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The good, the bad and the ugly: Australian snake taxonomists and a history of the taxonomy of Australia's venomous snakes

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Abstract

The Australian snake fauna is unique in harbouring more venomous species than non-venomous ones. Although taxonomic research on the elapid snakes of Australia goes back to the late 18th century, in stark contrast to other developed regions of the world (e.g. the continental USA), Australian snake taxonomy is very much in its infancy. Despite this, or perhaps because of this, the taxonomy of Australian snakes has been extraordinarily controversial, and many of the taxonomists involved correspondingly colourful. In this review, we explore the sometimes-tortured history of the taxonomic exploration of the venomous snake fauna of Australia, looking at some of the more colourful and notable contributors and highlighting systematic pitfalls that persist even today.

1. Introduction

For anyone interested in venomous animals, Australia represents a Mecca of toxic biodiversity. The island continent has a long-standing reputation for its chemically armed fauna, including the world's most lethal jellyfish, spider, octopus and snake—a reputation that has been, and continues to be, carefully cultivated and nurtured by Australians of all walks of life, as any discussion of venomous animals in any pub will soon show. Indeed, it is a matter of common experience that the dangers to personal safety posed by Australia's venomous animals are considerably less than the risk incurred by publicly doubting the country's supremacy in this sphere in a bar room conversation.

As well as containing some of the reputedly most lethal snakes, the Australian snake fauna is of course infamous for being the only continental ophiofauna to boost a greater number of venomous than non-venomous species: the family Elapidae accounts for a total of 90 species (57.7%) out of the total of 156 terrestrial snake species found in Australia (Wilson and Swan, 2003).

However, despite the high profile of the Australian venomous snake fauna, and the high levels of popular awareness of at least some of its components, the study of the taxonomy of these snakes has lagged behind that of other developed countries. Part of the reason is the uniquely Australian combination of a very large land area with high biodiversity coupled with low human population

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density (Aplin, 1999). This results in a very high per capita species count, and consequently and unavoidably, a lower level of research effort per species. With a similar surface area to Australia, the Continental USA is home to 142 species of snake (Crother et al., 2000, 2003) for a human population of approx. 290 million (0.49 species/million people). In comparison, Australia houses 156 snake species, but only 19.7 million people (7.9 species/million people). Even considering any plausible differences in the number of researchers per million inhabitants, it is clear that Australia's herpetofauna will be studied by far fewer researchers per species than that of North America. To this demographic impediment can be added the uneven spread of the human population of Australia and the consequent extreme remoteness of many parts of the continent, which combine to make comprehensive biodiversity studies both logistically and financially difficult. These impediments have resulted in Australia remaining what Keogh and Smith (1996) aptly described as "a virtual frontier of taxonomic research", where many groups remain largely unstudied except in terms of species descriptions, and where a more detailed study of variation will often reveal long-accepted, widespread species to be composites. Much of the history of the systematics of Australian elapids is thus one of the initial species descriptions, followed by various compendia of species lists and keys or descriptions, but a dearth of in-depth analyses. Even today, new species are still being discovered on a regular basis (Fig. 1), including large and conspicuous species such as *Pseudechis butleri* (Smith, 1982) and *Acanthophis wellsi* (Aplin and Donnellan, 1999), while others are being redefined (e.g., Shea, 1998), and the use of genetic markers is uncovering evidence for hitherto unsuspected patterns of diversity in other species (e.g., *Acanthophis*—Wüster et al., 2005).

Moreover, extreme instability of the nomenclature of many taxa persists, particularly concerning the generic classification of the smaller elapids, many of which have been classified in three, four or more different genera in the space of a few decades (reviewed in Mengden, 1983; Cogger, 1985; Hutchinson, 1990). Reasons for this instability include both new insights from the analysis of novel sources of evidence, but also procedural reasons such as name changes for reasons of homonymy and/or priority. As an extreme example, the Lake Cronin snake was first described as *Brachyaspis atriceps* by

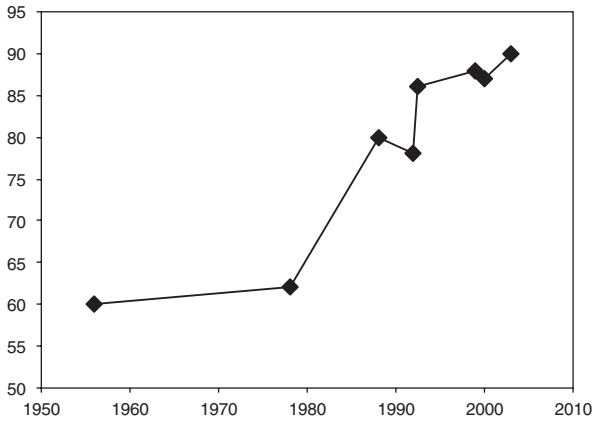

Fig. 1. Number of Australian elapid species recognised in major compendia of the Australian reptile fauna. From left to right: Kinghorn (1956), Cogger (1979), Wilson and Knowles (1988), Cogger (1992), Ehmann (1992), David and Ineich (1999), Cogger (2000) and Wilson and Swan (2003).

