Entomol Gener | 20(1/2): 011-019 | Stuttgart 1995-09 | ISSN: 0171-8177

EGT-Nr 880 II

The Predaceous Fly Lispe candicans (Diptera: Muscidae) and its Chemically Protected Prey, the Rove Beetle Bledius furcatus (Coleoptera: Staphylinidae)

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Received: 1994-07-11 / 1995-05-02 Accepted: 1995-05-12

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Lispe candicans Kowarz 1892 is a predator of the rove beetle *Bledius furcatus* (Olivier 1812) (Staphylinidae: Oxytelinae). In encounters, the fly attempts to pierce the beetle and suck it out by using its proboscis. The proboscis is adapted for this purpose by strong prestomal teeth, which can produce large holes in the beetle's integument. *B. furcatus* defends itself with an abdominal defensive gland, although in 23% of the encounters observed individuals of *B. furcatus* were killed. In the course of the mating of *L. candicans* the **M** presents a characteristic courtship behaviour. During egglaying the **F** is accompanied by a **M**.

K e y w o r d s: *Lispe candicans* - *Bledius furcatus* - predator-prey-relationship - proboscis - chemical defence.

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Lispe candicans Kowarz 1892 ist ein Räuber des Kurzflügelkäfers *Bledius furcatus* (Olivier 1812) (Staphylinidae: Oxytelinae). Wenn sie auf einen Käfer trifft, versucht die Fliege, ihn mit Hilfe ihrer Proboscis anzubohren und auszusaugen. Die räuberische Lebensweise der Fliege wird durch den Besitz von starken Prästomalzähnen an der Proboscis ermöglicht. Mit diesen Zähnen kann die Fliege große Löcher in den Körper des Käfers schlagen. *B. furcatus* verteidigt sich durch Sekretabgabe aus einer abdominalen Wehrdrüse. In 23% der beobachteten Begegnungen wurde *B. furcatus* durch die Fliege getötet. Bei der Paarung von *L. candicans* zeigt das **M** ein charakteristisches Balzverhalten. Während der Eiablage wird das **F** von einem **M** begleitet.

S c h l ü s s e l w ö r t e r: *Lispe candicans* - *Bledius furcatus* - Räuber-Beute-Beziehung - Proboscis - chemische Verteidigung.

0171-8177/95/0020-0011 $ 2.25

1 Introduction

During a study of the natural predators of the rove beetle *Bledius furcatus* (Olivier 1812) on a dried up salt lake in Greece, STEIDLE & DETTNER [1994] found the muscid fly *Lispe candicans* Kowarz 1892 attacking these chemically protected beetles. Imagines of the genus *Lispe* are known to be predaceous. According to literature, however, their prey consists of soft-bodied Diptera, i e larvae or just moulted imagines of Chironomidae, Culicidae and Simulidae [ATKINSON 1909, CHARBONNIER 1918, LAMBORN 1920, BALAY & GRENIER 1964, HENNIG 1964, HOBBY 1931, SZADZIEWSKI 1983]. These nearly defenceless insects are pierced and sucked out with the fly's proboscis.

The question arises how *L. candicans* is able to overcome *B. furcatus*. This beetle is more strongly sclerotized than Diptera and in addition is provided with a defensive gland, located dorsally at the abdominal tip [ARAUJO 1973]. This is the topic to be examined in this paper through field observations of encounters between *L. candicans* and *B. furcatus*, and by SEM-examinations of the proboscis of *L. candicans* and of killed specimens of *B. furcatus*. As the eidonomy of *L. candicans* is almost unknown, also observations are to be presented concerning the mating and egg laying behaviour of this fly species.

2 Material and Methods

Intraspecific behaviour of *L. candicans* was continuously observed and recorded for 4 h/day on IX-7/8 [1991] in their natural habitat, a dried up saltlake on Amuliani Island, Greece. Encounters between *L. candicans* and *B. furcatus* were observed at the saltlake in September 1991. Living specimens of *B. furcatus* were collected at the saltlake and were blown with a straw into the close vicinity of a fly (about 20 cm). Usually the beetles were immediately attacked. The behavioural traits displayed during the encounters were recorded continuously.

