27
Parasitology (1962), **52**, 401–424
With 54 text-figures
Printed in Great Britain

The mites parasitic in the lungs of birds. The variability of *Sternostoma tracheacolum* Lawrence, 1948, in domestic and wild birds

By A. FAIN and K. E. HYLAND*

Laboratoire de Zoologie Medicale, Institut de Médecine Tropicale Prince Léopold, Antwerp, Belgium

(*Received* 4 *October* 1961)

The acarines parasitizing the lungs and air-sacs of birds are few in number. The oldest known and most widely scattered is a sarcoptiform, *Cytodites nudus* (Vizioli). This species recently re-described by one of us in a revision of the family Cytoditidae (Fain, 1960*a*) is cosmopolitan and parasitizes various birds, principally the chicken and turkey. It is usually well tolerated in the chicken and it is only at the time of intense infestation that it is able to produce an irritation of the respiratory tract, which is indicated by an accumulation of mucus in the bronchi and trachea, and by coughing. The inflammation develops in a chronic fashion and pneumonia has never been reported.

According to Higby (1946) this mite can produce some serious respiratory manifestations in the canary. It is necessary to note, however, that at the time (1946) when Higby made his statement, *Sternostoma tracheacolum*, another species occurring frequently in canaries, had not yet been described. It is probable that the lesions described by Higby should be attributed to this species rather than to *Cytodites nudus*.

C. nudus has been encountered also in wild birds. In the United States it has been found in the air-sacs of the ruffed grouse (Edminster, 1947). In Ruanda-Urundi we have found it in the nasal passages of a *Merops apiaster* L., and in the bronchi of *Turdoides melanops sharpei* Reich. A second species, *Cytodites psittaci* Fain, 1960, has been described from Ruanda-Urundi from the lung of a parrot, *Poicephalus meyeri* Cretz.

An acarine belonging to an entirely different group and much more pathogenic was described by Lawrence (1948) in South Africa under the name of *Sternostoma tracheacolum*. It was taken in 1947 by Stephan, Kaschula & Canham (1950) in the bronchial tree, the lungs, and the air-sacs of canaries dying from pneumonia or from other severe inflammations of the respiratory organs (tracheitis, aerocystitis)

Since the description of Lawrence this species has been found also in canaries dead from pneumonia in Brazil (Torres, Lent & Moreira, 1951), in Uruguay (Cassamagnaghi, 1952), and in South Carolina in the United States (Baker *et al.* 1950). The mites found by Higby (1946) are probably this same species. Also *Sternostoma meddai* Lombardini (1953), described from canaries and goldfinches

* Fulbright Research Scholar (1960–61) in Belgium, from Department of Zoology, University of Rhode Island, Kingston, U.S.A.

dead from pneumonia in Sardinia (Medda 1953, 1957), is considered here a synonym of *S. tracheacolum* (see below). In addition, this same species has been found in canaries and in reared parakeets *Melopsittacus undulatus* (budgerigar) that died at the Antwerp Zoo (Fain, 1958; Fain & Carpentier, 1958, and present work).

S. tracheacolum has been reported repeatedly from wild birds from various regions of the globe: In the U.S.S.R. in *Hirundo rustica* and *Acrocephalus arundinaceus* (Bregetova, 1951); in Ruanda-Urundi (under the name of *S. castroae*) in the nasal cavities, trachea and bronchi of *Macronyx croceus* (Fain, 1957); in the United States (California) in *Icterus bullocki* (nasal cavities, trachea and lungs), and *Agelaius tricolor* (Furman, 1957); in Thailand in *Nectarinia jugularis flammaxilaris* (Strandtmann, 1960). Concerning *Agelaius tricolor*, Furman stated that the mites came from the nasal cavities; however, the two preparations which we have been kindly supplied by Furman are labelled visceral cavity and trachea. Therefore, it seems certain that in wild hosts the location of the parasite is likewise in the trachea-bronchial tract but their presence in the higher passages (nasal cavity, trachea) appears to be more frequent than in the canaries.

To this list of wild hosts must be added the goldfinches (respiratory passages) in Sardinia (= *Sternostoma meddai* Lombardini, 1953); the parakeet *Agapornis cana* Gmelin (lungs) of Madagascar (= *Agapornyssus faini* Grétillat, Capron et Brygoo, 1959); the sugar bird *Cyanerpes cyanea* (L.) (lungs) imported from Brazil and the starling *Cinnyricinclus leucogaster verreauxi* (Bocage) (free in body cavity) from Central Africa, dead in the Antwerp Zoo; and a series of birds coming from the United States (Michigan, Massachusetts and Rhode Island). Those from Michigan are: indigo bunting, *Passerina cyanea* (L.) (trachea and lungs); song sparrow, *Melospiza melodia* (Wilson) (trachea and lungs); eastern field sparrow, *Spizella pusilla* (Wilson) (bronchus); eastern meadowlark, *Sturnella magna* (L.) (lungs); bank swallow, *Riparia riparia* (L.) (lungs); vesper sparrow, *Pooecetes gramineus* (Gmelin) (trachea); and the house sparrow, *Passer domesticus* (L.) (trachea and lungs). Those from Massachusetts are: fox sparrow, *Passerella iliaca* (Merrem) (bronchus); oven bird, *Seiurus aurocapillus* (L.) (nasal cavity and bronchi); and the northern water thrush, *Seiurus noveboracensis* (Gmelin) (trachea). From Rhode Island, the cowbird *Molothrus ater* (Boddaert) (nasal cavity, trachea and bronchi).

To our knowledge the existence of lesions or inflammation of the respiratory organs in the parasitized wild birds, living at large, has not been reported. We have observed a high tolerance for the parasite in the wild host living in his natural biotope. It is only in three cases that lesions were found associated with parasitism. In 1957, Medda described respiratory symptoms in five goldfinches which had been kept for over a year in an aviary together with canaries infested with *Sternostoma tracheacolum* (= *S. meddai*).

Respiration distress, followed by death, was also observed by Cumming (1959) in Gouldian finches parasitized by *S. tracheacolum*. These birds were obtained from a breeder of German roller canaries.

The third time when associated lesions were observed was in three sugar birds (*Cyanerpes cyanea*) that died in captivity at the Antwerp Zoo. These birds had unilateral or bilateral pneumonia and presented an intense infestation of the whole

respiratory tract including the air sacs. A few mites were also found in the nasal cavities. It is probable that the intense parasitism in these birds can be attributed to a lowered general health and resistance brought on by their captivity.

The multiplicity and diversity of the wild hosts parasitized by this species, as well as the high degree of tolerance which they present against this parasitism, lead us to think that the wild birds are probably the natural hosts for *S. tracheacolum*.

Aside from *Cytodites nudus* and *S. tracheacolum*, which are the species most frequently found in the lungs and bronchi of birds, the senior author has found other mites in this site. In Ruanda-Urundi some hypopial nymphs were found which were assigned to the genus *Falculifer* and which apparently constitute two different species distinct from *F. rostratus*. They were found in large numbers encysted in the air-sacs, on the surface of the lungs and other organs of *Bubulcus ibis* L., and in the lungs of *Phalacrocorax africanus* Gmelin. In this same country mites of the subfamily Speleognathinae (Ereynetidae) were found, some free in the trachea of *Scopus umbretta* (adult females of *Speleognathus poffei* Fain), and others (larval skins containing nymphs) enclosed in the pulmonary tissue of a domestic pigeon. The latter apparently are *Speleognathus striatus* Crossley, 1952 (Fain, 1955). One nymph belonging to the genus *Boydaia* was found free in the lung of *Limnodromus griseus* (Gmelin) from Rhode Island (U.S.A.).

For our work it has been desirable and expeditious to take certain routine measurements, and we suggest that for purposes of completeness and ease in comparing descriptive work that these measurements always be given for this group of mites. The following are the abbreviations used in descriptions:

LId	Length of idiosoma
WId	Width of idiosoma (between coxae III and IV)
LPP	Length of podosomal plate
WPP	Width of podosomal plate (maximum)
LOP	Length of opisthosomal plate
WOP	Width of opisthosomal plate (maximum)
LpP	Length of pygidial plate
WpP	Width of pygidial plate
Lper	Length of peritreme (total length including diameter of rounded peristigmatic membrane)
LAP	Length of anal plate
WAP	Width of anal plate
LG	Length of gnathosoma, ventral view, palps included
WG	Width of gnathosomal base (maximum)
LP	Length of palps
LCH	Total length of chelicera including fixed digit
LCh	Length of movable digit of chelicera
LLeg	Length of leg, including coxa, excluding ambulacra (L Leg I to LLeg IV)
LSP	Length of sternal plate
WSP	Width of sternal plate (maximum)
LGP	Length of genital plate (extending to the anterior border of the genital lip)
WGP	Width of genital plate (maximum in the posterior half)
WLeg	Width of leg (= maximum width of femur)
Av	Average (of all structures measured)

All of the material was mounted in Hoyer's medium to render the measurements as uniform as possible. The specimens of Furman, Lombardini, Lawrence and Grétillat have been remounted. All measurements given are in microns.

REDESCRIPTION OF *STERNOSTOMA TRACHEACOLUM*

Sternostoma tracheacolum Lawrence, 1948

Synonyms: *Sternostoma meddai* Lombardini, 1953: 187, syn.nov.
S. castroae Fain, 1956: 393.
Agapornyssus faini Grétillat, Capron, Brygoo, 1959: 375, syn.nov.

