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OBSERVATIONS ON THE STRUCTURE OF THE SPIRACLES OF ADULT FEMALE COCCIDAE

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ABSTRACT

This paper describes the basic structure of the spiracle of adult female soft-scales. The variation found in the Coccidae is reviewed and it is concluded that there are small but significant differences in spiracular structure in most subfamilies of soft-scales. In particular, the structure of the spiracles within the subfamily Myzolecaniinae is highly variable and some of this variability is described.

KEYWORDS: Coccoidea, Coccidae, spiracle structure.

INTRODUCTION

Little work has been published on the structure of spiracles in the Coccoidea. However, Savage (1914) studied the abdominal and thoracic spiracles of female *Monophlebus stebbingi* var. *octocaudata* Green (now a synonym of *Drosicha mangiferae* Green) in considerable detail, and the basic structure described below is largely based on this work.

THE BASIC STRUCTURE (Fig. 1)

The spiracle consists of an outer, oval, sclerotised cavity which is cone-shaped but which is usually broader dorsally than ventrally; this cavity is often referred to as the peritreme. At its inner end there are two valves, one lying dorsally and the other ventrally, which regulate the rate of gaseous exchange. The spiracular atrium is placed just inside these valves and on slide-mounted specimens can often be seen as a round hole from which the tracheae arise and branch. Lying ventrally to the valves and appearing to arise from the ventral margin of the peritreme is a broad, sclerotised, finger-like structure which extends medially for about twice the width of the peritreme and then broadens into a knob-like area, shaped like the transverse section of a toadstool. This is the muscle plate and the two parts of it are here referred to as the stem and bulb. The muscles to move the ventral valve arise from this plate.

Usually a shallow groove extends from the peritreme to the margin of the insect within which lies a band of multilocular (generally 5-locular) disc-pores (here referred to as spiracular disc-pores); this groove is referred to as the spiracular or stigmatic groove. At the margin end of the groove there are generally one or more spinose setae (the stigmatic spines) which are usually differentiated from the marginal setae and may be located in a cleft (the stigmatic cleft). The margin on the dorsal surface around this cleft is sometimes sclerotised

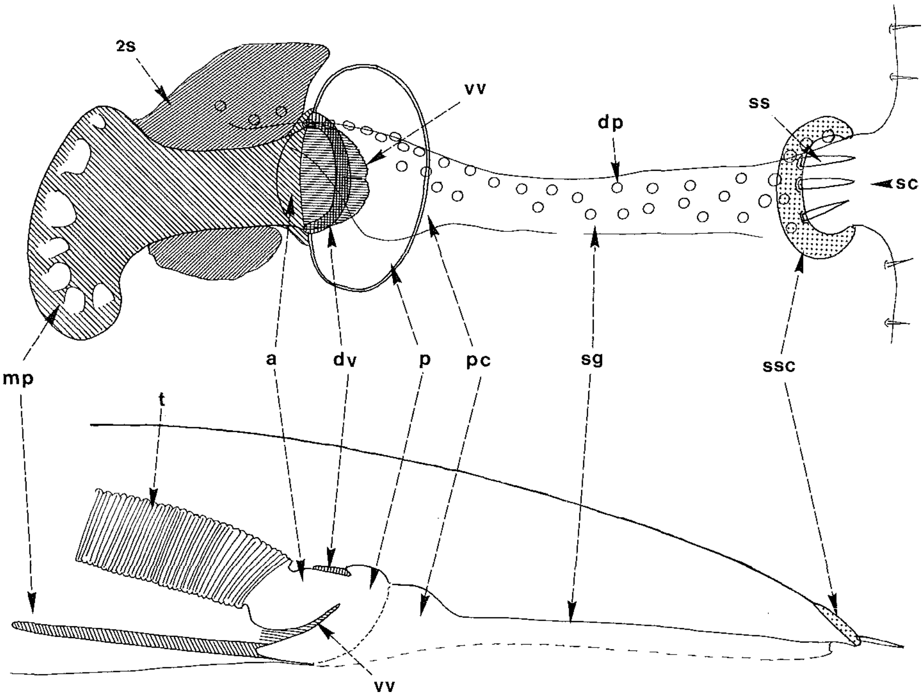


Fig. 1. Ventral view and longitudinal section through the spiracle of a hypothetical coccid; a = spiracular atrium; dp = disc-pores; dv = dorsal valve; mp = muscle plate; p = peritreme; pc = peritreme cavity; sg = spiracular groove; ss = stigmatic spines; ssc = stigmatic sclerotisation; t = tracheae; vv = ventral valve and 2s = secondary sclerotisation.

