Digestive physiology and feeding behaviour of equids – a comparative approach

Marcus Clauss

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

Gent 2022

University of Zurich
Vetsuisse Faculty

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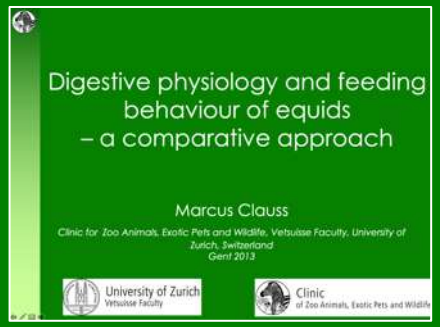

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Digestive physiology and feeding behaviour of equids – a comparative approach

… or
how horseshit
was replaced by bullshit
in evolutionary time

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Equid diversity and evolution

THE EVOLUTION OF THE HORSE. A RECORD AND ITS INTERPRETATION

By W. D. MATTHEW

The Quarterly Review of Biology, Vol. 1, No. 2 (Apr., 1926), pp. 139-185

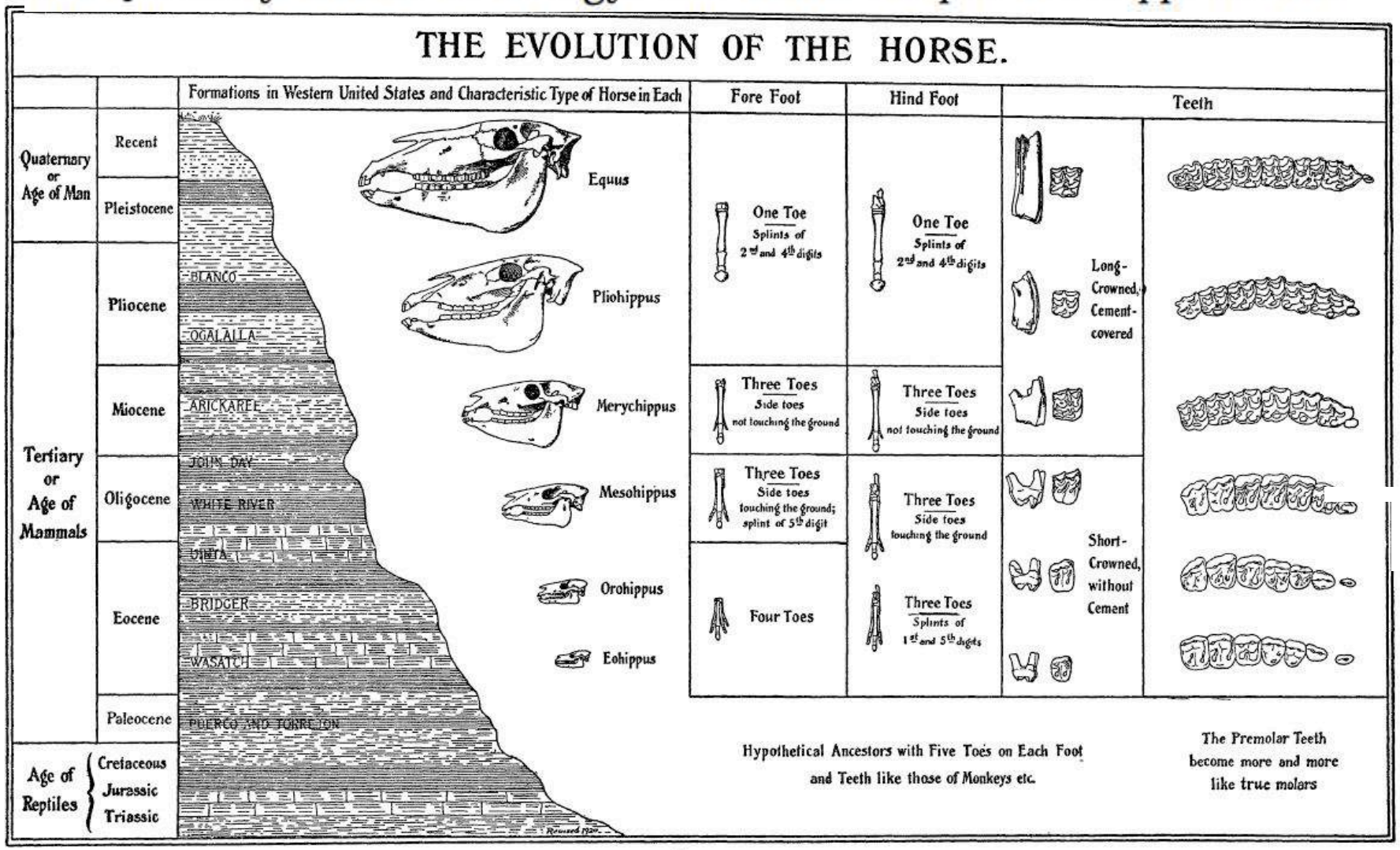

FIG. 27

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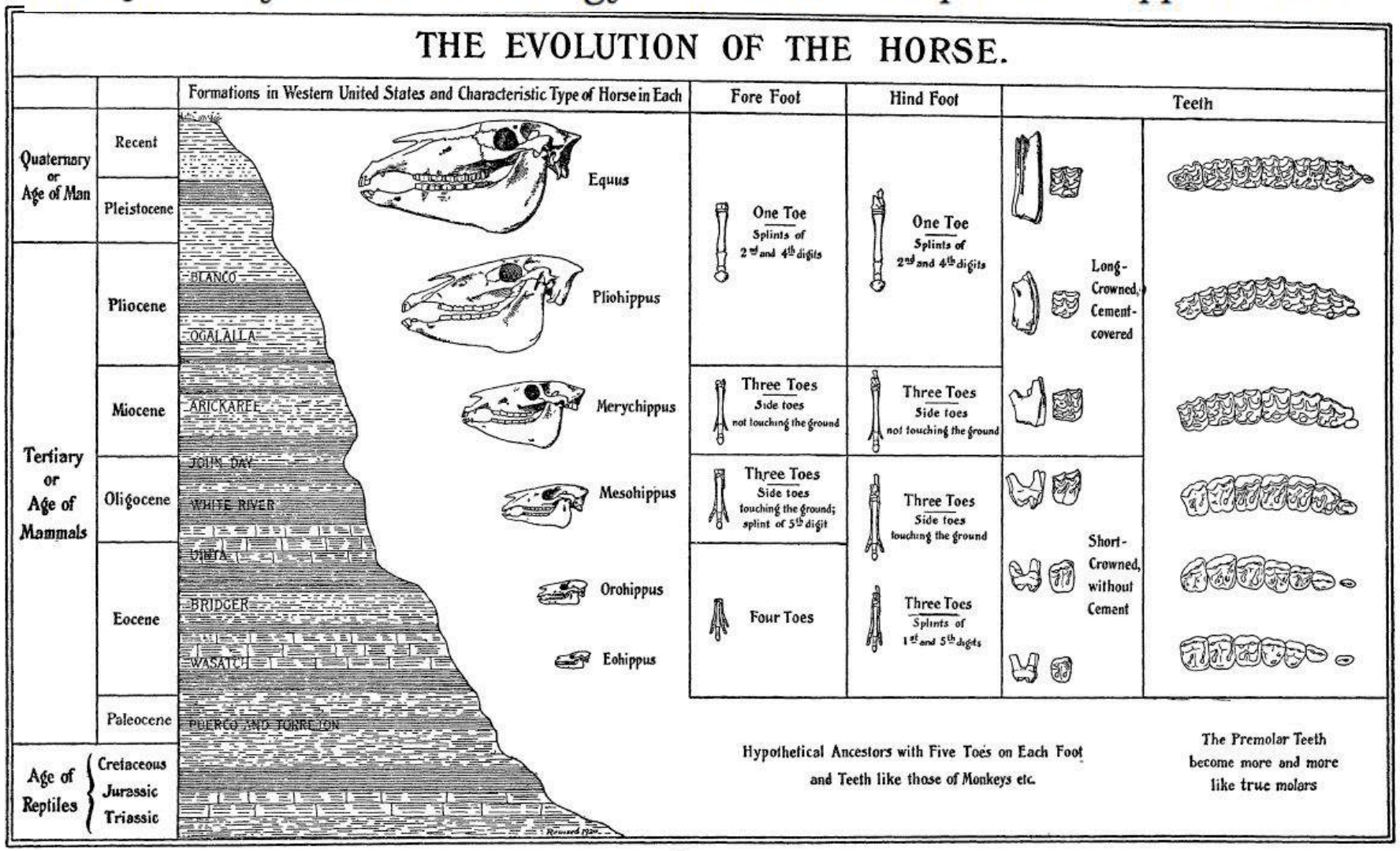
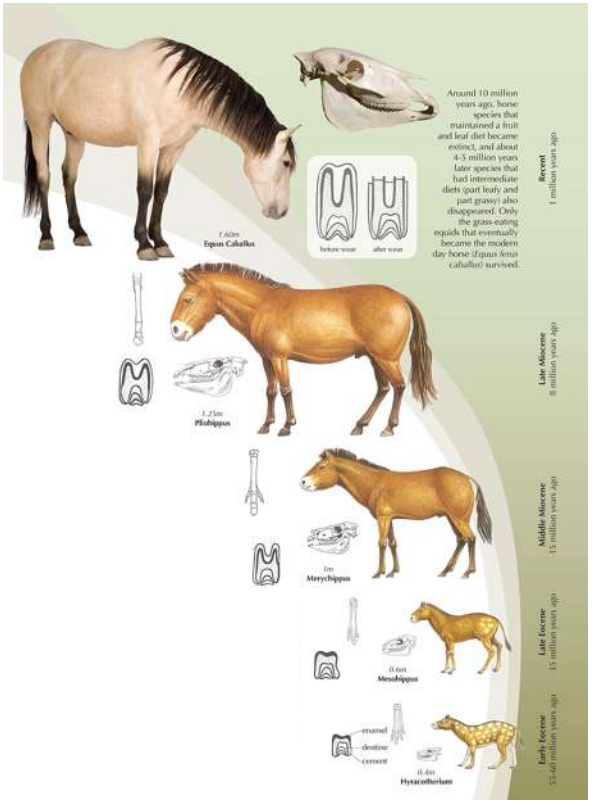


FIG. 27



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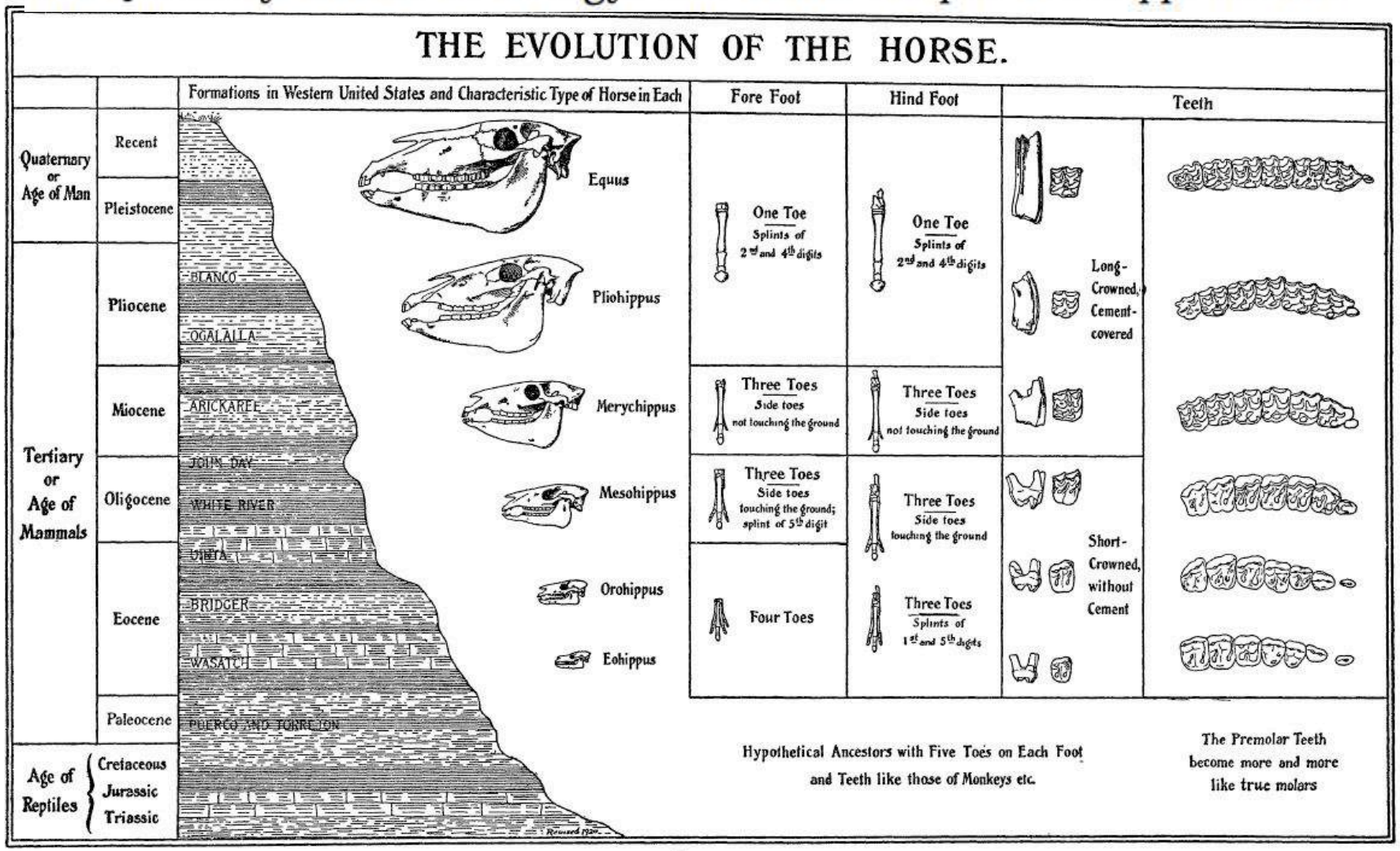
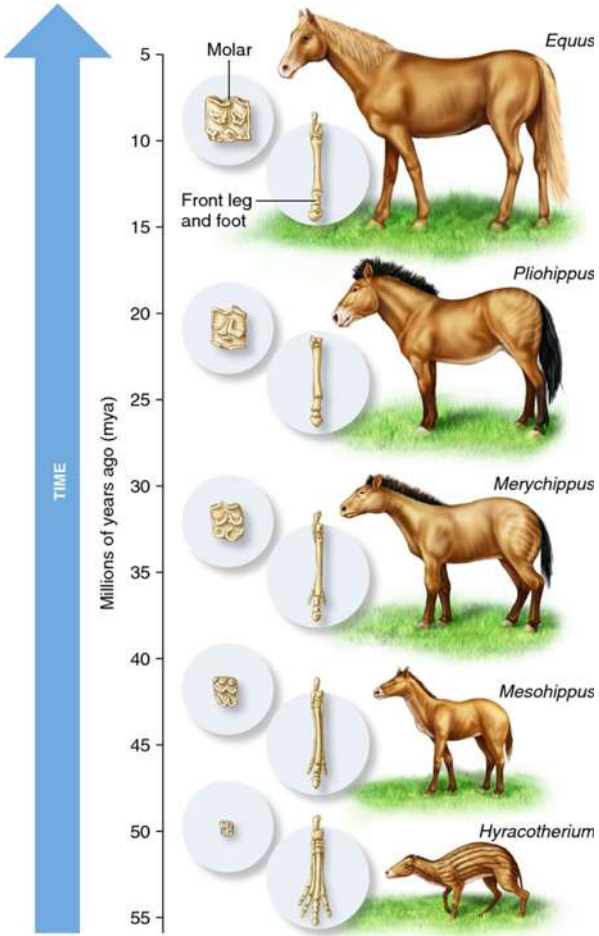
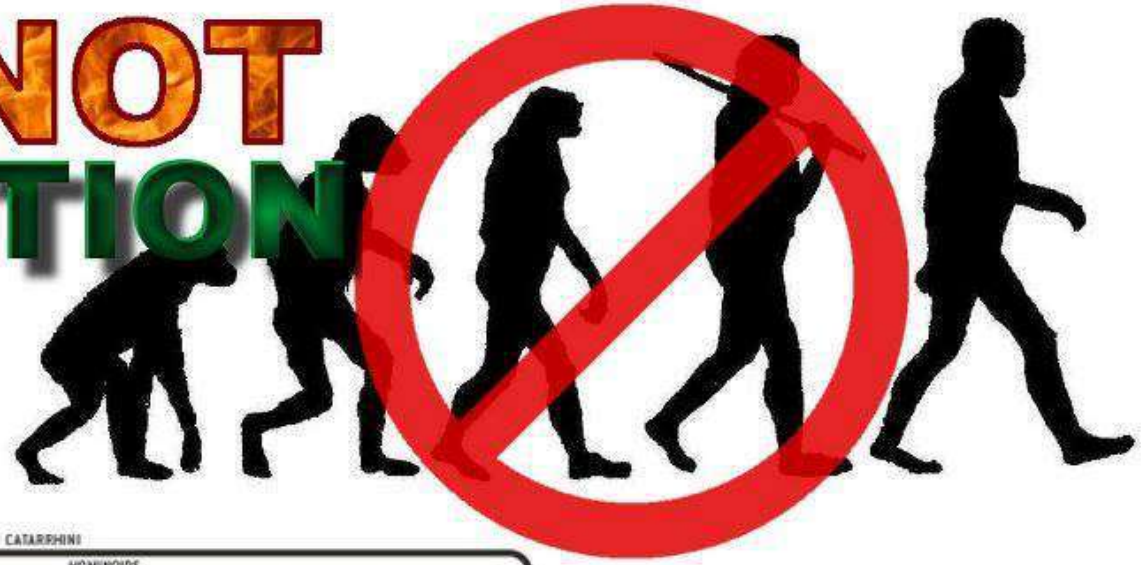


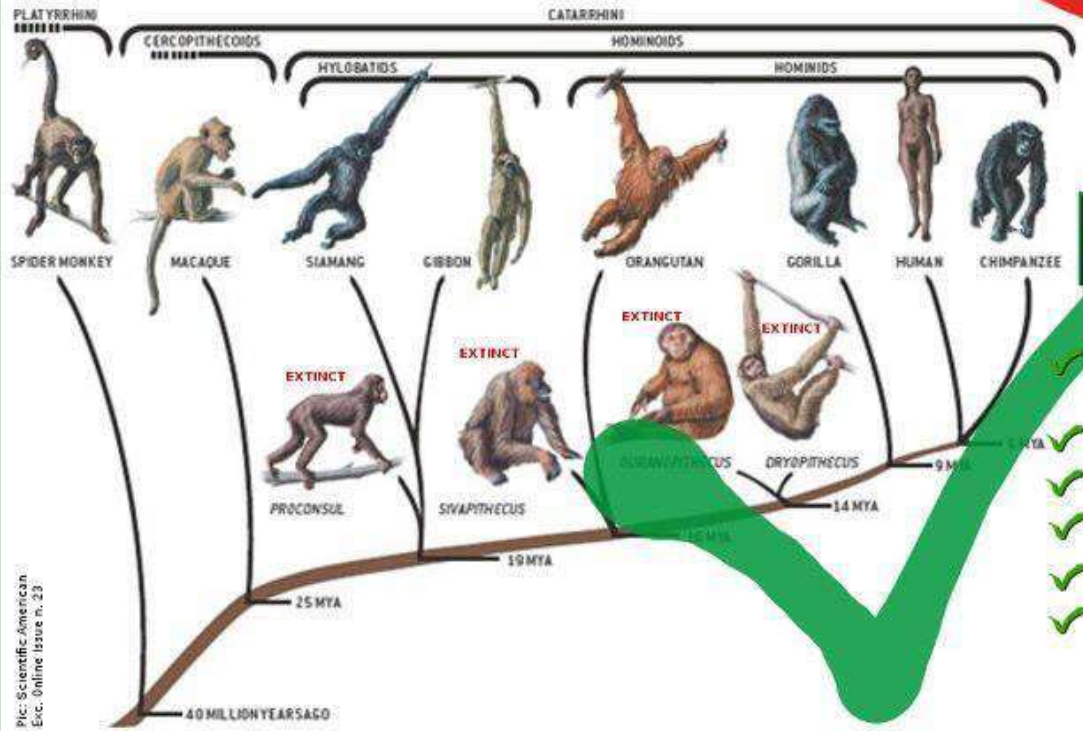
FIG. 27



THIS IS NOT EVOLUTION

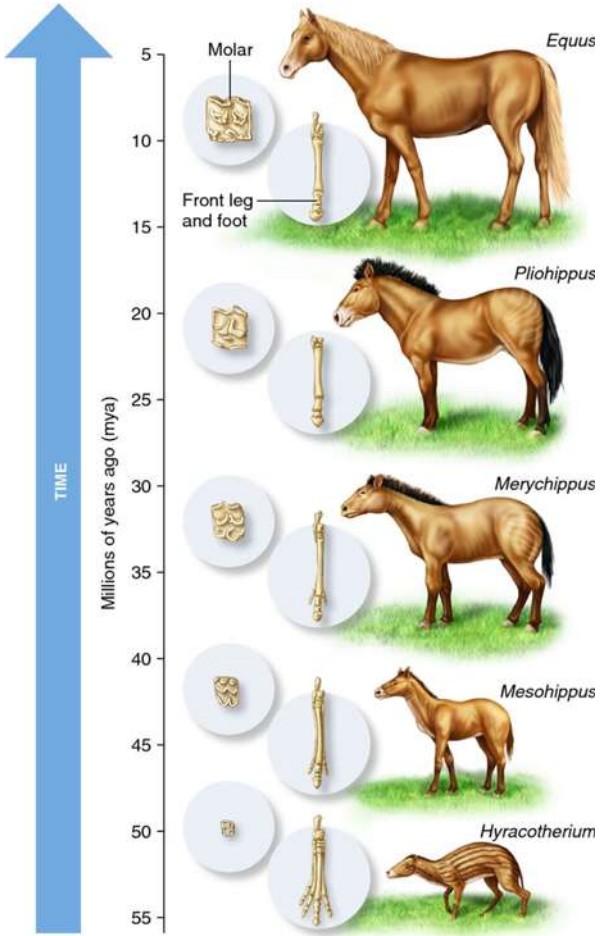


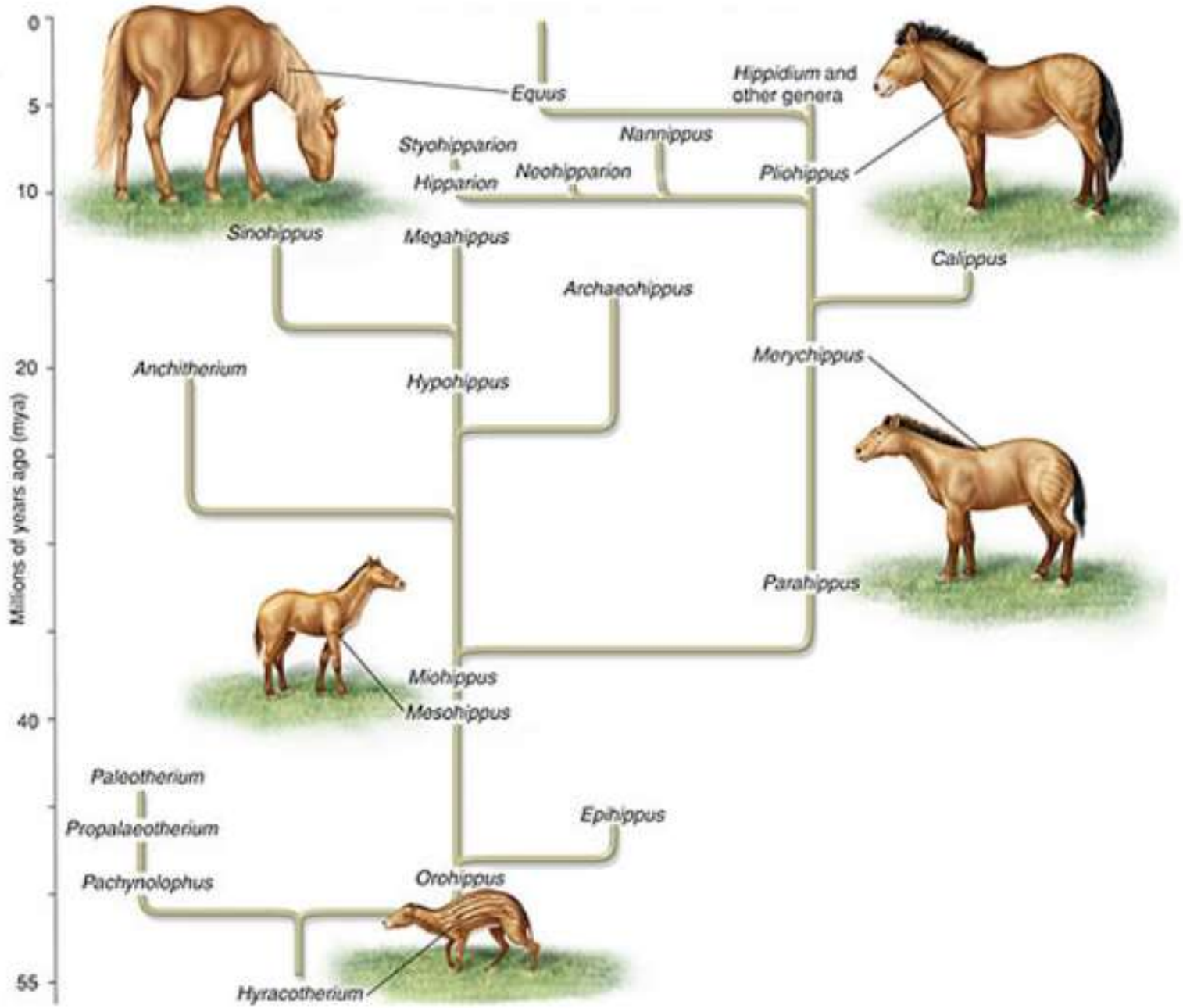
- This is *Scala Naturae*, an incorrect pre-evolutionary concept
- Suggests progress, not adaptation
- Human is a target, superior being
- Ancestor being resembles a chimp
- No branches or extinctions

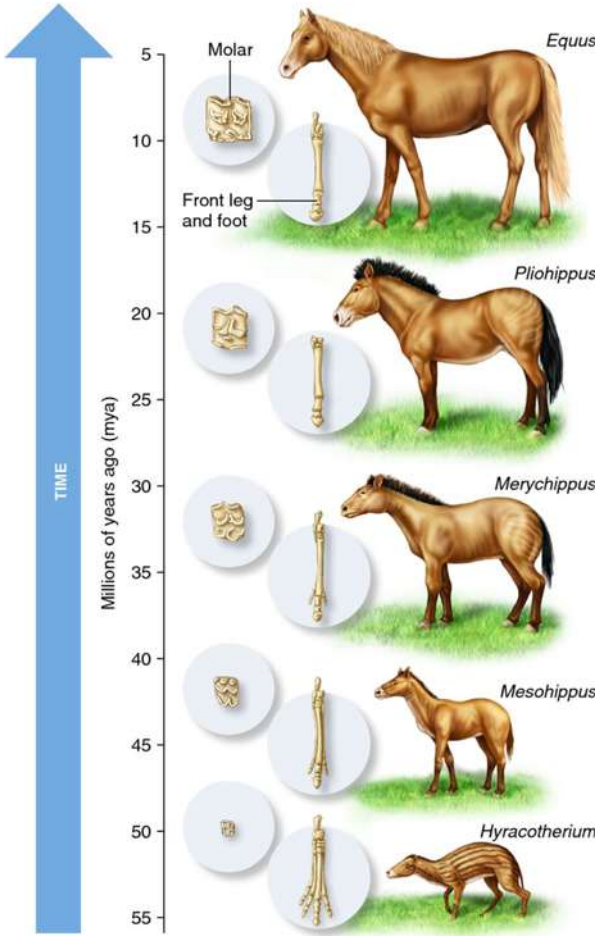


THIS IS EVOLUTION

- Humans are not special. Just a species, not superior, "more evolved" or a target.
- Some species become extinct (99% of them)
- Chimps are not portraited as ancestors
- Individual beings do not change. Populations do
- Ancestor species branches into other species
- Adaptations might lead to smaller size, loss of unused features and extinction

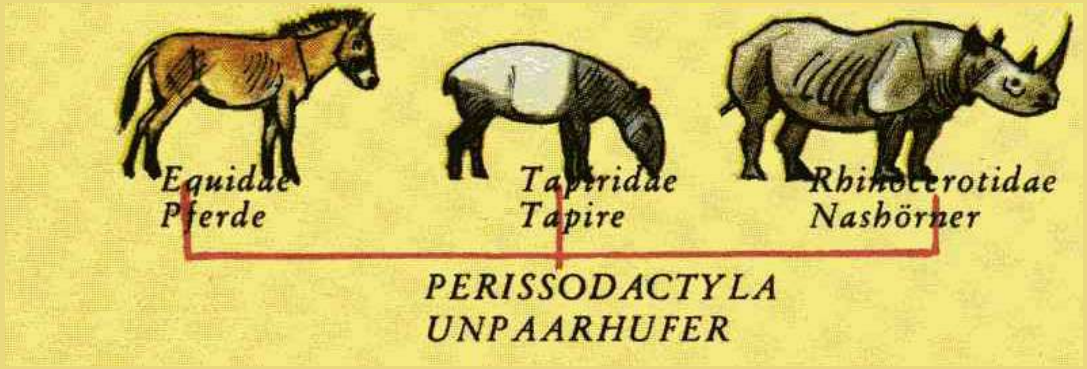



Millions of years ago (mya)
0
5
10
20
40
55
Equus
Hippidium and other genera
Nannippus
Stylohipparion
Hipparion
Neohipparion
Pliohippus
Sinohippus
Megahippus
Calippus
Archaeohippus
Merychippus
Anchitherium
Hypohippus
Parahippus
Miohippus
Mesohippus
Paleotherium
Propalaeotherium
Epihippus
Pachynolophus
Orohippus
Hyracotherium


TIME
Millions of years ago (mya)
5
10
15
20
25
30
35
40
45
50
55
Molar
Front leg and foot
Equus
Pliohippus
Merychippus
Mesohippus
Hyracotherium

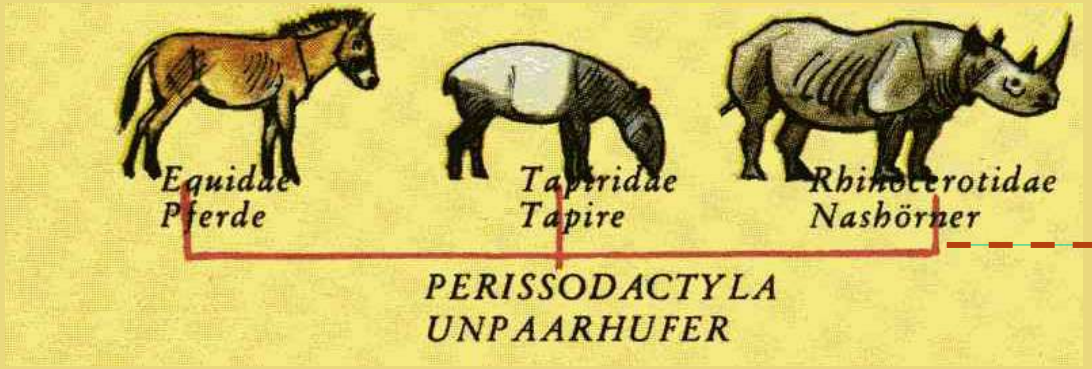
Large herbivore diversity in deep time: Perissodactyls

Large herbivore diversity in deep time: Perissodactyls



Large herbivore diversity in deep time: Perissodactyls

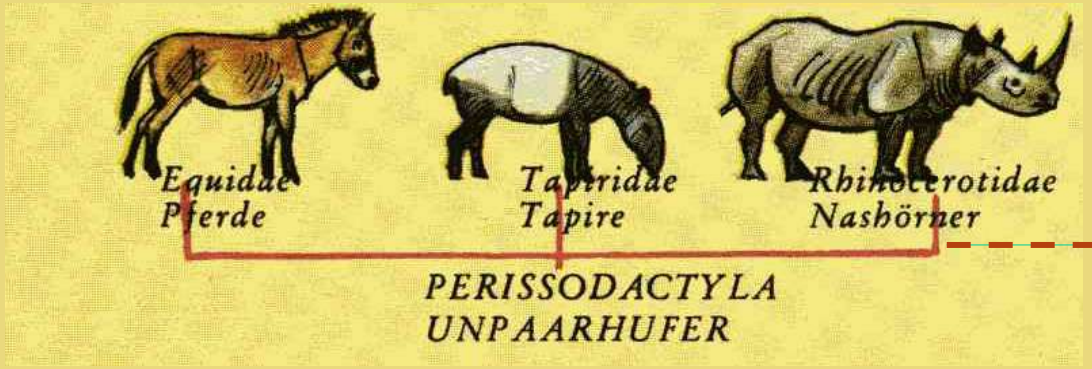
Chalicotheres



Large herbivore diversity in deep time: Perissodactyls

Brontotheres

Chalicotheres



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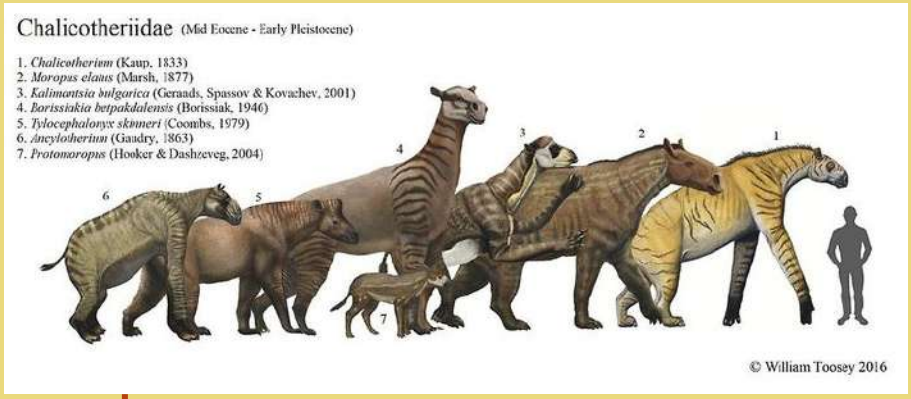
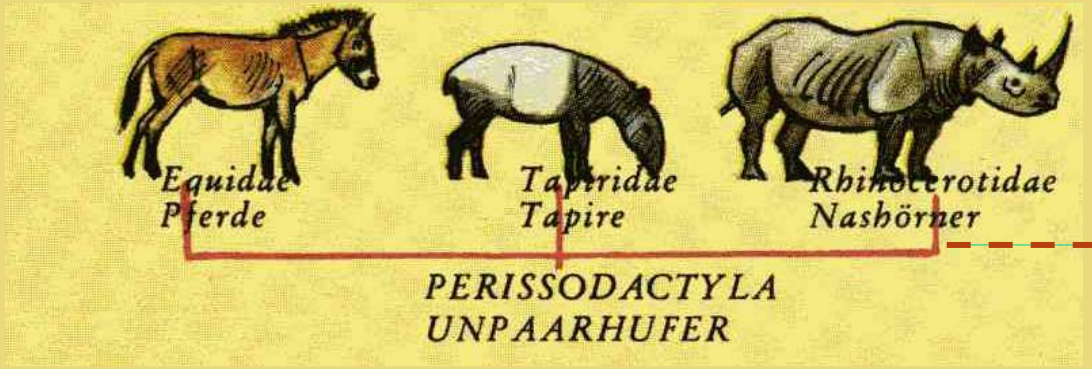


Brontotheres

Chalicotheres



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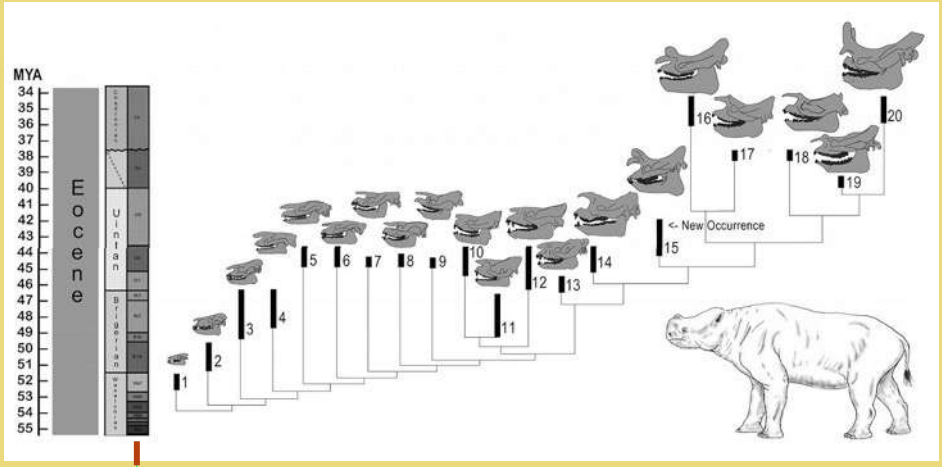
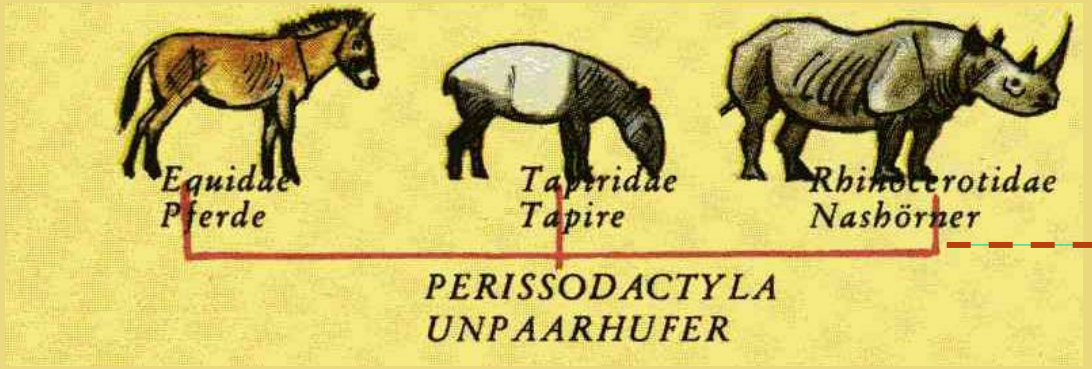


Brontotheres

Chalicotheres



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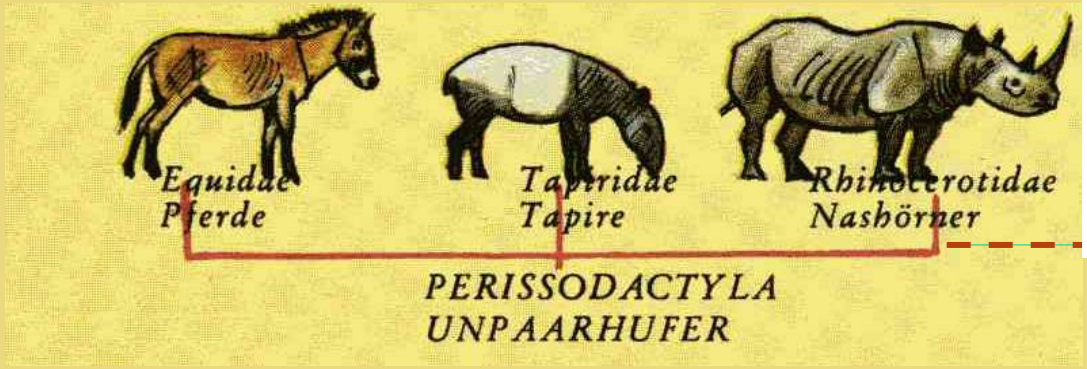

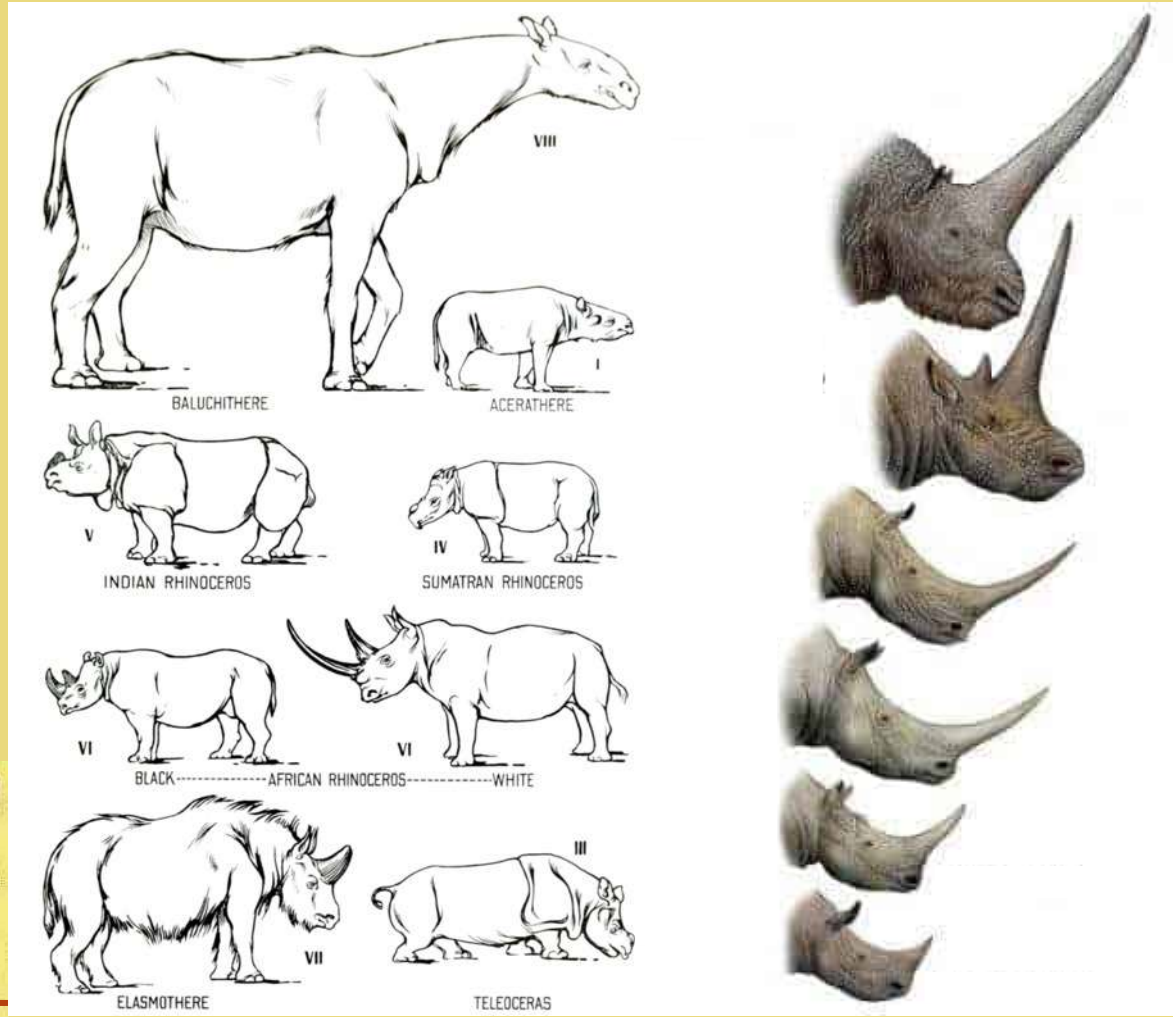

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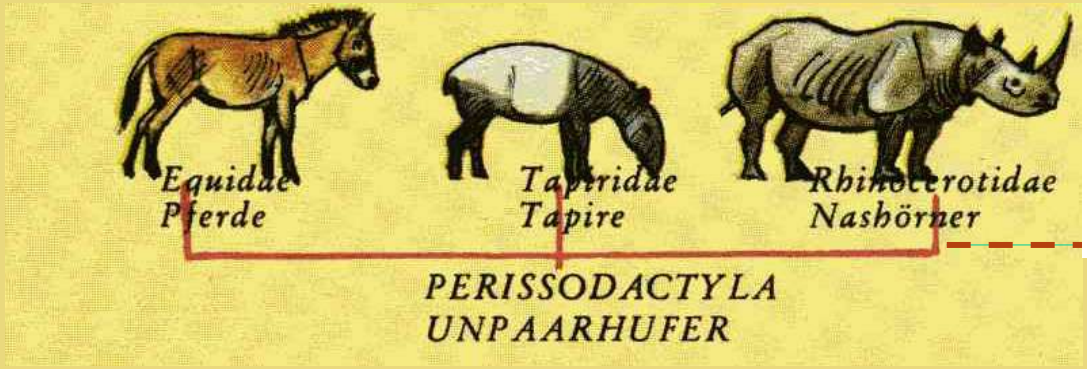

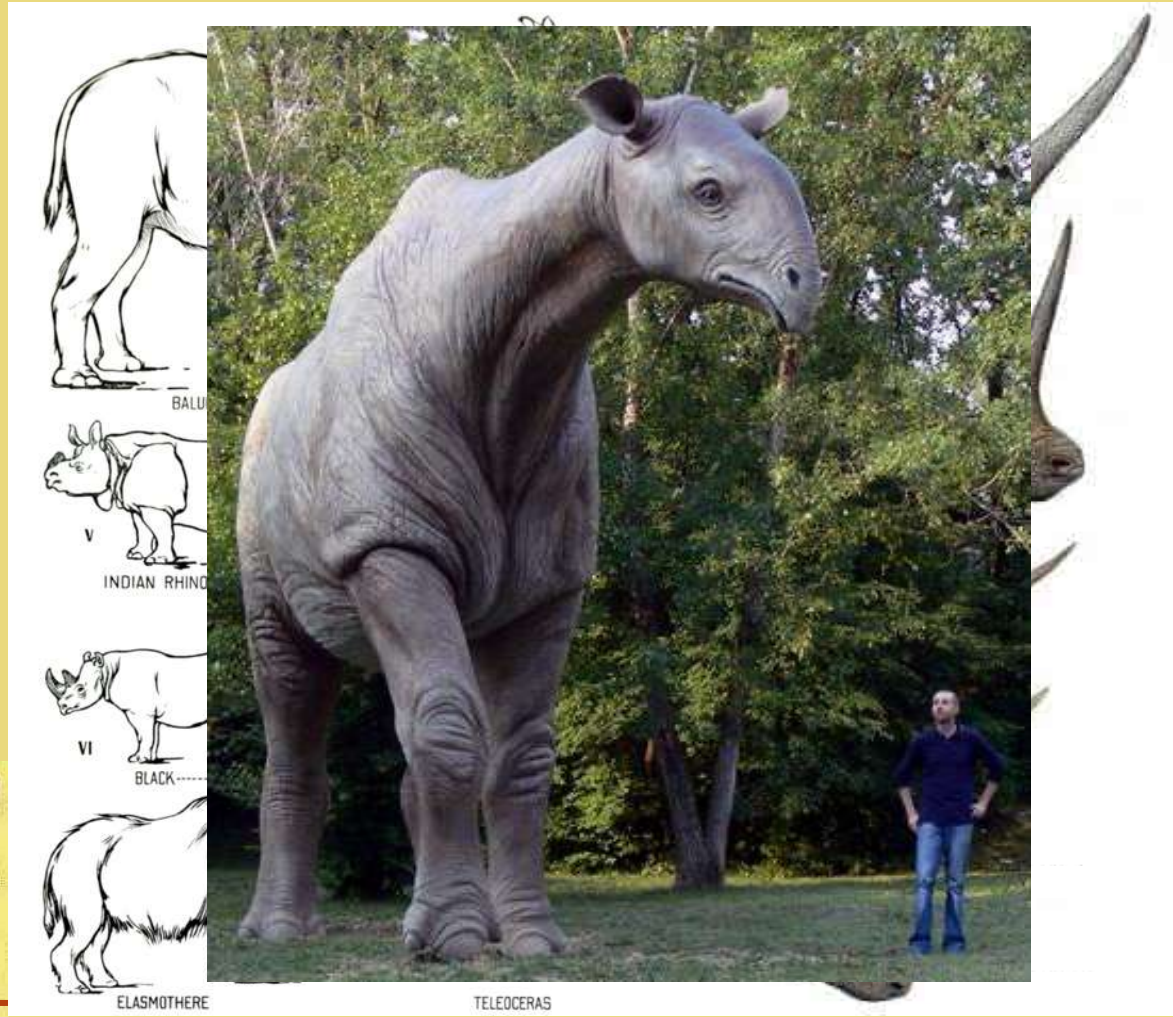

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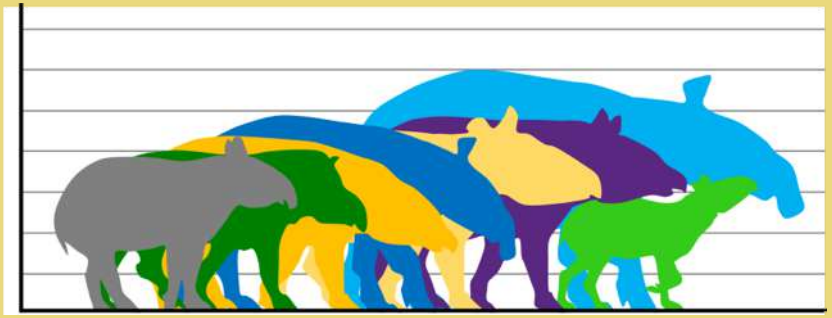
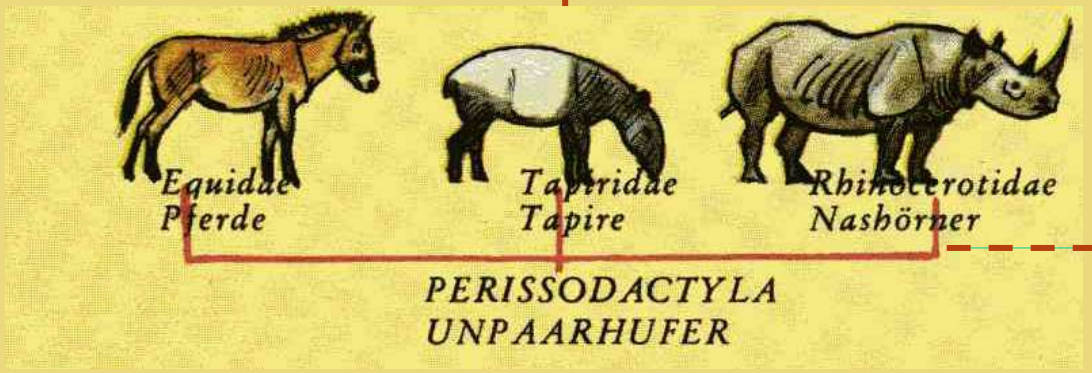


Brontotheres

Chalicotheres



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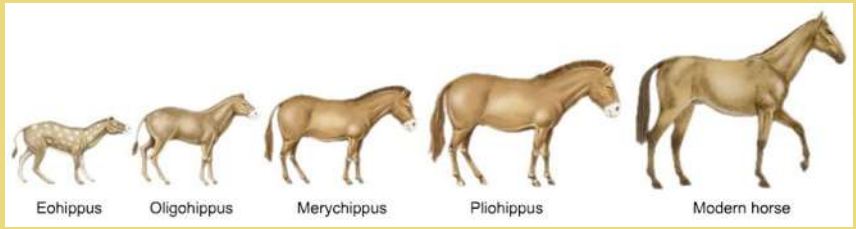
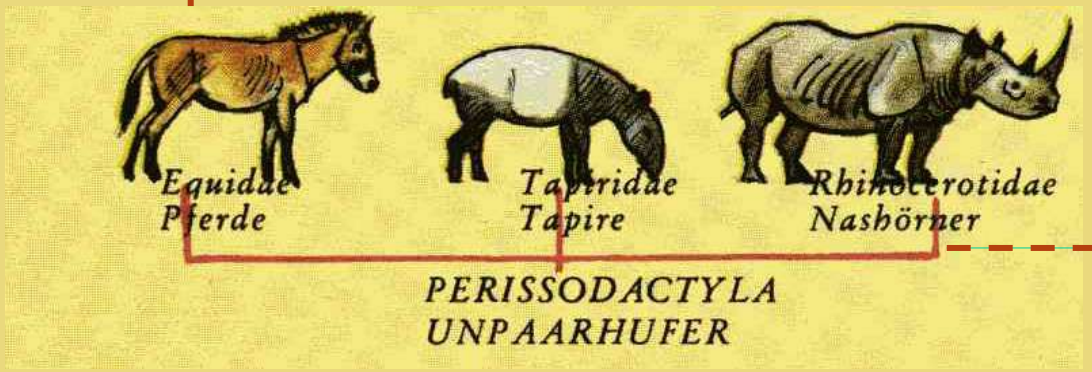


Brontotheres

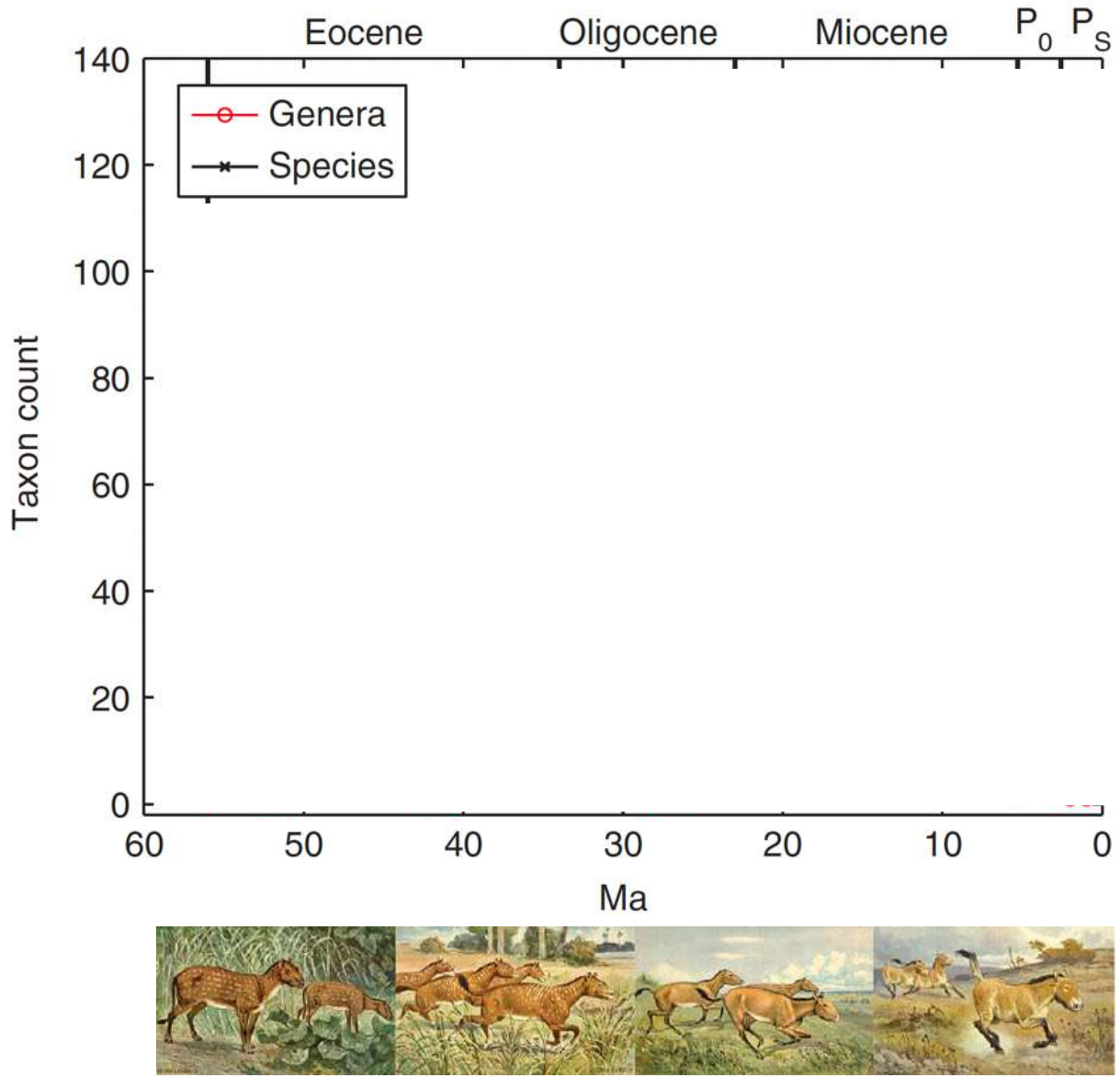
Chalicotheres



Body mass evolution and diversification within horses (family Equidae)

Ecology Letters, (2014) **17**: 211–220

Lauren Shoemaker[1,2] **and Aaron Clauset**[2,3,4]*



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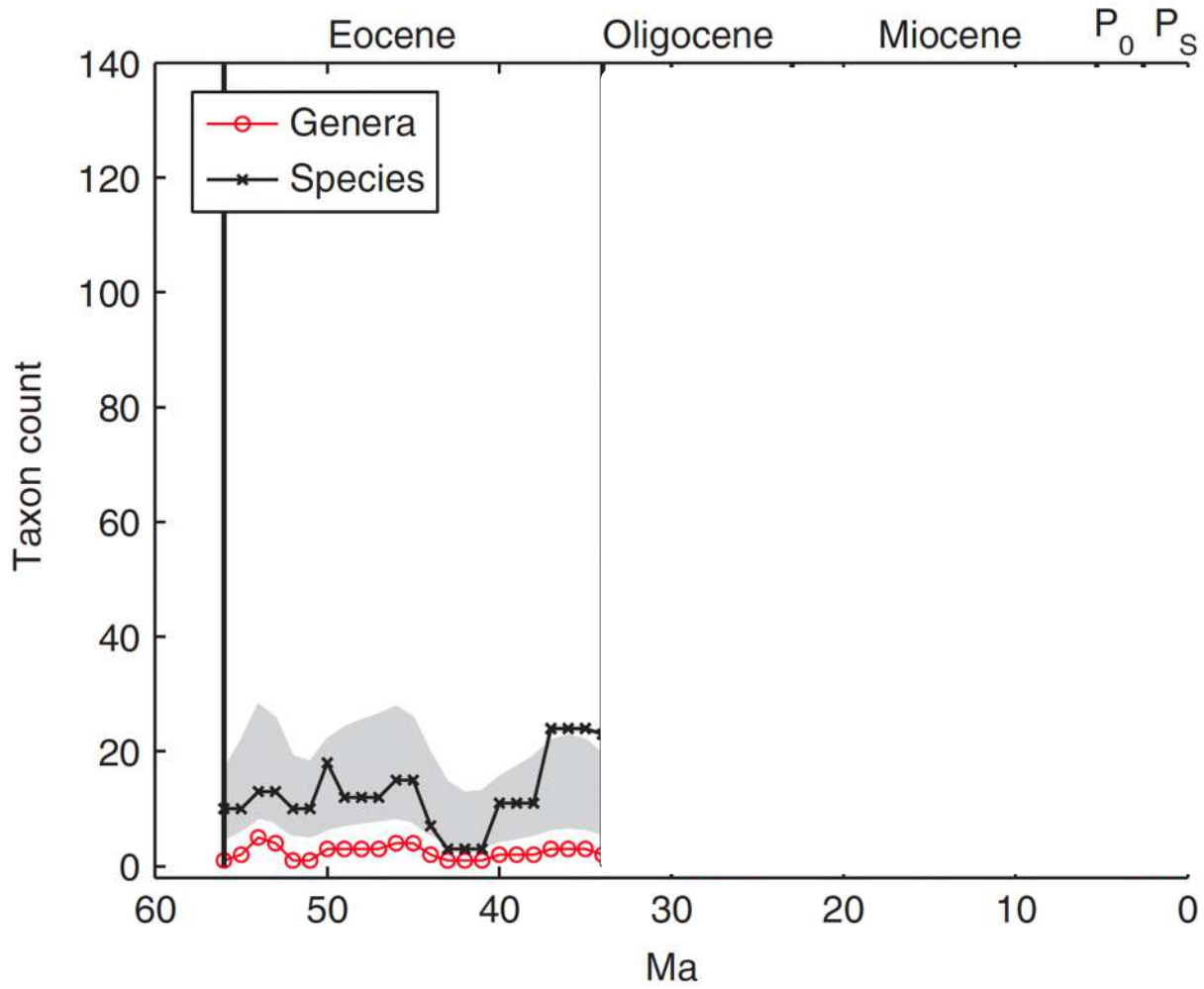

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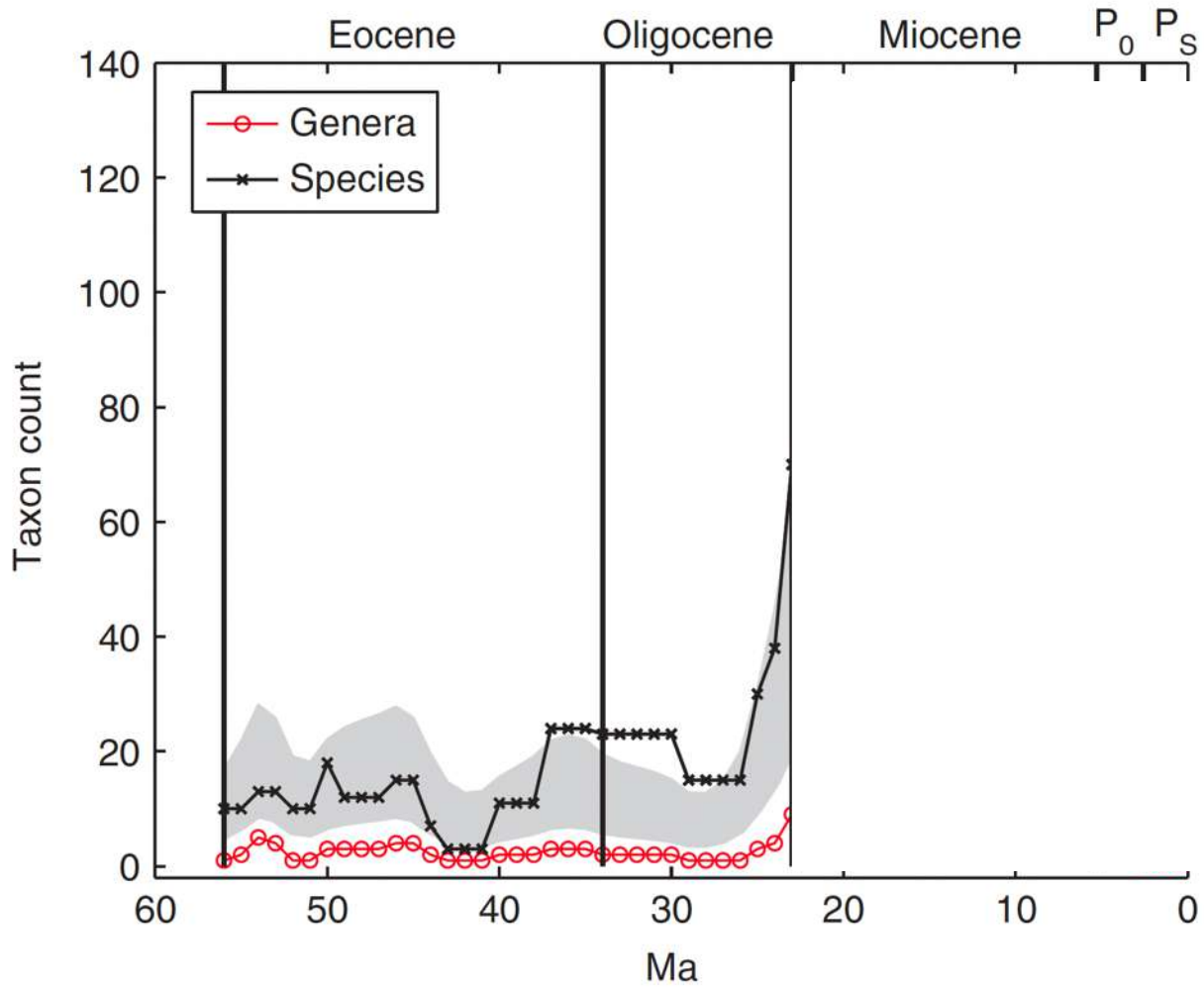

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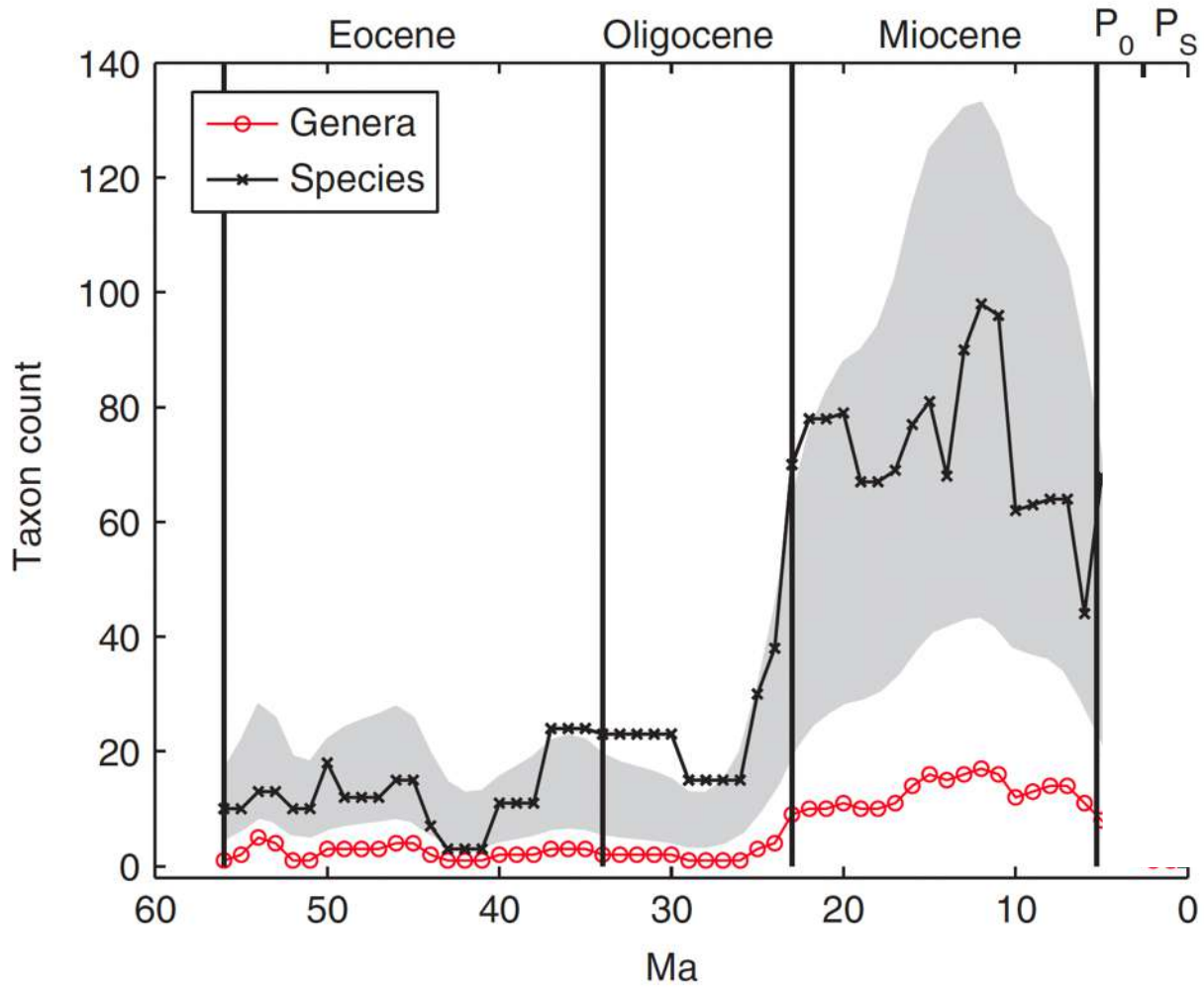

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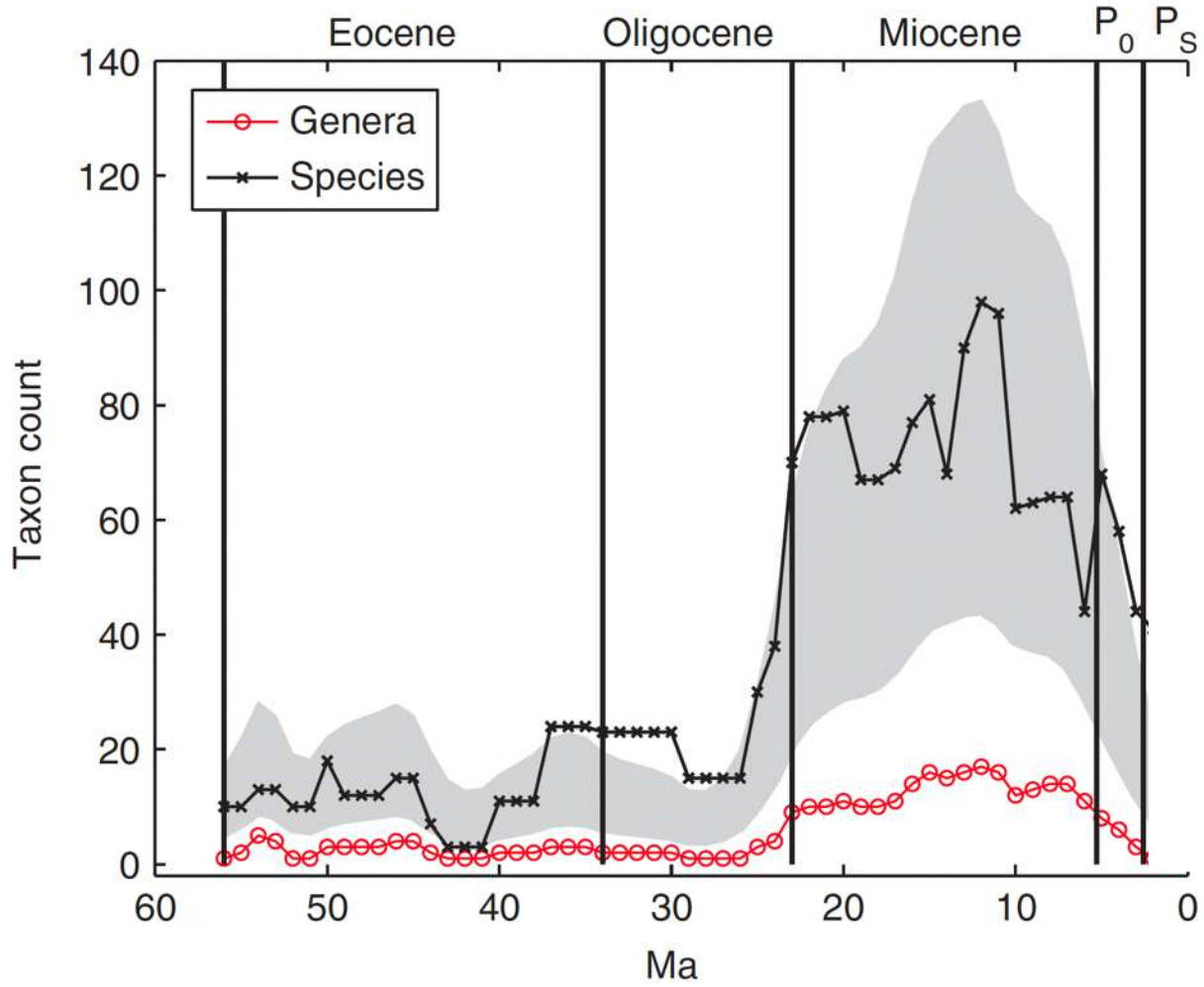

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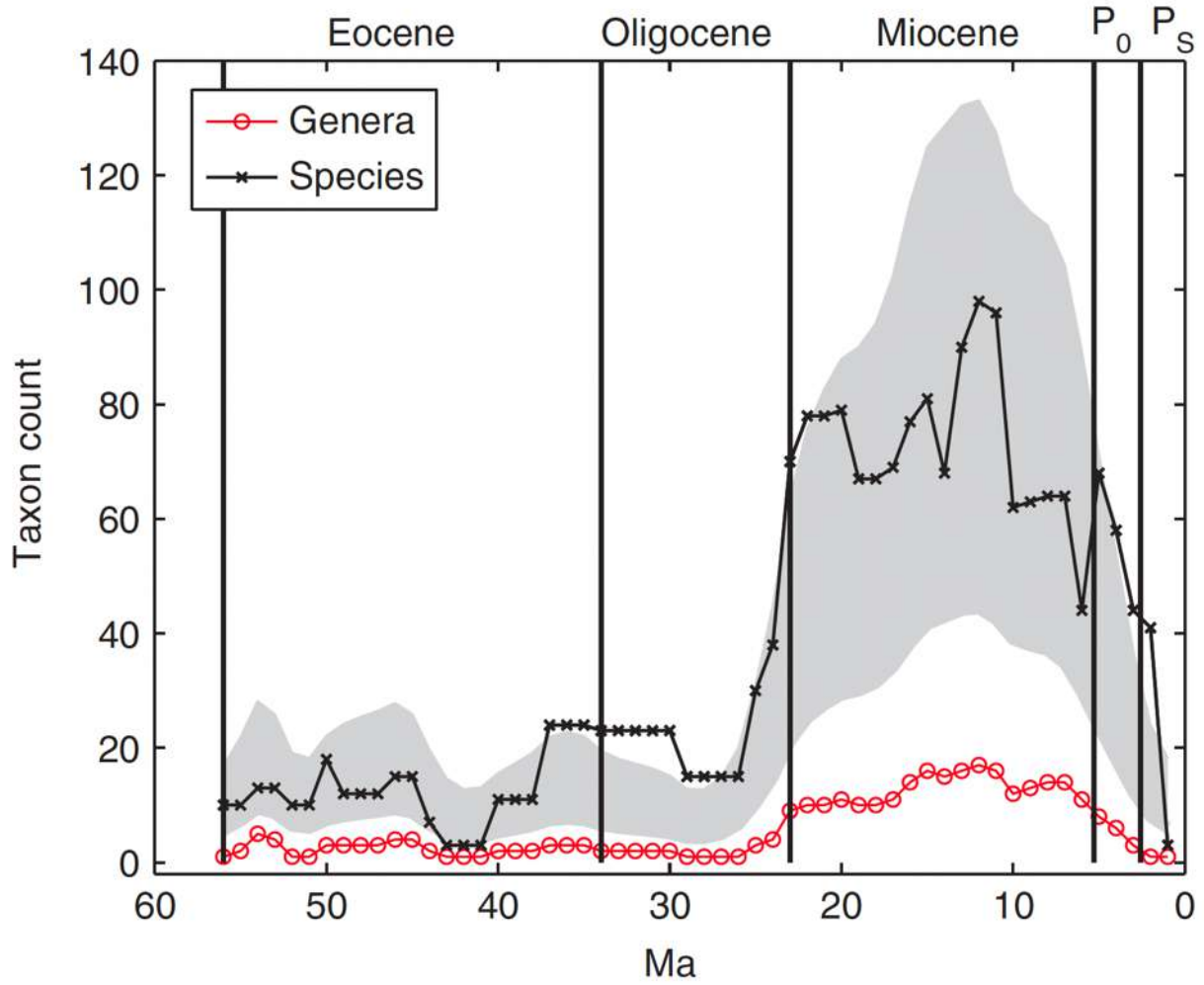
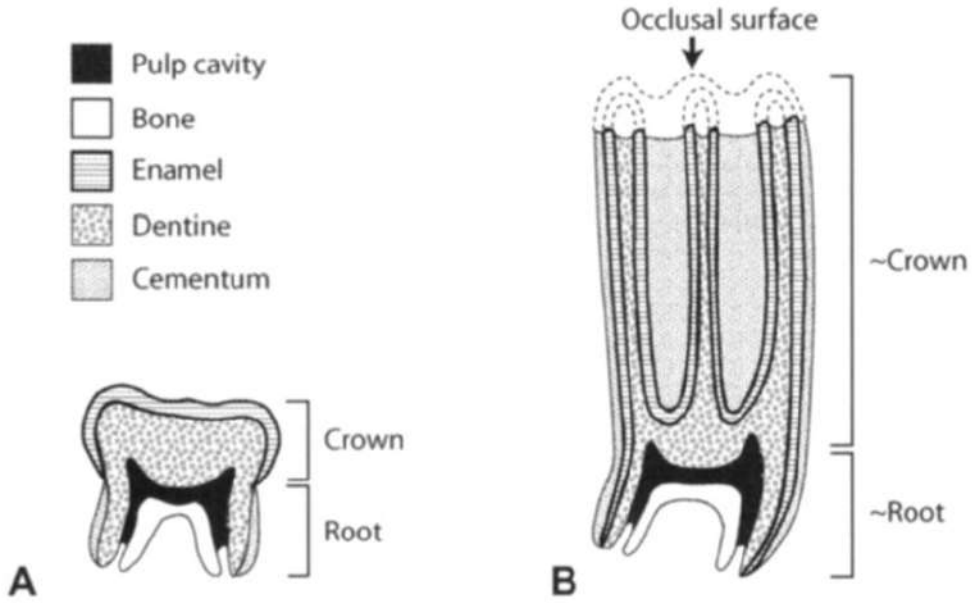


Evolution of hypsodonty in equids: testing a hypothesis of adaptation

Caroline A. E. Strömberg

Paleobiology, 32(2), 2006, pp. 236–258



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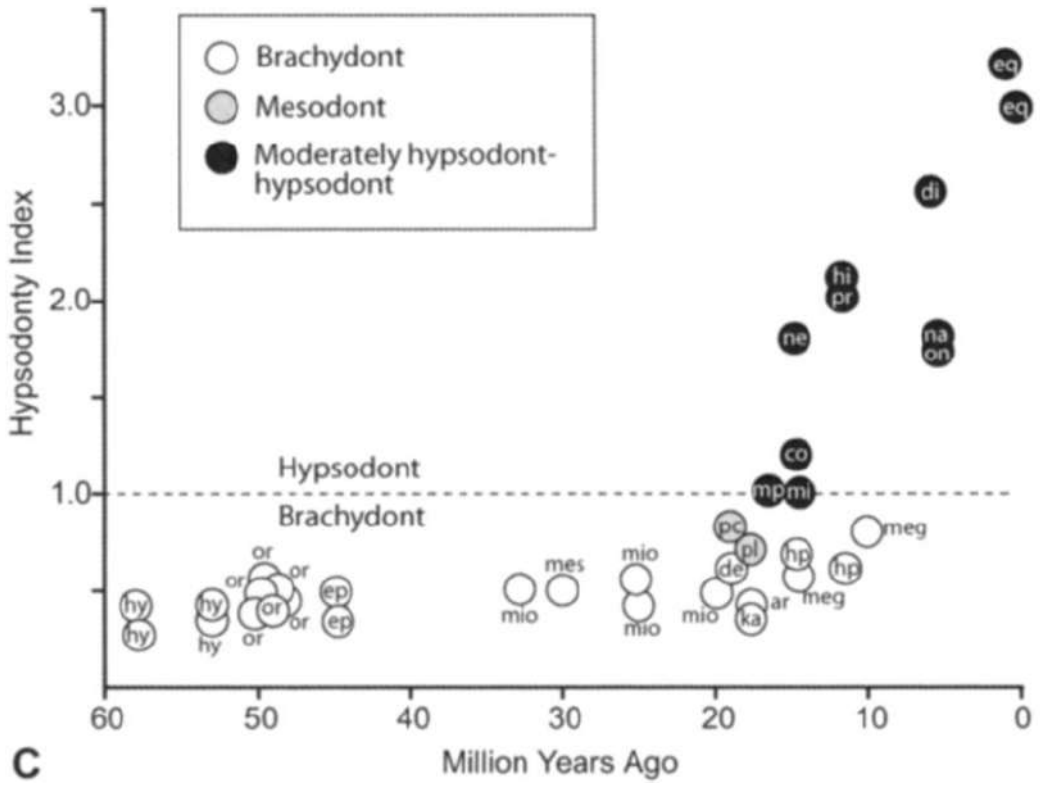

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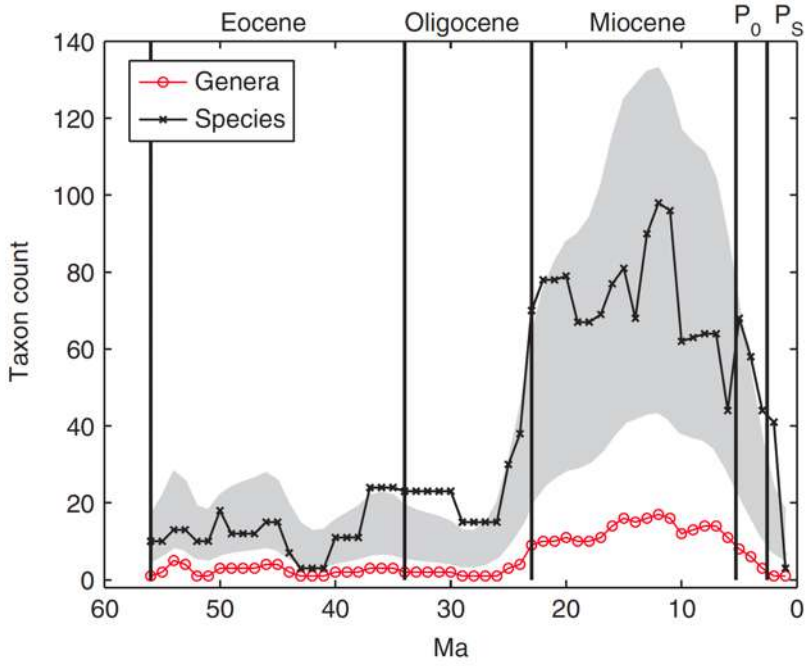

