Examples of evolutionary sequences and concepts of evolutionary constraints

Marcus Clauss

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

Wildlife Digestive Physiology Course Vienna 2013

University of Zurich
Vetsuisse Faculty

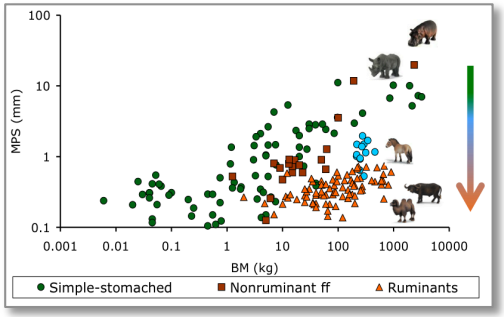
Clinic
of Zoo Animals, Exotic Pets and Wildlife

Evolutionary sequences: narratives using physiological and life history characteristics

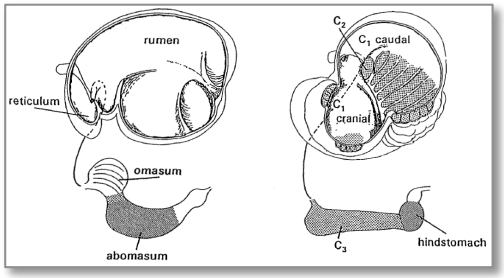
Application: large herbivore diversity through time

Equids, Camelids, Pecora:

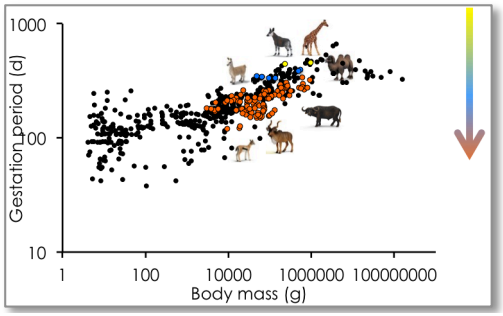
- Higher feeding efficiency due to higher digestibility (particle size reduction) in ruminants



- Higher sorting efficiency => higher potential food intake in Pecora



- Shorter gestation periods in Pecora vs. Camelids



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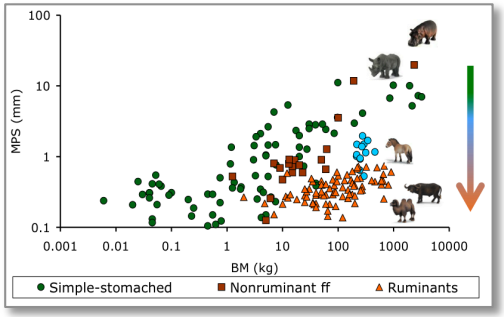

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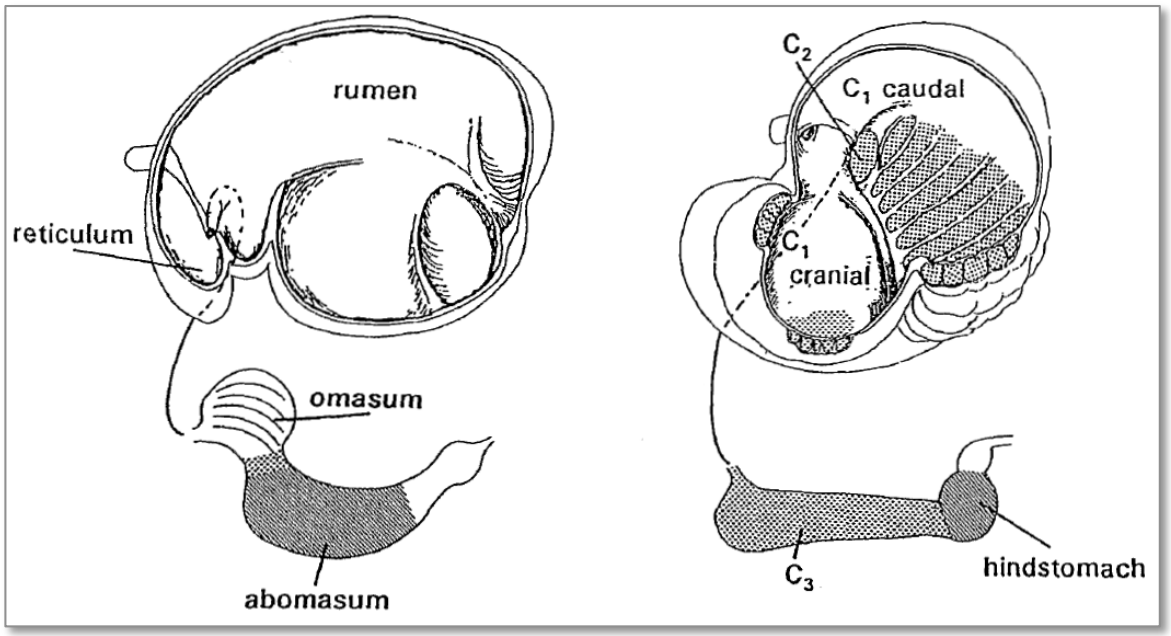

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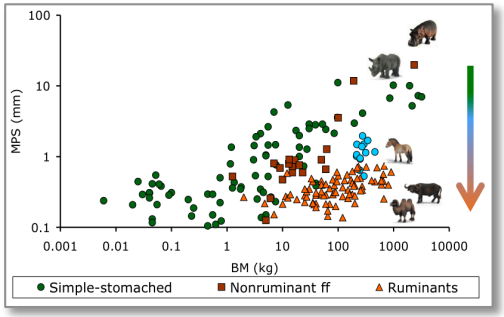

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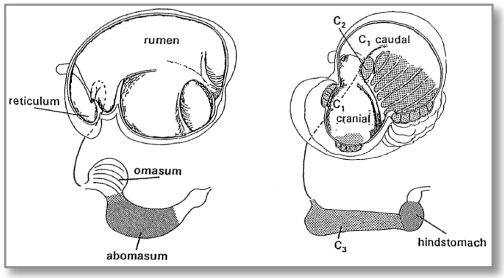

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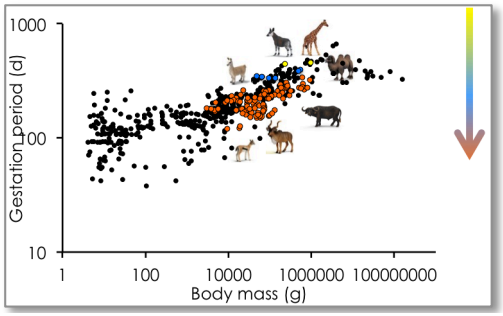

Application: large herbivore diversity through time

Historical Biology, 1994, Vol. 8, pp. 15–29
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MODELLING EQUID/RUMINANT COMPETITION IN THE FOSSIL RECORD

CHRISTINE M. JANIS[1], IAIN J. GORDON[2] and ANDREW W. ILLIUS[3]

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[2]*Macaulay Land Use Research Institute, Craigiebuckler, Aberdeen AB9 2QY, UK*
[3]*School of Agriculture, University of Edinburgh, West Mains Road, Edinburgh EH9, 3JG, UK*

(Received November 2, 1993)

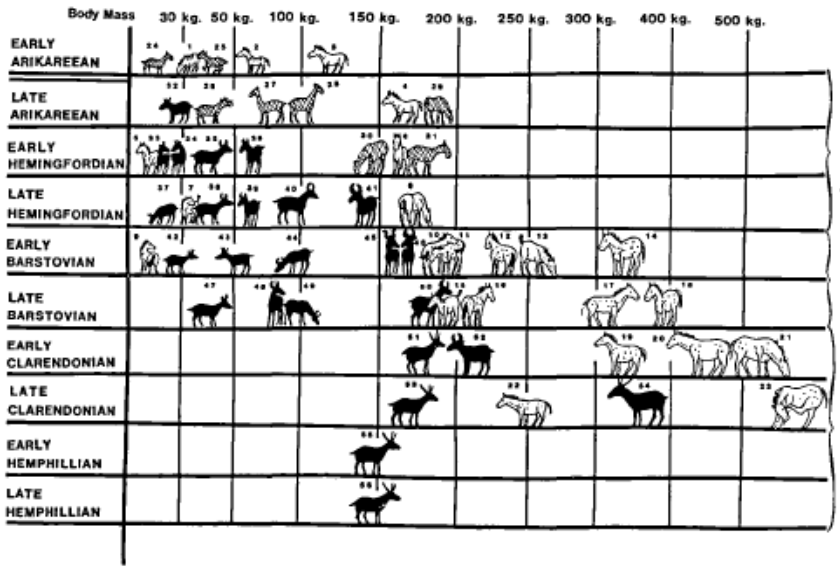

Figure 3 Body size distribution of browsing Miocene equids and ruminants. Key to ungulate taxa: A. Color of taxon: Striped horses=Mesohippines; white horses=Anchitherines; spotted horses=Hypohippines; black artiodactyls=Pecorans; cross-hatched artiodactyls=Tylopods.

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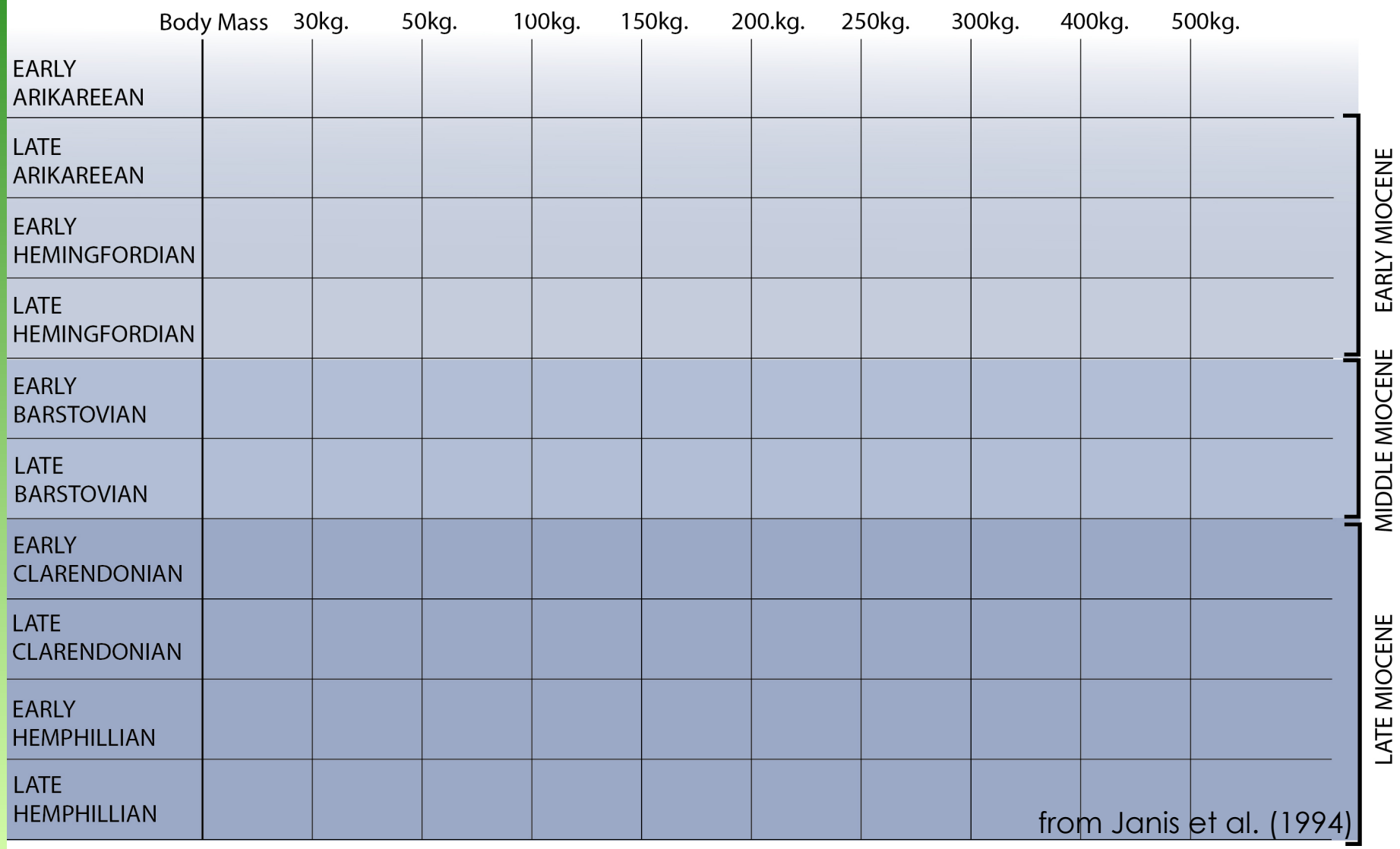

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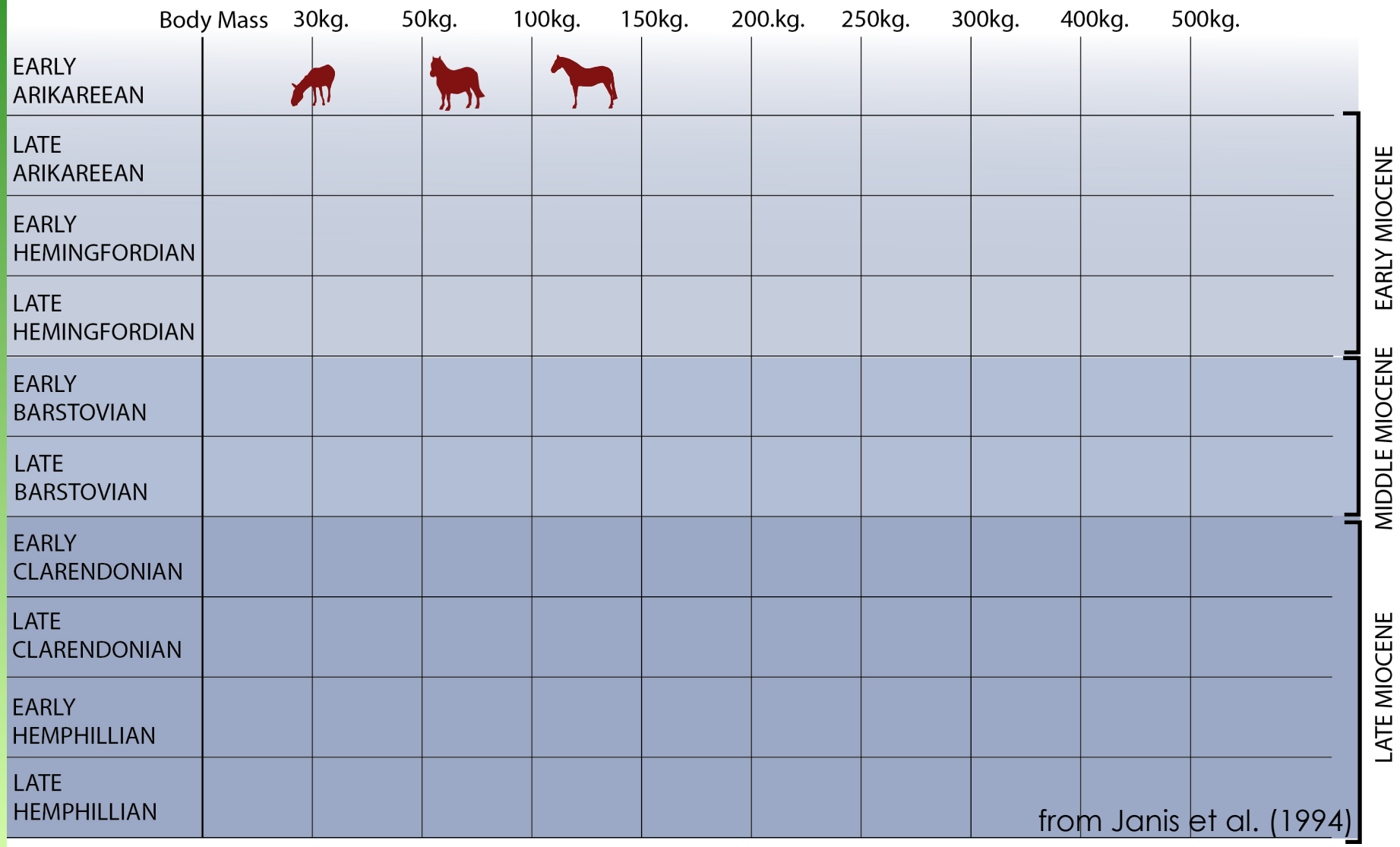

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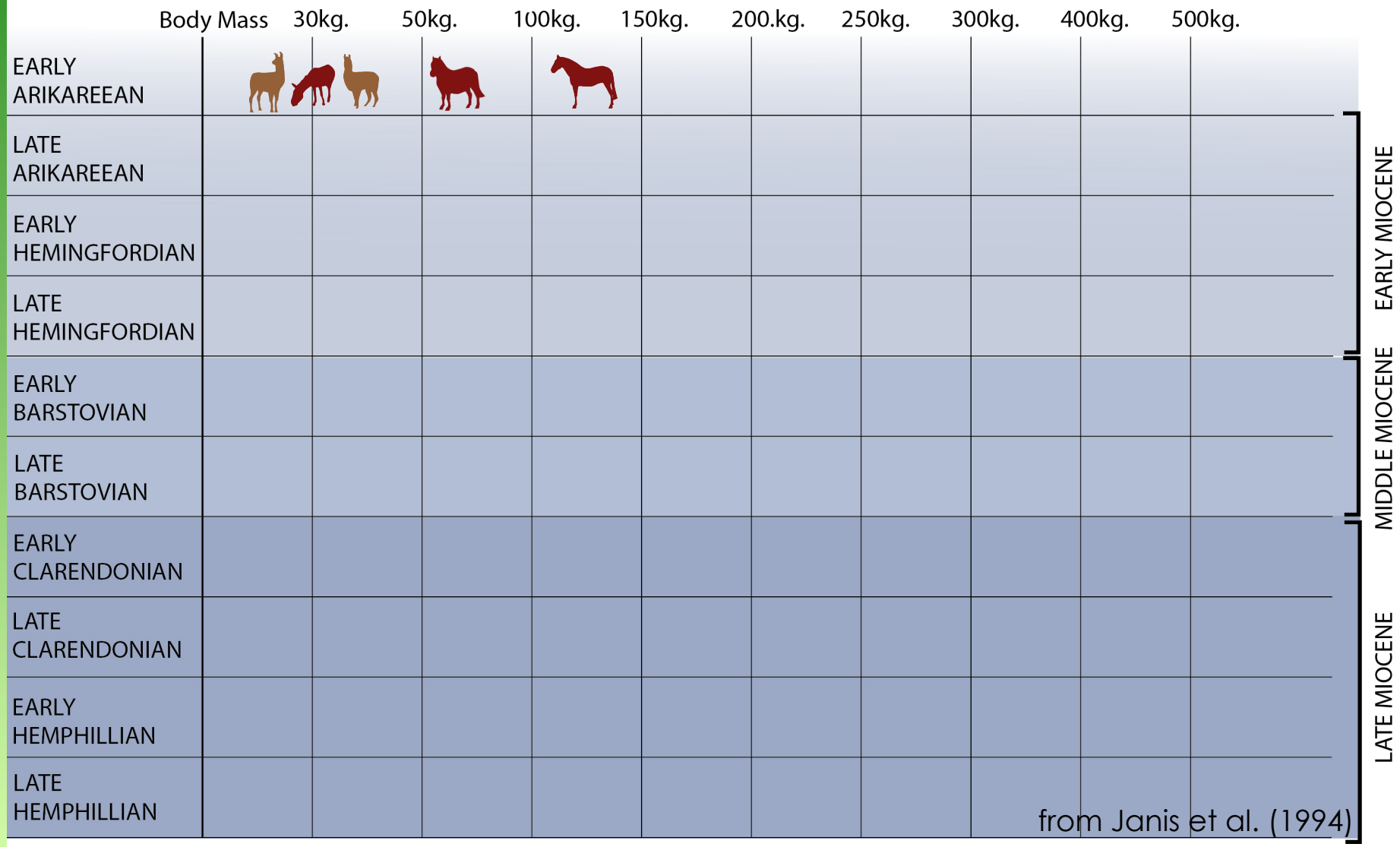

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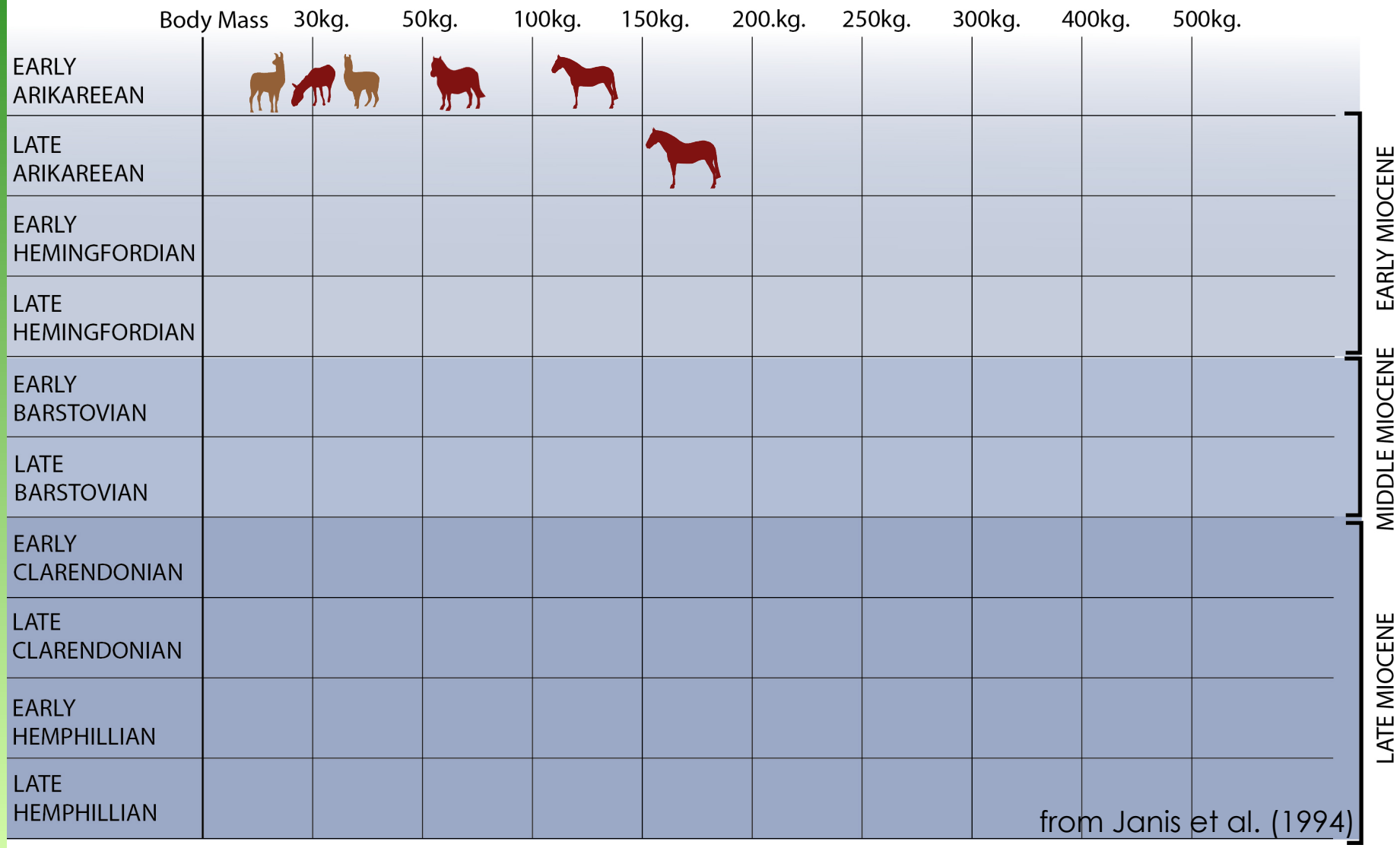

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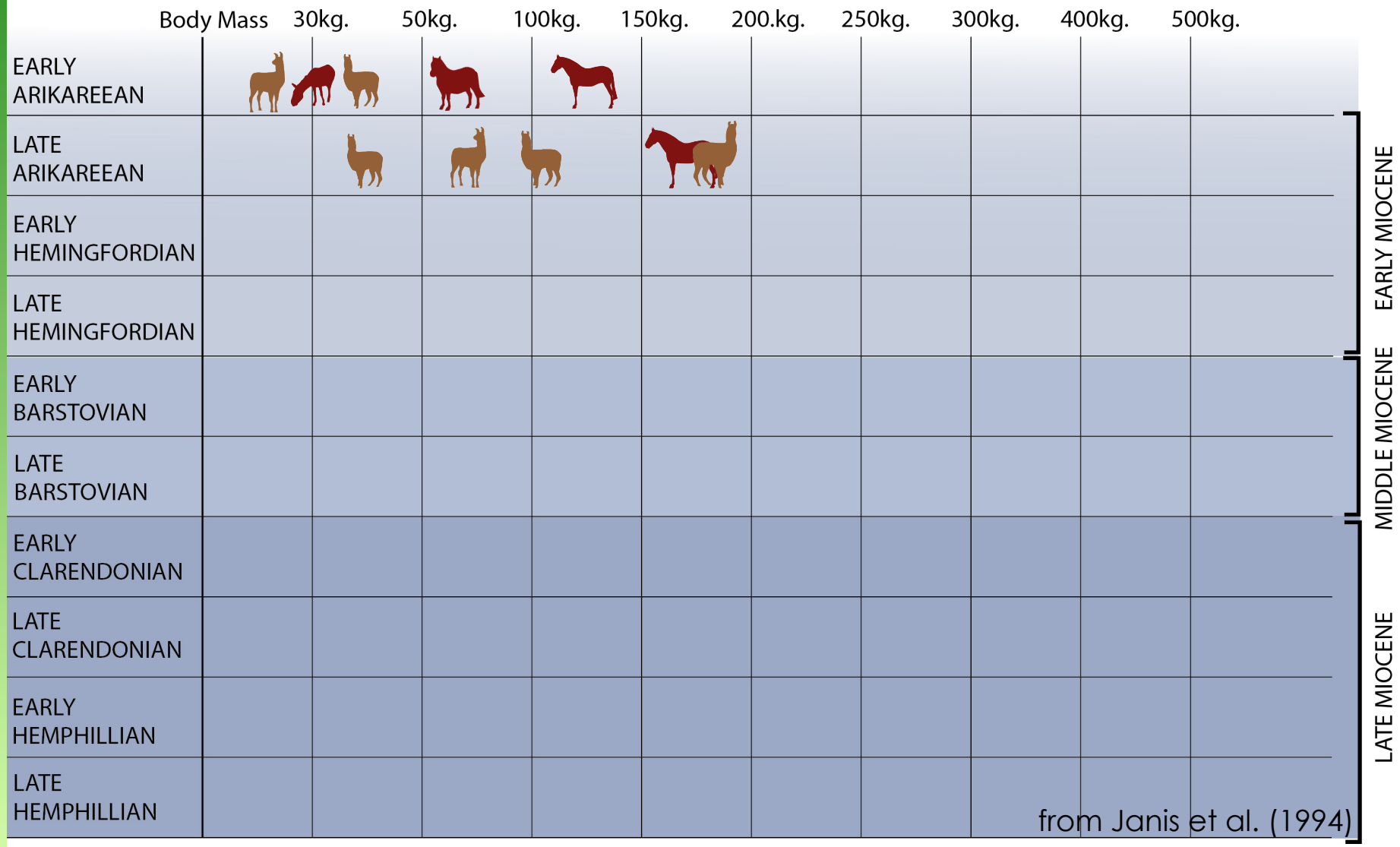

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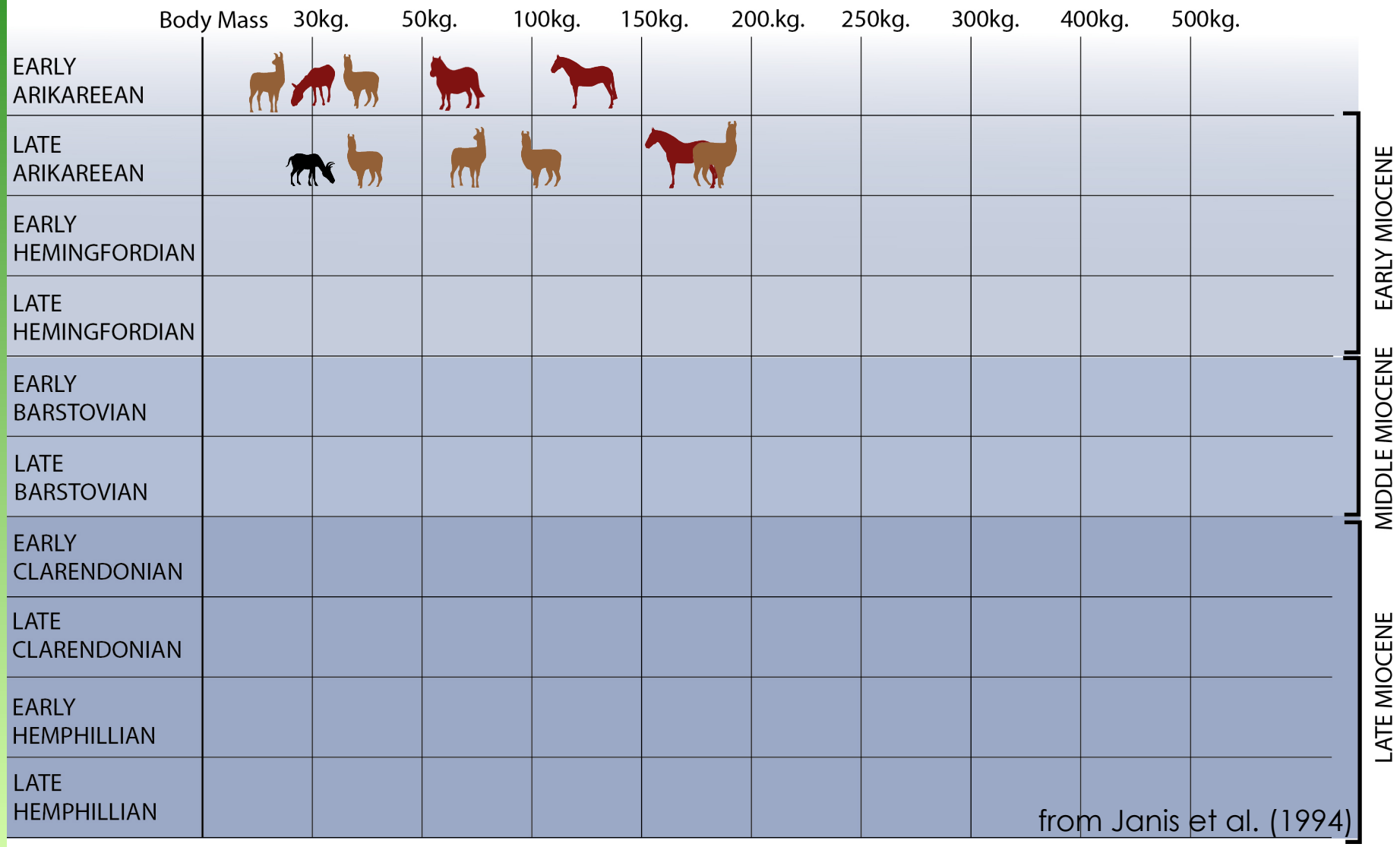

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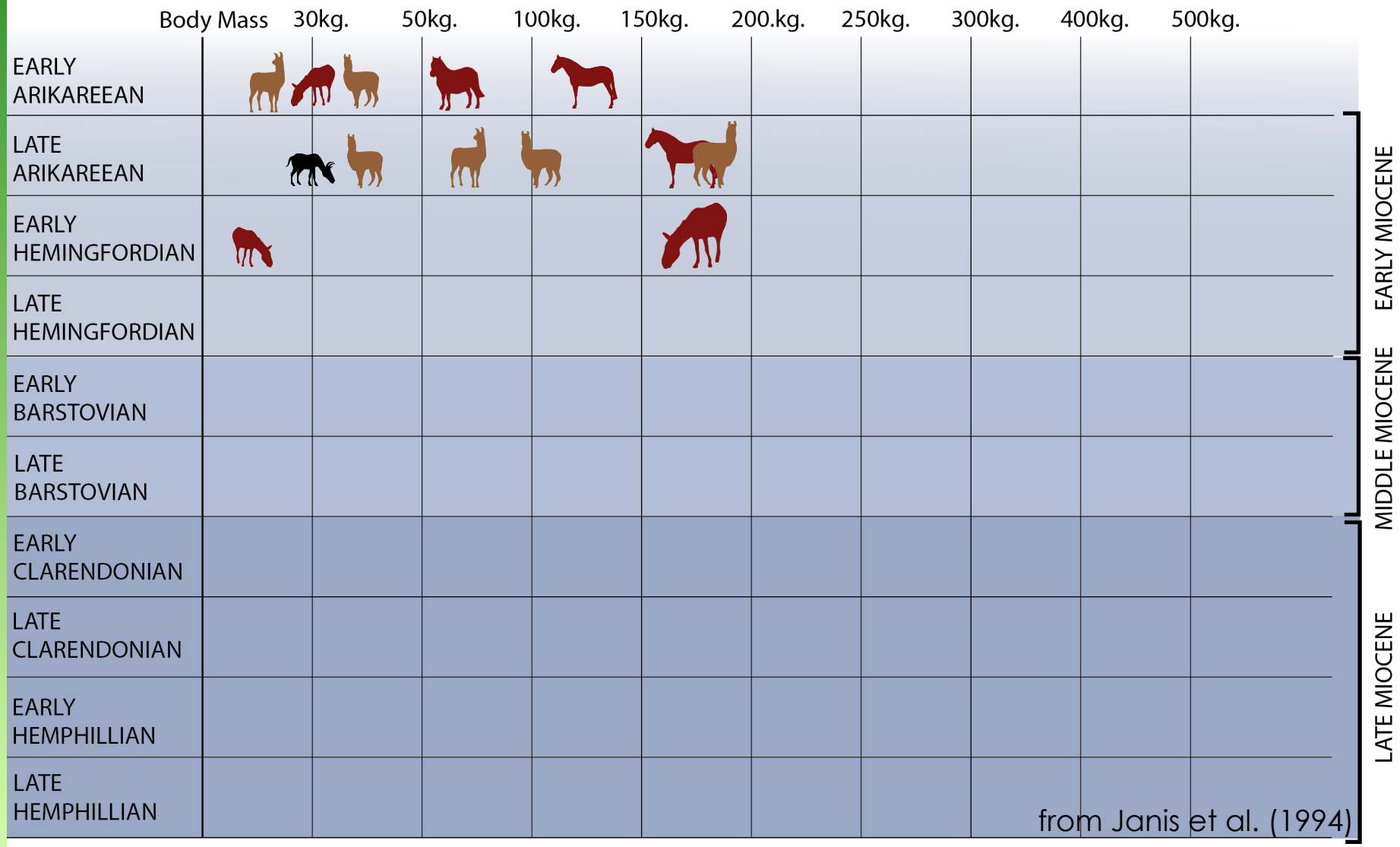

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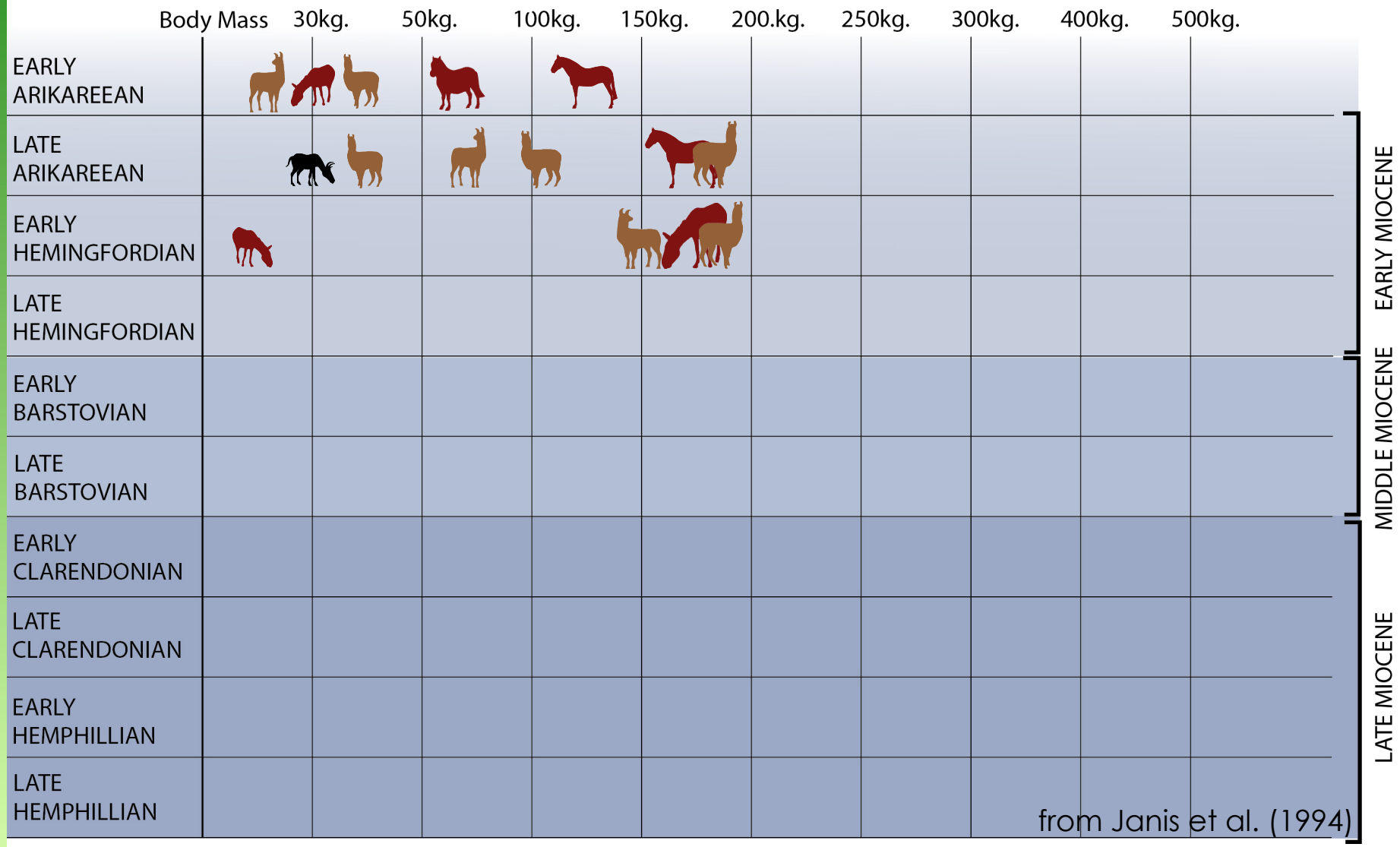