Lawrence's original description of this species was quite good at the time. Since then, however, numerous new species have been described in the genus *Sternostoma* and a new description, taking into account a larger number of characters, has become necessary. For the purpose of filling this need Furman (1957), and later Fain (1957) redescribed this species from the South African specimens in the collection of Dr Lawrence. Recently one of us discovered in canaries from Belgium mites which first appeared identical to *S. tracheacolum* but which differed from this species by the much shorter cheliceral digits. A comparative study has permitted us to throw light on certain poorly known characters in this species and prompts us to give a new description based on the examination of specimens originating in South Africa along with principal differences of specimens from other hosts and localities (Tables 1 and 2).

South African specimens (Figs. 1, 11, 21, 29, 33, 42, 48; Table 1).

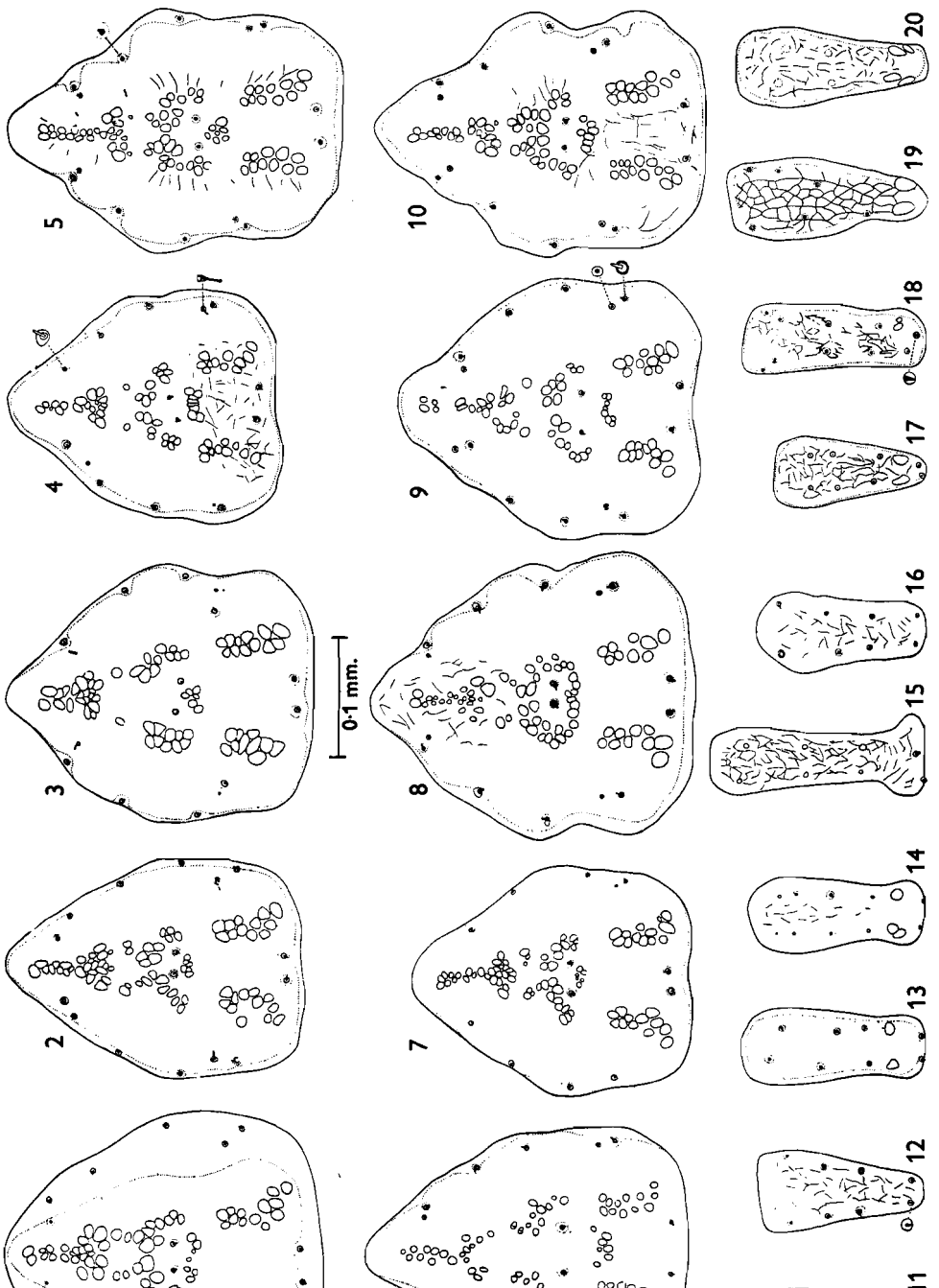
The seven specimens examined had kindly been sent by Dr Lawrence to the senior author in 1956. They had been collected in the trachea of canaries at Pietermaritzburg (Natal) in September 1947.

FEMALE: Dimensions (in microns): LId 552–914 (Av 730); WId 270–497 (Av 395); LPP 240–276 (Av 257); WPP 170–233 (Av 203); LOP 118–142 (Av 130); WOP 44–56 (Av 50); LSP 104–155 (Av 138); WSP 89–96 (Av 93); LGP 93–118 (Av 101); WGP 41–64 (Av 56); LG 93–107 (Av 98); WG 81–98 (Av 91); LP 39–47 (Av 44); LCH 102–122 (Av 115); LCh 11–12 (Av 11·8); LCH : LCh 8·5–10·7 (Av 9·67); LLeg I 271–349 (Av 313); WLeg I 58–72 (Av 67); LLeg IV 230–289 (Av 264); WLeg IV 45–54 (Av 50).

Only the female has been fully described. Medda (1957) has given a very brief description of the male. We also have taken a male from *Cyanerpes cyanea* at the Zoo, but unfortunately the preparation containing the specimen has been lost. The large variations of the idiosoma can be explained in part by the fact that this species is very thick and nearly ovoid, which makes it more easily deformed when mounted between slide and coverslip. *Dorsum*: Podosomal plate triangular in shape, the anterior angle is rounded and in certain of our specimens it is rather elongated toward the apex. This plate is often chitinized only in the median part; in other specimens the chitinization goes farther but it always becomes less distinct along the edges; without a network of lines; six pairs of cylindrical setae which are very thin and very short, arranged in a pattern 2–2–4–2–2. In addition to these setae are two pairs of small pores with chitinous outlines which are the orifices of very small scutal glands which have been described recently in the Entonyssidae (Fain, 1961). These glands are always smaller and less distinct here than they are in the Entonyssidae. The first pair is situated at the level of the anterior setae,

Table 1. *Comparative measurements (in microns) of* Sternostoma tracheacolum *from canaries and parakeets (females only)*

