. ON THE IMMATURE AND ADULT STAGES
OF *NOTOEDRES ALEPIS* (Railliet & Lucet, 1893) AND ITS EFFECT
ON THE SKIN OF THE RAT

BY

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INTRODUCTION.

The purpose of this paper is to describe the immature stages, including the protonymph, which has not been described previously, and adults of *Notoedres alepis* and their effect on the skin of the host. Differences between *N. alepis* and *N. muris* are given, for there is a certain amount of confusion in the literature.

The females was originally described by RAILLIET and LUCET (1893). Other descriptions of the male and female were given by TIRABOSCHI (1904), WARBURTON (1920) and OUDEMANS (1926).

N. alepis is found on the ears and genitalia of rats. The mites invade the outer epidermal layers of the skin and give rise to a characteristic mange. GORDON, UNSWORTH and SEATON (1943) worked out the life history of *Notoedres* sp. and gave methods of control of the mite. Control has also been investigated by GMEINER (1906), ELMES (1945), TAYLOR (1945) and OSBORNE (1947).

Anatomy of the Mite.

Female (figs 1 and 2).

The female is globular, white and 405 μ long and 355 μ wide (an average of ten individuals, the width being taken at the level of the third and fourth pair of legs). There is a great deal of variation in the size of the females ; small animals of 332 μ by 274 μ being found, while a great many reached a length of 433 μ and a width of 390 μ, with newly moulted females at one end of the range and gravid females at the other.

The propodosomal shield is smooth, rectangular, bears one pair of setae and partly overhangs the gnathosoma.

There is no hysterosomal shield or transverse groove. The cuticle is finely striated dorsally, the pattern consisting of undulating transverse lines over most of the cuticle and approximately concentric circles posteriorly. There is a clear area or " plaque " round the posterior dorsal anus.
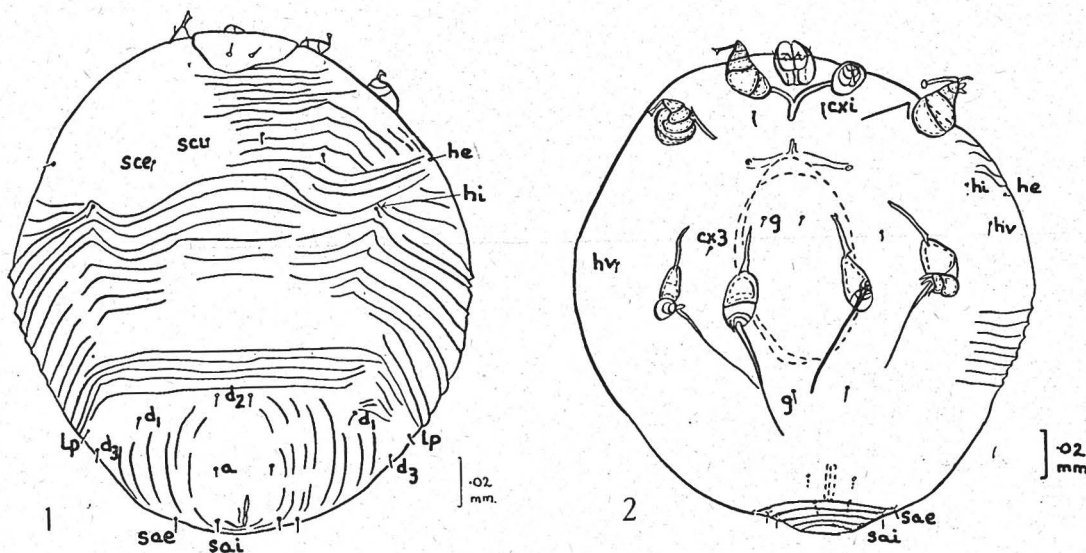

FIG. I. — *N. alepis*, dorsal view of female. Setae of idiosoma ; d_1 to d_3 (dorsals) ; he, hi (external and internal humeral) ; lp (lateral posterior) ; sa e, sa i (external and internal sacral) ; sc e, sc i (external and internal scapular). — FIG. 2. — *N. alepis*, ventral view of female. Setae of idiosoma ; cx (coxal) ; g (genital) ; hv (ventral humeral).

In a ventral view, some indication of transverse striations is seen laterally and there is another small area of transverse striations at the posterior edge of the body. At the lateral edges, these striations are seen as fine cuticular uprisings.

The apodemes of legs I are joined to give a Y-shaped structure, and thus, a small sternum. The apodemes of legs II are free and each is Y-shaped, the prongs encircling the trochanter base and affording extra muscle attachment areas.

The genital aperture is transverse and has the two anterior lips corresponding in position to the paired longitudinal folds of free-living Tyroglyphidae. On the internal surface of the lips are the " genital suckers " or sense organs.