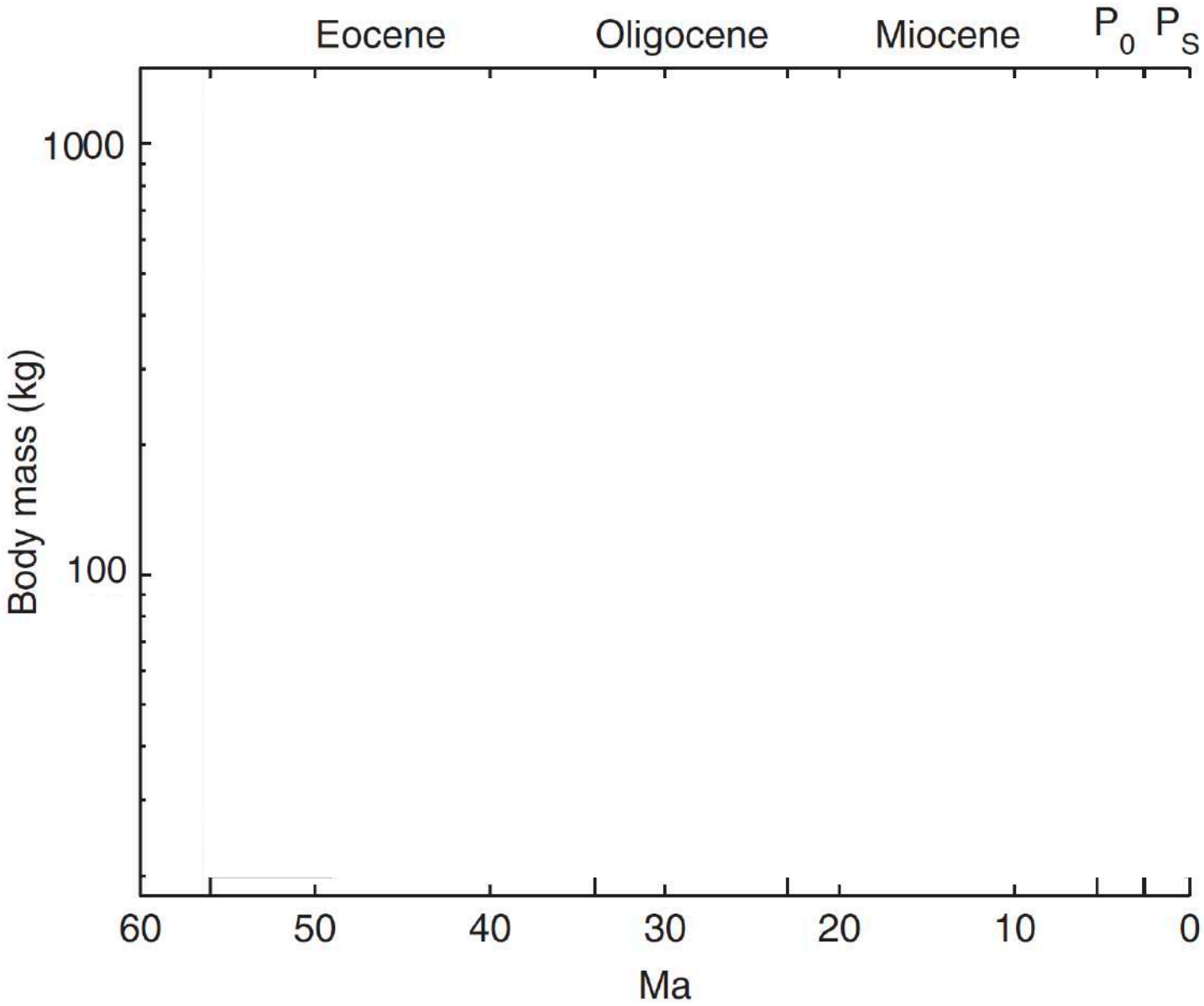

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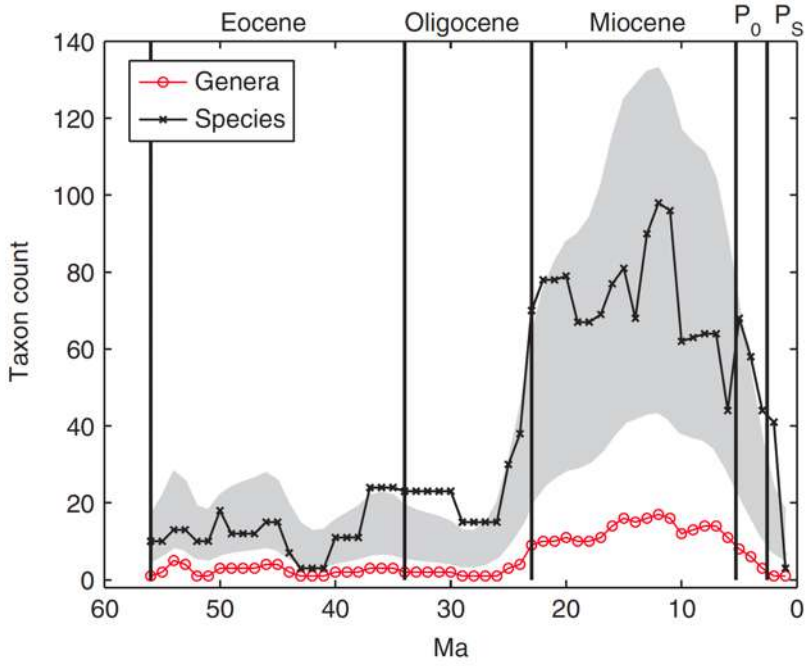

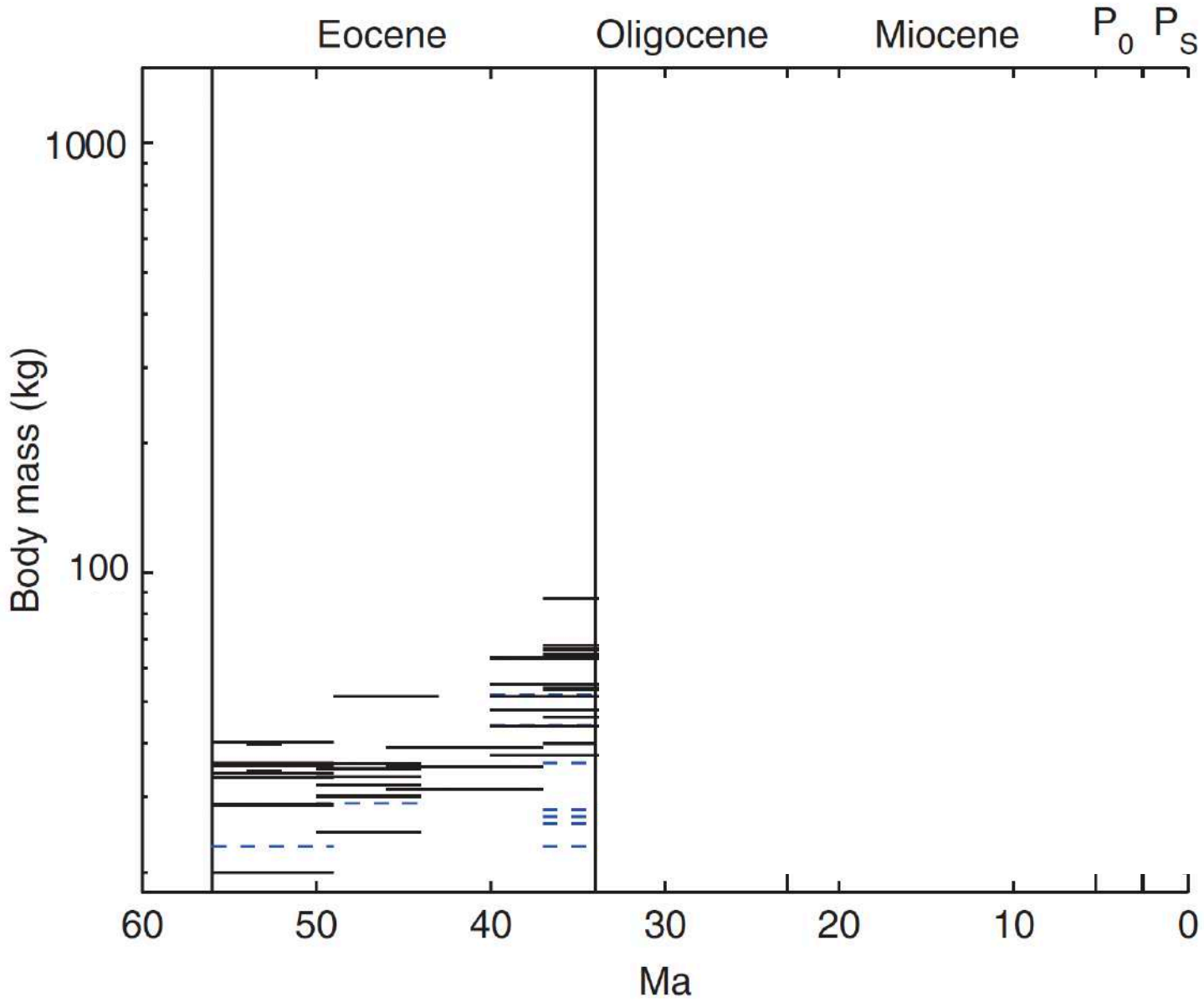

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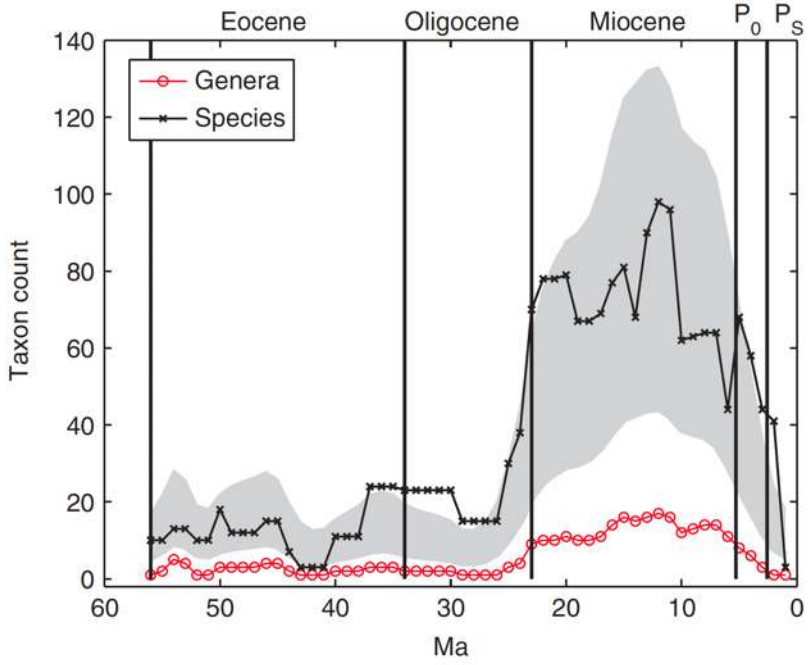

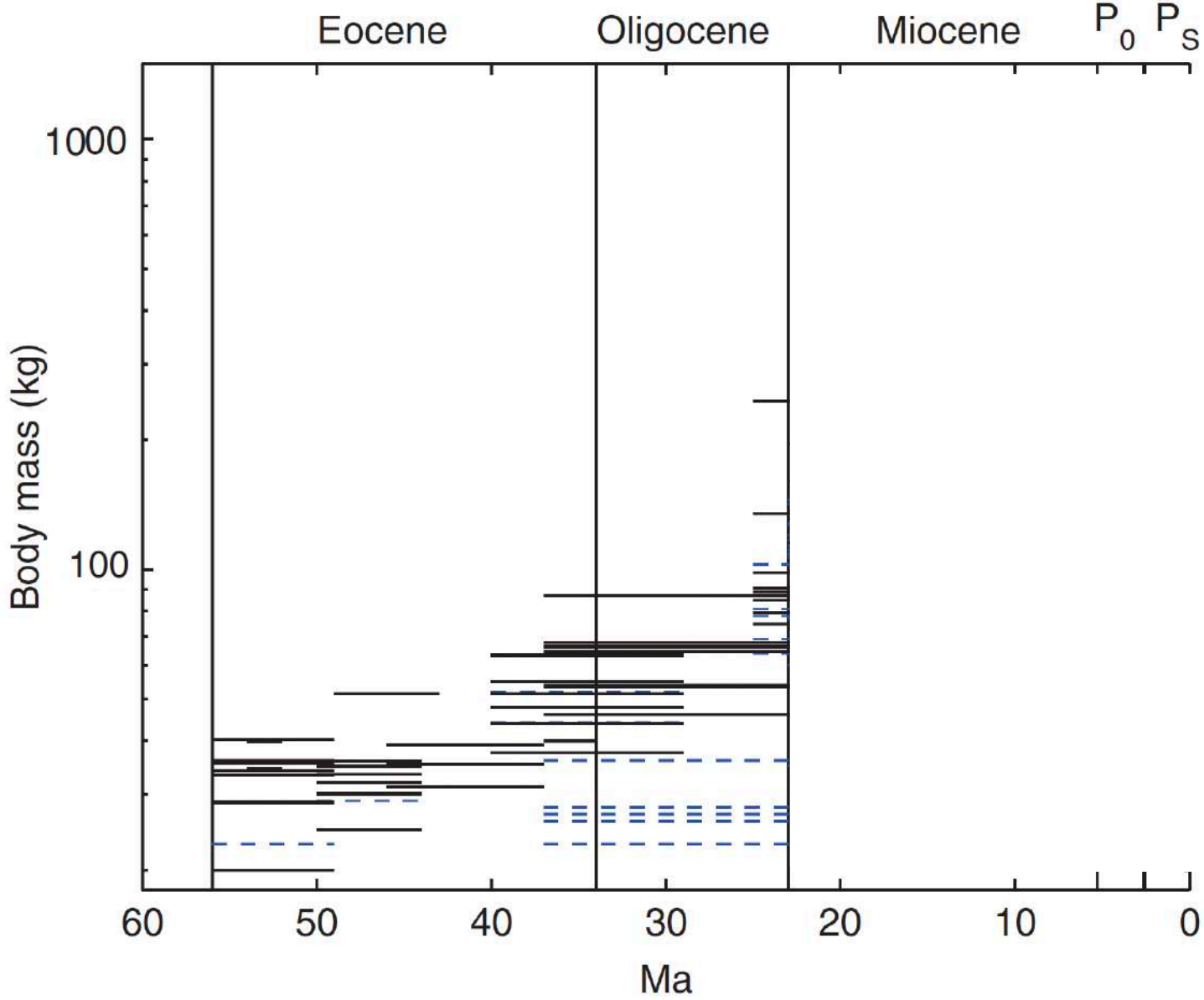

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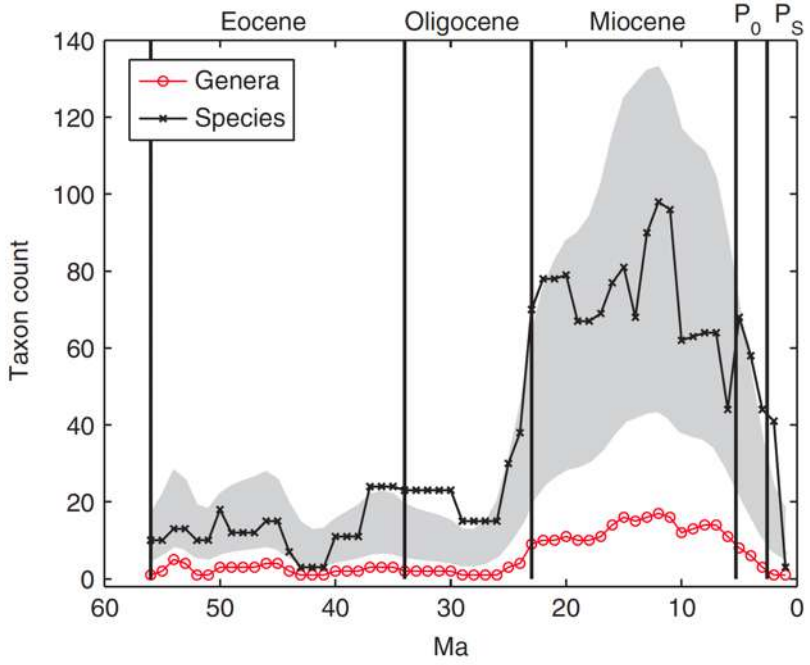

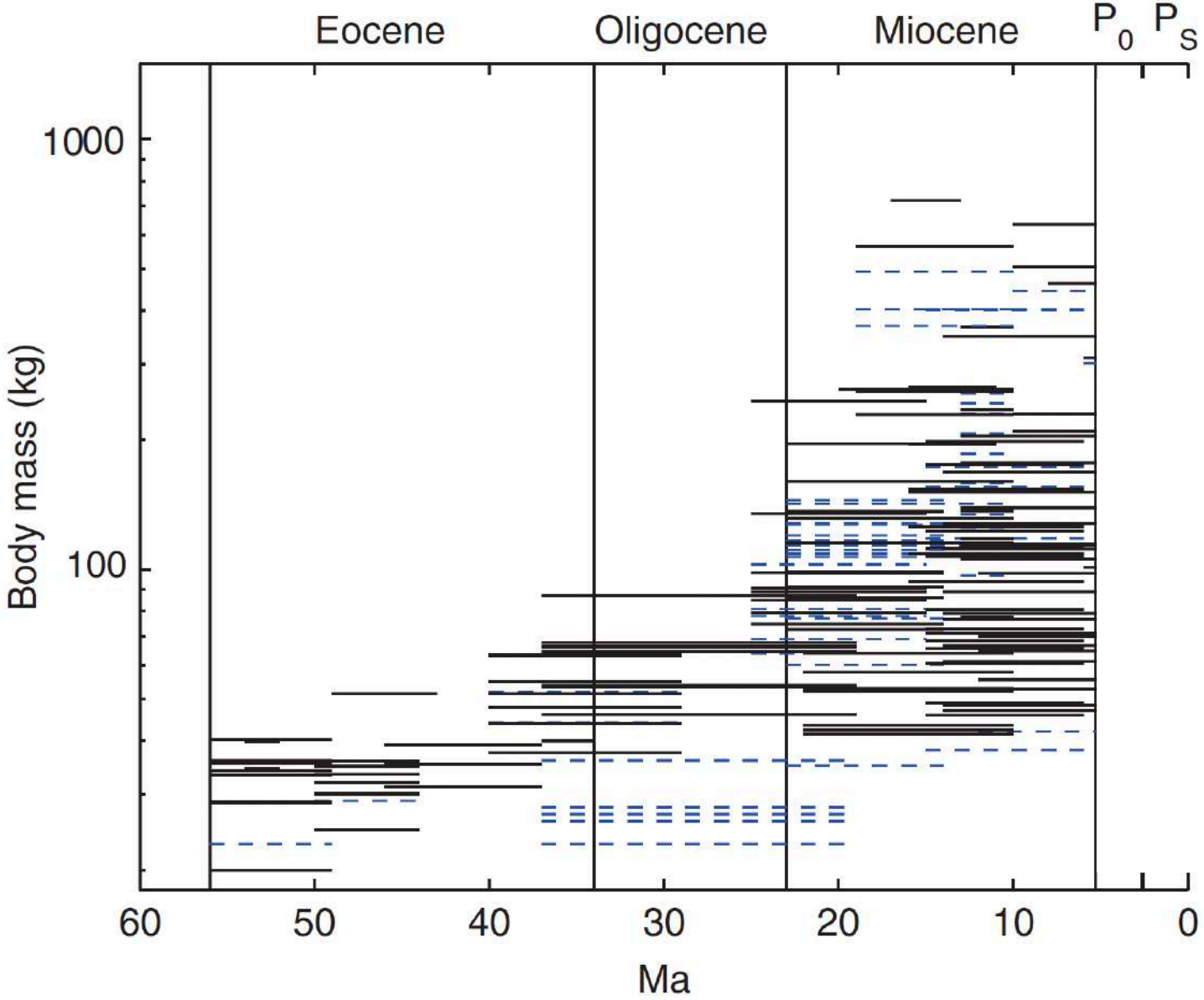

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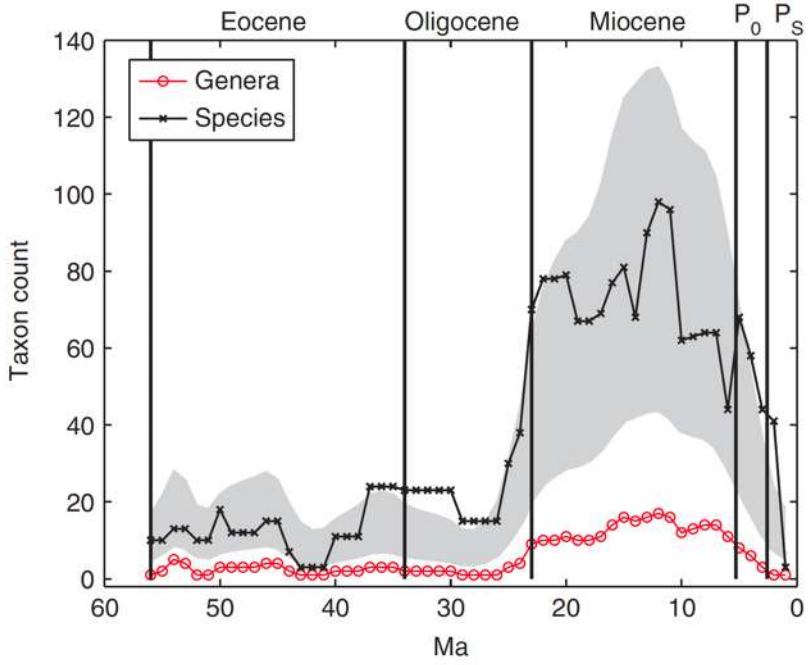

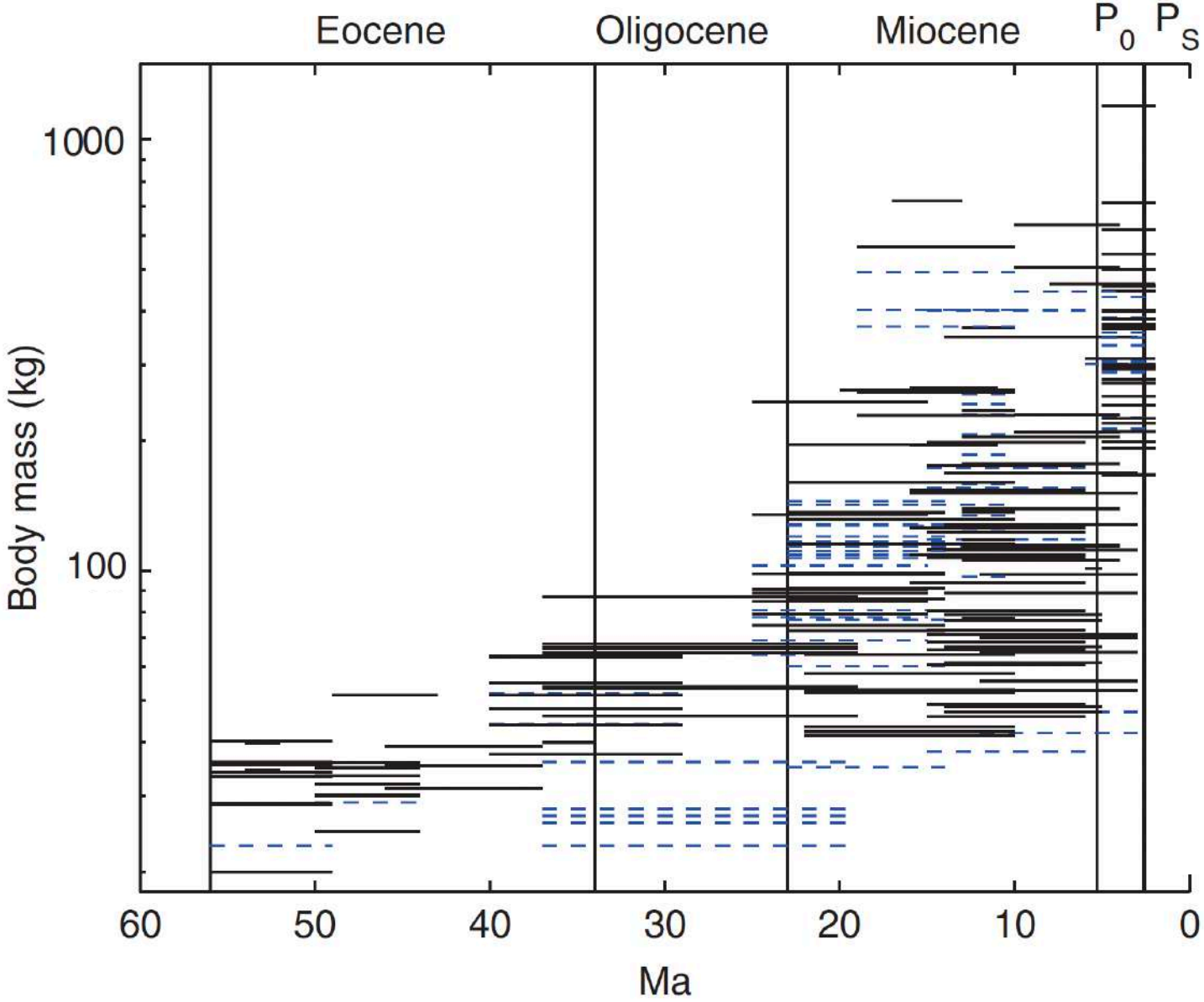

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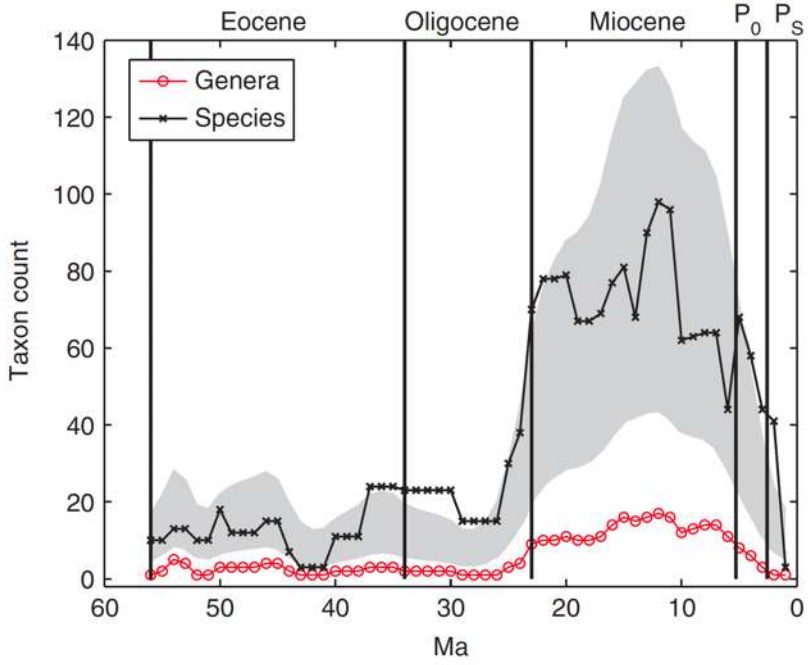

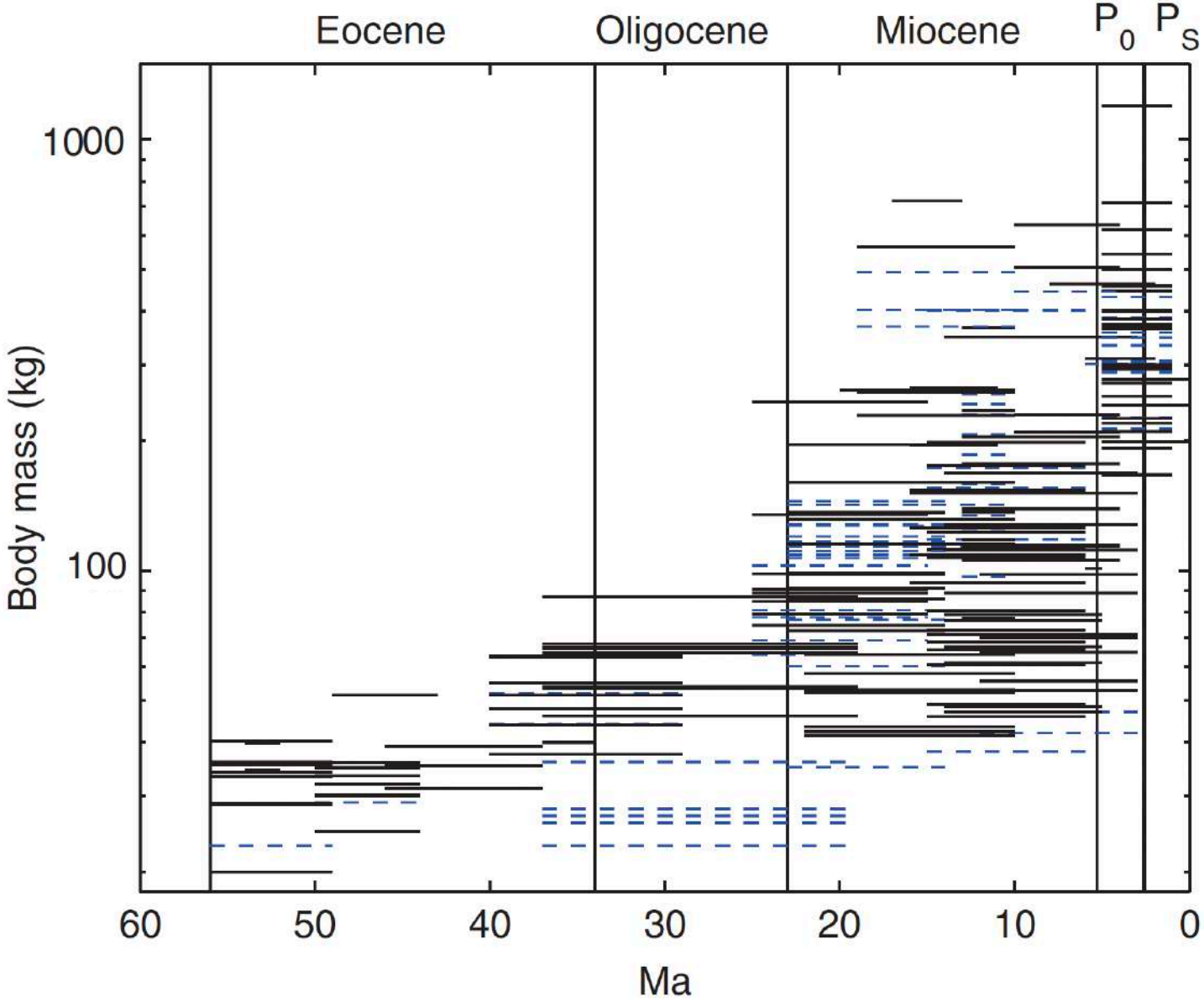

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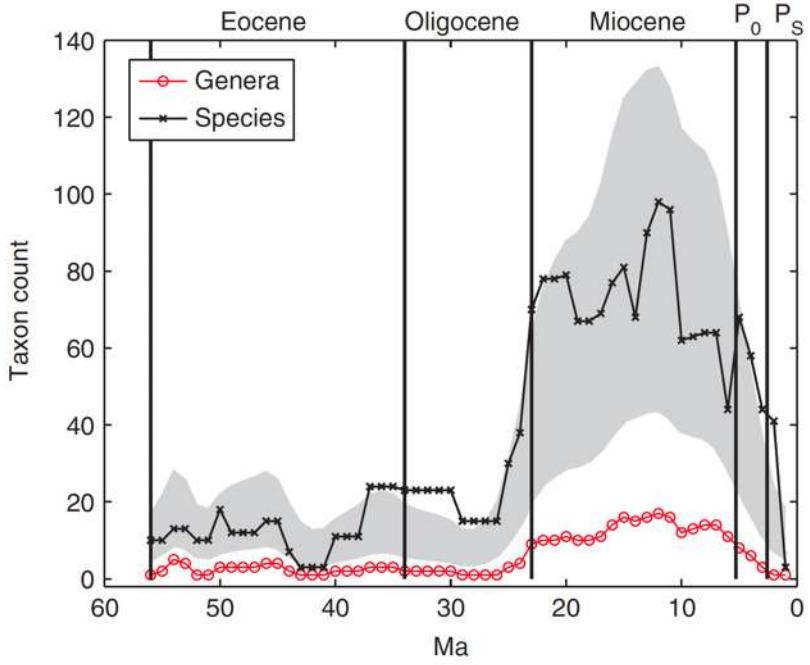

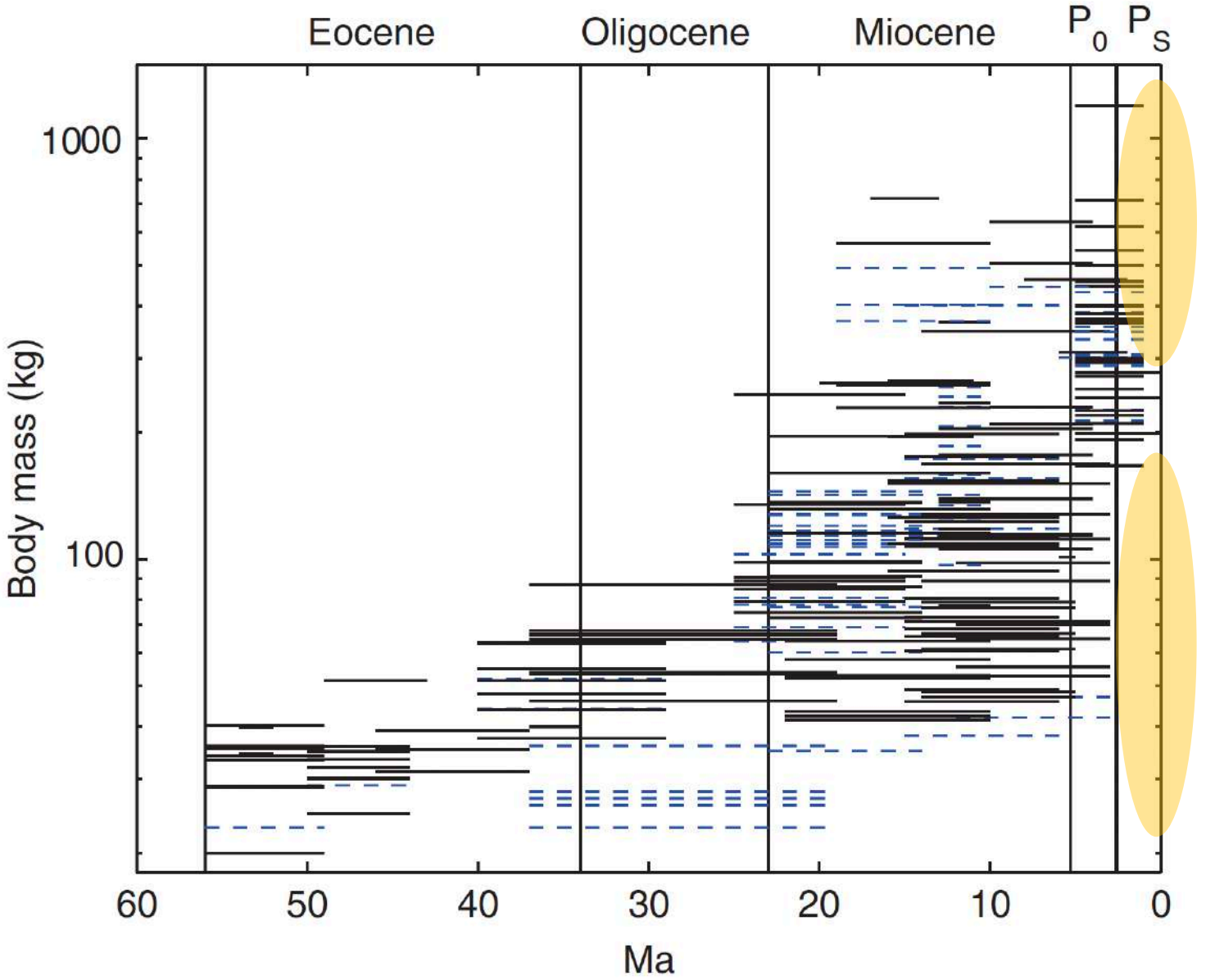

What led to the decline of equid diversity ?

MODELLING EQUID/RUMINANT COMPETITION IN THE FOSSIL RECORD

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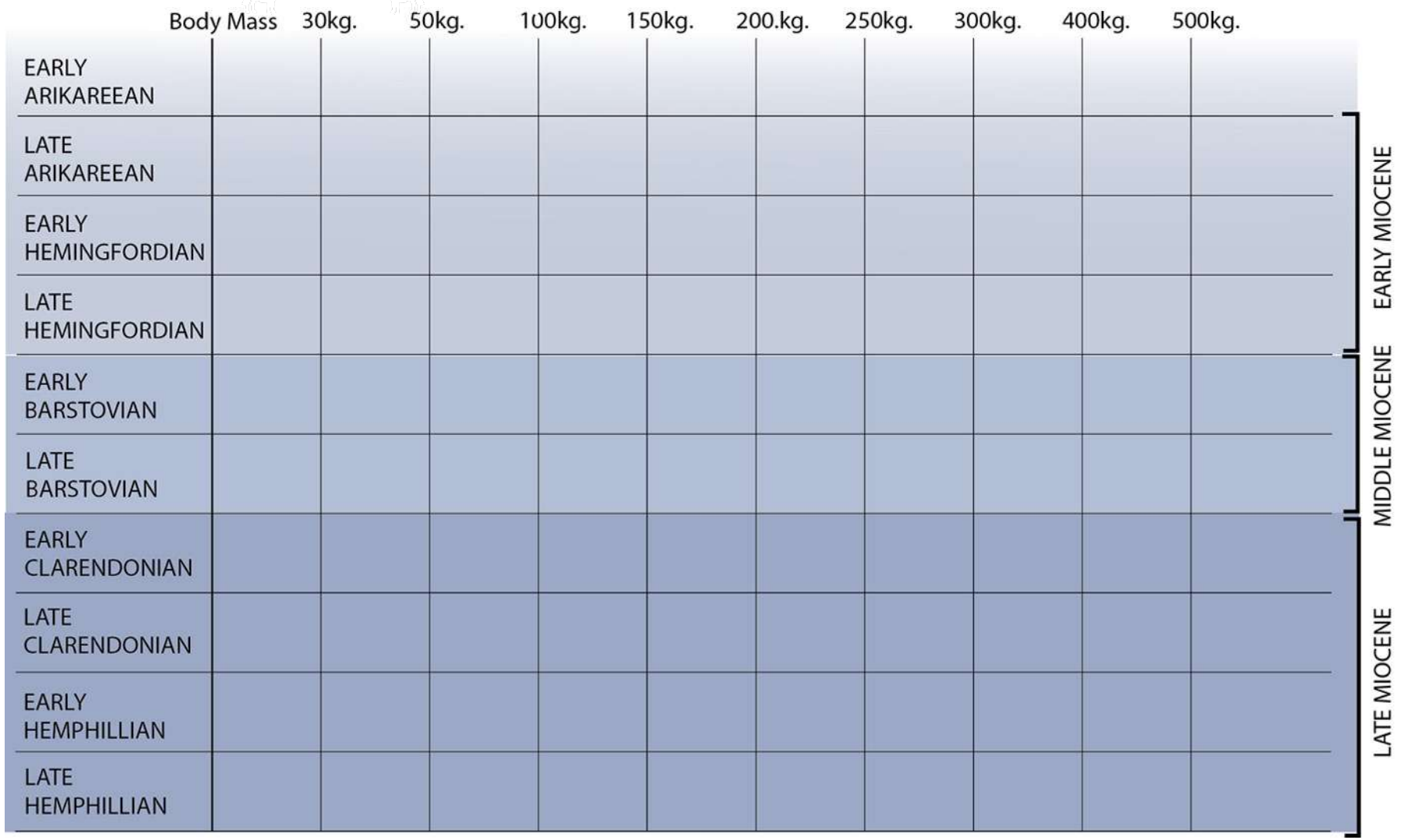

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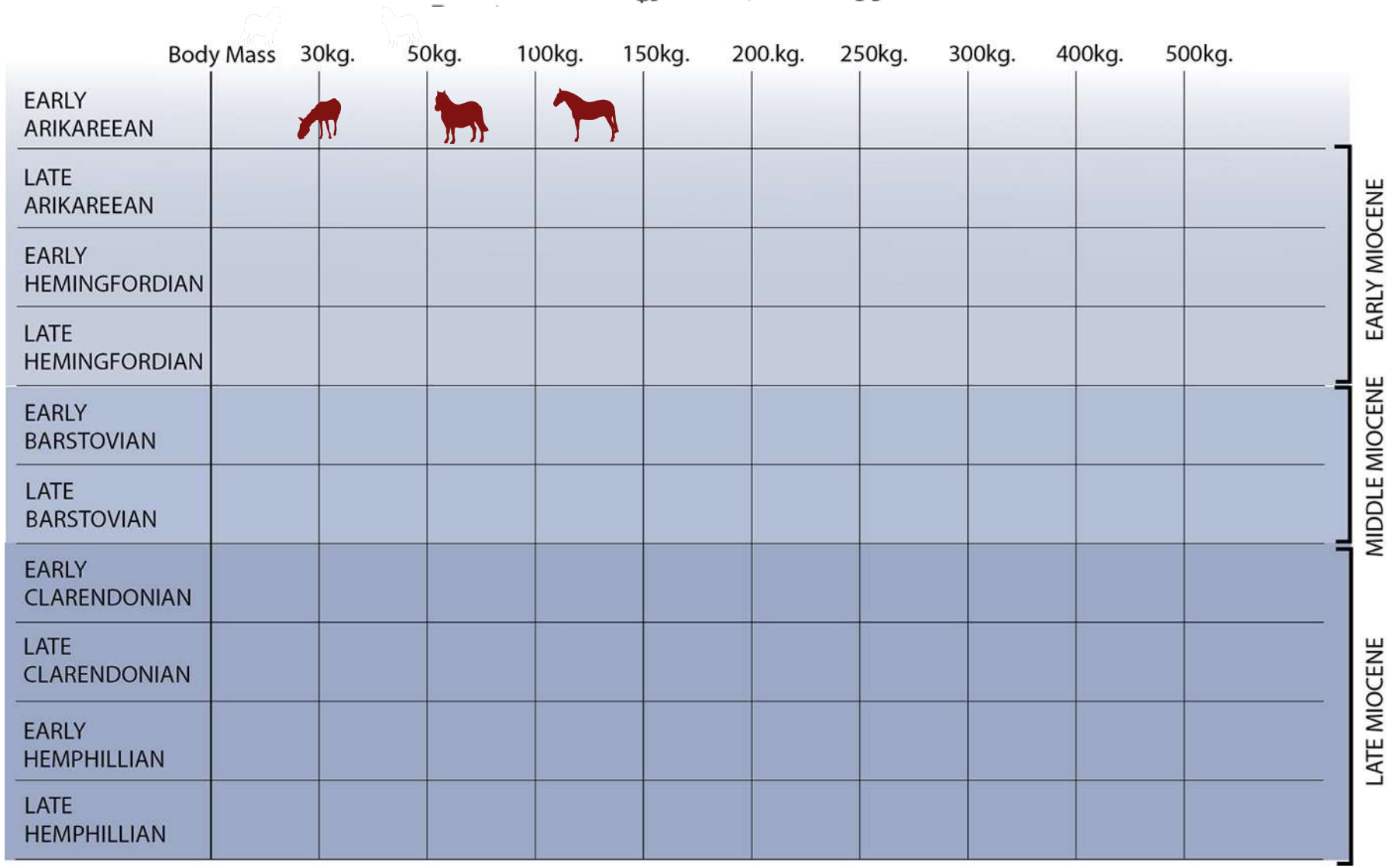

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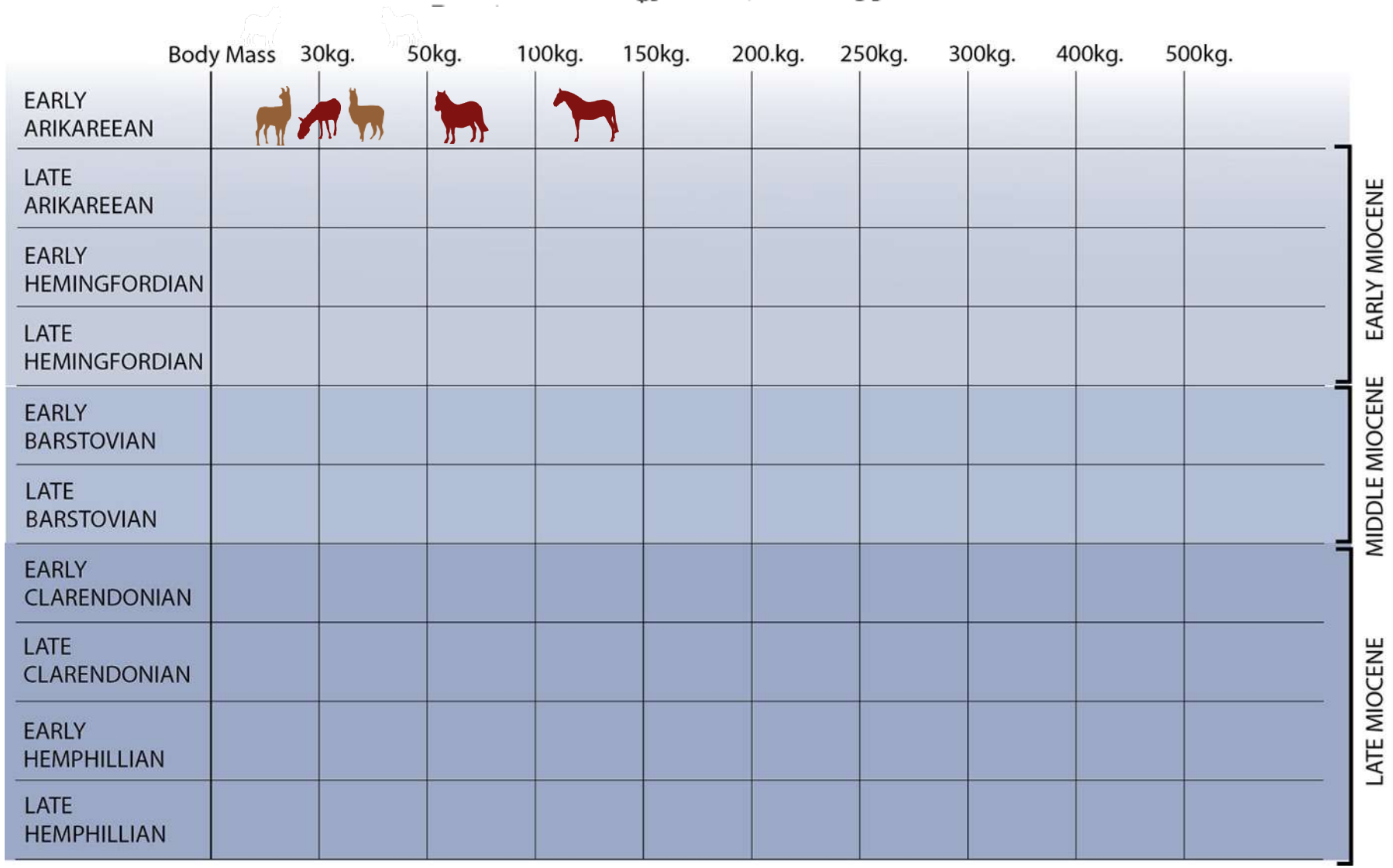

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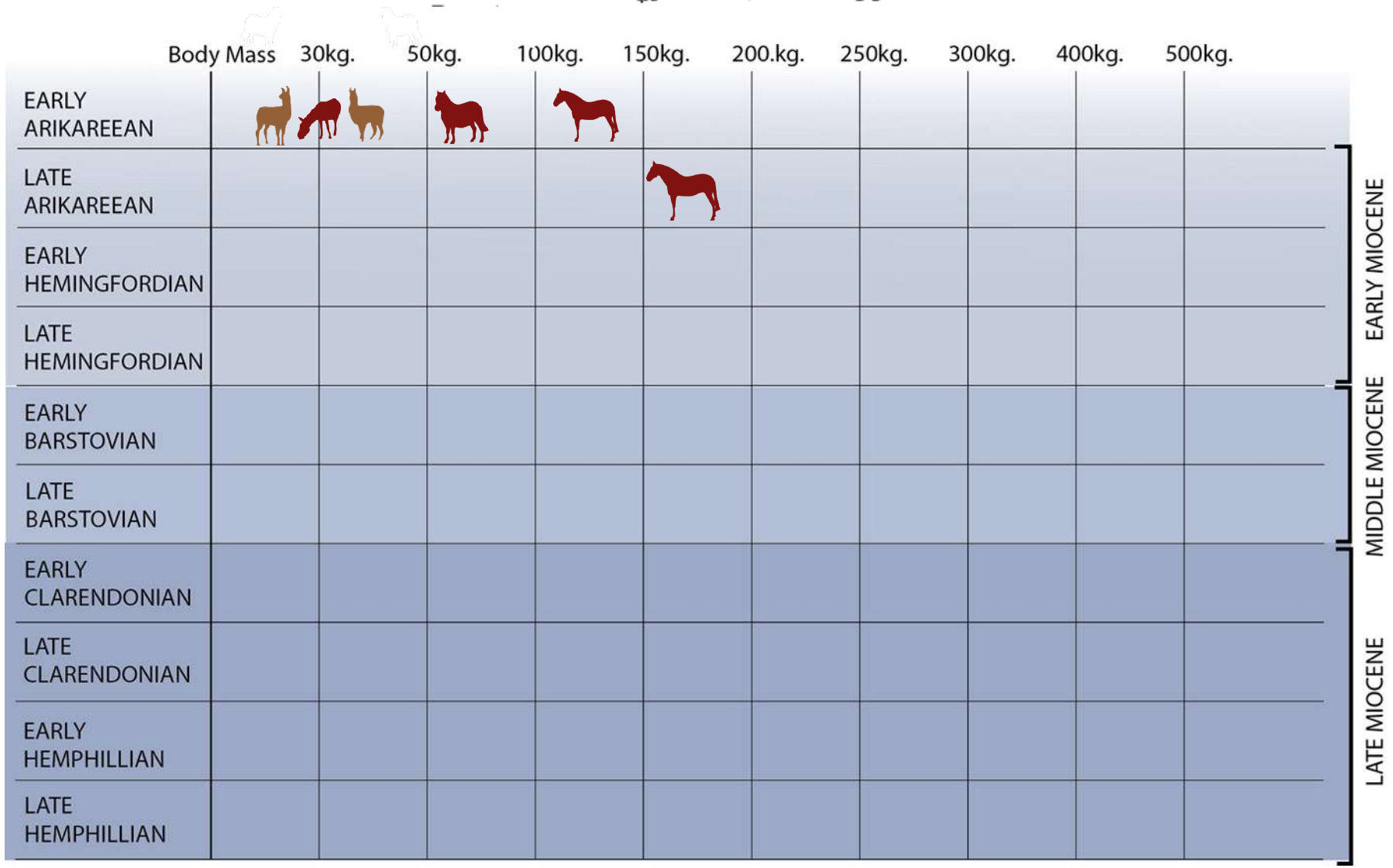

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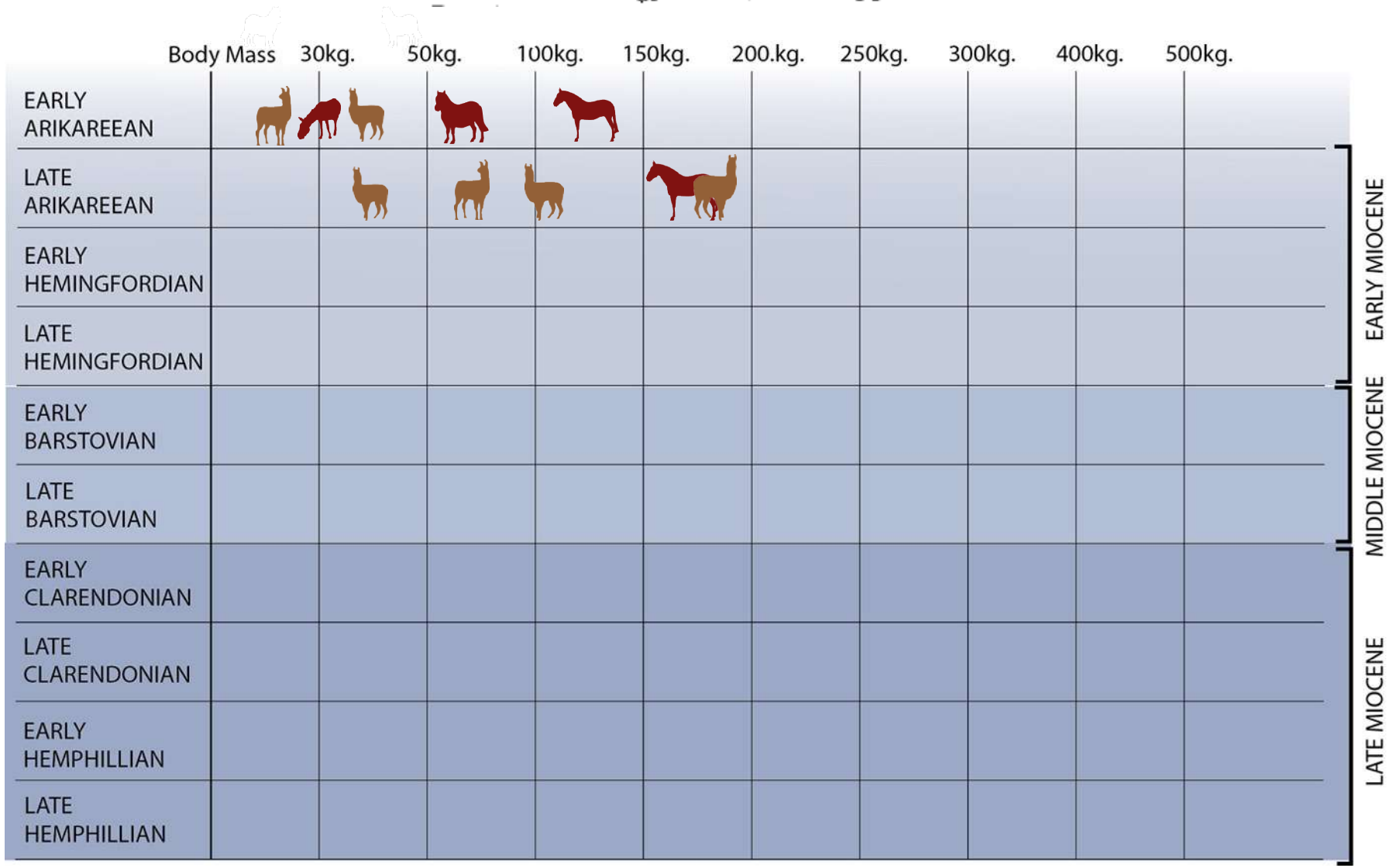

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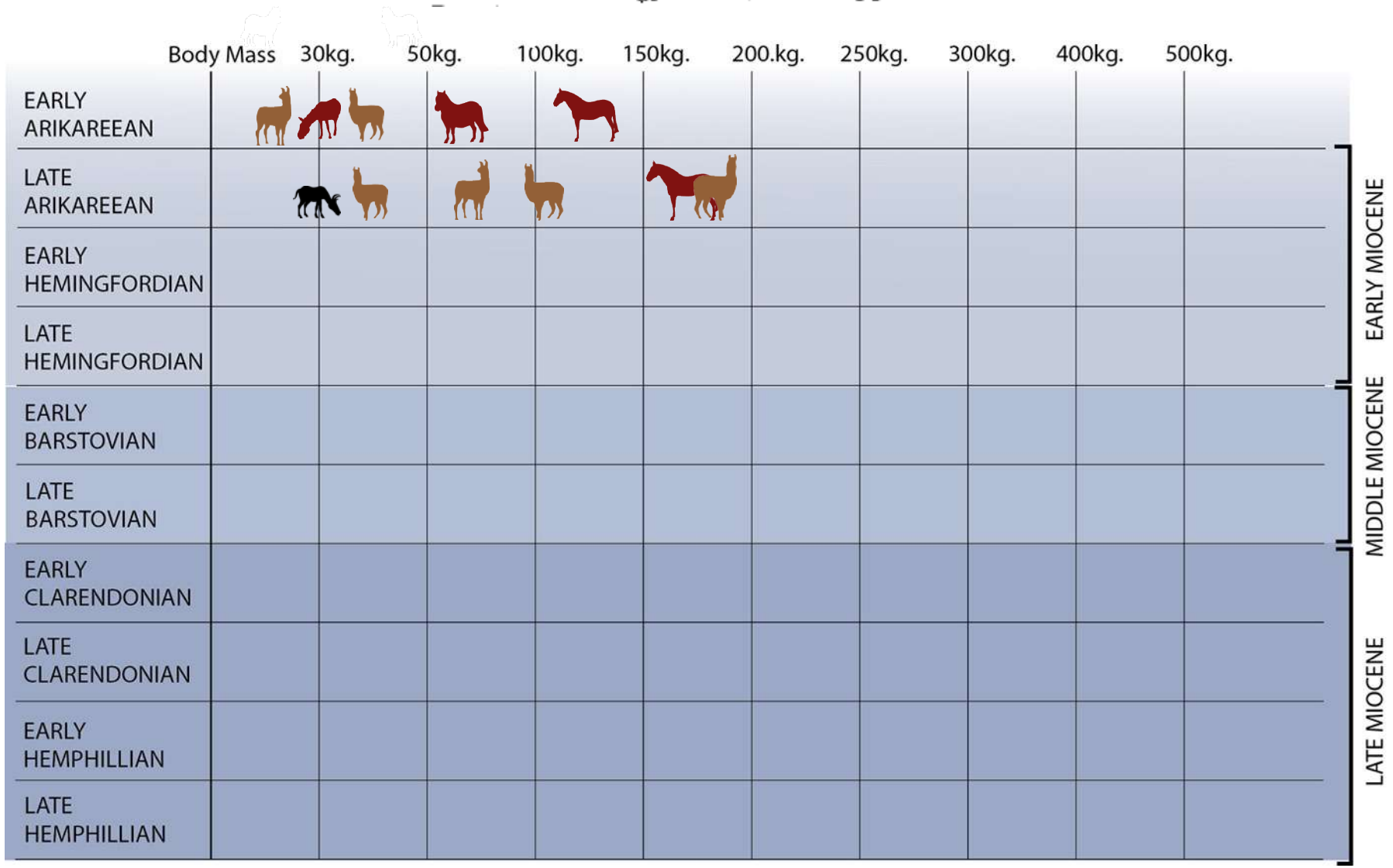

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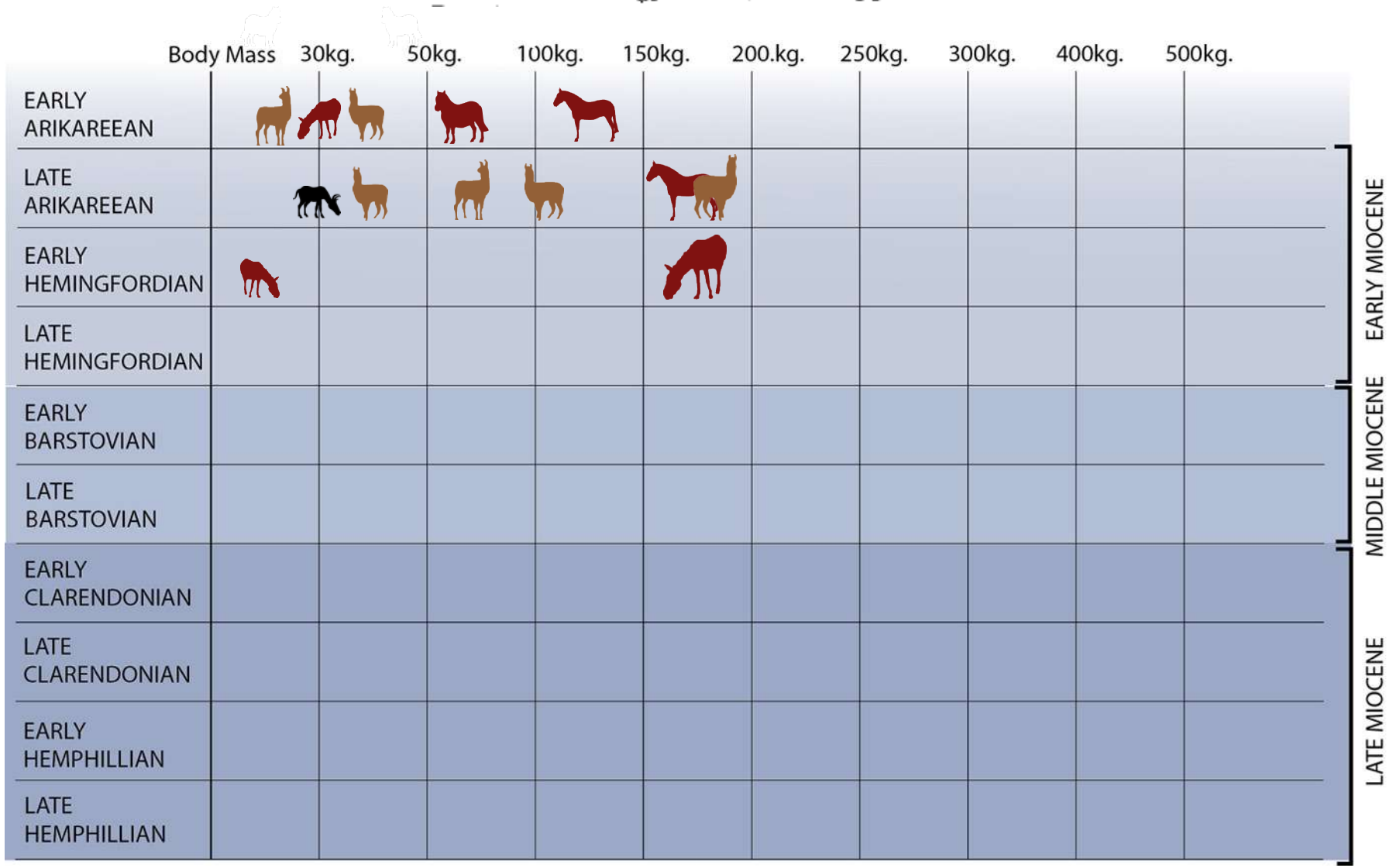

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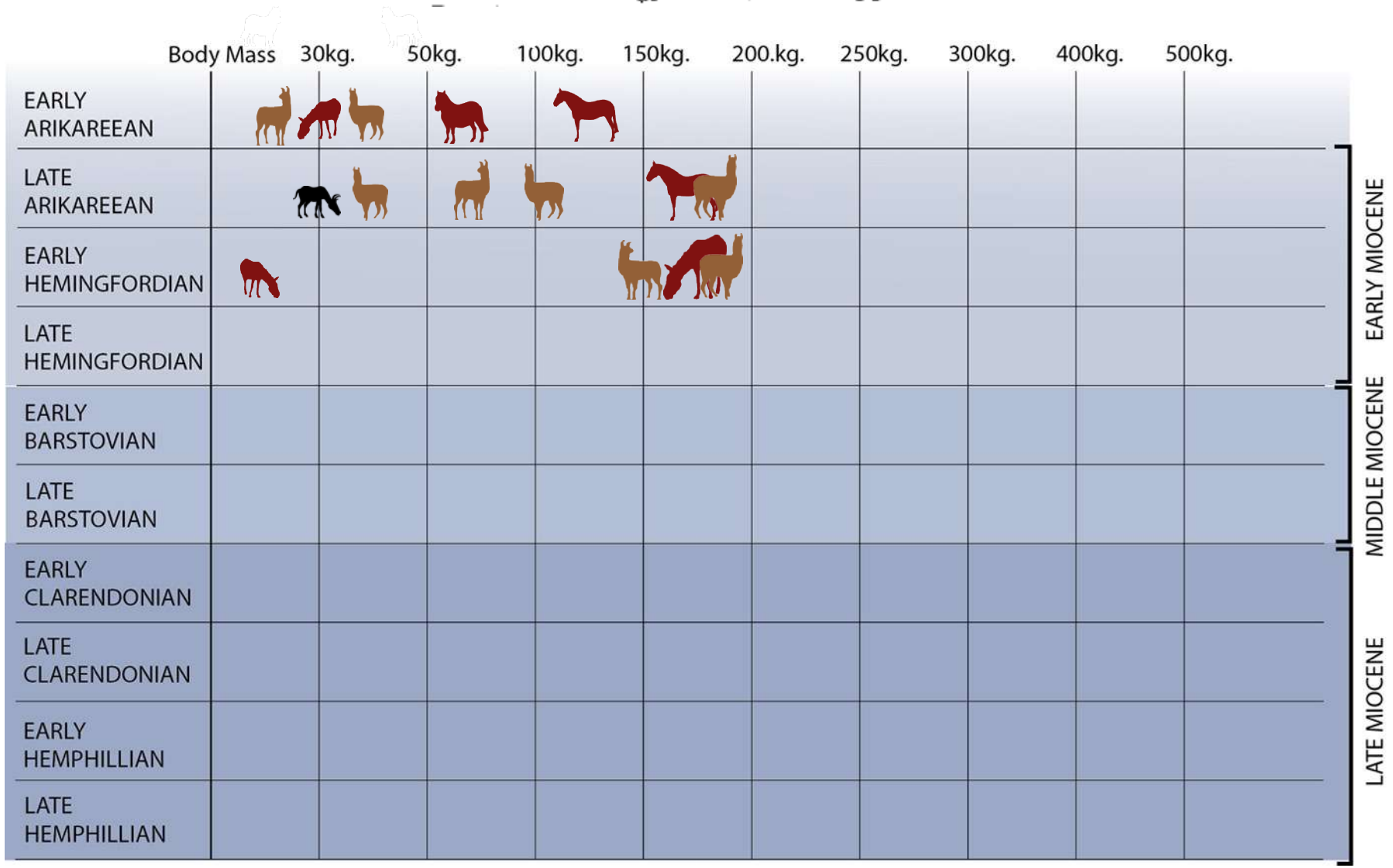

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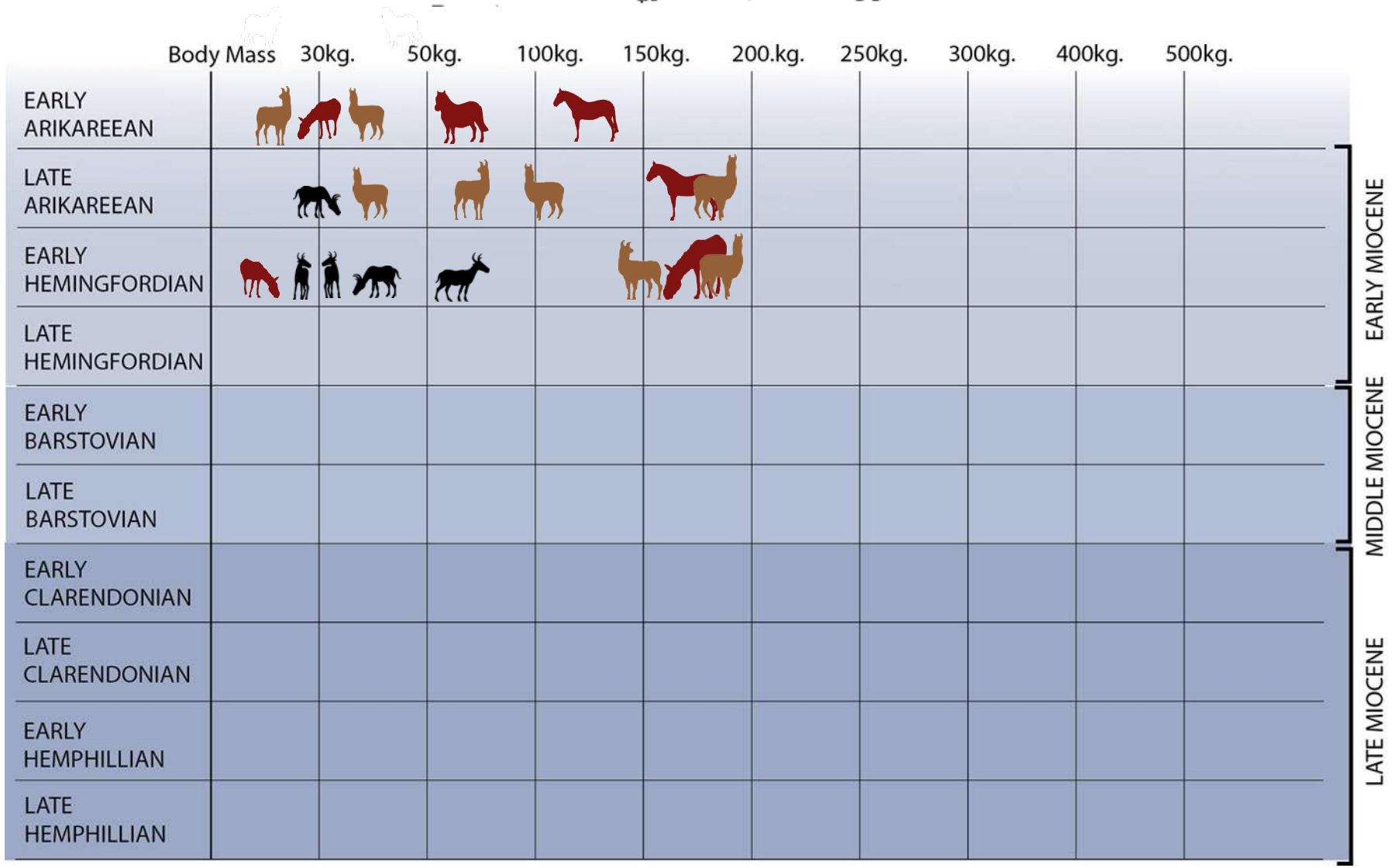

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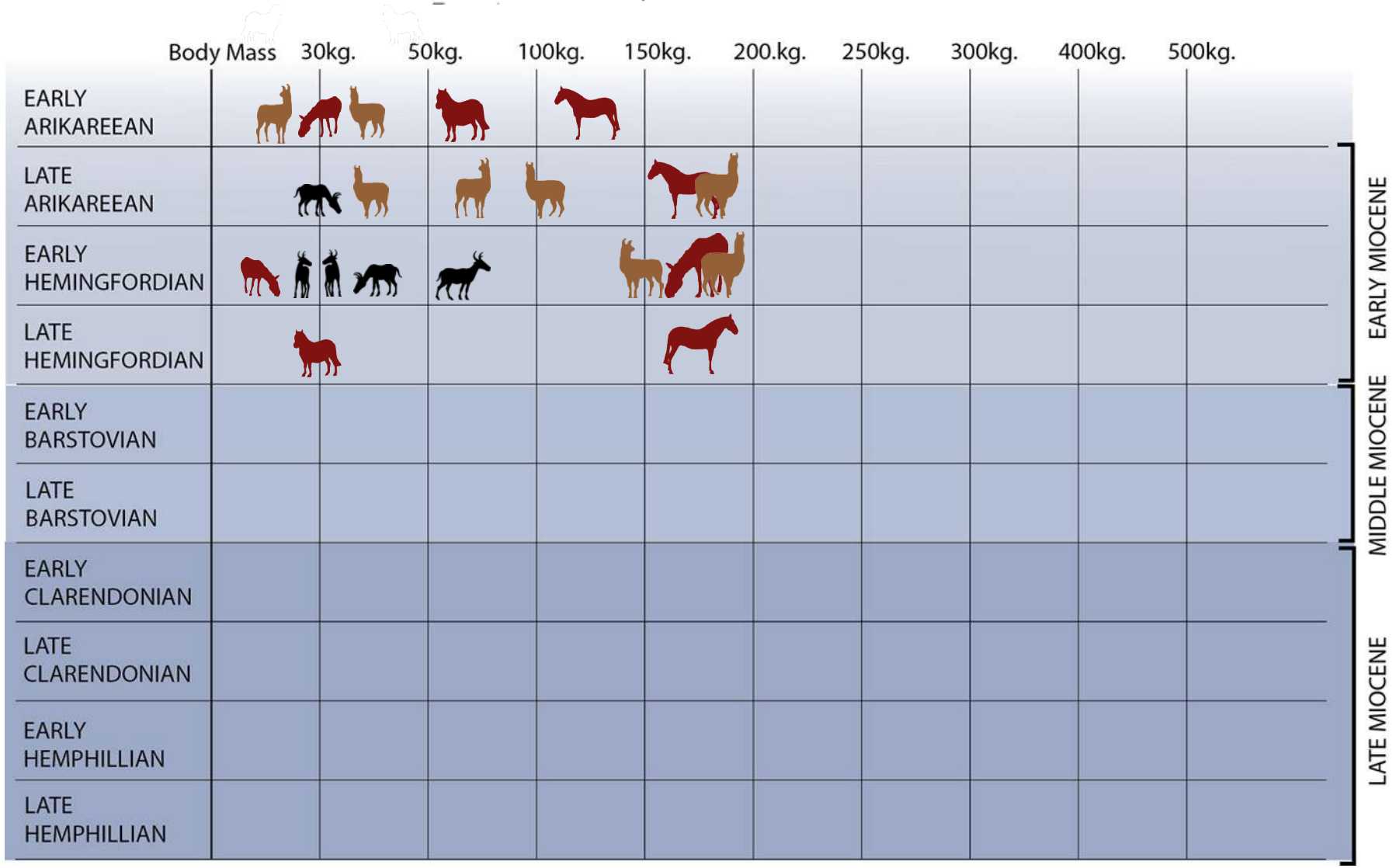

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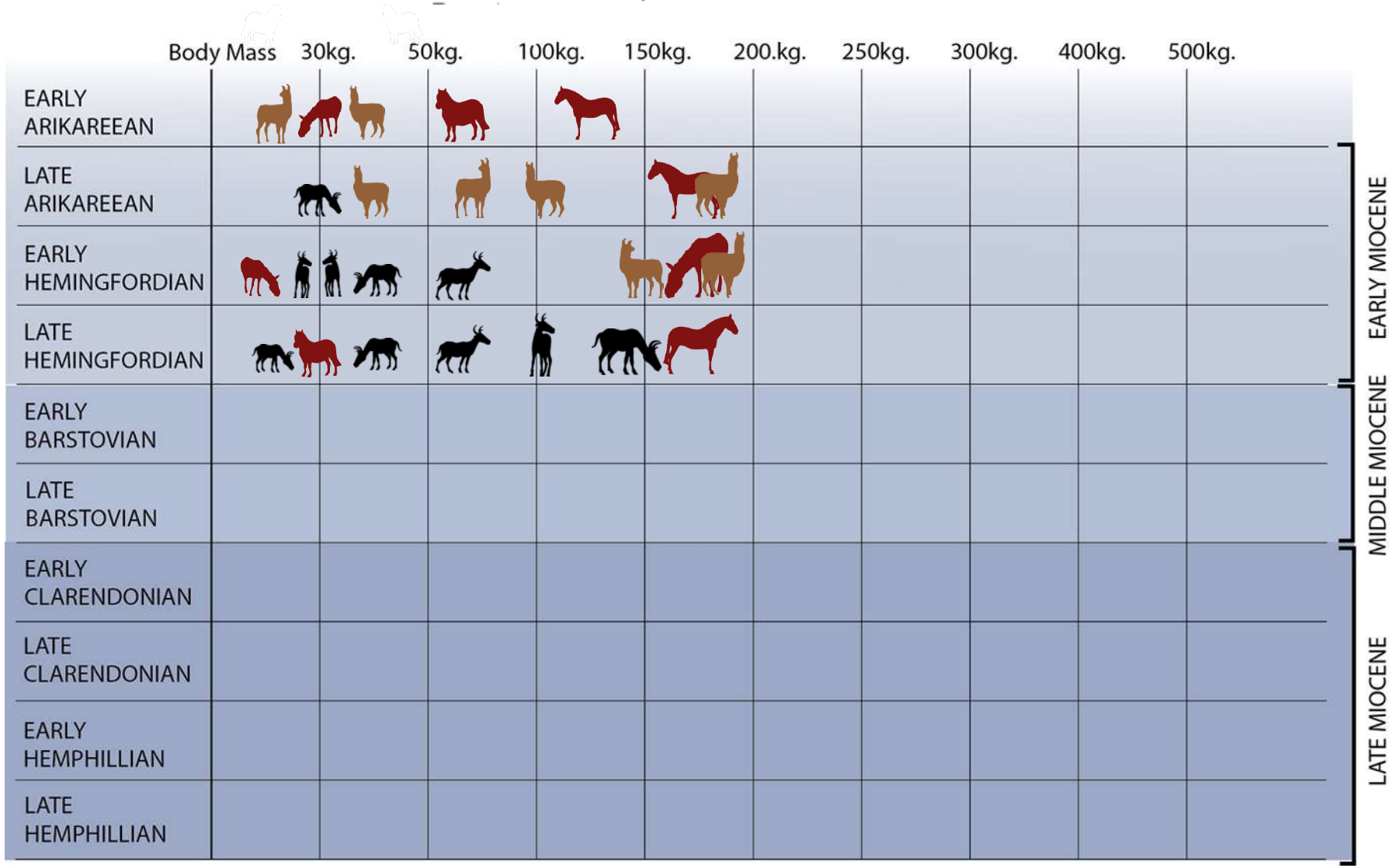

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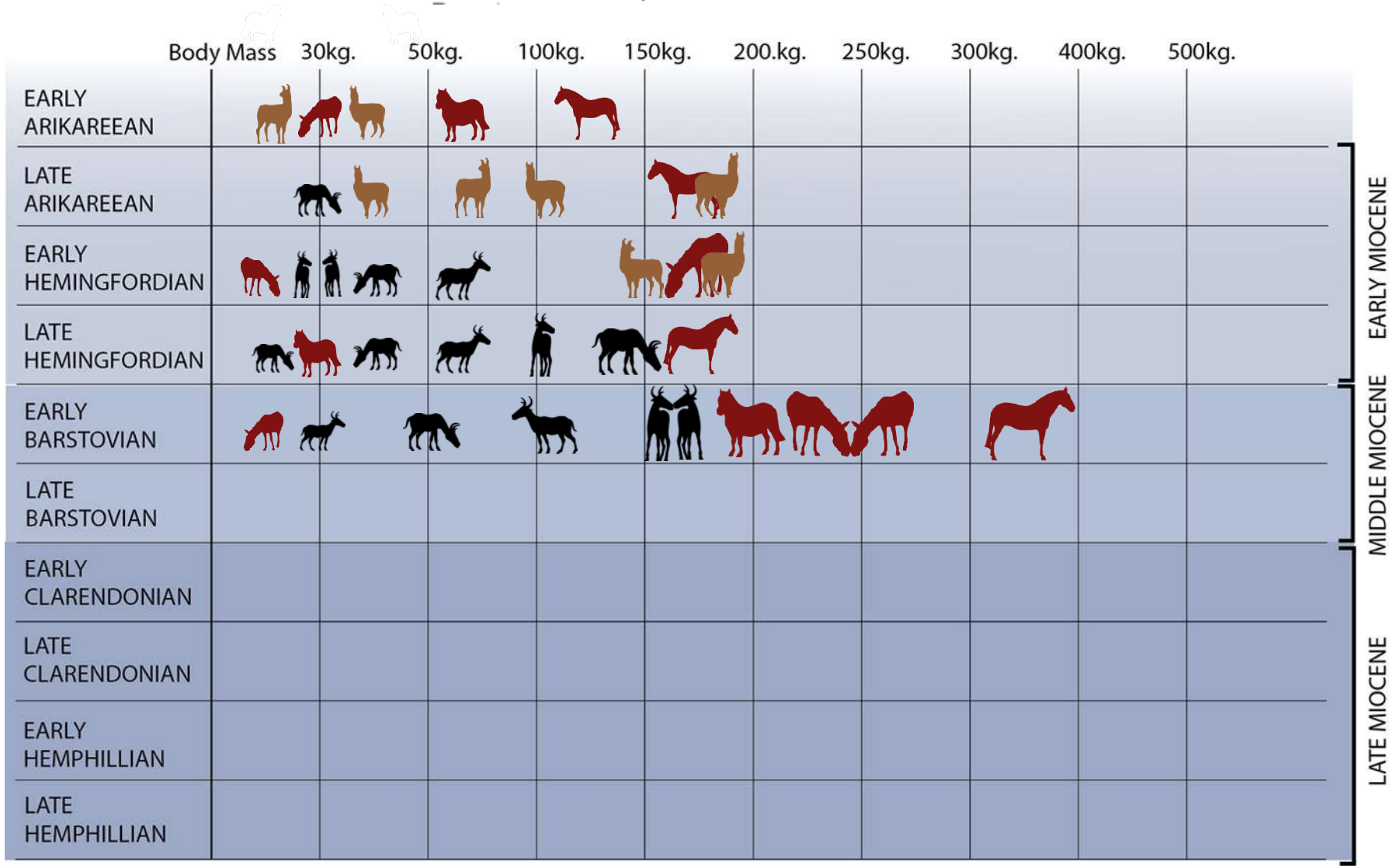

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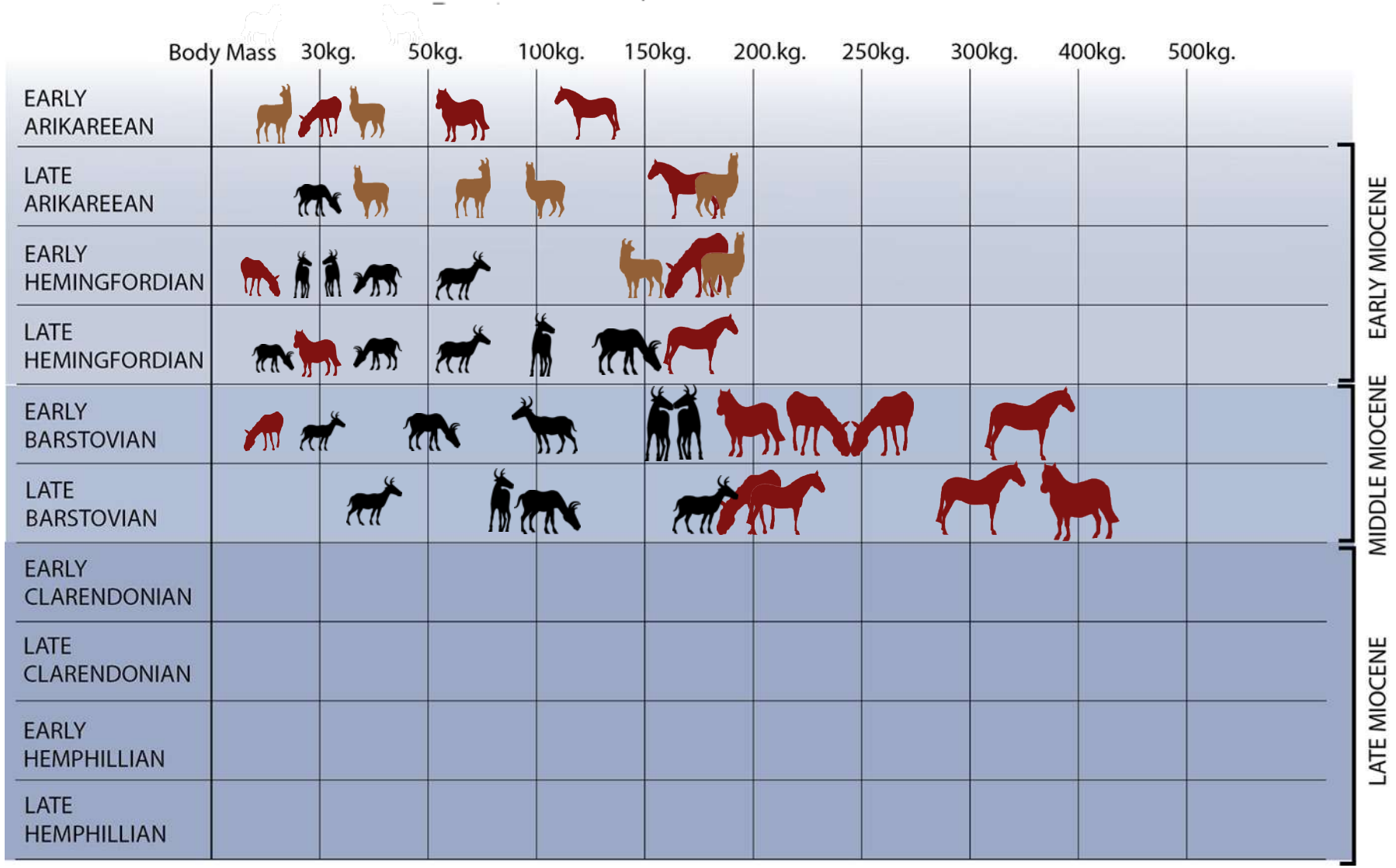

