

M.B. Hoar

*The Ninth Meeting
of
Comparative Physiologists*

The University of Sydney - 1992
December 4 - 6
School of Biological Sciences

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*The Ninth Meeting
of
Comparative Physiologists*

The University of Sydney - 1992
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*Organized by
Steve Morris & Mike Thompson*

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PROGRAMME

Friday, 4 December

10.00am - 1.45pm **Registration (Zoology Building)**

1.45pm **Introduction**

2.00pm - 5.20pm **Session 1**

Saturday, 5 December

8.00am - 8.40am **Registration (Zoology Building)**

8.40am **Session 2**

12.50am **Lunch (on Zoology lawn)**

2.00pm - 5.20pm **Session 3**

7.30pm **Conference Dinner (University of Sydney Club)**

Sunday, 6 December

8.00am - 8.40am **Registration (Zoology Building)**

8.40am **Session 4**

12.50am **Lunch (on Zoology lawn)**

2.00pm - 5.00pm **Session 5**

5.00pm **Award of Student Prize**

Business

All paper presentations will be in Lecture Theatre 1, Zoology

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PROGRAMME
Friday - December 4 (afternoon)

- 10.00am - 2.00pm **Registration**
- SESSION 1**
- 2.00pm **Osmotic and ionic regulation during breeding migrations of the land crab *Gecarcoidea natalis* on Christmas Island.**
Peter Greenaway
- 2.20pm **Respiratory and exercise physiology of the Christmas Island red crab *Gecarcoidea natalis*.**
Agnieszka M. Adamczewska & Steve Morris.
- 2.40pm **The *corrected* energetic cost of locomotion in the tammar wallaby.**
R.V. Baudinette, G.K. Snyder & P.B. Frappell
- 3.00pm **Oxygen carriage by blood of a very small newborn marsupial**
R.A.B. Holland, S.J. Calvert, R.M. Hope & C.M. Chesson
- 3.20pm **The hypoxic ventilatory threshold hemoglobin oxygen affinity relationship in burrowing owls.**
D.L. Kilgore, Jr., T.J. Kilgore, D.F. Boggs, C. Colby, B.R. Williams, Jr., & A.H. Oram
- 3.40pm **Tea/Coffee**
- 4.00pm **Developmental changes in the erythrocyte metabolism in bandicoot *Isoodon macrourus*.**
N.S. Agar and R.T. Gemmell
- 4.20pm **Effects of water acidification on the respiratory, acid-base and ion physiology of the "Yabby" *Cherax destructor*.**
Bronwyn A. Ellis and Steve Morris
- 4.40pm **Characterization of the ultrastructural properties of muscle fibres from the claw muscle of the yabby (*Cherax destructor*)**
Jan M. West, Danielle C. Humphris and D. George Stephenson
- 5.00pm **The role of the dorsoventral muscles in control of haemolymph pressure in crabs.**
H.H. Taylor, G.W. Davidson, L.H. Field & E.W. Taylor
- 5.20pm **END OF SESSION**

Saturday - December 5 (morning)

- 8.15 - 8.40am **Registration**
- SESSION 2**
- 8.40am **The benefits of dietary omega-6 fatty acids during protein-energy deprivation.**
Kerry Withers & A.J. Hulbert
- 9.00am **The maintenance nitrogen requirements of the Zebra Finch (*Poephila guttata*).**
L. R. (Rick) Allen
- 9.20am **The effect of starvation on the chemical composition of various tissues of the golden perch *Macquaria ambigua*.**
Adrian L. Collins & Trevor A. Anderson
- 9.40am **Effects of acclimation, starvation and dehydration on the thermal physiology of the scorpion *Urodacus manicatus*.**
Chris Holden
- 10.00am **Energy charge and inosine monophosphate accumulation in abdominal muscle of the brown tiger prawn *Penaeus esculentus* following trawl stress and simulated commercial shipment out of water.**
Brian Paterson
- 10.20am **Valve closure responses of the tropical freshwater mussel *Velesunio angasi* (Sowerby) exposed to sublethal uranium water concentrations.**
Scott J. Markich
- 10.40am **Tea/Coffee**
- 11.10am **Postural reflexes in the crayfish abdomen.**
Joanne M. Hausknecht and David L. Macmillan
- 11.30am **The muscle receptor organ of crustaceans - a window on neural evolution**
Elycia J. Wallis, David L. Macmillan & Laurence H. Field
- 11.50am **Spermatogenesis in the Japanese quail.**
M. Lin & R.C. Jones
- 12.10pm **Significance of the strategy of sperm production in birds**
R.C. Jones, J. Clulow & M. Lin
- 12.30pm **Experimental test of the energetic cost of parasitism in a wild host population.**
David T. Booth, Dale H. Clayton & Barbara Block
- 12.50pm **LUNCH**

Saturday - December 5 (afternoon)

SESSION 3

- 2.00pm **Radical evolutionary changes in embryonic development: mechanisms and consequences.**
R.A. Raff
- 2.20pm **Energetic costs of brooding young in the King quail**
J. Pearson
- 2.40pm **Energy budgets during lactation in the koala.**
A. Krockenberger
- 3.00pm **Short term and diurnal variation in plasma androgen concentration in captive male Koalas (*Phascolarctos cinereus*).**
Gina Cleva & Grant Stone
- 3.20pm **Oxytocin induces birth behaviour in marsupials**
A.S. Macfadyen, R.W. Rose & S.M. Jones
- 3.40pm **Tea/Coffee**
- 4.00pm **Variations in the pattern of energy metabolism in Australian desert rodents.**
Martin Predavec
- 4.20pm **Ventilation in the emu.**
S. Maloney & T.J. Dawson
- 4.40pm **Hypothermia and the maintenance of tissue potassium levels: effects of thyroid status, dietary fats and hypothermia.**
Michael Kennedy & A.J. Hulbert
- 5.00pm **Structure and functions of the genital ducts of the male Port Jackson shark, *Heterodontus portusjacksoni*.**
R.C. Jones & M. Lin
- 5.20pm **End of Session**

Sunday - December 6 (morning)

8.15 - 8.40am

Registration

SESSION 4

8.40am

The development of thermoregulation in the marsupial brushtail possum *Trichosurus vulpecula*.

Robert T. Gemmell & Gino Cepon

9.00am

Revving up the sodium pump during the evolution of endothermy: the influence of annular lipid.

M. Andrews & P.L. Else

9.20am

Membrane fatty acids and body size in mammals: liver and heart

Patrice Couture & A.J. Hulbert

9.40am

Structural correlates of fluid transport in the ductuli efferentes testis (DE) and proximal tubules of the kidney (PT) of the rat

S. Wang, J. Clulow & R.C. Jones

10.00am

Renal phosphate reabsorption and its regulation in red kangaroos.

A.M. Beal & S. Watson

10.20am

Comparative effects of vagal nerve stimulation in different vertebrate groups.

Elaine Preston & Gillian Courtice

10.40am

Tea/Coffee

11.10am

The MTF of clear natural waters and the design of aquatic eyes

W.S. Jagger & W.R.A. Muntz

11.30am

The nature of the image formed by the vertebrate eye

W.S. Jagger

11.50am

Cardiovascular effects of amphibian and mammalian tachykinins in the toad, *Bufo marinus*.

Gillian Courtice, Elizabeth Burcher, Rosaria Carlo-Stella & Michael Conlon

12.10pm

Steroidogenic response to angiotensin II in the Australian lungfish, *Neoceratodus forsteri*

Jean Joss & Richard Balment

12.30pm

The uptake of Radium-226 and radiocalcium from the aquatic medium by freshwater turtles from Magela Creek, Northern Territory

Ross A. Jeffree

12.50pm

LUNCH

Sunday - December 6 (afternoon)

SESSION 5

- 2.00pm **Liposomes from mammalian liver mitochondria are both more polyunsaturated and leakier to protons than those from reptiles.**
A.J. Hulbert, Patrice Couture & Martin D. Brand
- 2.20pm **Sex determination under fluctuating temperature regimes in the marine turtle *Caretta caretta*.**
Arthur Georges & Colin Limpus
- 2.40pm **Ovarian development in sexual and parthenogenetic geckos of the *Heteronotia binoei* complex.**
J.M. Whittier, C. Moritz, J.D. Roberts & D. Stewart
- 3.00pm **Investigating the periodic surfacing behaviour of *Limnodynastes peroni* larvae.**
Sharon Wong
- 3.20pm **Thermal, metabolic, and respiratory consequences of sleeping-site selection in the eastern water dragon, *Physignathus lesueurii lesueurii*.**
Matthew White
- 3.40pm **The effect of dietary fats on the selected body temperature and the tissue fatty acid composition of Central Netted Dragons**
Fritz Geiser
- 4.00pm **Tea/Coffee**
- 4.20pm **Scaling of anaerobic muscle work in estuarine crocodiles**
John Baldwin & Roger Seymour
- 4.40pm **How do Caiman tolerate salt water habitats in southern Brazil?**
G.C. Grigg, L.A. Beard, T. Moulton & M.T. Queirol Melo
- 5.00pm **END OF SESSION**
- Award of Student Prize**
- Preparations for 1993 - Hobart**
- Selection of venue for 1994**

Respiratory and exercise physiology of the Christmas Island red crab *Gecarcoidea natalis*.