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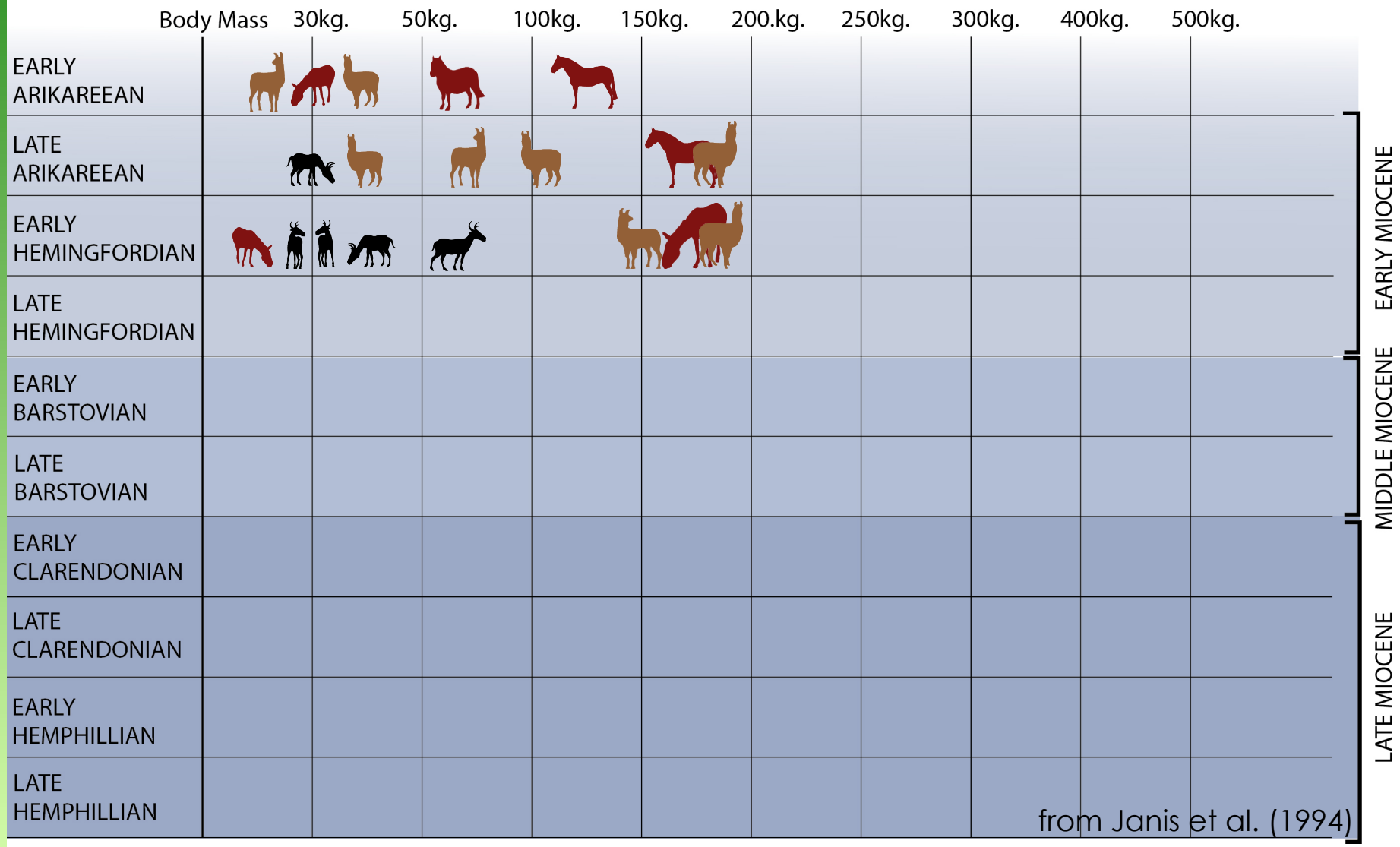

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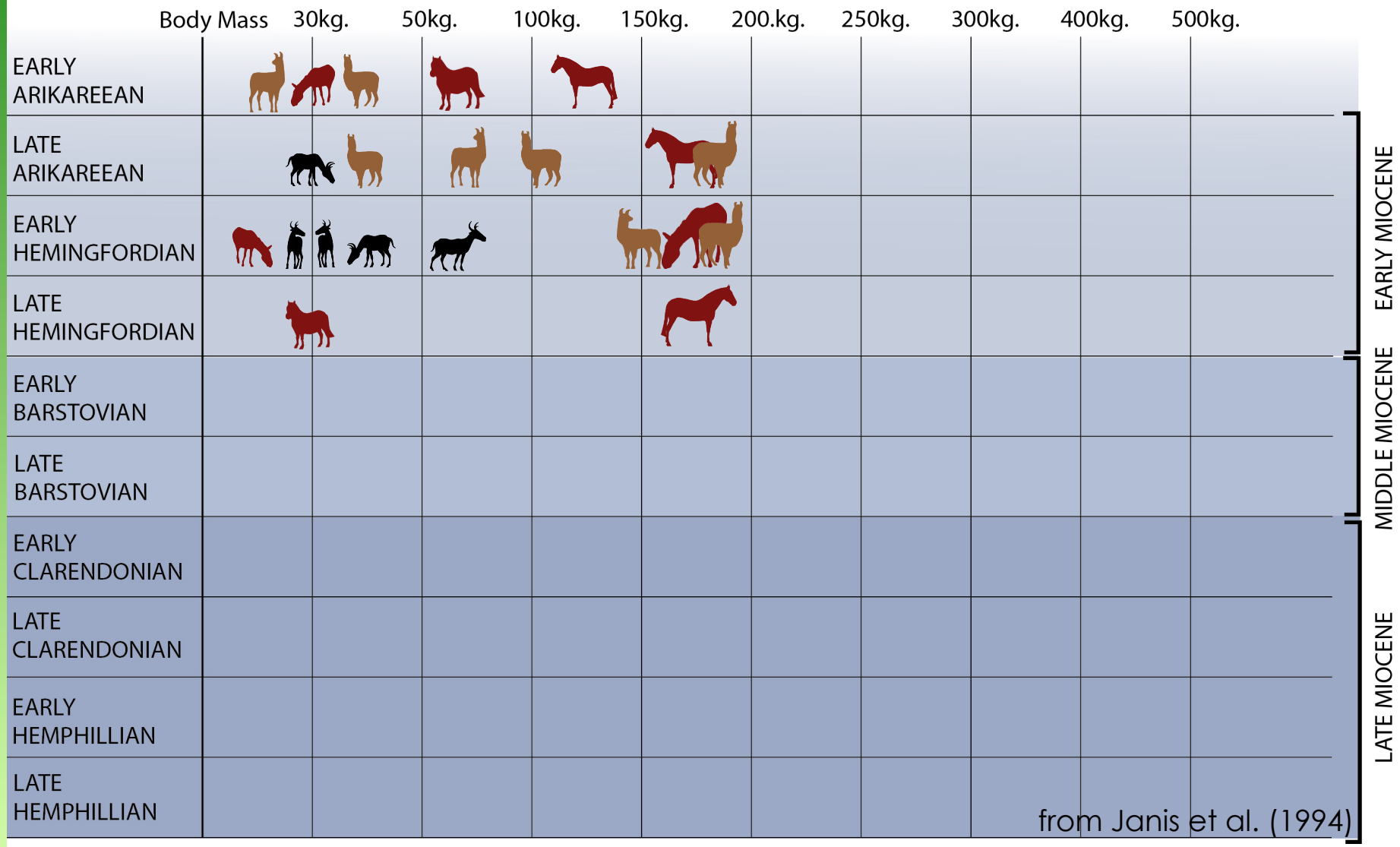

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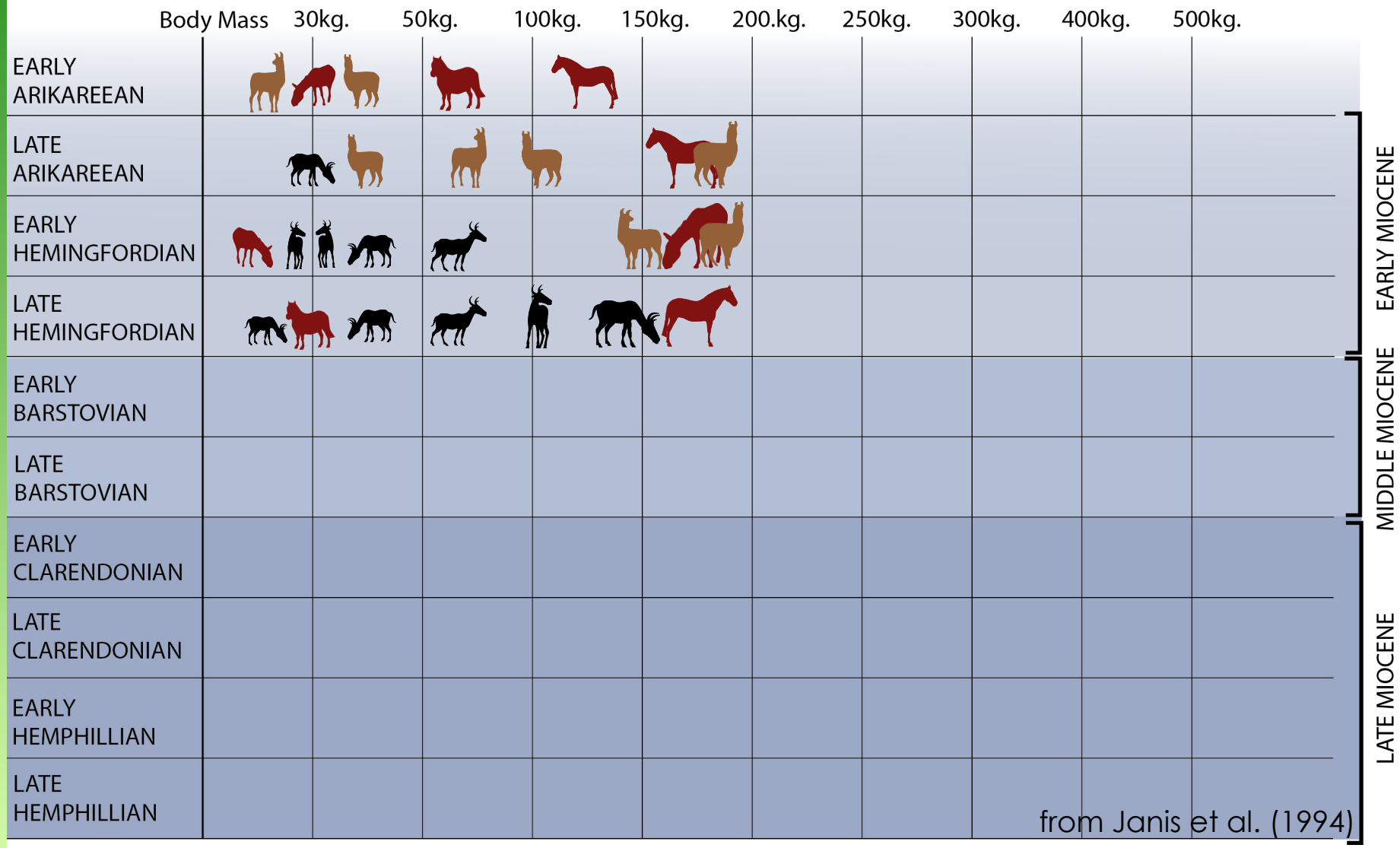

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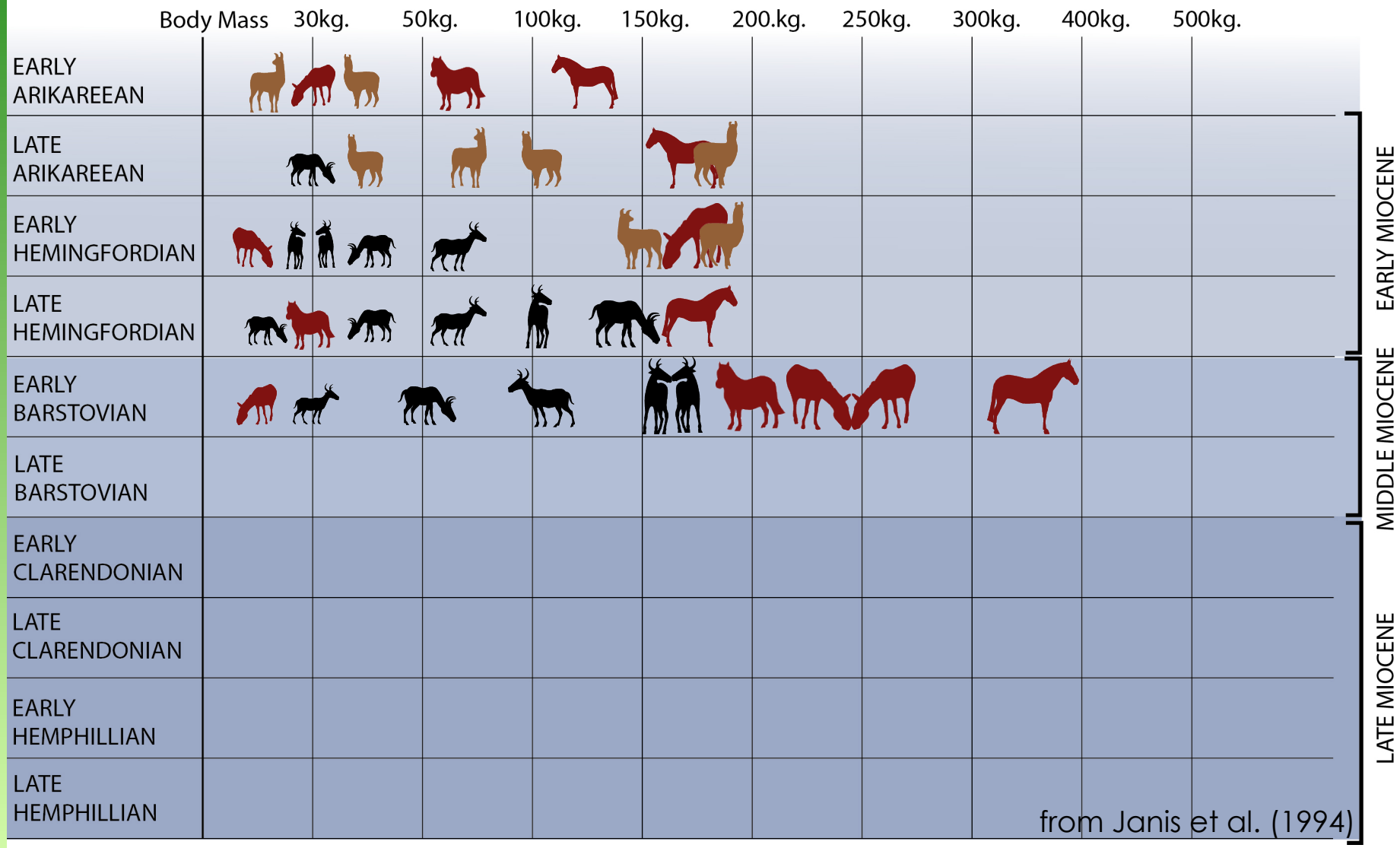

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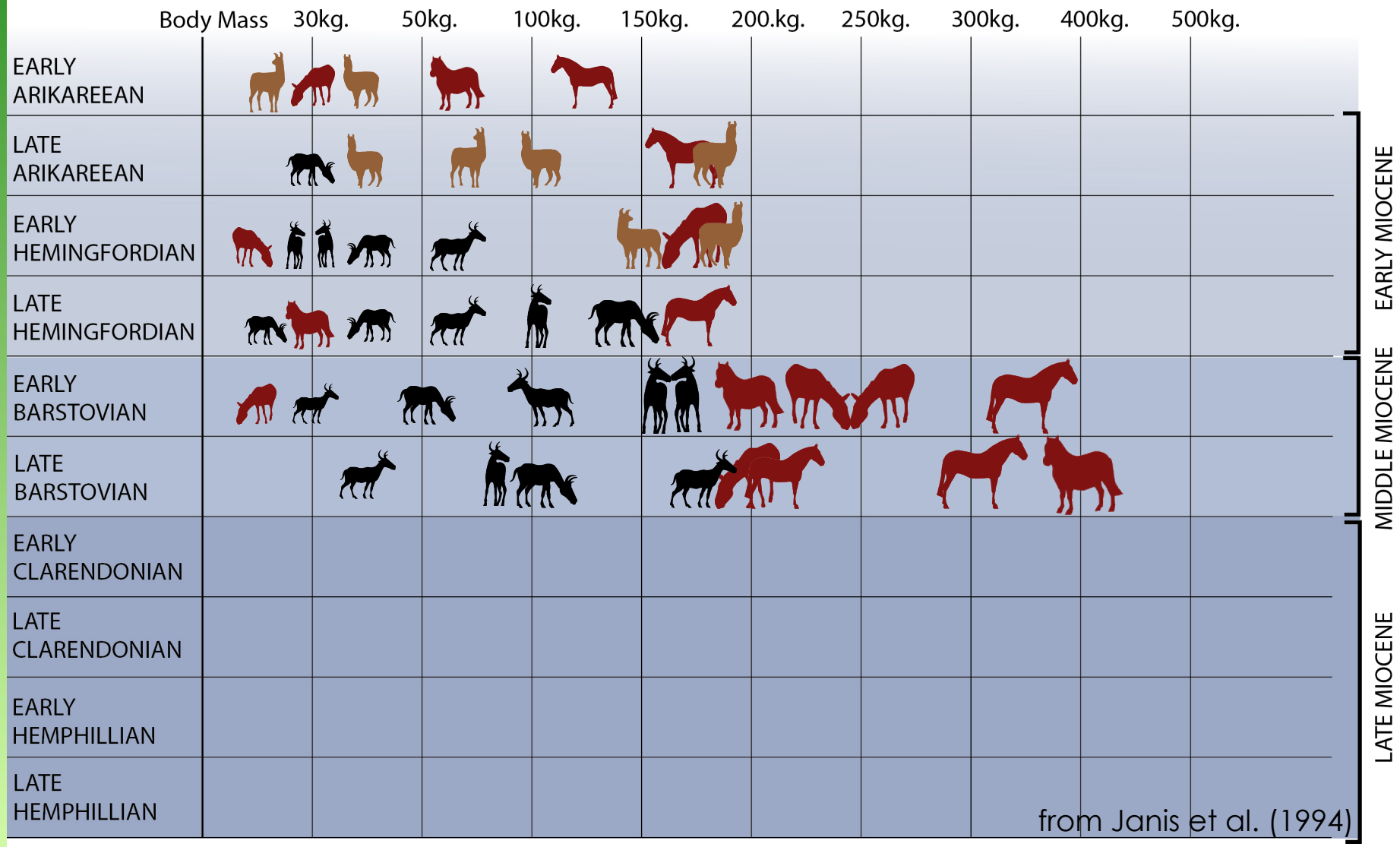

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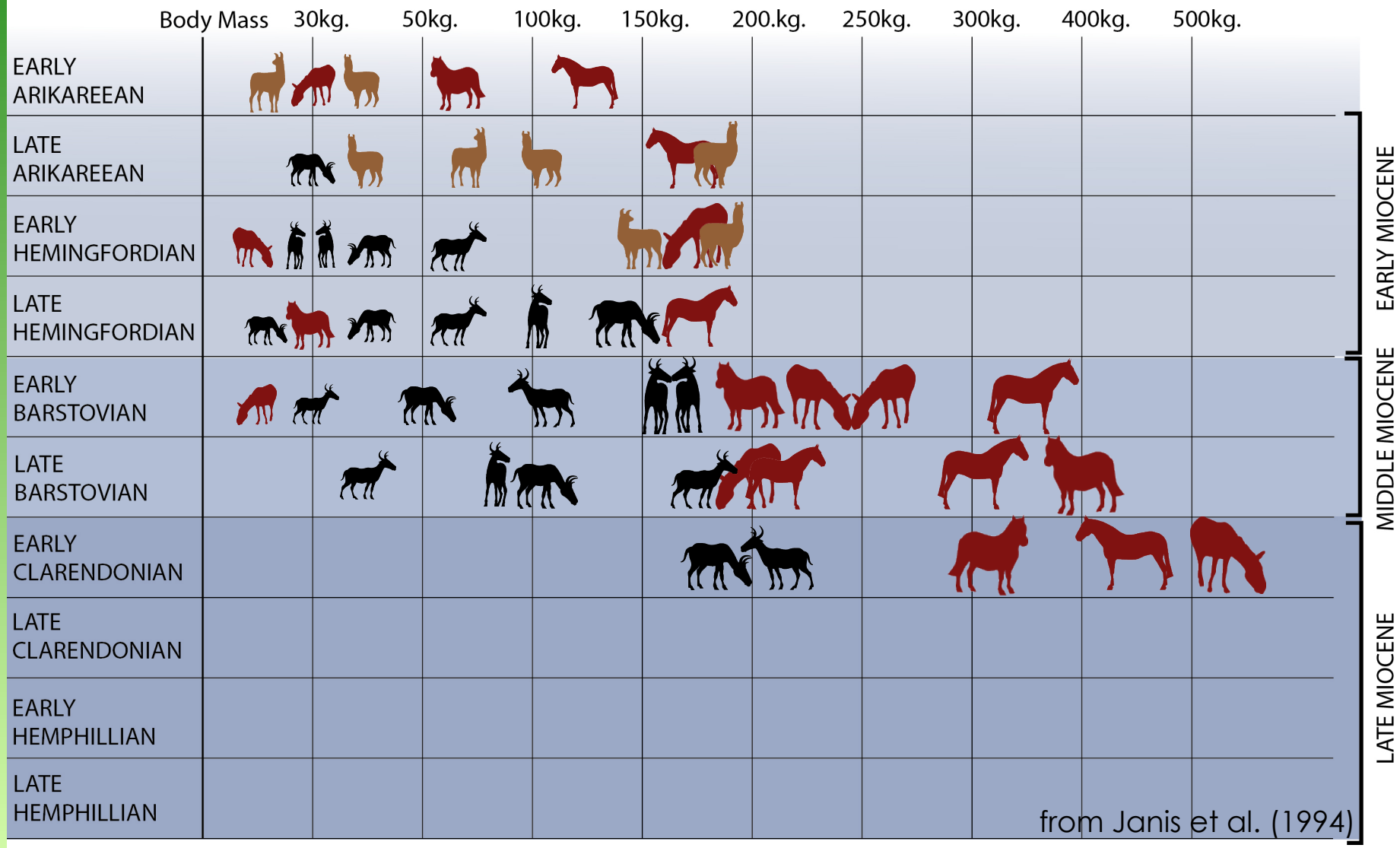

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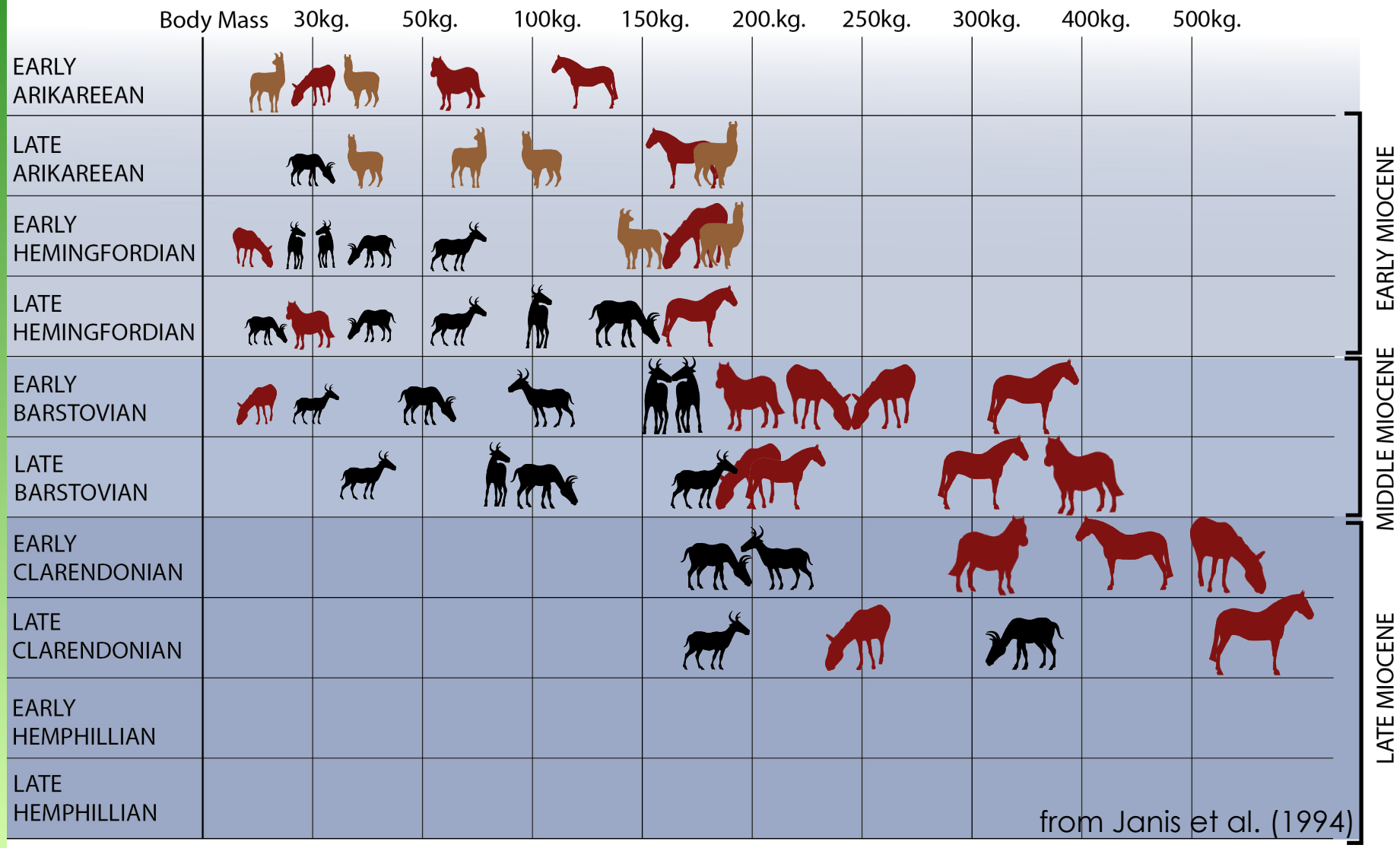

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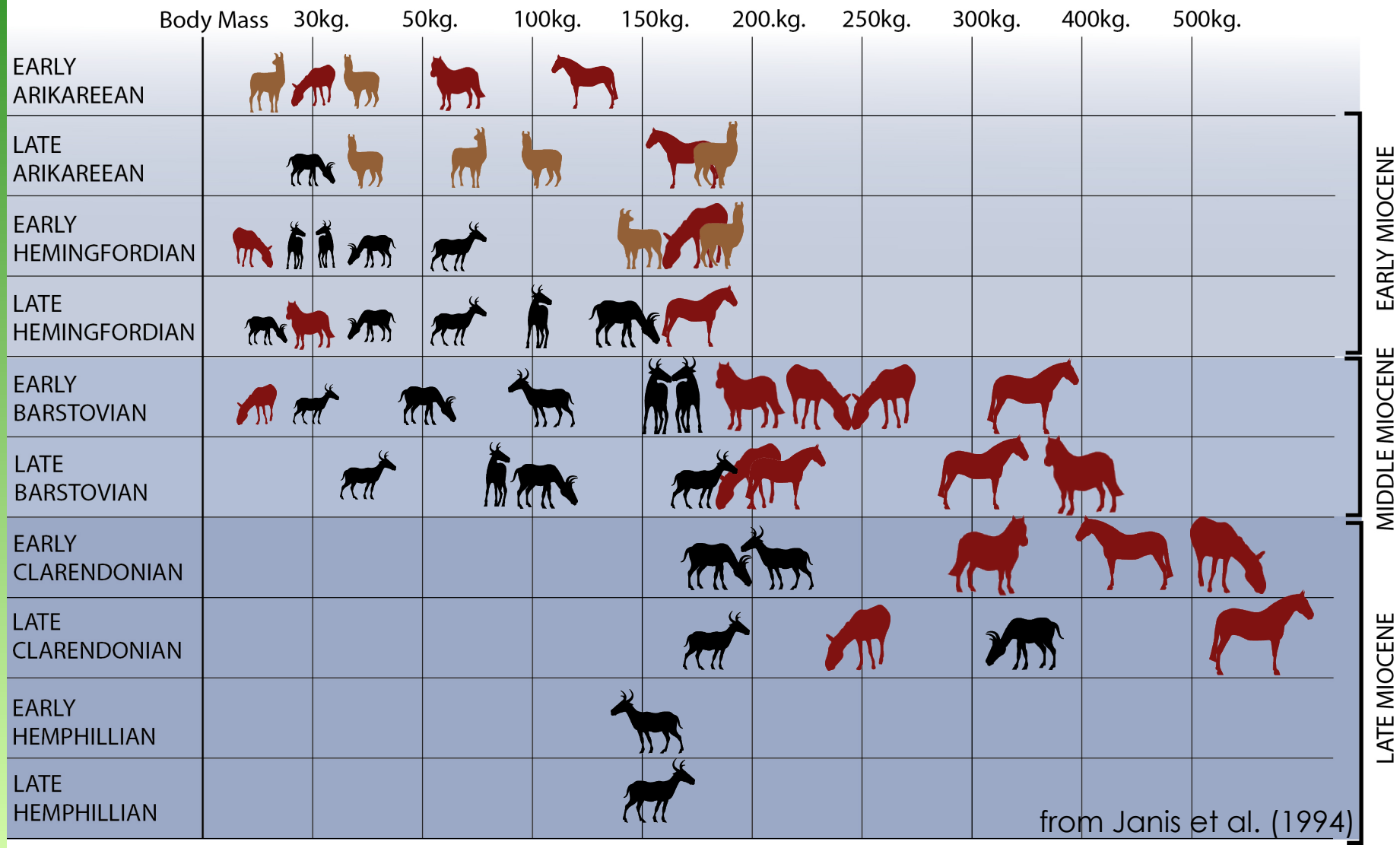

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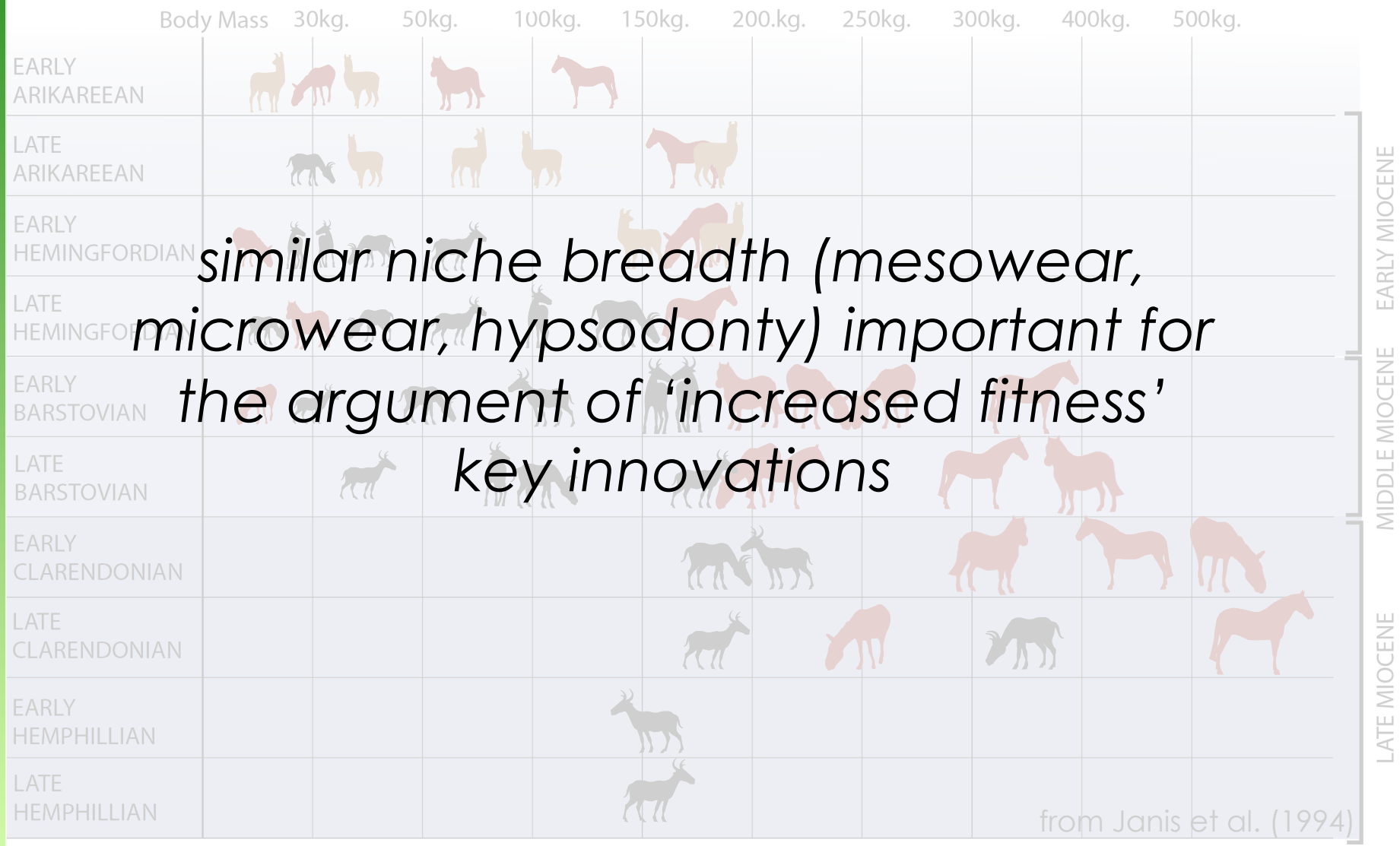

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Application: ruminant diversity through time

Tragulids and Pecora:

- Higher feeding efficiency due to the omasum in Pecora

from Clauss & Rössner (subm.)