The setae of the idiosoma are short, smooth and simple, the posterior ones having rather blunt tips. The dorsal setae are arranged as in figure I. The dorsals are found about the posterior " plaque ", due to the elongation of the central part of the body. The d_2 setae are towards the centre and are close together as is usual, the d_1 and d_2 setae completing the half circle either side. In the larva and proto-nymph stages, the d_1 is anterior to the d_2 and the reason for the naming used here is more apparent ; this arrangement is lost in the female because of the more globular shape of the animal. There are no d_4 setae : sa e could have bee designatend

d_4 in the female except that this seta is present in the larva (d_4 is generally absent) and is in line with the sa i seta : this pair of setae is, therefore called sa e here. A small lp present.

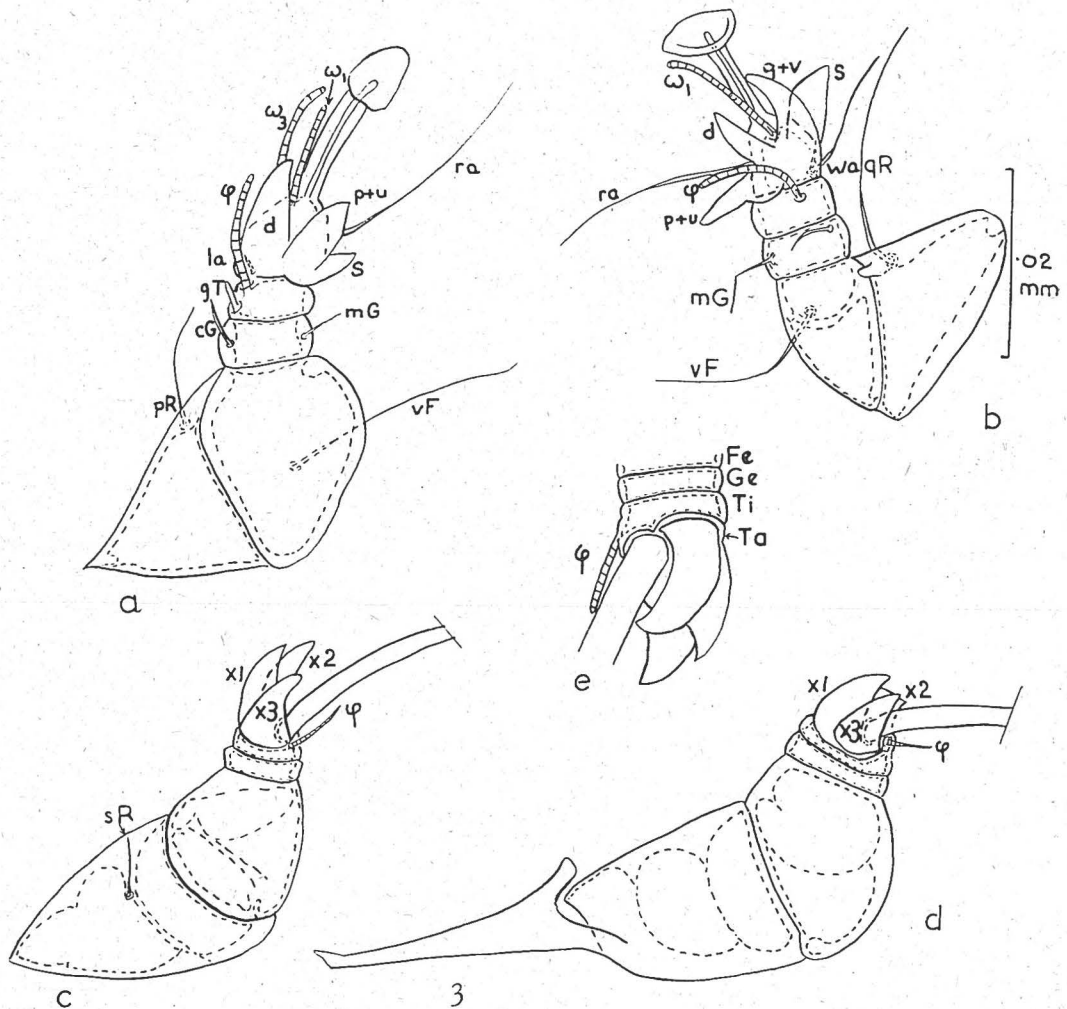The humerals are grouped laterally about one third of the way along the body,

FIG. 3. — *N. alepis*, a) dorsal view of right leg I of female ; b) dorsal view of left leg II ; c) dorsal view of right leg III ; d) dorsal view of right leg IV ; e) end-on view of tarsus of leg III. ω_1, ω_3, φ, solenidia ; cG, gT, la, mG, pR, ra, sR, vF, wa setae ; d, p + u, q + v, s, xl-3 spines ; Ta tarsus, Ti tibia, Ge genu, Fe femur, (segments of the leg).

there are two dorsal setae (hi and he) and one ventral member (hv). There are the usual two scapulars (sc i and sc e), these are displaced somewhat, again because of the shape of the body, but are seen more typically in the young stages.

