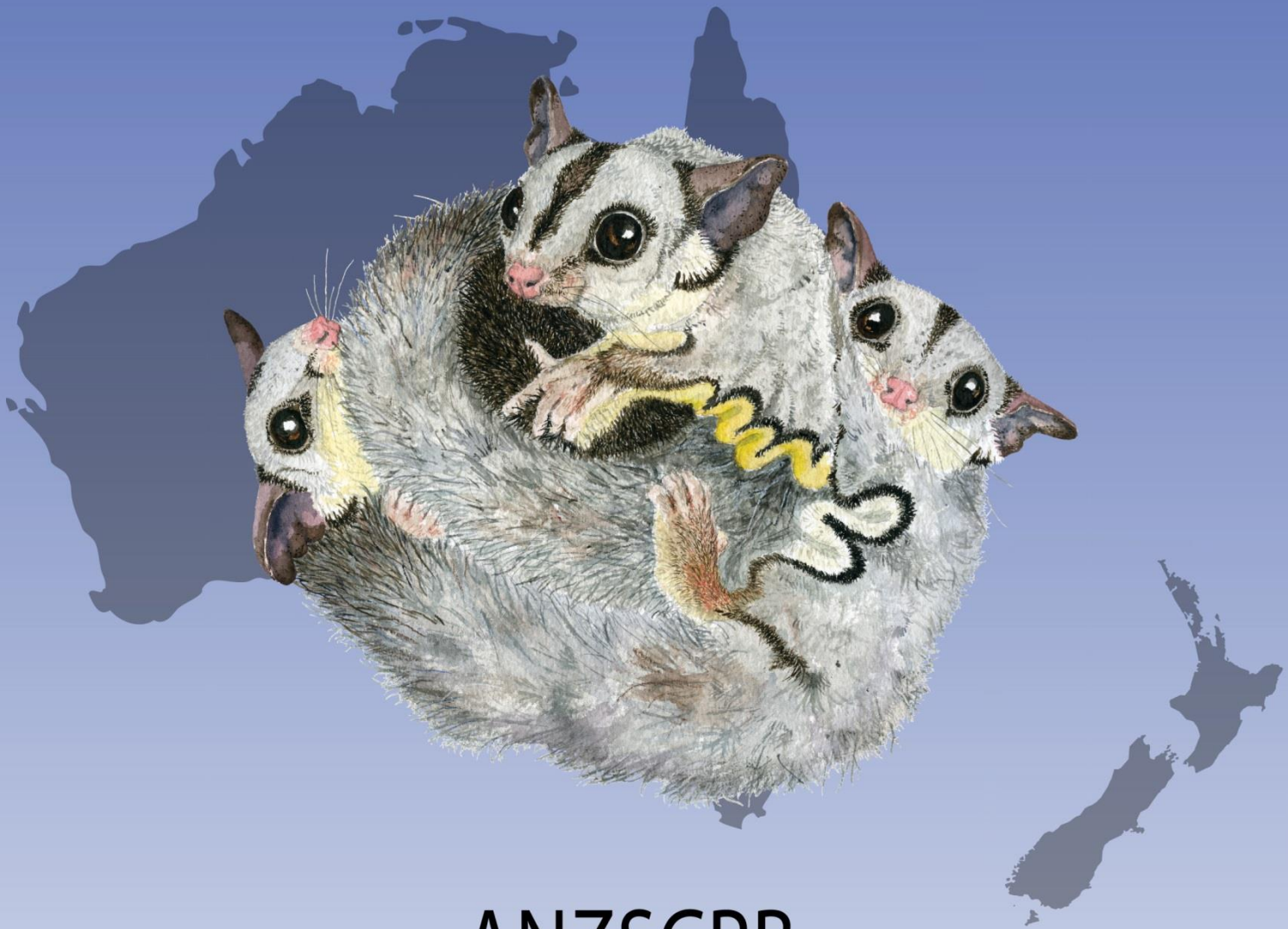
Australian and New Zealand Society for Comparative Physiology and Biochemistry 31st Annual Meeting



ANZSCPB

University of New England, Armidale

4 - 7 December 2014

PROGRAM and ABSTRACTS

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We would also like to thank Mariana Campbell, Bronwyn McAllan, Kodie Noy, Julie Roberts and Amanda Watson for their help with the meeting

The abstract book was prepared by Clare Stawski

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Abstract book cover, T-shirt and mug by Gerhard Körtner

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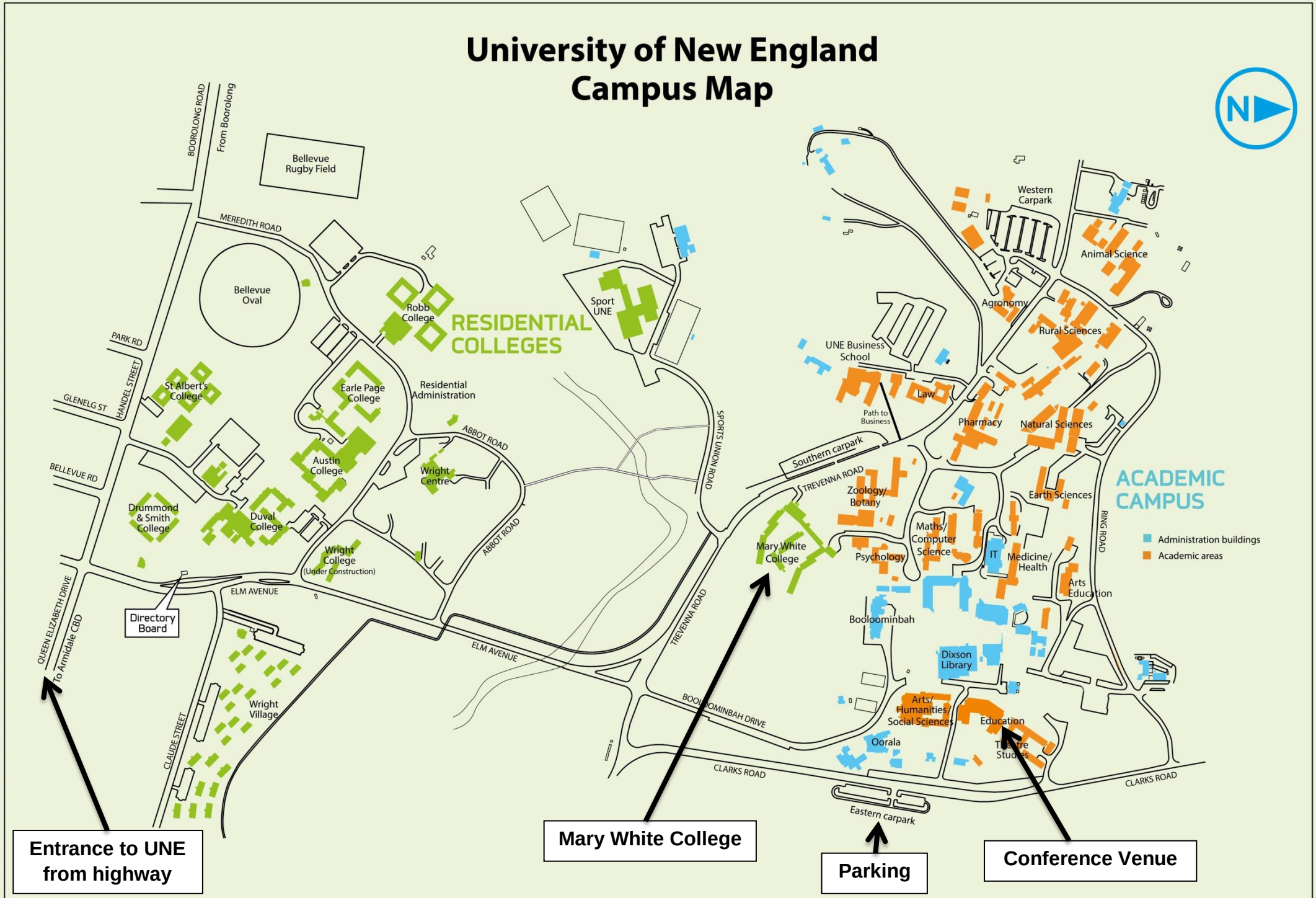
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Campus Map
N
BOOROLONG ROAD
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Southern carpark
TREVENNA ROAD
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ACADEMIC CAMPUS
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Mary White College
Psychology
IT
Medicine/ Health
RING ROAD
Arts Education
Booloominbah
Dixson Library
BOOLOOMINBAH DRIVE
Arts/ Humanities/ Social Sciences
Education
Oorala
Theatre Studies
CLARKS ROAD
Eastern carpark
Entrance to UNE from highway
Mary White College
Parking
Conference Venue

Program Overview

Time	Thursday 4 December	Time	Friday 5 December	Time	Saturday 6 December	Time	Sunday 7 December
		8:45-9:00	Announcements	8:45-9:00	Announcements	8:45-9:00	Announcements
		9:00-10:00	Plenary lecture	9:00-10:00	Plenary lecture	9:00-10:00	Plenary lecture
		10:00-10:30	Presentations	10:00-10:30	Presentations	10:00-10:30	Presentations
		10:30-11:00	Morning tea	10:30-11:00	Morning tea	10:30-11:00	Morning tea
		11:00-12:30	Presentations	11:00-12:30	Presentations	11:00-12:30	Presentations
		12:30-13:30	Lunch	12:30-13:30	Lunch	12:30-13:30	Lunch
		13:30-15:00	Presentations	13:30-15:00	Presentations	13:30-	Workshop
15:00-20:00	Registration	15:00-15:30	Afternoon tea	15:00-15:30	Afternoon tea		
		15:30-17:30	Speed session and AGM	15:30-17:30	Presentations		
17:00-20:00	Welcome drinks and finger food	18:00-22:30	Conference dinner at Booloominbah	18:00-22:30	Pizza dinner at Dumaresq Dam		

Conference Program

Thursday 4 December

15:00	Registration open – Education Building
17:00	Welcome drinks and finger food – Education Building

All lectures in the Education Building, room 111

Friday 5 December

*** indicates PhD students and ^ indicates honours students eligible for prizes**

Chair: Michael B. Thompson	
8:45	**General announcements**
9:00	**Plenary lecture: John Lighton** Metabolic measurement: new challenges, new horizons
10:00	**Craig R. White** Is metabolic rate related to fitness?
10:15	R. J. Mason, P. W. Bateman and **C. E. Cooper** Is there a locomotory cost of limb autotomy for house crickets, and can they compensate?
10:30	**Morning tea**
Chair: Lesley A. Alton	
11:00	**Roger S. Seymour**, Karl K. Jones and Stefan K. Hetz Function of the incompressible gas gill of the aquatic insect *Aphelocheirus aestivalis*
11:15	**Karl K. Jones^**, Roger S. Seymour, Edward P. Snelling and Amy P. Watson Gas exchange in the backswimmer, *Anisops deanei*
11:30	**Francesca van den Berg***, Michael B. Thompson and Dieter Hochuli To eat or overheat: linking behaviour and habitat use during a summer heatwave, to thermal tolerances in an orb-web spider
11:45	**Essie M. Rodgers***, Rebecca L. Cramp, Matthew Gordos, Anna Weier, Sarah Fairfall, Marcus Riches and Craig E. Franklin Facilitating upstream passage of small-bodied fishes: linking the thermal dependence of swimming ability to culvert design
12:00	**Sarah J. Andrewartha**, Nick G. Elliott and Peter B. Frappell Identifying hypoxia tolerant salmon families

12:15	**Leonardo Guida***, Terence I. Walker and Richard D. Reina The adenylate energy charge as a novel biomarker of capture stress in chondrichthyans
12:30	**Lunch**
Chair: Camilla M. Whittington	
13:30	**Rebecca L. Cramp**, Stefanie Reid, Frank Seebacher and Craig E. Franklin Synergistic interaction between UVB and temperature increases susceptibility to parasitic infection in a fish
13:45	**Lesley A. Alton**, Manuel Hernando Bernal, Toby Mitchell, Vincent O. van Uitregt, Rebecca L. Cramp, Craig R. White, Robbie S. Wilson and Craig E. Franklin Understanding the causes of global amphibian declines: a lesson in complex interactions between multiple environmental stressors
14:00	**Emma Ceccato^**, Rebecca Cramp, Michel Ohmer and Craig E. Franklin Carry-over effects of early larval UV-B exposure: implications for immune function in *Limnodynastes peronii* metamorphs
14:15	**Hugh S. Winwood-Smith***, Lesley A. Alton, Craig E. Franklin and Craig R. White Does greater thermal plasticity facilitate range expansion of an invasive terrestrial anuran into higher latitudes?
14:30	**Tim S. Jessop** At world's end: evidence for how glucocorticoid stress hormone mediated trade-offs influences vertebrate range margins
14:45	**Elizabeth L. Sim***, David T. Booth and Colin J. Limpus Non-modal scute patterns, morphology, and locomotor performance of loggerhead (*Caretta caretta*) and flatback (*Natator depressus*) turtle hatchlings
15:00	**Afternoon tea**
Speed Session Chair: Tim S. Jessop	
15:30	**Pieter Arnold*** and Craig R. White Physiology, behaviour and movement: trait correlations and dynamics during the life of adult red flour beetles, *Tribolium castaneum*