Storr (1980), and has been variously classified as *Notechis atriceps* (Storr, 1982), *Echiopsis atriceps* (Cogger et al., 1983), *Denisonia atriceps* (Storr, 1984), and *Suta atriceps* (Golay et al., 1993), before finally being placed in its own, monotypic genus as *Paroplocephalus atriceps* (Keogh et al., 2000). Critical, evidence-based assessments of the status of many taxa have only appeared in the latter decades of the 20th century, and many genera and groups of species remain inadequately known.

In the following paragraphs, we intend to provide an overview of the history of the study of the systematics of the Australian elapid fauna, incorporating both a historical perspective and recent trends.

The history of the description and cataloguing of the Australasian elapid fauna is as colourful and diverse as are the various species themselves. From the days of the first European colonisation of the Australian continent, naturalists have sought to identify, describe and classify the various species of venomous snakes and elucidate their inter-relationships, both in the quest for knowledge, and in the individual pursuit of professional stature and recognition.

Many of the earliest contributors to this cause never set foot on Australian soil, and carried out their work in the relative comfort and civility of 19th Century European museums and private menageries. Others braved the rigors of the fledgling nation and were avid explorers, entrepreneurs and adventurers. While some were exceptionally skilled

and left behind contributions of enduring value, others were singularly incompetent and their ineptitude produced little more than temporary taxonomic confusion.

Throughout the early part of the 20th Century, significant contributions continued to be made towards our understanding of elapid diversity both by professional scientists ensconced in institutions, and by dedicated and skilled "amateurs", some of whose work was extremely competent indeed. Over the last three decades advances in science and particularly in molecular biology have increased the precision with which taxonomists, systematists and phylogeneticists have been able to probe and explore the taxonomic and evolutionary relationships of Australasian snakes. However, unfortunately, the late 20th Century has also produced new controversies arising from taxonomic contributions by a small minority of non-academic authors who have sought to circumvent the normal conventions of systematic publishing, and have turned what should be the epic undertaking of describing this planet's dwindling biodiversity into a whirlpool of recrimination, competition and confusion. Issues of poor science and unethical publications are particularly sensitive in taxonomy: whereas poor publications can simply be ignored in other fields of science, this does not apply to inadequate descriptions of new species, due to the Principle of Priority underlying the International Code of Zoological Nomenclature. Once a new name has been published, it forms a permanent part of the scientific record, however poor the original publication. Consequently, poor taxonomic work has the potential to cause chaos for many years to come (Aplin, 1999; Wüster et al., 2001).

For toxinologists all this may seem quite irrelevant, especially if one's venom samples arrive neatly lyophilised from a chemical supplier! To the contrary however, taxonomy is crucially important to venom research (Wüster and McCarthy, 1996; Wüster et al., 1997). This is especially so where the identification of the species from which venom has been obtained is concerned. Knowing the origin and identity of the species whose precious toxin fractions are eluting in the lab governs the reproducibility and validity of all of our published results. Taxonomic imprecision in the toxinological literature is rife (Wüster and McCarthy, 1996), and critically undermines what would otherwise be useful data. Toxinologists have an obligation to be able to identify the actual species that venoms and toxins are derived from, and to ensure that they will also remain identifiable in the light of future taxonomic discoveries and consequent changes in nomenclature. This commits them irrevocably to developing an understanding of current taxonomic schemes and revisions, and to providing adequate levels of information on the origin of venoms to enable later workers to replicate their results irrespective of later taxonomic changes (Wüster and McCarthy, 1996). This is particularly important due to the well-established variations in venom composition that can occur even within a relatively genetically homogeneous group (e.g., Fry et al., 2001, 2002), and may cause antivenoms to fail to neutralise venoms even of species closely related to those used to raise them (Fry et al., 2003; Harrison et al., 2003). Thus the search for novel toxins for use in drug design and development is greatly hampered by taxonomical inaccuracy.

Our review of Australia's taxonomic history is an introduction to some of the outstanding names and faces whose taxonomic work underpins the status of the species whose venoms we explore and hope to understand.