Agnieszka M. Adamczewska & Steve Morris.

School of Biological Sciences, University of Sydney, Sydney, NSW 2006

The terrestrial Christmas Island Red Crab *Gecarcoidea natalis* is renowned for its annual breeding migration. The respiratory and circulatory physiology of *G. natalis* was investigated with respect to exercise. During a 45 min exercise period the function of the lungs in gas exchange, the circulatory system in gas transport and the energy status of the red crabs were determined.

The lungs of *G. natalis* were very efficient at O₂ uptake, pulmonary blood was 80-90% saturated. The respiratory pigment, haemocyanin delivered most of the O₂ to the tissues during rest (86%) and during exercise (97%). Determination of the site of CO₂ excretion was inconclusive but indirect evidence suggested the lung was involved in CO₂ excretion. The affinity of haemocyanin for O₂ decreased during the exercise period as a result of acidification of the blood but O₂ loading at the lungs was not impaired.

Energy production during the exercise required both aerobic and anaerobic contributions. Anaerobiosis resulted in extreme acidification of the haemolymph (0.79 pH units) during the 45 min of exercise. The glucose concentration increased in response to exercise, providing metabolic fuel for oxidation during increased energetic demands of locomotion. Aerobic metabolism during exercise in *G. natalis* is limited by O₂ diffusion from the blood into the tissues.

During the migration the red crabs must avoid L-lactate build up in the blood by either walking slowly or intermittently. However, *G. natalis* are exceptionally well adapted to cope with sustained locomotion and high acidification of the blood.

Developmental changes in the erythrocyte metabolism in bandicoot *Isodon macrourus*

N.S. Agar¹ and R.T. Gemmell²

¹Department of Physiology, University of New England, Armidale, NSW 2351

²Department of Anatomy, University of Queensland, Brisbane, QLD 4072

There are several structural and metabolic differences between the erythrocytes of the newborn and those of the adult humans. Erythrocytes of newborn infants possess a higher level of ATP, higher activity of many glycolytic enzymes and consume glucose at rates considerably faster than those observed in the cells of the normal adult. More or less similar situations exist in other eutherian animals studied.

In order to find out whether these metabolic features were also common in the marsupial red cells, we investigated the activities of 11 different enzymes associated with the glycolytic pathway, two miscellaneous enzymes and the lactate production using 5 different substrates in the red blood cells of young and adult bandicoots. Blood samples were obtained from 6 adult (4 males, body weight 1741, 1715, 1799 and 1842g and two females, body weight 948 and 994g) and four juveniles (two males, body weight 711 and 746 g and two females, body weight 525 and 578 g). The bandicoots were lightly anaesthetised with a halothane-oxygen mixture and 3 to 5 ml of blood obtained by cardiac puncture. The blood was placed into heparinised tubes and transported overnight on ice to Armidale.

The results indicate that the erythrocytes from the juvenile bandicoots had significantly greater activity of many of the enzymes and produced higher concentration of lactate from different substrates. It is therefore concluded that, similar to eutherian mammals, young marsupials also possess red cells that are metabolically more active than those of adult animals.

The Maintenance Nitrogen Requirements of the Zebra Finch (*Poephila guttata*)

L. R. (Rick) ALLEN

Charles Sturt University, Albury, NSW 2640

Comparison of the Maintenance Nitrogen Requirements (MNR) of mammals adapted to xeric, with that of mammals adapted to mesic or hydric environments, demonstrates the ecological significance of this physiological parameter for this taxon of animals.

The absence of any method for separating the nitrogen output of birds into components of metabolic and non-metabolic origin which does not introduce a new suite of sources of error, has resulted in little attention being given to this parameter in the avian literature.

Using a collation of results from other authors, Robbins (1981) calculated a value of $430 \text{ mgN.kgW}^{0.75}.\text{d}^{-1}$ as the MNR for "all birds" to be used as a baseline for comparison with values determined for individual species.

The Zebra Finch (*Poephila guttata*), an arid adapted granivorous passerine, has significantly lower Maintenance Nitrogen Requirements than Robbin's value for birds in general.

Revvng up the sodium pump during the evolution of endothermy: the influence of annular lipid

M. Andrews and P.L. Else

Biological Sciences, Deakin University, Geelong, Victoria 3217

An increase in sodium pump metabolism is part of the increased energy turnover of mammals (i.e. endotherms) versus ectothermic vertebrates (i.e. reptiles, amphibians and fish). Compared to tissues from ectothermic vertebrates, mammalian tissues show similar sodium pump densities yet greater ATP turnover when enzyme activities are measured. This suggest that mammalian sodium pumps have a higher turnover of ATP (i.e. molecular activity). This increased molecular activity was examined by purifying sodium pumps from mammalian and amphibian kidneys, which had previously been found to possess large molecular activity differences in intact tissue preparations. Specifically, the importance of annular lipid was examined by its graded removal using mild detergent (deoxycholate) treatment. Molecular activities were determined for these preparations. The molecular activity of the mammalian and amphibian sodium pumps converged towards a similar value as annular lipids were removed. These results would suggest that during the evolution of endothermy, sodium pump activity has been facilitated by the ability to alter the lipid environment possibly as a result of higher and constant body temperatures.

Scaling of anaerobic muscle work in estuarine crocodiles

John Baldwin¹ and Roger Seymour²

¹Department of Ecology & Evolutionary Biology, Monash University, Clayton, Vic. 3168

²Zoology Department, University of Adelaide, S.A. 5001.

The maximum rates of ATP consumption achieved by vertebrate skeletal muscle during exercise usually exceed the capacity for aerobic ATP production, and additional ATP is derived from anaerobic glycolysis. While mass specific aerobic metabolism scales inversely with body mass, the scaling of anaerobic metabolism is less well understood. Although several studies show an increase in maximum activity of glycolytic enzymes with body size, interpretation is obscured by the choice of non-rate limiting enzymes, and differences in locomotory behaviour which complicate intraspecific comparisons.

Estuarine crocodiles (*Crocodylus porosus*), because of their heavy dependence on anaerobic metabolism during exercise and large size range, provide an excellent system in which to study interspecific scaling of anaerobic muscle work. Wild crocodiles (0.3 - 180 kg) were exercised to exhaustion during capture in the Adelaide River, N.T., and the following parameters were measured: time to exhaustion; blood lactate, pH, PO_2 , PCO_2 ; tail muscle lactate, glycogen, pH, buffering capacity, maximum activities of phosphorylase, phosphofructokinase, lactate dehydrogenase, creatine kinase, citrate synthase, and pH sensitivity of rate limiting glycolytic enzymes. The major conclusions of this study are : 1. large animals exercise for longer and produce higher lactate concentrations and lower pH values than smaller animals; 2. smaller animals have higher activities of rate limiting glycolytic enzymes, and produce lactate faster; 3. the anaerobic capacity of crocodiles probably is limited by muscle glycogen stores. These conclusions have important implications for the management of large crocodiles during recovery from capture stress.

