Merycism and Rumination – a comparative view of an evolutionary adaptation and a behavioural disorder

Marcus Clauss

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5. Zürcher Dyphagietagung, 24.-25.01.2014

University of Zurich[UZH]

Clinic of Zoo Animals, Exotic Pets and Wildlife

JOH. CONRADI PEYERI

Med. Doct. & Acad. Nat. Cur. Collegæ

cognomento Pythagoræ

MERYCO-LOGIA

SIVE DE

RUMINANTIBUS *ET* RUMINATIONE COMMENTARIUS.

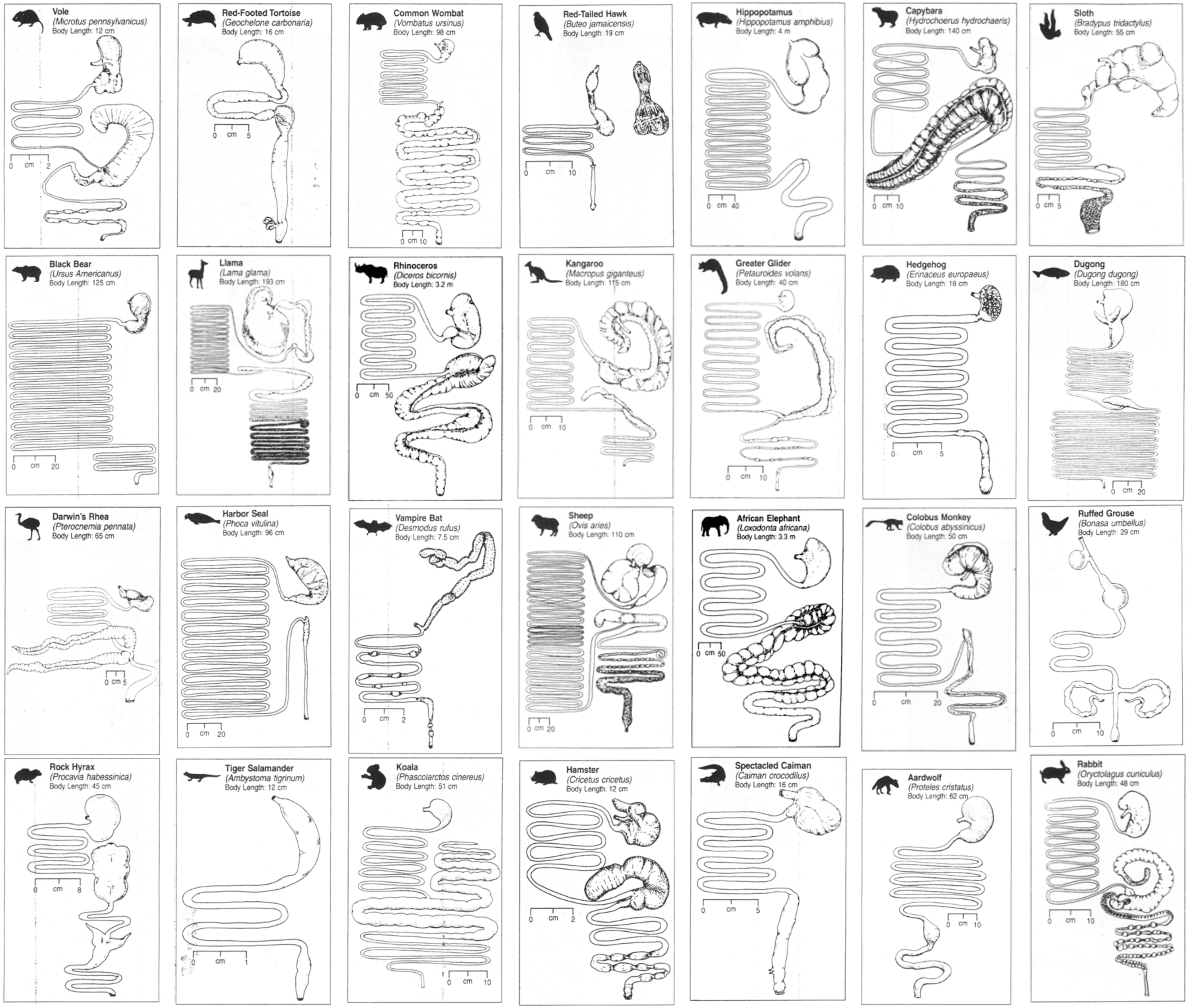
Quo primùm exponuntur

RUMINANTIUM SPECIES ET DIFFErentiæ, per omnia animalium genera; deinde organorum ruminationi inservientium admiranda structura detegitur, & iconibus æri incisis ante oculos ponitur: denique de ruminatione ipsa ejusque causis ac utilitate disseritur.

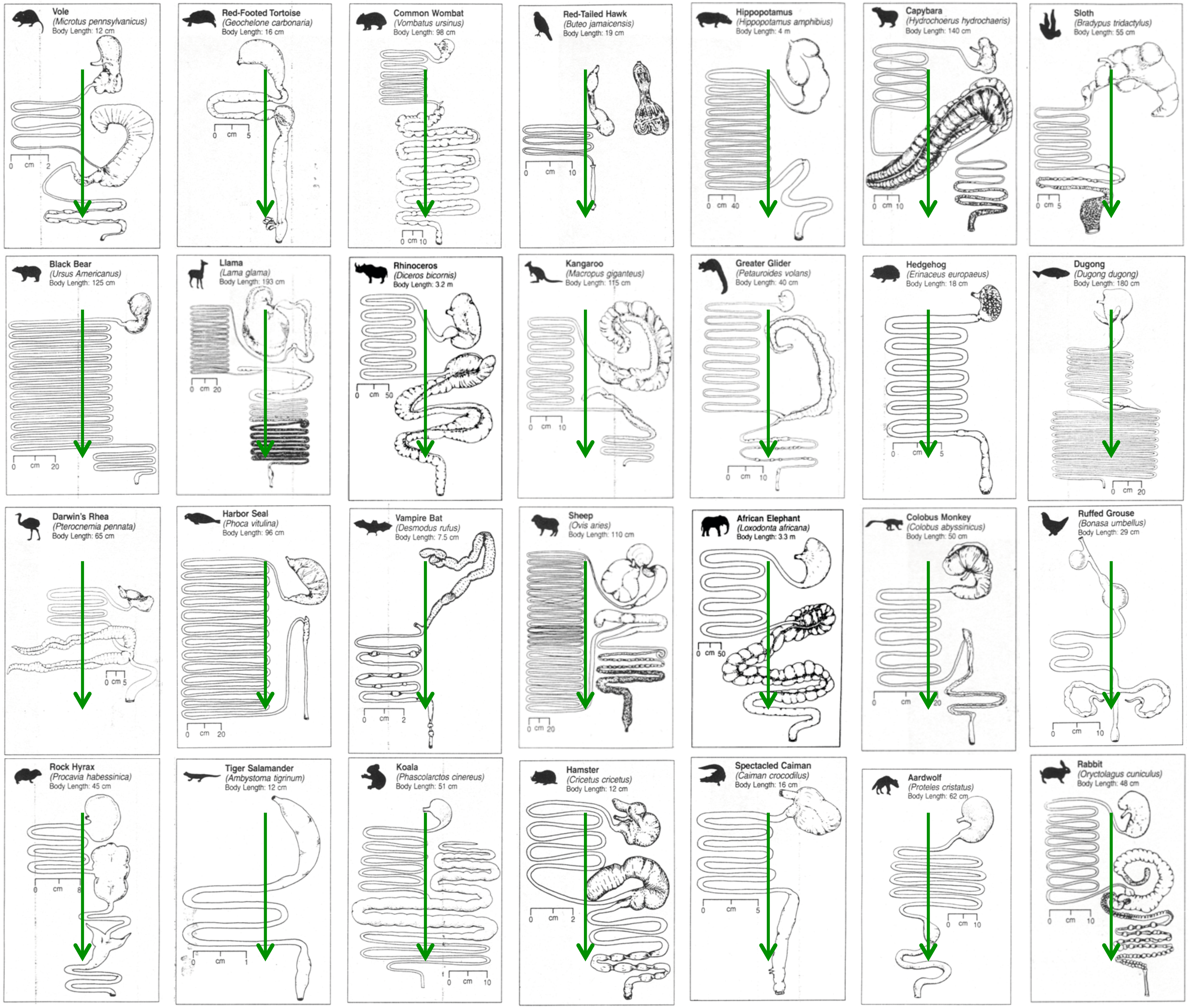
BASILEÆ

Apud JOH. LUDOVICUM KOENIG & JOH. BRANDMYLLERUM.

M DC LXXXV.



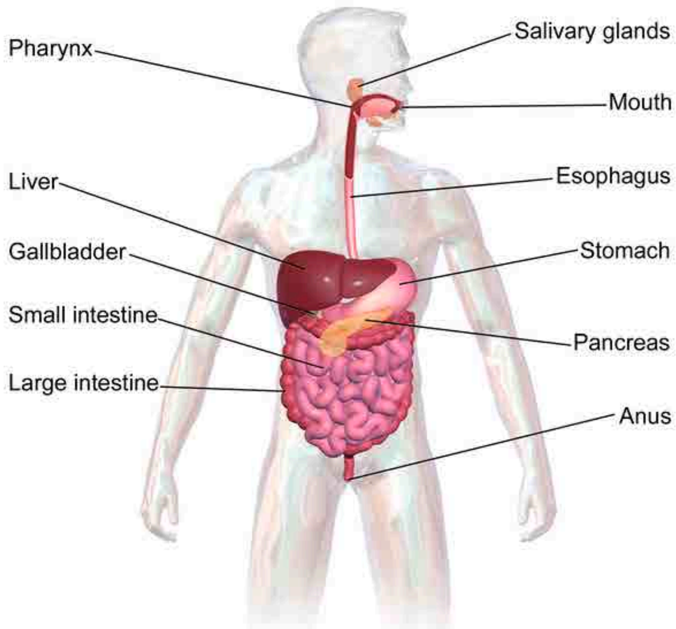
from Stevens und Hume (1995)

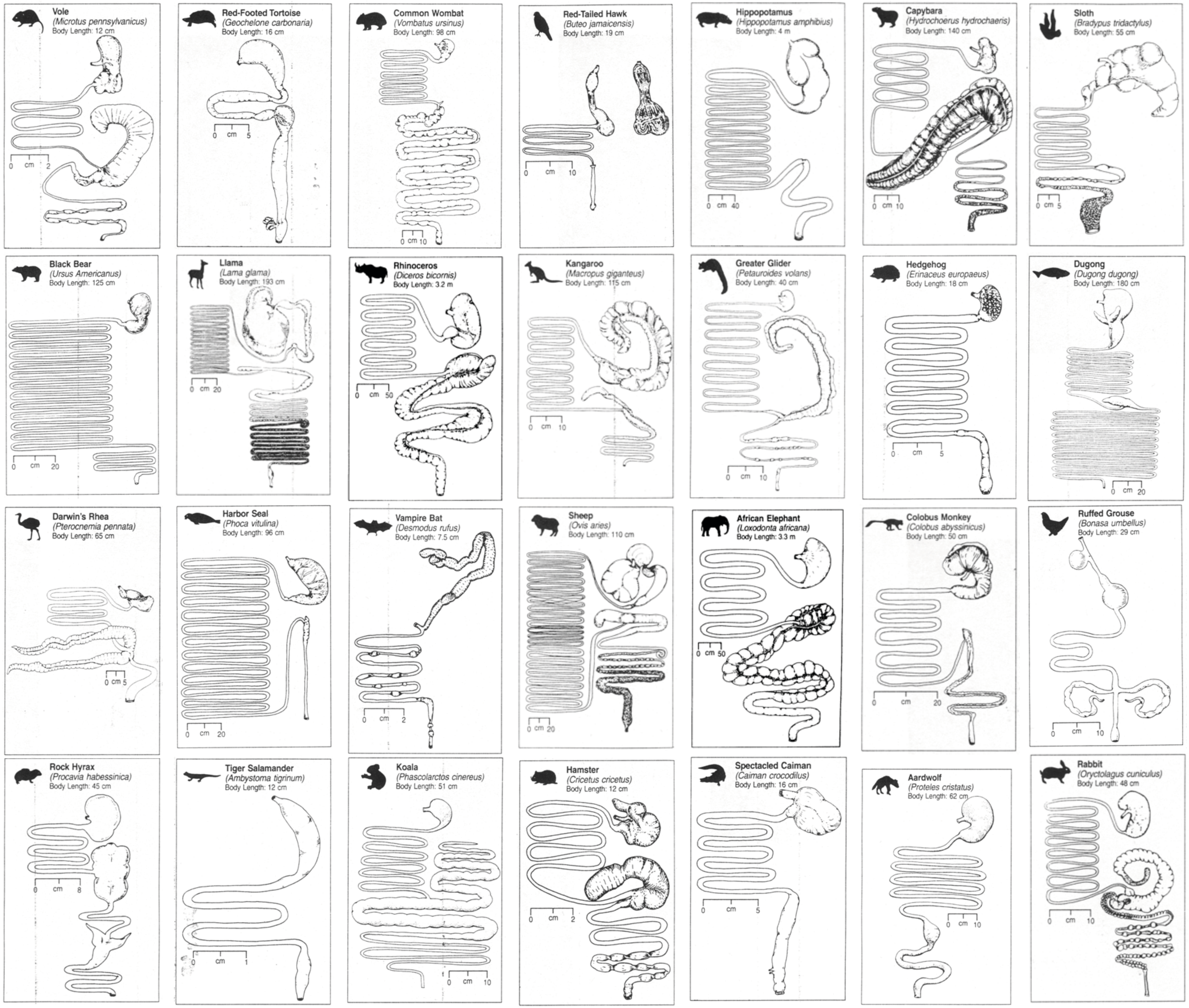


from Stevens und Hume (1995)

Definitions

- Digestion
  - mechanical and chemical breakdown of food into smaller components that can be absorbed
  - takes place during the retention in, and passage through, the digestive tract





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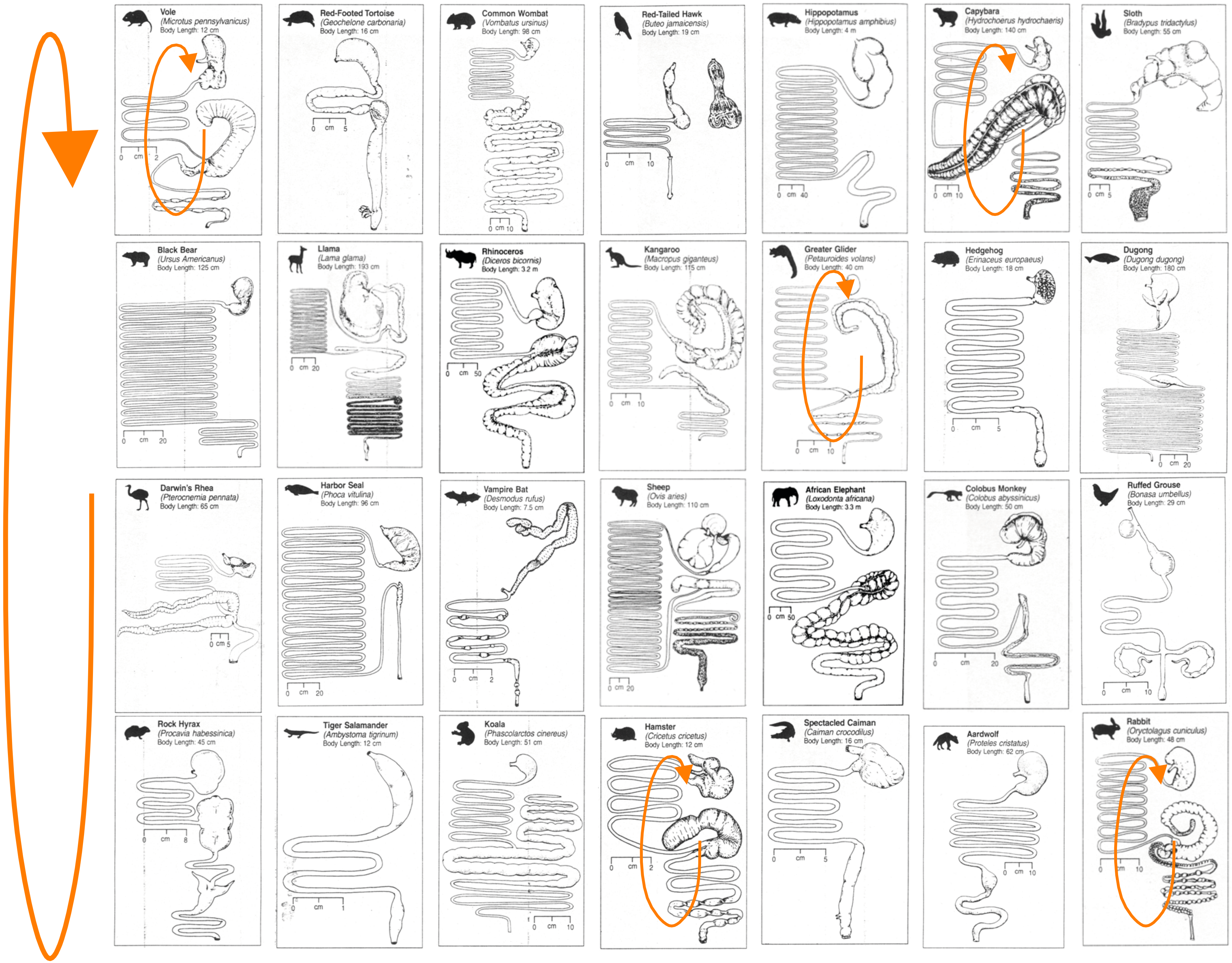


from Stevens und Hume (1995)

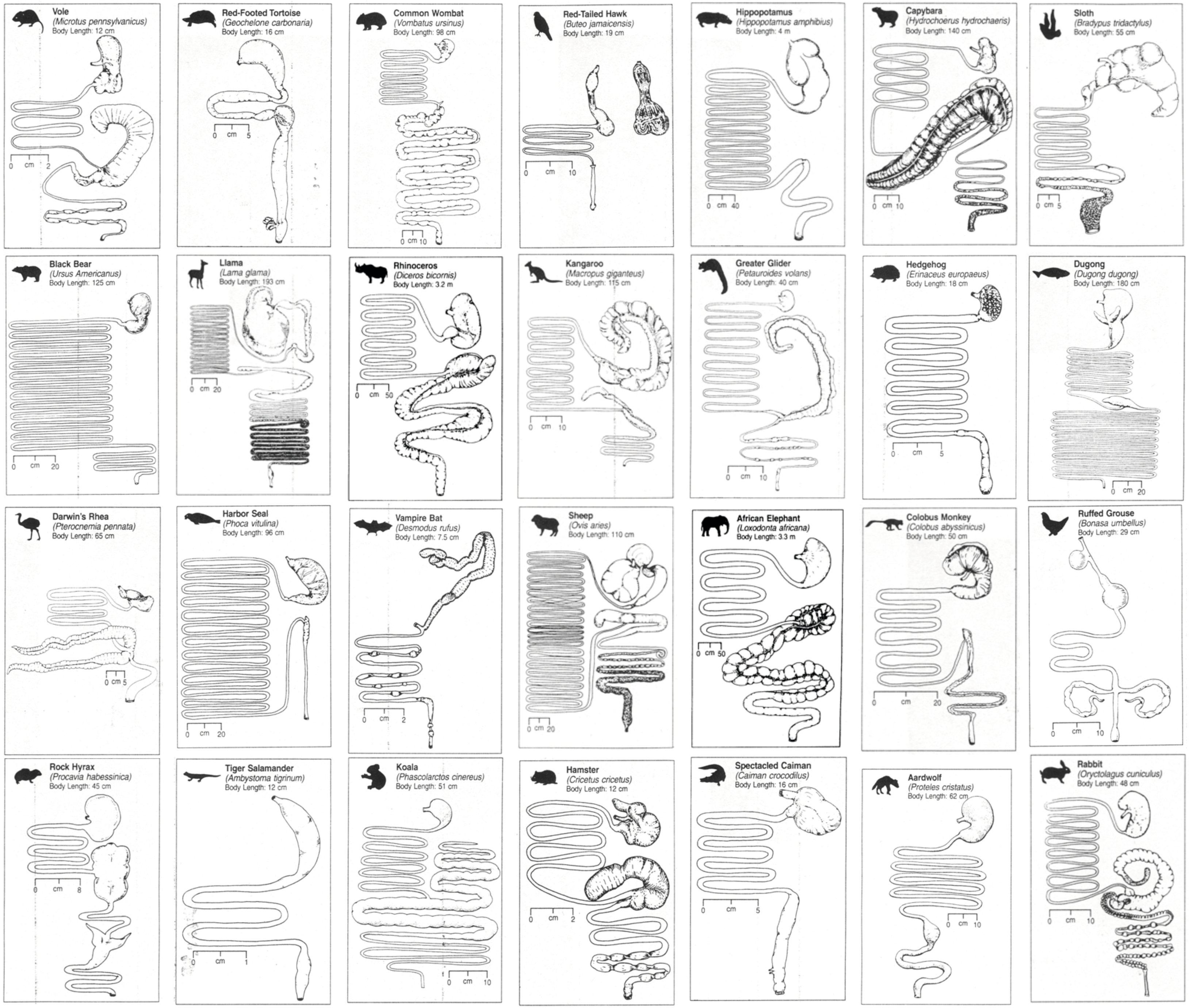
Definitions

- Coprophagy

  - ingestion of regular faeces
    => normal feeding behaviour ('detritivores')
    => behavioural mechanism to ensure inoculation of GIT with symbiotic microbes (rare)
    => abnormal behaviour

  - ingestion of special faeces ('caecotrophs')
    => separation mechanism in the hindgut
    => recycling of bacterial protein
    => near-obligatory in many rodents and lagomorphs

Photo: A. Tschudin



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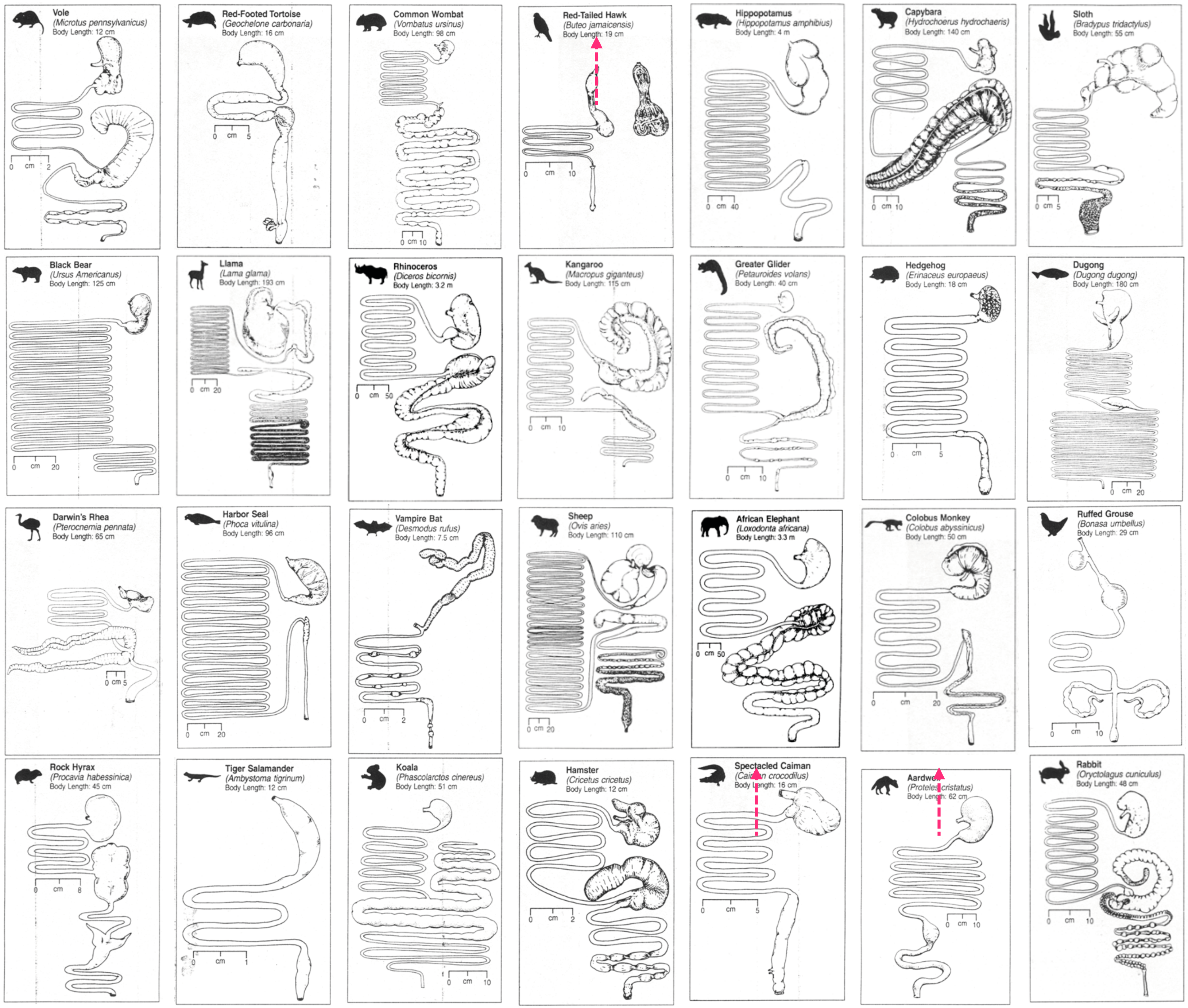

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- Vomiting
  - involuntary (forceful) expulsion of stomach contents

    => linked to aversive condition (gastritis, poisoning)

    => 'does not stop in the mouth'

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- Regurgitation
  - voluntary/intentional expulsion of material from mouth/pharynx/ esophagus/stomach

    => transport: feeding young/sharing food

      - production of special products in GIT (crops milk in pigeons, bee honey)

    => elimination: indigestible products (pellets/‘casting‘ in carnivorous/piscivorous birds; stomach eversion in sharks)

Crocodile regurgitating

Shark stomach eversion

Eagle pellet

Shrike pellet

Owl pellet

Owl pellet

Owl pellet

http://en.wikipedia.org/wiki/File:Pelotes_r%C3%A9jection_Asio_Otus.jpg

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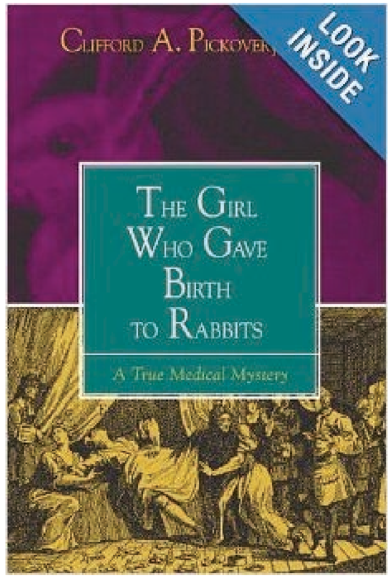
    => 'regurgitating artists'

Regurgitators

- 1621 ‘nail-vomiting boy of Boston’
- 1642 Catharina Geisslerin, the ‘toad-vomiting woman of Germany’
- 1694 Theodorus Döderlein (vomiting newts and frogs)
- 1834 Henriette Pfenning (vomiting frogs)

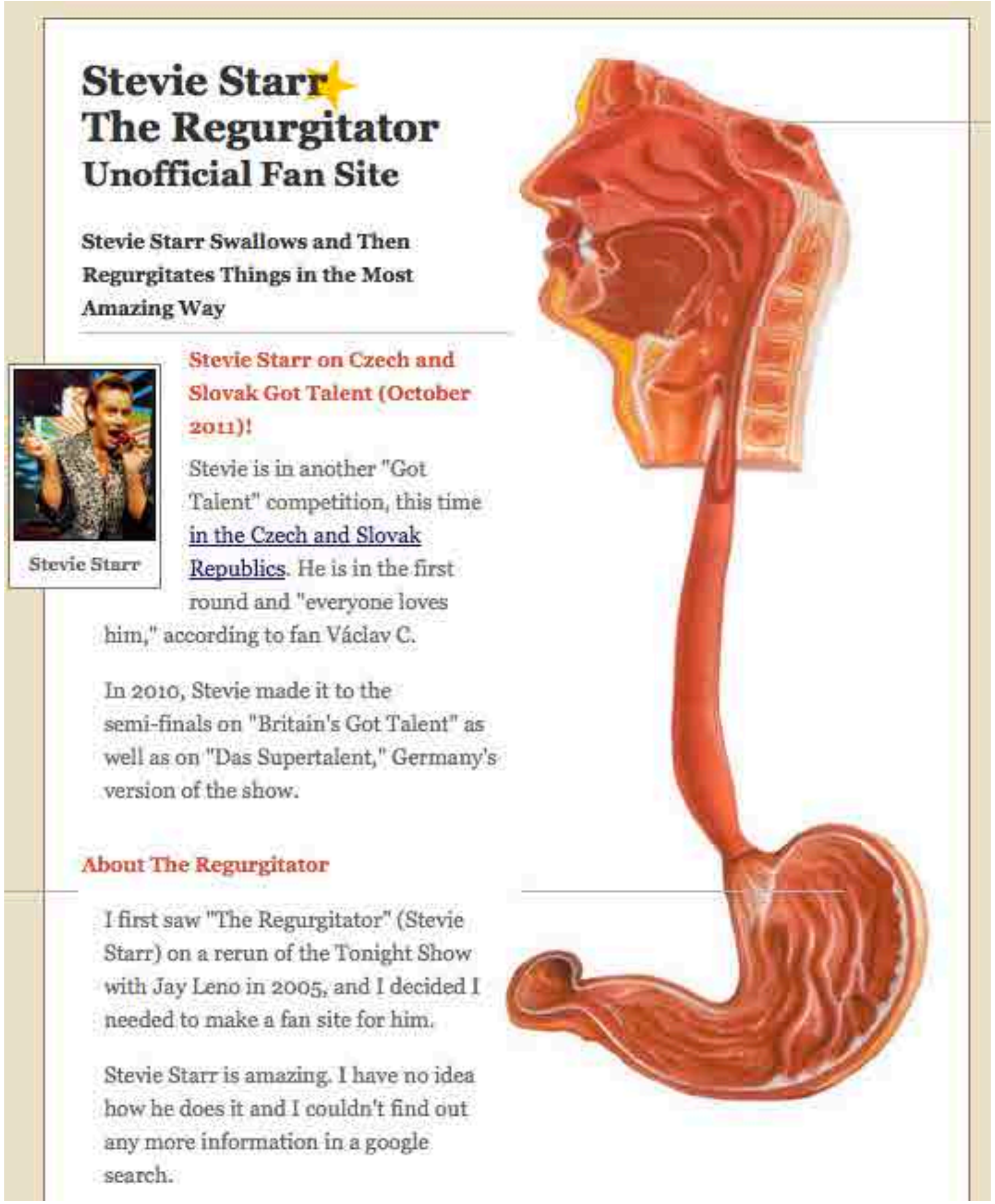
- compulsive swallowers (1927 patient with toothbrushes and disposable razor handles in his stomach)

- Stevie Starr – the ‘professional regurgitator’



http://sprott.physics.wisc.edu/pickover/vomit.html

Regurgitators



Stevie Starr The Regurgitator

Unofficial Fan Site

Stevie Starr Swallows and Then Regurgitates Things in the Most Amazing Way

Stevie Starr on Czech and Slovak Got Talent (October 2011)!

Stevie Starr

Stevie is in another "Got Talent" competition, this time in the Czech and Slovak Republics. He is in the first round and "everyone loves him," according to fan Václav C.

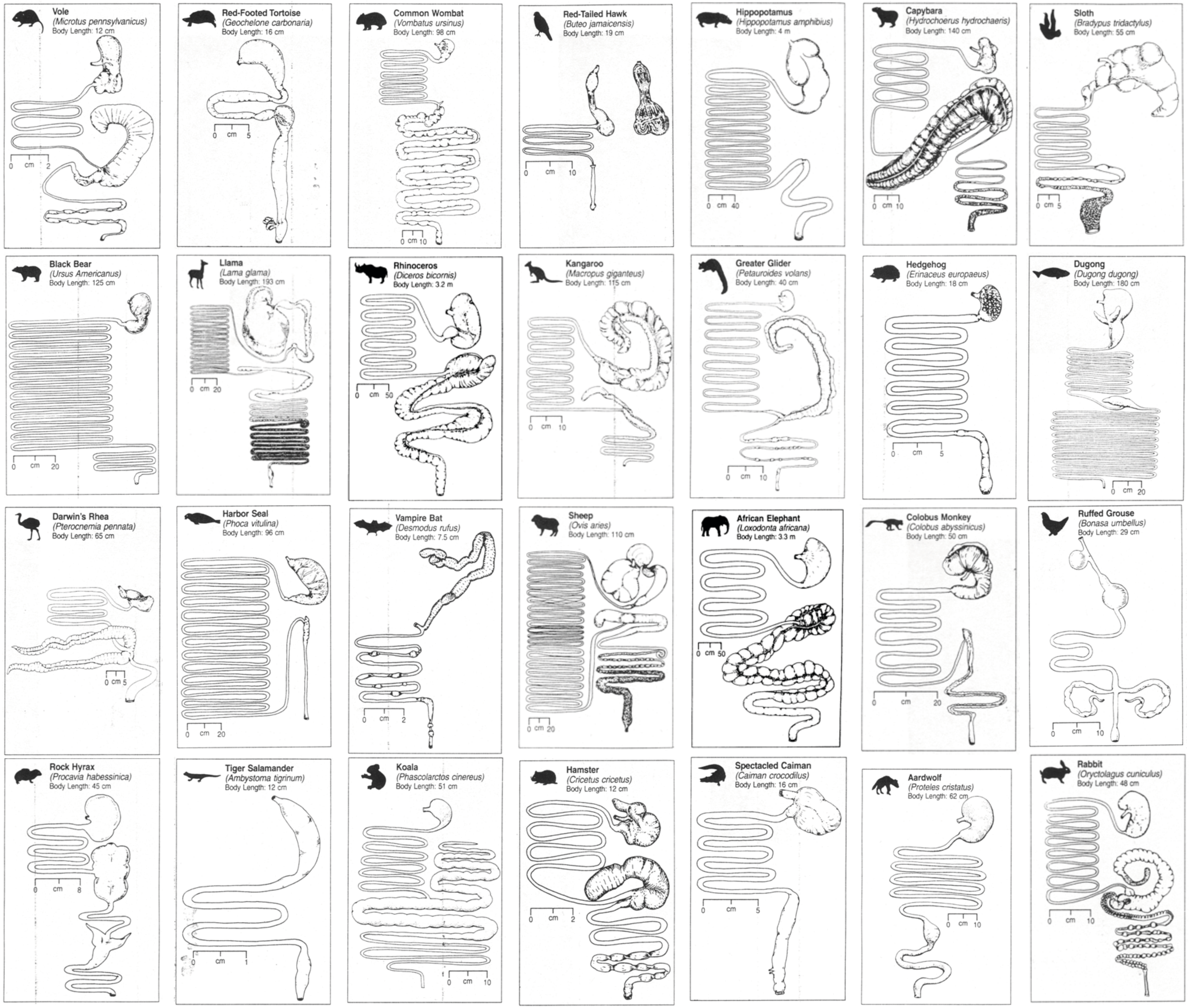
In 2010, Stevie made it to the semi-finals on "Britain's Got Talent" as well as on "Das Supertalent," Germany's version of the show.

About The Regurgitator

I first saw "The Regurgitator" (Stevie Starr) on a rerun of the Tonight Show with Jay Leno in 2005, and I decided I needed to make a fan site for him.

Stevie Starr is amazing. I have no idea how he does it and I couldn't find out any more information in a google search.

