapiti and white-tailed deer in Cervidae; on debris from three species of antelopes (impala, nyala and eland); on material from the Indian water buffalo and zebu among the oxen; as well as on epidermic debris from the donkey and Grant's zebra. Mites on most material tested, however, showed prolongation of the early developmental stages and premature death. Prolongation was sometimes marked. Compare the standard survival period of 3 to 5 days for larvae on Holstein-Freisian material with the persistance of some larvae up to 31 days on material from one white-tailed deer, or up to 32 days on debris from a moose. Sometimes nymphal prolongation was marked also on some members of the two species above (from 20 to 48 days on white-tailed deer and from 11 to 50 days on moose), as well as on one nyala (5 to 43 days), a Harnessed antelope (9 to 44 days), and a Chapman's zebra (10 to 37 days). As perhaps already implied, results varied between wide limits on material from different individuals of the same species.

TABLE XVIII

In Vitro Survival of Mites Emergent from Eggs on
Epidermal Material from Various Mammals

ANIMAL	INDIVIDUAL NUMBER	SITE	PERIOD (DAYS) EGGS AND LARVAE	NYMPHS†	ADULT MALE	ATTACHMENT PAIR	OVIGEROUS FEMALE	WHOLE CYCLE	SUMMARY*
Order Artiodactyla									
Family Camelidae (See Tables VIII and X)									
Family Cervidae									
Reindeer, Rangifer tarandus	1	hock	1-9	5-16	11	11	19	21	C
	2	hock	1-32	17-32	23	N.P.*			P
Wapiti, Cervus canadensis	1	side	1-14	9-25	17	17	23	26	C
	1	shoulder	1-18	10-35	22	22	31-45	N.P.	P
	2	back	1-5	N.P.					D
White-Tailed Deer, Odocoileus virginianus	1	feet	1-9	9-23	16	16	24	26	C
	2	front feet	1-7	5-17	14	14	17	19	C
	2	hind feet	1-12	7-36	N.P.				P
	2	tail base	1-13	11-18	N.P.				P
	3	feet	1-12	9-34	N.P.				P
	3	feet	1-14	12-28	N.P.				P

* Key: N.P. Not produced. When N.P. occurs under "Whole Cycle", it denotes that all stages developed, but that the ovigerous female failed to produce eggs.

C Life cycle completed in the usual three week period.

P Prolongation of early developmental stages with only the occasional, if any, mite reaching maturity.

D Death from apparent starvation in the larval stage following the hatching of the eggs.

† May include one or more nymphal stages.

ANIMAL		INDIVIDUAL NUMBER	SITE	PERIOD (DAYS) EGGS AND LARVAE	NYMPHS†	ADULT MALE	ATTACHMENT PAIR	OVIGEROUS FEMALE	WHOLE CYCLE	SUMMARY*
White-Tailed Deer, Odocoileus virginianus (cont'd)		4	side	1-31	20-48	36	36	N.P.		P
		4	side	1-23	12-42	29	N.P.			P
		4	side	1-25	13-43	N.P.				P
		5	--	1-11	N.P.					P
	fawn	6	feet	1-15	13-18	N.P.				P
	fawn	7	feet	1-20	7	N.P.				P
	fawn	8	feet	1-19	8-22	N.P.				P
Mule Deer, Odocoileus hemionus		1	side	1-16	14-21	N.P.				P
		1	side	1-6	6-10	N.P.				-
Fallow Deer, Dama vulgarus	fawn	1	feet	1-12	12-15	N.P.				P
	fawn	1	feet	1-9	N.P.					P
	fawn	2	feet	1-21	N.P.					P
Moose, Alces americana		1	shoulder	1-31	11-50	31	31	N.P.		P
		1	shoulder	1-32	15-32	N.P.				P
		1	shoulder	1-16	16-42	N.P.				P
		2	side	1-4	N.P.					D
Family Bovidae										
Antilocaproidea										
Antilocaprinae										
Pronghorn, Antilocapra americana	kid	1	feet	1-11	9-25	N.P.				P
	kid	1	feet	1-12	12-19	N.P.				P
	kid	2	feet	1-16	8-23	N.P.				P
	kid	2	feet	1-9	9-24	N.P.				P
Aegodontia										
Caprinae										
Domestic Goat, Capra hircus (See Tables VIII and XIX)										
Asiatic Ibex, Capra sibirica		1	--	1-14	12-18	18	N.P.			P
		1	--	1-8	N.P.					P

ANIMAL	INDIVIDUAL NUMBER	SITE	PERIOD (DAYS) EGGS AND LARVAE	NYMPHS†	ADULT MALE	ATTACHMENT PAIR	OVIGEROUS FEMALE	WHOLE CYCLE	SUMMARY*
Markhor, Capra falconeri	1	shoulder	1-7	N.P.					D
Domestic Sheep, Ovis vignei X O. musimon (See Tables VIII and XIX)									
European Mouflon, Ovis musimon	1	--	1-20	N.P.					P
	2	--	1-5	N.P.					D
Bighorn, Ovis canadensis	1	side	1-20	N.P.					P
	2	--	1-5	N.P.					D
Barbary, Ammotragus lervia	1	side	1-15	N.P.					P
	1	side	1-7	N.P.					D
Saiga, Saiga tatarica	1	--	1-9	8-10	N.P.				P
	1	--	1-16	15-17	N.P.				P
	2	--	1-19	14-21	N.P.				P
	3	--	1-19	N.P.					P
Ovibovinae									
Greenland Musk-Ox, Ovibos moschatus	1	--	1-7	N.P.					D
Neotraginae									
No Representative									
Gazellinae									
Impala, Aepyceros melampus	1	--	1-11	7-28	19	19	29	32	P
	1	--	1-9	7-28	17	19	24	27	C
Blackbuck, Antilope cervicapra	1	--	1-7	7-19	N.P.				P
	1	--	1-15	N.P.					P
No Name									
Alcelaphinae									
White-Bearded Gnu, Connochaetes albojubatus	1	--	1-14	8	N.P.				P
	1	--	1-11	N.P.					P

ANIMAL	INDIVIDUAL NUMBER	SITE	PERIOD (DAYS) EGGS AND LARVAE	NYMPHS†	ADULT MALE	ATTACHMENT PAIR	OVIGEROUS FEMALE	WHOLE CYCLE	SUMMARY*
Hippotraginae									
No Representative									
Reduncinae									
Bohor, Cervicapra Bohor	1	--	1-21	7-51	N.P.				P
	1	--	1-28	12-23	N.P.				P
Cephalophinae									
Yellow-Backed Duiker	1	--	1-26	15-26	N.P.				P
Cephalophus sylvicultrix	1	--	1-16	14-16	N.P.				P
Tragelaphoidea									
Tragelaphinae									
Nyala, Tragelaphus angasi	1	--	1-7	7-20	14	14	17	20	C
	2	--	1-16	8-21	16	16	17	21	C
	3	--	1-8	5-43	19-38	21-35	N.P.		P
Harnessed Antelope,	1	--	1-10	7-16	14	14	35	N.P.	P
Tragelaphus scriptus	1	--	1-12	9-44	26	N.P.			P
Delamere's Bushbuck,	1	--	1-18	9-25	N.P.				P
Tragelaphus delamerei									
Eland, Taurotragus oryx	1	--	1-11	7-27	16	18	23	27	C
Boselaphinae									
Nilgai, Boselaphus	1	--	1-9	9-31	31	N.P.			P
tragocamelus	1	--	1-15	N.P.					P
Bovinae									
Indian Water Buffalo, Bubalus bubalis	1	buttocks	1-3	8-32	16	16	18	20	C
African Buffalo, Syncerus	1	--	1-20	15-34	N.P.				P
caffer	1	--	1-22	N.P.					P
Yak, Poephagus grunniens	1	--	1-10	N.P.					P
	2	--	1-4	N.P.					D

