Digestive efficiency for protein and fat in mammals of different trophic guilds and digestive strategies

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Clinic of Zoo Animals, Exotic Pets and Wildlife

Zoo Biology 29 : 687–704 (2010)

RESEARCH ARTICLE

Carnivorous Mammals: Nutrient Digestibility and Energy Evaluation

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Estimating the energy content is the first step in diet formulation, as it determines the amount of food eaten and hence the concentration of nutrients required to meet the animal's requirements. Additionally, being able to estimate the energy content of a diet empirically known to maintain body condition in an animal will facilitate an estimation of maintenance energy requirements. We collated data on nutrient composition of diets fed to captive wild canids, felids, hyenids, mustelids, pinnipeds, and ursids and the digestibility coefficients from the literature (45 species, 74 publications) to test whether differences in protein and fat digestibility could be detected between species groups, and whether approaches suggested for the estimation of dietary metabolizable energy (ME) content in domestic carnivores (NRC [2006] Nutrient requirements of dogs and cats. Washington, DC: National Academy Press.) can be applied to wild carnivores as well. Regressions of digestible protein or fat content vs. the crude protein (CP) or fat content indicated no relevant differences in the digestive physiology between the carnivore groups. For diets based on raw meat, fish, or whole prey, applying the calculation of ME using "Atwater factors" (16.7 kJ/g CP; 16.7 kJ/g nitrogen-free extracts; 37.7 kJ/g crude fat) provided estimates that compared well to experimental results. This study suggests that ME estimation in such diets is feasible without additional digestion trials. For comparative nutrition research, the study implicates that highly digestible diets typically fed in zoos offer little potential to elucidate differences between species or carnivore groups, but research on diets with higher proportions of difficult-to-digest components (fiber, connective tissues) is lacking. Zoo Biol 29:687–704, 2010. © 2010 Wiley-Liss, Inc.

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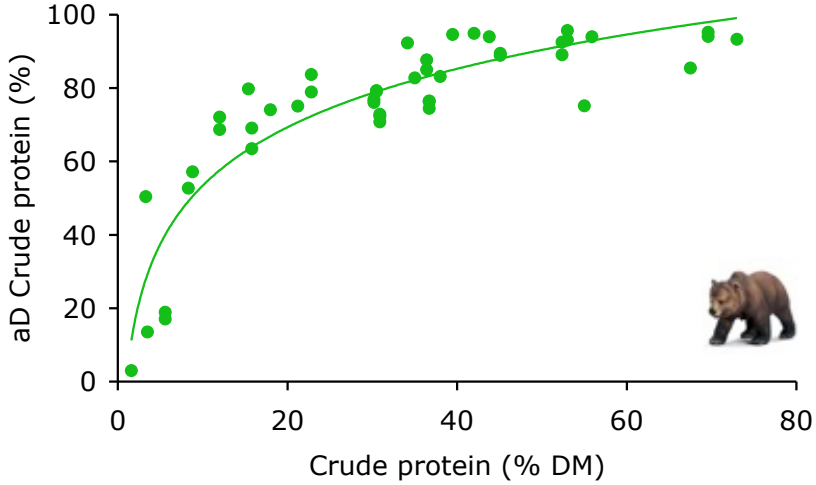
Received 20 February 2009; Revised 3 September 2009; Accepted 23 November 2009

DOI 10.1002/zoo.20302
Published online 13 January 2010 in Wiley Online Library (wileyonlinelibrary.com).

Nutrient content and digestibility

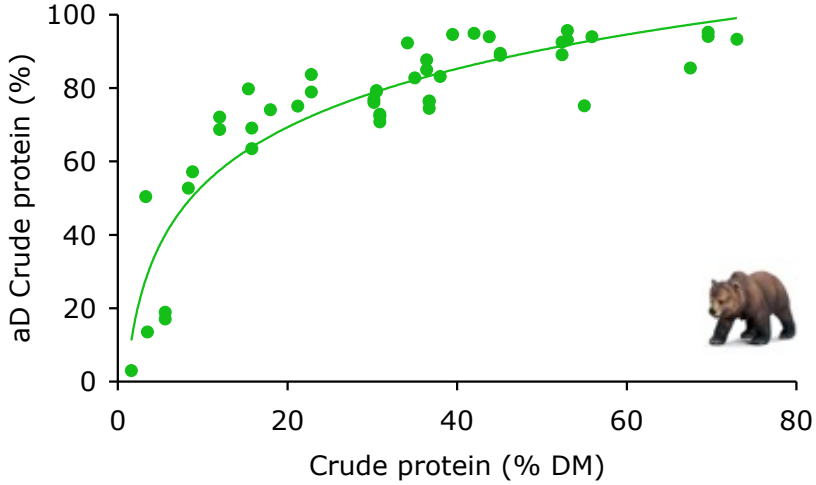
plotting of apparent digestibility vs. nutrient content

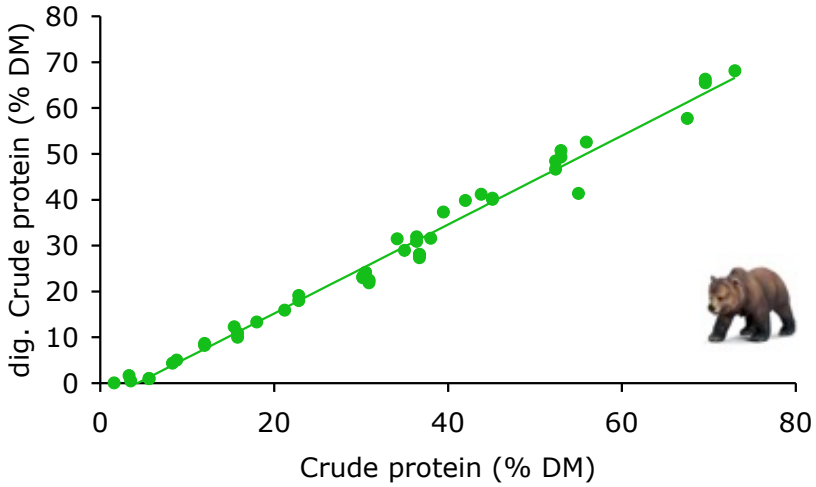


from Clauss et al. (2010)

Lucas Plots

plotting of digestible nutrient content vs. nutrient content





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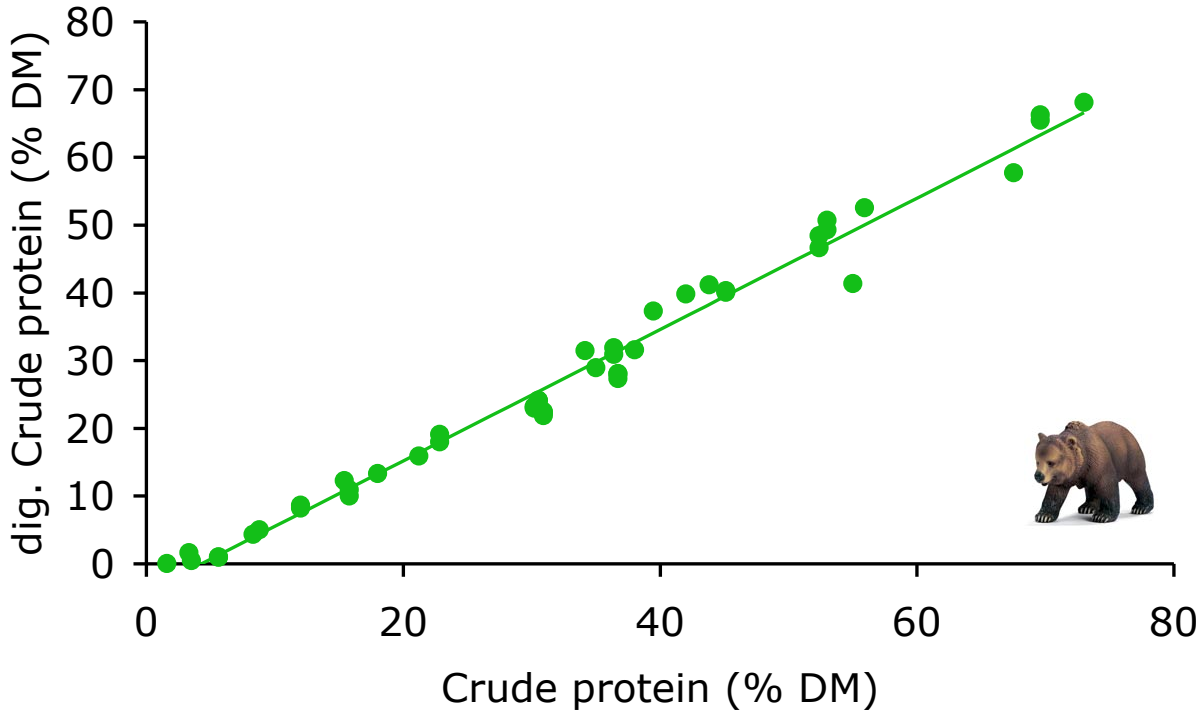

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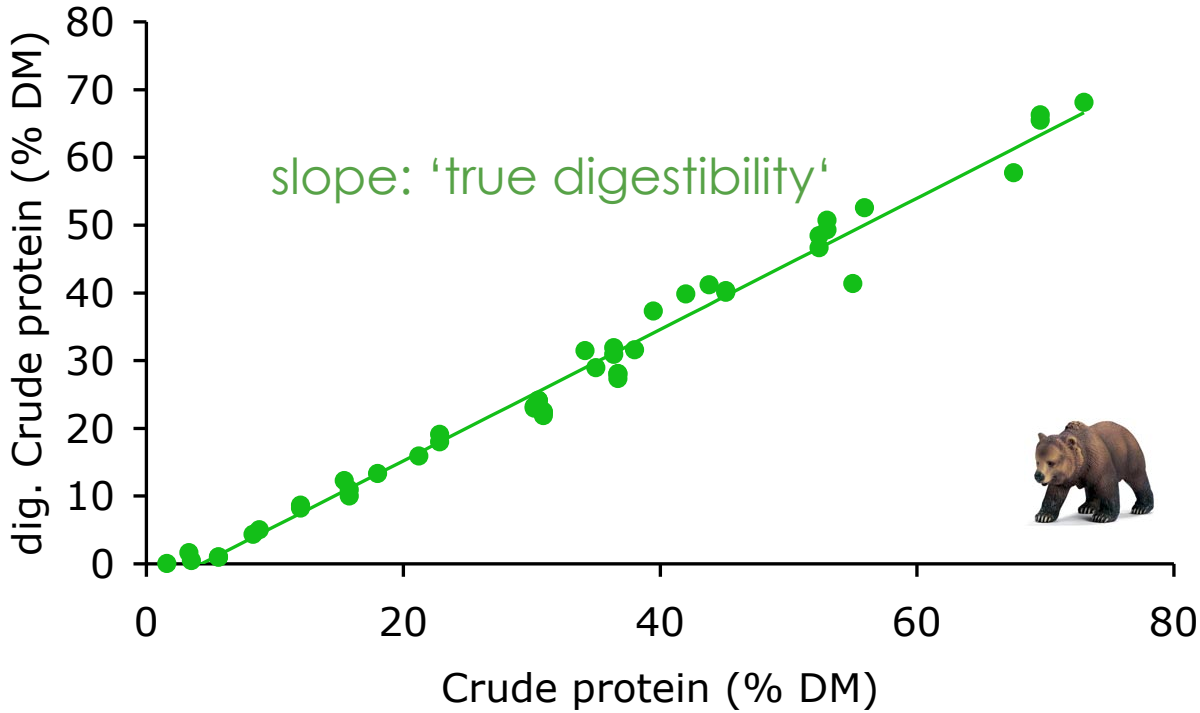

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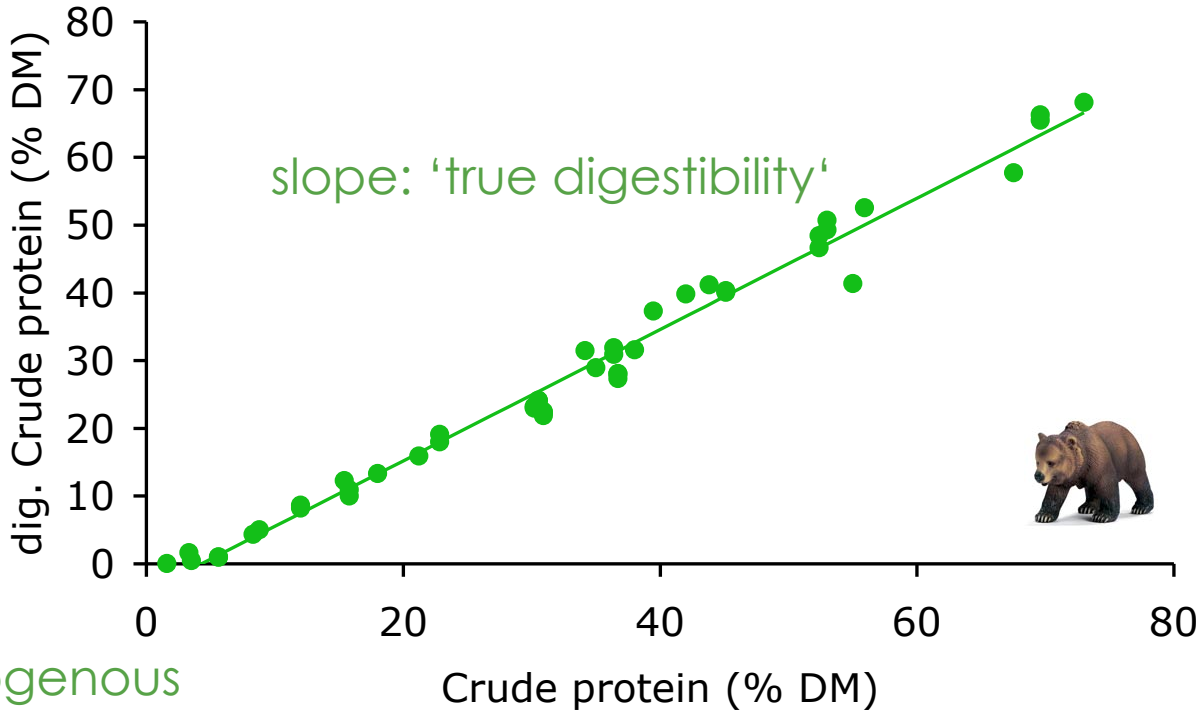

intercept: endogenous losses

from Clauss et al. (2010)

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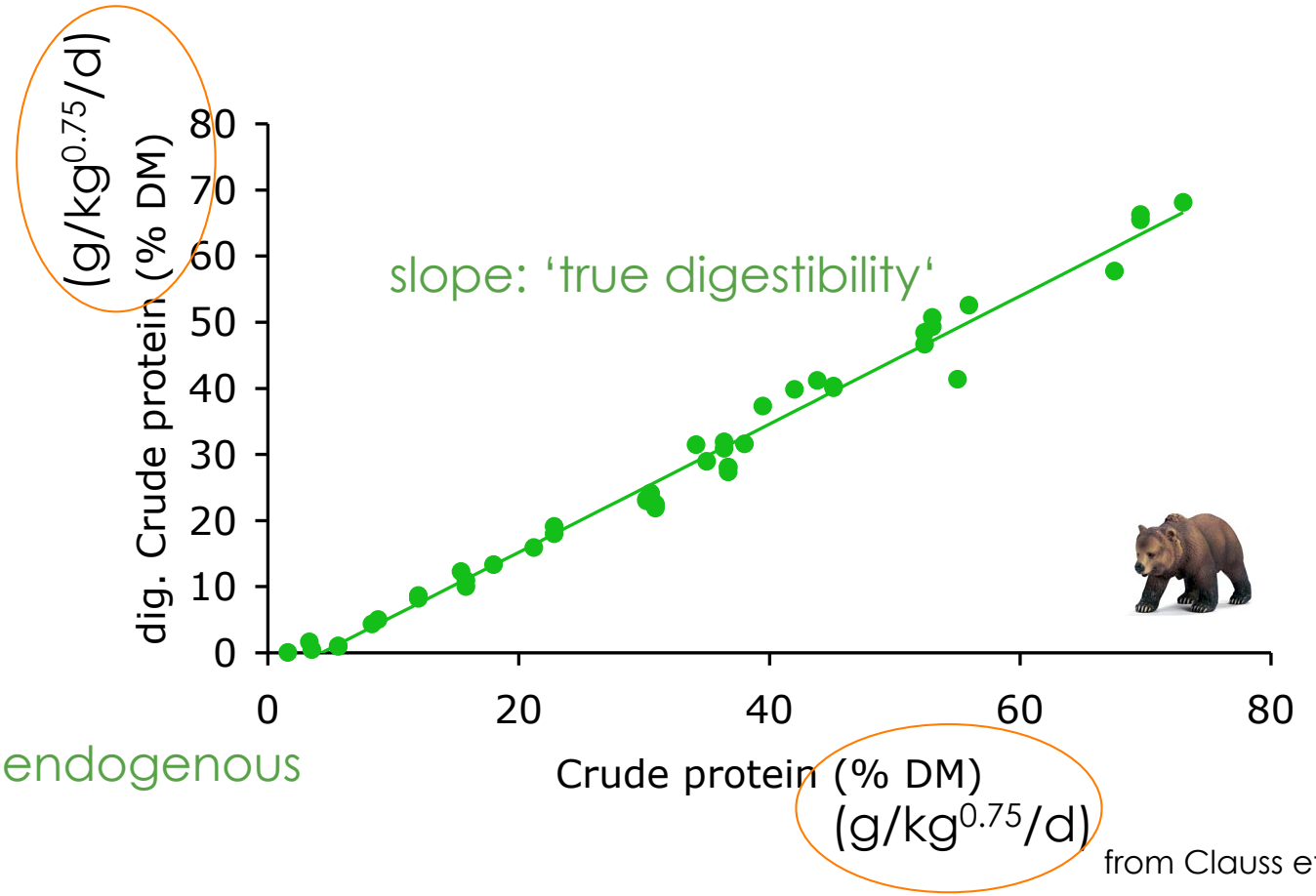

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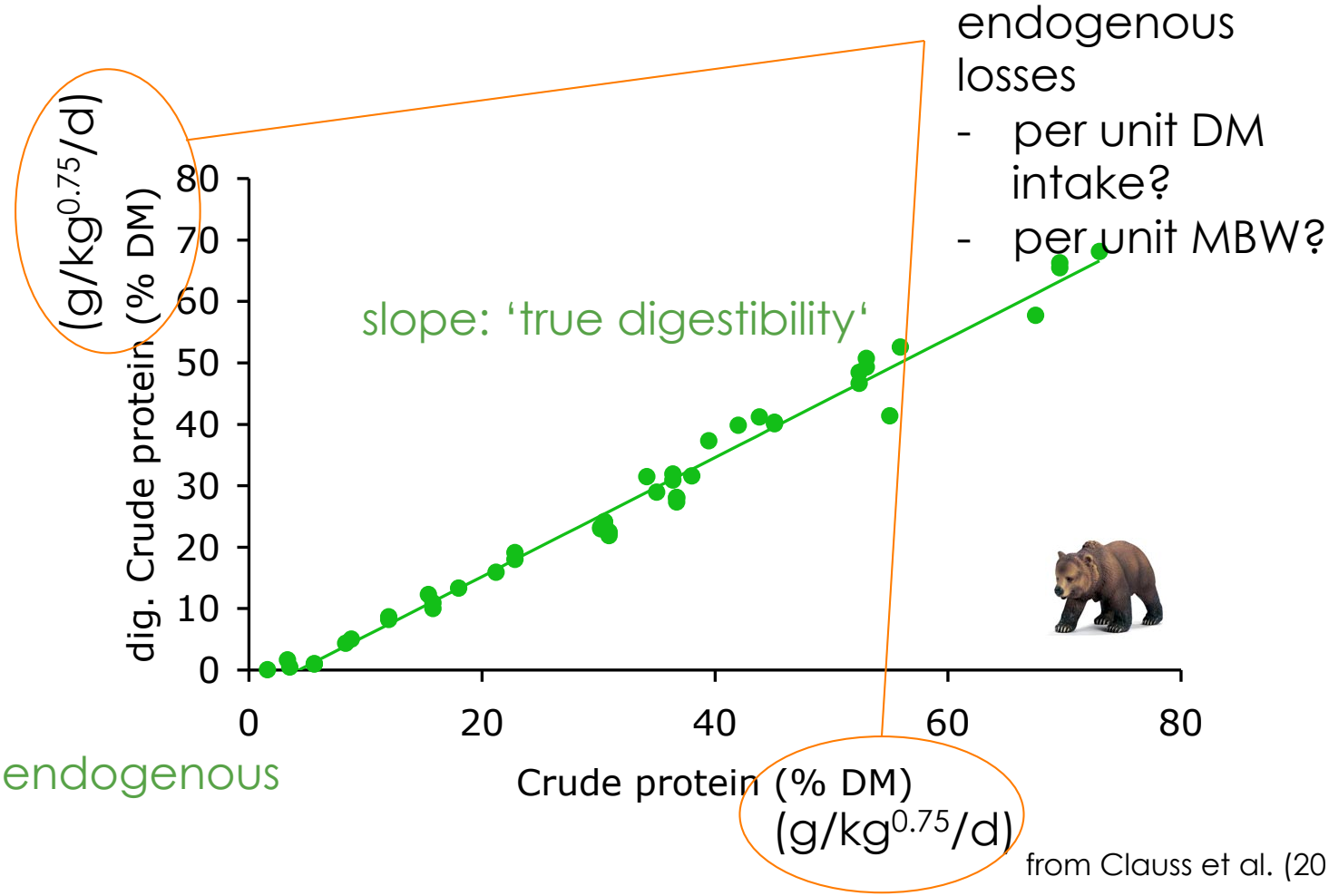

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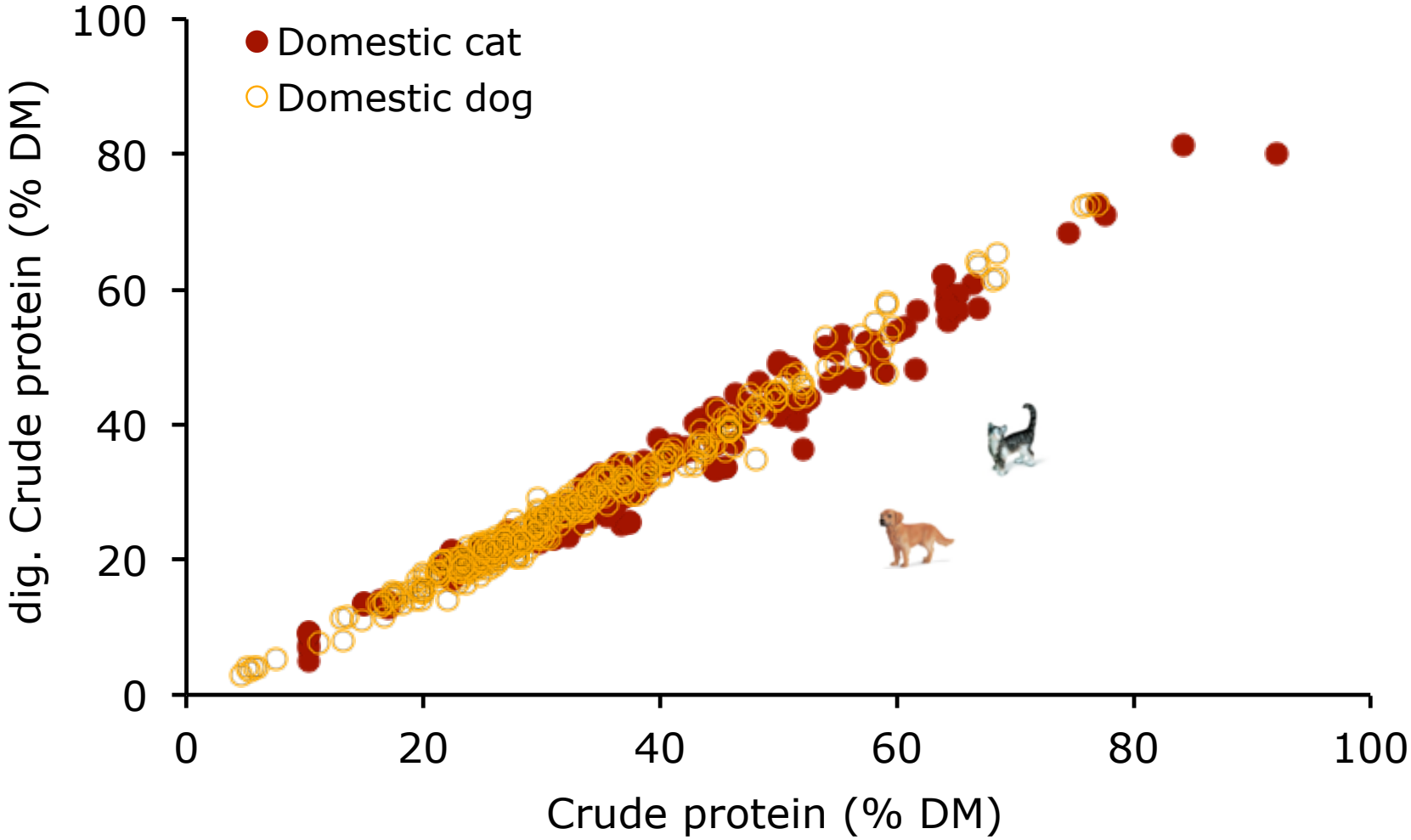
Protein digestion



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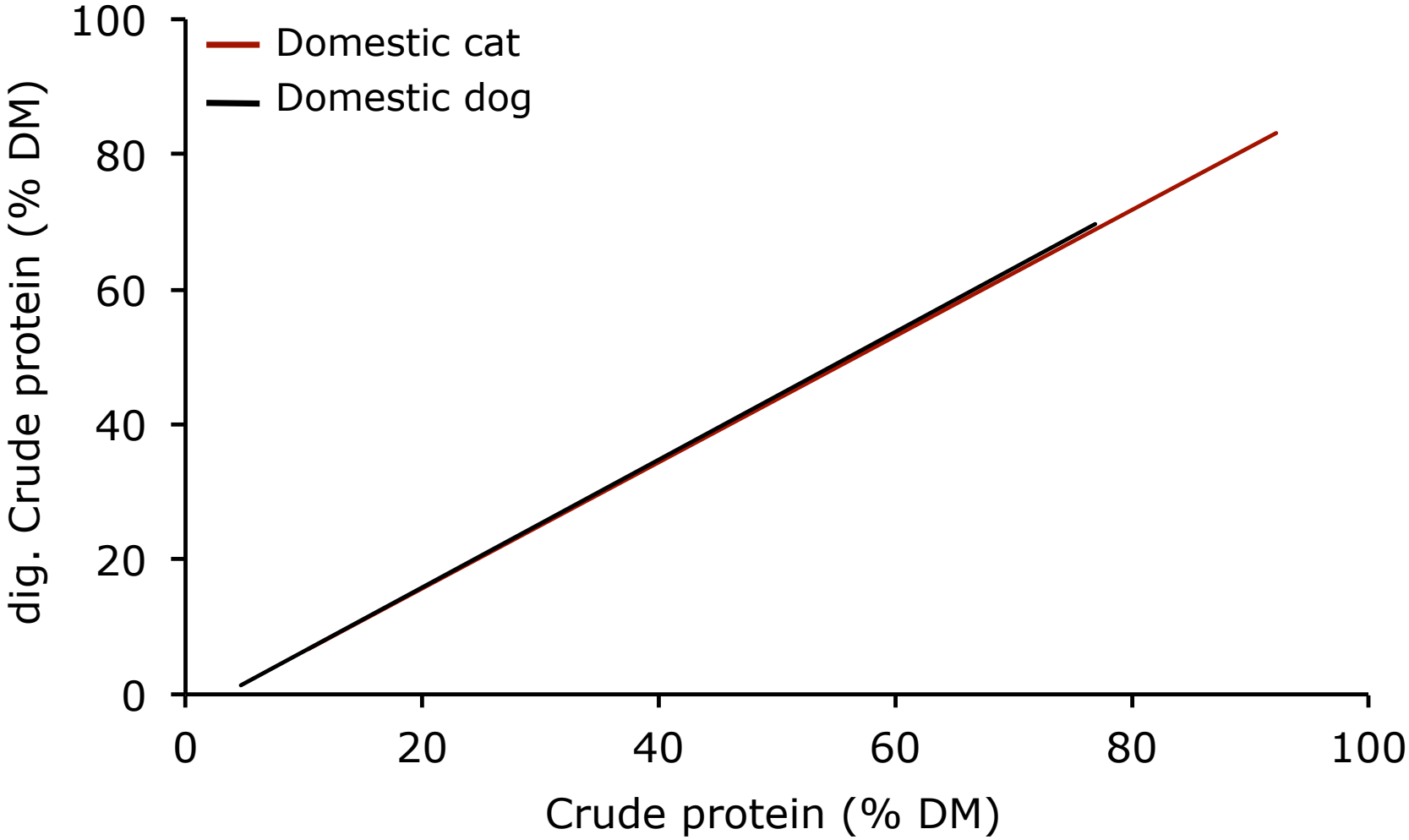

