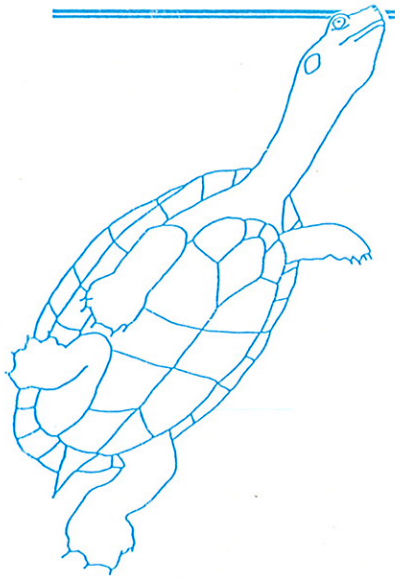
SEVENTH
COMPARATIVE PHYSIOLOGISTS MEETING



30 November - 1 December 1990

Tony HULBERT

PROGRAM
&
ABSTRACTS

Department of Zoology
University of Melbourne

Organisers: B.K. Evans & J. Baldwin

SEVENTH
COMPARATIVE PHYSIOLOGISTS MEETING
30 November - 1 December 1990

PROGRAM

FRIDAY

Registration	from 8.30 am
Housekeeping info.	9.25 am

Session 1: **Chair:** P. Else

Title	Author	Time
Trans-epidermal transport and storage of calcium in decapod crustaceans.	P. Greenaway K. Brouwer C. Farrelly	9.30 am
Nitrogenous excretion in the terrestrial crab, *Geograpsus grayi*.	G. Varley P. Greenaway	9.50 am
The structure and function of a complex receptor organ in the crayfish, *Cherax destructor*.	P. Vescovi D.L. Macmillan	10.10 am
Comparative study of contractile activation in different muscle fibre types from the yabby (*Cherax destructor*).	J.M. West D.G. Stephenson	10.30 am
☕ COFFEE		10.50 am

Session 2: **Chair:** S. Skinner

Title	Author	Time
Adaptations associated with high speed running in the emu.	A. Patak J. Baldwin	11.20 am
The feeding hagfish: a metabolic wolf in sheep's clothing.	J. Baldwin W. Davison M.E. Forster	11.40 am
"Leaky mitochondria": another part of the explanation for the high metabolic rate of mammals.	A.J. Hulbert P. Couture M. Brand	12.00
Toads, toxins and sodium pumps.	P.L. Else	12.20 pm
🍴 LUNCH		12.40 pm

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FRIDAY

Session 3: **Chair:** S. Nicol

Title	Author	Time
Respiratory responses to increasing metabolic rate in the dasyurid marsupial, *Dasuroides byrnei*.	J.F. Hallam T.J. Dawson	2.00 pm
X-cell gill disease and oxygen uptake in an antarctic teleost.	W. Davison C. Franklin	2.20 pm
The oxygen transporting properties of crustacean haemocyanins - new data for air-breathing species.	S. Morris P. Greenaway	2.40 pm
Oxygen carriage by adults and young of two Australian elapid snakes; one viviparous (*Pseudechis porphyriacus*) and one oviparous (*Pseudechis guttatus*).	R.A.B. Holland J.F. Hallam M.B. Thompson R. Shine P. Harlow	3.00 pm
COFFEE		3.20 pm

Session 4: **Chair:** J. McLean

	Author	Time
The innervation of the large arteries and veins of the rat snake, *Elaphe obsoleta*.	P. Davies J.A. McDonald G.D. Campbell	3.50 pm
Co-transmitters in the toad heart.	G. Courtice	4.10 pm
Sympathetic transmission in the toad heart.	N.J. Bramich F.R. Edwards G.D.S. Hirst	4.30 pm
Does the heart work against gravity.	R.S. Seymour	4.50 pm
Cardiovascular physiology of the giant earthworm *Megascolides australis*.	D.R. Jones B.K. Evans P.G. Bushnell J. Baldwin	5.10 pm

DINNER University Cafe
257 Lygon Street — approx — 7.00 pm

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SATURDAY

Session 5: **Chair:** T. Hulbert

Title	Author	Time
A possible role for mucus in coral calcification	A.T. Marshall O.P. Wright	9.30 am
Functional differentiation of secretory epithelia in an insect excretory system: hypo- and hyperosmotic secretion	A.T. Marshall G.D. Rippon P. Cooper A. Patak	9.50 am
Regulation of the exocrine pancreas of the toad *Bufo marinus*	P. A. Carr G.D. Campbell	10.10 am
Mechanisms of saliva formation in kangaroo parotid glands	A.M. Beal	10.30 am
COFFEE		10.50 am

Session 6: **Chair:** R. Rose

Title	Author	Time
The development of the vestibular and auditory system of the northern native cat, *Dasyurus hallucatus*.	R. Gemmell J. Nelson	11.20 am
Salinity tolerance in the eastern water dragon, *Physignathus lesueurii* (Agamidae: Reptilia).	F. Downey	11.40 am
A role for Ca^{2+} in hormonal regulation of hepatic glycogenolysis in *Trachydosaurus rugosa*.	P. Janssens J. Grigg	12.00
Development of the hypothalamo-pituitary-gonadal axis in tammar wallabies.	T.P. Fletcher S.C. Williams P. Williamson M.B. Renfree	12.20 pm
LUNCH		12.40 pm

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SATURDAY

Session 7: **Chair:** B. Gemmell

Title	Author	Time
Response of the platypus to the stress of capture	I.R. McDonald K.A. Handasyde B.K. Evans	2.00 pm
Aspects of reproduction in the Australian lungfish	J. Joss	2.20 pm
Evidence for the essential role of prostaglandins in parturition of the tammar wallaby	M.B. Renfree G. Shaw T.P. Fletcher	2.40 pm
Prostaglandin control of parturient behaviour in the tammar wallaby *Macropus eugenii*	G. Shaw	3.00 p.m.
COFFEE		3.20 pm

Session 8: **Chair:** K. Handasyde

Title	Author	Time
Plasma progesterone levels in female bettongs	S.M. Evans R.W. Rose	3.50 pm
Sexual differences: thermoregulation in the emu	S.K. Maloney T.J. Dawson	4.10 pm
Thermal relations of echidnas - geographic correlates	G.C. Grigg L.A. Beard M.L. Augee	4.30 pm
Relationship between the hibernation cycle and reproduction in echidnas	L.A. Beard G.C. Grigg M.L. Augee	4.50 pm

CLOSING COMMENTS: SITE OF NEXT MEETING

THE FEEDING HAGFISH:

A METABOLIC WOLF IN SHEEP'S CLOTHING

J. Baldwin, W. Davison[1] and M.E. Forster[1]
Department of Ecology & Evolutionary Biology, Monash University
Clayton, Victoria 3168, Australia
[1]Department of Zoology, University of Canterbury, Christchurch,
New Zealand

Fish white myotome is specialized for powering short bursts of rapid swimming using ATP generated from the anaerobic catabolism of glycogen. The highest sustained glycolytic rates and lactate concentrations occur in endothermic scombrids such as skipjack tuna, which can accumulate 85 μmol lactate g^{-1} wet wt muscle after 10 min of burst swimming. Adaptations for maximizing glycolytic flux in this muscle include large glycogen reserves, the highest intracellular pH buffering capacity recorded and impressive activities of glycolytic enzymes.