ANIMAL	INDIVIDUAL NUMBER	SITE	PERIOD (DAYS) EGGS AND LARVAE	NYMPHS†	ADULT MALE	ATTACHMENT PAIR	OVIGEROUS FEMALE	WHOLE CYCLE	SUMMARY*
Wisent, Bison bonasus	1	--	1-4	N.P.					D
American Bison, Prairie Race, Bison bison typicus	1	shoulder	1-11	9-14	21	21	N.P.		P
	2	--	1-6	N.P.					D
Gaur, Bibos gaurus	1	--	1-4	N.P.					D
Domestic Cow, Bos taurus (See Tables VIII and XIX)									
Zebu, Bos indicus	1	feet	1-11	9-19	17	17	22	27	C
	2	feet	1-19	7-31	17	17	24	N.P.	P
Order Perissodactyla									
Family Equidae									
Domestic Horse, Equus caballus (See Tables VIII and XIX)									
Donkey, Equus africanus	1	feet	1-9	9-28	19	19	24	28	P
	2	feet	1-7	7-21	15	18	21	23	C
	3	feet	1-14	9-20	N.P.				P
	4	feet	1-15	15-32	N.P.				P
Grant's Zebra, Equus burchelli granti	1	buttocks	1-10	7-18	15	15	23	25	C
Chapman's Zebra, Equus burchelli chapmani	1	shoulder	1-11	8-28	28	N.P.			P
	1	shoulder	1-24	10-37	N.P.				P

Hair was from diverse, and sometimes unknown, body areas, but the significance of this on the survival of the mites is unknown. The complete life cycle observed on material from one wapiti was in contrast with results on material from another where no survival whatever could be induced. Material from one Bighorn sheep, a European mouflon and a yak supported larvae for a prolonged period, while fairly rapid larval death occurred on material from another individual of each species. Early larval death was observed also on material from 1 of 2 Fallow deer, 1 of 2 moose, one Markhor goat, one Greenland musk-ox, one gaur and one wisent. Like the European bison, rapid larval death occurred on epidermal material from one American bison, but some mites developed right up to attachment pairs on debris from another. These data suggest the presence of marked differences between individuals in their capacity to support C. caprae, with little precise reference to the actual species tested. The experiment also indicates no trend concordant with the phylogenetic relation between the possible hosts. It seems possible, too, that sylvatic infestations may occur, although natural infestations have been observed only on animals in captivity.

The individual variation noted for wild ungulates may be more consistent within a species or perhaps breed of domestic stock. It is also true that an unsusceptible breed would not require treatment in a farm eradication

program. To determine the susceptibility of various farm animals, hair with epidermic debris was collected from 45 breeds of cattle, goats, sheep and horses of purebred, registered stock. Table XIX shows that the life cycle was completed *in vitro* in the usual three week period on epidermal material from 12 of 14 cattle breeds, but showed developmental prolongation or early death on material from members of the two remaining breeds. Results also showed individual variation within a breed among Jersey, Guernsey and Brown Swiss cattle, and such might have been more general on other breeds if larger numbers of individuals had been sampled. No relation existed between mite survival and whether the animal was bred mainly for milk or meat production. A fair abstraction would be that most cattle breeds, but not all individuals within those breeds, appear to be susceptible to *C. caprae*.

Fewer life cycles were completed on debris from breeds of goats, sheep and horses (Table XIX) than on material from cattle. The observations on material from sheep make it convenient to divide the breeds of sheep into three groups:

(a) "bare-legged" breeds -- those with hair, rather than wool, on the lower legs and head. Principally, these are the mutton breeds.

(b) breeds with hair confined to the feet, having wool on

TABLE XIX

In Vitro Survival of Mites Emergent from Eggs on Epidermal Material from Different Breeds of Cattle, Goats, Sheep, and Horses

ANIMAL	NUMBER OF INDIVIDUALS	SITE	PERIOD (DAYS) EGGS AND LARVAE	NYMPHS	ADULT MALE	ATTACHMENT PAIR	OVIGEROUS FEMALE	WHOLE CYCLE	SUMMARY*
Domestic Cattle									
Holstein-Freisian	10	feet	--	--	--	--	--	16-27	C
Ayrshire	4	feet	--	--	--	--	--	18-24	C
French Canadian	3	feet	--	--	--	--	--	16-18	C
Jersey	2	feet	--	--	--	--	--	22-27	C
	1	feet	1-8	6-18	16	16	N.P.*		-
	2	feet	1-8	6-20	N.P.				-
Guernsey	1	feet	--	--	--	--	--	19	C
	2	feet	1-14	7-14	N.P.				P
	1	feet	1-14	12-37	N.P.				P
	1	feet	1-7	N.P.					-
Brown Swiss	3	feet	--	--	--	--	--	18-20	C
	1	feet	1-14	N.P.					P
Red Poll	2	feet	1-6	N.P.					D
Charallais†	1	feet	1-5	N.P.					D
Hereford	1	feet	--	--	--	--	--	21	C
Shorthorn	2	feet	--	--	--	--	--	18-20	C
Aberdeen Angus	4	feet	--	--	--	--	--	19-27	C
Belted Galloway	1	buttocks	1-13	9-26	16	16	N.P.		P
	1	buttocks	1-11	9-21	16	17	19	21	C
Devon	3	feet	--	--	--	--	--	19-23	C
Scotch Highland	2	feet	--	--	--	--	--	21-23	C

* See key to Table XVIII for explanation.
† Sample too small for a truly satisfactory trial.

ANIMAL	NUMBER OF INDIVIDUALS	SITE	PERIOD (DAYS) EGGS AND LARVAE	NYMPHS	ADULT MALE	ATTACHMENT PAIR	OVIGEROUS FEMALE	WHOLE CYCLE	SUMMARY*
Goats									
Toggenburg	3	feet	--	--	--	--	--	19-22	C
Nubian	1	feet	--	--	--	--	--	22	C
	2	feet	1-9	N.P.					P
Saanen	1	feet	1-8	N.P.					P
	1								
Sheep									
Group (a)									
Suffolk	2	feet	--	--	--	--	--	25-27	C
	1	feet	1-19	15-39	27	25	N.P.		P
	1	feet	1-10	10-31	15	15	N.P.		P
	2	muzzle	1-21	16-23	N.P.				P
	6	feet	1-12	N.P.					P
North Country Cheviot	2	feet	1-20	9-26	N.P.				P
	1	feet	1-22	6-29	19	19	22	N.P.	P
South Country Cheviot	2	feet	--	--	--	--	--	25-27	C
	1	feet	1-17	9-30	17	17	N.P.		P
	1	feet	1-15	9-32	N.P.				P
Leicester	1	feet	--	--	--	--	--	26	C
	3	feet	1-11	7-35	15-20	15-27	28-34	N.P.	P
	2	feet	1-9	9-30	17-34	N.P.			P
	1	feet	1-16	N.P.					P
Lincoln	1	feet	--	--	--	--	--	21	C
Cotswald	1	feet	1-6	N.P.					D
Ryeland†	1	feet	1-15	N.P.					P
Group (b)									
Hampshire Down	1	feet	--	--	--	--	--	22	C
	2	feet	1-11	7-23	16-23	N.P.			P
Oxford Down	2	feet	1-15	11-30	25-28	27	N.P.		P
Dorset Horn	1	feet	1-21	18-24	N.P.				P
	1	muzzle	1-16	14-28	N.P.				P

ANIMAL	NUMBER OF INDIVIDUALS	SITE	PERIOD (DAYS) EGGS AND LARVAE	NYMPHS	ADULT MALE	ATTACHMENT PAIR	OVIGEROUS FEMALE	WHOLE CYCLE	SUMMARY*
Group (c)									
Rambouillet	2	feet	1-14	12-21	N.P.				P
Shropshire	1	feet	1-7	N.P.					P
Southdown	2	feet	1-5	N.P.					D
Horses									
Clydesdale	3	feet	--	--	--	--	--	21-25	C
Belgian	2	feet	--	--	--	--	--	22-25	C
Percheron	1	feet	1-16	12-23	N.P.				P
Suffolk	1	feet	1-14	9-29	21	21	N.P.		P
French Canadian	1	feet	1-24	19-28	23-32	N.P.			P
	2	feet	1-15	9-23	N.P.				P
Palomino	1	feet	1-24	14-24	N.P.				P
Arabian	1	feet	1-16	7-22	19	19	28	31	P
	2	feet	1-17	8-27	N.P.				P
Hunter	2	feet	1-13	9-29	N.P.				P
	1	feet	1-11	9-25	18	18	N.P.		P
American Saddle	1	feet	1-18	16-20	N.P.				P
Thoroughbred	1	feet	1-16	11-28	28	28	35	N.P.	P
	1	feet	1-17	11-31	20	23	N.P.		P
Standard Bred	1	feet	1-18	9-25	N.P.				P
French Coach	1	feet	1-7	7-31	16	16	24	27	C
Tennessee Walking	1	feet	1-19	17-37	27-39	N.P.			P
Hackney	2	feet	1-28	8-25	N.P.				P
Shetland Pony	2	feet	1-16	9-25	25-27	N.P.			P

the body and legs above the pastern. Heads only partly covered by wool.

