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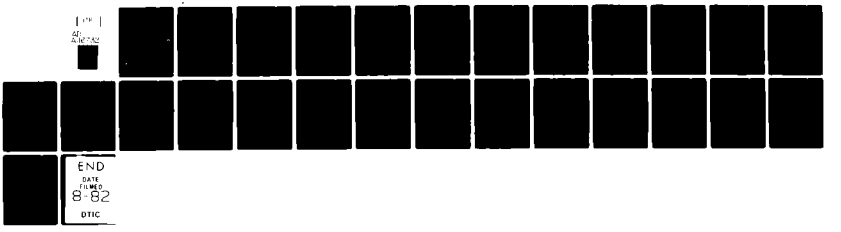

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LAND LEECHES OF THE g. *Haemadipsa* (Haemadipsoidea: Haemadipsidae)
I. Conditions Essential to Laboratory Colonization

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DIVISION OF CUTANEOUS HAZARDS

MAY 1982

LETTERMAN ARMY INSTITUTE OF RESEARCH
PRESIDIO OF SAN FRANCISCO, CALIFORNIA 94129

Land Leeches of the g. *Haemadipsa* (Haemadipsoidea:Haemadipsidae)
I. Conditions Essential to Laboratory Colonization
--Wilson and Eisenberg

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References to sanguivorous land leeches of the g. Haemadipsa are difficult to collect since they are poorly cross-referenced and are in obscure journals. We have prepared this review of conditions essential to laboratory colonization of the sanguivorous land leeches to aid other investigators studying these leeches.

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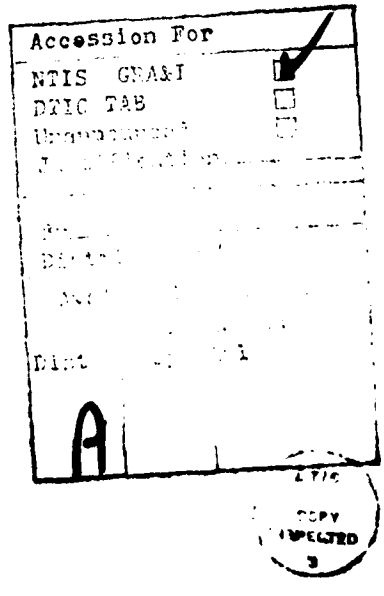

PREFACE

In preparation for the research program to evaluate effectiveness of candidate repellents against sanguivorous terrestrial leeches of the g. *Haemadipsa*, which are commonly known as "land leeches" (Appendix A), we conducted an extensive review of the literature to obtain maximum information to support their laboratory colonization and propagation. We especially sought details concerning their behavior, breeding habits, environmental requirements, and response to repellents.

We thought it important to write this review and a bibliography (1) due to the difficulties that we encountered in obtaining usable information. References were widely scattered in obscure journals and were poorly cross-referenced. Many references contained mostly taxonomic data of various *Haemadipsa sp.* and little concerning their biology. Those articles that discussed their biology were mainly descriptive and provided a minimum of quantitative data. We are not aware of any comprehensive study of the biology of *Haemadipsa sp.* leeches.

The protocol to evaluate formulations as potential leech repellents (Project No.: 3A161101A91C, Work Unit 052, 20 December 1979) was suspended before a laboratory colony of *Haemadipsa zeylanica* could be established. We wish to express our appreciation to LTC Michael Groves, U.S. Army Medical Research Unit, Kuala Lumpur, Malaysia, and LTC Herbert Segal, U.S. Army Medical Component, SEATO, Bangkok, Thailand, who agreed to direct the field collection of *H. zeylanica* and arrange for their shipment to Letterman Army Institute of Research. The present affiliation of Dr. Wilson is: Department of Microbiology, Burroughs Wellcome Co., 3030 Cornwallis Road, Research Triangle Park, NC 27612.