The discovery of an equally high intracellular pH buffering capacity in the toothplate retractor muscles of the sluggish New Zealand hagfish Eptatretus cirrhatus lead us to examine the glycolytic potential of these unusual muscles.

The retractor muscles of feeding hagfish out-perform the white myotome of burst-swimming tuna by accumulating higher concentrations of lactate faster. Both the hagfish retractors and tuna white myotome have in common large diameter fast white fibres, high glycogen content and high pH buffering. However, an apparent paradox arises when the activities of glycolytic enzymes are compared, as the hagfish retractors generally show less than 20% of the activities found in tuna white myotome.

These observations give rise to a number of questions concerning the maximum activities of enzymes and the regulation of anaerobic glycolysis in fish white muscle.

MECHANISM OF SALIVA FORMATION IN KANGAROO PAROTID GLANDS.

A.M. Beal, School of Biological Science, University of N.S.W.

Intracarotid infusion of drugs, which block ion transport in various epithelia, was used to ascertain the mechanism initiating fluid secretion by the parotid gland of red kangaroos. Both methazolamide (500 μmol/l) and amiloride (500 μmol/l) reduced fluid secretion and [bicarbonate] substantially whereas [phosphate] and particularly [chloride] were elevated. Furosemide (2.0 mmol/l) had no effect on salivary flow or electrolyte concentrations. No significant changes in arterial BP, heart rate, haematocrit or carotid loop plasma flow occurred during the infusion of these diuretics. SITS (500 μmol/l) increased fluid secretion but, under stable flow conditions, did not alter salivary electrolyte concentrations. As the excurrent ducts of kangaroo parotid glands constitute less than 2 % of total gland volume, their contribution to total bicarbonate excretion can only be minor. Consequently, these data indicate that the primary fluid of kangaroo parotid glands is a high-bicarbonate, low-chloride solution; the bicarbonate being derived from hydration of CO_2 by glandular carbonic anhydrase with subsequent export of protons to the blood by a basolateral Na/H^+ antiport. No evidence for the involvement of either the Na-K-2Cl symport or the Cl/HCO_3 antiport was found.

RELATIONSHIP BETWEEN THE HIBERNATION CYCLE AND REPRODUCTION IN ECHIDNAS

L.A. Beard, G.C. Grigg, *M.L. Augee

Department of Zoology, The University of Queensland
*School of Biological Sciences, The University of NSW

The discovery in 1987 of hibernation in echidnas from Kosciusko National Park presented an apparent puzzle, as they appeared to hibernate right through the known breeding season, in July/August. The puzzle has now been resolved with further data which indicates that mature animals "wake up" in time for mating, while smaller presumably immature individuals may hibernate through until Spring. The pattern of entry to and exit from hibernation may be dictated by breeding and nursing constraints.

EFFECTS OF SYMPATHETIC NERVE STIMULATION AND APPLIED ADRENALINE ON PACEMAKER CELLS IN THE TOAD, *Bufo Marinus*.

By Narelle Bramich, F.R. Edwards, Megan Klemm and G.D.S. Hirst.
Department of Zoology, University of Melbourne, Parkville, Victoria, 3052.

In toads, sympathetic nerves release adrenaline to produce a tachycardia that is unaffected by beta-adrenoceptor blockade but reduced by dihydroergotamine. Adrenaline, applied by superfusion, produces a tachycardia which is sensitive to beta-adrenoceptor antagonists (Bramich, Edwards and Hirst, 1990).

Membrane potentials were recorded, (for methods see Bramich, Edwards and Hirst, 1990) either from beating sinus venosus cells or from preparations in which beating had been abolished by adding the organic calcium antagonist nicardipine ($1x10^{-5}M$).

Sympathetic tachycardias were associated with a decreased peak diastolic potential and an increased rate of diastolic depolarization. In 'arrested' preparations sympathetic nerve stimulation evoked excitatory junction potentials, e.j.p.s, which were mimicked by rapidly applied adrenaline ($1\text{-}50x10^{-6}M$) but not by the phosphodiesterase inhibitor IBMX ($1x10^{-5}M$) or the adenlyate cyclase activator forskolin ($1x10^{-5}M$). The amplitudes of e.j.p.s were unaffected by adding IBMX ($1x10^{-5}M$) to the physiological saline. Thus the tachycardia produced by sympathetic nerve stimulation is unlikely to involve cyclic-AMP. The tachycardias produced by applied adrenaline, ($0.1\text{-}10x10^{-6}M$) were associated with an increased peak diastolic potential and an increased rate of diastolic depolarization; they were mimicked by IBMX ($1x10^{-5}M$) or forskolin ($1x10^{-5}M$), suggesting that applied adrenaline causes tachycardia by activating adenylate cyclase.

The observations suggest that neuronally released adrenaline activates specialized junctional receptors and that circulating adrenaline activates extrajunctional beta-adrenoceptors.

Bramich, N.J., Edwards, F.R. and G.D.S. Hirst. *J. Physiol.* 429, 349-375.

Regulation of the Exocrine Pancreas of the Toad *Bufo marinus*

P. A. Carr & G. Campbell. Dept. of Zoology, University of Melbourne.

A study was made of the actions of acetylcholine (ACh) and of porcine secretin, cholecystokinin octapeptide (CCK-8), and vosoactive intestinal peptide (VIP) on the pancreas of the toad *Bufo marinus*. The rate of fluid secretion was measured *in vivo*, and the protein output was shown by zymogen degranulation *in vitro*. Secretin and VIP caused an increase in pancreatic fluid secretion and had no effect on protein output. ACh and porcine CCK-8 had no effect on fluid secretion but caused an increase in protein output. Atropine had no effect on basal fluid secretion, or secretion induced by secretin. Stimulation of the right and left vagosympathetic trunks had no effect on fluid secretion. Duodenal perfusion with HCl caused an increase in pancreatic fluid secretion. The results are discussed in relation to the pancreatic secretory responses to these drugs observed in mammals.

CO-TRANSMITTERS IN THE TOAD HEART

Gillian Courtice. School of Physiology and Pharmacology, University of New South Wales, P.O. Box 1, Kensington. Sydney. N.S.W. 2033

The anuran heart is innervated by vagal inhibitory fibres and by sympathetic excitatory fibres, arriving at the heart via combined vago-sympathetic trunks. In the Cane Toad, *Bufo marinus* both types of fibres contain more than one possible transmitter; vagal fibres contain acetylcholine (ACh), somatostatin (SOM) and galanin (GAL) while sympathetic fibres contain adrenaline (Ad), ATP, Neuropeptide-Y (NPY) and possibly GAL. This paper investigates the action of these cotransmitters at the heart.