and this is referred to as the stigmatic sclerotisation. At its inner end, the spiracular groove broadens into a shallow cavity (the peritreme cavity) into which the peritreme opens; in some preparations, this cavity is very distinct as it contains much wax. Frequently there is a fold along the anterior margin of the peritreme cavity and the band of spiracular disc-pores is often concentrated along the fold and may then extend medially along the anterior margin of the spiracles (Fig. 1).

Other significant features are areas of secondary sclerotisation which arise on either side of the muscle plate. This secondary sclerotisation may be difficult or impossible to observe in young adults but becomes more extensive and more heavily sclerotised in older specimens. Sometimes it is very pronounced, extending laterally around each side of the peritreme. In addition, this sclerotisation may also extend as a narrow band mesad to the muscle plate.

The initial impression when viewing a spiracle on a slide-mounted specimen under the light microscope is that most of the above-mentioned structures should also be visible in unmounted specimens, particularly the broad opening to the peritreme and the dorsal and ventral valves. However, when the ventral surface of a soft scale is viewed under the Scanning Electron Microscope, the opening to the spiracle is relatively small and no structures within the peritreme can be seen. When the peritreme cavity is looked at under the light microscope

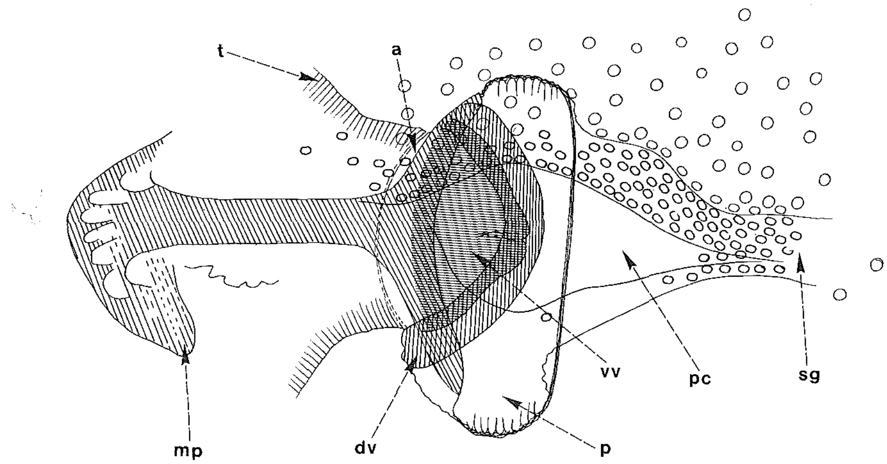


Fig. 2. Ventral view of a spiracle of *Toumeyella liriodendri* (Gmelin). Note: (i) the basically normal structure; (ii) that the margins of the spiracular groove have closed under the peritreme cavity, leaving a relatively small opening; (iii) that the width of the dorsal and ventral valves is quite broad; and (iv) that the peritreme appears to be expandable along its anterior and posterior borders. Lettering as in Fig. 1.

at high power, it is clear that the membranous margins of the spiracular groove can often almost enclose the spiracular cavity (Fig. 2), leaving just a small opening.

VARIATIONS IN SPIRACULAR STRUCTURE

(i) The peritreme cavity. This is always present but varies slightly in size and structure. In some species, the anterior and posterior margins are folded slightly, like a concertina (Fig. 2) and it is likely that in these species the width can be modified by extension and contraction. In others species, the size and shape of the cavity appears to be fixed (e.g. *Messinea conica* De Lotto, Fig. 3). The size also varies depending on the size of the valves and can be proportionately small when the valves are large (Figs. 4 and 5).

(ii) The valves. The dorsal valve is probably not movable, as it appears to be merely the outer, dorsal margin of the atrium which is sclerotised. The valve may be broadly sclerotised and very obvious or only slightly sclerotised and indistinct. The ventral valve, on the other hand, is more membranous, the outer margin slightly serrate, usually with a distinct indentation in the middle of the outer margin from which a short sclerotised ridge extends inwards. It is likely that the ventral valve arises from the outer margin of the muscle plate, from which the muscles to move it arise.

