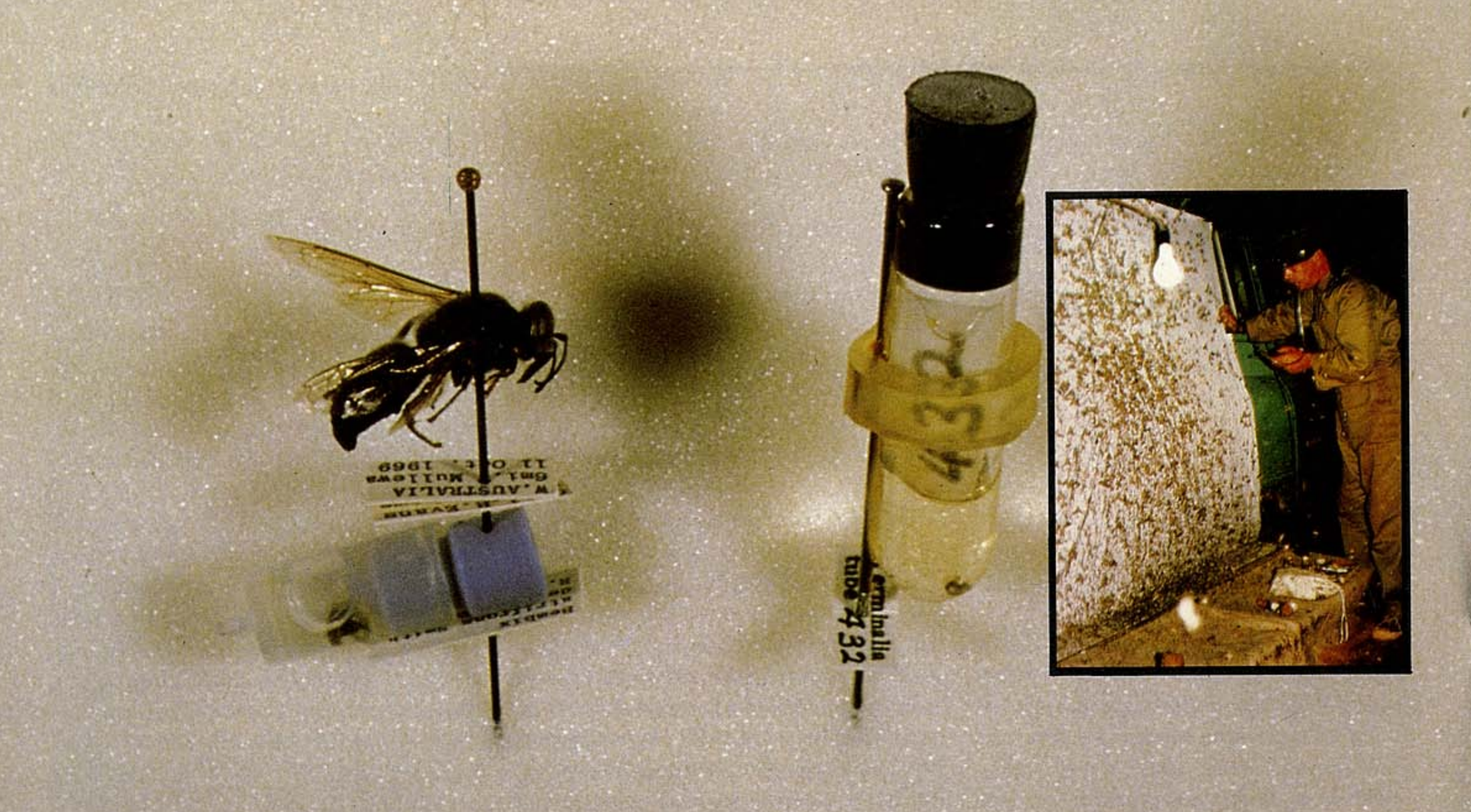


Australia's insect collection

If you were not among the 2200 visitors to the Australian National Insect Collection on its open day last June, you possibly imagine it as a large hall full of cabinets, whose drawers are crammed with rows of labelled specimens. Perhaps your memory involuntarily revives childhood impressions of a sombre 19th Century building in some Australian or overseas city.