Human regurgitators



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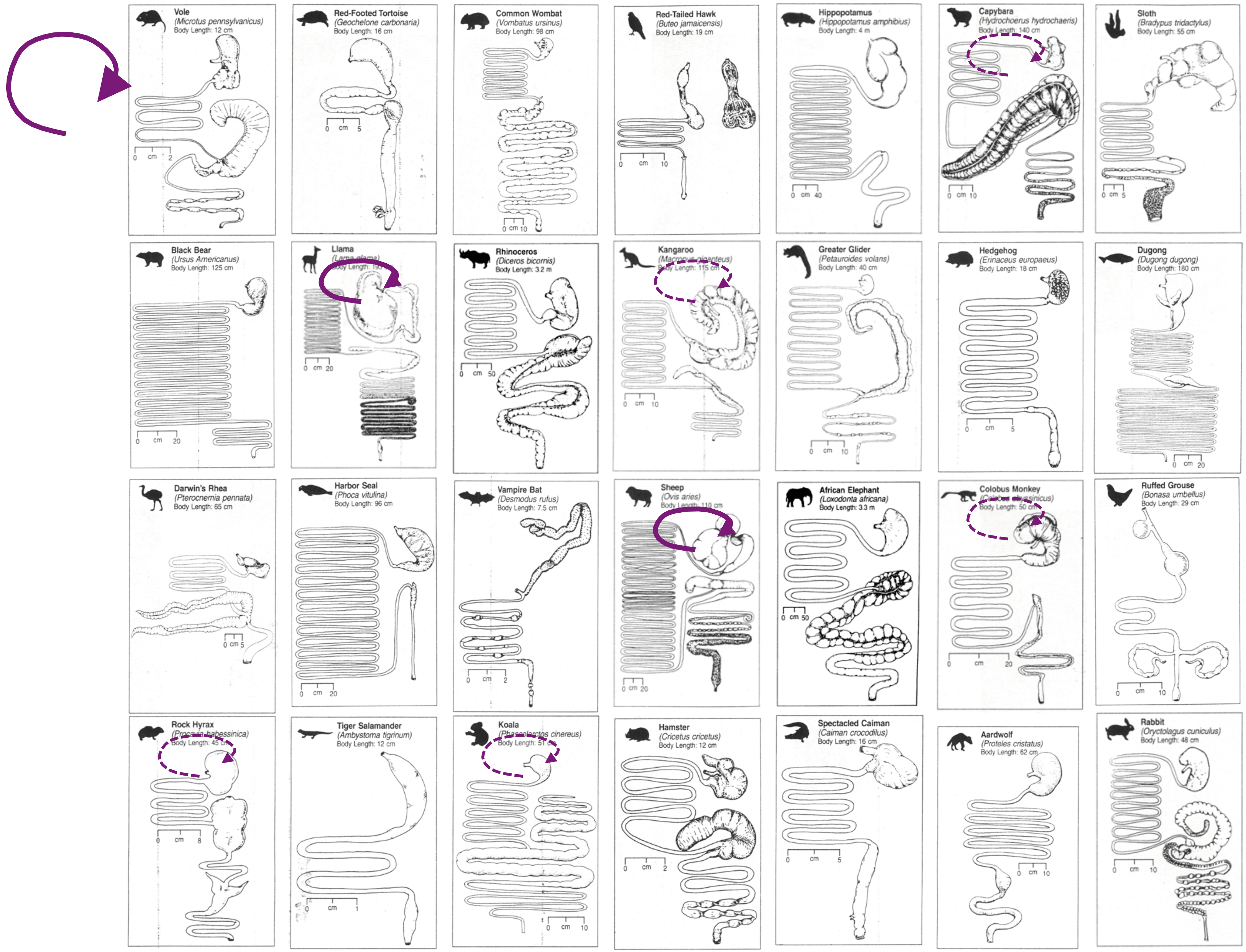

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    ‘rumination syndrome’ / ‘RR’

Gorilla R/R

Gorilla R/R

A review of nutritional and motivational factors contributing to the performance of regurgitation and reingestion in captive lowland gorillas (*Gorilla gorilla gorilla*)

Kristen E. Lukas *

Applied Animal Behaviour Science 63 (1999) 237–249

Despite findings that provision of browse and removal of fruit from the diet reduces R/R (Loeffler, 1982; Gould and Bres, 1986a; Ruempler, 1992; Wiard, 1992; Velderman, 1997), no one has yet documented the elimination of this behavior from an individual's repertoire. Ruempler (1992), however, reported that one gorilla's R/R had completely ceased for over a year after removing all but huge portions of vegetables and browse (18 kg per adult animal per day) from the diet at Cologne Zoo in Germany. For comparison, an adult male gorilla consumes approximately 6 kg/day at Zoo Atlanta (G. Hamor, personal communication), 13 kg/day at Brookfield Zoo (C. Demitros, personal communication), and 30 kg/day in the wild (*G.g. beringei*, Goodall, 1977). Unfortu-

Removing Milk from Captive Gorilla Diets: The Impact on Regurgitation and Reingestion (R/R) and Other Behaviors

Kristen E. Lukas,[1,2,3*] Gloria Hamor,[3] Mollie A. Bloomsmith,[2,3]
Charles L. Horton,[3] and Terry L. Maple[2,3]

Zoo Biology 18:515 - 528 (1999)

TABLE 6. Comparisons of gorilla behavior between conditions in Phase 2

	Baseline (32 oz milk)	Treatment 32 oz diluted (fruit juice)	Baseline (32 oz milk)	Hypothesis test: baselines vs. treatment	Probability ($\alpha = 0.05$)
Scan data (percentage of time)					
R/R	5.9%	3.7%	6.3%	F = 8.508	*P* = 0.010
Eat hay	1.3%	1.6%	0.3%	F = 0.767	ns
Inactive	45.5%	46.6%	46.3%	F = 0.115	ns
Drink water	3.4%	3.3%	2.9%	F = 0.011	ns
Social (affiliative)	8.4%	8.0%	11.7%	F = 1.221	ns
Other undesirable	1.0%	1.2%	2.0%	F = 0.594	ns
Self-directed behavior	17.1%	17.5%	13.9%	F = 1.681	ns
Social (agonistic)	0.1%	0.3%	0.4%	F = 0.136	ns
Other active behavior	16.0%	16.7%	15.0%	F = 0.605	ns
All-occurrence data (no. per 5 - min)					
R/R attempts	0.022	0.017	0.011	F = 0.000	ns
R/R bouts	0.428	0.256	0.422	F = 4.684	*P* = 0.045
Feed on another's regurgitant	0.061	0.061	0.072	F = 0.239	ns
Examine another engaging in R/R	0.056	0.056	0.072	F = 0.221	ns
Agonistic behavior	0.089	0.111	0.233	F = 1.342	ns

Chimpanzee R/R

Chimpanzee R/R

An analysis of regurgitation and reingestion in captive chimpanzees

Kate C. Baker [a,*], Stephen Phillip Easley [b]

Applied Animal Behaviour Science 49 (1996) 403–415

of cagemates or housing history; nor were sex differences detected. Meal composition was not found to effect the time devoted to R/R. Statistical tests did show a strong positive relationship between rates of R/R and elapsed time since feeding. These results suggest that increasing meal frequency or providing consistently available edible material may prove more broadly effective than altering meal composition. Temporal distributions of R/R differed from those of abnormal

old male) (Morgan et al., 1993). That study found that R/R occurred within minutes of each meal, and was most frequent following meals consisting of fruit. Reductions in R/R occurred during behavioral training sessions and when more browse was provided.

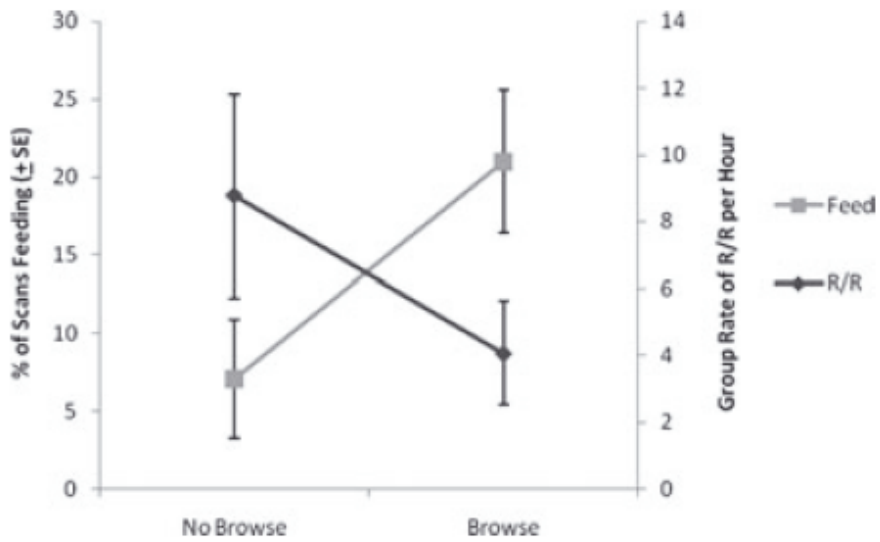
Orangutan R/R

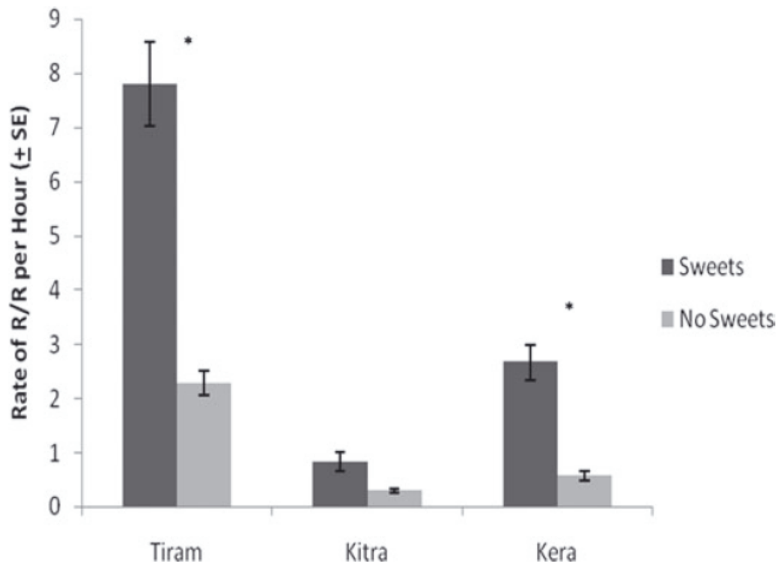
Orangutan R/R

Prevalence of Regurgitation and Reingestion in Orangutans Housed in North American Zoos and an Examination of Factors Influencing its Occurrence in a Single Group of Bornean Orangutans

Zoo Biology 31: 609–620 (2012)

Christine M. Cassella,[1,2*] Alyssa Mills,[1] and Kristen E. Lukas[1,2]





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DEVELOPMENTAL AND BEHAVIORAL PEDIATRICS

Vol. 7, No. 5, October 1986
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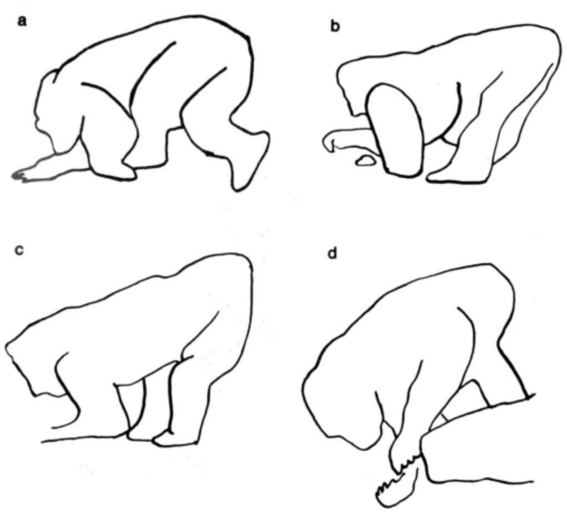
Special Articles

Regurgitation in Gorillas: Possible Model for Human Eating Disorders (Rumination/Bulimia)

EDWIN GOULD, PH.D.
Department of Mammalogy, National Zoological Park, Smithsonian Institution, Washington, D.C.
MIMI BRES, M.S.
Department of Biological Sciences, The George Washington University, Washington, D.C.



Rumination disorder in man

MAY 4, 1907.] MEMORANDA. [THE BRITISH MEDICAL JOURNAL 1053

MERYCISM OR RUMINATION IN MAN.

BY J. GRANT MILLAR, M.B., CH.B.GLASG.,

BRITISH MEDICAL JOURNAL VOLUME 287 23 JULY 1983

Habitual rumination: a benign disorder

D F LEVINE, D L WINGATE, J M PFEFFER, P BUTCHER

British Journal of Psychiatry (1994), **165**, 303–314

Review Article

Merycism or Rumination Disorder
A Historical Investigation and Current Assessment

BRENDA PARRY-JONES

Rumination disorder in man

- historically: linking to bovine ancestry (incl. autopsies to check for chambered forestomach)

  => 'the mark of the beast' (primitive impulse)

- 6-10 % of institutionalized persons with severe mental retardation
- complications: malnutrition, weight loss, aspiration/choking

  => aspiration cause of death 5-10% of ruminators

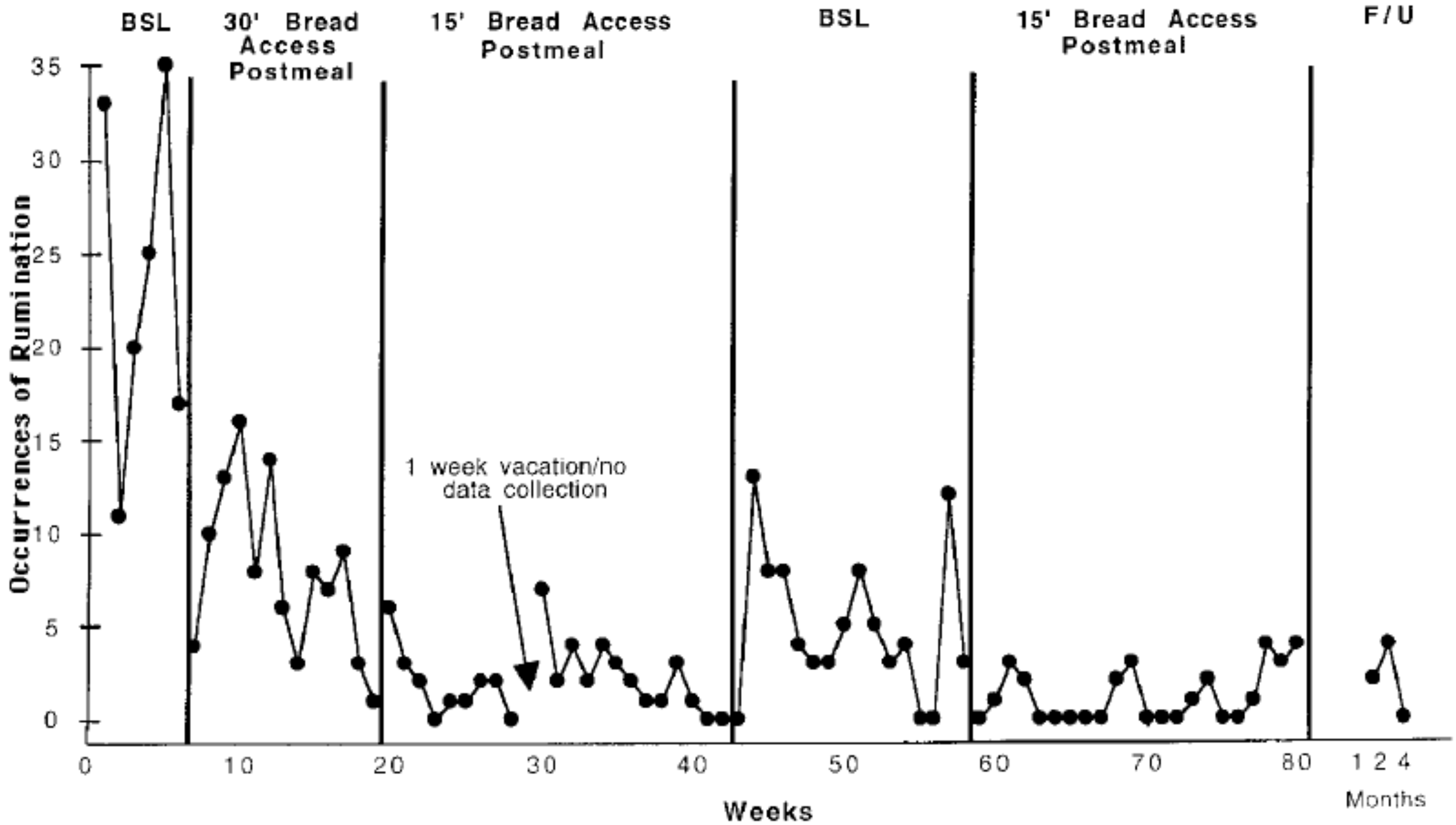
- social isolation

- treatment option: ad libitum feeding/satiety

BRIEF REPORT: EFFECTS OF SUPPLEMENTAL FEEDINGS OF WHITE BREAD ON CHRONIC RUMINATION

Behavioral Interventions
Behav. Intervent., 13, 227–233 (1998)

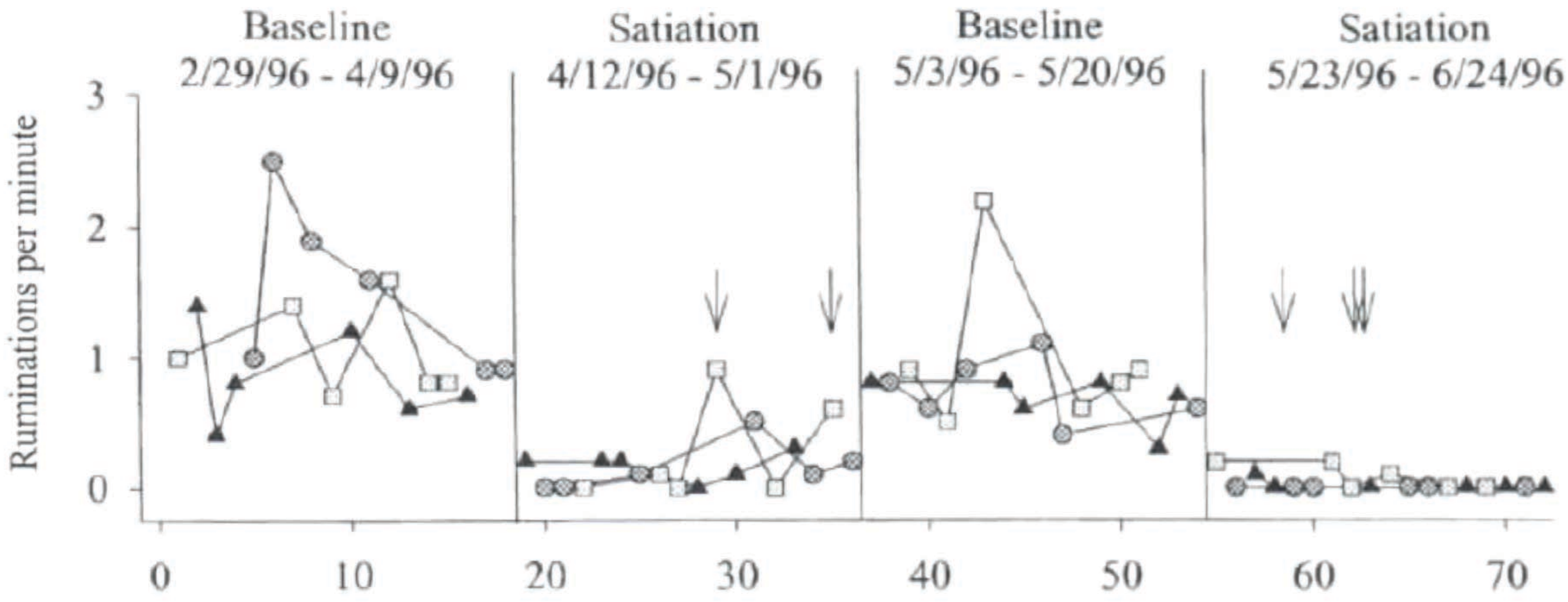
Christopher J. Masalsky* and James K. Luiselli



Behavioral Interventions
Behav. Intervent. **17**: 21–29 (2002)

DECREASING RUMINATION USING A STARCHY FOOD SATIATION PROCEDURE

Laura L. Dudley[1,2]*, Cammarie Johnson[1,2]* and R. Scott Barnes[1]



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Regurgitation in Gorillas: Possible Model for Human Eating Disorders (Rumination/Bulimia)

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Department of Mammalogy, National Zoological Park, Smithsonian Institution, Washington, D.C.
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TABLE 1. Comparison of Regurgitation and Reingestion with Two Human Disorders

	Bulimia	Rumination	r/r Gorilla
Ontogeny			
Failure to engage mother to interact	O	X_i [36,43]	X
Age at onset	11–22 yr[46]	3–6 mo[42,43]	> 5 yr
Parental separation	X[46]	O	X
Lacks control of eating	X[46,50]	O	X
Motor pattern			
Neck swelling	—	X[3]	X
Chews	O	X[3,7]	X
Mouth fills	O	X[7]	X
Reingest	O	X[7,47–49]	X
Valsalva maneuver	X_i	X[2]	X_i
Mueller maneuver	X_i	X[5]	X_i
Rhythmic chest, neck movement	O	X[36]	X
Induced with finger	X[46,41]	X[36]	X
No effort required	X[46]	O	X
Bends deeply prior to vomit ejection	X_i	O[47,48]	X
Timing			
Interval between eating and regurgitation	> 1 min[46]	0–30 min[47,48,49]	0–8.3 hr
Interval between regurgitations	O	2–4 min[3]	1.5–3 min
Duration of bouts	—	30–60 min[3]	2 min–6 hr
Frequency/day	1[46]	15–20/30–60[43]	1–175
Context			
Do it alone	X	O	X
Favorite foods	O	X	X
Enjoy the taste	O	X[2,49]	X
Treatment			
Reduced if more food	O[46]	X (one study)[35]	X (browse)
Increased mother contact	—	X[36]	X_i

Definitions: X_i, inferred; X, observed; —, unknown; O, doesn't occur.

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  - “to turn over in the mind”
  - “to chew the cud”

    => implies regurgitation, chewing, re-swallowing

    => maladaptive in humans as well as certain zoo animals

    ‘rumination syndrome’ / ‘RR’

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    => ‘bubbling’ in certain flies

Fly bubbling

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    => 'bubbling' in certain flies

    => obligatory mechanism in functional ruminants
    => probably facultative mechanism in several herbivores

Rumination in ruminants

Rumination in ruminants

Rumination in camelids

Why rumination?

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- Anti-predation strategy
  - *"Rumination seems to allow herbivores to ingest in haste and masticate at leisure"* (Karasov & Del Rio 2007)

    => Ruminants should ingest similar amounts of food as other herbivores and just 'chew later' - or become time-constrained in intake

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- Energy-saving mechanism
  - Rumination occurs in a state of 'drowsiness' similar to rest; may represent an energy-saving strategy - less time spent 'wide awake' (Gordon 1968)

    => Ruminants should have lower energy requirements/higher productivity than other herbivores

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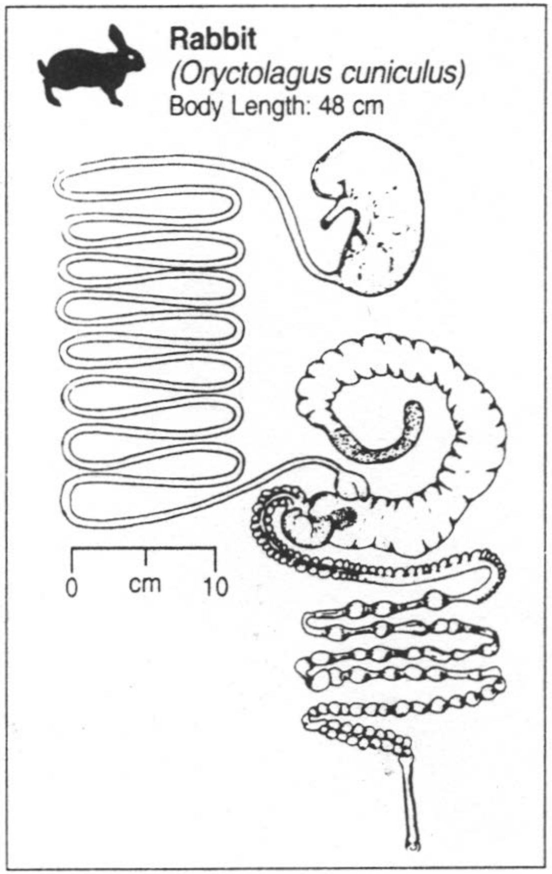
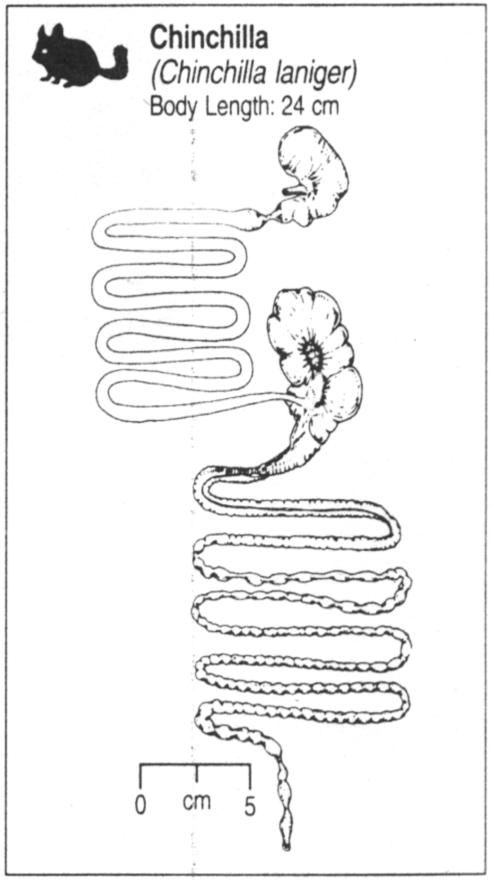
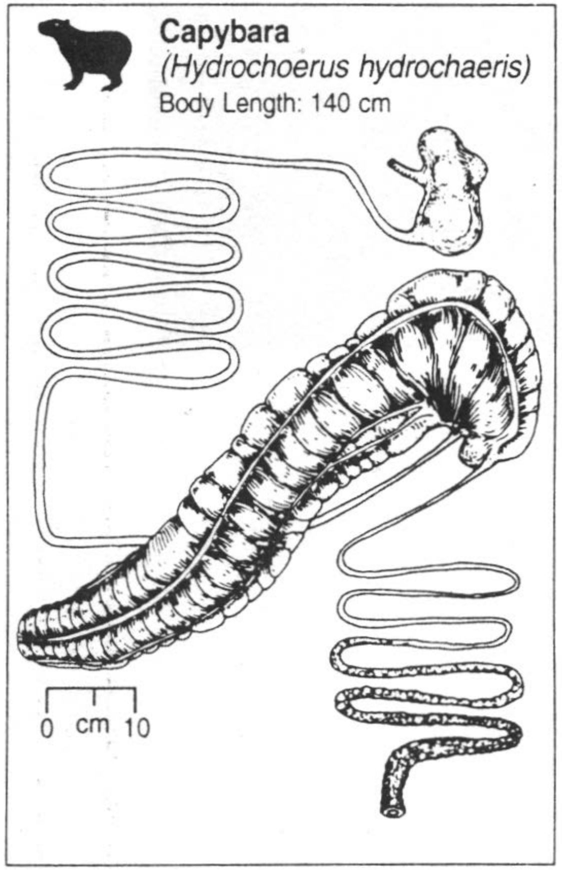
- Enhancement of digestive efficiency
  - Rumination reduces particle size and hence allows faster digestion at constant intake

    => Ruminants should have smaller digesta particle sizes (and higher intakes) than other herbivores

Hindgut Fermentation - Caecum







from Stevens und Hume (1995)

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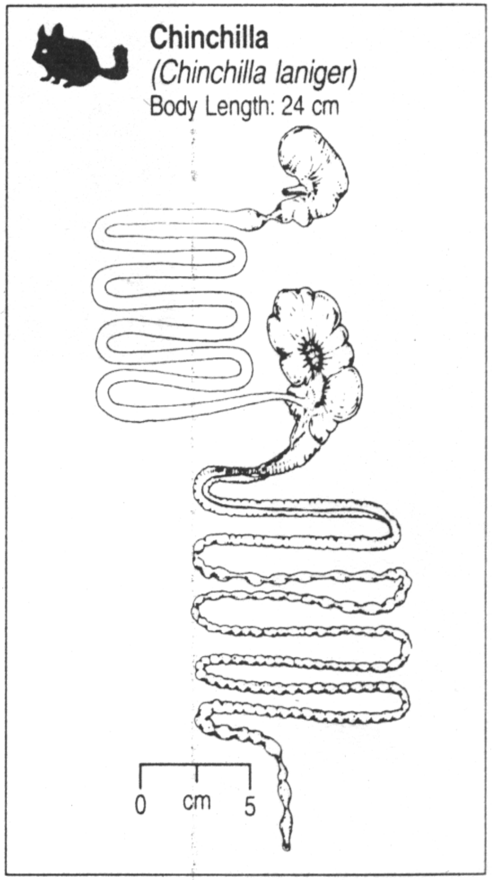
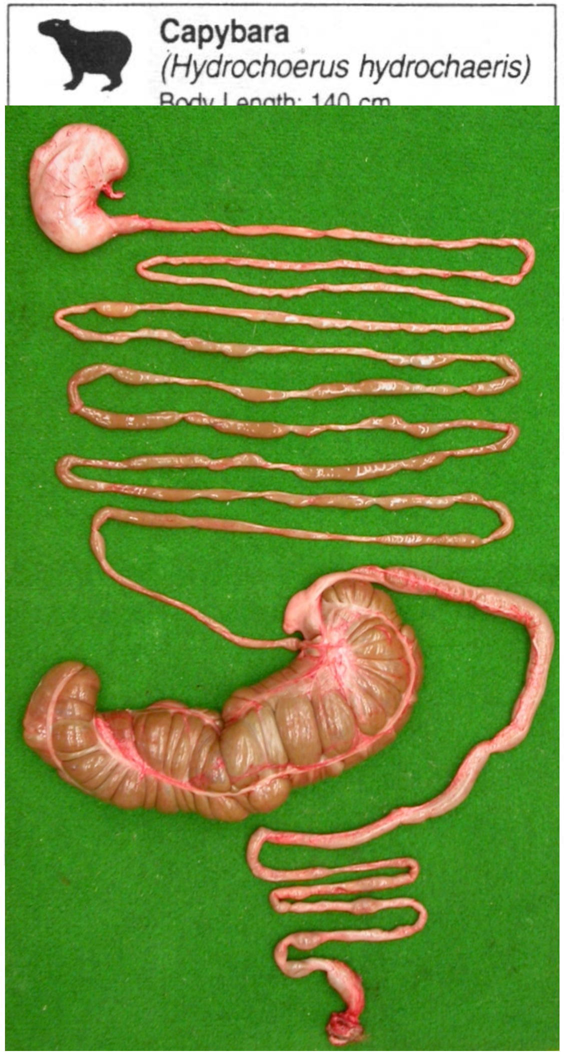
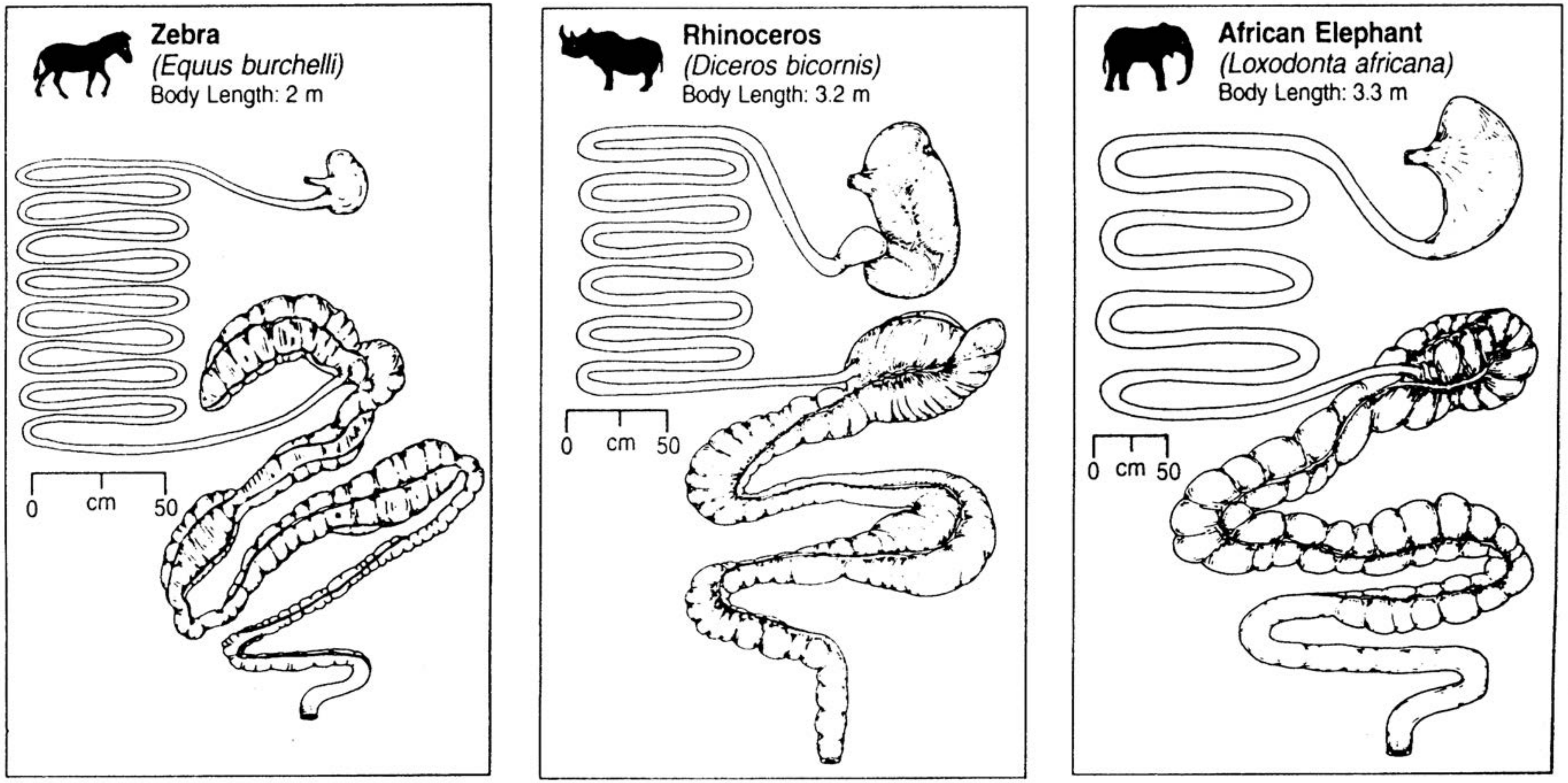




from Stevens und Hume (1995), Fotos J. Fritz/M. Clauss

Hindgut Fermentation - Colon



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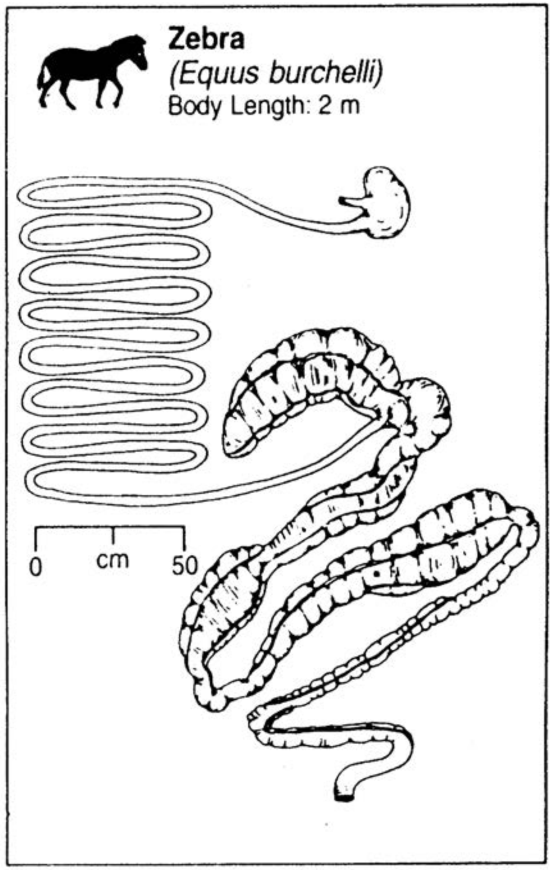