The corrected energetic cost of locomotion in the tammar wallaby

R.V. Baudinette,¹ G.K. Snyder² and P.B. Frappell³

¹School of Biological Sciences, Flinders University, Adelaide

²University of Colorado at Boulder; ³La Trobe University, Melbourne

Using a new respiratory gas sampling technique rates of oxygen consumption and blood lactate levels were measured in tammar wallabies (*Macropus eugenii*) trained to hop on a treadmill. In addition, the work required to overcome wind resistance during forward locomotion was measured in a wind tunnel. At speeds up to 2.0 m/s, rates of oxygen consumption increased linearly with speed and were not significantly different from rates of oxygen consumption for a quadruped of similar body mass. Between 2.0 and 9.5 m/s, rates of oxygen consumption were independent of hopping speed, and between 3.9 and 7.9 m/s, the range over which samples were obtained, blood lactate levels were low (0.83 ± 0.13 mmol·min⁻¹, kg⁻¹) and did not increase with hopping speed. The work necessary to overcome drag increased exponentially with speed but increased the energy cost of locomotion by only 10% at the average speed attained by our fast hoppers. Thus, during hopping, the energy cost of locomotion is effectively independent of speed. At rates of travel observed in the field, the estimated energy cost of transport in large macropods is less than one-third the cost for a quadruped of equivalent body mass.

Renal phosphate reabsorption and its regulation in red kangaroos.

A.M. Beal and S. Watson

School of Biological Sciences, University of N.S.W.

In most mammals, the capacity of the kidney to reabsorb phosphate from the filtrate is sufficiently low that normal plasma concentrations (1.0-1.5 mmol/l) approximate the plasma threshold concentrations for excretion. Ruminants are an exception in that the renal tubular maximum for phosphate reabsorption ($T_m\text{-PO}_4$) is substantially higher (sheep, 9-11 $\mu\text{mol.kg}^{-1}.\text{min}^{-1}$) than other mammals (e.g. man, $2.3 \pm 0.10 \mu\text{mol.kg}^{-1}.\text{min}^{-1}$) presumably because, as foregut fermenters, they need to conserve phosphate for secretion in the saliva. Kangaroos were investigated to ascertain whether the kidneys of these foregut fermenters also conserved phosphate by having a relatively-high renal $T_m\text{-PO}_4$. The kangaroos (24.5-29.5 kg) were anaesthetized and ventilated, tail vein and carotid artery loop cannulated, hydrated by i.v. infusion of dilute lactated-Ringer solution, bladder catheterized, primed and infused with inulin and PAH, and infused with phosphate for 4 h. Serial clearances (15 min duration) were taken throughout. The $T_m\text{-PO}_4$ was estimated to be $2.96 \pm 0.38 \mu\text{mol.kg}^{-1}.\text{min}^{-1}$. Acute i.v. infusion of salmon hormone 1-34 (12-18 nmol loading, 205-330 pmol/min for 210 min), or administration of 1,25 dihydroxycholecalciferol (5 nmol/12 h for 36 h im) did not alter phosphate reabsorption significantly ($T_m\text{PO}_4 = 2.9 \pm 0.34, 3.47 \pm 0.34 \text{ \& } 3.7 \pm 0.43 \mu\text{mol.kg}^{-1}.\text{min}^{-1}$ respectively).

Experimental test of the energetic cost of parasitism in a wild host population

David T. Booth¹, Dale H. Clayton² and Barbara Block³

¹Department of Zoology University of Queensland, St Lucia, QLD 4072

²Department of Zoology, Oxford University, Oxford, U.K.

³Department of Organismal Biology & Anatomy, University of Chicago, U.S.A.

Parasites may reduce host fitness through their influence on host energetics. Although laboratory studies reveal that parasites can alter host energetics, few attempts have been made to investigate the energetic cost of parasitism in wild populations. In this study we report the results of a long-term field study which, to our knowledge, constitutes the first experimental demonstration of an energetic cost of parasitism in wild hosts.

We experimentally increased the number of Ischnoceran chewing lice (Insecta: Phthiraptera) on wild Rock doves, *Columba livia*. We quantified feather damage caused by lice and their effect on molt. We also measured the effect of lice on host body temperature, thermal conductance, oxygen consumption and body mass. Although lice had no effect on body temperature or feather molt, they significantly reduced feather mass and increased thermal conductance and metabolic rate. Birds with high louse numbers also experienced a significant reduction in body mass over the course of the study. We suggest that the energetic cost of lice explains the poorer winter survival and mating success of lousy Rock doves noted in previous studies.

Short term and diurnal variation in plasma androgen concentration in captive male Koalas (*Phascolarctos cinereus*).

Gina Cleva and Grant Stone

Department of Veterinary Physiology, University of Sydney, Sydney 2006

As part of a programme to study the reproductive characteristics of koalas in captivity, six koalas were fitted with vascular access ports (Access Technologies™, Illinois). This system allowed single-handed and serial blood collection with minimal disturbance to the animal. Blood from ported males was collected for the measurement of androgen concentration in the peripheral plasma. To monitor possible stresses associated with blood collection, plasma cortisol was also measured.

During the 1991-92 breeding season, two male koalas were monitored every second day for 74 days, and then weekly for a further 17 weeks. Blood samples were taken at approximately the same time every day. The peripheral androgen concentration fluctuated widely over consecutive days, sometimes ranging from 6 ng/ml to below the limits of detection of the assay. These changes were not associated with changes in plasma cortisol concentration, which remained low throughout, only increasing at surgery or the introduction to a new enclosure or to females.

Five males, including the 2 fitted with ports were also bled monthly. Plasma samples were collected 6 times over 5 hours, from 09.00 h to 14.00h. The short term variation indicates large diurnal fluctuations in circulating androgen concentration. Most animals had their lowest levels early in the day, with an apparent peak a few hours later, these changes may result from the normally episodic nature of androgen secretion, however the results show the importance of awareness of the natural variation in a system when interpreting results from single samples.

The effect of starvation on the chemical composition of various tissues of the golden perch *Macquaria ambigua*.

Adrian L. Collins and Trevor A. Anderson

Faculty of Aquatic Science, Deakin University, Geelong, Victoria 3217.

The depletion of energy reserves in fish appears highly variable, with the three major energy stores lipid, glycogen, and protein being utilized in different orders and at different rates depending on the species. This study investigated the role of nutrition in regulating the chemical composition of selected tissues from golden perch (*Macquaria ambigua*). Fish were either fed daily to satiety, subjected to prolonged starvation (up to 210 days), or starved for 150 days then fed daily to satiety. Animals were sacrificed every 30 days, and the proximate composition of epaxial muscle, hepatic tissue, and whole carcass was determined for each specimen. In addition, glycogen levels were determined in epaxial muscle and liver. This information will be presented to demonstrate the influence of food deprivation on the energy metabolism of *M. ambigua*.

**Cardiovascular effects of amphibian and mammalian tachykinins
in the toad, *Bufo marinus*.**

Gillian Courtice, Elizabeth Burcher, Rosaria Carlo-Stella and Michael Conlon

*School of Physiology & Pharmacology, University of New South Wales,
Kensington, NSW 2033*

The tachykinins are a family of structurally related peptides which have been identified in the central nervous system and peripheral tissues from a wide range of vertebrate and invertebrate species, and which are known to have cardiovascular actions. Although the mammalian tachykinin, Substance P, has profound vasodilator effects in mammals, it seems likely that Substance P itself does not occur in other vertebrates, but rather other similar peptides may exist. We compared the cardiovascular actions of Substance P, 2 amphibian tachykinins, ranakinin and physalaemin, and neurokinin B which is found in both groups, in anaesthetised toads. All four produced dose-dependent decreases in blood pressure, though ranakinin was the most potent. None produced effects on heart rate or affected the ability of the vagus nerves to slow the heart. A selective antagonist for mammalian Substance P-preferring receptors (NK1 receptors) had no effect on the depressor action of ranakinin or Substance P in the toad. It is suggested that the observed depressor effects in the toad are mediated by an NK1-like receptor, which differs substantially from its mammalian counterpart.

Membrane fatty acids and body size in mammals: liver and heart

Patrice Couture and A.J. Hulbert

Department of Biology, University of Wollongong, Wollongong, NSW 2522

Many metabolic processes are indirectly dependent on the properties of the cell membranes, such as fluidity and permeability, and in turn, these properties are influenced by the fatty acid composition of the phospholipids that form the membrane bilayer. Higher polyunsaturation leads to increased permeability and fluidity of a lipid bilayer. In a comparison of the high level of metabolism in endotherms compared to ectotherms it has been shown that liver cell membranes are "leakier" to sodium and potassium and also that liver mitochondrial membranes are "leakier" to protons in rats compared to lizards. Phospholipids from liver, kidney and skeletal muscle of rats are more polyunsaturated than those from lizards. Similarly, liver mitochondrial membranes from the rat are more polyunsaturated than lizard liver mitochondrial membranes. We have examined the membrane fatty acid composition from another situation where metabolic rate varies; the well known body size - metabolic rate relationship. Phospholipids have been extracted from liver and heart of eutherian mammals ranging in size from mice to cattle and their fatty acid composition determined. As with the endotherm-ectotherm comparison, the animals with the higher metabolic rates also have more polyunsaturated cell membranes. There was an increase in the relative polyunsaturation of cell membranes in both liver and heart from cattle to mice. Whilst membrane fatty acid composition is tissue-specific, in each animal investigated the unsaturation index (an indicator of the number of double bonds in the fatty acid chains, or the degree of unsaturation) is always higher in the heart. The implications of these findings in terms of the relationship between membrane composition and metabolic rate will be discussed.