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Land Leeches of the g. *Haemadipsa* (Haemadipsoidea: Haemadipsidae) (1). I. Conditions Essential to Laboratory Colonization

Leeches are segmented aquatic and terrestrial worms that belong to the Order Hirudinea, (Annelida: Clitellata, Scriban and Autrum (2)) and are most closely related to the Order Oligochaeta, which contains the common garden earthworm (Appendix B). There are 4 suborders of leeches of which only the Gnathobdellae (Greek: "jawed leeches") are principally sanguivorous (3). Other leeches are either parasitic and feed on tissues and tissue fluids, or are predaceous and swallow their prey whole.

The important aquatic sanguivores are found in the superfamily Hirudinoidea (Lat. *Hirudo* = leech). The best known examples of this superfamily are the medicinal leeches *Hirudo medicinalis* of Europe and *Macrobdella decora* of North America. Other important leeches in this group are *Hirudinaria manillensis*, the "Buffalo leech" of the Philippines; *Dinobdella ferox*, the "Nasal leech" of Africa and India, and members of the g. *Limnatus*, small leeches scattered throughout Europe, Africa, India and Asia which enter and feed in body orifices.

The g. *Haemadipsa* (fam. Haemadipsidae) is a member of the largest and most widely distributed group of sanguivorous terrestrial leeches, the superfamily Haemadipsoidea (4). The Haemadipsoidea are found in areas of India, Southeast Asia, Indonesia, Australia, the Philippines, China, and Japan. Other groups of sanguivorous terrestrial leeches have been described in South America (5) and southern Europe (6), but are much more restricted in distribution. The family Haemadipsidae has recently been drastically redefined by Richardson (4). As a result of this revision, only the type-species of *Haemadipsa* (*H. zeylanica*, Moquin-Tandon, (7)) from the type-locality of Ceylon can be assigned to this genus with any certainty at the present time (4; L. R. Richardson, Ph.D., Grafton, NS Wales, personal communication, 1980). However, it should be noted that leeches which are apparently identical with *H. zeylanica* have been reported from Thailand, Malaya, Nepal, the Ryukyu Islands, and North Borneo (8). Also, the majority of those leeches of India, Southeast Asia, Malaysia, Indonesia, China, Taiwan, the Philippines and Japan which were previously assigned to g. *Haemadipsa* (8-10) form an obviously closely related group on the basis of their behavior and certain anatomic characteristics. Therefore, we have treated them as members of the g. *Haemadipsa* in this review and in our bibliography (1).

MILITARY SIGNIFICANCE

Attacks on U.S. and other troops by sanguivorous invertebrates such as mosquitoes, flies, ticks and leeches can produce strong, negative emotional responses in addition to physical problems (8,11,16). However, unlike the other invertebrates mentioned, leeches are not known to transmit infectious agents to man (8,13,14; L. R. Richardson, Ph.D., Grafton, NS Wales, personal communication, 1979), although there is a pronounced tendency for bacterial infections to develop at the bite wound of terrestrial leeches (15,17,18). Thus, the actual leech bite assumes secondary importance to the psychological effects of infestation (12,16; H. L. Keegan, Ph.D., Dept. of Preventive Medicine, University of Mississippi Medical Center, Jackson, Mississippi, 39216, Personal Communication, 1979.

During World War II, Wilson (19) stated that "...(terrestrial leech) attacks produce a subjective effect quite out of proportion to the physical damage produced." Allen (16) independently came to a similar conclusion when he summarized the negative psychological impact of leech attacks in Vietnam: "... leeches attained a prominence out of proportion to their true significance because of the wide circulation of exaggerated stories concerning the frequency of attacks and the results of infestation." For example, certain reports mistakenly imply that terrestrial leeches enter and engorge in body orifices (20-22), attack characteristics that properly belong to small aquatic leeches of the g. *Limnatus* (23). Accordingly, invasion of the penile urethra becomes a serious but unwarranted concern of troops operating in areas infested solely by terrestrial leeches (13-16): on occasion, troops have been reported to wear condoms for protection while sleeping (13).