The sa i and sa e setae are seen near the posterior edge of the idiosoma dorsally,

it is as if the posterior part of the animal had been rolled over, this is also suggested by the dorsal position of the anus.

There are a few setae on the ventral surface ; the first and third coxal setae are present, there is, too, the humeral member. Only two pairs of genital setae are present and these are found just posterior to the genital aperture, and behind legs IV.

The gnathosoma is of the normal sarcoptiform pattern, consisting of simple chelate chelicerae overhanging the fused pedipalps and is used for chewing the superficial skin layers of the host in burrow and pocket formation.

All the legs are very short ; legs I and II are unmodified, consist of five segments and end in a small long-stalked sucker ; they project beyond the edge of the body. Legs III and IV also consist of five segments, the femur and trochanter are large and give the characteristic bell shape to the leg (fig. 3 d) reminiscent of the specialised legs III and IV of the female of *Myocoptes*. They do not extend beyond the edge of the body ; in the gravid female, they form a line approximately half way along the ventral body surface.

There is considerable shortening in the length of the leg segments, this is especially apparent in the tibia, tarsus and genu. There is too, a reduction in the number of setae and solenidia, as occurs in other parasitic mites. The arrangement, however, still closely follows that for *Otodectes* (GRANDJEAN, 1937).

Leg I (fig. 3 a) differs from that of free-living Tyroglyphidae in a number of respects. ω_2 is missing, as it is in *Dermatophagoides* sp. which may be parasitic or free-living. γ is somewhat longer than that of leg II and is blunt-ended, in free-living forms it ends in a point. σ is not represented, there are generally two in free-living acarids, although some free-living forms, for example species of *Schweibea*, only have one and *Myocoptes* had one. ω_1 is sub-terminal on the dorsal surface of the tarsus, in many parasitic acarid mites it is terminal, for example in *Myocoptes*, *Otodectes* and *Dermatophagoides*.

There is a spine in the usual d position, so this has been designated d : p and u have probably fused to give one of the lateral terminal spines (external), and q and v are represented by the other lateral terminal spine (internal) : s is ventral. The remaining setae of leg I are arranged as in *Otodectes* except that e, f, aa and ba are missing from the tarsus. The chaetotaxy of leg II (fig. 3 b) is essentially as that of leg I : ω_1 is on the anterior half of the tarsus, is longer than ω_1 of leg I and ends in a blunt hook.

Legs III and IV are similar (figs 3 c, d) and show characteristic patterning of their chitin, especially in the femur and trochanter regions. This is seen in other parasitic mites and may be a way of saving chitin without loss of muscle attachment areas or general strength. The three terminal segments are again foreshortened in a proximal-distal direction. There are three spines present surrounding the long seta, and named x1, x2, and x3 after GRANDJEAN (1938) ; x3 of leg IV is rather low. There is one solenidion present, γ on the tibia, and end-on view of this segment is shown by fig. 3 e.

Male (figs 4, 5).

A great deal of searching produced only one whole male, and this was found at the edge of an ear lesion. It was 200 μ long and 130 μ wide (the width being taken just posterior to the second pair of legs, this being the widest part). It is more ovoid than the female and more heavily sclerotised.
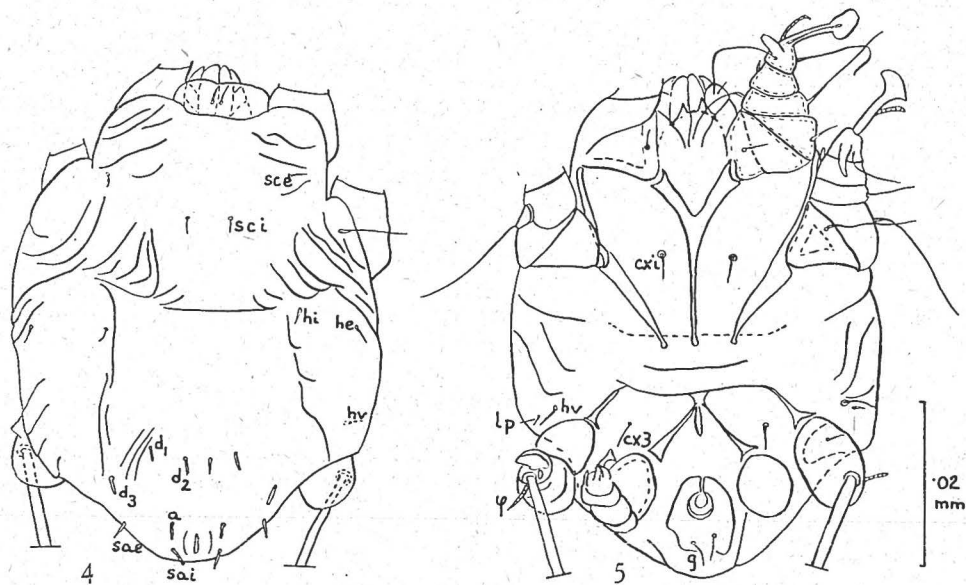

FIG. 4. — *N. alepis*, dorsal view of male. Setae of idiosoma : a (anal), d_1 to d_3, he, hi, hv, sa e, sa i, sc e, sc i. — FIG. 5. *N. alepis*, ventral view of male. Setae of idiosoma ; cxi, cx3, g, hv, lp.