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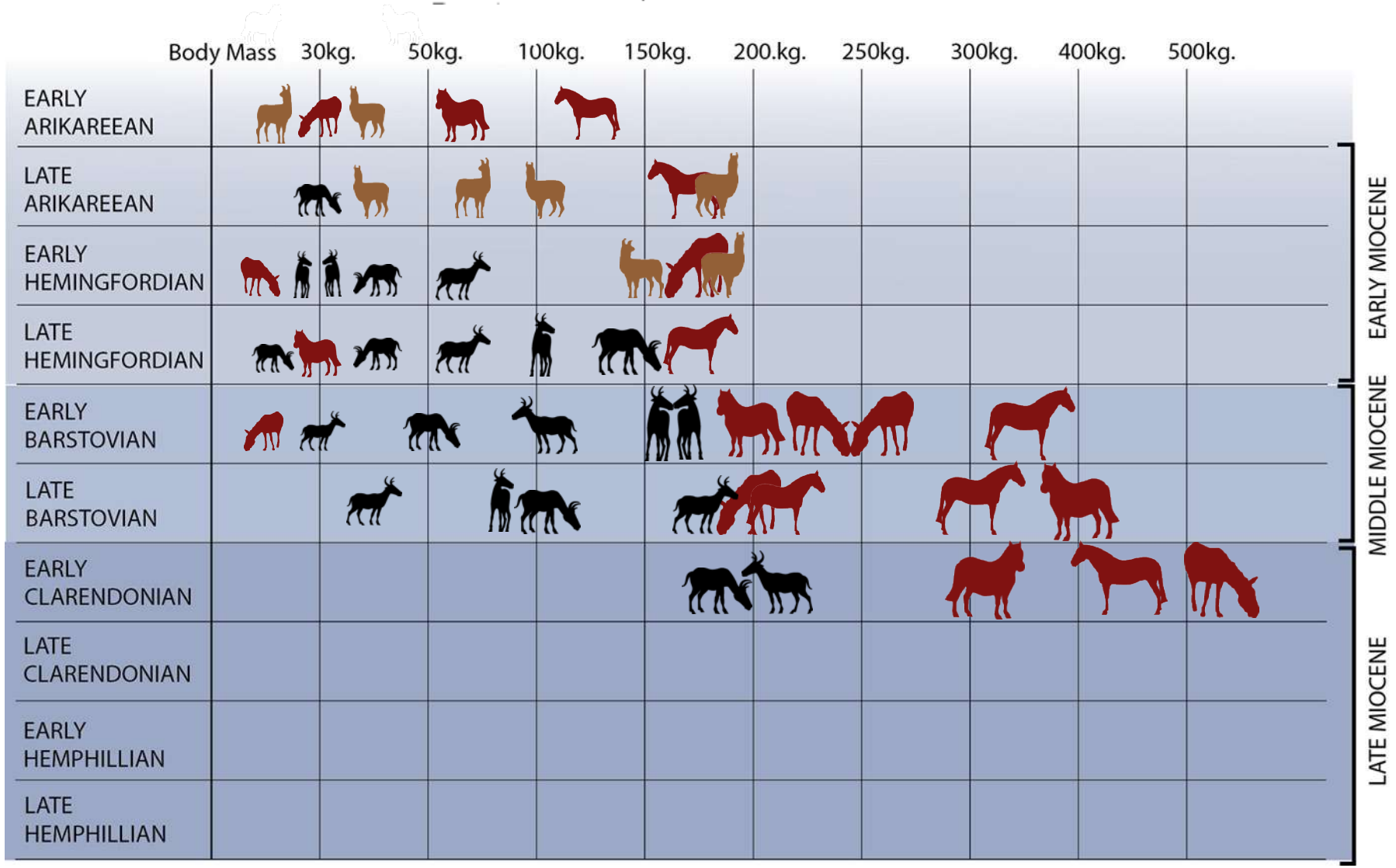

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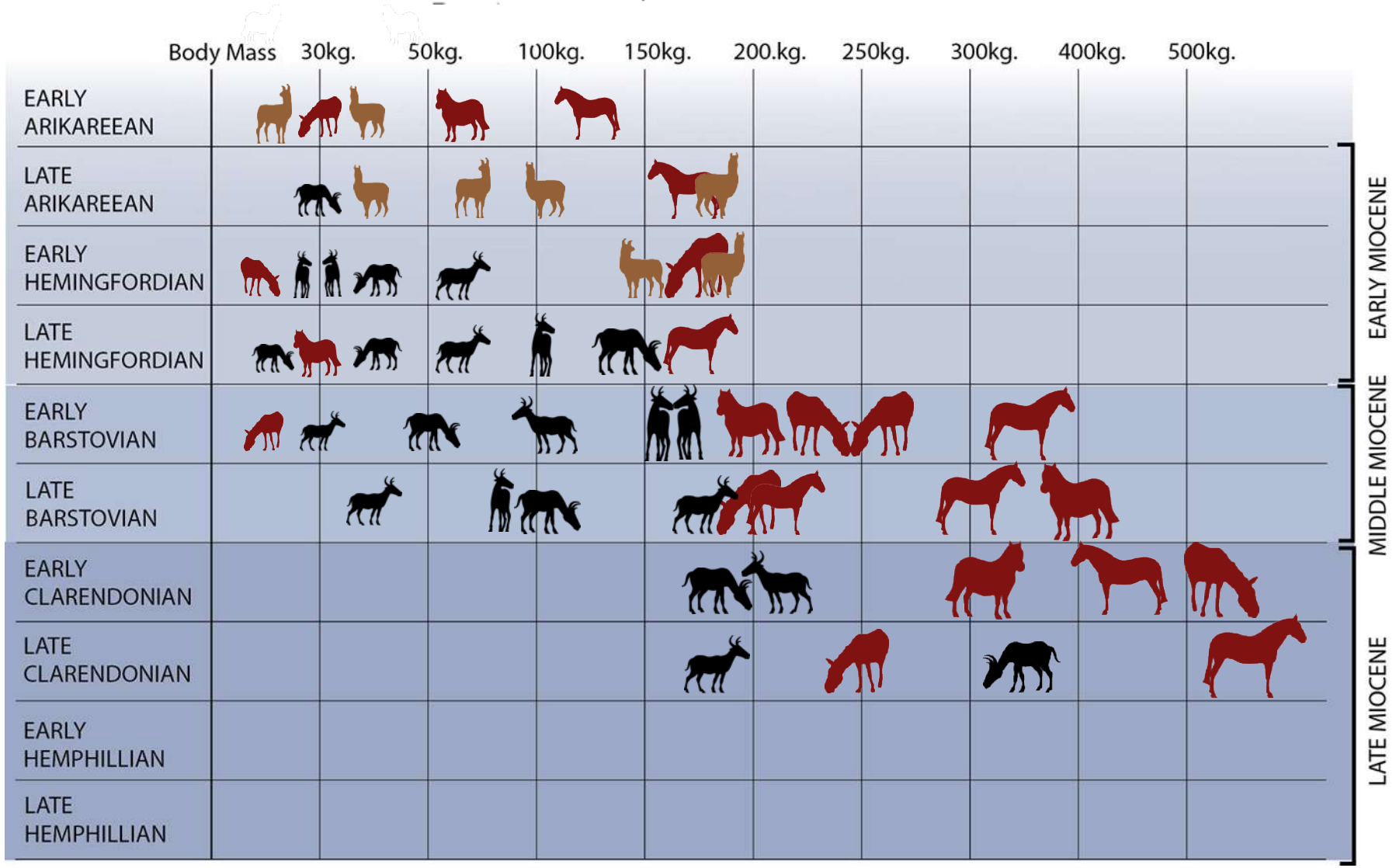

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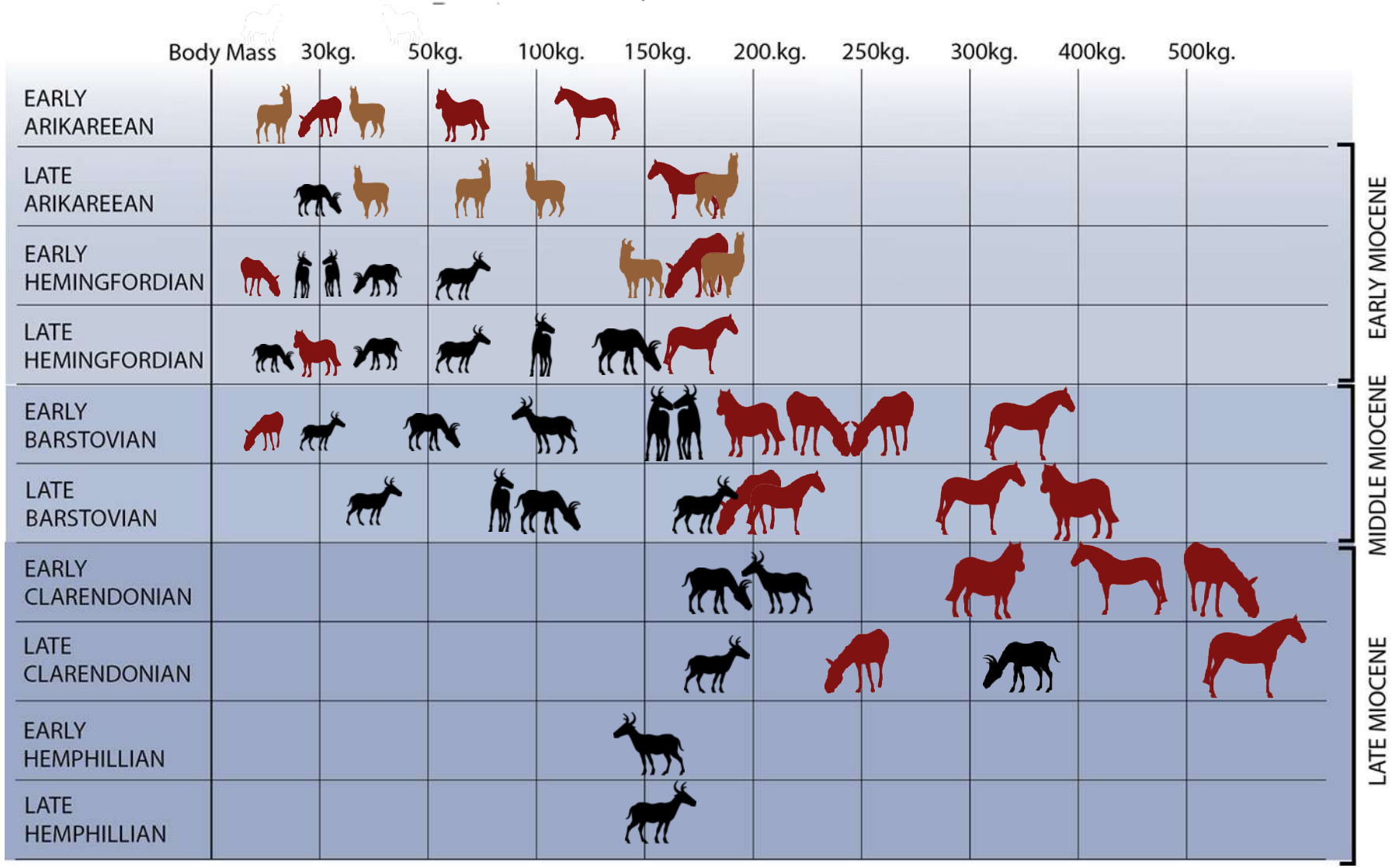
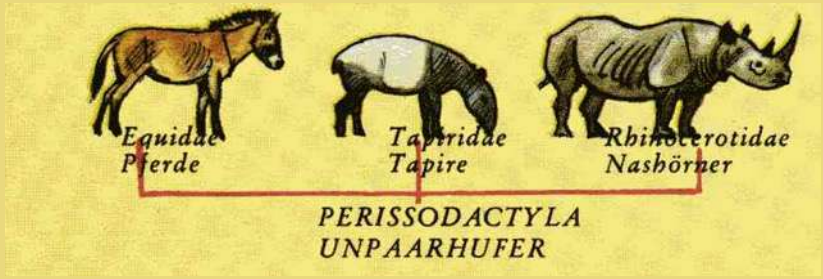


Large herbivore diversity in deep time: hoofed mammals



≈ 16 species

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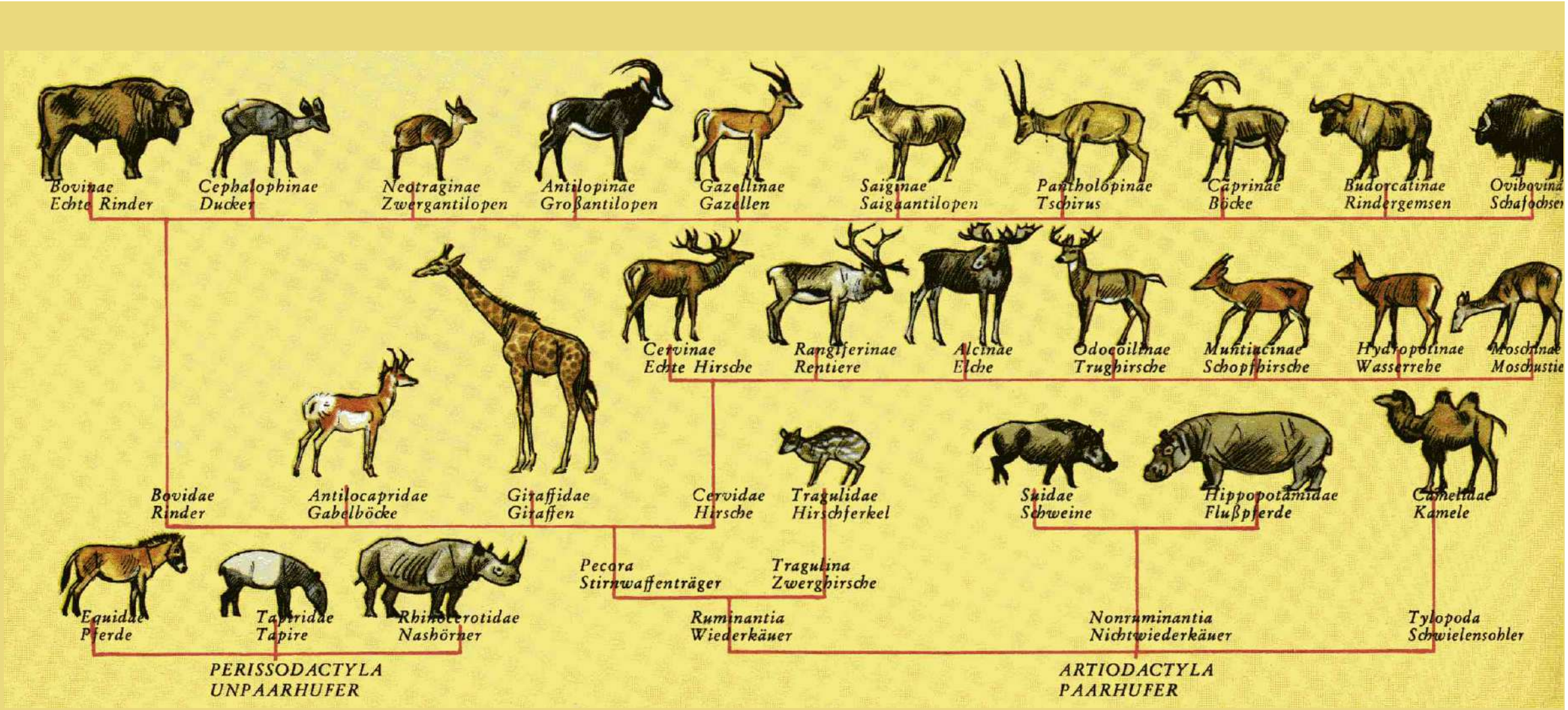

≈ 16 species

> 300 species

What are possible reasons for an evolutionary advantage of ruminants ?

Differences in hoof function ?

Differences in hoof function ?

Differences in hoof function ?

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Differences in hoof function ?

Differences in water dependence flexibility ?

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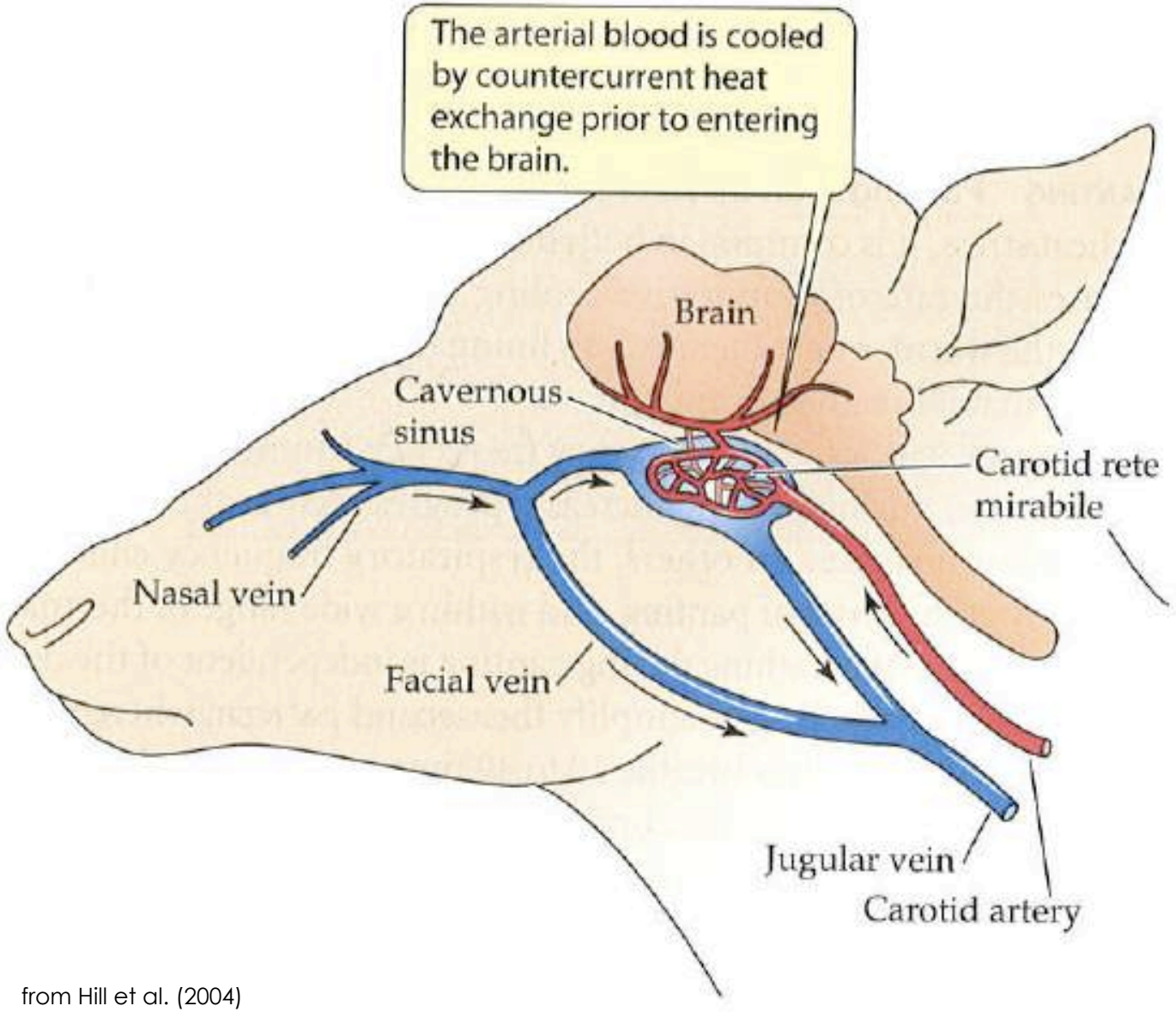
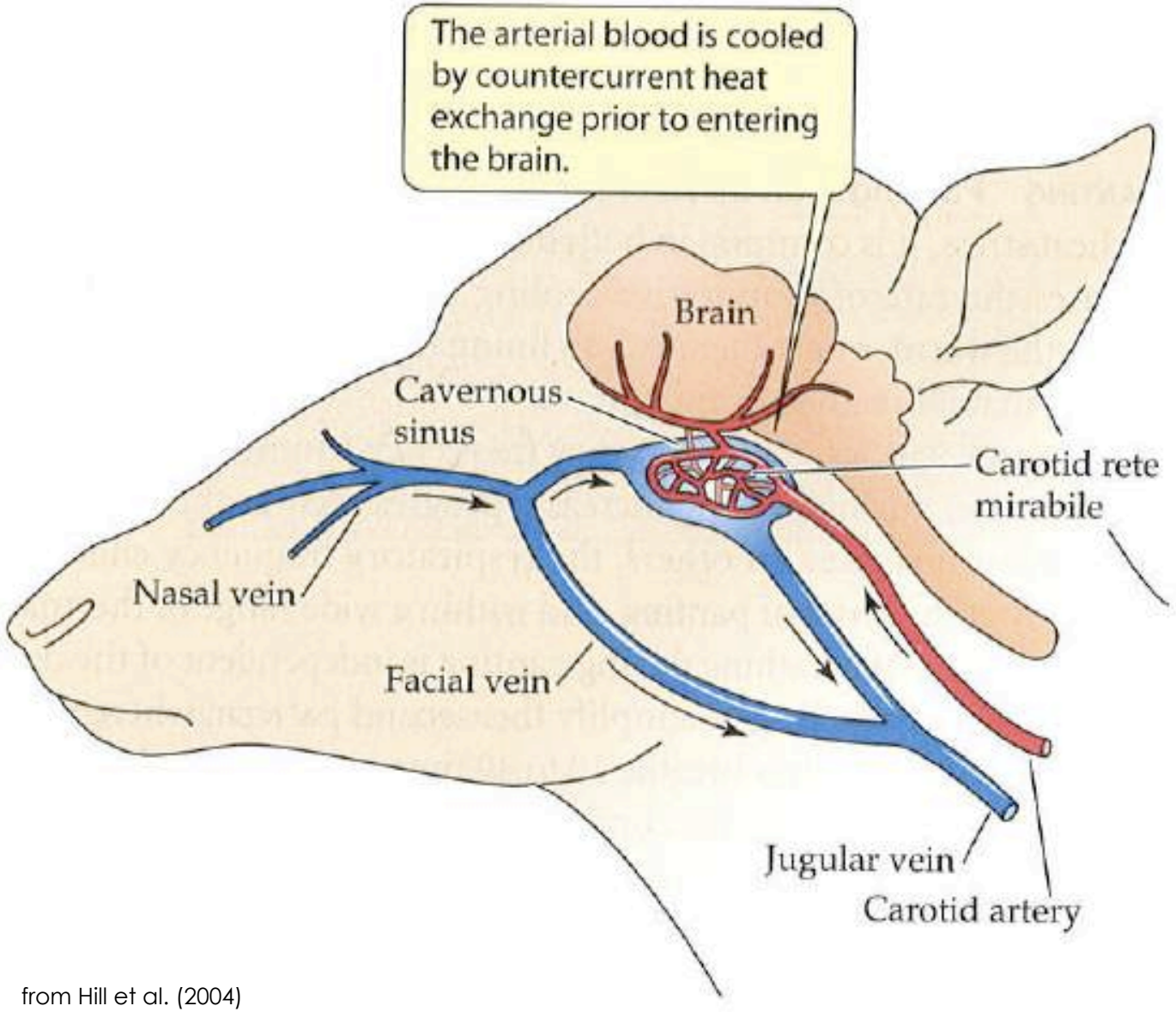


from Hill et al. (2004)

Differences in water dependence flexibility ?



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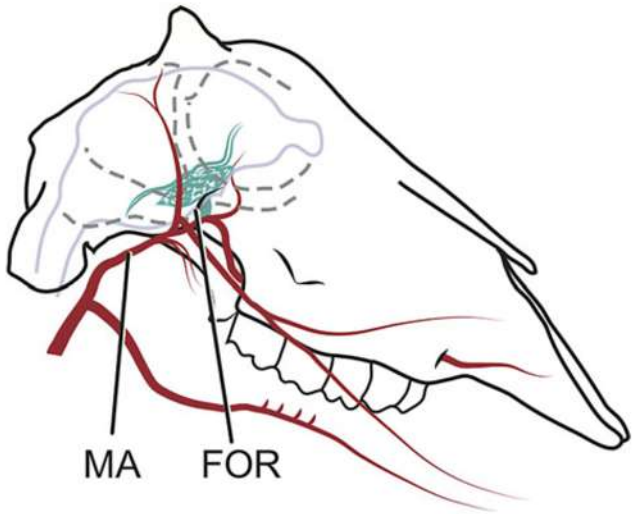

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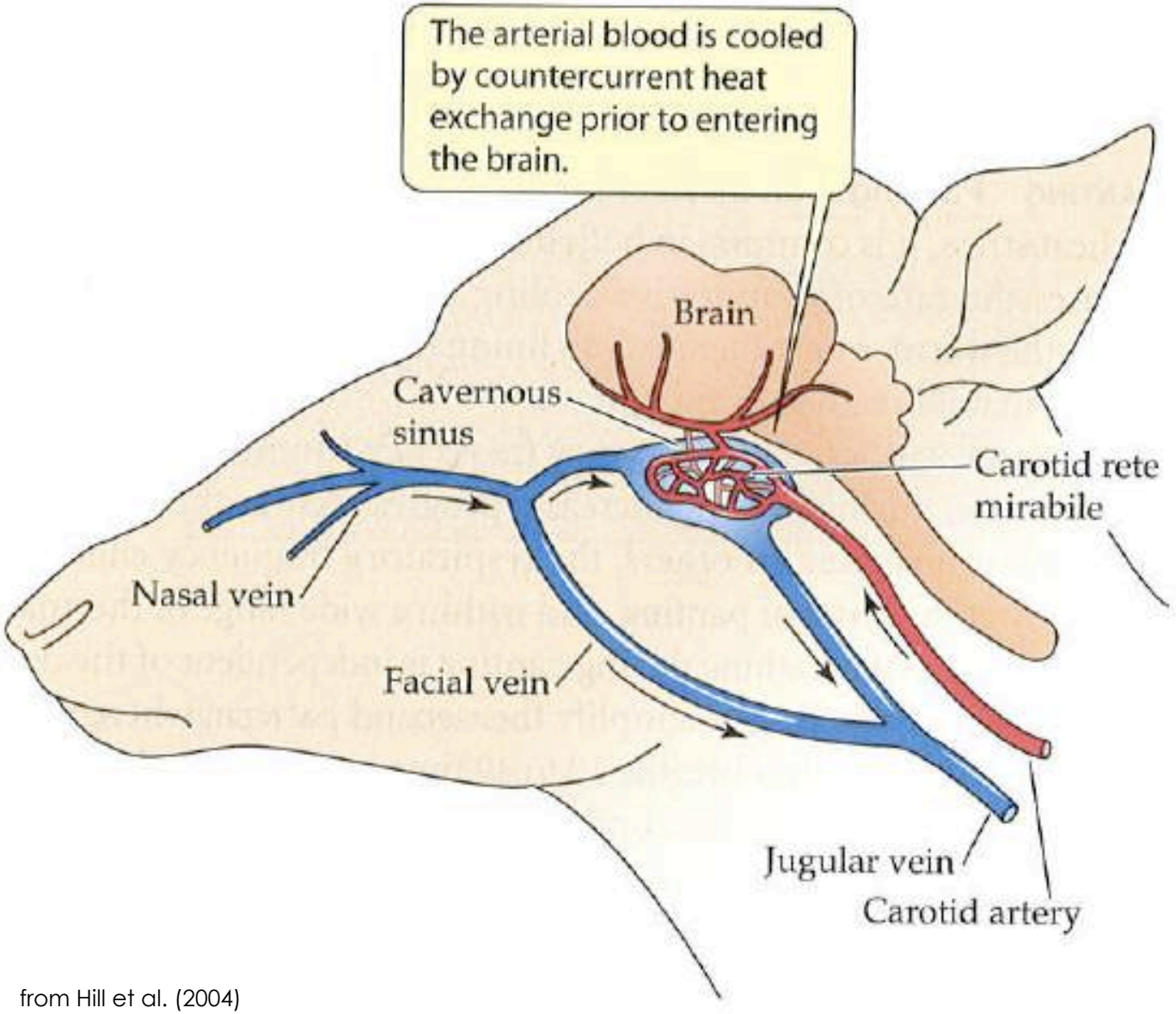

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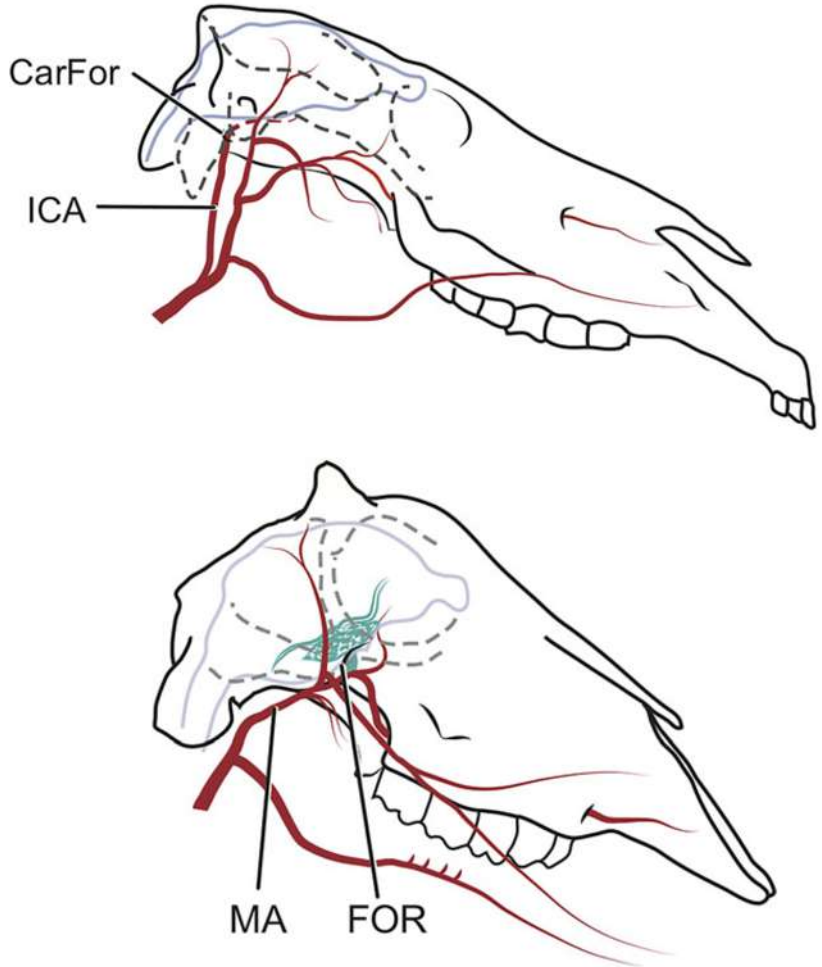

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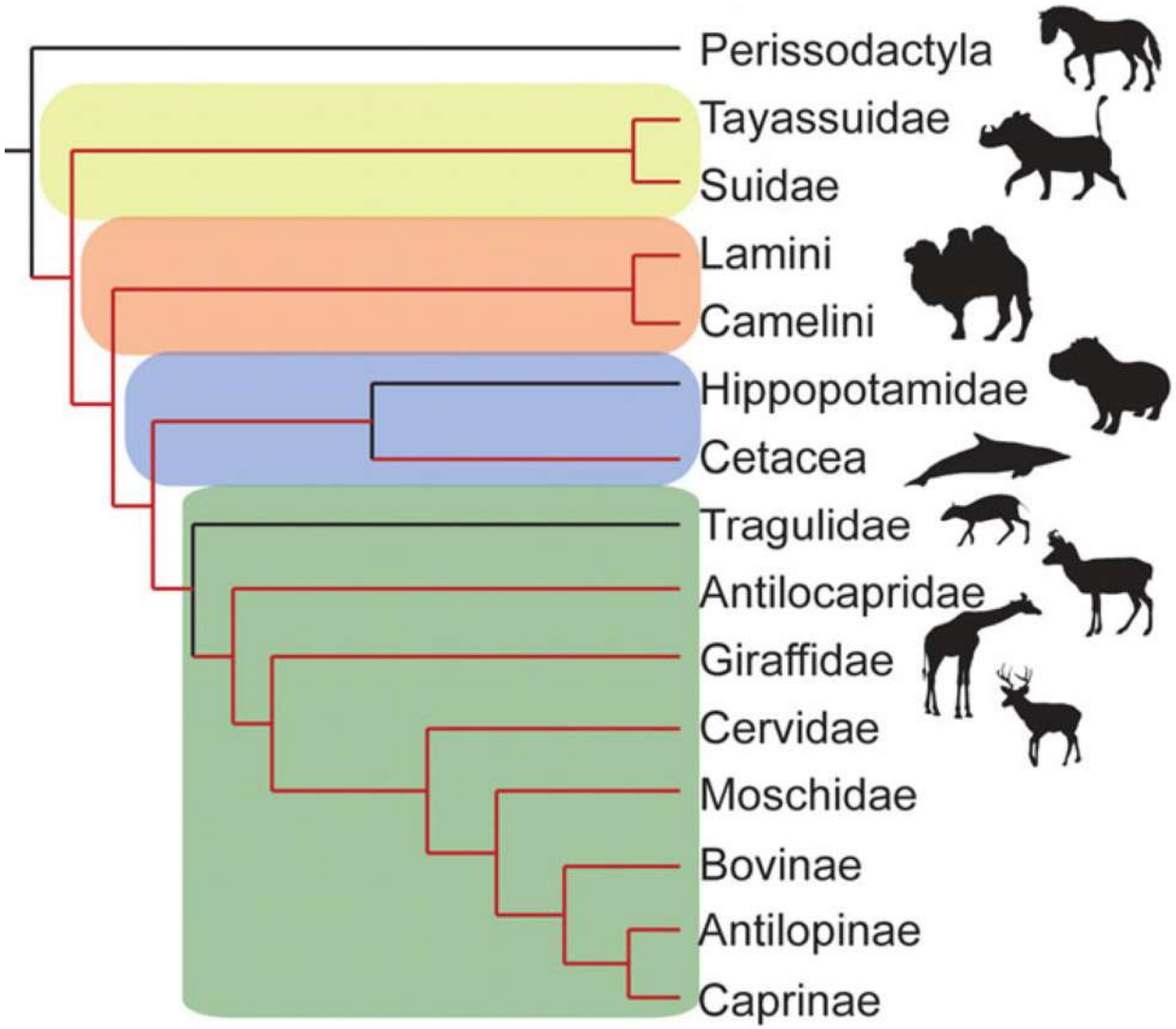

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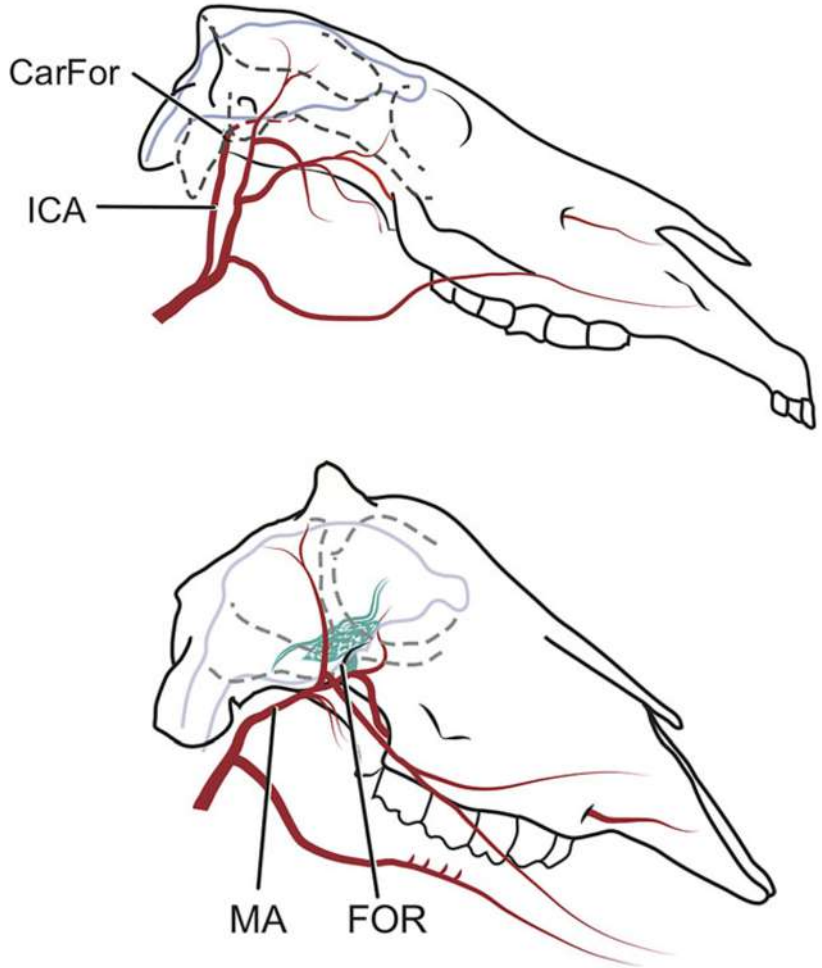

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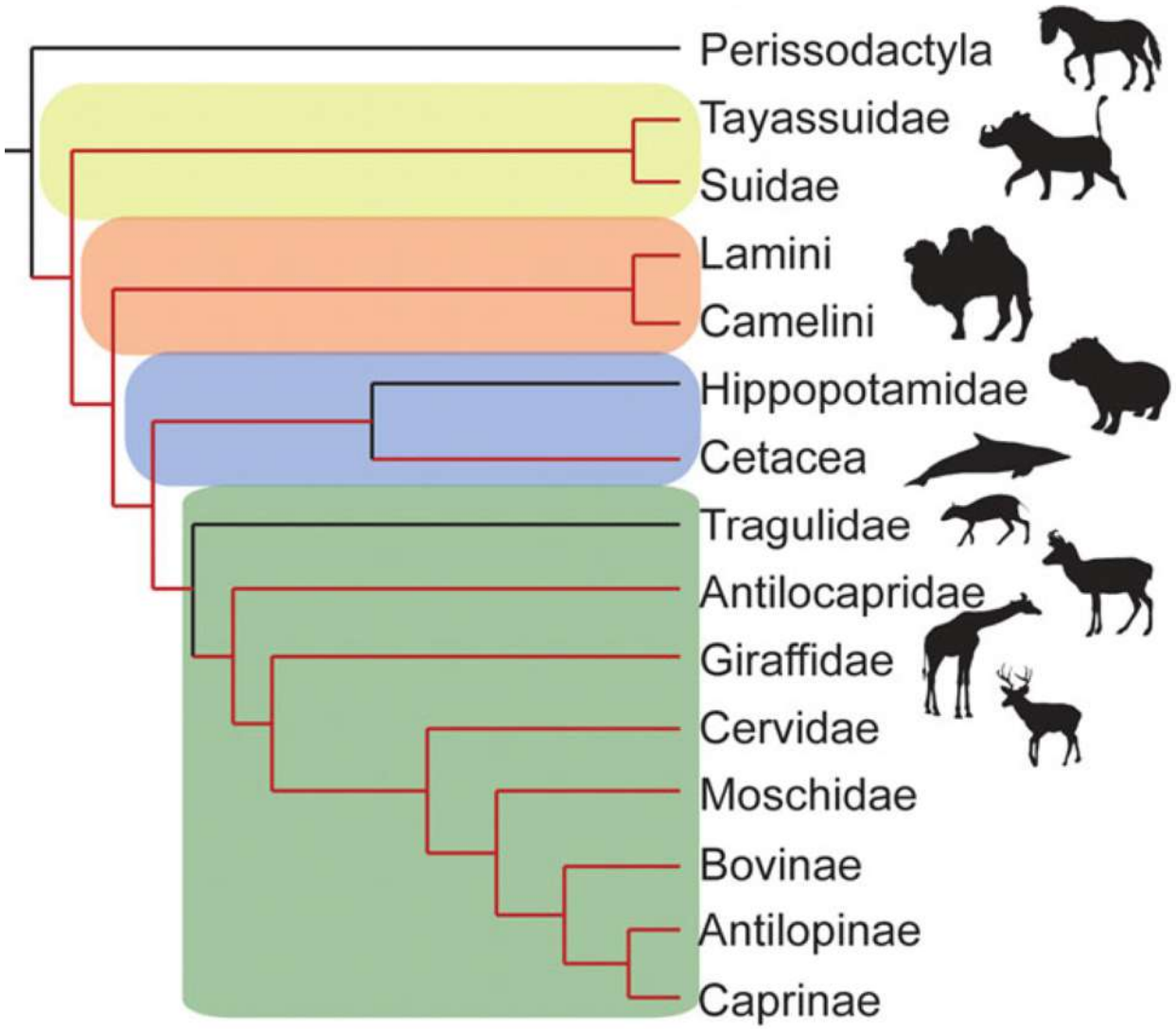

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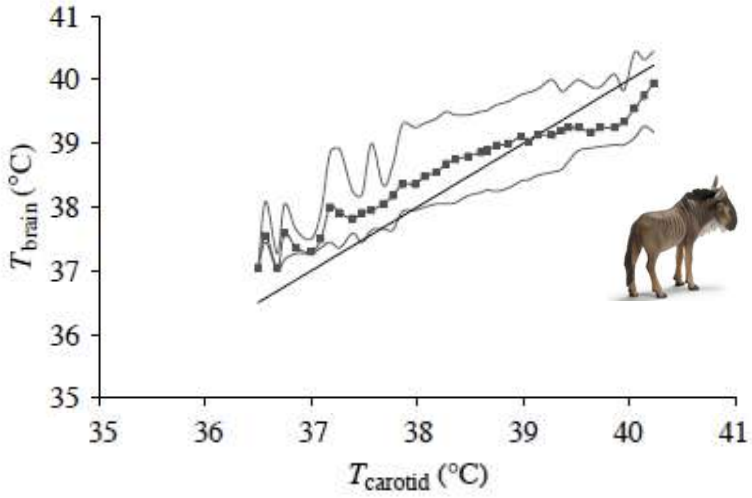

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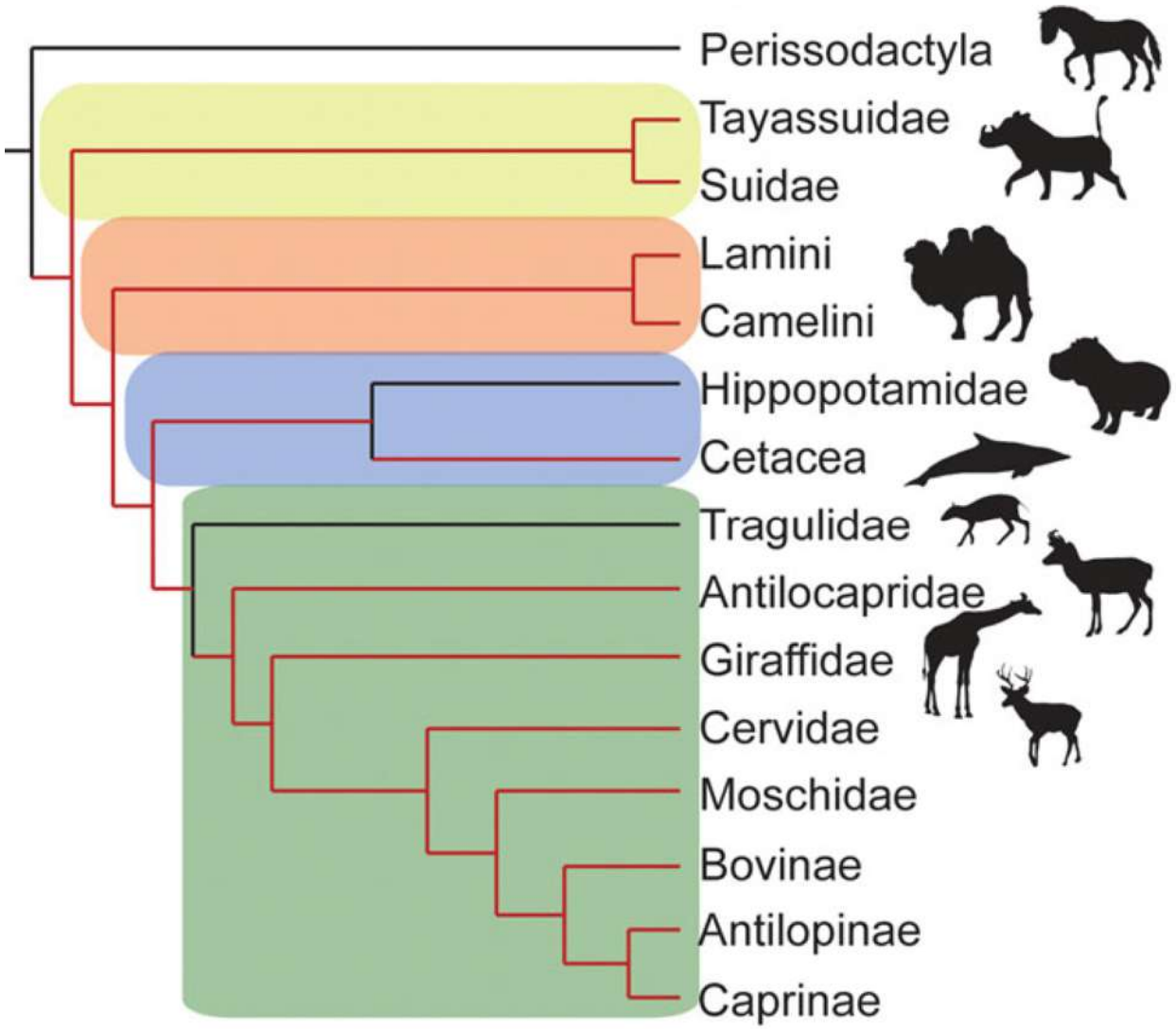

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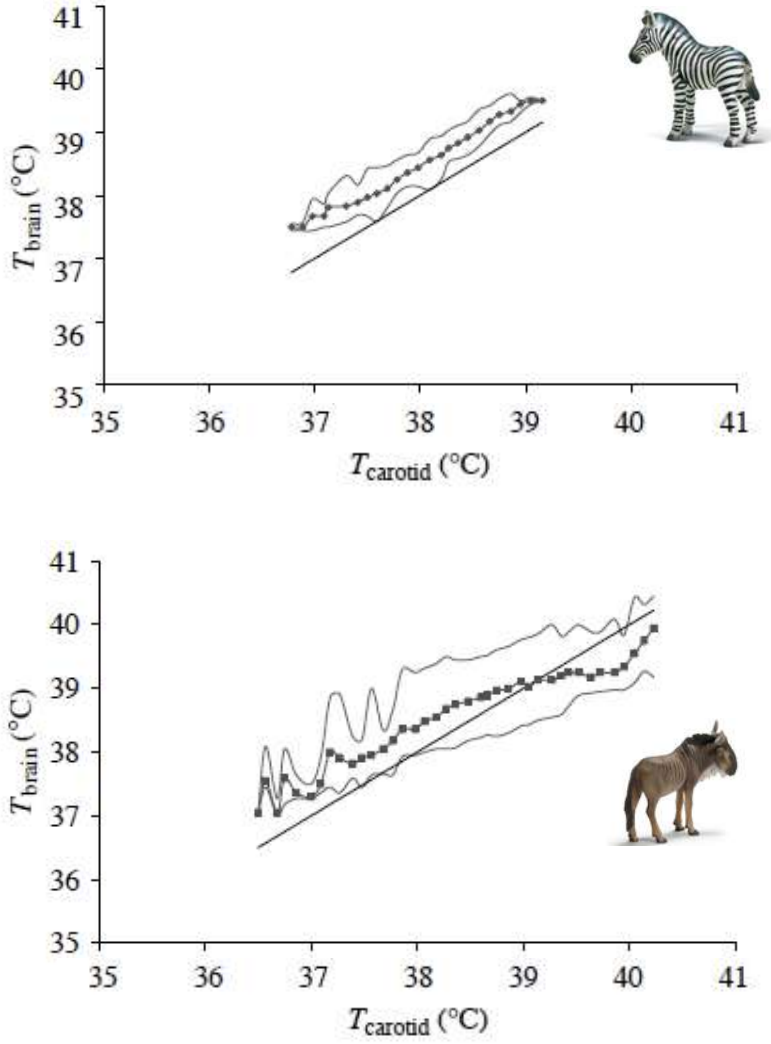

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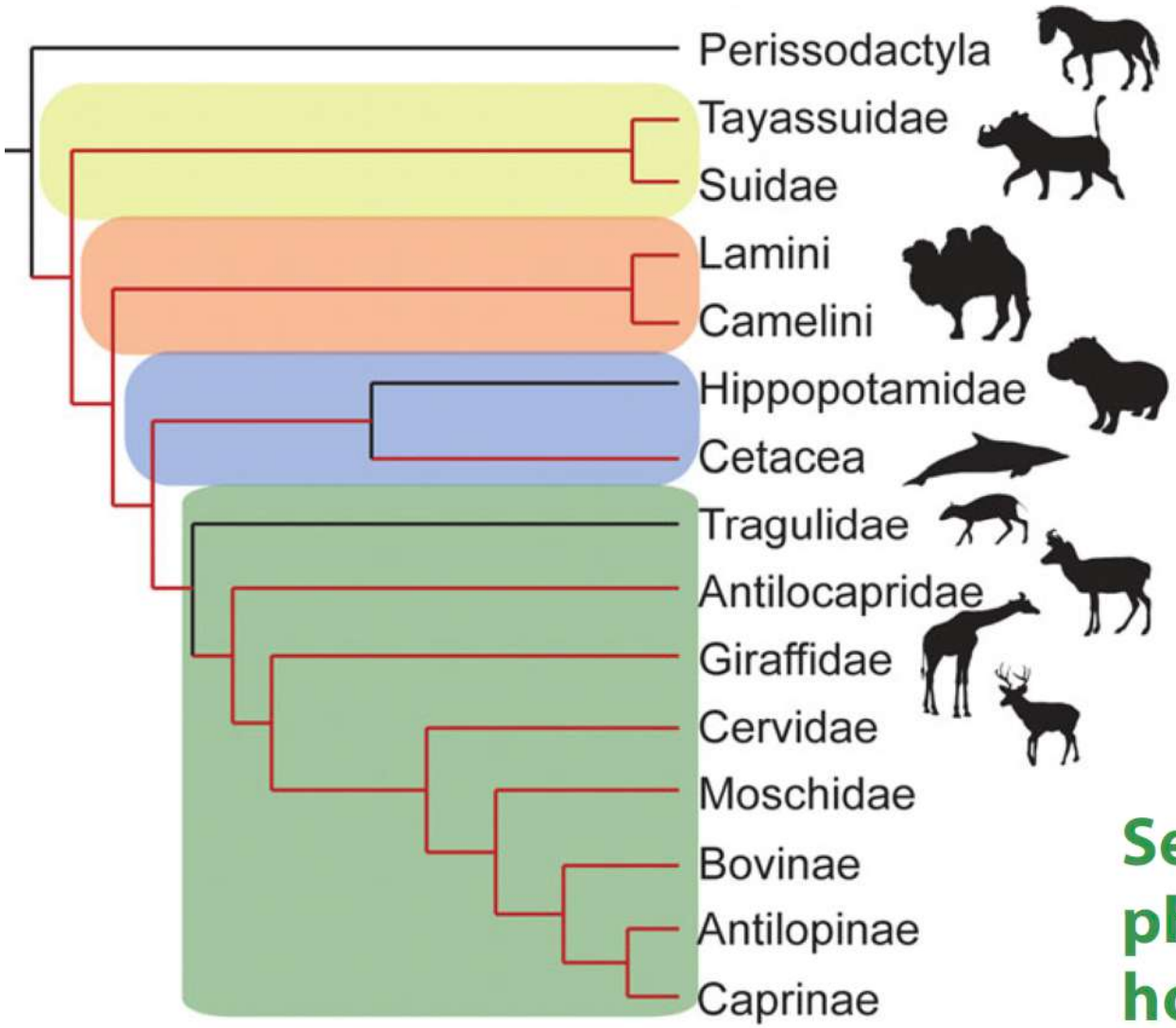

Selective brain cooling as a physiological feature for surviving hotter and drier environments

from Strauss et al. (2017)

Differences in reproductive ***rate*** ?

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Gestation period

280 days

340 days

390 days

440 days

from Clauss et al. (2014)

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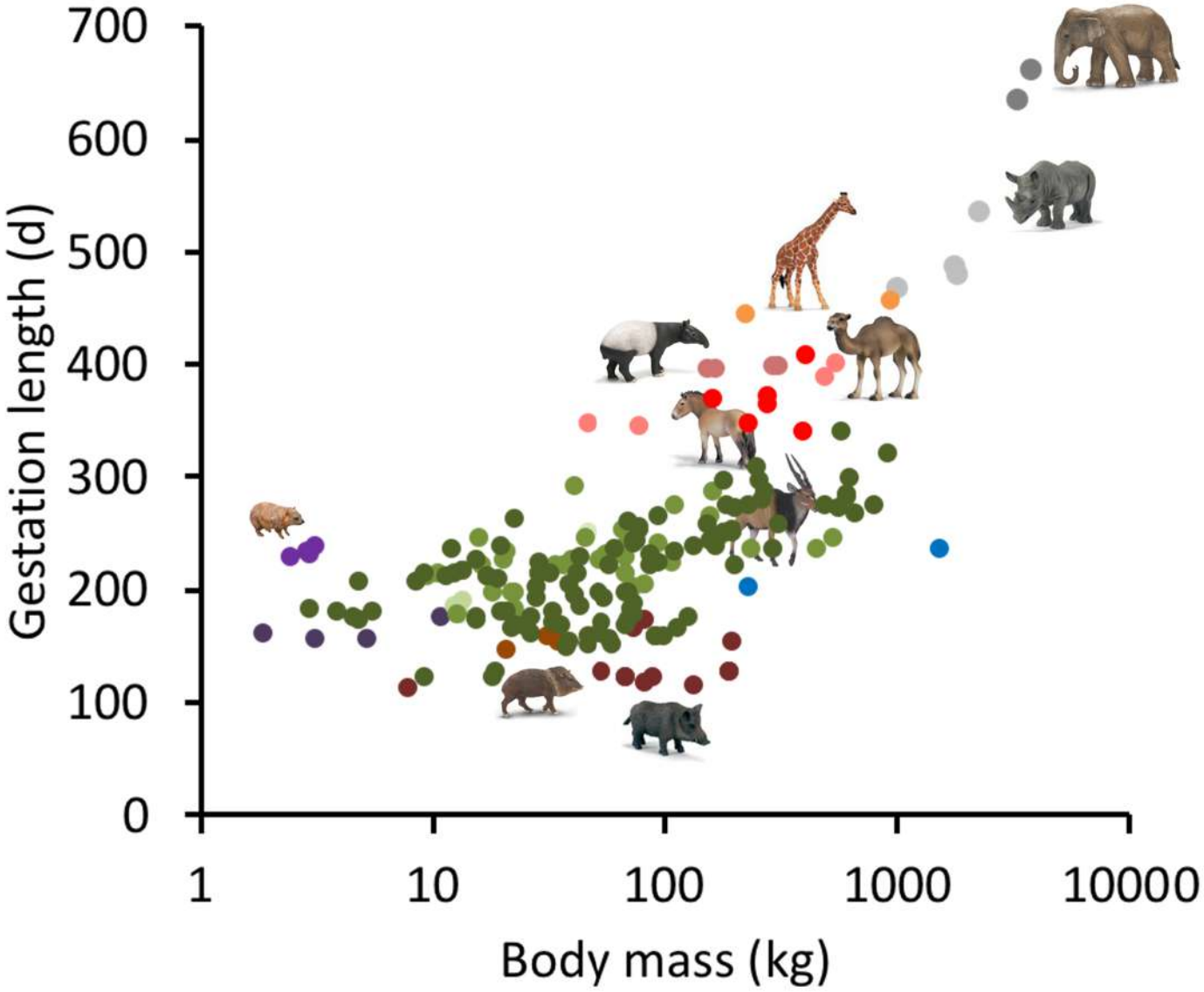

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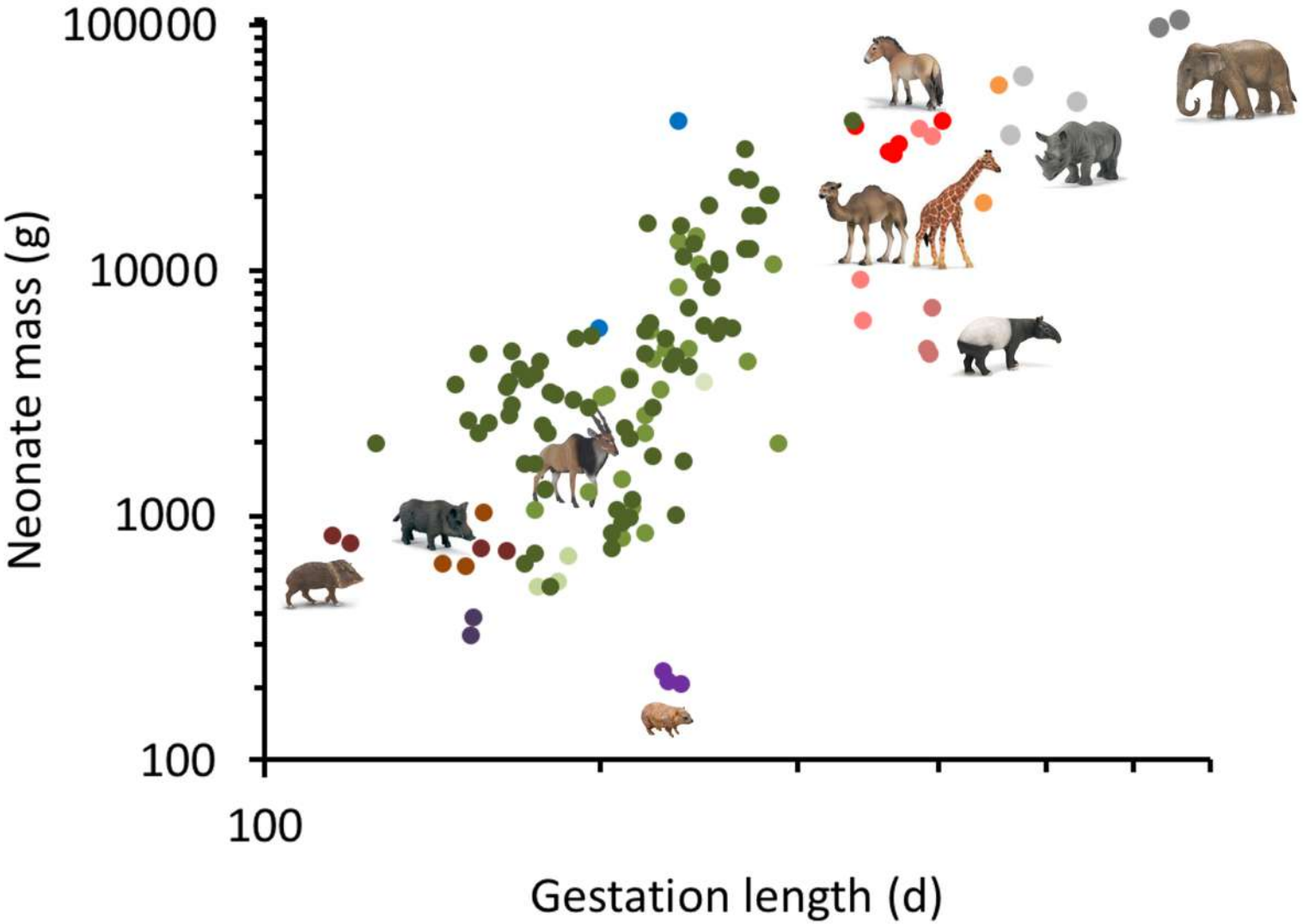

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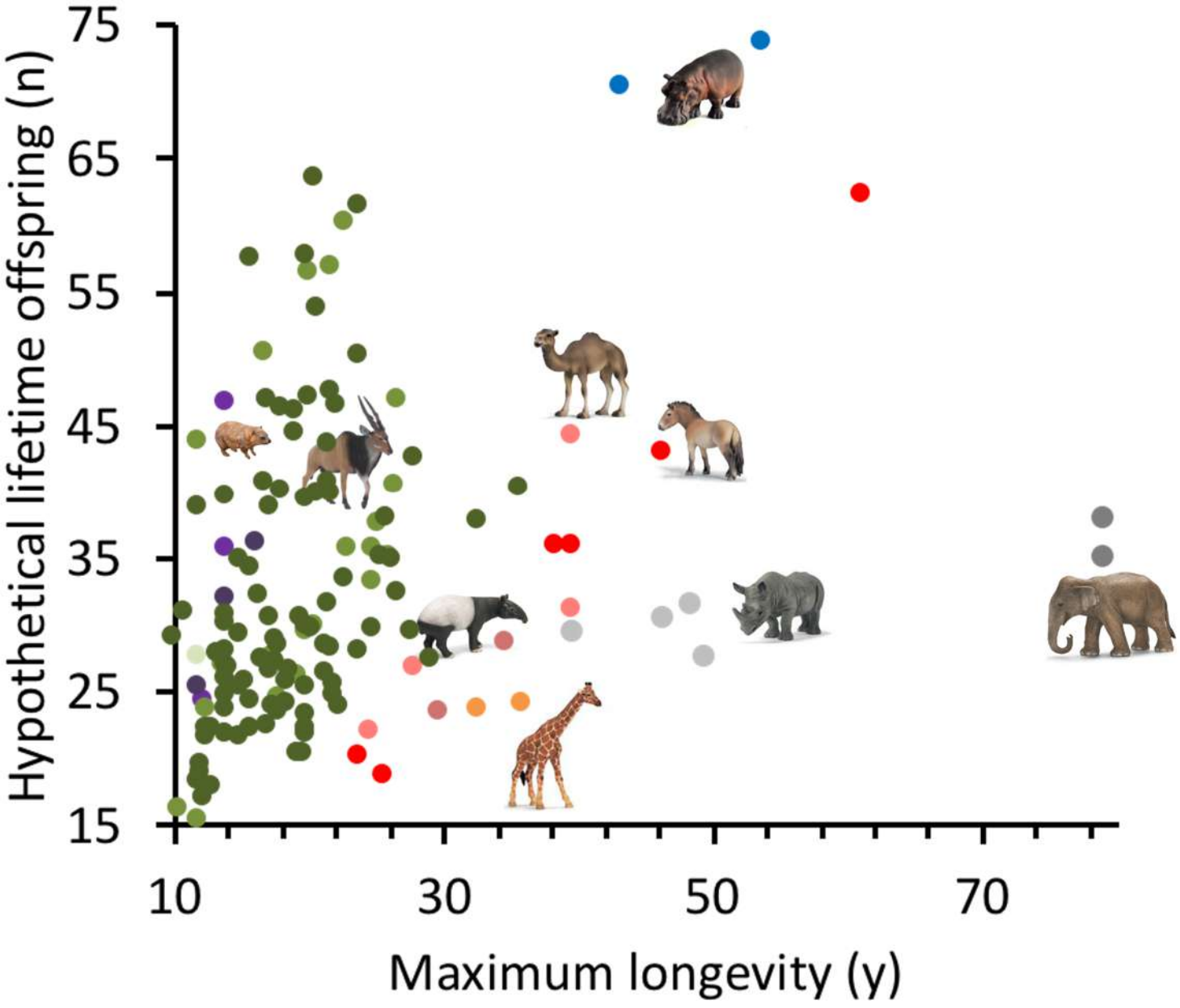

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Differences in digestive physiology between equids and ruminants: digestive efficiency and intake

Differences in digestive efficiency ?

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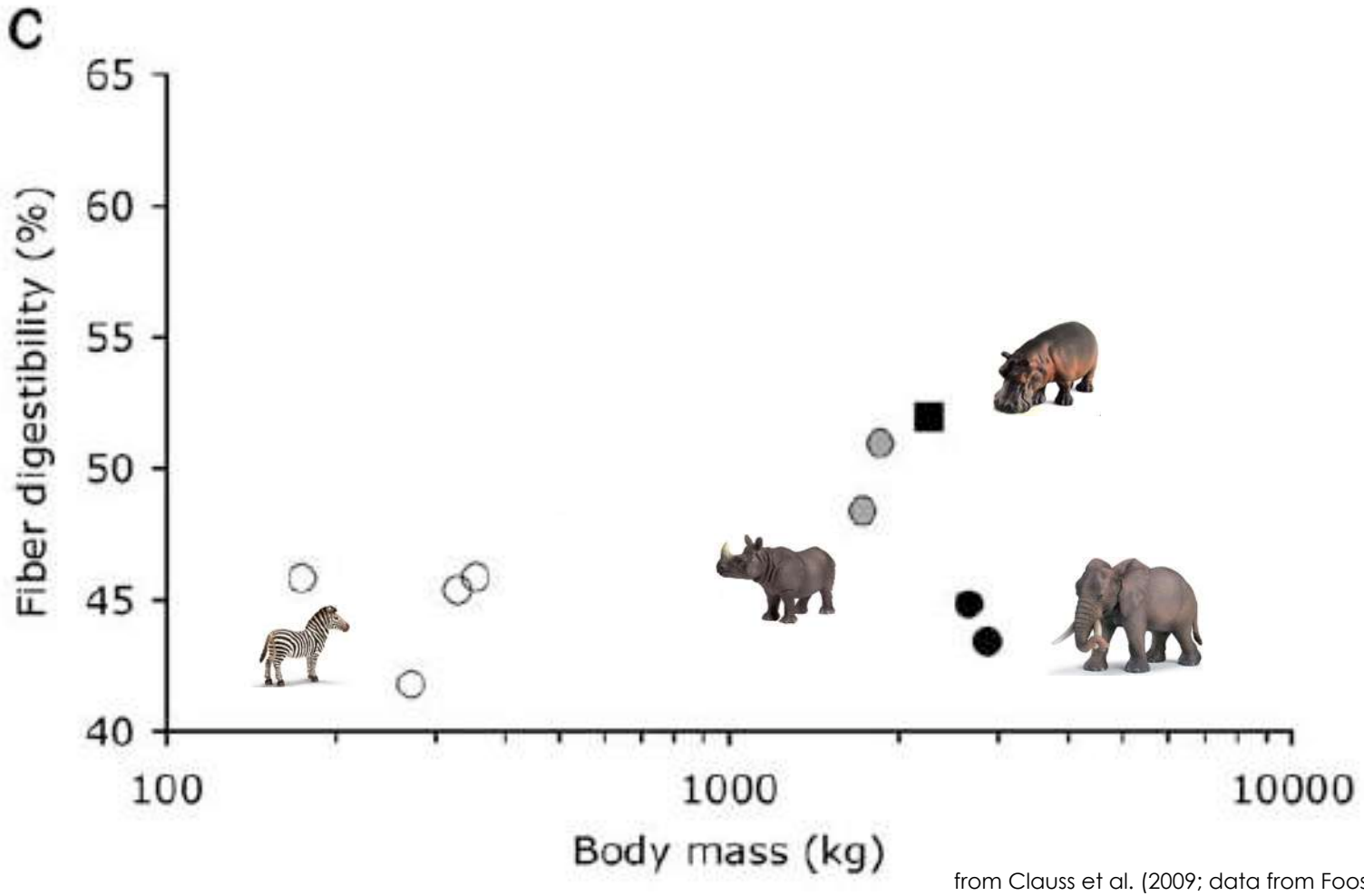

from Clauss et al. (2009; data from Foose 1982)

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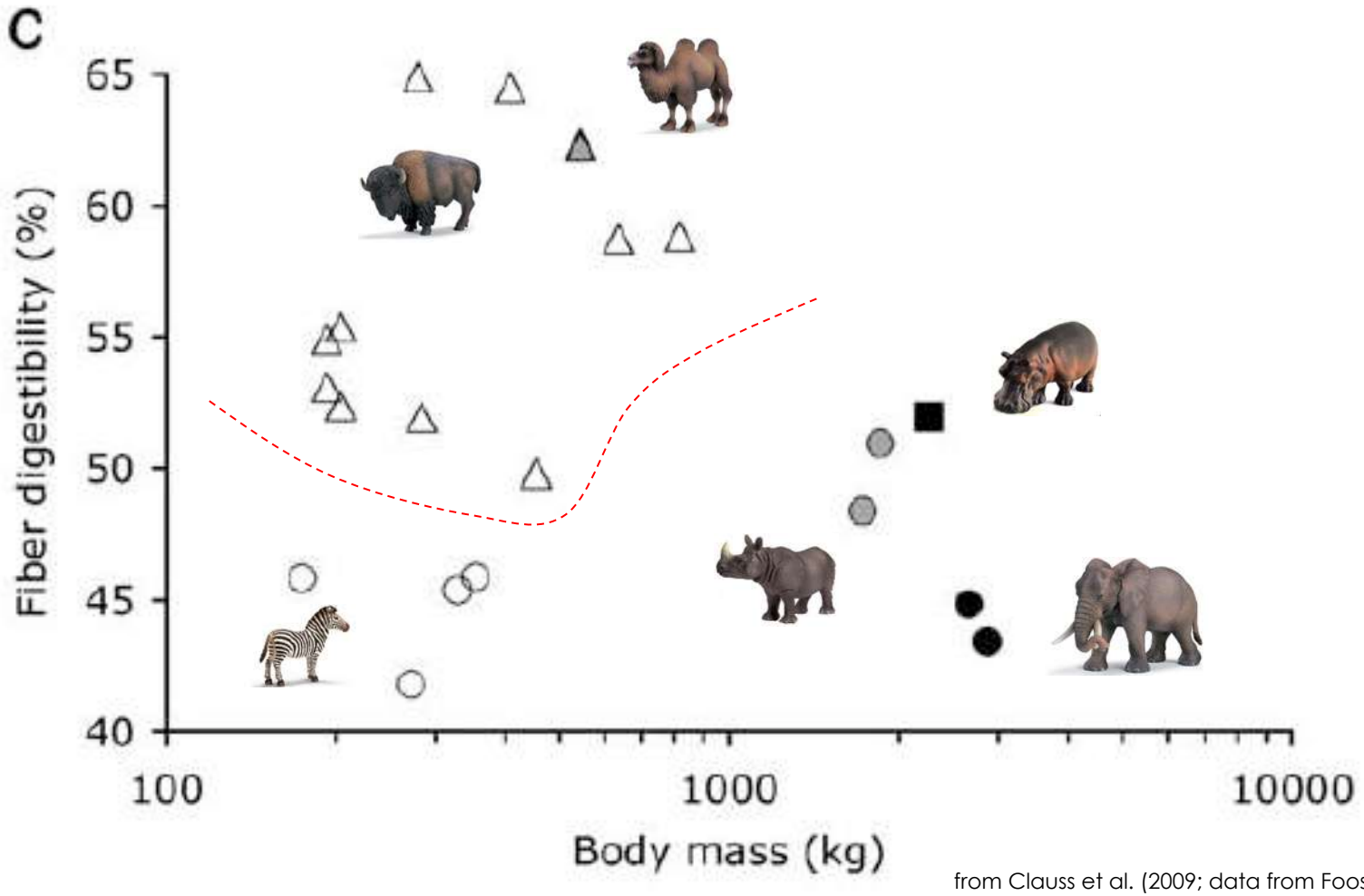

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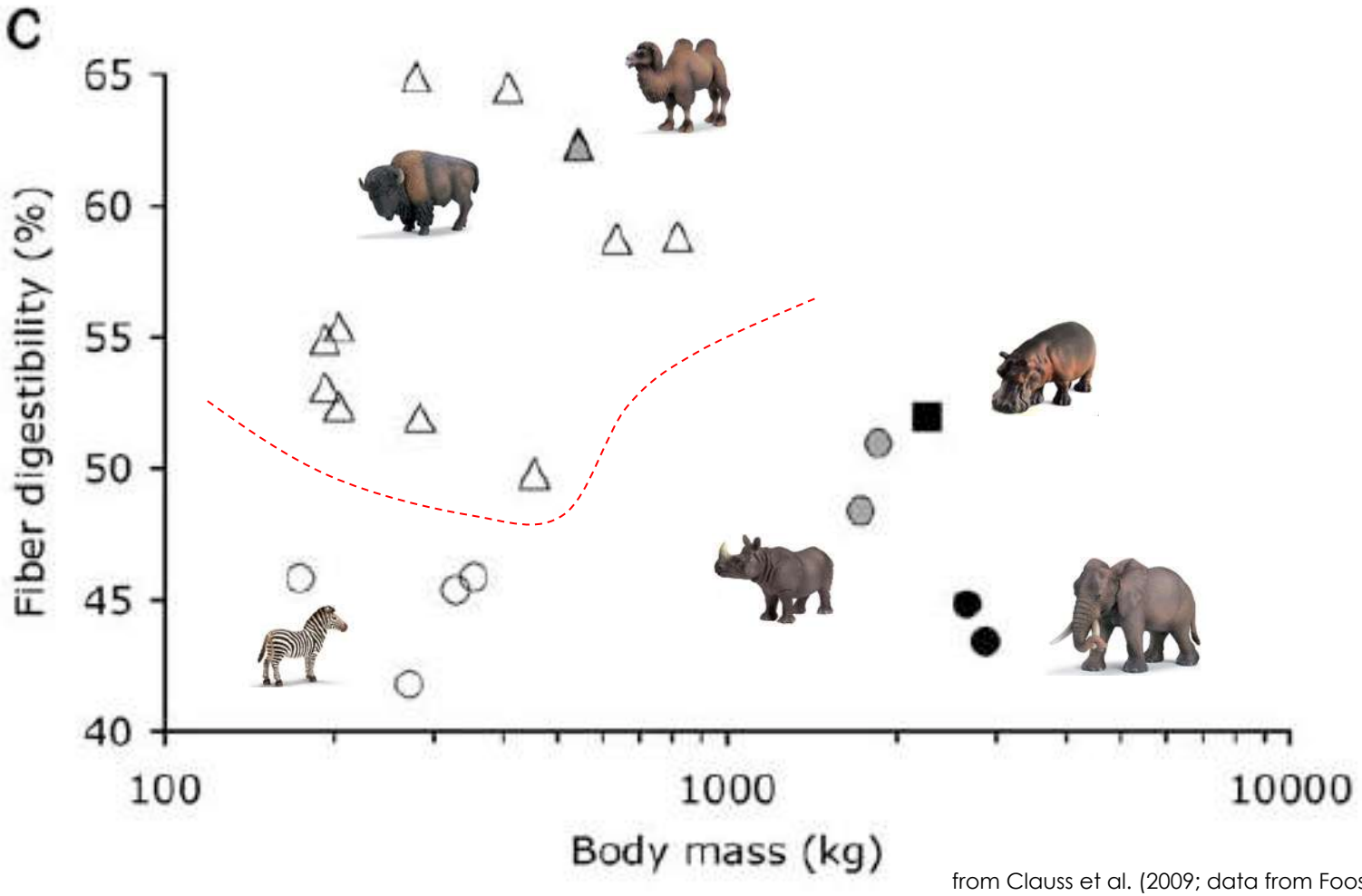
Differences in digestive efficiency ?