This exaggerated awareness to leech attacks appears to be due both to their aggressive host-seeking responses (19,24) and to the feelings of revulsion and disgust on finding an attached, engorged leech (16). This situation compounds the usual problems of morale: troops anxiously watch for leeches and are distracted from essential duties (15,16,21). This distraction could result in a marked decrease in combat efficiency (8).

CONDITIONS ESSENTIAL TO LABORATORY COLONIZATION

Nutrition and Feeding

All members of the g. *Haemadipsa* are strictly sanguivorous (25-28) and do not have apparent host preferences. Thus, Keegan, *et al.*, (8) reported that *H. zeylanica* fed "readily" on rabbits, mice, chicks, frogs, and snakes in addition to man. *Haemadipsa* have also been reported to feed on domestic dogs, cats, horses, cattle (29), buffalo, sheep, goats (30)

fowl (31) guinea pigs (32), and rats (33,34). In view of this variety of domestic animals which do serve as hosts, it is not clear whether there are certain wild animals on which *Haemadipsa* will actually not feed (29), or whether such observations are incomplete.

Haemadipsa have been reported to ingest anywhere from 2 to 11 times their weight in blood (25,28,35,36). These figures probably underestimate the actual amount consumed, since they do not take into account a substantial exudation of fluid from the nephropores which occurs during feeding (25,37,38). This loss of fluid suggests concentration of the ingested blood by the leech.

Certain stimuli affecting host-seeking and feeding behavior of *Haemadipsa* have been studied. Both carbon dioxide (31) and a puff of breath (8,12,28) elicit aggressive host-seeking responses; a directed stream of warm, moist air may cause a similar reaction (12). A sudden reduction in laboratory illumination or a shadow passed over the cephalic region results in host-seeking activity of *H. zeylanica* (12). Neither lactic acid (35) nor contact of the anterior sucker with freshly drawn blood have any effect (12). Variable responses to vibration have been reported (31,37).

Membrane feeding has been accomplished with the aquatic leeches *Hirudo medicinalis* (39,40) and *Macrobdella decora* (40) but has not been reported for *Haemadipsa*. Since *Haemadipsa* do not respond to direct contact with blood (12), the addition of phagostimulating substances to the blood or membrane surface may be required. The strong preference of *Haemadipsa* to feed on damaged areas of the skin, i.e., on abraded skin (25,32), the cut edge of skin removed from the host (12) healing sores, and previous bite sites (14,41), indicates that phagostimulating substances may be present in the skin and influence feeding behavior. Studies should be performed to determine the phagostimulating activity of various substances for *Haemadipsa* as have been done with *Hirudo medicinalis* (39).

Following attachment, the sequence of penetration of the skin and initiation of engorgement proceeds rapidly. Penetration begins immediately when the leech finds a "suitable spot" (38) and is completed in 80 to 90 seconds (8).

Sensations associated with penetration vary with the species of *Haemadipsa* involved and are generally minimal (38). Koshi and Varma (31) reported that the bite of *H. zeylanica* was often not felt at all, while *H. zeylanica montivindicus* produced only a slight initial irritation. The two members of the genus known for painful skin penetration are *H. ornata* and *H. picta*. *H. ornata* produces a stinging sensation during penetration (31) and has been given the common name of "The

Stinging Land-Leech" (9). Moore (42) characterized the bite of *H. picta* as "pungent." *H. ornata* is the only species reported which produces a feeling of mild irritation during engorgement (31). Engorgement of other species is either not felt (38,43) or has not been commented on in detail. Rhythmic contraction of the pharyngeal region begins immediately following penetration and indicates ongoing engorgement (38).