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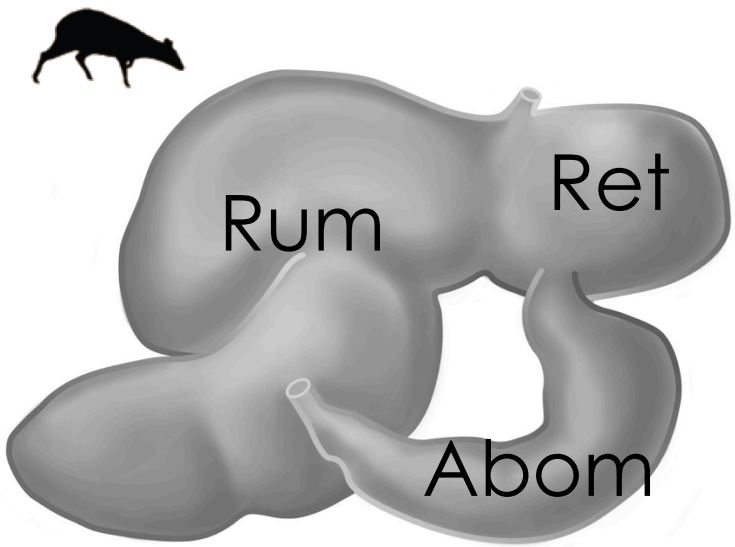

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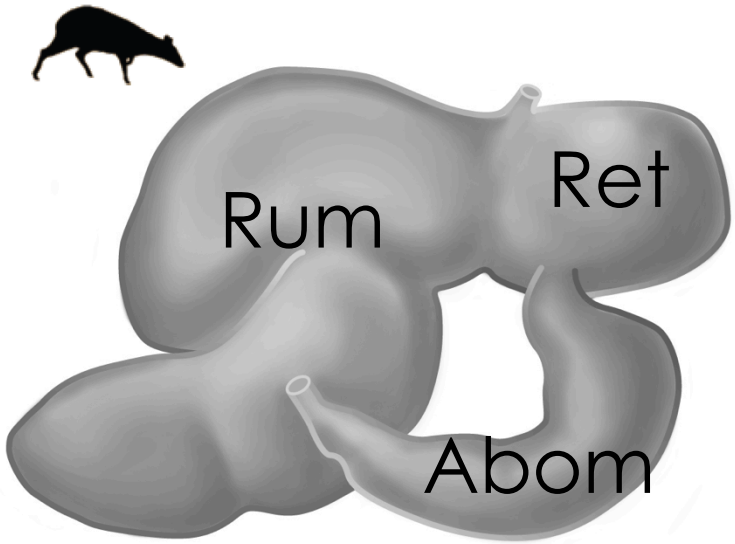

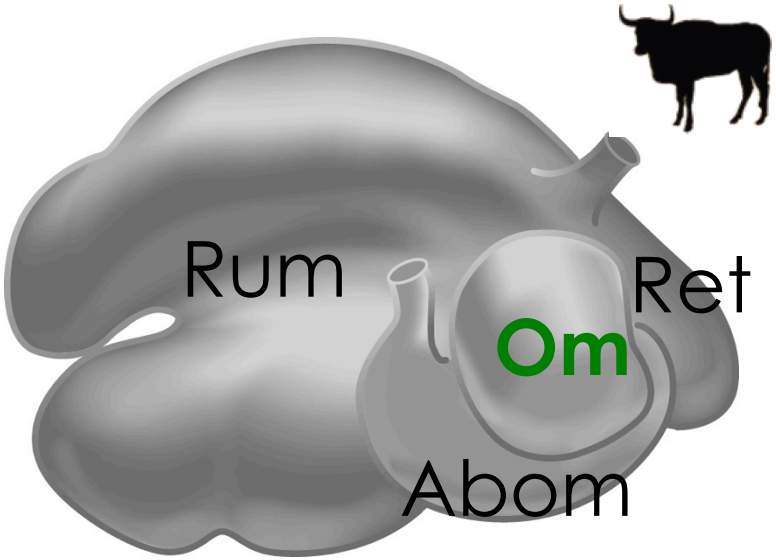

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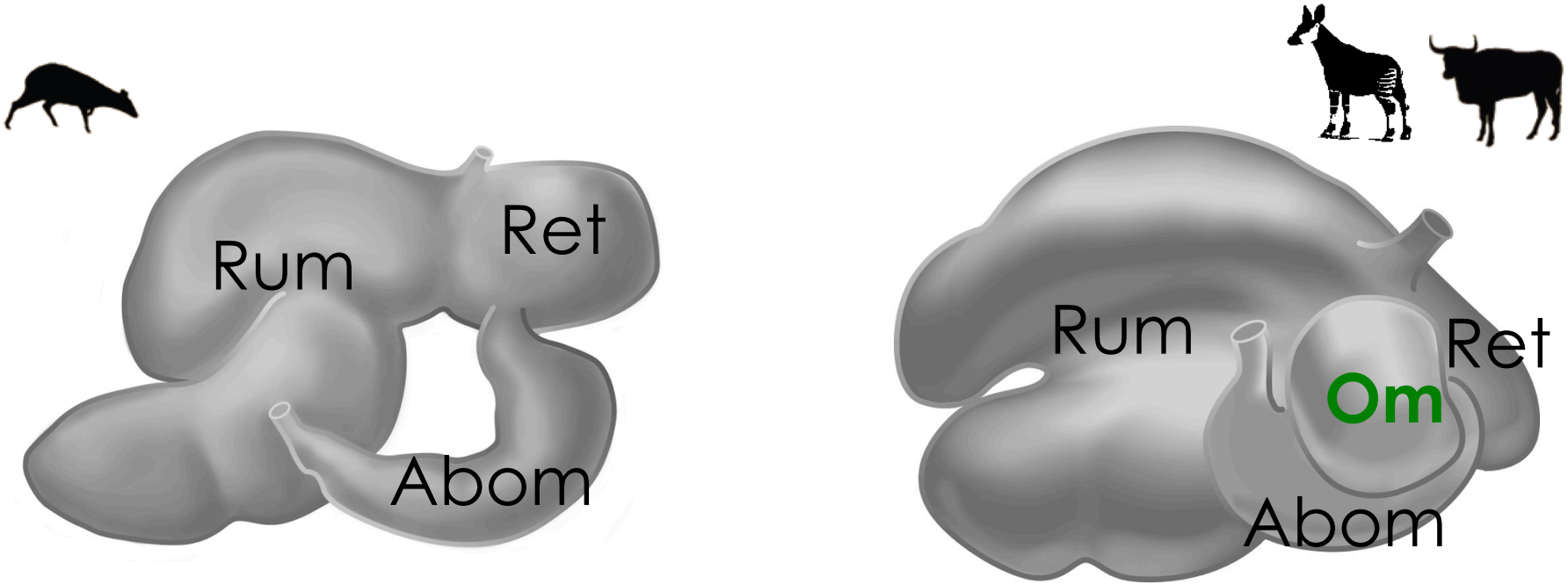

(should allow higher fluid throughput – harvest of forestomach bacteria; less strain on acid/enzyme production in abomasum)

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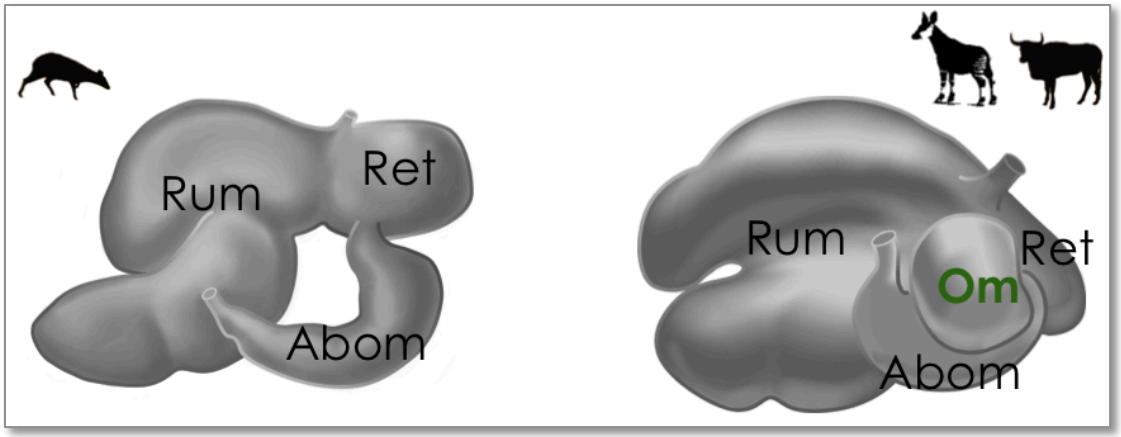

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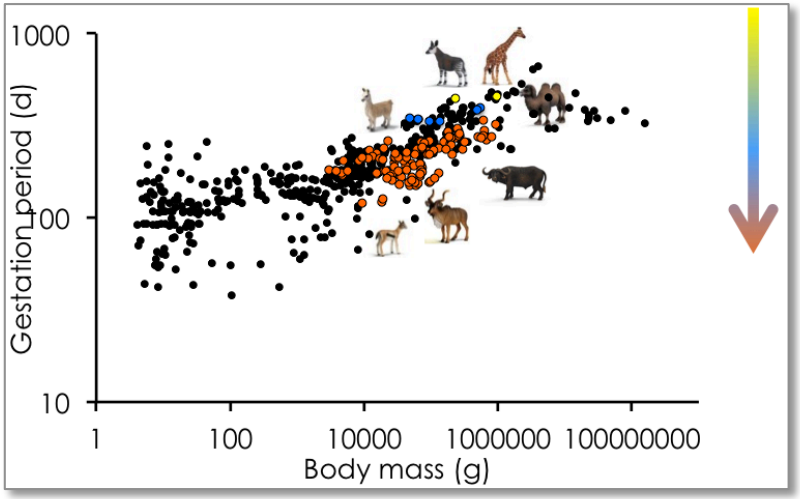
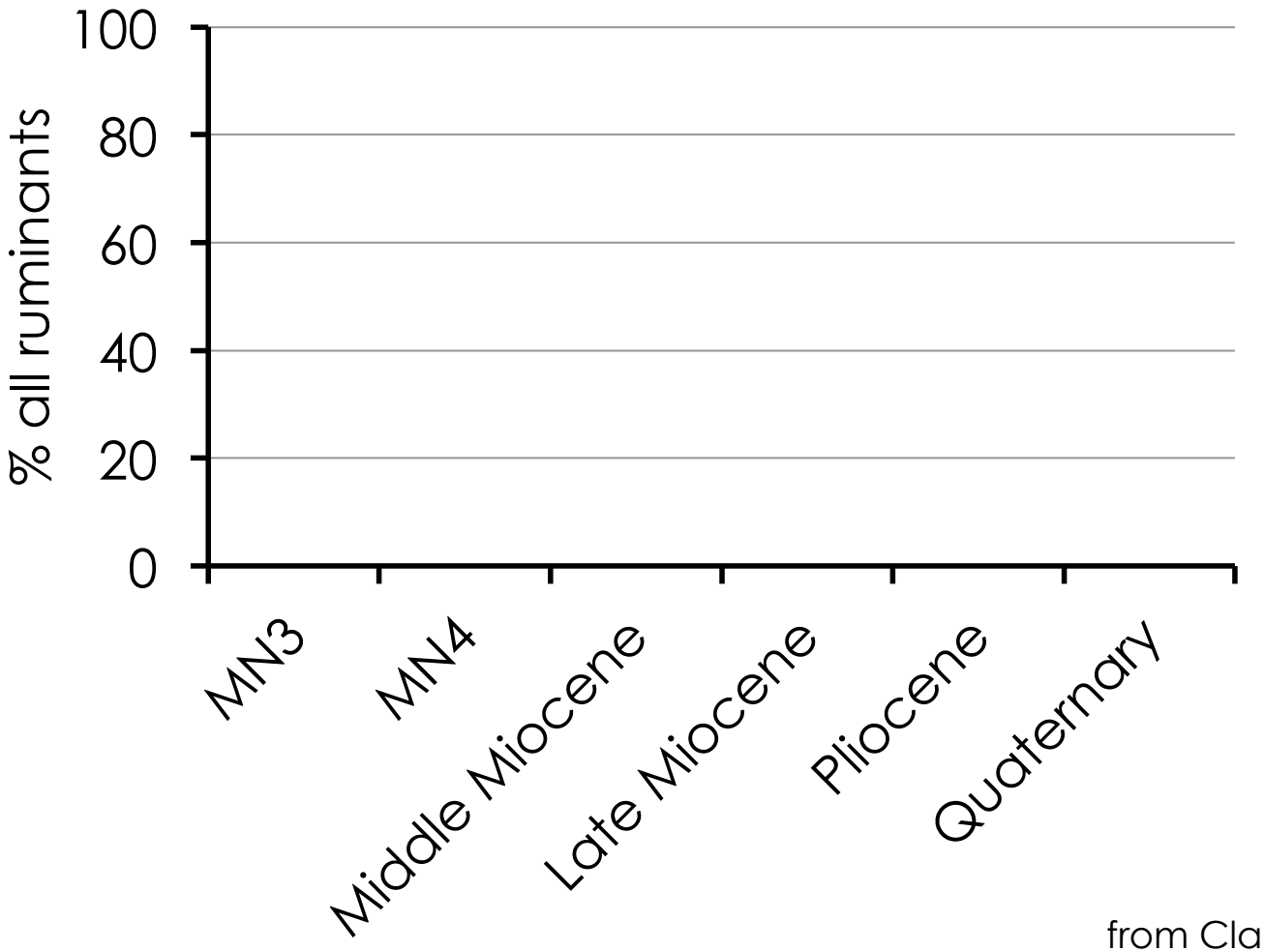


Application: ruminant diversity through time - Africa



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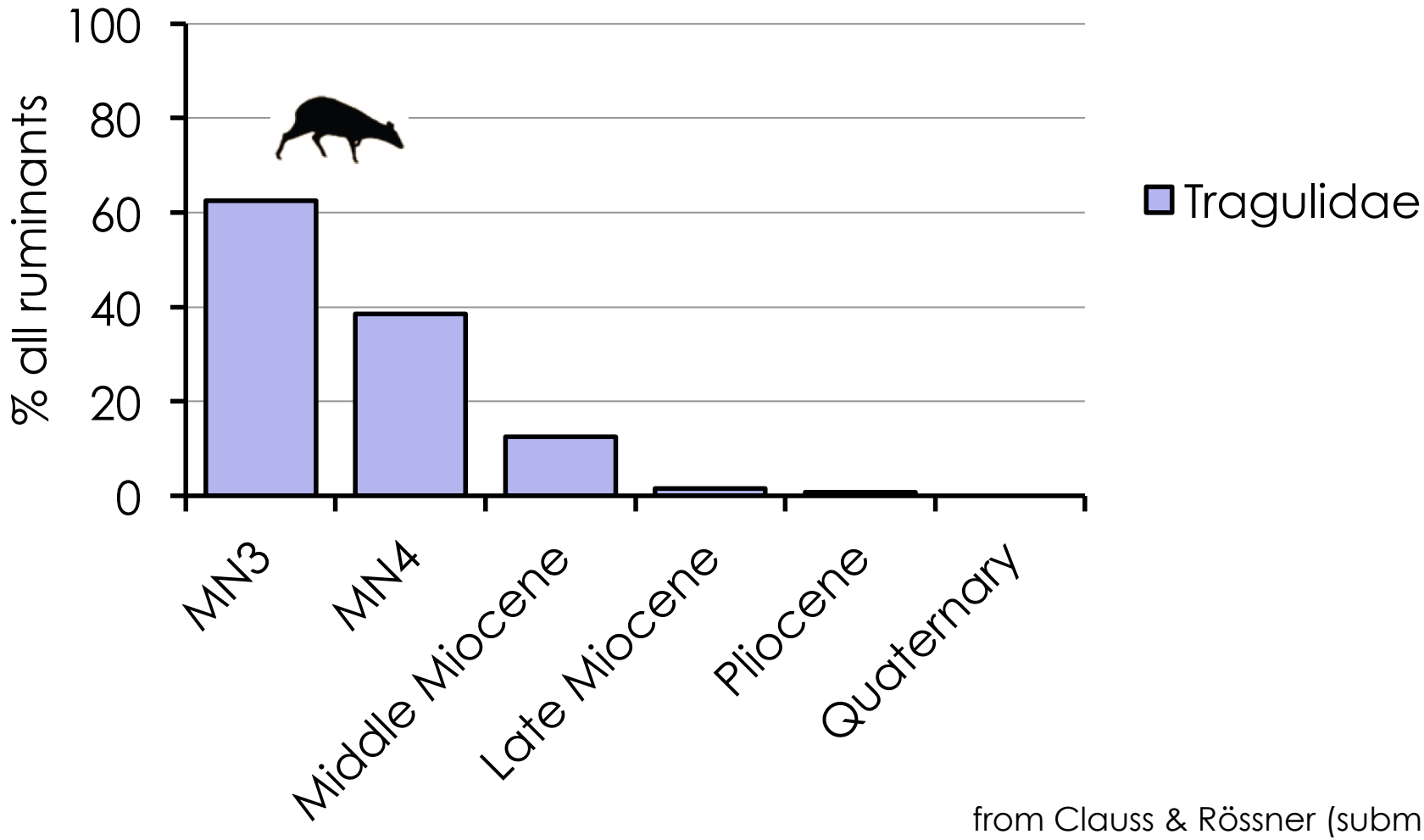

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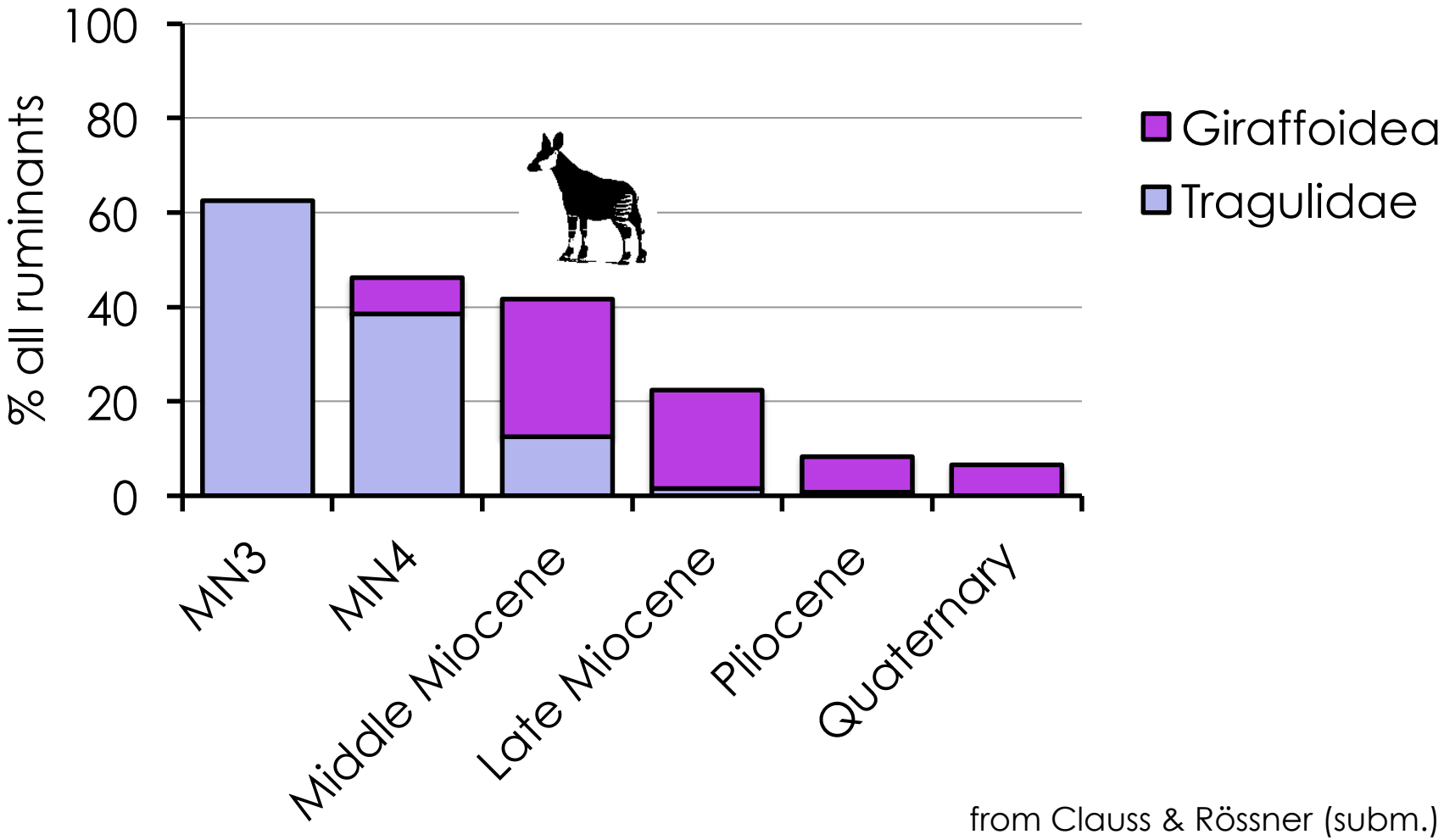

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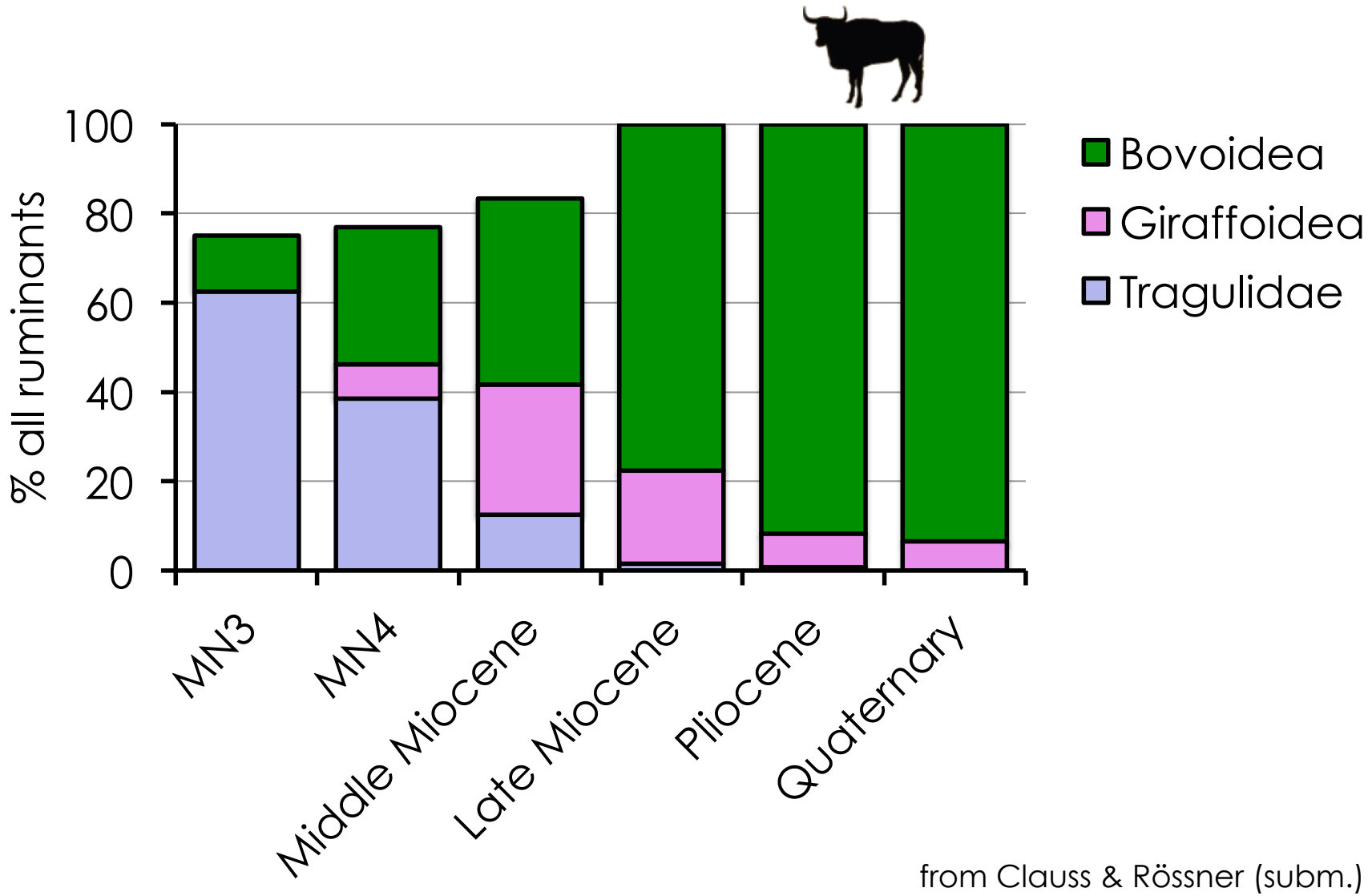

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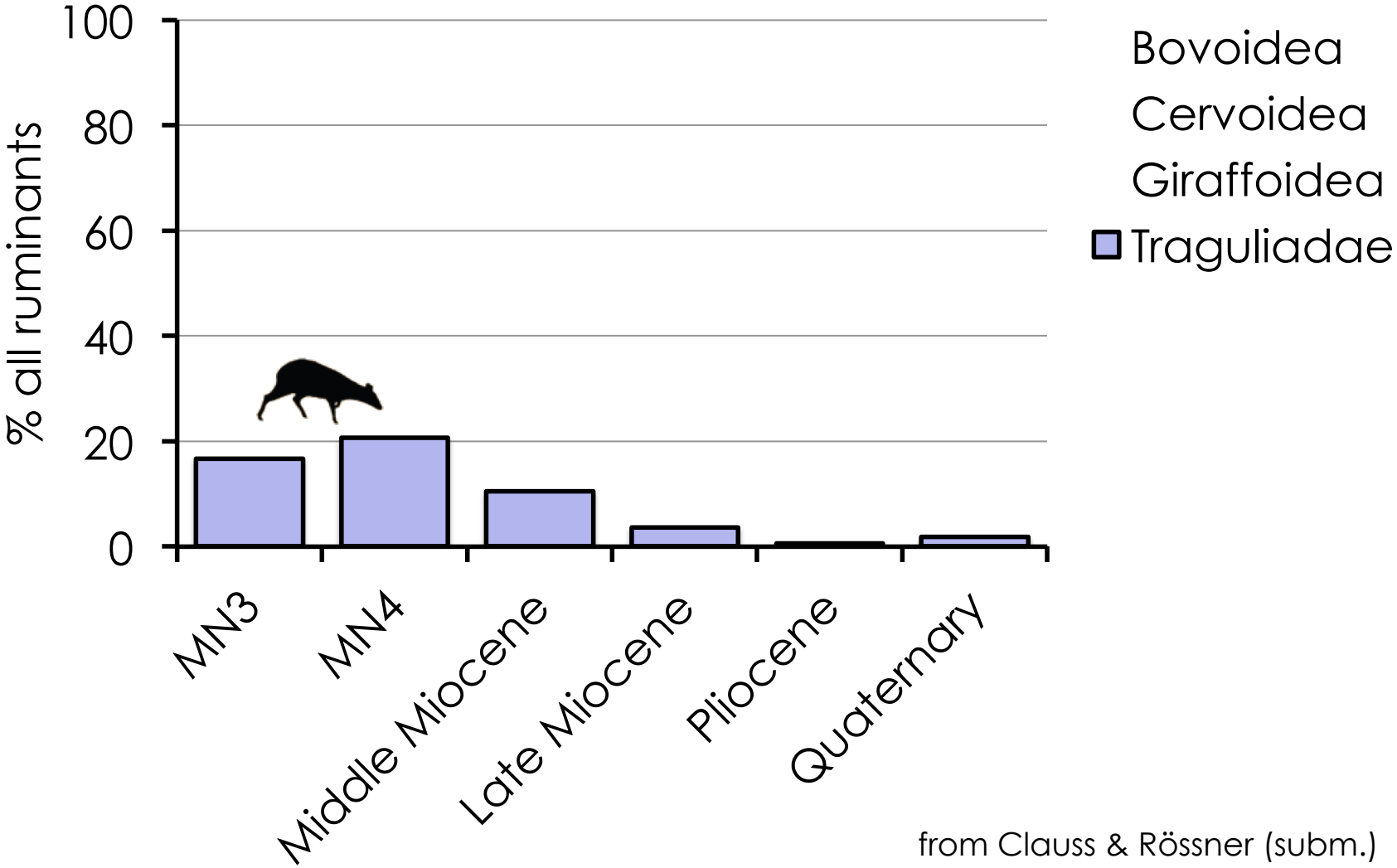

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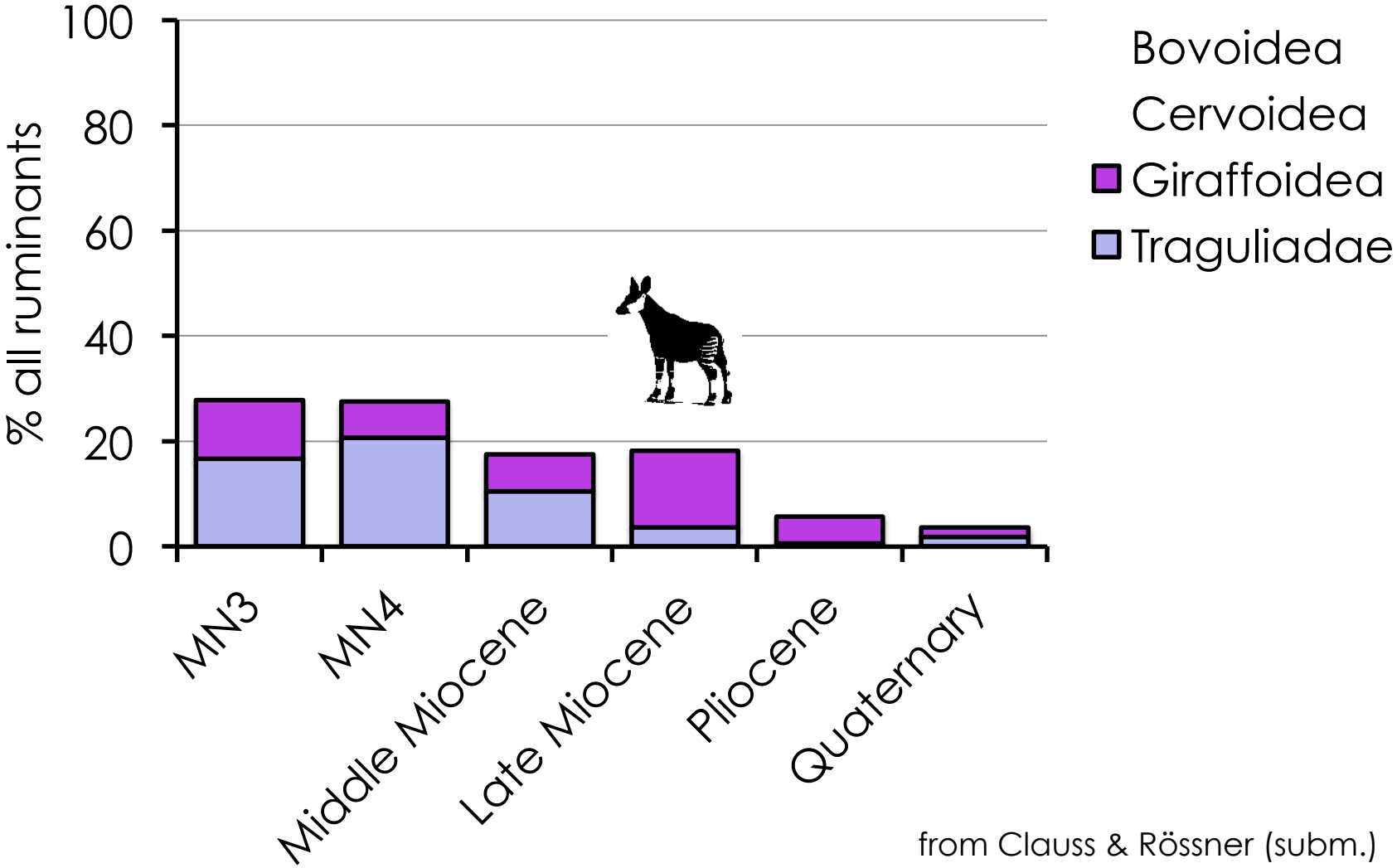

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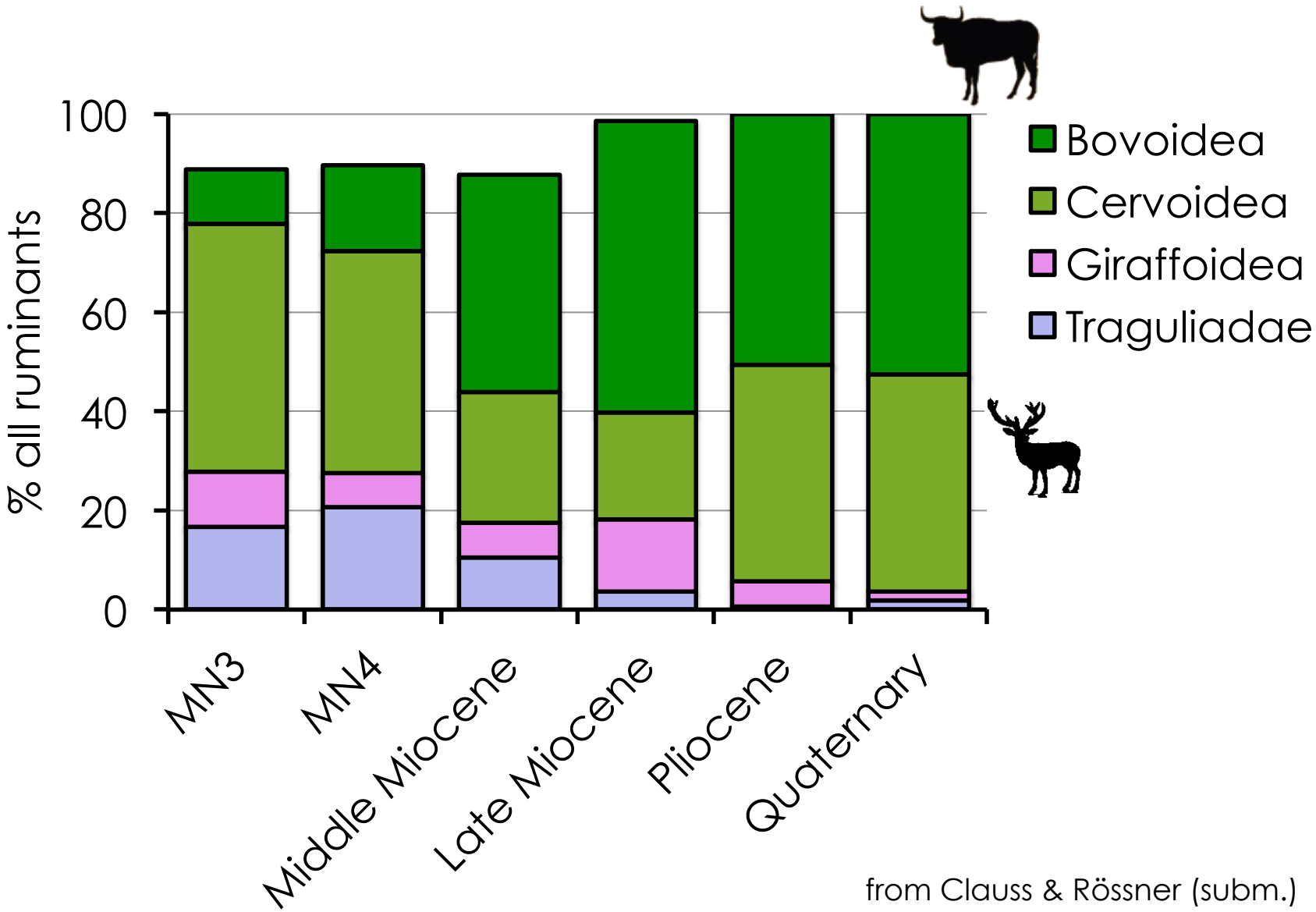

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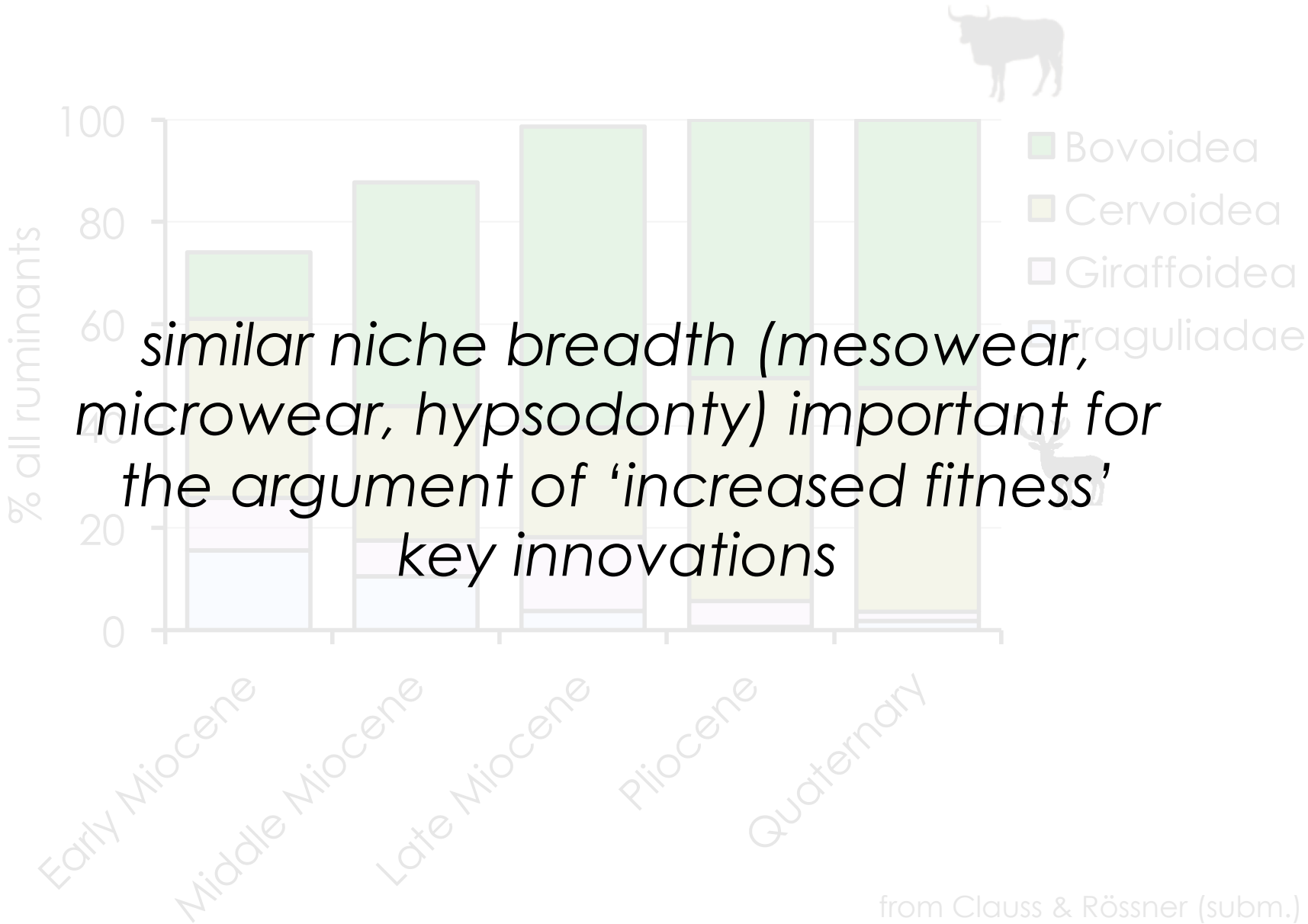

