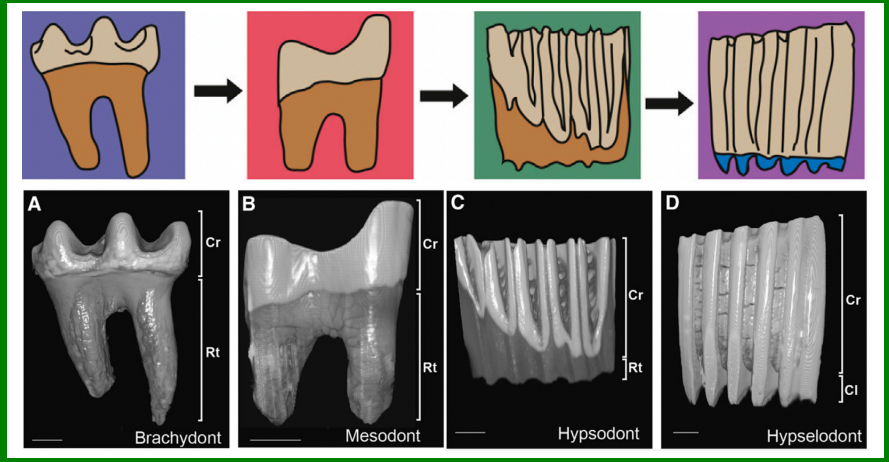
Zähne und Zahnabrieb

wie Säugetiere ihr Leben verlängern



Marcus Clauss

Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty, University of Zurich, Switzerland

Seniorenuniversität UZH 2021

University of Zurich[UZH]

Clinic
of Zoo Animals, Exotic Pets and Wildlife

Gliederung

Verdauung und Partikelgrösse

Zahnoptimierung: Kauleistenverlängerung

Zahnabrieb: intrinsische und extrinsische Faktoren

Zahnoptimierung: höhere Zahnkronen
Zahnoptimierung: kontinuierliches Wachstum

(Zahnabrieb im Zoo)

Verdauung und Partikelgrösse

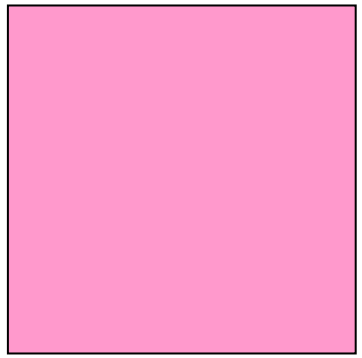
Verdauung braucht … Zeit ?

Verdauung braucht … Zeit ?

Tierische Zelle ---------- Pflanzenzelle

Verdauung braucht … Zeit ?

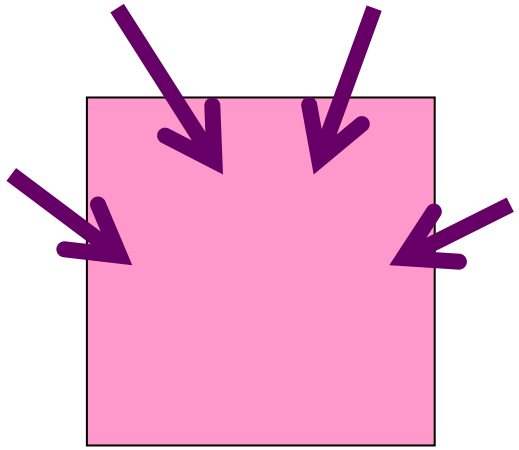
Tierische Zelle ---------- Pflanzenzelle



Zellmembran

Verdauung braucht … Zeit ?

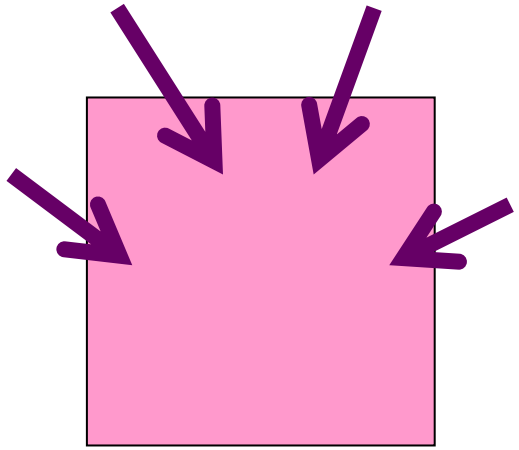
Tierische Zelle ---------- Pflanzenzelle



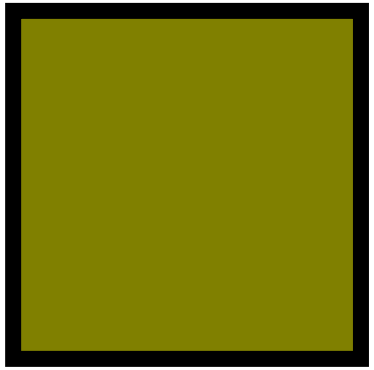
Zellmembran

Verdauung braucht … Zeit ?

Tierische Zelle ---------- Pflanzenzelle



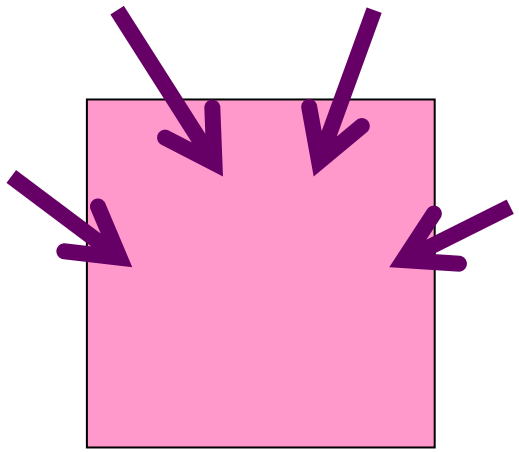
Zellmembran



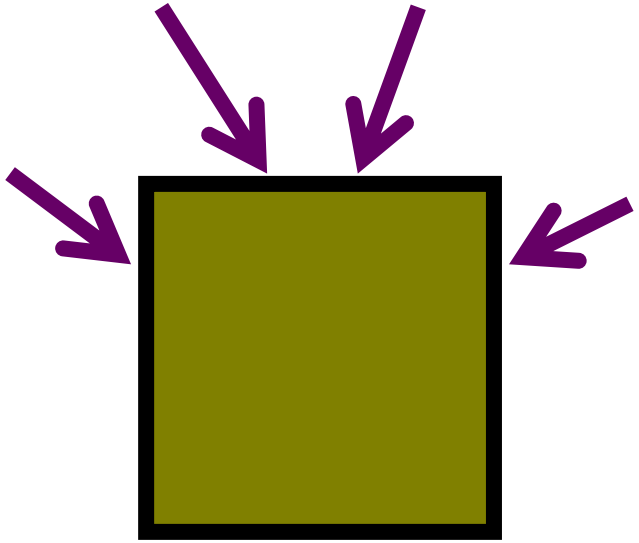
Zellwand

Verdauung braucht … Zeit ?

Tierische Zelle ---------- Pflanzenzelle



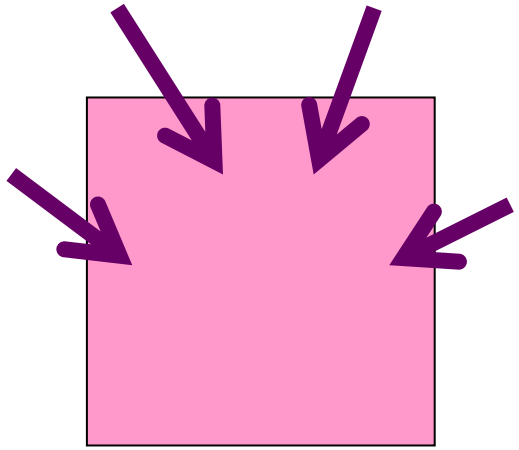
Zellmembran



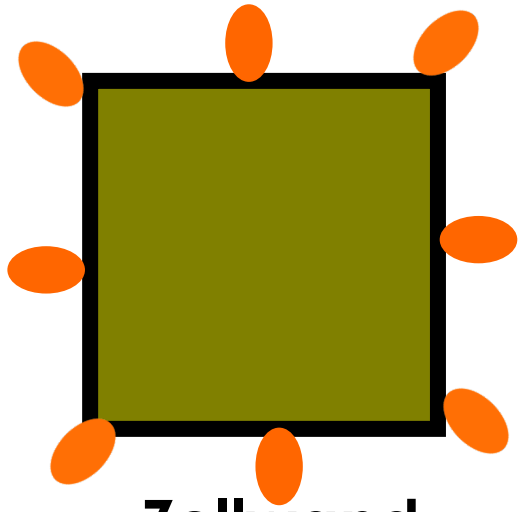
Zellwand

Verdauungs braucht … Zeit ?

Tierische Zelle ---------- Pflanzenzelle



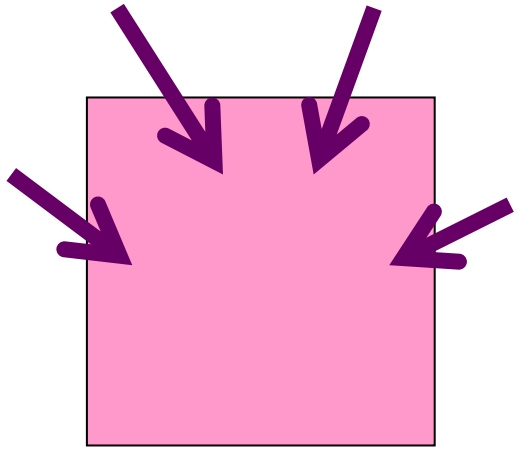
Zellmembran



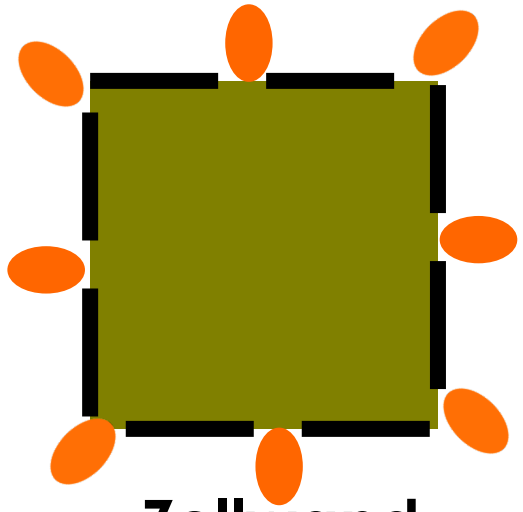
Zellwand

Verdauung braucht … Zeit ?

Tierische Zelle ---------- Pflanzenzelle



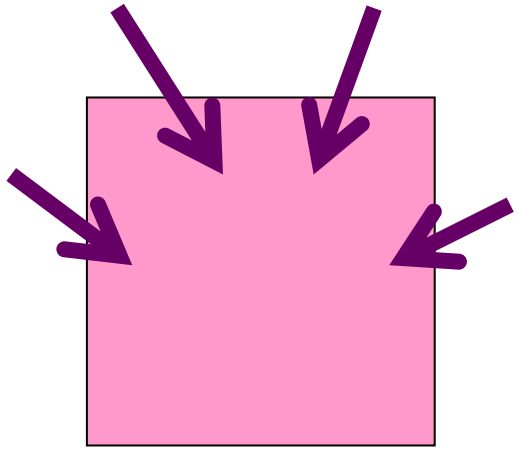
Zellmembran



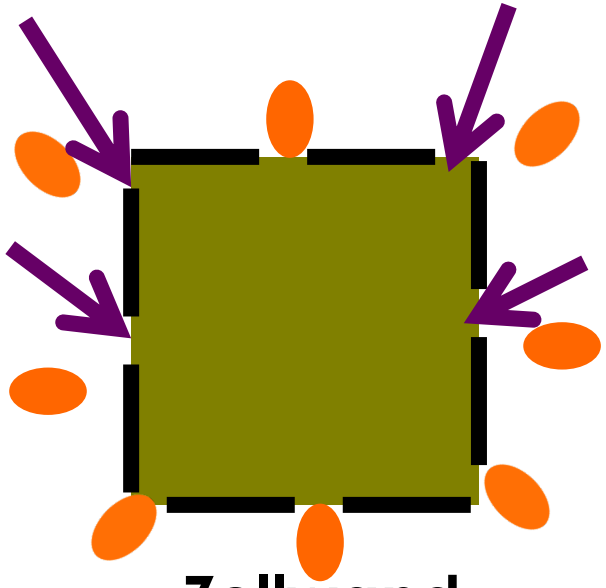
Zellwand

Verdauung braucht … Zeit ?

Tierische Zelle ---------- Pflanzenzelle



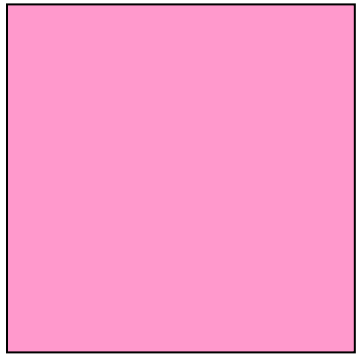
Zellmembran



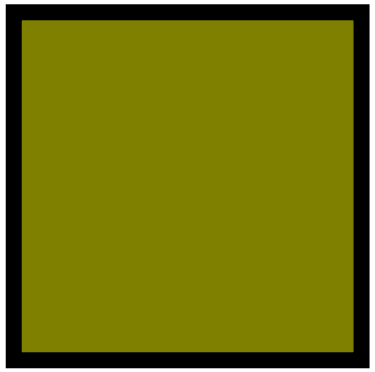
Zellwand

Verdauung braucht … Zeit ?

Tierische Zelle ---------- Pflanzenzelle



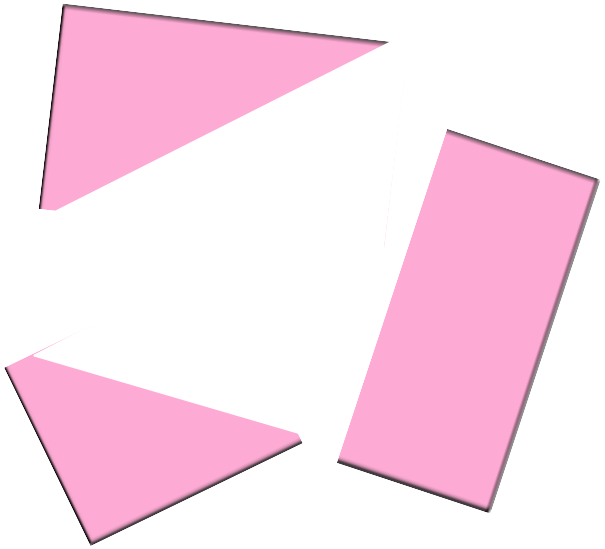
Zellmembran



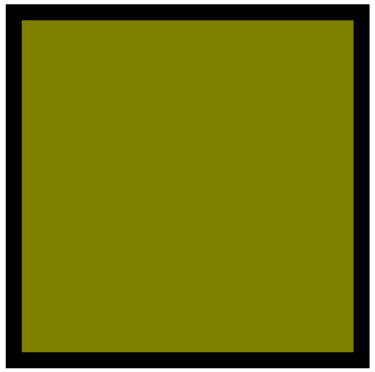
Zellwand

Verdauung braucht … Zeit ?

Tierische Zelle ---------- Pflanzenzelle



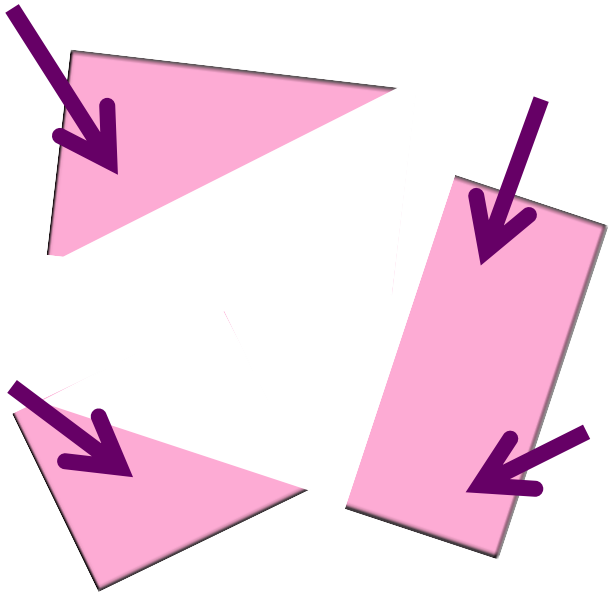
Zellmembran



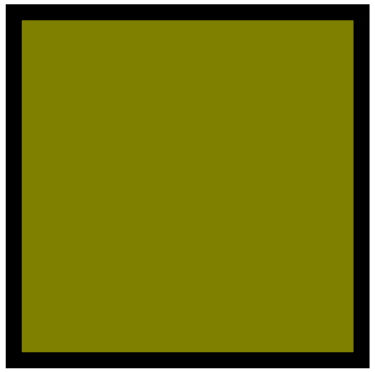
Zellwand

Verdauung braucht … Zeit ?

Tierische Zelle ---------- Pflanzenzelle



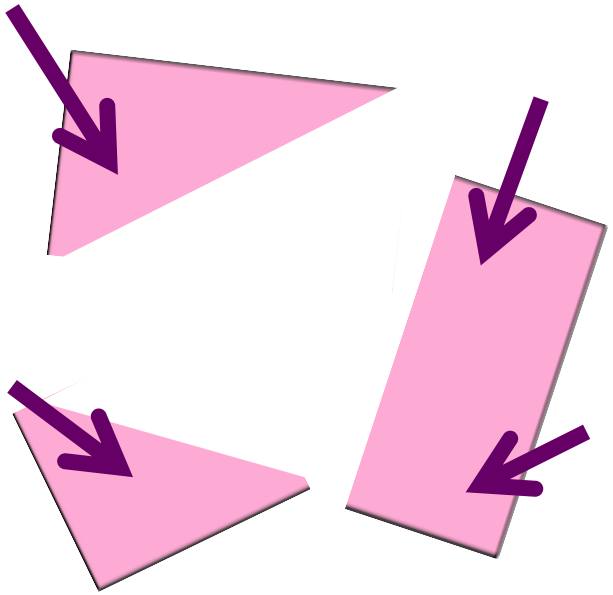
Zellmembran



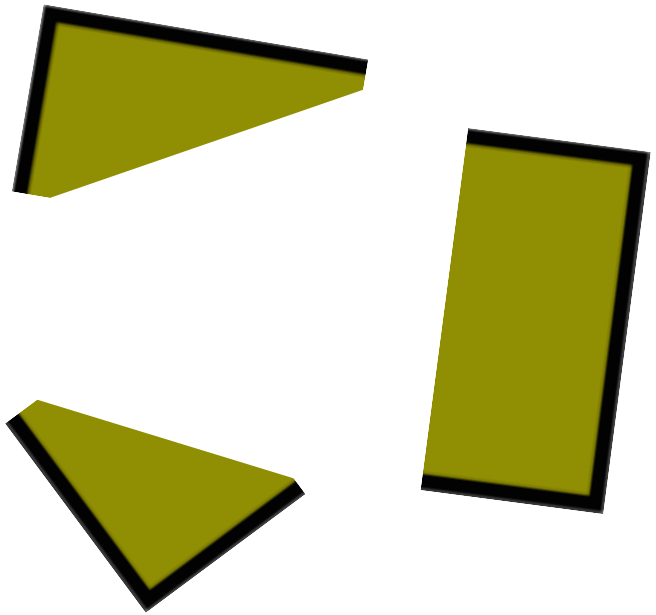
Zellwand

Verdauung braucht … Zeit ?

Tierische Zelle ---------- Pflanzenzelle



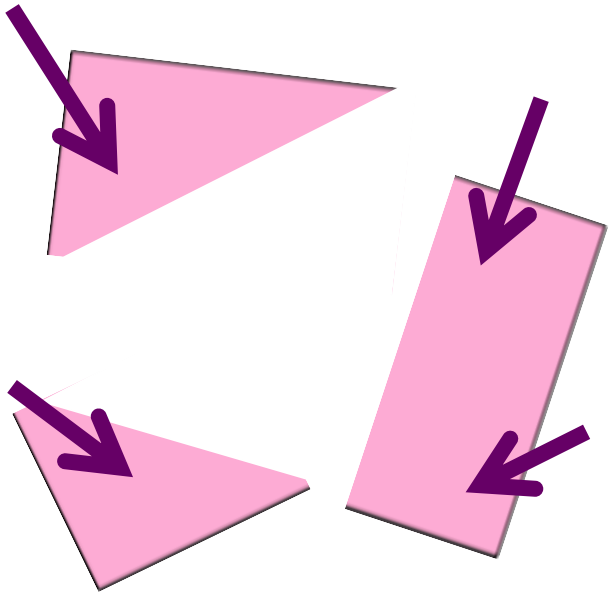
Zellmembran



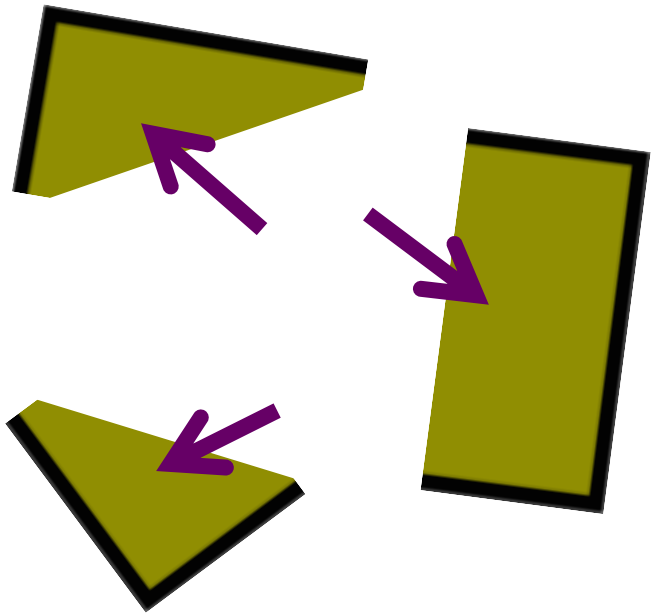
Zellwand

Verdauung braucht … Zeit ?

Tierische Zelle ---------- Pflanzenzelle



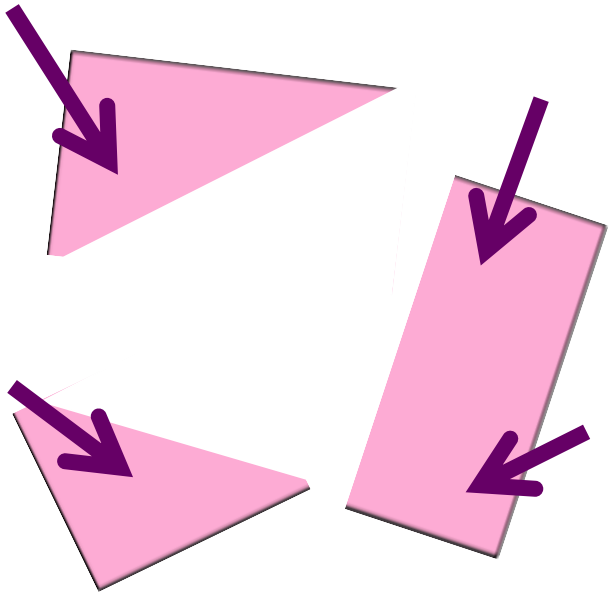
Zellmembran



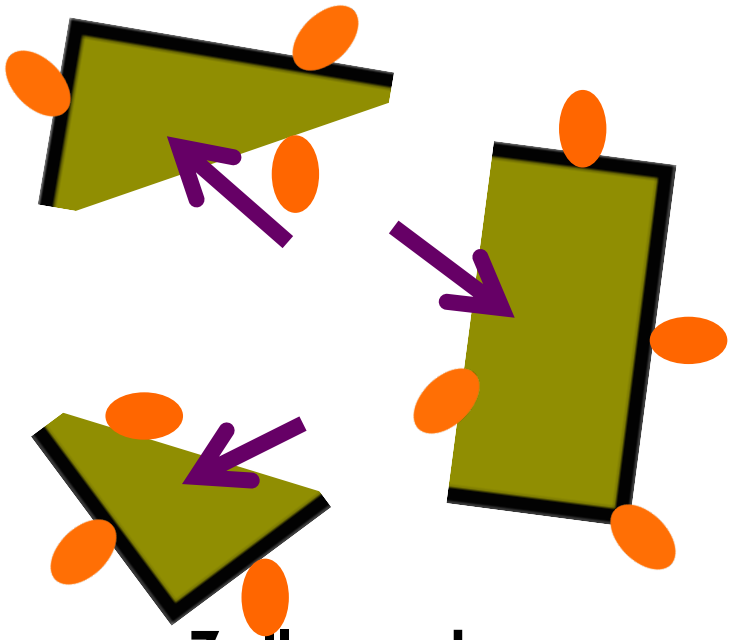
Zellwand

Verdauung braucht … Zeit ?

Tierische Zelle ---------- Pflanzenzelle

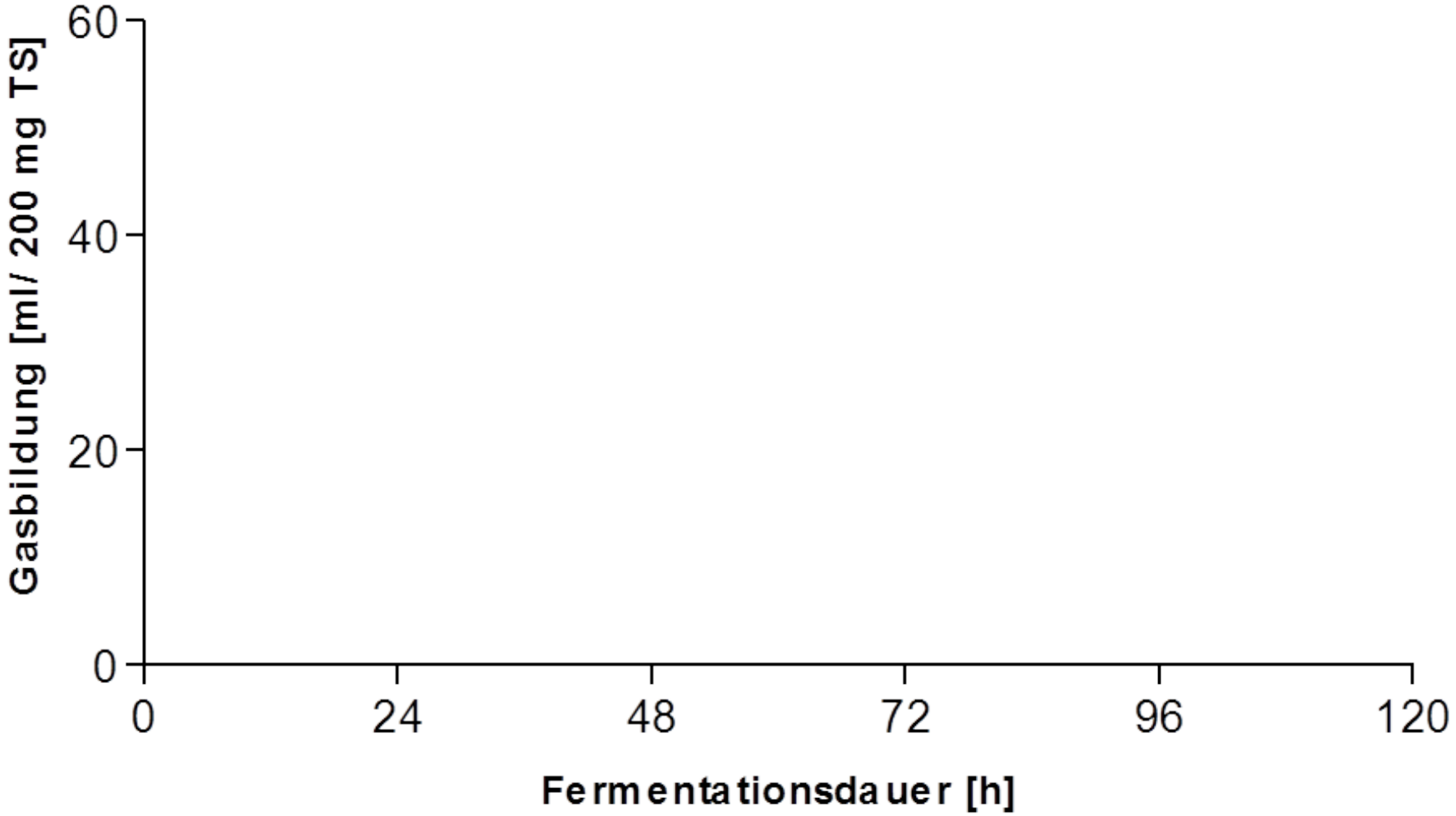


Zellmembran



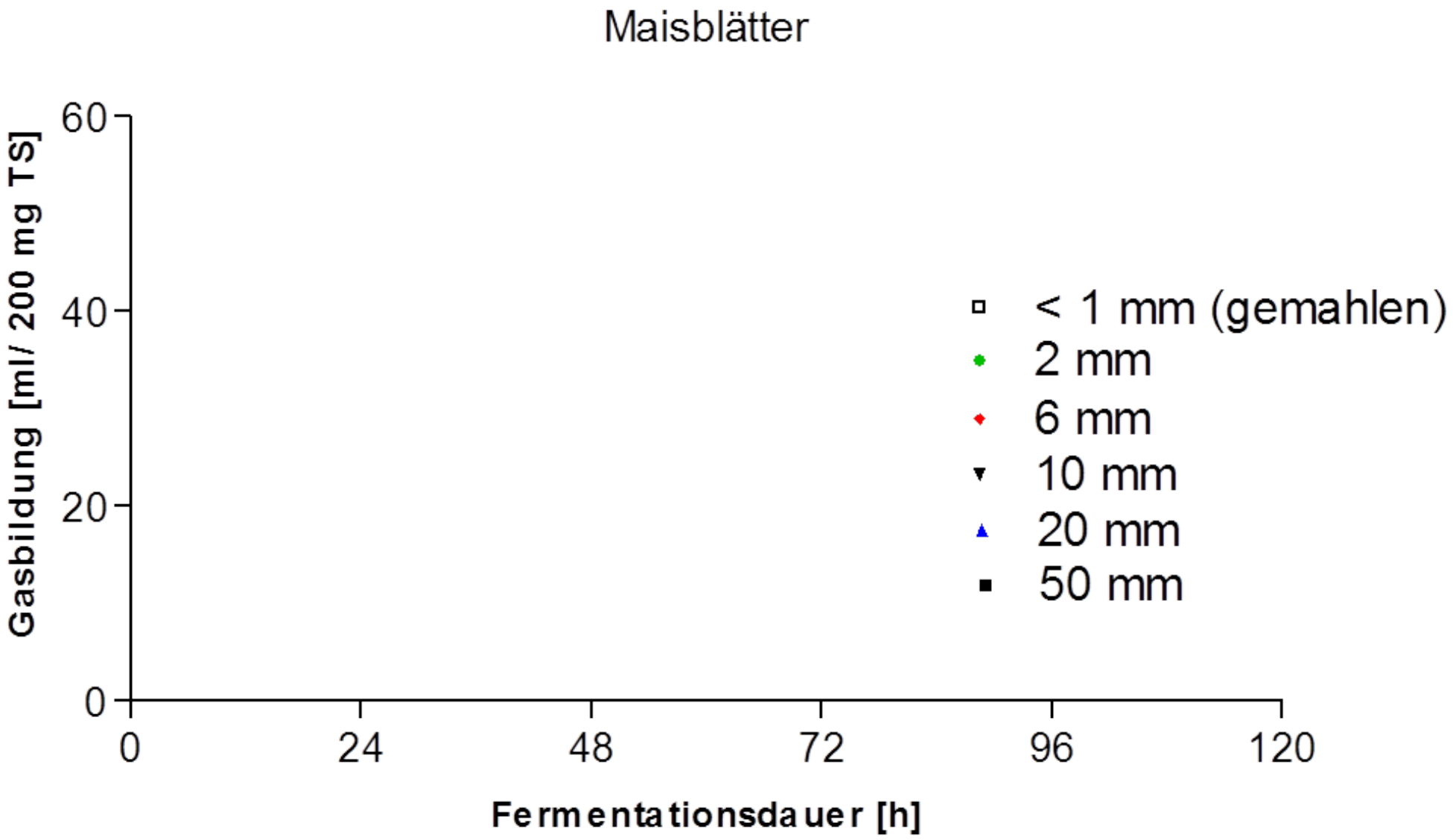
Zellwand

in vitro Fermentation und Partikelgrösse



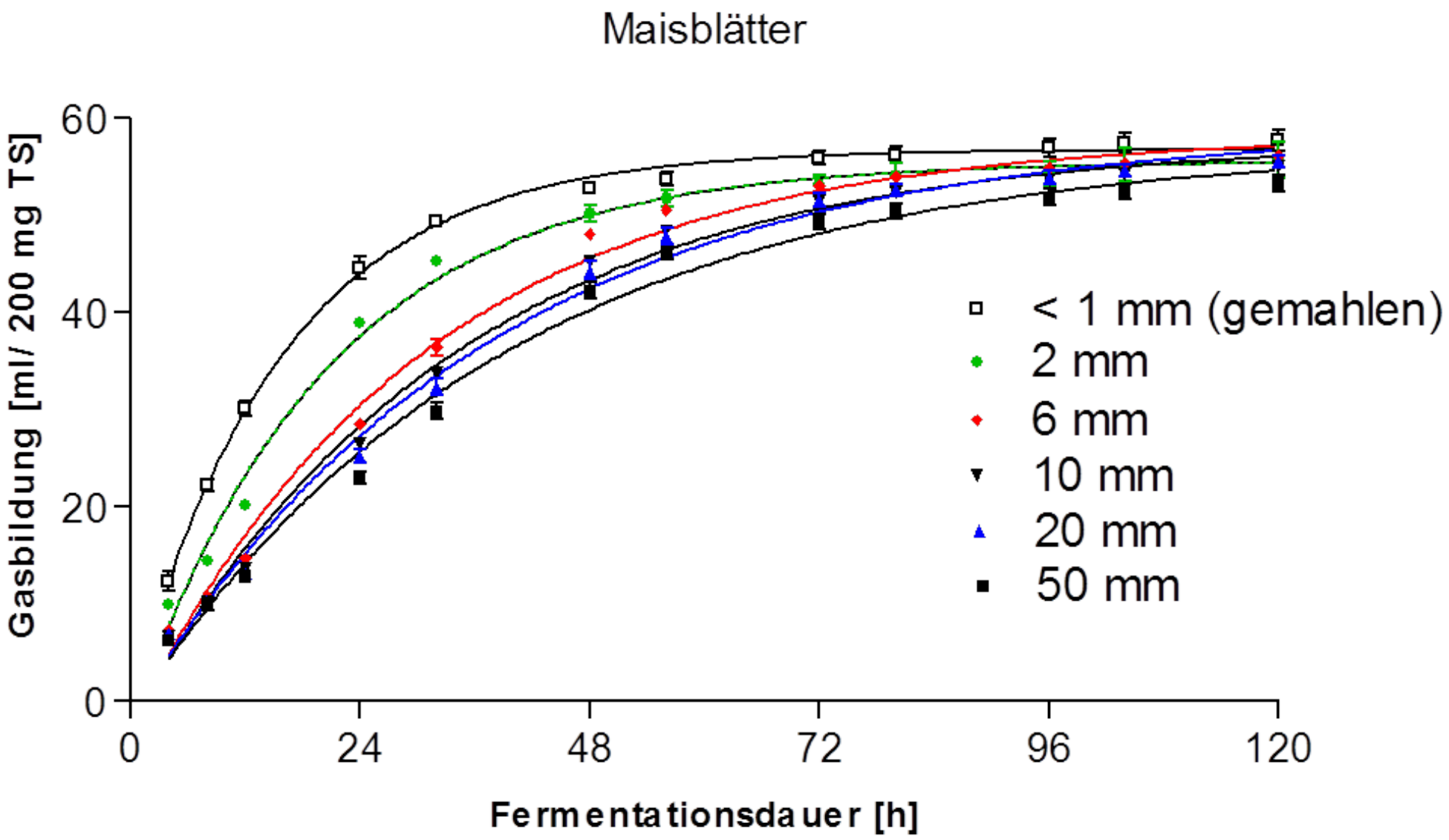
Hummel (unpubl.)

in vitro Fermentation und Partikelgrösse



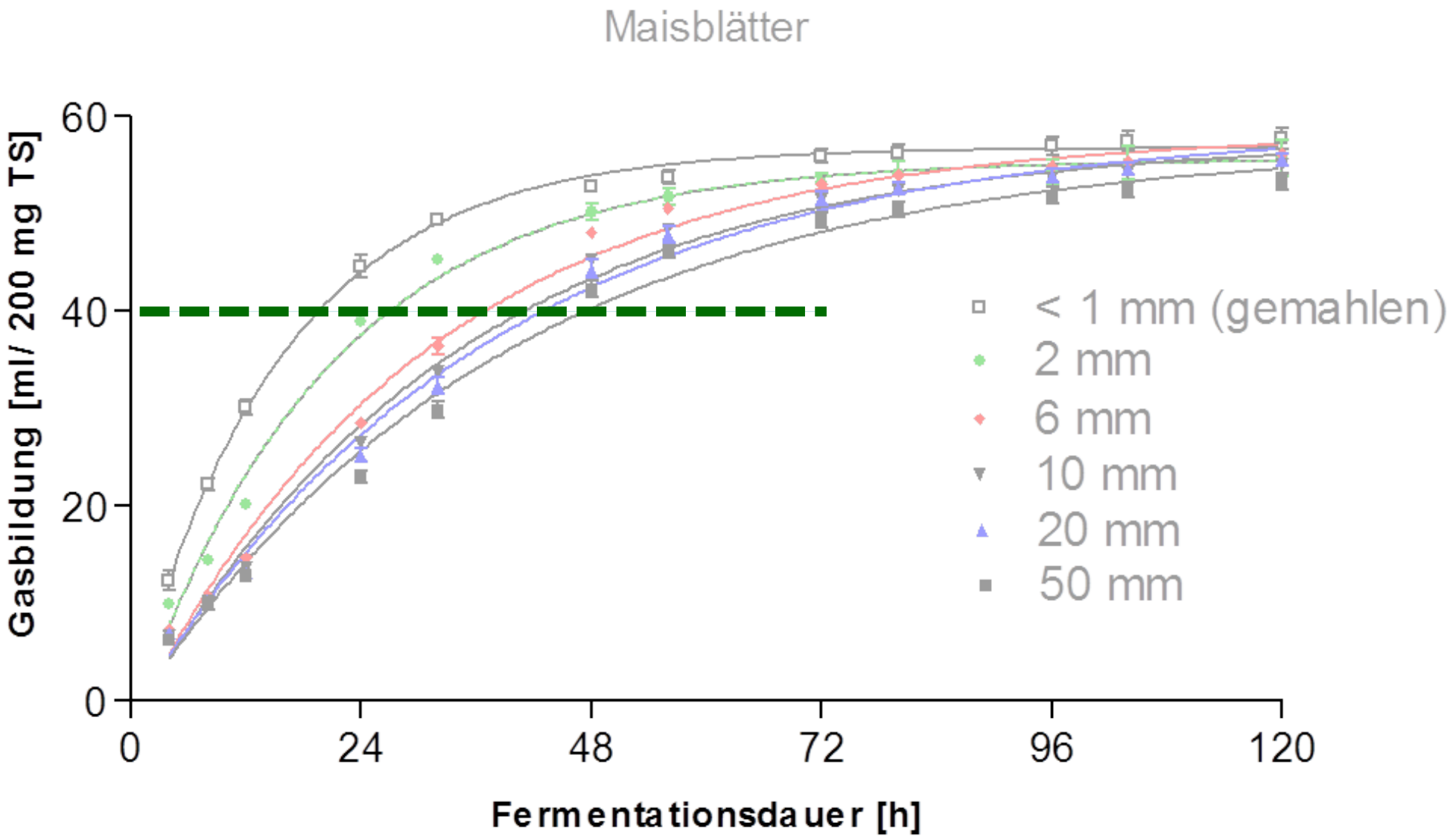
Hummel (unpubl.)

in vitro Fermentation und Partikelgrösse



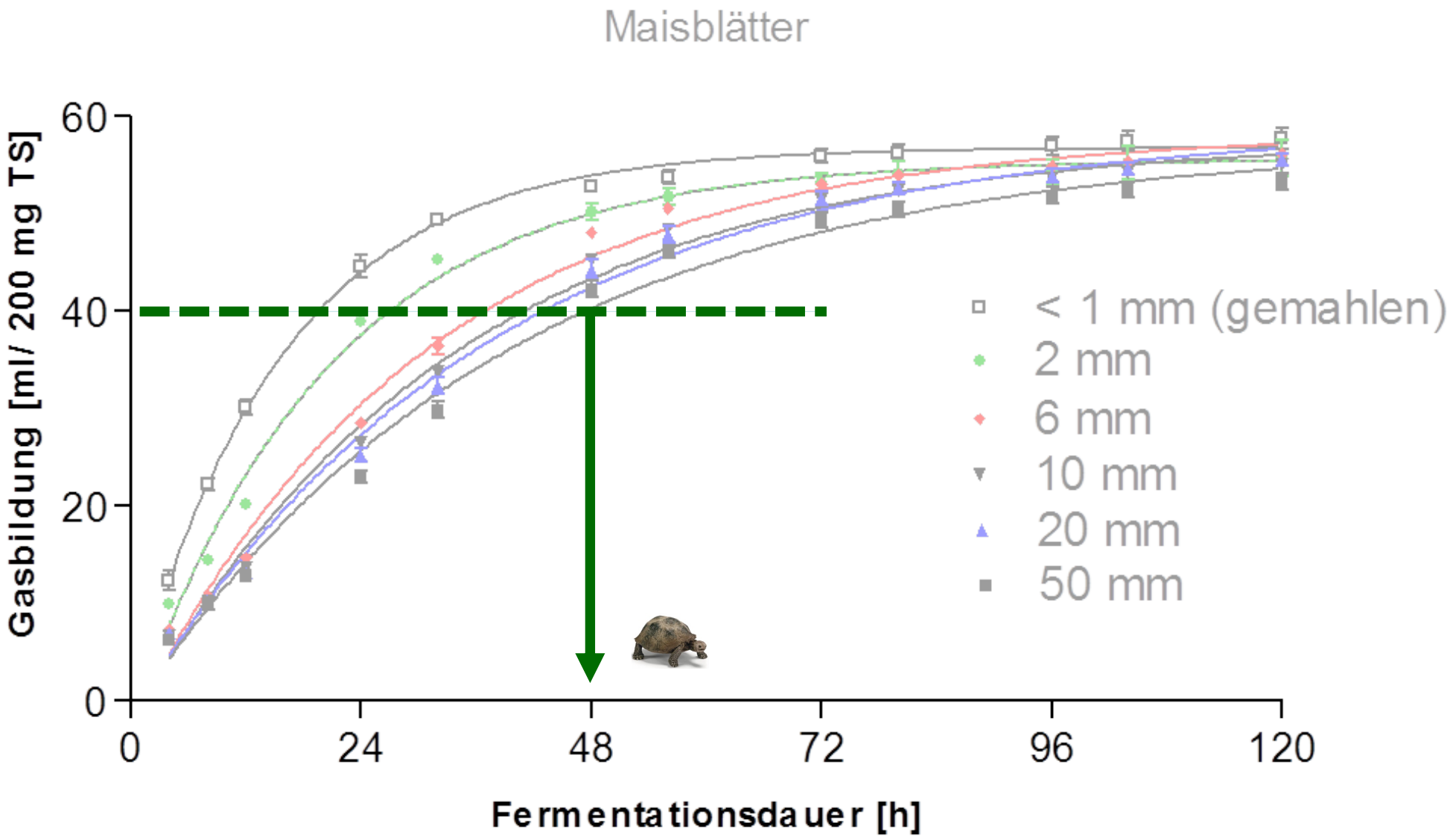
Hummel (unpubl.)

in vitro Fermentation und Partikelgrösse



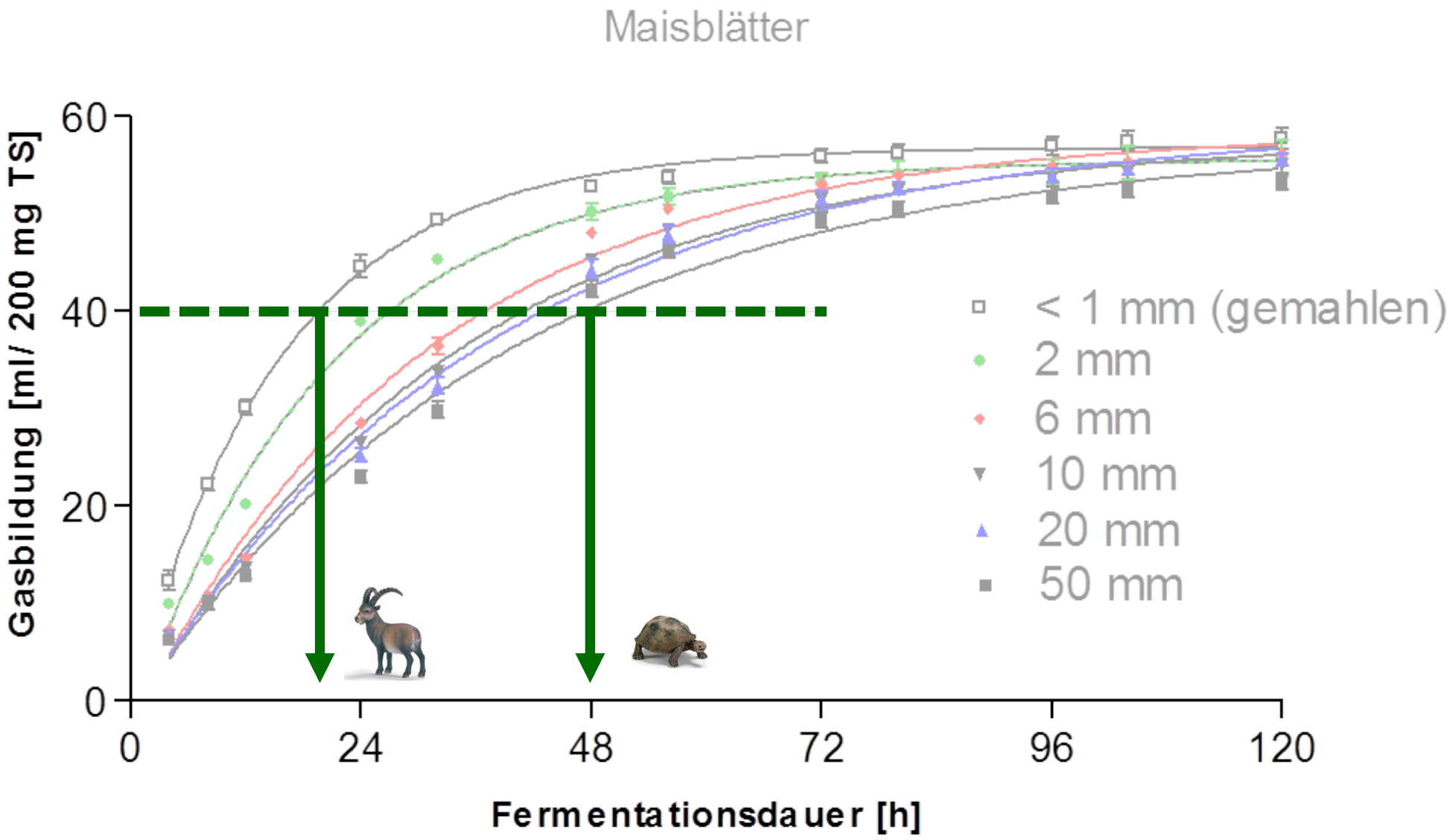
Hummel (unpubl.)

in vitro Fermentation und Partikelgrösse



Hummel (unpubl.)

in vitro Fermentation und Partikelgrösse



Hummel (unpubl.)