The striations of the idiosoma, as seen in dorsal view, are more coarse and more complicated than in the female ; there is, too, a very short median transverse groove. Only two or three lateral body striations are seen in a ventral view.

The apodemes are strong and Y-shaped, the prongs of the Y embracing the coxa of the respective leg. The apodemes of legs I are joined to give a long slender sternum. Those of legs II are separate and also long, giving the characteristic long-waisted appearance of the male. Posteriorly the apodemes of legs III and IV join up to a transverse strut. This strut also sends a short branch towards the penis and this may be the seat of attachment of errector peni muscles.

The penis is found between legs IV and is bell-shaped and the genital folds are elongate, the whole structure being as big as the base of the legs.

The setae of the idiosoma generally are as for the female ; they are, however, stouter and the dorsal setae tend to be blunt-ended. There is no posterior flap or setal decoration so common in the male, the only setae projecting beyond the edge being the sa i and sa e, and the long setae of the third pair of legs.

The gnathosoma is as in the female and there is a fine protective propodosomal shield overhanging it.

The legs are five segmented as in the female, legs III and IV being posterior in position, due to the shortness of the body, and are capable of extension beyond the posterior edge. Legs I and II end in stalked suckers, legs III in a long tapering seta, as for the female ; leg IV ends in a sucker and bears no tapering seta.
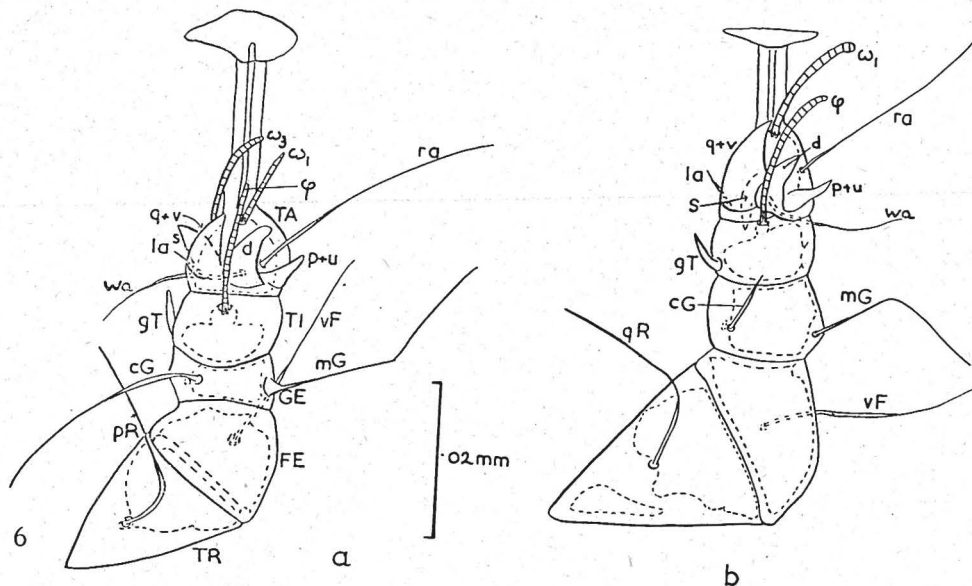

FIG. 6. — *N. alepis*, a) dorsal vieq of right leg I of male, b) dorsal view of right leg II of male. ω_1, ω_3, ϕ, solenidia ; cG, gT, la, mG, pR, qR, ra, vF, wa setae ; d, p + u, q + v, s spines.

The chaetotaxy of the legs is very like that of the female. On leg I cG and mG are, however, twice as long as those of leg I of the female (fig. 6 a). mG of leg II is also (fig. 6 b) approximately twice that of the corresponding leg of the female, while cG is the same size as for the female. Leg III is as for the female ; leg IV ends in a sucker and bears two spines and a blunt projection (ve of GRANDJEAN, 1938), γ is present on the tibia.

Larva (fig. 7).

The larva is 150 μ by 130 μ (average of ten individuals). It is tulip-shaped, if viewed from the ventral side, and spherical if viewed from the dorsal, white and has three pairs of legs. The propodosomal shield is as that of the female, while the cuticular striations are not so complicated as those of the female. They consist of concentric circles, with a slight undulation behind the second pair of legs. Posteriorly the circles are complete, round the anus, and resemble closely the pattern found in the female in this region. A few lateral striations are seen, if the animal is viewed from the ventral aspect, as in the female.