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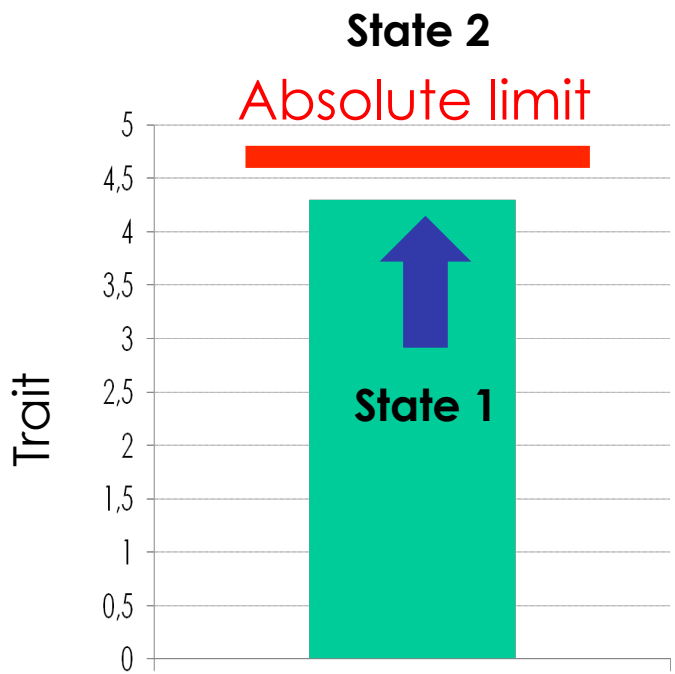
Evolutionary constraints: examples of (digestive) physiology

Evolutionary constraints – perspectives

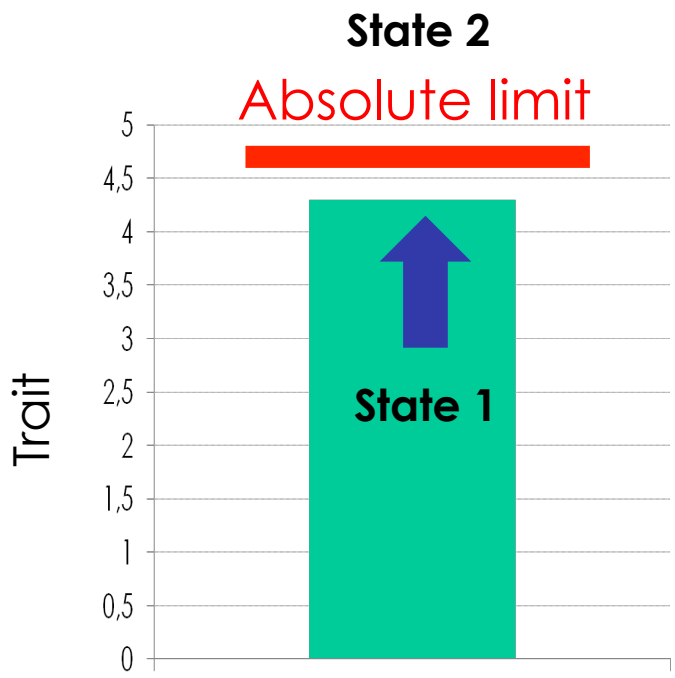
Absolute (extrinsic or intrinsic) constraints (like environmental or developmental/ Bauplan constraints)

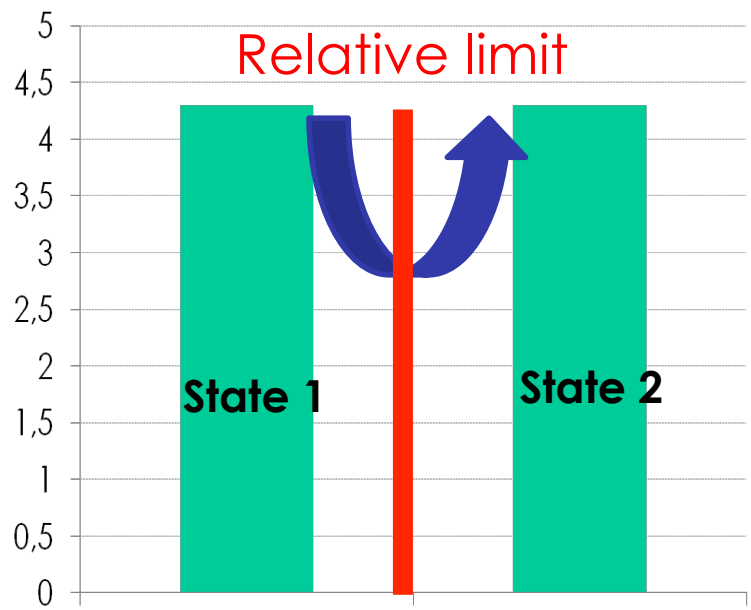


Evolutionary constraints – perspectives

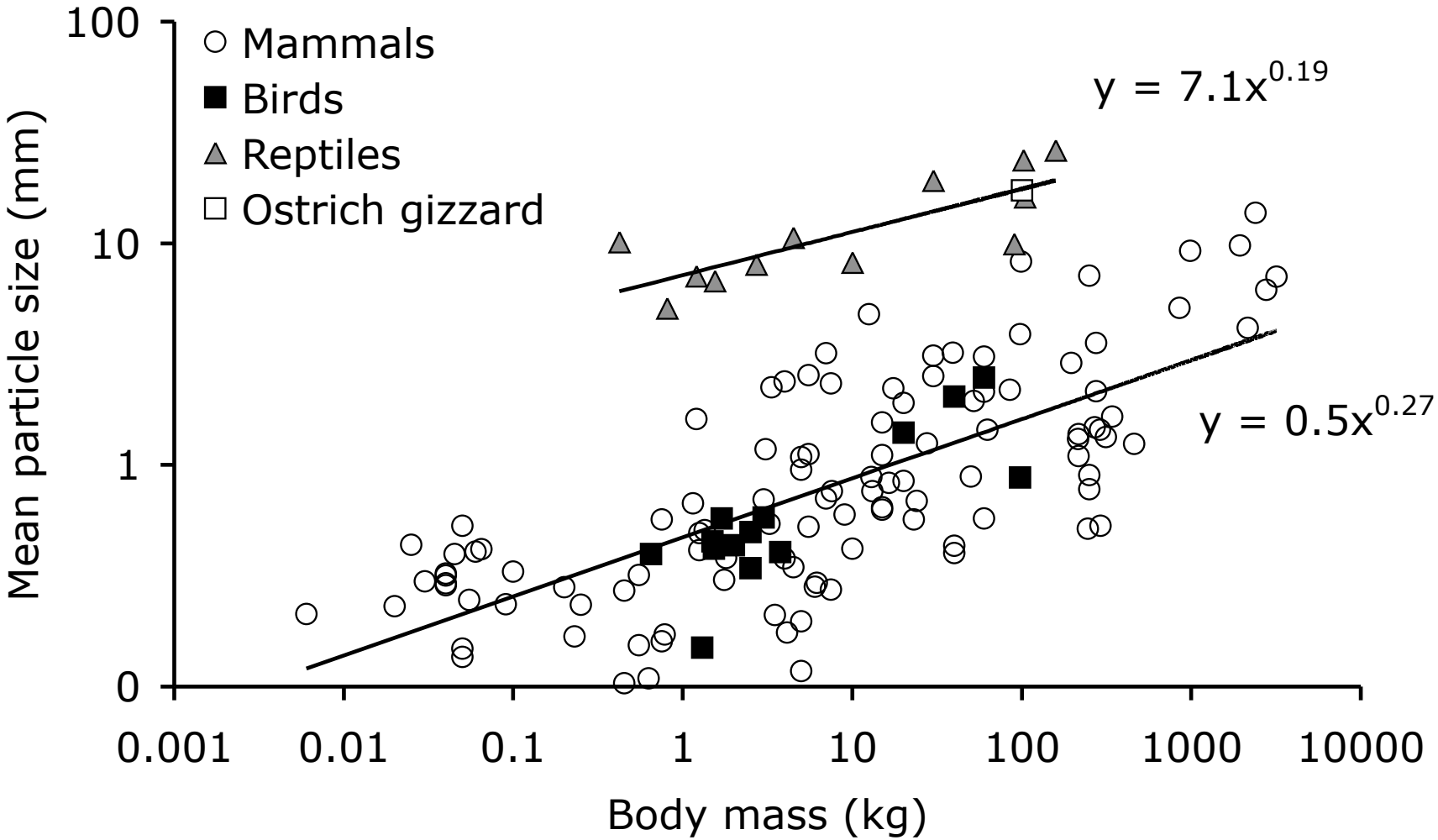
Absolute (extrinsic or intrinsic) constraints (like environmental or developmental/ Bauplan constraints)

Relative (competition) constraints – (competition with other species prevents evolutionary spread in other niches)



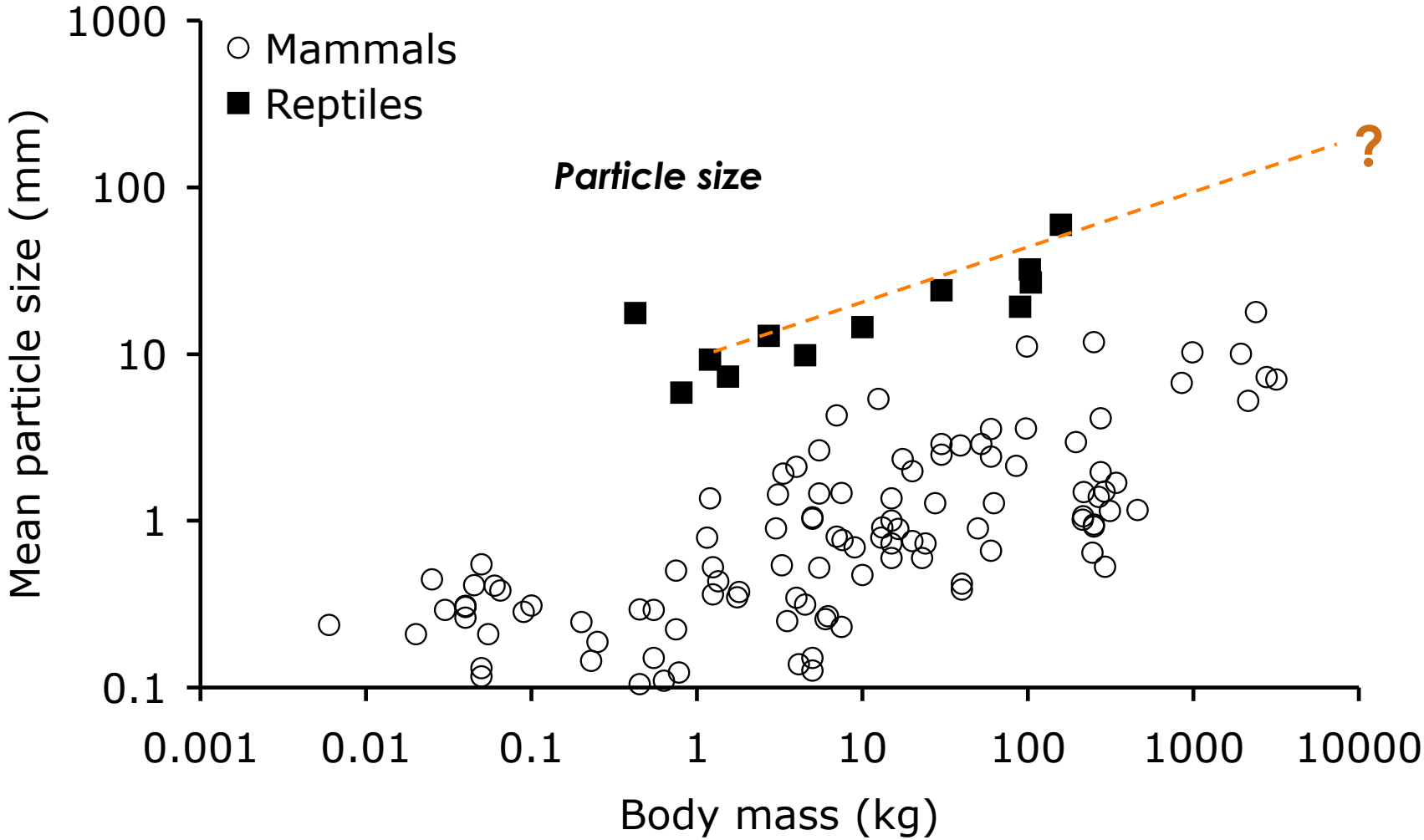


Faecal particle size allometry in herbivores



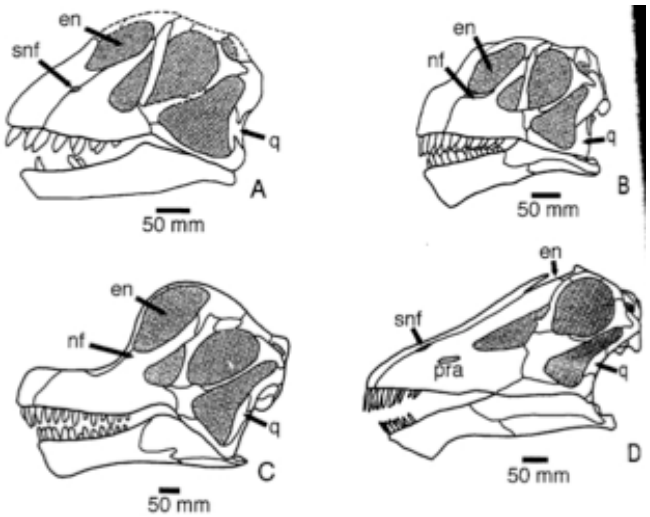
(Fritz et al. 209, 2010, 2011)

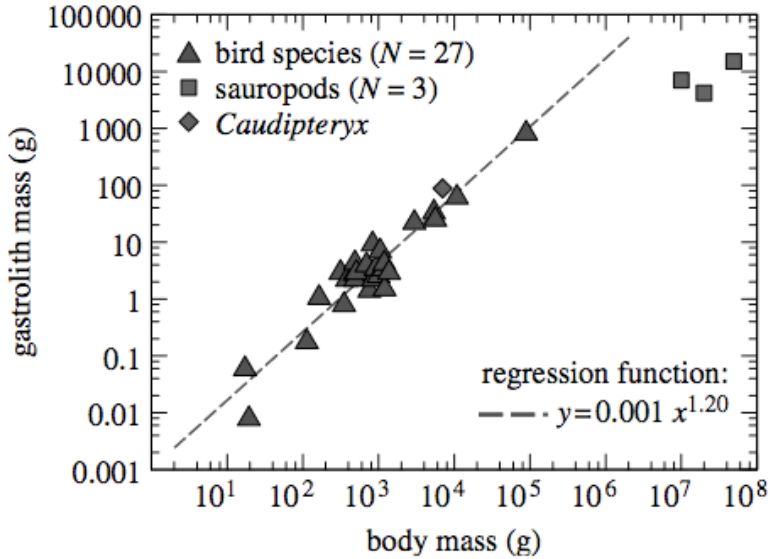
Extrapolating to sauropods



Sauropods

Absence of mastication apparatus (no grinding teeth, no cheeks) and absence of gastric mill





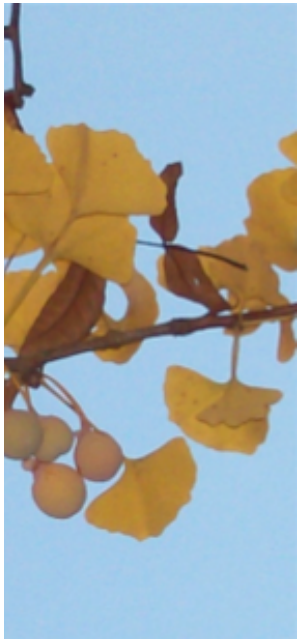
sauropods are special - they did not comminute their food

from Calvo (1994)

from Wings & Sander (2007)

General allometric considerations

At a certain body mass, ingesta particle size will only depend on plant morphology



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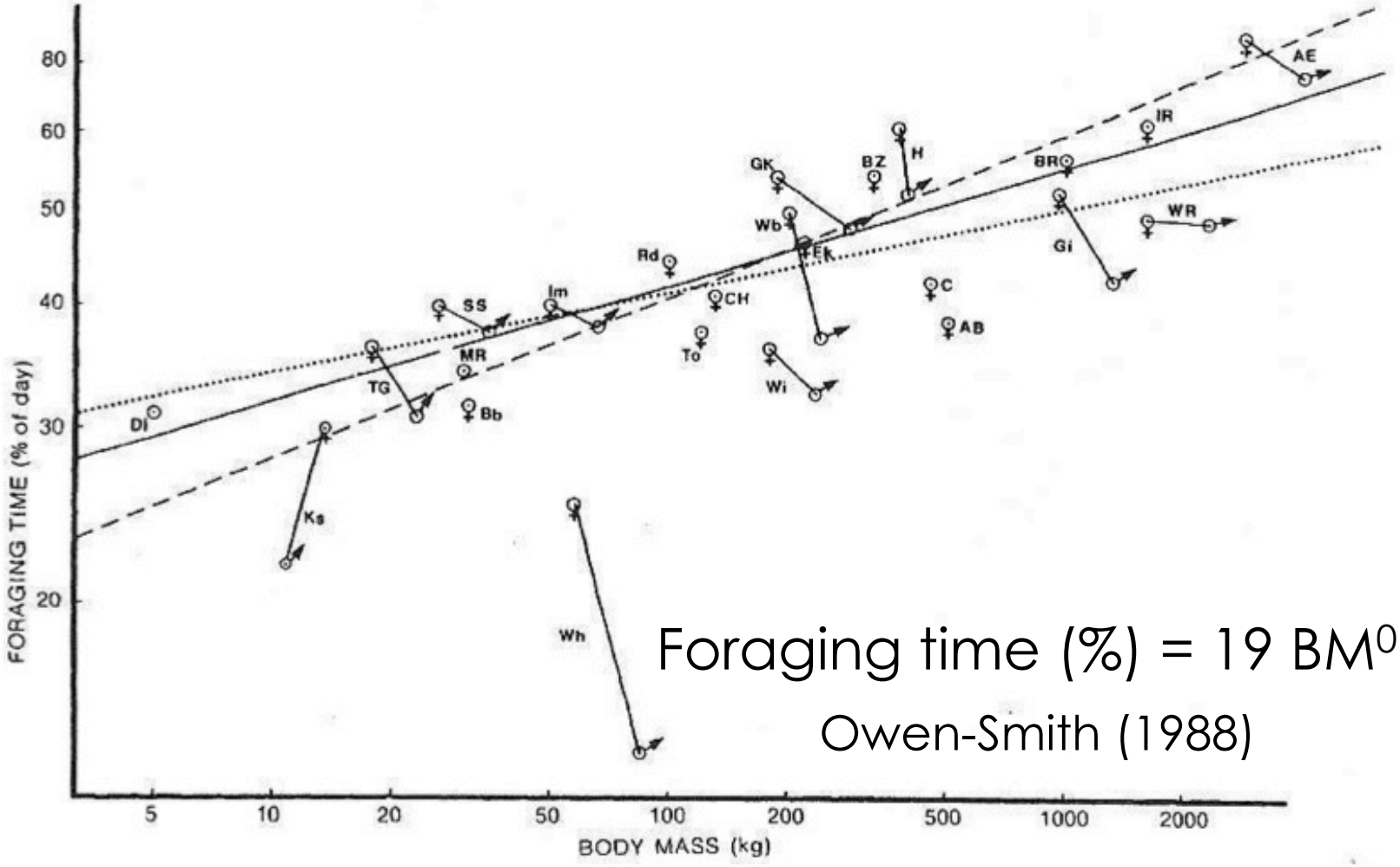
Foraging time and body size



Foraging time (%) = 19 $BM^{0.17}$

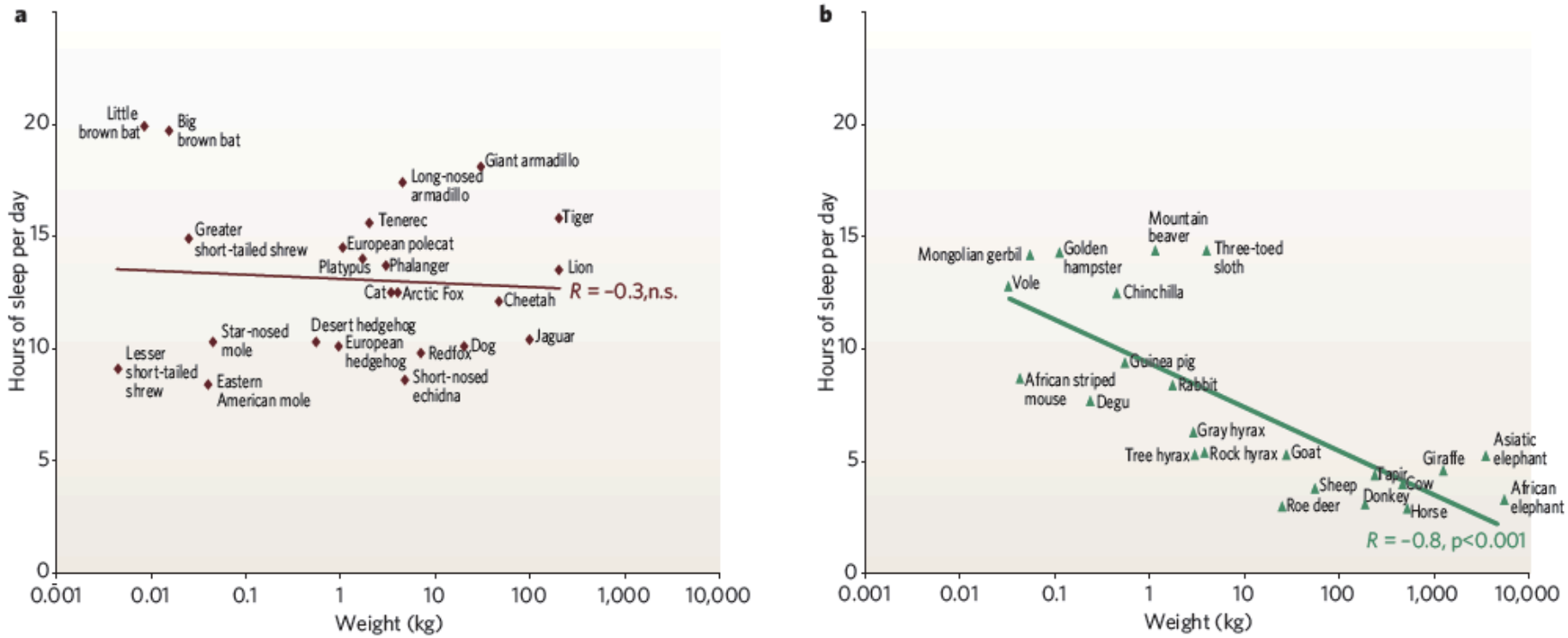
Owen-Smith (1988)

Foraging: Sum of searching, cropping and chewing

Clues to the functions of mammalian sleep

Jerome M. Siegel[1]

NATURE|Vol 437|27 October 2005|doi:10.1038/nature04285



Chewing limits body size

Chewing constrains the time available for feeding and therefore ultimately limits the body size of chewers.

Feeding time (in % day) = 19 Body mass$^{0.17}$

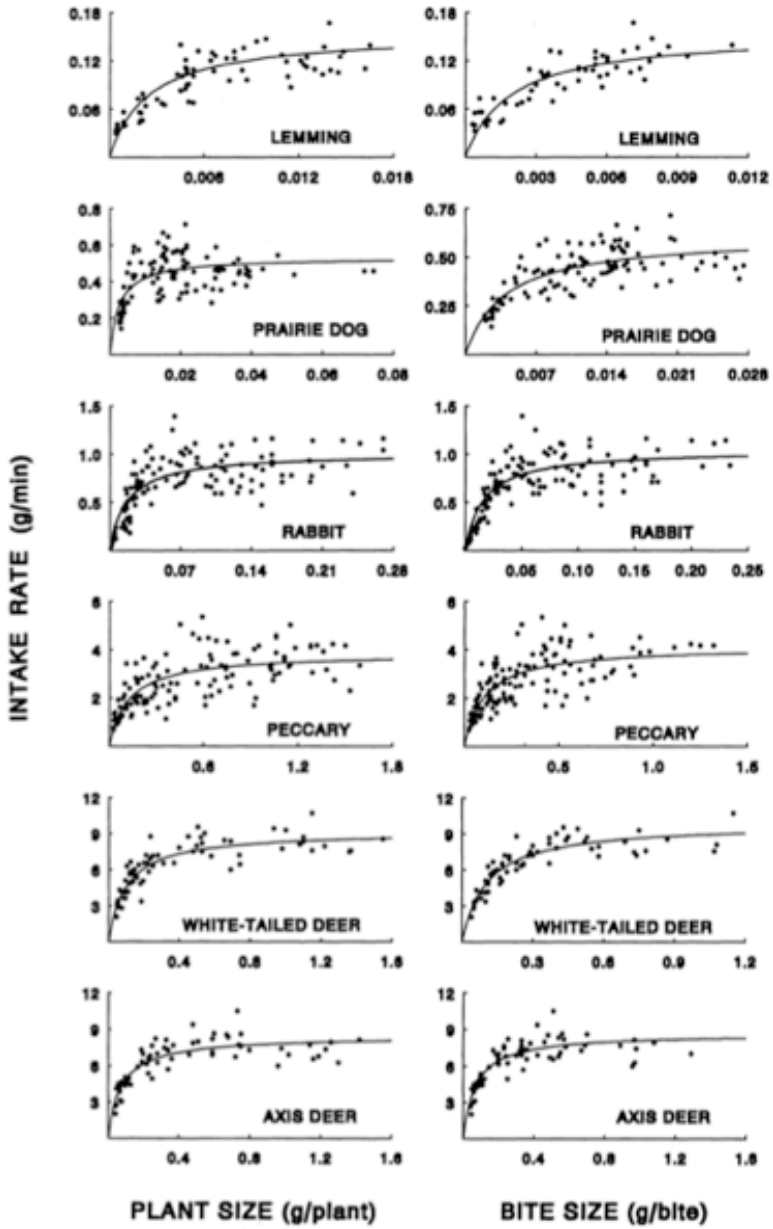
from app. 18 tons onwards, herbivores would have to feed more than 24 hours per day!

from Owen-Smith (1988)

The “Functional Response”

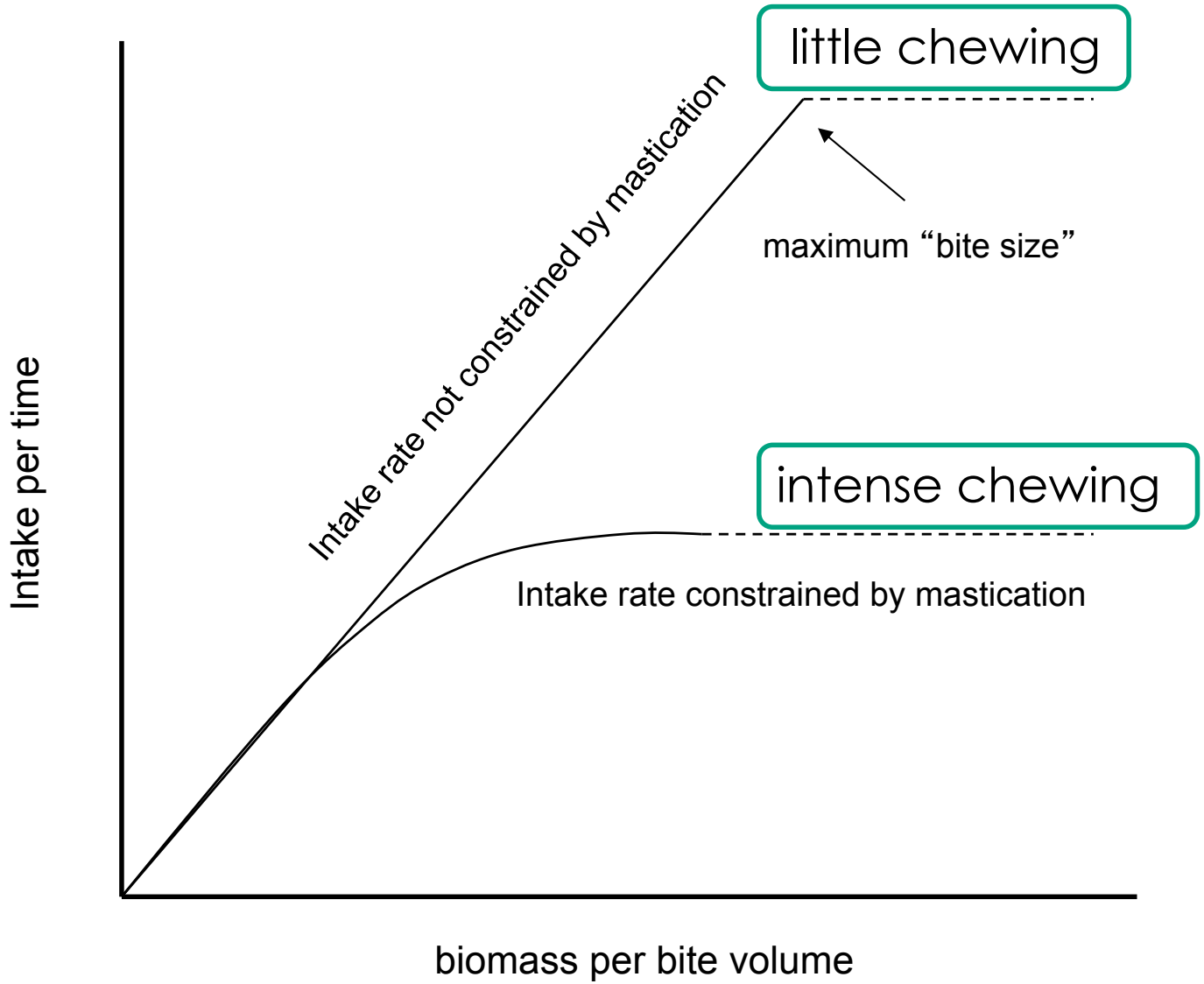
Chewing = food processing is a rate-limiting step

=> at a certain amount of food on offer, intake rate cannot increase due to chewing

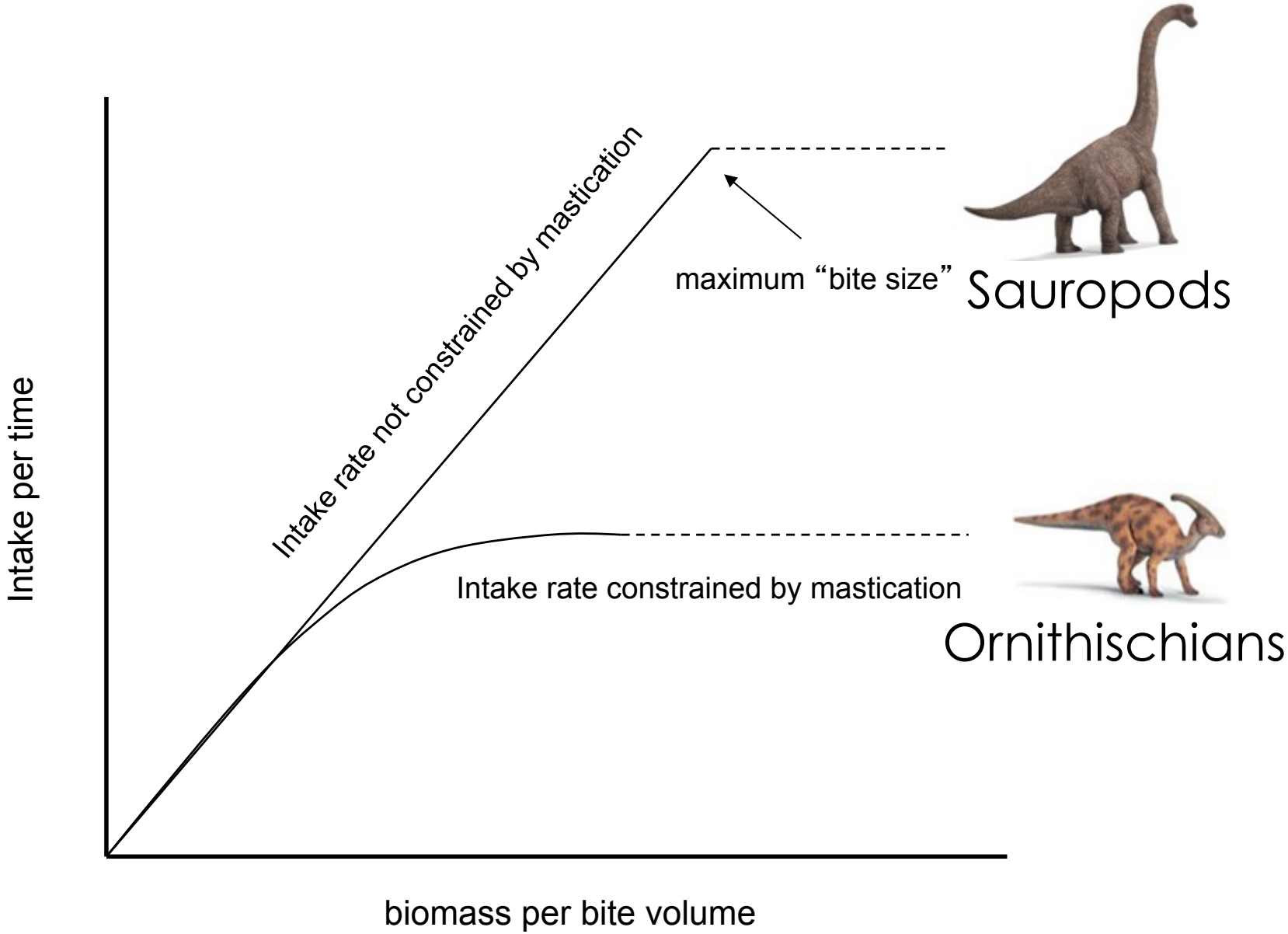


from Gross et al. (1993)

