PROGRAMME AND ABSTRACT BOOK

AN INTEGRATIVE BIOLOGY OF THE EGG: FROM THE SHELL'S STRUCTURE TO THE PHYSIOLOGY WITHIN

3 JULY 2016

BRIGHTON CENTRE, UK

CRACKING THE EGG

SOCIETY FOR EXPERIMENTAL BIOLOGY

AN INTEGRATIVE BIOLOGY OF THE EGG: FROM THE SHELL'S STRUCTURE TO THE PHYSIOLOGY WITHIN

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ORGANISED BY:
DR STEVE PORTUGAL
ROYAL HOLLOWAY UNIVERSITY OF LONDON, UNITED KINGDOM
PROF MARK HAUBER
HUNTER COLLEGE, UNITED STATES

MEETING SPONSORED BY:

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DELEGATE INFORMATION

BADGES

Participants are required to wear name badges at all times for proof of registration, security purposes and catering identification.

CATERING

Lunch and refreshments during the meeting are included in your registration fee and will be served in the Syndicate Room 2.

CERTIFICATE OF ATTENDANCE

Delegates requiring a certificate of attendance should visit the SEB registration desk on their departure.

VENUE

Brighton Centre
Kings Road, Brighton,
BN1 2GR
Tel: **+44 (0)1273 292671**
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The scientific sessions will be taking place in Syndicate Room 1. Posters will be displayed in the catering area in Syndicate Room 2.

LIABILITY

Neither the Society for Experimental Biology nor the Brighton Centre will accept responsibility for damage or injury to persons or property during the meeting. Participants are advised to arrange their own personal health and travel insurance.

PHOTOGRAPHY

No photographs are to be taken of the speakers and their slides during the symposium.

**Please note: The SEB will be taking photos during the event for promotional purposes. If you have any concerns, please visit the SEB registration desk.*

POSTERS

Posters will be on display in the breakout area (Syndicate Room 2) throughout the meeting from **08:20-17:00** on **Sunday 3 July 2016**. Poster presenters are invited to hang their poster on their arrival (Velcro will be provided) and asked to remove their posters by **17:00 on Sunday 3 July**. Any posters left behind will be disposed of.

REGISTRATION

The registration desk will be open during the hours of the meeting and SEB staff members will be on hand during the refreshment and lunch breaks should you require any assistance.

TWITTER

We're looking to increase the conversation at the meeting using Twitter so please get tweeting!
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SEB - **@SEBiology**

INTERNET ACCESS

There is free Wi-Fi is available throughout the Brighton Centre. No login details are required.

PROGRAMME

SUNDAY 3 JULY 2016

08:20 REGISTRATION

CHAIR: DR STEVE PORTUGAL

08:50
Introduction
Dr Steve Portugal
Royal Holloway University of London, United Kingdom
Prof Mark Hauber
Hunter College, United States

09:00
Dr Claire N Spottiswoode
University of Cambridge, United Kingdom & University of Cape Town, South Africa
Eggs as battlegrounds: coevolutionary arms races between brood-parasitic birds and their hosts
AS16.1

09:35
Mr Sean A Williamson
Monash, Australia
Embryonic development is constrained by *in utero* oxygen availability prior to oviposition.
AS16.2

10:00
Ms Jasmina Wiemann
University of Bonn, Germany
Opening a window in time: How dinosaur eggshell chemofossils store palaeobiological information
AS16.3

10:15
Dr David T Booth
University of Queensland, Australia
Incubation temperature: A critical factor determining reptile hatchling quality
AS16.4

10:35 REFRESHMENT BREAK / POSTERS

CHAIR: DR DANIEL HANLEY

11:05
Dr Denis Charles Deeming
University of Lincoln, United Kingdom
Life support systems for avian embryos: interaction between the incubation environment and the physiology of the embryo
AS16.5

11:30
Miss Marina R Sartori
University of Sao Paulo State, Brazil
Hydrostatic pressure in flexible-shelled reptilian eggs
AS16.6

PROGRAMME

11:45
Mr Tzu-Ruei Yang
Steinmann-Institut für Geologie Mineralogie Paläontologie Universität Bonn, Germany
New evidences from complete oviraptorid clutches explain why oviraptorid dinosaur did not brood
AS16.7

12:00
Prof David Taylor
Trinity College Dublin, Ireland
How tough is eggshell?
AS16.8

12:15
Dr Marian Y Hu
Institute of Physiology University of Kiel, Germany
pH regulatory mechanisms enable cephalopod embryos to develop in a naturally acidified environment
AS16.9

12:30 LUNCH / POSTERS

CHAIR: MR SEAN WILLIAMSON

13:30
Dr Wendy Reed
North Dakota University, United States
Hormones in avian eggs: Perspectives on pattern, process and mechanism
AS16.10

13:55
Dr Shelly Druyan
ARO, Israel
Physiological effects of hypoxic conditions during the plateau period on the chicken embryo
AS16.11