Nahrungszerkleinerung bei Landwirbeltieren

Comparative chewing efficiency in mammalian herbivores

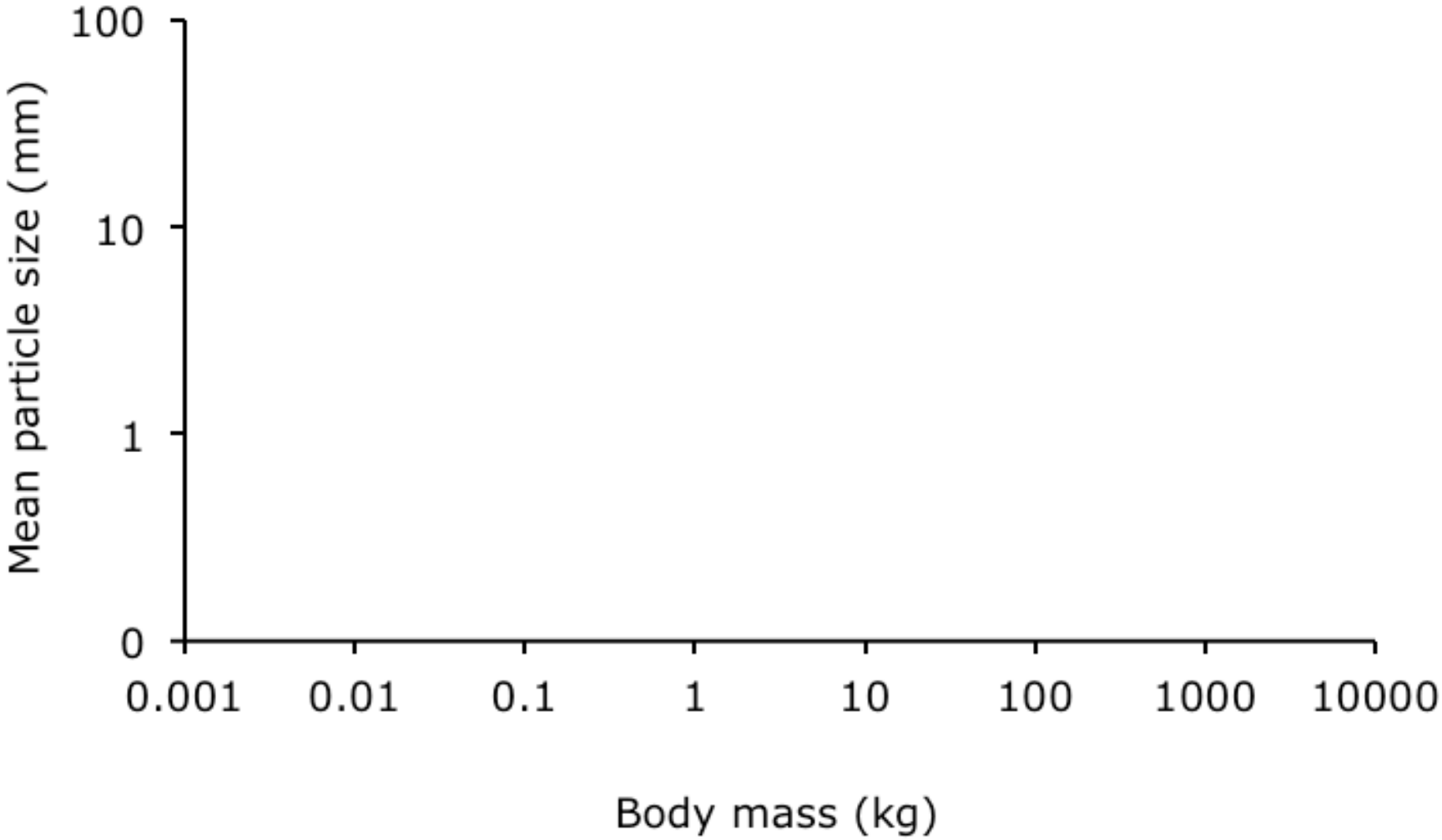
Julia Fritz, Jürgen Hummel, Ellen Kienzle, Christian Arnold, Charles Nunn and Marcus Clauss

Oikos 118: 1623–1632, 2009

Comparative chewing efficiency in mammalian herbivores

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

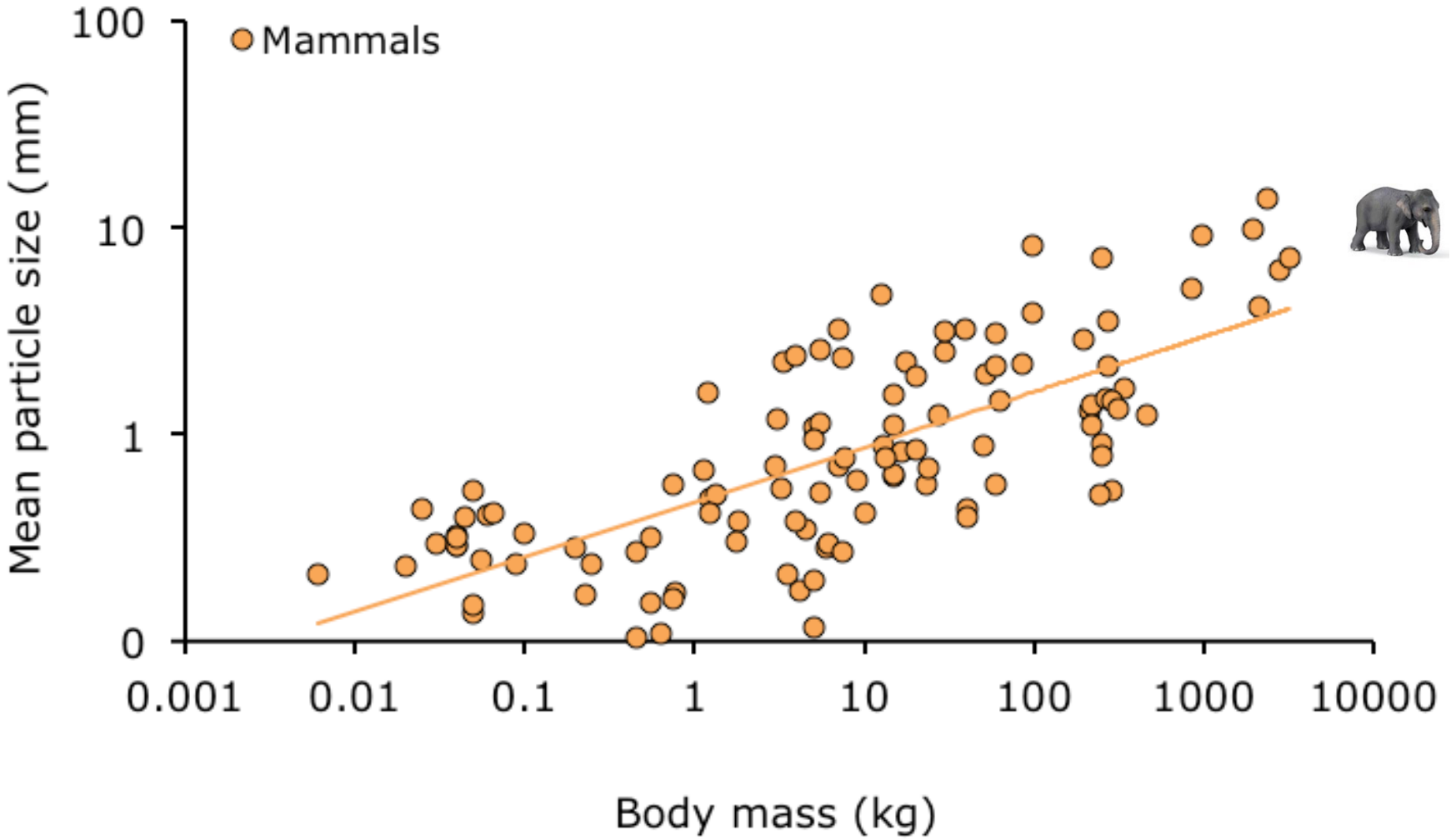
Oikos 118: 1623–1632, 2009



Comparative chewing efficiency in mammalian herbivores

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

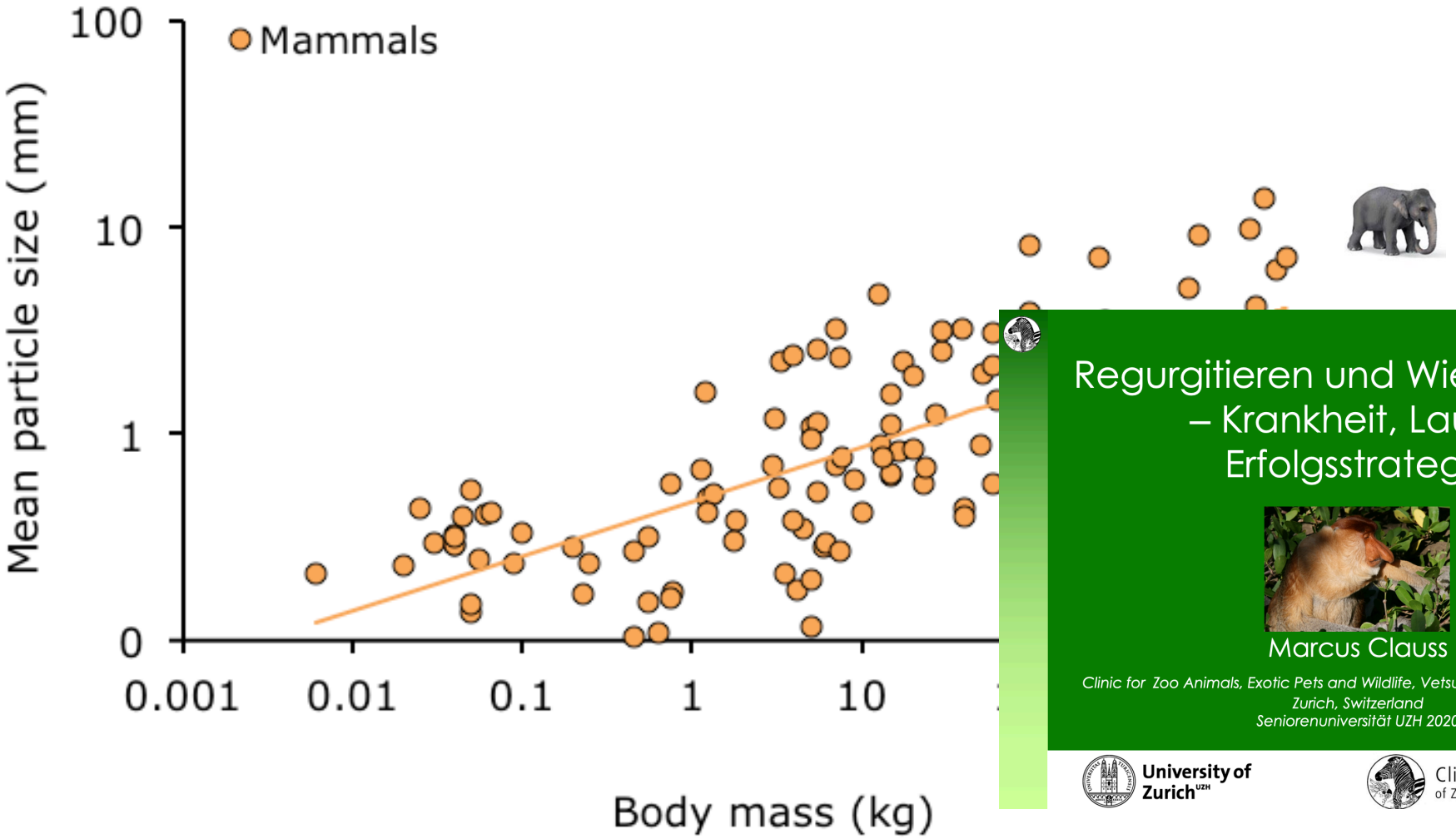
Oikos 118: 1623–1632, 2009



Comparative chewing efficiency in mammalian herbivores

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

Oikos 118: 1623–1632, 2009



Regurgitieren und Wiederkauen – Krankheit, Laune, Erfolgsstrategie

Marcus Clauss

Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty, University of Zurich, Switzerland

Seniorenuniversität UZH 2020

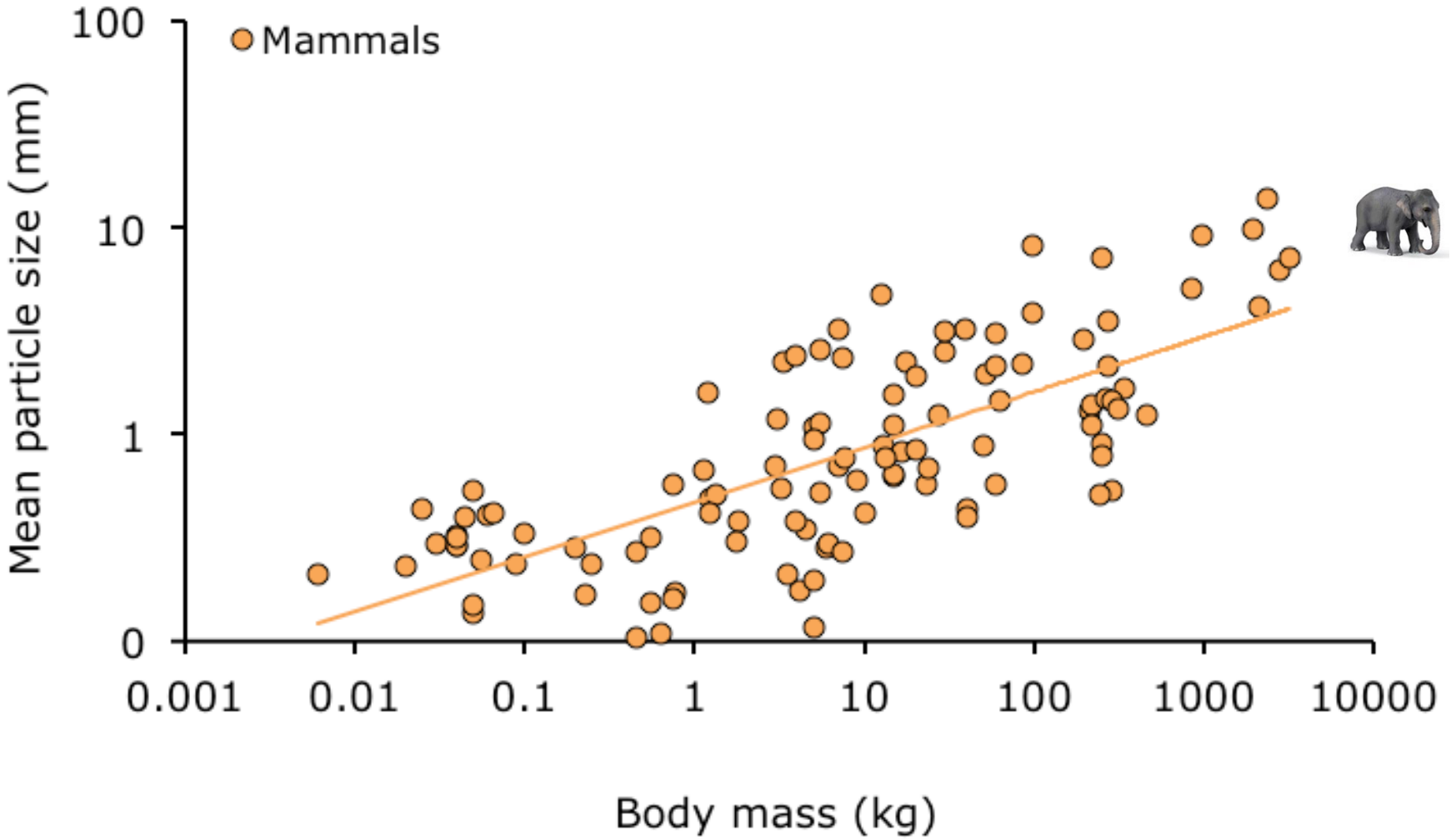
University of Zurich[UZH]

Clinic of Zoo Animals, Exotic Pets and Wildlife

Comparative chewing efficiency in mammalian herbivores

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

Oikos 118: 1623–1632, 2009



To Chew

To Chew or Not to Chew

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

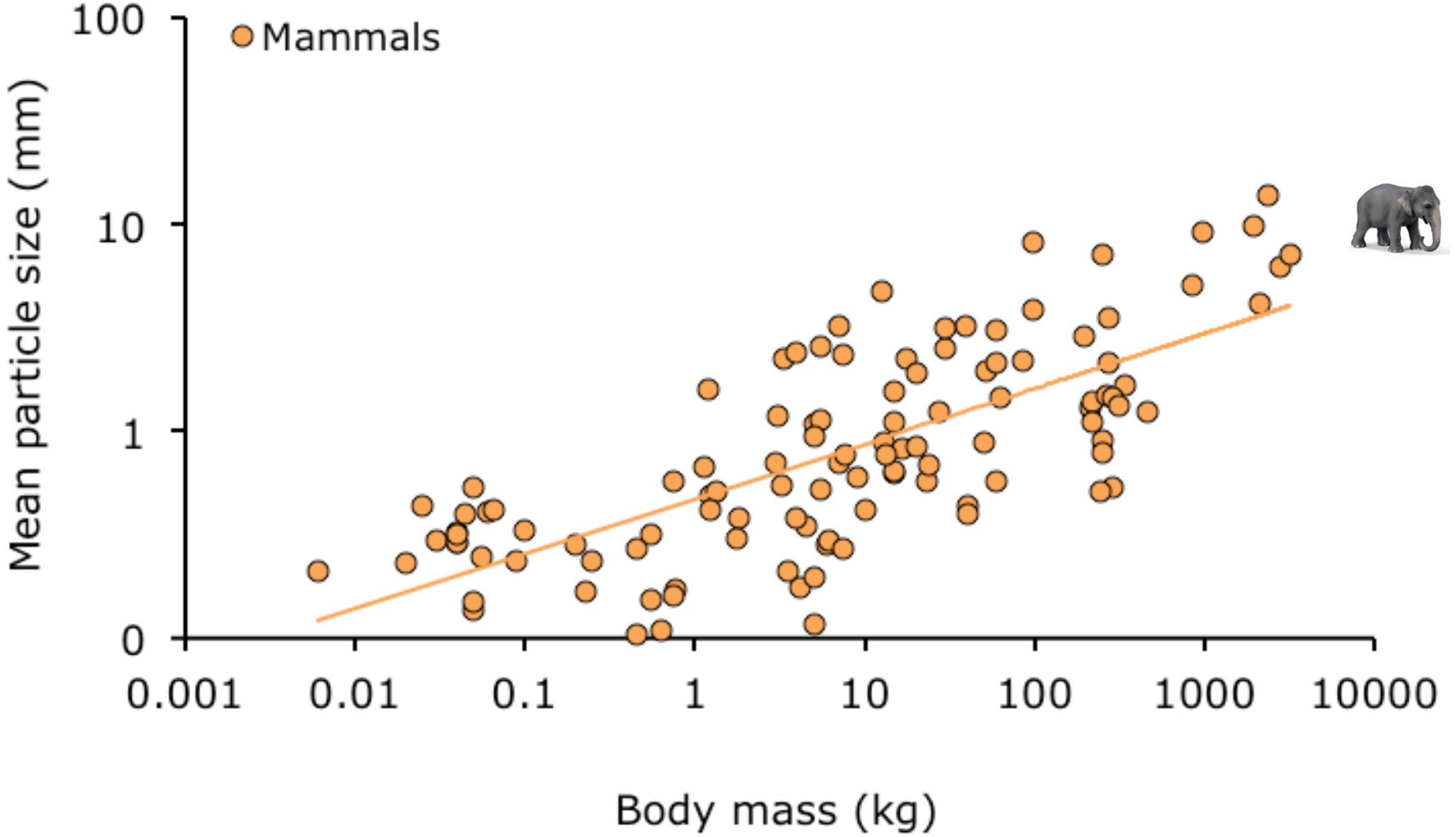
JULIA FRITZ[1*], JÜRGEN HUMMEL[2], ELLEN KIENZLE[1], W. JÜRGEN STREICH[3], AND MARCUS CLAUSS[4]

J. Exp. Zool. 313A:579–586, 2010

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

J. Exp. Zool. 313A:579–586, 2010

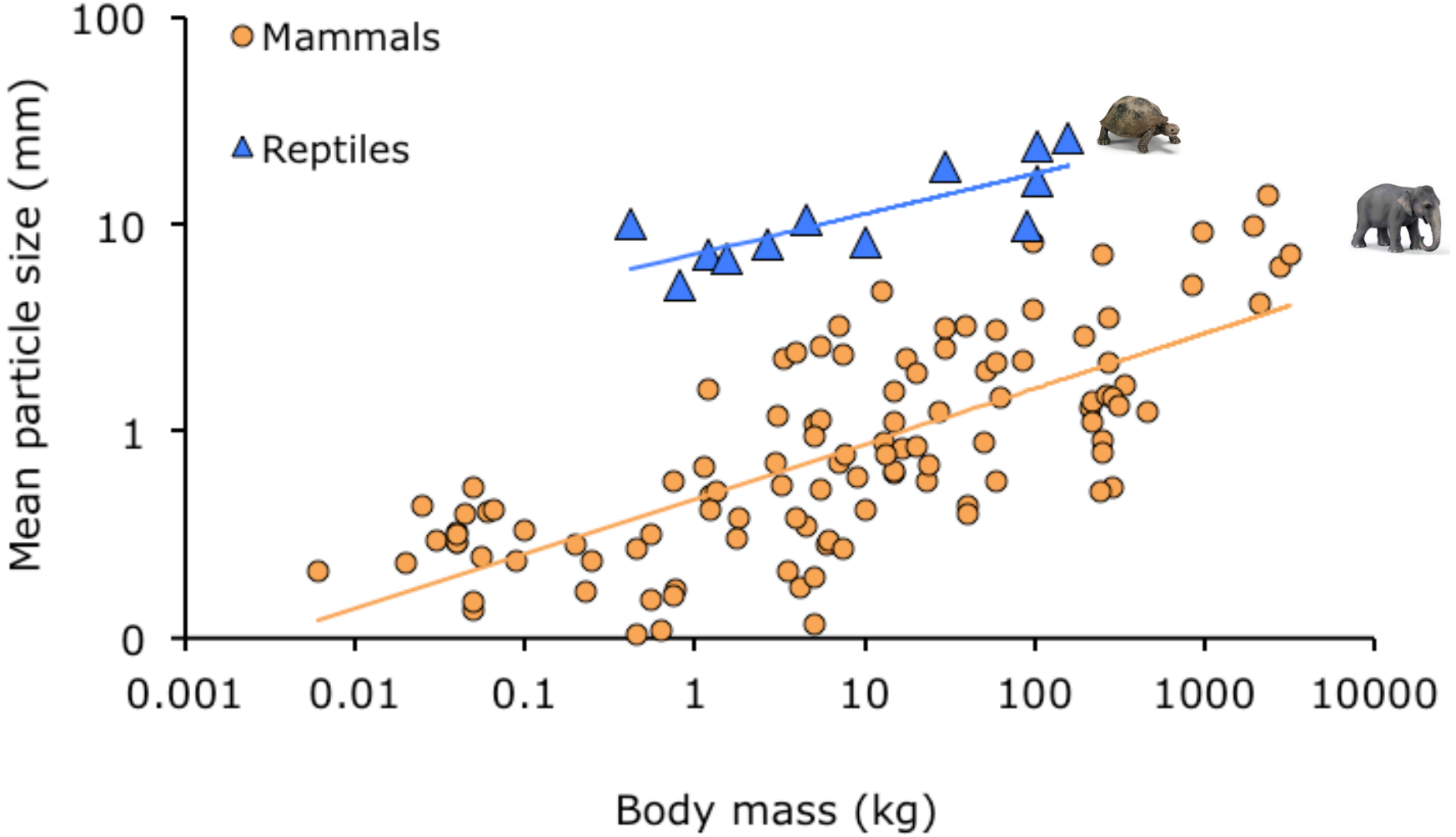
JULIA FRITZ[1*], JÜRGEN HUMMEL[2], ELLEN KIENZLE[1], W. JÜRGEN STREICH[3], AND MARCUS CLAUSS[4]



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

J. Exp. Zool. 313A:579–586, 2010

JULIA FRITZ[1*], JÜRGEN HUMMEL[2], ELLEN KIENZLE[1], W. JÜRGEN STREICH[3], AND MARCUS CLAUSS[4]



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

J. Exp. Zool. 313A:579–586, 2010

JULIA FRITZ[1*], JÜRGEN HUMMEL[2], ELLEN KIENZLE[1], W. JÜRGEN STREICH[3], AND MARCUS CLAUSS[4]

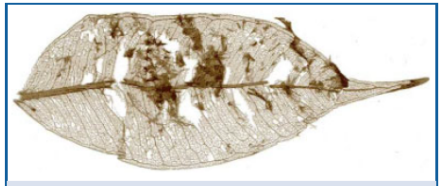
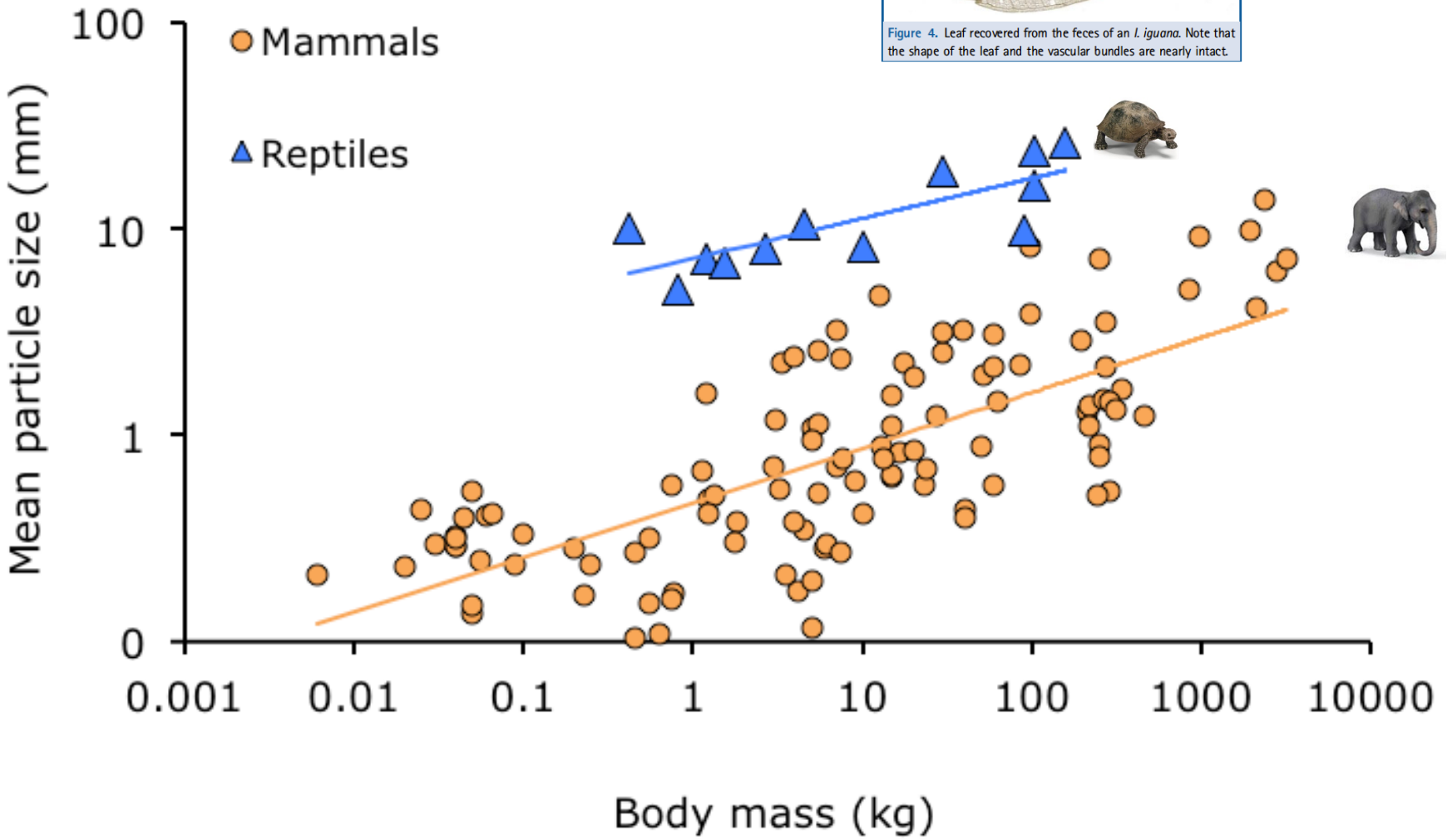
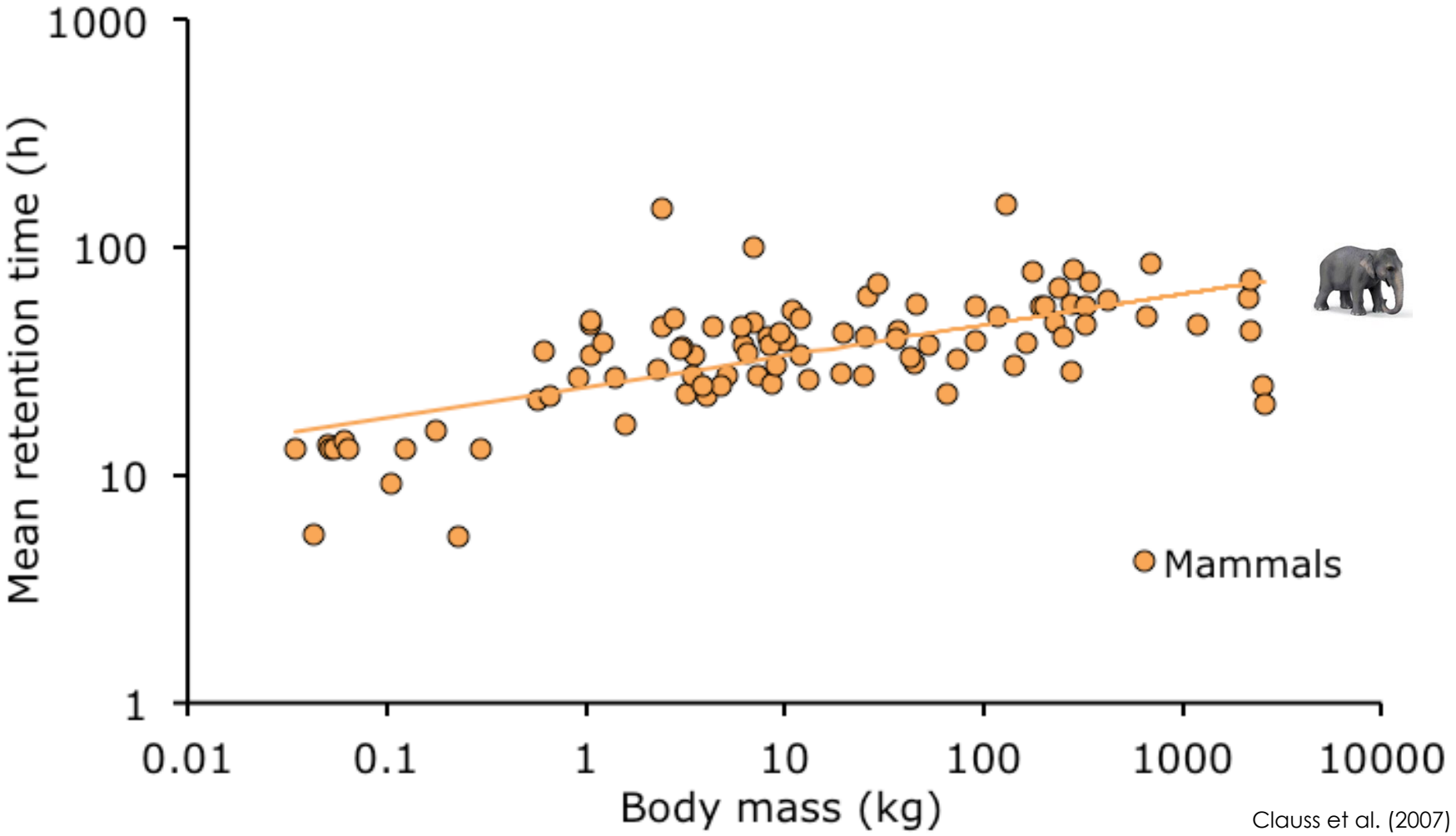


Figure 4. Leaf recovered from the feces of an *I. iguana*. Note that the shape of the leaf and the vascular bundles are nearly intact.

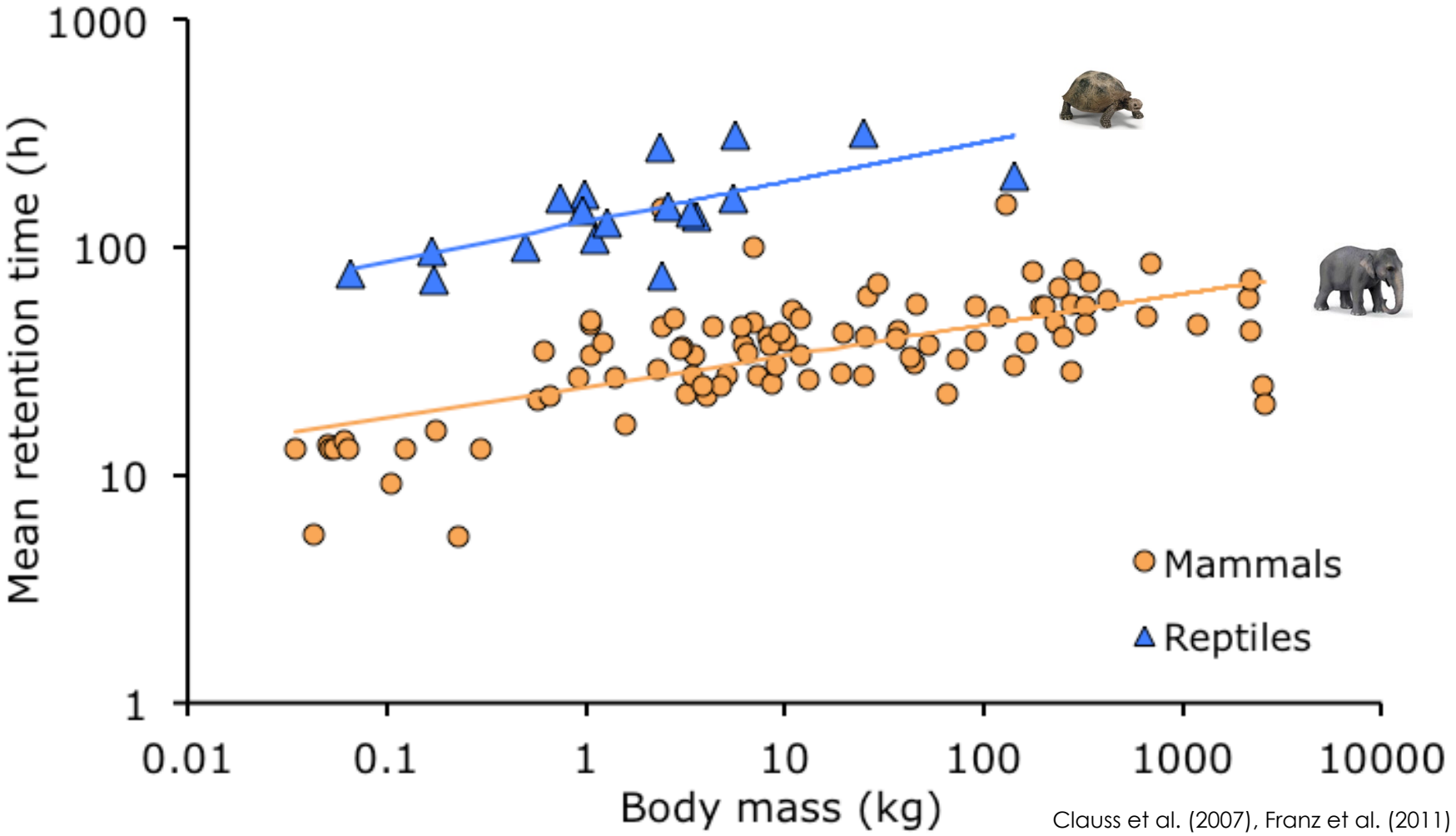


Verweilzeit im Verdauungstrakt



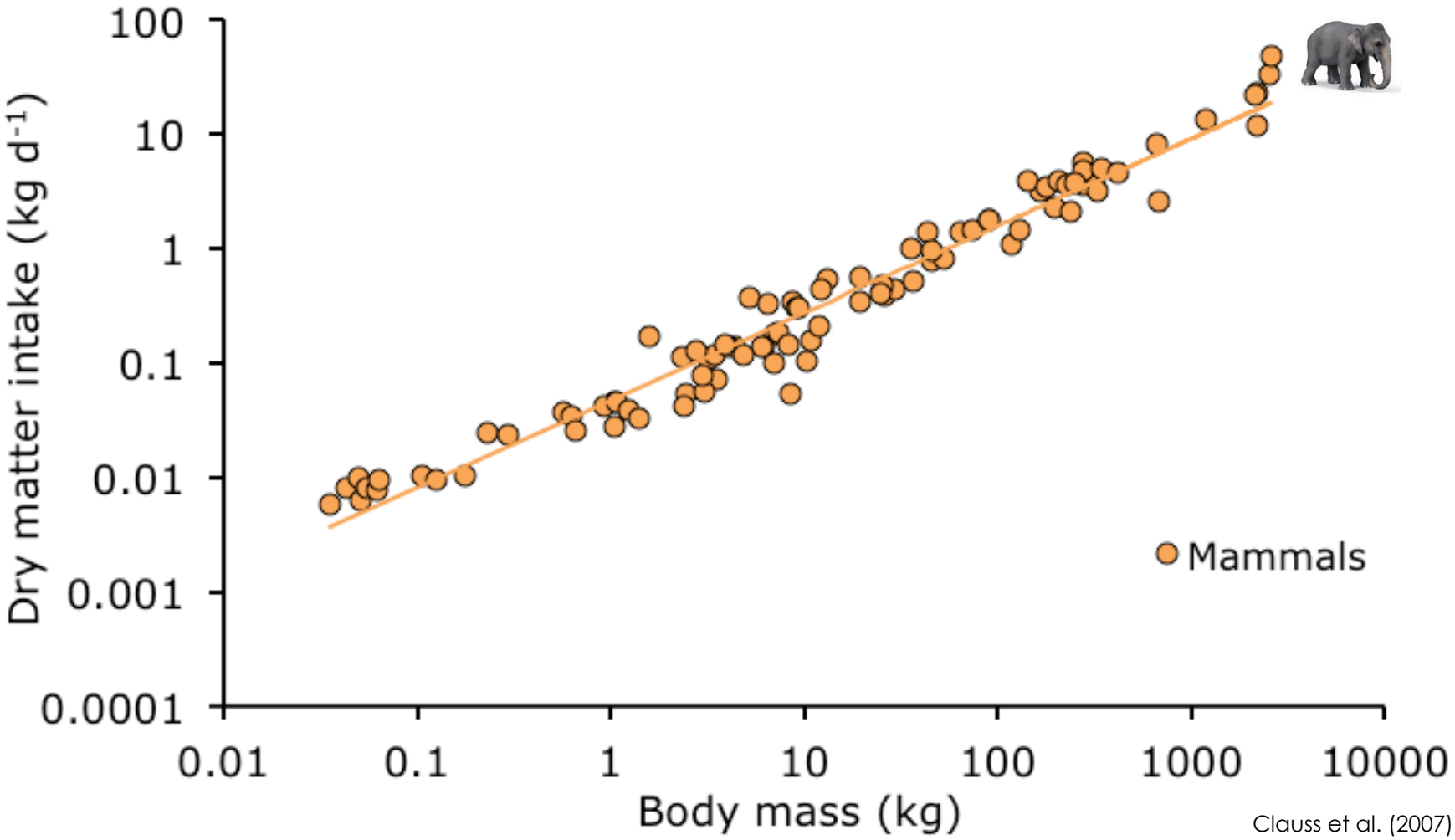
Clauss et al. (2007)

Verweilzeit im Verdauungstrakt



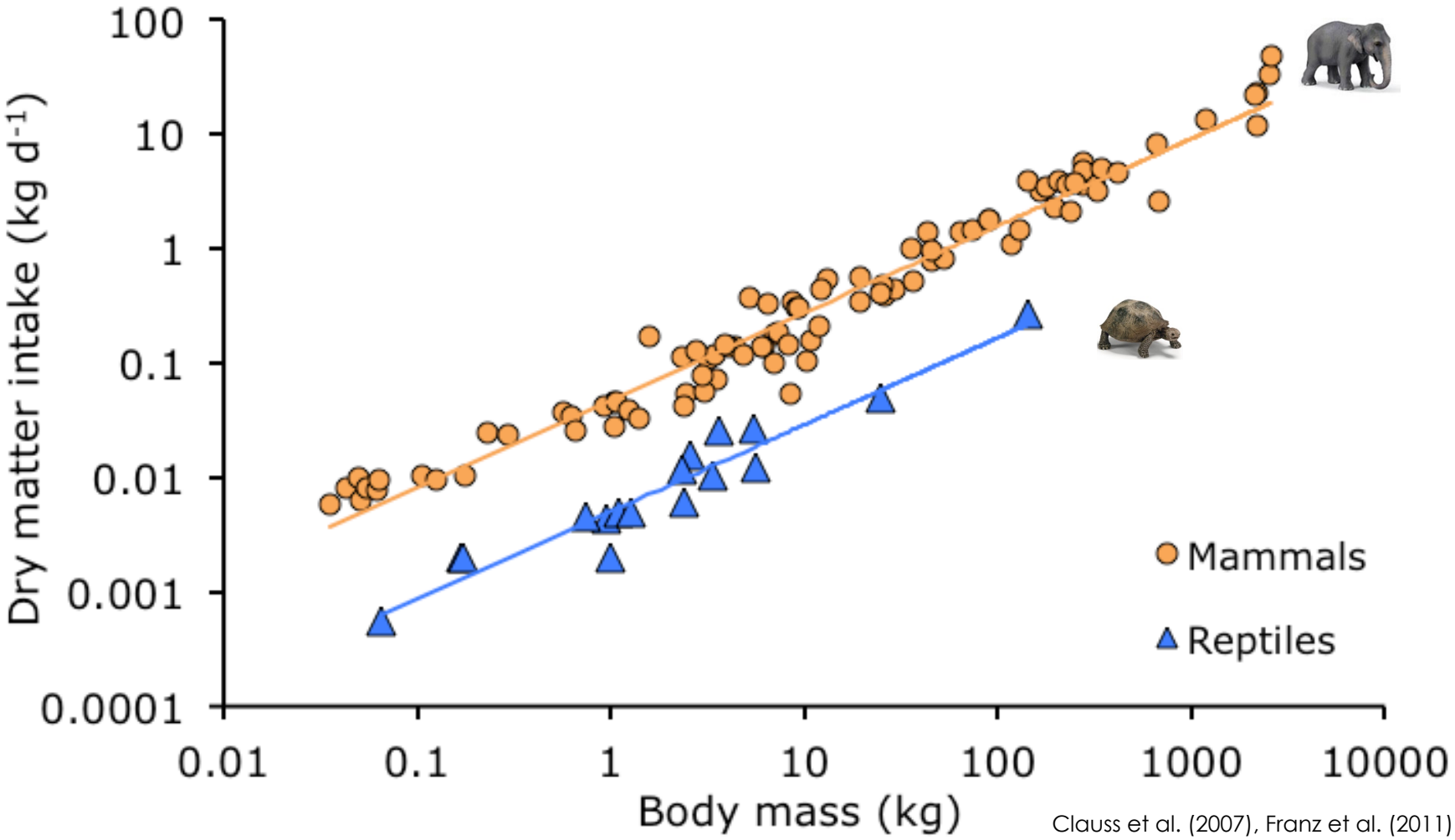
Clauss et al. (2007), Franz et al. (2011)

Futteraufnahme



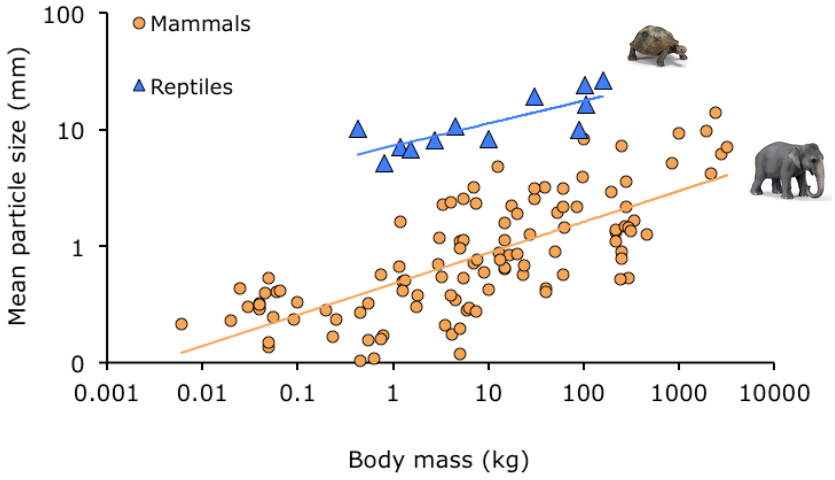
Clauss et al. (2007)

Futteraufnahme



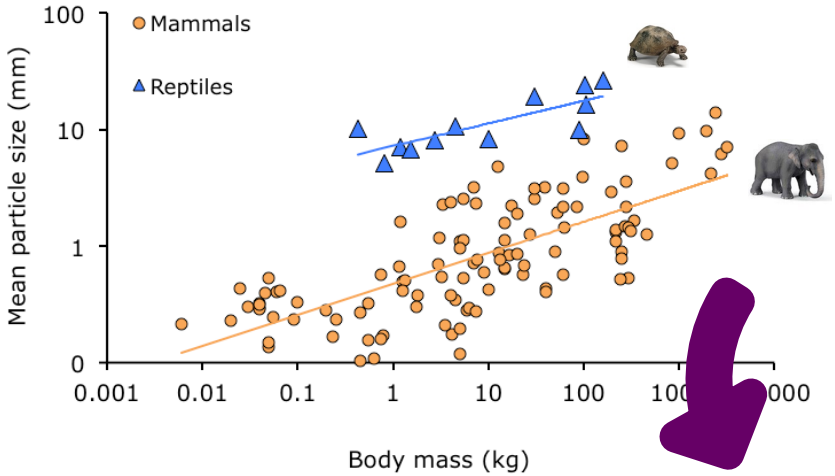
Clauss et al. (2007), Franz et al. (2011)

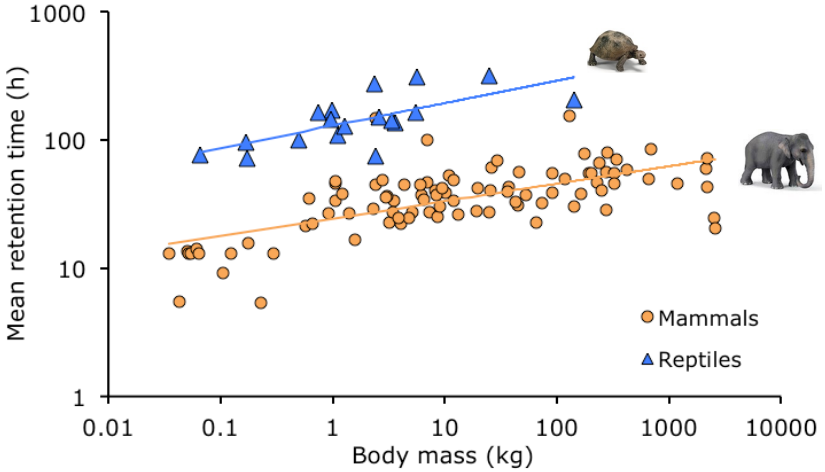
Kauen ...



