



# Schlecht gekaut – halb verdaut

## Nahrungszerkleinerung im Tierreich



Marcus Clauss

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Zurich, Switzerland  
Biologie und Erkrankungen der Wildtiere 2017*



**University of  
Zurich** <sup>UZH</sup>



**Clinic**  
of Zoo Animals, Exotic Pets and Wildlife



# Gliederung

Verdauung und Partikelgrösse

Zerkleinerung bei Landwirbeltieren

Zahnoptimierung: Lebensdauer I

    Zahnfunktion 1: Schwerkraft?

Zahnoptimierung: Kauleistenverlängerung

Zahnoptimierung: Schmelzfalten

    Zahnfunktion 2: Partikelbewegungen?

Zahn- vs. Kauoptimierung: Wiederkäuen

Zahnoptimierung: Lebensdauer II



# Verdauung und Partikelgrösse



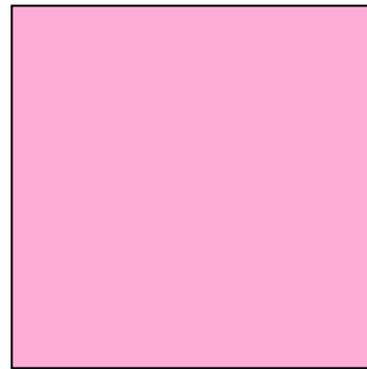
# Verdauung braucht ... Zeit?

Tierische Zelle – Pflanzenzelle



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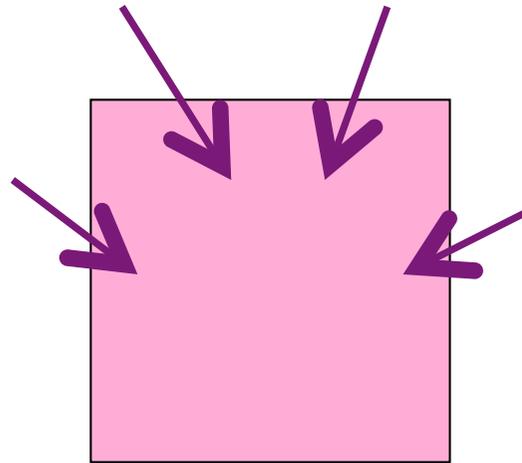


**Zellmembran**



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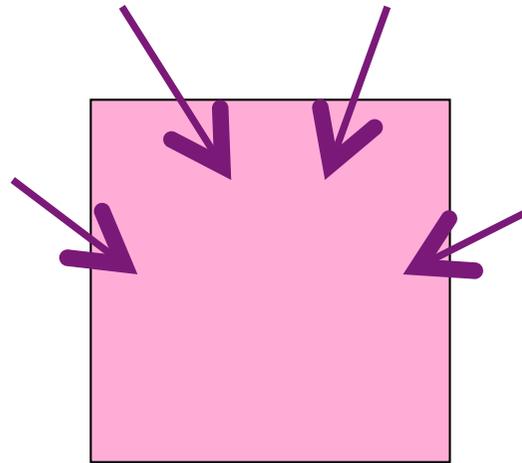


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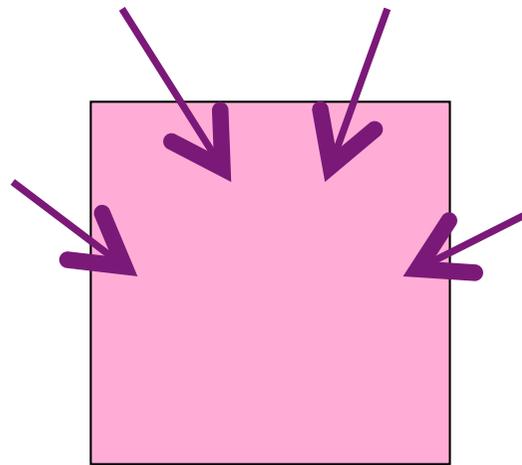


**Zellwand**

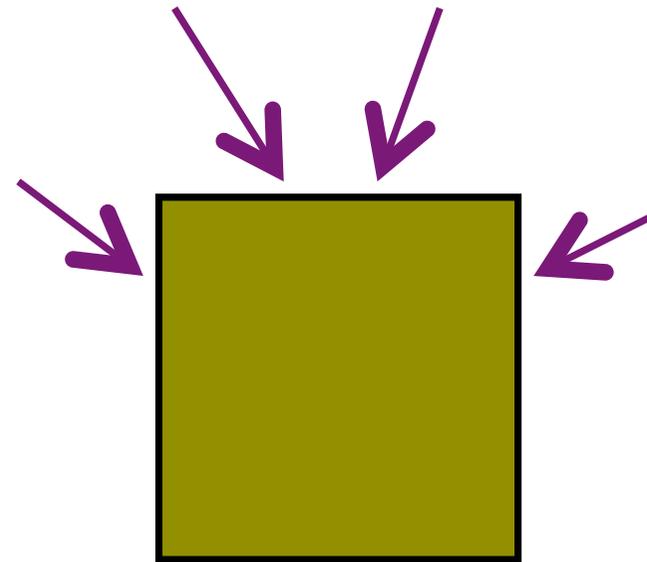


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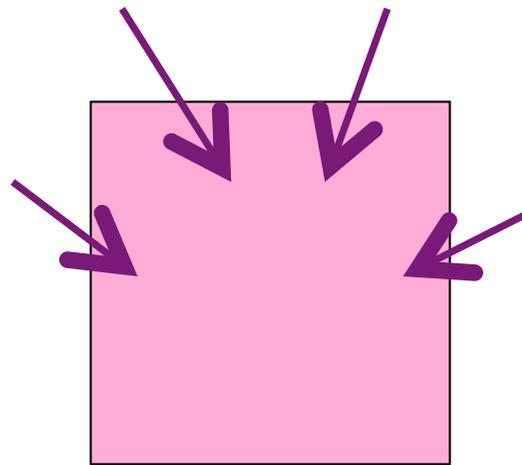


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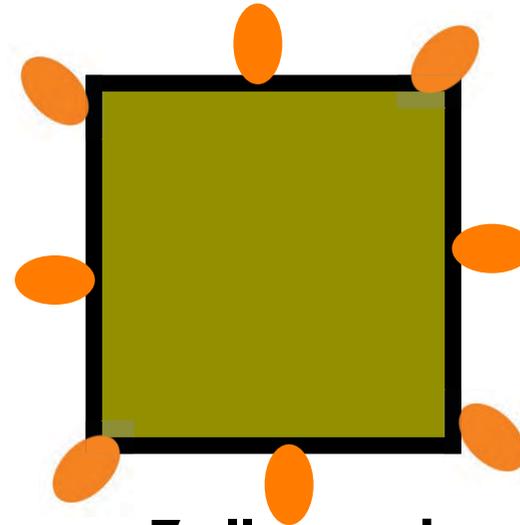


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## Tierische Zelle – Pflanzenzelle



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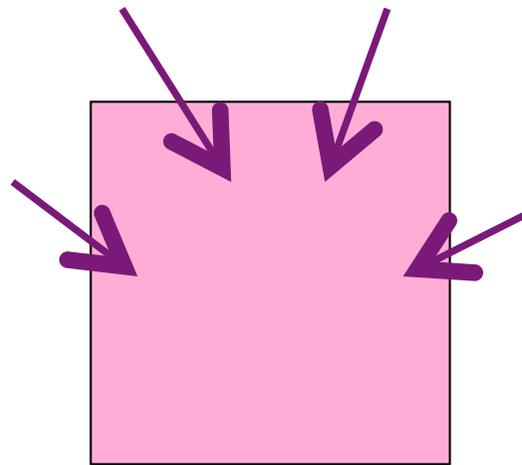


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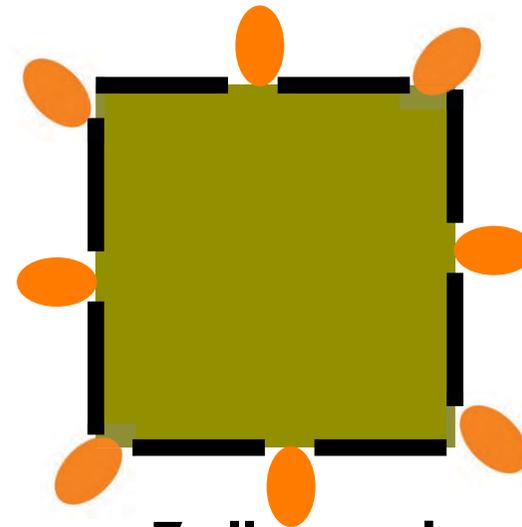


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## Tierische Zelle – Pflanzenzelle



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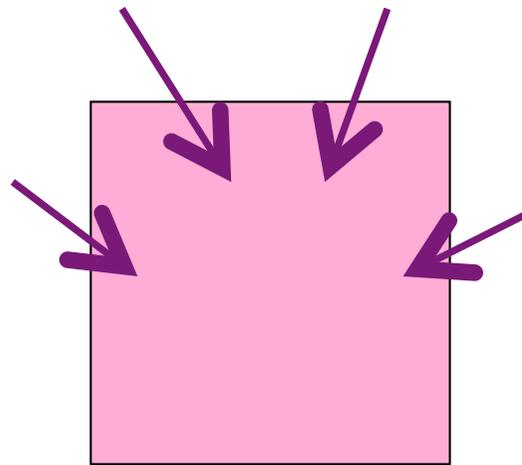


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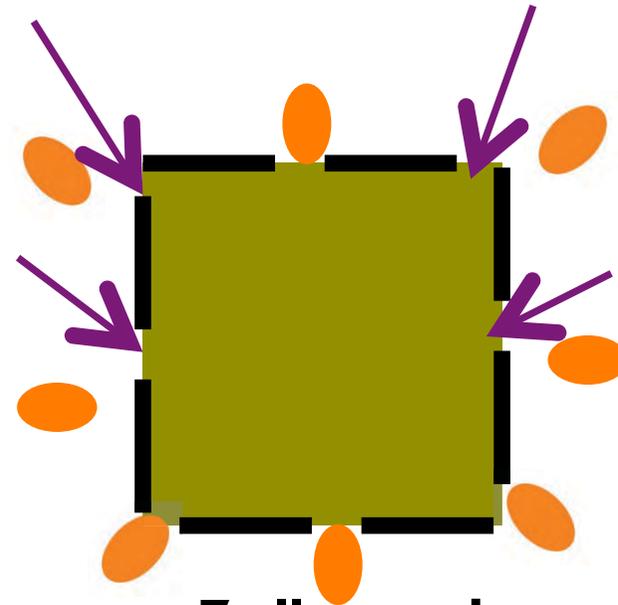


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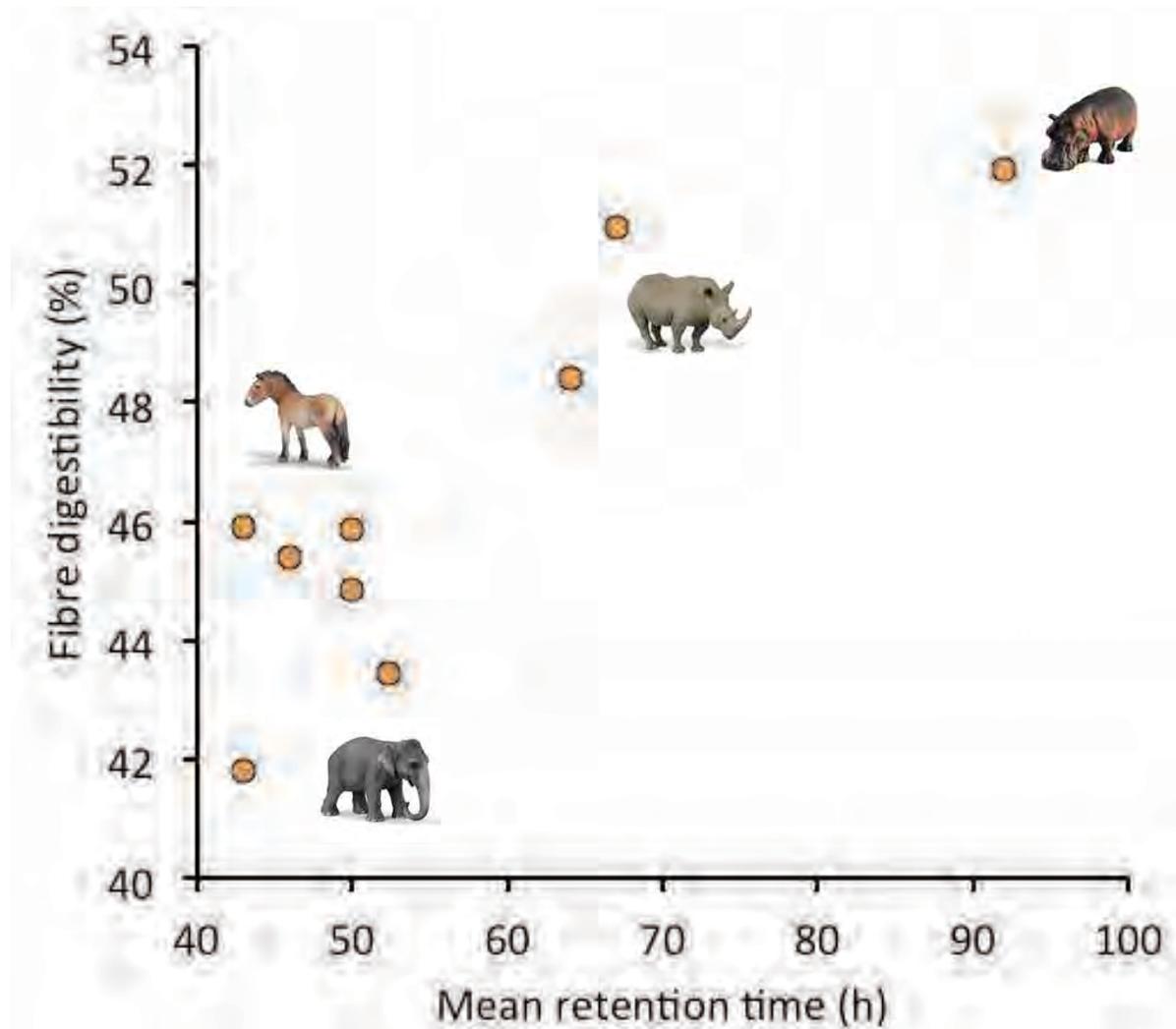
**Zellwand**



# Evidence for a tradeoff between retention time and chewing efficiency in large mammalian herbivores

Marcus Clauss<sup>a,\*</sup>, Charles Nunn<sup>b,c</sup>, Julia Fritz<sup>d</sup>, Jürgen Hummel<sup>e</sup>

Comparative Biochemistry and Physiology, Part A 154 (2009) 376–382

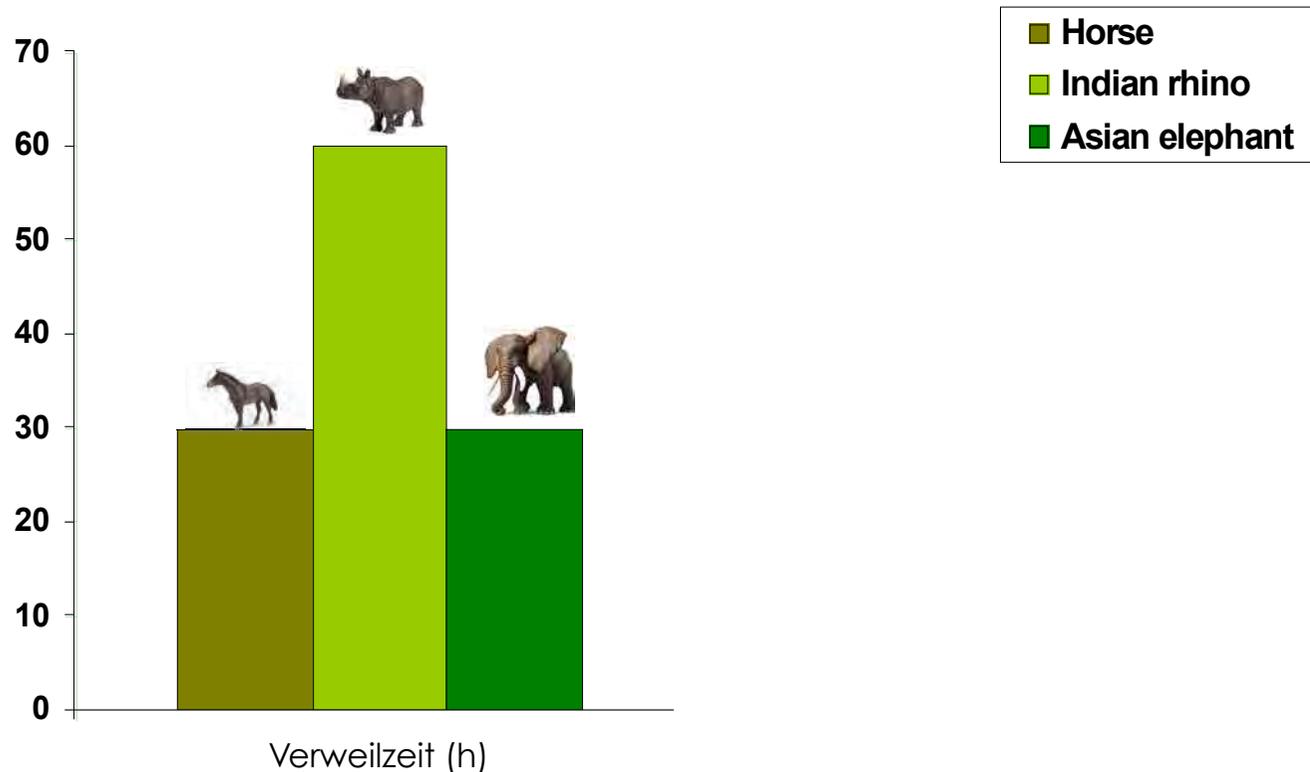




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M. Clauss<sup>1</sup>, C. Polster<sup>1</sup>, E. Kienzle<sup>1</sup>, H. Wiesner<sup>2</sup>, K. Baumgartner<sup>3</sup>, F. von Houwald<sup>4</sup>, S. Ortmann<sup>5</sup>, W. J. Streich<sup>5</sup> and E.S. Dierenfeld<sup>6</sup>

Journal of Animal Physiology and Animal Nutrition **89** (2005) 229–237

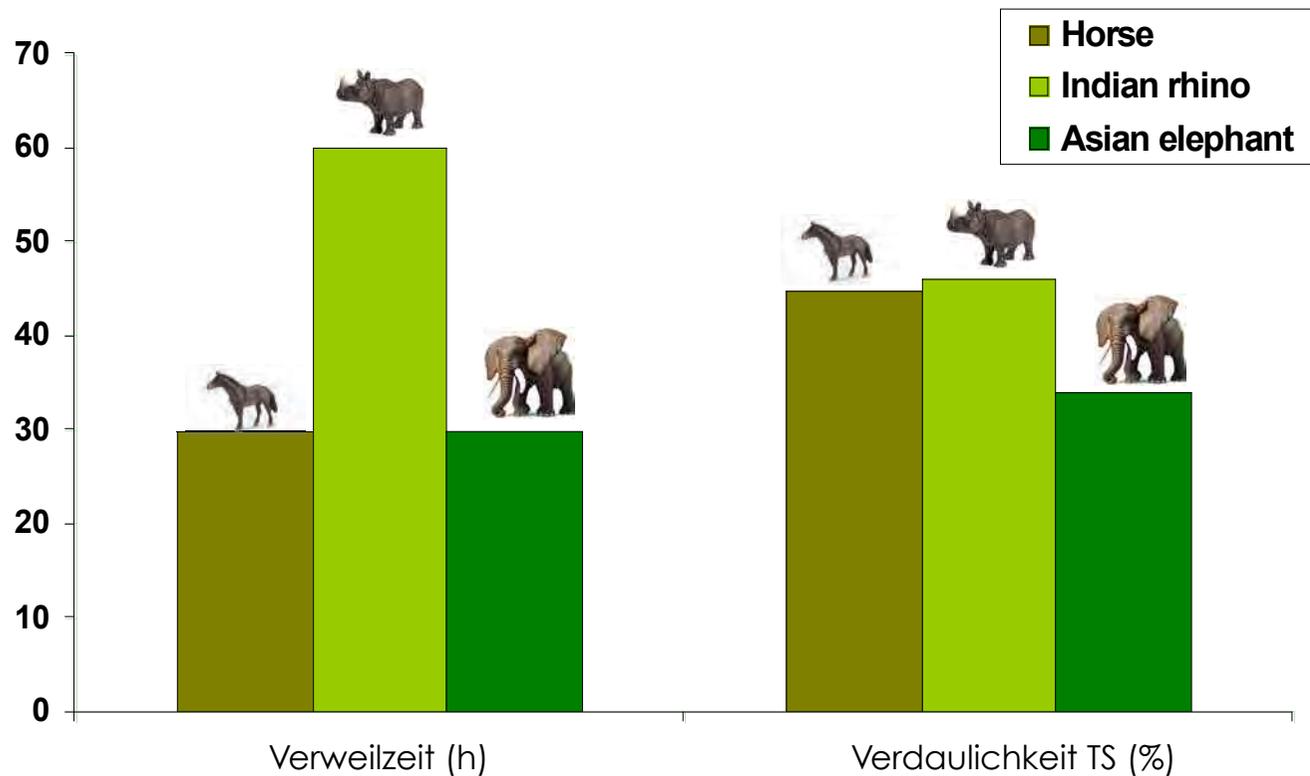




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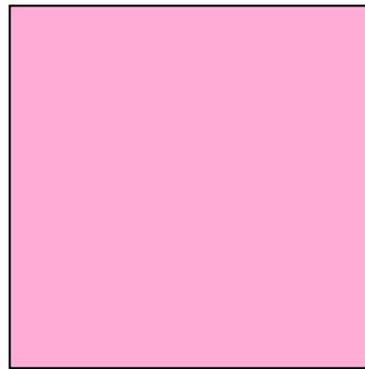
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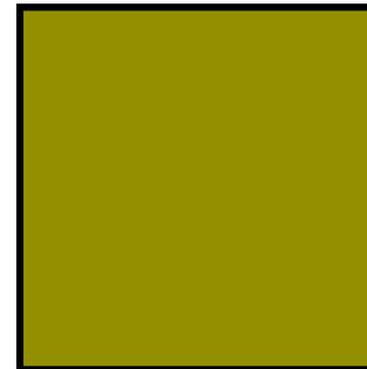


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**Zellmembran**

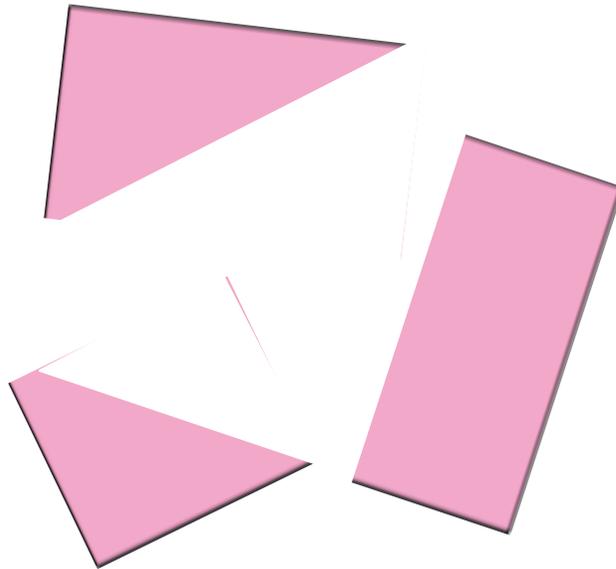


**Zellwand**



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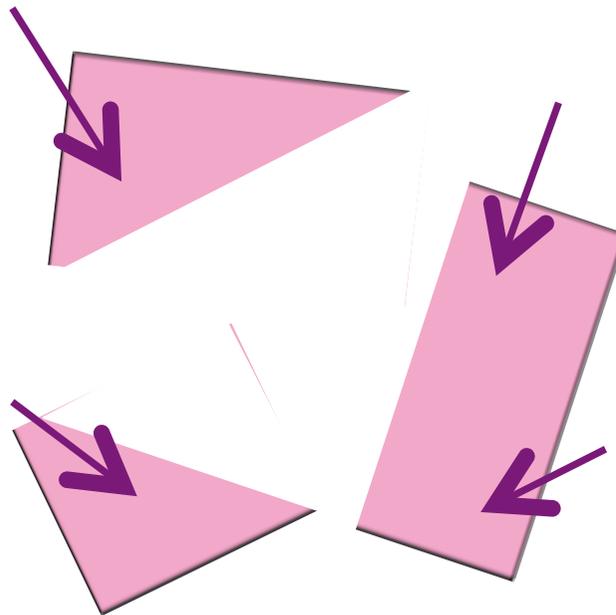


**Zellwand**



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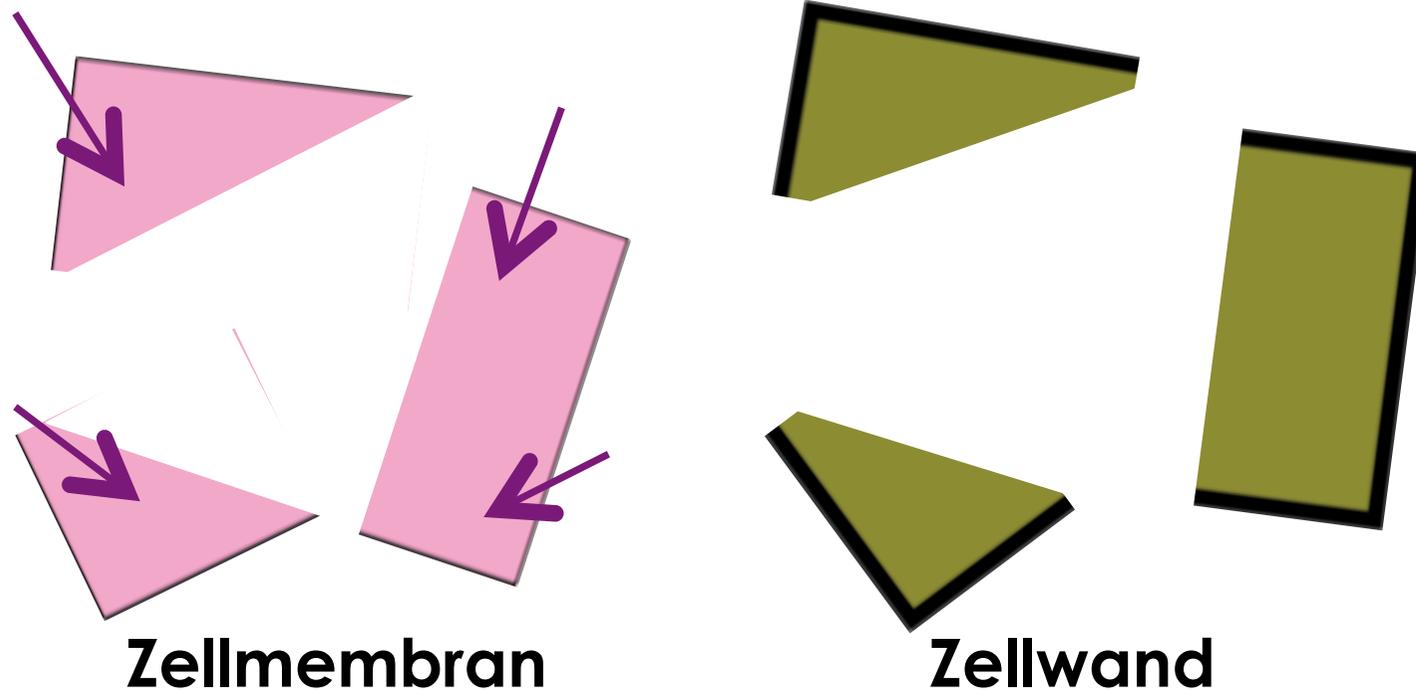
**Zellmembran**

**Zellwand**



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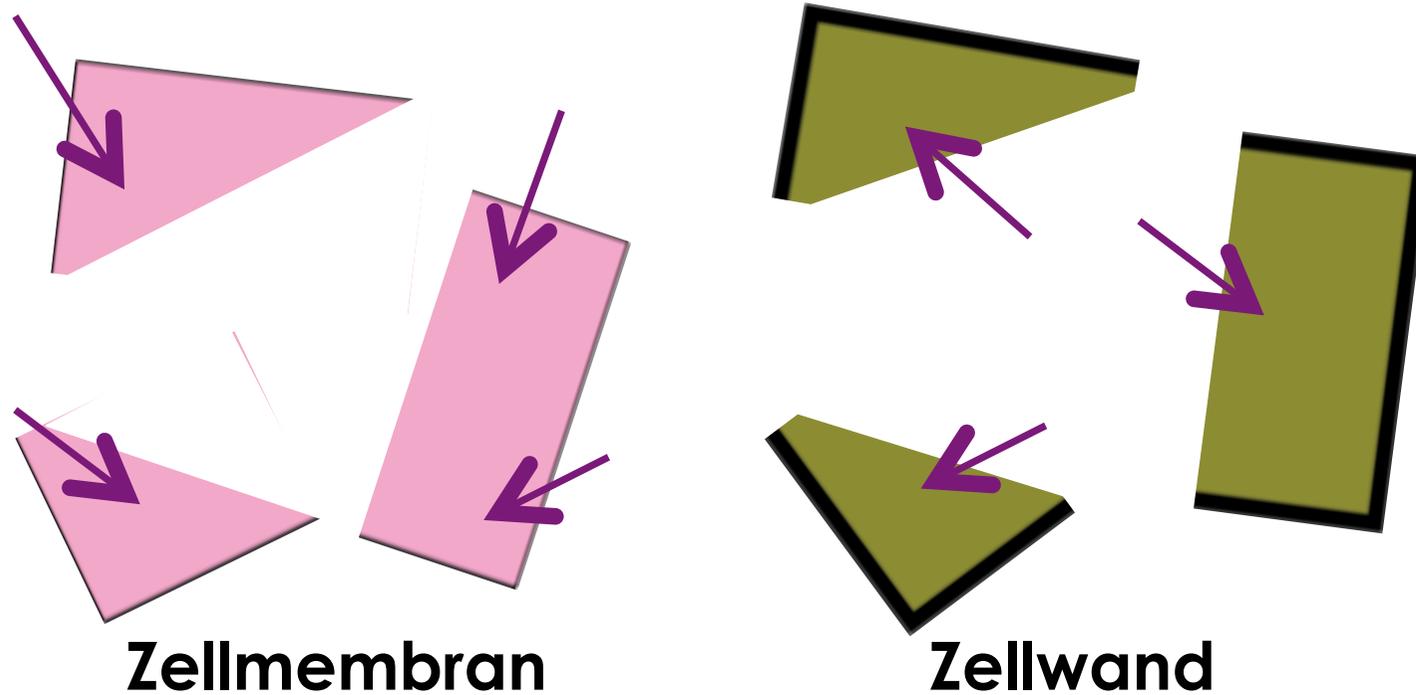
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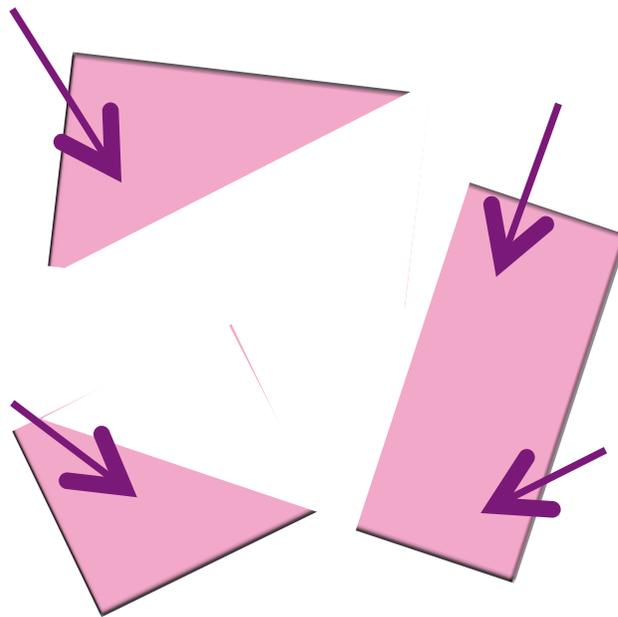
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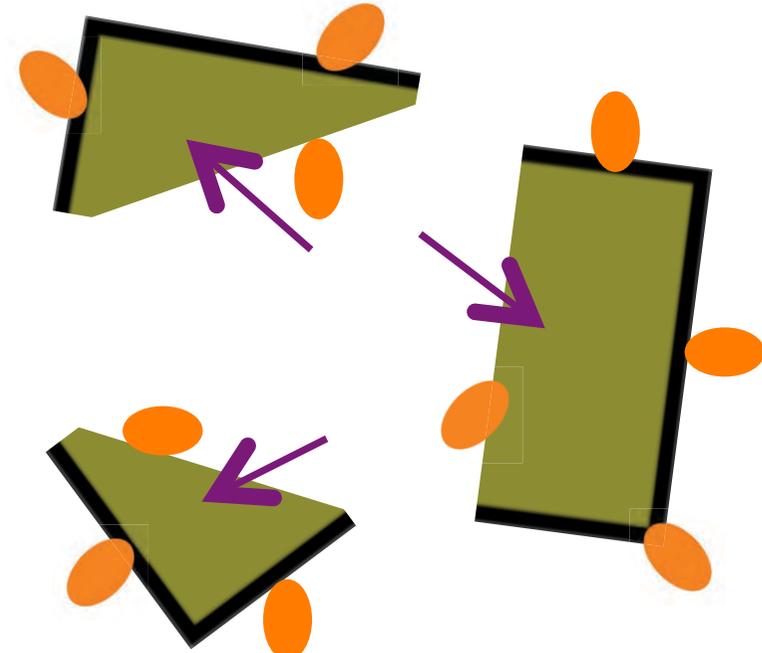


# Verdauung braucht ... Zeit?

Tierische Zelle – Pflanzenzelle



**Zellmembran**



**Zellwand**



# **Digestive Fermentation in Herbivores: Effect of Food Particle Size**

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*Physiological Zoology* 63(4):710-721. 1990.

**Karen A. Bjorndal<sup>1</sup>**

**Alan B. Bolten<sup>1</sup>**

**John E. Moore<sup>2</sup>**



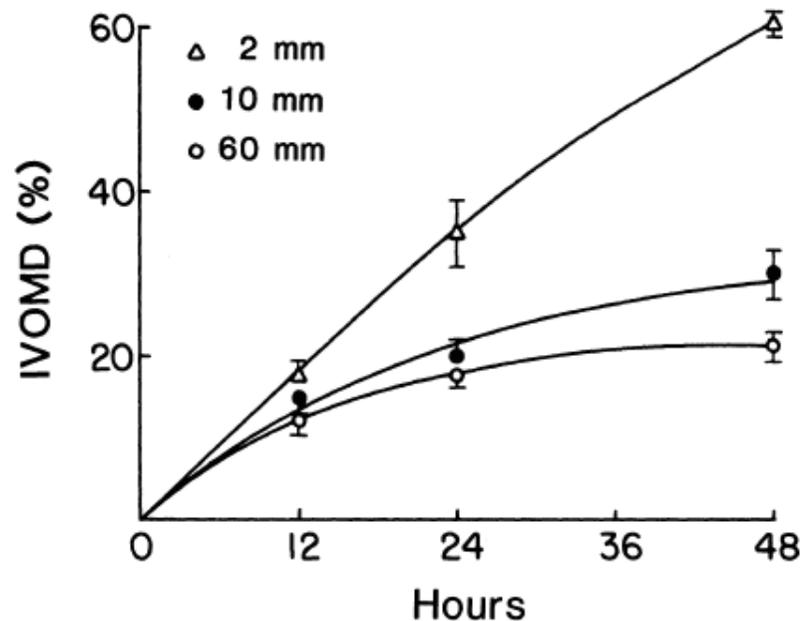
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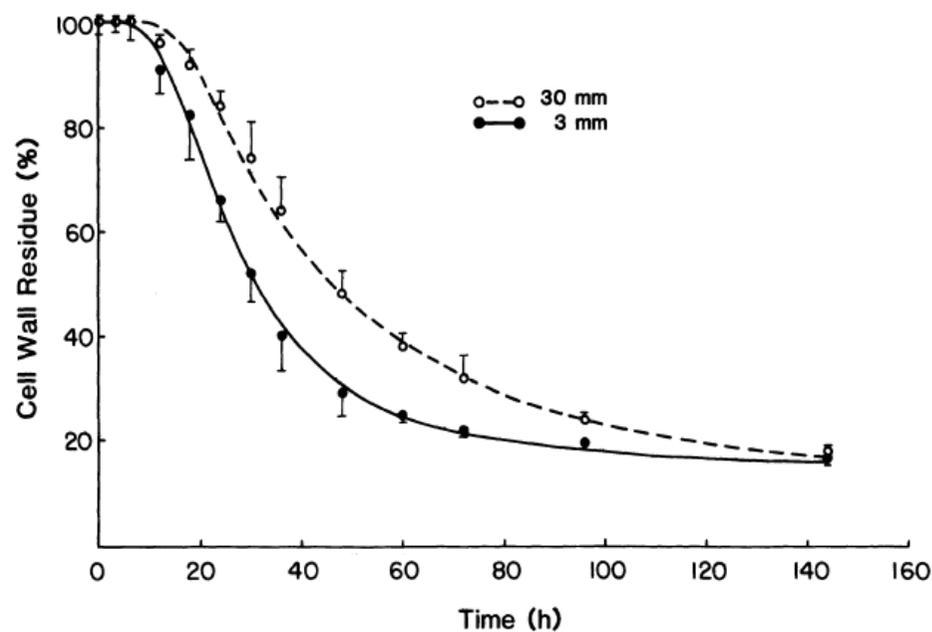
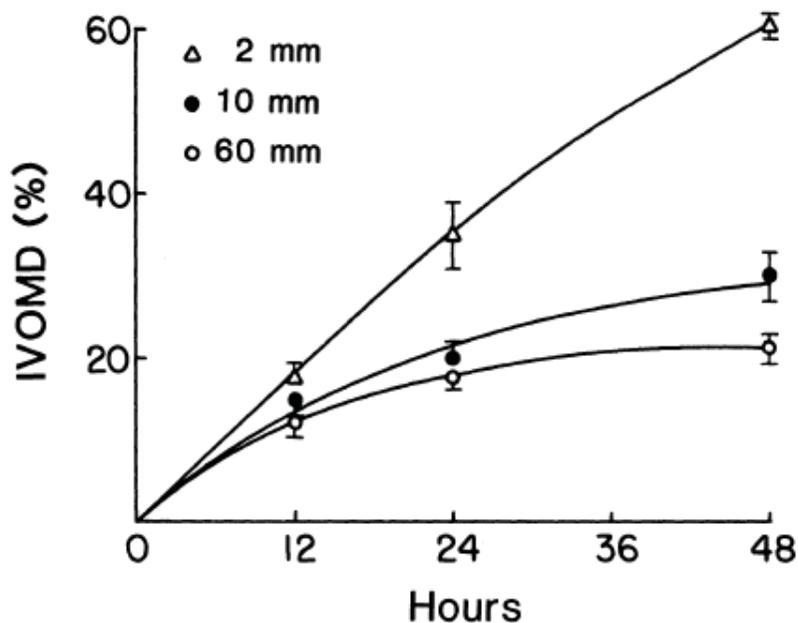
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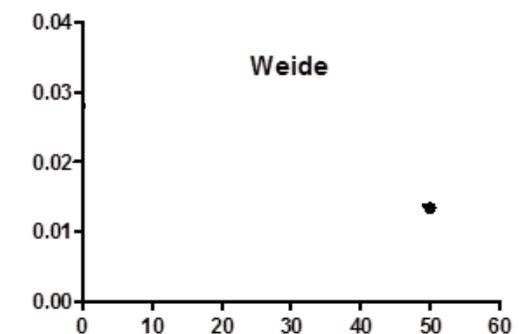
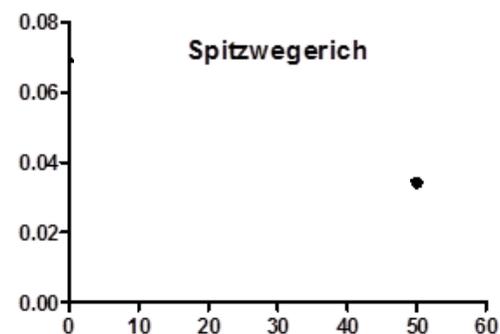
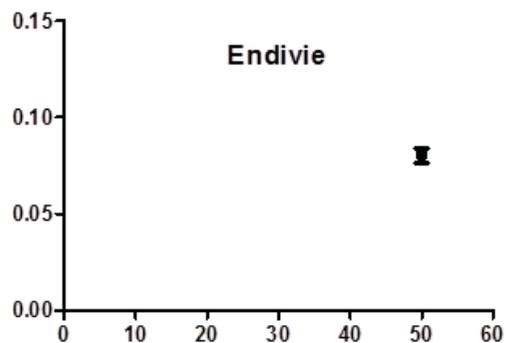
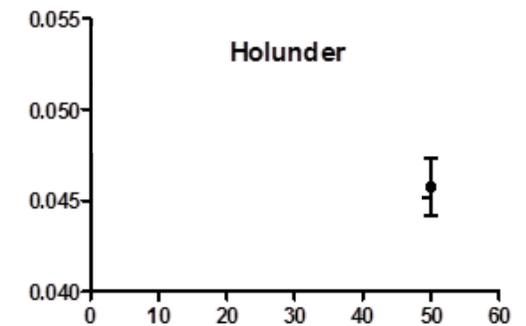
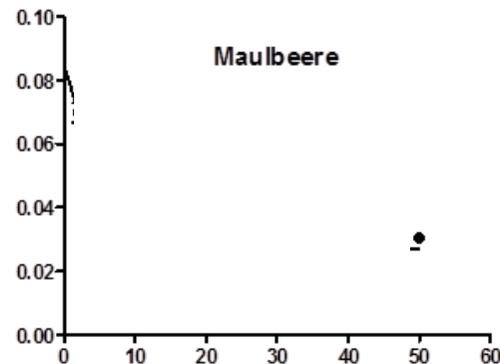
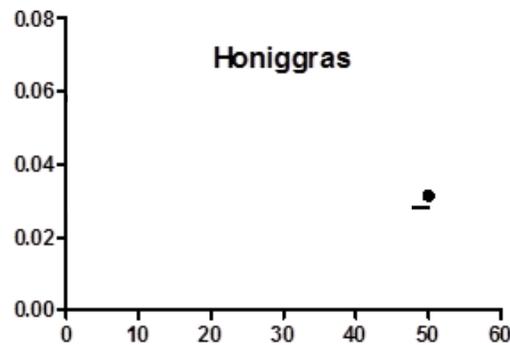
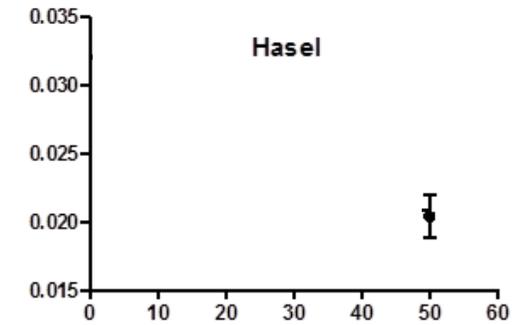
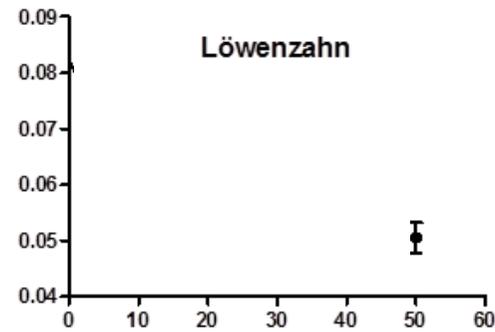
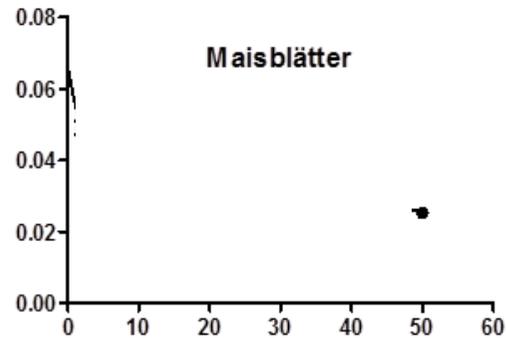
**John E. Moore<sup>2</sup>**





# In vitro Fermentation und Partikelgrösse

Gasbildungsrate ( $\text{h}^{-1}$ )

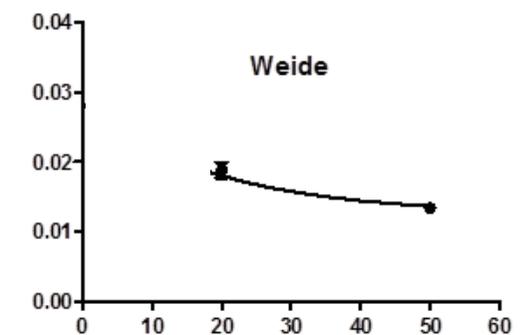
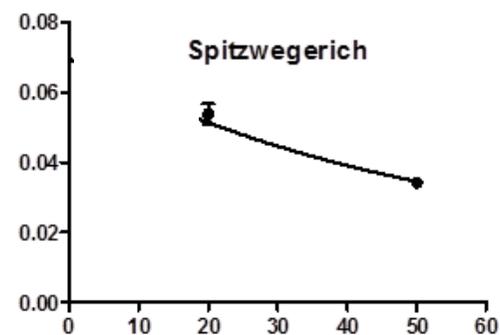
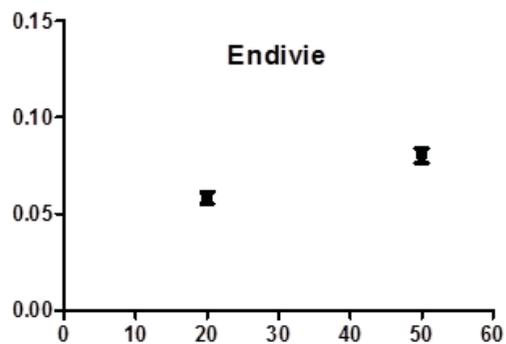
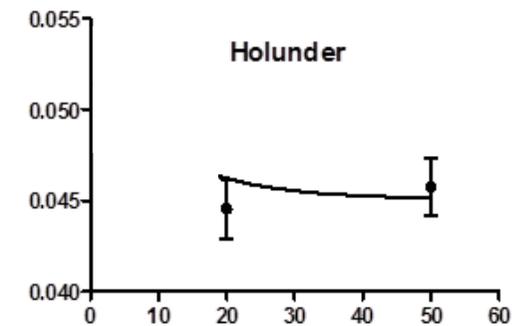
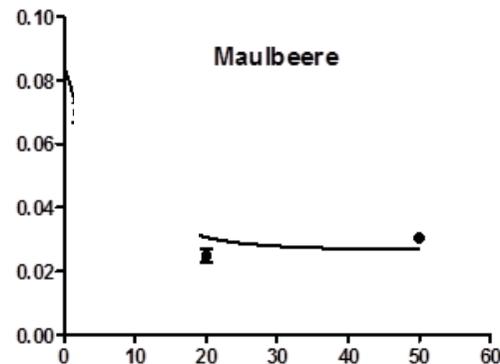
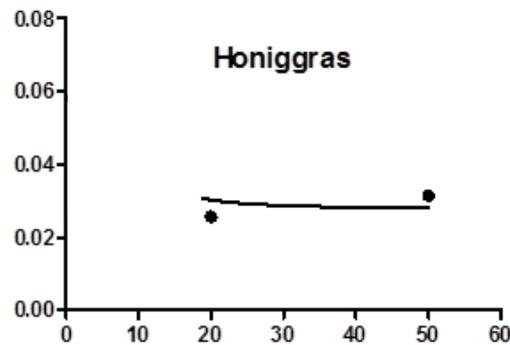
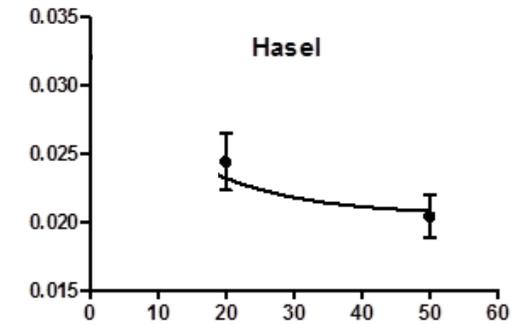
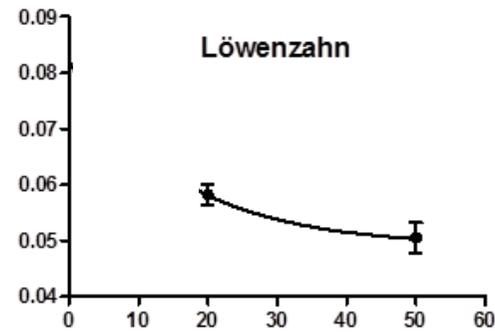
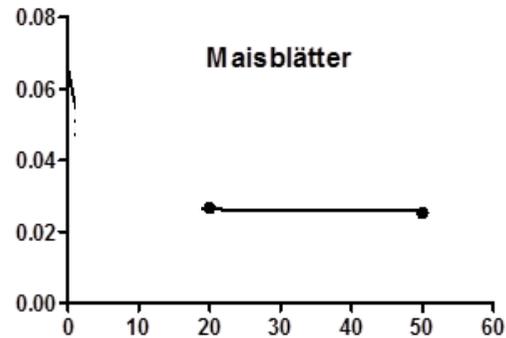


Partikelgrösse (mm)



# In vitro Fermentation und Partikelgrösse

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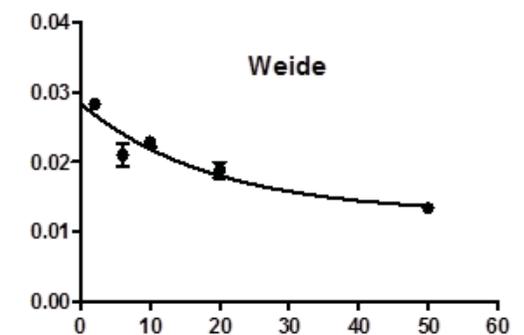
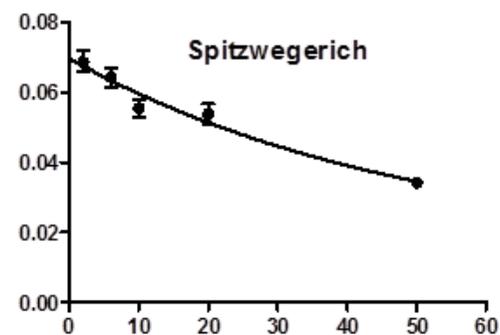
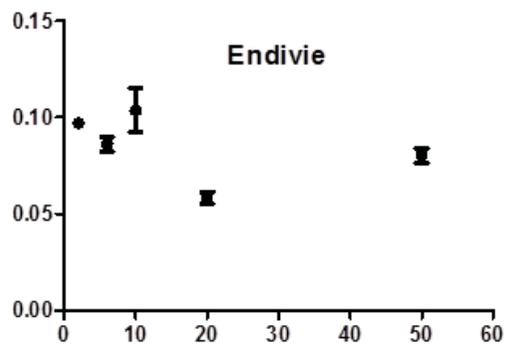
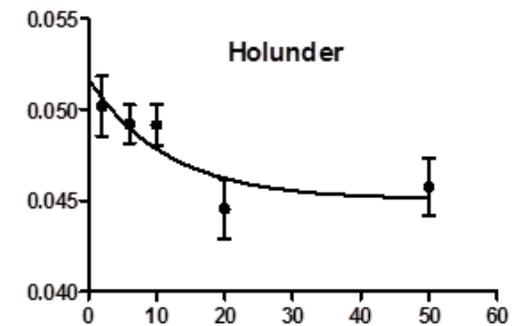
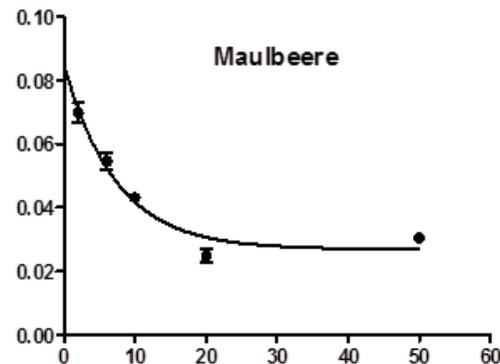
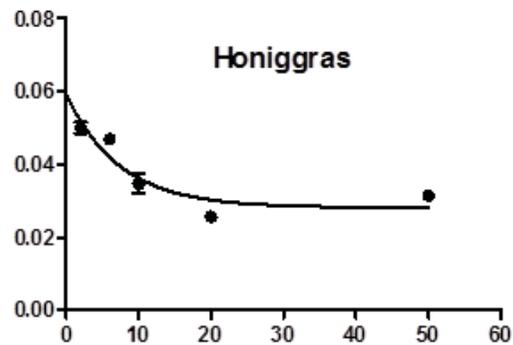
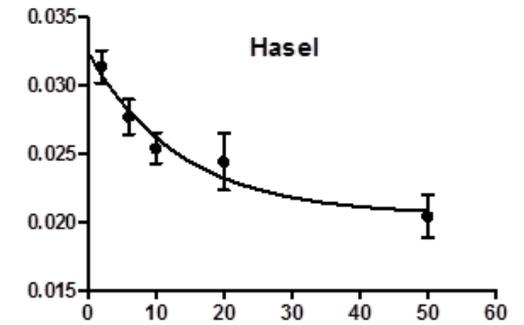
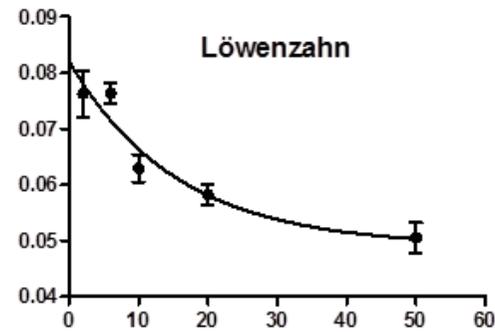
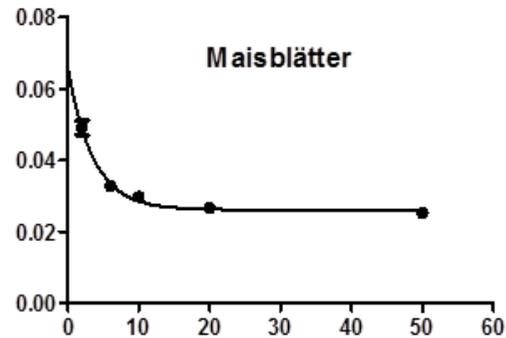


Partikelgrösse (mm)



# In vitro Fermentation und Partikelgrösse

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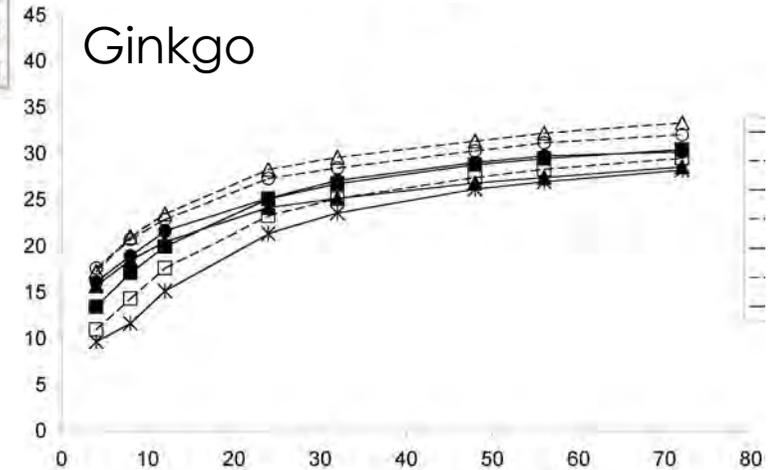
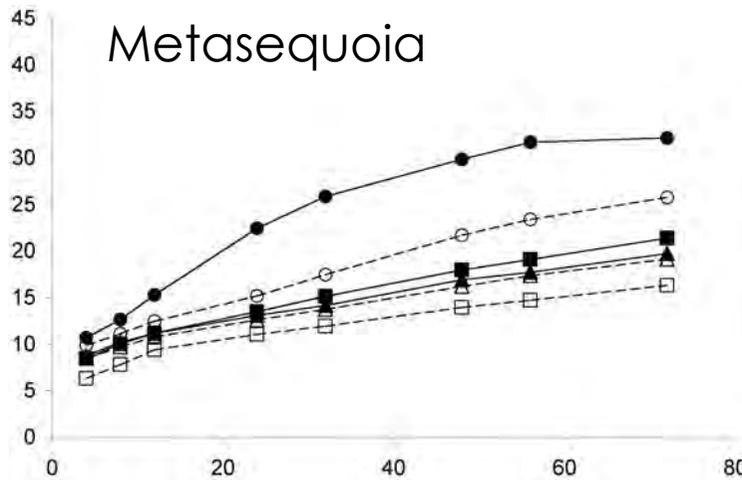
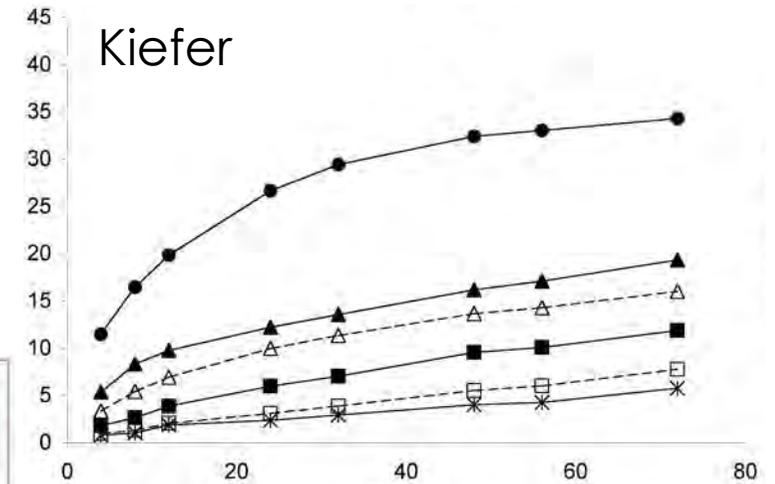
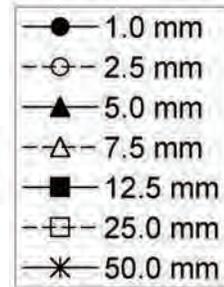
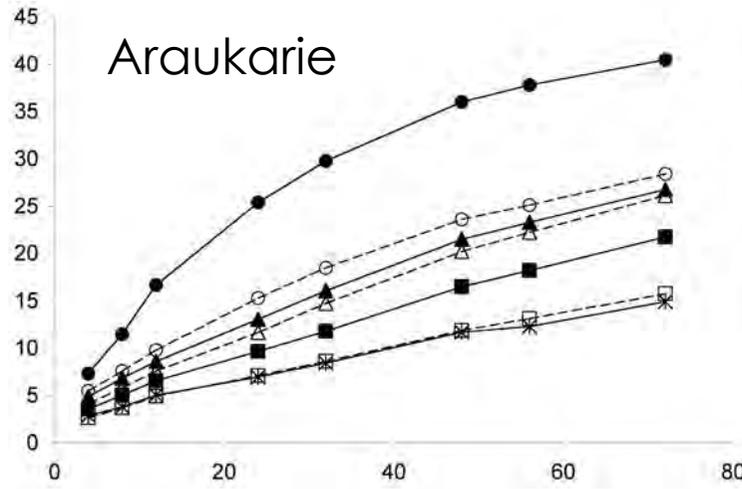


Partikelgrösse (mm)



# In vitro Fermentation und Partikelgrösse

Gasbildungsrate (ml/200mgTS)

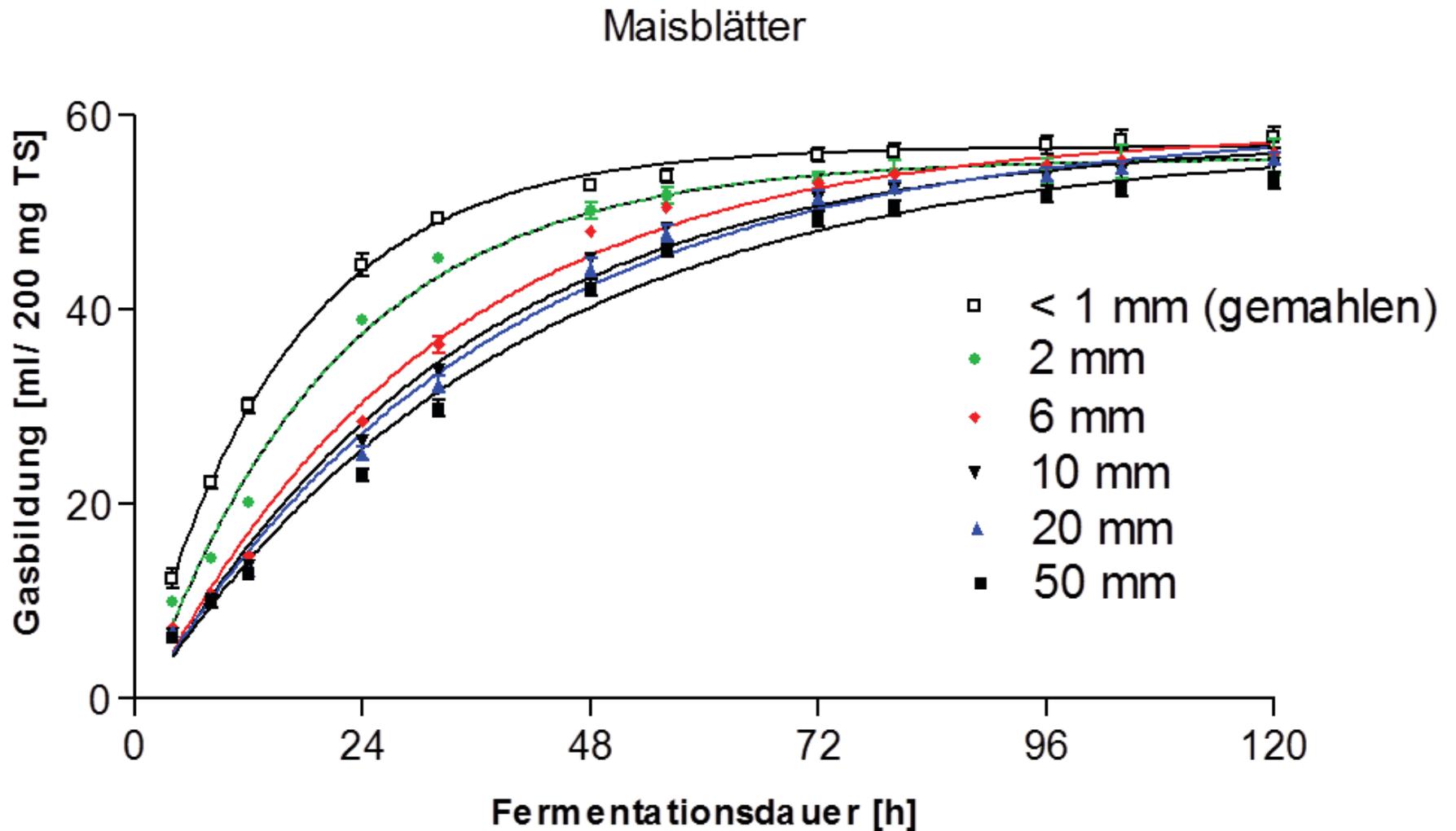


Zeit (h)

Hummel (unpubl.)



# In vitro Fermentation und Partikelgrösse

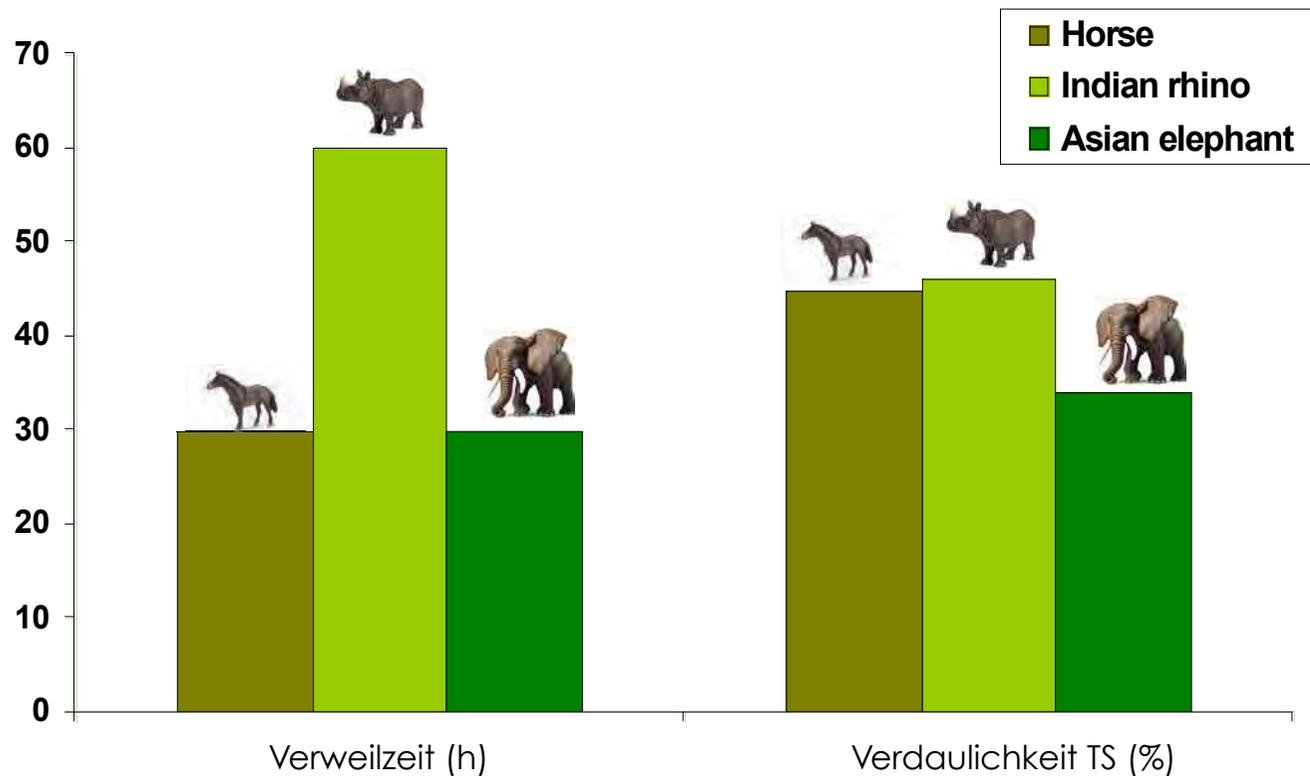




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Journal of Animal Physiology and Animal Nutrition **89** (2005) 229–237





# Zerkleinerung bei Landwirbeltieren





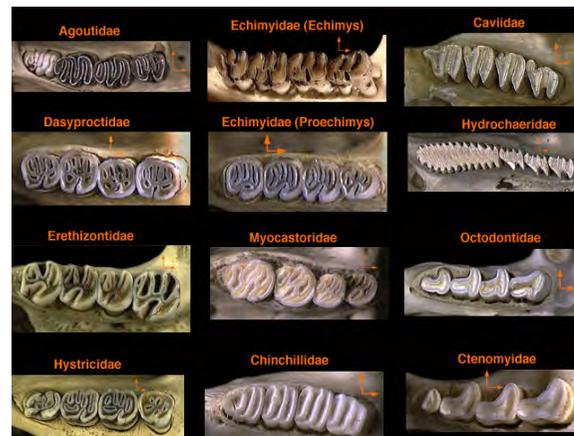


# Prey processing in amniotes: biomechanical and behavioral patterns of food reduction

S.M. Reilly<sup>a,\*</sup>, L.D. McBrayer<sup>a</sup>, T.D. White<sup>b</sup>

Comparative Biochemistry and Physiology Part A 128 (2001) 397–415

## Mammals: the definitive chewers





# Comparative chewing efficiency in mammalian herbivores

Julia Fritz, Jürgen Hummel, Ellen Kienzle, Christian Arnold, Charles Nunn and Marcus Clauss

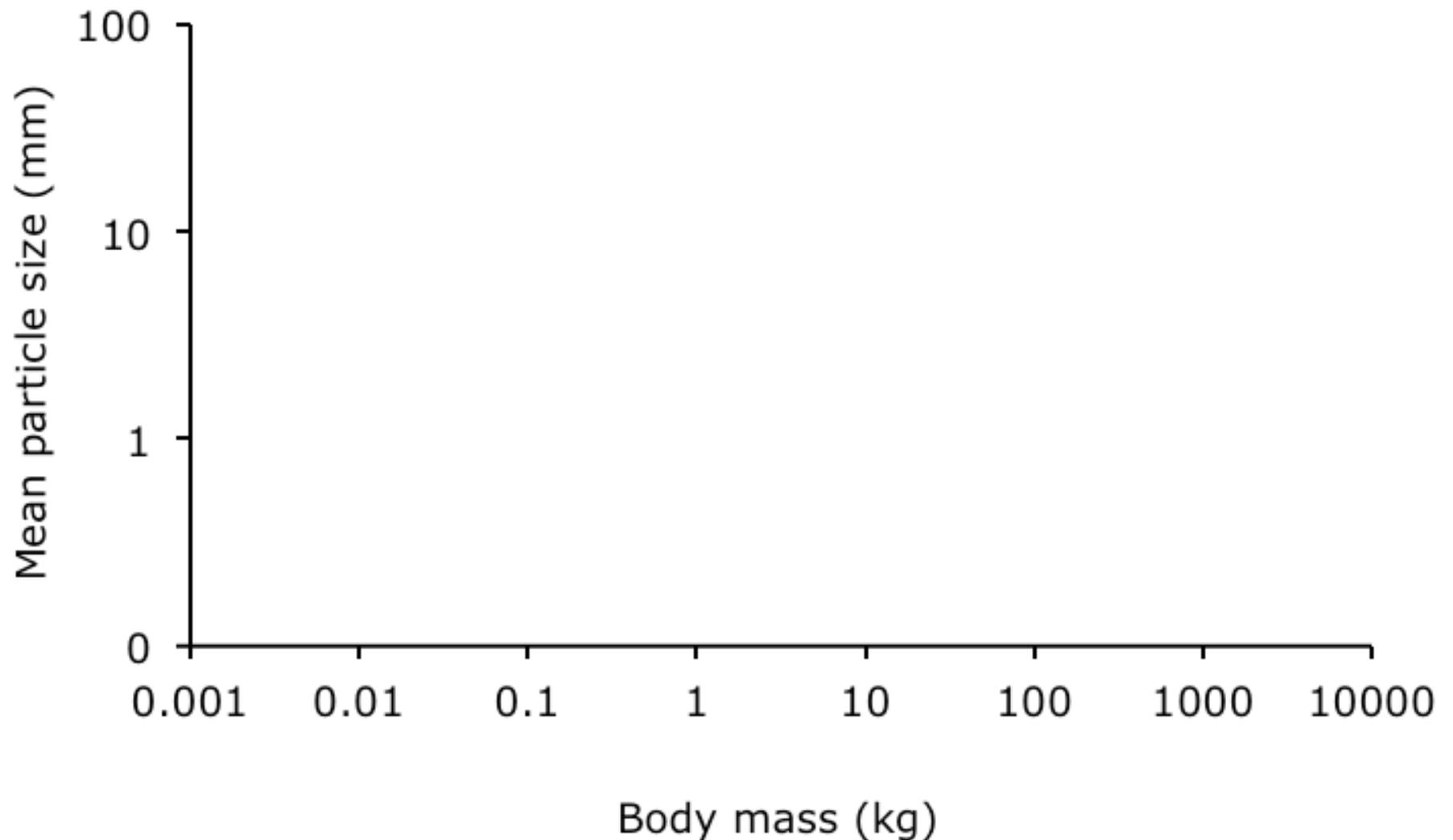
*Oikos* 118: 1623–1632, 2009



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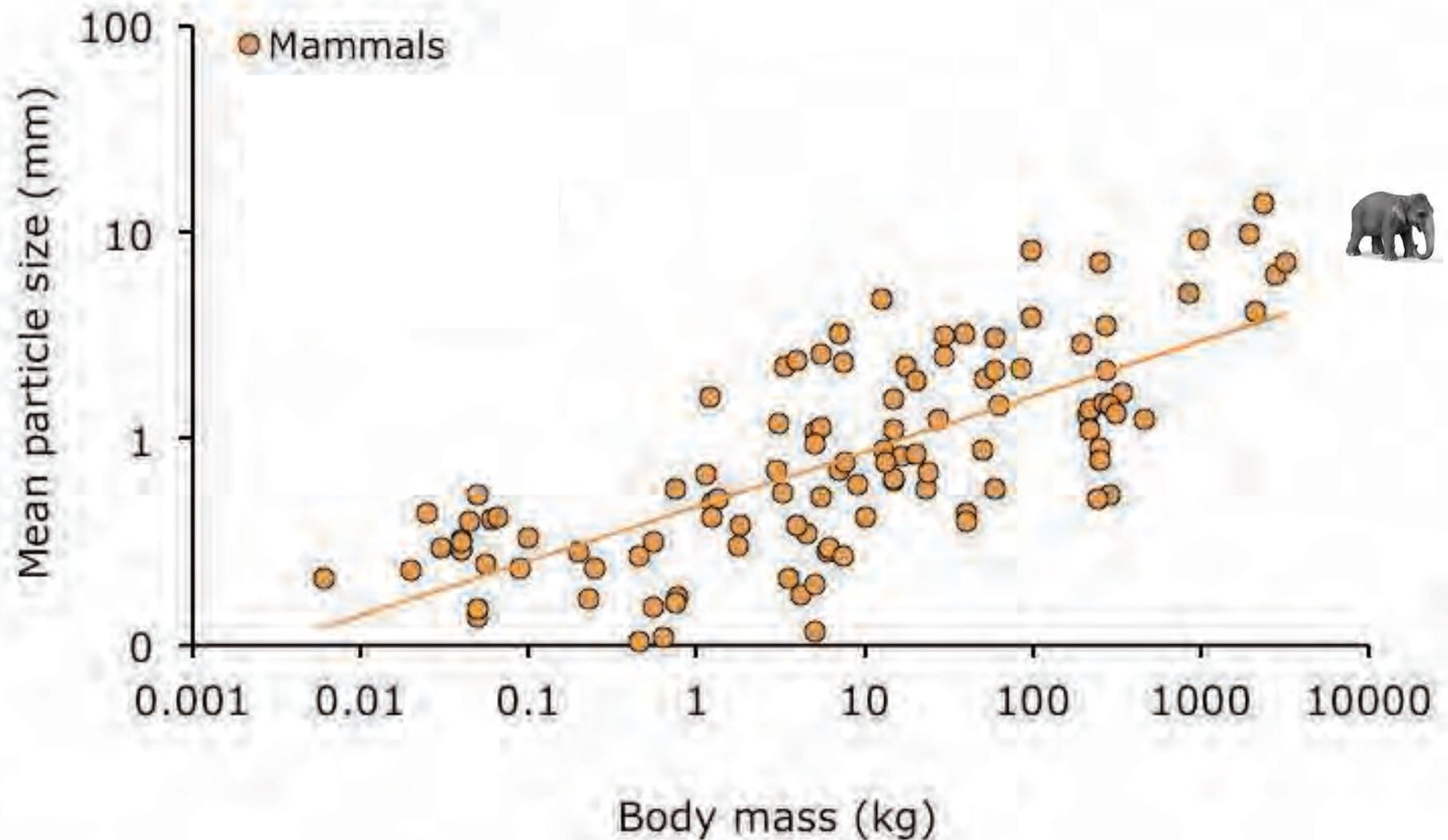




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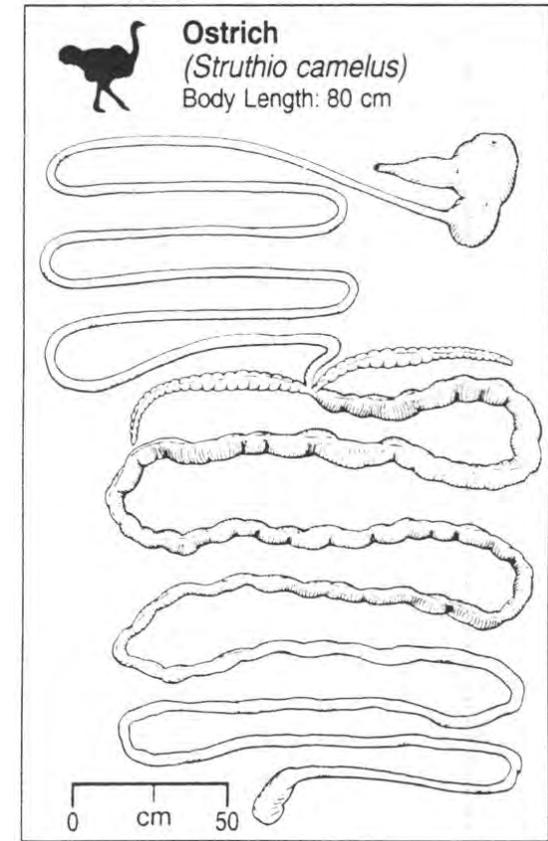
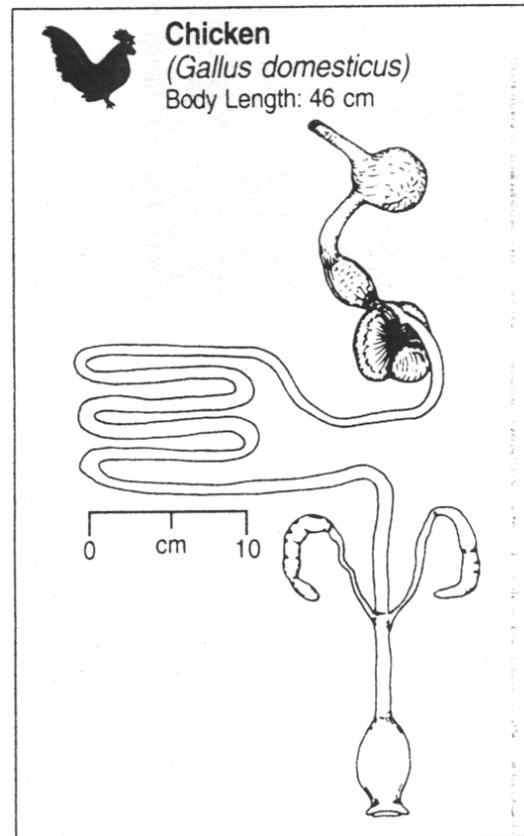
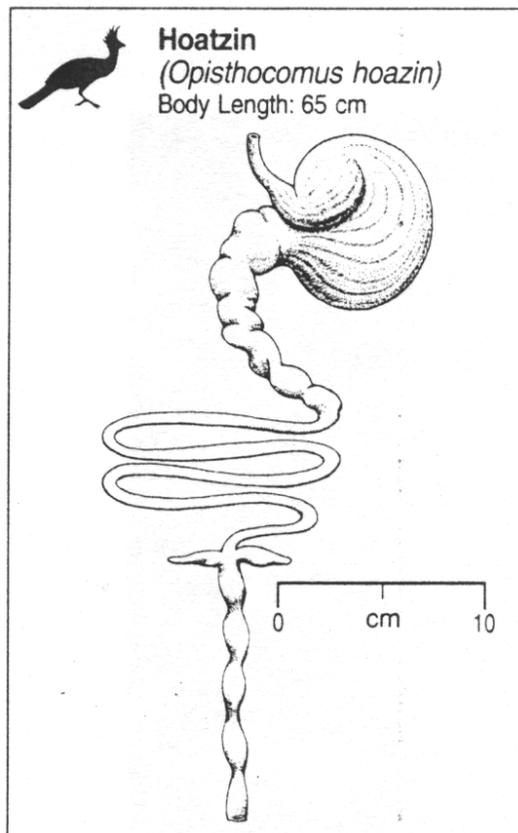
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Oikos 118: 1623–1632, 2009





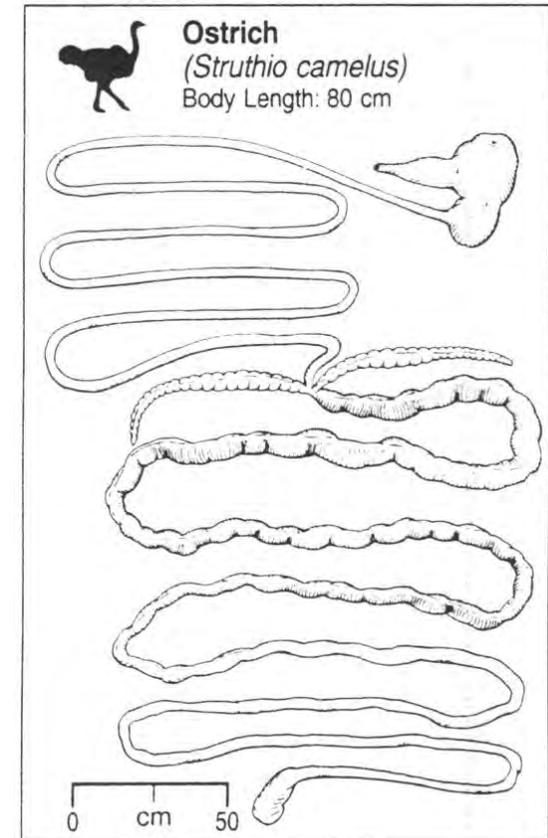
# Herbivores - Birds



from Stevens und Hume (1995)



# Herbivores - Birds



from Stevens und Hume (1995)  
Photo: J. Fritz



# Herbivores - Birds



Photos: J. Fritz



# Gizzard vs. teeth





# Gizzard vs. teeth, it's a tie: food-processing efficiency in herbivorous birds and mammals and implications for dinosaur feeding strategies

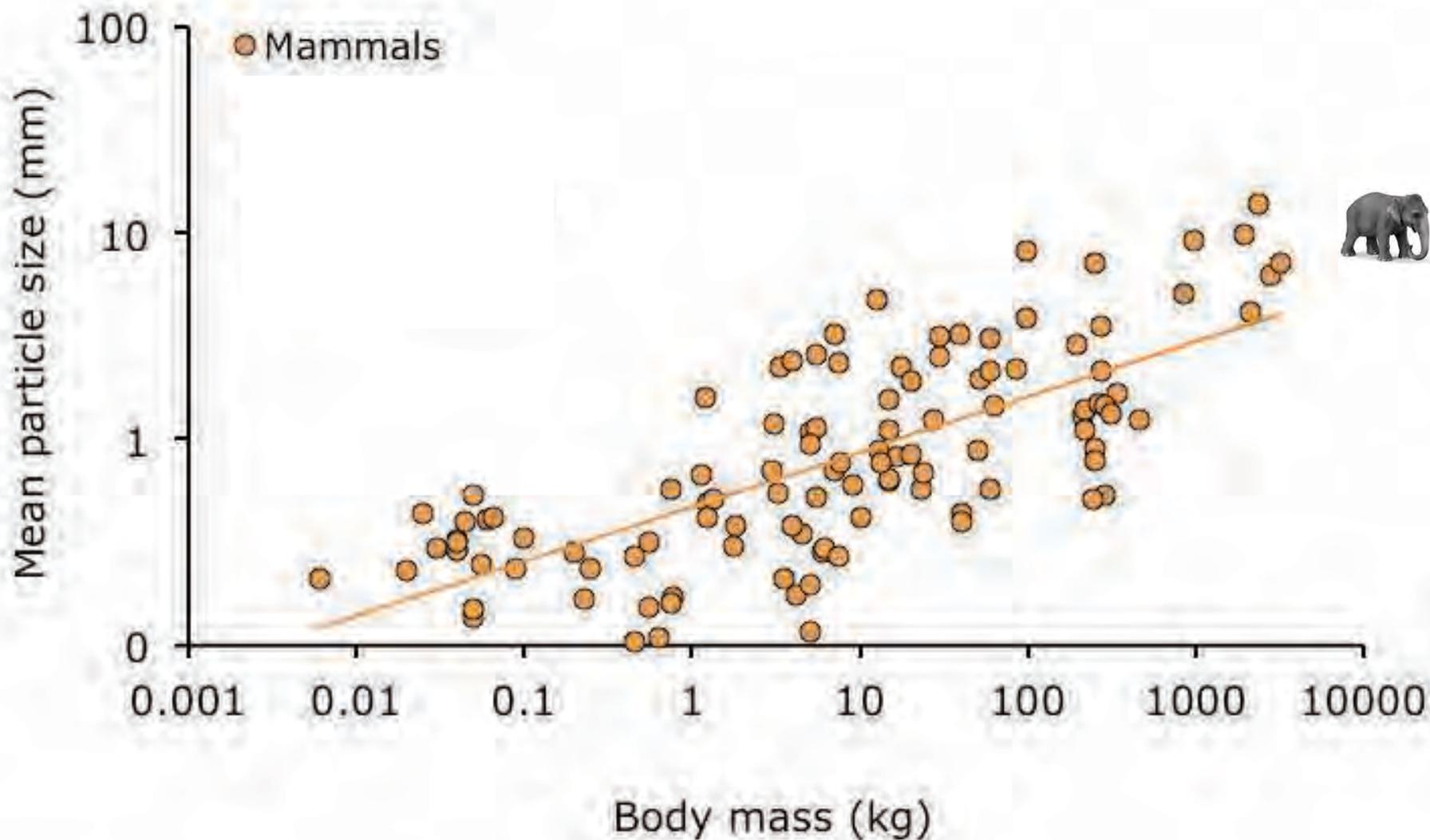
*Julia Fritz, Jürgen Hummel, Ellen Kienzle, Oliver Wings, W. Jürgen Steich, and Marcus Clauss*  
*Paleobiology, 37(4), 2011, pp. 577–586*





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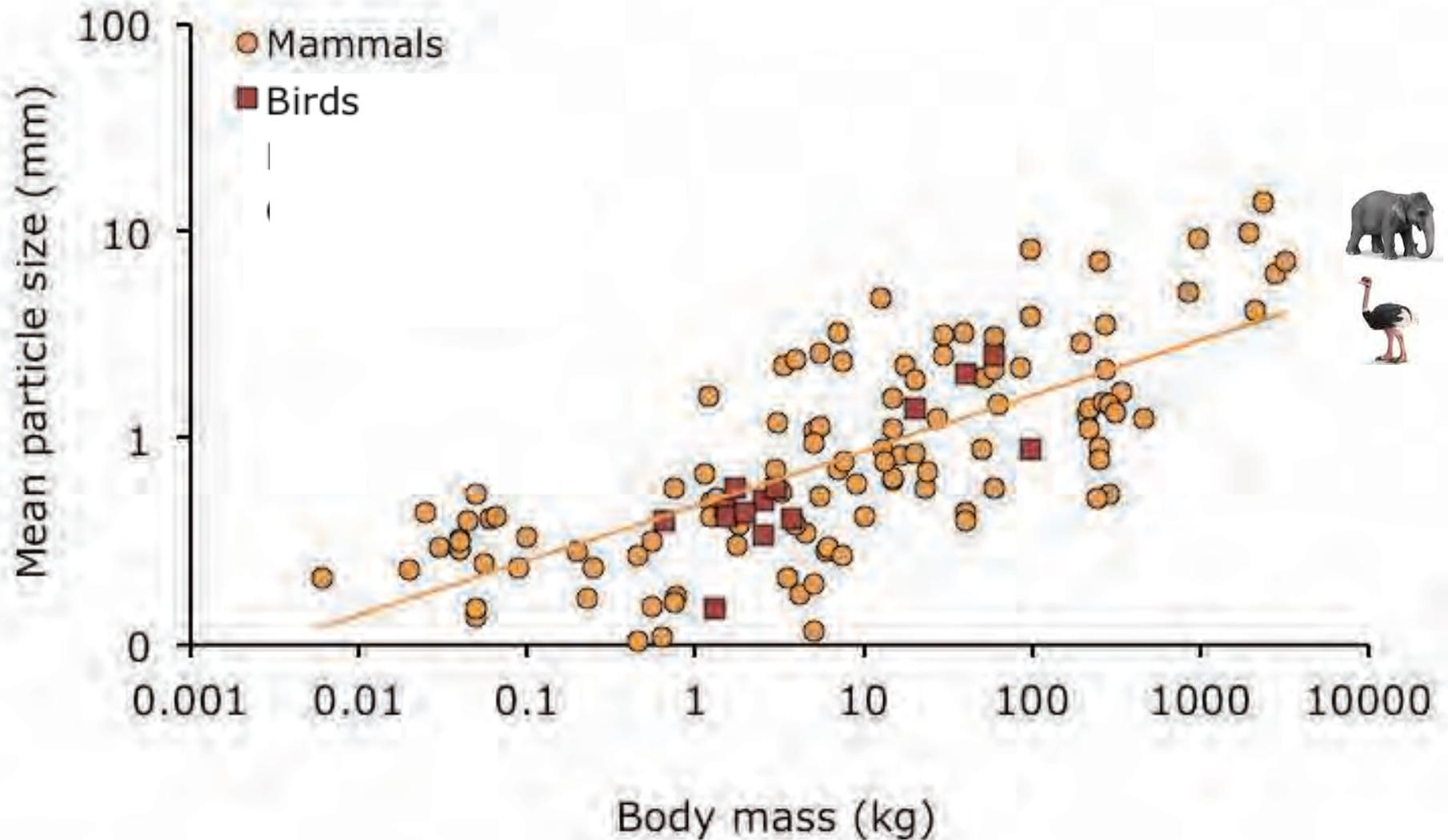




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# To Chew





# To Chew or Not to Chew





# To Chew or Not to Chew: Fecal Particle Size in Herbivorous Reptiles and Mammals

JULIA FRITZ<sup>1\*</sup>, JÜRGEN HUMMEL<sup>2</sup>, ELLEN KIENZLE<sup>1</sup>,  
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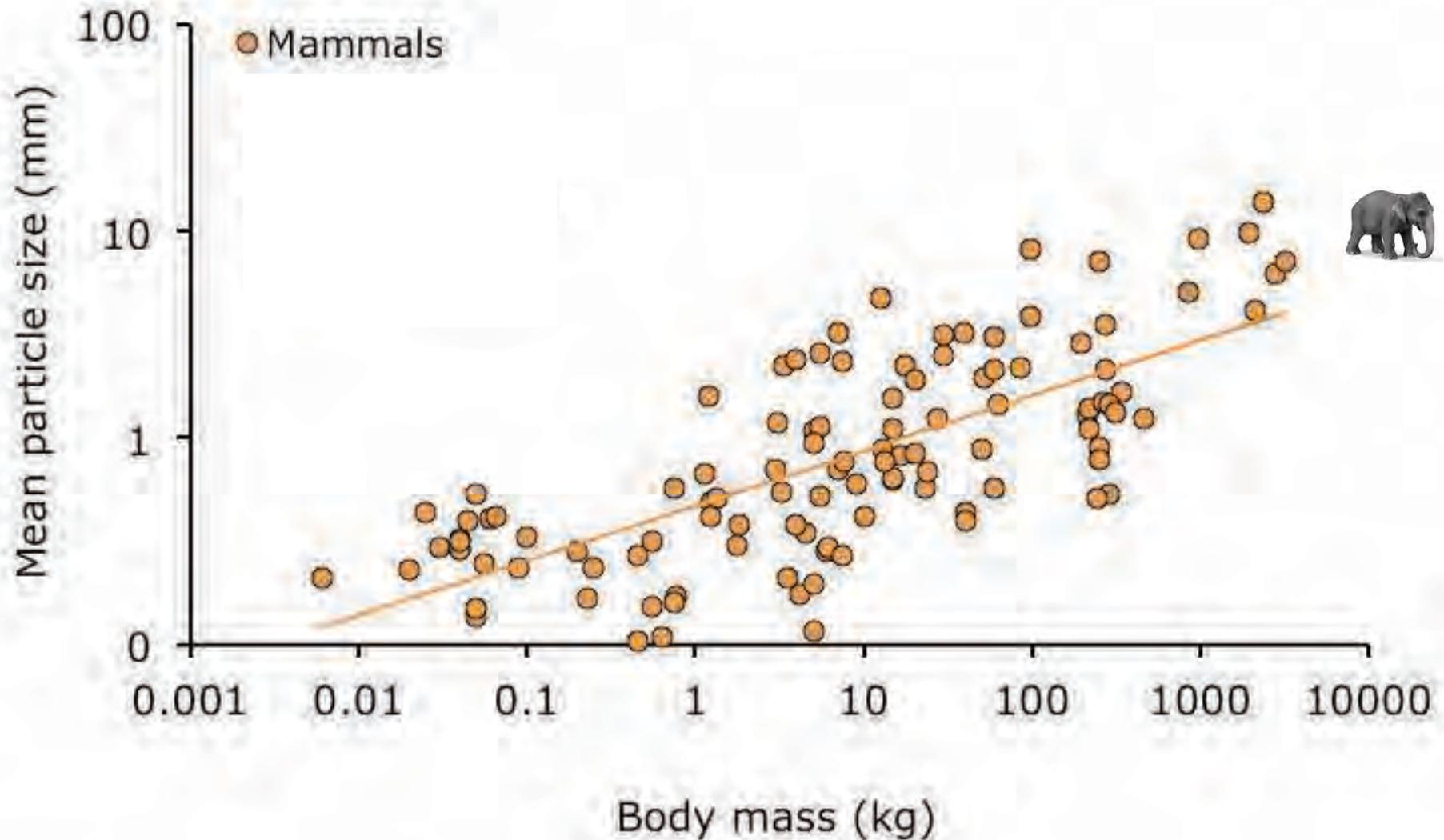
*J. Exp. Zool.*  
313A:579–586,  
2010



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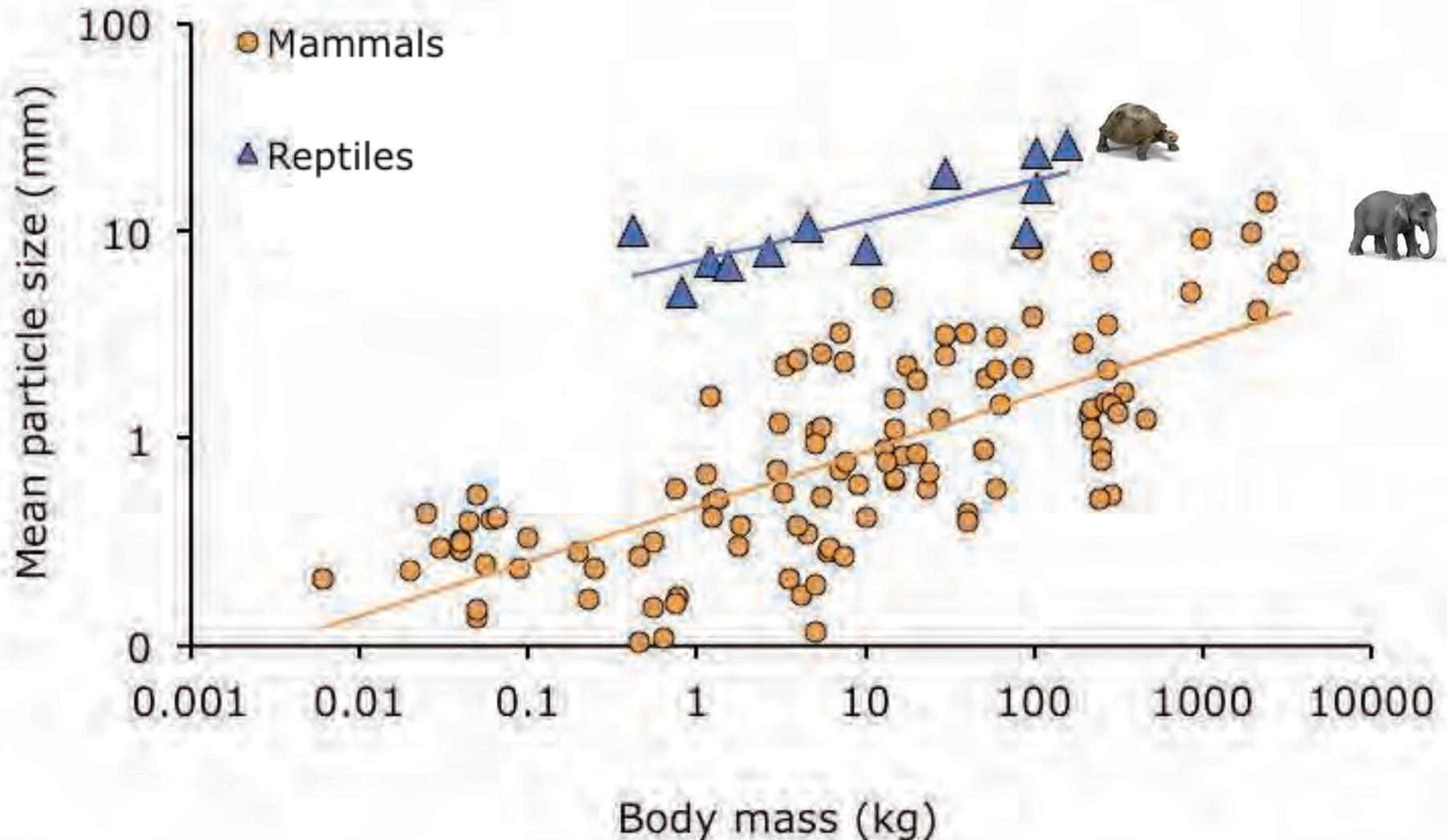




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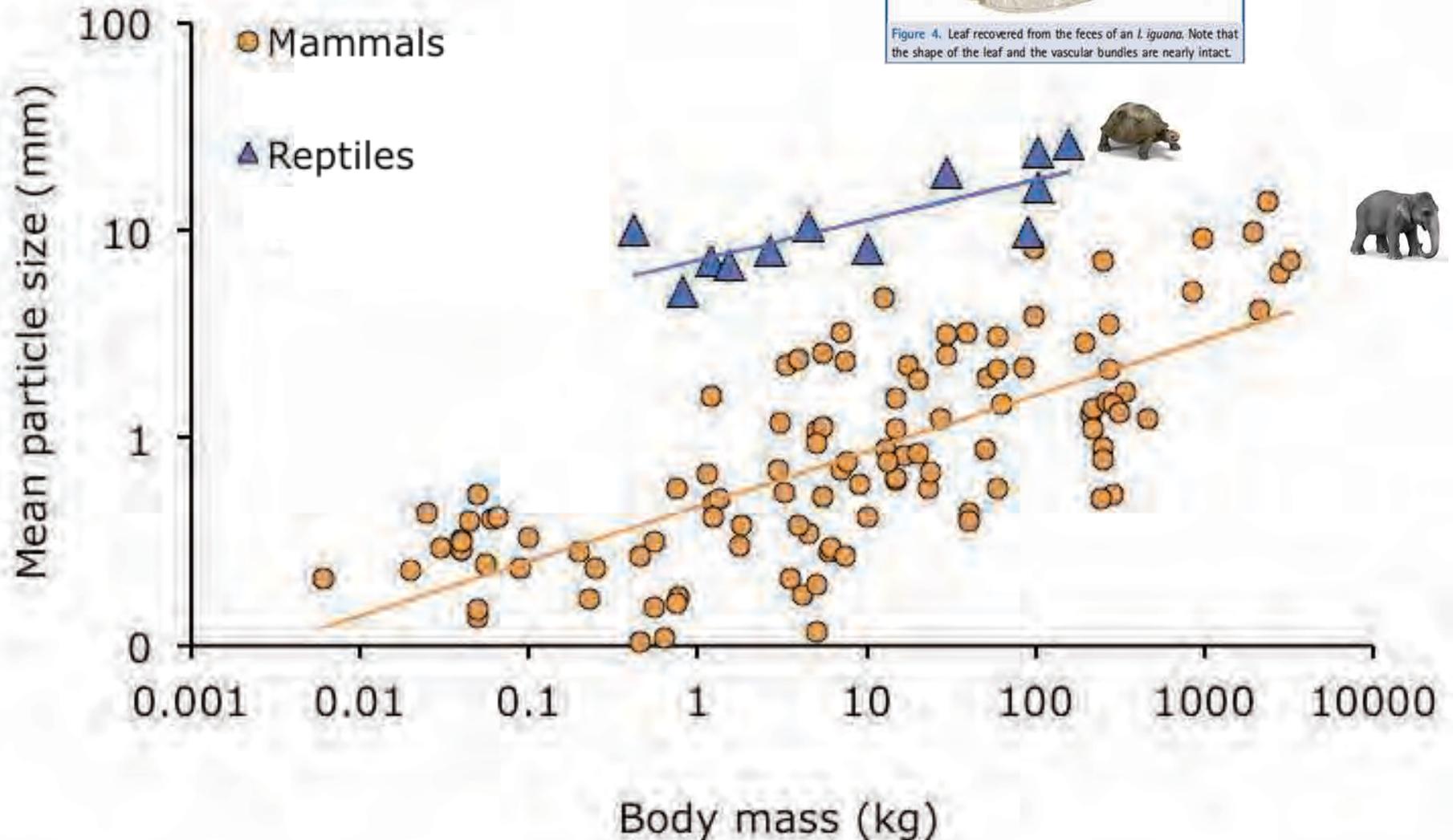
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Figure 4. Leaf recovered from the feces of an *I. iguana*. Note that the shape of the leaf and the vascular bundles are nearly intact.