Ruminants achieve higher digestive efficiencies



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Digestive physiology meets herbivore diversity

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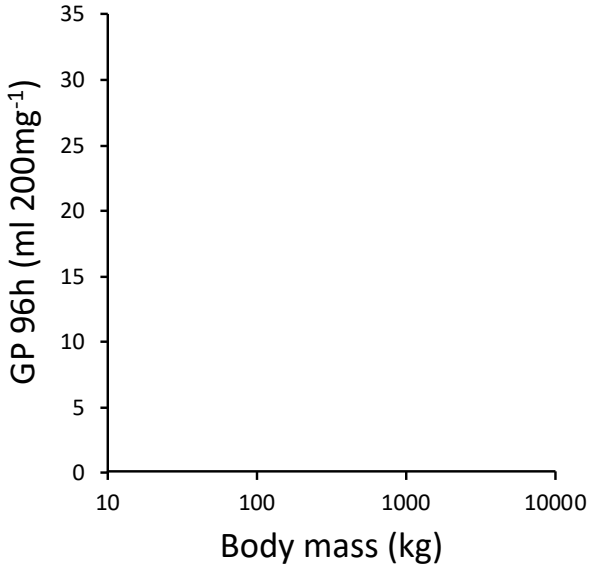
Comparative Biochemistry and Physiology, Part A 179 (2015) 182–191

Residual digestibility in faeces



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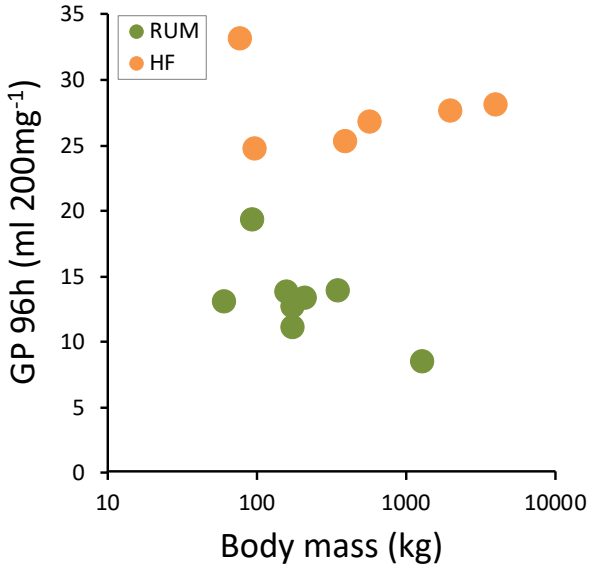

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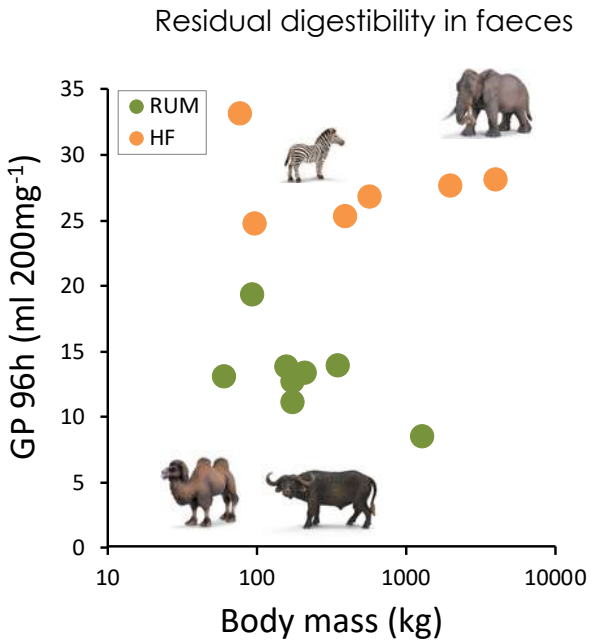

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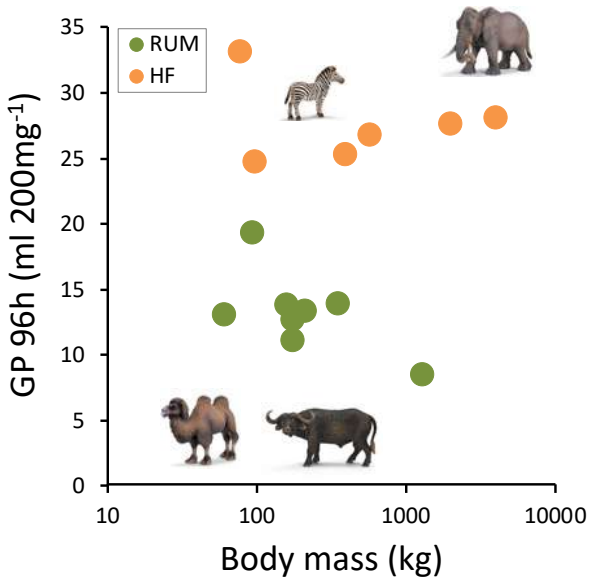
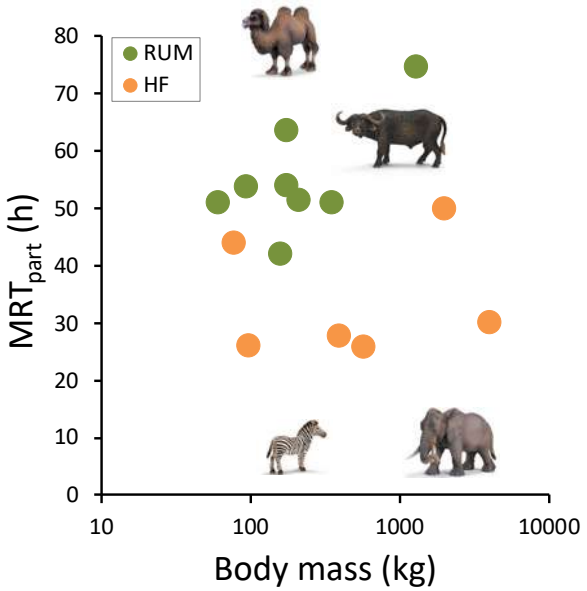


Digesta retention



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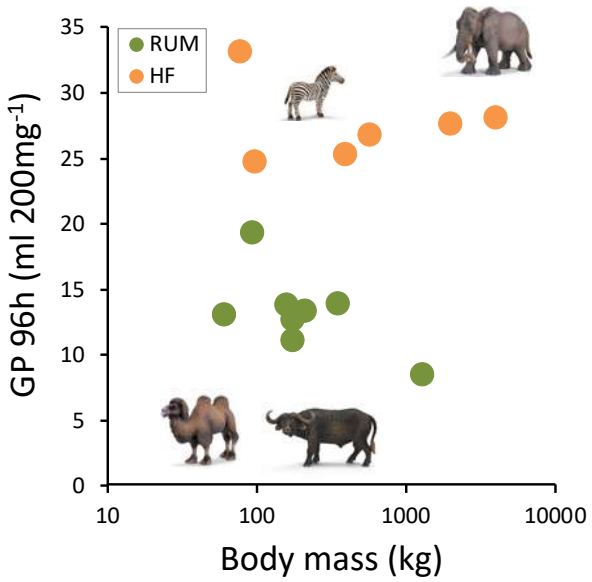

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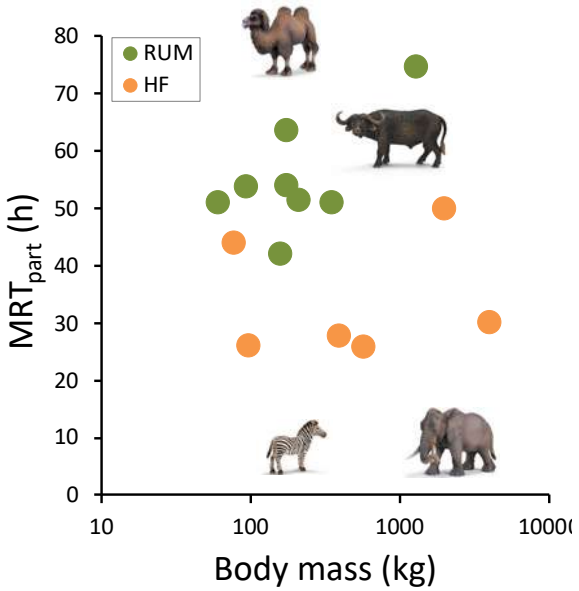
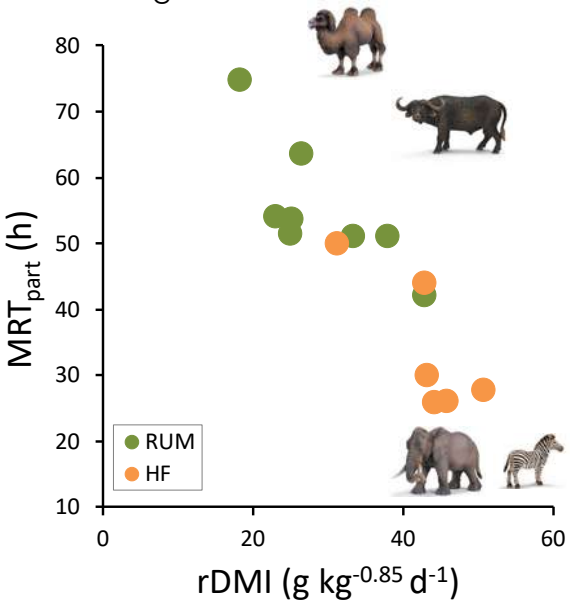


Digesta retention vs. intake



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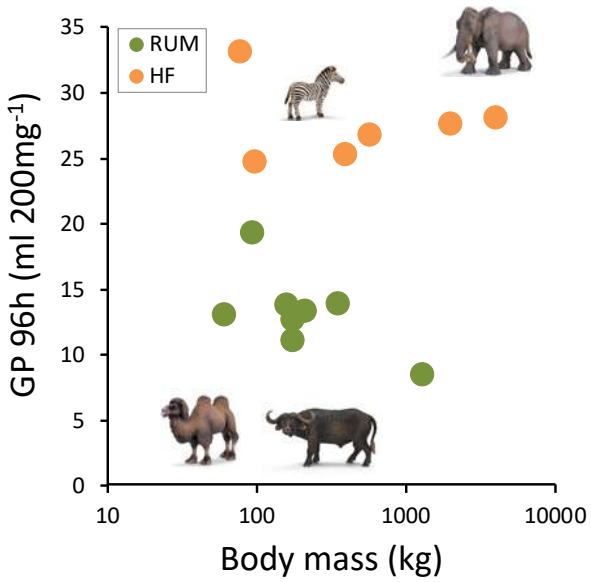
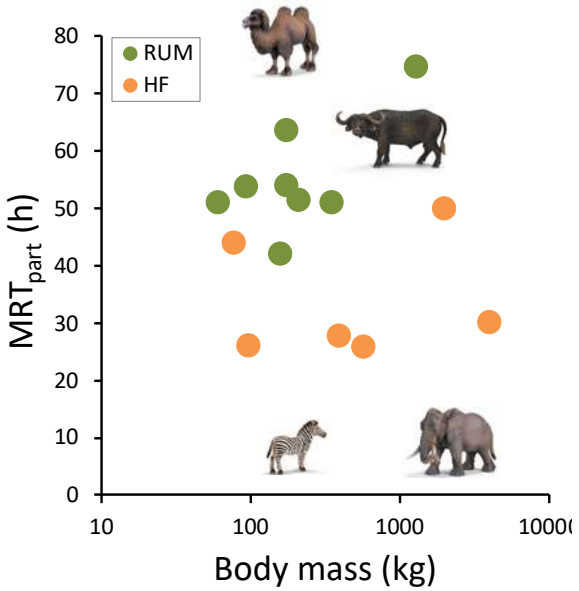
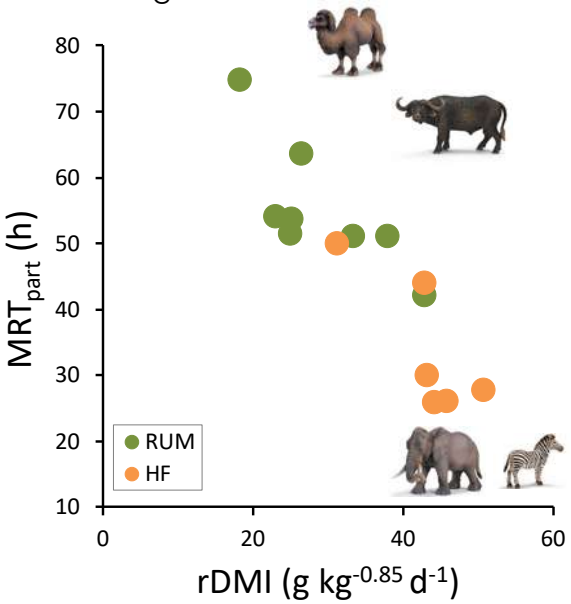


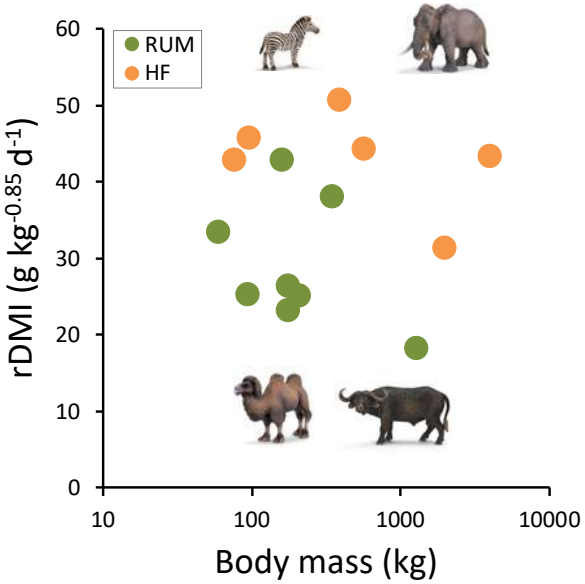
Digesta retention



Digesta retention vs. intake



Relative intake



Digestive physiology meets herbivore diversity

Marcus Clauss [a], Patrick Steuer [b], Kerstin Erlinghagen-Lückerath [b], Jacques Kaandorp [c], Julia Fritz [a], Karl-Heinz Südekum [b,*], Jürgen Hummel [b,d]

Comparative Biochemistry and Physiology, Part A 179 (2015) 182–191

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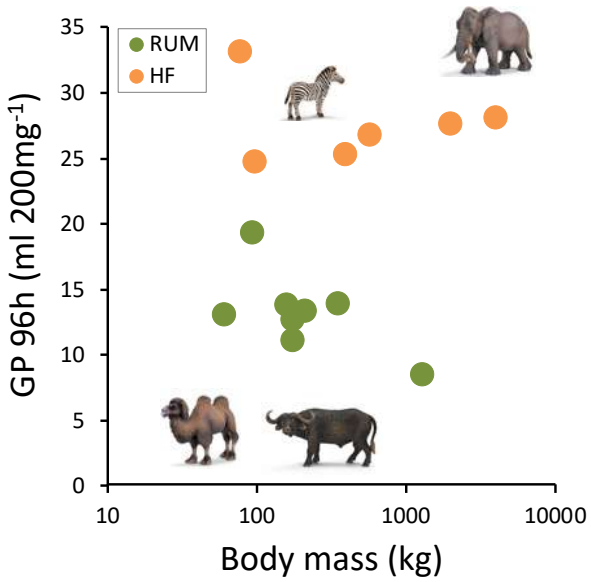

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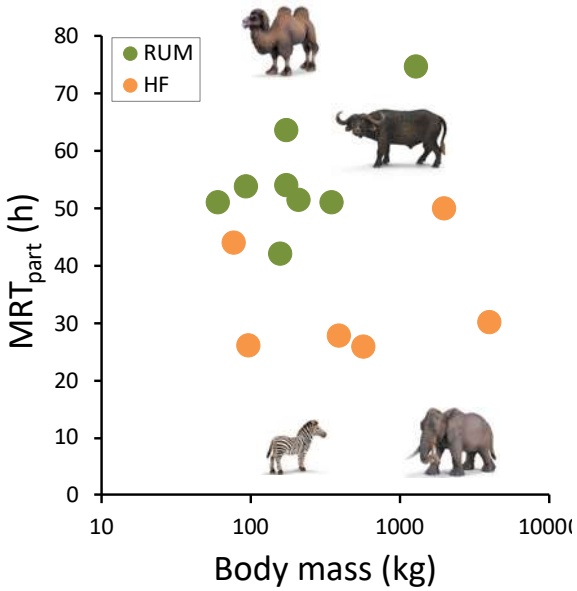
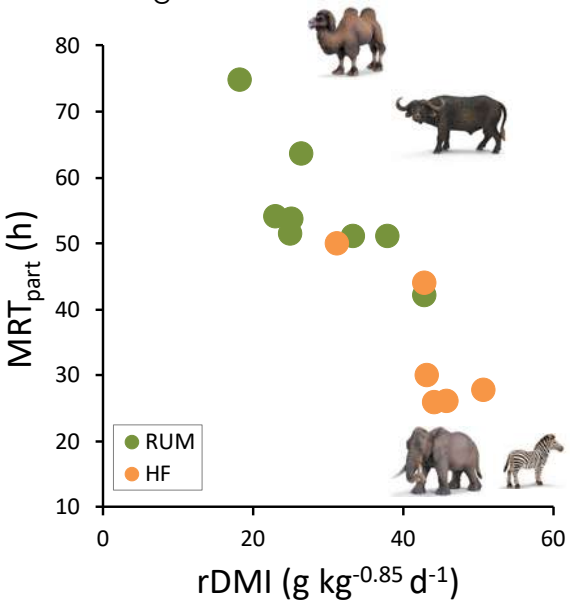
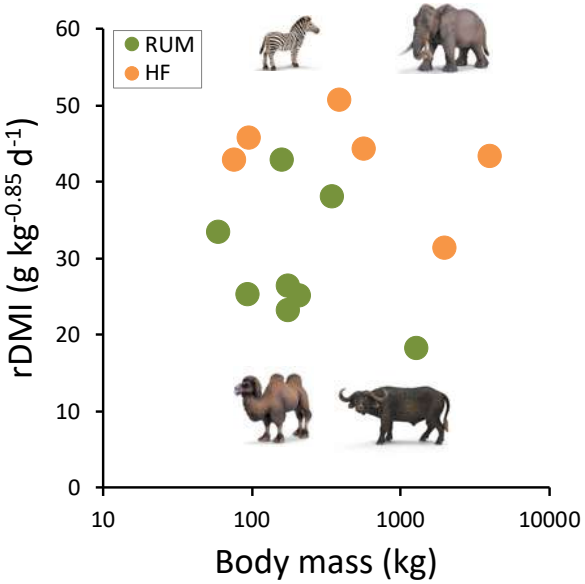


Digesta retention vs. intake



Relative intake

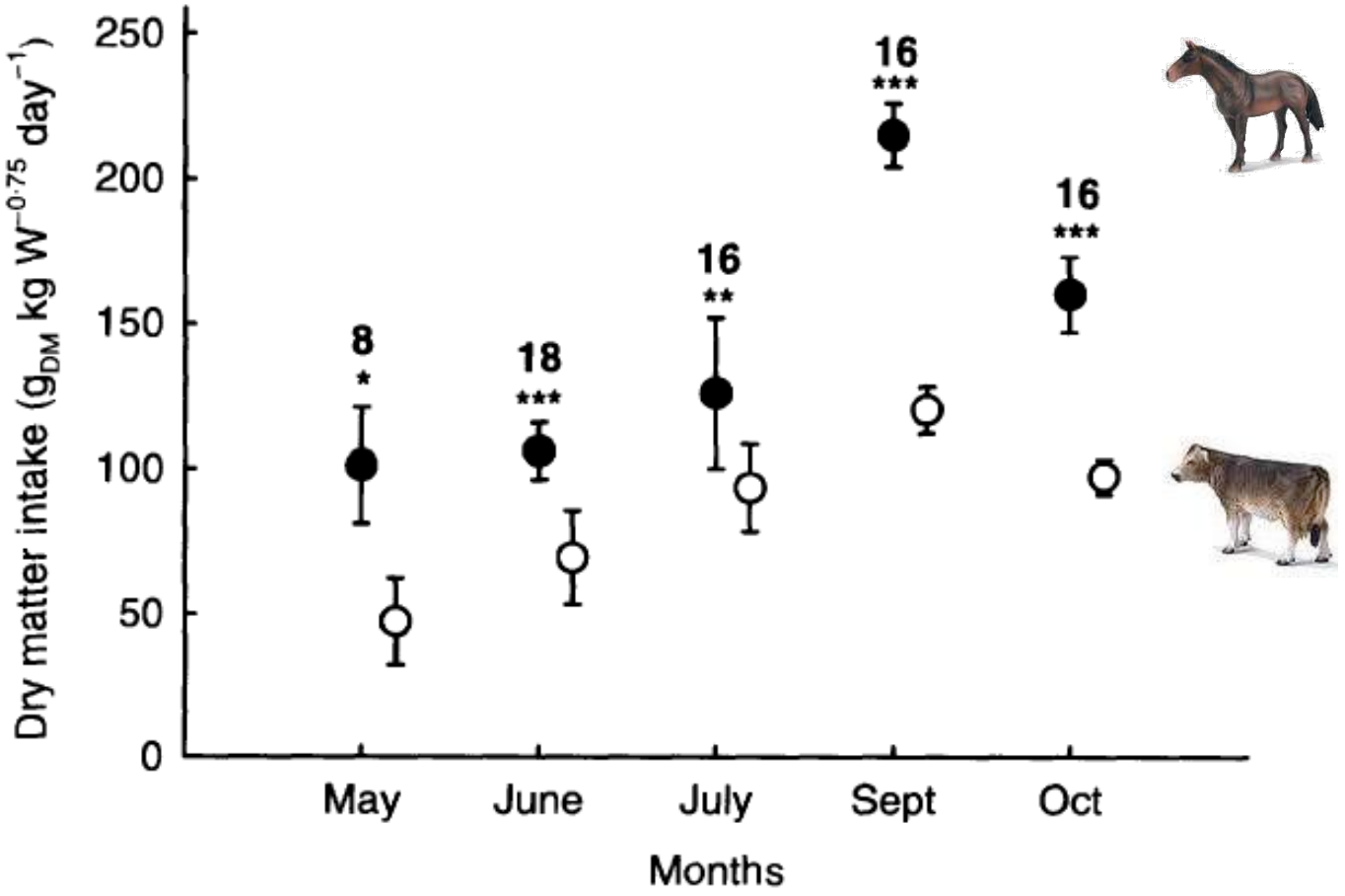


=> Equids have a strategy of lesser digestive efficiency compensated by higher intake

Comparative foraging and nutrition of horses and cattle in European wetlands

Journal of Applied Ecology 2002
39, 120–133

CATHERINE MENARD*, PATRICK DUNCAN*†, GERALDINE FLEURANCE*‡, JEAN-YVES GEORGES* and MARC LILA§



Comparative nutrient extraction from forages by grazing bovids and equids: a test of the nutritional model of equid/bovid competition and coexistence

Oecologia (1990) 84:411–418

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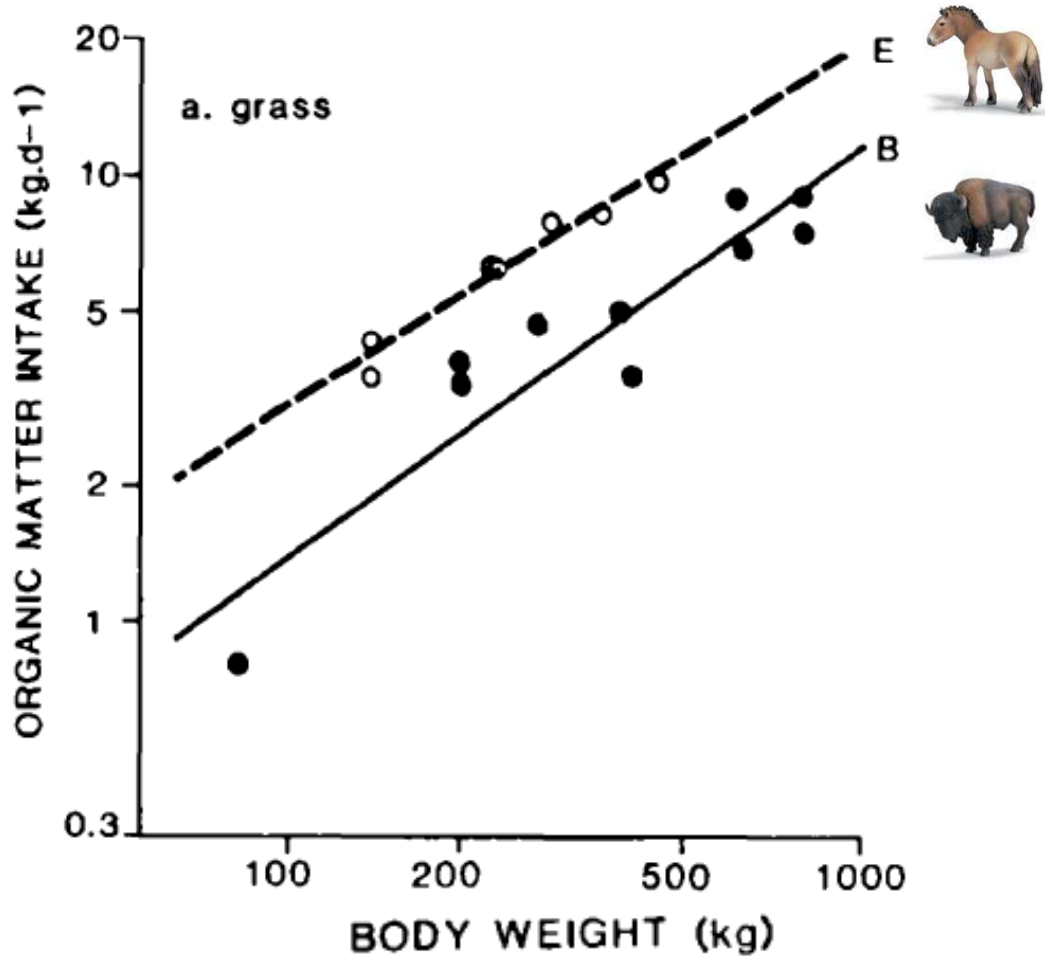
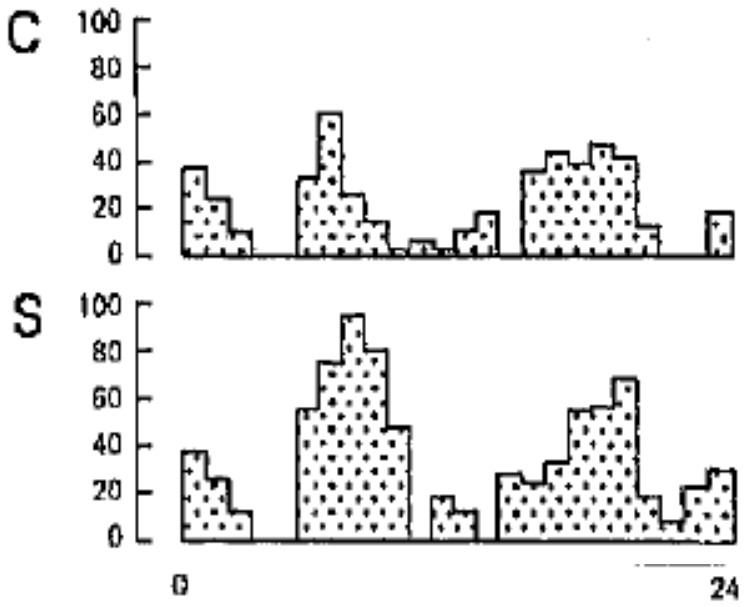


COMPARISON OF THE TIME BUDGETS AND CIRCADIAN PATTERNS OF MAINTENANCE ACTIVITIES IN SHEEP, CATTLE AND HORSES GROUPED TOGETHER

G.W. ARNOLD

Applied Animal Behaviour Science, 13 (1984/85) 19—30

Grazing



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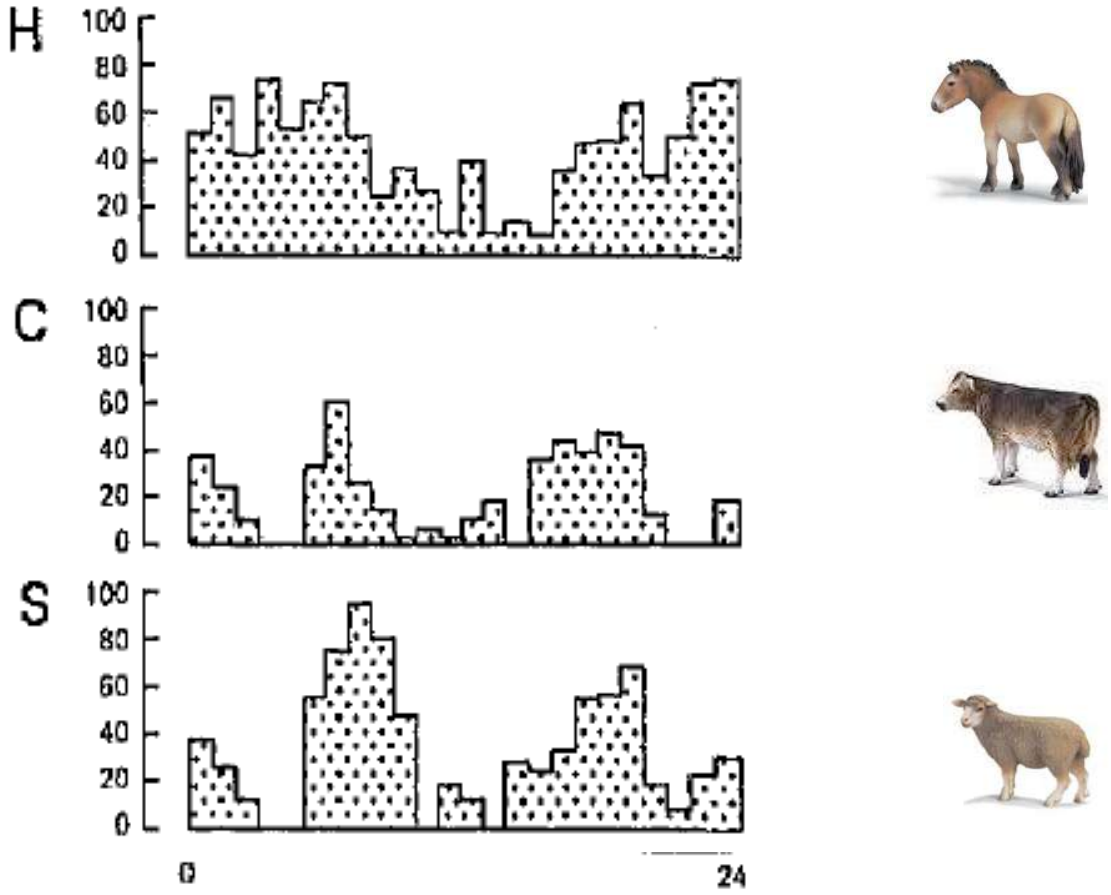
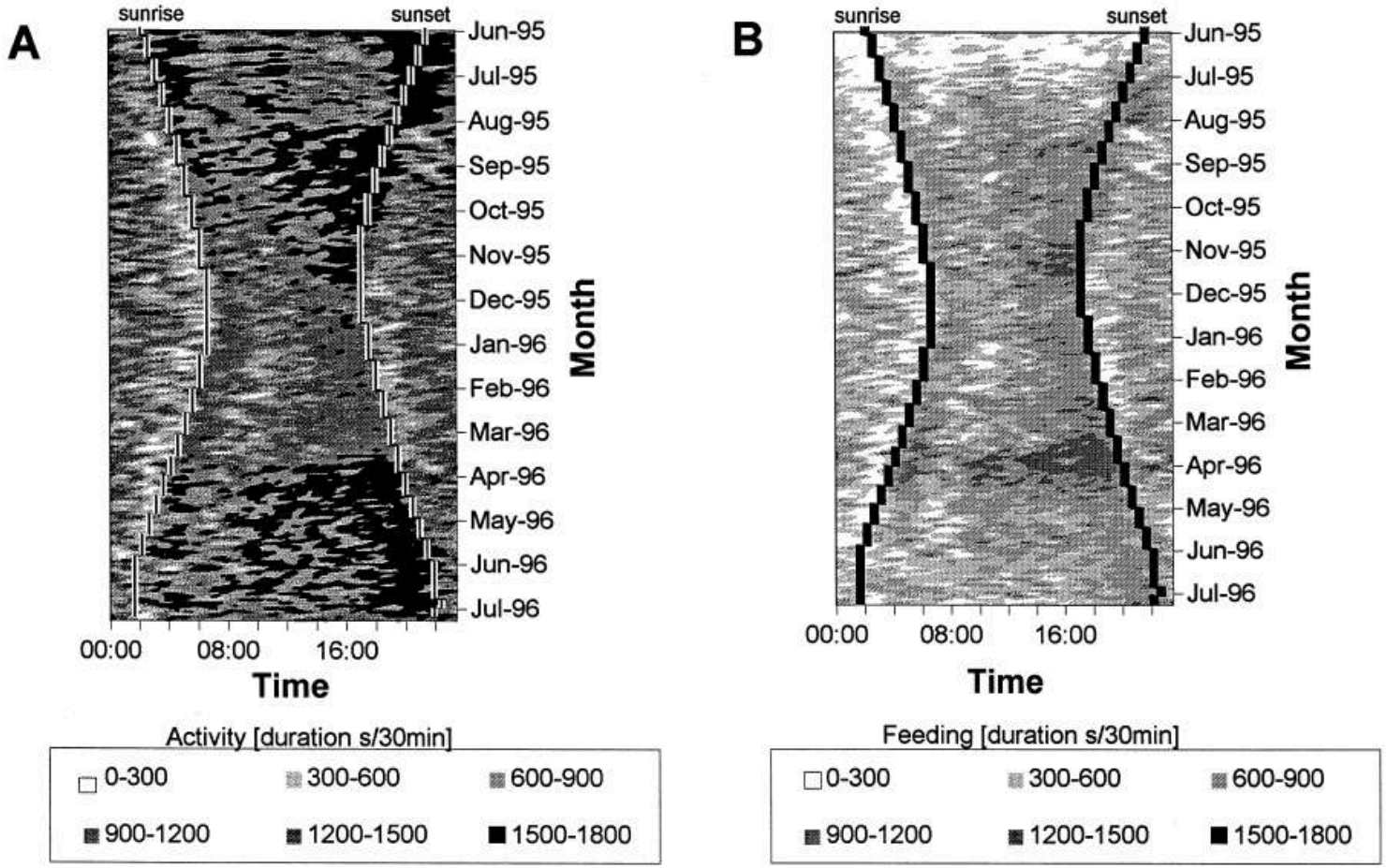


Diurnal and ultradian rhythms of behaviour in a mare group of Przewalski horse (*Equus ferus przewalskii*), measured through one year under semi-reserve conditions

Anne Berger *,1, Klaus-M. Scheibe, Knut Eichhorn,
Annemarie Scheibe, Jürgen Streich

Applied Animal Behaviour Science 64 (1999) 1–17



Differences in digestive physiology between equids and ruminants: a historical myth ?

A drawing dominates comparative concepts

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THE EVOLUTIONARY STRATEGY OF THE EQUIDAE AND THE ORIGINS OF RUMEN AND CECAL DIGESTION

CHRISTINE JANIS

EVOLUTION 30:757–774. December 1976

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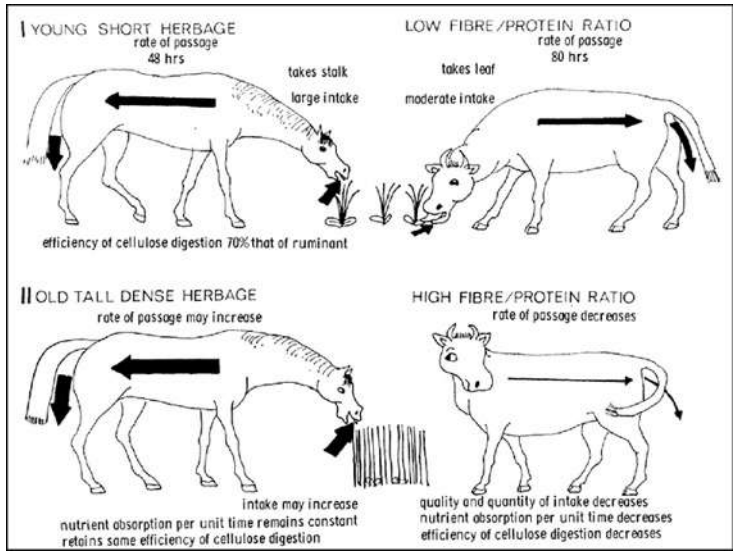

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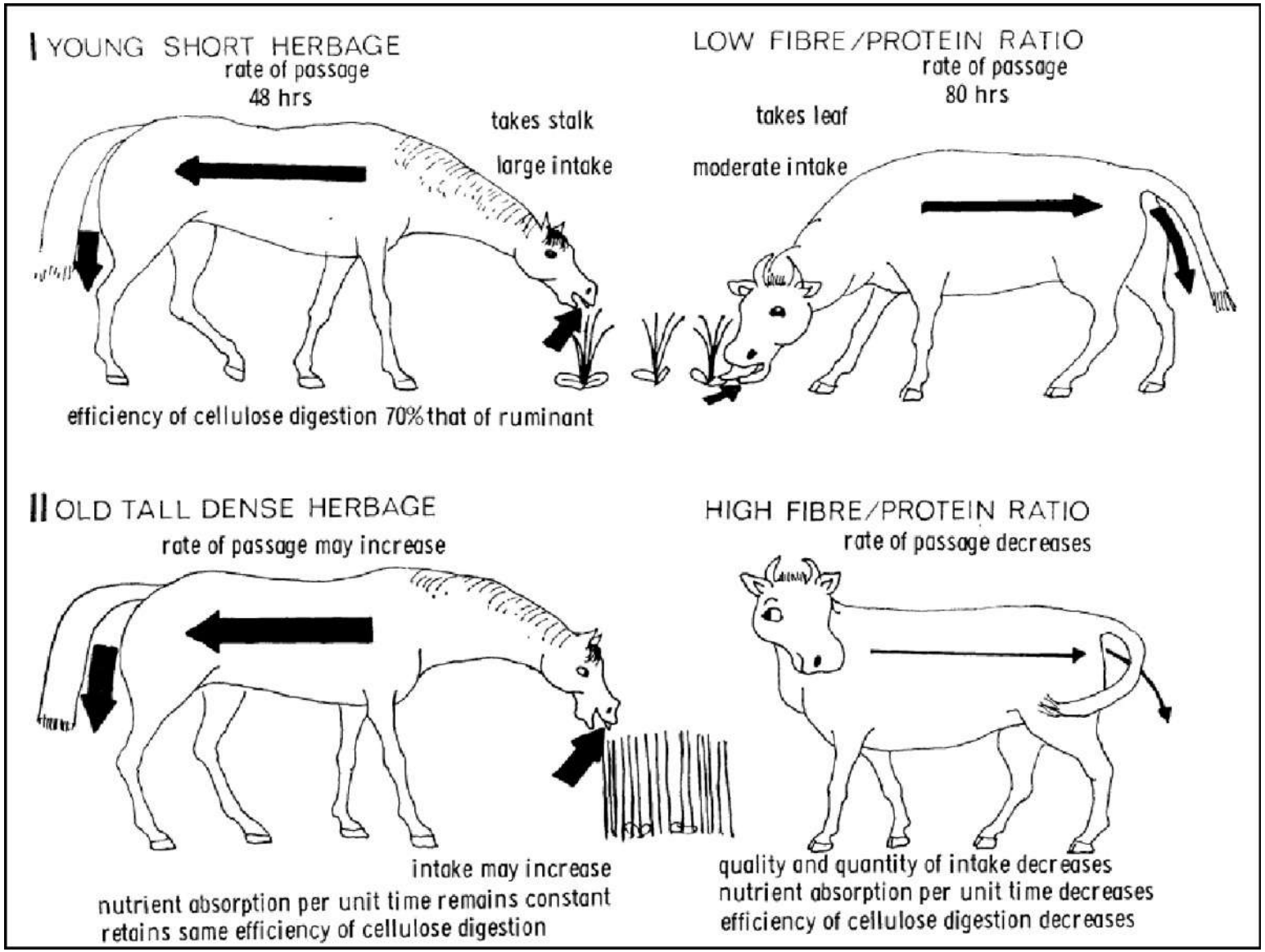

Janis (1976)

A drawing dominates comparative concepts

COMPARATIVE DIGESTIVE CAPACITIES OF HERBIVOROUS ANIMALS

P.J. Van Soest, T. Foose and J.B. Robertson

Proceedings of the Conrell Nutrition Conference 1983, 51-59

A. Young, short grass ; fibre / protein low

Intake	:	moderate	moderate
Passage rate	:	48 hrs.	80 hrs.
Cellulose digestion	:	70% that of ruminants	

B. Old, long grass ; fibre / protein high

Intake	:	increased	decreased
Passage rate	:	faster	slower
Nutrient absorption	:	similar	less
Cellulose digestion	:	decreased	similar-decreased

(adapted from Janis, 1976)

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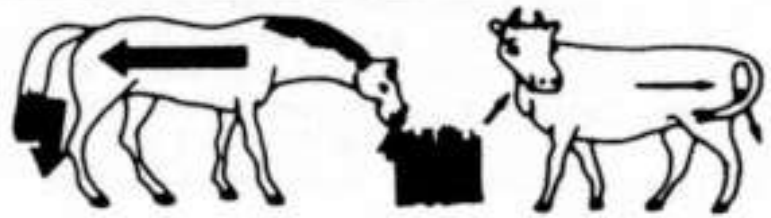

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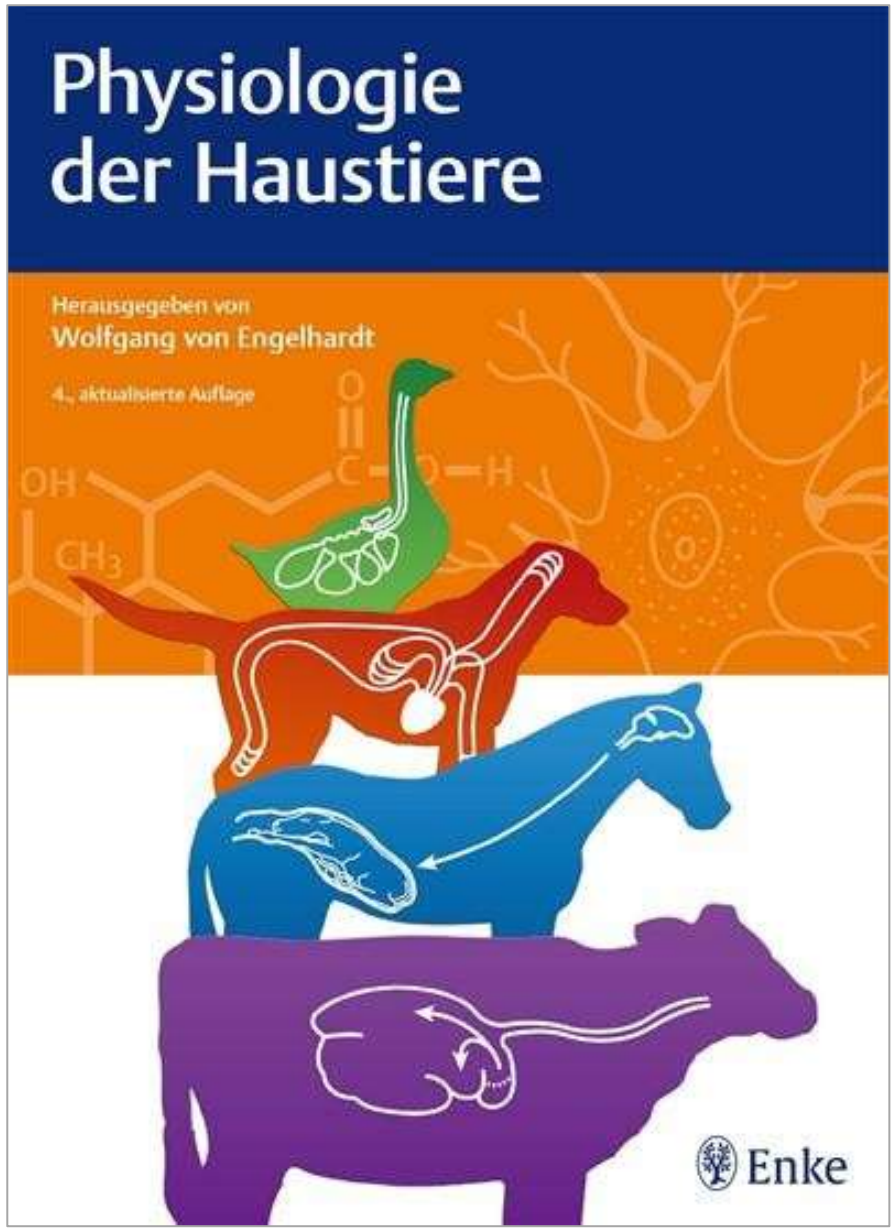
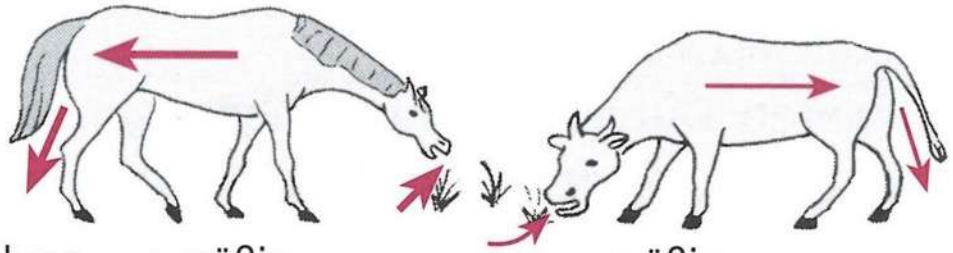
(adapted from Janis, 1976)

The principle may explain why bullshit has replaced horseshit over evolutionary time (Foose pers. comm.). Figure courtesy of W. von Engelhardt.

A drawing dominates comparative concepts

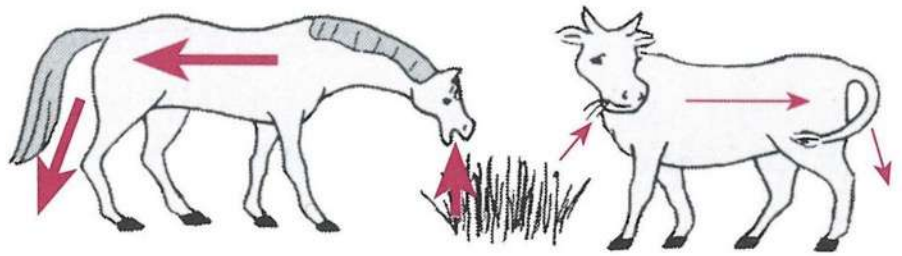


A Junges, kurzes Gras: Quotient Rohfaser zu Protein ist niedrig



Futteraufnahme	: mäßig	mäßig
Passage durch MDK	: 48 Std.	80 Std.
Celluloseverdauung	: 70% der Wiederkäuer	

B Altes, langes Gras: Quotient Rohfaser zu Protein ist hoch



Futteraufnahme	: erhöht	vermindert
Passage durch MDK	: schneller	langsamer
Nährstoffresorption	: gleich	weniger
Celluloseverdauung	: vermindert	gleich - vermindert

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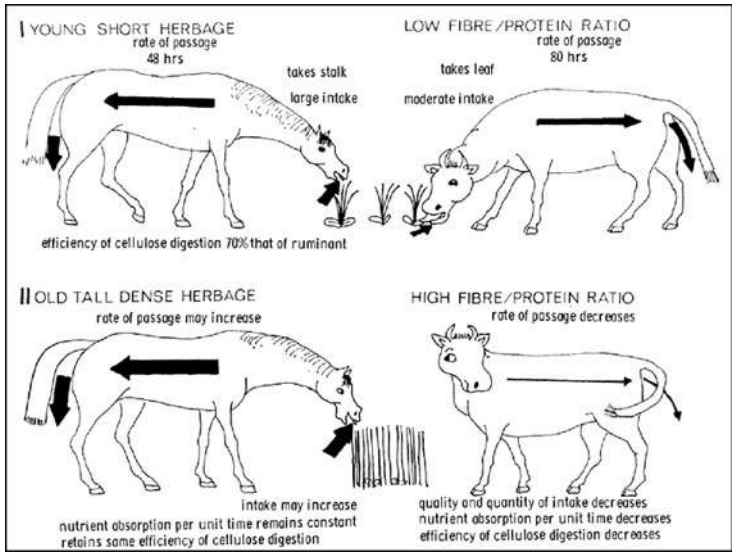

Experiments on domestic ponies indicate that rate of intake may actually decrease with increasing fiber content of the food, although proportionally much less than in ruminants

The Effects of Caloric Dilution on Meal Patterns and Food Intake of Ponies

JANE E. LAUT, KATHERINE A. HOUPT,[1] HAROLD F. HINTZ AND T. RICHARD HOUPT

Physiology & Behavior, Vol 35, pp 549–554

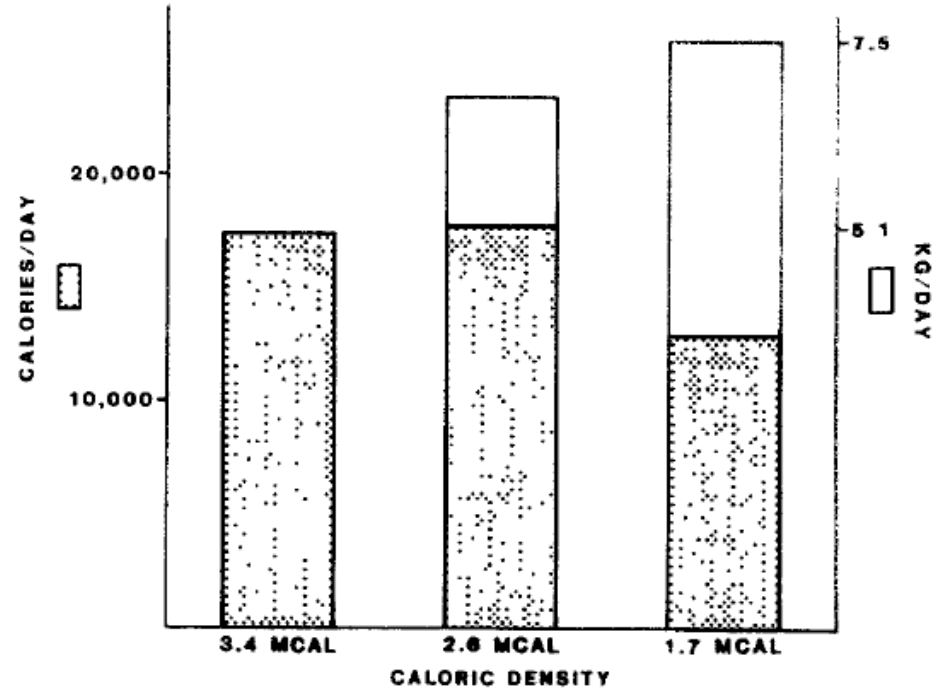

FIG 1. The intake of ponies on 3 diets varying in caloric density The total height of the column indicates the mean weight of feed eaten per day (left ordinate) The dark portion of the column indicates the mean calories consumed per day (right ordinate)

SYMPOSIUM ON FACTORS INFLUENCING THE VOLUNTARY INTAKE OF HERBAGE BY RUMINANTS: VOLUNTARY INTAKE IN RELATION TO CHEMICAL COMPOSITION AND DIGESTIBILITY [1]

P. J. VAN SOEST

Journal of Animal Science 1965 24: 834-843

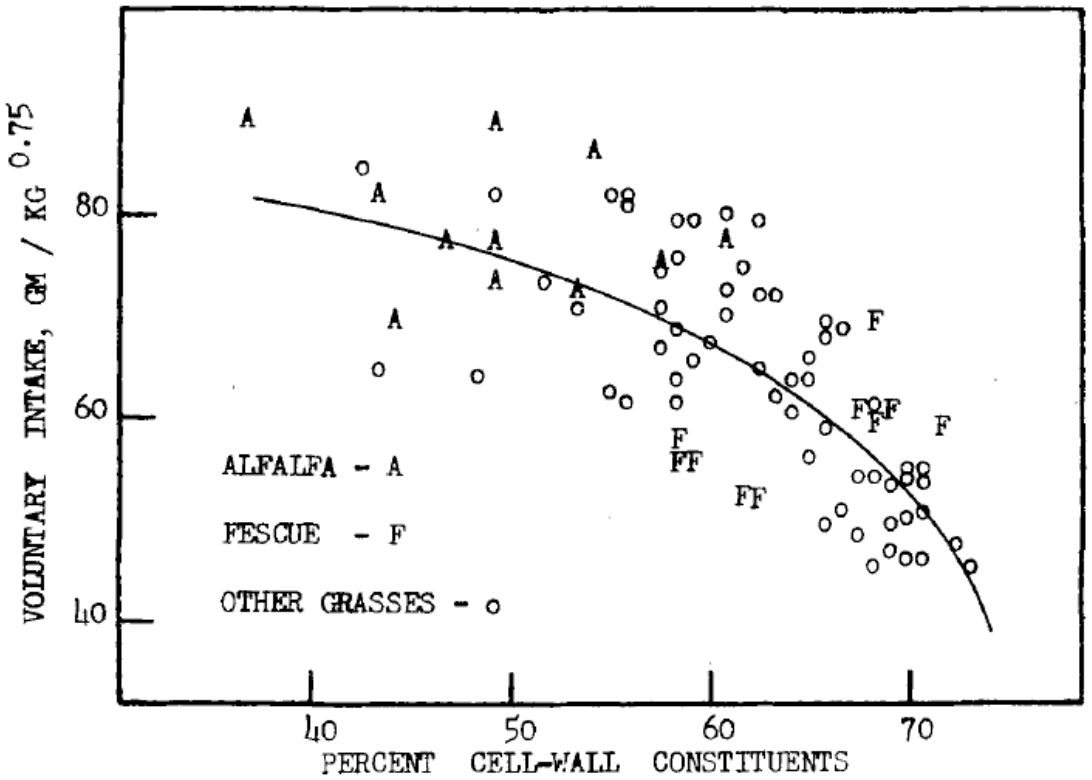

Figure 2. Relationship between voluntary intake and cell-wall constituents of 83 forages from West Virginia. Regression equation: $Y=110.4-1716/(100-X)$.

Comparative nutrient extraction from forages by grazing bovids and equids: a test of the nutritional model of equid/bovid competition and coexistence

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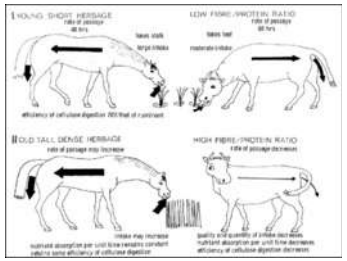
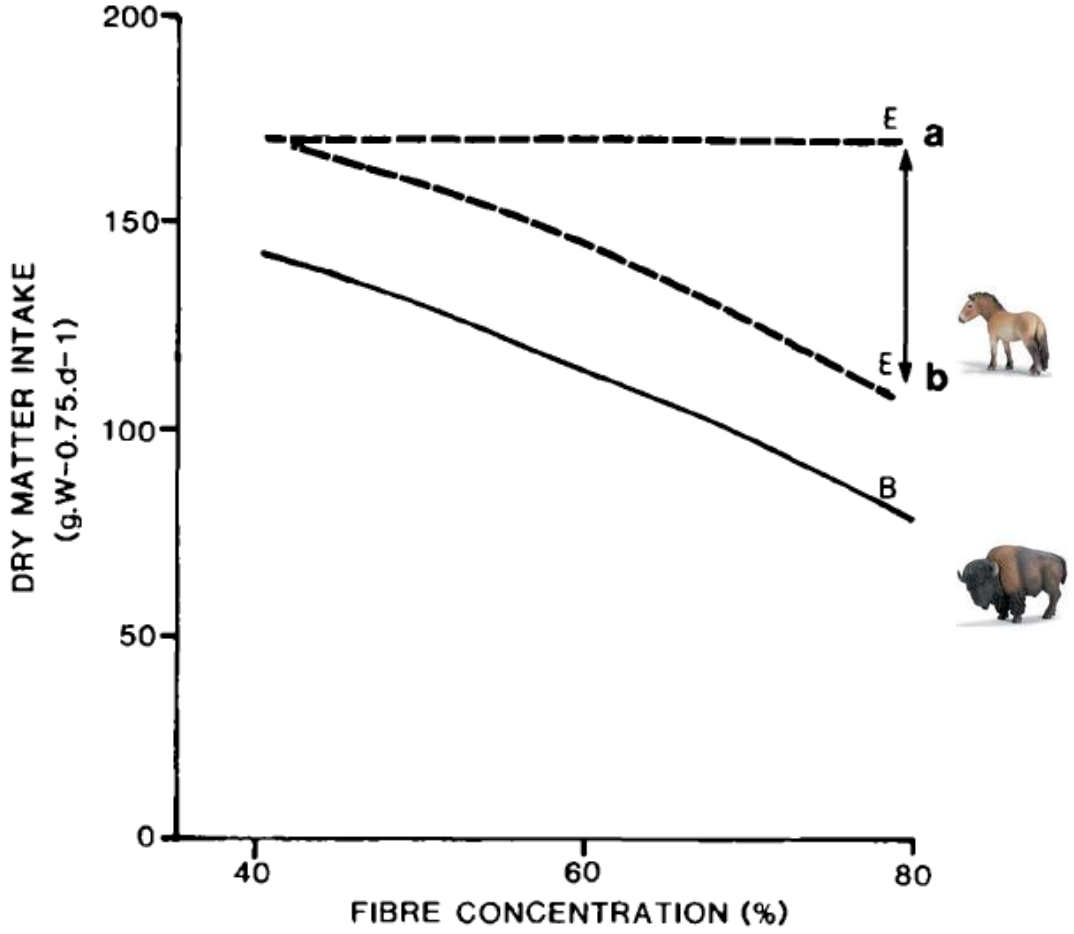
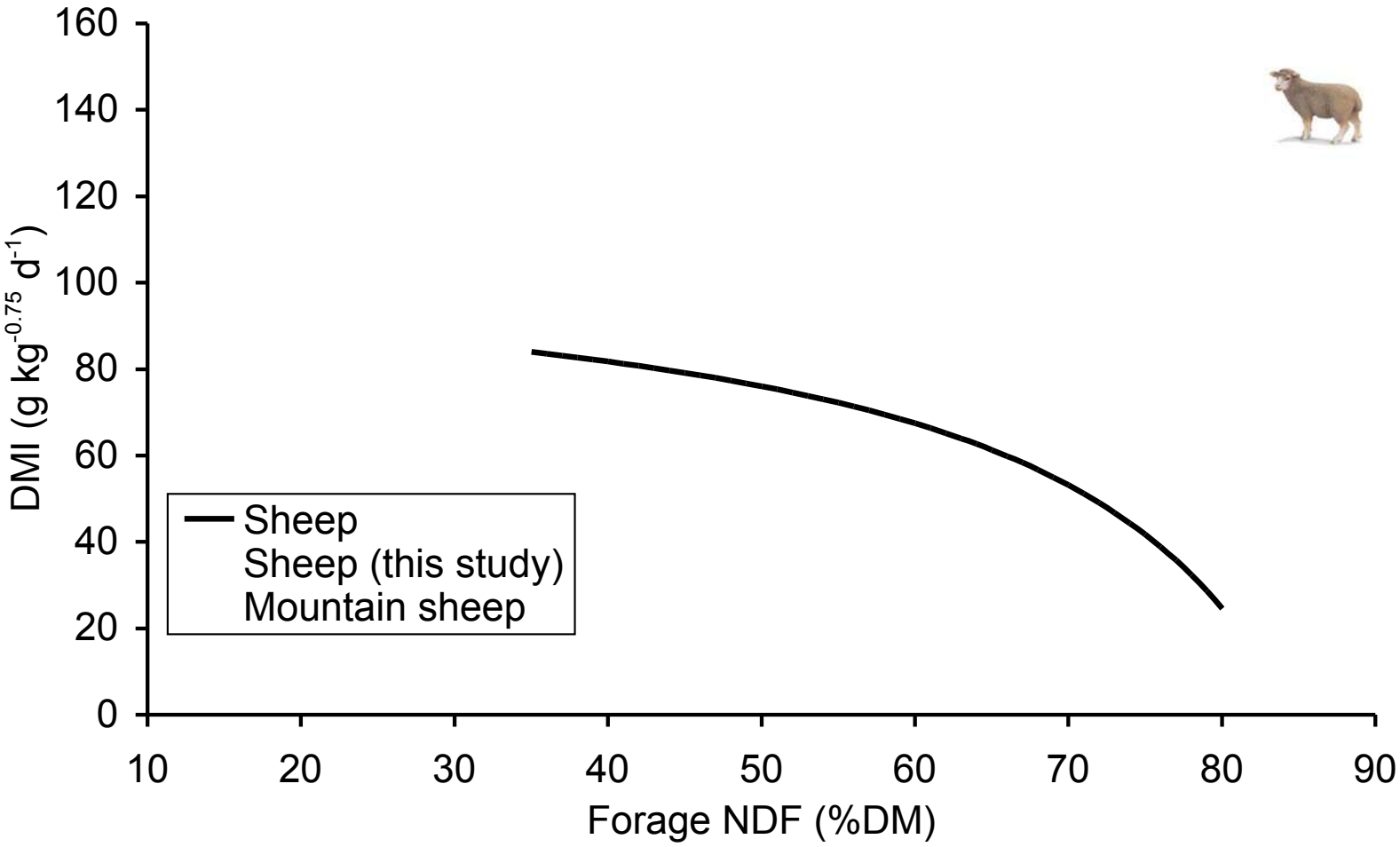




The relationship between forage cell wall content and voluntary food intake in mammalian herbivores

Kerstin MEYER Jürgen HUMMEL Marcus CLAUSS*

Mammal Rev. 2010, Volume 40, No. 3, 221–245



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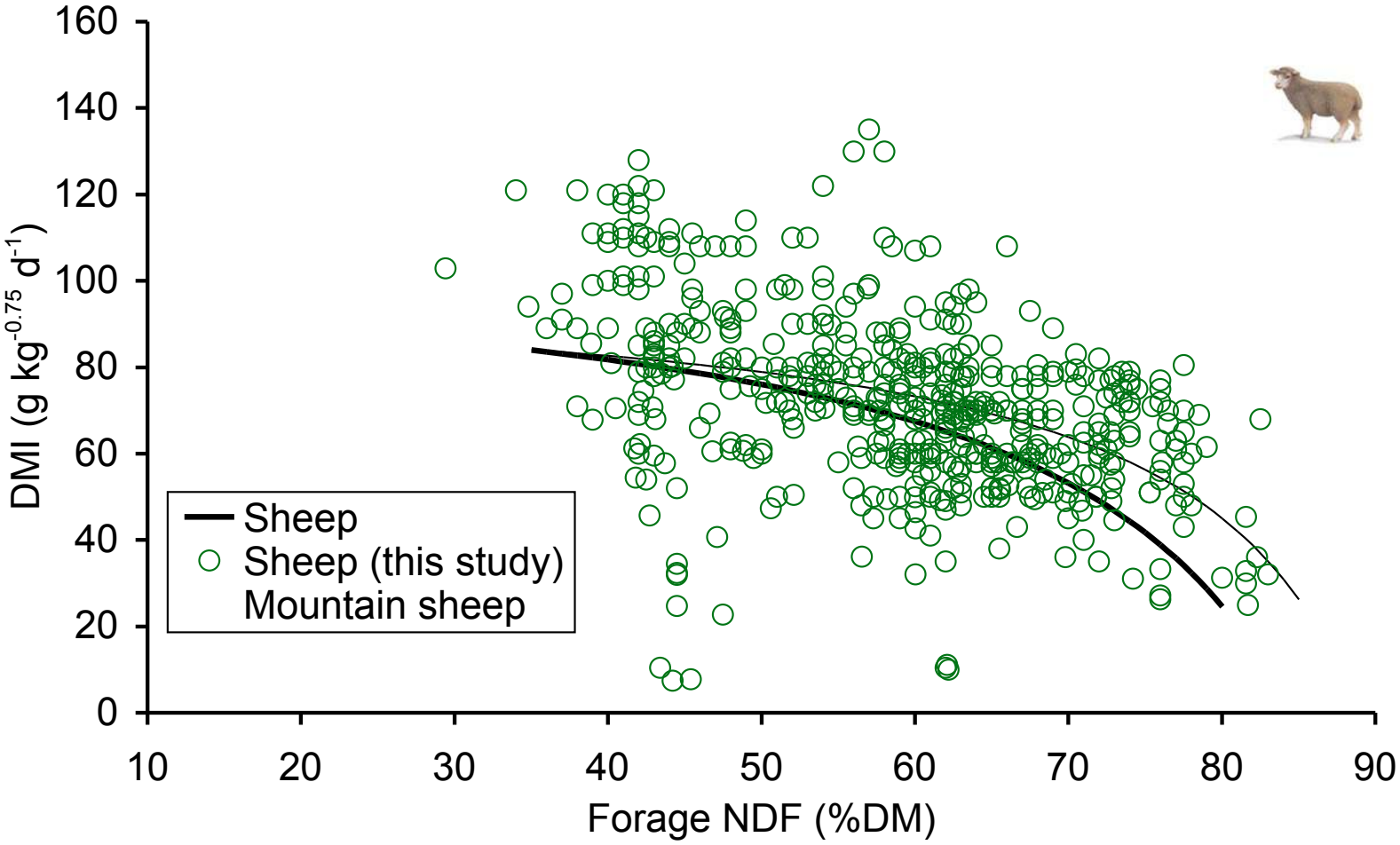

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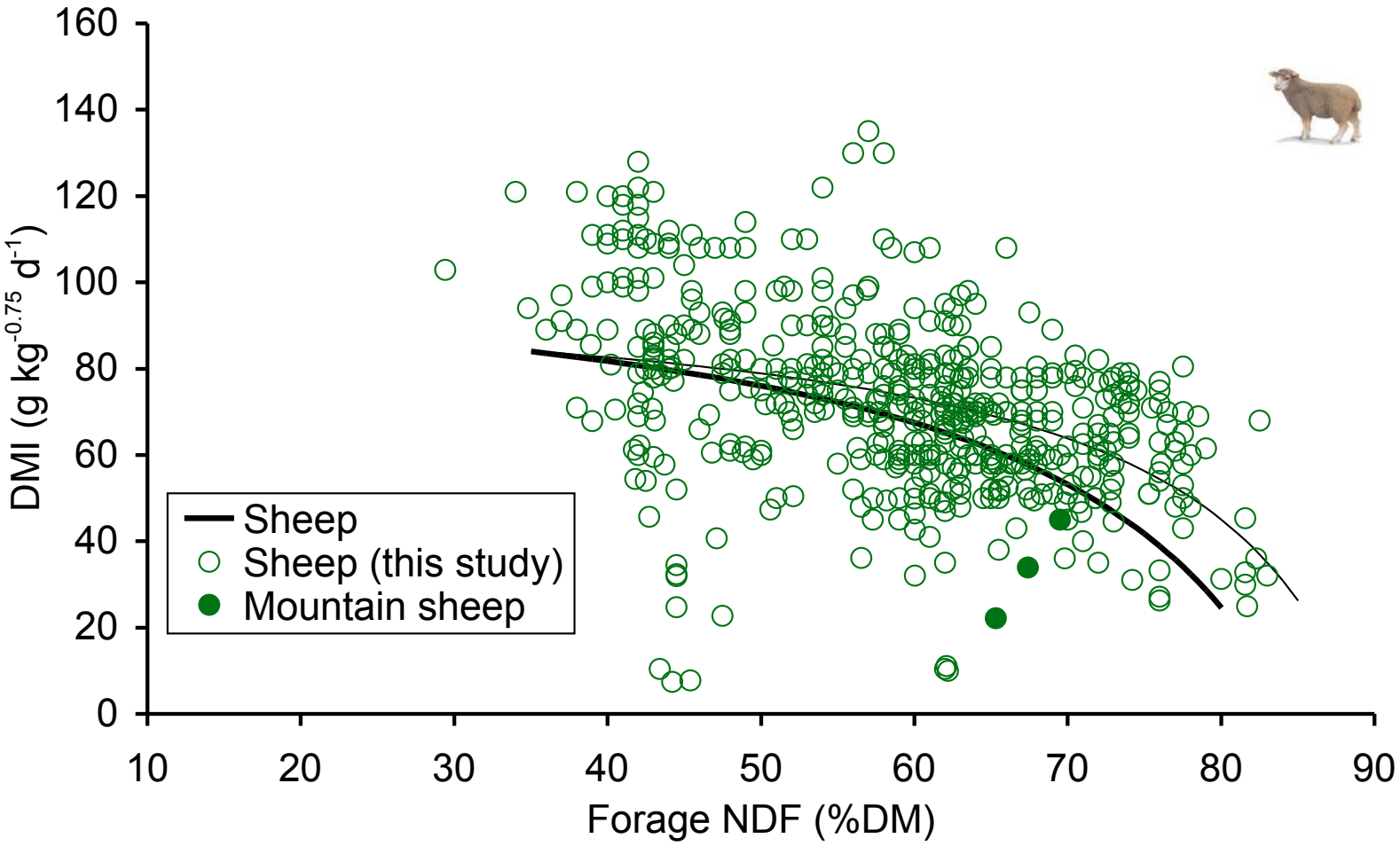

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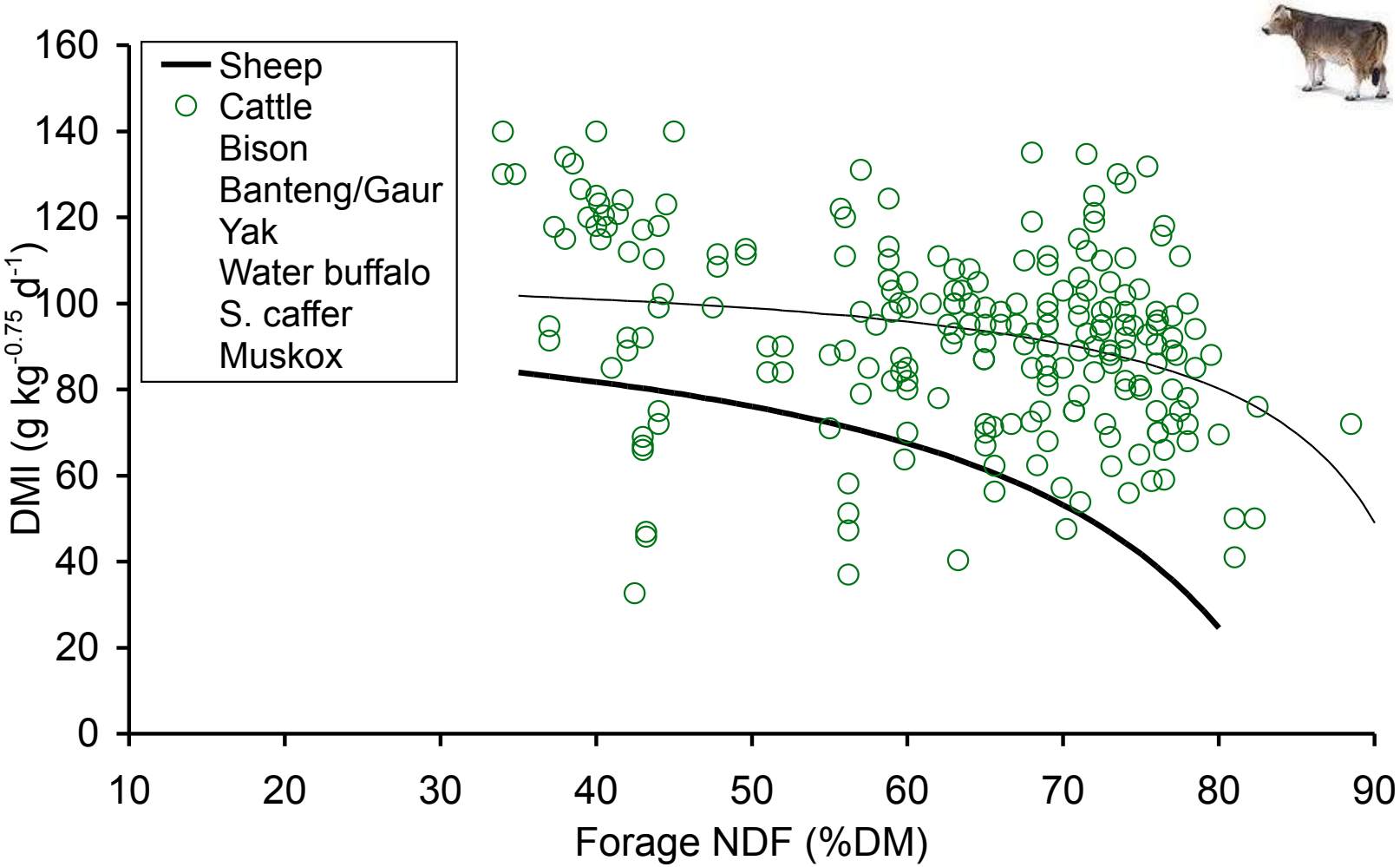

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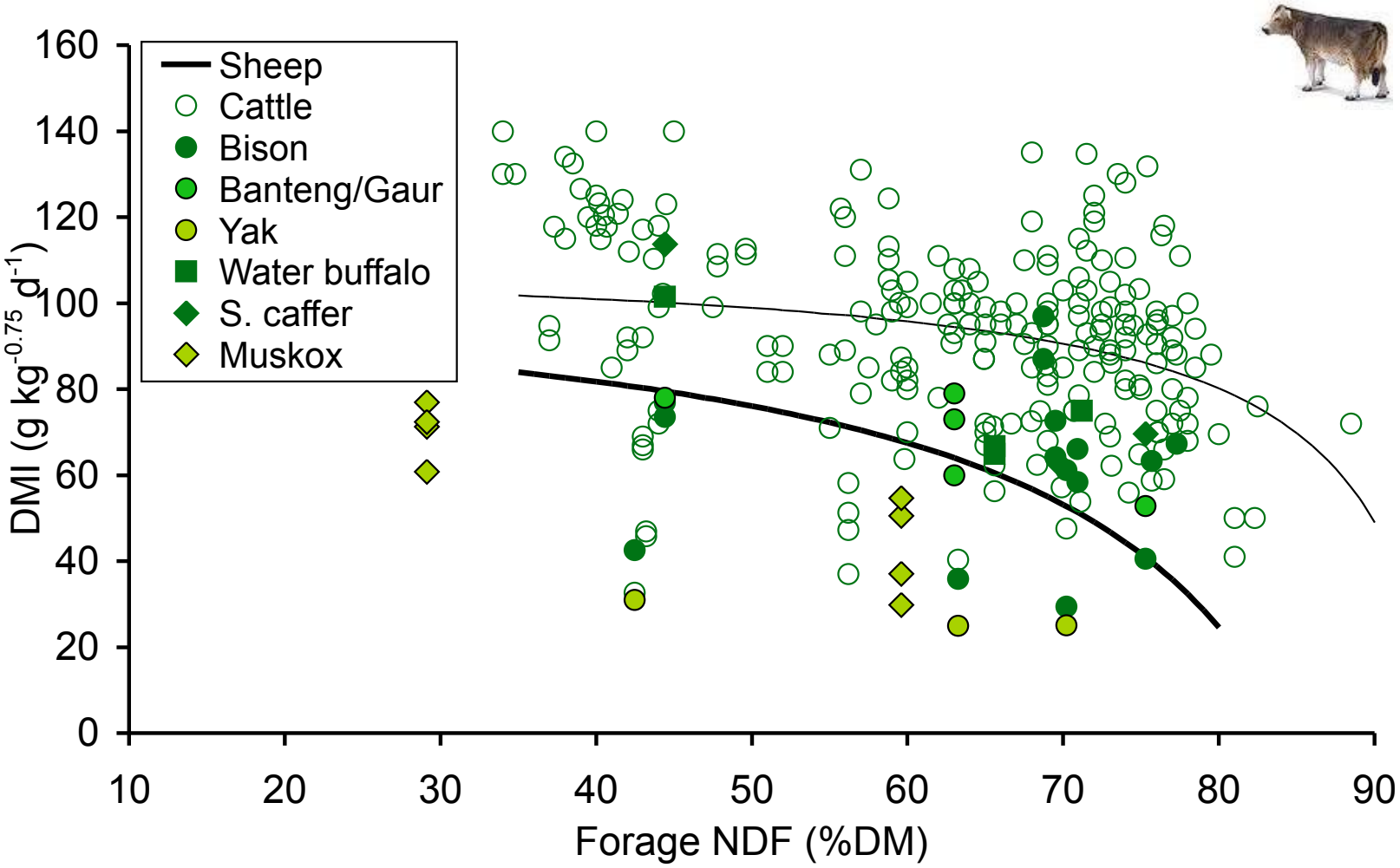

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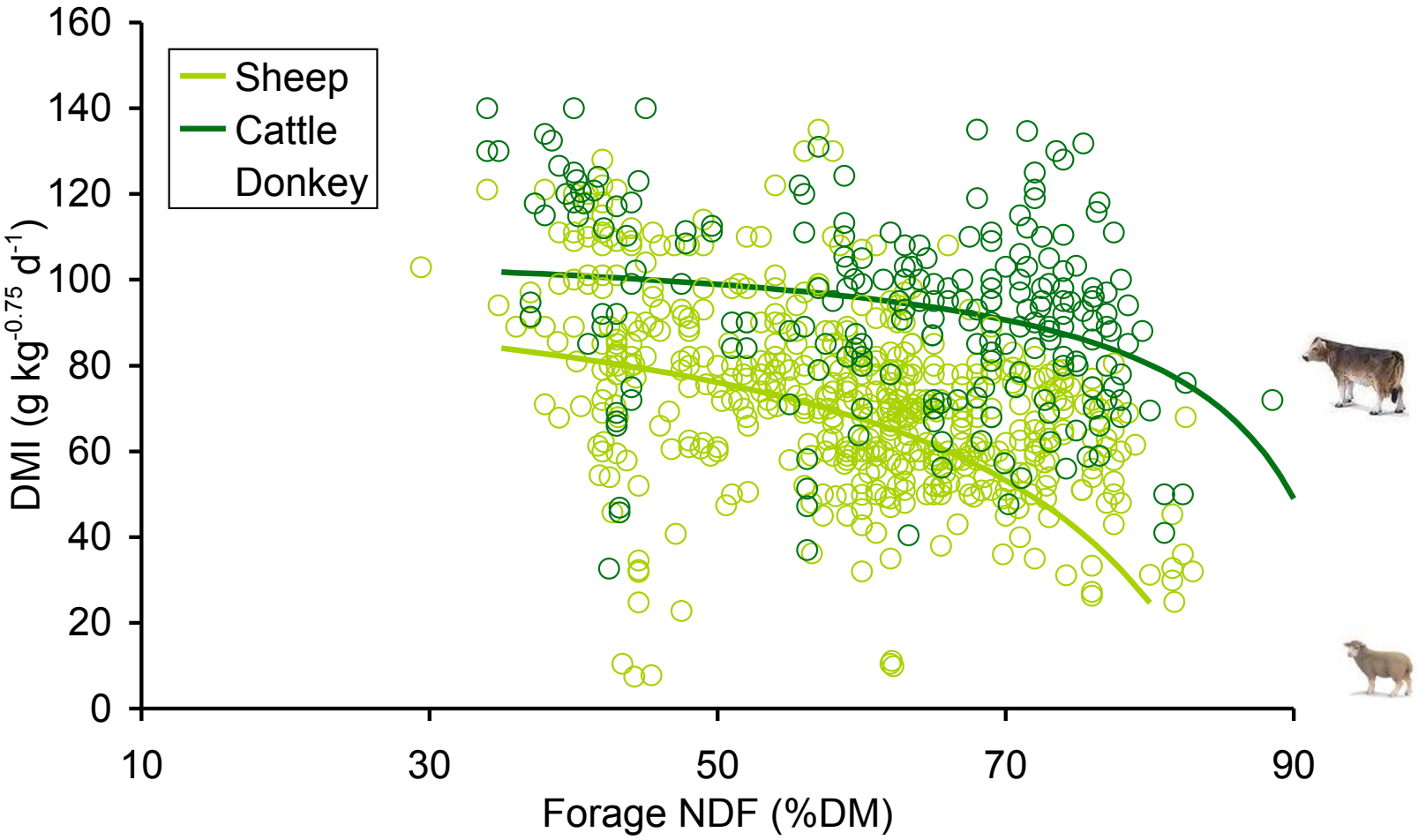

Meyer et al. (2010)

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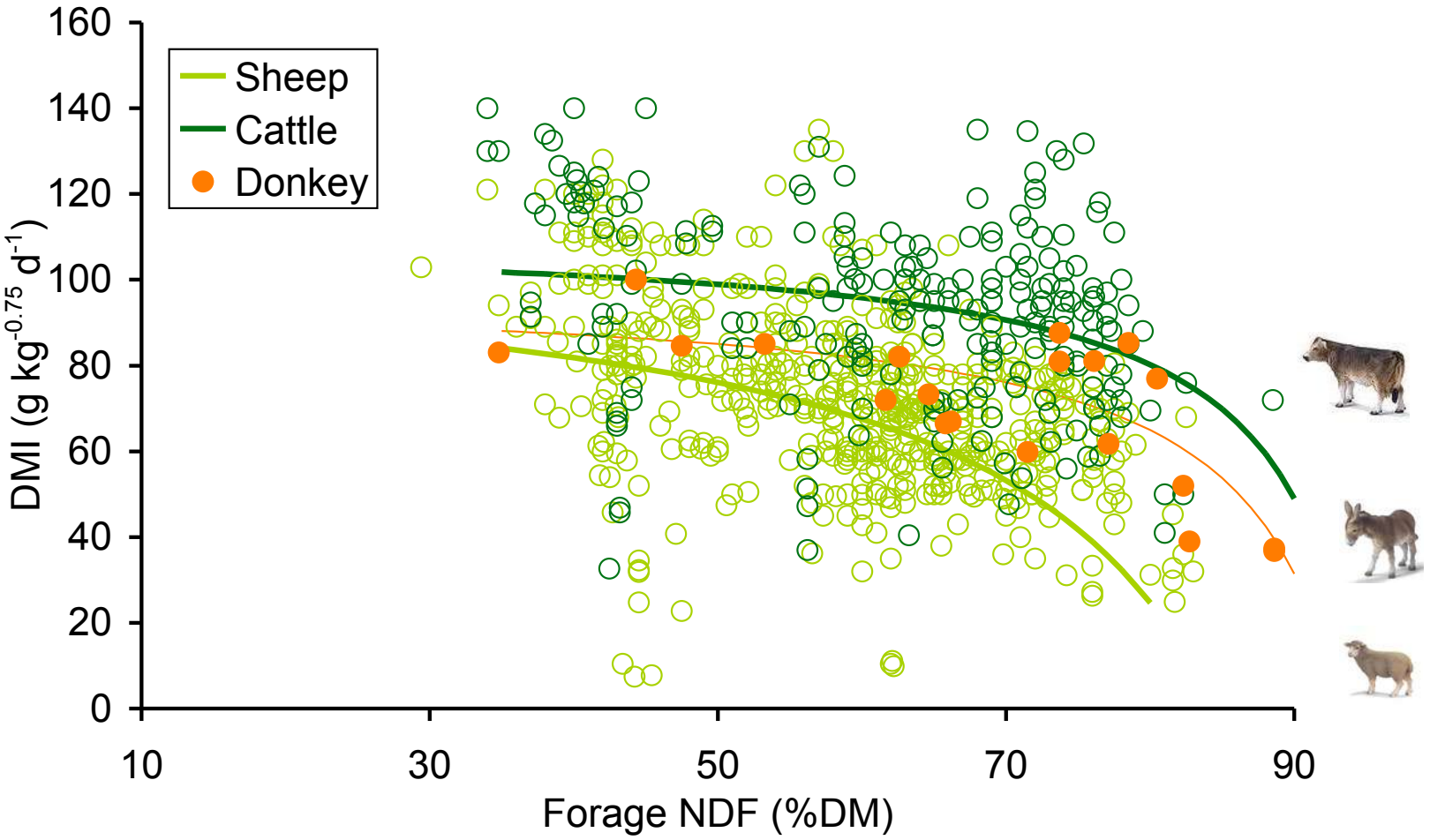

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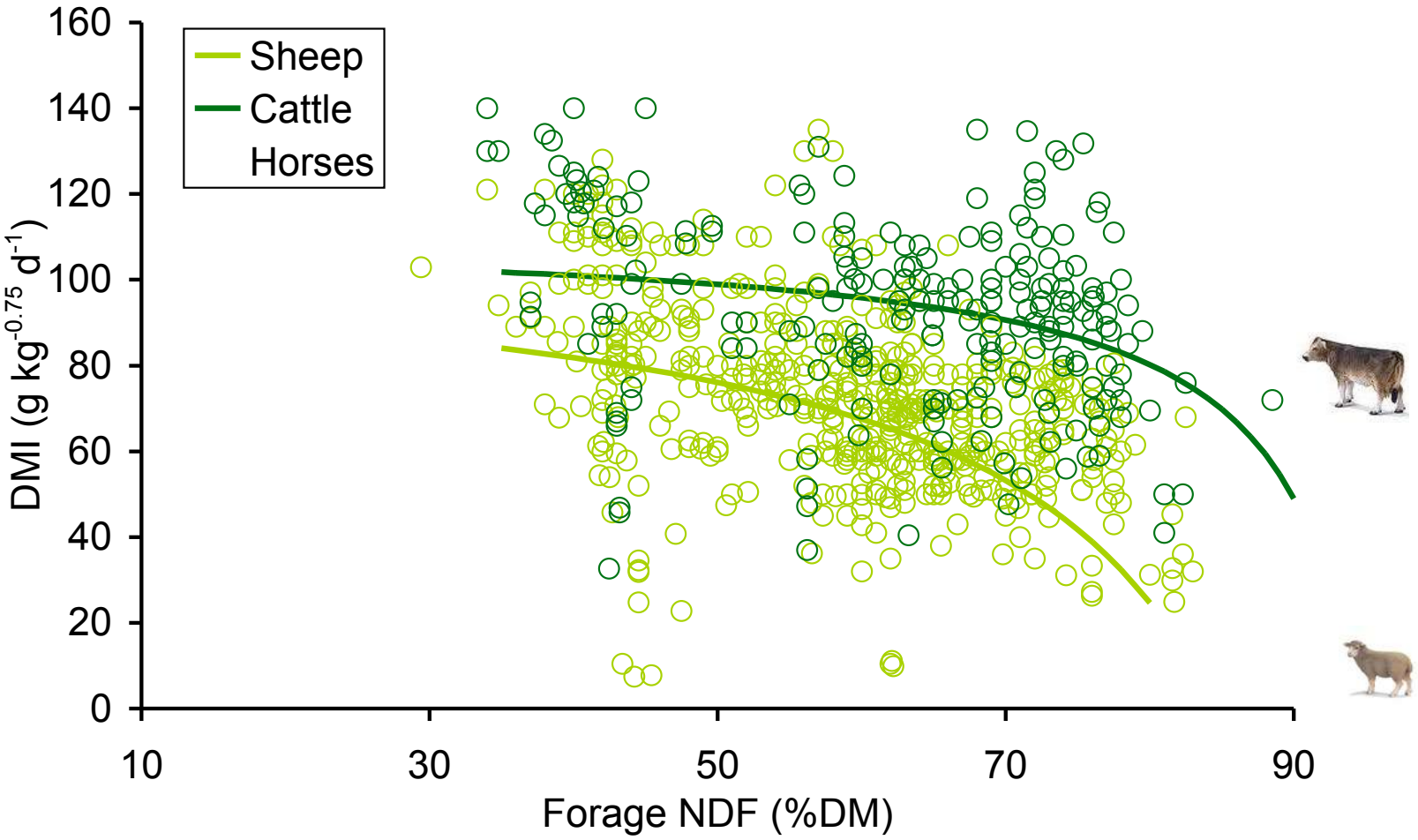

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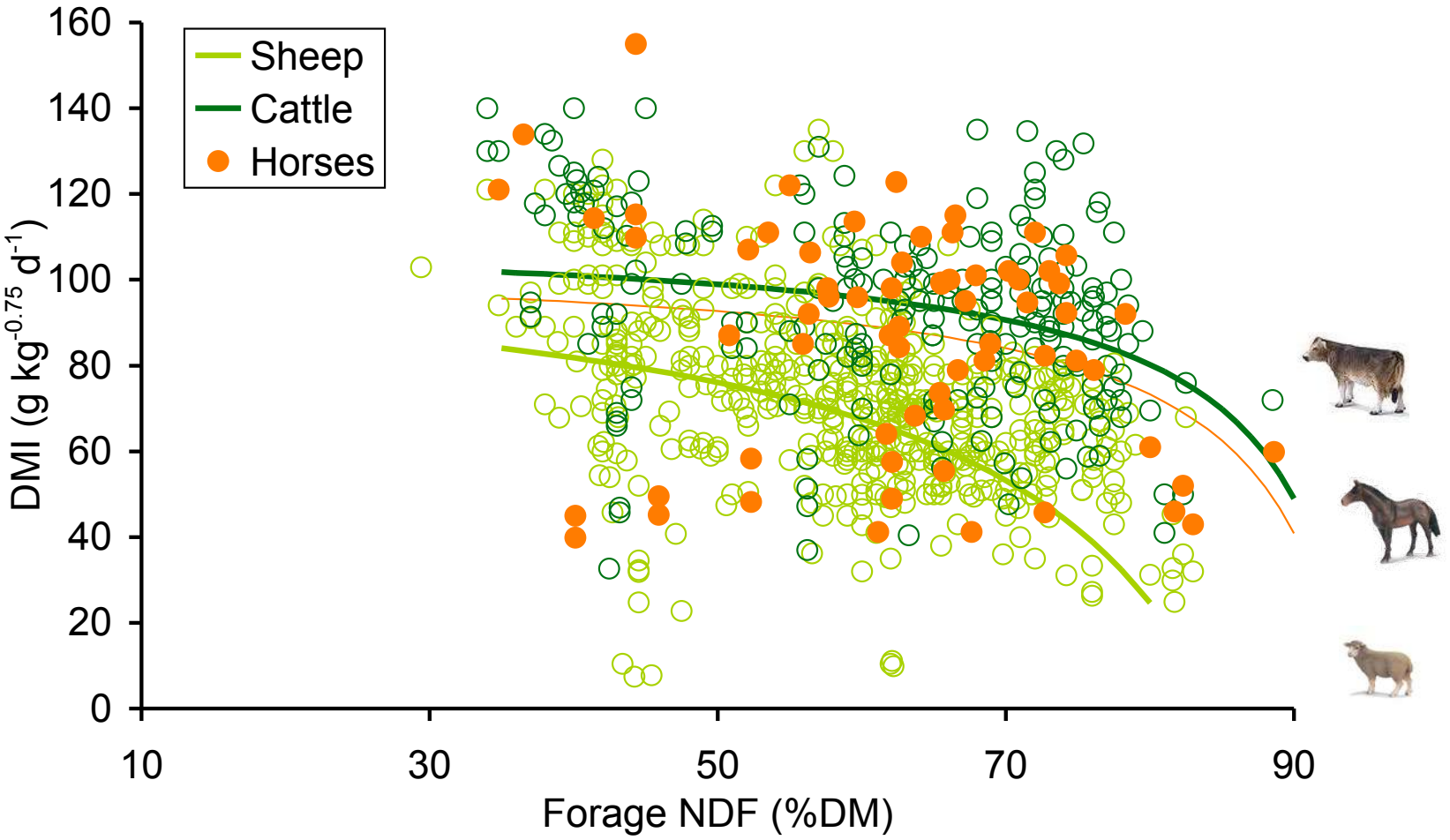

