Taking Darwin into the 21st century

"There is grandeur in this view of life ... from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved." Charles Darwin, *On the Origin of Species.*

Charles Darwin's five-year round-the-world natural history explorations on HMS *Beagle* revealed to the world the complex web of interdependence that continues to shape life on earth.

In classifying the hundreds of specimens of plants and animals he collected and the diverse forms he encountered in far-flung places, the young scientist speculated about their common ancestry and about the minute and ingenious adaptations that, over millions of years, allowed one variety to survive while another disappeared. As he charted the rise and fall of oceans, the warming and cooling of continents, he was also able to document climate change as a driver of evolution and mass extinction. And he was astonished at the ingenuity of the survival strategies – insects resembling twigs, beetles flaunting the colours of poisonous fruit as a protection against predatory birds, a moth with the appearance of a scorpion and another with wings decorated with luminous false eyes.

Two hundred years after his birth and 150 years since the publication of *On the Origin of Species*, the

science Darwin pioneered is being advanced by another generation of scientists, and evolutionary biology has become a key area of research at universities around the world.

Today scientists at UWA's Centre for Evolutionary Biology continue to study the means by which species win an advantage – exploiting reproductive strategies, filling an ecological niche, vanquishing a competitor for space or food, or forming a cooperative alliance that strengthens the odds of survival.

Darwin would be delighted to know that evolutionary biology has become one of the 'sexiest' disciplines in contemporary universities and that it remains an area of study still capable of stirring dissent and controversy.

UWA's Centre for Evolutionary Biology brings together expertise in population, evolutionary and molecular genetics. It adopts a multidisciplinary approach in exploring selective processes in a range of creatures, from rainbow fish and dung beetles, to honey bees and frogs. Not surprisingly, its research outcomes feed into many areas, including conservation, biodiversity and natural resource management.

Most importantly, this work takes Darwin's theories into a century in which understanding how species adapt and cope with change will be a major challenge.

The UWA centre came into being in 2004, when evolutionary biologist Professor Leigh Simmons was awarded a Federation Fellowship – something of a dream-come-true for Australia's leading university researchers, for not only does their expertise get wide exposure and acknowledgement, but they receive funding to advance and broaden their area of research. The funding is significant: \$250,000 a year over a five-year period, with matching funding from their own university. When Professor Simmons became a Federation Fellow in 2004, he was able to establish the Centre of Evolutionary Biology at UWA and the State Government came to the party by acknowledging his research hub as a Centre of Excellence, an accolade bringing further funding.

The money has clearly been well spent, for the centre rapidly attracted high calibre postdoctoral and postgraduate researchers whose academic papers are regularly published in key journals such as *Nature, Science, Evolution* and the *Proceedings* of the Royal Society of London.

"When you get this sort of funding, you can actively seek people at the top of their field," says Professor Simmons, a recently-elected Fellow of the Australian Academy of Science. Attendance at international conferences and membership of key editorial boards allows him to spot top performers and, as Darwin confirmed, success breeds success. The UWA centre is now held in such high regard internationally, that it has attracted researchers from Spain, Switzerland, Sweden, Finland, the United Kingdom, the United States and Brazil including some who arrive with funding from their own governments (see *Darwin's 'dream pond'*).

Swiss evolutionary biologist Dr Boris Baer, whose research could help Australian beekeepers avoid the problems plaguing hives in the United States and Europe, chose Western Australia to advance his research because of its clean green environment, healthy bees and UWA's winning combination of expertise and high-tech equipment.

He says that UWA was attractive because he can collaborate with both biochemists in the ARC Centre of Excellence in Plant Energy Biology and evolutionary biologists in the Centre for Evolutionary Biology.

"It is the only place on the globe that I have found this combination of technical equipment in the form of mass spectrometry and expertise," he points out (see *The secret life of bees*).

Leigh Simmons is pursuing research in an area of study that began to emerge a century after the first edition of *On the Origin of Species* was published – and sold out in a day!

"Darwin devoted a whole section of his book to sexual selection, but he explored the subject from the natural selection perspective whereby favoured traits enable organisms to survive stresses such as lack of food or a changing environment," explains Professor Simmons.

"Sexual selection has now emerged as a distinct area of study in that it explores reproductive traits that maximise a male's success in fathering offspring. These traits range from high quality sperm to features that might initially appear to be counter-productive: bright plumage that attracts both predators and females, or antlers that are costly to produce but allow the male to become dominant and to mate with many females. When such characteristics prove attractive to females they become part of the selection process."

Professor Simmons says that for a long time the notion of sexual selection and female choice was rejected.