Effects of water acidification on the respiratory, acid-base and ion physiology of the "Yabby" *Cherax destructor*

Bronwyn A. Ellis and Steve Morris

School of Biological Sciences, University of Sydney, Sydney, NSW 2006

The physiology of the Australian freshwater crayfish *Cherax destructor* was investigated with regard to the potential acidification of its environment. The study examined how well the crayfish coped with acid exposure and whether water calcium modulates the physiological response. Acid water ($500 \mu\text{mol.L}^{-1} \text{Ca}^{2+}$) caused a minor blood acidosis in *Cherax*, a 35% decrease in blood $[\text{Na}^+]$ and carapace demineralisation after 4 days. Maintenance of blood pH of *Cherax* in lower $[\text{Ca}^{2+}]$ water was only prevented *via* a more severe ion disequilibrium. Oxygen extraction from the blood decreased during acid water exposure. Metabolic rate was depressed by at least 75%. Anaerobiosis was not required for energy supplementation. The data provide evidence that the limitations placed on the energy production of *Cherax* in $500 \mu\text{mol.L}^{-1} \text{Ca}^{2+}$ acid water are exacerbated in lower $[\text{Ca}^{2+}]$ water. The physiological response of *Cherax* to acid water essentially re-establishes homeostasis in the face of reduced energy availability, thereby maintaining an environment for vital cellular processes. It appears that this can only be achieved *via* a reduced capacity to carry out normal physical processes such as growth, feeding and movement.

The effect of dietary fats on the selected body temperature and the tissue fatty acid composition of Central Netted Dragons

Fritz Geiser

Department of Zoology, University of New England, Armidale, NSW 2351

The composition of tissue and cellular membrane fatty acids in ectothermic vertebrates is influenced by temperature acclimation and diets. If such changes in body lipid composition and thermal physiology were linked, a diet-induced change in body lipid composition should result in a change in thermal physiology. Therefore, the effect on the selection of body temperature (T_b) of two diets, that differed in the content of polyunsaturated fatty acids, was examined in central netted dragons, *Amphibolurus nuchalis* (body mass 20 g). Tissue fatty acid composition was also determined. The selected T_b in two groups of lizards was indistinguishable before dietary treatments. The selected T_b in lizards after 3 weeks on a diet containing high amounts of saturated fatty acids rose by 2.1°C (photophase) and 3.3°C (scotophase); whereas the T_b of lizards on a diet containing high amounts of unsaturated fatty acids fell by 1.5°C (photophase) and 2.0°C (scotophase). Significant diet-induced differences were observed in the composition of total lipid fatty acids of depot fat, liver and muscle. The saturated/unsaturated fatty acid ratio of tissues (an indicator of lipid fluidity) was positively correlated with the selected T_b . These observations suggest that dietary lipids may influence selection of T_b in ectotherms via alterations of body lipid composition. The diet-induced change in thermal physiology also suggests a role of nutritional ecology in the seasonal acclimatization of ectotherms.

**The development of thermoregulation in the marsupial
brush-tail possum *Trichosurus vulpecula***

Robert T. Gemmell and Gino Cepon

Anatomical Sciences, University of Queensland, St Lucia, QLD 4072

Small transmitters were used to monitor temperature over the 24 hour period without disturbance to the mother and young. Adult possums showed a circadian rhythm of with a peak in body temperature around midnight and a trough at noon. The young possum within the pouch displayed a circadian rhythm with the highest temperatures during the day and the lowest in the early evening. Occasionally the body temperature of the young possum exceeded that of the mother, however for the major part of the 24 hours it was lower than that of the mother. The circadian temperature rhythm was first observed in the young possum between day 165 and 190 post partum.

**Sex determination under fluctuating temperature regimes
in the marine turtle *Caretta caretta***

Arthur Georges¹ and Colin Limpus²

¹Applied Ecology Research Group, University of Canberra

²Queensland National Parks and Wildlife Service

Numerous laboratory studies have demonstrated an influence of constant incubation temperatures on hatchling sex ratios. In natural nests, however, seasonal trends and diel cycles in nest temperature can be expected to complicate the influence temperature has on sexual differentiation. When temperatures cycle, it becomes important to know whether it is time spent at a particular temperature, or proportion of total development that occurs at that temperature, that best predicts the outcome of sexual differentiation. A model has been developed to distinguish between these two possibilities and has been tested using the marine turtle *Caretta caretta*. Eggs incubated at a mean male-producing temperature of 26°C yielded sex ratios ranging from 0% females (26 ± 0, 26 ± 3°C) to ca. 50% females (26 ± 5°C) to 100% females (26 ± 7, 26 ± 8°C) when temperatures were fluctuated daily. These results are in close agreement with the model's predictions. An extension of the model is presented, based on degree-hours relative to a developmental zero, which allows for variations from strict sinusoidal daily cycles in temperature and for species with dual thresholds.

**Osmotic and ionic regulation during breeding migrations
of the land crab *Gecarcoidea natalis* on Christmas Island.**

Peter Greenaway

School of Biological Science, University of New South Wales, Kensington 2033

Gecarcoidea moves from all parts of the Island to the coast in a coordinated migration commencing at the start of the wet season. On arrival at the coast they immerse themselves in seawater for many hours. The effect of migration, and the period of immersion, on the concentration and inorganic composition of the blood were determined and an osmoregulatory rationale for the immersion behaviour is suggested.

How do Caiman tolerate salt water habitats in southern Brazil?

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The Broad-snouted Caiman, *Caiman latirostris*, has a primarily freshwater distribution in South America, but occurs also in estuaries. Unlike Crocodylidae, Alligatoridae are not known to have lingual (or other) salt glands.

In May 1992 we visited Ilha do Cardoso in southern Brazil and captured 18 *C. latirostris* in freshwater and in estuarine conditions as concentrated as 24‰, more than twice the osmolarity of crocodylian blood plasma. Analyses of blood and urine samples revealed that the animals are competent hyperosmotic and hypoosmotic regulators. In this paper we will discuss the mechanism of their regulation and speculate about the significance of the findings to ideas about the evolution of salt water adaptation by crocodylians.

Postural reflexes in the crayfish abdomen

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Neural processes controlling posture in the crayfish abdomen have been used to produce models for investigating principles of motor system organisation. The vertebrates provide numerous situations in which it is possible to compare open-loop and closed-loop organisation of motor control, but feedback situations can be difficult to analyse as they involve large numbers of neurons. Crustaceans have far fewer neurons so that the organisational principles are more accessible. Peripherally located muscle receptor organs (MROs) have an important role in maintaining abdominal posture. The MROs lie in parallel with the abdominal extensor muscles of the crayfish abdomen and have been implicated in load-compensating postural reflexes. The current project involves an intracellular investigation of MRO reflexes in *Cherax destructor*, with emphasis on the load compensation reflex. The techniques of extracellular and intracellular stimulation and recording are combined with intracellular dye filling to give a clear picture of the processes involved in maintaining abdominal posture. Current results reveal a number of cells that respond to intrasegmental and nerve cord stimulation. These cells have been collected on the basis of their physiology and structure.

Effects of acclimation, starvation and dehydration on the thermal physiology of the scorpion *Urodacus manicatus*

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Little is known about how environmental factors influence temperature selection and metabolism of scorpions. Therefore, effects of temperature acclimation, starvation and dehydration on body temperature (T_{skin}) selection and standard metabolic rate (SMR) were investigated in the scorpion *Urodacus manicatus*.

All individuals were acclimated to T_a 25°C for 21 days. Animals were divided into two groups acclimated to either T_a 15°C or 35°C for 7 days. Acclimation to 15°C resulted in a 6 to 9°C greater selected T_{skin} than that of scorpions acclimated to 35°C. SMR was indistinguishable suggesting that temperature acclimation induced behavioural rather than physiological changes.