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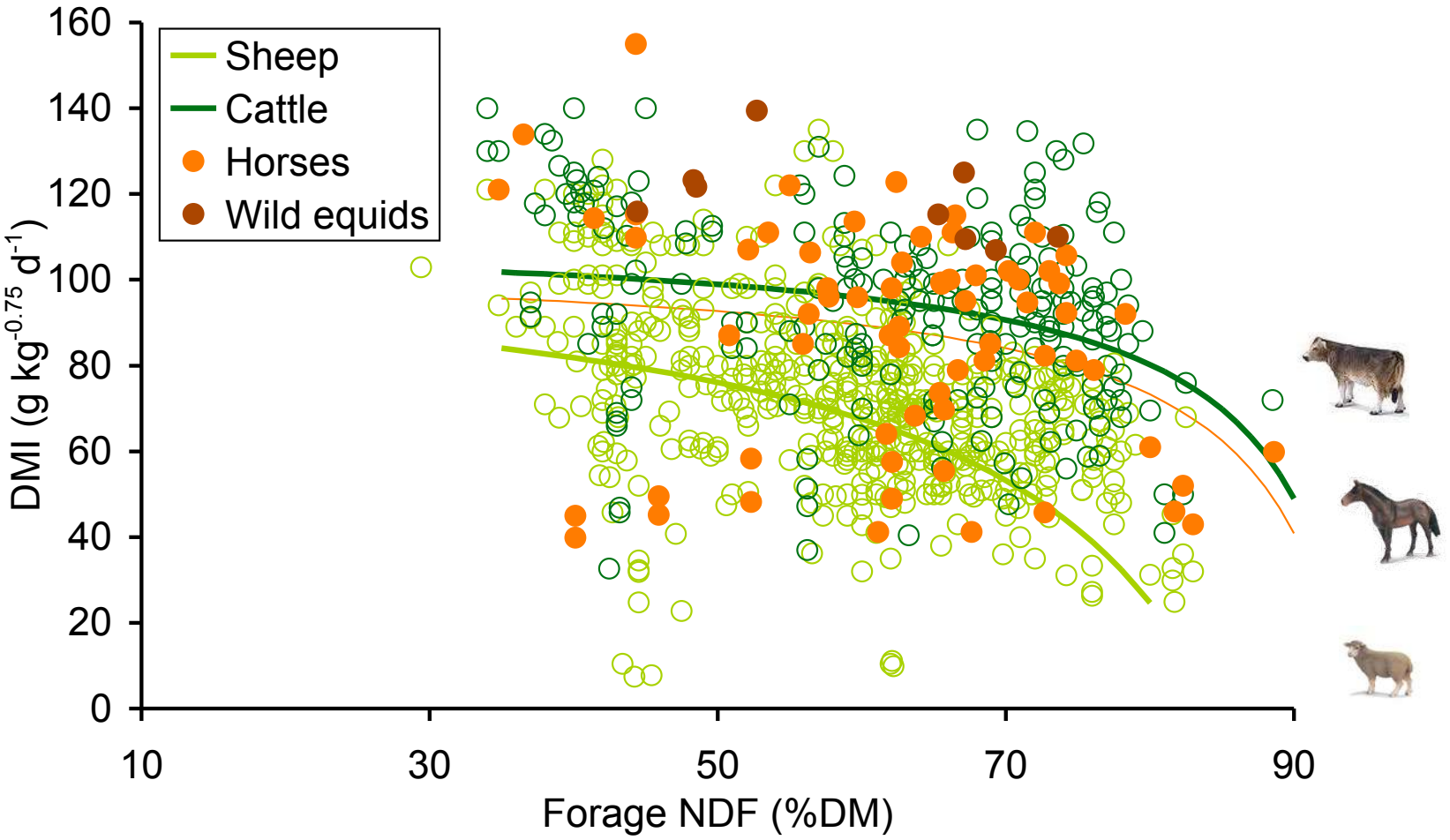

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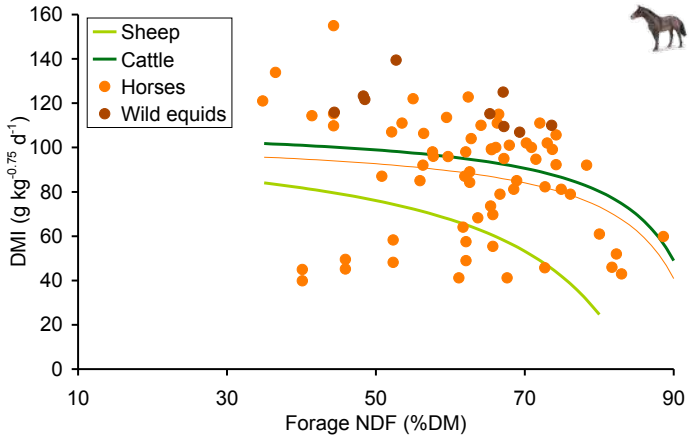

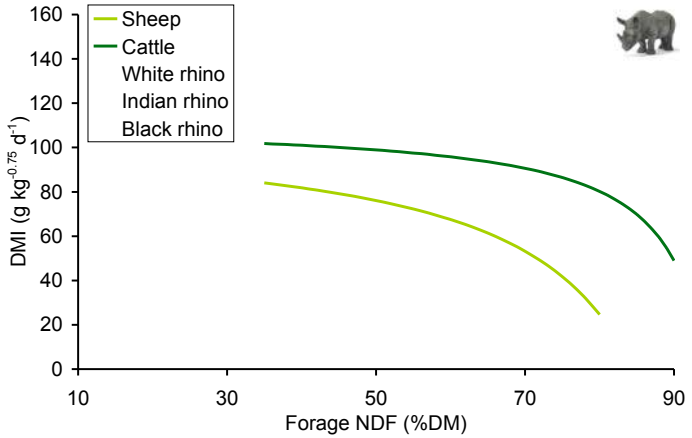

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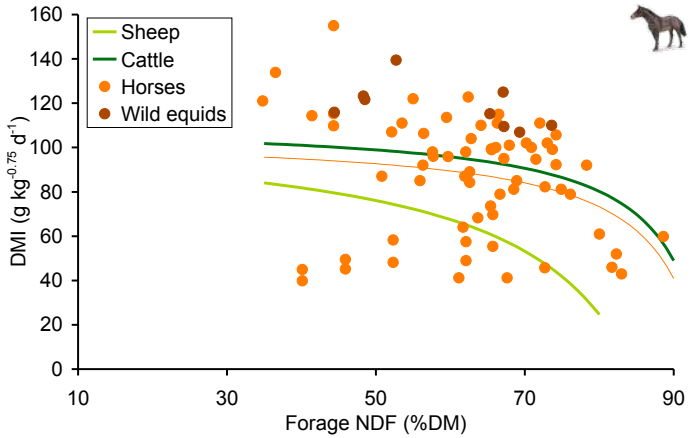

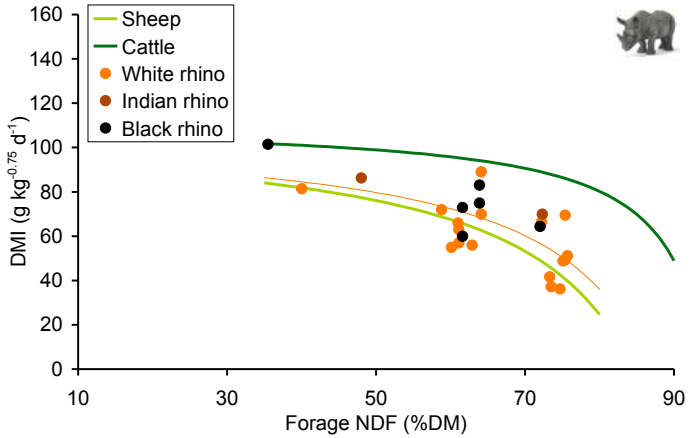

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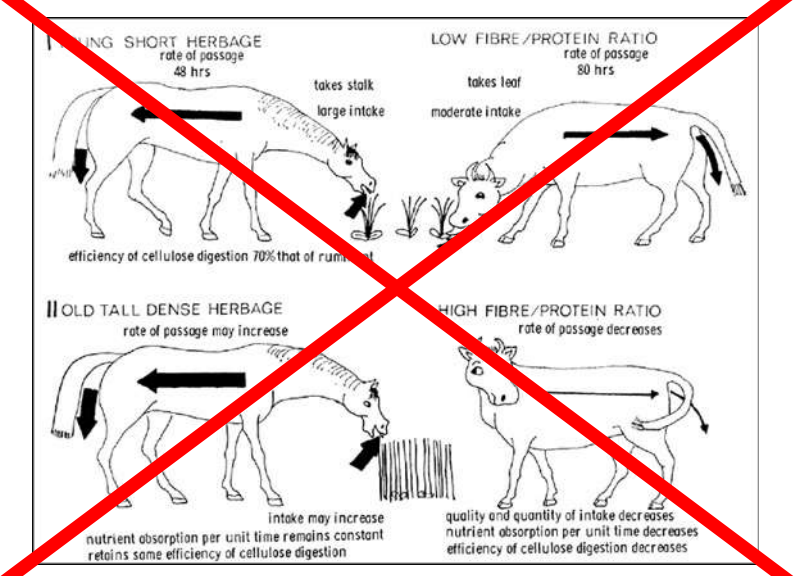

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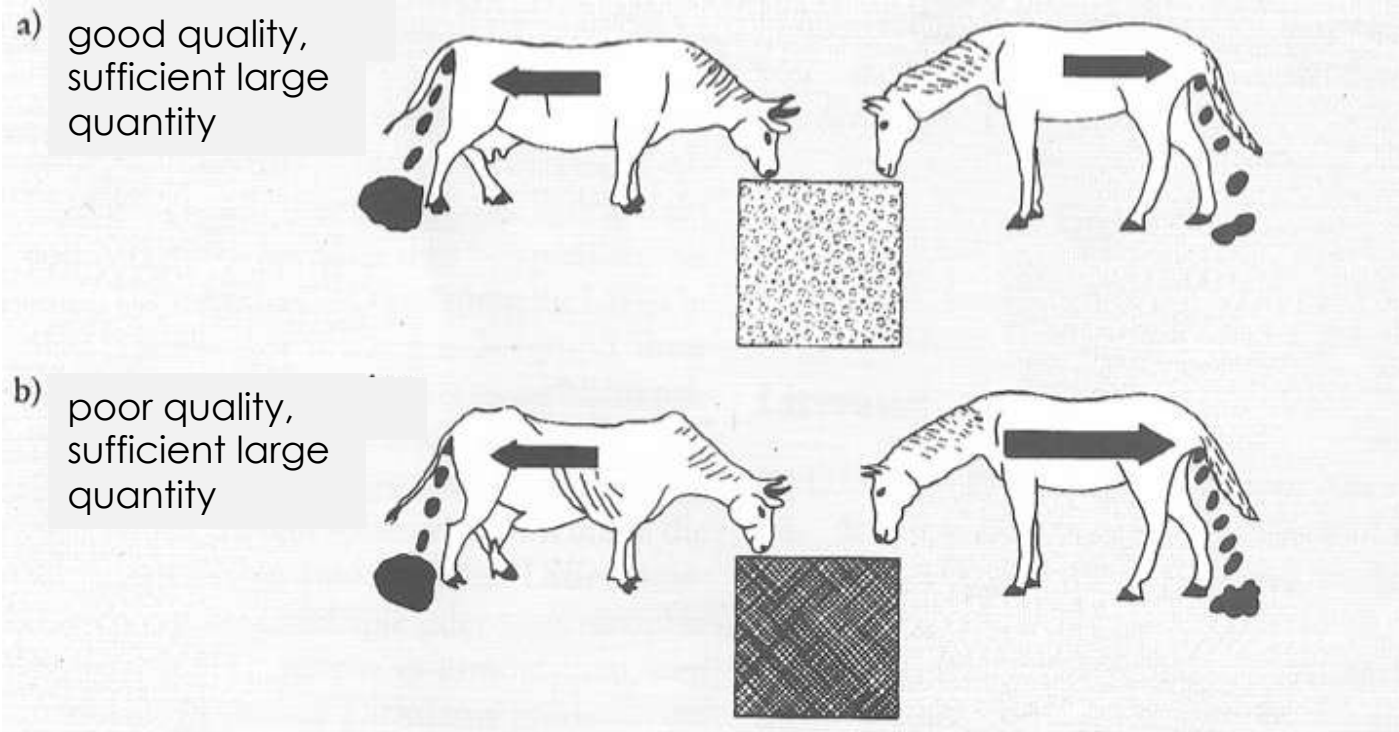
The digestive tract of herbivorous mammals

Peter Langer

Biologie in unserer Zeit
1987 17: 9-14



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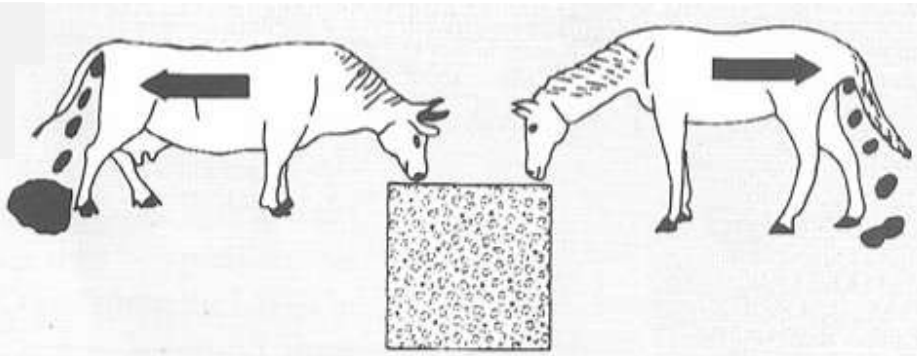
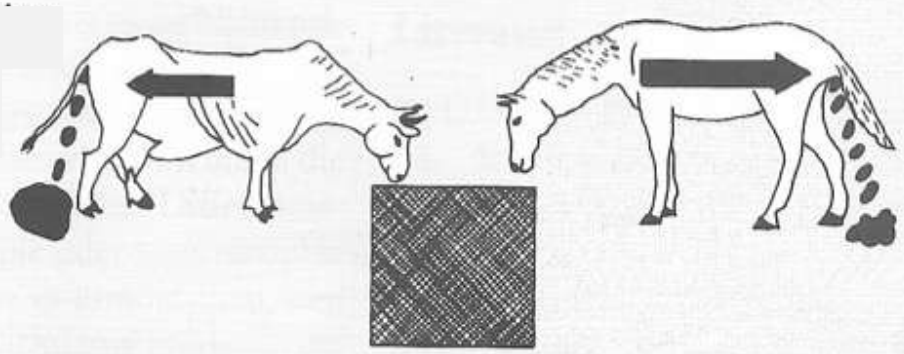
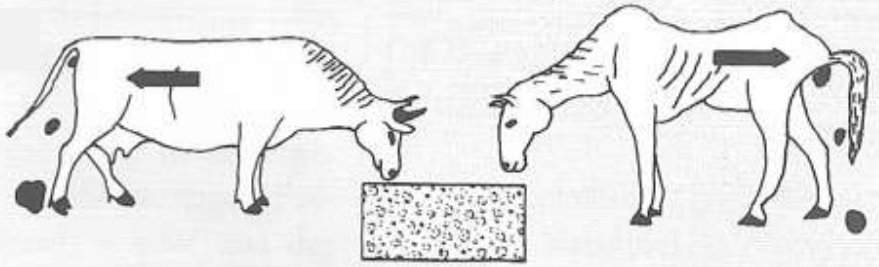


b) poor quality, sufficient large quantity



c) good quality, limited quantity

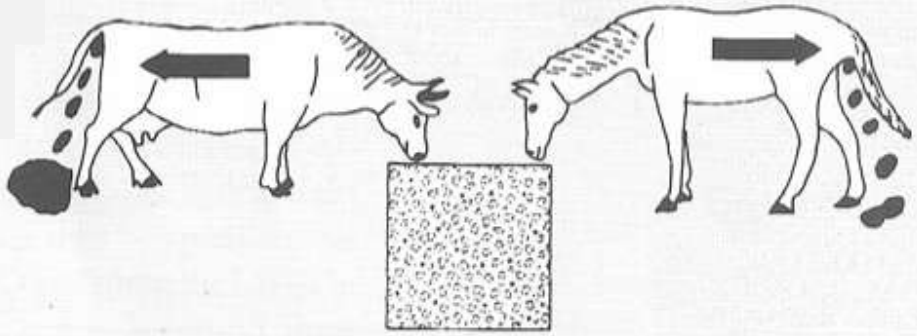


The digestive tract of herbivorous mammals

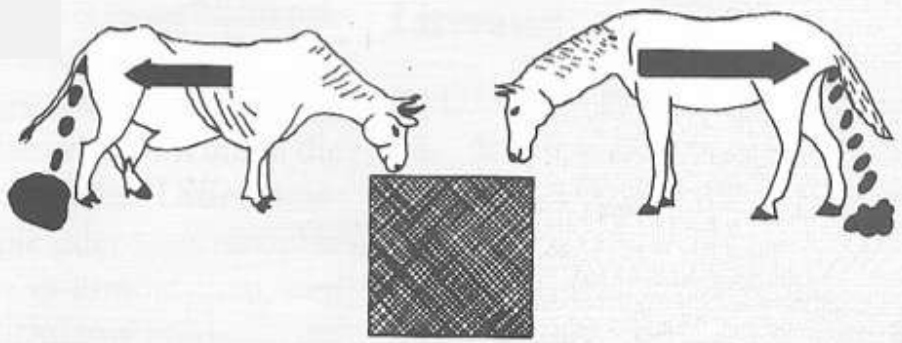
Peter Langer

Biologie in unserer Zeit
1987 17: 9-14

a) good quality, sufficient large quantity



b) poor quality, sufficient large quantity



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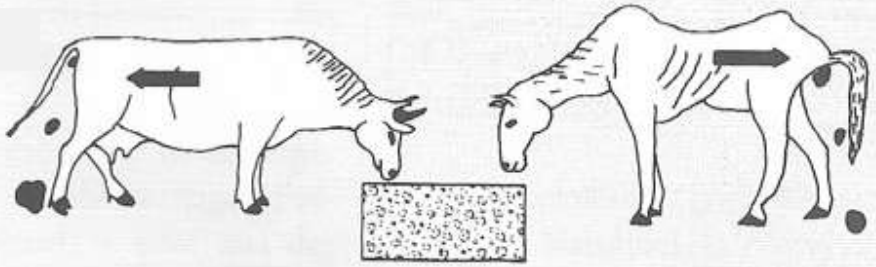
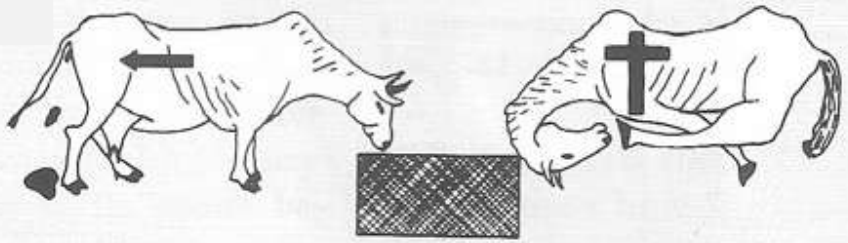


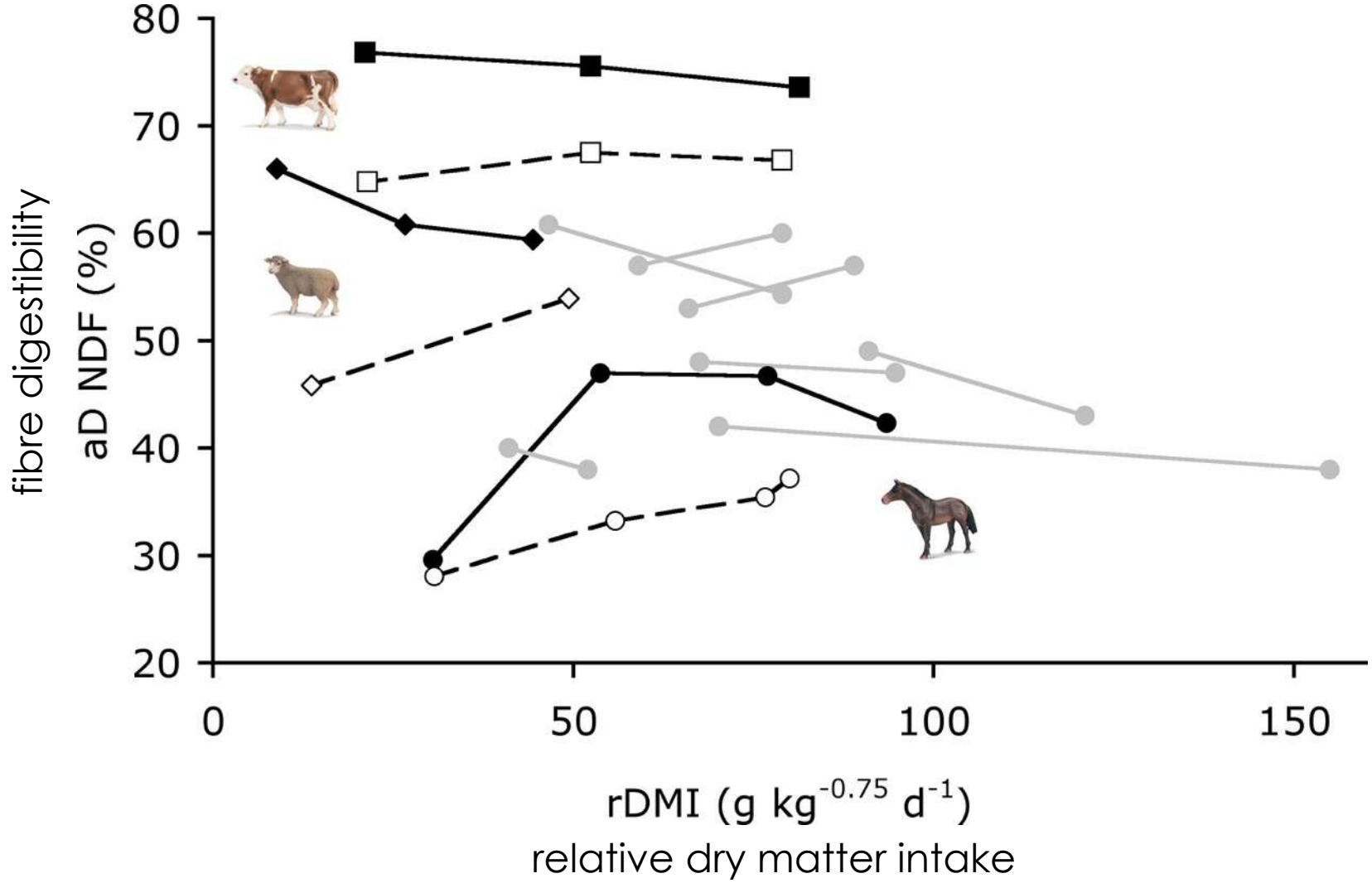
d) poor quality, limited quantity



The effect of very low food intake on digestive physiology and forage digestibility in horses

M. Clauss[1], K. Schiele[2], S. Ortmann[3], J. Fritz[2], D. Codron[1], J. Hummel[4] and E. Kienzle[2]

Journal of Animal Physiology and Animal Nutrition **98** (2014) 107–118



Differences in digestive physiology between equids and ruminants: selective particle retention

Selective particle retention

In ruminants, large particles are selectively retained in the rumen.

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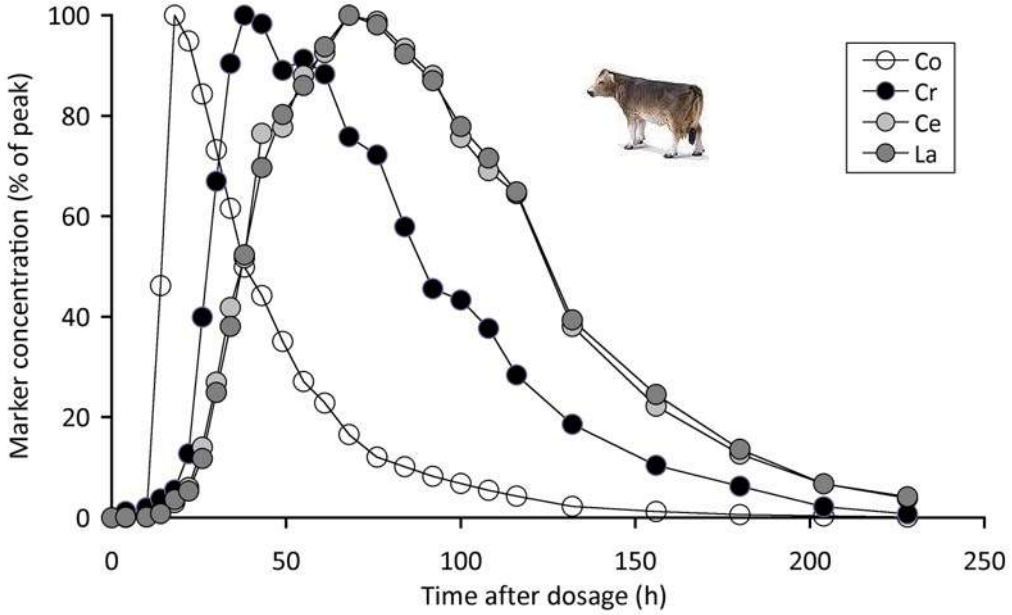

from Lechner et al. (2010)

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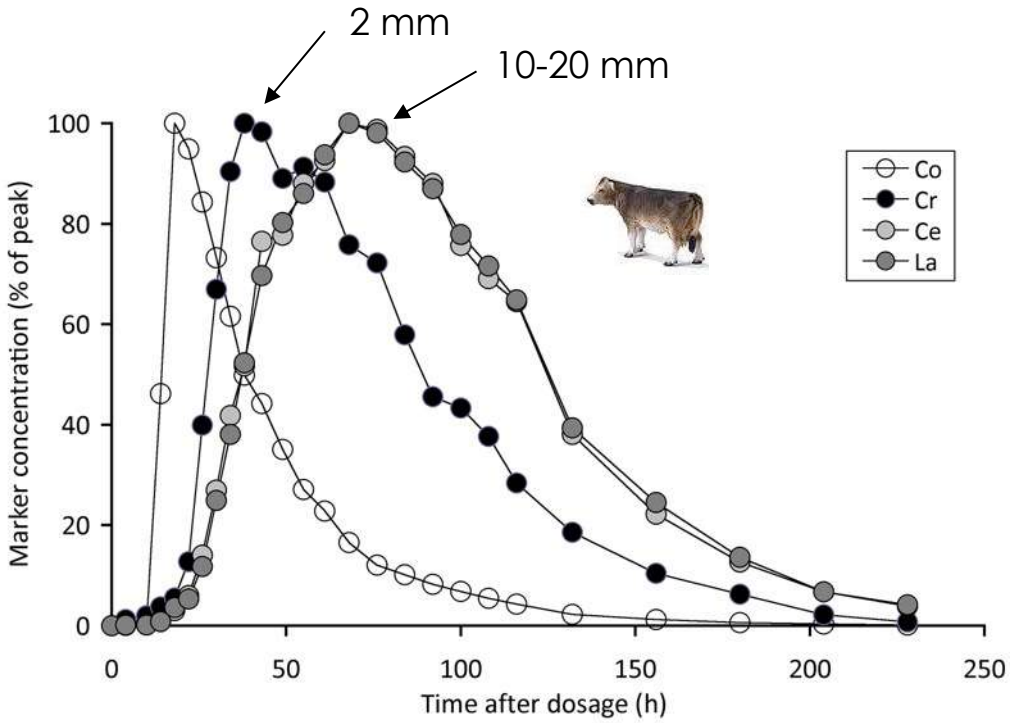

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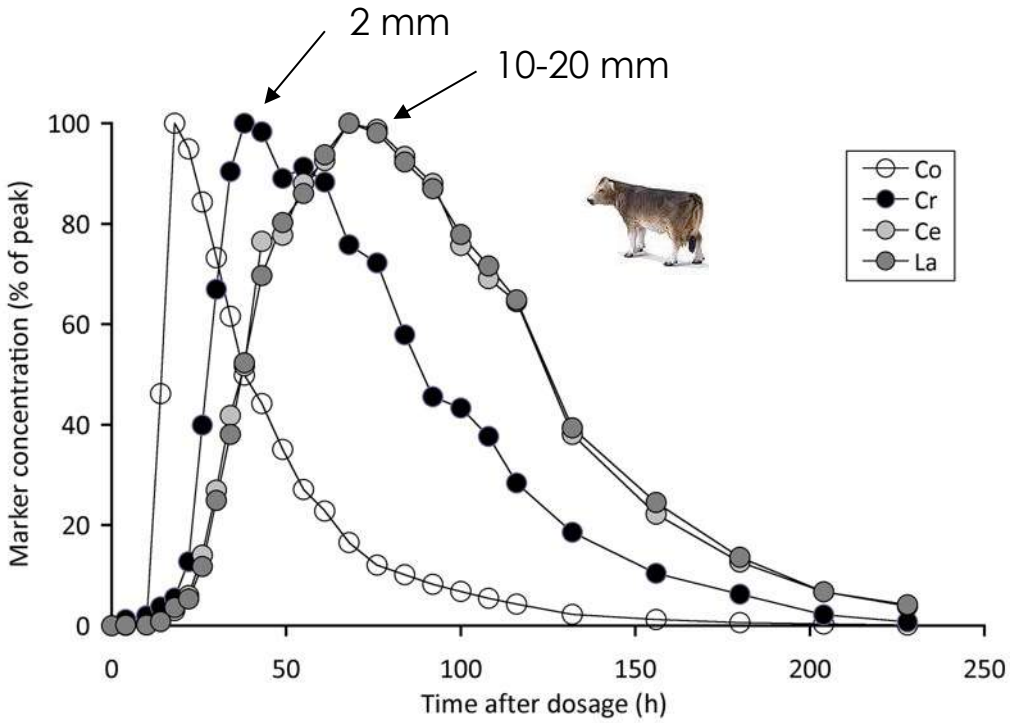

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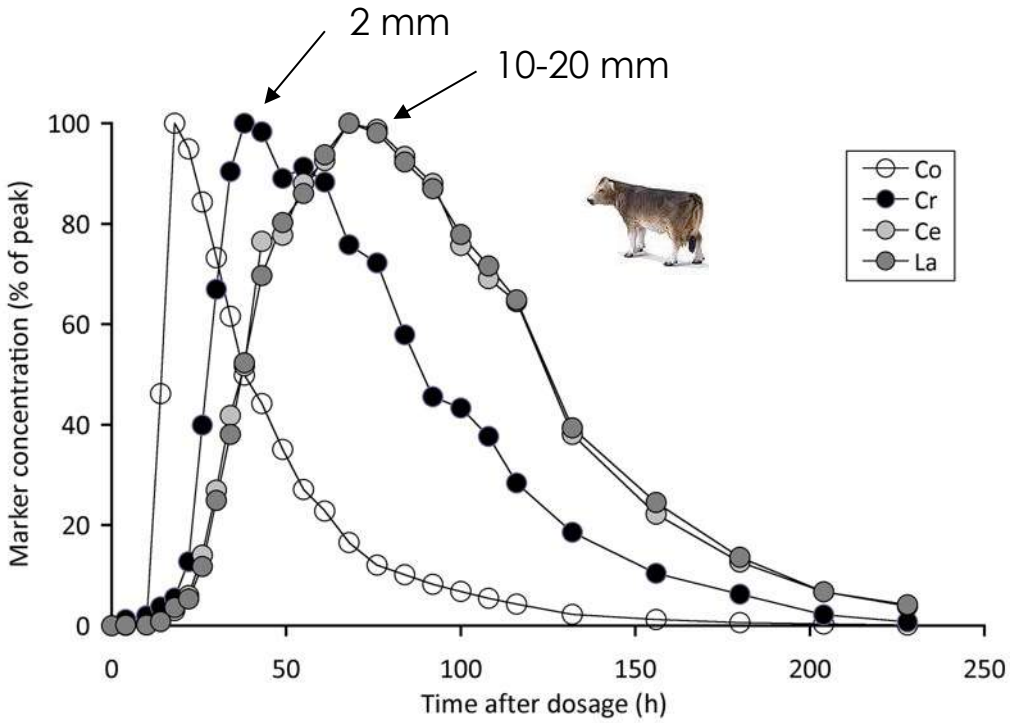

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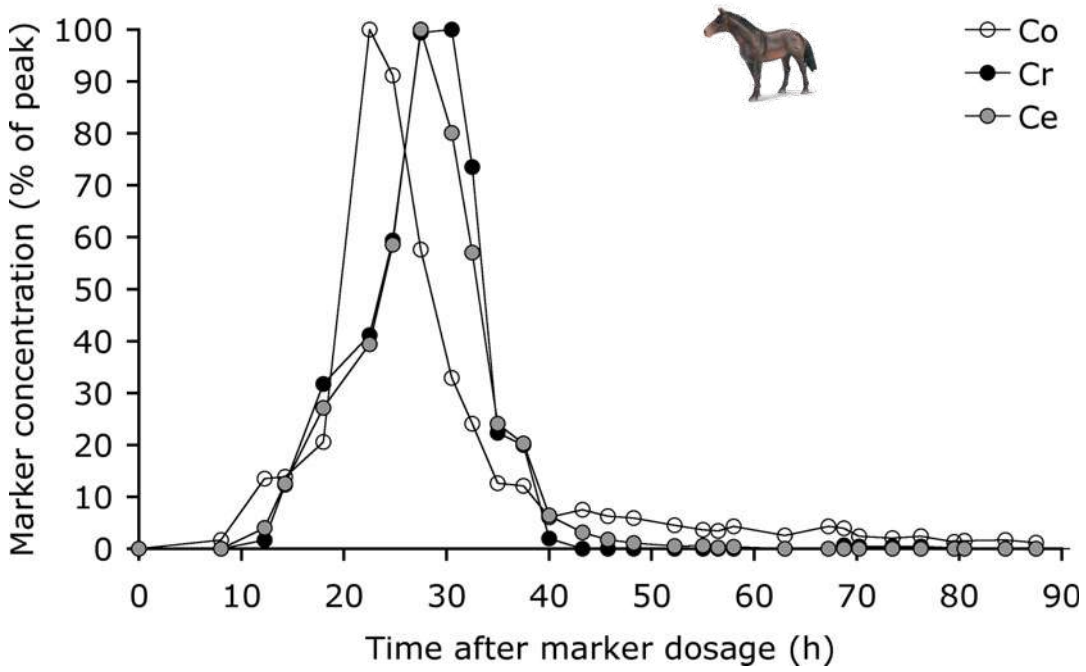

Clauss et al. (pers. obs.)

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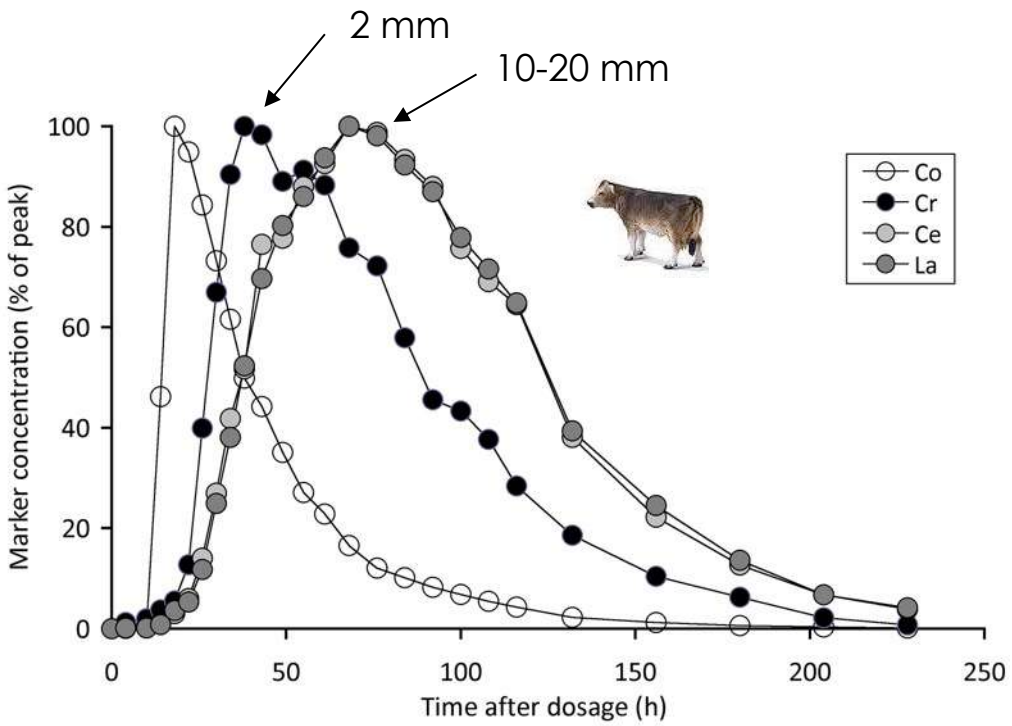

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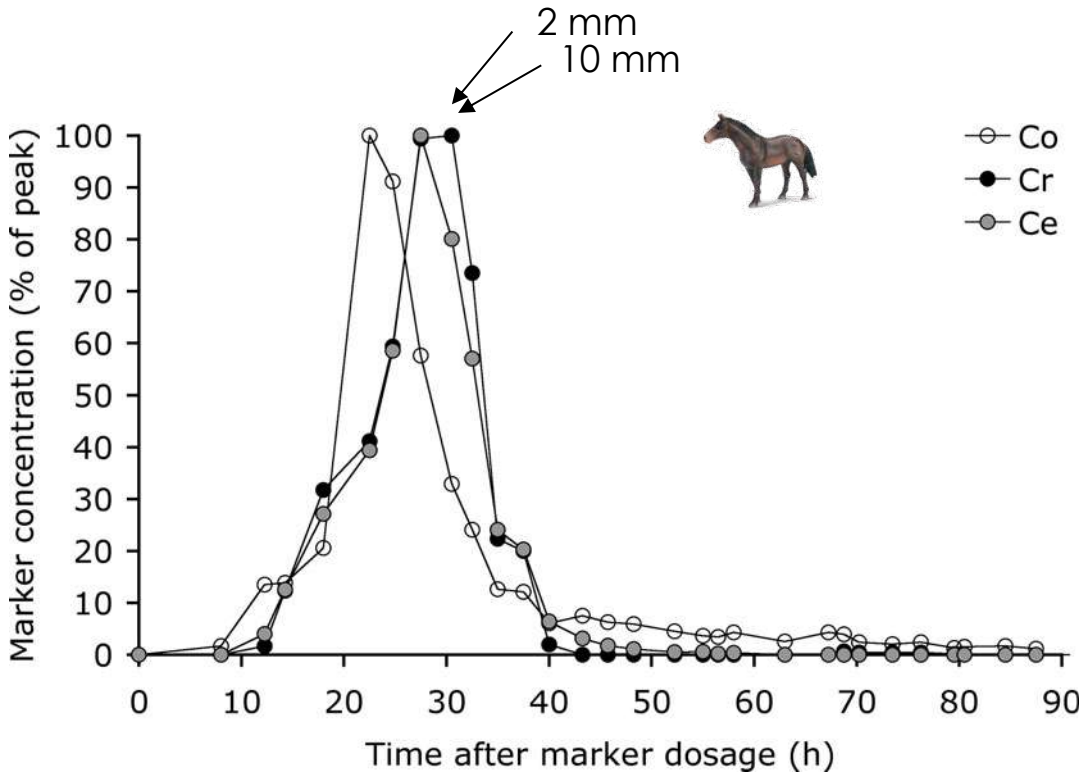

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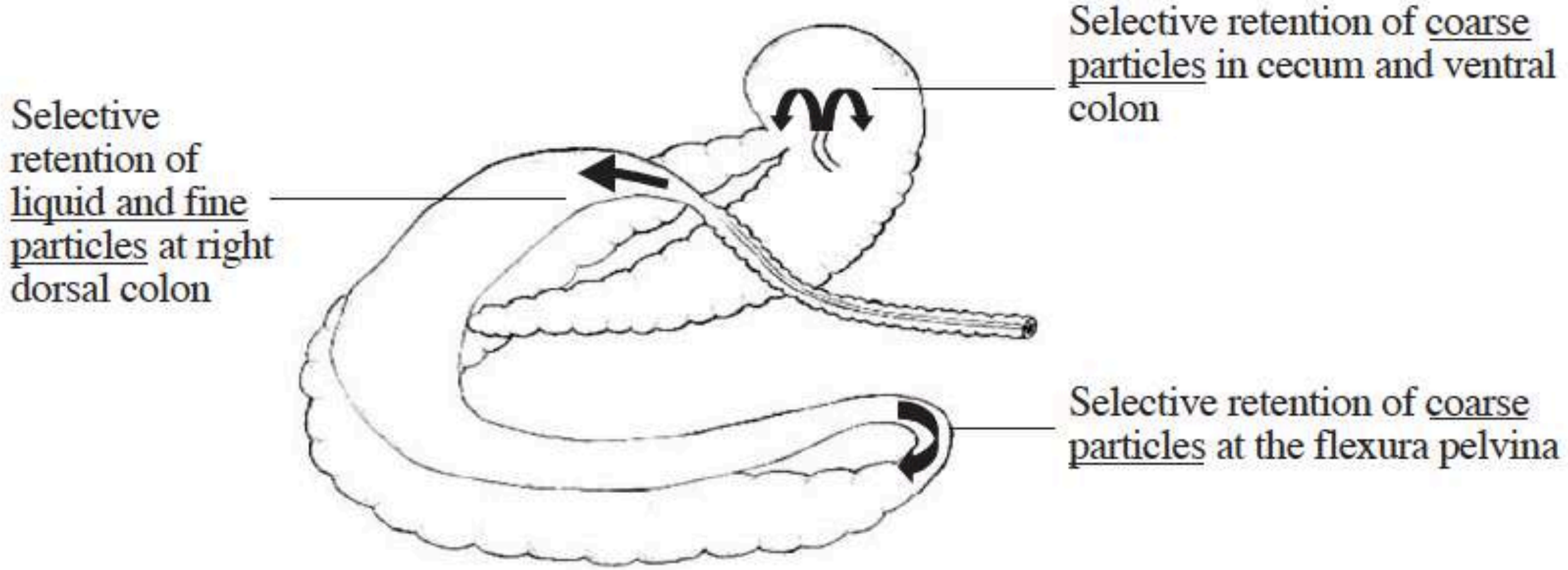
Passage rate of digesta through the equine gastrointestinal tract: A review

S. Van Weyenberg *, J. Sales, G.P.J. Janssens

Livestock Science 99 (2006) 3–12



Comparative selective retention of particle size classes in the gastrointestinal tract of ponies and goats

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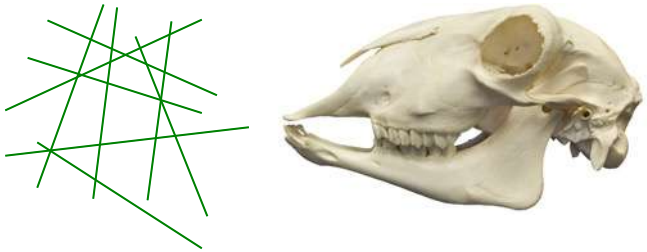

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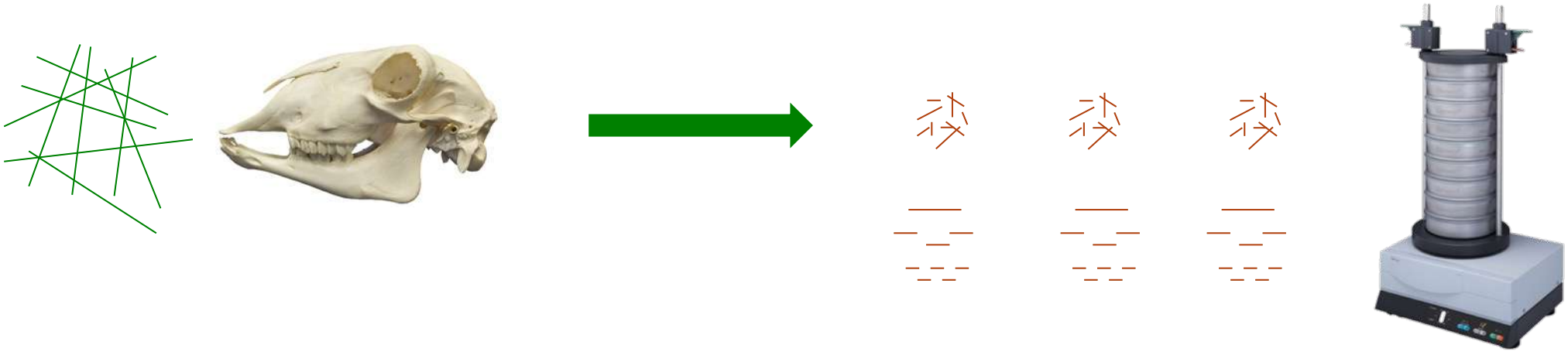

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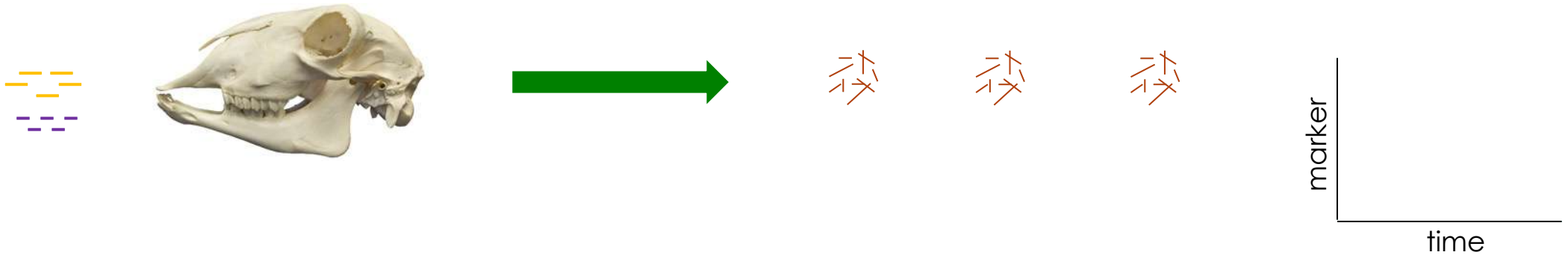

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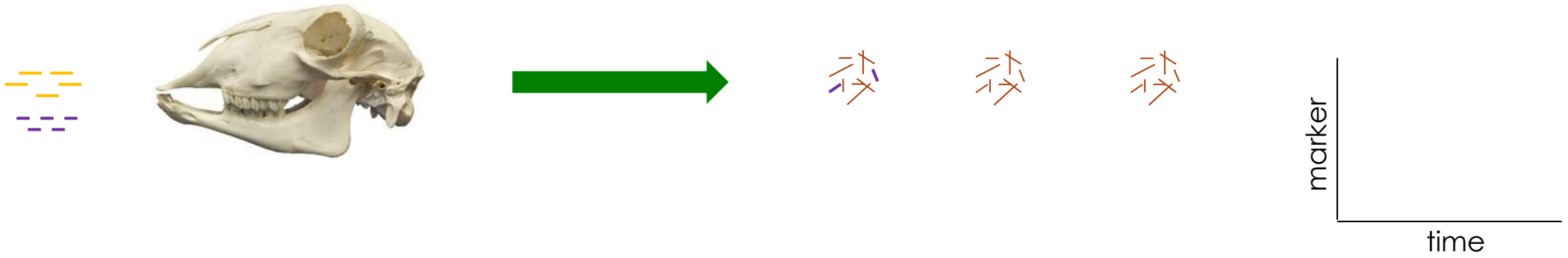

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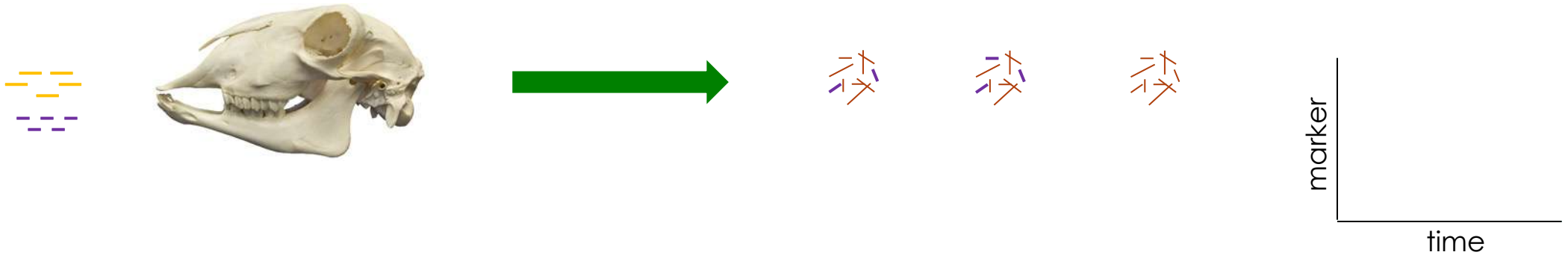

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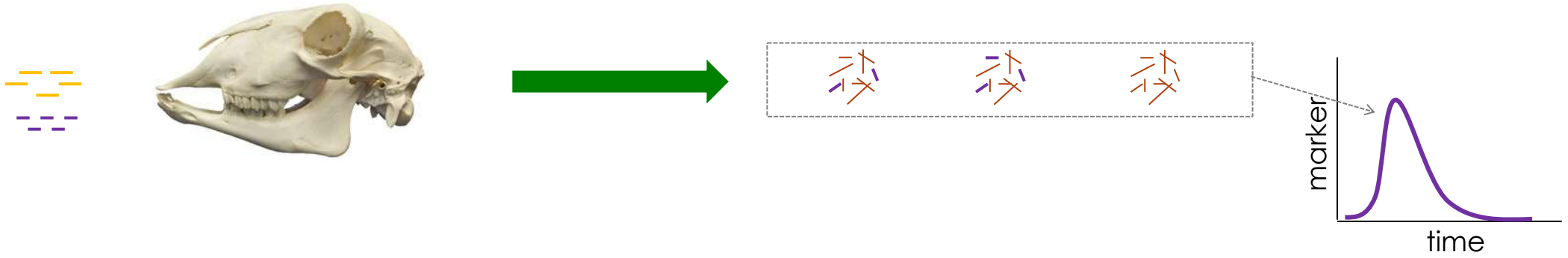

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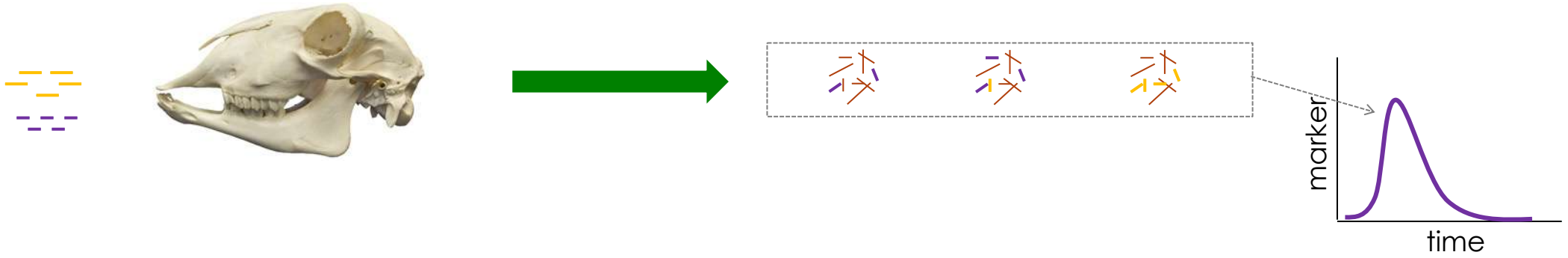

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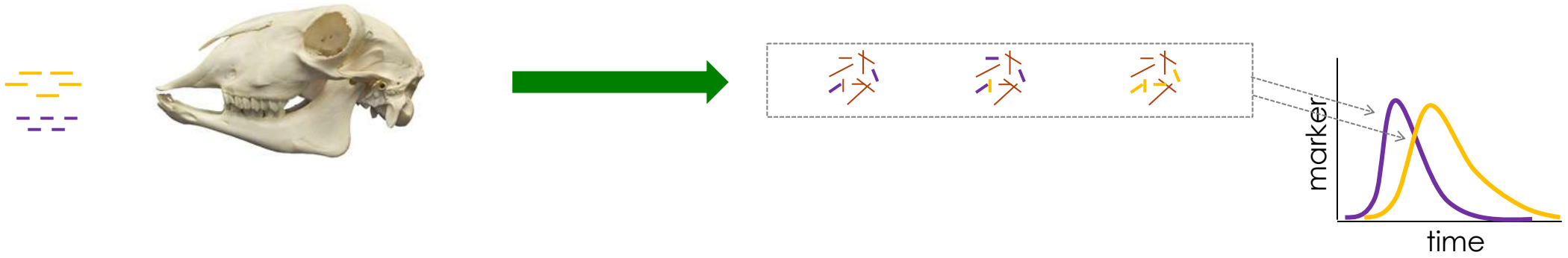

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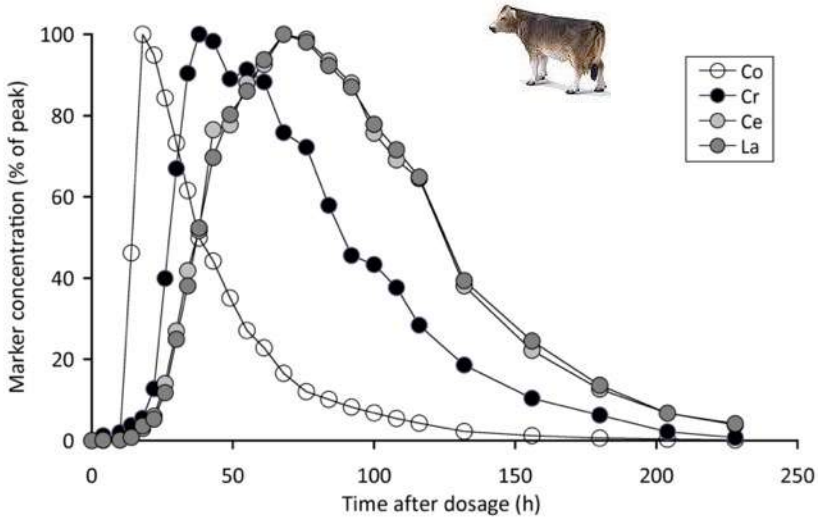

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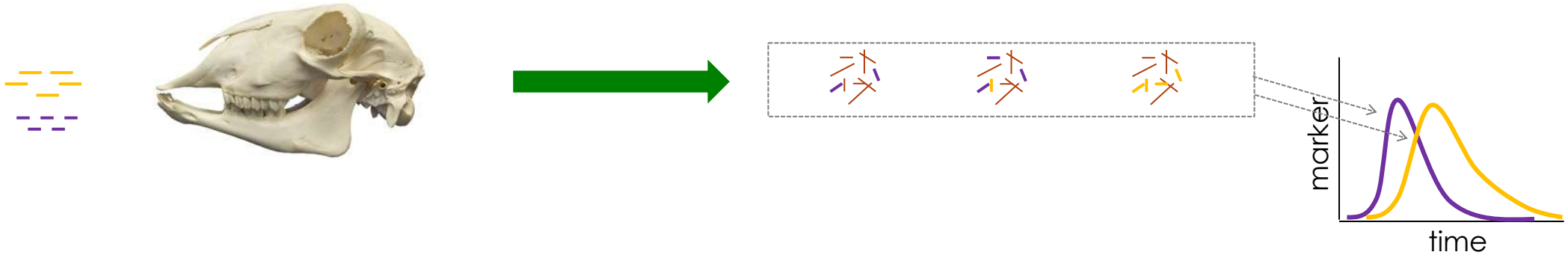

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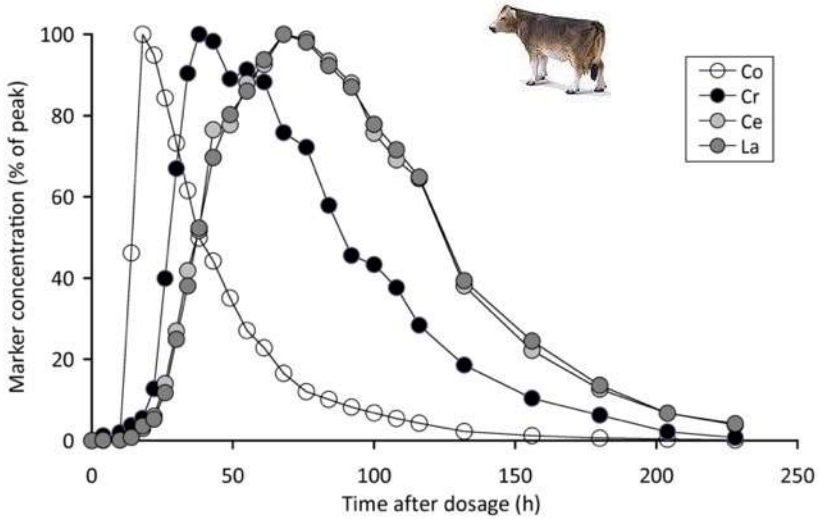

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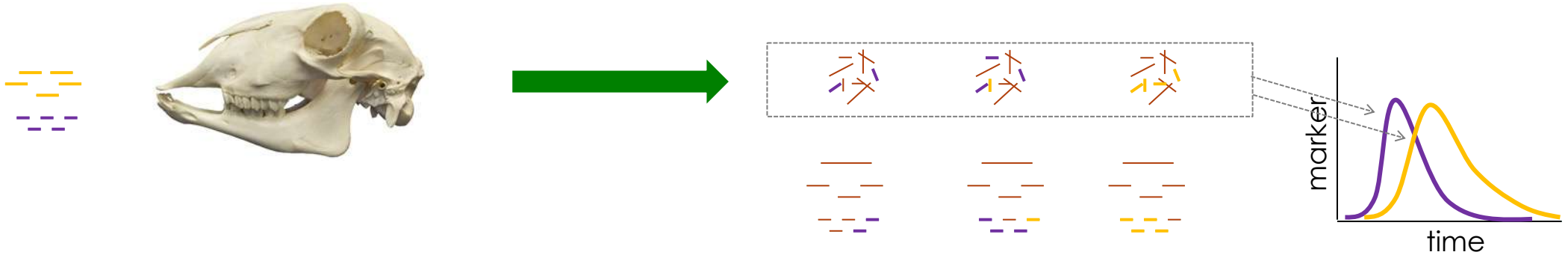

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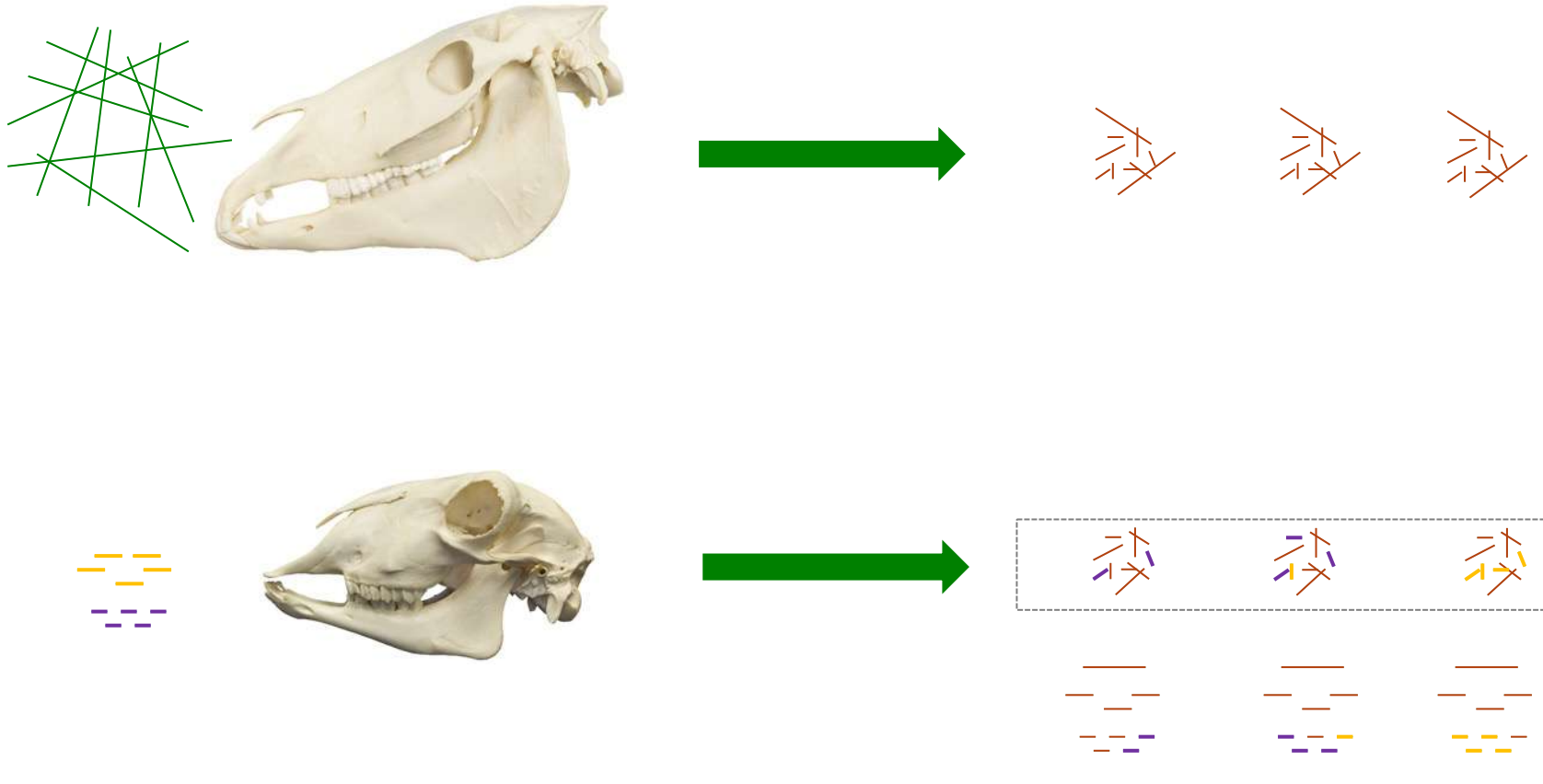

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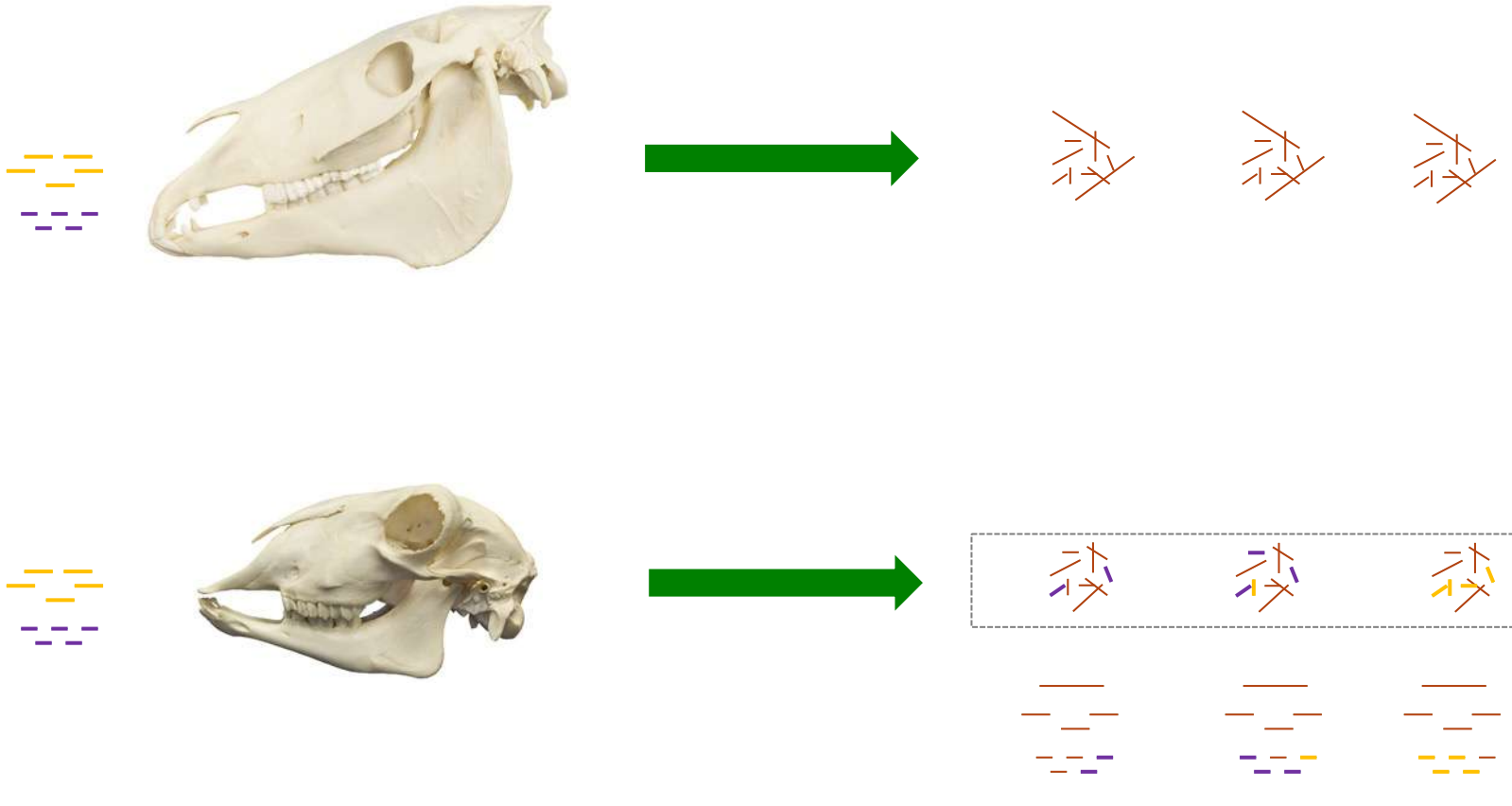

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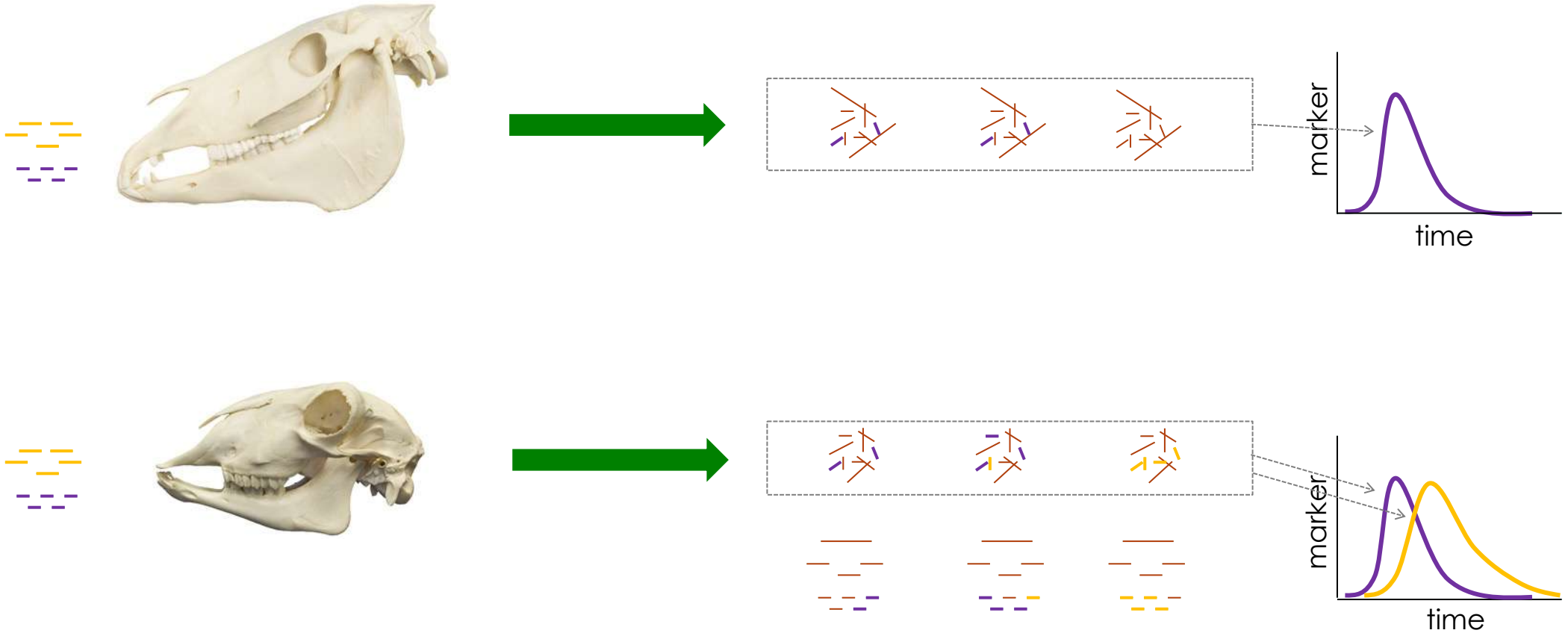

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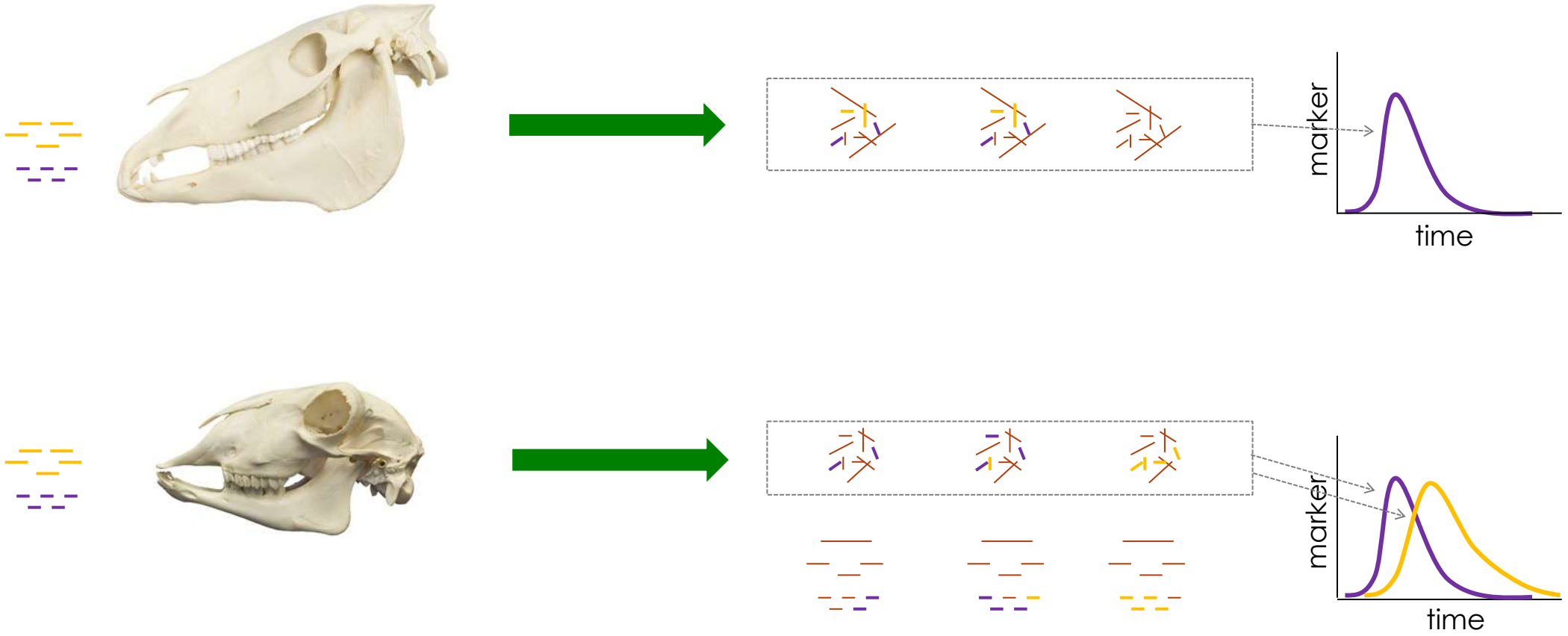

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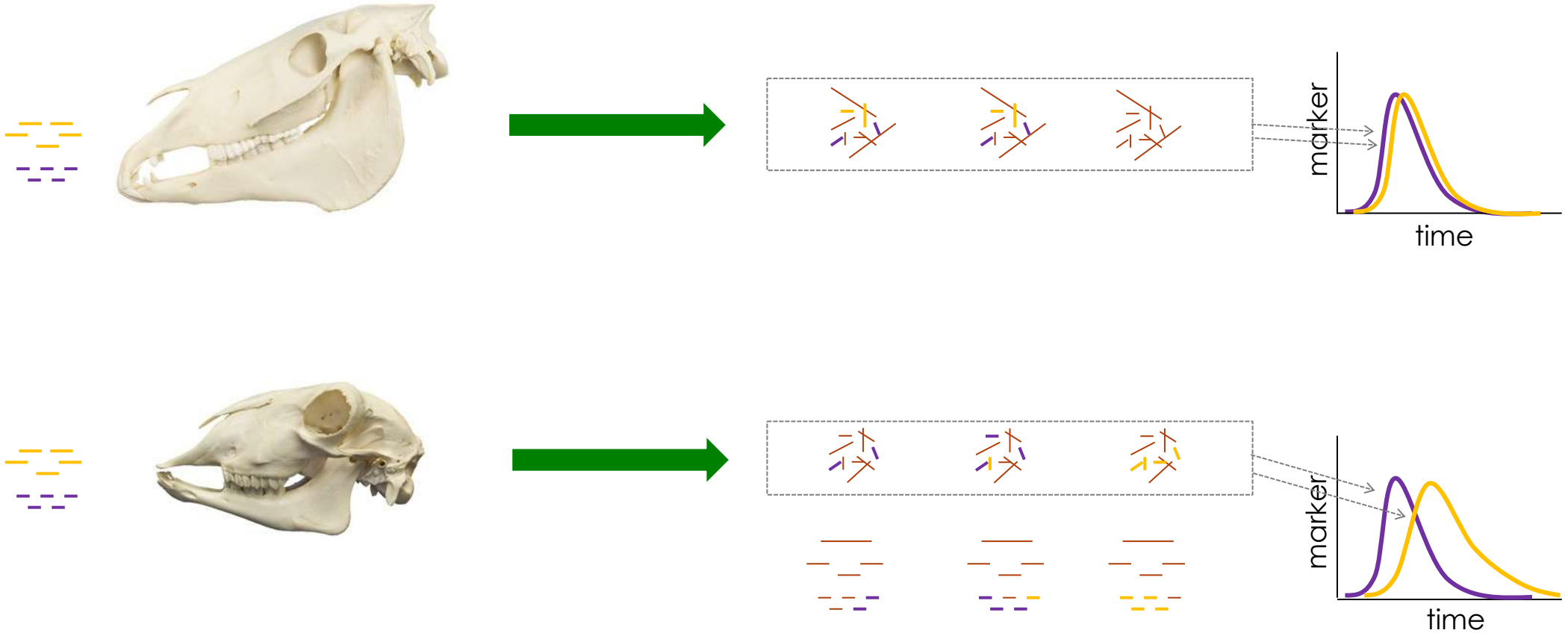

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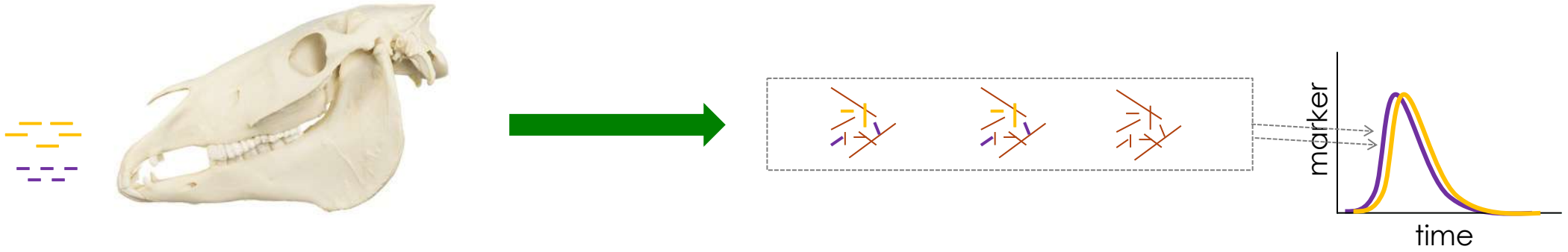

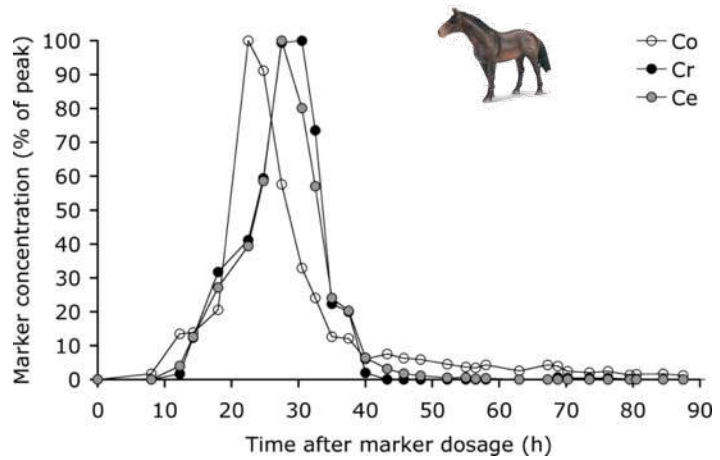

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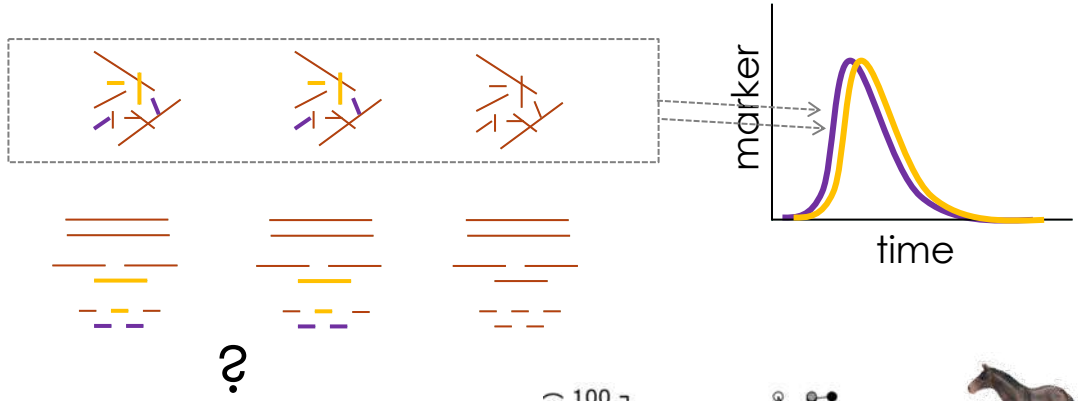

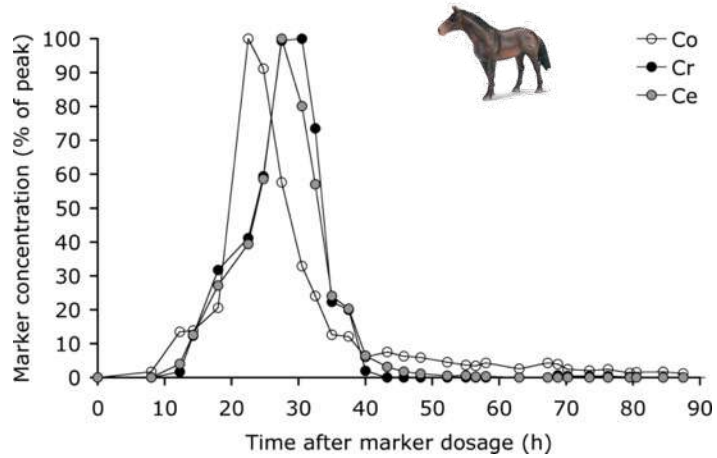

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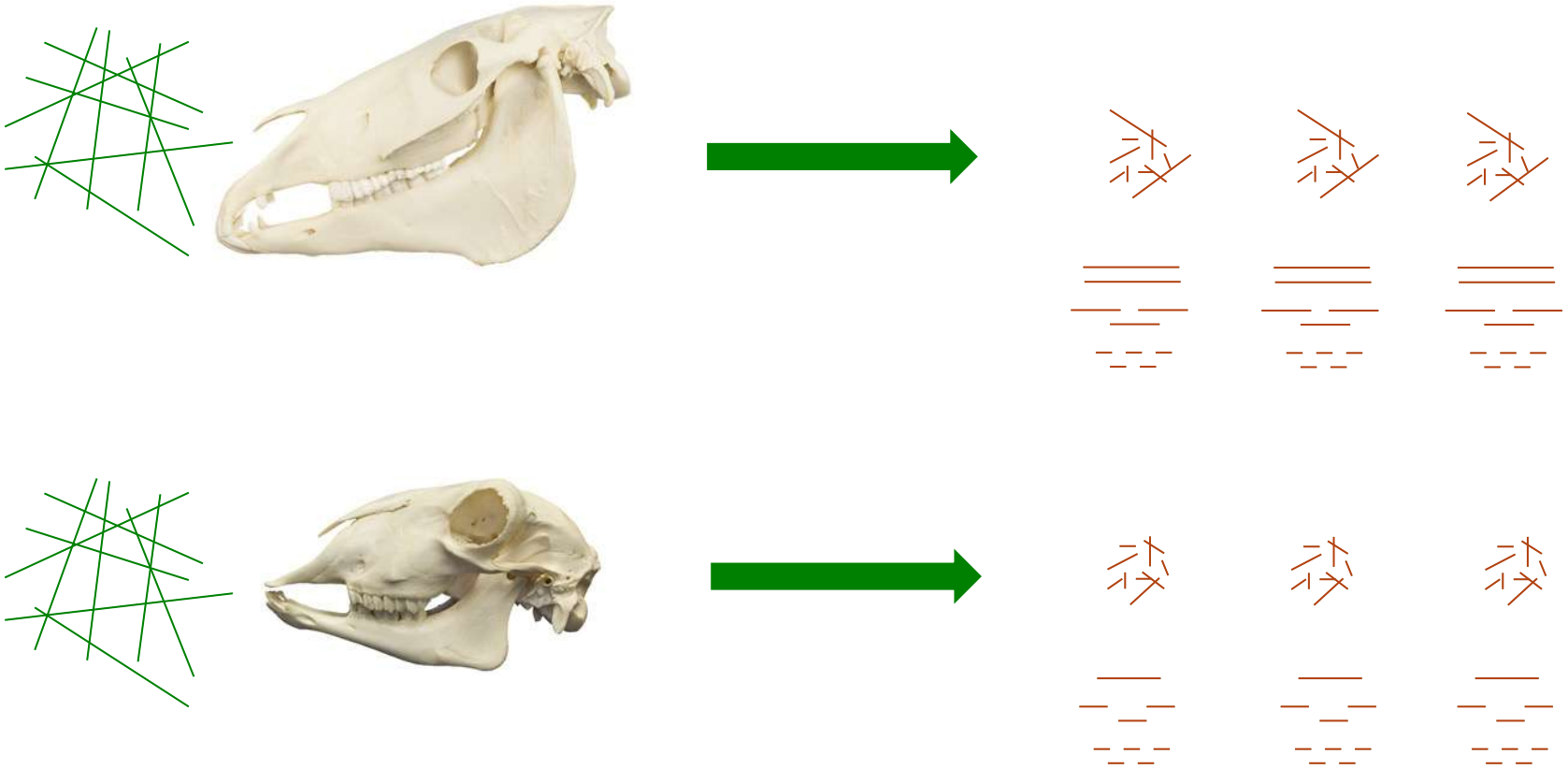

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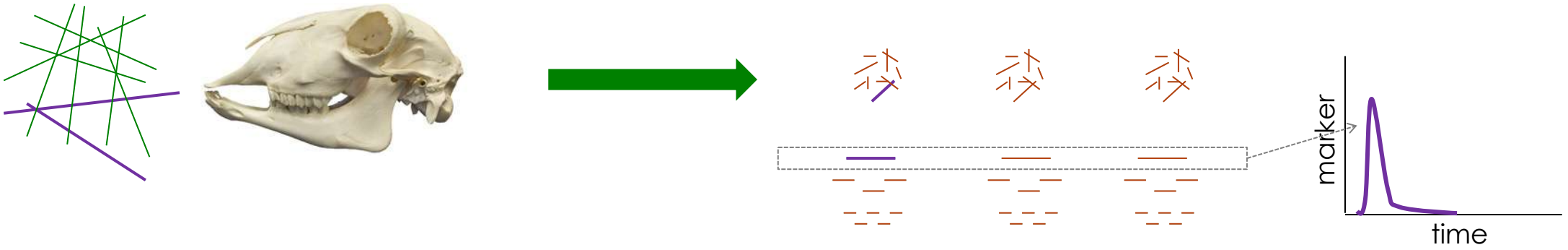

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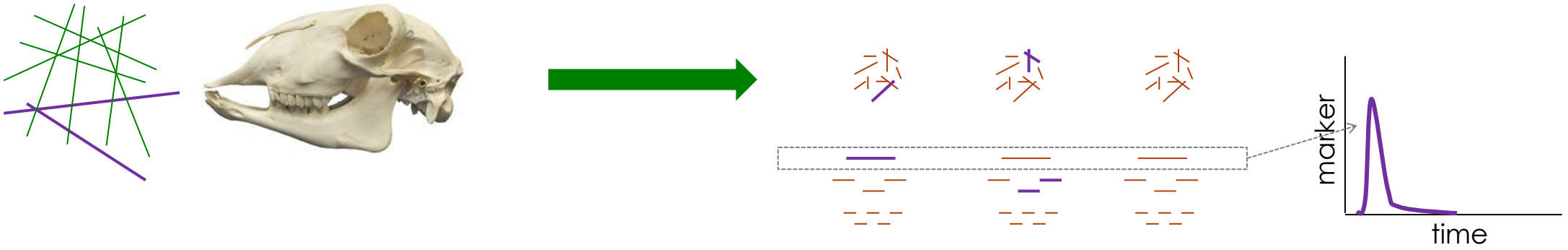

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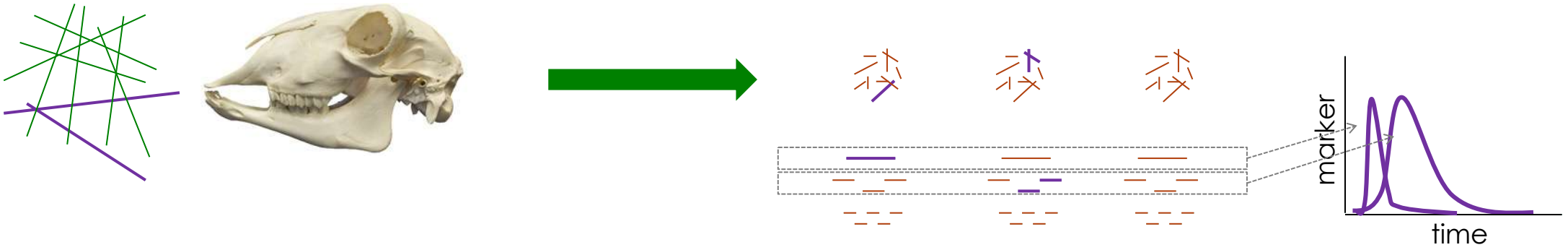

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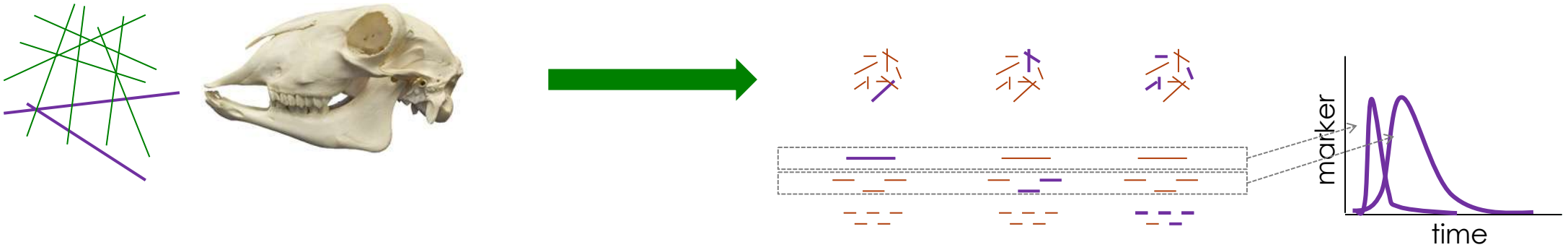
J Anim Physiol Anim Nutr. 2018;102:429–439.