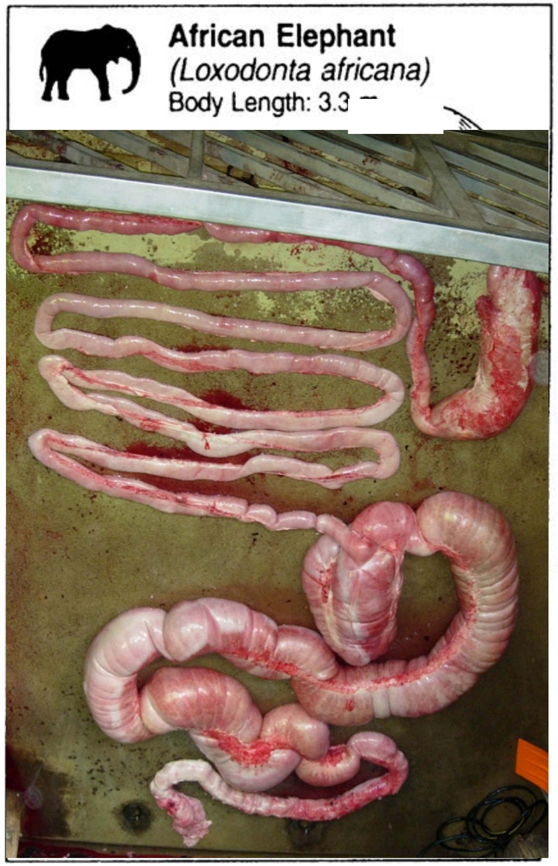

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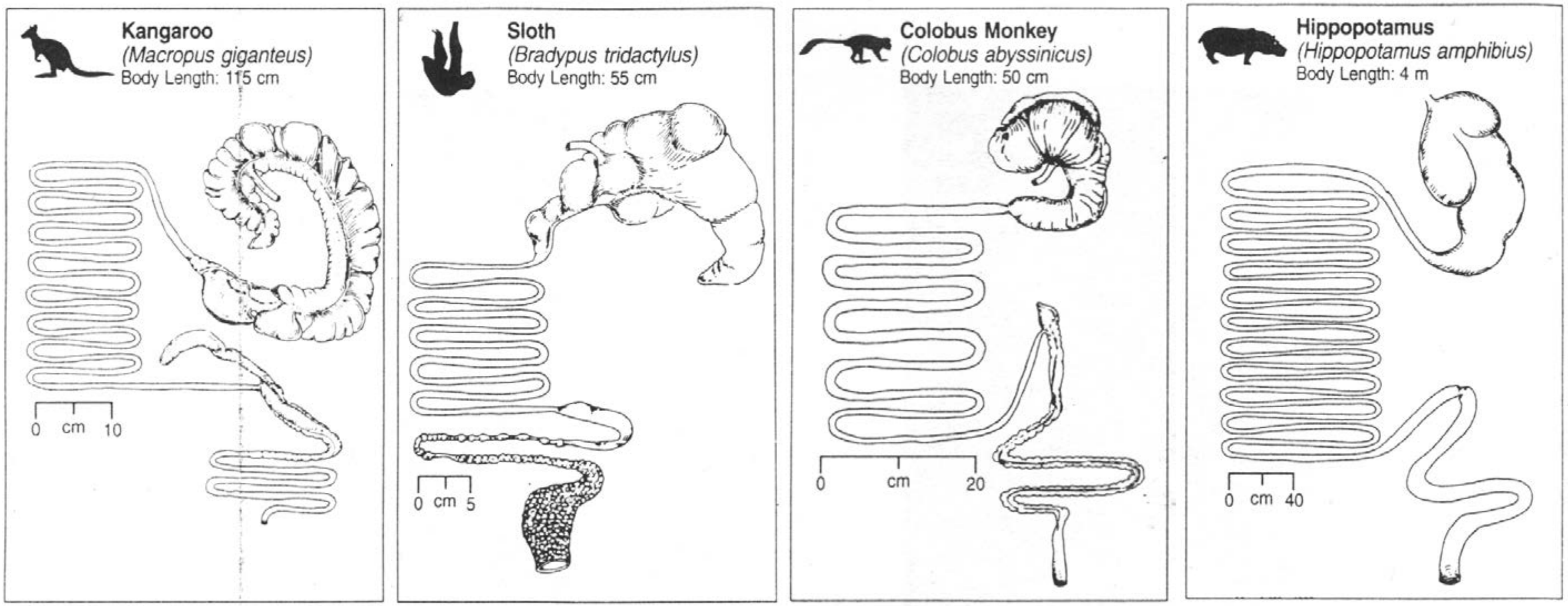
Foregut Fermentation



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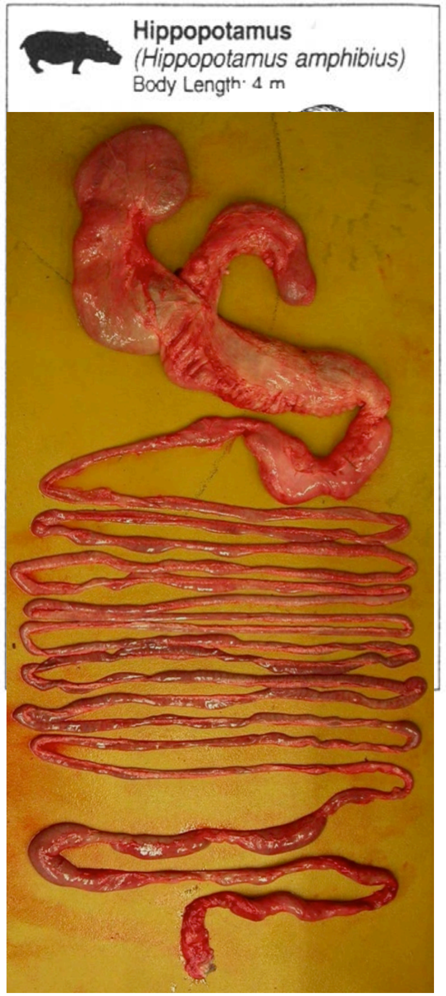
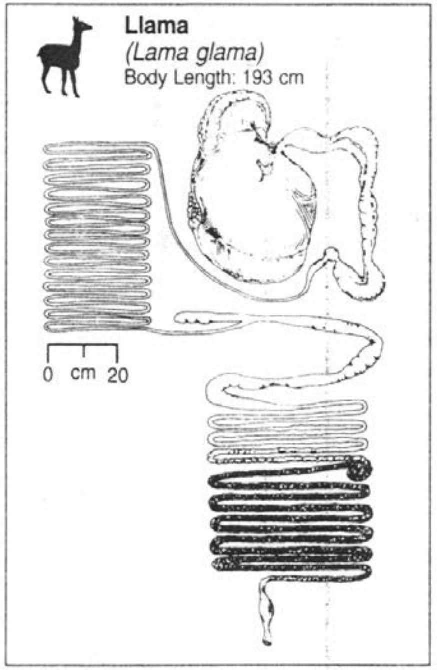
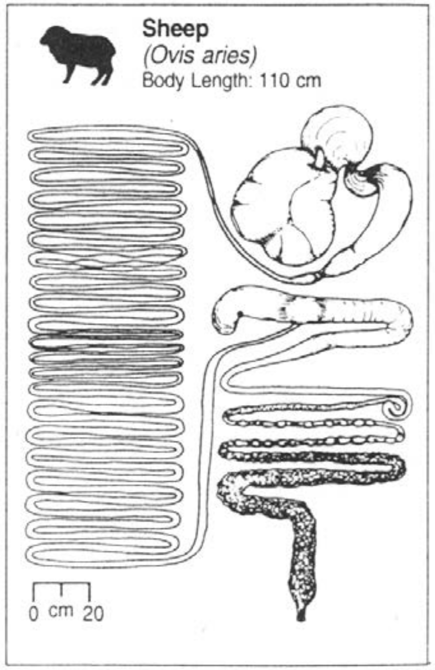


Photos A. Schwarm/
M. Clauss

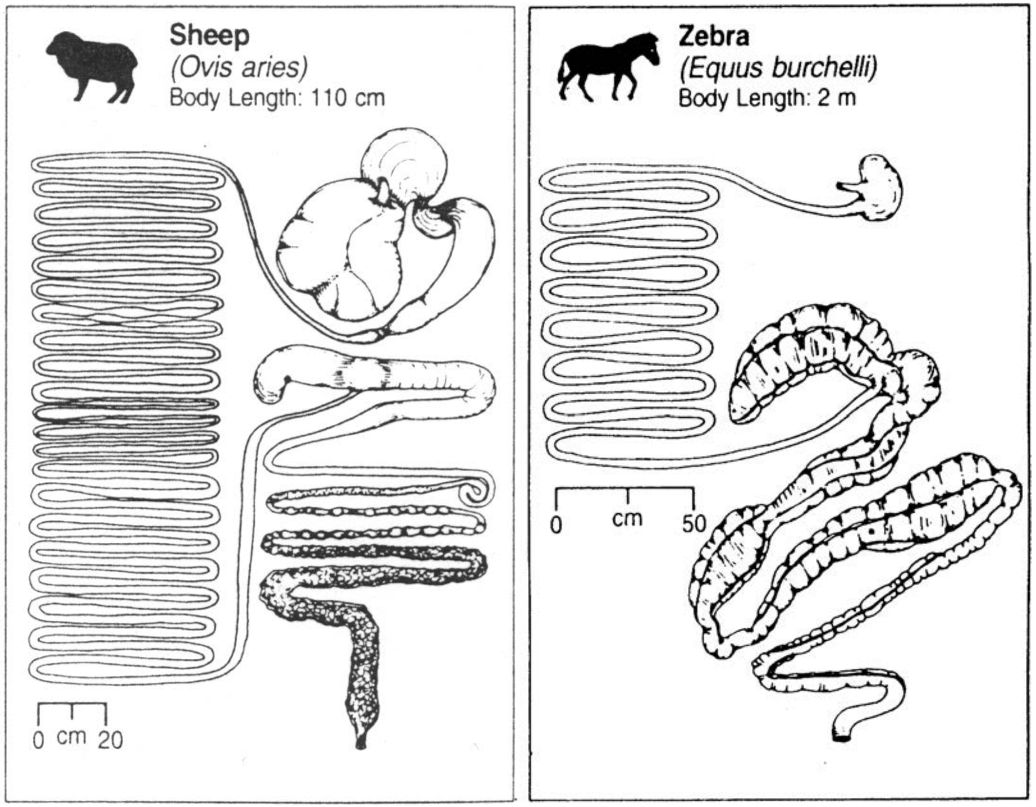
Foregut Fermentation - Ruminant





aus Stevens & Hume (1995)
Photo Llama: A. Riek

Foregut vs. Hindgut Fermentation



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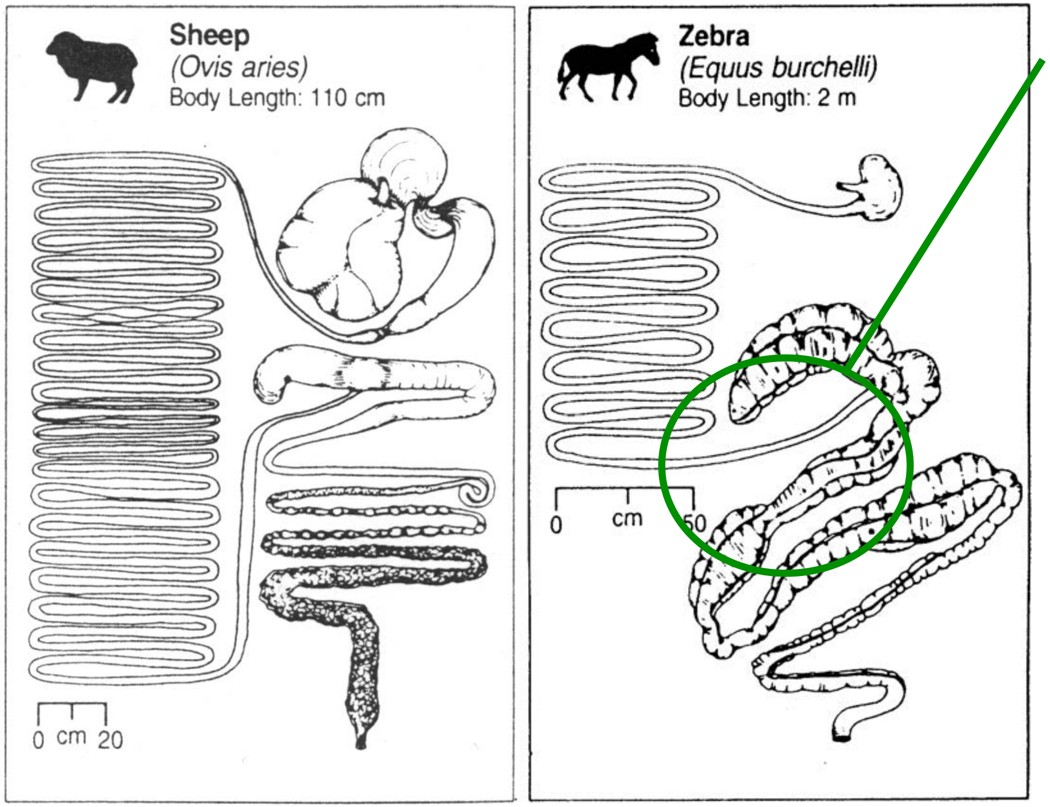
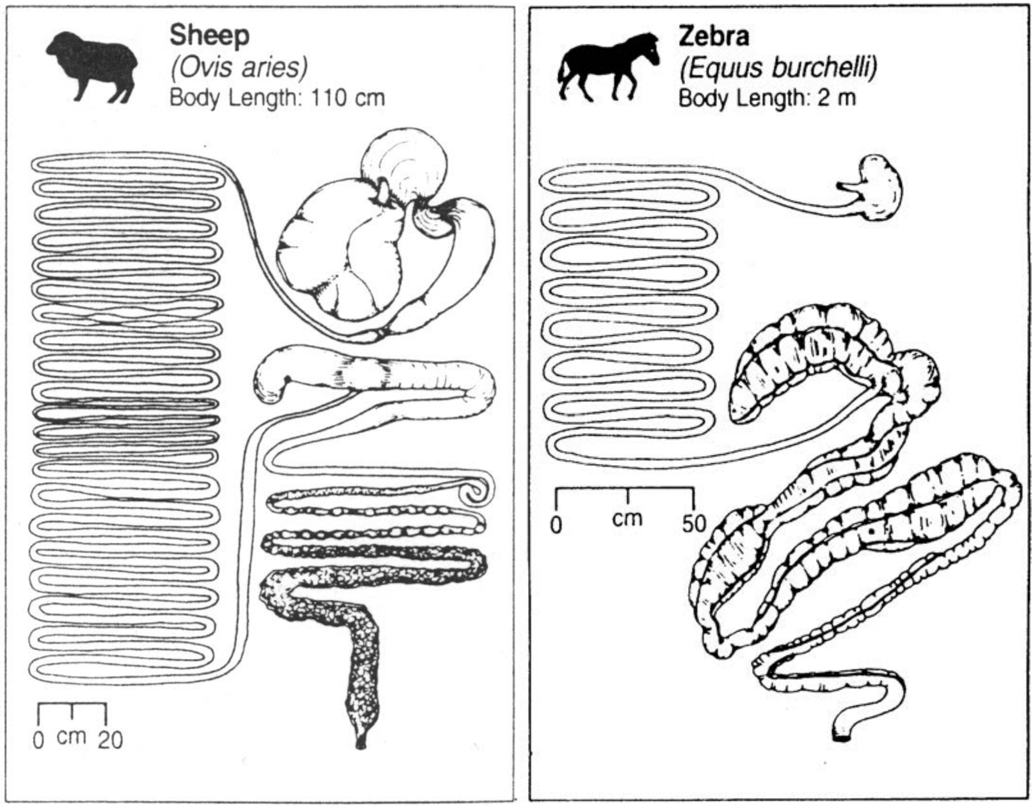
Foregut vs. Hindgut Fermentation



Fermentation <u>after</u> enzymatic digestion and absorption:

from Stevens & Hume (1995)

Foregut vs. Hindgut Fermentation



Fermentation <u>after</u> enzymatic digestion and absorption:

<u>'Loss'</u> of bacterial protein, bacterial products (B-Vitamins?)

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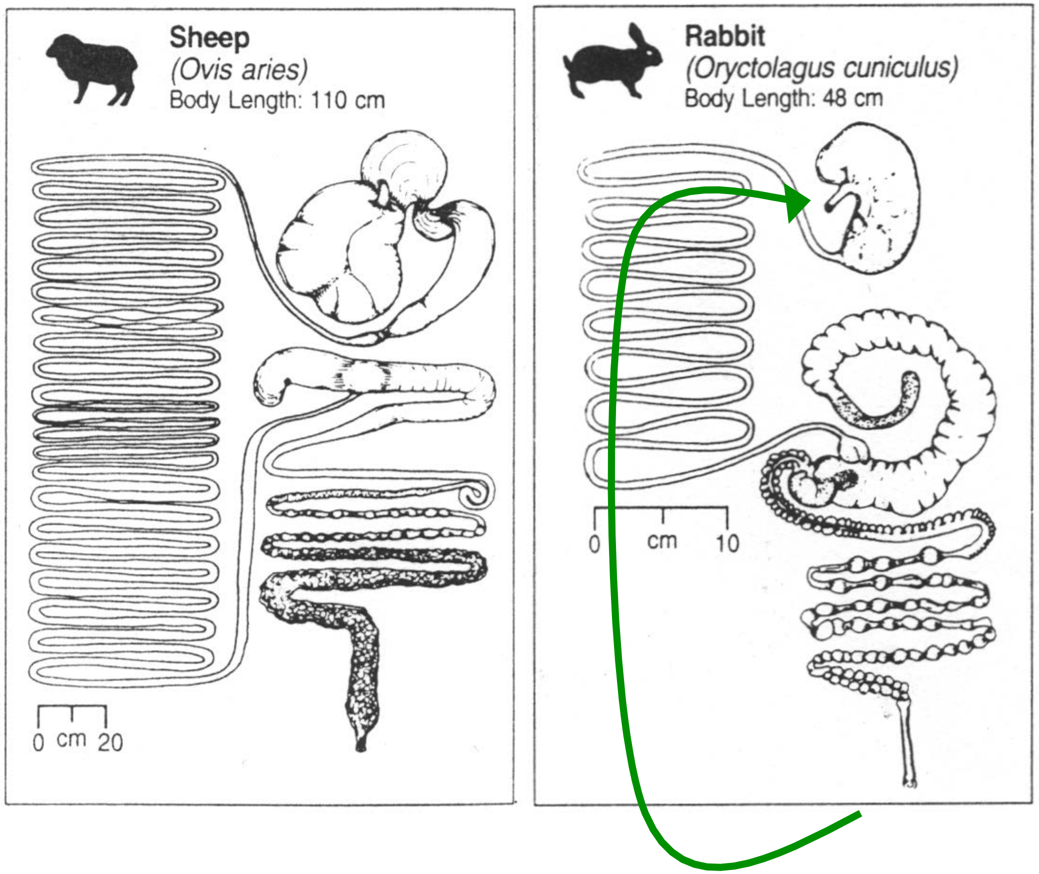

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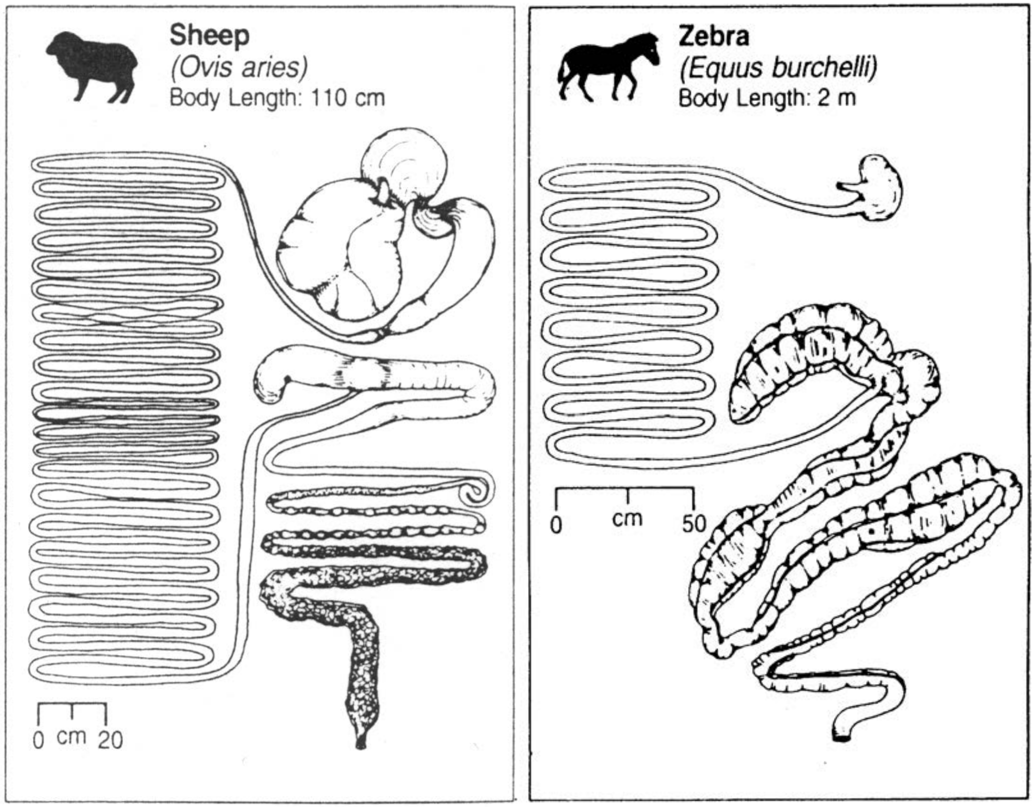

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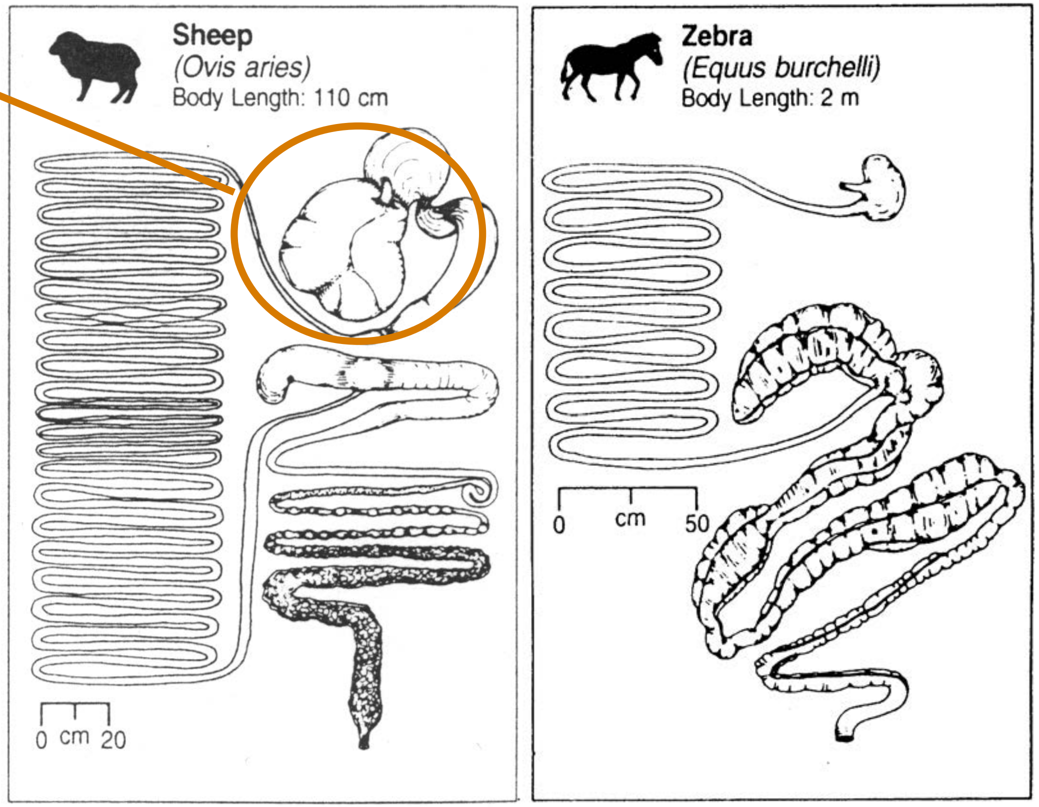
<u>Use</u> of easily digestible substrates

from Stevens & Hume (1995)

Foregut vs. Hindgut Fermentation

Fermentation prior to enzymatic digestion and absorption:



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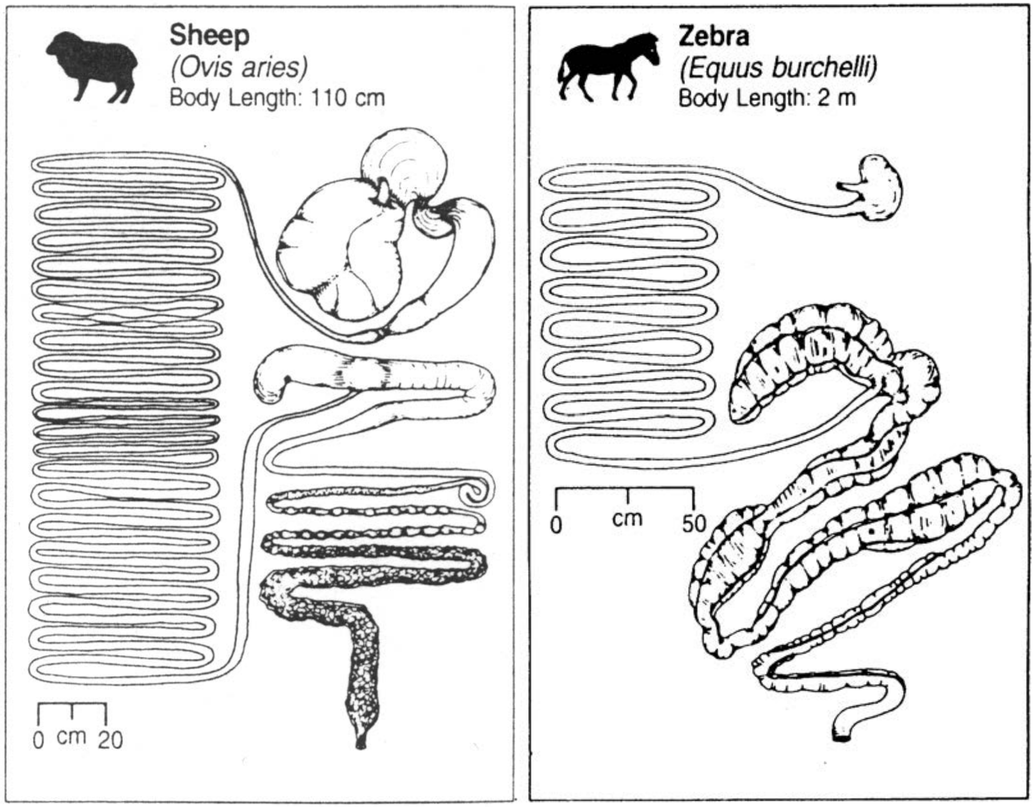

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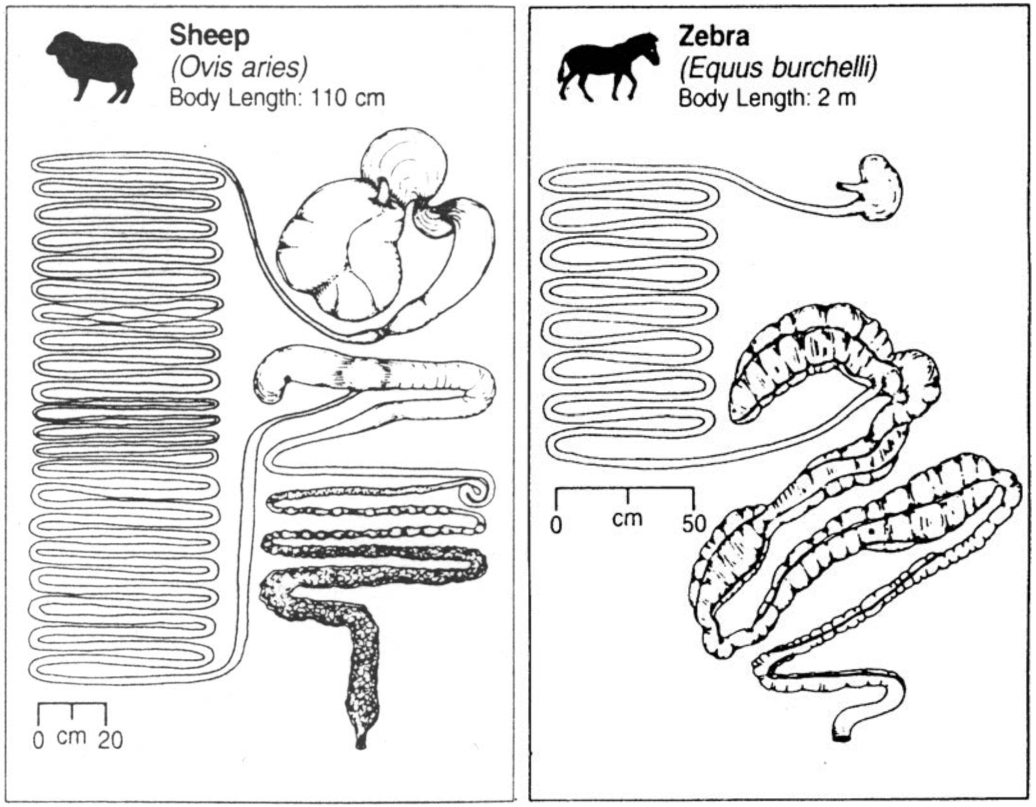
Bacterial detoxification?



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Foregut vs. Hindgut Fermentation

Fermentation <u>prior</u> to enzymatic digestion and absorption:

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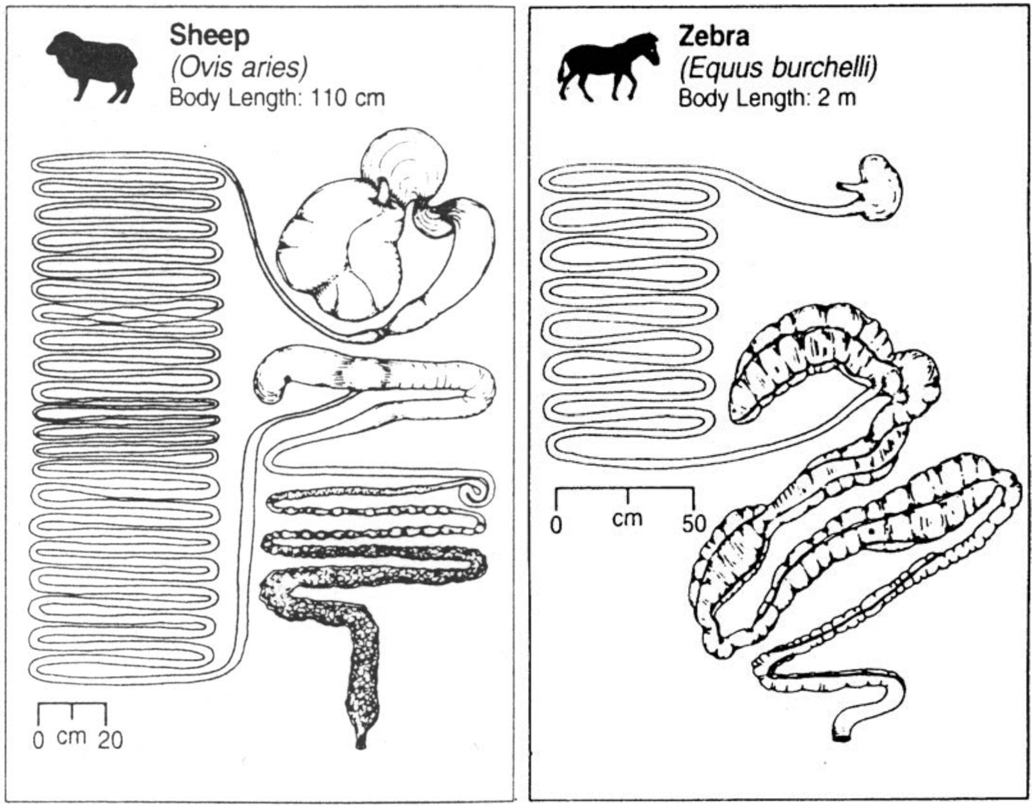
Bacterial detoxification?