The valves vary in at least two ways. Firstly, they may be as broad as the peritreme cavity and shallow as in *Eulecanium tiliae* (Linnaeus) and *Parthenolecanium corni* (Bouché) (Figs. 4 and 5); or they can be rather narrow and deep, as in *Cryptinglisia lounsburyi* Cockerell (Fig. 7). Secondly, as indicated above, the degree of sclerotisation of the dorsal valve also varies considerably. In *Xenolecanium eugeniae* Takahashi (Fig. 8), the muscle plate appears to have an extension that forms the dorsal surface of the peritreme and presumably therefore acts as the dorsal valve.

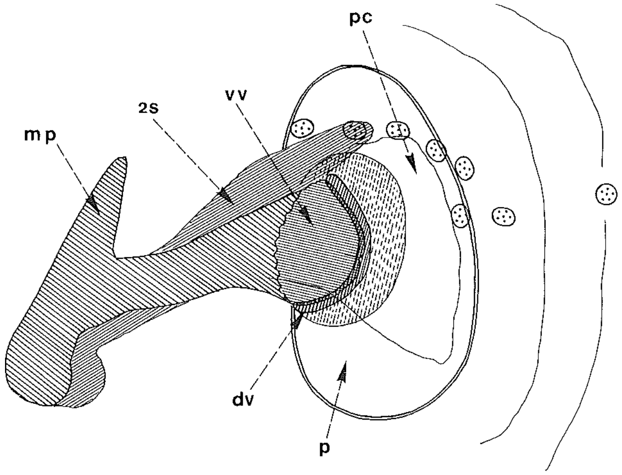
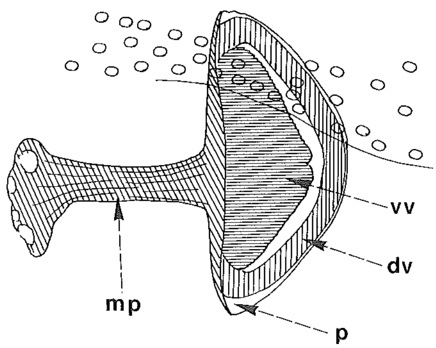


Fig. 3. Ventral view of a spiracle of *Messinea conica* De Lotto. Note: (i) that there is no spiracular groove; (ii) the opening over the peritreme cavity is 'roundish'; (iii) that the dorsal and ventral valves are rather narrower than in Fig. 2; (iv) that there is some secondary sclerotisation on either side of the muscle plate; and (v) the peritreme appears to have a fixed oval shape. Lettering as in Fig. 1.

(iii) The muscle plate. This is usually large and distinct but occasionally can appear relatively unsclerotised. Typically, the narrow stalk part of the plate arises level with the atrium, midway along the width of the peritreme. However, this point of attachment varies and may even arise from the anterior edge of the peritreme, as in *X. eugeniae* (Fig. 8). Another



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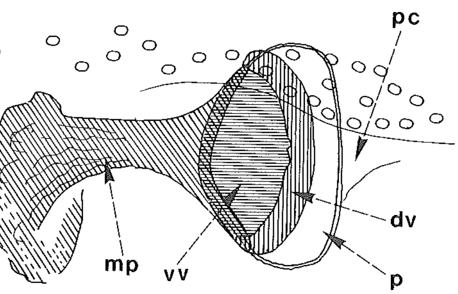


Figs. 4–5. Coccidae, female spiracle. 4. Ventral view in *Eulecanium tiliae* (Linnaeus). Note: (i) that the dorsal and ventral valves are almost as wide as the peritreme; and (ii) that the stem and bulb of the muscle plate are relatively small compared with the peritreme (lettering as in Fig. 1). 5. Ventral view in *Parthenolecanium corni* (Bouché). Notes as for Fig. 4 but the proportions of the peritreme and muscle plate are different (lettering as in Fig. 1).

structure which varies between species and genera is the size and shape of the bulb of the muscle plate. Although this is usually rather like a section through a toadstool, the actual shape can vary greatly and, in *X. eugeniae*, in which the stem of the plate arises from the anterior end of the peritreme, the entire bulb extends posteriorly (Fig. 8). In addition, the proportions of the muscle plate to the width of the peritreme can vary considerably.