Fritz et al. (2009, 2010)

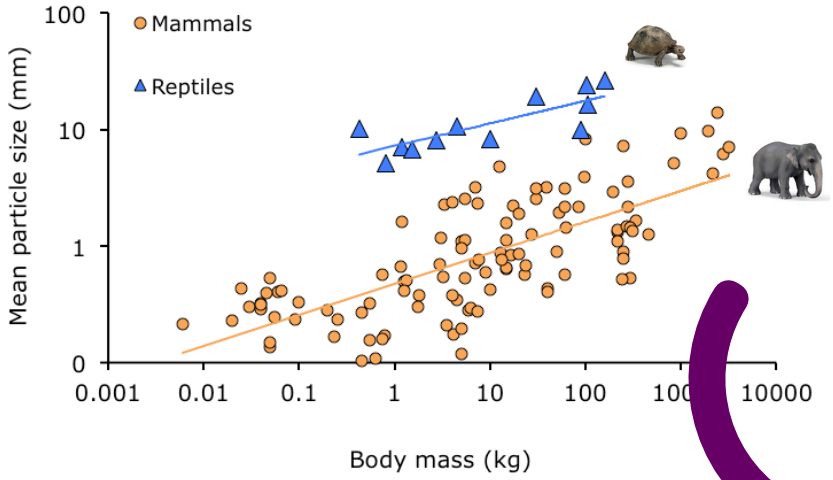
Kauen … ermöglicht kurze Verweildauer

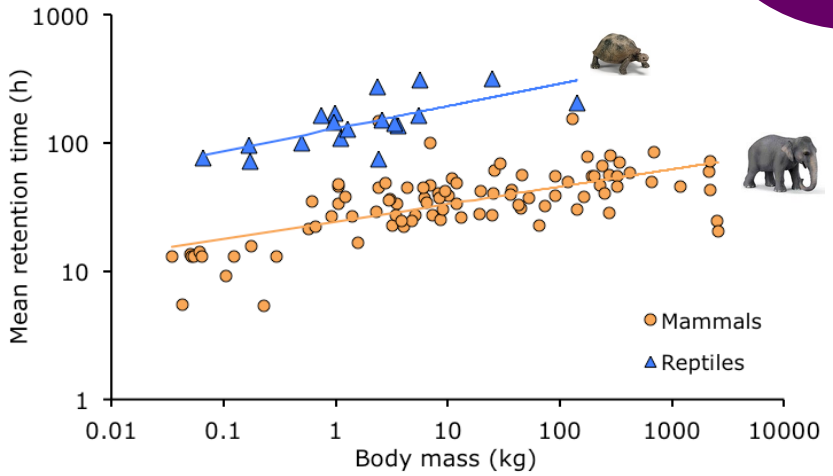


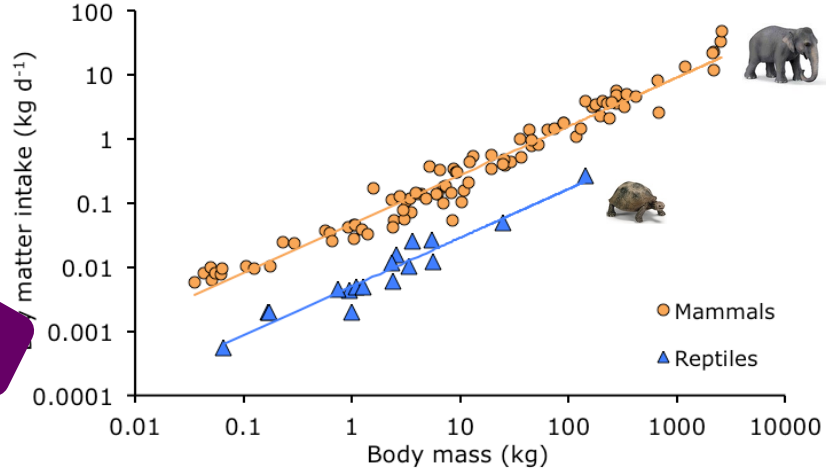


Clauss et al. (2007), Fritz et al. (2009, 2010), Franz et al. (2011)

Kauen … ermöglicht hohe Futteraufnahme



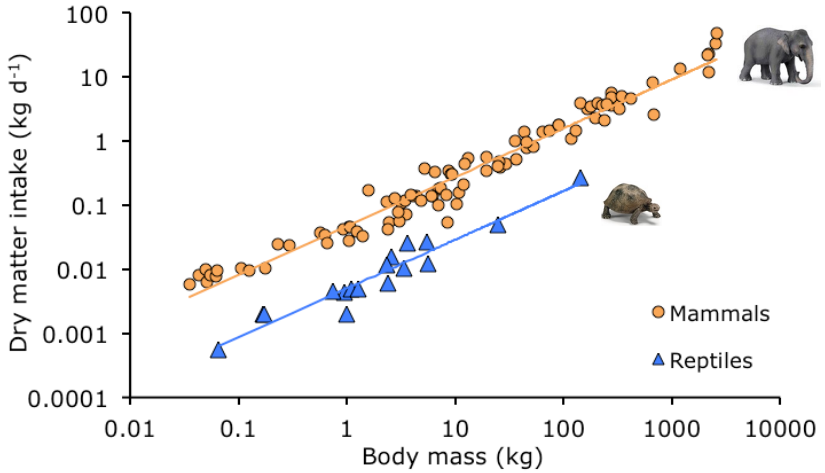




Clauss et al. (2007), Fritz et al. (2009, 2010), Franz et al. (2011)

Kauen … ermöglicht hohe Futteraufnahme

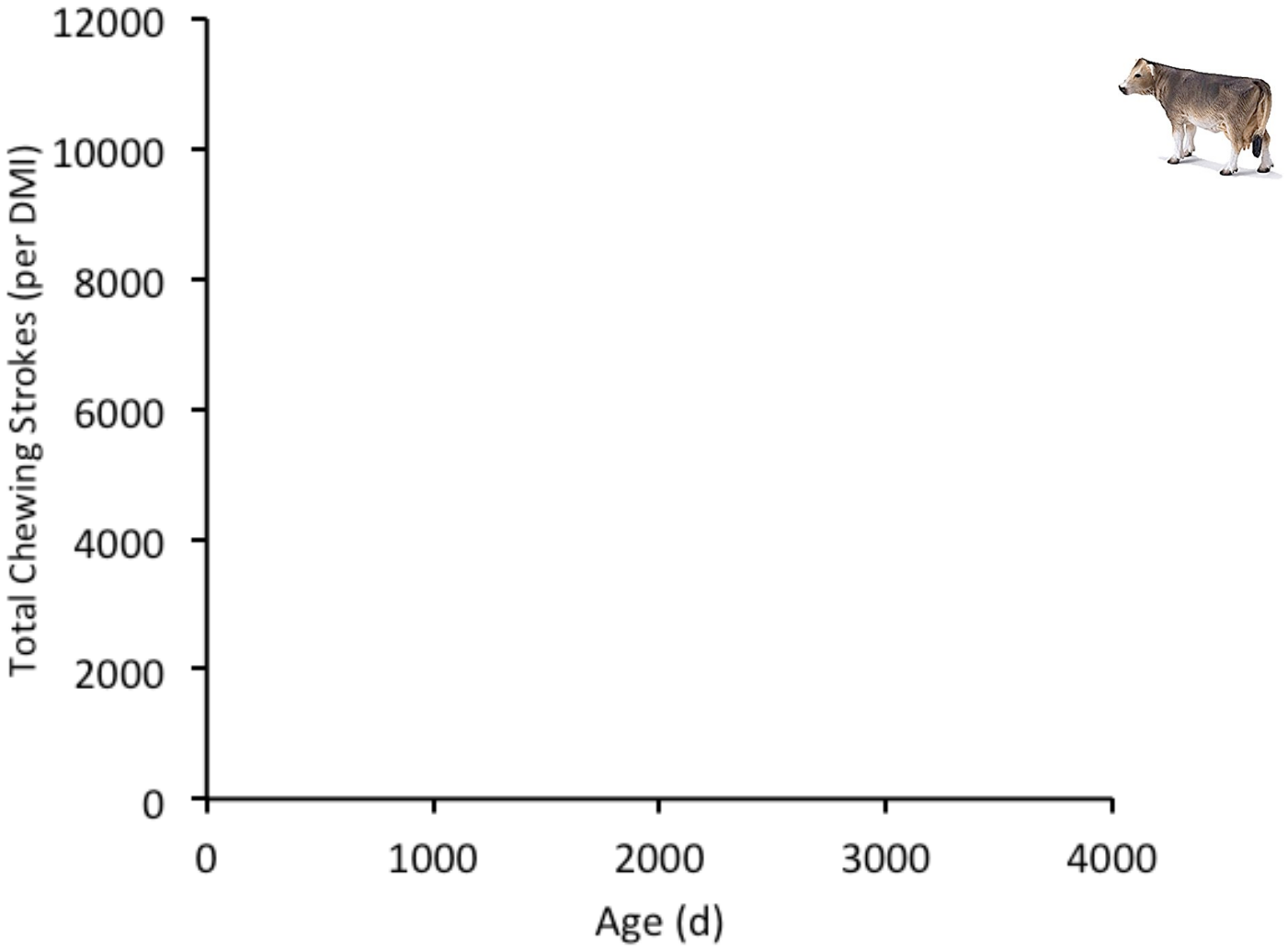
für Pflanzenfresser ist Futterzerkleinerung die Voraussetzung für Endothermie !



Clauss et al. (2007), Fritz et al. (2009, 2010), Franz et al. (2011)

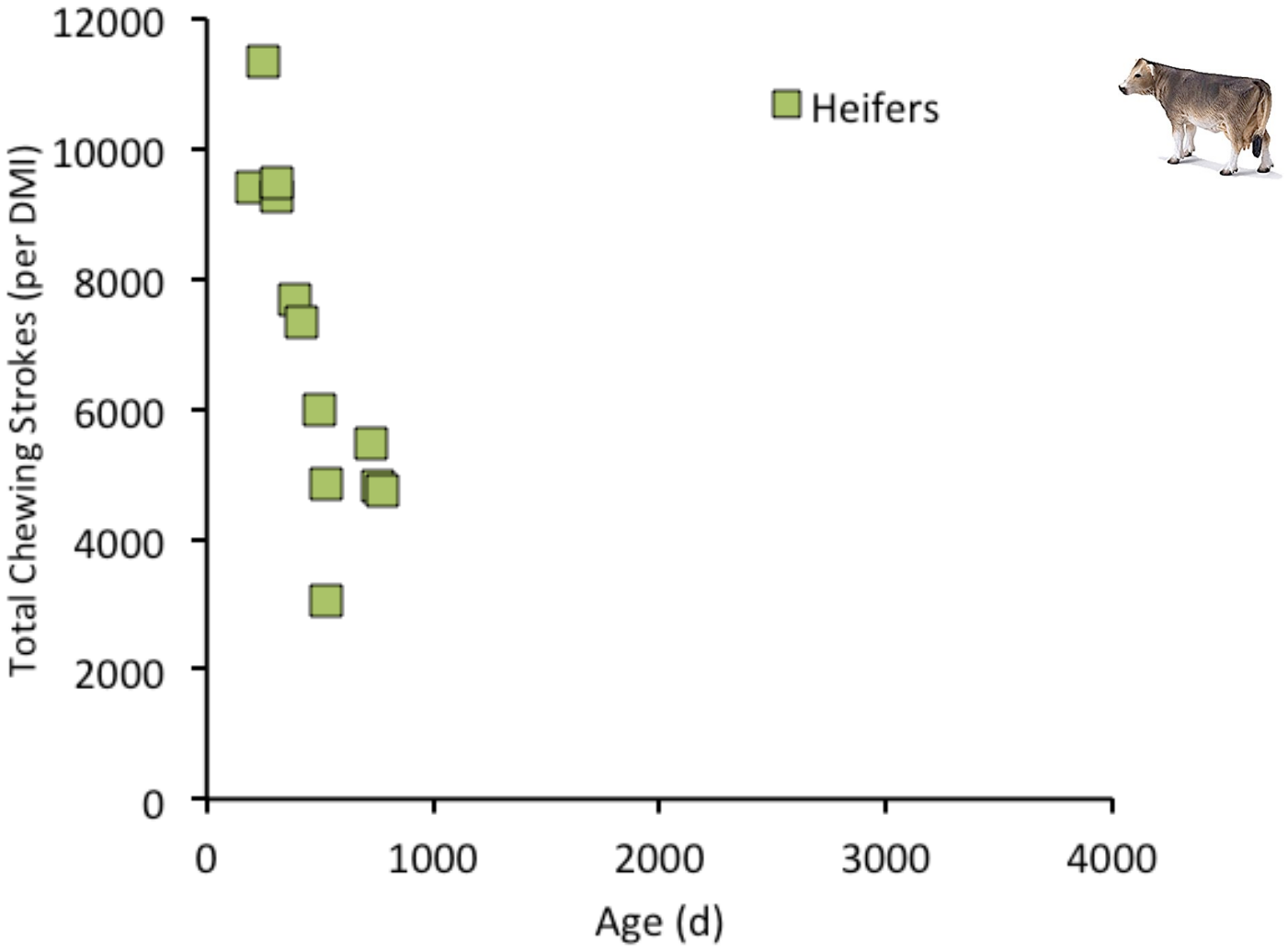
Zahnoptimierung I

Kauschläge



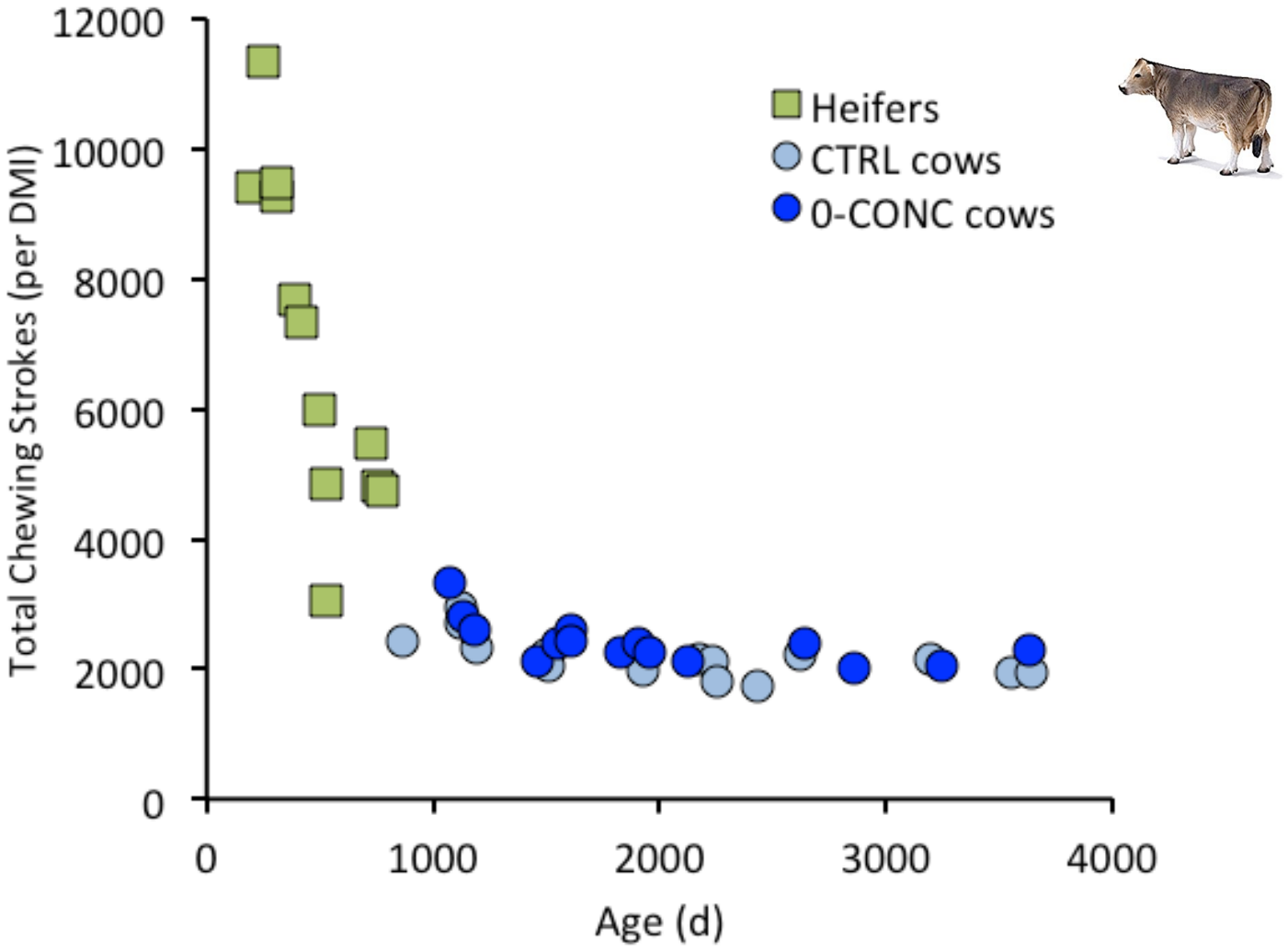
Grandl et al. (2018)

Kauschläge



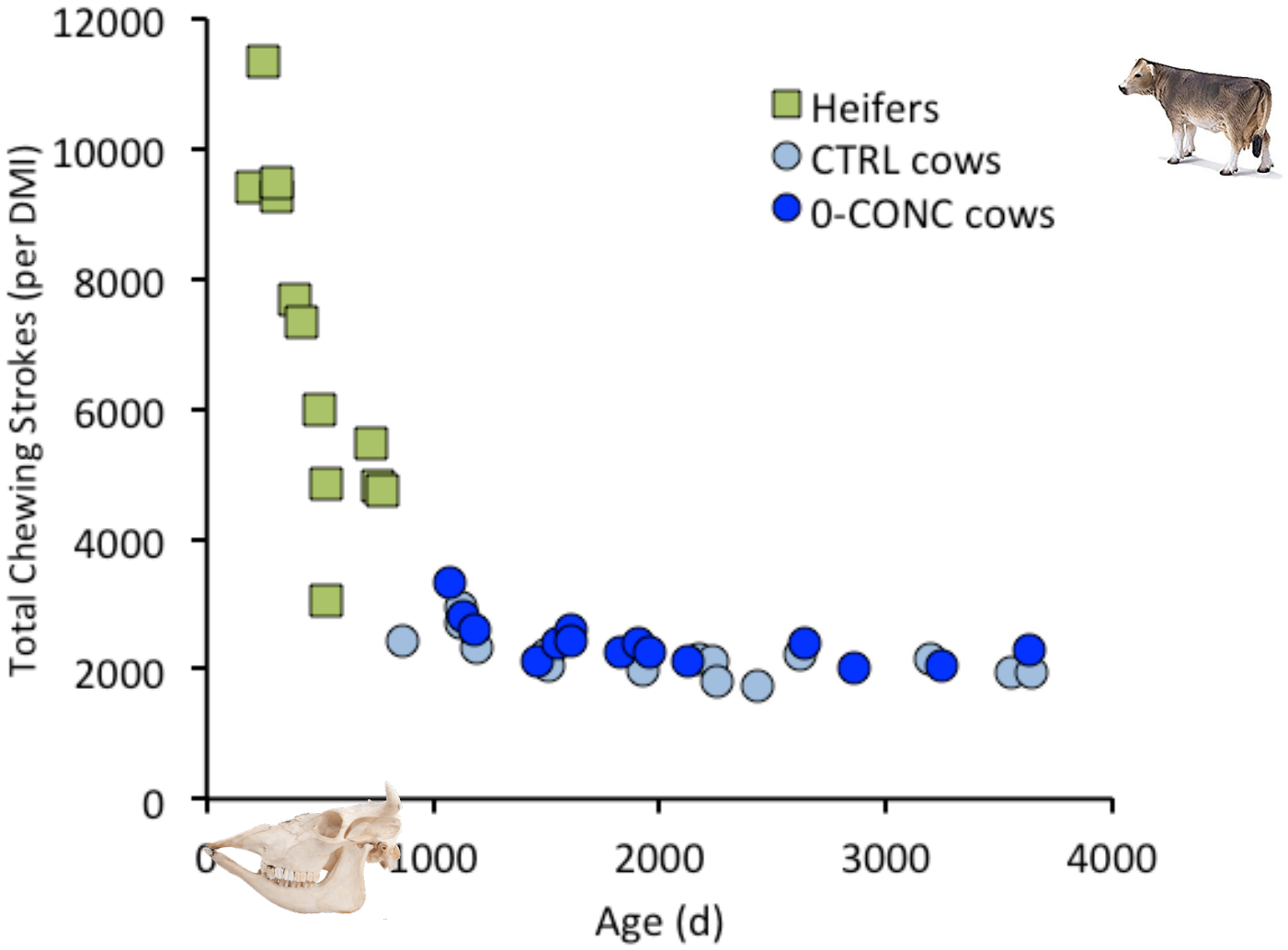
Grandl et al. (2018)

Kauschläge



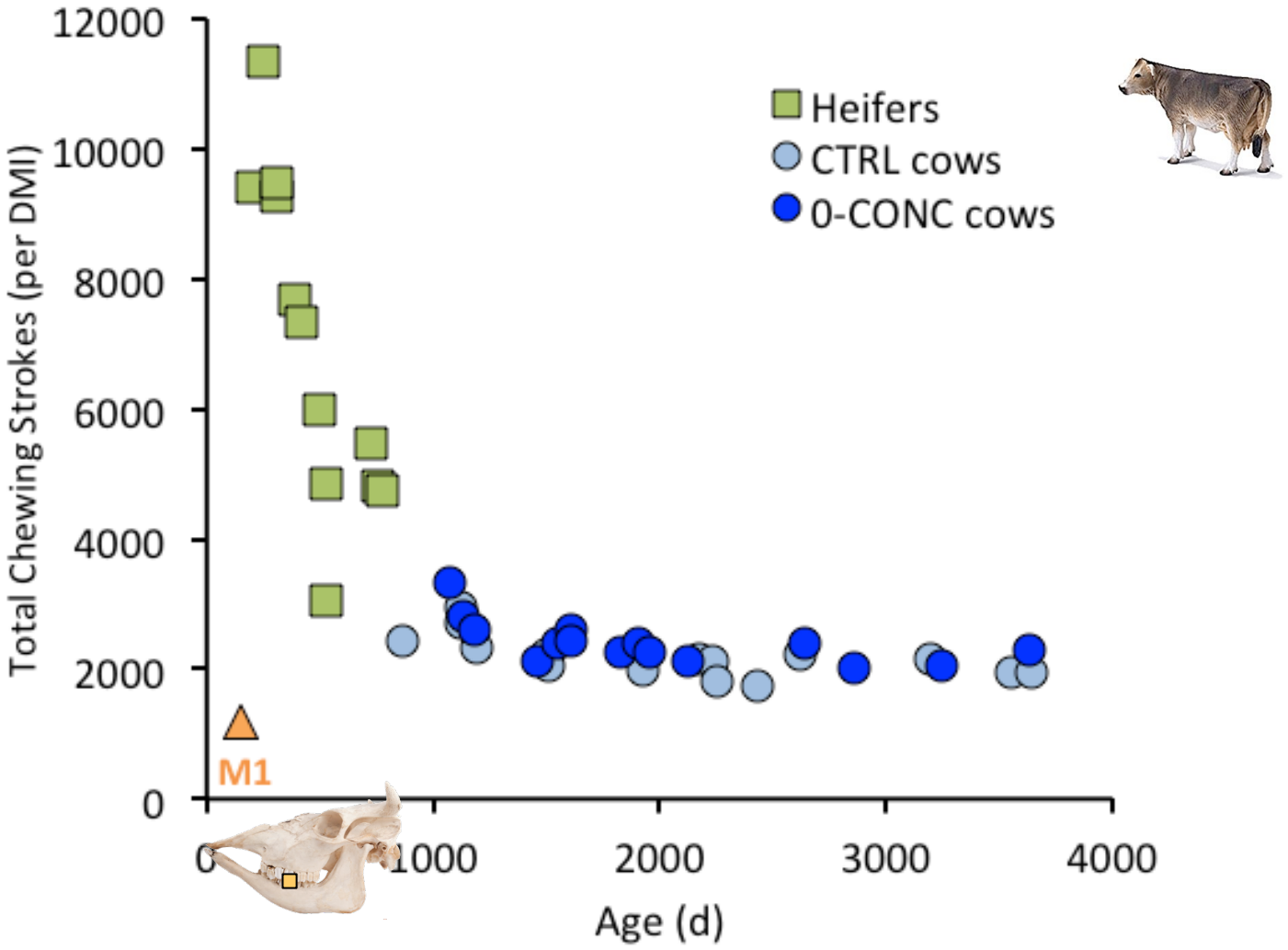
Grandl et al. (2018)

Kauschläge



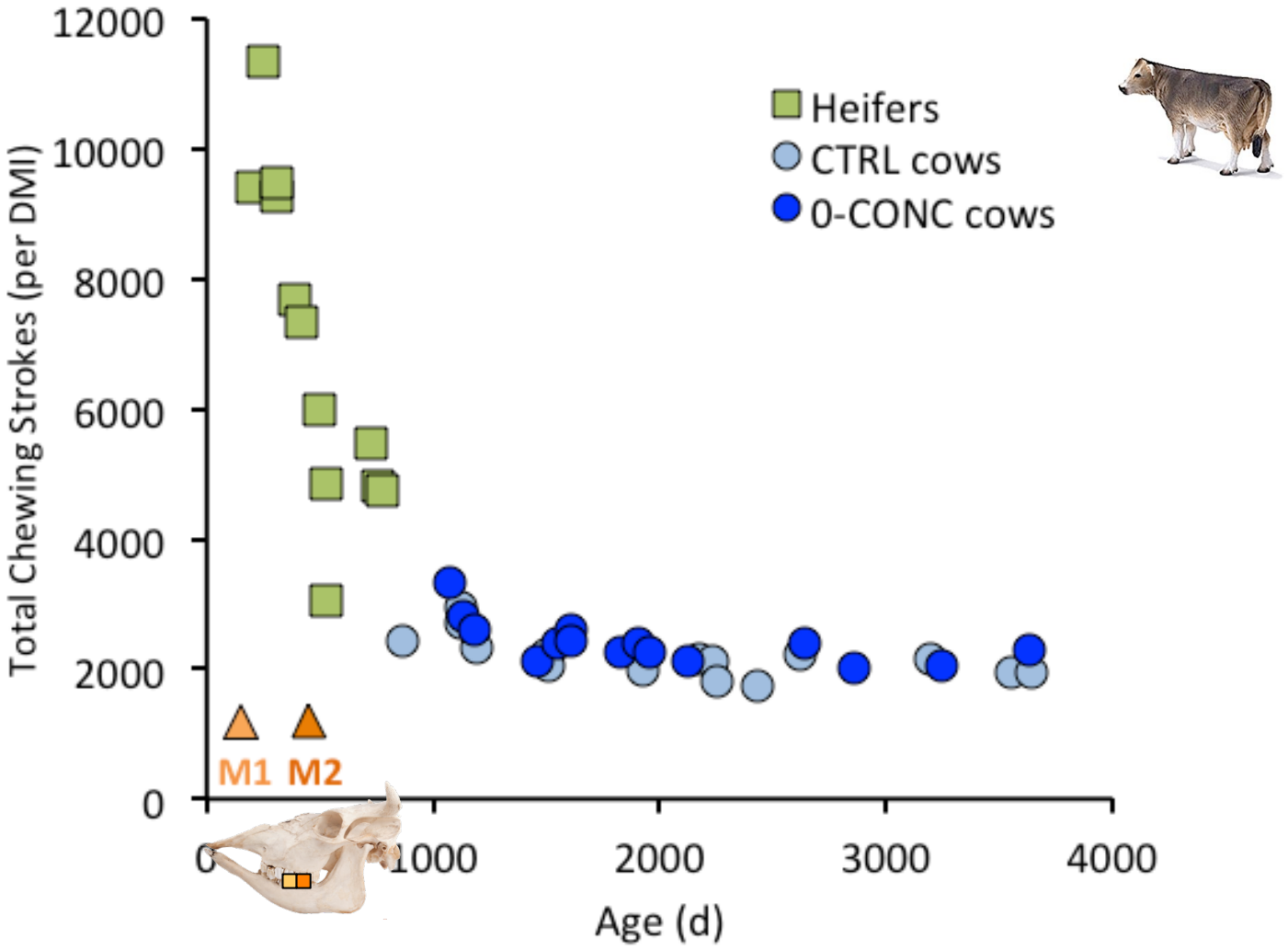
Grandl et al. (2018)

Kauschläge



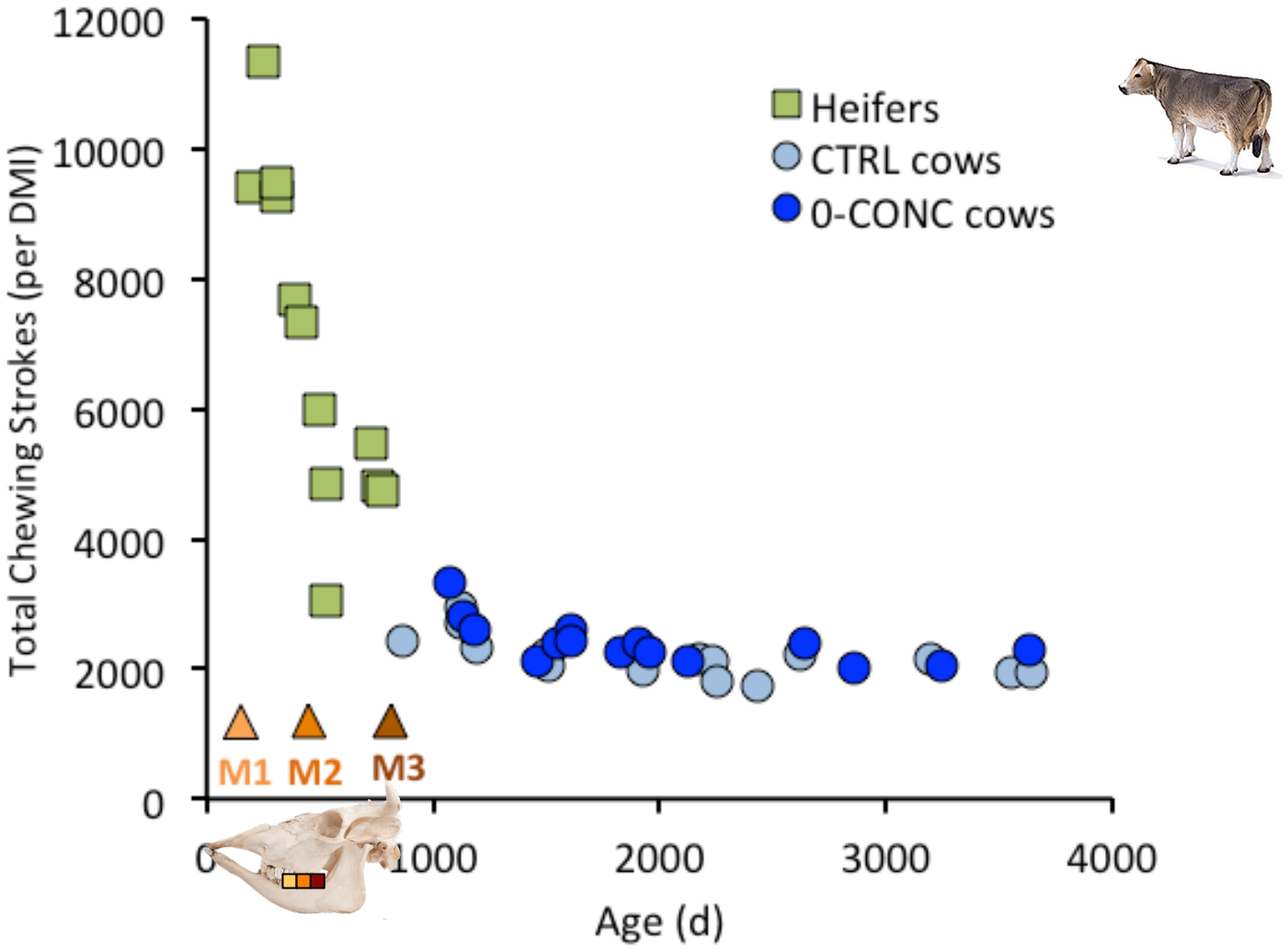
Grandl et al. (2018)

Kauschläge



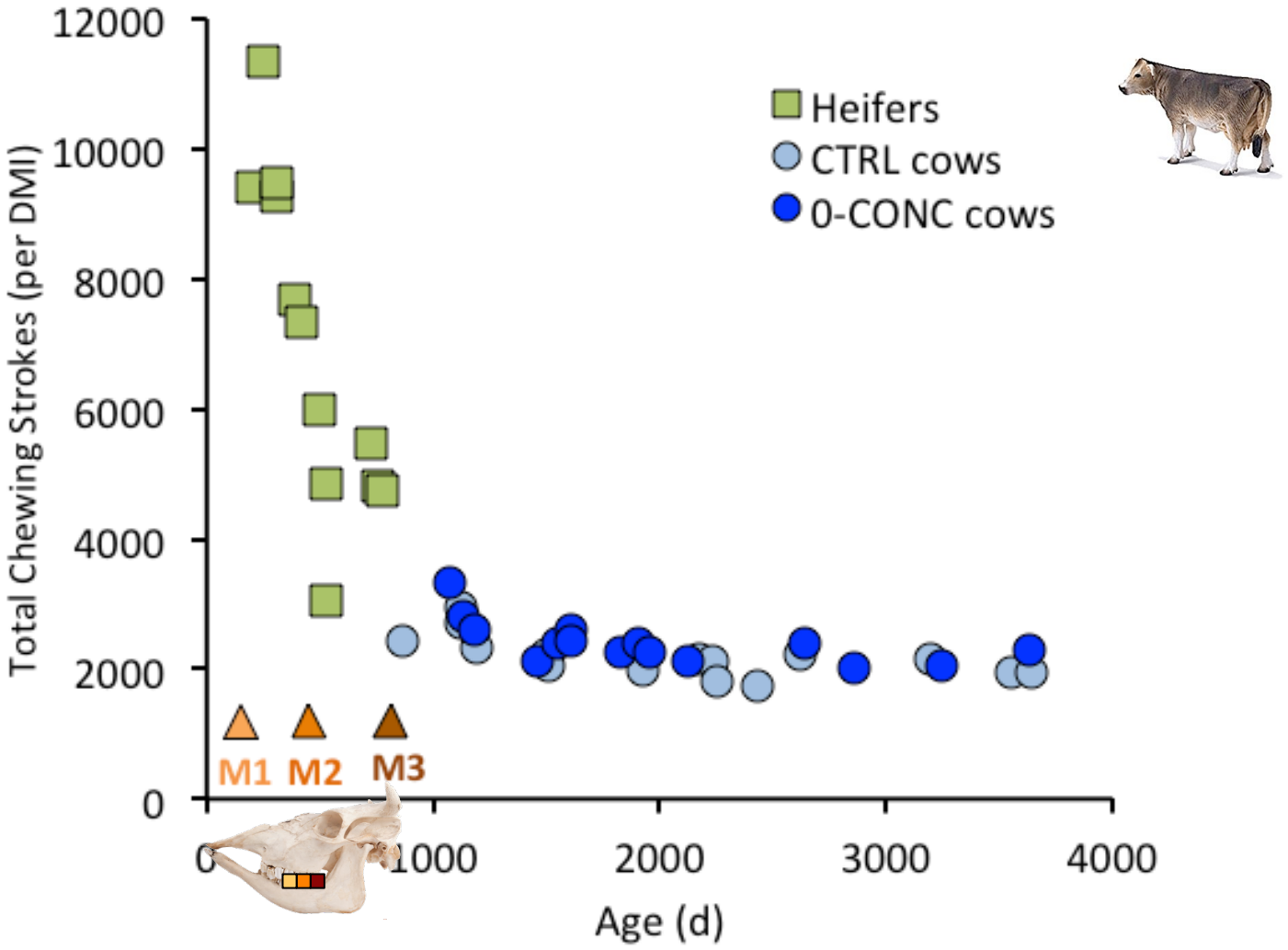
Grandl et al. (2018)

Kauschläge



Grandl et al. (2018)

Kauschläge



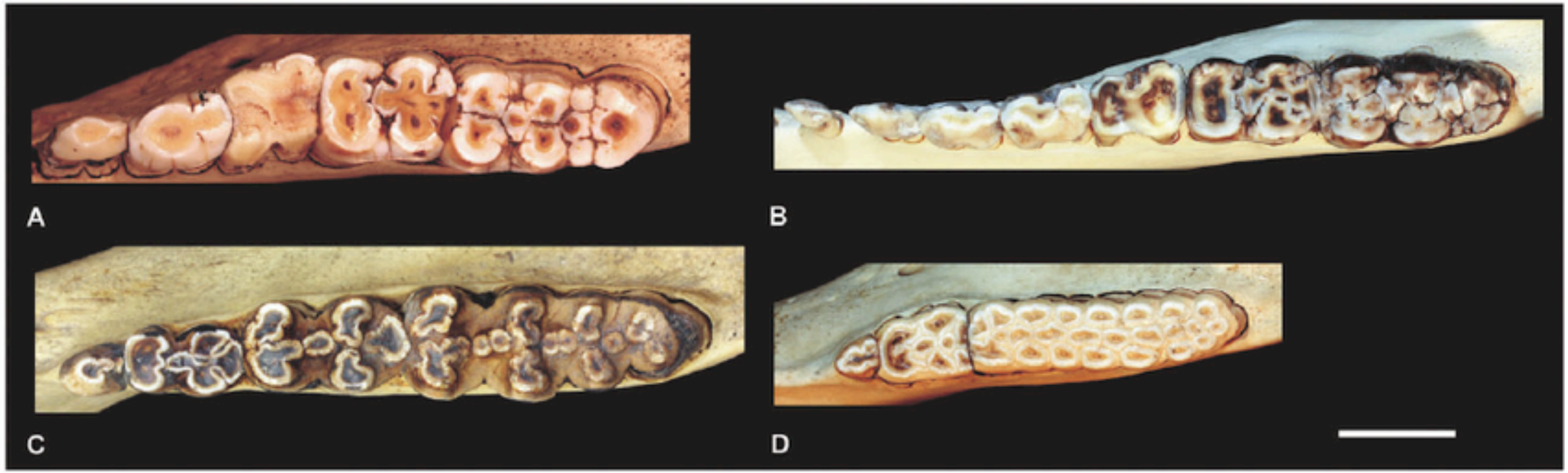
Alterseffekt auf Kauintensität
(aufgrund Molaren-Eruption)

Grandl et al. (2018)

Zahnoptimierung I

Verlängerung der Kauleiste

Verlängerung des ‘Weisheitszahnes’ bei Schweinen



from Souron et al. (2014)

‘Molarisierung’ der ‘Prämolaren’ bei Equiden

Zahnabrieb

Wodurch werden Zähne abgerieben ?

- ‘Härte’ der Nahrung (typische Vorstellung: Zweige, trockenes Brot)

- Abrasiva in/auf der Nahrung

- Zahn-Zahn-Kontakt => Kauen !

Wodurch werden Zähne abgerieben ?

- ~~‘Härte’ der Nahrung (typische Vorstellung: Zweige, trockenes Brot)~~

- Abrasiva in/auf der Nahrung

- Zahn-Zahn-Kontakt => Kauen !

Wodurch werden Zähne abgerieben ?

- ~~‘Härte’ der Nahrung (typische Vorstellung: Zweige, trockenes Brot)~~

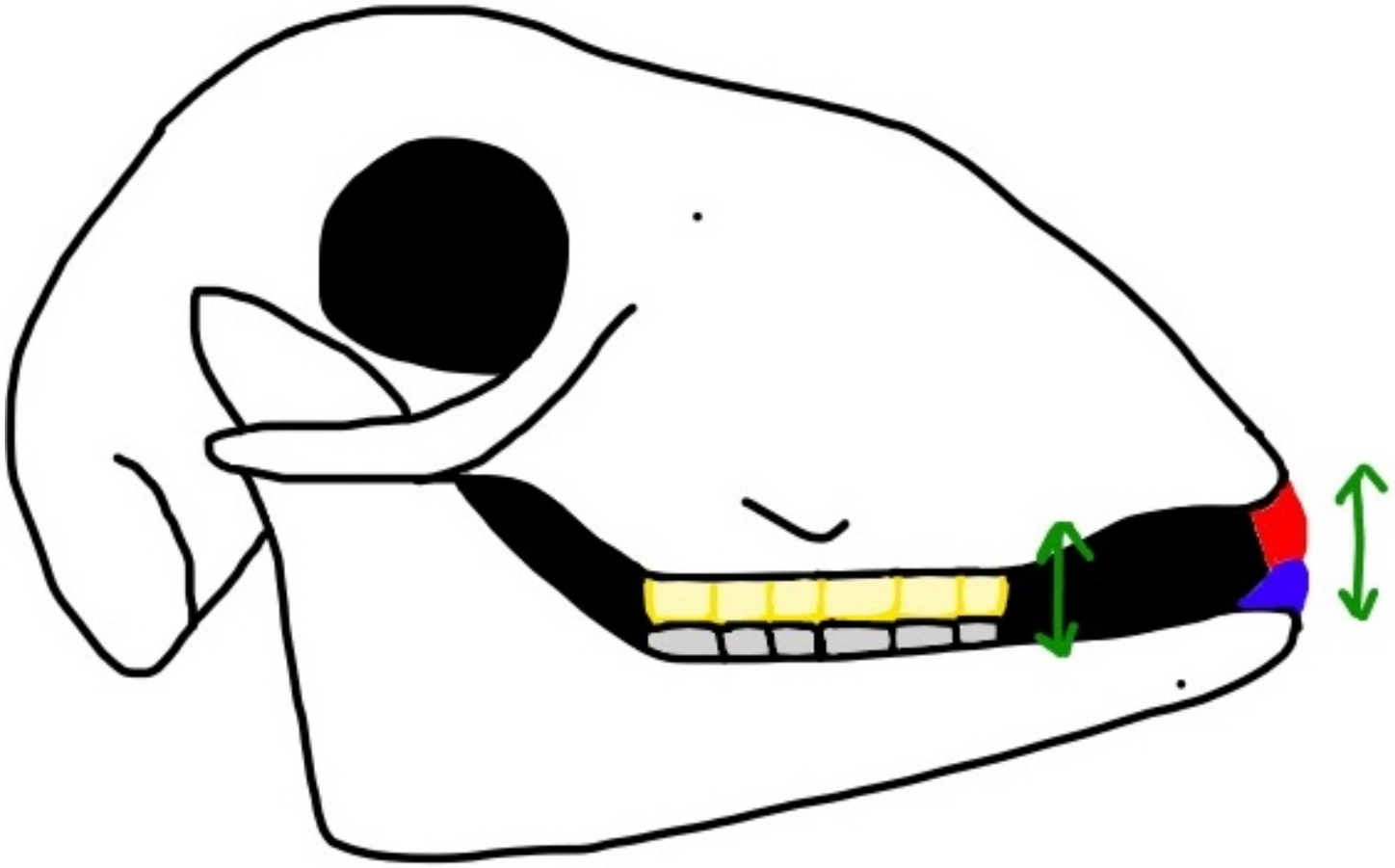
- Abrasiva in/auf der Nahrung

- Zahn-Zahn-Kontakt => Kauen !

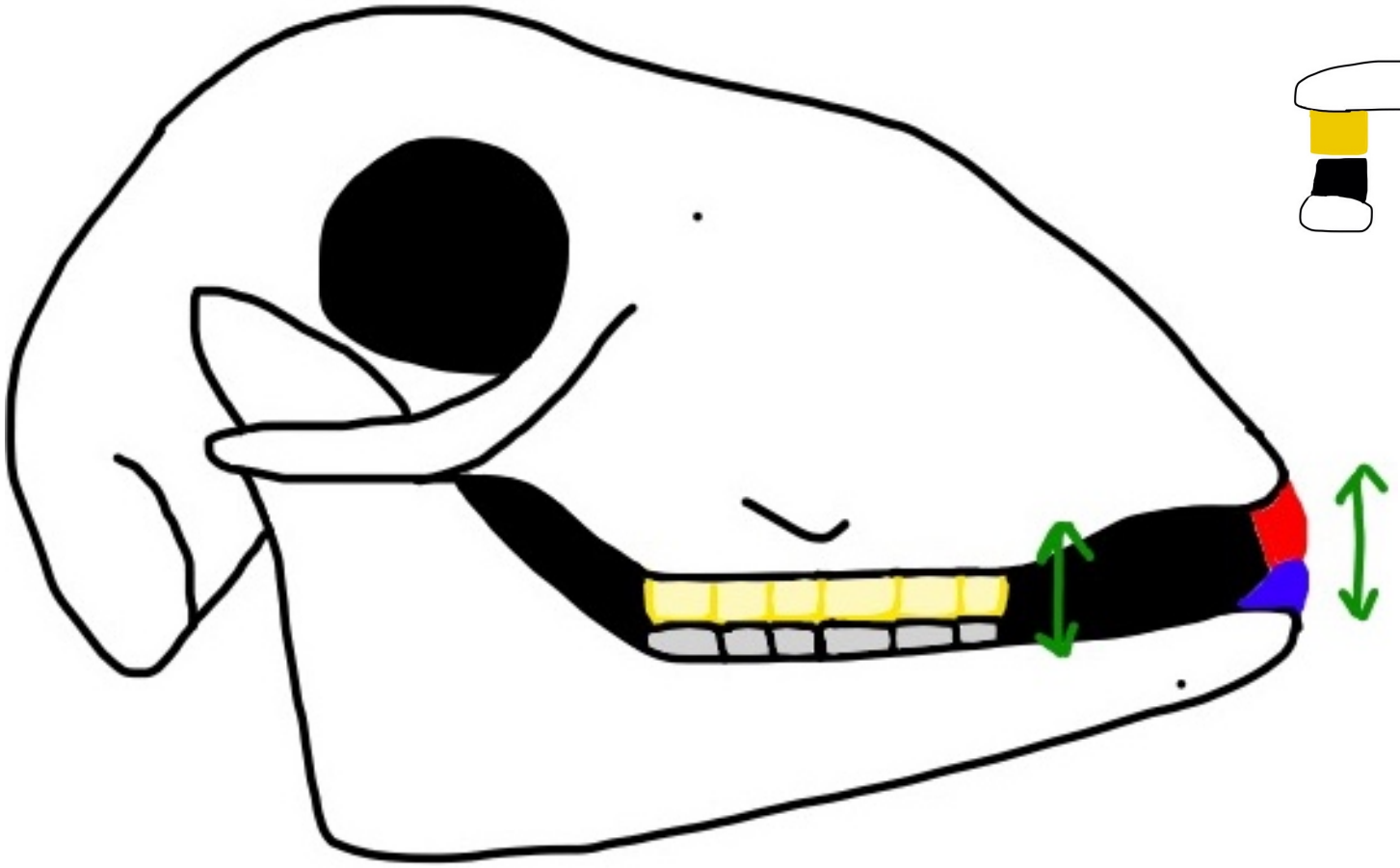
Zahnoptimierung II

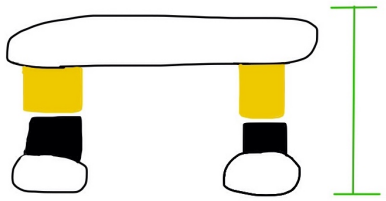
Vermeidung von Zahn-Zahn-Kontakten

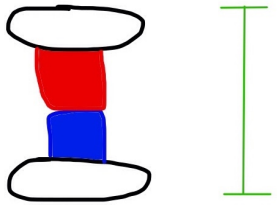
eine mechanische Herausforderung



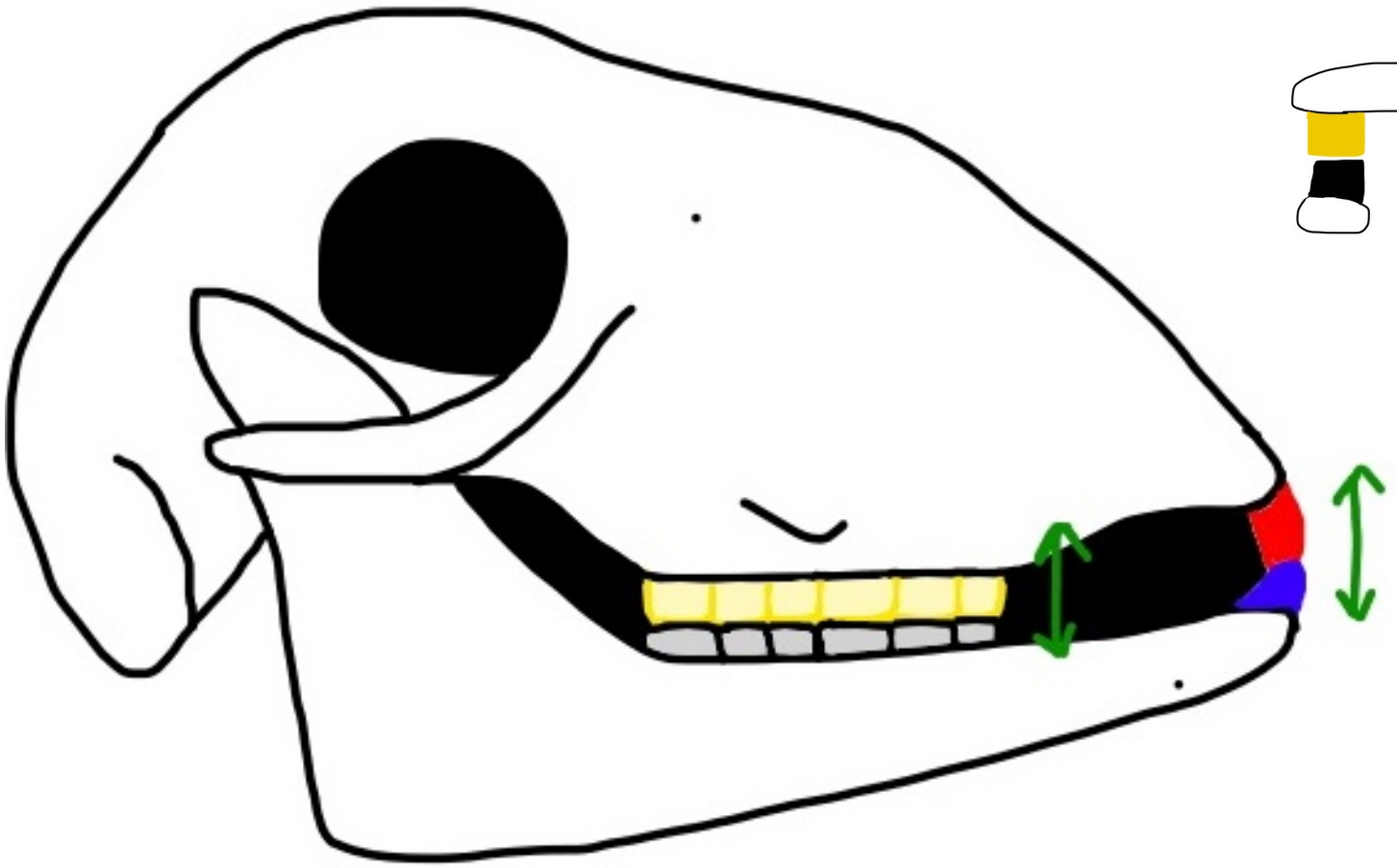
eine mechanische Herausforderung

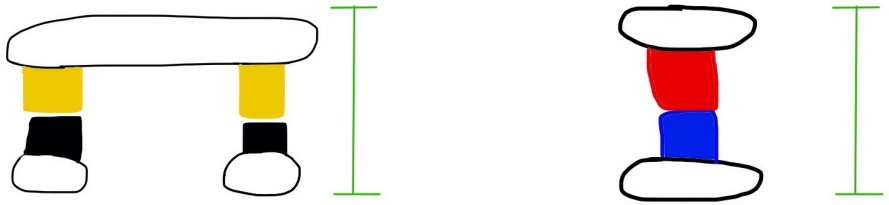




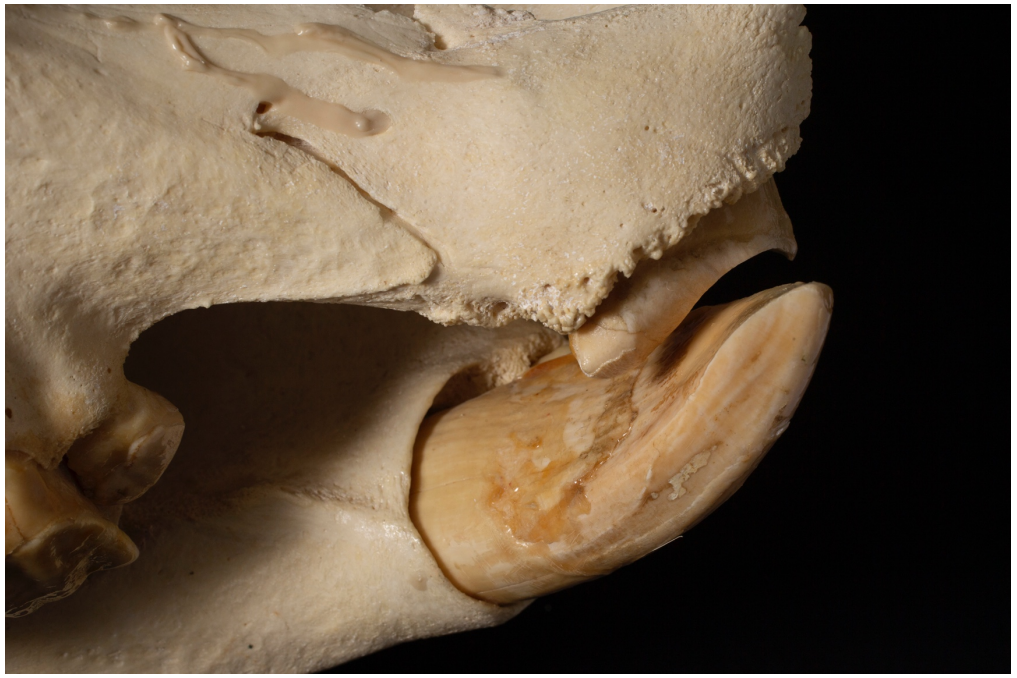


eine mechanische Herausforderung





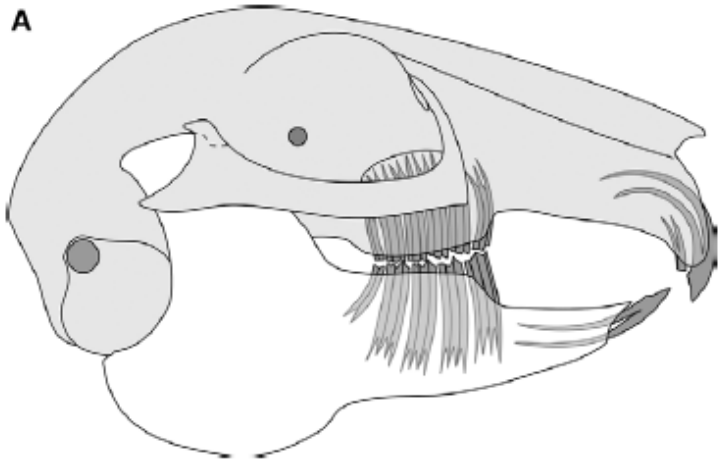
eine mechanische Herausforderung



Panzernashorn: Abrieb auf den vorderen Zähnen aufgrund der mahlenden Kaubewegung für die Backenzähne