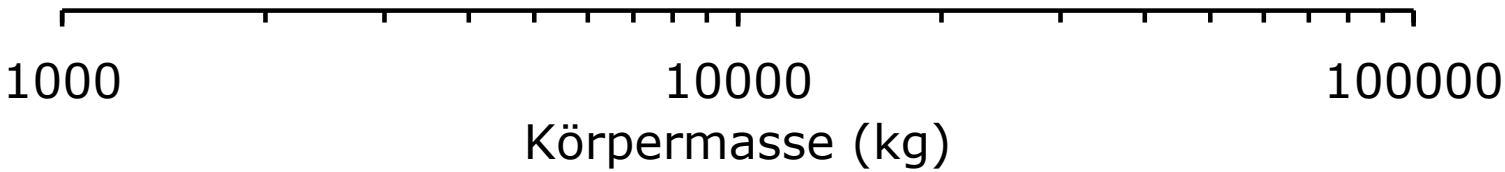
Feeding time and body size



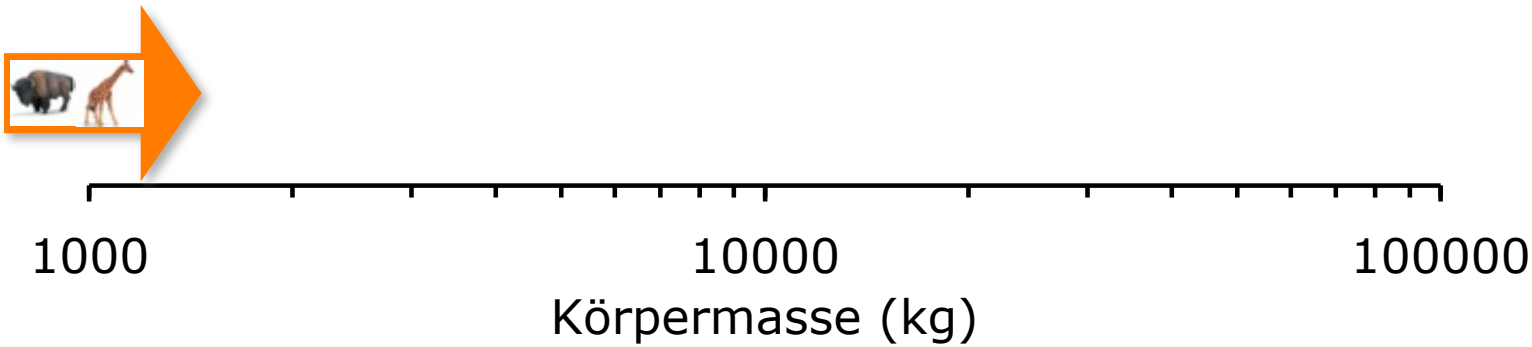
Feeding time and body size



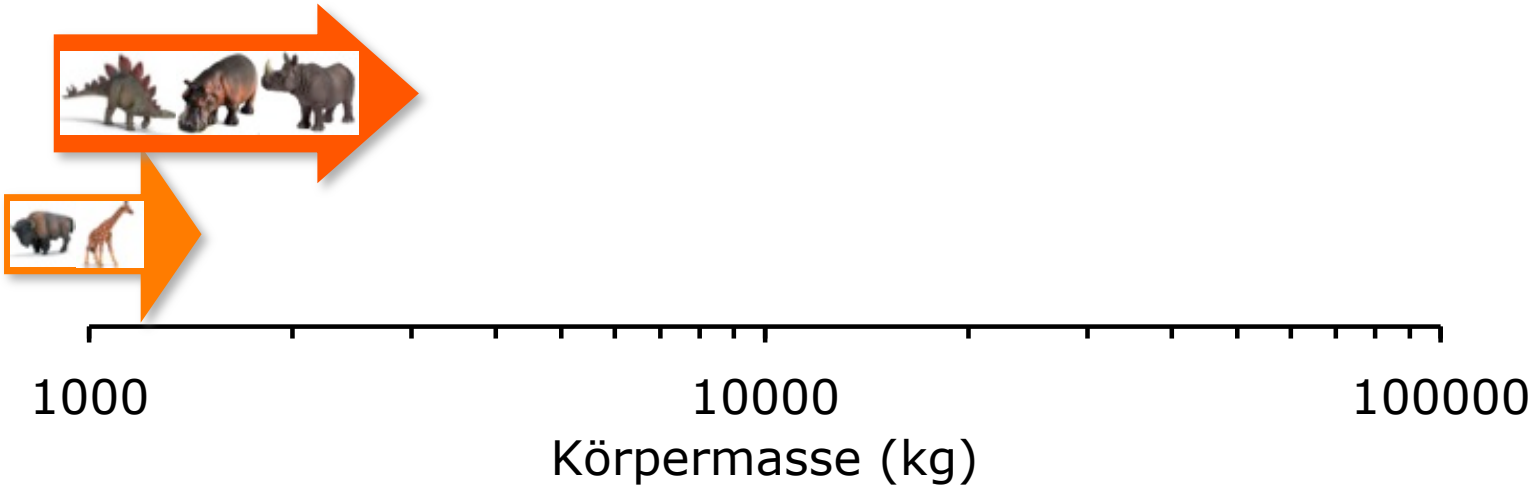
Sizing up herbivores



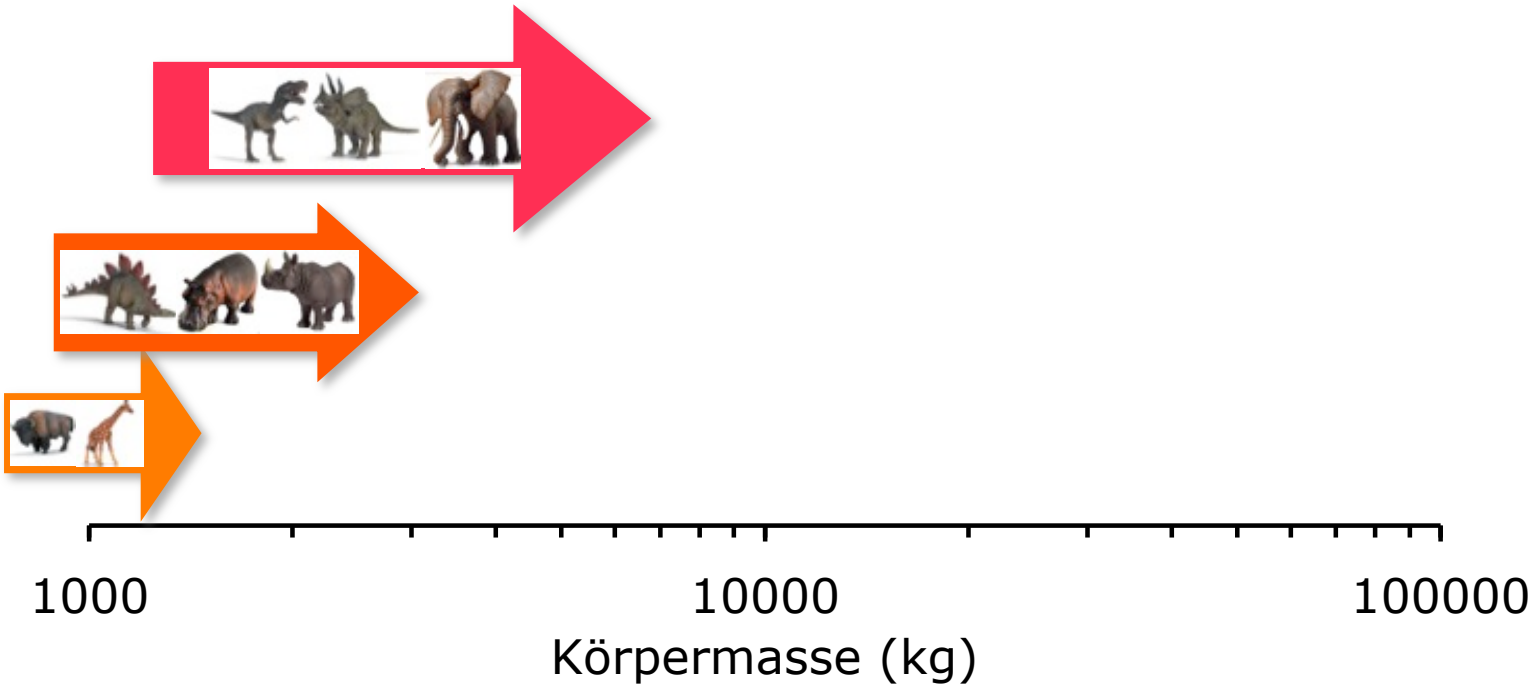
Sizing up herbivores



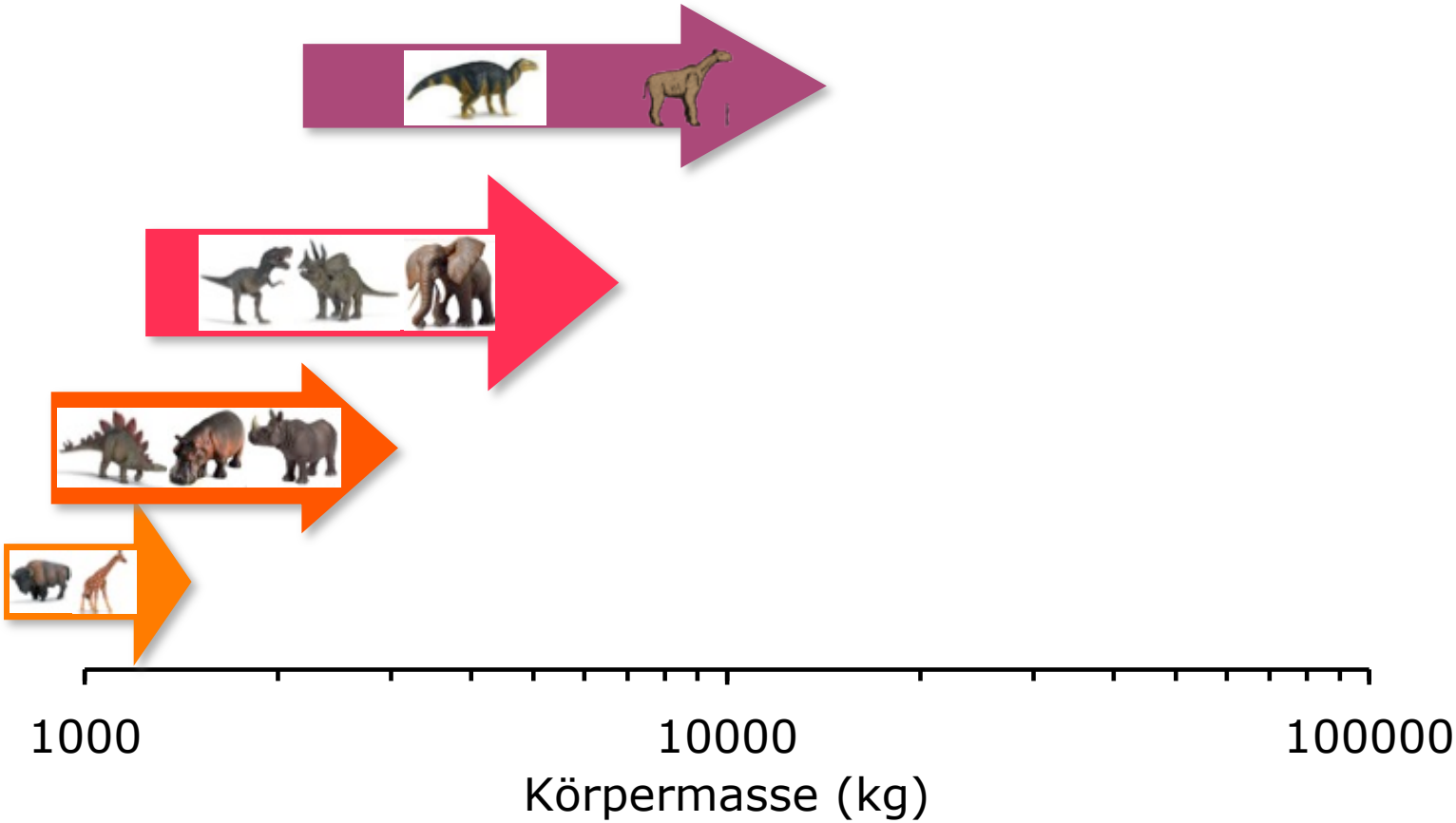
Sizing up herbivores



Sizing up herbivores



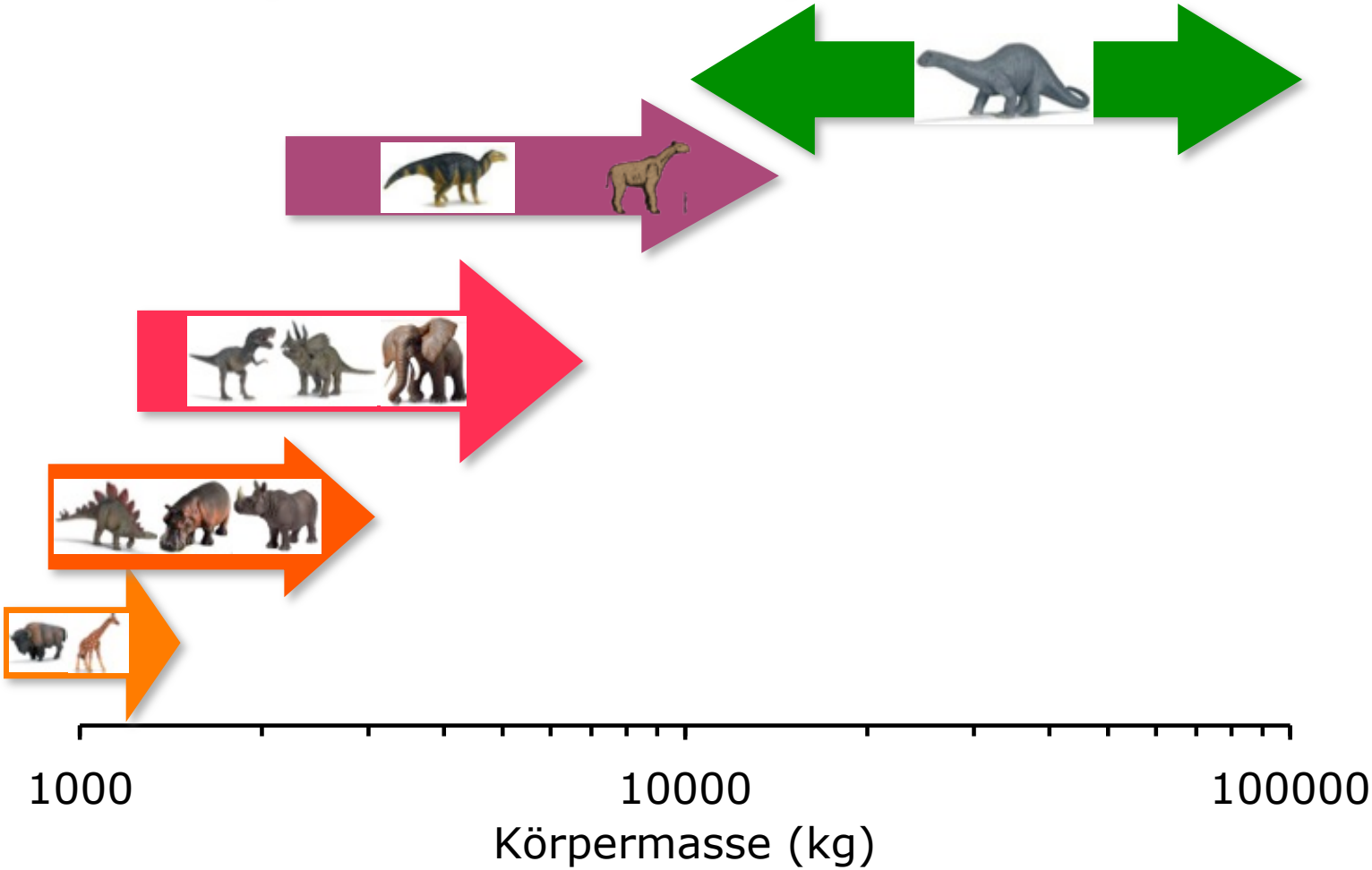
Sizing up herbivores




(C) NHK

Sizing up herbivores

- Sauropods were the largest terrestrial animals (and herbivores) ever



Sizing up herbivores

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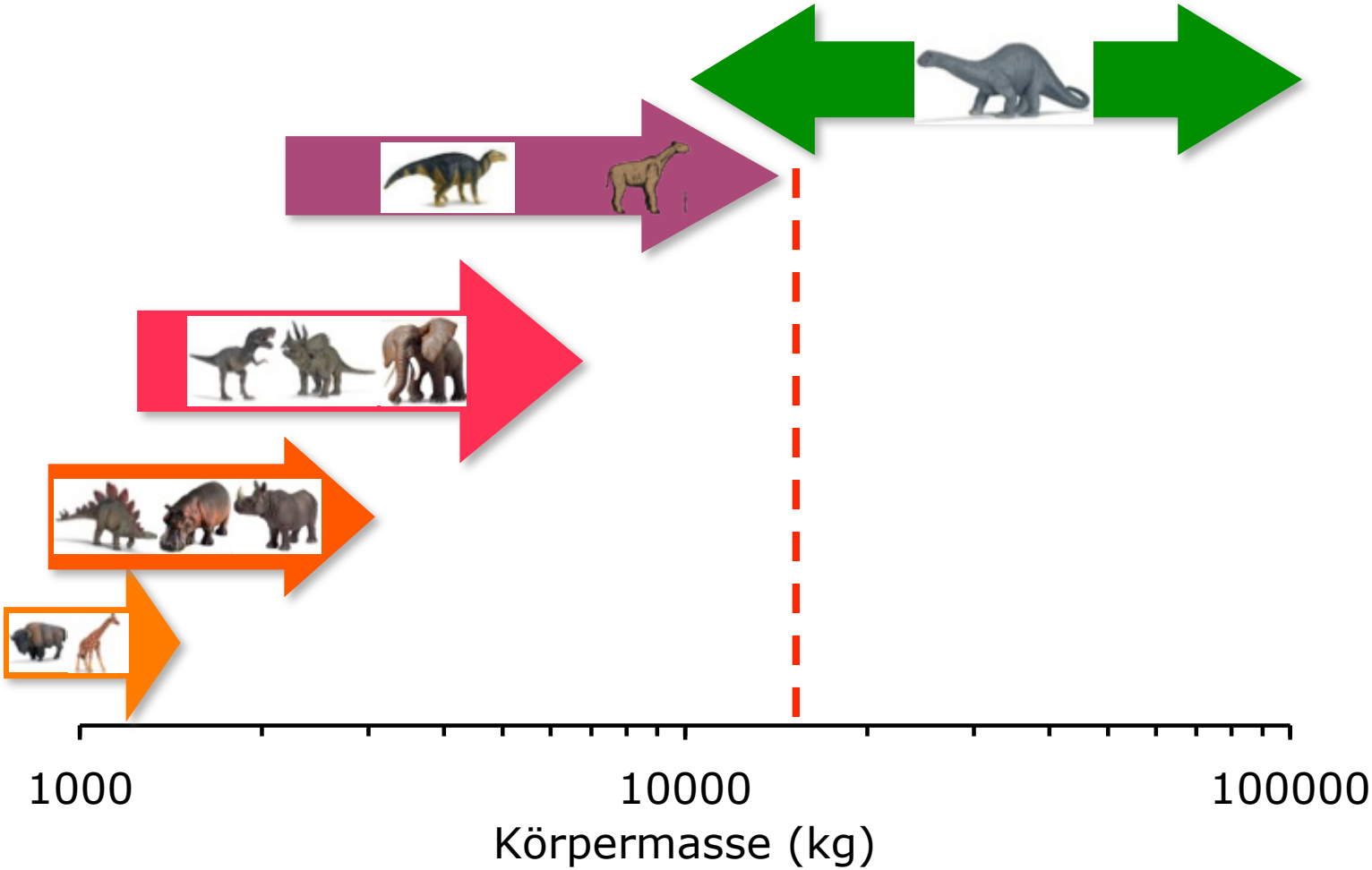
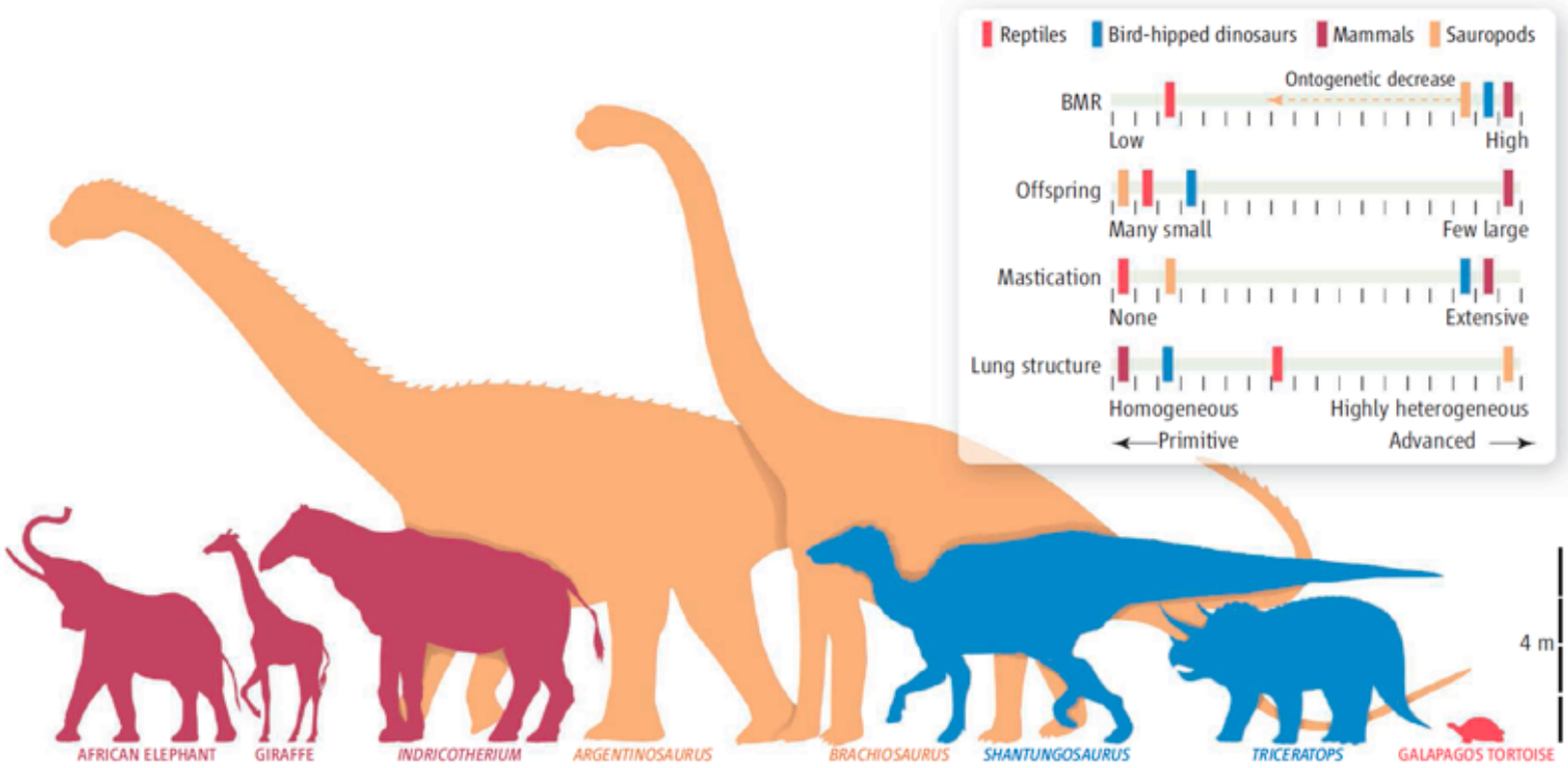


Sauropods

Absence of mastication is considered a "permissive factor" for sauropod gigantism



from Sander & Clauss (2008)

Digestive and Metabolic Strategies

			
Low intake ⇒ long passage ⇒ ***low metabolsim***	✓	✓	
High intake ⇒ differentiated passage ⇒ ***high metabolism***	✓	✗	

Digestive and Metabolic Strategies

			
Low intake ⇒ long passage ⇒ ***low metabolsim***	✓	✓	✓ 
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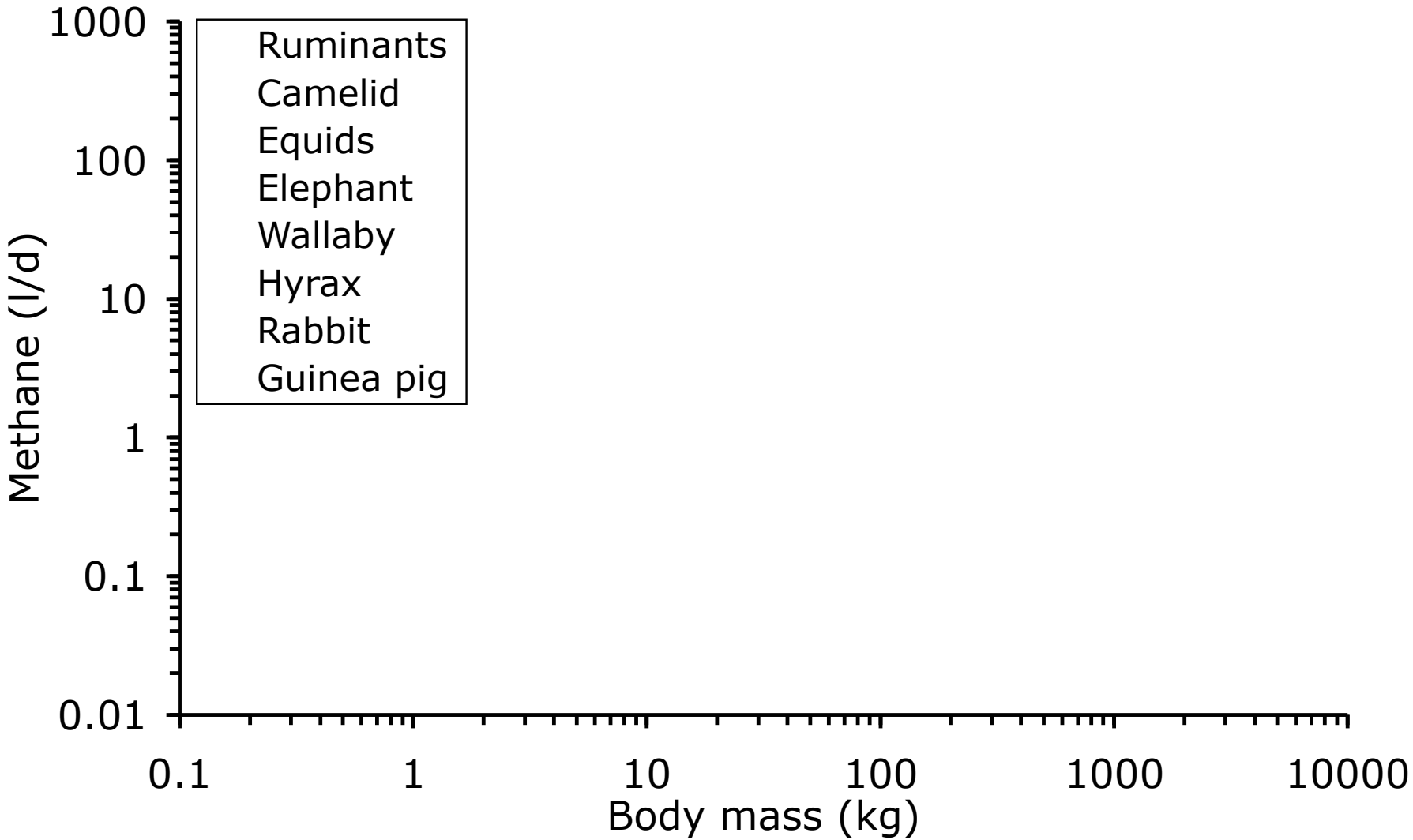
Digestive and Metabolic Strategies

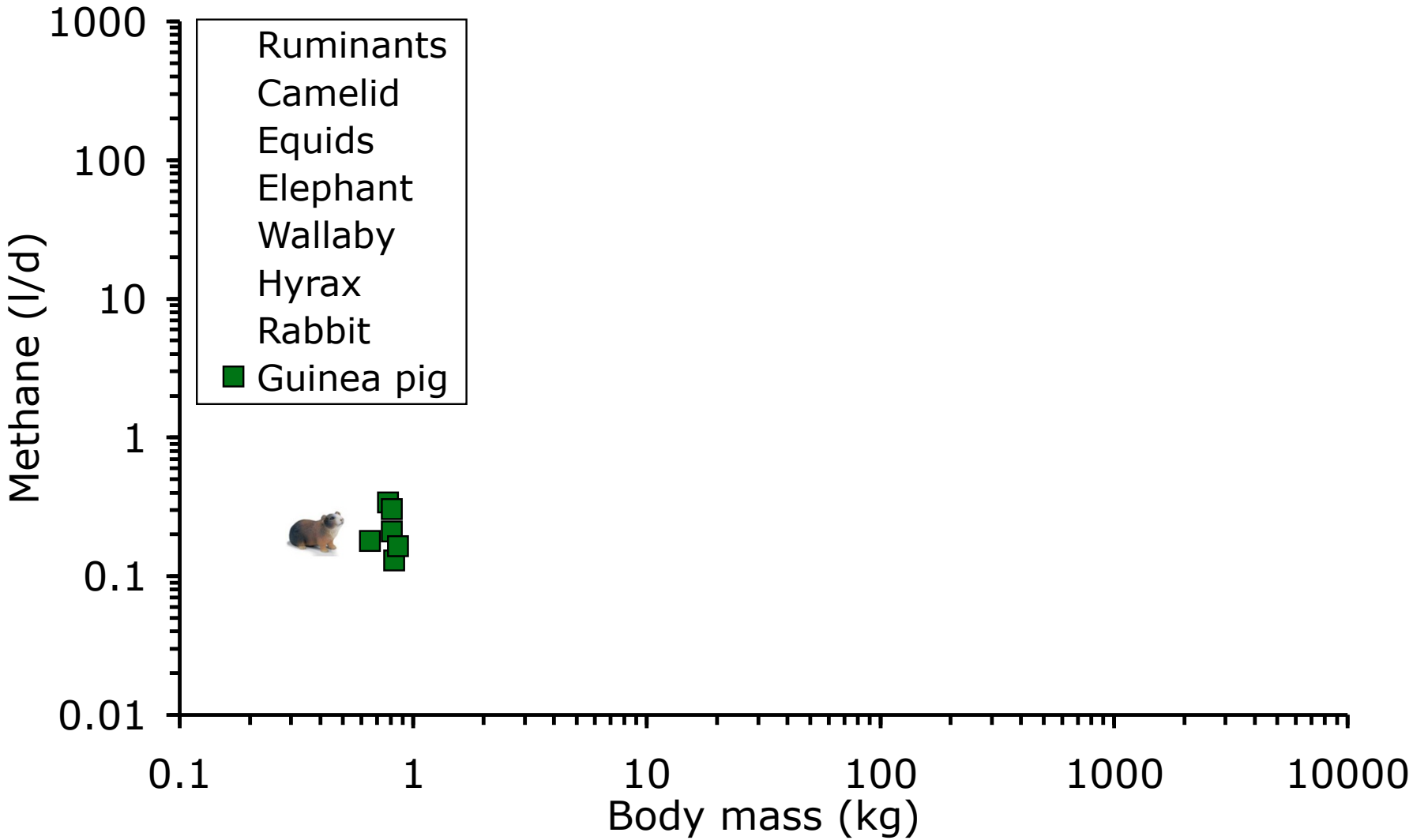
			
Low intake ⇒ long passage ⇒ ***low metabolsim***	✓	✓	✓ 
High intake ⇒ differentiated passage ⇒ ***high metabolism***	✓	✗	✓ 

Methane allometry in herbivores



from Franz et al. (2010)

Methane allometry in herbivores



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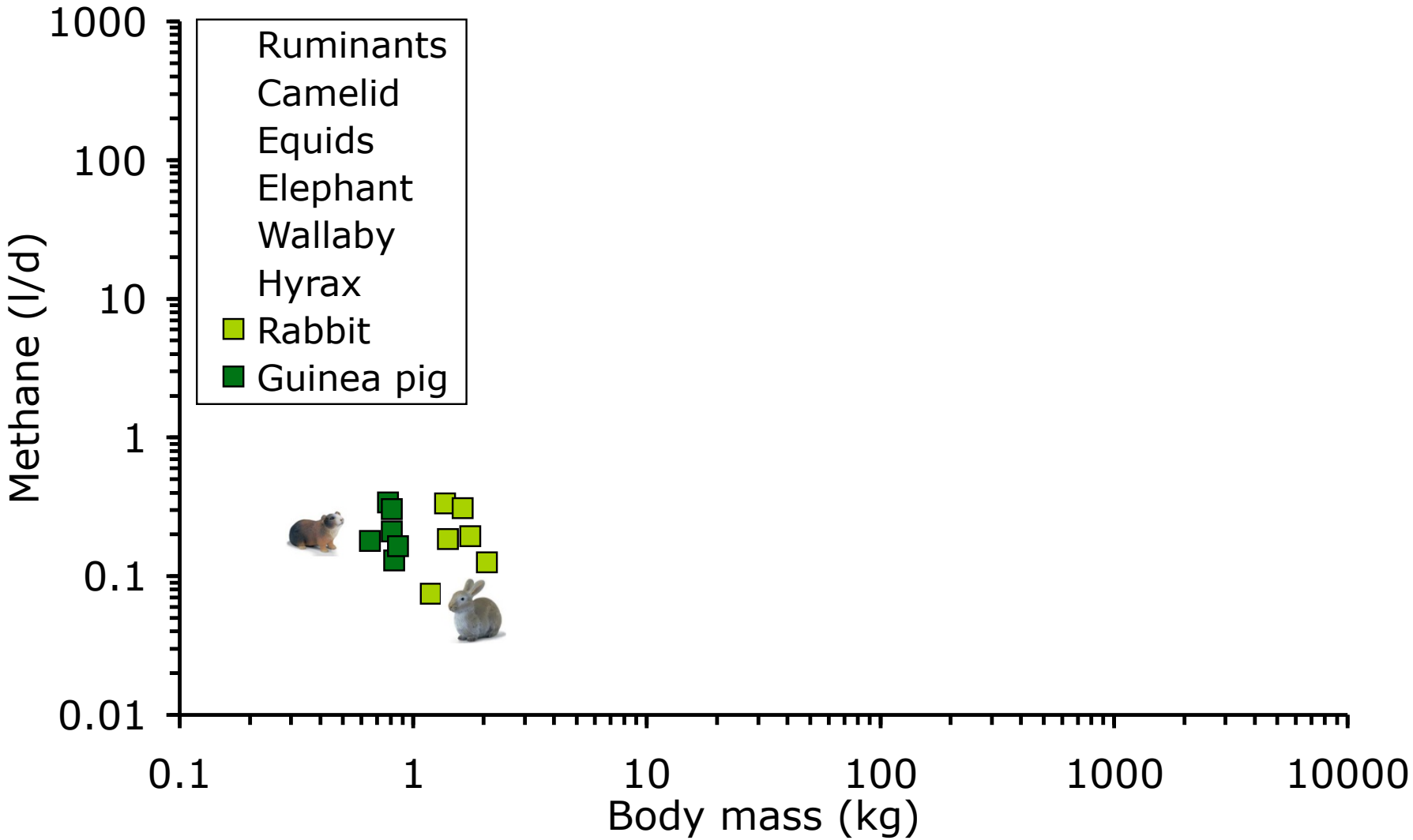
Methane allometry in herbivores



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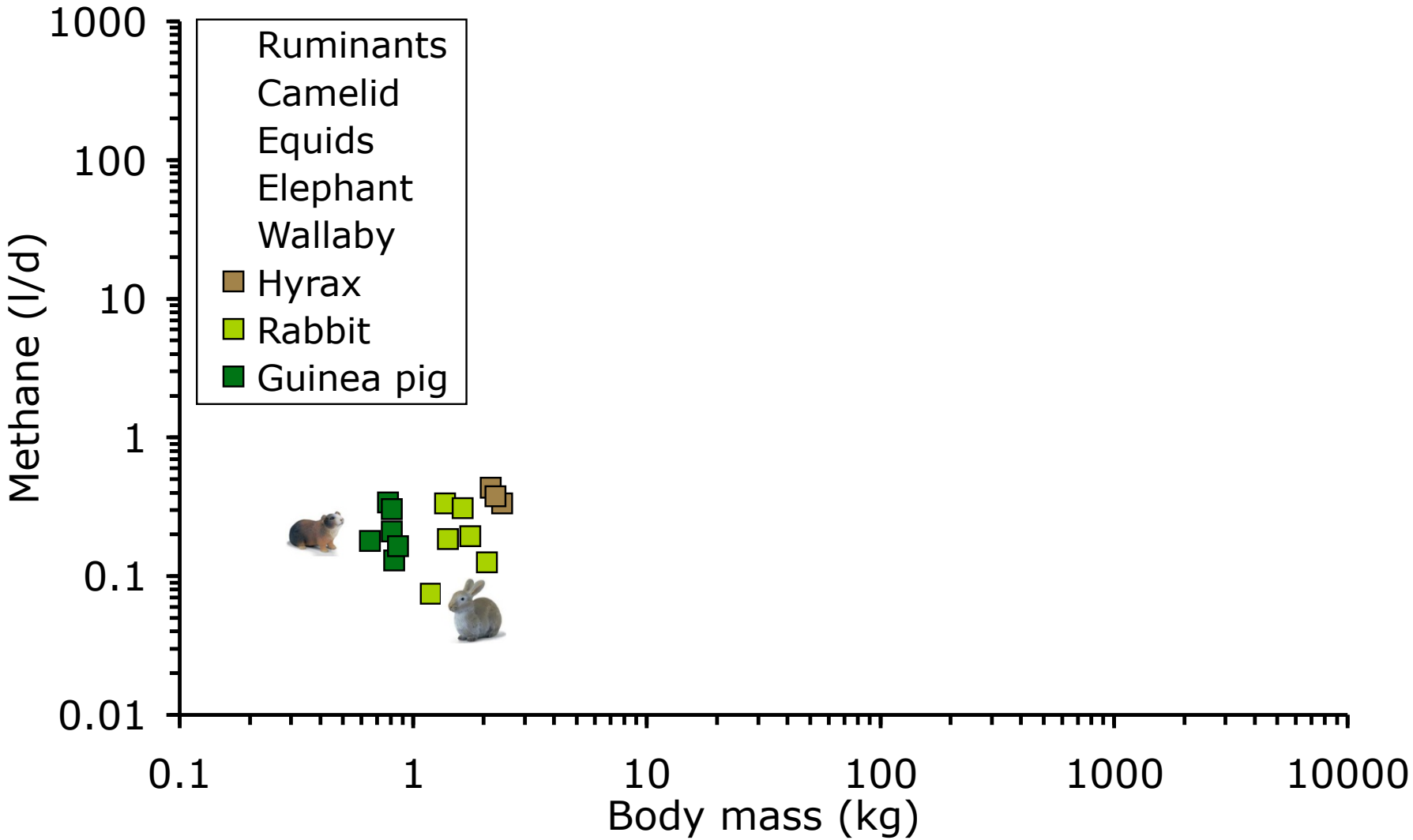

from Franz et al. (2010)