To some extent you would be right. Approximately five million specimens form the heart of the Collection — the larger ones, such as big beetles, pinned into trays, and the rest gummed to pieces of cardboard that are in turn pinned into place. Specimens with softer bodies — like caterpillars, grubs, and other larvae — occupy glass tubes of preservative in other drawers.

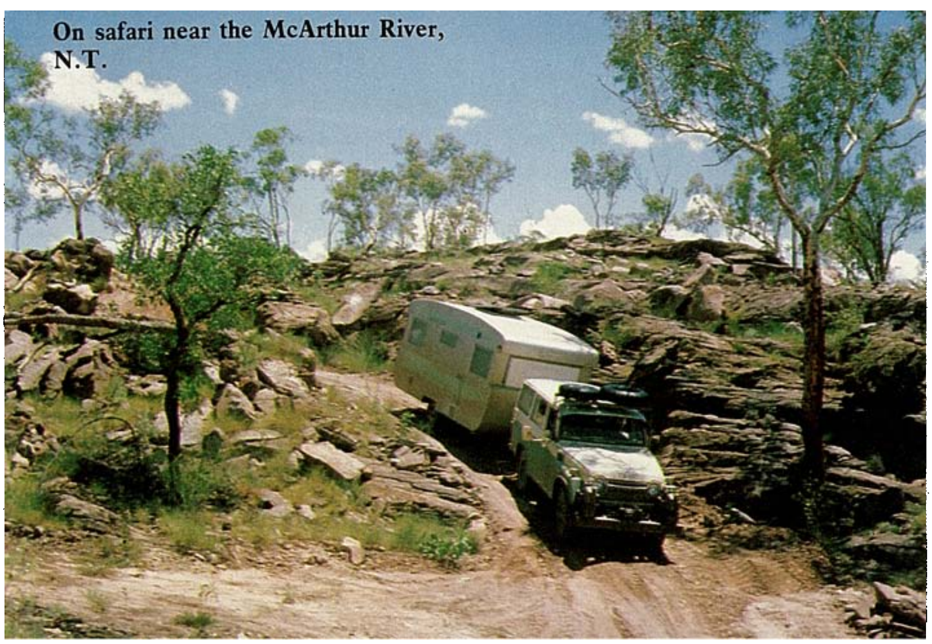
You would perhaps be surprised, though, to see a pair of black beetles crawling about in a small aquarium tank, and, in other glass dishes, what appear to be maggots burrowing through sawdust — in fact, beetle larvae taking part in an investigation into their diet.

Modern taxonomists take an all-round interest in the subjects of their study, gathering information not only on the number of segments in an antenna or the pattern of hairs and bumps on a thorax but also on behaviour and ecology. 'We are really taxonomists and biologists', remarked one of them, adding pointedly 'the taxonomist must be a first-rate field worker'. All this information, gathered in both field and laboratory, clearly cannot be accommodated on specimen labels.

Not only specimens

The Collection, housed in the CSIRO Division of Entomology's headquarters in Canberra, contains tape recordings of the sounds — often valuable aids to identification — made by grasshoppers and crickets. Colour transparencies show caterpillars and other young stages as well as specimens in foreign museums, including some 3000 photographs of small moths in the British Museum taken by Dr Ian Common, who recently retired from the Division. And of the large number of microscope slides (perhaps 40 000), some carry entire specimens of small insects such as fleas and other arthropods like mites, and some preserve dissected internal organs that are valuable in identification and comparative studies.

The collections of books and scientific papers are growing, too, supplementing the card indexes of information, some of it now being transferred to computer.



On safari near the McArthur River, N.T.

Collecting goes on all the time, but major expeditions fill gaps in our knowledge of particular districts, especially those remote from centres of population.

Computers play a growing role in modern taxonomy, not only storing facts but also sorting them to produce identification keys and even classifications (see the box on page 20).