14:20
Dr Daniel Hanley
Palacký University, Czech Republic
How hosts recognize parasitic eggs: asymmetrical egg discrimination along an eggshell colour gradient
AS16.12

14:35
Dr David Labonte
University of Cambridge, United Kingdom
The role of the collagenous membrane in the fracture resistance of eggs
AS16.13

14:50
Dr Branislav Igic
Australian National University, Australia
Recent insights into the function and evolution of avian eggshell structure and colouration
AS16.14

15:15 REFRESHMENT BREAK

CHAIR: MS JASMINA WIEMANN

15:45
Mark E Clark
North Dakota State University, United States
Within-season variation in the shape and conductance of American white pelican eggs
AS16.15

PROGRAMME

16:00
Dr Steve J Portugal
Royal Holloway University of London, United Kingdom
Cuckoo eggs: Is the mimicry just skin deep?
AS16.16

16:20
Dr Tony D Williams
Simon Fraser University, Canada
Synergistic or antagonistic effects of two maternally-derived egg components (antibodies and testosterone) on offspring phenotype
AS16.17

16:35
Dr Caren Cooper
North Carolina Museum of Natural Sciences, United States
Cracking mysteries at the museum: citizen science revival of egg collection
AS16.18

17:00 CLOSE OF MEETING

POSTER SESSION SUNDAY 3 JULY 2016

Mr Syafiq M Musa
University of Manchester, United Kingdom
Elasmobranch egg case development in 7 key stages
AS16.19

Joris Wiethase
University of Glasgow, United Kingdom
Egg turning and incubation temperature in parrots: Influences of breeding behaviour and implications for artificial incubation
AS16.20

AN INTEGRATIVE BIOLOGY OF THE EGG: FROM THE SHELL'S STRUCTURE TO THE PHYSIOLOGY WITHIN

AS16.1 EGGS AS BATTLEGROUNDS: COEVOLUTIONARY ARMS RACES BETWEEN BROOD-PARASITIC BIRDS AND THEIR HOSTS

SUNDAY 3 JULY 2016 **09:00**

CLAIRE N SPOTTISWOODE (UNIVERSITY OF CAMBRIDGE, UNITED KINGDOM & UNIVERSITY OF CAPE TOWN, SOUTH AFRICA)

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Brood-parasitic birds are cheats that lay their eggs in the nests of other species, and are renowned for their egg mimicry of their hosts. This talk will ask how such coevolutionary interactions can escalate into arms races between host signatures and parasitic forgeries, played out across the egg's surface. I will report on research on several African brood-parasitic species (mainly the cuckoo finch, *Anomalospiza imberbis*) by myself and collaborators, using field experiments to test reciprocal selection pressures on host and parasitic eggs, and genetic approaches to test how the resulting coevolutionary arms races may be shaped by the genetic mechanisms that underpin them.

AS16.2 EMBRYONIC DEVELOPMENT IS CONSTRAINED BY *IN UTERO* OXYGEN AVAILABILITY PRIOR TO OVIPOSITION

SUNDAY 3 JULY 2016 **09:35**

SEAN A WILLIAMSON (MONASH, AUSTRALIA), ROGER G EVANS (MONASH UNIVERSITY, AUSTRALIA), ANTHONY R RAFFERTY (MONASH UNIVERSITY, AUSTRALIA), RICHARD D REINA (MONASH UNIVERSITY, AUSTRALIA)

SEAN.WILLIAMSON@MONASH.EDU

Oxygen availability has been shown to heavily influence patterns of embryonic development and even constrain the evolution of reproductive mode in several taxa. Here we present current evidence that *in utero* oxygen availability of egg-laying reptiles determines the level of embryonic development possible prior to oviposition. We have recently shown that turtle eggs will enter embryonic arrest until they move from the low oxygen environment of the oviduct to the normoxic environment of the nest. Similarly, we have shown that crocodilian eggs are unable to successfully develop after oviposition without sufficient oxygen availability. Preliminary measurements and calculations of the oxygen availability for egg-laying squamates suggest that oxygen supply *in utero* is increased in species that develop embryos to later stages within the mother. Research on birds also suggests that oxygen constrains the evolution of reproductive mode within this taxon. However, there is a current lack of information on the cellular and genetic processes that are controlled by changes in oxygen availability during the early stages of development. Significant changes to morphology and physiology are required in order to supply sufficient oxygen *in utero* to enable prolonged egg retention and more advanced stages of embryonic development within the mother. We think an exciting area for investigation is the interface between evolutionary and physiological ecology to better understand how oxygen availability constrains evolution in egg laying taxa. There is large potential for novel research on this evolutionary question, particularly in understudied oviparous taxon that exhibit a range of reproductive modes.