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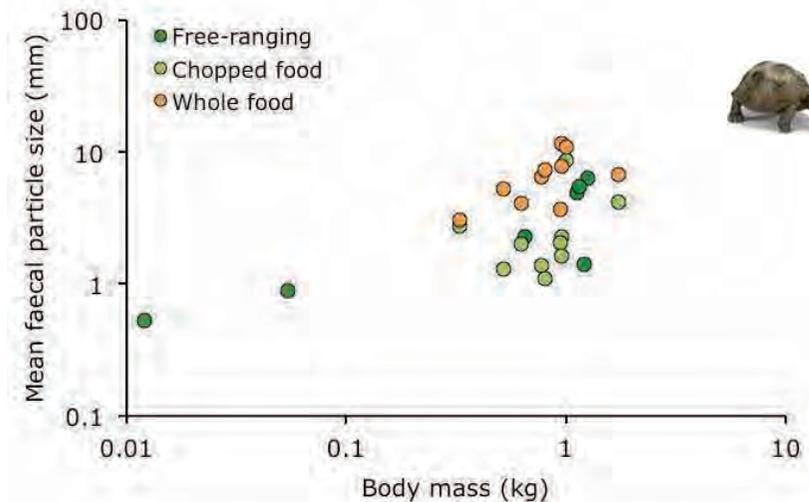
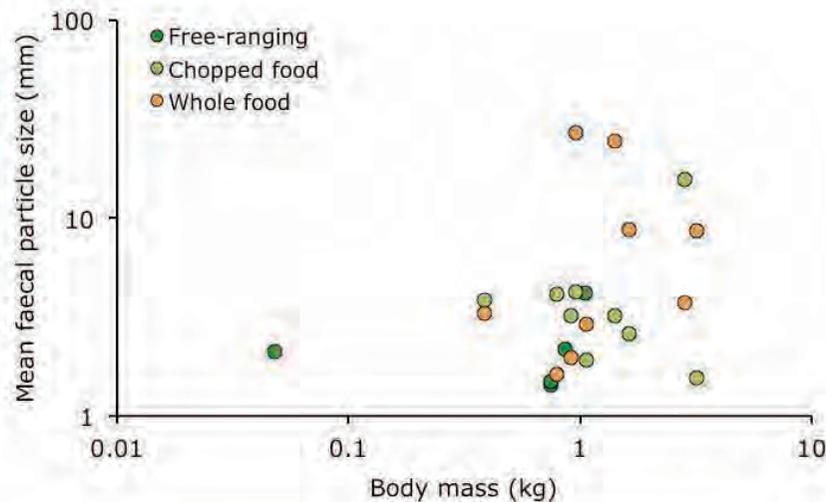




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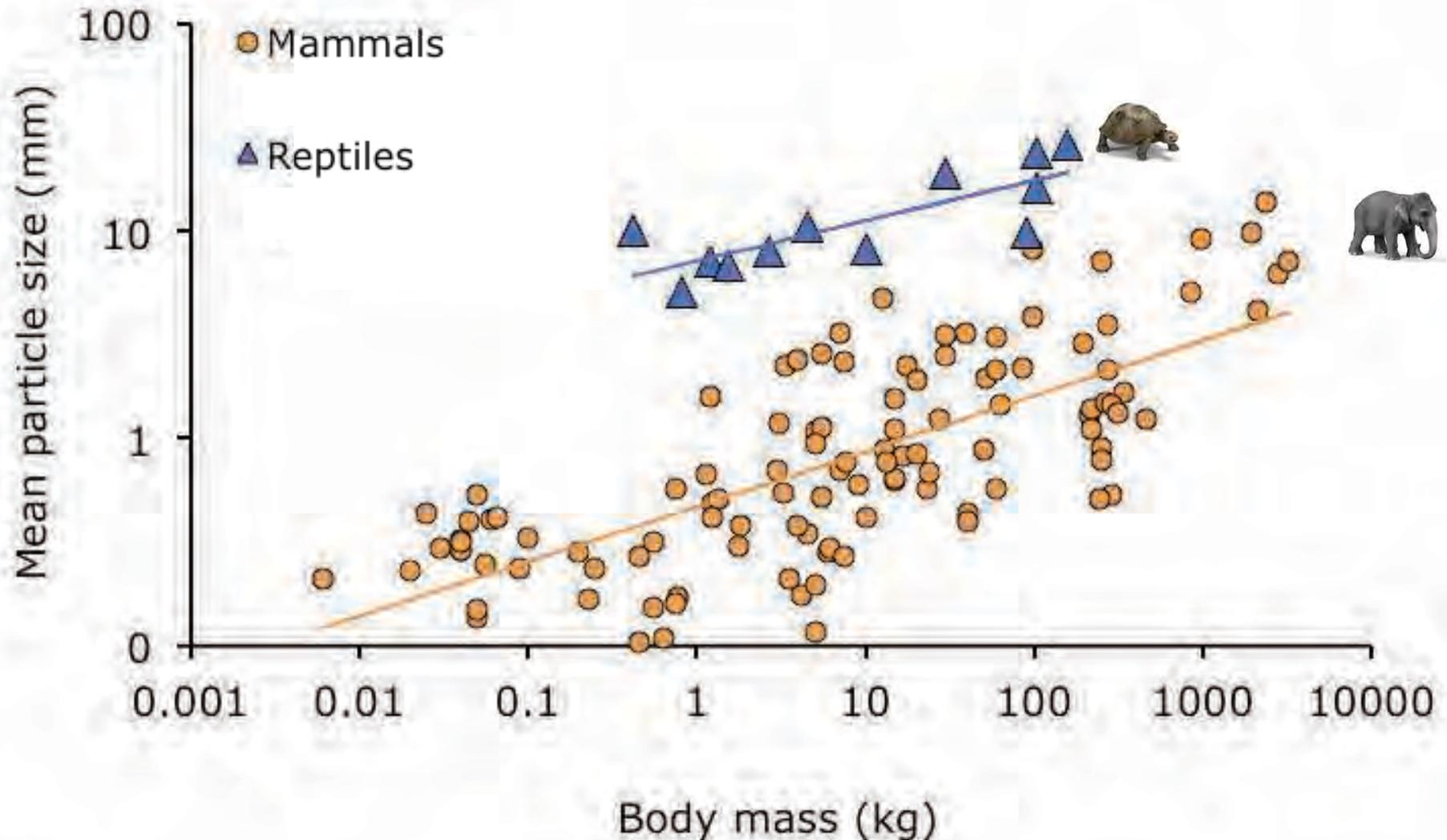
**Figure 2.** Mean faecal particle size in individuals of (A) *T. graeca* and (B) *T. hermanni* from the wild, or from captivity fed chopped and whole food.



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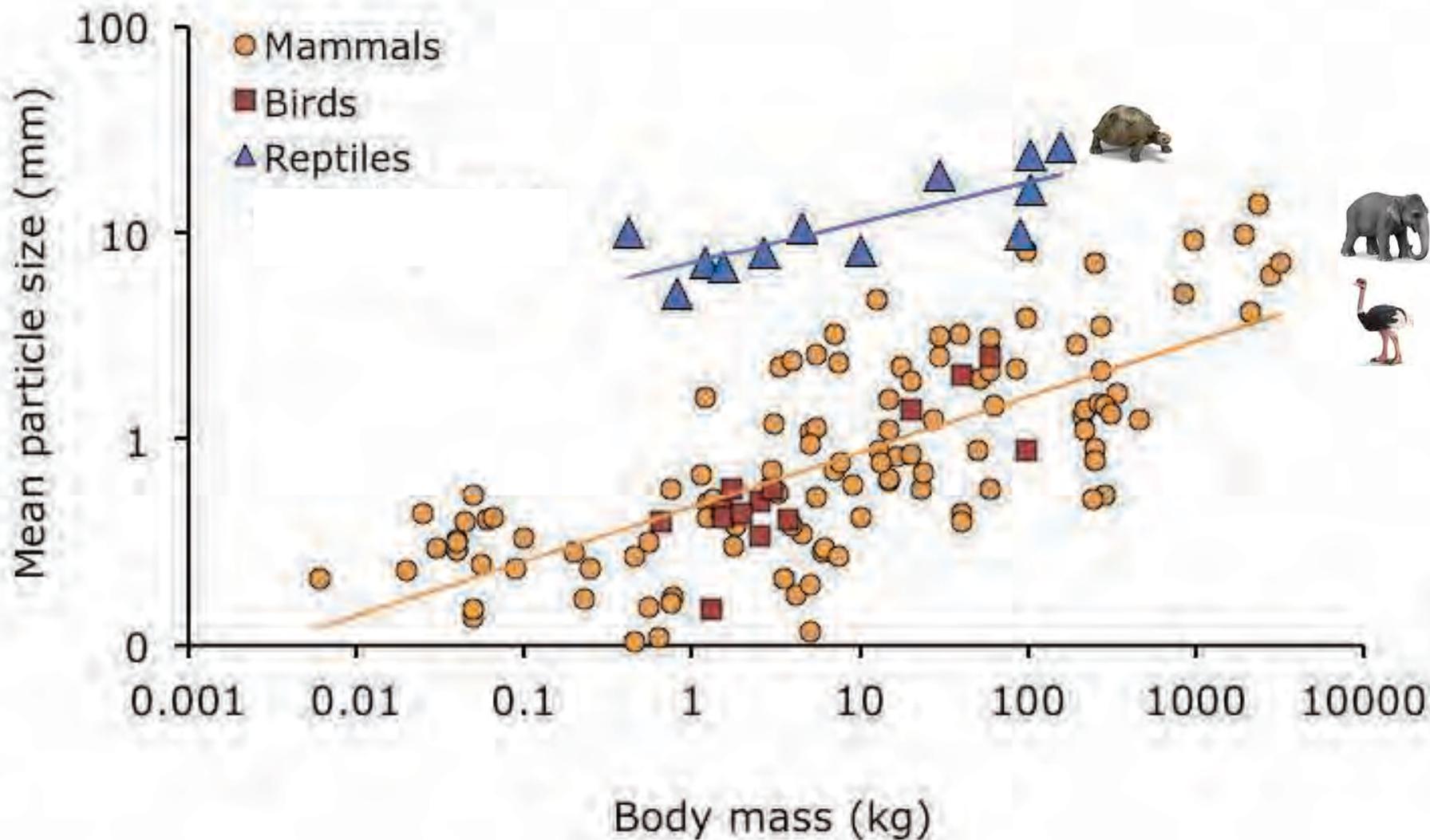
JULIA FRITZ<sup>1\*</sup>, JÜRGEN HUMMEL<sup>2</sup>, ELLEN KIENZLE<sup>1</sup>,  
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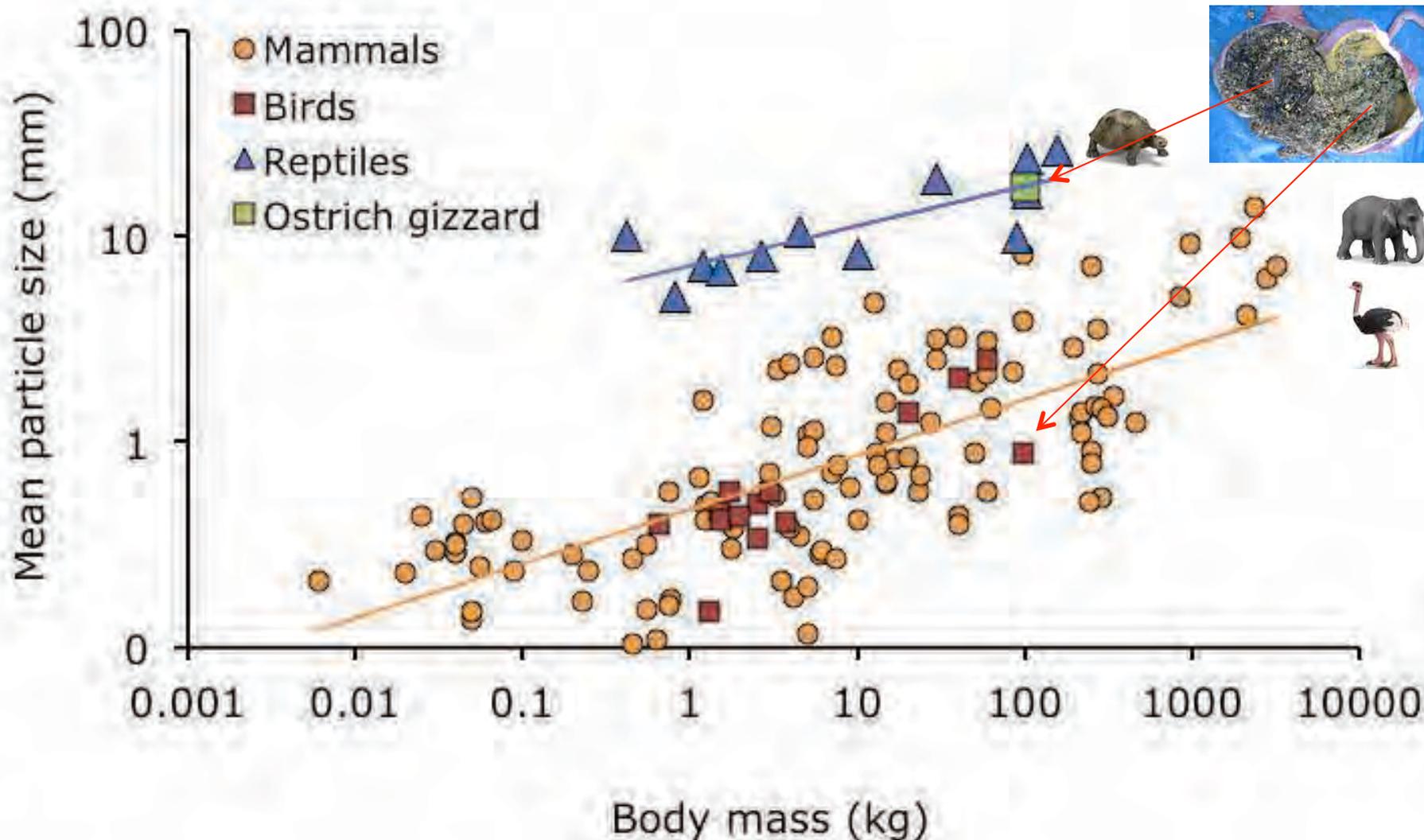
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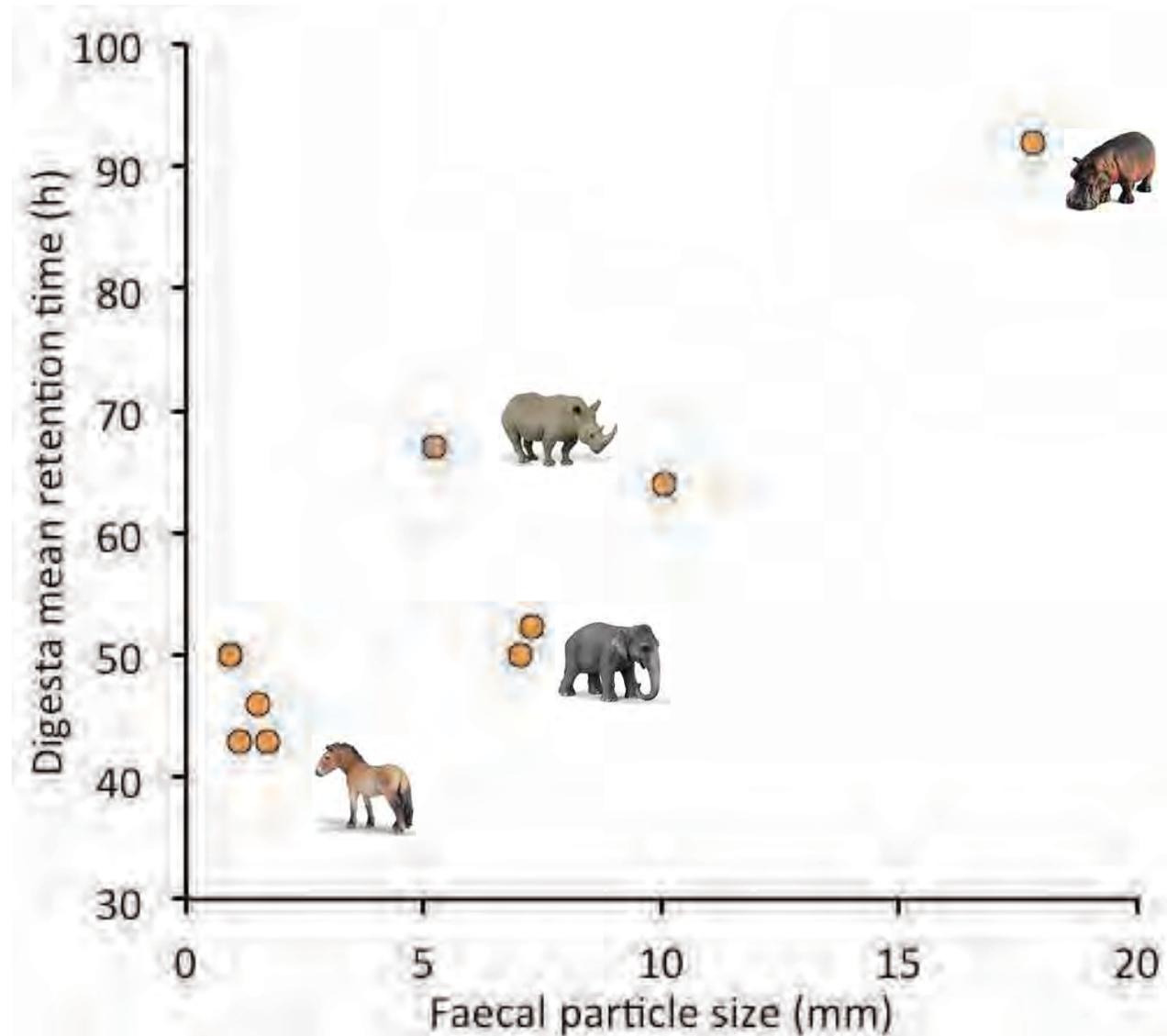




# Evidence for a tradeoff between retention time and chewing efficiency in large mammalian herbivores

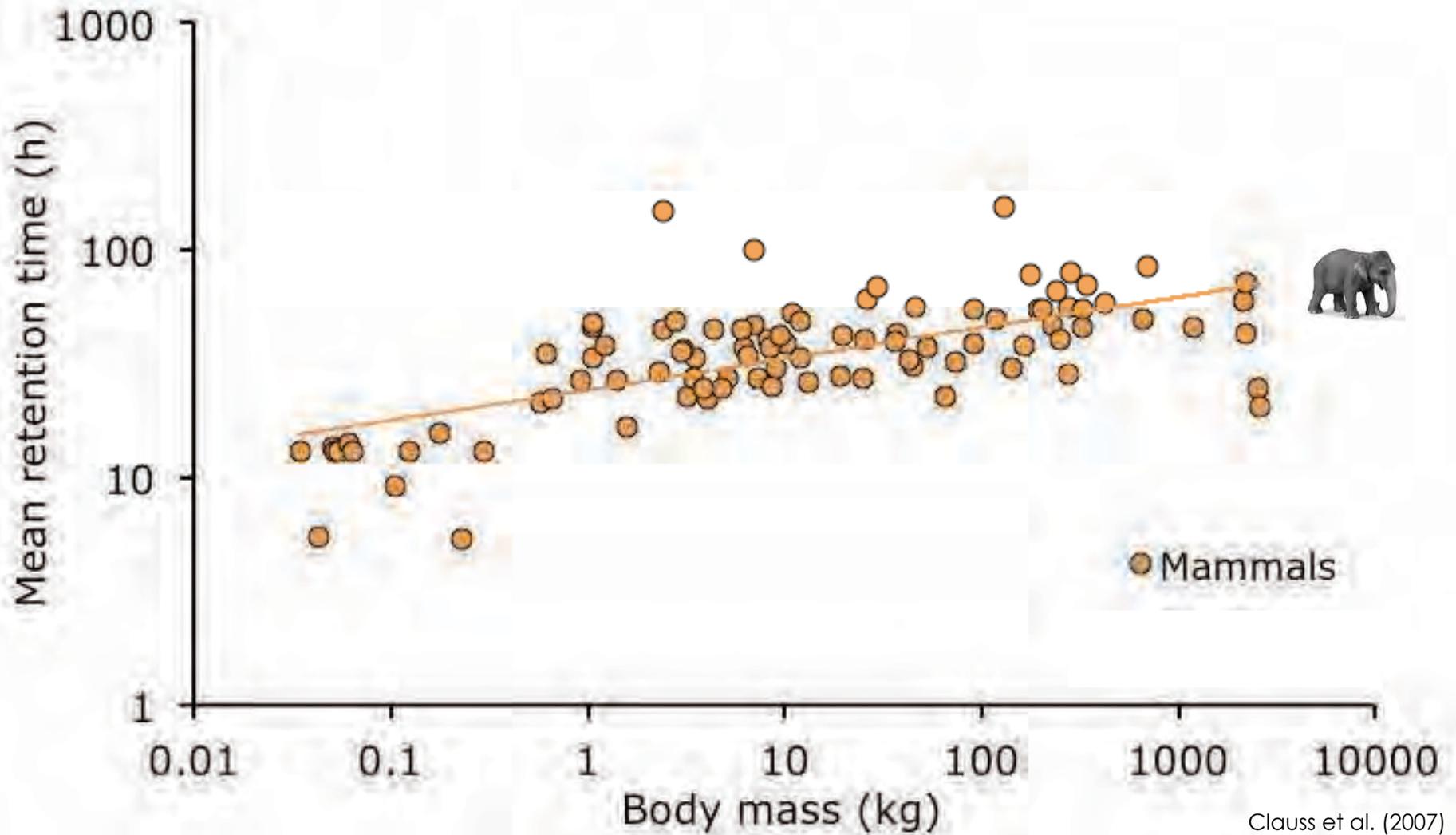
Marcus Clauss<sup>a,\*</sup>, Charles Nunn<sup>b,c</sup>, Julia Fritz<sup>d</sup>, Jürgen Hummel<sup>e</sup>

Comparative Biochemistry and Physiology, Part A 154 (2009) 376–382



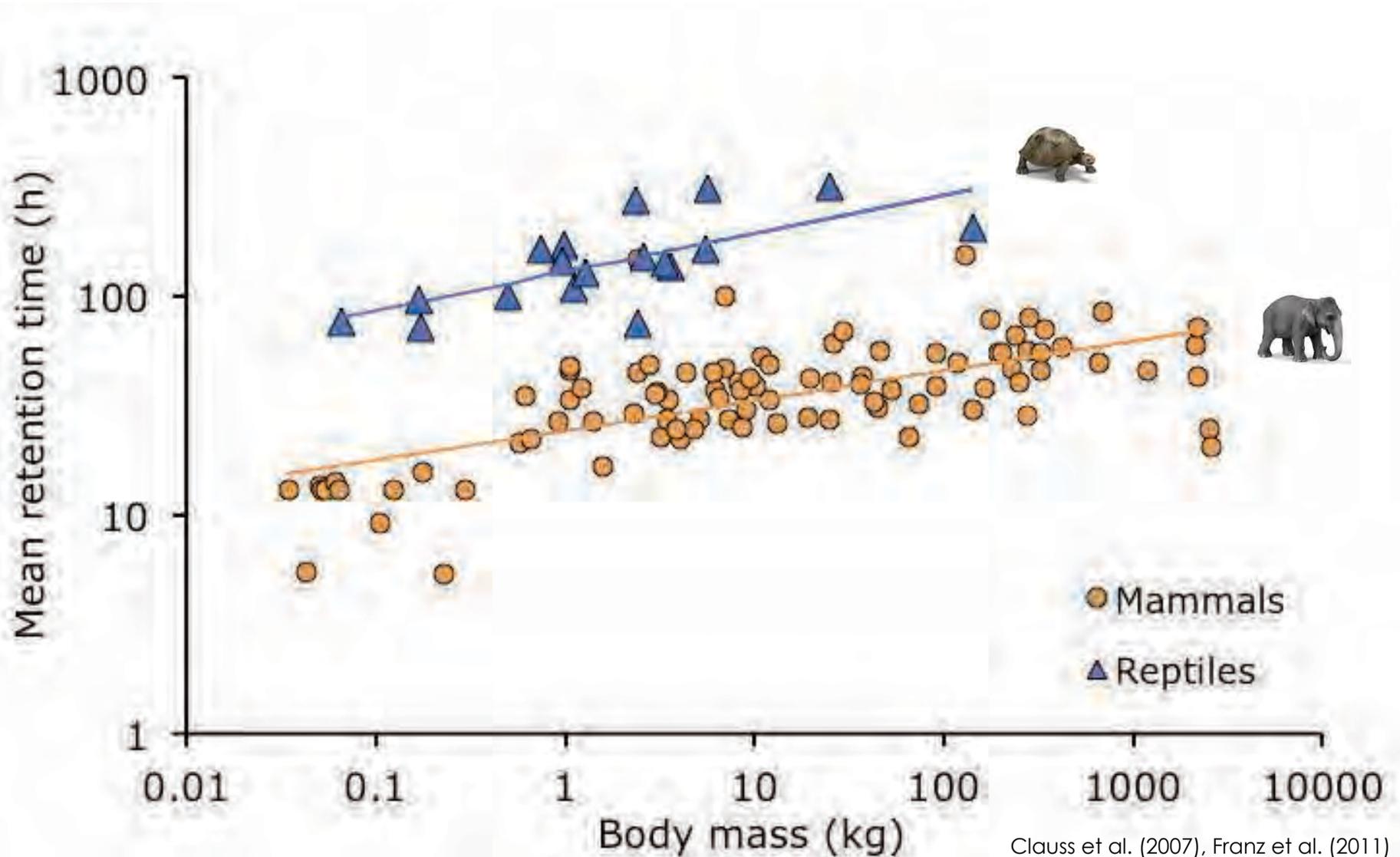


# Verweilzeit im Darmtrakt





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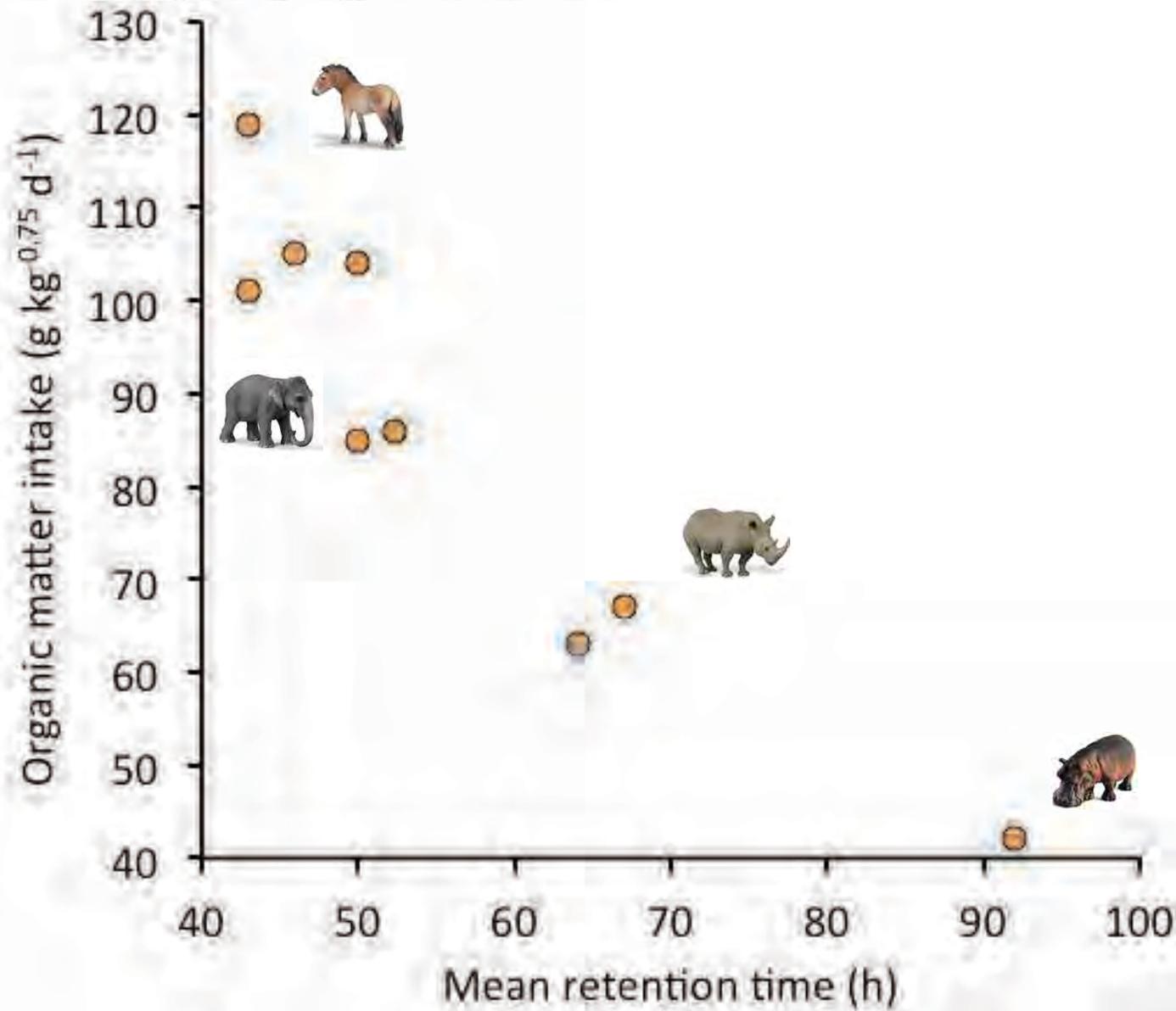




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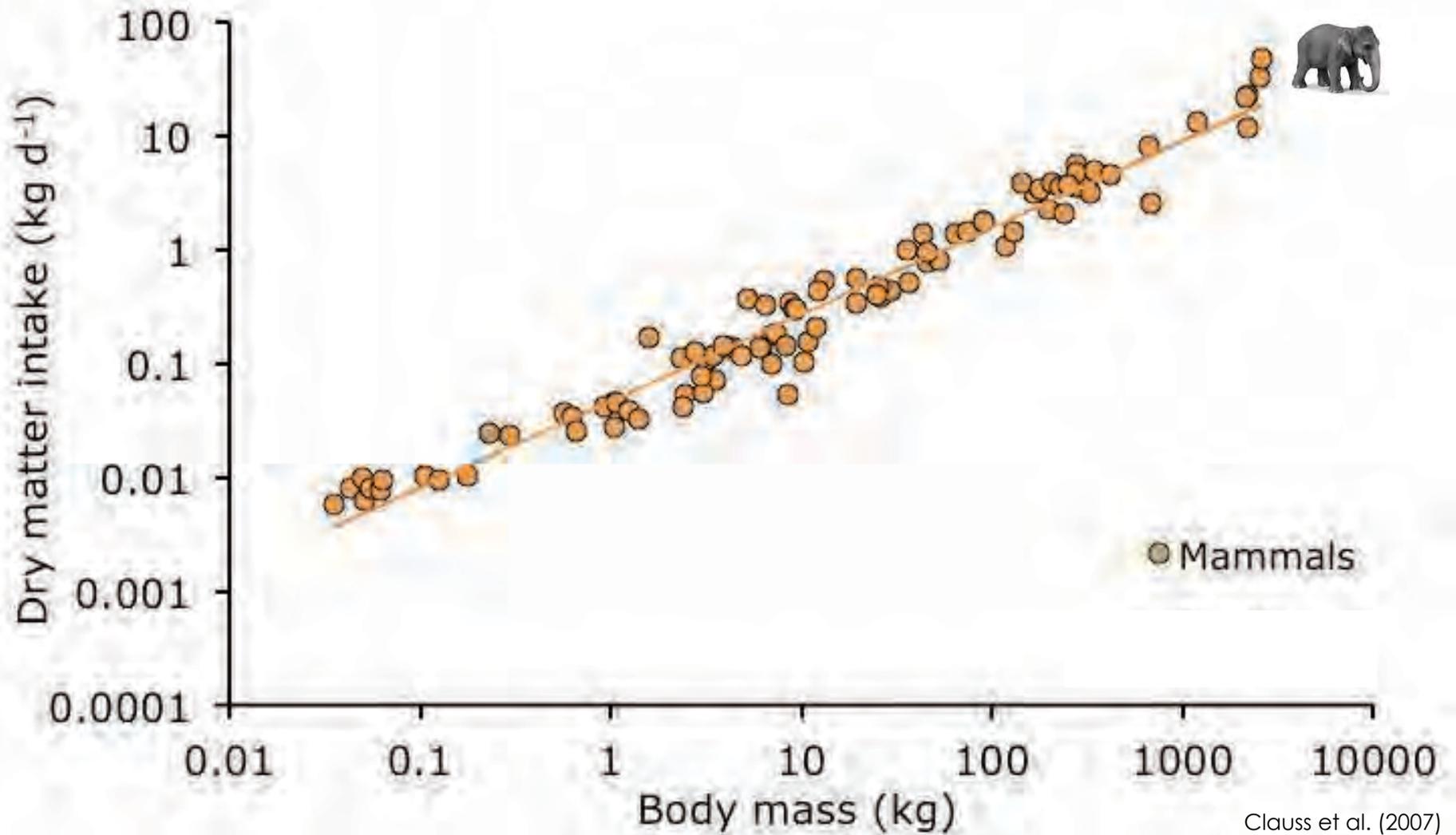
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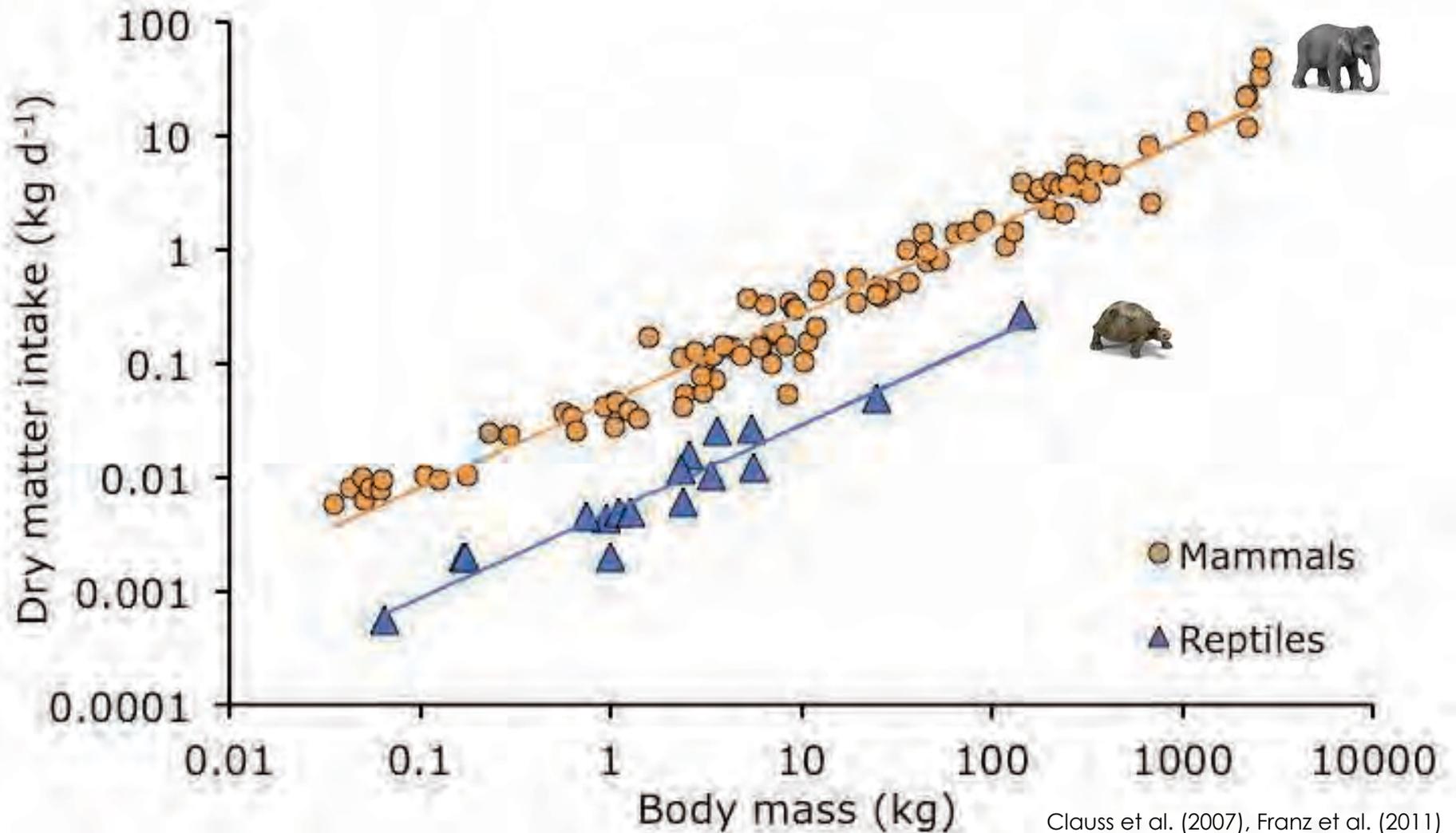


# Futteraufnahme



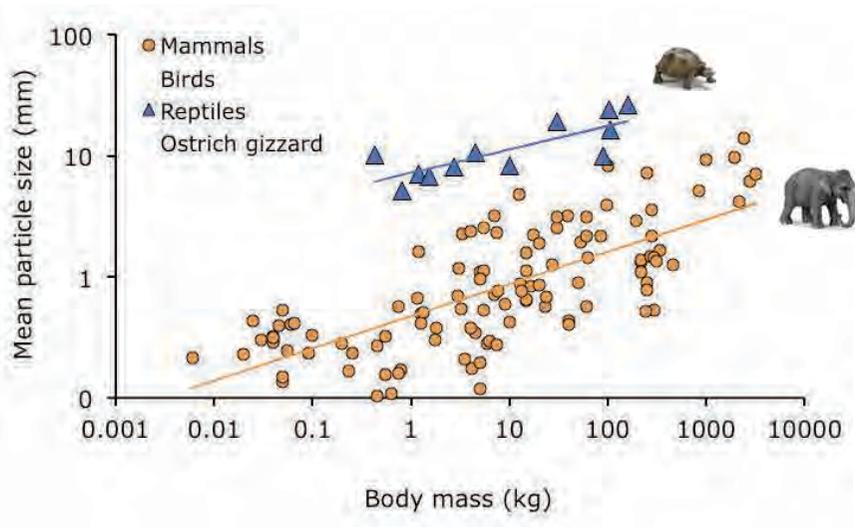


# Futteraufnahme



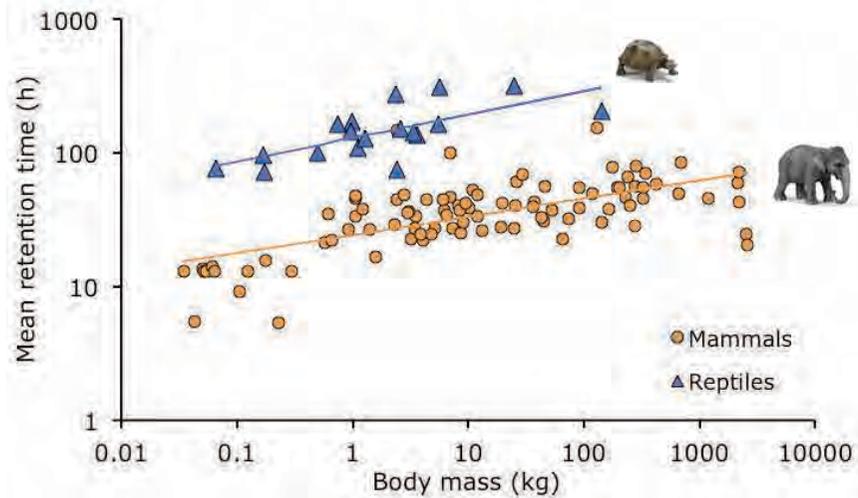
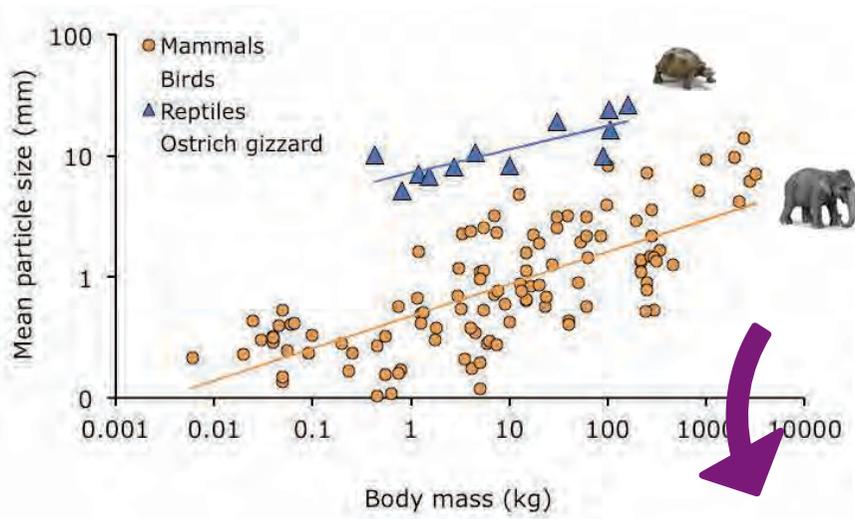


# Kauen ...



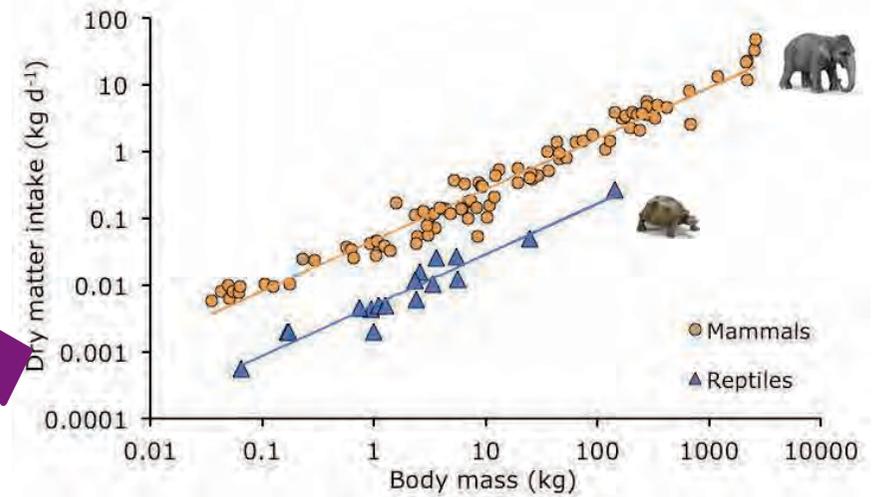
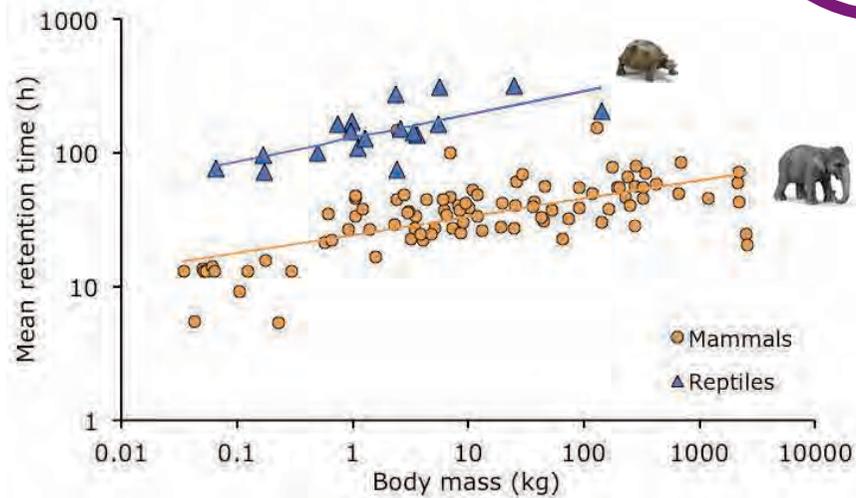
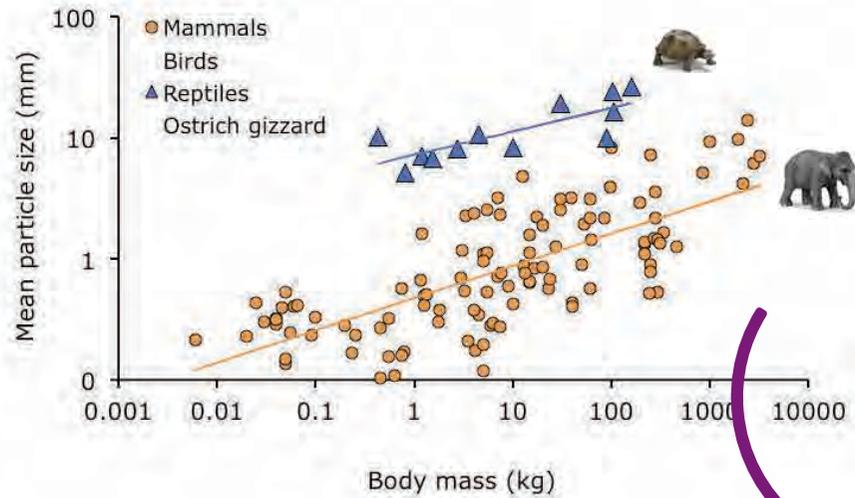


# Kauen ... ermöglicht kurze Verweildauer



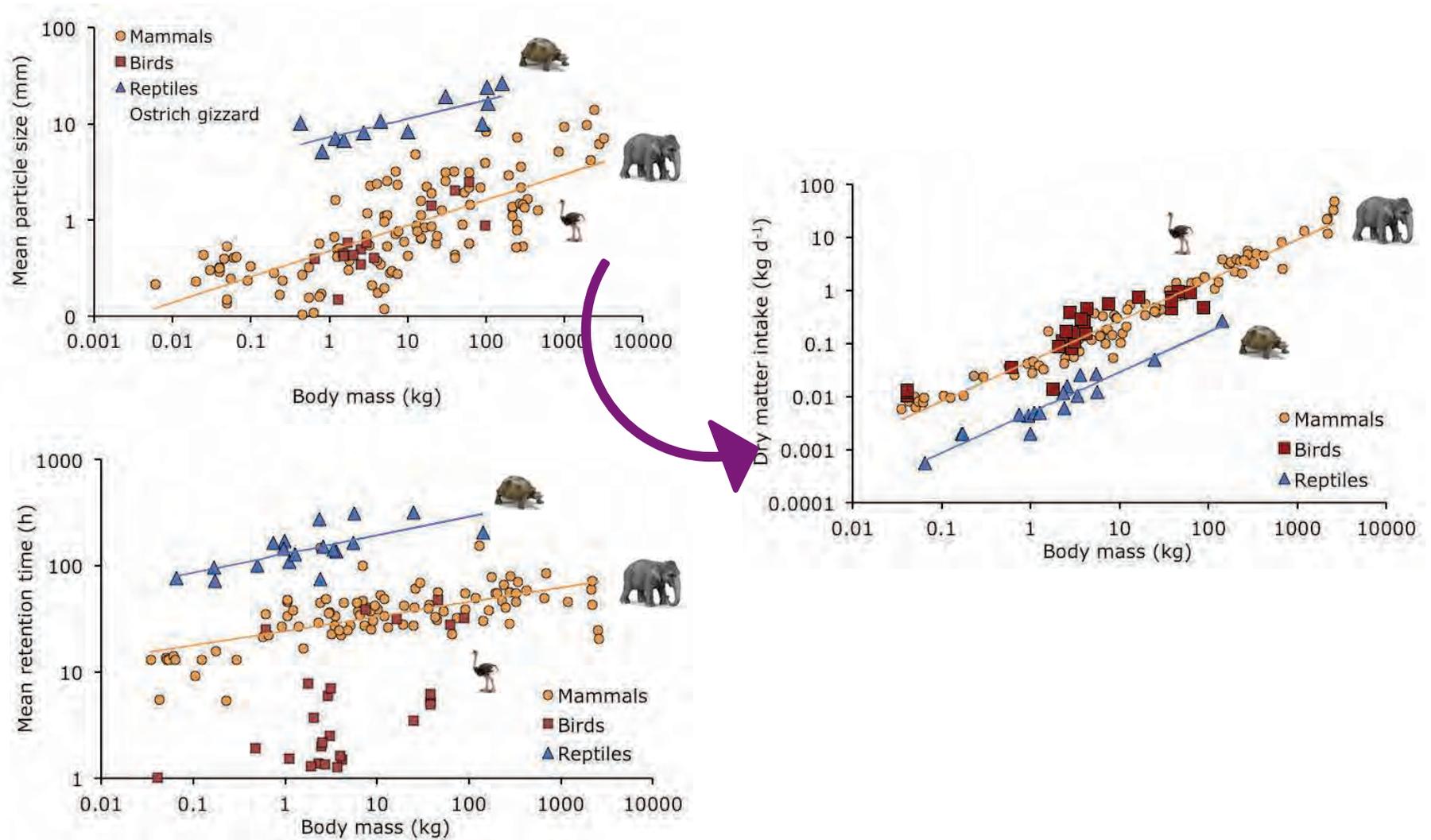


# Kauen ... ermöglicht hohe Futteraufnahme





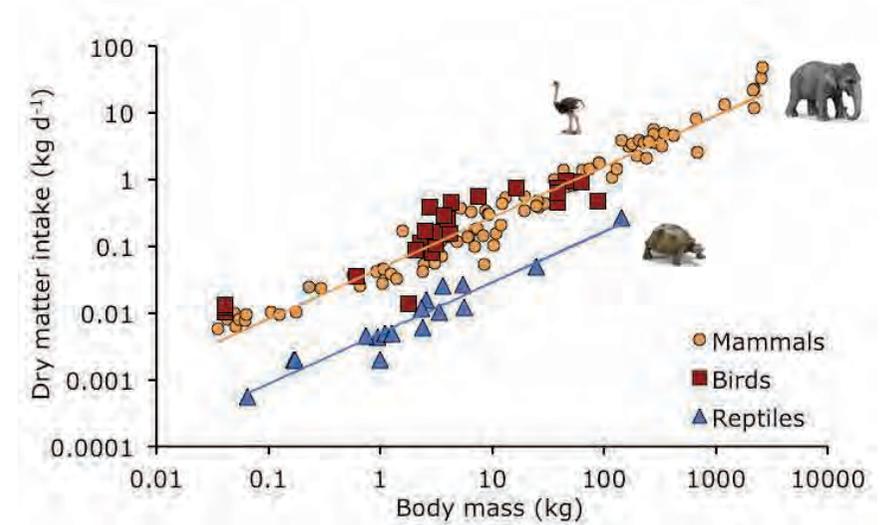
# Zerkleinern .. ermöglicht hohe Futteraufnahme





# Zerkleinern .. ermöglicht hohe Futteraufnahme

**für Pflanzenfresser ist  
Futterzerkleinerung die  
Voraussetzung für  
Endothermie !**





# Zahnoptimierung: Langlebigkeit I



## *Wodurch werden Zähne abgerieben ?*

- 'Härte' der Nahrung (typische Vorstellung: Zweige, trockenes Brot)
- Abrasiva in/auf der Nahrung
- Zahn-Zahn-Kontakt => Kauen !



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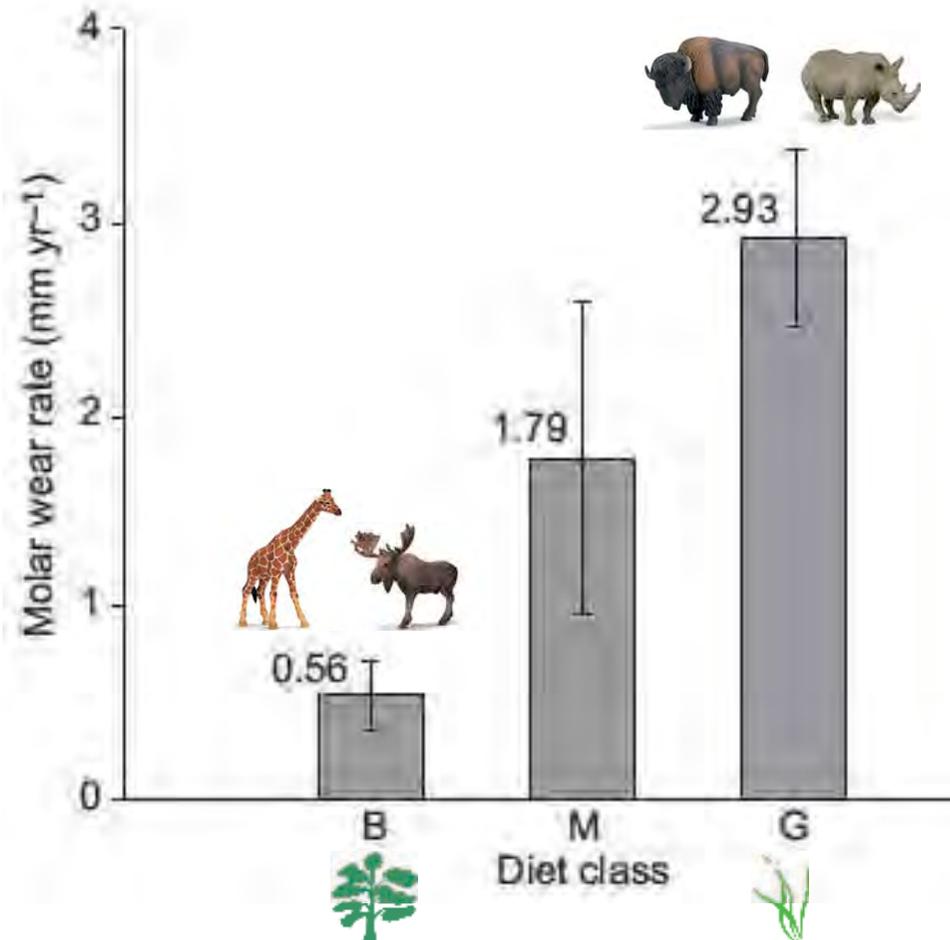
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# A comparison of observed molar wear rates in extant herbivorous mammals

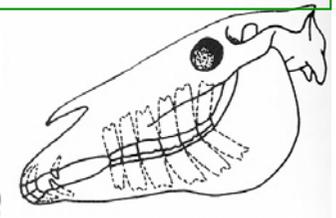
John Damuth<sup>1</sup> & Christine M. Janis<sup>2</sup>

*Ann. Zool. Fennici* 51: 188–200  
Helsinki 7 April 2014

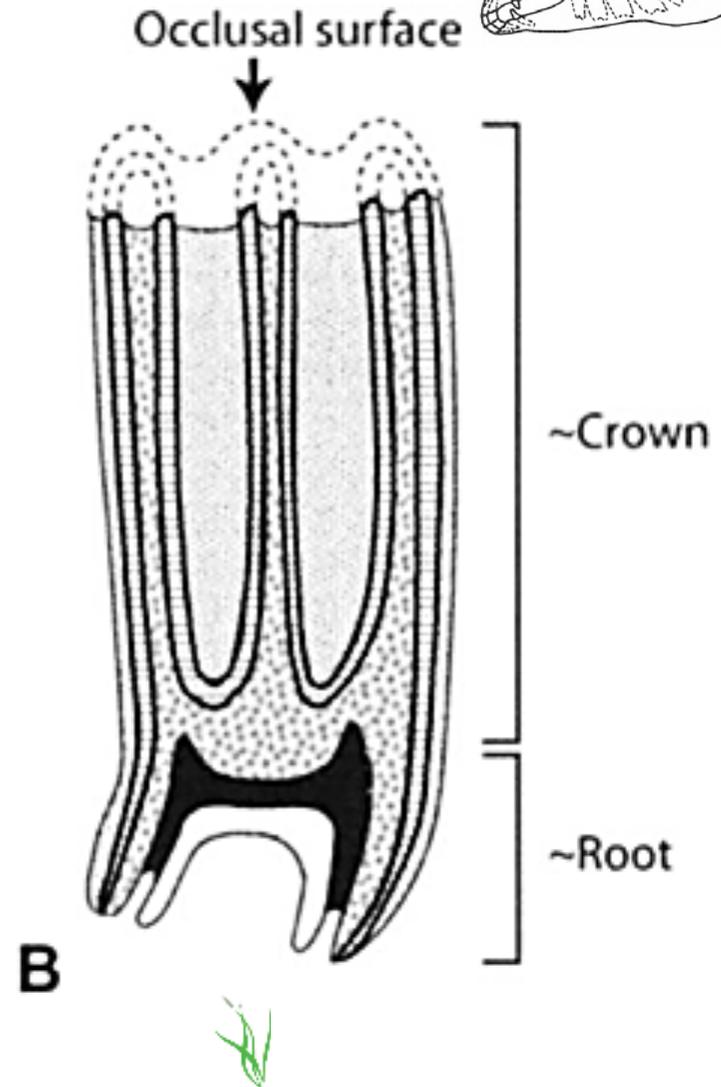
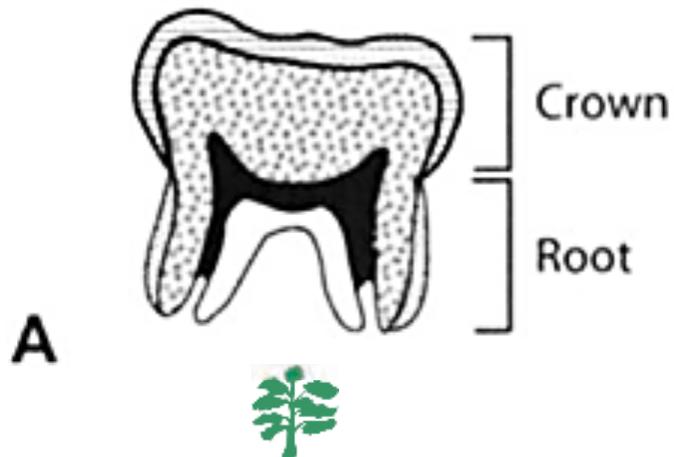




# Hypsodontie



-  Pulp cavity
-  Bone
-  Enamel
-  Dentine
-  Cementum



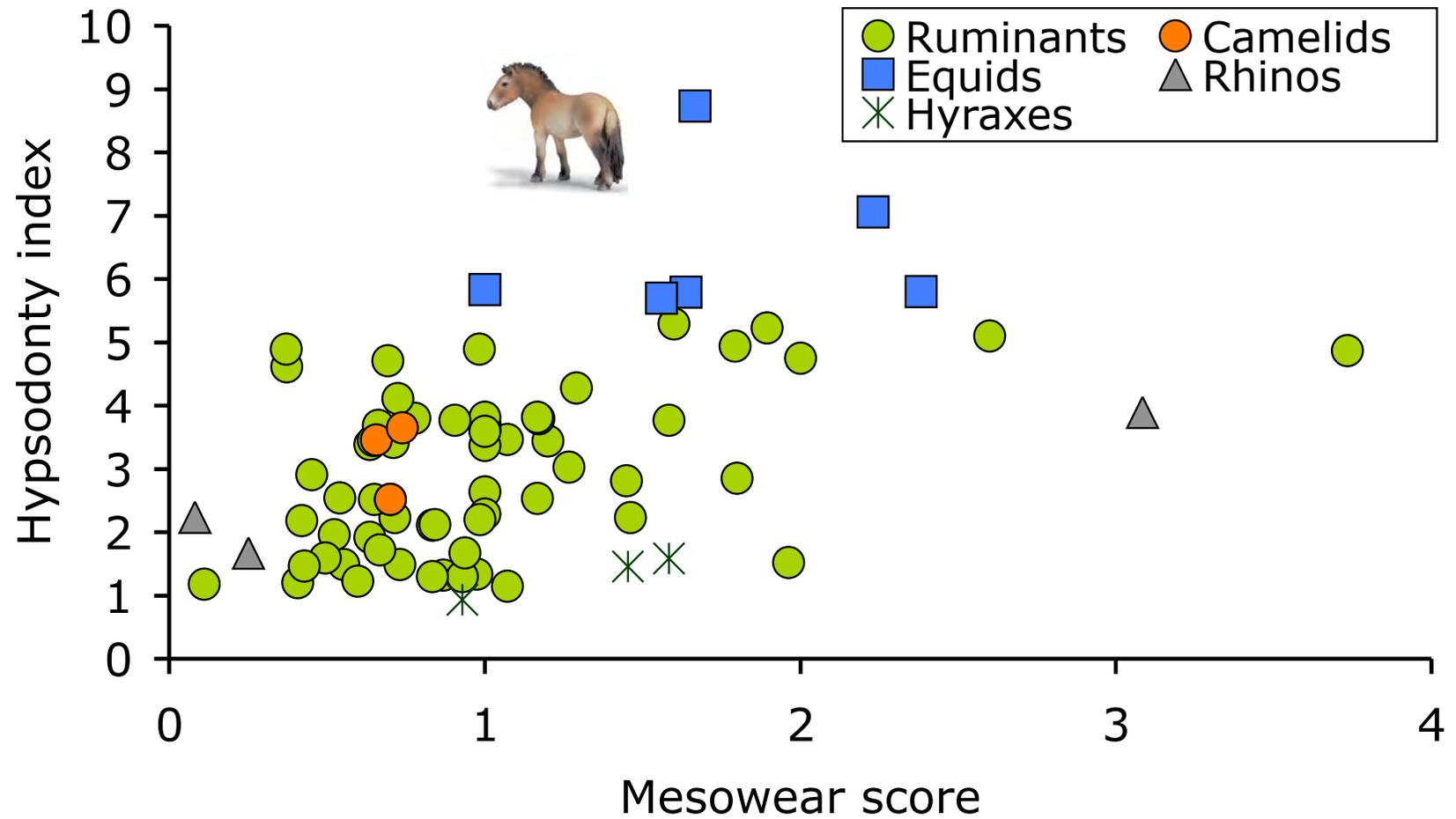


# Hypsodontie





# Hypsodontie

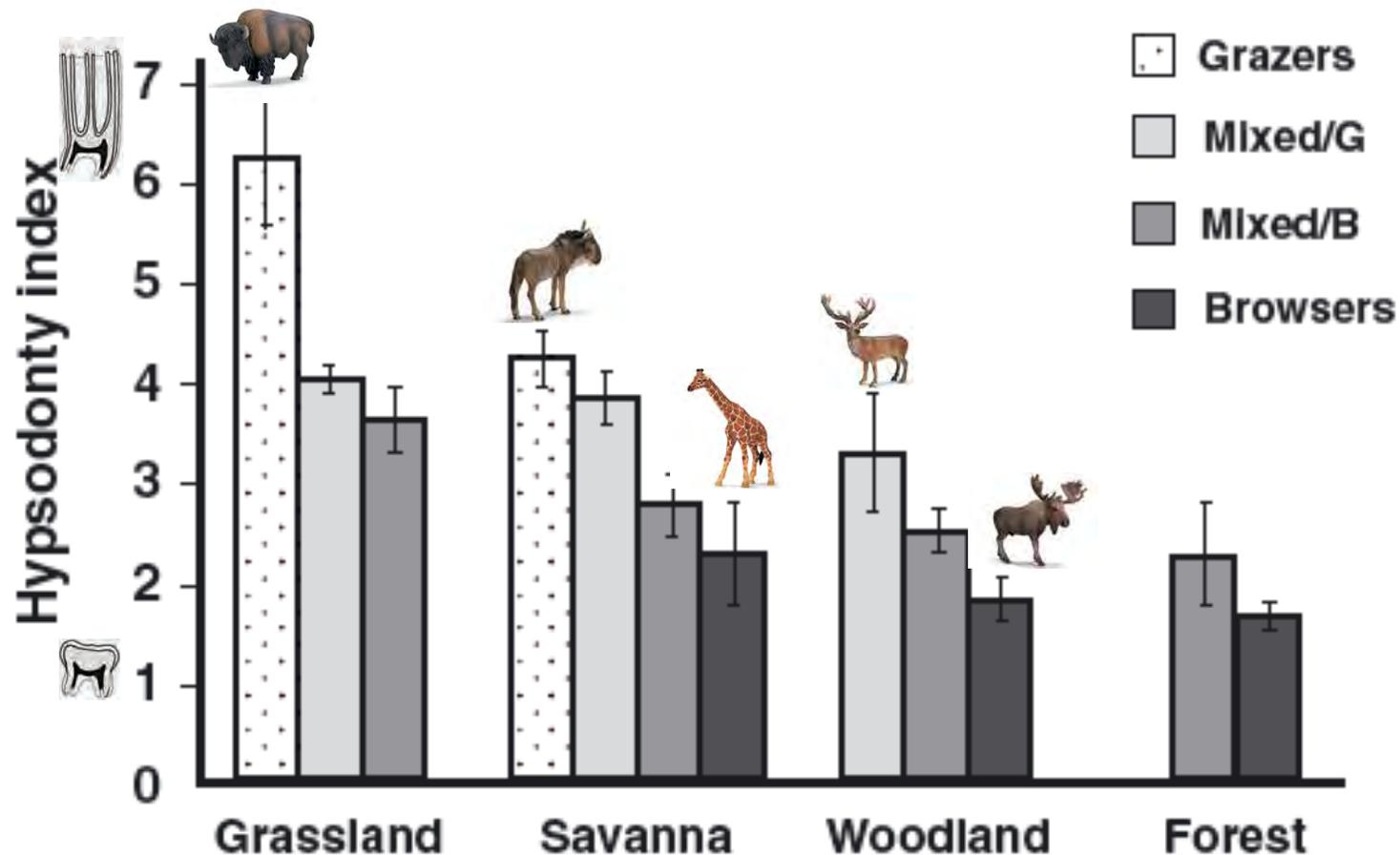




# On the relationship between hypsodonty and feeding ecology in ungulate mammals, and its utility in palaeoecology

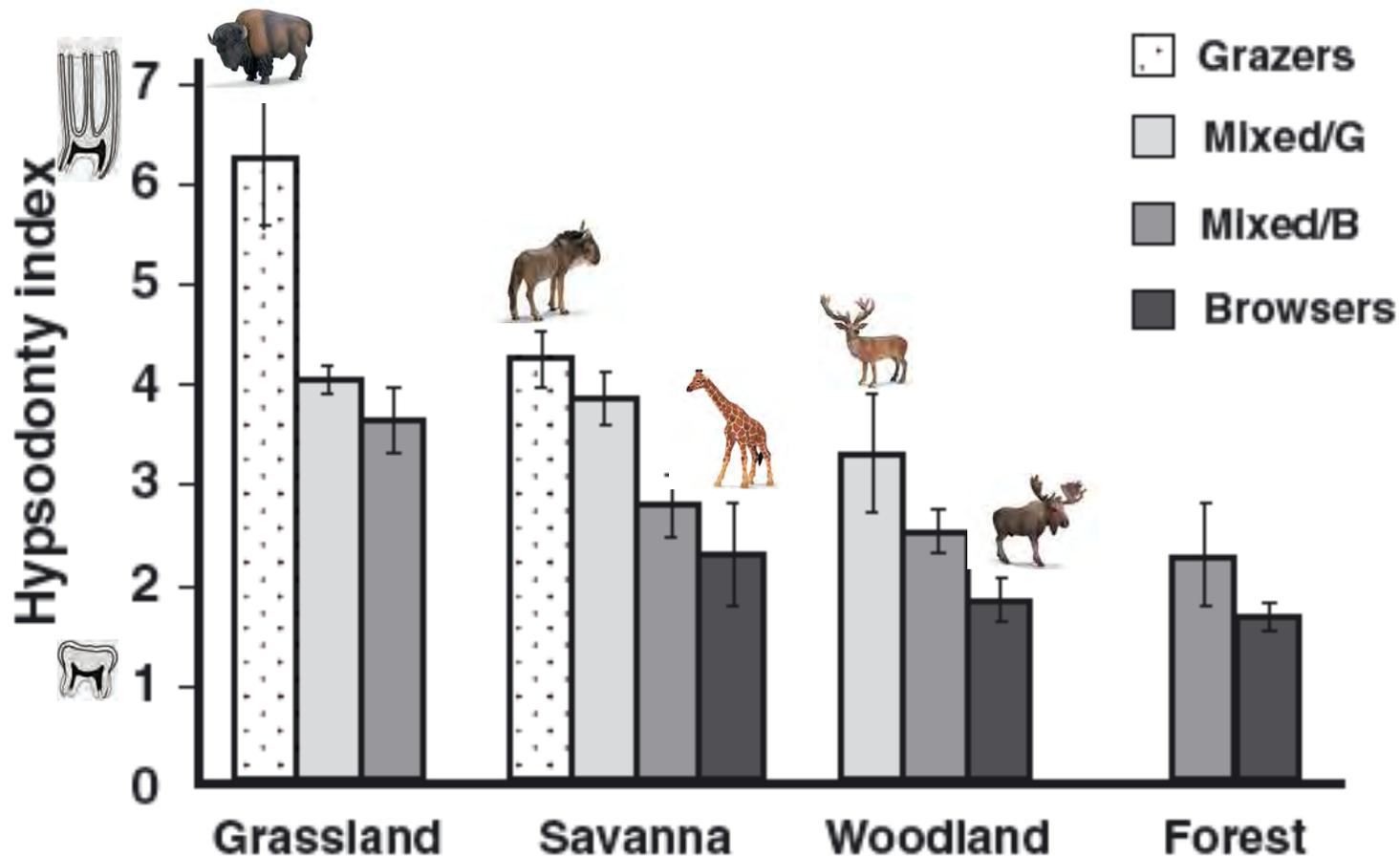
John Damuth<sup>1\*</sup> and Christine M. Janis<sup>2</sup>

*Biol. Rev.* (2011).





# Womit korreliert Hypsodontie ?





# **Another one bites the dust: faecal silica levels in large herbivores correlate with high-crowned teeth**

**Jürgen Hummel<sup>1,\*</sup>, Eva Findeisen<sup>1</sup>, Karl-Heinz Südekum<sup>1</sup>,  
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*Proc. R. Soc. B* (2011) 278, 1742–1747





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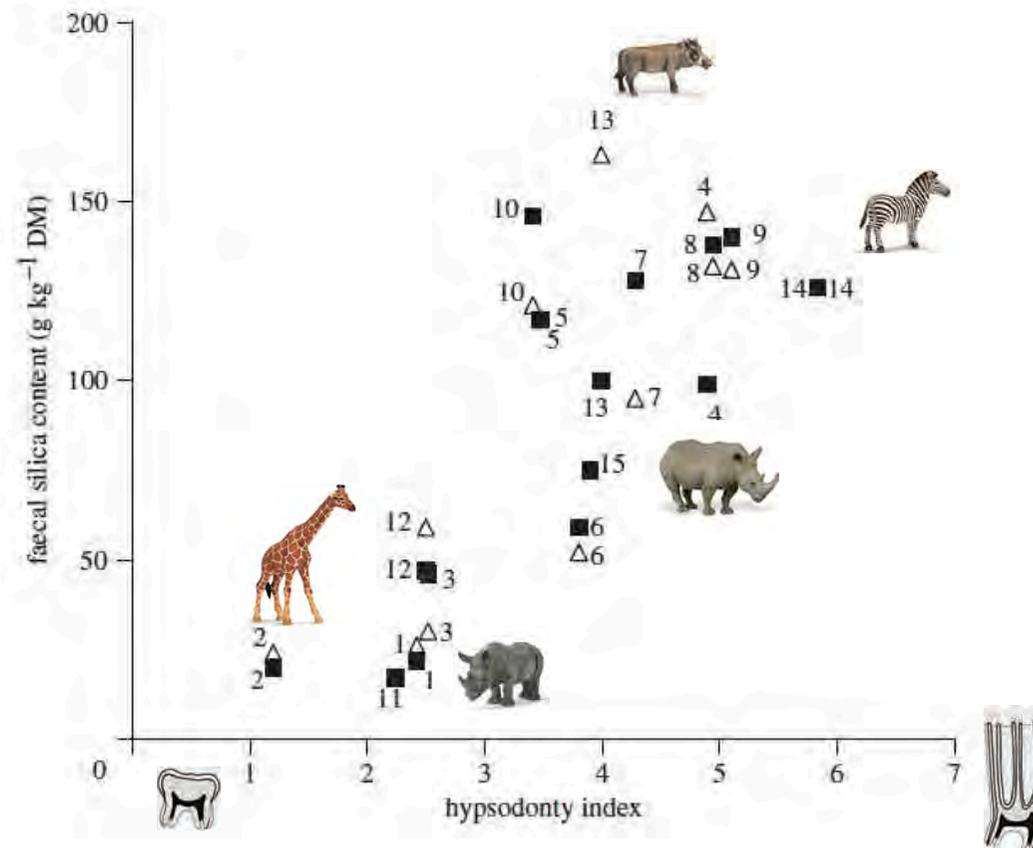




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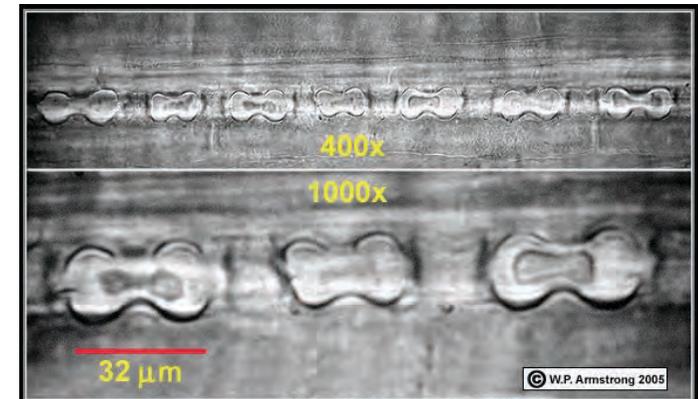
*Proc. R. Soc. B* (2011) 278, 1742–1747





## Woher das Silikat ?

- Staub/Schmutz  
(externe Abrasiva)?
- Phytolithe  
(interne Abrasiva)?





## *Sind Phytolithe abrasiv ?*

Do silica phytoliths really wear mammalian teeth?

Gordon D. Sanson<sup>a,\*</sup>, Stuart A. Kerr<sup>a</sup>, Karlis A. Gross<sup>b</sup>

*Journal of Archaeological Science* 34 (2007) 526–531

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**Interface**

2013

[rsif.royalsocietypublishing.org](http://rsif.royalsocietypublishing.org)

J R Soc Interface 10: 20120923.

Mechanisms and causes of wear in tooth enamel: implications for hominin diets

Peter W. Lucas<sup>1</sup>, Ridwaan Omar<sup>2</sup>, Khaled Al-Fadhalah<sup>3</sup>, Abdulwahab S. Almusallam<sup>4</sup>, Amanda G. Henry<sup>6</sup>, Shaji Michael<sup>5</sup>, Lidia Aroekia Thai<sup>5</sup>, Jörg Watzke<sup>6</sup>, David S. Strait<sup>7</sup> and Anthony G. Atkins<sup>8</sup>

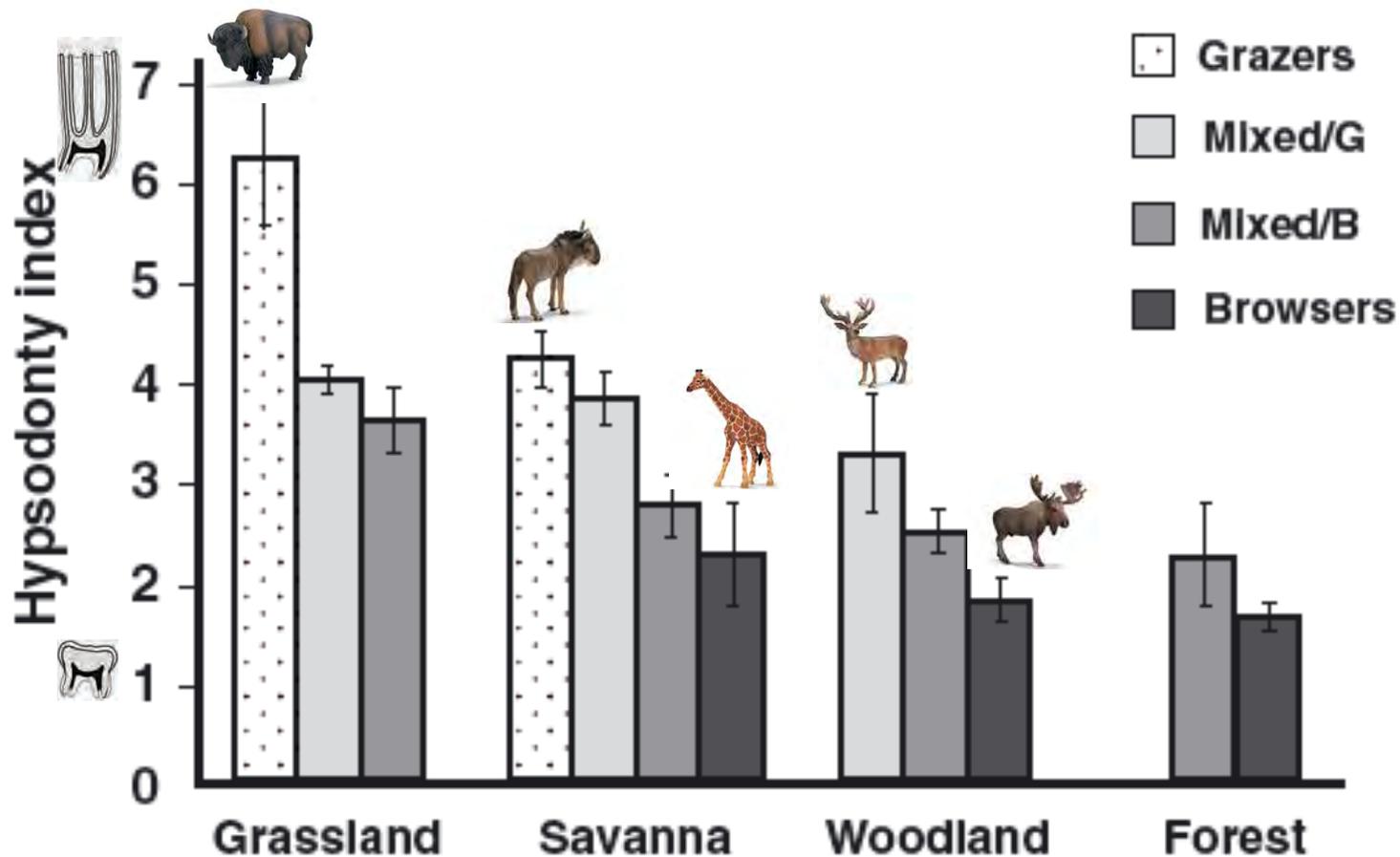
Untangling the environmental from the dietary: dust does not matter

*Proc. R. Soc. B*  
283: 20161032.

Gildas Merceron<sup>1</sup>, Anusha Ramdarshan<sup>1</sup>, Cécile Blondel<sup>1</sup>,  
Jean-Renaud Boisserie<sup>1,2</sup>, Noël Brunetiere<sup>3</sup>, Arthur Francisco<sup>3</sup>, Denis Gautier<sup>4,5</sup>,  
Xavier Milhet<sup>3</sup>, Alice Novello<sup>6</sup> and Dimitri Pret<sup>7</sup>



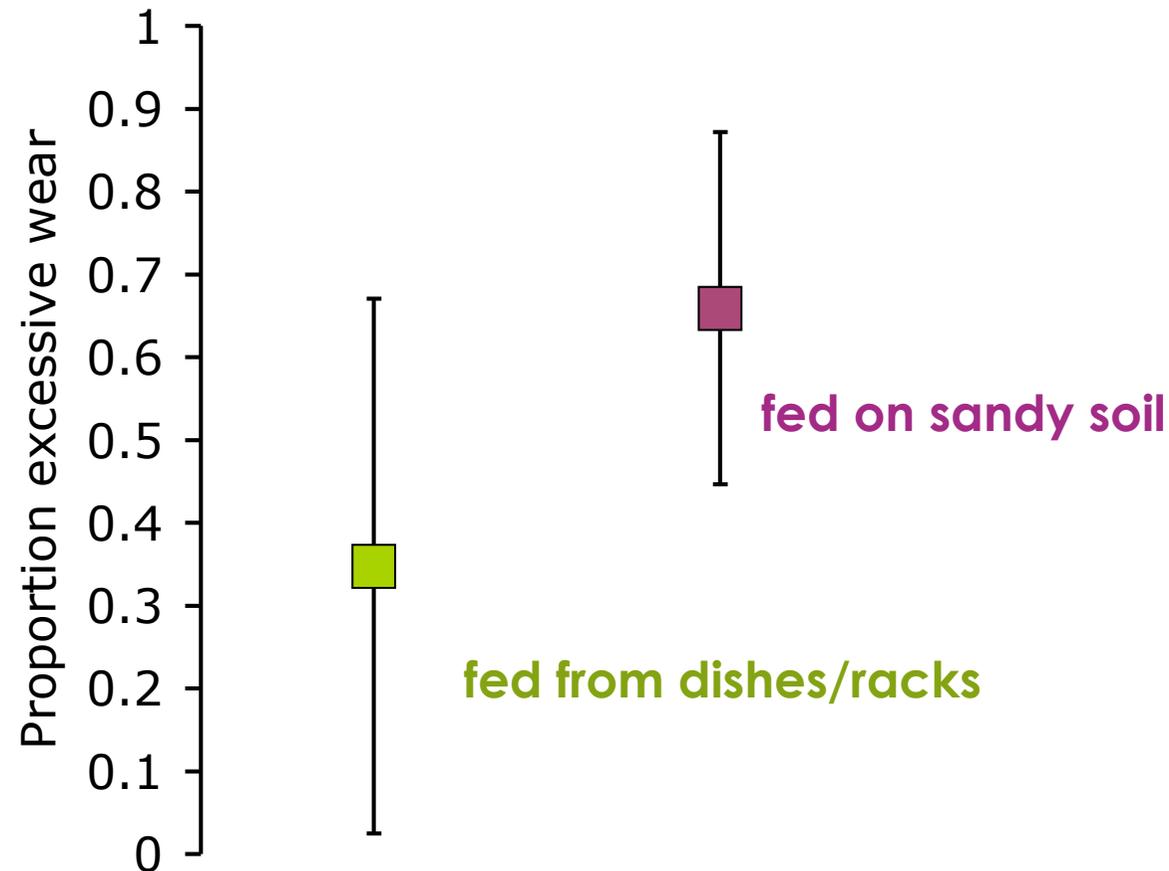
# Womit korreliert Hypsodontie ?





## IRREGULAR TOOTH WEAR AND LONGEVITY IN CAPTIVE WILD RUMINANTS: A PILOT SURVEY OF NECROPSY REPORTS

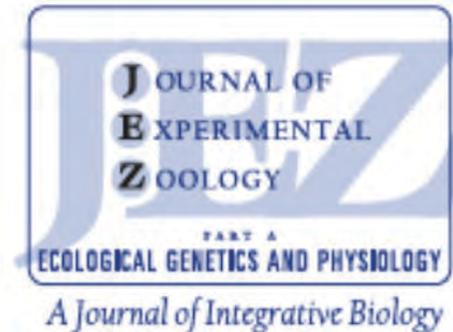
Olga Martin Jurado, med.vet., Marcus Clauss, M.Sc., Dr.med.vet., Dipl. E.C.V.C.N., W. Jürgen Streich, Dr.rer.nat., and Jean-Michel Hatt, M.Sc., Prof. Dr.med.vet., Dipl. E.C.A.M.S., Dipl. A.C.Z.M.





RESEARCH ARTICLE

# Growth and Wear of Incisor and Cheek Teeth in Domestic Rabbits (*Oryctolagus cuniculus*) Fed Diets of Different Abrasiveness



JACQUELINE MÜLLER<sup>1</sup>, MARCUS CLAUSS<sup>1\*</sup>,  
DARYL CODRON<sup>1,2</sup>, ELLEN SCHULZ<sup>3</sup>, JÜRGEN HUMMEL<sup>4</sup>,  
MIKAEL FORTELIUS<sup>5</sup>, PATRICK KIRCHER<sup>6</sup>, AND  
JEAN-MICHEL HATT<sup>1</sup>



*J. Exp. Zool.*  
321A:283–298,  
2014

Journal of  
**Animal Physiology and Animal Nutrition**

Journal of Animal Physiology and Animal Nutrition © 2014 DOI: 10.1111/jpn.12226

ORIGINAL ARTICLE

# Tooth length and incisal wear and growth in guinea pigs (*Cavia porcellus*) fed diets of different abrasiveness

J. Müller<sup>1</sup>, M. Clauss<sup>1</sup>, D. Codron<sup>1,2</sup>, E. Schulz<sup>3,4</sup>, J. Hummel<sup>5</sup>, P. Kircher<sup>6</sup> and J.-M. Hatt<sup>1</sup>



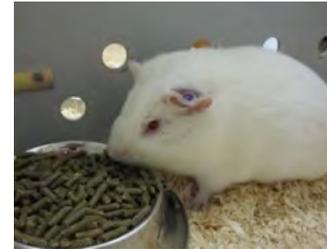


# Versuche Kaninchen





# Versuche Meerschweinchen

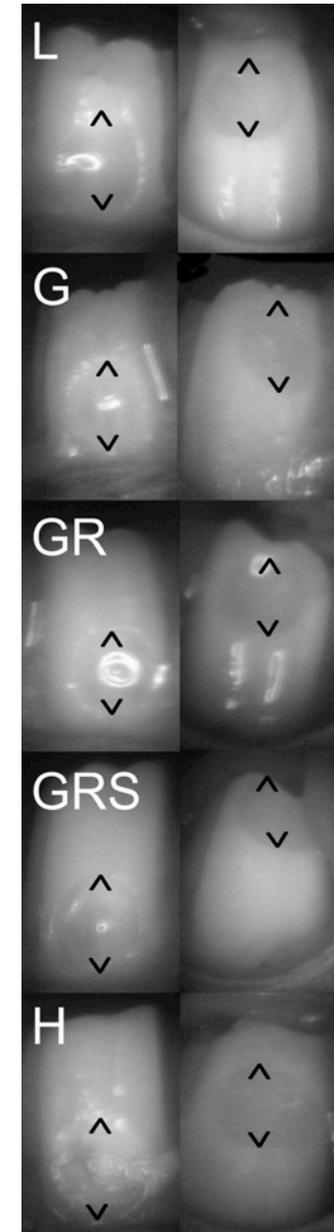




# Methode

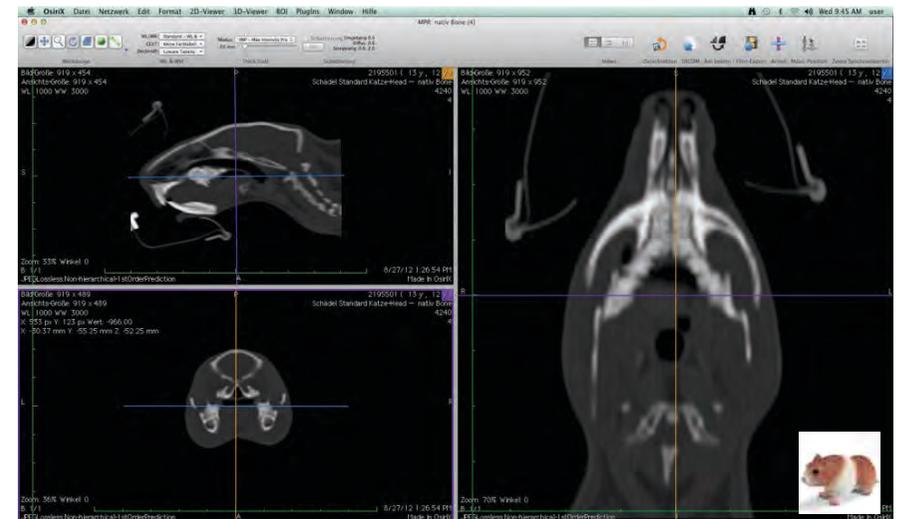
16 Tiere, 5 Futter, je Futter 2  
Wochen

Markierungen auf  
Schneidezähnen und  
(Kaninchen) p3





# Computertomographie





# Diet design

Table 1. Composition of different complete pelleted diets (lucerne L, grass G, grass and rice hulls GR, grass and rice hulls and sands GRS) and grass hay (H).

	L	G	GR	GRS	H
<b>Ingredients</b>					
Lucerne meal (%)	60.0	—	—	—	—
Grass meal (%)	—	60.0	64.8	64.8	—
Rice hulls (%)	—	—	20.0	20.0	—
Sand <sup>a</sup> (%)	—	—	—	5.0	—
Pure lignocellulose (%)	33.8	27.4	5.0	—	—
Soybean meal (%)	—	7.0	5.0	5.0	—
Molasses (%)	3.0	3.0	3.0	3.0	—
Lignobond (%)	2.0	2.0	2.0	2.0	—
Soy oil (%)	1.0	0.4	—	—	—
Mineral/vitamin premix (%)	0.2	0.2	0.2	0.2	—
Dry matter (% as fed)	91.4	91.9	91.8	92.2	90.8
<b>Nutrient composition (g/kg DM)</b>					
Total ash	79	64	75	130	104
Crude protein	102	90	97	85	109
aNDFom <sup>b</sup>	578	600	487	459	579
ADFom <sup>c</sup>	434	403	322	299	354
ADL <sup>d</sup>	131	110	74	65	52

Dry matter digestibility (%)      39.7 ± 9.3      34.3 ± 8.1      41.2 ± 5.7      40.7 ± 11.1      45.1 ± 4.1

<sup>a</sup>Sand for playgrounds, grain size 0–1 mm, REDSUN garden products B.V., Hejlen, Denmark; mean particle size measured by sieve analysis as d<sub>MEAN</sub> (Fritz et al., 2012) of 0.233 mm.

<sup>b</sup>aNDFom neutral detergent fiber, determined using amylase and ash corrected.

<sup>c</sup>ADFom acid detergent fiber, ash corrected.

<sup>d</sup>ADL acid detergent lignin ash corrected.

<sup>e</sup>ADIA acid detergent insoluble ash (a measure for abrasives).





# Diet design

Table 1. Composition of different complete pelleted diets (lucerne L, grass G, grass and rice-hulls GR, grass and rice-hulls and sands GRS) and grass hay (H).

	L	G	GR	GRS	H
Ingredients					
Lucerne meal (%)	69.8	—	—	—	—
Grass meal (%)	—	60.0	64.8	64.8	—
Rice hulls (%)	—	—	20.0	20.0	—
Sand <sup>a</sup> (%)	—	—	—	5.0	—
Pure lignocellulose (%)	33.8	27.4	5.0	—	—
Soybean meal (%)	—	7.0	5.0	5.0	—
Molasses (%)	3.0	3.0	3.0	3.0	—
Lignobond (%)	2.0	2.0	2.0	2.0	—
Soy oil (%)	1.0	0.4	—	—	—
Mineral/vitamin premix (%)	0.2	0.2	0.2	0.2	—
Dry matter (% as fed)	91.4	91.9	91.8	92.2	90.8
Nutrient composition (g/kg DM)					
Total ash	79	84	75	130	104
Crude protein	102	80	97	85	109
aNDFom <sup>b</sup>	578	600	487	459	579
ADFom <sup>c</sup>	434	403	322	299	354
ADL <sup>d</sup>	131	110	74	85	52
<b>ADIA<sup>e</sup></b>	<b>05</b>	<b>16</b>	<b>24</b>	<b>77</b>	<b>38</b>
Dry matter digestibility (%)	39.7 ± 9.3	34.3 ± 8.1	41.2 ± 5.7	40.7 ± 11.1	45.1 ± 4.1

<sup>a</sup>Sand for playgrounds, grain-size 0–1 mm, REDSUN garden products B.V., Heijen, Denmark; mean particle size measured by sieve analysis as d<sub>MEAN</sub> (Fritz et al., 2012) of 0.233 mm.

<sup>b</sup>aNDFom neutral detergent fiber, determined using amylase and ash corrected.

<sup>c</sup>ADFom acid detergent fiber, ash corrected.

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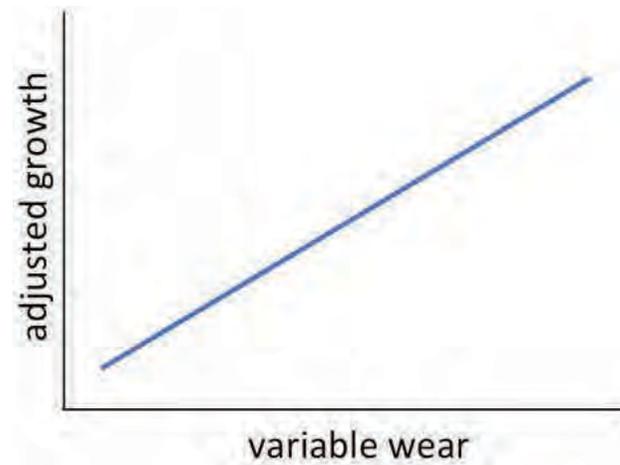
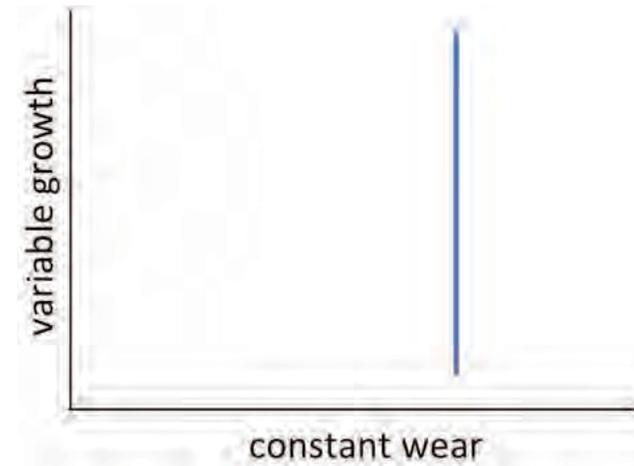
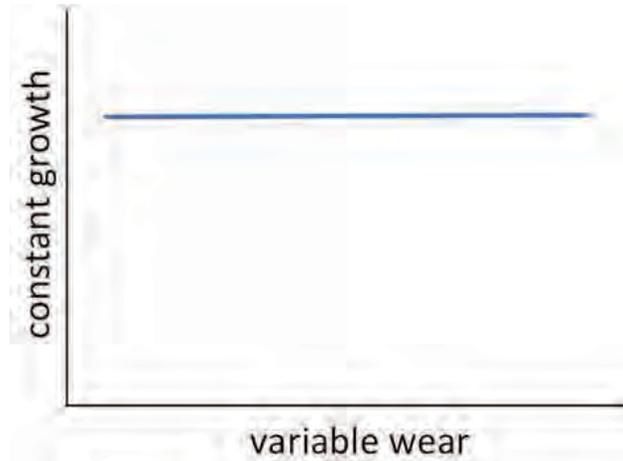
<sup>e</sup>ADIA acid detergent insoluble ash (a measure for abrasives).