15:35	**Julian Beaman*** and Craig R. White Relative humidity and food availability during juvenile development determine growth rate and metabolic rate in the cockroach *Nauphoeta cinerea* (Blaberidae)
15:40	**Alyssa Bowden***, Ben Maynard, Sarah Andrewartha, Andrea Morash, Nick Elliott and Peter B. Frappell Do Atlantic salmon and brown trout hybrids have superior metabolic physiology and swimming performance?
15:45	**Taryn S. Crispin*** and Craig R. White Metabolic rate and water loss rate show a positive phenotypic association in *Drosophila serrata*, but are not correlated with desiccation resistance along a latitudinal gradient
15:50	**Anna Doty**, Clare Stawski, Gerhard Körtner and Fritz Geiser It's black and white: why microbats prefer warmer roosts
15:55	**Ursula Ellenberg** ANZ conservation physiology: understanding and managing human-wildlife interaction
16:00	**Behnaz Ghaedi*** and Nigel R. Andrew Can aphids take the heat: again…and again... and again... and again?
16:05	**Michael R. Kearney** and John Deutscher Diverse diapause and quiescence strategies in closely related arid zone grasshoppers
16:10	**Pippa Kern***, Rebecca L. Cramp, Frank Seebacher and Craig E. Franklin Temperature does not affect oxidative damage from UV-B radiation in *Limnodynastes peronii* tadpoles
16:15	**Essie M. Rodgers***, Frank Seebacher and Craig E. Franklin Physiological resilience: how will diving ectotherms fare in warmer environments?
16:20	**Eleanor Stalenberg***, Jörg Ganzhorn, Andrew Krockenberger, Michael Hutchinson and William J. Foley Climate change and the energetics of a nocturnal lemur in Southern Madagascar

16:25	**Lisa Stojanovski^** and Christopher Turbill Energetic consequences of antipredator behaviour in house mice
16:30	**James U. Van Dyke**, Laura A. Lindsay, Christopher R. Murphy and Michael B. Thompson Placental carbonic anhydrase II is a multirole waste disposal mechanism in a viviparous lizard
16:35	**Camilla M. Whittington**, Oliver W. Griffith and Anthony B. Wilson Signals of parturition in male pregnant seahorses
16:40	**Andrew T. Wood***, Sarah J. Andrewartha, Andrea J. Morash, Nick G. Elliott and Peter B. Frappell The effect of oxygen concentration on the developmental physiology of Atlantic salmon (*Salmo salar*)
16:45	**Annual General Meeting**
18:00	**Conference dinner at Booloominbah**

Saturday 6 December

*** indicates PhD students and ^ indicates honours students eligible for prizes**

Chair: Philip C. Withers	
8:45	**General announcements**
9:00	**Plenary lecture: Walter Arnold** Seasonal acclimatization: from the whole organism to fatty acid composition of membranes
10:00	**Vincent Careau**, Mylene M. Mariette, Katherine L. Buchanan and William A. Buttemer Correlational selection acting on repeatable physiological and behavioural traits
10:15	**Peter Derbyshire*** Cardiac innervation of the reptile *Ctenophorus ornatus*
10:30	**Morning tea**
Chair: Terence J. Dawson	
11:00	**Gordon Grigg** Long submergences by crocodylians and their physiological support: a working hypothesis
11:15	**Sean A. Williamson***, Roger G. Evans, Charlie S. Manolis, Grahame J. Webb and Richard D. Reina The need to breathe: experimental evidence that crocodilian eggs lack the ability to arrest embryonic development
11:30	Philipp Comanns, **Philip C. Withers**, Falk J. Esser and Werner Baumgartner Cutaneous water collection by a moisture-harvesting lizard, the thorny devil (*Moloch horridus*)
11:45	**Tegan K. Douglas***, Christine E. Cooper, Philip C. Withers and Stephen J. J. F. Davies Babbler it's cold outside: the energetic benefit of communal roosting in white-browed babblers

12:00	**Matthew J. Noakes***, Blair O. Wolf and Andrew E. McKechnie Seasonal and geographical variation in heat tolerance and evaporative cooling capacity in a southern African passerine bird
12:15	**Ryan S. O'Connor***, Blair O. Wolf and Andrew E. McKechnie Evaporative cooling capacity in two southern African caprimulgid birds, the rufous-cheeked nightjar (*Caprimulgus rufigena*) and freckled nightjar (*Caprimulgus tristigma*)
12:30	**Lunch**
Chair: Christine E. Cooper	
13:30	**B. O. Wolf,** A. E. McKechnie, T. J. McWhorter, A. R. Gerson, E. K. Smith, W. A. Talbot, B. Smit, M. Whitfield and J. J. O'Neil Sensitivity to heat stress varies widely across avian orders
13:45	**Andrew E. McKechnie**, Matthew J. Noakes, Tanja van de Ven and Ingrid A. Minnaar Summit metabolism in birds and bats: new insights from Afrotropical taxa
14:00	**Justine M. Barker***, Christine E. Cooper, Philip C. Withers and Stewart C. Nicol Plasticity in short-beaked echidnas (*Tachyglossus aculeatus*)
14:15	**Terence J. Dawson** An overview of kangaroo locomotion: energetics and thermoregulation
14:30	**Edward P. Snelling**, David A. Taggart, Shane K. Maloney, Anthony P. Farrell and Roger S. Seymour Biphasic allometry of cardiac growth in the developing kangaroo *Macropus fuliginosus*
14:45	**Koa N. Webster** and Kerryn Parry-Jones Faecal glucocorticoid monitoring of flying-foxes: observations of colony-level disturbance in Sydney, Australia
15:00	**Afternoon tea**

Chair: Craig R. White	
15:30	**Jessica S. Dudley***, Bronwyn M. McAllan, Michael B. Thompson and Christopher Murphy Changes to the uterine epithelial cells during pregnancy among mammals with endotheliochorial placentation
15:45	**Melanie K. Laird***, Michaela Turancova, Bronwyn M. McAllan, Christopher R. Murphy and Michael B. Thompson Uterine focal adhesion dynamics during pregnancy in a marsupial (*Sminthopsis crassicaudata*; Dasyuridae)
16:00	**Camilla M. Whittington**, Georges Grau, Christopher R. Murphy and Michael B. Thompson Angiogenic genes in the skink uterus and the evolution of live birth
16:15	**Kevin Hendrawan^**, Camilla Whittington, Matthew Brandley and Michael B. Thompson Inflammatory gene expression in the uterus of a live-bearing lizard
16:30	**Lisa Bromfield***, Paul Rymer, Peter Biro and Christopher Turbill Individual strategies to cope with environmental change: a test of the pace-of-life syndrome hypothesis
16:45	**Elle McDonald^**, Paul Rymer and Christopher Turbill Telomere dynamics as an index of oxidative damage in mice
17:00	**Robert A. Hart*** and Jim McFarlane Leptin in the gut of male mice
17:15	**Christine Morton***, Geoff Hinch and Alison Small Utilisation of distress vocalisation to assess neonate viability
18:00	**Pizza dinner at Dumaresq Dam – bus provided (weather permitting)**

Sunday 7 December

*** indicates PhD students and ^ indicates honours students eligible for prizes**

Chair: Roger S. Seymour	
8:45	**General announcements**
9:00	**Plenary lecture: Keith Christian** Behavioural physiology: measurement and evaluation of thermoregulation & hydroregulation
10:00	**Christopher Turbill** and Samantha Prior A thermal gradient in annual survival rate among populations of hibernating rodents: lower survival in warmer climates
10:15	**Julia Nowack** and Kathrin H. Dausmann Can heterothermy facilitate the colonization of new habitats?
10:30	**Morning tea**
Chair: Andrew E. McKechnie	
11:00	**Artiom Bondarenco**, Gerhard Körtner and Fritz Geiser Seasonality of torpor and extreme heat tolerance in desert bats
11:15	**Clare Stawski**, Gerhard Körtner, Julia Nowack and Fritz Geiser Is torpor an important post-fire survival strategy for small marsupials?
11:30	**Gerhard Körtner**, Alexander Riek, Chris Pavey and Fritz Geiser Torpor and activity patterns in two carnivorous marsupials in central Australia in relation to precipitation and reproduction
11:45	**A. Daniella Rojas**, Gerhard Körtner and Fritz Geiser A laboratory-field comparison of a small marsupial: differences in morphology, activity patterns and thermal biology
12:00	**Shannon E. Currie**, Kodie Noy and Fritz Geiser Passive rewarming reduces cardiac demands and energy expenditure in bats
12:15	**Chris B. Wacker** and Fritz Geiser The development of thermoregulation and torpor in the fat-tailed dunnart

12:20	**Presentation of prizes and close**
12:30	**Lunch**
13:30	**Workshop:** Michael R. Kearney Introducing mechanistic models of microclimates and animal heat budgets

Abstracts
Plenary Lectures (A-Z)

Seasonal acclimatization: from the whole organism to fatty acid composition of membranes

Walter Arnold

Research Institute of Wildlife Ecology, University of Veterinary Medicine, Vienna, Austria

Mammals and birds living in seasonal environments face during winter a two-fold challenge: the energetic cost of maintaining a high body temperature is higher at lower ambient temperatures while food availability and quality is poor. Hibernators and daily heterotherms cope with these challenges by switching to fat reserves as the major metabolic fuel, reducing foraging activity, size of organs, and, most importantly, by abandoning maintenance of a high body temperature. We found similar reactions in several non-hibernating large mammals, except that temperature changes were only substantial in peripheral body parts. Nevertheless, metabolic rate, approximated by continuous measurement of heart rate, is in these species during winter also remarkably reduced, to about half of the summer level. On top of seasonal variation, energy expenditure is influenced by food availability. Experimental food restriction results in a further decrease of heart rate and core body temperature. The reduction of body temperature is in hibernators preceded by incorporation of essential polyunsaturated fatty acids (PUFA) into phospholipids (PL). Upon termination of hibernation, these PUFA are cleared again from PL. First results from red deer suggest that similar remodeling of membranes also occurs in species undergoing only minor seasonal changes of core body temperature. A change of the PL environment apparently can compensate temperature (Arrhenius) effects on membrane-bound enzymes, but with specific roles for different PUFA. For instance, activity of the sarcoplasmic reticulum Ca^{++}-ATPase (SERCA) is increased in membranes rich in omega-6 linoleic acid (LA), a mechanism presumably pivotal during hibernation by ensuring proper Ca^{++} handling in cardiac myocytes at body temperatures close to the freezing point. Comparing non-hibernating mammals, we identified a positive relation between LA and the maximum running speed of a species, presumably due to the very same mechanism, i.e. improved contractibility of muscle cells with higher activity of SERCA. In contrast to LA, PL-omega-3 docosahexaenoic acid seems to improve ATP production but has detrimental effects on SERCA, as does LA-derived arachidonic acid in PL. I conclude that seasonal acclimatization, in particular hypometabolism and voluntary hypothermia seem to be ubiquitous among endotherms, as is associated membrane remodelling. Specific effects of PUFA in PL suggest trade-offs determining a state-dependent optimization of the fatty acid composition of membranes.

Behavioural physiology: measurement and evaluation of thermoregulation & hydroregulation

Keith Christian

Research Institute for the Environment & Livelihoods, Charles Darwin University, Darwin, NT

Thermal and hydric states of animals in their natural environments are important physiological parameters in their own right, and they also underpin other physiological parameters. In the context of amphibians and reptiles, there is a strong behavioural component to the regulation of temperature and, for amphibians, the regulation of hydration.

Many approaches have been used to quantify thermoregulation, but not all of these adequately incorporate the availability of the thermal environment. Without this context, simple measurements of body temperature may be impossible to interpret. Two approaches have been used to quantify the thermal environment and its effect on animals: computational energy balance models, and physical models. Each of these approaches has advantages and disadvantages. Several indices of thermoregulation have been developed that incorporate information from both the environment and the animal. These techniques can reveal information that cannot be obtained by simply measuring body temperatures alone. Furthermore, they can provide information about thermoregulation in circumstances where it may be impossible to directly measure body temperatures. Computational energy balance models can be expanded to incorporate parameters such as blood flow, body size, and the consequences of thermal transients. Physical models are easy to use, but an understanding of the ways that animals interact with the physical environment is important to their design and use. Not all physical models are appropriate.

The behavioral regulation of water balance is, in some ways, analogous to behavioral thermoregulation, in the sense that the animal must select micro-environments, postures, and shuttling behaviors to adequately regulate their physiological state. In wet-skinned animals, body temperature and hydration are linked via the cooling effects of evaporation, complicating both the regulatory processes of the animal and the evaluation of these processes by investigators. Techniques for quantifying hydroregulation in amphibians are less well developed than those used to study thermoregulation in reptiles, but amphibian water exchange can similarly be quantified by using computational energy and mass equations, or by using physical models. Although the analogy is not perfect, it is possible to use techniques and indices that parallel those for quantifying thermoregulation, with “hydric state” being analogous to body temperature. We studied the hydric state of 15 species of frogs in the wet-dry tropics and found that hydration state varied with season and habitat use. Arboreal species might be expected to be more variable, because they are often removed from water sources, but physiological characteristics that result in significant cutaneous resistance to water loss allow them to reduce the effects of their dehydrating microenvironment. In a study of a diurnally active frog, *Litoria meiriana,* the hydration environment was more limiting to the activity of this small frog than the thermal environment, despite the fact that environmental temperatures were high.

Metabolic measurement: new challenges, new horizons

John Lighton

President and Chief Scientist, Sable Systems International, 6000 S Eastern Ave, Bldg 1, Las Vegas, NV 89119 USA

Respirometry or indirect calorimetry is a key component in comparative physiology research. Several key insights and approaches have evolved over the past couple of decades that deserve to be more widely known and applied. The purpose of this talk is to summarize the present state of the field and describe some specific research projects that benefit from these new approaches.

First, though water vapor has been thermally or chemically scrubbed from analyte air streams for many decades, I show that in most applications it is unnecessary to do so if both water vapor pressure and barometric pressure data are available. I describe the simple math of the correction technique, which is merely an application of Dalton's law of partial pressures, and demonstrate using direct gas concentration data that it provides near-perfect compensation for water vapor dilution while adding an additional and valuable water flux datastream. This demonstration is then extended to animals, showing equality of respiratory and food quotients, and agreement between calculated and measured metabolic water production. Second, I revisit the topic of metabolic measurements on multiple animals, showing (a) that baselining, or measurement of incurrent concentrations, not only compensates for analyzer drift and shifts in actual ambient conditions, but also serves as a reference calibration for oxygen span in normoxic studies; (b) that careful application of the "instantaneous transformation" can substantially accelerate baseline equilibration, leading to greatly increased sampling frequency in multiplexed applications, and negligible baseline durations in non-multiplexed applications; (c) the interaction between chamber time constant and baselining frequency, and how this can be used to advantage; and (d) methods for extracting pseudo-"continuous" data on a per-animal basis from multiplexed metabolic data, which is compared and contrasted to continuous acquisition of metabolic data with 1 Hz temporal resolution.