(c) breeds essentially covered with wool.

The experiments were purposely biased in favour of the first group, and to a lesser extent the second, because of preliminary *in vitro* success on hair from the feet of Suffolk sheep compared with utter failure on wool from their bodies. Mites in the wool adhered to the globules of lanolin, preventing much of their motility and apparently causing their death by gradual starvation. Similar results occurred on material from the feet of the Shropshire and Southdown (Table XIX) in group (c). This was not true, however, on material from the Rambouillet, where prolongation of the nymphal stages occurred, nor does it have an absolute relation with natural infestations, some of which have occurred on the scrota (where there is generally much lanolin) of Negretti and Corriedale rams (see Natural Infestations). The explanation may lie in an increased tackiness of the lanolin under *in vitro* conditions at 35°C., a temperature that is probably a little higher than that in the wool on the host.

Complete development occurred *in vitro* on epidermal material from the feet of an individual in each breed of Suffolk, Leicester, South Country Cheviot, and Lincoln, but premature death occurred on material from other individuals from the first three of these breeds. The complete cycle

occurred on material from only one individual (a Hampshire Down) in group (b), and failed to produce mature mites on material from four other individuals among the three breeds in this group. These data suggest considerable variation in susceptibility between individuals irrespective of breed insofar as groups (a) and (b) are concerned, and together with what is known on natural infestations, indicate that sheep are less suitable hosts for C. caprae than domestic cattle.

Material from 15 horse breeds was tested (Table XIX). C. caprae completed its cycle on only four of these, two of which were draft breeds (Clydesdale and Belgian). The third breed, a French Coach, is rare in Canada, and mites on material from the fourth breed (Arabian) showed prolonged development on three individuals but completed the cycle on one of these even though it took 31 days.

Taken as a whole, the different breeds of cattle appear to be more suitable for the survival of C. caprae than the breeds of sheep and horses. Too few goats of purebred stock were available to justify a generalization regarding them, but the scant results listed in Table XIX and the fact that the life cycle was completed on material from all six individuals tested that were of mixed breeding, together with the natural infestations, suggest that goats may be more suitable hosts than sheep or horses. It seems likely from the results on material from both wild and

domestic ungulates that the domestic cow is the most natural host species, and is probably the host primarily responsible for the current cosmopolitan distribution of the parasite.

Some survival of C. caprae has occurred on epidermal material from a few unrelated animals. Prolongation of the larval and nymphal stages (up to 18 days) occurred on epidermic debris from three guinea pigs, but on material from a fourth, one ovigerous female developed, lived six days and produced two eggs, completing the life cycle in 32 days. Observations on material from domestic rabbits are included elsewhere in this report. No growth occurred on epidermic debris from man, swine, dog, cat, Little brown bat (Myotis lucifugus), Bumble bee (Bombus sp.) or House fly (Musca domestica). Nor did mites survive on debris from the bodies of domestic chickens, but larvae lived for prolonged periods up to 19 days on material from the shank of three breeds (Barred Plymouth Rock, Rhode Island Red, Buff Orpington) as well as for periods up to 17 days on similar material from a Black duck (Anas rubripes), Ruffed grouse (Bonasa umbellus) and Domestic turkey. On the last host, the larvae transformed into protonymphs that lived up to 15 days. Clearly some of the nutritional requirements of C. caprae appear to occur on various animals.

It is now necessary to return to the taxonomic problem that underlies this communication. Since variation in susceptibility is referable to the individual rather than

the species of ungulate, it seems to the present writer that it would be more realistic to regard the *in vitro* early death of *C. caprae* on material from a Barbary sheep (Table XVIII), in contrast with the natural infestation observed on another individual of this species and named *C. bovis ammotragi* by Railliet and Mouquet (1919), as an example of individual differences in susceptibility rather than maintaining the mite as a distinct parasite. The same argument is applicable to the *in vitro* results on material from a guanaco (Table X) and the natural infestation observed on this host by Hirst (1922). Two other reports require special comment. Apparently Gurlt (in Gerlach, 1857) observed a chorioptic mite from an elephant, although no details were recorded. Elephants become infested with the burrowing sarcoptic mite, but it is difficult to imagine how an elephant's hide would be suitable for maintaining a surface-feeding mite. Adult elephants are, of course, hairless. An immature Indian elephant (*Elephas maximus*) with some hair was scraped in the present study for the purpose of collecting hair and debris for attempts to rear chorioptic mites *in vitro*. No scurf, however, could be collected, making it impossible to conduct the experiment.

In 1874, Zürn found canker mites in a rabbit's ear of which he said "...ich nun nicht als Dermatophagen (Chorioptes) ansprechen konnte, sondern die zur Gattung Dermatokoptes (Psoroptes) gehörten...". Since this was in

an addendum to a paper, the author may have written it in haste and in so doing inadvertently interchanged Dermatophagus (Chorioptes) and Dermatokoptes (Psoroptes) when attempting to report dermatophagic (chorioptic) mites for the first time from the rabbit. Zürn did not give a specific name to the new mite, although Railliet (1893) and other subsequent authors gave him credit for naming it cuniculi. The matter is confused further, since Zürn went on to state that the new mite was not essentially different from Dermatokoptes communis (Psoroptes communis), the common ear mite of rabbits. Additional error is possible since the ear canker mite of carnivores (dog, cat, fox and ferret), that we know now as Otodectes cynotis, was at the time of Zürn considered to be a dermatophagic (chorioptic) mite. Therefore, it is at least possible that Zürn, according to the current classification, had observed otodectic and not chorioptic mites. Experimental evidence in the present study shed no light on a possible truism. Otodectic mites from the ear of a dog were maintained in vitro using the same method employed for Chorioptes, except that the hair and debris were from the inner ear surface of the infested dog. Eggs from this culture were placed with hair and debris taken from inside the pinnae of four rabbits, but the larvae that emerged died from apparent starvation within five days. On the other hand, some chorioptic mites from the cow did complete their life cycle in vitro in 27 days on rabbit ear debris -- but only on the twenty-first trial; the other

trials having shown prolonged development of the larval and nymphal stages (up to 30 days), and died before reaching maturity. On the basis of the original report and experimental data, it seems possible that Zürn did observe chorioptic mites in the ear of a rabbit, but it might be best to hold this record -- as well as Gurlt's report of chorioptic mites on an elephant -- in abeyance until additional observations are made from these hosts.

This author is of the opinion that the chorioptic mites reported by others from the guanaco, Barbary sheep, and possibly the rabbit and elephant, and, with one exception, given a distinct name, are really C. caprae. Another species, C. texanus, described by Hirst (1924) from the domestic goat is maintained as being valid. Hirst's description was sufficiently short for the significant section in it to be repeated here in toto. He wrote: " male with the flattened blade-like hairs on the abdominal (opisthosomal) lobes very much narrower than in (Chorioptes caprae). Outermost hair on each lobe also very different, being quite short and fine, whereas in (C. caprae) this hair is very long and thickened basally." Hirst examined "a few specimens...", ruling out the possibility of an anomaly, a phenomenon which does sometimes occur in this genus (Fig. 37). Measurements were given as 260 u long (with the gnathosoma) and 185 u wide for the adult male. The ovigerous female measured 298 u x 205 u, and was morphologically identical with that of C. caprae. Clearly two species of Chorioptes

are being recognized -- C. caprae (Delafond and Bourguignon, 1857-58) Gervais and Van Beneden, 1859* and C. texanus Hirst, 1924.