AS16.3 OPENING A WINDOW IN TIME: HOW DINOSAUR EGGSHELL CHEMOFOSSILS STORE PALAEOBIOLOGICAL INFORMATION

SUNDAY 3 JULY 2016 **10:00**

JASMINA WIEMANN (UNIVERSITY OF BONN, GERMANY), TZU-RUEI YANG (UNIVERSITY OF BONN, GERMANY), P. MARTIN SANDER (UNIVERSITY OF BONN, GERMANY)

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Although several recent studies changed our view on the limits of biomolecular stability during fossilisation, studies on organic compounds in fossil eggshell material remain the exception. Here we present the first holistic approach on endogenous eggshell degradatomics in a behavioural and evolutionary context. Therefore, we investigated all potentially preserved organic compounds from fossil eggshell samples of sauropod, oviraptorid, and troodontid dinosaurs, as well as subfossil *Psammornis* material in comparison with extant *Struthio*, *Rhea*, *Dromaius*, and *Gallus* eggshells. Using UV/Vis spectrophotometry, Raman spectroscopy, HPLC ESI MS, EMPA and XRD, we identified (1) preserved cuticle (lipids and polypeptides, colour pigments), (2) proteinaceous remnants of the spongy layer, and first hints for (3) remains of a *membrana testacea*, and a chorioallantoic membrane. Regarding endogenous molecular preservation, we observed a strong taphonomic bias, which seems to be mainly affected by the type of the embedding sediment, and the chemical milieu based on pH, Eh, and character of the circulating fluids. From a palaeobiological perspective, the composition of preserved cuticle (1) provides information about the nesting environment, incubation strategy, and parental investment. The chemical composition and spatial arrangement of the spongy layer (2) reflects the rigidity of the eggshell and might also be related to incubation strategies. Preservation of a chorioallantoic membrane (3) would represent a fertilisation proxy for fossil eggs. Thus, our study offers a first assessment of the preservability of eggshell biomolecules and opens up a new avenue of investigation for the evolution of avian reproductive traits.

AS16.4 INCUBATION TEMPERATURE: A CRITICAL FACTOR DETERMINING REPTILE HATCHLING QUALITY

SUNDAY 3 JULY 2016 **10:15**

DAVID T BOOTH (UNIVERSITY OF QUEENSLAND, AUSTRALIA)

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It is now well known that incubation temperature plays a crucial role in determining hatchling phenotype in most oviparous reptiles. Studies in this field of research are becoming increasingly relevant to conservation biology because of the well documented fact that air temperatures and consequently nest temperatures are increasing globally. The best described and studied effect is the phenomenon of temperature dependent sex determination (TSD) found in all crocodilians and many species of lizards and chelonians, but incubation temperature can also influence the amount of yolk converted to tissue at hatching, the size, shape and colour patterns of hatchlings, and hatchling locomotion performance and behaviour. With the exception of several recent studies focusing on TSD, studies to date have been restricted to a description of the effects of incubation temperature on hatchling phenotype, and the possible consequences on hatchling fitness that these differences in phenotype might have. The next obvious new direction of research relating to incubation temperature induced difference in locomotion performance of hatchlings is to discover, the molecular, cellular and physiological mechanisms that cause these differences. Here I discuss this exciting new field.

AS16.5 LIFE SUPPORT SYSTEMS FOR AVIAN EMBRYOS: INTERACTION BETWEEN THE INCUBATION ENVIRONMENT AND THE PHYSIOLOGY OF THE EMBRYO

SUNDAY 3 JULY 2016 **11:05**

DENIS CHARLES DEEMING (UNIVERSITY OF LINCOLN, UNITED KINGDOM)

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The avian egg has been described the perfect 'space capsule' - with the exception of heat and oxygen, it contains all that an embryo requires for safe development through to hatching in a harsh environment. For many years the study of embryonic physiology has focussed on the domestic fowl incubated in artificial systems but there have been forays into the study of embryonic physiology in the more natural environment of the nest. We are relatively confident of how the incubation environment impacts on embryonic development and physiology in some species but there is a need to better understand incubation in the vast majority of species. This presentation will describe the interaction between key elements of embryonic physiology, such as water balance and respiration, with the egg's structure and its incubation environment. Recent research is highlighting the role of nest construction and function in the incubation process, particularly for small passerine species. Whilst nests may seemed to serve as receptacles for eggs during incubation, there is a growing awareness that nest construction may not simply reflect the result of evolutionary processes aimed at minimising the thermal energetics of incubation. Rather the bird and nest interact as an incubator to ensure successful development.