In summary, I show the practical application of these approaches in an investigation carried out with a continuous metabolic measurement system in collaboration with Frank van Breukelen, on hibernating Madagascan tailless tenrecs. These animals typically hibernate in a soil-plugged burrow at a normal ambient temperature, which their body temperature tracks during hibernation. In spite of their relatively high body temperature compared to other hibernators, they undergo profound metabolic depression combined with long apneic periods with negligible gas exchange, discontinuously interrupted by brief episodes of convective gas exchange every 20-30 minutes. We speculate that restricting gas exchange to brief intervals at a low frequency maximizes the concentration gradient of respiratory gases between the interior of the burrow and the pulmonary/cardiovascular system of the tenrec. Similar strategies may have facilitated the survival of the earliest mammals after the K/T extinction event, which Barry Lovegrove has also suggested for other, related reasons.

Abstracts
Regular Presentations (A-Z)

Understanding the causes of global amphibian declines: a lesson in complex interactions between multiple environmental stressors

Lesley A. Alton, Manuel Hernando Bernal, Toby Mitchell, Vincent O. van Uitregt, Rebecca L. Cramp, Craig R. White, Robbie S. Wilson and Craig E. Franklin

School of Biological Sciences, The University of Queensland, Brisbane QLD 4072, Australia

The phenomenon of global amphibian declines is a testament to the profound effects of human-induced global change on natural environments. With amphibians being the most threatened of all vertebrate taxa, and also important bioindicators of environmental health, understanding the causes of their declines is critical for their conservation, and possibly the conservation of other species. While research over the past two decades has identified a range of potential causative agents, it has become widely accepted that amphibian declines are likely to be a result of complex interactions between multiple environmental stressors. In a series of multi-factor experimental studies, we have examined the interactive effects of ultraviolet-B radiation (UV-B) combined with a number of natural stressors, including low temperature, predation stress, high conspecific density and hypoxia, on a suite of traits of a model amphibian species. The results from these studies reveal that multiple stressors can interact in ways that are not necessarily predictable from single-factor studies, and that examination of one stressor in the absence of others potentially underestimates the impact of that stressor on amphibian populations in natural systems. Researchers in amphibian conservation biology should therefore continue to utilise a multi-factor experimental approach if we are to gain a comprehensive understanding of the stressors and mechanisms responsible for causing global amphibian declines.

Identifying hypoxia tolerant salmon families

Sarah J. Andrewartha[1,2], Nick G. Elliott[1] and Peter B. Frappell[2]

[1]CSIRO, Agriculture Flagship, Castray Esplanade, Hobart, TAS, 7000
[2]IMAS, University of Tasmania, Castray Esplanade, Hobart, TAS, 7000

The Australian $0.5b salmon aquaculture industry is expanding by $1 million per week. Salmon hatch in freshwater hatcheries and are later reared in large seawater cages. While every effort is made in the hatchery to provide ideal, stable growing conditions, little can be done to control the seawater environment where potential growth limiting factors such as oxygen concentration can be highly variable. The industry selective breeding program produces families of fish with superior characteristics such as flesh quality, rapid growth and disease resistance. This project aims to identify families within the breeding program that are additionally hypoxia tolerant and will therefore be likely to be more robust and productive at sea. Metabolic rate was measured in normoxia and across a range of hypoxic oxygen concentrations at 8°C for thirty-seven families at the eyed-egg stage of development. Twenty-six of the families were measured again once the alevins were newly hatched. Differences in normoxic metabolic rate and in metabolic response to hypoxia indicate that some families have a more robust metabolic physiology for hypoxia exposure. The ability to identify hypoxia tolerant families early on in development has the potential to inform breeding programs and help produce more robust salmon in our increasingly variable climate.

Plasticity in short-beaked echidnas (*Tachyglossus aculeatus*)

Justine M. Barker[1], Christine E. Cooper[1,2], Philip C. Withers[2] and Stewart C. Nicol[3]

[1]Department of Environment and Agriculture, Curtin University, Western Australia
[2]Department of Animal Biology, University of Western Australia, Western Australia
[3]Physiological Ecology, School of Zoology, University of Tasmania, Hobart

Echidnas are the only Australian mammal known to inhabit all major terrestrial environments, yet there have been few studies investigating adaptations of the regional sub-species. Here we investigate the physiological plasticity of short-beaked echidnas in terms of seasonal and geographic variation for two morphologically distinct sub-species; *Tachyglossus aculeatus acanthion* and *Tachyglossus aculeatus setosus* from Western Australia and Tasmania respectively. Both sub-species conform to the typical endothermic pattern for most physiological variables, except body temperature. Both sub-species are thermolabile, and body temperature varies with ambient temperature. Tasmanian echidnas maintain a significantly higher body temperature (approximately 2°C) and metabolic rate (up to 60%) than West Australian echidnas. Despite obvious pelt differences, thermal conductance did not differ between the two sub-species. Evaporative water loss was higher for Tasmanian echidnas than West Australian echidnas, presumably due to the cooler, wetter climate. A typical endothermic pattern of metabolic rate is maintained seasonally, and there is no difference between seasons for *T. aculeatus acanthion*. However, body temperature is lowered during summer, creating a larger buffer and reducing the chance of overheating. Accompanying this lowered body temperature is an increase in evaporative water loss to dissipate excess heat. It has previously been thought that echidnas rely almost entirely on behavioural adaptations to cope with thermal challenges, however this study shows that they do in fact have physiological adaptations to deal with climatic variation.

Seasonality of torpor and extreme heat tolerance in desert bats

Artiom Bondarenco, Gerhard Körtner and Fritz Geiser

Centre for Behavioural and Physiological Ecology, Zoology, University of New England, Armidale NSW 2351, Australia

Despite extreme daily and seasonal fluctuations in ambient temperature (T_a), food abundance and unpredictable weather patterns, desert bats are among the most taxonomically diverse group of mammals in Central Australia. As little is known about their thermal biology and energetics, we used temperature-telemetry to quantify the thermal physiology of tree-roosting inland freetail bats (*Mormopterus* species 3, ~9 g) at Sturt National Park over summer and winter (2010-13). Bats used torpor during both seasons, but torpor patterns differed. In winter, *Mormopterus* entered torpor on 100% of all bat-days vs 59.5% in summer. *Mormopterus* expressed multiday torpor, with torpor bout duration (TBD) of up to 7.7 days in winter and 1.6 days in summer. Importantly, although torpor was deeper and longer in winter because of lower T_a, under the same thermal conditions, TBD was significantly longer (~40%) in summer than in winter. This demonstrates a reverse seasonal acclimation possibly to reduce water loss in summer. In addition to a long main torpor bout, *Mormopterus* often employed one or two short 'auxiliary' bouts, which may represent another important part of its energy and water saving strategies. Facilitated by low thermal insulation of tree roosts and intense solar radiation, bats rewarmed from torpor using entirely passive heating during 70% of all arousals in summer and 40% in winter. During three days of extreme heat, all monitored *Mormopterus* survived skin temperatures of up to 45.8ºC and bats were mostly thermoconforming at T_as < 45ºC. Our study provides the first seasonal comparison of thermal biology in a free-ranging desert microbat. Extensive use of torpor, passive rewarming and auxiliary torpor bouts in addition to seasonal physiological acclimation and extreme heat tolerance demonstrate that this desert bat is well adapted to exploit pronounced daily and seasonal fluctuations in resources and weather.

Individual strategies to cope with environmental change: a test of the pace-of-life syndrome hypothesis

Lisa Bromfield[1], Paul Rymer[1], Peter Biro[2] and Christopher Turbill[1]

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The pace-of-life syndrome (POLS) hypothesis is an important and potentially game-changing hypothesis in ecology. It suggests that variation in single traits (e.g. metabolic rate) cannot be understood in isolation because suites of traits have co-evolved as integrated syndromes that optimise an individual's fitness depending on their intrinsic and environmental conditions. This hypothesis provides a compelling argument for shifting our research paradigm away from its current focus on mean values of single traits for a population or species and towards an integrative study of individual variation in correlated suites of behavioural, physiological and life-history traits. Co-variation of traits provides an explanation for the perplexing variation in behavioural and physiological traits that seem likely to be under strong directional selection. Metabolic rate, for example, often varies several-fold even among individuals of the same population. Such variation could be explained if it represents one component of a correlated suite of traits that provides an individual with increased fitness under specific conditions. Moreover, the existence of individual diversity in the form of syndromes is thought to be important for population stability during times of environmental variability. Despite its theoretical appeal, research is needed to test the assumptions underlying the POLS hypothesis: 1) consistent differences in trait values among individuals (or populations), 2) correlations among traits across environment contexts, and 3) differential fitness consequences of contrasting pace-of-life syndromes. Here, I will discuss my current experimental research that aims to provide a robust test of the POLS hypothesis in a wild population of house mice (*Mus musculus*). This will help answer a fundamental question in physiological ecology and increase our understanding of the ecological significance of variation in key behavioural, physiological and life-history traits.

Correlational selection acting on repeatable physiological and behavioural traits

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When a trait's effect on fitness depends on its interaction with other traits, the resultant selection is correlational and may lead to the integration of functionally related traits. Correlational selection is thought to play a particularly important role in the co-adaptations among behavioural and physiological traits. The objective of this study was to test for the presence of correlational selection acting on a suite of metabolic, hormonal, and behavioural traits in male zebra finches. We repeatedly measured basal metabolic rates (BMR), stress-induced corticosterone levels (CORT), and activity in both novel and familiar environments. We then released these males into an outdoor aviary and monitored their reproductive output over the following 7 months. We found that selection acting on CORT and BMR followed a saddle-shaped surface with clear fitness peaks at high CORT and low BMR and at low CORT and high BMR. Moreover, CORT and BMR were negatively correlated. The correspondence of this phenotypic pattern of covariation with the shape of selection suggests that CORT and BMR are functionally related traits in zebra finches. Finally, a canonical analysis of the non-linear selection gradients revealed that the overall fitness landscape was characterised by a rising ridge, with highest fitness obtained at intermediate levels of CORT and activity in a familiar environment, and low activity levels in a novel environment. Our results demonstrate the potential of applying analytical methods developed in evolutionary biology to explore the causes and consequences of co-variation among suites of behavioural and physiological traits.

Carry-over effects of early larval UV-B exposure: implications for immune function in *Limnodynastes peronii* metamorphs

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Amphibians have declined dramatically worldwide, with many of these declines being described as enigmatic due to their occurrence in 'pristine' areas where no obvious anthropogenic stressors are present. It is proposed that in these areas factors such as elevated UV-B radiation and emerging pathogens could be responsible, perhaps in combination. This study investigated the effect of increased UV-B radiation on immune function in larvae and the subsequent effect on susceptibility to *Batrachochytrium dendrobatidis (Bd),* an influential pathogen to amphibians. In addition, the presence of any carry-over effects on metamorphs following early larval exposure was also examined. *Limnodynastes peronii* larvae were exposed to an ecologically relevant level of UV-B radiation for six weeks and their immunocompetence and susceptibility to *Bd* infection was examined. Larvae were also reared to post-metamoprhic stages, in which immune parameters and *Bd* susceptibility of metamorphs were assessed. There was no effect of UV-B exposure on any parameters tested in larvae, however a carry-over effect of decreased immunocompetence was found in metamorphs demonstrated by decreased leukocyte count and decreased response to PHA injection. The presence of this carry-over effect suggests that the larvae were able to repair the energetically costly damage of UV-B exposure although this may have been traded off with immune function development, resulting in decreased immunocompetence in metamorphs and potentially increased susceptibility to pathogens. This study suggests that the effect of UV-B radiation should not be underestimated, as the carry-over effects induced by early larval exposure have the potential to impact on success in later life.

Cutaneous water collection by a moisture-harvesting lizard, the thorny devil (*Moloch horridus*)

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Moisture-harvesting lizards, such as the Australian thorny devil (*Moloch horridus*) have a remarkable adaptation for water acquisition in the arid habitats. A specialised skin structure, consisting of micro-structured surface and capillary channels in between imbricate overlapping scales, enables water collection and transport to the mouth for ingestion. Water can potentially be acquired from various sources such as light rainfall, puddles, dew, condensation on the skin, or from moist sand. We quantified water collection and ingestion by thorny devils from water puddles to determine the filling volume of capillary channels required for drinking to occur and the mechanism and rate of water ingestion. We also investigated the potential for water uptake via standing on moist sand and condensation from air, and we used bio-replicas to mimic the potential role of sand shoveling on the dorsal skin. We found that the water volume of the skin capillary system was about 3.36% of body mass for thorny devils in liquid water, and water in excess of this was ingested by rhythmic jaw movements with about 0.8 µL ingestion per movement. There is probably not enough water uptake by the capillary system for ingestion by either standing on moist sand (1.84 %) or condensation (0.22 %), but sand shoveling onto the dorsal surface provides additional capillary water uptake compared to ventral contact. We conclude that water collection from puddles (or rain) occurs readily, and that water collection from standing on moist sand is unlikely but spreading of moist sand on the dorsal skin might be the most likely water source for thorny devils on a regular basis.

Synergistic interaction between UVB and temperature increases susceptibility to parasitic infection in a fish

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Levels of UVB radiation (UVB) and mean temperatures have increased substantially over recent decades in many regions of the world. Both stressors independently can compromise immune function, disease resistance, and fitness in fish. The impact of UVB can also be exacerbated by interactions with environmental temperatures. Here we tested the hypothesis that UVB and temperature act synergistically to influence patterns of energy consumption and susceptibility to disease. We exposed mosquitofish, *Gambusia holbrooki*, to a factorial design of low and high UVB levels and low (18^{o}C) and high (25^{o}C) temperatures. The combination of high UVB and high temperature interacted synergistically to suppress metabolism and exacerbate infection intensity by the fish pathogen, whitespot (*Ichtyophthirius multifiliis*). Given the rapid changes in the thermal environment globally, the interaction between UVB and temperatures on energy use and disease resistance could pose significant problems for aquatic animal health in the context of both preexisting and emerging diseases.