2.1 SEM of *Lispe* proboscis: Prior to examination with the SEM, flies were placed into distilled water at 20°C for 14 days. Formalin [0.5%] was added to prevent bacterial and fungal growth. This treatment increased the body pressure of the specimens and thereby forced the labellar lobes to evert [ELZINGA & BROCE 1986]. Afterwards specimens were cleaned for 30 s by ultrasonic treatment, critical point-dried (CPD 020 by Balzers) and sputtered with gold (sputter coater S150B by Edwards). Examinations were performed using a Stereoscan 90 SEM (Cambridge Instruments).

2.2 SEM of killed *B. furcatus*: To detect the most usual puncture sites on the body of the beetles, single flies were kept in a closed box together with several specimens of *Bledius*. The killed beetles were collected and the holes made by the fly's proboscis were examined. For SEM-photographs, some specimens were cleaned in soap water, dried and sputtercoated with gold (see above).

3 Results

3.1 Biology of *Lispe candicans*

The sexes of *L. candicans* can be distinguished by the silver-white sprinkled frons, genae and praefrons of the **M**. Contact between 2 flies of the same sex usually lasts only 1-2 s and ends up with the flight of one specimen. During encounters of **FF** and **MM**, courtship and mating behaviour was observed. When approaching, the **M** moves in a series of jerks and short flights around the **F**. Meanwhile the **F** elevates her abdomen, the tip of which then makes contact with the **M** caput. After this contact, the flies either

separate immediately (end of the encounter) or copulate. The very peculiar ovipositional behaviour of *L. candicans* was observed once: the **MM** and **FF** behave in a manner similar to the tandem running of ants [HÖLLDOBLER & WILSON 1990], with the **M** holding onto the **F** wings with its front legs. For oviposition the tandem stops, the **F** bends its abdomen and lays one single egg under the layer of dried algae covering the whole surface of the saltlake. Afterwards the tandem separates.

3.2 Encounters of *L. candicans* and *B. furcatus*

When *Lispe candicans* encounters a specimen of *B. furcatus* a fierce struggle begins. The fly attempts to penetrate the beetle's body with its proboscis in order to suck it out. *B. furcatus*, on the other hand, tries to defend itself with its abdominal gland (Fig 1): The beetle bends its abdomen towards the aggressors and tries to smear the flies with its gland secretion. When touched by the secretion, the flies display grooming behaviour or even show total disorientation and swaying. During this distraction, the beetles generally succeed to escape and to bury themselves in the ground.