AS16.6 HYDROSTATIC PRESSURE IN FLEXIBLE-SHELLED REPTILIAN EGGS

SUNDAY 3 JULY 2016 **11:30**

MARINA R. SARTORI (UNIVERSITY OF SAO PAULO STATE, BRAZIL), LAURA B.T. CARREIRA (UNIVERSITY OF SAO PAULO STATE, BRAZIL), EDWIN W. TAYLOR (UNIVERSITY OF BIRMINGHAM, UNITED KINGDOM), AUGUSTO S. ABE (UNIVERSITY OF SAO PAULO STATE, BRAZIL)

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Reptilian eggshells exhibit a wide variation in structure, presenting rigid eggshells in crocodilians, similar to birds, and flexible eggshells, present in most of the Squamata and some turtles. The degree of mineralization of the eggshell influences the capacity of eggs to absorb water from the environment. Several species of lizards and snakes can take up large volumes of water during the incubation period, swelling and increasing in mass, thus generating an increase in pressure in the internal fluid system. Therefore, the structure of the eggshell is of importance to water balance and the course of development. We investigated how internal hydrostatic pressure and compliance changes during embryonic incubation in the flexible-shelled lizard *Iguana iguana*. We glued and sealed a port in the eggshell using Playdough and cyanoacrylic glue for the passage of a hypodermic needle connected to a pressure transducer. We recorded changes in baseline pressure after puncturing the eggshell and after a series of 0.2 ml saline injections. From the time of oviposition to close to hatching egg mass increased 130% and calculated volume 113% due to water uptake from the incubation media. Internal hydrostatic pressures varied from -0.27 ± 0.09 kPa to 22.2 ± 3.76 kPa. Mean compliance after serial injections was 8.3 x 10-3 ml cmH_2O^{-1} both at inicial and final incubation. Our results highlight the remarkable capacity of expansion of the flexible eggshells of lizards and raises the question of how developing embryos cope with varying pressures during the incubation period and how this may affect development.

AS16.7 NEW EVIDENCES FROM COMPLETE OVIRAPTORID CLUTCHES EXPLAIN WHY OVIRAPTORID DINOSAUR DID NOT BROOD

SUNDAY 3 JULY 2016 **11:45**

TZU-RUEI YANG (STEINMANN-INSTITUT FÜR GEOLOGIE MINERALOGIE PALÄONTOLOGIE UNIVERSITÄT BONN, GERMANY), JASMINA WIEMANN (STEINMANN-INSTITUT FÜR GEOLOGIE MINERALOGIE PALÄONTOLOGIE UNIVERSITÄT BONN, GERMANY), YEN-NIEN CHENG (NATIONAL MUSEUM OF NATURAL SCIENCES, TAIWAN), XIAO-CHUN WU (CANADIAN MUSEUM OF NATURE, CANADA)

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Previous studies on the egg clutch specimen with an associated oviraptorid dinosaur implied the 'prehatching brooding' behavior of oviraptorosaur dinosaurs. The inference was based on the remain of an adult oviraptor sitting atop a clutch with an avian-like brooding posture. However, the previously reported 'brooding oviraptor' specimens have clutch size of 6 and 22, which are significantly smaller than the complete clutches (>30) we investigated in this study. Besides, no embryo remains have been reported in the clutch of 'brooding' specimens, which indicates that the embryo development did not initiate since avian embryos start developing as the adult starts prehatching brooding (incubation). Intact eggshell microstructure also supports that the embryo development did not initiate yet. Three to four rings of eggs with sediments interbedded and high inclining angle of eggs make body-heat transfer insufficiently, and hence it is unlikely for an adult to sit and incubate the eggs. Hence, we propose a new alternate explaination that the 'brooding' oviraptors were actually laying eggs. We also reconstruct the oviraptorid nest structure as a piled-up mound with paired eggs lying on the slope with their blunt ends pointing inward to a center devoid of eggs. The eggs were partially buried in sediments according to porosity estimation and pigmentation detection of eggshells. The cryptic function suggested by the pigmentation detection of oviraptorid eggshells also implies that the eggs had camouflage other than being covered by the adult (prehatching brooding).

AS16.8 HOW TOUGH IS EGGSHELL?

SUNDAY 3 JULY 2016 **12:00**

DAVID TAYLOR (TRINITY COLLEGE DUBLIN, IRELAND), PETER O'REILLY (TRINITY COLLEGE DUBLIN, IRELAND), MEGAN WALSH (TRINITY COLLEGE DUBLIN, IRELAND), ALEX CULLEN (TRINITY COLLEGE DUBLIN, IRELAND)

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The shells of avian eggs are very brittle, but how brittle? We carried out tests to obtain the first accurate measurements of the fracture toughness of eggshell. There have been some previous measurements of this quantity, but they were so inaccurate as to be misleading. We designed a new experiment, applying axial compressive forces to eggs containing introduced defects (notches and holes). By analysing the stresses in the areas around the defects we calculated a fracture toughness value of 0.3MPa$\sqrt{m}$ for the shells of commercial hen's eggs. This is a very low value, about half the toughness of glass and only one tenth that of other natural materials based on calcium carbonate (e.g. nacre, mussel shells). We showed by microscopic analysis that this difference is due to the suppression of toughening modes. Unlike most natural materials, low toughness is essential for the egg, to allow the chick to break it when hatching. Eggshell has an unusual combination of low toughness (K_c) with high stiffness (Young's modulus, E): in fact it has the highest ratio of E/K_c of any biological material.