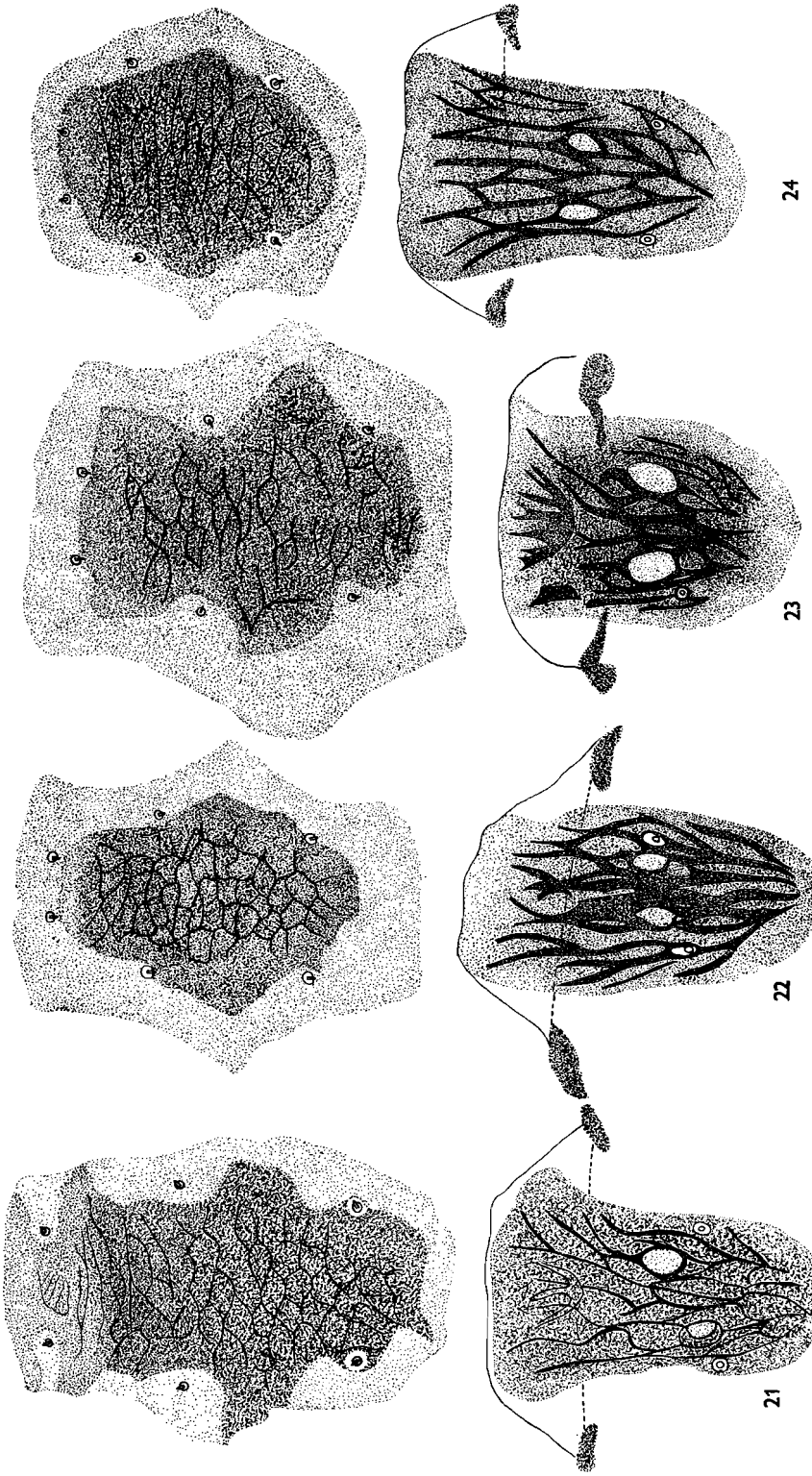
	Canaries					Parakeets		
Structures (see p. 403) for abbreviations)	South Africa (7 mites)	Italy (= *S. meddai*) (3 mites)	Brazil (4 mites)	Belgium (10 mites)	North America (New Jersey) (3 mites)	Antwerp Zoo (*Melopsittacus undulatus*) (5 mites)	Madagascar (*Agapornis cana*) (= *Agapornyssus faini*) (2 mites)	Madagascar (*Agapornis* sp.) (3 mites)
LId	552–914	828–950	690–782	492–842	520–680	421–598	598	547–828
Av	730	909	725	634	615	497	598	644
WId	270–497	391–500	230–460	276–460	276–313	230–312	285–303	299–414
Av	395	427	247	344	293	266	294	337
LPP	240–276	234–259	229–262	226–281	226–235	253–272	245–265	235–255
Av	257	248	243	249	227	260	255	248
WPP	170–233	187–197	188–196	183–207	190	163–199	181–189	190–192
Av	203	194	191	183	190	188	185	191
LOP	118–142	126–133	155–164	148–168	137–145	145–156	152–157	154–161
Av	130	130	160	155	142	152	154·5	158
WOP	44–56	49–67	57–61	63–74	56–63	47–66	64–65	56–63
Av	50	56	59	68	61	60	64·5	60
LSP	104–155	97–106	133	111–133	116–118	136–145	144–148	127
Av	138	102	133	125	117	140	146	127
WSP	89–96	82–94	99	74–91	76–81	80–85	93–96	81
Av	93	87	99	83	79	82	94·5	81
LGP	93–118	110–113	126–128	100–120	99–109	119–128	124–129	118–127
Av	101	111	127	111	104	123	126·5	123
WGP	41–64	54–62	59–63	44–52	43–47	52–59	63	54
Av	56	59	61	49	45	57	63	54
LG	93–107	90–105	87–93	85–96	76–78	67–98	93	85–89
Av	98	95	90	89	77	92	93	81
WG	81–98	83–96	63–71	70–84	66–72	63–69	69–71	72–74
Av	91	88	69	74	69	65	70	73
LP	39–47	Not	36–39	36–40	31–35	40–42	39–42	36–38
Av	44	measurable	37	38	33	41	41	37
LCH	102–122	120–131	98–102	100–109	101–104	101–109	102–105	109–116
Av	115	125	100	104	103	106	104	114
LCh	11–12	11–12·0	8·1–8·8	6–6·5	6·0–6·6	11–12	12	13
Av	11·8	11–12·0	8·3	6·1	6·4	11·5	12	13
LCH:LCh	8·5–10·7	8·5–10·9	11·5–12·6	16·1–17·8	15·3–17·8	9·2–9·3	8·5–8·8	8·4–9·1
Av	9·7	8·5–10·9	12·2	16·7	16·05	9·3	8·7	8·9
LLeg I	271–349	264–270	284–290	270–324	244–273	281–285	280–283	279
Av	313	266	287	294	258	282	281·5	279
WLeg I	58–72	54–58	56–60	58–72	54–58	60–53	58–60	62–69
Av	67	57	58	64	57	62	59	65
LLeg IV	230–289	228–246	226–248	230–275	199–210	272–276	270–285	252
Av	264	236	238	252	205	273	278	252
WLeg IV	45–54	45–49	40–49	42–54	38–45	45–51	46–48	54–56
Av	50	47	44	45	41	49	47	55



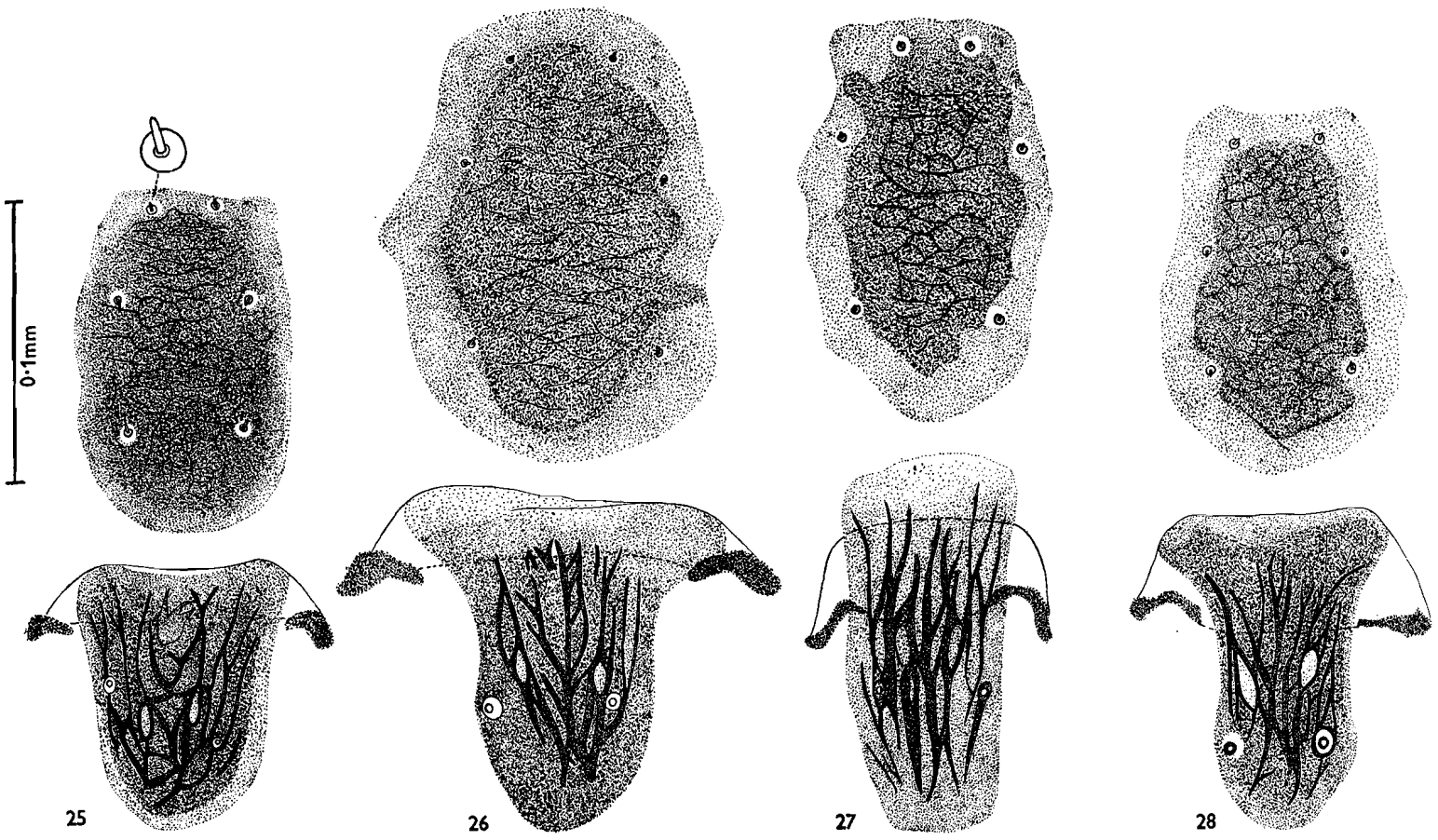
Figs. 1–20. Podosomal and opisthosomal plates of *Sternostoma tracheacolum*: specimen from South Africa (1 and 11); specimen from Belgian Canaries (2 and 13); specimen from *Passerina cyanea*, group B (3 and 15); specimen from *Cyanerpes* (4 and 17); paratype of *Agapornyssus faini* (5 and 19); cotype of *S. meddai* (6 and 12); specimen from New Jersey (7 and 14); paratype of *S. castroae* (8 and 16); specimen from *Icterus* (9 and 18); specimen from *Melopsittacus* (10 and 20).