Stammers (12) demonstrated at least two substances that *H. zeylanica* uses to promote bleeding. The first had anticoagulant properties: clotting time of blood flowing from the wound immediately following detachment was increased 2.6 times, although it rapidly returned to normal by 10 minutes following detachment. However, since these wounds continued to bleed for 30 minutes or longer, he suggested that there was a second substance present which had vasodilating activity. On the basis of some earlier studies with *Hirudo medicinalis*, Stammers (12) proposed that the second substance might be related to histamine.

Engorgement in the laboratory is usually completed in 45 to 70 minutes (8,35,36,38); however, engorgement and detachment can be accomplished in the field in less than 30 minutes (44). Engorged haemadipsid leeches exhibit such obvious distension of their body that some observers have compared their appearance to "clusters of sausages" (45).

Haemadipsa can survive for extended periods without feeding. Although frequency of feeding in the field is unknown, Bhatia and Bora (28) kept *H. zeylanica agilis* and *H. montana* for three years by feeding them only once a year. They noted that a full blood meal took 8 to 10 months to digest. However, *H. sylvestris* would feed within 2 to 4 months of a previous feeding (31,36), and Keegan *et al.* (8) offered *H. zeylanica* the opportunity to feed monthly, presumably to preclude food becoming a limiting factor in reproduction.

Reproduction

Reproduction in *Haemadipsa* is similar in general aspects to the other hermaphroditic clitellate annelids (8,28). Copulation, in which cross-fertilization takes place, has been described in detail by Bhatia and Bora (28), and also by Leslie (46) and Harrison (47). Briefly, two adult leeches stand erect on their posterior suckers and entwine their anterior ends during a "mating dance". When the male and female genital pores of each leech are opposed to those of the other, seminal fluid is transferred by the projected male organs. Separation occurs in 40 to 65 minutes (28) but may be extended up to 1.5 hours (47).

Ova are laid in oval cocoons secreted by glands in the clitellar

region. The cocoons consist of a frothy outer layer that hardens upon contact with the air and a smaller inner layer which contains the ova (28). Cocoons are generally laid in moist, shady areas on or under leaf litter, bark, or stones (8,25,26,28,36). The hardened froth protects the cocoon from environmental trauma such as crushing and desiccation. Hatching of young leeches occurs in approximately 20 days (8,28,36).

A blood meal may stimulate cocoon production. Keegan *et al.* (8) observed 6 specimens of *H. zeylanica japonica* which had neither fed nor laid cocoons in the preceding two months; five of the 6 leeches began laying cocoons in 15 to 17 days following engorgement. Once laying was initiated, cocoons were laid about every 4 days, with a range of 1 to 17 days. The same 4 day interval has also been noted for the Indian species *H. zeylanica agilis* and *H. montana* (28).

The number of leeches hatching from a cocoon appears to vary with the species. Bhatia and Bora (28) noted 6 to 9 leeches for *H. zeylanica agilis* and *H. montana;* Keegan *et al.* (8) recorded an average of 5.2 for *H. zeylanica japonica* and 11.5 for *H. zeylanica zeylanica* from Malaysia. In contrast, Rajak *et al.* (36) reported only 3.1 leeches per cocoon for *H. sylvestris*. However, since they were unable to maintain the vitality of their colony into the second laboratory generation, their data may underestimate the true capabilities of this leech.

Leeches matured and laid cocoons in 3 to 4 months in the Keegan colony, and 7 to 12 months in the Rajak colony.

Environmental Factors

Abundant moisture is critical to the vitality and survival of Haemadipsid leeches (25). Rapid loss of vigor and death are usually reported when any degree of dehydration occurs in the laboratory (25,31,32). In their natural environment, short dry spells result in many *Haemadipsa* secreting themselves in the mud under rocks, bark, and other litter (25,28). Within 48 hours after a heavy rain, they emerge and are easily found once again (29). They exhibit maximum activity on misty, drizzly days (21,25,29,31). Even when they are not regularly found elsewhere, *Haemadipsa* are still active in the immediate proximity of streams in shady, damp ravines (26,30,37,38,48,49). Richardson's observations for the Australian terrestrial sanguivore *Chtonobdella limbata (Quaesitobdella bilineata,* (4)) also appear to typify the general moisture requirements for *Haemadipsa,* namely, that these leeches are found in "areas having relatively prolonged periods of stable (and high) ground moisture levels."