Toads were anaesthetised by immersion in 0.2% solution of ethyl m-aminobenzoate (MS222, Sandoz). Arterial blood pressure and pulse interval (PI), triggered from the blood pressure trace, were recorded on a Grass polygraph. The vago-sympathetic trunks to the heart were cut and the right peripheral end stimulated with a standard stimulus, comprising a train of supramaximal shocks (1-2Hz, 1ms, 4V) for 10s every 3 min. Such a stimulus caused a reproducible slowing of the heart under control conditions. After a 2 min period of intense vagal stimulation (10Hz), there was a prolonged cardiac slowing and the standard stimulus became more effective at slowing the heart. That is, the action of the vagus at the heart was potentiated. These cardiac effects could be mimicked by injection of exogenous SOM, but not by GAL. GAL had no effect on heart rate and inhibited cardiac vagal action. It is suggested that cardiac slowing and the potentiation of vagal action after high frequency stimulation of the vagus nerves is caused by the release of SOM from vagal nerve endings.

Cardiac vagal action is affected also by transmitters contained in sympathetic nerves. Infusion of Ad or bolus doses of NPY or GAL inhibited cardiac vagal action at the heart, suggesting that strong interactions between sympathetic and vagal fibres may occur in the toad.

CHEMICAL CODING OF PARASYMPATHETIC NEURONS OF THE TOAD, *BUFO MARINUS*

Philip Davies, Helen Cousins and Graeme Campbell, Department of Zoology, University of Melbourne, Parkville, Victoria 3052, Australia.

In recent years it has been established that neurons contain and can release more than one chemical substance. The association of a particular array of colocalized transmitters with a discrete population of functionally similar neurons, a phenomenon refered to as chemical coding, has been reported in a variety of mammals (Furness et al., 1989). We have examined the chemical content of a group of cranial and sacral parasympathetic neurons of an amphibian, the cane toad, in order to determine whether toad parasympathetic neurons, like those in mammals show "chemical coding".

Tissues were obtained from animals over-anaesthetized by immersion in 0.5% tricaine methanesulphonate (MS222, Sandoz). Dual-labelling immunohistochemical techniques were used to determine the coexistence of neuropeptides using antibodies for calcitonin gene-related peptide (CGRP), galanin (GAL), 5-hydroxytryptamine (5-HT), somatostatin (SOM), substance P (SP) and vasoactive intestinal polypeptide (VIP). Due to the lack of a suitable histochemical marker for acetylcholine (ACh), *in vitro* physiological experiments were used to determine the presence or absence of cholinergic neurons.

Based on their chemical content determined by a combination of physiological and immunohistochemical techniques, post-ganglionic parasympathetic neurons can be divided into two distinct groups. First, cholinergic parasympathetic postganglionic nerves innervating the lung, pulmonary artery, urinary bladder and rectum contain immunoreactivity (IR) to two peptides, GAL and SOM; those in the rectum were found to contain, the indoleamine 5-HT as well. Second, non-cholinergic parasympathetic postganglionic nerves innervating the lingual vasculature, pulmonary artery, lung and rectum contain IR to VIP; those innervating the lingual vasculature also contain GAL-IR.

Preganglionic parasympathetic fibres in the vagus nerve forming synaptic boutons on postganglionic nerve cell bodies, contain colocalized CGRP and SP: synaptic boutons containing CGRP- and SP-IR are associated with both ACh/GAL/SOM and VIP/- cell bodies. Preganglionic parasympathetic nerves forming boutons on GAL/SOM nerve cell bodies in the rectum and urinary bladder contain CGRP and VIP without SP.

Furness, J.B., Morris, J.L, Gibbins, I.L. & Costa, M. (1989) Annu. Rev. Pharmacol. Toxicol., 29, 289-306.

THE INNERVATION OF THE LARGE ARTERIES AND VEINS OF THE RAT SNAKE, *ELAPHE OBSOLETA*

Philip Davies, *John A. Donald and Graeme Campbell, Department of Zoology, University of Melbourne, Parkville, Victoria and *Department of Zoology, University of Florida, Gainesville, Florida, U.S.A.

In many vertebrates, neuropeptides are contained in peripheral autonomic and unmyleinated sensory neurons supplying the large arteries and veins. In the present study, we have examined the distribution of peptides in axons innervating blood vessels of a semi-arboreal snake, the yellow rat snake, *Elaphe obsoleta*. Some snakes were pretreated with 6-hydroxydopamine (6-OHDA) prior to sacrifice. Some blood vessels were also incubated in physiological saline containing capsaicin prior to fixation. Single and dual-label immunohistochemistry was used to determine the distribution and coexistence of neuropeptides using antibodies for calcitonin gene-related peptide (CGRP), galanin (GAL), neuropeptide Y (NPY), somatostatin (SOM), substance P (SP) and vasoactive intestinal polypeptide (VIP). Due to the elongate body form, vessels were sampled from four regions: 1-the anterior vessels including the carotid and vertebral arteries, right and left jugular veins and the vertebral vein; 2-the central vasculature including vessels lying 3cm anterior and posterior to the heart, including the carotid artery, left and right lateral aortae, jugular and vertebral veins, posterior caval vein and dorsal aorta; 3-hepatic portal and posterior caval veins, dorsal aorta and mesenteric arteries just posterior to the liver; 4-dorsal and renal arteries, renal and intestinal veins.

A moderate to dense distribution of VIP-like immunoreactive (-IR) axons were found in all arteries and veins except in vessels from the most posterior region of the rat snake. Almost all VIP-IR axons also contained colocalized SP-IR. NPY-IR axons were observed in all arteries and veins, though NPY-IR axons were more abundant in blood vessels posterior to the heart. The majority of NPY-IR axons also contained GAL-IR. NPY-IR axons were absent in blood vessels from 6-OHDA pretreated snakes, suggesting NPY and probably GAL are colocalized in adrenergic perivascular neurons. CGRP-IR axons were observed in all vessels being particularly dense in the carotid and jugular veins. All CGRP-IR axons contained SP-IR but lacked VIP-IR. The CGRP/SP-IR axons appeared damaged after capsaicin treatment suggesting they are projections of afferent sensory neurons. SOM-IR axons were observed only in the most posterior vessels. The distribution of these various groups of axons may be related to the functional cardiovascular specializations involved in an arboreal lifestyle.

X-CELL GILL DISEASE AND OXYGEN UPTAKE IN AN ANTARCTIC TELEOST.

by William **DAVISON** and Craig **FRANKLIN**

Department of Zoology, University of Canterbury, Christchurch, New Zealand.