Table 2. *Comparative measurements (in microns) of* Sternostoma tracheacolum *from wild passeriform birds (females only)*

Structures (see p. 403 for abbreviations)	Lark, Central Africa (*Macronyx croceus*) (= *S. castroae*) (4 mites)	Sugar bird, Antwerp Zoo (*Cyanerpes cyanea*) (5 mites)	Wild birds, North America (California) (Furman) (4 mites)	Wild birds, North America (Michigan) Group A (5 mites)	Wild birds, North America (Michigan) Group B (4 mites)	House sparrow, North America (Michigan) (*Passer domesticus*) (5 mites)	Starling, Antwerp Zoo (*Cinnyricinclus leucogaster verreauxi*) (9 mites)
LId	497–736	400–610	483–713	460–754	851–897	484–715	497–593
Av	657	510	613	565	874	632	557
WId	308–500	211–300	345–432	276–382	345–483	262–385	276–322
Av	425	280	368	332	402	336	297
LPP	244–274	201–226	248–280	233–272	246–253	245–269	237–266
Av	261	218	264	246	250	262	251
WPP	224–237	176–207	192–215	192–250	192–222	201–245	185–217
Av	229	187	205	214	207	214	201
LOP	133–148	119–144	151–161	134–148	178–192	127–142	127–154
Av	141	130	155	140	186	133	139
WOP	59–67	53–67	63–78	53–74	54–63	59–68	54–67
Av	64	59	72	62	58	63	61
LSP	130–145	114–120	141–162	111–144	104–116	106–118	—
Av	138	117	153	127	110	111	
WSP	96–100	76–84	74–111	85–104	70–74	92–100	—
Av	98	80	106	95	72	97	
LGP	99–104	83–90	111–127	101–120	107–119	108–118	98–109
Av	103	88	122	108	114	116	102
WGP	59–74	58–65	67–74	50–67	44–54	60–65	45–54
Av	68	61	69	60	51	62	50
LG	93–107	85–103	98–105	93–106	77–81	89–109	91–96
Av	98	94	101	97	80	96	93
WG	81–93	67–79	81–100	73–87	65–76	83–89	67–72
Av	87	70	93	78	70	85	68
LP	41–44	39–45	42–48	37–53	30–33	34–44	36–41
Av	42	40	44	45	31	39	40
LCH	110–118	103–116	118–126	105–130	96–98	122–132	91–100
Av	113	109	122	115	97	128	96
LCh	11–12	11–13	12–13	12–13	6·6	13–14	8·7–9·6
Av	11·7	12·4	12·5	12·5	6·6	13·5	9
LCH:LCh	9·2–10·7	8·0–9·7	9·5–10·7	8·6–10·0	14·5–14·6	9·2–10·1	10·4–10·8
Av	9·6	8·9	9·8	9·1	14·5	9·6	10·6
LLeg I	311–338	250–277	335–362	272–308	278–282	283–293	284–302
Av	325	265	349	290	280	290	292
WLeg I	63–72	52–56	79–94	56–74	56–58	56–62	62–72
Av	66	54	87	65	57	60	65
LLeg IV	262–279	210–228	286–315	232–279	231–244	260–266	244–273
Av	268	221	297	248	240	262	257
WLeg IV	40–54	40–43	54–63	41–45	45–54	45–50	45–49
Av	46	42	60	43	49	47	46



Figs. 21–24. For legend see opposite page.



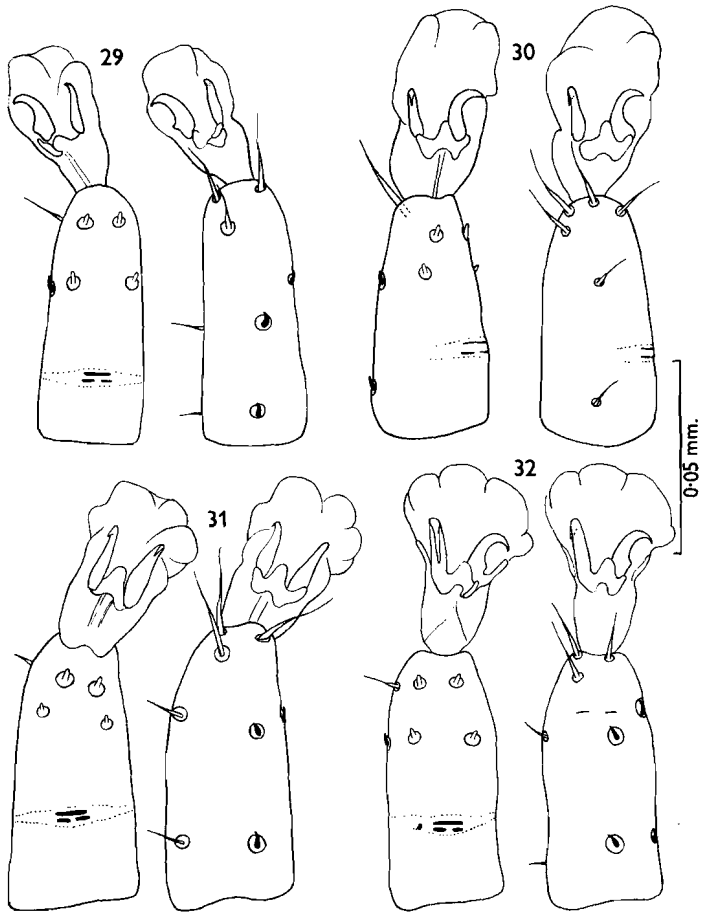
Figs. 21–28. Sternal and genital plates of *Sternostoma tracheacolum*: South African specimen (21); paratype of *Agapornyssus faini* (22); paratype of *S. castroae* (33); cotype of *S. meddai* (24); specimen from *Cyanerpes* (25); specimen from *Icterus* (26); specimen from *Melopsittacus* (27); specimen from Belgian canaries (28).

and the second pair near the postero-lateral setae. These four pores exist in all the specimens of *S. tracheacolum* examined from different hosts. In the specimens from *Cyanerpes cyanea*, however, the pair of anterior setae are missing. Stigmata without peritreme, located at the level of coxae IV, diameter 4 to 7. Opisthosomal plate much longer than wide and narrows slightly but rather regularly toward the posterior; without a network of lines; it bears several pairs of small pores or glands and near the posterior border a pair of very small, extremely short setae. Two pairs of very small, thin setae are present on the soft cuticle lateral to the opisthosomal plate. *Venter*: Sternal plate rectangular, relatively well chitinized in the median part, with a network of lines mostly oriented horizontally; the chitinization becomes progesssively indistinct on the borders and makes the measuring of the plate quite delicate. The six sternal setae are very short and fine. Genital plate with a very well-defined network of lines mostly longitudinally arranged. There are no genital setae but we have observed two small pores on the posterior half of the plate. Anus terminal, or slightly dorsal. Anal plate, dorsally prolonged into a small cribrum and with two small setae posterior to the level of the anal orifice. There are two pairs of very thin and short setae on the soft cuticle, between the anal and the genital plates. The anal plate has been figured previously (Fain, 1957). *Gnathosoma*: nearly completely ventral. The palps gradually curve inward and are convergent apically. They possess a very abbreviated chaetotaxy (Fig. 33). A peculiarity which merits mention is the absence in *S. tracheacolum* of the small spines which occur in many species of *Sternostoma* on the internal face of coxa I as described by Hyland & Clark (1959) for *S. kelloggi*. These spines probably serve to fix and hold the gnathosoma in place during the introduction of the chelicerae and during feeding, although the ventral position of the rostrum may render these spines useless. The base of the gnathosoma and the hypostome are without setae, and there are no deutosternal spines. *Chelicerae* are greatly swollen at the base (maximum width of the bulb 21–34, length 63–67). The base of the movable finger is sinuous and with projecting angles. Note that in *S. tracheacolum* the ratio CH:Ch is the lowest of all the Ptilonyssinae (Fain, 1960*b*). *Legs*: First pair of legs thicker and distinctly larger than leg IV and possess some very short hairs and very small spines. Coxa I thicker (107–127) than coxa IV (91–103). Claw I greatly modified, claws II to IV well developed. Sensory zone on tarsus I carries a single simple seta 30 long; two short simple setae with conical bases; one solenidion 6–8 long; one short but thick conical seta; two very short spherical setae and one very thin and short simple seta implanted in a chitinous ring which continues to the interior of the tarsus by a small canal. Tarsus IV possesses dorsally three simple rather long setae with a conical base and two small spines; ventrally in its apical half two pairs of short cylindrical and transparent setae; its anterior side bears one small spine, and its posterior side three simple setae with an expanded base, and a small spine.