Foto: Michelle Aimée Oesch

Lösung I: verschiedene Kieferstellungen

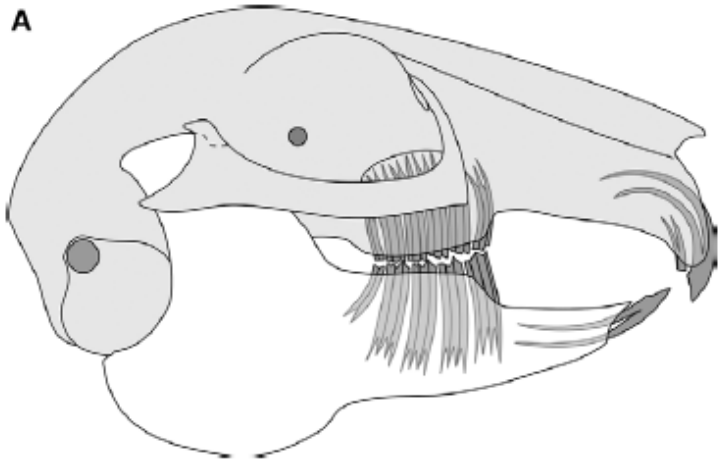


Kau-Position

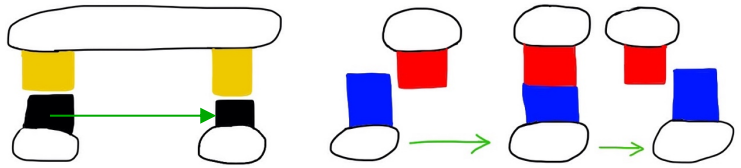
Crossley (2003)

Das Kiefergelenk erlaubt verschiedene Stellungen: beim Mahlkauen bewegen sich die Vorderzähne hintereinander vorbei

Lösung I: verschiedene Kieferstellungen



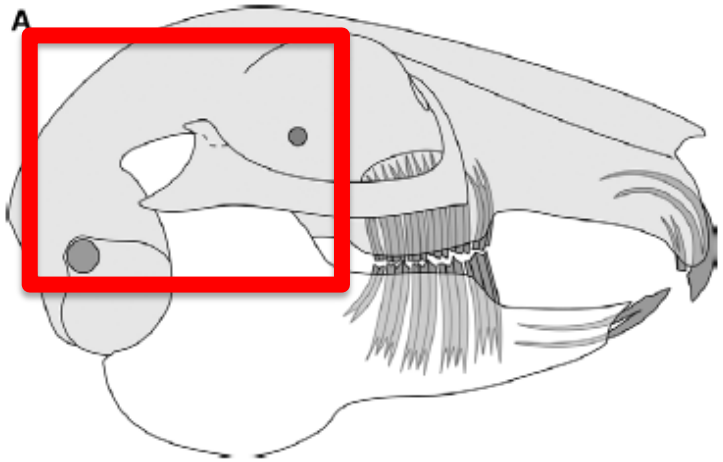
Kau-Position



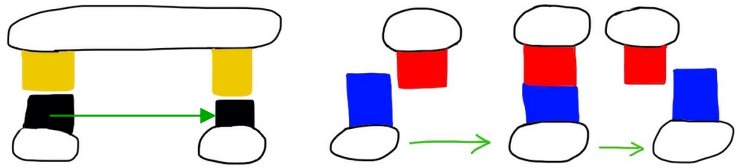
Crossley (2003)

Das Kiefergelenk erlaubt verschiedene Stellungen: beim Mahlkauen bewegen sich die Vorderzähne hintereinander vorbei

Lösung I: verschiedene Kieferstellungen



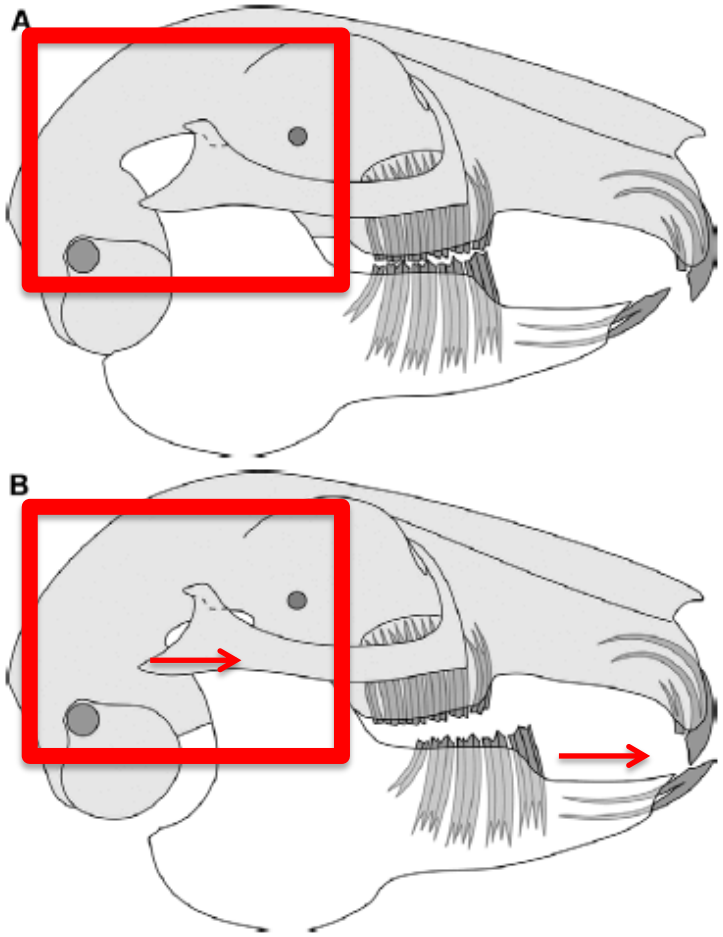
Kau-Position



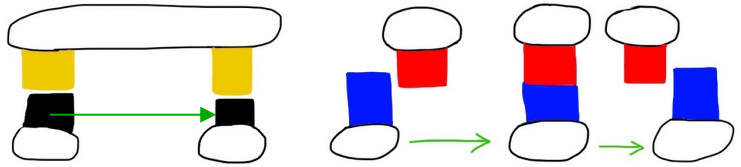
Crossley (2003)

Das Kiefergelenk erlaubt verschiedene Stellungen: beim Mahlkauen bewegen sich die Vorderzähne hintereinander vorbei

Lösung I: verschiedene Kieferstellungen



Kau-Position

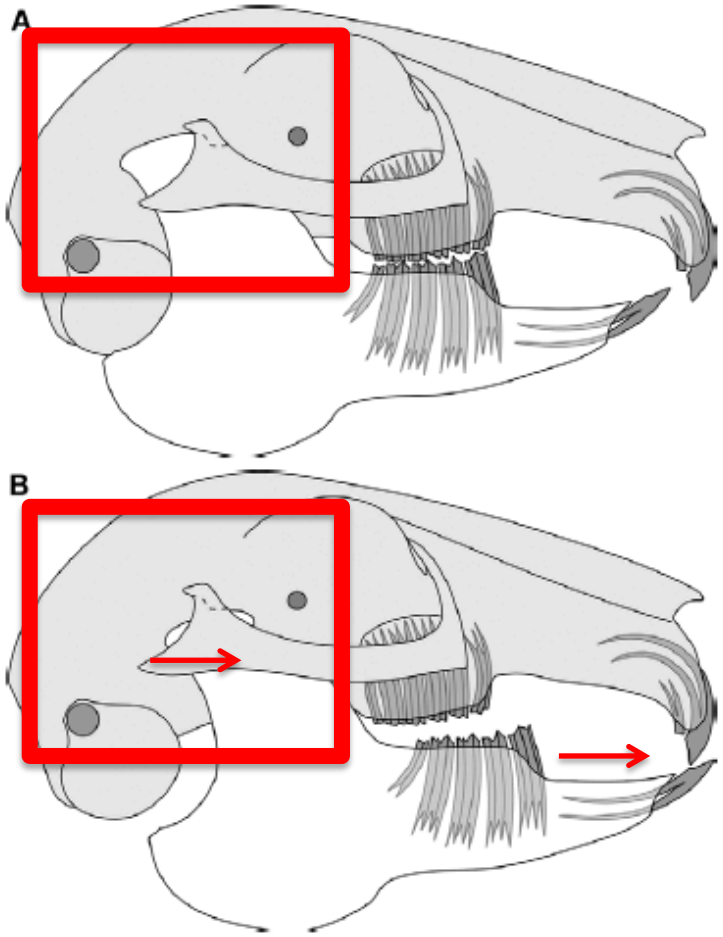


Nage-Position

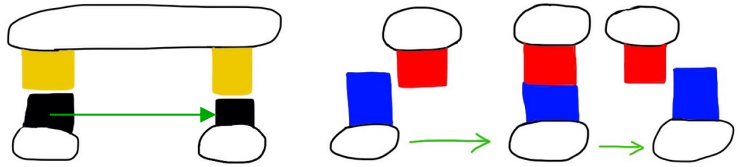
Crossley (2003)

Das Kiefergelenk erlaubt verschiedene Stellungen: beim Mahlkauen bewegen sich die Vorderzähne hintereinander vorbei

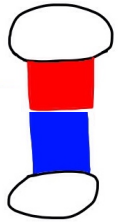
Lösung I: verschiedene Kieferstellungen



Kau-Position



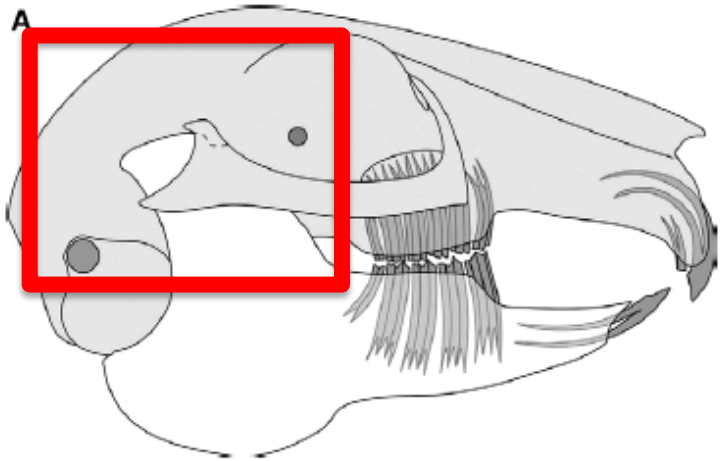
Nage-Position



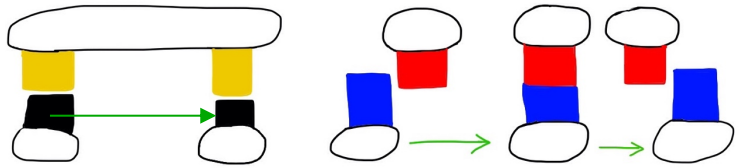
Crossley (2003)

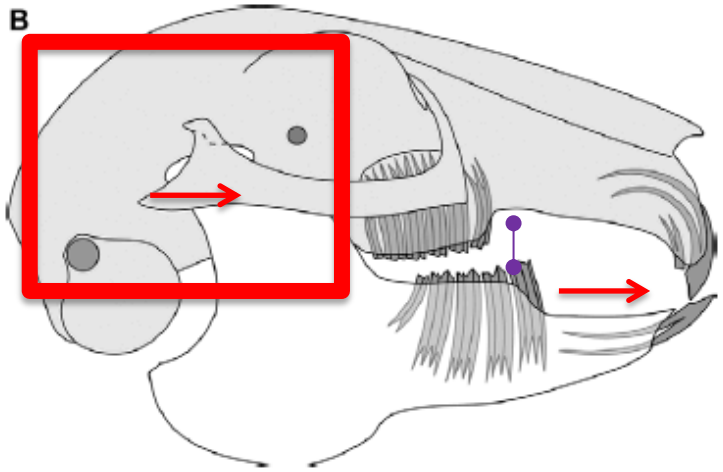
Das Kiefergelenk erlaubt verschiedene Stellungen: beim Mahlkauen bewegen sich die Vorderzähne hintereinander vorbei

Lösung I: verschiedene Kieferstellungen

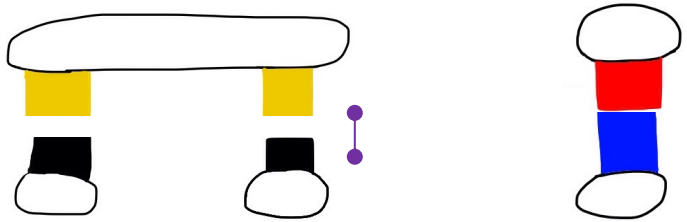


Kau-Position





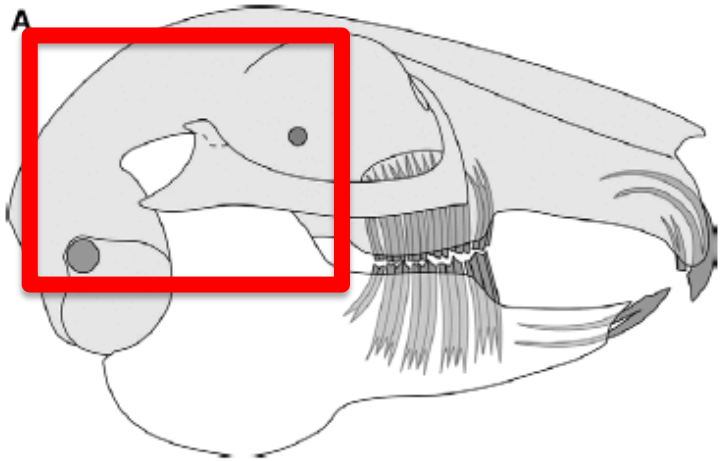
Nage-Position



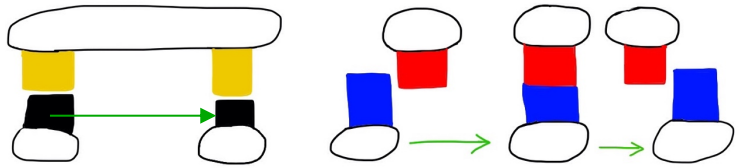
Crossley (2003)

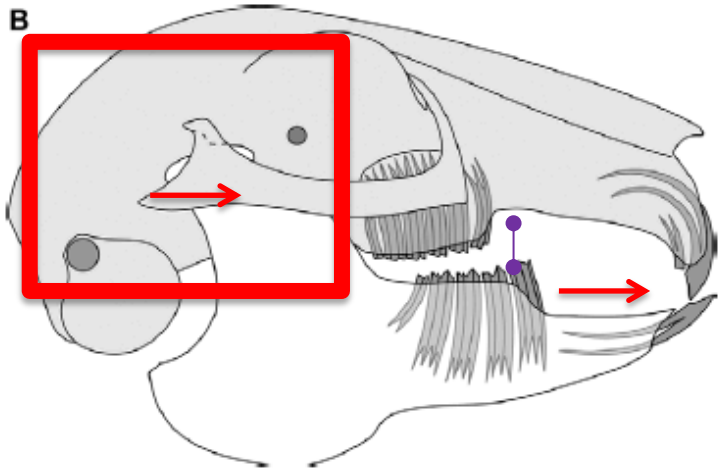
Das Kiefergelenk erlaubt verschiedene Stellungen: beim Mahlkauen bewegen sich die Vorderzähne hintereinander vorbei

Lösung I: verschiedene Kieferstellungen

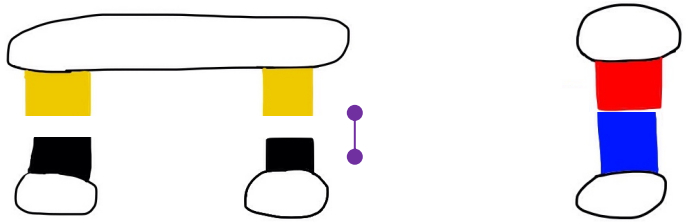


Kau-Position





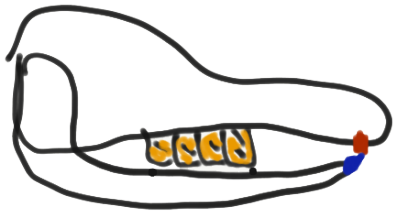
Nage-Position



Crossley (2003)

Das Kiefergelenk erlaubt verschiedene Stellungen: beim Mahlkauen bewegen sich die Vorderzähne hintereinander vorbei; zum Abbeissen wird der Unterkiefer vorgeschoben und beim Abbeissen berühren sich die Backenzähne nicht (z.B. Kaninchen, Menschen)

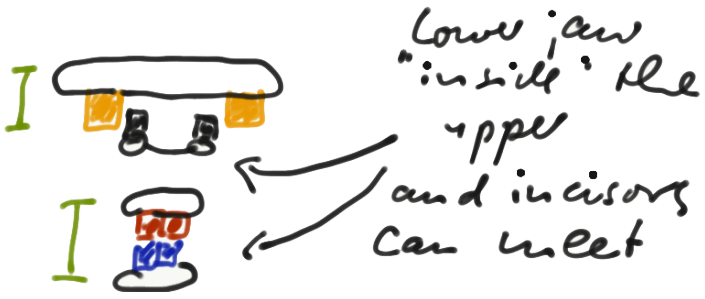
Lösung II: Backenzähne ‘verschachteln’

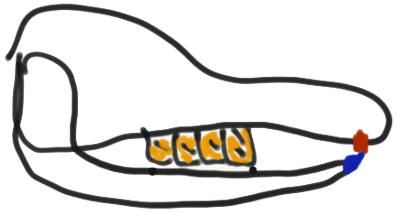


die oberen Backenzähne ‘überlappen’ die unteren

Die Backenzähne des Unterkiefers ruhen ‘innerhalb’ derer des Oberkiefers (bei sich treffenden Schneidezähnen) – durch enge Unterkiefer,

Lösung II: Backenzähne ‘verschachteln’

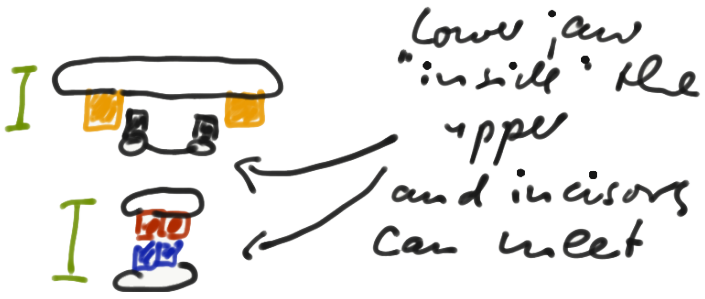


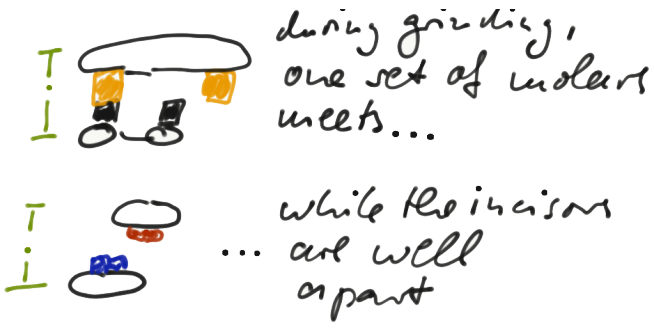


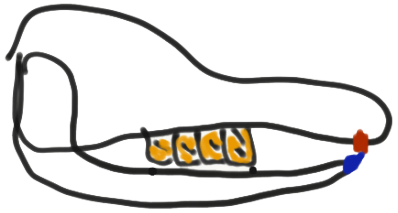
die oberen Backenzähne ‘überlappen’ die unteren

Die Backenzähne des Unterkiefers ruhen ‘innerhalb’ derer des Oberkiefers (bei sich treffenden Schneidezähnen) – durch enge Unterkiefer,

Lösung II: Backenzähne ‘verschachteln’



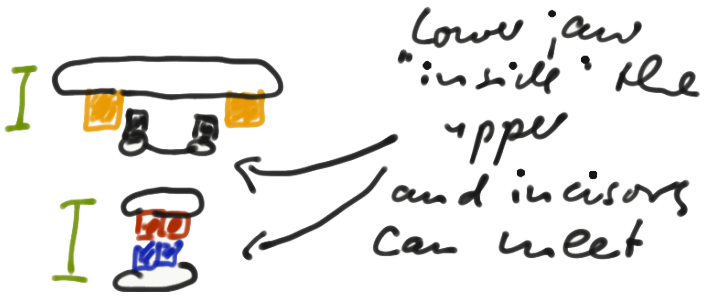


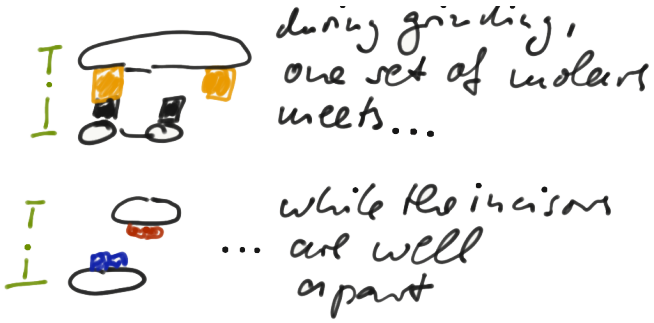


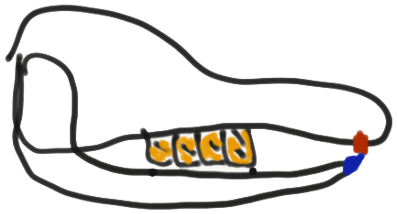
die oberen Backenzähne ‘überlappen’ die unteren

Die Backenzähne des Unterkiefers ruhen ‘innerhalb’ derer des Oberkiefers (bei sich treffenden Schneidezähnen) – durch enge Unterkiefer,

Lösung II: Backenzähne ‘verschachteln’



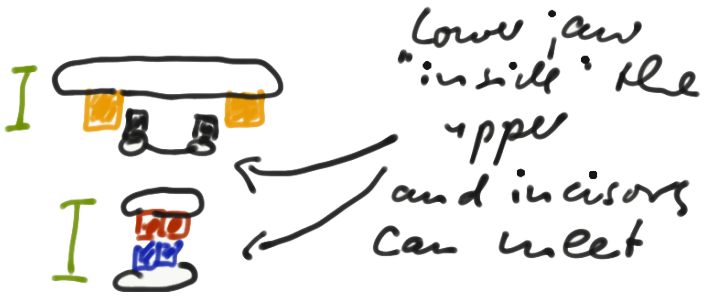


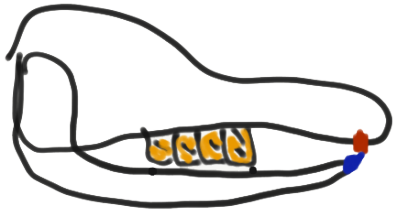


die oberen Backenzähne ‘überlappen’ die unteren

Die Backenzähne des Unterkiefers ruhen ‘innerhalb’ derer des Oberkiefers (bei sich treffenden Schneidezähnen) – durch enge Unterkiefer, schräge Okklusionsflächen oder beides – z.B. Pferde

Lösung II: Backenzähne ‘verschachteln’



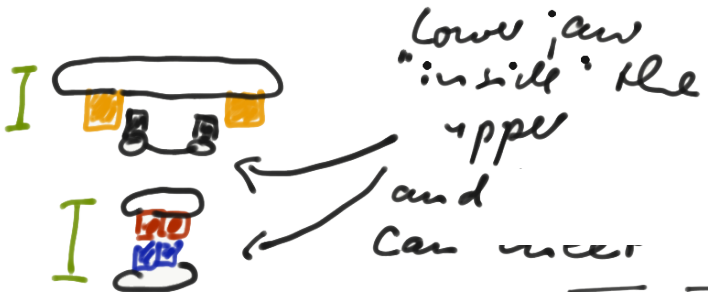


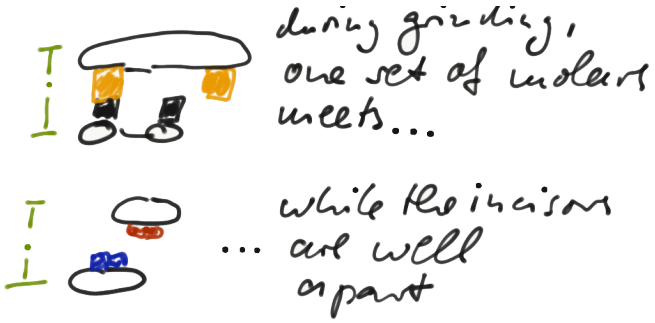
die oberen Backenzähne ‘überlappen’ die unteren

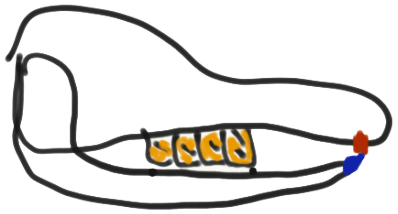

Foto: Michelle Aimée Oesch

Die Backenzähne des Unterkiefers ruhen ‘innerhalb’ derer des Oberkiefers (bei sich treffenden Schneidezähnen) – durch enge Unterkiefer, schräge Okklusionsflächen oder beides – z.B. Pferde

Lösung II: Backenzähne ‘verschachteln’







die oberen Backenzähne ‘überlappen’ die unteren

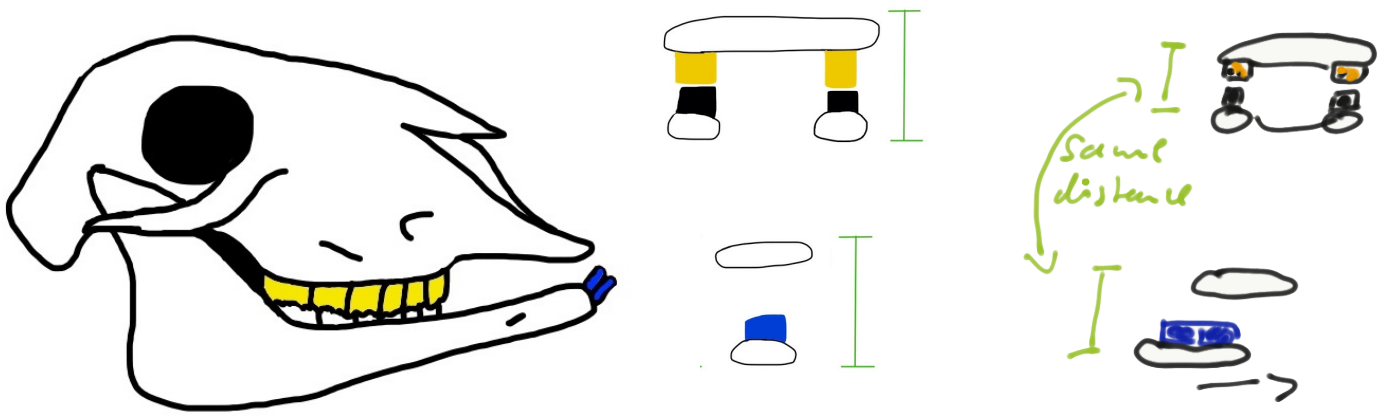
Die Backenzähne des Unterkiefers ruhen ‘innerhalb’ derer des Oberkiefers (bei sich treffenden Schneidezähnen) – durch enge Unterkiefer, schräge Okklusionsflächen oder beides – z.B. Pferde

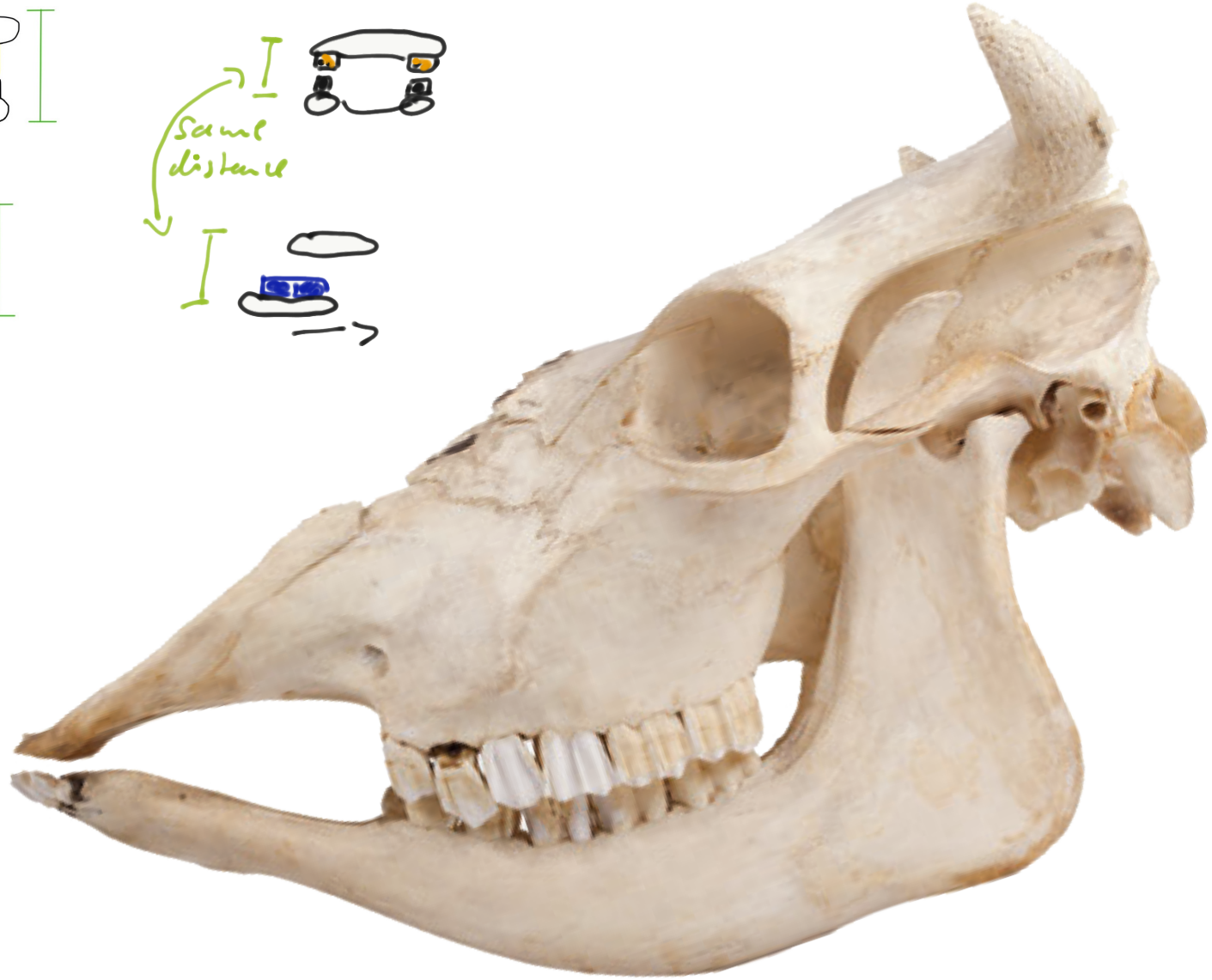
Lösung II: Backenzähne ‘verschachteln’

Lösung II: Backenzähne ‘verschachteln’

Foto: Michelle Aimée Oesch

Lösung III: Schneidezähne verlieren





Lösung III: Schneidezähne verlieren

Foto: Michelle Aimée Oesch

Lösung III: Schneidezähne verlieren

Foto: Michelle Aimée Oesch

Lösung III: Schneidezähne verlieren

Foto: Michelle Aimée Oesch

Zahnoptimierung III

mehr Verschleissmaterial: höhere Kronen

Wodurch werden Zähne abgerieben ?

- ~~‘Härte’ der Nahrung (typische Vorstellung: Zweige, trockenes Brot)~~

- Abrasiva in/auf der Nahrung

- Zahn-Zahn-Kontakt => Kauen !

Wodurch werden Zähne abgerieben ?

- ~~‘Härte’ der Nahrung (typische Vorstellung: Zweige, trockenes Brot)~~

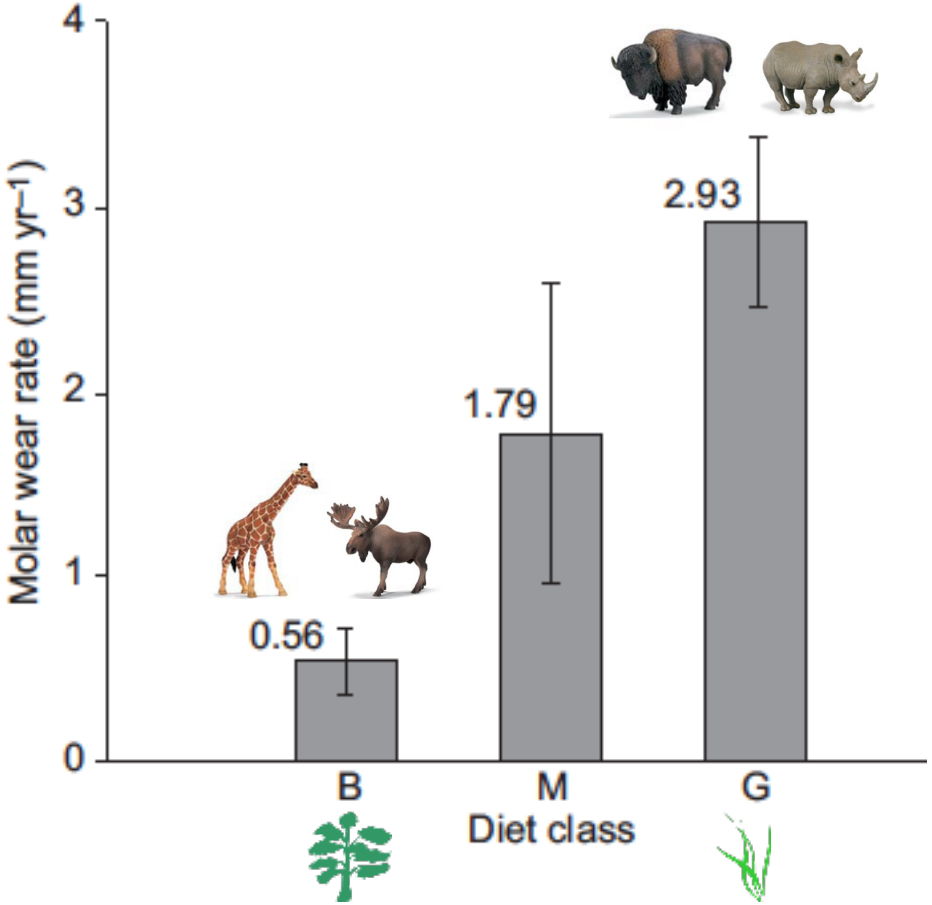
- Abrasiva in/auf der Nahrung

- Zahn-Zahn-Kontakt => Kauen !

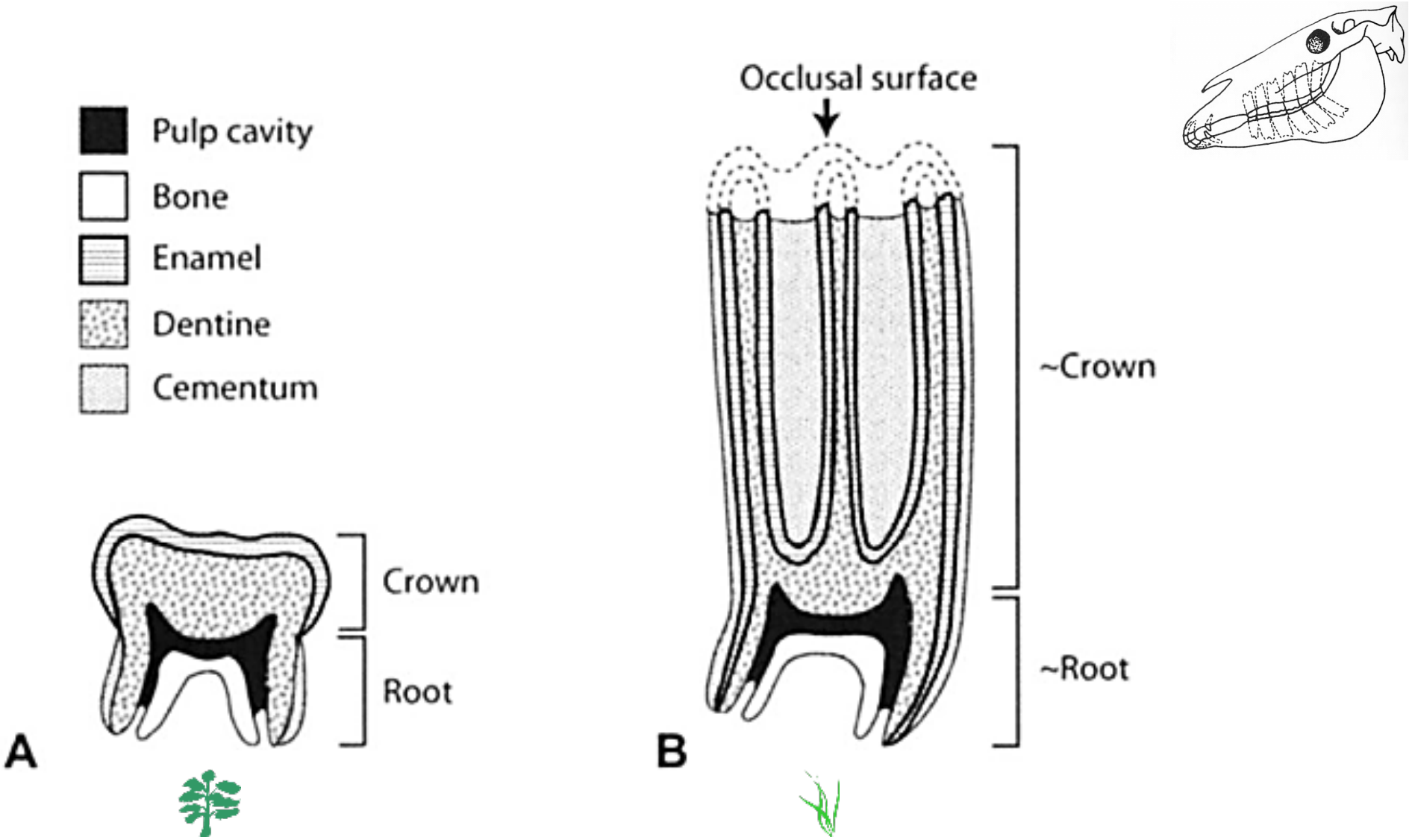
A comparison of observed molar wear rates in extant herbivorous mammals

John Damuth[1] & Christine M. Janis[2]

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



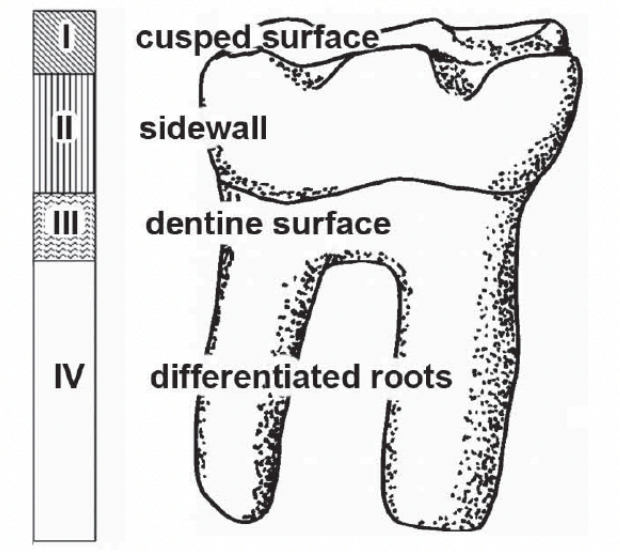
Hochkronigkeit – ‘Hypsodontie’

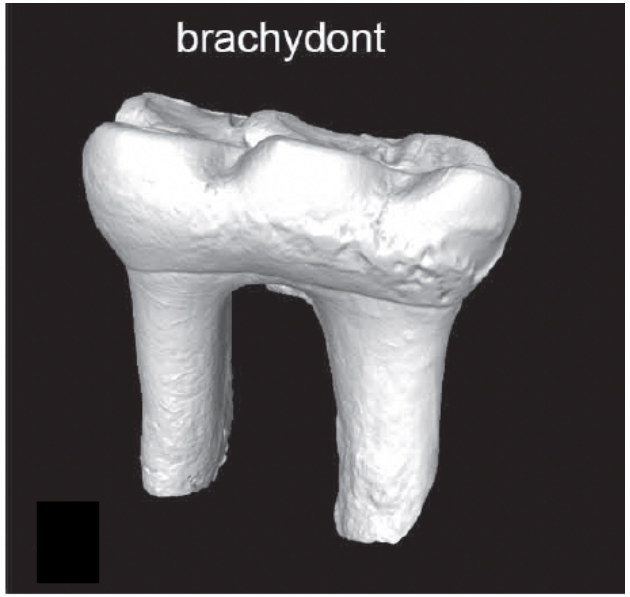


Hochkronigkeit – ‘Hypsodontie’

Hummel et al. (2020)

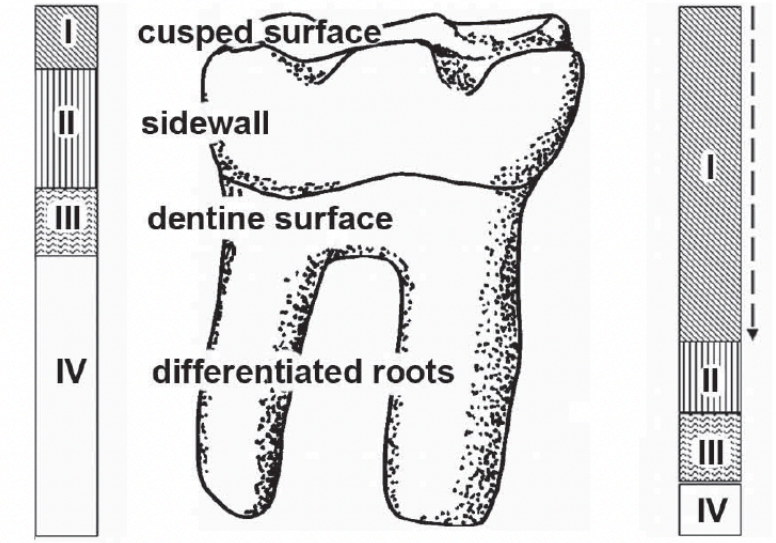
Hochkronigkeit – ‘Hypsodontie’





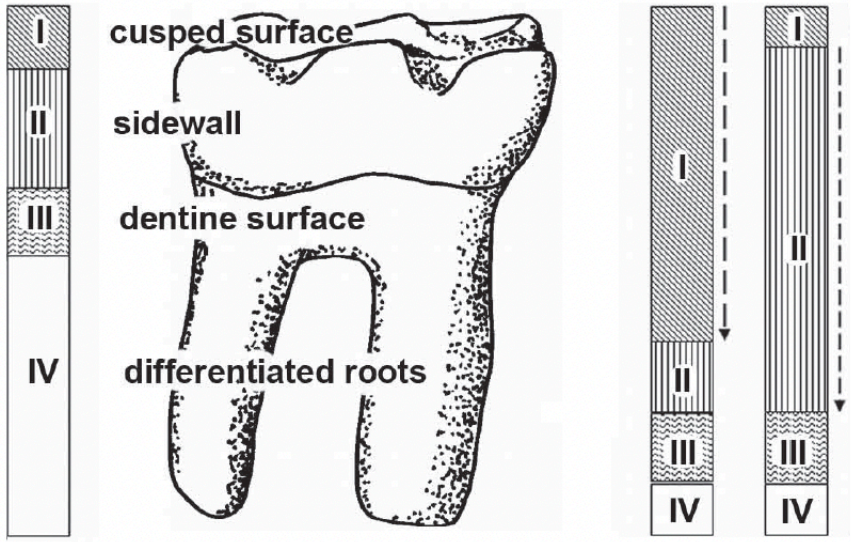
von Königswald (2011)