<u>'Loss'</u> of easily digestible substrates and bacterial modification



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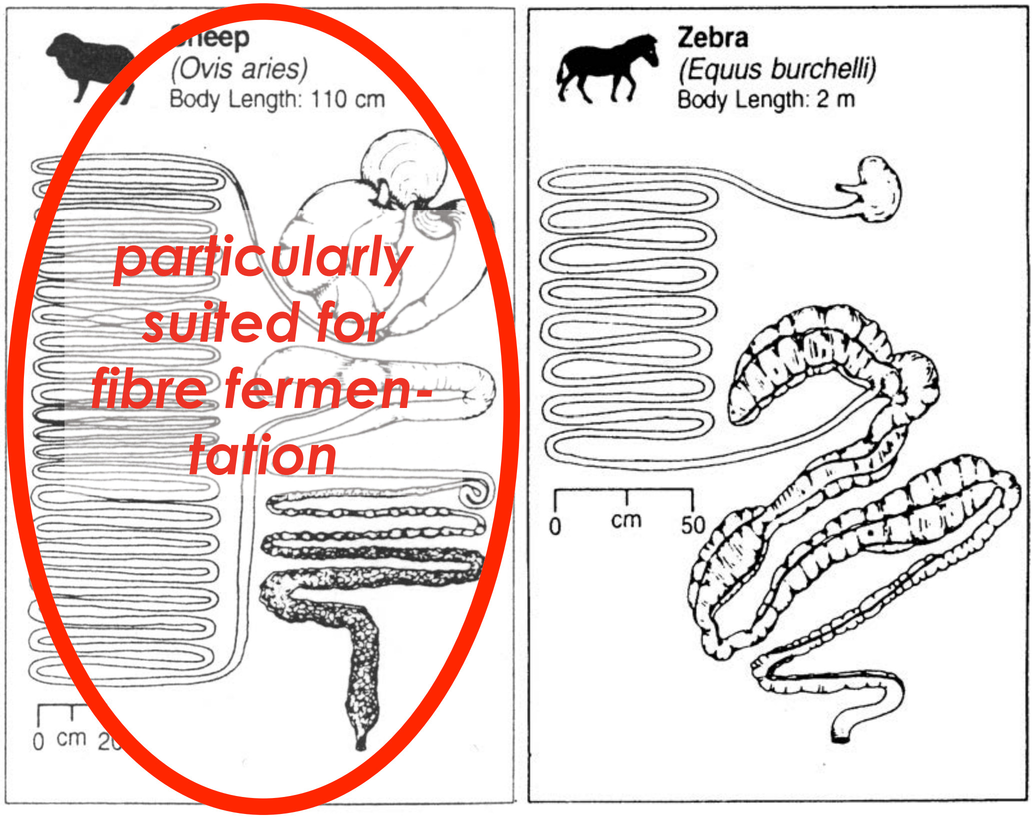

Fermentation after enzymatic digestion and absorption:

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Use of easily digestible substrates

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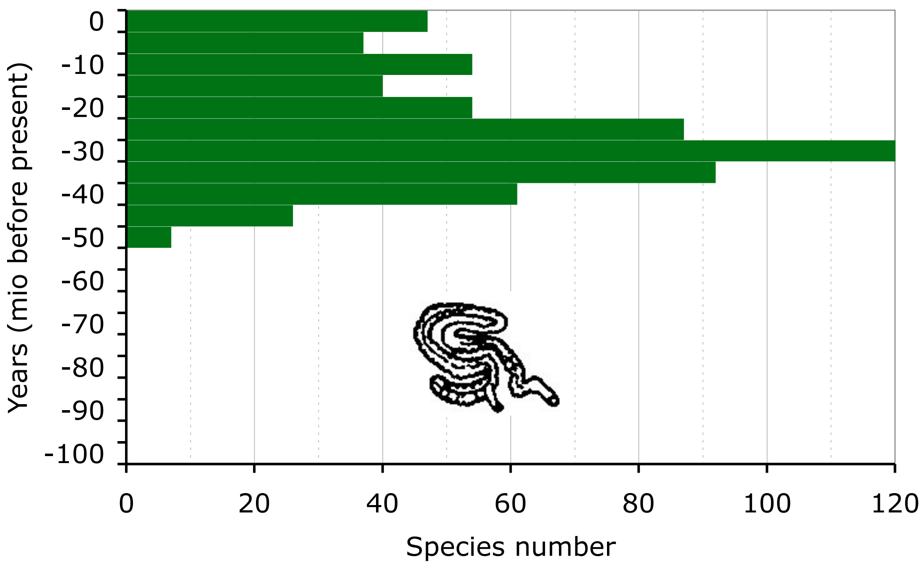
European Mammal Herbivores in Deep Time



from Langer (1991)

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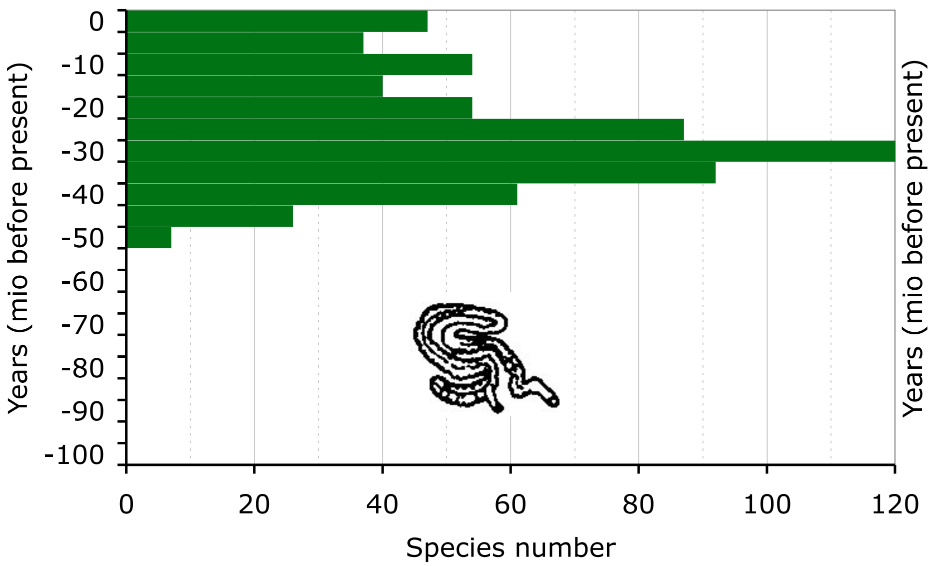
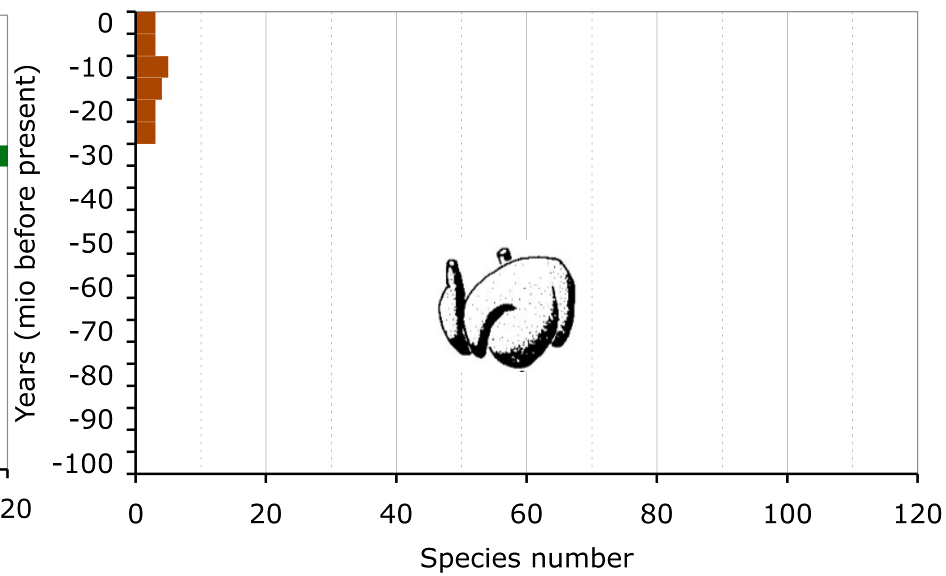
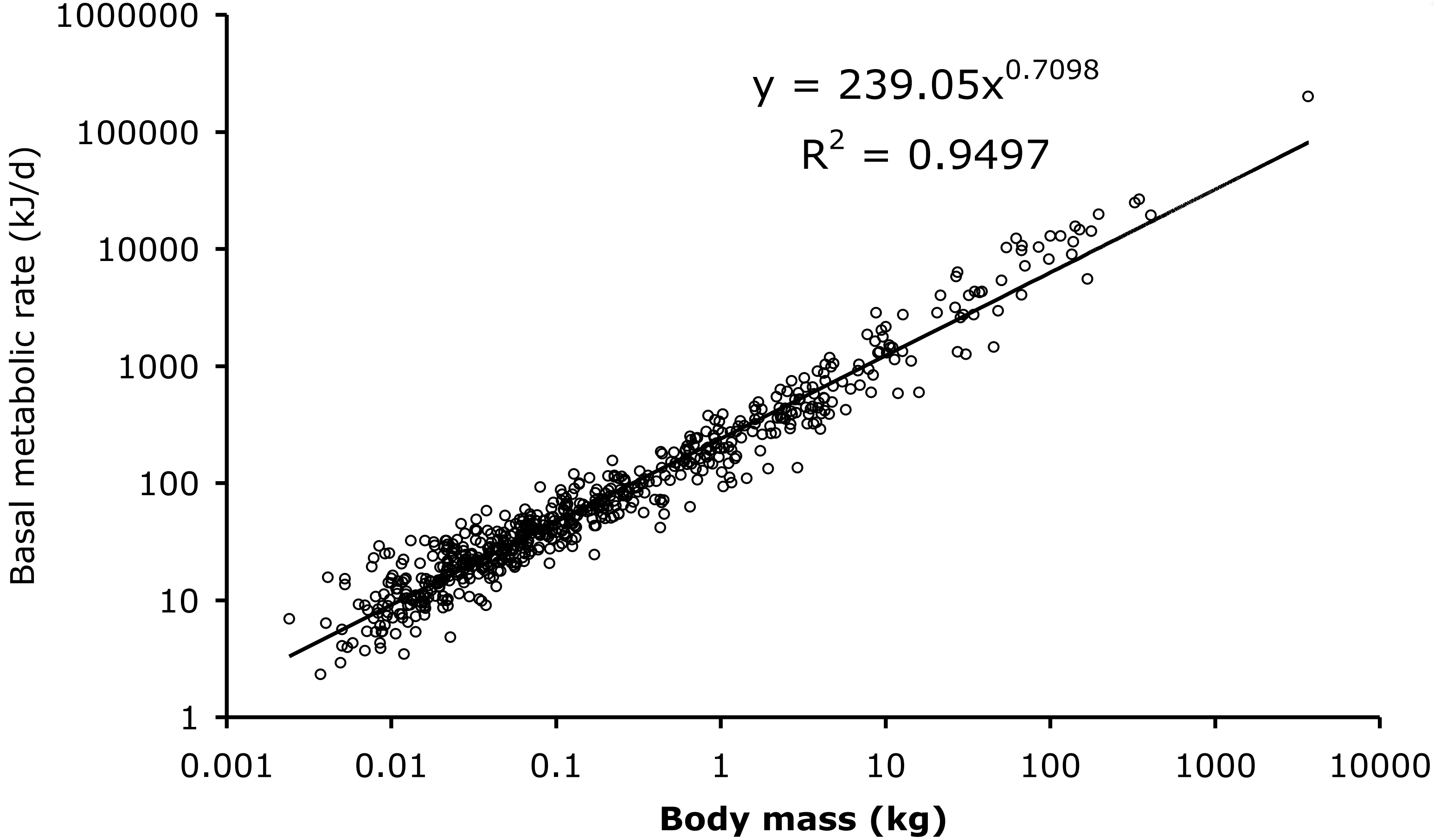




from Langer (1991)

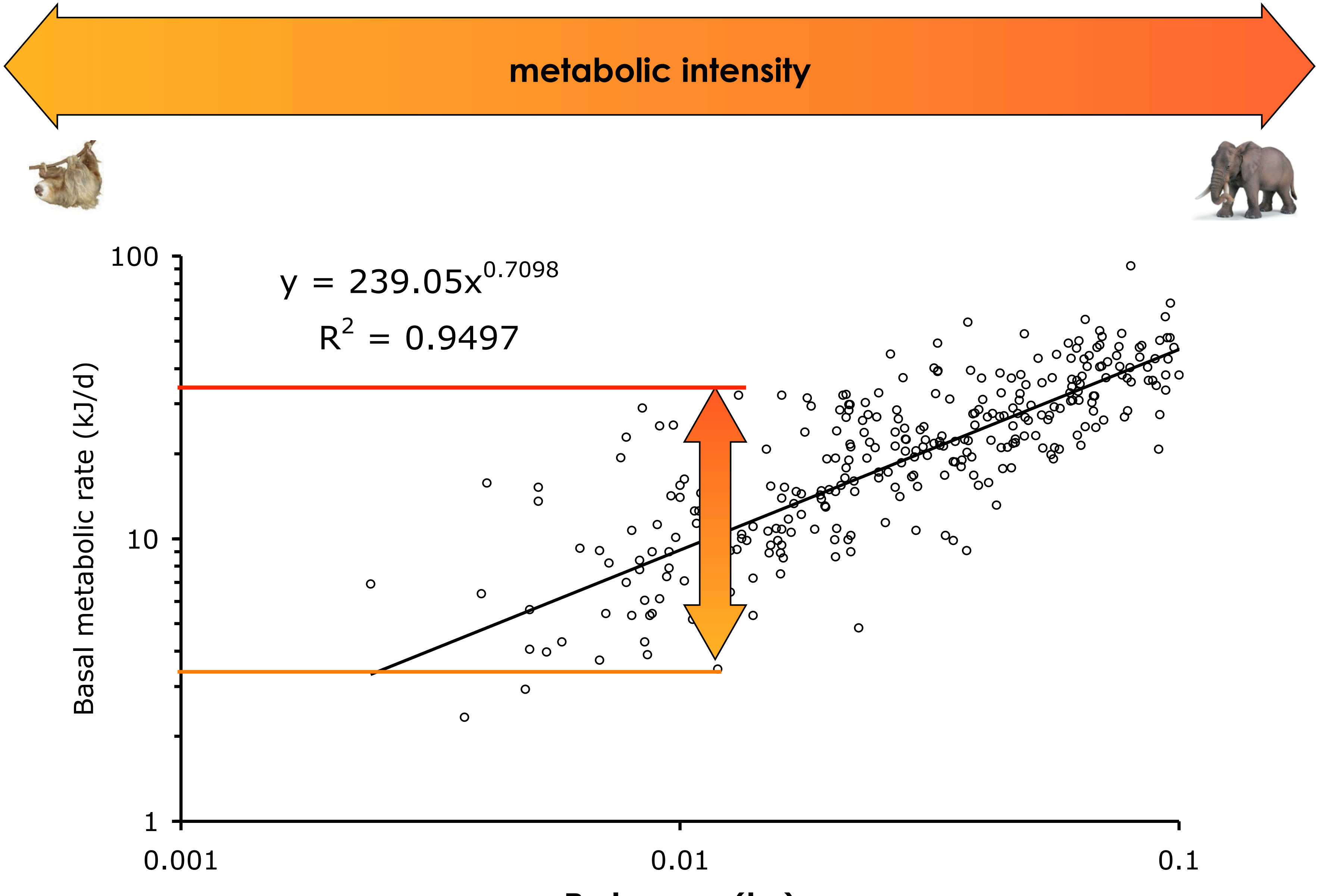
Conceptualizing herbivore diversity

metabolic intensity



Data from Savage et al. (2004)

Conceptualizing herbivore diversity



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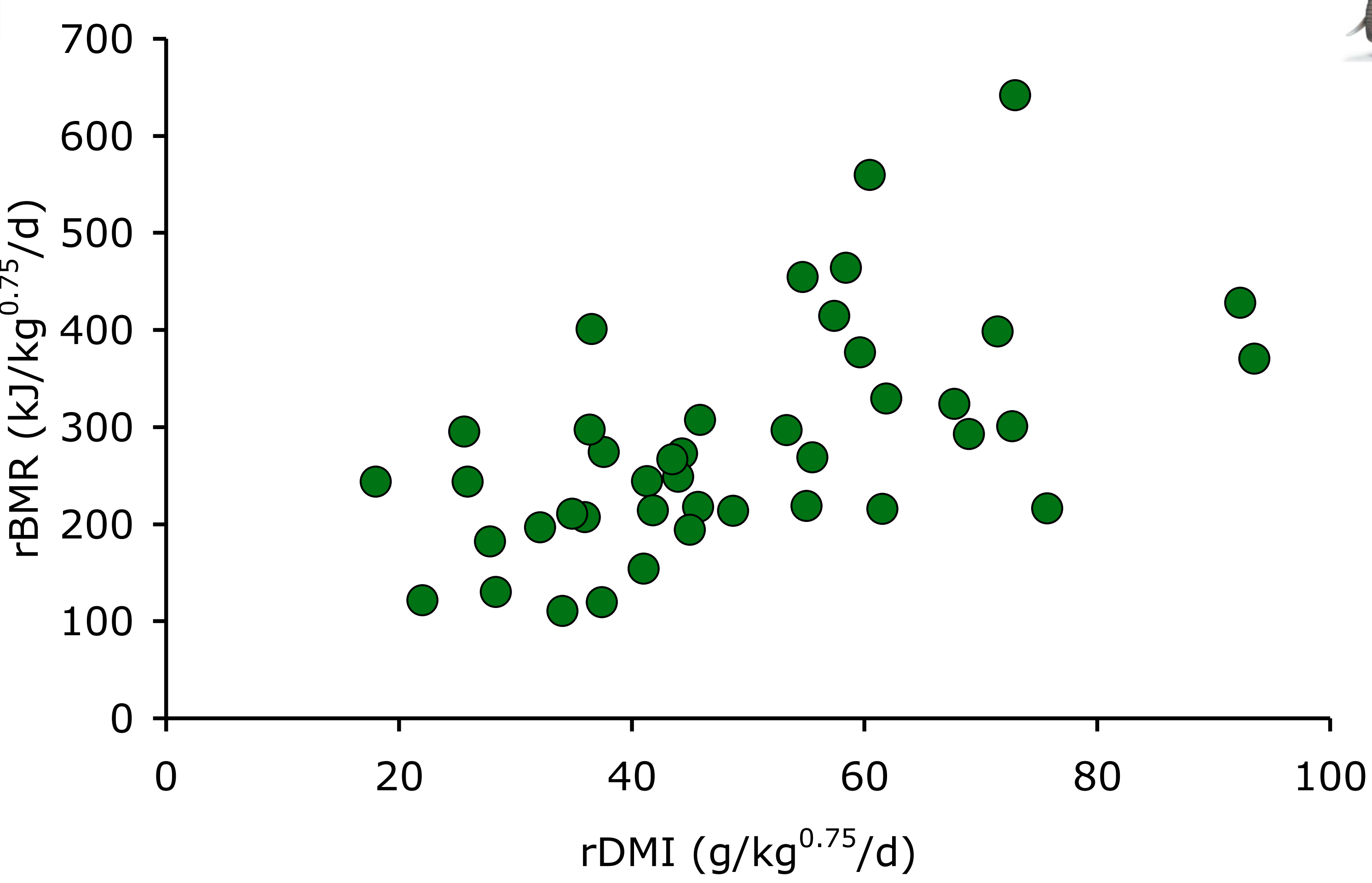
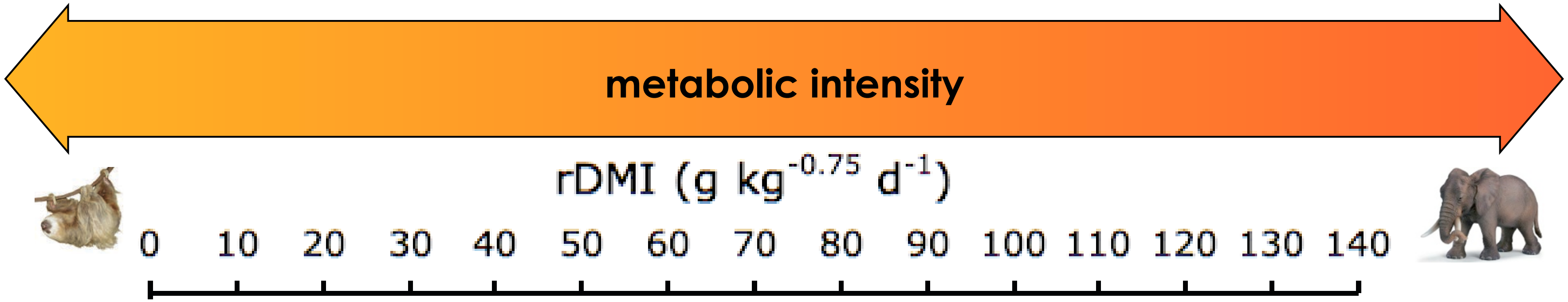


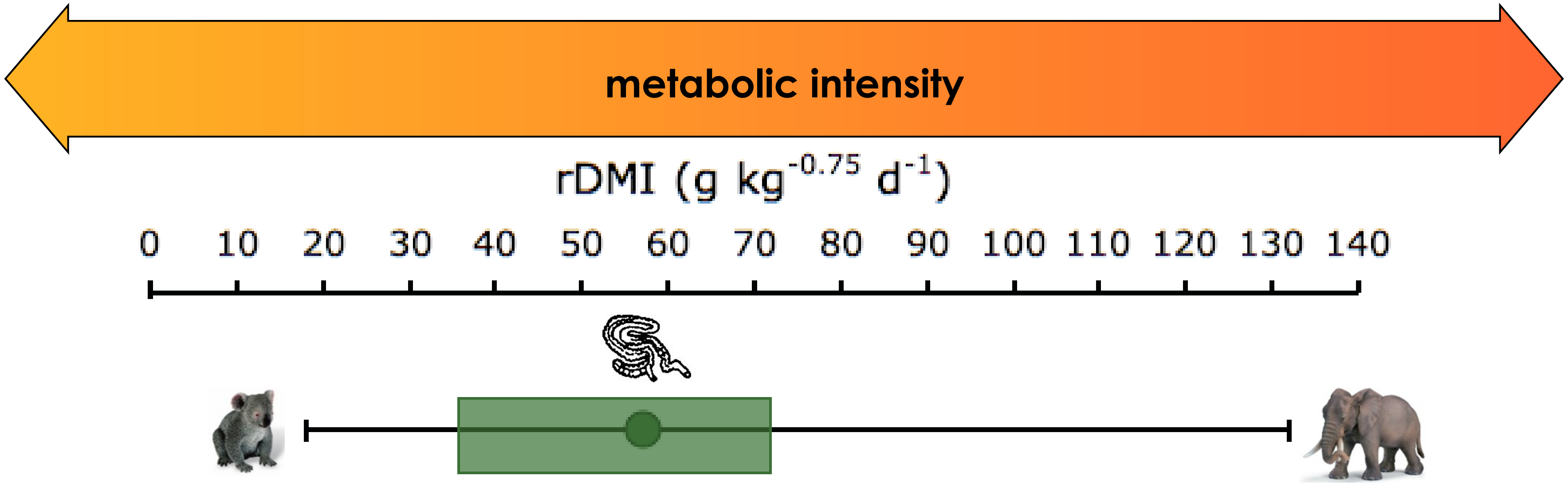
Data overlap from Savage et al. (2004) and Clauss et al. (2007)

Conceptualizing herbivore diversity



from Clauss et al. (2010)

Conceptualizing herbivore diversity



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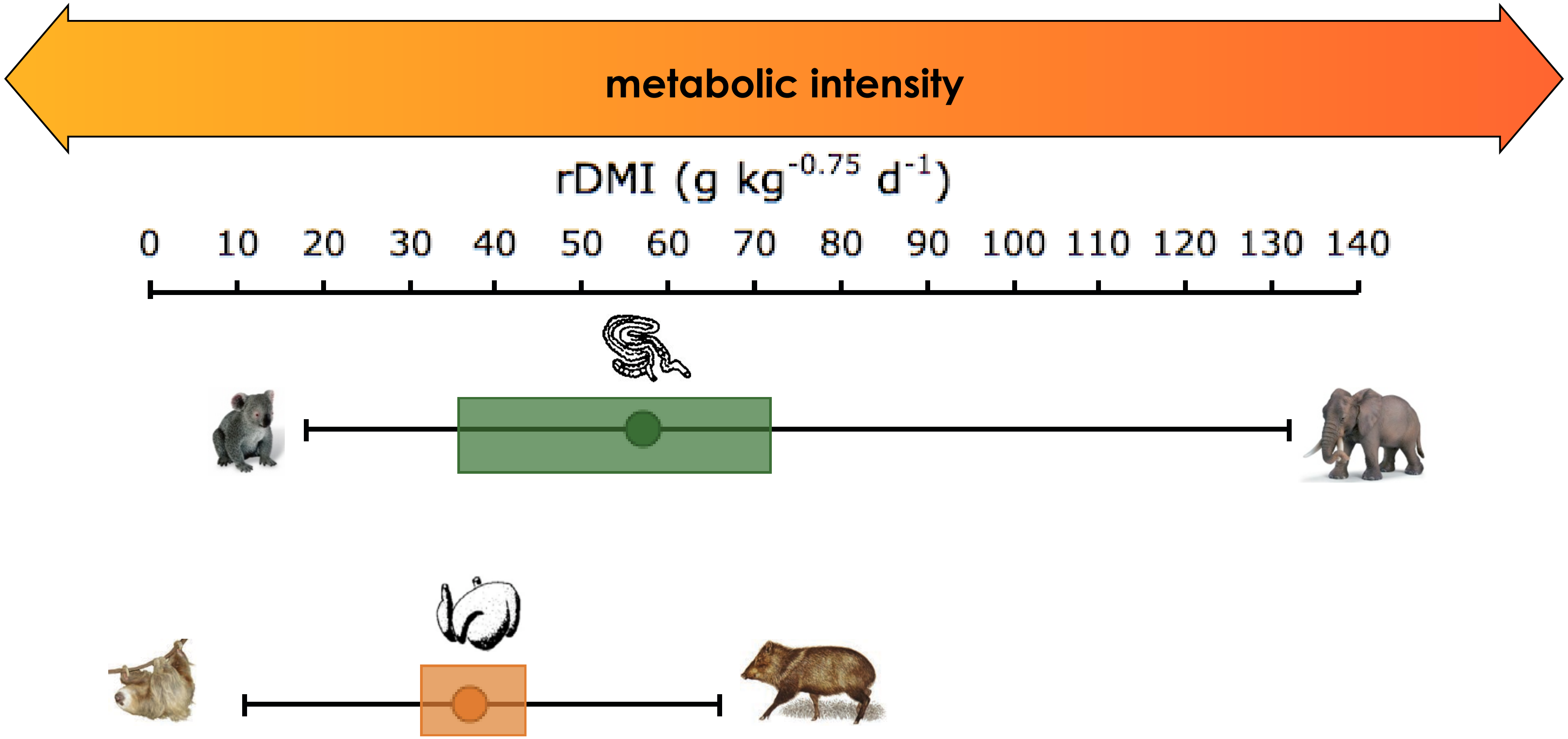

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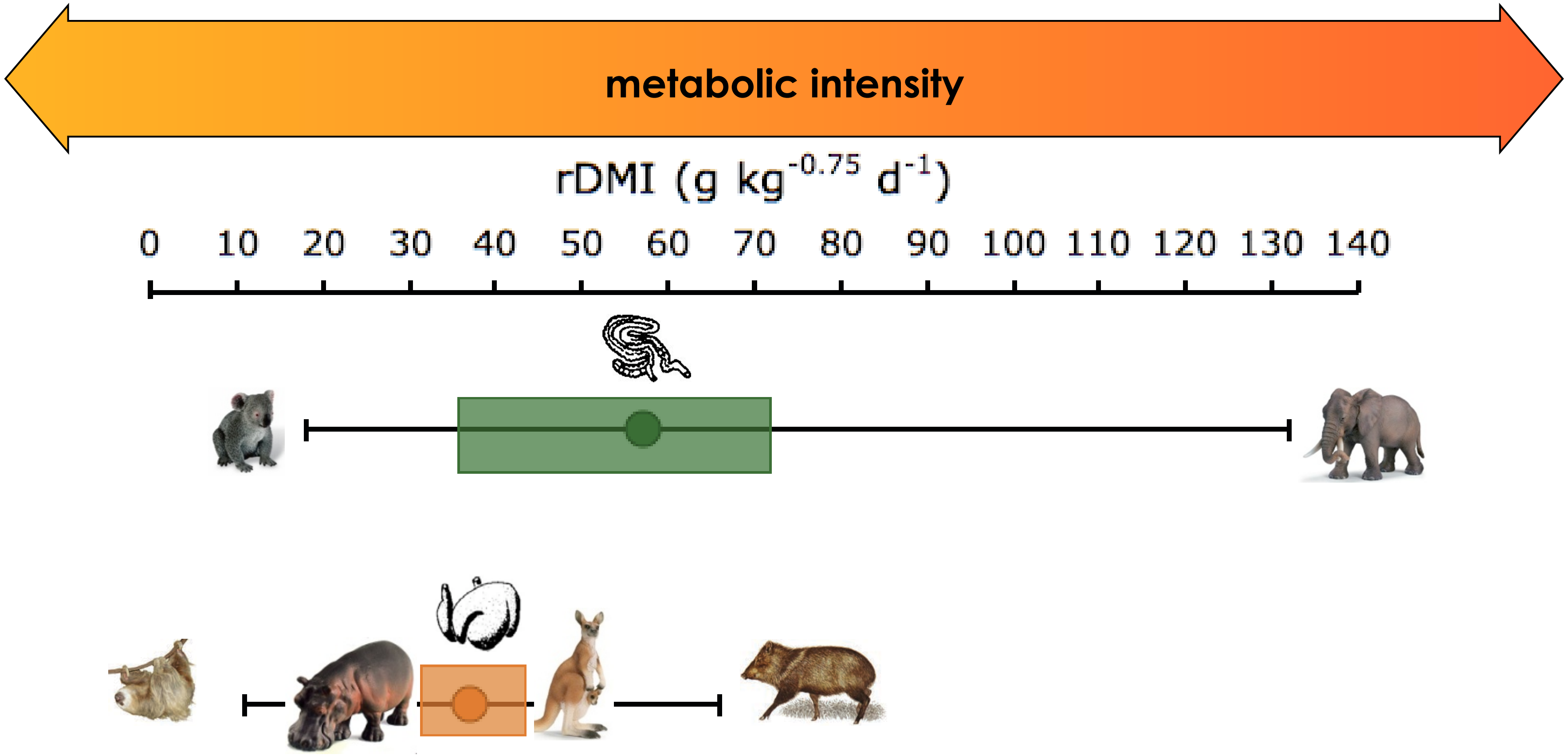

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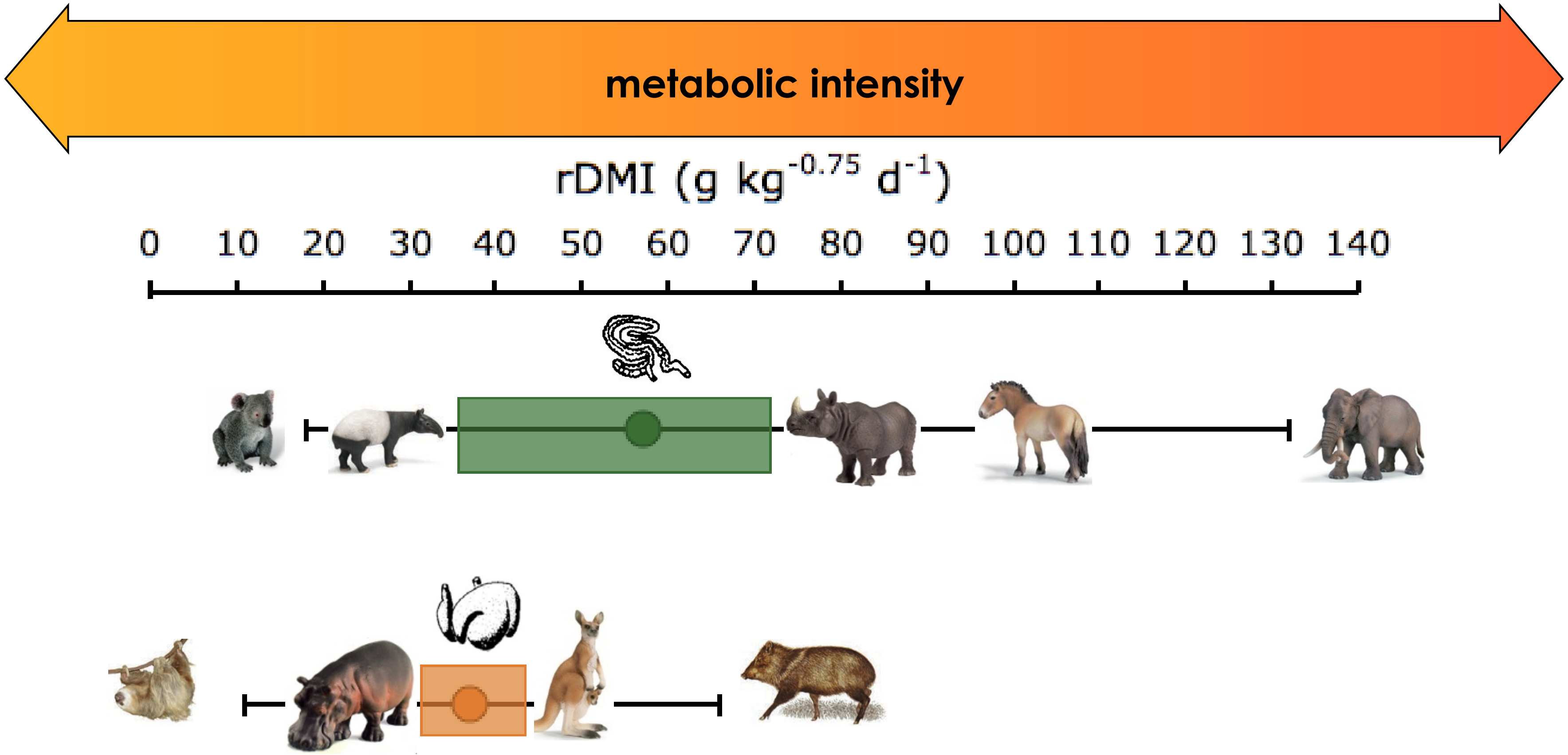
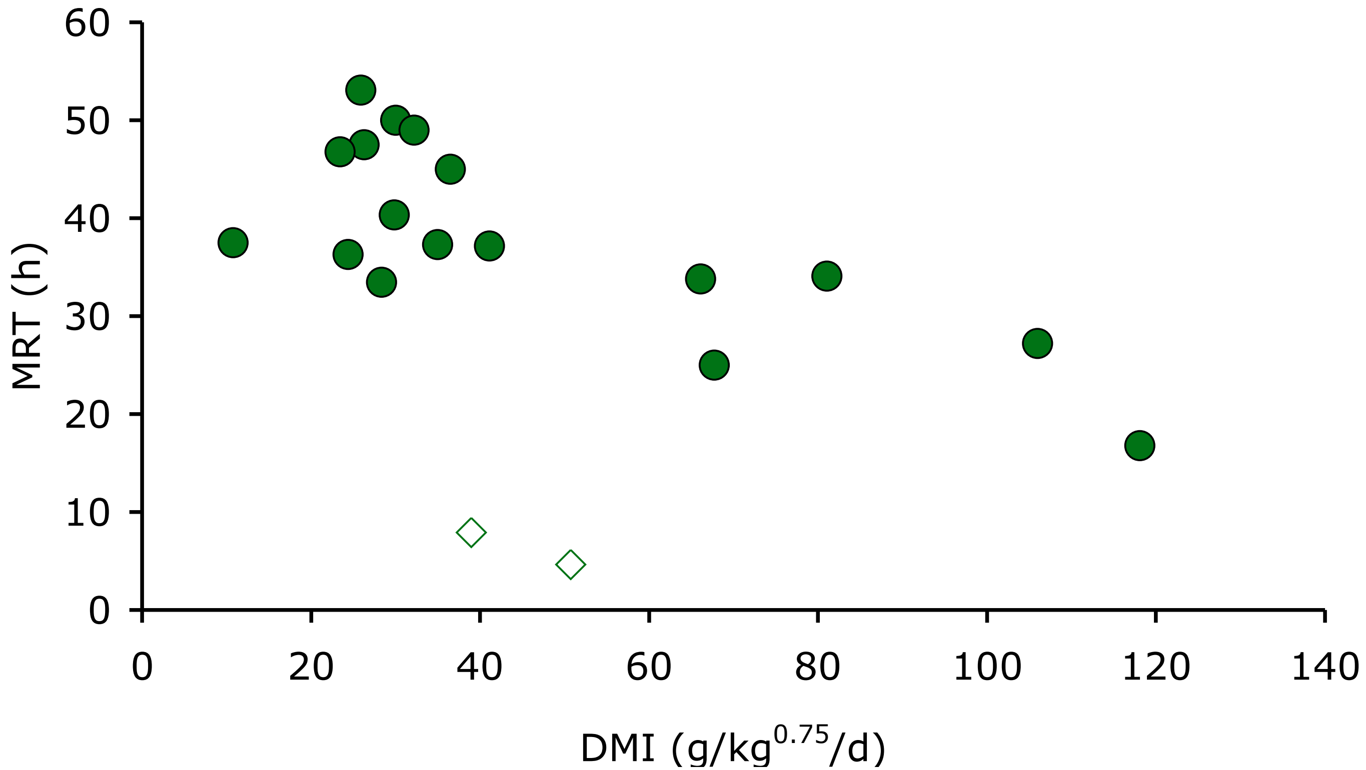


from Clauss et al. (2010)

