

universities within the context of tertiary education in South Africa. It would be impossible, and even inappropriate, to address in this article all the wider issues and questions which the brochure has raised. It would, however, be remiss not to highlight two of the main ones, namely the wide polarity in research funds received by specific universities (Fig. 2), and the fact that almost half of the teaching staff are unrated by FRD, the main provider of funds (Fig. 1). These statistics in themselves indicate that in the case of botany, the majority of universities (and individuals) are experiencing difficulty in fulfilling one of their main

societal roles, namely striving to be leaders in basic research. Bearing in mind the opinion of the CUP that 'teaching and research are inseparable and symbiotically bound to each other and that teaching can only be effective if it is supported by thorough scientific research',¹ such a situation is indeed one for concern.

Although the data are only for botany in 1990, the FRD brochure raises the issue that this might be the tip of an iceberg and that a similar situation could exist in many of the other strategic disciplines. Quite clearly, this concern can only be substantiated through a more

extensive investigation than the one which was undertaken.

Thanks are extended to Professor Hannes van Staden, University of Natal, who was the stimulus for the investigation; to Marie Breitenbach, Louise Botten, Rhyne de Bruyn and Jay Walmsley, who helped access and process the information; and to all heads of department and individuals who participated in the survey.

1. Committee of University Principals (1987). *Macroaspects of the university within the context of tertiary education in the RSA*.
2. Walmsley R.D. (1991). *Some statistical information on staff and students of botany departments in South Africa for the year 1990*. FRD, Pretoria.

Diuresis in the desert? Unexpected excretory physiology of a Namib Desert beetle

S.W. Nicolson

Physiological ecologists currently contend that desert animals are not unique.¹⁻³ Desert reptiles, for example, can be viewed as not uniquely adapted to their harsh environment, but pre-adapted, employing the characteristics useful for terrestrial living which are possessed by all reptiles.⁴ The same can be said of the other group of ectotherms so successful in deserts, the arthropods.⁵ Here, I wish to consider the uniqueness of desert arthropods, using research on the excretory physiology of Namib Desert beetles.

Insect excretory physiology involves a secretion-reabsorption system.⁶ Malpighian tubules secrete varying volumes of a fluid isosmotic to the haemolymph (blood), but containing relatively more potassium ions (or in some cases sodium ions). This fluid is discharged into the hindgut, where solutes and/or water are reabsorbed according to the circumstances of the insect. Both secretion and reabsorption are under the control of peptide hormones.^{7,8} It is this control which determines the final volume and composition of the fluid excreted.

Insect diuretic hormones

The diuretic factors accelerating fluid secretion by Malpighian tubules originate in the nervous system. The distribution of diuretic activity within the nervous system varies between species, but commonly the corpora cardiaca (analogous to the vertebrate pituitary gland) are storage and release sites for diuretic factors, synthesized in the neurosecretory cells of the brain.^{7,8} All insects investigated possess at least one diuretic factor (in comparison with vertebrate systems, their status as hormones is generally unproven). In contrast, an antidiuretic factor acting on

Malpighian tubules has so far been demonstrated only in the house cricket *Acheta*.⁸ Insect diuretic factors increase tubular secretion rates dramatically (10-1 000 times) in insects taking intermittent, large blood meals, but have a modest stimulatory effect (2-4 times) on the tubules of insects that feed continuously.⁶

Major advances are currently being made in isolating and characterizing insect diuretic factors. The complete sequences for diuretic peptides of *Locusta*, *Manduca* and *Acheta* have been published recently,⁹⁻¹² an impressive achievement considering the tedious bioassays required, and the minute amounts of material present in individual insects.¹³

A 'diuretic hormone' in a desert beetle

Water relations of the Namib tenebrionid beetles have been reviewed recently:¹⁴ almost all of the research has been on a few species of the most conspicuous genus, *Onymacris*. *Onymacris* species exhibit low rates of evaporative water loss relative to other insects¹⁵ and are efficient osmoregulators^{16,17} during times of water scarcity and after the opportunistic drinking of fog water (Fig. 1). Tenebrionid beetles possess a rectal

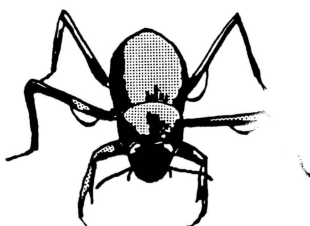


Fig. 1. *Onymacris unguicularis* in fog-basking position (from a photograph by M.K. Seely).

complex, in which the terminal portions of the Malpighian tubules form a sheath around the rectum and generate exceptionally high osmotic pressures for living tissue (9 Osmol in *Onymacris*¹⁸), causing water to be withdrawn from the rectal contents. The rectal complex allows the production of extremely dry excreta and, in larvae only, the absorption of water from unsaturated air.