AS16.9 pH REGULATORY MECHANISMS ENABLE CEPHALOPOD EMBRYOS TO DEVELOP IN A NATURALLY ACIDIFIED ENVIRONMENT

SUNDAY 3 JULY 2016 **12:15**

MARIAN Y HU (INSTITUTE OF PHYSIOLOGY UNIVERSITY OF KIEL, GERMANY), YUNG-CHE TSENG (DEPARTMENT OF LIFE SCIENCE NATIONAL TAIWAN NORMAL UNIVERSITY, TAIWAN)

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Cephalopod embryos develop inside a protective egg capsule that creates an extreme microenvironment in terms of low pH and oxygen concentrations. I order to tolerate these environmental stressors, embryonic stages must possess physiological mechanisms to cope with CO_2 induced acid-base disturbances. This microenvironment of the developing embryo is particularly interesting in the context of CO_2 induced seawater acidification as increases in environmental pCO_2 (hypercapnia) are additive to the already high pCO_2 inside the egg.

We used squid (*Sepioteuthis lessoniana*) and cuttlefish (*Sepia officinalis*), which are known as powerful acid-base regulators to investigate the pH regulatory machinery with a special focus on proton secretion pathways during environmental hypercapnia. We cloned acid-base transporters including a Rhesus protein (sIRhP), V-type H^+ -ATPase (sIVHA) and the Na^+ /H^+ exchanger 3 (sINHE3), which are hypothesized to represent key players in proton secretion pathways among different animal taxa. Cephalopod specific antibodies demonstrated the sub-cellular localization of these transporters in epidermal (skin and yolk epithelium) ionocytes of early life stages. Functional genomics underline the role of sINHE3, sIVHA and sIRhP during acclimation to environmental hypercapnia. H^+ selective microelectrode measurements were used to detect increased proton gradients on ion-regulatory epithelia in CO_2 treated embryos.

Our results demonstrate that in convergence to teleosts, also cephalopod embryos have evolved a unique acid-base regulatory machinery located in epidermal ionocytes. These vertebrate like pH regulatory systems can be regarded a key feature of cephalopod early life stages to cope with hypercapnia induced pH fluctuations during an oviparous development.

AS16.10 HORMONES IN AVIAN EGGS: PERSPECTIVES ON PATTERN, PROCESS AND MECHANISM

SUNDAY 3 JULY 2016 **13:30**

WENDY REED (NORTH DAKOTA UNIVERSITY, UNITED STATES), MARK E CLARK (NORTH DAKOTA STATE UNIVERSITY, UNITED STATES), NICOLE SNYDER (NORTH DAKOTA STATE UNIVERSITY, UNITED STATES)

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Maternally derived hormones in eggs are bioactive compounds that can influence embryonic growth and development. Hormones in eggs of free-living birds were first characterized nearly 20 years ago and the research on patterns, processes and mechanisms of hormone deposition and action provide some insight into flexible phenotypes. One hypothesis is that hormones in eggs can be a conduit for maternal adjustment of offspring phenotypes to match post-hatching environments. In this system offspring are expected to perceive and respond to maternal egg environments and adjust development, in a system of maternal signal and offspring response. We use this context to explore the influence of maternal melatonin in egg yolks and impact on growth and development in a variety of species. Melatonin is a hormone that varies with day length and could signal seasonal timing of breeding, which is strongly associated with offspring survival and reproductive value across many species. We propose that embryos are using maternally derived melatonin as a signal of when during the season they are developing to adjust growth and development to match their hatch date.

AS16.11 PHYSIOLOGICAL EFFECTS OF HYPOXIC CONDITIONS DURING THE PLATEAU PERIOD ON THE CHICKEN EMBRYO

SUNDAY 3 JULY 2016 **13:55**

SHELLY DRUYAN (ARO, ISRAEL), AMIT HARON (HEBREW UNIVERSITY, ISRAEL)

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The chick embryo employs several adaptive responses to hypoxic challenges, affecting both metabolism and oxygen transport. The present study assessed the effects of hypoxic conditions (17% O_2) during the plateau phase on embryonic metabolic rate, cardiovascular parameters and development up to hatching. The chicks were into 3 treatments: (1) control; 17% O_2 for 12 h/d on E16 - E18 (12H), and 17% O_2 continuously on E16 - E18, a total of 72h (72H). Hypoxic embryos exhibited a significant increase in heart rate and an upward trend in hematocrit and hemoglobin levels. We observed a decrease in metabolism in 12H and 72H embryos during the plateau period; their oxygen consumption as well as yolk consumption were lower compared to control and they hatched with a significantly lower body temperature, indicating lower heat production. Exposure to 72h of hypoxic conditions led to significant physiological changes and had a detrimental influence on embryonic development and growth. In contrast, exposure to 12h/d produced moderate hypoxic changes, which helped the embryo to cope with the stress, without significant influences on its growth and development. The decrease in metabolism may represent a metabolic adaptation through a decrease in resting metabolic rate and lower heat production. Such alterations may affect post-hatch performance and energy allocation between maintenance and growth, especially under stress when there is increased oxygen demand.