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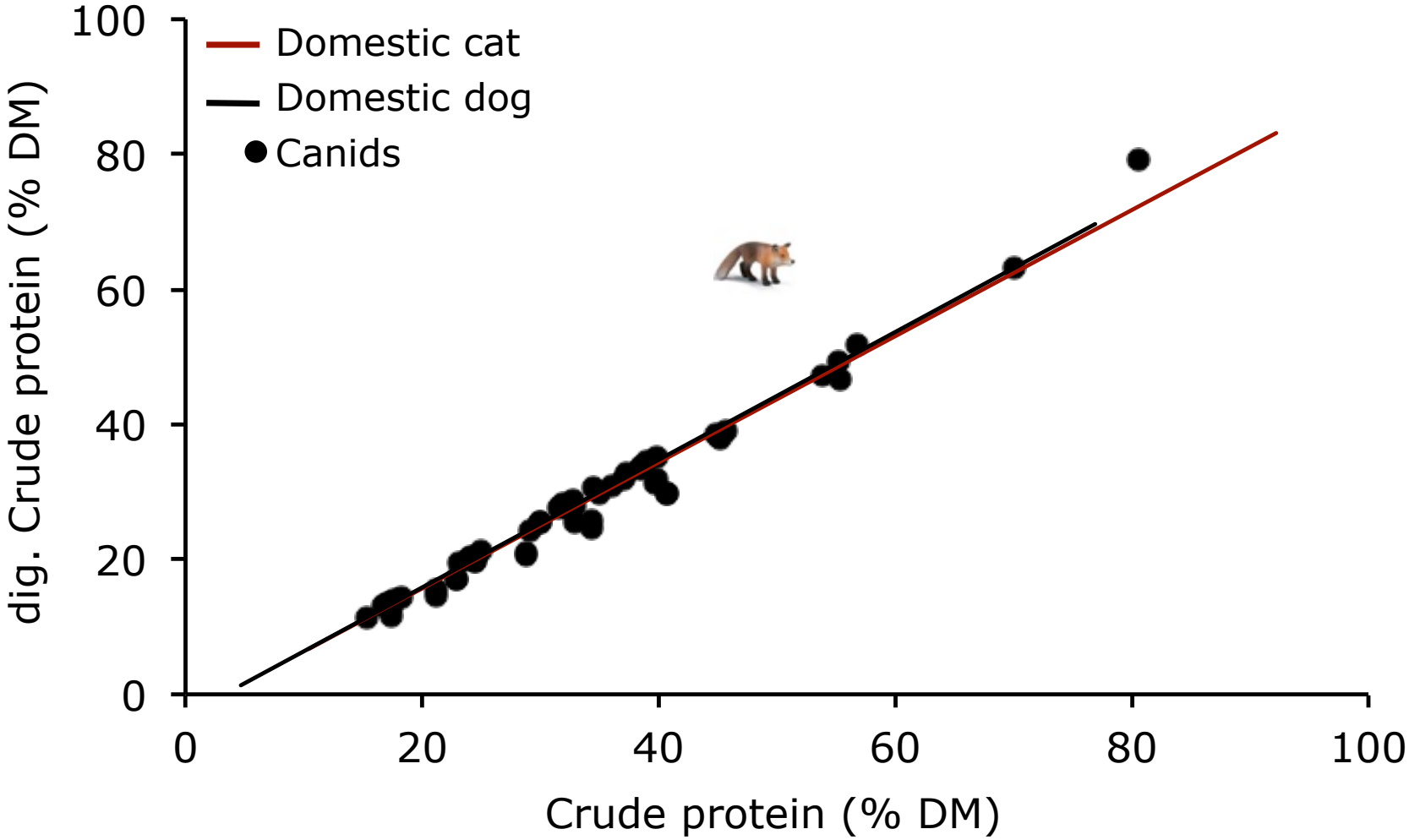

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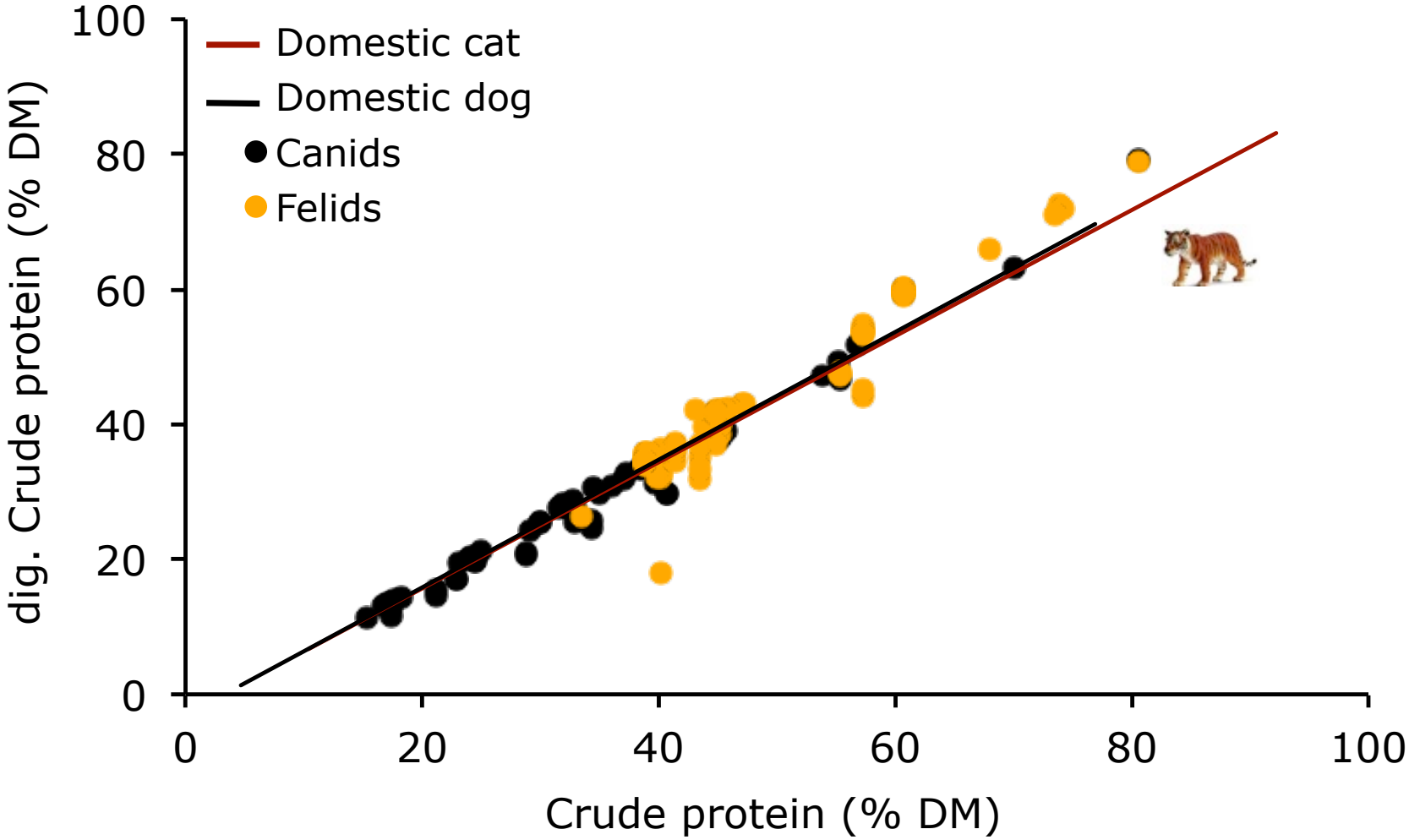

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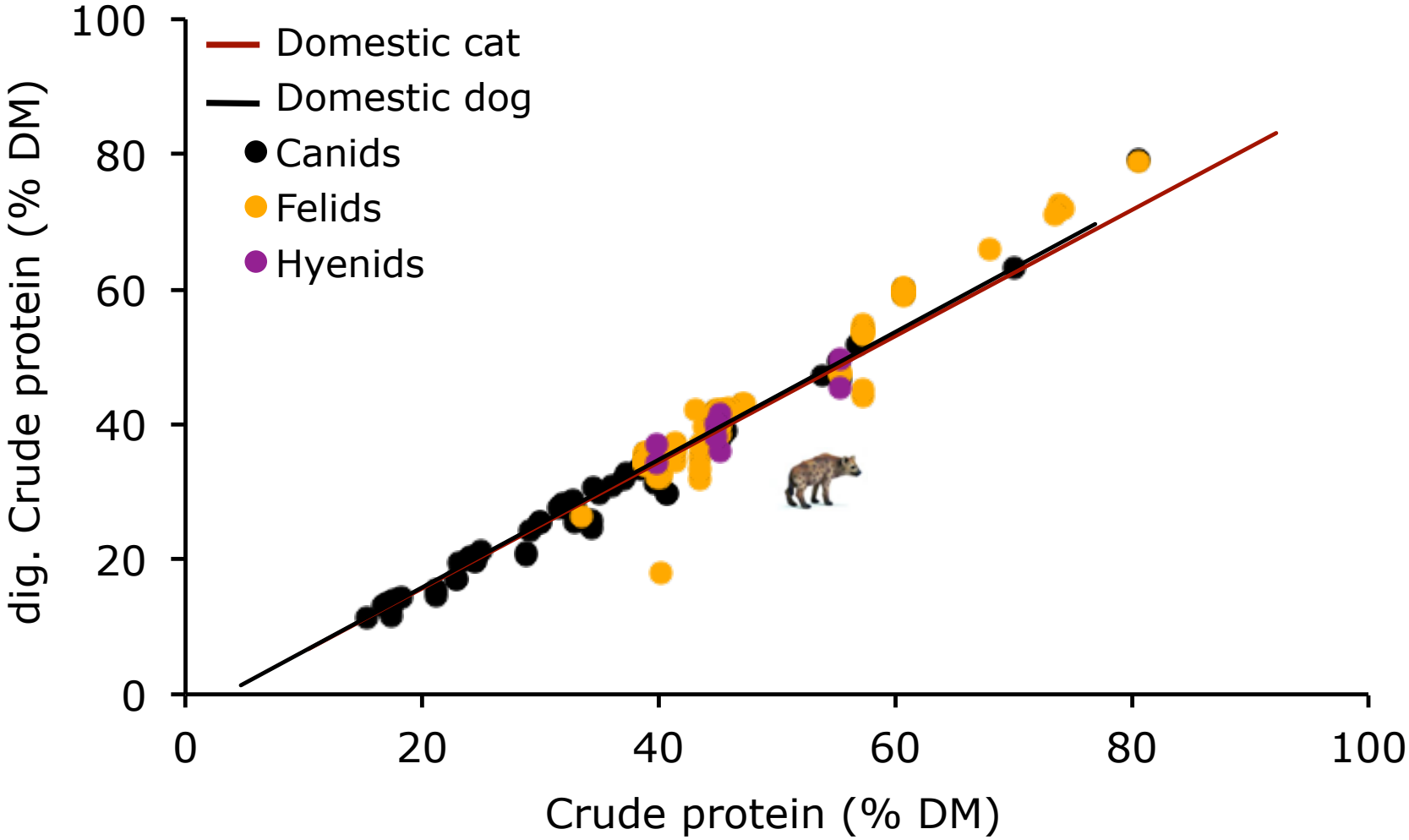

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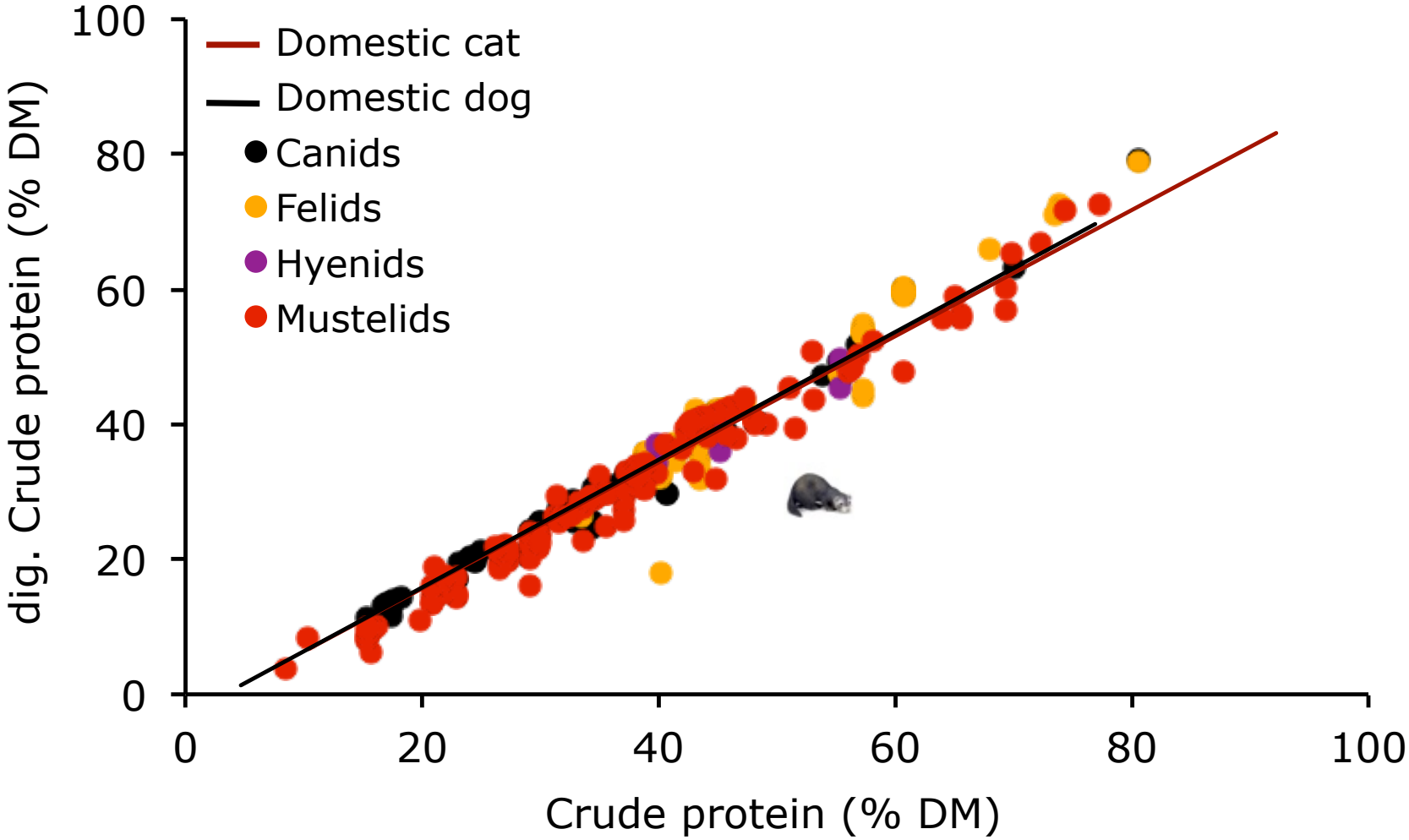

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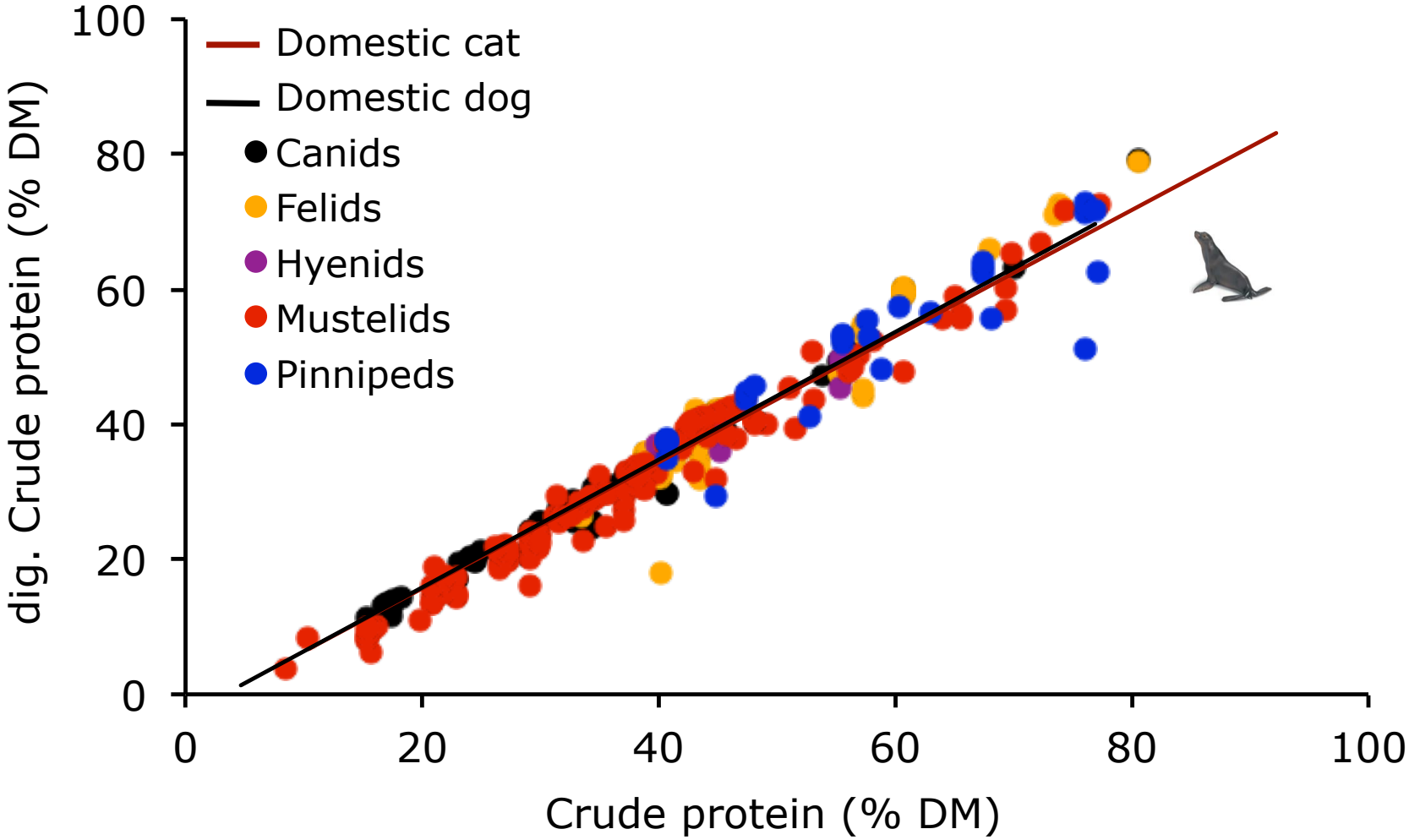

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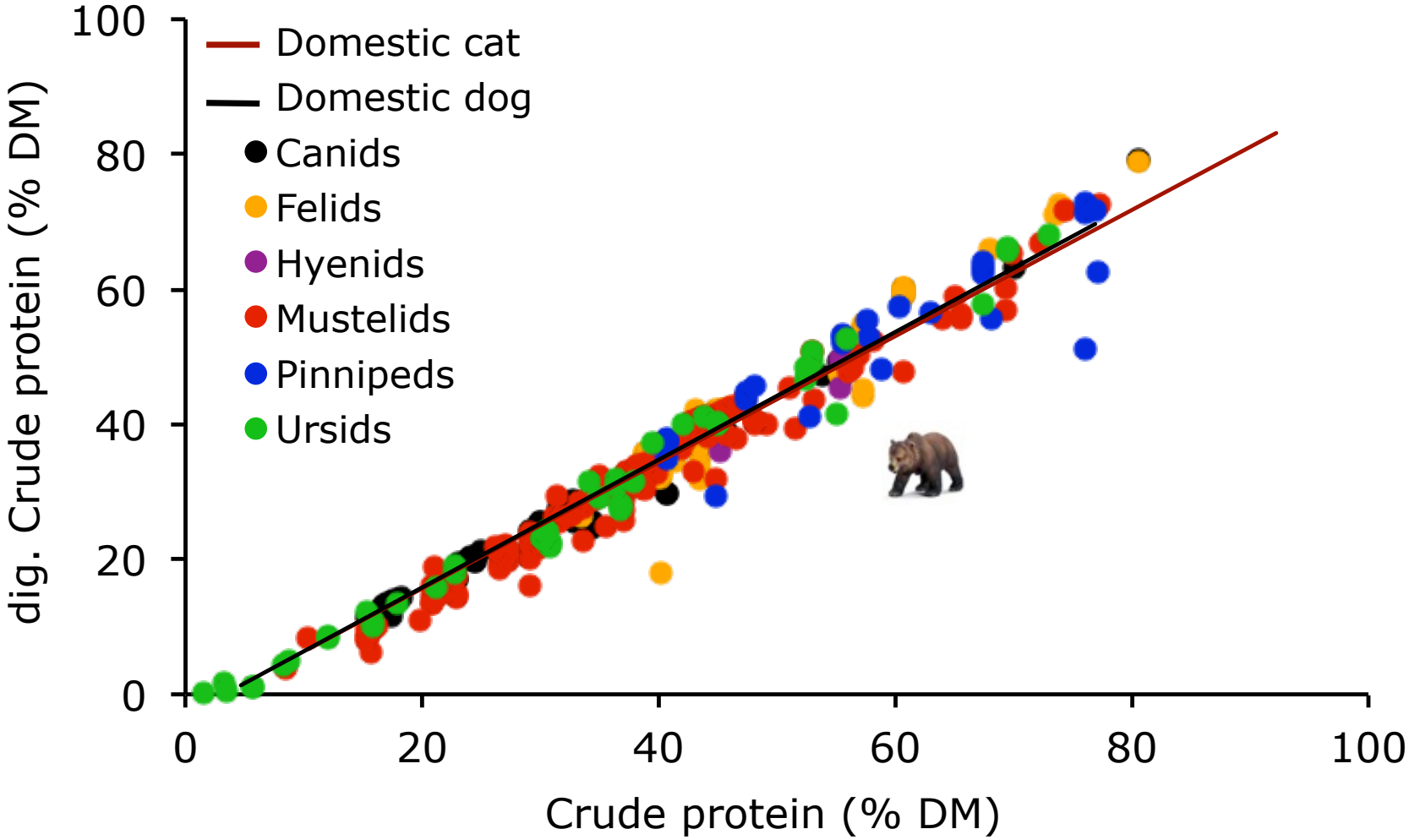

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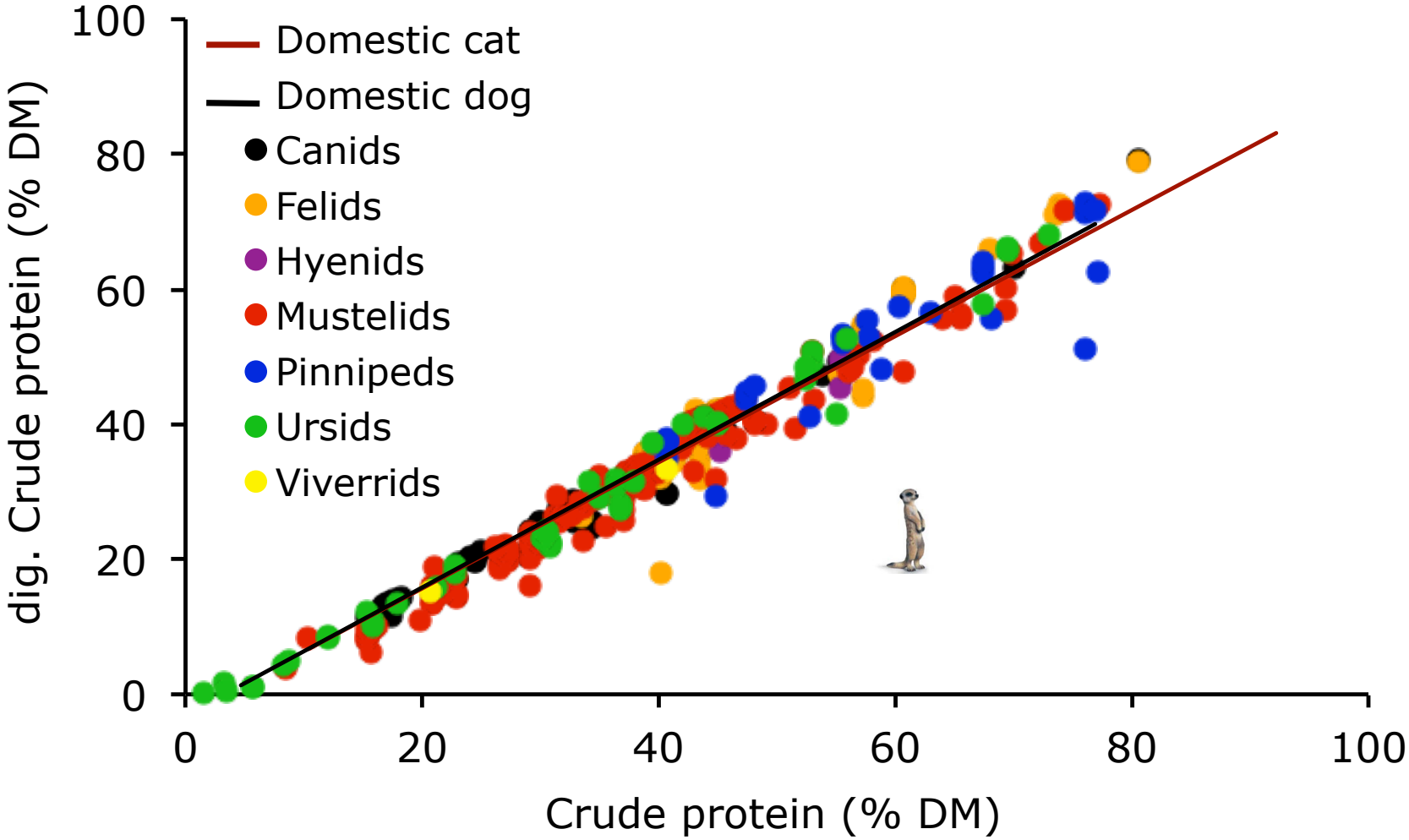

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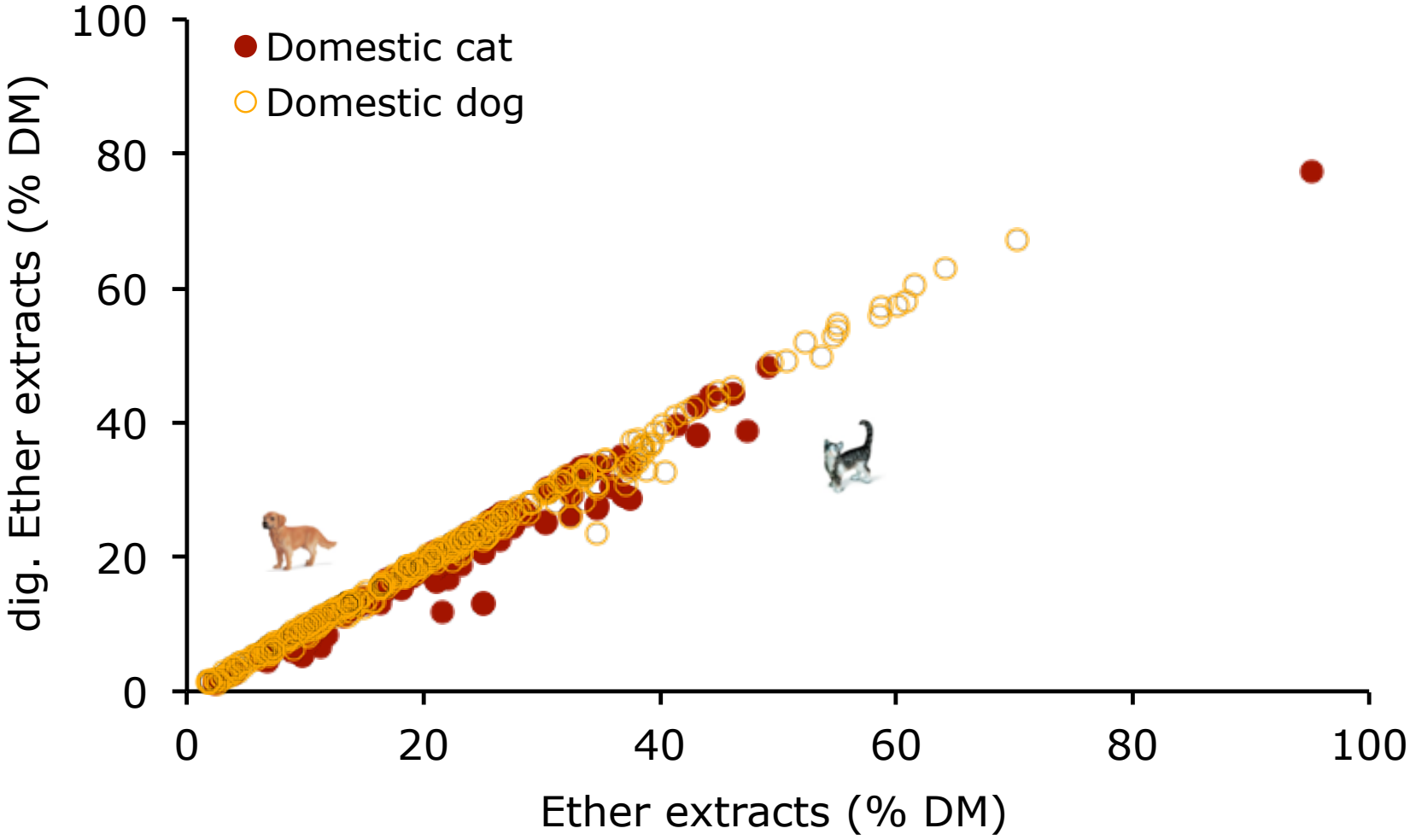