DISCUSSION

The synonymy of 7 of the 8 species and subspecies of Chorioptes with C. caprae may epitomize what can be done with at least some of the mange mites in other genera. Radford (1950) lists 27 species of Demodex, 18 species of Sarcoptes, three species of Notoedres, six species of Psoroptes, and Baker and Wharton (1952) state that there are four subspecies of Otodectes. At the present time, each of these 58 species or subspecies is considered to be virtually host specific, physiologically different, but morphologically the same or at least similar. It seems unreasonable to the present writer that all 28 processes of speciation produced the same kind of result. Physiologically distinct parasites with no or only slight morphological differences do, of course, occur. There are the two strains of Ascaris lumbricoides in man and swine, Syngamus trachea in the domestic chicken and some wild birds including the American robin (Turdus migratorius), and possibly the head

* Specimens from the present study have been deposited in the British Museum of Natural History where there is also the holotype of C. texanus.

and body louse (Pediculus humanus) of man. In Chorioptes, observed differences seem to be referable, not to the mite or the species of host, but to the susceptibility of the individual. It seems likely, therefore, that what has been done for Chorioptes may be true for other mange mites with the probable result that many of the recognized species will fall into synonymy. Herein lies one possible explanation for the apparent inability of former students to transfer chorioptic mites from one host species to another. The error probably lay in the unconscious choice of an unsuitable individual. Insofar as C. caprae is concerned, and this may also apply someday to other mange mites, knowledge of the non-specificity and life history has immediate application in suggestions for changes in the control measures now used in Canada and other countries. This will be dealt with elsewhere.

Most of the foregoing experiments were carried out in vitro. It is desirable therefore to estimate the relation between the in vitro culture method with possible or real natural infestations. In cattle there was a direct relation. Mites were readily cultured at 35°C. and 80% R.H. on epidermic debris and hair from various cattle breeds with natural infestations. This was also true for goats of mixed breeding, and for Clydesdale and Belgian horses. However, a Percheron horse was found with a few mites on its pasterns,

but epidermal material from the same sites would not support survival *in vitro* beyond that of nymphs (Table XIX). Prolongation of the larval and nymphal stages was observed in this instance. Similar prolongation and premature death occurred *in vitro* on epidermal material from 6 of 8 Suffolk sheep, although each was infested naturally. These results suggest that the *in vitro* culture method is probably not perfectly suitable for the mites. This is also borne out since the mites, although they can be maintained for many months by this method, could not, it would seem, be perpetuated *in vitro* indefinitely. These results in turn suggest that the *in vitro* prolongation, that was observed on some of the cervids, bovids and equids, could possibly reflect potential natural infestations in nature in addition to those individuals which provided epidermal material suitable for completion of the life cycle. The prolongation itself on epidermal material from different sources in a constant environment suggests that feeding influences the period required for completion of a stage in the life cycle of the mite. It would seem that much of the variation even on epidermal material from the domestic cow is attributable to differences in feeding.

Because of the suitability of epidermic debris from a variety of mammals in different families and even orders for the *in vitro* rearing of *C. caprae*, it is impossible

to conjecture on a possible geological age of the parasite from its hostal relations. No sylvatic infestations of C. caprae have been observed, but as more mammals become domesticated and important agriculturally, chorioptic mites may acquire veterinary importance on additional ungulates. Potential animals in this category are the reindeer in Lapland and the northwestern parts of North America, deer in British Columbia and elsewhere, llamas in South America, zebus and Indian water buffaloes in Asia, and the eland in Africa. The geographical location of the hosts, or their habits, may influence the size of a potential mite population. This will become apparent in the following section which includes observations on the effects of extrinsic factors on the mites.

IV. ON THE SUMMER DISAPPEARANCE OF CHORIOPTIC MANGE MITES

INTRODUCTION

It has been established by others and also by the present writer in the first part of this study that the numbers of C. caprae become greatly reduced on, and sometimes virtually eliminated from, cattle on pasture during summer. Cattle kept indoors in stanchions, however, maintained large general infestations. The current study was designed to determine the reason(s) for the former phenomenon. A number of theoretical possibilities may be conjured up as possible explanations, some of which are presented herewith:

(a) Moulting hair and the mechanical effect of desquamation which, when shed, could simply carry off the mites.

(b) Rubbing and licking (auto-grooming) by the animals.

(c) Removal or destruction by skin secretions, or physiological changes in the skin that might modify conditions to such an extent as to be detrimental to an animalcule the size of a mite.

(d) Extrinsic factors, such as rain, changes in temperature, humidity and exposure to direct sunlight.

(e) Intraspecific factors.

RESULTS

Moulting and normal desquamation will be dealt with rationally rather than experimentally. According to Duerden and Whitnall (1930), shedding of hair by cattle, at least in South Africa where the experiments were conducted, is in progress throughout the year. In our climate, shedding is not a conspicuous process on animals that have been in barns during winter, and the hair never mats or falls out in irregular patches ("cotting") as it does on northern breeds of domestic sheep, wild sheep or goats, the camel, or musk-ox. Nothing definite can be said about the possible effect of desquamation on the disappearance of mites. However, since moulting and desquamation are probably fairly constant processes, it is being assumed that as many mites would be lost by this means in winter as in summer.

Vigorous rubbing and licking generally occur when animals, whether infested or not, are on pasture for the first time in spring. Snowball (1956) observed that licking contributes to the reduction of the numbers of the tick, Boophilus microplus, on cattle, but these are much larger creatures than C. caprae and are probably affected directly by the rasping of the tongue. Cattle in stanchions in winter are prohibited from auto-grooming except for regions on the front quarters. The actual area that a cow in a non-rotating stanchion can lick is shown in Fig. 67. Three animals maintained under these conditions had general mite

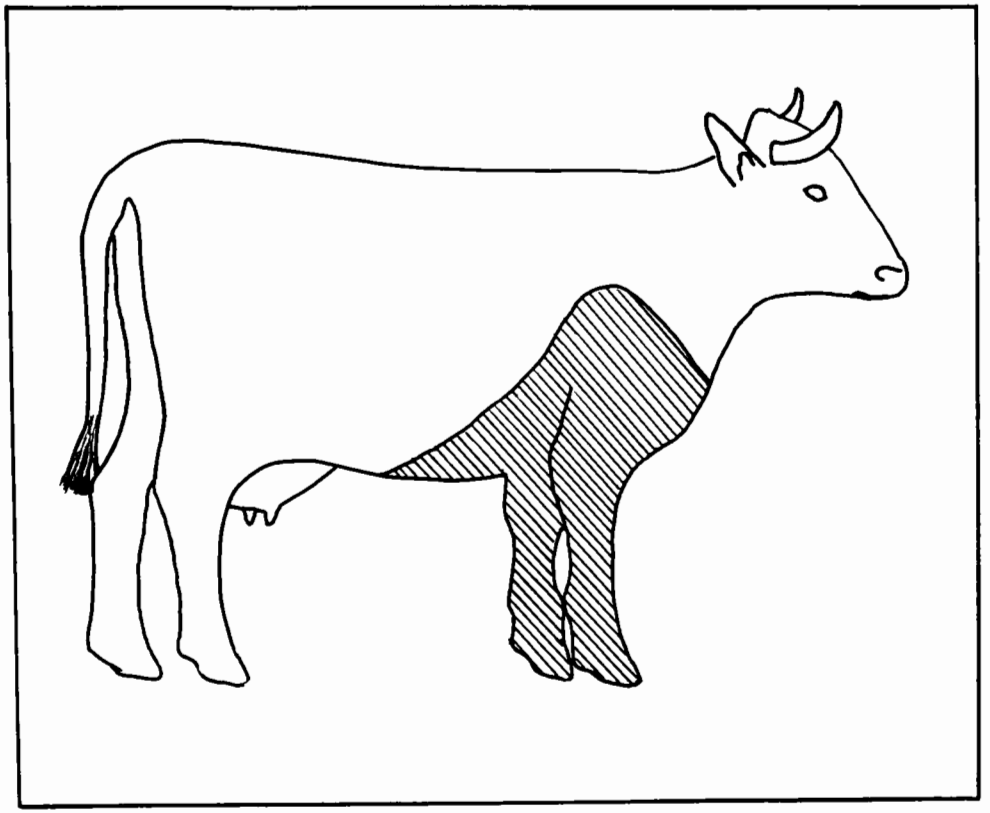


Fig. 67. Area that a cow can lick when maintained in a non-rotating stanchion.

infestations. Scrapings were made from the licked shoulder areas and the non-licked areas contiguous with them. Mites were observed from both regions and there were fewer mites in the licked areas, but probably no fewer than would be expected on a more anterior part of the body. The animals also licked their front feet, and these were often heavily infested. Auto-grooming by animals in stanchions does not appear, therefore, to be excessively, if at all, detrimental to the mite population.