2. Early taxonomists (1790—mid-late 20th century)

The earliest contributor to cataloguing Australia's elapid diversity was the naturalist, George Shaw (1751–1813) who was an assistant keeper at the British Museum. Shaw, who had been a lecturer in botany at Oxford University, and was also a medical practitioner, published the first description of an Australian elapid, the red-bellied black snake (*Coluber porphyriacus*—now *Pseudechis porphyriacus*) (Shaw, 1794). It is quite remarkable that this large, venomous species of elapid snake was explicitly stated to be harmless by Shaw, a lapse that was no doubt quickly remedied shortly after the first serious snakebite. This description was soon followed by that of *Boa antarctica* Shaw and Nodder, 1802, which is better known today as the common death adder, *Acanthophis antarcticus*.

Over the next 80 years a number of prominent naturalists were to make their mark upon the Australian elapid fauna. Most prominent among them all would have to have been another medical practitioner, Dr. Albert Günther (1830–1914). At the age of 27, he became an assistant to John Edward Gray (1800–75), the describer of *Naja australis* Gray, 1842 (now *Pseudechis australis*), at the British Museum. In his 38 years at the museum,

Günther described 18 Australian elapids, 15 of which are still recognised today. Among these are three species whose venoms have been used widely in research including *Hoplocephalus superbus* Günther, 1858 (now *Austrelaps superbus*), *Pseudonaja nuchalis* Günther 1858, and *Pseudonaja affinis* Günther 1872.

Sir Frederick McCoy enjoyed a highly successful career as a Museum director in Britain before emigrating to Australia in 1854 as the foundation Professor of Natural Science at the soon-to-become prestigious University of Melbourne. He also occupied the position of Director of the National Museum of Victoria from 1858 until his death in 1899, and described four species of elapids himself, the most famous being *Diemenia microlepidota* McCoy, 1879, which we now know as *Oxyuranus microlepidotus*, the inland taipan. McCoy firmly believed that Museum's were to be places of research and education, and at the time of his death the NMV housed more than 500,000 specimens, and was regarded as one of the world's greatest Museums.

Many early researchers of the Australian elapid fauna were unanimously recognised as giants in their field, but this did not mean that controversy escaped them all. The lives of some early taxonomists provided a preview to later dramas that were to haunt Australian herpetological systematics in the late 20th and early 21st centuries.

One of the most controversial early taxonomists was Johann Ludwig Gerard Krefft (1830–81), who set out for the Victorian goldfields on his arrival in Australia in 1852, but failed to make a living panning for gold, and took a position in the National Museum of Victoria. In 1864, Krefft became the Curator of the Australian Museum in Sydney, a position he held until his bitter arguments with the Museum's Board of Trustees saw him thrown bodily into the street and the doors locked behind him in 1874. During his years at the Australian Museum, Krefft described a number of elapid species of medical importance, including *Hoplocephalus carinatus* Krefft 1863, *Hoplocephalus ramsayi* Krefft 1864, *Hoplocephalus ater* Krefft 1866 and *Hoplocephalus stephensi* Krefft 1869 (now known, respectively, as *Tropidechis carinatus*, *Austrelaps ramsayi*, *Notechis ater* and *Hoplocephalus stephensi*). Perhaps his greatest herpetological contribution was the self-publication of "*The Snakes of Australia*" (Krefft, 1869), the first book to bring together all that was known of the country's ophiofauna in a form accessible to laymen. Krefft used this work to include *Acanthophis* in the Elapidae for the first time, couching his assessment with the proviso that he considered it "*intermediate*" between the viperids and the elapids.

Krefft's downfall was brought about in large part by William John Macleay (1820–91), yet another self-taught naturalist who, in addition to having been a wealthy pastoralist and Member of the New South Wales Parliament, was President of Museum's Board of Trustee's, and a man with personal ambitions that drove him and Krefft to loggerheads time and time again. Macleay used his wealth and status to amass his own private collection of zoological treasures, inherited from a long line of zoological collectors in his ancestry. Krefft publicly objected to Macleay's perceived abuse of the Institution's resources to build up the family collection, and a parliamentary inquiry essentially agreed that the presence of the Board hindered Krefft's effective management of the Institution. Macleay and the other trustees endeavoured to sack Krefft, claiming among a litany of petty infringements and incompetencies that he was intemperate and had fabricated Museum figures. With nowhere to turn Krefft barricaded himself in the Museum until finally on 21 September 1874, bailiffs broke into his office, and carried both him and his leather chair out into the Street! In addition to these political shenanigans, Macleay also described a total of 13 Australian elapid species, the most notable being *Diemenia ferox* Macleay 1882—a junior synonym of *D. microlepidota* McCoy 1879 (now *O. microlepidotus*).