Certain *Haemadipsa sp.* may have greater requirements for moisture than others. Walton *et al.* (44) observed that the bush-climbing *H. picta* was active only "... during or immediately following a rainfall,

when the shrubbery was wet and the humidity approached 100%."

Despite the need for high levels of moisture, water per se is avoided by *Haemadipsa* except possibly in the case of *H. sylvestris* (50). *Haemadipsa* are not known to be capable of swimming (4), and they are not found in areas where there is standing water (28,50). If purposefully immersed, they will try to escape the water (28) and will even detach during feeding (29).

The optimal temperature for reproduction of any *Haemadipsa sp.* is not known. Whitman (37) was able to keep *H. zeylanica* alive at 7 C for an unspecified period of time, but Bhatia (41) noted that *H. zeylanica agilis* contracts and becomes motionless at 10 C. *Haemadipsa* may actually seek warmth during relatively cold periods. Sykes (30) observed that partially engorged *H. montana* entered his tent at 3,200 m on a late September night in Nepal but did not attempt to feed. *H. zeylanica* will not feed at 13 C, and feeding is minimal at 16 C (8). Various *Haemadipsa* feed readily at temperatures between 19 C and 27 C (8,12,14, 51-53). Keegan *et al.* (8) reported that their colony of *H. zeylanica* "thrived and reproduced" between 21 C and 23 C. *H. zeylanica agilis* are only found in forests in which the mean temperature does not exceed 26 C (28). Rajak *et al.* (36) were unable to maintain the vitality of a colony of *H. sylvestris* kept at 27 C into the second generation. Bhatia and Bora (28) observed that *H. zeylanica agilis* and *H. montana* became restless at 30 C. At 33 C they became limp and dull, and actively sought shelter under layers of humus. They died at about 40 C. The times required for these responses to occur were not reported.

The amount of light conducive to laboratory propagation of *Haemadipsa sp.* is also not known; however, leeches characteristically exhibit photonegative responses except in the case of unfed aquatic and terrestrial sanguivores (3). Consequently, low to moderate levels of light may be expected to enhance *Haemadipsa* activity. Sonchai (54) observed that *Haemadipsa* were most abundant in the early morning and evening; they were least abundant at night. However, Keegan *et al.* (8) observed that *Haemadipsa* fed readily in the laboratory in total darkness, and Miller (18) observed that land-leeches of the Borneo rain forest attacked and fed on him equally as well at night as during the day. The increase in the activity of *Haemadipsa* on cloudy, misty days (21,25, 27,53), and their disappearance when full sunlight strikes an area (8,25,28,51,55) are well known. The stimulating effect of a sudden reduction of light on the host-seeking responses of *Haemadipsa* was noted previously.

Leeches seek cracks and crevices in which to retreat and thus exhibit positive thigmotaxis (3); unfed aquatic and terrestrial sanguivores stimulated to host-seeking activity again prove the exception (3). Once *Haemadipsa* have fed, they also seek a place to crawl into or

under until their meal is at least partially digested (25,38). This pronounced tendency of *Haemadipsa* to crawl into, and through tight places (26) also results in their escaping from "the most unlikely looking crevices" in laboratory cages (8).

Surface texture of a colony should permit efficient sucker action for locomotion. Presumably, Bailey's observation that leeches would not cross sand in a heavily leech-infested region in Assam (17) could be explained by inefficient sucker action on this surface. *Haemadipsa* are not normally found in pine (28) or heath forests. However, since these forests are also xerophytic, the lack of moisture may be as much of a limiting factor as surface texture.

An acidic soil pH may be quite important to successful colonization. *Haemadipsa* are normally found in forests with soils made acid by the litter or certain minerals (28,29). Williams (29) observed that they are unaffected by acid reagents and will readily withstand "strong" solutions of hydrochloric acid. In contrast, alkaline solutions were lethal (29).