This same problem was approached in summer in conjunction with determination of the effect of extrinsic factors on the mites. Two cows with general mite infestations were maintained individually in non-shaded pastures surrounded by electric fences. Each animal was allowed complete freedom within its pasture, but lateral movements of the head were prevented by means of a slat-board collar. This prevented licking; the electric fence rubbing. Cattle do not roll. Vertical head movement was not inhibited by the collar so that the beast could feed normally. One animal (#1 in Table XX) had been on pasture for only seven days (June 7 to 14, 1956) when it was no longer possible to find mites on its torso, including the base of the tail. Mites persisted, however, on the lower hind legs. After two weeks (June 6 to 19, 1956) on pasture, no mites were found on the torso or base of the tail of the second animal (#2 in Table XX) with the exception of a single

TABLE XX

Period of Disappearance of Mites from Different Sites on Cattle and the Subsequent Suitability of Epidermal Material from those Sites for Rearing Mites in Vitro

ANIMAL NUMBER	SURFACE AREA	PERIOD FOR DISAPPEARANCE OF MITES (DAYS)	SUBSEQUENT PERIOD FOR IN VITRO LIFE CYCLE (DAYS)
1	middle back	7	21
(isolated)	base of tail	7	21;26
	buttocks	14	21
	hind foot	positive throughout	20
2	middle back	13+	--
(isolated)	base of tail	13	21
	buttocks	76	--
	feet	76	19
3	base of tail	7	22
(in herd)	buttocks	98	24
4	buttocks	62	23
5	base of tail	31	--
	buttocks	31	23
6	base of tail	7	26
7	base of tail	45	24
	buttocks	37	--
8	buttocks	7	25
9	buttocks	40	--
10	buttocks	positive throughout	23

mite located in the middle of the back on the thirty-third day. Mites persisted from the escutcheon to the feet of this animal from June 6 to August 21, but in chronologically decreasing intensity. After August 21, no mites were ever located anywhere on this individual. Lesions that had persisted at the hocks since the animal was placed on pasture disappeared by August 30. On these two animals, the mites disappeared in spite of the fact that the animals could not auto-groom. This does not necessarily show that auto-grooming would not remove mites, but other factors, either extrinsic, physiological or intraspecific, seem more impressive.

Could physiological changes in the skin be detrimental to the mites? It will be remembered that most cattle have a fairly sudden change in the kind and sometimes quality of feed when first placed on a pasture in spring. This may have some effect presumably on the skin. More extensive sweating is another possible factor among frolicking animals that are outdoors. Kelly (in Norris, 1947) stated that European breeds of cattle have almost lost the power of sweating. The Holstein-Freisian cattle in the present experiments did some sweating, but possible physical drowning of the mites by this medium did not seem significant. The products of sweat would be collected with the epidermic debris and hair in the following experiments.

Eight cows in a Holstein-Freisian herd had mites on their feet, base of the tail, and/or buttocks prior to

being placed on pasture in spring. Other areas of the back were negative. The herd was maintained on a typical eastern Canadian pasture with available shade trees. Mites on these cattle were exposed to possible intraspecific factors as well as auto-grooming and typical extrinsic factors. (Typical, since the animals were not obliged to remain in direct sunlight as were the two previous animals corralled individually within electric fences.) After the animals were permanently on pasture (except for milking purposes), material from the tail base and buttocks was examined individually for mites every few days. Table II (animals #3 to 9 incl.) shows that the period necessary for the disappearance of mites from these sites on all but one animal varied between 7 to 45 days for the tail base and 7 and 98 days for the buttocks. When the hair and epidermic debris were first found negative, they were placed in a vial with eggs that had been collected from the in vitro culture vials. The vial was then held under the in vitro conditions suitable for culturing C. caprae, and observations were made on the development of the mites emergent from the eggs. Table XX shows that in all cases tested, the life cycle was completed under these conditions in the usual three week period established previously for naturally infested epidermal material collected in winter. This same period was also necessary for the two control areas (on animals #1 and 10 in

Table XX) that remained positive throughout the summer. It seems likely, therefore, that any physiological change that may have taken place in the skin, hair or epidermic debris of the cows was not significant insofar as C. caprae was concerned.

Two of the original theoretical possibilities remain -- the effect of extrinsic and intraspecific factors. Water, or the effect of rain, will be the first extrinsic factor discussed. Some relevant experiments were carried out in vitro. A total of 251 eggs (four trials) were placed on filter paper made wet with water and maintained in vitro at 35° C. and 80% R.H.. Five eggs failed to hatch, whereas larvae emerged from all control eggs that had been held under similar conditions on dry filter paper. Two exposures of water 24 hours apart under in vitro conditions apparently prevented a larger percentage of eggs from hatching. In one lot, 54 of 200 eggs failed to hatch, and in another 120 of 207 eggs did not hatch. Observations on the host using isolation unit #2 showed that a single or double application of water prevented some eggs from hatching (27 of 169 eggs and 12 of 149 eggs that had been exposed once, and 10 of 239 eggs and 14 of 235 eggs that had been exposed twice), but not nearly the numbers observed in vitro. Water alone, therefore, that is in an environment suitable for its evaporation, prevents some eggs from hatching. Additionally, water was

sprayed on a total of 122 eggs (four trials) that were kept continuously wet by changing the *in vitro* environment to 100% R.H. and 35° C.. None of these eggs hatched. Continuous soaking is therefore lethal.

The effect of water on quiescent mites was observed also. Most, but not all, survived one exposure of water under *in vitro* conditions. Two exposures of water 20 hours apart, however, killed all but 3 of 61 quiescent mites in three *in vitro* trials.

The effect of water on natural infestations on the host was determined (a) following a rainstorm, and (b) on members of a positive herd that walked across a river with water up to the dewlap four times a day to and from milking. In the first instance, the number of mites seemed to be about the same both before and after the storm. The cattle that crossed the river each day maintained mites on their feet for about as long as cattle in other herds on dry ground. The infestation within the herd persisted from one year to the next. Because of these *in vitro* and *in vivo* observations, one cannot ignore the effects of rain or water, but extensive permanent damage to the mite population by these factors seems unlikely, except perhaps where its effect is continuous such as might occur in tropical rain forests, or on animals that wallow in mud and water. Indian water buffalo do this in the rice paddies of Asia. This behaviour would probably prevent this species from maintaining an infestation even

though at least some individuals in the species appear to be physiologically suitable (Table XVIII).

Some effects of temperature were examined. As a preface to these observations, it is noteworthy that Galuzo (1943) observed that the tick Dermacentor sp. on sheep in Russia infested the back of the host at night, and migrated to the abdomen and thorax during the day in the heat of the sun. He stated also that larvae of the tick Hyalomma detritum, which infest cattle in October and November, attached themselves to that part of the body most exposed to the sun, while the adults, which occur in June and July, attached themselves to the underparts.

For the current experiment, the two cows maintained within the electric fences were utilized, together with four other cows in a herd. By the use of a calibrated contact pyrometer, skin temperature determinations were made in the noonday sun (1 P.M., E.S.T.) on the warmest days of the 1956 summer near Montreal. It was a comparatively cool summer, and the air temperatures on these days ranged between 75° and 90°F., but were usually 80° to 85°F.. The atmospheric relative humidities ranged between 41 and 65% at 1 P.M., E.S.T. on the days that temperatures were recorded. Since these were bright sunny days, the relative humidities at other times of the day were usually higher than those at 1 P.M.. The recorded mean monthly relative humidities at 1 P.M. at nearby Dorval Airport were 64%, 60% and 56% for June, July and August respectively. Wind speeds, that might

have an effect on the rate of evaporation from the skin and a consequent cooling effect, were generally around 11 M.P.H.. The four animals in the herd, which had shade available, had surface (shoulder, middle back, tail base, and escutcheon) temperatures of 36° to 38.5° C. for two of them and 35° to 39.5° C. for the other two. Areas with white hair were generally about 0.5 C.° cooler than areas of black hair. These temperatures were higher than the 31° to 35° C. noted for these same areas when the animals were stanchioned in barns in winter. The two animals within the electric fences that were exposed to direct sunlight and other extrinsic factors had skin temperatures on the torso that ranged from 36° to as high as 43.5° C.. (No sunburn occurred.) The temperature of their feet never reached that maximum temperature, but ranged between 36° and 41.5° C.. Some cooling effect of the feet would be probable in pastures with long grass, particularly on damp ground. The torso surface temperatures were similar to those listed by Galuzo (1943) for cattle on pasture in Tadzihikistan and eastern Uzbekistan, U.S.S.R.. When the atmospheric temperature was 74° F., Galuzo observed that an animal in direct sunlight had a surface temperature of 43° C., whereas protection from the sun reduced the temperature to 36° C..