**Unterschied in Abrasiva !**

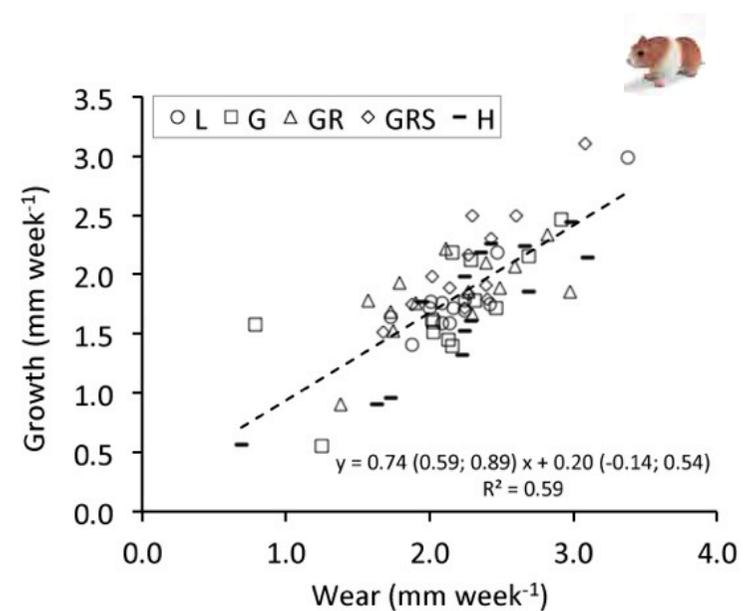
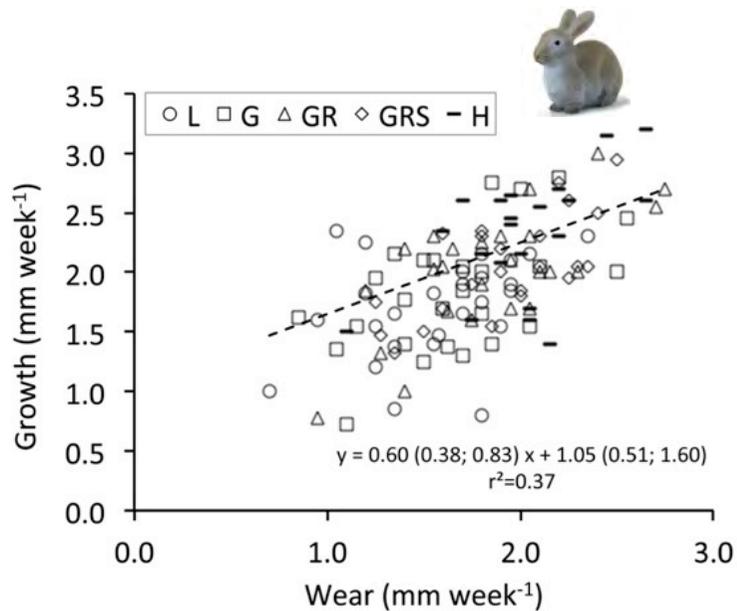
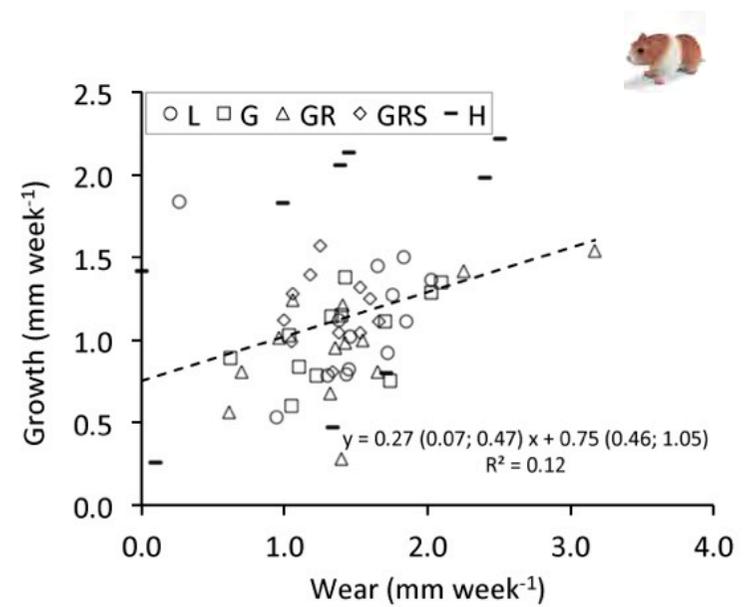
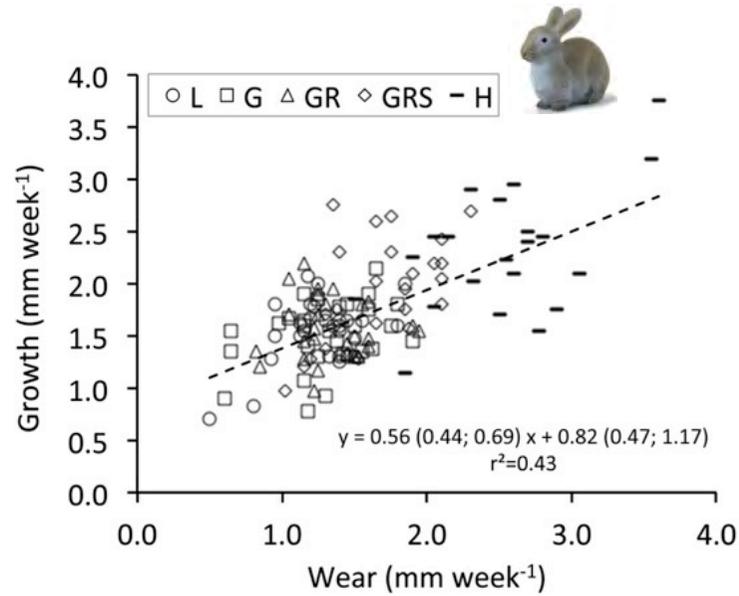


# Wachstum



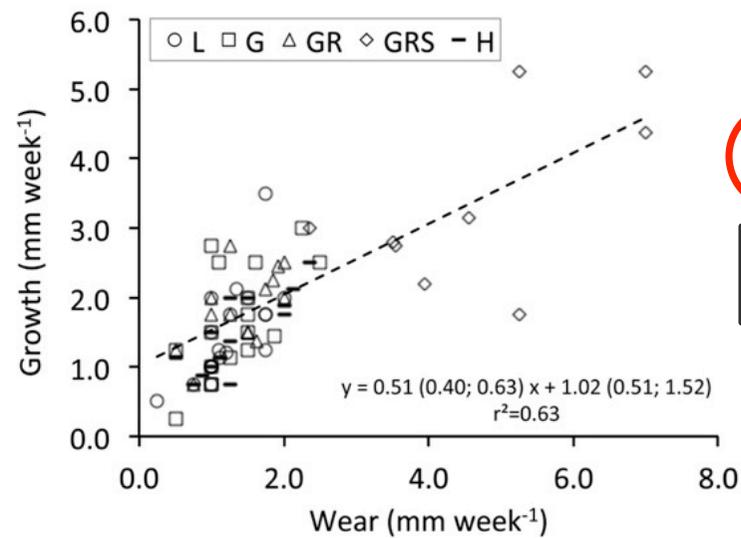
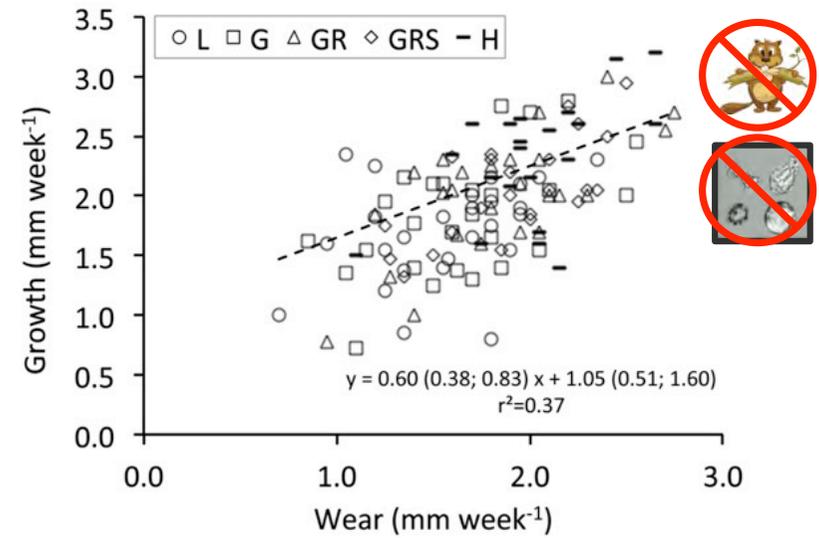
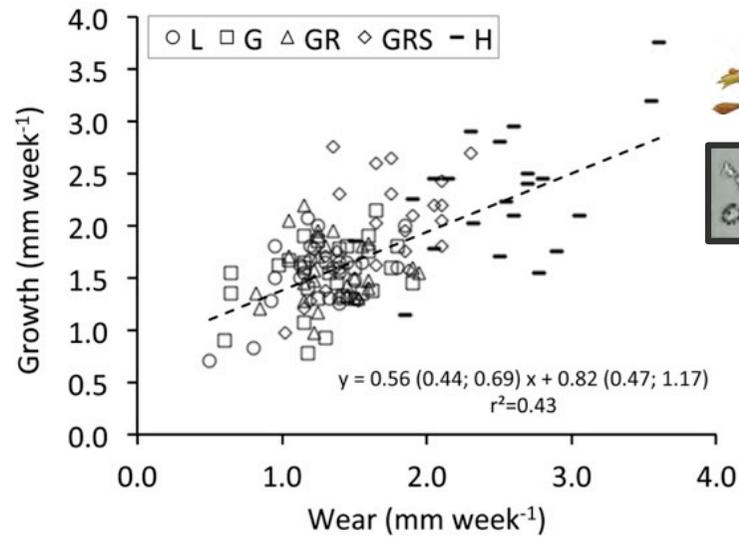


# Schneidezahn-Wachstum



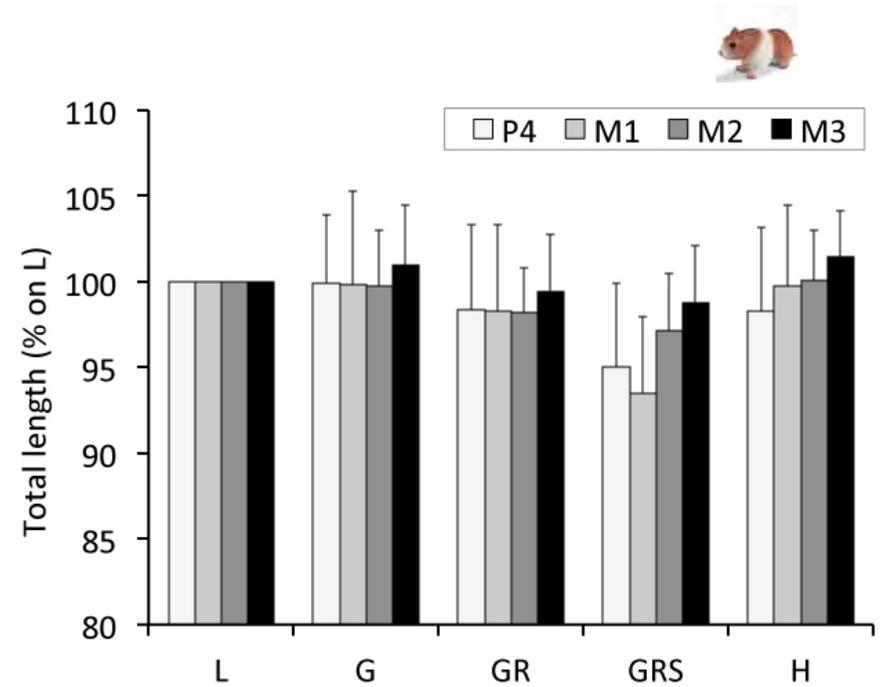
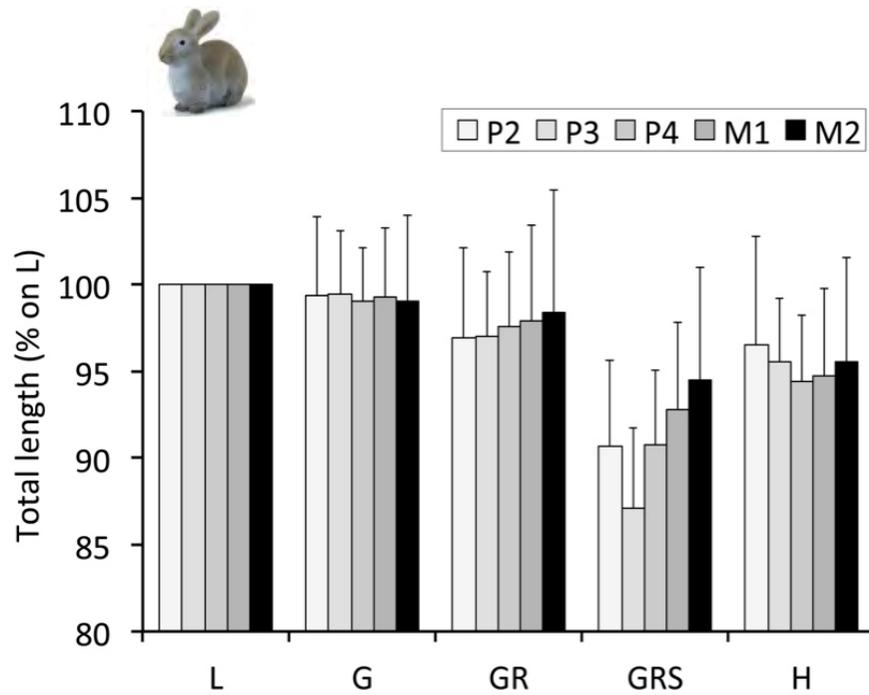


# Schneide-/Backenzahn-Wachstum



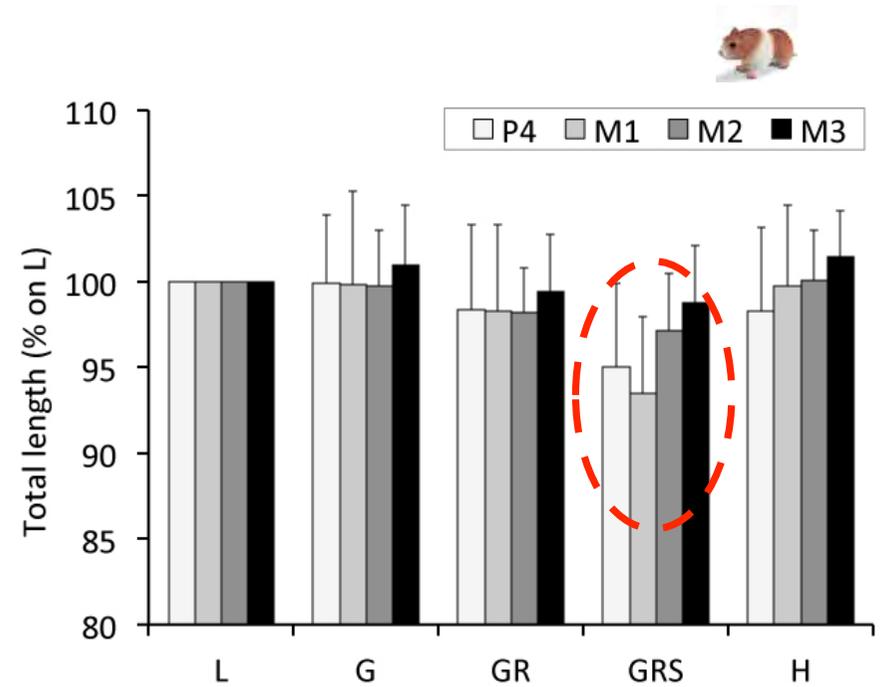
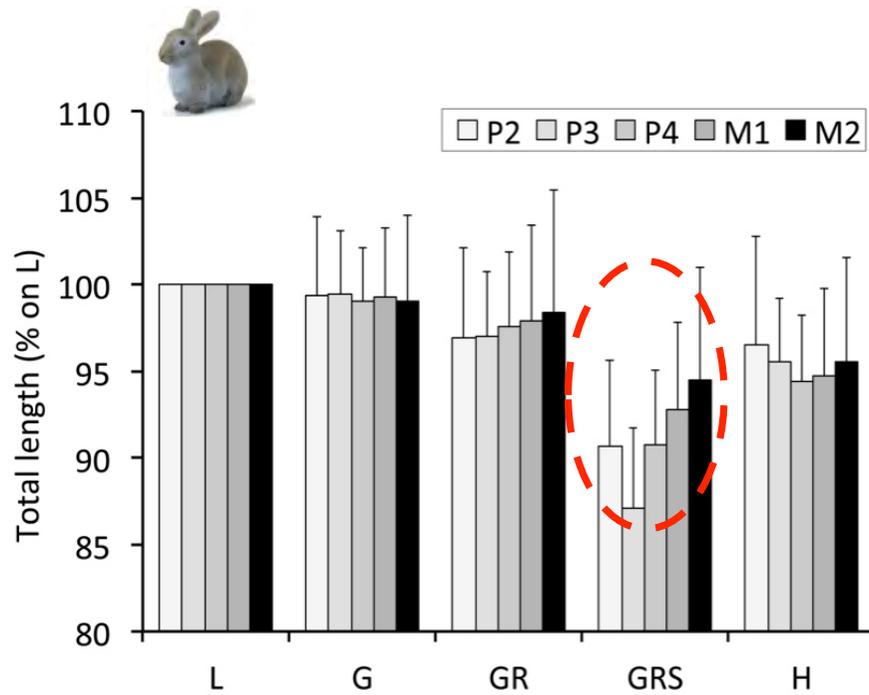


# Relative Zahnlänge



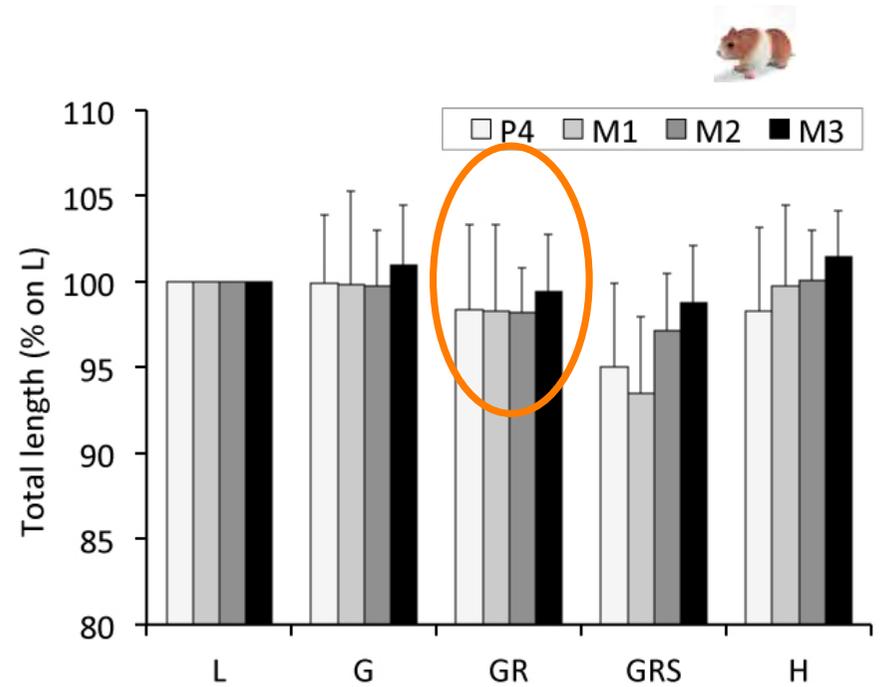
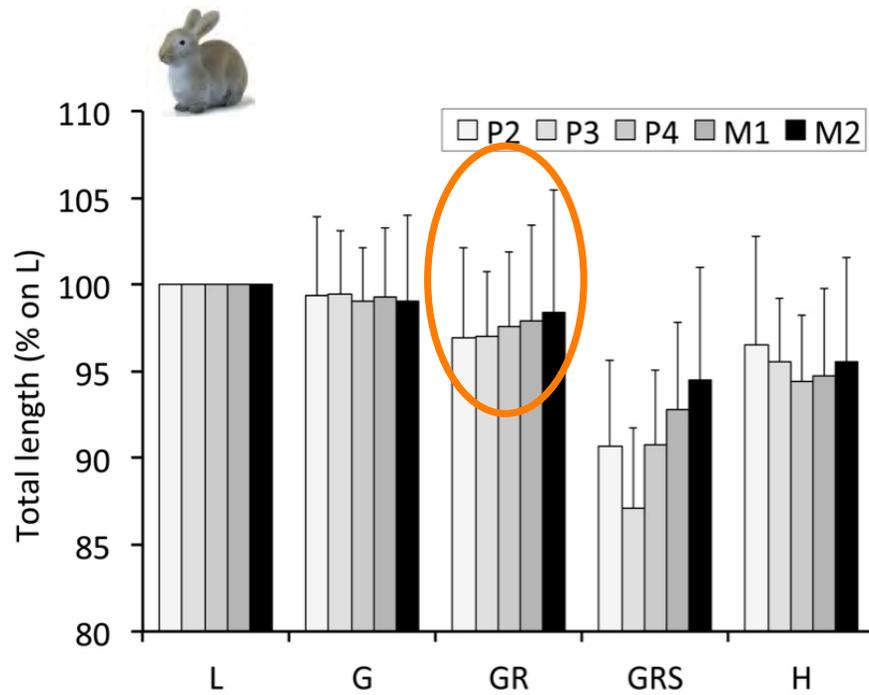


# Sand ist abrasiv





# Phytolithe sind auch abrasiv

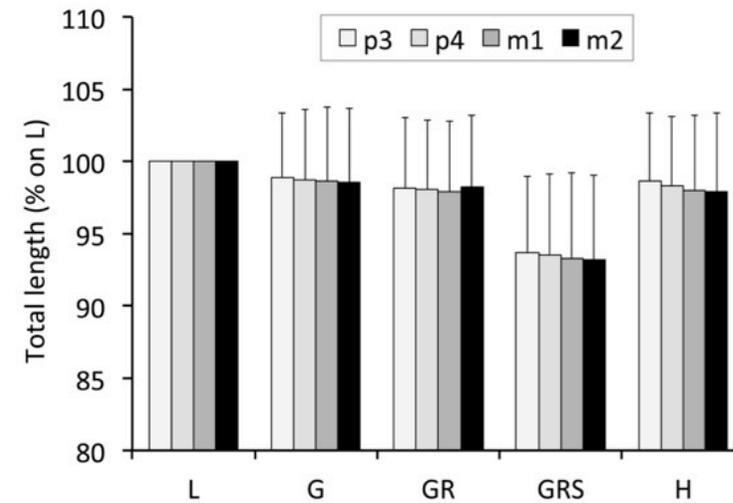
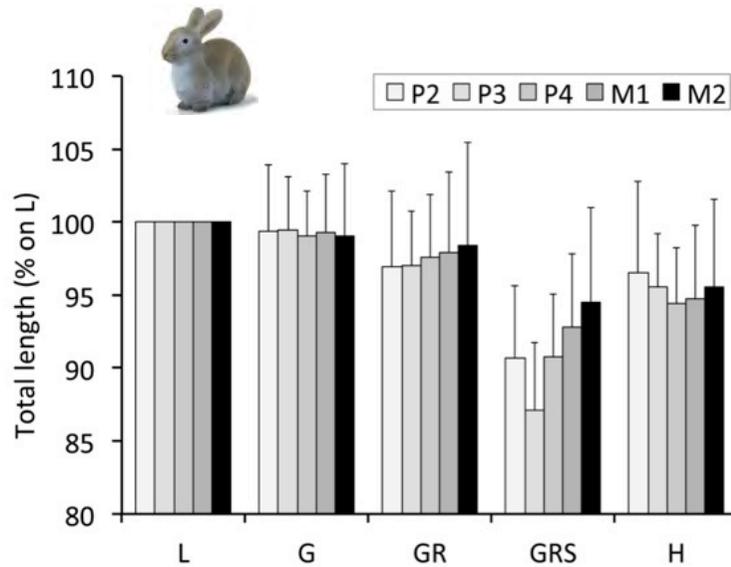




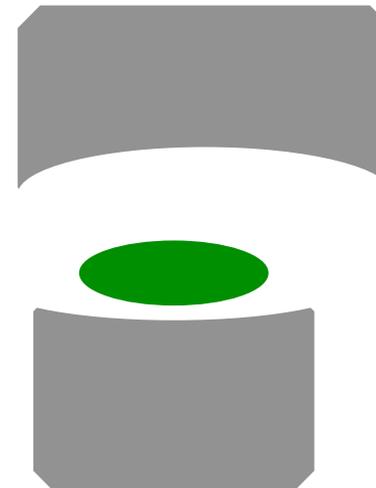
Zahnfunktion:  
Schwerkraft ?



# Oberkiefer vs. Unterkiefer

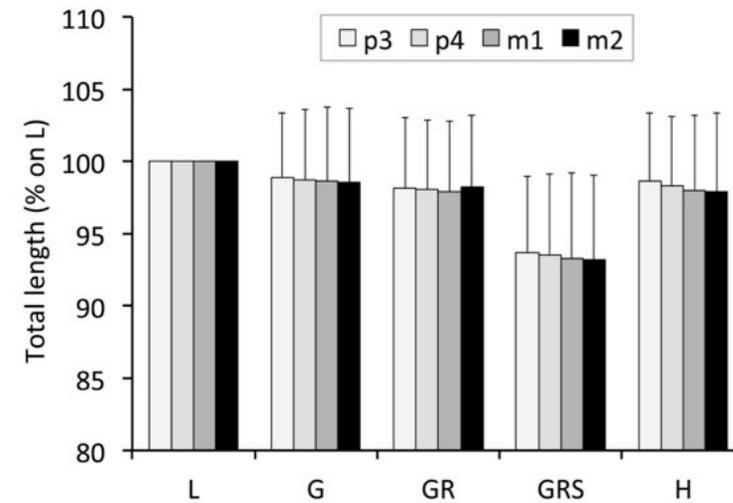
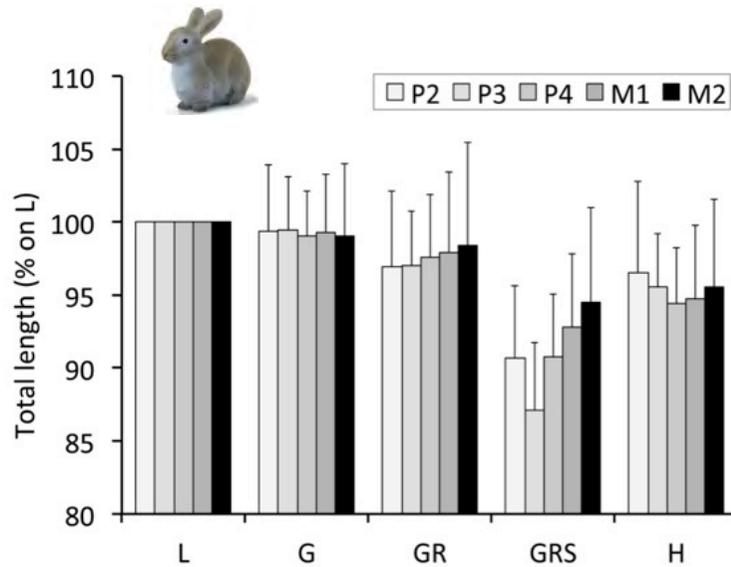


## Inverted pestle-and-mortar system:





# Oberkiefer vs. Unterkiefer

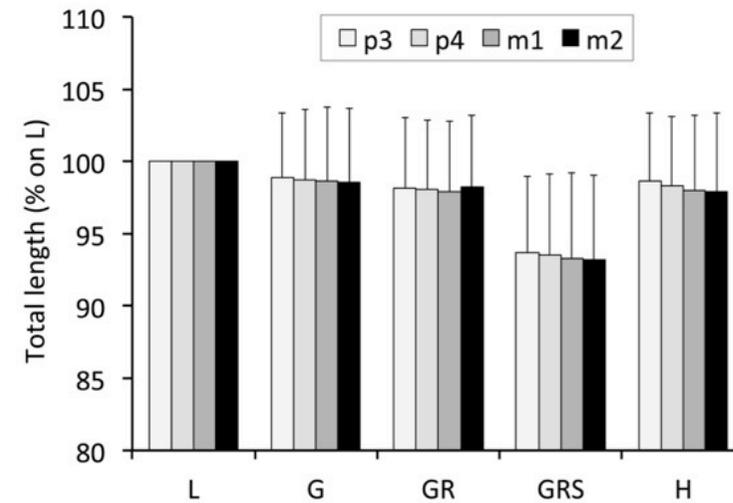
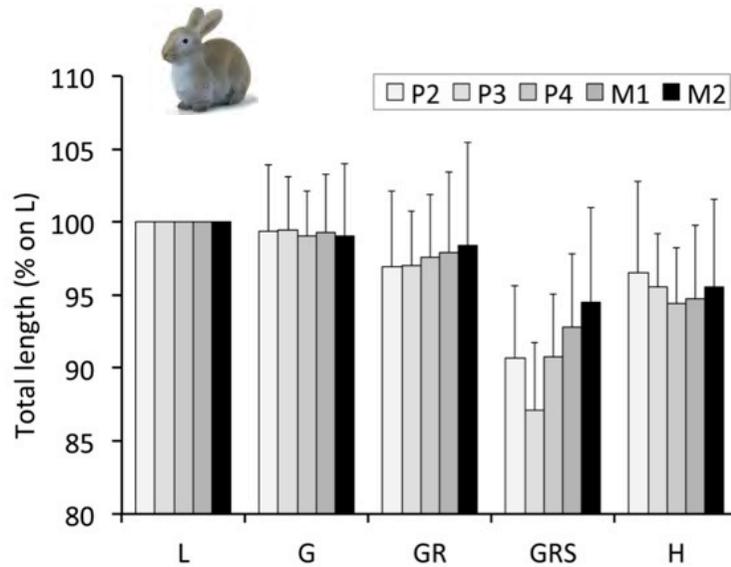


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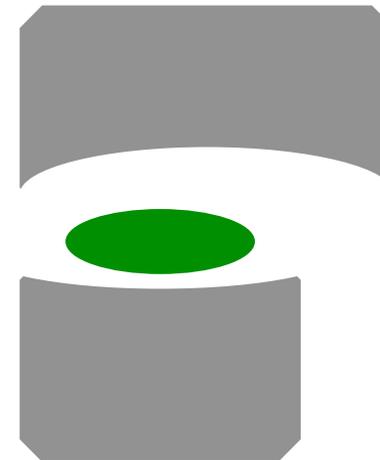




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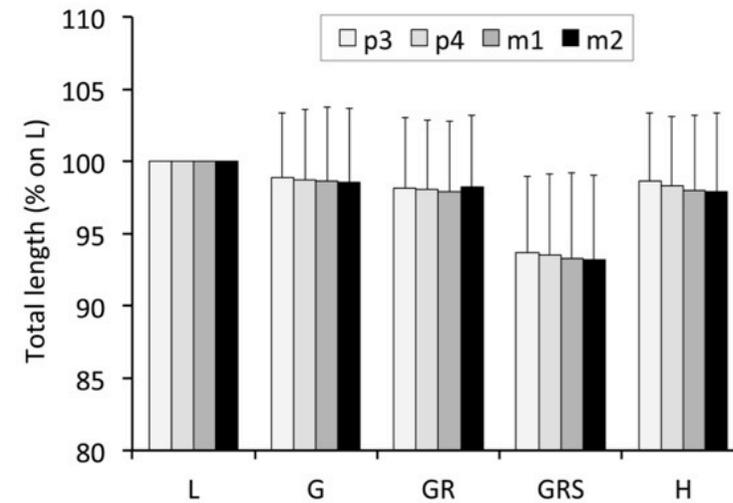
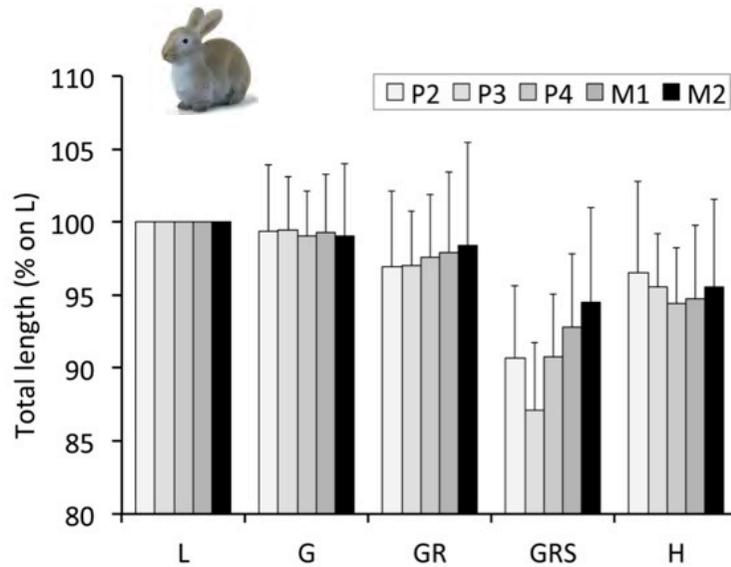


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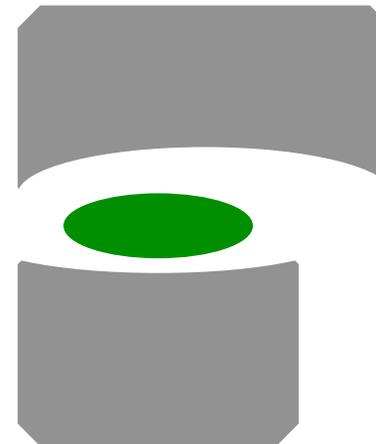




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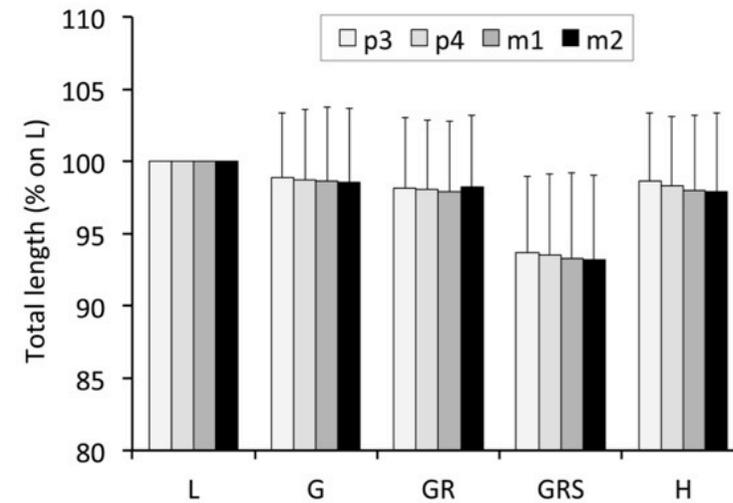
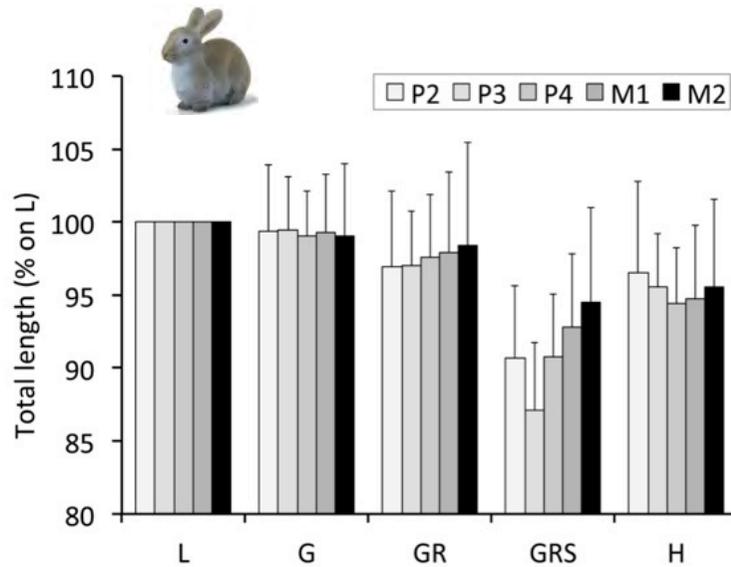


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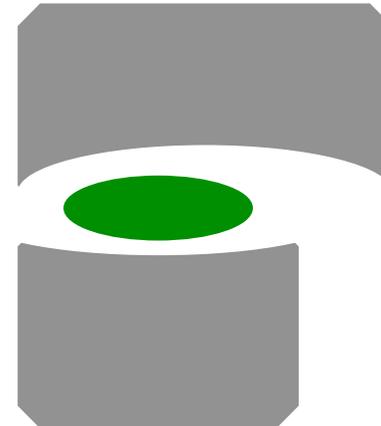
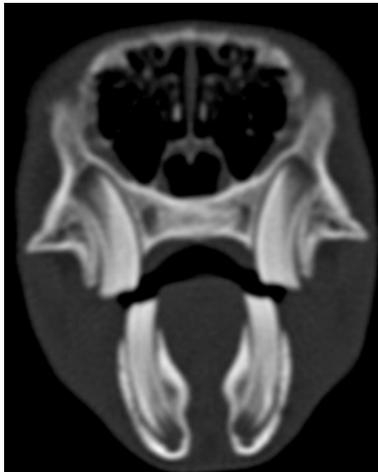




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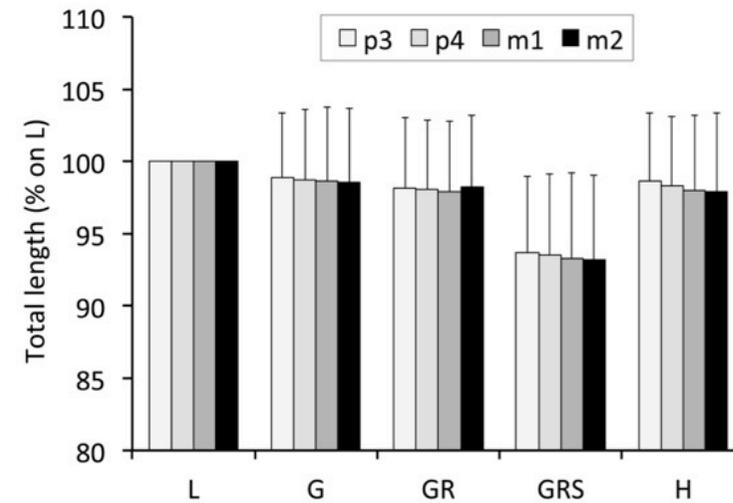
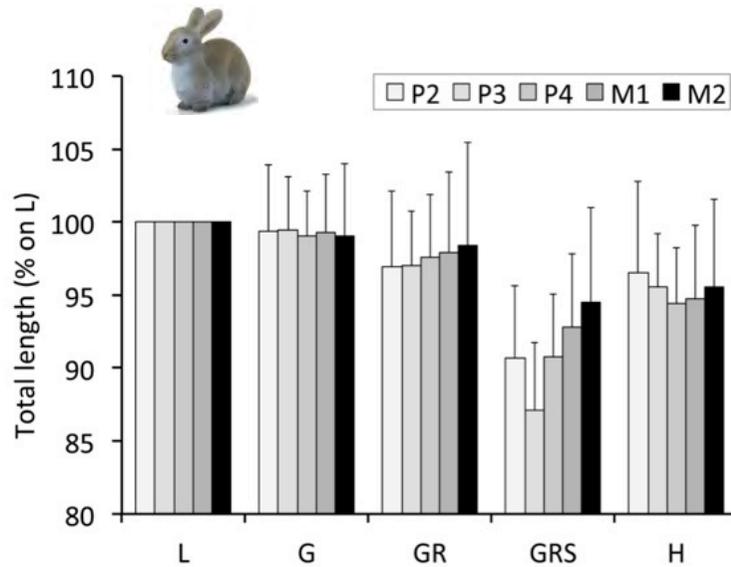


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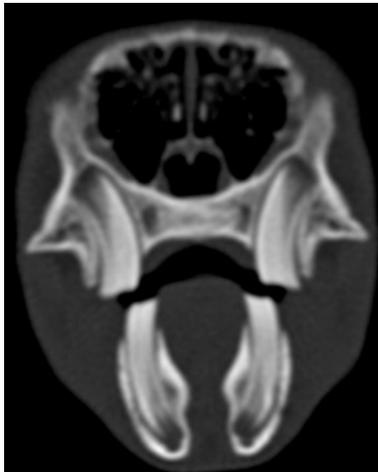




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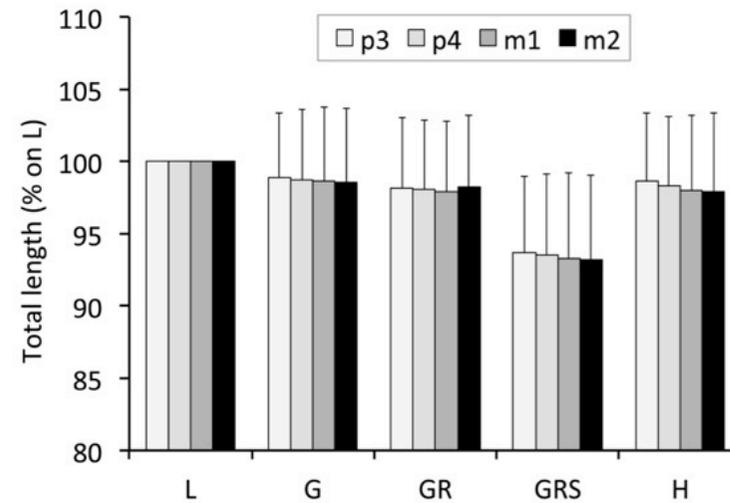
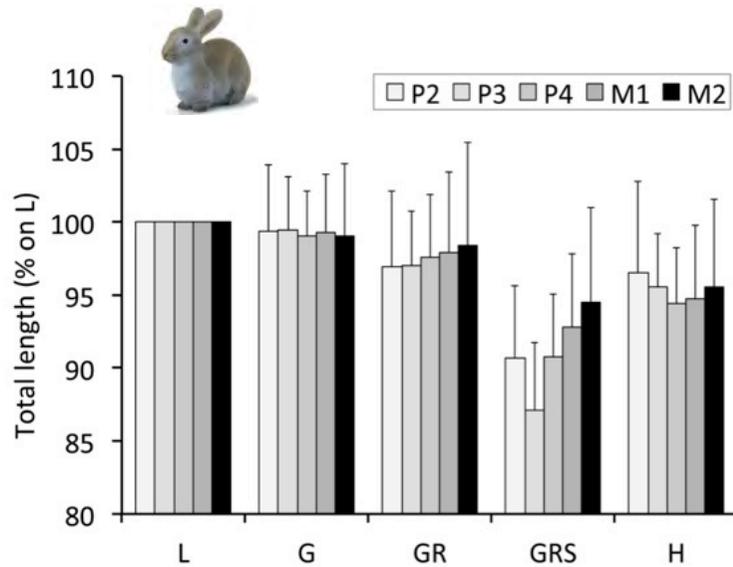


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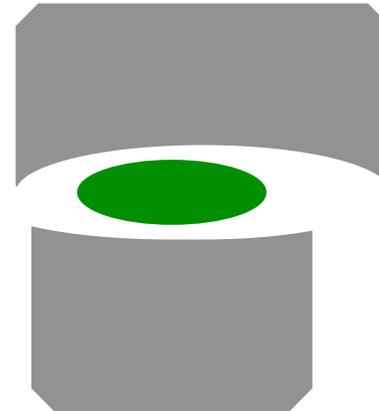
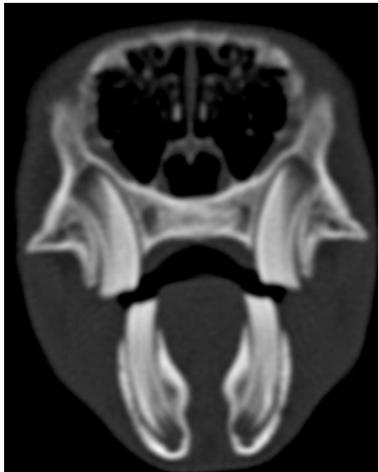




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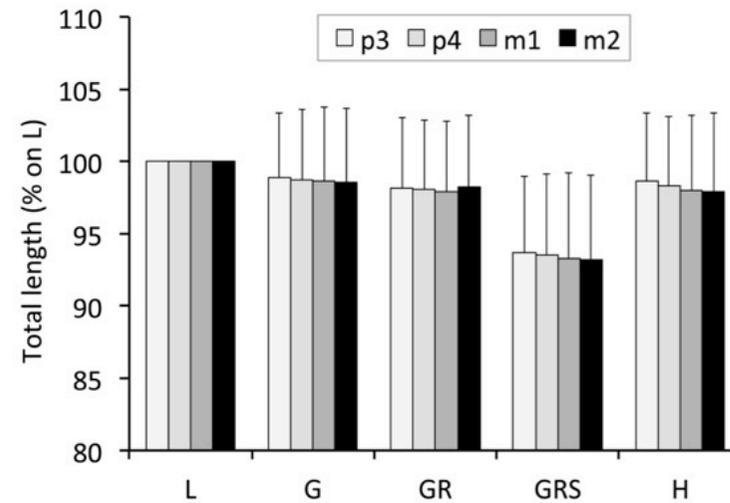
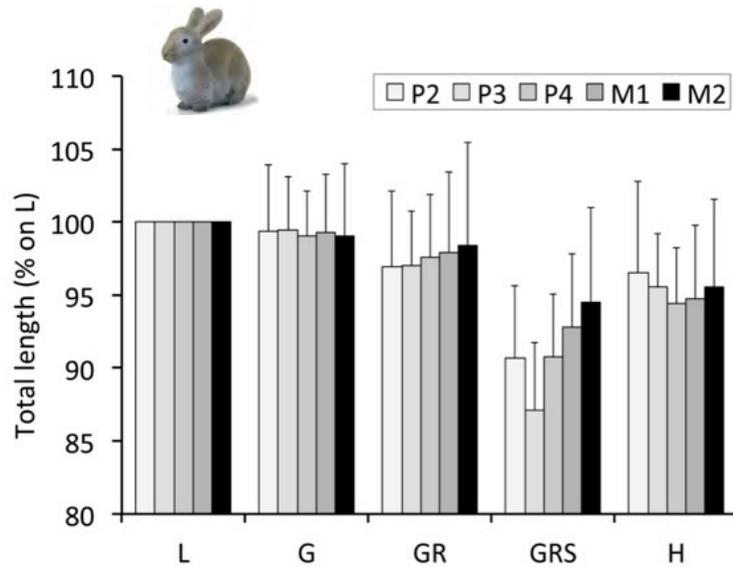


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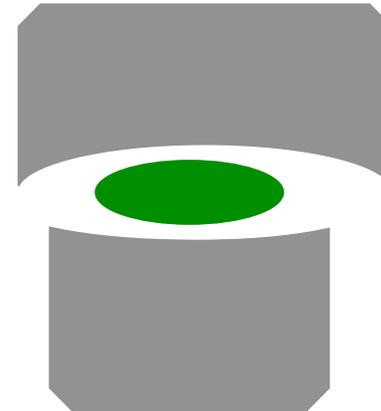
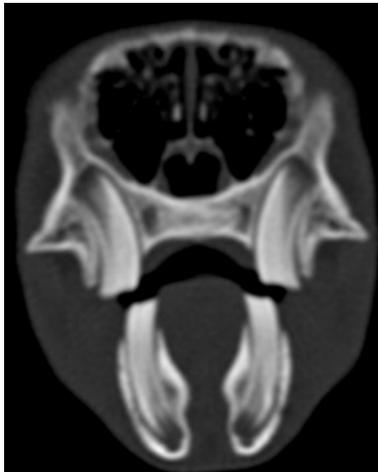




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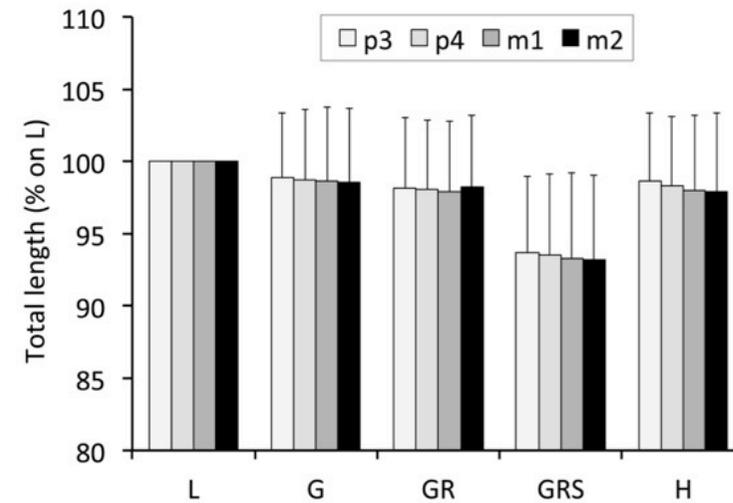
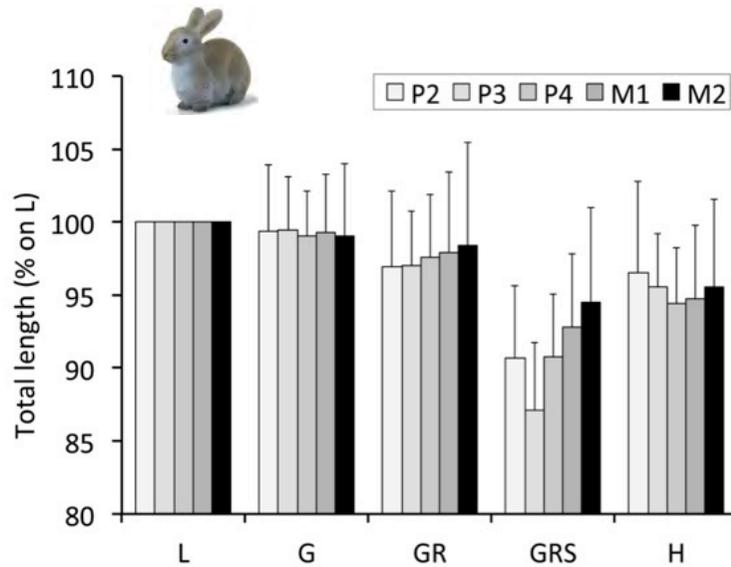


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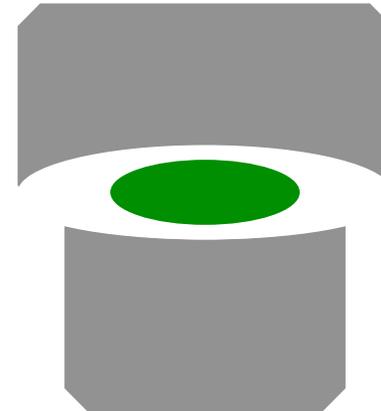
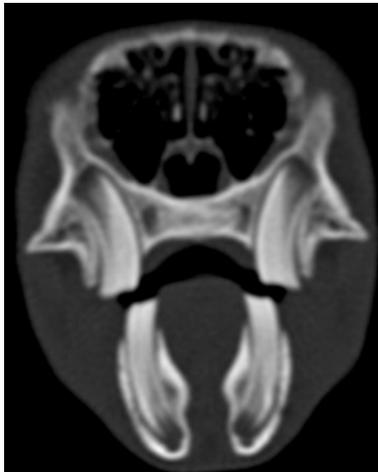




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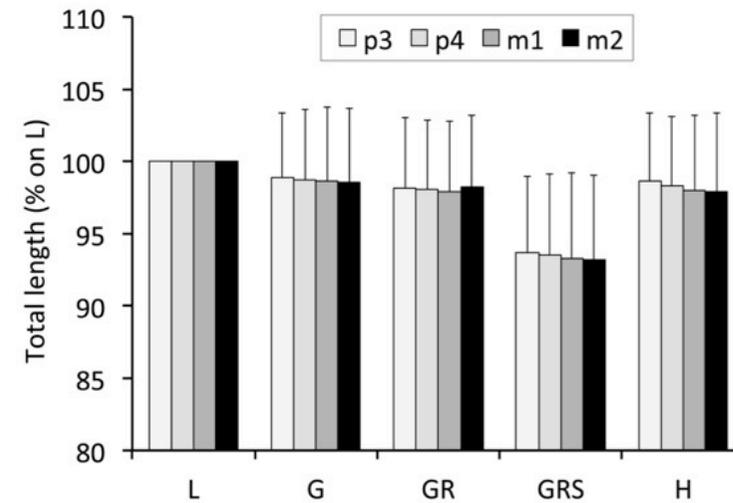
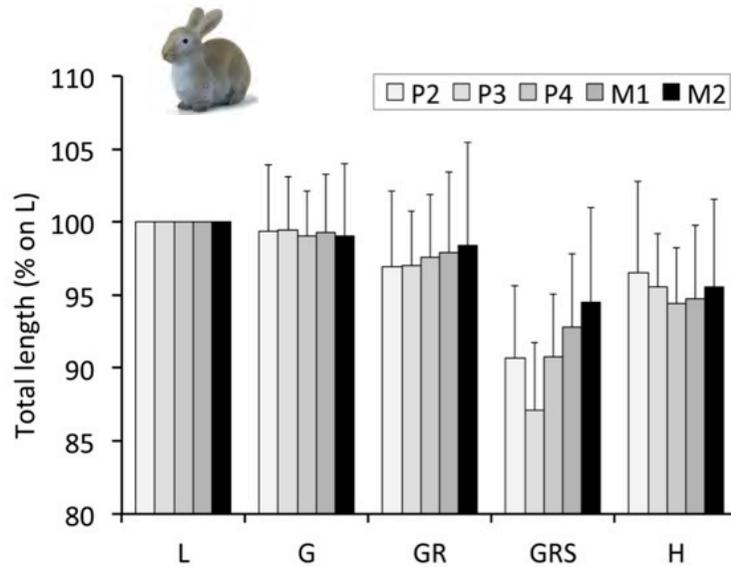


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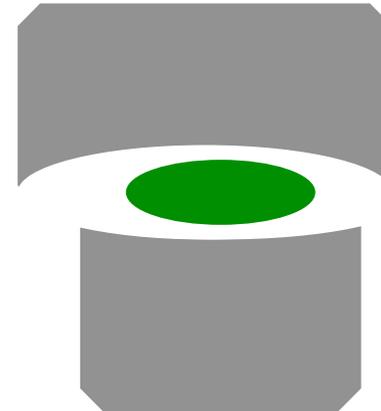




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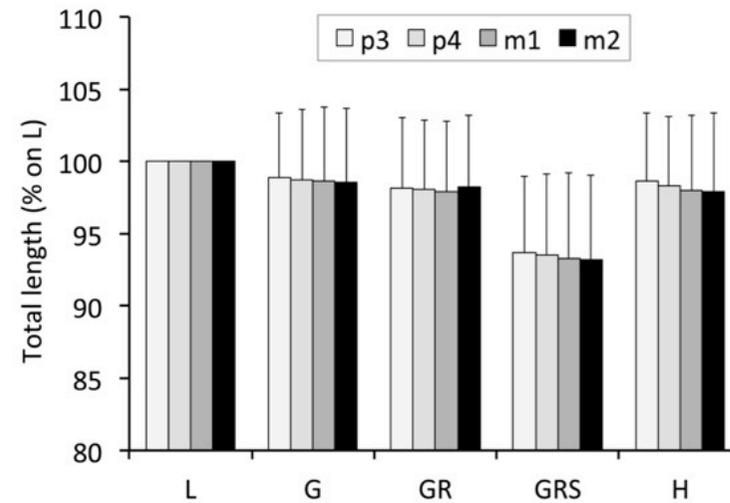
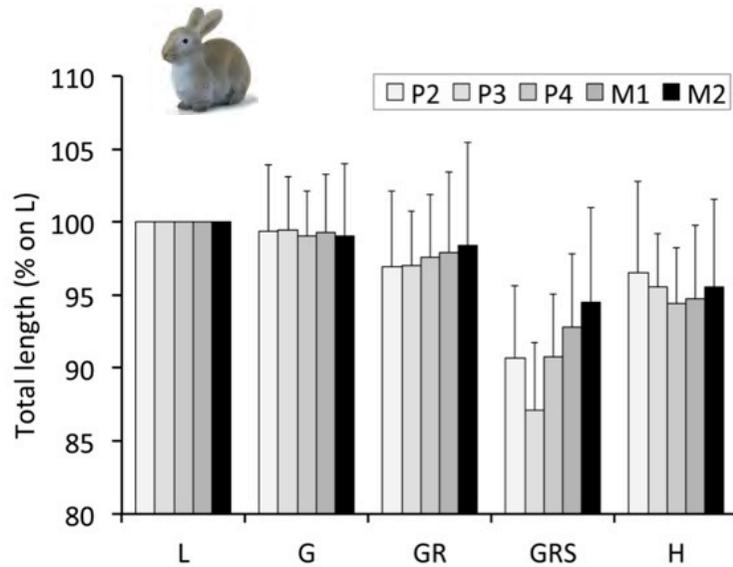


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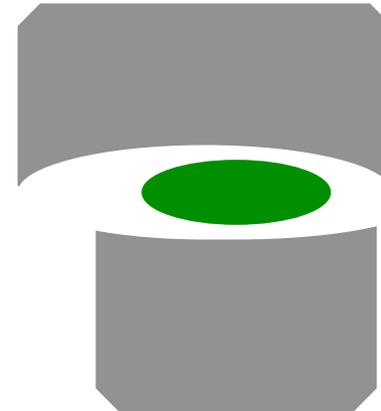




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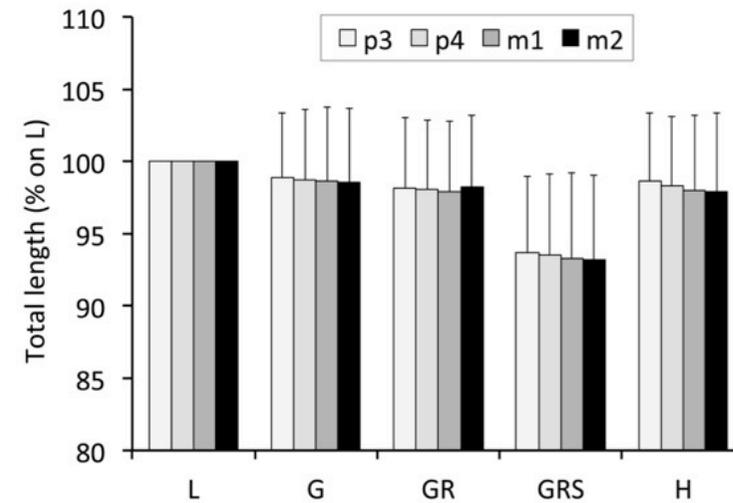
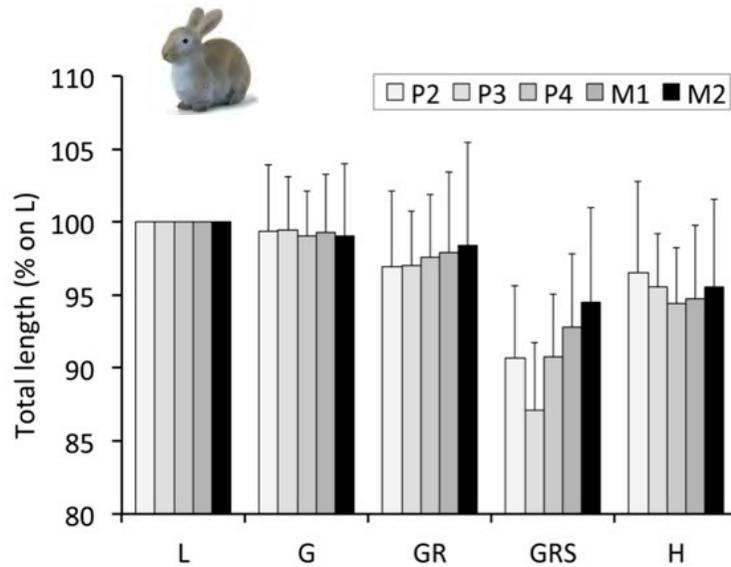


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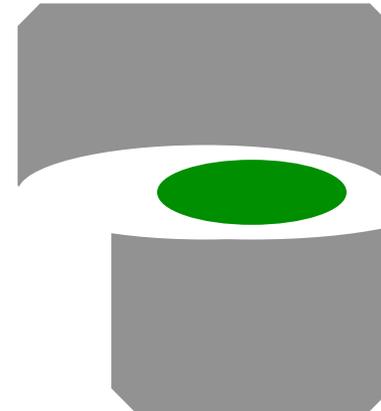




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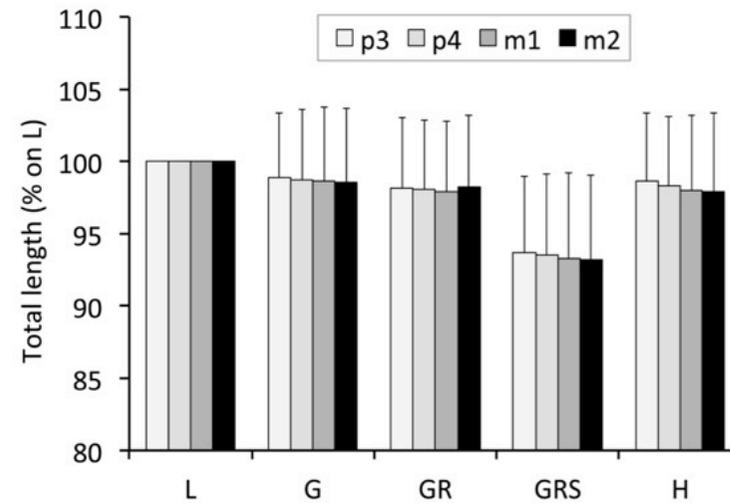
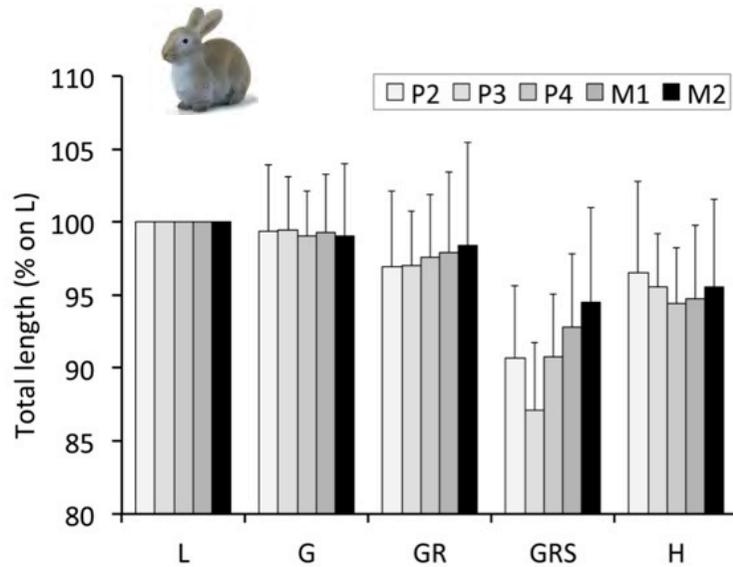


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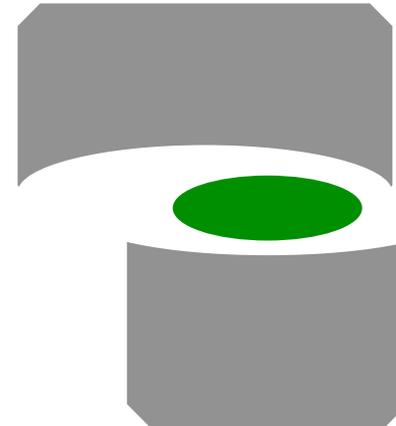




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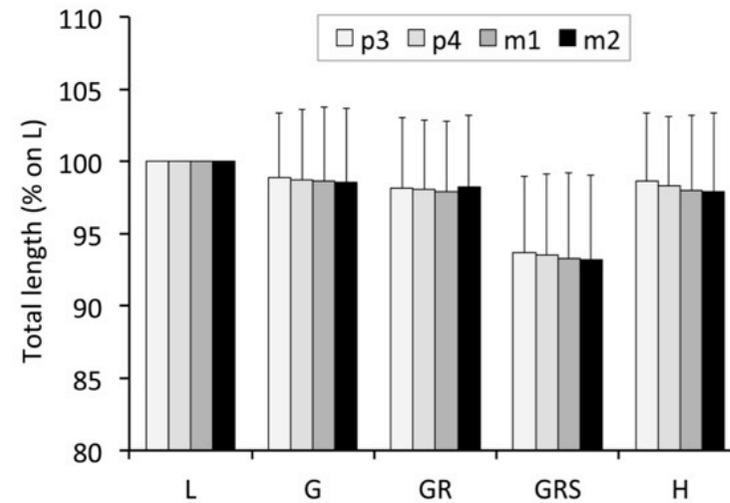
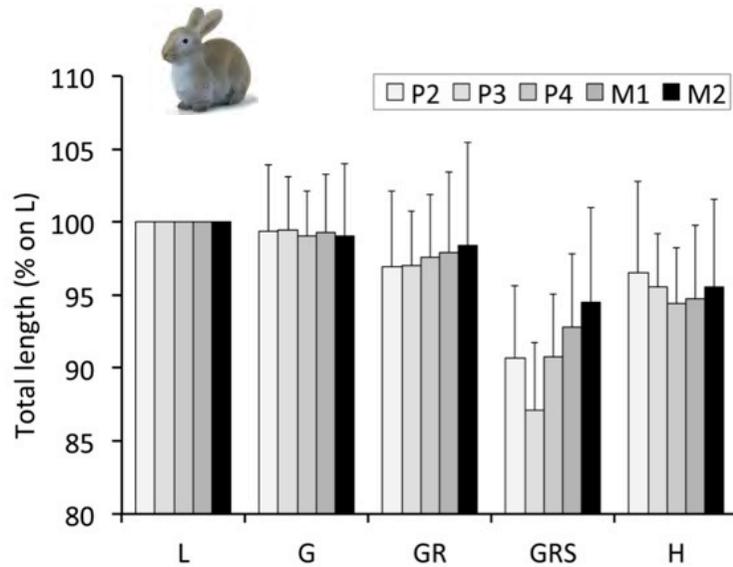


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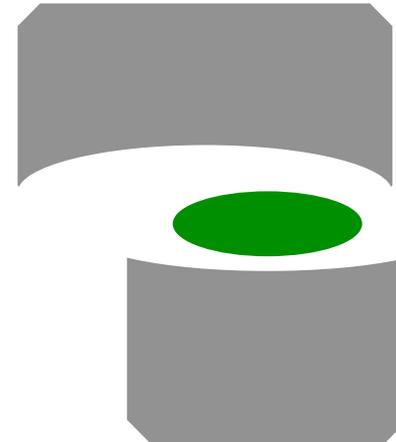




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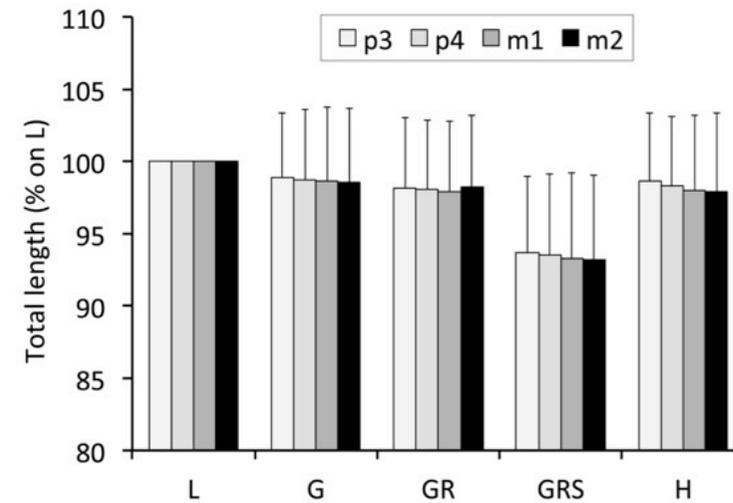
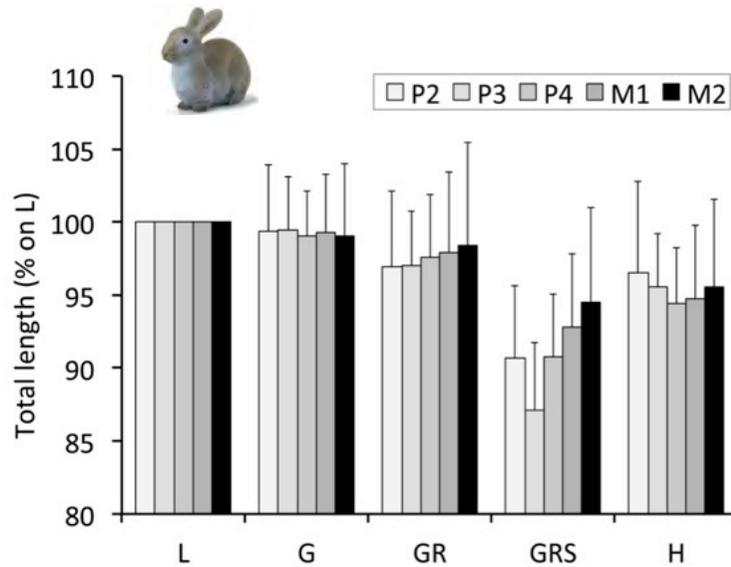


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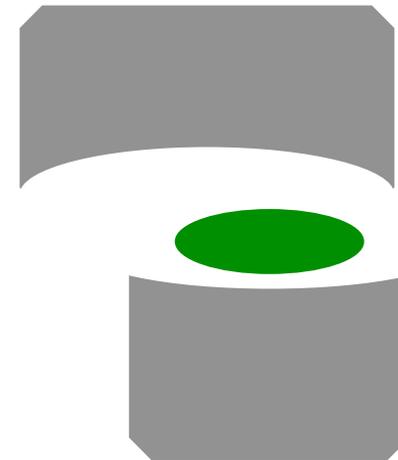




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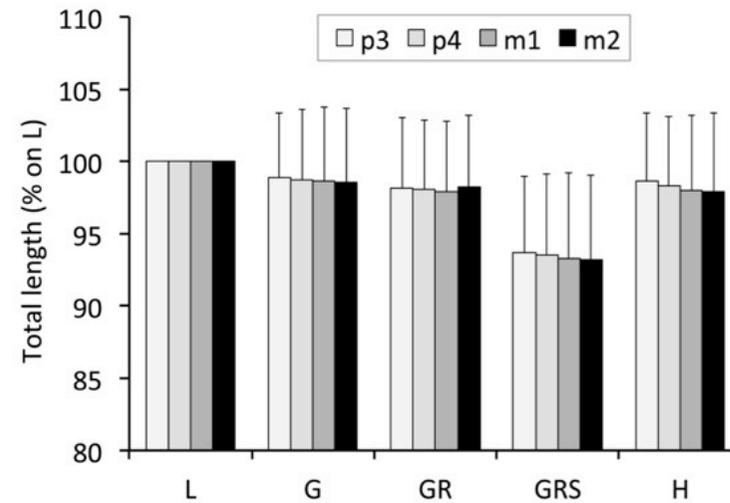
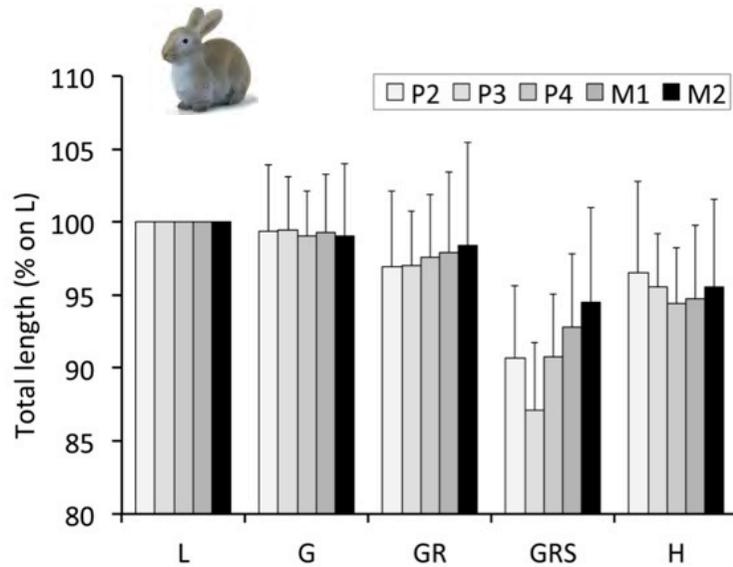


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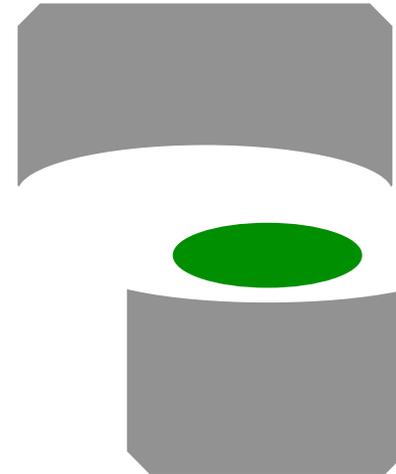




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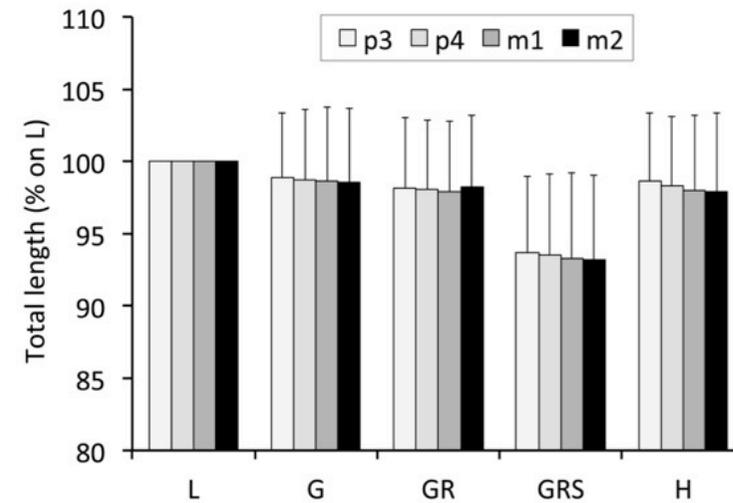
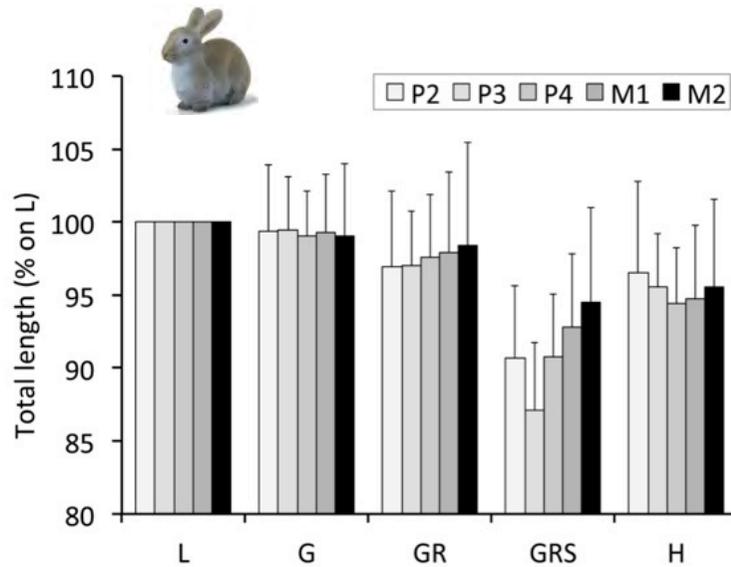


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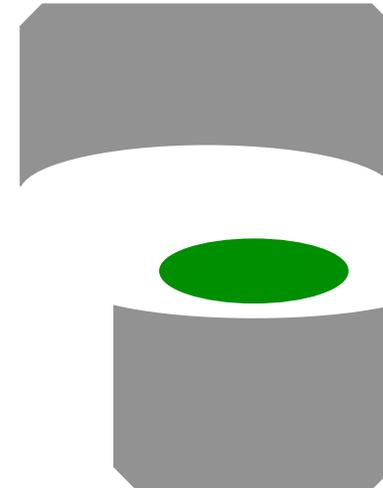




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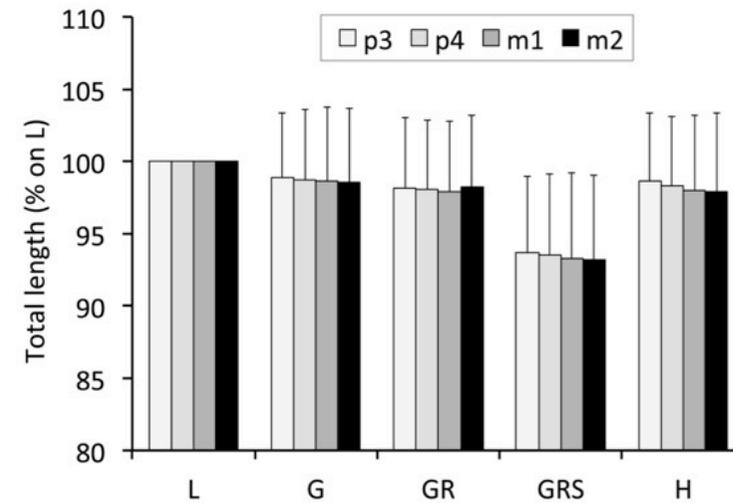
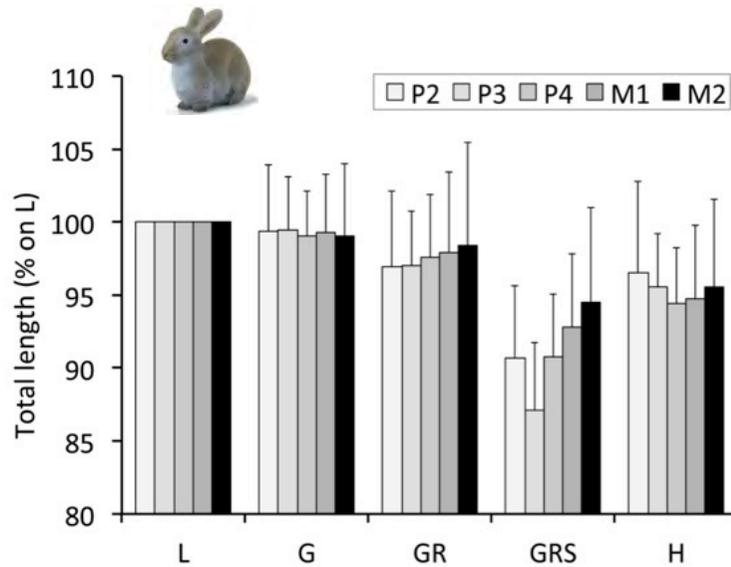


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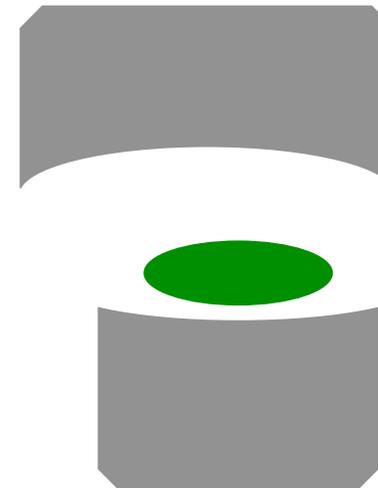




# Oberkiefer vs. Unterkiefer

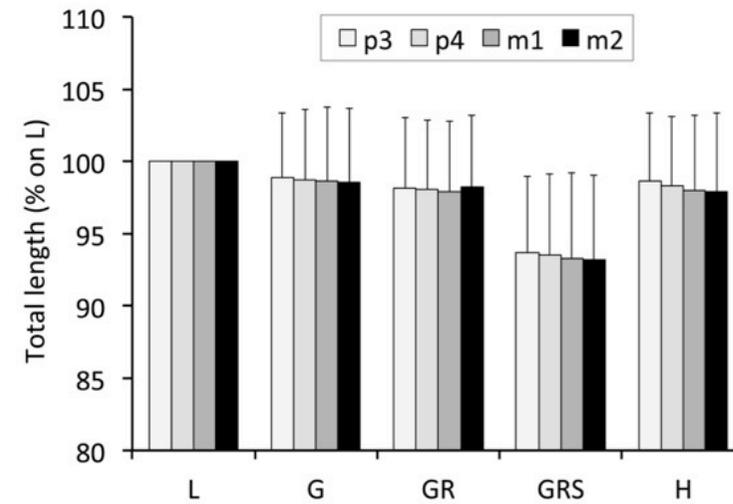
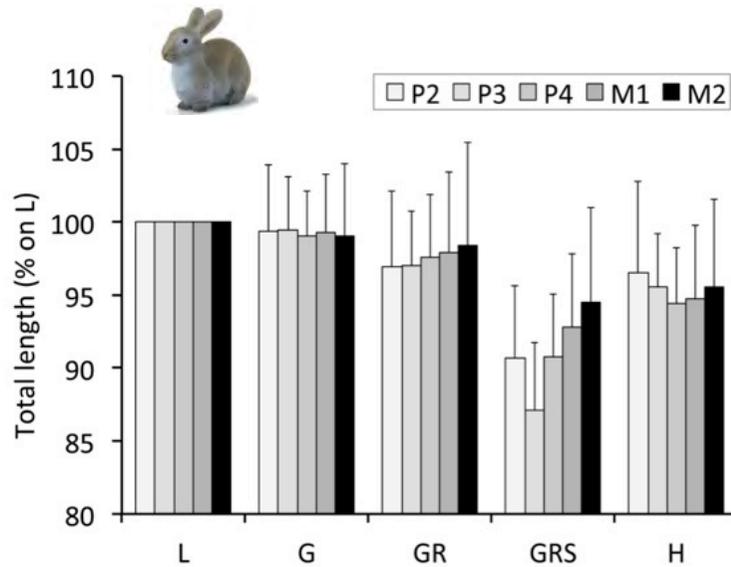


**Inverted pestle-and-mortar system:**

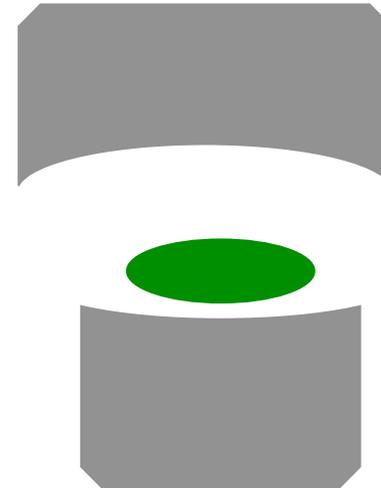




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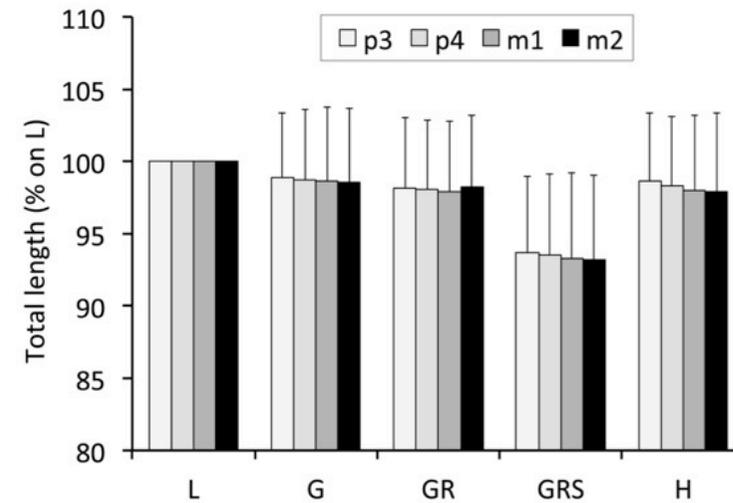
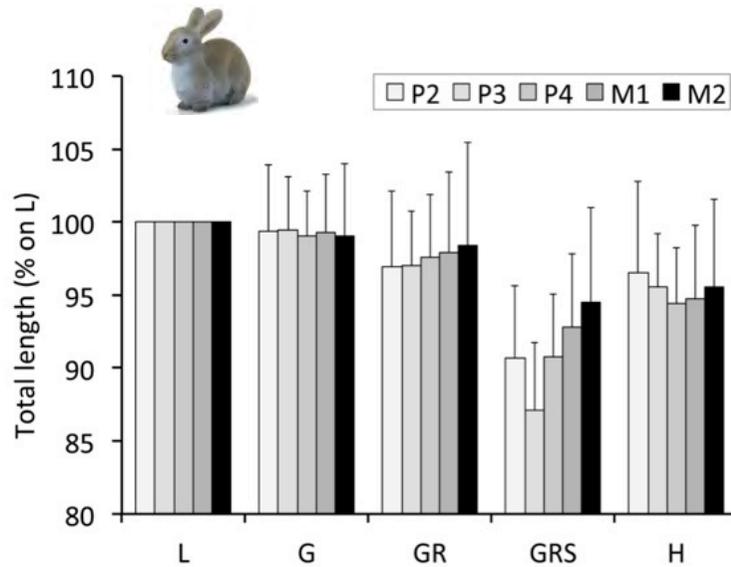


**Inverted pestle-and-mortar system:**

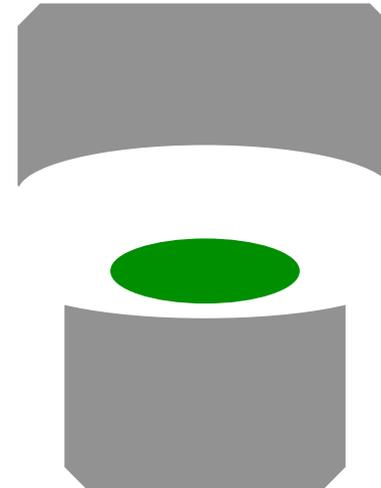




# Oberkiefer vs. Unterkiefer



**Inverted pestle-and-mortar system:**

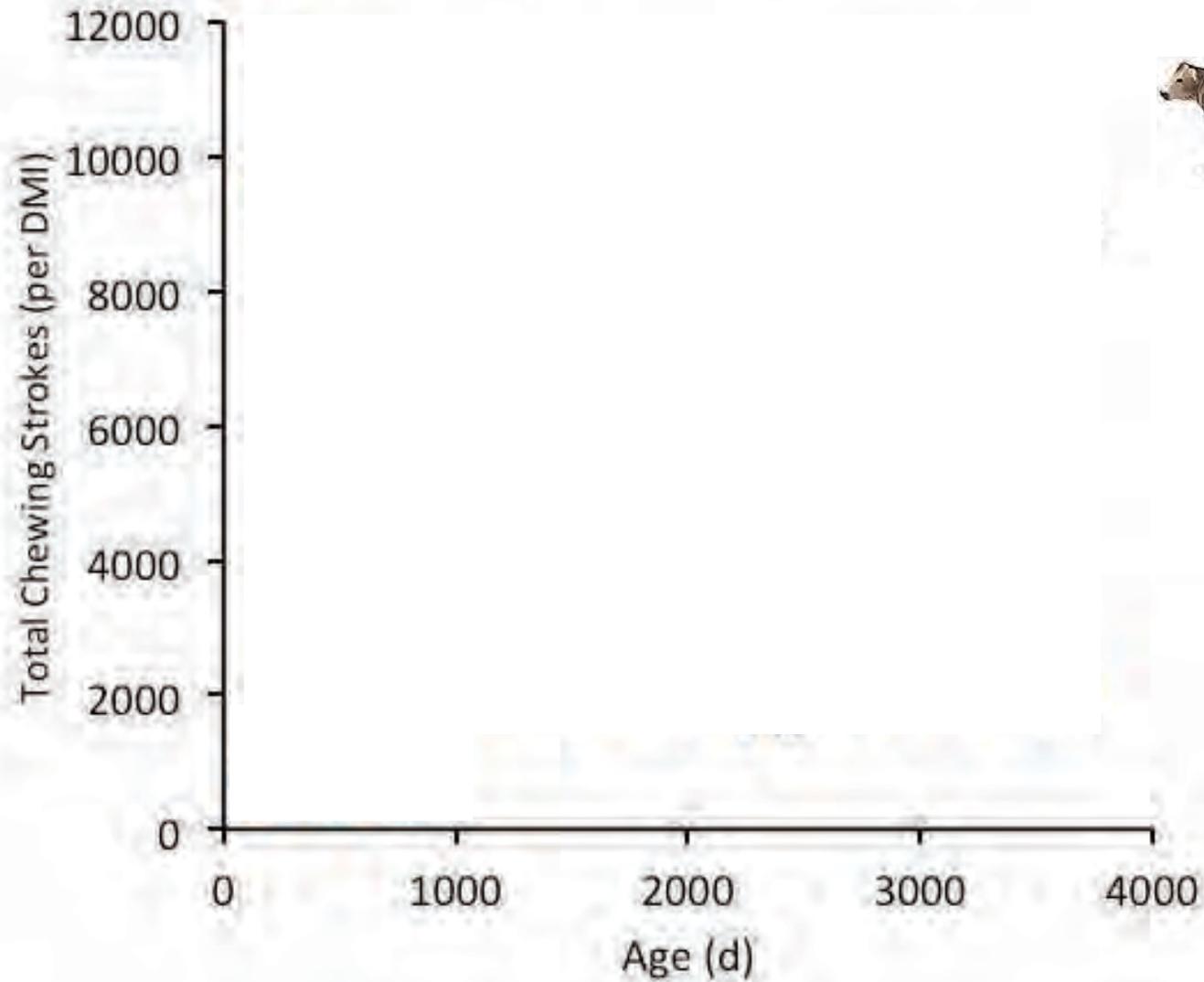




# Zahnoptimierung: Verlängerung der Kauleiste

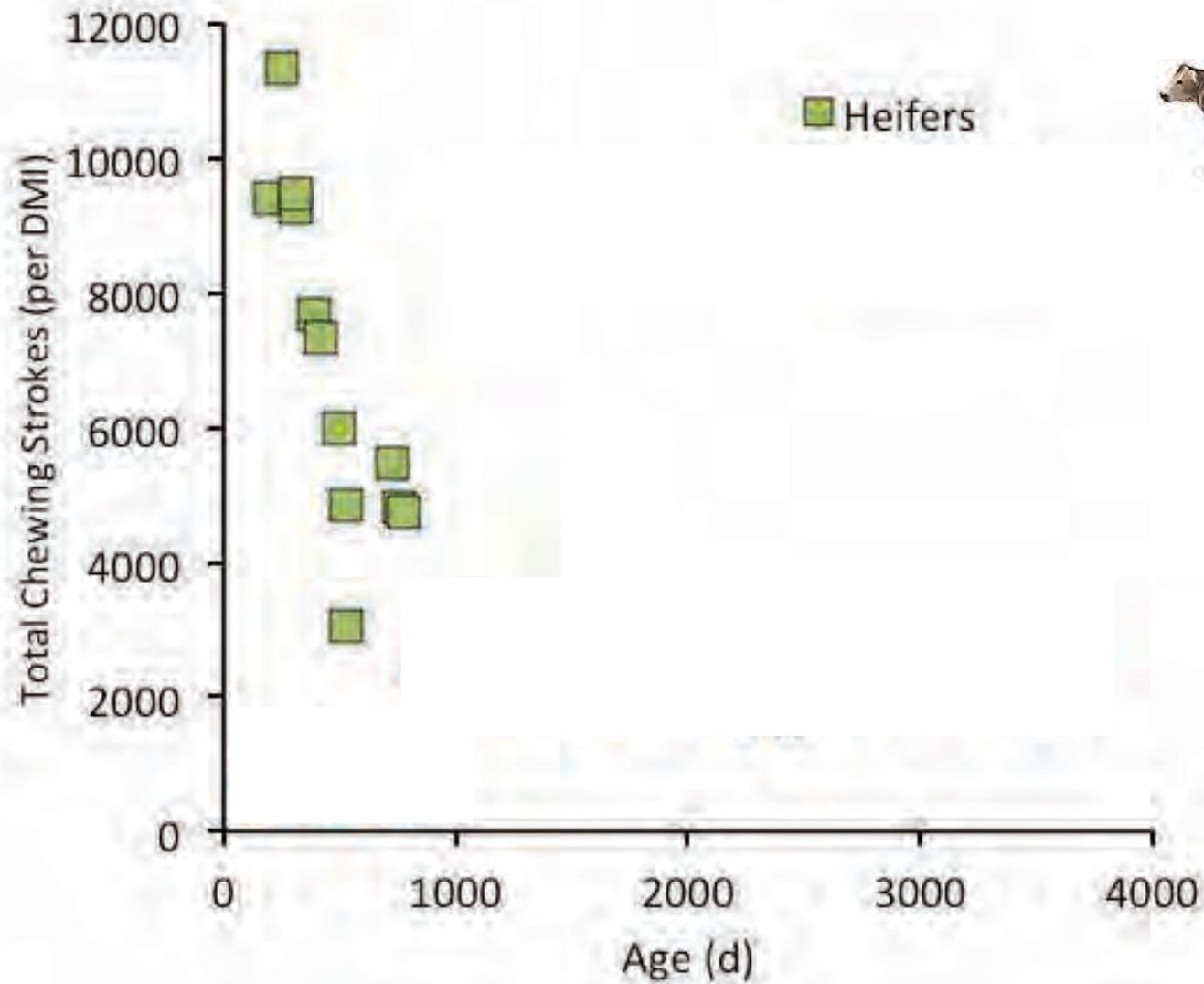


# Kauschläge



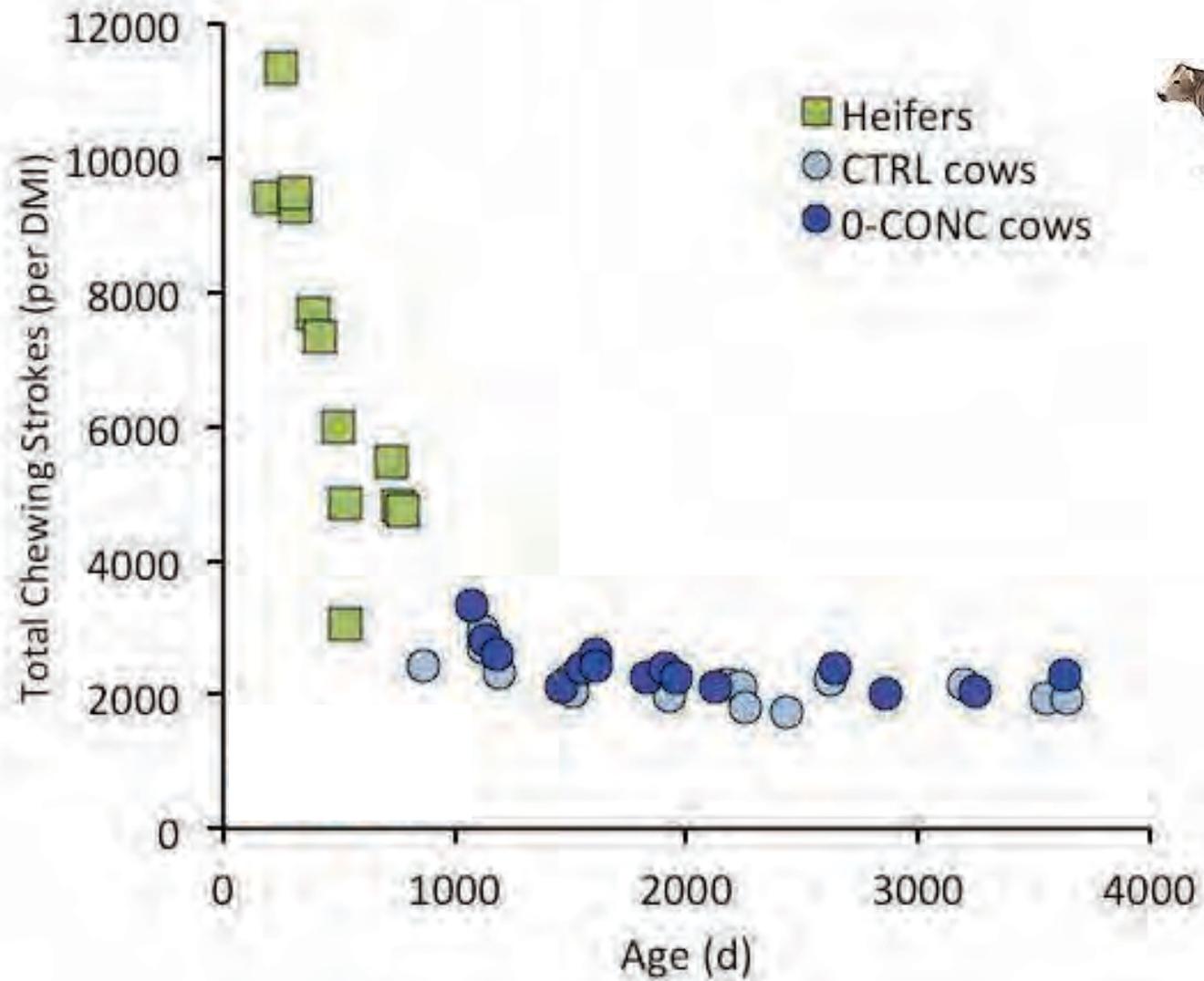


# Kauschläge



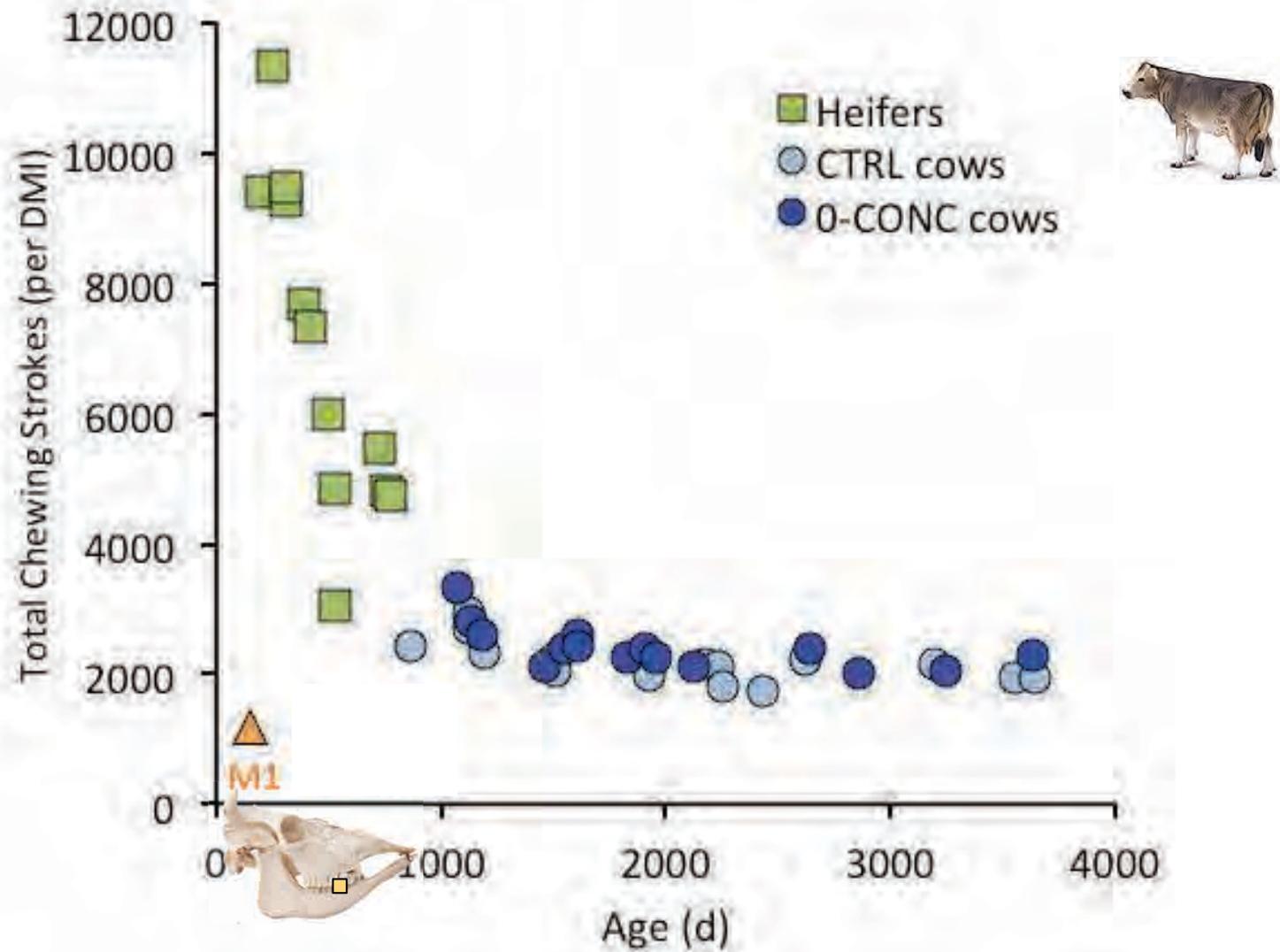


# Kauschläge



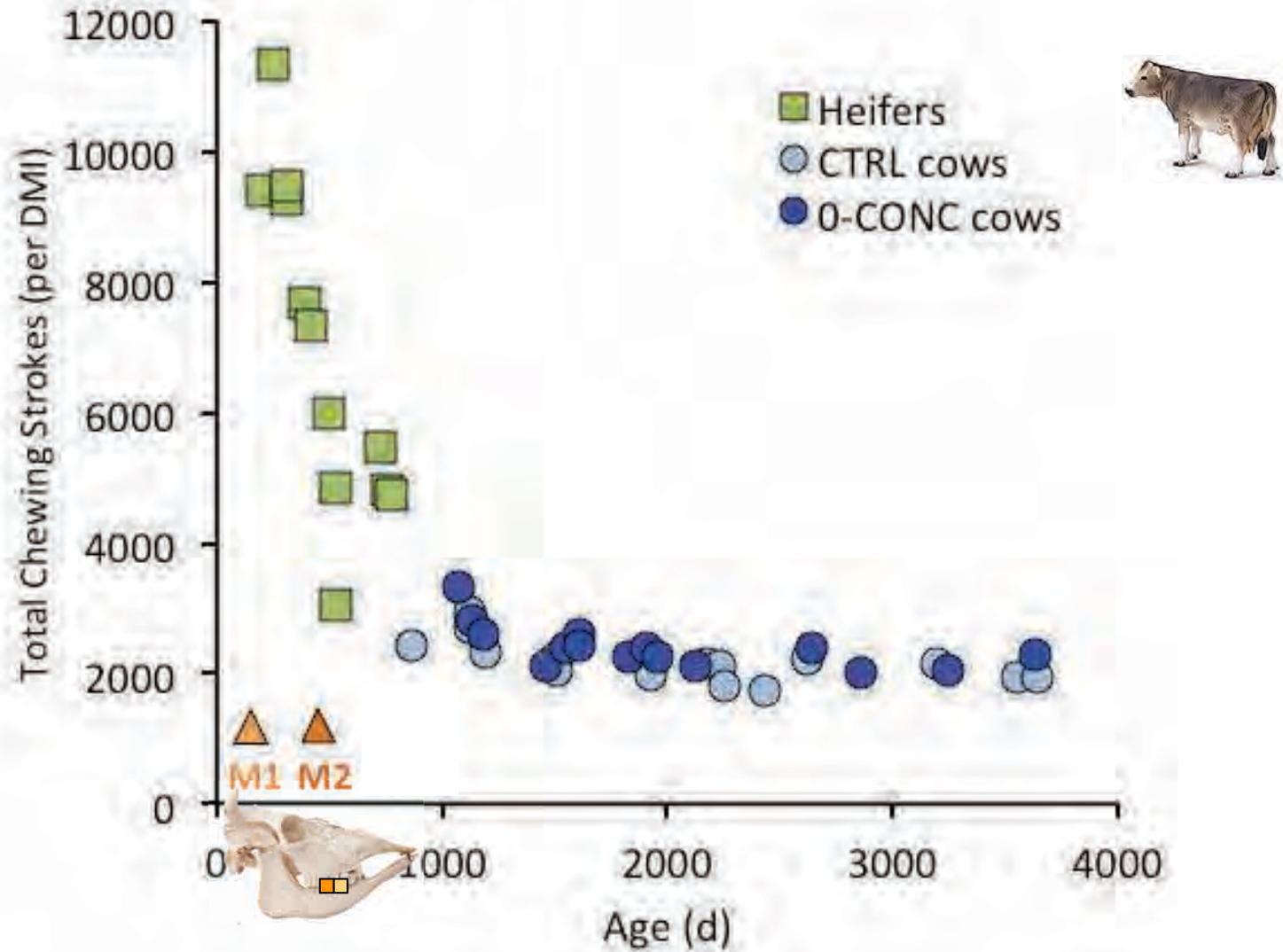


# Kauschläge



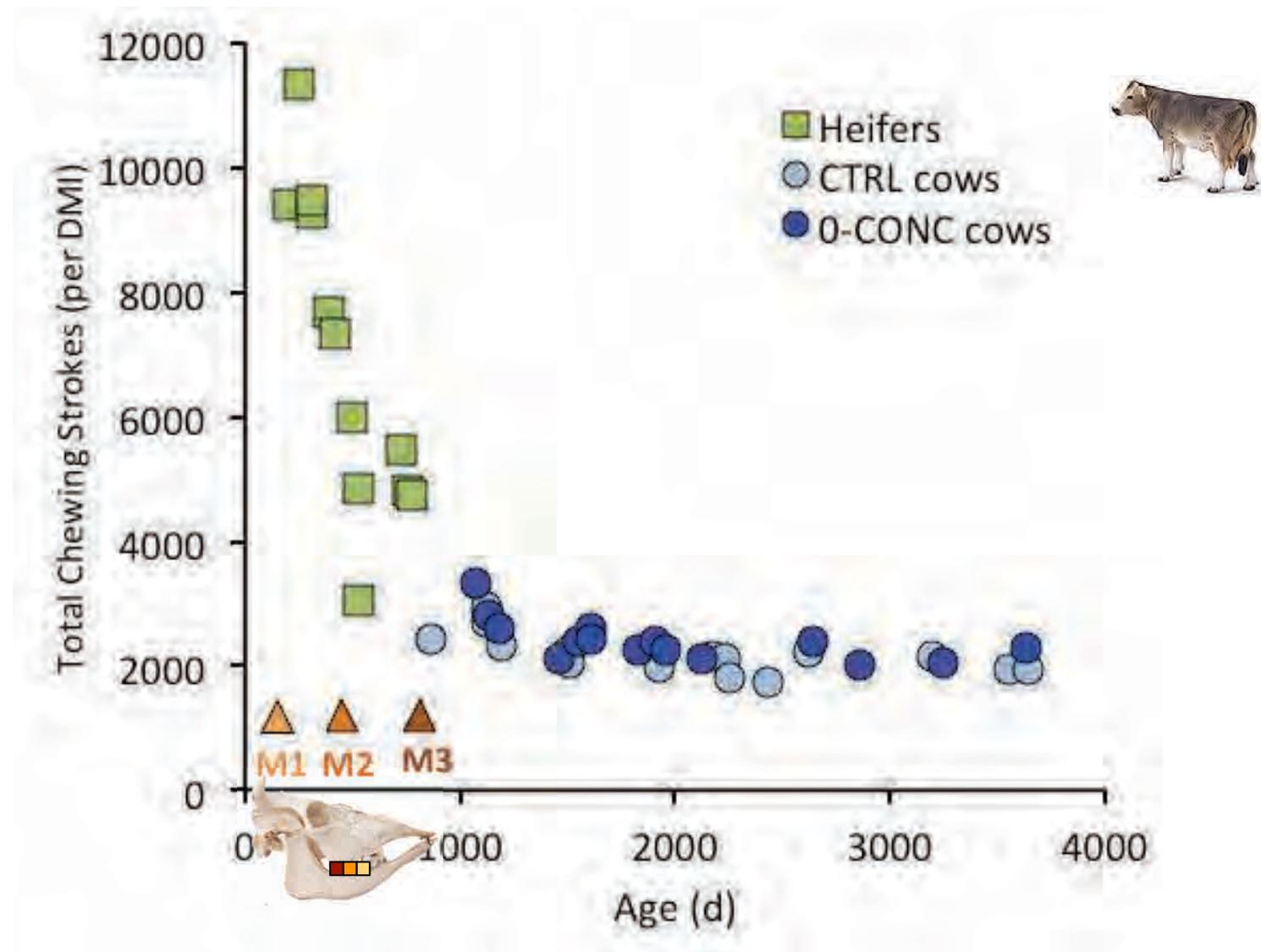


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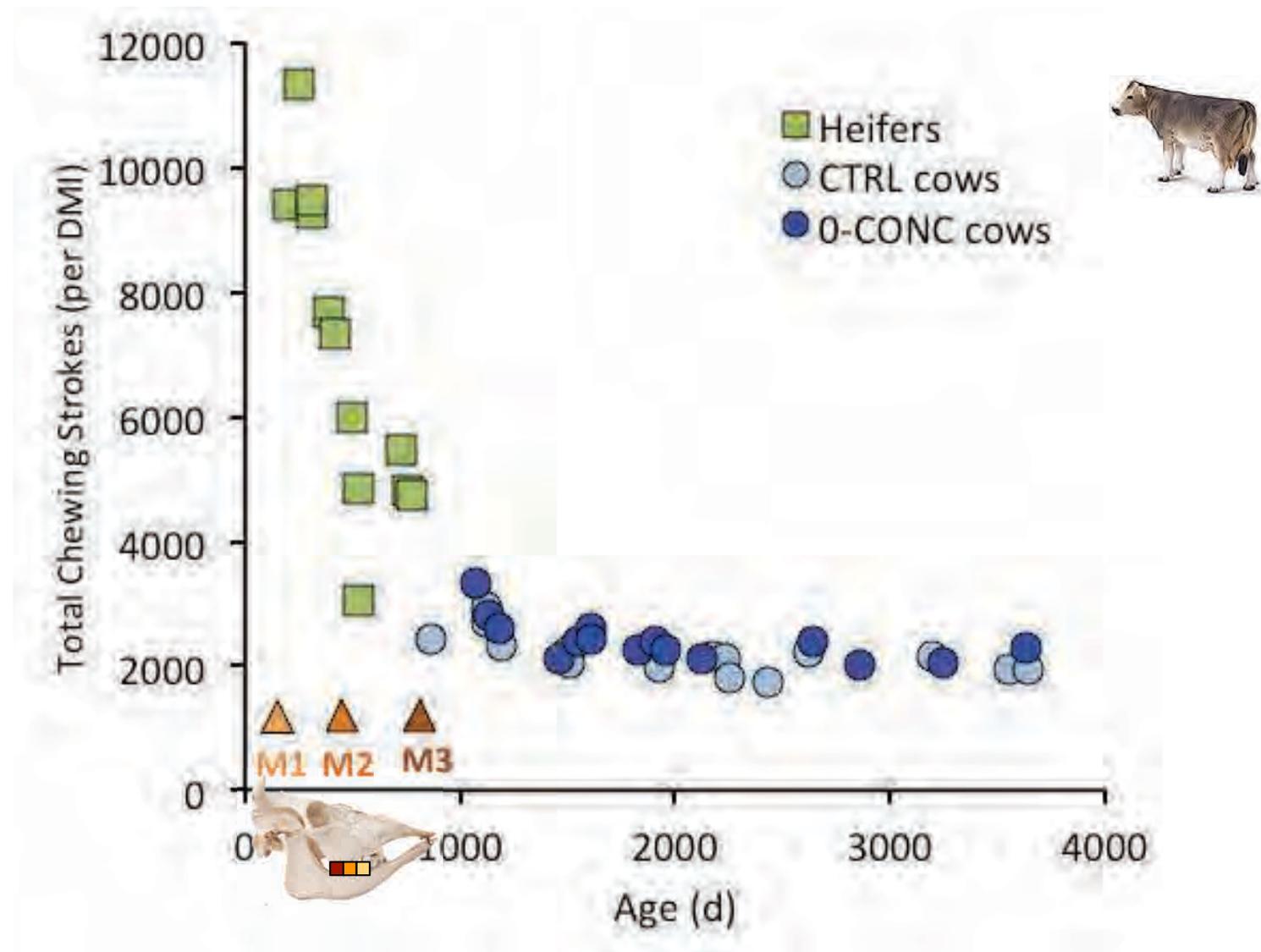