Comparative selective retention of particle size classes in the gastrointestinal tract of ponies and goats

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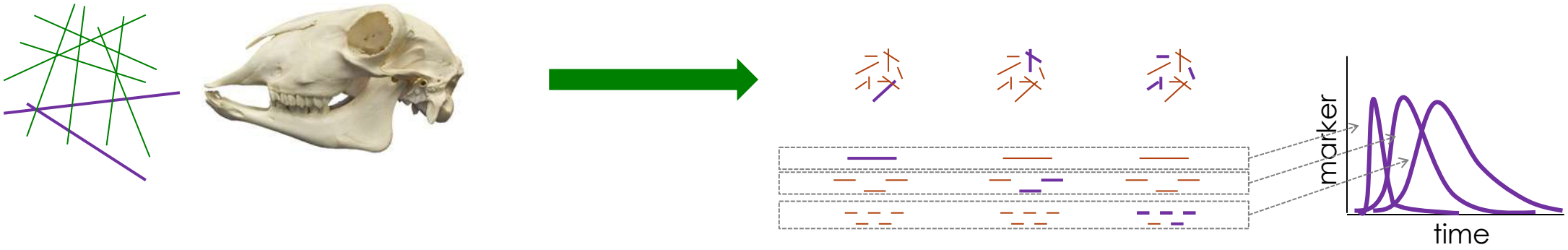

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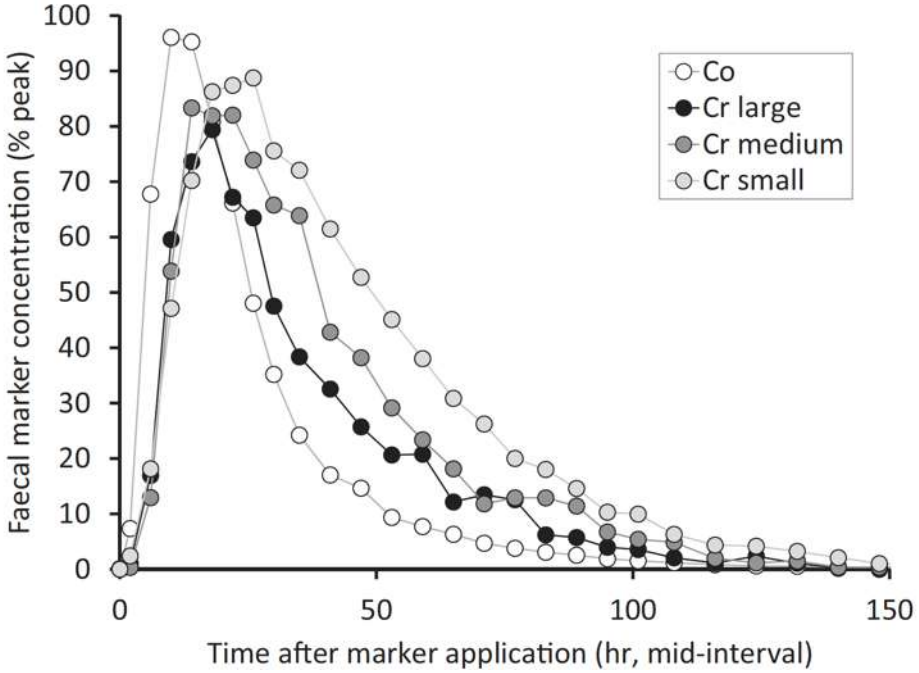

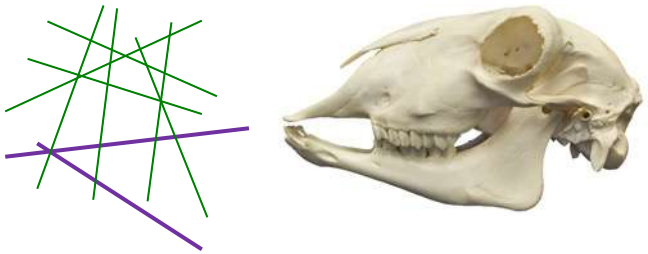

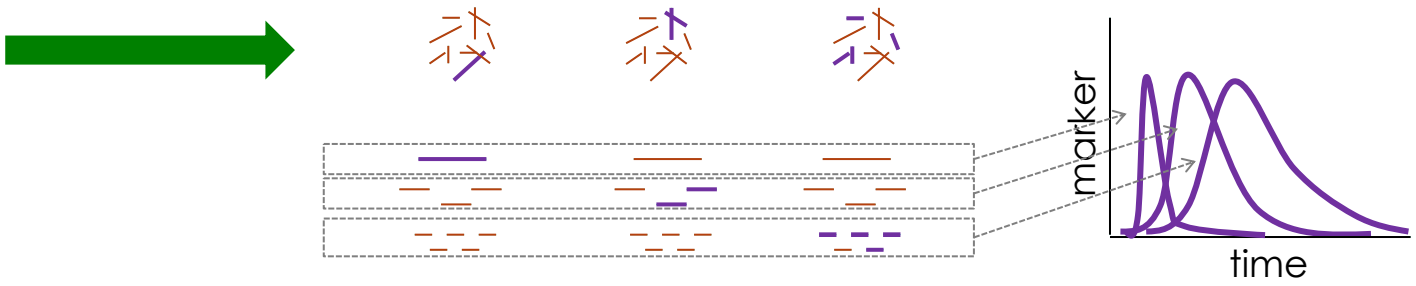

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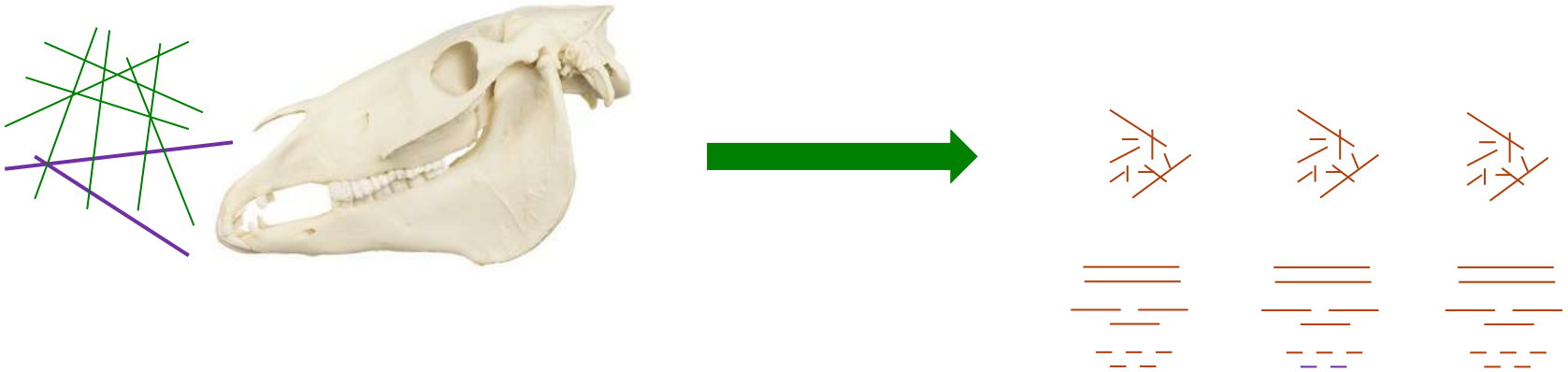

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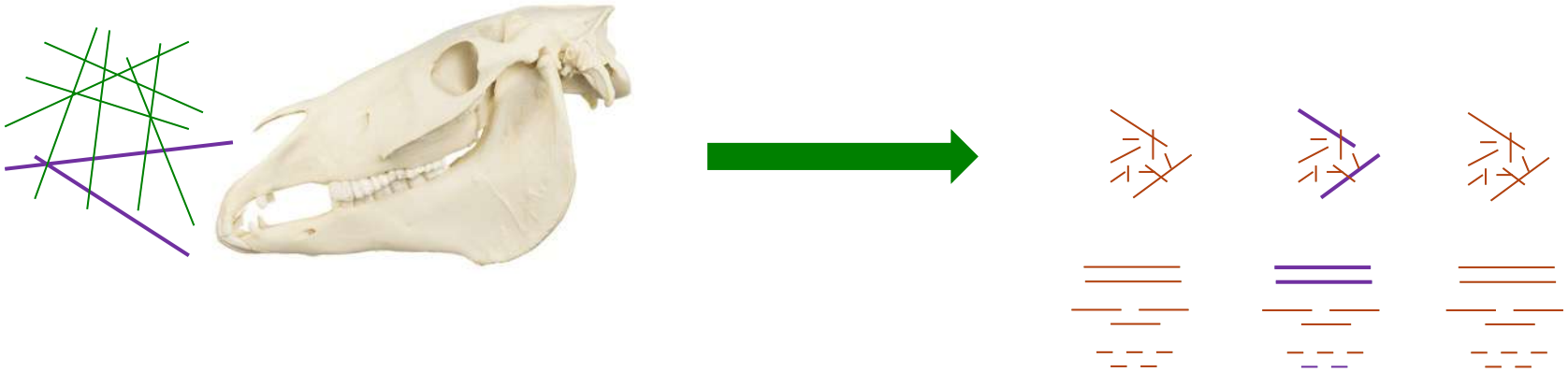

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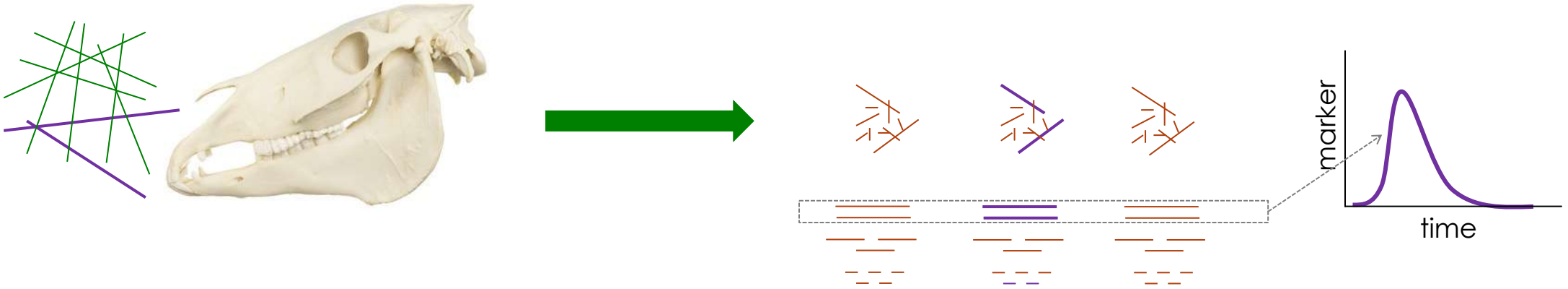

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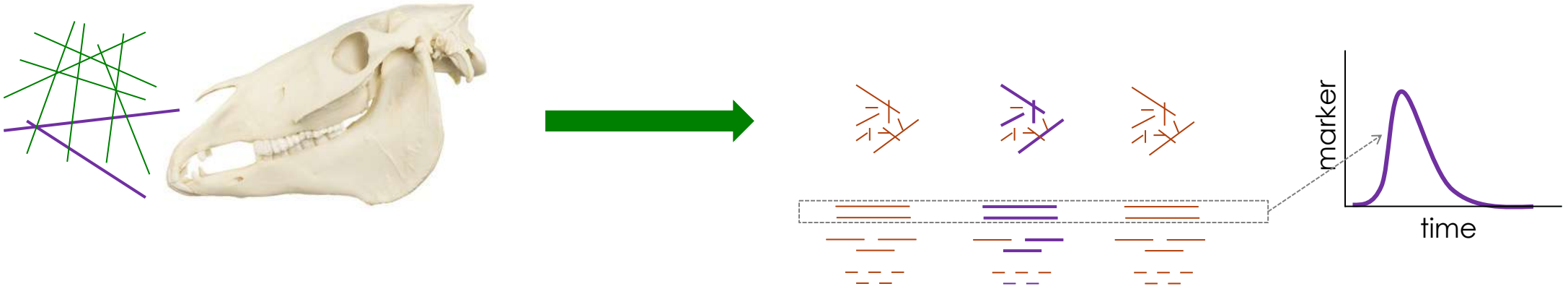

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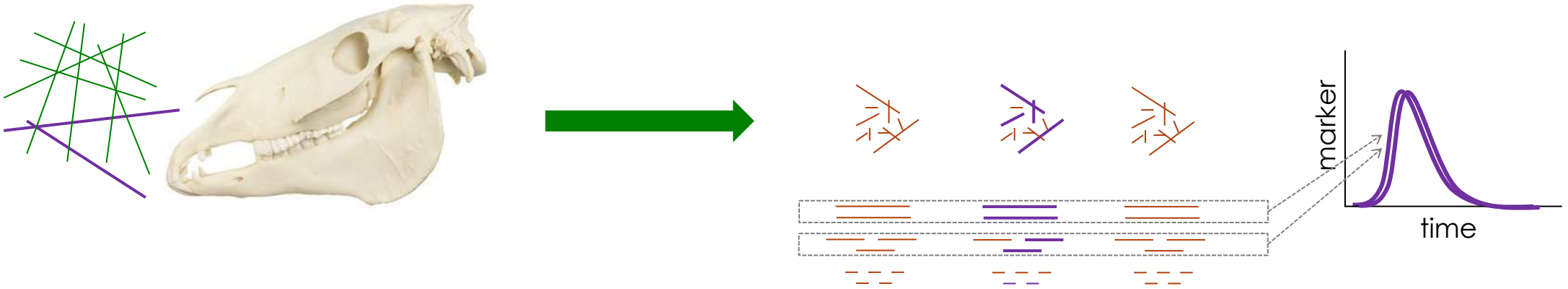

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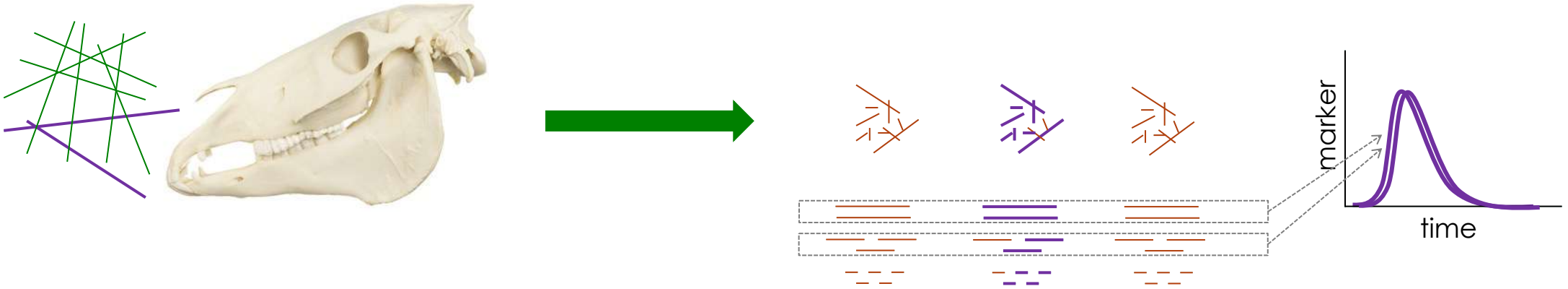

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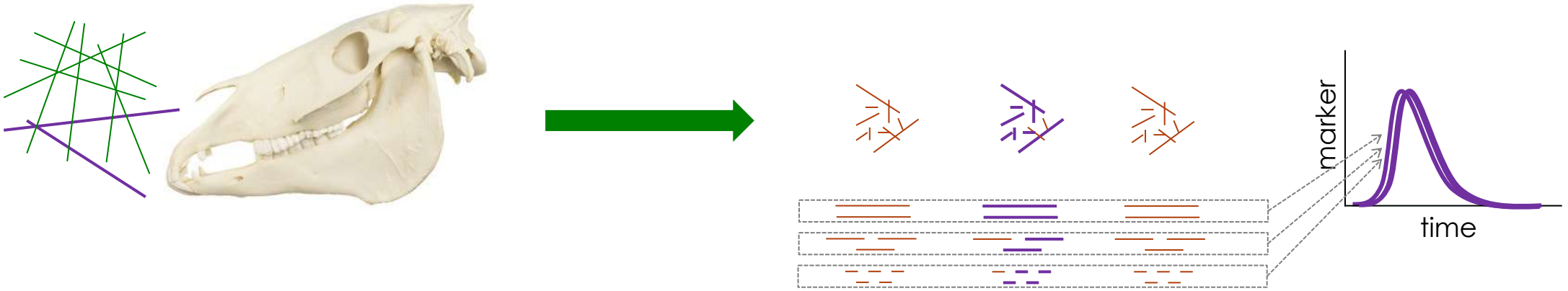

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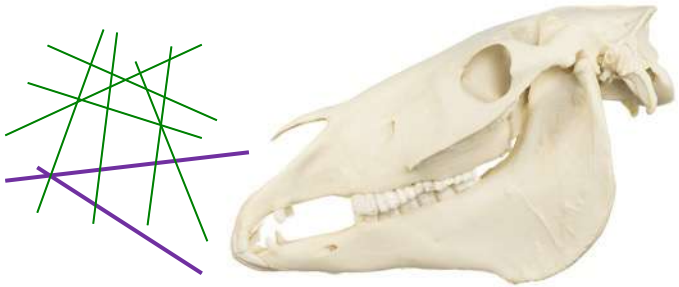
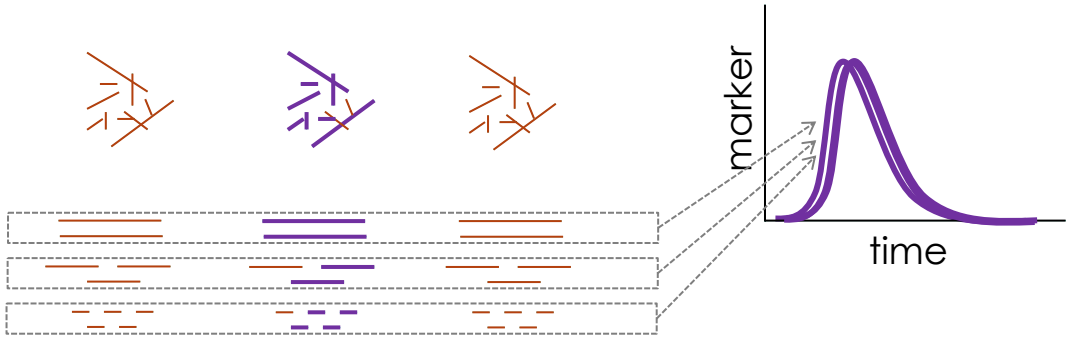
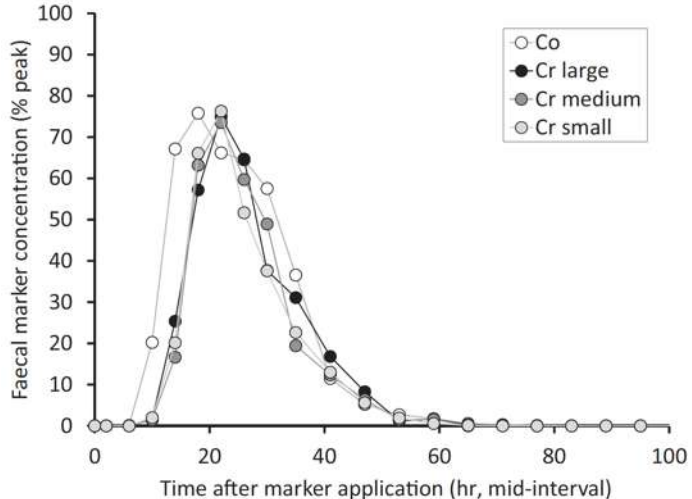
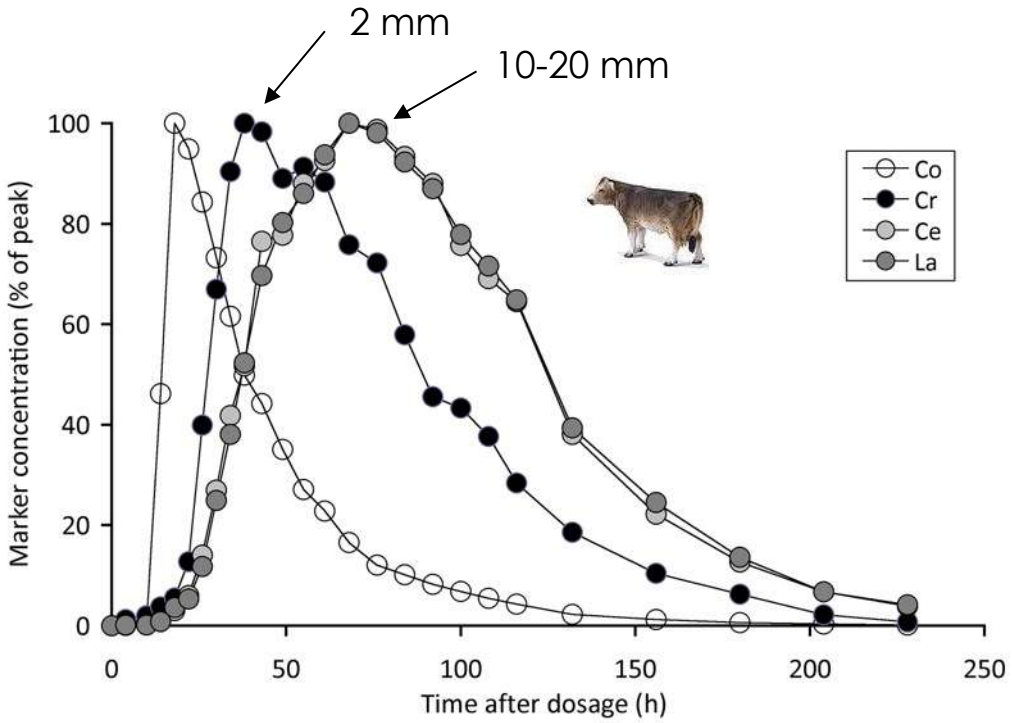






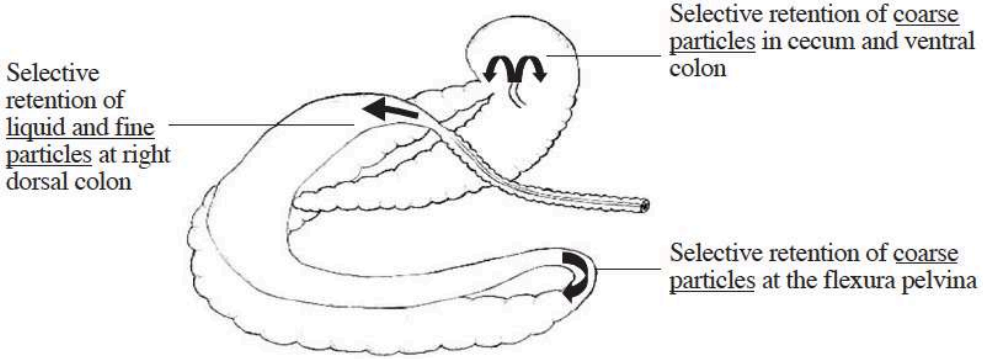
Selective particle retention

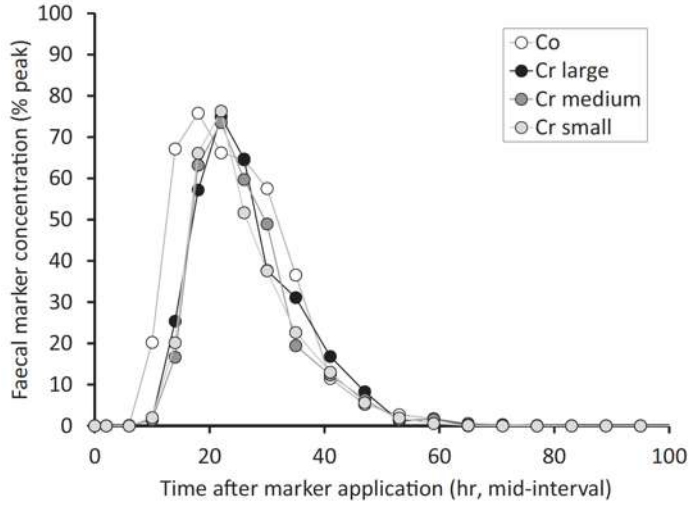
In ruminants, large particles are selectively retained in the rumen.



from Lechner et al. (2010)

In equids, there is no *net* selective retention by particle size.



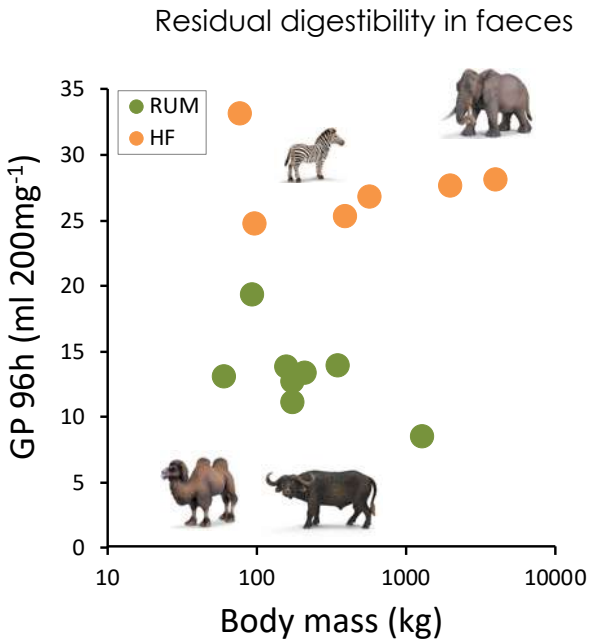


Differences in digestive physiology between equids and ruminants: chewing efficiency

Digestive physiology meets herbivore diversity

Marcus Clauss [a], Patrick Steuer [b], Kerstin Erlinghagen-Lückerath [b], Jacques Kaandorp [c], Julia Fritz [a], Karl-Heinz Südekum [b,*], Jürgen Hummel [b,d]

Comparative Biochemistry and Physiology, Part A 179 (2015) 182–191



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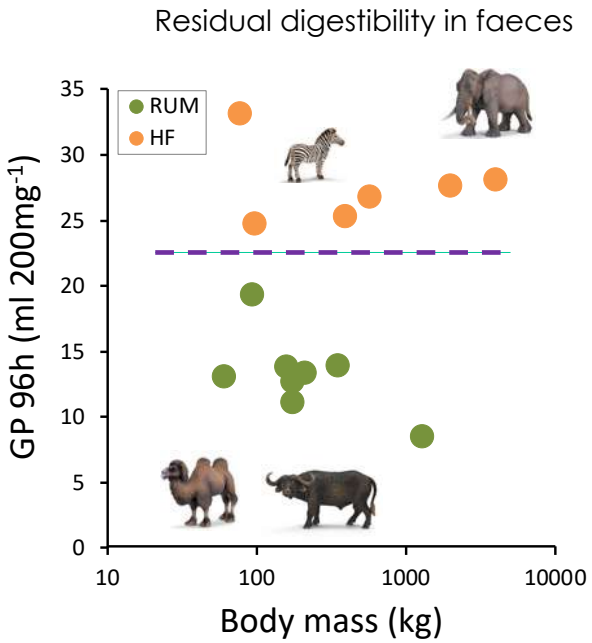

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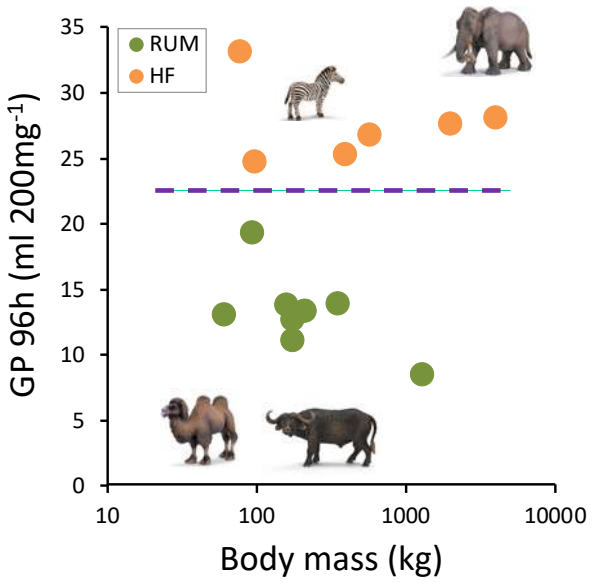
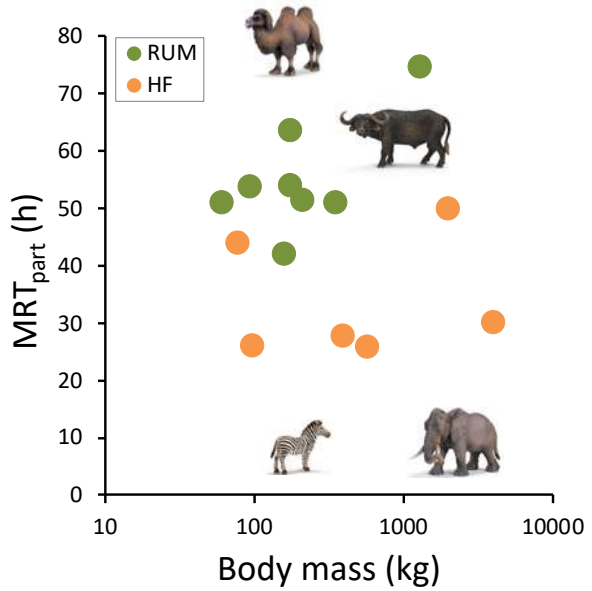
Residual digestibility in faeces



Digesta retention



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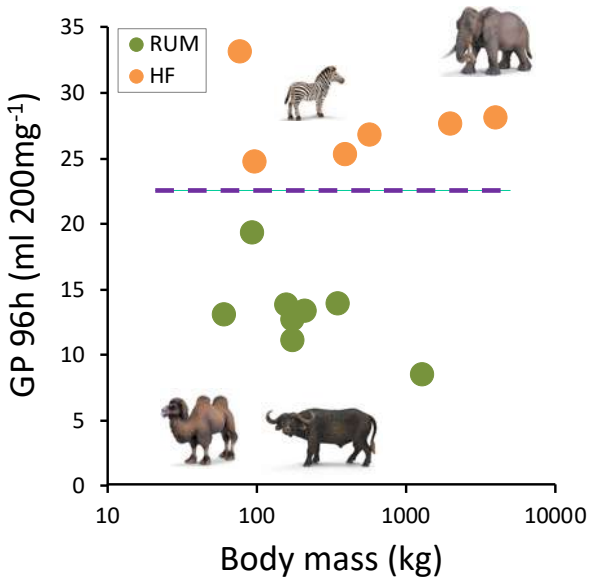

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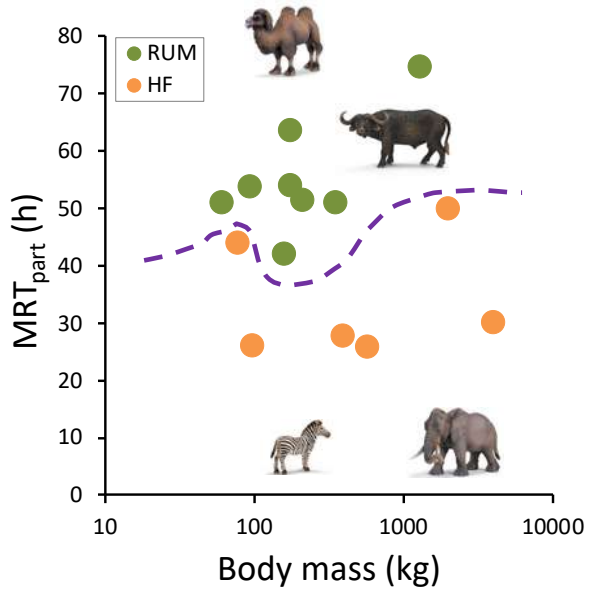

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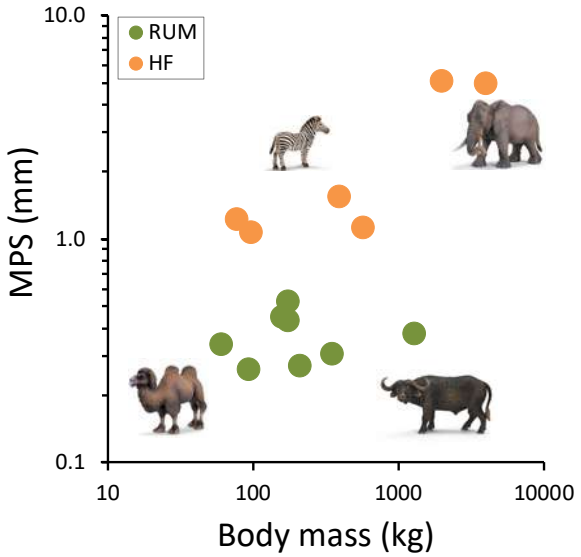

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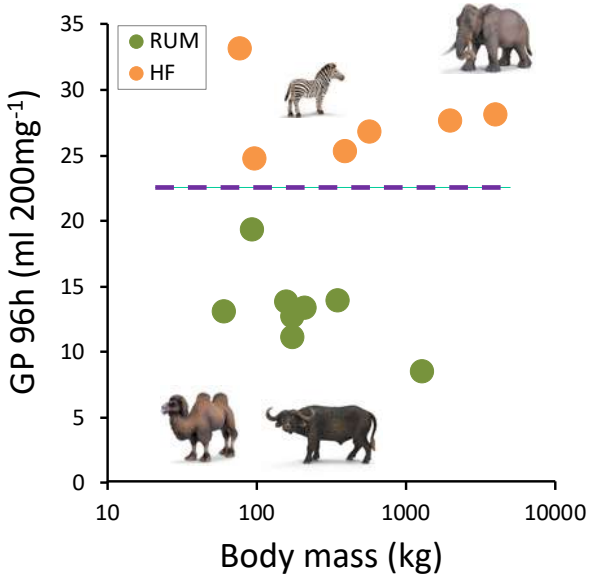

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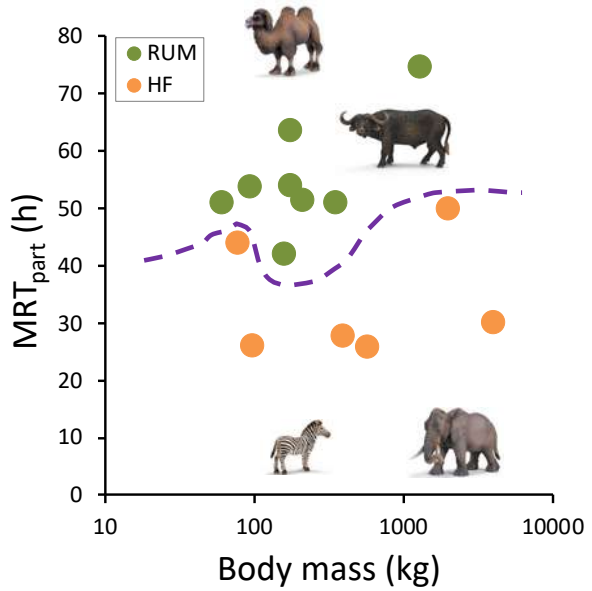

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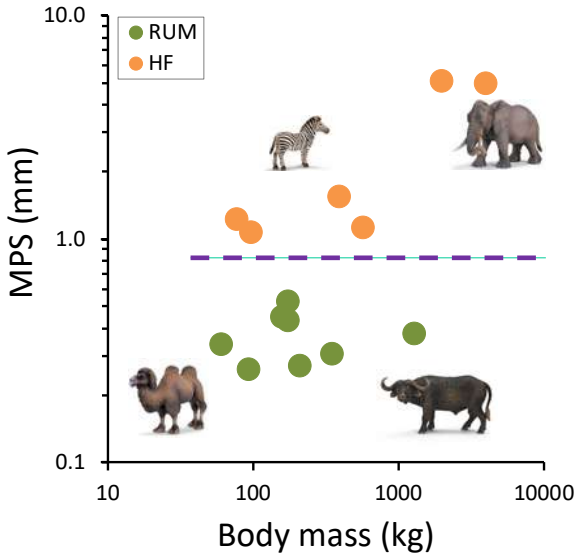

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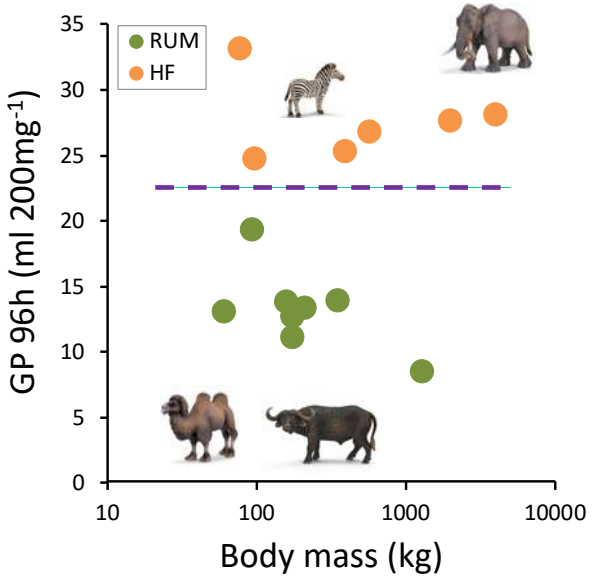

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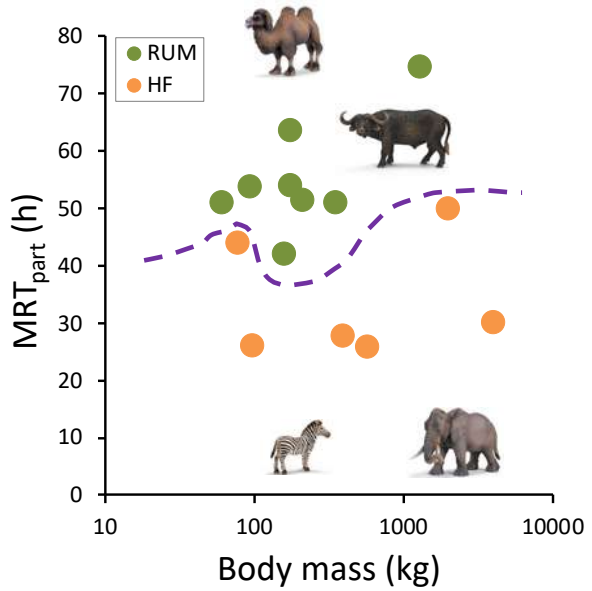

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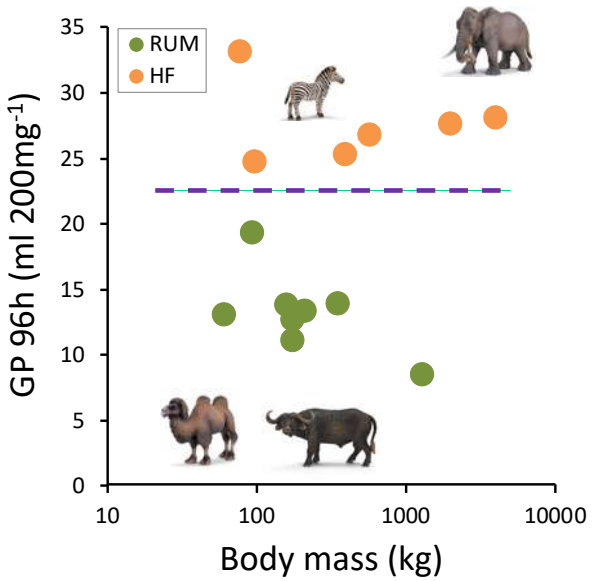
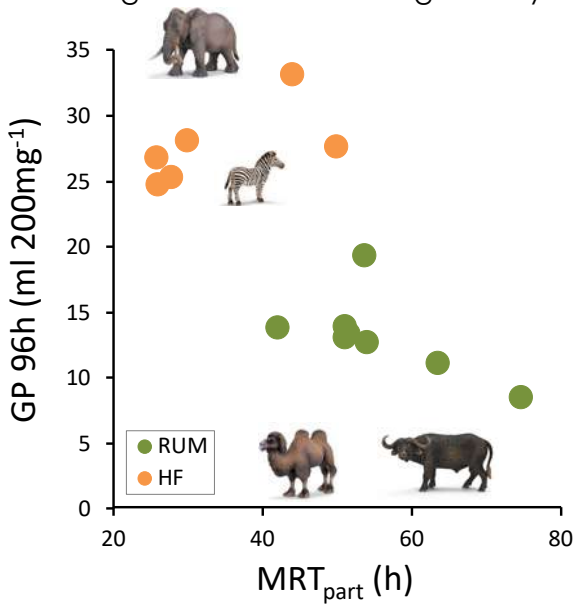


Digesta retention vs. digestibility



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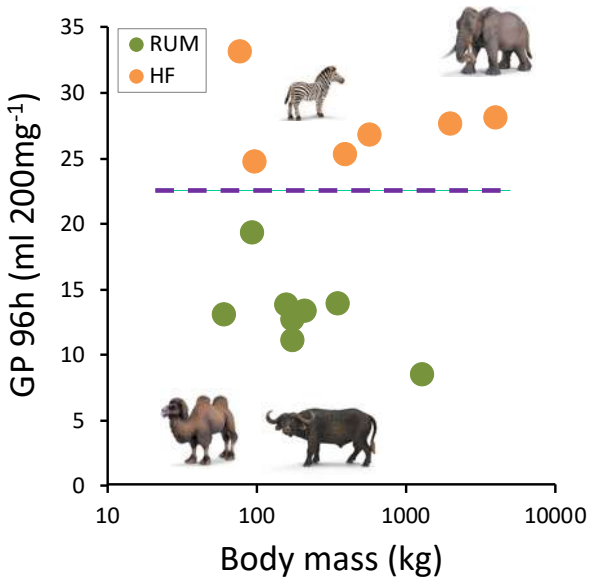

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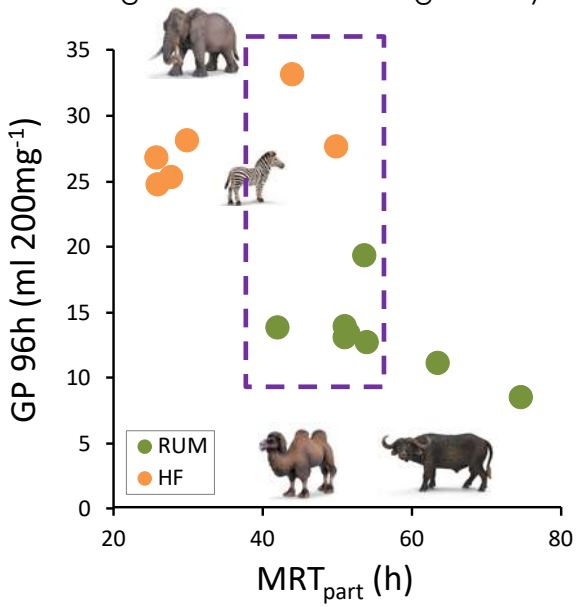

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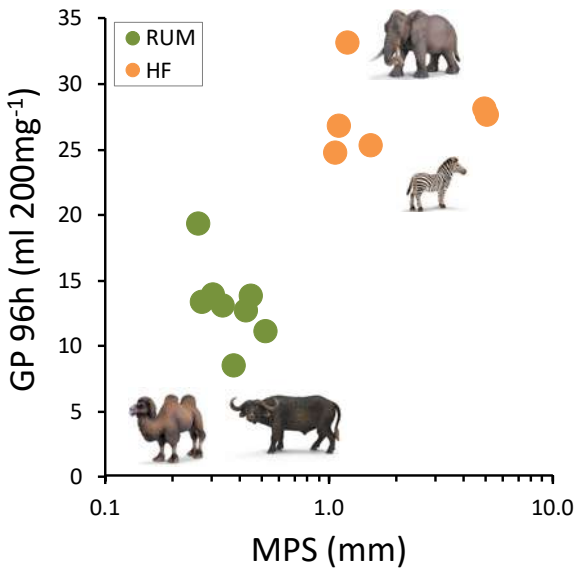
Faecal particle size vs digestibility



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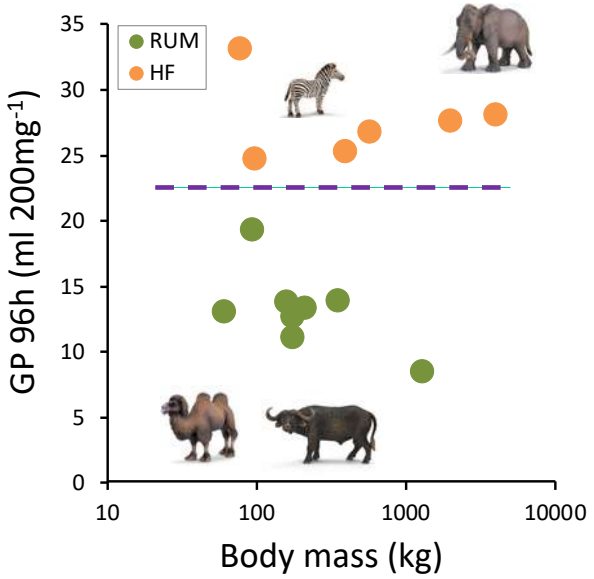
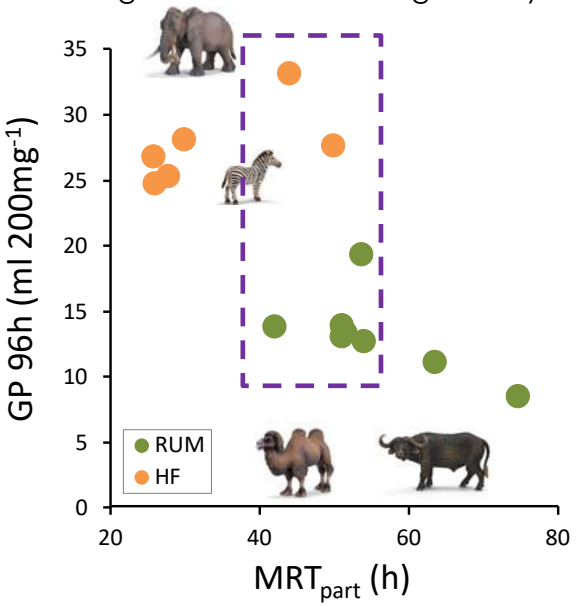


Digesta retention vs. digestibility



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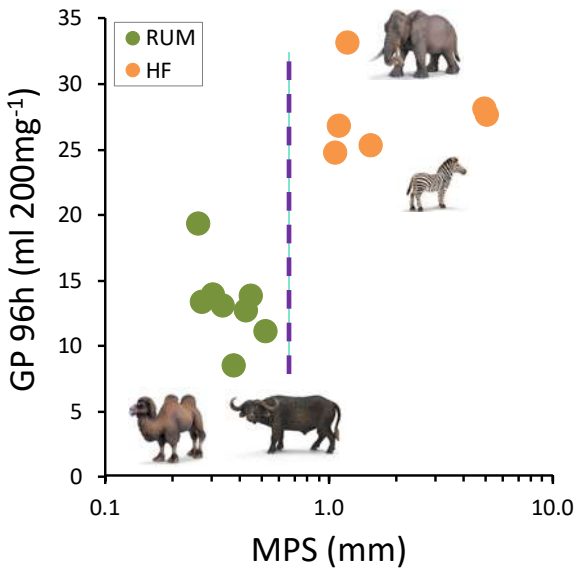

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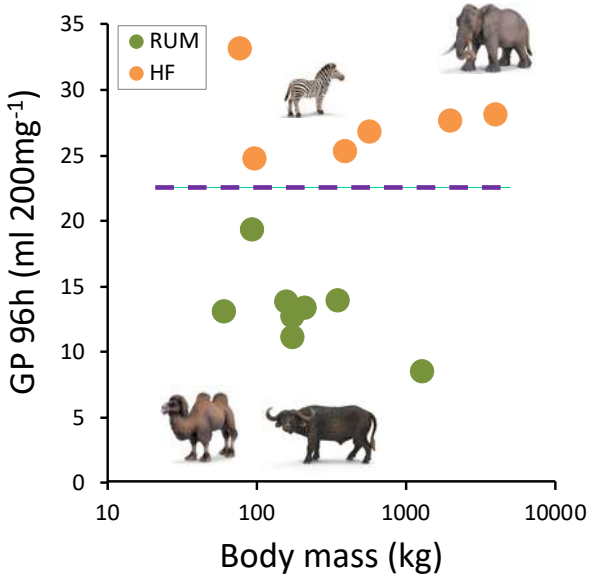

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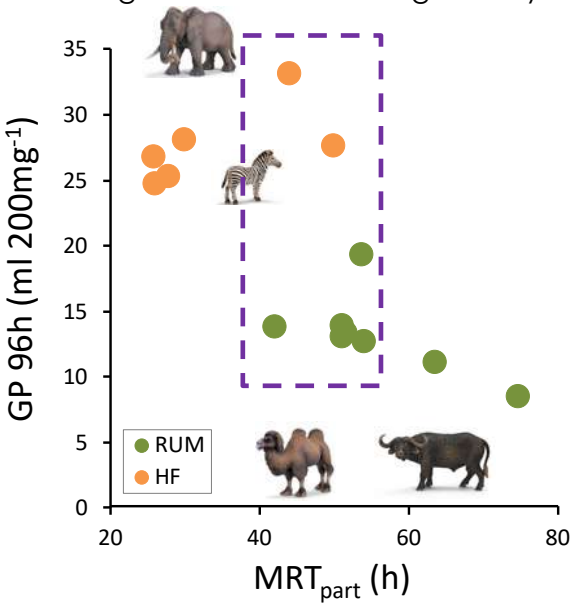

Faecal particle size: Digestive physiology meets herbivore diversity

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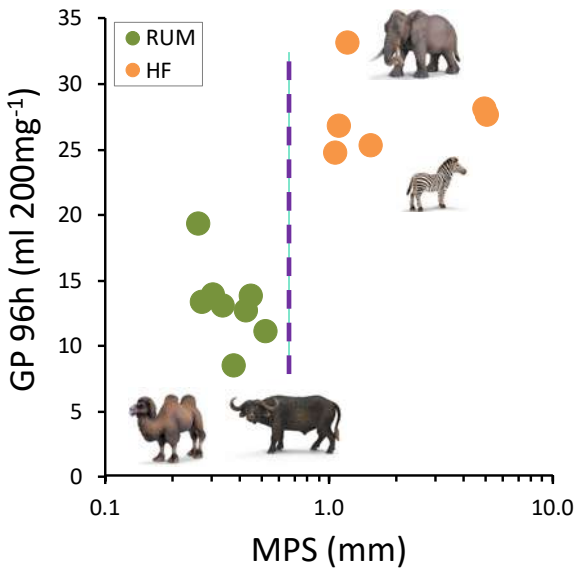

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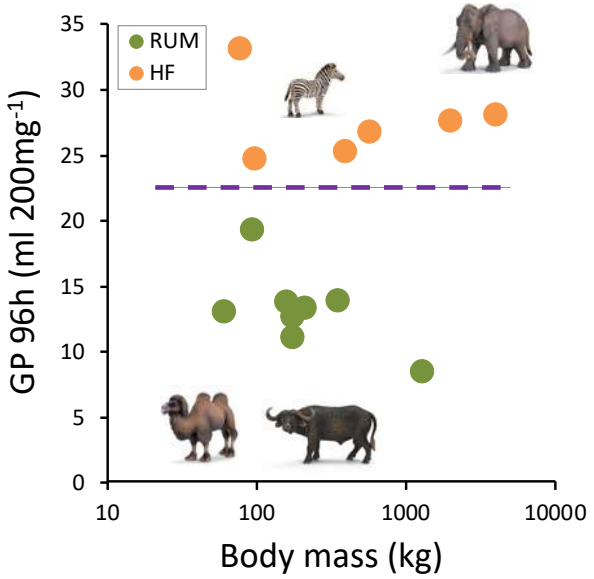

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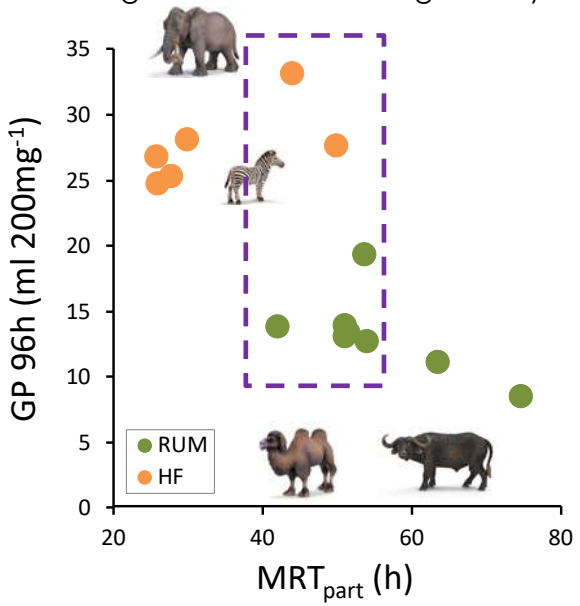


Parallel evolution

among

Perissodactyls

Artiodactyls

Parallel evolution

Perissodactyls

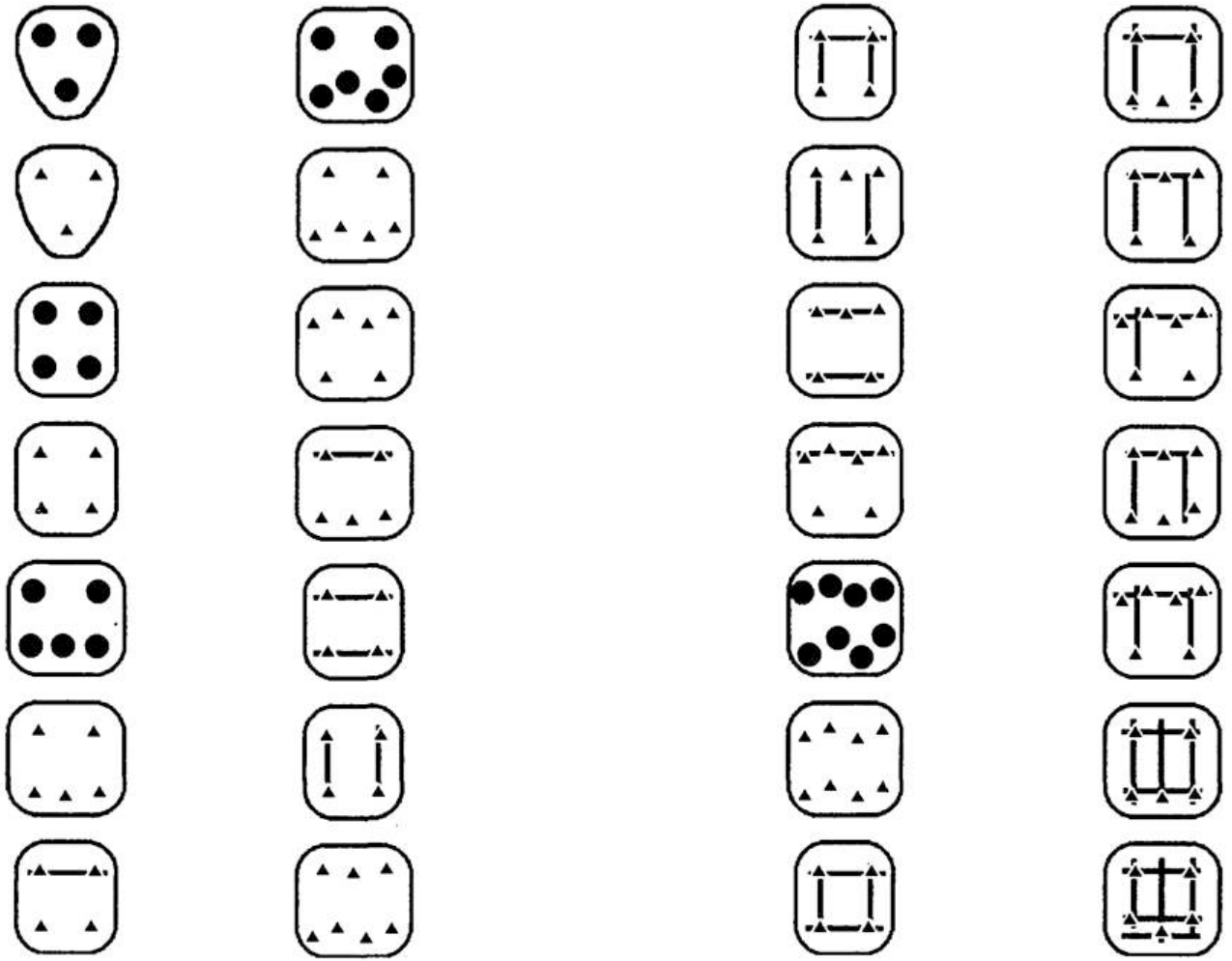
among

Artiodactyls

Equids

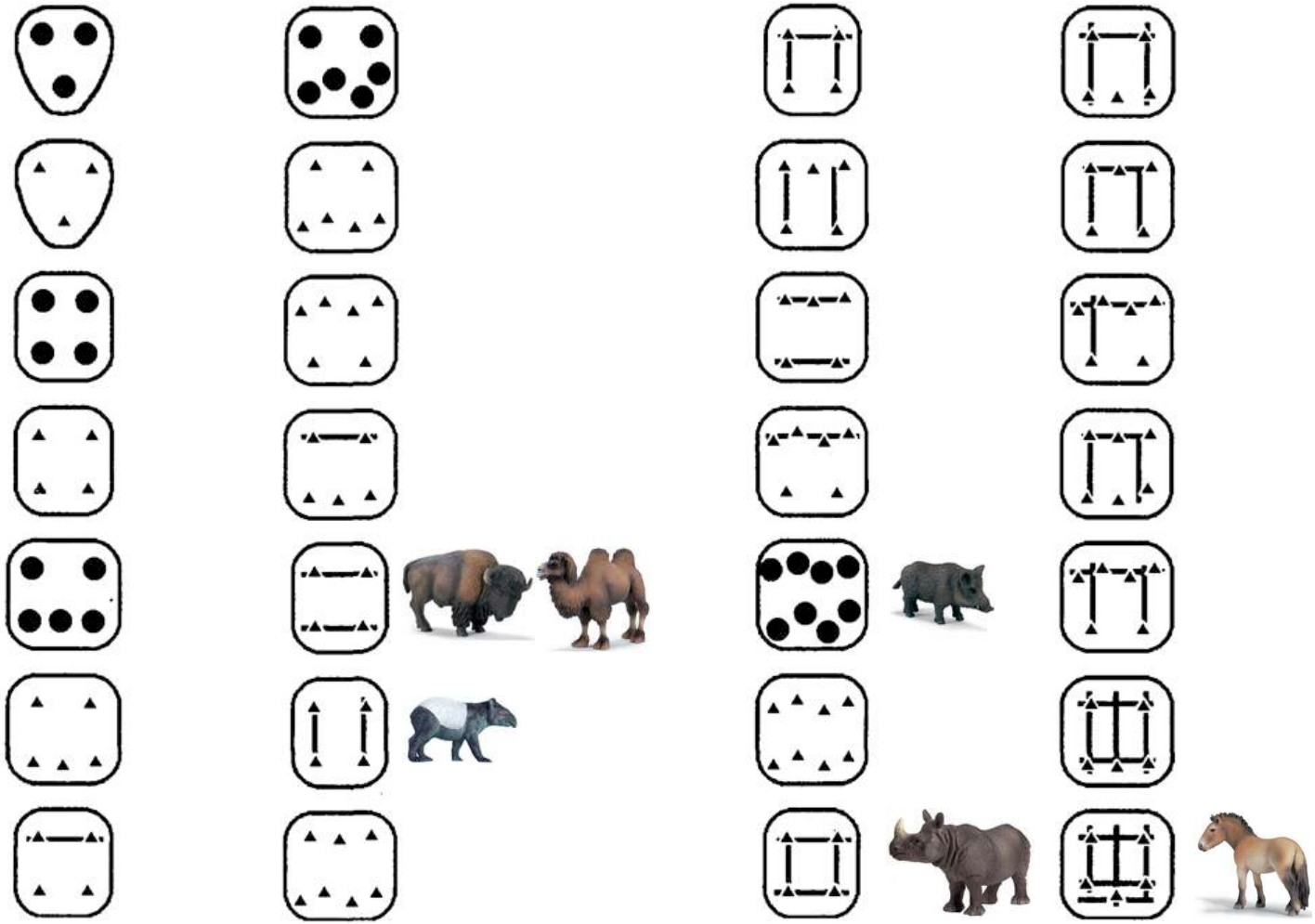
achieve
comparatively high
chewing efficiencies
and food intakes

Large mammal molar surfaces



from Jernvall et al. (1996)

Large mammal molar surfaces



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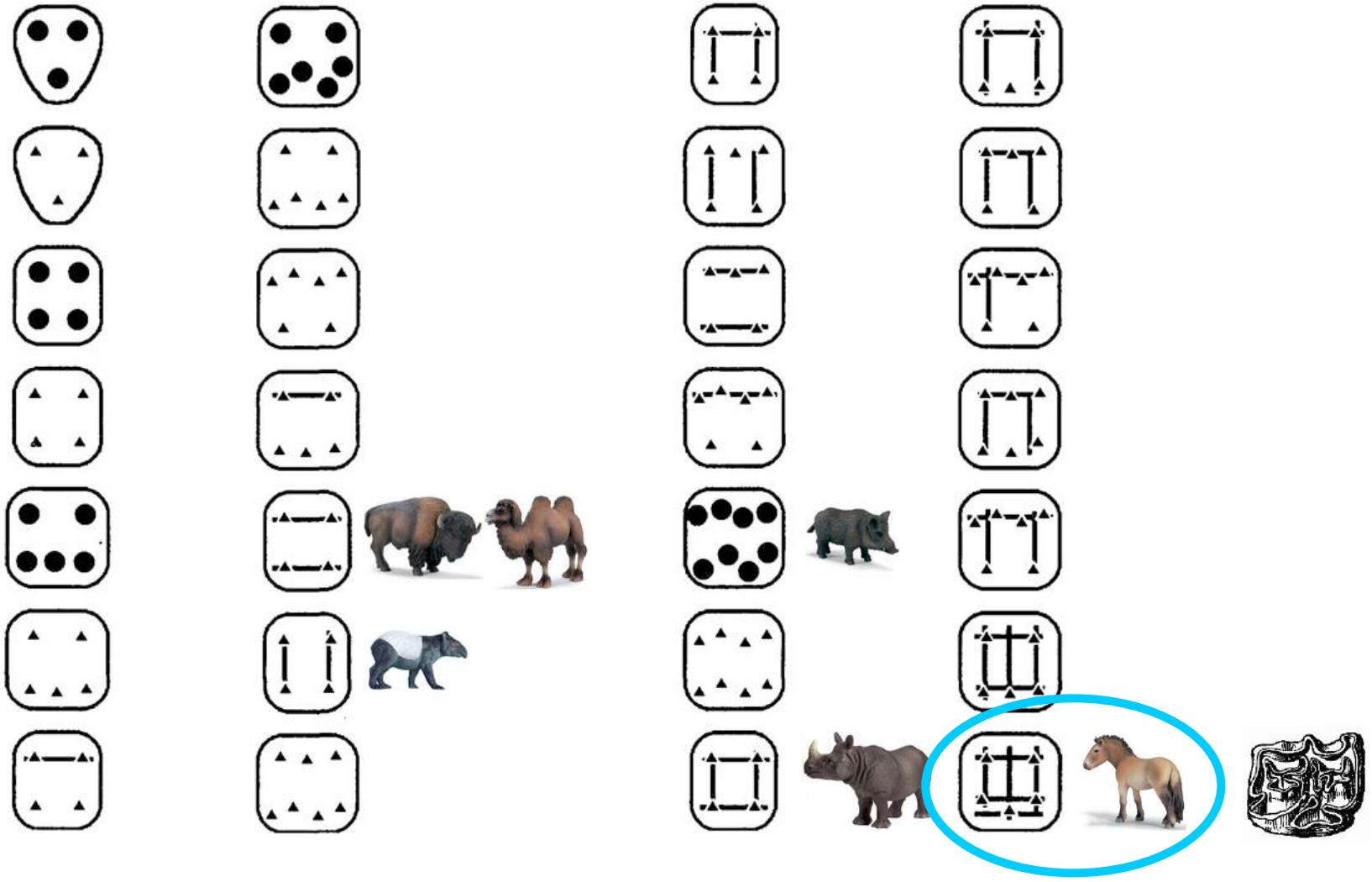

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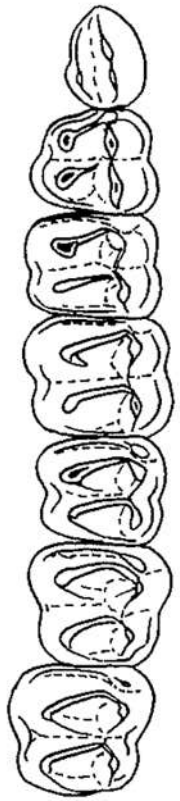
Equids: masters of complex enamel folding

https://www.sciencedaily.com/releases/2011/04/110404151341.htm

Parallel evolution



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Artiodactyls

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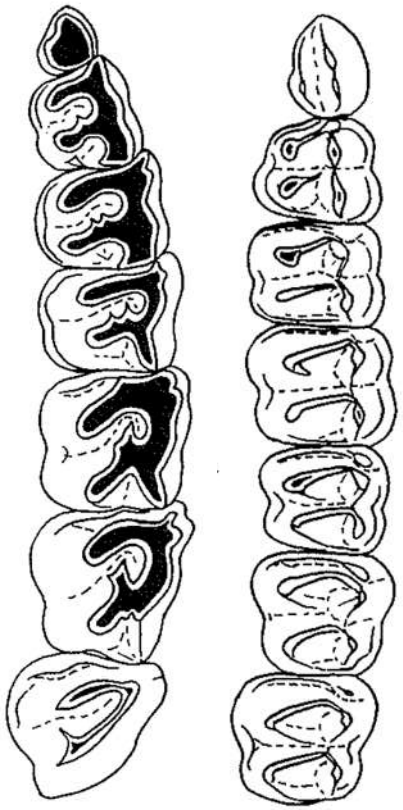
Parallel evolution



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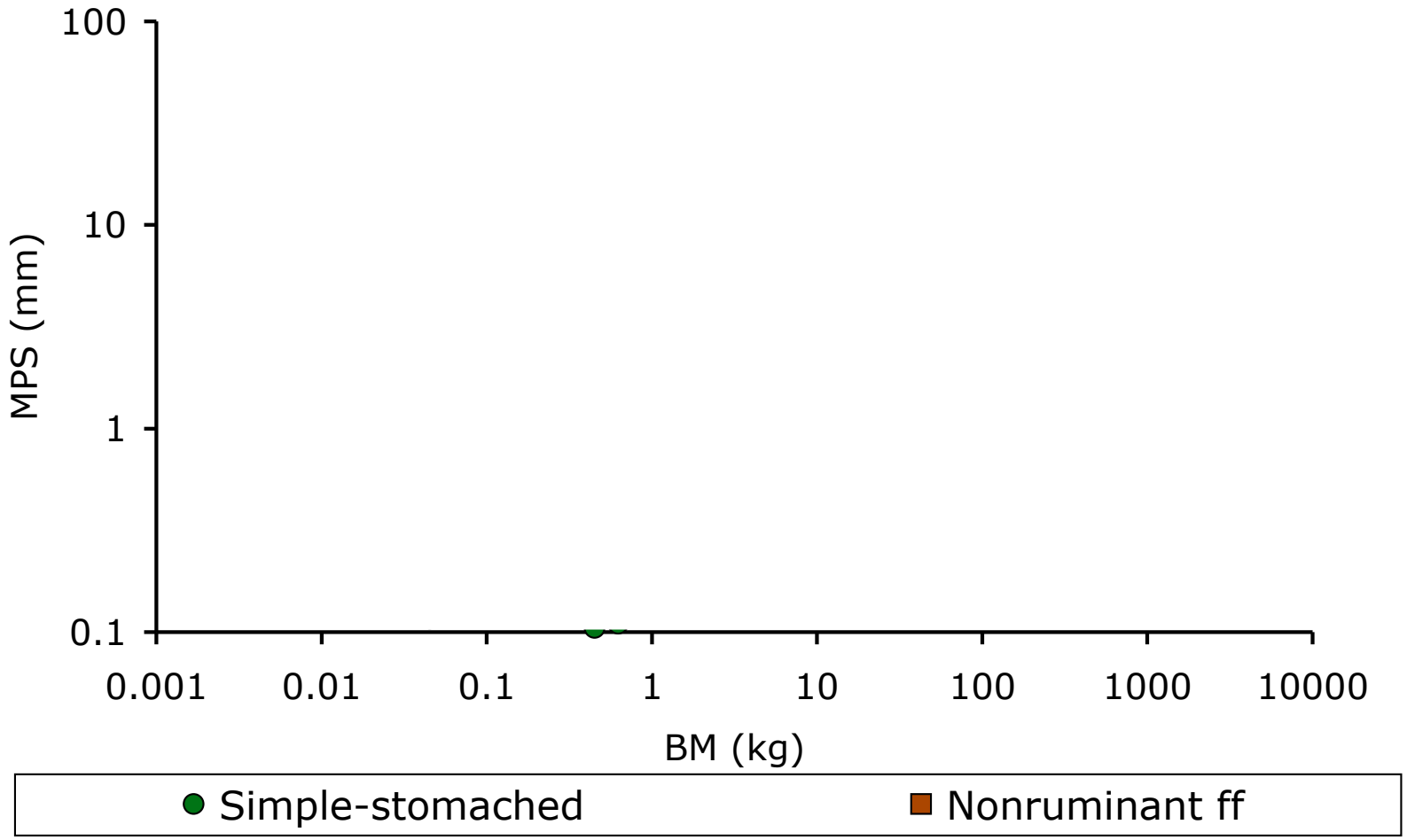

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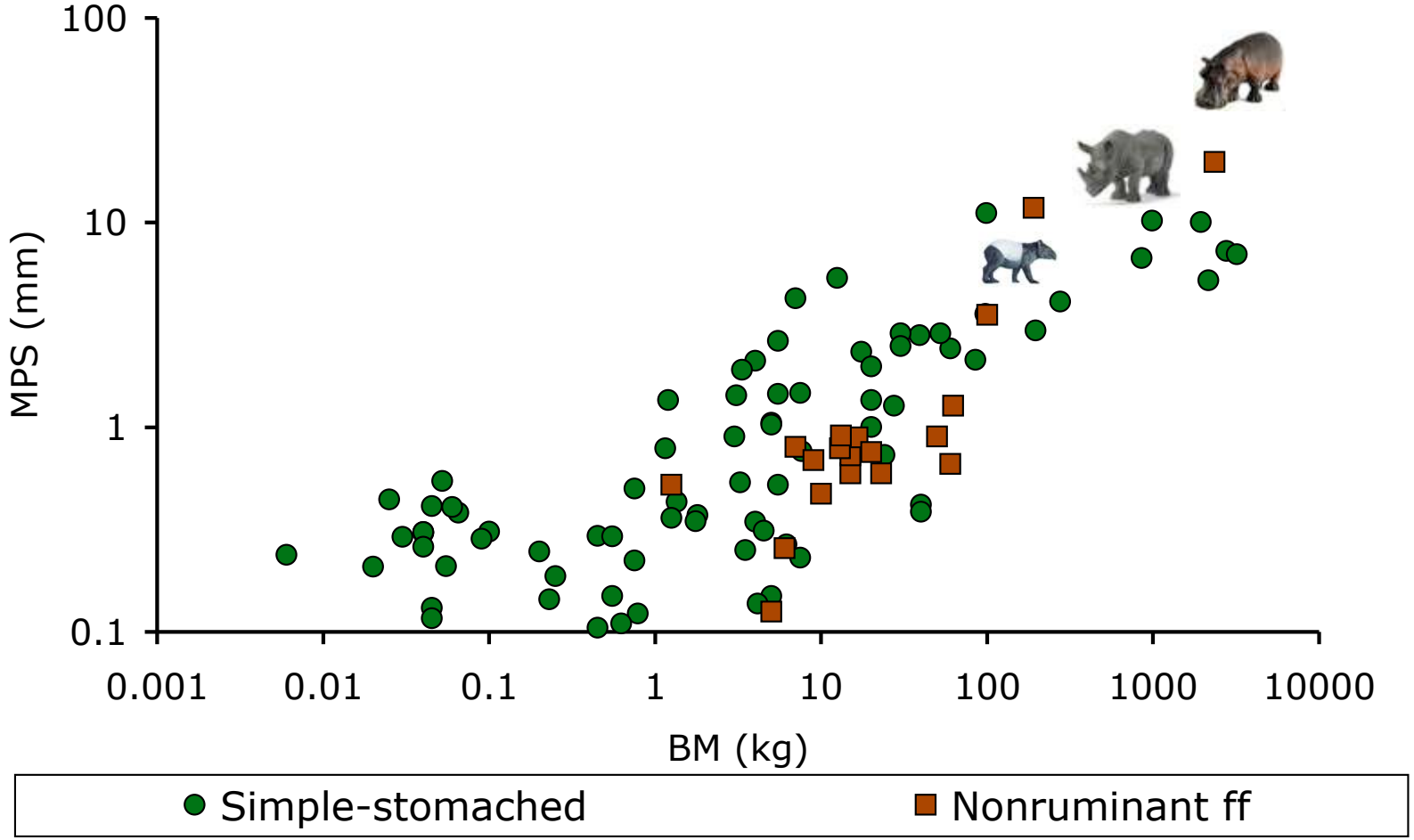

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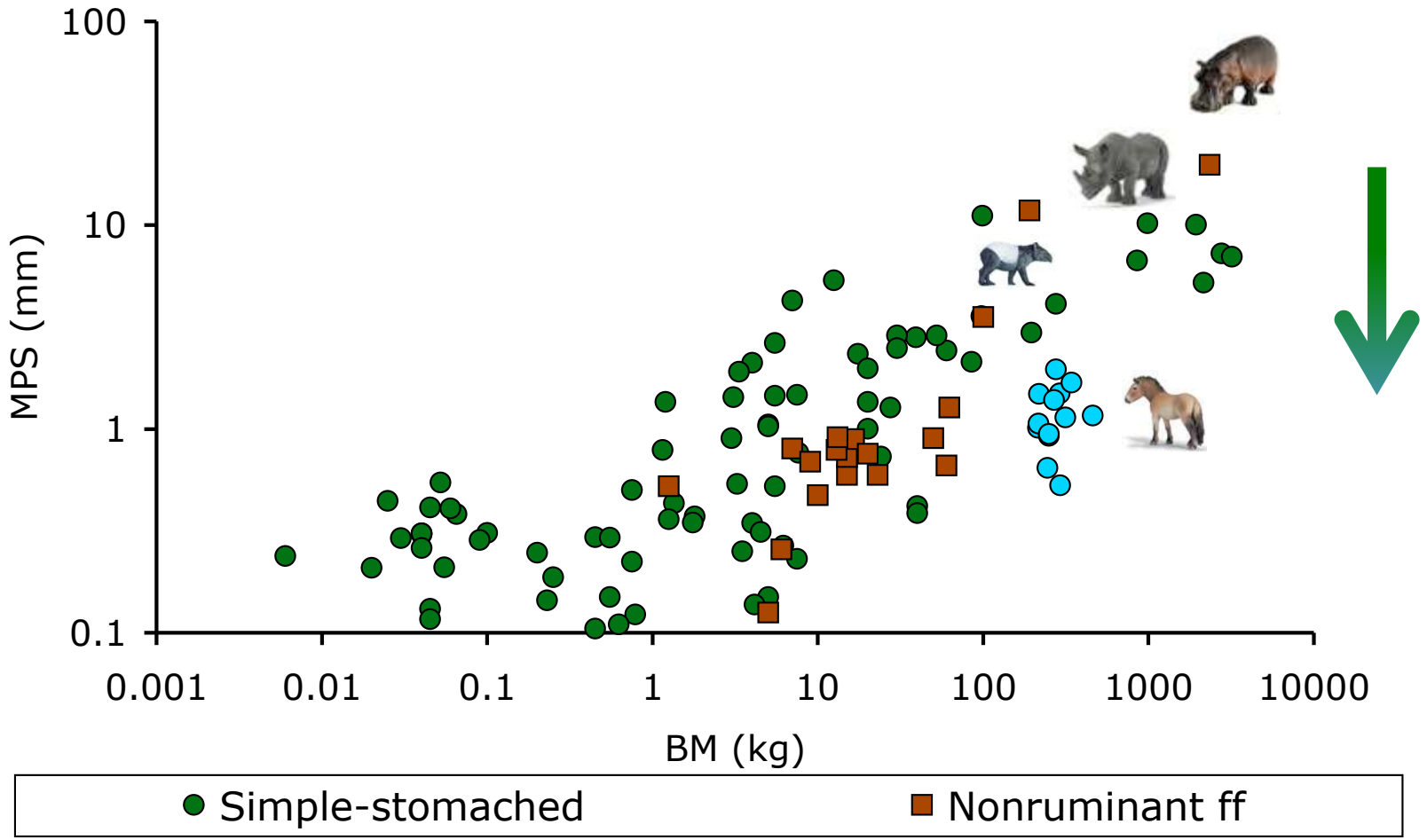