Passive rewarming reduces cardiac demands and energy expenditure in bats

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Endothermic arousal from torpor is energetically costly and imposes enormous demands on the cardiovascular system, particularly during early stage arousal from low body temperature (T_b). To minimize these costs many bats and other heterothermic endotherms rewarm passively from torpor using solar radiation or fluctuating ambient temperature (T_a). The heart plays a critical role in the arousal process in terms of blood distribution and as a source of heat production, and therefore it is desirable to understand how the function of this organ responds to passive rewarming and how this relates to changes in T_b and metabolism. We investigated heart rate (HR) in hibernating long-eared bats (*Nyctophilus gouldi*) and its relationship to oxygen consumption ($\dot{V}O_2$) and subcutaneous temperature (T_{sub}) during exposure to increasing T_a in comparison to endogenous arousals at constant low T_a. During passive rewarming, HR and $\dot{V}O_2$ remained low over a large T_{sub} range and increased concurrently with increasing T_a (Q_{10} 2.4 and 2.5, respectively). Absolute values were higher than during steady-state torpor, but below those measured during torpor entry. During active arousals, mean HR and $\dot{V}O_2$ were substantially higher than during passive rewarming at corresponding T_{sub}. In addition, partial passive rewarming reduced the cost of arousal from torpor by 53% compared to entirely active arousal. Our data show that passive rewarming considerably reduces arousal costs and arousal time; we suggest this may also contribute to minimizing exposure to oxidative stresses as well as demands on the cardiovascular system.

An overview of kangaroo locomotion: energetics and thermoregulation

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Locomotion in kangaroos and their kin is bizarre in most aspects. Both slow and fast gaits differ greatly from those perceived as normal in larger quadrupedal mammals. These unusual characteristics also impact on their energetic and thermoregulatory patterns during locomotion relative to those seen in similar sized quadrupedal mammals. Probably the most distinct feature of kangaroo locomotion is bipedal hopping, which is unique amongst large vertebrates. Apparent benefits of hopping are the ability to travel relatively economically at moderate speeds and to achieve comparatively high speeds. Such characteristics can only have evolved in the face of cursorial predation. From where did this predation come? The slow gait of the kangaroos is also unique. It involves the use of the tail as a 'fifth leg', while hind legs are moved forward synchronously, as are the fore legs, in sequence. Unexpectedly, the tail provides a significant proportion of the forward propulsion, while the fore legs act largely only as supportive struts. The kangaroo's gaits determine its energy use during locomotion but what are the corresponding thermoregulative responses that allow such patterns of energy expenditure to be maintained? This will be considered.

Cardiac innervation of the reptile *Ctenophorus ornatus*

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The control of cardiac output in vertebrates depends on a combination of hormonal and nervous inputs to the various chambers. Patterns of nervous control are variable within and between the vertebrate classes. Studies into the cardiac innervation in snakes has demonstrated the presence of adrenergic and cholinergic nerves in the atrial chambers however no cholinergic nerves in the ventricular chamber. These previous studies however were performed at a low temperature and without the capacity to sufficiently stimulate the nerves within the ventricular walls in order to elicit a response. The hearts of 24 anesthetised Ornate dragons (*Ctenophorus ornartus*) were removed and dissected into a double atrial preparation and a ventricular preparation. Preparations were kept in Mckenzie's solution, bubbled with 95% Oxygen and suspended in an organ bath via a force transducer with proximate platinum electrodes. A nervous response was characterised by electrically stimulating the nerves, mimicking the response using exogenously applied adrenaline or acetylcholine before using known receptor blockers to block a response before electrically stimulating the nerves. All tests were performed at 3 temperatures that would show a response at environmentally significant temperatures. The results of this nerve characterisation have indicated the presence of cholinergic and adrenergic nerves in the atrial and the ventricular chambers. Stimulation of the nerves at supra-maximal frequencies resulted in an increased neural cholinergic and adrenergic response in the ventricular muscle. The presence of both adrenergic and cholinergic nerves in all chambers indicates a cardiac innervation pattern that is more complex than has been previously demonstrated. Such a pattern does, however, show similarities with the pattern observed in heterothermic mammals such as bats and marsupials, if not in form then at least in function. This finding sheds light on the importance of precise control over cardiac function in vertebrates that can withstand large temperature fluctuations.

Babbler it's cold outside: the energetic benefit of communal roosting in white-browed babblers

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White-browed Babblers (*Pomatostomus superciliosus*) are socially gregarious, ground-frequenting birds of central and southern Australia. Living in close-knit family groups, they construct domed nests in which they roost communally. In temperate *Eucalyptus wandoo* woodland, free-living babblers implanted with temperature-sensitive radio transmitters maintain homeothermy in winter, even at below-freezing ambient conditions. To investigate how this is achieved we used a range of field and laboratory techniques to examine the thermal and energetic strategies of babblers, incorporating individual physiology, social thermoregulation, roost nest microclimate and diurnal behaviour. Standard open-flow respirometry was used to measure metabolic rate, evaporative water loss and body temperature for solitary and small groups (2-5 individuals) of captive babblers over a range of ambient temperatures (10 – 32.5°C). Solitary babblers had a typical endothermic response to ambient temperature, with no evidence of torpor. Huddling yielded significant energy savings at low temperatures. The thermal properties of roost nests create a microclimate that buffers against low temperatures. Diurnal observations of babblers provide no evidence they rely on specific thermoregulatory behaviours such as basking to buffer energetic costs on cold mornings. In conclusion, both communal roosting behaviour and the insulation of roost nests are important in aiding nocturnal thermoregulation of this species, conferring energetic benefits that aid in meeting daily energy requirements even in habitats with extreme diurnal temperature fluctuations and/or very low overnight minimums.

Changes to the uterine epithelial cells during pregnancy among mammals with endotheliochorial placentation

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The uterine luminal epithelium is the first site of contact between foetal and maternal tissues and so must undergo specialised changes for successful implantation to occur. These changes, collectively termed the 'plasma membrane transformation' (PMT), occur regardless of the placentation type in studied viviparous amniotes. There are similarities in morphological and molecular changes in these viviparous species during the PMT. Within eutherian species such as the pig, rat, and rabbit the pre-implantation period is characterised by the loss or reduction of microvilli on the uterine epithelial cells leaving a smooth, flat surface for blastocyst attachment. Similar changes occur within viviparous lizards and a marsupial, the fat-tailed dunnart, *Sminthopsis crassicaudata*. Changes during pregnancy to the adherence molecules and junctions such as desmosomes and epithelial cadherin may be common among mammals. We have observed the epithelial changes that occur in the fat tailed dunnart (*Sminthopsis crassicaudata*) as well as uterine epithelium from early stages of pregnancy in the domestic cat (*Felis catus*). We plan to compare uterine remodelling across differing clades of marsupial and eutherian mammals with endotheliochorial placentae to determine how this placenta type evolved and what cellular mechanisms may be crucial for successful pregnancy in these mammalian species.

Long submergences by crocodylians and their physiological support: a working hypothesis

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Recent field studies on Australia's fresh water crocodile, *Crocodylus johnstoni*, (not by me) have shown that these animals submerge voluntarily for long periods, apparently resting on the bottom. Whether other crocodylians do likewise is unknown but (in my opinion) highly likely. Long dives by crocodylians are often assumed to rely on anaerobic metabolism. This assumption is probably influenced by the prevailing (but questionable) belief that crocs rely heavily on anaerobic metabolism for most of their activity. This paper suggests that these long, resting dives are supported aerobically. Until the 1980s long dives by mammals and birds also were thought to be supported anaerobically, but it is now accepted that almost all their dives are aerobic; surfacing with high plasma lactate is unusual. Might this be the case in crocodylians too? Data describing the patterns and context of diving behaviour from free range crocs has been lacking. However, the recent data from *C. johnstoni* suggest that short, active dives are associated with foraging, whereas the longest dives are associated with 'resting'. Neither short nor long voluntary dives showed an accumulation of plasma lactate in laboratory studies on *C. porosus*, and calculations imply that the longest voluntary field submergences recorded so far can be accommodated aerobically. Recovery from significant anaerobic metabolism incurs a cost, and it seems reasonable to propose that, as in other diving vertebrates, the long voluntary submergences by crocodylians are aerobic. This hypothesis is consistent with crocodylians' use of water for rest and refuge, and also with the only so far unrefuted hypothesis about the function of gastroliths, that they increase the oxygen store at submergence. More behavioural data from the wild are desirable, ideally combined with plasma lactate data from end-dive plasma samples (challenging!) whenever that is possible.

The adenylate energy charge as a novel biomarker of capture stress in chondrichthyans

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Globally, chondrichthyan (sharks, rays and holocephalans) populations are experiencing alarming declines from the effects of fishing. Measuring the physiological stress of capture is critical to accurately estimating mortality rates but the biomarkers of chondrichthyan stress currently used show significant interspecific variation in both a species' physiological response and tolerance to capture stress. To improve our understanding of chondrichthyan stress physiology and potentially reduce variation when quantifying the stress response, we investigated the use of the adenylate energy charge (AEC) as a novel biomarker of capture stress. The AEC is an indication of the metabolic energy available, measured by the proportion of available ATP relative to the total adenylate concentration (ATP + ADP + AMP), with a value ranging between 0 ('low' energy, entirely AMP) and 1('high' energy, entirely ATP). To determine tissues sensitive to metabolic stress, we extracted brain, heart, liver, muscle and blood from gummy sharks (*Mustelus antarcticus*) following gillnet capture and recovery under laboratory conditions. Capture caused significant declines in the respective AEC of liver, muscle and blood. Heart and brain AEC remained unchanged from 'unstressed' values. Following three hours of recovery from capture, the respective AEC of liver and blood returned to unstressed levels, however muscle remained significantly lower at levels similar to those immediately after capture. The greatest proportional decline in AEC was seen in liver, making it particularly sensitive to metabolic stress. Our results also indicate that muscle and blood can be used to non-lethally sample individuals *in situ*. The AEC can be used to quantify capture stress in chondrichthyans and highlight tissues vulnerable to physiological collapse. Since cellular metabolism is highly conserved across many organisms, further examination of the AEC across other chondrichthyan species may also help resolve the issue of interspecific variation when measuring stress.

Leptin in the gut of male mice

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Leptin is a protein hormone originally identified from adipose tissue and known for its effects on appetite. Leptin is now known to be produced in many tissues including the stomach, and our earlier work showed that when a physiologic dose was injected intravenously approximately 10% of the dose was recovered intact from the lumen of the gastrointestinal tract (GIT) after 60 minutes. To examine the pharmacokinetics of leptin in the GIT, non-fasted mice were lightly anaesthetised before oral gavage of 12 ng of ^{125}I-labelled leptin. Samples were analysed by gel permeation HPLC to confirm that the leptin was not degraded and the amount present was determined using a γ-counter.

Two main reservoirs of leptin were identified, with leptin retained within the stomach and a smaller distally moving peak. 30 min after administration 53% of the dose was recovered from the stomach, declining to 24% 120 min after administration. The smaller peak was detected in the caecum and colon 120 min after administration, accounting for 4% of the total dose administered. Throughout the experiment a low level of exogenous leptin was detected in the blood, representing 3-4% of the dose.

The retention of leptin in the GIT seems to indicate that it has a major role here, while finding a portion of leptin entering circulation is suggestive of a role within the liver. We have previously found that leptin is a constituent of bile, thus if leptin is leaving the GIT it would enter the hepatic portal system and be processed by the liver, potentially cycling in the enterohepatic circulation. The finding of leptin in the faeces was unexpected and is a novel route of elimination. It may also relate to coprophagy/cecophagy seen in rodents.

Inflammatory gene expression in the uterus of a live-bearing lizard

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Viviparity (live-birth) is a reproductive strategy that requires the prolonged co-existence between the mother and her embryo during pregnancy. The embryo is a combination of both maternal (from the ovum) and paternal (from the sperm) genomes, and thus, the maternal immune system may recognise it as foreign and attack it. Hence, the evolution of viviparity may require the co-evolution of maternal immune system regulations that will prevent the immunological rejection of the embryo during pregnancy. Squamate reptiles (lizards and snakes) are excellent models to investigate evolutionary aspects of viviparity, because this reproductive mode has independently evolved more than 115 times in this group. To determine whether maternal immune system regulations are present during squamate pregnancy, we examined whether inflammation is regulated in their uterus during pregnancy. Inflammation is a destructive immune response that is regulated during mammalian pregnancy by the regulation of inflammatory genes that would otherwise terminate pregnancy. Hence, we tested whether the inflammatory genes interleukin 1β (IL-1β), tumour necrosis factor (TNF) and tumour necrosis factor superfamily 1A (TNFRSF1A) are regulated in the uterus of the viviparous lizard, *Pseudemoia entrecasteauxii* during pregnancy. Although the expression of IL-1β and TNFRSF1A did not differ between pregnant and non-pregnant lizards, TNF expression was significantly lower in pregnant than in non-pregnant lizards. A further examination of IL-1β using immuno-histology reveals that it appears to be stored as an inactive form within the uterine cells during pregnancy. Such modulation of IL-1β and TNF suggests that inflammation is regulated in the uterus of pregnant *P. entrecasteauxii.* Therefore, we conclude that the regulation of maternal immune systems during pregnancy is a universal prerequisite for the evolution of viviparity.