# Kauschläge





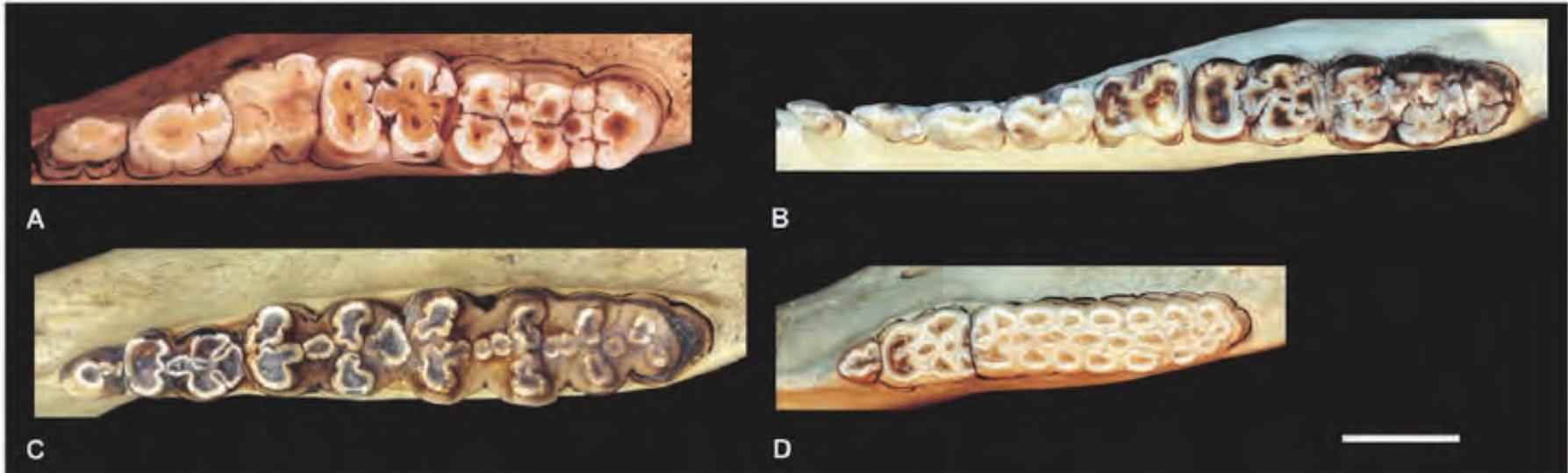
# Kauschläge



Alterseffekt auf Kauintensität  
(aufgrund Molaren-Eruption)



# Verlängerung des 3. Molaren bei Schweinen





# Molarisierung der Prämolaren bei Equiden

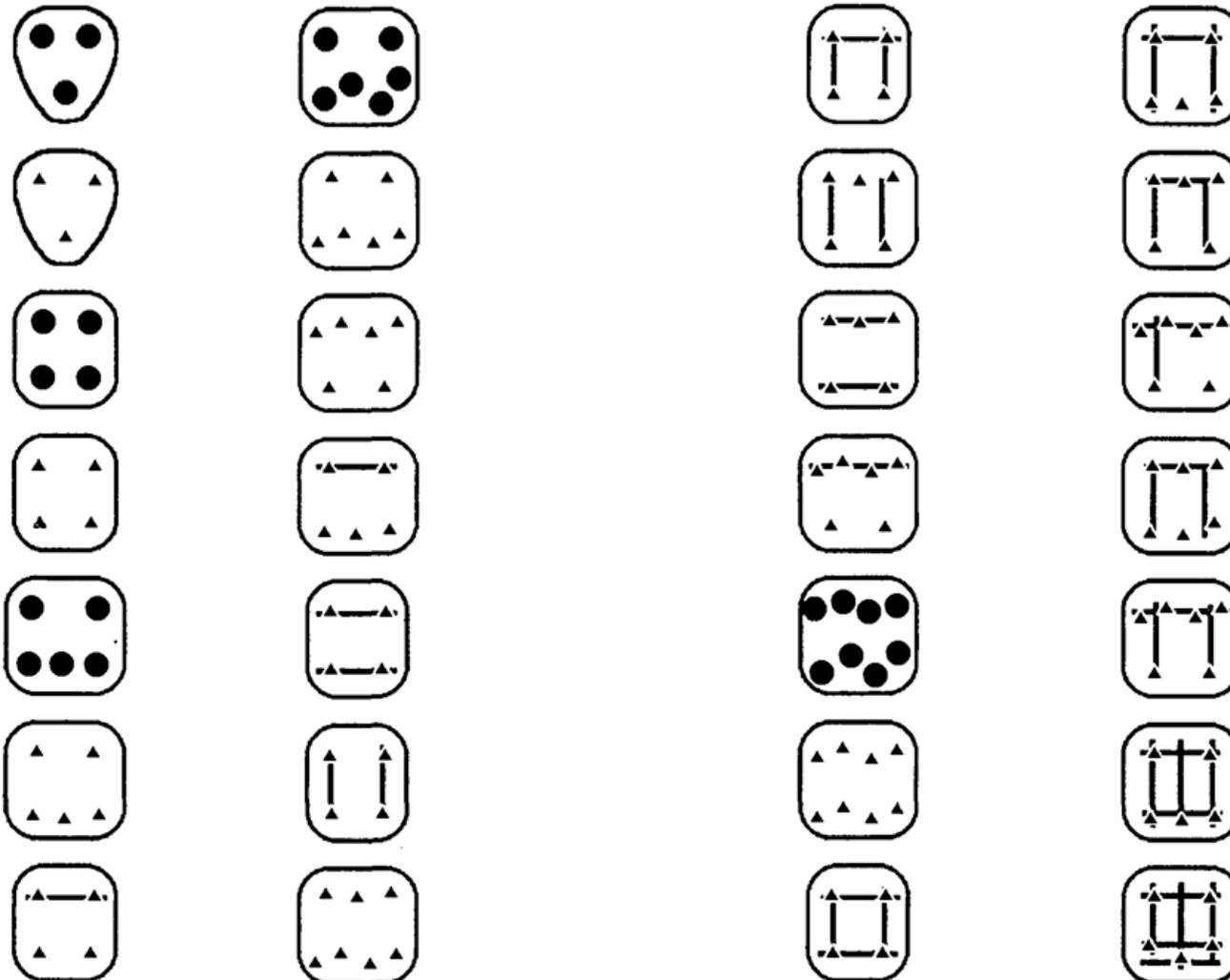




# Zahnoptimierung: Schmelzfalten



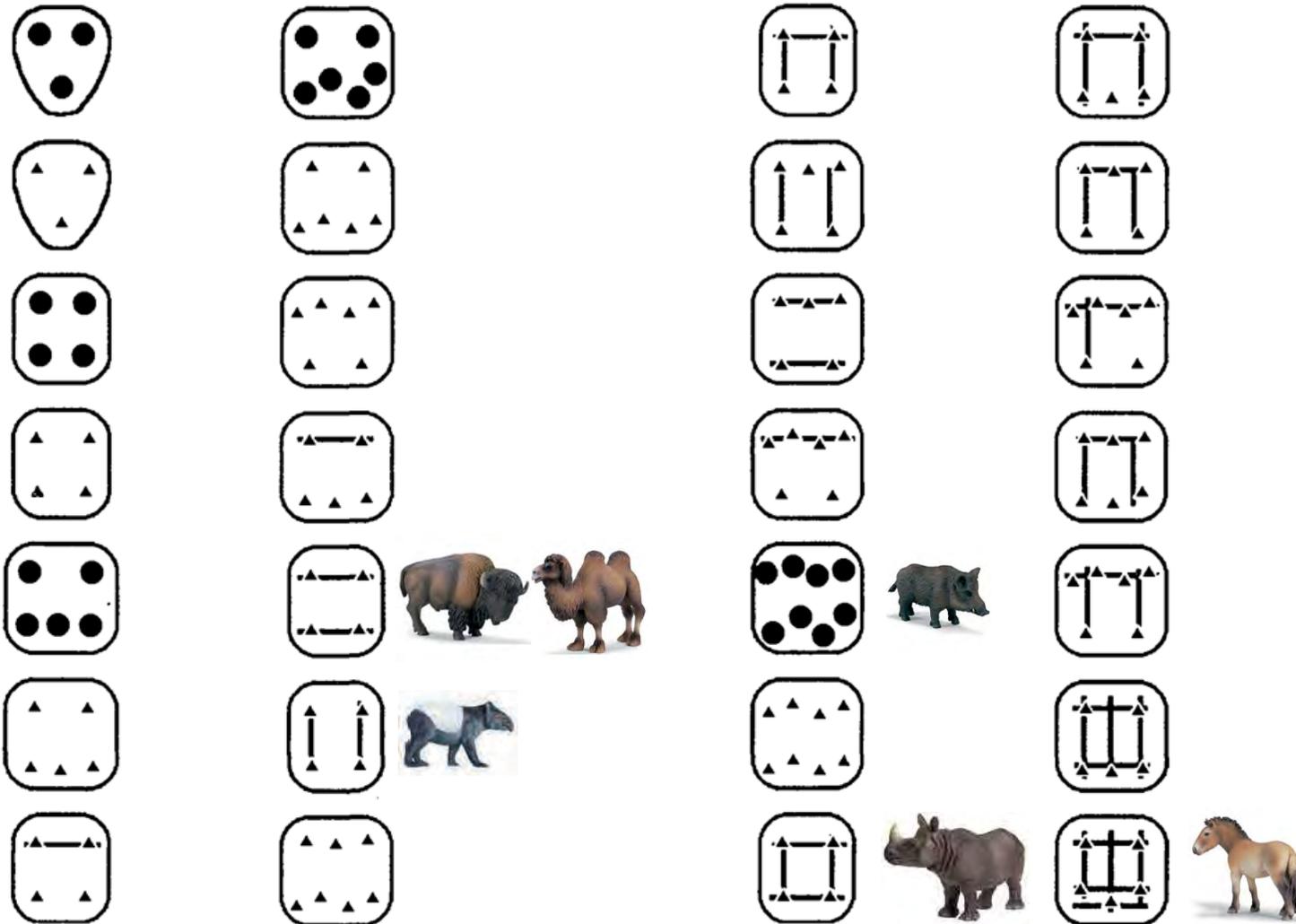
# Backenzahn-Oberflächen



aus Jernvall et al. (1996)



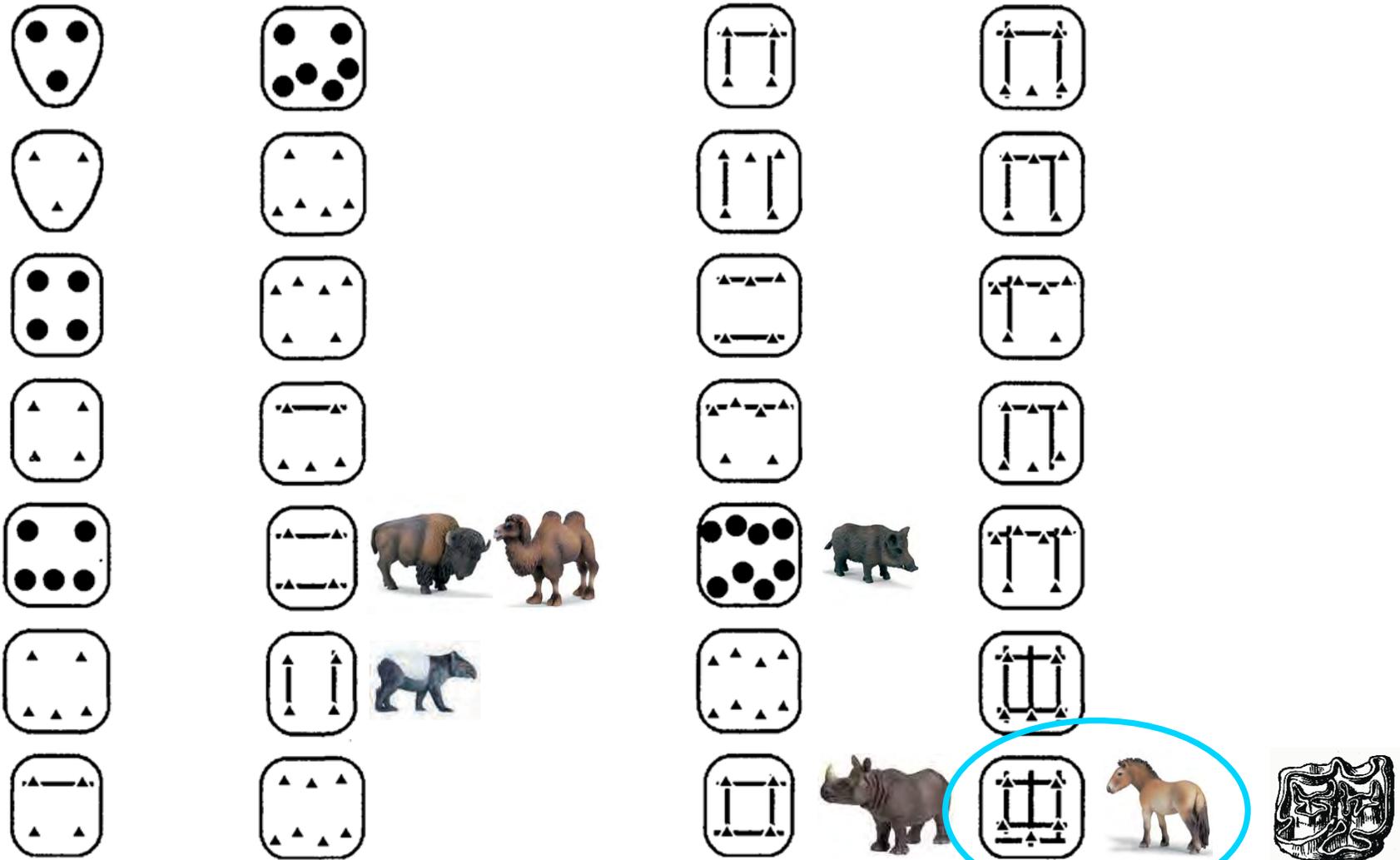
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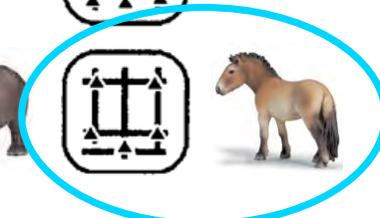
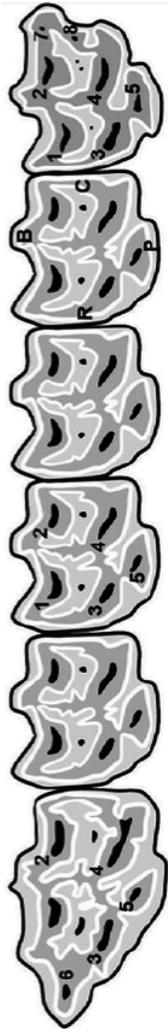
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# Backenzahn-Oberflächen



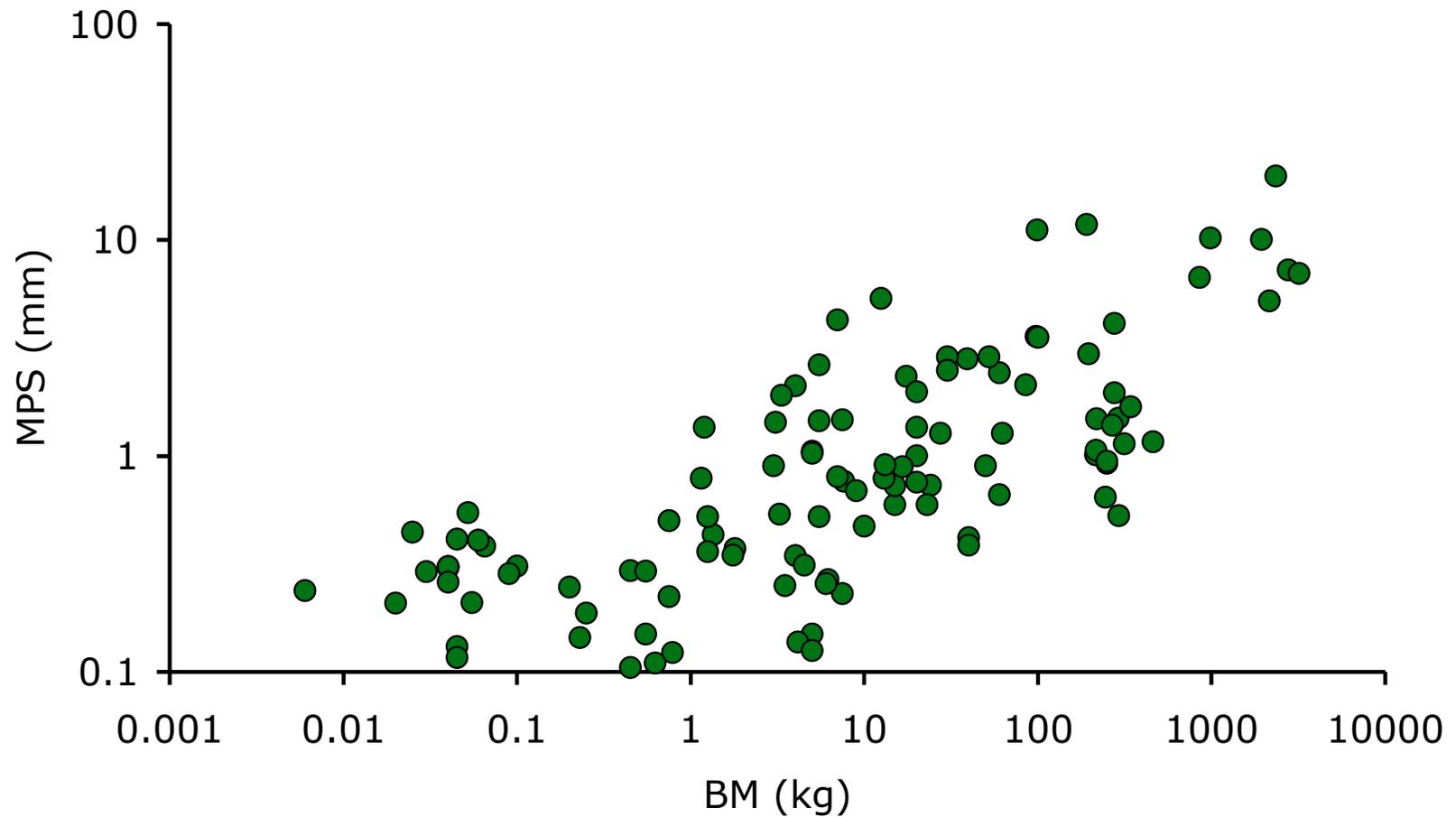
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# Comparative chewing efficiency in mammalian herbivores

Julia Fritz, Jürgen Hummel, Ellen Kienzle, Christian Arnold, Charles Nunn and Marcus Clauss

*Oikos* 118: 1623–1632, 2009

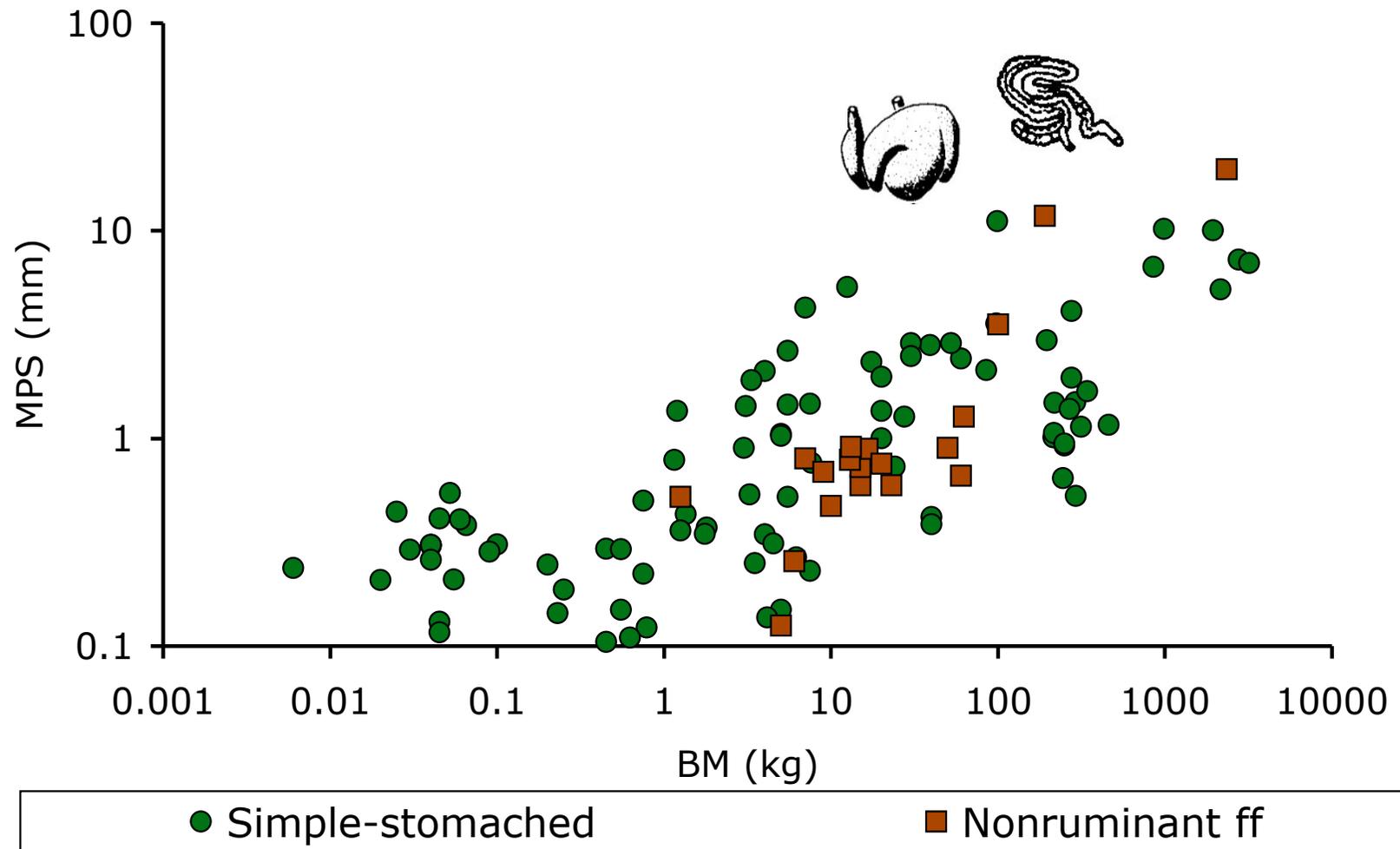




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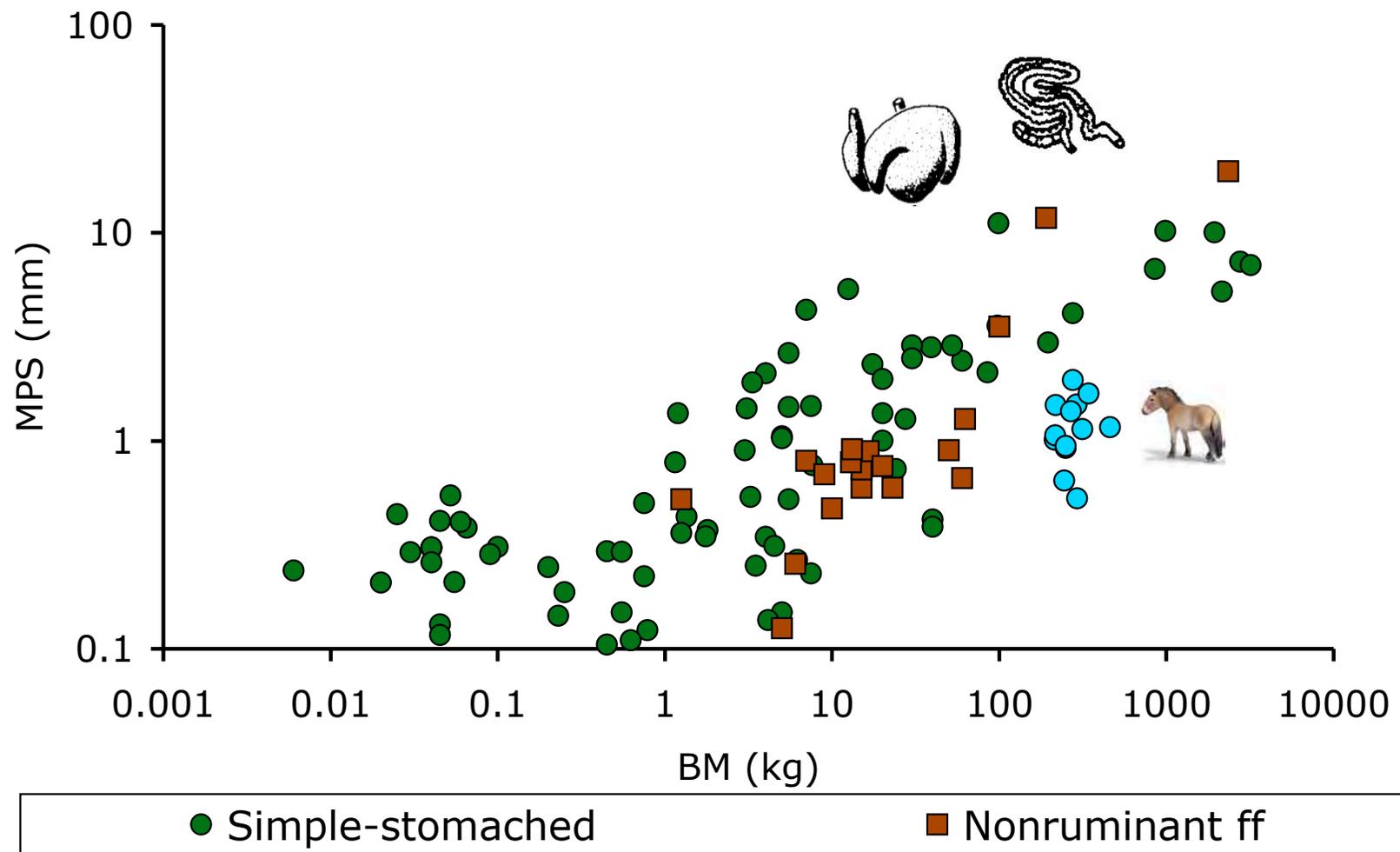




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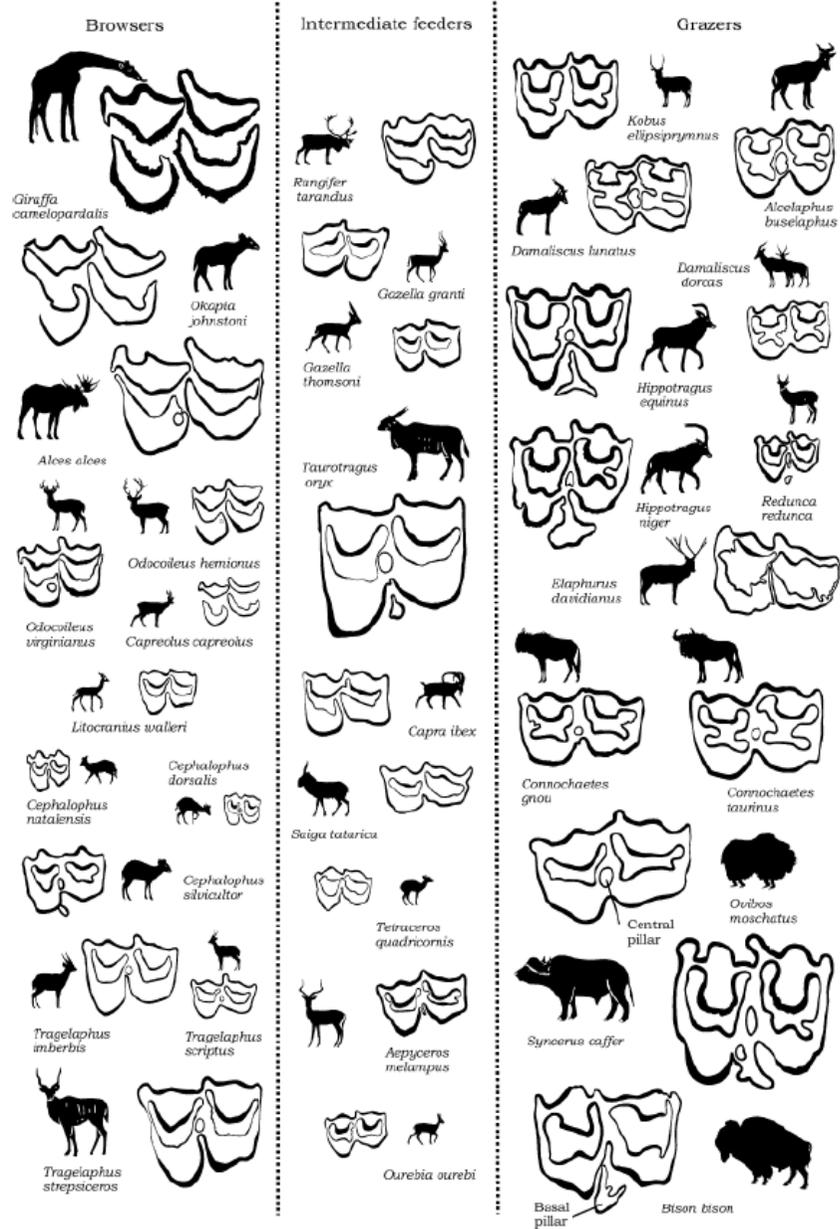
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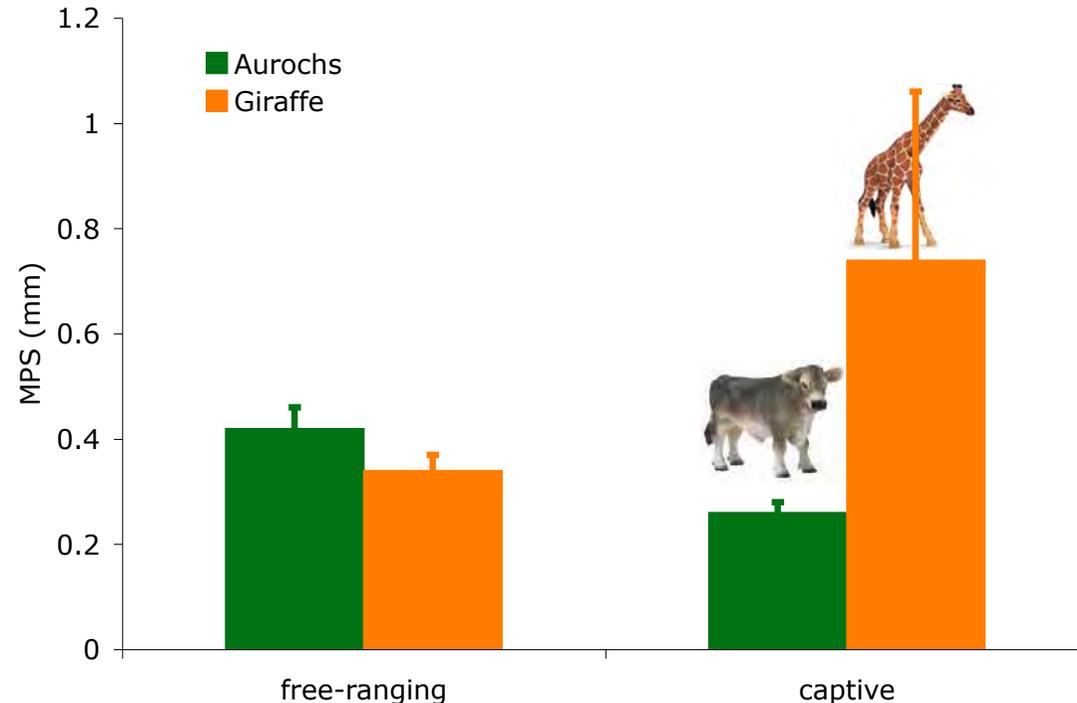
# Backenzahn-Oberflächen





# Fecal particle size in herbivores

- We expect captive herbivores to have finer faecal particles than free-ranging conspecifics (due to pellet feeding)
- This is confirmed in Aurochs but not in giraffes!
- Indication that giraffe teeth are adapted to chewing something else - not the diets offered in captivity.

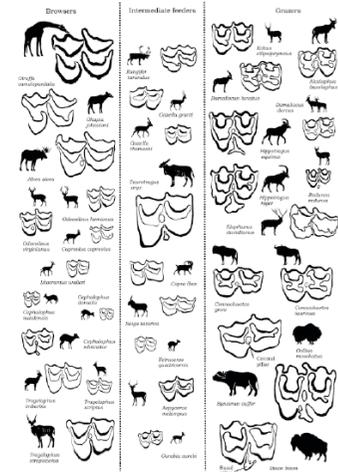
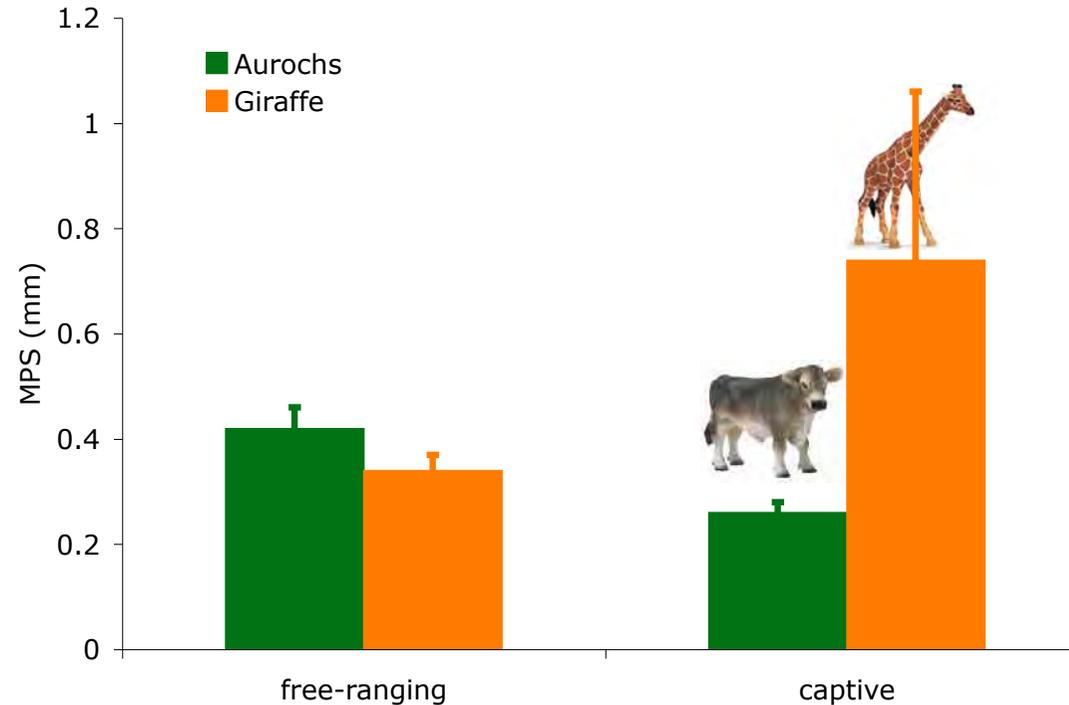


from Hummel et al.  
(2008)



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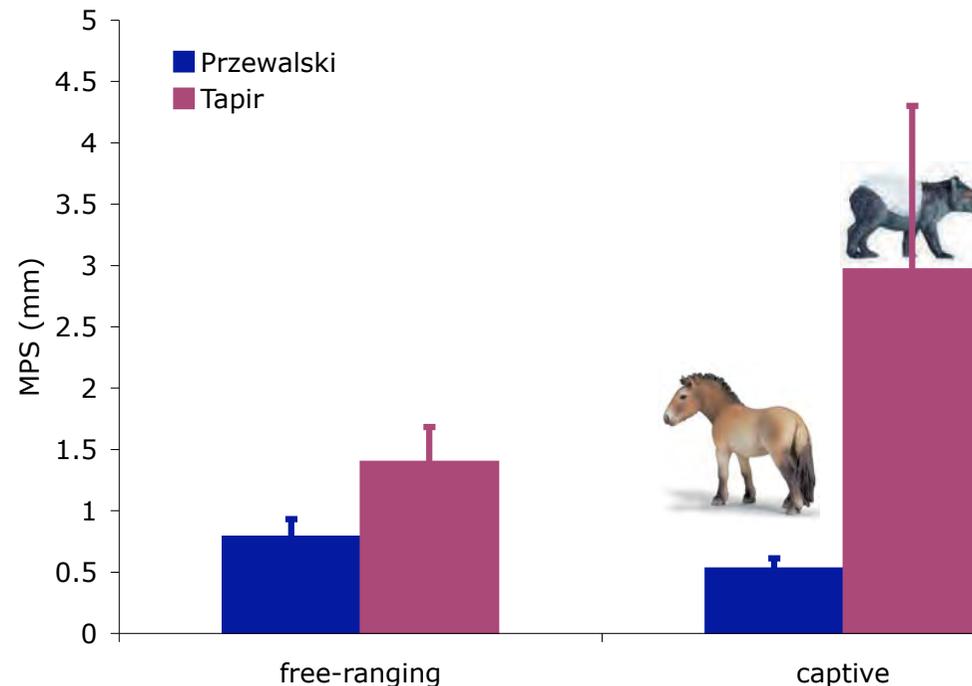
# Backenzahn-Oberflächen



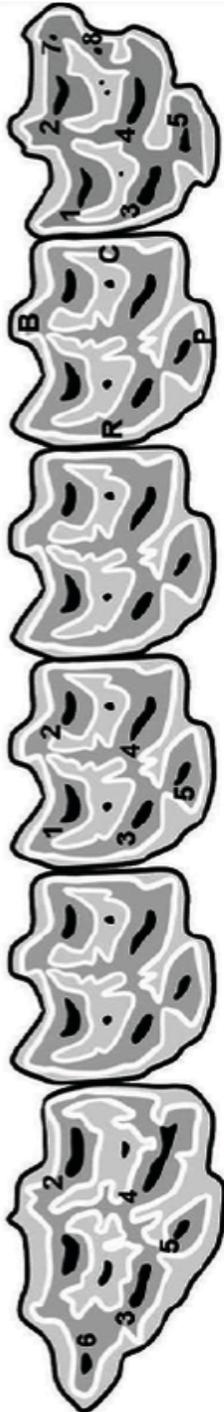


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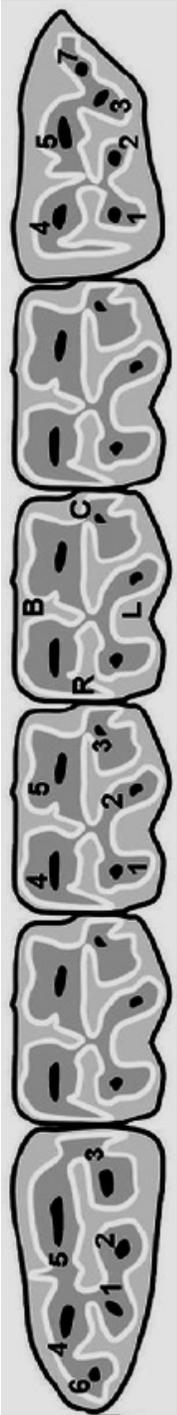
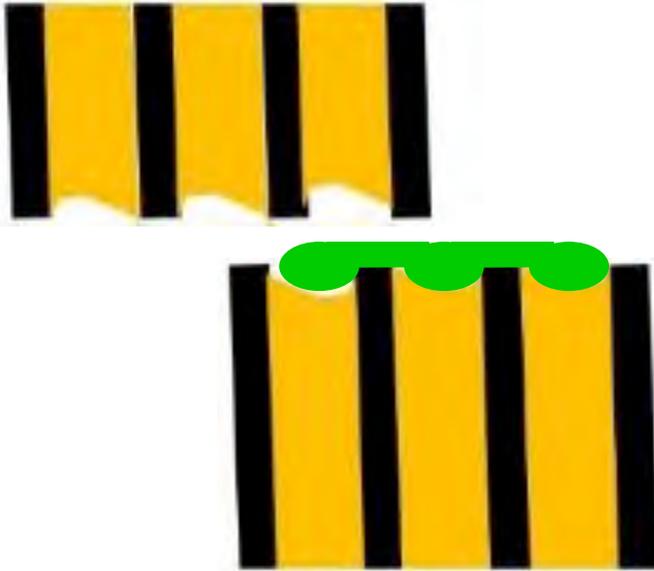
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- This is confirmed in Przewalski horse but not in tapirs!
- Indication that tapir teeth are adapted to chewing something else - not the diets offered in captivity.

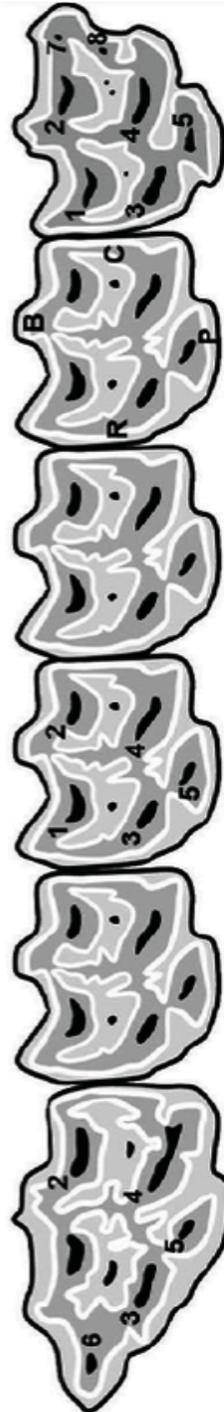


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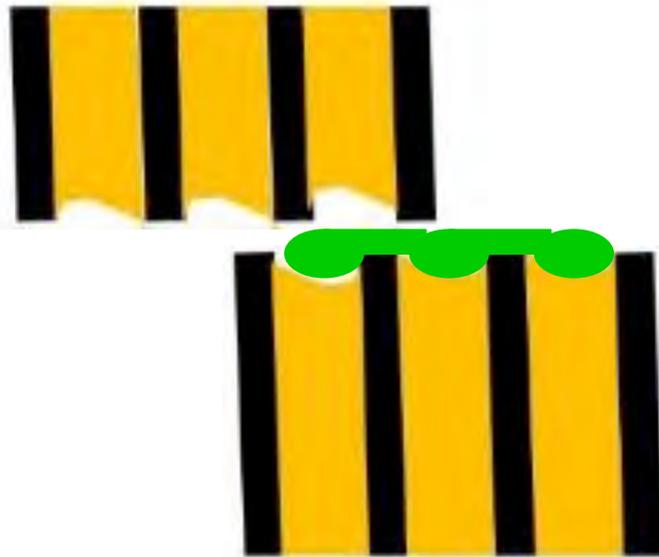


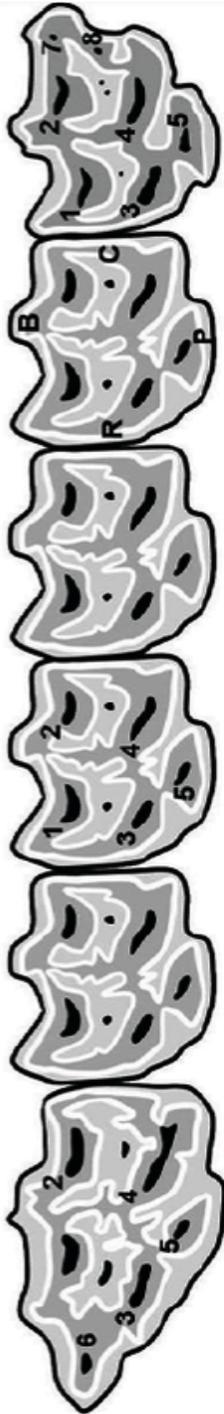
Was passiert beim Kauen wirklich?



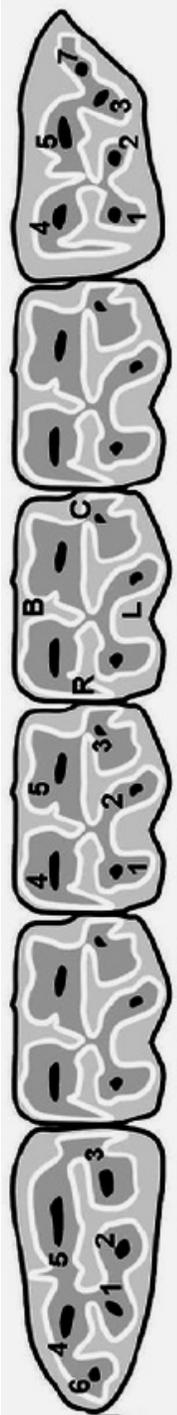
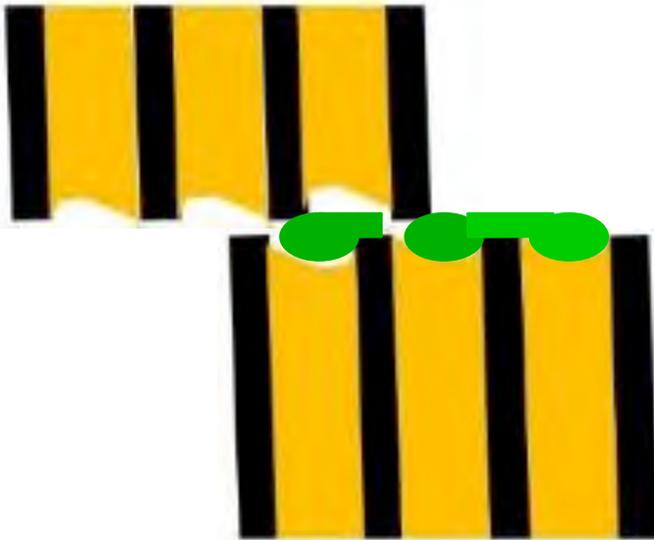


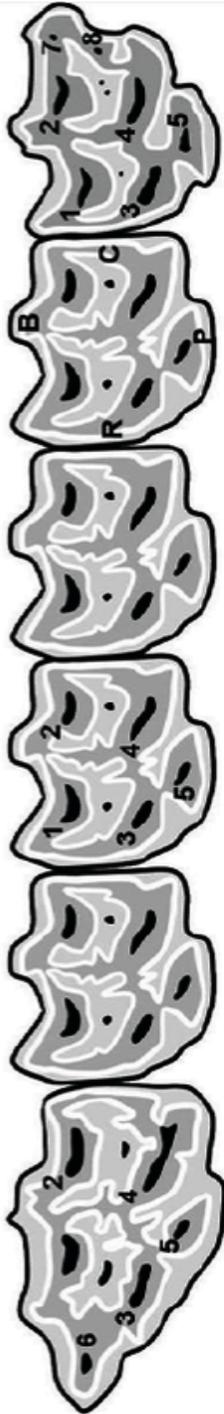
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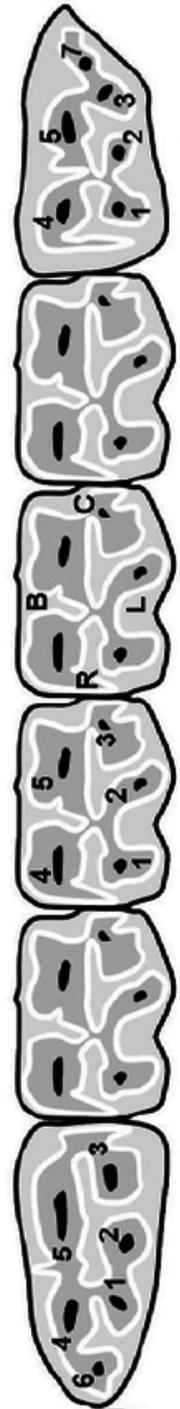
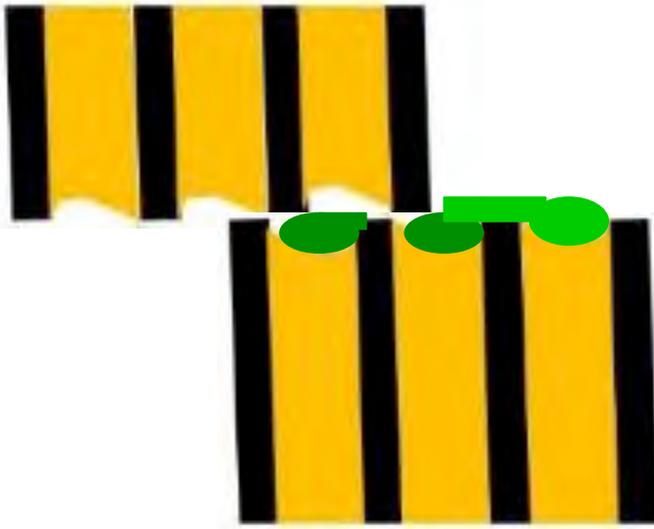


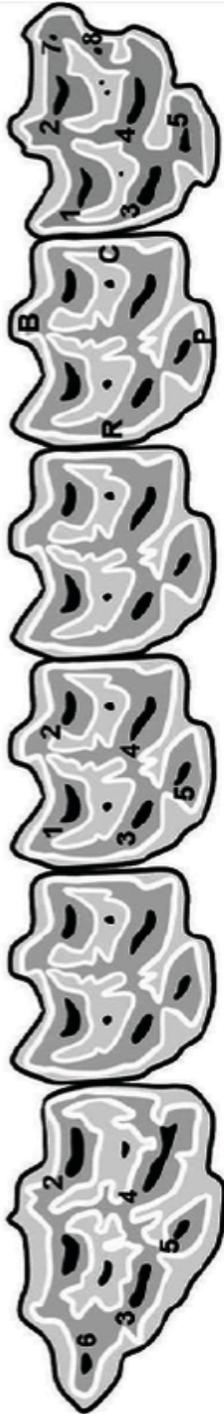
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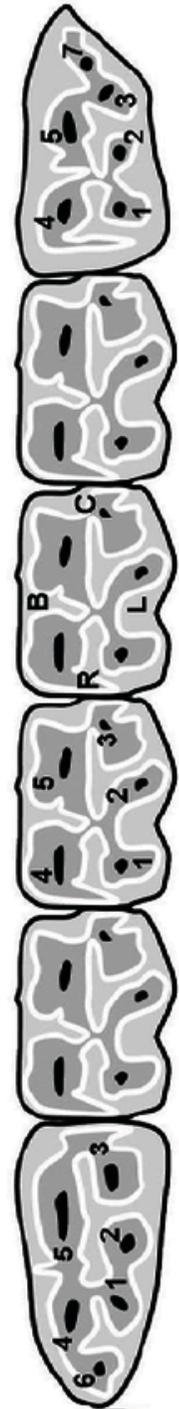
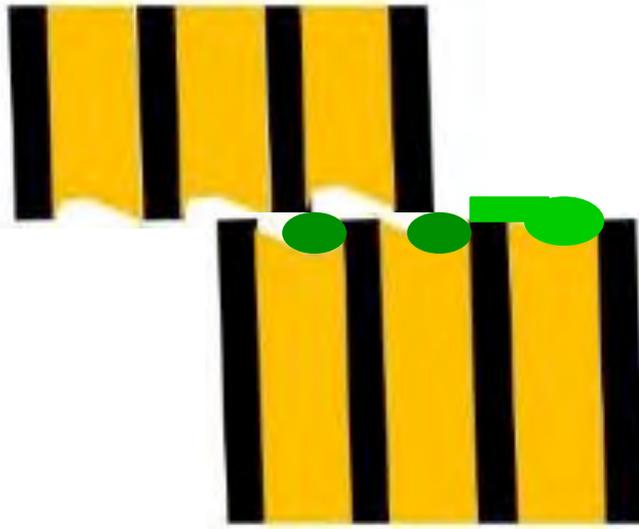


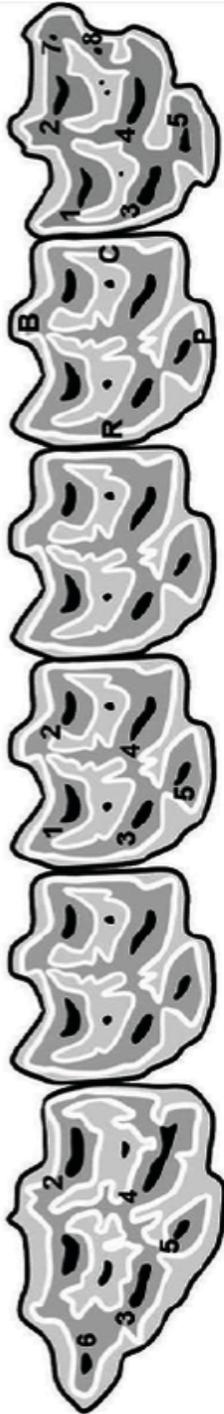
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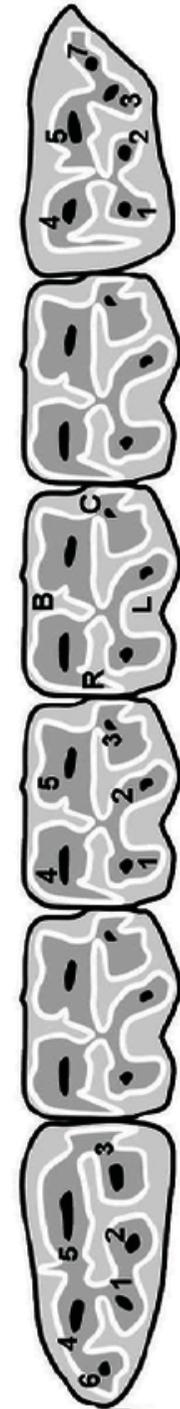
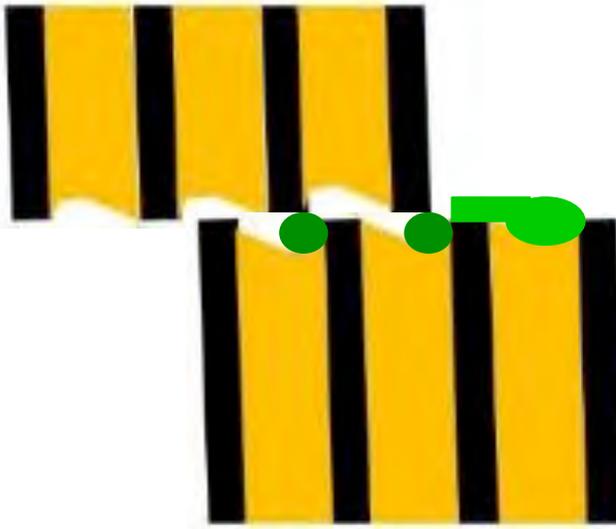


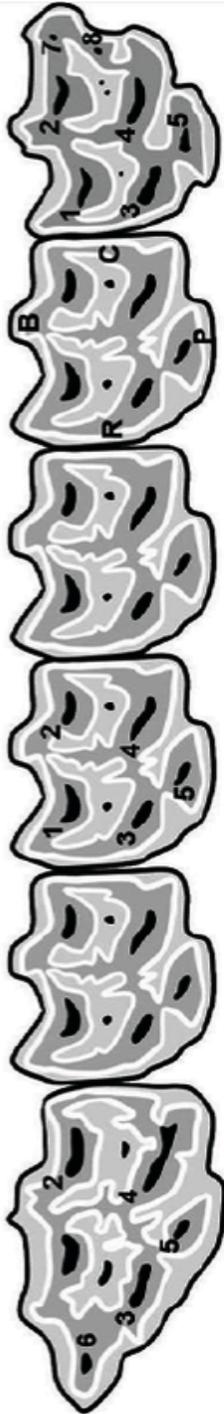
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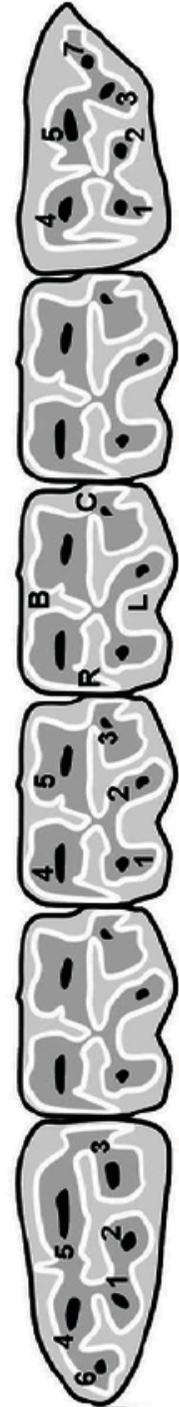
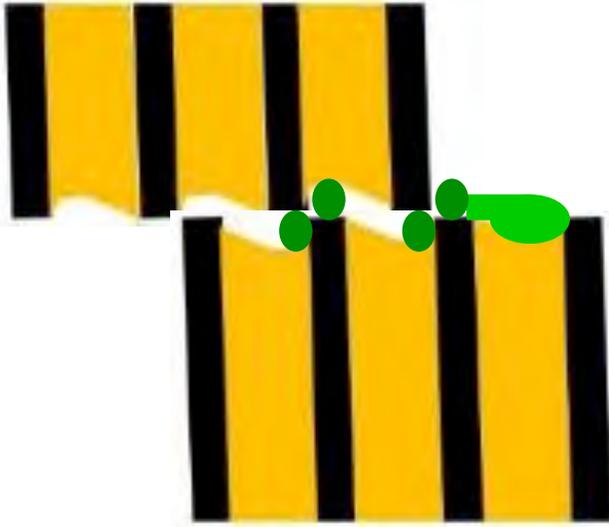


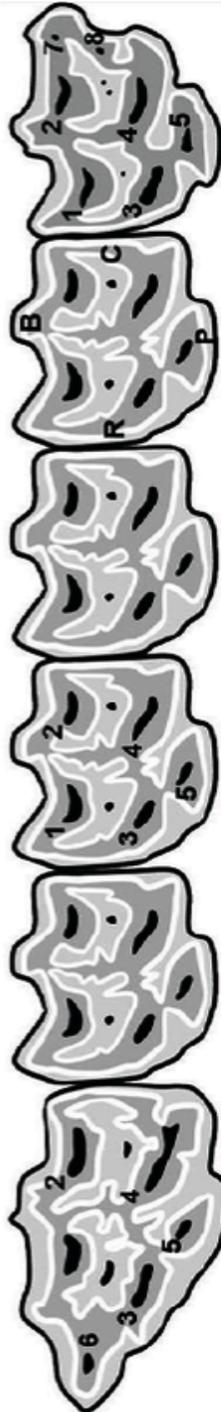
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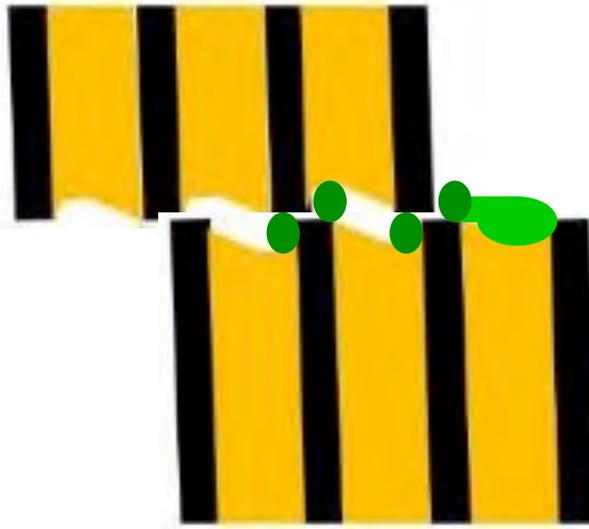


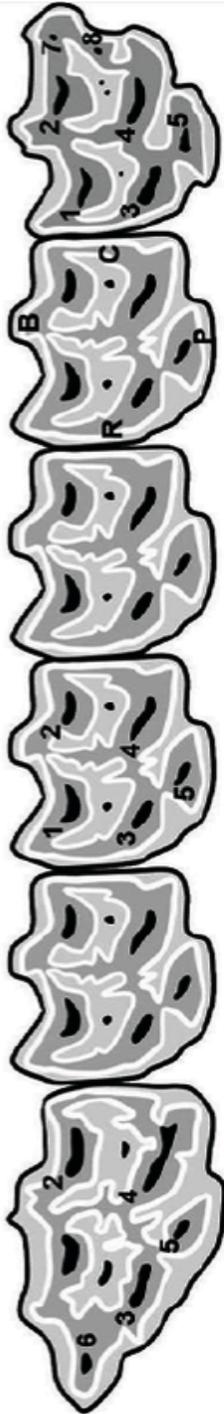
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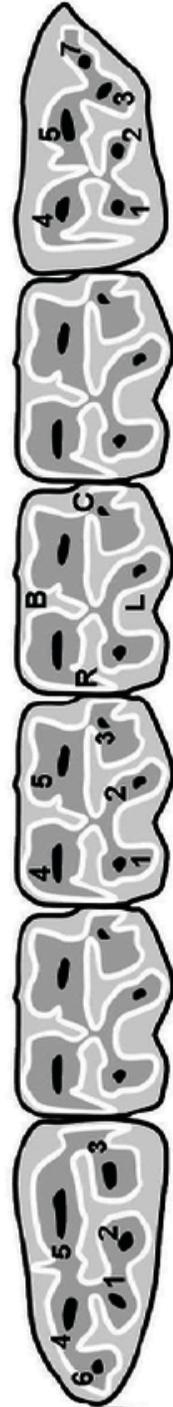
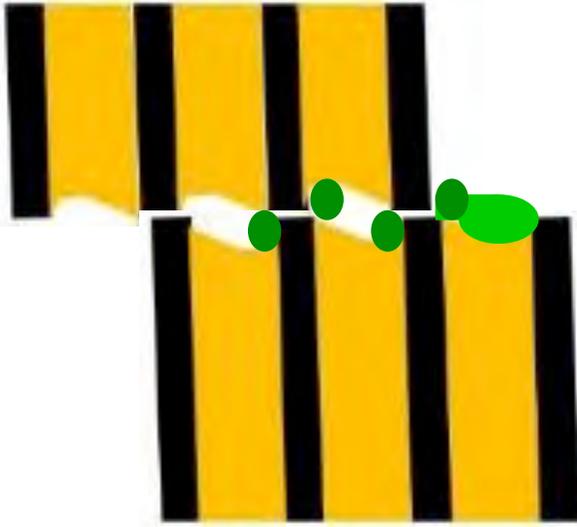


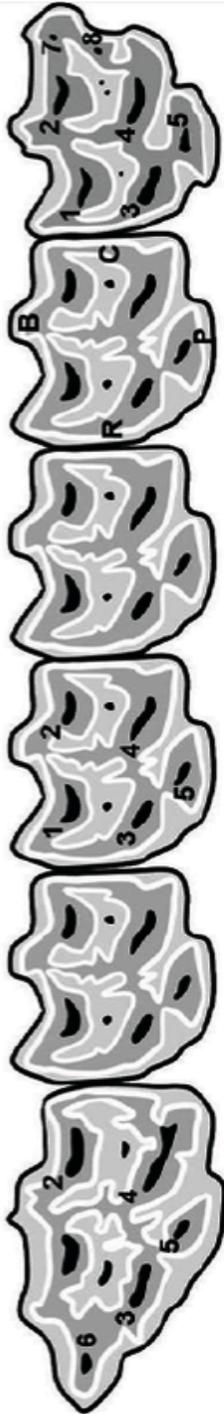
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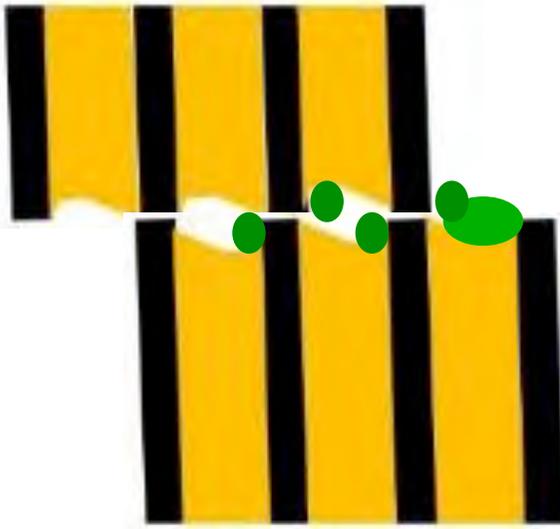


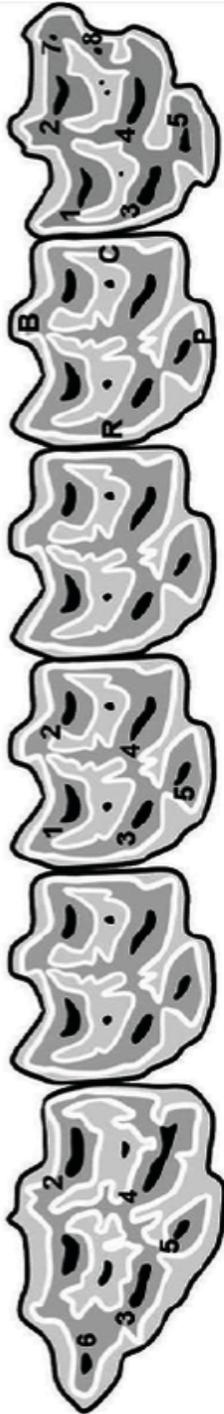
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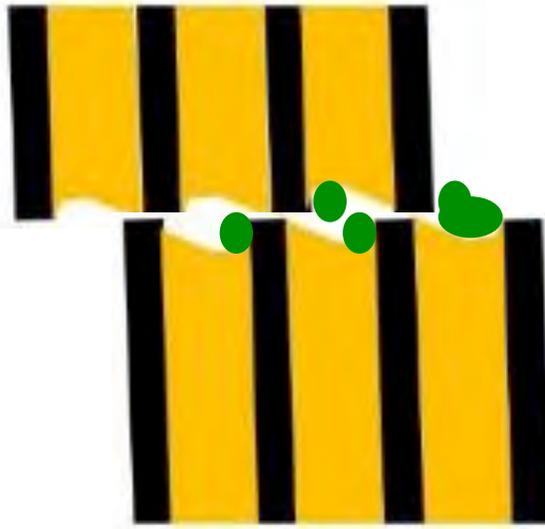


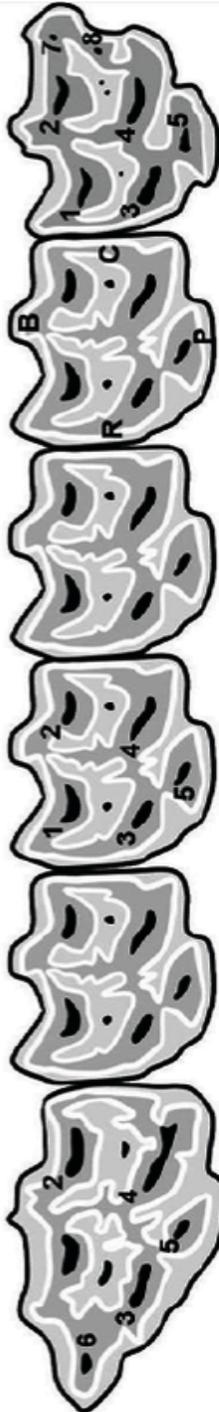
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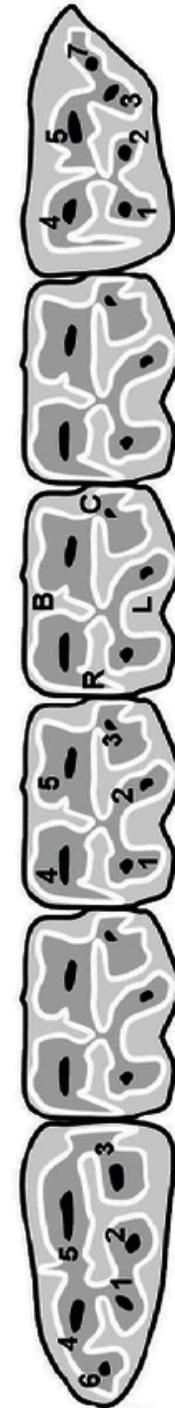
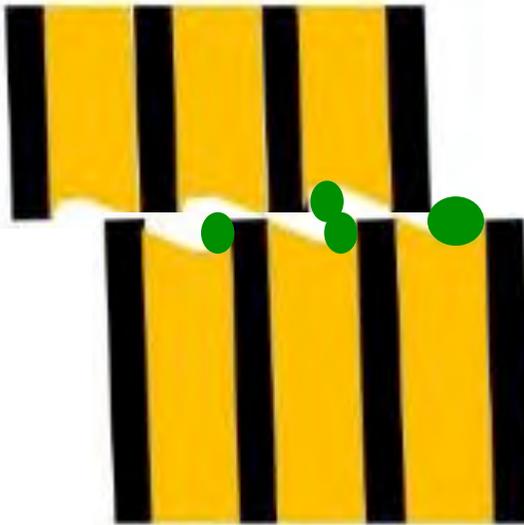


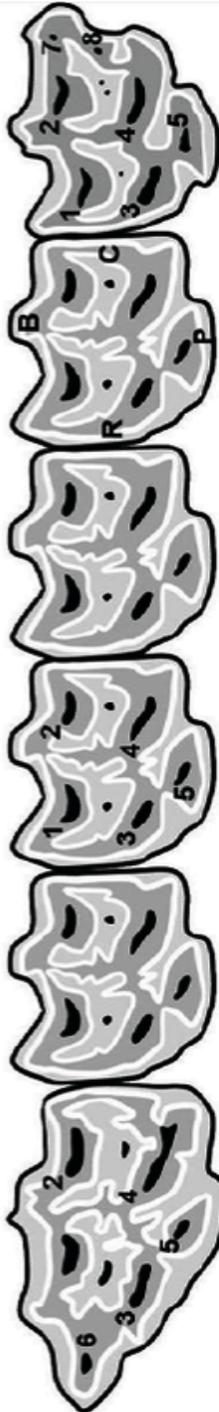
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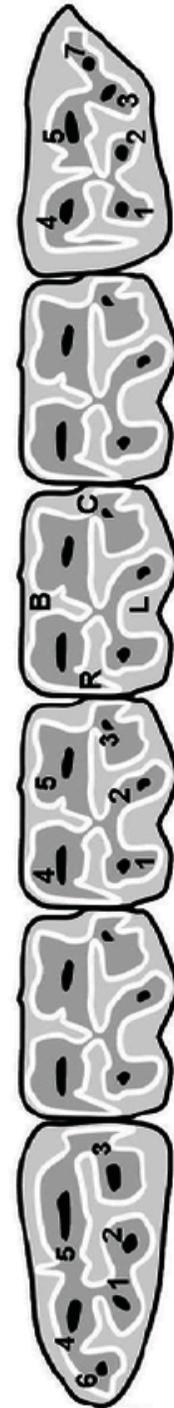
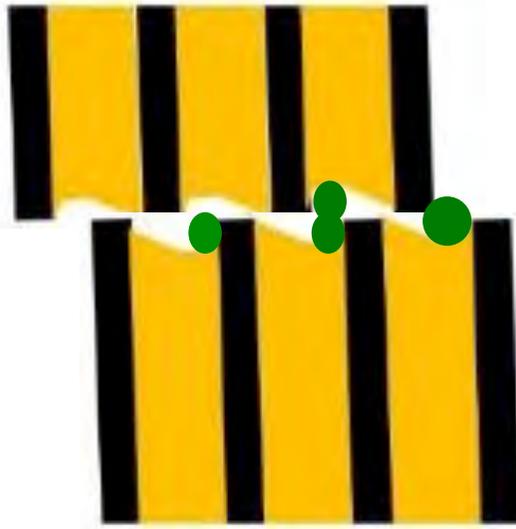


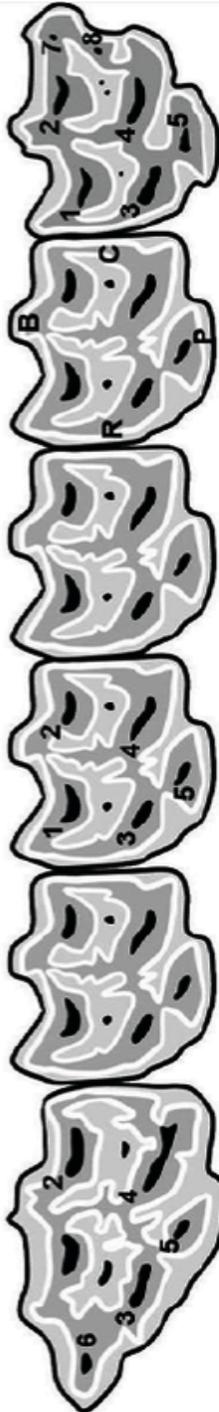
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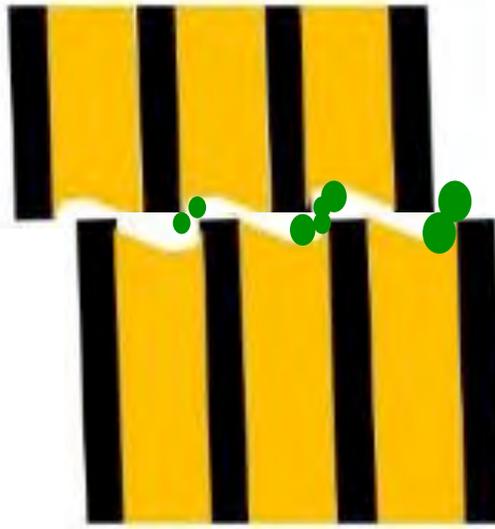


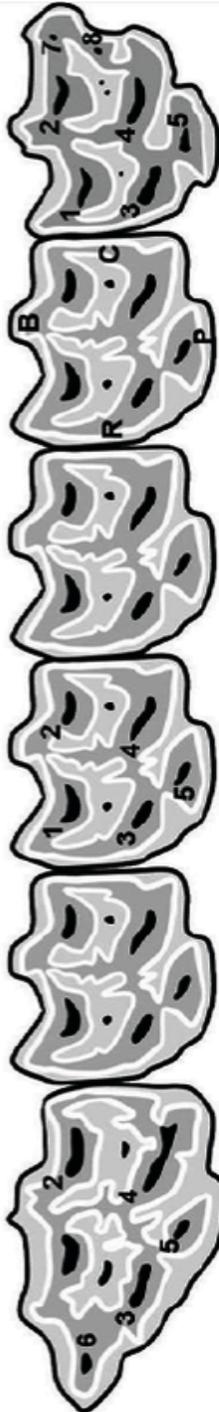
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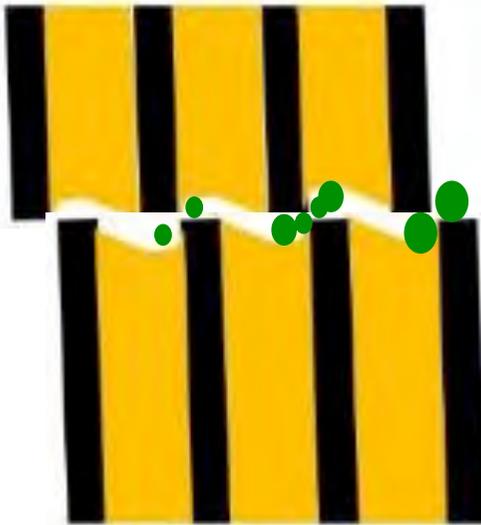


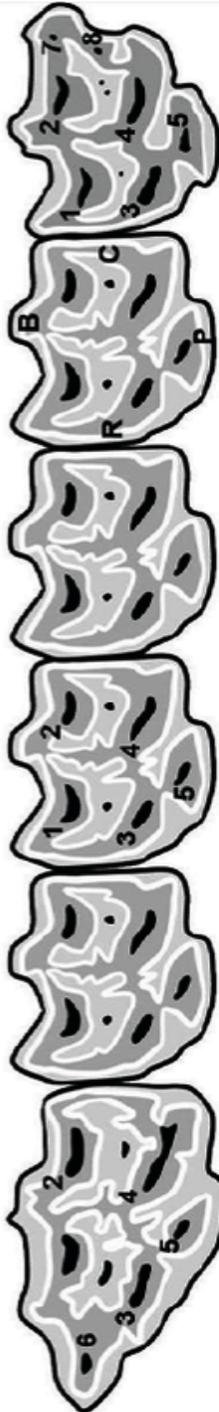
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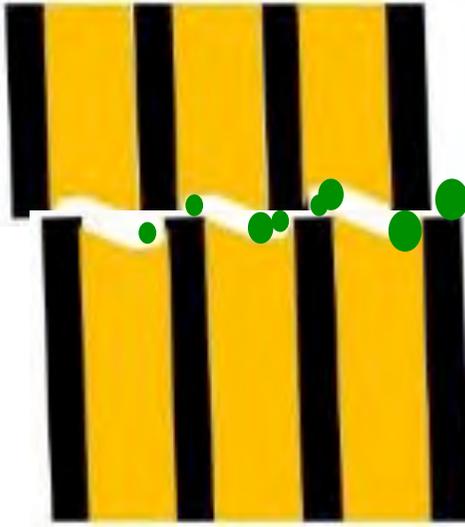


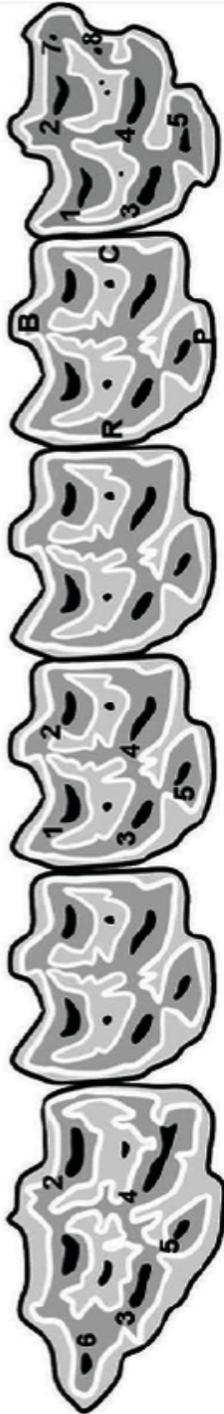
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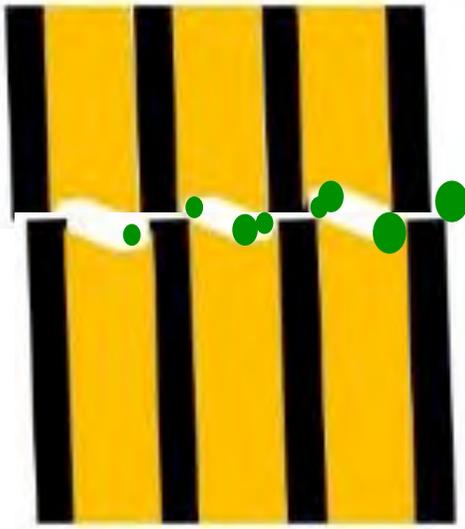


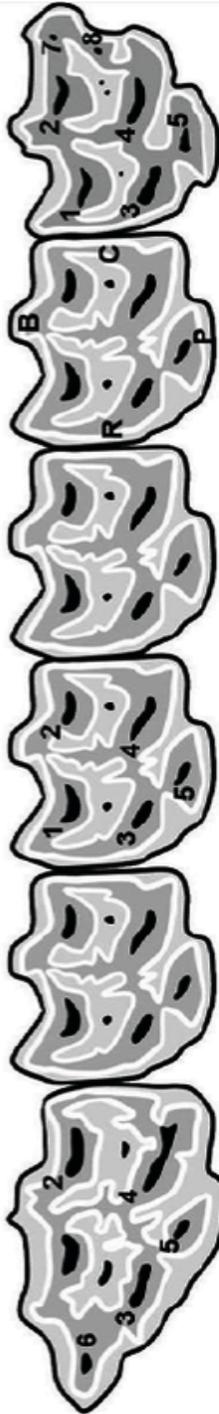
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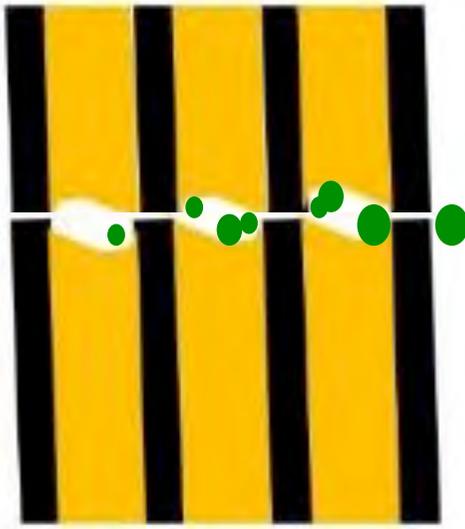


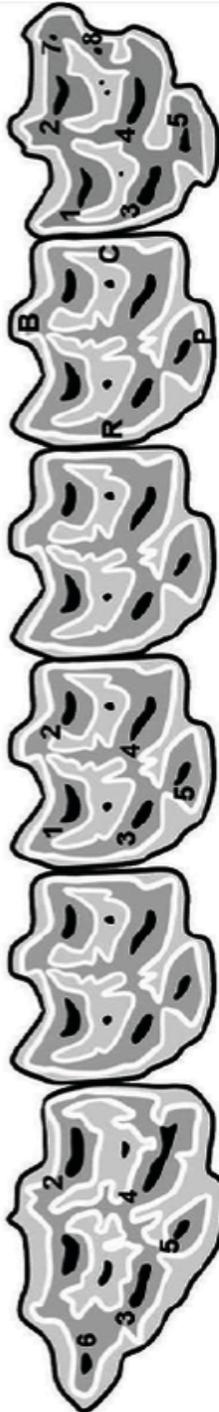
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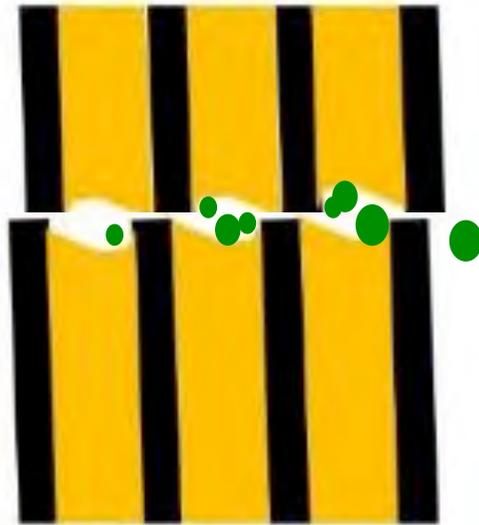


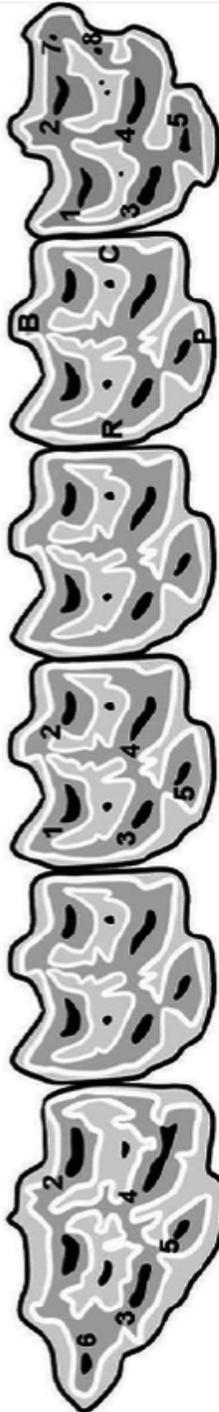
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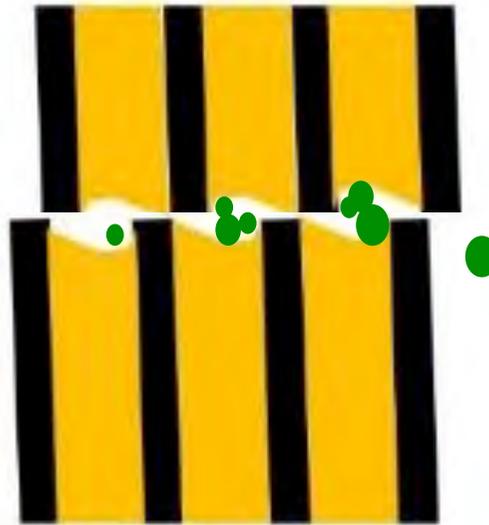


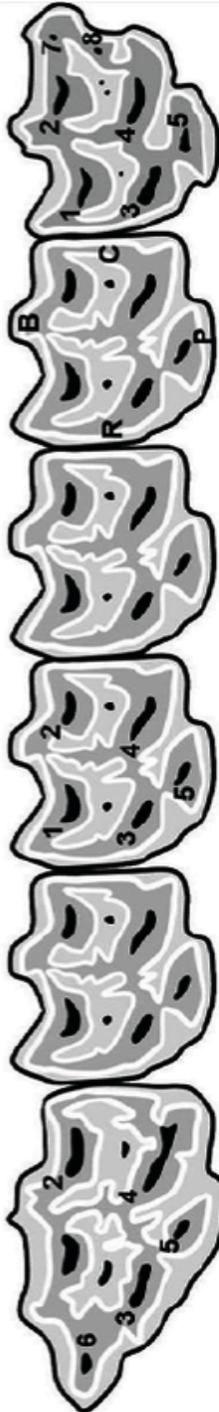
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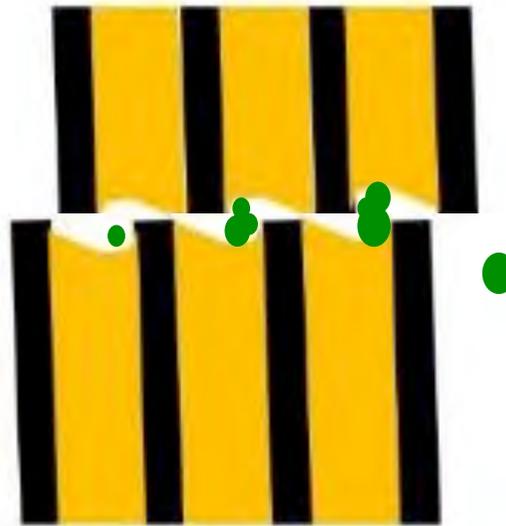


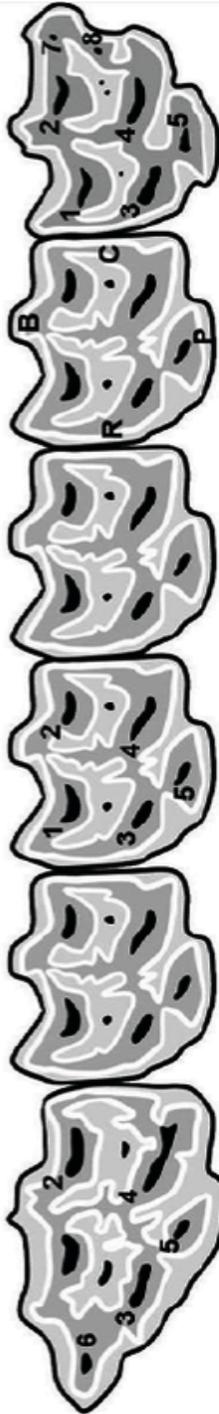
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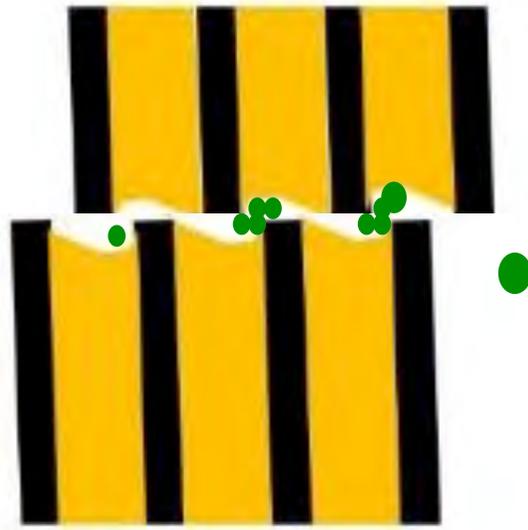


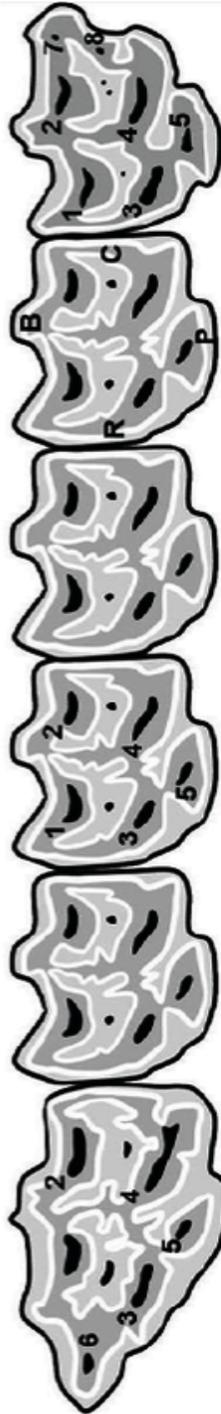
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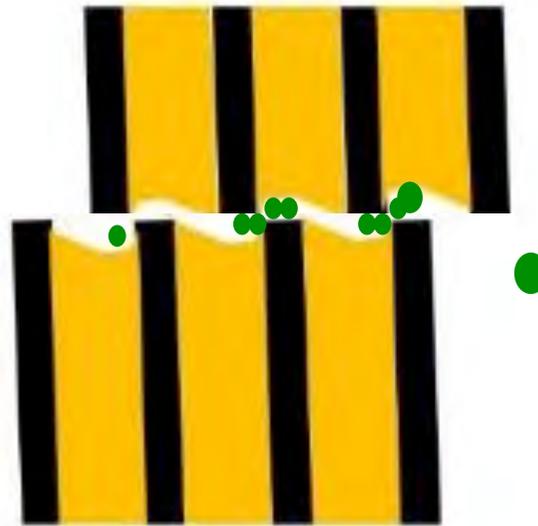


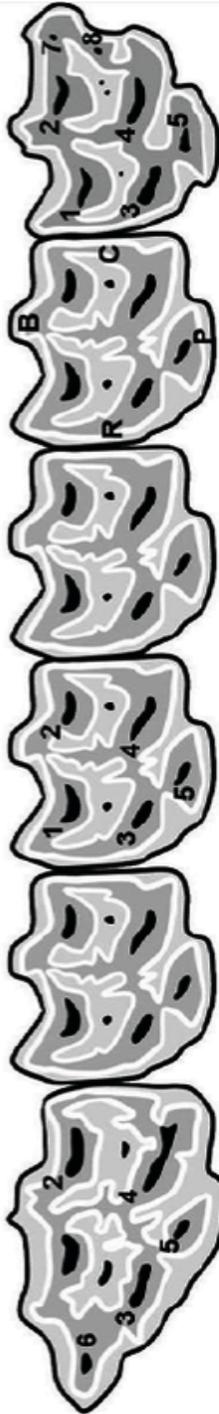
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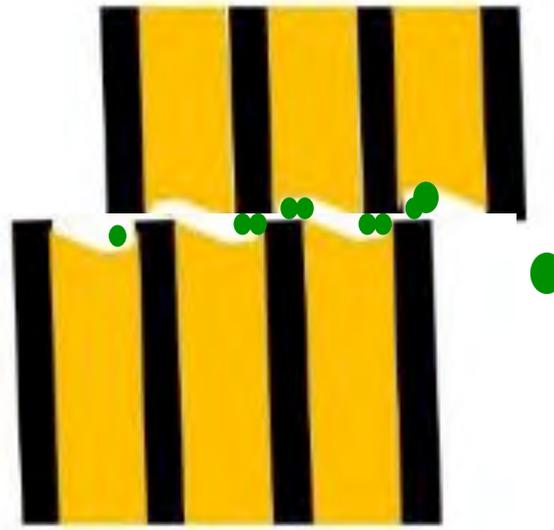


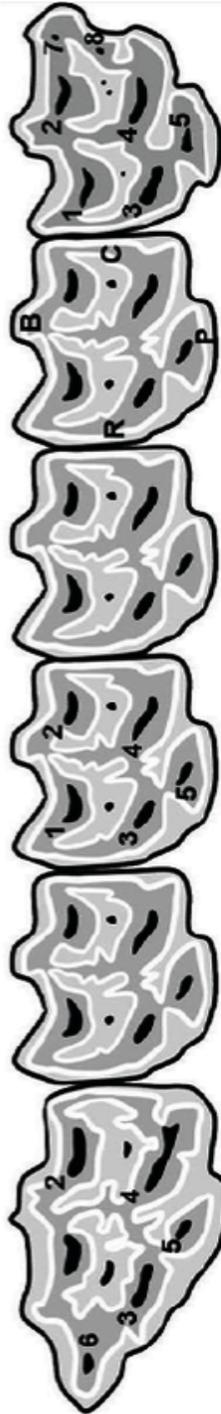
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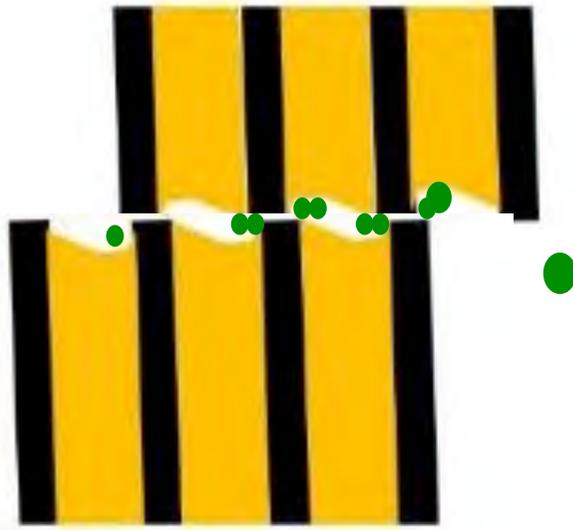


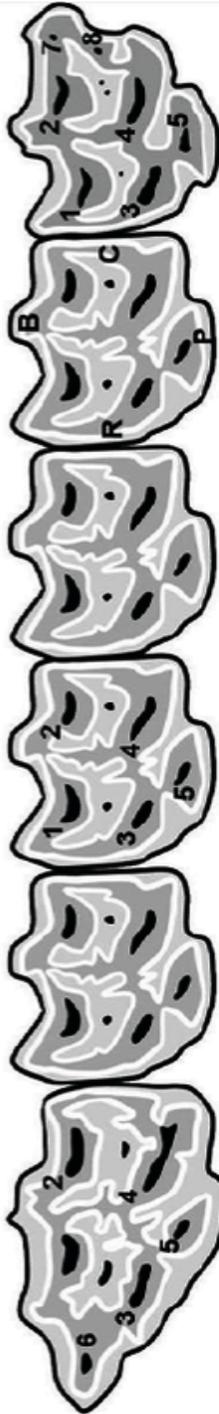
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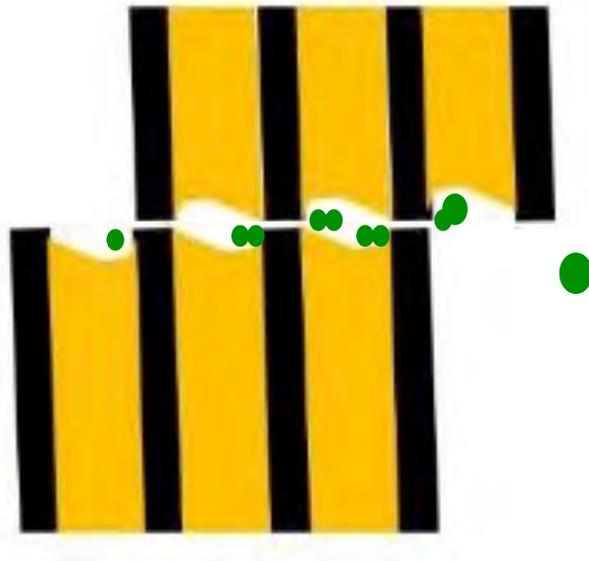


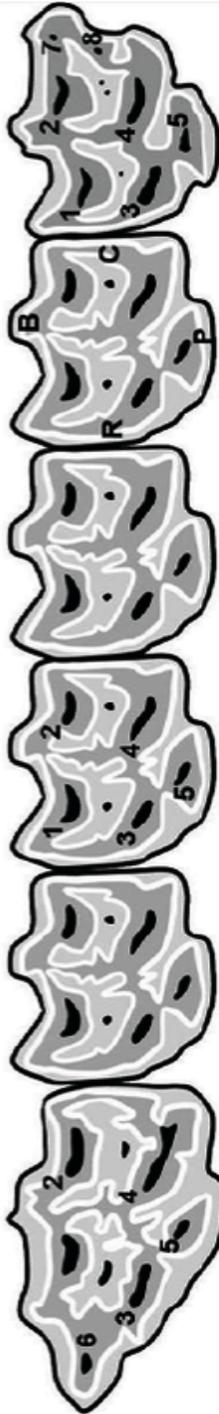
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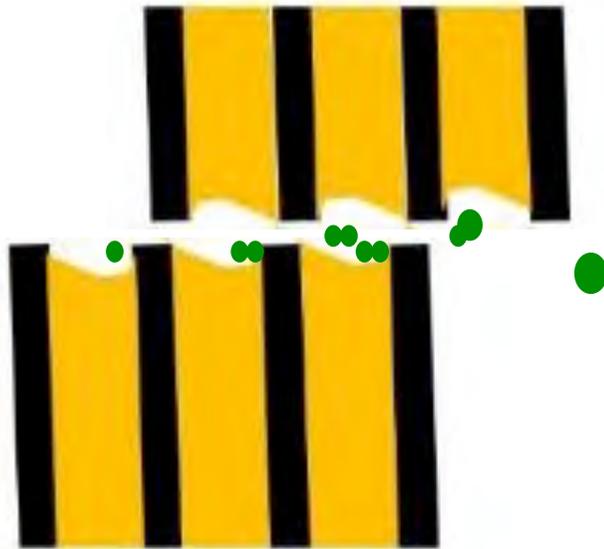


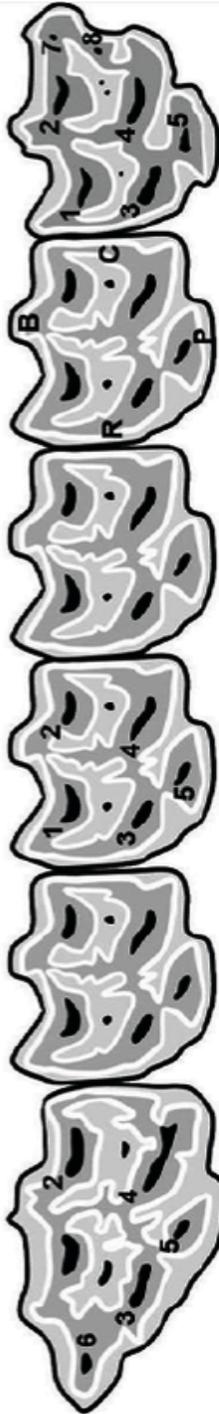
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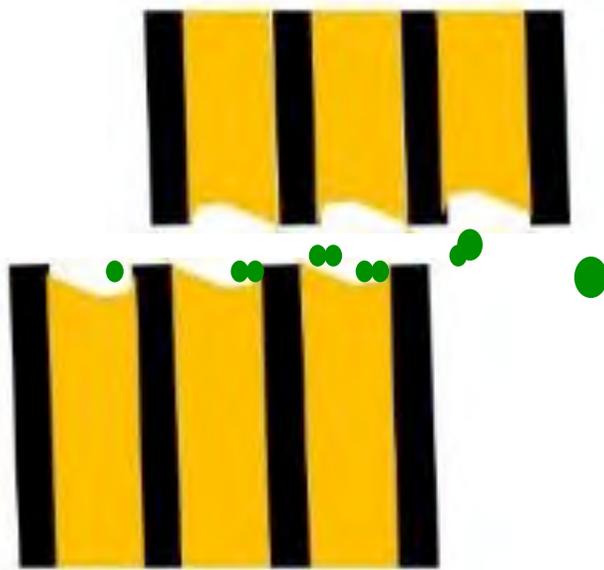


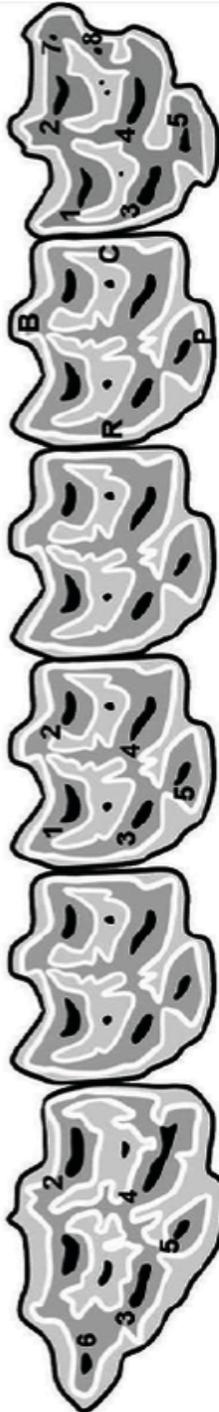
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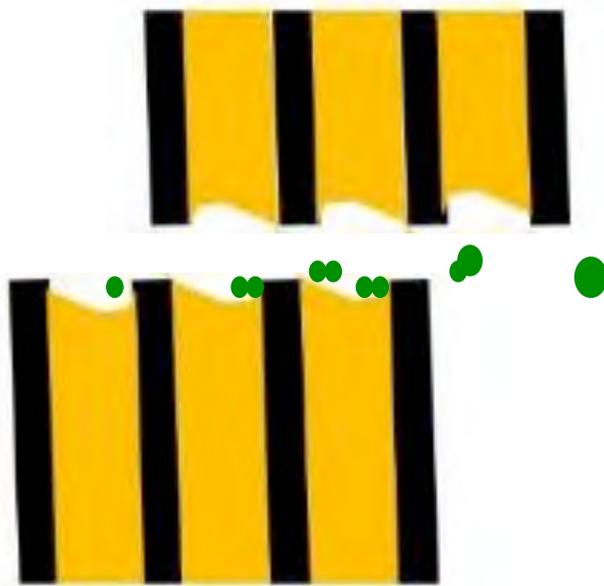