The SMR increased 1 day after feeding, fell to pre-feeding values 5 days after feeding and the lowest values were observed 42 days after feeding. The selected T_{skin} fell 1 day after feeding but rose again 21 days after feeding. A reduced metabolism after prolonged periods without food conserves food stores while predatory activity is maintained by selecting higher temperatures.

A reduction in mass by 20% during dehydration resulted in a decrease of whole animal SMR and an increase in mass specific SMR. The selected T_{skin} was lowered by 8 to 10°C suggesting that both physiological and behavioural mechanisms exist to conserve water.

The present study suggests that *Urodacus manicatus* can physiologically tolerate long term temperature changes, however, reduced food and water availability appear more critical. The appropriate selection of body temperature may enhance survival during starvation and dehydration.

Oxygen carriage by blood of a very small newborn marsupial

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Previous work has shown that the oxygen equilibrium curve (OEC) of 2 newborn marsupials (Tamar Wallaby and Brushtail Possum) is shifted to the right of the maternal OEC. This right shift has also been shown prenatally in the Wallaby which is in contrast to findings in all other viviparous species. We wished to see if the special features of these newborn and prenatal OECs were also found in the Dasyurid family of marsupials, which are much smaller at birth. In this study, the young of the fat-tailed Dunnart (*Sminthopsis crassicaudata*) were studied. The adults weigh about 15g, and at birth, the young weigh about 10 mg. The animals were obtained from the colony in the Genetics Department, University of Adelaide. From 6 young, 3 days old or less, the mean P_{50} was 39 mmHg at 36°C and at $PCO_2 = 42$ mmHg. This was less than that of the mothers, which was 59 mmHg under the same conditions. The newborn P_{50} is less than that in other newborn marsupials (Wallaby 45 mmHg; Possum 43 mmHg) which are larger at birth, but is higher than that reported in any eutherian embryo or foetus. However the right shifted position of the adult OEC in these very small animals means that the neonatal OEC is to the left of the mother's. Features found in newborn Wallabies and Possums (Hill $n > 4$, decreased Bohr effect, and multiple haemoglobins) were also found in this species.

Liposomes from mammalian liver mitochondria are both more polyunsaturated and leakier to protons than those from reptiles

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The very high level of basal metabolism of the endothermic mammal relative to the ectothermic reptile is associated with liver mitochondria whose inner membranes are considerably leakier to protons and are also considerably more polyunsaturated than the liver mitochondrial membranes from the reptile. In order to determine if there is any connection between these two findings we have examined the proton permeability of liposomes prepared from phospholipids extracted from liver mitochondria of the rat (*Rattus norvegicus*) with those from the bearded dragon (*Amphibolurus vitticeps*), an agamid lizard. Proton permeability was measured at an imposed membrane potential of 160mV and was significantly greater in liposomes prepared from mammalian liver mitochondrial phospholipids than in liposomes prepared for reptilian liver mitochondrial phospholipids. The mammalian phospholipids were also more polyunsaturated and there was a significant correlation between the omega 3 fatty acid content of the liposomes and their proton permeability. These findings suggest that at least part of the high level of metabolism in endothermic mammals compared to their ectothermic reptilian predecessors can be explained by an increased proton leak across the more polyunsaturated mitochondrial membrane bilayer.

The MTF of clear natural waters and the design of aquatic eyes

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Do natural waters limit the transmission of high spatial frequencies and the potential usefulness of high acuity to aquatic animals? The highest reported behaviourally determined acuity for aquatic animals is only about 8 c/deg. Turbid water obviously limits the useful range of aquatic vision, but many natural waters are relatively clear. We examined the ability of water from the Great Barrier Reef, Bass Strait, and the Steavenson River, a clear mountain stream, to transmit high spatial frequencies.

The modulation transfer function (MTF) of samples of these clear natural waters was measured under unlighted and diffusely lighted conditions for path lengths up to 4 m and spatial frequencies up to 150 c/deg. The measuring conditions simulated horizontal aquatic vision.

The modulation transfer properties of these waters do not preclude high aquatic visual acuity. However, the useful range of high acuity vision in diffusely lighted water is much less than in unlighted water. This places special requirements upon the design of high-acuity aquatic eyes.

The nature of the image formed by the vertebrate eye

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What is the nature of the image of a point object (the pointspread function or PSF) formed by the vertebrate eye? The PSF offers the key to understanding the optical performance of an eye. The optical design of an eye is affected by structural irregularity and scattering within the media, and by the lack of media of differing dispersion, which might allow correction of chromatic aberration. As a result, the optical performance differs strongly from that of a high-quality camera lens.

In monochromatic light, the trout PSF is irregular in shape as a result of deviations from rotational symmetry in the lens structure. In addition, the PSF is modulated by high-contrast speckle due to light scattering within the lens and cornea. Speckle presents a granular image structure, usually associated with the highly coherent light of lasers. In the absence of speckle, the PSF is broad and is not diffraction-limited. In white light, the dispersion of lens substance results in strong chromatic aberration. The PSF exhibits concentric coloured bands, and the speckle is reduced.

The implications for vertebrate vision of this image irregularity, speckle, and dispersion are discussed.

The uptake of Radium-226 and radiocalcium from the aquatic medium by freshwater turtles from Magela Creek, Northern Territory

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Freshwater turtles from Magela Creek are components of the traditional diet of Aboriginal communities living downstream of the Ranger Uranium Mine. These turtles may become exposed to elevated Radium-226 water concentrations in mine effluents. Experimental studies were conducted to investigate their ability to accumulate radium and radiocalcium from their aquatic medium under varying Ca and Mg water concentrations. Studies on the anatomical sites of their accumulation from the aquatic medium compared the importance of the cloacal and buccopharyngeal routes.

Significance of the strategy of sperm production in birds

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We previously suggested that, compared to mammals, sperm production in birds involves rapid formation, maturation and transport through the male genital ducts, in association with a limited capacity for long term storage. However, considering that most birds are monogamous the adaptive advantage of the greater rate of sperm production in birds than mammals is not obvious. Recent work indicates that there is selective pressure for cock birds to produce numerous ejaculates per day as hens mate outside the monogamous pair, and the last sperm to be inseminated prior to ovulation have the greatest chance of fertilising the egg. In this report we propose that, because hens ovulate daily for days or weeks to produce a clutch, cock birds have evolved a rapid rate of sperm production in order to deliver numerous inseminations per day over the period that a clutch is laid. By comparison, even polytocous mammals ovulate all of the eggs of a litter within a few hours, so that mating only extends over a day or so, and the sperm available for ejaculation may accumulate in the epididymis over several days or a week. For example, whereas a quail cock may produce 26 inseminations daily only a rested ram can deliver that number of inseminations in a day, and only 2 inseminations per day thereafter.

Structure and functions of the genital ducts of the male Port Jackson shark, *Heterodontus portusjacksoni*

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The genital ducts of *H. portusjacksoni* consist of the sperm carrying ducts (the rete testis, ductuli efferentes, and initial and terminal segments of the ductus epididymidis) and the Leydig glands. The ducts are lined by a ciliated epithelium which maintains a barrier to the transport of solute between blood and the lumen of the duct. Spermatozoa, Sertoli cell bodies, Sertoli cell cytoplasm and cellular 'debris' are released from spermatocysts into the rete testis. However, only the Sertoli cell cytoplasm persists throughout the sperm ducts. The epithelia lining the initial segment of the ductus epididymidis and secretory tubules of the Leydig glands are specialized for protein secretion and must be the main source of luminal protein in the ductus epididymidis. The epithelium lining the terminal segment of the ductus epididymidis also secretes protein, reabsorbs fluid and sodium, and may carry out heterophagic digestion. Spermatozoa develop the capacity for motility in the extratesticular sperm ducts, but do not undergo structural changes. However, they form spherical bundles in the terminal segment of the ductus epididymidis. It is suggested that the reduction in ratio of sodium:potassium from 48.8 in the ductuli efferentes to 3.4 in the distal end of the terminal segment of the ductus epididymidis may favour sperm survival.