Intake and Passage in Primates



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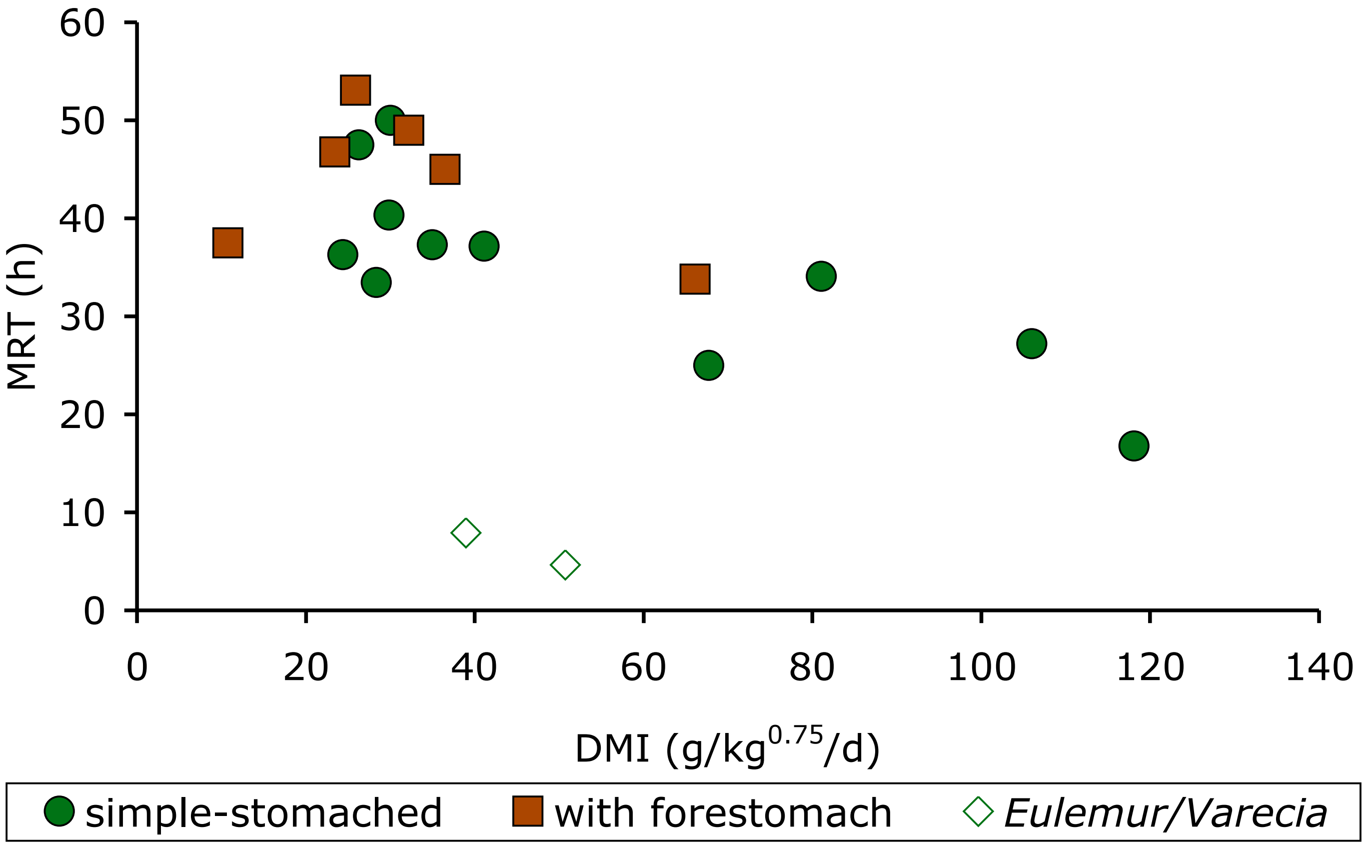
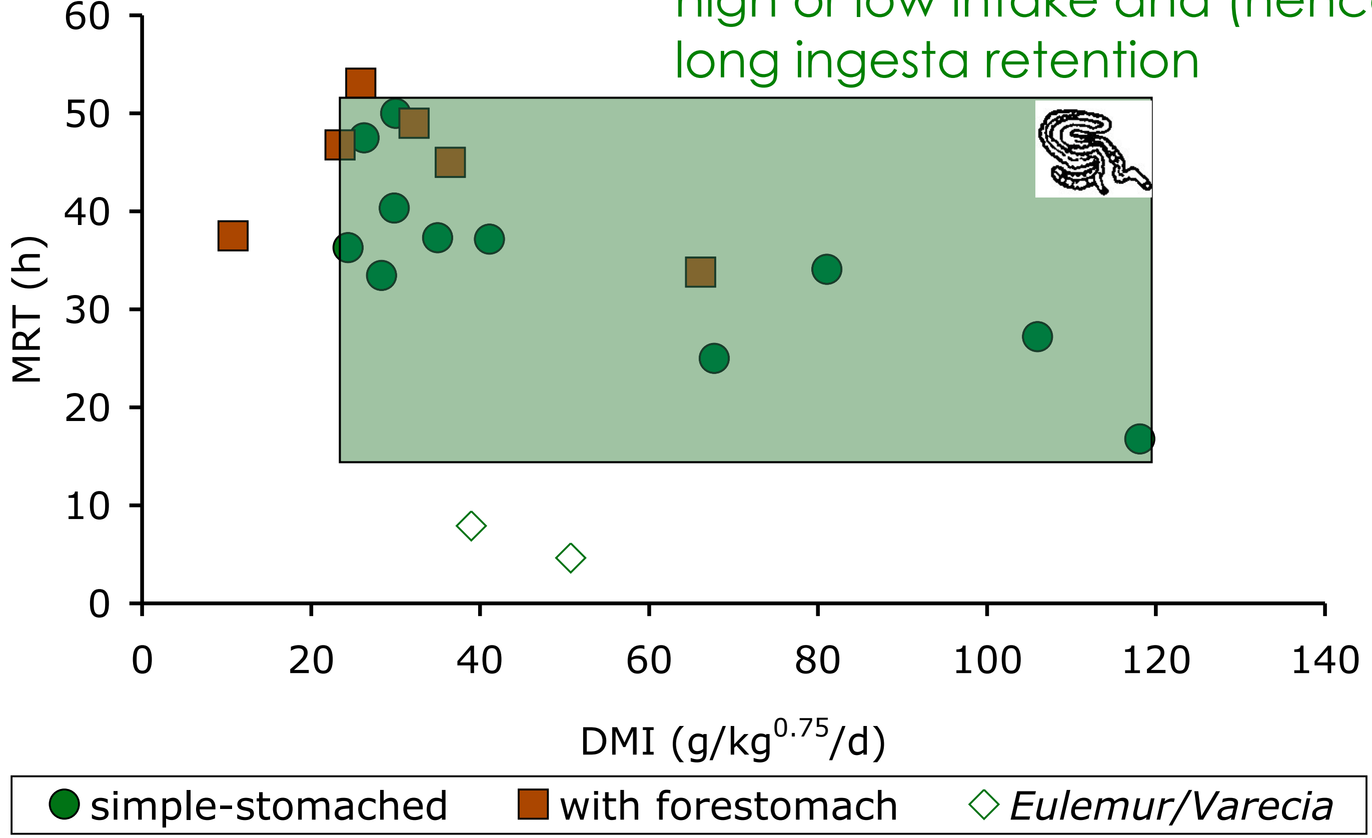


from Clauss et al. (2008)

Intake and Passage in Primates

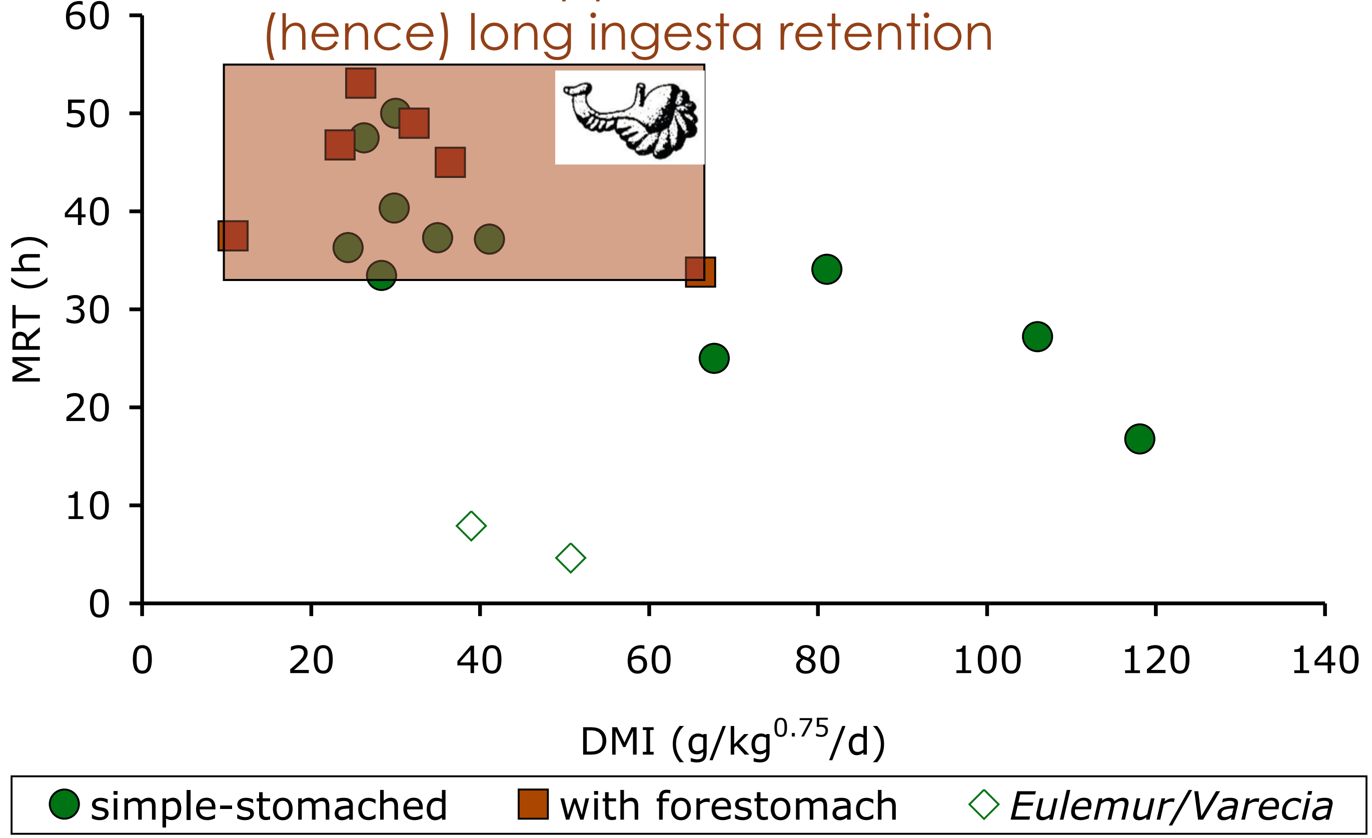
Hindgut fermenters can have either - high or low intake and (hence) short or long ingesta retention



from Clauss et al. (2008)

Intake and Passage in Primates

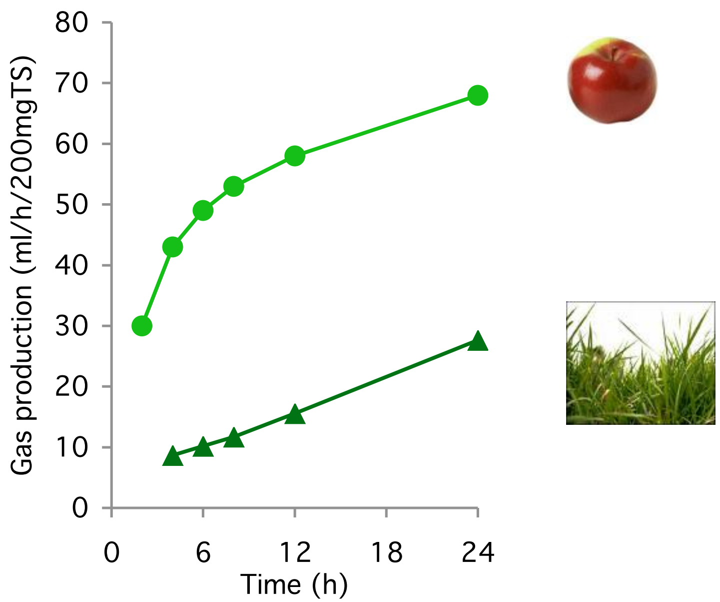
Nonrum. ff appear limited to a low food intake and (hence) long ingesta retention



from Clauss et al. (2008)

Two Preconditions

1. It is energetically favourable to digest 'autoenzymatically digestible' components autoenzymatically, not by fermentative digestion.
2. Autoenzymatically digestible components are fermented ***at a drastically higher rate*** than plant fiber.



from Hummel et al. (2006ab)

Digestive Strategies

		
Low intake ⇒ long passage		
High intake ⇒ short passage		

Digestive Strategies

		
Low intake ⇒ long passage	Autoenzymatic digestion followed by thorough fermentative digestion ✓	
High intake ⇒ short passage		

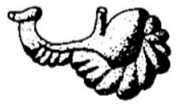
Digestive Strategies

		
Low intake ⇒ long passage	Autoenzymatic digestion followed by thorough fermentative digestion ✓	
High intake ⇒ short passage	Autoenzymatic digestion followed by cursory fermentative digestion ✓	

Digestive Strategies

Low intake ⇒ long passage	Autoenzymatic digestion followed by thorough fermentative digestion ✓	Fermentative digestion followed by autoenzymatic digestion of products (and remains) ✓
High intake ⇒ short passage	Autoenzymatic digestion followed by cursory fermentative digestion ✓	

Digestive Strategies



Low intake ⇒ long passage	Autoenzymatic digestion followed by thorough fermentative digestion ✓	Fermentative digestion followed by autoenzymatic digestion of products (and remains) ✓
High intake ⇒ short passage	Autoenzymatic digestion followed by cursory fermentative digestion ✓	*Cursory fermentative digestion mainly of autoenzymatically digestible components followed by ineffective autoenzymatic digestion of undigested fiber?*

Digestive Strategies

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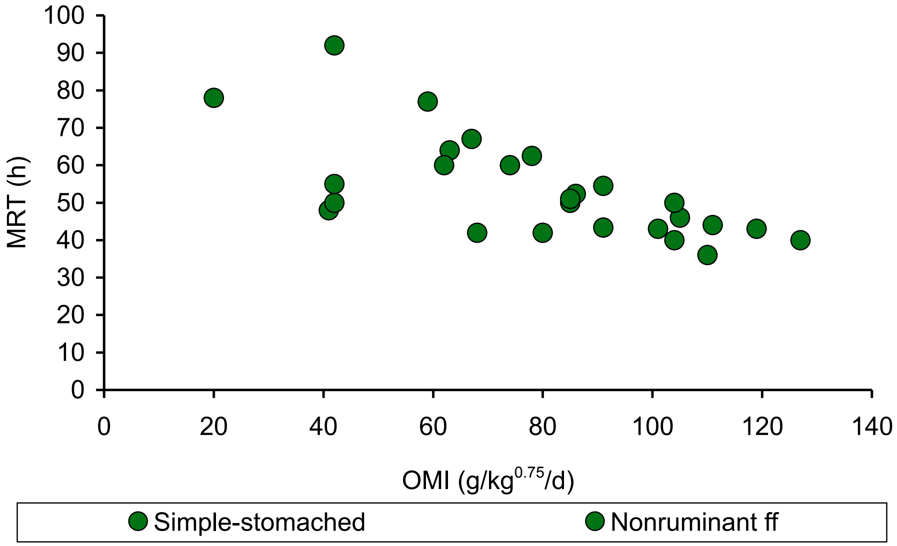
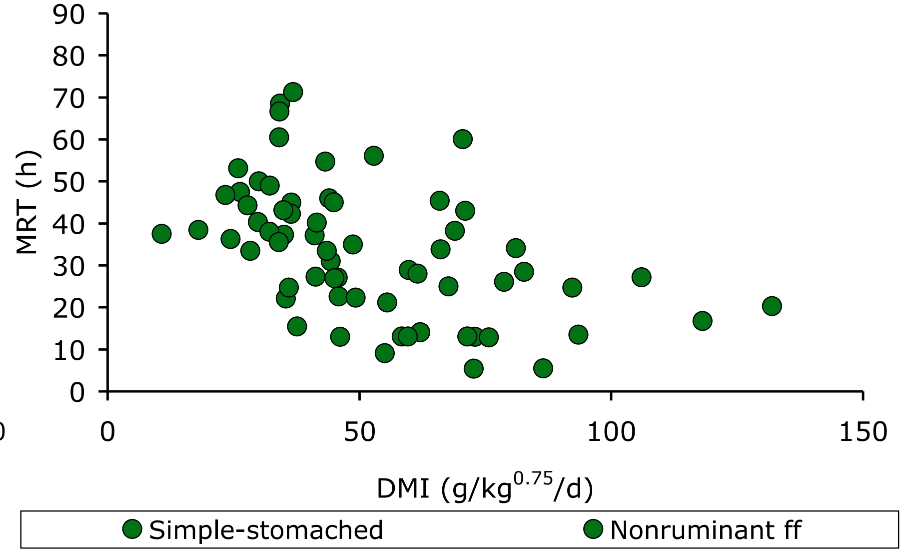
Intake and Passage

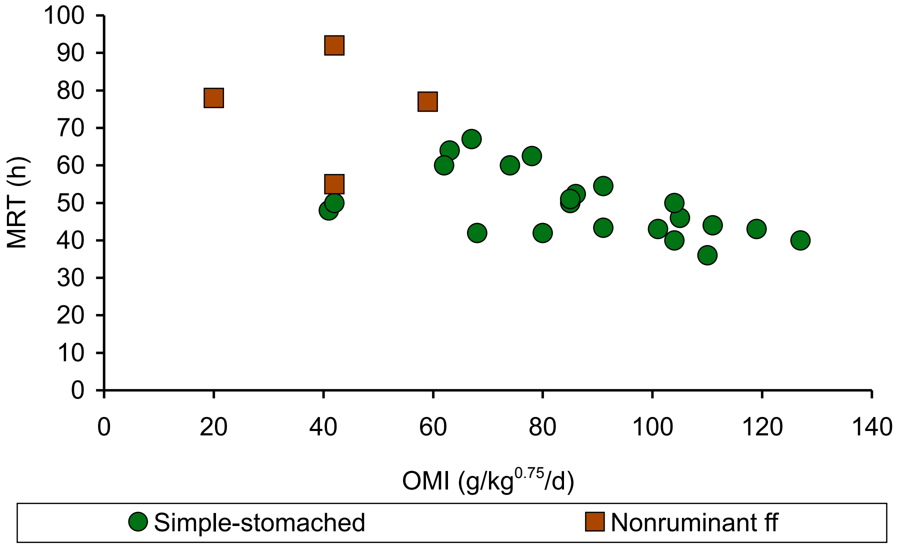


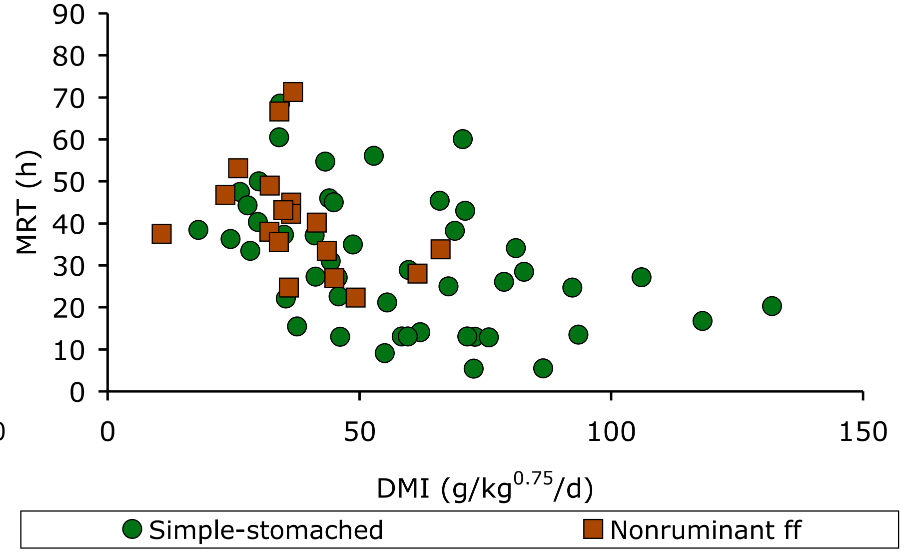
ungulates
from Foose (1982)



mammal herbivores
Clauss et al. (2007)

Intake and Passage





ungulates
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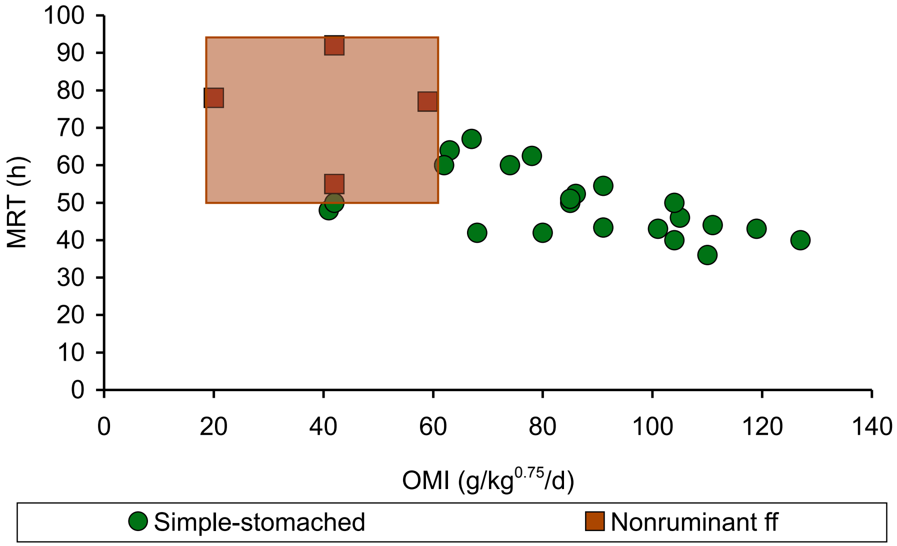
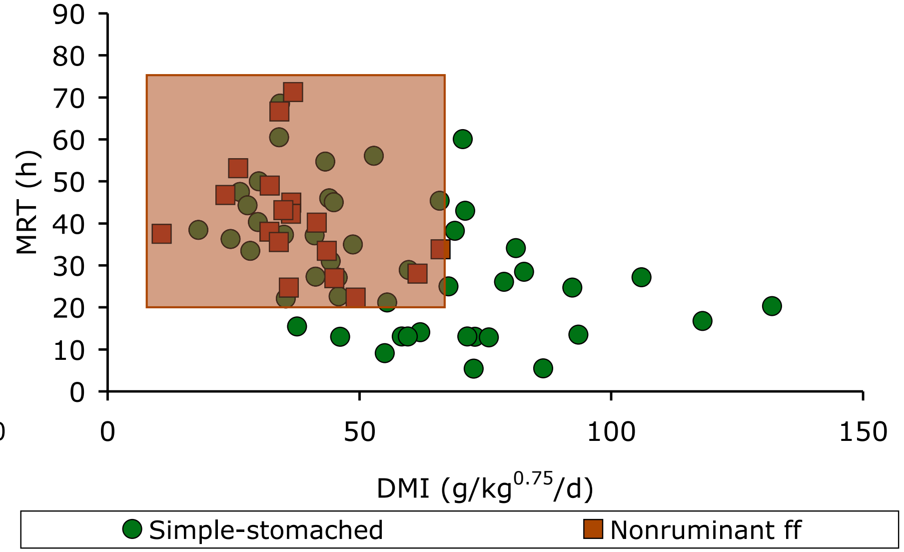
Clauss et al. (2007)

Intake and Passage

Nonrum. ff appear limited to a low food intake and (hence) long ingesta retention

while hindgut fermenters can cover the whole range





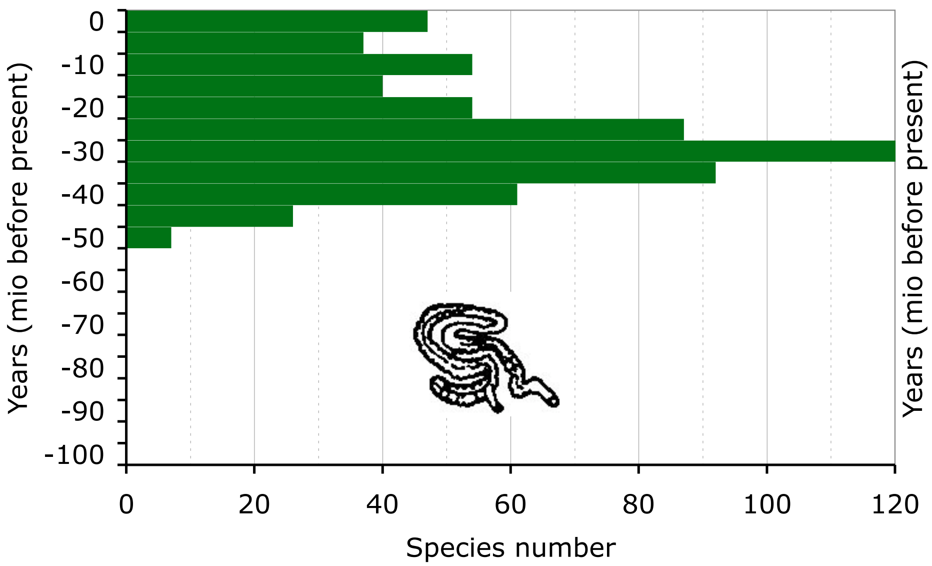
ungulates
from Foose (1982)

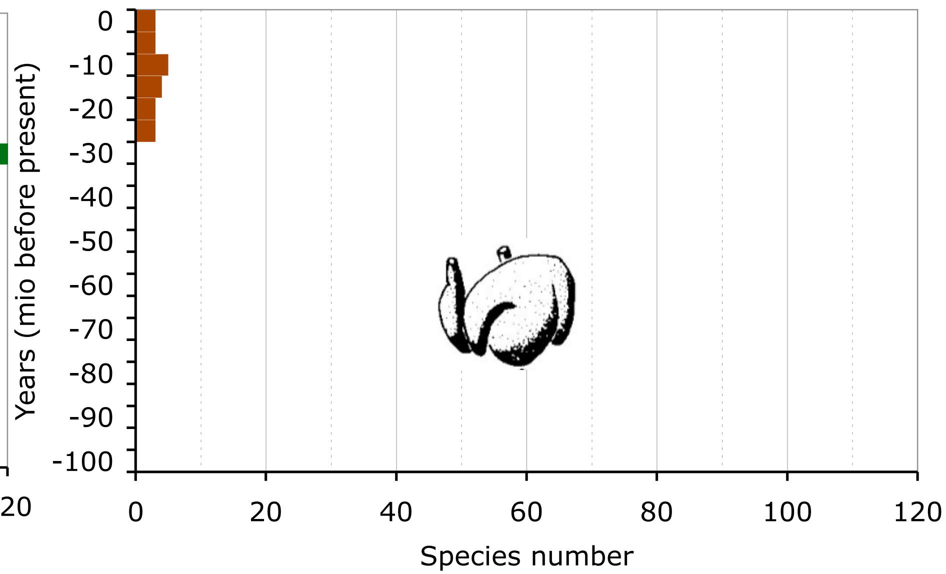
mammal herbivores
Clauss et al. (2007)

From Digestive to Metabolic Strategies

		
Low intake ⇒ long passage ⇒ ***low BMR***	✓	✓
High intake ⇒ short passage ⇒ ***high BMR***	✓	✗

European Mammal Herbivores in Deep Time





from Langer (1991)

How can you increase fermentative digestive efficiency?

- Digestion of plant fibre by bacteria is the more efficient ...
  - the more time is available for it
    = the longer the mean gastrointestinal retention time.
  - the finer the plant fibre particles are
    = the finer the ingesta is chewed.

How can you increase energy intake?

- higher food intake

- higher digestive efficiency

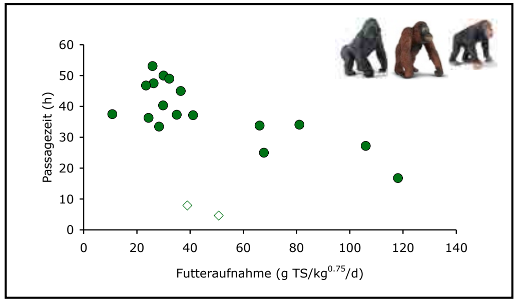
How can you increase energy intake?

- higher food intake
- longer retention
- finer chewing

How can you increase energy intake?

- higher food intake

?



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higher gut volume

How can you increase energy intake?

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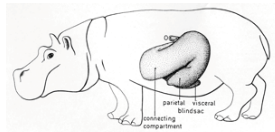
→ higher gut volume



How can you increase energy intake?

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- longer retention
- finer chewing

→ sorting !

If you do not sort ...

If you do not sort ...

If you do not sort ...

If you do not sort ...

If you do not sort ...

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If you do not sort ...

The power of sorting

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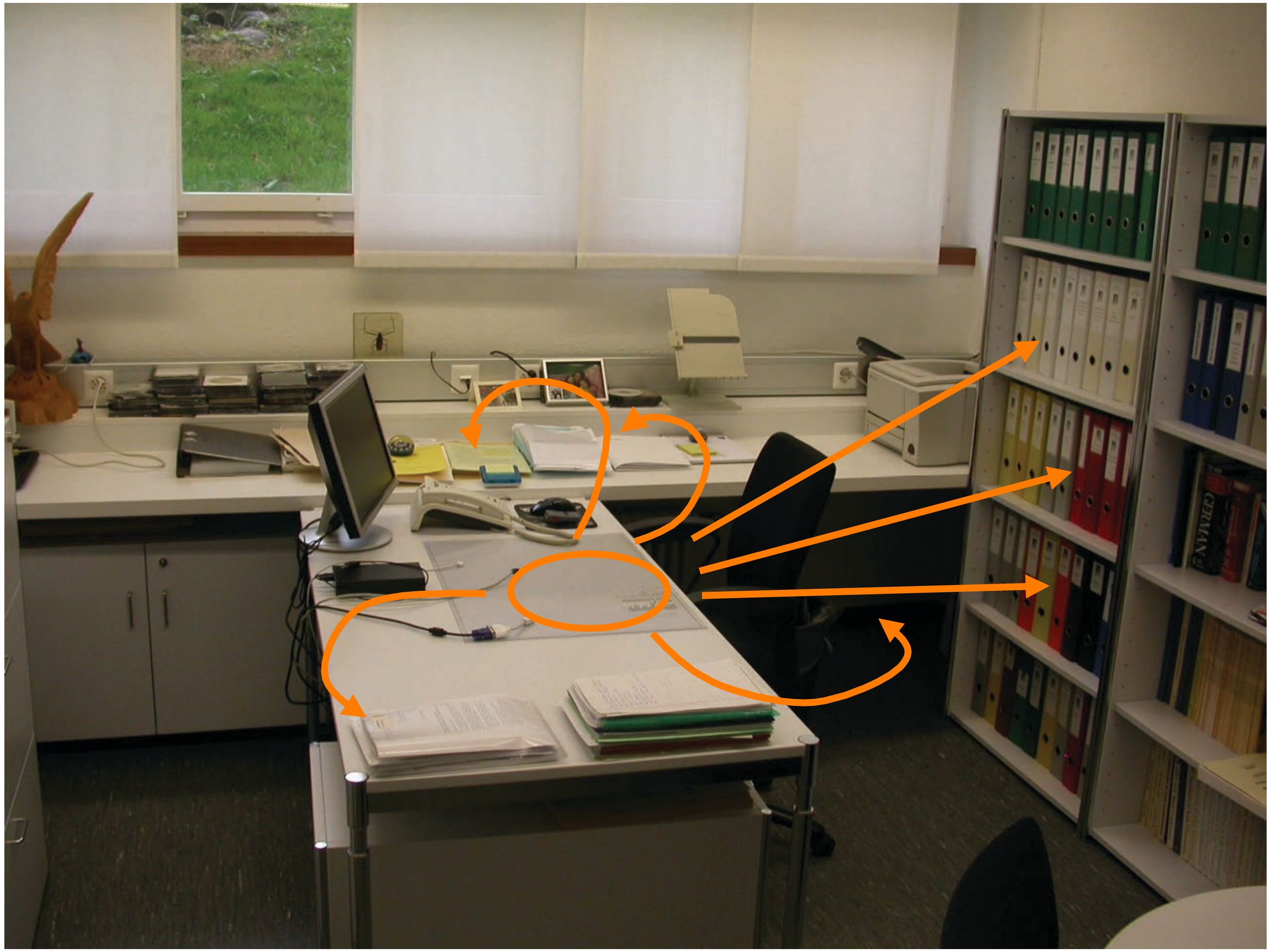

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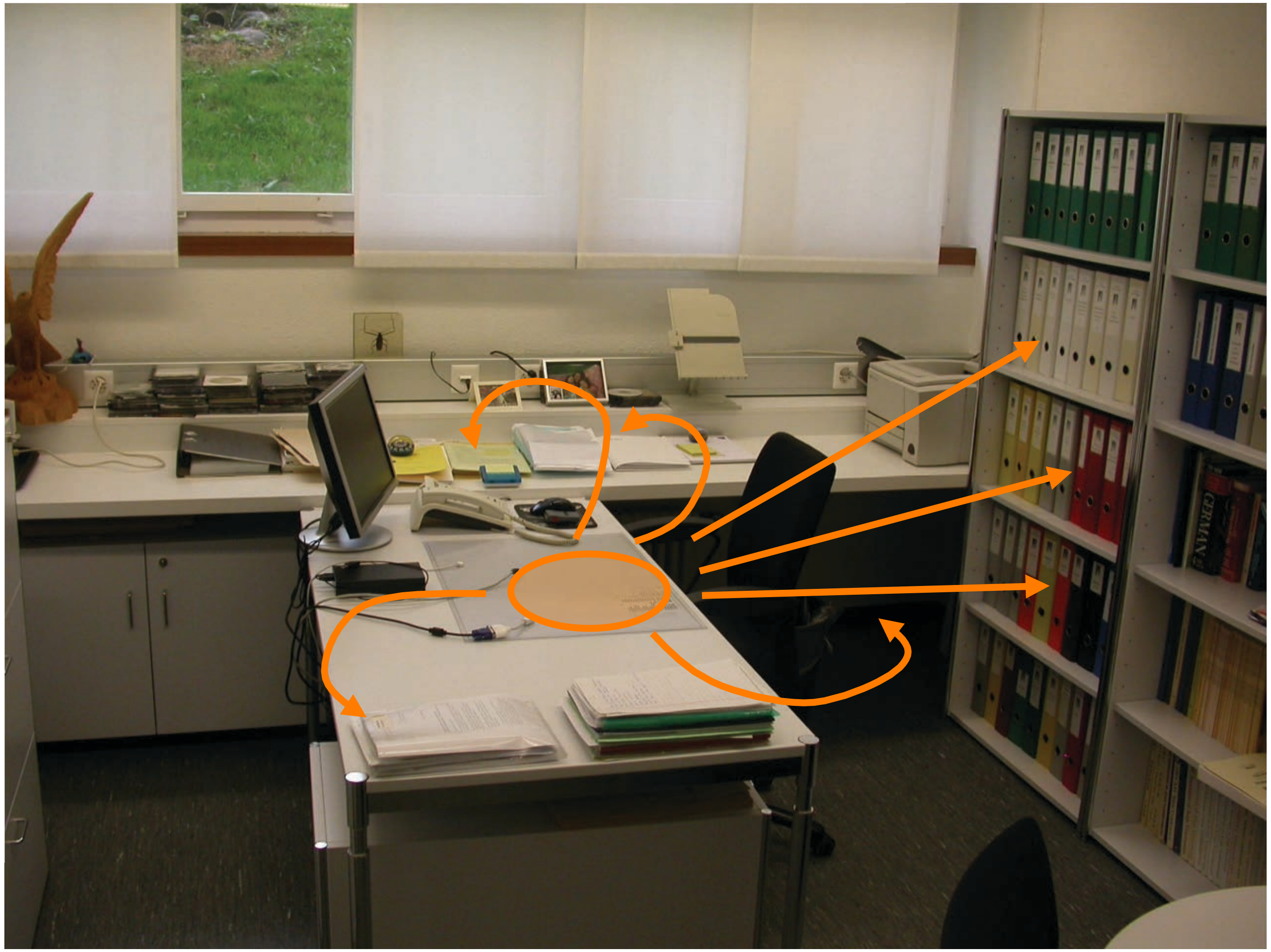
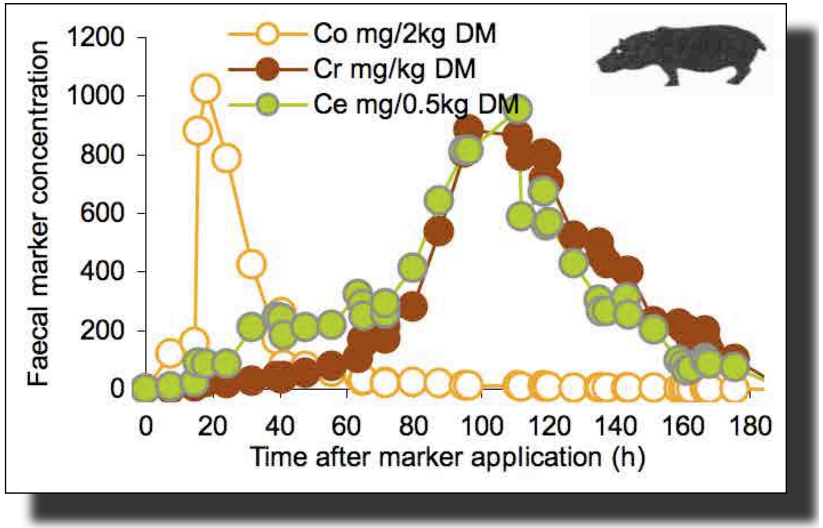