The skin temperatures observed in the current study were corroborated with some <u>in vitro</u> effects of these

temperatures on the mites under darkness at a few relative humidities. Conditions* maintained at a constant 43.5° C. (the highest skin temperature observed) with a relative humidity of 80% and complete darkness caused most mites to be moribund after eight hours. It killed some mites in that time interval, and all within 15 hours. A constant environment of 40° C., complete darkness, and 60% R.H. or 80% R.H. caused a continuous mite mortality from 3 to 10 days, at the end of which all mites were dead. The constant conditions carried out to date, together with the atmospheric relative humidities and skin temperatures, suggest that future studies for determination of the cause(s) for the summer reduction of the mite population should revolve around (a) the effects of relative humidities at various temperatures, and (b) the interrelationship between temperature, relative humidity, and light on mite survival.

Not a great deal can be said about intraspecific factors. One animal maintained continuously indoors for 20 months had developed a large general infestation. This animal was then transferred to a different barn and maintained by itself. The mites then began to disappear rather suddenly

* For these high temperature experiments it was necessary to replace the paraffin wax as shown in Fig. 1 with stainless steel plates elevated by legs and punched with holes of an appropriate size to support the glass vials. The sulphuric acid was replaced also with appropriate concentrations of potassium hydroxide or saturated salt solutions according to the data listed by Peterson (1953).

from the cow's body even though it was still indoors. At the end of six weeks, no mites could be found anywhere on the animal. The change of environment may have been only coincidental with some lethal factor. Other animals have been moved around without any noticable change in the size of the mite population. McEnerney (1953) observed, however, that changing an animal from one herd to another was sometimes associated with a reduction in the number of C. caprae. Fig. 2 of the present study, and to a lesser extent Fig. 1, demonstrate that animals in stanchions in winter may begin to loose their mites after March, which is about eight weeks before they are placed on pasture. These phenomena are difficult to explain. One possibility frequently conjured up in such situations is the development of a resistance by the host which had been developing over a period of time (acquired immunity). This seemed unlikely in the present case, though, since epidermic debris and hair from various sites on the cow in question maintained mites under the in vitro conditions that completed their life cycle in the usual three week period. Because of this, it would also seem untenable to suggest intraspecific competition for nutritive requirements. One cannot help wonder about the possibilities of the rapid disappearance being caused by an epizootic among the mites. This is possible insofar as the individual cow was concerned, but would not explain the decline in incidence in a herd during winter.

From the foregoing discussions it seems possible to rule out moulting, desquamation, auto-grooming and physiological skin changes as deleterious factors to a population of C. caprae. The value of an environmental "change" per se or intraspecific factors may be important. When cattle are on pasture, extrinsic factors by themselves appear to kill many C. caprae, but more observations are required pertinent to the effects of light, temperature and relative humidity before one or more factors can be singled out as limiting the numbers of C. caprae on cattle on pasture in summer. These same factors would probably be significant in killing many of the mites on hosts in tropical countries.

V. THE EFFECT OF LINDANE ON THE MITE, WITH COMMENTS ON THE PRESENT METHODS OF CONTROL

INTRODUCTION

A number of empirical observations have been made in various countries on the efficacy of lindane (99% pure gamma isomer of benzene hexachloride) against chorioptic mange on cattle (Steward, 1946; Goodwin and Schwardt, 1952; McEnerney, 1953; Pullin, 1956), horses (Steward, 1946; Seddon, 1951) and goats (Kemper et al., 1952). In Canada, a 0.046% lindane suspension is used routinely by the Health of Animals Division for the treatment of chorioptic mange. Two treatments are given 10 to 14 days apart. A third treatment may be carried out in severe cases. The premises are disinfected also. This procedure successfully controls the condition, but does not always eradicate it. However, lindane appears to be as effective as other drugs, and has the additional feature of being easily applied to the bodies of large animals, and, unlike other isomers of benzene hexachloride, is non-irritating to the eyes, nose, throat, and skin (Rohwer in Brown, 1951).

Throughout this report, it is essential for the reader to distinguish between simply the presence of mites on animals with or without mange, and the occurrence of disease or mange. Most authors have reported the

effectiveness of a drug on its capacity to cure mange and rid the host of mites from favoured areas of examination. McEnerney (1953) observed in New York state that a one spray treatment gave immediate relief and frequently removed signs of the disease for two to three months. Mange even appeared eradicated in some herds, since it was not seen in them during the rest of the season or the following year. A one treatment method was used for a while in Canada also, but had to be abandoned.

Studies have been made on the acute oral LD_{50} of lindane in laboratory animals, and the degree of toxicity by the skin-absorption route in various animals including cattle. A 1.5% lindane suspension sprayed on adult cattle kills them. A 0.05% suspension is toxic to two-week-old calves, but a 0.15% suspension is not harmful to calves 6 to 8 months of age, and a 0.25% suspension is entirely innocuous to adult cattle (Bushland et al., 1948; Lehman, 1950; Radeleff et al., 1955). Hence, the recommendation of a 0.046% suspension includes a good margin of safety for animals over eight months old. This concentration was arrived at on the basis of field trials carried out in various places in the United States (McEnerney, 1953). The interval between treatments was also determined arbitrarily. The actual toxicity to the mites was not determined. The in vitro culture method described herein made it possible to determine the effects of lindane on the mites under in vitro conditions.

It also provided a source of eggs and quiescent mites, as well as active stages, which could be transferred to isolation units on a cow, and, following exposure to lindane, be recovered and examined microscopically for determinations of drug efficiency.

RESULTS

Observations were made on the effect of lindane* on the eggs, quiescent stages, and active mites under both *in vitro* and *in vivo* conditions. *In vitro* tests were conducted by placing the mites in vials on filter paper made wet with 0.046% lindane suspension and maintained at 35° C. and 80% R.H.. Controls consisted of: (a) mites on dry filter paper, and (b) mites on filter paper made wet with tap water. The drug was rapidly fatal to all active mites. None of the 72 quiescent mites of various stages (four trials) emerged after exposure to lindane. Water alone apparently prevented the emergence of the occasional quiescent mite, while all on dry filter paper emerged successfully. Water alone also prevented the hatching of the occasional egg, and the drug was lethal to all eggs exposed to it (262 eggs in 20 trials). All control eggs hatched that were on dry filter paper. These observations show the effectiveness of a single exposure of lindane suspension against all stages of *C. caprae* under the *in*

*C-I-L 25% Lindane Wettable Powder.

vitro conditions. Additionally, filter paper made wet with lindane was allowed to dry, and then eggs were placed on it. All of these eggs hatched, demonstrating that lindane following drying does not prevent hatching of the eggs.

The toxicity of lindane suspension to *C. caprae* under *in vitro* conditions required corroboration with observations on the host. Sufficient observations have been made by others (see Introduction) to demonstrate that lindane is not so effective in the general treatment of the host. A number of possible explanations exist for this, one of which is the resistance of some stage in the life cycle of the mite to the effects of lindane suspension when applied to the host. To determine this, motile mites, quiescent mites or eggs were removed from the *in vitro* culture vials and placed on the clipped (not shaved) hide of an isolated and negative cow in a series of isolation units (#1). The area within the column of each unit was then sprayed with 0.046% lindane suspension using a hand atomizer. By way of control, mites were placed in units that were not sprayed with lindane. Units were removed after one day in the case of motile mites, after 2 or 3 days for quiescent mites, and after 4 to 7 days for eggs. After removal, the hair and debris under and around the column of the unit were shaved off and examined for mites under a stereoscopic microscope. The collected material was then incubated at 35° C. and 80% R.H. for any subsequent

hatch or emergence. Under the *in vivo* conditions, a single exposure of standard strength lindane appeared to be 100% lethal to motile mites, although the percentage recovery was low. Mites emerged, however, from some quiescent stages, and larvae hatched from eggs. Again, the percentage recovery was low. Table XXI shows this, and demonstrates also that not many more mites were recovered from the hair and debris removed from treated units than from untreated controls. It was impossible to know from these data, therefore, just how many quiescent mites and eggs escaped the effects of the drug. Hence, isolation unit #2 was designed. It was possible to examine this unit daily and recover virtually all the eggs or quiescent mites that were placed originally in the unit. Mites within this unit would be exposed to essentially the same physical environment as natural infestations on a cow, even though bolting silk separated the mites from actual contact with the cow's hide. It will be recalled that not all eggs or quiescent mites are attached to the hide anyway. This technique would be unsuitable, however, for use with drugs reputed to be effective only after interaction with the skin of the host. Mellanby *et al*. (1942) showed that sulphur ointment would not destroy sarcoptic mites of man when they were placed simply in the ointment, but it was effective when applied to the infested skin. Lindane is thought to have no such interaction. Indeed, the *in vitro* results showed that lindane can act directly on *C. caprae*.