"Darwin was asking people to accept that they had a common lineage with animals and when he later went on to suggest that female choice played a part in the selection process, initially it was just too much to accept for many people! However, it was not until the 1980s that the area of research I am exploring – sperm competition and cryptic female choice – became widely accepted."

As a postdoctoral researcher, Professor Simmons worked with the University of Liverpool's Professor Geoff Parker who pioneered sperm competition research in the 1970s. This explored the female strategy of multiple mating to ensure that her eggs would be fertilised by sperm with the highest genetic quality.

"The research coming out of the University of Liverpool laid the foundations for a whole new area of study, and we continue to collaborate with their researchers," recalls Professor Simmons. "It took some time for scientists to accept this research, but that is the way new theories are tested and refined. Publishing new work in learned journals may be just the beginning of a long scientific debate, as others replicate your experiment to see whether it is flawed, or repeat it, perhaps with a different species, drawing their own conclusions and seeking general trends across different taxa."

In evolutionary terms, sperm competition results in improved male fertility. Professor Simmons says producing sperm is a costly investment for males and in a league table of primate promiscuity the bonobo chimpanzee ranks as the most promiscuous and the most fertile. The monogamous gorilla is at the other end of the scale.

Researchers in Professor Simmons' team are currently studying seminal fluid – the rich soup of proteins that nourishes sperm – to understand the components that influence sperm mobility, a key factor in fertility in all animals. Endangered species are often plagued by reductions in fertility, and recent studies link impaired sperm quality brought on by inbreeding.

One of the Centre's researchers, Australian Research Council QEII Research Fellow Dr Jonathan Evans, is currently doing research on inbred species. Findings suggest they have more sperm abnormalities and few mobile sperm and that inbreeding can severely reduce male reproductive fitness.

Centre scientists have also recorded declines in the production and quality of sperm when multiple mating species such as mice and beetles are forced to become monogamous under laboratory breeding regimes.



UNDERSTANDING OUR PLACE IN THE NATURAL WORLD WILL BE CRUCIAL TO OUR SURVIVAL

"To a certain extent, what you learn from studying animals can be useful when studying humans," observes Professor Simmons. "I personally think it is very important that people view themselves as just another of our planet's animals.

"I believe we won't seriously tackle issues like global warming unless we appreciate we are just as vulnerable to climate change as the countless species that, in the past, were wiped out by dramatic environmental change.

"Darwin certainly appreciated that climate change was a driver of evolution and one of the agents of mass extinction. Understanding ourselves and our place in the natural world will be crucial to our survival."

>>CONTACT

Professor Leigh Simmons, ARC Federation Fellow, School of Animal Biology Phone: +61 8 6488 2221 Email: Isimmons@cyllene.uwa.edu.au

Previous page: O. rangifer This page (top): Professor Leigh Simmons (inset): Sunset frogs

The secret life of bees

"Darwin is a huge source of inspiration because he provided the basis for my research," says UWA researcher Dr Boris Baer, an evolutionary biologist exploring the complex world of social insects such as bees.

Evolutionary biologists and socio-biologists have long been fascinated by social insects such as bees and ants.

In the rainforests of Brazil, Charles Darwin observed the spectacle of a 90 metre-column of almost sightless army ants functioning as a single super-organism. The approach of the column sent lizards and spiders scurrying for safety, but the ants often succeeded in cutting off escape, encircling and attacking. Within minutes there was no trace of the victim and the column moved on.

Later Darwin wrote of this effective joint strategy, observing that in the case of ants, natural selection has been applied "to the family and not to the individual for the sake of gaining a serviceable end".

UWA's Boris Baer, a QEII Fellow who came to this University from Denmark, shares Darwin's fascination with the highly successful collegiate existence of bees and ants.

"Social insects have a long success story, far longer than our own," he explains. "In some ways they mirror our civilisations in that they fight wars, police their societies, create sophisticated dwellings, store and grow things, and have very strict rules within their societies. But of course you wouldn't want to live with them because social insects have basically eradicated any form of individualism."

The Atta leafcutter ants of Central and South America are one of the model systems that Boris Baer studies. Living in colonies of up to eight million, they are probably the world's oldest farmers, growing a fungus in large subterranean nests.



The ants feed the fungus with plant material and the fungus provides food for the colony. To run such a complex endeavour, leaf cutter ants have evolved a sophisticated division of labour. The largest ants have powerful jaws to cut leaves and defend the colony, others carry leaves to the nest, while the smallest work in the fungus gardens.

Dr Baer's research also focuses on another social insect that has been around since dinosaurs walked the Earth: honey bees. Countless livelihoods across the globe depend on functioning, healthy colonies of honey bees that build wild hives, pollinate crops, sustain commercial hives – and reward backyard beekeepers.