AS16.12 HOW HOSTS RECOGNIZE PARASITIC EGGS: ASYMMETRICAL EGG DISCRIMINATION ALONG AN EGGSHELL COLOUR GRADIENT

SUNDAY 3 JULY 2016 **14:20**

DANIEL HANLEY (PALACKÝ UNIVERSITY, CZECH REPUBLIC), TOMÁŠ GRIM (PALACKÝ UNIVERSITY, CZECH REPUBLIC), MARK E. HAUBER (HUNTER COLLEGE AND THE GRADUATE CENTER OF THE CITY UNIVERSITY OF NEW YORK, UNITED STATES)

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Accurately recognizing and responding to cues is crucial for the fitness and survival. However, these tasks can be challenging in a natural context because novel stimuli inevitably differ from previously encountered stimuli. Despite being of great scientific interest, the underlying sensory and cognitive processes behind these decisions remain poorly understood. We used the avian host-brood parasite system to explore how hosts respond to foreign eggs displaying a range of novel colours. These differently coloured foreign eggs represented unfamiliar stimuli (unnatural colours, i.e., variation from green to purple) and stimuli representing ecologically relevant risks (eggs spanning the full range of eggshell coloration, i.e., variation from blue-green to brown). If hosts responded symmetrically to this colour variation, they would reject these foreign eggs from their nests based on their degree of colour dissimilarity to their own eggs, regardless of their particular colour (e.g., blue or brown). By contrast, if hosts responded asymmetrically, they would reject foreign eggs based on their particular colour (i.e., colour category) despite their perceived colour dissimilarity to their own eggs. We found that hosts responded asymmetrically to a natural gradient of eggshell colours; hosts rejected brown but accepted blue-green eggs that were, to host perception, equally dissimilar in colour to their own eggs. Contrary to these findings, unnaturally coloured eggs did not predict host responses. These findings illustrate a novel cognitive decision rule with important implications for the coevolutionary arms race between hosts and their brood parasites.

AS16.13 THE ROLE OF THE COLLAGENOUS MEMBRANE IN THE FRACTURE RESISTANCE OF EGGS

SUNDAY 3 JULY 2016 **14:35**

DAVID LABONTE (UNIVERSITY OF CAMBRIDGE, UNITED KINGDOM), H. BURAK CALISKAN (UNIVERSITY OF CAMBRIDGE, UNITED KINGDOM), MICHELLE L. OYEN (UNIVERSITY OF CAMBRIDGE, UNITED KINGDOM)

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Maintaining the structural integrity of eggs is of considerable biological relevance and a central problem for the poultry industry. While failure criteria for eggs are clear-cut in an industrial context, it is less obvious what exactly constitutes critical failure of an egg during incubation. In both contexts, the egg's shell has attracted most of the attention, and its strength has even been suggested to pose a limit to bird body size. However, it is unlikely that the failure of eggs is stress-limited, as the egg's shell is brittle, and thus failure is expected to be energy-limited instead: it should occur via the propagation of a crack. However, the crack-pattern that ensued when blown-out eggs were fractured between two flat plates was not dominated by a few long cracks. Instead, the eggs' shells broke into multiple small fragments, which were held together by the collagenous membrane. As a result, the eggs retained a significant fraction of their initial load-carrying capacity, even when compressed to half their original height. Strikingly, the fracture resistance changed completely when the collagenous membrane was removed. Firstly, eggs without a membrane lost their load-carrying capacity immediately after the initiation of the first macroscopic crack. Secondly, the ensuing crack-pattern was dominated by a small number of long and straight cracks, and the number of fragments decreased, while their size increased correspondingly. Together, these results constitute strong evidence for a mechanical function of the collagenous membrane: it deflects cracks and hence prevents catastrophic failure of the eggs after crack-initiation.

AS16.14 RECENT INSIGHTS INTO THE FUNCTION AND EVOLUTION OF AVIAN EGGSHELL STRUCTURE AND COLOURATION

SUNDAY 3 JULY 2016 **14:50**

BRANISLAV IGIC (AUSTRALIAN NATIONAL UNIVERSITY, AUSTRALIA), MARK E HAUBER (HUNTER COLLEGE CITY UNIVERSITY OF NEW YORK, UNITED STATES), MATTHEW D SHAWKEY (UNIVERSITY OF GHENT, BELGIUM)

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Bird eggs have astonished naturalists for centuries due to their diverse and beautiful colours and appearances. Although aesthetically appealing for us humans, these colours and patterns play some very important roles in the reproductive biology of birds worldwide. For example, eggshell pigments may aid embryonic development by controlling the transmission of light through the eggshell or help parents to identify parasitic eggs in their nests. Surprisingly, despite the huge diversity in the phenotypic appearance of eggshells between and within species, only two pigments are considered primary contributors to eggshell colouration, whereas structural features that may influence eggshell appearance are rarely investigated. In this talk I will discuss our current understanding of both the pigmentary and structural factors that affect the optical appearance of avian eggshells, and suggest some interesting avenues for future research. In the spirit of the meeting, I will take an integrative approach by illustrating how technologies and techniques commonly used in material and chemical sciences can help further our understanding of the evolutionary ecology of avian eggshells.