Like a library, the Collection is much less static than a single glance suggests. New specimens continually come in: a major expedition may add tens of thousands. And each year about 100 000 specimens go out on loan to taxonomists elsewhere in Australia and overseas.

The Collection occupies the D.F. Waterhouse Laboratory of Insect Taxonomy, a two-storey building opened in May 1982 by the Minister for Science and Technology, Mr David Thomson, and named after Dr Doug Waterhouse, who was the Division's Chief for 21 years until his retirement in 1981.

It now seems natural that Australian insects should be studied and preserved here in Australia, but things were different in the days of the first European explorers, who saw Australian animals and plants as exotic specimens to intrigue both naturalists and the general public. For many species, therefore, the 'type' specimens — the ones examined by the entomologists who first described them, and accepted by international convention as the ultimate reference point for checking scientific names — reside in European institutions. Many taxonomists find, as Dr Common did, that they have to inspect type specimens from foreign collections, either by borrowing them or by travelling to see them.

Two centuries of taxonomy

Australian insect taxonomy may be said to date from 1775. In that year the Danish entomologist Johann Fabricius published his 'Systema Entomologiae', the first scientific work to describe specimens from this continent. The insects Fabricius studied had been collected 5 years earlier by Joseph Banks, Daniel Solander, and other members of Captain Cook's *Endeavour* party.

Among these insects was a scarab beetle, which Fabricius named *Scarabaeus barbarossa*. His description of the species appeared in Latin, the international scientific language of the day, and included the phrase '*Habitat in nova Hollandia*'. A large model of this beetle (made by a Canberra dentist) and a photograph of the relevant entry in 'Systema Entomologiae' adorn the D.F. Waterhouse Laboratory, to commemorate this, the first scientific description of an Australian animal.

In his book, Fabricius described 221 species of Australian insects; by the time the Division of Entomology was founded a century and a half later, in 1928, the number of known species had exceeded 37 000. (It is now approaching double that figure.)

A Malaise trap: insects fly into its walls, then travel up into the collecting jar at the top.

From the Division's earliest days, scientists appreciated that entomological research — and, most urgently, the search for ways of controlling pest species — could not proceed without accurate identification of the animals being studied. Often the large economic difference between a pest and a closely related harmless species is not accompanied by conspicuous structural distinctions, and without thorough taxonomic studies ecologists and laboratory workers could spend valuable time and energy pursuing the wrong quarry.

Thanks to gifts and purchases of collections made by amateurs, and to field work by CSIRO scientists, the Division's collection grew rapidly, and in 1962 the federal government acknowledged its importance to science and to the national estate by gazetting it as the Australian National Insect Collection.

The head of the taxonomy section, Dr Bob Taylor, estimates that the Collection must hold representatives of about two-thirds of Australia's insect fauna (which he puts at about 110 000 species). However, there is still much work to do; about 55% of the continent's insect species have yet to be scientifically named and described.

Small-game-hunting

If the Collection forms, in the jargon of our time, a data base, then much of the input in the last 15 years has come from specially mounted expeditions to remote corners of the country. Some five to eight scientists make up a typical party, driving their equipment the long distances from Canberra to Cooktown, Kakadu, or the Kimberleys, say, in four-wheel-drive vehicles and caravans.

Over the years the leader of these expeditions, Mr Murray Upton, has evolved a detailed procedure designed to minimize the risk of things going wrong and to make the most of the 3 weeks or so available in the study area. Each expedition takes about 6 months to plan.

Apart from a fire inside one vehicle near Ayers Rock and a flash flood that added unexpected excitement to a crossing of the South Alligator River, the trips have been free of 'incident' and remarkably productive. Generally, one-third or more of all the specimens collected in remote places prove to belong to previously undescribed species.

The two most recent expeditions — to the Endeavour River district near Cooktown, where Banks and Solander collected some of their specimens more than 200 years ago — produced about 100 000 specimens between them. Because, as Mr Upton puts it, 'at every time of day there's an insect to be found somewhere', the scientists find little time to relax in the field.