At world's end: evidence for how glucocorticoid stress hormone mediated trade-offs influences vertebrate range margins

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Adaptation at range margins defines the distribution of species in time and space. Understanding physiological processes that adapt or constrain species fitness at range margin has broad scale implications for understanding species distribution limits under rapid global change or during invasion. Here we examine if selection on glucocorticoid (GC) stress hormones mediates trade-offs among different phenotypic processes that influence organismal performance necessary to permit ongoing range expansion in an invasive species. Near their semi-arid range front, cane toads experience strong dry season mortality that reduces variation in their acute glucocorticoid stress response. By comparing two different performance components (desiccation tolerance and dispersal capacity) it was evident that both traits responded differently to GC phenotype manipulations causing opposing fitness outcomes. These results highlight how differential selection on physiological performance traits necessary for range expansion, that share a common mechanistic basis, may lead to trade-offs that constrain overall organismal performance and help to explain the delimitation of species distribution boundaries.

Gas exchange in the backswimmer, *Anisops deanei*

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Many aquatic insects utilise air bubbles on the surface of their bodies to accommodate respiration while underwater. These bubbles include air stores that store oxygen from air above the water, and gas gills that facilitate oxygen diffusion from the water. Some gas gills have finite lifetimes due to outward diffusion of nitrogen. These are termed compressible gas gills and have sufficient volume to act as an air store. Backswimmers of the genus *Anisops* are unique among aquatic insects as they have the ability to occupy the mid-water zone. These backswimmers utilise an air store with haemoglobin to achieve near neutral buoyancy. Oxygen is released from the haemoglobin after a period of submergence. This release of oxygen has been said to allow the backswimmers to become nearly neutrally buoyant for a period of their dive. These conclusions come from the measurement of buoyancy and PO_2 decline in tethered backswimmers. Previous evidence suggested that gas exchange between the air store and water was quite low to reduce nitrogen loss and promote neutral buoyancy. We measured the buoyancy in free-swimming backswimmers and the impacts of substituting nitrogen in air with the inert gases, helium and sulphur hexafluoride, that have differing diffusivities from nitrogen. If gas exchange with the water is limited, decline in buoyancy should mimic that of tethered backswimmers and there should be no differences between gas treatments. This was found not to be the case. Buoyancy decline occurs while oxygen is released from the haemoglobin, and inert gas treatments cause differences in dive duration. These results indicate gas exchange with the water is significant and modelling suggests oxygen gain from the water may contribute up to 20% of oxygen consumed during a dive. Despite the decline in buoyancy resulting from nitrogen loss, oxygen diffusion from the water extends the duration of the dive.

Torpor and activity patterns in two carnivorous marsupials in central Australia in relation to precipitation and reproduction

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It is generally assumed that in unpredictable environments daily torpor use is largely dependent on environmental thermal conditions and resource availability. We therefore compared the thermal biology and activity patterns of two species of mulgaras (*Dasycercus blythi* and *D. cristicauda*) at three sites in central Australia using temperature telemetry. The work was conducted over different habitat types during a rather dry period in comparison to a wet period. The seasonal expression of torpor differed significantly between males and females, but surprisingly, torpor expression as well as seasonal timing was similar among sites and periods despite differences in rainfall and habitat. In contrast, it appeared that reproductive activity governed torpor depth and duration in all populations. The most obvious functional difference among populations was observed in the timing of the onset of activity, which began significantly earlier in dense unburnt spinifex (on average 17.7 min before sunset) than in burned spinifex (4.6 min after sunrise) and on gibber plains (21.8 min after sunset). Our study suggests that while the timing of activity is modulated by the amount of vegetation cover, torpor expression and winter reproduction in mulgaras are functionally linked and largely independent of resource availability. Apparently, in mulgaras daily torpor is not necessarily expressed in response to immediate energy shortage but rather allows energy resources to be reallocated towards reproduction.

Uterine focal adhesion dynamics during pregnancy in a marsupial (*Sminthopsis crassicaudata*; Dasyuridae)

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Successful implantation of mammalian embryos requires substantial remodeling of the uterus in early pregnancy. Cells lining the uterus undergo a suite of membrane changes, termed the plasma membrane transformation, to become receptive to the embryo. Common changes in both eutherian and marsupial species occur in the apical and lateral membrane regions of these cells, irrespective of implantation type, leading to the assumption that these changes are essential and ubiquitous in mammalian pregnancy. Basal membrane changes, however, are likely to differ between groups with different types of implantation. Species with highly invasive embryos (including humans and rats) require sloughing of the uterine lining to facilitate invasion of the maternal vasculature by the embryo. Sloughing requires disassembly of the focal adhesions anchoring cells to the basal lamina. As marsupial embryos are not highly invasive, and cells are not removed, focal adhesions likely play a different role in marsupial pregnancy. Hence focal adhesion dynamics in marsupials provide an ideal system to test the assumption that basal membrane changes are also ubiquitous in mammalian pregnancy.

Here we used immunofluorescence microscopy and Western blotting to describe localisation patterns of two key focal adhesion molecules (talin and paxillin) during pregnancy in the fat-tailed dunnart (*Sminthopsis crassicaudata*; Dasyuridae). Basal staining of both molecules occurs in early pregnancy, and is absent by mid pregnancy, consistent with the localisation pattern in the rat. However, strong basal localisation of talin returns just before implantation in *S. crassicaudata*, indicating that focal adhesions do not disassemble during pregnancy in this species. Additionally, talin and paxillin do not colocalise at all stages of pregnancy as they do in the rat. Hence differences in localisation patterns among mammalian species demonstrate that some early pregnancy changes are not ubiquitous in mammalian pregnancy, and may instead be related to mode of implantation.

Is there a locomotory cost of limb autotomy for house crickets, and can they compensate?

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Autotomy is the voluntary self-amputation of an appendage to increase the probability of escape from a predatory attack. Although the obvious advantage of autotomy is avoiding predation, there may also be a variety of costs, including reduced mating success, foraging efficiency, and locomotory performance. Compensatory strategies to overcome the loss of the appendage may reduce these costs. We examined the impact of hind leg autotomy on the locomotory performance and energetics of the common house cricket (*Acheta domestica*), and investigated if crickets were able to compensate for leg loss over time. Resting metabolic rate of crickets decreased with age, but there was no effect of autotomy. Autotomy did not impact on the average metabolic rate of running crickets, and there was no effect on their cost of transport. However, older autotomised crickets ran further and faster than intact crickets. We conclude that there is no energetic cost of autotomy on locomotion for house crickets; they are able to compensate for loss of a hindlimb for general locomotion. However, autotomy may increase a cricket's motivation to avoid potential predators, presumably as prior autotomy reduces their future options for escape from predacious attack.

Telomere dynamics as an index of oxidative damage in mice

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The occurrence of trade-offs between life-history traits is a fundamental concept in evolutionary ecology. Abundant evidence demonstrates a genetically determined physiological cost associated with reproduction that reduces survival, but the physiological mechanism that underlies this trade-off remains largely unknown. Oxidative stress caused by an imbalance between production of reactive oxygen species (ROS) and anti-oxidant capacity has been hypothesised to mediate life-history trade-offs. Studies attempting to link oxidative stress with reproduction have produced conflicting results, because assays often represent only one component or a brief 'snap-shot' of the oxidative state of an organism. Telomere dynamics provide a cumulative measure of oxidative damage to nuclear DNA. Telomeres are specialised nucleotide structures which cap the end of linear chromosomes and their triple guanine structure makes them susceptible to degradation via ROS. Consequently, rate of telomere shortening is sensitive to exposure to ROS and telomere dynamics have been linked with increased oxidative stress in cell cultures and whole animals, including humans.

This project aimed to develop and optimise a quantitative PCR protocol to measure relative telomere length (RTL) in a strain of genetically modified mice that lack telomerase – an enzyme that is able to restore telomere length. We then used this technique to determine whether rate of telomere loss was associated with oxidative damage, as induced by depleting a key anti-oxidant, glutathione. The optimisation process led to the development of a protocol that consistently produced a reproducible measure of RTL in mice. However, we did not find an increased rate of telomere shortening in mice with moderately reduced levels of glutathione. We are continuing to optimise this protocol to validate it as a method for measuring oxidative damage. In addition we are developing a protocol to allow optimisation and validation in a wide range of non-model bird and mammal species.

Summit metabolism in birds and bats: new insights from Afrotropical taxa

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Summit metabolism (M_{sum}, the upper limit of resting metabolic rate in endotherms) has been the subject of relatively few comparative analyses, particularly compared with basal metabolic rate (BMR). Like BMR, M_{sum} appears to be a highly flexible physiological trait that is rapidly adjusted in response to environmental variables. Two groups of endotherms for which data on phenotypic flexibility in M_{sum} are notably absent are bats and subtropical birds. We investigated seasonal changes in M_{sum} in two southern African bird species, the southern red bishop (*Euplectes orix*) and white-browed sparrow-weaver (*Plocepasser mahali*), and found that a) M_{sum} varies considerably among populations, and b) increases in M_{sum} during winter may be quantitatively comparable to those that occur in birds resident in cold, north-temperate climates. We also measured seasonal changes in M_{sum} in Wahlberg's epauletted fruit bats (*Epomophorus wahlbergi*), expecting to find a relatively modest capacity for resting metabolic heat production. Surprisingly, M_{sum} in captive individuals during winter was equivalent to approximately 13 X BMR, a metabolic expansibility (ME) value far exceeding those of most mammals and birds. Resting heat production capacity differed between wild and captive populations of *E. wahbergii*, with M_{sum} and ME being significantly higher in the captive population, possibly reflecting elevated resting heat production capacity in response to reduced exercise levels. A comparison of the few available M_{sum} data for bats to those for other mammals reveals that this metabolic parameter is highly variable in bats. Collectively, these findings highlight how little we know about global patterns of variation in M_{sum} among birds and bats.

Utilisation of distress vocalisation to assess neonate viability

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The neonate separation or distress cry, which is highly effective in attracting and compelling parental care, is reported to have a similar acoustic structure across a range of mammalian species. Evidence of the same neural circuitry across mammalian and bird species, and alignment of critical periods of vocal behaviour, has been used to support the evolutionary theory that the infant cry pathway has remained relatively unchanged or has converged toward a similar configuration to ensure reproductive success within a range of environments and social situations. In support of this premise, distress vocalisation features including latency, fundamental frequency and other acoustic parameters are now commonly recognised to reflect neurobehavioral integrity and viability in both the human and rodent neonate. The aims of this study were to investigate neurobehavioural associations with acoustic parameters of neonate lamb separation vocalisations in the first 12 hours post birth. In the first stage of the study, a separation stimulus was applied to lambs at specific times over 12 hours postpartum and latency to early milestone behaviours and test arena performance measured. In the second stage of the study, acoustic analysis of lamb distress signals was undertaken. The results of this study indicate that lambs able to initiate a separation distress vocalization in under 2 seconds were also more likely to locate and reunite with their mother more quickly than lambs showing delayed vocalisation responses ($p<0.001$). Lambs with delayed vocal responses following separation were also more likely to emit fewer vocalisations and low intensity, inefficient vocal signals. The results support the possibility that neonate lamb vocalisation indices including distress vocalisation latency and signal characteristics may be similar to the human and rodent neurobehavioural model, and that lambs emitting inappropriate and delayed vocal responses when separated from the dam are more likely to suffer abandonment and compromised survival rates.

Seasonal and geographical variation in heat tolerance and evaporative cooling capacity in a southern African passerine bird

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Relatively few studies have investigated intraspecific variation in avian heat tolerance, despite the importance of such studies in light of the rising temperatures associated with anthropogenic climate change. We investigated heat tolerance and evaporative cooling capacity in an Afrotropical ploceid passerine, the white-browed sparrow-weaver (*Plocepasser mahali*) during summer and winter at three sites (Askham, Frankfort and Polokwane) that vary substantially in seasonal temperature extremes. Resting metabolic rates (RMR) and evaporative water loss rates (EWL) were measured using flow-through respirometry, and core body temperature (T_b) recorded using passive-integrated transponder tags. Sparrow-weavers were exposed to progressively higher air temperatures (T_a) ranging from 30 – 52°C in a stepwise fashion, and were removed when they approached levels of dangerous heat stress (T_b = ~ 44°C). The maximum T_a (T_{max}) sparrow-weavers reached before becoming hyperthermic varied significantly with the interaction between site and season. Season had a significant effect only at the hottest site (Askham), where birds reached significantly higher T_{max} in summer compared to winter. Moreover, birds at the hottest site reached significantly higher T_{max}s compared to birds at the cooler sites. At T_a = ~ 42°C, Askham birds had significantly lower EWL in summer compared to winter, and during summer had significantly lower EWL at T_a = ~ 42°C compared to Polokwane. Intraspecific seasonal and spatial variation in heat tolerance in this species therefore appears to be associated with the substantially higher temperature maxima experienced in Askham during summer compared to winter, as well as in comparison to the two cooler sites during summer.

Can heterothermy facilitate the colonization of new habitats?

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The colonization of virtual inaccessible habitats, such as volcanic islands, has intrigued ecologists for centuries but despite all this interest, the underlying mechanisms required for these colonisations are still only rudimentarily understood. We examined whether the ability to use heterothermy could facilitate the colonization of new habitats when animals have to cross unsuitable, and/or barren landscapes, survive inclement weather conditions, and promote successful establishment of a founder population. This hypothesis was first proposed in the context of the colonization of Madagascar and is supported by recent studies on the African lesser bushbaby (*Galago moholi*) and the Australian sugar glider (*Petaurus breviceps*), which not only use torpor in winter but also for survival of emergency situations. Our analysis shows that although several findings support the hypothesis that lowering the need for food and water intake facilitates the colonization of new habitats, hibernation and daily torpor might not be equally helpful for survival of unexpected, severe conditions. Furthermore we point out that torpor can positively affect the establishment of a founder population in a new habitat. Torpor is not only a mechanism to conserve energy, but is also known to prolong sperm storage and to delay parturition, enabling reproductive arrest phases until conditions are better. Moreover, given that viable offspring are born after arrival, this might reduce the necessity of encountering individuals of the opposite sex. Altogether, it seems therefore consequential that heterothermic mammals with the ability to enter daily torpor indeed have higher prospects of success to arrive in a new habitat in a body condition that allows successful settlement and reproduction and that torpor might have facilitated the colonization of Madagascar.