TABLE XXI

Survival of Eggs and Quiescent Mites Exposed Once
to Standard Strength Lindane on a Cow in Isolation Unit #1

NUMBER OF UNITS	NUMBER OF EGGS PER UNIT RANGE	MEAN	TOTAL	NUMBER OF LARVAE RECOVERED PER UNIT RANGE	MEAN	TOTAL	PERCENTAGE
EXPER.							
16	123-473	282	4,506	0-7	2-	26	0.6
CONTROL							
7	50-293	186	1,302	1-20	6	41	3.1

	NUMBER OF QUIESCENT MITES			NUMBER OF EMERGENT MITES RECOVERED			
EXPER.							
8	10-36	22	175	0-6	2	15	8.6
CONTROL							
6	6-31	17	104	3-12	7	42	40.4

Over a thousand eggs were exposed in eight trials to standard strength lindane (0.046%) in isolation unit #2. Table XXII shows that most eggs were killed by one exposure of the drug, but 11.4% survived and produced larvae. Double strength lindane (0.092%) reduced the percentage hatch, but 1.7% of the eggs hatched even then. Some preliminary observations have been carried out using concentrations of lindane $2\frac{1}{4}$ and $2\frac{1}{2}$ times the standard strength, but some larvae hatched even from these eggs. No eggs hatched, however, at a concentration of 0.25% ($5\frac{1}{2}$ times standard strength), which is the maximum strength that is still innocuous to adult cattle. Table XXII shows that best results with weaker concentrations were obtained when eggs were exposed to standard strength lindane on two occasions 24 hours apart. Only 0.7% of these eggs hatched.

A number of quiescent mites were collected at random and also exposed to lindane in various ways. The results followed the same pattern observed for eggs. A single exposure to standard strength lindane was ineffective against 16.0% of the quiescent mites while a double exposure 24 hours apart was 100% effective. One exposure of double strength lindane was almost completely lethal -- only 1 of 127 mites emerged in 10 trials (Table XXII). Lindane, therefore, is more effective against quiescent mites than against eggs.

TABLE XXII

Survival of Eggs and Quiescent Mites Exposed to Different Strengths of Lindane on a Cow in Isolation Unit #2

NUMBER OF UNITS	NUMBER OF EGGS PER UNIT RANGE	MEAN	TOTAL	NUMBER OF LARVAE RECOVERED PER UNIT RANGE	MEAN	TOTAL	PERCENTAGE
One Exposure to Standard Strength							
8	95-197	140	1,116	0-44	16	128	11.4
Two Exposures to Standard Strength 24 Hours Apart							
11	114-312	188	2,070	0-10	1	14	0.7
One Exposure to Double Strength							
12	141-306	216	2,587	0-19	4	44	1.7
Dry Control							
2	160&196	--	356	--	--	354	99.7

	NUMBER OF QUIESCENT MITES			NUMBER OF EMERGENT MITES RECOVERED			
One Exposure to Standard Strength							
7	9-15	11	75	0-7	2	12	16.0
Two Exposures to Standard Strength 24 Hours Apart							
7	7-16	11	78	0	0	0	0
One Exposure to Double Strength							
10	7-27	13	127	0-1	0	1	0.8
Dry Control							
2	15&18	--	33	--	--	33	100.0

The Canadian recommendations for application of lindane state that the drug should be applied when warm. This may have been based on the belief that insecticides generally kill more quickly as the temperature rises. The availability of enough hot water on a farm for the treatment of a herd of cattle (about two gallons per animal), however, is not always realized. Therefore, our experiments were designed to ascertain the efficacy of lindane in water at room temperature, as described above, and also in warm water. The temperature decided on for the latter was 45° C.. This is probably a little warmer than that used routinely on farms, particularly following its passage through a spraying machine, Hence, any survival of C. caprae under the experimental conditions would, if anything, be expected to be even less than that experienced in practice. Only preliminary results are available at the present time. They show, contrary to what was anticipated, that a single exposure of standard strength lindane, a double exposure of standard strength, and a single exposure of double strength lindane at 45° C. permit as many quiescent mites to emerge, and eggs to hatch, as at a cooler temperature. If lindane is effective only as a wet drug, then, since a warm suspension would evaporate more quickly than a cool suspension, the wet drug would be in actual contact with the mites for a shorter period. The importance of actual contact with the drug was demonstrated in vitro at 35° C. and 80% R.H.

when mites were suspended in hair and epidermic debris on bolting silk in vials over a suspension of lindane. These mites were unaffected by the presence of the nearby drug. Dry, full strength, lindane powder sprinkled on eggs did not prevent them from hatching, even under *in vitro* conditions. Hence, direct contact with lindane suspension is necessary to kill the mites. And it is not unreasonable that the longer that wet lindane is in contact, the more effective it is. Regardless, the results suggest that the use of warm lindane suspension has no advantage over cool lindane suspension.

The preceding experimental results demonstrate why lindane is capable of controlling *C. caprae*, and why it is unsuitable under the usual conditions of application for eradication of the mite.

DISCUSSION

It is possible, judging from the above and other preliminary data, that a concentration of lindane suspension will be found below the minimum tolerance level for adult cattle that is lethal in one exposure to the active and quiescent mites as well as the eggs of *C. caprae*. Lindane is unsuitable for use on young calves, however, because even a standard strength suspension (0.046%) affects a few of them adversely (Radeleff *et al.*, 1955), and the drug at that concentration will not kill all *C. caprae*. A single

treatment method at a higher concentration would be useful in practice on adult animals only if lindane were not absorbed by the cow to an extent to either taint the meat or be secreted in the milk. Furman and Hoskins (1948) showed that benzene hexachloride was secreted in cow's milk when an animal was administered an oral dose at the rate of 40 mg./kg.. The milk contained approximately 5 ppm of lindane and smelled musty for about 10 days. On the other hand, Cuff (1949 et seq.) stated that lindane applied to livestock did not taint the meat. A higher concentration than that used at the present time may, therefore, be suitable for use as a one treatment method for eradication of C. caprae on adult beef cattle.

The experimental results showed that most eggs and all motile and quiescent mites were killed by a double exposure of standard strength lindane 24 hours apart. Therefore, as far as control of the mites is concerned, this procedure would be more effective than treating cattle at intervals of 10 to 14 days, as is now done. From observations on the life history of C. caprae, it is clear that any eggs which escaped the effects of the first lindane spraying would have hatched and could be quiescent larvae or even quiescent protonymphs at a second spraying 10 to 14 days later when some again would probably resist the effects of the drug. These would emerge subsequently and perpetuate the infestation. A third or more treatment would kill more

mites, but again it is likely that the infestation would be perpetuated by unaffected quiescent mites. Any quiescent pubescent female that escaped the effects of the drug would emerge into an ovigerous female, but it, however, would not lay eggs. This is so, since the drug (assuming thorough treatment) would have killed the active adult male in attachment with the quiescent pubescent female, and since the latter is not normally bred by the male until it is actually in the process of its final moult. It is also known that eggs are not laid parthenogenetically. Active ovigerous females would, therefore, probably occur following the spraying of the host, but these would die a normal death without reproducing. In practice, a 24 hour interval between treatments would not only be more effective against C. caprae, but would also be generally more convenient than one of 10 to 14 days. But this procedure should not be instigated on dairy herds until experiments have been conducted on (a) the possibility of a residual effect of lindane against C. caprae, and (b) the amount of lindane secreted in the milk of animals sprayed on two successive days.