In view of the characteristics of water handling in *Onymacris* so consistent with desert adaptations, it was a surprise to find that the Malpighian tubules of *Onymacris plana*, which normally secrete about 3 nl of fluid per minute *in vitro*, were stimulated 20-25 times by a diuretic factor in the corpora cardiaca, occasionally exceeding secretion rates of 100 nl min⁻¹.¹⁹ Such stimulation is reminiscent of the tubules of blood-sucking insects, in which the high rates are associated with secretion of a sodium-rich fluid. *Onymacris* tubules, however, achieve these high rates of secretion while producing the potassium-rich fluid which is characteristic of the tubules of insects other than blood-suckers.⁶

Electrical responses of tubules

Because of their potassium-rich secretion and dramatic response to stimulation, and because they are unusually large, the Malpighian tubules of *Onymacris* have proved useful for studying the electrical events associated with fluid secretion and its control. Stimulation of secretion by extracts of the corpora cardiaca is accompanied by pronounced electrical responses in the tubule cells, which have been investigated in both unperfused and perfused tubules of *O. plana*.^{20,21} *In vitro* microperfusion of tubule segments, widely used for mammalian and amphibian renal tubules, has

Dr Sue Nicolson is in the Department of Zoology, University of Cape Town, Rondebosch, 7700 South Africa.

NIC 92

NHBS

been applied to only one other insect, the mosquito *Aedes aegypti*.²²

The high potassium permeability of the basal membrane in *Onymacris* Malpighian tubules has been explored further in a patch clamp study.²³ The physiological relevance of the study is that potassium ions might diffuse rapidly through channels in the basal membrane to reach the potassium pumps located on the apical membrane.⁶ As a comment on uniqueness in physiology, I should point out that the existence of the potassium pump, thought to be unique to insect epithelia, is now in doubt.²⁴

Does *Onymacris* really possess a diuretic hormone?

An insect diuretic hormone could be defined as one which increases fluid secretion by the Malpighian tubules, or one which increases fluid loss by the whole insect.⁸ This distinction is especially important for *Onymacris*, in which maximum rates of fluid secretion (sufficient to dehydrate the insect in a few hours) can be induced in isolated tubules by as little as one pair of corpora cardiaca homogenized in 1 ml of Ringer solution.¹⁹ Biogenic amines released by homogenization of the corpora cardiaca are not responsible.²⁵ Diuretic activity occurs throughout the nervous system, but depolarization with high potassium concentrations releases it only from the natural release site, the corpora cardiaca.¹⁹

Even when beetles have replenished their body water after a period of dehydration, diuretic activity cannot be detected in their haemolymph,^{19,25} indeed, haemolymph partly inactivates diuretic activity in corpora cardiaca extracts.¹⁹ A classic endocrinological experiment is to inject a putative active agent: *O. rugatipennis* injected with corpora cardiaca homogenates or methanolic extracts showed no diuresis.²⁵ Amaranth dye included with these injections was transferred mostly anteriorly to the midgut lumen, rather than posteriorly to the hindgut. It seems likely, therefore, that when fluid is secreted rapidly by the Malpighian tubules, it is recycled via the

midgut and returned to the haemolymph (Fig. 2).

Is *Onymacris* special?

It is fortunate for *Onymacris*, a desert beetle, that fast fluid secretion by its Malpighian tubules does not result in diuresis. Perhaps its 'diuretic hormone' should rather be called a clearance hormone, because it could lead to rapid clearance of accumulated waste products from the haemolymph without wasting water. Such filtration of the haemolymph might be useful when fog moisture becomes available to a Namib beetle after a long period without free water.

Hormonal stimulation of the Malpighian tubules is evident in another Namib tenebrionid, *Physadesmia globosa*, and in larval and adult mealworms (*Tenebrio molitor*).^{25,26} Mealworms live in the arid environment of stored grain products, and are in no more need of diuresis than *Onymacris*. Larvae of both *Tenebrio* and *Onymacris* maintain their water reserves by absorption of water via the rectal complex and do not normally drink. The accumulation of Malpighian tubule fluid in the midgut may be advantageous in providing a more fluid medium for digestion and absorption, given their diet of dry grain products or desert detritus.