The apodemes are arranged as in the female, but the arms of the Y-shaped sternum and the other apodemes are rather long, giving the body a cleft appearance and, hence, the tulip-shape. There is no genital aperture or setae.

The anus is dorsal and may be at the posterior edge or further forward.

The dorsal setae of the idiosoma are simple, short and arranged as for the female with the exception that the d group of setae are more spread out, the d_1 being found in the expected position, that is anterior to the d_2 setae. The anterior pair of anals (a) are missing in the larva.
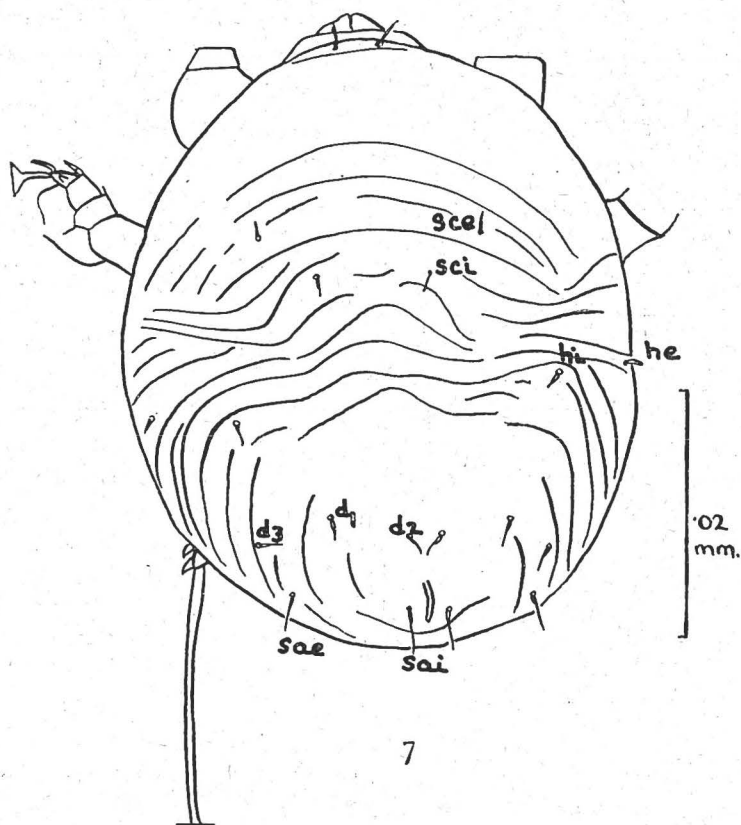

FIG. 7. — *N. alepis*, dorsal view of larva.
Setae of idiosoma : d_1 to d_3, he, hi, sa e, sa i, sc e, sc i.

The chaetotaxy of the legs is as for the female generally. There is no ω_3 on the tarsus of leg I, it is missing in other larval acarids too. Leg III is as that of the female, with the exception that there is no seta on the trochanter. Trochanters I, II and III are without setae, as is common and is mentioned in the rules laid down by GRANDJEAN (1937).

Protonymph.

The protonymph is 184 μ by 170 μ and is spherical. It has three pairs of legs and is bigger than the larva, otherwise there is little difference. The pattern of the striations of the cuticle is as for the larva.

Ventrally, because of the general body shape and size, the sternum appears shorter.

The chaetotaxy of the idiosoma is as for the larva, that of the legs also resembles the larva, ω_3 being still missing from leg I, and there are no setae on the trochanters.

Tritonymph (fig. 8).

The tritonymph is 260 μ by 245 μ, being approximately spherical. There are four pairs of legs as in the female, which it closely resembles : however, the third and fourth pair of legs are nearer the posterior margin of the body, and there is no genital aperture.

The body striations are as for the female ; ventrally, there are rather more transverse posterior striations.

The apodemes are short and strong. Between the apodemes of legs II and III is a group of three small pits, these are found only in the tritonymphal stage and may become the genital sense organs of the female.

The chaetotaxy of the idiosoma is as for the female. The arrangement of the dorsals is seen in fig. 8 ; the anterior pair of anal setae (a) are present in this stage ; ventrally there are the usual two pairs of genital setae.

The chaetotaxy of all the legs is as for the female. ω_3 on leg I is present for the first time in this stage and legs I, II and III have a seta on the trochanter, while leg IV has no seta in this position.

Egg.

The egg measures 27 μ by 15 μ. It is elongate and tapering and has an anterior cap. Several eggs are laid at a time (three or four a day, in all fifty eggs per female according to GORDON, UNSWORTH & SEATON, 1943), those towards the outside, that is towards the skin surface and not necessarily the periphery of the lesion, are older and will hatch prior to those placed more deeply in the tunnel.

Differences between N. alepis and N. muris.