Different species behave in different ways, and entomologists must use a variety of devices to catch them. Some insects fly into tent-like traps; others come to lights after dark. Pitfall traps catch beetles and other animals walking over the surface of the ground; special extraction funnels use heat and light to drive specimens out of leaf litter and topsoil. Bait attracts certain species, and good old-fashioned hunting

Computers make some key changes

Taxonomists' rooms in the D.F. Waterhouse Laboratory are equipped with wall sockets for computer terminals. The word 'computer' is perhaps misleading in this setting. In their early days, computers were indeed developed particularly for high-speed numerical calculations, but over the years they have come to be valued as much as anything for their capacity to 'carry a lot of information in their heads'.

Because this information may generally be retrieved in print-out form, a computer represents, in modern offices, a combined filing cabinet and typewriter — operating very fast. To appreciate the importance of a computer to a taxonomist, it may help to pursue the office analogy a little further. Imagine that an employer instructs a clerk to sort the last 20 years' correspondence, at present heaped randomly on the floor, and file it in alphabetical order. After enormous effort, the clerk announces the job is done.

'Oh, look, I've changed my mind', declares the employer, who has modelled himself on a John Cleese creation. 'Put everything in date order. We'll see how that works, and if we don't like it . . .' The clerk's reply may be left unrecorded.

In practice, of course, the huge amount of labour invested in a major filing system rules out such changes. But if all the necessary information has been suitably stored in a computer, it may be retrieved in a variety of different forms at the press of a few buttons. This flexibility can be a great help to taxonomists, particularly in compiling keys.

A key is any aid to identification. It usually takes the form of a list of printed questions. By referring to his specimen, the user answers the first question and, in the light of his answer, the key directs him to another. Each successive question eliminates some possibilities and so shortens the list of candidates. Eventually the user reaches a question that identifies the specimen.

Keys have enormous value, but traditionally they have proved laborious to compile and, like a filing system, resistant to change. The discovery of a new species that does not 'fit' the characters chosen by a compiler for the early questions in his key could require him to start all over again. In practice, his second edition would probably carry a footnote saying 'this character does not apply to some species . . .'

Computers have changed that. Once the characters of the relevant genera or species have been electronically stored, a taxonomist can rapidly retrieve this information grouped in different ways, and so see how best to construct a key.

Dr Mike Dallwitz of the CSIRO Division of Entomology has written a program that obtains keys automatically from a computer, following general commands supplied by the taxonomist. If he wants the shortest possible key, for example, the taxonomist can instruct the computer to arrange its information into the minimum number of questions.

On the other hand, if a short key would compromise reliability, the taxonomist can, if he chooses, command the computer to supply a more reliable, albeit longer, key. (The taxonomist provides his computer with information on the reliability of alternative characters.)

The computer can also sort the information for special purposes to produce, say, plant keys that treat only vegetative characters, for use outside the flowering season.

In 1980 Dr Dallwitz developed a 'language' that can be understood readily by both taxonomists and computers, for use in producing keys and descriptions of genera or species. He called it DELTA (DEscription Language for TAxonomy). A good example of what can be achieved with a computer and DELTA is provided by a book compiled by Mr Leslie Watson of the Australian National University and Dr Dallwitz.

Titled 'Australian Grass Genera', this book contains a description of each

(beating foliage, chopping rotten wood, and so on) produces further specimens.

Some of these expeditions have been supported by mining companies carrying out environmental impact studies of areas in which they are prospecting. Thiess–Toyota helped finance the Cooktown trips. Other expeditions, entirely financed by CSIRO, have visited sparsely inhabited regions to help fill gaps in entomologists' knowledge of insect distributions. To some extent the Division is racing against time: perhaps 40 000 or more species remain to be collected, yet many are disappearing, especially through habitat destruction.

Each year about 100 000 specimens go out on loan.

What's in a name?

After preliminary sorting, the specimens collected on these expeditions may well have to wait several years for their scientific baptism: an illustrated description (no longer in Latin, and often including information such as chromosome numbers that Fabricius could not have dreamed of) and a formal double name (a binominal) in the manner adopted by Fabricius's teacher Linnaeus and accepted for all animals and plants by the international scientific community ever since.