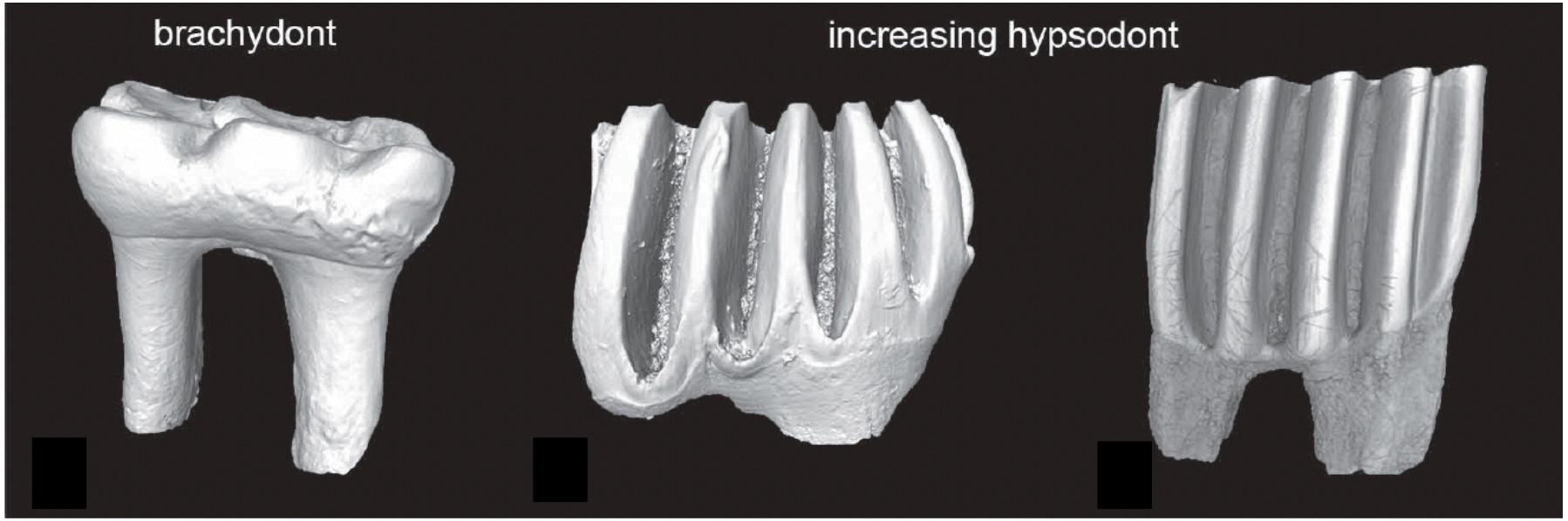
Hochkronigkeit – ‘Hypsodontie’



von Königswald (2011)

Hochkronigkeit – ‘Hypsodontie’





von Königswald (2011)

Continuously Growing Rodent Molars Result from a Predictable Quantitative Evolutionary Change over 50 Million Years

Cell Reports *11*, 673–680, May 5, 2015

Vagan Tapaltsyan,[1,8] Jussi T. Eronen,[2,3,8] A. Michelle Lawing,[4] Amnon Sharir,[1] Christine Janis,[5] Jukka Jernvall,[6,*] and Ophir D. Klein[1,7,*]

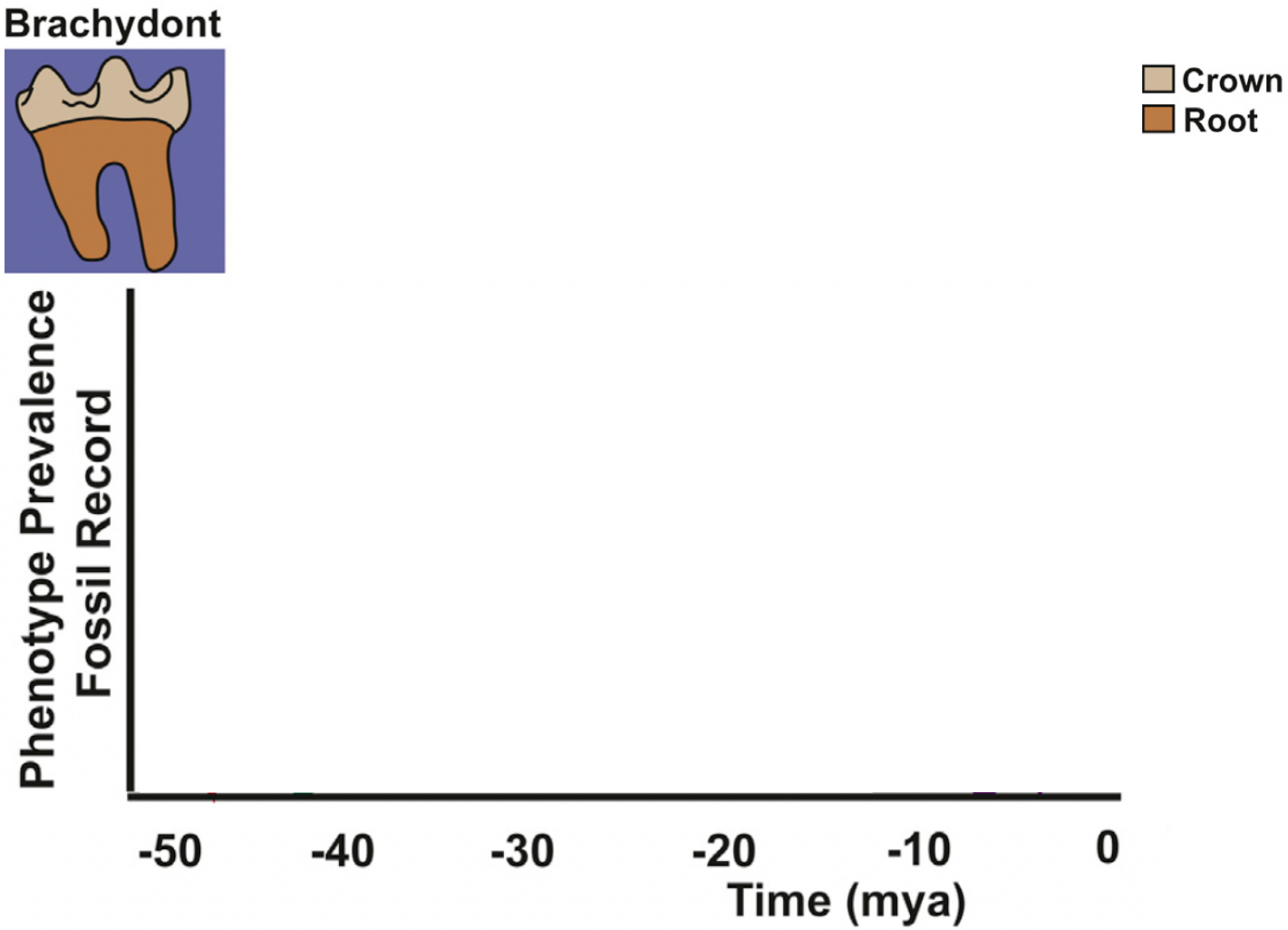
Brachydont

Crown
Root

Continuously Growing Rodent Molars Result from a Predictable Quantitative Evolutionary Change over 50 Million Years

Cell Reports *11*, 673–680, May 5, 2015

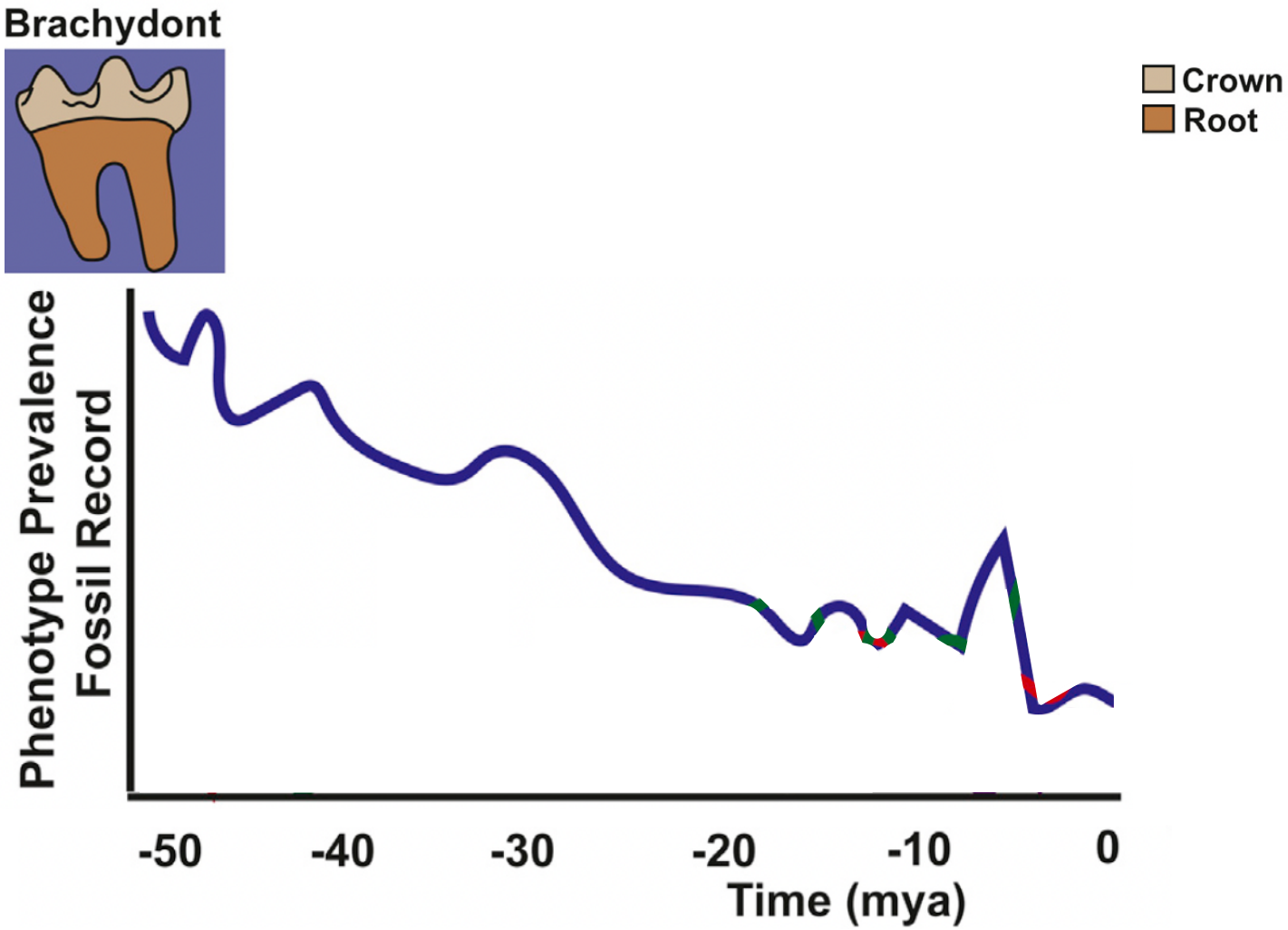
Vagan Tapaltsyan,[1,8] Jussi T. Eronen,[2,3,8] A. Michelle Lawing,[4] Amnon Sharir,[1] Christine Janis,[5] Jukka Jernvall,[6,*] and Ophir D. Klein[1,7,*]



Continuously Growing Rodent Molars Result from a Predictable Quantitative Evolutionary Change over 50 Million Years

Cell Reports *11*, 673–680, May 5, 2015

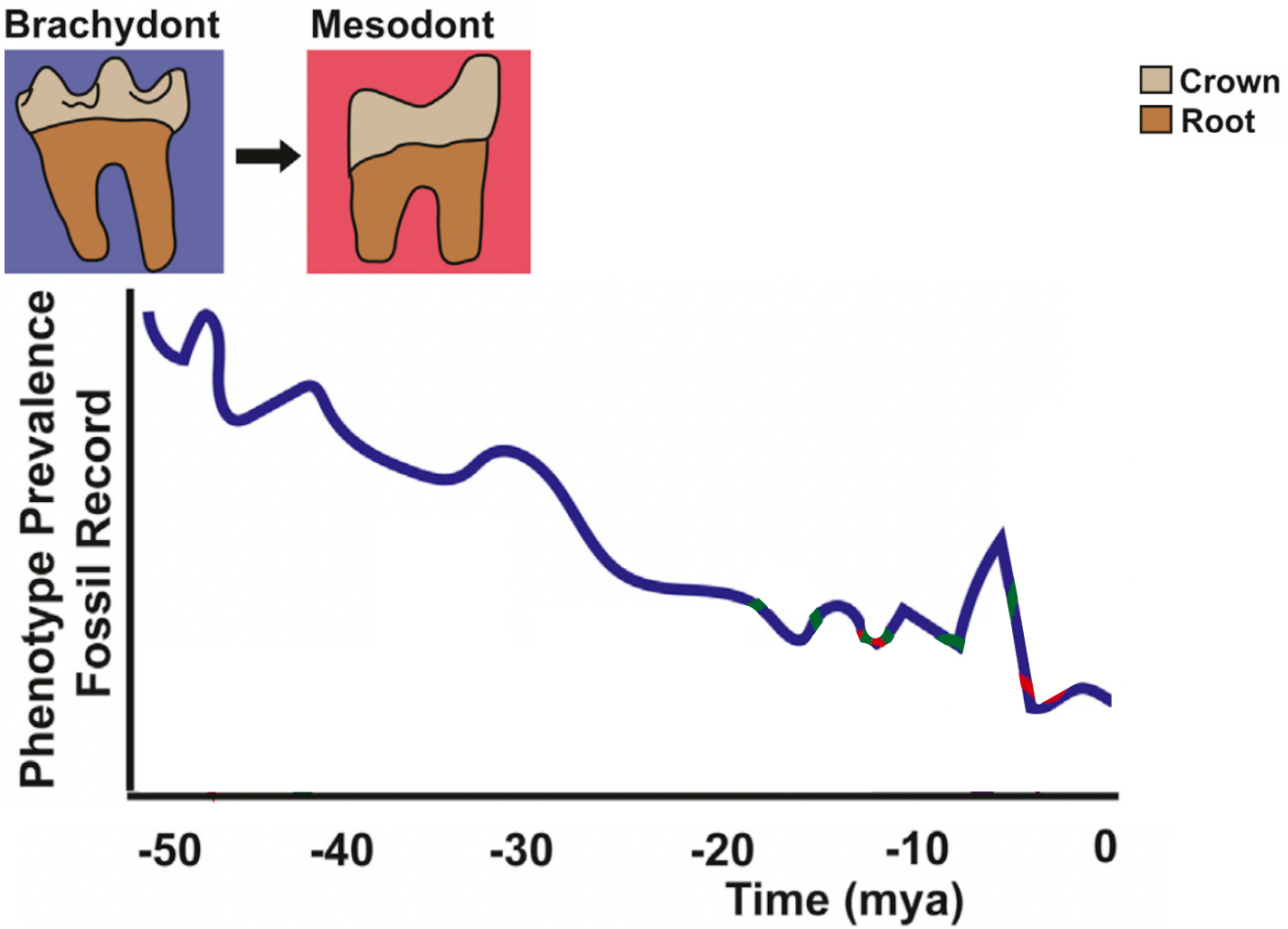
Vagan Tapaltsyan,[1,8] Jussi T. Eronen,[2,3,8] A. Michelle Lawing,[4] Amnon Sharir,[1] Christine Janis,[5] Jukka Jernvall,[6,*] and Ophir D. Klein[1,7,*]

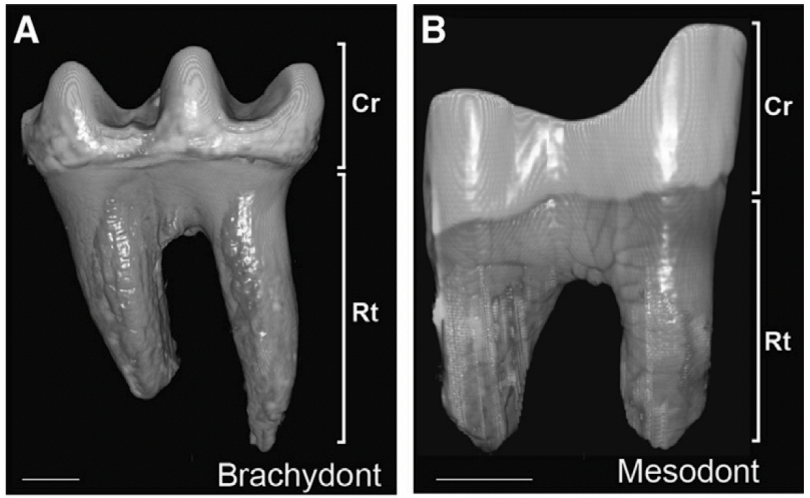


Continuously Growing Rodent Molars Result from a Predictable Quantitative Evolutionary Change over 50 Million Years

Cell Reports *11*, 673–680, May 5, 2015

Vagan Tapaltsyan,[1,8] Jussi T. Eronen,[2,3,8] A. Michelle Lawing,[4] Amnon Sharir,[1] Christine Janis,[5] Jukka Jernvall,[6,*] and Ophir D. Klein[1,7,*]

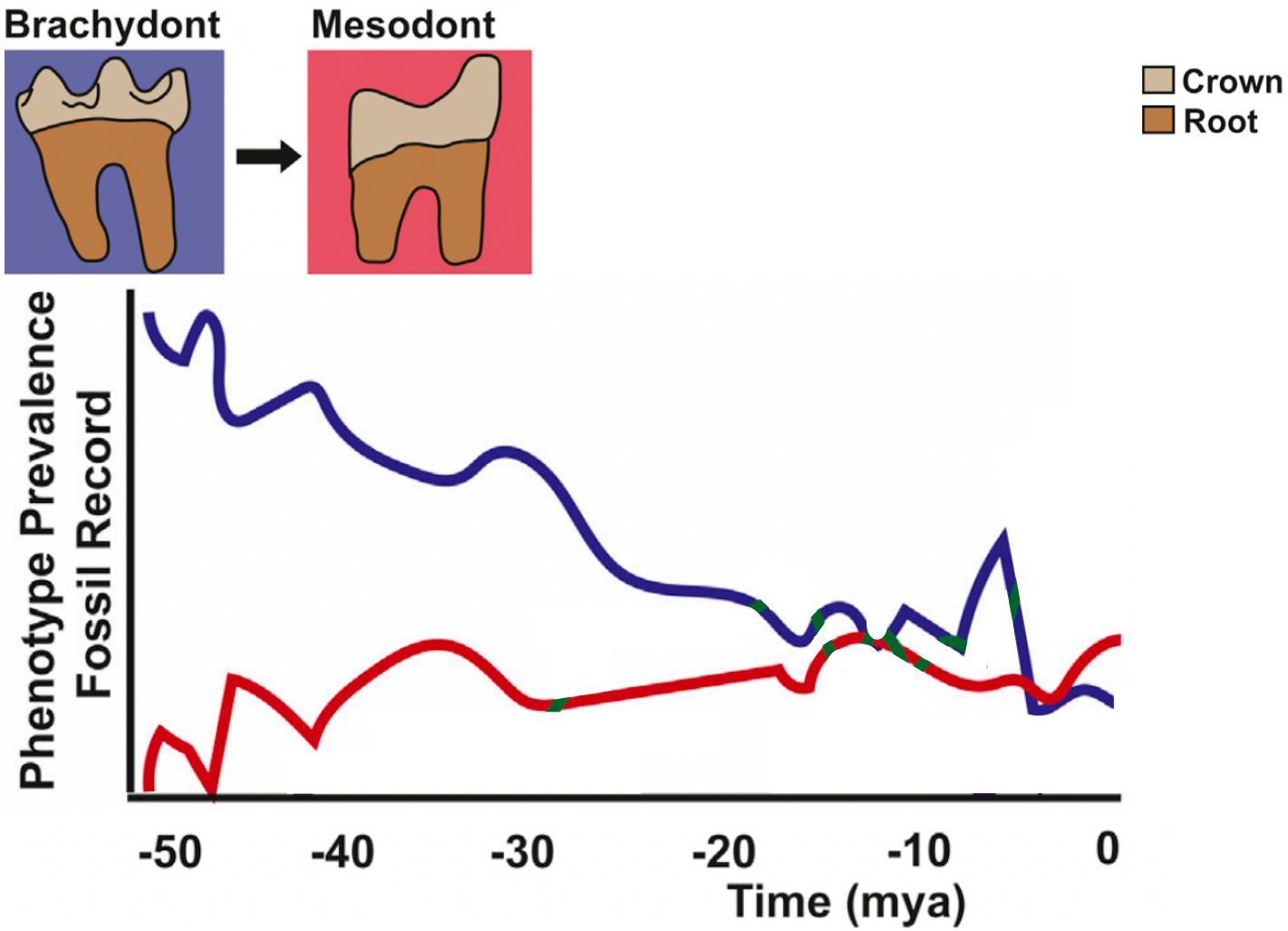


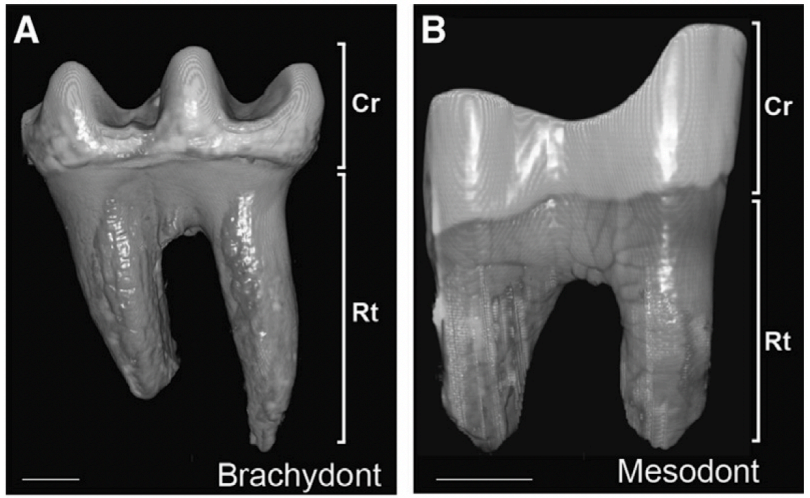


Continuously Growing Rodent Molars Result from a Predictable Quantitative Evolutionary Change over 50 Million Years

Cell Reports *11*, 673–680, May 5, 2015

Vagan Tapaltsyan,[1,8] Jussi T. Eronen,[2,3,8] A. Michelle Lawing,[4] Amnon Sharir,[1] Christine Janis,[5] Jukka Jernvall,[6,*] and Ophir D. Klein[1,7,*]

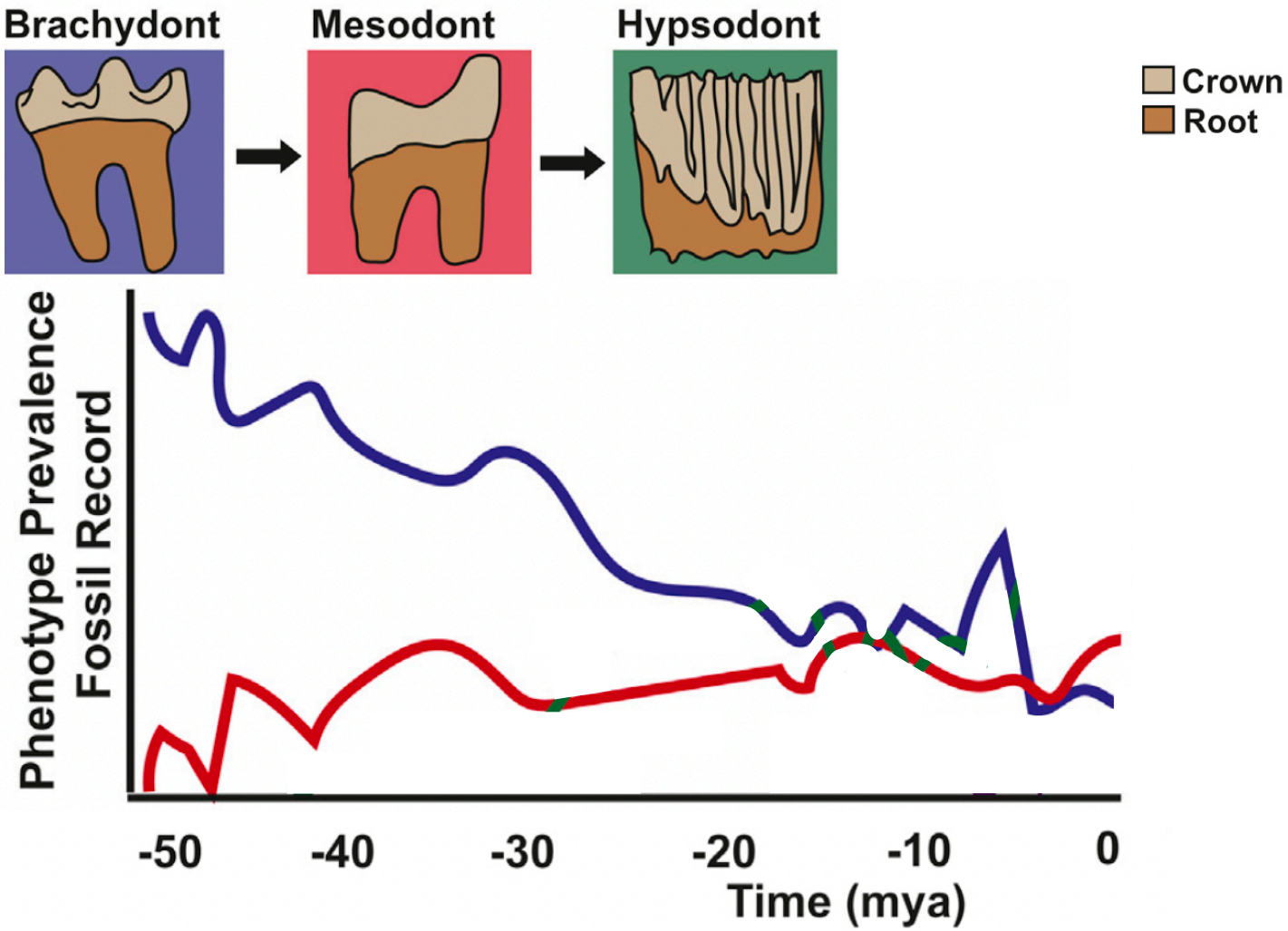


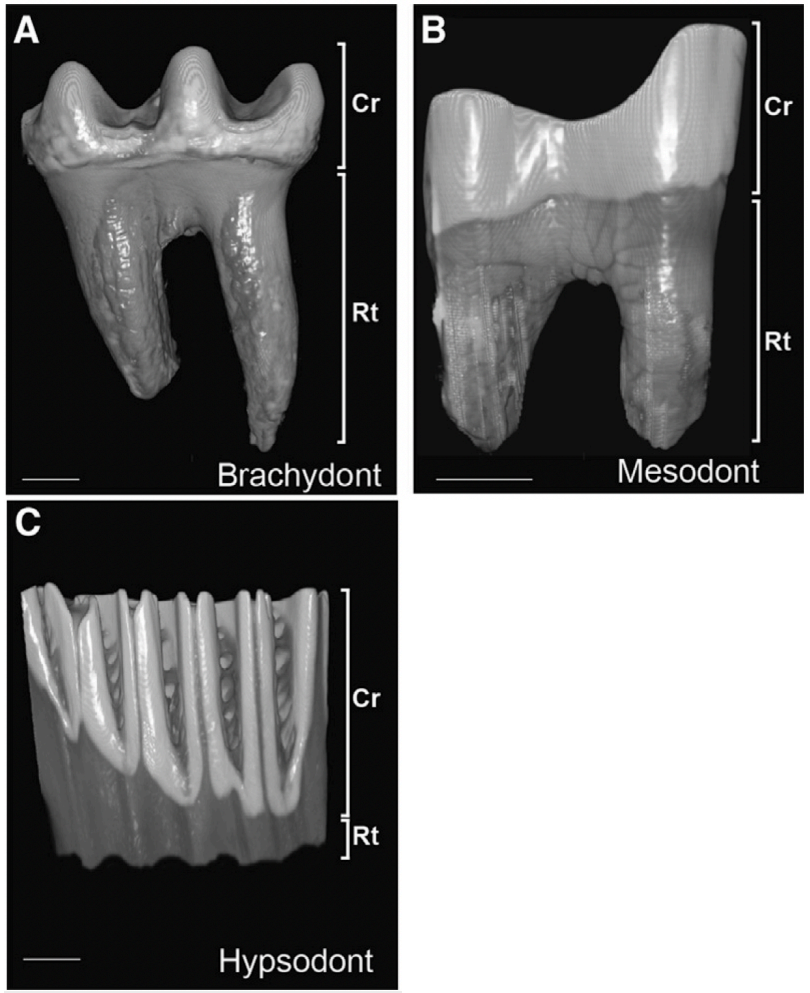


Continuously Growing Rodent Molars Result from a Predictable Quantitative Evolutionary Change over 50 Million Years

Cell Reports *11*, 673–680, May 5, 2015

Vagan Tapaltsyan,[1,8] Jussi T. Eronen,[2,3,8] A. Michelle Lawing,[4] Amnon Sharir,[1] Christine Janis,[5] Jukka Jernvall,[6,*] and Ophir D. Klein[1,7,*]

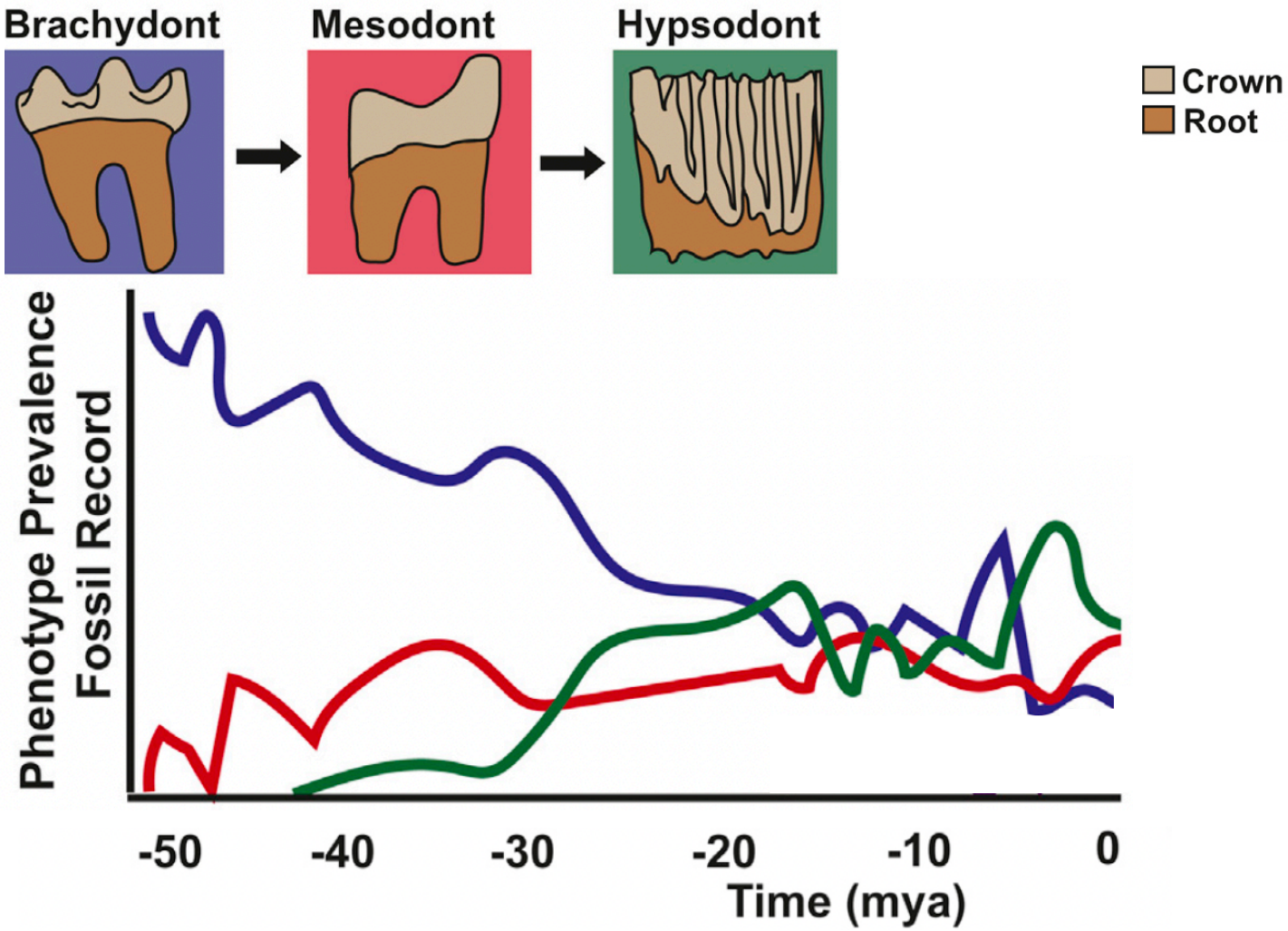


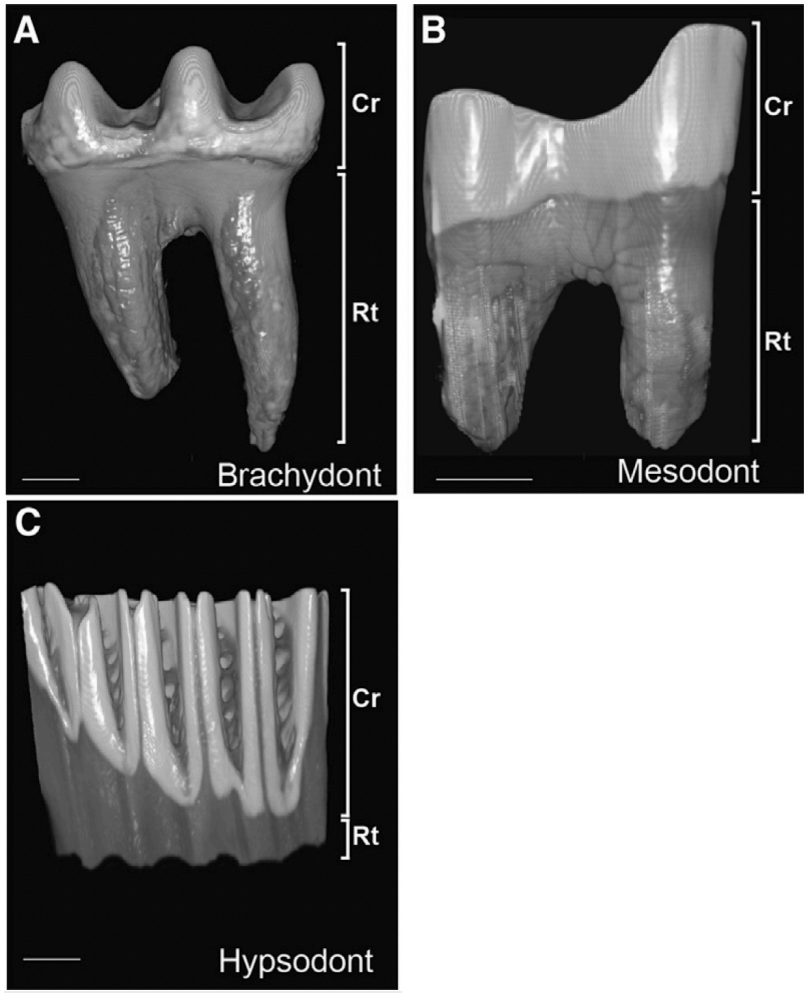


Continuously Growing Rodent Molars Result from a Predictable Quantitative Evolutionary Change over 50 Million Years

Cell Reports *11*, 673–680, May 5, 2015

Vagan Tapaltsyan,[1,8] Jussi T. Eronen,[2,3,8] A. Michelle Lawing,[4] Amnon Sharir,[1] Christine Janis,[5] Jukka Jernvall,[6,*] and Ophir D. Klein[1,7,*]

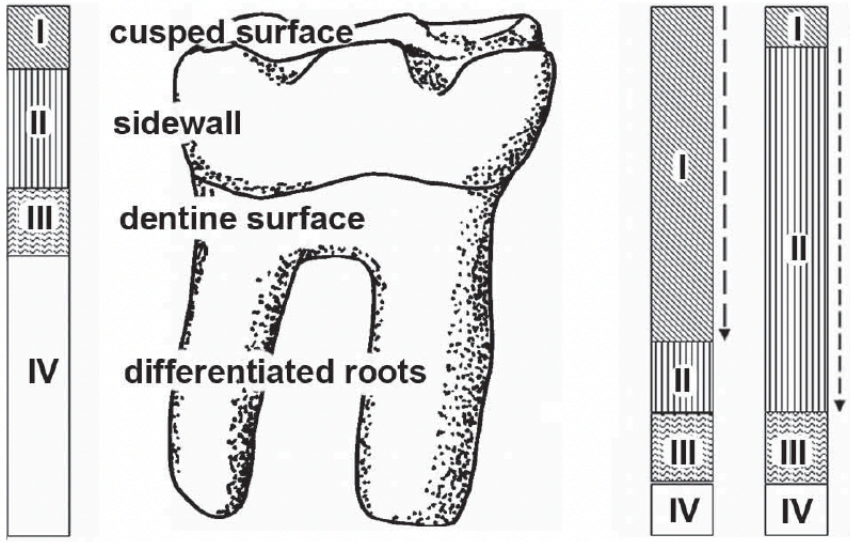


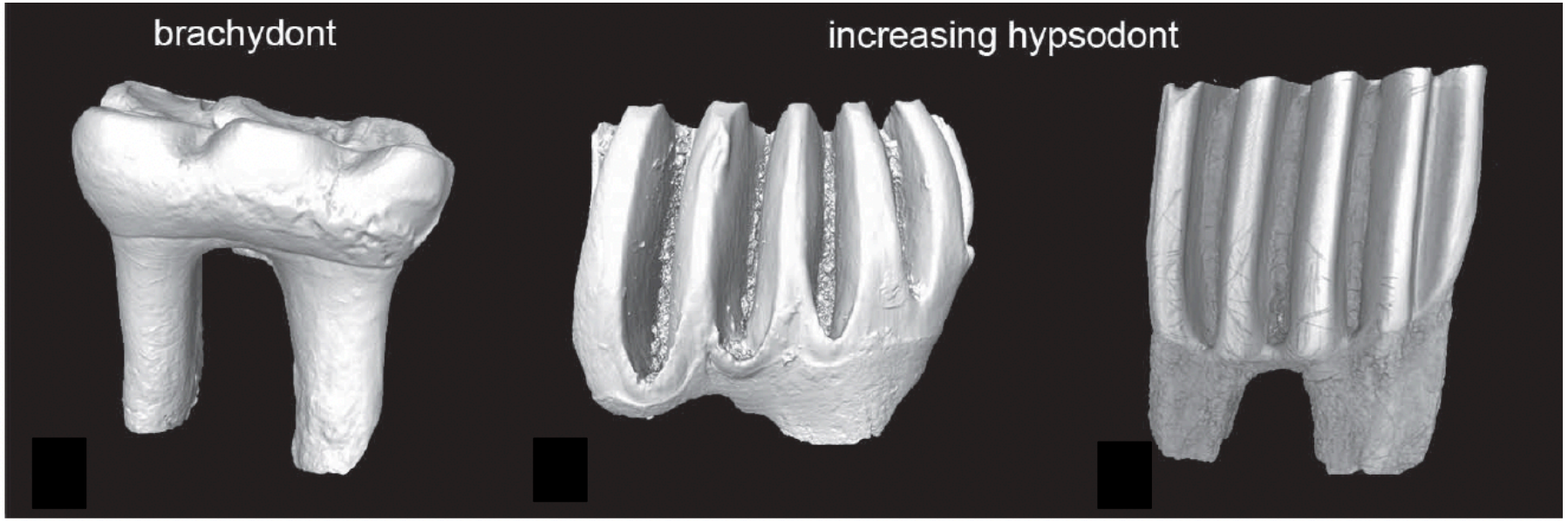


Zahnoptimierung IV

immer wachsende Zähne

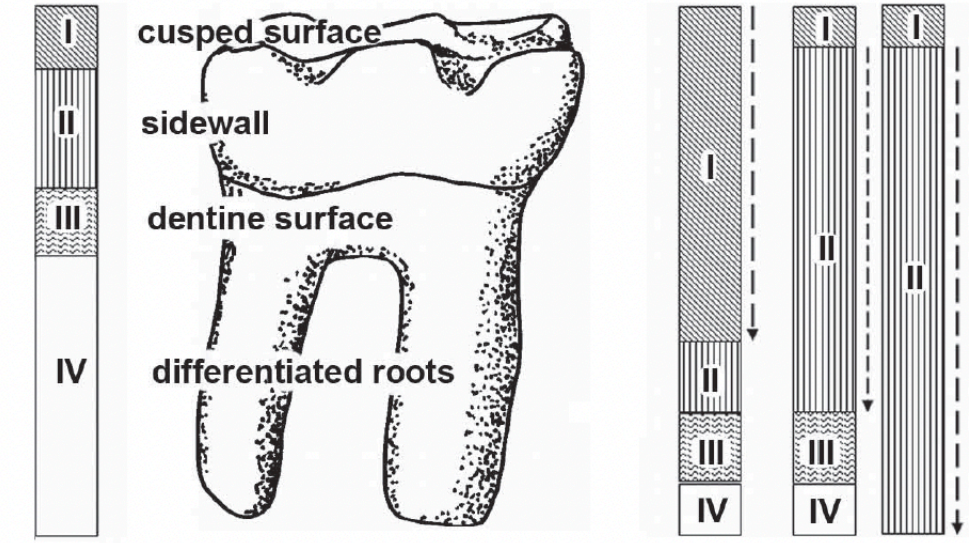
Hochkronigkeit – ‘Hypsodontie’

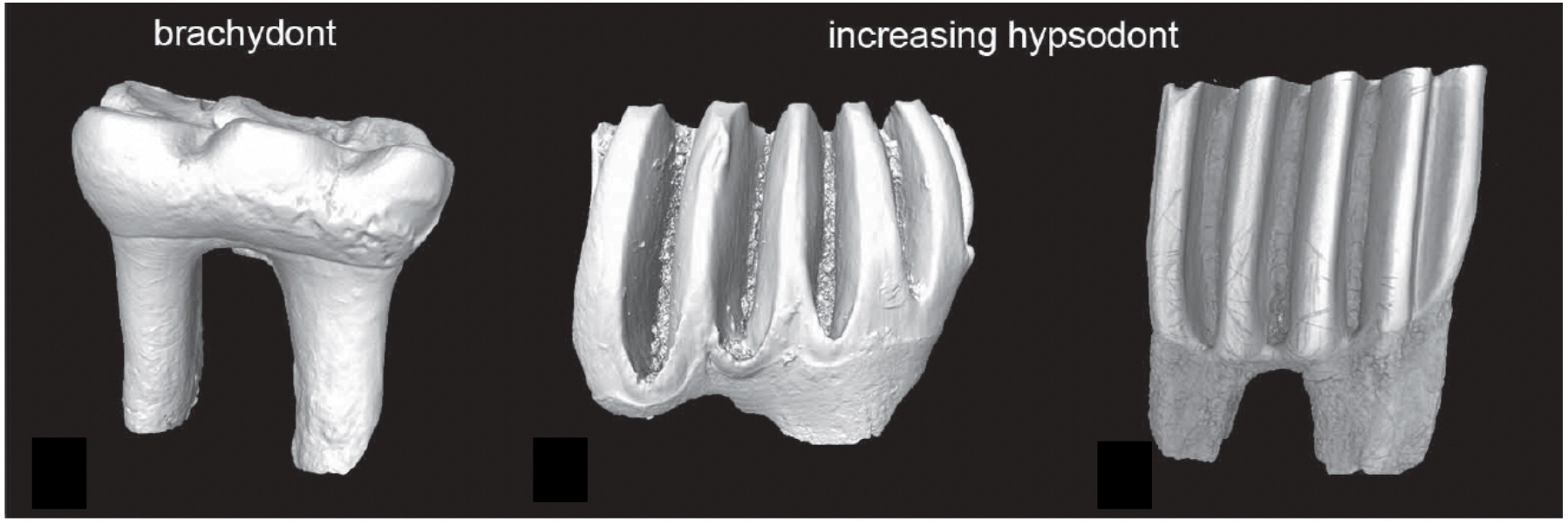




von Königswald (2011)

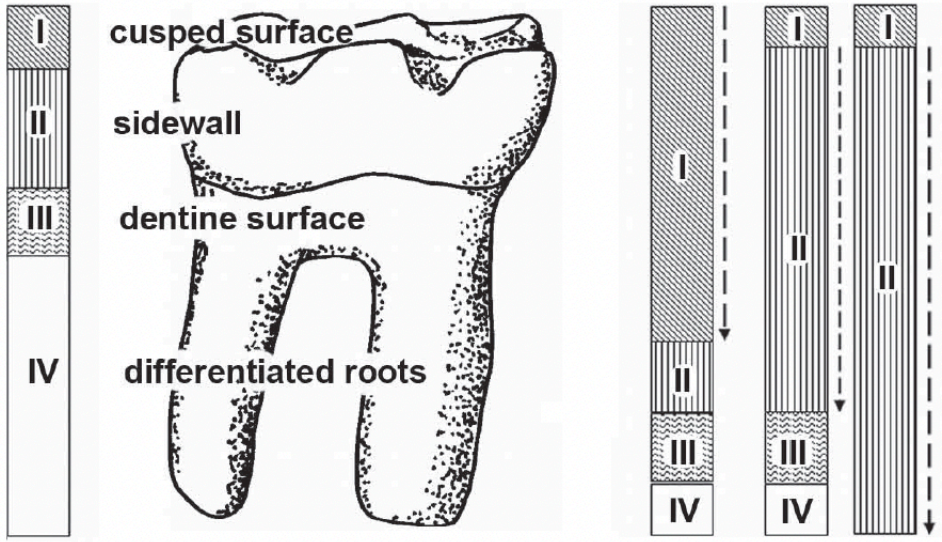
immerwachsende Zähne – ‘Euhypsodontie’

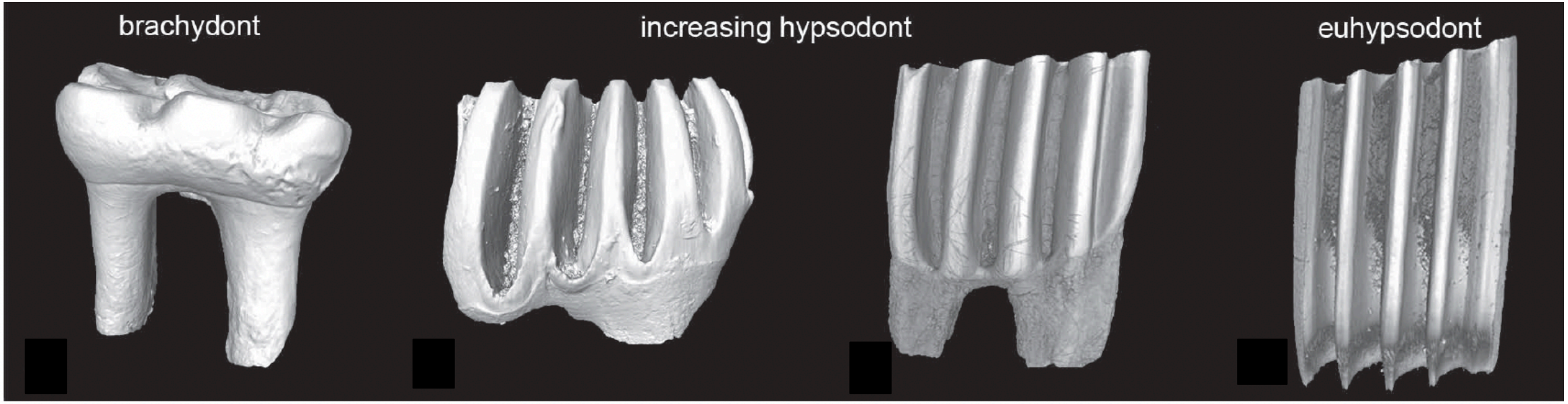




von Königswald (2011)

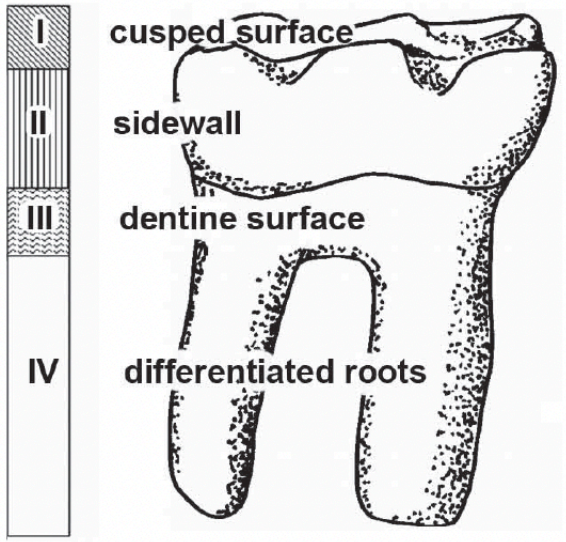
immerwachsende Zähne – ‘Euhypsodontie’