N. alepis is larger than *N. muris* in all stages of the life cycle. The other main differences are seen in the larvae. *N. muris* has dorsal scales, while *alepis* has fairly unbroken lines. *N. muris* has more striations, especially longitudinal ones extending between legs III, while *alepis* has fewer ventral body striations and none extending up between legs III. Further the larva of *N. muris* generally has stout spines, especially the d setae encircling the anus, while *N. alepis* has fine tapering setae.

The male of *N. muris* has a complete transverse groove and further back a

prominent curved groove running right across the animal just in front of the stout setae flanking the anus, according to OUDEMANS (1926).

All the other stages agree rather closely in the patterning of the body and in the presence and arrangement of setae in the two species, except that the setae of *muris* are stouter than those of *alepis*. The position of the dorsal anus seems to be variable in all stages and cannot, therefore, be used to distinguish between the two species.
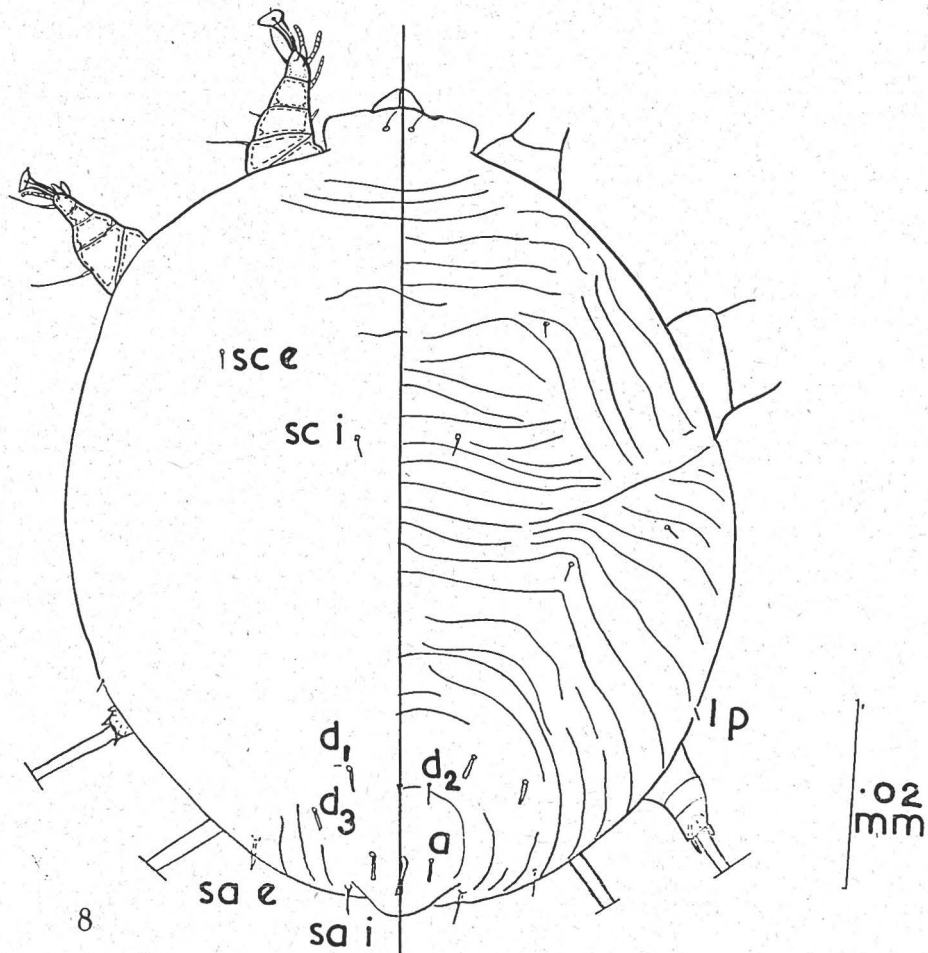

FIG. 8. — *N. alepis*, dorsal view of tritonymph.
Setae of idiosoma : a, d_1 to d_3, lp, sa e, sa i, sc e, sc i.

Symptoms of notoedric mange.

The lesions caused by *N. alepis* are confined to the ears and genitals of the rat. They are seen as yellowish glutinous excrescences, bound together with serum, and

restricted to the pinnae. They may be small (pin-head size) and clearly demarcated, or two or three may run together, giving irregular masses, or the whole ear may be, in fact, one large lesion. The mite does not ssem to have an untoward effect on the health of the rat, unlike *N. cati* which has been known to be responsible for the death of the cat.

The mite burrows into the superficial layers of the skin, generally on the external surface of the pinna. In severe infections, the lesions may extend to the internal surface, too. They do not penetrate the external auditory meatus.

Invasion of the skin of the host.

GORDON, UNSWORTH & SEATON (1943) have observed this invasion of the skin of the rat by all stages of *Notoedres* and state that it is essentially the same as that described for *Sarcoptes scabiei* (HEILESEN, 1946 ; HUGHES, 1959). The mite pulls up a cell corner, using the gnathosoma, and possibly cutting with the chelicerae, in a rapid side to side movement, and gets the hind legs under this and chews and scrapes until a shallow depression is formed. This is extended in like manner. All stages of *N. alepis* have strong chelate chelicerae, which may be used for tearing a way into the outer tissues of the skin.

