Johannesburg, 17 of June, 2014

Dr Bernhard Zipfel
Curator
Evolutionary Studies Institute
University of the Witwatersrand

Dear Dr Zipfel,

I would like to ask your permission and advice about the loan of materials for a research project on the evolution of the periodontal ligament in therapsids (see following proposal). This project is in collaboration with Dr Robert Reisz, from Toronto and his student Mr Aaron LeBlanc. The drawback is that a destructive technique will be used for this research.
I revised the Evolutionary Studies Institute collection of therapsids to identify fossil material that may be sacrificed as they are incomplete or poorly preserved. I am presenting a list of the materials below:

BP/1/4652: isolated postcanine series of Diademodon
BP/1/2523: isolated left lower jaw of Bauria.
BP/1/4851: fragment of lower jaw with teeth, dinocephalia
BP/1/5417: fragment of jaw with teeth, dinocephalia
BP/1/6854: fragment of jaw of dinocephalia with teeth
BP/1/172: partial lower jaw, therocephalia
BP/1/7257: fragment of right lower jaw of basal Therocephalia
BP/1/1770: fragment of right lower jaw of basal Therocephalia
BP/1/784: lower jaw gorgonopsia
BP/1/3395a: partial skull gorgonopsia
BP/1/4408"lower jaw gorgonopsia
BP/1/6097: lower jaw Cynognathus

It is important to highlight that the scope of this research will allow an integrated knowledge of the evolution of the periodontal ligament in the synapsid lineage (involving ~ 300 millions of years). The information in mammal-like therapsids is of prime importance as they represent the transition to the origin of mammals. The colleagues in this project already have comparative material of very basal forms ("pelycosaurus") and of Mesozoic mammals to integrate in to this project.
The specimens to be used for the research (see attached photos) will be casted previous to the study.
I would appreciate very much your advice to handle the material for this investigation.

Best regards,

Dr Fernando Abdala
Senior Research
Evolutionary Studies Institute
University of the Witwatersrand

The Origin of the Mammalian Periodontal Ligament

Aaron R. H. LeBLANC*, Kirstin BRINK, Fernando ABDALA, and Robert R. REISZ

*Department of Ecology and Evolutionary Biology, University of Toronto Mississauga, 3359 Mississauga Road, Mississauga, Ontario, L5L 1C6, Canada,
aaron.leblanc@mail.utoronto.ca

Proposed research:

Mammal teeth are unique in that they are housed in sockets and suspended by periodontal ligaments. This type of tooth attachment prolongs the life of teeth by creating a shock absorbing system that dissipates the forces of tooth occlusion. Having a periodontal ligament also allows teeth to move along the jaw post-eruption, creating a mechanism for fine-scale adjustments to the positions of teeth. Whereas the development of tooth tissues in mammals is well studied, the evolutionary origins of these tissues from the therapsid condition are unknown. This is due to two factors: (1) virtually no histological studies have documented the types of attachment tissues that anchor the teeth into the jaws of any therapsid (Jasinoski and Chinsamy, 2012); and (2) the homologies of non-mammalian and mammalian tooth tissues have not been properly documented.

We propose to track the evolution of the mammalian tooth attachment tissues by examining histological sections of several therapsid taxa. Given our previous research (LeBlanc and Reisz, 2013), we know that stem amniotes were able to produce the same attachment tissues that are present in mammals, but many taxa did not possess a non-mineralized periodontal ligament. By examining key therapsid taxa, we aim to determine the timing of the development of the periodontal ligament in relation to the appearance of dental occlusion and diphyodonty in synapsids. Did the periodontal ligament develop in response to dental occlusion? Did it appear in conjunction with diphyodonty? Or did it evolve in response to other selective forces? What attachment tissues gave rise to the periodontal ligament? These questions can only be answered by examining therapsids, because basal synapsid teeth are fused to the socket as they are in most other tetrapods (Peyer, 1968). The process will require thin sections of the requested material, because CT scans do not provide the appropriate resolution to see the attachment points of periodontal ligaments (Sharpey's fibers), the presence and type of root cementum, or the boundaries of the tooth sockets. Furthermore, we hope to use fragmentary specimens that are of limited scientific value beyond occurrence data. We have previously compared CT images to thin sections and have shown that CT data is not sufficient to see most of these finer details of tooth and tooth attachment tissues (MacDougall et al., 2014). Nevertheless, we would first provide molds and casts and, if needed, 3-D models of the specimens using our imaging facility at the Royal Ontario Museum in Toronto, Canada. This would ensure that any subsequent researchers could still examine the anatomy of the specimens we are requesting.

This project has the potential to shed light on the origins of mammalian tooth attachment, the timing of this key innovation, and its function in therapsids. To date, no attempt has been made to actually document this transition from tooth ankylosis in basal synapsids to the complex tooth attachment in mammals, despite numerous evolutionary and developmental hypotheses addressing this question (Peyer, 1968; Osborn, 1984; Gaengler and Metzler, 1992). We believe that the findings from this project will have broad implications for our understanding of tooth development across deep time and for providing the first detailed look at the origin of mammalian tooth attachment.

REFERENCES

Gaengler, P., and E. Metzler. 1992. The periodontal differentiation in the phylogeny of teeth – an overview. Journal of Periodontal Research 27: 214–225.

Jasinoski, S. C., and A. Chinsamy. 2012. Mandibular histology and growth of the nonmammaliaform cynodont *Tritylodon*. Journal of Anatomy doi: 10.1111/j. 1469-7580.2012.01494.x.

LeBlanc, A. R. H., and R. R. Reisz. 2013. Periodontal ligament, cementum, and alveolar bone in the oldest herbivorous tetrapods, and their evolutionary significance. PLoS One 8: e74697.

MacDougall, M. J., A. R. H. LeBlanc, and R. R. Riesz. 2014. Plicidentine in the Early Permian parareptile *Colobomycter pholeter*, and its phylogenetic and functional significance among coeval members of the clade. PloS One 9: e96559.

Osborn, J. W. 1984. From reptile to mammal: evolutionary considerations of the dentition with emphasis on tooth attachment. Symposium of the Zoological Society of London 52: 549–574.

Peyer B (1968) Comparative odontology (Zangerl R, Transl.). Chicago: University of Chicago Press. 347 p.

Specimens from the collection of the ESI to be used in the research

BP/1/4652: isolated postcanine series of *Diademodon*

BP/1/6097: lower jaw Cynognathus?

BP/1/2523: isolated left lower jaw of Bauria

BP/1/1770: fragment of right lower jaw of basal Therocephalia

BP/1/7257: fragment of right lower jaw of basal Therocephalia

BP/1/172: partial lower jaw, Therocephalia

BP/1/3395a: partial skull Gorgonopsia

BP/1/784: lower jaw Gorgonopsia


BP/1/5417: fragment of jaw with teeth, Dinocephalia


BP/1/4851: fragment of lower jaw with teeth, Dinocephalia


BP/1/6854: fragment of jaw of Dinocephalia with teeth