On the basis of the foregoing studies, it would seem desirable to examine critically the whole approach to the control of chorioptic mites on farm animals. For purposes of diagnosis, the feet of all host species should be examined for mites even though the lesions frequently appear

on the buttocks of cattle and possibly the scrota of sheep. In an earlier section, the host specificity generally attributed to chorioptic mites was disproven. It was shown that the mite from the cow, goat, horse and sheep, known previously as C. bovis, C. caprae, C. equi and C. ovis respectively, are all the same species, and the name with priority is C. caprae. Because of the former belief in host specificity, the practice adopted throughout the world for treating farm stock infested with chorioptic mites has been to treat only the host species found infested. For example, a few cattle infested with the mites (or probably chorioptic mange) required that all cattle in the herd be treated in an attempt to eradicate the mite. Horses, sheep, and goats that may have been on the same premises, however, would have been ignored, unless, of course, they too showed lesions. The results of the current study show that all farm animals may well be infested with the same mite, although only one host species or none at all may be manifesting lesions. To effect an eradication, therefore, it is necessary to treat all mammalian livestock on the farm. On many premises, this would be a formidable task. If lindane were the drug employed and used in the same manner as it is today, the chances of eradicating the mites on a farm would be slim indeed. Besides these, the mites appear to be distributed more generally on many farms than is usually maintained. Hence, unbeknown to the owner,

the buying, selling and distribution of animals facilitates the spread and perpetuation of the mites. The economic importance seldom lies with the mites anyway, but rather with the mange sometimes associated with them. The degree and incidence of pathology is generally low and appears to revolve around a variety of factors that are not understood. If eradication of the mite is insisted on, the best time to approach the problem is in summer when the mite population is normally low. To the present writer, it would seem more realistic to treat only those animals showing lesions, and then perhaps only in the local areas where the lesions occur. This would probably remove or at least reduce the pathology. Persistance of the mites seems inevitable, but would be essentially insignificant on cattle that are pastured seasonally and maintained under good management throughout the year. A recommendation is therefore made to conduct field trials in winter in which cattle with lesions associated with C. caprae are the only animals in the herd treated locally with cool or warm lindane suspension.

SUMMARY AND CONTRIBUTION TO KNOWLEDGE

1. The pasterns, particularly those of the hind feet, are important sites of infestation of chorioptic mites on all hosts. On cattle, other regions over the entire body are sometimes infested, but these are less significant in the maintenance of the parasite.

2. Summer pasture conditions are necessary for a natural reduction in the number of mites on cattle, and associated with this are a decreased incidence and fewer sites of infestation.

3. A large and general infestation of the mite can be induced on cattle by stanchioning them continuously indoors in summer as well as the previous winter. The manifestation of lesions was also induced by this method.

4. Lesions are caused by something other than direct rasping of the skin by the chelicerae of the mites, but the mechanism remains unknown.

5. Chorioptic mites can be reared *in vitro* for some months on epidermic debris from the host at 35° C. and 80% R.H..

6. A single cycle of the mite consists of an egg, larva, protonymph, deutonymph and adult. (The last two stages in the female cycle are called the pubescent female and ovigerous female respectively.) Each stage is described. Each stage, with the exception of the larva, and of course the egg, shows sexual dimorphism.

7. Under the in vitro conditions, each immature stage but one usually persists from 3 to 5 days. The pubescent female, however, generally persists for 7 or 8 days. All motile stages feed actively. There is an obligatory quiescence between each motile stage which lasts about one day. The complete life cycle encompasses about three weeks, and the longevity of egg-laying ovigerous females may also be as long as three weeks. Non-laying females and adult males live up to 7 or 8 weeks.

8. The pubescent female is generally attached with the adult male by copulatory anal suckers during both the active and quiescent phases of the pubescent female stage (up to eight days). Copulation, however, does not occur during this long period of attachment, but takes place between the adult male and the ovigerous female at a precise moment during the female's final moult.

9. Eggs are not laid parthenogenetically. Bred ovigerous females, under the in vitro conditions, lay their eggs singly at the rate of about one a day for periods of 3 to 16 days. Females frequently return to common sites to oviposit. The period of embryonation after the egg is laid is usually four days. Oviposition is followed by a period of senescence that lasts from 1 to 5 days.

10. Chorioptic mites from five hosts (cow, horse, goat, sheep, and llama), the first four representing four species of Chorioptes (C. bovis, C. equi, C. caprae, and C. ovis), were shown (1) to survive in vitro on each others' epidermic debris and complete the life cycle in the standard three week period; (2) to cross-breed and produce fertile progeny in the second generation; (3) to display similar survival periods on some foreign epidermal material (three species of oxen, two equids and three camelids); (4) to display similar results on epidermal material from some antelopes, which, in the family Bovidae, link the oxen on the one hand to the sheep and goats on the other; (5) to transmit from one host species to another; and (6) to display no morphological differences. Because of these data, the four species above were reduced to synonymy and declared non-specific. The name with priority is C. caprae.

11. Chorioptic mites are potentially ubiquitous. The life cycle was completed *in vitro* on epidermal material from some, but not all, individuals of reindeer, wapiti, and white-tailed deer in Cervidae; impala, nyala, and eland among the antelopes; Indian water buffalo and zebu among the oxen; and the donkey and Grant's zebra in Equidae. Prolongation of the early developmental stages with premature death also occurred *in vitro* on epidermic debris from a wide variety of wild ungulates. Survival appeared to be related to the individual rather than the species. From these and other data, the three of the four remaining species or subspecies of *Chorioptes* were also synonymized with *C. caprae*. This leaves in the genus *C. caprae* (Delafond and Bourguignon, 1857-58) Gervais and Van Beneden, 1859 and *C. texanus* Hirst, 1924.

12. The susceptibility of different breeds of domestic stock was tested. The life cycle was completed *in vitro* on epidermal material from 12 of 14 cattle breeds, 2 of 3 goat breeds, 3 of 15 horse breeds, and 5 of 13 sheep breeds. Domestic cattle appear to be the important host species.

13. Experiments were conducted to ascertain why the chorioptic mite population becomes greatly reduced

on cattle on pasture in summer. The results showed that moulting, normal desquamation, auto-grooming (licking and rubbing), and physiological skin changes are not deleterious factors to a population of C. caprae. Extrinsic factors appear to be significant, and the possible importance of an environmental "change" per se and intraspecific factors cannot be ignored.

14. Lindane suspension (the acaricide usually used when treating infested animals) used at the recommended strength is not 100% lethal in a single exposure to all the eggs and quiescent mites on the host. Some eggs even survived an additional exposure 24 hours later, but the second exposure was lethal to all quiescent mites.

ACKNOWLEDGMENTS

Prof. T. W. M. Cameron, Head, Department of Parasitology, kindly made himself available for consultation at all times. His criticisms and advice are much appreciated. Dr. Chas. A. Mitchell, Chief, Animal Pathology Division, Canada Department of Agriculture, indicated to the writer the value of a study on chorioptic mange mites, and made it possible to conduct the research as a divisional project at the Montreal Area Branch Laboratory at Macdonald College. His interest and encouragement are appreciated. I am grateful also to Dr. J. W. Pullin who assisted in various ways concordant with his position as Officer-In-Charge of the above laboratory. It is a pleasure to acknowledge the enthusiastic assistance of Messrs. D. V. Conlon and J. Mackie. Mr. W. Goulet ably maintained the experimental animals. Material was obtained from various ungulates through the courtesy of numerous farmers, veterinary practitioners, and officials of the London Zoological Society; New York Zoological Society; Société Zoologique de Granby; Jardin Zoologique de Québec; Smithsonian Institution, National Zoological Park, Washington; the Chicago Zoological Society; and the Institute of Northern Agricultural Research, Tunturi, Vermont. Persons who assisted in various ways were Prof. A. R. Ness and Mr. J. Houston, Macdonald College; Dr. G. Owen Evans,

British Museum of Natural History; Dr. G. W. Wharton, University of Maryland; Dr. E. W. Baker, United States National Museum; and Dr. A. M. Fallis and Dr. R. S. Freeman, Ontario Research Foundation.

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