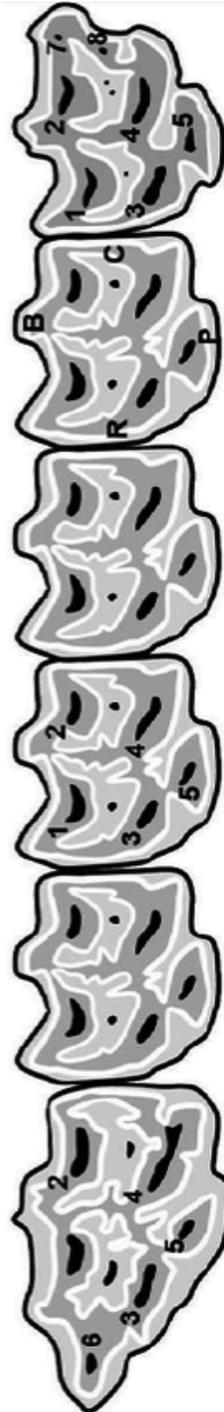
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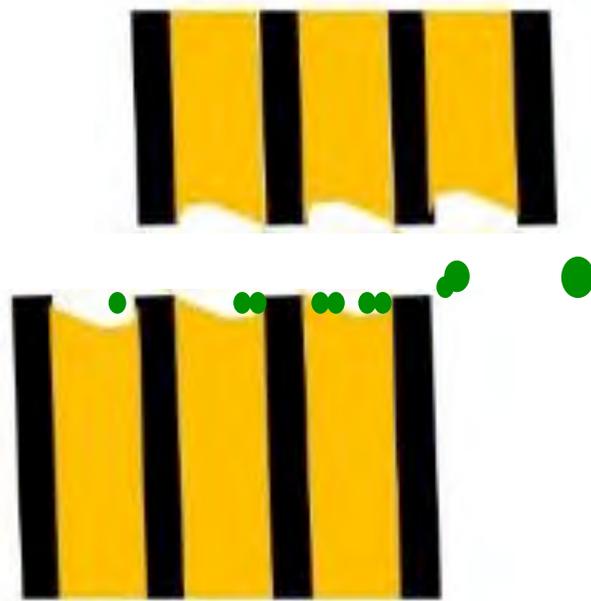


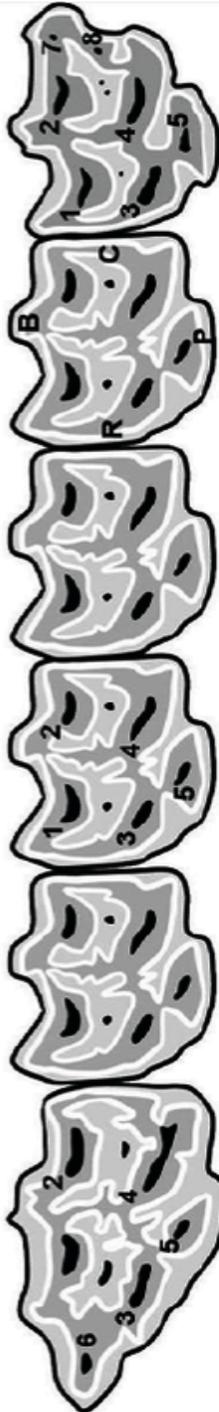
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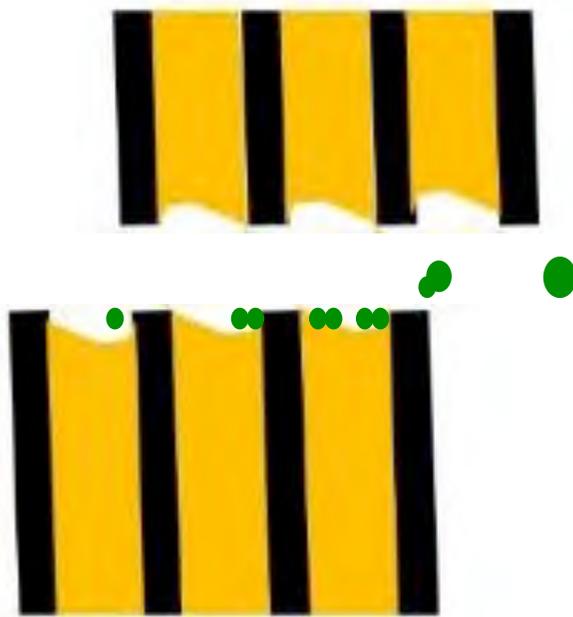


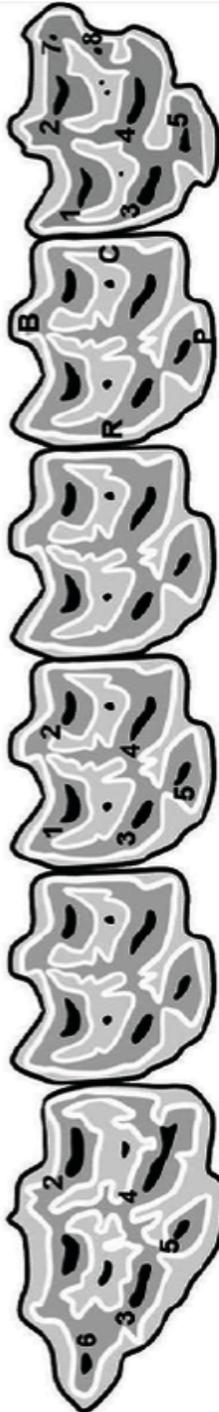
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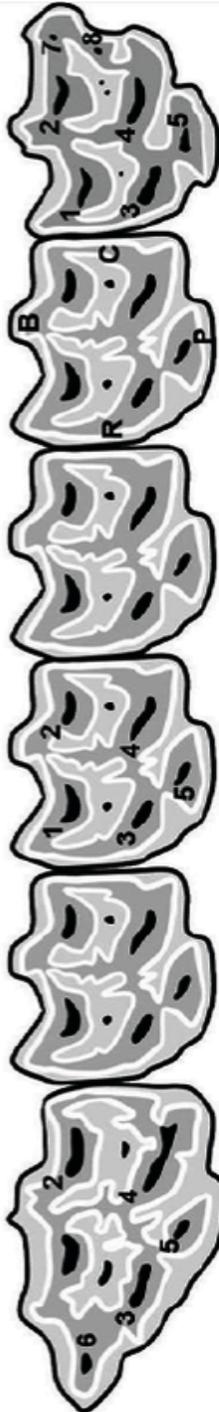
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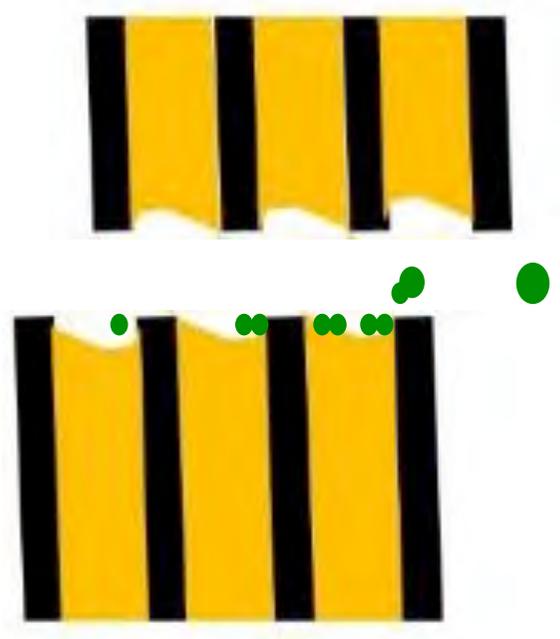


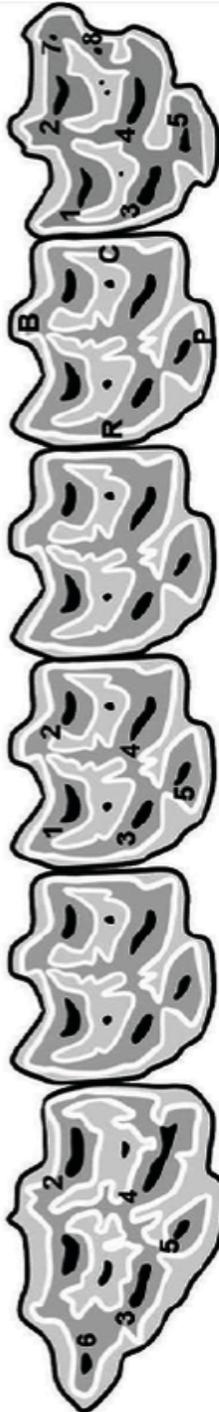
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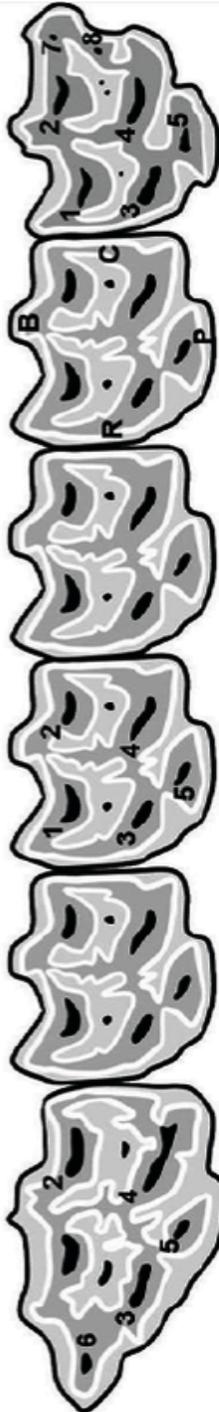
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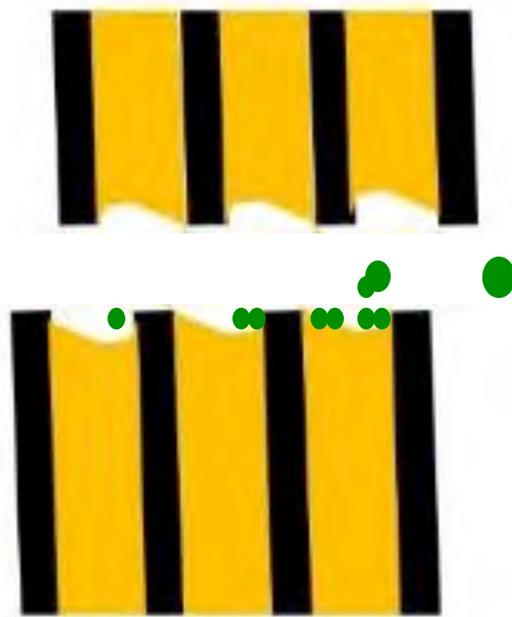


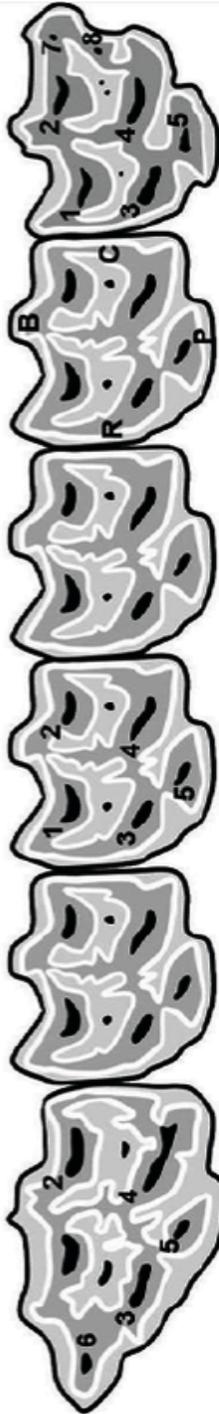
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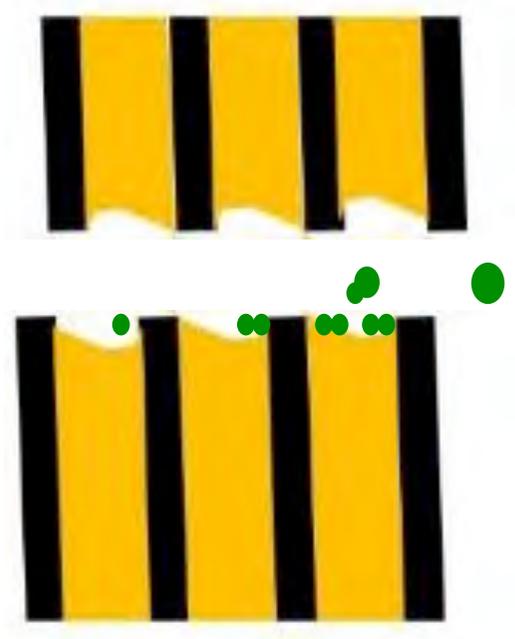


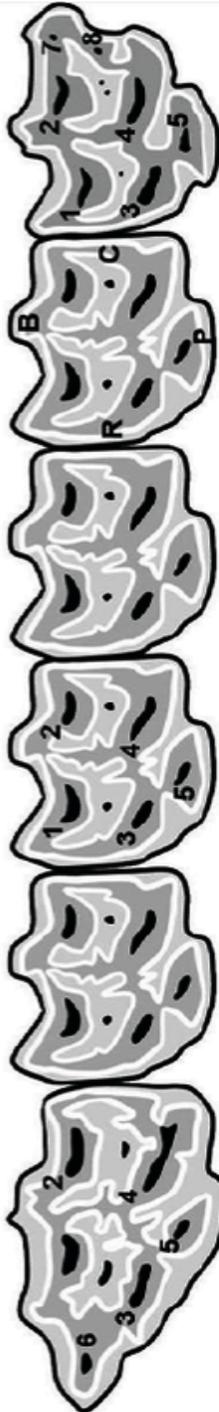
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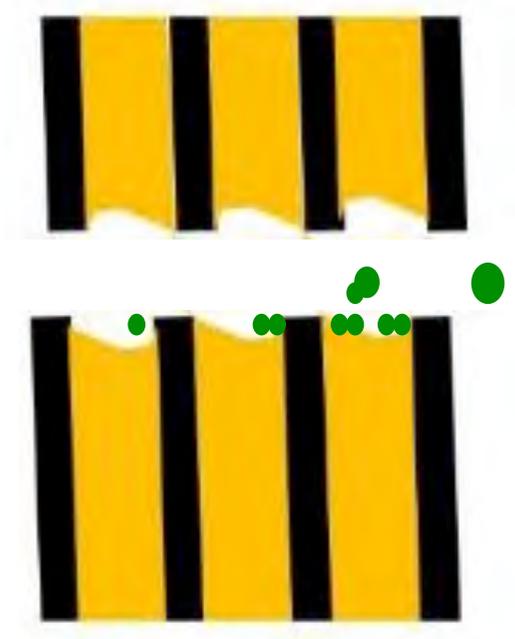


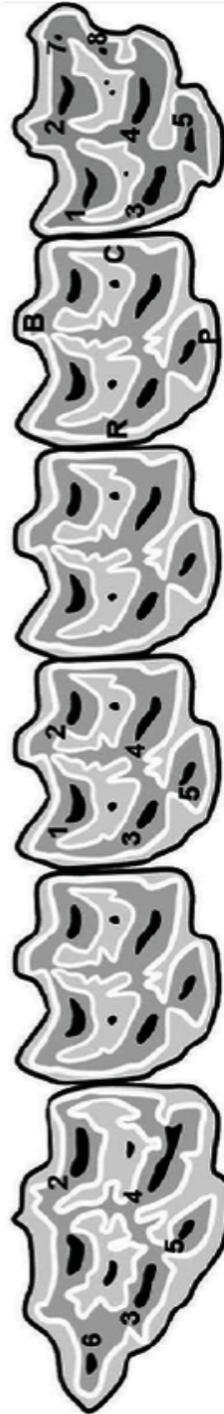
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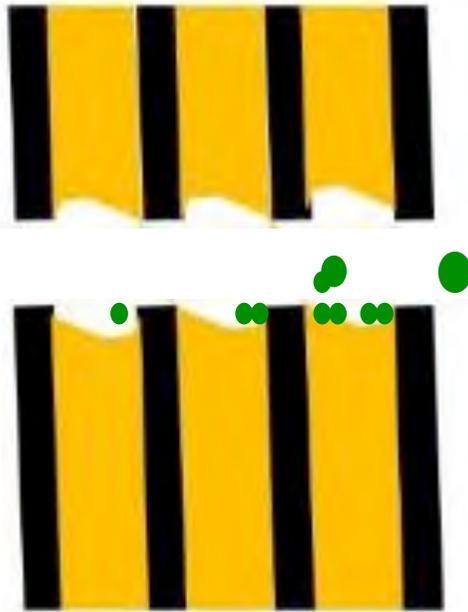


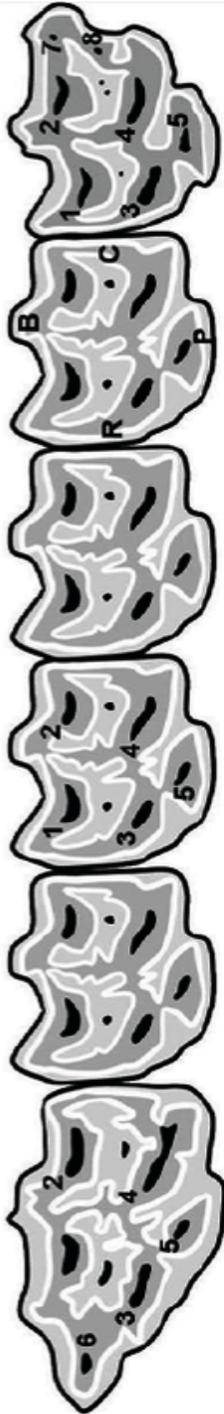
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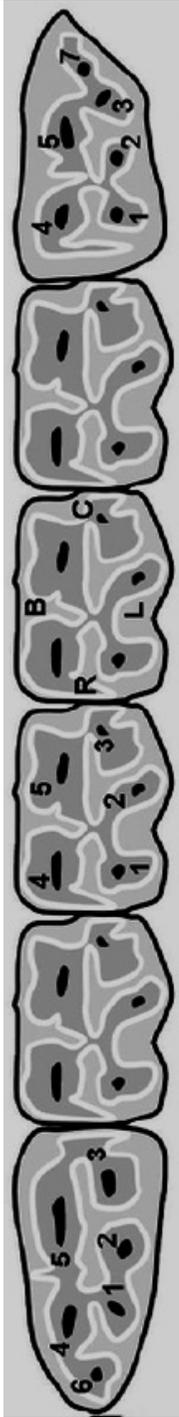
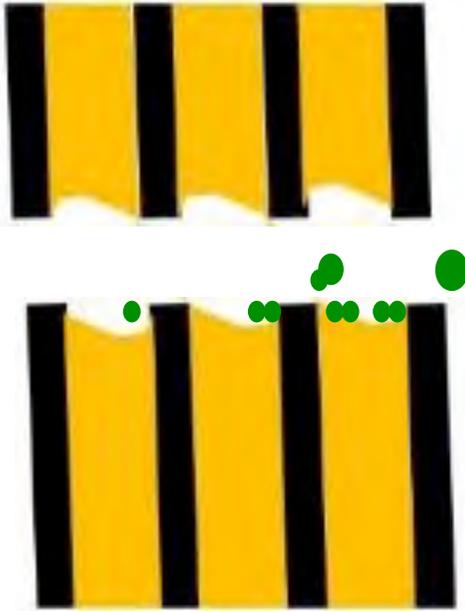


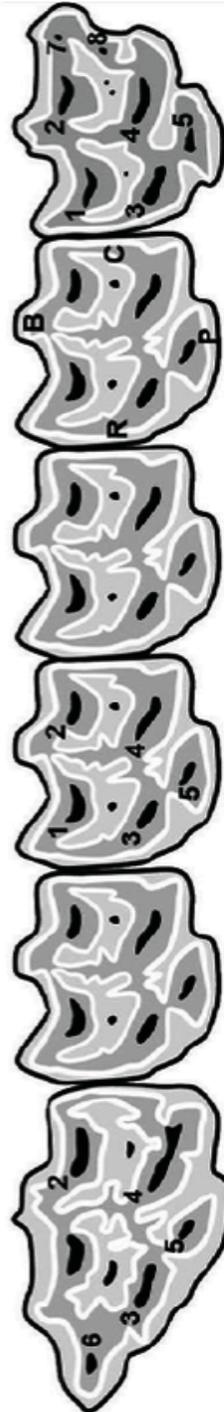
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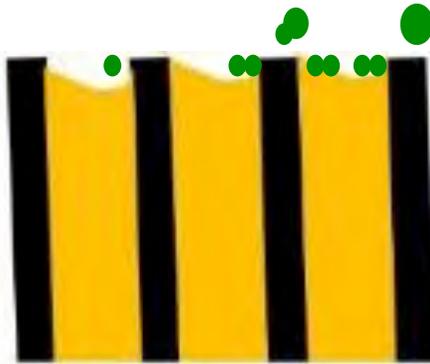
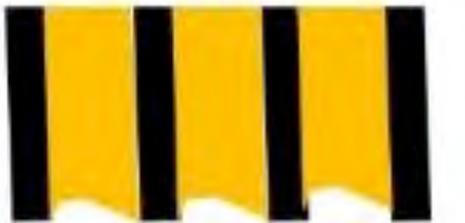


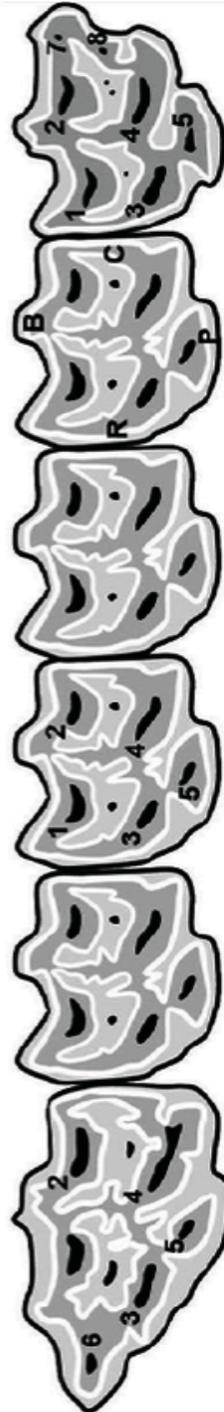
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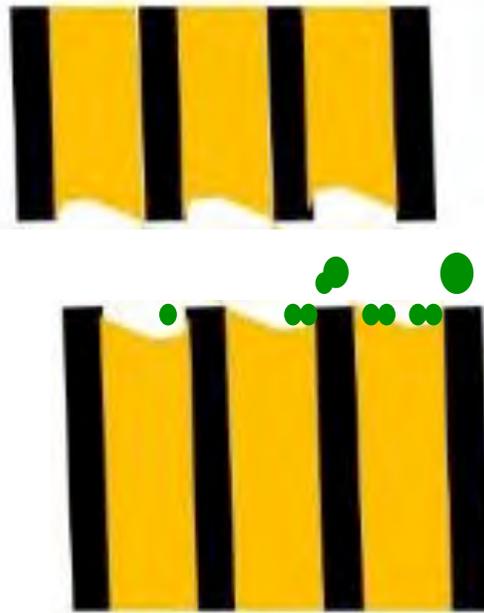


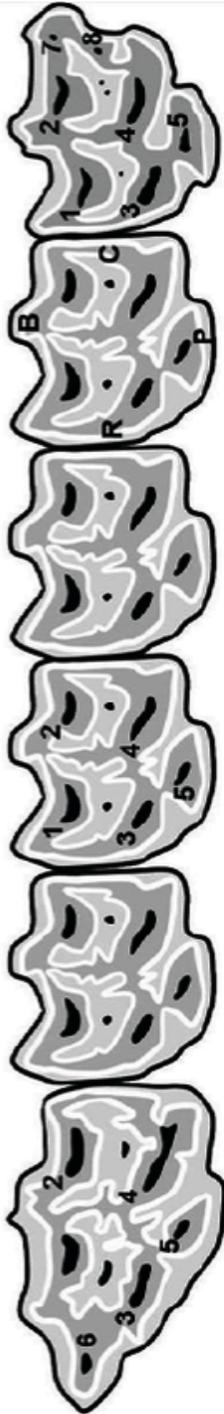
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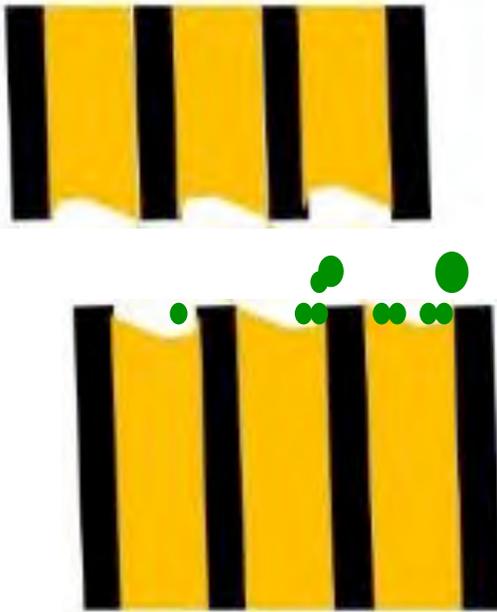


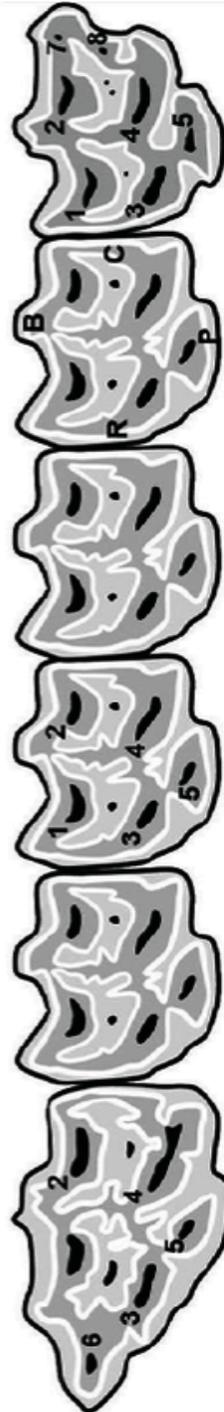
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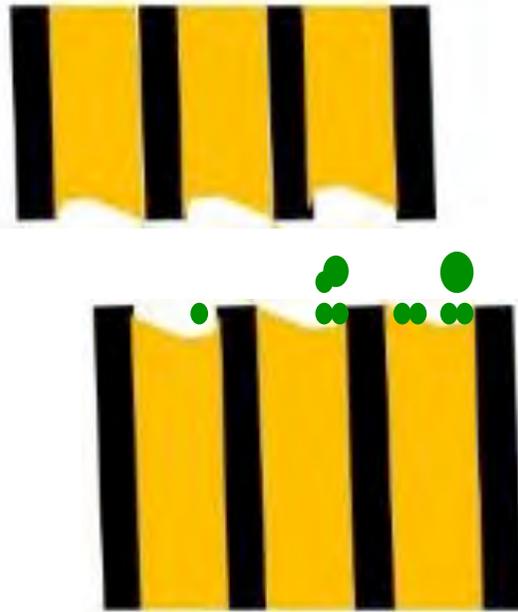


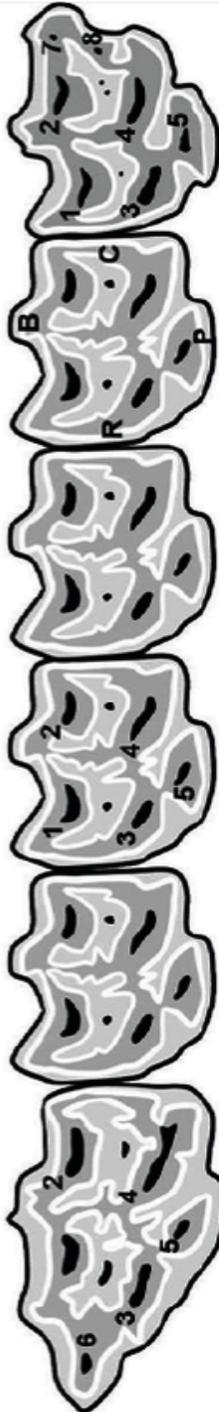
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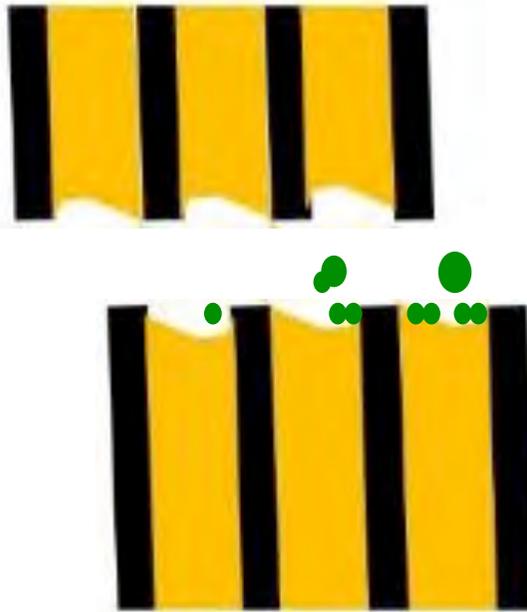


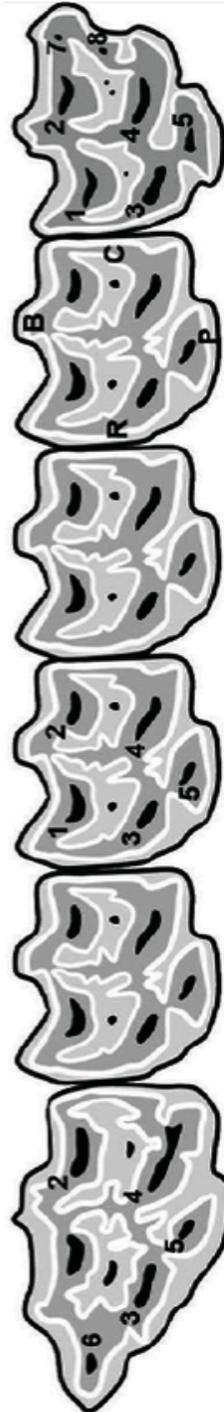
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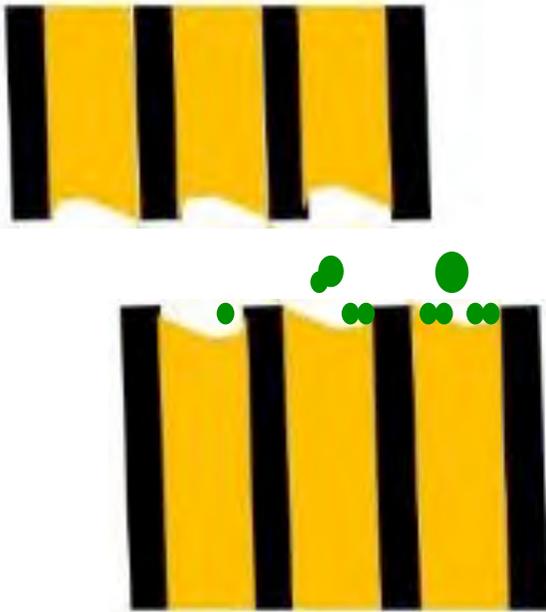


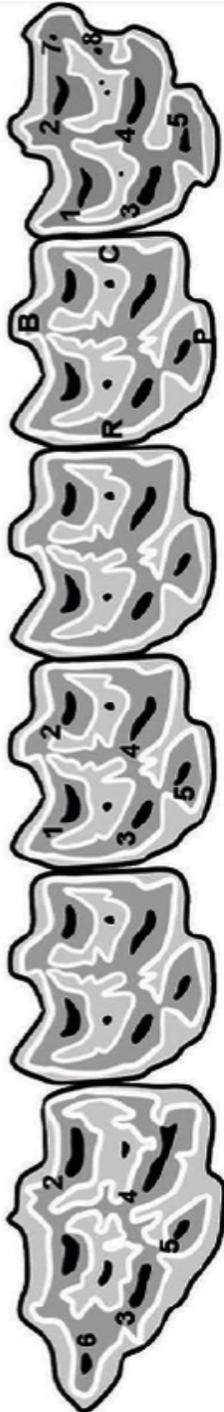
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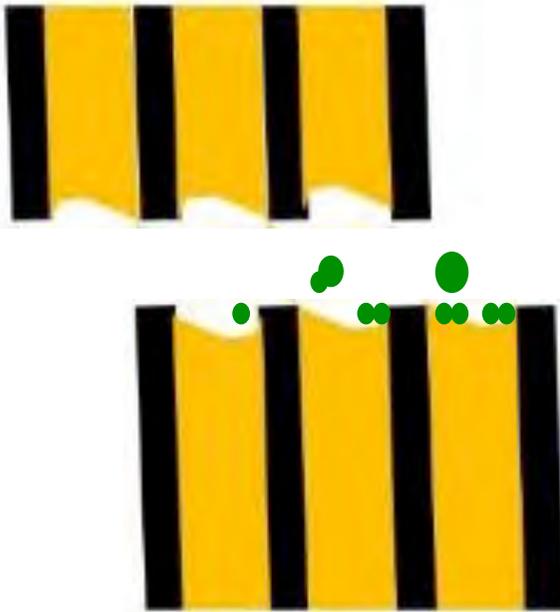


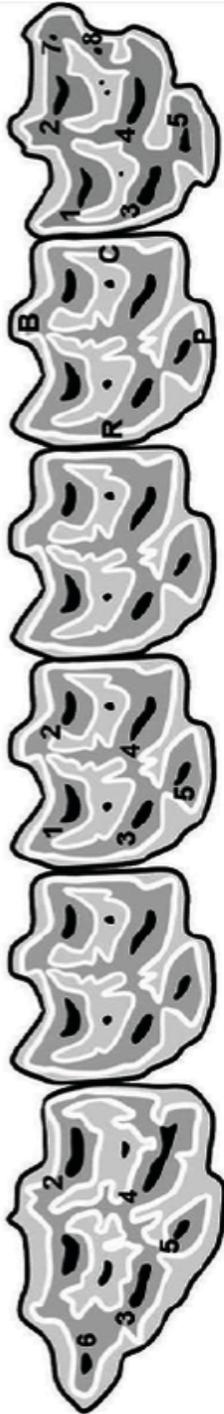
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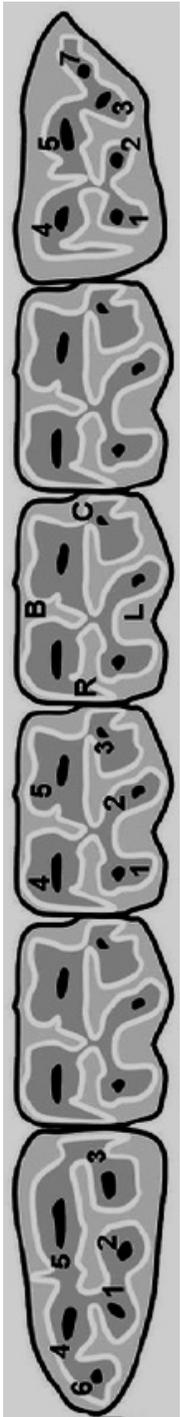
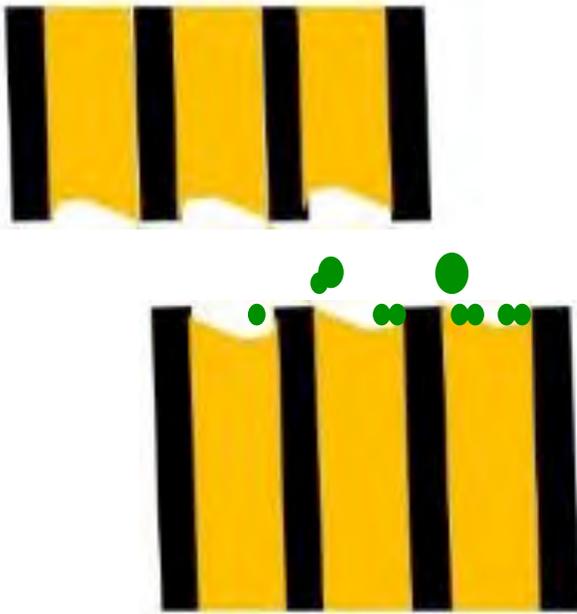


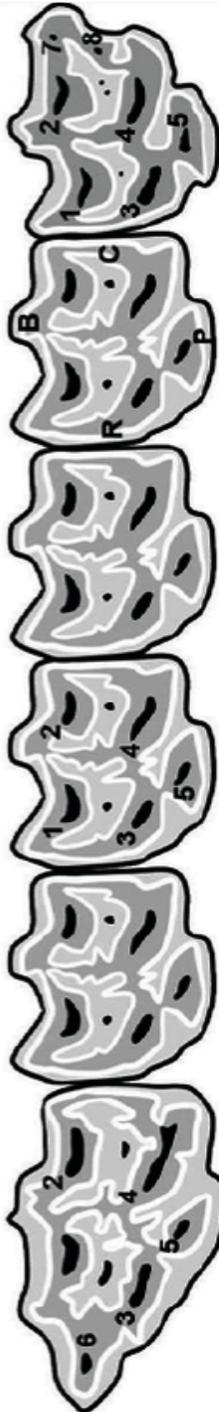
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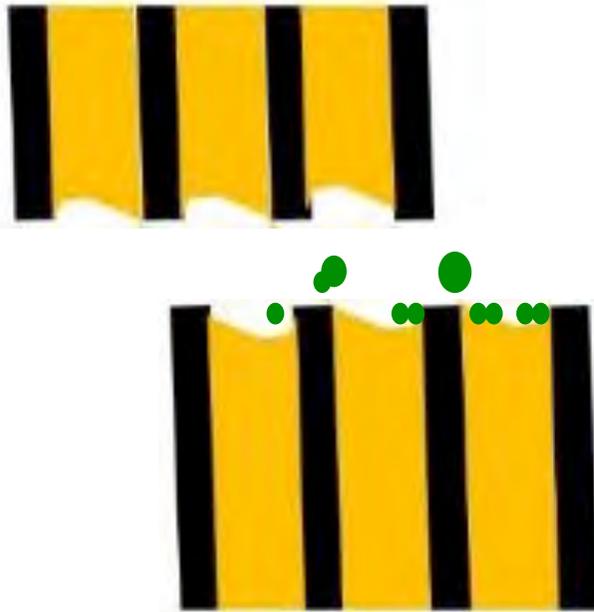


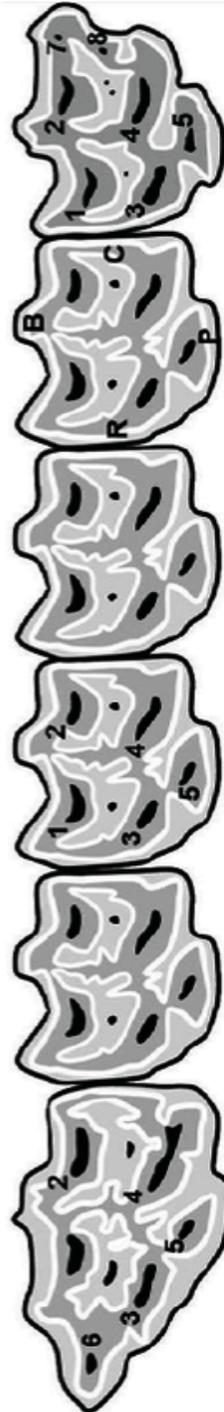
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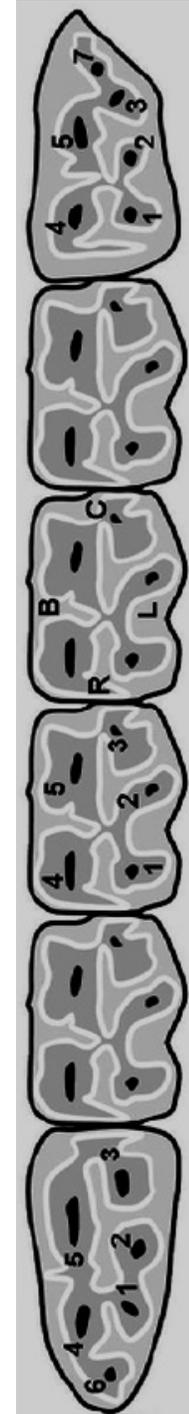
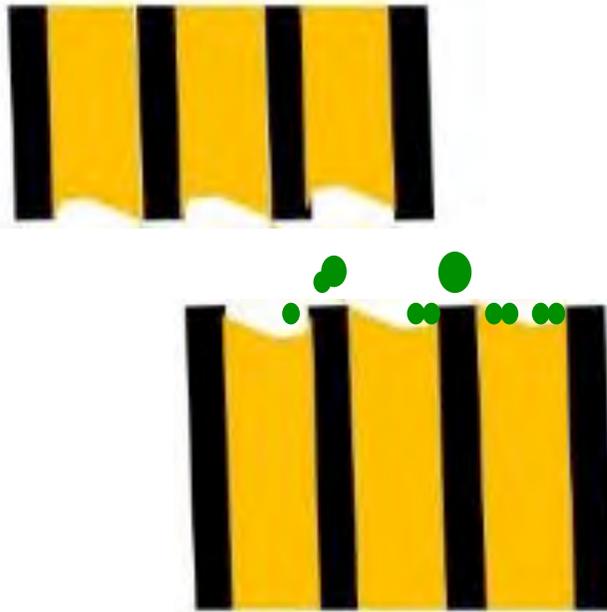


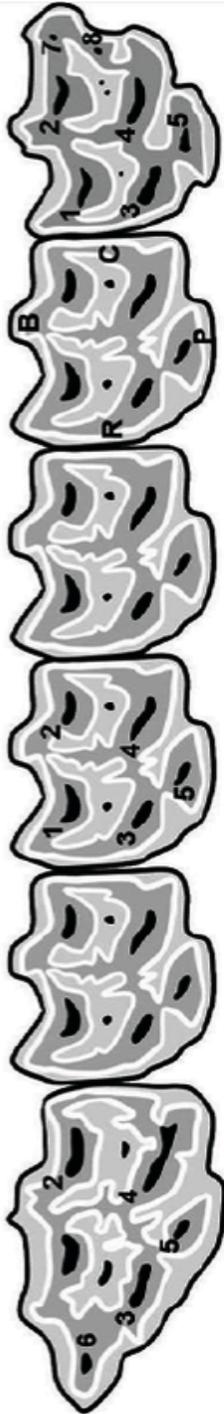
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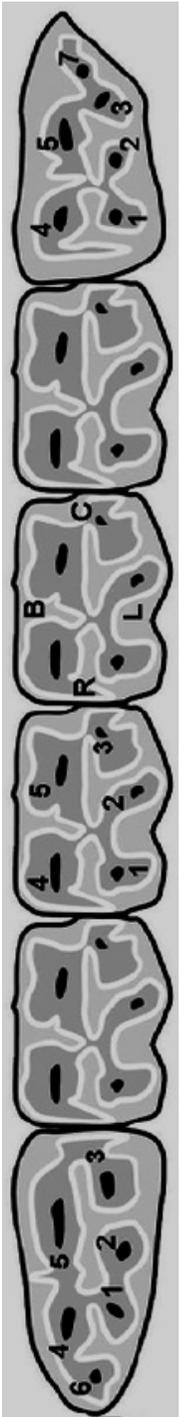
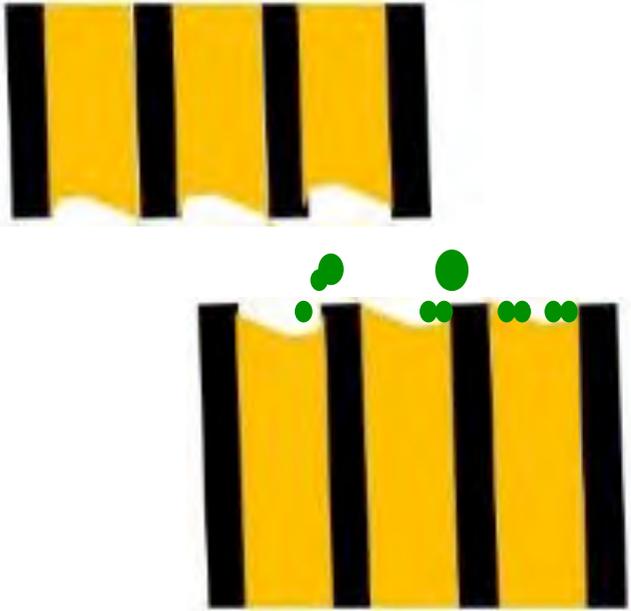


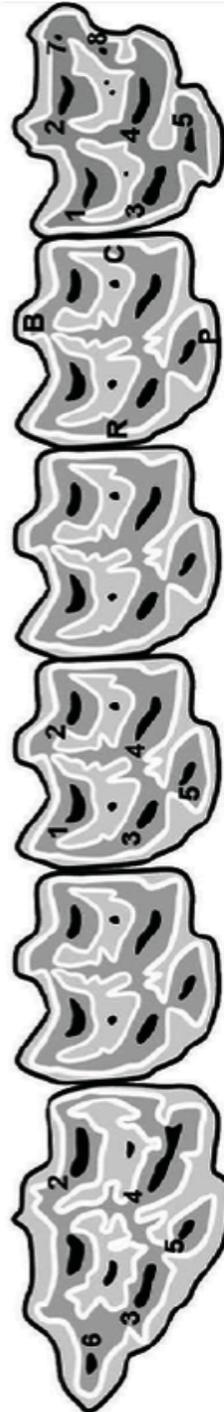
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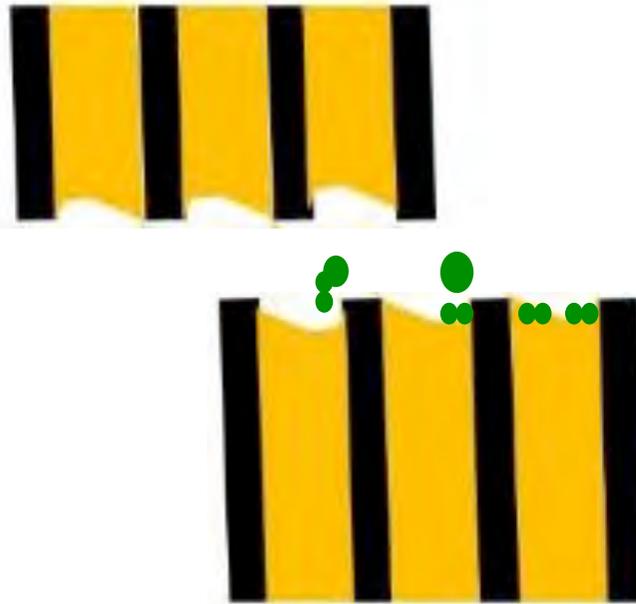


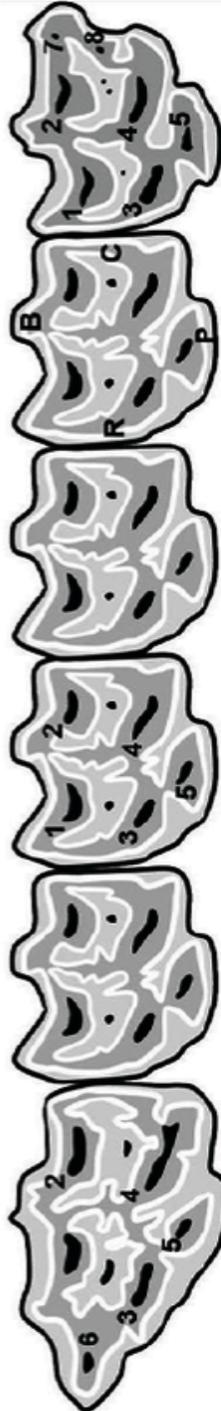
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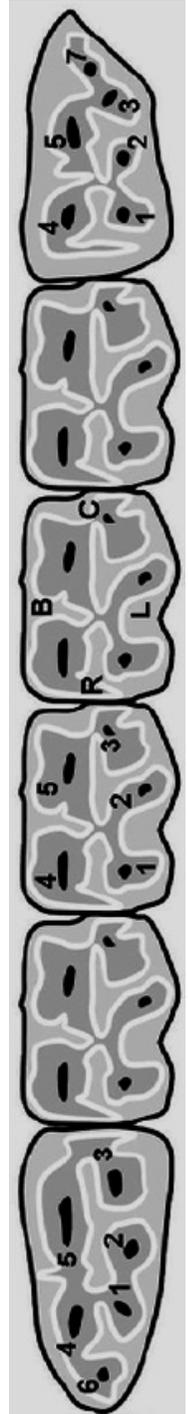
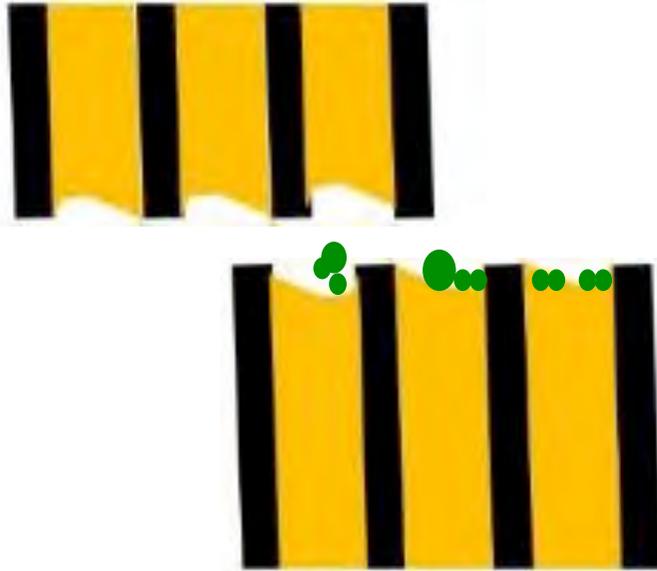


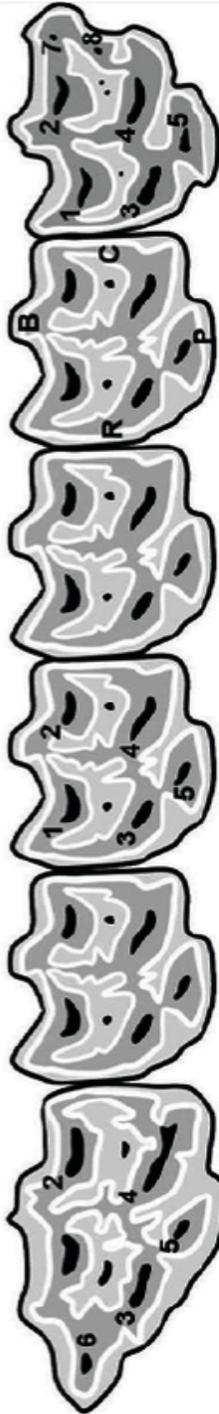
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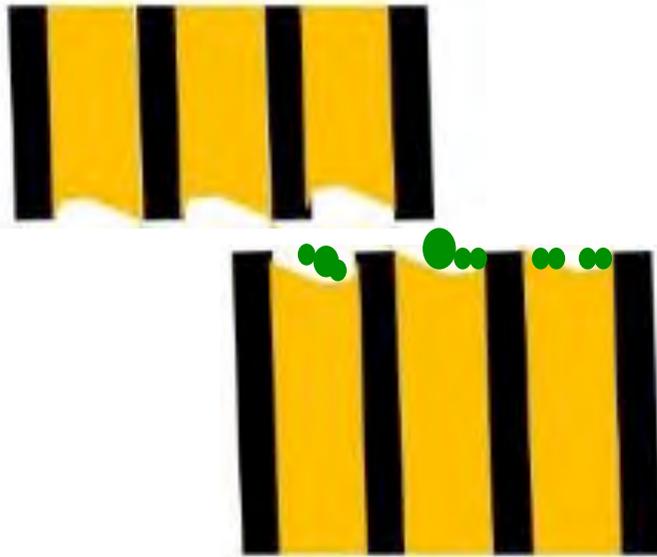


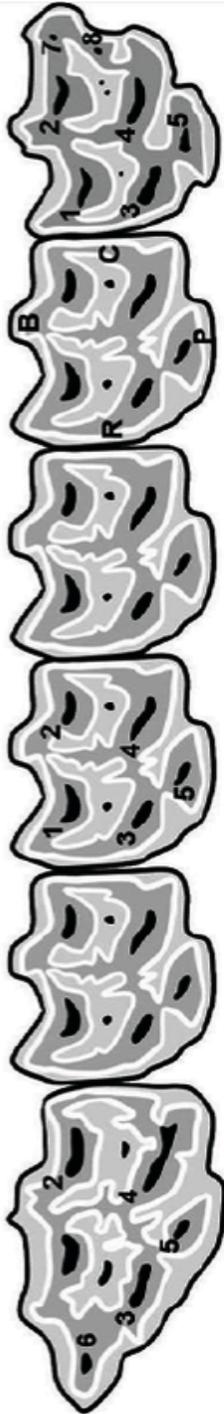
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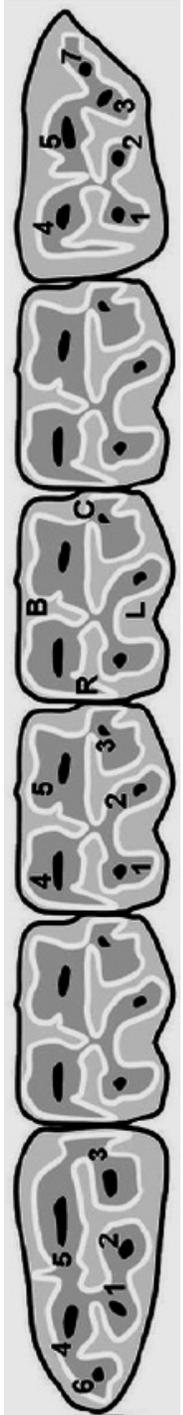
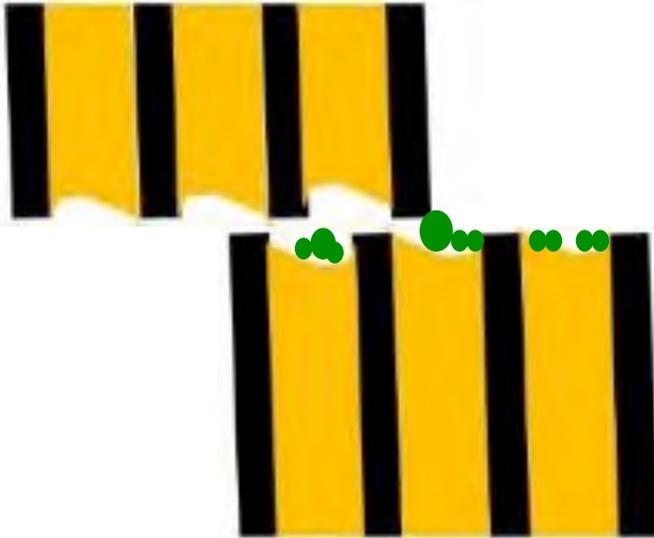


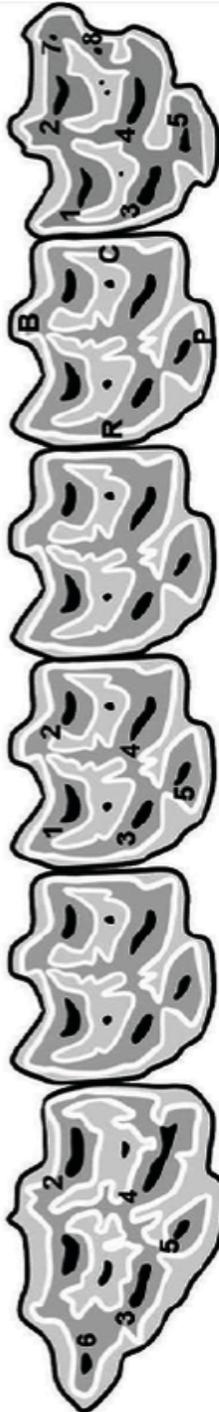
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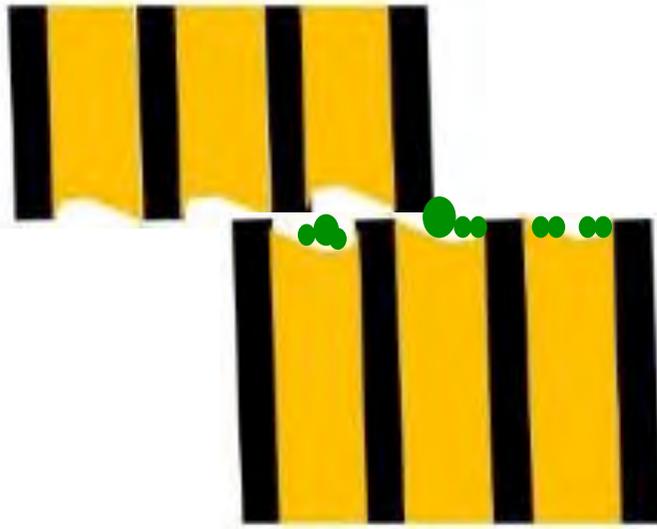


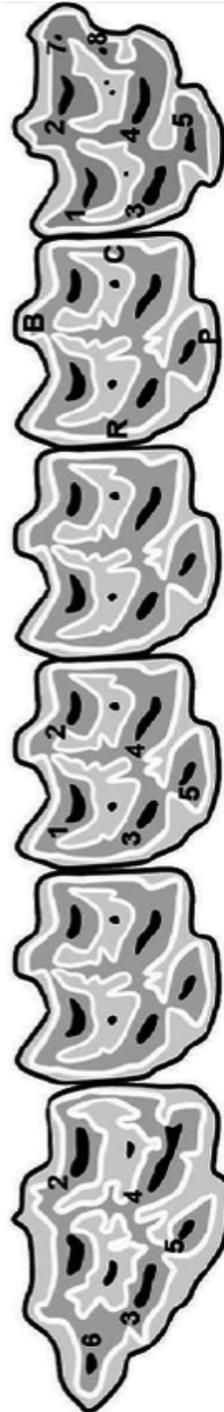
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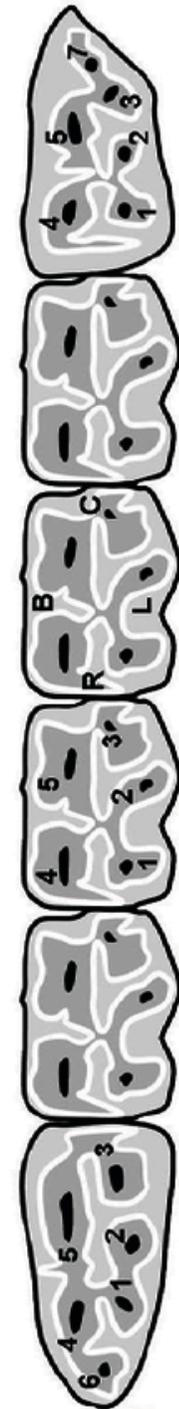
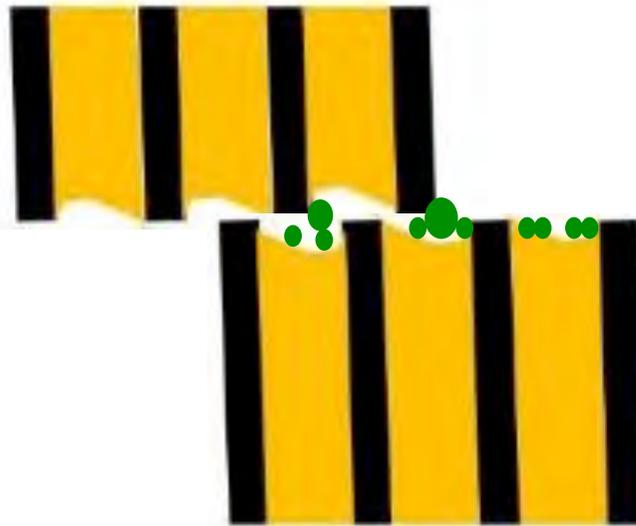


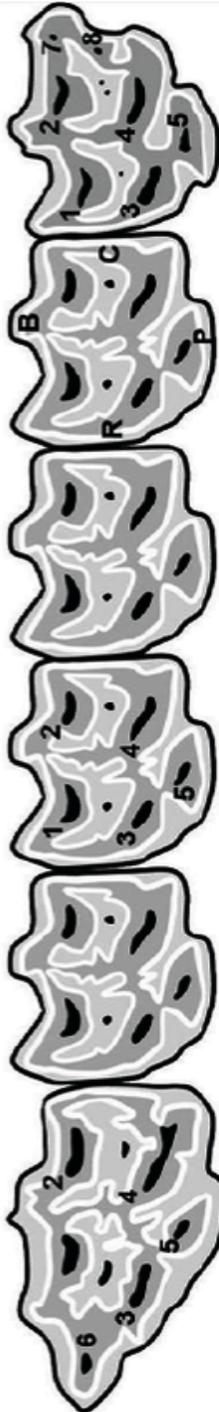
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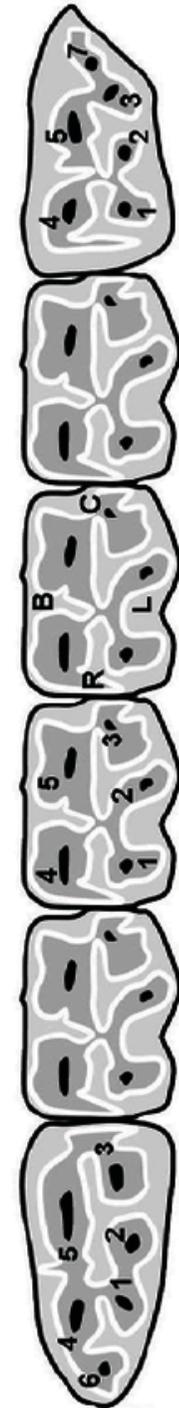
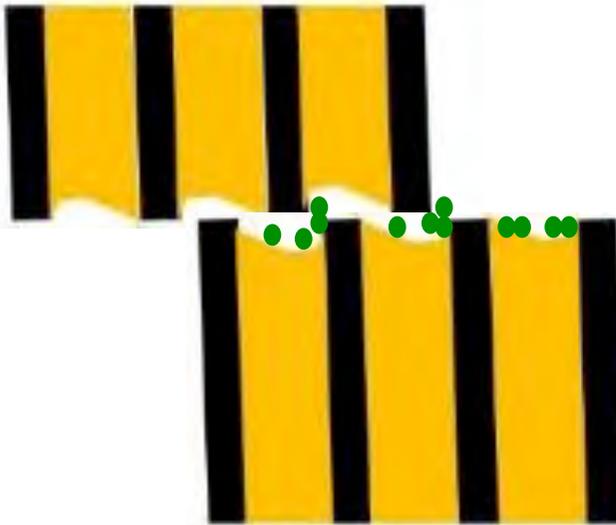


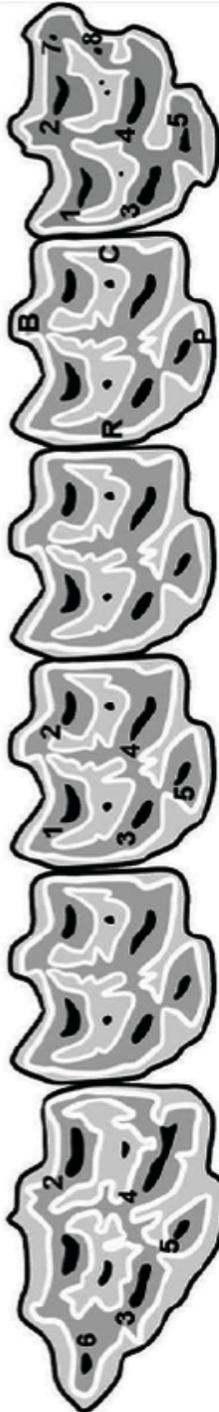
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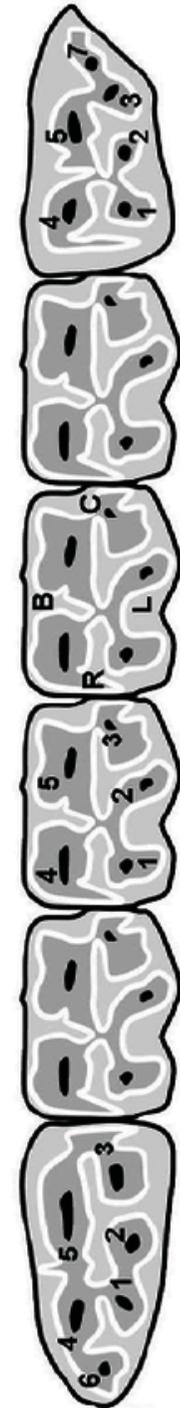
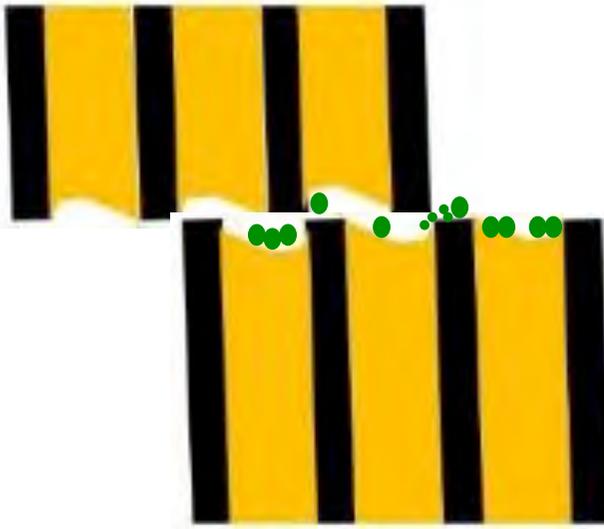


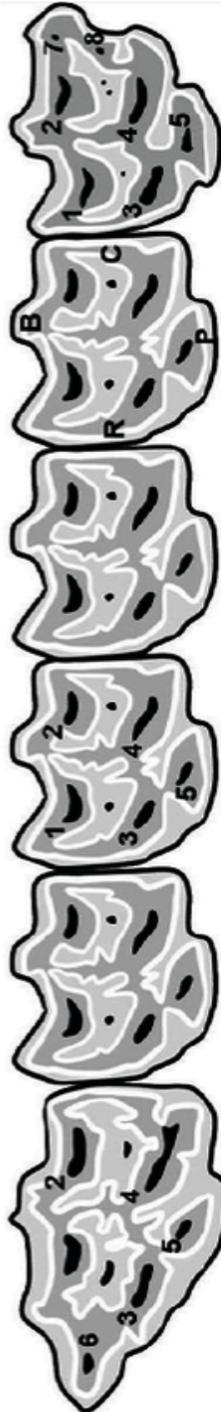
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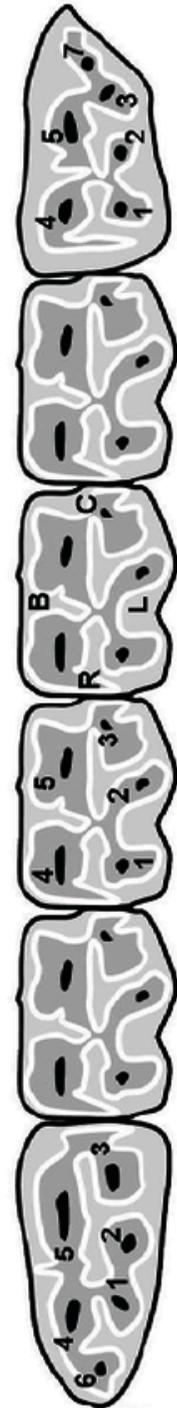
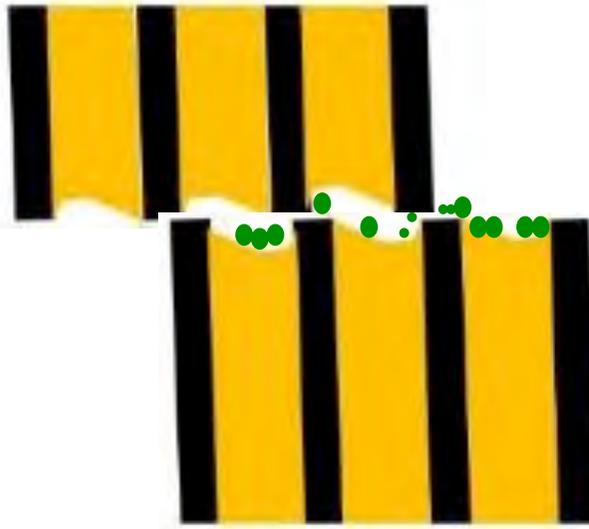


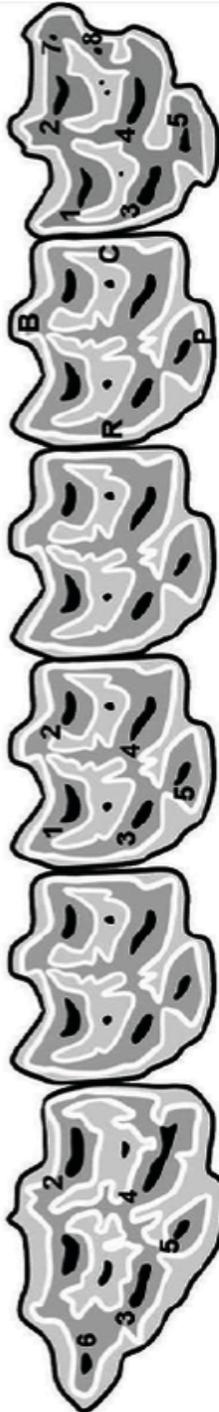
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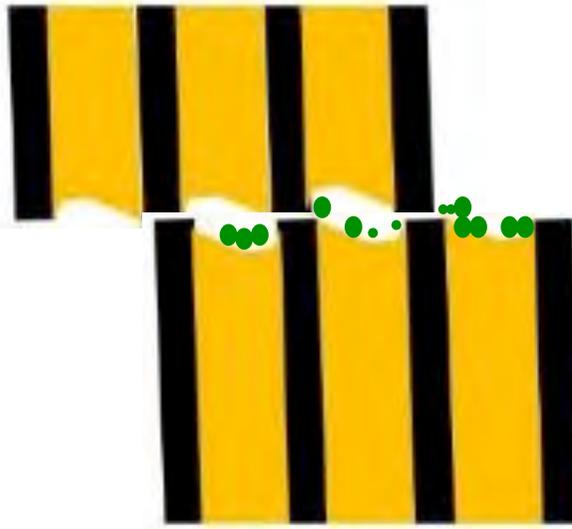


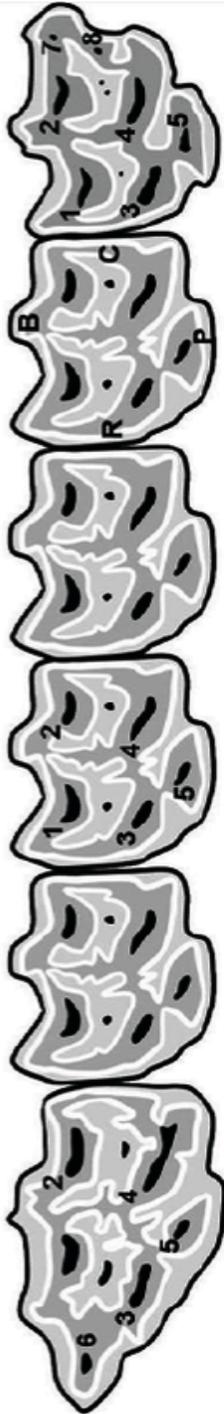
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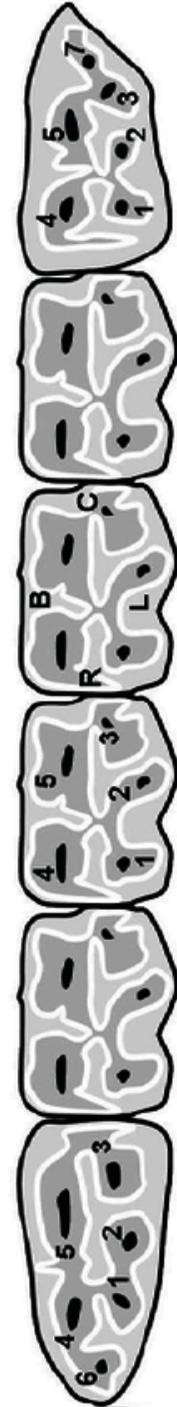
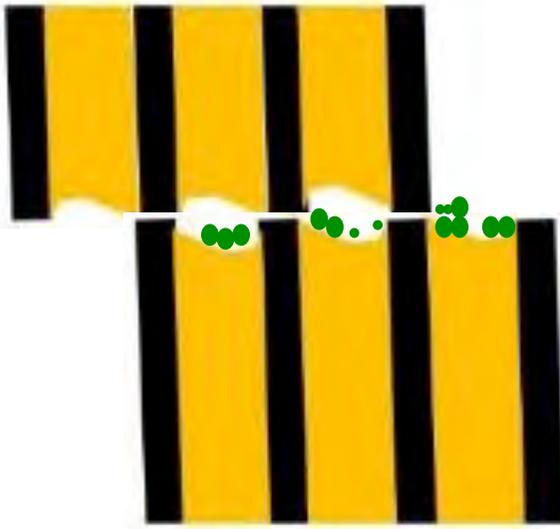


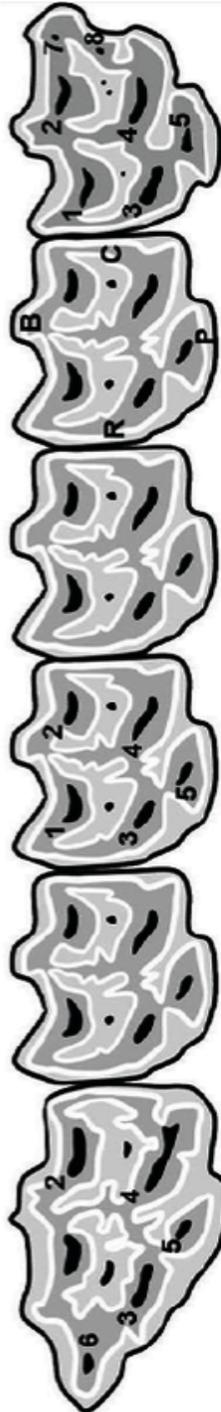
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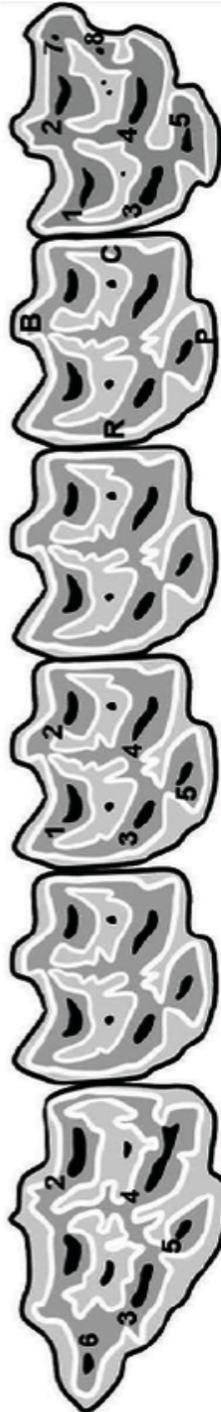
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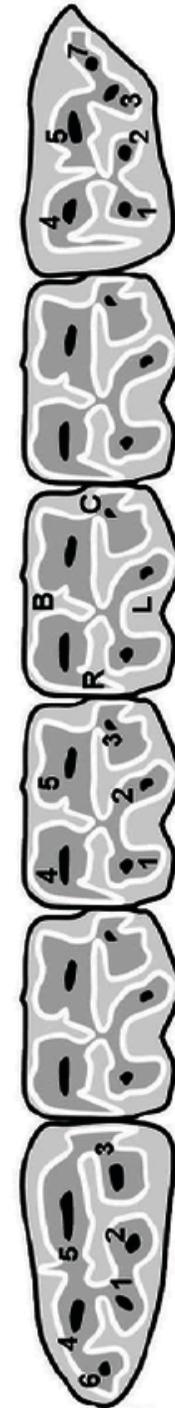
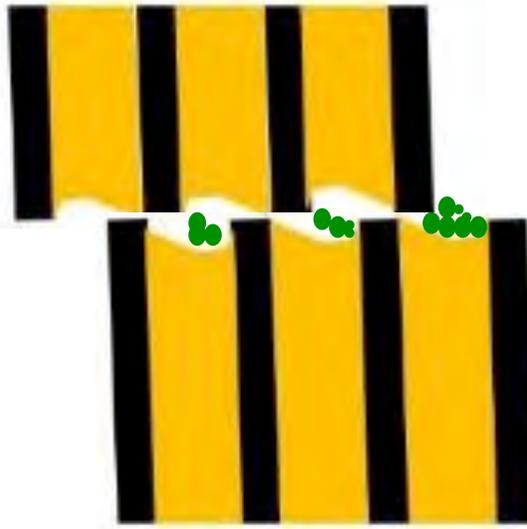


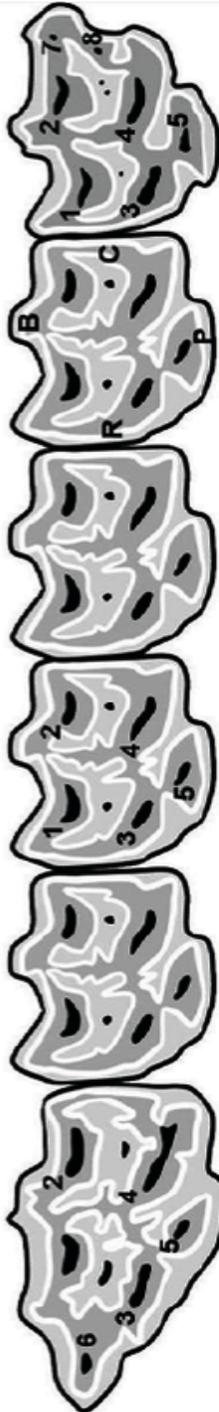
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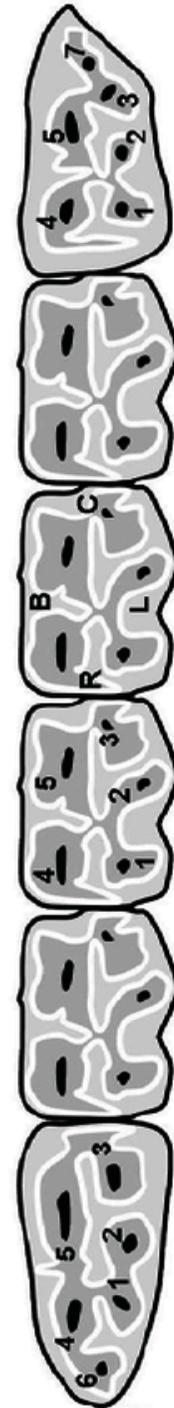
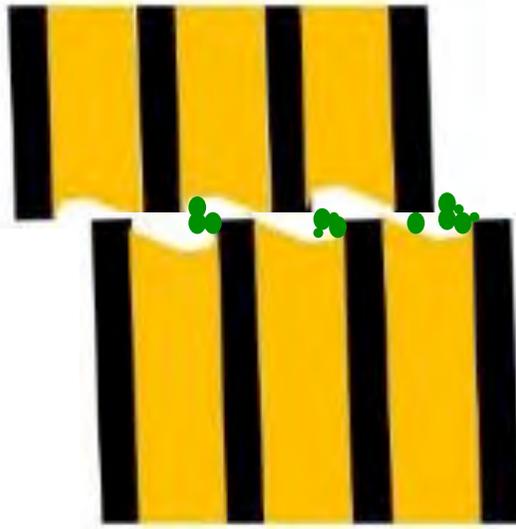


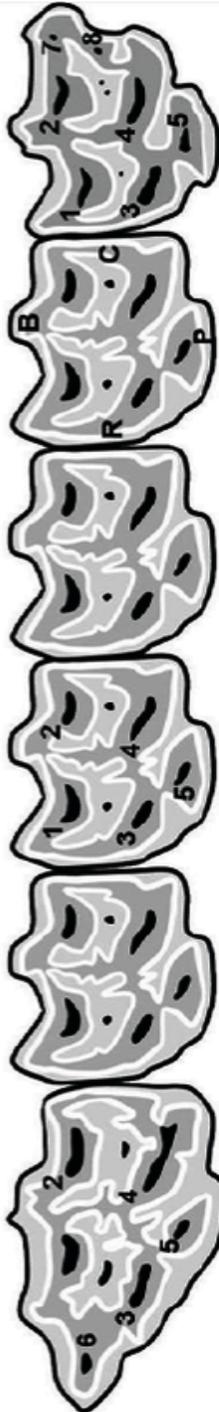
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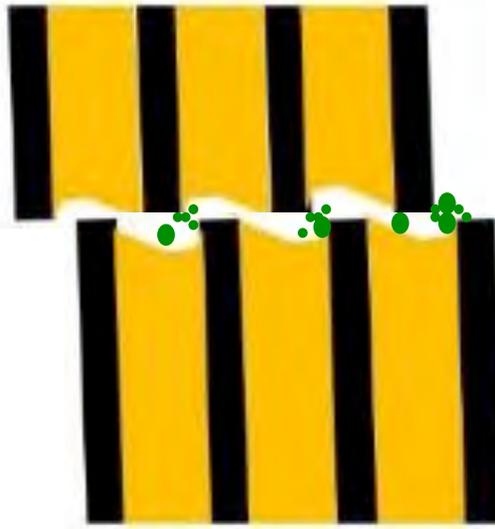


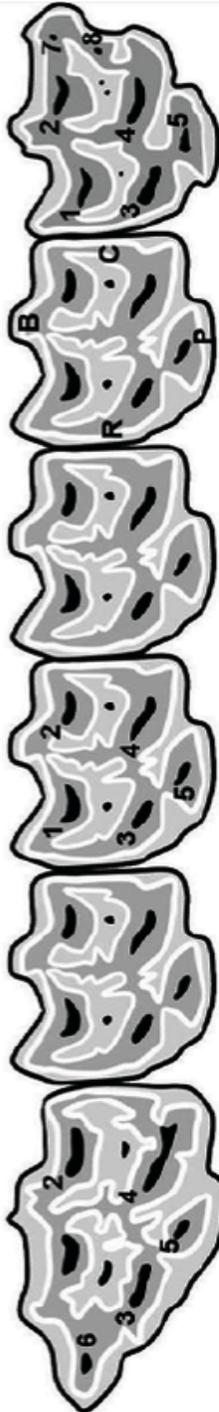
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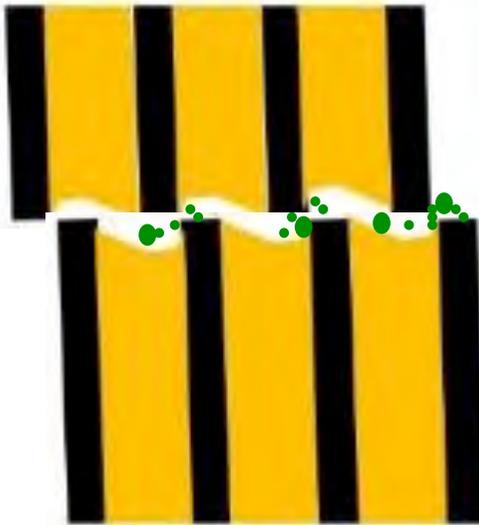


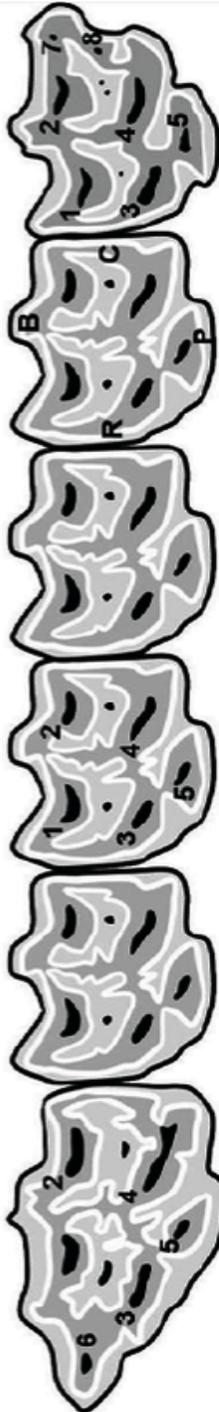
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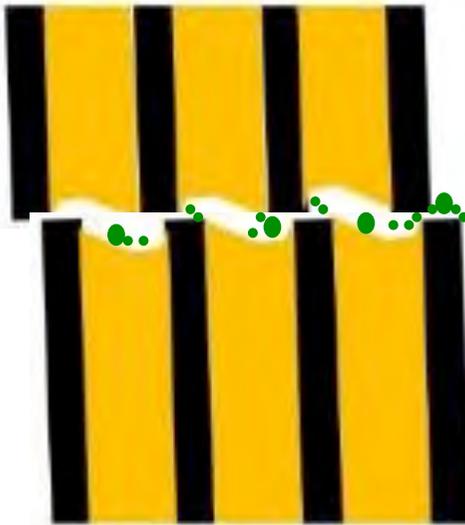


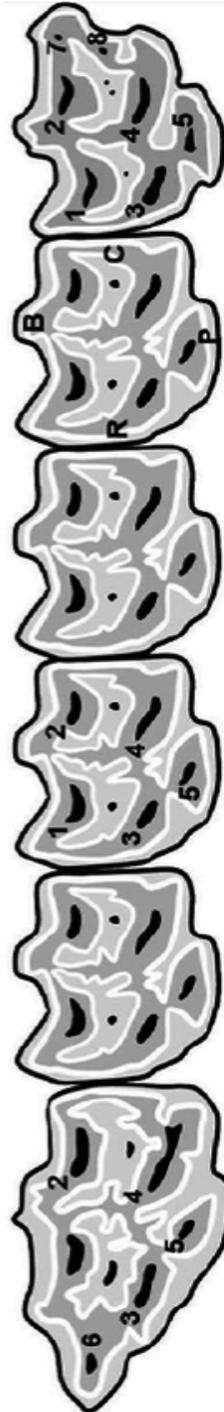
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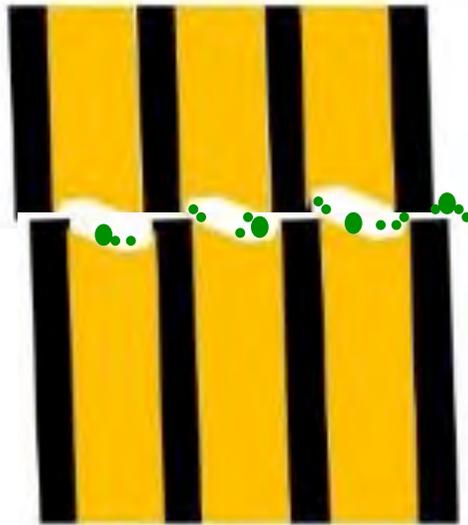


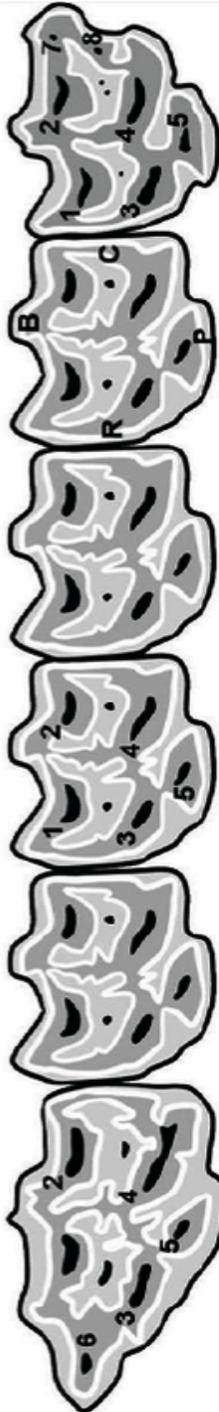
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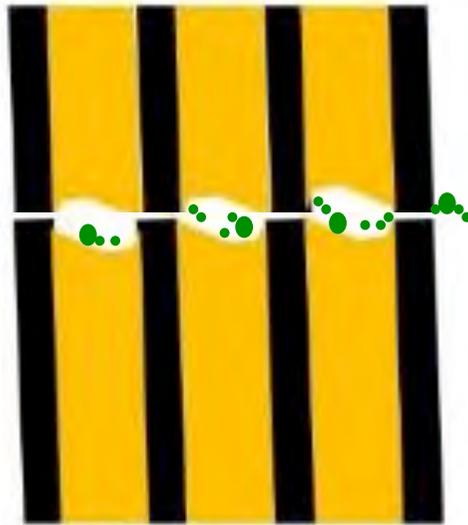


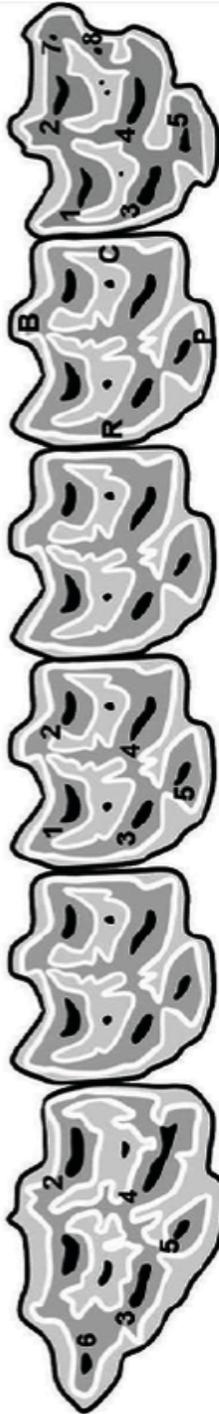
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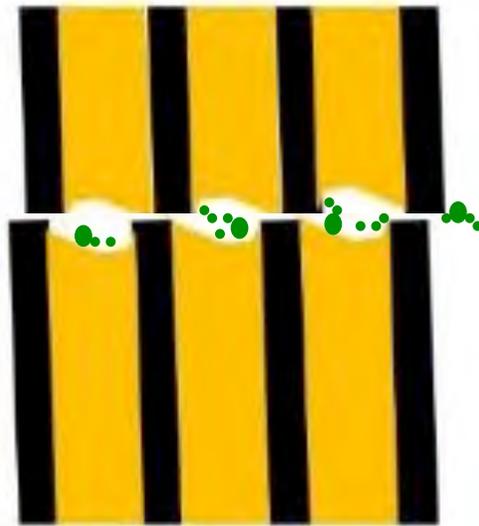


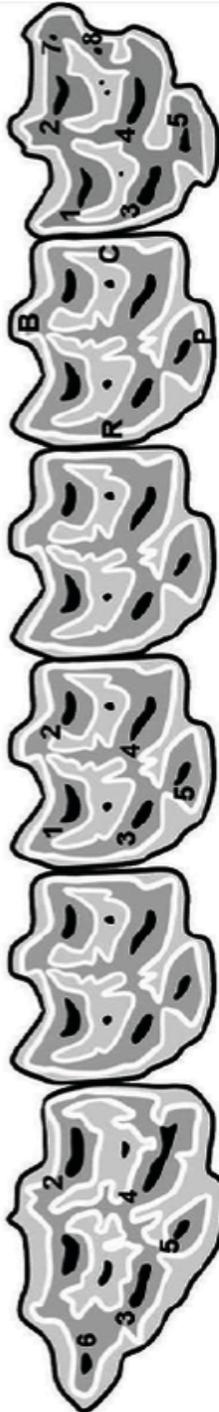
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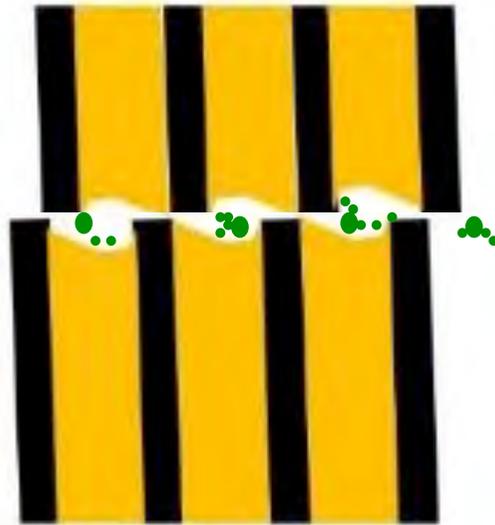


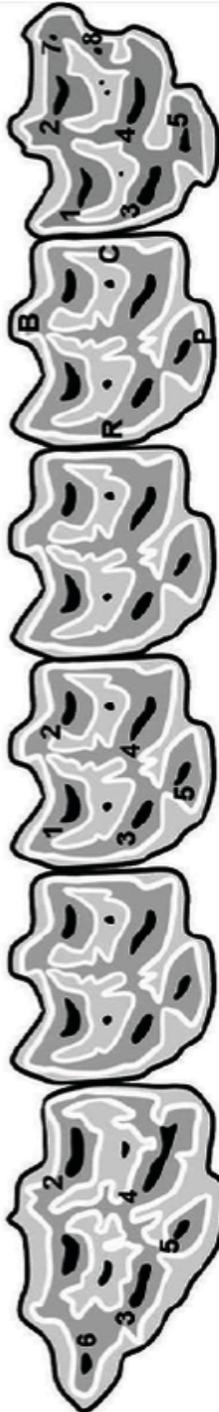
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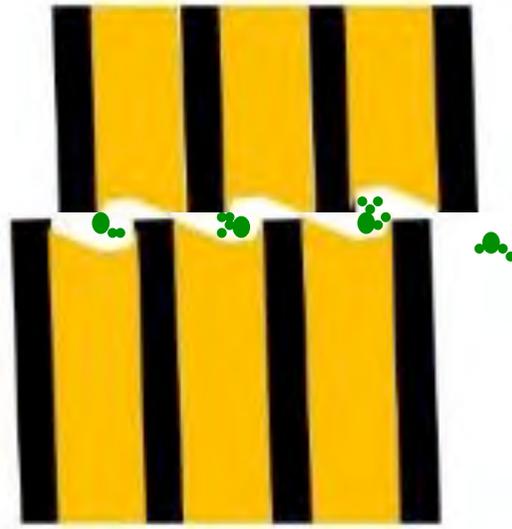


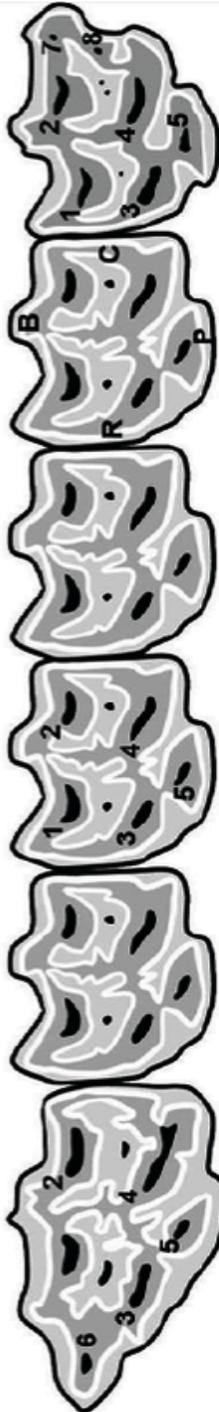
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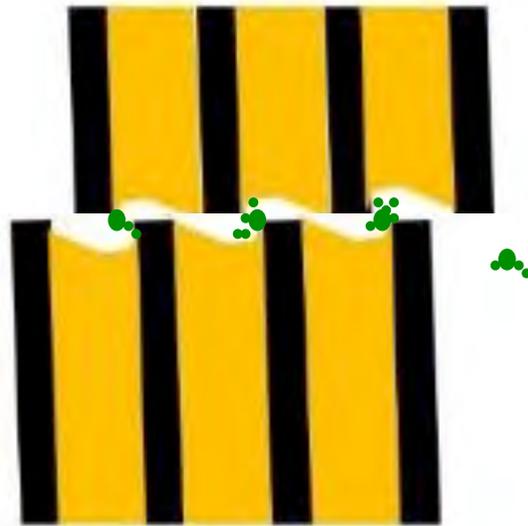


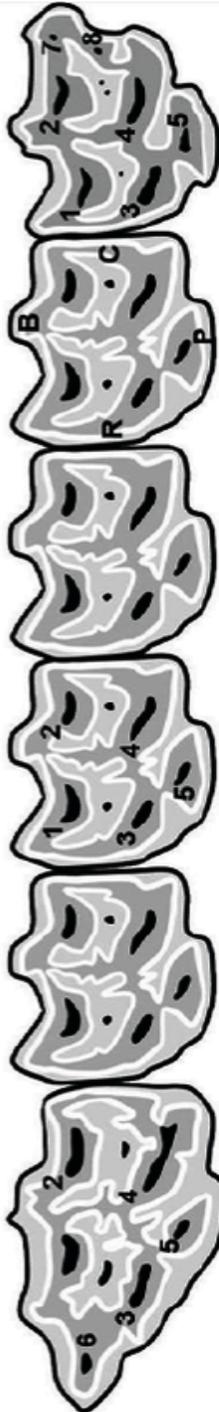
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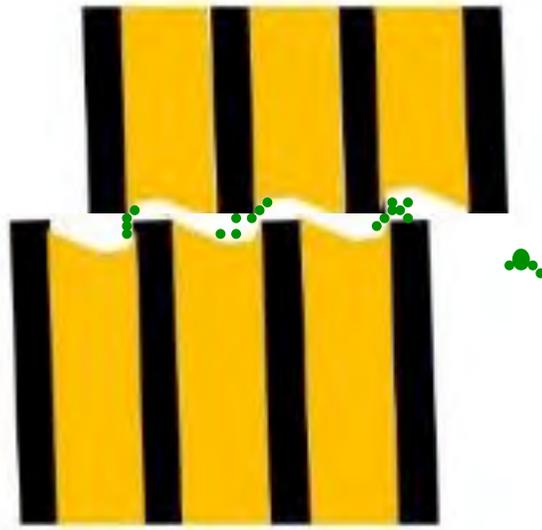


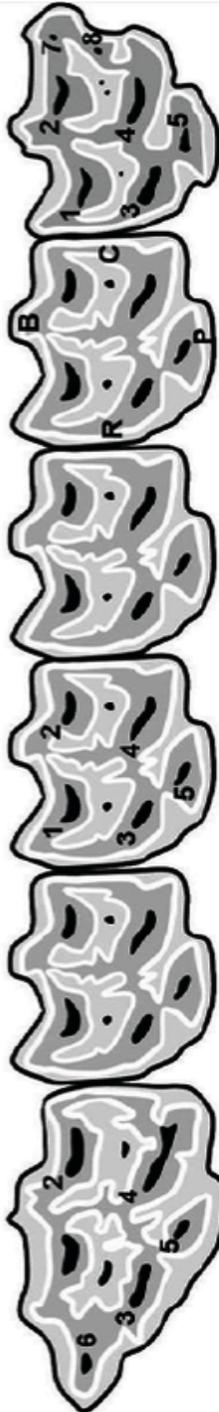
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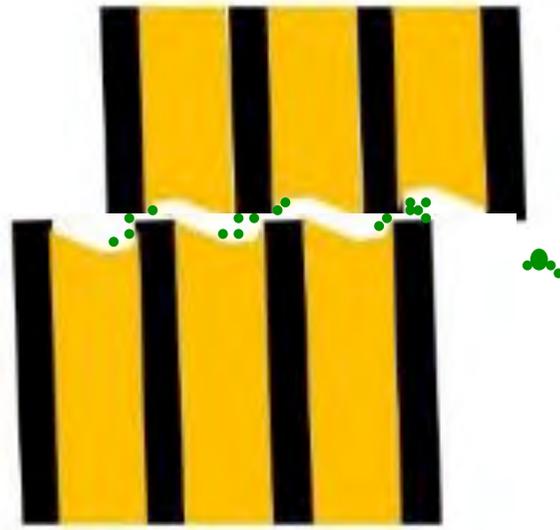


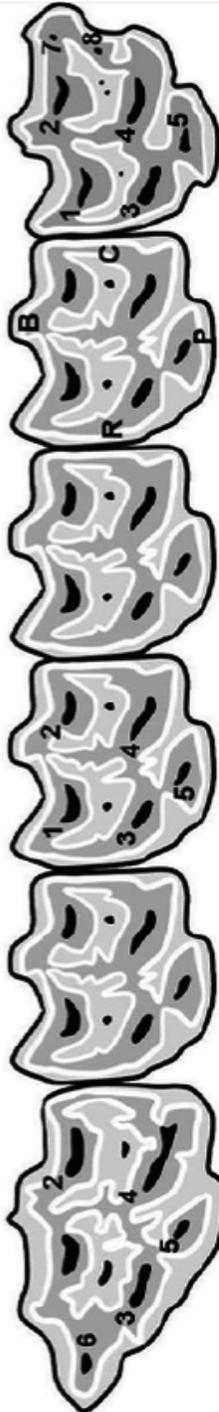
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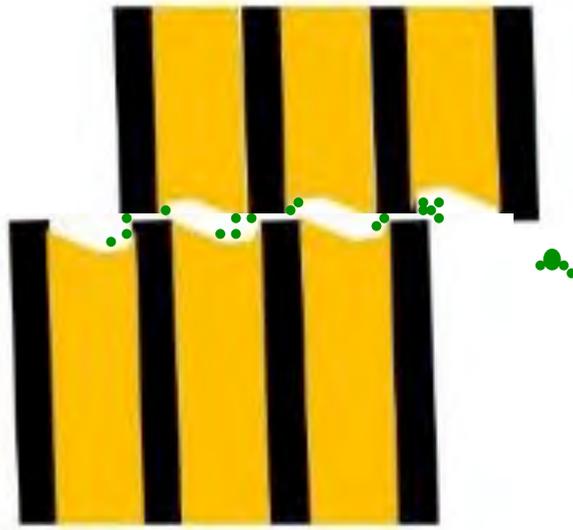