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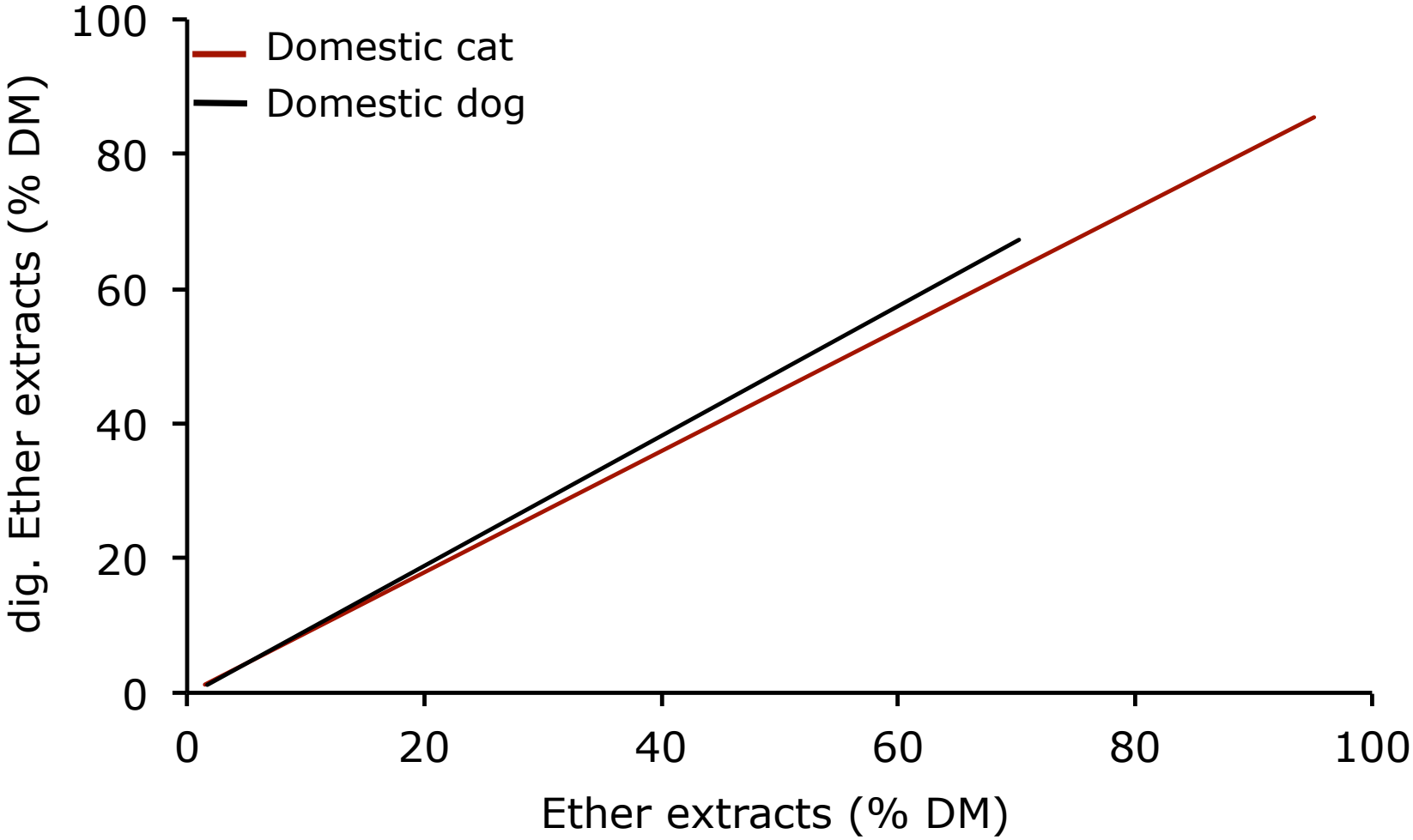

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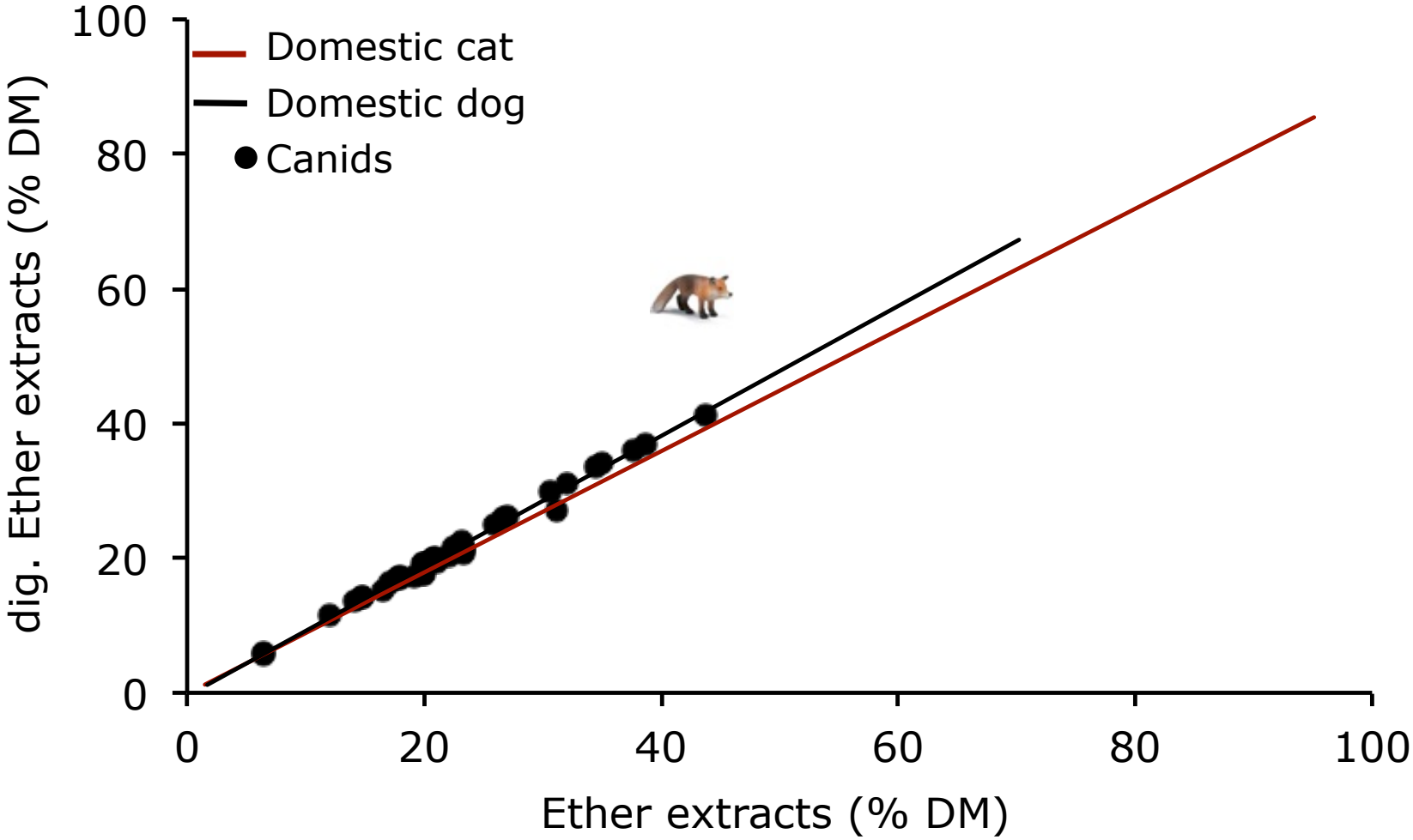

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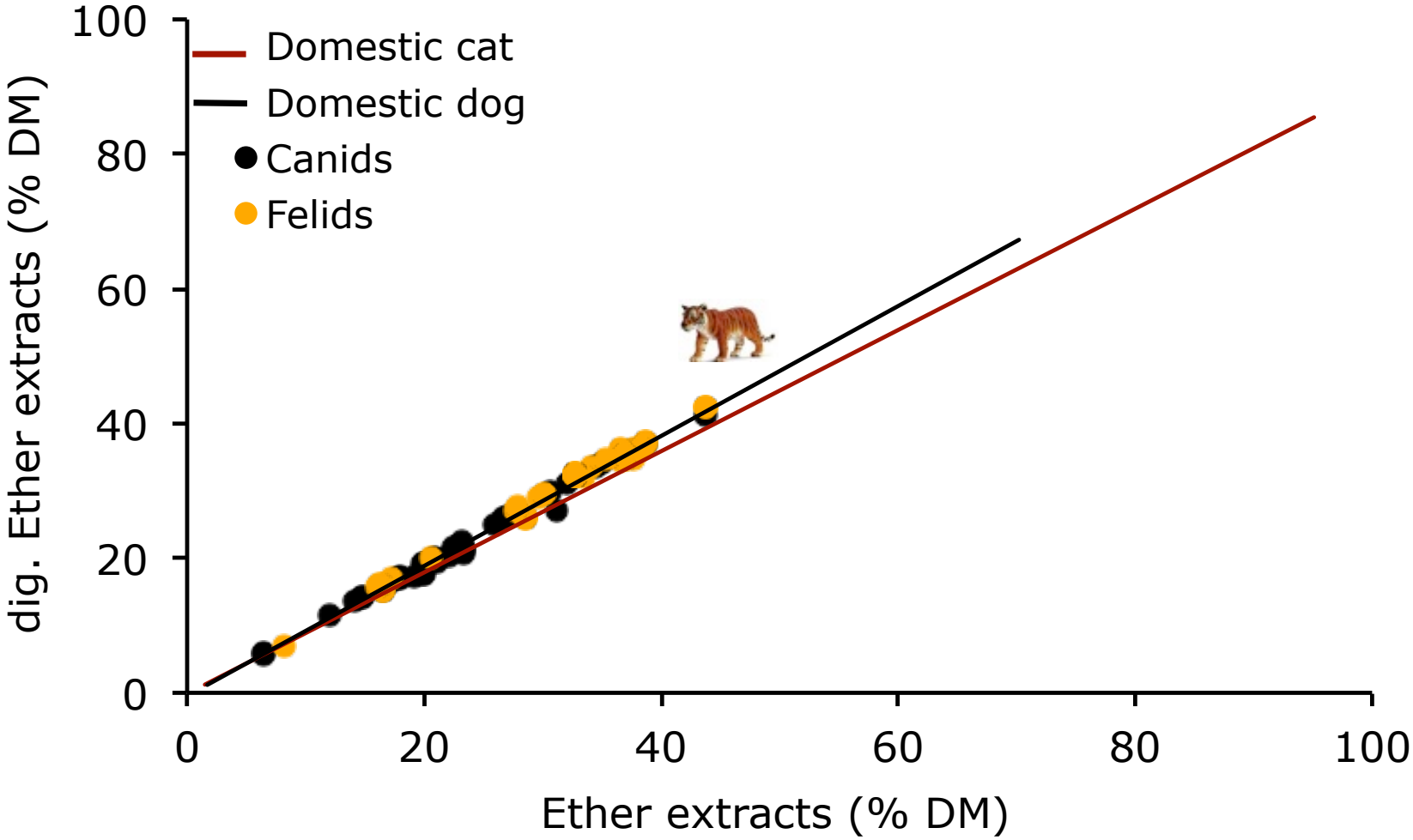

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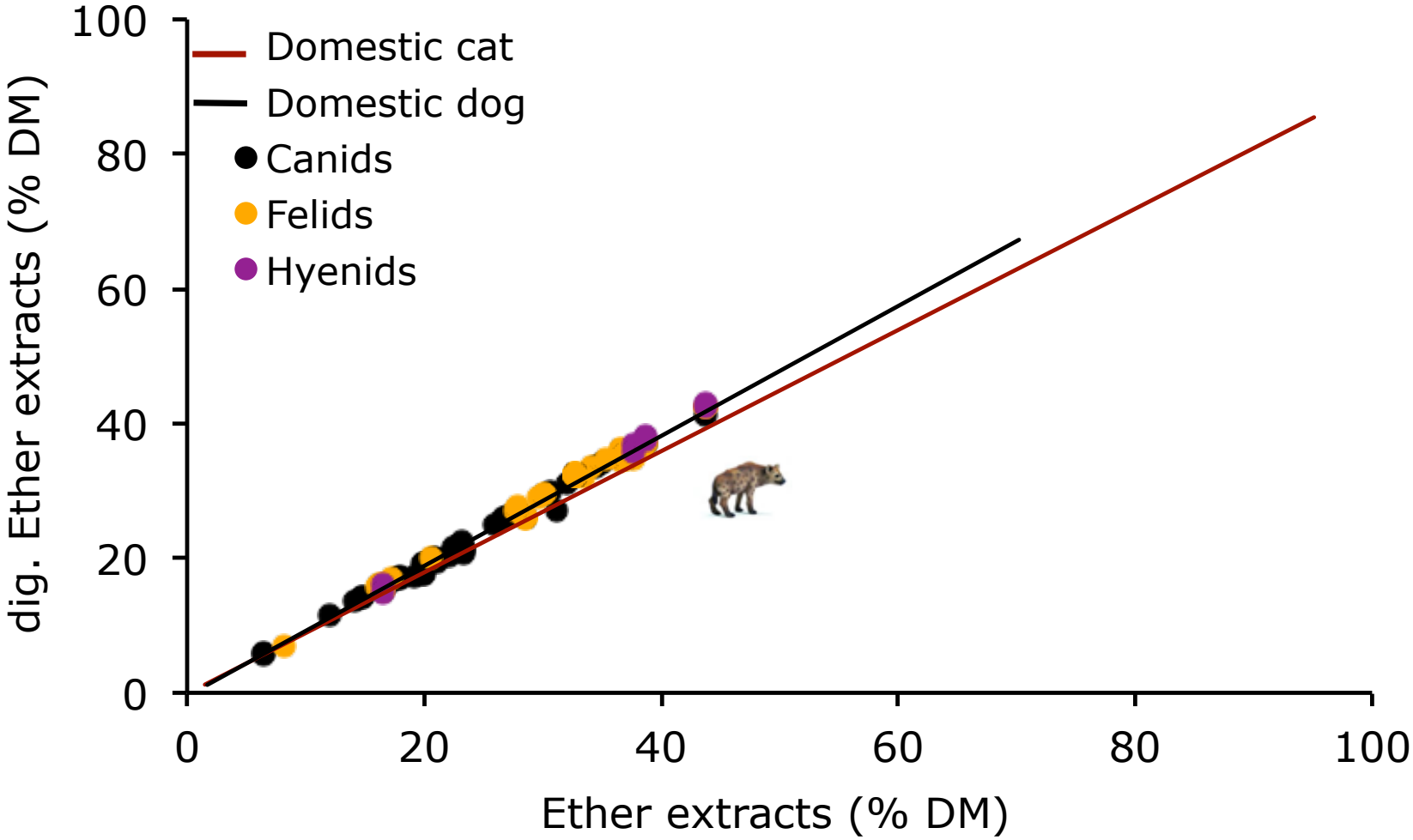

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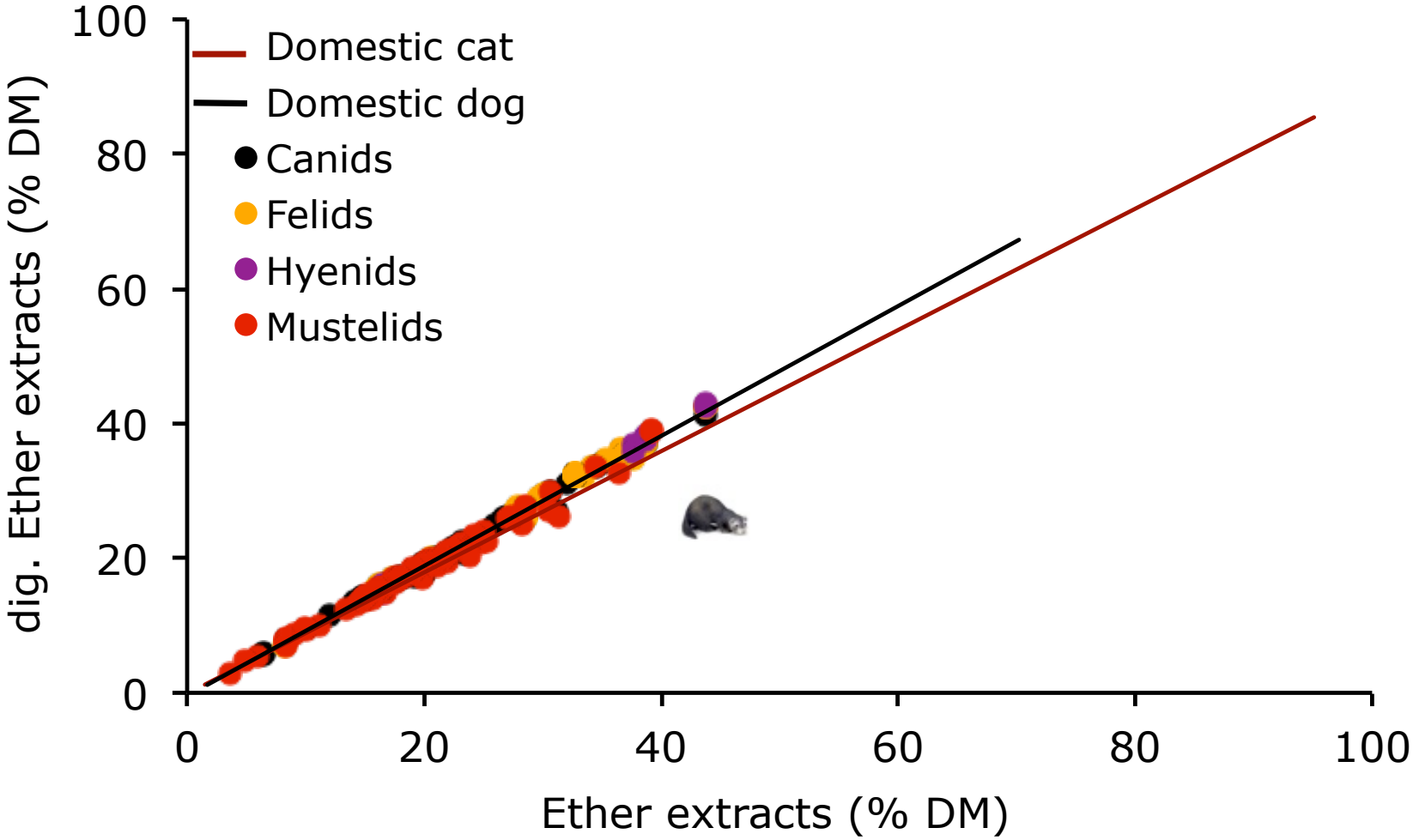

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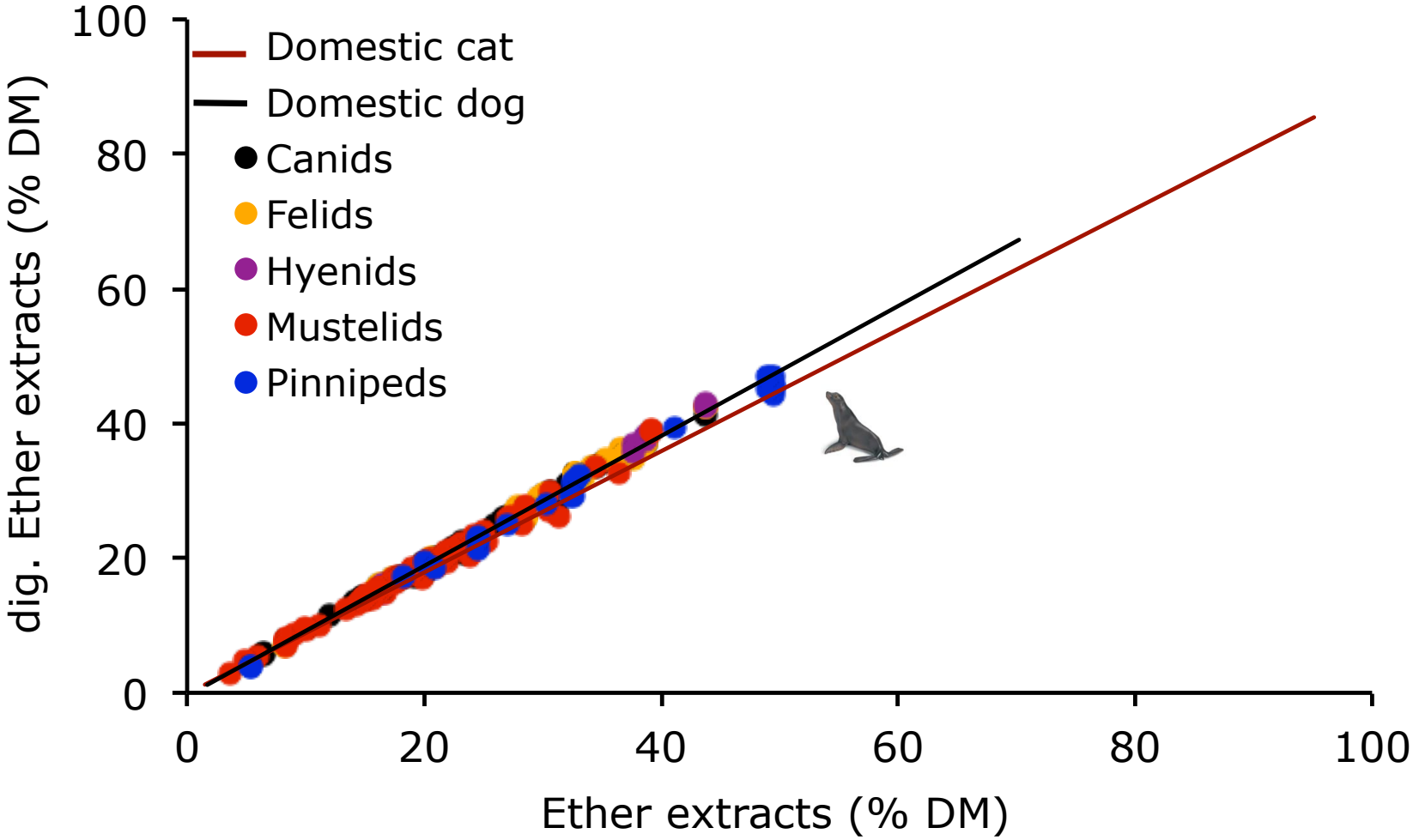

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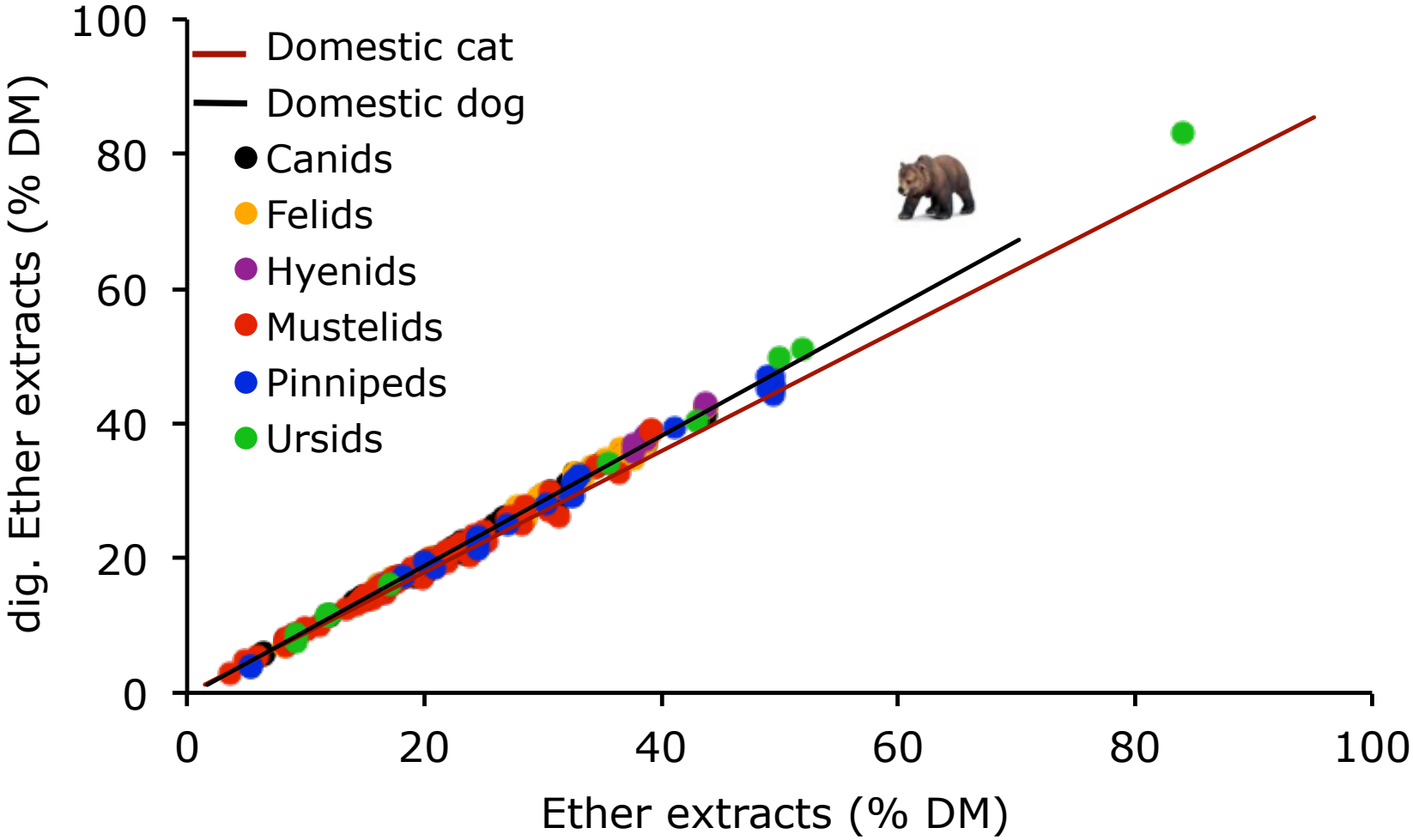

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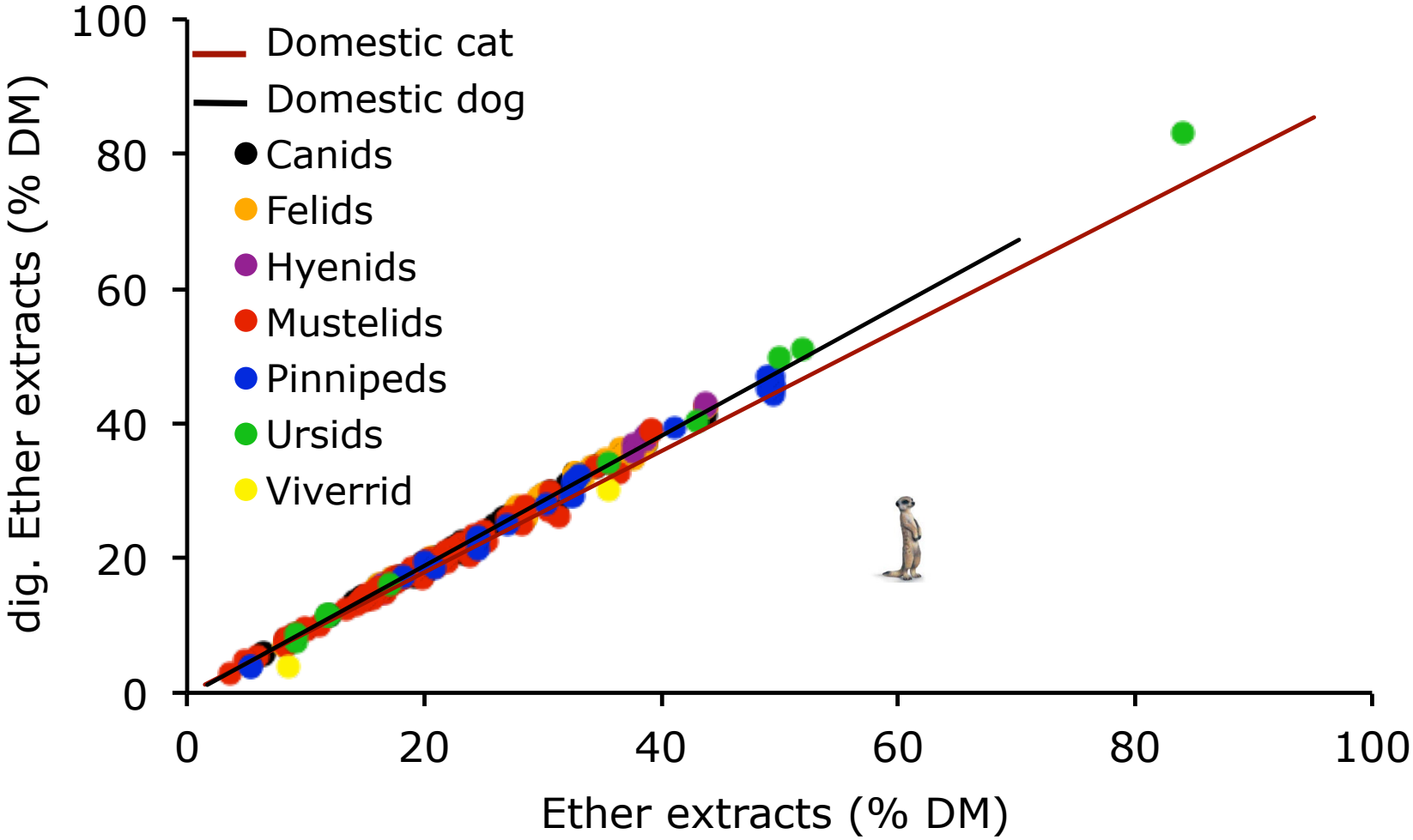