Why is there such a delay over the seemingly simple matter of choosing a name? Of the two main reasons, one involves the strict but necessary 'rules' that must be followed before a new name can be accepted by scientists in every country in the world. Without a detailed, and therefore time-consuming, published description, and a 'type' specimen deposited in a major collection, no name can be approved.

The other, and more inhibiting, reason involves the first half of the binominal — that is, the genus name. In selecting this name, a taxonomist makes a statement of opinion about the biological affinity of that species to others that seem closely related.

Accordingly, and to reduce the number of scientific papers to which taxonomists must refer in order to keep up with new nomenclature, new species are often described not individually but as part of a major revision of a complete genus. This sizeable task may necessitate consulting literature and type specimens from several countries and sifting painstakingly through the fruits of a number of expeditions — not to mention scrutinizing museum collections for possible misidentifications from earlier times.

But without an internationally agreed name, a species could remain for years out of reach of ecologists, physiologists, and others who wish to study it. How can they write about an animal if they cannot tell the world which species it belongs to?

To short-circuit what Dr Taylor calls this 'taxonomic impediment', specimens

genus, followed by separate keys for each State and for the Northern Territory, as well as an eighth key to cover all the genera, numbering more than 300, of the continent. Early in the book appears a list of more than 200 numbered characters: no. 11, for example, concerns whether the shoots are aromatic, and no. 51 deals with the length of the female-fertile spikelets.

Every grass genus displays some 'state' for each of these characters. Some grasses give off an aroma when crushed, but the others do not; every genus therefore has one of the two states for character no. 11. The state of another character may be a number, or a range of measurements.

Over many years, Mr Watson has amassed information on the states of the 200-odd characters in the list, and these data are now stored on computer in DELTA language.

One of the beauties of this system is that descriptions and keys can be produced automatically once the data have been loaded into the computer's memory. To write the description of a genus, the computer works its way down the character list, noting after each one the particular state that applies in this case.

The computer automatically builds the description, therefore, out of the phrases used in the character list and the numbers and other information on states stored in the data bank. Likewise, using the key program written by Dr Dallwitz, the computer automatically generated the eight keys in the book.

Of course, somebody has to 'type', and later proof-read, the character list and the information on states, but once this is done, the descriptions and keys, being compiled automatically, may be taken as read — no small advantage, when you consider that the character list occupies only six pages of the grass book, while the descriptions and keys between them take up 187 pages.

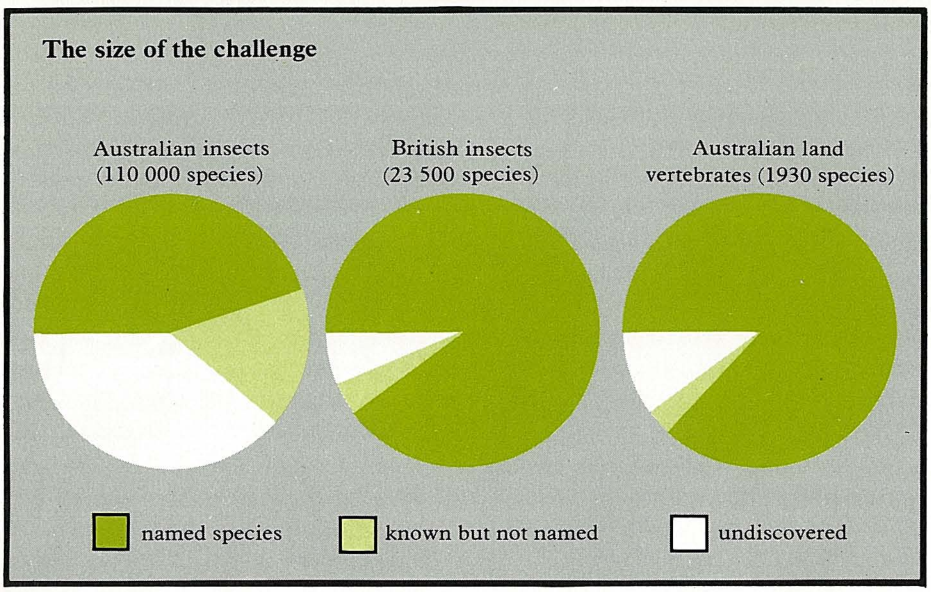
The character list may be compiled in languages other than English, in which case the keys and descriptions will automatically come out in the appropriate language too. Dr Taylor is compiling an English–French paper on the ant genus *Lordomyrma* of New Caledonia, where both languages are spoken, and Mr Watson is collaborating with a Canadian botanist on a bilingual account of Canadian grass genera. Indeed, taxonomists could compile a multilingual work quite simply, by referring to the characters and states only by code numbers in the descriptions, and translating the code numbers into several languages in the introductory part of the work.