Histological examination of the skin.

Histological examination of the skin of the rat, by means of sections cut in the normal way and stained with haematoxylin and eosin, shows the mites to be only in the superficial keratinized layers ; at no time is the malpighian layer invaded. The underlying fibrous elastic tissue of the dermis may become very thin, due to the pressure of the parasites in the extensive burrows (fig. 13), but even here the malpighian layer is intact. It appears to stretch and multiply in order to accommodate the mite within the outer keratinized layers. Generally, the skin is greatly thickened, the epidermal cells proliferate below as well as round the mite and gradually cornify, giving a leathery crust which grows progressively from below.

CRANSTON-LOWE (1911) did observe one lesion where the malpighian layer was perforated and suggested the perforation was due to secondary infection and ulceration.

The mites are very closely applied to the surrounding tissues ; the walls of the small cavity being lined by granules, which may be excretory products or cellular breakdown products, such as chromatin. No fibrous capsule is seen, that is there is no host reaction in the form of " walling off " the parasite by means of fibrous tissue. There is, however, quite considerable increase in the number of cells, at the periphery of the lesion, in the surrounding connective tissue. These cells are products of localised inflammation and consist of polymorphs and lymphocytes, which may be so numerous as to totally obscure the fibrous tissue matrix of the dermis underlying the lesion. The whole ear responds to the infection, resulting in an increase in the products of the malpighian layer and an increase in inflammatory cells generally, though both reactions are greatest in the immediate neigh-
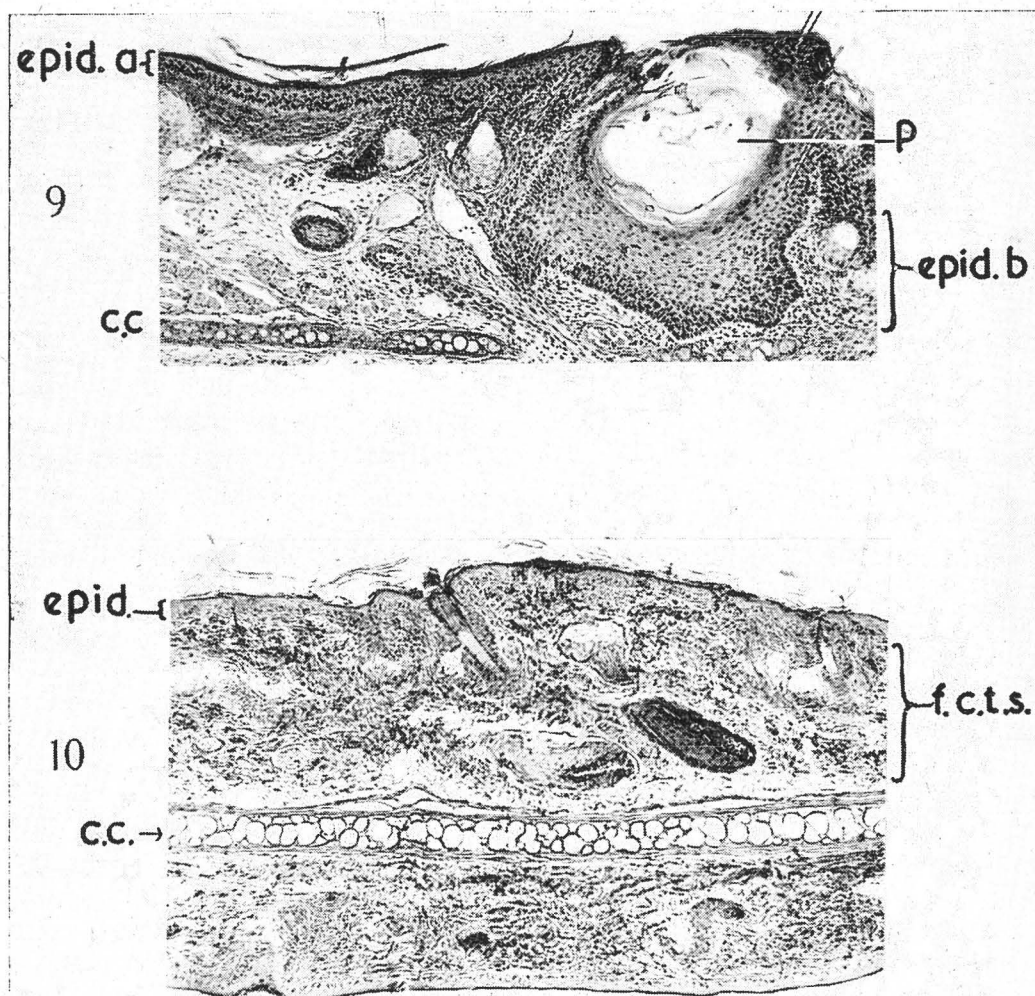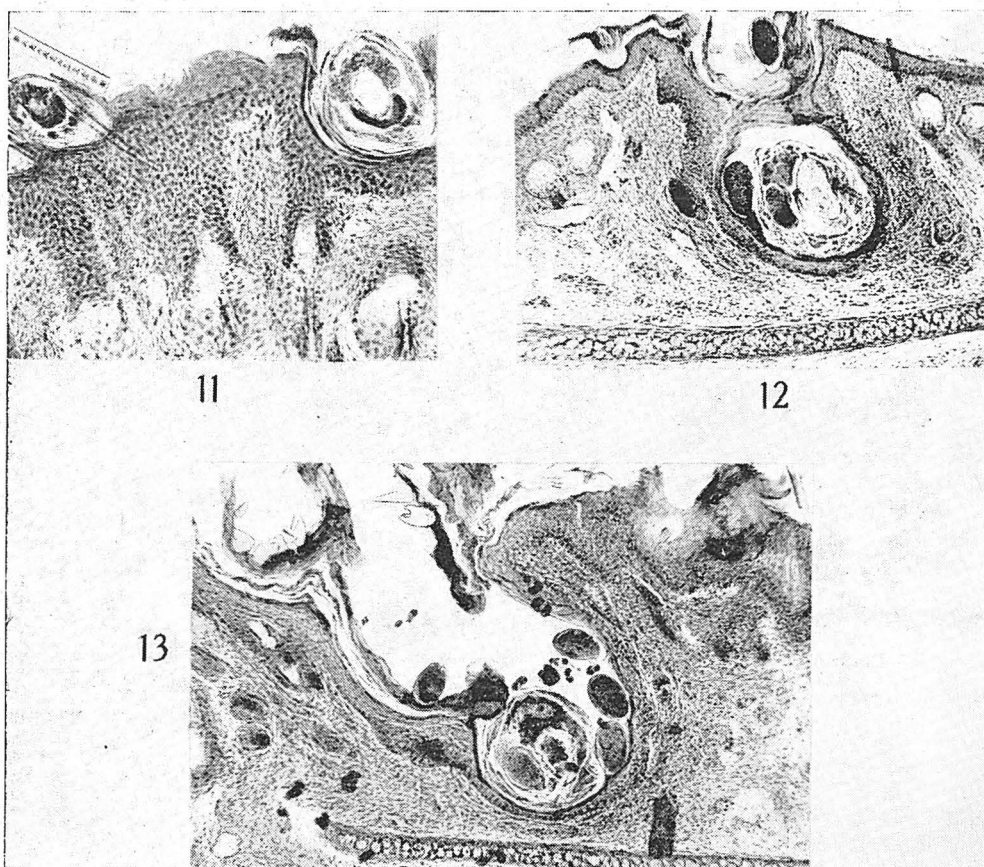
FIG. 9. Vertical section of skin showing proportion of dermis to epidermis in different parts (areas a and b) of infected ear of rat. cc, central cartilage ; epid., epidermis ; f.c.t.s, fibrous connective tissue stroma ; p, pocket previously occupied by *Notoedres*. — FIG. 10. Vertical section of normal of rat (note fibrous connective tissue, f.c.t.s.).