Ruminant vs. Nonruminant Foregut Fermentation



Schwarm et al. (2008)

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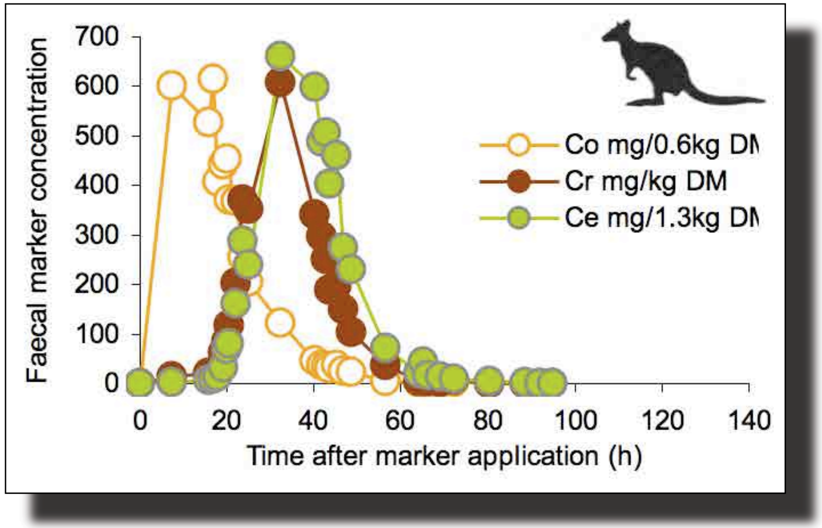

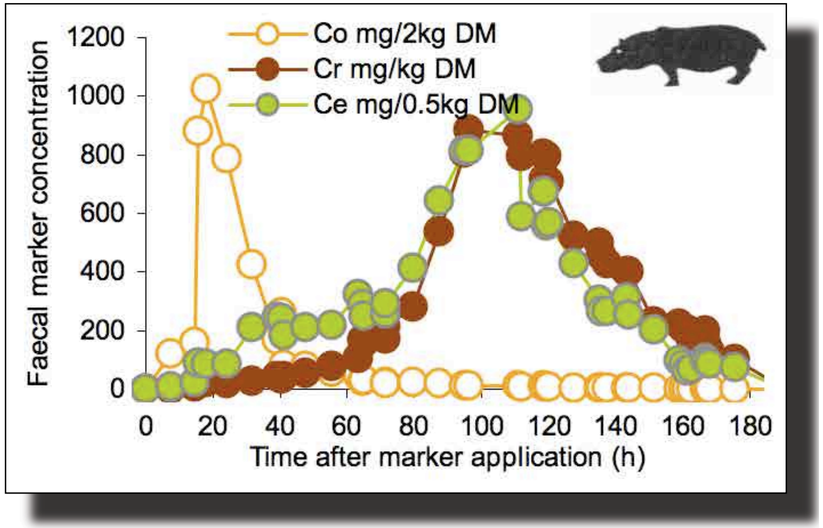

Schwarm et al. (2008,2009)

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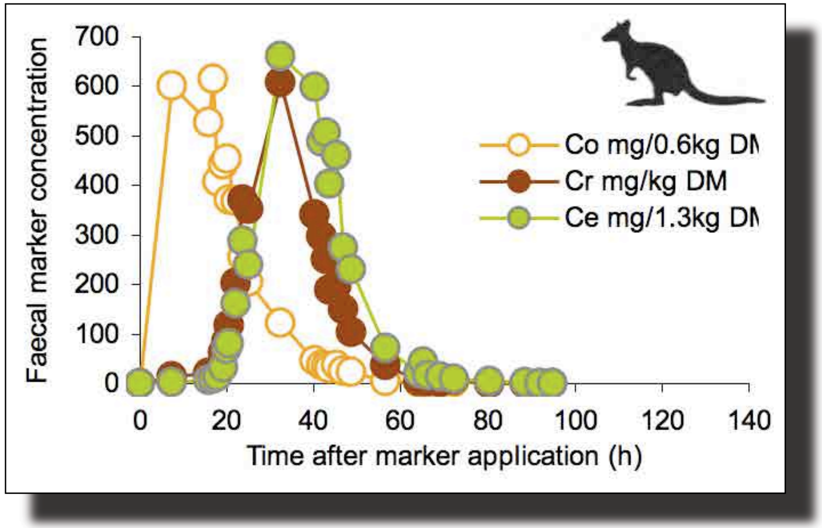

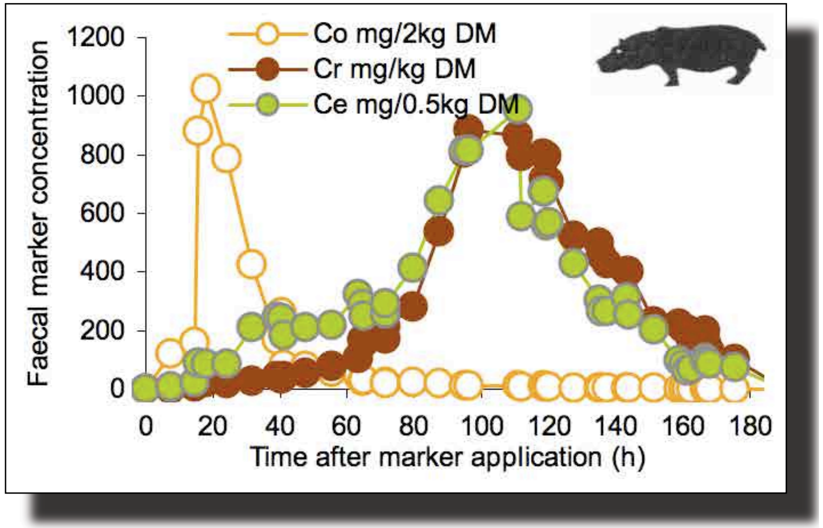

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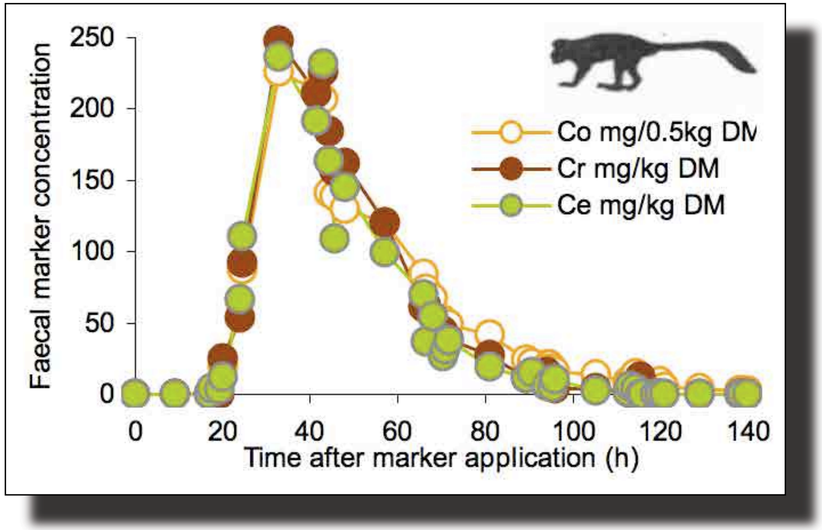

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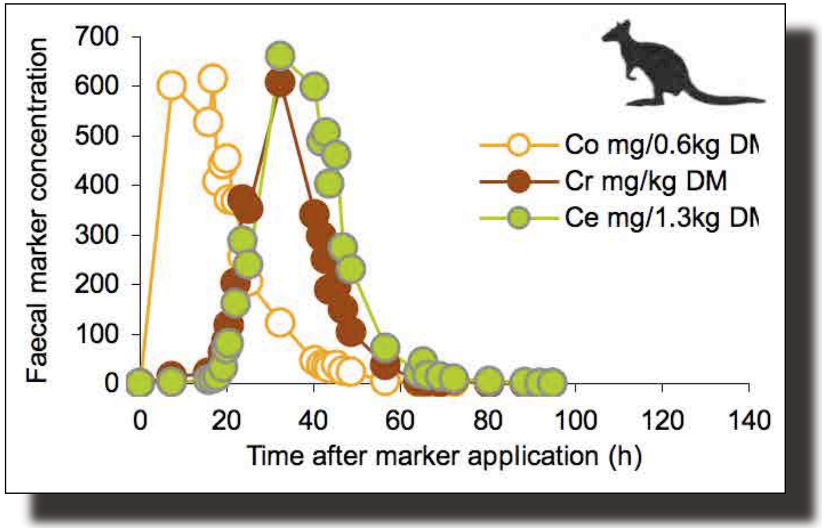

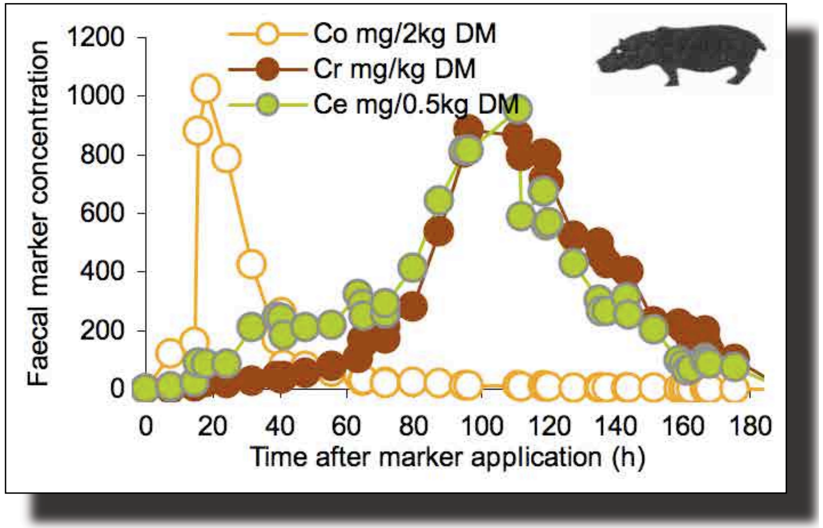

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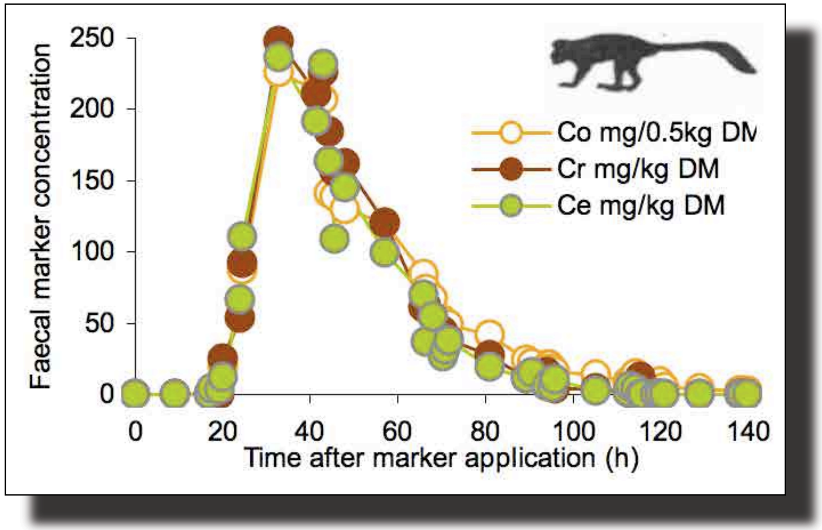

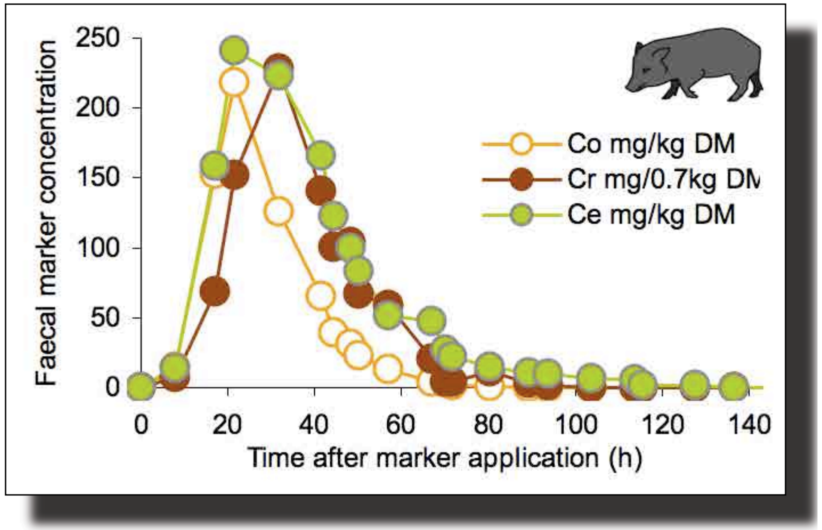

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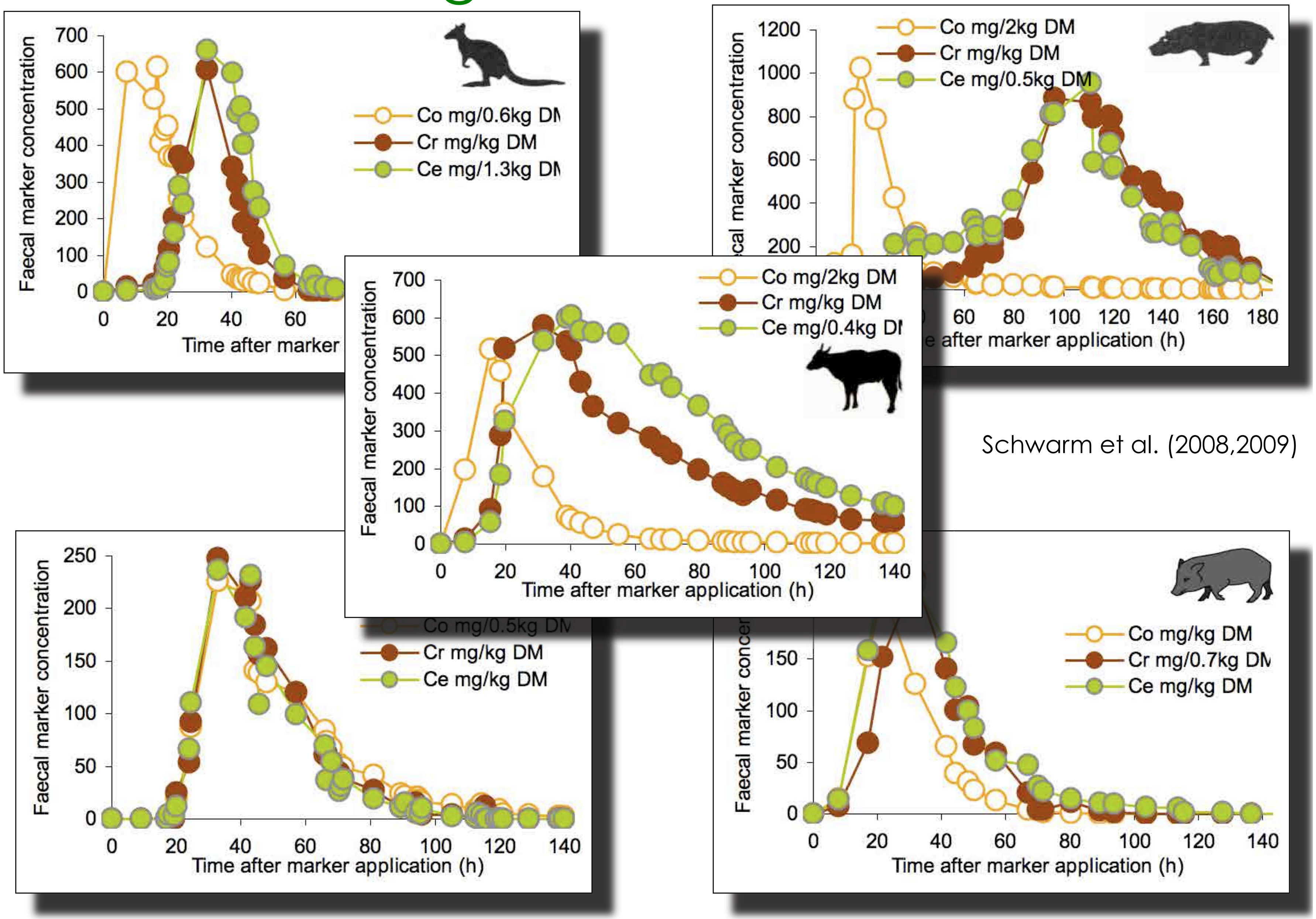

Schwarm et al. (2008,2009)

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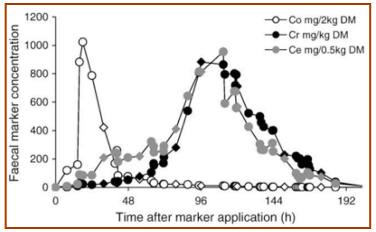
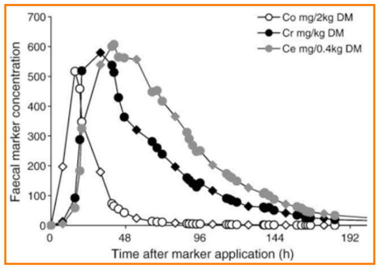
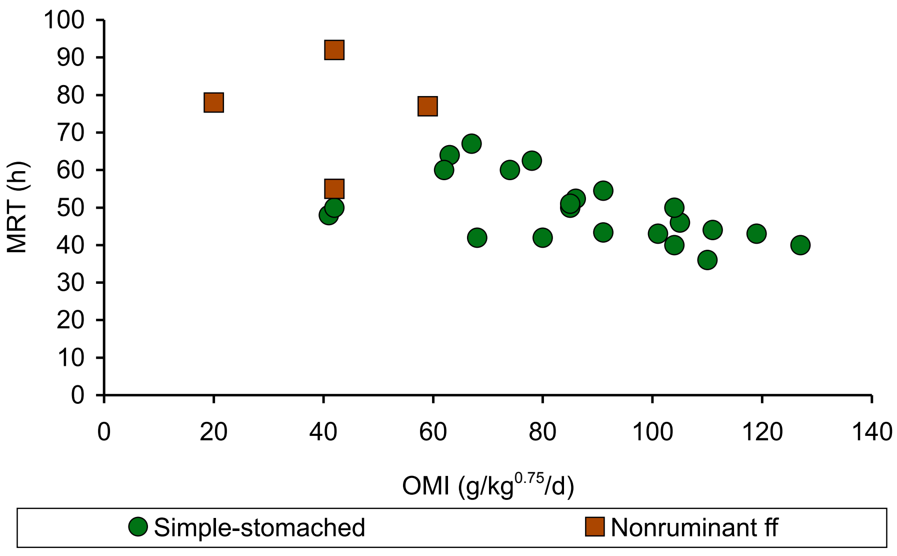
- higher food intake
- longer retention
- finer chewing

→ sorting !

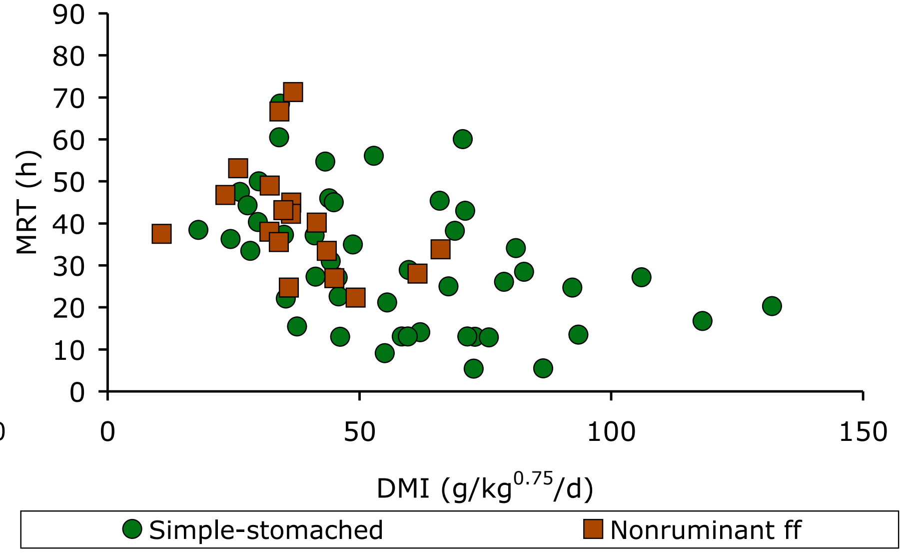




Intake and Passage

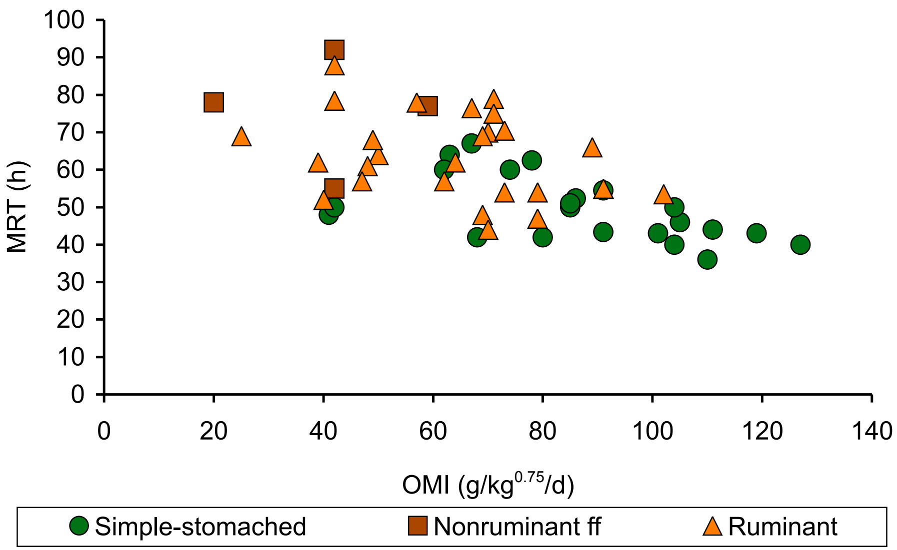


ungulates
from Foose (1982)



mammal herbivores
Clauss et al. (2007)

Intake and Passage



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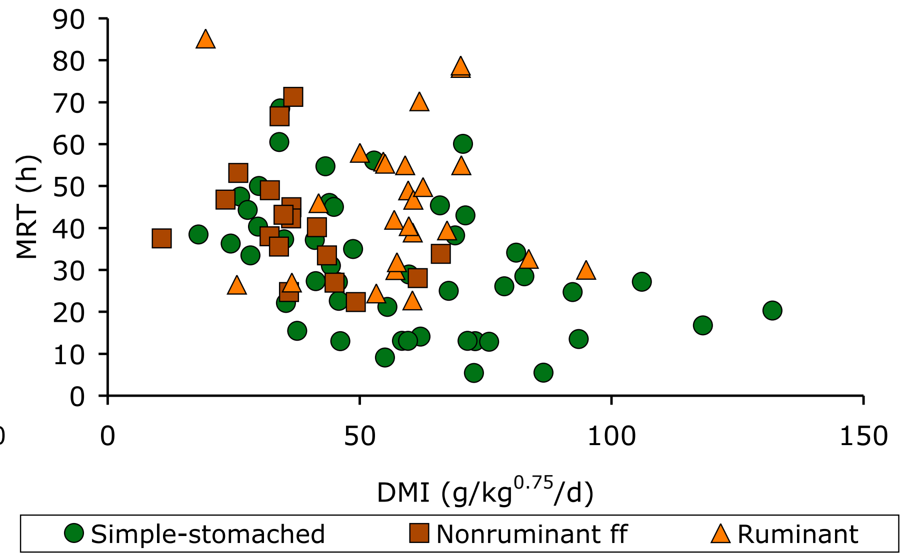
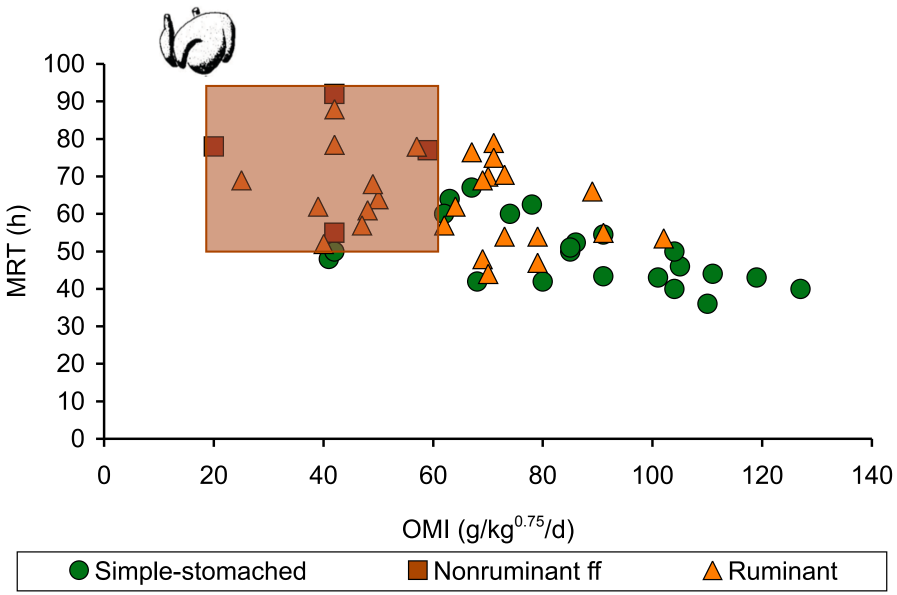
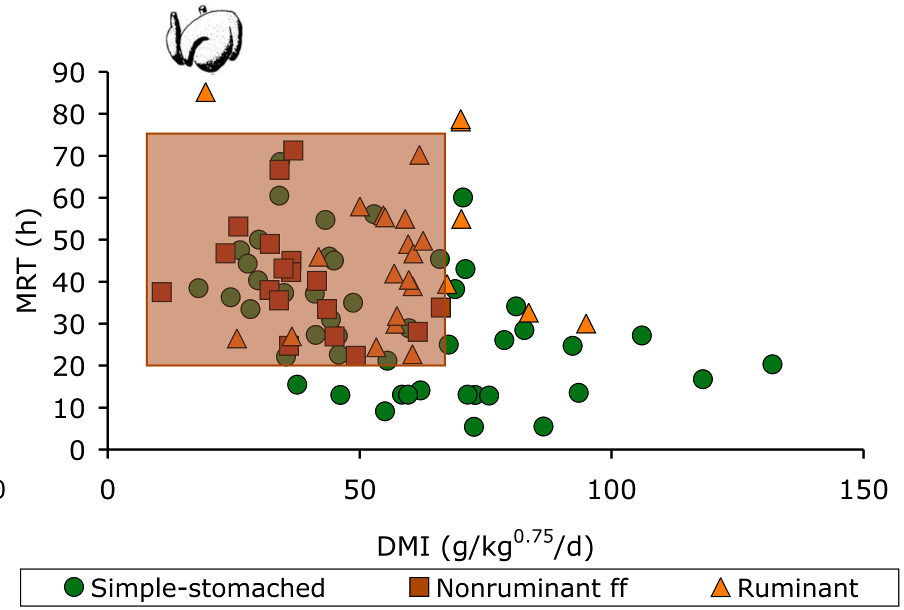


mammal herbivores
Clauss et al. (2007)

Intake and Passage



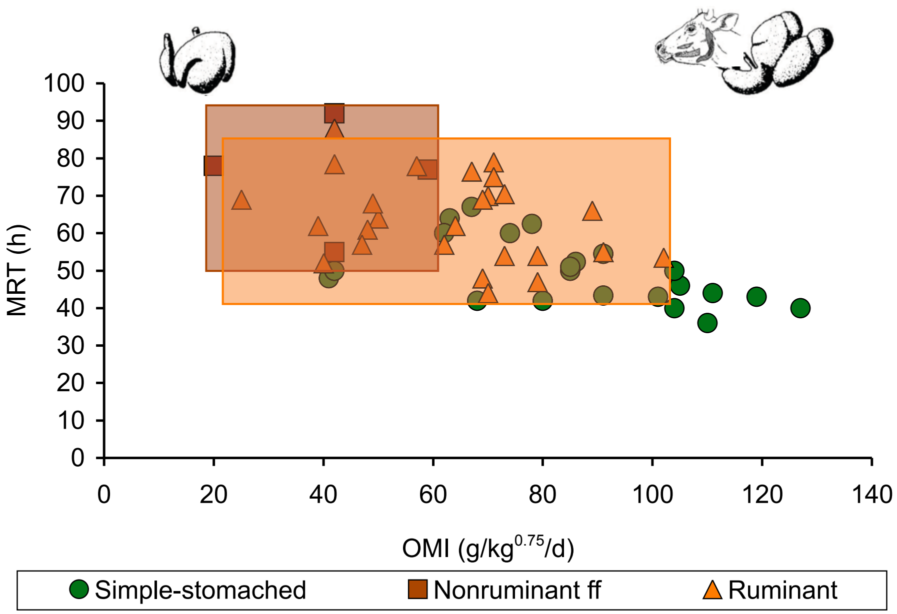


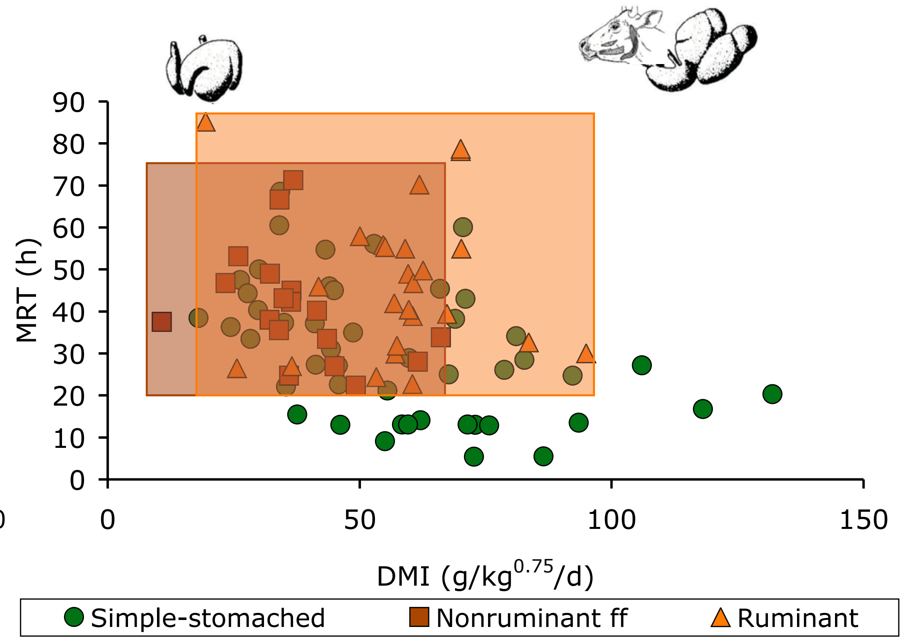
ungulates
from Foose (1982)

mammal herbivores
Clauss et al. (2007)

Intake and Passage

Ruminants expand the intake range of foregut fermenters (while retaining long retention times)





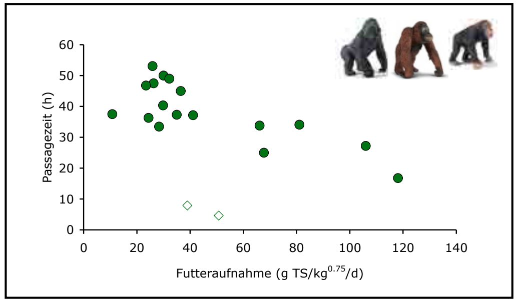
ungulates
from Foose (1982)

mammal herbivores
Clauss et al. (2007)

How can you increase energy intake?

- higher food intake

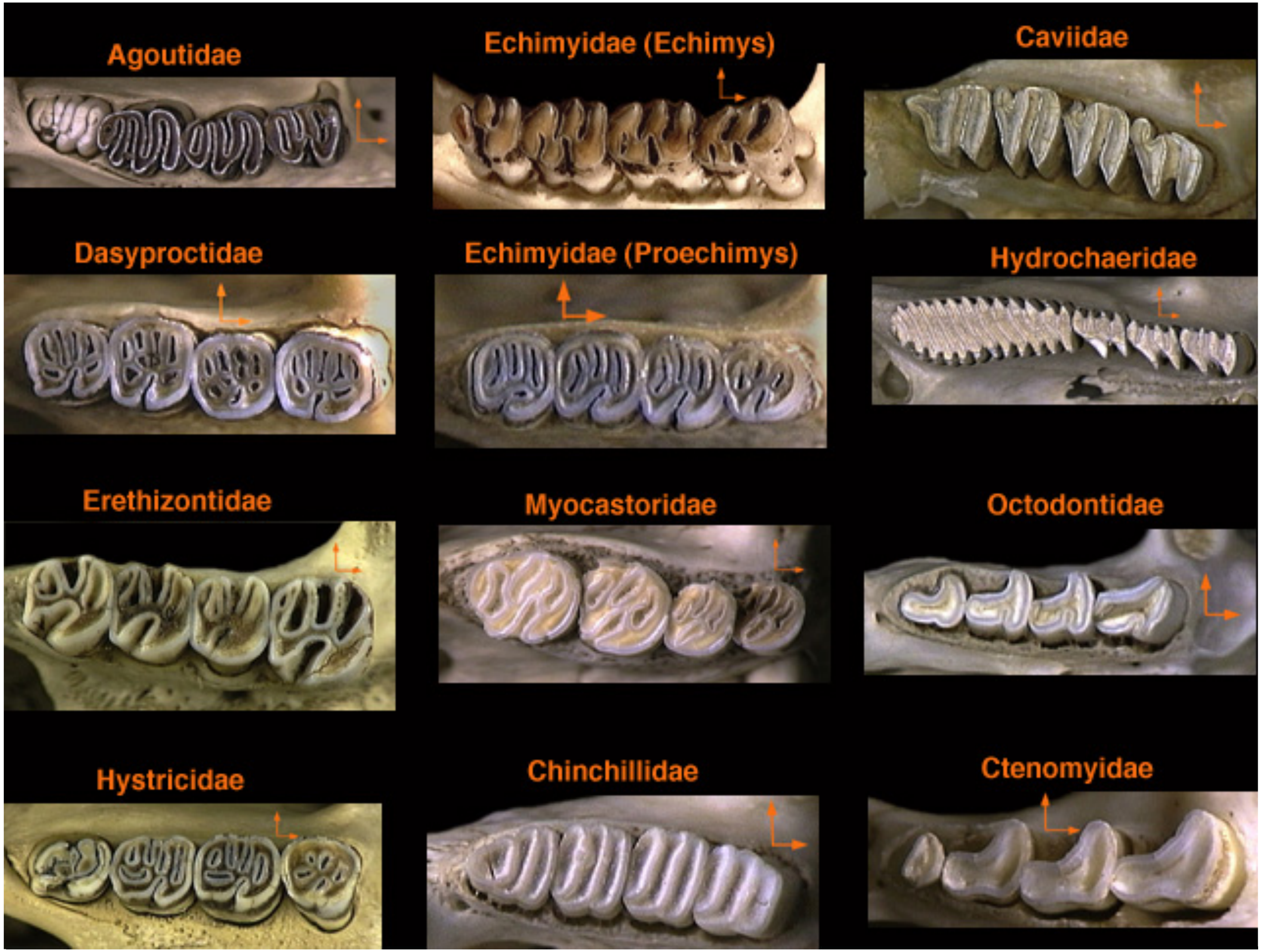
?