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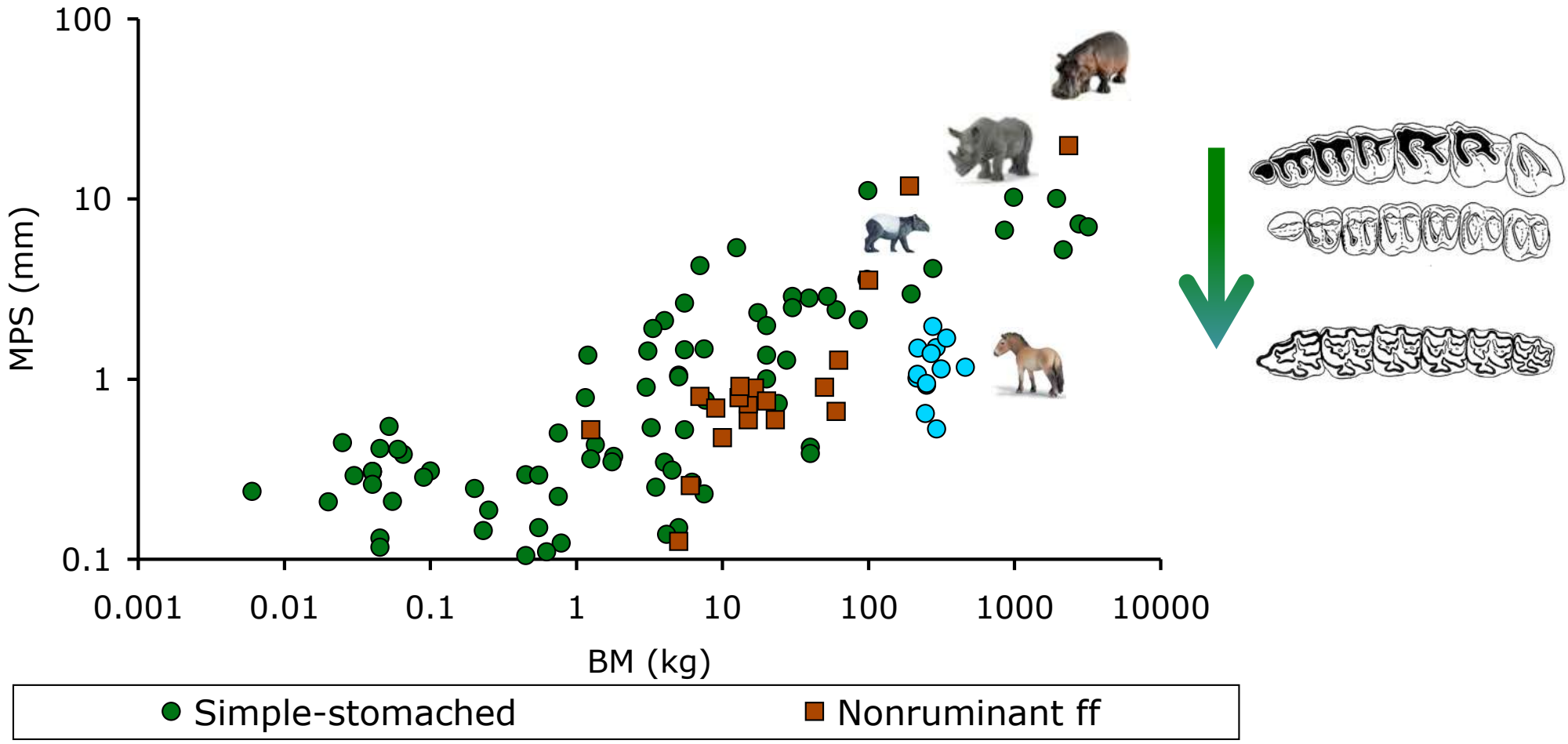

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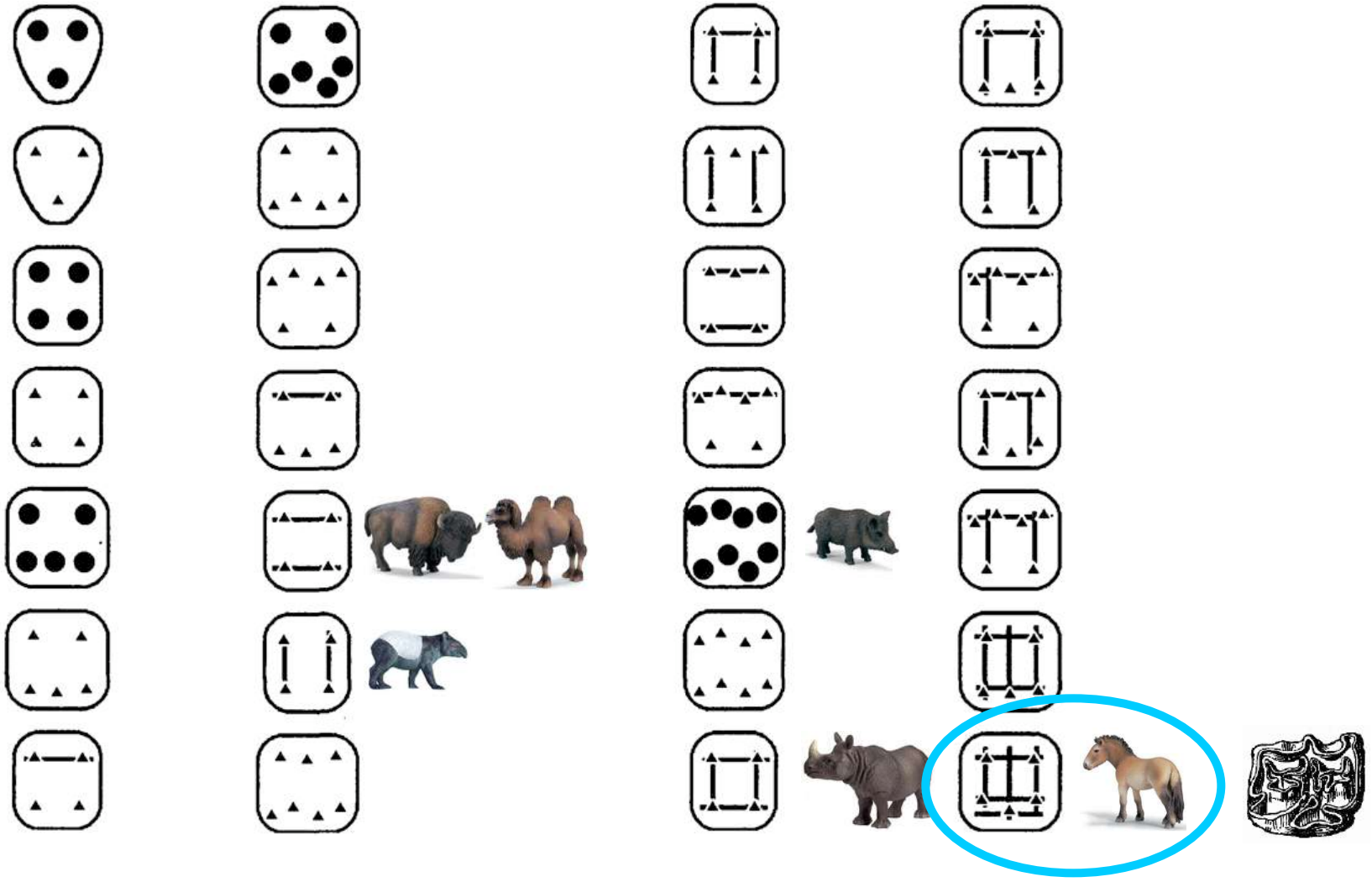

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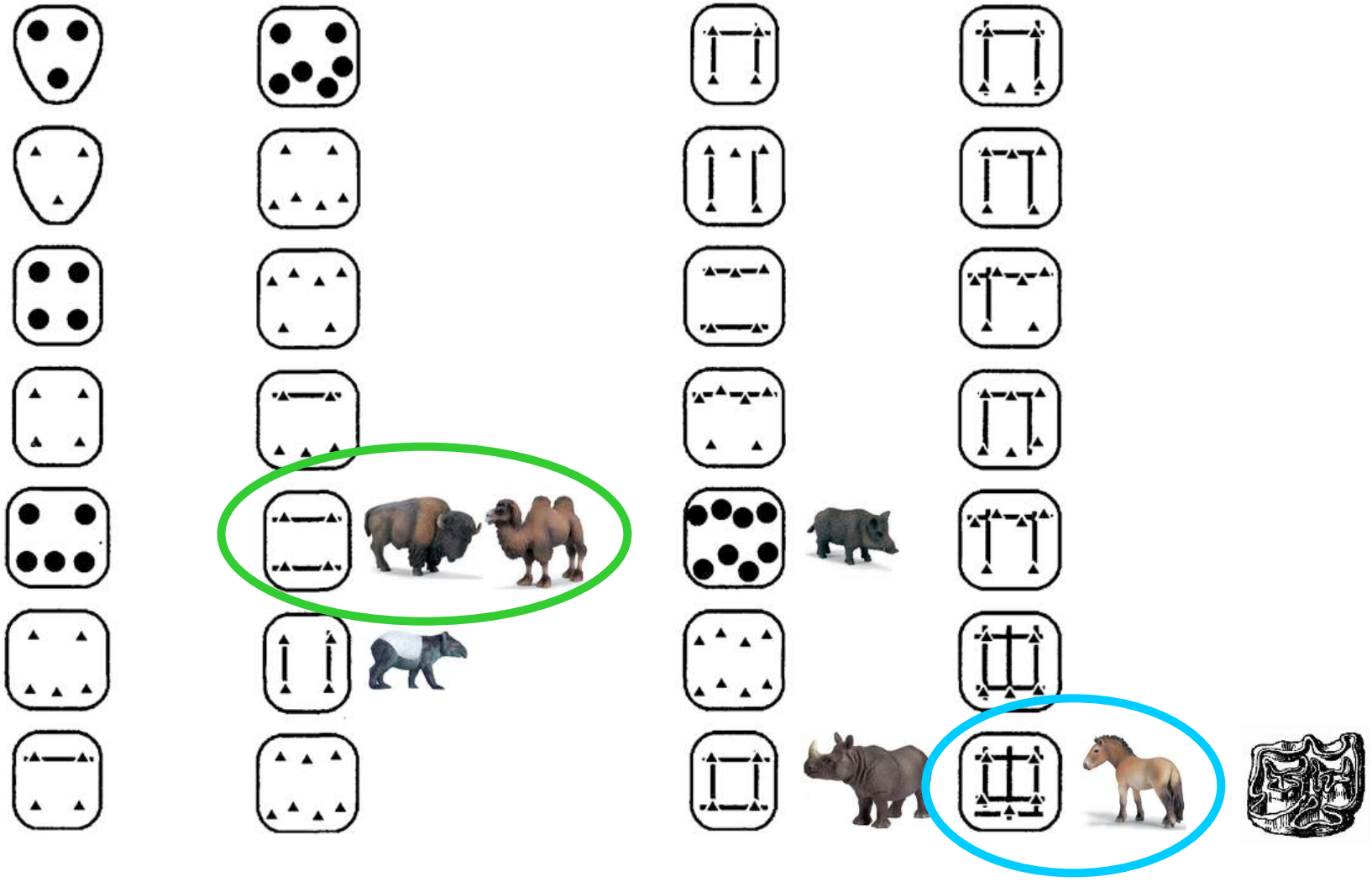

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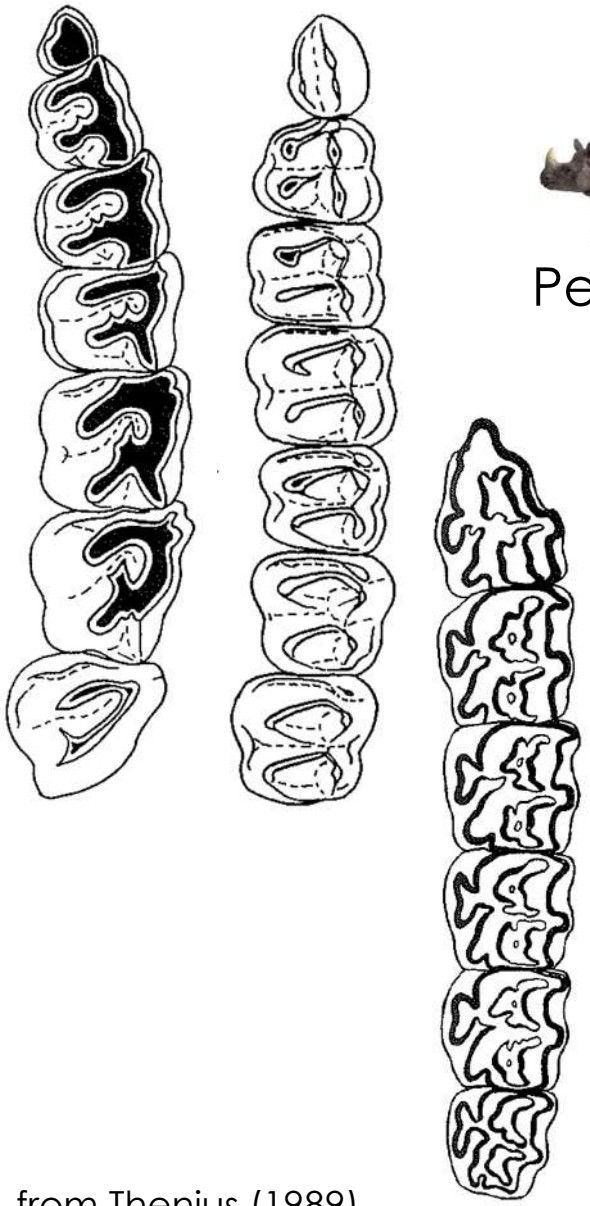

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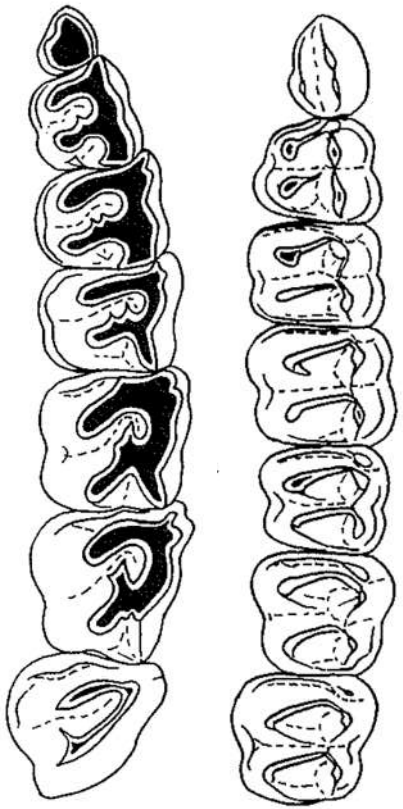

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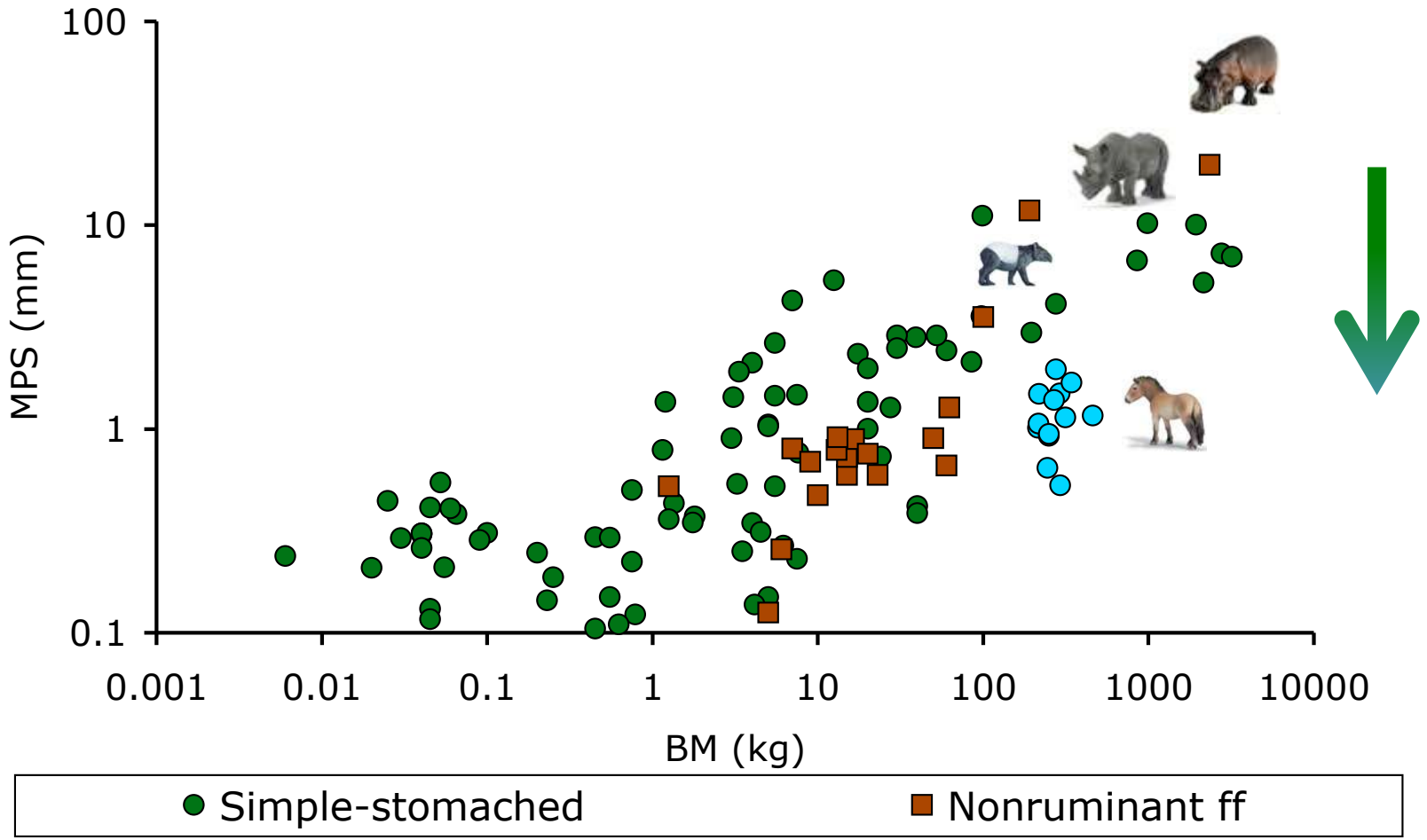

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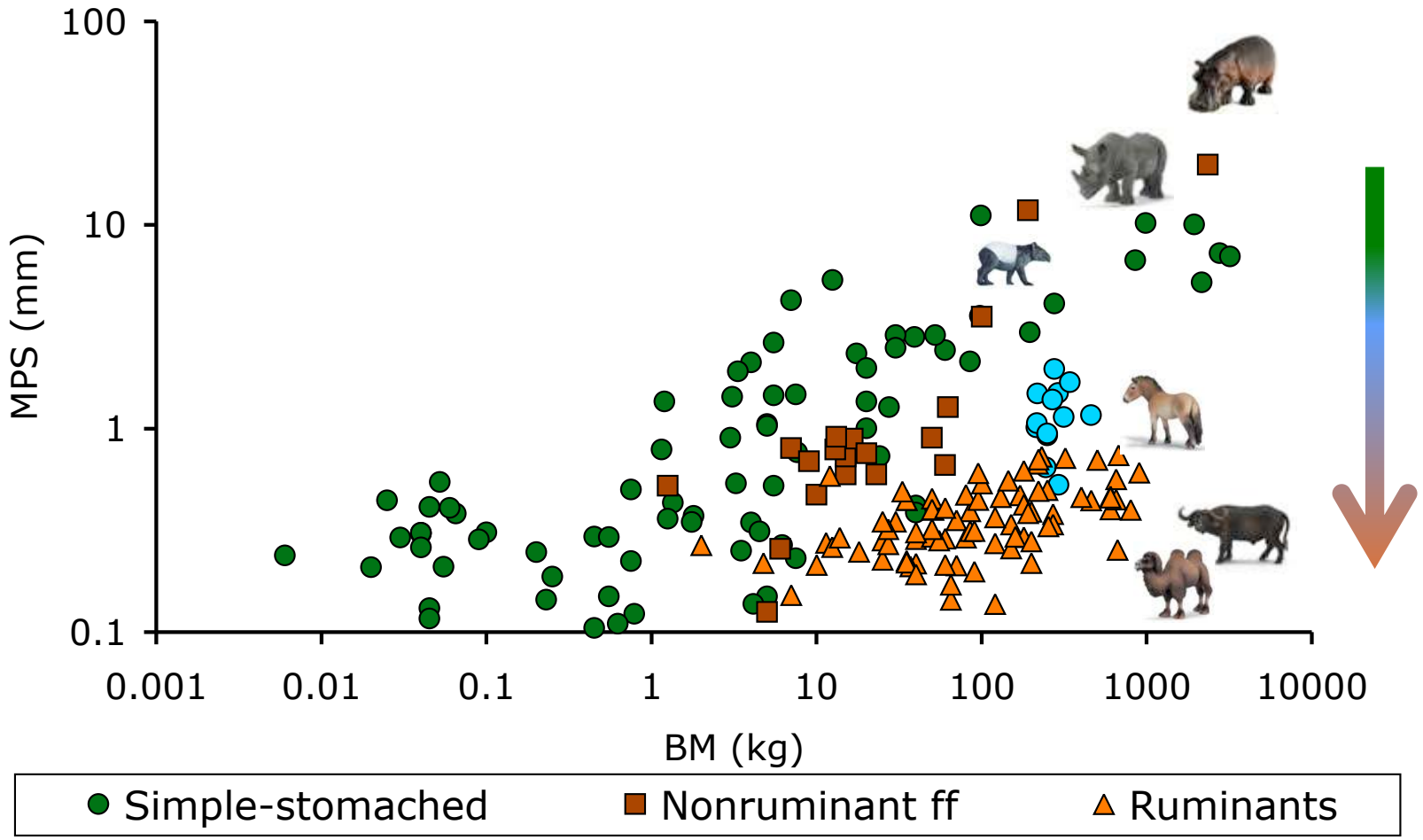

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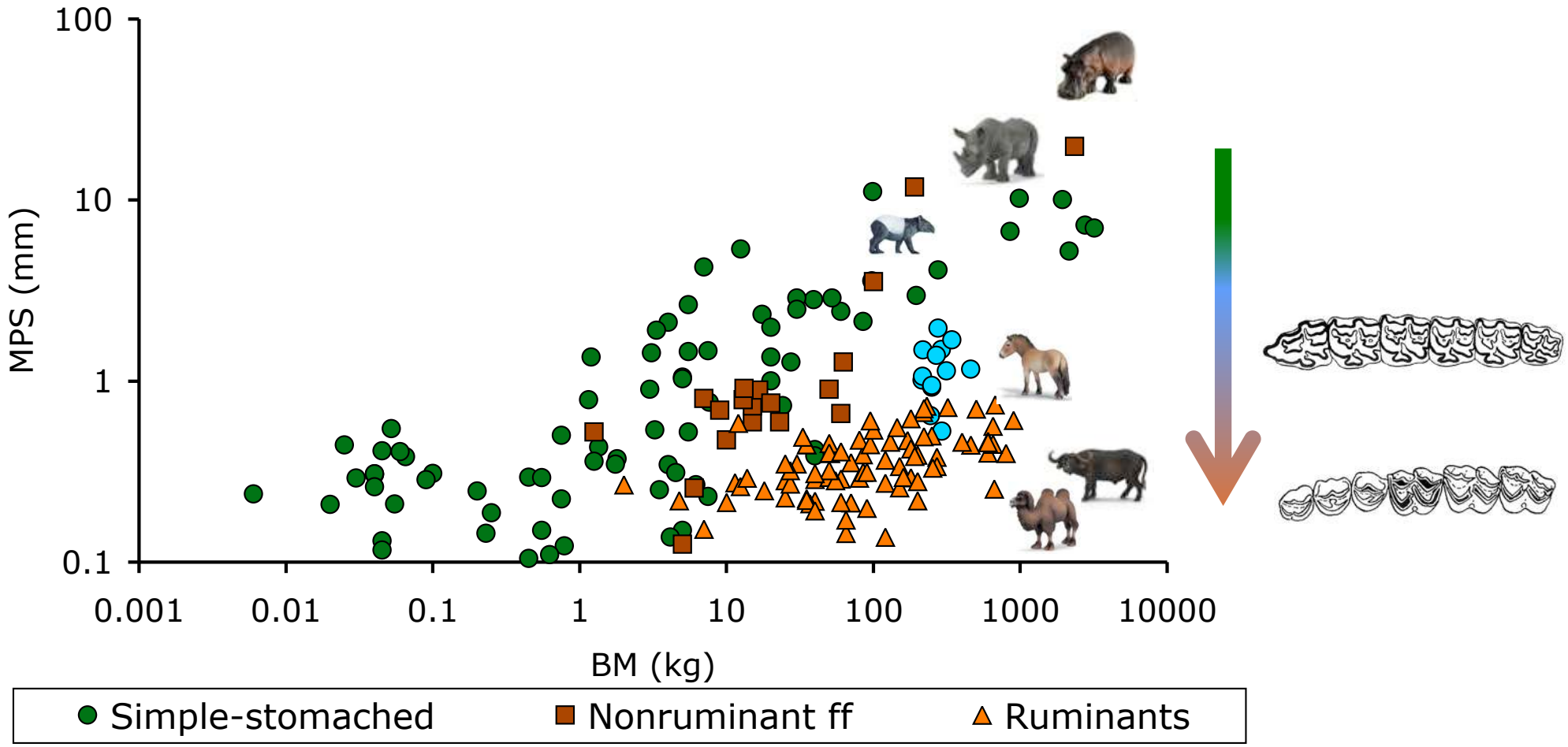

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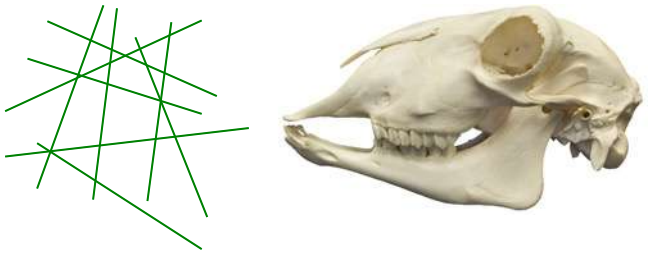

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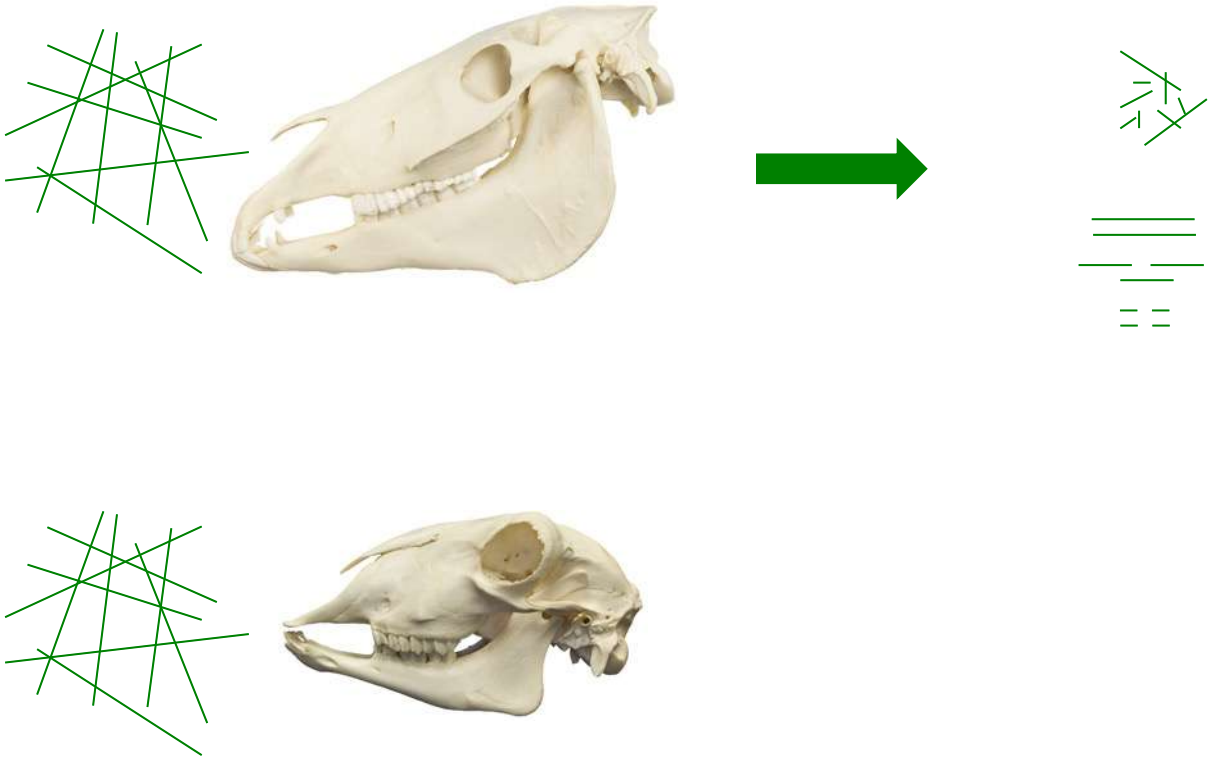

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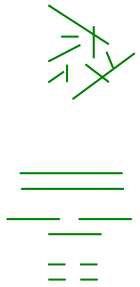

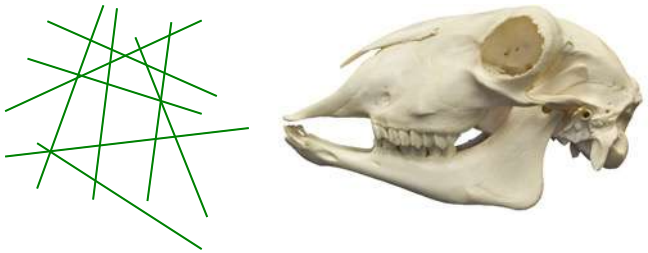

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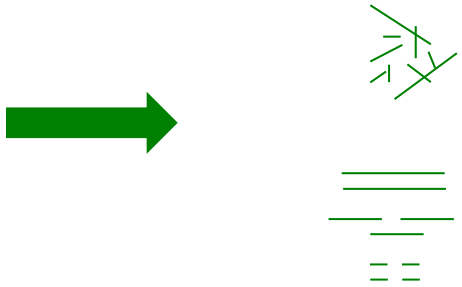

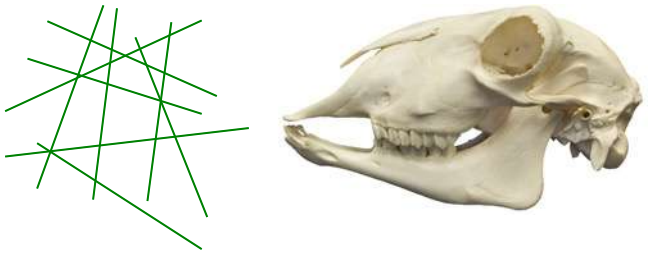

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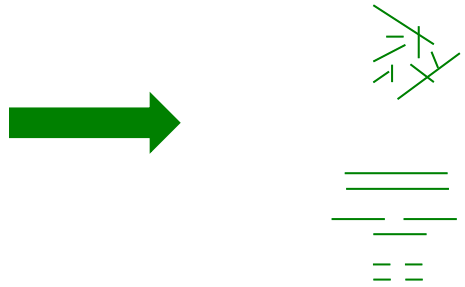

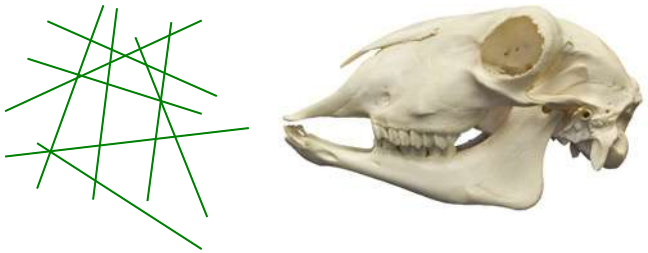

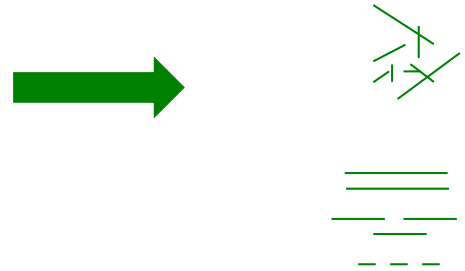

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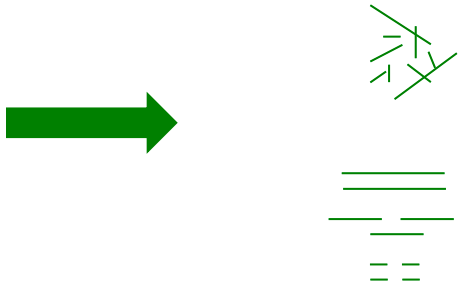

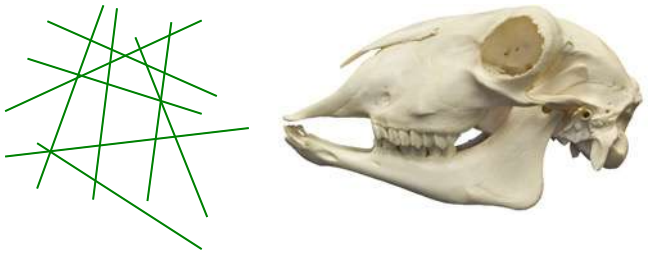

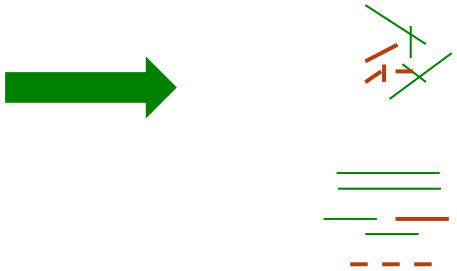

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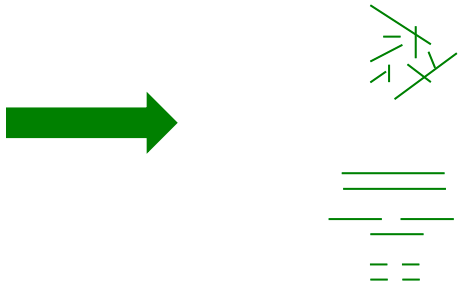

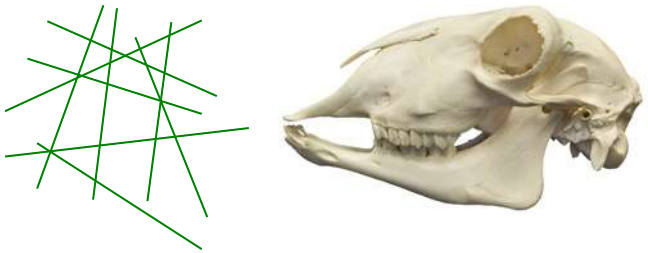

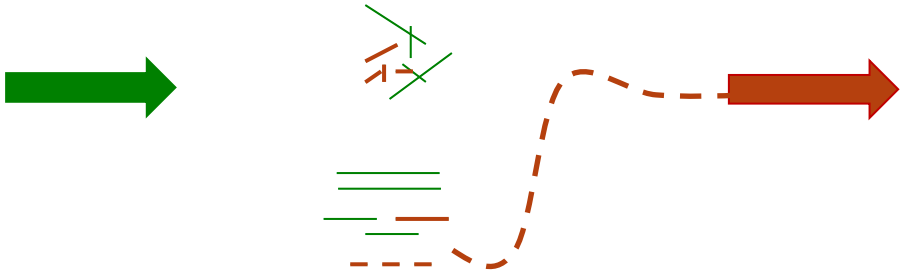

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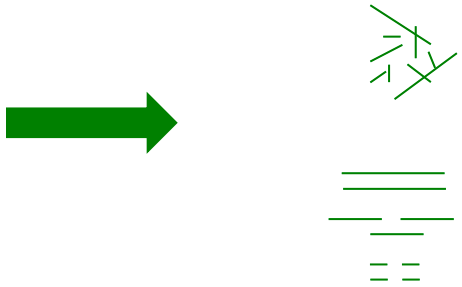

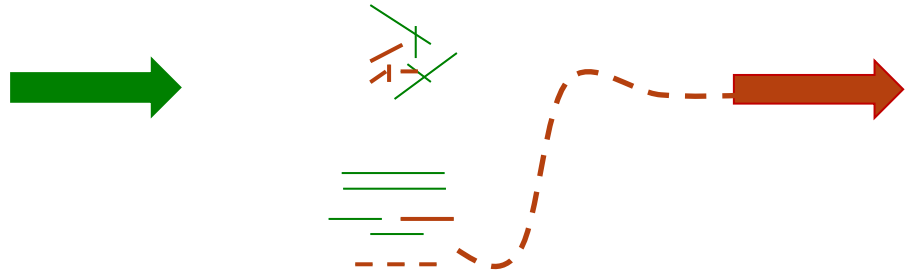

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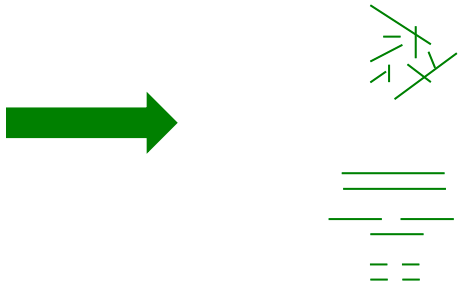

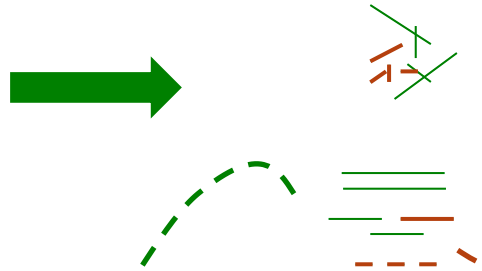

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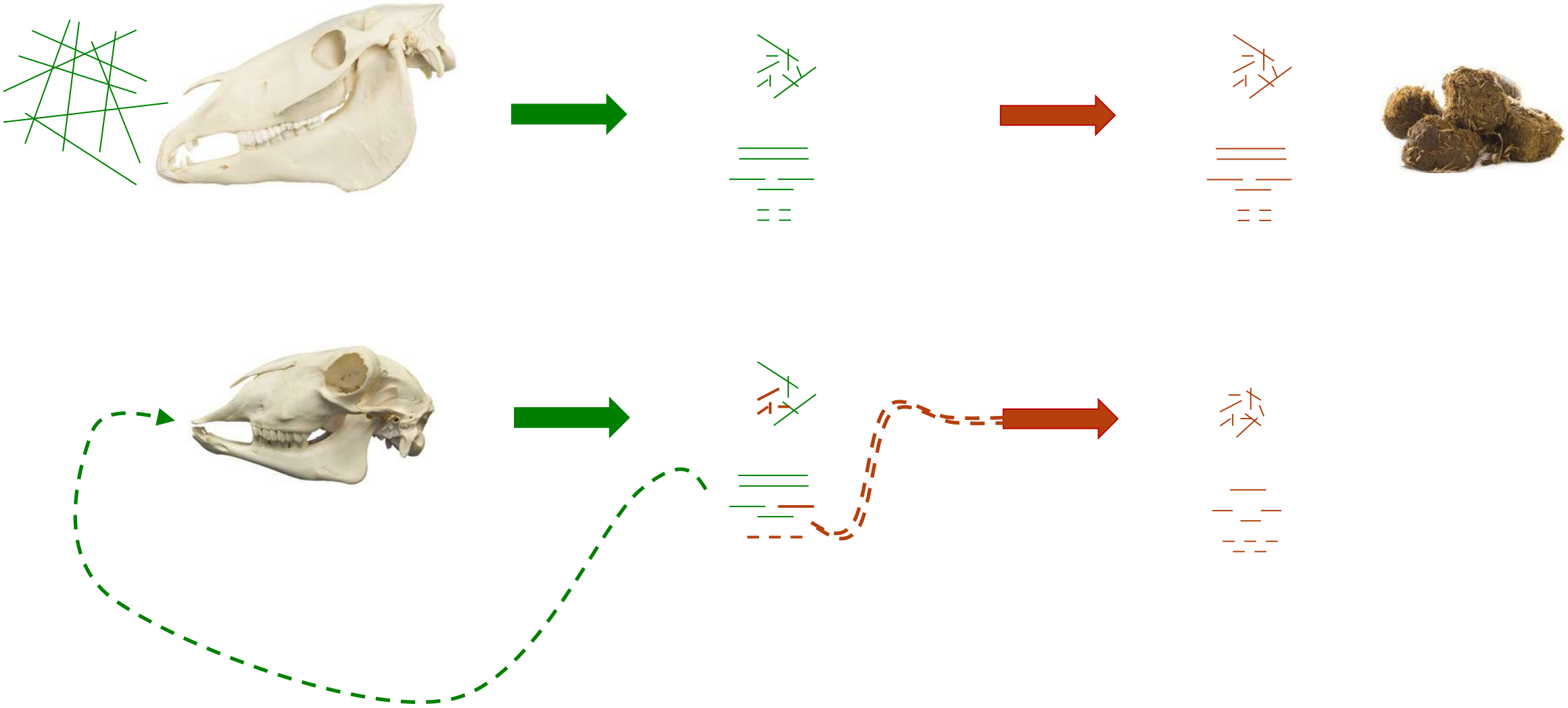

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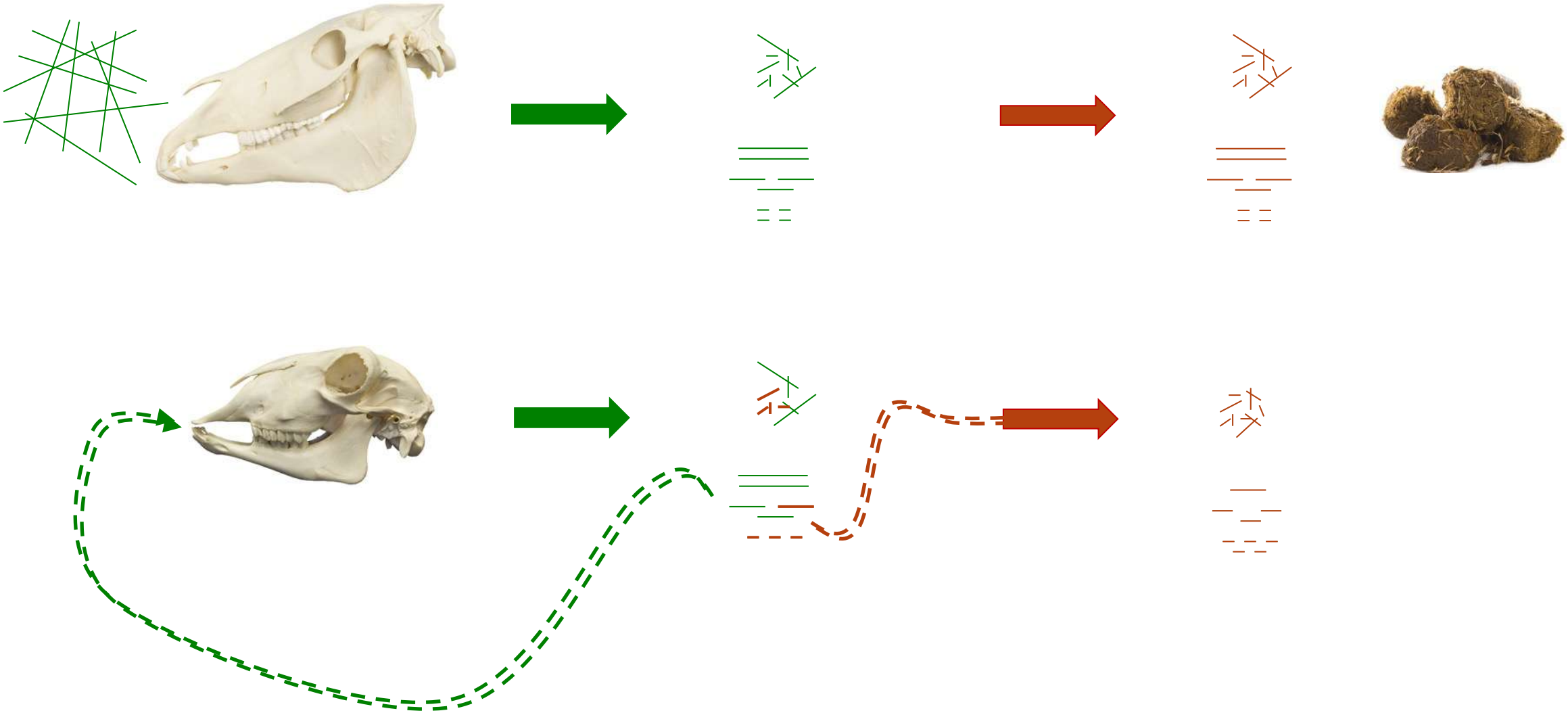

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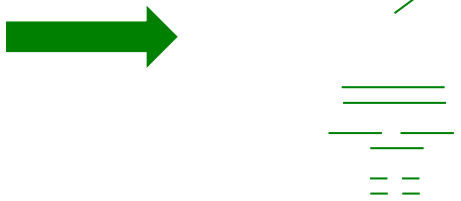

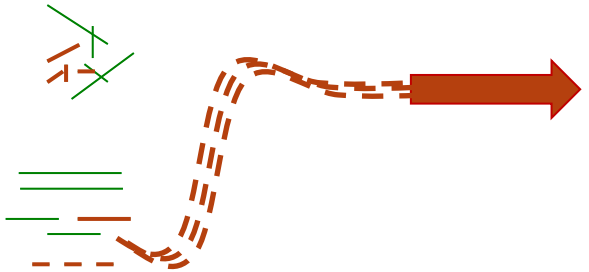

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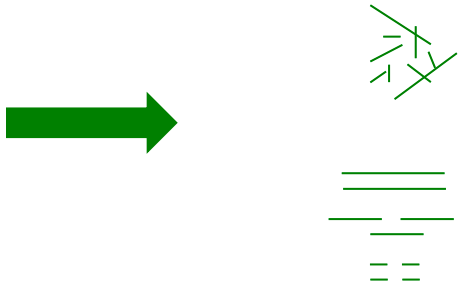

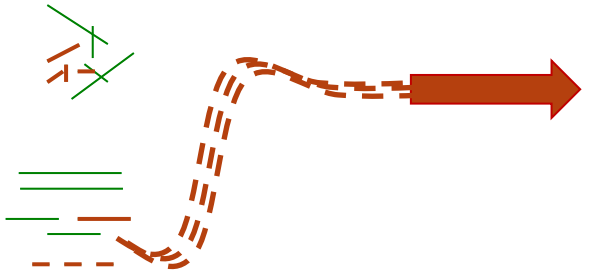

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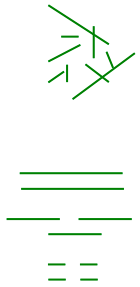
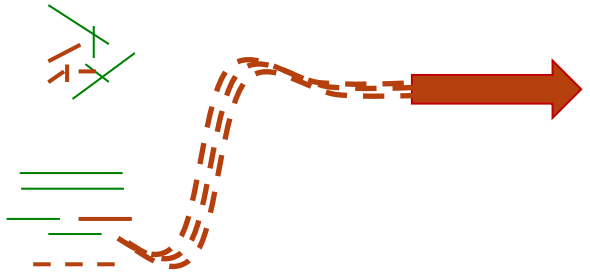
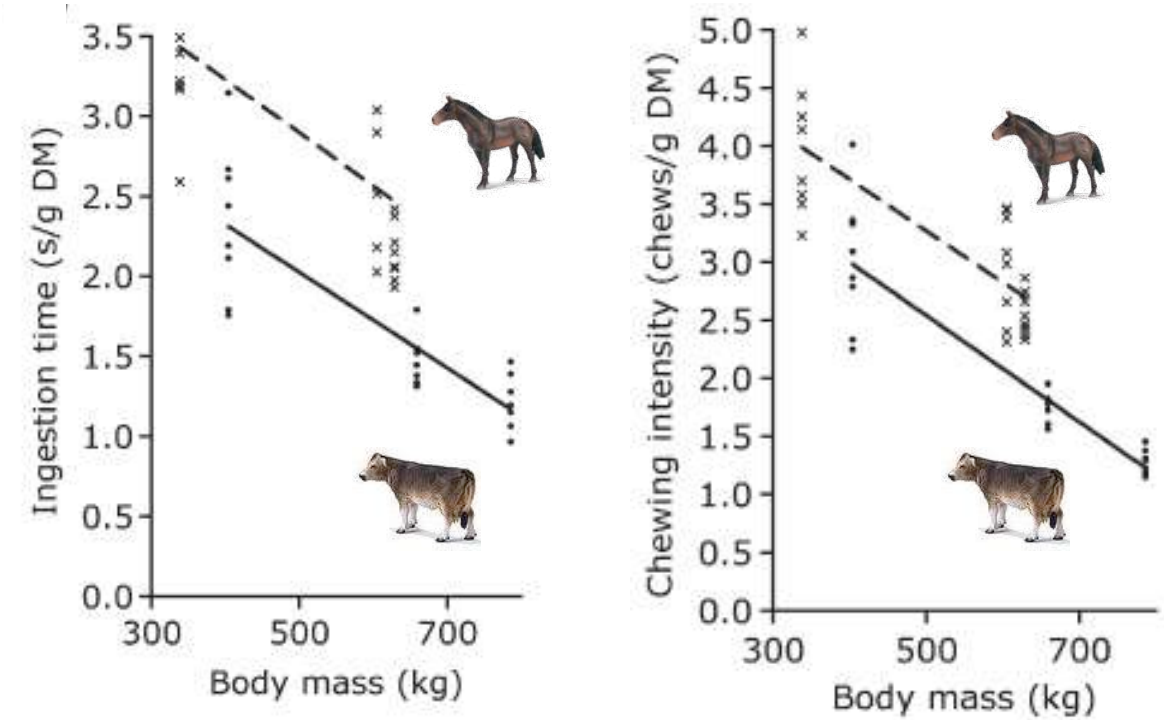




Comparative ingestive mastication in domestic horses and cattle: a pilot investigation

C. M. Janis[1], E. C. Constable[1,2], K. A. Houpt[3], W. J. Streich[4] and M. Clauss[5]

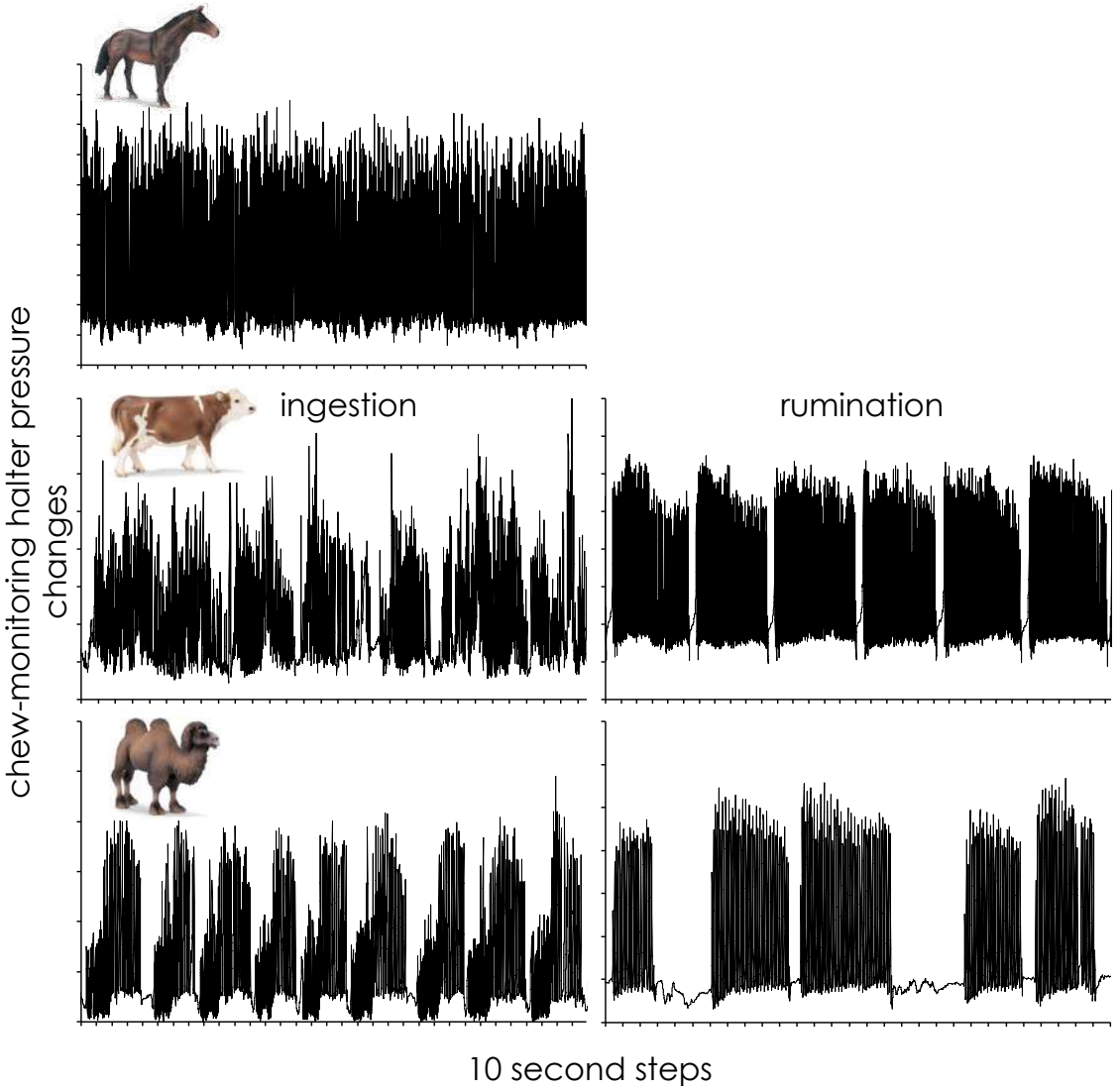
Journal of Animal Physiology and Animal Nutrition **94** (2010) e402–e409



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

J. Exp. Zool. 2017;327:98–109.

Marie T. Dittmann[1,2,3] | Michael Kreuzer[2] | Ullrich Runge[4] | Marcus Clauss[3]



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… but ruminants have evolved the more efficient system

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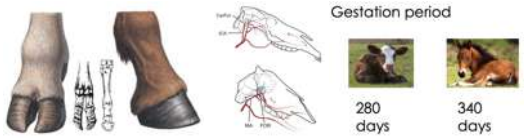

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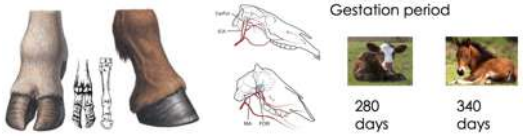

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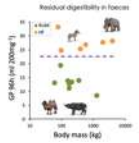

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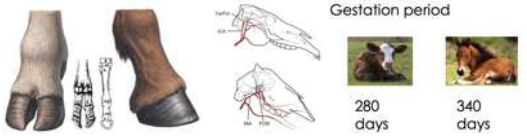

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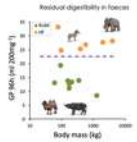
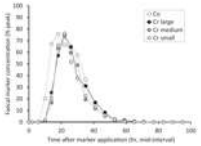


3. Equids do not have a proven tolerance for lower-quality forage and no size-discriminating retention mechanism



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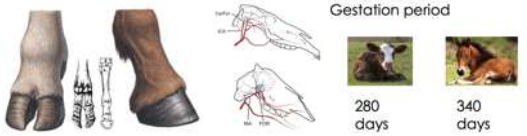

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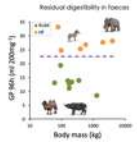

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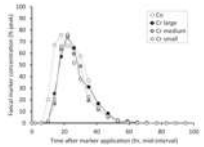
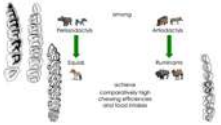
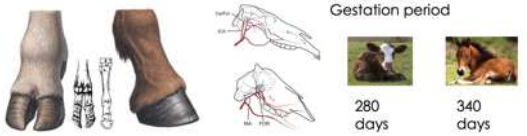


4. The most distinct feature of both equids and ruminants is the relatively high chewing efficiency within their respective orders

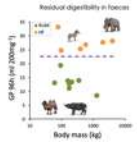


Summary

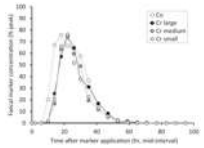
1. The evolutionary decline in equid diversity has been linked to ‘disadvantages’ compared to bovid/cervid ruminants



2. Digestive efficiency is prominent among these disadvantages



3. Equids do not have a proven tolerance for lower-quality forage and no size-discriminating retention mechanism



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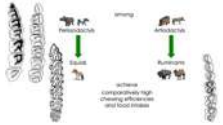
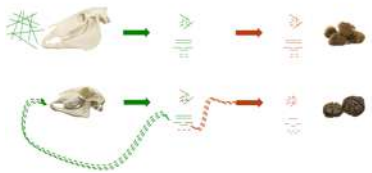
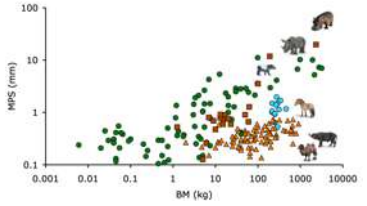
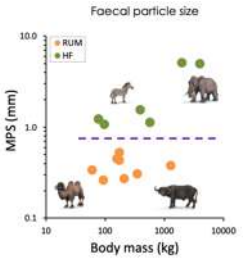
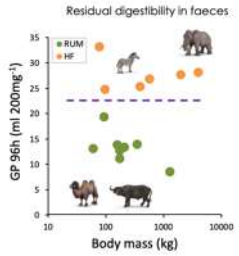


5. The ruminant approach to achieving a high chewing efficiency is more efficient (and conveys additional advantages)

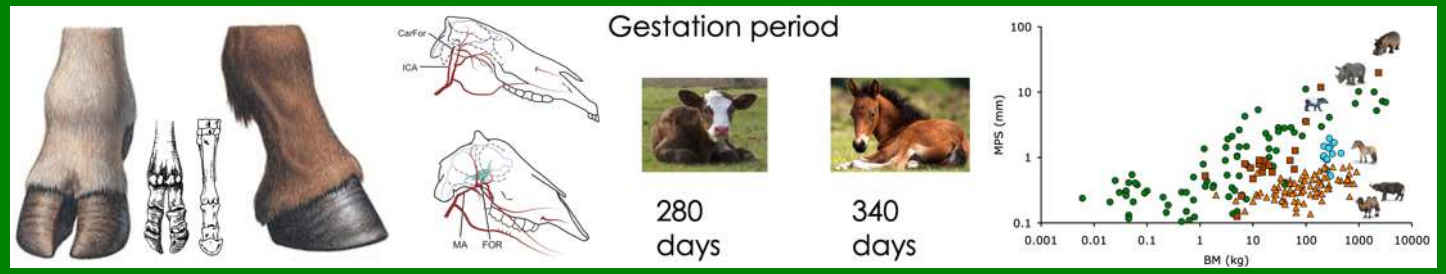


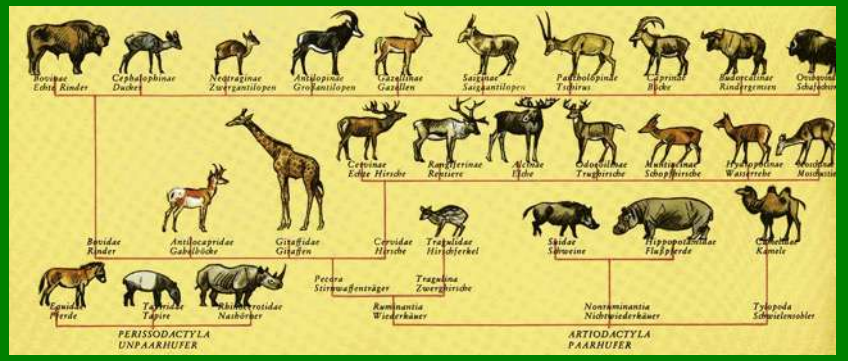






… so maybe the most intriguing question is not "why have equids largely disappeared?"





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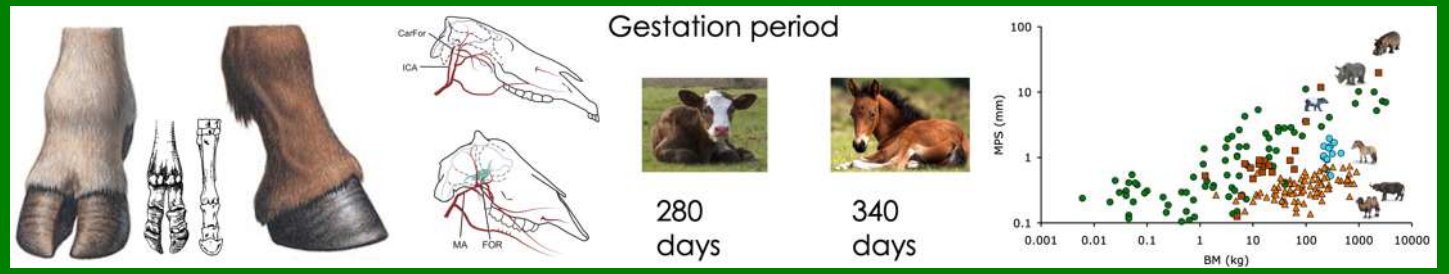
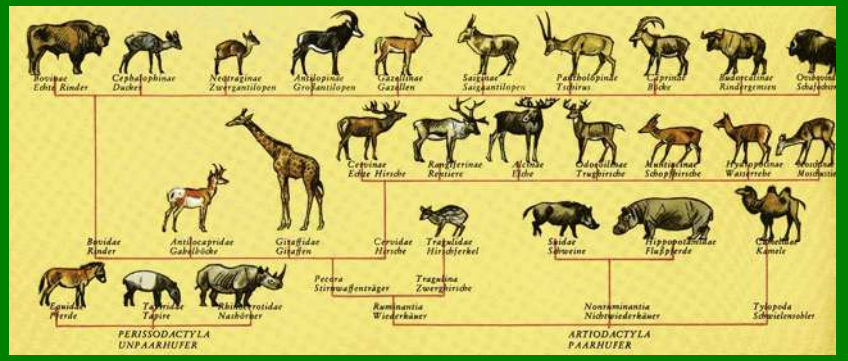


… but "why have some equid species survived?"

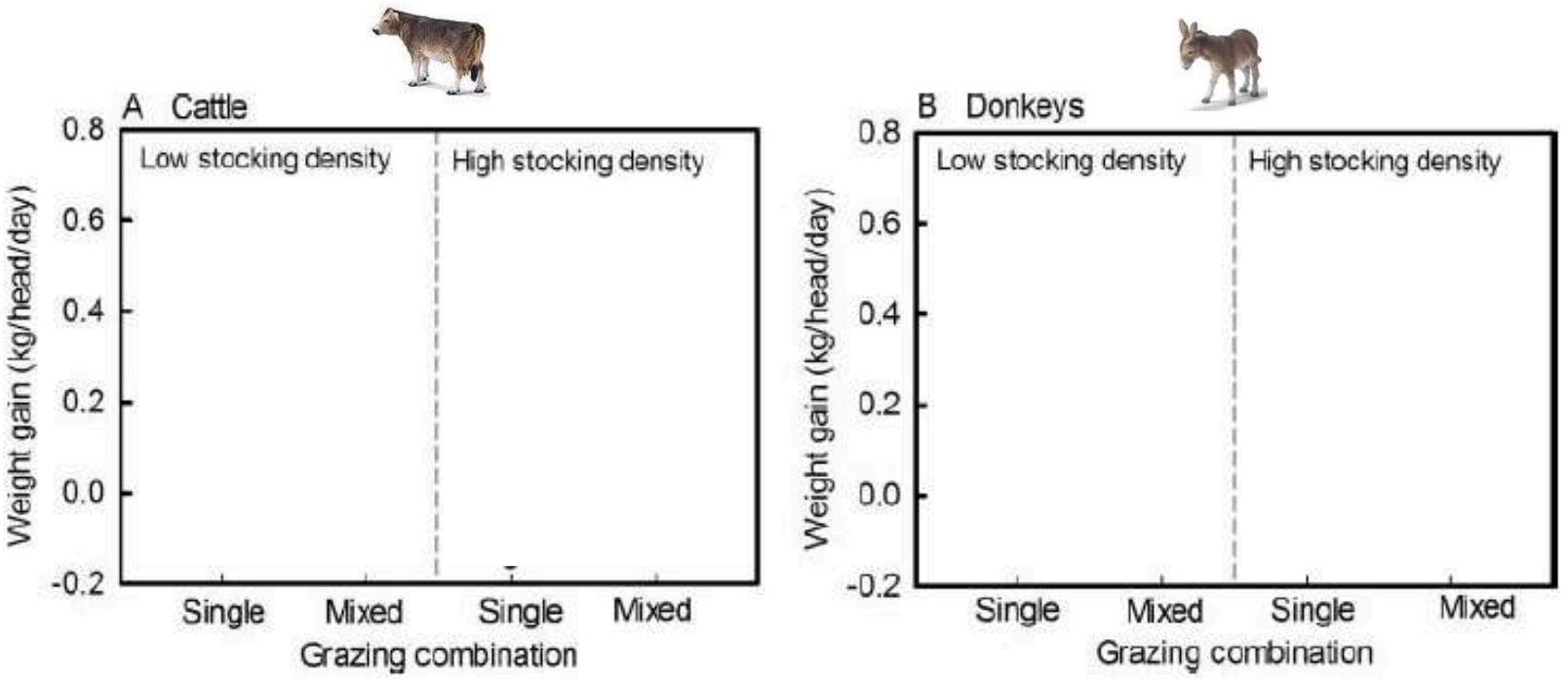


Ruminant – Equid – Facilitation?

Facilitation between bovids and equids on an African savanna

Wilfred O. Odadi[1,2,3], Meha Jain[1,4], Sipke E. Van Wieren[5], Herbert H.T. Prins[5] and Daniel I. Rubenstein[1,2]

Evolutionary Ecology Research, 2011, **13**: 237–252



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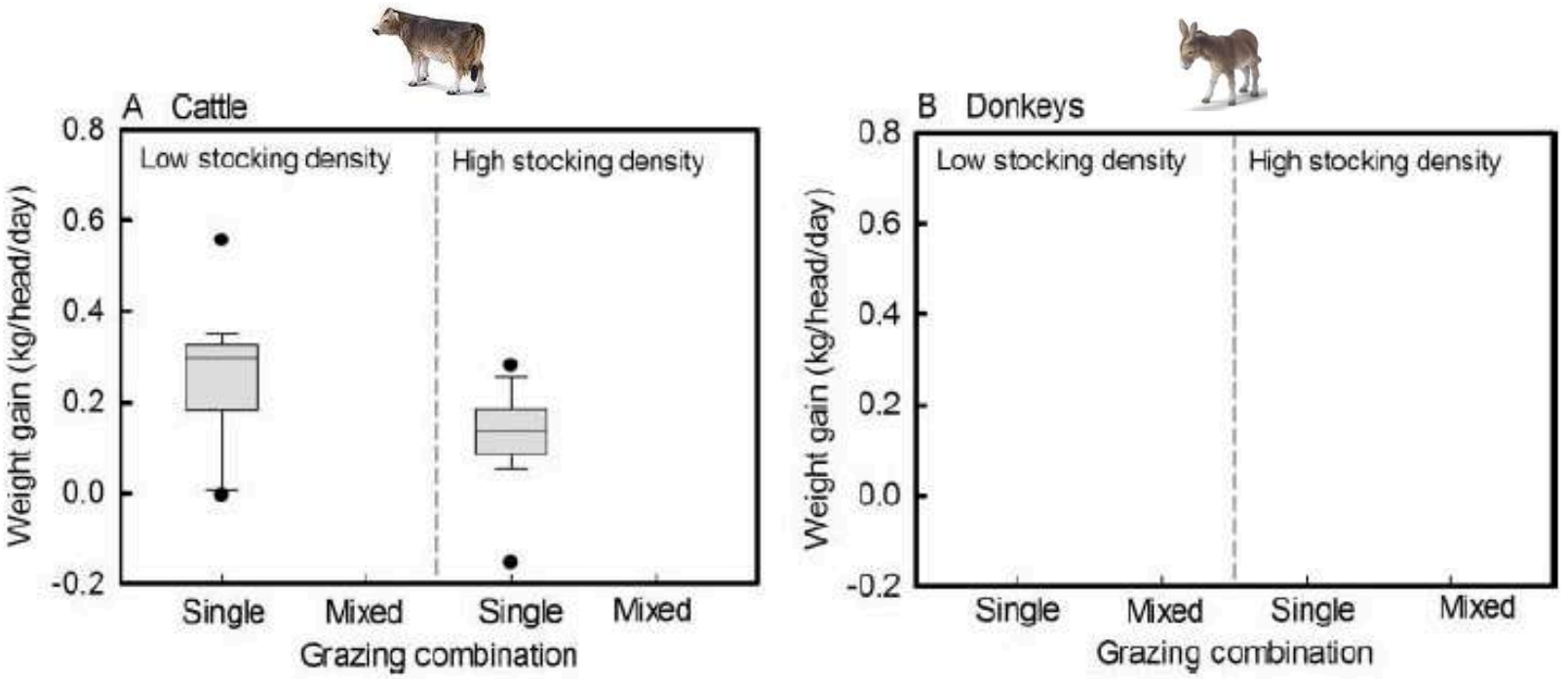

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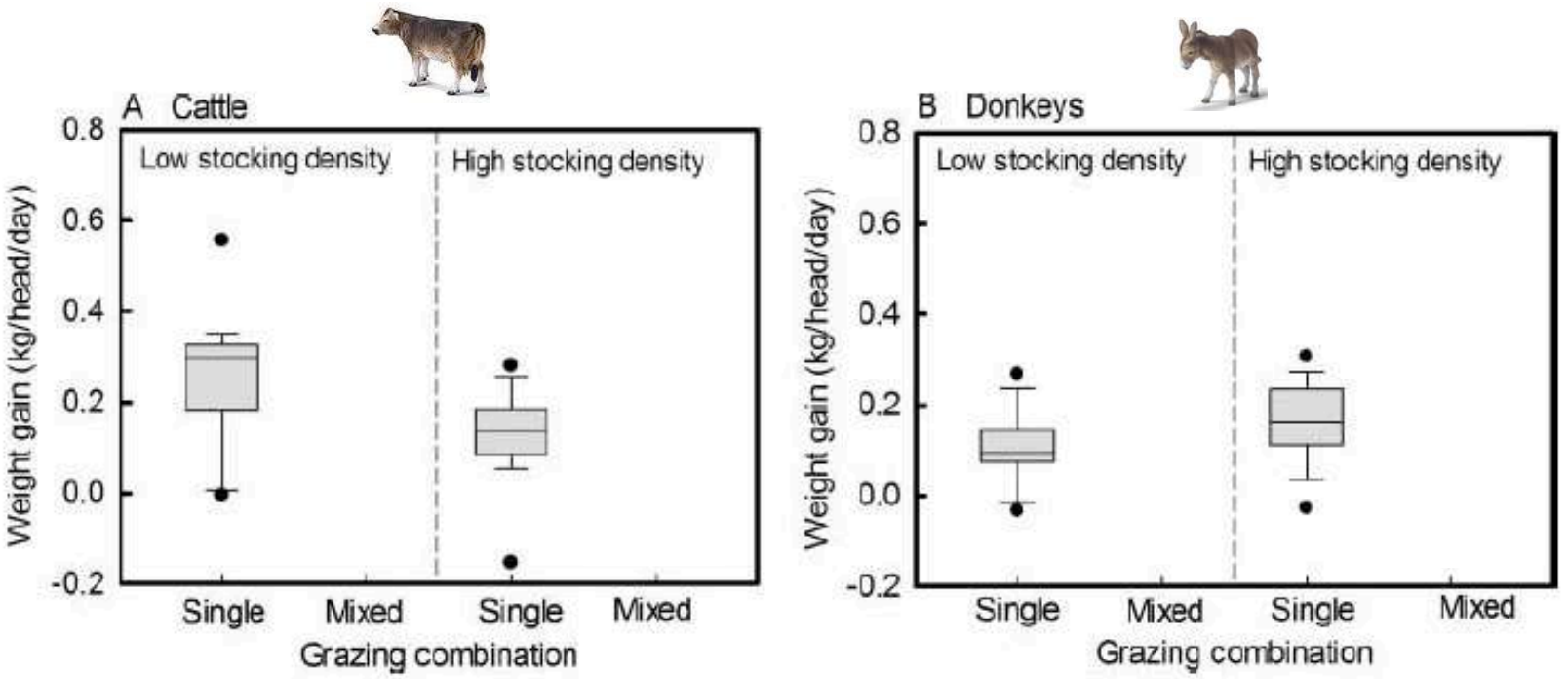

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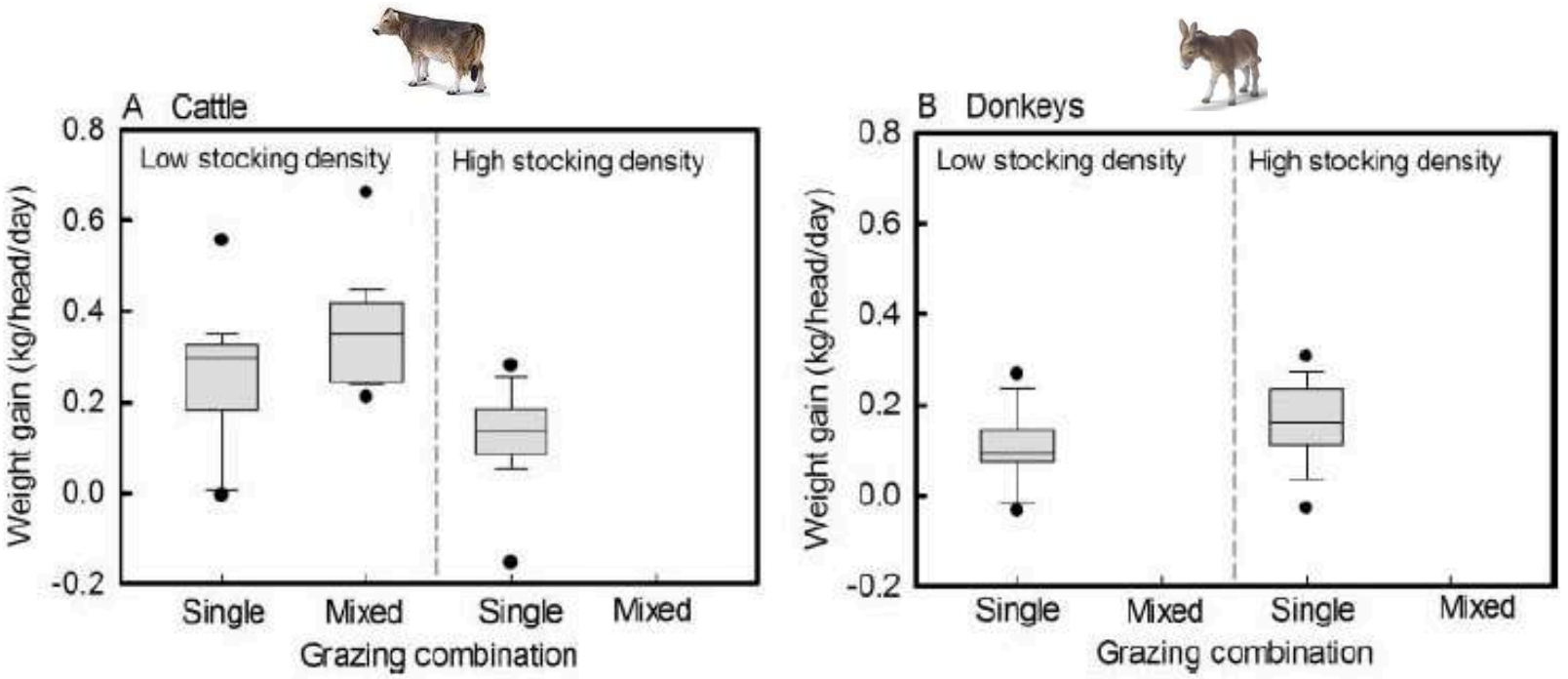

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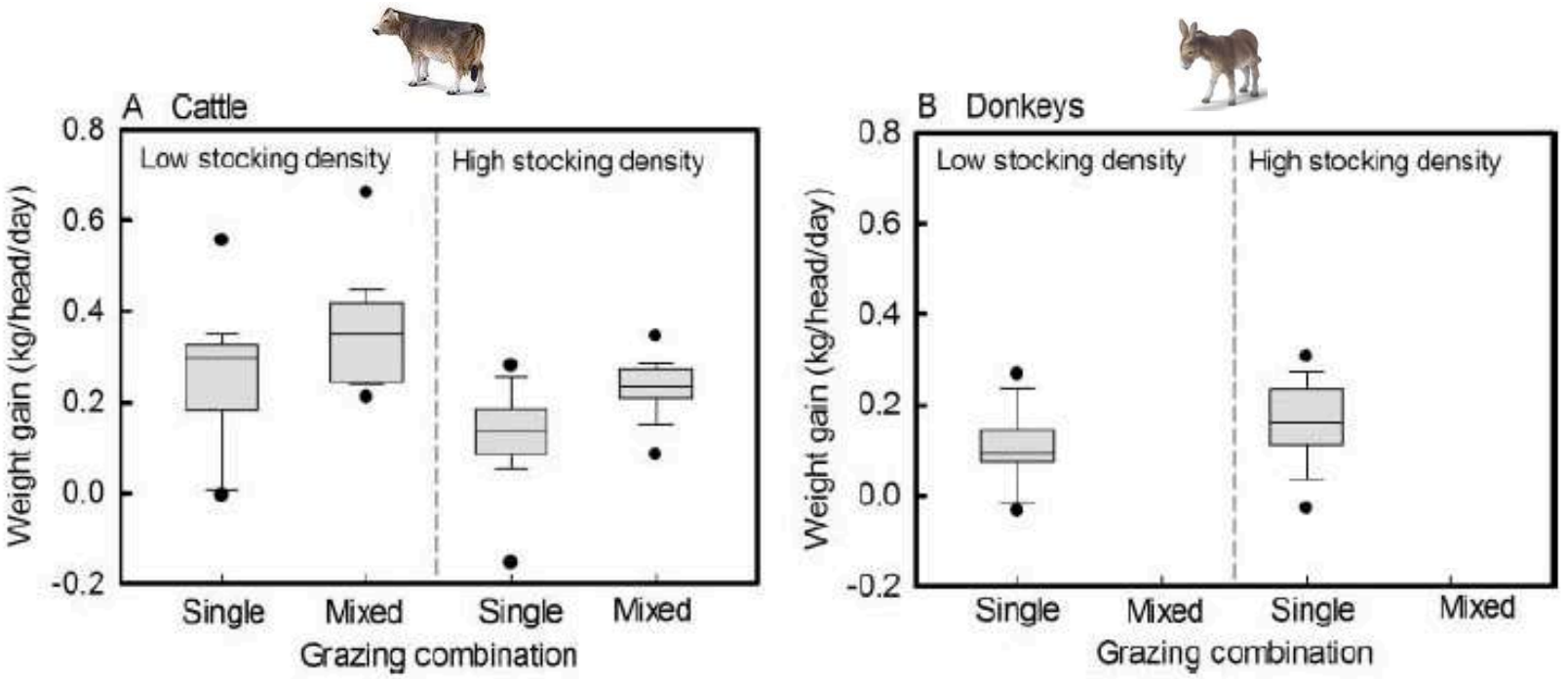