Like Krefft, Queensland Museum Curator Charles Walter De Vis (1829–1915) was a self-taught naturalist/palaeontologist who eventually met with controversy. De Vis was a church minister before being appointed to the Museum in 1882 and his subsequent blundering efforts at elapid taxonomy drew derisive ridicule from several of his peers. Indeed, of 17 new species described by De Vis, only two are still recognised today: *Cacophis warro* De Vis 1884 (now *Simoselaps warro*) and *Pseudechis guttatus* De Vis, 1905. A common criticism of De Vis was that his research prior to proposing names was manifestly deficient, as witnessed by the fact that he named several taxa twice, including *Pseudechis guttatus*, which he later (De Vis, 1911) described again as *Pseudechis mortonensis*. The ineptitude of these efforts moved the eminent Belgian-born Curator of the British Museum of

Natural History, George Albert Boulenger (1858–1937), to write as early as 1885 that "It is painful to have to record such contributions as Mr. De Vis's herpetological papers…" and that "through his [De Vis'] incompetence and want of care he will do much harm", and proclaiming that De Vis was "manifestly ignorant" about the taxa he chose to write about. Boulenger was one of the gentleman naturalists of his time, and De Vis' works must have provoked him extraordinarily in order to draw such a stringent rebuke.

Boulenger's own contributions to Australian herpetology were extensive and while his classic "Catalogue of the Snakes in the British Museum (Natural History)" (Boulenger, 1896) is the most often cited, his later descriptions of *Acanthophis pyrrhus* Boulenger 1898, *Pseudechis colletti* Boulenger 1902, and *Diemenia ingrami* Boulenger 1908 (now *Pseudonaja ingrami*) were important contributions to elapid taxonomy that have endured to the present day.

Edgar Waite (1866–1929) who had served as Curator at the Australian Museum from 1893, and then the South Australian Museum from 1906 until his death published two books, his "Popular Account of Snakes" (Waite, 1898), and (posthumously) "Reptiles and Amphibians of South Australia" (Waite, 1929). Waite also described *Demansia textilis inframacula* Waite 1925 (now *Pseudonaja inframacula*) from South Australia's Eyre Peninsula.

James Roy Kinghorn (1891–1983) produced his own text, "The Snakes of Australia" (Kinghorn, 1929), a work that became the mainstream text on Australian snakes for more than 30 years. Kinghorn began work at the Australian Museum in 1907 when he was just 16 years old, taking a leave of absence in 1915 to join thousands of other young Australians on the front lines of World War I. He served as a driver for the 4th Field Artillery Battery and then returned to the Museum in 1918 and remained there until 1956. His contributions to elapid taxonomy included describing *Notechis ater niger* Kinghorn, 1921 and *Glyphodon barnardi* Kinghorn, 1939, and, perhaps most famously, the description (Kinghorn, 1923) of the genus *Oxyuranus* to accommodate the most notorious of Australia's elapid snakes, the coastal taipan (*Oxyuranus scutellatus*). Another significant description (Kinghorn, 1955) was that of the genus *Parademansia* to accommodate two previously described species *D. microlepidota* McCoy, 1879 and *D. ferox* Macleay, 1882, which Kinghorn recognised as being one and the same taxon. This species was later found to be a second species of taipan, *O. microlepidotus* (Covacevich et al., 1981).

Eric Worrell (1924–87) was a self-taught naturalist and herpetologist who made a number of contributions to Australian elapid taxonomy. Worrell is best known as the founder of the Australian Reptile Park in Gosford, a private zoo that was the principal provider of Australian snake and spider venoms to the Commonwealth Serum Laboratories and to researchers for many years. In the 1950s he was instrumental in the provision of *O. scutellatus* venom during the push to create specific antivenom for treating bites by this species, and during the 1970s Worrell played a crucial part in the collection of *Atrax robustus* venom in the quest to produce specific antivenom for that species. In his taxonomy, Worrell's approach was traditional, relying upon physical descriptions and key characteristics such as cranial morphology and dentition to describe taxa. His contributions to elapid taxonomy were substantial, including the resurrection of the genus *Pseudonaja* Günther, 1858 (Worrell, 1961) for 6 species in the genus *Demansia*. Worrell also described a considerable number of other genera, several of which have become established names in Australian herpetology, including *Austrelaps* (1963a), *Cryptophis* (1961), *Drysdalia* (1961), *Drepanodontis* (1961), *Melwardia* (1960), *Narophis* (1961), *Parasuta* (1961), and *Suta* (1961). Eric Worrell described three other enduring species, *Glyphodon dunmalli* Worrell 1955, *Denisonia dwyeri* Worrell 1956 and *Melwardia minima* Worrell 1960 (now *Furina dunmalli*, *Suta dwyeri* and *Simoselaps minimus*). His "Reptiles of Australia" (Worrell, 1963b) contained descriptions of several new subspecies of *Notechis* and *Pseudonaja*. Although Worrell personally believed that some museum-based herpetologists of the day dismissed him as an unqualified amateur, many criticisms arose from disagreements over the 'quality' of the work, its publication outside the peer-reviewed framework, and poor use of the rules of nomenclature.