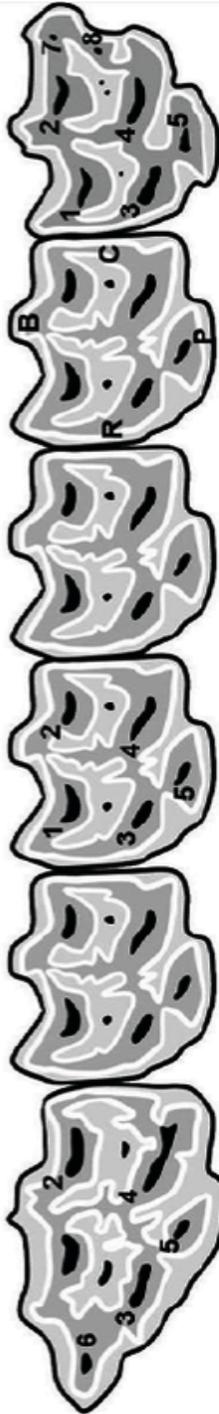
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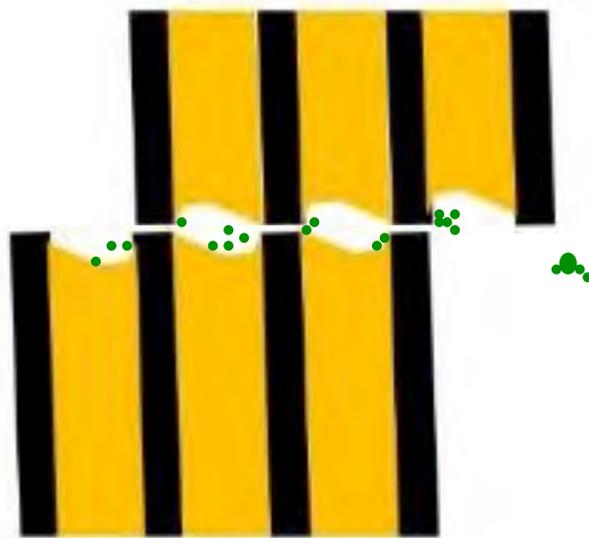


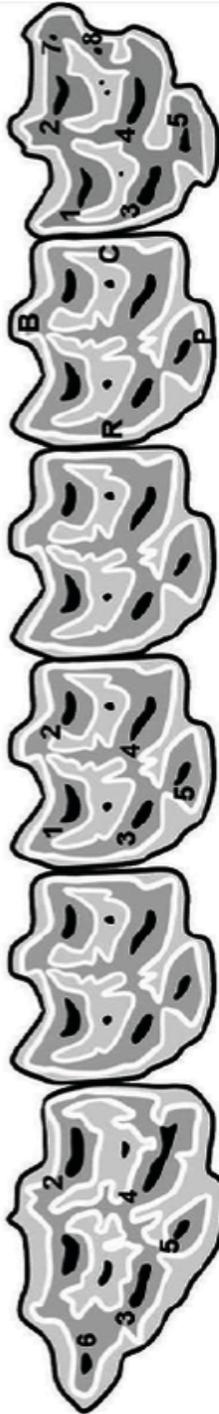
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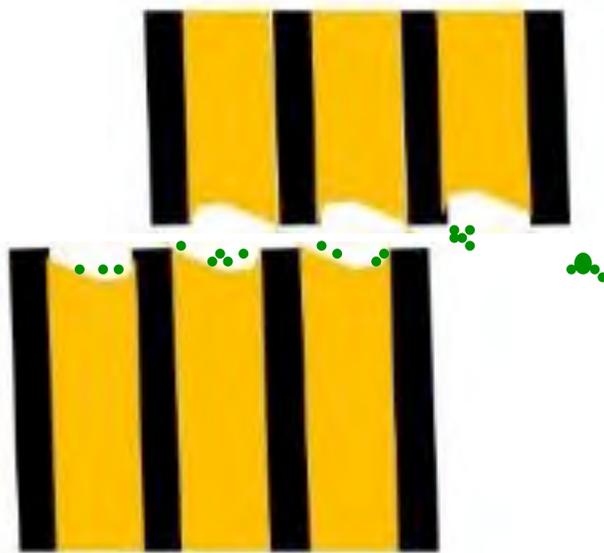


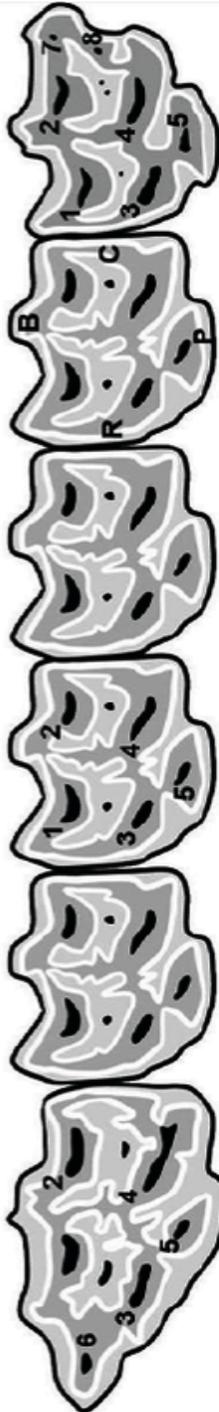
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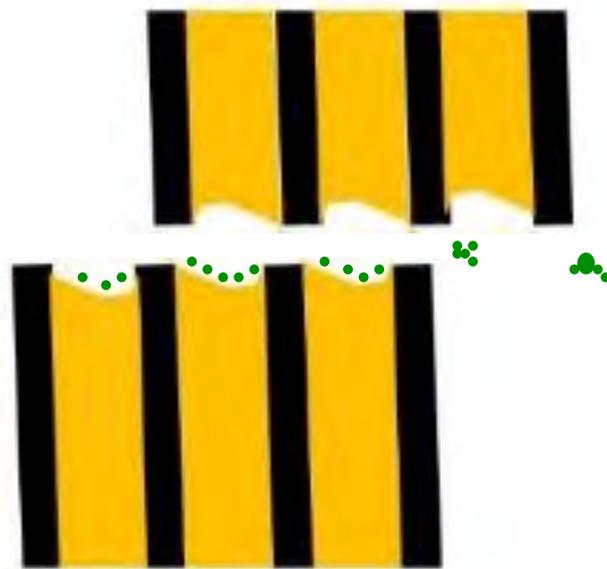


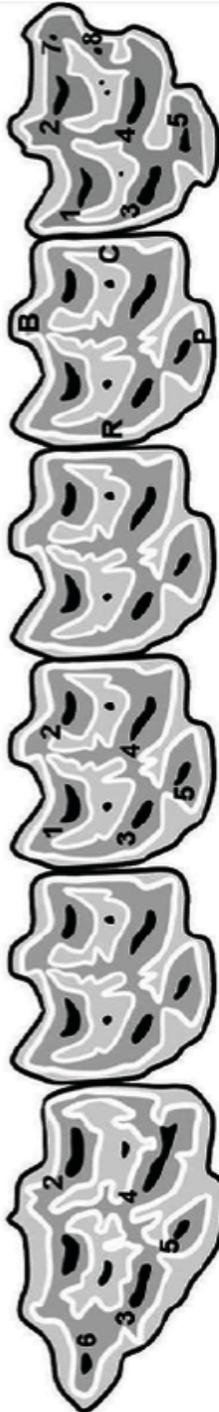
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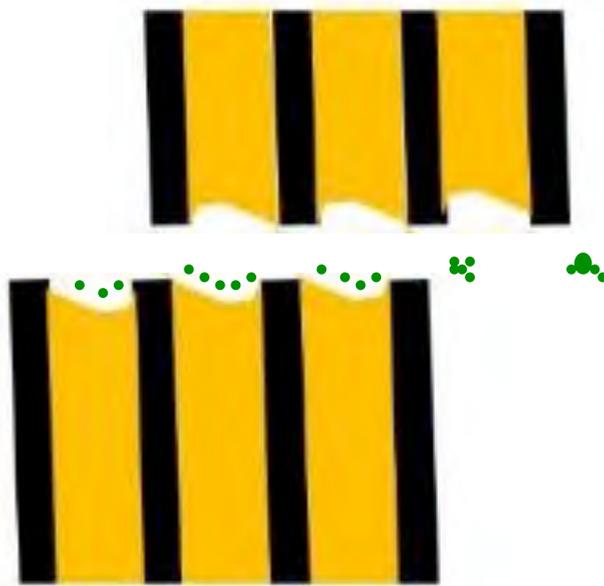


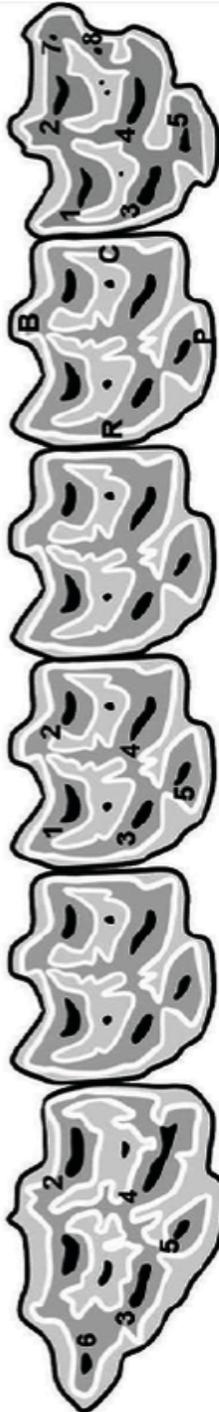
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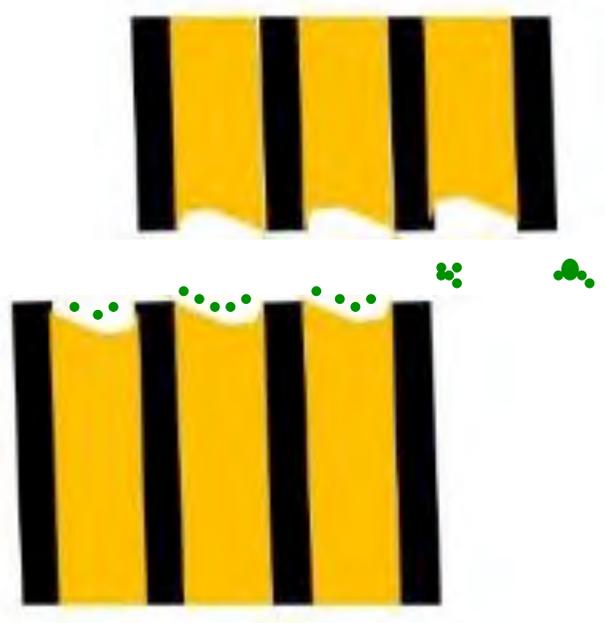


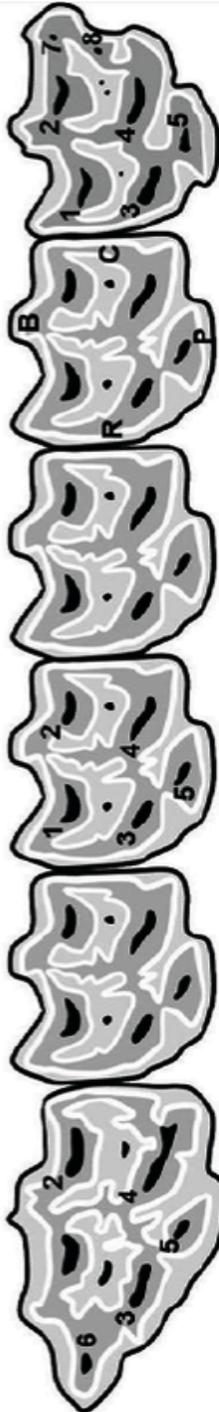
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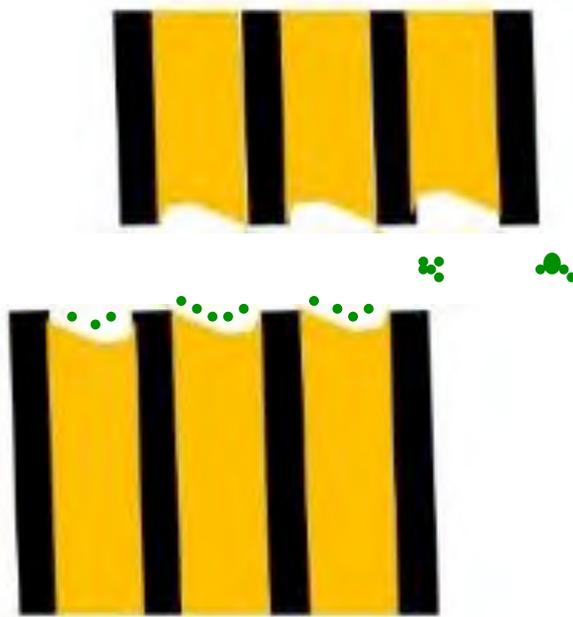


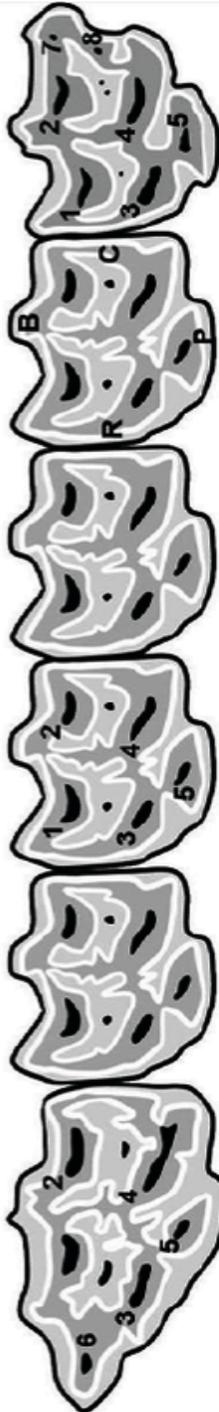
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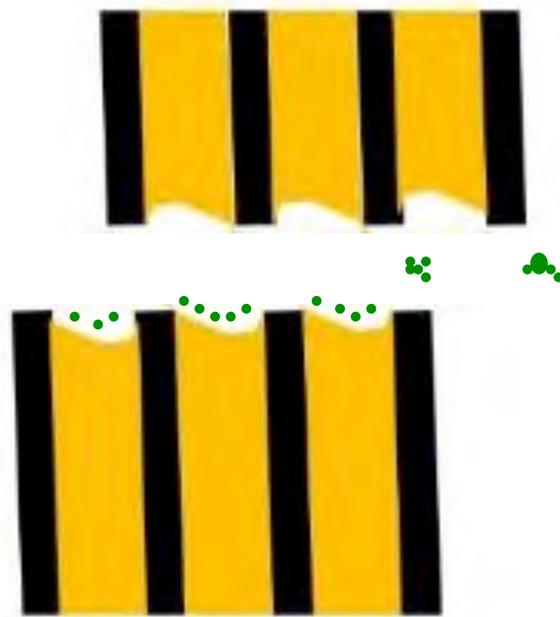


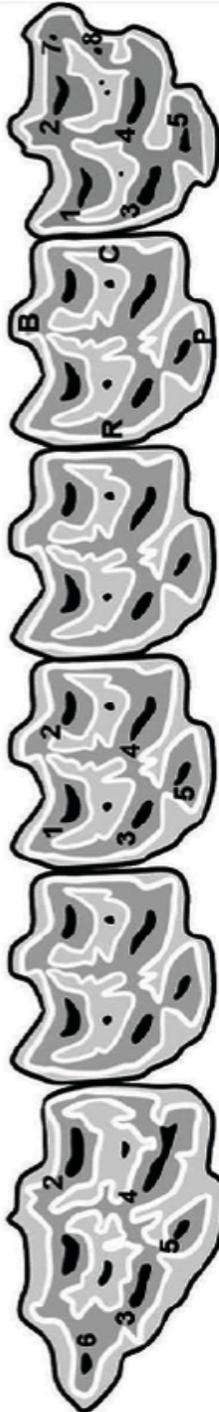
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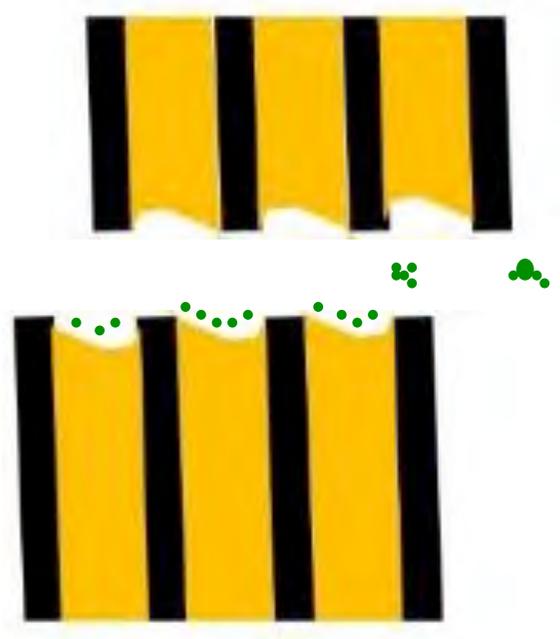


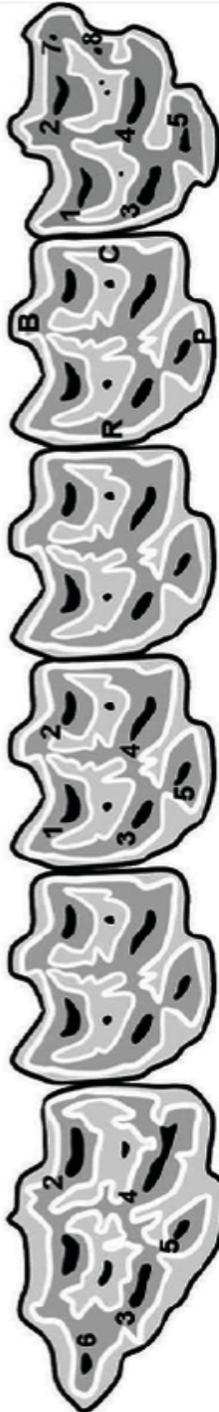
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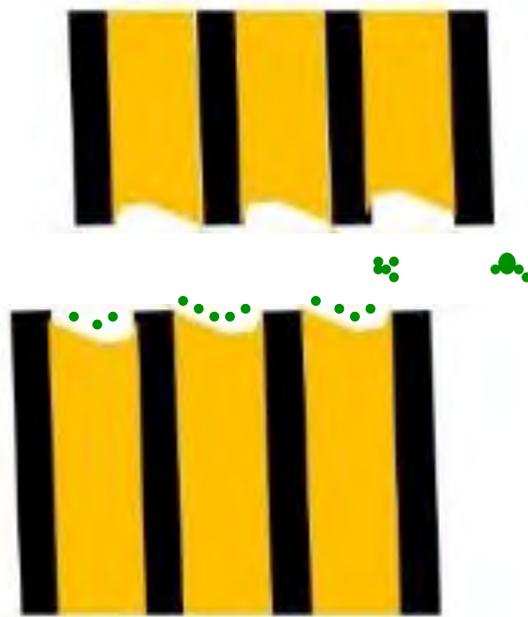


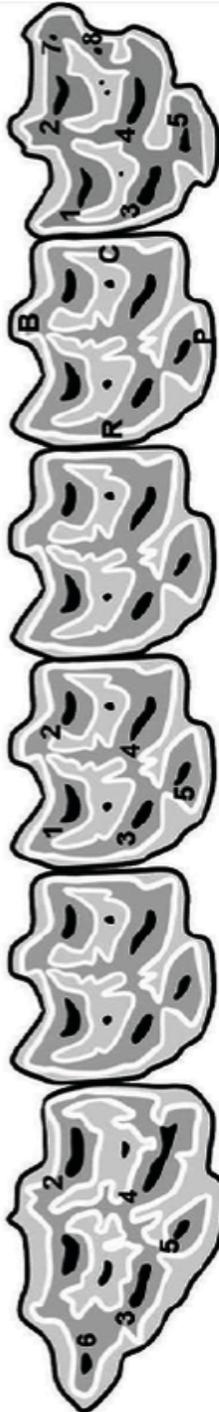
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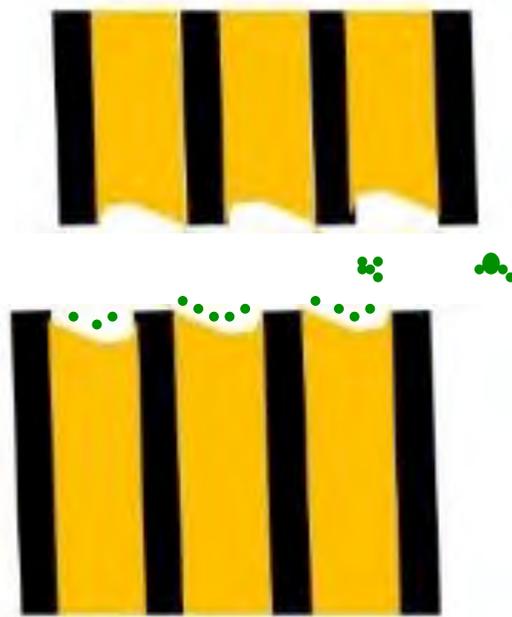


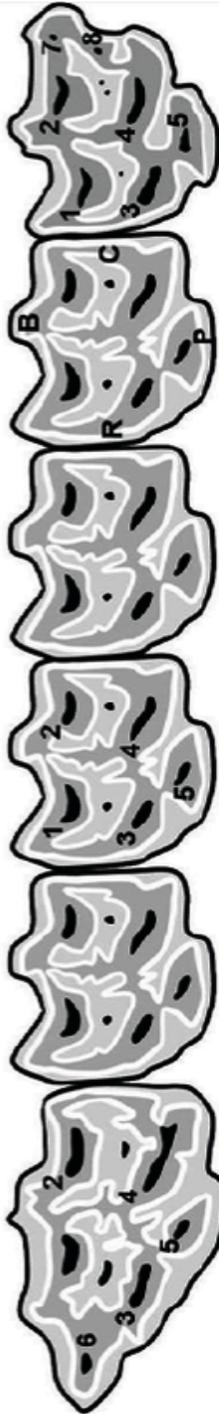
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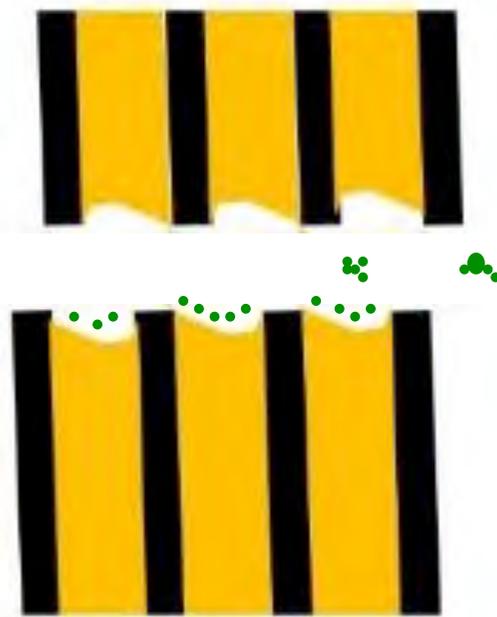


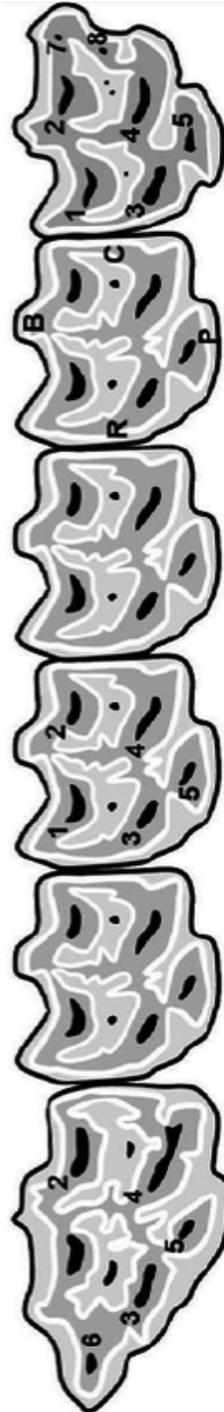
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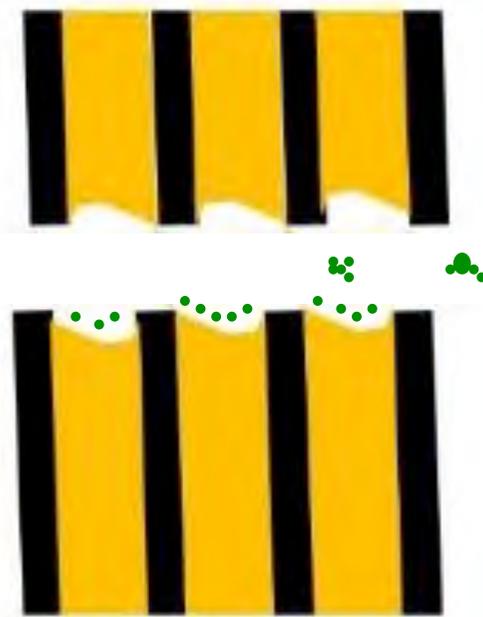


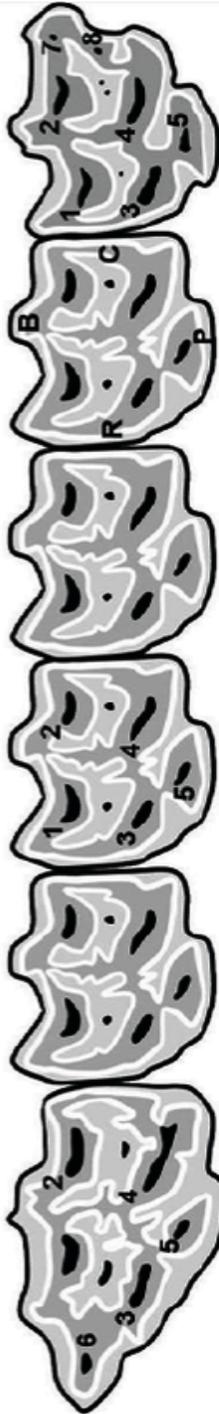
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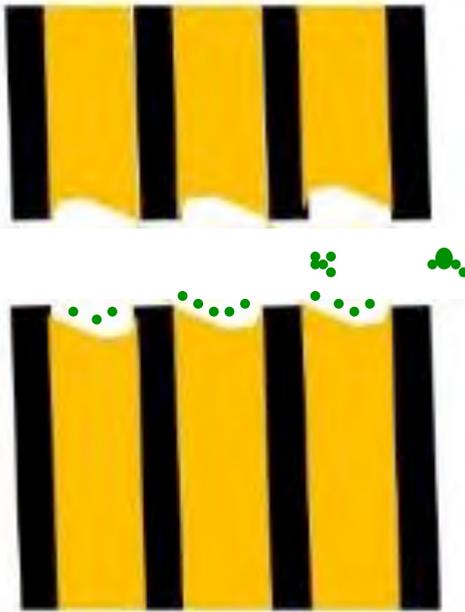


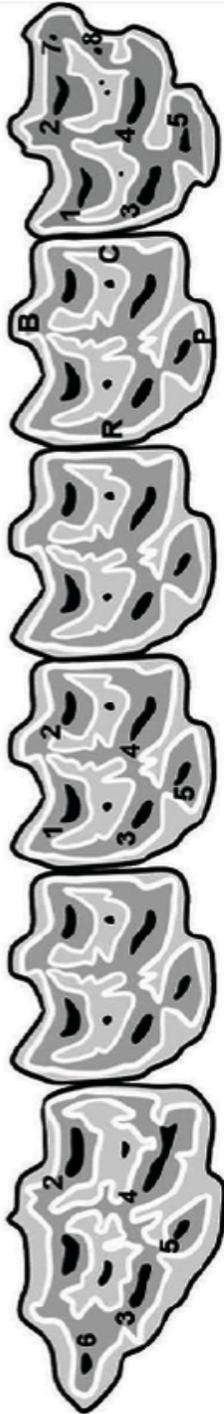
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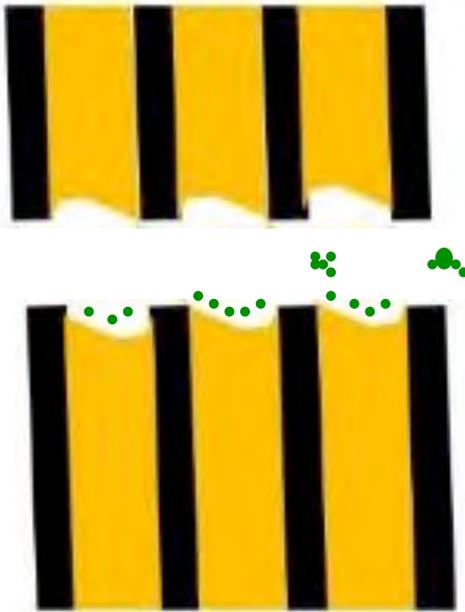


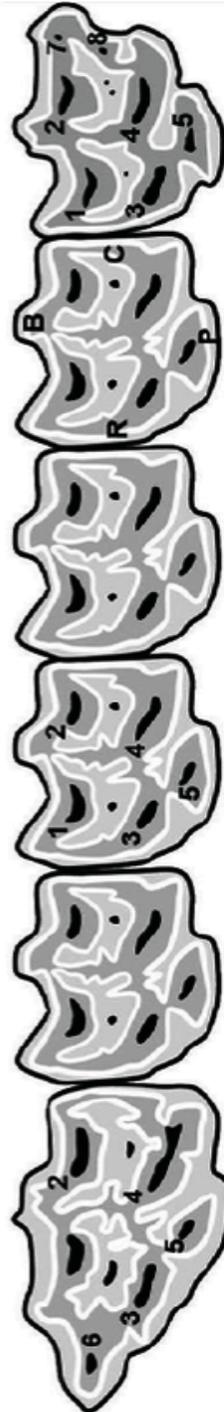
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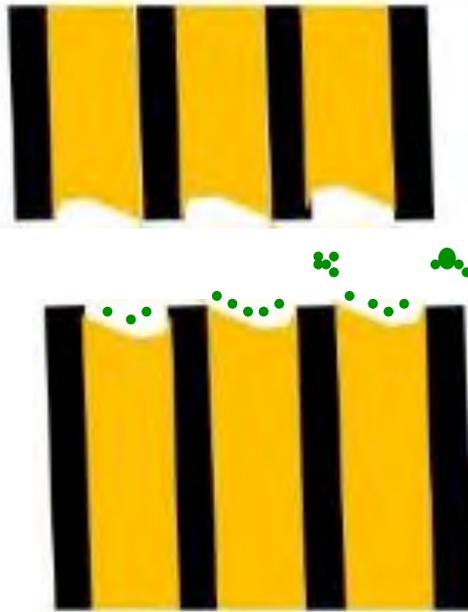


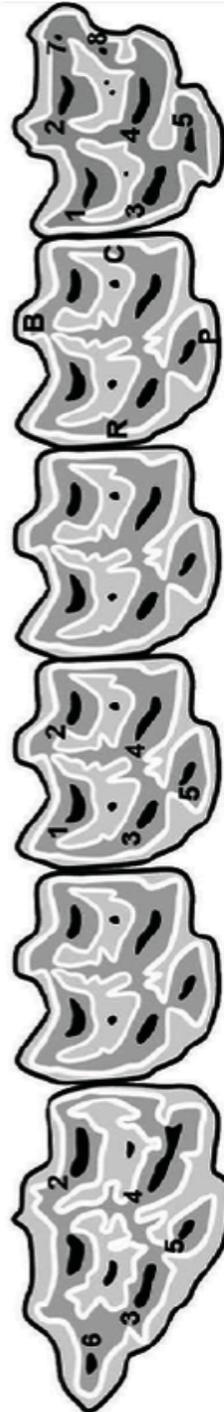
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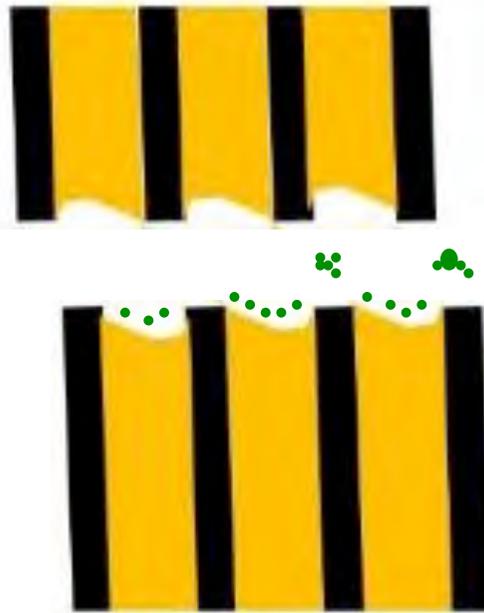


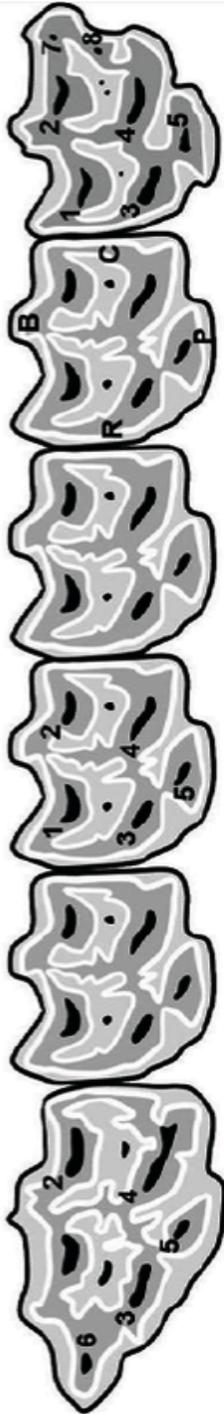
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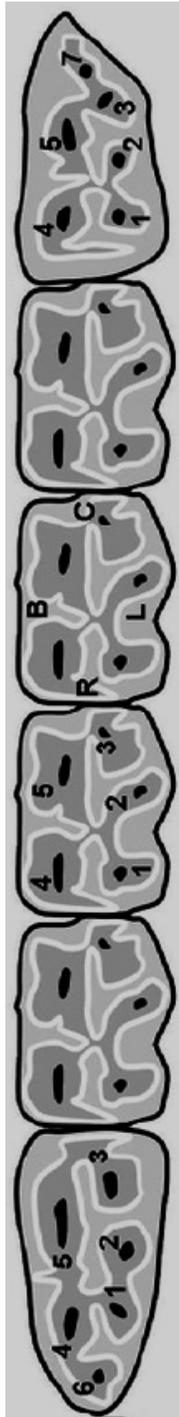
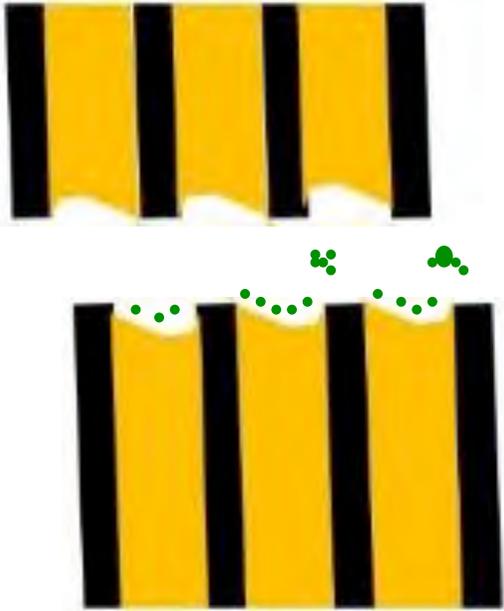


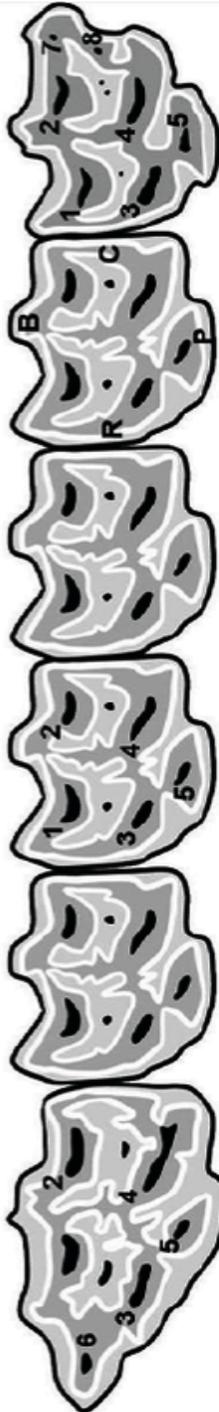
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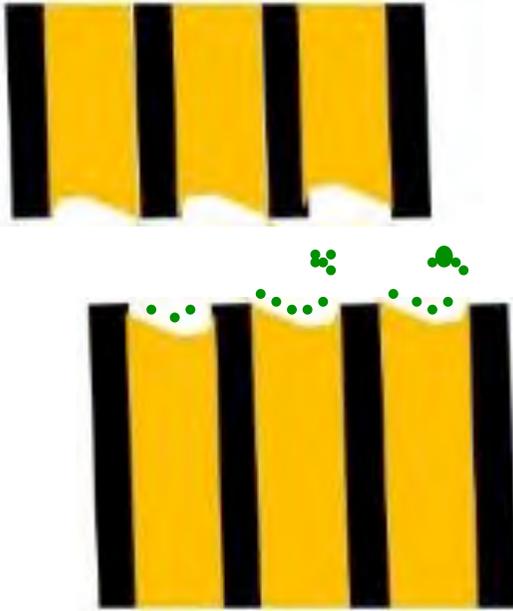


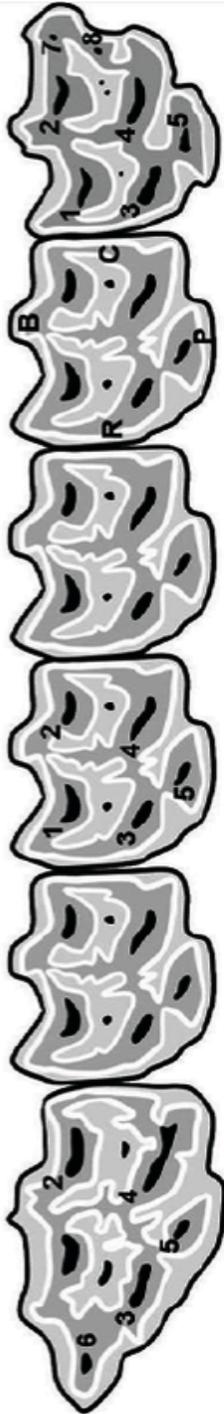
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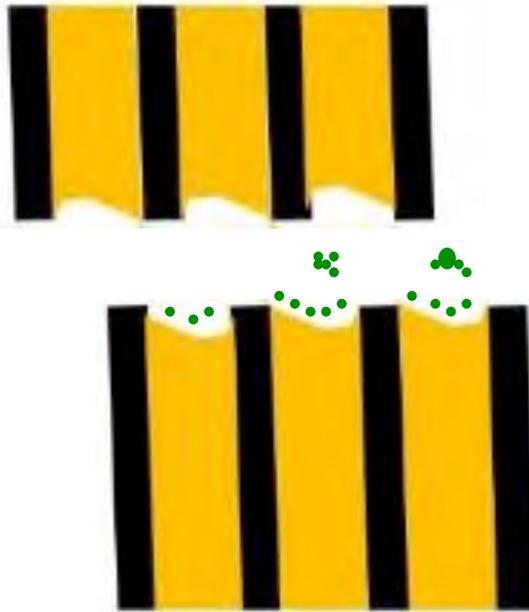


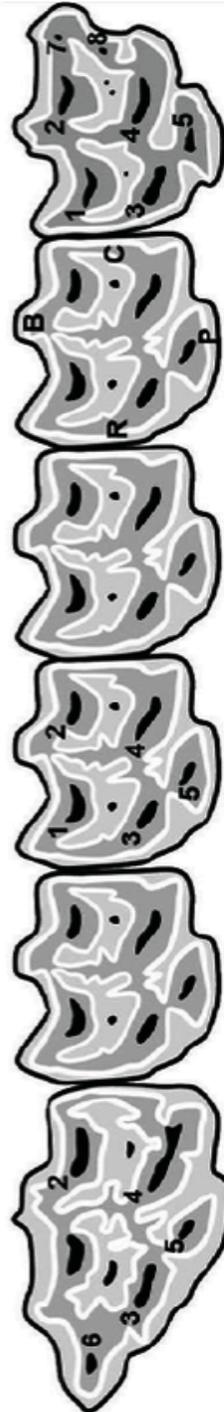
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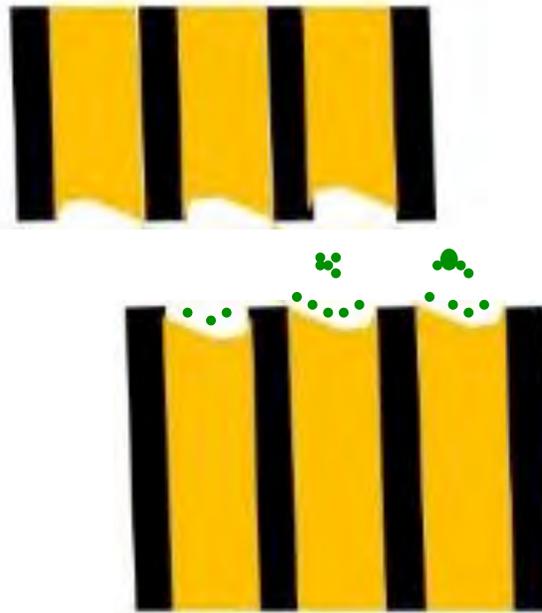


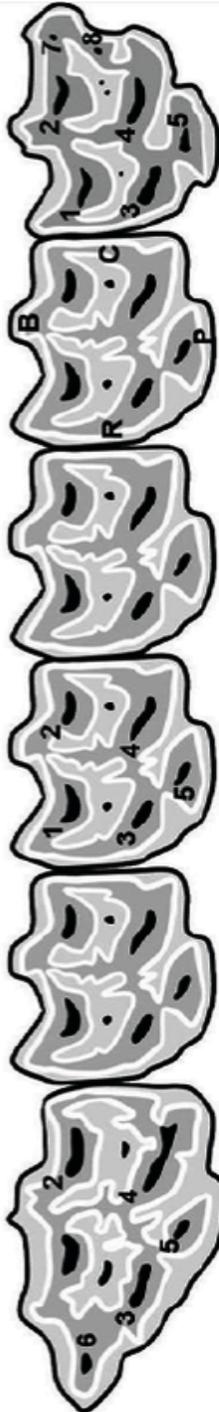
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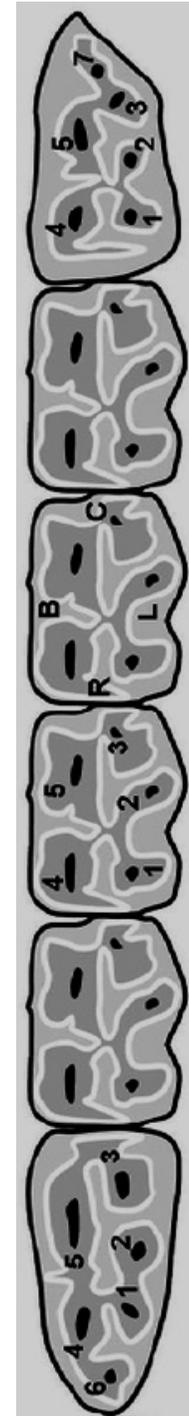
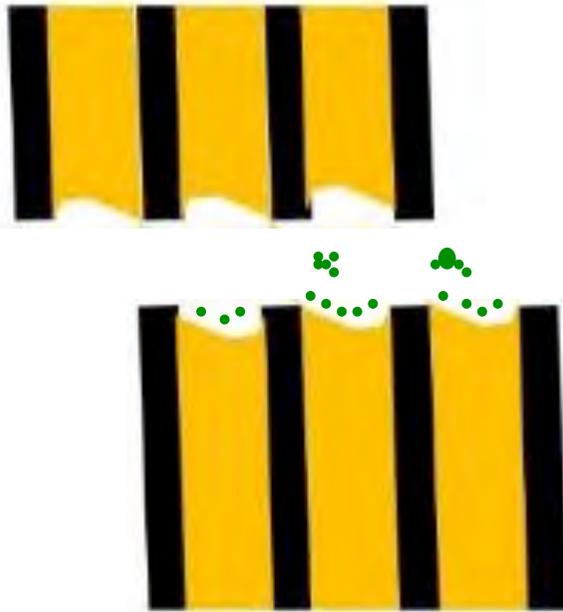


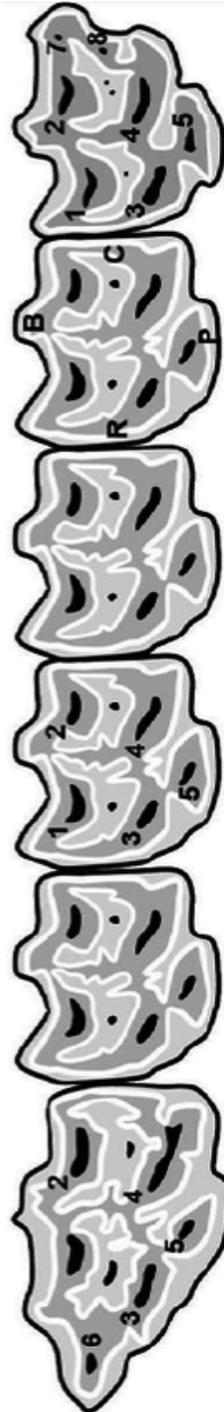
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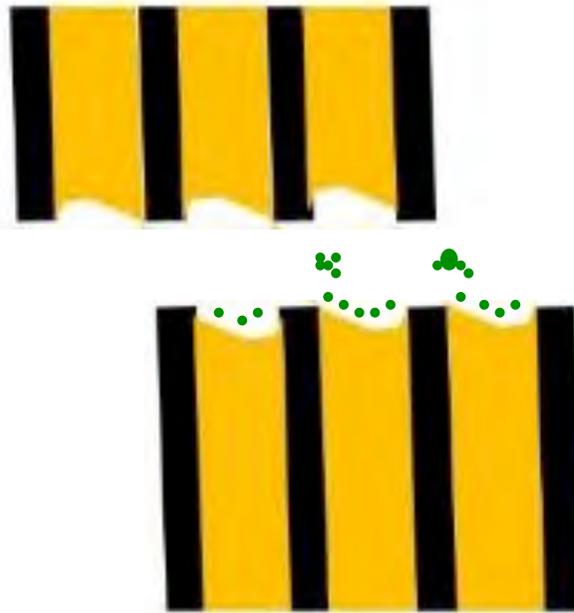


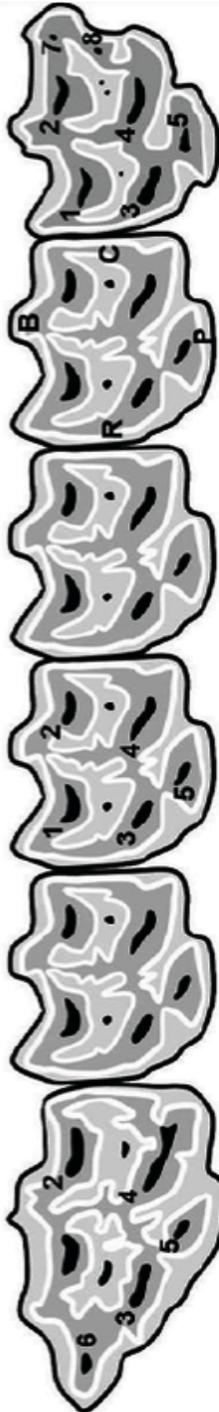
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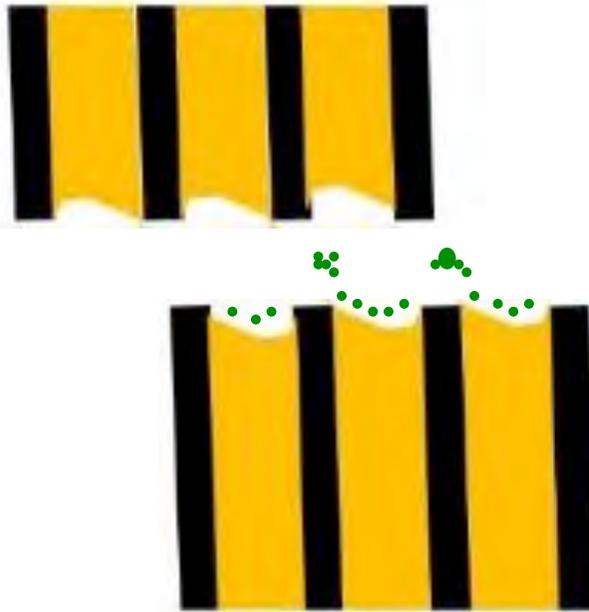


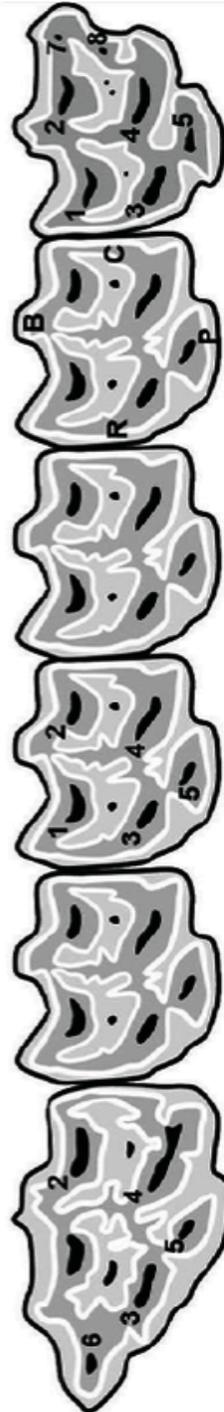
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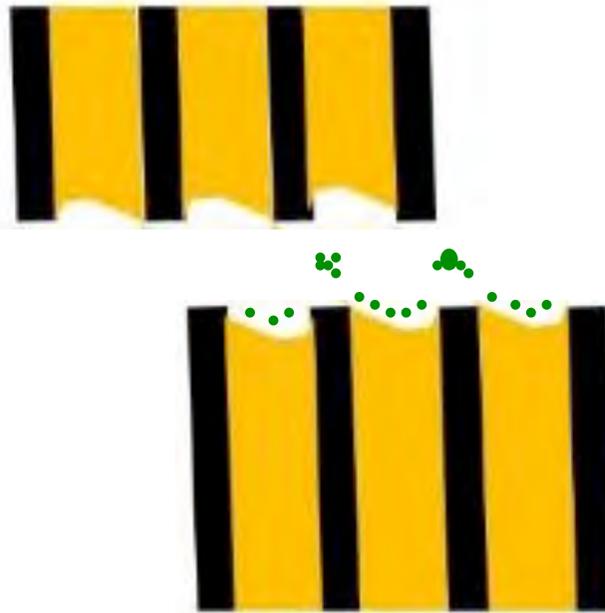


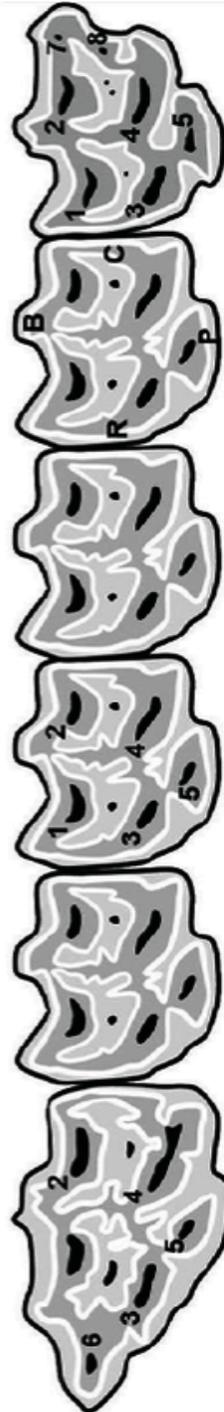
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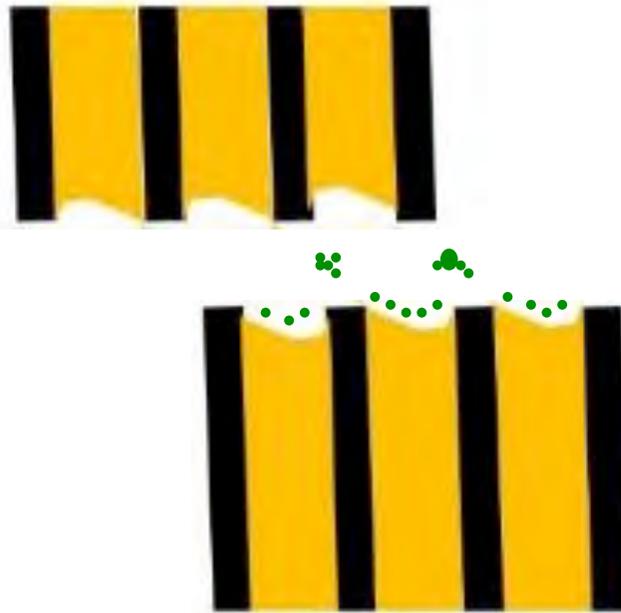


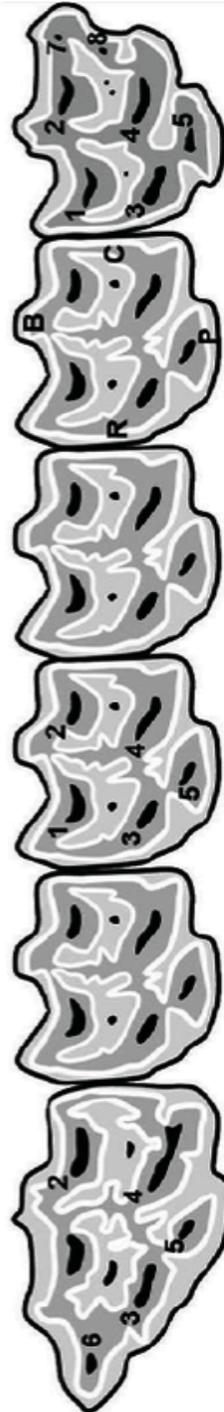
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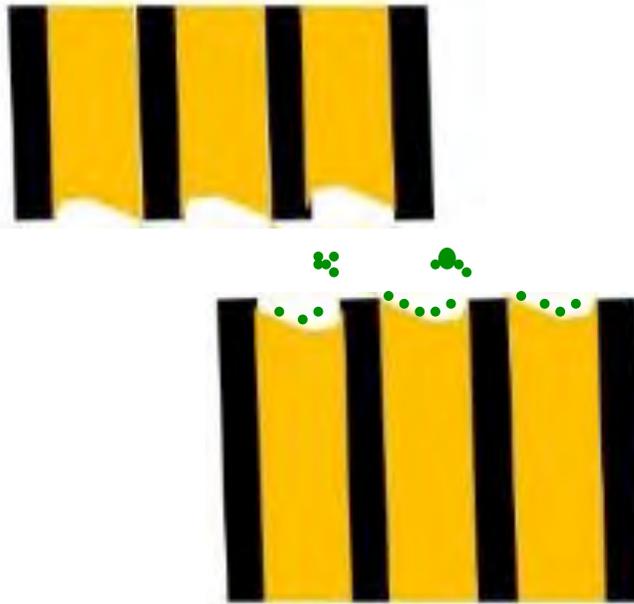


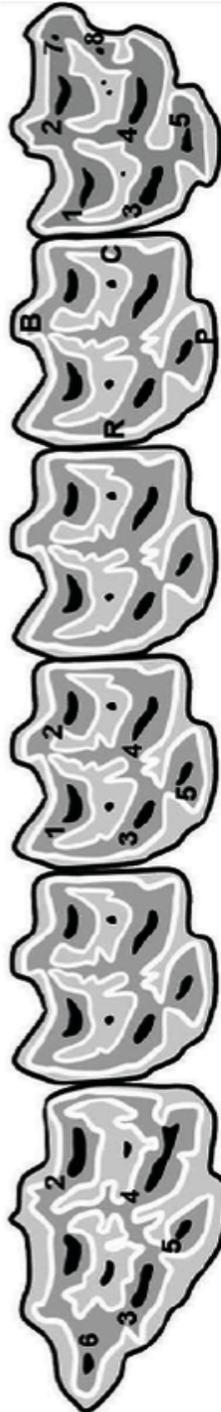
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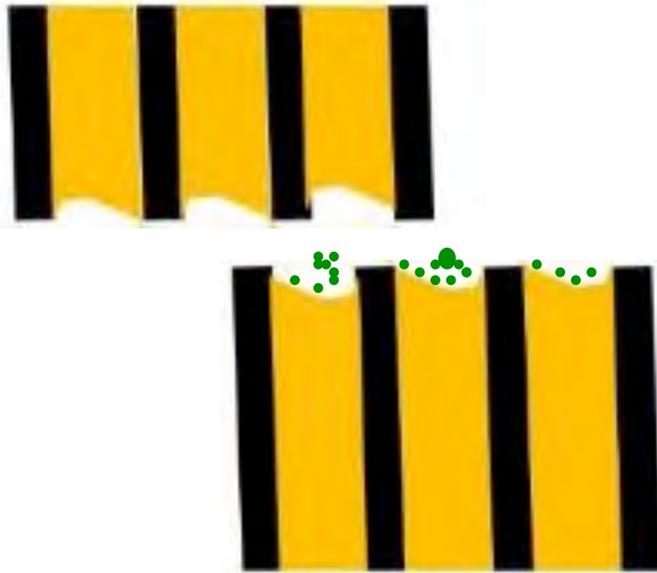


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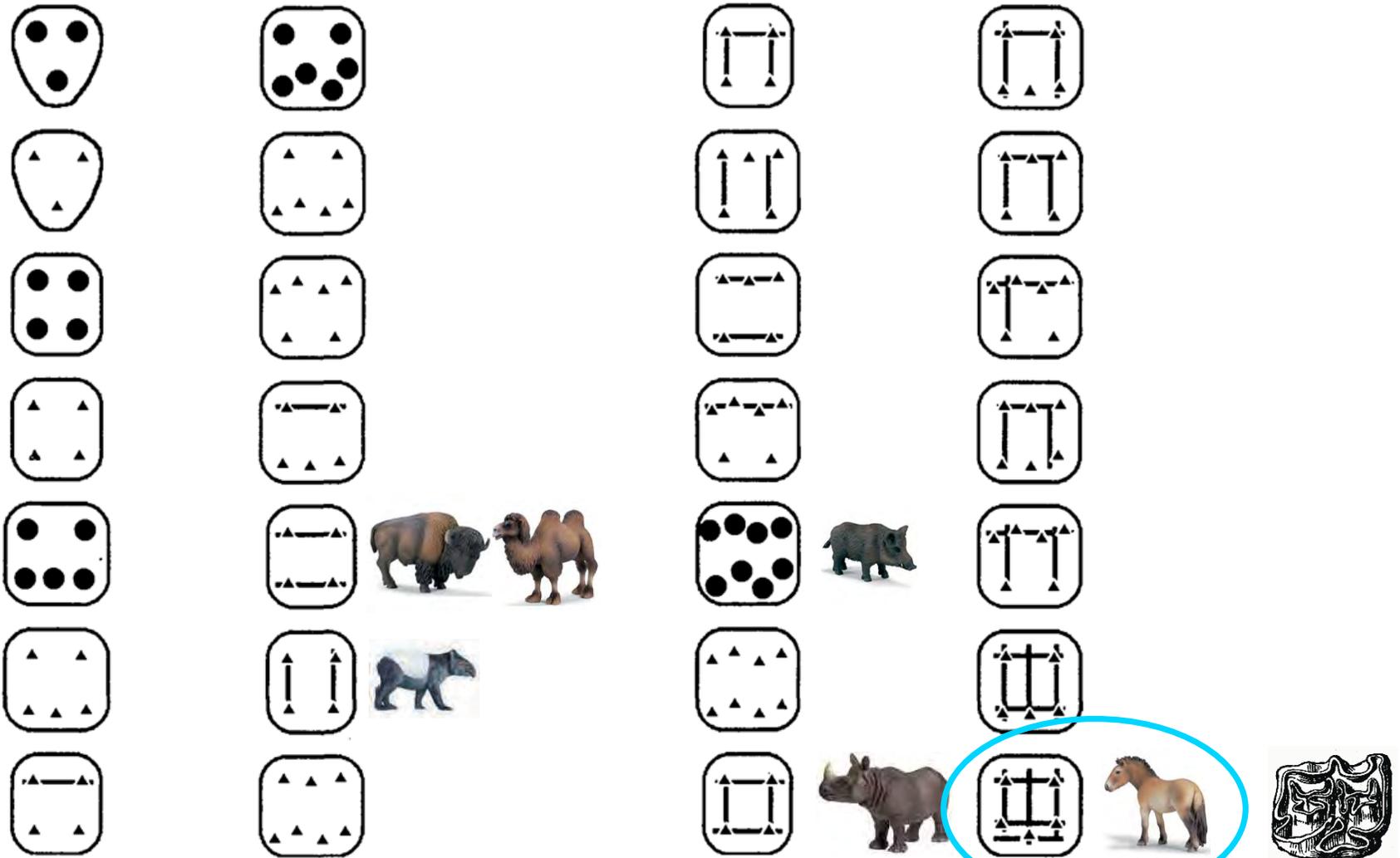




# Zahnoptimierung vs. Kau- Optimierung: Sortieren und Wiederkäuen



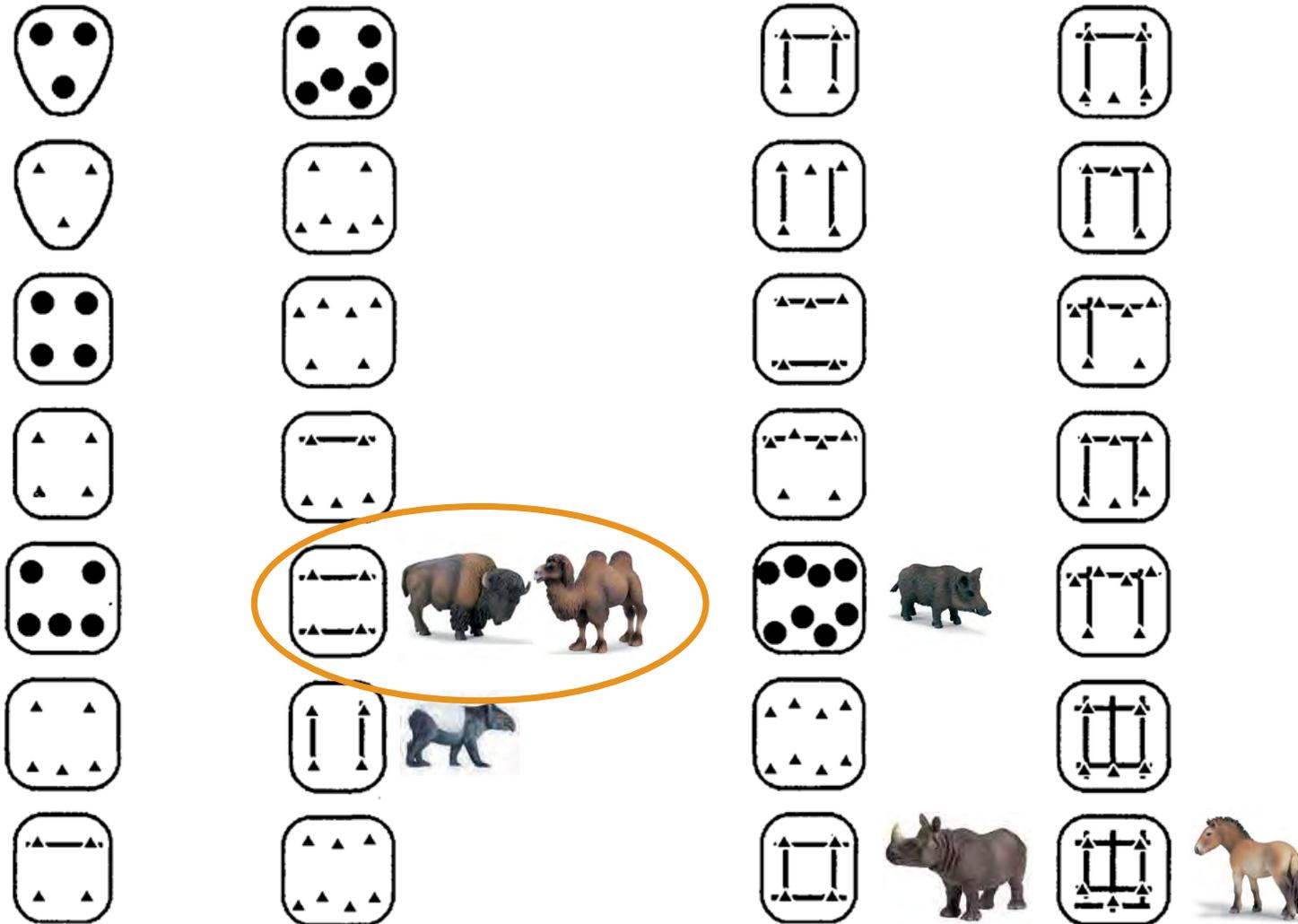
# Backenzahn-Oberflächen



aus Jernvall et al. (1996)



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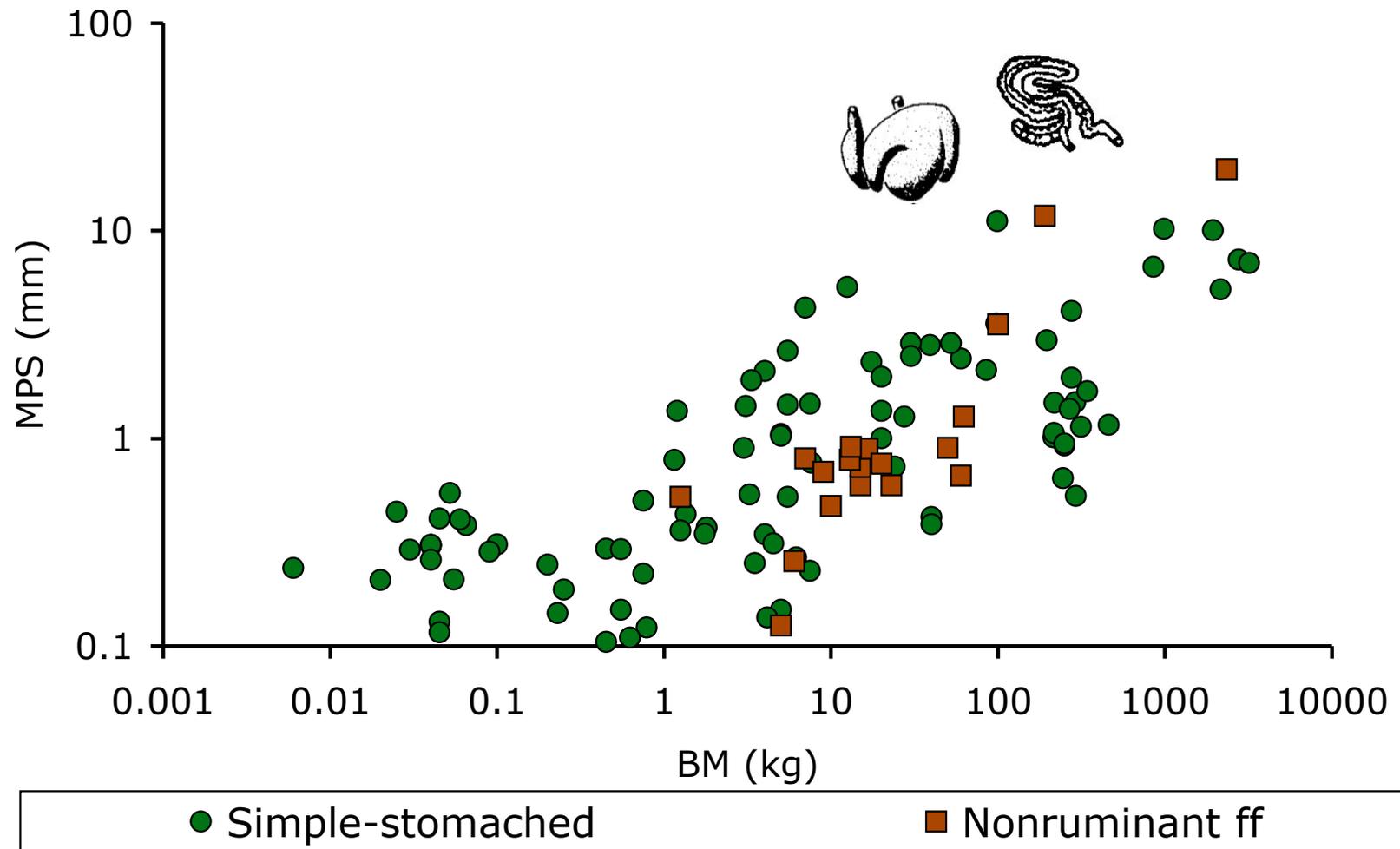
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# Comparative chewing efficiency in mammalian herbivores

Julia Fritz, Jürgen Hummel, Ellen Kienzle, Christian Arnold, Charles Nunn and Marcus Clauss

Oikos 118: 1623–1632, 2009

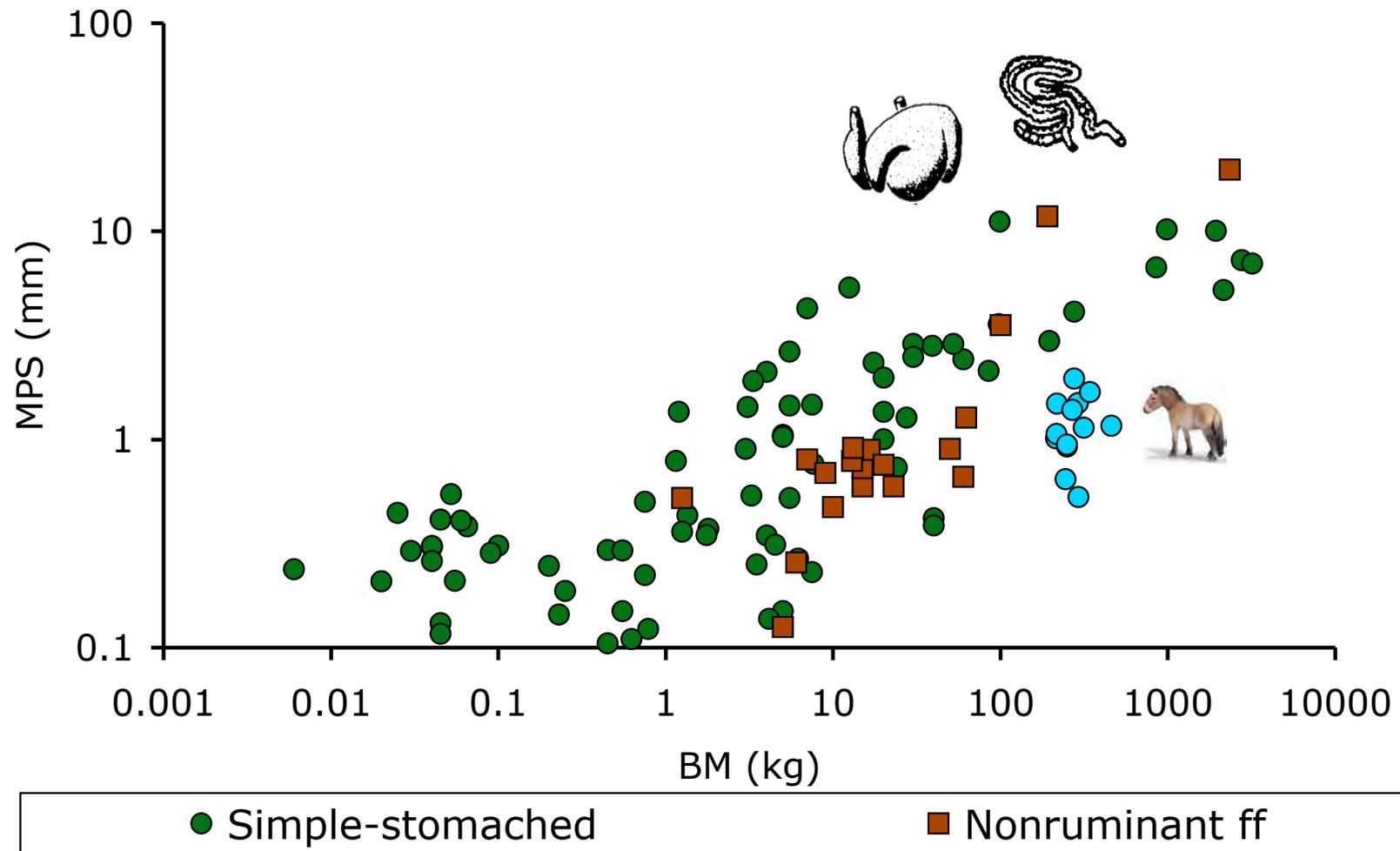




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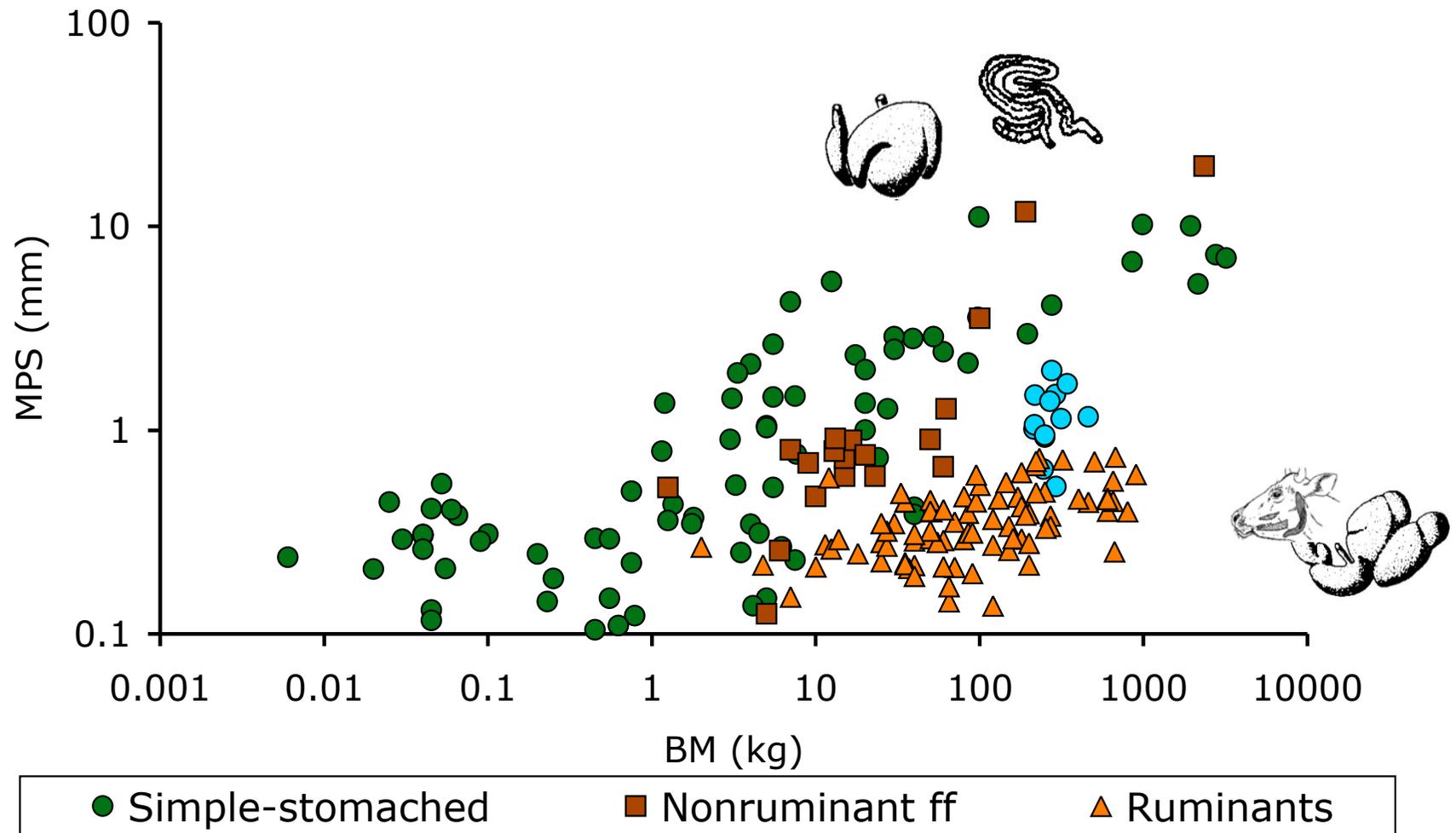




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Einfach öfter kauen ?





# Kotpartikel bei Wiederkäuer und Nicht-Wiederkäuer

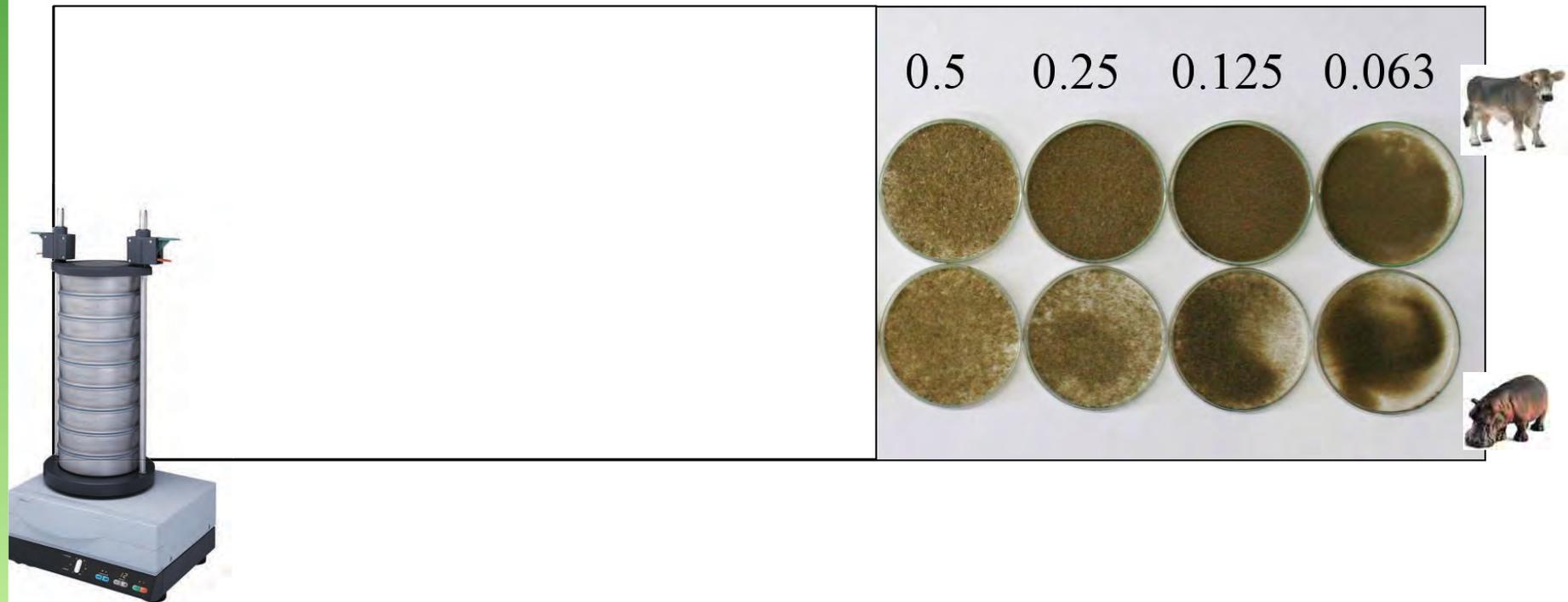


Photo A. Schwarm



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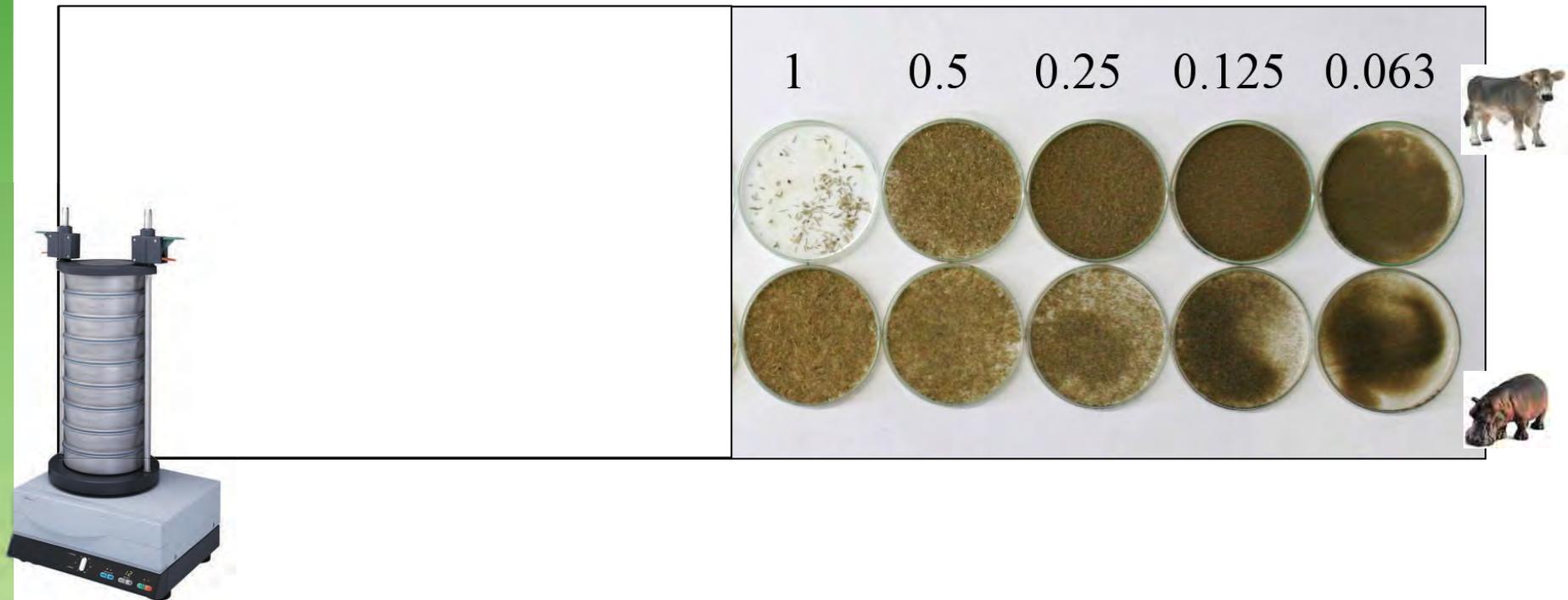


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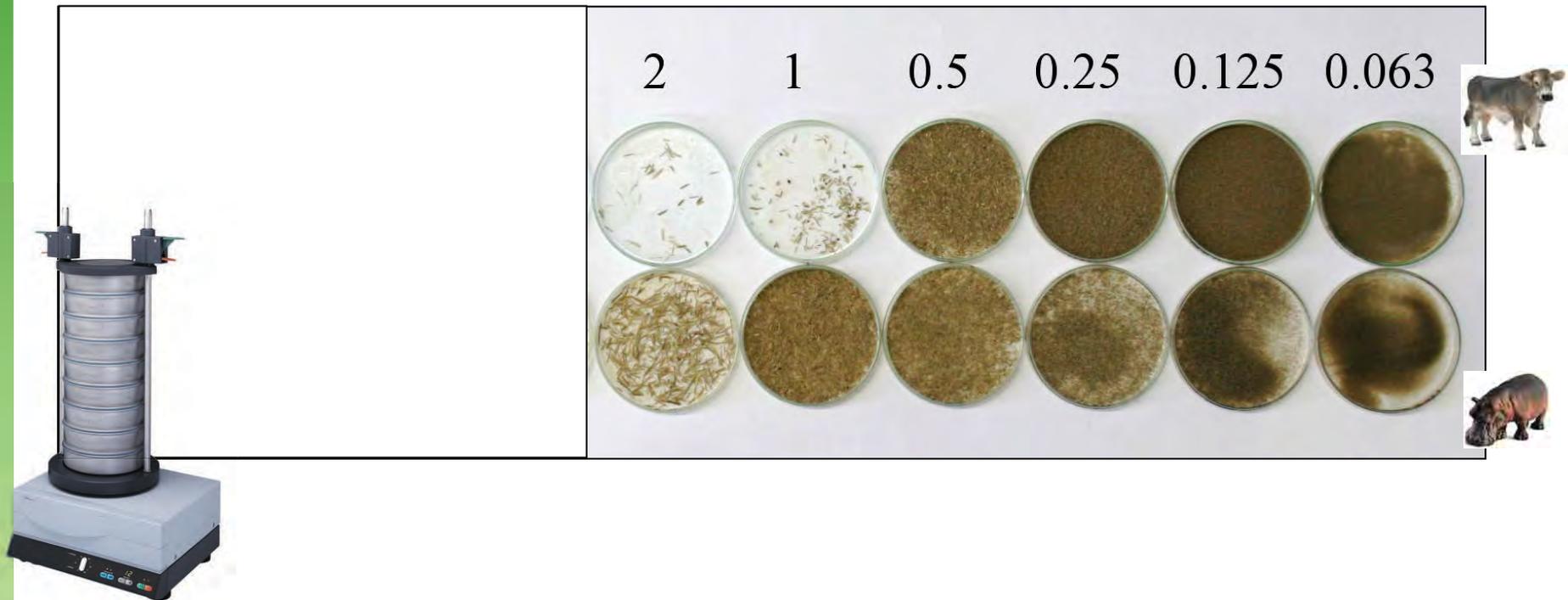


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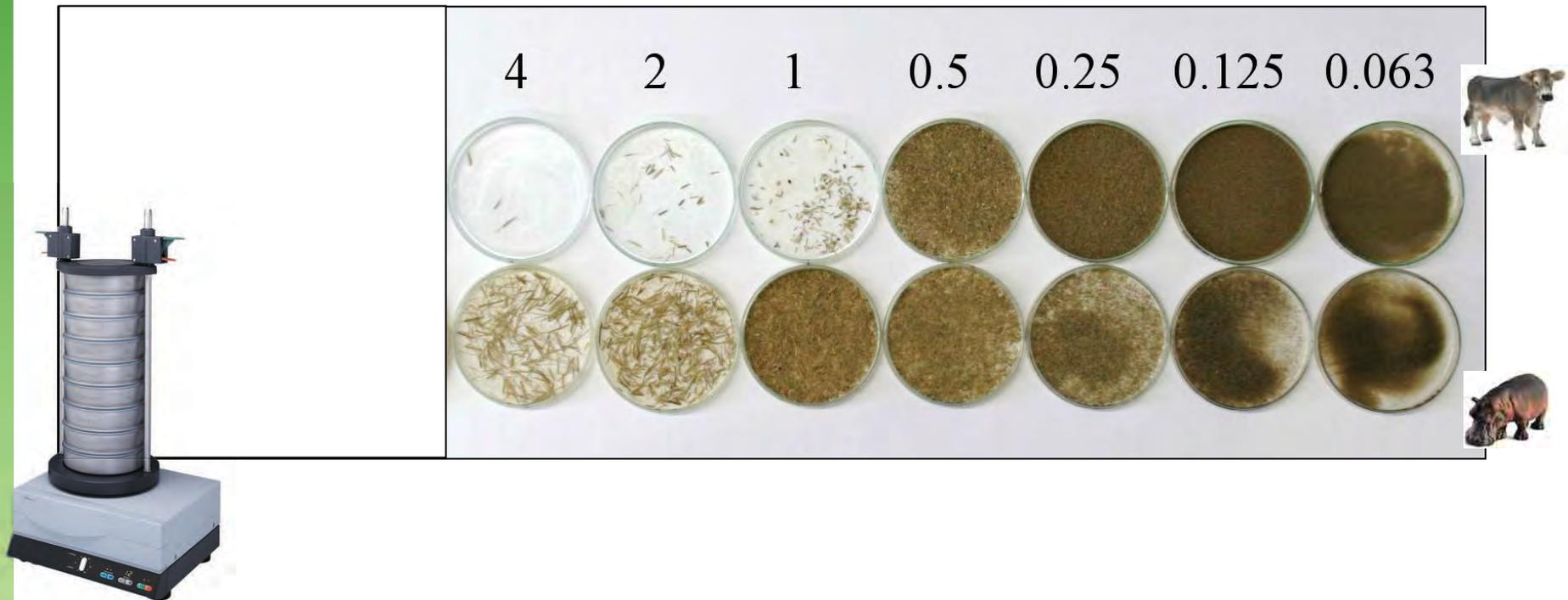


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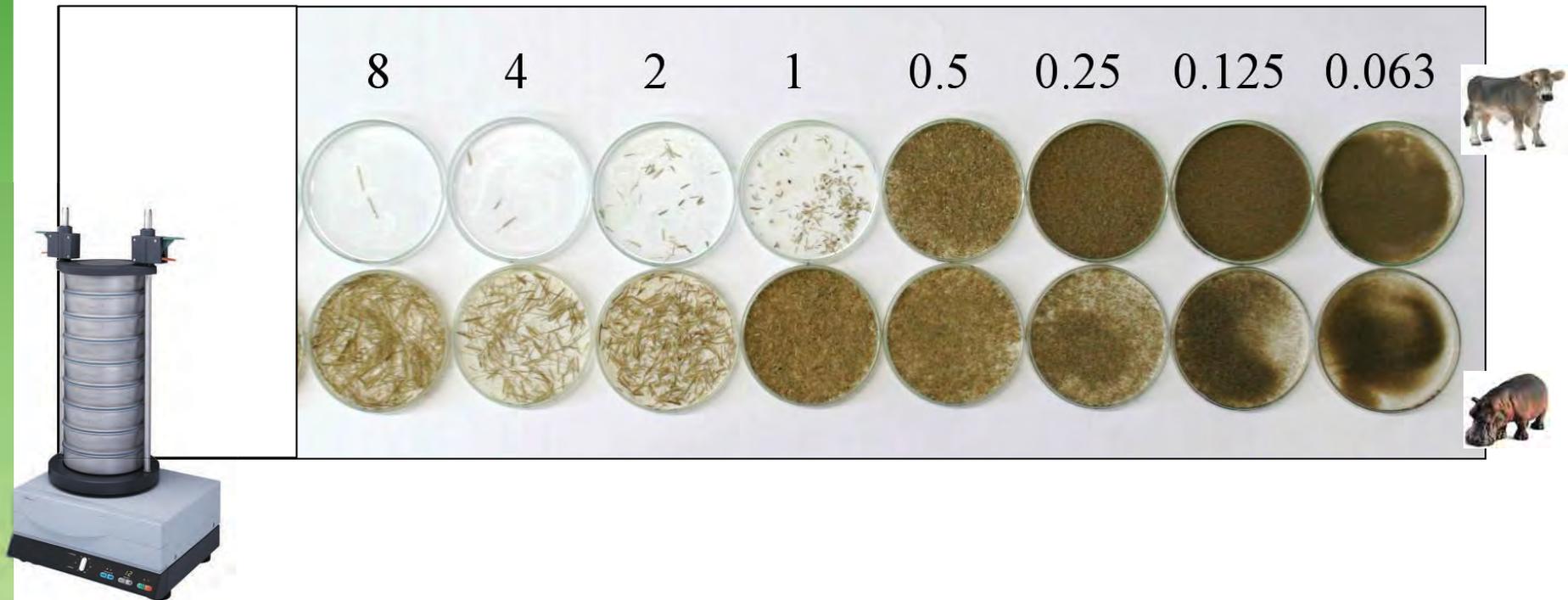


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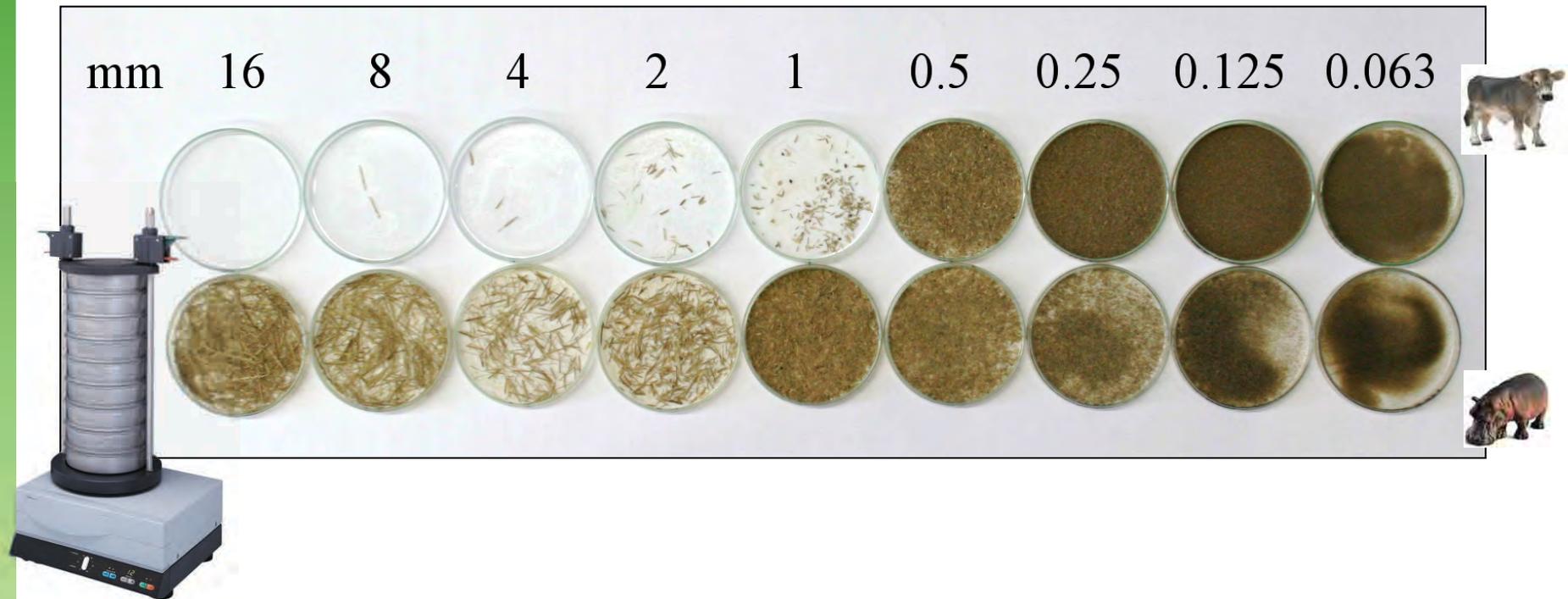


Photo A. Schwarm



# Wiederkäuen - Wiederkäuer





# Wiederkäuen - Wiederkäuer





# Wiederkäuen - Kamele





# *Warum Wiederkäuen ?*



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- **Predations-Vermeidung**

- *“Wiederkäuen erlaubt es Pflanzenfressern, rasch zu fressen und das Kauen auf später zu verschieben”* (Karasov & Del Rio 2007)
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**Life cycle period and activity of prey influence their susceptibility to predators**

A. Molinari-Jobin, P. Molinari, A. Loison, J.-M. Gaillard and U. Breitenmoser

ECOGRAPHY 27: 323–329, 2004



We found more chamois predated when feeding, whereas roe deer were predated mainly when ruminating.