In theory the DELTA system could handle information on any objects or ideas, provided the same features of all the items are described. The system has already helped to store and sort information on beetles, ants, grasses, legumes, viruses (in an international survey co-ordinated by the Virus Ecology Research Group at the Australian National University), and the vegetation types — such as lowland mixed forest and various plant associations — of Lord Howe Island.

Using facilities of the CSIRO Division of Computing Research in Canberra, taxonomists can obtain computer 'print-outs' in a number of forms, including microfiche and film as well as printed paper. This means that scientists can, if need be, rapidly obtain a drastically revised version of a key on microfiche, and mail it inexpensively to interested workers anywhere in the world. The computer is transforming not only taxonomy but also publishing.

A general system for coding taxonomic descriptions. M.J. Dallwitz. *Taxon*, 1980, **29**, 41–6.

'Australian Grass Genera: Anatomy, Morphology, and Keys.' L. Watson and M.J. Dallwitz. (Australian National University Research School of Biological Sciences: Canberra 1980.)



Taxonomists estimate that two-fifths of Australia's insects have still to be found, and that fewer than half have been named. By contrast, British insects and Australian land vertebrates are well known.

in the Australian National Insect Collection often receive a provisional appellation, such as 'genus F, species 16'. Using that code name, taxonomists can accumulate and lodge with the Collection information on the insect's habits and habitat, ecologists can refer to it in scientific literature, and the Division's staff can identify specimens sent in, for example, by anxious farmers who find them chewing into a crop.

Similarly, a biologist working on an unidentified species can lodge 'voucher' specimens with the Collection; these receive a provisional code name, then join related specimens in the appropriate cabinet to await future formal naming. Hundreds of Australian grasshoppers bear such temporary names, enabling ecological work to proceed ahead of taxonomic revision.

Without this procedure, years of study could have been either prevented or wasted because of subsequent doubt over the identity of the study populations.

John Seymour

More about the topic

Some statistics relevant to Australian insect taxonomy. R.W. Taylor. *CSIRO Division of Entomology Report* No. 8, 1979.

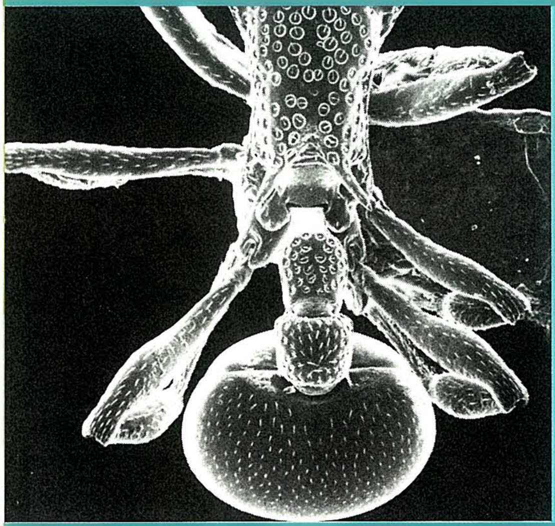
The scanning electron miscroscope fills a valuable entomological niche. It gives us photographic images with a good depth of field (three-dimensional effect) at the magnifications at which scientists carry out much of their examination of insects — between those of the hand lens (up to ×20) and the monocular light microscope (from about ×100 upwards).