Glenn Storr (1921–90) worked at the Western Australian Museum for 28 years, and was another prolific taxonomist, who, despite working in the recent past, adopted views that were occasionally significantly outside the mainstream. Storr (1967) produced a number of taxonomic revisions involving Australian elapid genera, including *Vermicella*, *Denisonia* (Storr, 1981a, 1984), *Acanthophis* (Storr,

1981b), *Furina* (Storr, 1981c) and *Notechis* (Storr, 1982). Storr (1985) summarised his concept of the Western Australian Elapidae, and criticised Worrell (1963b) for having recognised too many genera, a claim he also levelled at Boulenger (1896). Storr's contention was that both Boulenger and Worrell relied too heavily on character states that were linked to the subduing of prey and feeding, and he believed that there was a necessity to avoid these characters in favour of those that were without direct connection to biological processes. Relying upon features such as iris colour, pupil shape, the colour of skin-connecting scales, the shape, texture and imbrications on scales, and ventral scale colouring, Storr (1982, 1985) consolidated the Western Australian elapids into just 10 genera and 4 subgenera. He absorbed the genera *Drysdalia*, *Austrelaps*, *Brachyaspis* (*Echiopsis*) and *Elapognathus* into *Notechis*, and the genera *Simoselaps*, *Neelaps* and *Brachyurophis* were absorbed as subgenera within *Vermicella*. Storr's assignments remained largely unadopted outside Western Australia.

3. The modern era (1960s–present)

In the modern era a number of contributors to Australian elapid taxonomy stand out for mention, some for the singular quality of their work, and others for the equally singular lack of it. As the latter half of the 20th century progressed new developments in the biological and molecular sciences have enabled us to probe the relationships among species, and their evolution much more thoroughly and with greater precision. A wide variety of techniques were applied to taxonomic and systematic questions, including the extensive applications of morphological approaches (McDowell, 1967, 1970; Gillam, 1979; Covacevich et al, 1981; Storr, 1982, 1985; Wallach, 1985; Greer, 1997; Shea, 1998; Keogh, 1999; Keogh and Smith, 1996; Aplin and Donnellan, 1999; Scanlon, 2003), karyotyping and protein electrophoretic analysis (Mengden, 1985a, b, 1986; Aplin and Donnellan, 1999); immunological distances (Schwaner et al., 1985); toxin amino acid sequence alignments (Tamiya, 1985; Slowinski et al., 1997), and DNA sequence analysis (Keogh, 1998; Keogh et al., 1998, 2000, 2005; Slowinski and Keogh, 2000; Kuch et al., 2005; Wüster et al., 2005) and multidisciplinary approaches (Mengden et al., 1986; Scanlon and Lee, 2004).

This advent of new techniques led to a revolution in our understanding of the phylogeny and history of the Australian elapids. For instance, it has become unambiguously clear that the Australian elapids are much more closely related to the sea snakes (conventionally classified in a separate family, the Hydrophiidae) than to the terrestrial elapids of Africa and Asia (e.g., McDowell, 1970; Smith et al., 1977; Slowinski et al., 1997; Keogh, 1998; Keogh et al., 1998; Slowinski and Keogh, 2000; Scanlon and Lee, 2004), and an increasing number of systematists thus now classify all Australian terrestrial elapids together with the marine proteroglyphs in the subfamily Hydrophiinae of the family Elapidae (e.g., Slowinski et al.., 1997; Slowinski and Keogh, 2000; Pough et al., 2001; Scanlon and Lee, 2004). At the same time, new palaeontological finds are beginning to improve our grasp of the time frame and mode of elapid evolution in Australia (Scanlon et al., 2003). Nevertheless, the phylogenetic relationships among many Australian elapid genera and species remain inadequately resolved, and a thorough and comprehensive analysis that robustly resolves the phylogeny of the entire group remains to be published. Only such a phylogenetic background will lead to a stabilisation of the chaotic nomenclature of these animals.