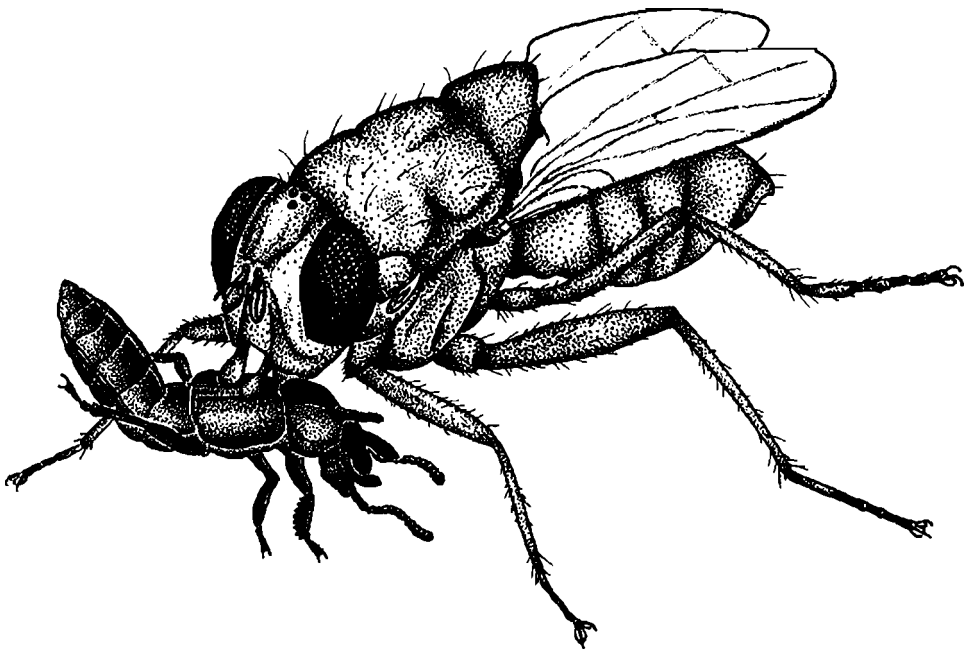

Fig 1: Attack of a specimen of *Lispe candicans* Kowarz 1892 [Diptera: Muscidae] on a male of *Bledius furcatus* (Olivier 1812) [Coleoptera: Staphylinidae: Oxytelinae].

Thus, only 23% of the observed encounters end up with the death of a *B. furcatus* (Tab 1). The flies approach the beetles most often from the side (52% of attacks) or from behind (38%), though occasionally changing the direction of attack during one encounter. Approaches to the beetles from the front (10%) are rare. Remarkably, *L. candicans* specimens are able to overcome beetles only when attacking from the side or from the front. Encounters of the flies by rear approach are hardly ever successfull.

Tab 1: *Lispe candicans* Kowarz 1892 [Diptera: Muscidae] vs *Bledius furcatus* (Olivier 1812) [Staphylinidae: Oxytelinae]. Probability of survival of *B. furcatus* depending on direction of approach of *L. candicans*. Probability-level (Fisher-test): Survived vs killed specimens of *B. furcatus* depending on direction of approach.

attack occured	Nr of *B. furcatus* survived	Nr of *B.furcatus* killed	p
from behind	24	1	0,001
from other directions	10	9	0,001
total number	**34**	**10**	

3.3 Proboscis of *L. candicans*

The 2 labellar lobes on the tip of the proboscis of *L. candicans* can be everted to various feeding positions [GRAHAM-SMITH 1930, ELZINGA & BROCE 1986]. From a resting position [stage I = **st-I**] the lobes are straightened out and the pseudotracheal membrane is exposed to form a flat surface in the filtering and cupping positions (st-II/-III). As the lobes continue to evert, the intermediate position is reached (st-IV)when the tips of the prestomal teeth appear (Fig 2a). Further eversion results from stretching the pseudotracheal membrane backwards and turning the prestomal teeth outwards to the scraping position (st-V), and finally to the direct feeding position (st-VI). During the last 2 stages, the prestomal teeth are fully expanded (Fig 2b, d). The proboscis of *L. candicans* is provided with 5 prestomal teeth on each labellar lobe. All teeth are single pointed and smooth without microteeth or tines. The largest teeth on each side are at 150 µm long and 100 µm wide. When fully expanded, the width of the tip of the proboscis, including the teeth, measures 350 µm, without teeth 170 µm. The prestomal teeth are surrounded by the folded pseudotracheal membrane, equipped with 9 pseudotracheae per labellar lobe with a proximal diameter of 8-9 µm.

3.4 Puncture sites on the beetle's body

The preferred targets on the beetle's body for penetration with the proboscis are presented in Fig 3 and illustrated in Fig 4. Holes in the integument are mainly to be found between the tagmata, most often between thorax and abdomen but also between pro- and mesothorax and caput and prothorax. Seldomly, the flies also penetrate the thin cuticular layer under the elytrae or crush the prothorax. No injuries can be found on the abdomen of the beetles.