Steroidogenic response to angiotensin II in the Australian lungfish, *Neoceratodus forsteri*

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Immediately following capture, lungfish were given an intramuscular injection (0.31 mg/kg in saline 1.0 ml/kg) of [Asp¹, Ile⁵] - angiotensinII (AII). Control fish received the saline alone. Plasma aldosterone, corticosterone and cortisol levels were measured from blood samples taken 1-2 hours after injection. Cortisol was not detected in the plasma of either AII-injected or vehicle-injected fish. Both aldosterone and corticosterone were measurable, corticosterone being present in approximately 40-fold the concentration of aldosterone. Only the aldosterone levels, however were significantly elevated in response to the AII injection (27.26 ± 2.70 to 44.29 ± 3.79 pg/ml). The raised level of aldosterone in the plasma was not correlated with corresponding changes in the concentration of sodium or potassium ions.

The specific steroidogenic action of [Asp¹] AII observed is in contrast to the failure of Blair-West *et al* (1) in their study of *Neoceratodus* to observe an effect of [Asn¹] AII on plasma steroid levels. This may be related to the difference in type of AII administered, in the dose (0.2-0.4 ug/kg.h), in the mode of administration (i.v. infusion) or in the use of chronically cannulated animals in laboratory conditions. The use of a tetrapod-type AII, [Asp¹] AII, rather than the teleostean-type, [Asn¹] AII, employed by Blair-West *et al* is probably the most important difference between the two studies. Although it is not yet known which type of AII is present in lungfish, the difference in response between the two studies suggest that it is more likely to be of the tetrapod-type.

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Hypothermia and the maintenance of tissue potassium levels: effects of thyroid status, dietary fats and hypothermia

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Although they have evolved from ancestors that can tolerate low body temperatures, homeothermic mammals are in general unable to survive body temperatures much below 20°C. One explanation as to why this is the case is that at low body temperatures they are unable to maintain ion gradients across their cell membranes, specifically potassium/sodium gradients. We have compared the ability of isolated liver slices from the rat and the cane toad to maintain tissue potassium levels at temperatures ranging from 37°C to 7°C. Whilst toad liver slices were able to maintain reasonable tissue potassium levels at all temperatures rat liver slices were only able to maintain tissue potassium levels at temperatures above approximately 20-25°C. At temperatures of 19°C and below the rat liver slices showed a significant loss of tissue potassium. In the light of information gained from studies of hibernating mammals we also examined the effect of (i) thyroidectomy, (ii) increased dietary polyunsaturated fatty acids (both omega-6 and omega-3 polyunsaturates) and (iii) previous hypothermia on the ability of rat liver slices to maintain tissue potassium levels. All treatments examined enhanced the ability of the liver slice to maintain tissue potassium at low temperatures to varying degrees. Compared to the normal rats there was not a significant loss of tissue potassium at 19°C in liver slices from any of the experimental treatments.

The hypoxic ventilatory threshold hemoglobin oxygen affinity relationship in burrowing owls

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Earlier reports of a blunted ventilatory response of burrowing owls to low levels of inspired oxygen (F_{I,O_2}) are enigmatic considering the relatively low oxygen affinity of their hemoglobin (Hb). If, as has been suggested, selection favors a strong linkage between ventilation and oxygen transport in hypoxia, owls expectedly might have a high rather than low hypoxic ventilatory threshold (HVT). Consequently, we measured ventilation and blood gases in 8 burrowing owls breathing hypoxic gas mixtures. Ventilation remained unchanged at P_{I,O_2} 's greater than 55 Torr. By comparison, the HVT of the pheasant, with a similar P_{50} , is nearly 20 Torr higher. However, ventilation in burrowing owls is elevated at approximately 80-85% Hb- O_2 saturation as in other species. The steep upper limb of the oxygen equilibrium curve in burrowing owls (Maginniss and Kilgore, *Respir. Physiol.* 76: 205-214, 1989) probably accounts for what appeared to be an exception to the HVT/Hb- O_2 affinity relationship in birds. Supported by NSF grant DCB-8811413 to DLK.

Energy budgets during lactation in the koala

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Koalas, as well as other arboreal folivores, are perceived to be limited by the energetic constraints of their diet and mode of life. Reproduction, especially lactation, places large energetic demands on mammalian mothers and is potentially of great significance to an energetically limited animal. Energy budgets for average (6 kg) lactating and non-lactating koalas were been calculated to assess their requirements for reproduction and the effects of those on their ecology. The calculations use measured values of field and resting metabolic rates and lactational energy output.

The field metabolic rate of lactating and non-lactating females are equal at peak lactation (1700 $\text{kJ}\cdot\text{d}^{-1}$), but there is considerable seasonal variation (1232 $\text{kJ}\cdot\text{d}^{-1}$ in Spring/Summer to 2238 $\text{kJ}\cdot\text{d}^{-1}$ in winter). Resting fed metabolic rates (RMR) of lactating females (0.303 $\text{ml O}_2\cdot\text{g}^{-1}\cdot\text{h}^{-1}$ or 878 $\text{kJ}\cdot\text{d}^{-1}$) are greater than those of non-lactating females (0.249 $\text{ml O}_2\cdot\text{g}^{-1}\cdot\text{h}^{-1}$ or 720 $\text{kJ}\cdot\text{d}^{-1}$). The standard metabolic rate (fasted 24h, non-lactating) measured in this study (0.253 $\text{ml O}_2\cdot\text{g}^{-1}\cdot\text{h}^{-1}$ or 1.41 $\text{W}\cdot\text{kg}^{-1}$) is 12% greater than the only previous measurement (1.26 $\text{W}\cdot\text{kg}^{-1}$) and 98% of the predicted level for marsupials.

The energetic costs of milk production in koalas are not compensated by a reduction in maintenance metabolism. The difference in RMRs of lactating and non-lactating females (878-720=158 $\text{kJ}\cdot\text{d}^{-1}$) accounts for 90% of the production costs (173 $\text{kJ}\cdot\text{d}^{-1}$). As total budgets (FMR) are equal in lactating and non-lactating females, the milk production costs (173 $\text{kJ}\cdot\text{d}^{-1}$) must be met by a decrease in activity and/or thermoregulatory requirements.

Spermatogenesis in the Japanese quail

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Spermatogenesis in birds is of particular interest as a cellular association of the seminiferous epithelium occupies only a small area of tubule as in primitive mammals and primates such as man. However, the small associations and the filiform structure of avian spermatozoa make it technically difficult to determine the process of spermatogenesis in the bird. Nevertheless, by examining epoxy embedded material we have determined 10 cellular associations in the Japanese quail. This report describes the stages, spermatogonial renewal and proliferation (4 mitotic divisions), the total duration of spermatogenesis (estimated to be 12.77 days from the division of A₄ spermatogonia to sperm release) and the spiral arrangement of the stages of spermatogenesis along the seminiferous tubule. Counts of the number of spermatids per bundle (31.7 ± 0.3) indicate that there is no loss of germ cells during spermatogenesis in the quail. Differences in the processes of spermatogenesis in the quail and mammals will be discussed.

Oxytocin induces birth behaviour in marsupials

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Birth in the Tasmanian bettong (*Bettongia gaimardi*), is followed by a post-partum oestrus and mating, resulting in blastocyst formation. Whilst the pouch is occupied, this blastocyst remains quiescent until near the end of pouch life when re-activation occurs. The subsequent birth precipitates final pouch vacation and we have shown that one of the hormones involved in uterine contractions and birth behaviour, Prostaglandin F₂α, also induces pouch vacation. We now report that another hormone, Oxytocin, long known to cause uterine contractions at birth in mammals also results in both birth behaviour and pouch vacation in the bettong and in several other marsupials. The dosage of 0.5-1.0 I.U. intramuscularly has similar effects to PGF₂α but with a longer latency, reduced intensity and diminished duration. As this response was blocked by prior administration of PGF₂α inhibitors, we believe that this response to Oxytocin is mediated via Prostaglandin synthesis.

Ventilation in the emu

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We studied ventilation in the emu at a range of ambient temperatures from -5 to 45°C. At low ambient temperatures the ventilatory system must accommodate the increased metabolic demand for oxygen. In the emu this is achieved by a combination of increased Tidal Volume (V_t) and Oxygen Extraction (EO_2). EO_2 can exceed 50%.

At higher ambient temperatures ventilation is increased to facilitate Respiratory Water Loss. The emu achieves this via increased respiratory frequency (f). At moderate heat loads (30-35°C), V_t falls. This is usually interpreted as a mechanism whereby RWL can be increased without increasing alveolar ventilation. At 45°C V_t increases, however past studies (Jones, Grubb and Schmidt-Neilsen 1983) have shown CO_2 washout is minimal under these conditions. The mechanism whereby this is possible is discussed.