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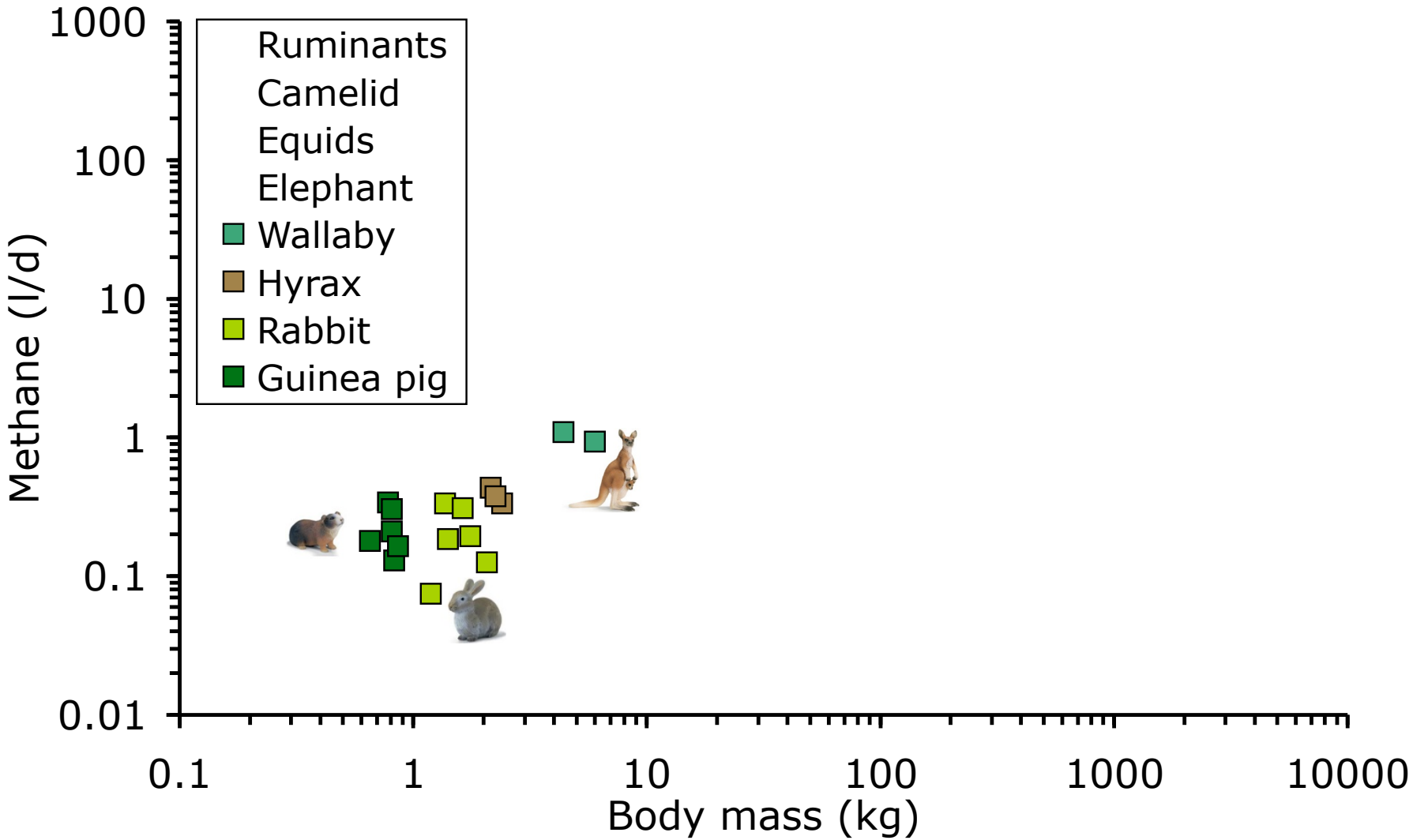

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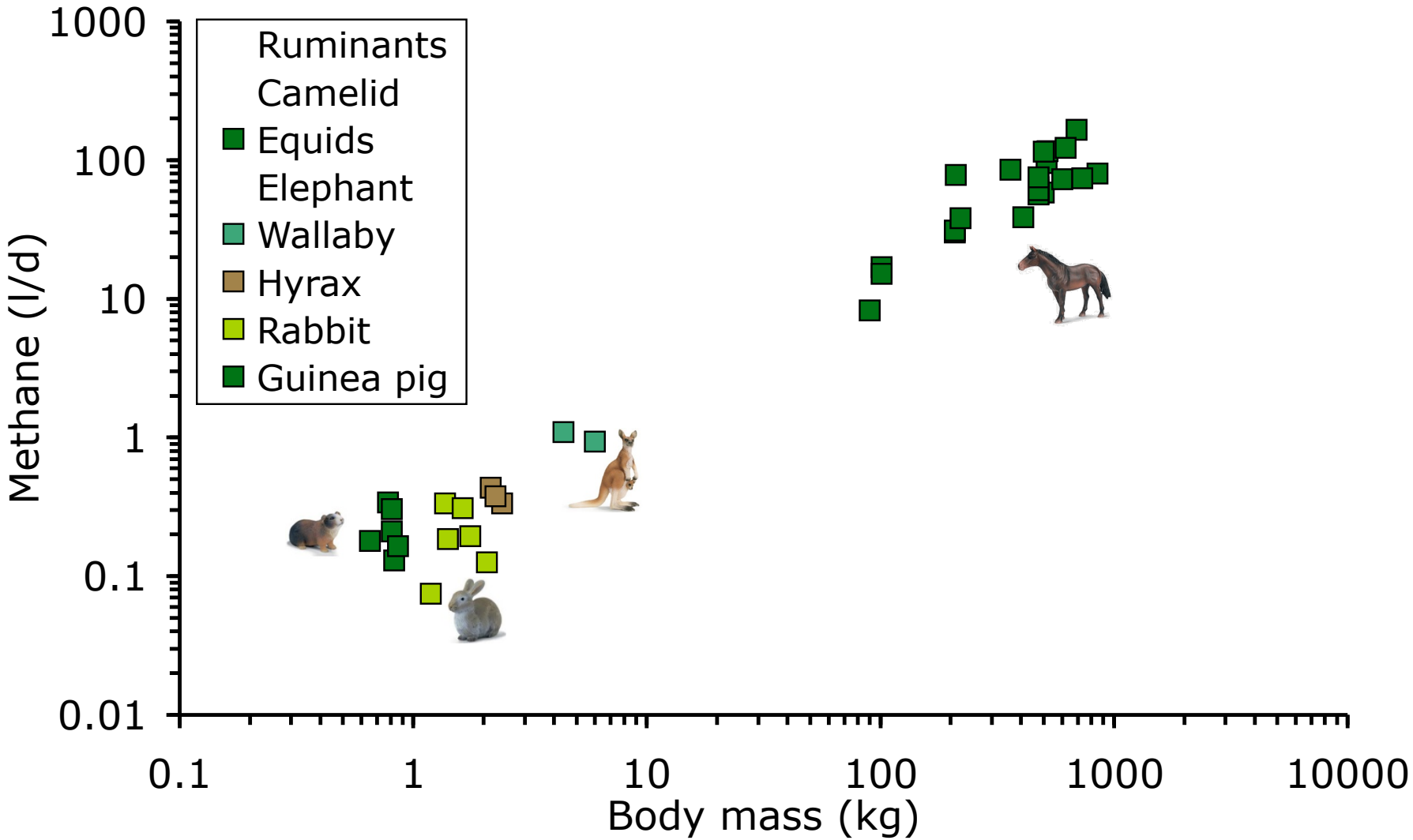

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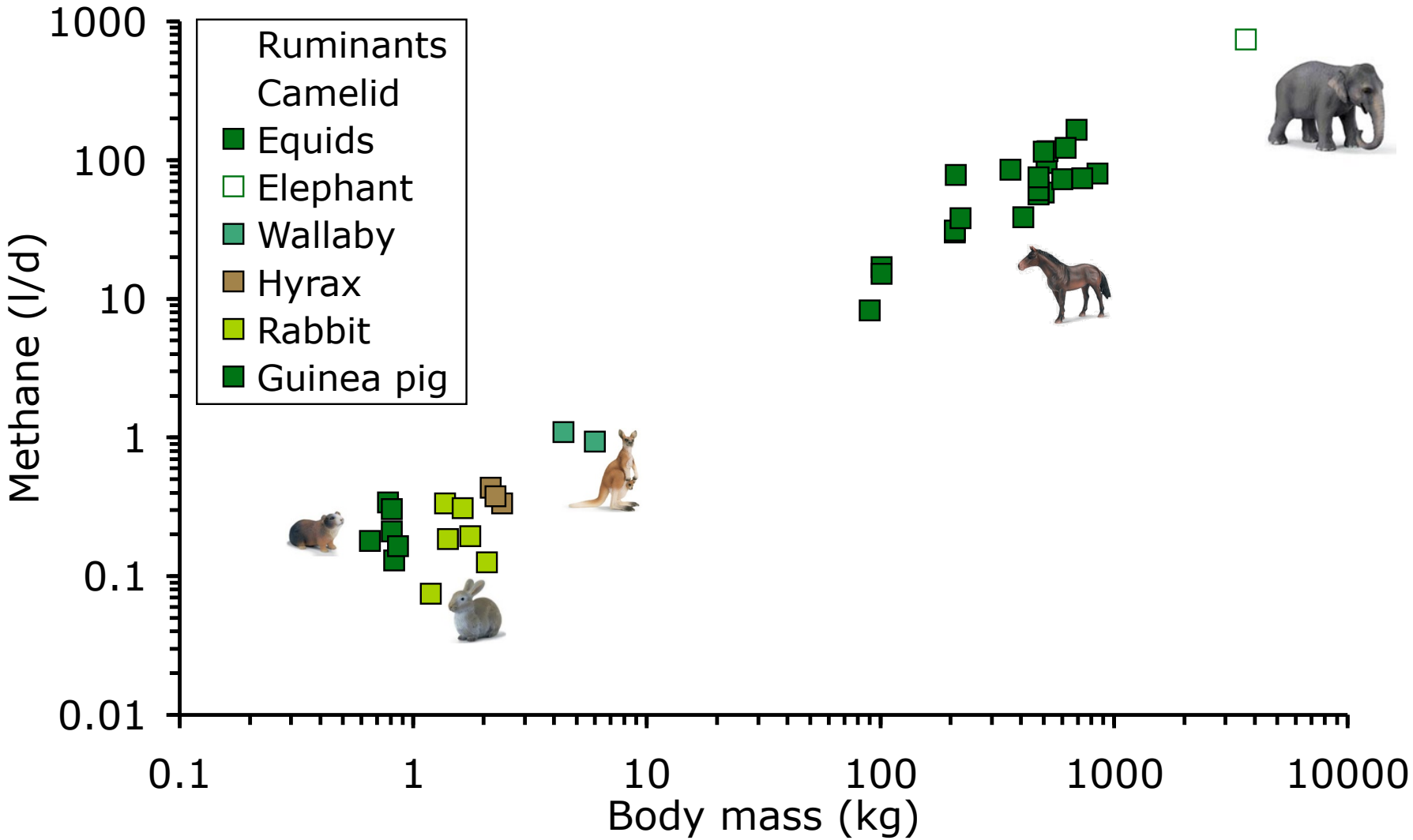

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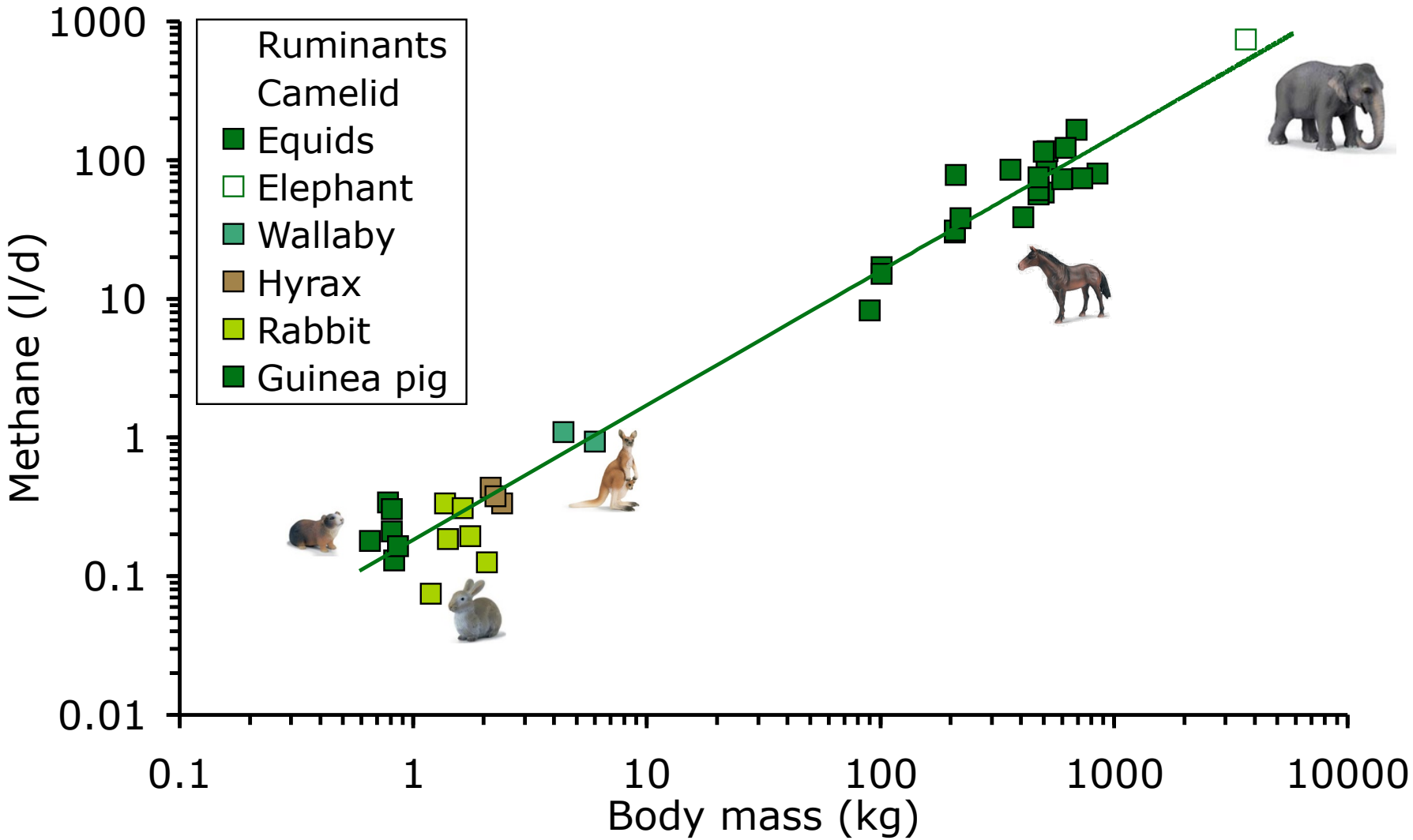

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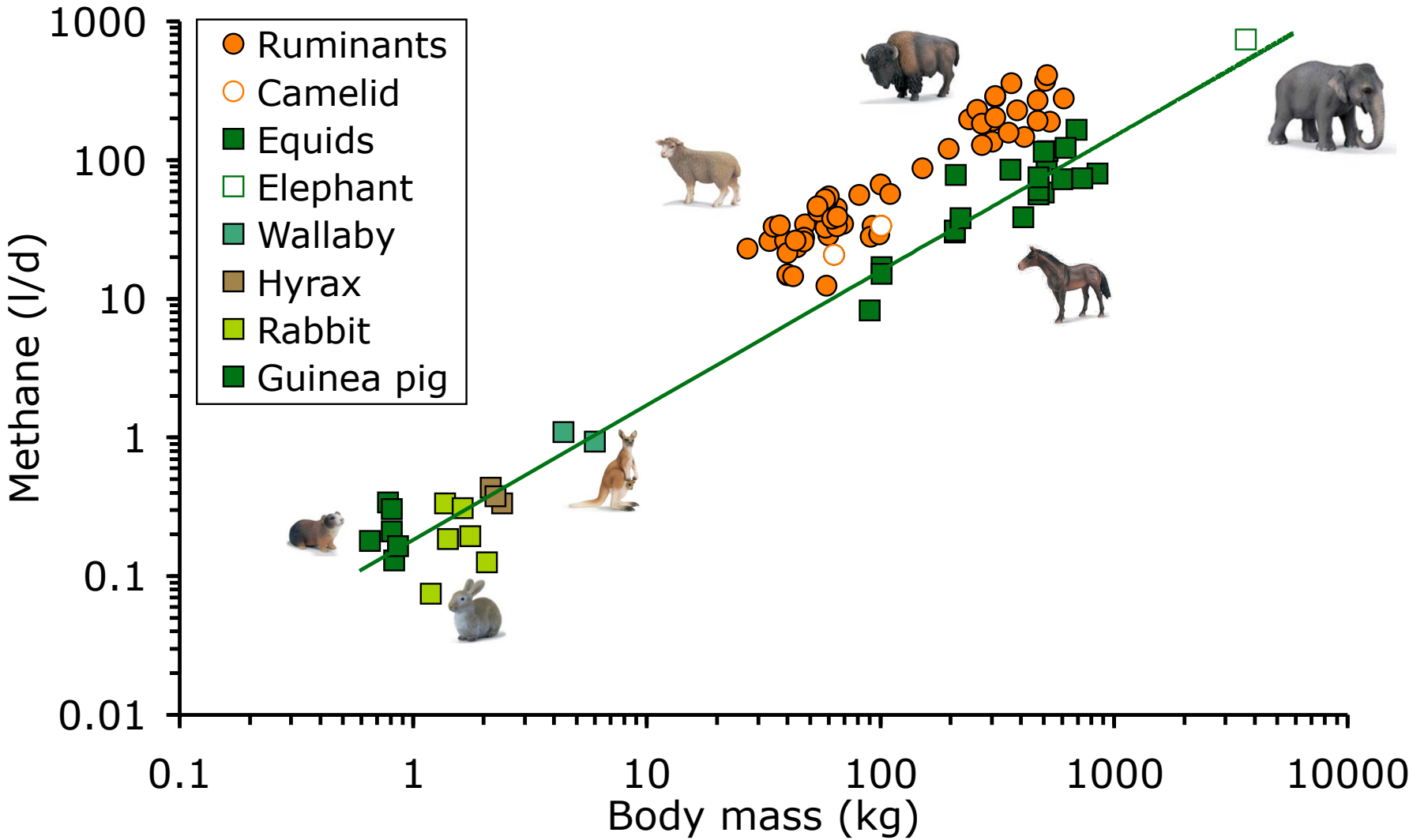

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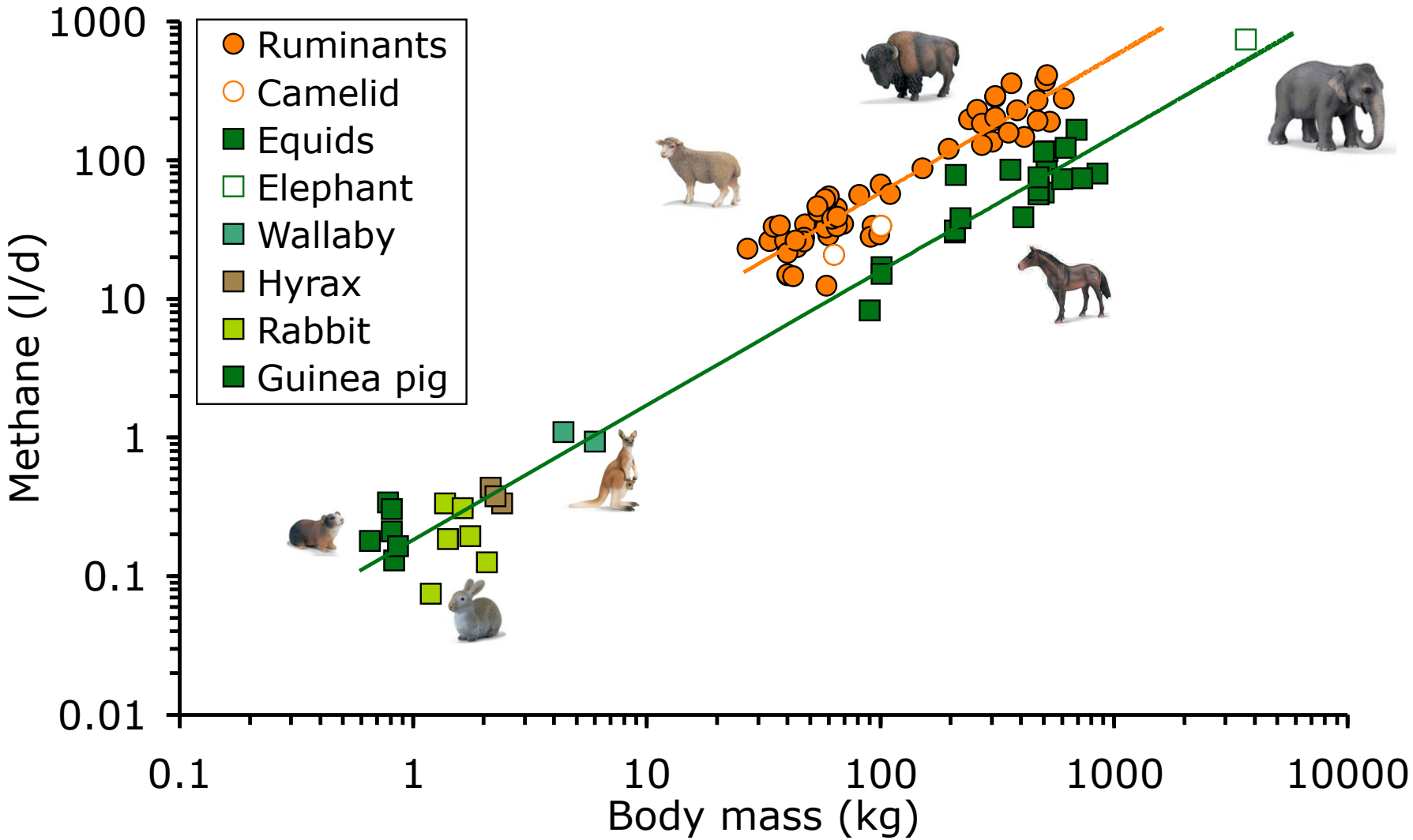

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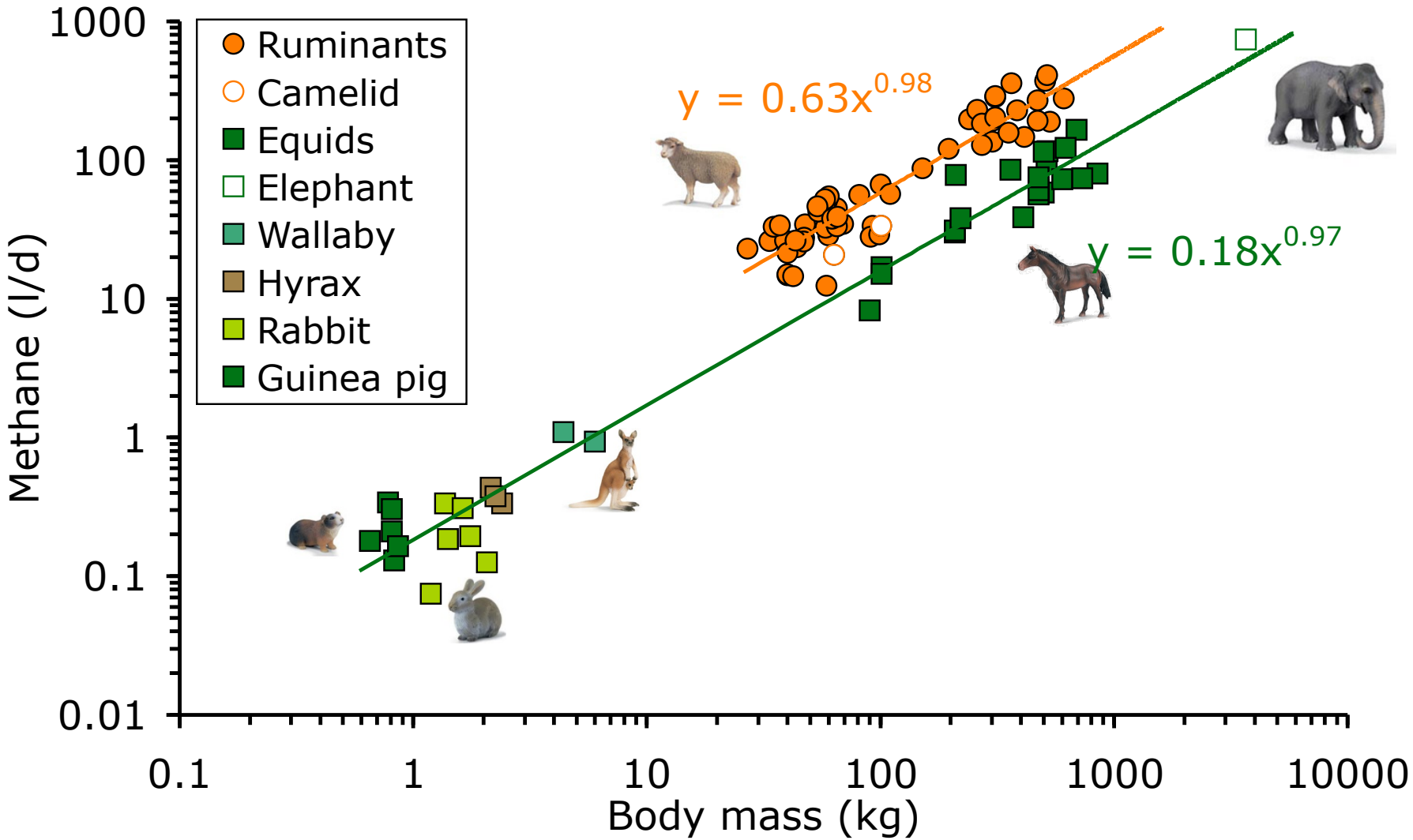

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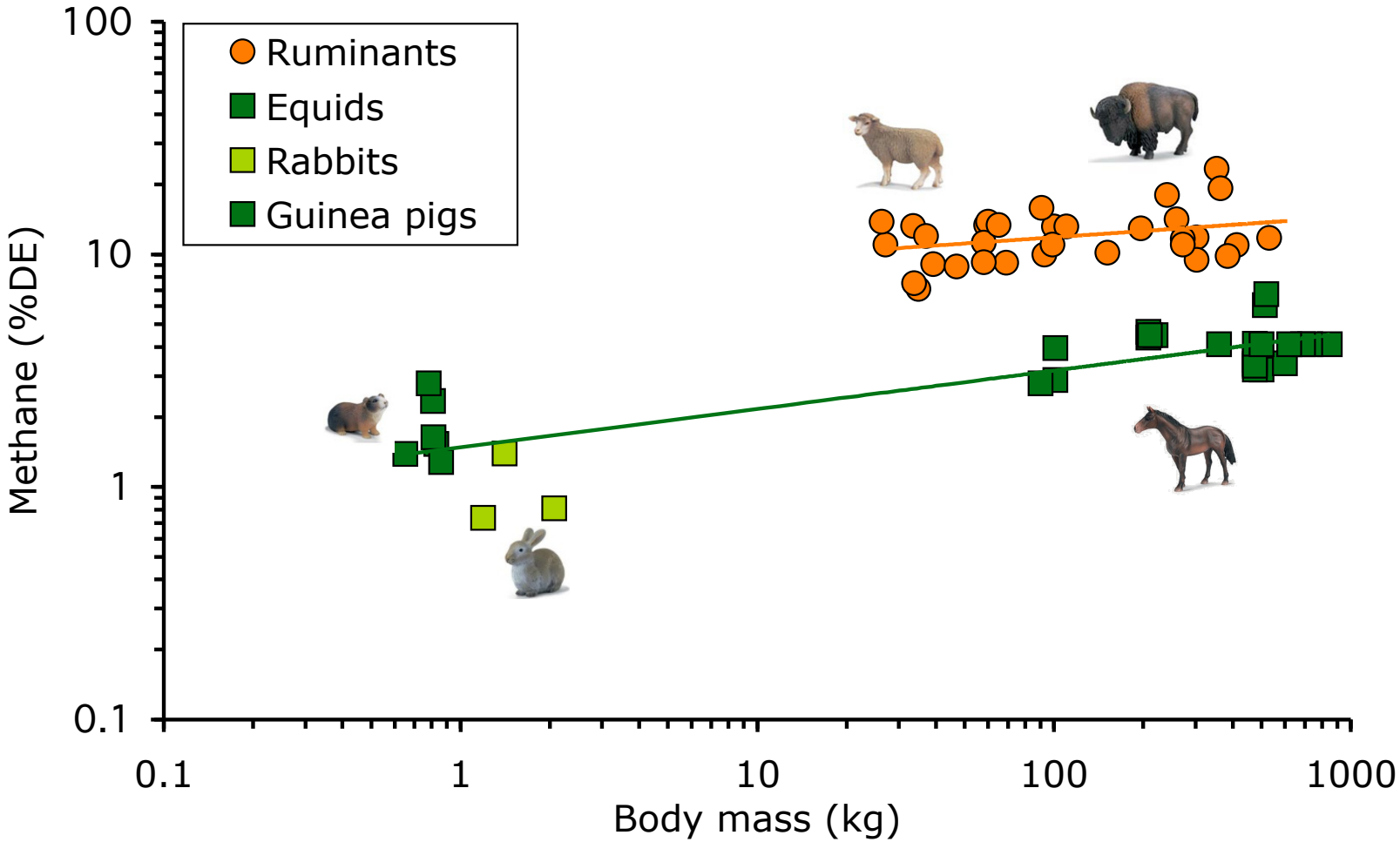

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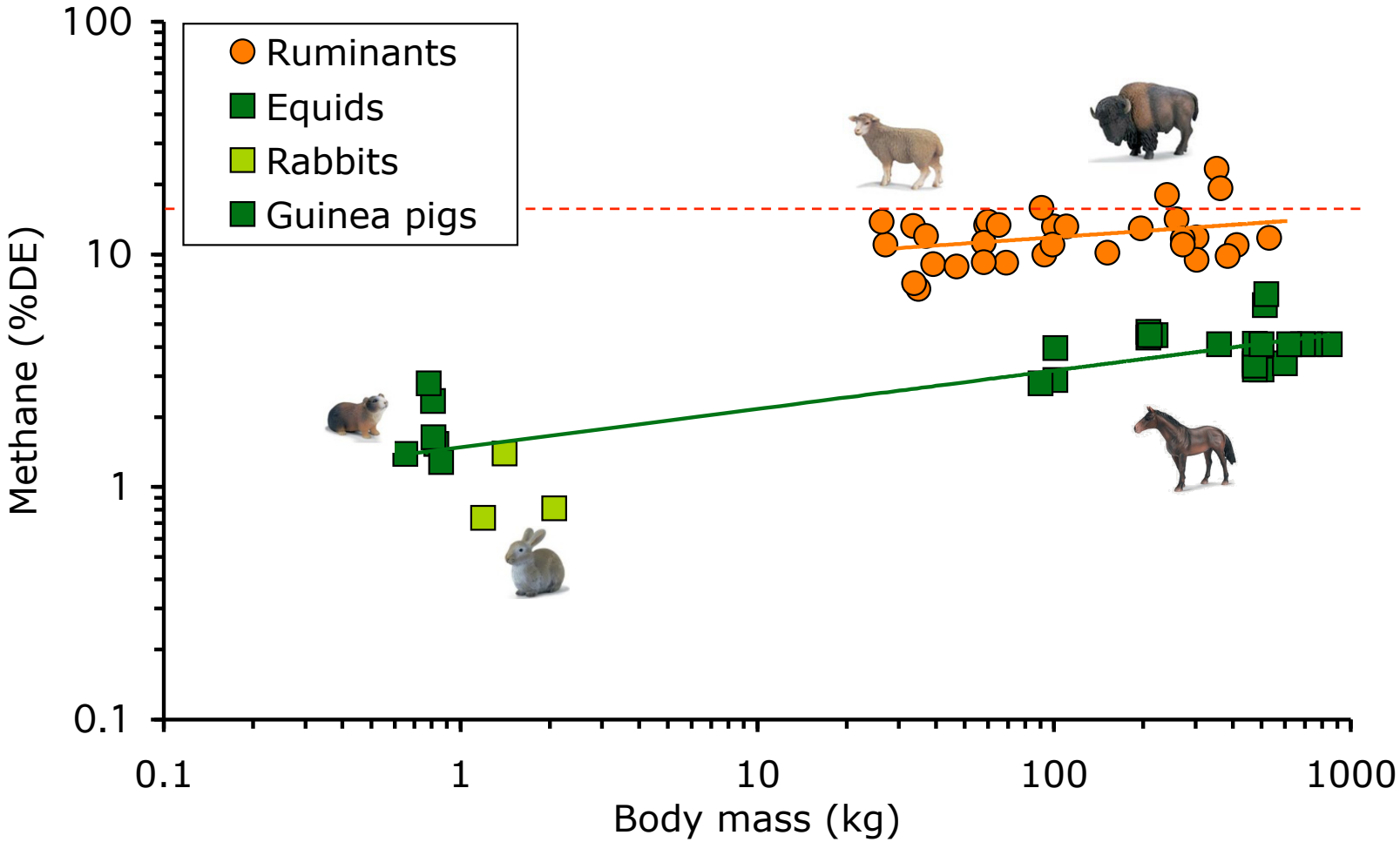

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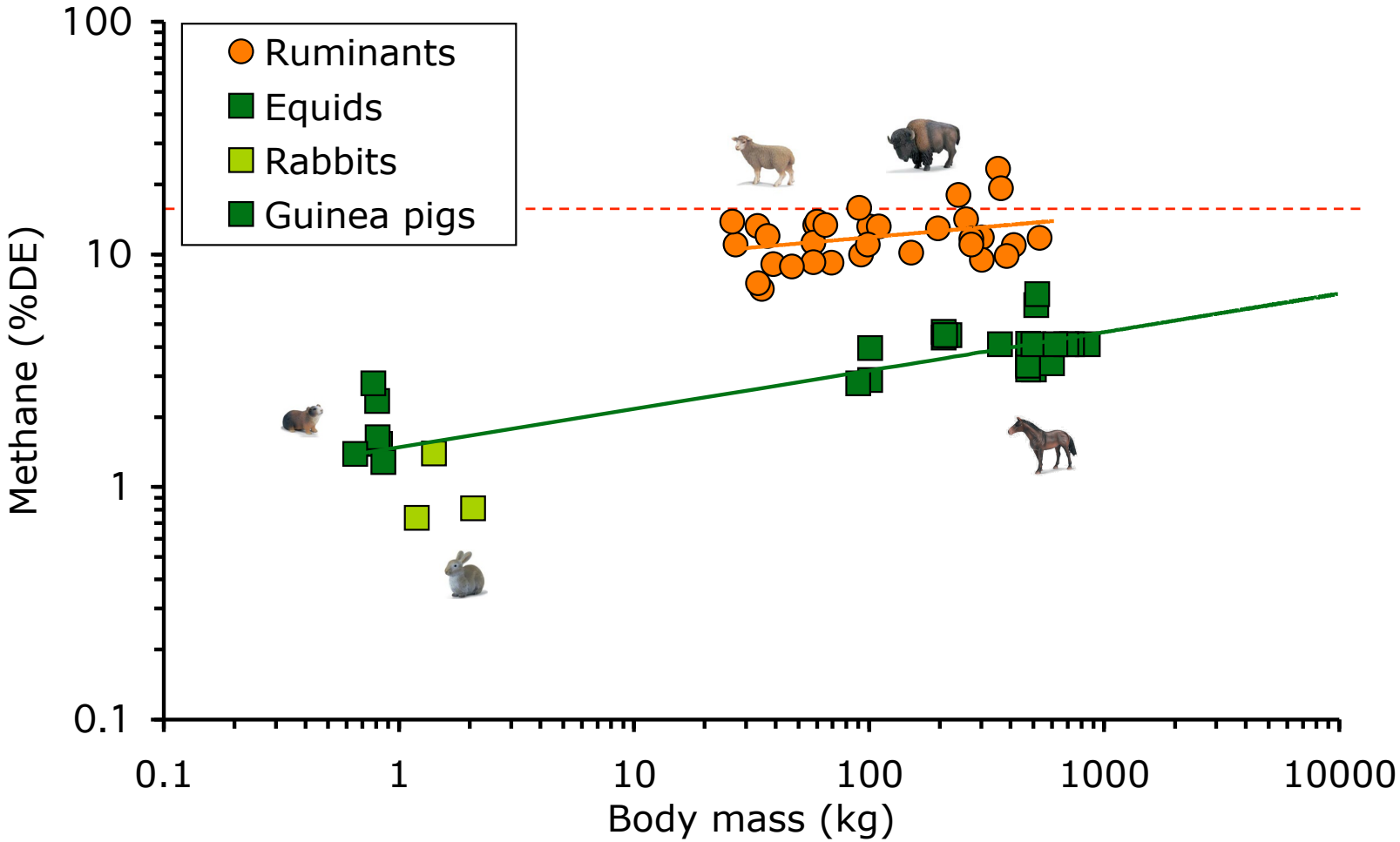