4 Discussion

Descriptions of the eidonomy and ethology of flies of the genus *Lispe* are scarce. To our knowledge mating behaviour is described only for *Lispe caesia* Meigen 1826 [ALFKEN 1924, cited in HENNIG 1964]. Therefore it seems to be justified to include the above mentioned superficial observations on the mating and oviposition of *L. candicans* in this paper. These show that the courtship, mating and oviposition of the genus *Lispe* raise many different and interesting questions. The presence of the **M** during oviposition in *L. candicans* seems to be especially remarkable. Is the exact place of oviposition selected by the **M**? Apparently the tandem is not formed subsequent to courtship and mating. Therefore this behaviour seems to be no mate-guarding which can be observed in damselflies [KREBS & DAVIES 1993].

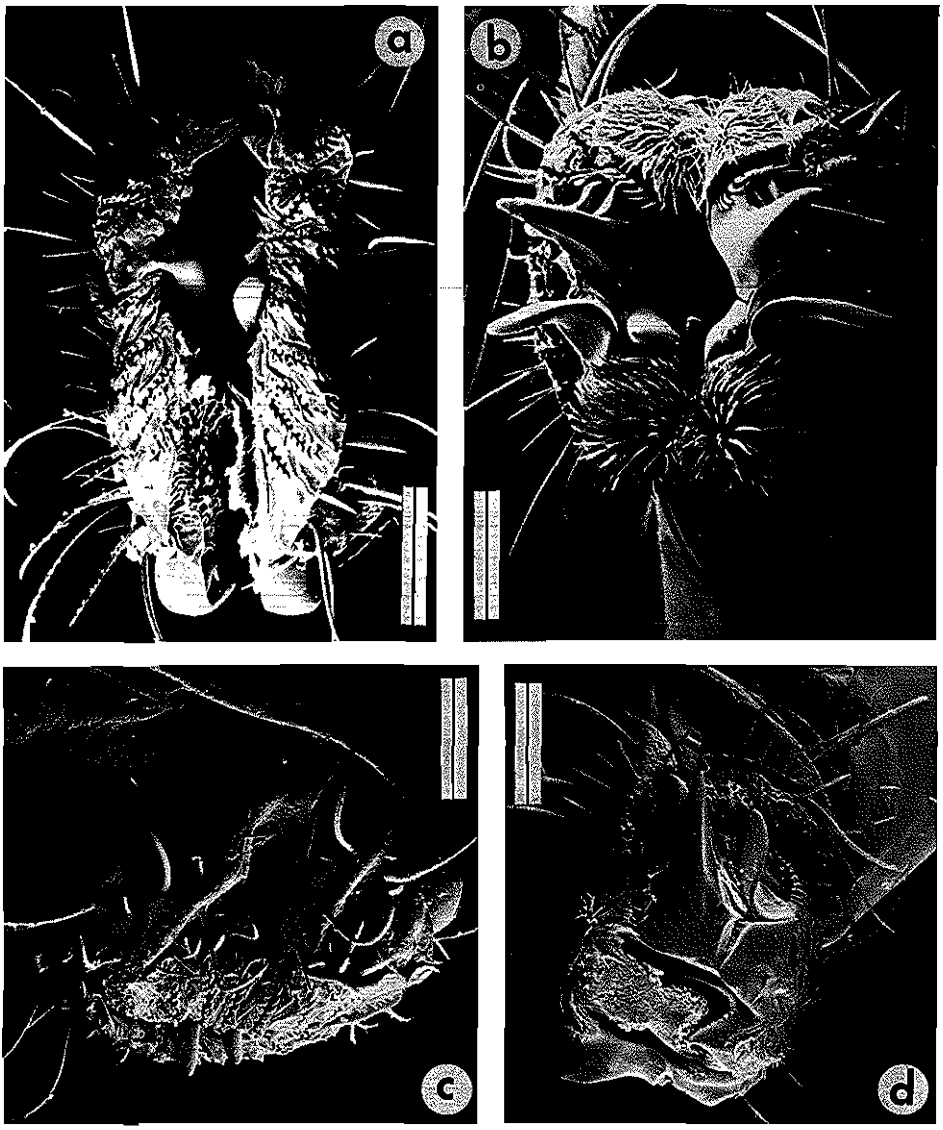

Fig 2: SEM photographs of the tip of the proboscis of *Lispe candicans* Kowarz 1892 [Diptera:Muscidae] in different feeding positions [GRAHAM -SMITH 1930, ELZINGA & BROCE 1986]. **a**: stage III-IV, frontal; **b**: st-V, frontal; **c**: st-III-IV, lateral; **d**: st-VI, lateral. B a r 100 µm.