The antarctic notothenioid fish *Pagothenia borchgrevinki* is found immediately below the annual ice in McMurdo Sound, Ross Sea. Many of the fish are affected by a condition known as X-cell disease which is characterised by gross swelling of the gill filaments resulting in the loss of secondary lamellae. This is due to proliferation of X-cells within the gills (Franklin & Davison, 1988). One aspect of this is that there is an increase in the water/blood diffusion distance and so presumably a decrease in the ability of these affected fish to extract oxygen from the water.

P. borchgrevinki acquires 95% of is oxygen via the gills. There is no shift to cutaneous respiration with X-cell disease. Resting VO_2 is not affected, although VO_2 max is much compromised, and this is related to the extent of the disease. Oxygen uptake at low ambient PO_2 is reduced, although in the natural environment it is unlikely that these fish would ever encounter hypoxic conditions.

It appears that *P. borchgrevinki* can survive with a much reduced gill surface area due to: a) a low routine metabolic rate; b) high concentrations of O_2 in cold water; c) a relative lack of predators so that the fish do not need to rely on a high oxygen consumption.

Reference.

Franklin, C.E. & Davison, W. 1988. X-cells in the gills of an Antarctic teleost *Pagothenia borchgrevinki*. *J. Fish Biol.* 32: 341-353.

SALINITY TOLERANCE IN THE EASTERN WATER DRAGON, PHYSIGNATHUS LESUEURII (AGAMIDAE: REPTILIA).

Fiona Downey
School of Biological Sciences (A08), University of Sydney, N.S.W. 2006.

Eastern water dragons are large, semi-arboreal lizards commonly associated with non-saline waterways along the east coast of Australia. However, a small number of populations have been reported in saline areas where fresh water is occasionally limited. Under experimental conditions, dragons from these locations are able to tolerate exposure to half- and full-strength sea water longer than those with fresh water histories, and blood ion concentrations are generally the same, or lower, after exposure to saline conditions for a number of weeks. Disparities between histories are probably a result of behavioural differences. When salt water is the only water available, fresh water history dragons spend a significantly greater proportion of their time in saline treatment water and, it is hypothesised, they drink salt water whereas those with previous exposure to salt water in their natural habitat do not.

TOAD, TOXINS AND SODIUM PUMPS

P.L. Else, School of Science and Technology, Charles Sturt University, P.O. Box 588, Wagga Wagga, NSW, Australia.

Toad parotid glands and skin are sources of a concentrated toxin cocktail. A major toad toxin is mono-hydroxy-14,15-epoxy-20,22-dienolide glycoside or resibufogenin. Resibufogenin is a potent sodium pump inhibitor and occurs in the skin of toads at concentrations around 1mM. Toads, like other amphibians, also have highly permeable skin and therefore it is not surprising that these toxins should be found in high concentrations in the blood of these animals. In the cane toad (*Bufo marinus*) the concentration is estimated to be $10^{-7}M$, a concentration more than a1000 times that required to produce toxicity in man.

The question examined, and asked about all such organisms, was how does the toad avoid inhibiting its own sodium pumps? The methods utilized the 3H-ouabain binding technique to determine the numbers of sodium pumps in the toad heart (*Bufo marinus*), since the heart is a primary candidate for the action of such a toxin. The competitive interaction between ouabain and resibufogenin (using plasma) was examined and the effect of ouabain on the force of contraction of the heart (inotropic response) was also measured. The results showed that the toad has a unique answer to its problem one that may help us understand how the sodium pump functions, its relationship to the inotropic response and why its difficult to block toad sodium pumps.

Plasma progesterone levels in female bettongs

S.M. Evans and R.W. Rose
Department of Zoology, University of Tasmania

Bettongs differ from the well-studied tammar and Bennett's wallabies in two important respects. First, they are continuous breeders with a relatively short pouch life (106 days), allowing more than one young per year. Second, gestation usually occurs during lactation, towards the end of pouch life. Pouch vacation usually occurs on the same night as birth and /or post- partum oestrus.

Blood samples were obtained from female bettongs during gestation following removal of pouch young and during the latter stages of pouch life (d.80 - d.110). Plasma progesterone levels were measured by radioimmunoassay following column chromatography of plasma samples.

Similar progesterone profiles were obtained from both groups of animals. Progesterone levels were initially low, 0.3-0.4 ng/ml, rising to peak levels of 1.2-1.5 ng/ml during the later stages of gestation and falling abruptly to basal levels the day before birth (or pouch vacation). These levels show a similar trend to the pattern reported for the pregnant tammar wallaby but are approximately twice as high.

Development of the hypothalamo-pituitary-gonadal axis in tammar wallabies.

T.P. Fletcher, S.C. Williams, P. Williamson* and M.B. Renfree

Departments of Anatomy and Physiology, Monash University and * School of Veterinary Studies, Murdoch University.

Studies of growth and development of both wild and captive populations of tammars have revealed a sexual dichotomy in the time of attainment of sexual maturity. Young females born in the Jan-Feb breeding season undergo puberty in Oct-Nov of the same year, not long after permanent exit from the pouch at about 10 months of age. Young males from the same cohort undergo puberty between 18 and 24 months of age and are capable of a fertile mating at the next breeding season.

Growth and maturation of the testis in male mammals is acutely dependant on stimulation by the pituitary gonadotrophins, LH and FSH. In male mammals, LH is secreted in a pulsatile pattern, which gives rise to the tonic levels measurable in peripheral plasma. Secretion of LH by the pituitary in female mammals follows two patterns, a tonic release that is pulsatile in nature, which produces the basal levels of LH necessary for normal development of the ovarian follicles and steroid production, and an acute release, causing a surge in LH levels, resulting in ovulation. The pulsatile nature of LH release is a result of negative feedback by steroids secreted by the gonad which is determined by the maturity of the hypothalamo-pituitary-gonadal axis.

Maturation of the hypothalamic-pituitary-gonadal axis was assessed in male and female tammars by challenging the system with LH-RH and histological examination of the gonads. A further group of female tammars were ovariectomized prior to puberty and the development of the pulsatile pattern of release of LH was compared with intact females.

Results show that in male and female tammar's the pituitary is capable of secreting LH well before sexual maturity occurs and in females the pulsatile pattern of LH secretion is well established.

THE DEVELOPMENT OF THE VESTIBULAR AND AUDITORY SYSTEM OF THE NORTHERN NATIVE CAT, DASYURUS HALLUCATUS

Robert Gemmell and John Nelson,
University of Queensland and Monash University.

In mammals, the inner ear has six endorgans; three semi circular canals which provide rotational sensitivity; a utricle and a saccule which provide linear motion and gravity sensitivity and a cochlea which provides auditory sensitivity. The newborn native cat possesses a utricle which presumably assists the newborn in the passage from the uterus to the pouch. In this study, the morphological development of the other five endorgans of the native cat were examined with the light and electron microscope. The saccule appeared to be functional, prior to the semi circular canals and the cochlea was the last endorgan to reach morphological maturity. The vestibular and auditory system is not fully functional until the latter half of the lactation period. This sequence of development of the endorgans supports the view that the various parts of the vestibular and auditory system develop as required by the developing native cat.