As well as many new insights into the phylogeny and systematics of Australian elapids, the rise of new methods and technologies as well as conceptual advances, such as the advent of cladistics, in the late 20th century also had a number of sociological side-effects which have impinged to some extent on the work of systematists. First, whereas the traditional taxonomic approach was generally accessible to most interested laymen, many of the new methods and approaches are now outside the grasp of all but the most committed amateur, while becoming the expected norm in most scientific journals. At the same time, the work pressures on academics in museums and universities changed with the economic climate and the availability of new methods, so that taxonomy has become something of an orphan science in the eyes of funding agencies and thus university and museum managements. As a result, the simple description and study of diversity has been put on the back burner compared to the use of more novel techniques, particular of the molecular variety. While the potential usefulness of these modern methods, particularly in conjunction with morphological approaches, cannot be

overstated, it has also removed many herpetologists from the immediate contact with the animals on which their efforts are focussed. In Australia, this development came earlier in relation to the process of herpetological discovery than in other parts of the world: whereas, for example, the basic outlines of herpetological diversity in North America have been understood for many decades, this process had not been completed to the same extent in Australia, due to the much greater species:researcher ratio.

At the same time as novel scientific developments pushed academics into the molecular laboratory, herpetology has enjoyed a worldwide upsurge in popularity in the general population: reptiles have become popular both as pets, and as objects of fascination to natural historians. Unfortunately, the coincident upsurge in amateur interest and the development of more remote techniques for systematists has resulted in an increasing gap between academic systematists and interested amateurs (Aplin, 1999). Many of these non-institutional herpetologists have acquired, during their fieldwork and through captive breeding, a very thorough instinctive grasp of what populations are similar and which are distinct. This visceral feeling of "knowing" what was going on, coupled with the perceived slowness of progress in the full documentation of Australia's herpetological diversity by academic herpetologists, has led to a number of instances where these frustrations among amateur herpetologists led to rash publications, in one case with ensuing acrimony that made global headlines in the world of taxonomy (Thulborn, 1986).

By far the most controversial contributions to the taxonomy of Australian venomous snakes (and indeed Australian reptiles in general) were the 1984 and 1985 monographs of Richard Wells and Ross Wellington. The Australian herpetological community reeled in shock when Wells used his capacity as Editor of the Australian Journal of Herpetology to publish "A synopsis of the class Reptilia in Australia" (Wells and Wellington, 1984). This work was quickly followed by "A classification of the Amphibia and Reptilia of Australia" (Wells and Wellington, 1985a) and "A classification of the Amphibia and Reptilia of New Zealand" (Wells and Wellington, 1985b). All three papers contained the descriptions of a plethora of new species and genera, as well as the resurrection of taxa consigned to synonymy by other workers. All in all, hundreds of new species were described or resurrected, the three papers collectively proposing changes to the nomenclature and taxonomic arrangements of virtually every frog and reptile in both countries. In the case of the elapids, Wells and Wellington's papers resurrected 37 species from synonymy, and described three new genera and 24 new species.

In most cases, Wells and Wellington provided minimal new information on the taxa they described or recognised. As a result, many of their new species descriptions do not fulfil the requirements of the International Code of Zoological Nomenclature, so that any attempt to deal with Australian herpetological nomenclature will from now on requires either a certain amount of detective work to determine which Wells and Wellington names are available, and for what species, or the pursuit of appropriate submissions for rulings by the ICZN based on arguments of taxonomic stability or universal lack of acceptance (see Iverson et al., 2001).

In the years immediately following the publication of the Wells and Wellington papers, and as a result of resolutions passed by the Australian Society of Herpetologists, a huge campaign was mounted by more than 150 Australian herpetologists led by Professor Rick Shine, Professor Gordon Grigg and others, who unsuccessfully petitioned the International Committee on Zoological Nomenclature to suppress the publications (The President, Australian Society of Herpetologists, 1987)—which would have effectively rendered their taxonomic proposals null and void. Strong arguments for the suppression of all three papers were published broadly by a total of at least 91 authors (e.g., Grigg and Shine, 1985; King and Miller, 1985; Tyler, 1985; Hutchinson, 1988; Ingram and Covacevich, 1988; Tyler, 1988), with the usual professional decorum being notable by its absence in some of the attacks upon Wells and Wellington. Other than being lambasted for having failed to submit their work for peer review, both men were attacked openly as being unqualified amateurs and were accused of having been unscientific and unethical in their methods, for instance by describing species they had never seen, designating as types specimens they had not examined, or scooping other authors in the process of describing the taxa concerned. Much was made of their apparently mischievous and frivolous approach to designating names for new taxa, and certainly names like *Vaderscincus* (in honour of Mr. Darth Vader!) do tend to give that impression. In the face of this onslaught of criticism, Wells in particular strongly defended the works to the ICZN.

This did not prevent him from withdrawing and becoming seemingly reclusive—washing his hands of herpetologists.