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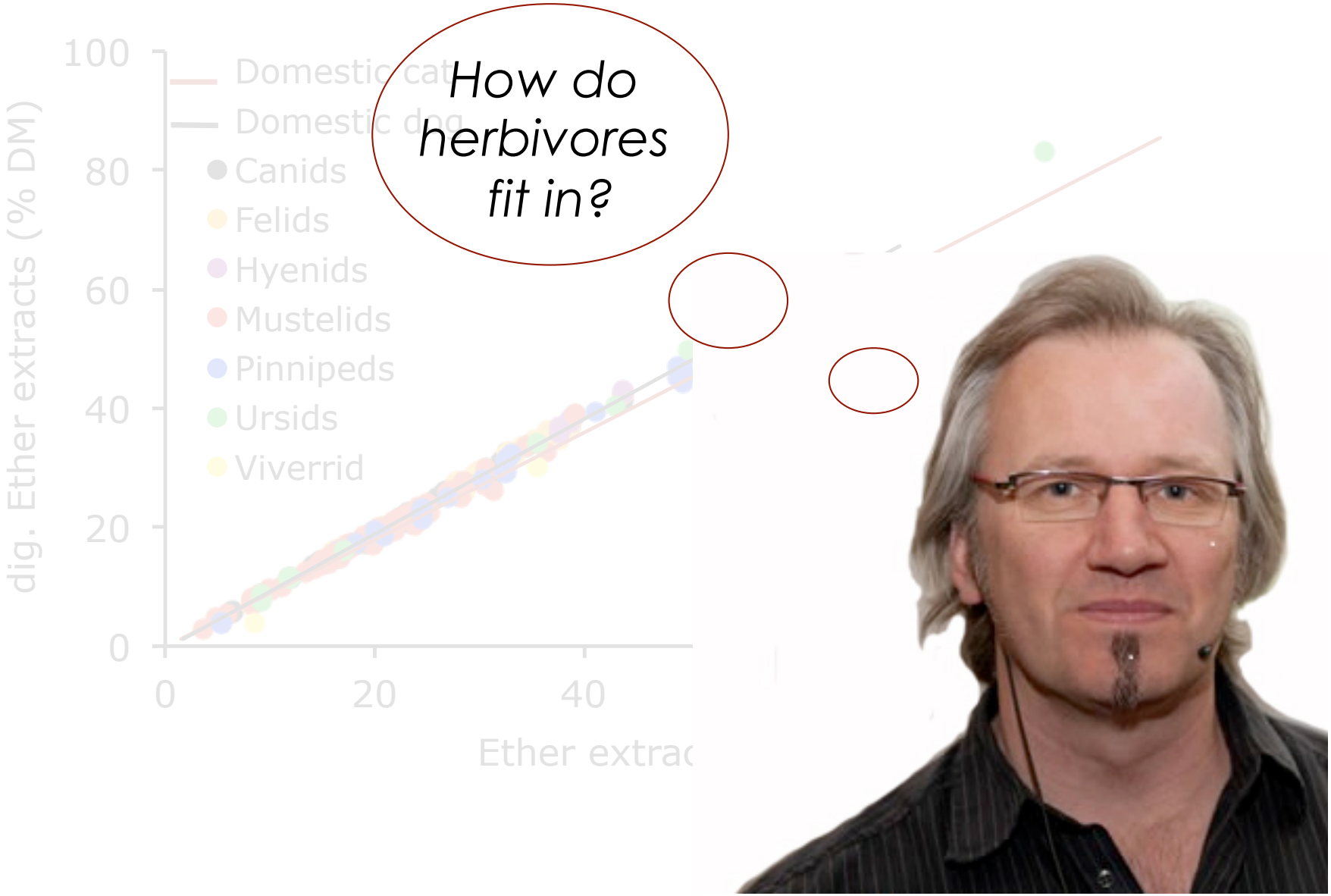
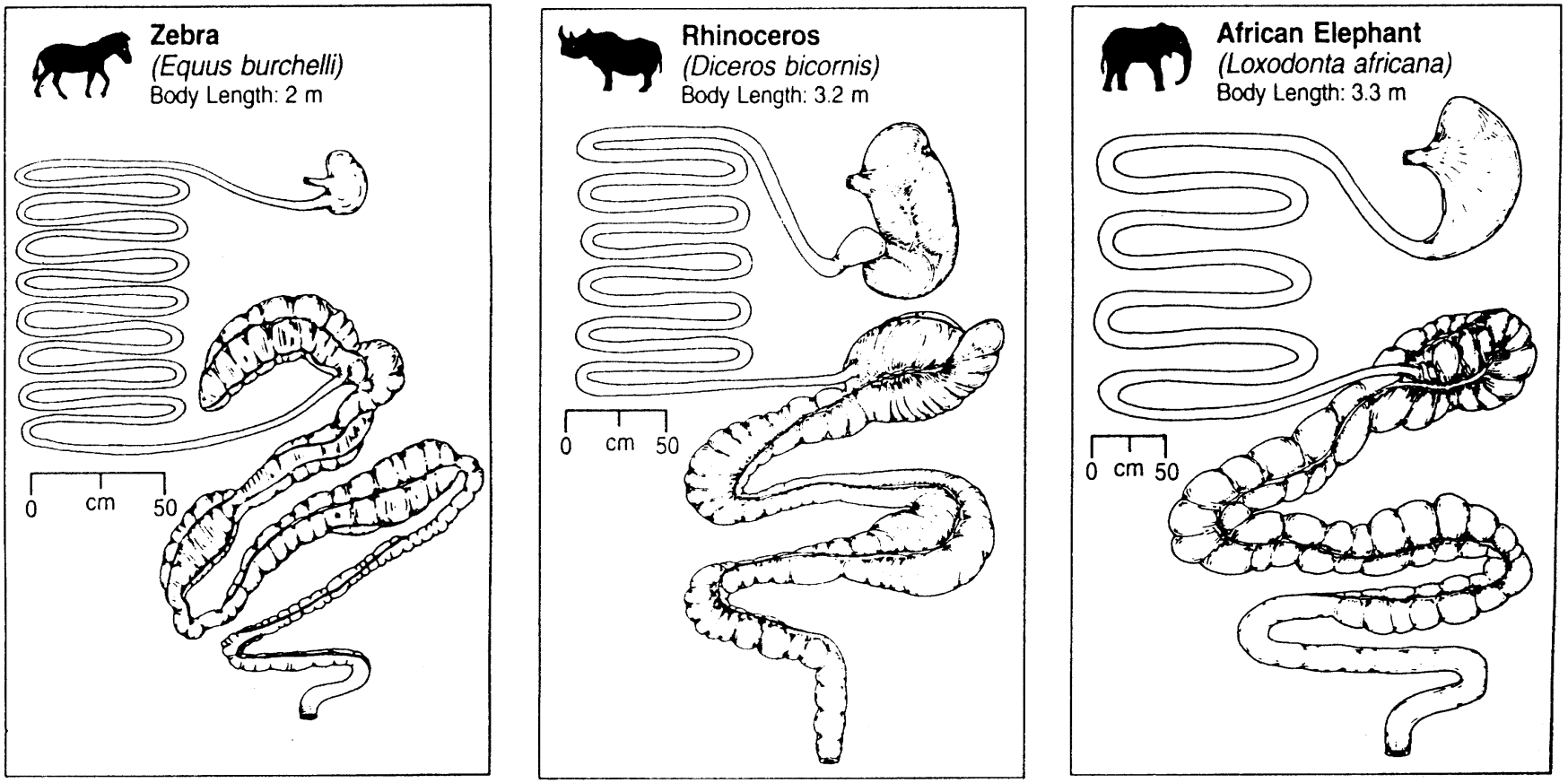
… but:


How do herbivores fit in?
dig. Ether extracts (% DM)
100
80
60
40
20
0
Domestic cat
Domestic dog
Canids
Felids
Hyenids
Mustelids
Pinnipeds
Ursids
Viverrid
0
20
40
Ether extrac

Material and Methods

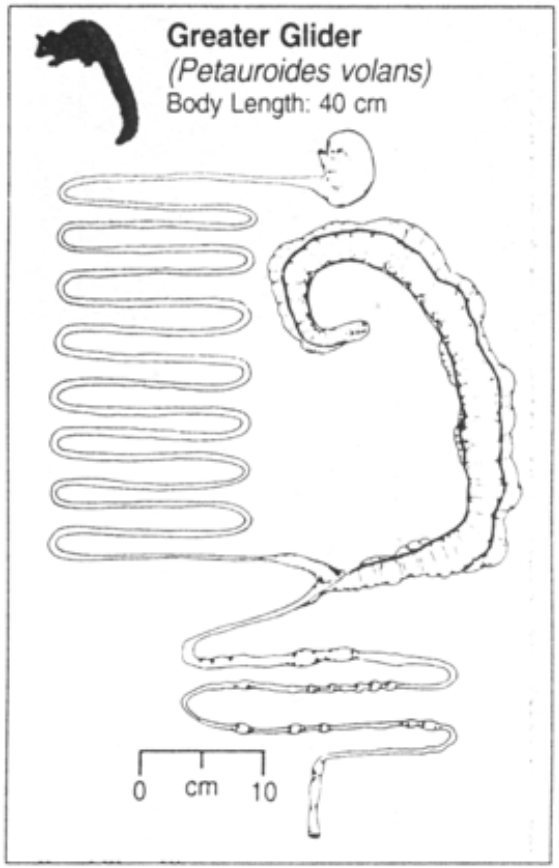
Literature research (268 individual publications)
Data collection in EXCEL spreadsheet
- Species (*n* = 157)
- Trophic guild (carni-/omni-/herbivore)
- Digestion type
- Nutrient composition
  - Crude protein CP
  - Ether extracts EE
- ... and the corresponding intake and apparent digestibility (aD) data

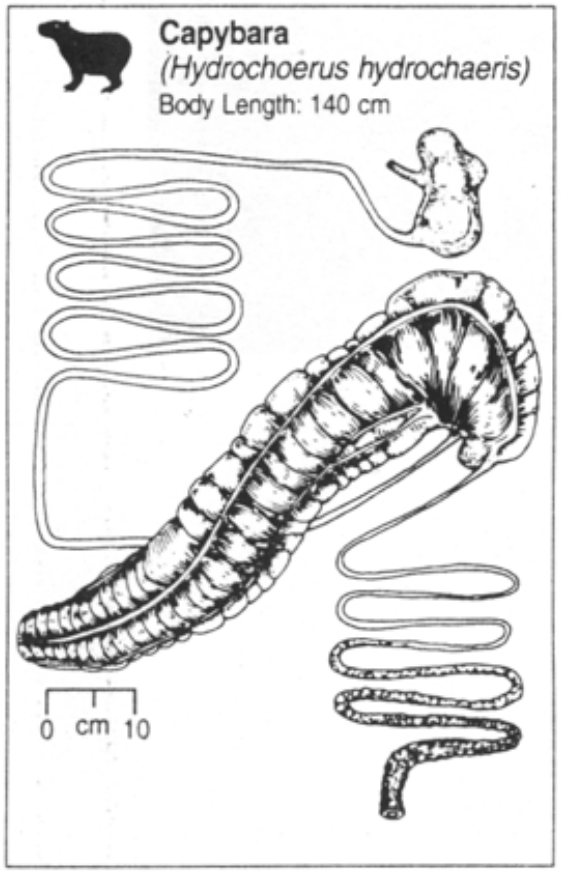
Hindgut Fermentation - Colon

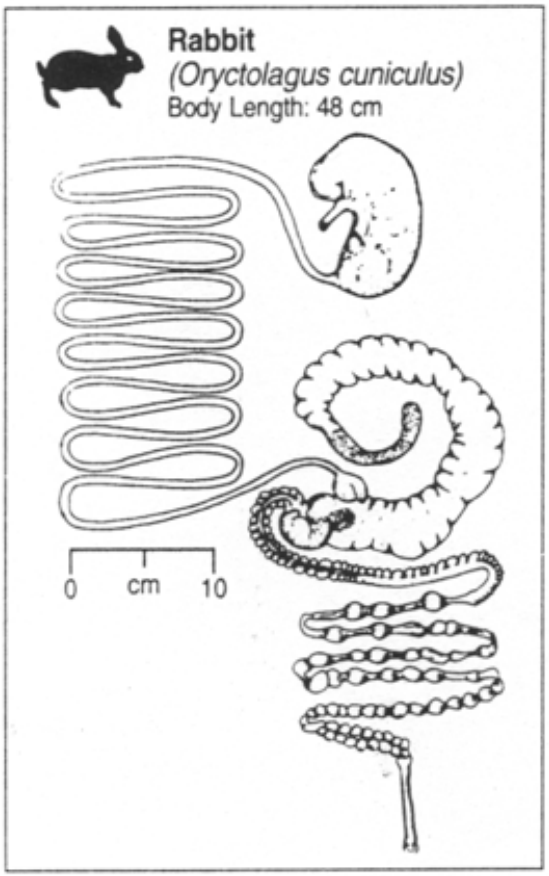


from Stevens & Hume (1995)

Hindgut Fermentation - Caecum

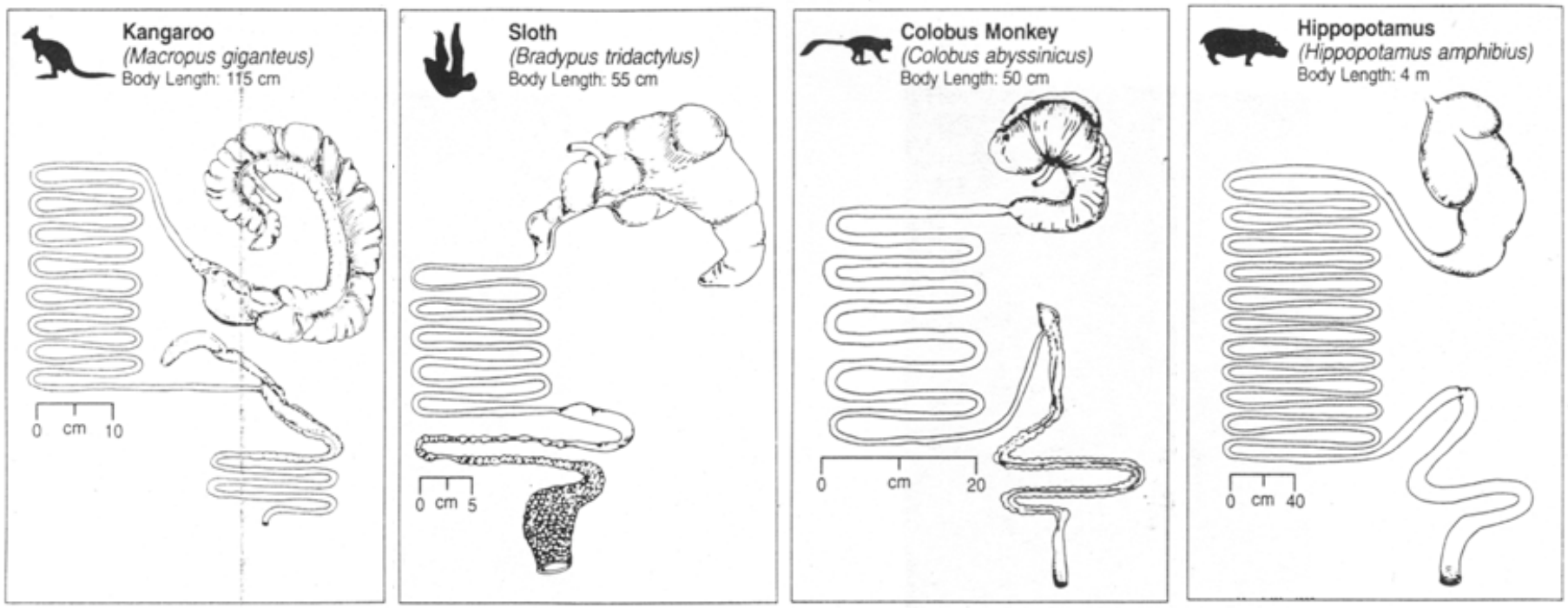






from Stevens & Hume (1995)

Foregut Fermentation - Nonruminants



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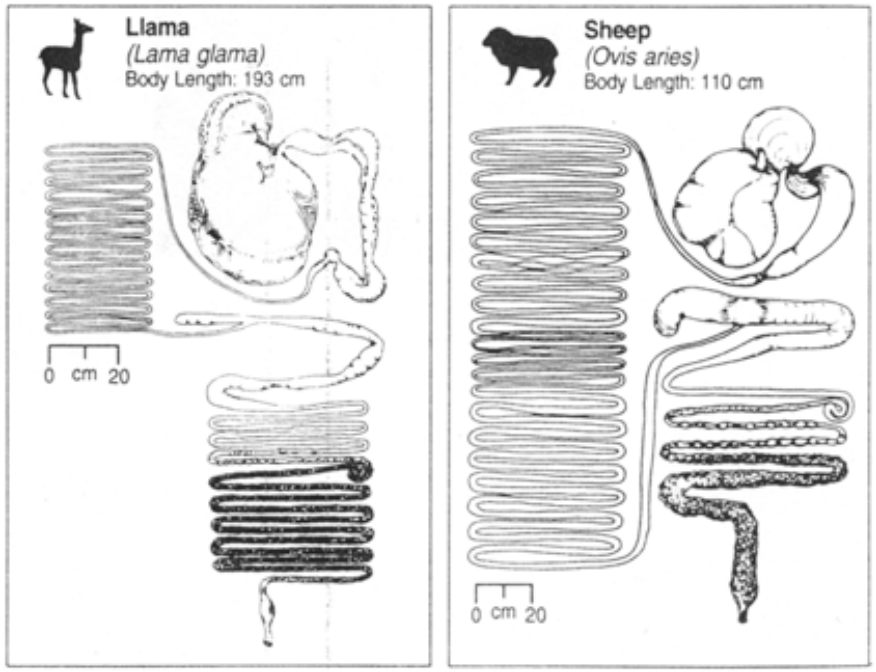
Foregut Fermentation - Ruminants



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Predictions: Trophic Guilds

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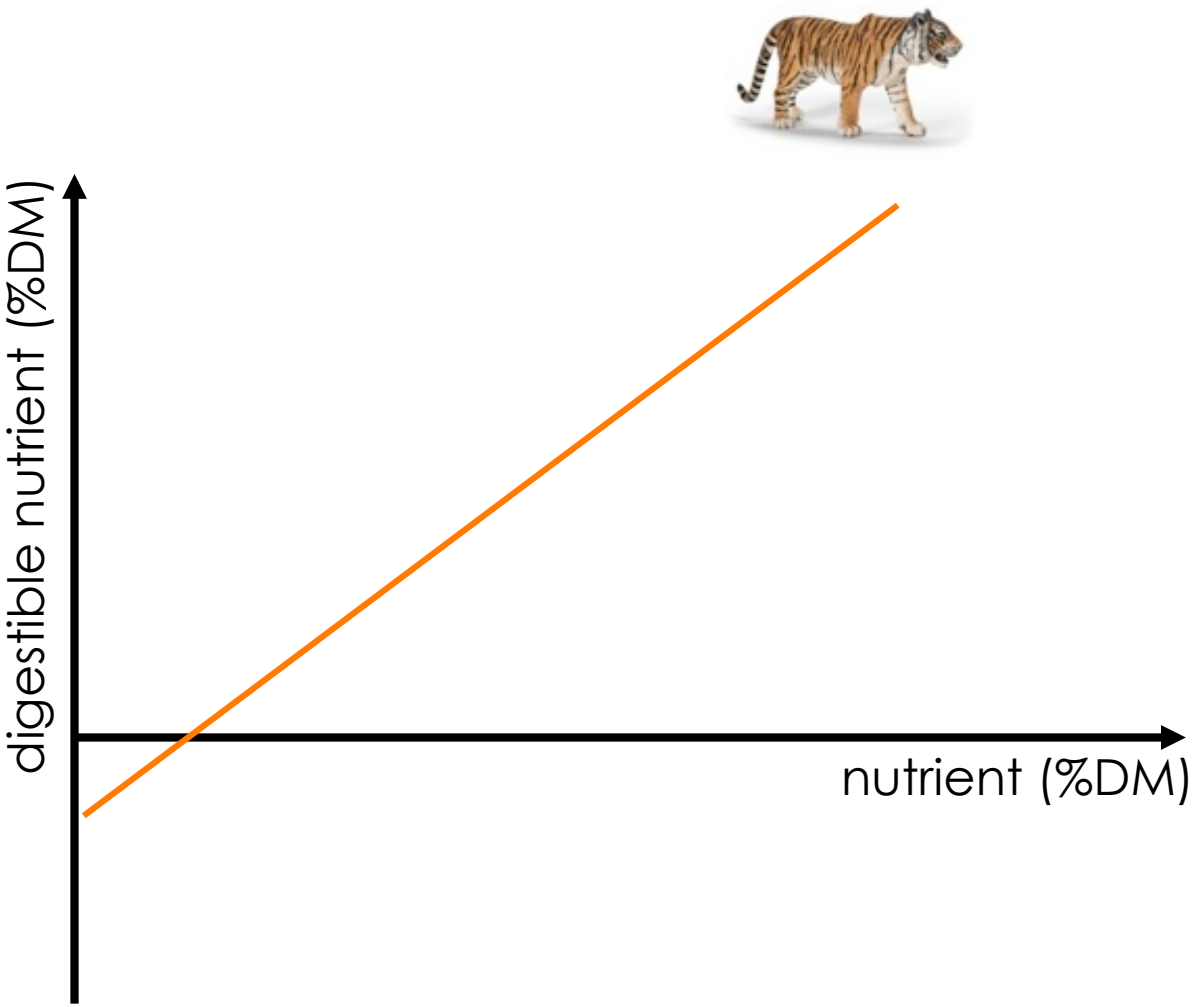

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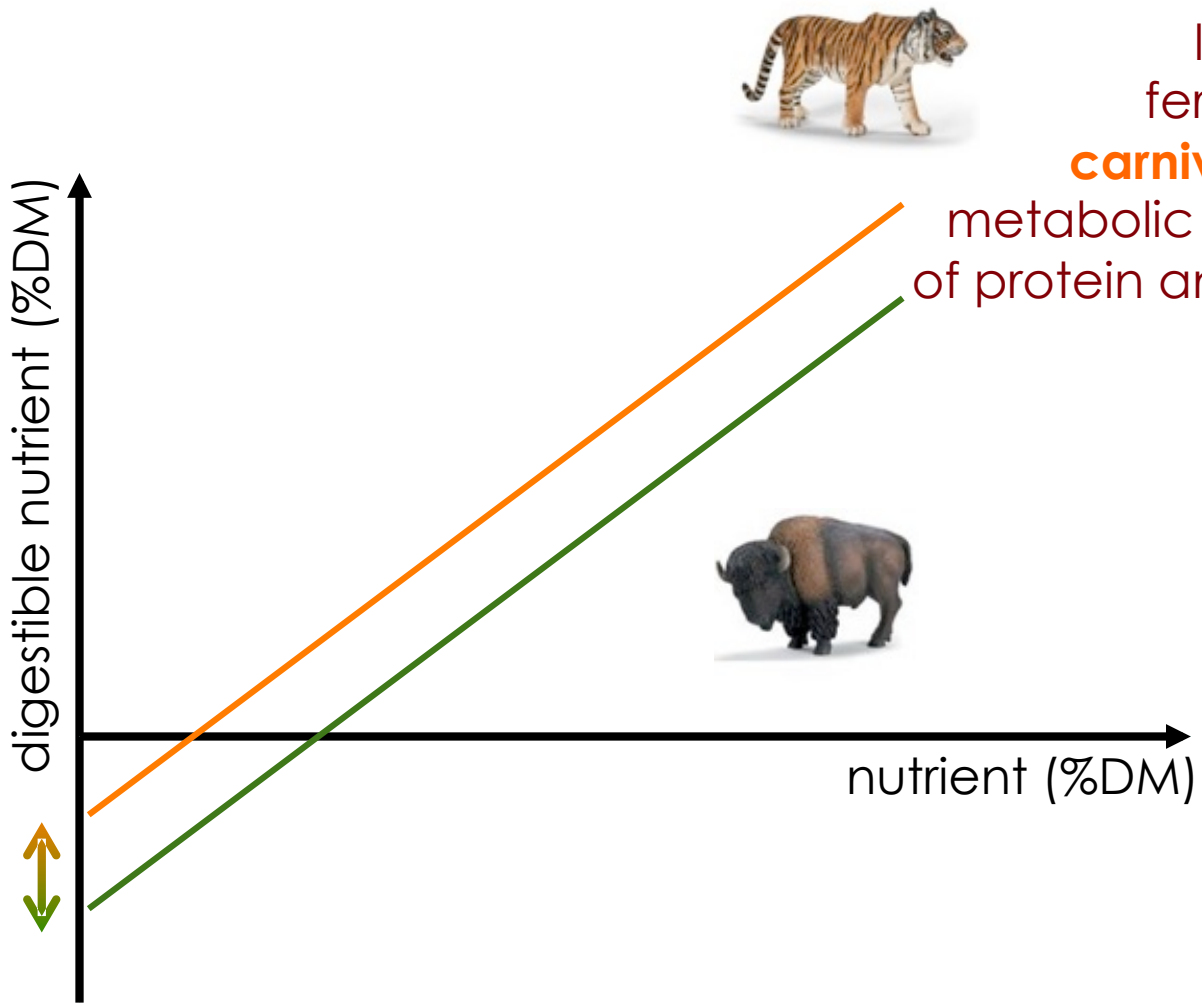

less microbial fermentation in **carnivores**, i.e. less metabolic faecal losses of protein and lipdis than **herbivores**

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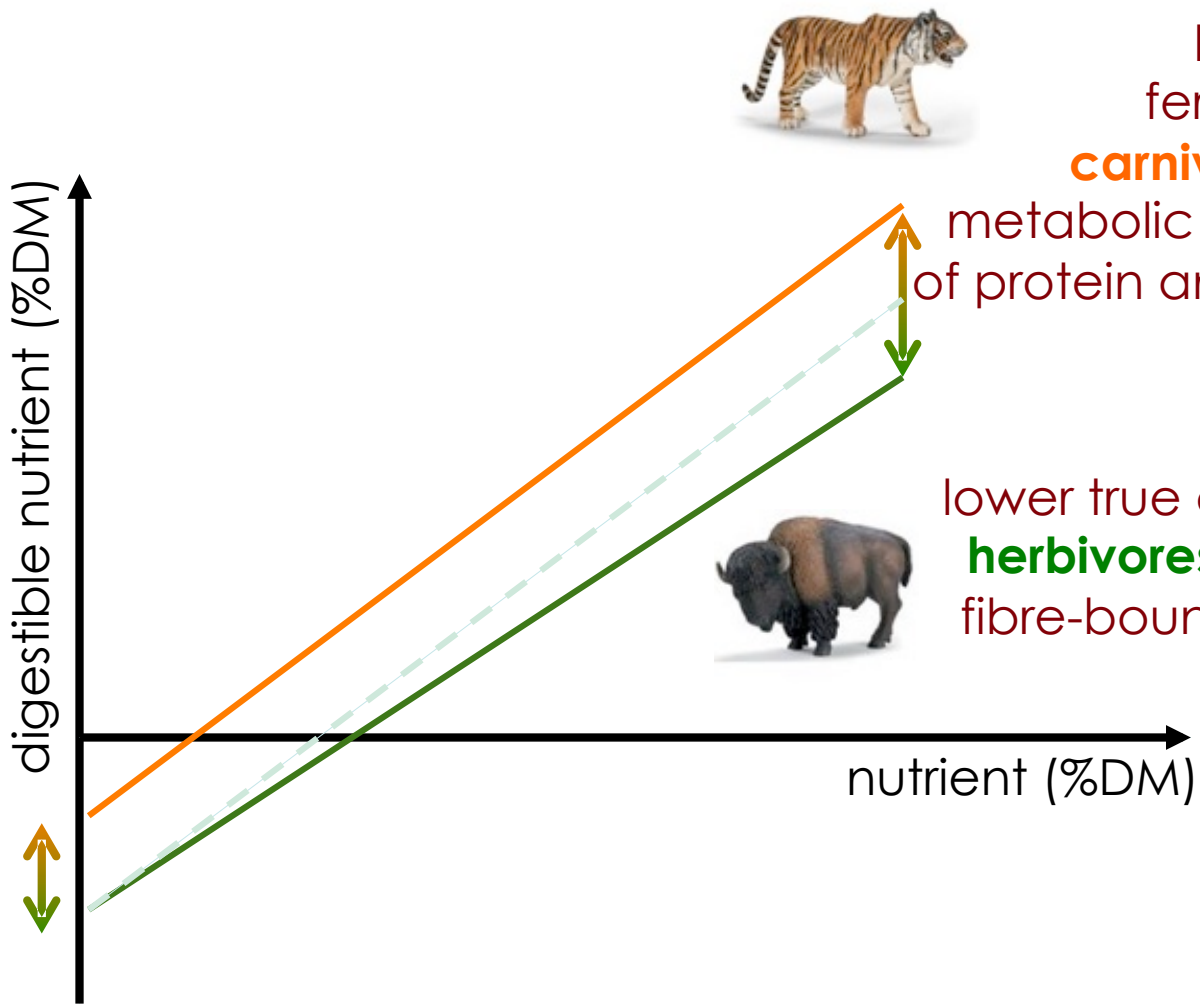


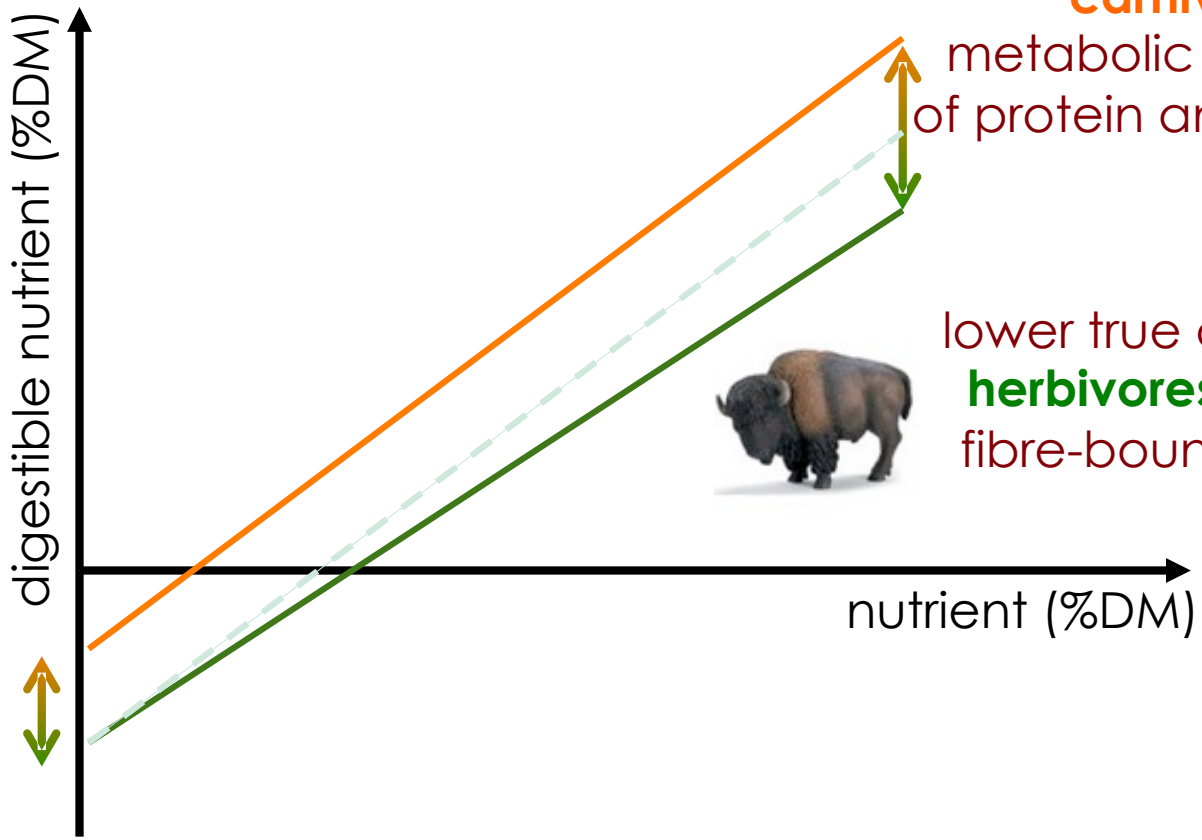
less microbial fermentation in **carnivores**, i.e. less metabolic faecal losses of protein and lipdis than **herbivores**

lower true digestibility in **herbivores**, e.g. due to fibre-bound nitrogen in feeds