Specimens of Sternostoma tracheacolum *from canaries of other countries*

(1) *Canaries of Belgium* (Figs. 2, 13, 28, 32, 34, 44, 46, 52; Table 1)

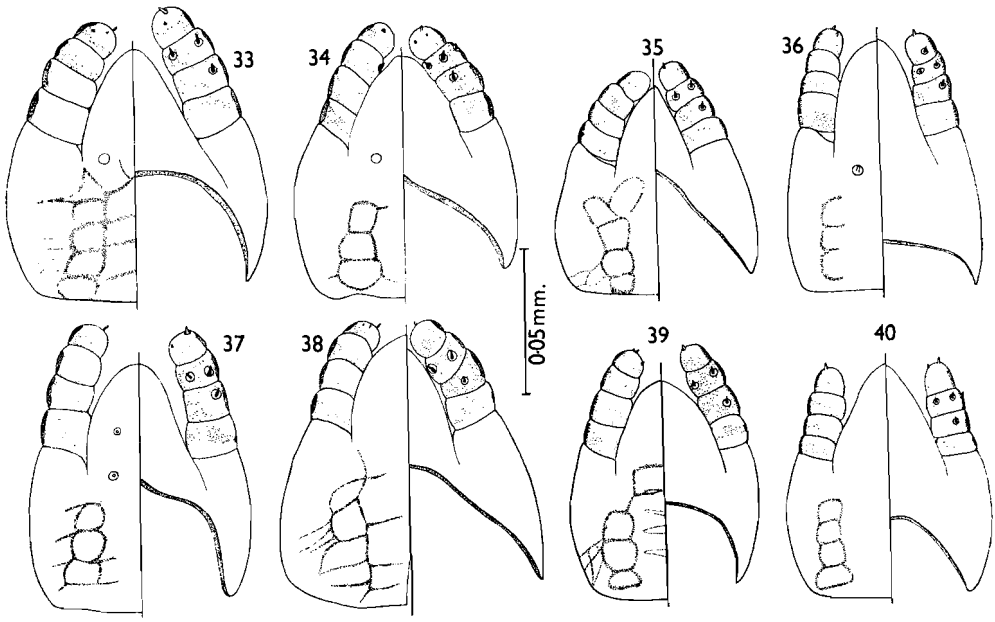
Fain (1958) reported the presence of *S. tracheacolum* Lawrence in the lungs of two canaries collected on 6 January 1958 in the environs of Antwerp, Belgium. Later he found these same parasites in the lungs of two other canaries, one from the Zoo (26 March 1958), and the other from the city of Bruges (14 October 1958). All canaries had died of pneumonia.



Figs. 29–32. Tarsus IV (ventrally and dorsally in 29, 31, 32; laterally in 30) of *Sternostoma tracheacolum*: South African specimen (29); paratype of *Agapornyssus faini* (31); cotype of *S. meddai* (30); specimen of Belgian canaries (32).

All the specimens collected were females. The ten specimens examined differ from the South African ones chiefly in the length of the movable digit, which never exceeds 6·5 in length (6–6·5) and in the higher ratio of chelicera to movable digit which varies between 16·1 and 17·8 (average 16·74). The other characters by which these specimens are differentiated from the South African ones are relatively unimportant. They are namely the smaller size of the body and of the podosomal plate; the distinctly longer and wider opisthosomal plate; the shorter gnathosoma

along with a distinctly narrower base; the shorter and thinner palps; the shorter chelicerae; the slightly different disposition of the sensory plate of tarsus I which bears three short simple setae with conical base (instead of two), and a small cone which terminates apically in a very fine seta and is prolonged basally by a canal which sinks into the interior of the tarsus (instead of a thin seta implanted in a chitinized cup).



Figs. 33–40. Gnathosoma of *Sternostoma tracheacolum*: South African specimen (33); specimen from Belgian canaries (34); specimen from New Jersey (35); specimen from Brazilian canary (36); paratype of *Agapornyssus faini* (37); cotype of *S. meddai* (38); specimen from *Cinnyricinclus* (39); specimen from *Passerina cyanea*, group 'B' (40).

(2) *Canary of North America* (*New Jersey*) (Figs. 7, 14, 35, 53; Table 1)

These three specimens from this locality are in the collection of the U.S. National Museum, Washington, D.C., and were kindly sent by Dr E. W. Baker. They were labelled: Denville N.J. Odenwald Bird Co. colrs, Mar.15.1959: In Canary's trachea.

They agree in all respects with the specimens of the Belgian canaries except that the opisthosomal plate, the gnathosoma, the palps and legs are shorter. The chelicerae are 101–104 long, the movable digit measures 6–6·6 (average 6·4) and the ratio CH:Ch is 15·3–16·8 (average 16·05).

(3) *Canary of Brazil* (*Porto Alegre*) (Figs. 36, 50; Table 1)

Four specimens from the U.S.N.M. also sent by Dr E. W. Baker are labelled: Canary air sac, from Antonio Ronna, Porto Alegre, Brazil, Let. Oct.23.1945, no. 3.

These specimens agree closely with those of Belgian canaries except that they

have a distinctly larger genital plate (LGP: 126–128, WGP 59–63) and a longer movable digit (8·1–8·8) with a lower ratio (CH:Ch 11·5–12·6; average 12·2). The sensory zone of tarsus I is similar to the South African specimens. By the intermediate length of the movable digit these specimens constitute a link between the specimens of South African canaries and those of Belgium.

(4) *Canaries of Italy* (= Sternostoma meddai *Lombardini*)

The three paratypes of *S. meddai* which we have studied agree closely with the specimens of South African canaries. We shall discuss this question in a paragraph on synonyms of *S. tracheacolum*.

Specimens of Sternostoma tracheacolum *from Parakeets* (*Psittaciformes*)

(1) Melopsittacus undulatus (*S. & N.*) (Figs. 10, 20, 27; Table 1)

The five female specimens were found in the lung of two parakeets dead at the Antwerp Zoo on 13 March 1958 (one specimen) and 22 March 1961 (4 specimens). These specimens present characters of the South African group, and of the Belgian group. The movable digit is 11–12 long, with a ratio CH:Ch 9·2–9·3 as in the South African specimens but the size of the body is smaller (average 497 in length for 266 in width). The opisthosomal plate is longer and wider (average 152 × 60); the genital plate distinctly longer (average 123); the gnathosoma more narrowed basally (65). By these characters they are closer to the specimens from the Belgian canaries. Legs I and IV are nearly the same length (average: 282 (I) and 273 (IV)), whereas in all the specimens from the canaries leg I is always much longer than leg IV.

(2) Agapornis cana *Gmelin*

The specimens from a parakeet from Madagascar will be discussed in the paragraph 'Synonyms of *S. tracheacolum*'. (Agapornyssus faini *Grétillat, Capron et Brygoo* = S. tracheacolum.)

(3) Agapornis *sp.* (*Love bird*) (Table 1)

Three female specimens from a parakeet of Madagascar (29 August 1956) in the collection of the British Museum. They agree with the other specimens from parakeets but the difference between the relative lengths of legs I and IV is a little greater than in the latter.

Specimens of Sternostoma tracheacolum *from wild passeriform birds*

(1) Cyanerpes cyanea *L.* (Figs. 4, 17, 25; Table 2)

A number of acarines were collected from the lungs and air-sacs of three specimens of this bird which originated in Brazil and had died from pneumonia at the Antwerp Zoo (27 May 1960 and 15 February 1961). The six female mites studied are intermediate between the South African canary specimens and the specimens from *Melopsittacus undulatus*, but legs I and IV are very short and thin as in the specimens of New Jersey canaries. The genital plate is shorter than in all the

Table 3. *List of acarines found in the lower respiratory tract of birds*

Parasitic acarine	Host	Order and family of host	Locality	Author
MESOSTIGMATA				
Sternostoma tracheacolum Lawrence, 1948	Canary	PASSERIFORMES: Fringillidae	South Africa	Lawrence, 1948
			Belgium (Antwerp, Bruges)	Present work
			Brazil (Rio de Janeiro)	Torres, Lent & Moreira, 1951
			Uruguay	Cassamagnaghi, 1952
			Brazil (Porto Alegre, 1945)	Present work
			U.S.A.	Baker *el al.* 1956
			U.S.A. (New Jersey, 1939)	Present work
	Passerella iliaca (Merrem)	Fringillidae	U.S.A. (Massachusetts)	Present work
	Passerina cyanea (L.)	Fringillidae	U.SA. (Michigan)	Present work
	Melospiza melodia (Wilson)	Fringillidae	U.S.A. (Michigan)	Present work
	Spizella pusilla (Wilson)	Fringillidae	U.S.A. (Michigan)	Present work
	Pooecetes gramineus (Gmelin)	Fringillidae	U.S.A. (Michigan)	Present work
	Hirundo rustica L.	Hirundinidae	U.S.S.R.	Bregetova 1951
	Riparia riparia (L.)	Hirundinidae	U.S.A. (Michigan)	Present work
	Acrocephalus arundinaceus (L.)	Sylviidae	U.S.S.R.	Bregetova, 1951
	Cinnyrinclus leucogaster verreauxi (Bocage)	Sturnidae	Congo (dead at Antwerp Zoo)	Present work
	Nectarinia jugularis flammaxilaris Blyth	Nectariniidae	Thailand	Strandtmann, 1960
	Seiurus aurocapillus (L.)	Parulidae	U.S.A. (Massachusetts)	Present work
	S. noveboracensis (Gmelin)	Parulidae	U.S.A. (Massachusetts)	Present work
	Passer domesticus (L.)	Ploceidae	U.S.A. (Michigan)	Present work
	Agelaius tricolor (Audubon)	Icteridae	U.S.A. (California)	Furman, 1957
	Icterus bullocki (Swainson)	Icteridae	U.S.A. (California)	Furman, 1957
	Sturnella magna (L.)	Icteridae	U.S.A. (Michigan)	Present work

Table 3 (*continued*)