Derived from the nectar of plants, the 'liquid gold' produced by honey bees is harvested, transformed and stored. It matures into a blend of sugars, protein, enzymes, amino acids and minerals. A Federal Government parliamentary committee looking into increasing biosecurity measures and research to protect the local industry has estimated that honey bees contribute to some \$6 billion worth of agricultural production. The Australian Honey Bee Industry Council believes that "one-third of everything we eat is directly related to the humble honey bee."

Dr Baer's research focuses on the complex interactions between competing ejaculates at work in bees. It aims to advance our understanding of the mechanisms of fertilisation because bee breeding and production of resistant honey bees is essential to compensate for the alarming decline in hives that is happening in the United States and Europe.

"More than two million hives have been lost in the US in the last 18 months, partly caused by a newly emerging threat termed colony collapse disorder (CCD) where bees leave the hive and don't return, abandoning the queen," explains the UWA researcher. "In the US, the decline is now viewed as seriously as global warming, because honey bees pollinate more than 80 crops of economic interest."

Scientists speculate that Australian honey bees have been spared such declines because of our geographic isolation and strict quarantine regulations.

Western Australia still has large populations of non-managed feral bees that provide a large part of bee pollination in our gardens. In contrast, the US agricultural industry is now almost entirely dependent on commercial hives trucked across the country to pollinate crops and orchards. This practice causes further declines as bees become stressed and diseases are spread over long distances. In China, where intensive pesticide use has reduced populations, some crops now need pollination by hand, using brushes.

Dr Baer completed his PhD at the Swiss Federal Institute for Technology in Zurich, followed by postdoctoral research at the Centre for Social Evolution in Copenhagen. He moved to Western Australia for several reasons including his belief that this State is one of the very few locations left on the planet with a large and healthy bee population.

"The mysterious CCD and a serious hive pest known as the varroa mite haven't yet made it to Australia and this gives us a great advantage – but it's probably only a matter of time before we will get hit. What is clear is that Australian hives are highly vulnerable," emphasises Dr Baer. "Indeed, another serious honey bee pest species, the small hive beetle was accidently imported to Australia during the Olympic Games in Sydney and has started its spread throughout Australia. An incursion into Western Australia occurred recently but we hope it has been eradicated."

To tackle the worldwide decline in wild and managed populations caused by parasites and pathogens, several UWA researchers have formed the Collaborative Initiative for Bee Research (CIBER, see www.ciber.science.uwa.edu.au). This initiative facilitates interdisciplinary research alongside industry partners. It combines expertise from beekeepers with decades of experience, sociobiologists with insights into the functioning of bee societies, molecular biologists exploring the honey bee genome and evolutionary biologists.

The UWA researcher is impressed that local beekeepers decided many years ago not to use chemicals to treat diseases because ultimately they weaken the bee and strengthen the parasites that become resistant. The alternative is to breed bees that are able to cope with diseases, which is one of CIBER's aims.

Given his research interests, Dr Baer says that UWA is the obvious place to advance his research because he can collaborate with both biochemists in the ARC Centre of Excellence in Plant Energy Biology and evolutionary biologists in the Centre for Evolutionary Biology.

Dr Baer's research team is studying the molecular make-up of bee semen using mass spectrometry which, among other things, allows researchers to identify biomarkers for diseases and to learn about the proteins that boost immunity.

"We still have a lot to learn about what happens when the virgin honey bee queen embarks on her one and only mating flight that typically spans less than an hour," says Dr Baer. "The queen can





SOCIAL INSECTS HAVE A LONG SUCCESS STORY, FAR LONGER THAN OUR OWN

be accompanied by 10,000 or more males but as copulations happen 30 metres above the ground, they are tricky to observe and our knowledge is therefore still limited. We know that, post-copulation, a sperm battle takes place within the queen's body. From the initially acquired 600 million sperm, she retains not even five per cent to fertilise the 1.7 million eggs throughout the rest of her life."

Dr Baer uses sophisticated techniques to analyse sperm and gland secretions that both males and females add to the ejaculate. His team hopes to identify proteins instrumental in boosting the assets of sperm selected for storage.

"While we know quite a bit about the processes during the crucial period when sperm battles sperm and when seminal fluid mingles with the queen's spermathecal fluid, we now need to pinpoint the molecular details of how evolution works on a biochemical proteomic scale," says Dr Baer. "That remains a big but extremely exciting challenge."

>>CONTACT

Dr Boris Baer, QEII Fellow, ARC Centre of Excellence in Plant Energy Biology Phone: +61 8 6488 4495 Email: bcbaer@cyllene.uwa.edu.au

Above: Atta leafcutter ants Inset: A bee colony