The recycling of Malpighian tubule fluid is not unique to *Onymacris*. For the three insect species (*Locusta*, *Manduca* and *Acheta*) for which the 'diuretic' hormones have recently been sequenced, the term clearance hormone might be more appropriate: there is evidence that fluid is recycled via the midgut in locusts,²⁷ and the rectum in *Acheta*⁸ and larval *Manduca*.²⁸ Such recycling may be common to all insects except those which must void a large quantity of fluid in a short time. Even some insects which exhibit a true diuresis reabsorb a significant proportion of the initial tubule fluid.²⁹

Onymacris is an extreme example of the secretion-reabsorption excretory system of insects in that the secretion is fast and the recycling is complete. Though its attributes make it a good subject for studying the basic physiological process-

es, this desert insect is clearly not unique. Fast fluid secretion accompanied by complete reabsorption may be related to the dependence of *Onymacris* on occasional rapid drinking of fog water in the Namib. Its subelytral cavity allows for expansion of the abdomen during drinking,³⁰ and, after hormonally controlled filtration of the haemolymph, the water is returned to the haemolymph for storage.¹⁷ The excretory system of *Onymacris* resembles the mammalian kidney, in which filtration is fast but most of the fluid is recycled.

Implications for insect control

Chemical insecticides have long been known to cause diuresis in *Rhodnius*,³¹ which offers the opportunity for the design of new insecticides, possibly involving insect hormones. A recent example is the insertion of a synthetic gene for *Manduca sexta* diuretic hormone into a baculovirus; the genetically engineered virus, however, killed infected caterpillars only about 20% faster than the original virus.³² A possible reason for the marginal value of this manipulation is that any increase in fluid secretion would be diminished by increased cycling through the hindgut of the caterpillars.²⁸ If insect diuretic hormones are to be used as designer insecticides, they may be suitable only for species exhibiting a real diuresis.

I am grateful to Dr M.K. Seely of the Desert Ecological Research Unit of Namibia for her generosity in supplying beetles over the years, Dr G.N. Louw and Professors D. Mitchell and G. Gäde for commenting on drafts of the manuscript, and to the FRD and University of Cape Town for financial assistance.

1. Dawson W.R., Pinshow B., Bartholomew G.A., Seely M.K., Shkolnik A., Shoemaker V.H. and Teeri J.A. (1989). What's special about the physiological ecology of desert organisms? *J. arid Environ.* 17, 131-143.
2. Seely M.K. (1989). Desert invertebrate physiological ecology: is anything special? *S. Afr. J. Sci.* 85, 266-270.
3. Louw G.N. (1990). Physiological studies on the Namib fauna: a brief critique. In *Namib Ecology: 25 Years of Namib Research*, ed. M.K. Seely, pp. 203-207. Transvaal Museum, Pretoria.
4. Bradshaw S.D. (1988). Desert reptiles: a case of adaptation or pre-adaptation? *J. arid Environ.* 14, 155-174.
5. Cloudsley-Thompson J.L. (1991). *Ecophysiology of Desert Arthropods and Reptiles*. Springer-Verlag, Berlin.
6. Phillips J. (1981). Comparative physiology of insect renal function. *Am. J. Physiol.* 241, R241-R257.
7. Phillips J.E. (1983). Endocrine control of salt and water balance: excretion. In *Endocrinology of Insects*, eds R.G.H. Downer and H. Laufer, pp. 411-425. Alan R. Liss, New York.
8. Spring J.H. (1990). Endocrine regulation of diuresis in insects. *J. Insect Physiol.* 36, 13-22.

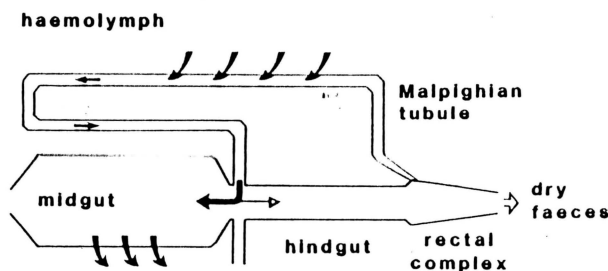


Fig. 2. Diagram of the excretory system of *Onymacris*. During fast fluid secretion by the Malpighian tubules (only one is shown), most of the tubule fluid passes anteriorly into the midgut so that valuable water can be returned to the haemolymph.