PETER GREENAWAY, KAREN BROUWER & CAROLINE FARRELLY, School of Biological Science, University of New South Wales.

Trans-epidermal transport and storage of calcium in decapod crustaceans.

During premoult, massive fluxes of calcium occur across the epidermis as calcium from the old exoskeleton is reabsorbed and transferred to the blood. The reabsorbed calcium may be stored in a variety of depots or excreted. It is unlikely that calcium crosses the epidermal cells in ionized form as this would raise the intracellular concentration of Ca^{2+} by several orders of magnitude with deleterious effects. Ultrastructural techniques have been used to examine the mechanism of transport in the crab Holthuisana transversa and the crayfish Cherax destructor. Additionally, data will be presented for calcium storage in these species during premoult.

THERMAL RELATIONS OF ECHIDNAS - GEOGRAPHIC CORRELATES

G.C. Grigg, L.A. Beard, *M.L. Augee

Department of Zoology, The University of Queensland
*School of Biological Sciences, The University of NSW

Over 140 months of body temperature data have been recorded from 12 echidnas free-ranging in Kosciusko National Park between February 1987 and October 1989 at altitudes of 1000-1800 metres. Although only three of the animals encountered significant periods of snow cover, all undertook a prolonged classical hibernation in the autumn and winter months.

During the active season the animals were predominantly diurnal with a pronounced daily cycle in body temperature. Neither daily maximum nor minimum body temperatures were conspicuously dependent on seasonal changes in ambient temperature.

Limited data are available from Mudgee NSW and from studies now in progress at Texas (Qld) and near Brisbane. Hibernation has been observed at all of these (progressively warmer) locations.

Clearly, hibernation in echidnas occurs over a very wide geographic range, including areas with very mild winters. Also, although echidnas may be classified as heterotherms, their heterothermy is obviously well regulated and they are far from the "inadequate homeotherms" they are often said to be.

RESPIRATORY RESPONSES TO INCREASING METABOLIC RATE IN THE DASYURID MARSUPIAL, *Dasyuroides byrnei*

J.F. Hallam & T.J. Dawson, School of Biological Science, University of NSW.

Previous research has indicated that the pattern of ventilation in marsupials differs from that of placental mammals, with resting tidal volumes being $1\frac{1}{2}$ times larger and respiratory rates only about half those predicted for a placental mammal. We have simultaneously measured metabolic and respiratory parameters in the kowari, *Dasyuroides byrnei* , from basal metabolic levels to VO_2max. Maximum sustainable metabolic rate measured at 0°C in a helium/oxygen mixture (0.135 ± 0.003 ml.min.g^{-1}) was 10.4 times the resting metabolic rate. Tidal volume at basal metabolic rate (1.42 ± 0.07ml) was 138% of the value predicted for a placental mammal of this body mass and respiratory rate (41 ± 2 breaths.min^{-1}) was 46% of the predicted value. Increasing oxygen demand was met by an increase in minute volume and there was no significant difference in oxygen extraction at any temperature. Tidal volume increased to a maximum of 3.7 ± 0.2 ml at 0°C in air and there was no significant decrease at higher metabolic rates. Respiratory rate reached a maximum of 3.6 times basal rate. These increases in tidal volume and respiratory rate are comparable to those measured in man undergoing heavy exercise. The different pattern of marsupial ventilation is confirmed in this animal although the kowari's responses to a cold environment follow those of mammals generally, with typically mammalian oxygen extractions and increases in oxygen demand being met by an increase in minute volume.

OXYGEN CARRIAGE BY ADULTS AND YOUNG OF TWO AUSTRALIAN ELAPID SNAKES; ONE VIVIPAROUS (*Pseudechis porphyriacus*) AND ONE OVIPAROUS (*Pseudechis guttatus*)

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It is well known that the oxygen equilibrium curves (OECs) of prenatal eutherian mammals are to the left of the corresponding OEC of the mother. This left shift assists O_2 uptake during intrauterine life. In the viviparous red bellied black snake (*P. porphyriacus*) blood was obtained from gravid and non-gravid adults, from embryos of approximately 2 weeks before birth was due, and from young within 2 days after birth. OECs were determined on a modified Hem-O-Scan, standard conditions being 30°C, pH 7.23, PCO_2 = 21 Torr. No significant metHb was found. Only one Hb type was found with isoelectric focussing. The OEC in the non-gravid adult, was to the right of the usual mammalian position, mean P_{50} being 45 Torr. Embryo P_{50}s were low -- about half the normal adult value. In the newborn the OEC was of embryonic type (low P_{50}) in five animals; and in two others, of the adult type. In adults, newborn, and embryos, there was a bent Hill plot, n_H typically being 1.6-2.0 below 50% saturation, and 2.9-3.8 above 50%. This increase in n_H indicates a steepening of the OEC, helping O_2 uptake at PO_2 values greater than the P_{50}. The Bohr effect was a little above normal mammalian levels in the embryos but was much lower in adults. Five gravid females had a P_{50} between 60 and 75 Torr -- considerably higher than the P_{50} of our non-gravid adults. Thus the strategy for keeping the maternal P_{50} higher than the embryonic P_{50} includes not only shifting the embryonic OEC to the left, but also shifting the maternal OEC to the right. This has not been found before in any species.

Similar studies in the oviparous blue bellied black snake (*P. guttatus*) showed similar shaped adult OECs but with a P_{50} of 40 Torr. The embryo about 2 weeks before hatching was due had a P_{50} about half the adult value. The OEC in the hatchling was of the adult type.

"Leaky mitochondria": another part of the explanation for the high metabolic rate of mammals.

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The standard metabolic rate of the rat (*Rattus norvegicus*) is about 7 times that of the lizard *Amphibolurus vitticeps* at 37°C (a reptile of the same mass as the rat). Isolated rat hepatocytes respire fourfold faster than hepatocytes from the lizard. The inner membrane of isolated rat liver mitochondria has a proton permeability that is 4-5 fold greater than that of the lizard liver mitochondrial membrane. This difference is not due to the differences in the surface area of the mitochondrial membrane but may be caused by more long chain polyunsaturated fatty acids in the rat mitochondrial membrane compared to the reptilian mitochondria. This mitochondrial proton leak is a substantial contributor to the high standard metabolic rate of the mammal.

A role for Ca^{2+} in hormonal regulation of hepatic glycogenolysis in *Trachydosaurus rugosa*.

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Catecholamines stimulate hepatic glycogenolysis via α-adrenergic mechanisms with Ca^{2+} as intra-cellular messenger in some mammals, but we have found no evidence for the presence of α-adrenergic receptors in livers of teleosts, lungfishes, amphibians, and some reptiles. At this meeting last year, we reported that α-adrenergic receptors may play some role in control of hepatic glycogenolysis in *Amphibolurus nuchalis* and today we report the involvement of Ca^{2+} in another reptile *Trachydosaurus rugosa*.