Which other advantage does the **M** gain from participating in oviposition? Due to the high abundance of *L. candicans* on the site, various **MM** could be considered as the parent of a laid egg.

The here presented behavioural observations show that - in contrast to other species of the same genus - *L. candicans* is able to overcome not only soft-bodied and defenceless prey [ATKINSON 1909, CHARBONNIER 1918, LAMBORN 1920, BALAY & GRENIER 1964, HENNIG 1964, HOBBY 1931, SZADZIEWSKI 1983] but also strongly sclerotized prey like the rove beetle *B. furcatus*. In addition to its sclerotized cuticula, *B. furcatus* is protected by a defensive gland.

This paired gland is located in the tip of the beetle's abdomen (Fig 3), and the 2 reservoirs open up the 2 parts of the divided tergitum-9 [ARAUJO 1973]. The gland secretion consists mainly of the toxic p-toluquinone dissolved within 1-undecene and γ-dodecalactone [STEIDLE 1993, STEIDLE & DETTNER 1994]. Due to the deterrent effect of this defensive secretion, the beetle's chance of surviving an encounter with the ant *Cataglyphis bicolor* (F.) is increased fivefold [STEIDLE 1993, STEIDLE in press]. In attacks by *L. candicans* as well, the defensive secretion increases the chance of survival: *B. furcatus* succeeds in escaping when *L. candicans* is hit by the secretion and *L. candicans* can overcome the beetle only by lateral or frontal attacks. The distribution of puncture sites on the beetle's body highlights the fact that the secretion especially protects the abdomen of the beetle. Although *L. candicans* apparently prefers to pierce its prey through the intersegmental membranes between sclerites, no holes can be found in the beetle's abdomen, even though it consists of numerous sclerites and intersegmental membranes.

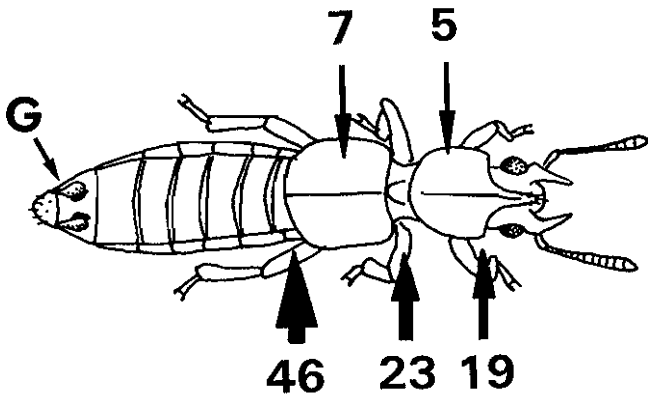

Fig 3: Puncture sites of *Lispe candicans* Kowarz 1892 [Diptera: Muscidae] on the body of *Bledius furcatus* (Olivier 1812) [Coleoptera: Staphylinidae: Oxytelinae]. Numbers indicate frequency [%], n = 43 holes in 28 beetles examined. **G** abdominal defensive gland.

The proboscis of *L. candicans* morphologically corresponds to the proboscis of the 3 other *Lispe* species examined so far (Tab 2) and to the proboscis of other predaceous flies [HOBBY 1934, SYCHEVSKAYA 1981, ELZINGA & BROCE 1986, KÜHNE 1992]. In all *Lispe* species, the proboscis is adapted to a predaceous life style by a small number of pseudotracheae (9-13; *Musca domestica* L. has 29-32 pseudotracheae [ELZINGA & BROCE 1986]) and a small number of single-pointed, smooth prestomal teeth.