Predictions: Trophic Guilds

because microbes consist of both proteins and lipids, parallel patterns for protein and fat are expected

less microbial fermentation in **carnivores**, i.e. less metabolic faecal losses of protein and lipdis than **herbivores**



lower true digestibility in **herbivores**, e.g. due to fibre-bound nitrogen in feeds

Predictions: Herbivore Strategies

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high metabolic losses in
non-corpophagic
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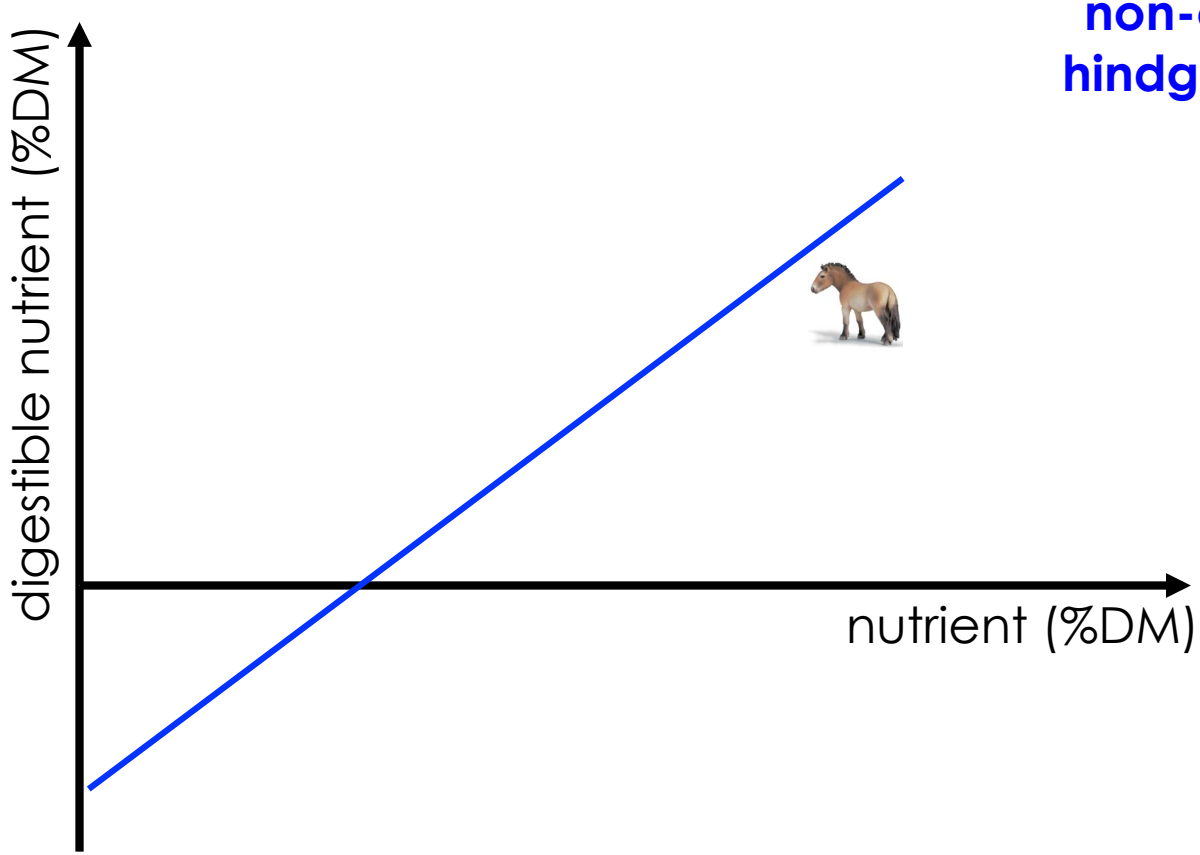
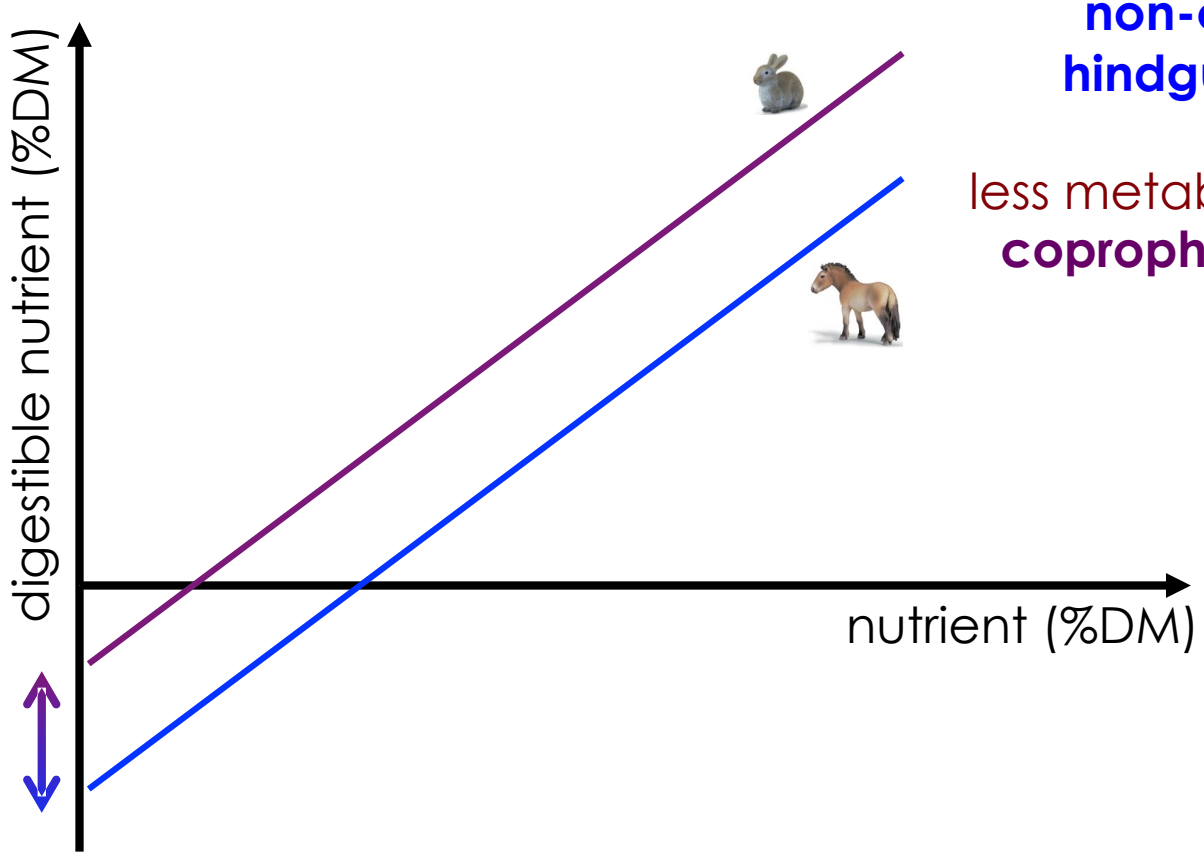


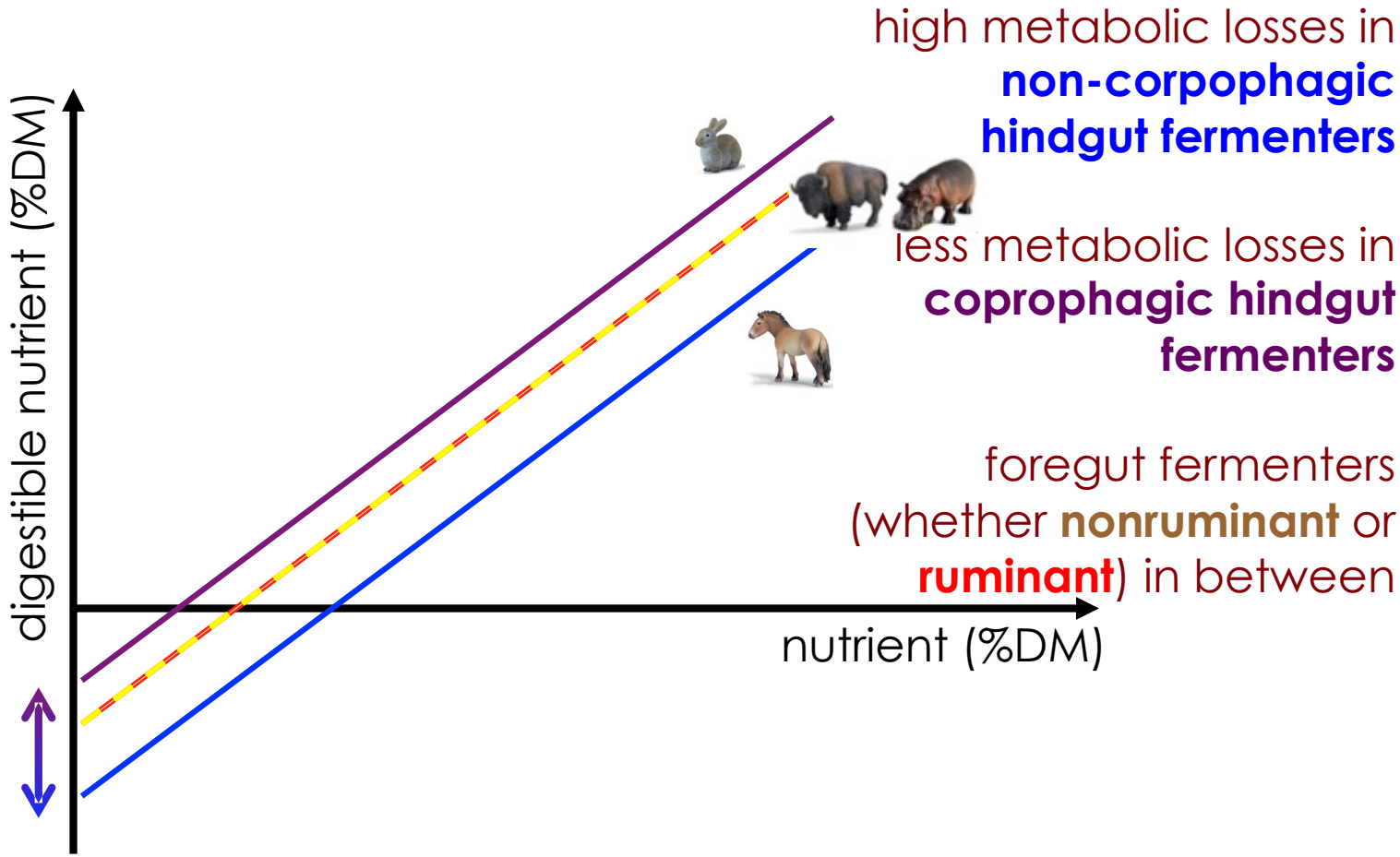
Predictions: Herbivore Strategies



high metabolic losses in **non-corpophagic hindgut fermenters**

less metabolic losses in **coprophagic hindgut fermenters**

Predictions: Herbivore Strategies



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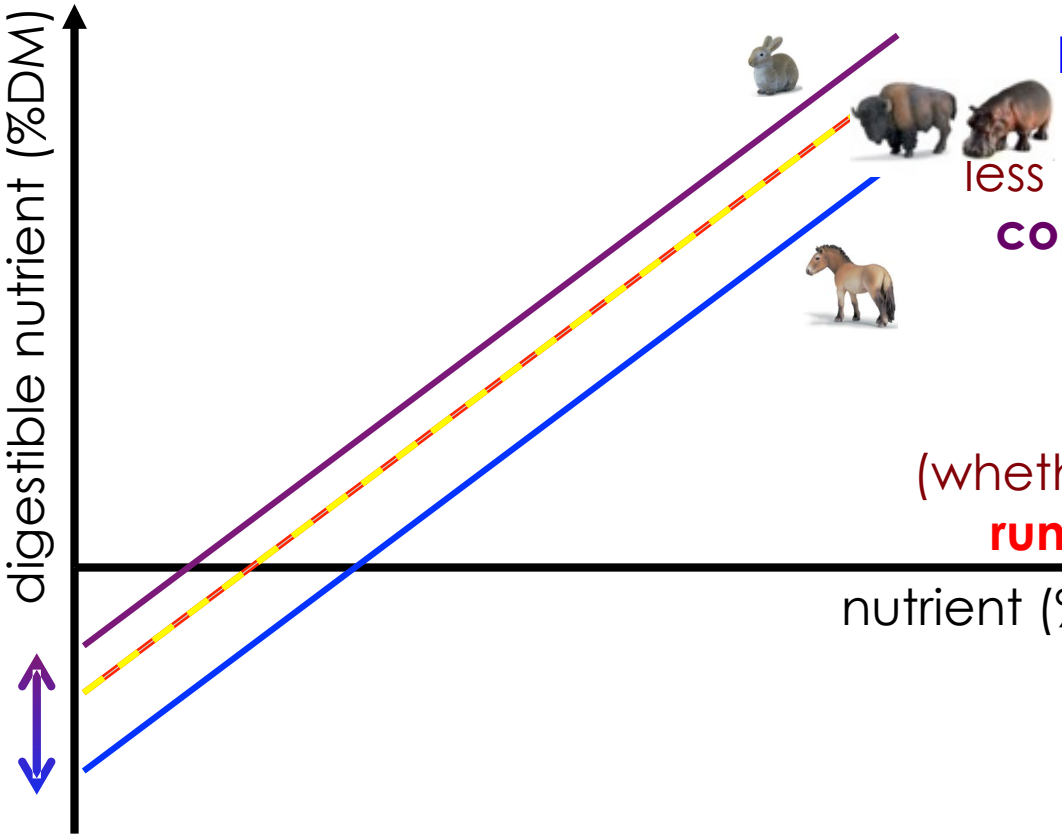
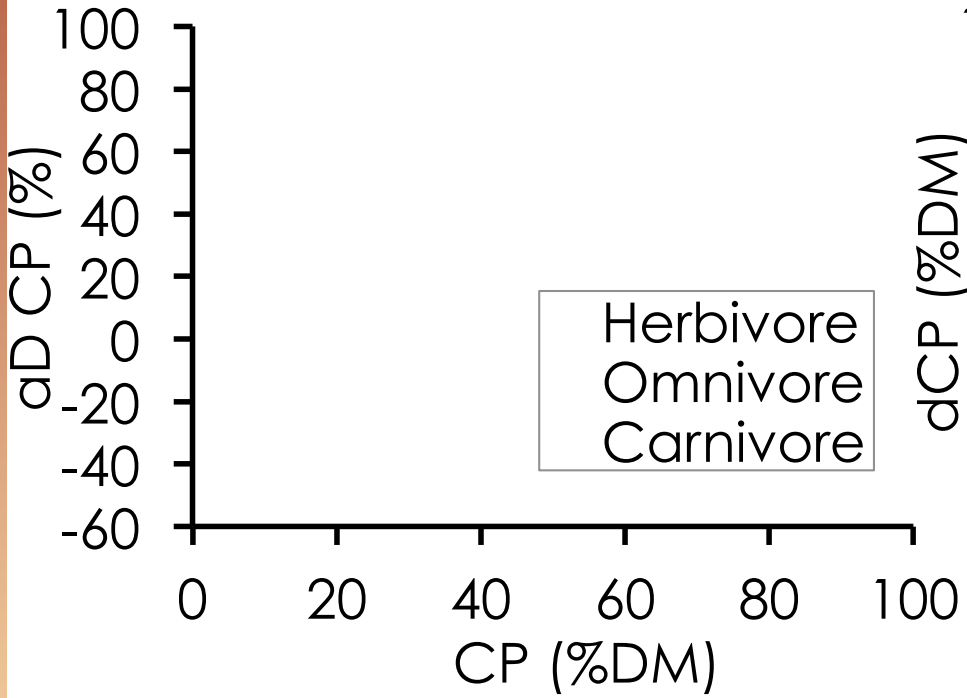


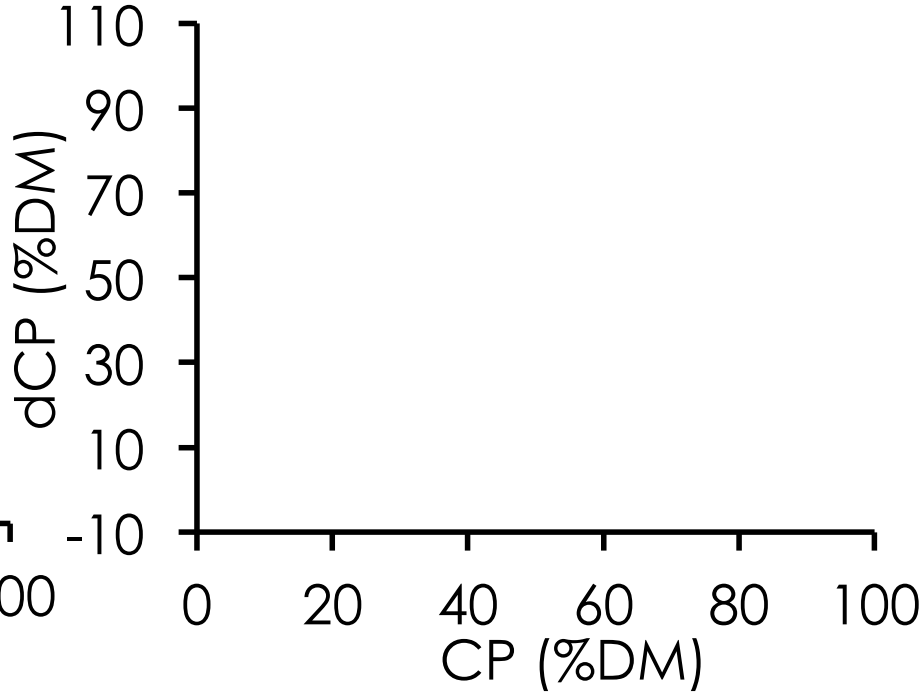
high metabolic losses in **non-corpophagic hindgut fermenters**

less metabolic losses in **coprophagic hindgut fermenters**

foregut fermenters (whether **nonruminant** or **ruminant**) in between

Protein digestion





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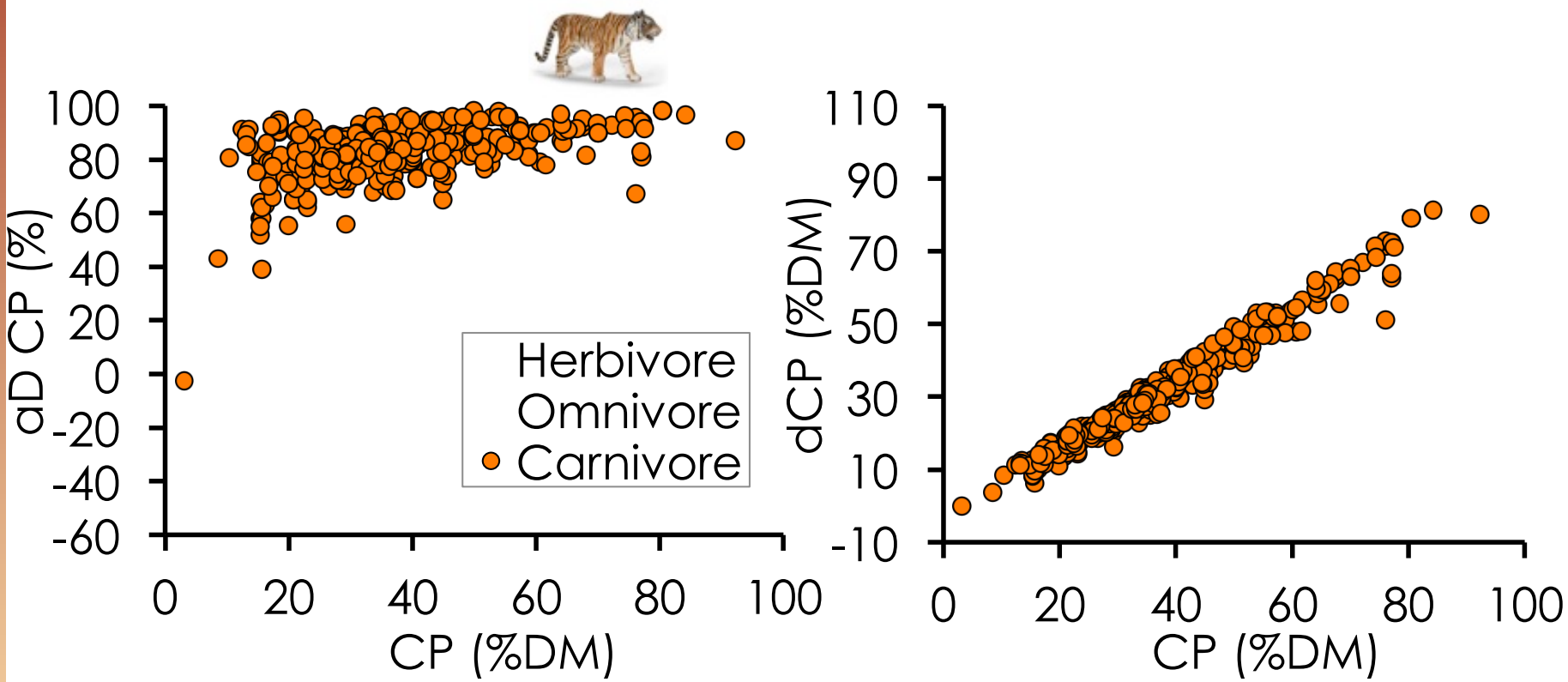

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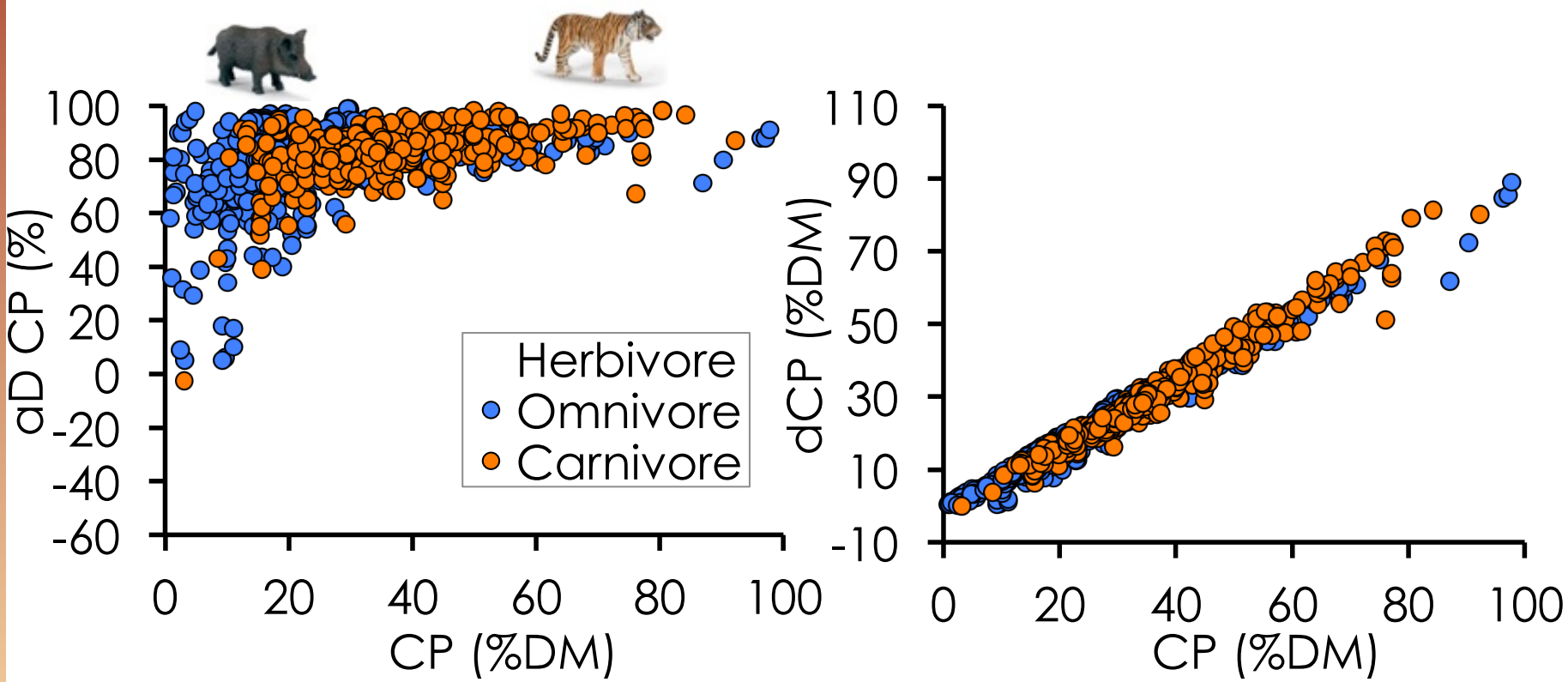

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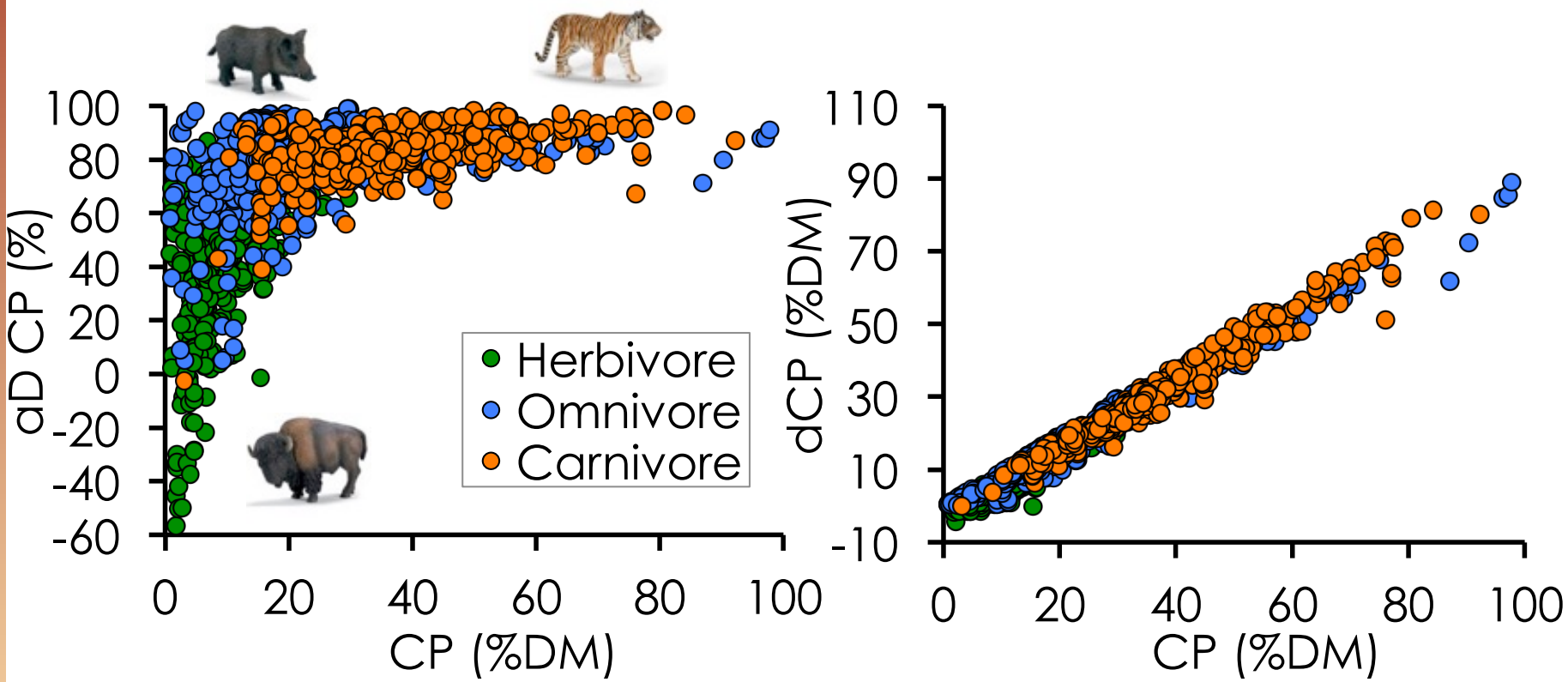
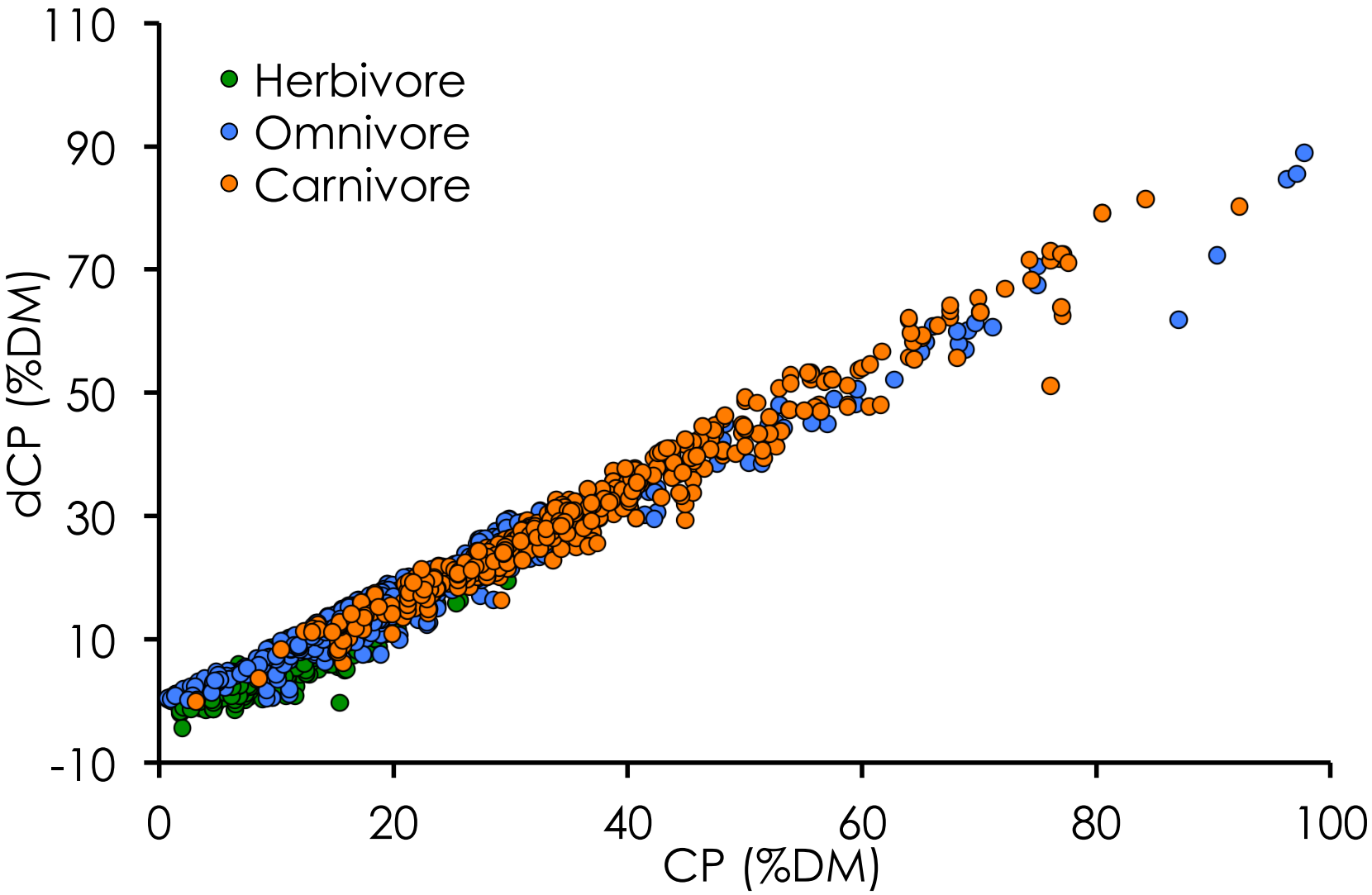