Both glucagon and adrenaline stimulated glucose release from liver pieces from *T. rugosa* incubated in vitro. Both hormones acted via cyclicAMP but, with both hormones, glucose release was reduced in Ca^{2+}-free media containing EGTA and the reduction was partially overcome if Ca^{2+} was added. The action of adrenaline, but not of glucagon, was stimulated in the presence of A23187 + Ca^{2+}. Neither EGTA nor A23187, either with or without Ca^{2+}, had any effect upon tissue cyclicAMP levels or glycogen phosphorylase activity in the presence of adrenaline. Ligand-binding studies indicated the presence of ß-adrenergic receptors but not of α_1- or α_2-adrenergic receptors.

We conclude that primary regulation of hepatic glycogenolysis in *T. rugosa* is via modulation of tissue cyclicAMP levels. Intra-cellular Ca^{2+} concentrations also influence the rate of glucose release, but not at the level of glycogen phosphorylase activity.

CARDIOVASCULAR PHYSIOLOGY OF THE GIANT EARTHWORM *Megascoloides australis*.

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Pressures in the ventral (VV) and dorsal vessels (DV), lateral hearts (LH), and coelom (C) were measured in unanesthetized giant earthworms using either a modified servo nulling micropressure measuring system or conventional pressure manometers. Blood pressure in the DV (5-25 mmHg) < LH (15-30 mmHg) < VV (30-40 mmHg) in horizontal animals. Coelomic contractions were reflected in the VV, LH and DV pressure profiles as changes in baseline pressure (10-15 mmHg) of similar shape and magnitude as coelomic pressure increases, but a hydrostatic load, placed on the anterior end by raising the tail 0.5 m did not cause any pressure increase. Obviously, the circulatory system can be compartmentalized at the segmental level.

ASPECTS OF REPRODUCTION IN THE AUSTRALIAN LUNGFISH

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Lungfish have been sampled over two summer seasons (Jan-Feb), two autumn seasons (March-May) and four spring seasons (Sept-Oct). Histology of the gonads indicates that in males spermatogenesis is active in autumn and mature sperm are stored in the testis and kidneys until mating which probably occurs in late October and November. The testes regress over the summer months. In the females, vitellogenesis begins in autumn, appears to arrest over winter and resumes in spring. The ovary contains many large, yolky but not fully mature eggs in early October, indicating that ovulation must be somewhat later. Testosterone is high in mature males in autumn and spring and low in females except in spring when it approaches levels of immature males (20-40 nmol/l). Estradiol-17B is highest in females during autumn, at the time of initiation of vitellogenesis and is always low to undetectable in males. Progesterone levels are generally higher in females than in males and show no apparent seasonal fluctuations. Pituitary gonadotropins have not yet been isolated or characterised but presumptive gonadotropes have been identified in the anterior pituitary. Hypothalamic GnRH has been characterised as being identical to mammalian GnRH. Lungfish respond to mGnRH (2μg/Kg) by a rapid increase in plasma steroid levels. This response is transitory and resembles that observed for mammals.

RESPONSE OF THE PLATYPUS TO THE STRESS OF CAPTURE

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We have investigated the short- and long-term adrenal and metabolic responses of wild platypuses to the stress of capture in gill nets. In blood samples obtained from a vascular sinus in the bill 2-10 mins after entanglement plasma cortisol concentration was within the range 20-75 nmol/l, rising to the range 350-720 nmol/l 30-35 min later and fluctuating within the range 100-500 nmol/l in samples taken up to 14 h after capture. Plasma catecholamine concentrations were high, with noradrenaline and adrenaline concentrations of 2427±236 and 491±91 ng/ml in the first samples, falling to 1335±160 and 274±69 ng/ml 5 h after capture. Plasma glucose concentrations were low at the time of capture, in the range 2-3 mmol/l and did not change significantly. There was a marked rise in plasma free fatty acid concentration from a mean of 0.390±0.06 mequiv/l to 0.986±0.06 mequiv/l 30 mins later, falling again to 0.681±0.06 mequiv/l 3-6 h after capture. Injection of 0.1 mg dexamethasone/kg 30-60 mins after capture caused a marked fall in plasma cortisol but had no effect on plasma glucose concentration. However, the initial rise in plasma free fatty acids was sustained for up to 6 h. In one male that was brought into captivity and was feeding normally, plasma cortisol concentration was in the range 328-373 nmol/l between 8 and 61 h after capture. Plasma glucose concentration rose from 3.3 to 7.39 mmol/l between 0.5 and 29 h after capture but fell to 3.38-4.19 mmol/l while FFA rose from 0.44 to 1.01 mequiv/l. The animal stopped feeding and was listless 87h after capture. Plasma cortisol was 689 nmol/l. Injection of dexamethasone caused an increase in activity and marked reduction in plasma cortisol concentration. We conclude that the adrenocortical response to capture is marked and sustained, being associated with high levels of plasma catecholamines but with little change in plasma glucose concentration. The major metabolic response appears to be mobilization of fatty acids. The consistently high plasma cortisol concentration in the captive animal indicates that it was stressed by its new environment.

SEXUAL DIFFERENCES: THERMOREGULATION IN THE EMU.

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Basal metabolism of the female emu (1.02 W/kg) is 75% of that predicted (1.35 W/kg) from the allometric equation of Aschoff and Pohl (1970) for a non-passerine in the resting phase of its diurnal cycle. During the breeding season (June- September) the Basal metabolism of the male emu is 55% of that predicted (0.744 W/kg). This may be a phenomenon of the breeding season. Within the thermoneutral zone, body temperature of females is higher than males (38.2°C and 37.6°C). At temperatures below the lower critical temperature, an animal must increase metabolism in order to maintain body temperature. This has been quantified in the emu. The lower body temperature of the male in association with lower dry conductance (higher insulation) makes this maintenance metabolically less expensive for the male. At an ambient temperature of 45°C, body temperature of both sexes increases marginally and is maintained by the evaporation of water amounting to a heat loss of 200% of metabolic heat.

FUNCTIONAL DIFFERENTIATION OF SECRETORY EPITHELIA IN AN INSECT EXCRETORY SYSTEM: HYPO- AND HYPEROSMOTIC SECRETION

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The excretory system of crickets (*Teleogryllus oceanicus*) consists of some 150 tubules. The tubules have three morphologically distinct segments; two secrete ions and the third proximal segment secretes mucus. The distal segment is small and has been regarded as being non-secretory. We show that it secretes at a higher specific rate than the main segment, the fluid is hyperosmotic and becomes very hyperosmotic on stimulation by diuretic hormone. The inorganic ionic composition accounts for only about 40 percent of the total osmotic concentration, we assume that organic osmolytes or bicarbonate accounts for the deficit.