(iv) The secondary sclerotisation. In some species there is an extensive sclerotisation on either side of the muscle plate, frequently increasing its width by 3–4 times (Figs. 6 and 7). This is particularly pronounced in the Cardiococcinae (see Hodgson, 1994) (e.g. *Cryptinglisia lounsburyi* Cockerell, Fig. 7). In many species of this subfamily the sclerotisation extends laterally on either side of and around the peritreme, where the two arms may meet, completely surrounding the actual opening into the peritreme cavity, which then appears as an opening through the sclerotisation. This is most pronounced in fully developed adults in which the sclerotisation is most dense. Although almost enclosed, the peritreme cavity may still contain several spiracular disc-pores (Fig. 7).

The secondary sclerotisation may also extend medially and then around the muscle plate bulb, again sometimes meeting a similar posterior extension (as in *Chloropulvinaria psidii* (Maskell), Fig. 6); this sclerotisation is sometimes referred to as the spiracular plate.

(v) The spiracular groove. In most Coccidae, this is a shallow groove extending from the peritreme cavity to the margin. However, it may be so shallow as to appear totally absent in some species (e.g. *Cardiococcus umbonatus* Cockerell), whilst in others it may be quite deep and the margins of the groove may actually meet below the groove. Thus, the spiracular disc-pores then lie within a sort of tube, although the pore openings are still flush with the derm surface (Figs. 2 and 8). However, in the subfamily Myzolecaniinae (see Hodgson, 1994) the spiracles are exceptionally large and the form of the spiracular groove (in particular) can vary considerably.

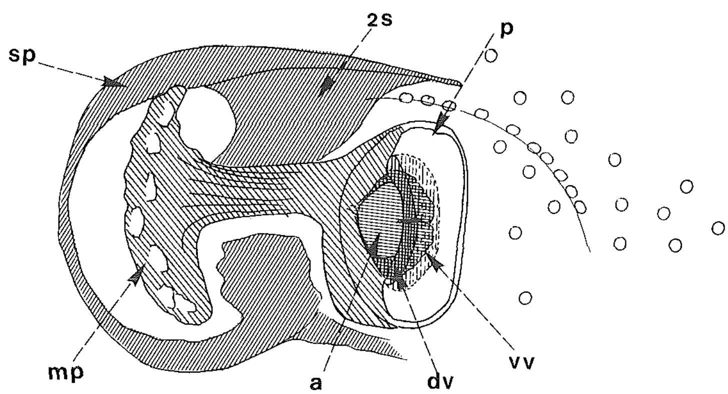


Fig. 6. Ventral view of a spiracle of *Chloropulvinaria psidii* (Maskell). Note: (i) that this structure is similar to Fig. 2 except that the dorsal and ventral valves are narrower; and (ii) that the secondary sclerotisation is very extensive and extends completely round the medial end of the muscle plate and may also extend laterally and almost surround the peritreme. Lettering as in Fig. 1; sp = spiracular plate.