Evaporative cooling capacity in two southern African caprimulgid birds, the rufous-cheeked nightjar (*Caprimulgus rufigena*) and freckled nightjar (*Caprimulgus tristigma*)

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In hot, arid environments birds frequently experience environmental temperatures above body temperature (T_b). Nightjars are nocturnal aerial insectivores that often roost and/or nest in open microsites exposed to solar radiation. These hot microsites, combined with a lack of diurnal water intake, may make these birds highly susceptible to dehydration. We investigated the relationships between air temperature (T_a), T_b, carbon dioxide production (VCO_2) and evaporative water loss (EWL) using flow-through respirometry in rufous-cheeked nightjars (*Caprimulgus rufigena*; n=14, hereafter RCNJ) and freckled nightjars (*Caprimulgus tristigma*; n=16, hereafter FRNJ). In both species T_b and EWL was approximately constant at moderate T_a, but rapidly increased when T_a exceeded normothermic T_b. At T_a = 35 – 40°C, mean T_b was 40.1 ± 0.7°C and 39.2 ± 0.8°C in RCNJ and FRNJ, respectively, but increased to 42.1 ± 0.9°C at T_a = 54°C and 41.6 ± 0.7°C, respectively, at T_a = 52°C. Both species typically began gular fluttering at T_a = 40 - 42°C, at which point EWL increased sharply. Mean (±SD) EWL at T_a = 35 - 40°C for RCNJ and FRNJ, respectively, was 5.26 ± 1.76 and 6.53 ± 2.81 mg H_2O min^{-1}, whereas at T_a = 42°C EWL increased to 10.35 ± 1.77 and 10.77 ± 3.41 mg H_2O min^{-1}, respectively. Interestingly, VCO_2 did not noticeably increase until T_a = 54°C in RCNJ and 46°C in FRNJ. These data support the idea that gular flutter represents an energetically efficient avenue of evaporative cooling in caprimulgids and other birds.

Facilitating upstream passage of small-bodied fishes: linking the thermal dependence of swimming ability to culvert design

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Fish passage through road culverts is poorly understood, particularly for small-bodied fishes, despite this information being integral to the restoration of waterway connectivity. We assessed the prolonged swimming performance of a small-bodied fish, empire gudgeon (*Hypseleotris compressa*), and juvenile Australian bass (*Percalates novemaculeata*). Swimming trials were conducted in a hydraulic flume across a range of fixed and increasing velocities in response to acute and long-term thermal treatments. A new statistical approach (Tobit analysis) was used to relate the thermal dependence of swimming endurance to hydraulic characteristics of culverts, providing estimates of maximum water velocity allowing upstream fish passage. Reductions in water temperature of 10°C, similar to those caused by cold-water releases from dams, significantly impaired critical swimming speeds of both species. Traversable water-velocity models identified *H. compressa* as a weak swimmer, requiring very low water velocities (≤ 0.10 m s^{-1} or 2.86 body lengths (BL) s^{-1}) for unrestricted passage, whereas *P. novemaculeata* was predicted to traverse water velocities of ≤ 0.39 m s^{-1} or 12.12 BL s^{-1}. Culvert designs can be improved by limiting water velocities to accommodate weak-swimming fishes and by accounting for the thermal sensitivity of swimming performance.

A laboratory-field comparison of a small marsupial: differences in morphology, activity patterns and thermal biology

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Although quantitative data on thermal biology provide an understanding of an animal's thermal constraints in the wild, most work has been conducted in captivity because of the ease for manipulation of experimental variables, and technological limitations. Nevertheless, such findings are typically inferred to wild animals despite a lack of validation. This is of concern as animals are exposed to different environmental and energetic stresses and often differ in fat storage, which likely will influence thermal biology especially of heterothermic species. We aimed to provide the first data on morphological variables, body temperature (T_b) and activity patterns of captive in comparison to wild, male and female antechinus (*Antechinus stuartii*), which have a highly unusual life history and are known to express daily torpor. Captive-reared males were fatter than their con-specifics in the wild throughout the year, however, activity and T_b patterns were similar. Females, on the other hand, were similar in size in captivity and in the wild. Nevertheless, differences were observed in T_b and activity patterns. While captive and wild females had the same resting and active T_b, torpor expression was greater in the wild with all individuals employing torpor, in contrast to only one female in captivity. Moreover, activity during the photophase was more pronounced in captive than free-ranging females. Although the discrepancies observed between captive and free-ranging individuals may potentially be related to differences in food supply and ambient temperature, our study shows that morphology, behaviour and physiology can differ markedly between the field and captivity, and that these differences are not consistent between the sexes.

Function of the incompressible gas gill of the aquatic insect *Aphelocheirus aestivalis*

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Several diving insects carry an air-store gathered at the surface with them to supply O_2 to the tracheal system. In most species, the air-store is a bubble attached to the outer surface and overlays the spiracle openings. Not only does the air-store supply O_2 from the air, but also the surface of the bubble acts as a physical gill and can take up dissolved O_2 from the water. These compressible gas gills have to be renewed at the surface regularly, because N_2 loss from the bubble causes it to shrink in volume. The function of compressible gas gills has been studied recently by measuring the P_{O_2} with fiber-optic optodes. However, a few insects have incompressible gas gills ("plastrons") that resist collapse by suspending the bubble surface on rigid structures, thereby making the gas exchange surface permanent and allowing the insect to dive indefinitely. One of these insects is the iconic plastron bug, *Aphelocheirus aestivalis*, which has 4 million hairs per mm^2 that support a layer of gas 3 μm thick and 0.14 μL in total. We measured the P_{O_2} in the plastron gas and found it sensitive to water convection over the surface. With moderate-high convection of air-equilibrated water (P_{O_2} = 20.8 kPa), the mean plastron gas P_{O_2} was 10.5 kPa. In stagnant water, P_{O_2} dropped to 2.3 kPa and may have limited respiration rate. In stagnant water, the thickness of the stationary boundary layer around the plastron was 300 – 700 μm, while in convected water, it fell to about 100 – 300 μm. The study shows why these plastron insects are small (40 mg) and commonly occur in moving, well-oxygenated water.

Non-modal scute patterns, morphology, and locomotor performance of loggerhead (*Caretta caretta*) and flatback (*Natator depressus*) turtle hatchlings

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Non-modal scute patterns are observed more frequently in hatchlings than in adult sea turtles, which suggests greater survival of hatchlings with the modal scute pattern. We compared morphological parameters and fitness correlates of hatchlings of *Caretta caretta* and *Natator depressus* with the modal scute pattern against those with non-modal scute patterns. We found hatchlings with the modal scute pattern were larger (*C. caretta*: $F_{2,1441} = 3.87$, $P = 0.02$; *N. depressus*: $F_{2,250} = 6.56$, $P = 0.002$) and heavier (*C. caretta*: $F_{2,1441} = 5.60$, $P < 0.001$; *N. depressus*: $F_{2,250} = 4.63$, $P = 0.01$) than those with non-modal scute patterns; however, this size difference did not translate into a difference in crawling speed or self-righting ability for either species. There was also no difference in swim thrust produced by hatchlings of *C. caretta* over the first four hours of swimming; however, hatchlings of *N. depressus* with the modal pattern produced greater swim thrust during the first 40 minutes of swimming than those with non-modal scute patterns ($P = 0.005$). Additionally, up to two thirds of *C. caretta* embryos that died during development exhibited non-modal scute patterns, a much greater proportion than in hatched hatchlings ($X^2_4 = 23.88$, $P < 0.001$). This suggests that non-modal scute patterns may be indicative of other, lethal abnormalities. These differences suggest that hatchlings with non-modal scute patterns are lower quality and may have reduced survivorship to breeding age.

Biphasic allometry of cardiac growth in the developing kangaroo *Macropus fuliginosus*

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Interspecific studies of adult mammals show that heart mass (M_h, g) increases in direct proportion to body mass (M_b, kg), such that $M_h \propto M_b^{1.00}$. However, intraspecific studies on heart mass in mammals at different stages of development reveal considerable variation between species, $M_h \propto M_b^{0.70 - 1.00}$. Part of this variation may arise due to the narrow body size range of growing placental mammals, from birth to adulthood. Marsupial mammals are born relatively small and offer an opportunity to examine the ontogeny of heart mass over a much broader body size range. Data from 29 western grey kangaroos *Macropus fuliginosus* spanning 800-fold in body mass (0.084 – 67.5 kg) reveal the exponent for heart mass decreases significantly when the joey leaves the pouch (c.a. 5 – 6 kg body mass). In the pouch, the heart mass of joeys scales with hyperallometry, $M_{h(in\text{-}pouch)} = 6.39M_b^{1.10 \pm 0.05}$, whereas in free-roaming juveniles and adults, heart mass scales with hypoallometry, $M_{h(post\text{-}pouch)} = 14.2M_b^{0.77 \pm 0.08}$. Measurements of heart height, width and depth support this finding. The relatively steep heart growth allometry during in-pouch development is consistent with the increase in relative cardiac demands as joeys develop endothermy and the capacity for hopping locomotion. Once out of the pouch, the exponent decreases sharply, possibly because the energy required for hopping is independent of speed, and the efficiency of energy storage during hopping increases as the kangaroo grows. The right:left ventricular mass ratios (0.30 – 0.35) do not change over the body mass range and are similar to other mammals, reflecting the principle of Laplace for the heart.

Supported by the Australian Research Council.

Is torpor an important post-fire survival strategy for small marsupials?

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In Australia fires are an important natural phenomenon that can rejuvenate landscapes and increase biodiversity. However, many species and ecosystems may not be able to cope with the predicted increase in the frequency and intensity of wildfires with climate change. To determine how animal communities may persist after a fire it is important to understand how individuals survive during and after fires. Therefore, we radiotracked and gathered body temperature (T_b) data of free-ranging brown antechinus (*Antechinus stuartii*) in relation to a low-intensity prescribed fire during autumn 2014. The main aim of our study was to examine whether the persistence of small mammals that have to deal with the reduced availability of food resources after a fire is aided by the energy savings and reduced foraging requirements afforded by using torpor. Data were collected on 16 antechinus in a prescribed fire site before and after a fire and also in a control site; individuals did not move out of their original sites during the study. On average torpor bout durations (TBD) of female antechinus inhabiting the fire site were 2.7-fold longer and minimum T_b were 3.6°C lower after the fire in comparison to both the fire site before the fire and the control site. For male antechinus TBD and minimum T_b after the fire were similar at the fire site and the control site, but TBD were 3.3-fold longer and minimum T_b were 1.6°C lower in comparison to before the fire. Our results reveal that antechinus increase both the depth and duration of torpor bouts in response to a low-intensity prescribed fire, suggesting that the use of torpor increases the chance of survival for small mammals by saving energy in a post-fire landscape where available refuges, food and water are reduced.

A thermal gradient in annual survival rate among populations of hibernating rodents: lower survival in warmer climates

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Environmental gradients in life-history traits can reveal the drivers underlying variation and indicate how life histories might be affected by future climate change. Hibernation is associated with high monthly and annual survival rates and relatively slow life-histories among small mammals. Among populations of rodent species, the duration of the hibernation season varies according to local thermal conditions. Therefore, we hypothesised that because populations at colder locations hibernate for a greater proportion of the year, they will have greater annual survival rates than populations at warmer locations. Our analysis of published data revealed a strong negative within-species effect of local mean annual temperature on spatial variation in duration of the hibernation season and adult annual survival rate in hibernating but not non-hibernating rodent species. The observed thermal gradient in survival appears to be matched by co-variation in other life-history traits. A climate-linked spatial relationship between activity and survival in hibernating rodents could be extrapolated to predict that future warming will lead to shorter hibernation seasons and consequently a reduction in adult survival rates. Whether a predicted decrease in adult survival in a warmer climate might be compensated by increased juvenile survival or increased production of offspring will depend on an interaction between changes in local environmental conditions, intrinsic constraints to plasticity in relevant traits (e.g. growth rate, litter size and frequency) and the capacity for gene flow among populations.

To eat or overheat: linking behaviour and habitat use during a summer heatwave, to thermal tolerances in an orb-web spider

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Although animals should thermoregulate when the fitness benefits outweigh the costs, many thermoconforming animals only thermoregulate to avoid thermal extremes. We tested how an orb-web spider, *Argiope keyserlingi* balances prey capture and thermoregulation costs, using web behaviour to assess the trade-off. *Argiope keyserlingi* often build webs in sun-exposed areas, potentially exposing it to near lethal body temperatures (T_{body}), especially during heat waves. To determine the relationship between behaviour, habitat use and T_{body}, we measured field active T_{body}, web traits and web behaviours (including web position and posturing) of *Argiope* during a summer heat wave. Spiders experienced a wide range of T_{body} but rarely left the hub of their webs, even when T_{body} exceeded 40°C. During high temperature periods, we frequently observed spiders posturing their body towards the sun which would minimise heat gain. *Argiope* T_{body} was affected by shading with some web locations consistently exposing spiders to high T_{body}.To survive consistently high T_{body}, we predicted that spiders in 'high temperature' microhabitats would have high thermal tolerances. We measured *Argiope* upper thermal tolerances (critical thermal maximum; CT_{Max}, commonly referred to as "ecological death") and found spiders after 40(±0.29)°C would start hanging limply from their webs or display escape behaviour until their CT_{Max} at 42(±0.33)°C. We found maximum field T_{body} correlated with thermal tolerances following prolonged heat stress in the laboratory. Field T_{body}'s were significantly lower than the CT_{Max}. We argue that on hot days, spiders use posturing to stay at web hub, however CT_{Max} trials demonstrate that when temperatures approach lethal limits, spiders will abandon their webs. Our results highlight how orb-weaving spiders prioritise foraging, even at sub-optimal temperatures, until temperatures approach their CT_{Max} when spiders switch to thermoregulation.