Valve closure responses of the tropical freshwater mussel *Velesunio angasi* (Sowerby) exposed to sublethal uranium water concentrations

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Elevated uranium concentrations present in waste waters from the Ranger Uranium mine may limit discharge into the receiving waters of the Magela Creek, Alligator Rivers Region, Northern Territory, Australia, during the Wet Season, when large volumes of water may accumulate at the mine site. The valve movement patterns of the freshwater mussel *Velesunio angasi* (Sowerby), which is ubiquitous and abundant throughout the Magela Creek, were monitored during exposure to varying sublethal levels of uranium, in the context of using the valve closure (behavioural) responses of this bivalve to indicate the biological significance of elevated uranium water concentrations. The results indicate that selected valve closure responses of *V. angasi* provide promise as behavioural endpoints for the evaluation of waters containing elevated levels of uranium. Globally, bivalves may serve as useful early warning systems for aquatic contaminants by providing a rapid and sensitive evaluation of water quality.

Energy charge and inosine monophosphate accumulation in abdominal muscle of the brown tiger prawn *Penaeus esculentus* following trawl stress and simulated commercial shipment out of water.

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The adenylates (ATP, ADP and AMP) and inosine monophosphate (IMP), a degradation product of AMP, were measured in the abdominal muscle of brown tiger prawns *Penaeus esculentus* caught by trawling and during live transport. The energy charge of the prawns was very low after trawling (0.3 to 0.5) and high levels of lactate and IMP were present in their tissues. Prawns that were allowed to recover in holding tanks showed fluctuations in total adenylate pool which suggest that purine metabolism is disturbed by trawl stress, though resting ratios of adenylates were resumed. When these prawns were subsequently cooled and packed in dry sawdust, according to commercial practise, their energy charge fell steadily. Lactate only accumulated after the energy charge fell to pathological levels (about 0.5) however, the IMP level increased prematurely at an AEC of 0.86. AMP is not deaminated in crustaceans when the energy charge falls this low during exercise, so the faster than expected rise in IMP level in the prawns may be a sign of injury during trawling.

Energetic costs of brooding young in the King quail

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Female King quail *Coturnix chinensis* (40-60g) typically form a well developed broodpatch during early incubation. This small species broods the young for prolonged periods after hatching until about fledging, dependent on ambient temperature. The role of the broodpatch in heat transfer to the chicks is poorly understood, and so this study considers how the adult quail meet the high thermal requirements of small precocial quail chicks.

Aspects of the thermoregulatory physiology of both breeding and non-breeding quail were compared to determine if the presence of a broodpatch affects the metabolism of broody female quail. Energy expenditure of adult quails whilst brooding chicks of different ages, was measured using open-flow respirometry to determine if there were any significant brooding costs above resting metabolic levels.

Oxygen consumption of broods during brooding was determined by placing broods of chicks in a metabolic chamber with an artificial hen maintained at adult body temperature. Brood metabolism was subsequently subtracted from adult brooding VO_2 measurements to determine the adult metabolic contribution.

Despite visible increases in vascularisation of the broodpatch regions and large arteria, breeding female King quail were not significantly different from non-breeding quail in resting metabolic rates. However, adult quail brooding chicks were found to increase metabolism above resting levels at all ambient temperatures below 30°C. Though relatively inactive whilst brooding chicks, adult quail appear to have an additional energetic burden throughout the developmental period of their chicks in this species of quail.

Variations in the pattern of energy metabolism in Australian desert rodents

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Many desert rodents have physiological adaptations to desert life, that include using hyperthermia under conditions of high ambient temperature (T_A), and torpor in conditions of low T_A or restricted food. Australian desert rodents show many of these adaptations but, until now, it has been thought that no Australian rodent entered torpor. In the present study, *Pseudomys hermannsburgensis* showed a marked reduction in metabolic rate at T_A lower than 20°C, with a corresponding decrease in body temperature. This result differs from that in the published literature for the same species, where the animals did not enter torpor. In addition, the animals' body temperatures were 3 - 4°C lower than the published body temperature, within the thermal neutral zone, and the metabolic rates in the thermal neutral zones were also correspondingly lower. Furthermore, animals kept in the laboratory for long periods show increased basal metabolic rates and body temperatures. Also, animals captured in the field in different years showed variation in the pattern of energy metabolism. It is clear that *P. hermannsburgensis* can display remarkable variation in energy metabolism, though the extent to which this is used in natural situations, and the adaptive significance, is unclear. This study emphasises that we must be careful basing findings on a single sample, or on long-term captive animals, especially for species which live in such a variable and unpredictable environment.

Comparative effects of vagal nerve stimulation in different vertebrate groups

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The autonomic nerves controlling the heart have developed from vagal innervation only, in Elasmobranchs, to an antagonistic system of vagus and sympathetic nerves in mammals. In mammals the right vagus mainly innervates the sino-atrial node and is more effective at slowing the heart than the left, which preferentially innervates the atrio-ventricular node. However, there is thought to be considerable overlap in the target sites of the right and left vagi. In the present study we investigated the effects of stimulating the right and left vagi in another vertebrate group, the Amphibia. Stimulation of each nerve separately and together in the toad, *Bufo marinus*, at 5 frequencies between 0.2-1Hz showed no significant difference between the response of the right and left vagi. In addition, when both nerves were stimulated together the effect was equal to the sum of the responses when the nerves were stimulated separately. The cardiac vagal nerve endings in the toad also contain neuropeptides which have potent cardiac effects. The results above are compared with the cardiac response to release of the neuropeptide, somatostatin from both left and right vagi. The results suggest that there is limited overlap in receptor fields of each nerve in this group.

Radical Evolutionary changes in embryonic development: mechanisms and consequences

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Early development is generally regarded as conserved in evolution. However, there are cases, such as in the Australian sea urchin genus *Heliocidaris*, in which closely related species have evolved strikingly different modes of development. *H. tuberculata* produces a feeding pluteus larva, whereas *H. erythrogamma* develops directly into a juvenile sea urchin from an egg 100 times the volume of that of its congener. We have shown that these changes took place within the past 8 to 10 million years. Our investigations of mechanisms underlying the change in developmental mode have shown that a profound remodelling of development has taken place. Changes include distribution of maternal information in the egg, dorso-ventral axis determination, cleavage patterns, decisions in the allocations and timing of cell lineages, cell fates, gastrulation and morphogenetic movements. Genetic regulatory changes will be discussed, as will implications for the stability of body plans in evolution, and for the structure of ontogenetic processes.

The role of the dorsoventral muscles in control of haemolymph pressure in crabs

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The dorsoventral muscles (DVM) are a series of short muscles that extend through the branchiostegites from the carapace to the flexible roof of each branchial chamber. We propose that the DVM contribute to a baroreflex that compensates for short-term changes in internal volume and hydrostatic pressure. Such changes could occur routinely (e.g., during ingestion, defecation, urine release, osmosis, desiccation) and, because of the crab's rigid exoskeleton, might otherwise distort the highly compliant gills and interfere with respiratory haemolymph flow. Methylene blue staining and electromyography (EMG) indicate that the anterior DVM of *Ovalipes catharus* receive a single motor axon that generates shared tonic excitatory spikes of 3 - 10 Hz, at rest. Haemolymph removal, and saline infusion, (via either pericardial or infrabranchial sinuses), stimulate increases and decreases respectively in the EMG frequency, in *O. catharus* and *Carcinus maenas*. It is inferred that removal of haemolymph induces contraction of the DVM, leading in turn to elevation of the branchial roof, displacement of haemolymph back into the gills and restoration of haemolymph pressure, while augmentation of the internal volume relaxes the DVM. Inhibition of the DVM EMG during transient ventilatory reversals is consistent with gill compression to facilitate a cough-like cleansing of the gills, while maintained (or increased) EMG frequency during sustained reverse ventilation, associated with burrowing or emersion, is consistent with the maintenance of branchial perfusion and gas exchange in these modes.

The muscle receptor organ of crustaceans - a window on neural evolution

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Invertebrate nervous systems are experimentally accessible and govern stereotyped behaviours, and so provide many opportunities to study evolutionary processes. Malacostracan crustaceans are particularly useful subjects as they are metamerically segmented. The consequence of serial segmentation is that homologous neurons, that is, those with identical embryonic lineage can be compared within one animal - an intersegmental comparison. Further, if neural evolution is conservative, then comparisons can also be made between animals which are thought to share a common ancestor - an interspecies comparison.