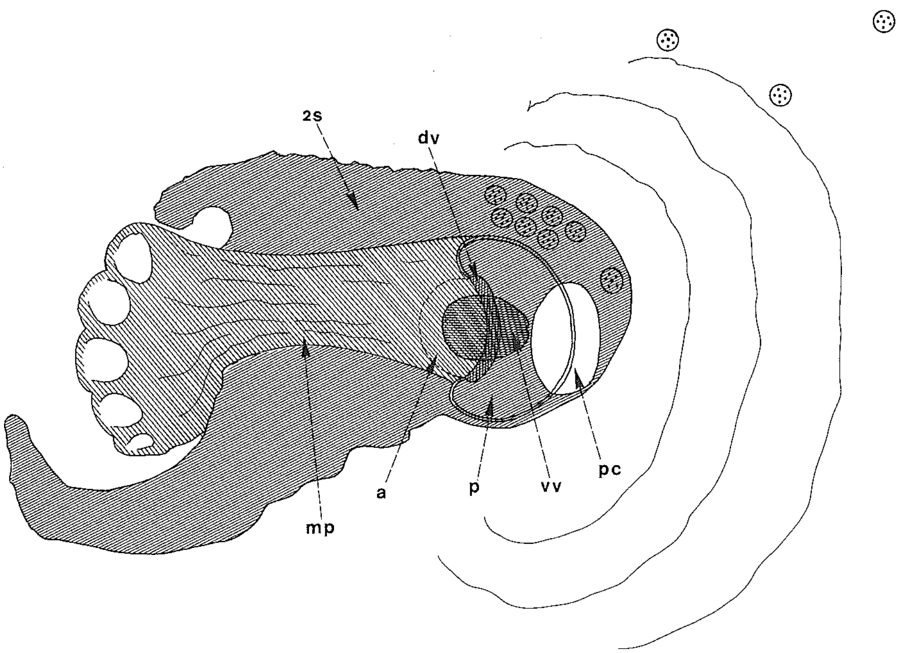


Fig. 7. Ventral view of a spiracle of *Cryptinglisia lounsburyi* (Cockerell). Note: (i) that even though this species does have a shallow spiracular groove, the opening into the peritreme cavity is small; (ii) that the disc-pores are probably in the peritreme cavity; and (iii) that the secondary sclerotisation is very extensive and extends laterally over and around the peritreme, completely surrounding the opening into the peritreme cavity. Lettering as in Fig. 1.

VARIATIONS WITHIN THE MYZOLECANIINAE

Species such as *Toumeyella liriodendri* (Gmelin) (Fig. 2) have normal spiracles, except that the bands of spiracular disc-pores are unusually broad. In *X. eugeniae* (Fig. 8), the spiracular groove appears to be typical but a closer look shows that the peritreme cavity extends medially, so that there is an inner, tube-like invagination which extends medially and ventrally to the rest of the spiracular structures and contains some spiracular disc-pores. The invaginated structure of these grooves can be verified by the fact that the setae and dermal pores of the venter 'overlie' the peritreme tube. This type of tube is fairly frequent in the Myzolecaniinae (Figs. 8–12).

Another modification occurs in *Houardia troglodytes* Marchal (Fig. 9). At first glance it appears as though there is a deep spiracular groove, surrounded at the outer marginal end by a sclerotised collar. In fact, the entire structure is invaginated like the finger of a glove, the outer opening guarded by the collar-like stigmatic sclerotisation which has become invaginated along with the rest of the spiracle. In this species also, the pores and setae of the dorsum and venter can be seen above and below the entire structure. The sclerotised collar (composed of the stigmatic sclerotisation) has a gap ventrally, suggesting that this arrangement evolved by the fusion of the lips of the spiracular groove ventrally.

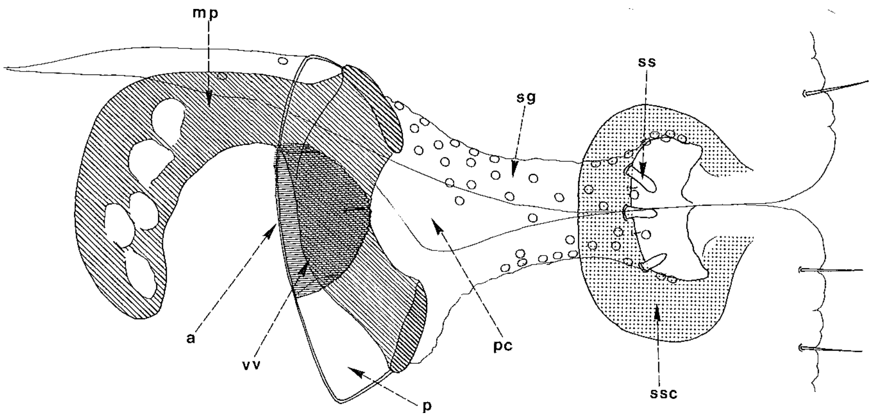


Fig. 8. Ventral view of a spiracle of *Xenolecanium eugeniae* Takahashi. Note that the structure of the spiracle is very similar to that of *T. liriodendri* (Fig. 2) except that (i) the muscle plate arises from the anterior margin of the peritreme and the bulbous end of the muscle plate only extends posteriorly; (ii) that the lateral margins of the muscle plate extend over the dorsal area of the peritreme and may form the dorsal valve; and (iii) that the peritreme cavity extends between the muscle plate and the venter as a finger-like invagination in which the disc-pores lie. Lettering as in Fig. 1.