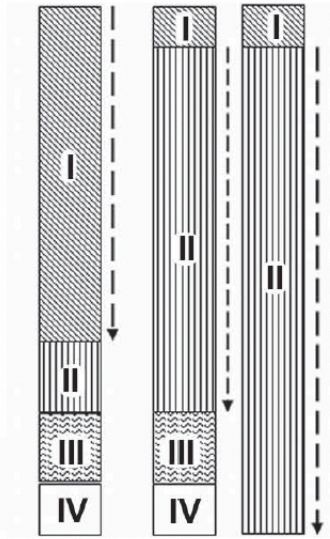


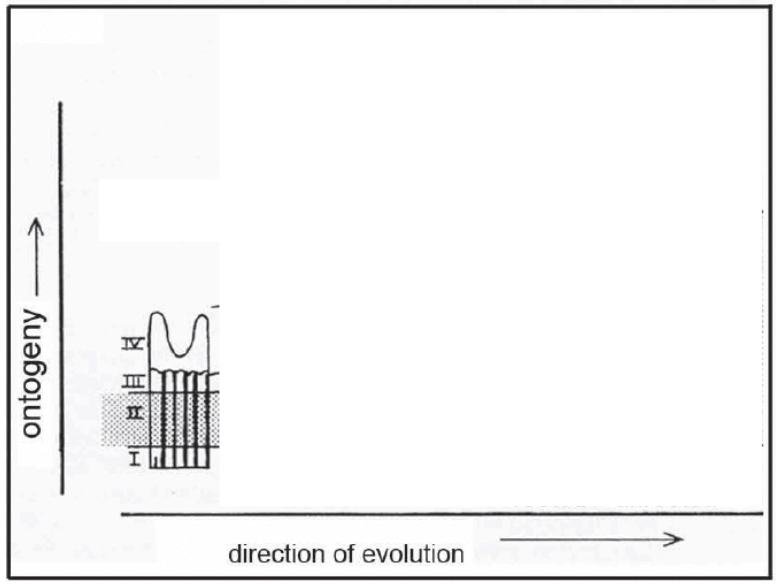


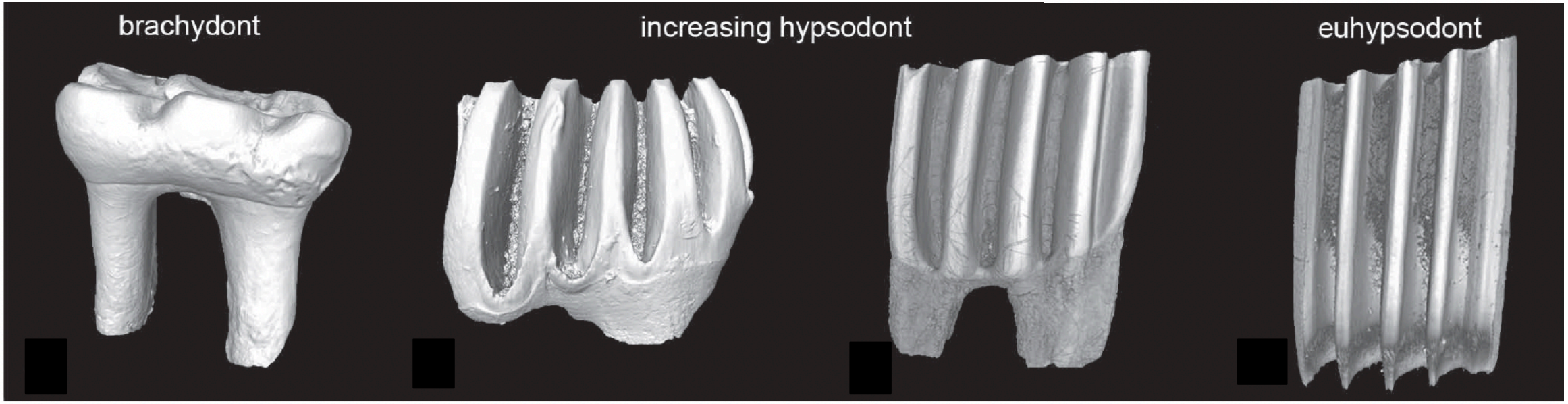
von Königswald (2011)

immerwachsende Zähne – ‘Euhypsodontie’



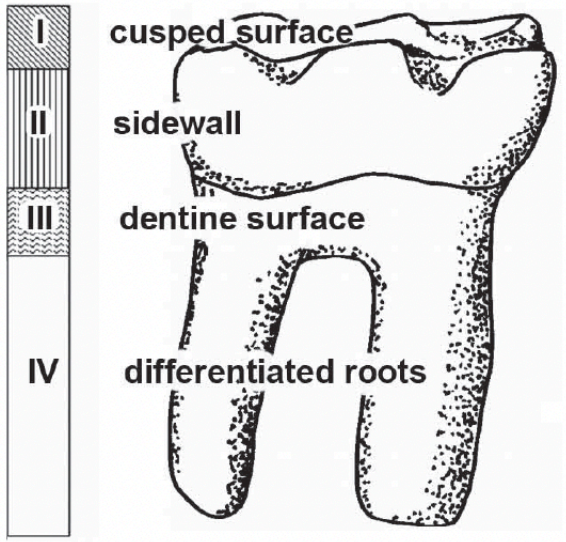


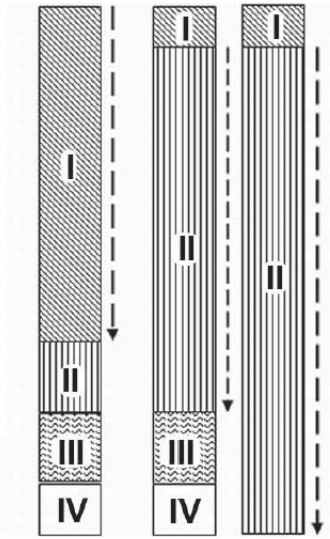


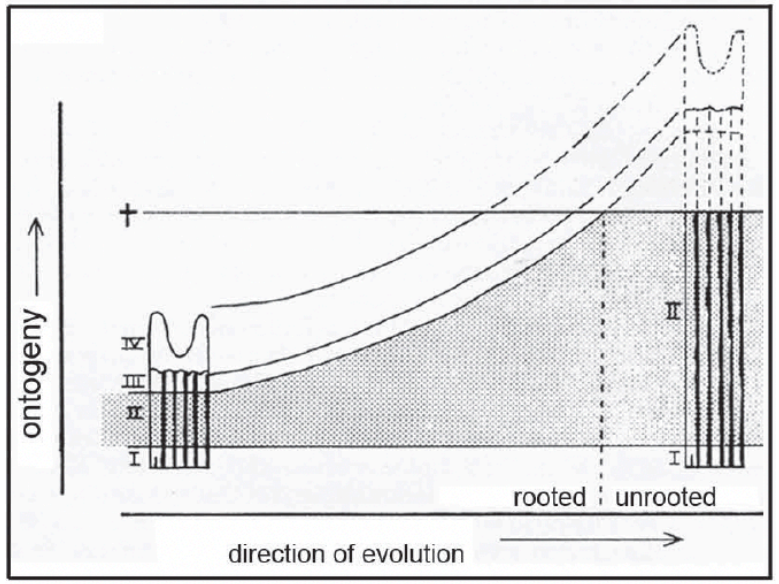


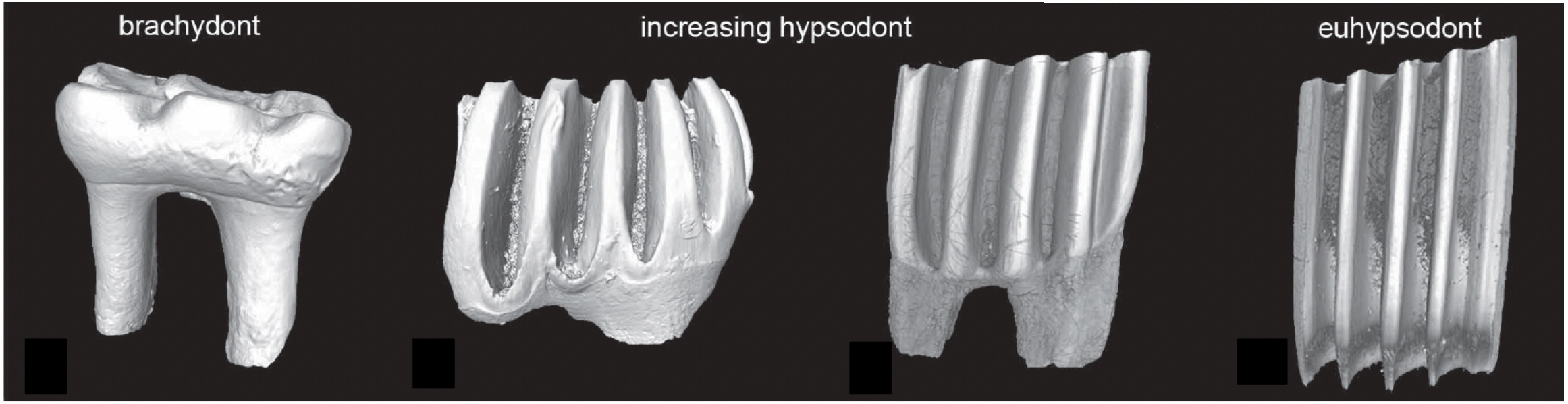
von Königswald (2011)

immerwachsende Zähne – ‘Euhypsodontie’







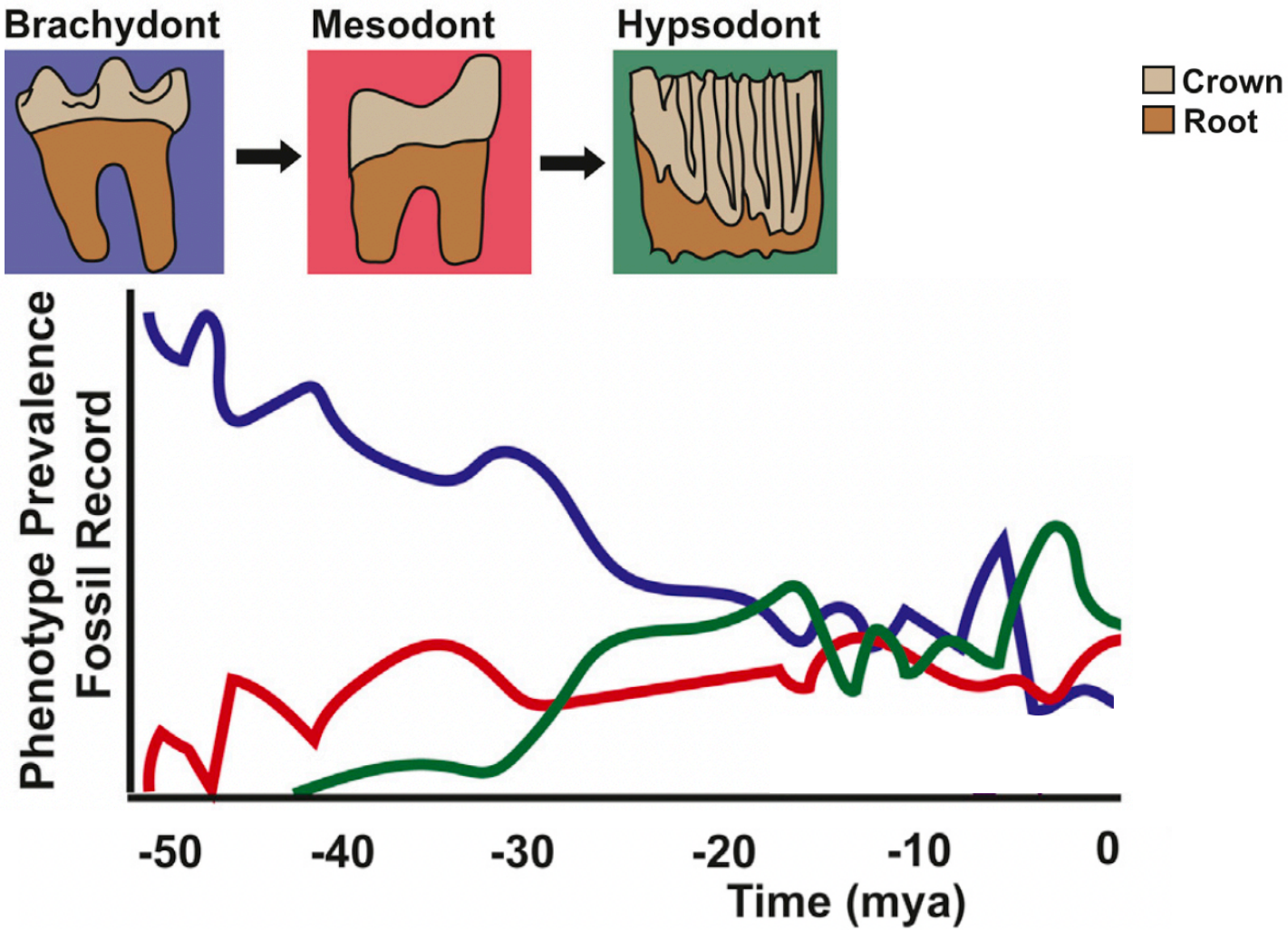


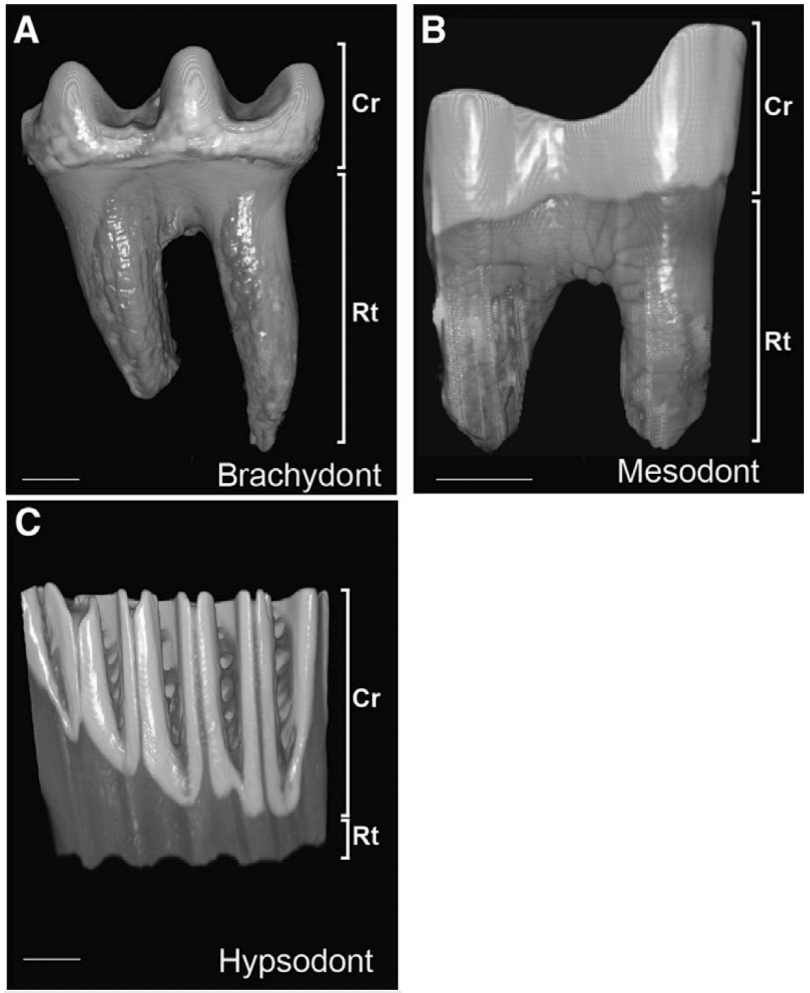
von Königswald (2011)

Continuously Growing Rodent Molars Result from a Predictable Quantitative Evolutionary Change over 50 Million Years

Cell Reports *11*, 673–680, May 5, 2015

Vagan Tapaltsyan,[1,8] Jussi T. Eronen,[2,3,8] A. Michelle Lawing,[4] Amnon Sharir,[1] Christine Janis,[5] Jukka Jernvall,[6,*] and Ophir D. Klein[1,7,*]

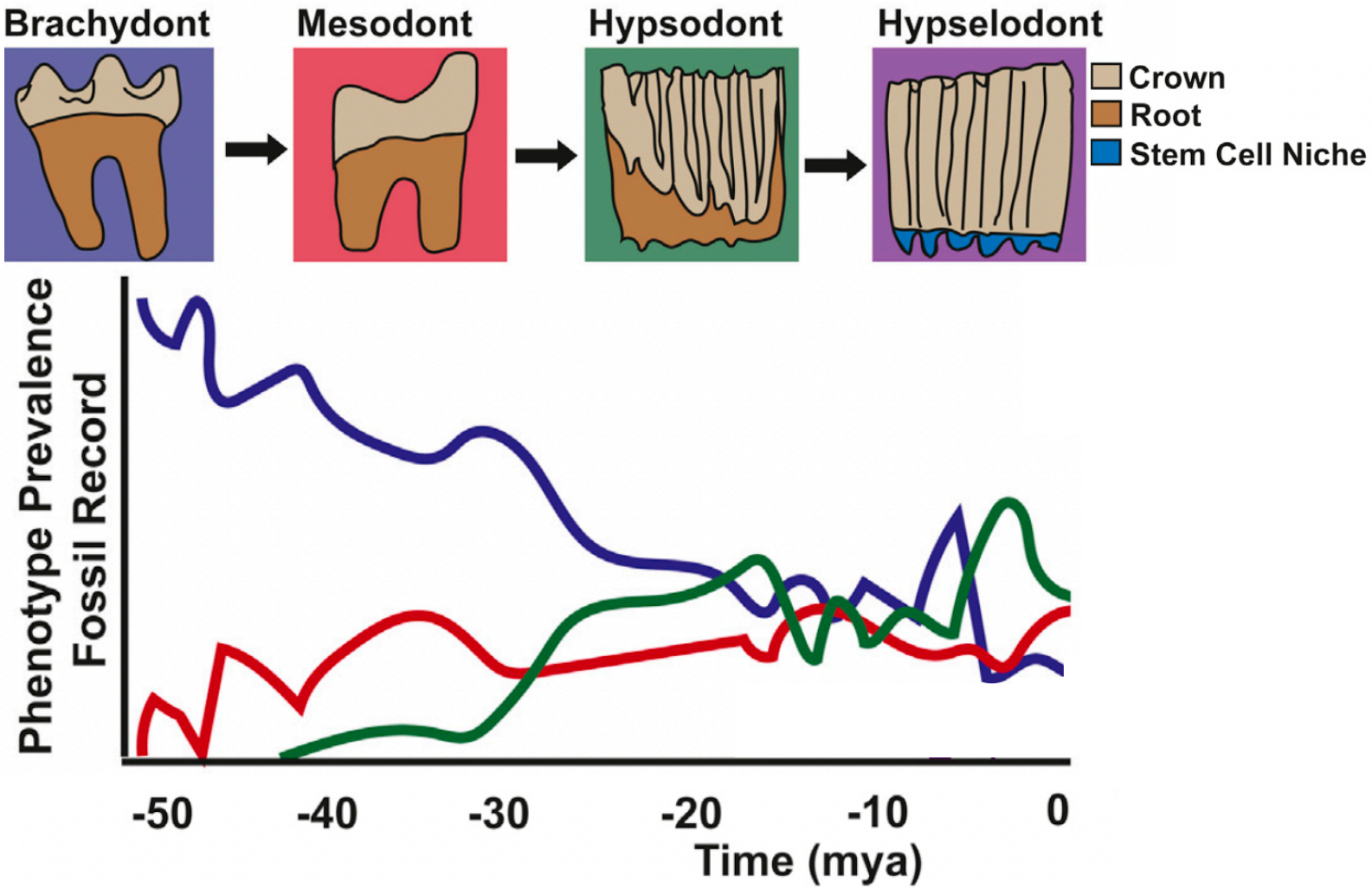


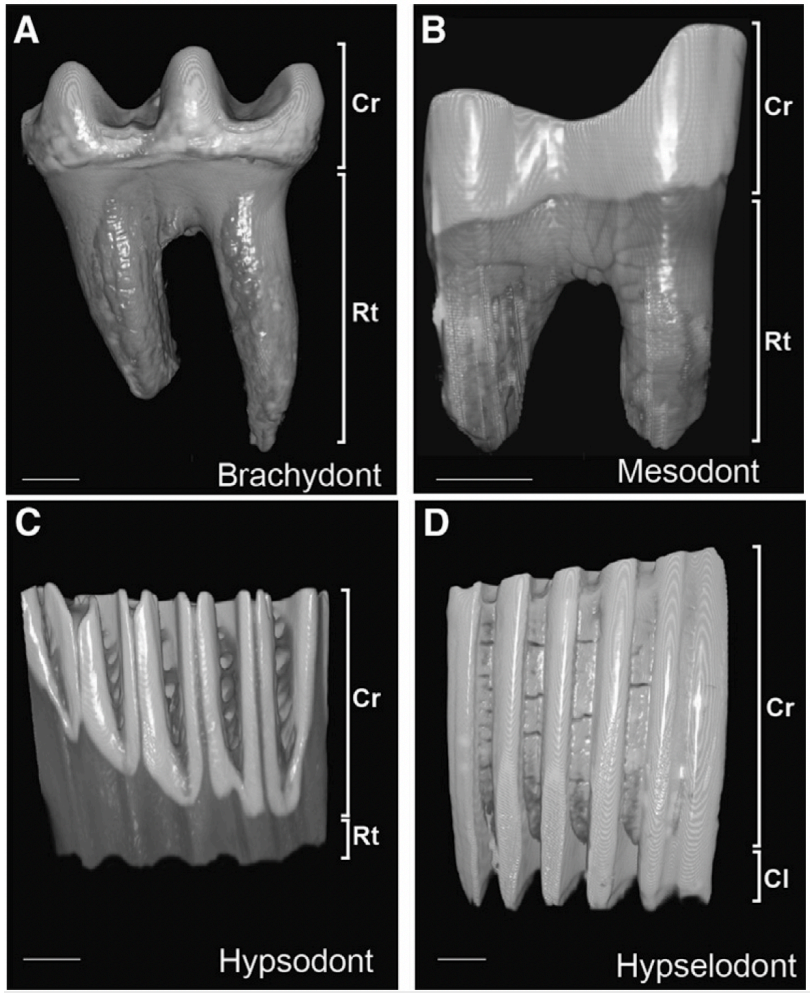


Continuously Growing Rodent Molars Result from a Predictable Quantitative Evolutionary Change over 50 Million Years

Cell Reports *11*, 673–680, May 5, 2015

Vagan Tapaltsyan,[1,8] Jussi T. Eronen,[2,3,8] A. Michelle Lawing,[4] Amnon Sharir,[1] Christine Janis,[5] Jukka Jernvall,[6,*] and Ophir D. Klein[1,7,*]

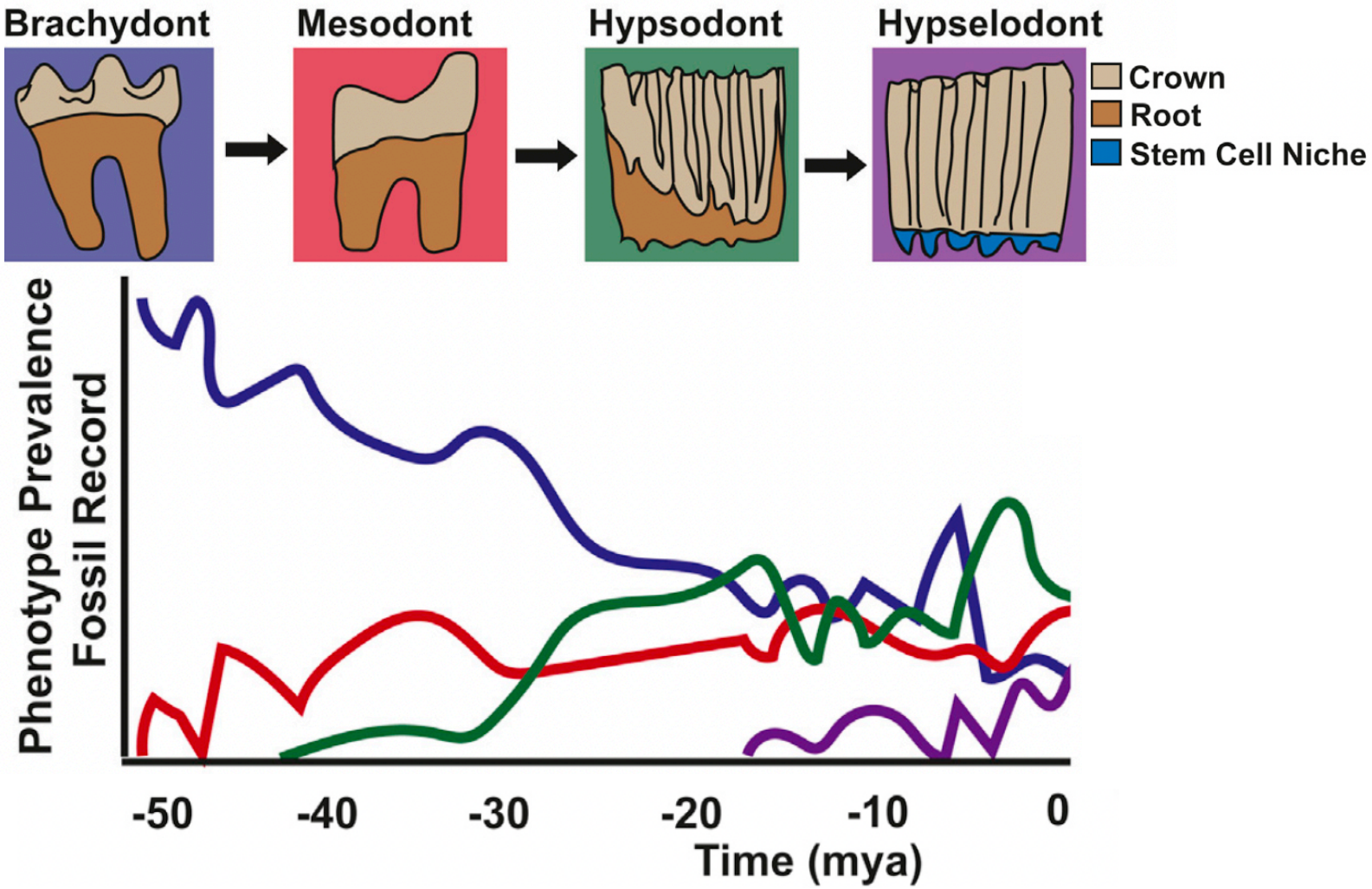


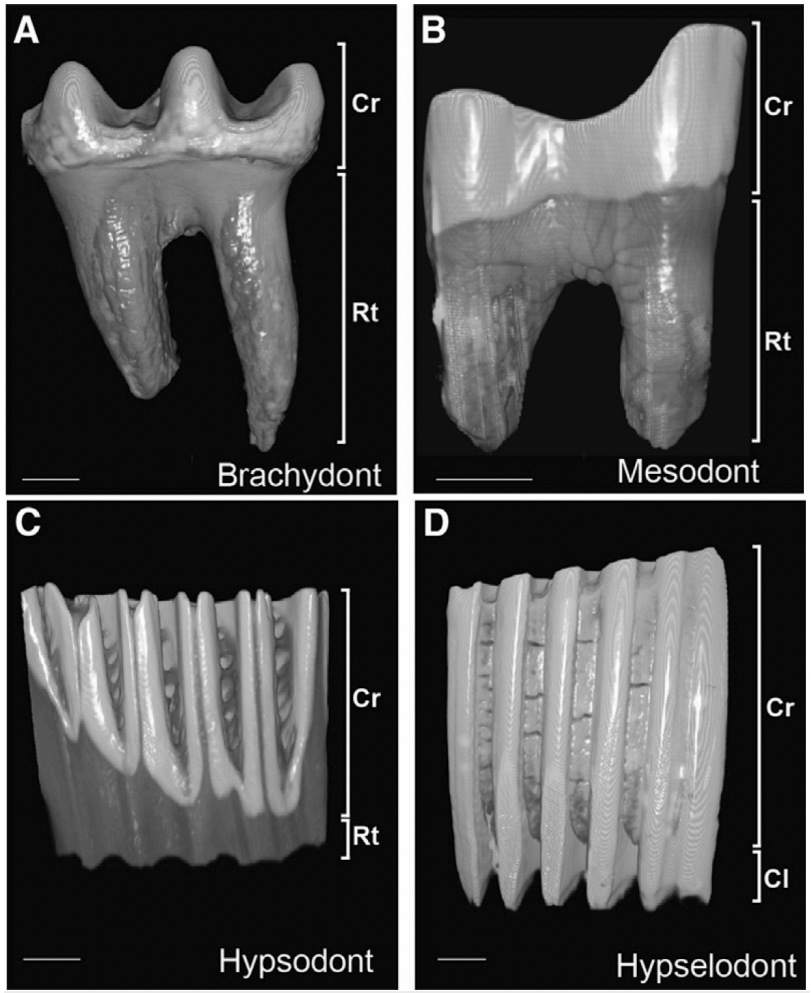


Continuously Growing Rodent Molars Result from a Predictable Quantitative Evolutionary Change over 50 Million Years

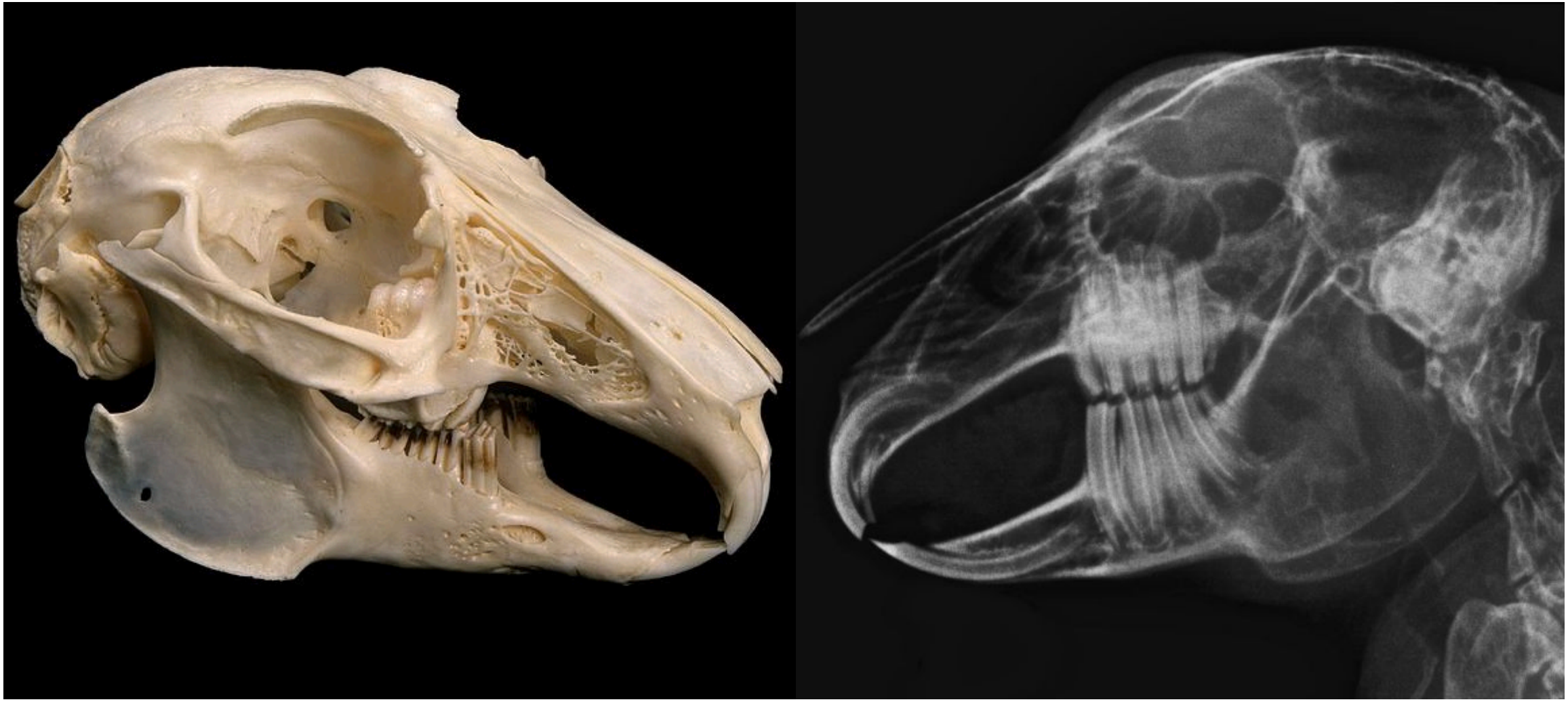
Cell Reports *11*, 673–680, May 5, 2015

Vagan Tapaltsyan,[1,8] Jussi T. Eronen,[2,3,8] A. Michelle Lawing,[4] Amnon Sharir,[1] Christine Janis,[5] Jukka Jernvall,[6,*] and Ophir D. Klein[1,7,*]





immerwachsende Zähne – ‘Euhypsodontie’



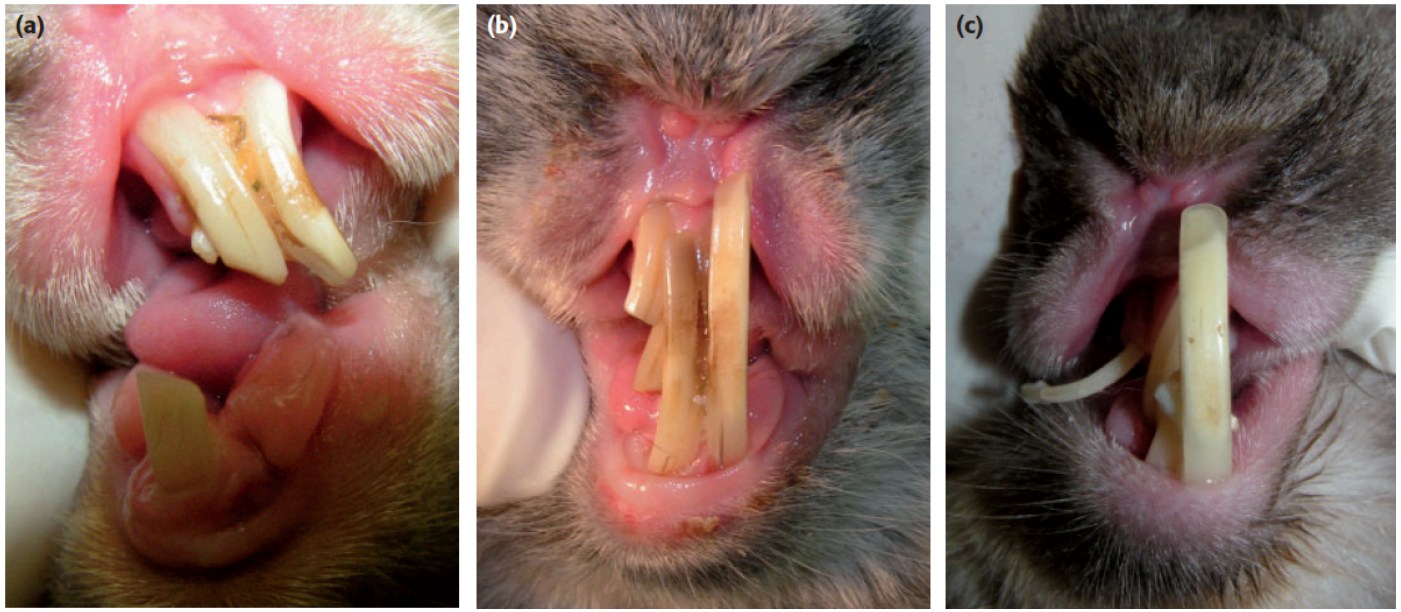
immerwachsende Zähne – ‘Euhypsodontie’

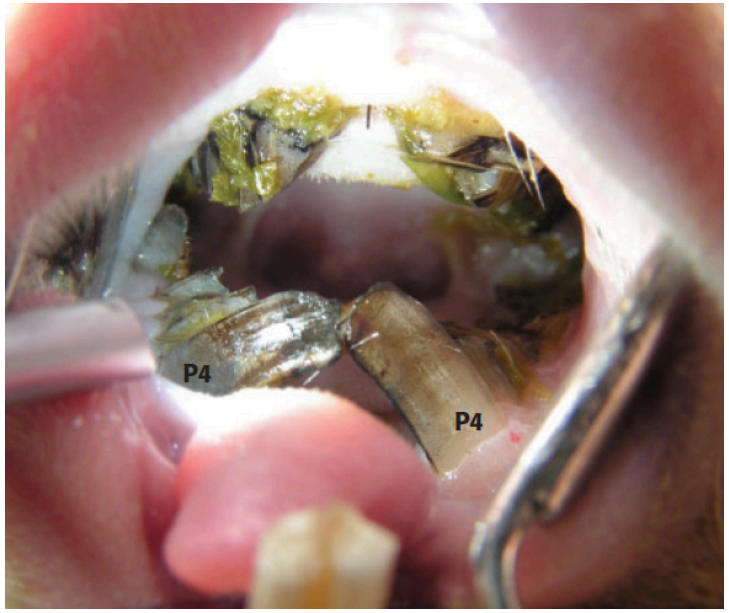
Quantitative and qualitative assessments of intraoral lesions in 180 small herbivorous mammals

Veterinary Record (2008)
162, 442-449

V. Jekl, K. Hauptman, Z. Knotek

Between 2002 and 2005 210 rabbits, 257 guinea pigs and 123 chinchillas were examined; oral disease was diagnosed in 38·1 per cent of the rabbits, 23·4 per cent of the guinea pigs and 32·5 per cent of the chinchillas.





Tab. VI.8.1: **Längenwachstum (mm/Woche) der Schneidezähne bei verschiedenen Spezies**

Spezies	Unterkiefer	Oberkiefer
Ratte	1,8–3,9	1,5–2,6
Chinchilla	1,0–1,6	1,0–2,0
Meerschweinchen	1,2–1,9	1,4–1,7
Kaninchen[1]	1,1–1,8	1,3–1,7

[1] Werte von Zwergkaninchen.

Eine länger dauernde, intensive Nutzung der Zähne (und damit ihre Abnutzung) ist nicht zuletzt wegen des kontinuierlichen Zahnwachstums (**Tab. VI.8.1**) erforderlich.

Tab. VI.8.1: **Längenwachstum (mm/Woche) der Schneidezähne bei verschiedenen Spezies**

Spezies	Unterkiefer	Oberkiefer
Ratte	1,8–3,9	1,5–2,6
Chinchilla	1,0–1,6	1,0–2,0
Meerschweinchen	1,2–1,9	1,4–1,7
Kaninchen[1]	1,1–1,8	1,3–1,7

[1] Werte von Zwergkaninchen.

Was ich gelernt – und gelehrt – habe

Eine länger dauernde, intensive Nutzung der Zähne (und damit ihre Abnutzung) ist nicht zuletzt wegen des kontinuierlichen Zahnwachstums (**Tab. VI.8.1**) erforderlich.

Tab. VI.8.1: **Längenwachstum (mm/Woche) der Schneidezähne bei verschiedenen Spezies**

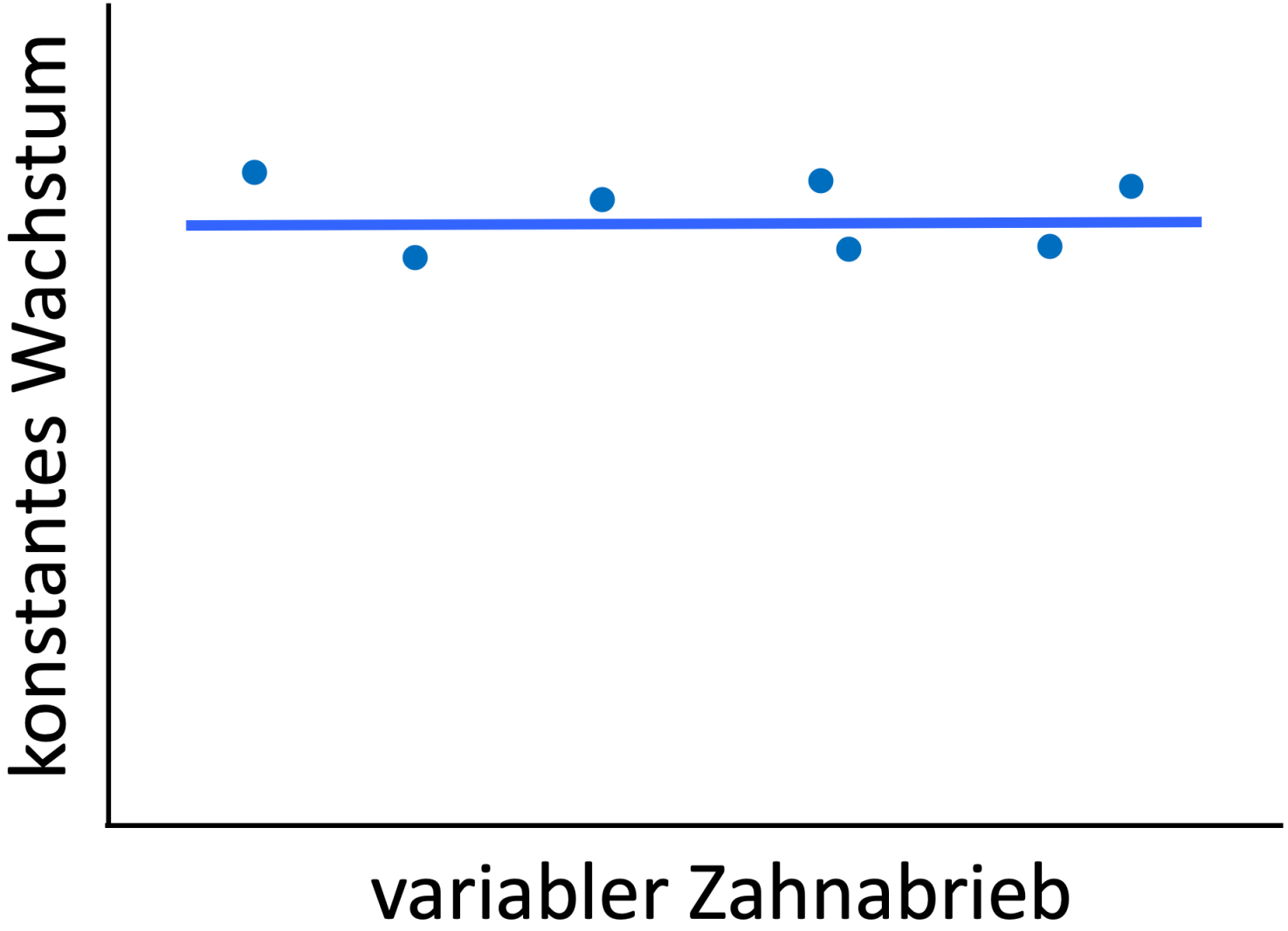
Spezies	Unterkiefer	Oberkiefer
Ratte	1,8–3,9	1,5–2,6
Chinchilla	1,0–1,6	1,0–2,0
Meerschweinchen	1,2–1,9	1,4–1,7
Kaninchen[1]	1,1–1,8	1,3–1,7

[1] Werte von Zwergkaninchen.

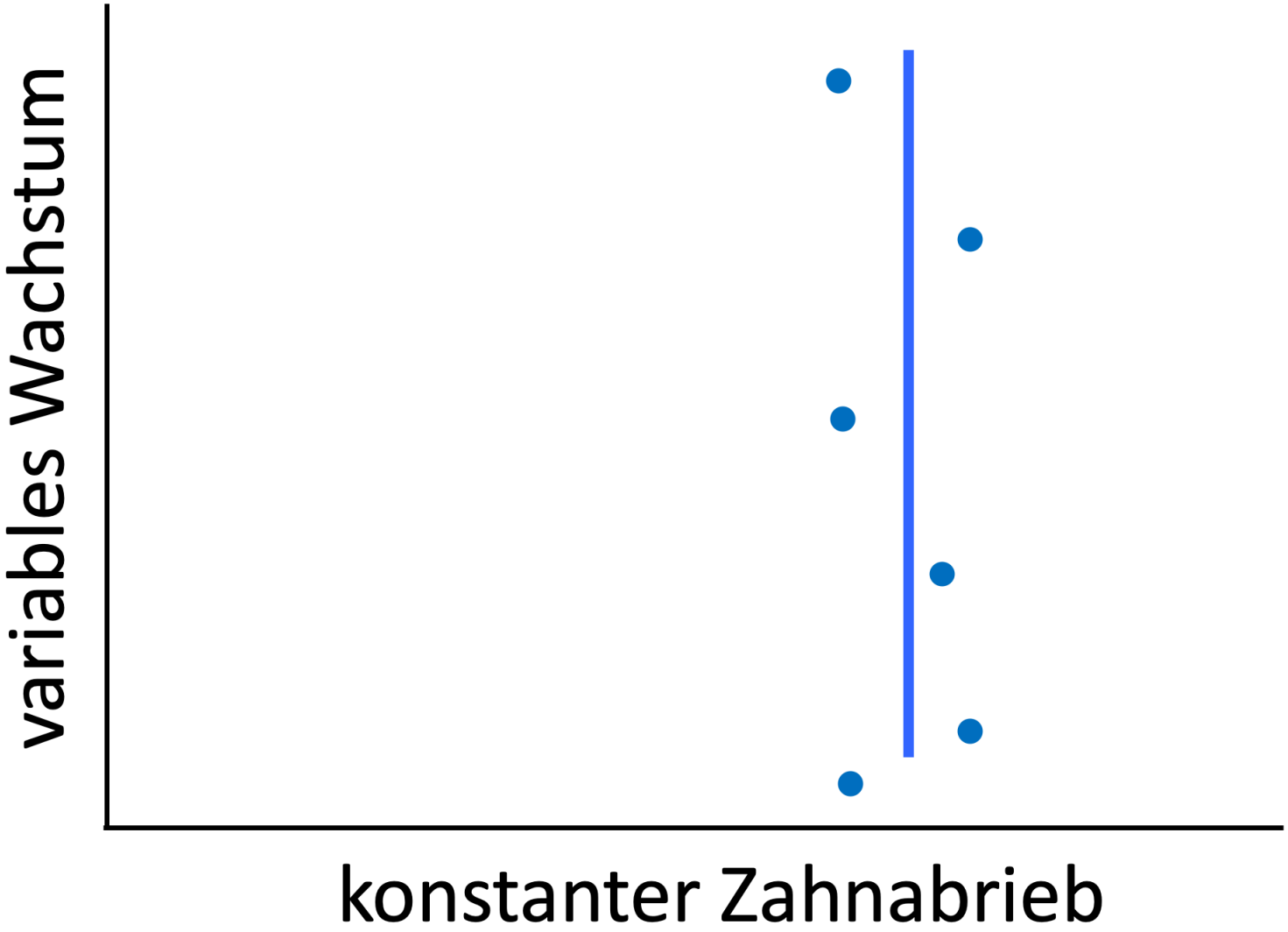
Denken hilft

Wie stellen wir uns Biologie vor ?

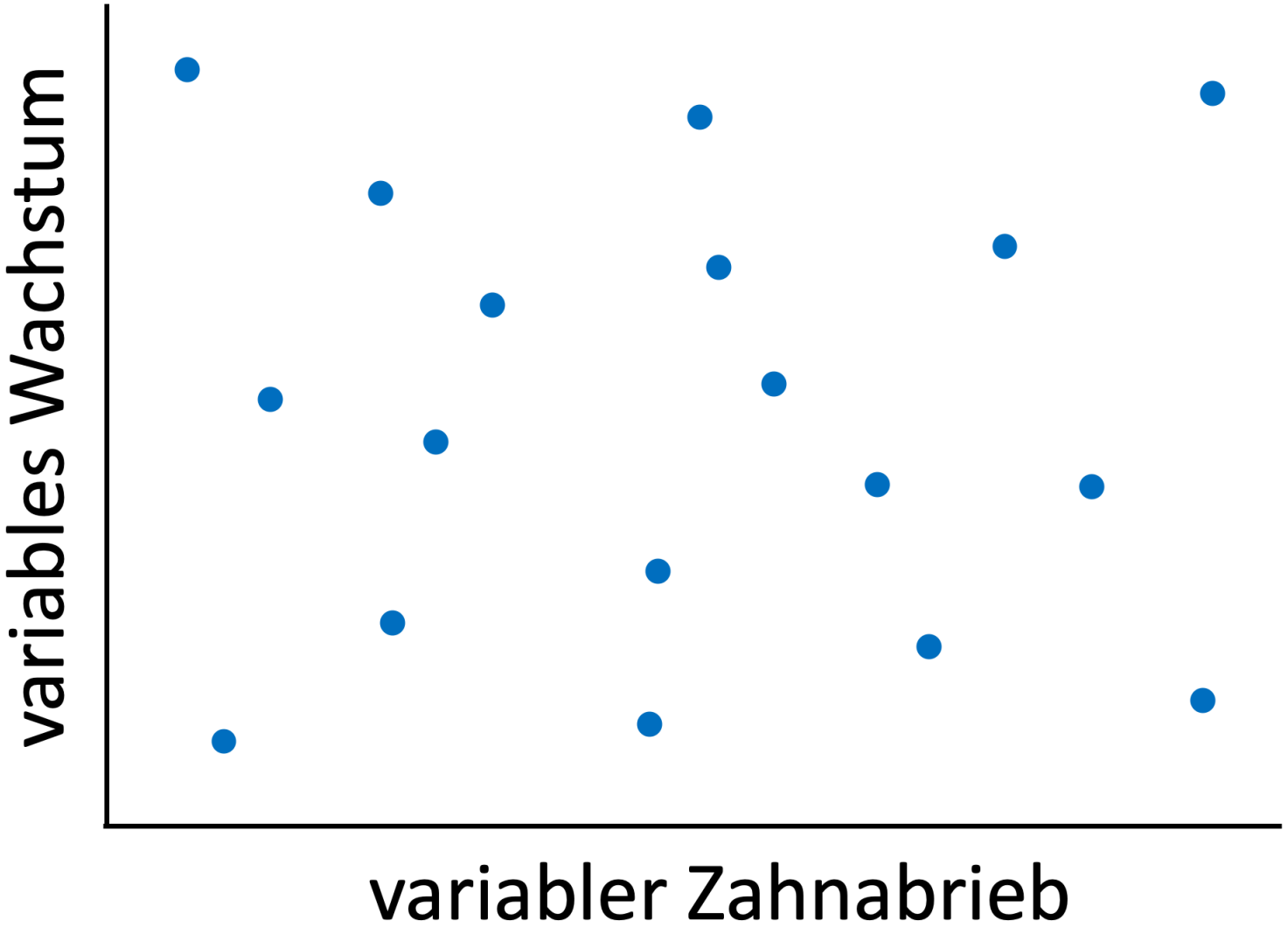
Wie stellen wir uns Biologie vor ?