Tab 2: Proboscis of examined species of the genus *Lispe* Latreille 1776 [Diptera: Muscidae]

L. tentaculata (De Geer 1776)	4 pairs of strong, conical single-pointed teeth; Nr of pseudotracheae reduced.	HOBBY [1934]
L. orientalis Wiedemann 1824	4 pairs of single-pointed teeth; 10-12 pseudotracheae per labellar lobe	IWASA [1983]
L. nasoni Stein 1898	5 to 7 pairs of smooth, single-pointed teeth; middle tooth enlarged; 11-13 pseudotracheae per labellar lobe; Ø of pseudotracheae: 8-10 µm.	ELZINGA & BROCE [1986]
L. candicans Kowarz 1892	5 pairs of smooth, single-pointed teeth; middle tooth enlarged, 150 µm long, 100 µm broad; 9 pseudotracheae per labellar lobe; Ø of pseudotracheae: 8-9 µm.	present paper

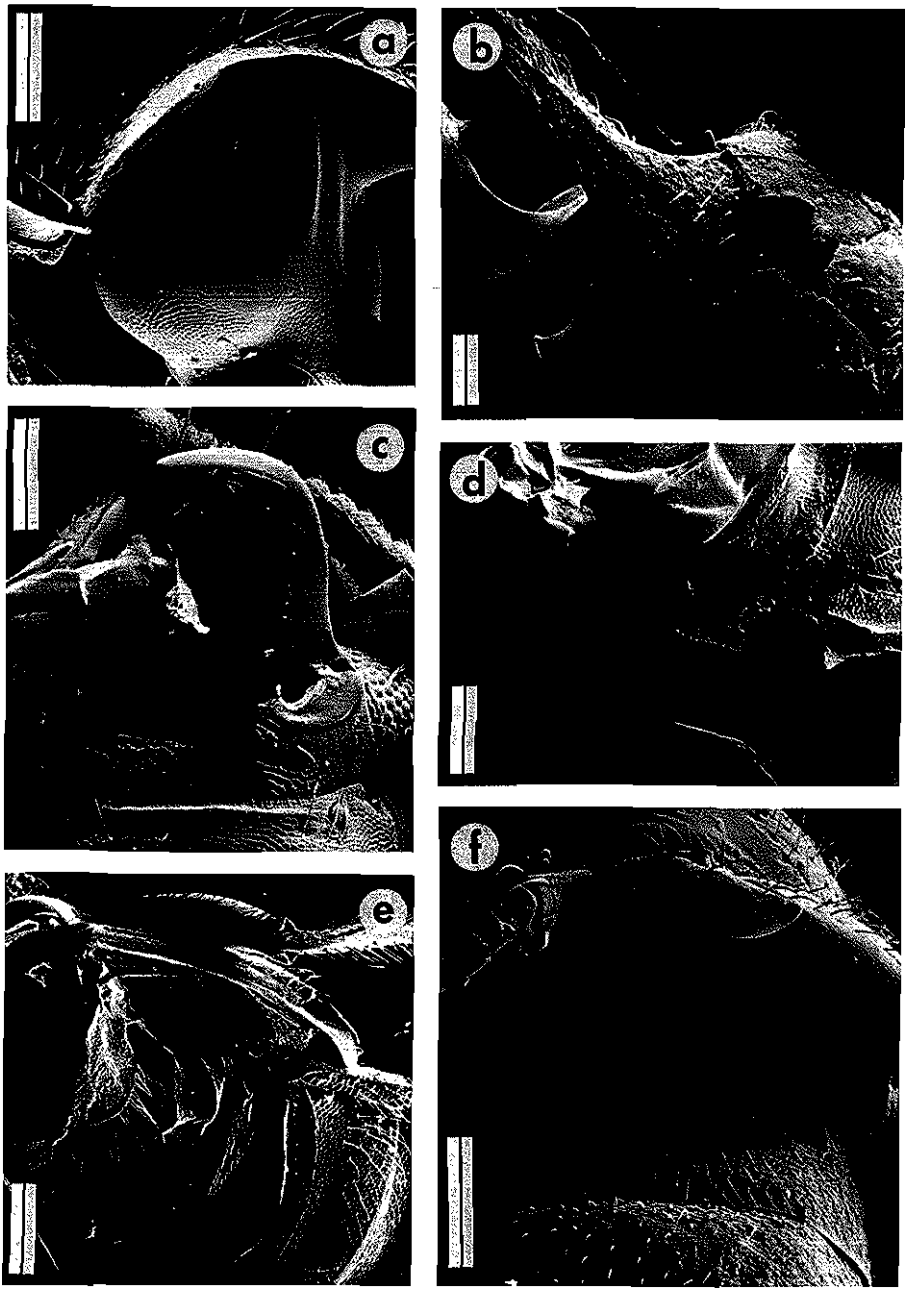

Fig 4: SEM photographs of wounds on the body of *Bledius furcatus* (Olivier 1812) [Coleoptera: Staphylinidae: Oxytelinae] caused by *Lispe candicans* Kowarz 1892. [Diptera: Muscidae].- **a** hole between caput and prothorax; **b** crushed prothorax; **c** crushed gula; **d** holes dorsal on the left side of the thorax, elytrae removed; **e** holes dorsal at the right side of the thorax and between thorax and abdomen; **f** ventral hole in sternitum-1. B a r 250 µm

Furthermore in *L. nasoni* and *L. candicans*, the middle tooth is enlarged. Compared to the prestomal teeth of other Diptera, the middle tooth of *L. candicans* represents one of the largest prestomal teeth of muscomorpha flies found so far [ELZINGA & BROCE 1986].

Piercing into the cuticula of the prey, using the proboscis, can be imagined as follows: The proboscis is straightened in the direction of the prey and the labellar lobes are everted until st-IV is reached. In this position the prestomal teeth point forward and cut through the tissue of the prey. Probably this cutting action is achieved principally by the enlarged middle tooth. Own examinations, as well as bibliographical references, indicate that the membranes between the tagmata of the prey (caput-thorax, thorax-abdomen) are especially suited as puncture sites [EVANS 1930, BALAY & GRENIER 1964, SYCHEVSKAYA 1981, KÜHNE 1992].