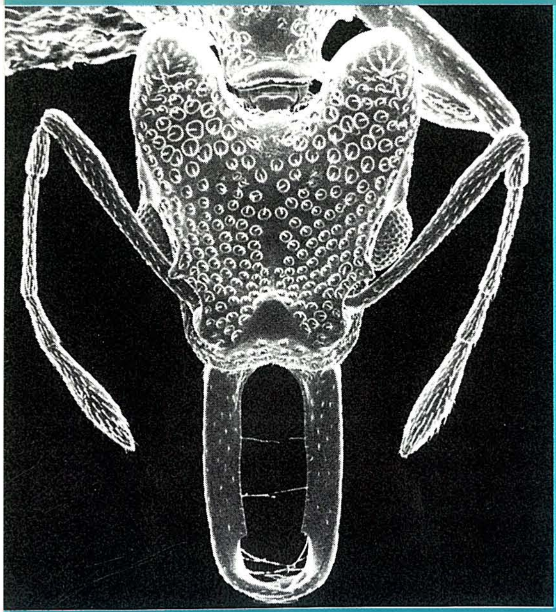
To examine specimens at intermediate magnifications of about ×50, entomologists generally use binocular light microscopes, with one hand continuously on the focusing knob because the microscopes have a shallow depth of field. A camera can record only what is in focus under the microscope at one time — and that must be only a small part of the specimen.

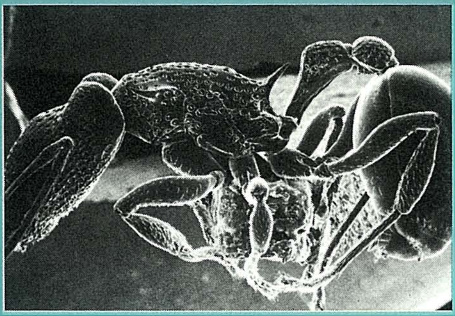
The excellent depth of field of scanning electron micrographs gives them a 'three-dimensional' quality that entomologists in the CSIRO Division of Entomology are using in at least two ways. Dr Taylor has found that micrographs of ants can satisfactorily replace the traditional drawings in formal published descriptions of species. The accuracy and speed of the scanning microscope offer clear advantages.

And Dr John Lawrence uses scanning pictures of mouth-parts to assist his study of Australian beetle larvae. The images enable him to infer the functions of the mouth-parts, and helpfully complement laboratory and field studies of the beetles' feeding ecology.

Scanning electron micrographs now replace drawings in the published descriptions of some new species like this ant, *Orectognathus robustus*, from eastern Queensland, described by Dr Taylor in 1977. The specimen was coated with a thin film of gold–palladium alloy to reflect electrons. The pictures below and left show dorsal views of the head and thorax and a lateral view of the thorax of a worker.







Beetle larvae show great diversity in their diets and therefore in their mouth-parts. This diversity becomes particularly clear under the scanning electron microscope, which provides '3-D' images at a convenient magnification. The images help scientists clarify a larva's method of feeding.

From the front, a helodid larva (1, above right) looks rather like a crab. It feeds similarly, too, filtering edible particles from the water in which it lives, often on the bottom of a pond. The tips of the maxillae carry fine brushes (2) to trap the food. The insect periodically 'wipes' these brushes across the floor of the mouth, where combs pick up the food. The mandibles then go into action, their hairy edges sweeping the food to the back of the mouth to be crushed by their molar bases.

By contrast, the larvae of long-horned beetles (3) chew their way through wood. Their powerful mandibles work like a pair of chisels, biting off pieces of wood that are swallowed whole.

The mandibles of the predatory Texas beetle (4) take yet another form. Like curved hypodermic needles, they pierce a small spider or other prey before administering an injection of digestive juices. Other species in the same genus as this North American beetle inhabit the Kimberley Range, W.A. They probably feed the same way, but await study.