LABORATORY REPELLENT EVALUATIONS

The locus of repellent activity has not been studied in *Haemadipsa sp.* leeches. The ventral surface of the first segment (the prostomial lobe) and margin of the anterior sucker of *Haemadipsa* are richly supplied with nerve endings, a portion of which have chemosensory activity (25,28). It is probable that the location of these chemoreceptors results in certain behavioral characteristics of *Haemadipsa*. Frequently described activities of the unfed leech include standing rigidly upright on its posterior sucker in an attitude of "attention" (25) and "searching" (41), the rapid waving back and forth of the anterior sucker when attempting to locate a nearby host (25,37,41,48,55), and especially the use of the anterior sucker to search the environment carefully like "the sniffing of a dog determining the direction of its quarry" (38). Thus, it seems likely that repellency would primarily be effected through the chemoreceptors on the anterior sucker. A direct toxic effect of repellents is also possible since Ribbands (56) observed that *H. sylvestris* was rapidly immobilized and killed by exposure to dimethylpthalate.

Primary laboratory evaluations of repellency against *Haemadipsa sp.* have been based on the photonegative responses of these invertebrates (12,31,56-58) rather than on positive stimuli as would be provided by a host. The most sophisticated of these avoidance methodologies was reported by Ramachandran *et al.* (58). They determined repellency by having *H. sylvestris* attempt to cross repellent-impregnated cloth barriers from a square of white cloth. The percentage of attempts repelled was transformed to probits, and the repellent concentration which repelled 50% of attempted probes (RC_{50}) was calculated by regression analysis.

CONCLUSIONS AND RECOMMENDATIONS

It is clear that a suitable environment for the maintenance of a colony of *Haemadipsa sp.* can readily be achieved. However, studies to optimize each environmental factor need to be conducted. Essential environmental features include moderate ambient temperatures in the range of 19 C to 23 C, high levels of moisture, and a "litter layer" to satisfy the thigmotactic responses of these leeches and provide a suitable, moist microenvironment. We previously suggested the use of water-saturated pieces of broken, unglazed clay flower pots to fulfill such litter requirements (59). Light intensity approaching that of sunlight must be avoided; normal laboratory illumination should be acceptable for initial studies. We recommend using a slightly acid soil as a substrate and for cocoon laying. A repellent evaluation methodology should be developed which utilizes a positive stimulus such as carbon dioxide to simulate the presence of a host: such a test could provide a more realistic estimate of repellency than one based on avoidance responses.

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QUOTATIONS FROM THE LITERATURE

APPENDIX A

APPENDIX A

QUOTATIONS FROM THE LITERATURE

Not all Indians are familiar with the leech. Familiarity breeds contempt, and I remember what delight tea pluckers used to show when a 'new girl' from the plains saw her first leech and ran shrieking with fright from it.
CHAMPION-JONES, R.N. Leeches. J Bombay Nat Hist Soc 52:650-651, 1954

There were three species (of leeches), all of them of the ground-leech type (*Haemadipsa zeylanica spp.*), an inch or so long when hungry ... All three kinds fastened themselves on you as you went by. They seemed to direct themselves by a sense of smell. Poised on the small sucker at the base, the big sucker at the head waved in, leaning directly at you. If you moved a yard to another position, the leech would immediately sway like a compass needle and still keep pointed right at you.

Every ten or twelve steps my Naga porters stopped and cut leeches off their feet with their long dahs... I tried flicking them off with thumb and middle finger. I soon found you couldn't budge them if you snapped at them while the head sucker was attached. But they would fly off into the bushes at once if you flicked just as the head sucker was about to take over from the tail sucker. This was a pretty lesson in timing. The flick had to be correct to the split second or you could flick in vain all day.
SEAGRAVE, G.S. Burma Surgeon Returns. New York: W.W. Norton and Co. 1946. pp. 60-61.