When the proboscis has passed through the cuticula, the prestomal teeth are everted and reach st-VI. Now the teeth can enlarge the hole in the cuticula or serve as barbs to keep a firm hold on the prey. During feeding, the prestomal teeth are probably used to cut up the tissue and to scrape out the prey's body as described in the predaceous flies of the genus *Coenosia* [EVANS 1930, KÜHNE 1992].

During st-II/-IV the food is ingested using the pseudotracheae. When st-V is reached, food can be ingested directly into the oral aperture. This avoids the pseudotracheae with their narrow diameters and allows the ingestion of suspended particulate matter [ELZINGA & BROCE 1986]. Thus, *L. candicans* is well adapted to a predatory way of life by the morphology of its proboscis.

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Acknowledgements - Danksagung: We are highly indebted to Dr Peter Hartmann (Bayreuth) for his support during our studies in Greece and to Nick Baragwanath MA (Brighton, UK) for kindly improving the English version of the manuscript. This project was financially supported by the DFG (De 258 / 5-1, 2).

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PRESCOTT D M & FLEXER A S: **Krebs. Fehlsteuerung von Zellen, Ursachen und Konsequenzen.**- Nach der im Verlag Sinauer Ass Inc 1982/1986 unter dem Titel "Cancer: The Misguided Cell" erschienen amerikanischen Originalausgabe übersetzt durch E-D JARASCH.-- [333 pp, 165 x 240 mm, mult fig 6 tab, balacr soft-cov].- **Publ:** Spektrum der Wissenschaft Verlagsges mbH, Heidelberg 1990; **ISBN:** 3-89330-706-0; **Pr:** DM 44.--. --- [EGR-Nr 1992].