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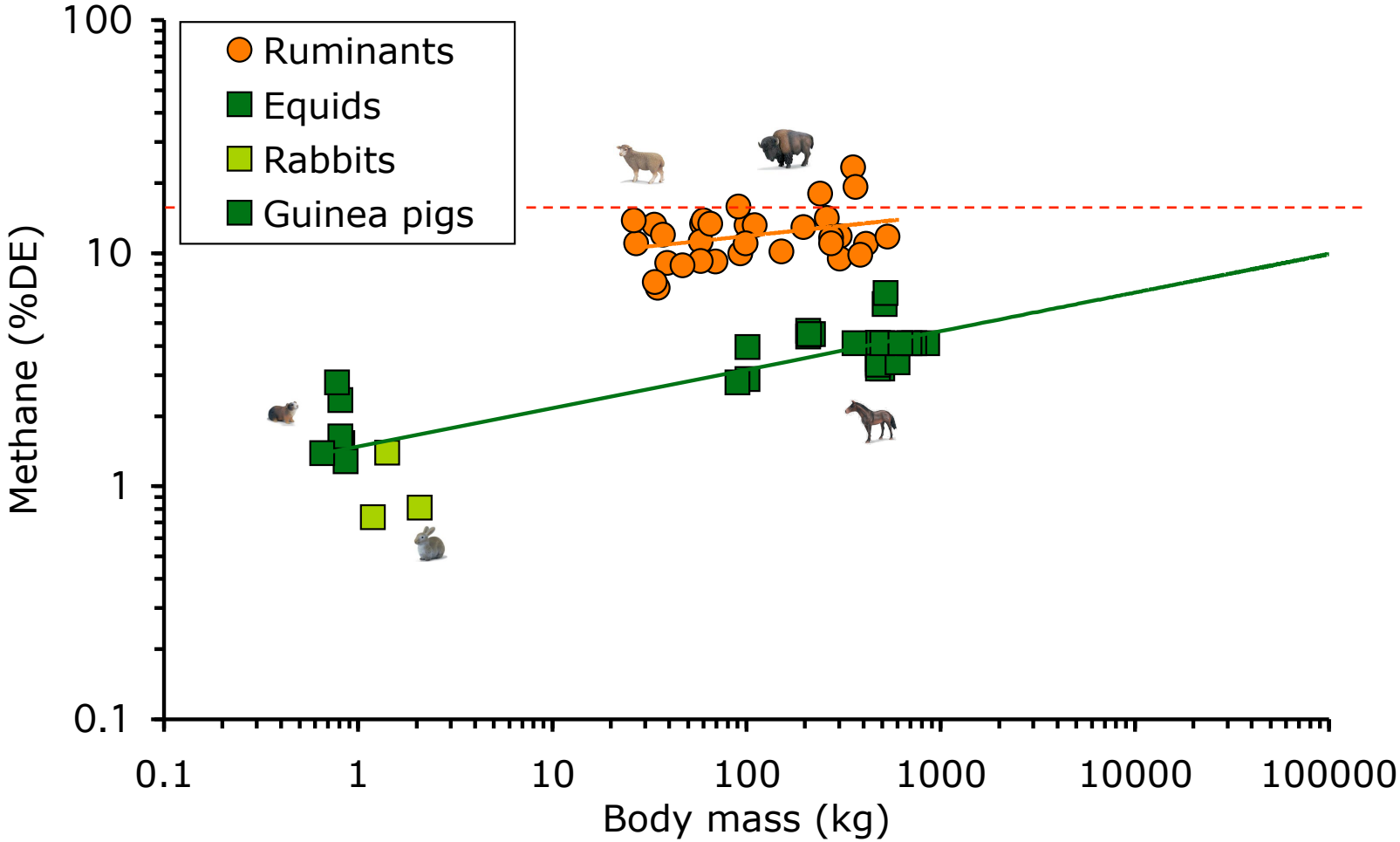
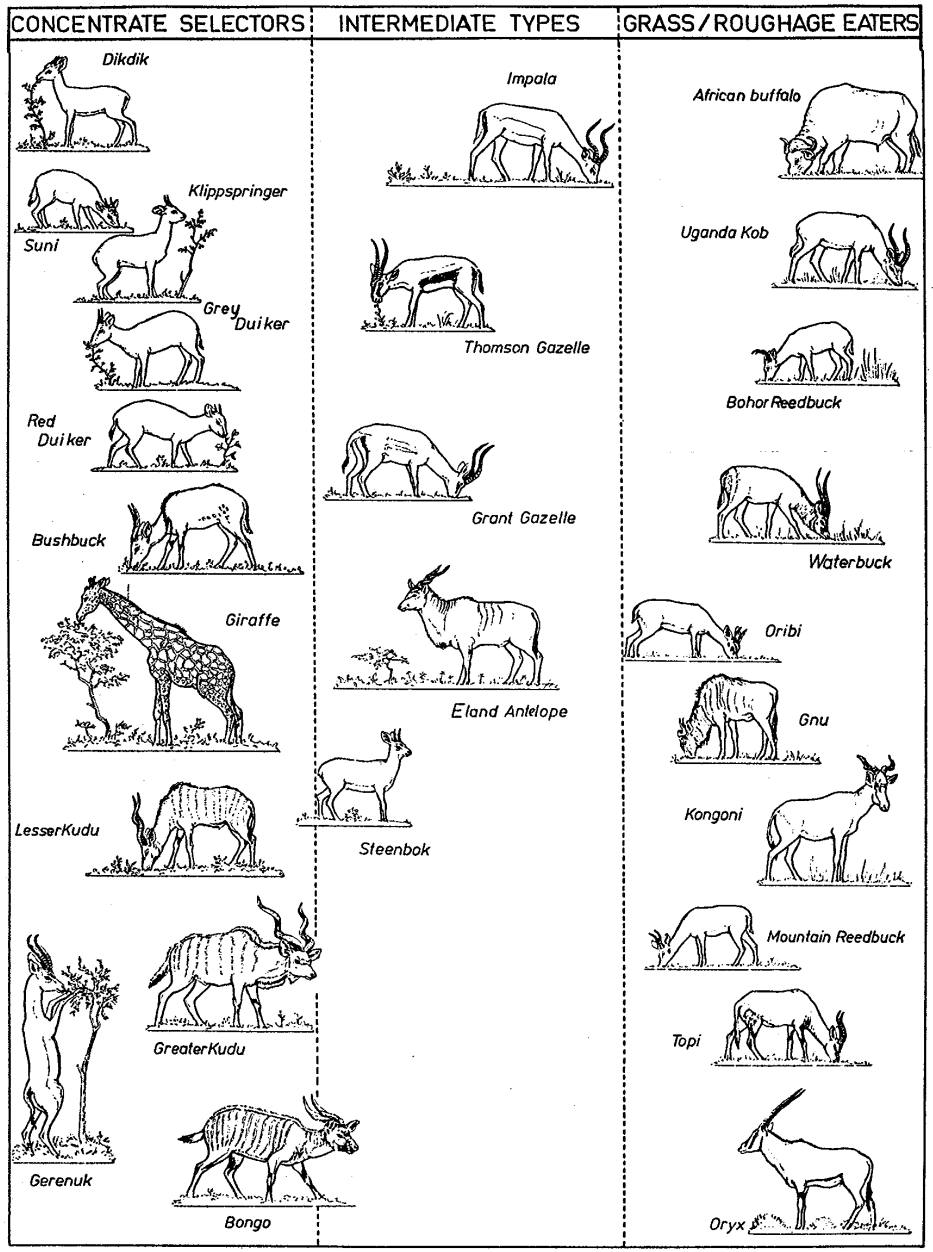


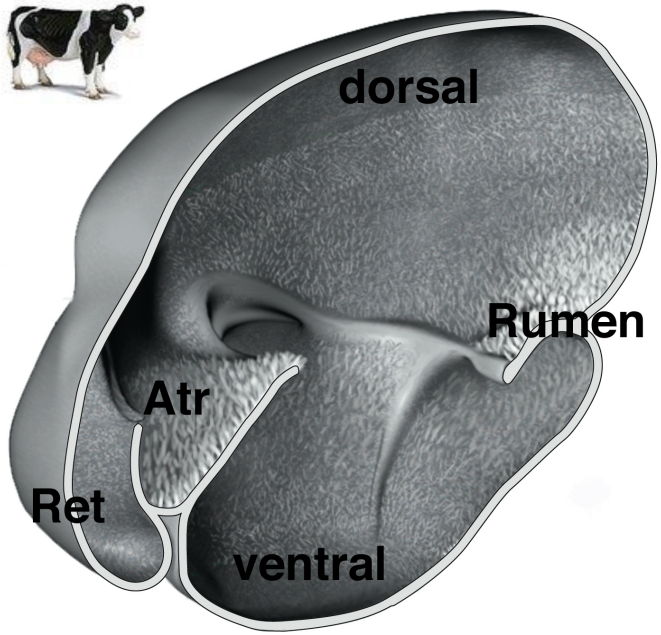
from Franz et al. (2010)

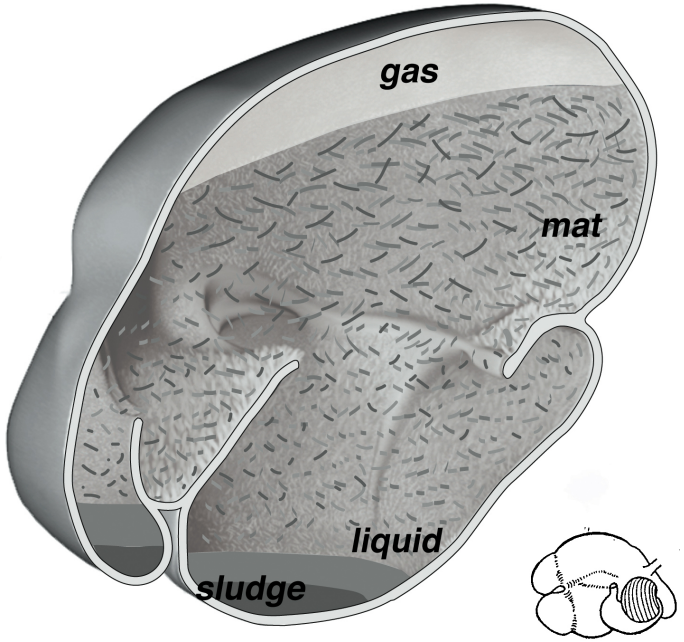
Ruminant feeding types



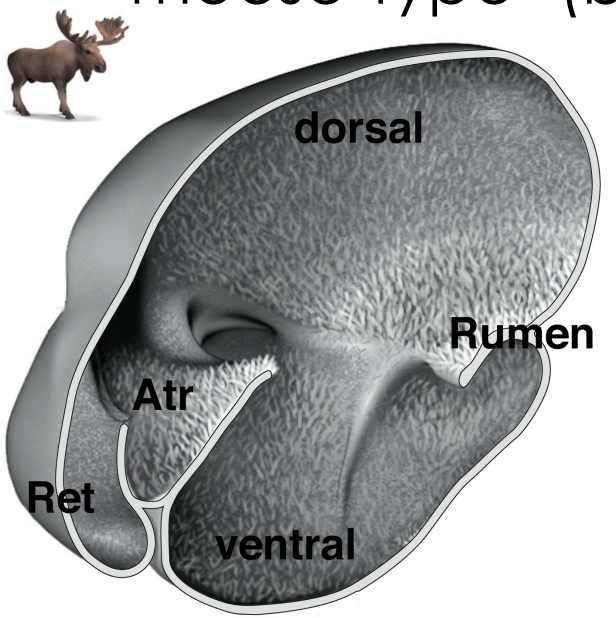
from Hofmann (1989)

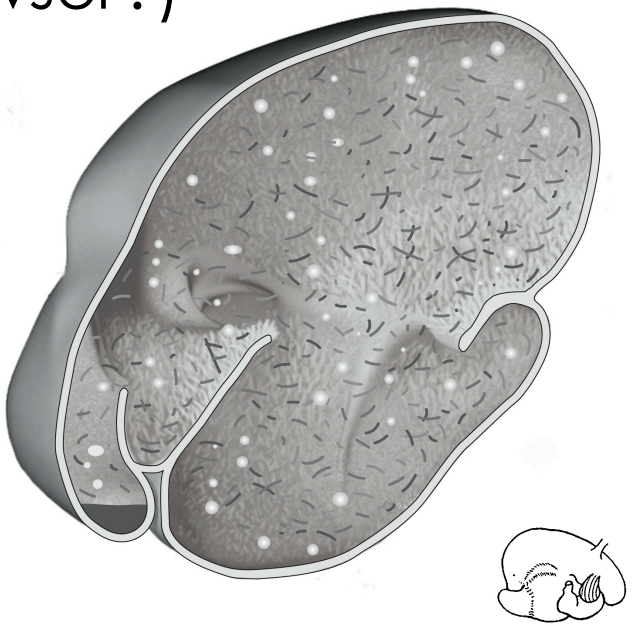
‘cattle-type’ (grazer?)





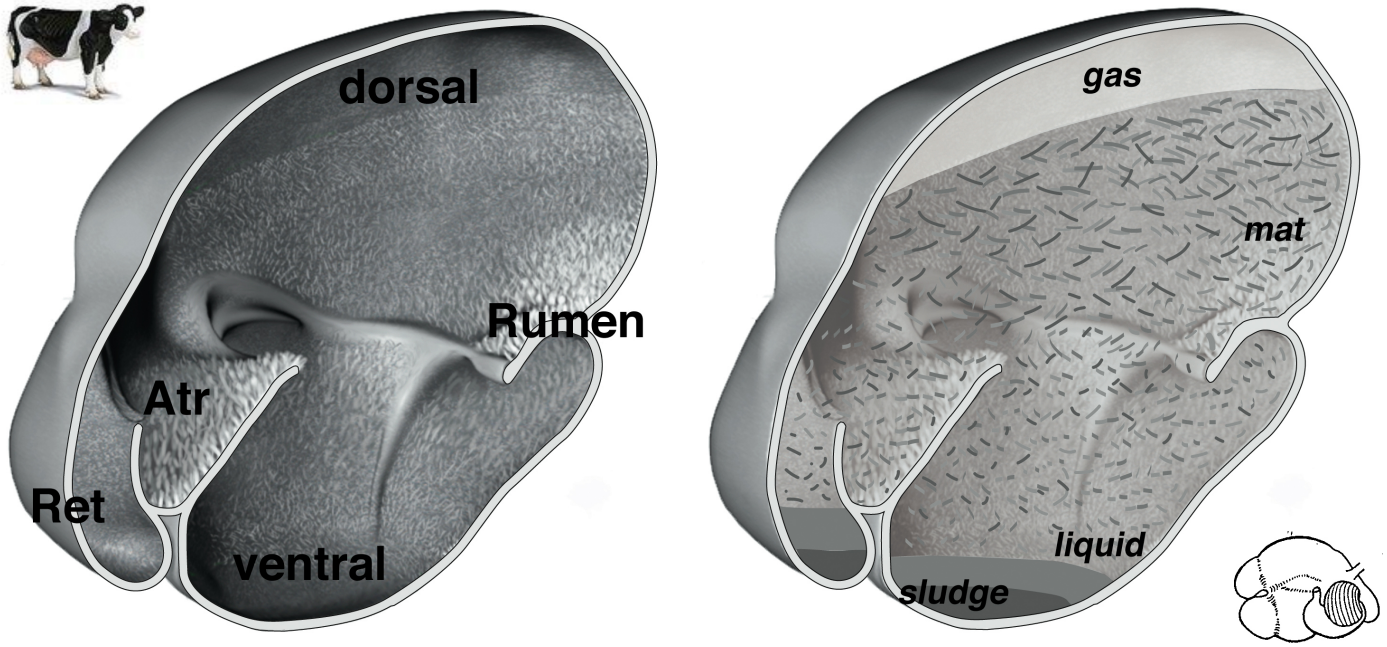
‘moose-type’ (browser?)



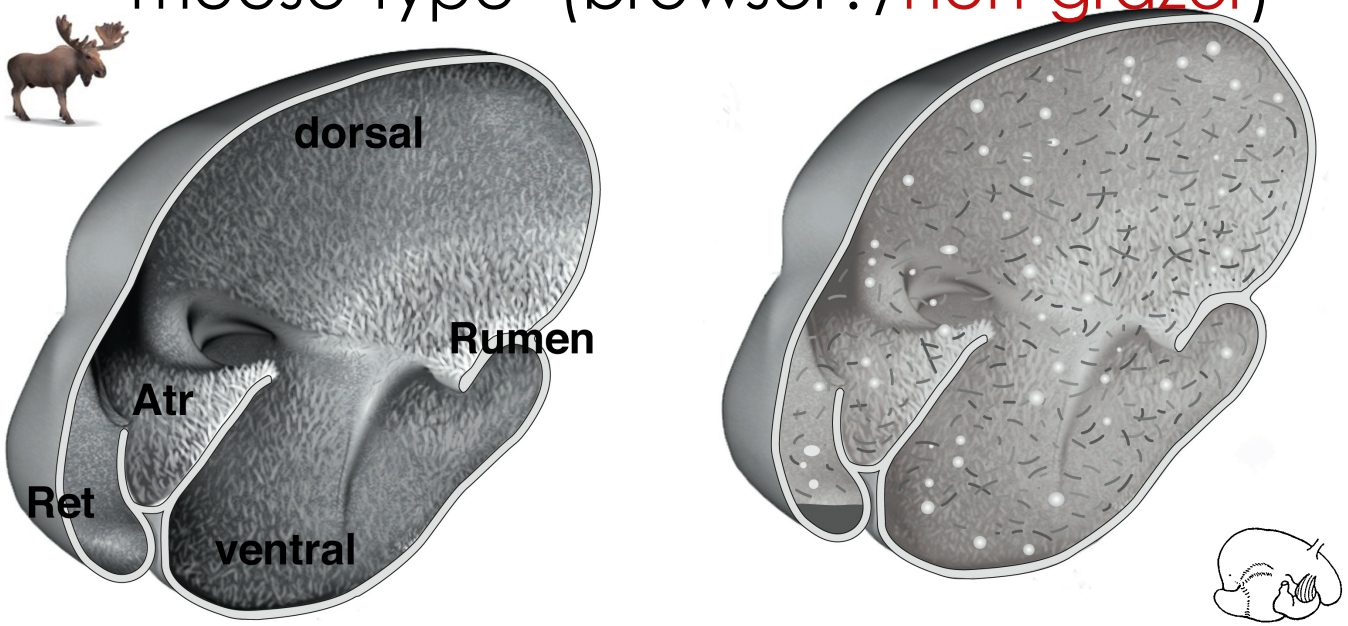


from Clauss, Hume & Hummel (2010)

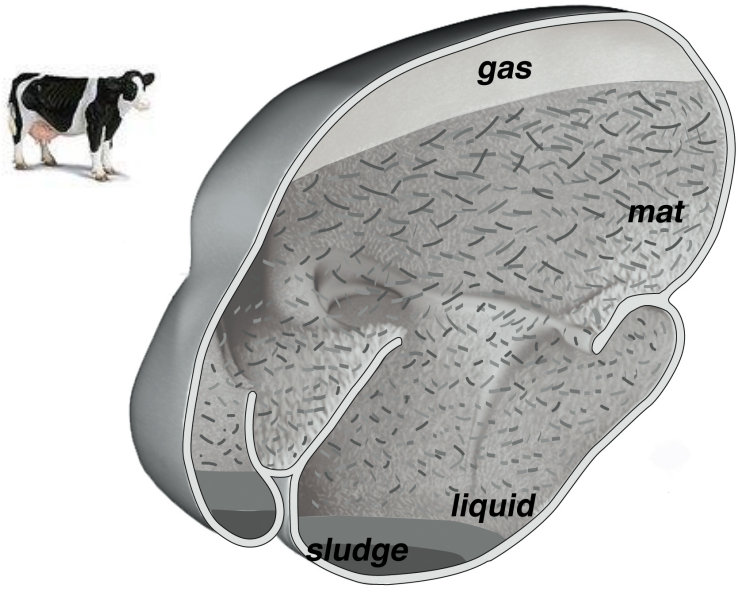
‘cattle-type’ (grazer?/universalist)



‘moose-type’ (browser?/non-grazer)

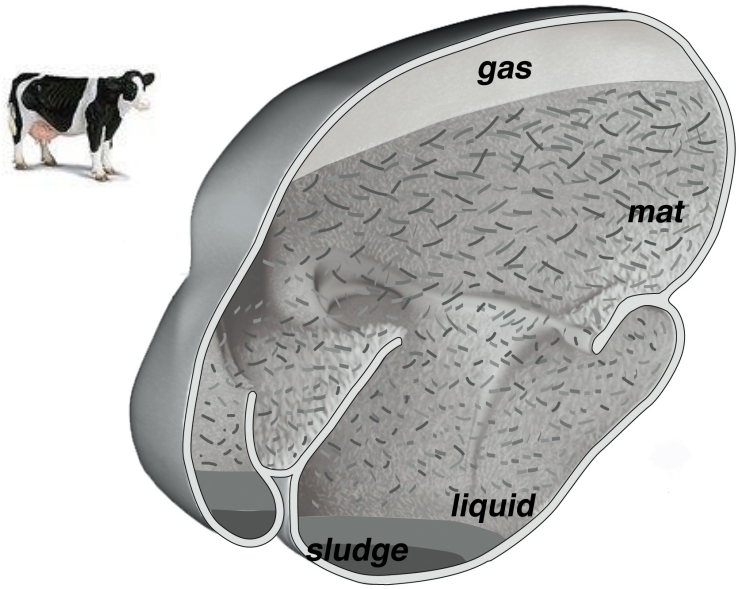


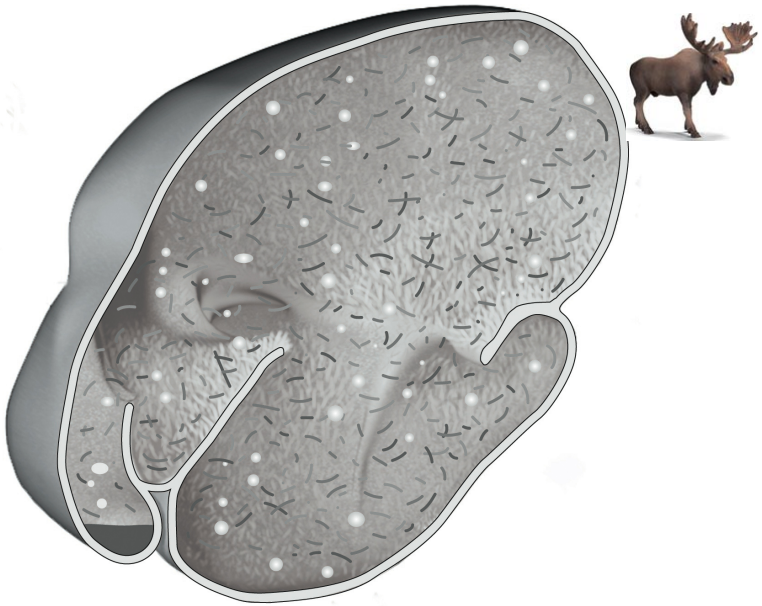
from Clauss, Hume & Hummel (2010)



High concentrations of salivary tannin-binding proteins make saliva viscous and limit saliva production:
Defence against secondary plant compounds

from Clauss, Hume & Hummel (2010)



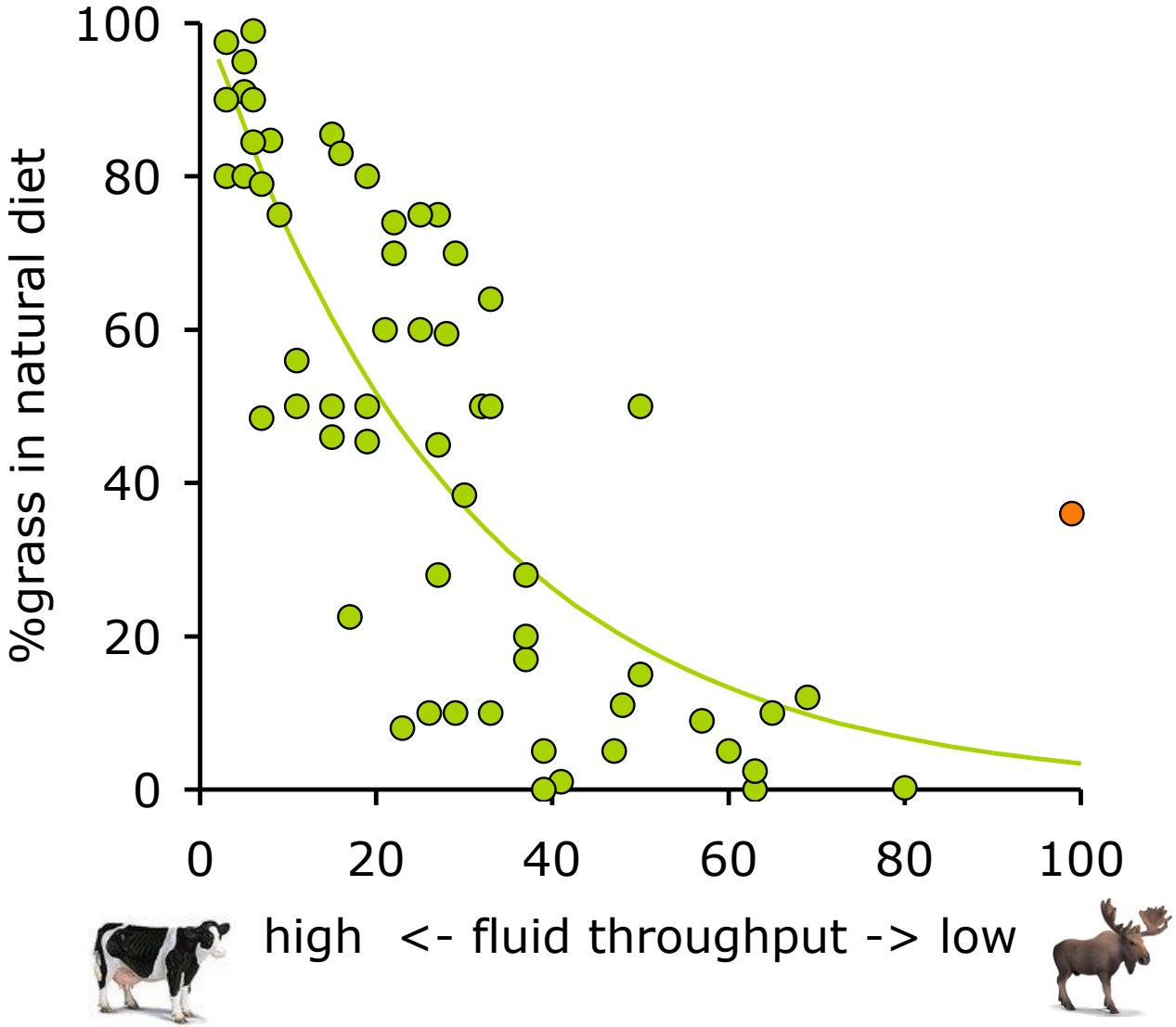


Large amounts of low-viscosity saliva increase 'harvest' of bacteria from forestomach (but defence against secondary plant compounds is compromised)

High concentrations of salivary tannin-binding proteins make saliva viscous and limit saliva production: Defence against secondary plant compounds

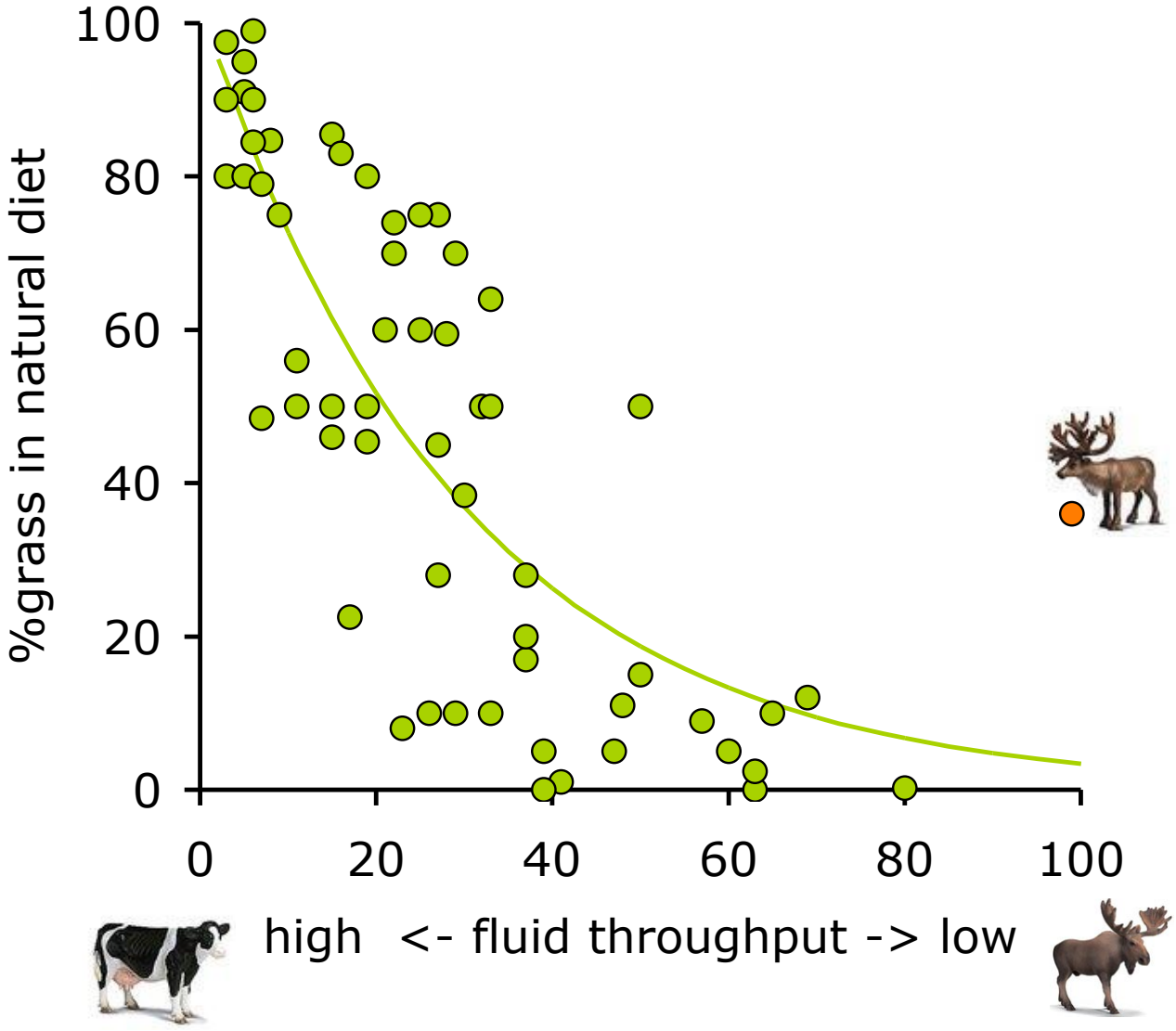
from Clauss, Hume & Hummel (2010)

Ruminant feeding types



from Codron & Clauss (2010)

Ruminant feeding types



from Codron & Clauss (2010)

Evolutionary Constraints

not A vs. B ...

Evolutionary Constraints

not A vs. B ...

... but A B

Evolutionary Constraints

not A vs. B ...

... but A ← B

Bauplan / developmental / physiological constraint

Evolutionary Constraints

not A vs. B ...

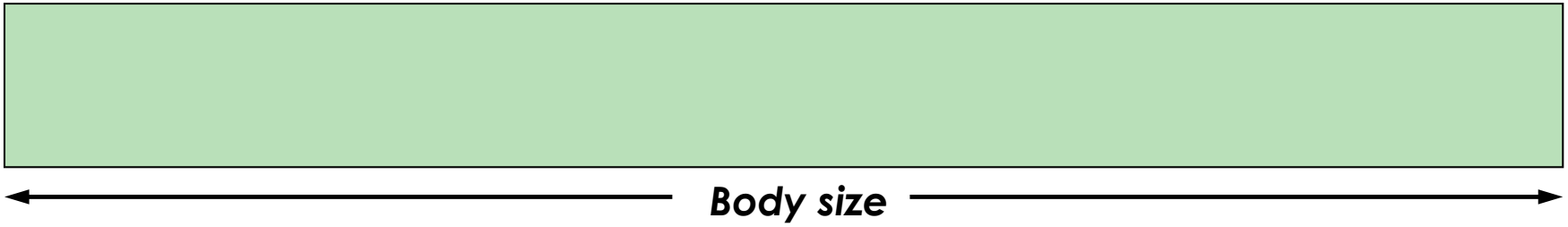
... but A → ← B

Competitional constraint →

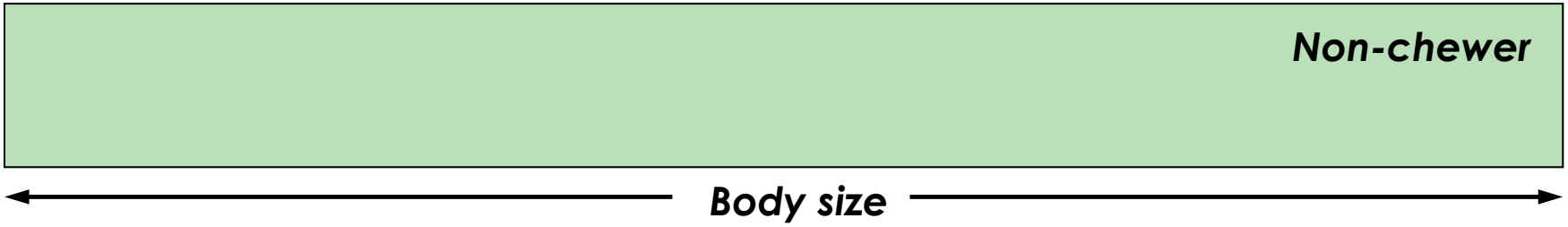
← Bauplan / developmental / physiological constraint

Evolutionary Constraints

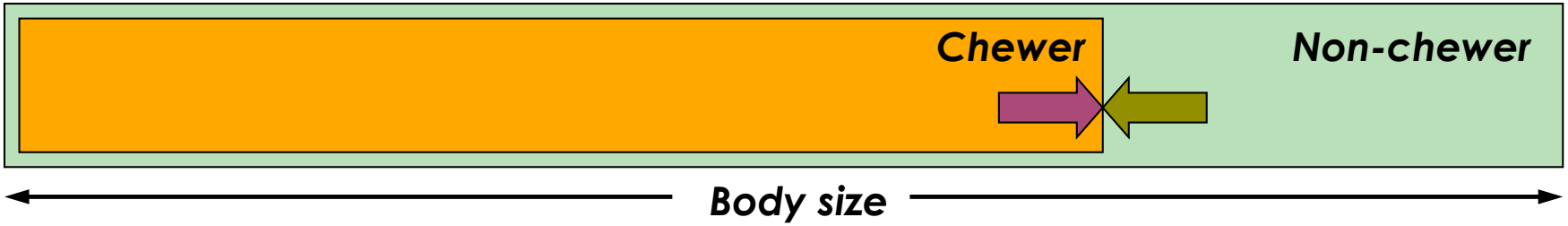
Evolutionary Constraints



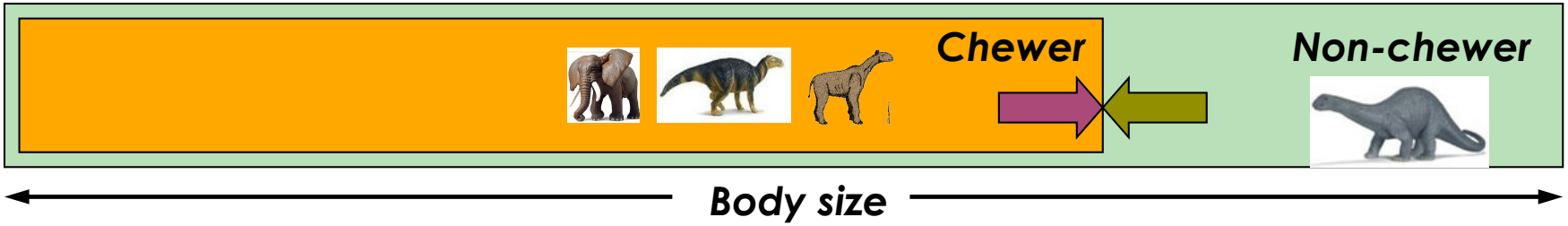
Evolutionary Constraints



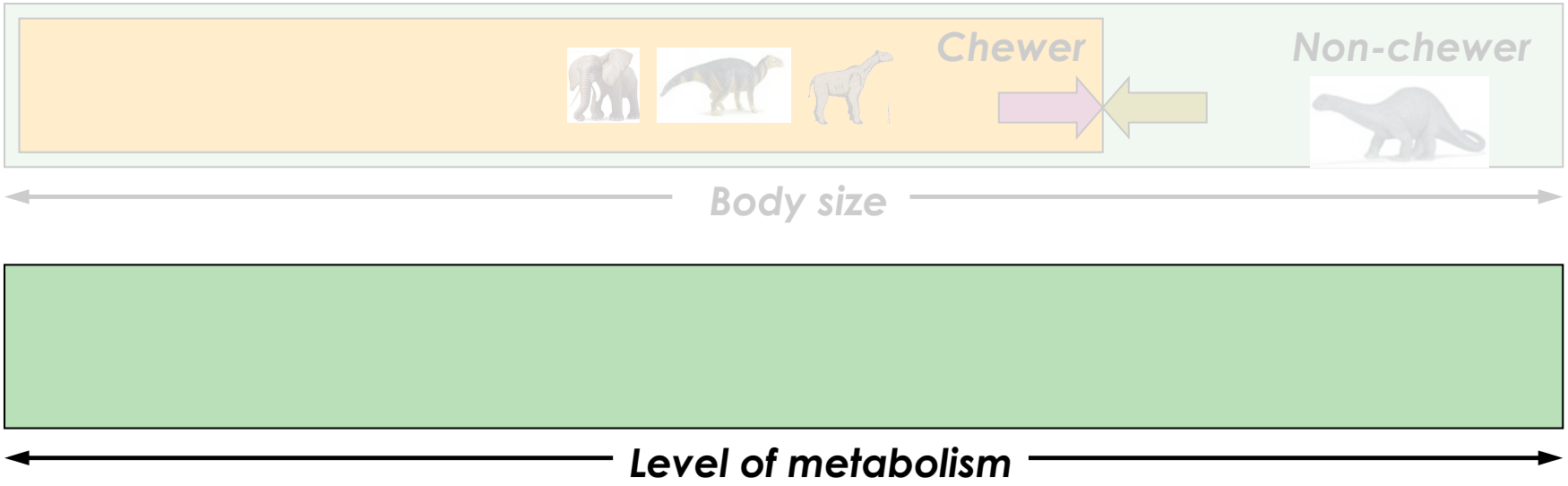
Evolutionary Constraints



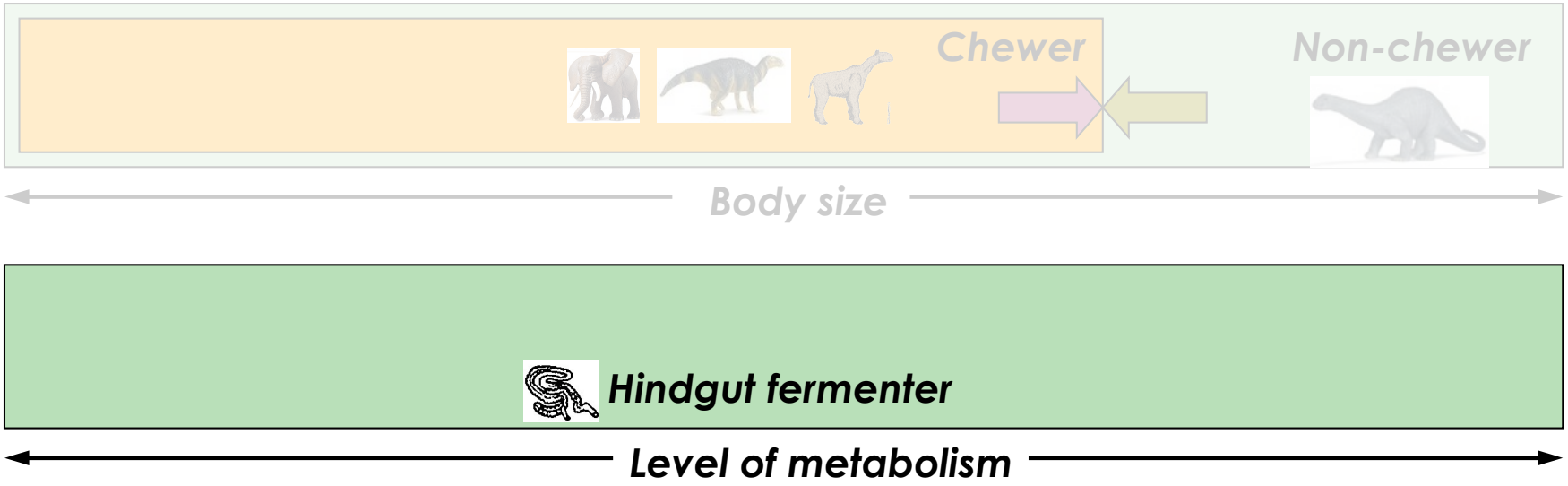
Evolutionary Constraints



Evolutionary Constraints



Evolutionary Constraints



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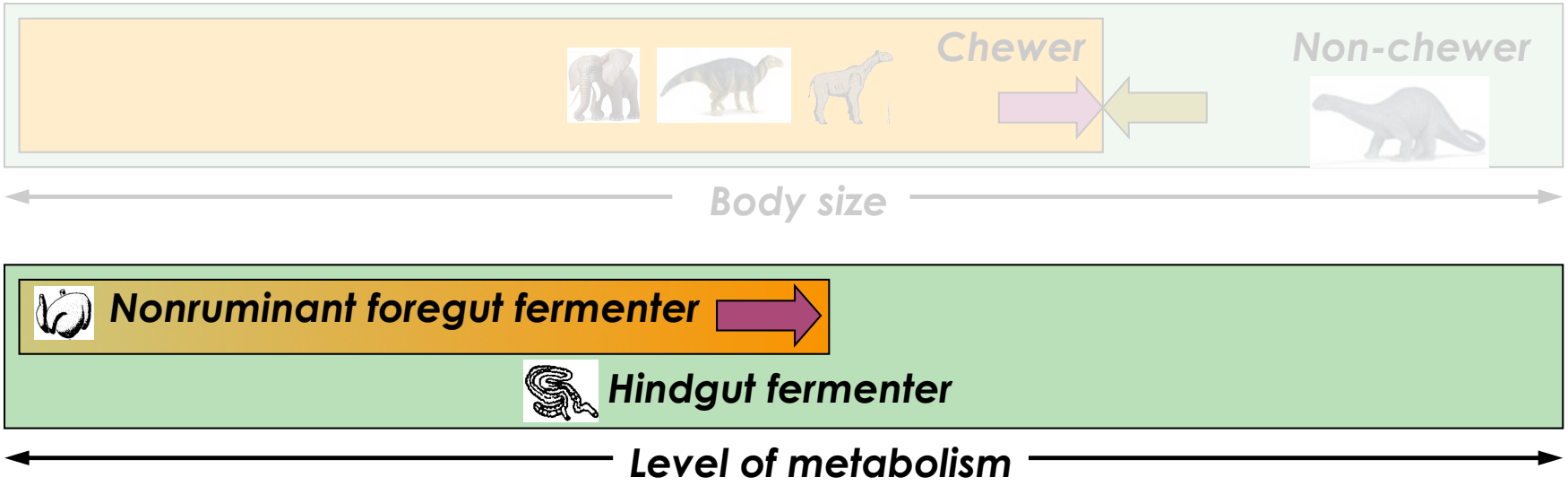