The main segment secretes slightly hyposmotic fluid which becomes more hyposmotic on stimulation by diuretic hormone, and the rate of secretion shows a substantial increase. The inorganic ionic composition accounts almost entirely for the measured osmotic concentration.

In the whole tubule the effect of diuretic hormone is to promote a substantial increase in secretion rate and a change from slightly hyposmotic to slightly hyperosmotic secretion.

The mechanism of hyposmotic secretion in the main segment is unknown.

A POSSIBLE ROLE FOR MUCUS IN CORAL CALCIFICATION

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Calcification in corals has been investigated for more than a century but the mechanism is still not understood. We show that mucus may play a hitherto unsuspected role in this process.

Ca^{2+} appears to be actively transported across the oral epithelium of scleractinian corals. The transport of Ca^{2+} is competitively inhibited by Sr^{2+} which is present in seawater at a concentration two orders of magnitude lower than Ca^{2+}. The Ca/Sr ratio in the skeleton is similar to that in sea water. We show by X-ray microanalysis that molar concentrations of Sr^{2+} are concentrated and bound in mucocytes in the oral and aboral epithelia together with lower but substantial concentrations of Ca^{2+}. The Sr/Ca ratio in mucocytes of the four cell layers between the outside surface and the skeletal surface increases as the skeleton is approached.

We suggest that Sr^{2+} may be transported at a higher rate than Ca^{2+} and that its concentration is subsequently regulated by its uptake by mucocytes.

The Oxygen Transporting Properties of Crustacean Haemocyanins - New Data For Air-Breathing Species

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The functioning of haemocyanin in the blood of water-breathing decapod crustaceans is now relatively well understood. A review of relevant work in the past 10 years shows that the modulation of oxygen binding by haemocyanin is analogous but also quite different from that of haemoglobins. L-lactate is the prime anaerobic end product in these animals and can increase haemocyanin oxygen affinity (Truchot, 1980). Similar effects due urate and the neuroamine dopamine have also been reported and confirmed (Morris *et al.*, 1985; Morris and McMahon, 1989). It is understood that these "modulators" help adapt crustaceans to both long and short term "stress".

Relatively few data are available from either truly amphibious or terrestrial species and these suggest fundamental differences *cf.* aquatic species. The present study reports the findings from an investigation of several air-breathing decapods from Christmas Island. The data indicate that modulators have little or no role to play in regulating haemocyanin function and instead morphological and mechanical changes seem more important. The study included species from the same genus, one endemic to Christmas Island the other widely distributed. Apparent divergence of haemocyanin function was demonstrated in these two species.

ADAPTATIONS ASSOCIATED WITH HIGH SPEED RUNNING IN THE EMU

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Flying is the dominant form of locomotion in birds, and the muscles which power flight display a range of specializations associated with various types of flying behaviour. In contrast to flight, the muscles powering high speed running in birds have received little attention. Differences in the structural and metabolic organization of the locomotory muscles of running and flying birds could be expected because (a) flying birds must produce net vertical as well as horizontal propulsion, whereas running birds produce net horizontal propulsion only, (b) muscle weight potentially is limiting in a flying bird, but not obviously so in a running bird, and (c) the locomotory muscles of running birds have a role in maintaining posture in addition to locomotion, whereas those involved in flapping flight generally do not.

The emu, a giant flightless bird, provides an extreme example of avian cursorial locomotion. In this study, anatomical, histochemical and biochemical properties of several lower leg muscles of the emu were investigated. Our major findings illustrate some of the similarities as well as differences between flying and running: (a) the leg muscles of the emu constitute a similar proportion of total body mass as the flight muscles of flying birds, and a much greater proportion than the leg muscles of flying birds; (b) the emu gastrocnemius (the largest and most powerful lower leg muscle) is more similar in its ability to generate energy from the breakdown of fuels and in its fibre type composition to the flight muscles of flying birds than to the leg muscles of flying birds; and (c) the capacity of emu leg muscles for short bursts of high power output is much less than that of the flight muscles of flying birds. The first two points illustrate that the rates of high energy work which flying birds and the emu can sustain are similar, whereas the last point can be attributed to differences between flying and running in power demand during take-off.

EVIDENCE FOR THE ESSENTIAL ROLE OF PROSTAGLANDINS IN PARTURITION OF THE TAMMAR WALLABY

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In the tammar at the time of birth there is a pulse of prolactin and prostaglandin. The pulse of maternal prolactin is associated with the presence of a fetus, and not the stage of the ovarian cycle, and is responsible for inducing luteolysis earlier than occurs in the non-pregnant cycle. The prolactin peak is apparently triggered by the rise in prostaglandin-$F_{2\alpha}$. Whilst luteolysis is not essential for parturition, it was thought that prolactin was necessary for luteolysis and parturition. We have recently shown that abolishing the prolactin pulse with bromocriptine does not inhibit parturition or luteolysis. This study was designed to test the role of prostaglandin in parturition in the presence or absence of prolactin and prostaglandin.

Two experiments were conducted. In the first experiment, 6 pregnant females were treated with CB154 and indomethacin to suppress prolactin and prostaglandin respectively. In the second only indomethacin was given. Bromocriptine abolished the peri-partum pulse of prolactin as we have previously shown. Indomethacin did not completely remove prostaglandin from the plasma, but it did abolish the very high peak observed in controls at birth. Ten of 12 control treated females gave birth on 26.9 ± 1.0 days of gestation. By contrast none of the 12 treated animals gave birth. At autopsy fetuses were recovered from 10/12: 7 had dead fetuses; 3 had live fetuses, and the other 2 females had aborted. The fetuses were markedly post-mature (weight 499.8 ± 78.3 mg vs 407.4 ± 23.6 for control neonates). 1

We conclude that the prostaglandin-synthetase inhibitor Indomethacin interferes with the parturient release of prostaglandin, and delays parturition regardless of the presence or absence of a prolactin pulse. These results emphasize the importance of prostaglandin for tammar births, and tend to support the suggestion that the corpus luteum has an intrinsic control of its life span in the wallaby.

Does the Heart Work Against Gravity?

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There is a current conceptual controversy as to the effectiveness of the siphon principle in blood flow above the heart in animals, especially the giraffe. Badeer and Hicks propose that the heart does not work against gravity to raise the blood to the head because the circulatory system is closed, and the principle of the siphon operates (Badeer 1985, 1986, 1988; Hicks and Badeer 1989). On the other hand, we consider that the blood flowing down the collapsible superior veins is ineffective in helping the blood rise in the arteries (Seymour and Johansen 1987; Hargens et al. 1987, 1988; Seymour and Hargens, 1991). We conclude that a significant fraction of heart work is involved in raising the blood against gravity, and this fraction is directly related to the height of the superior blood column.