Faecal glucocorticoid monitoring of flying-foxes: observations of colony-level disturbance in Sydney, Australia

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Glucocorticoid ('stress') hormone levels can be measured indirectly as metabolites in faeces, and are typically investigated at the individual animal level. In this study, we piloted a colony-level approach for monitoring faecal glucocorticoid metabolites (FGCMs) in flying-foxes, to look for evidence of colony-level disturbance. Our principal colony site was Centennial Park in central Sydney, with comparison sites also sampled at North Avoca (northern beaches region of Sydney), Singleton and Tocal (Hunter Valley region). Samples were collected on several collection dates from April to October 2012, by placing grid-marked plastic sheeting on the ground underneath trees inhabited by flying-foxes.

Between May and July 2012, the Royal Botanic Gardens Sydney (RBGS) used a noise disturbance protocol to relocate grey-headed flying-foxes resident in the Gardens. Intermittent recorded noises were played for up to 75 minutes per 24 hours (up to 45 minutes pre-dawn and 30 minutes at sunset). As expected, flying-foxes relocated to other colony sites within the Sydney area, with the closest option being the Centennial Park site.

Preliminary analysis shows that samples collected at Centennial Park in late May 2012 (during the disturbance program at RBGS) have a higher mean FGCM concentration and more variation in FGCMs than samples collected in April from the same site. A comparable increase in FGCMs was not seen in samples collected during May at the Hunter Valley sites. This suggests that individuals displaying an acute physiological stress response to the RBGS noise disturbance relocated to Centennial Park (but not the Hunter Valley). In September 2012, FGCMs at Centennial Park returned to levels comparable with the April sample collection. We propose that using colony-level faecal collection is appropriate for investigating questions of colony-level disturbance by observing broad-scale patterns in faecal glucocorticoid levels.

Is metabolic rate related to fitness?

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Animals expend energy to process information, to forage for and digest food, to move, to grow and reproduce, and to generate or dissipate heat. Measures of metabolic rate integrate these processes, so it is reasonable to expect that variation in metabolic rate should be related to variation in fitness, but empirical demonstrations of such associations are surprisingly rare. Using data drawn from phenotypic and quantitative genetic studies, I will discuss the association between metabolic rate and fitness for a range of animals including lizards and cockroaches, and will identify several key challenges facing tests of the hypothesis that metabolic rate is related to fitness.

Angiogenic genes in the skink uterus and the evolution of live birth

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The potent angiogenic factor VEGF111 is a rare isoform of vascular endothelial growth factor (VEGF) found previously only in DNA-damaged human cells. VEGF111 is expressed in the uterus of viviparous (live-bearing) members of the bimodally reproductive three-toed skinks (*Saiphos equalis*), providing a possible link between the evolution of live birth and cancer susceptibility. We are investigating the expression and occurrence of VEGF111 in Australian skinks in tandem with experiments in laboratory mice and cultured cells. VEGF111 is upregulated during pregnancy in skinks, which correlates with the requirements for gas exchange in the growing embryo, but unexpectedly, we found that VEGF111 is expressed in oviparous sister taxa to *S. equalis*. Hence, the role of VEGF111 in viviparity is more complicated than previously thought.

The need to breathe: experimental evidence that crocodilian eggs lack the ability to arrest embryonic development

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Captive crocodilians that are withheld from appropriate nesting sites will either lay eggs in the water, or delay oviposition until a site has been provided. This delay will often result in developmental limitations or an increase in embryonic mortality, and would suggest that unlike many other aquatic reptiles, crocodilians lack the capacity to arrest embryonic development prior to oviposition. We have previously shown hypoxia extends developmental arrest in turtles, hence we hypothesise that hypoxia would also extend development arrest if it were present in crocodilians. We examined how extended exposure to hypoxic environments during incubation altered crocodilian development and mortality. We also tested whether increased oxygen availability during incubation altered hatching success. Freshly laid saltwater crocodile (*Crocodylus porosus)* eggs (*N*=83) were incubated in one of five treatments; control (normoxia; 21% O_2), 3-day hypoxia (1% O_2), 6-day hypoxia (1% O_2), 3-day hyperoxia (42% O_2), and 6-day hyperoxia (42% O_2). There was a significant effect of treatment on survival of embryos through to hatching ($p<0.001$). The hypoxic treatments experienced almost no hatching success (6.7% and 0% survival for the 3- and 6- day treatments respectively), while the hyperoxic and control treatments experienced normal to high hatching success rates (86.6%, 100% and 64.2% for the control, 3- and 6- day hyperoxic treatments respectively). Our results provide the first experimental confirmation that, unlike turtles, crocodiles do not exhibit preovipositional arrest. An absence of embryonic arrest is of ecological significance as crocodilians therefore lack an ability to avoid adverse environmental conditions through delayed nesting.

Does greater thermal plasticity facilitate range expansion of an invasive terrestrial anuran into higher latitudes?

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Temperature has pervasive effects on physiological processes and is critical in setting species distribution limits. Since invading Australia, cane toads have spread rapidly across low latitudes, but slowly into higher latitudes. Low temperature is the likely factor limiting high latitude advancement. Previous efforts to predict future cane toad distributions in Australia have not adequately addressed thermal plasticity or adaptation. Previous research demonstrates the cane toad's considerable thermal metabolic plasticity, but suggests limited thermal plasticity of locomotor performance. Additionally, the oxygen limited thermal tolerance hypothesis predicts that reduced aerobic scope sets thermal limits for ectotherm performance. Metabolic plasticity, locomotor performance and aerobic scope are therefore predicted targets of natural selection as cane toads invade colder regions. We measured these traits at temperatures of 10, 15, 22.5, and 30°C on low and high latitude toads acclimated to 15 and 30°C, to test the hypothesis that cane toads have adapted to cold temperatures. High latitude toads show increased metabolic plasticity and higher resting metabolic rates at low temperatures. Burst locomotor performance was lower for high latitude toads. Other traits showed no regional differences. We conclude that increased metabolic plasticity may facilitate invasion into higher latitudes by maintaining critical physiological function at low temperatures.

Sensitivity to heat stress varies widely across avian orders

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We studied thermoregulatory performance of summer-acclimatized wild birds to heat stress in the deserts of Australia, North America and South Africa. We measured evaporative water loss (EWL), resting metabolic rate (RMR) and body temperature (T_b) continuously using ramped temperature profiles with increasing air temperatures in 40+ species, which included 10 orders with body size ranging from 7- 450g. We estimated the upper critical thermal max (CTM) for each species by tracking T_b, EWL and RMR and activity when exposed to air temperatures ranging from 30-64°C. We found that birds from the orders Columbiformes (pigeons and doves) and Caprimulgiformes (nighthawks and nightjars) had the highest CTMs and were able to effectively thermoregulate at air temperatures as high as 60°C. Passerine birds, in contrast, showed a much more limited capacity for thermoregulation at high air temperatures and exhibited CTMs near 50°C. We found that thermal tolerance is primarily driven by the primary pathway of evaporative heat loss, where birds that evaporate water from the skin or have a well-developed gular apparatus were most effective at heat dissipation at high air temperatures. Body size was also a critical factor in determining the capacity of a species to tolerate high temperatures. This work greatly expands our knowledge of avian tolerance to heat and provides insights into how rapid warming and more intense heat waves may change avian distributions and community structure.

Abstracts
Speed Presentations (A-Z)

Physiology, behaviour and movement: trait correlations and dynamics during the life of adult red flour beetles, *Tribolium castaneum*

Pieter Arnold and Craig R. White

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The successful movement of an individual or population from one habitat, through an inter-habitat matrix and into another suitable habitat, necessitates an appropriate phenotype for dispersal; a suite of traits that pertain to efficient movement, speed and distance travelled. The rust-red flour beetle (*Tribolium castaneum*) is a significant pest species and primary coloniser of grain and stored products, which in a given population, has a spectrum of dispersal abilities ranging from sedentary individuals to active dispersers. At present, it is not well understood whether this range of dispersal abilities in *T. castaneum* has an underlying physiological or behavioural basis. In a laboratory population of *T. castaneum*, I assessed the associations between several physiological and behavioural traits which were postulated to play a significant role in producing dispersal phenotypes. Whole-animal metabolic rate, spontaneous activity, mass, body size morphometrics and the characteristics of speed (average, lower and upper 5^{th} percentiles), distance travelled, intermittency and tortuosity while moving through a complex environment were quantified for 290 individuals of known age and sex. It was hypothesised that routine metabolic rate (RMR) would be a strong predictor for many movement traits, and that spontaneous activity during RMR measurement, body size, sex and age would likely affect the RMR of an individual. While RMR was found to be positively correlated with body size and spontaneous activity, RMR itself had only weak associations with most movement characteristics. The strongest predictor for speed, intermittency, tortuosity and distance travelled was adult age, where older adults have declining movement ability. Age appears to play a significant role in determining movement ability for this species, which may be a reflection of their optimal age range for dispersal and reproduction.

Relative humidity and food availability during juvenile development determine growth rate and metabolic rate in the cockroach *Nauphoeta cinerea* (Blaberidae)

Julian Beaman and Craig R. White

School of Biological Sciences, University of Queensland

Limited food availability can constrain growth rate. The extent to which food restriction limits growth, however, may depend on variation in abiotic factors such as temperature and humidity. For example, food restriction reduces growth rate to a greater extent at higher temperatures presumably due to a trade-off between allocation of energy to metabolism and growth. In this brief presentation I present data on the effect of relative humidity and food availability on the growth rate and metabolic rate of juvenile cockroaches (*Nauphoeta cinerea*, Blaberidae). The insect fat body plays an important role in the storage of energy that can later be diverted to growth or metabolism. The additional role of the insect fat body in the regulation of body water content and production of cuticular molecules creates a potential trade-off between growth, energy production and water conservation and will be investigated further as part of the current project.

Do Atlantic salmon and brown trout hybrids have superior metabolic physiology and swimming performance?

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Amoebic gill disease (AGD) is one of the biggest challenges for the Tasmanian Atlantic salmon industry and accounts for 10-20% of production costs. The disease is caused by amoeba that proliferates during the summer months when temperature and salinity increase. AGD is characterised by hyperplastic lesions upon the gills and causes fusion of the secondary lamellae. The functional surface area available for oxygen uptake is effectively decreased which potentially affects performance characteristics such as metabolic rate and swimming capabilities. Atlantic salmon (*Salmo salar*) are the most susceptible while other salmonids such as brown trout (*Salmo trutta*) exhibit much greater resistance. Hybrids of brown trout and Atlantic salmon are being experimentally tested for disease resistance and to help elucidate the physiological mechanisms associated with AGD infection. Our aim was to measure routine and maximal oxygen consumption and critical swimming speed (U_{crit}) of Atlantic salmon (S x S), brown trout (T x T), and both the hybrid crosses (T x S; S x T) to compare swimming performance and properties of oxygen utilization of pure species and hybrid crosses that may confer resistance to AGD. Uninfected individuals were used in order to compare the metabolic physiology of the crosses. Preliminary analyses show no difference in routine oxygen consumption between the crosses. Ongoing analysis of critical swimming speed and aerobic scope will determine whether superior metabolic physiology of the hybrids may result in increased AGD tolerance compared with pure Atlantic salmon.

Metabolic rate and water loss rate show a positive phenotypic association in *Drosophila serrata*, but are not correlated with desiccation resistance along a latitudinal gradient

Taryn S. Crispin and Craig R. White

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It is widely accepted that variations in metabolic rate (MR) may occur in response to climatic factors, and this variation is generally considered to be adaptive. As an arid environment presents a higher degree of desiccation stress to an animal, a low MR should reduce energy turnover and thus reduce overall rates of water loss. Thus, two broad, adaptive hypotheses were proposed; (1) selection should favour a lower MR towards high latitudes and, (2) selection should favour insects with a greater tolerance to desiccation stress towards high latitudes. Using fruit flies, *Drosophila serrata*, as a model species, we compared MR, water loss rate, and desiccation tolerance, among full-sibling families from populations along a latitudinal gradient, raised under common artificial conditions. Results indicate a positive phenotypic association between MR and water loss, yet there was no latitudinal variation in these traits when treated either independently or in association. There was, however, a strong pattern of latitudinal variation in dehydration tolerance suggesting that sub-tropical populations are more desiccation tolerant, and a positive phenotypic and genetic association was found between dehydration tolerance and survival time under chronic desiccation stress. We thus conclude that there is no evidence to suggest that variation in *D. serrata* MR is a consequence of adaptation to desiccation stress along a tropical to subtropical latitudinal gradient, and suggest that aridity-driven selection may instead favour desiccation tolerance traits, rather than resistance traits, at these latitudes.

It’s black and white: why microbats prefer warmer roosts

Anna Doty, Clare Stawski, Gerhard Körtner and Fritz Geiser

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Microbats inhabit a large range of ecological niches and use a variety of roosts that have very different thermal characteristics. However, little is known about whether tree-roosting bats actively choose where they will roost based on thermal characteristics and potential energy savings. In this study, we present temperature telemetry data from a captive Australian microbat, *Nyctophilus gouldi* (n=7, ~10g), to determine how roost choice influences use of torpor. All individuals were housed together in an aviary exposed to natural fluctuations of ambient temperature and offered the choice of black- or white-coloured roost boxes that were well insulated and otherwise identical. Black boxes were on average 4˚C (maximum 7.5°C) warmer than white boxes at their maximum daytime temperature. Bats chose black boxes on most nights (90.7%); only two individuals chose a white box on one night over the course of the study, immediately returning to a black box on the next evening. Therefore, to allow for a comparison in heterothermy use between black and white roosts, we removed black boxes after 8 days. Bats rewarmed at midday on 78% of days when using black boxes, and only 65% of days when using white boxes. Independent of box colour, bats always used passive rewarming before they actively aroused in the day. Bats in black boxes started active arousal at a higher temperature (19.2˚C ± 3.2˚C) than bats in the white boxes (16.2˚C ± 2.3˚C) and 30 min earlier (*Black:* 11:43 hours ± 21 min, *White:* 12:13 hours ± 21 min). Our study shows that this microbat most likely chooses warmer roosts in order to passively rewarm to higher body temperatures and thus save more energy prior to active midday arousals.