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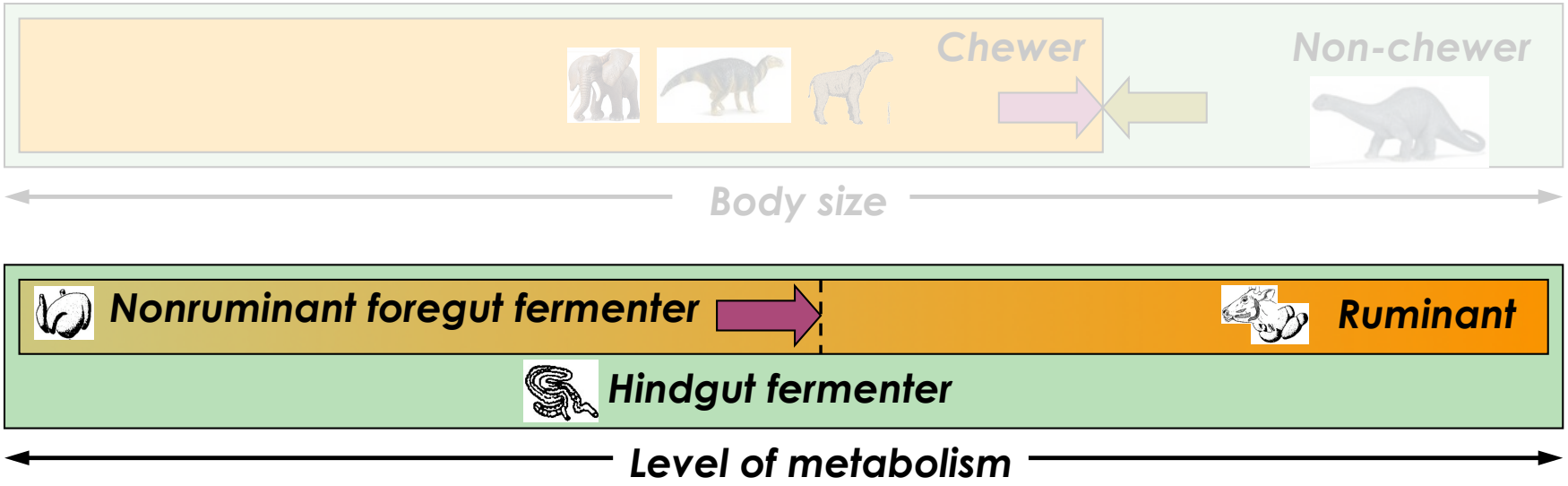

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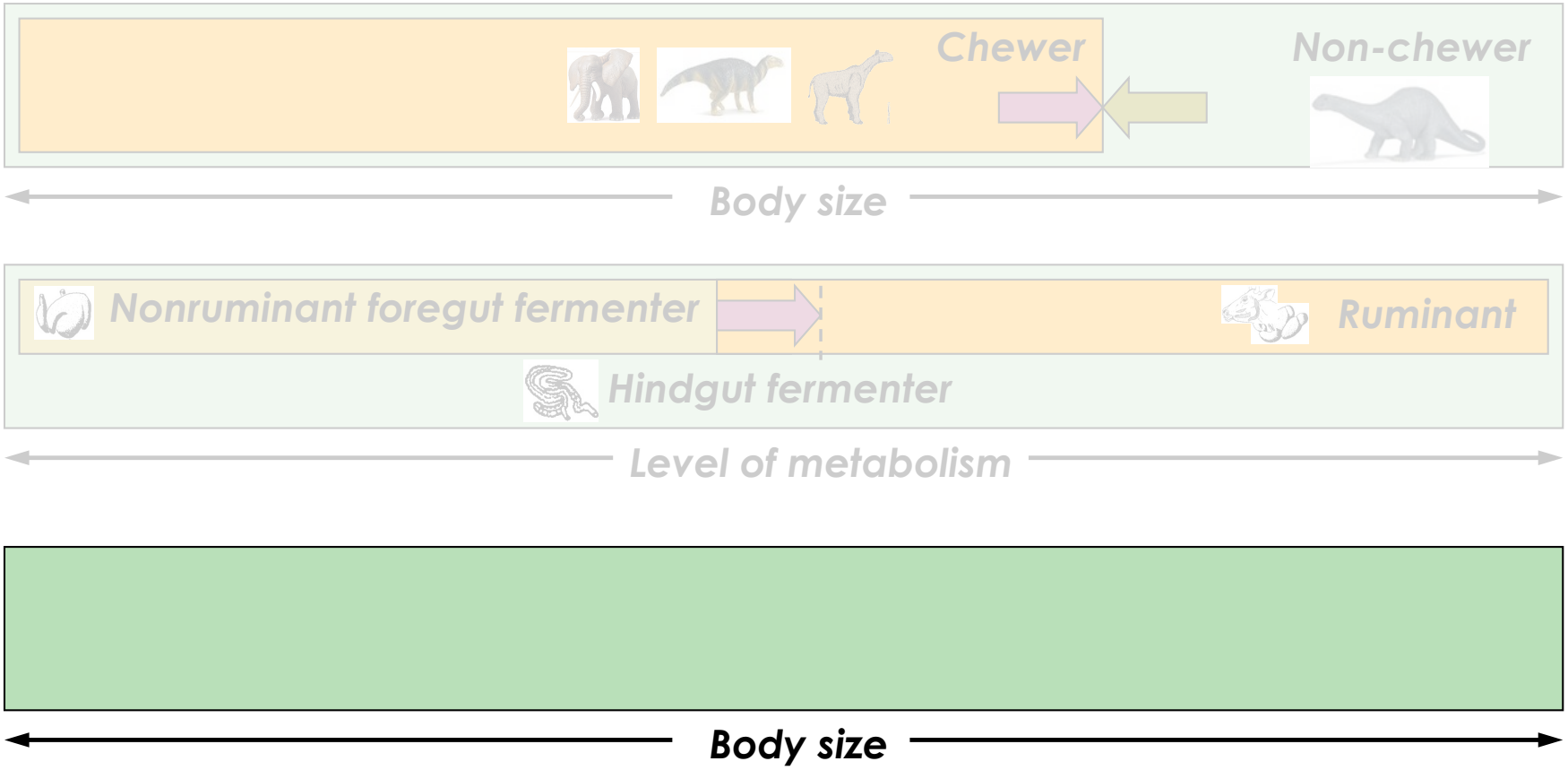

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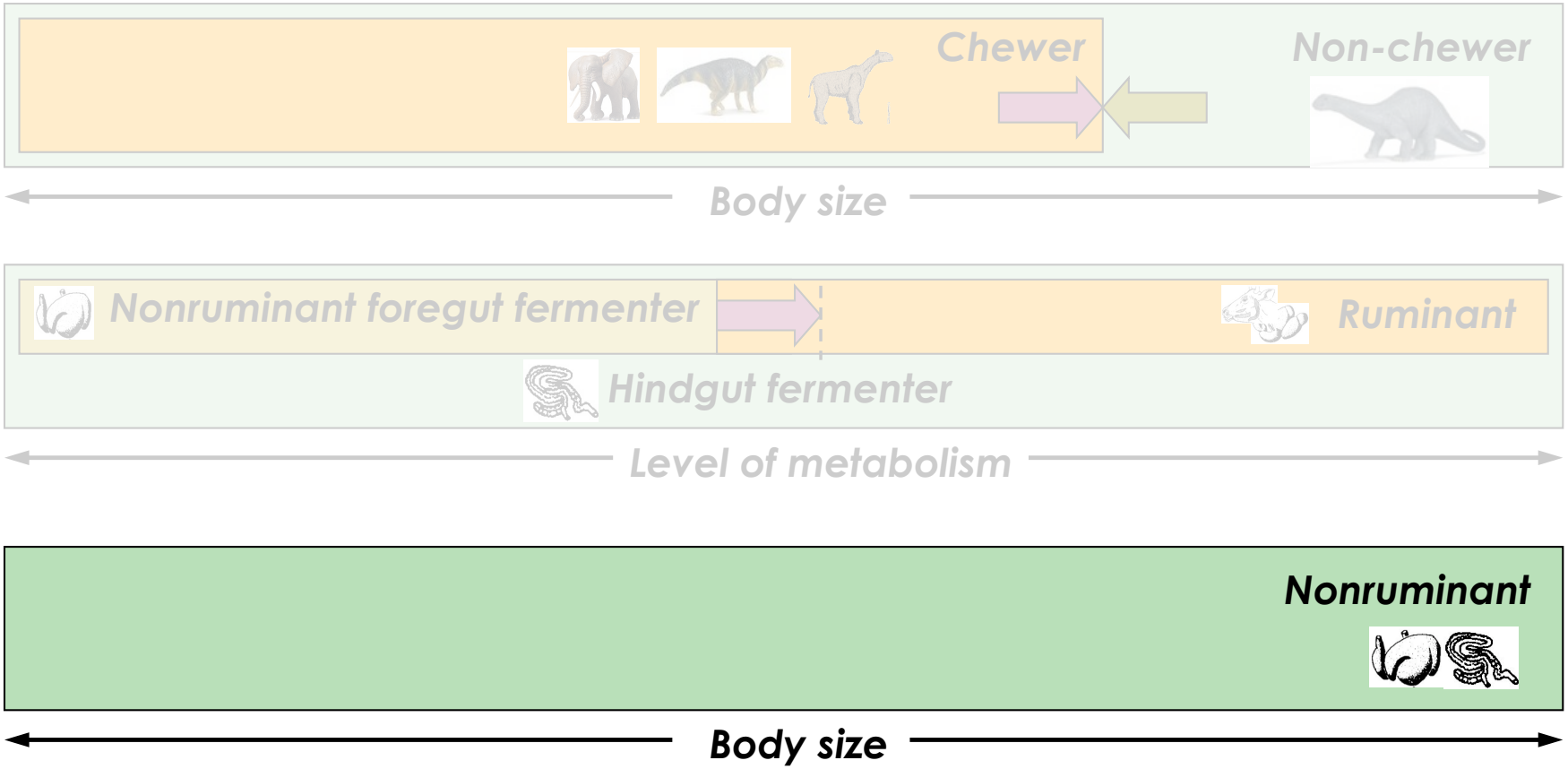

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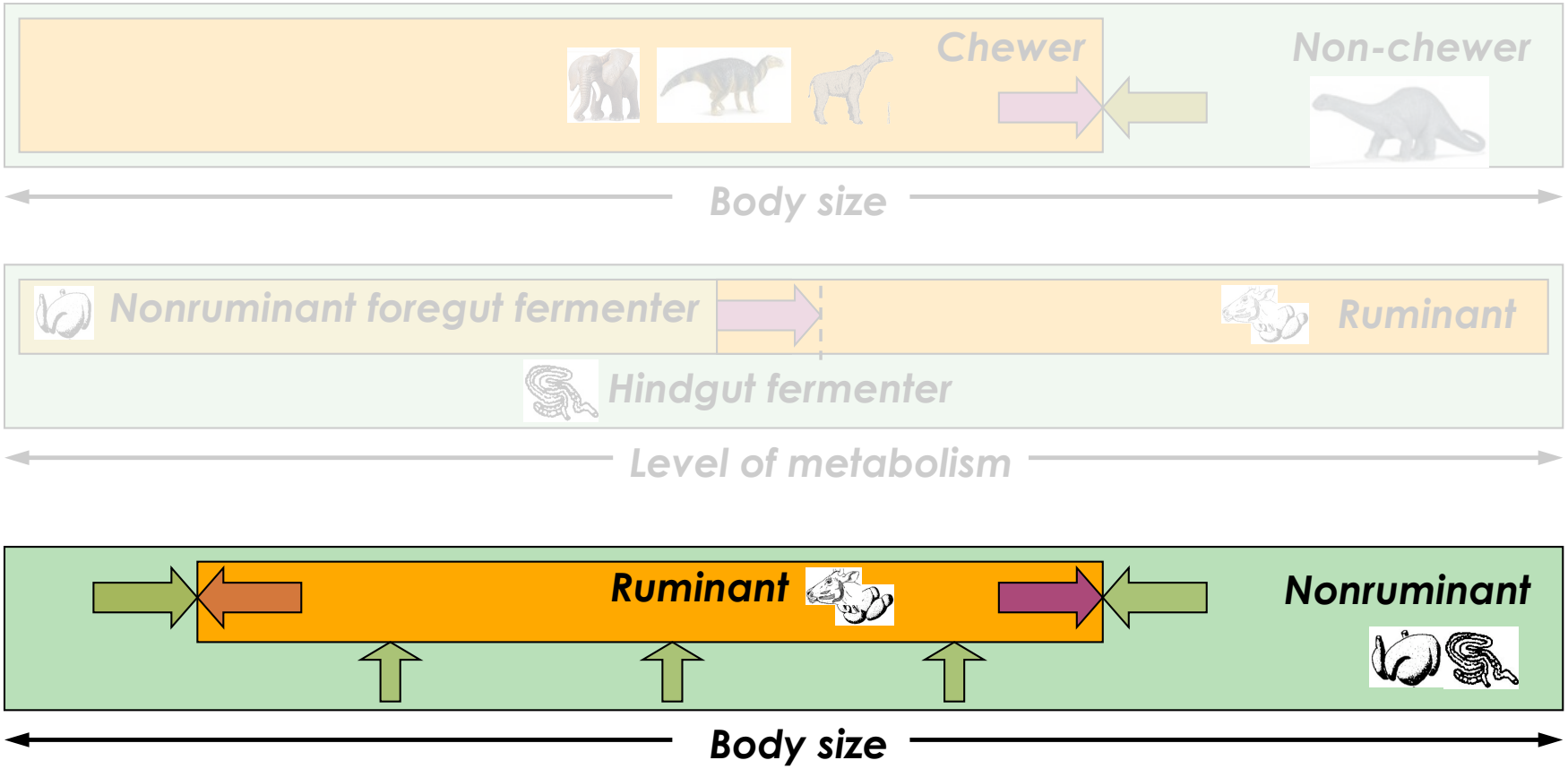

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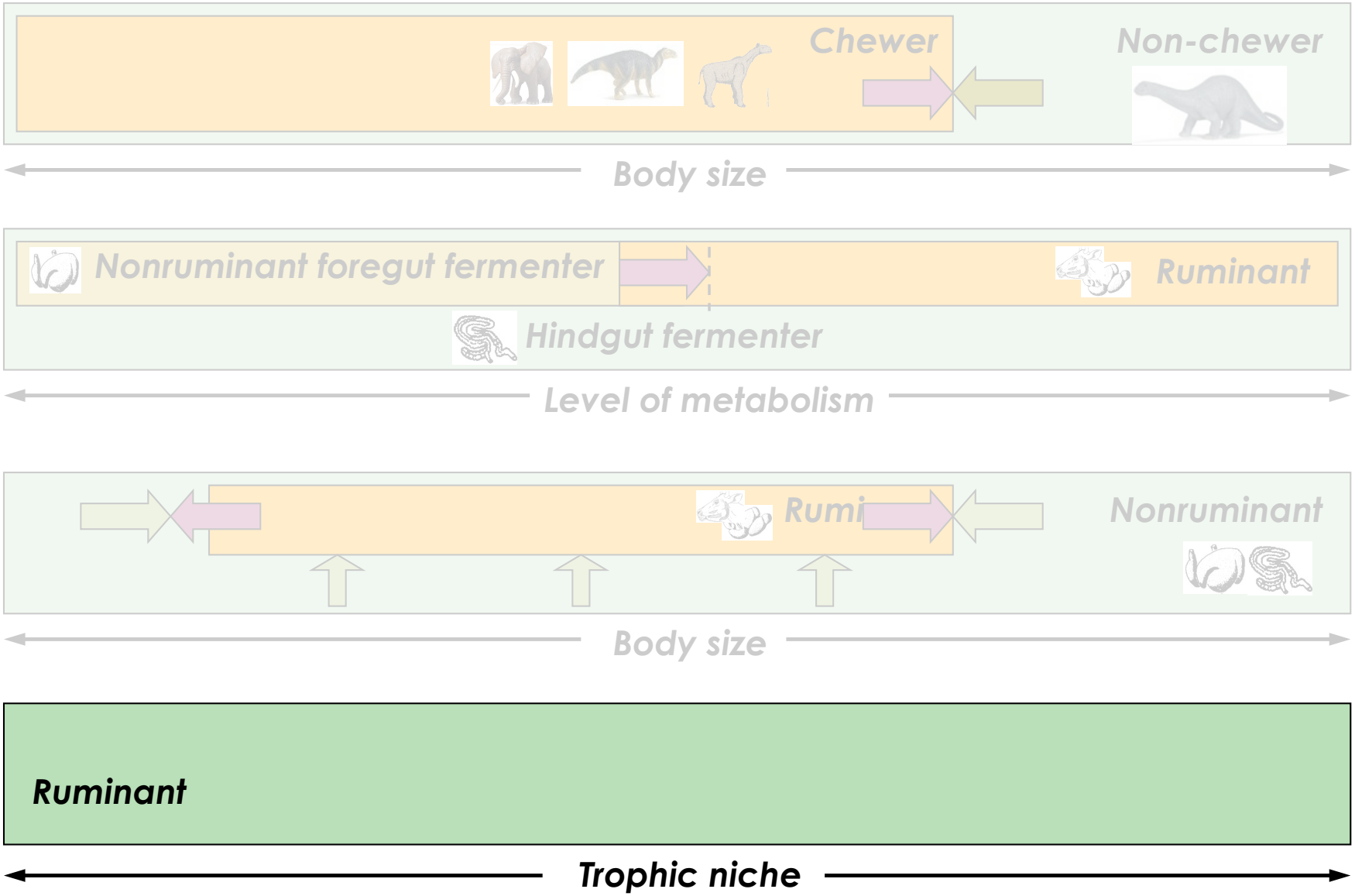

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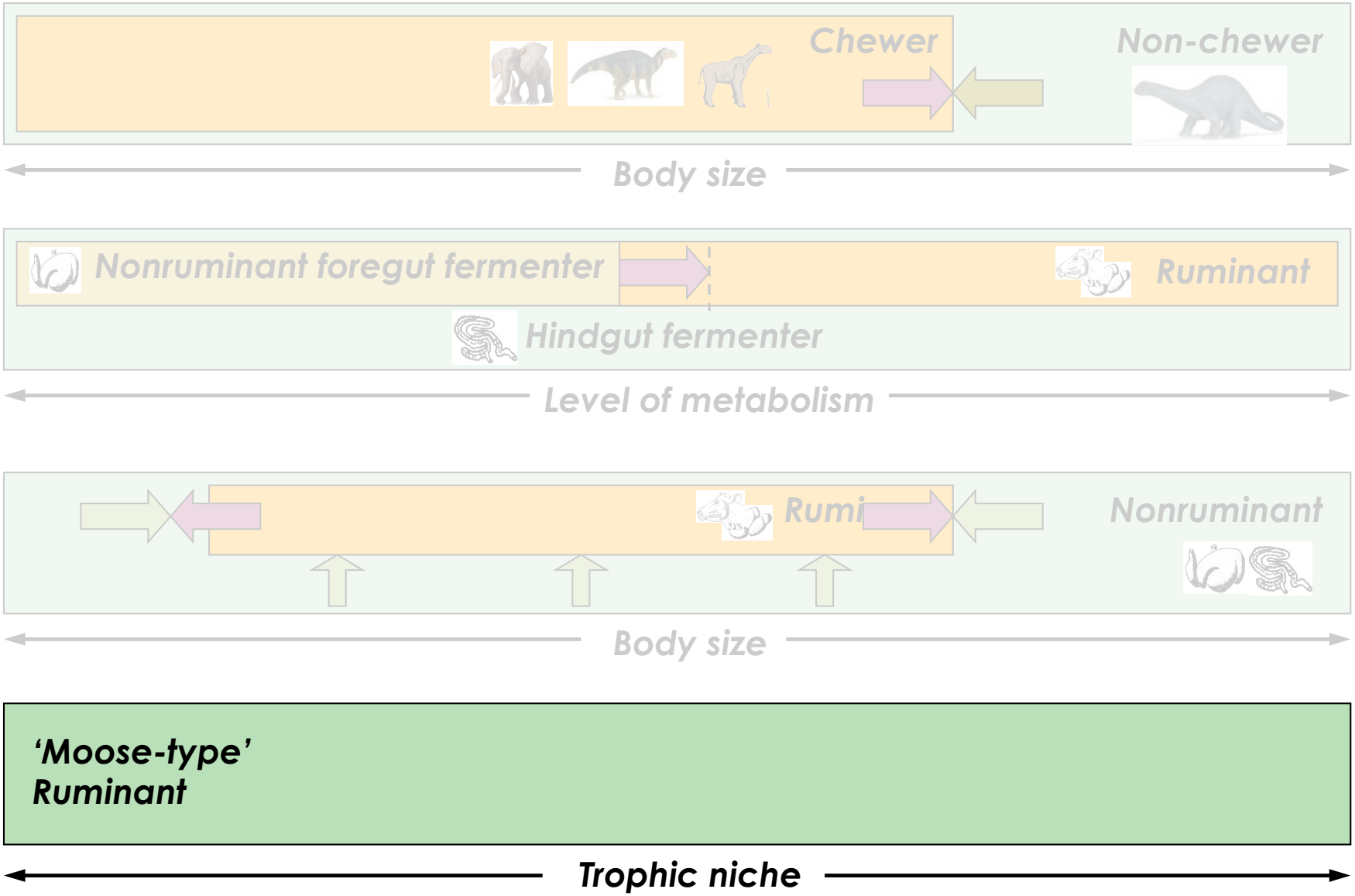

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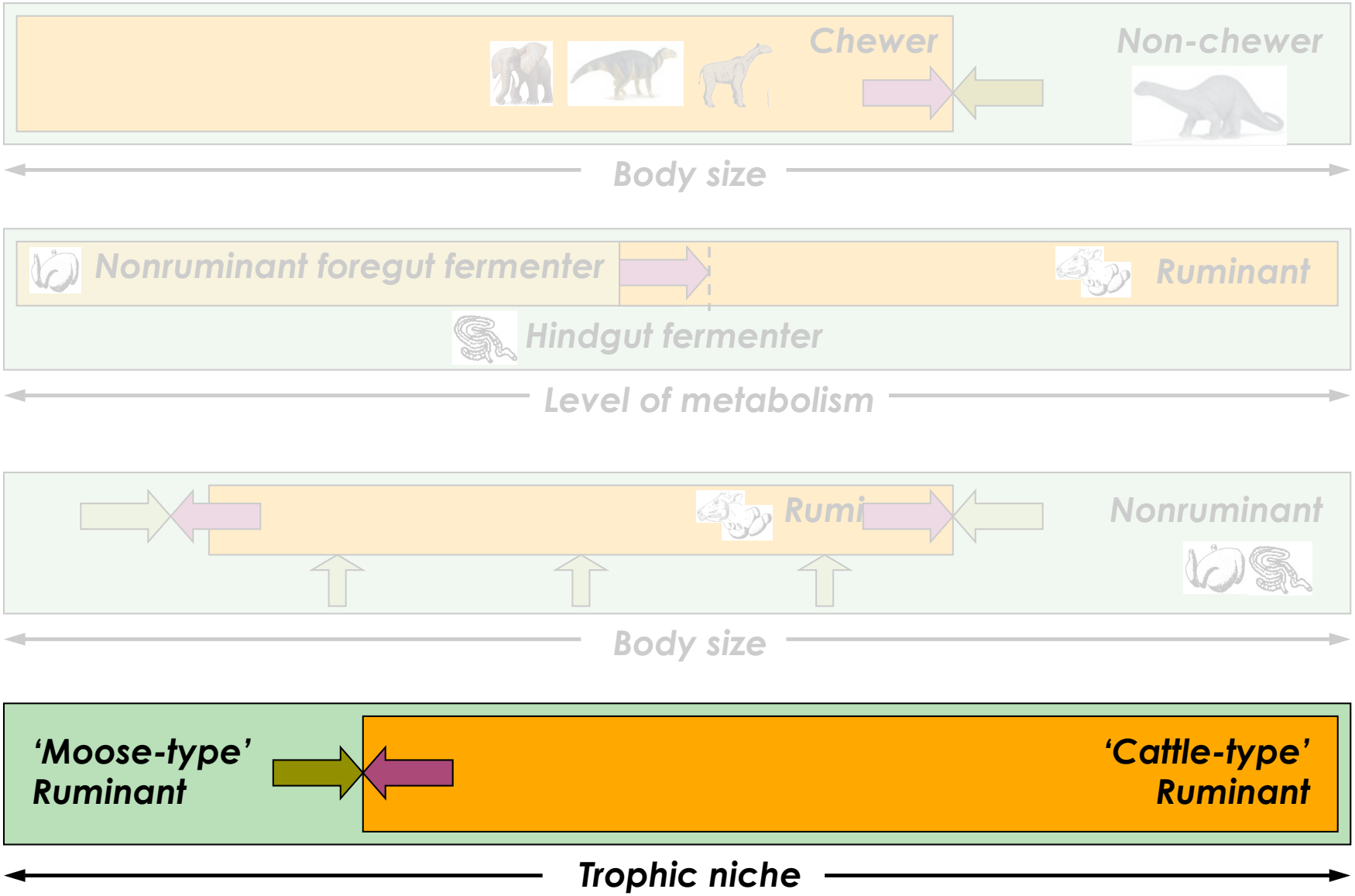

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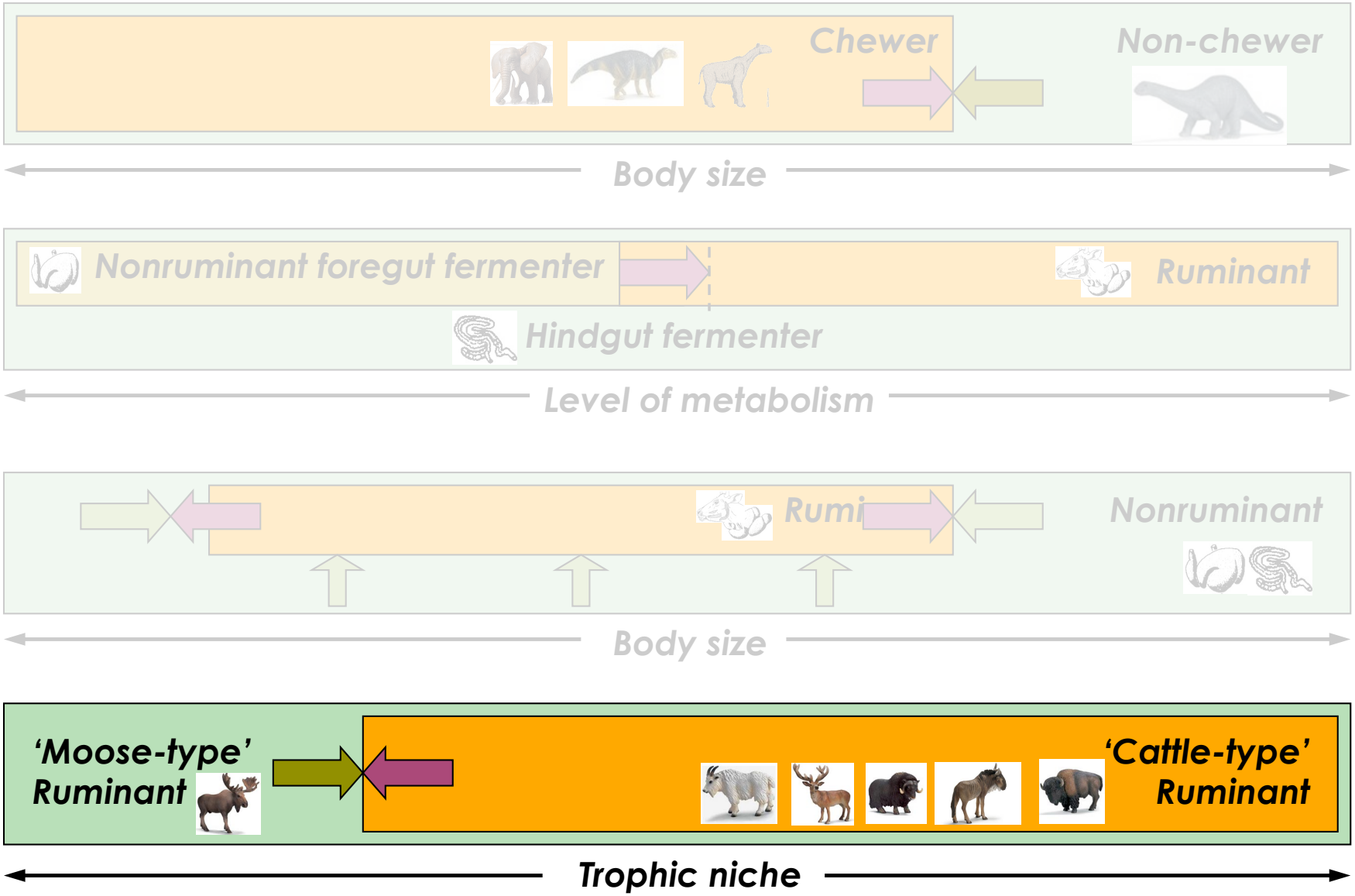

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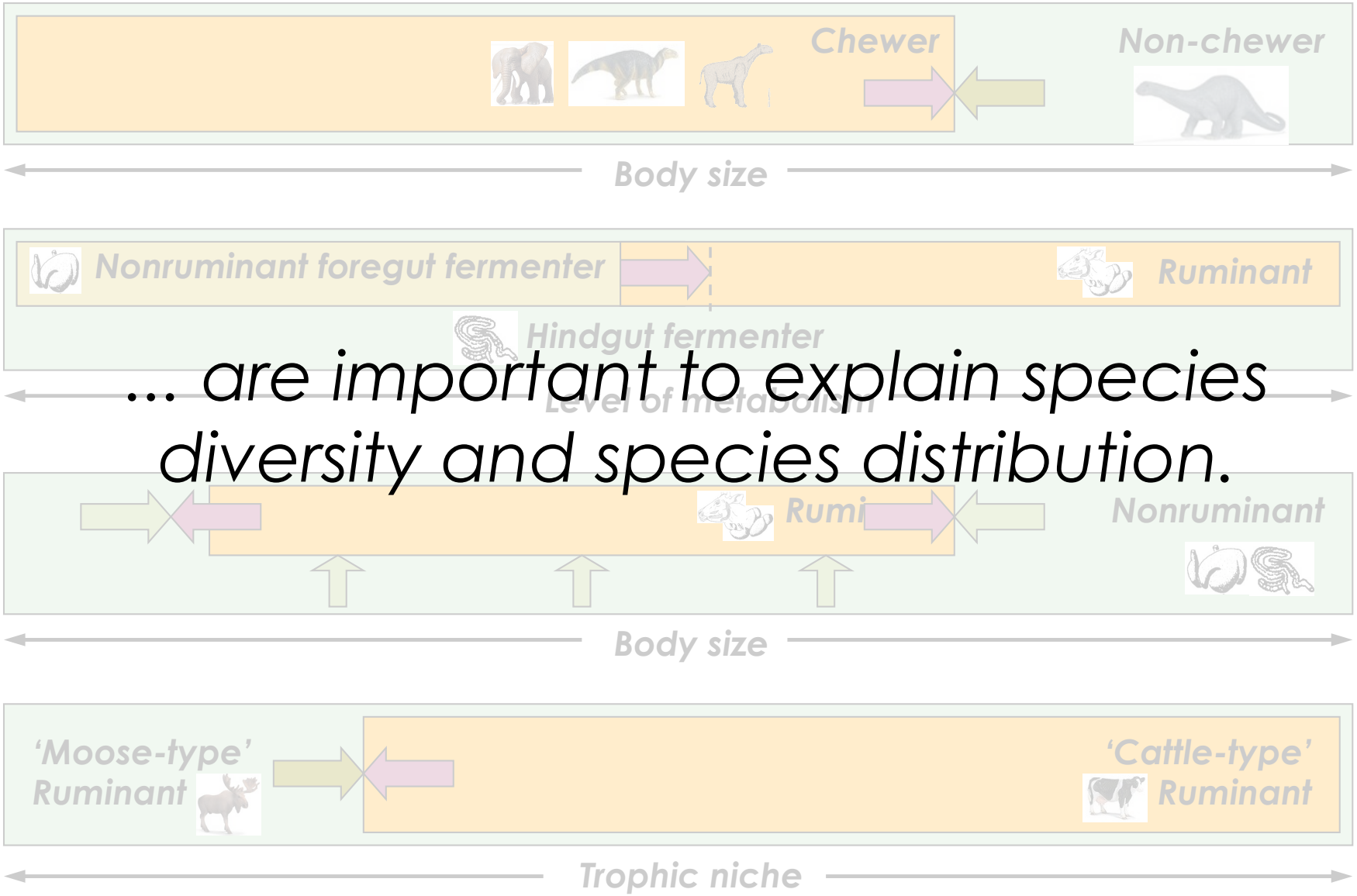

... are important to explain species diversity and species distribution.