Parasitic acarine	Host	Order and family of host	Locality	Author
	Molothrus ater (Boddaert)	Icteridae	U.S.A. (Rhode Island)	Present work
	Cyanerpes cyanea L.	Thraupidae	Brazil (dead at Antwerp Zoo)	Present work
	Poephila gouldiae (Gould)	Fringillidae	South Africa	Cumming, 1959
		PSITTACIFORMES:		
	Melopsittacus undulatus (Shaw. et Nod.)	Psittacidae	(Antwerp Zoo)	Present work
	Love bird *Agapornis* sp.	Psittacidae	Madagascar	Present work
(= *Agapornyssus faini* Grétillat, Capron et Brygoo, 1959)	*Agapornis cana* Gmelin	Psittacidae	Madagascar	Grétillat *et al.* 1959
		PASSERIFORMES:		
(= *Sternostoma meddai* Lombardini, 1953)	Canary	Fringillidae	Italy (Sardinia)	Lombardini,
	Carduelis carduelis tschussi Arrig	Fringillidae	Italy	Lombardii, 1953; Medda, 1953
(= *Sternostoma castroae* Fain,	*Macronyx croceus* Vieillot	Motacillidae	Ruanda-Urundi	Fain, 1956
SARCOPTIFORMES				
		GALLIFORMES		
Cytodites nudus (Vizioli, 1870)	*Gallus domesticus* L.	Phasianidae	Cosmopolitan	
	Meleagris gallopavo L.	Meleagrididae	Cosmopolitan	
	Bonasa umbellus (L.)	Tetraonidae	U.S.A.	Edminster, 1947
		PASSERIFORMES:		
	Turdoides melanops sharpei Reich.	Timaliidae	Ruanda-Urundi	Fain, 1960*a*
		CORACIIFORMES:		
	Merops apiaster L. (nasal cavity)	Meropidae	Ruanda-Urundi	Fain, 1960*a*
		PSITTACIFORMES:		
Cytodites psittaci Fain, 1960	*Poicephalus meyeri* Cretz.	Psittacidae	Ruanda-Urundi	Fain, 1960*a*
		PELECANIFORMES:		
Falculifer spp. (hypopus)	*Phalacrocorax africanus* Gmelin	Phalacrocoracidae	Ruanda-Urundi	Present work
		CICONIIFORMES:		
	Bubulcus ibis L.	Ardeidae	Ruanda-Urundi	Present work

Table 3 (*continued*)

TROMBIDIFORMES				
		COLUMBIFORMES:		
Speleognathus striatus Crossley, 1952 (nymphs in their cocoon)	Domestic pigeon	Columbidae	Ruanda-Urundi	Fain, 1955
		CICONIIFORMES:		
Speleognathus poffei Fain,	*Scopus umbretta* Gmelin (in the trachea)	Scopidae	Ruanda-Urundi	Fain, 1955
		CHARADRIIFORMES:		
Boydaia sp.	*Limnodromus griseus* (Gmelin) nasal cavity and lung (1 nymph)	Scolopacidae	U.S.A. (Rhode Island)	Present work

preceding specimens. The movable digit is 11–13, and the total length of the chelicera is 103–116; ratio of chelicera to movable finger is 8·0–9·7.

(2) *Wild birds from California (U.S.A.)* (described by Furman, 1953) (Figs. 9, 18, 26; Table 2)

The four specimens which we have examined came from the respiratory tract of *Icterus bullocki* (Swainson) and *Agelaius tricolor* (Audubon), both of the family Icteridae. In these specimens the dimensions of the podosomal plate, gnathosoma, palps and the chelicerae are similar to those of the South African specimens. By contrast the dimensions of the opisthosomal plate (length 151–161; width 63–78) and the longer genital plate (average 122) are nearer to those of the specimens from *Melopsittacus*. These specimens are therefore intermediate between the two groups. This intermediate position is further substantiated by the size of the body. Besides these convergent characters there is however a divergent one. The legs I and IV are longer (I, 335–362; IV, 286–315) and wider (femur I, 79–94; IV, 54–63; coxa I, 118–141, IV, 96–100) than in all the other specimens of *S. trachealcolum* in our collection. Length of chelicera is from 118 to 126, and the movable digit measures 12–13 (ratio 9·5–10·7, average 9·8).

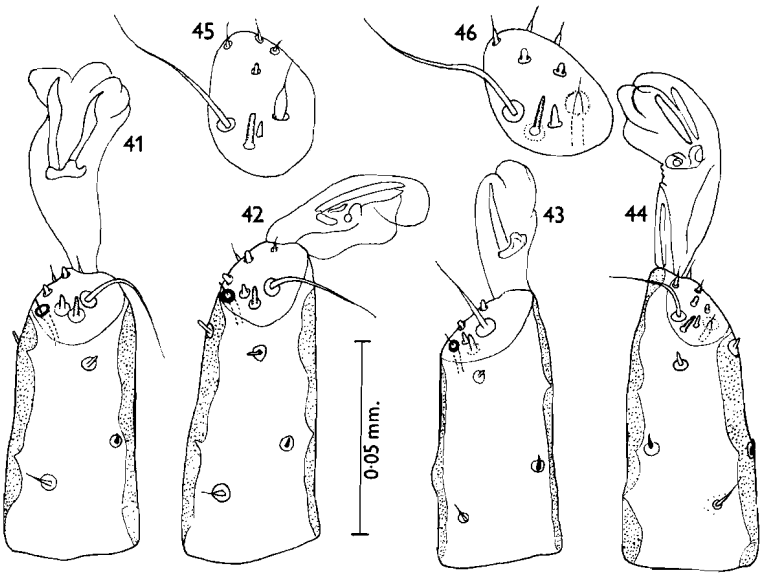
(3) *Wild birds from Michigan (U.S.A.)* (Figs. 3, 15, 40, 45, 54; Table 2)

Hosts include *Riparia riparia* (L.) (Hirundinidae); *Sturnella magna* (L.) (Icteridae); *Passerina cyanea* (L.), *Melospiza melodia* (Wilson), *Pooecetes gramineus* (Gmelin), *Spizella pusilla* (Wilson) (Fringillidae), and *Passer domesticus* L. (Ploceidae).

We can distinguish two distinct groups: group 'A' with long movable digits as in the specimens of South African canaries (12–13) and group 'B' with small movable digits (6·6) as in the Belgian ones.

Group 'A' consists of eleven specimens which have been found in lung, bronchus or trachea of *Riparia riparia* (L.), *Sturnella magna* (L.), *Melospiza melodia* (Wilson),

Spizella pusilla (Wilson), *Passerina cyanea* (L.), and *Passer domesticus* L. These specimens in the aggregate are very close to the South African material (e.g. podosomal plate, gnathosoma, palps, chelicerae, sensory zone on tarsus I). In these specimens the chelicerae are 105–132 long, and the movable chela 12–13 long (ratio 8·6–10·0, average 9·1).



Figs. 41–46. Tarsus I, dorsal view of *Sternostoma tracheacolum*: paratype of *Agapornyssus faini* (41); South African specimen (42); cotype of *S. meddai* (43); specimen from Belgian canaries (44 and 46). Sensory zone of tarsus I from specimen from *Melospiza melodia*, group 'B' (45).

Group 'B' consists of four specimens found in the trachea of three different birds (*Pooecetes gramineus* (Gmelin) (2 specimens), *Melospiza melodia* (Wilson) and *Passerina cyanea* (L.) (1 specimen each) (Figs. 3, 15, 40, 45, 54; Table 2). The chelicerae measure 96–98, the movable digit 6·6 (ratio 14·5–14·6). The other characters are as in the specimens of Belgian canaries except that they have an opisthosomal plate much longer (average 186) than in all the other specimens of *S. tracheacolum* examined, very short palps (30–33), and a slightly different arrangement of the sensory zone of tarsus I.

We mention that *Melospiza melodia* and *Passerina cyanea* are both parasitized by specimens of the two groups. However, these mites were not found associated in the same host specimen but came from the same species of bird from the same general locality (Barry and Kalamazoo counties).

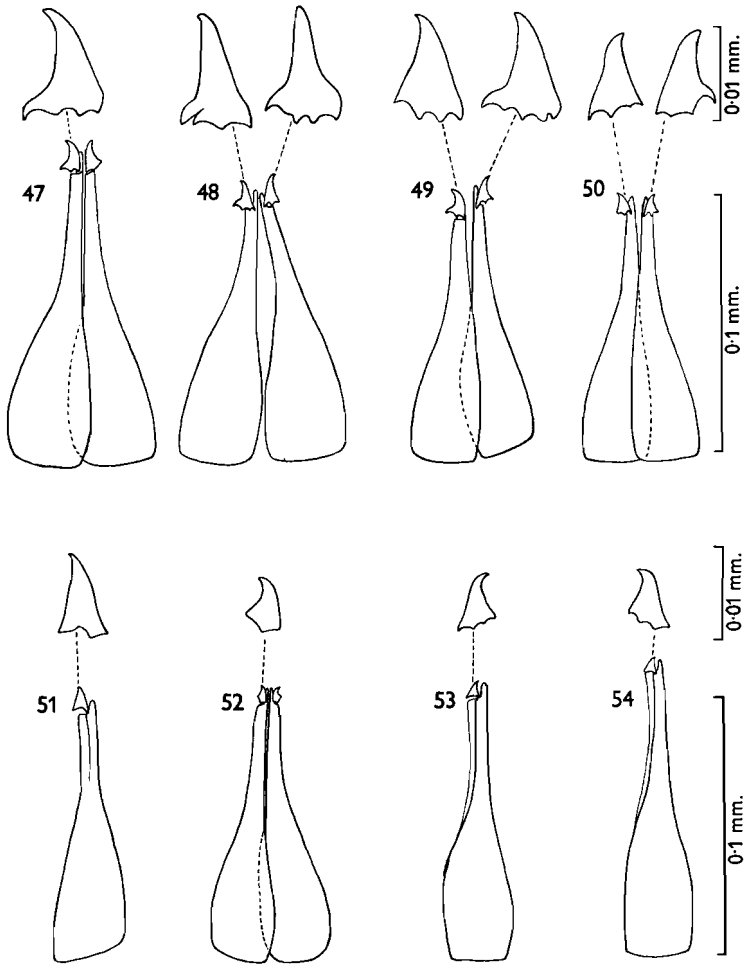
(4) *Wild birds from Rhode Island and Massachusetts (U.S.A.)*

Seven specimens have been examined from the following hosts: *Passerella iliaca* (Merrem), *Seiurus aurocapillus* (L.), *Seiurus noveboracensis* (Gmelin), and *Molothrus ater* (Boddaert). The specimens from the first three hosts agree very closely with group 'A' of Michigan, while the specimens of *M. ater* show some differences such

as a longer opisthosomal plate, and sternal plate, but these specimens are in poor condition and difficult to study.