When asked why they chose to publish such resoundingly controversial taxonomic works in the manner that they used, Richard Wells (pers. commun.) said that they had actually hoped to stimulate genuine herpetological research in Australia by forcing researchers who in some cases had failed to publish any work for many years to actually generate output, even if only to either dismiss or ratify one of the Wells and Wellington proposals. Wells had been a collector for several Australian museums, and felt that many of the specimens he had provided had simply been ignored by qualified professionals who were comfortably polishing their chairs while producing little if anything of scientific value. In fairness, it has also turned out to be the case that many of the changes proposed by Wells and Wellington have been substantiated by later, evidence-based studies. However, this cannot be regarded as a vindication for the modus operandi of the pair: a scientific description of a new species requires first and foremost that the author provides the evidence required to demonstrate the reality of the species. Conviction is no substitute for evidence, however, correct the conclusion.

Following the precedent set by Wells and Wellington (1984, 1985a, b), another amateur taxonomist has been causing taxonomic controversy since the late 1990s. Raymond Hoser published two coffee-table books, ''Australian Reptiles and Frogs'' (Hoser, 1989) and ''Endangered Animals of Australia'' (Hoser, 1991), which were generally sound contributions. More recently, Hoser has produced numerous taxonomic papers in successively more obscure amateur publications, describing new species and genera and resurrecting synonyms. His treatments, accompanied by strident self-publicity campaigns on the internet, have included the genera *Acanthophis*, *Pseudechis*, *Oxyuranus*, *Pseudonaja* and *Tropidechis* and have led so far to the description of 12 new species, 10 new subspecies and a new genus of elapid snake (as well as a plethora of pythonid snakes). As in the case of Wells and Wellington, the level of evidence provided by Hoser to justify his taxonomic acts is minimal (Aplin, 1999; Wüster et al., 2001), some of his taxa were described on the basis of e-mails from museum staff, without Hoser ever seeing the animal (Wüster et al., 2001; Wüster, 2003), and Hoser's frequent mention of DNA sequence data to diagnose his taxa is disingenuous since no such data existed at the time of his writings. Additionally, a few of Hoser's descriptions appear to lack the diagnoses required to make them available under the provisions of the Code of Zoological Nomenclature, leaving a new legacy of taxonomic confusion. Like Wells and Wellington, in addition to the inadequate nature of the scientific evidence presented by Hoser, a number of his taxa were reported to have been described with the manifest intention of scooping other researchers working on them (Wüster et al., 2001), a form of behaviour generally regarded as ethically repugnant. The century-old words of Boulenger (1885) once again spring to mind: ''It is painful to have to record such contributions…''

4. Future prospects

Leaving aside the acrimony generated by over-zealous and often self-promoting amateur descriptions, research on Australian elapid systematics and phylogeny is buoyant in a number of laboratories. A considerable number of systematic problems remain to be resolved. In particular, a comprehensive and robustly supported phylogeny of the entire Australian elapid radiation is required to resolve the phylogeny as a whole, as well as settling the previously chaotic classification at genus level, particularly for the smaller species. Such efforts are currently under way (e.g., Scanlon and Lee, 2004). In addition, the systematics of a number of genera and species groups, in particular some of medical importance requires resolution. The genera *Acanthophis*, *Pseudonaja*, the *Pseudechis australis* group and *Notechis* all require a comprehensive revision in order to establish species limits within these complex groups. Again, this is in progress in a number of research groups (e.g., Keogh et al., 2005; Kuch et al., 2005; Wüster et al., 2005). Undoubtedly, revisions of some of the smaller elapids will also reveal hitherto unsuspected diversity, and the discovery of additional new species is likely in many of these genera.

5. Australian elapid systematics and the toxinologist

The systematics of any group of organisms is the absolute cornerstone on which all further work has to be based. It is virtually impossible to carry out any meaningful biological work on any organism if the identity of said organism has not been

adequately established, and sufficient information to allow reidentification in the case of future changes provided. The most important taxonomic level where problems are common are at the species level, where multiple species may be very similar, and where taxonomic changes can most easily cause confusion later on. In the case of the Australian elapid snakes, there are known taxonomic problems in a number of medically important taxa, which may be of importance for toxinological work.

The history of interaction between toxinology and taxonomy is not a happy one. Toxinologists often pay little attention to matters taxonomical, and any browse through even the latest issues of leading toxinological journals will quickly reveal names that are misspelled, grossly out of date or entirely contrived. Surveys of the toxinological literature (e.g., Wüster and McCarthy, 1996) have revealed that, in some cases, up to 75% of experimental venoms could not reliably be assigned to any given species, a deplorable state of affairs that simply would not be tolerated with any other laboratory chemical or reagent, or any natural product in just about any other field of research. Given the ubiquity of variation in venom composition (Chippaux et al., 1991), this is likely to result in a number of potential problems, ranging from difficulty in reproducing research results, such as the isolation of a given toxin of interest, to the ineffectiveness of antivenoms (Fry et al., 2003).