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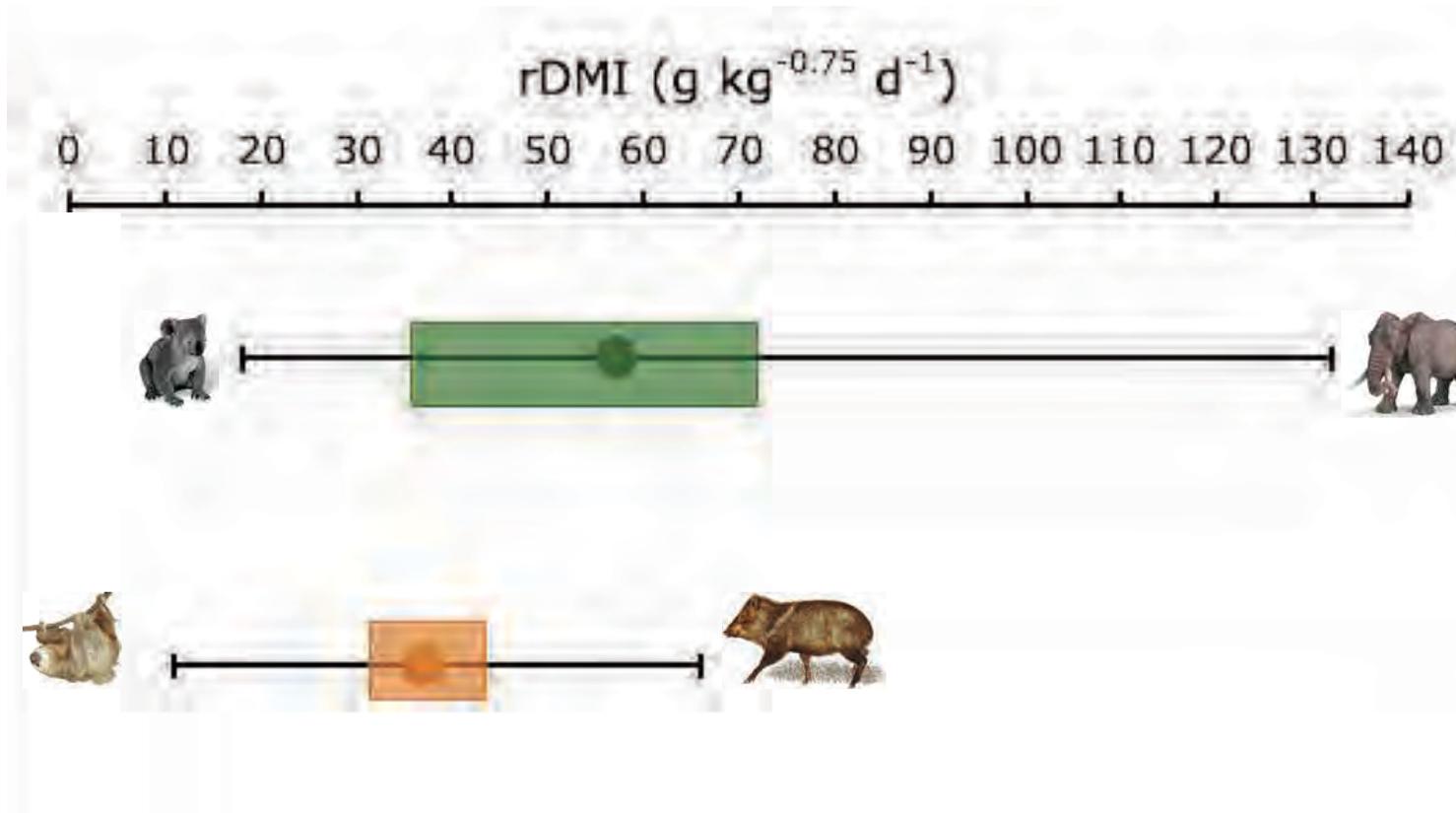


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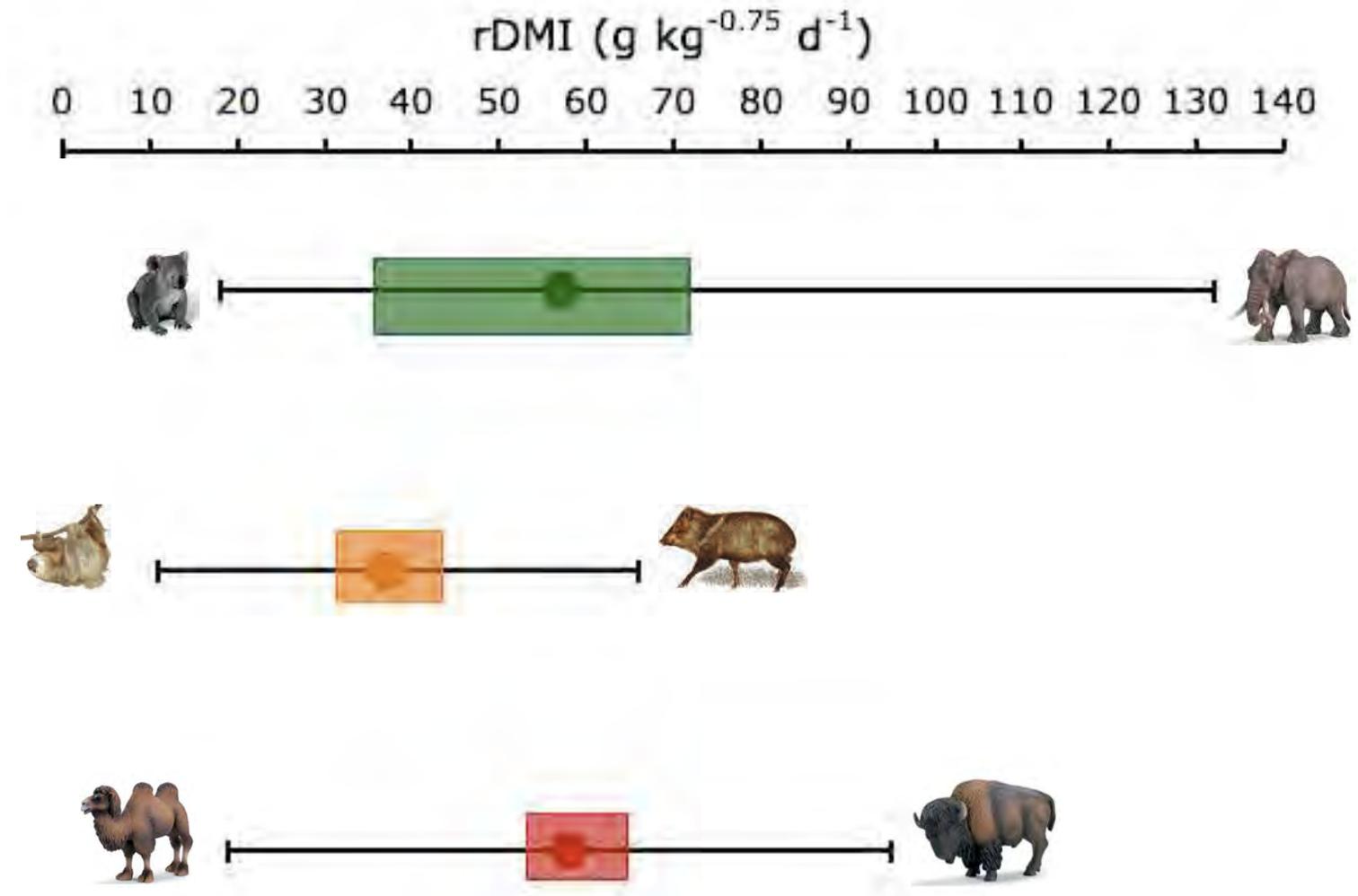


# Futteraufnahme bei Pflanzenfressern





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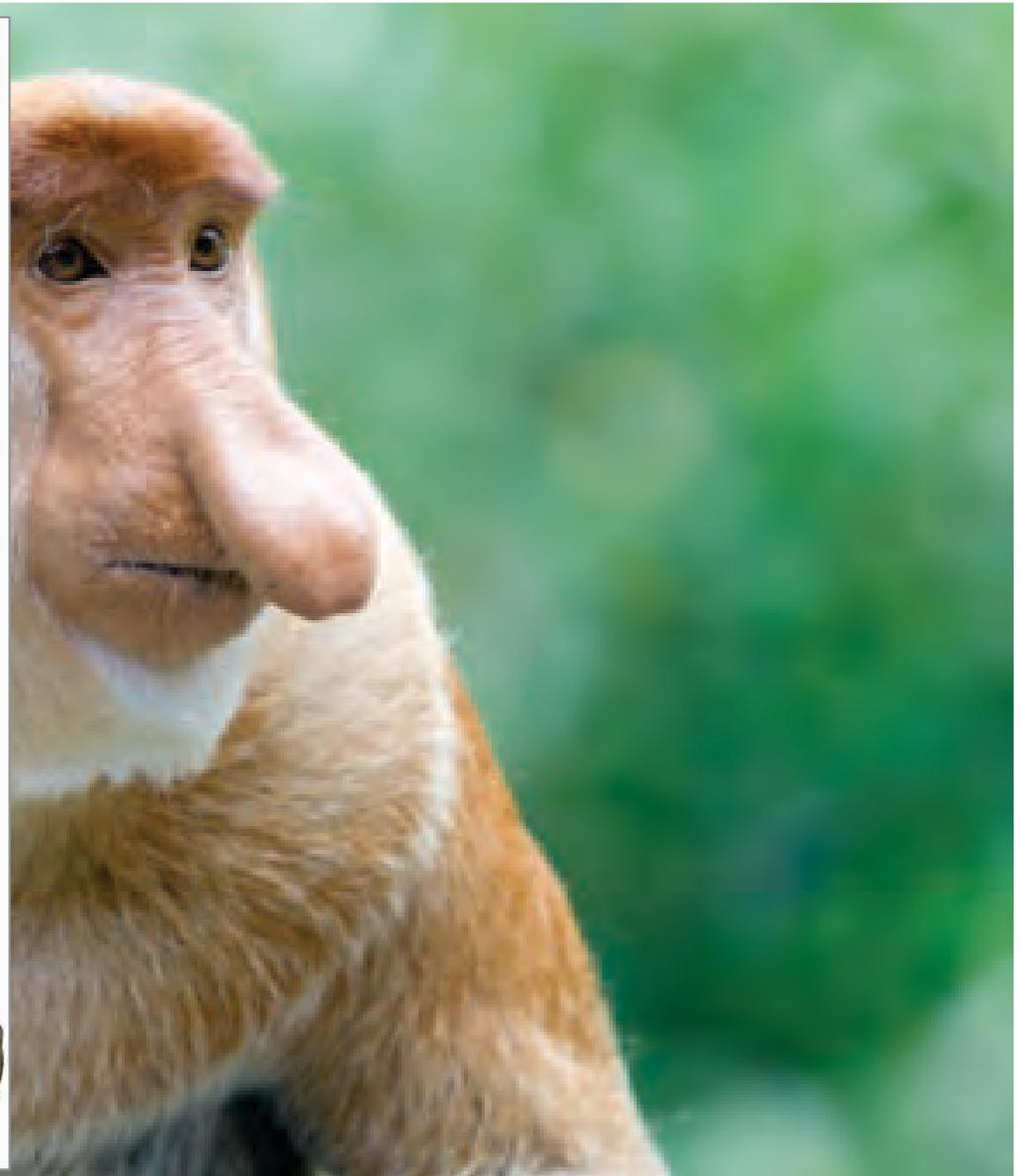
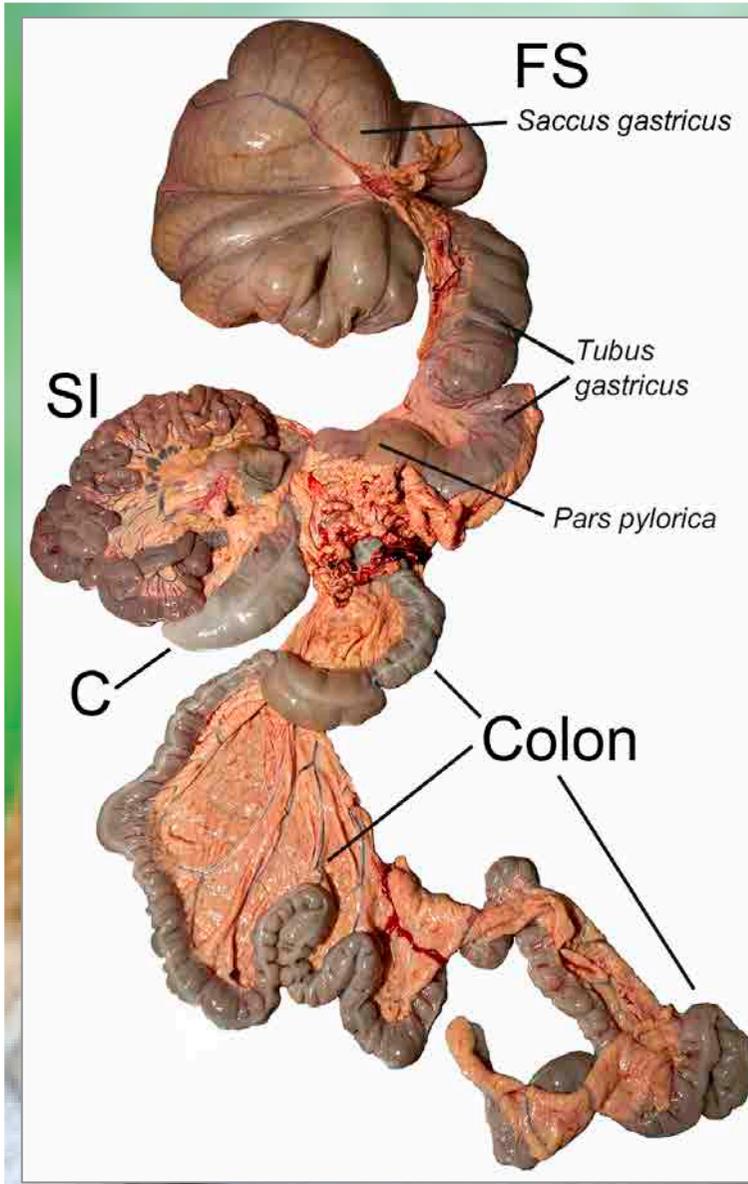


## Nasennaffen (*Nasalis larvatus*)





# Nasenaffen (*Nasalis larvatus*)



from Matsuda et al. (2015)



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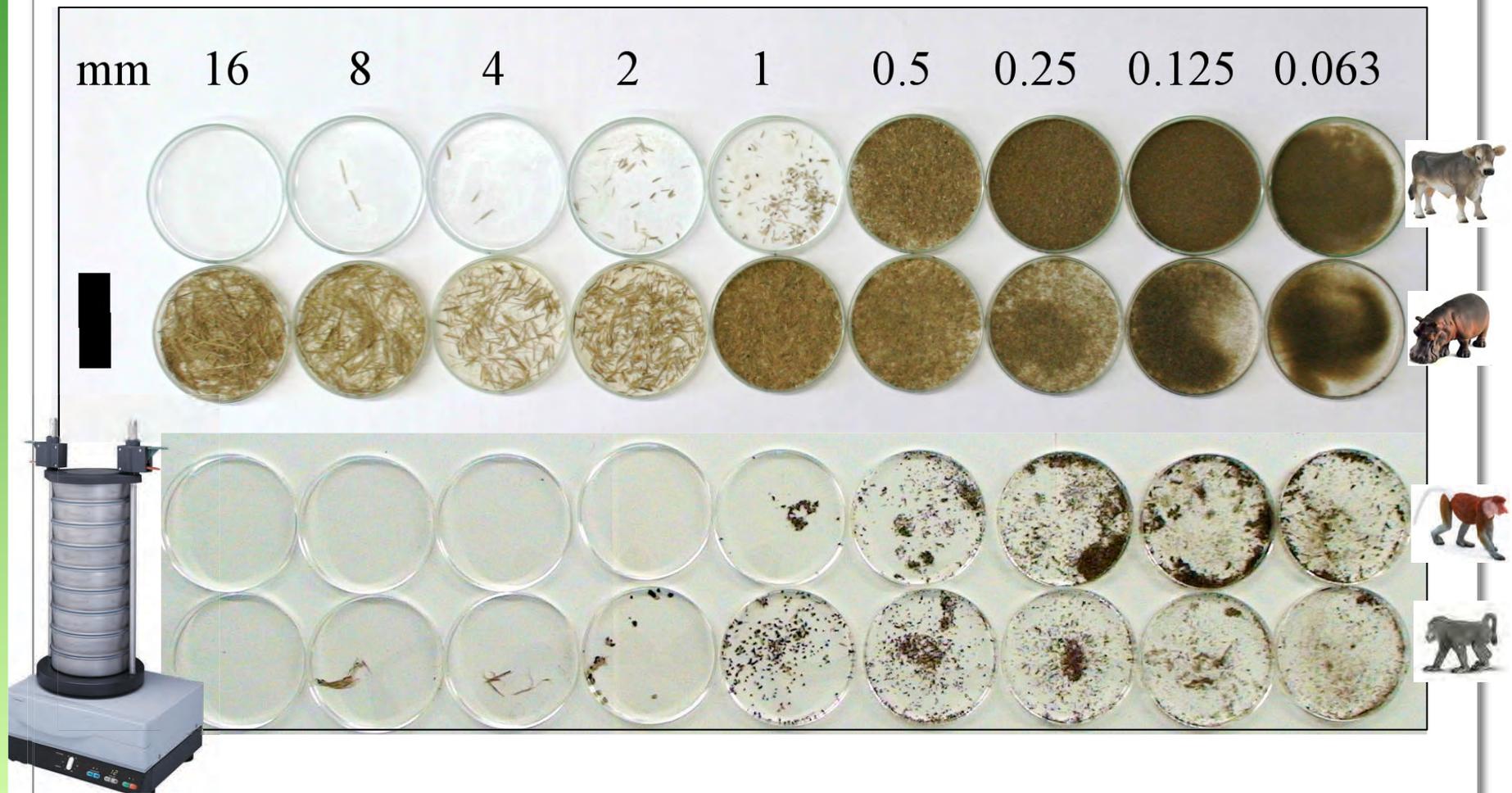




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Ikki Matsuda · Augustine Tuuga · Chie Hashimoto · Henry Bernard ·  
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Oecologia  
DOI 10.1007/s00442-013-2863-9

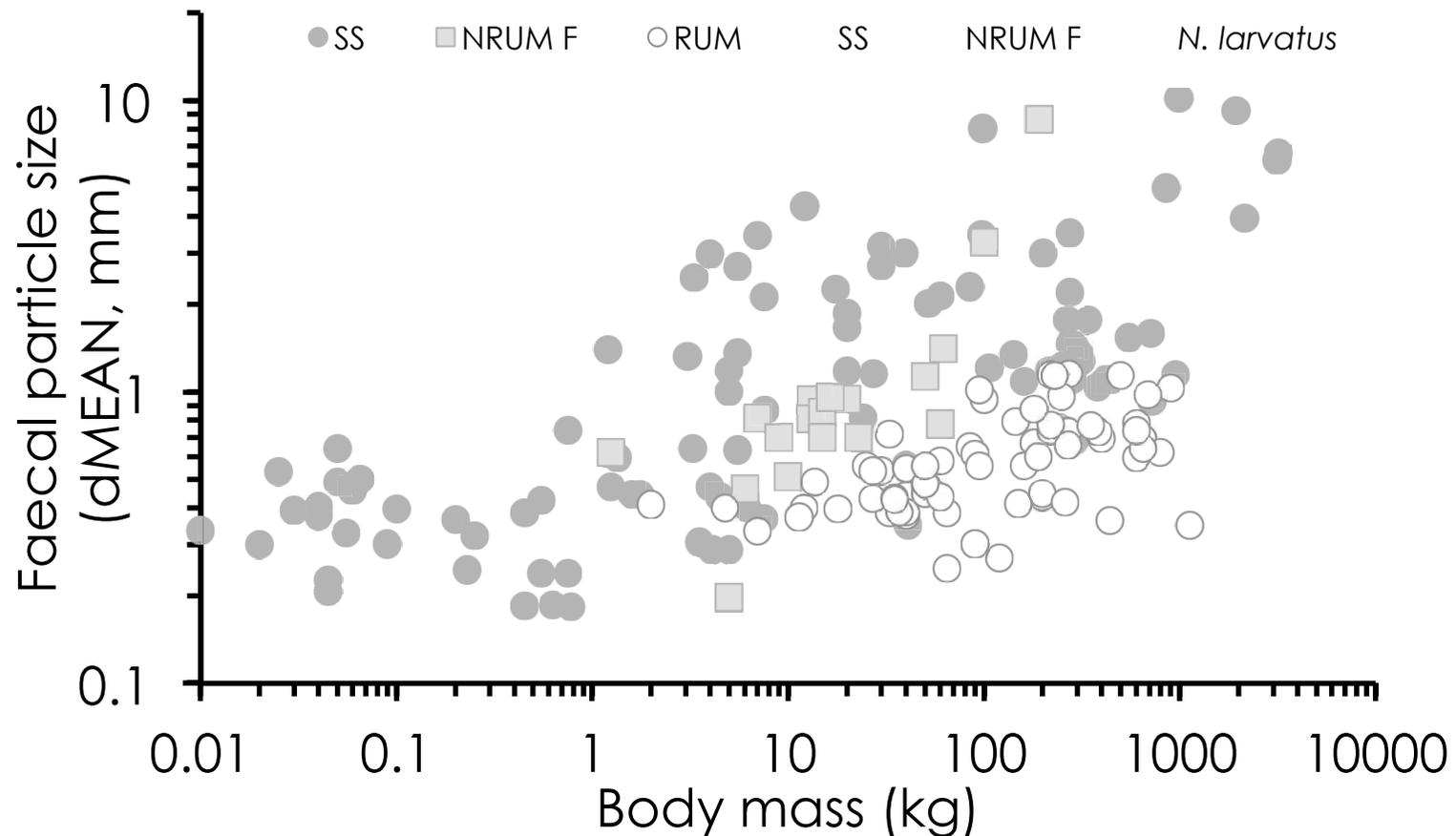




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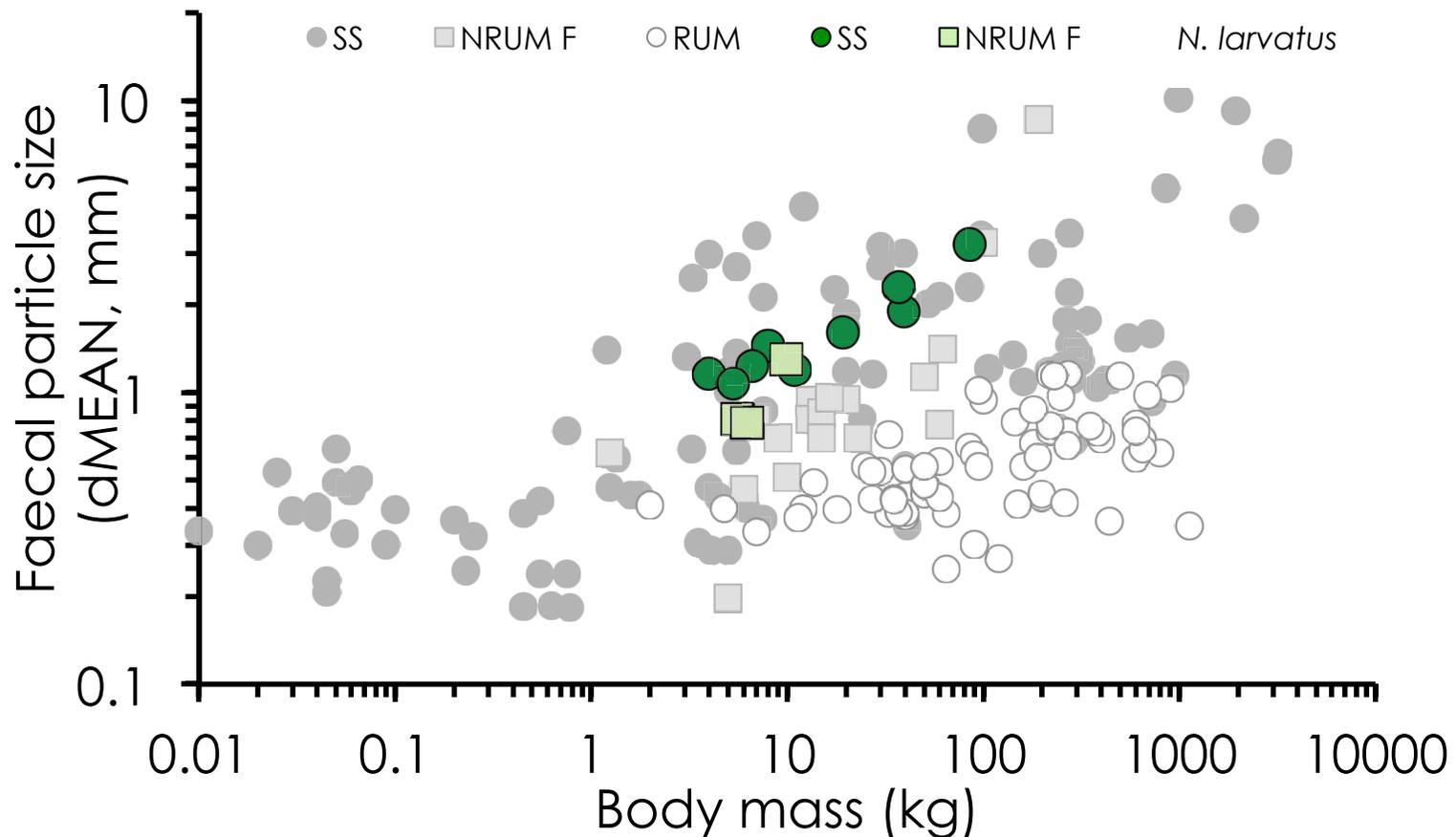




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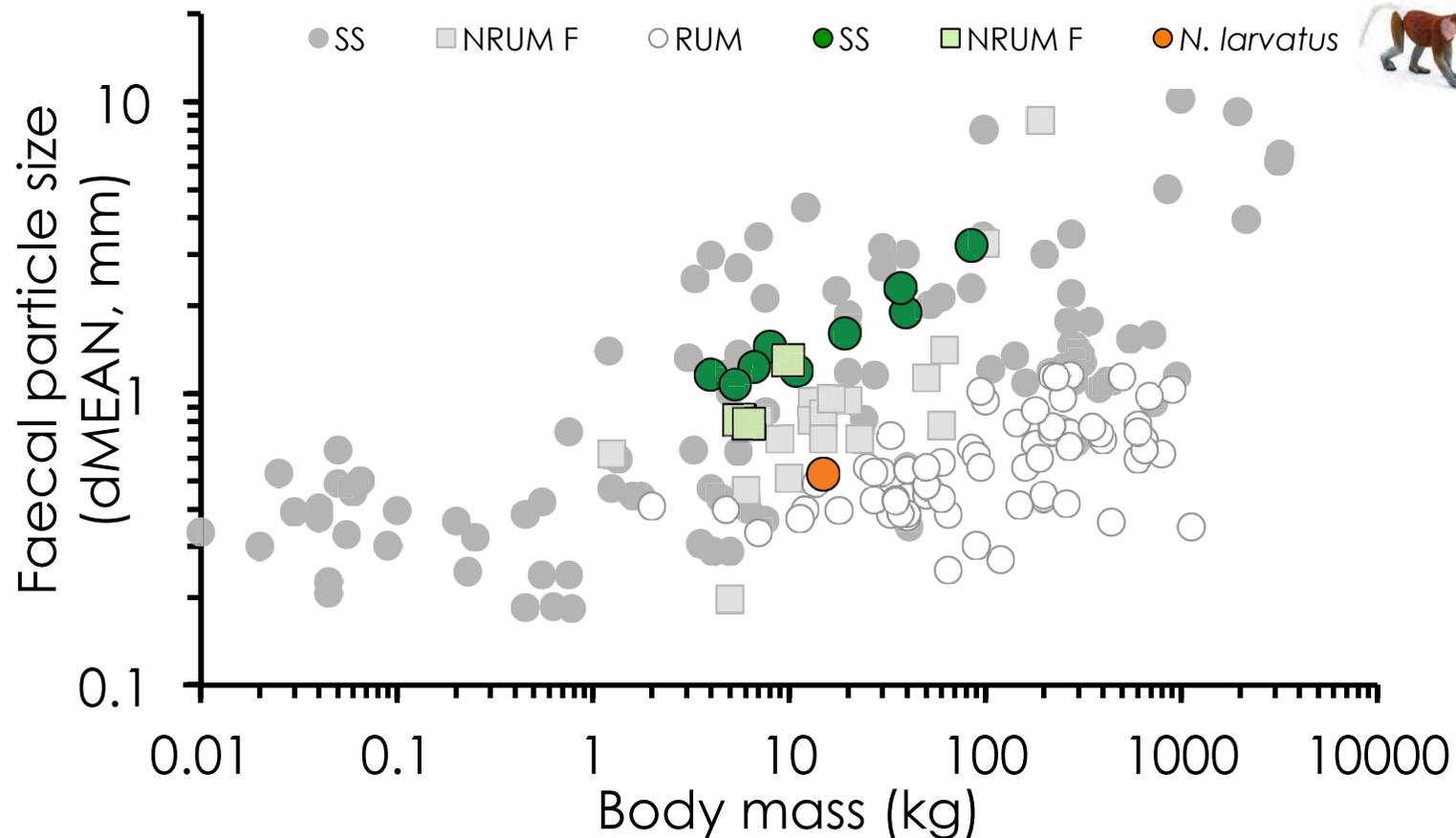




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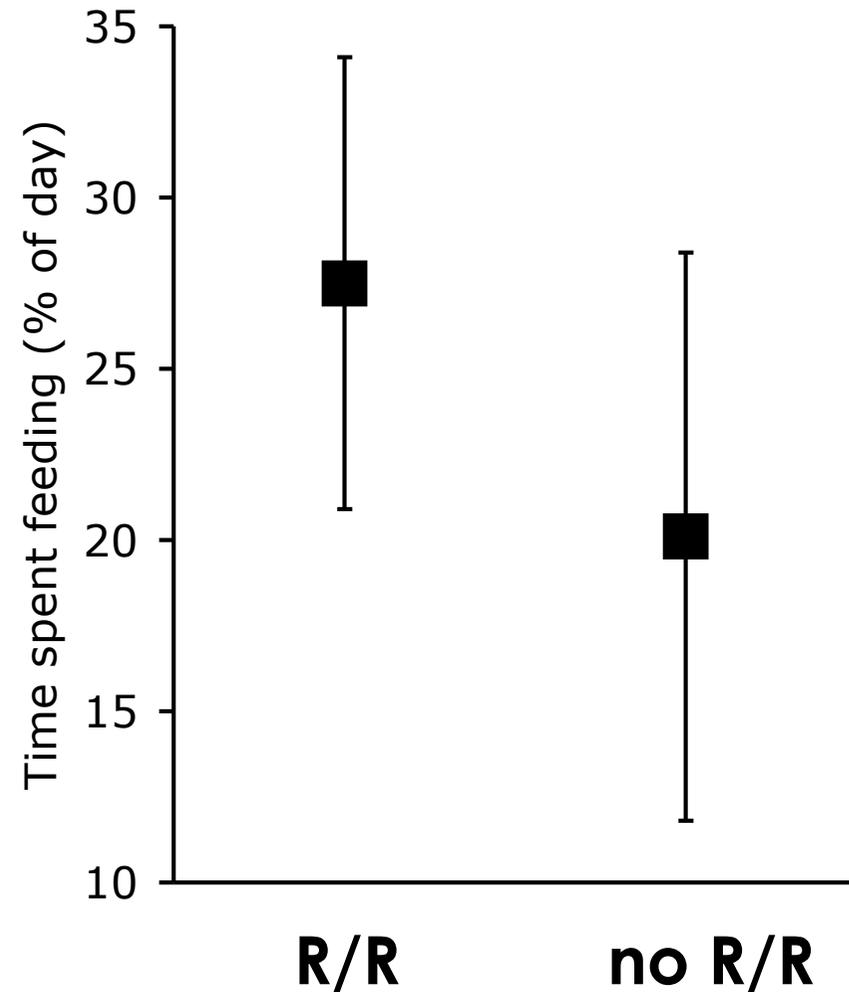
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## Regurgitation and remastication in the foregut-fermenting proboscis monkey (*Nasalis larvatus*)

Ikki Matsuda<sup>1,\*</sup>, Tadahiro Murai<sup>1</sup>,  
Marcus Clauss<sup>2</sup>, Tomomi Yamada<sup>3</sup>,  
Augustine Tuuga<sup>4</sup>, Henry Bernard<sup>5</sup>  
and Seigo Higashi<sup>6</sup>



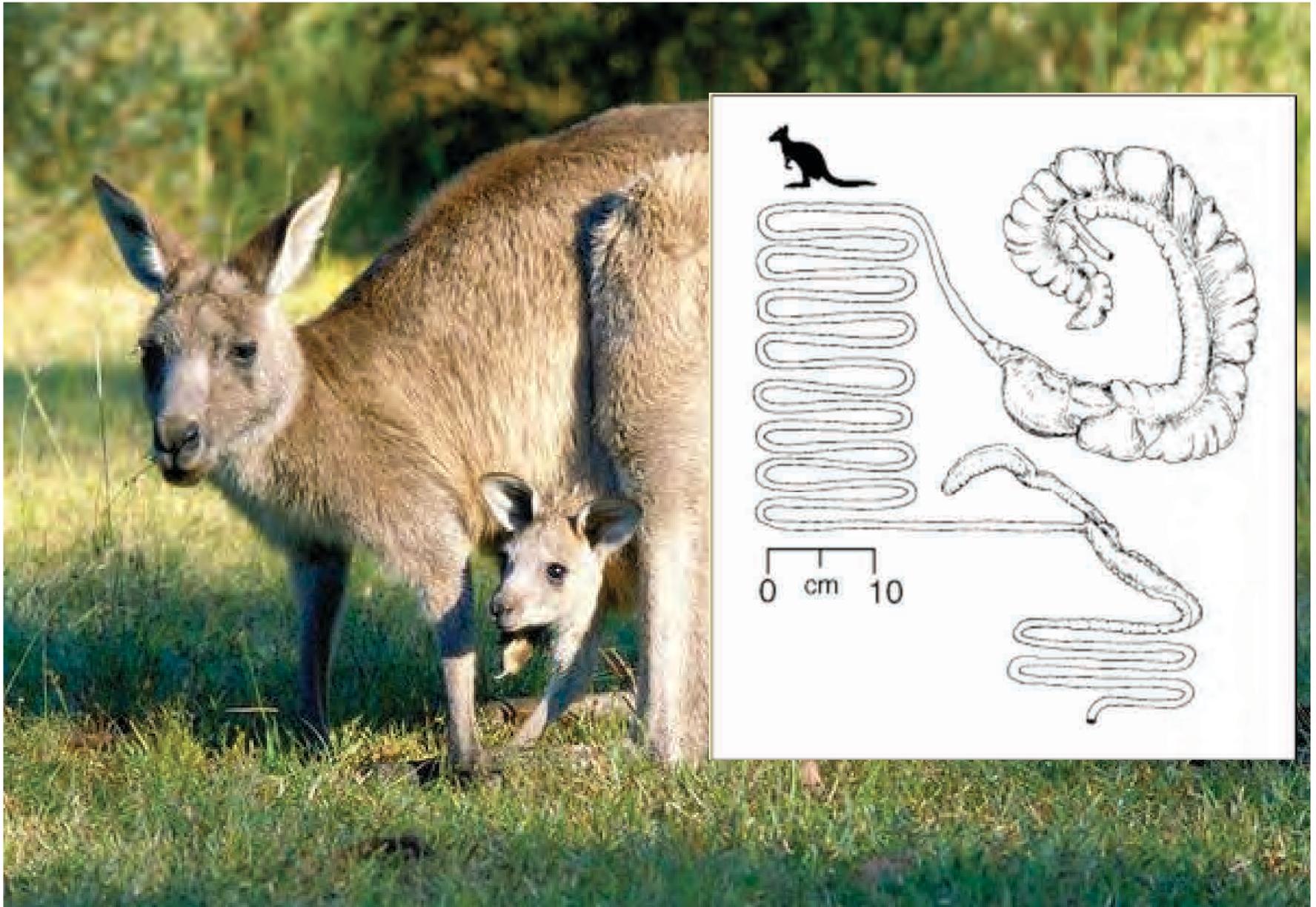


# Kängurus





# Kängurus



from Stevens und Hume (1995)



# Kängurus

430

THE AUSTRALIAN JOURNAL OF SCIENCE

APRIL

## Food Regurgitation in the Macropodidae

S. BARKER,\* G. D. BROWN† and J. H. CALABY\*

Merycism in western grey (*Macropus fuliginosus*) and red kangaroos (*Macropus rufus*)

Catharina Vendl<sup>a,c,\*</sup>, Adam Munn<sup>a</sup>, Keith Leggett<sup>b</sup>, Marcus Clauss<sup>c</sup>

[Mammalian Biology 86 \(2017\) 21–26](#)



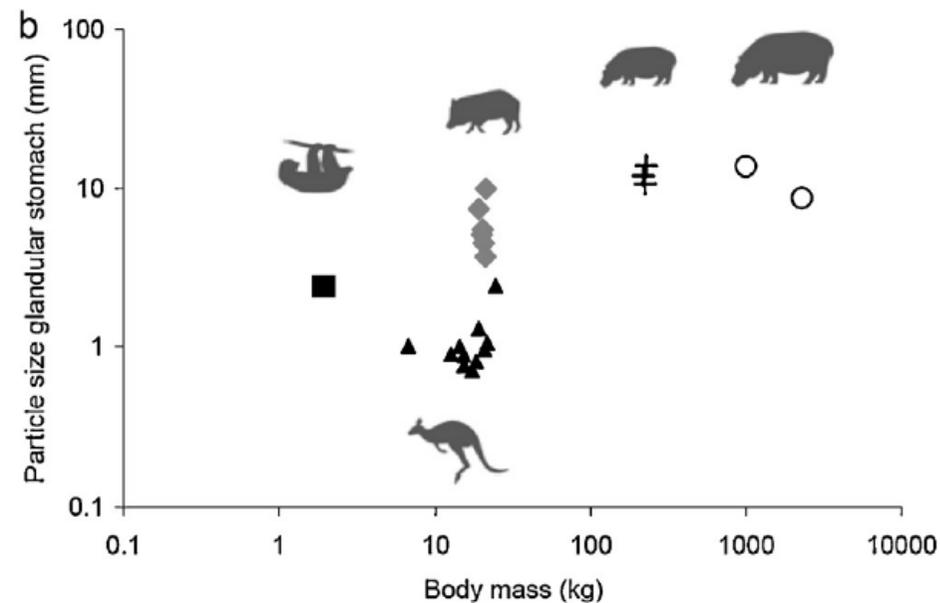


# Kängurus

No distinct stratification of ingesta particles and no distinct moisture gradient in the fore-stomach of non-ruminants: The wallaby, peccary, hippopotamus, and sloth

Angela Schwarm<sup>a,b,\*</sup>, Sylvia Ortmann<sup>a</sup>, Julia Fritz<sup>c</sup>, Edmund Flach<sup>d</sup>,  
Wolfram Rietschel<sup>e</sup>, Marcus Clauss<sup>f</sup>

[Mammalian Biology 78 \(2013\) 412–421](#)



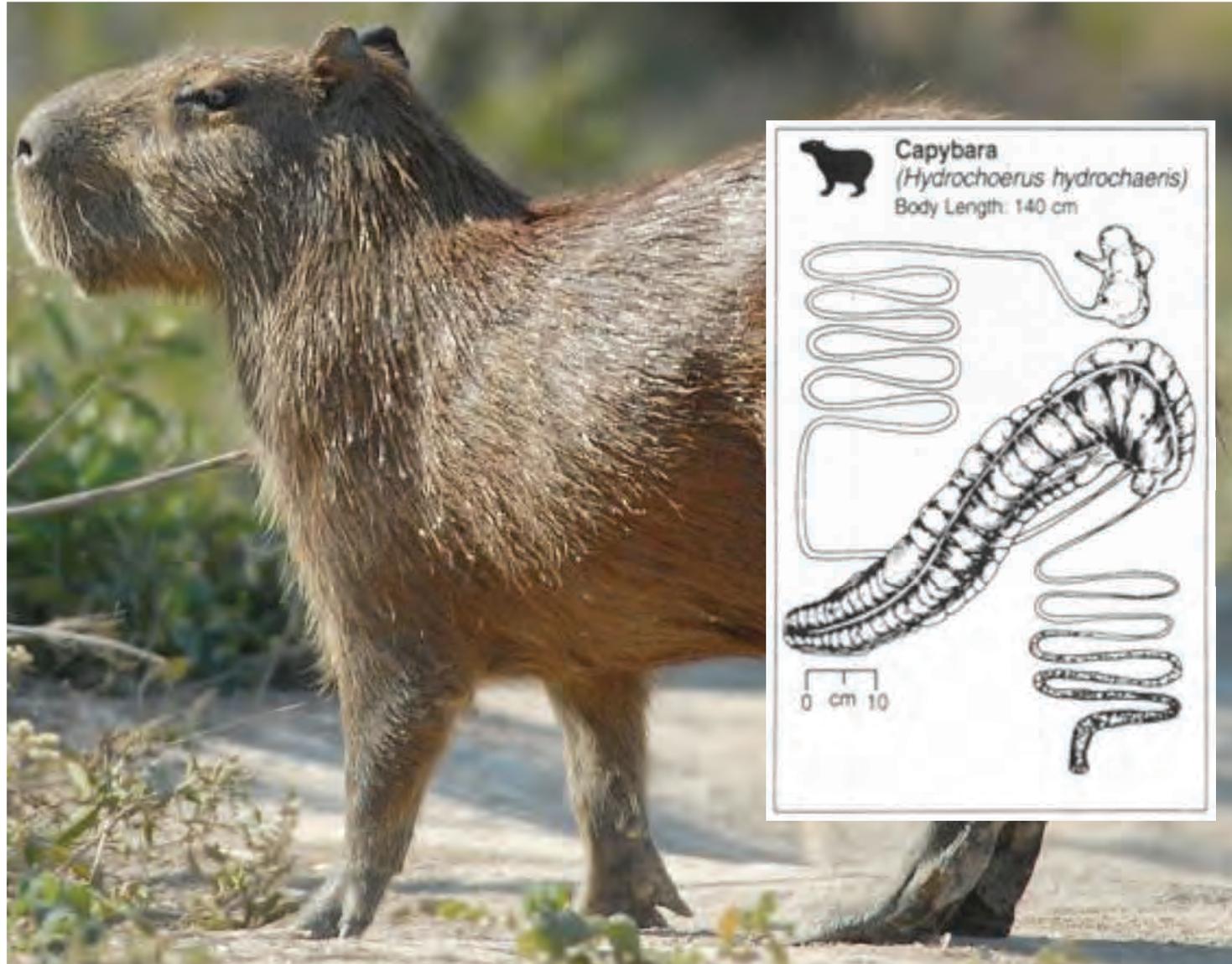


# Wasserschwein (*Hydrochoerus hydrochaeris*)





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from Stevens und Hume (1995)



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Studies on Neotropical Fauna and Environment  
Vol. 29 (1994), No. 1, pp. 11-22

## A Descriptive Account of Capybara Behaviour

**Rexford D. LORD**



**Regurgitation and Coprophagy.** – A significant new finding of this study was observations of capybaras regurgitating and masticating their food while resting, a parallel of rumination among the ruminants such as cattle.

Regurgitation and mastication of food by capybaras was seen only while resting on land, throughout the day, unlike coprophagy which is practised primarily in the morning (Lord 1991, Herrera 1985). Regurgitation is frequently preceded by a gaping yawn, followed by stretching of the neck, then about a minute of mastication. Sometimes the food material could be seen in the mouth and on occasion spilled out. A young capybara was videotaped eating some spilled regurgitation material from an adult female. The gape yawn may be preceded by a half roll on one side, and/or sitting up. Videotape analysis of this practice has shown the pattern to be somewhat ritualized. It is practised much more frequently than coprophagy, but was probably overlooked because it appears to be a simple yawn.

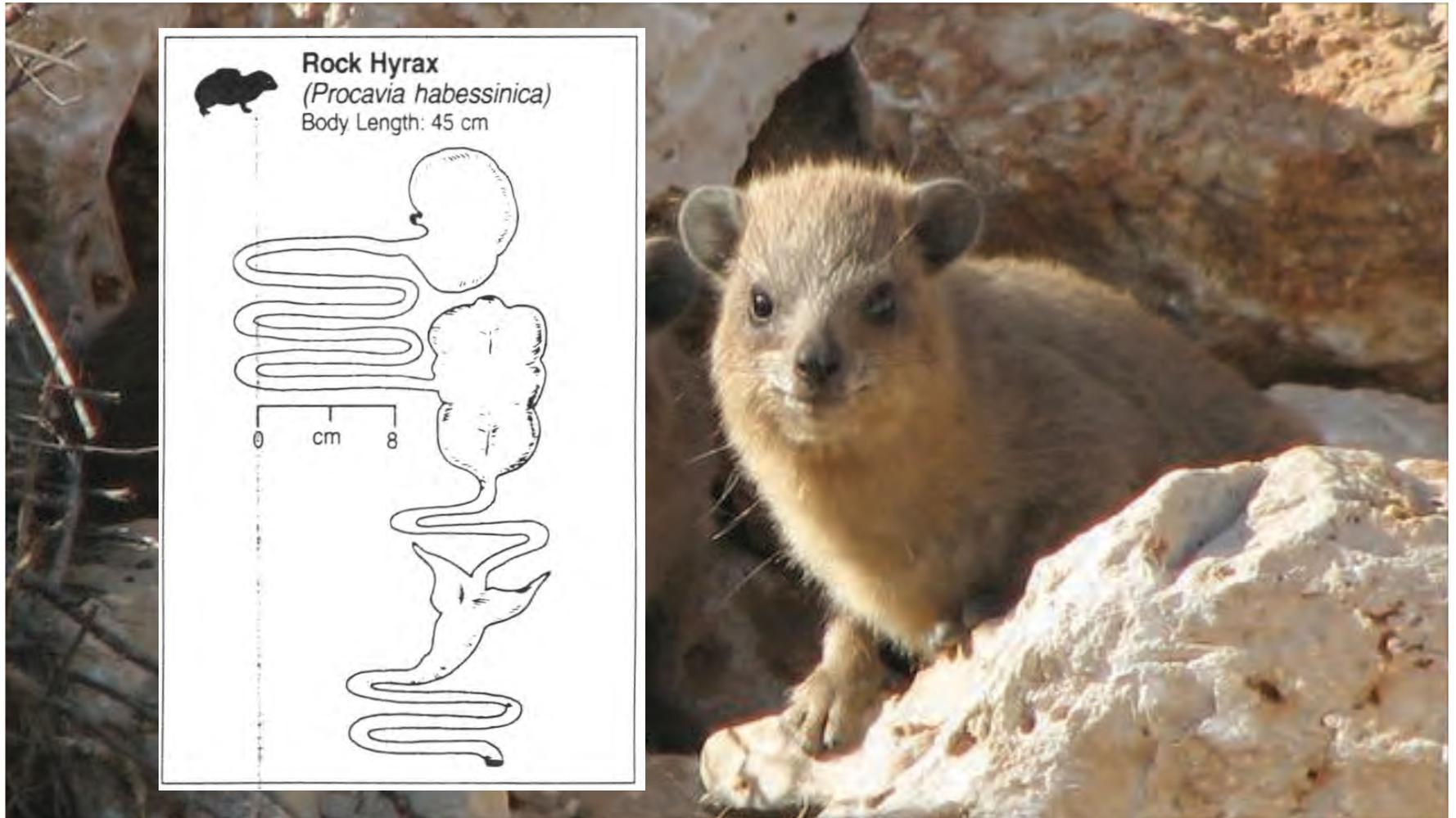


## Klippschliefer (*Procavia* spp.)





# Klippschliefer (*Procavia* spp.)



from Stevens und Hume (1995)



## Klippschliefer (*Procavia* spp.)





# Klippschliefer (*Procavia* spp.)



## Leviticus 11 (New International Version NIV) Clean and Unclean Food

11 The Lord said to Moses and Aaron, <sup>2</sup>“Say to the Israelites: ‘Of all the animals that live on land, these are the ones you may eat: <sup>3</sup>You may eat any animal that has a divided hoof and that chews the cud. <sup>4</sup>“There are some that only chew the cud or only have a divided hoof, but you must not eat them. The camel, though it chews the cud, does not have a divided hoof; it is ceremonially unclean for you. <sup>5</sup>The hyrax, though it chews the cud, does not have a divided hoof; it is unclean for you.



# Klippschliefer (*Procavia* spp.)

## BIOLOGISCHES ZENTRALBLATT

Band 84

November–Dezember 1965

Heft 6

### Vergleichende Untersuchung des Wiederkauverhaltens

VON HUBERT HENDRICH<sup>1)</sup>

#### *VI. Entdeckung von Wiederkauen bei einer Säugetierordnung*

bereiste, schreibt vom „Aschkoko“, dem Klippschliefer: „Ich hörte nie einen Laut von ihm, aber er käuete zuverlässig wieder: um dies zu untersuchen unterhielt ich ihn hauptsächlich eine Zeitlang lebendig“.





# Klippschliefer (*Procavia* spp.)



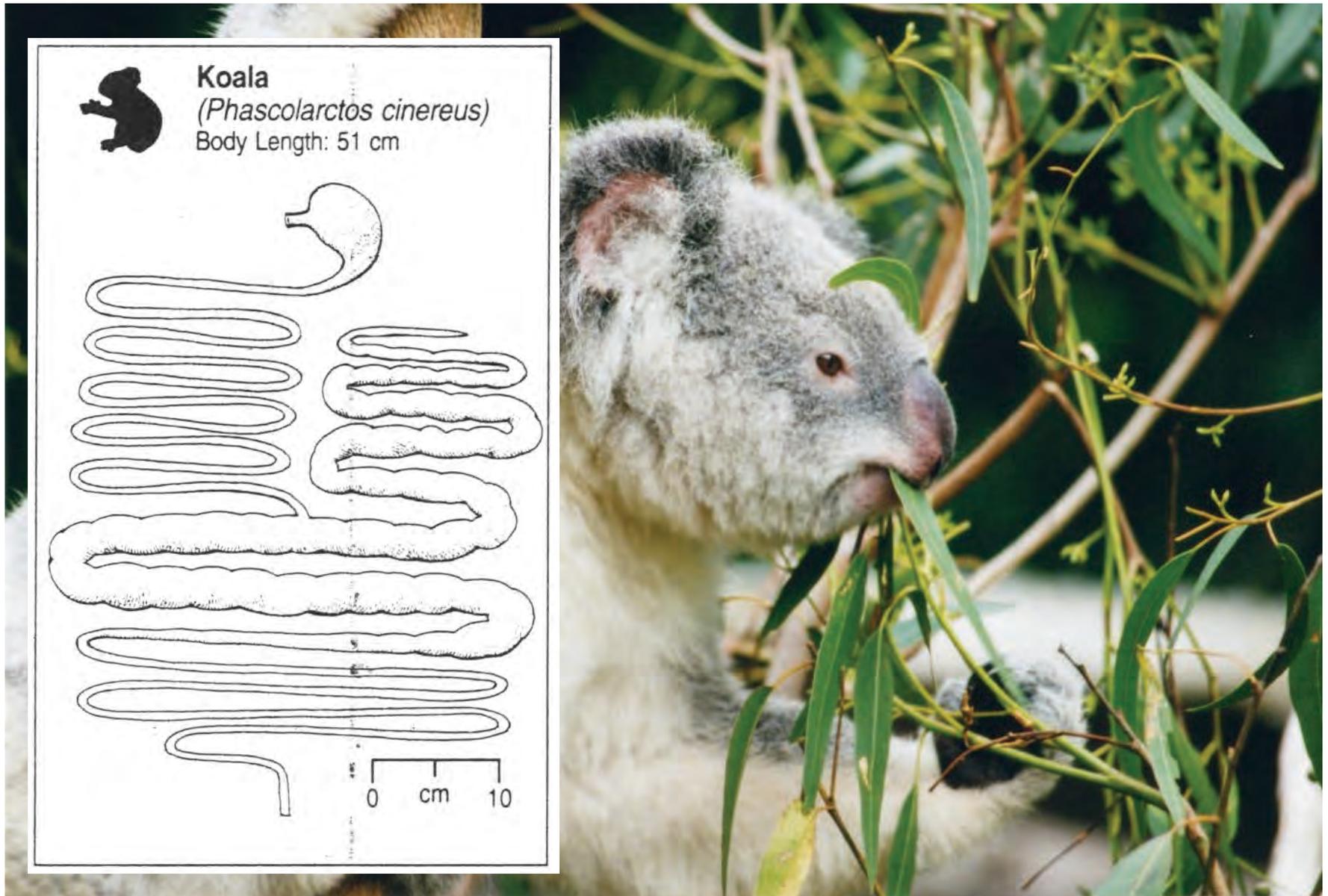


# Koala (*Phascolarctos cinereus*)





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from Stevens und Hume (1995)



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*J. Zool., Lond.* (2001) **255**, 83–87 © 2001 The Zoological Society of London Printed in the United Kingdom

Evidence for the occurrence of rumination-like behaviour, or merycism, in the koala (*Phascolarctos cinereus*, Goldfuss)

M. Logan



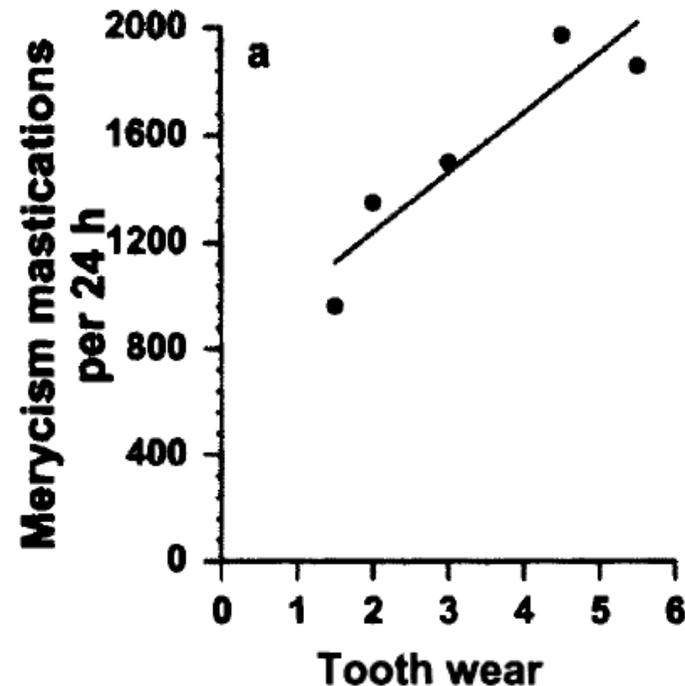


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## EFFECT OF TOOTH WEAR ON THE RUMINATION-LIKE BEHAVIOR, OR MERYCISM, OF FREE-RANGING KOALAS (*PHASCOLARCTOS CINEREUS*)

M. LOGAN\*

*Journal of Mammalogy*, 84(3):897-902, 2003



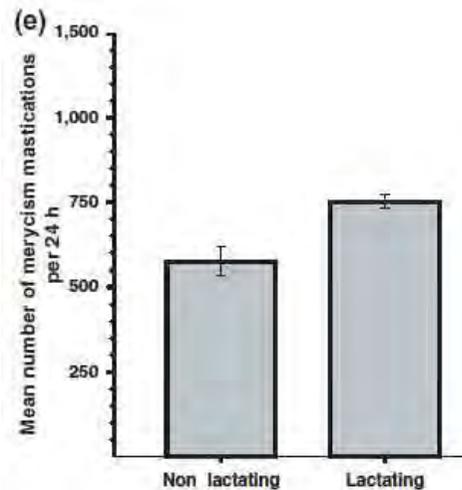


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*Australian Journal of Zoology*, 2003, 51, 415–428

*M. Logan and G. D. Sanson*



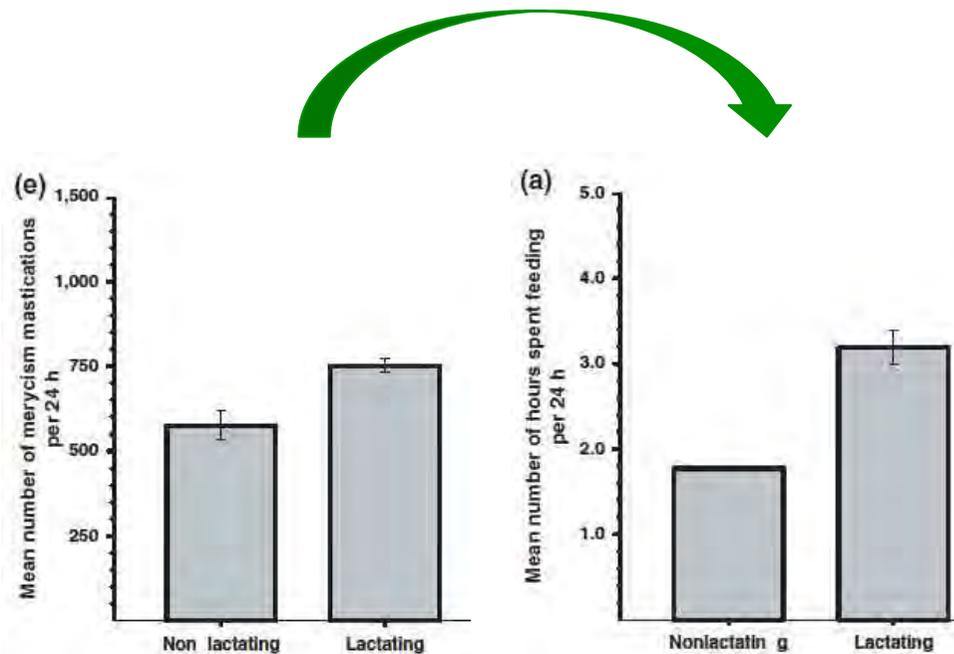


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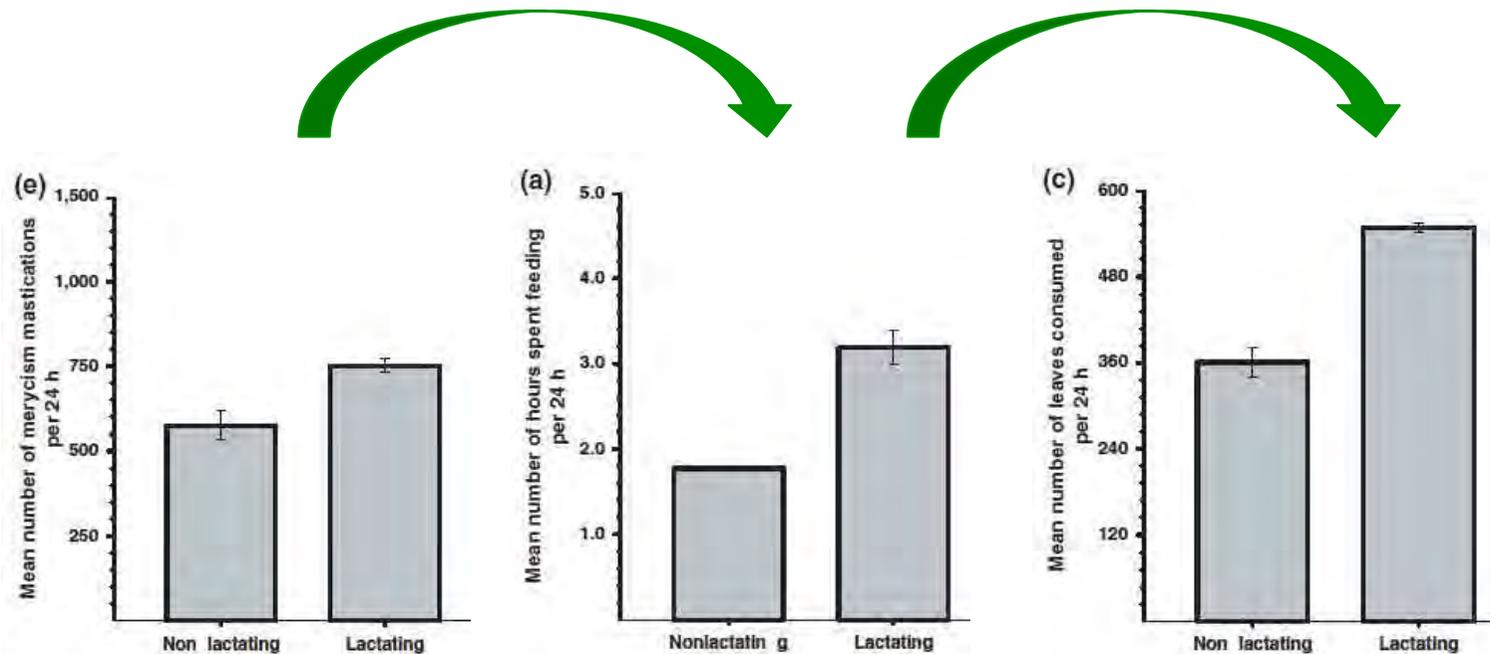


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- **Beschleunigung/Verbesserung der Verdauung**

- Wiederkäuen reduziert die Partikelgröße und ermöglicht so eine schnellere Verdauung bei gleicher Futteraufnahme

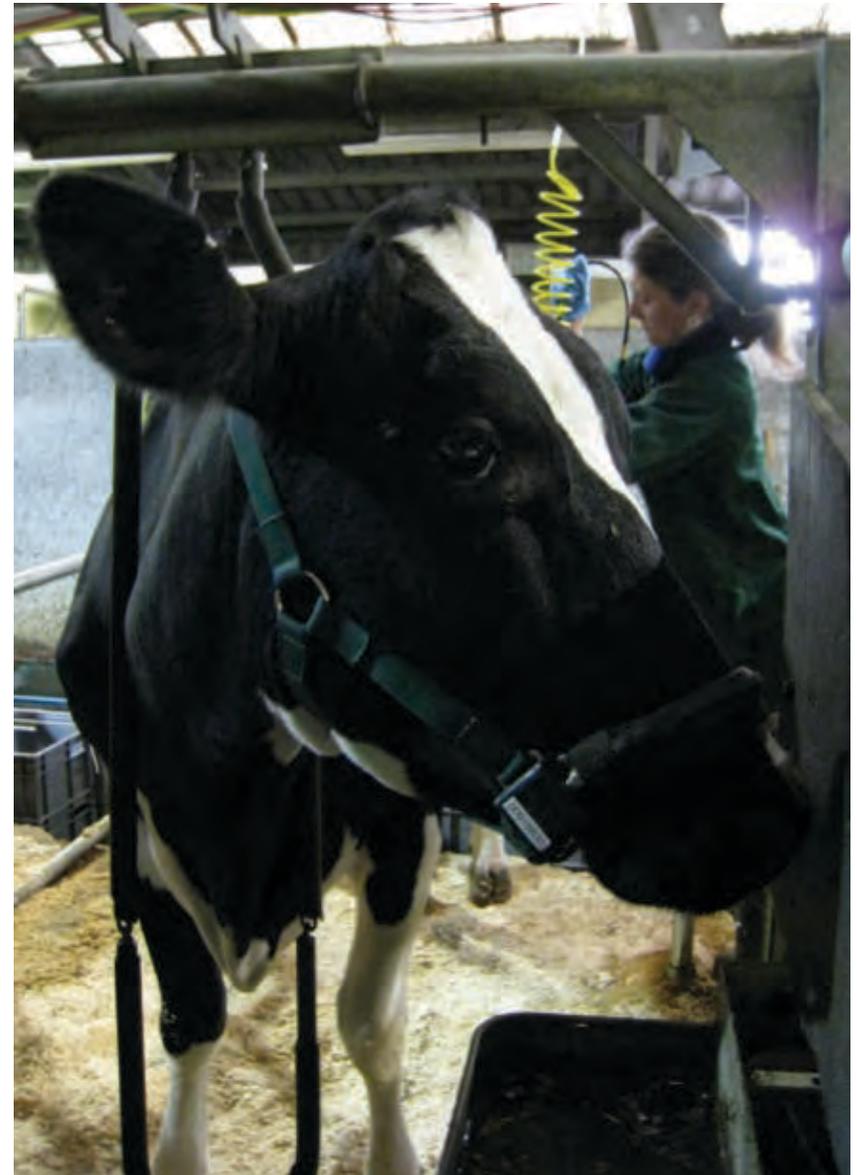
=> Wiederkäuer sollten kleinere Kotpartikel und höhere Futteraufnahmen haben als andere Pflanzenfresser



# Kau-Optimierung: Rhythmisches Kauen



# Kauhalftermessungen





# Kauhalftermessenungen

Applied Animal Behaviour Science 174 (2016) 19–25

Contents lists available at ScienceDirect

Applied Animal Behaviour Science

Journal homepage: [www.elsevier.com/locate/applanim](http://www.elsevier.com/locate/applanim)

Validation of a pressure sensor-based system for measuring eating, rumination and drinking behaviour of dairy cattle

Salla Ruuska<sup>a,b,c,\*,1</sup>, Sari Kajava<sup>b,c,\*,1</sup>, Mikaela Mughal<sup>d</sup>, Nils Zehner<sup>c</sup>, Jaakko Mononen<sup>a,b</sup>

<sup>a</sup> University of Eastern Finland, Department of Biology, Kuopio, Finland  
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**ARTICLE INFO**

**Article history:**  
Received 12 June 2015  
Received in revised form 27 October 2015  
Accepted 15 November 2015  
Available online 26 November 2015

**Keywords:**  
Eating  
Rumination  
Drinking  
Sensory  
Measurement  
Dairy cattle

**ABSTRACT**

The main objective of our study was to validate, for dairy cows, a new pressure-based system (RumiWatch noseband sensor, Ite+ Hoch GmbH, Liestal, Switzerland; RWS) that measures eating, rumination and drinking time. In experiment 1, eating, rumination and drinking time (RWS, min/h) measurements were compared with continuous behaviour recording (CR) of six dairy cows in tie-stalls (a total of 72 h). In addition, eating time measured by RWS was compared with the visiting time at automated feeders of a widely used type (Roughage Intake Control, RIC, Invertec BV, Marknesse, The Netherlands) to gain experience of the utility of RWS in a loose-housing system (experiment 2). A total of 403 h of RWS and RIC data from 18 cows was used for these two comparisons in experiment 2. In experiment 1, RWS and CR had a very dependable relationship (random coefficient regression model) for eating and rumination: eating,  $y = 0.98 (0.89 - 1.07)x + 3.25 (1.35)$  (the slope with the 95% confidence interval and the intercept with standard error of the mean) and rumination,  $y = 0.88 (0.73 - 1.02)x + 1.77 (1.00)$ . The  $R^2$  values were 0.94 and 0.93, respectively, i.e. random error was small. The 95% confidence intervals of the slopes included value 1, and the intercepts did not differ from 0; i.e. there was no significant systematic error. However, experiment 2 confirmed a tendency observed in experiment 1 that RWS overestimated eating, since RWS eating time ( $5.1 \pm 2.7$  h/24 h) exceeded significantly visiting time (RIC) ( $3.2 \pm 1.1$  h/24 h; paired *t*-test,  $n = 18$ ) in the setup where, in principle, eating was possible only in the RIC feeders. In experiment 1, the relationship between drinking time (RWS) and CR was poor:  $R^2 = 0.26$ , and  $y = 0.49 (0.12 - 0.85)x + 0.54 (0.13)$ . However, this may reflect more the challenges in measuring drinking in general than merely with RWS. In conclusion (i) the RWS results were relatively free from random errors for rumination and eating, but not for drinking, (ii) there was systematic error for eating and drinking, but not for rumination, and (iii) due to the relatively limited size of our data, further validation of RWS is recommended and RWS needs further development at least for eating and drinking measurements.

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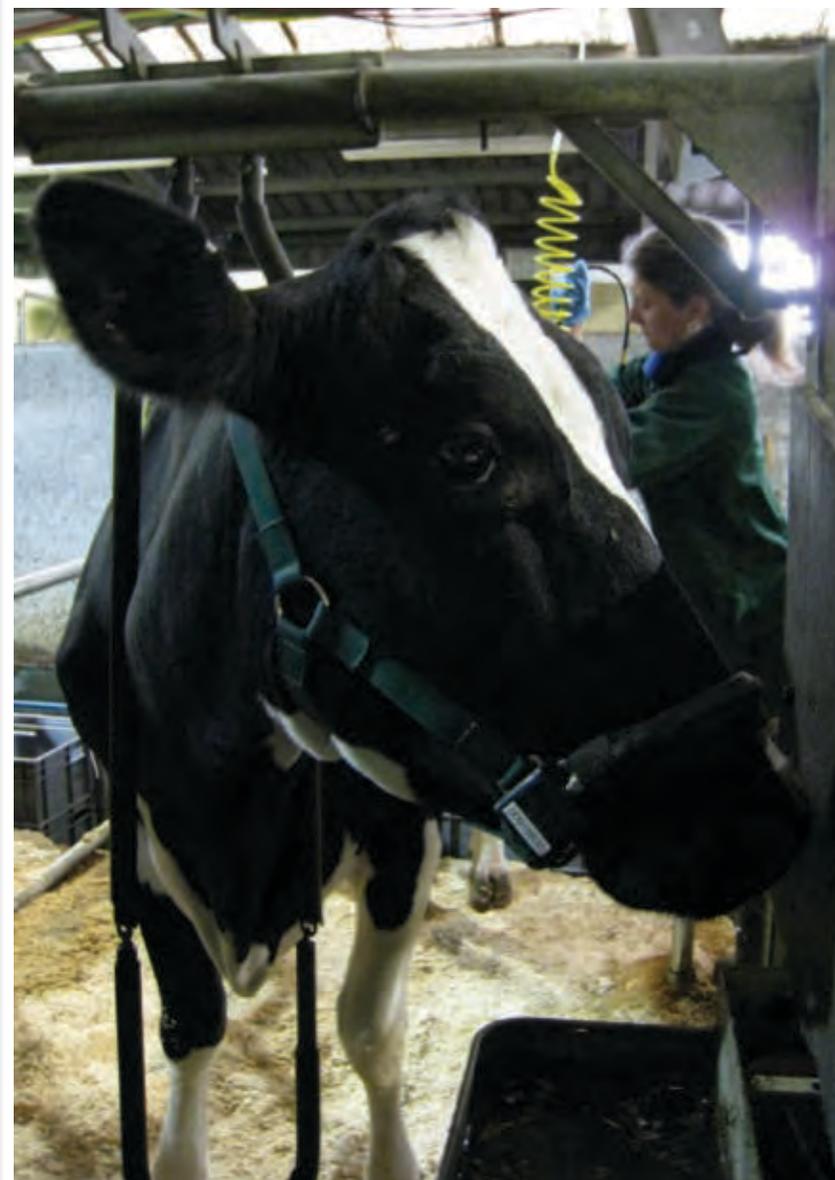
**1. Introduction**

Eating, rumination and drinking are essential components of the nutritional behaviour of dairy cows (Phillips, 2002). In scientific studies, the feeding behaviour of loose-housed cattle has been measured traditionally by direct observation methods. Automated equipment for measuring feeding behaviour and feed intake of cattle is, however, used more and more widely, because of the very labour-intensive requirements for conducting visual observations of behaviour (Beauchemin et al., 1989; Elischer et al., 2013). These types of automated equipment could also be of great benefit in large commercial dairy herds because ingestive behaviour can also be regarded as an important parameter for predicting health issues (as reviewed by Weary et al., 2009).

Devices used for measuring the feeding behaviour of dairy cows can be classified into two categories: stationary systems and systems based on sensors attached to animals. Stationary feeding systems use transponder tags that identify the individual animals and measure either the duration of visits at a feed alley (DeVries et al., 2003) or the visit duration and feed intake at feed troughs

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E-mail addresses: [salla.ruuska@luke.fi](mailto:salla.ruuska@luke.fi) (S. Ruuska), [sari.kajava@luke.fi](mailto:sari.kajava@luke.fi) (S. Kajava).  
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<http://dx.doi.org/10.1016/j.applanim.2015.11.005>  
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# Kauhalftermessungen

Computers and Electronics in Agriculture 136 (2017) 31–41

Contents lists available at ScienceDirect



Computers and Electronics in Agriculture

journal homepage: [www.elsevier.com/locate/compag](http://www.elsevier.com/locate/compag)



Original papers

System specification and validation of a noseband pressure sensor for measurement of ruminating and eating behavior in stable-fed cows



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## ARTICLE INFO

### Article history:

Received 22 August 2016

Received in revised form 14 February 2017

Accepted 20 February 2017

### Keywords:

Precision dairy farming

Health monitoring

Dairy cow

RumiWatch

Chewing activity

## ABSTRACT

Rumination and eating behavior are important indicators for assessing health and well-being in cattle. The objective of this study was to develop and validate a novel scientific monitoring device for automated measurement of ruminating and eating behavior in stable-fed cows to provide research with a measuring instrument for automated health and activity monitoring. The RumiWatch noseband sensor (Itin+Hoch GmbH, Liestal, Switzerland) incorporates a noseband pressure sensor, a data logger with online data analysis, and software. Automated measurements of behavioral parameters are based on generic algorithms without animal-specific learning data. Thereby, the system records and classifies the duration of chewing activities and enables users to quantify individual ruminating and eating jaw movements performed by the animal. During the course of the development, two releases of the system-specific software RumiWatch Converter (RWC) were created and taken into account for the validation study. The results generated by the two software versions, RWC V0.7.2.0 and RWC V0.7.3.2, were compared with direct behavioral observations. Direct observations of cow behavior were conducted on 14 Swiss dairy farms with an observation time of 1 h per animal, resulting in a total sample of 60 dairy cows. Agreement of sensor measurement and direct observation was expressed as Spearman correlation coefficients ( $r_s$ ) for the pooled sample. For consolidated classification of sensor data (1-h resolution), correlations for rumination time were  $r_s = 0.91$  (RWC V0.7.2.0) and  $r_s = 0.96$  (RWC V0.7.3.2), and for eating time  $r_s = 0.86$  (RWC V0.7.2.0) and  $r_s = 0.96$  (RWC V0.7.3.2). Both software versions provide a high standard of validity and measuring performance for ruminating and eating behavior. The high to very high correlations between direct observation and sensor data demonstrate that the RumiWatch noseband sensor was successfully developed and validated as a scientific monitoring device for automated measurement of ruminating and eating activity in stable-fed dairy cows.

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## 1. Introduction

Research in the field of Precision Livestock Farming has put a major effort on development and evaluation of technologies allowing early recognition of pathological and management-relevant behavioral changes and assessment of the individual health state in dairy cows (cf. review by Rutten et al., 2013). Hence, sensor devices for automated detection of health impairments in livestock are increasingly available and can provide effective management support in various types of farming systems. In dairy cattle nutrition, chewing activity has been identified as an important parameter to assess the adequate composition of a diet and the risk of

ruminal acidosis (Yang and Beauchemin, 2007). Furthermore, ruminating activity may provide meaningful information on calving time and subclinical diseases or health disorders (Goff and Horst, 1997; Soriani et al., 2012). Accordingly, continuous measurements of cow feeding variables enable us to develop a more complete understanding of the dietary effects on digestive function and performance (Dado and Allen, 1993). The timeline and intensity of feeding activity provide information on the diurnal pattern of the behavior of ruminants, and identification of deviations may be used for detection of health impairments (Weary et al., 2009; Braun et al., 2014). Direct observation for measurement of ruminating and eating behavior is labor intensive, error-prone and hardly applicable for continuous observations on several animals simultaneously (Penning, 1983). For these reasons, several methods have been developed for automated, non-invasive measurement of chewing activity in ruminants. The working principle of

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<http://dx.doi.org/10.1016/j.compag.2017.02.021>

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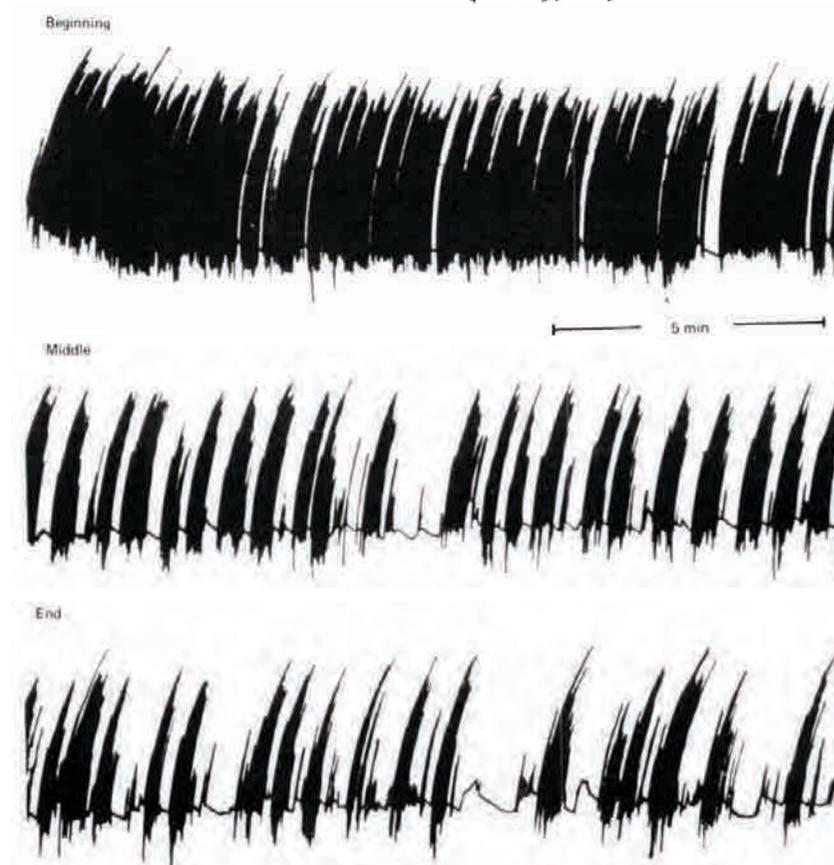




# Silage intake, rumination and pseudo-rumination activity in sheep studied by radiography and jaw movement recordings

BY A. G. DESWYSEN\* AND H. J. EHRLEIN

*Br. J. Nutr.* (1981), 46, 327

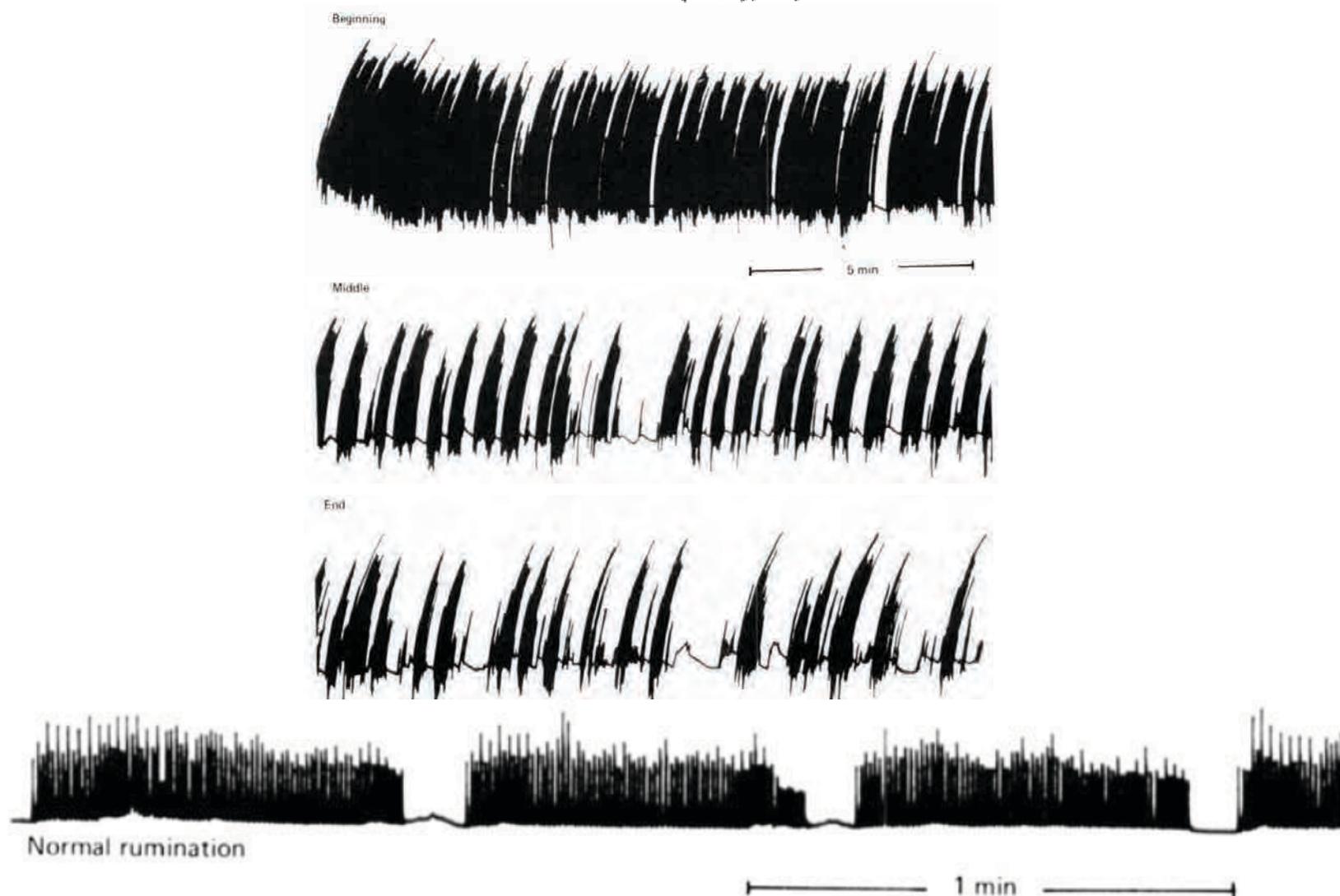




# Silage intake, rumination and pseudo-rumination activity in sheep studied by radiography and jaw movement recordings

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*Br. J. Nutr.* (1981), 46, 327





# Kauhalftermessungen





# Kauhalftermessungen

Livestock Science 86 (2016) 53–58

Contents lists available at ScienceDirect

**Livestock Science**

Journal homepage: [www.elsevier.com/locate/livsci](http://www.elsevier.com/locate/livsci)

**Validation of a sensor-based automatic measurement system for monitoring chewing activity in horses**

J. Werner<sup>a,\*</sup>, C. Umstatter<sup>a</sup>, N. Zehner<sup>a</sup>, J.J. Niederhauser<sup>b</sup>, M. Schick<sup>a</sup>

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**ARTICLE INFO**

**Article history:**  
Received 12 January 2015  
Received in revised form 10 June 2015  
Accepted 27 July 2015

**Keywords:**  
Animal welfare  
Feeding behaviour  
Feeding management  
RumWatch  
RumWatch  
Stenoxyptics

**ABSTRACT**

The aim of this study was to determine the feasibility of using a jaw movement measuring system developed for cattle, the "RumWatchSystem", on horses. The system records the chewing activity and consists of a mouth and pressure sensor, integrated into a halter, and a software package. In order to investigate the accuracy of the system, 10 horses (5 mares, 5 stallions) were equipped with the device. Additionally, they were observed visually as a reference method, while feeding three different feeds (hay, haylage and concentrate). To ensure similar conditions, the horses were stabled individually and fed twice daily with roughage and twice or three times with concentrate. The results of the visual observation were compared to the automatic measurement as an evaluation of the accuracy of the automatic measurement system.

The overall agreement of the observed and automatically measured data within all feedstuffs was 93%. The agreement of feeding roughage was even higher with 95%. However, for concentrate the visual observations and automatic measurements agreed only in 91.4%. The decreased agreement compared to the roughage is due to the high sensitivity of the automated system. Horses tend to display a high amount of lip movements towards the end of the concentrate intake. This is different compared to cattle behaviour and their feeding regime. However, the system was not specifically adapted to horses so far and can be optimized in order to improve accuracy. Consequently, the system has a high potential to become a reliable tool for research and practical use.

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**1. Introduction**

The chewing activity of horses can be a suitable parameter for health and welfare assessment as the prevalent housing and feeding conditions often leave horses unscruffed. Evolutionary, horses adapted over a long period of time to their ecological niche (Janis, 1976). They used to live as grazers in steps with poor vegetation. Therefore, they are adjusted to a low energy and high fibre diet. The feed intake behaviour is defined by a long intake time of 12–16 h (Zickler-Frischt, 2008; McGreevy, 2004) and travelling long distances of up to 28 km a day (Hampton et al., 2010). Because of the natural food resource, the gastric system is well adapted to small feeding bouts and a consistent filling of the stomach. With the help of microbial fermentation in the large caecum, it is possible to split high fibre feed (Frappé, 2010). In modern housing systems, compared to the natural behaviour, horses are often fed roughage restrictive (twice daily) with an additional feeding of grains. This leads to a high amount of starch over a small period of time and can cause illness of the gastrointestinal system like gastric ulcers (Hymettler et al., 2012). Even in pleasure horses the prevalence of gastric ulcers is 40–80% (Niedzwiedz et al., 2013). Additionally, horses are mostly individually stabled and there is often little or no possibility of social contact to other horses. In Northern Germany, 10% of stabled horses do not even have the possibility to observe their environment (Peterson et al., 2005). This deviation of natural behaviour may lead to abnormalities or stenoxyptics (Goepfer and Albonetti, 2005) and even to serious health problems. To evaluate and monitor the feed intake behaviour of a horse, it would be very valuable to measure the chewing activity automatically. The "RumWatchSystem" could provide us with an assessment tool for different feeding regimes and husbandry systems.

There are still a number of unanswered questions, e.g. why such a high number of stomach ulcers occur in horses. Analyzing the chewing behaviour linked to different feeding regimes would provide us with valuable information and might lead us to the solution how to reduce stomach ulcers. Another possibility to use

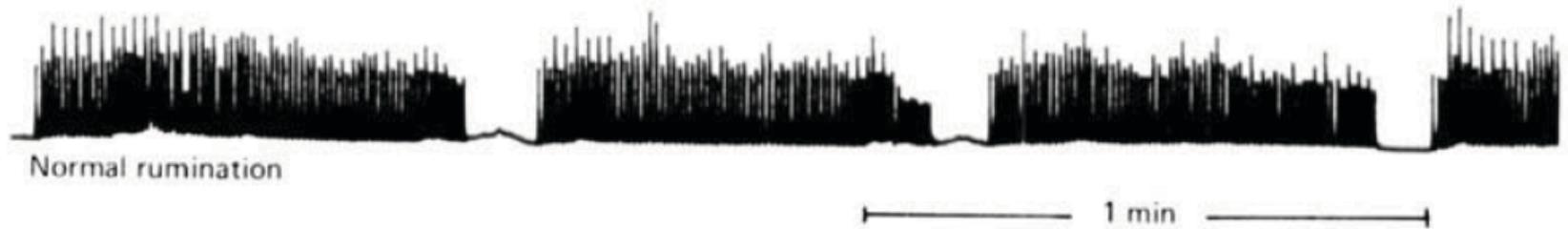
\* Corresponding author.  
E-mail address: [jwerner@agroscope.admin.ch](mailto:jwerner@agroscope.admin.ch) (J. Werner).

<http://dx.doi.org/10.1016/j.livsci.2015.07.019>  
S0167-6369(2015)00019-0





# Hypothese





# Hypotheses



Normal rumination

1 min





# Methoden

- 6 Simmental Färsen (*Bos taurus*,  $459 \pm 110$  kg)
- 6 Trampeltiere (*Camelus bactrianus*,  $645 \pm 60$  kg)
- 6 Warmblutpferde (*Equus caballus*,  $563 \pm 44$  kg)

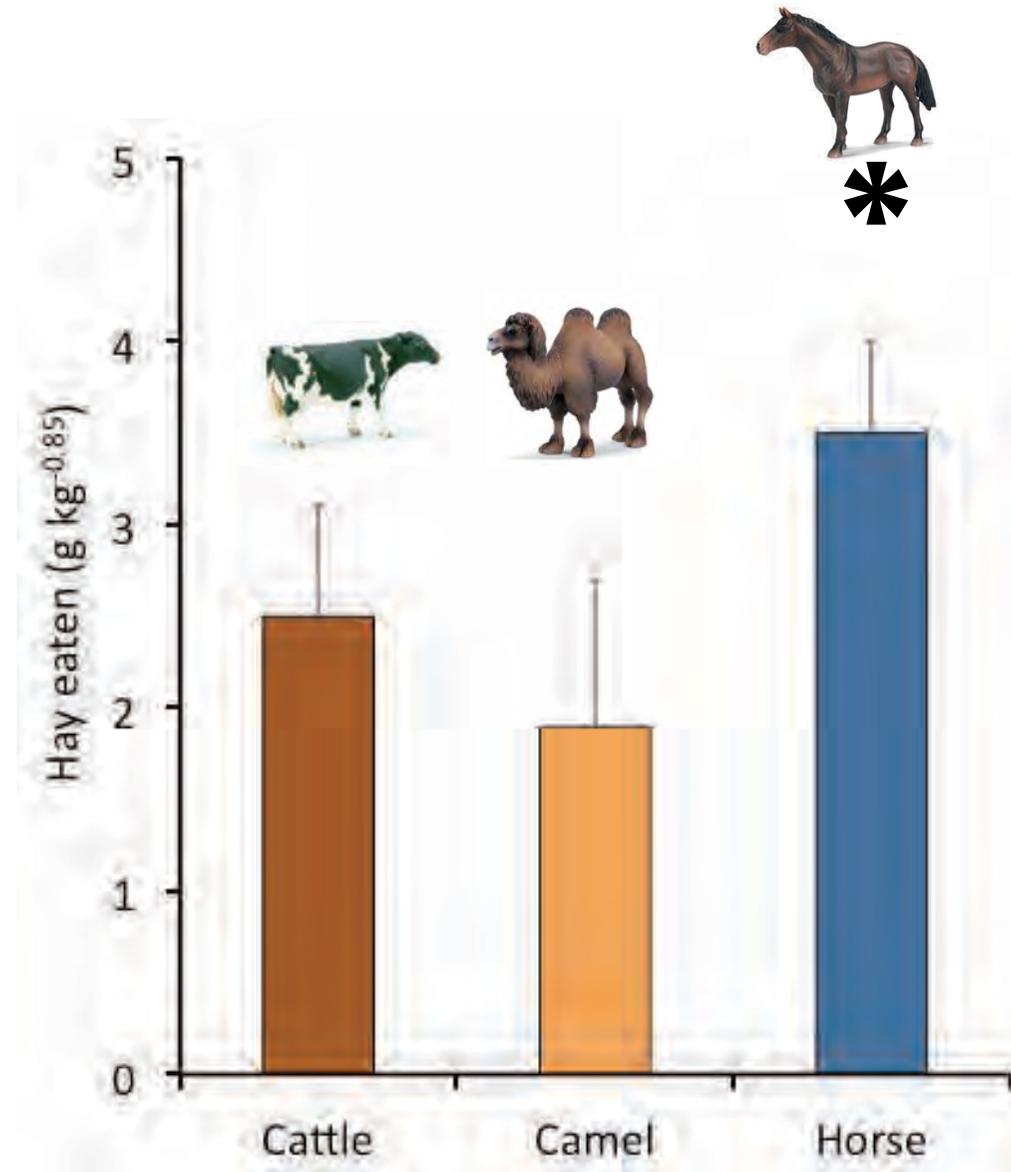
Rumiwatch Kauhalfter

Ganzes Heu (CP 74, NDF 607, ADF 324 g/kg DM)  
für 15 Minuten (plus 2 h max. bis Wiederkäuen)  
Futteraufnahme gemessen





# Futteraufnahme





# Methoden

Rumiwatch Messungen:

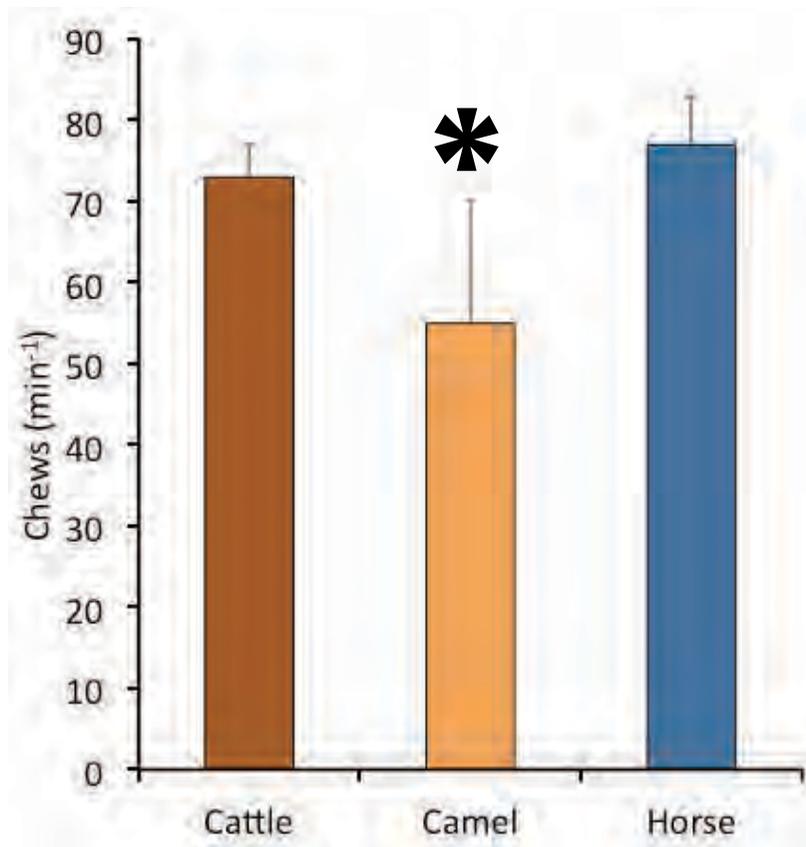
1. Kauschläge



# Kauschläge

Rumiwatch Messungen:

## 1. Kauschläge

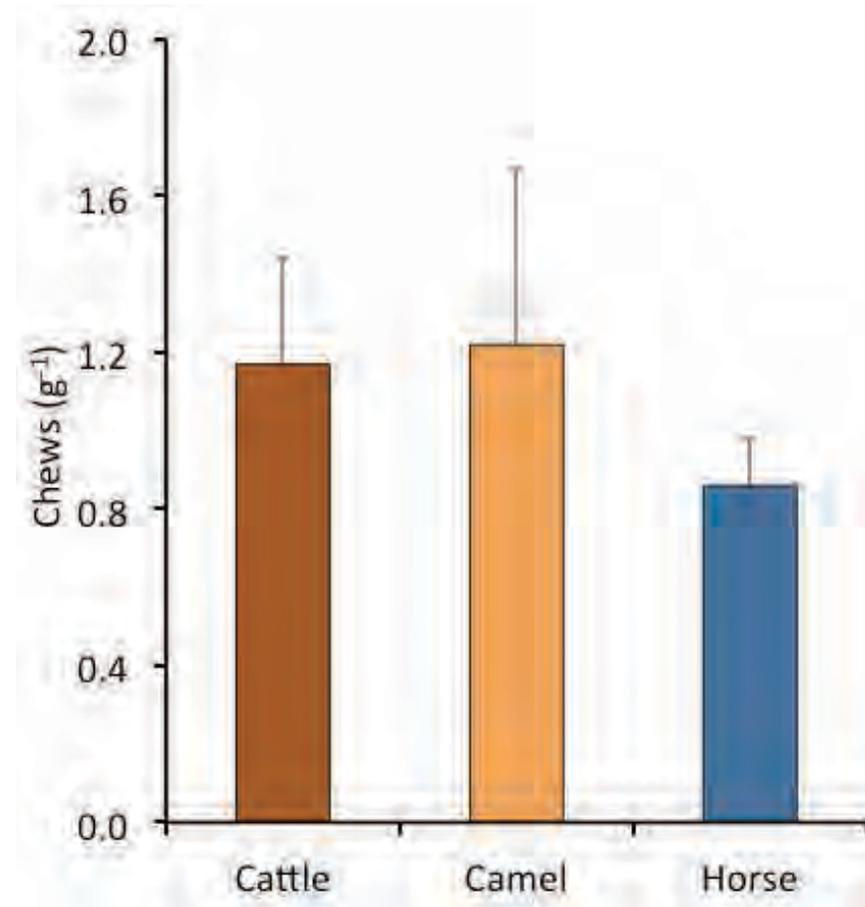
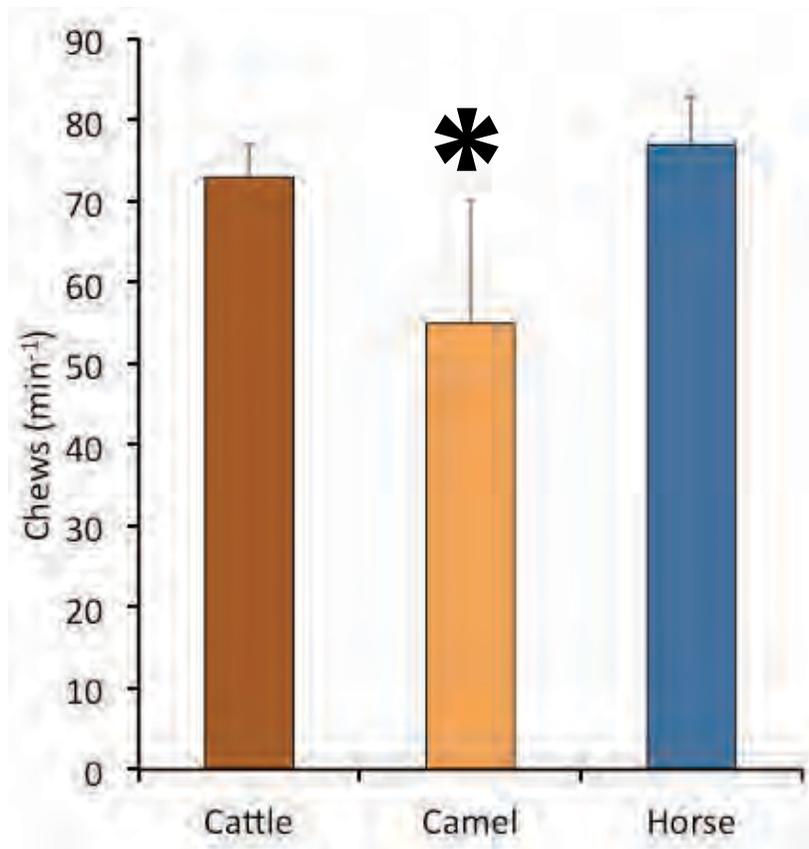




# Kausschläge

Rumiwatch Messungen:

## 1. Kausschläge

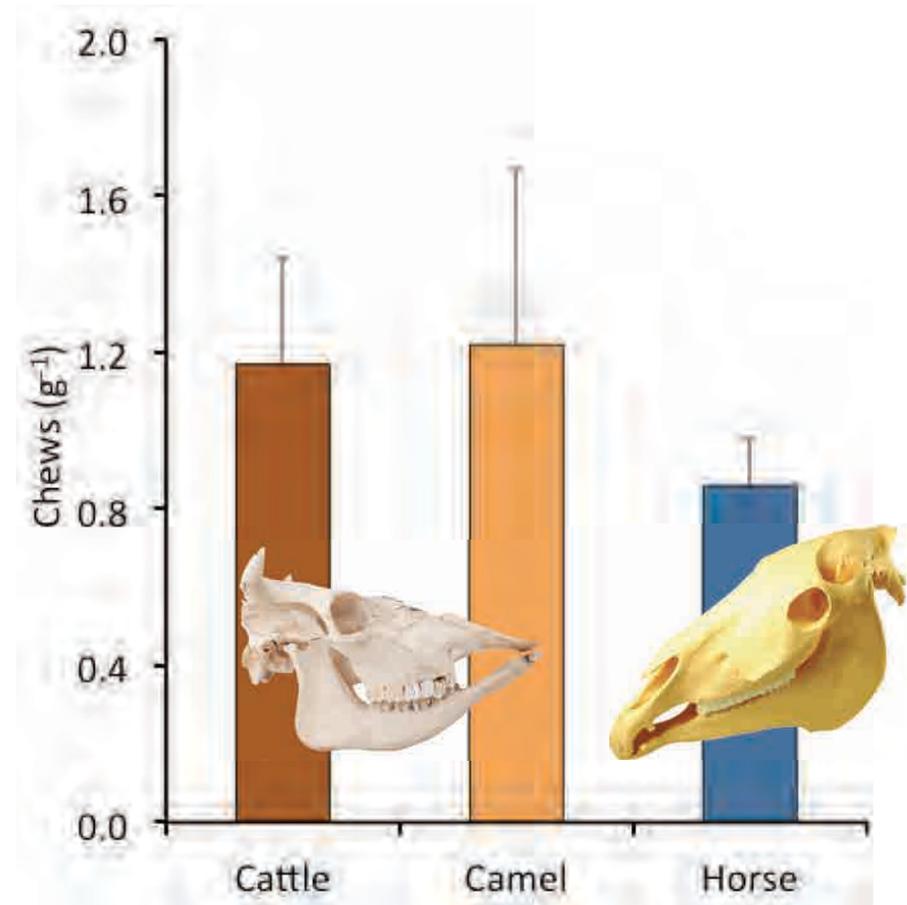
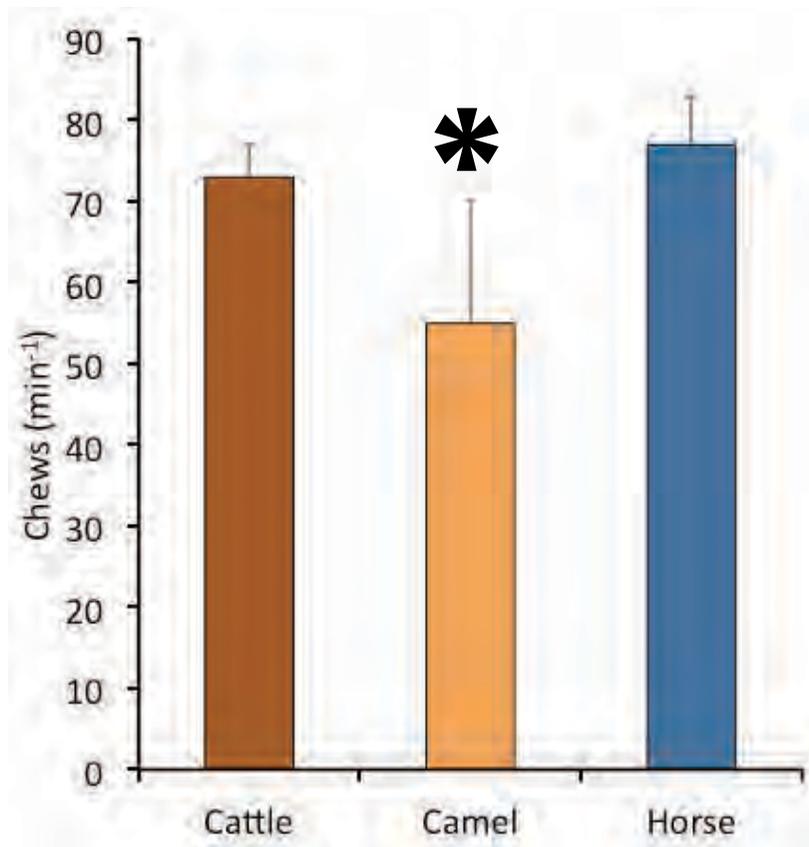




# Kauschläge

Rumiwatch Messungen:

## 1. Kauschläge





# Methoden

Rumiwatch Messungen:

2. Fresskauen / Wiederkäuen

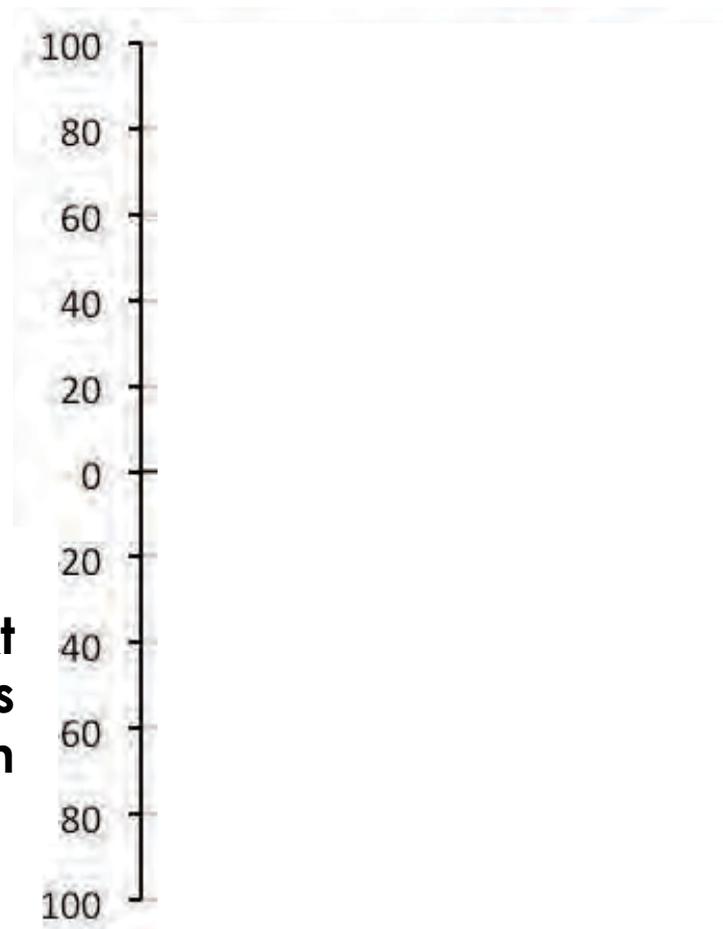


# Kau-Art Identifizierung

Rumiwatch Messungen:

## 2. Fresskauen / Wiederkäuen

**% korrekt  
identifiziert als  
Fresskauen**



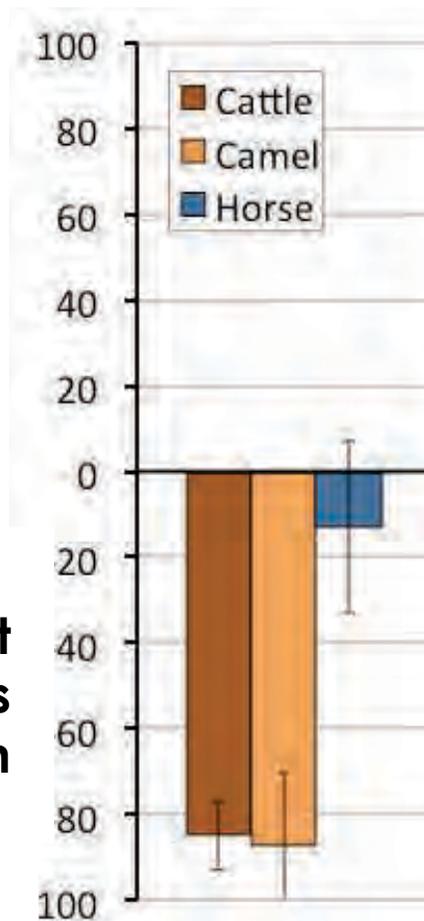


# Kau-Art Identifizierung

Rumiwatch Messungen:

## 2. Fresskauen / Wiederkäuen

**% korrekt  
identifiziert als  
Fresskauen**

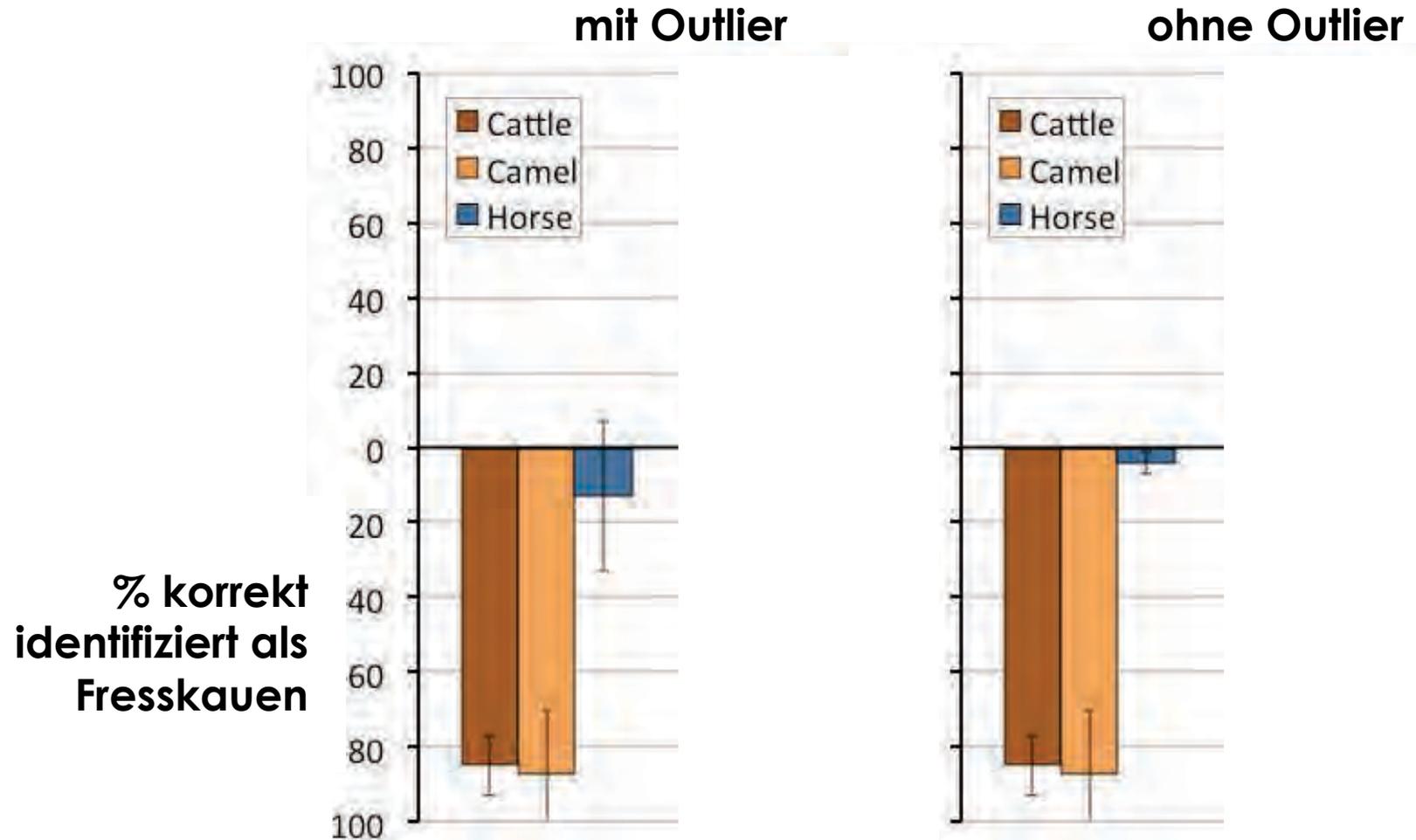




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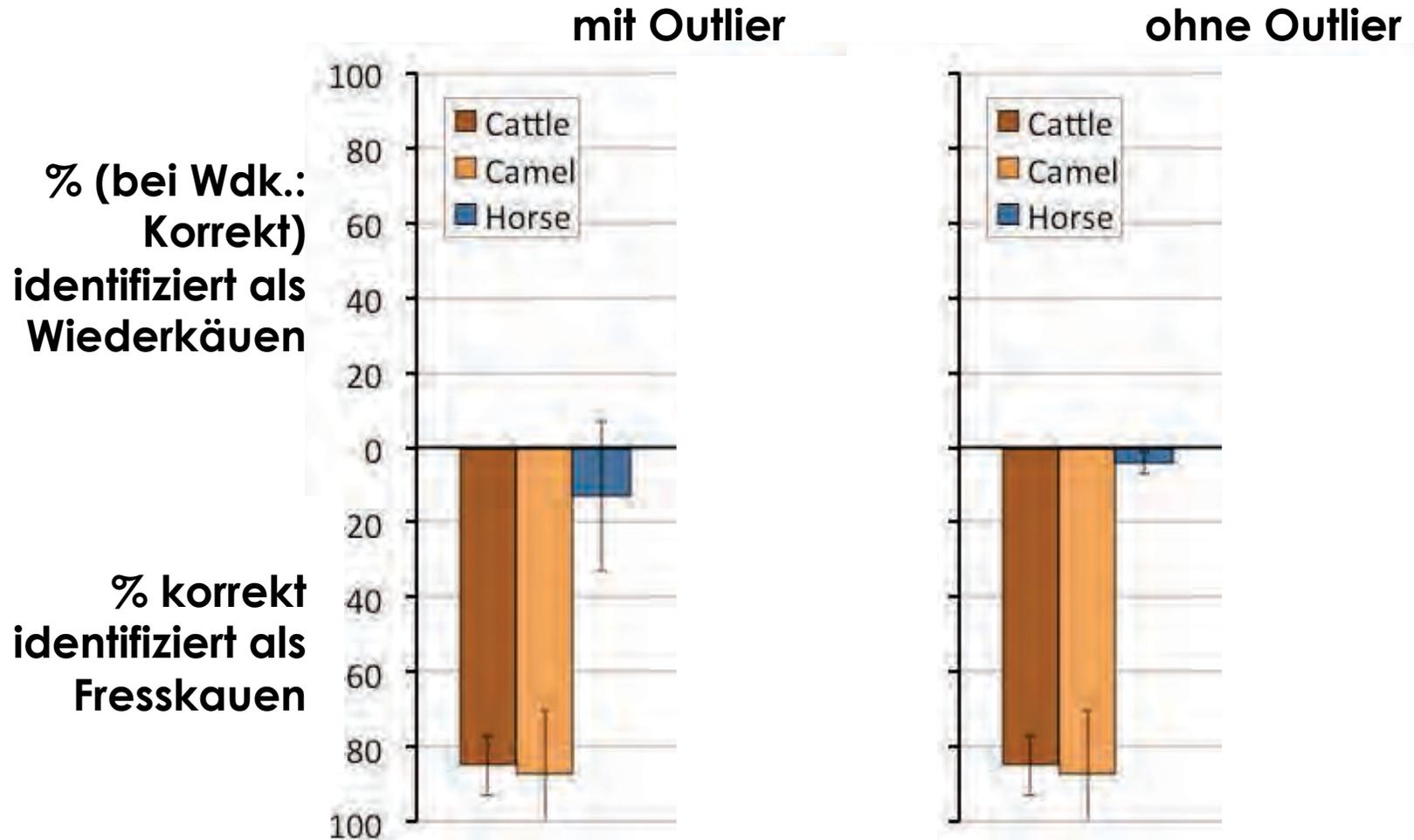




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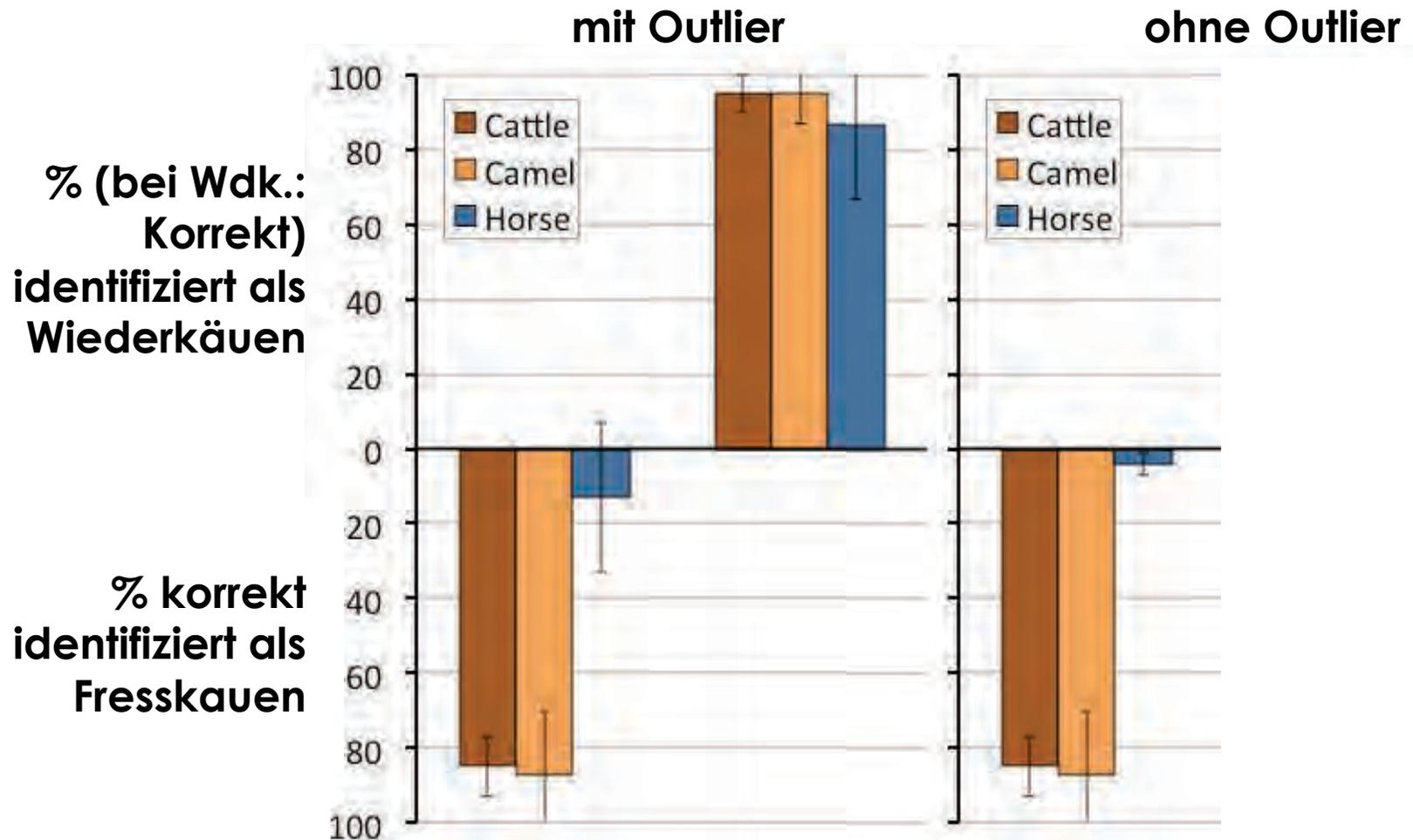




# Kau-Art Identifizierung

Rumiwatch Messungen:

## 2. Fresskauen / Wiederkäuen

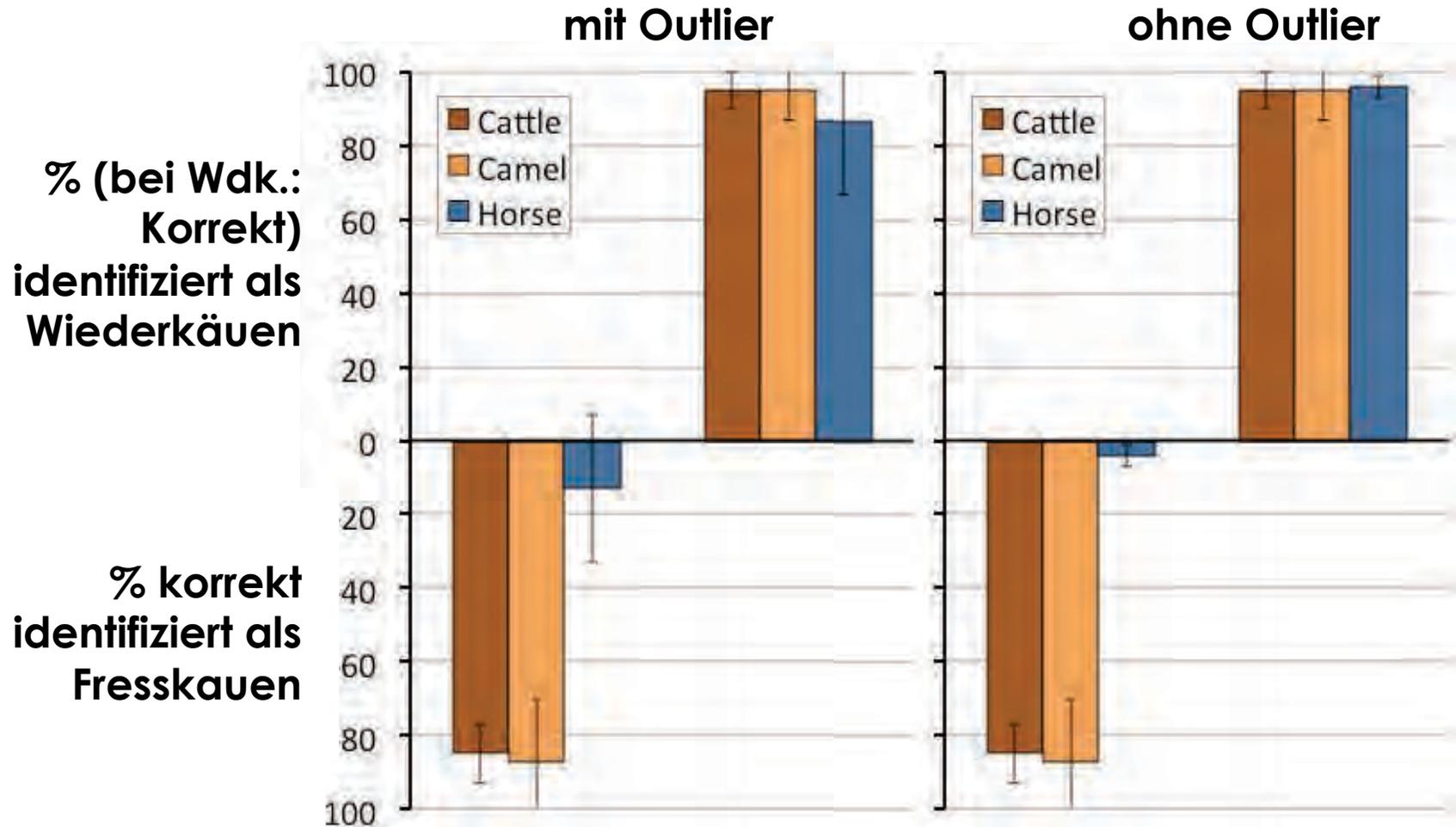




# Kau-Art Identifizierung

Rumiwatch Messungen:

## 2. Fresskauen / Wiederkäuen





# Methoden

Rumiwatch Messungen (zusätzl. Software):

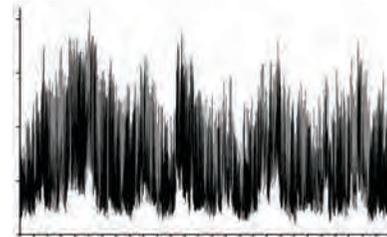
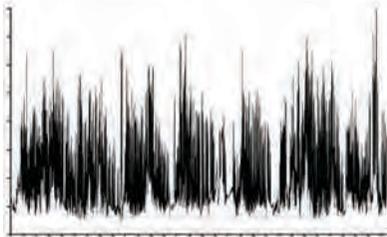
3. Visualisierung der Rohdaten



# Methoden

Rumiwatch Messungen (zusätzl. Software):

## 3. Visualisierung der Rohdaten

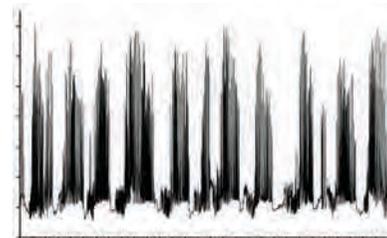
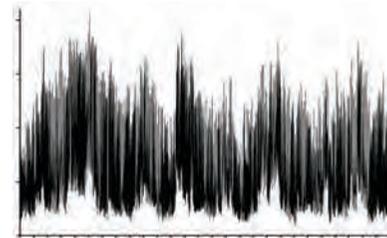




# Methoden

Rumiwatch Messungen (zusätzl. Software):

## 3. Visualisierung der Rohdaten

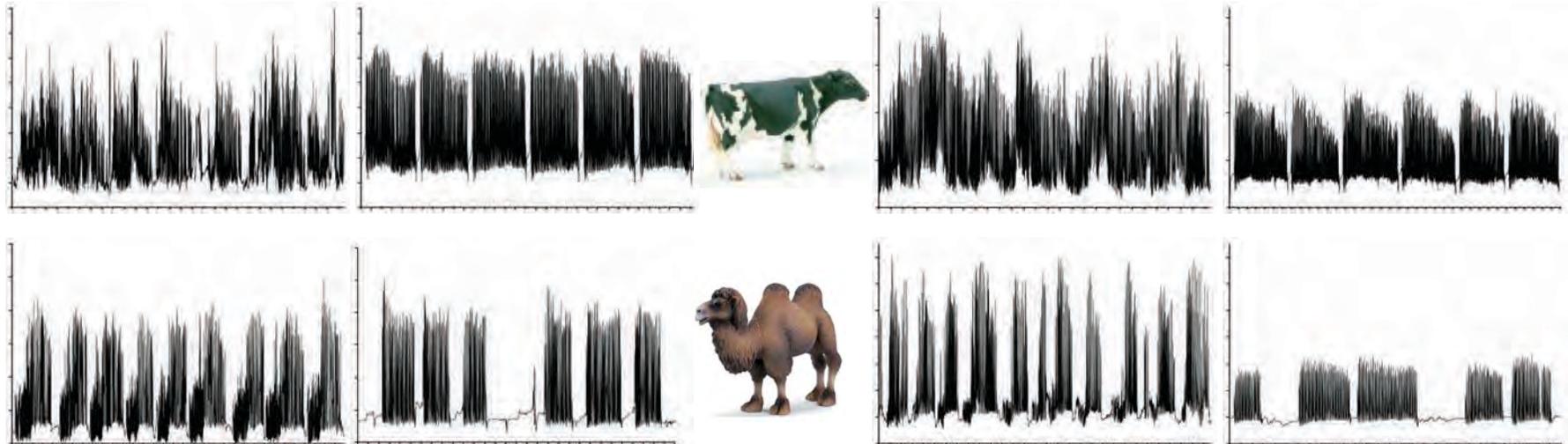




# Methoden

Rumiwatch Messungen (zusätzl. Software):

## 3. Visualisierung der Rohdaten

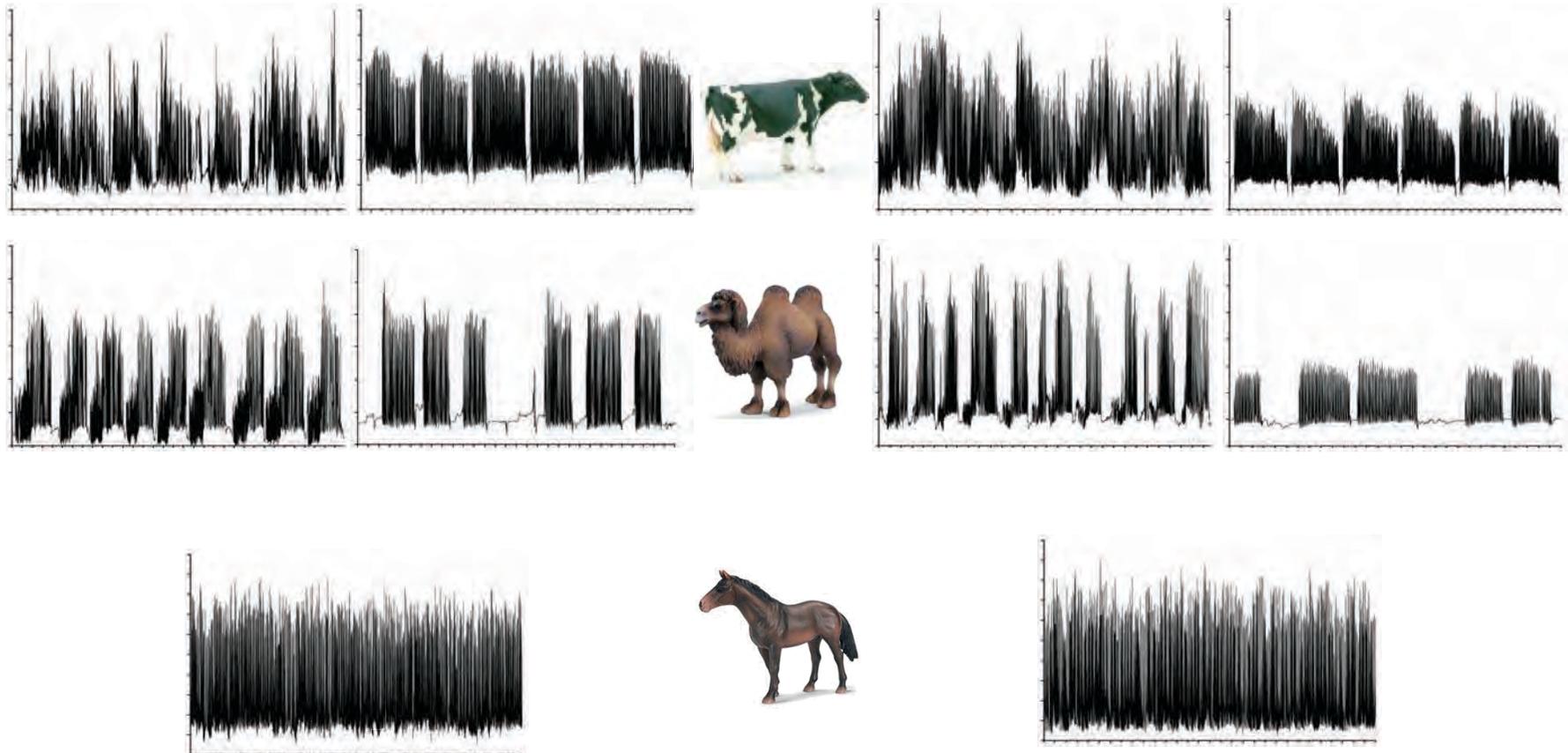




# Methoden

Rumiwatch Messungen (zusätzl. Software):

## 3. Visualisierung der Rohdaten

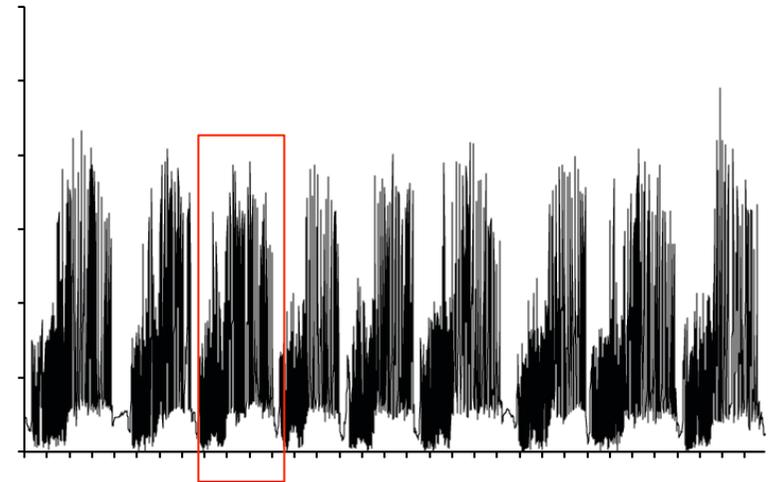
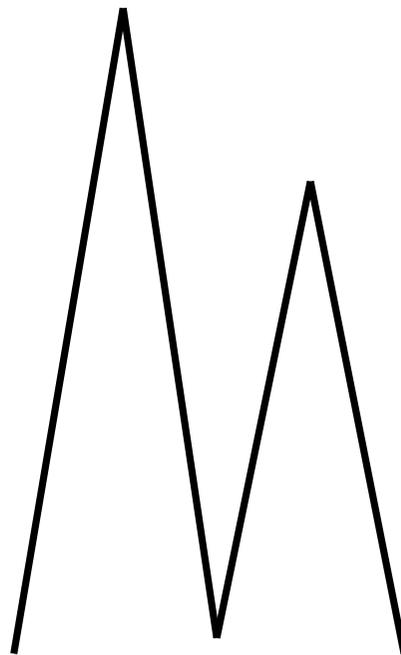




# Methoden

Rumiwatch Messungen (zusätzl. Software):

4. für 10 aufeinanderf. Kauphasen: Berechnung der Standardabweichung

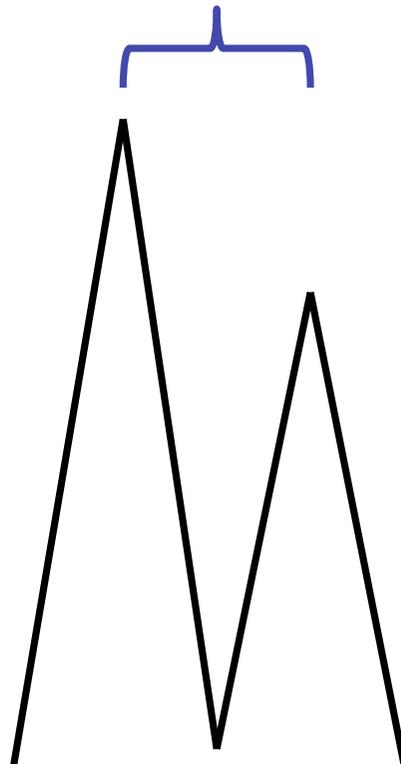




# Methoden

Rumiwatch Messungen (zusätzl. Software):

4. für 10 aufeinanderf. Kauphasen: Berechnung der Standardabweichung Peak-Interval (s)

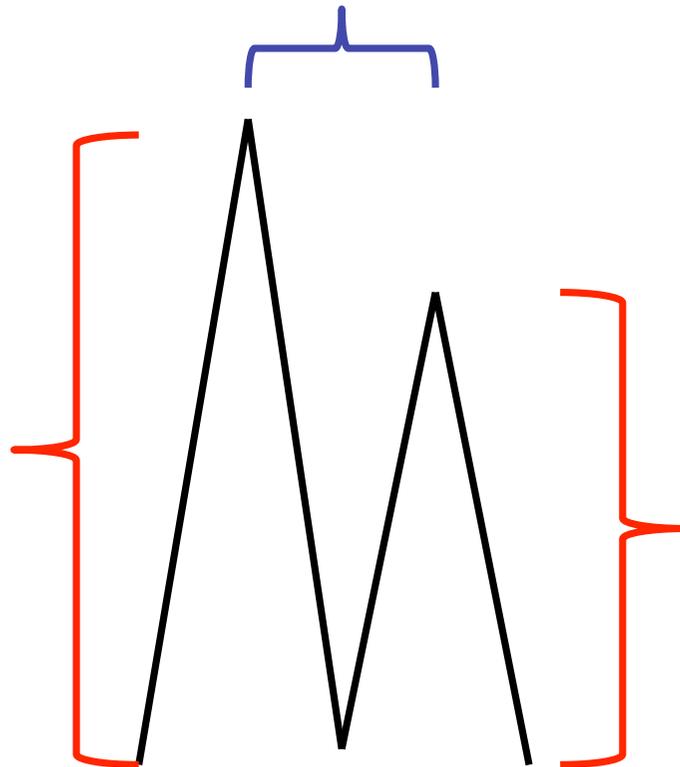




# Methoden

Rumiwatch Messungen (zusätzl. Software):

4. für 10 aufeinanderf. Kauphasen: Berechnung der Standardabweichung Peak-Interval (s), Peak-Höhe (mbar)

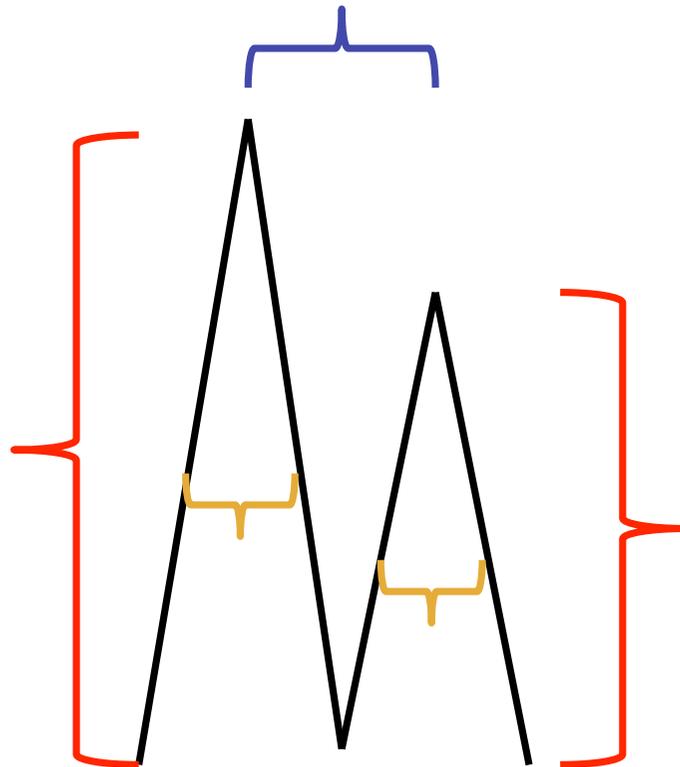




# Methoden

Rumiwatch Messungen (zusätzl. Software):

4. für 10 aufeinanderf. Kauphasen: Berechnung der Standardabweichung Peak-Interval (s), Peak-Höhe (mbar), Peak-Breite (s)

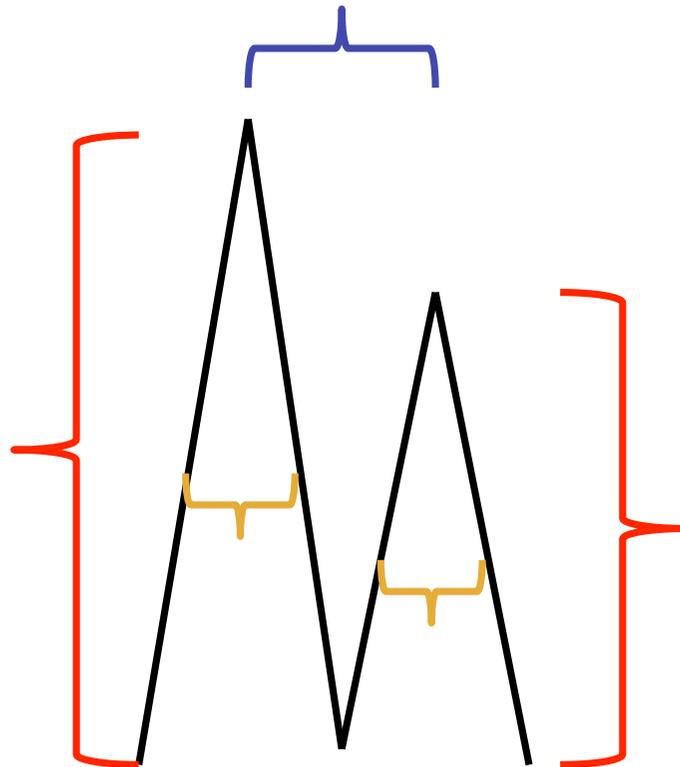




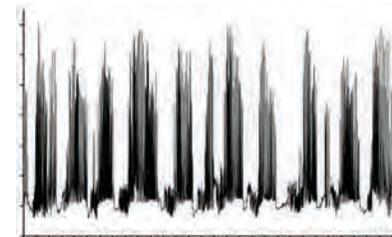
# Methoden

Rumiwatch Messungen (zusätzl. Software):

4. für 10 aufeinanderf. Kauphasen: Berechnung der Standardabweichung Peak-Interval (s), Peak-Höhe (mbar), Peak-Breite (s)

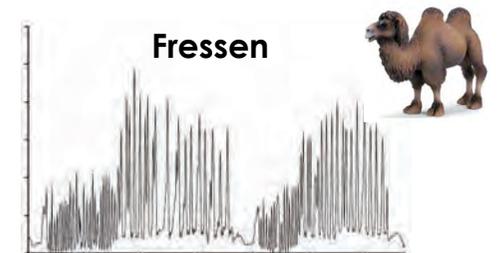
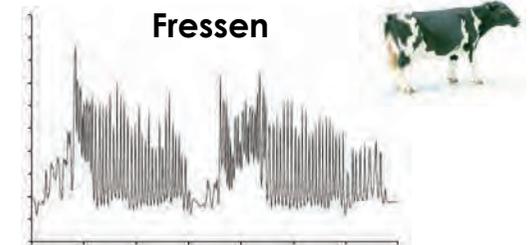
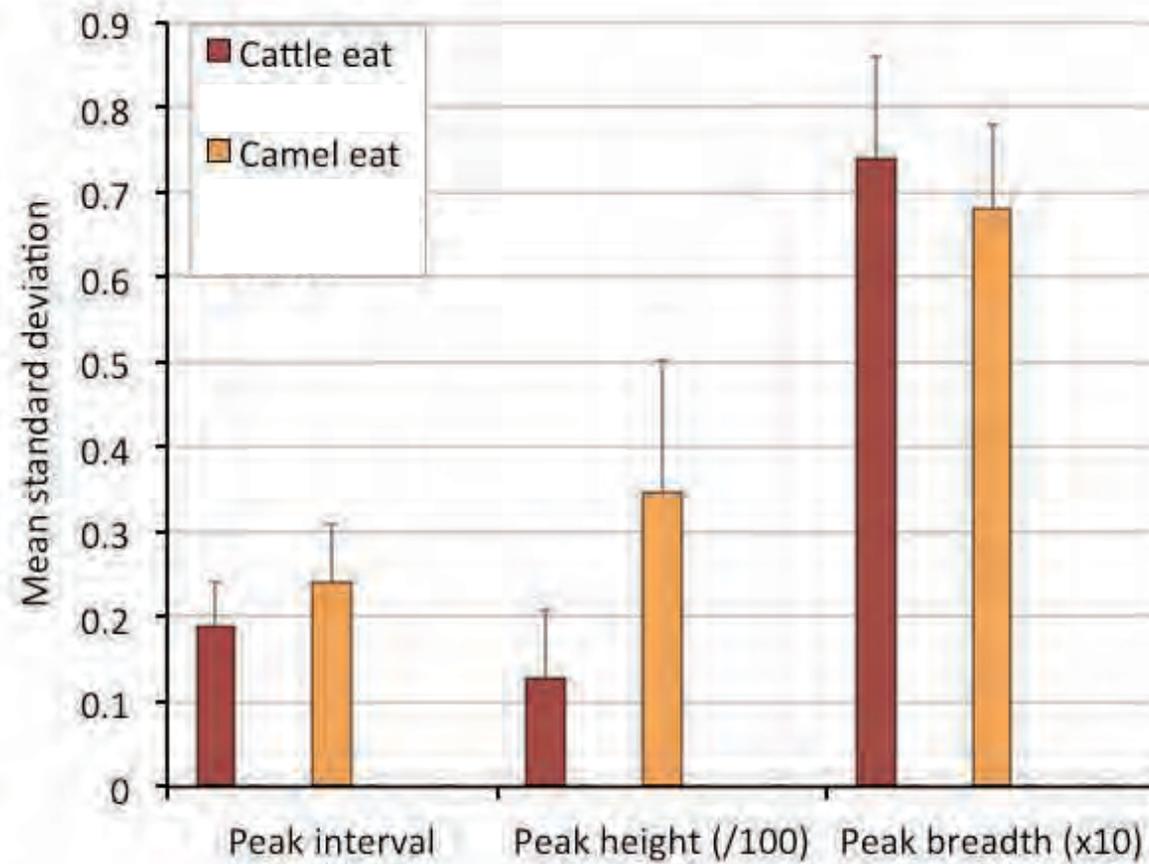


5. Berechnung der durchschnittl. SD der 10 Kauphasen



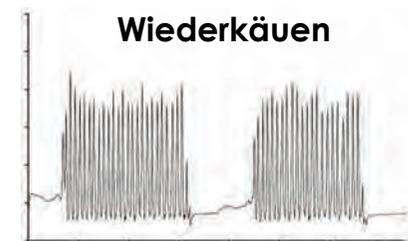
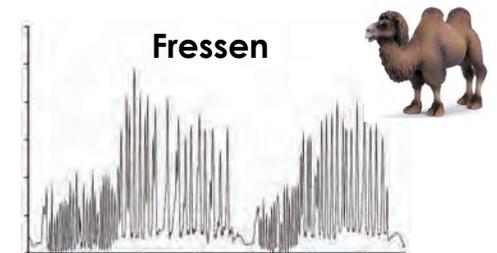
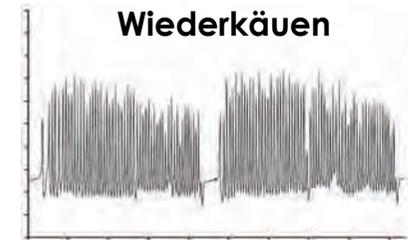
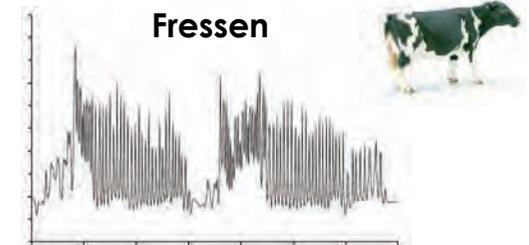
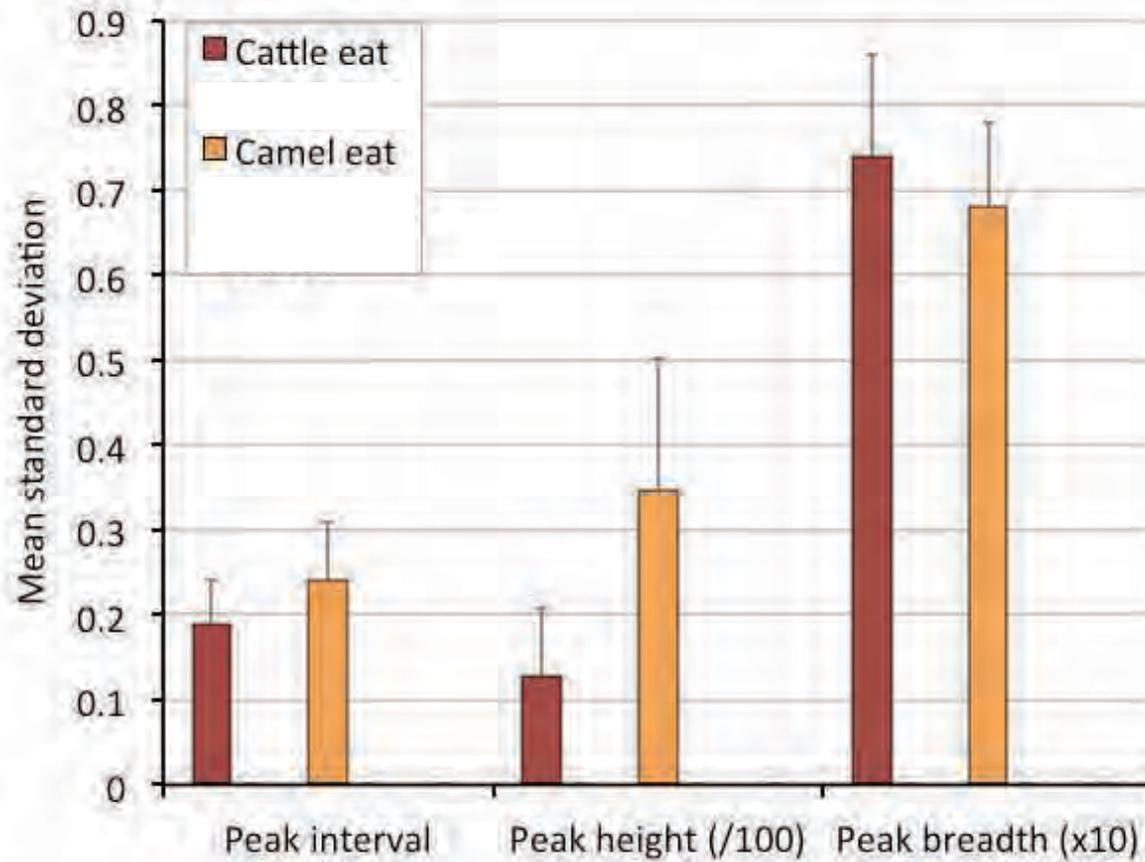


# Kau-Rhythmik



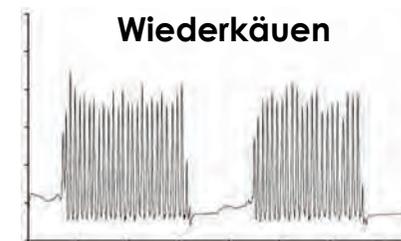
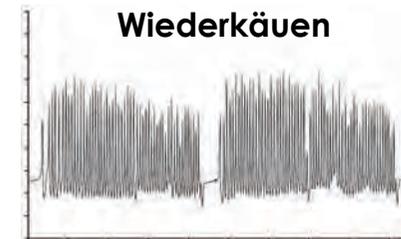
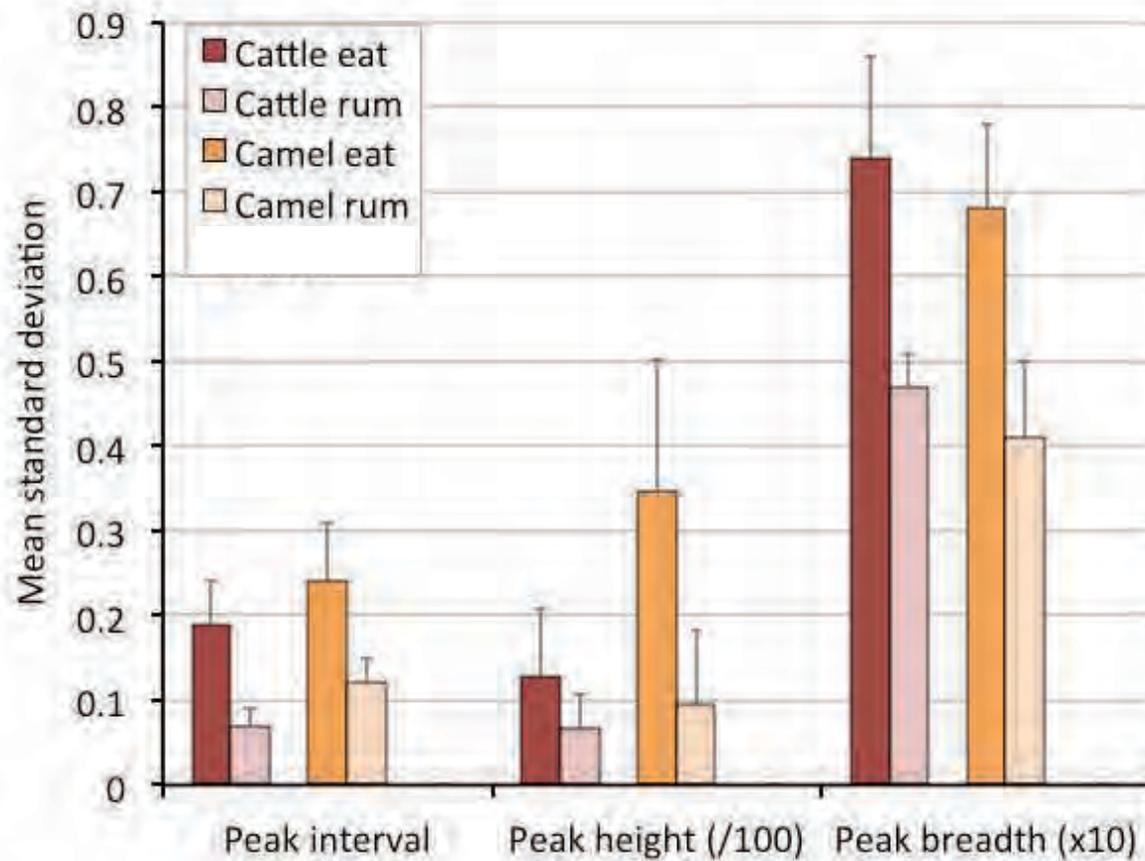


# Kau-Rhythmik



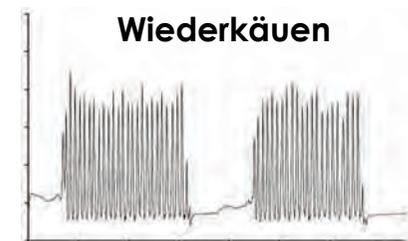
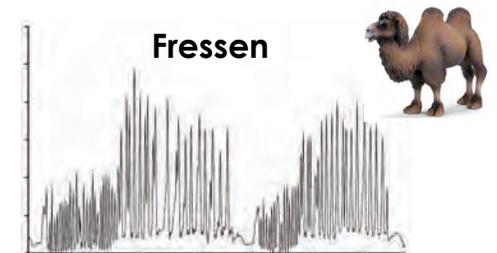
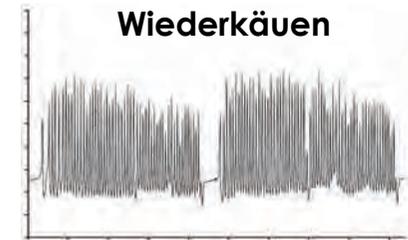
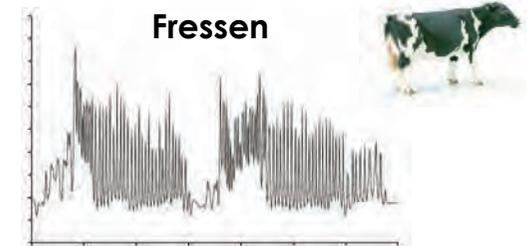
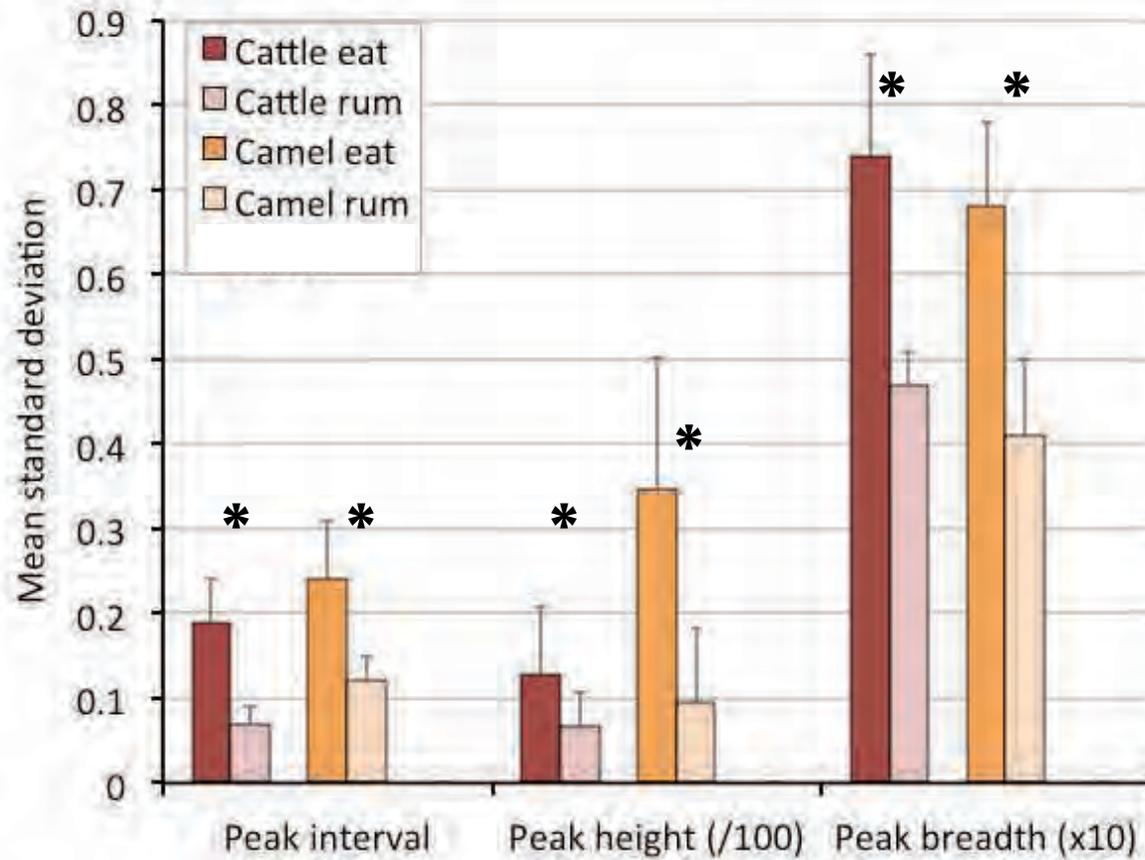


# Kau-Rhythmik



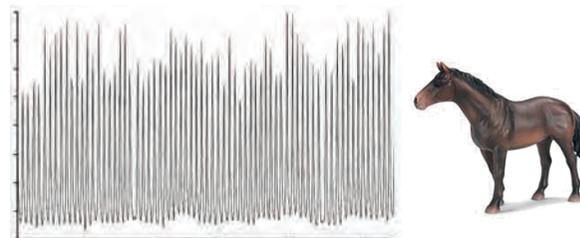
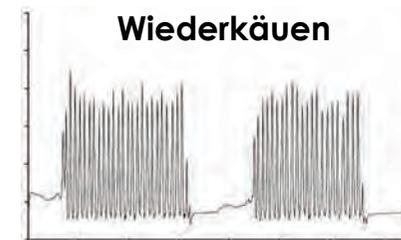
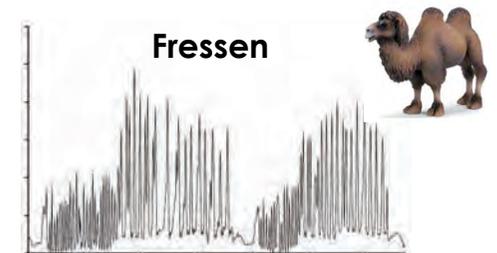
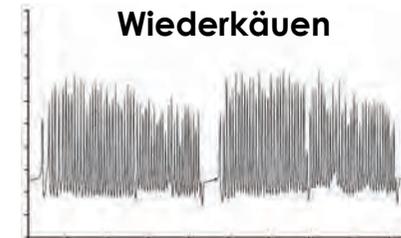
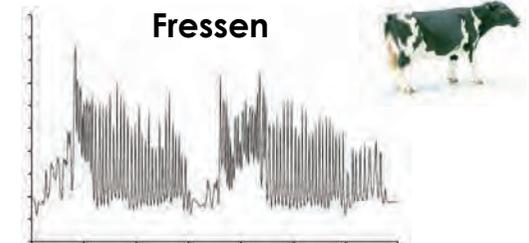
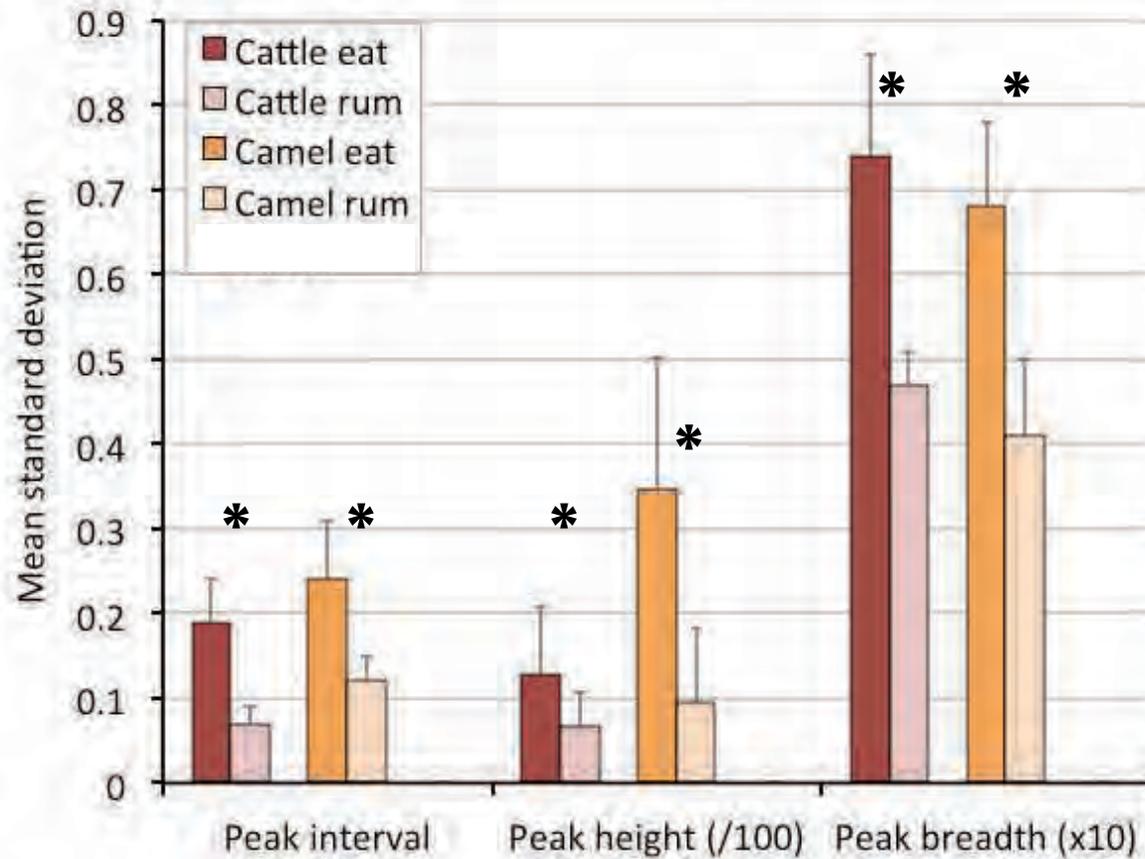


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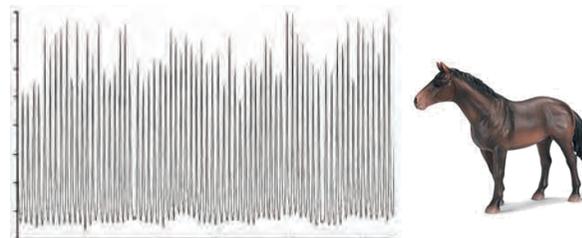
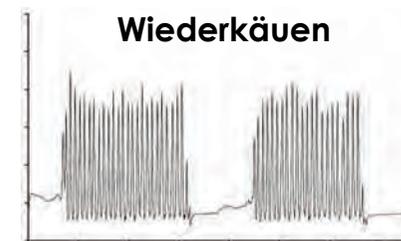
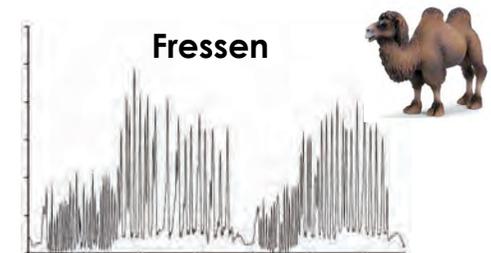
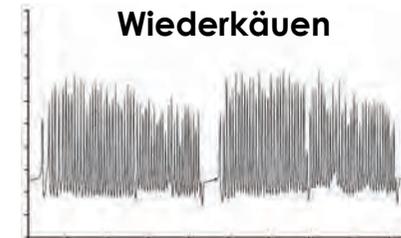
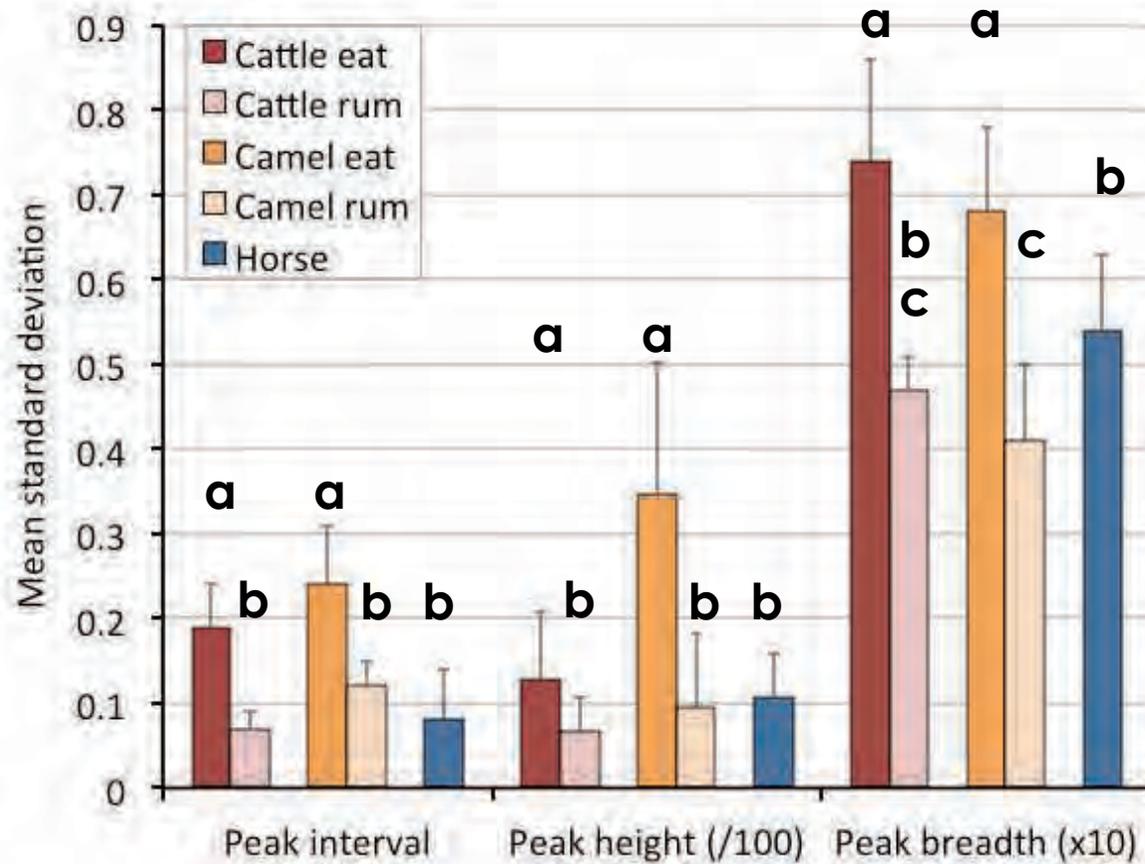


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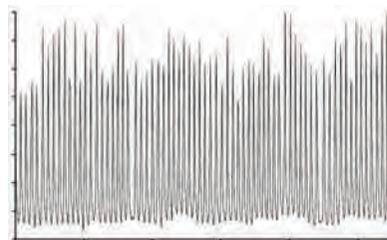
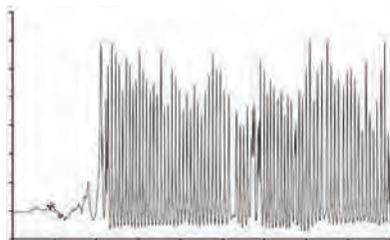
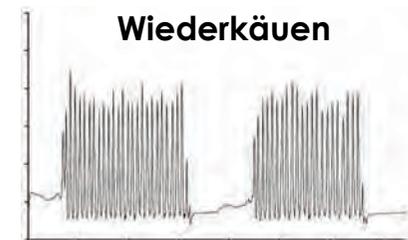
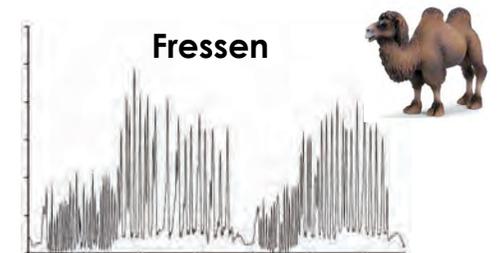
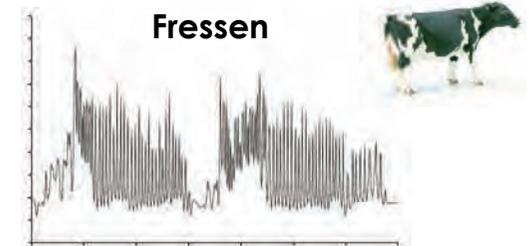
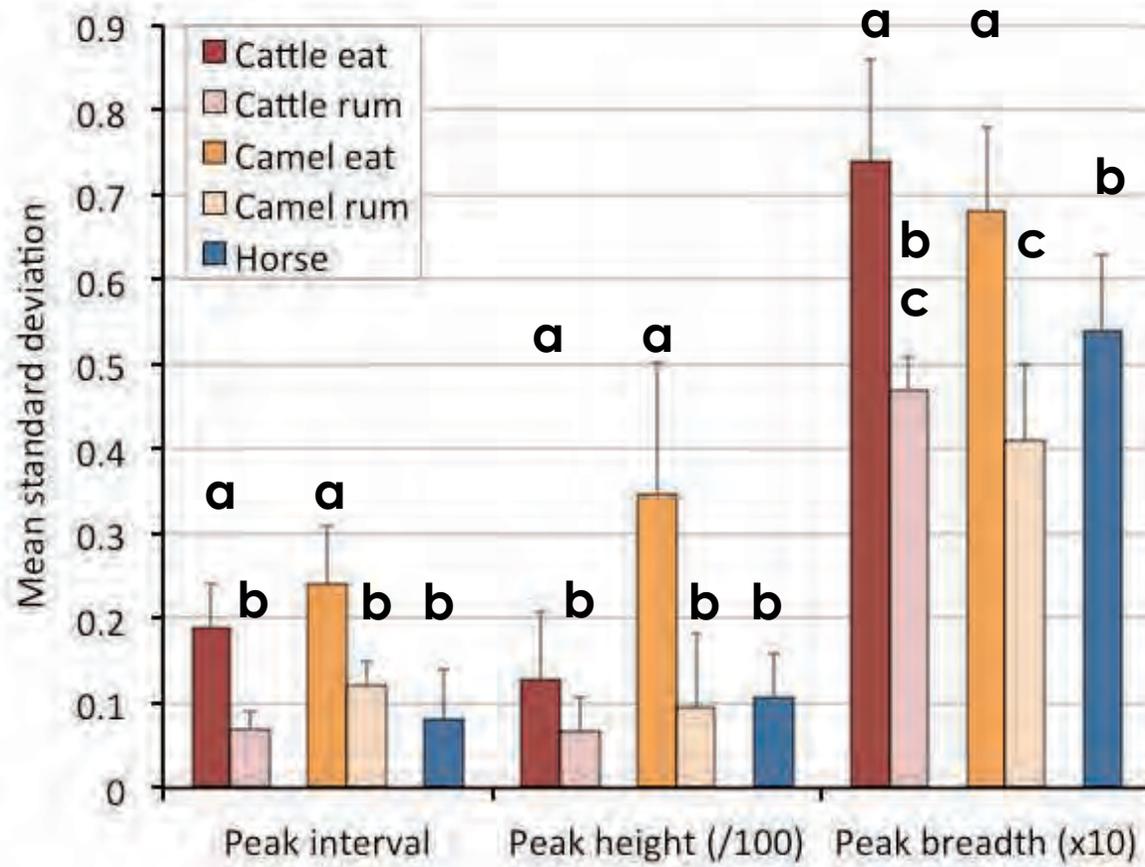


# Kau-Rhythmik





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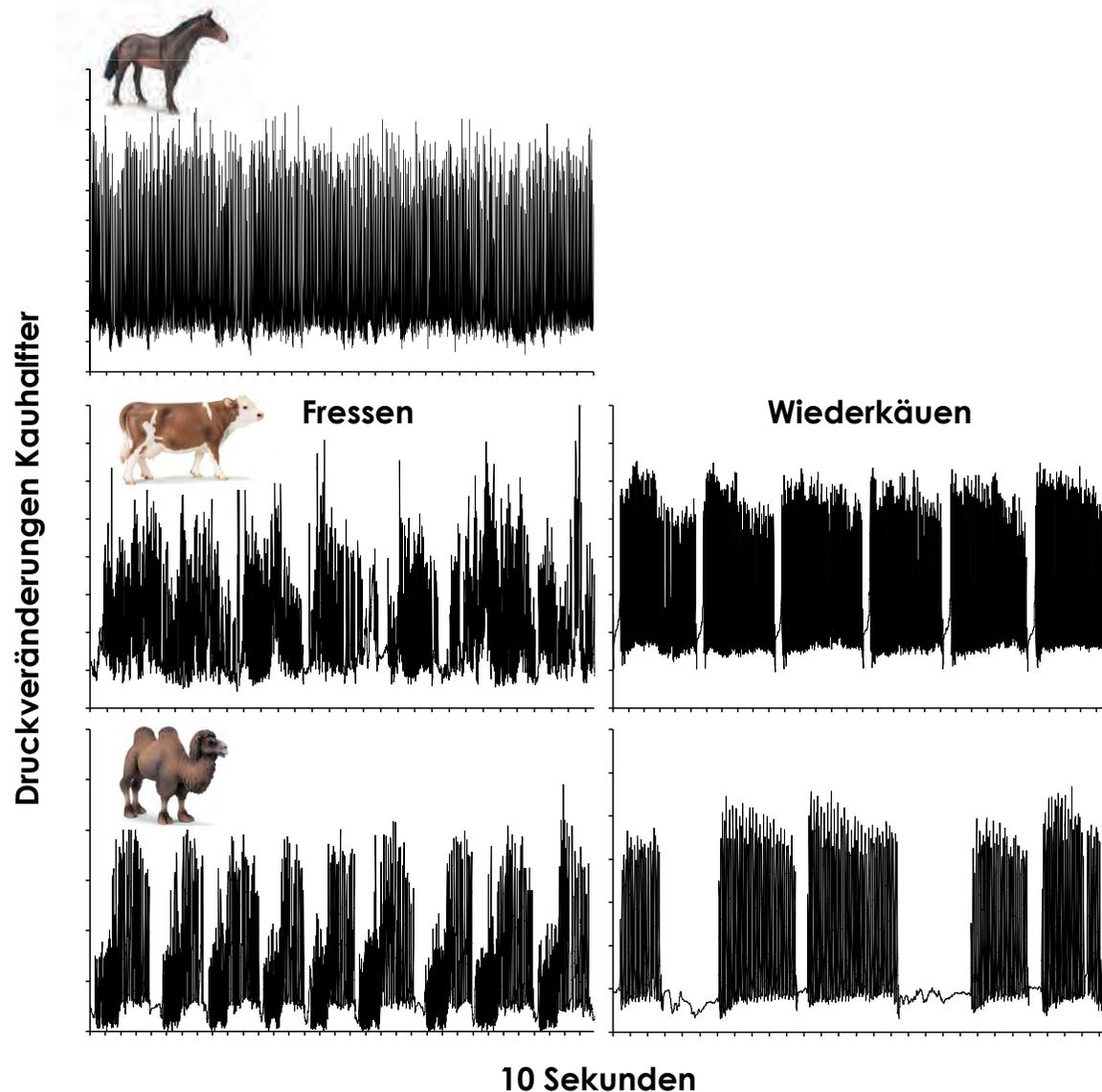




# Ingestive mastication in horses resembles rumination but not ingestive mastication in cattle and camels

*J. Exp. Zool.* 2017;327:98–109.

Marie T. Dittmann<sup>1,2,3</sup> | Michael Kreuzer<sup>2</sup> | Ullrich Runge<sup>4</sup> | Marcus Clauss<sup>3</sup>

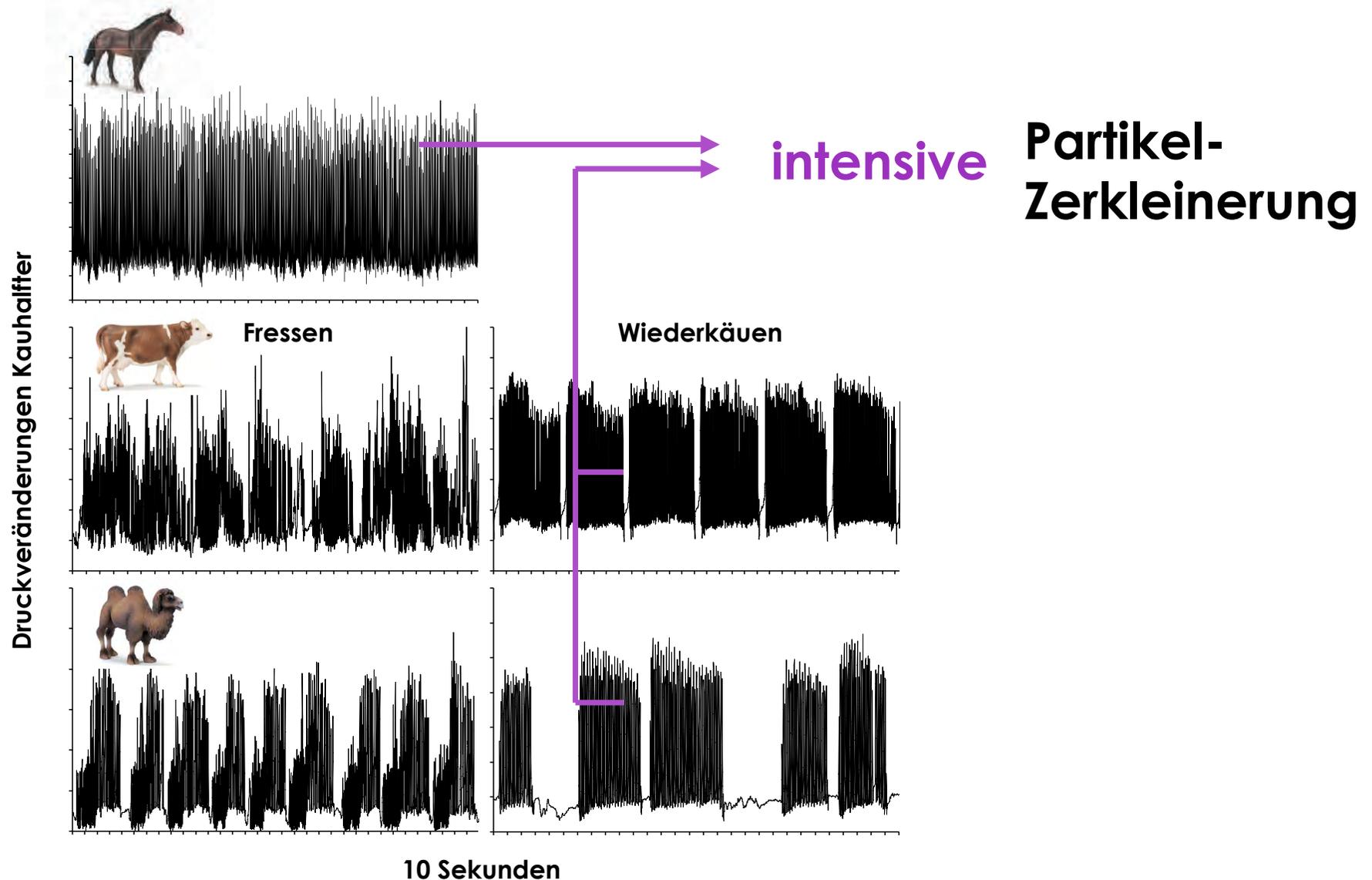




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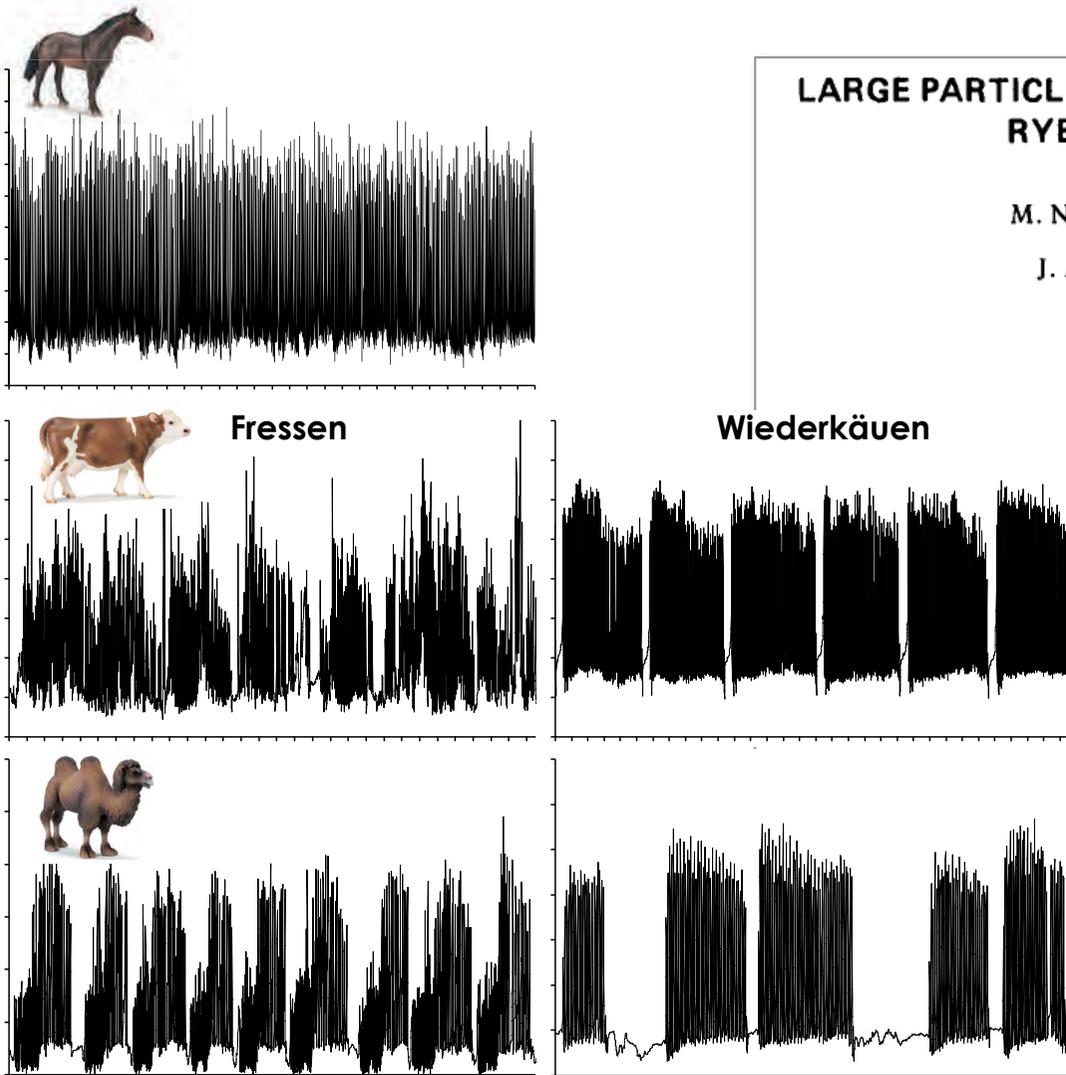


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Druckveränderungen Kauhalfter

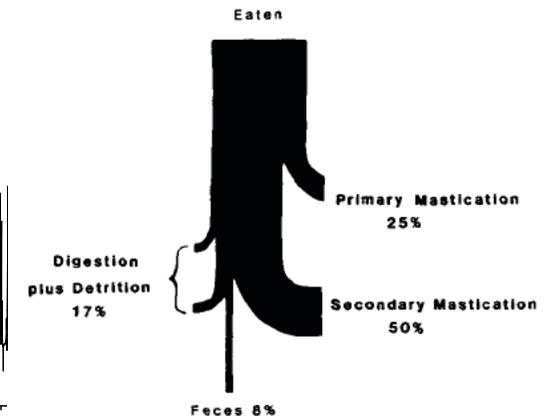


10 Sekunden

## LARGE PARTICLE BREAKDOWN BY CATTLE EATING RYEGRASS AND ALFALFA

M. N. McLeod<sup>1</sup> and D. J. Minson<sup>1</sup>

*J. Anim. Sci.* 1988. 66:992–999

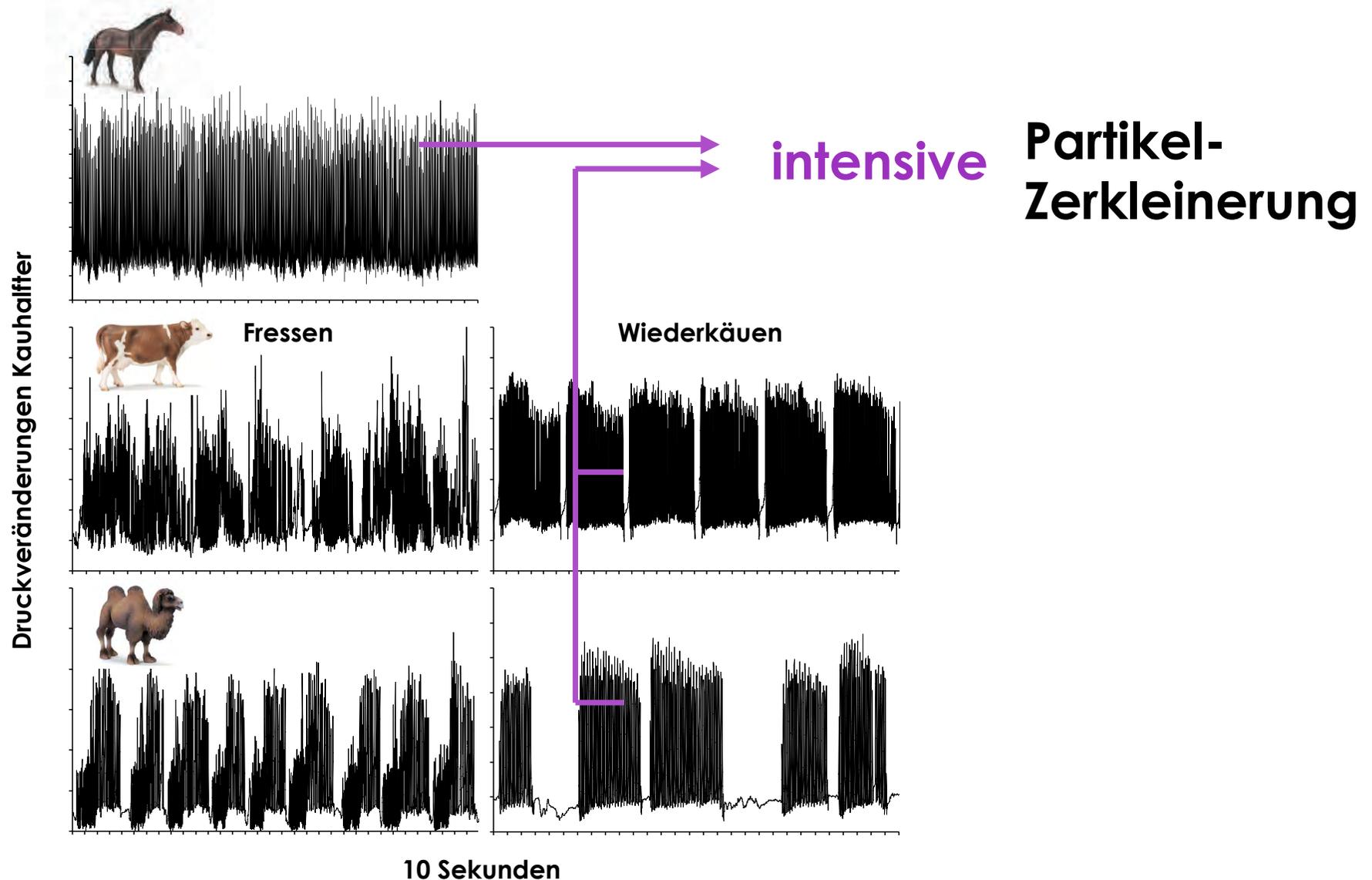




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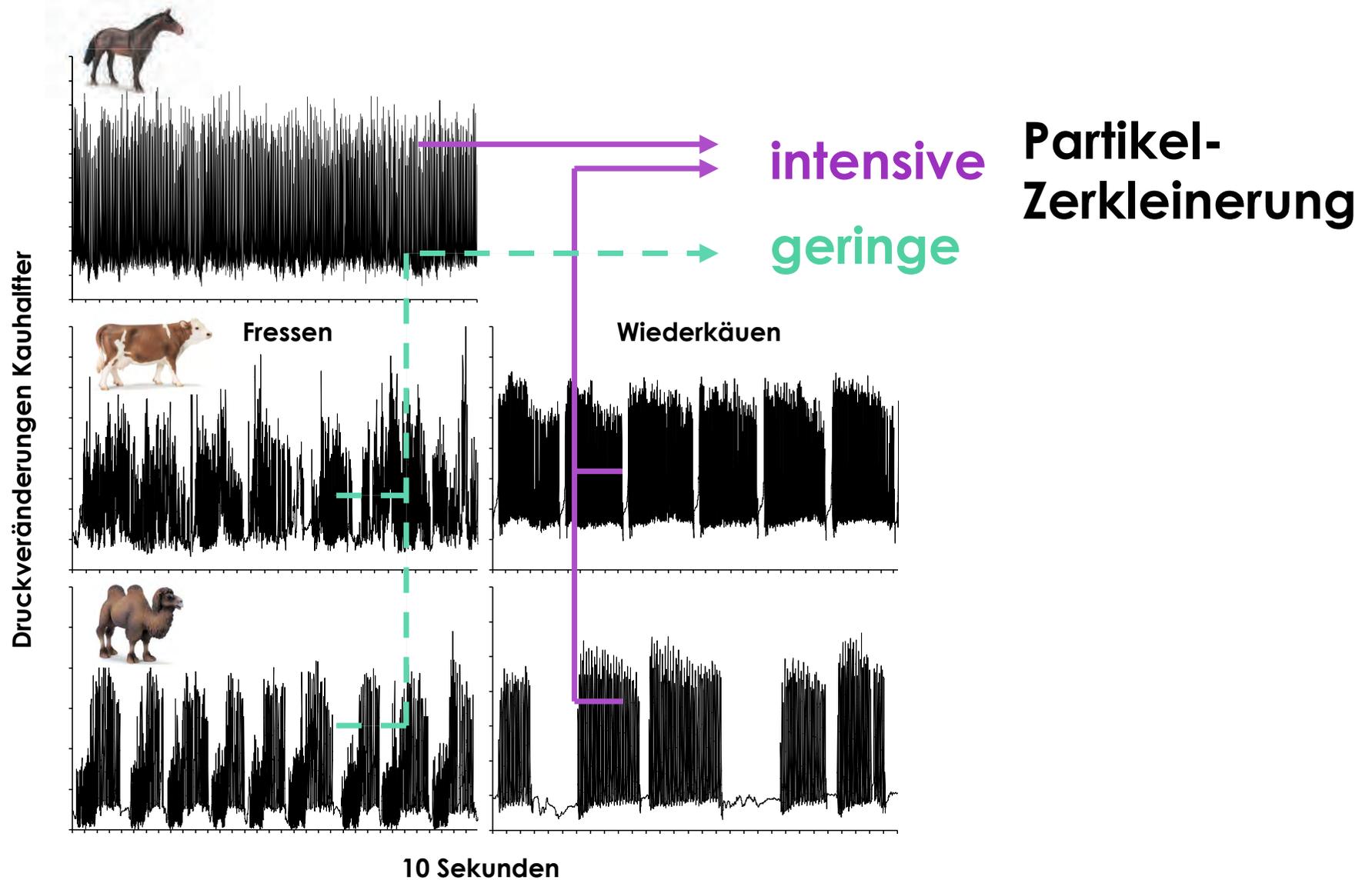




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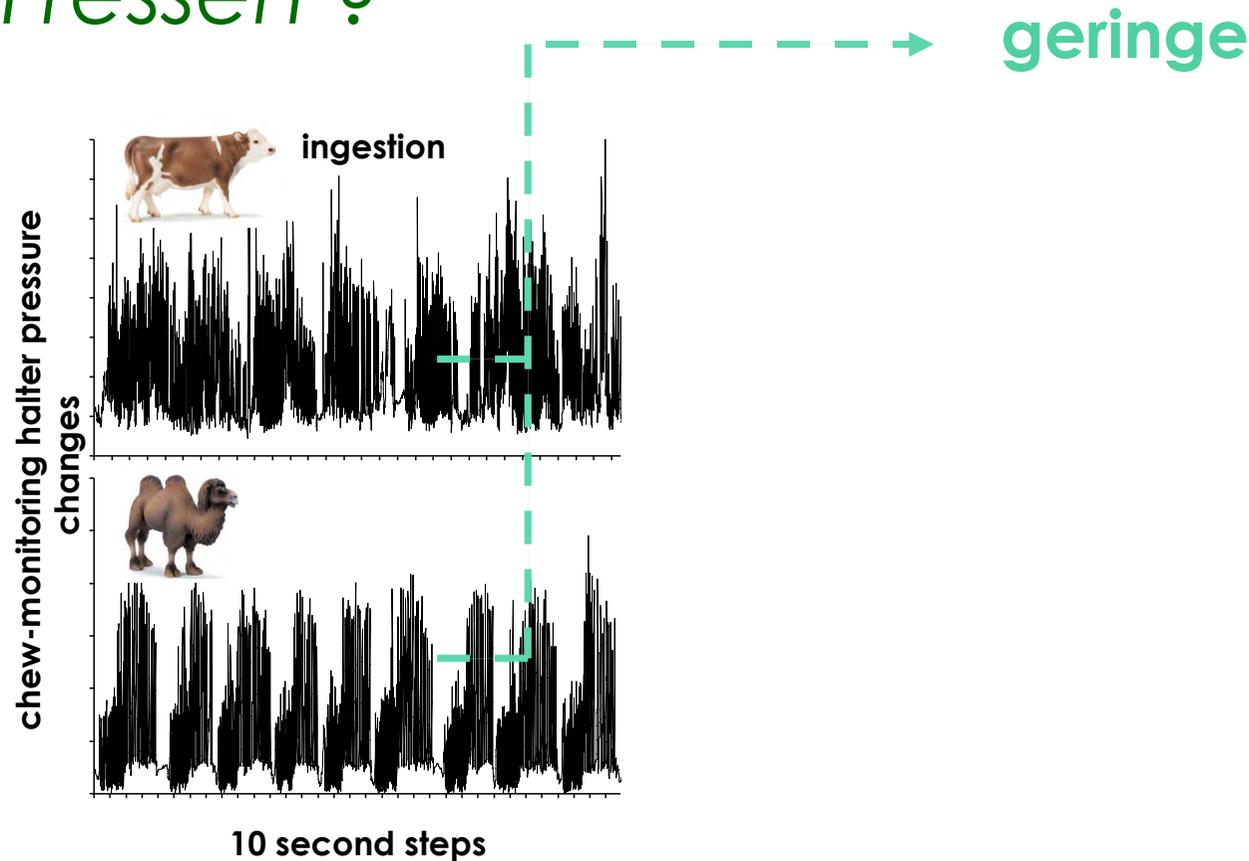




*Die wirklich spannende Frage ist ...*

*... warum kauen Wiederkäuer  
so 'nachlässig' beim  
Fressen ?*

**Partikel-  
Zerkleinerung**



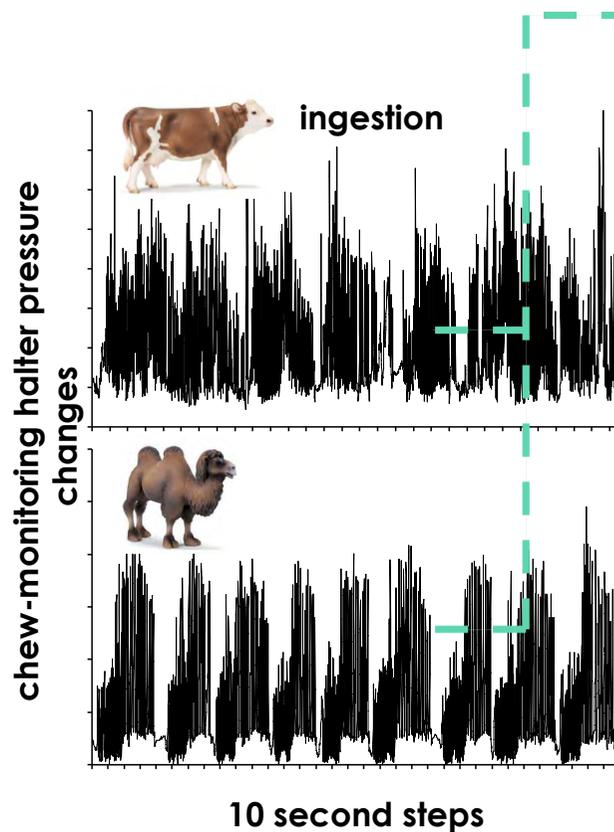


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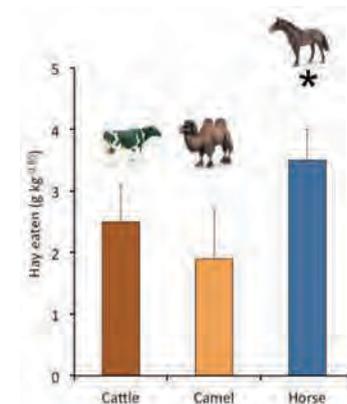
... warum kauen Wiederkäuer so 'nachlässig' beim Fressen ?

**Partikel-  
Zerkleinerung**

geringe



... wenn es nicht um die Futteraufnahme geht ?





# Zahnoptimierung: Langlebigkeit II



*Die wirklich spannende Frage ist ...*

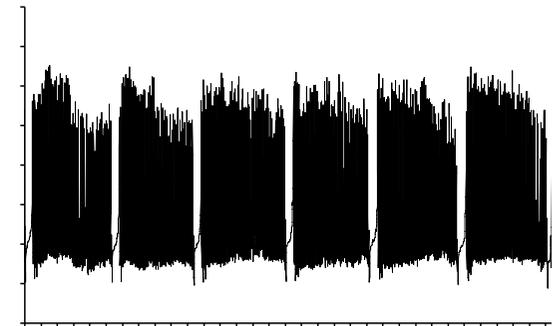
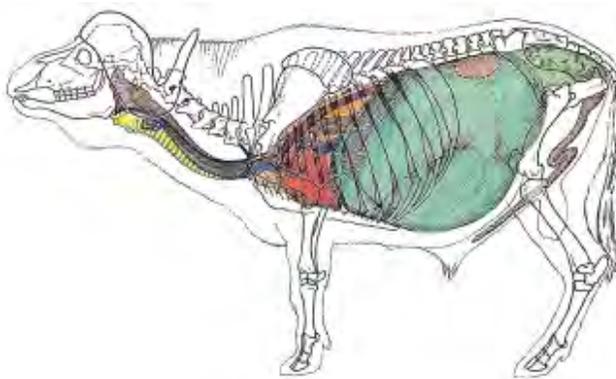
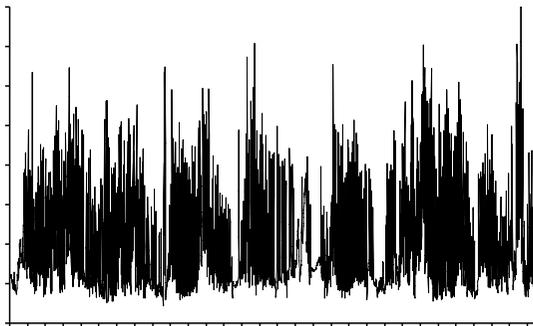
*Wenn es um eine Optimierung der Partikelzerkleinerung ginge, sollten Wiederkäuer schon beim Fressen den rhythmischen/gleichmässigen Kauschlag verwenden.*



## Ein zusätzlicher Vorteil für Wiederkäuer ?

### *Wiederkäuer-Kau-Strategie:*

*Die Abriebs-intensiven gleichmässigen Kauschläge erst anwenden, wenn der Nahrungsbrei im Vormagen von Staub/ Erde freigewaschen wurde ?*





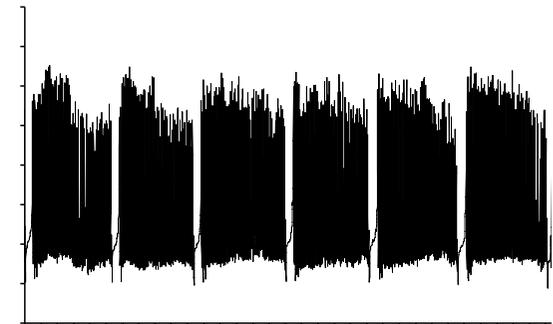
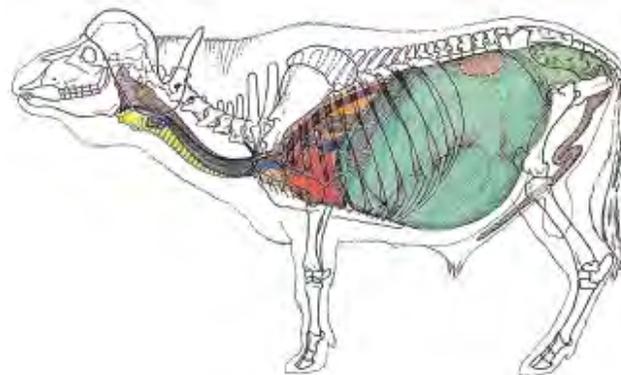
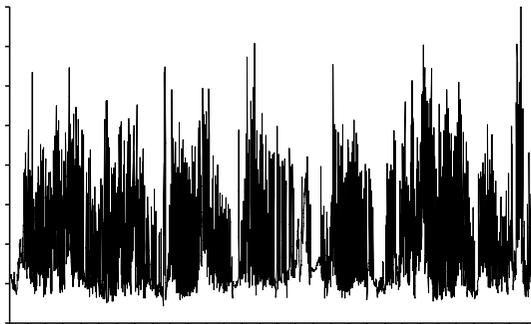
# Ein zusätzlicher Vorteil für Wiederkäuer ?

## Untangling the environmental from the dietary: dust does not matter

Proc. R. Soc. B  
283: 20161032.

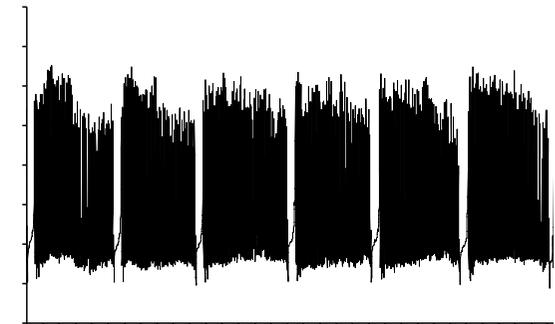
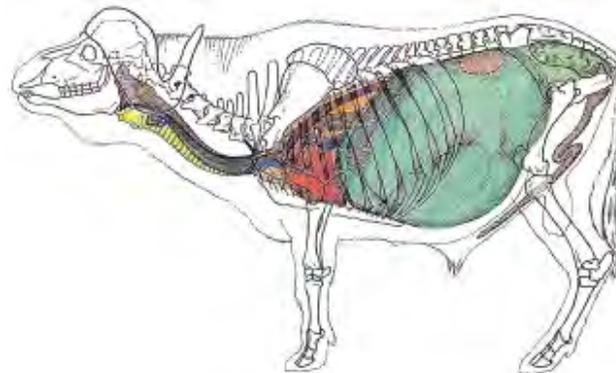
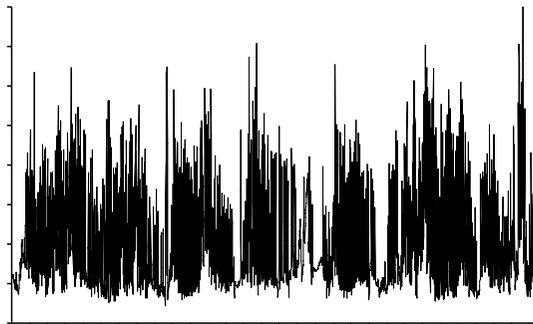
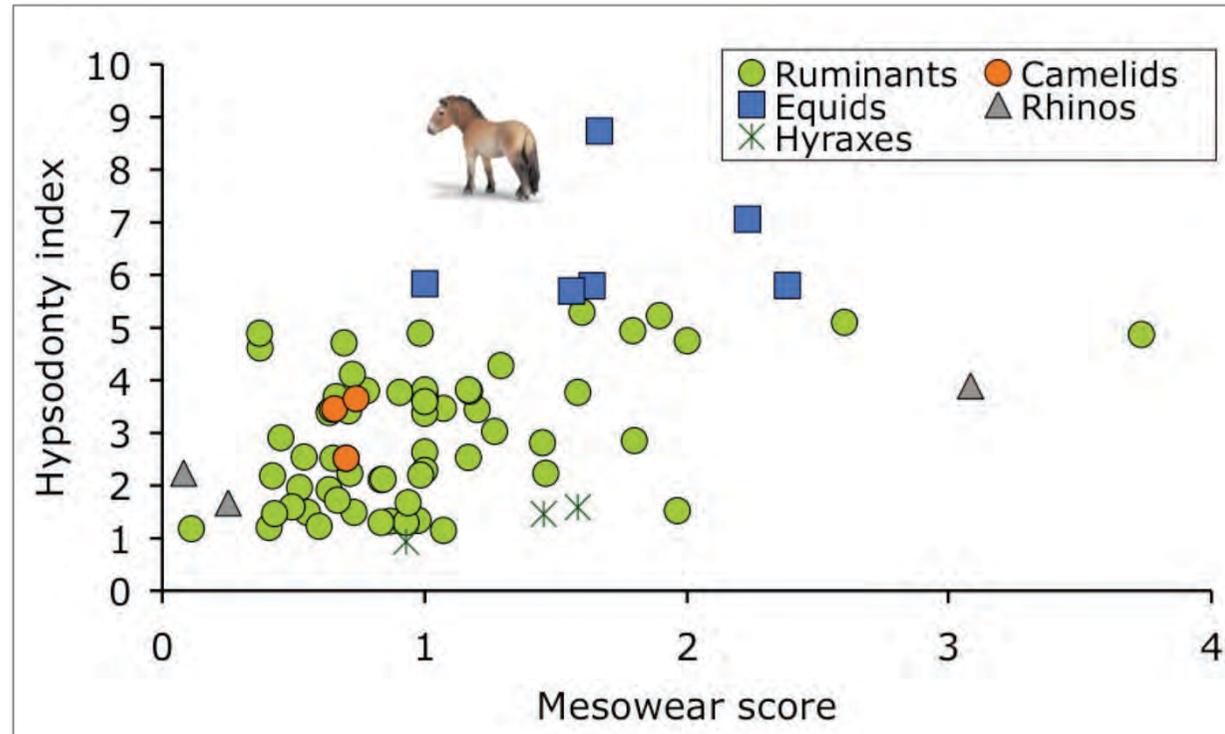


Gildas Merceron<sup>1</sup>, Anusha Ramdarshan<sup>1</sup>, Cécile Blondel<sup>1</sup>,  
Jean-Renaud Boisserie<sup>1,2</sup>, Noël Brunetiere<sup>3</sup>, Arthur Francisco<sup>3</sup>, Denis Gautier<sup>4,5</sup>,  
Xavier Milhet<sup>3</sup>, Alice Novello<sup>6</sup> and Dimitri Pret<sup>7</sup>





# Ein zusätzlicher Vorteil für Wiederkäuer ?





# Gliederung

Verdauung und Partikelgrösse

Zerkleinerung bei Landwirbeltieren

Zahnoptimierung: Lebensdauer I

    Zahnfunktion 1: Schwerkraft?

Zahnoptimierung: Kauleistenverlängerung

Zahnoptimierung: Schmelzfalten

    Zahnfunktion 2: Partikelbewegungen?

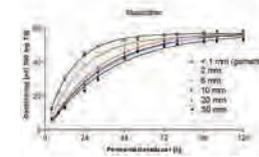
Zahn- vs. Kauoptimierung: Wiederkäuen

Zahnoptimierung: Lebensdauer II



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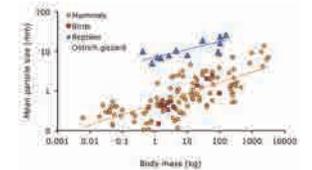
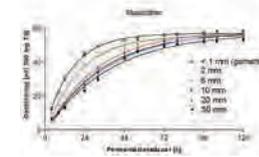
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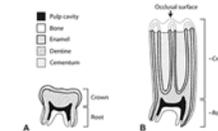
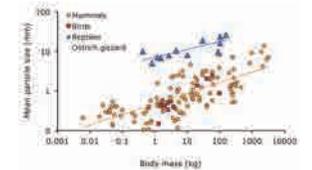
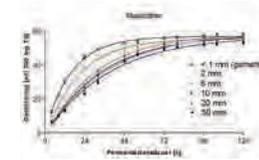
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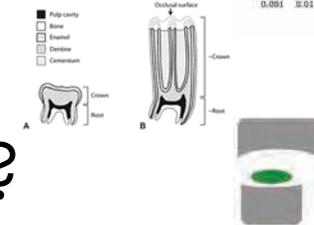
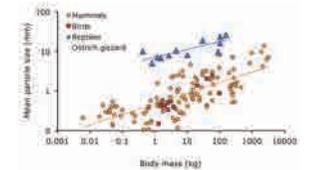
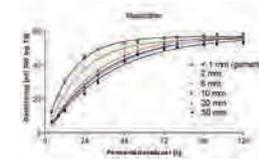
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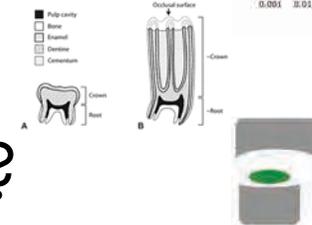
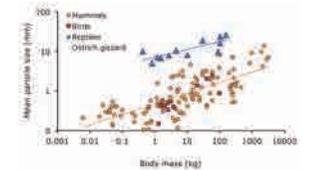
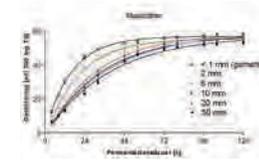
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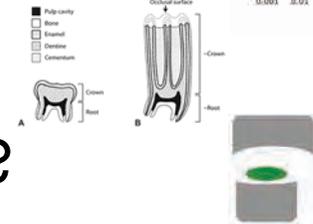
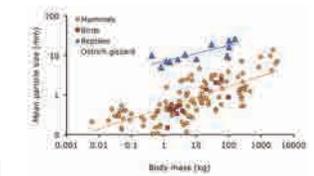
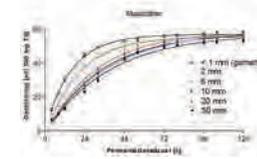
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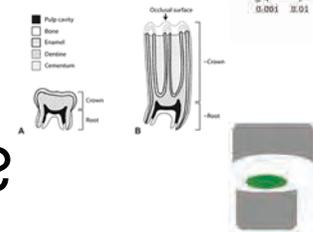
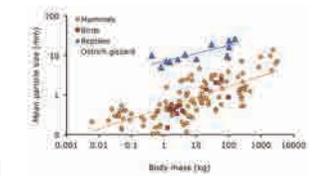
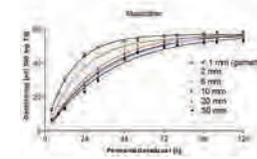
Zahnoptimierung: Kauleistenverlängerung

Zahnoptimierung: Schmelzfalten

Zahnfunktion 2: Partikelbewegungen?

Zahn- vs. Kauoptimierung: Wiederkäuen

Zahnoptimierung: Lebensdauer II





# Gliederung

Verdauung und Partikelgrösse

Zerkleinerung bei Landwirbeltieren

Zahnoptimierung: Lebensdauer I

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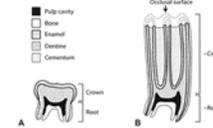
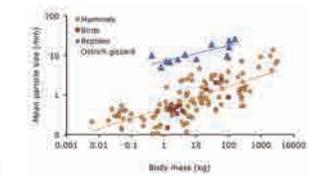
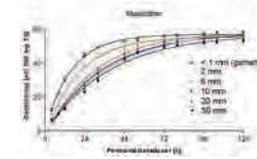
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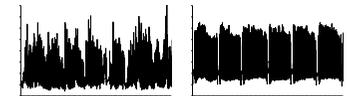
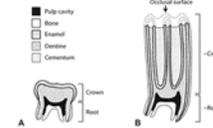
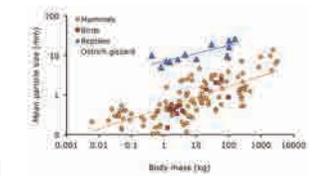
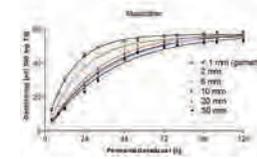
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*vielen Dank für Ihre  
Aufmerksamkeit*