It is interesting to watch the behaviour of hungry specimens confined in a bottle which is kept moist by wet moss at the bottom... At rest the head and anterior half of the body are often raised as if held in readiness for the attack. If the bottle is opened and a puff of breath blown upon them, they are instantly thrown into a state of great excitement; after a few hasty reaches in different directions have convinced them that the disturber is not in immediate reach, they begin to ascend; and the foremost among them, reaching the rim of the bottle, halt for a moment, standing quite erect and extended as if hestitating in which direction to advance; another puff or a slight jar sets them again in commotion, and they swing to and fro, reaching in all directions for the object of their search. If one attempts to put them back,

he finds them more than a match; for while trying to thrust one back, a dozen others rush on to the hand, and in a few moments are scattered over the body.

WHITMAN, C.O. The Leeches Japan I. The ten-eyed leeches, or the Hirudinidae. Q J Micro Sci 26:317-346, 1886.

Land leeches may be encountered or collected when one walks through damp ravines or similar moist situations. They frequently are detected first on one's shoes. If it is desired not to permit them to feed, one naturally tries to remove them and throw them away. This is about as easy as trying to rid one's fingers of a wad of chewing gum that has begun to stick. The leech's leathery or rubbery integument seems almost insusceptible of injury, and even rough treatment, from hand to hand, does not dissuade the worm from fastening itself by one sucker or both to each new grasping forefinger and thumb.

When a leech is placed purposely on the back of one's hand, in order to observe it conveniently through a lens, it quickly avails itself of the opportunity to feed without disturbance. The anterior sucker is apparently some sort of testing or tasting mechanism, for the leech is not always satisfied with the first spot encountered. However, one or two looping steps usually suffice to bring the animal into feeding frame of mind.

Immediately when the leech finds a location suitable for feeding, the human subject may feel a slight stinging or irritating sensation. This lasts for half a minute or less; were the observer engaged in other activities, the chances are that nothing at all would be noticed. But even the intent student feels nothing more after this short initial period of minimal discomfort...

Just before voluntary detachment, the leech exhibits maximal peristaltic activity. Detachment takes place during an exhibition of peristalsis, as if the worm were still reluctant to let go, but in its bloated and unwieldy condition were unbalanced by the violence of its somatic activities...

The engorged leech, on relinquishing its hold, encounters difficulties in locomotion, since it is now so greatly distended. It shows no hesitation in dropping to the ground, which must be a rather uncomfortable experience for a worm with a full stomach. Upon reaching such environment, it continually falls over to right or left, since its pot belly interferes with easy progress. The anterior end apparently still functions as a sense receptor, appraising the organism of the state of local conditions. Thus, the leech succeeds at last in dragging itself to the edge of a pebble, beneath which it secretes itself within a few moments.

WORTH, C.B. Description and discussion of the biting of an Indian land leech (Annelida; Hirudinea). J Bombay Nat Hist Soc. 50:423-426, 1951.

Haemadipsa zeylanica is the only member of the virulent variety of the leech family with which I have personally come in contact... it is small, being only an inch in length, and of the thickness of a knitting needle... Personally, I regard it as carnivorous rather than parasitic.

On the East Indies Station, one is made to realize that this land leech can be not only an annoyance, but even a positive danger... The Royal Naval Camp, Diyatalawa, Ceylon... lies in typical leech country... Within a few hours of our arrival, casualties began to report. One rating dozed for ten minutes on the ground, and returned in a state of panic with numerous black bodies hanging from his neck; another woke one morning to find himself bleeding severely from the groin and scrotum. Firing parties on the open range were the chief victims, being attacked while marching to and from their destination, and finding it almost impossible to lie down and shoot owing to the attacks of leeches. In fact, when walking about the surrounding country one had to possess not only the usual snake-sense, but also leech-sense.