Fehlverhalten von Körperzellen bzw Veränderungen bestimmter Gene, die ihr Wachstum und ihren Teilungsverlauf stören, können mit dem Übergang auf die nachfolgenden Zellgenerationen zur Entartung eines Gewebes und zur bösartigen Tumorbildung führen. Die auch für Laien und Vertreter anderer Wissenschaften leicht verständliche Darbietung dieser biologischen Grundlagen, die zum allgemeinen Verständnis der Krebsentstehung notwendig sind, bildet den Schwerpunkt des vorliegenden Werkes. Daneben befaßt es sich auch mit therapeutischen Maßnahmen und vor allem mit den Möglichkeiten der Prävention. Das somit gelieferte Basiswissen dürfte bei jedem Interessierten und potentiell Betroffenen zu Verhaltensänderungen führen und dazu beitragen, das allgemeine und vielseitig bedingte Krebsrisiko zu senken. Besonders jedoch sollte dieses Werk diejenigen in Wirtschaft, Wissenschaft und Politik ansprechen, die verantwortlich zeichnen für die Produktion, Verbreitung, Zulassung und Benutzung kanzerogener Agenzien. In diesem Sinne kommt ihm große Bedeutung zu als Anleitung und Mahnruf zur Vorsorge für Gesundheit und Umwelt.

A Wilhelm Steffan (Ruhr-Universität Bochum)

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BURGESS J, MARTEN M & TAYLOR R: **Mikrokosmos: Faszination mikroskopischer Strukturen.** Aus dem Engl übers von BRIGITTE DITTAMI.- [XIV, 218 pp >300 fig 290 x 350 mm, hard-cov].- **Publ:** Engl Erstausgabe: Cambridge University Press Cambridge 1987.- Deutsche Ausgabe: Spektrum der Wissenschaft, Verlagsgesellschaft mbH Heidelberg 1990; **ISBN:** 3-89330-695-1. ---- [EGR-Nr 1993]

Der mir in deutscher Übersetzung vorliegende Bildband dokumentiert Strukturen und Feinstrukturen der belebten und der unbelebten Natur sowie der Welt der Technik. Eine kurze Einführung in die behandelten Objekte erfolgt am Anfang eines jeden Abschnitts. Die historische und technische Entwicklung der Mikroskopie wird in einem 24-seitigen, mit Skizzen und Kleinphotos illustrierten Anhang dargestellt. Das Werk besticht durch die Ästhetik der Schwarzweiß- und Farbabbildungen. Es richtet sich an den interessierten Laien, kann aber auch dem Wissenschaftler als optisch ansprechende Freizeitlektüre dienen. In die Abbildungen wurden keine Pfeile oder Schriftzeichen gesetzt, offenbar um die Wirkung der Photos nicht zu stören. Viele Strukturen, auf die in den Bildlegenden hingewiesen wird, offenbaren sich durch die fehlende Bildbeschriftung nur dem Kenner der Objekte. In Abb 313 heißt es z B: "Sie besitzen außerdem ein Verdauungssystem; man kann es hier schwach als ein Paar von Darmröhren erkennen, die vom Bereich der Saugnäpfe am Vorderende des Tiers (oben) den ganzen Körper durchziehen". Der Leser muß den abgebildeten Pharynx für einen zweiten Saugnapf halten; auf den ebenfalls im Bild zu sehenden Bauchsaugnapf wird in der Legende dagegen nicht hingewiesen. In der Legende entdeckt man zahlreiche Ungenauigkeiten, kleine Fehler und ungeschickte oder unwissenschaftliche Formulierungen. Der Begriff "karpfenartige Fische" wäre z B präziser gewesen als die Formulierung "Fische aus der Familie der Elritzen und Karpfen". Ungenauigkeiten kommen auch dadurch zustande, daß manchmal biologische Gruppenmerkmale mit den spezifischen Daten einer abgebildeten Art dieser Gruppe gemischt werden. Trotz der aufgeführten Mängel ist das Buch dazu geeignet, auch bei dem Studenten einer Naturwissenschaft Interesse an der wissenschaftlichen Feinstrukturforschung zu wecken.

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