(5) *Starling*, Cinnyricinclus leucogaster verreauxi (Bocage) (Figs. 39, 51; Table 2)

The nine specimens were found dead in a starling imported from the Congo and which died in the Zoo at Antwerp (6 February 1961). They were engorged and free in the general body cavity of the bird but the air-sacs, lungs, bronchi and trachea were devoid of parasites. The nasal cavity contained several live specimens belonging to another species (*Sternostoma straeleni* Fain). No lesions were observed in the respiratory organs. The bird was still in good condition, and without signs of putrefaction. The manner and route by which these mites invaded the body cavity of its host is puzzling.



Figs. 47–54. Chelicerae and movable chela of *Sternostoma tracheacolum*: cotype of *S. meddai* (47); South African specimen (48); paratype of *Agapornyssus faini* (49); specimen from Brazilian canary (50); specimen from *Cinnyricinclus* (51); specimen from Belgian canaries (52); specimen from New Jersey (53); specimen from *Passerina cyanea*, group 'B' (54).

These specimens have rather short chelicerae (91–100), but the movable digit is of intermediate length (8·7–9·6). The ratio LCH:LCh (10·4–10·8) however, is still very near that of the South African canary specimens. Sensory zone of tarsus I as in specimens from Belgian canaries but other characters are more like those in the specimens of South African canaries.

Synonyms of Sternostoma tracheacolum

(1) Sternostoma meddai *Lombardini*, 1953, *Syn. nov.* (Figs. 6, 12, 24, 30, 38, 43, 47; Table 1)

The characters on which Dr Lombardini has based his species in order to separate it from *S. tracheacolum* are: (1) the presence of a 'trichome' on the sensory zone on tarsus I and (2) the presence of stigmata. We have seen that these characters exist in all the specimens of *S. tracheacolum* examined. Dr Lombardini has kindly sent us the types and upon examination we are certain that *S. meddai* is a synonym of *S. tracheacolum*. The types consist of four female specimens mounted on one slide. All are in rather poor condition; they are flattened and the legs were in part flexed and retracted which makes their accurate measurement very difficult. In addition, the idiosoma is split and stretched in two others so it is difficult to ascertain their dimensions. The size and form of the plates, the gnathosoma, and cheliceral fingers are similar to those of the South African specimens. It should be noted, however, that the chelicerae are slightly longer (120–131) and the movable digit is 11–12·0 long with a ratio of LCH:LCh of 8·5–10·9. The legs are slightly shorter than in the specimens of Lawrence, but it is difficult to pass judgement because of the condition of the specimens. The original slide carries the following information, '*Sternostoma meddai* n.sp., female, Tipii, Apparato respiratorii di canarini. S.Vito, Sarrabas, Sardegna, 1953'. The specimens have been remounted in Hoyer's medium on two slides by us.

(2) Sternostoma castroae *Fain*, 1956 (Figs. 8, 16, 23; Table 2)

This species was synonymized earlier (Fain, 1957). It agrees completely with all the characters of the South African specimens. Length of chelicerae is from 110 to 118, and the movable digit measures 11–12 (ratio 9·6).

(3) Agapornyssus faini *Grétillat, Capron & Brygoo*, 1959, *syn.nov.* (Figs. 5, 19, 22, 31, 37, 41, 49; Table 1)

Dr Grétillat has kindly sent us two female paratypes of this species. They are the same as the specimens of *S. tracheacolum* from South Africa.

The genus *Agapornyssus* erected for this species has been made a synonym of *Sternostoma* by Fain (1960*c*), and the new subfamily Agapornyssinae falls thus into synonymy with Ptilonyssinae. The characters on which this genus is based are as follows: 'Chelicerae terminate in two short digits of which the longer comprises between a sixth and a tenth of the chelicera. Movable digit triangular, much longer than wide, with the base posterior. Stigmata at the level of the podosoma and provided with a peritreme. Gnathosoma ventral. Tritosternum absent. Claw I modified.' These characters are found in the genus *Sternostoma* except for (1)

the presence of a peritreme and (2) the relative length of the movable digit. A study of the two paratypes has revealed a stigmata deprived of a peritreme and a ratio of chelicera to movable finger of 8·5–8·8. The chelicera is slightly oblique which would make the ratio slightly larger. (The total length of the chelicerae is 102–105 and the movable digit 12.) These specimens have been collected from the lungs of a parakeet in Madagascar. They do not agree perfectly with any of the other specimens, but rather they have characters intermediate between them. Notably they have relatively long (124–129) genital plate, a relatively large opisthosomal plate (152–157 by 64–65); legs I and IV are subequal in length and the corresponding coxae the same width (91–94). They resemble the most the other specimens from parakeets (*Melopsittacus undulatus* and *Agapornis* sp.).

Variability of Sternostoma tracheacolum

The study of this collection of mites taken from various domestic and wild hosts in different parts of the globe (Africa, South and North America, Europe and Asia) has permitted us to make certain interesting notations on the variability of this species. Most concerned in this variation are the size of the body, plates, legs, chelicerae and gnathosoma. Certain plates (opisthosomal, genital, sternal) seem more subject to variation. It should be pointed out that the sternal plate is difficult to measure exactly because its limits are very vague. The length of the movable digit fluctuates between 6 and 14. Between these two limits we have found various intermediates. The ratio of chelicera to movable digit varies between 8·0 and 17·8. In general the shape of the plates, gnathosoma and base of chelicerae as well as the basic chaetotaxy of all specimens examined is very near or identical to the South African specimens.

(1) *Variations in the specimens from canaries*

In certain localities canaries harbour specimens of *S. tracheacolum* which differ from the typical form by one or more, more or less important characters.

The specimens discovered in the Belgian canaries differ essentially from the South African specimens in that the length of the movable digit is half as long (6–6·5 in the first group and 11–12 in the second) while the total length of the chelicera in the two groups is nearly the same (100–109 and 107–122). The ratio CH : Ch. in the two groups is very different, i.e. 8·5–10·7 in the first and 16·1–17·8 in the second.

Since the length of the movable digit and even more so the ratio of CH : Ch constitutes a character which is usually very stable in specimens from the same locality, one is inclined to ask if the specimens from Belgian canaries do not represent a new species. However, the discovery of specimens with some characters intermediate between the two extreme groups has shown that this is not the case. For instance in the specimens from canaries originating in Brazil, we found measurements of the movable chela which were intermediate (8·1–8·8 with a ratio of 11·5–12·6).

We found, on the other hand, that the New Jersey canaries harboured specimens which were very close to those of the Belgian canaries in the length of the digits

(movable digit 6–6·6; ratio CH:Ch 15·3–17·8) and that the specimens parasitizing the Italian canaries (= *S. meddai*) correspond perfectly to those described from the South African canaries (movable digit 11·0–12·0; ratio CH:Ch 8·5–10·9).

(2) *Variations in specimens from parakeets and wild passeriform birds*

The specimens from *Cyanerpes cyanea* as well as those from wild birds from Africa and North America, and from parakeets all differ from the specimens from canaries by various characters which seem insufficient, however, for excluding them from *S. tracheacolum*.

The variability observed in the specimens from wild birds is as great as in those specimens from canaries. We find here also some forms with the movable digit measuring only 6·6 (group 'B' of Michigan), other forms with movable digit of 12–13 (group 'A' of Michigan and specimens from various passeriform and psittaciform hosts) and a form with a digit of intermediate length (8·7–9·6) (*Cinnyricinclus leucogaster verreauxi* (Bocage). In this regard the other characters vary as much and in the same proportion.

Note that the specimens collected from parakeets in the Antwerp Zoo cannot be separated from the specimens parasitizing parakeets in Madagascar. The specimens from parakeets (Psittaciformes) are differentiated, on the other hand, from all the specimens from passeriforms (domestic or wild) by the subequal length of legs I and IV. Knowing the constancy of this character and the different nature of the host it is possible that these specimens represent a distinct subspecies.

DISCUSSION

The comparative study of all the specimens of *Sternostoma tracheacolum* from the Psittaciformes and Passeriformes, wild as well as domestic forms, shows that some important variations may appear in the specimens coming from the same host (canary) but living in localities much removed. The geographic isolation seems thus to have played a very important role in the evolution of this parasite.

In the light of this fact one can ask if the variations observed in the wild hosts of *S. tracheacolum* do not stem at least in part from a geographic isolation rather than on the nature of the host. It seems, on the other hand, that the simple biological isolation is able to bring about the same results. Some different hosts indeed living in the same locality can in effect remain completely isolated if their biotopes are different.