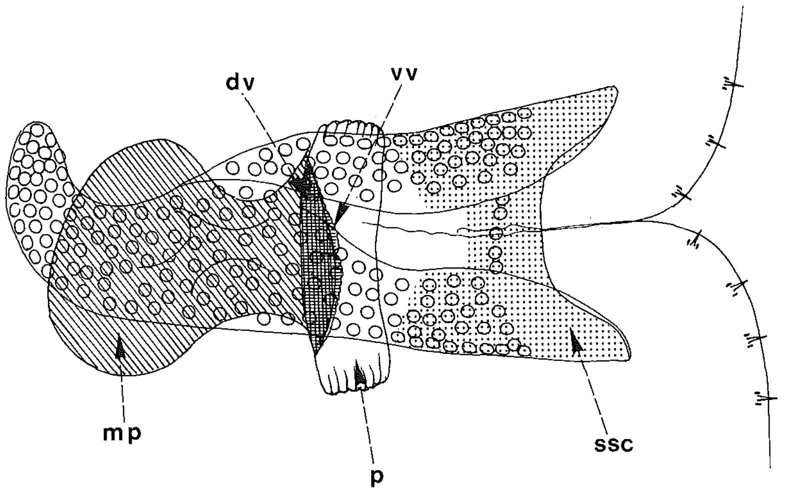
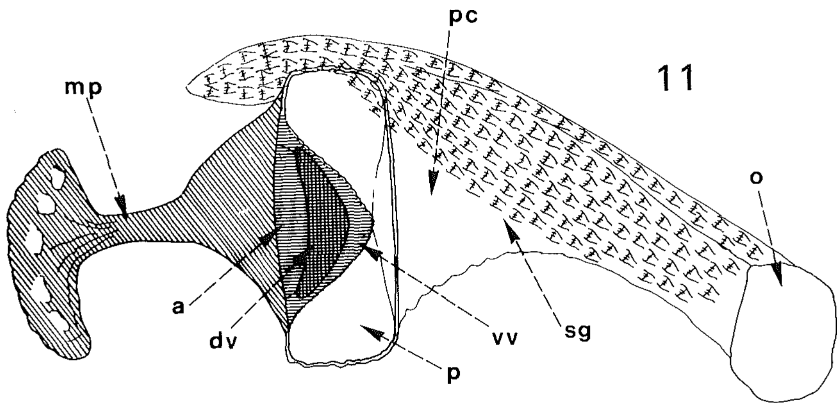
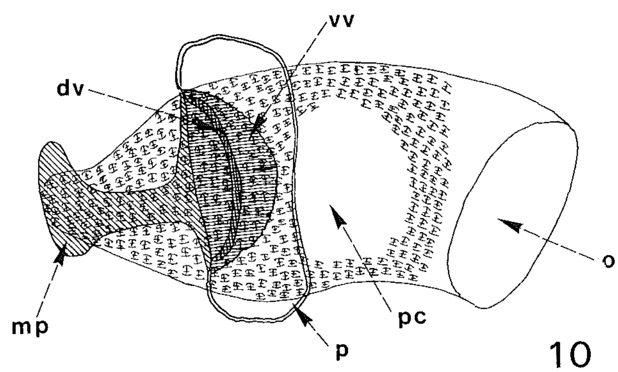


Fig. 9. Ventral view of a spiracle of *Houardia troglodytes* Marchal. Note: (i) the extension of the peritreme cavity under the muscle plate as a broad invagination with numerous spiracular disc-pores; and (ii) that the entire spiracular groove has been invaginated in from the margin and now opens onto the dorsal surface through the invaginated stigmatic sclerotisation. Lettering as in Fig. 1.

This invagination in *Cribrolecanium formicarum* Green and *Halococcus formicarii* Takahashi (Figs. 10 and 11) is even more extreme. As in *H. troglodytes*, the entire spiracle in these two species also lies within the body of the insect but appears to be otherwise quite typical. Hodgson (1994) illustrated this structure but assumed that the opening to the exterior





Figs. 10–11. Coccidae, female spiracle. 10. Ventral view in *Halococcus formicarii* Takahashi. Note that the structure resembles that of *H. troglodytes* (Fig. 9) but that (i) there is no stigmatic sclerotisation; (ii) the disc-pores face along the spiracular groove; and (iii) that the opening is now on the dorsal surface, some distance from the margin. Lettering as in Fig. 1; o = opening of spiracular groove onto dorsal surface. 11. Ventral view in *Cribrolecanium formicarum* Green. This is very similar to Fig. 10 but the spiracular groove (= tube) is longer. Lettering as in Fig. 1; o = opening of spiracular groove onto dorsal surface.

was ventral; however, further examination showed that it was through the dorsum, some way from the margin! One additional difference between these two species and most other Coccidae is that the spiracular disc-pores actually appear to face outwards along the spiracular groove, which is quite often full of wax in mounted specimens.