AS16.15 WITHIN-SEASON VARIATION IN THE SHAPE AND CONDUCTANCE OF AMERICAN WHITE PELICAN EGGS

SUNDAY 3 JULY 2016 **15:45**

MARK E CLARK (NORTH DAKOTA STATE UNIVERSITY, UNITED STATES)

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We investigated the relationship between laying date and the characteristics associated with gas exchange in American white pelican (*Pelecanus erythrorhynchos*) eggs. We collected 92 eggs (within 24 hours of laying) from 92 American white pelican nests located at Marsh Lake in Southwestern Minnesota, United States during the 2012 and 2015 breeding season. We measured size (mass, length and breadth), volume, surface area, conductance, shell thickness and porosity of the eggs in the lab. We found that size and volume of the eggs did not vary with laying date. However, surface area ($r^2 = 0.32, F_{1,62} = 28.9, p < 0.001$) and surface area:volume ($r^2 = 0.16, F_{1,62} = 11.8, p = 0.001$) increased with laying date. In addition, conductance (mg H_2O lost per day per torr) also increased with laying date ($r^2 = 0.15, F_{1,90} = 16.0, p < 0.001$). However neither shell thickness nor porosity were related to laying date. We conclude that the shape of American white pelican eggs changes across the season such that surface area relative to volume increases. The increase in surface area to volume ratio facilitates greater conductance, and may be a mechanism by which offspring from eggs laid later in the season develop more quickly.

AS16.16 CUCKOO EGGS: IS THE MIMICRY JUST SKIN DEEP?

SUNDAY 3 JULY 2016 **16:00**

STEVE J PORTUGAL (ROYAL HOLLOWAY UNIVERSITY OF LONDON, UNITED KINGDOM)

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Many cuckoos are obligate avian brood parasites, laying their eggs in hosts' nests and playing no role in the provisioning of the progeny. The eggs of Cuculus cuckoos mimic those of their hosts and hatch earlier, with the altricial chick evicting the hosts eggs and nestlings. Other members of the cuckoo family have different breeding strategies, including intra-specific cooperative breeding (e.g. anis), and a traditional non-parasitic bi-parental care approach (e.g. coucals). For each species, these different breeding strategies place different requirements on the egg and eggshell. Whether it be host egg mimicry and rapid laying in the Cuculus cuckoos, or coping with large clutch sizes in anis, each cuckoo egg has specific adaptations suited to their reproductive strategies. This talk will present data on how parasitic cuckoo eggs have adaptations to their parasitic lifestyle in terms of heat retention, potentially supporting rapid development, Similarly, new data will demonstrate how cooperative breeding anis have special adaptations in their eggshell structure for their large clutch sizes and multiple incubating parents. Lastly, data will demonstrate that low rates of gas exchange across the eggshell in Cuculus cuckoos in comparison to hosts is a trait of other parasitic bird species such as honeyguides and vidua finches.

AS16.17 SYNERGISTIC OR ANTAGONISTIC EFFECTS OF TWO MATERNALLY-DERIVED EGG COMPONENTS (ANTIBODIES AND TESTOSTERONE) ON OFFSPRING PHENOTYPE

SUNDAY 3 JULY 2016 **16:20**

TONY D WILLIAMS (SIMON FRASER UNIVERSITY, CANADA), EUNICE CHIN (SIMON FRASER UNIVERSITY, CANADA), ROWAN RAMPTON (SIMON FRASER UNIVERSITY, CANADA), ROXANA TORRES (UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO, MEXICO)

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Maternally-derived egg components (non-genetic parental contribution) are thought to modulate offspring development and, potentially, final adult phenotype. Eggs contain multiple maternally derived compounds (e.g. hormones, antibodies, mRNA, antioxidants) but most studies have focused on single egg components (most often yolk testosterone, or corticosterone), and on short-term effects. Here we simultaneously manipulated two egg components, maternally-derived antibodies (MAb) and yolk testosterone to assess potential synergistic or antagonistic effects on offspring phenotype. We used lipopolysaccharide treatment to generate a secondary immune response in female zebra finches (Taeniopygia guttata), which produced clutches of eggs with high (LPS-treated) or low (control) MAb. We then used a split design manipulating yolk testosterone within clutches of high- and low-MAb eggs using in ovo egg injection. We investigated a) short-term effects of experimental manipulation of both egg components at 30 days post-hatching on chick growth and immune function at fledging, and b) long-term effects at sexual maturity (>90 days post-hatching) on phenotypic quality of i/ males (sons) using standardise mating trials (courtship, song rate, etc); ii/ females (daughters) by measuring reproductive traits during breeding (egg size, clutch size etc), and iii/ cell-mediated and humoral immunity in both sexes.