Protein digestion



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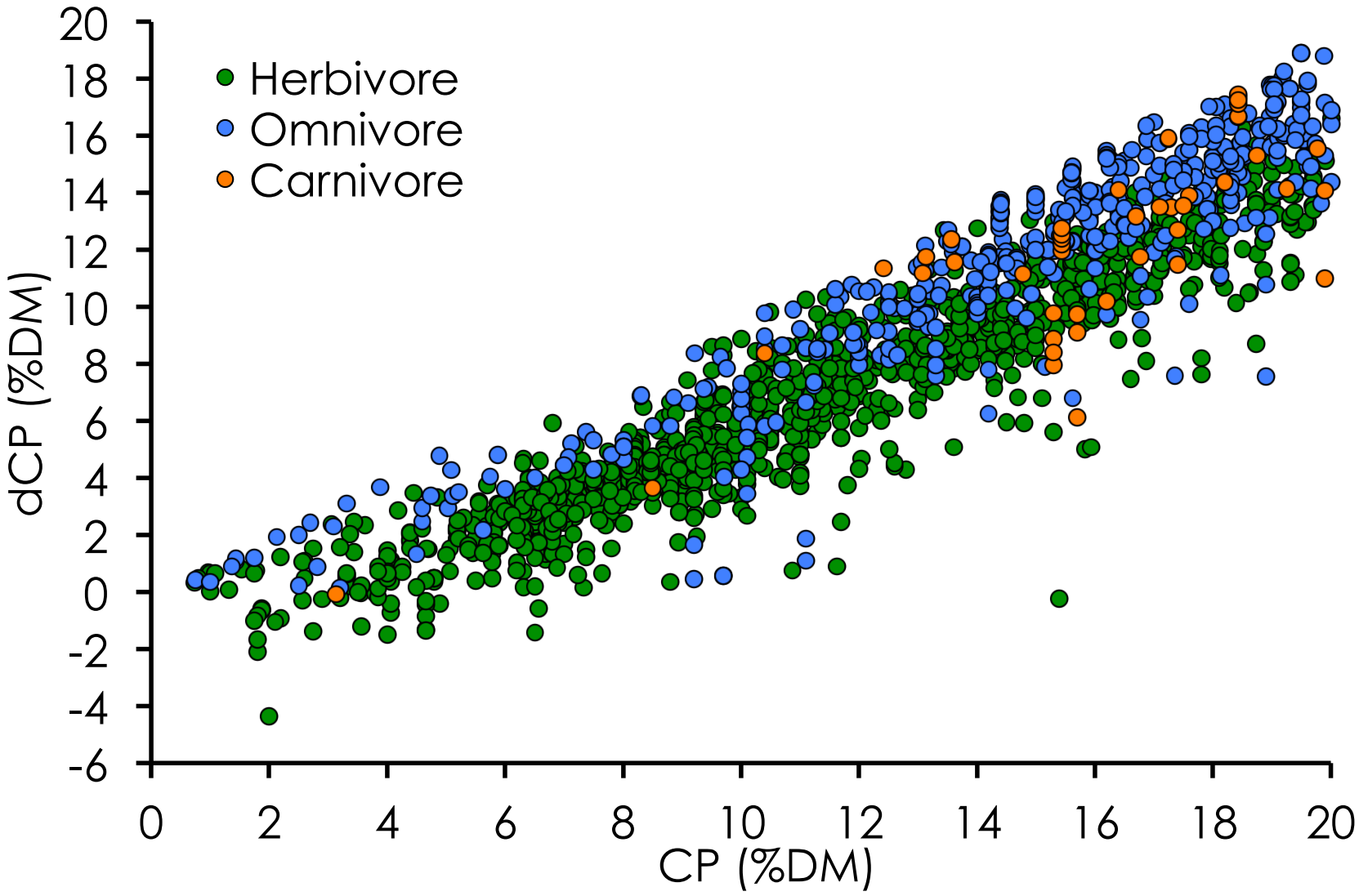

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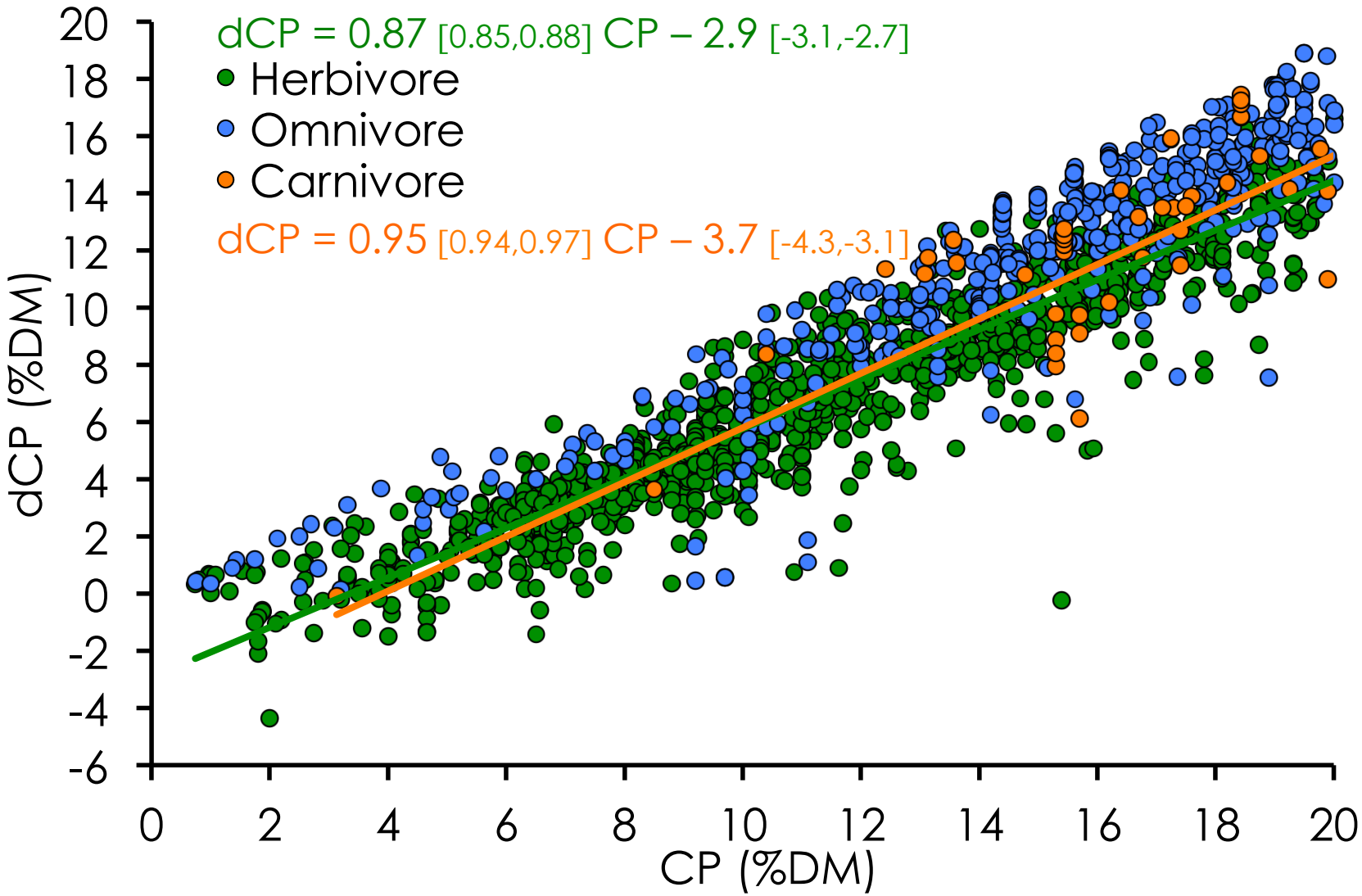
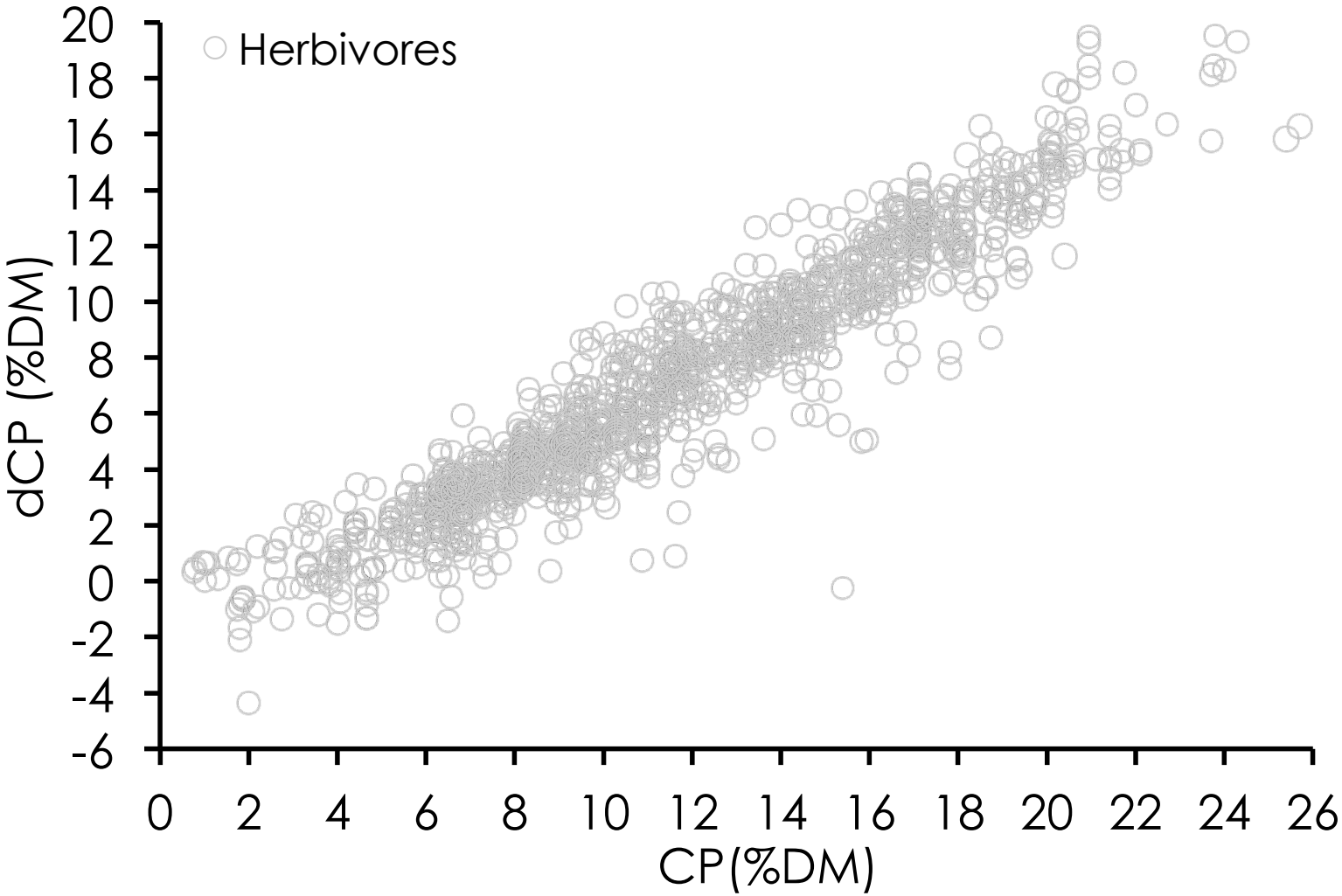


Protein digestion



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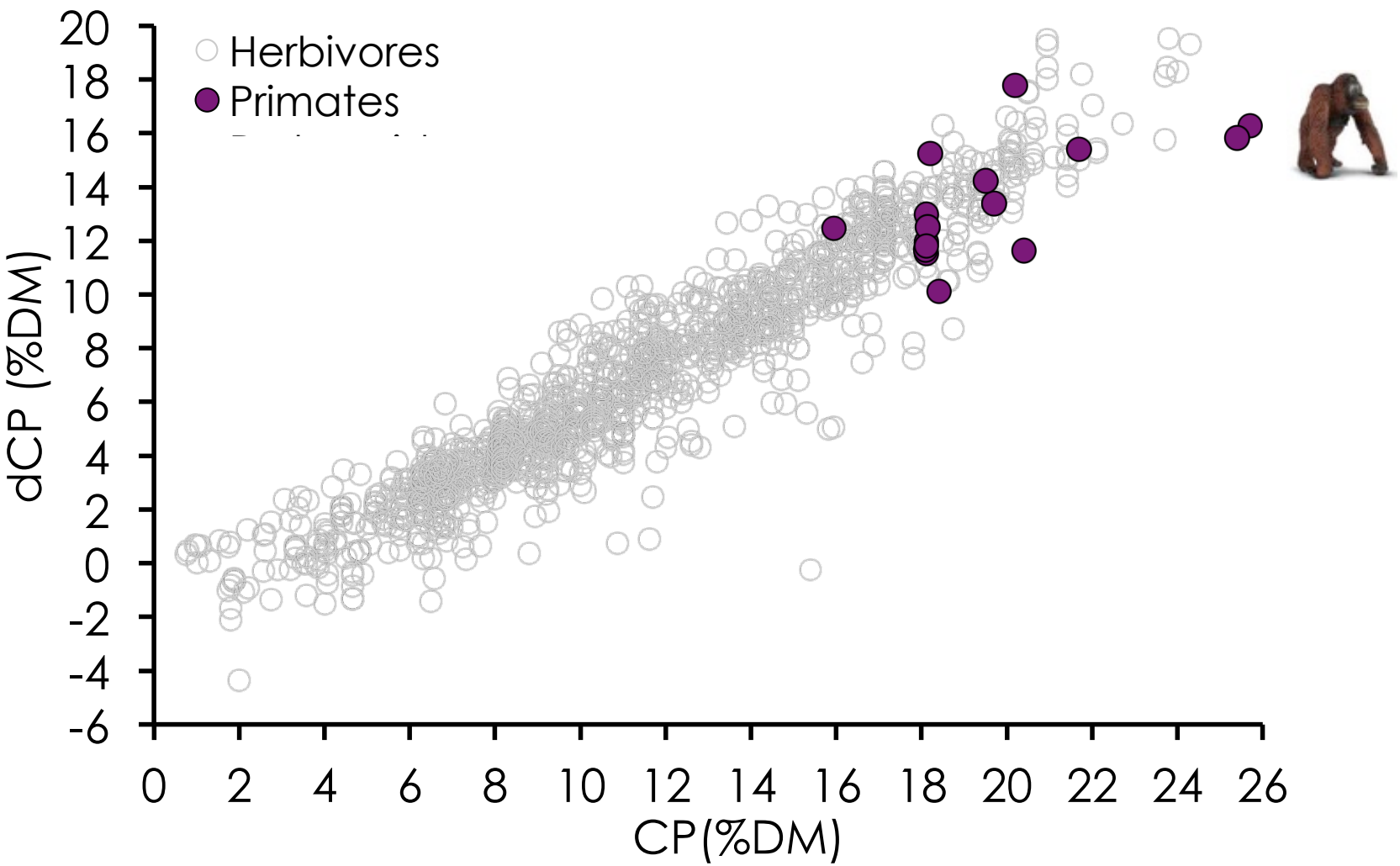

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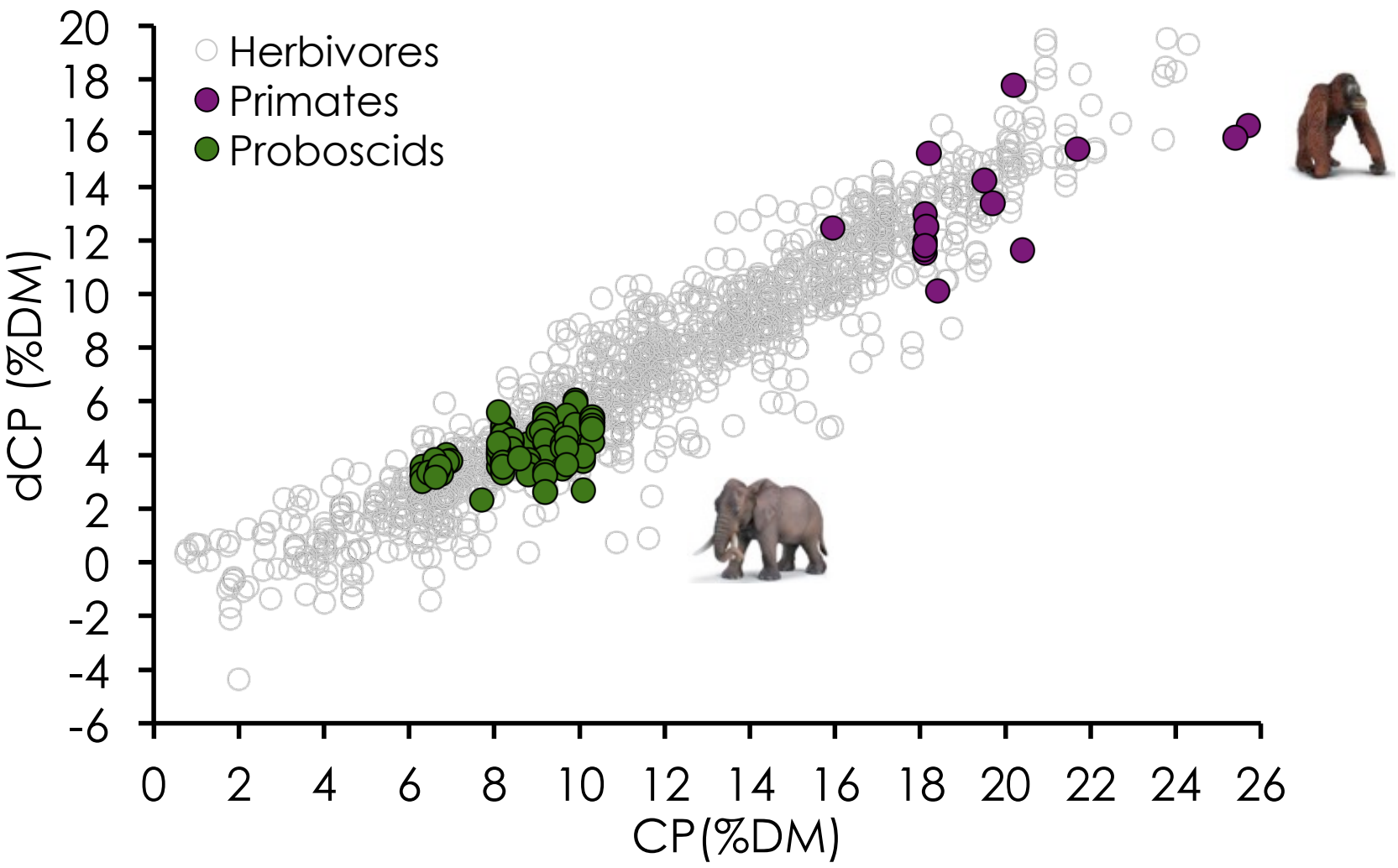

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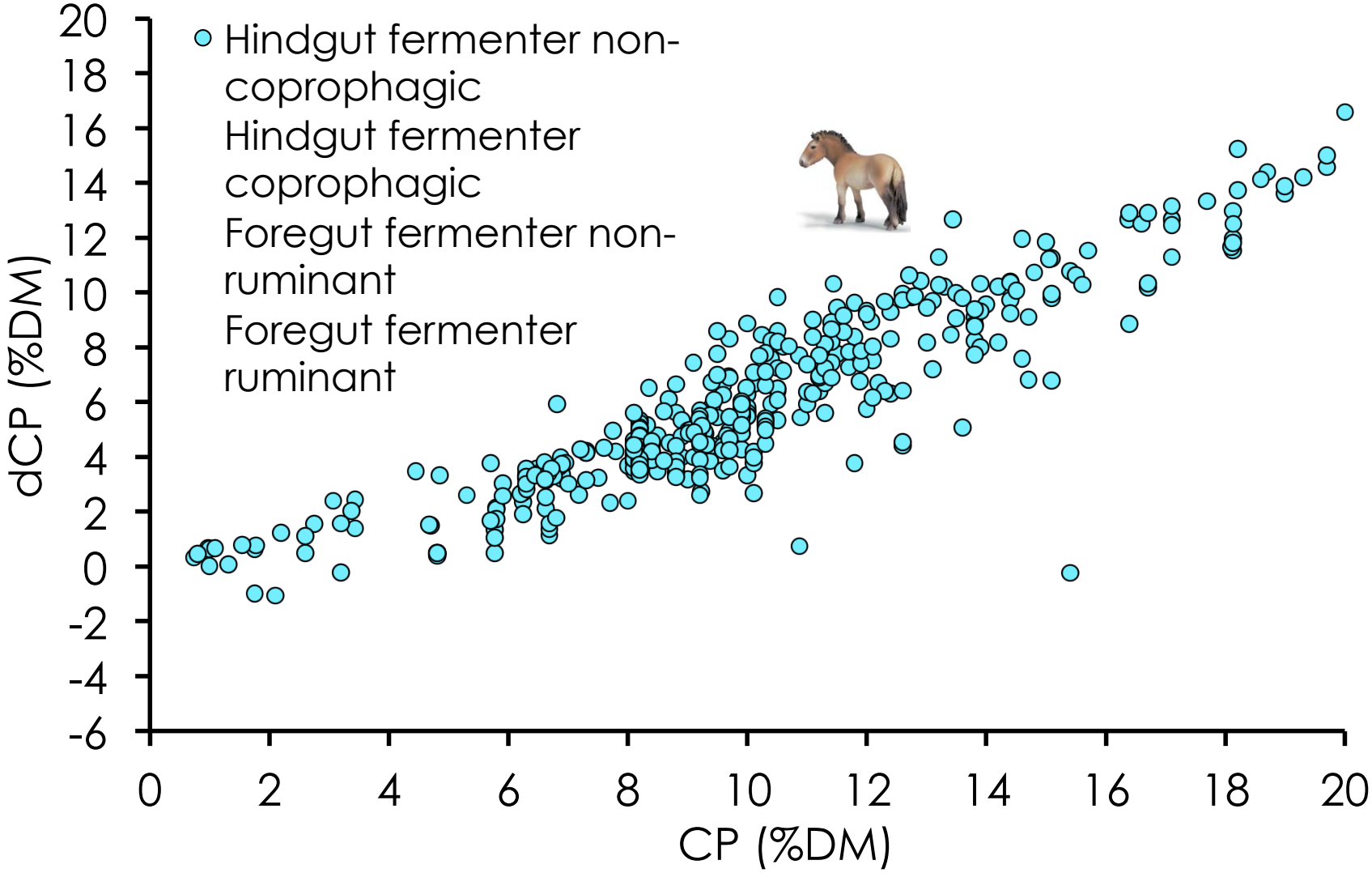

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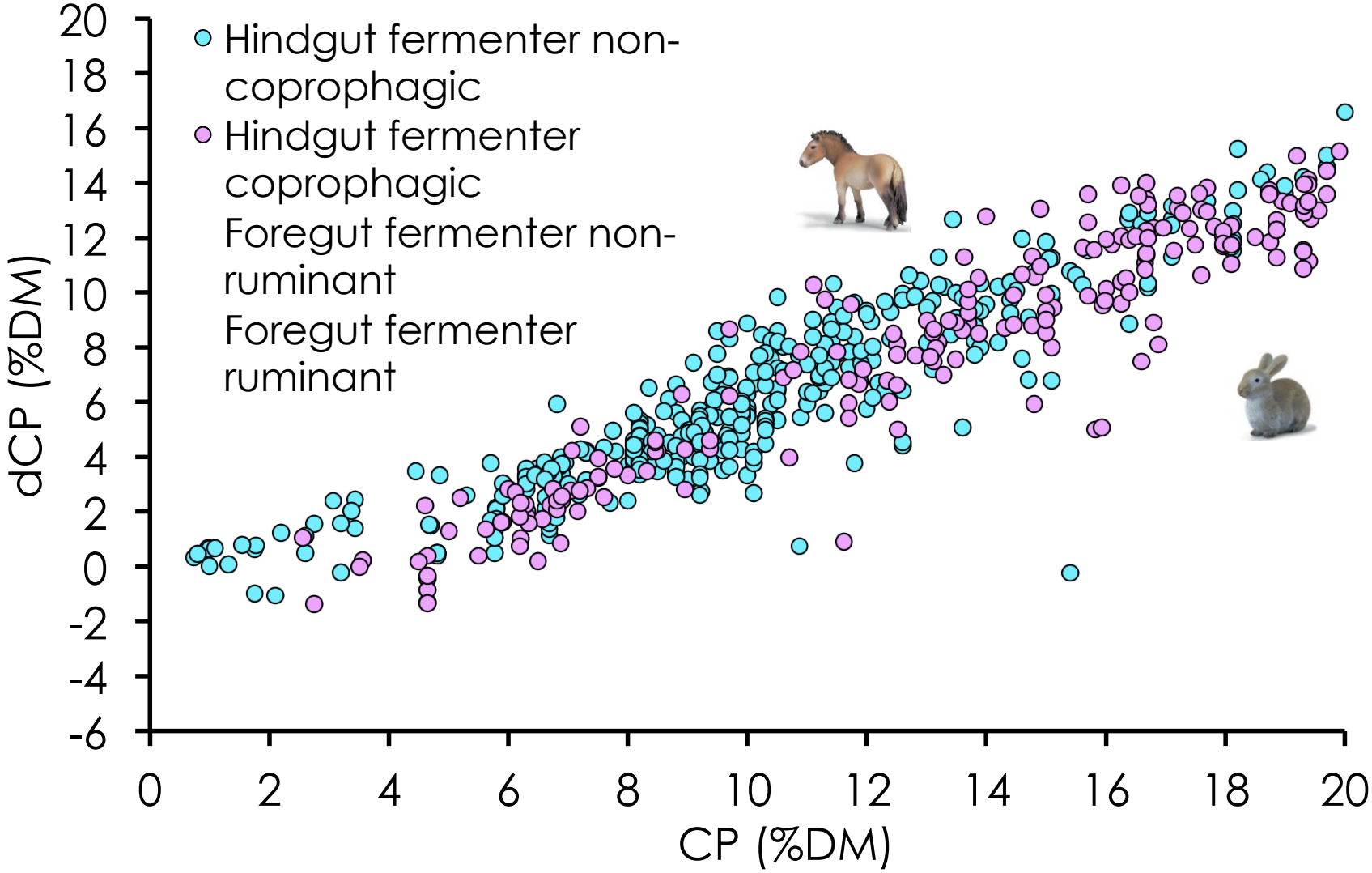