9. Proux J.P., Miller C.A., Li J.P., Carney R.L., Girardie A., Delaage M., and Schooley D.A. (1987). Identification of an arginine vasopressin-like diuretic hormone from *Locusta migratoria*. *Biochem. biophys. Res. Commun.* **149**, 180–186.
10. Kataoka H., Troetschler R.G., Li J.P., Kramer S.J., Carney R.L., and Schooley D.A. (1989). Isolation and identification of a diuretic hormone from the tobacco hornworm, *Manduca sexta*. *Proc. natn. Acad. Sci. USA* **86**, 2976–2980.
11. Kay I., Coast G.M., Cusinato O., Wheeler C.H., Totty N.F. and Goldsworthy G.J. (1991). Isolation and characterization of a diuretic peptide from *Acheta domesticus*: evidence for a family of insect diuretic peptides. *Biol. Chem. Hoppe-Seyler* **372**, 505–512.
12. Kay I., Wheeler C.H., Coast G.M., Totty N.F., Cusinato O., Patel M. and Goldsworthy G.J. (1991). Isolation and characterization of a diuretic peptide from *Locusta migratoria*. *Biol. Chem. Hoppe-Seyler* **372**, 929–934.
13. Wheeler C.H. and Coast G.M. (1990). Assay and characterisation of diuretic factors in insects. *J. Insect Physiol.* **36**, 23–24.
14. Nicolson S.W. (1990). Water relations of the Namib tenebrionid beetles. In *Namib Ecology: 25 Years of Namib Research*, ed. M.K. Seely, pp. 173–178. Transvaal Museum, Pretoria.
15. Nicolson S.W., Louw G.N. and Edney E.B. (1984). Use of a ventilated capsule and tritiated water to measure evaporative water losses in a tenebrionid beetle. *J. exp. Biol.* **108**, 477–481.
16. Couthie P.A. and Crowe J.H. (1979). Transport of water vapor by tenebrionid beetles. II. Regulation of the osmolarity and composition of the hemolymph. *Physiol. Zool.* **52**, 88–100.
17. Nicolson S.W. (1980). Water balance and osmoregulation in *Onymacris plana*, a tenebrionid beetle from the Namib Desert. *J. Insect Physiol.* **26**, 315–320.
18. Machin J. (1981). Water compartmentalisation in insects. *J. exp. Zool.* **215**, 327–333.
19. Nicolson S.W. and Hanrahan S.A. (1986). Diuresis in a desert beetle? Hormonal control of the Malpighian tubules of *Onymacris plana* (Coleoptera: Tenebrionidae). *J. comp. Physiol. B* **156**, 407–413.
20. Nicolson S.W. and Isaacson L.C. (1987). Trans-epithelial and intracellular potentials in isolated Malpighian tubules of tenebrionid beetle. *Am. J. Physiol.* **252**, F645–F653.
21. Isaacson L.C., Nicolson S.W. and Fisher D.W. (1989). Electrophysiological and cable parameters of perfused beetle Malpighian tubules. *Am. J. Physiol.* **257**, R1190–R1198.
22. Sawyer D.B. and Beyenbach K.W. (1985). Dibutylryl-cAMP increases basolateral sodium conductance of mosquito Malpighian tubules. *Am. J. Physiol.* **248**, R339–R345.
23. Nicolson S. and Isaacson L. (1990). Patch clamp of the basal membrane of beetle Malpighian tubules: direct demonstration of potassium channels. *J. Insect Physiol.* **36**, 877–884.
24. Bertram G., Schleithoff L., Zimmermann P. and Wessing A. (1991). Bafilomycin A₁ is a potent inhibitor of urine formation by Malpighian tubules of *Drosophila hydei*: is a vacuolar-type ATPase involved in ion and fluid secretion? *J. Insect Physiol.* **37**, 201–209.
25. Nicolson S.W. (1991). Diuresis or clearance: is there a physiological role for the 'diuretic hormone' of the desert beetle *Onymacris*? *J. Insect Physiol.* **37**, 447–452.
26. Nicolson S.W. (1991). Excretory function in *Tenebrio molitor*: fast tubular secretion in a vapour-absorbing insect. *J. Insect Physiol.* (in press).
27. Dow J.A.T. (1981). Countercurrent flows, water movements and nutrient absorption in the locust midgut. *J. Insect Physiol.* **27**, 579–585.
28. Reynolds S.E. and Bellward K. (1989). Water balance in *Manduca sexta* caterpillars: water recycling from the rectum. *J. exp. Biol.* **141**, 33–45.
29. Knowles G. (1976). The action of the excretory apparatus of *Calliphora vomitoria* in handling injected sugar solution. *J. exp. Biol.* **64**, 131–140.
30. Slobodchikoff C.N. and Wismann K. (1981). A function of the subelytral chamber of tenebrionid beetles. *J. exp. Biol.* **90**, 109–114.
31. Casida J.E. and Maddrell S.H.P. (1971). Diuretic hormone release on poisoning *Rhodnius* with insecticide chemicals. *Pest. Biochem. Physiol.* **1**, 71–83.
32. Maeda S. (1989). Increased insecticidal effect by a recombinant baculovirus carrying a synthetic diuretic hormone gene. *Biochem. biophys. Res. Commun.* **165**, 1177–1183.