- longer retention

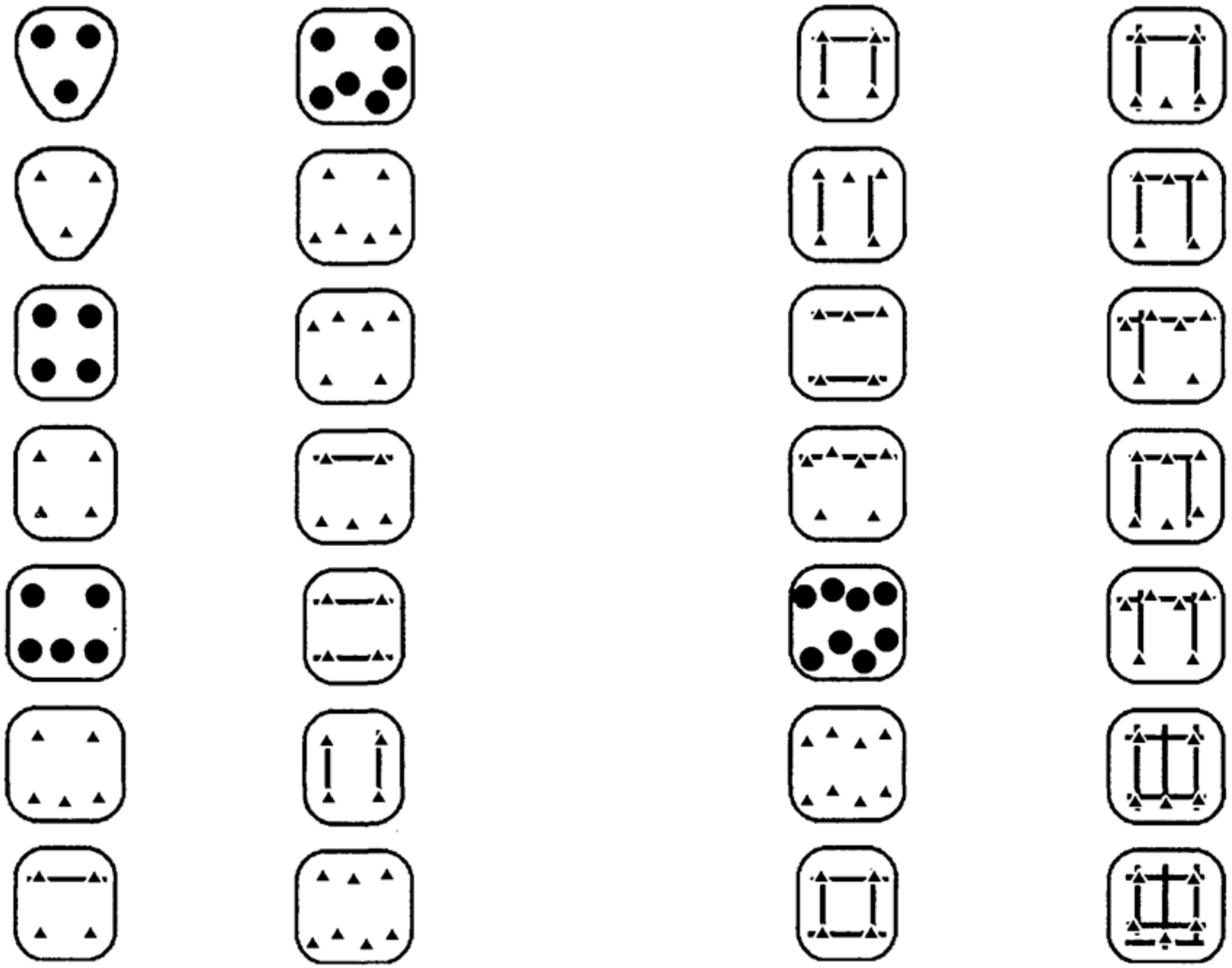
- finer chewing

“Mammals are the definite chewers”



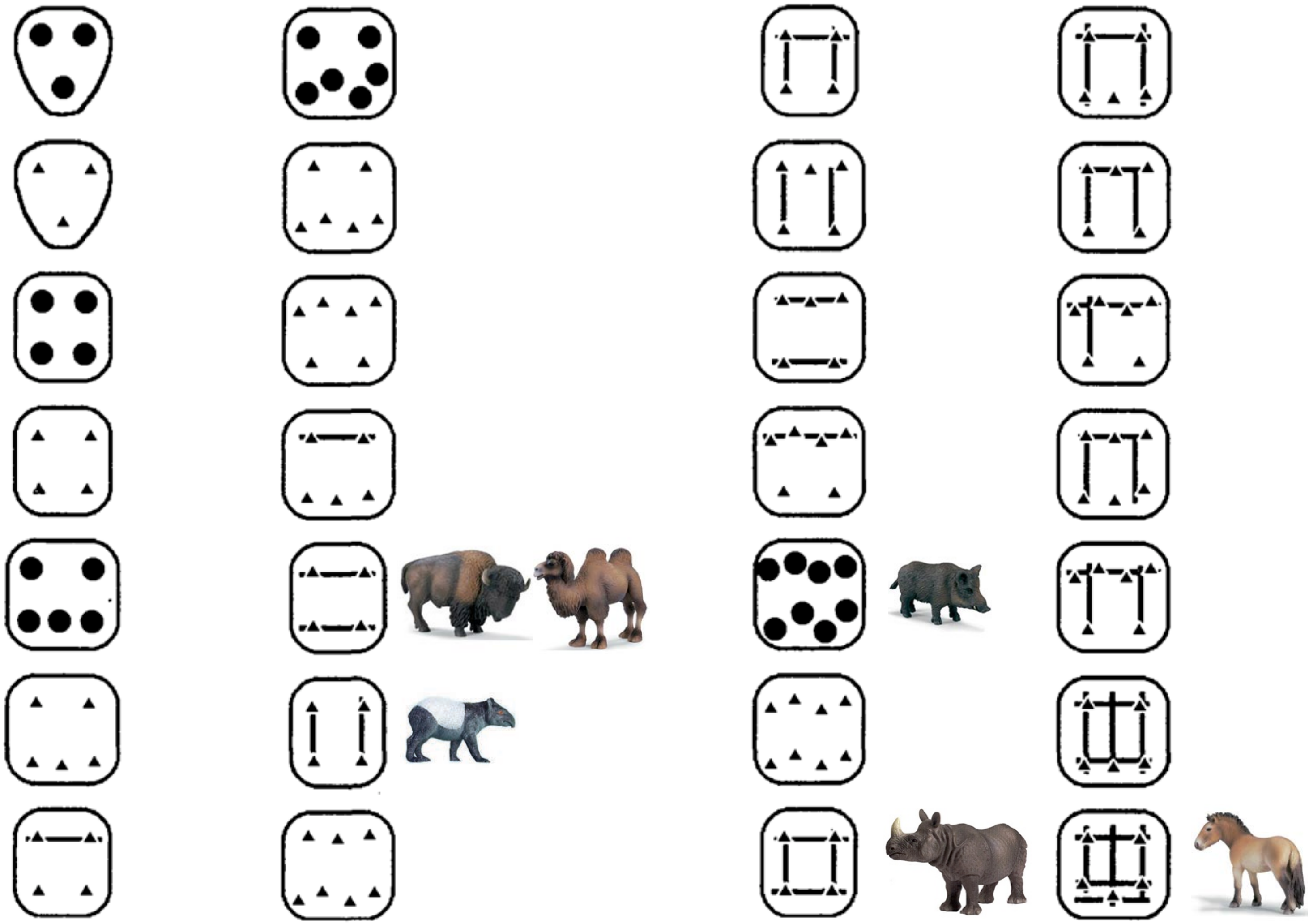
aus The Animal Diversity Web - http://animaldiversity.org

“Mammals are the definite chewers”



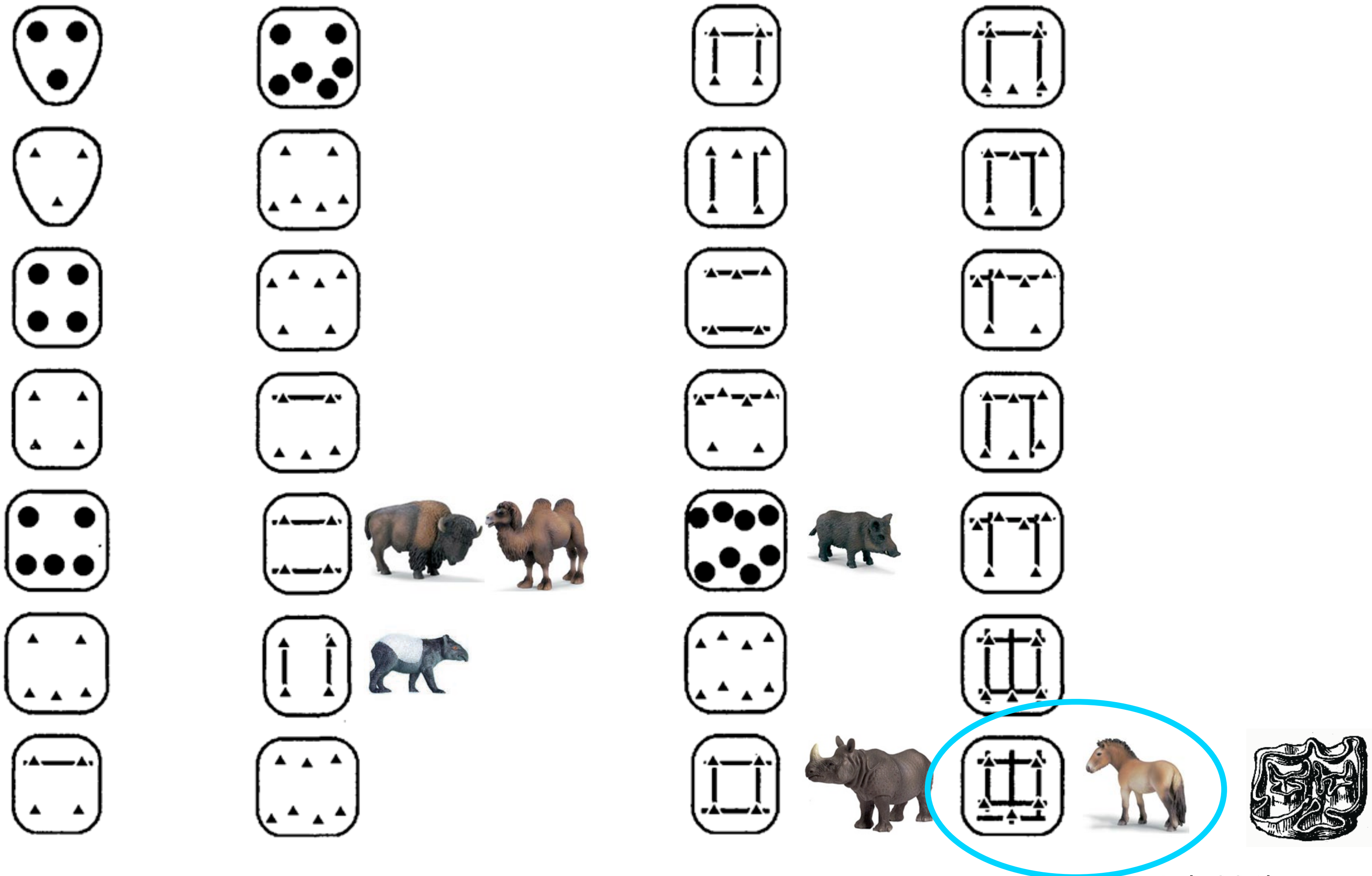
aus Jernvall et al. (1996)

“Mammals are the definite chewers”



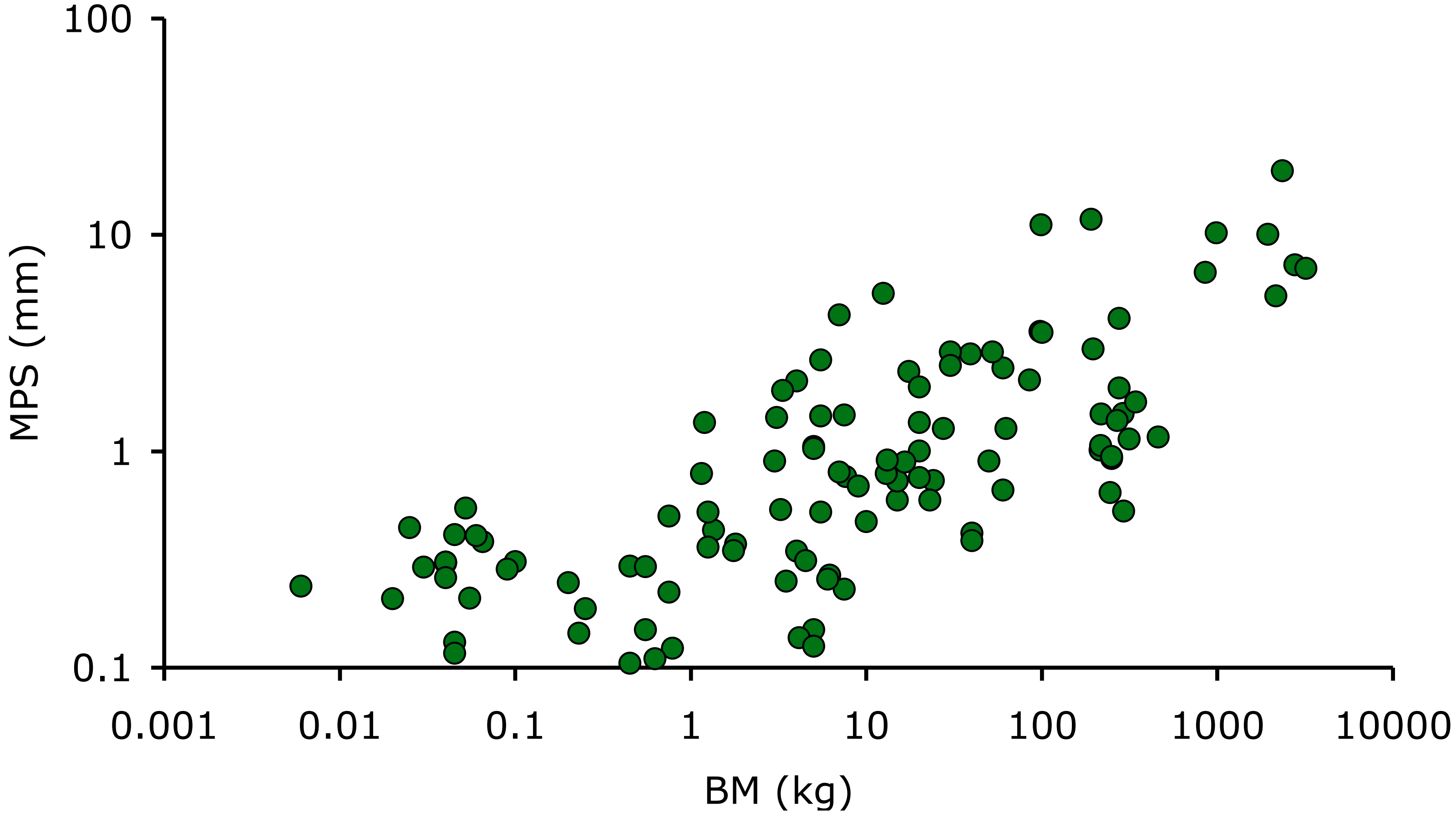
aus Jernvall et al. (1996)

“Mammals are the definite chewers”



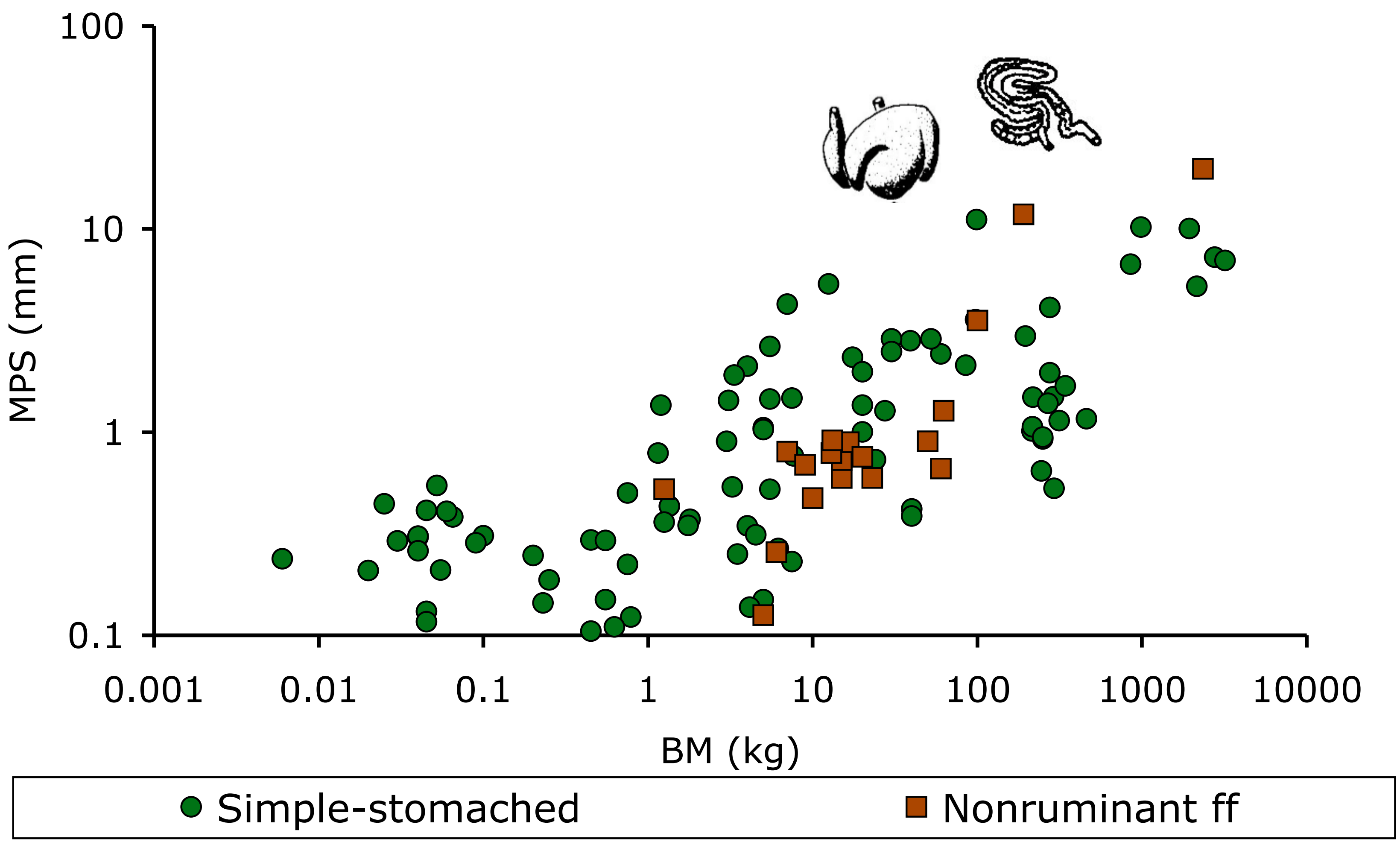
aus Jernvall et al. (1996)

Ingesta particle size (chewing efficiency)



from Fritz (2007)

Ingesta particle size (chewing efficiency)



from Fritz (2007)

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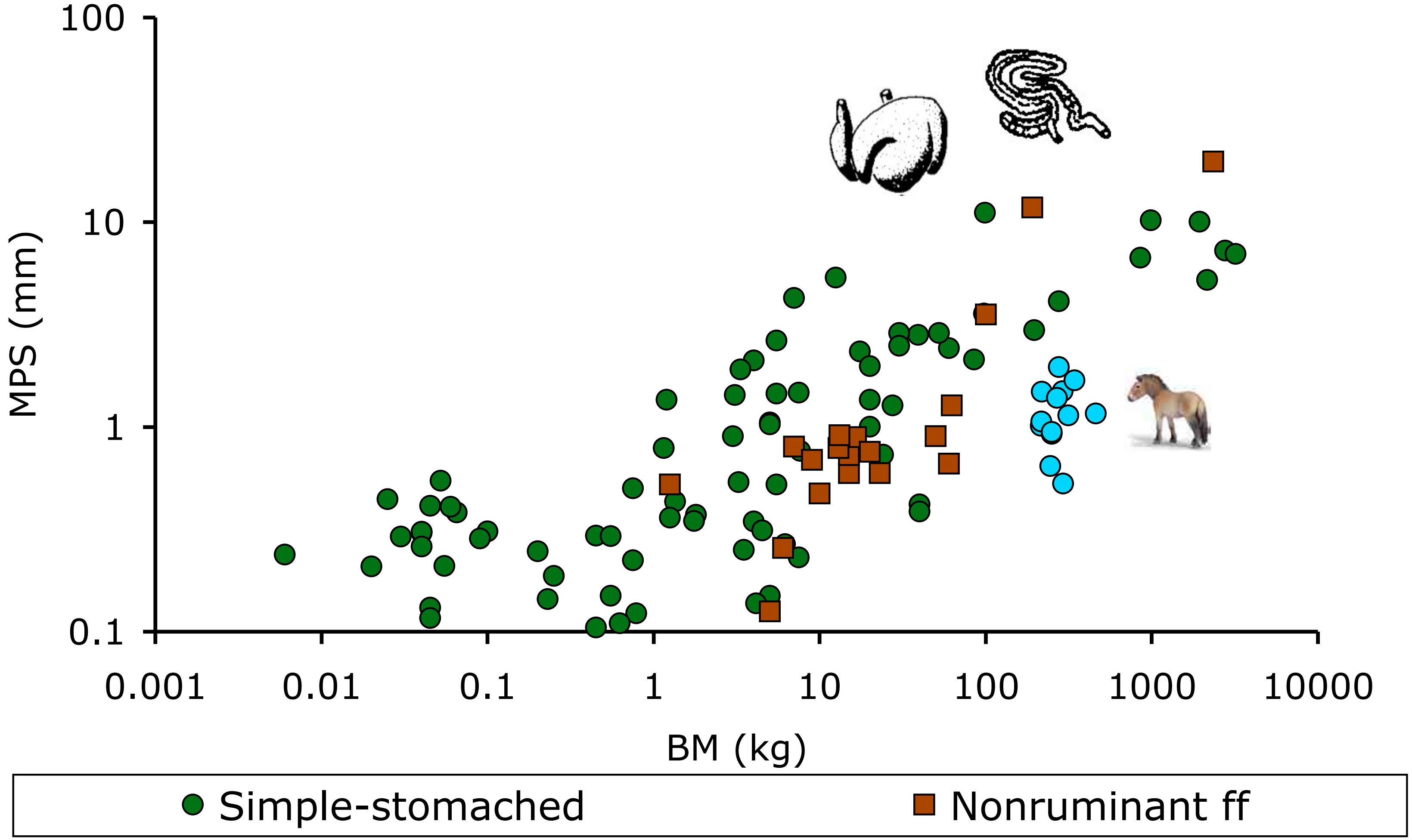

from Fritz (2007)

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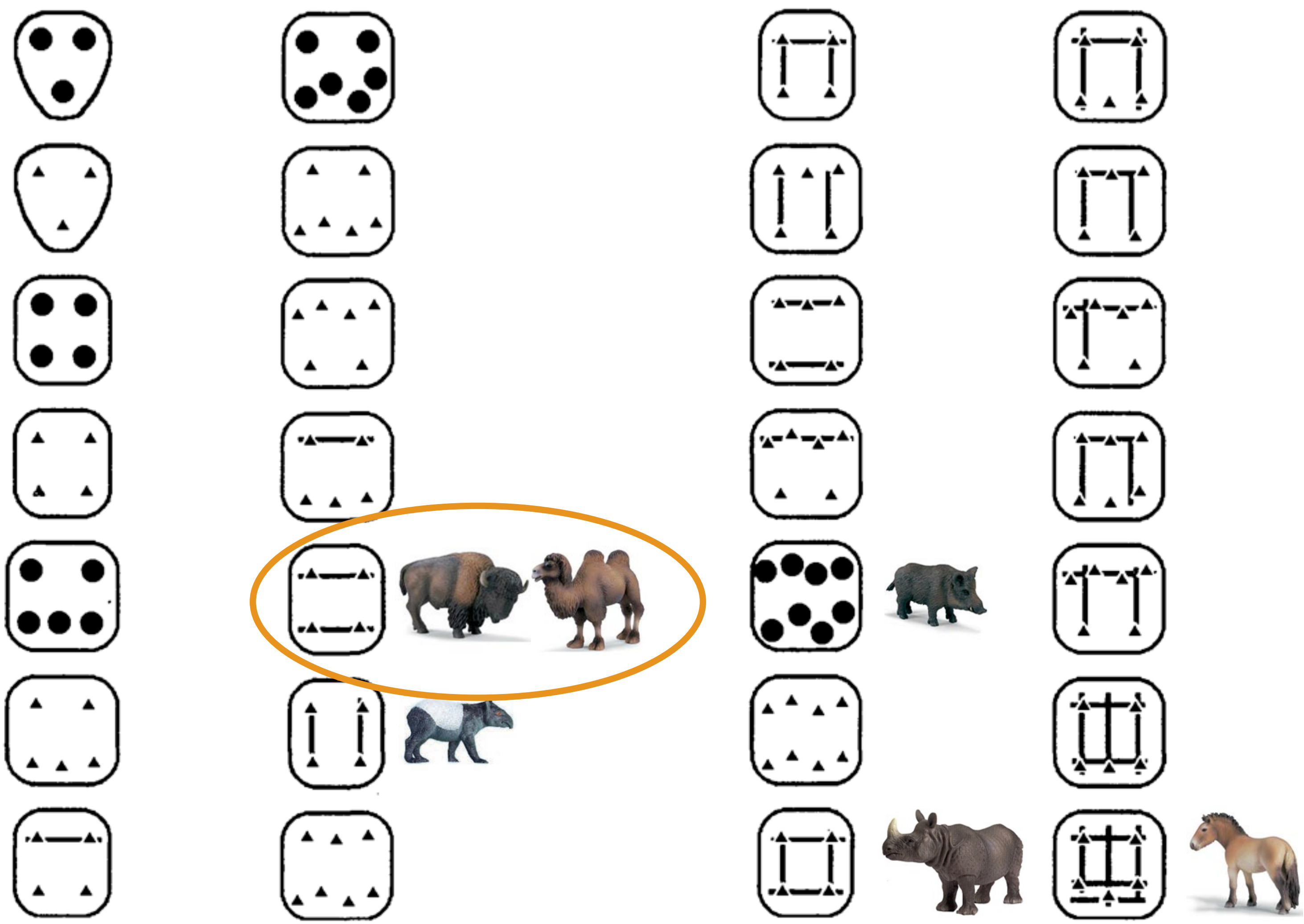

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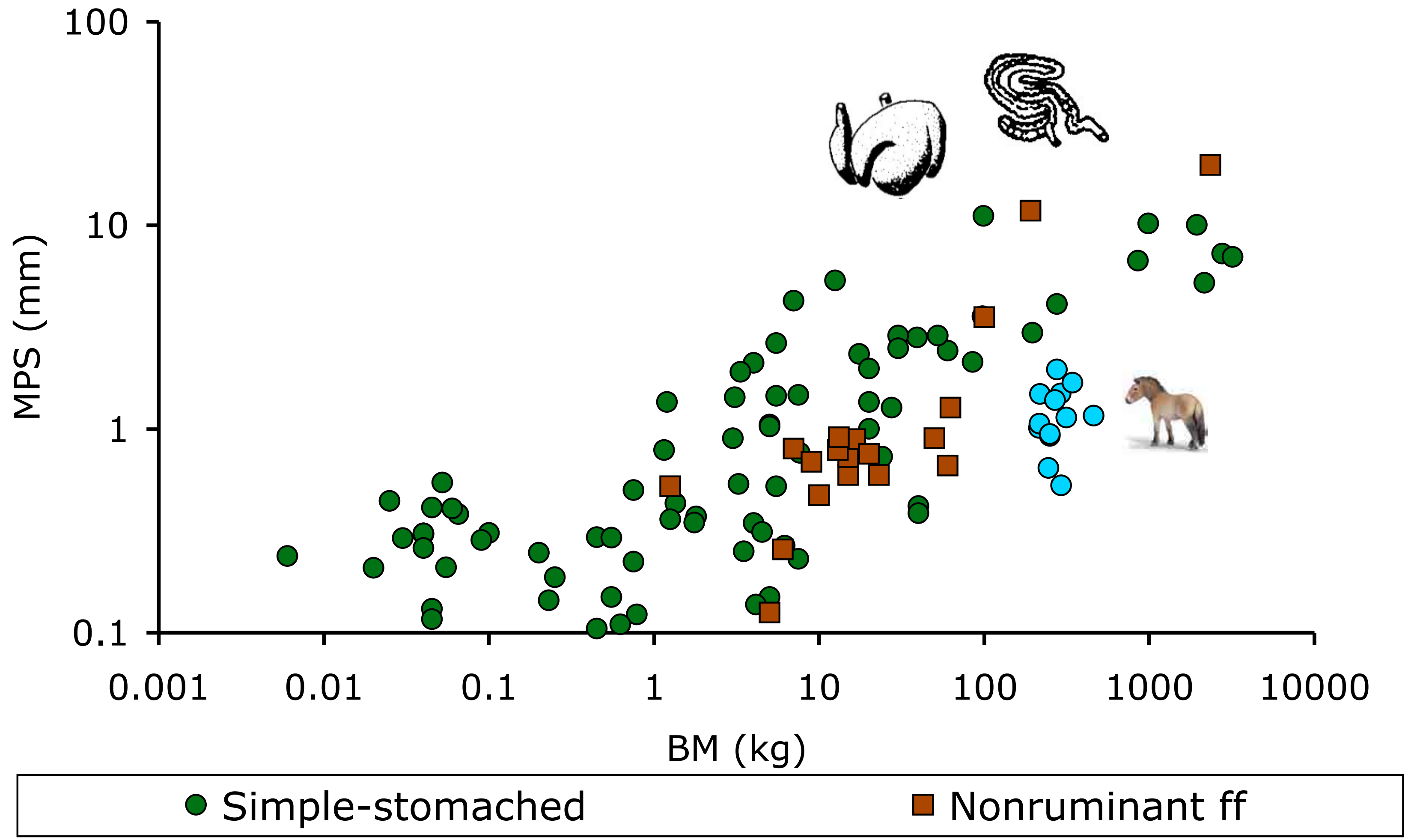
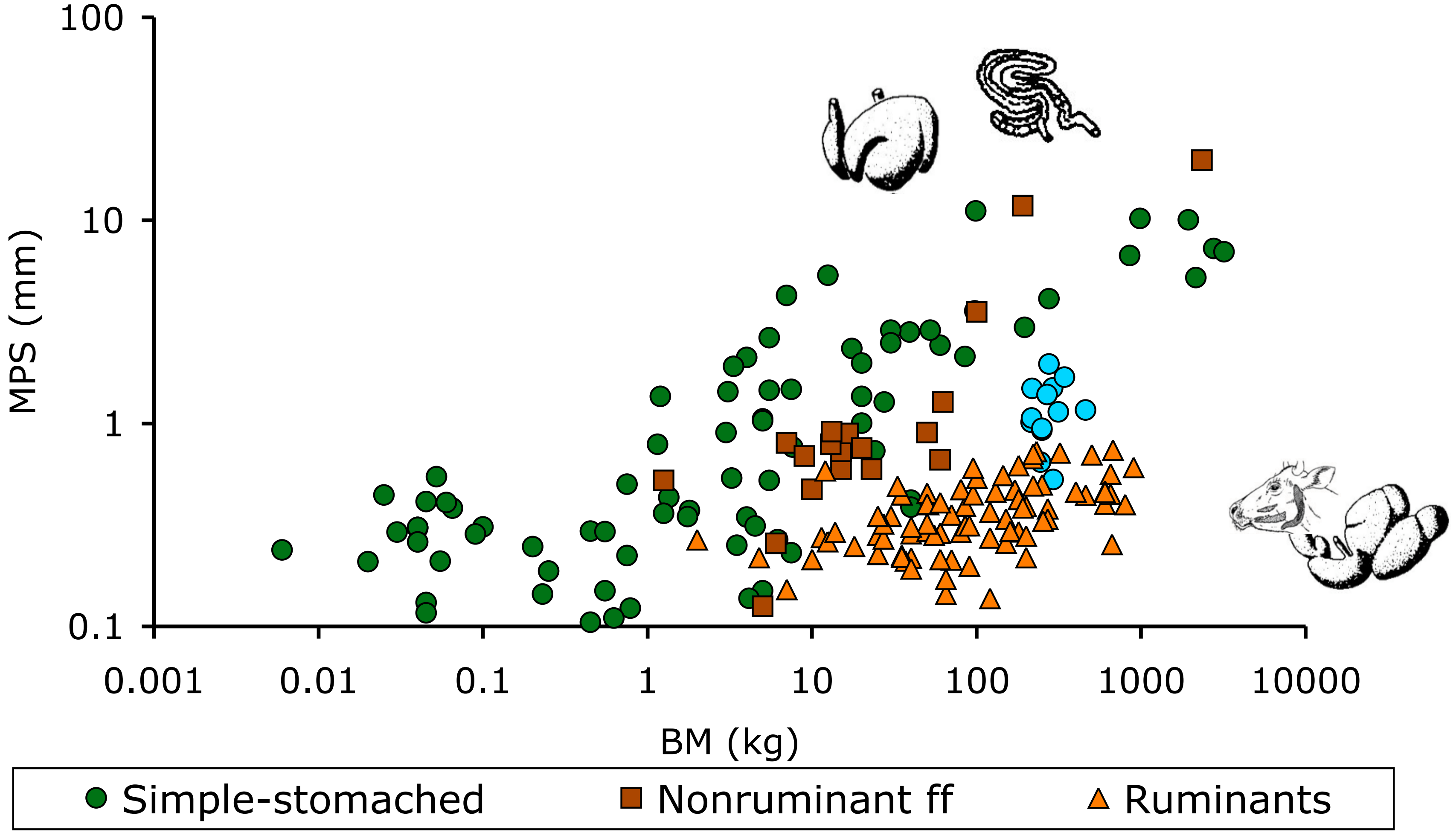


from Fritz (2007)

Ingesta particle size (chewing efficiency)



from Fritz (2007)

Why can ‘t everyone just chew more?