Muscle receptor organs in crustaceans are a homologous series of proprioceptors that monitor postural movements of the body. They provide a convenient physiological preparation, as well as good models for intersegmental or interspecies comparisons. In this study the muscle receptor organs of the primitive syncarid *Anaspides tasmaniae* are compared to homologous organs in the advanced decapod *Cherax destructor*.

Structural correlates of fluid transport in the ductuli efferentes testis (DE) and proximal tubules of the kidney (PT) of the rat

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The DE join the rete testis, which collects sperm in dilute suspension from the seminiferous tubules, to the ductus epididymidis which is involved in the post-testicular maturation and storage of sperm. We have been studying the mechanism of fluid transport in the DE which are considered to play an important role in post-testicular sperm maturation by concentrating sperm: their rate of fluid reabsorption ($9-30 \mu\text{l} \cdot \text{cm}^{-2} \cdot \text{h}^{-1}$) is about a tenth that of their homologue the PT. This report describes the ultrastructural features and estimates of membrane surface area of the DE epithelium and compares them with the PT.

We estimate that 17% of the epithelial cells in the DE are ciliated whereas none are ciliated in the PT. In both the DE and PT the surface density of the basolateral membrane of the non-ciliated cells increase considerably in the basal 20% of the cells to $2.32 \pm 0.20 \mu\text{m}^2 \cdot \mu\text{m}^{-3}$ for the DE and $9.23 \pm 0.45 \mu\text{m}^2 \cdot \mu\text{m}^{-3}$ for the PT. However, due to differences in duct diameter the corresponding estimates of absolute surface areas are $5.14 \times 10^6 \pm 0.11 \times 10^6 \mu\text{m}^2 \cdot \text{mm}$ and $1.45 \times 10^6 \mu\text{m}^2 \cdot \text{mm}^{-1}$ length of tubule.

It is suggested that the difference in surface density of the basolateral epithelium may indicate that there is a basic difference in the process of fluid transport between the DE and PT.

Characterization of the ultrastructural properties of muscle fibres from the claw muscle of the yabby (*Cherax destructor*)

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Moulting is a basic means of growth for animals with an exoskeleton. In decapod crustacea many morphological and physiological changes have been shown to occur during moulting and regeneration of lost limbs (epimorphic regeneration). However, little is known about the changes which occur in the muscle fibres during moulting although it is thought that the addition of sarcomeres may play an important role in their lengthening. In this study we have examined the morphological features of the claw muscle at different stages of the moult cycle. The muscle tissue was obtained from regenerating limb buds and from claws of animals in the post-moult stage.

Standard electron microscopy techniques have been used. The osmolality of the buffer was adjusted to match that of the haemolymph of the yabby at 381 mmol/kg with sucrose.

The ultrastructure of fibres from the regenerating limb chelae resembled that of fibres of short-sarcomere length from animals in the intermoult stage. However, the fibres from the regenerating limb had an usually long sarcomere length and produced very low maximum Ca^{2+} -activated tensions suggesting that the fibres do not have optimum actin and myosin filament overlap at this stage. In muscle fibres from animals in the post-moult stage several interesting morphological features were noted: both transverse sarcomere splitting and Z line splitting (which are thought to be involved in the lengthening of the myofibrils during periods of growth) were observed in fibres of short-sarcomere length. These features were not observed in the long-sarcomere fibres. In these fibres large electron dense structures were found which we believe are involved in a process of sarcomere elongation.

Thermal, metabolic, and respiratory consequences of sleeping-site selection in the eastern water dragon, *Physignathus lesueurii lesueurii*

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Unlike the crocodiles, snakes, and turtles, the lizards are the only major living reptile group containing no truly aquatic species. However, the eastern water dragon, *Physignathus lesueurii lesueurii*, uses water not only as a means of escaping terrestrial predators, but also sometimes as a sleeping-site. Such immoderate behavioral specialisations invoke attention as to whether their physiological specialisations are just as extreme. Parameters that influence their selection of sleeping-site may include those involved with metabolism, respiration, circulation, and thermoregulation.

In terms of thermoregulation, sleeping in water is a disadvantage because, in the field, dragons that have slept in water usually remain in the water for most of the morning, and therefore on most days warm much slower than when they sleep in trees.

When air temperature is decreased at night in the lab, the resting O₂ uptake is not significantly different between dragons in air and dragons almost fully submerged in water, even though body temperature will decrease more in air (or trees). This is because aquatic respiration whilst in water, combined with voluntary submerged periods at night, decrease ventilatory and cardiac O₂ consumption (through frequent apnoeic periods and bradycardia, respectively). In the morning, increasing air temperature causes the body temperature, and thus O₂ consumption, of dragons in trees to increase above that of those in water and therefore more energy is conserved by having spent the night in water.

Therefore, if energy conservation is important on a particular day, *P. lesueurii lesueurii* should select water as a sleeping site.

Ovarian development in sexual and parthenogenetic geckos of the *Heteronotia binoei* complex

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Ovarian development in sexual and parthenogenetic geckos of the *Heteronotia binoei* complex was analysed quantitatively by gross and histological examination. Females were classified into one of four stages of the reproductive cycle: nonreproductive, preovulatory, postovulatory and postoviposition. Parthenogens had significantly more developing follicles present in the ovaries than sexual females in prereproductive, preovulatory and postovulatory stages of the reproductive cycle. The larger number of developing follicles in parthenogenetic *Heteronotia* was correlated with the significantly larger body size of the parthenogenetic females at the localities examined. Maximum follicular size and rates of follicular atresia were not significantly different between sexual and parthenogenetic females. These findings raise the possibility that the reproductive output of the parthenogenetic females may be higher than that of sympatric sexual females at these localities due to an increase in follicular recruitment. Based on this evidence we predict that at these localities parthenogenetic females produce more clutches of two eggs than sexual females. If viability is equal, this would enhance the reproductive advantage of parthenogens over the two fold level already present. In all other respects the morphology of the ovaries appeared very similar between parthenogenetic and sexual females and was typical of geckos.

The benefits of dietary omega-6 fatty acids during protein-energy deprivation

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Animals (including humans) can endure periods of severe food deprivation. This study examined the effects of food (energy) deprivation, and energy-protein deprivation on the growth, metabolism and protein and energy balance of a rodent, the laboratory rat *Rattus norvegicus*. It also examined whether the fatty acid composition of a protein and energy deficient diet can influence the severity of protein-energy deprivation for the animal. During both food deprivation (one third of *ad lib* intake) and energy-protein deprivation (one third *ad lib* energy intake and 15% *ad lib* protein intake) body growth is severely retarded. The most affected tissues are skin (and fur), the reproductive system (in females only) and muscles, internal organs (such as liver, heart and kidney) are intermediate and the brain is the least affected tissue. Metabolisable energy as % energy intake is decreased. The apparent absorption of nitrogen is decreased but nitrogen retention is increased with apparent biological value of nitrogen being much greater than in *ad lib* fed controls. When body fat is taken into account, both food deprivation and protein energy deprivation resulted in a decrease in weight specific basal metabolic rate. During protein-energy deprivation the nature of the fatty acids in the food affected the animals response. Specifically the presence of omega-6 polyunsaturates in the food (without any change in energy or protein content) ameliorated many of the detrimental effects of protein and energy deprivation.

Investigating the periodic surfacing behaviour of *Limnodynastes peroni* larvae

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In their natural habitat, tadpoles of *Limnodynastes peroni* swim to the water surface periodically. Presumably, this is to breathe air, as these tadpoles possess functional lungs, even in early stages of development. In other species of tadpole, aerial respiration increases as a result of exposure to aquatic hypoxia. The behavioural and metabolic responses to hypoxia were observed in *L. peroni* tadpoles. At 30°C, the rate of aerial respiration increases rapidly at aquatic PO_2 levels below 10kPa. Low aquatic PO_2 levels only cause a slight increase in air-breathing rates at 20°C. The critical oxygen tension at 30°C is about 7kPa, below which the tadpoles become metabolic oxygen conformers. At high temperatures, hypoxic conditions cause an increase in the rate of aerial respiration because the tadpoles are unable to maintain aerobic metabolism by relying solely on aquatic oxygen consumption.

NOTES