These problems, and the historical taxonomic instability of the nomenclature of the Australian elapids, affect toxinologists in a variety of ways. Most importantly, the fact that some currently recognised, widespread species may in fact represent composites of multiple, previously unrecognised species places on the toxinologist the burden of ensuring that the source taxon of any venoms or taxon should be identifiable even if the species it came from is later found to be a composite. This requires at the very least information on the geographical provenance of the specimens, and preferably, voucher specimens deposited in museums. For instance, the *Acanthophis* populations form northern Queensland and the "Top End" were until now regarded as populations of *Acanthophis praelongus* (e.g., Storr, 1981a, b; Cogger, 2000; Wilson and Swan, 2003). However, recent genetic studies have shown that the northern Queensland populations (*A. raelongus* sensu stricto) are quite distinct from those of the Northern Territory, and that two species are likely to be present in the latter region (the *Acanthophis rugosus* complex and *Acanthophis hawkei*, which may be a valid species) (Wüster et al., 2005). Venom simply labelled as "*A. raelongus*", without locality information, would thus be to all intents and purposes unidentifiable. On the other hand, venom labelled "*A. raelongus* from Cairns" would be confidently assignable to *A. praelongus*. On the other hand, venom labelled "*A. raelongus*—northern Northern Territory could not be assigned to either of the two species found there without reference to a voucher specimen, illustrating the importance of connecting toxinological information with actual physical specimens of snake.

Compared with the difficulties of determining species limits, the problems caused by an unstable generic nomenclature are relatively minor. Whether a toxin is labelled "*E. atriceps*" or "*P. atriceps*" is not particularly relevant from the point of view of allowing replication of an experiment or isolation of a specific toxin. Nevertheless, it may affect the ease of information retrieval and thus lead to bibliographic omissions, especially since toxinologists tend to be unaware of the often-convoluted nomenclatural history of many taxa.

Thus, as has been noted elsewhere (Dixon (1993); Golay et al., 1993; Wüster and McCarthy, 1996; Wüster et al., 1997), the medical importance of venomous snakes requires a sense of responsibility both on the part of taxonomists and toxinologists.

From the taxonomic point of view, there is absolutely no place in elapid taxonomy for unprofessional, unreviewed and mischievous attempts to name new taxa, or to attempt the systematic rearrangement of existing classifications without presenting adequate evidence. Moreover, taxonomists should strive to publish studies relating to venomous snake systematics in widely abstracted and available journals, not in obscure institutional publications, and ensure that their presence receives sufficient publicity. The editors of amateur publications should be aware of the problems that can be caused by unreviewed taxonomic publications, and should take their responsibilities seriously and politely decline to publish them. Amateur magazines exist for an entirely worthy purpose, but a purpose that is different from that of professional journals. Confounding the two is of no benefit to anyone.

Toxinologists need to be aware of the importance of a sound taxonomic framework for their work. They need to have a working understanding of the taxonomy of the snakes they are working with, and

they need to keep abreast of developments in the taxonomy of these animals, which is in a constant state of flux as new methods and data become available. Most importantly, toxinologists need to provide adequate information on the sources of their venoms in their publications in order to guarantee the replicability and usefulness of their work, and as explained above, of particular importance is the locality of origin of the snakes providing any given experimental venom. Even if the taxonomy of a group of snakes is in a state of flux due to ongoing research work or controversy, information on locality of origin can often allow reliable identification once the systematics of the group has been resolved. Toxinologists should strive to work only with venoms sourced from specimens whose collection localities are well known and this means using reliable suppliers, requesting this information, and reporting it in future publications. Purchases from suppliers unable to provide locality information, or worse even providing erroneous taxonomic information (such as Sigma-Aldrich's entirely inaccurate "*Pseudechis colletti guttatus*" venom—product number V0876), should be avoided. Similarly, editors and reviewers of toxinological papers must insist that locality information is provided in all papers, something that remains to be achieved even in leading toxinological journals today.

Similarly, toxinologists should be wary of using the taxonomies of "amateur" taxonomists published in unreviewed hobbyist magazines. While the conclusions presented in such papers may be correct (the example of Eric Worrell demonstrates how non-institutional taxonomists can make tremendous contributions), this is difficult to ascertain, especially because some individuals deliberately eschew peer-reviewed journals to publish less than adequate descriptions or revisions. As a general rule, if a taxonomic revision or description was not published in a reputable peer-reviewed Journal, then toxinologists should seek professional taxonomic advice before relying upon it.

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