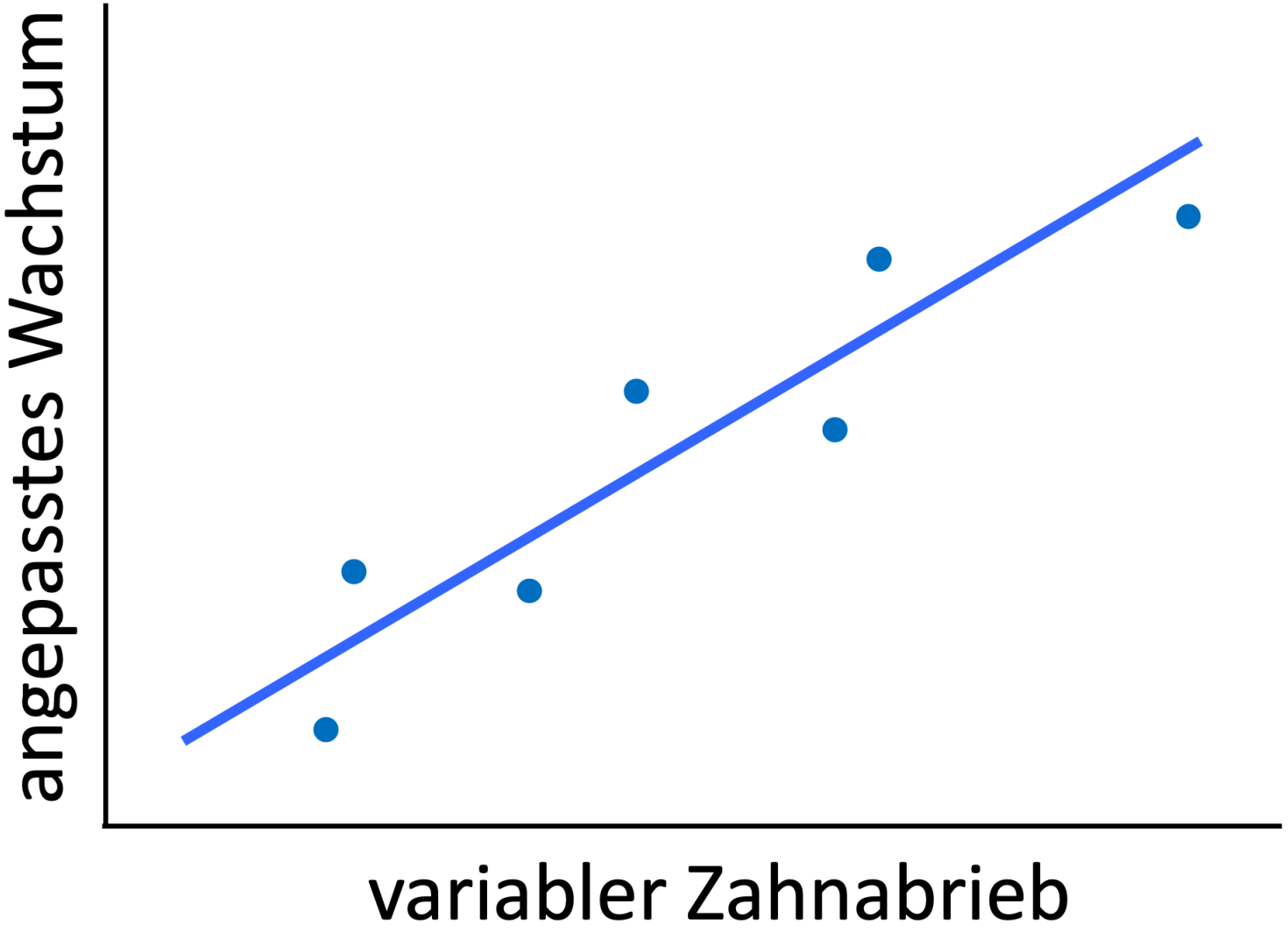
Wie stellen wir uns Biologie vor ?



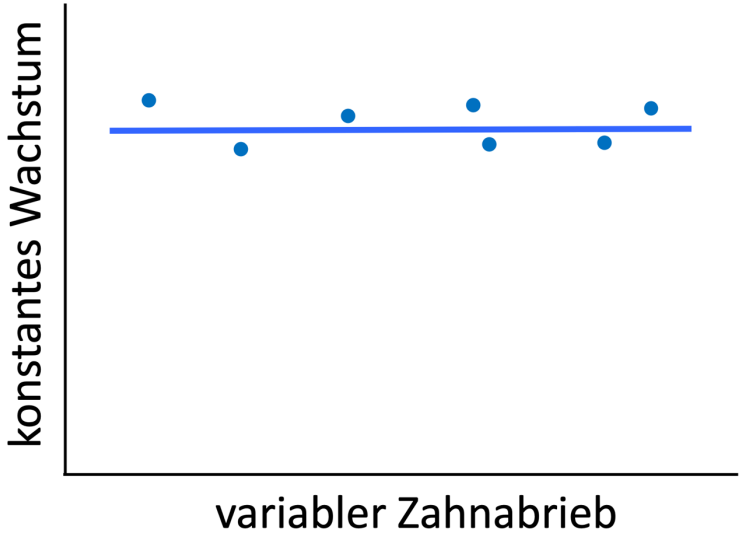
Wie stellen wir uns Biologie vor ?

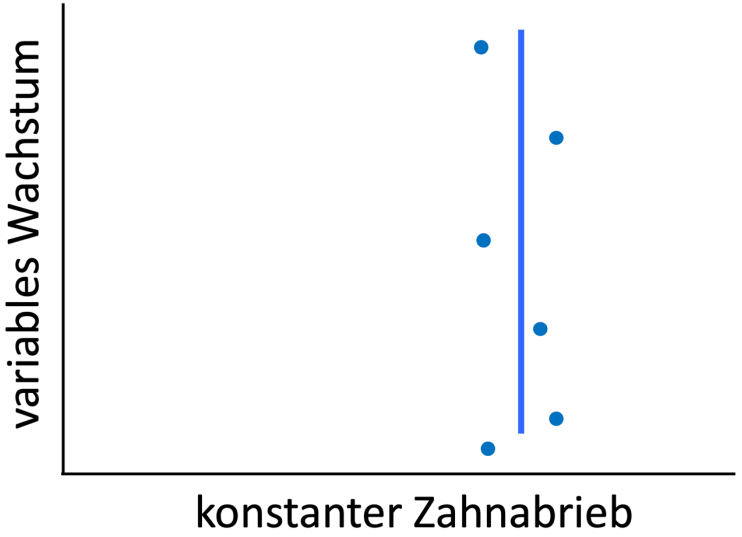


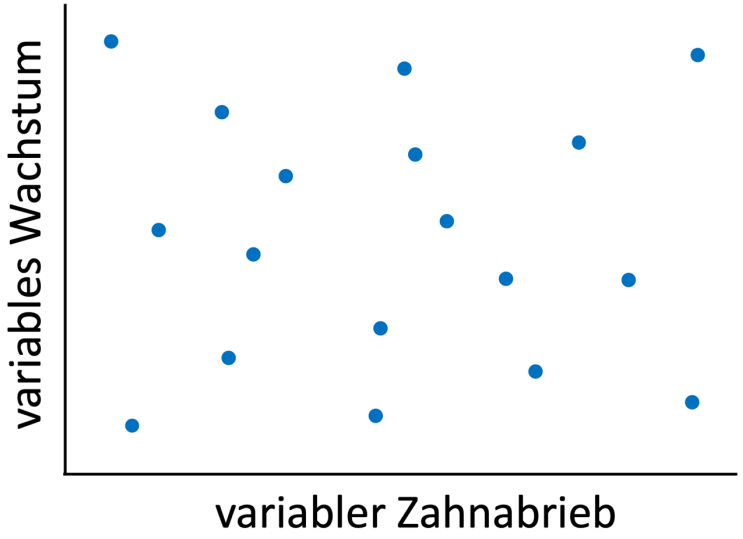
Wie stellen wir uns Biologie vor ?

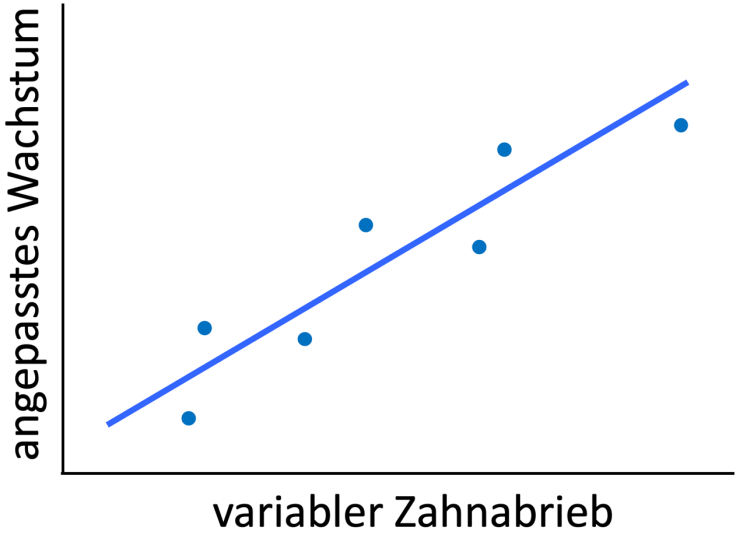


Wie stellen wir uns Biologie vor ?

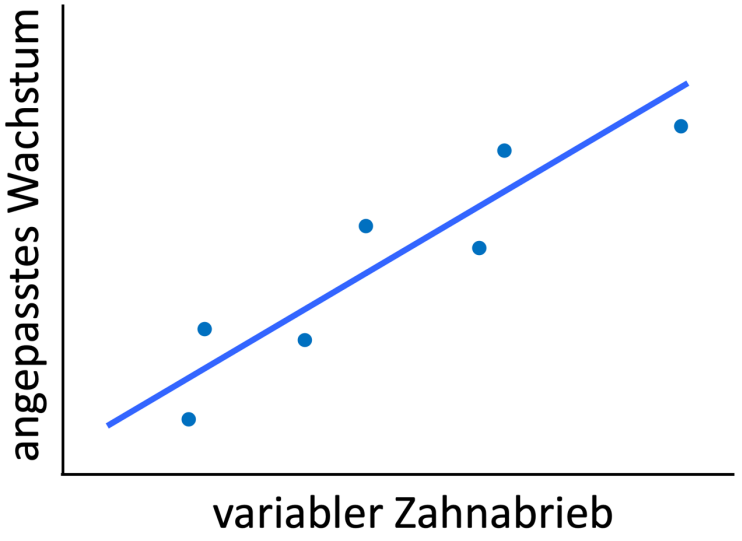








Wie stellen wir uns Biologie vor ?



Experimentieren hilft

RESEARCH ARTICLE

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

JOURNAL OF EXPERIMENTAL ZOOLOGY
PART A
ECOLOGICAL GENETICS AND PHYSIOLOGY
A Journal of Integrative Biology

JACQUELINE MÜLLER[1], MARCUS CLAUSS[1]*, DARYL CODRON[1,2], ELLEN SCHULZ[3], JÜRGEN HUMMEL[4], MIKAEL FORTELIUS[5], PATRICK KIRCHER[6], AND JEAN-MICHEL HATT[1]

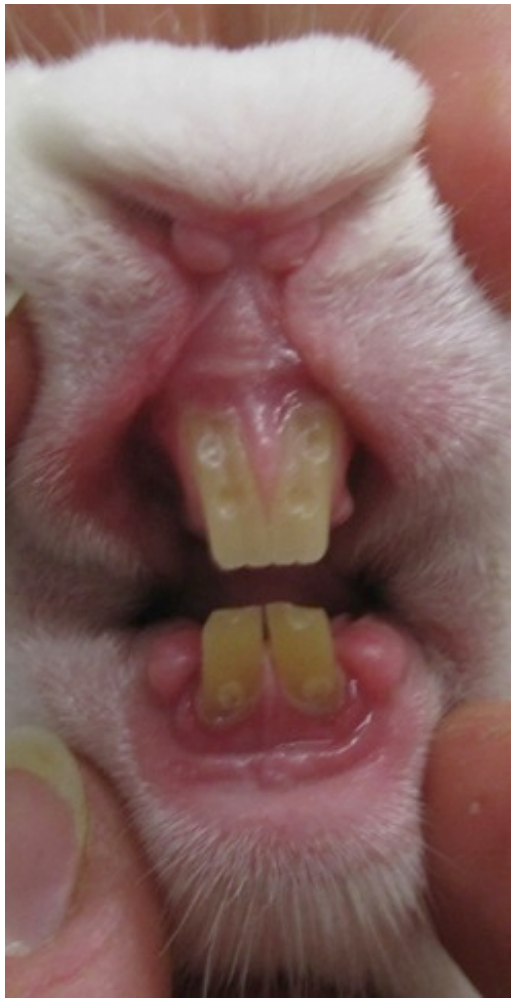
[1]Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty, University of Zurich, Zurich, Switzerland
[2]Florisbad Quaternary Research, National Museum, Bloemfontein, South Africa
[3]Biocenter Grindel and Zoological Museum, University of Hamburg, Hamburg, Germany
[4]Department of Animal Sciences, Ruminant Nutrition, Georg-August University, Göttingen, Germany
[5]Department of Geosciences and Geography, University of Helsinki, Helsinki, Finland
[6]Division of Diagnostic Imaging, Vetsuisse Faculty, University of Zurich, Zurich, Switzerland

ABSTRACT

Although patterns of tooth wear are crucial in palaeo-reconstructions, and dental wear abnormalities are important in veterinary medicine, experimental investigations on the relationship between diet abrasiveness and tooth wear are rare. Here, we investigated the effect of four different pelleted diets of increasing abrasiveness (due to both internal [phytoliths] and external abrasives [sand]) or whole grass hay fed for 2 weeks each in random order to 16 rabbits (*Oryctolagus cuniculus*) on incisor and premolar growth and wear, and incisor and cheek tooth length. Wear and tooth length differed between diets, with significant effects of both internal and external abrasives. While diet abrasiveness was linked to tooth length for all tooth positions, whole forage had an additional effect on upper incisor length only. Tooth growth was strongly related to tooth wear and differed correspondingly between diets and tooth positions. At 1.4–3.2 mm/week, the growth of cheek teeth measured in this study was higher than previously reported for rabbits. Dental abnormalities were most distinct on the diet with sand. This study demonstrates that concepts of constant tooth growth in rabbits requiring consistent wear are inappropriate, and that diet form (whole vs. pelleted) does not necessarily affect cheek teeth. Irrespective of the strong effect of external abrasives, internal abrasives have the potential to induce wear and hence exert selective pressure in evolution. Detailed differences in wear effects between tooth positions allow inferences about the mastication process. Elucidating feedback mechanisms that link growth to tooth-specific wear represents a promising area of future research. *J. Exp. Zool. 321A:283–298, 2014.* © 2014 Wiley Periodicals, Inc.

J. Exp. Zool. 321A:283–298, 2014

How to cite this article: Müller J, Clauss M, Codron D, Schulz E, Hummel J, Fortelius M, Kircher P, Hatt J-M. 2014. Growth and wear of incisor and cheek teeth in domestic rabbits (*Oryctolagus cuniculus*) fed diets of different abrasiveness. J. Exp. Zool. 321A:283–298.



RESEARCH ARTICLE

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

JOURNAL OF EXPERIMENTAL ZOOLOGY PART A ECOLOGICAL GENETICS AND PHYSIOLOGY
A Journal of Integrative Biology

JACQUELINE MÜLLER[1], MARCUS CLAUSS[1]*, DARYL CODRON[1,2], ELLEN SCHULZ[3], JÜRGEN HUMMEL[4], MIKAEL FORTELIUS[5], PATRICK KIRCHER[6], AND JEAN-MICHEL HATT[1]

[1]Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty, University of Zurich, Zurich, Switzerland
[2]Florisbad Quaternary Research, National Museum, Bloemfontein, South Africa
[3]Biocenter Grindel and Zoological Museum, University of Hamburg, Hamburg, Germany
[4]Department of Animal Sciences, Ruminant Nutrition, Georg-August University, Göttingen, Germany
[5]Department of Geosciences and Geography, University of Helsinki, Helsinki, Finland
[6]Division of Diagnostic Imaging, Vetsuisse Faculty, University of Zurich, Zurich, Switzerland

ABSTRACT

Although patterns of tooth wear are crucial in palaeo-reconstructions, and dental wear abnormalities are important in veterinary medicine, experimental investigations on the relationship between diet abrasiveness and tooth wear are rare. Here, we investigated the effect of four different pelleted diets of increasing abrasiveness (due to both internal [phytoliths] and external abrasives [sand]) or whole grass hay fed for 2 weeks each in random order to 16 rabbits (*Oryctolagus cuniculus*) on incisor and premolar growth and wear, and incisor and cheek tooth length. Wear and tooth length differed between diets, with significant effects of both internal and external abrasives. While diet abrasiveness was linked to tooth length for all tooth positions, whole forage had an additional effect on upper incisor length only. Tooth growth was strongly related to tooth wear and differed correspondingly between diets and tooth positions. At 1.4–3.2 mm/week, the growth of cheek teeth measured in this study was higher than previously reported for rabbits. Dental abnormalities were most distinct on the diet with sand. This study demonstrates that concepts of constant tooth growth in rabbits requiring consistent wear are inappropriate, and that diet form (whole vs. pelleted) does not necessarily affect cheek teeth. Irrespective of the strong effect of external abrasives, internal abrasives have the potential to induce wear and hence exert selective pressure in evolution. Detailed differences in wear effects between tooth positions allow inferences about the mastication process. Elucidating feedback mechanisms that link growth to tooth-specific wear represents a promising area of future research. *J. Exp. Zool. 321A:283–298, 2014.* © 2014 Wiley Periodicals, Inc.

J. Exp. Zool. 321A:283–298, 2014

How to cite this article: Müller J, Clauss M, Codron D, Schulz E, Hummel J, Fortelius M, Kircher P, Hatt J-M. 2014. Growth and wear of incisor and cheek teeth in domestic rabbits (*Oryctolagus cuniculus*) fed diets of different abrasiveness. J. Exp. Zool. 321A:283–298.

Received: 27 October 2020 | Accepted: 15 April 2021
DOI: 10.1111/jpn.13565

ORIGINAL ARTICLE

WILEY

Tooth wear, growth and height in rabbits (Oryctolagus cuniculus) fed pelleted or extruded diets with or without added abrasives

Louise F. Martin[1] | Nicole L. Ackermans[1] | Troy N. Tollefson[2] | Patrick R. Kircher[3] | Henning Richter[3] | Jürgen Hummel[4] | Daryl Codron[5] | Jean-Michel Hatt[1] | Marcus Clauss[1]

[1]Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty, University of Zurich, Zurich, Switzerland
[2]Mazuri® Exotic Animal Nutrition, PMI Nutrition International LLC, Saint Louis, MO, USA
[3]Clinic for Diagnostic Imaging, Vetsuisse Faculty, University of Zurich, Zurich, Switzerland
[4]Department of Animal Sciences, Ruminant Nutrition, Georg-August University, Göttingen, Germany
[5]Department of Zoology and Entomology, University of the Free State, Bloemfontein, South Africa

Correspondence
Marcus Clauss, Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty, University of Zurich, Winterthurerstr. 260, 8057 Zurich, Switzerland.
Email: mclauss@vetclinics.uzh.ch

Funding information
This study was part of project 31003A_163300/1 funded by the Swiss National Science Foundation. The work of LFM was funded in part by the Candoc Forschungskredit of the University of Zurich. The experimental diets were supplied by Mazuri® Exotic Animal Nutrition

Abstract

Among the different factors thought to affect dental wear, dietary consistency is possibly the least investigated. To understand tooth wear of herbivorous animals consuming different dietary consistencies with different abrasive potential, we fed 14 rabbits (*Oryctolagus cuniculus*) exclusively with a timothy grassmeal-based diet in either pelleted or extruded form, or the same diets with an addition of 5% fine sand abrasives (mean size 130 μm). First, we offered the rabbits the pelleted and extruded diets as well as the pelleted control and pelleted abrasive diet in a two-stage preference experiment. Then, the rabbits received each diet for 2 weeks in a randomised serial feeding experiment, where each animal served as its own control. Tooth measurements for wear, growth and height were achieved using a manual calliper, endoscopic examination and CT scans. The analysis of the diets as fed showed almost identical mean particle size, but the extruded diet had a lower density (volume/mass) and softer consistency compared to the pelleted one and was favoured by most rabbits. The rabbits selected against the diet with sand during the preference experiment, possibly because it caused more tooth wear, especially on the teeth most exposed to wear along the upper tooth row (upper P4 and M1). The maxillary teeth also showed evidence of an increased chewing laterality by the end of the experiment. The extruded diet led to a significantly lower cheek teeth height than the pelleted diet, potentially due to the higher chewing effort needed for a similar dry matter intake. The results suggest that dietary hardness alone is a poor predictor of dental wear. The regrowth of the teeth matched wear consistently.

KEYWORDS
abrasive properties, extrudates, pellets, preference, rabbits, tooth wear

1 | INTRODUCTION

Wild rabbits (*Oryctolagus cuniculus*) are very selective in their foraging habits. They strive to feed on energy-dense soft grasses (Williams et al., 1974) keeping the necessary foraging activity brief to reduce the risk of predation (Bakker et al., 2005). If given a choice, pet rabbits opt for energy-dense pellets instead of roughage (Prebble & Meredith, 2014). As a consequence, they are prone to clinically

Received: 7 July 2021 | Revised: 27 October 2021 | Accepted: 30 October 2021
DOI: 10.1002/jez.b.23104

RESEARCH ARTICLE

JEZ-B MOLECULAR AND DEVELOPMENTAL EVOLUTION WILEY

Macrowear effects of external quartz abrasives of different size and concentration in rabbits (*Oryctolagus cuniculus*)

Louise F. Martin[1] | Nicole L. Ackermans[1] | Henning Richter[2] | Patrick Kircher[2] | Jürgen Hummel[3] | Daryl Codron[4] | Marcus Clauss[1] | Jean-Michel Hatt[1]

[1]Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty, University of Zurich, Zurich, Switzerland
[2]Clinic for Diagnostic Imaging, Vetsuisse Faculty, University of Zurich, Zurich, Switzerland
[3]Divison of Ruminant Nutrition, Department of Animal Sciences, University of Goettingen, Goettingen, Germany
[4]Department of Zoology and Entomology, University of the Free State, Bloemfontein, South Africa

Correspondence
Louise F. Martin, Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty, University of Zurich, 8057 Zurich, Switzerland.
Email: lfmartin@vetclinics.uzh.ch

Present address
Nicole L. Ackermans, Nash Family Department of Neuroscience, Friedman Brain Institute, Center for Anatomy and Functional Morphology, Icahn School of Medicine at Mount Sinai, New York, New York, USA.

Funding information
National Research Foundation of South Africa, Grant/Award Number: 129172; Schweizerischer Nationalfonds zur Förderung der Wissenschaftlichen Forschung, Grant/Award Number: 31003A_163300/1; Candoc Forschungskredit of the University of Zurich, Grant/Award Number: FK-16-052

Abstract

External quartz abrasives are one of the driving forces of macrowear in herbivorous animals. We tested to what extent different sizes and concentrations influence their effect on tooth wear. We fed seven pelleted diets varying only in quartz concentration (0%, 4%, and 8%) and size (fine silt: ~4 μm, coarse silt: ~50 μm, fine sand: ~130 μm) to rabbits (*Oryctolagus cuniculus*, $n = 16$) for 2 weeks each in a randomized serial experiment. Measurements to quantify wear and growth of incisors and the mandibular first cheek tooth, as well as heights of all other cheek teeth, were performed using calipers, endoscopic examination, and computed tomography scans before and after each feeding period. Tooth growth showed a compensatory correlation with wear. Absolute tooth height (ATH) and relative tooth height (RTH); relative to the 0% quartz "control" diet) was generally lower on the higher concentration and the larger size of abrasives. The effect was more pronounced on the maxillary teeth, on specific tooth positions and the right jaw side. When offered the choice between different sizes of abrasives, the rabbits favored the silt diets over the control and the fine sand diet; in a second choice experiment with different diets, they selected a pelleted diet with coarse-grained sand, however. This study confirms the dose- and size-dependent wear effects of external abrasives, and that hypselodont teeth show compensatory growth. The avoidance of wear did not seem a priority for animals with hypselodont teeth, since the rabbits did not avoid diets inducing a certain degree of wear.

KEYWORDS
external abrasives, hypsodonty, macrowear, preference, quartz, rabbit

1 | INTRODUCTION

Continuously functioning teeth are a prerequisite for longevity in herbivorous mammals, which is, among other factors, limited by constant exposure to abrasion and attrition during the interaction of feed and teeth (Janis & Fortelius, 1988). Strategies of plasticity for continuing dental function have evolved to respond to dental wear, as has been documented in diverse domesticated populations of several mammalian species (Sánchez-Villagra, 2021).

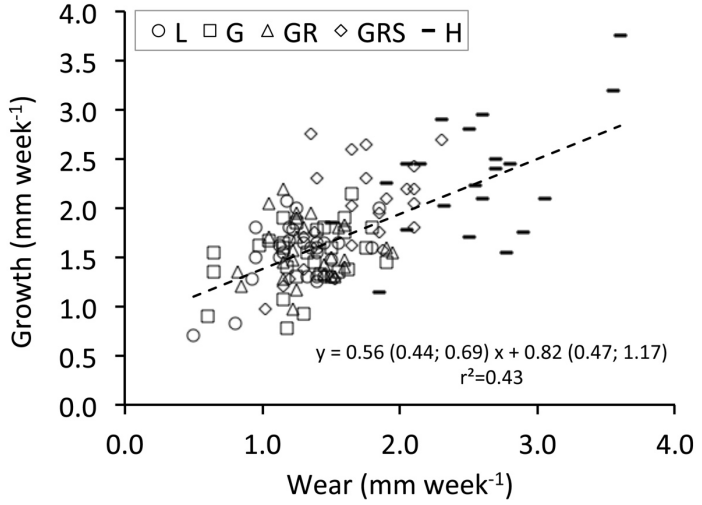
RESEARCH ARTICLE

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

JOURNAL OF EXPERIMENTAL ZOOLOGY PART A ECOLOGICAL GENETICS AND PHYSIOLOGY
A Journal of Integrative Biology

JACQUELINE MÜLLER[1], MARCUS CLAUSS[1]*, DARYL CODRON[1,2], ELLEN SCHULZ[3], JÜRGEN HUMMEL[4], MIKAEL FORTELIUS[5], PATRICK KIRCHER[6], AND JEAN-MICHEL HATT[1]

[1]Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty, University of Zurich, Zurich, Switzerland
[2]Florisbad Quaternary Research, National Museum, Bloemfontein, South Africa
[3]Biocenter Grindel and Zoological Museum, University of Hamburg, Hamburg, Germany
[4]Department of Animal Sciences, Ruminant Nutrition, Georg-August University, Göttingen, Germany
[5]Department of Geosciences and Geography, University of Helsinki, Helsinki, Finland
[6]Division of Diagnostic Imaging, Vetsuisse Faculty, University of Zurich, Zurich, Switzerland



Received: 27 October 2020 | Accepted: 15 April 2021
DOI: 10.1111/jpn.13565

ORIGINAL ARTICLE

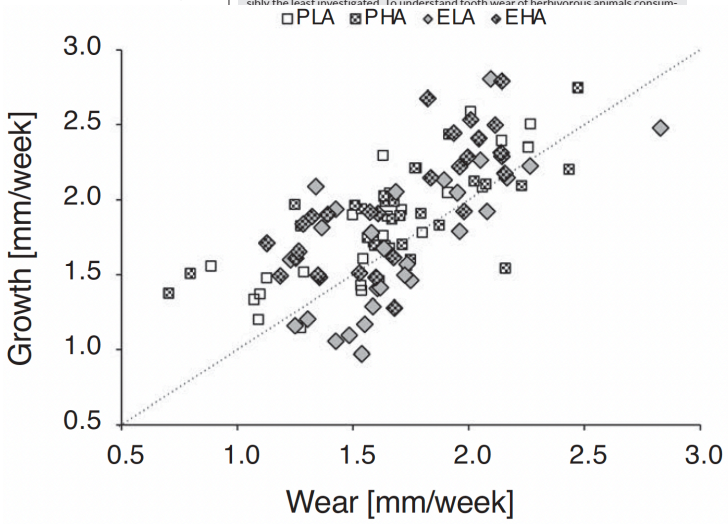
WILEY

Tooth wear, growth and height in rabbits (Oryctolagus cuniculus) fed pelleted or extruded diets with or without added abrasives

Louise F. Martin[1] | Nicole L. Ackermans[1] | Troy N. Tollefson[2] | Patrick R. Kircher[3] | Henning Richter[3] | Jürgen Hummel[4] | Daryl Codron[5] | Jean-Michel Hatt[1] | Marcus Clauss[1]

[1]Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty, University of Zurich, Zurich, Switzerland
[2]Mazuri® Exotic Animal Nutrition, PMI

Abstract
Among the different factors thought to affect dental wear, dietary consistency is pos-
sibly the least investigated. To understand tooth wear of herbivorous animals consum-



Received: 7 July 2021 | Revised: 27 October 2021 | Accepted: 30 October 2021
DOI: 10.1002/jez.b.23104

RESEARCH ARTICLE

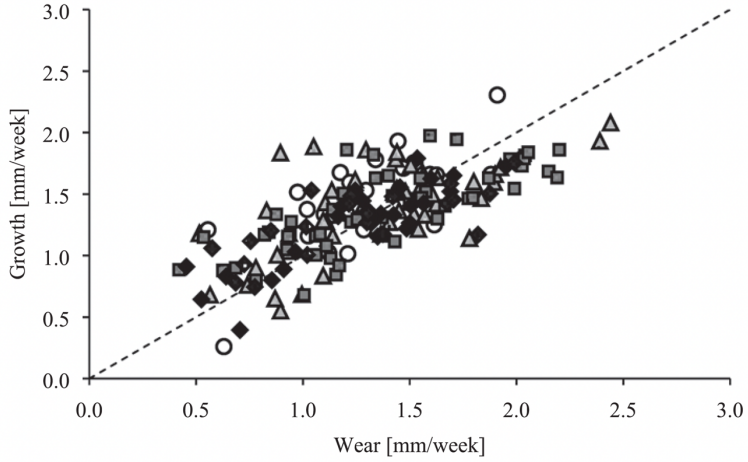
JEZ-B MOLECULAR AND DEVELOPMENTAL EVOLUTION WILEY

Macrowear effects of external quartz abrasives of different size and concentration in rabbits (*Oryctolagus cuniculus*)

Louise F. Martin[1] | Nicole L. Ackermans[1] | Henning Richter[2] | Patrick Kircher[2] | Jürgen Hummel[3] | Daryl Codron[4] | Marcus Clauss[1] | Jean-Michel Hatt[1]

[1]Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty, University of Zurich, Zurich, Switzerland
[2]Clinic for Diagnostic Imaging, Vetsuisse Faculty, University of Zurich, Zurich, Switzerland
[3]Divison of Ruminant Nutrition, Department of Animal Sciences, University of Goettingen, Goettingen, Germany
[4]Department of Zoology and Entomology, University of the Free State, Bloemfontein, South Africa

Abstract
External quartz abrasives are one of the driving forces of macrowear in herbivorous animals. We tested to what extent different sizes and concentrations influence their effect on tooth wear. We fed seven pelleted diets varying only in quartz concentration (0%, 4%, and 8%) and size (fine silt: ~4 μm, coarse silt: ~50 μm, fine sand: ~130 μm) to rabbits (*Oryctolagus cuniculus*, $n = 16$) for 2 weeks each in a randomized serial experiment. Measurements to quantify wear and growth of incisors and the mandibular first cheek tooth, as well as heights of all other cheek teeth, were performed using



RESEARCH ARTICLE

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

JOURNAL OF EXPERIMENTAL ZOOLOGY
PART A
ECOLOGICAL GENETICS AND PHYSIOLOGY
A Journal of Integrative Biology

JACQUELINE MÜLLER[1], MARCUS CLAUSS[1]*, DARYL CODRON[1,2], ELLEN SCHULZ[3], JÜRGEN HUMMEL[4], MIKAEL FORTELIUS[5], PATRICK KIRCHER[6], AND JEAN-MICHEL HATT[1]

J. Exp. Zool. 321A:283–298, 2014

RESEARCH ARTICLE

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

JOURNAL OF EXPERIMENTAL ZOOLOGY
PART A
ECOLOGICAL GENETICS AND PHYSIOLOGY
A Journal of Integrative Biology

JACQUELINE MÜLLER[1], MARCUS CLAUSS[1]*, DARYL CODRON[1,2], ELLEN SCHULZ[3], JÜRGEN HUMMEL[4], MIKAEL FORTELIUS[5], PATRICK KIRCHER[6], AND JEAN-MICHEL HATT[1]

J. Exp. Zool. 321A:283–298, 2014

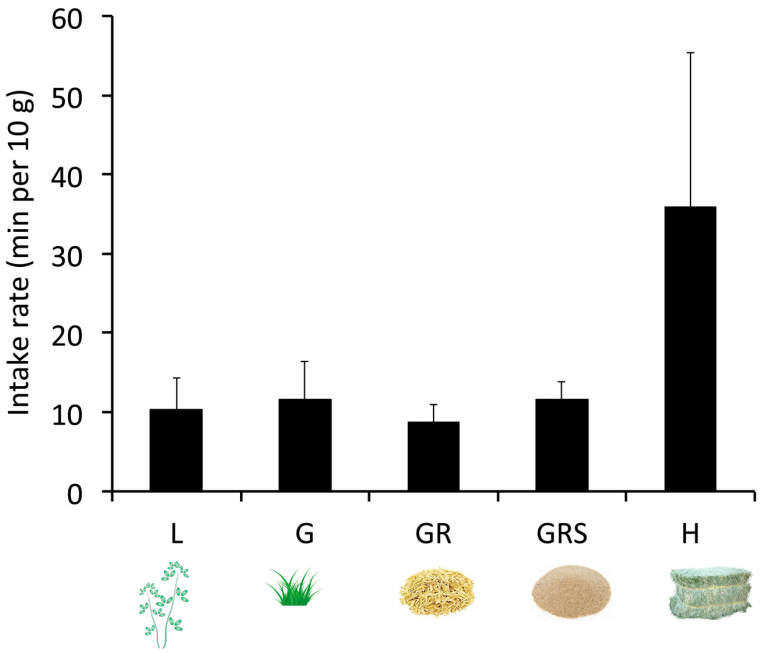
RESEARCH ARTICLE

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

JOURNAL OF EXPERIMENTAL ZOOLOGY PART A ECOLOGICAL GENETICS AND PHYSIOLOGY
A Journal of Integrative Biology

JACQUELINE MÜLLER[1], MARCUS CLAUSS[1]*, DARYL CODRON[1,2], ELLEN SCHULZ[3], JÜRGEN HUMMEL[4], MIKAEL FORTELIUS[5], PATRICK KIRCHER[6], AND JEAN-MICHEL HATT[1]

J. Exp. Zool. 321A:283–298, 2014



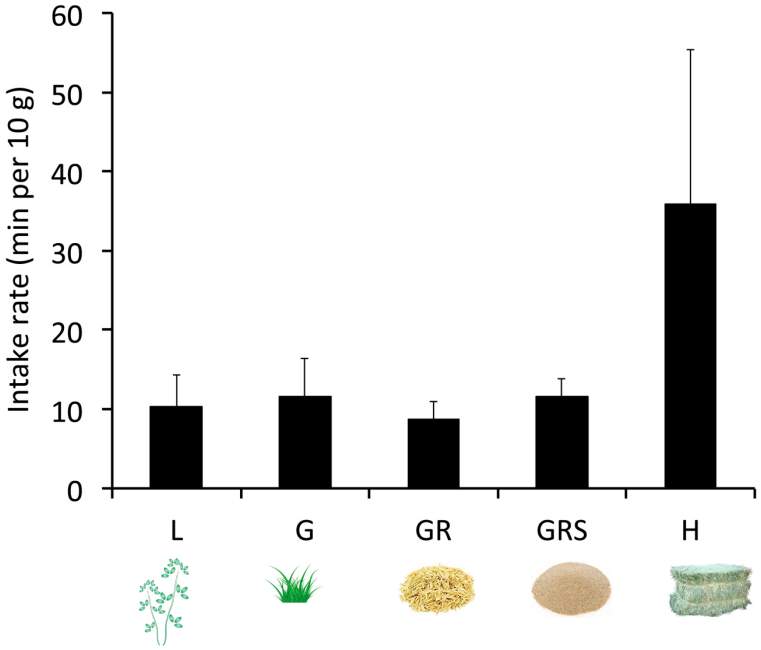
RESEARCH ARTICLE

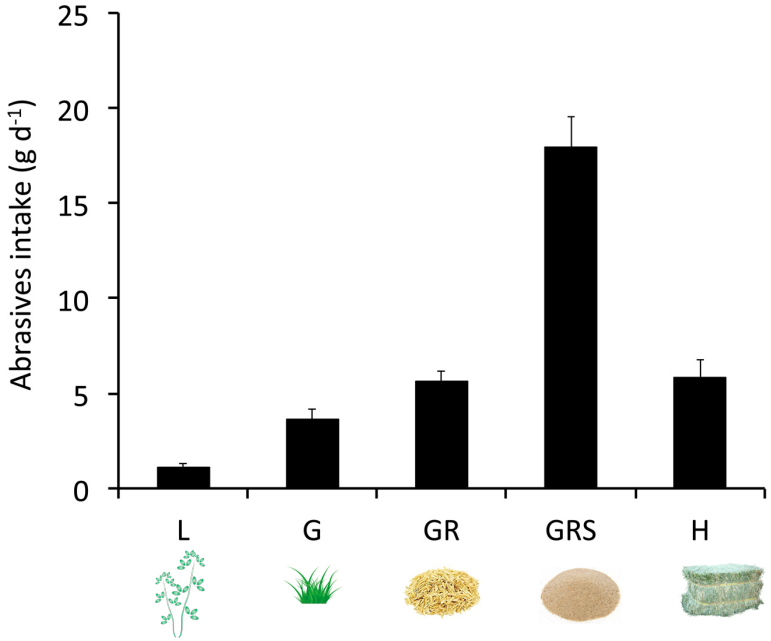
Growth and Wear of Incisor and Cheek Teeth in Domestic Rabbits (*Oryctolagus cuniculus*) Fed Diets of Different Abrasiveness

JOURNAL OF EXPERIMENTAL ZOOLOGY
PART A
ECOLOGICAL GENETICS AND PHYSIOLOGY
A Journal of Integrative Biology

JACQUELINE MÜLLER[1], MARCUS CLAUSS[1]*, DARYL CODRON[1,2], ELLEN SCHULZ[3], JÜRGEN HUMMEL[4], MIKAEL FORTELIUS[5], PATRICK KIRCHER[6], AND JEAN-MICHEL HATT[1]

J. Exp. Zool. 321A:283–298, 2014





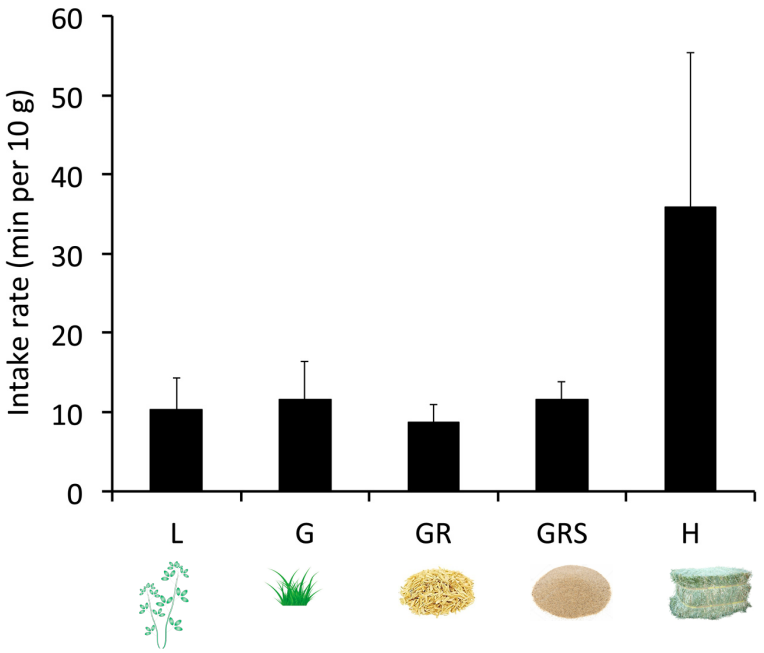
RESEARCH ARTICLE

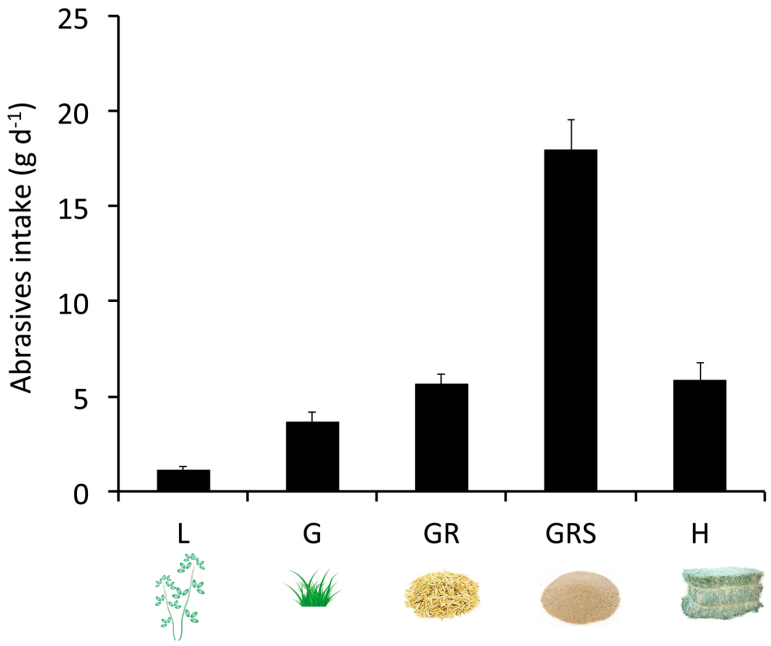
Growth and Wear of Incisor and Cheek Teeth in Domestic Rabbits (*Oryctolagus cuniculus*) Fed Diets of Different Abrasiveness

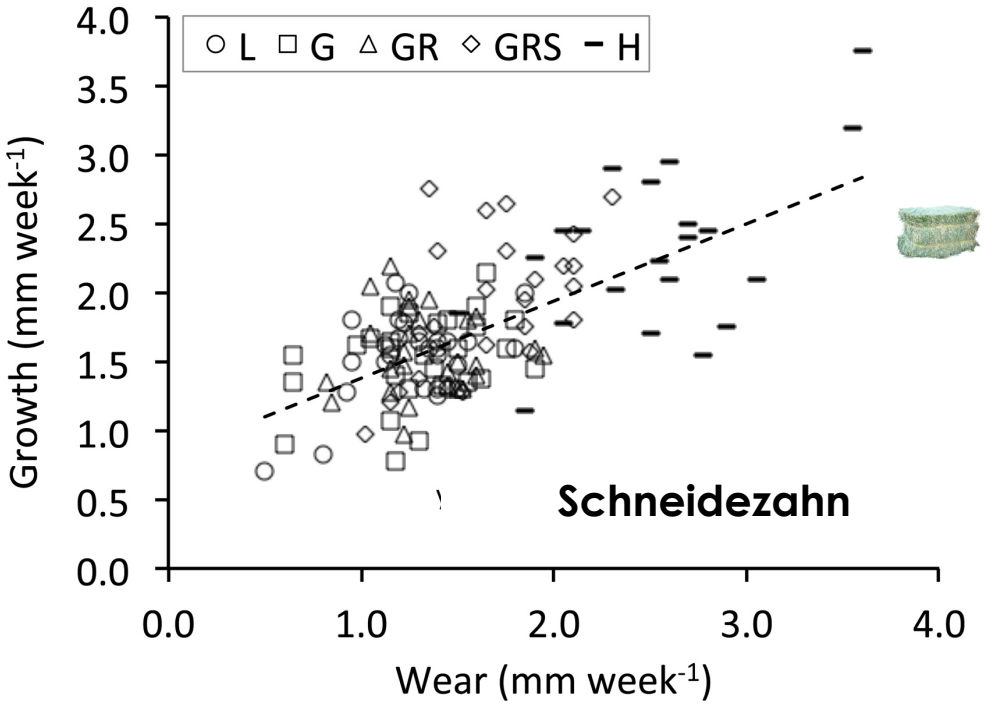
JOURNAL OF EXPERIMENTAL ZOOLOGY PART A ECOLOGICAL GENETICS AND PHYSIOLOGY
A Journal of Integrative Biology

JACQUELINE MÜLLER[1], MARCUS CLAUSS[1]*, DARYL CODRON[1,2], ELLEN SCHULZ[3], JÜRGEN HUMMEL[4], MIKAEL FORTELIUS[5], PATRICK KIRCHER[6], AND JEAN-MICHEL HATT[1]

J. Exp. Zool. 321A:283–298, 2014







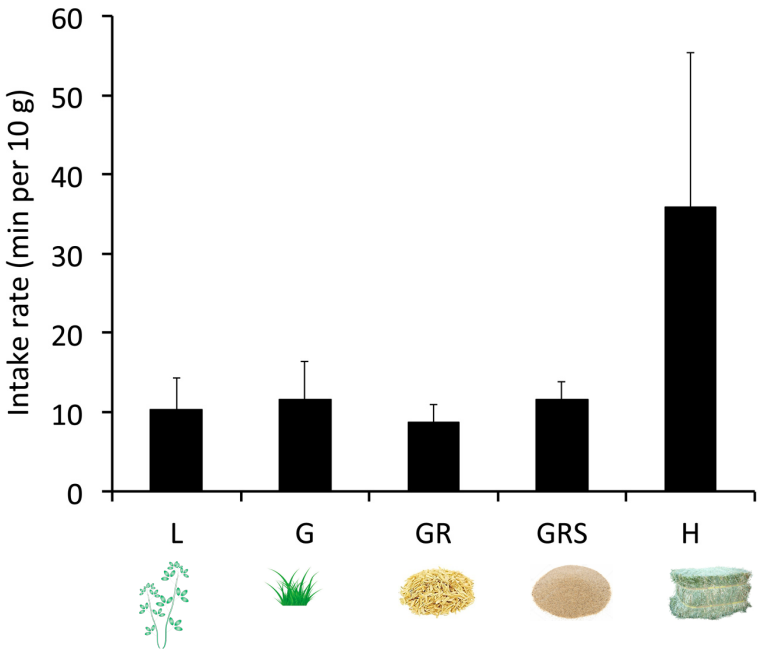
RESEARCH ARTICLE

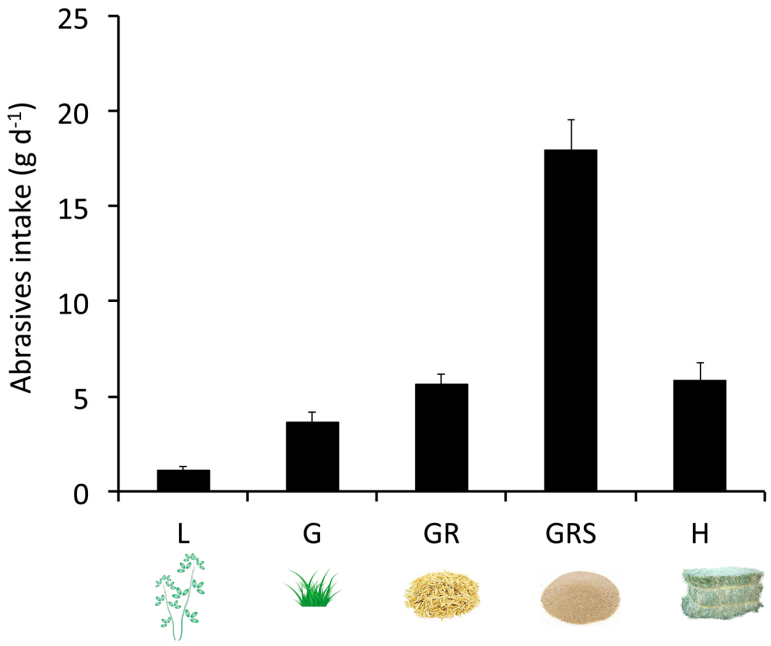
Growth and Wear of Incisor and Cheek Teeth in Domestic Rabbits (*Oryctolagus cuniculus*) Fed Diets of Different Abrasiveness