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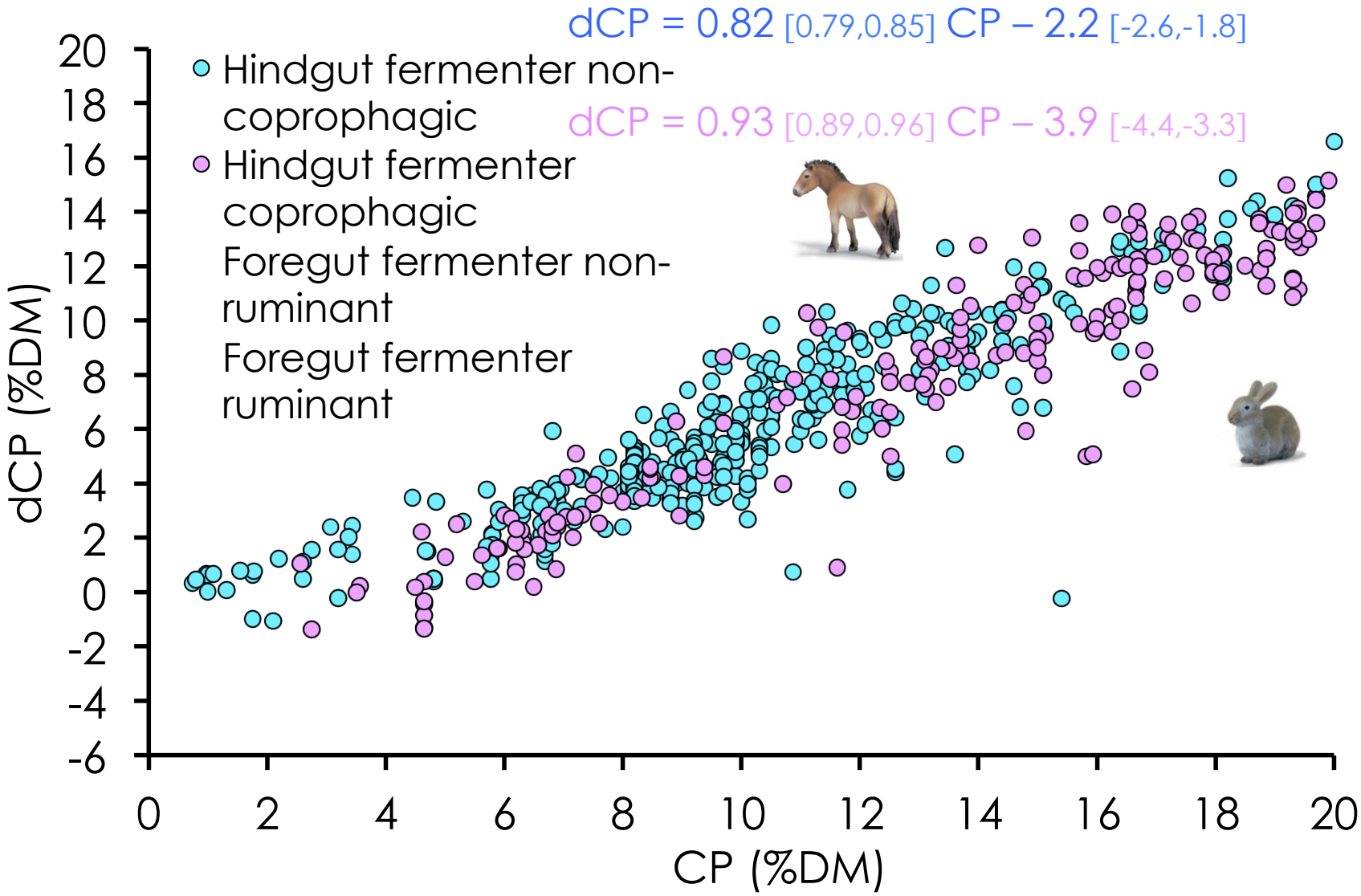

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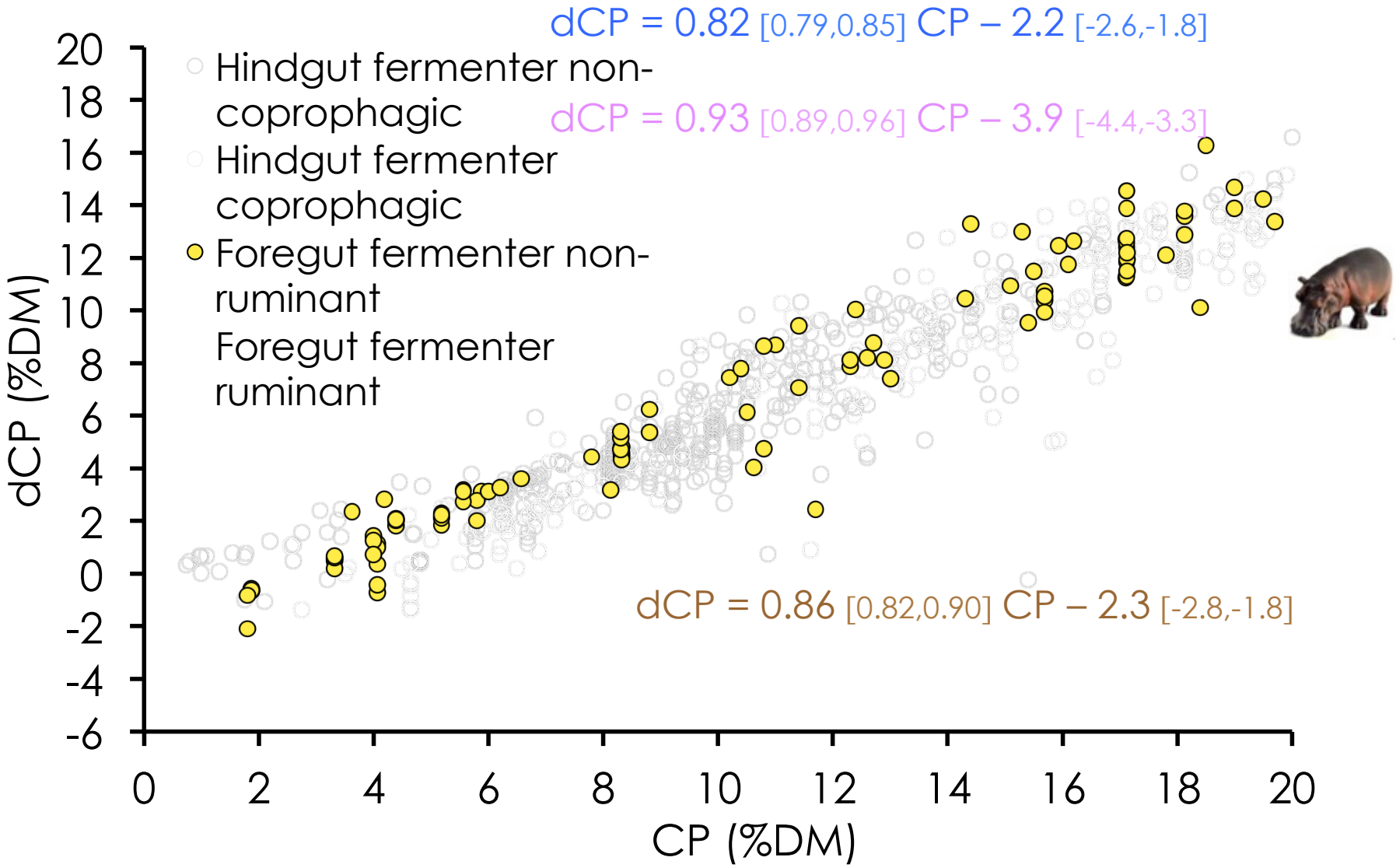
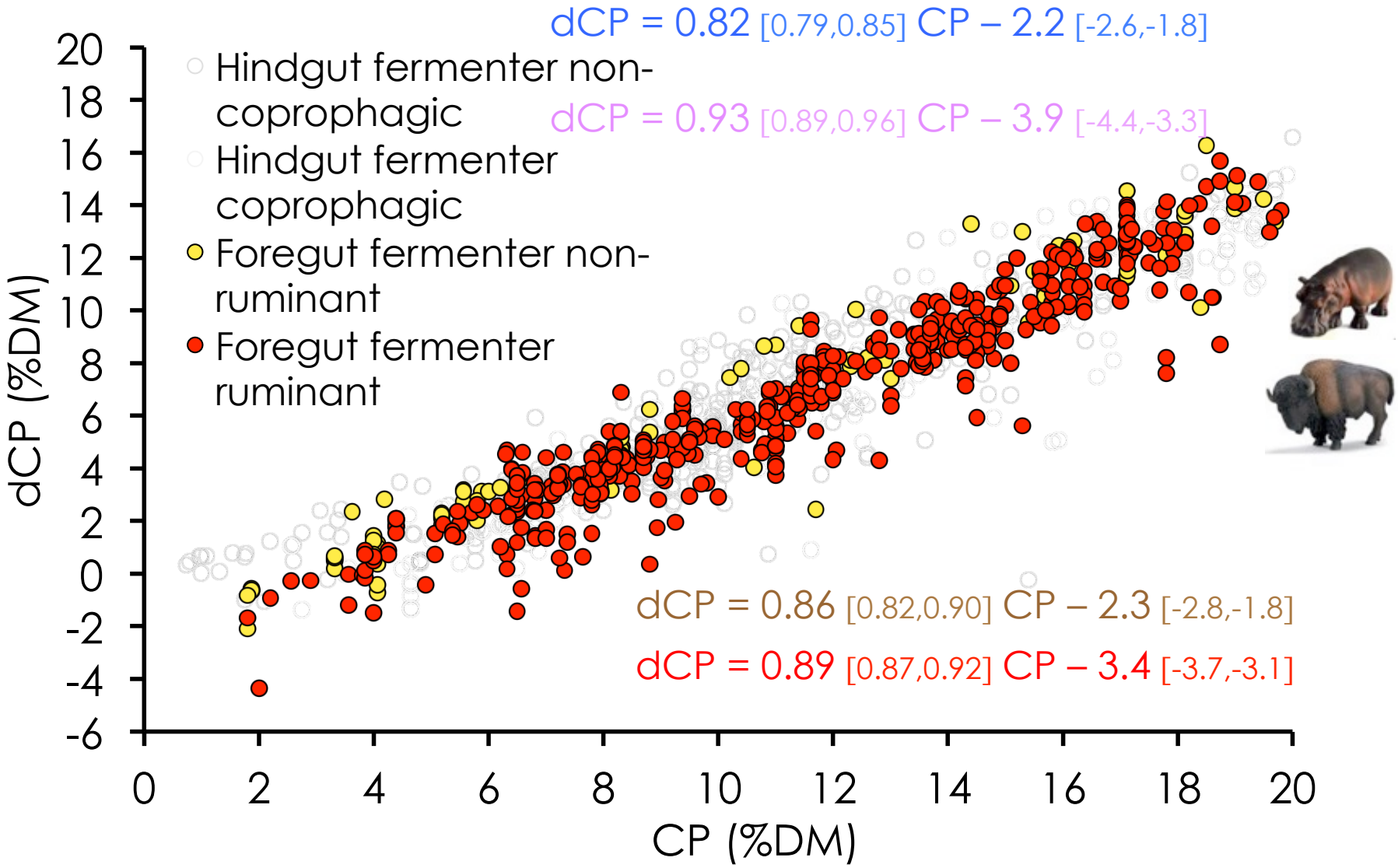


Protein digestion



Conclusions Protein

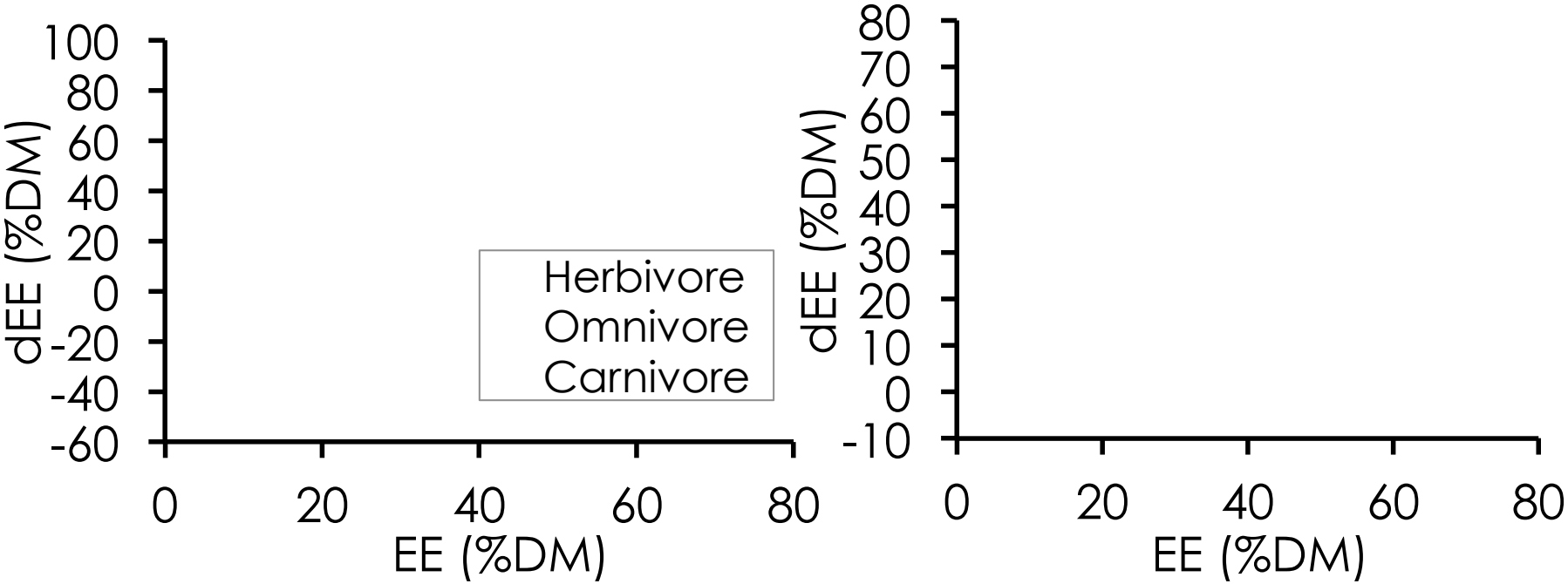
Dietary CP is the main determinant of across-species CP digestibility.

Similar levels of endogenous/metabolic protein losses between herbivores and carnivores.

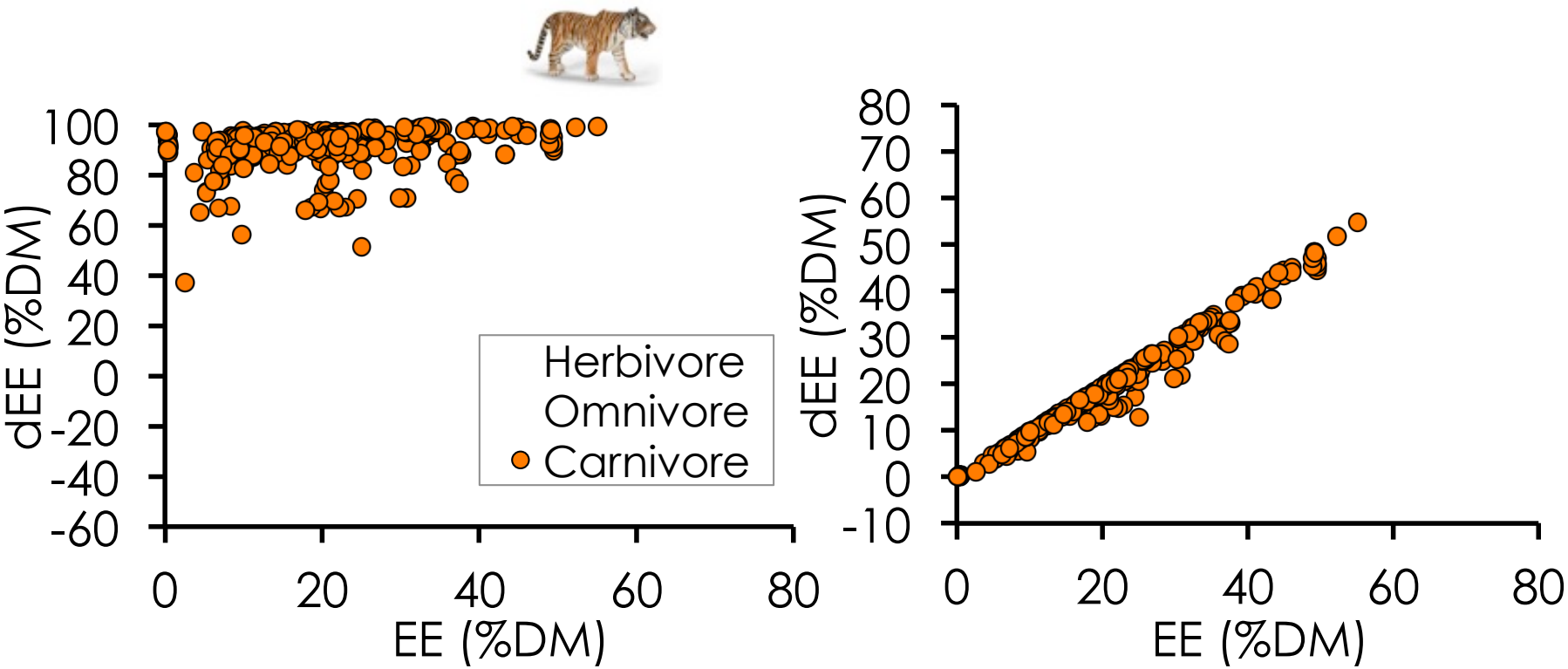
Lower true protein digestibility in herbivores – possibly linked to higher indigestible N levels in plant-based diets.

No evident difference between herbivore digestion types.