AS16.18 CRACKING MYSTERIES AT THE MUSEUM: CITIZEN SCIENCE REVIVAL OF EGG COLLECTION

SUNDAY 3 JULY 2016 **16:35**

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In US, egg collecting peaked from 1885 to the 1920s and dwindled to an end by 1970. Egg collecting was carried out almost exclusively by amateurs, but supported thousands of professional research projects. Thanks to the amalgamation of private collections into museum repositories, there are about 80 egg collections of research importance in the North America, which together contain less than 500,000 egg sets. These egg sets have been useful for anticipated, as well as unanticipated, reasons. The skills of egg collecting have been lost among amateur birdwatchers, and those who monitor nestboxes typically remove and discard House Sparrow eggs, an invasive species in North America. The Sparrow Swap is a citizen science project that is reviving amateur egg collecting by focusing on the eggs of House Sparrows because no permits are required. The short-term goals of the Sparrow Swap involve examining the effectiveness of nestbox management option, including comparing the outcomes of egg removal with egg swapping (removing eggs and replacing them with replicas). As the egg collection grows, the long-term goals of the Sparrow Swap involve investigations on whether various characteristics of House Sparrow eggs (color, pattern, thickness, porosity, etc) can be useful for mapping and monitoring environmental contaminants.

POSTER SESSION - SUNDAY 3 JULY 2016

AS16.19 ELASMOBRANCH EGG CASE DEVELOPMENT IN 7 KEY STAGES

SUNDAY 3 JULY 2016

SYAFIQ M MUSA (UNIVERSITY OF MANCHESTER, UNITED KINGDOM), JOHN L FITZPATRICK (STOCKHOLM UNIVERSITY, SWEDEN), HOLLY A SHIELS (UNIVERSITY OF MANCHESTER, UNITED KINGDOM)

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The classical embryological study by Ballard *et al.* (1993, J. Exp. Zoo. 267: 318-336) identified 34 stages in the oviparous elasmobranch development spanning the time between laying and hatch. The aim of the current work is to produce a simplified and more user friendly developmental staging that can be adopted by anyone who is interested in oviparous shark and skate embryonic development. Our aim was to provide a 'pocket guidance' for elasmobranch egg case developmental stage identification for members of the general public that is also relevant to aquarists and scientists. Each development stage is provided with diagrams and physiological and ecologically relevant details. Moreover, each stage can be identified by shining a light from the back of the egg case without requiring any additional magnification which makes it amenable to shark enthusiasts without specialised equipment. The 7 stage developmental table has been constructed in reference to the large spotted catshark, *Scyliorhinus stellaris*, but it can be applied to other oviparous elasmobranch species with only minor modification.

AS16.20 EGG TURNING AND INCUBATION TEMPERATURE IN PARROTS: INFLUENCES OF BREEDING BEHAVIOUR AND IMPLICATIONS FOR ARTIFICIAL INCUBATION

SUNDAY 3 JULY 2016

JORIS WIETHASE (UNIVERSITY OF GLASGOW, UNITED KINGDOM), JUAN CORNEJO (LORO PARQUE FUNDACIÓN, SPAIN), BARBARA HELM (UNIVERSITY OF GLASGOW, UNITED KINGDOM), AUGUSTE VON BAYERN (MAX PLANCK INSTITUTE FOR ORNITHOLOGY, GERMANY), SCOTT SHAFFER (SAN JOSE STATE UNIVERSITY, UNITED STATES)

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Despite the importance of correct egg turning and heating for the successful embryonic development of birds, those parameters are rarely studied in detail. This study aimed at investigating and quantifying for the first time egg turning rates and incubation temperatures in captive individuals of a particularly threatened group, the parrots (Psittaciformes). Additionally, it asked for factors influencing those breeding parameters, as well as for implications for improving artificial incubation techniques. We hypothesized that egg turning rates and egg temperatures of nesting parrots are not uniform between genera of different parental breeding systems, and that they are influenced by physical conditions. Furthermore, we hypothesized that those parameters deviate from those used in artificial incubation devices. Over one breeding season, we studied 25 captive breeding pairs of six species of the genera Ara, Amazona, Cacatua and Eclectus. The parrot's incubation parameters were measured through rotation and temperature sensors using novel data logging techniques within 3D-printed parrot eggs, combined with nest cameras and temperature-sensing iButtons. First results showed increasing trends in egg temperatures and number of daily rolling events during the first third of incubation for two of the genera. Strictly uniparental incubating species exhibited a

wider range of incubation temperatures than those with shared incubation. Based on these preliminary results, we draw first conclusions about the trends associated with different life history strategies in parrots, as well as for the optimization of artificial incubation methods.

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