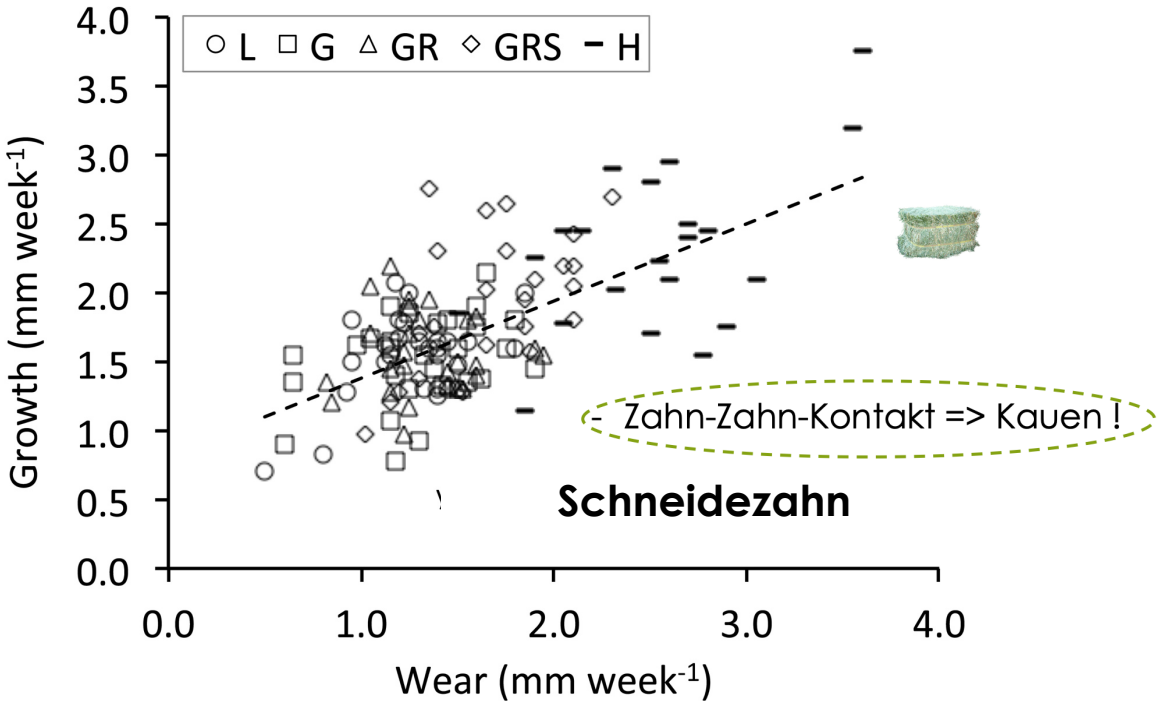
JOURNAL OF EXPERIMENTAL ZOOLOGY PART A ECOLOGICAL GENETICS AND PHYSIOLOGY
A Journal of Integrative Biology

JACQUELINE MÜLLER[1], MARCUS CLAUSS[1]*, DARYL CODRON[1,2], ELLEN SCHULZ[3], JÜRGEN HUMMEL[4], MIKAEL FORTELIUS[5], PATRICK KIRCHER[6], AND JEAN-MICHEL HATT[1]

J. Exp. Zool. 321A:283–298, 2014







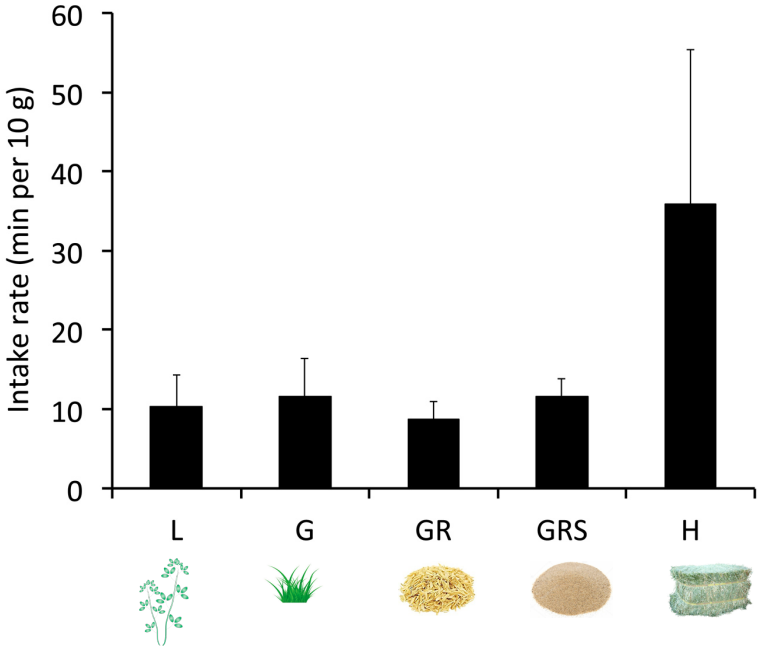
RESEARCH ARTICLE

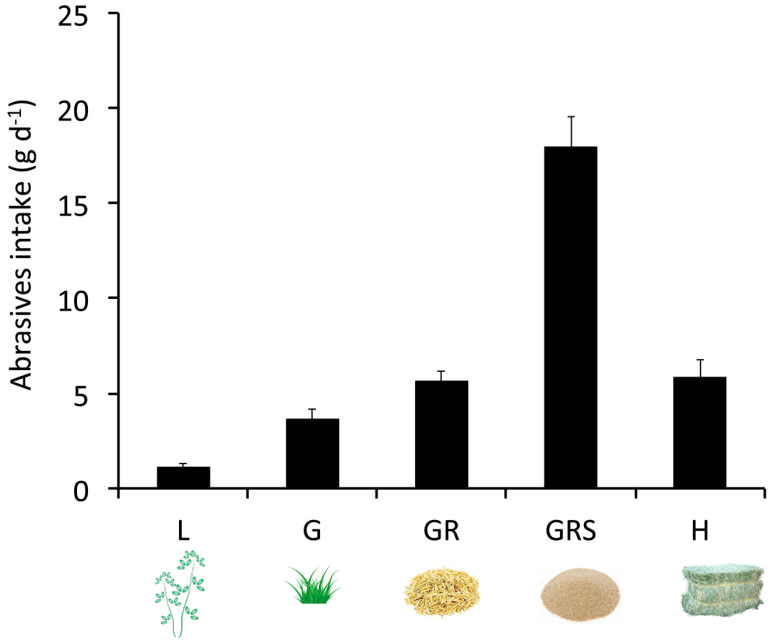
Growth and Wear of Incisor and Cheek Teeth in Domestic Rabbits (*Oryctolagus cuniculus*) Fed Diets of Different Abrasiveness

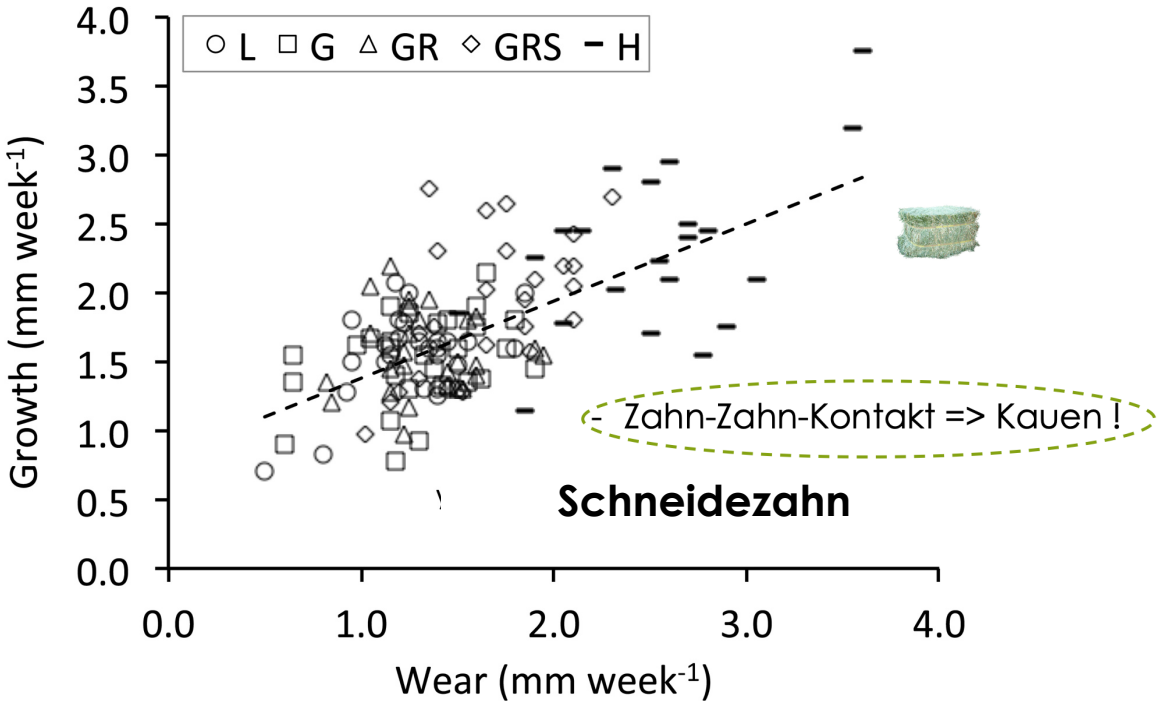
JOURNAL OF EXPERIMENTAL ZOOLOGY PART A ECOLOGICAL GENETICS AND PHYSIOLOGY
A Journal of Integrative Biology

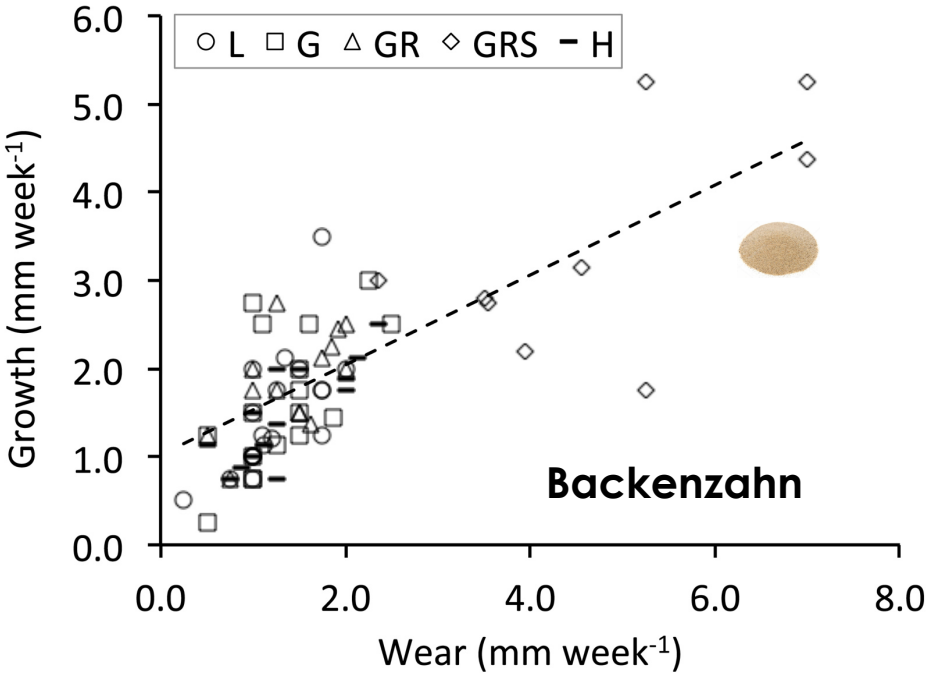
JACQUELINE MÜLLER[1], MARCUS CLAUSS[1]*, DARYL CODRON[1,2], ELLEN SCHULZ[3], JÜRGEN HUMMEL[4], MIKAEL FORTELIUS[5], PATRICK KIRCHER[6], AND JEAN-MICHEL HATT[1]

J. Exp. Zool. 321A:283–298, 2014









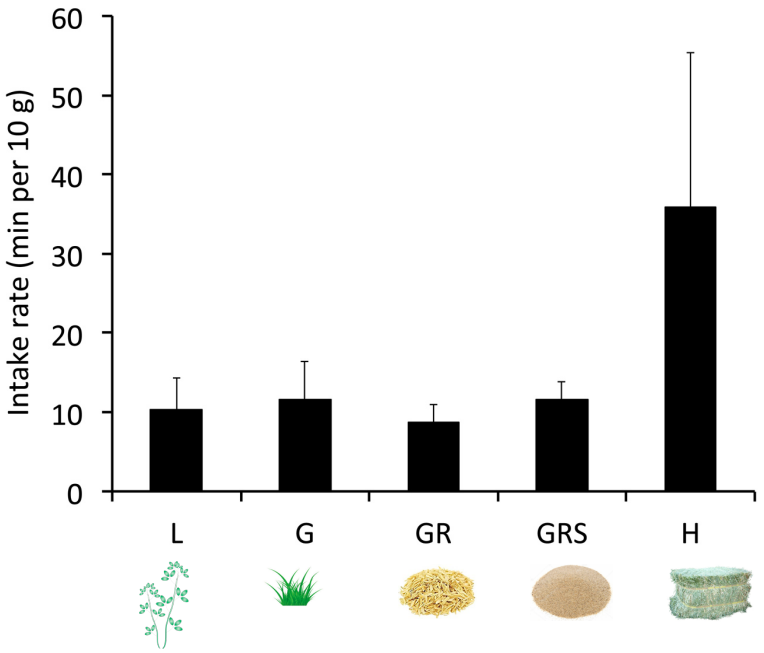
RESEARCH ARTICLE

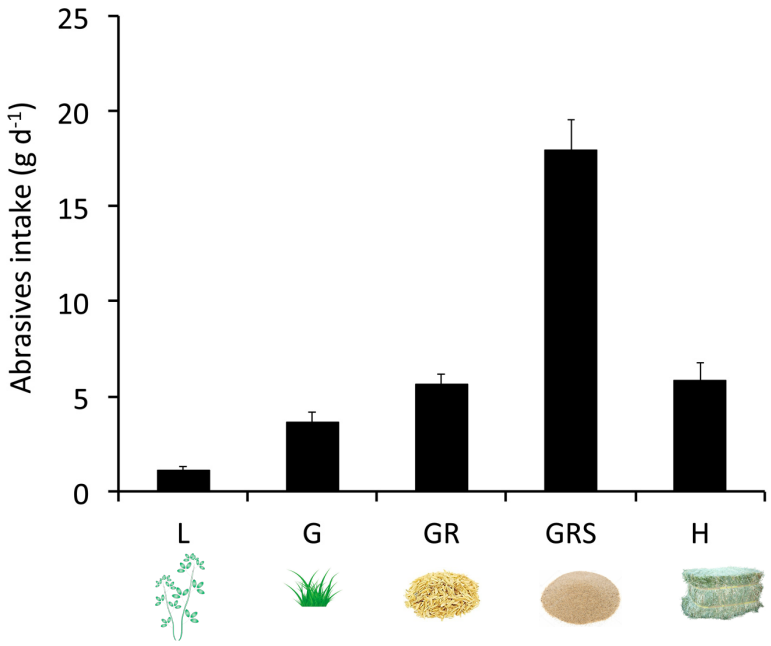
Growth and Wear of Incisor and Cheek Teeth in Domestic Rabbits (*Oryctolagus cuniculus*) Fed Diets of Different Abrasiveness

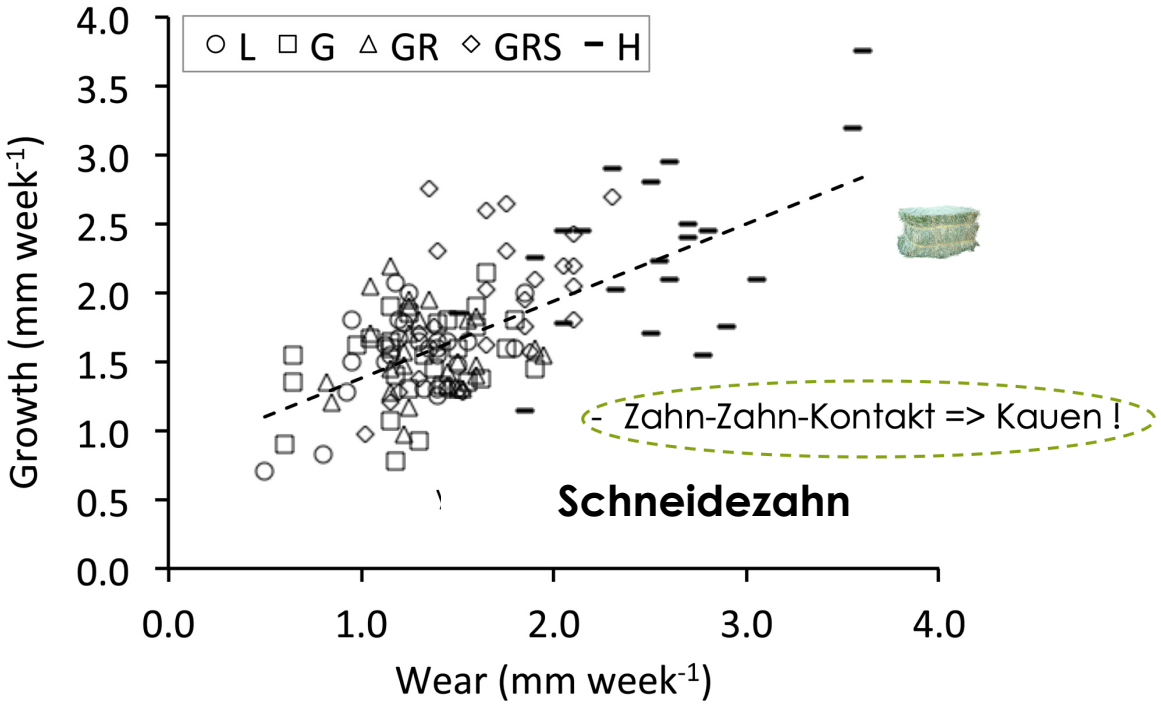
JOURNAL OF EXPERIMENTAL ZOOLOGY PART A ECOLOGICAL GENETICS AND PHYSIOLOGY
A Journal of Integrative Biology

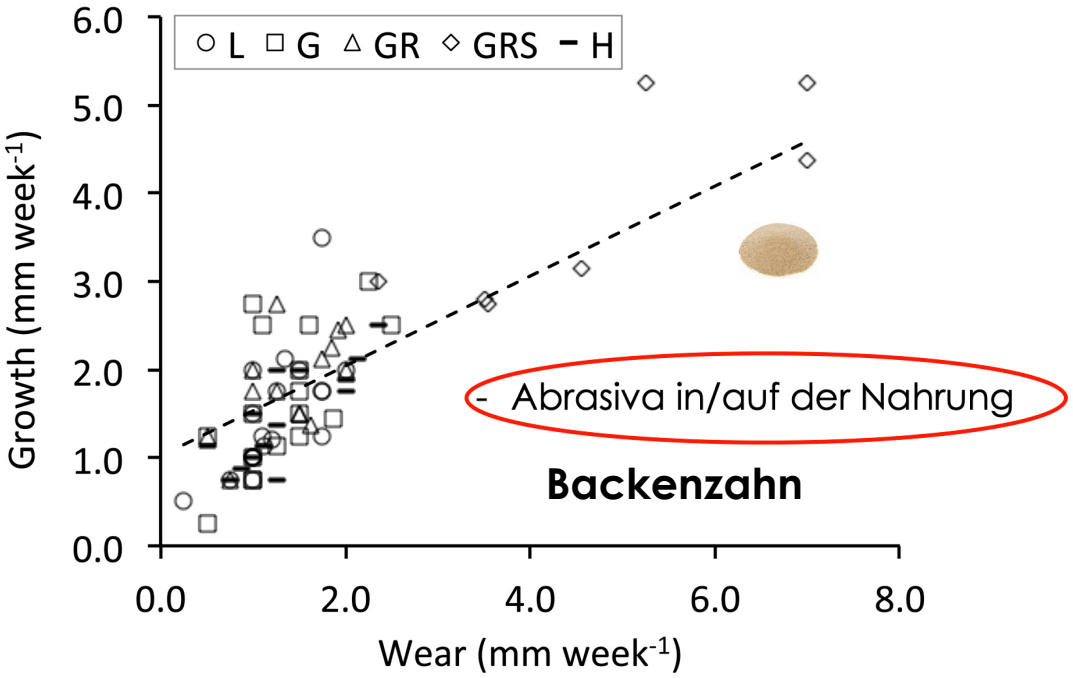
JACQUELINE MÜLLER[1], MARCUS CLAUSS[1]*, DARYL CODRON[1,2], ELLEN SCHULZ[3], JÜRGEN HUMMEL[4], MIKAEL FORTELIUS[5], PATRICK KIRCHER[6], AND JEAN-MICHEL HATT[1]

J. Exp. Zool. 321A:283–298, 2014









Lesen hilft

DIE REGULATIONEN DER NAGETIERSCHNEIDEZÄHNE.

Von

GEORG WETZEL,

(Eingegangen am 7. August 1927.)

DIE REGULATIONEN DER NAGETIERSCHNEIDEZÄHNE.

Von

GEORG WETZEL,

(Eingegangen am 7. August 1927.)

Ein durch Absägen gekürzter und nicht artikulierender unterer oder oberer Kaninchenschneidezahn zeigt eine um mehr als die Hälfte bis fast auf das Doppelte gesteigerte Wachstumsgeschwindigkeit.

Die normale Länge der Kaninchenschneidezähne wird in gesundem und durch Eingriffe nicht beeinflußtem Zustand durch ihre Betätigung beim Kau- und Nagegeschäft geregelt.

ÜBER DAS WACHSTUM DER KANINCHENSCHNEIDEZÄHNE UNTER VERSCHIEDENEN FUNKTIONSBEDINGUNGEN UND IHR TELEOLOGISCHES VERHALTEN.

WERNER MITTAG,

(Eingegangen am 28. Dezember 1931.)

ÜBER DAS WACHSTUM DER KANINCHENSCHNEIDEZÄHNE UNTER VERSCHIEDENEN FUNKTIONSBEDINGUNGEN UND IHR TELEOLOGISCHES VERHALTEN.

WERNER MITTAG,

(Eingegangen am 28. Dezember 1931.)

1. Bei Hartfütterung werden die Kaninchenschneidezähne stark abgenutzt; sie zeigen dabei einen bedeutenden täglichen Zuwachs. Bei Weichfütterung ist die Abnutzung und damit auch der Zuwachs gering.

ÜBER DAS WACHSTUM DER KANINCHENSCHNEIDEZÄHNE UNTER VERSCHIEDENEN FUNKTIONSBEDINGUNGEN UND IHR TELEOLOGISCHES VERHALTEN.

WERNER MITTAG,

(Eingegangen am 28. Dezember 1931.)

1. Bei Hartfütterung werden die Kaninchenschneidezähne stark abgenutzt; sie zeigen dabei einen bedeutenden täglichen Zuwachs. Bei Weichfütterung ist die Abnutzung und damit auch der Zuwachs gering.

3. Die tägliche Wachstumsgeschwindigkeit der Schneidezähne ist abhängig von dem Grade ihrer Benutzung und wird geregelt von dem jeweiligen Druck, welchem die Zähne ausgesetzt sind.

The Effect of Intermittent Forces on Eruption of the Rabbit Incisor

J Dent Res 65(2):118–122, February, 1986

W.R. PROFFIT and K.T. SELLERS

The Effect of Intermittent Forces on Eruption of the Rabbit Incisor

J Dent Res 65(2):118–122, February, 1986

W.R. PROFFIT and K.T. SELLERS

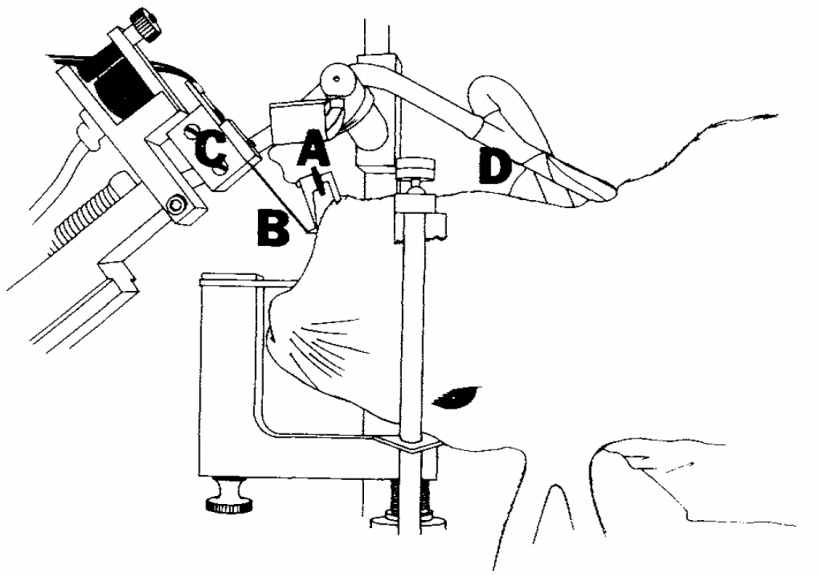


Fig. 1 — Line drawing showing a rabbit prepared for an eruption experiment. The plates of a VCDT (A) are mounted on the mandible and the erupting tooth. A cantilever-beam strain-gauge transducer (B) is mounted on a relay-controlled platform (C) so that it can be moved into and out of contact with the incisor, allowing for intermittent force application. The tracheostomy tube (D) is connected to a respirator.

The Effect of Intermittent Forces on Eruption of the Rabbit Incisor

J Dent Res 65(2):118–122, February, 1986

W.R. PROFFIT and K.T. SELLERS

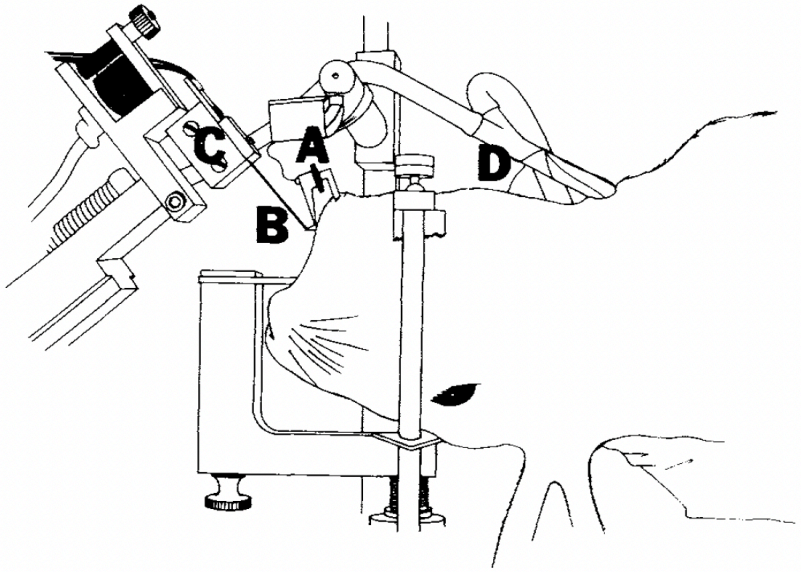


Fig. 1 — Line drawing showing a rabbit prepared for an eruption experiment. The plates of a VCDT (A) are mounted on the mandible and the erupting tooth. A cantilever-beam strain-gauge transducer (B) is mounted on a relay-controlled platform (C) so that it can be moved into and out of contact with the incisor, allowing for intermittent force application. The tracheostomy tube (D) is connected to a respirator.

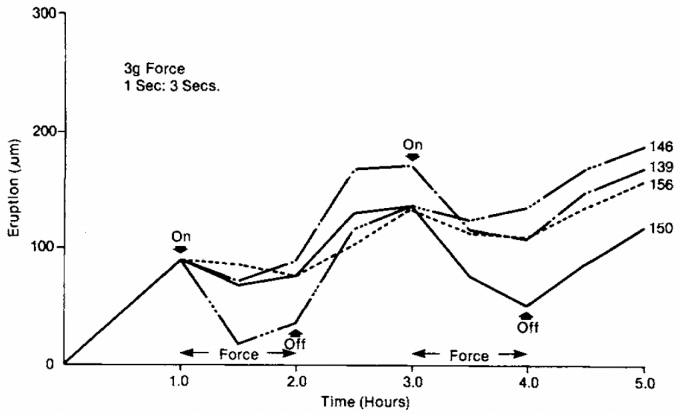


Fig. 8 — Effect of a three-g force applied one second on, three seconds off.

The Effect of Intermittent Forces on Eruption of the Rabbit Incisor

J Dent Res 65(2):118–122, February, 1986

W.R. PROFFIT and K.T. SELLERS

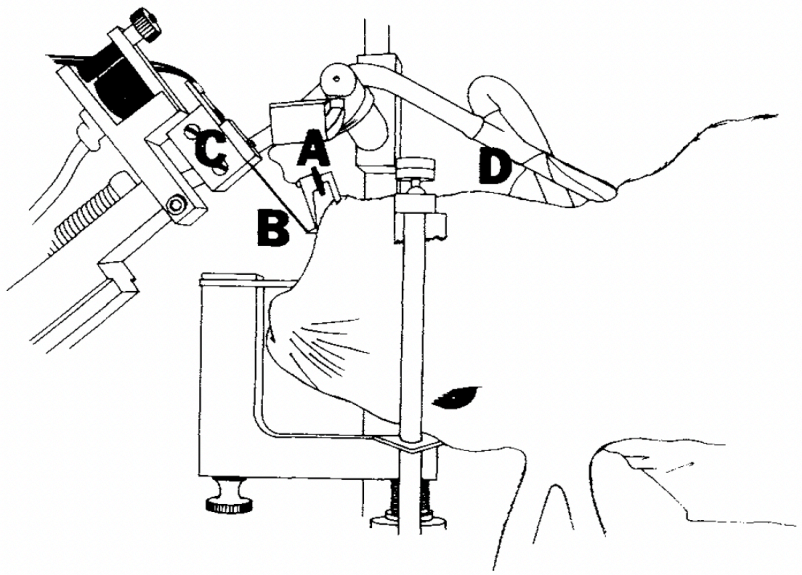


Fig. 1 — Line drawing showing a rabbit prepared for an eruption experiment. The plates of a VCDT (A) are mounted on the mandible and the erupting tooth. A cantilever-beam strain-gauge transducer (B) is mounted on a relay-controlled platform (C) so that it can be moved into and out of contact with the incisor, allowing for intermittent force application. The tracheostomy tube (D) is connected to a respirator.

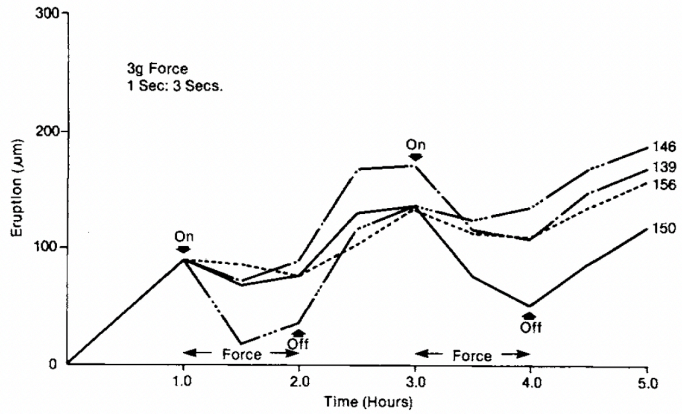


Fig. 8 — Effect of a three-g force applied one second on, three seconds off.

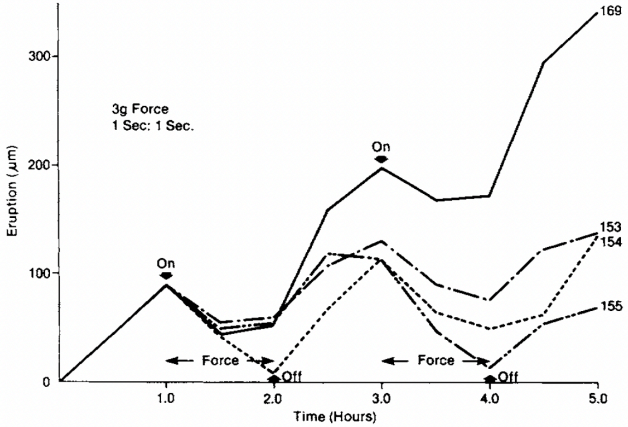
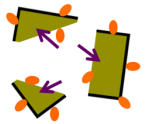


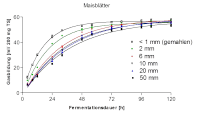
Fig. 6 — Effect of a 3-g force applied one second on, one second off.

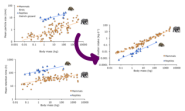
Zusammenfassung

Zusammenfassung

Verdauung und Partikelgrösse

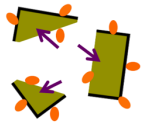


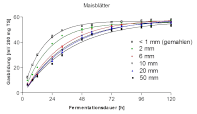


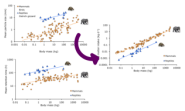


Zusammenfassung

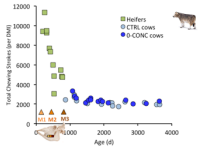
Verdauung und Partikelgrösse

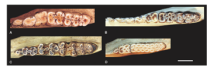






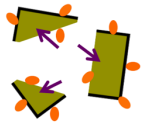
Zahnoptimierung: Kauleistenverlängerung

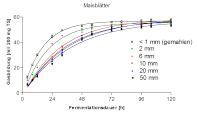


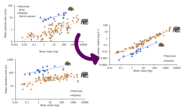


Zusammenfassung

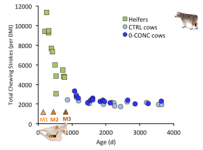
Verdauung und Partikelgrösse

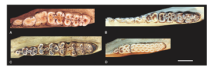






Zahnoptimierung: Kauleistenverlängerung



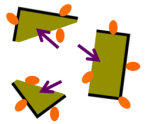


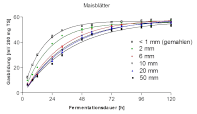
Zahnabrieb: intrinsische und extrinsische Faktoren

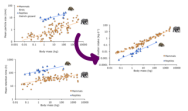
- Zahn-Zahn-Kontakt => Kauen !
- Abrasiva in/auf der Nahrung

Zusammenfassung

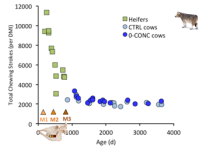
Verdauung und Partikelgrösse

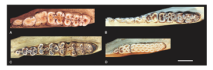






Zahnoptimierung: Kauleistenverlängerung





Zahnabrieb: intrinsische und extrinsische Faktoren

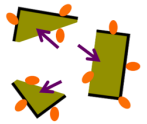
Zahn-Zahn-Kontakt => Kauen !

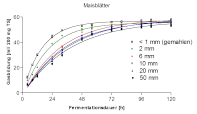
Abrasiva in/auf der Nahrung

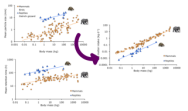
Zahnoptimierung: Vermeidung von Kontakten

Zusammenfassung

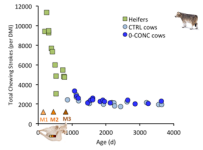
Verdauung und Partikelgrösse

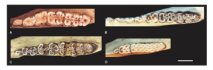






Zahnoptimierung: Kauleistenverlängerung





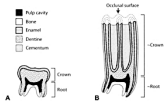
Zahnabrieb: intrinsische und extrinsische Faktoren

Zahn-Zahn-Kontakt => Kauen !

Abrasiva in/auf der Nahrung

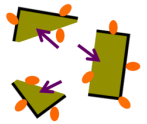
Zahnoptimierung: Vermeidung von Kontakten

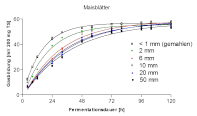
Zahnoptimierung: höhere Zahnkronen

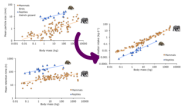


Zusammenfassung

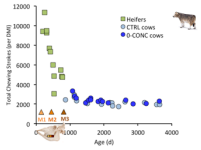
Verdauung und Partikelgrösse







Zahnoptimierung: Kauleistenverlängerung



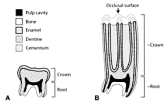
Zahnabrieb: intrinsische und extrinsische Faktoren

Zahn-Zahn-Kontakt => Kauen !

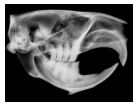
Abrasiva in/auf der Nahrung

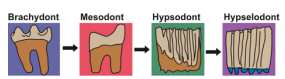
Zahnoptimierung: Vermeidung von Kontakten

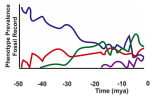
Zahnoptimierung: höhere Zahnkronen

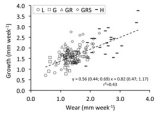


Zahnoptimierung: kontinuierliches Wachstum



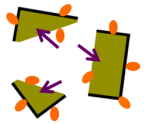


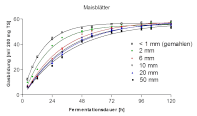


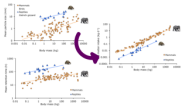


Zusammenfassung

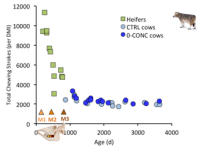
Verdauung und Partikelgrösse

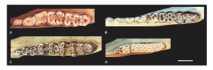






Zahnoptimierung: Kauleistenverlängerung





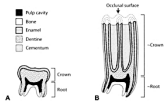
Zahnabrieb: intrinsische und extrinsische Faktoren

Zahn-Zahn-Kontakt => Kauen !

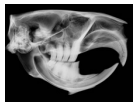
Abrasiva in/auf der Nahrung

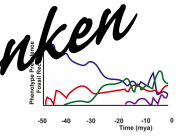
Zahnoptimierung: Vermeidung von Kontakten

Zahnoptimierung: höhere Zahnkronen

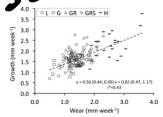


Zahnoptimierung: kontinuierliches Wachstum



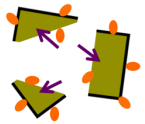


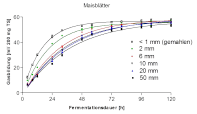
immer selber denken

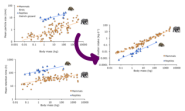


Zusammenfassung

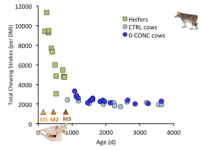
Verdauung und Partikelgrösse

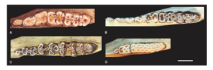






Zahnoptimierung: Kauleistenverlängerung





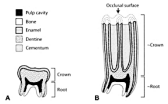
Zahnabrieb: intrinsische und extrinsische Faktoren

Zahn-Zahn-Kontakt => Kauen !

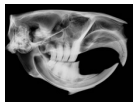
Abrasiva in/auf der Nahrung

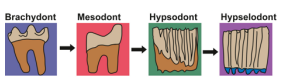
Zahnoptimierung: Vermeidung von Kontakten

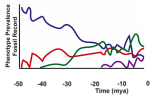
Zahnoptimierung: höhere Zahnkronen

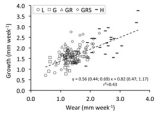


Zahnoptimierung: kontinuierliches Wachstum







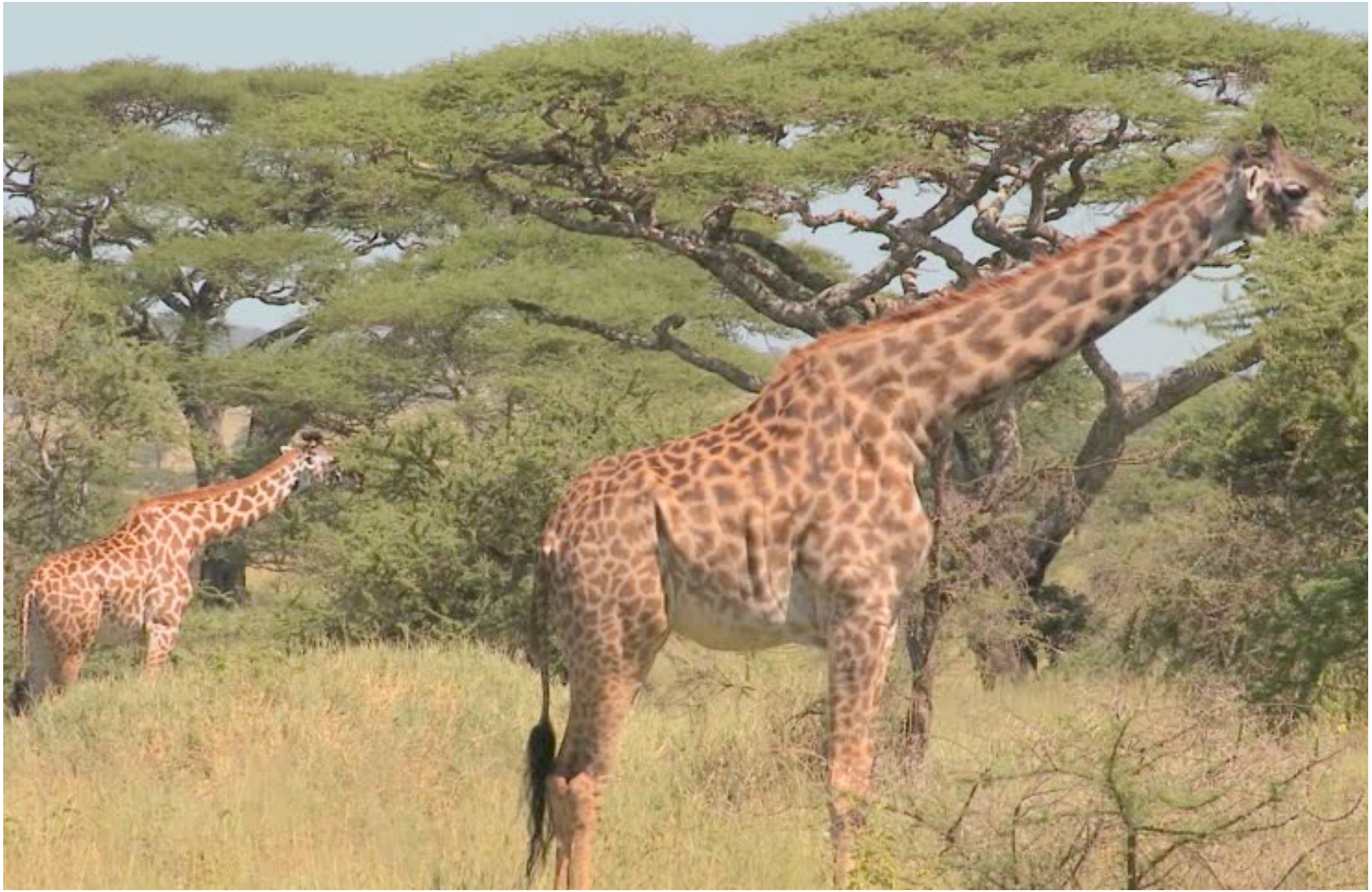


(Zahnabrieb im Zoo)

vielen Dank für Ihre Aufmerksamkeit

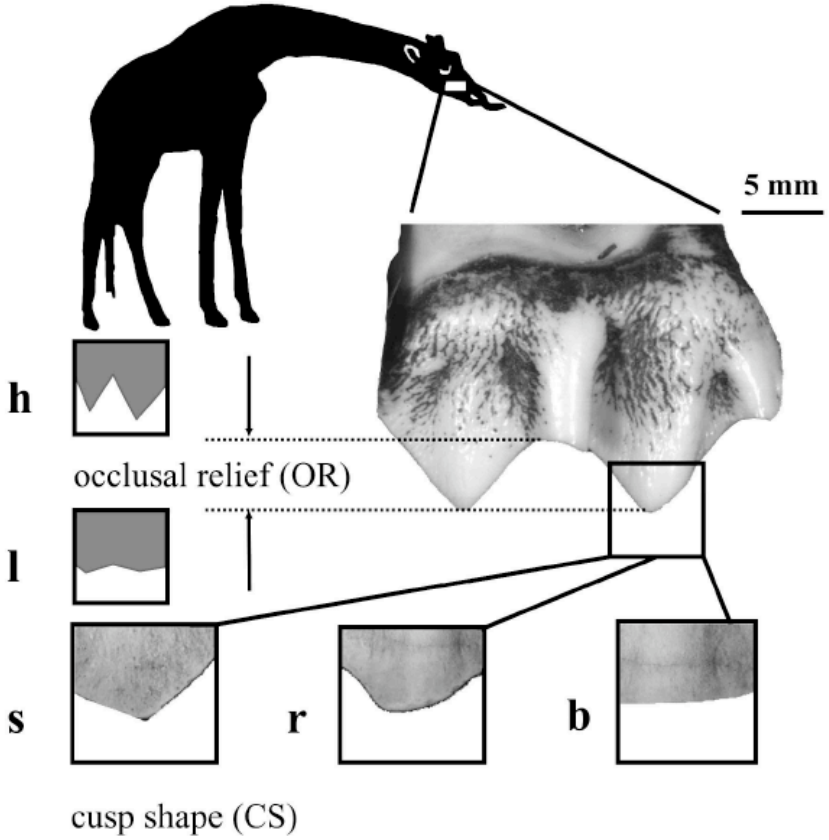
Schluss-Exkurs:

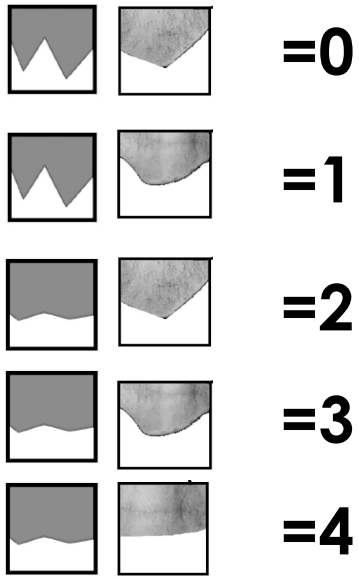
Zahnabrieb im Zoo




1911
2446 ♀.

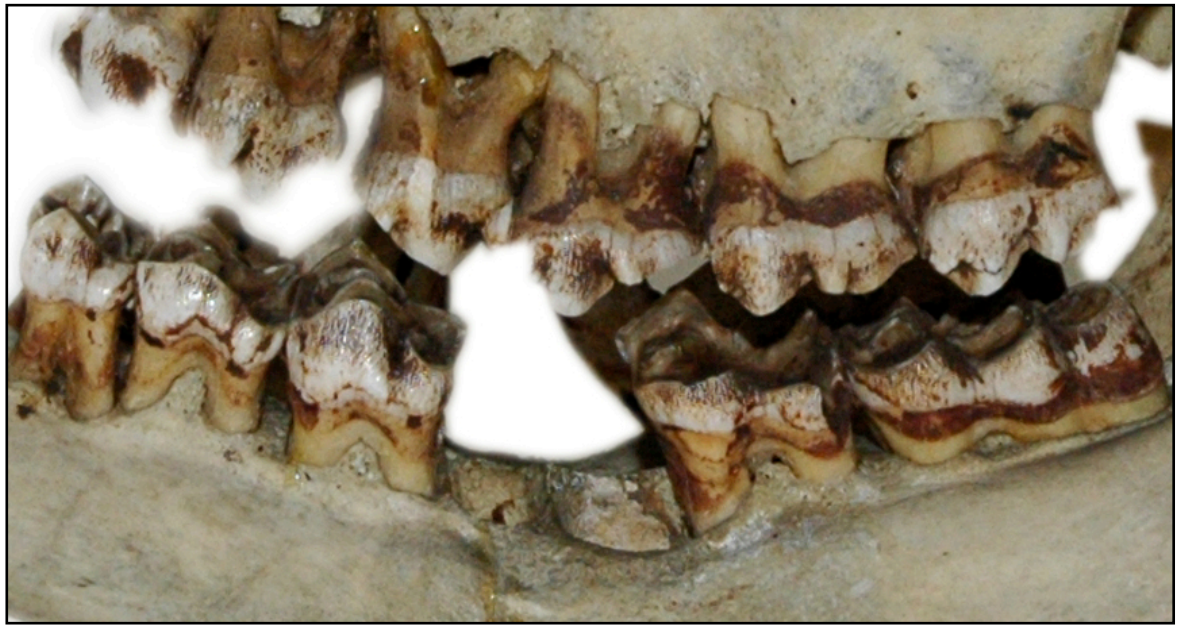

1911
1446 ♀.


5 mm
h
occlusal relief (OR)
l
s
r
b
cusp shape (CS)


=0
=1
=2
=3
=4


1911
1446 ♀.


Zool. Staats-Slg. München
1981/19 ♂
Giraffa camelo-pardalis reticulata
1981/19
♂
1981/19
reticulata
Giraffa camelopardalis
DeWindon 1897




♀
3 jähr.
1962/310
Alces a. alces (L., 1758)


Alces a. alces (L., 1758)


G.: Zoo Hellabrunn
17.2.1970