One fact which remains difficult to explain, however, is the presence in the same wild host in Michigan of the two extreme forms of *S. tracheacolum*—the one with long digits and the other with short ones. It can be explained perhaps on the biology of these hosts. One can suppose that, next to hosts harbouring specifically one or the other of these forms of *S. tracheacolum*, there are some birds whose biotope is less restricted and thus are better able to come occasionally into contact with the carriers of these two forms.

Another fact deserving comment is that in some populations, separated geographically, the important variations often concern only a limited number of

characters, sometimes only a single one. For example, the specimens parasitizing the canaries in Belgium differ principally from the South African specimens by the length of the movable digit. The maximum variations observed are from 6 in the first group to 13 in the second. Another example is that the specimens with short movable digits parasitizing the wild birds in Michigan (group 'B') have an opisthosomal plate longer than those from other hosts. The maximum variations of this plate are from 118 (certain specimens from South African canaries) to 192 (specimens from *Pooecetes gramineus*). In still other specimens it is the genital plate which varies in notable proportions (83 in some specimens from *Cyanerpes cyanea* to 129 in specimens from the parakeet). Note also that legs I and II are always very unequal except in specimens from the parakeets where they are equal or subequal.

The variations occurring in some specimens collected in the same host but from different localities are difficult to interpret. They are to be explained probably by geographic isolation of the host but the precise mechanism of their appearance is not understood. Perhaps they are the result of small mutations which have appeared spontaneously in these isolated populations, or else they may simply result from the normal evolutionary process being exercised in small local groups possessing different genotypes. In relationship to our observations it should be noted that Goksu, Wharton & Yunker (1960) point out that the extreme variation observed in the laboratory-reared chigger mite *Trombicula* (*Leptotrombidium*) *akamushi*, is probably attributable to a genetic influence rather than to an environmental one.

The present study has drawn attention to the important variations which might be found in a species of the family Rhinonyssidae following geographic isolation. The same causes which have produced these variations in *Sternostoma tracheacolum* can in effect manifest themselves in the other species of rhinonyssids; therefore, it is necessary to take this into account when describing new species in this group of mites.

SUMMARY

The mites known to parasitize the lower respiratory tract of birds are discussed and a host list of the various species is given.

Sternostoma tracheacolum Lawrence, 1948, is redescribed and the variations in specimens from various hosts and localities are analysed. The synonymy of *S. castroae* with *S. tracheacolum* is confirmed and *S. meddai* and *Agapornyssus faini* are made new synonyms of *S. tracheacolum*. The specimens found in canaries vary widely according to the origin of the host. Those from South African and Italian canaries are closely related morphologically and present relatively long chelae, while specimens from Belgian and North American canaries have much smaller chelae. An intermediate form is found in a Brazilian canary. *S. tracheacolum* is thought to use wild birds as its normal hosts since it has been found repeatedly in birds in North America, as well as in other parts of the world, and because its presence in the trachea and lungs in these birds seems to be much better tolerated than in the canaries. Canaries are thus probably infested secondarily, and it seems that *Passer domesticus* has served in the transfer of the mites between the two

groups. The specimens from wild birds present the same variability as those of the canaries, and one can also distinguish three different groups on the basis of the length of the chela. The origin of these variations is discussed. Geographical or biological isolation of the host probably plays a more important role than the host itself in the production of variation.

Hypopi representing probably two species of the genus *Falculifer* have been found in the air-sacs and lungs of two central African birds. Also *Speleognathus poffei*, *S. striatus* and *Boydaia* sp. have been taken from the lungs or trachea of their hosts in Ruanda–Urundi or U.S.A.

Collection of most North American material was carried out under a research grant (G-11035) from the National Science Foundation.

The authors wish to thank the following for their co-operation and assistance in this study by making available various collections of *Sternostoma tracheacolum*: E. W. Baker, U.S. National Museum, Washington, D.C.; G. Owen Evans, British Museum (Natural History), London; D. P. Furman, University of California, Berkeley; S. Grétillat, Laboratoire Central de l'Elevage, Dakar; R. F. Lawrence, Natal Museum, Pietermaritzburg; and G. Lombardini, Rome.

REFERENCES

Baker, E. W., Evans, T. M., Gould, D. J., Hull, W. B. & Keegan, H. L. (1956). A manual of mites of medical or economic importance. *Tech. Pub. Nat. Pest., Contr. Ass. New York*, 170 pp.

Bregetova, N. (1951). Mites parasitizing the nasal cavities of birds. *Parasit. Sbornik, Zool. Inst. Acad. Sci. U.S.S.R.*, **13**, 111–19.

Cassamagnaghi, A. (1952). Las endoparasitosis de nuestras especies domesticas. *Bol. Direct. Ganaderia, Uruguay*, **33**, 80–90.

Cumming, R. B. (1959). Respiratory acariasis of canaries and Gouldian finches. *J. S.Afr. Vet. Med. Ass.* **30**, 31–2.

Edminster, F. C. (1947). *The Ruffed Grouse*. New York: Macmillan Co.

Fain, A. (1955). Sur le parasitisme des fosses nasales chez les mammifères et les oiseaux par les Speleognathidae. *Ann. Soc. Belg. Méd. Trop.* **6**, 689–700.

Fain, A. (1956). Note complémentaire sur les Rhinonyssidae au Ruanda-Urundi. *Rev. Zool. Bot. Afr.* **53**, 392–8.

Fain, A. (1957). Les Acariens des familles Epidermoptidae et Rhinonyssidae parasites des fosses nasales d'Oiseaux au Ruanda-Urundi et au Congo Belge. *Ann. Mus. Congo belge T*, (Sér. in 8e), **60**, 1–176.

Fain, A. (1958). Acariens parasites nasicoles chez les oiseaux du Zoo d'Anvers. Description de trois espèces nouvelles. *Bull. Soc. Roy. Zool. Anvers*, **9**, 1–13.

Fain, A. (1960*a*). Révision du genre *Cytodites* (Mégnin) et description de 2 espèces et un genre nouveaux dans la famille Cytoditidae Oudemans. *Acarologia*, **2**, 238–249.

Fain, A. (1960*b*). Morphologie comparée des Rhinonyssidae. I. La longueur des doigts chélicéraux. *Bull. Ann. Soc. Roy. Ent. Belg.* **96**, 303–13.

Fain, A. (1960*c*). *Rallinyssus gallinulae* n.sp. et *Rallinyssoides* n.g., parasites de Rallidae, avec une clé des Rhinonyssinae. *Bull. Ann. Soc. Roy. Ent. Belg.* **96**, 293–302.

Fain, A. (1961). Les Acariens de la famille Entonyssidae parasites endopùlmonaires des Serpents. *Bull. Inst. Roy. Sci. Nat. Bɪlgique* **6**, 1–135.

Fain, A. &. Carpentier, J. (1958). Acariase pulmonaire mortelle chez des Canaris du Zoo. *Bull. Soc. Roy. Zool. Anvers*, **9**, 21–4.

Furman, D. P. (1957). Revision of the genus *Sternostoma* Berlese and Trouessart. *Hilgardia*, **26**, 473–95.

GOKSU, K., WHARTON, G. W. & YUNKER, C. E. (1960). Variation in populations of laboratory-reared *Trombicula* (*Leptotrombidium*) *akamushi* (Acarina: Trombiculidae). *Acarologia*, **2**, 199–209.

GRÉTILLAT, S., CAPRON, A. & BRYGOO, E. R. (1959). Acariens Rhinonyssidae de Madagascar. Agapornyssinae n.s.fam.; *Agapornyssus* n.g.; *Agapornyssus faini* n.sp.; *Ptilonyssus madagascariensis* n.sp. et *Neonyssus marcandrei* n.sp.; parasites des fosses nasales et des poumons d'Oiseaux malgaches. *Acarologia*, **1**, 375–84.

HYLAND, K. E. & CLARK, D. T. (1959). *Sternostoma kelloggi*, a new species of nasal mite from the catbird (Acarina: Rhinonyssidae). *J. Parasit.* **45**, 223–6.

HIGBY, W. E. (1946). A new canary plague. *All Pets Mag.* (Dec.), pp. 8–9.

LAWRENCE, R. F. (1948). Studies on some parasitic mites from Canada and South Africa. *J. Parasit.* **34**, 364–79.

LOMBARDINI, G. (1953). Acari nuovi XXIX. *Redia*, **38**, 181–94.

MEDDA, A. (1953). Acariasi delle vie respiratorie in *Serinus c. canarius* L. ed in *Carduelis carduelis tschussi* Arrig. *Atti. Soc. Ital. Sci. Vet.* **7**, 731–6.

MEDDA, A. (1957). Il dimorphismo sessuale dello *Sternostoma meddai* Lombardini. *Vet. Ital.* **8**, 763–8.

STEPHAN, S. A. R., KASCHULA, V. R. & CANHAM, A. S. (1950). Respiratory acariasis of canaries. *J. S. A. Vet. Med. Ass.* **21**, 103–7.

STRANDTMANN, R. W. (1960). Nasal mites of Thailand birds (Acarina-Rhinonyssidae). *J. Kansas Ent. Soc.* **33**, 137.

TORRES, C. M., LENT, H. & MOREIRA, L. F. (1951). Acarinose das respiratorias do canario ('*Serinus canarius*' L.) por '*Sternostoma tracheacolum*' Lawrence, 1948. *Rev. Brasil. Biol.* **11**, 399–406.