ANZ conservation physiology: understanding and managing human-wildlife interaction

Ursula Ellenberg

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While my research projects aim at advancing and informing conservation management, I come from a behavioural ecology background and I continue to ask questions on why and how individual differences affect behaviour (e.g. stress-coping styles, foraging strategies), and ultimately (life-time) reproductive success and survival. I am particularly interested in understanding and managing human-wildlife interaction. My research into human disturbance effects in seabirds has shown that generic visitor management guidelines cannot be applied. Rigorous species- and site-specific research is required for effective management. I found considerable differences in stress-coping styles and habituation potential even between individuals of the same species depending on sex, character and previous experiences with humans. These findings sparked my interest into the evolutionary ecology of individual differences. But how do we best measure such differences? I recognised that while behaviour can give us good clues as to how a stimulus is perceived, physiological parameters (e.g. heart rate, hormonal response) provide a more objective tool to evaluate responses. For effective conservation management, individual stress-coping styles need to be linked to reproductive success and survival via energetic and lost-opportunity costs of risk avoidance. Working hand in hand with managers I aim to provide data required for anticipatory management decisions (e.g. tourism, fisheries). Following a short overview of my past and current research projects in New Zealand I am keen to get your feedback on my ideas for future research in Australia.

Can aphids take the heat: again…and again... and again... and again?

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Repeated high extreme temperature are common and are increasing in frequency with climate change in many temperate locations, yet understanding of their impact on most insect taxa is extremely limited. We investigated the effects of repeated high extreme temperature on the adult aphid of the green peach aphid, *Myzus persicae* (L.) (Hemiptera: Aphididae) with attention to their physiology by subjecting individuals to either a single sustained 3h heating or six 30 minutes heating up to 37ºC.

Results showed that aphid's glycerol and triglyceride remained unchanged in response to repeated stress while glucose and protein contents increased in repeated treatment than prolonged group. In addition, thermal tolerance in multiple stresses is higher than prolonged group. In contrast metabolic rate (CO_2) production decreased in repeated stresses treatment than prolonged group.

Importantly though, fluctuating stressors are protective when compared to constant high temperature exposures, potentially due to an increase in total content proteins which include heat shock protein (HSP_s). However, aphids may suffer long-term fitness consequences compared to prolonged group exposures because are known to improve developmental rate but decreased fecundity and intrinsic rate based on previous studies and expression more proteins and decreasing metabolic rate in the aphids based on this study. In conclusion, it appears that fluctuating stressors are protective in green peach aphid when compared to constant stress conditions, likely through regulation of whole-animal metabolic rate and total proteins.

Diverse diapause and quiescence strategies in closely related arid zone grasshoppers

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For many species, adaptations at the egg stage are crucial to avoiding harsh environmental conditions and maximizing exposure to optimal conditions for growth and reproduction. The grasshopper genus *Warramaba* (Morabinae) occurs in arid and semi-arid Australia. It includes parthenogenetic forms that originated via hybridization from two of the sexual species. A comparative analysis of the thermal dependence of development between the sexual and parthenogenetic forms revealed a wide range of diapause and quiescence strategies including obligate cold diapause, high temperature-induced quiescence, and an absence of any diapause/quiescence. I will discuss these observations in relation to the seasonal patterns of environment experienced by the different lineages.

Temperature does not affect oxidative damage from UV-B radiation in *Limnodynastes peronii* tadpoles

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Both temperature and UV-B radiation are key environmental factors influencing the physiology of animals. Exposure to these factors can affect survival, growth, metabolism and performance. Simultaneous exposure to high or low temperatures and UV-B can result in interactions that exacerbate the deleterious consequences of one stressor alone. UV-B and temperature are linked mechanistically in their effects on cellular function as both high temperatures and UV-B exposure can lead to oxidative stress due to the production of reactive oxygen species. Additionally, repair mechanisms that respond to UV-B induced cellular damage are temperature sensitive. It is therefore predicted that oxidative damage from UV-B exposure would be greater at low temperatures due to thermodynamic effects on antioxidant enzymes. We investigated the interactive effects of UV-B and temperature on oxidative damage and catalase activity in *Limnodynastes peronii* tadpoles. Previous studies on this species have demonstrated increased UV-B induced mortality at low temperatures. In our study there was no interaction between temperature and UV-B radiation on oxidative damage or catalase activity. Oxidative damage was higher in tadpoles exposed to UV-B radiation. While catalase activity did not change with increased UV-B exposure, it was greater in tadpoles exposed to fluctuating temperatures. Our results indicate that cellular defences failed to prevent oxidative stress when exposed to UV-B radiation and that oxidative damage caused by UV-B radiation in this species does not appear to be temperature dependent.

Physiological resilience: how will diving ectotherms fare in warmer environments?

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Air-breathing, diving animals (e.g. marine turtles, iguanas and crocodilians) are a crucial component of the biodiversity and functioning of aquatic ecosystems. Diving behaviour serves multiple ecologically significant purposes and is important for predator avoidance and prey capture. Diving species must overcome challenges associated with diving in sub-optimal water temperatures, which unless combated may lead to shorter dive durations and greater surfacing frequency. We assessed the thermal sensitivity and plasticity of dive performance in juvenile estuarine crocodiles (*Crocodylus porosus*). Crocodiles were acclimated to one of three thermal treatments (28°C, 31.5°C or 35°C) emulating predicted water temperatures under low, moderate and high rates of climate warming, respectively. Dive capacity (duration, frequency and post-dive surface interval) was assessed across a range of water temperatures. We show how water temperature, heart rate and acclimation treatments interact to determine fright-dive capacity in response to a threat, and underwater foraging success.

Climate change and the energetics of a nocturnal lemur in Southern Madagascar

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Predicting future distributions of species in the face of environmental change is a key strategy for long-term conservation of wildlife. A common approach is through ecological niche models, or species distribution models (SDMs) that correlate current species occurrence with spatial data on climate, vegetation and terrain. These models are broadly informative, but say little about the causes of species limits and so have limited predictive power as conditions change. In contrast, mechanistic niche models determine energy demands of animals to model their physiological response to changing environments and have been shown to be a powerful predictive tool in determining species limits.

Madagascar is one of the world's top conservation hotspots; however extensive habitat loss, fragmentation and degradation mean that species have little capacity to adapt to environmental change. In this project, I apply both ecological and mechanistic niche approaches to model the effect of climate changes on an endangered lemur, the white-footed sportive lemur (*Lepilemur leucopus*) in the dry habitats of the far south. Here, I outline our work on two key components of the approach: climatic envelopes and animal energetics. Firstly, I present data on macroclimate surfaces for Madagascar over several decades derived from observational data from a suite of online and local sources. These surfaces form the climatic basis of our niche models and will also be a valuable resource for use by future researchers of the region. Secondly, I will briefly discuss our work on field metabolic rate and experiments measuring the short-term metabolic responses to a range of ambient temperatures in the field. Our overall aim is to identify ways to increase species' probability of survival such as by identifying new reserves and by assessing the suitability of habitat as climate refuges and thus contribute to the long-term conservation management of an endangered primate.

Energetic consequences of antipredator behaviour in house mice

Lisa Stojanovski and Christopher Turbill

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Non-lethal effects of predation can be equally as important as direct mortality in regulating the population dynamics of prey species. A major cost of behaviours that reduce the risk of predation (e.g. inactivity, vigilance) is a reduction in food intake. This can lead to a negative energy budget and thus decreased growth and birth rates, which underlie the non-lethal effects of predation. For endothermic animals, rates of energy expenditure while resting can be greatly reduced by even a small decrease in body temperature. The use of torpor bouts, when body temperature is allowed to decrease substantially for short periods, allows plasticity in the energy budget and might facilitate predator avoidance. We tested the hypothesis that small mammals like mice can use torpor as a mechanism to reduce their need to forage, and therefore, their exposure to a high risk of predation. In this study we exposed individual mice to different levels of ground-cover to simulate predation risk, and measured changes in food intake, body temperature, body mass and activity levels. Greater 'giving-up densities' of food indicated that a reduction in ground cover increased the perceived risk of predation. This experiment is currently underway and initial results will be presented at the conference. My study is significant because it contributes to our understanding of the wider ecological significance of thermoregulatory energy expenditure.

Placental carbonic anhydrase II is a multirole waste disposal mechanism in a viviparous lizard

James U. Van Dyke, Laura A. Lindsay, Christopher R. Murphy and Michael B. Thompson

University of Sydney

The evolution of viviparity requires the development of mechanisms that facilitate transport of respiratory gases between mother and developing embryo. Of particular importance is maternal excretion of embryonic carbon dioxide (CO_2), which increases as the embryo grows in size during development. The carbonic anhydrases are a family of enzymes that convert CO_2 to bicarbonate for transport throughout the cardiovascular system and which may also be important for CO_2 transport from embryo to mother. We used immunohistochemistry to localize carbonic anhydrase II in the placental tissues of a viviparous and highly placentotrophic lizard, *Pseudemoia entrecasteauxii*. Carbonic anhydrase II is localized in the uterine component of the paraplacentome, presumably to facilitate transport of embryonic CO_2 to the mother. Carbonic anhydrase II is also localized in both the uterine and embryonic components of the placentome, a region thought to be heavily involved in placental nutrient transport rather than respiratory gas exchange. In contrast, carbonic anhydrase II is not present in the uterine or embryonic components of the omphaloplacenta, another region that is probably responsible for nutrient transport. While carbonic anhydrase II in the paraplacentomal uterus is probably responsible for embryo-maternal CO_2 transport, the distribution of carbonic anhydrase II throughout the placentome indicates a different function. Instead of transporting embryonic CO_2 to the mother, placentomal carbonic anhydrase II may be responsible for transporting CO_2 produced by energetically-expensive nutrient transport mechanisms in both the uterus and the embryonic chorioallantoic membrane. This implies that possible mechanisms of nutrient transport in the placentome may be more energetically expensive than those that may occur in the omphaloplacenta.

The development of thermoregulation and torpor in the fat-tailed dunnart

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Torpor allows small mammals such as the fat-tailed dunnart (*Sminthopsis crassicaudata*) to balance energy budgets and to survive adverse conditions, but torpor expression varies greatly among individuals. Because body mass is known to affect torpor use, we examined the effect of body mass on cooling rate during torpor entry, torpor bout duration and rate of active rewarming from torpor. Dunnarts (n=12) were implanted with small temperature-sensitive transponders at between 2 and 3 months of age, while still sharing the nest with their mother. At 2, 3, 4, 5 and 6 months of age oxygen consumption and subcutaneous temperature (T_{sub}) were measured simultaneously for ~ 21 hours. Torpor bout duration decreased substantially with body mass (r^2=0.60). Smaller animals were more likely to thermoconform rather than thermoregulate during torpor entry and therefore had faster cooling rates and longer torpor bouts than thermoregulating animals. Cooling rate of T_b during torpor entry was negatively correlated with body mass (r^2=0.68). However, animals that cooled quickly during torpor entry also warmed slowly from torpor (r^2=0.61). Our data show that fat-tailed dunnarts reduce torpor duration and depth during growth. While large animals have slow cooling rates, their torpor bouts are shorter and shallower, but the rate of rewarming from torpor is faster than in small individuals. Since thermoconforming animals are smaller, they reduce energy expenditure during torpor entry, by using longer torpor bouts, and upon rewarming from torpor.

Signals of parturition in male pregnant seahorses

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Male seahorses and pipefish have specialised brooding structures (pouches) that provide protection, aeration, osmoregulation and nutrient provisioning to developing embryos. These structures differ widely across the lineage, offering an unprecedented opportunity to study the evolution of reproductive complexity in these viviparous fish. However, the physiological changes occurring during syngnathid pregnancy are largely unknown. To understand the basic biology underlying male seahorse pregnancy, we have used transcriptomic technologies (RNAseq) to sequence genes expressed in pouch tissue at key gestational stages. We identified a number of 'pregnancy genes', including a set putatively involved in the onset of labour. We show that parturition may be induced by the expression of homologous genes in both mammals and seahorses. Our work suggests a common genetic basis for reproductive innovations in divergent evolutionary lineages, and identifies the processes and functions occurring within the syngnathid brood pouch.

The effect of oxygen concentration on the developmental physiology of Atlantic salmon (*Salmo salar*)

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The environmental conditions experienced by developing fish can have lasting effects on their phenotype. Variation in dissolved oxygen concentration (DO) during fish development has been reported to affect metabolic rate, vascularisation and swimming speed, among other traits. However, few studies have reported the effects of oxygen availability at different stages of development to identify critical windows, or the persistent impacts on phenotype. Anecdotal evidence suggests that Atlantic salmon (*Salmo salar*) raised in commercial aquaculture systems may be exposed to variable DO concentrations, however this has not been quantified. It is important in Atlantic salmon aquaculture to understand the impacts of oxygen availability on early development and the subsequent impact on long term production performance in order to improve production efficiency. In the present study Atlantic salmon were exposed to environmental hyperoxia (150% DO), hypoxia (50% DO) and normoxia (100% DO) for various periods across 4 time windows during development from fertilisation to yolk absorption. Post exposure the metabolic rate, physiological development and growth was compared. Additionally, the DO concentration and temperature in multiple locations of a commercial hatchery system were monitored. Preliminary results indicate that DO in the commercial hatchery system was highly variable across short timeframes with bouts of hyperoxia and severe hypoxia. Furthermore, the growth of developing salmon in hypoxic conditions was slower than those raised in normoxia and hyperoxia, but may be dependent on developmental stage. Our results suggest that commercially grown Atlantic salmon experience large fluctuations in DO which are potentially affecting growth and development. Future results will help to elucidate the effect of oxygen availability on Atlantic salmon metabolic physiology, and the long term nature of phenotypic alterations.

List of Speakers

Plenary Lectures **Abstract page number**

Regular Presentations

Speed Presentations

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