In most preparations of adult female *Cryptostigma inquilina* (Newstead) (Fig. 12), the spiracles *do not* point towards the margin but medially. In addition, there is a broad band of sclerotisation mesad to the peritreme. Again, it is evident that these spiracles open dorsally. How has this arrangement evolved? In fact, the broad band of sclerotisation is clearly the stigmatic sclerotisation which has moved medially from the margin onto the dorsal surface, forming the inner end to a stigmatic groove. That this is the stigmatic sclerotisation is indicated by the presence of one or more stigmatic spines. It seems possible that the spiracles

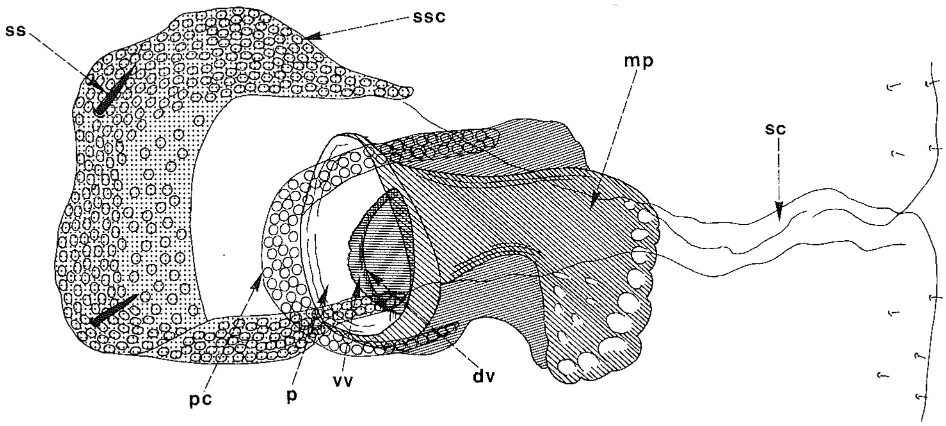


Fig. 12. Ventral view of a spiracle of *Cryptostigma inquilina* (Newstead). Note: (i) that the stigmatic sclerotisation has moved up onto the dorsal surface some distance from the margin; (ii) that this appears to have "pulled" the spiracle along with it so that the peritreme now faces medially rather than laterally and that the entire spiracle is now inverted, so that (iii) the ventral valve is now dorsal to the dorsal valve! Lettering as in Fig. 1.

of *C. inquilina* were once invaginated but that, as the stigmatic sclerotisation moved up onto the dorsum, it pulled the spiracle around with it, so that the spiracle is now inverted. That the spiracle is inverted is clear, because the finger-like extension from the peritreme cavity which encloses the spiracular disc-pores (which usually lies between the venter and the muscle plate) now lies between the dorsum and the muscle plate and also because the ventral valve now lies dorsad to the dorsal valve!

It is not clear why some Myzolecaniinae have evolved such a diverse range of modifications to their spiracles. Most species within this subfamily are intimately associated with ants — and in some species may even be entirely dependent on them for the removal of honeydew and perhaps even dispersal. How these changes in structure are related to this association is unclear.

CONCLUSION

This study indicates, firstly, that it is unwise to accept as evident even such obvious assumptions as the spiracles always opening onto the ventral surface in the Coccidae; and, secondly, that there is greater variation in the structure of the spiracles in the Coccidae than is apparent at first glance, suggesting that their structure could be useful taxonomically both in the family Coccidae and at higher levels of taxonomy of the Coccoidea.

REFERENCES

Hodgson, C.J. 1994. The Scale Insect Family Coccidae: An Identification Manual to Genera. CAB International, Wallingford. vi + 639 pp.

Savage, R.E. 1914. The respiratory system of *Monophlebus stebbingi* var. *octocaudata*. *Bulletin of Entomological Research* 5:45–47, plates V–IX.