My own experience alarmed me considerably. While playing golf in the rain one day I found myself standing on ground which was literally thick with leeches. By maintaining a steady gaze, it was possible to view hundreds of these beasts trekking towards one from many yards away. The speed at which they progressed was amazing, and they seemed to possess an uncanny instinct for detecting the distant presence of living creatures. Within a few seconds my feet were black with them; I was forced to abandon my game and return to remove a large number; even the eyeholes of my boots were used as a mode of entry to a vulnerable spot; my stockings were soaked with blood and my feet exceedingly painful for some days to follow.

COULTER, J.L.S. The land leech in Ceylon. J Roy Nav Med Serv 19:105-108, 1933

SYSTEMATICS OF LEECHES

APPENDIX B

TABLE

Systematics of Leeches with special emphasis on the Families Hirudidae and Haemadipsidae and their Suborder, the Gnathobdellae (after 2-6,60).

Phylum: Annelida
Class: Clitellata
Order: Hirudinea (=Hirudiniformes)
Suborder 1. Acanthobdellae
Aquatic; contains one Family with one genus; a parasite of salmonid fishes of Russia and Finland.
Suborder 2. Rynchobdellae
Aquatic, The "proboscis leeches"; mainly parasitic, feeding on tissue and tissue fluids of aquatic invertebrates and vertebrates; 2 families: are predominantly freshwater; the other, marine. Widely distributed, many general.
Suborder 3. Gnathobdellae (=Arynchelodellae), Aquatic and terrestrial. The "jawed leeches." Jaws are muscular ridges set in the oral cavity, some armed with teeth, which incise the integument of the host to engorge on blood; one family mostly macrophagous.
Superfamily 1. Hirudinoidea
Family 1. Hirudinidae
Freshwater, sanguivorous. Contains the well-known medicinal leech of Europe, *Hirudo medicinalis*, also *Hirudinaria manillensis*, and *Limnatus sp.*
Family 2. Richardsonianidae
Freshwater, sanguivorous; Australia and New Zealand.
Family 3. Ornithobdellidae
Terrestrial (?) amphibious, sanguivorous. Australia and New Zealand.
Family 4. Macrobdellidae
Freshwater, sanguivorous; north Central and South America, Asia. Contains the American medicinal leech, *Macrobdella decora*, nd the "Nasal leech" of Africa and India, *Dinobdella ferox*.
Family 5. Haemopidae
Freshwater, macrophagous scavengers, potential sanguivores.
Family 6. Mesobdellidae
Terrestrial, sanguivorous. Contains 2 genera restricted to Chile, Argentina and the Juan Fernandes Islandes in South America.
Family 7. Semiscolecidae
Amphibious, South America, 2 genera

Family 8. Cyclobdellidae.
Terrestrial, South America; 2 genera
Family 9. Xerobdellidae.
Terrestrial, southern Europe; one genus.

Superfamily 2. Haemadipsoidea
Terrestrial, sanguivorous; mainly distributed in the Australian and Oriental regions.
Family 1. Domanibdellae
Contains 4 subfamilies with a total of 23 genera; 2-jawed; distributed predominantly in the Australian region to include Oceania.
Family 2. Haemadipsidae
Contains 2 genera of 3-jawed leeches. Genus 1. *Haemadipsa* (s.l.), widely distributed in India, southeast Asia and the Orient; type-species: *H. zeylanica* from Ceylon. Currently recognized other species: *montana, ornata, picta, sylvestris, sylvestris interrupta, zeylanica agilis, zeylanica cochiniana, zeylanica japonica, zeylanica montivindicus, zeylanica subagilis, zeylanica sumatrana.* Genus 2. *Keibdella,* found only in the Kei Islands north of Australia. One species: *manmorata.*
Family 3. Idiobdella.
Contains 3 genera of 2-jawed leeches; restricted to the Sychelle Islands and Madagascar.

Suborder 4. Pharyngobdellae
Aquatic and terrestrial, predaceous, macrophagous. World-wide distribution.

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