An automatic telescope for Sutherland

David Kilkenny

An automatic photoelectric telescope (APT) for the Sutherland site of the South African Astronomical Observatory (SAAO) is currently under joint construction by the SAAO and the universities of Cape Town (UCT) and South Africa (UNISA). When completed, the telescope will carry out fully automatic photoelectric measurement of the brightnesses and colours of stars and will be used mainly for the detailed observation of variable stars.

The telescope, based on the Auto-scope¹ design, is being built under licence at the SAAO; almost all the auxiliary instrumentation and software will be of SAAO/UCT/UNISA origin. The Auto-scope design was chosen because several of these telescopes have been built, tested and are now operational, for example at Fairborn Observatory in Arizona. Figure 1 illustrates the main feature of the telescope. A Dall-Kirkham-type optical system, with a concave ellipsoidal primary and a convex spherical secondary mirror, is being figured by the Optical Engineering Programme of the CSIR's Production Technology Division. The primary mirror is of particular interest; the blank was produced by the Hextek Corporation of Tucson, USA, using the gas-fusion process. In this technique, two flat glass plates, separated by short glass

cylinders, are heated to approximately 1 000°C. Holes in the rear plate allow the cylinders to be pressurized so that they expand to meet, fusing to each other and to the front and rear plates. The result is a blank which is as rigid as a solid piece of glass under gravitational loading but substantially lighter, a great advantage in reducing the inertia of the telescope. Hextek can also 'slump' the blank to almost any desired curvature and in the case of the 0.75-m-diameter blank supplied for the Sutherland APT (illustrated in Fig. 2), this was done to give the requested f -ratio of $f/2.5$, simplifying the initial grinding of the mirror surface. When completed, the primary mirror will be the largest fine-optical component to have been figured in South Africa. The overall primary and secondary mirror system will operate at $f/7$.

The photometer planned for the APT will have a commercial charge-coupled device (CCD)² thermoelectrically cooled to about -40°C, for target identification and fine guiding of the telescope where necessary. The CCD is a 578 × 386 EEV chip used in frame-transfer mode. Several such units have been built at the SAAO, based on a design³ of the Rutherford Appleton Laboratory and the Royal Greenwich Observatory in Britain. The CCD units will also be used for acquisi-

tion/guiding on the other SAAO Sutherland telescopes, as well as for controlling visual and near infrared 'science-quality' CCD units.

The photometer itself is of fairly conventional design with the usual aperture wheel (for the isolation of individual targets) and optical filter wheel units. A GaAs photomultiplier will be used for observation of pass-bands in the region ~ 300–900 nm. Photoelectric photometers currently in use at the SAAO have computer (PC) control of the filter wheels so that a preprogrammed sequence of measurements with different pass-bands can be efficiently made on a star. The APT will require extra control for the aperture wheel and for all the tasks that an observer usually performs, such as setting the telescope, moving the dome, focusing the telescope, identifying the target star, checking data quality (for instance for cloud interference), and observing 'standard' stars for calibration purposes. A considerable amount of software already exists (written mainly by Luis Balona of the SAAO and Angela Jones and Greg Cox of UCT) for photometer control and data handling,⁴ pattern recognition for target acquisition,⁵ and programme management — the selection of sequences of stars to be observed on a given night and the priorities for observa-

Dr David Kilkenny is at the South African Astronomical Observatory, P.O. Box 9, Observatory, 7935 South Africa.