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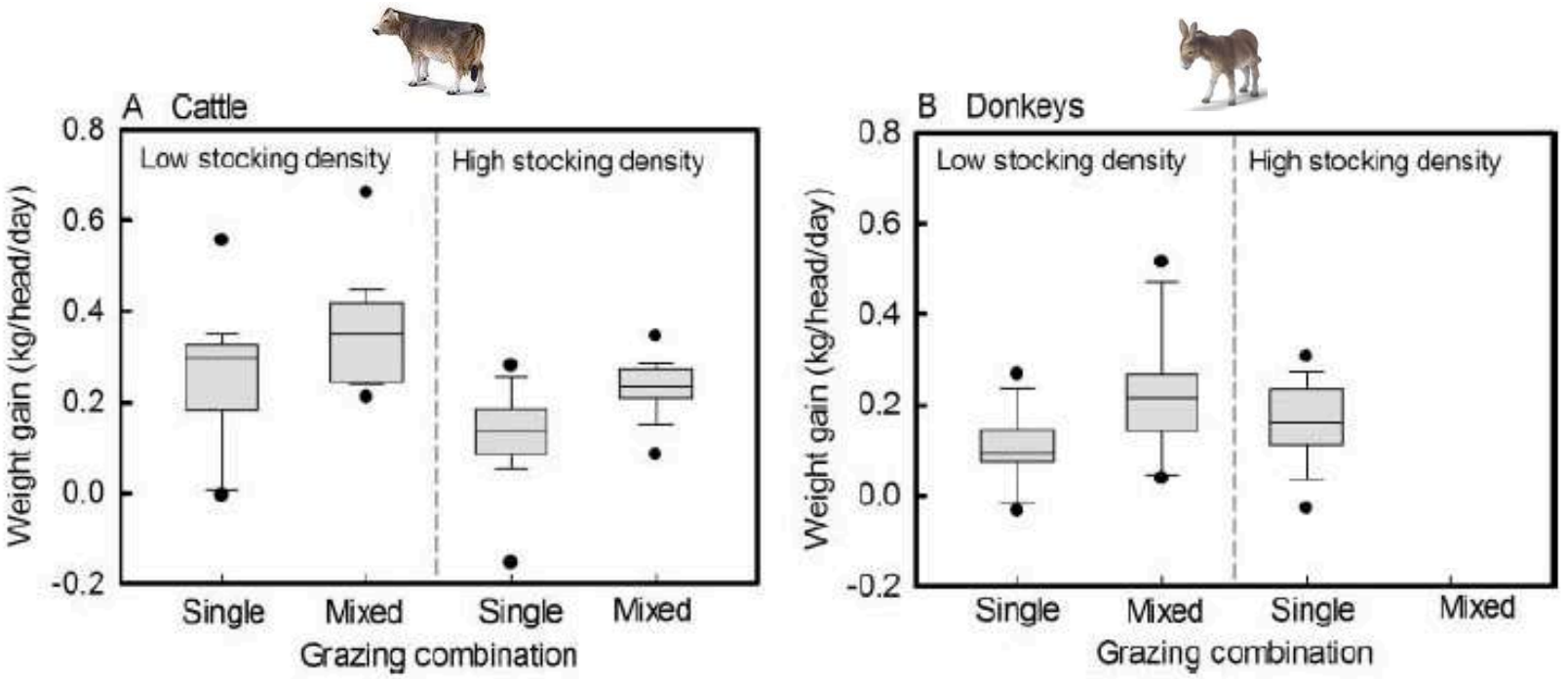

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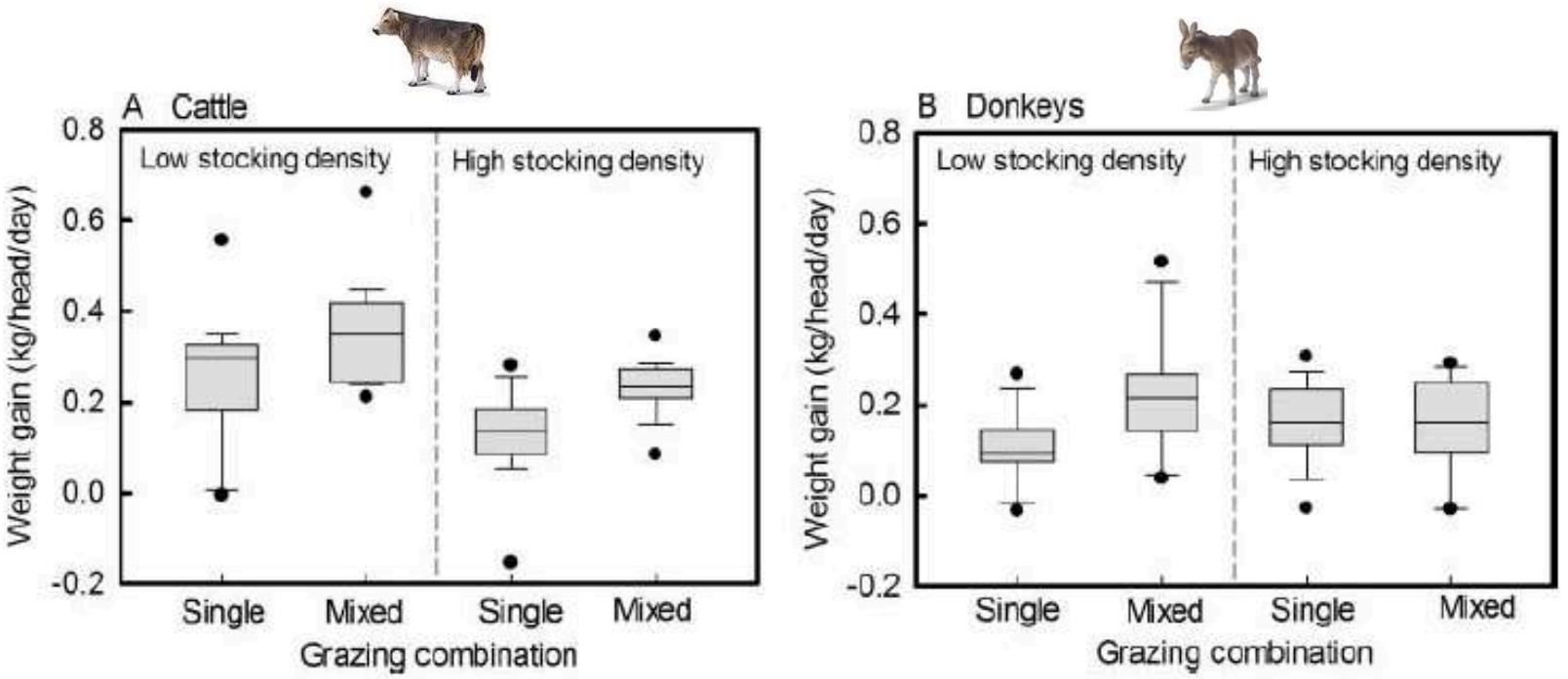

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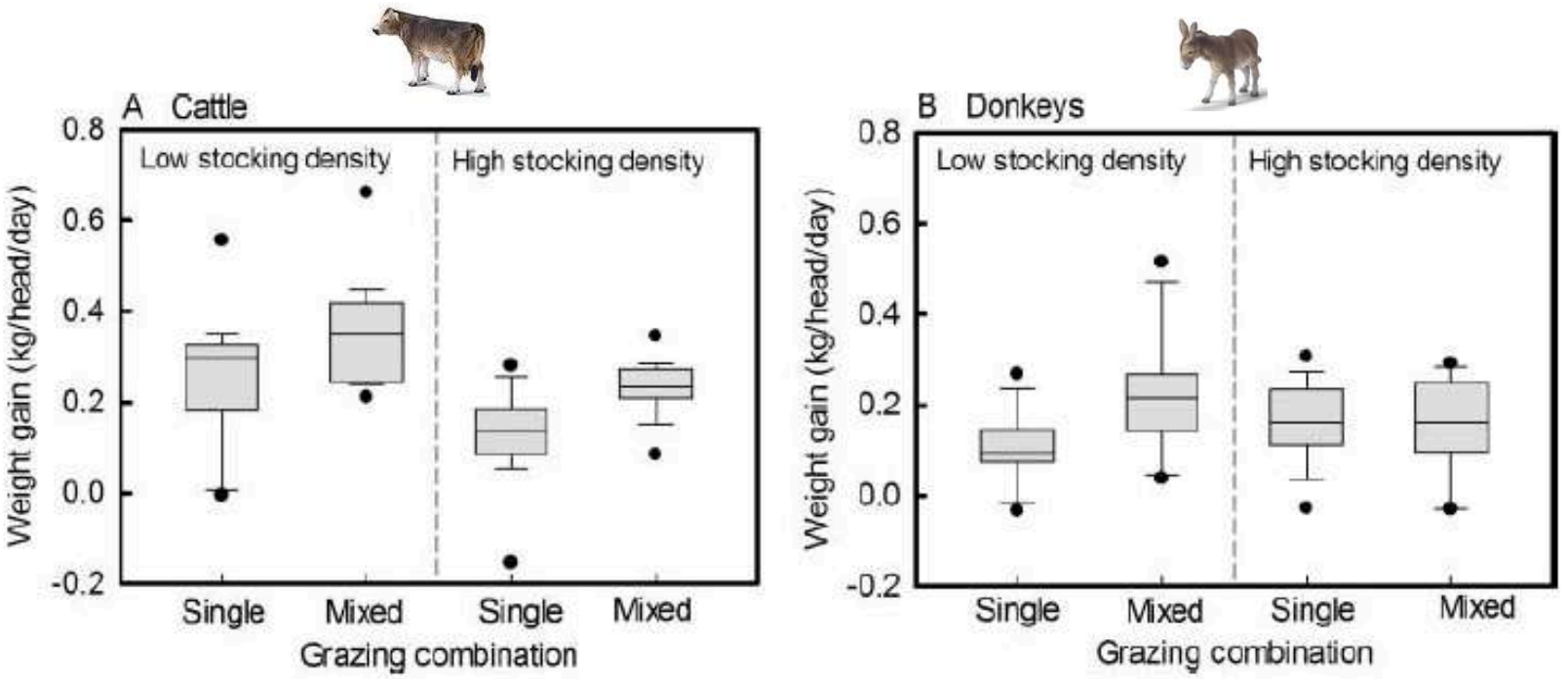
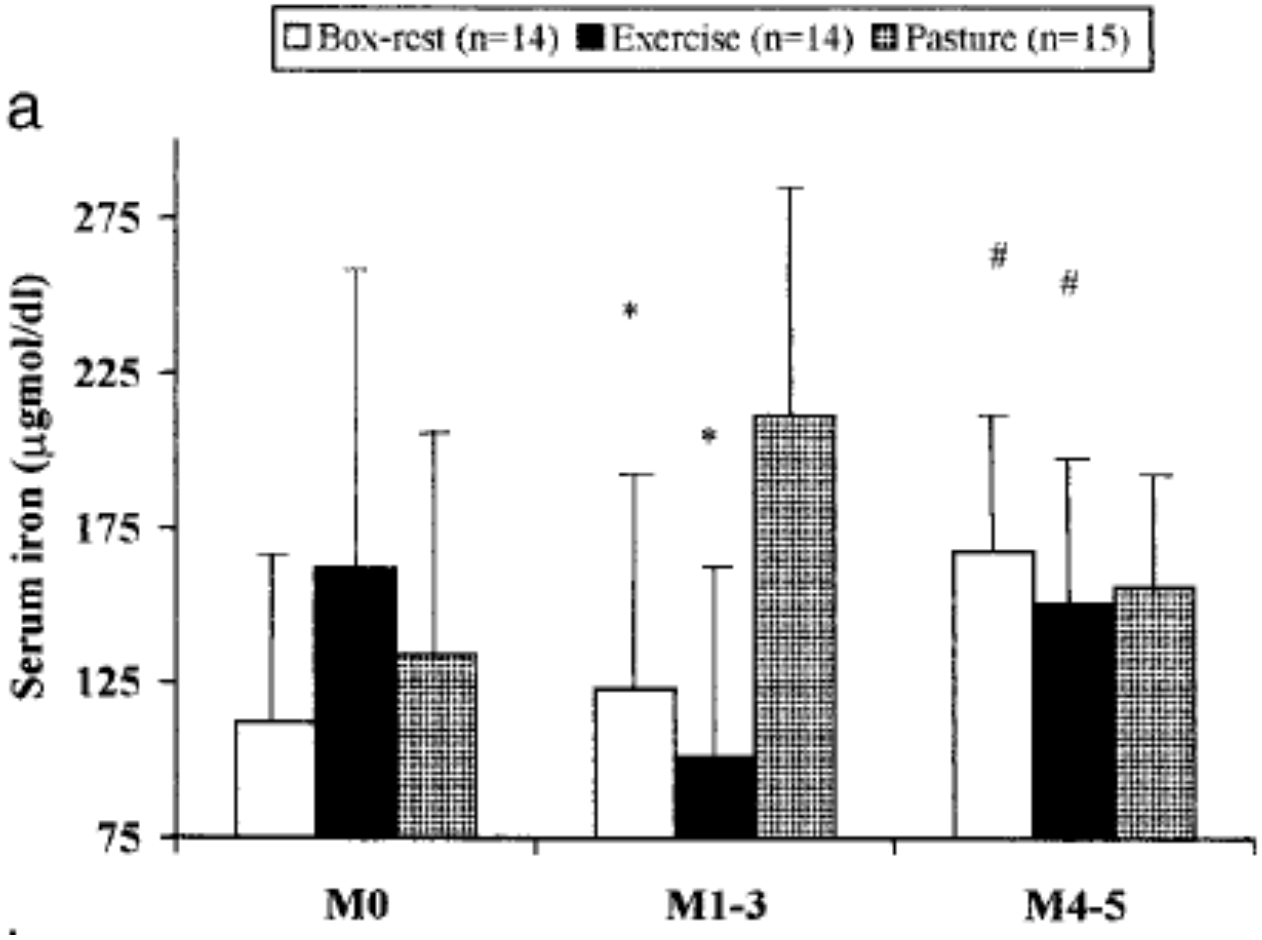


thank you
for your attention

Iron Deficiency in Stabled Dutch Warmblood Foals

H. Brommer and Marianne M. Sloet van Oldruitenborgh-Oosterbaan

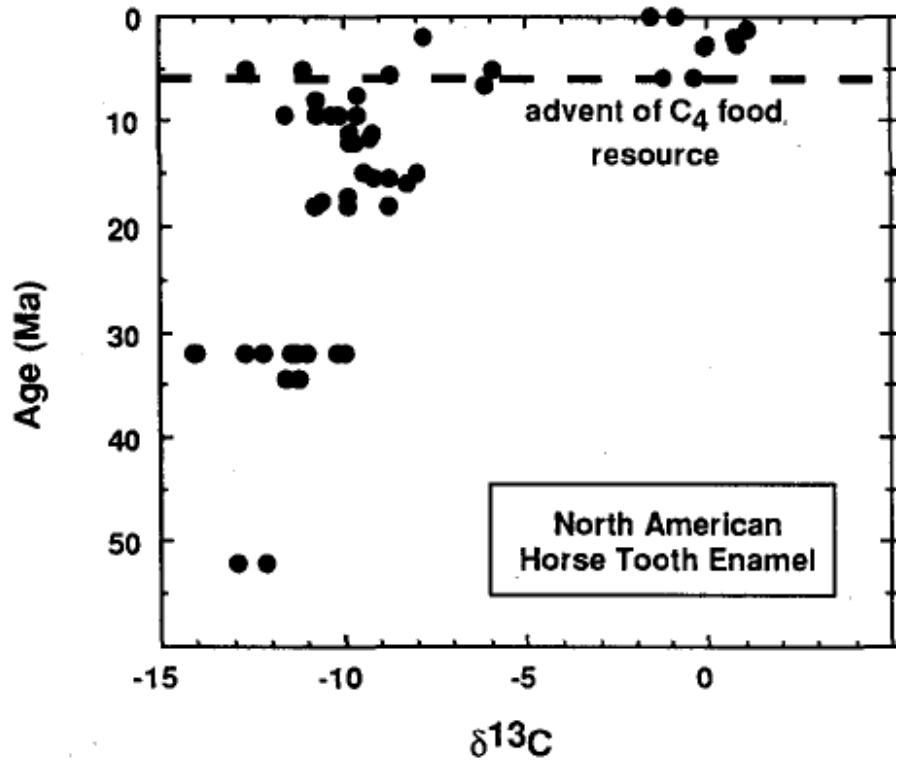
J Vet Intern Med 2001;15:482–485



Fossil horses and carbon isotopes: new evidence for Cenozoic dietary, habitat, and ecosystem changes in North America

Yang Wang[a], Thure E. Cerling[a] and Bruce J. MacFadden[b]

Palaeogeography, Palaeoclimatology, Palaeoecology, 107 (1994): 269–279



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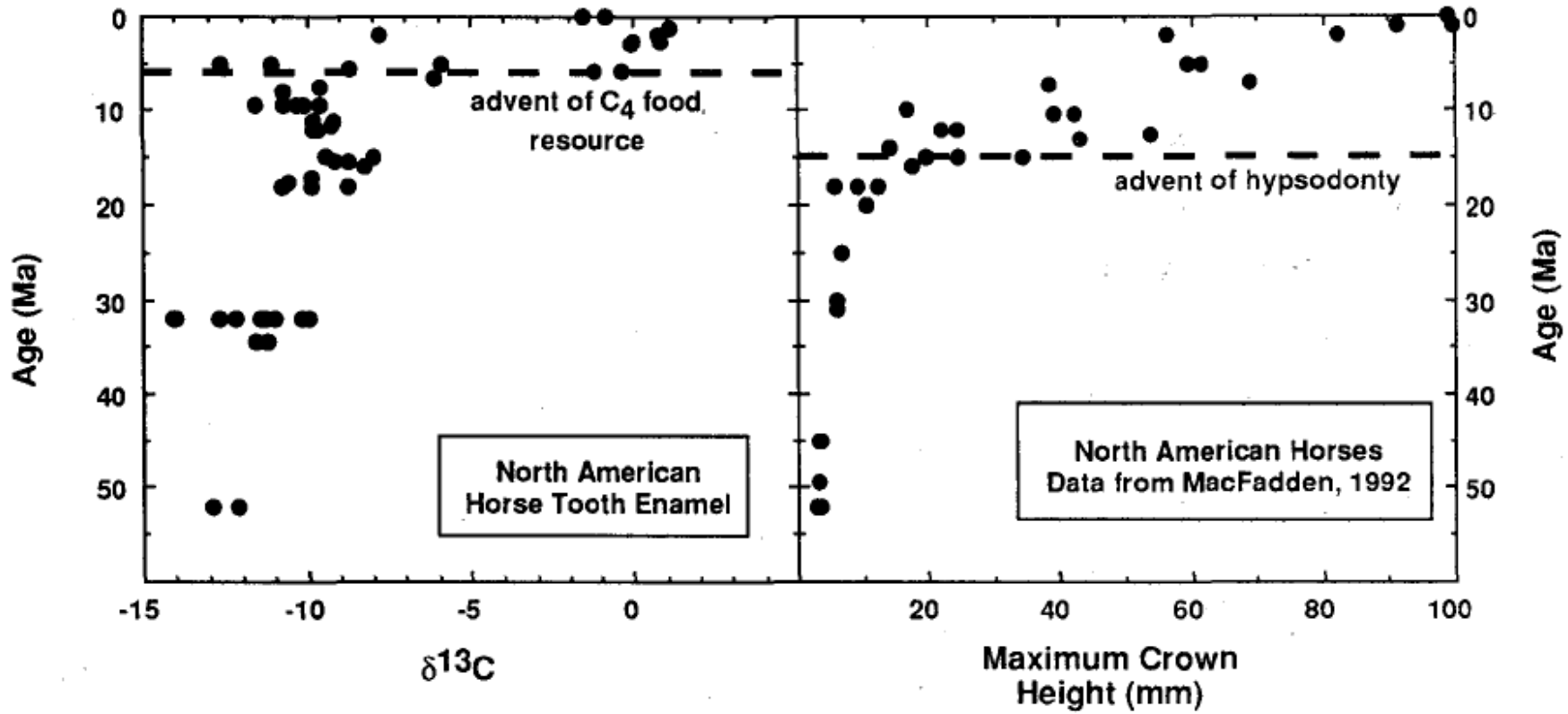
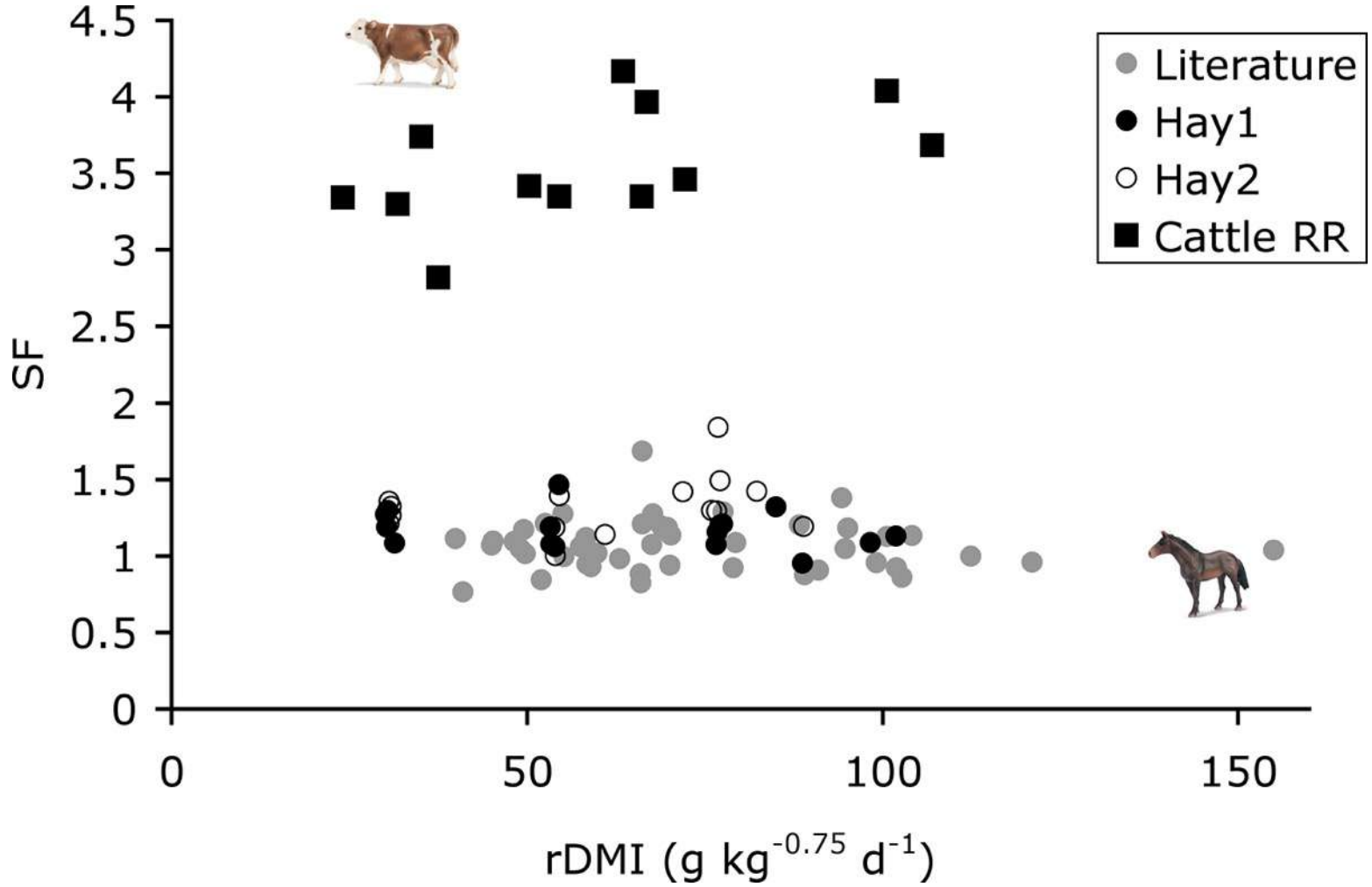
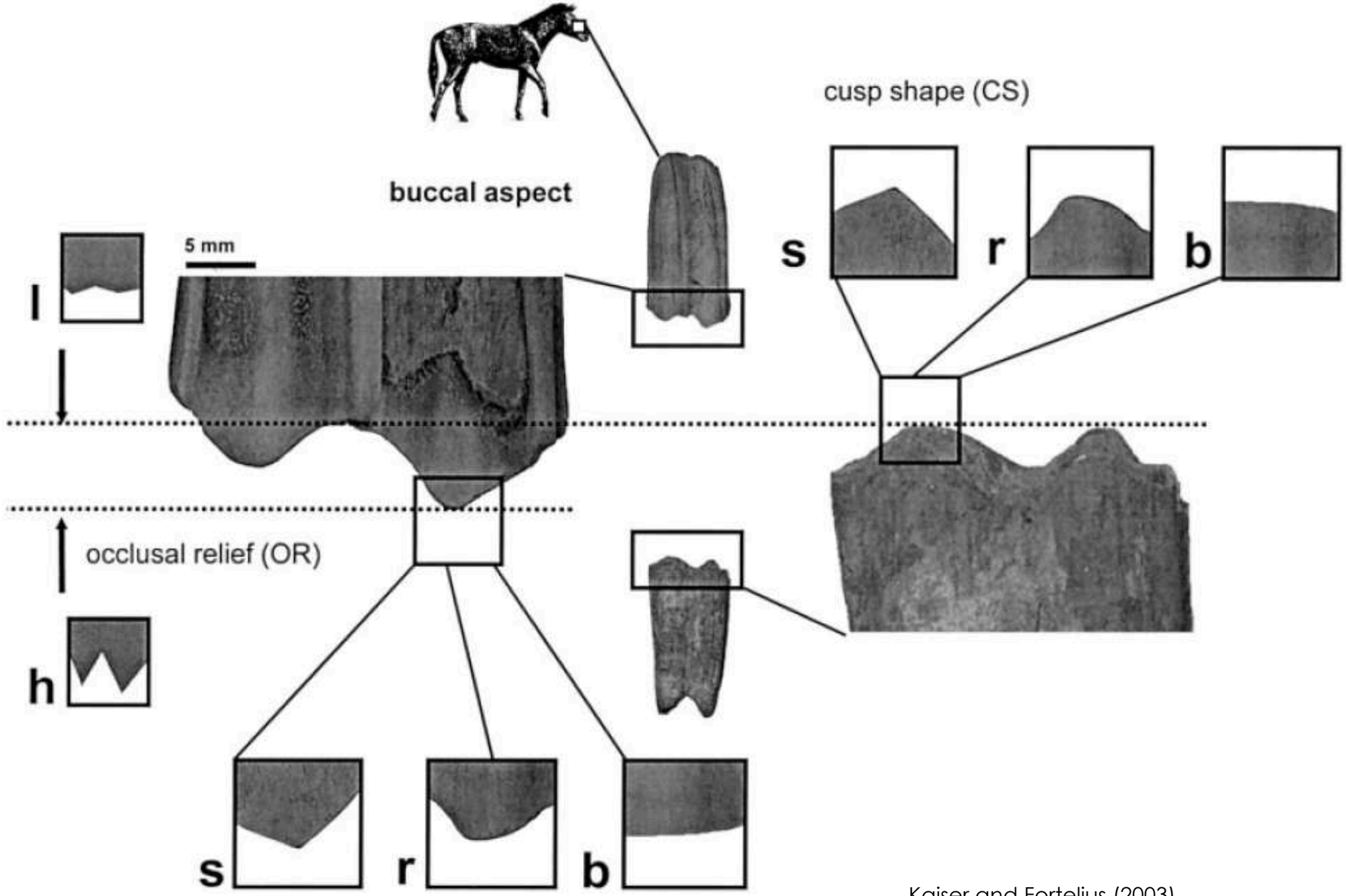


The effect of very low food intake on digestive physiology and forage digestibility in horses

M. Clauss[1], K. Schiele[2], S. Ortmann[3], J. Fritz[2], D. Codron[1], J. Hummel[4] and E. Kienzle[2]

Journal of Animal Physiology and Animal Nutrition **98** (2014) 107–118



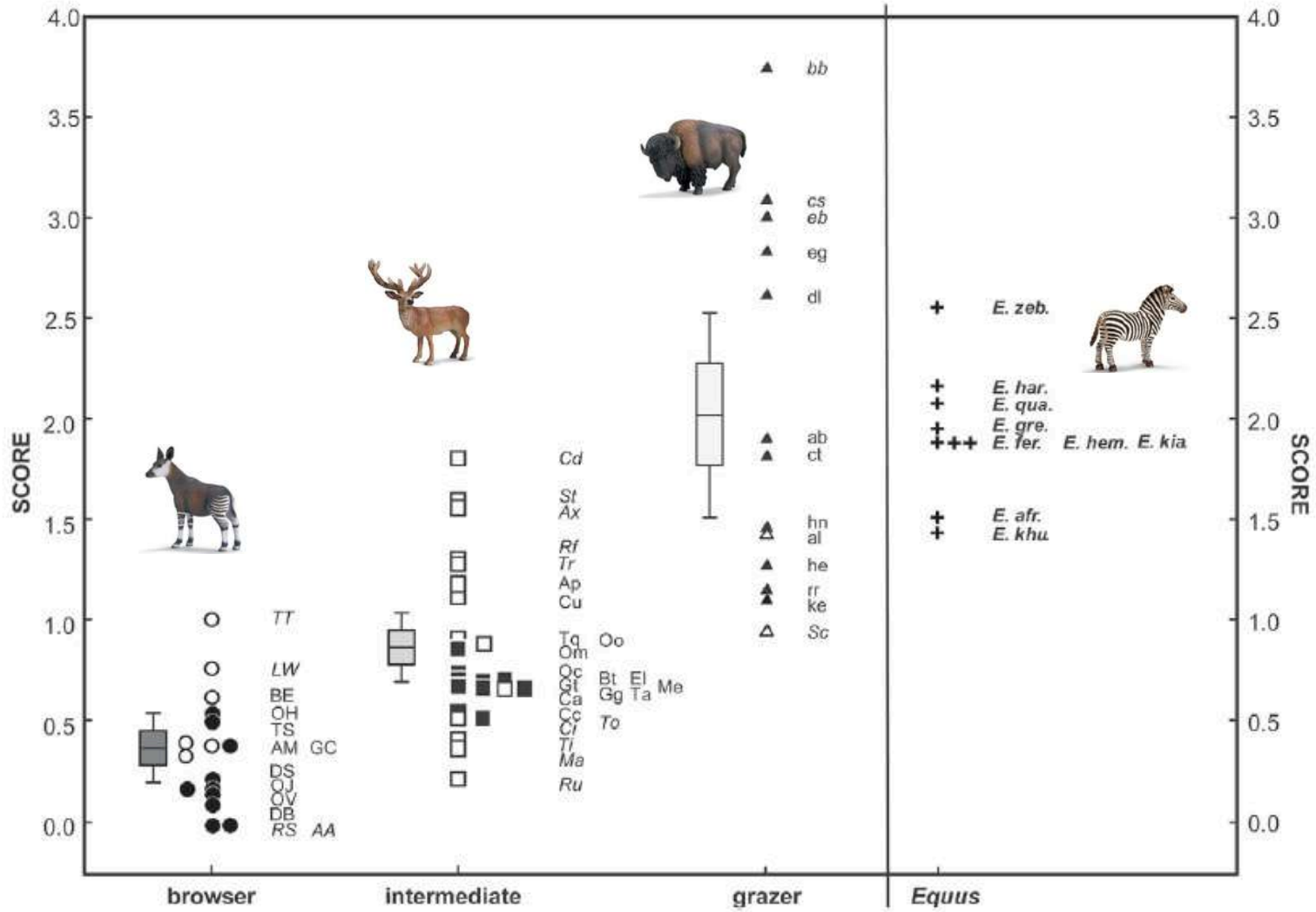


Kaiser and Fortelius (2003)

Historical distribution, habitat requirements and feeding ecology of the genus *Equus* (Perissodactyla)

Ellen SCHULZ* Thomas M. KAISER

Mammal Review **43** (2013) 111–123

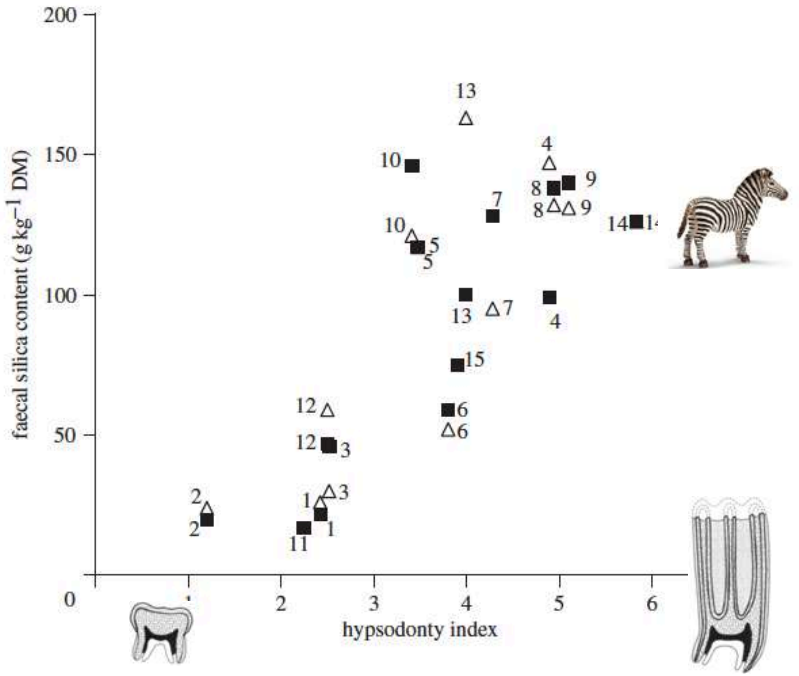


Adapted to abrasive diets

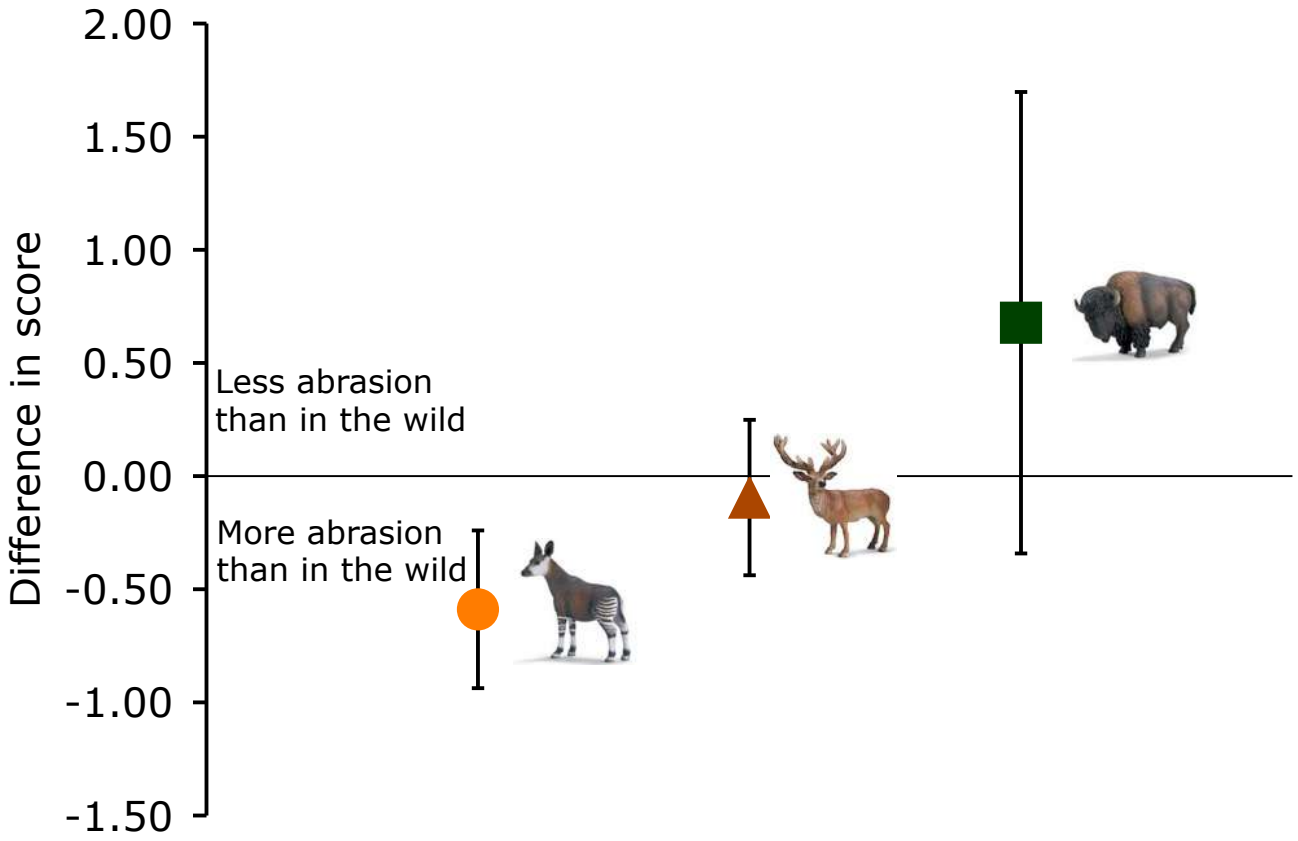
Another one bites the dust: faecal silica levels in large herbivores correlate with high-crowned teeth

Jürgen Hummel[1,*], Eva Findeisen[1], Karl-Heinz Südekum[1], Irina Ruf[2], Thomas M. Kaiser[3], Martin Bucher[4], Marcus Clauss[5] and Daryl Codron[5]

Proc. R. Soc. B (2011) 278, 1742–1747



Diet and mesowear: zoo vs. wild



from Kaiser et al. (2009)

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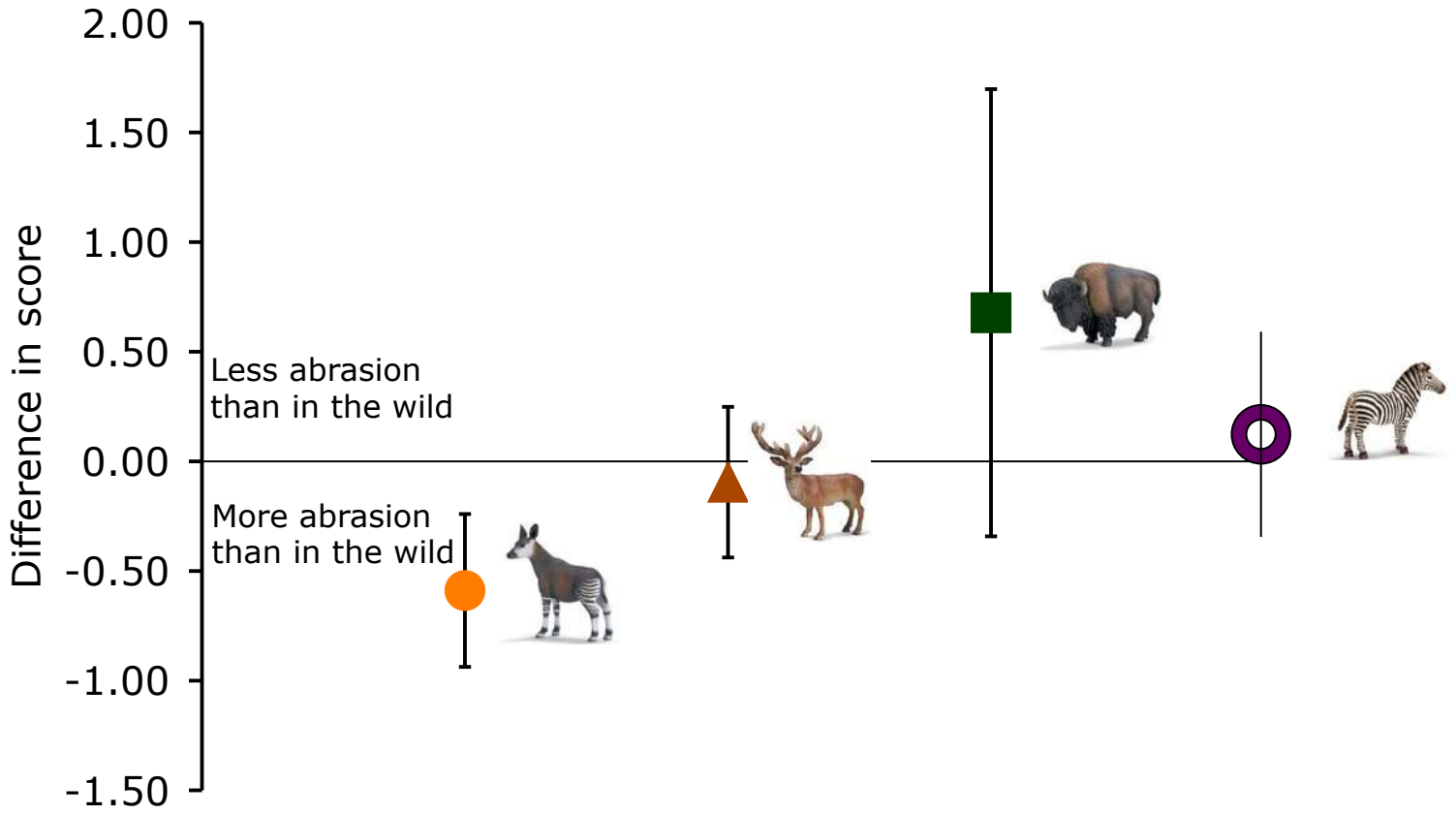

from Kaiser et al. (2009), Taylor et al. (in prep.)

Wild equids in captivity

Similar as in grazing ruminants, few health problems related to nutrition in captive wild equids (because zoo diets are typically more forage dominated?)

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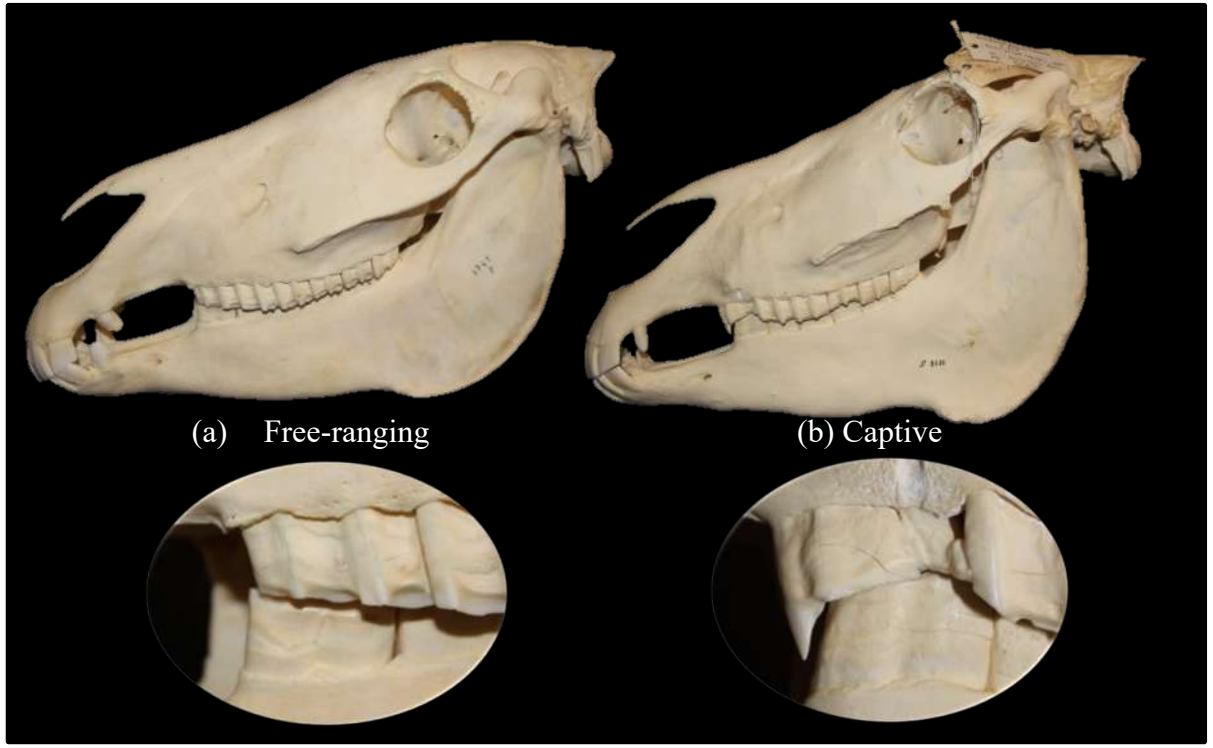

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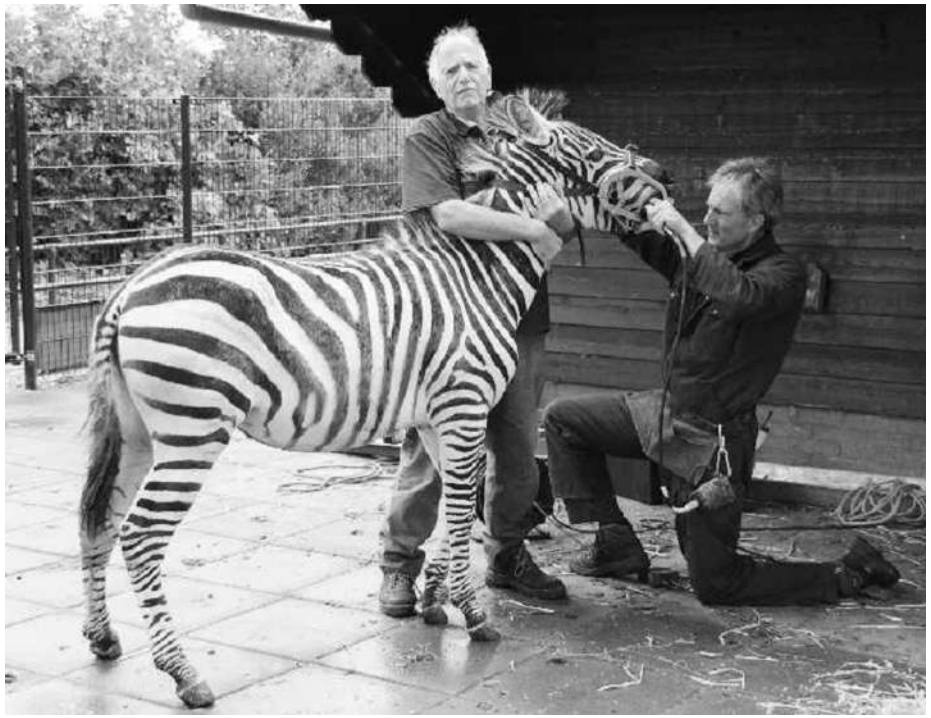

Hoyer et al. (2012)

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- *Incidents of dental abnormalities*

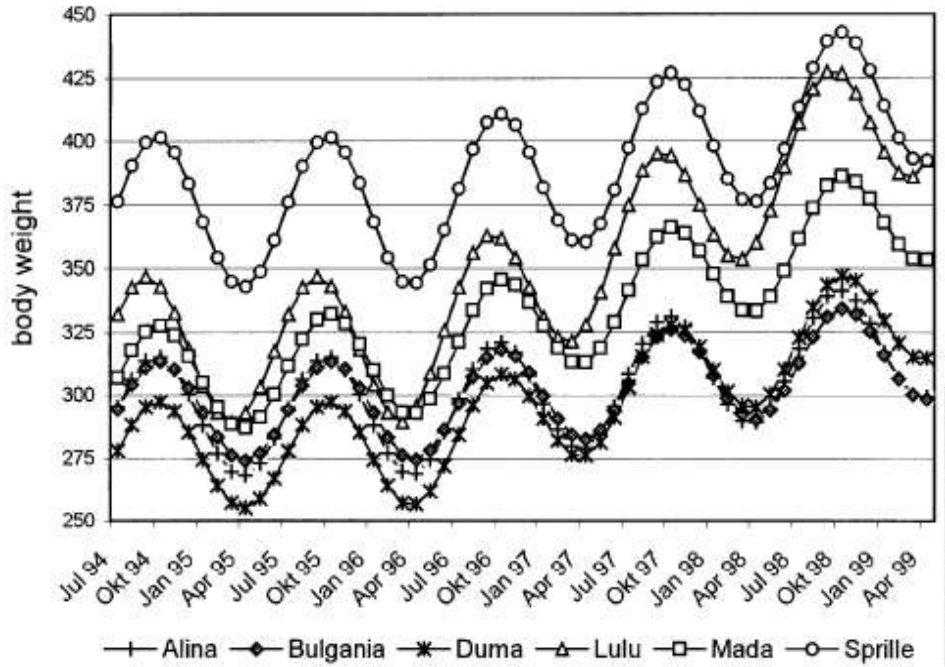
- *Hoof overgrowth/laminitis*

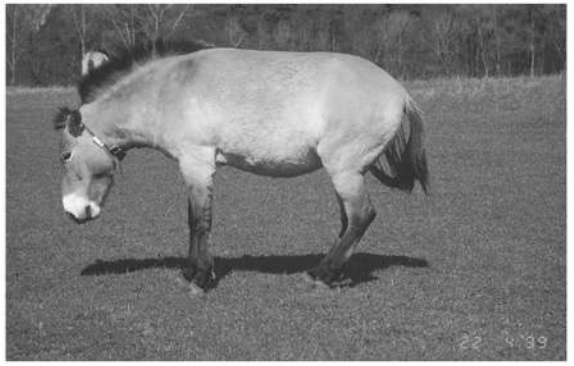
Equid seasonality

Laminitis in Przewalski horses kept in a semireserve

Klaus-Dieter Budras*, Klaus Scheibe[1], Bianca Patan, Wolf J. Streich[1] and Kabsu Kim[2]

J. Vet. Sci. (2001), **2**(1), 1–7





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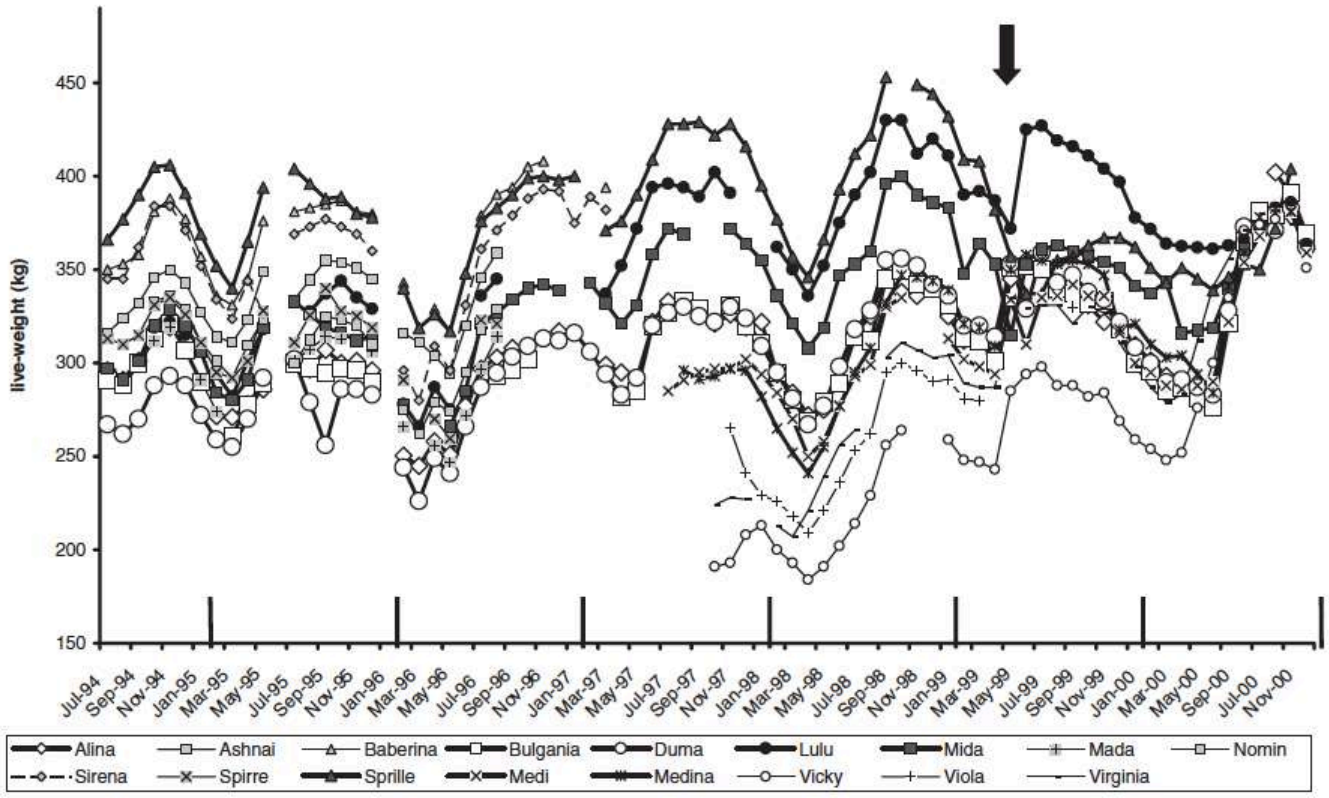
- *Incidents of dental abnormalities*
- *Hoof overgrowth/laminitis*
- *Obesity*

Equid seasonality

Annual Rhythm of Body Weight in Przewalski Horses (*Equus ferus przewalskii*)

Klaus M. Scheibe and Wolf J. Streich

Biological Rhythm Research
2003, Vol. 34 No. 4. pp. 383–395



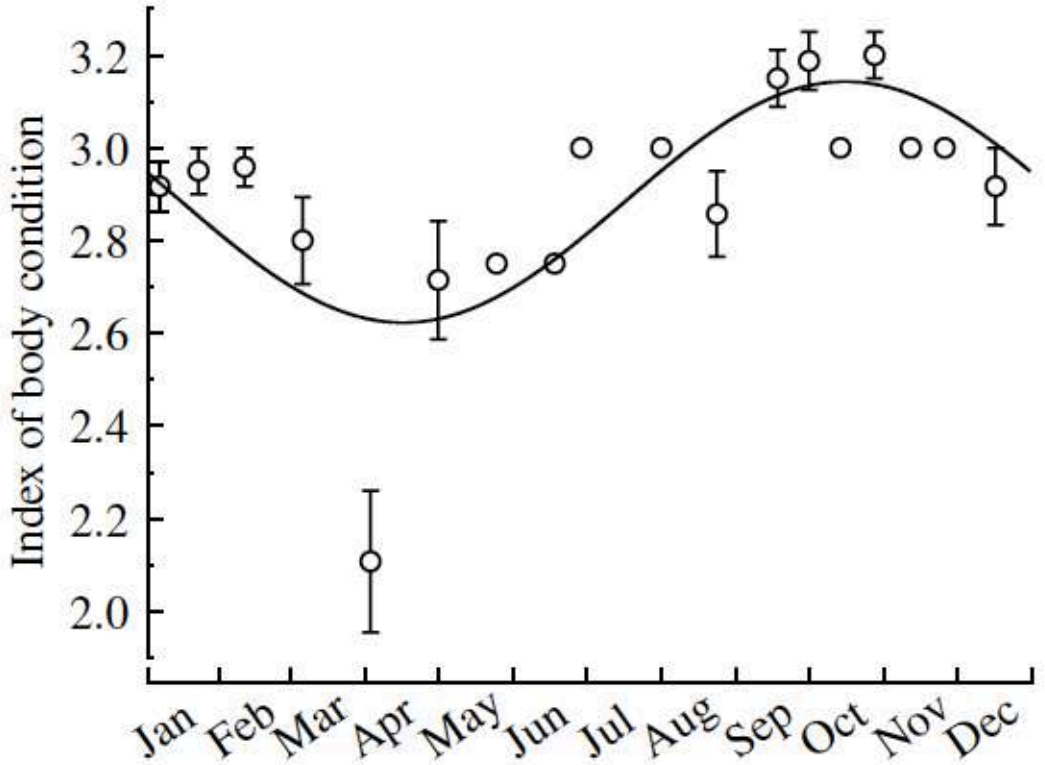
Equid seasonality

Seasonal adjustment of energy budget in a large wild mammal, the Przewalski horse (*Equus ferus przewalskii*)

I. Energy intake

Regina Kuntz, Christina Kubalek, Thomas Ruf, Frieda Tataruch and Walter Arnold*

The Journal of Experimental Biology 209, 4557-4565

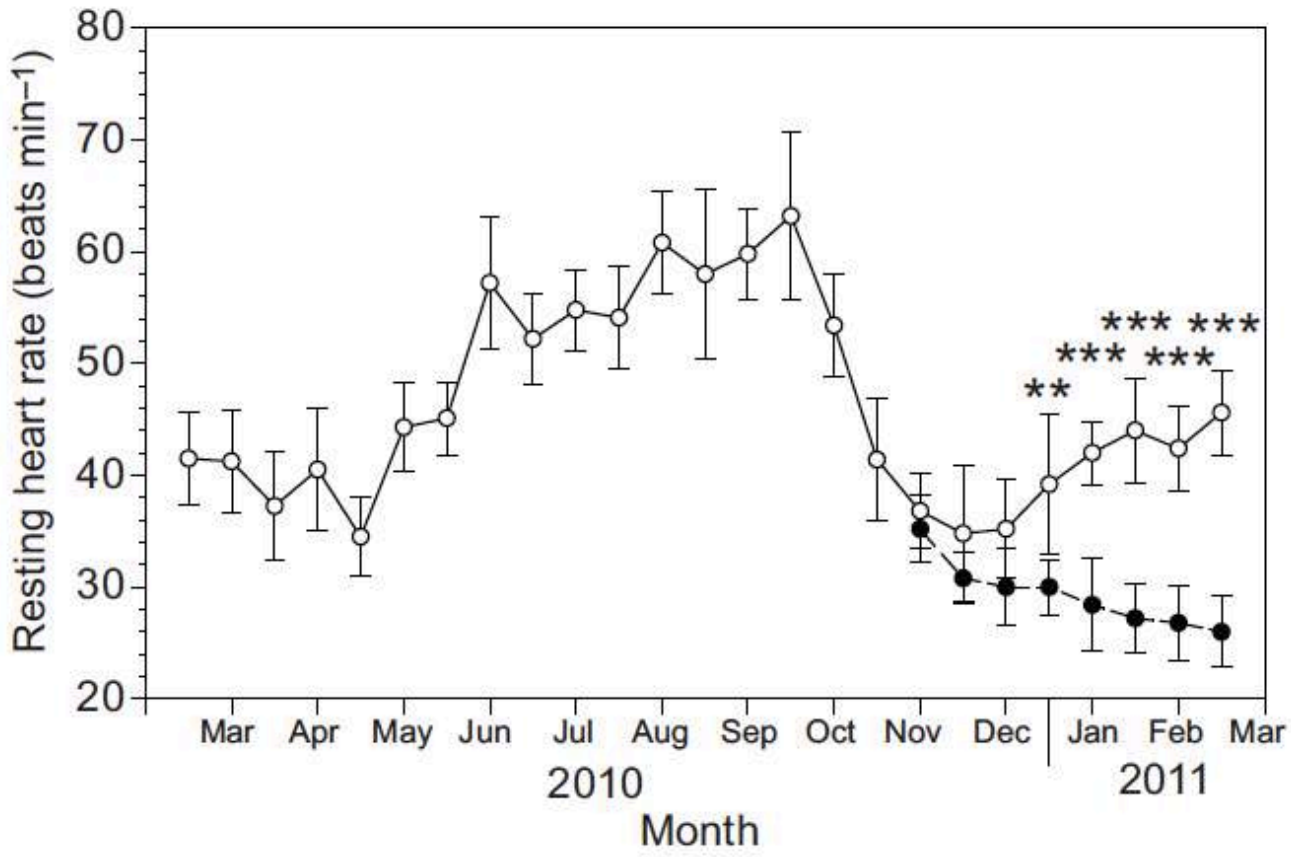


Equid seasonality

Adaptation strategies to seasonal changes in environmental conditions of a domesticated horse breed, the Shetland pony (*Equus ferus caballus*)

Lea Brinkmann, Martina Gerken and Alexander Riek*

The Journal of Experimental Biology 215, 1061-1068

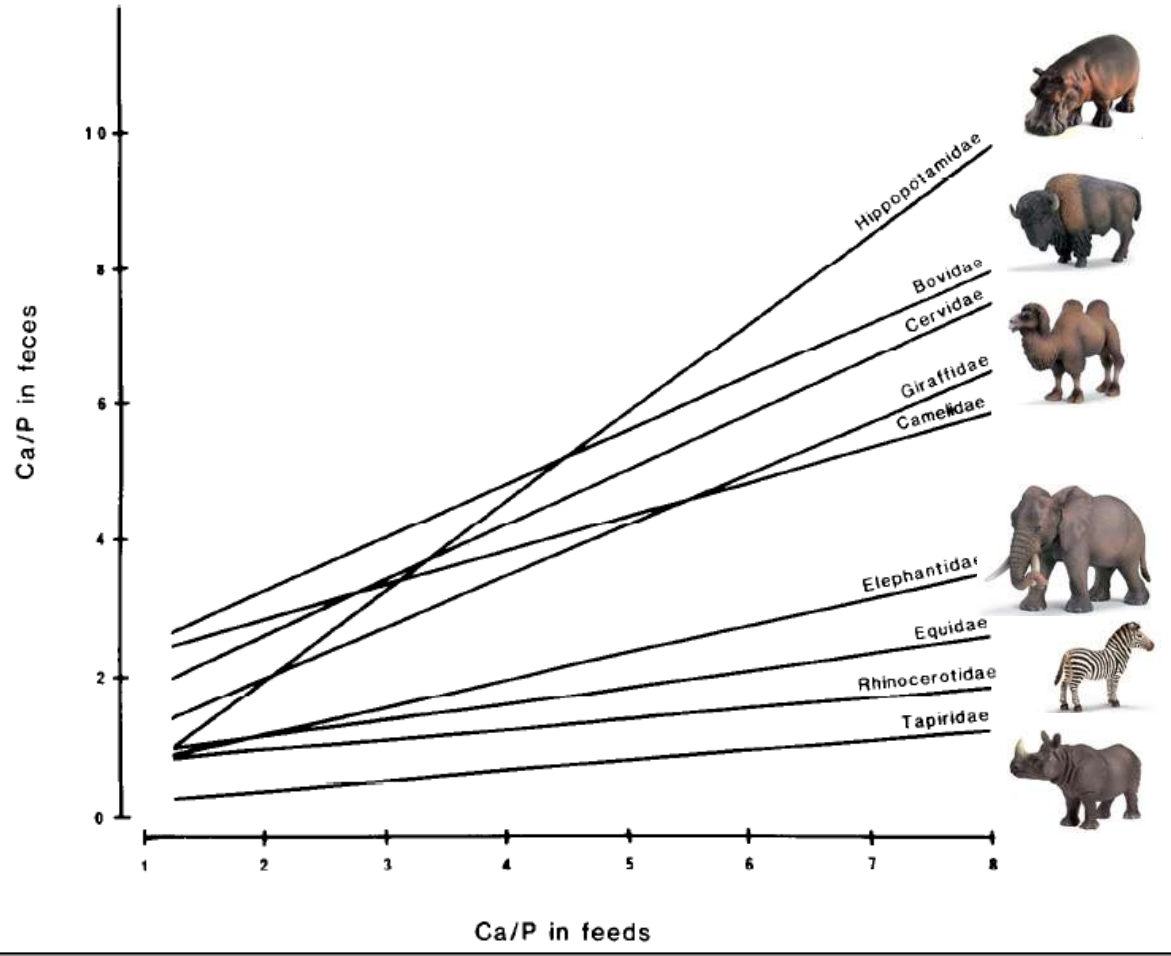


Other differences: Calcium digestibility

CALCIUM EXCRETION IN FECES OF UNGULATES

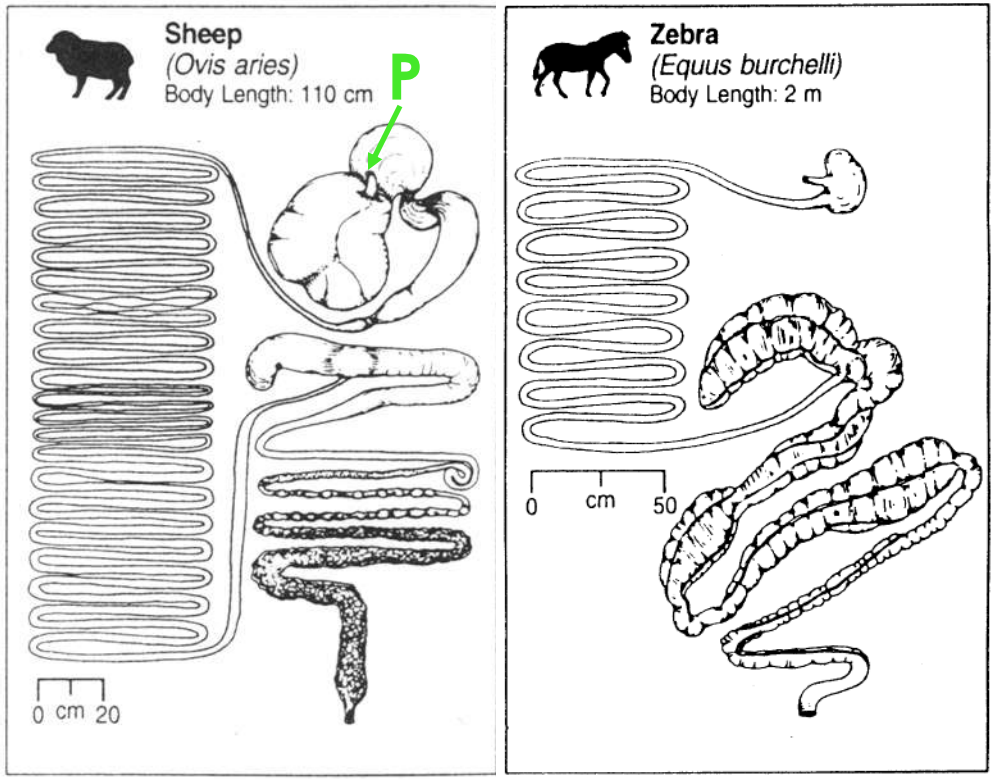
H. F. SCHRYVER, T. J. FOOSE*, J. WILLIAMS and H. F. HINTZ

Comp. Biochem. Physiol. Vol. 74A, No. 2, pp. 375 to 379, 1983



Other differences: Calcium digestibility

Phosphorus is supplied directly to microbes via saliva



from Stevens & Hume (1995)

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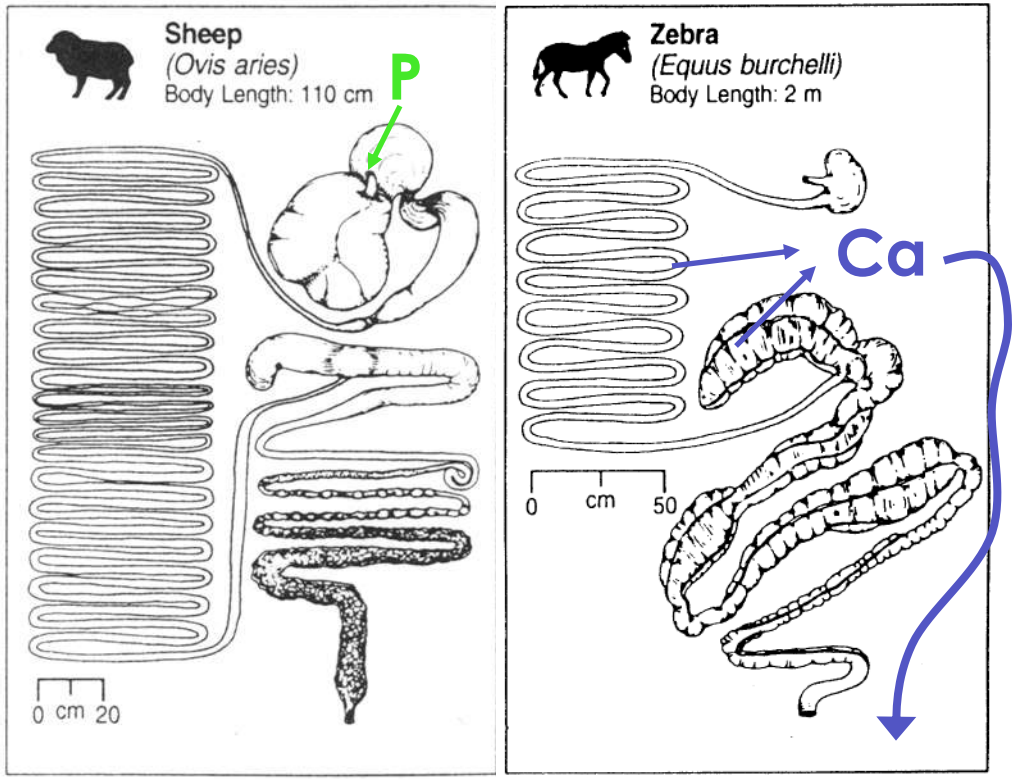


In order to guarantee **phosphorus** availability in the hindgut, **calcium** is actively absorbed from ingesta and excreted via urine

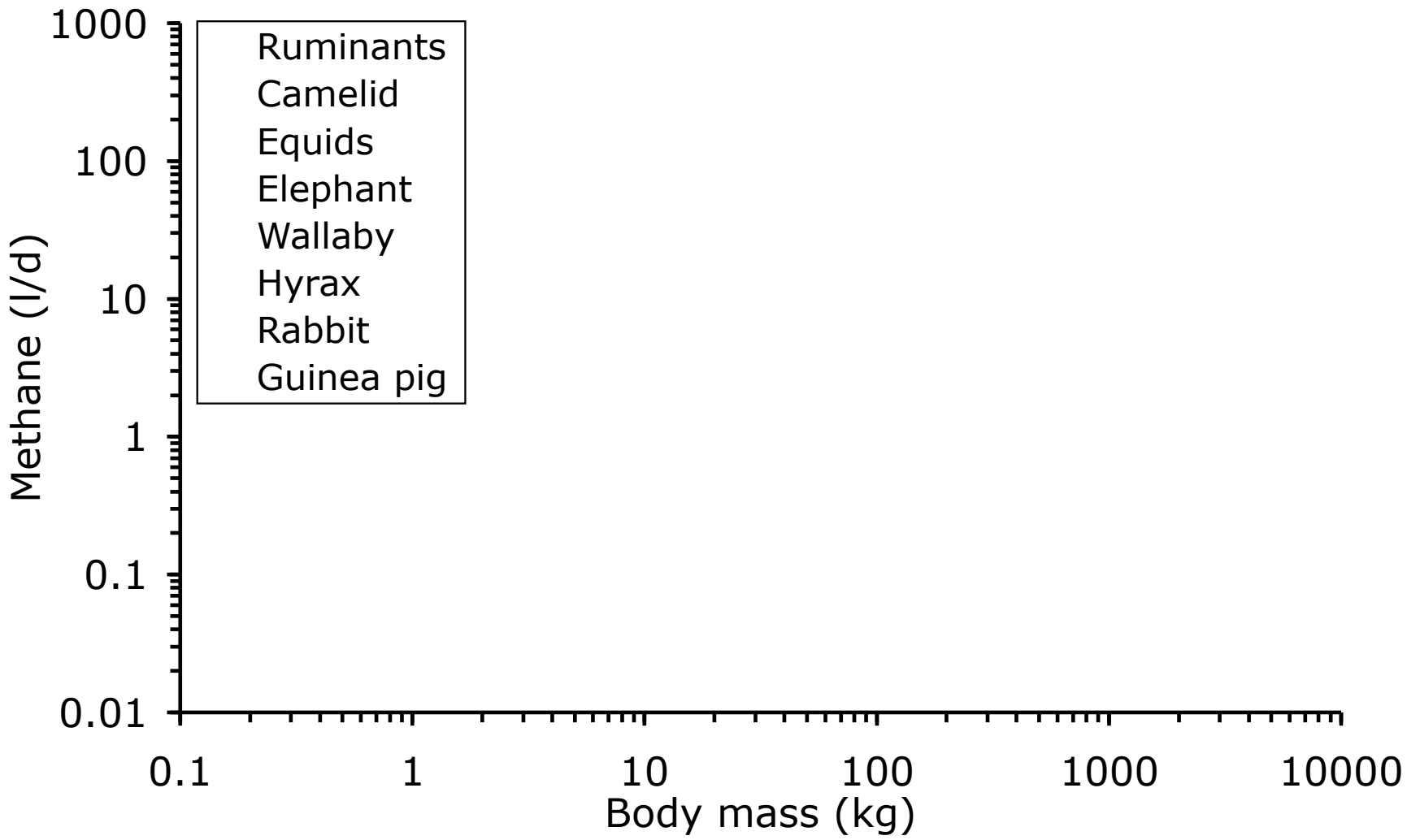
from Stevens & Hume (1995)
hypothesis by Clauss & Hummel (2008)

Why equids?

Other perissodactyls survive in body size ranges beyond the ruminant range (rhinos) or in absence of ruminant competition (tapirs).

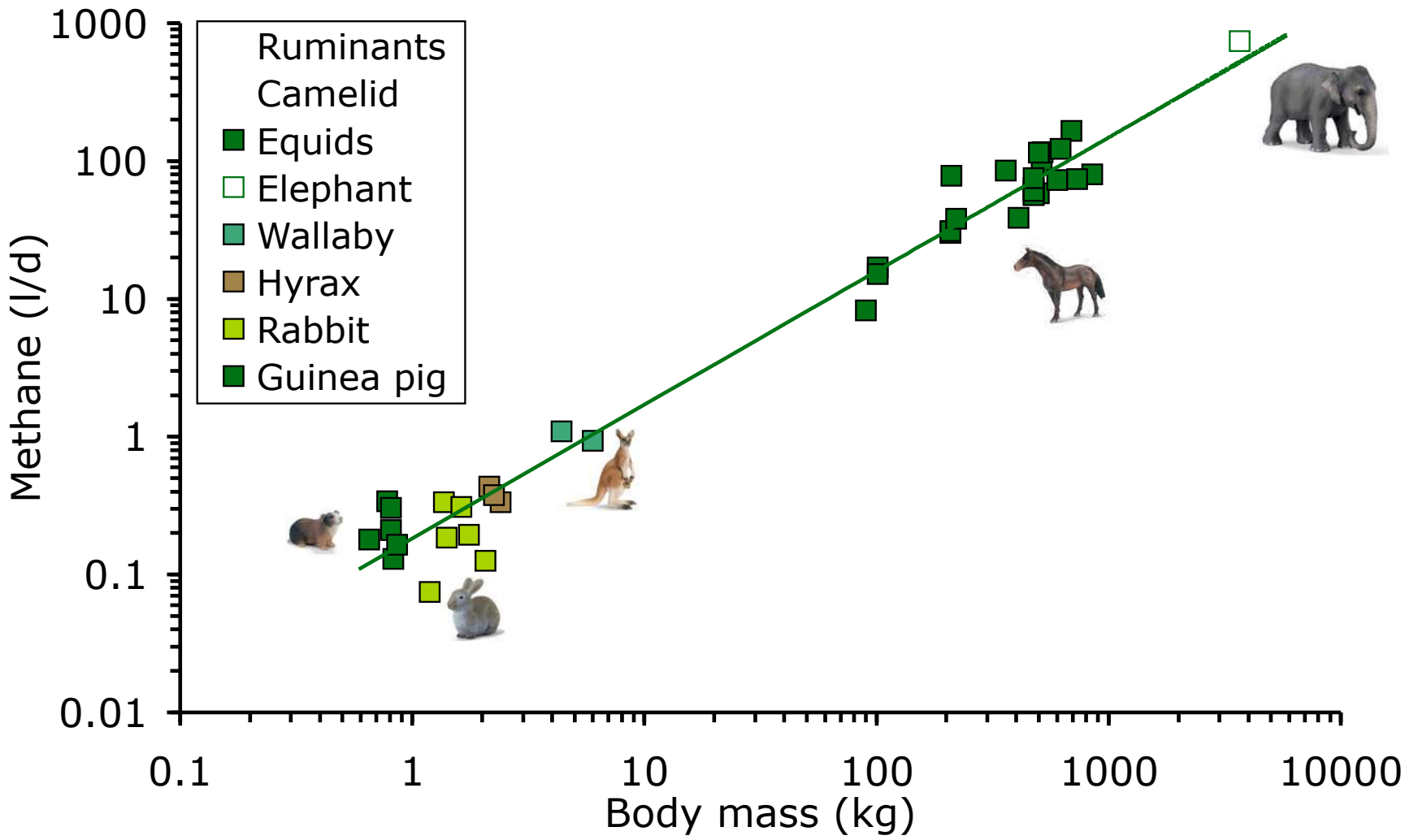
Why / how do equids survive (only in the upper ruminant body size range, and only in the grazing niche)?

Other differences: Methane production?



from Franz et al. (2010)

Other differences: Methane production?



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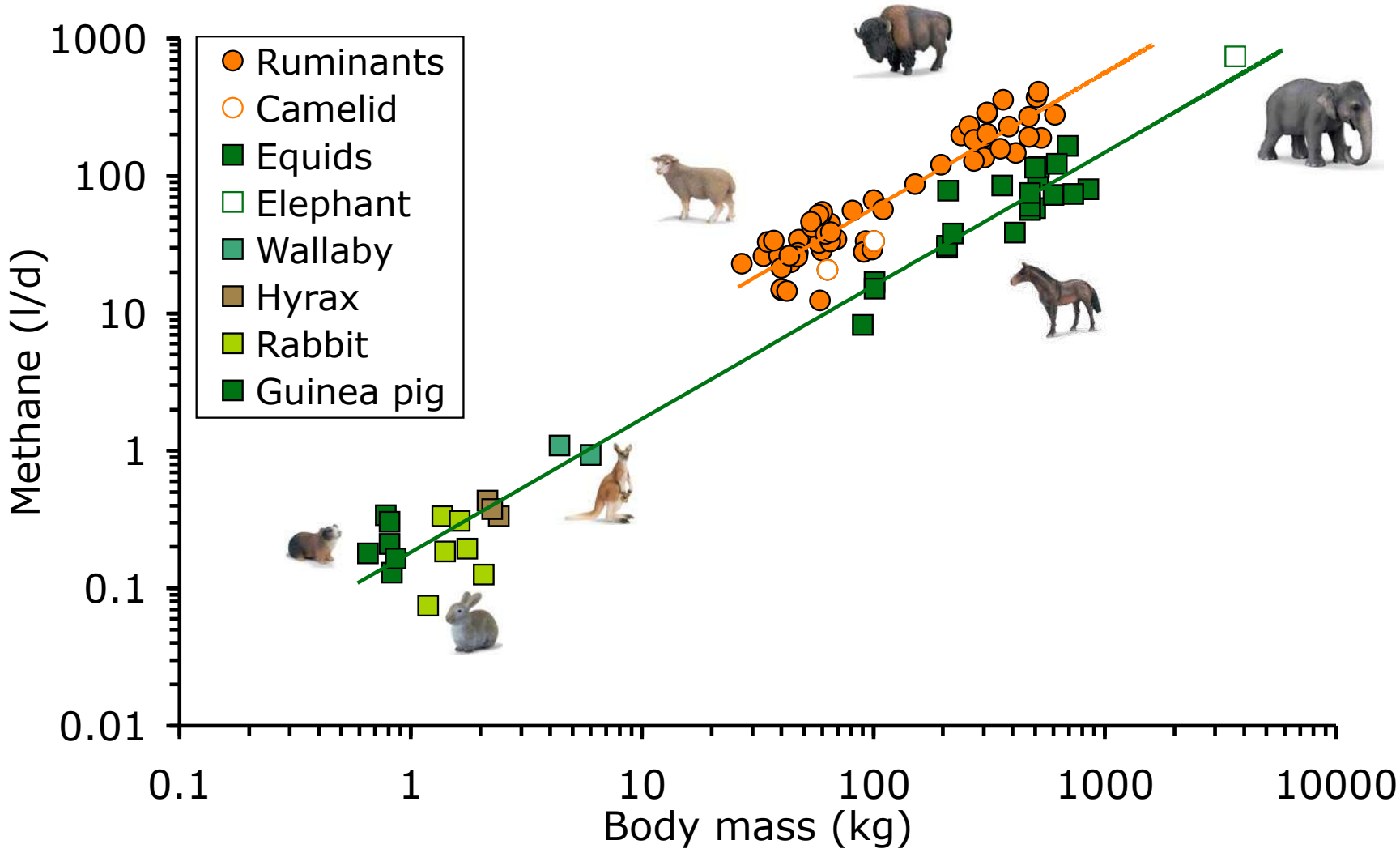
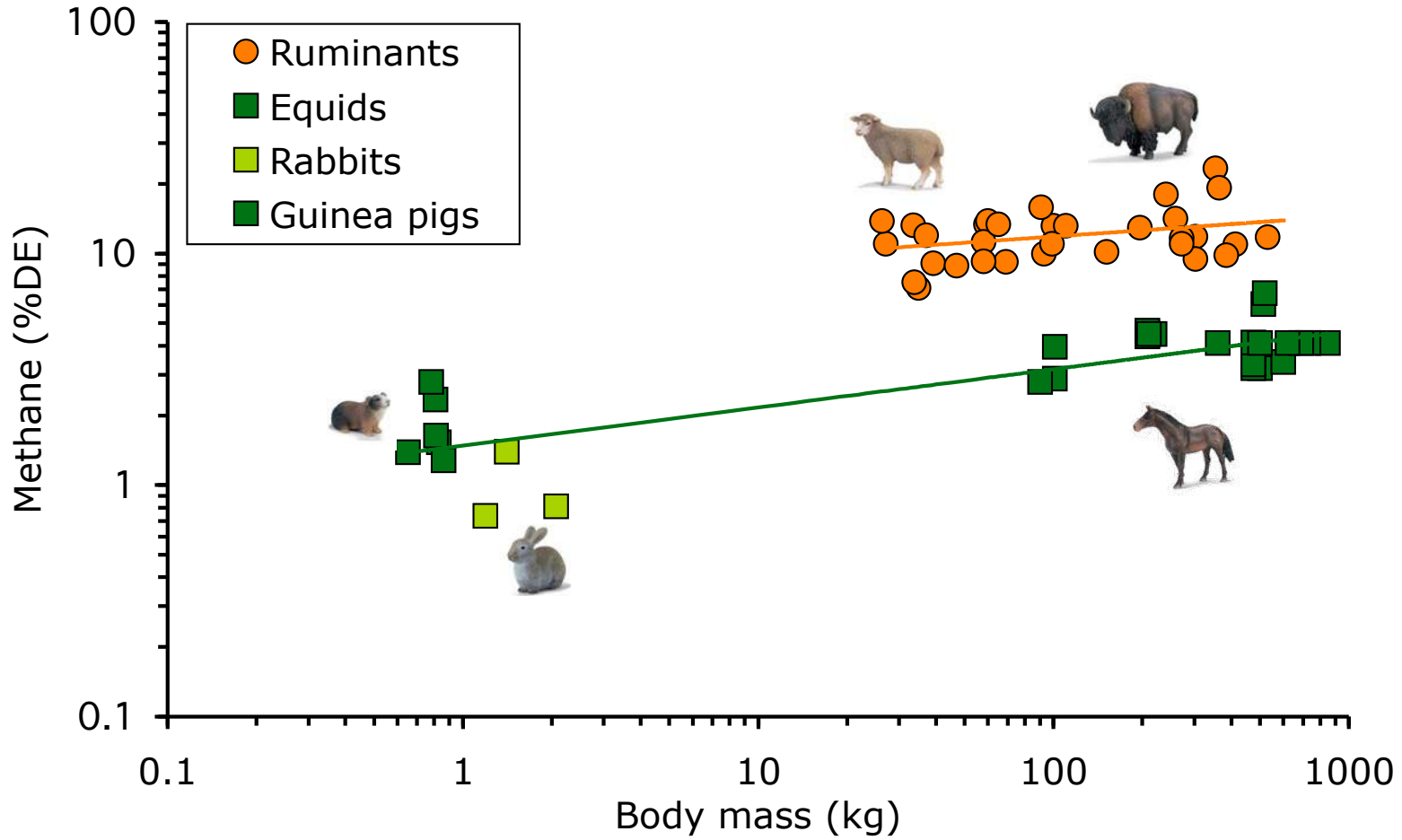


from Franz et al. (2010)

Other differences: Methane production?



from Franz et al. (2010)