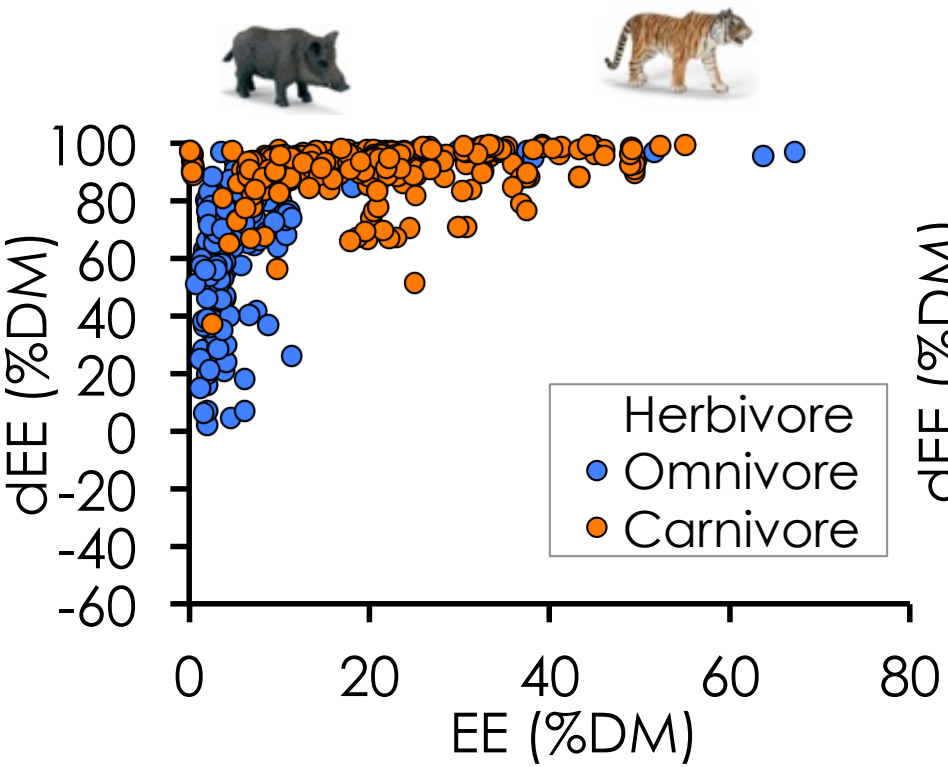
Fat digestion

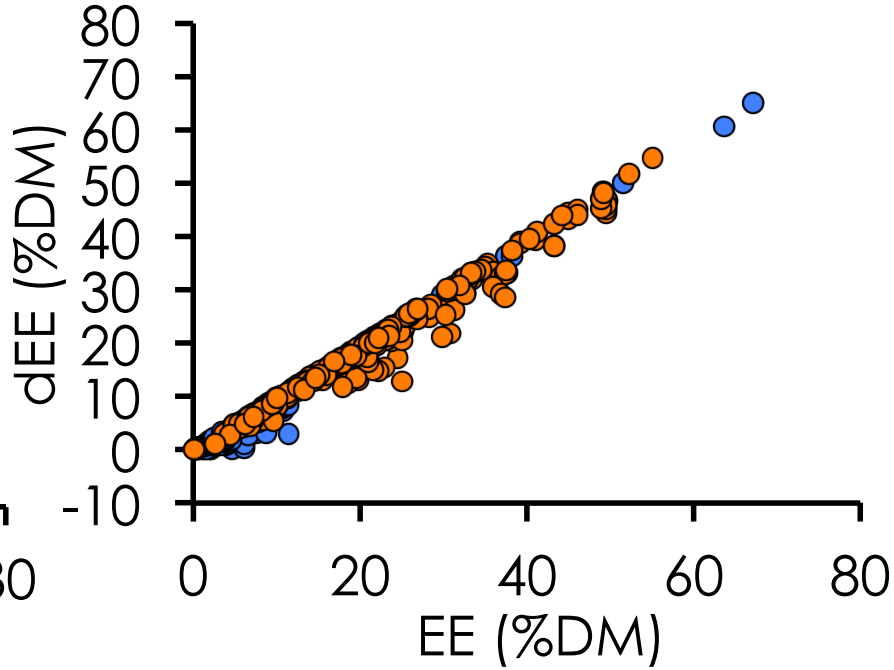


Fat digestion

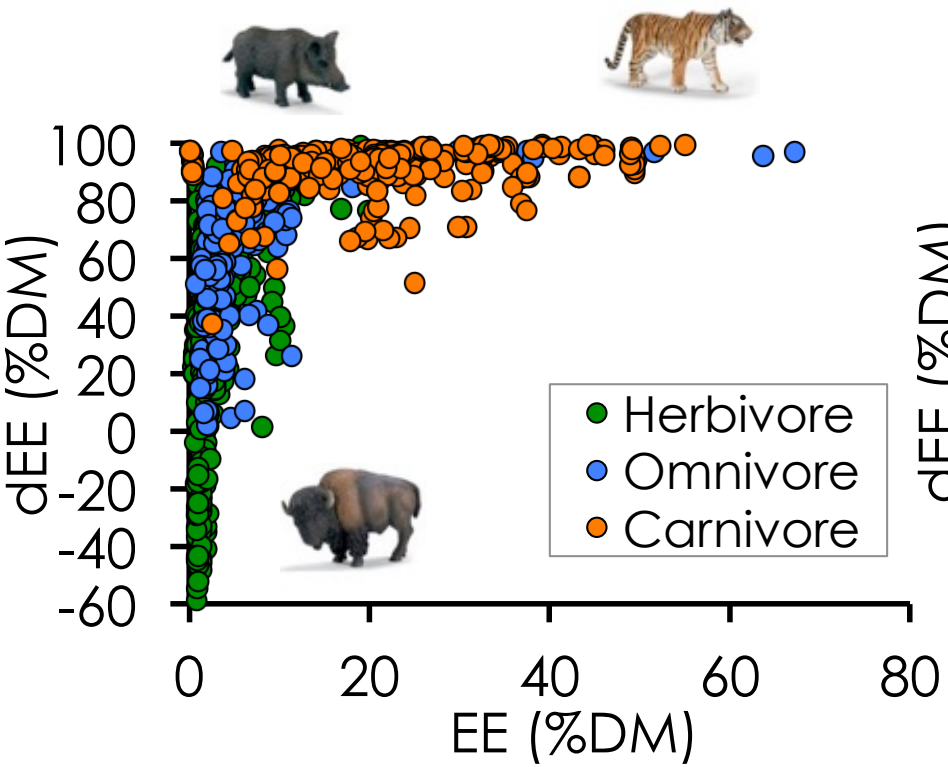


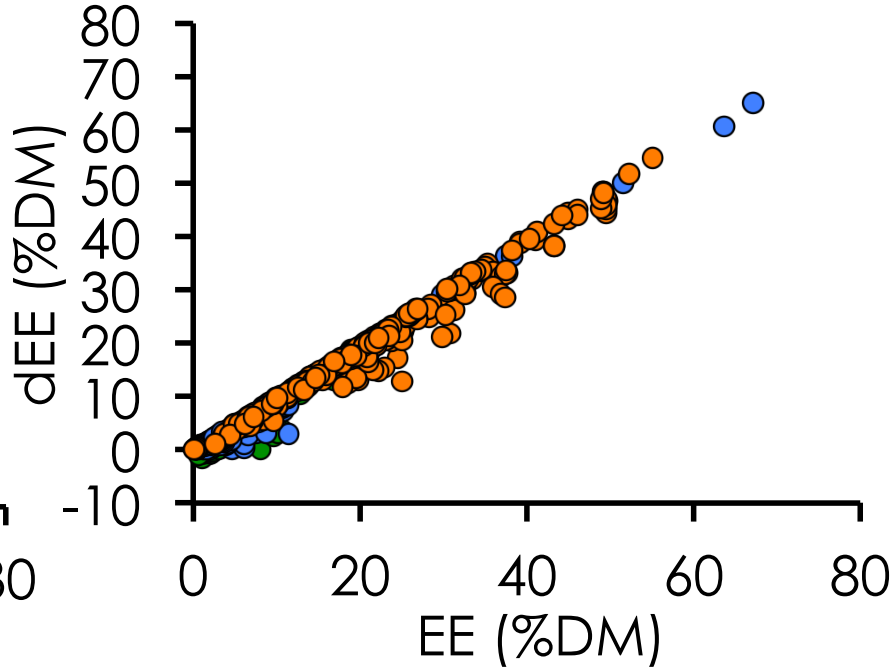
Fat digestion





Fat digestion





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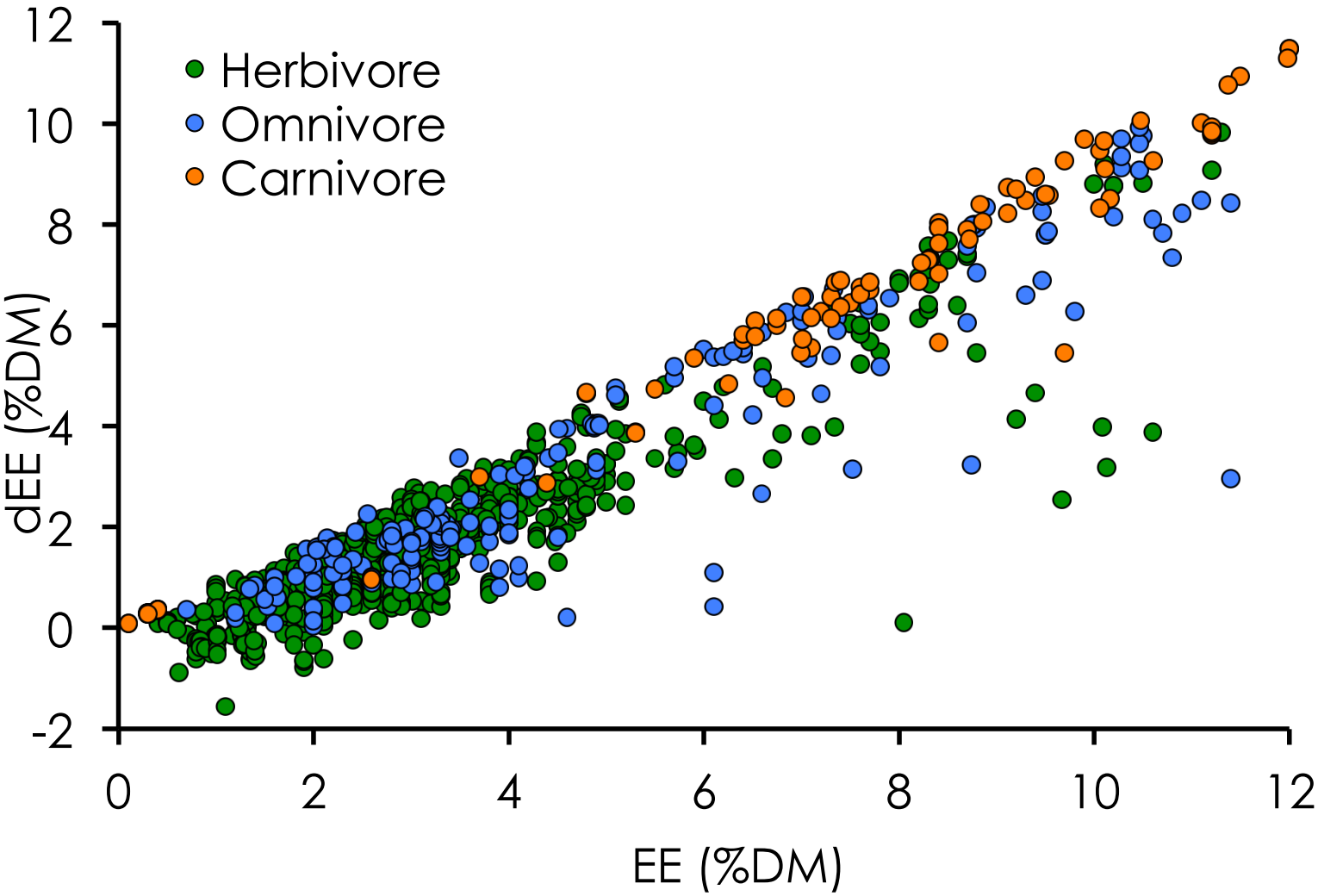
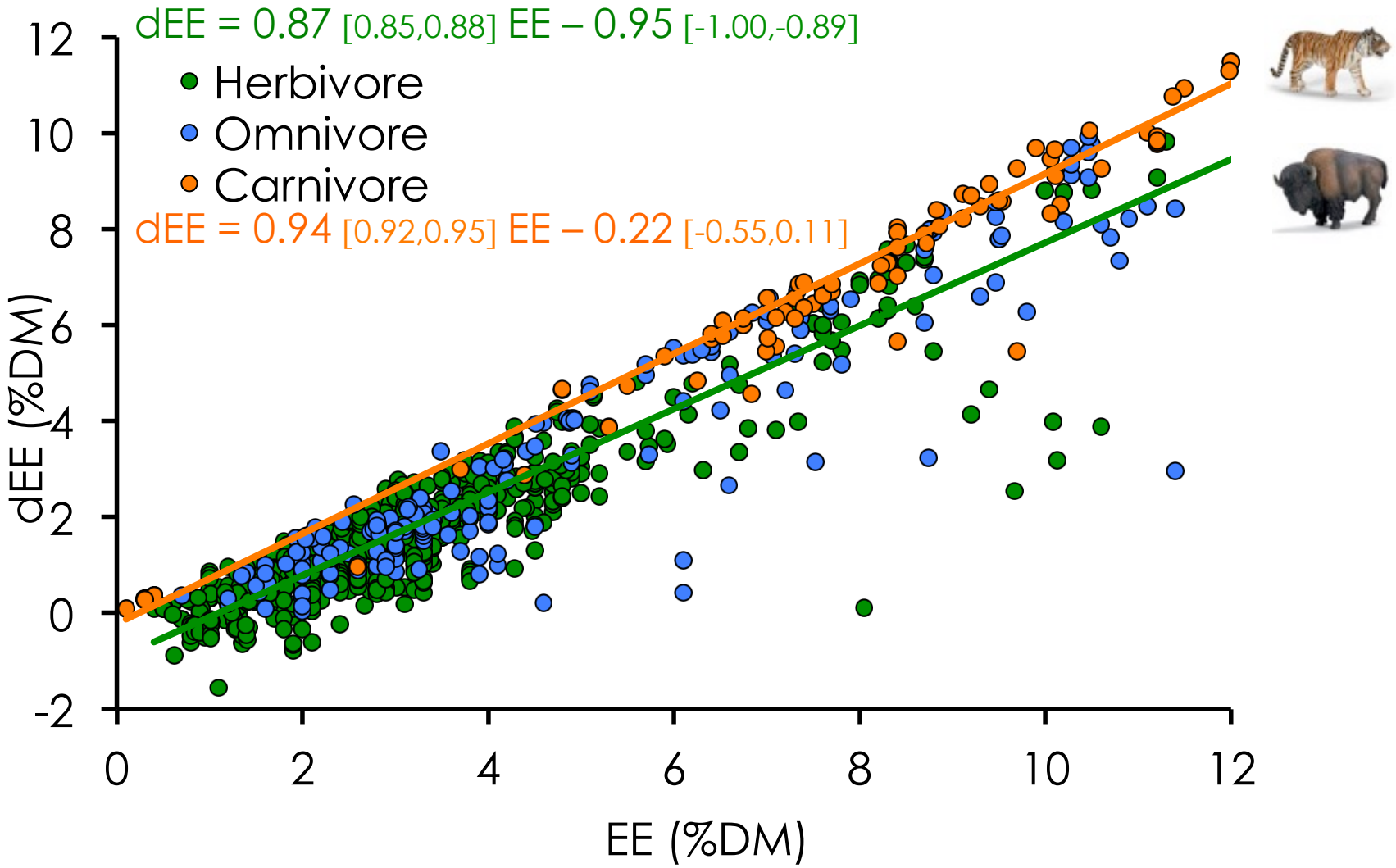
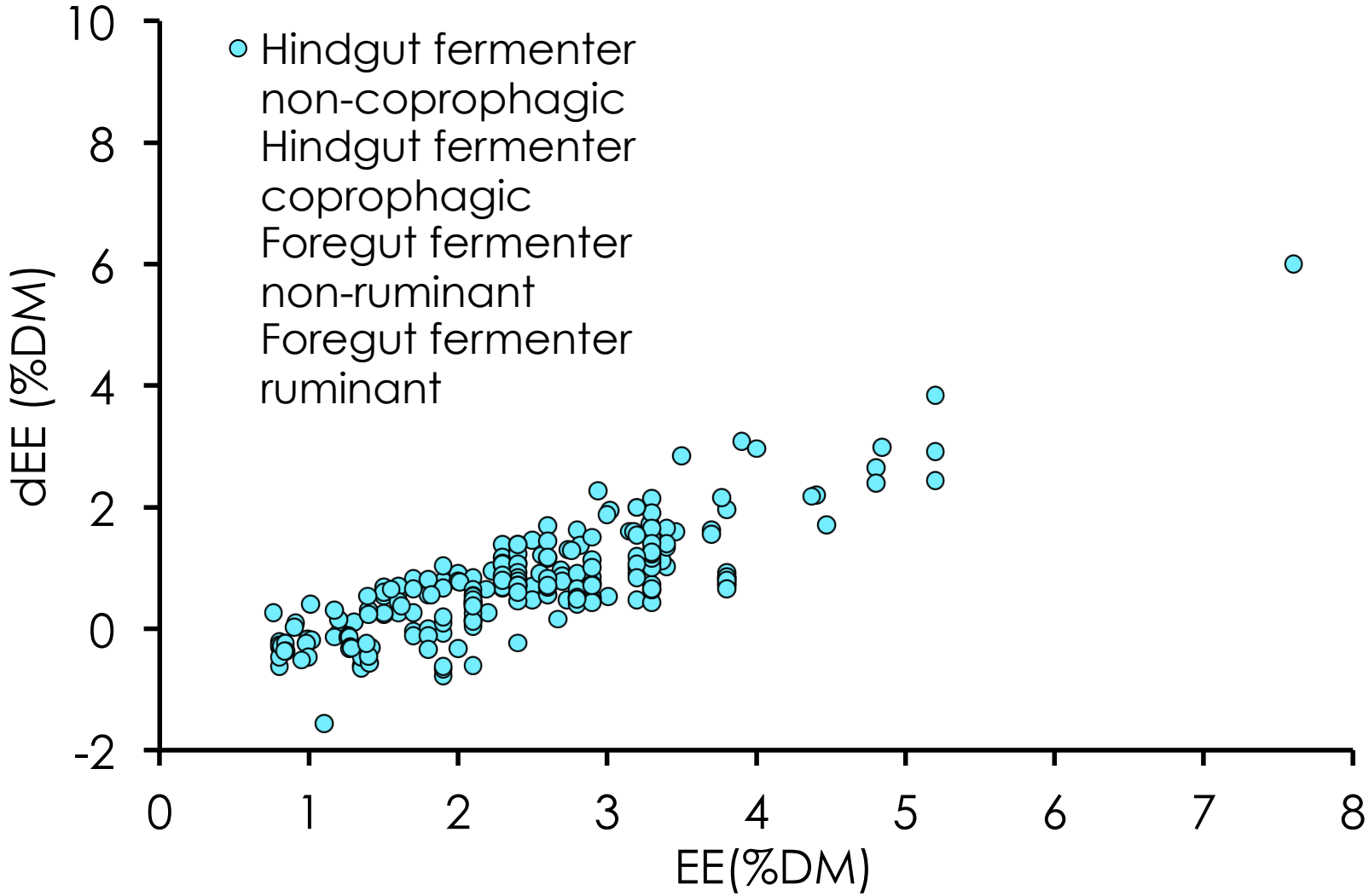


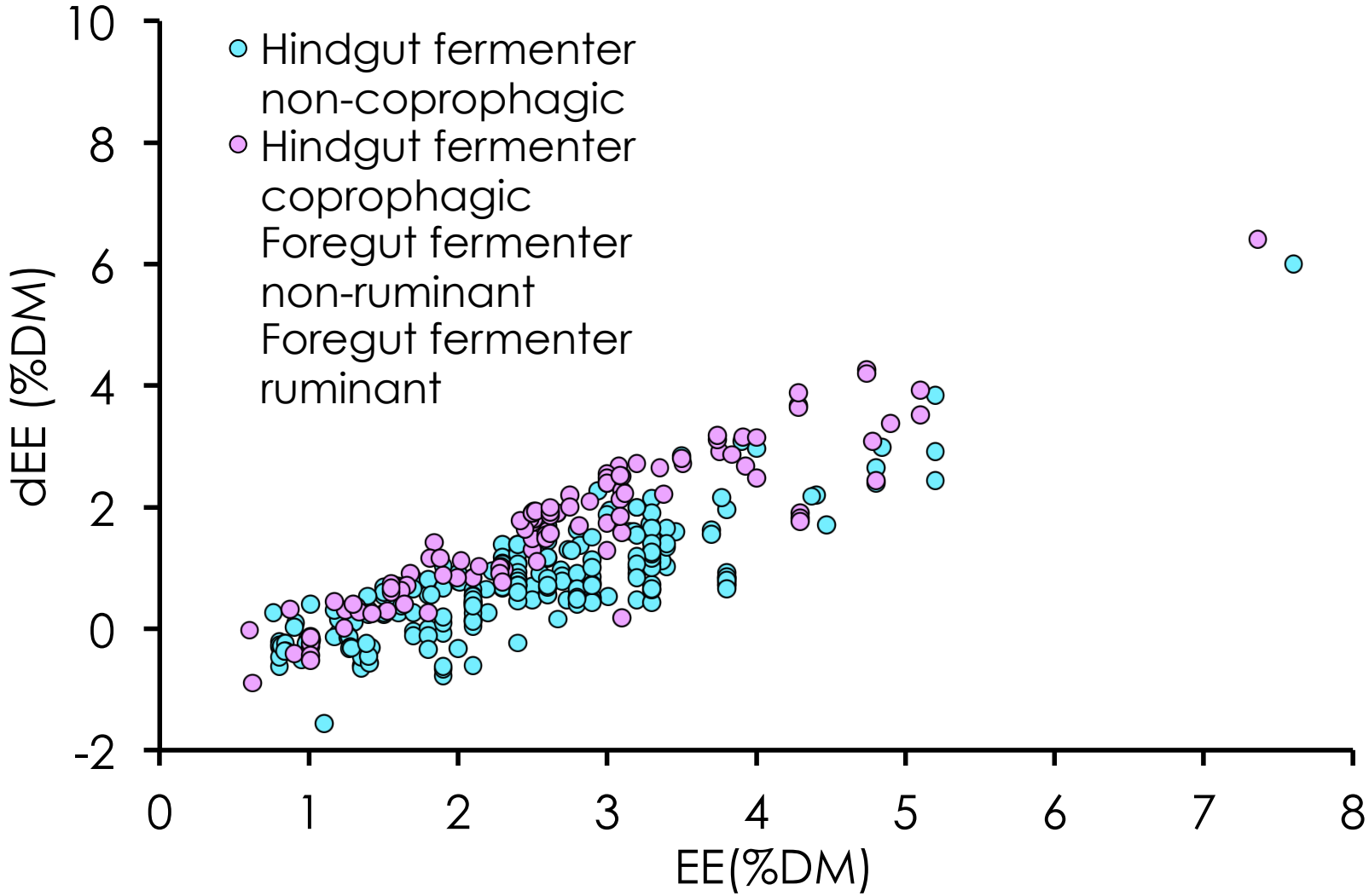
Fat digestion



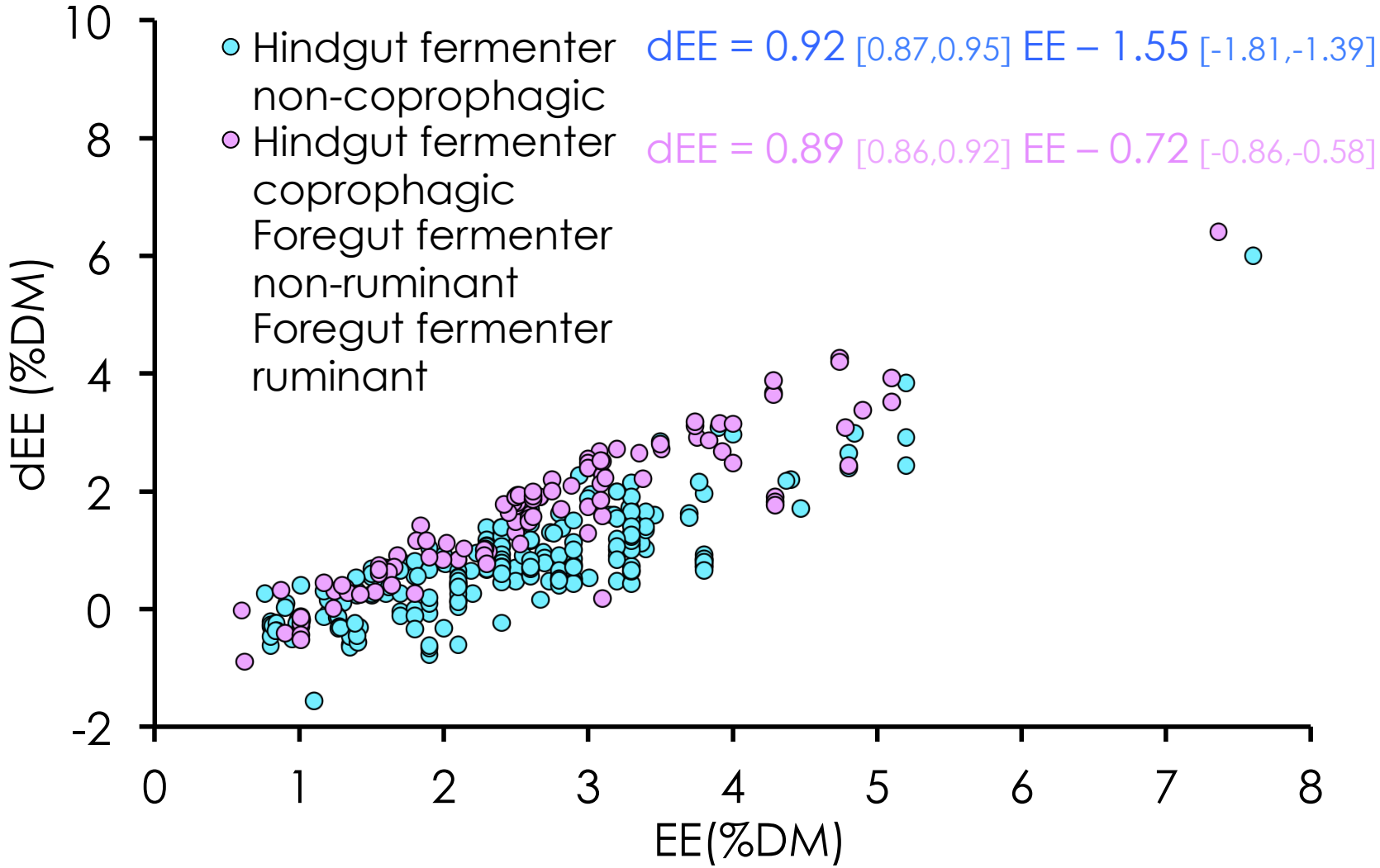
Fat digestion



Fat digestion



Fat digestion



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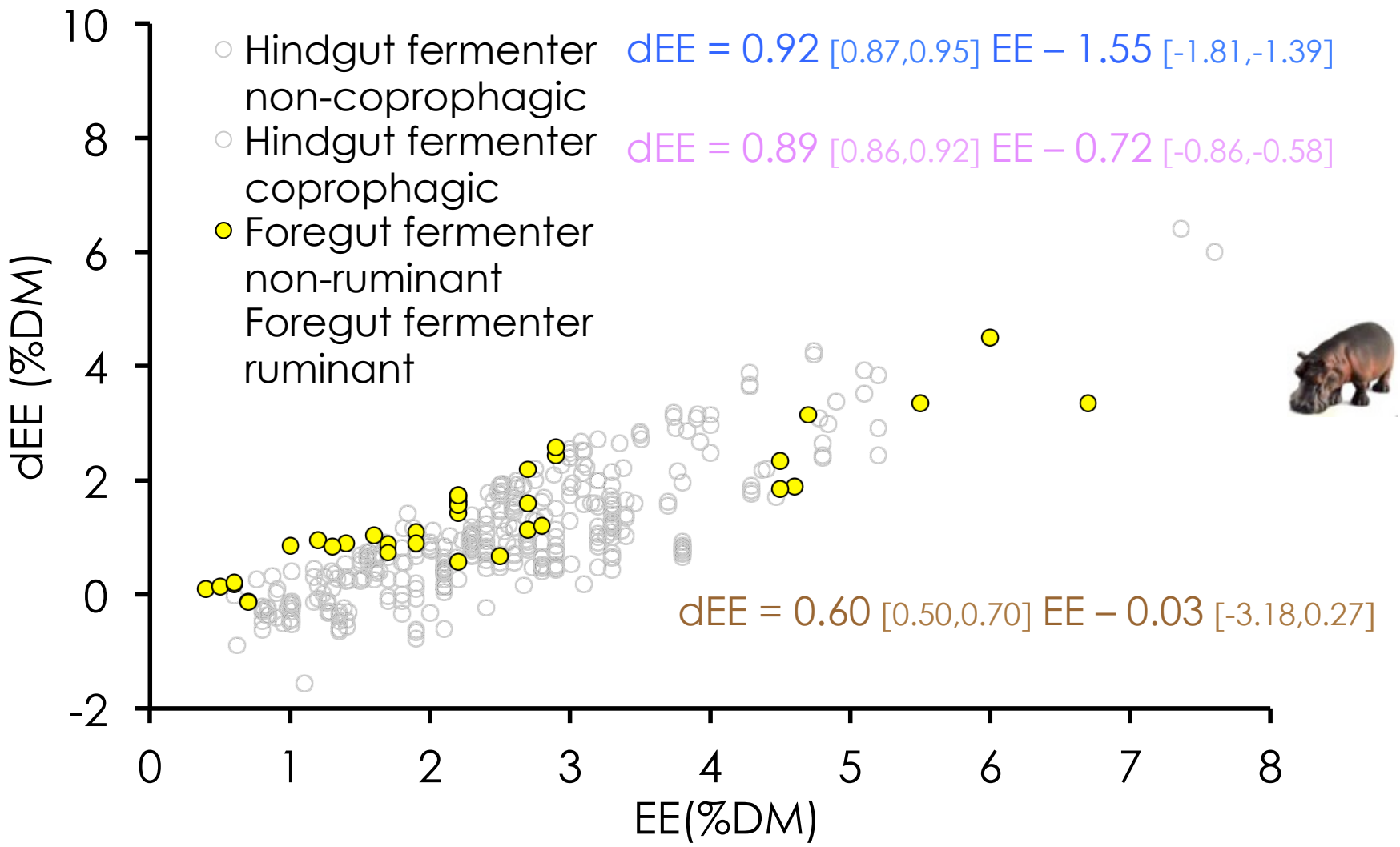
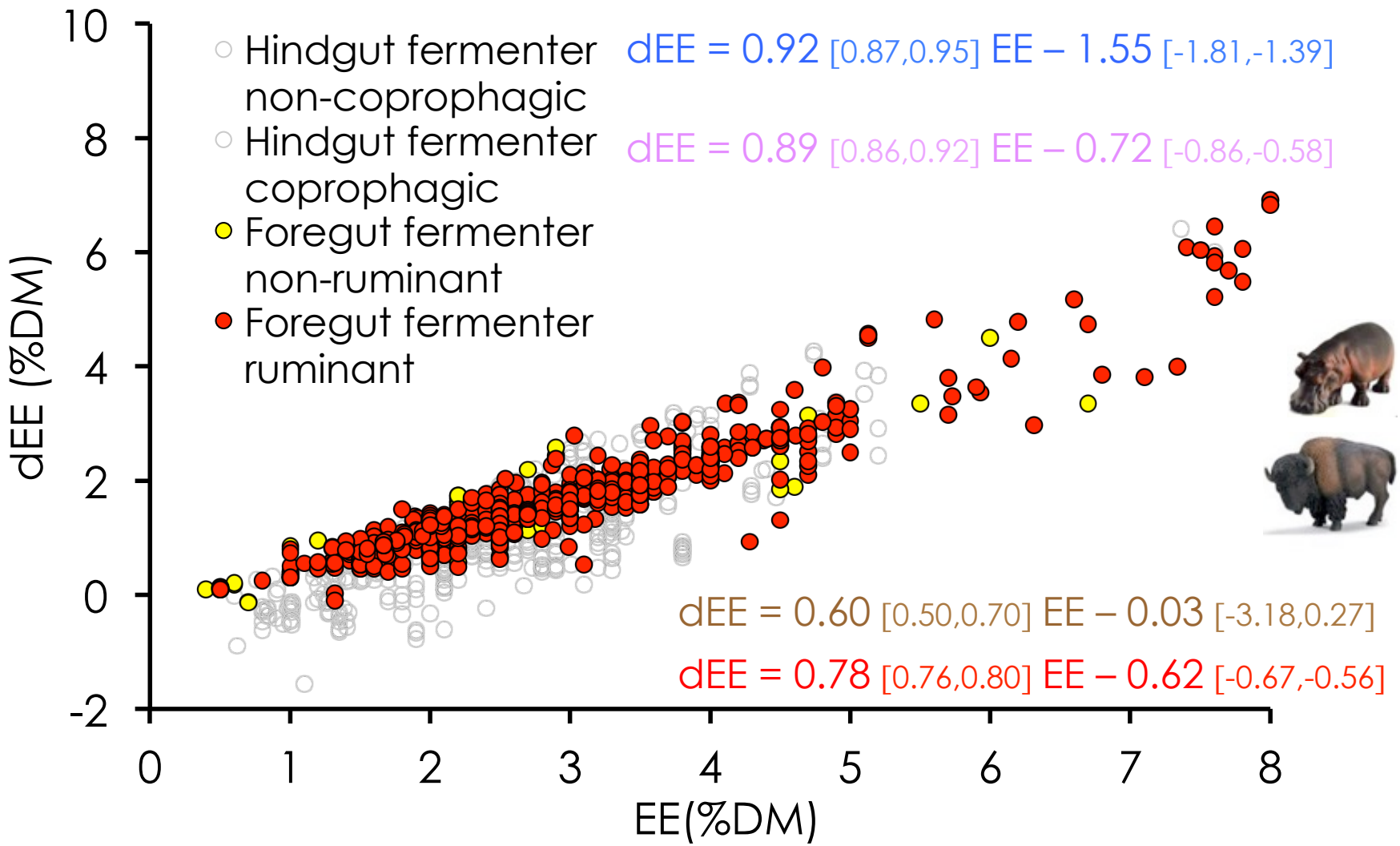


Fat digestion



Conclusions Fat

Dietary EE is the main determinant of across-species EE digestibility.

Higher levels of endogenous/metabolic lipid losses in herbivores compared to carnivores.

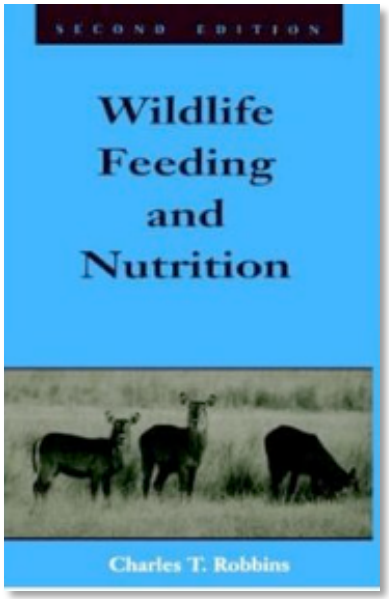
No evident difference between herbivore digestion types with respect to metabolic losses.

Lower true EE digestibility in foregut fermenting herbivores – possibly linked to foregut lipid production and hydrogenation.

What does the literature say?

What does the literature say?

no difference in true protein digestibility between trophic guilds



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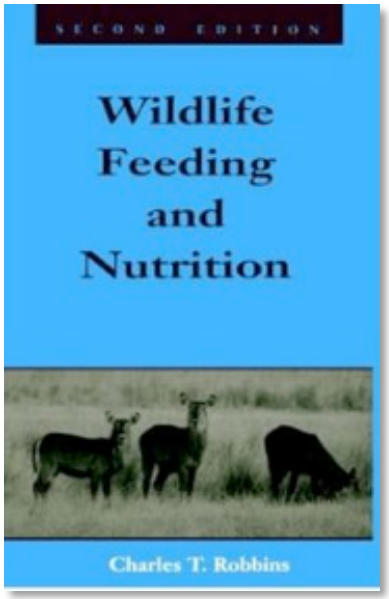

no difference in true protein/fat digestion between foregut-fermenting peccaries and hindgut-fermenting pigs

Zoo Biology 27:305–319 (2008)

RESEARCH ARTICLE

Comparative Digestion Studies in Wild Suids at Rotterdam Zoo

Marcus Clauss,[1*] Jojke Nijboer,[2] Jochem H. M. Loermans,[2] Thomas Roth,[3] Jan Van der Kuilen,[2] and Anton C. Beynen[2]

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[2]Royal Rotterdam Zoological and Botanical Gardens, Rotterdam, The Netherlands
[3]Department of Nutrition, Faculty of Veterinary Medicine, Utrecht University, Utrecht, The Netherlands

Among the artiodactyls, the suids are a group whose digestive physiology has hardly been investigated. The apparent digestibilities (aD) of macronutrients were measured in captive specimens of warthog (*Phacochoerus africanus*), red river hog (*Potamochoerus porcus*), and Visayan warty pigs (*Sus cebifrons*), and compared with those reported for babirusa (*Babyrousa babyrussa*) from the same facility on a similar diet. The animals were fed mixed diets of pelleted feed, grains, fruits, and vegetables, dietary neutral detergent fiber (NDF) ranged from 17 to 26% dry matter. aD of organic matter and protein ranged from 73 to 89 and 70 to 82%, respectively. Although red river hogs and warty pigs achieved aD of NDF of 42–54%, this value was higher both in warthogs (62–66%) and babirusa (61–67%). aD of acid detergent fiber was comparatively low in red river hogs (4%), warty pigs (25%), and babirusa (13–15%) but high in warthog (59–62%). Comparison with additional literature data (including peccaries) indicates that in spite of differences in digestive anatomy, suids and peccaries are similar, and resemble other herbivores in fundamental characteristics, such as the negative influence of fiber on overall digestibility, or the positive influence of dietary protein on protein digestion. Although the existing data are equivocal as to a superior fiber digestion in peccaries as compared with other wild suids, the results suggest that warthogs are more efficient than other wild suids or peccaries in terms of fiber digestion. *Zoo Biol* 27:305–319, 2008. © 2008 Wiley-Liss, Inc.

Keywords: warthog; red river hog; warty pig; babirusa; wild boar; peccary; digestion; nutrition; feeding

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Received 3 October 2007; Revised 4 May 2008; Accepted 30 May 2008

DOI 10.1002/zoo.20191
Published online 19 June 2008 in Wiley InterScience (www.interscience.wiley.com).

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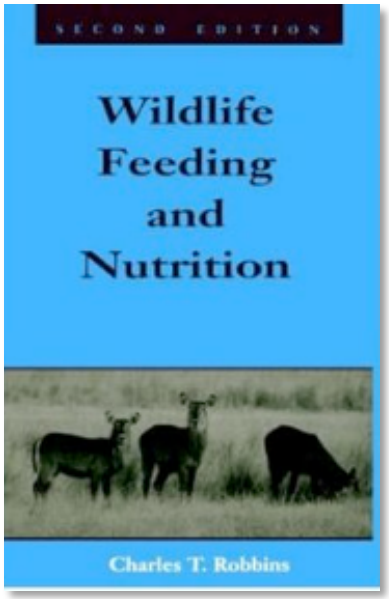
What does the literature say?

no difference in true protein digestibility between trophic guilds



no difference in true protein/fat digestion between foregut-fermenting peccaries and hindgut-fermenting pigs

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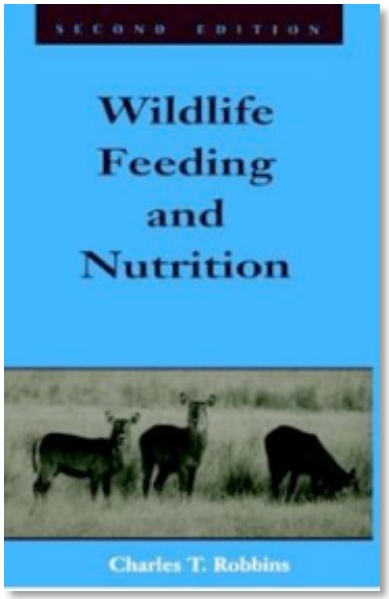

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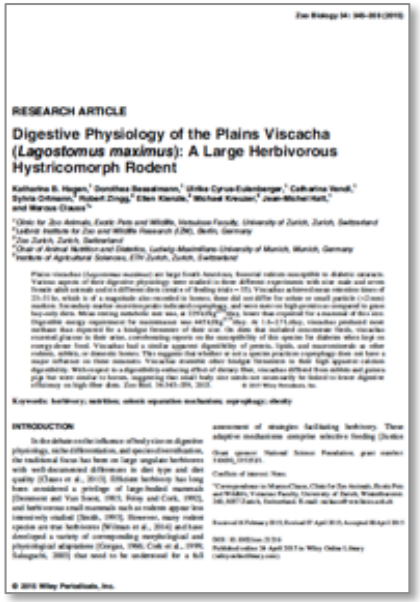

no difference in true protein/fat digestibility between coprophagic rodents/rabbits and horses

Interpretation Protein & Fat

Similar endogenous/metabolic losses of N occur across the trophic guilds, which are

- excreted as N-substances in carnivores and not 'so much' as microbial matter

- bound matter into microbial matter that includes also lipids in herbivores – hence their higher endogenous lipid losses.

Final Conclusion

Metabolic losses, as measured by CP and EE, do not differ between herbivore digestive strategies.

Digestive anatomy and physiology do not represent constraints with respect to CP and EE digestion, which could evolve to similar efficiencies across mammals.

Adaptations to special circumstances regarding protein or fat are more likely for metabolism/ requirements, not for digestion.

Interpretation of apparent digestibility data for CP and EE always in relation to their dietary content.

thank you
for your attention

… but:

How do birds & reptiles & fish fit in?