bourhood of a lesion, see fig. 9 areas a and b ; and, thus, the ratio of epidermal to dermal layers may be quite considerably altered. The amount of elastic fibrous tissue present does not increase ; the ear normally has quite a large amount of this tissue (see normal ear, fig. 10). At no time was damage to the central cartilage observed, although many lesions nearly approached this cartilage.

The increase in the products of the malpighian layer is very considerable as the female burrows to extend her egg-laying gallery, and is, presumably, to keep the parasite external to the main tissue of the ear. A thick layer of keratinized cells is often seen, too, between the gallery and the nucleated epidermal cells.

As a result of all this cellular increase, the hairs become partially buried and, therefore, appear short, but there is no change in their structure. They may, however, be somewhat displaced if the mite is resident between them. A series showing the various stages in the burrowing of the mites may be seen from the photographs of sections, figs 11 to 13 inclusive.

FIGS 11, 12, 13. — Series showing *Notoedres* invading skin of pinna of rat's ear.

Effect of Notoedres alepis on the skin.

From the foregoing, it is seen that *N. alepis* has a profound effect on the skin of the host.

No indication of the malpighian layer activity, as undertaken for *Myocoptes*, (WATSON, 1961), could be obtained due to the lack of live material. It is thought, however, that there should be increased activity as the malpighian layer seems to " dip " to accommodate the mite.

Summary.

1. The immature and adult stages of *N. alepis* are described.
2. The differences between *N. alepis* and *N. muris* are given.
3. The gross lesions and histology of the parasitised skin of the rat are described.

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