Hicks and Badeer (1989) indicate that the heart works only against the total viscous resistance of the circuit, much of the resistance lying in the neck veins. This view is correct in the sense that it conforms to Bernoulli and Poiseuille relationships, but it is deceptive because it implies that the resistance in the veins significantly determines the arterial blood pressure necessary to achieve an adequate rate of blood flow. In reality, however, the reverse is true. Arterial blood pressure and the resistance of the non-venous vessels are the major factors that determine blood flow rate which, in turn, determines the resistance of collapsible veins.

PROSTAGLANDIN CONTROL OF PARTURIENT BEHAVRIOUR IN THE TAMMAR WALLABY *MACROPUS EUGENII*

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The young of the tammar wallaby, like all marsupials, is poorly developed at birth. At parturition the mother adopts characteristic behavioural changes which facilitate the neonate's progress to the pouch. Typically the female sits with her tail thrust froward between her legs, and licks the urogenital opening, the pouch, and the fur in between. This behaviour commences only when birth is imminent, and within minutes of birth the mother will be standing again with the neonate in the pouch. This behaviour is normally seen only in females in the immediate peripartum period. The recent experiments described here show that it is controlled by prostaglandins, presumably released from the uterus and vaginae during the birth process.

In previous studies investigating the control of luteolysis we observed that 26 day non-pregnant tammars treated with large doses of PGF-2α adopted the birth posture and behaved as if they were giving birth. It was unclear from this observation whether prostaglandin was inducing this behaviour as a result of induced uterine or vaginal contractions, or whether it was an artefact of the large doses used.

In a series of experiments nulliparous juvenile female wallabies and adult male wallabies were treated with PGF-2α by i.m. injection in doses 1, 0.2, 0.04 and 0.008 mg/kg. A dose of 0.04 mg/kg produced peak plasma PGFM concentrations similar to those seen in parturient females. This and the higher doses also induced parturient behaviour within minutes of injection in both males and females. This behaviour was seen in only half of the wallabies following treatment with 0.008 mg/kg, and in no animals after control saline injection. Since both PGF-2α and PGE-2 concentrations are elevated in pregnant uterine tissues near term, a group of 4 males were treated with the same range of doses of PGE-2. As before all animals injected with 0.04 mg/kg PGE-2 or higher doses adopted the birth posture within minutes of injection. Little response was seen to 0.008 mg/kg.

It seems likely from these experiments that the peak of PG release at parturition serves as the physiological trigger for parturient behaviour, probably by a CNS action.

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Nitrogenous Excretion in the Terrestrial Crab *Geograpsus grayi*

The rate and mechanism of nitrogen excretion was examined in *G. grayi*. This species excretes waste nitrogen as gaseous NH_3 in bursts of 3 to 48 hours duration. The mean maximum rate of excretion during these bursts was 220.3 $\mu mol.kg^{-1}.h^{-1}$. The mean concentration of total ammonia (NH_3 plus NH_4^+) in the primary urine during bursts of excretion (1.64 $\pm$ 0.7 mmol/L) was not significantly different from the mean concentration during periods of minimal gaseous excretion (1.23 $\pm$ 0.2 mmol/L). The mean haemolymph total ammonia concentration during bursts of excretion (2.43 $\pm$ 0.3 mmol/L) was significantly different ($p<.05$) to the concentration in non-excreting crabs (0.89 $\pm$ 0.08 mmol/L). The mean concentration of total ammonia in fluid sampled from the branchial chamber during bursts of excretion was 107.9 $\pm$ 12 mmol/L. During periods of minimal gaseous excretion branchial fluid was present on only one sampling occasion and the concentration of total ammonia in this fluid was 0.76 mmol/L. Thus, the site of nitrogenous excretion in this species is the branchial chamber which is also the site of reprocessing of urine for ion regulation in other terrestrial crabs. The tissue most likely involved is the gill and the process of excretion could be achieved by a variety of mechanisms which will be discussed.

The structure and function of a complex receptor organ in the crayfish *Cherax destructor*

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Muscle receptor organs (MROs) which span the abdominal joints of a number of crustaceans are located so that they can monitor movement of the abdominal segments relative to one another (Field, 1976). MRO morphology and innervation is very complex because the receptors are attached to a fine muscle strand which receives its own motor innervation, and there are also inhibitory neurons that terminate on the surface of the receptor neurons. There is evidence that the MROs form part of a servo-loop controlling abdominal position but the reason for the complexity of the receptor system remains unknown. We present new evidence about the central projections of the MROs that will direct our physiological search for functional answers in a new direction.

Field, H.L. (1976) Crustacean abdominal muscle receptor organs. In: Structure and Function of Proprioceptors in the Invertebrates. Ed. P.J. Mill. Chapman & Hall: London. pp.65-114.

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rat vs toad muscle J. Physiol (1989) 410:351

A COMPARATIVE STUDY OF CONTRACTILE ACTIVATION IN DIFFERENT MUSCLE FIBRE TYPES FROM THE YABBY (Cherax destructor).

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Within the claw muscle of the yabby, two fibre types are evident. One type is characterized by short sarcomeres (<4μm) while the other by long sarcomeres (>6μm). The short sarcomere fibres are thought to be singly regulated (actin Ca^{++}-linked regulation) while the long sarcomere fibres doubly regulated (actin and myosin Ca^{++}-linked regulation), this making decapod crustaceans an interesting animal model to study muscular contraction.

In the present study we have used both long and short sarcomere fibres from the claw muscle of the yabby, and compared their contractile and Ca^{++}-activation properties under various physiological conditions. Single muscle fibres removed from the claw were mechanically skinned with fine forceps and attached to the force recording apparatus where myofibrillar MgATPase or fibre stiffness could be measured simultaneously with force in Ca^{++}- and Sr^{++}-buffered solutions by methods previously described (Stephenson et al.,1989 J.Physiol. 410:351-366).

The long and short sarcomere fibres were found to be different in their Ca^{++}- and Sr^{++}-activation properties. The long sarcomere fibres had a lower force threshold for contraction for both Ca^{++} and Sr^{++}, developed higher maximum tension and had less steep force-pCa ($-\log_{10}[Ca^{++}]$) curves. For both fibre types the force-pCa curves were sigmoidal whilst the force-pSr were shallower and biphasic in shape. Maximum Sr^{++}-activated force was markedly lower in both fibre types, however the ratio between maximum Sr^{++} and maximum Ca^{++}-activated force was 3 fold higher in the long sarcomere fibres.

These Ca^{++}- and Sr^{++}-activation force results correlate well with the MgATPase and stiffness observations in the same fibre types. Some noteworthy differences compared with vertebrate skeletal fibres were the very high MgATPase myofibrillar rate at full Ca^{++}-activation in short sarcomere fibres and the markedly higher (x1.6) fibre stiffness in rigor compared with full Ca^{++}-activation in both fibre types.

While several results can be explained based on differences in sarcomere and filament lengths between the fibre types, there are several findings that are strikingly different from reported observations found in other vertebrate and invertebrate muscles which can provide a deeper insight into the way divalent ions regulate muscle contraction.