Chewing in ruminants and nonruminants

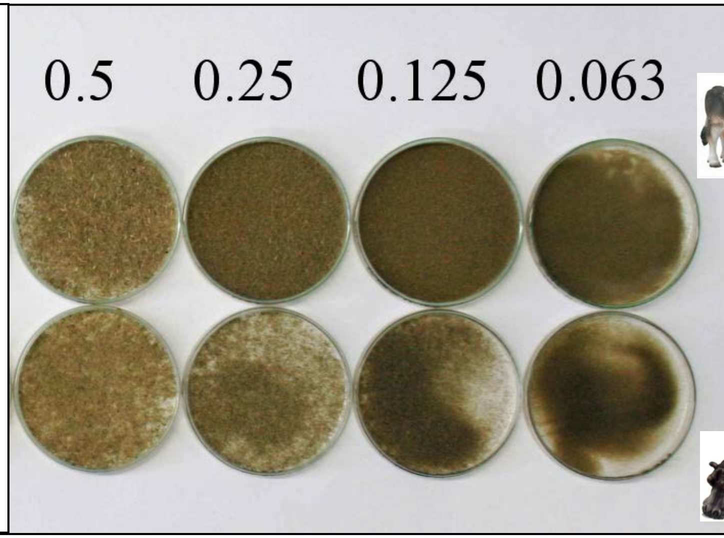


Photo A. Schwarm

Chewing in ruminants and nonruminants

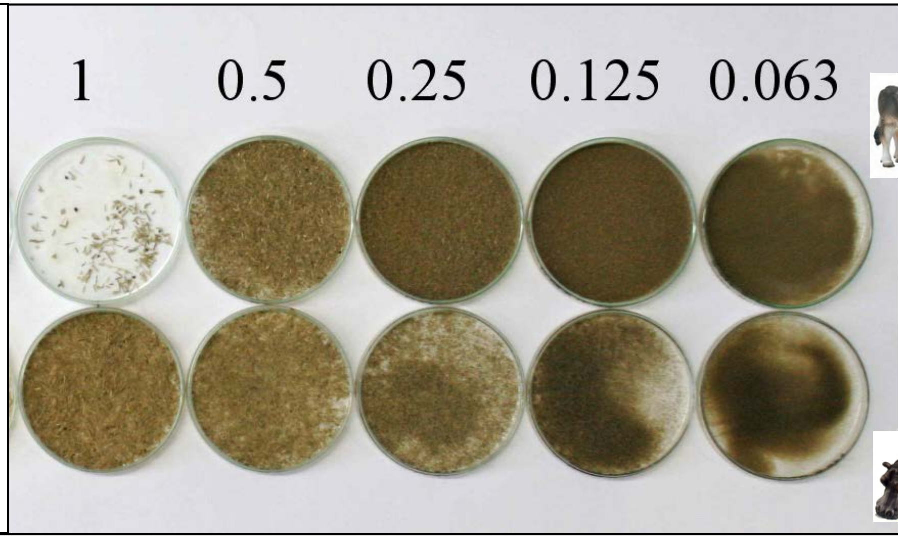


Photo A. Schwarm

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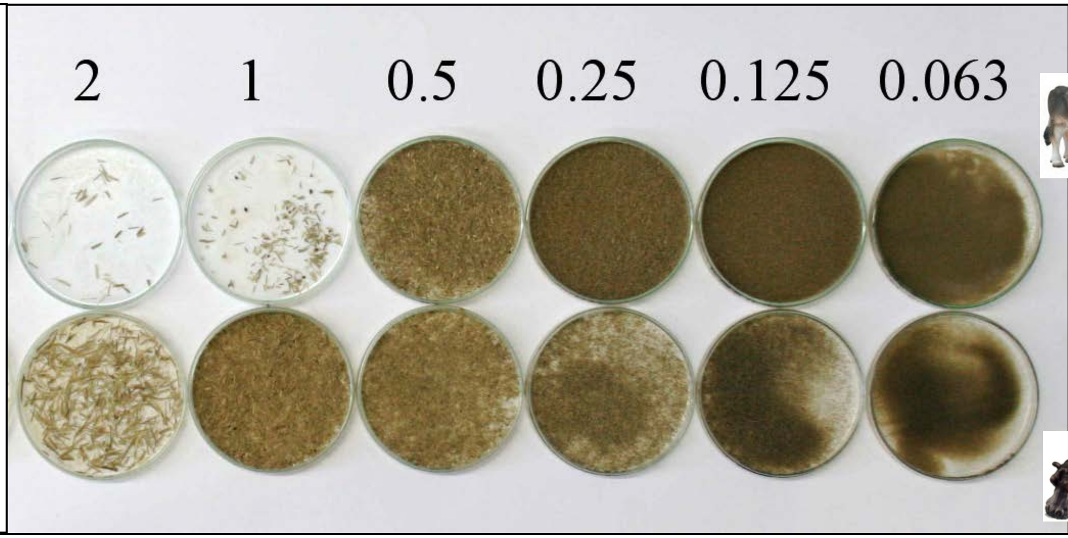

Photo A. Schwarm

Chewing in ruminants and nonruminants

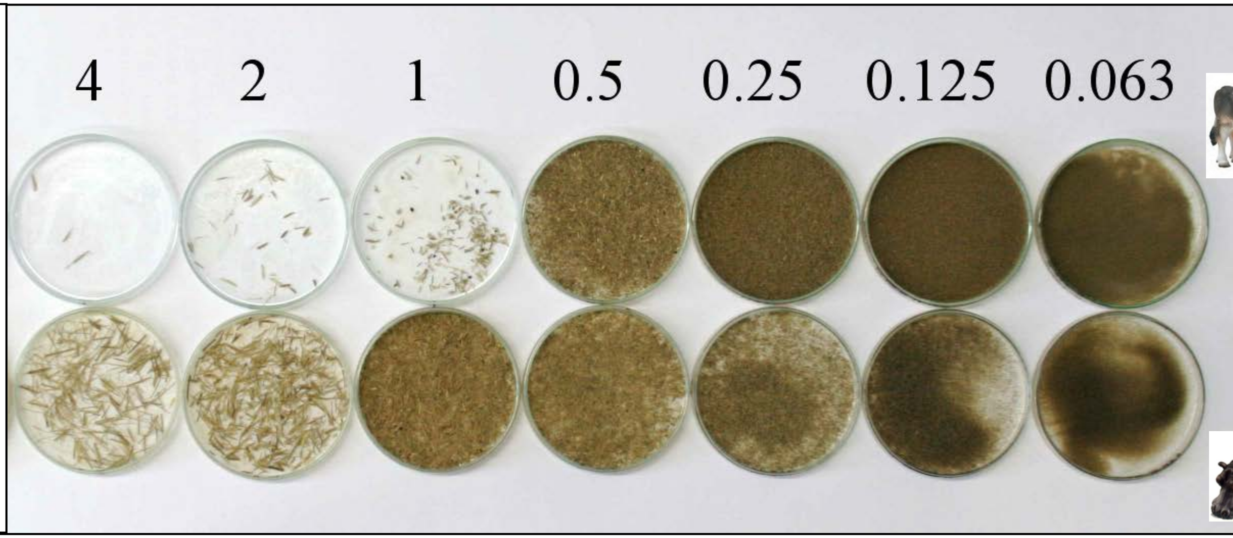

Photo A. Schwarm

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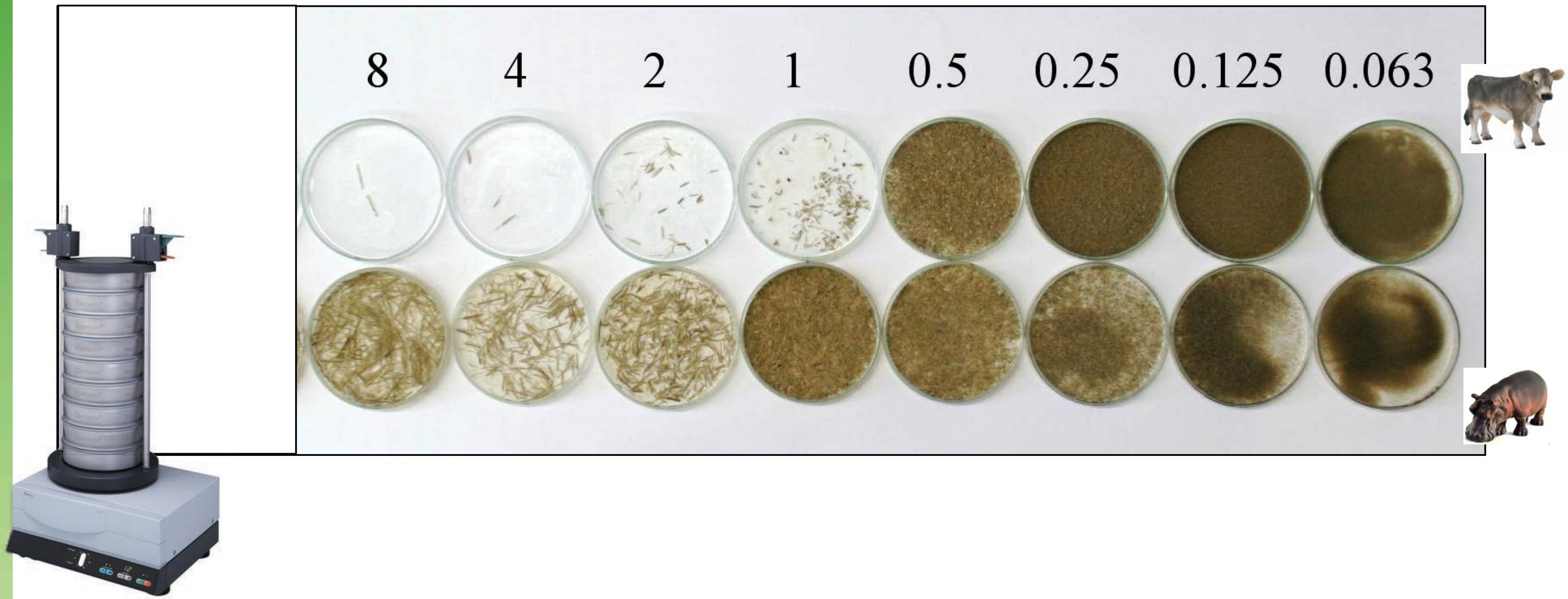


Photo A. Schwarm

Chewing in ruminants and nonruminants

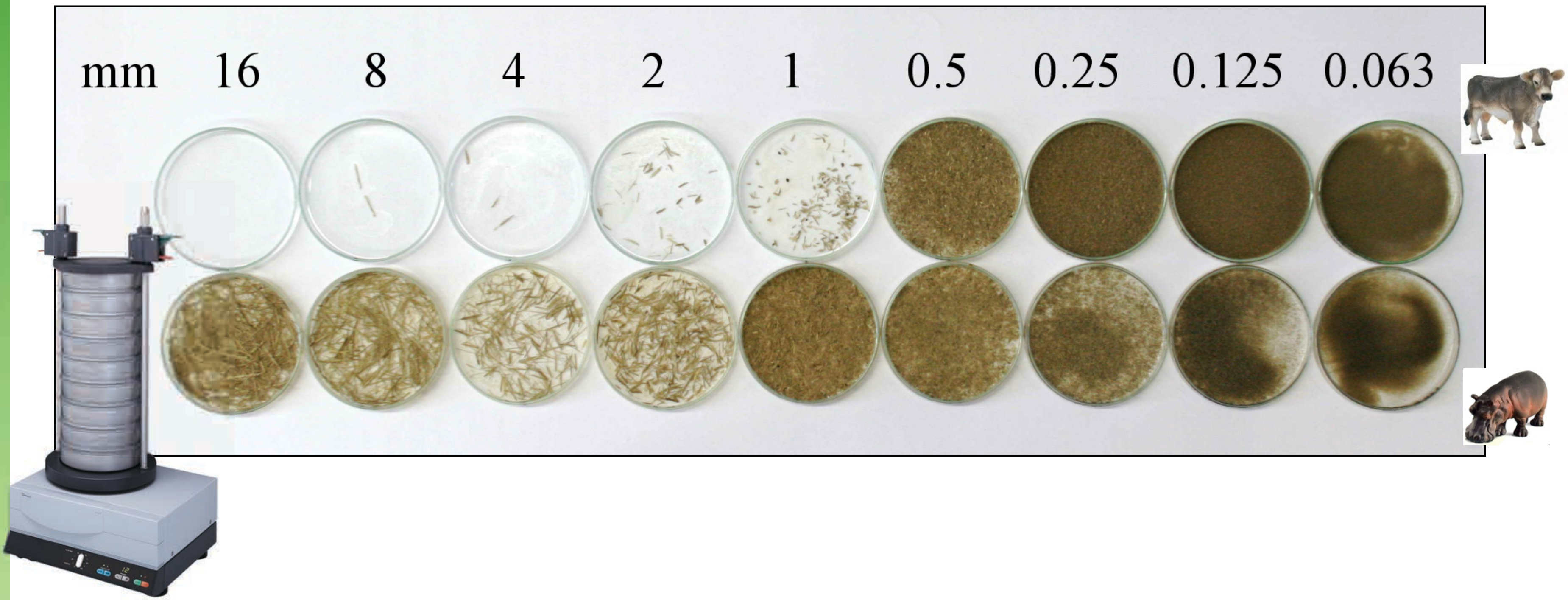
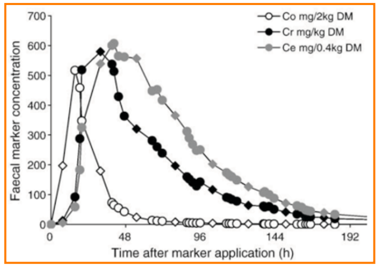


Photo A. Schwarm

How can you increase energy intake?

- higher food intake
- longer retention

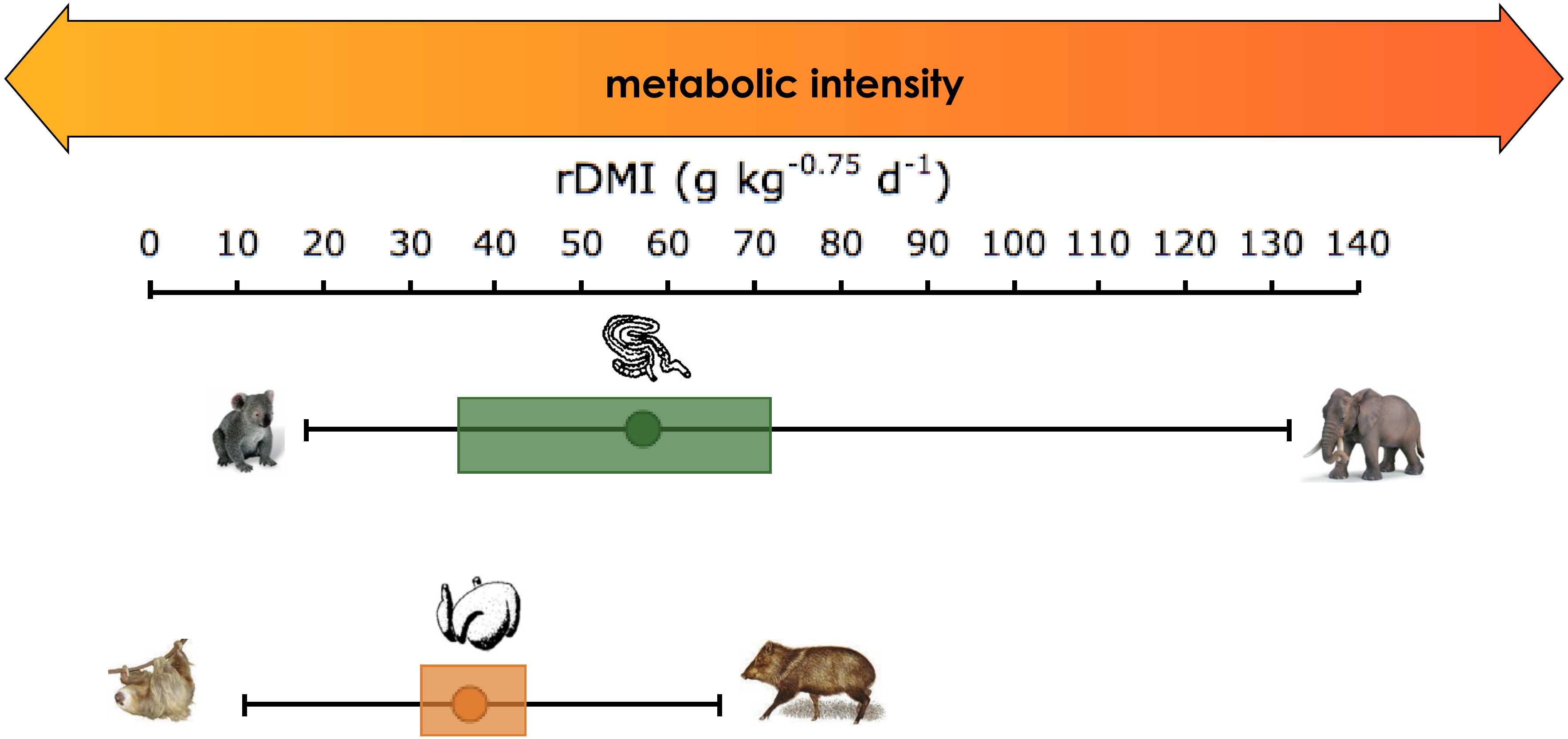
→ sorting !



- finer chewing

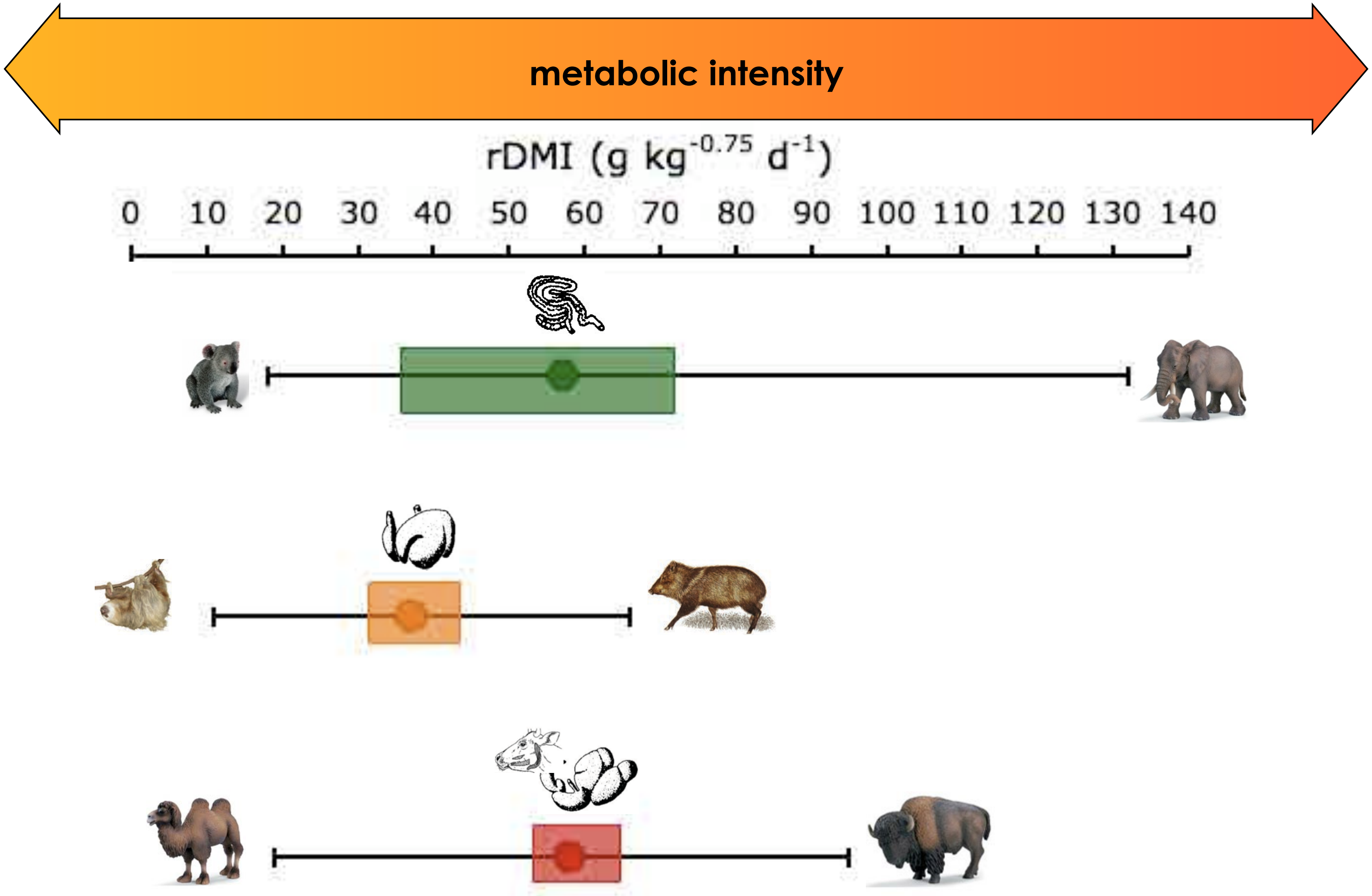
→ sorting !

Conceptualizing herbivore diversity



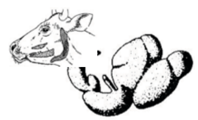
from Clauss et al. (2010)

Conceptualizing herbivore diversity



from Clauss et al. (2010)

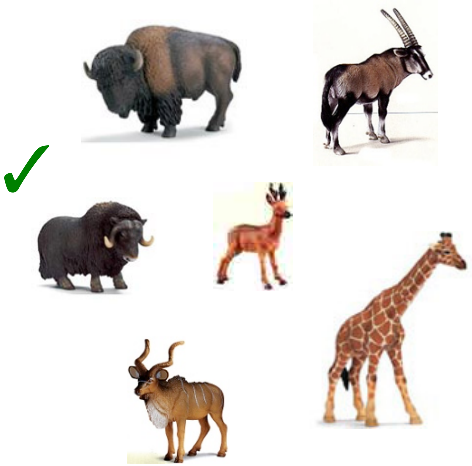
Digestive and Metabolic Strategies

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

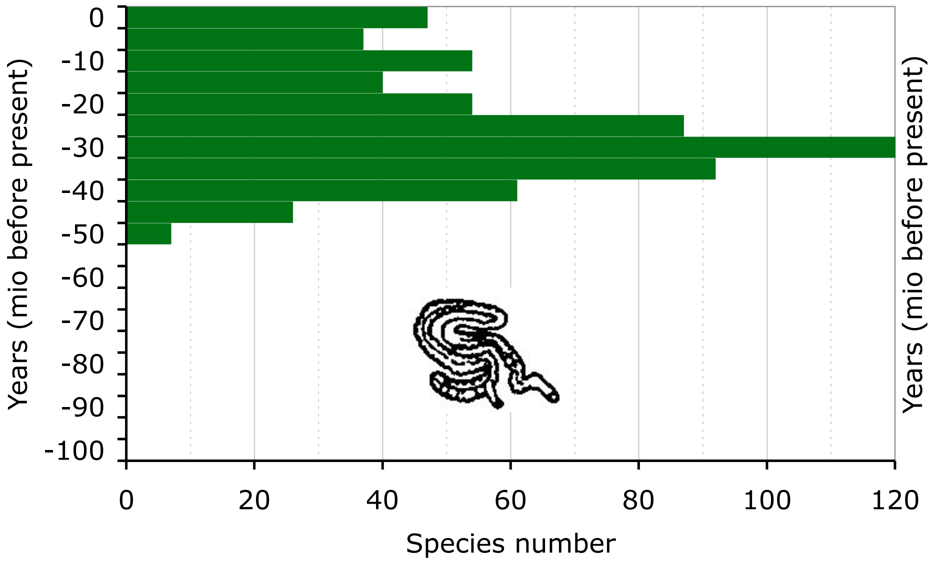
Digestive and Metabolic Strategies

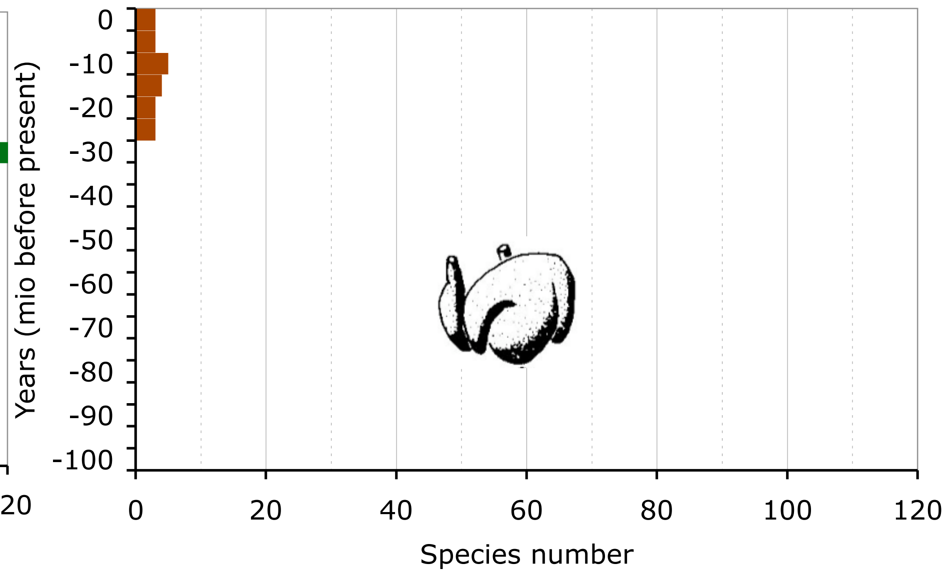
			
Low intake ⇒ long passage ⇒ ***low metabolism***	✓	✓	✓ 
High intake ⇒ differentiated passage ⇒ ***high metabolism***	✓	✗	

Digestive and Metabolic Strategies

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

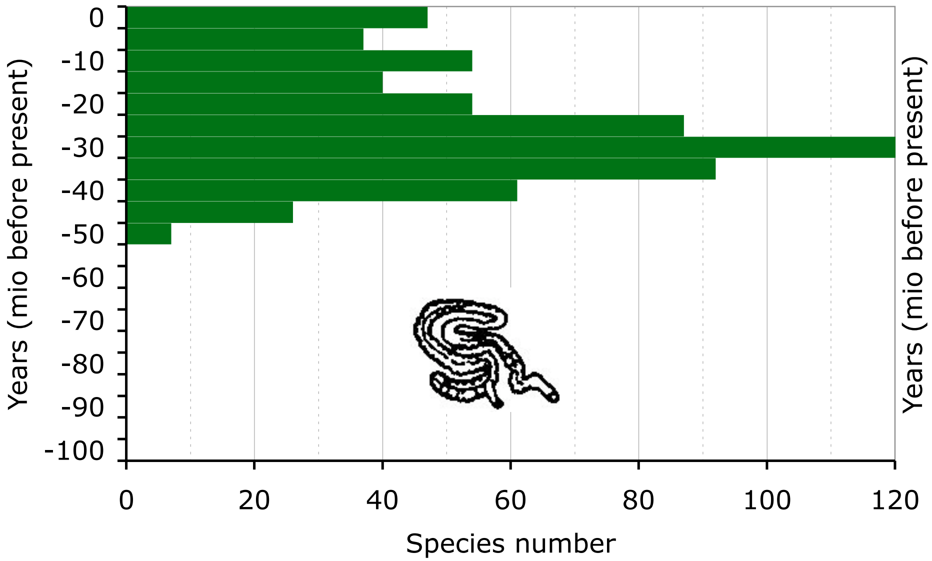
European Mammal Herbivores in Deep Time

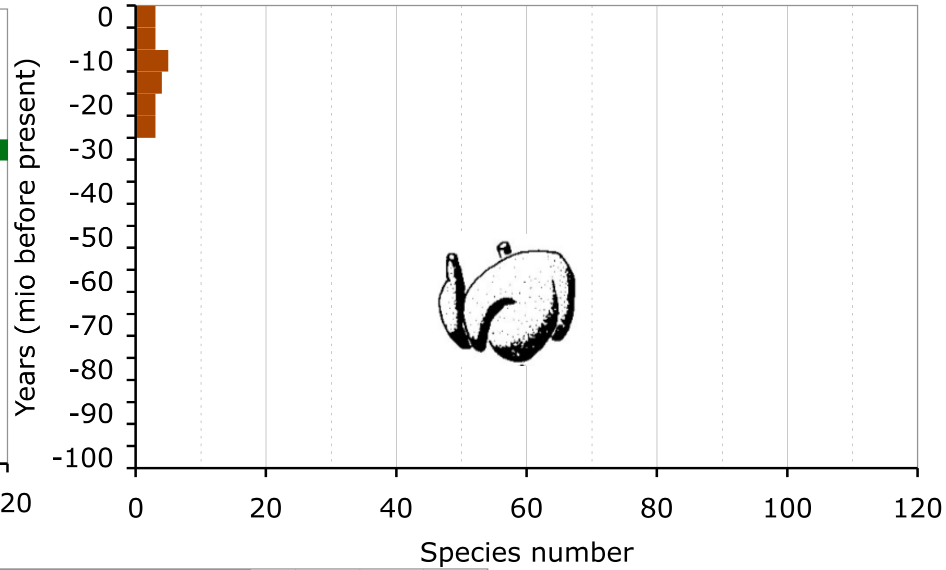


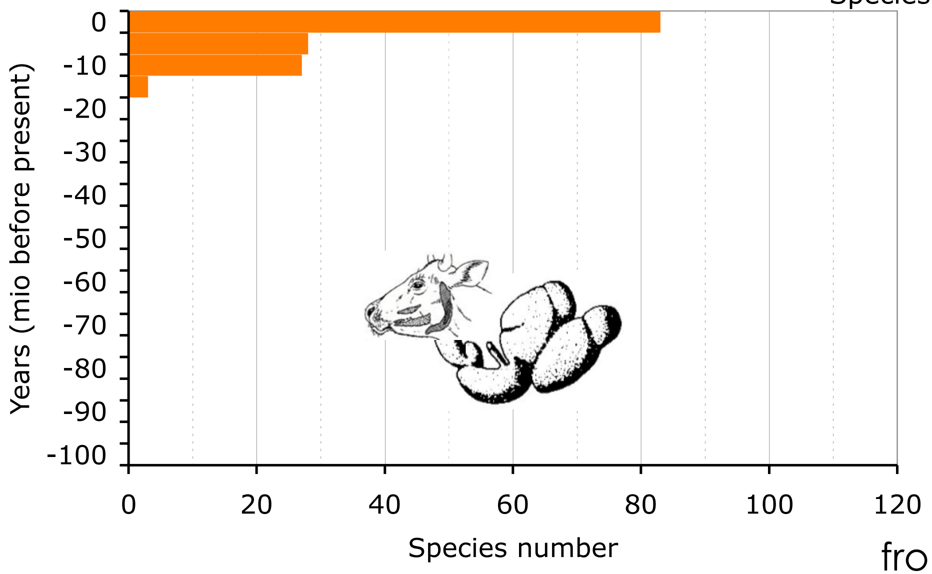


from Langer (1991)

European Mammal Herbivores in Deep Time

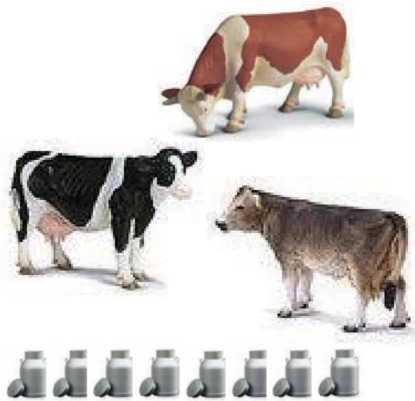




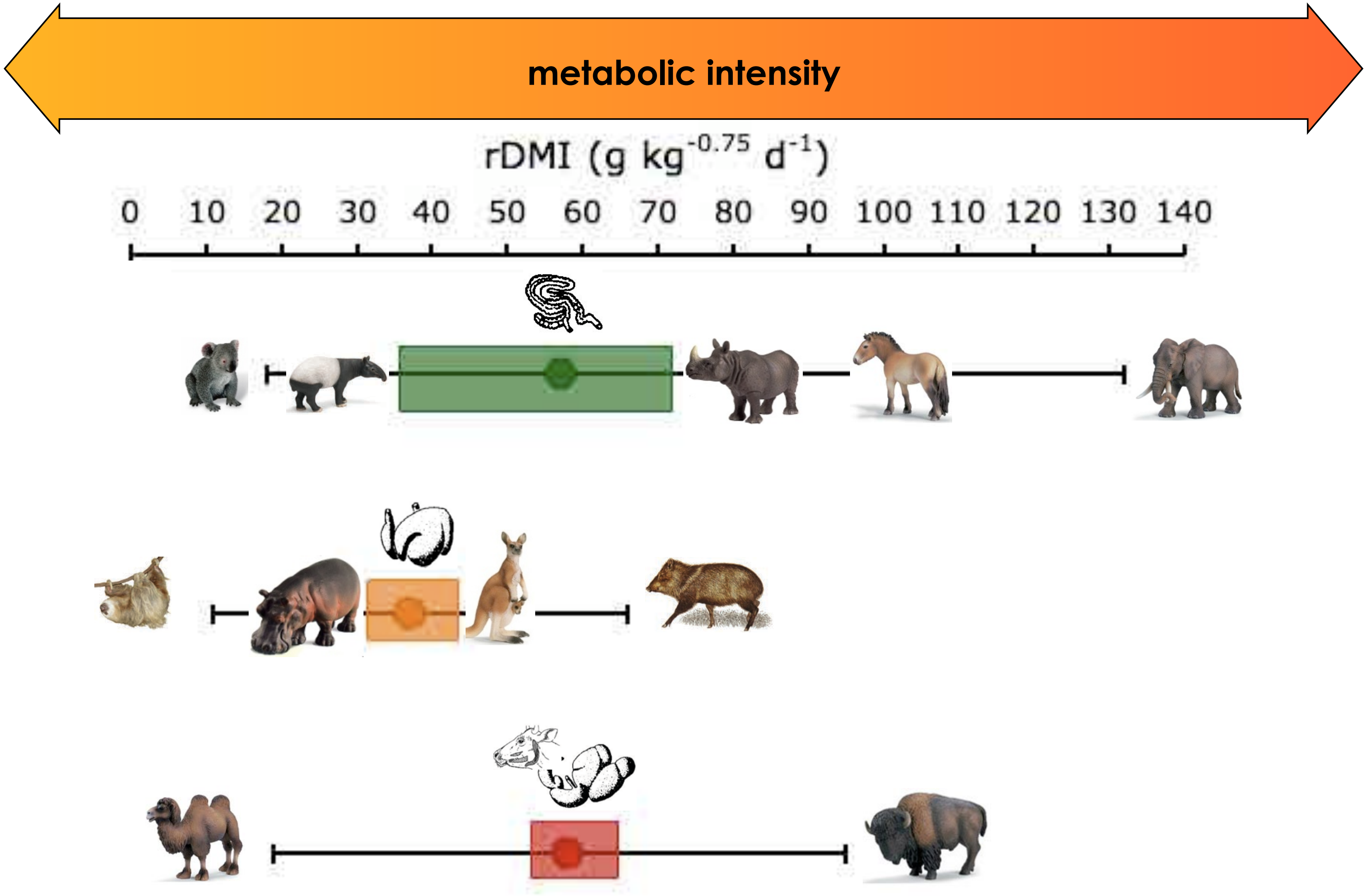


from Langer (1991)

Digestive and Metabolic Strategies

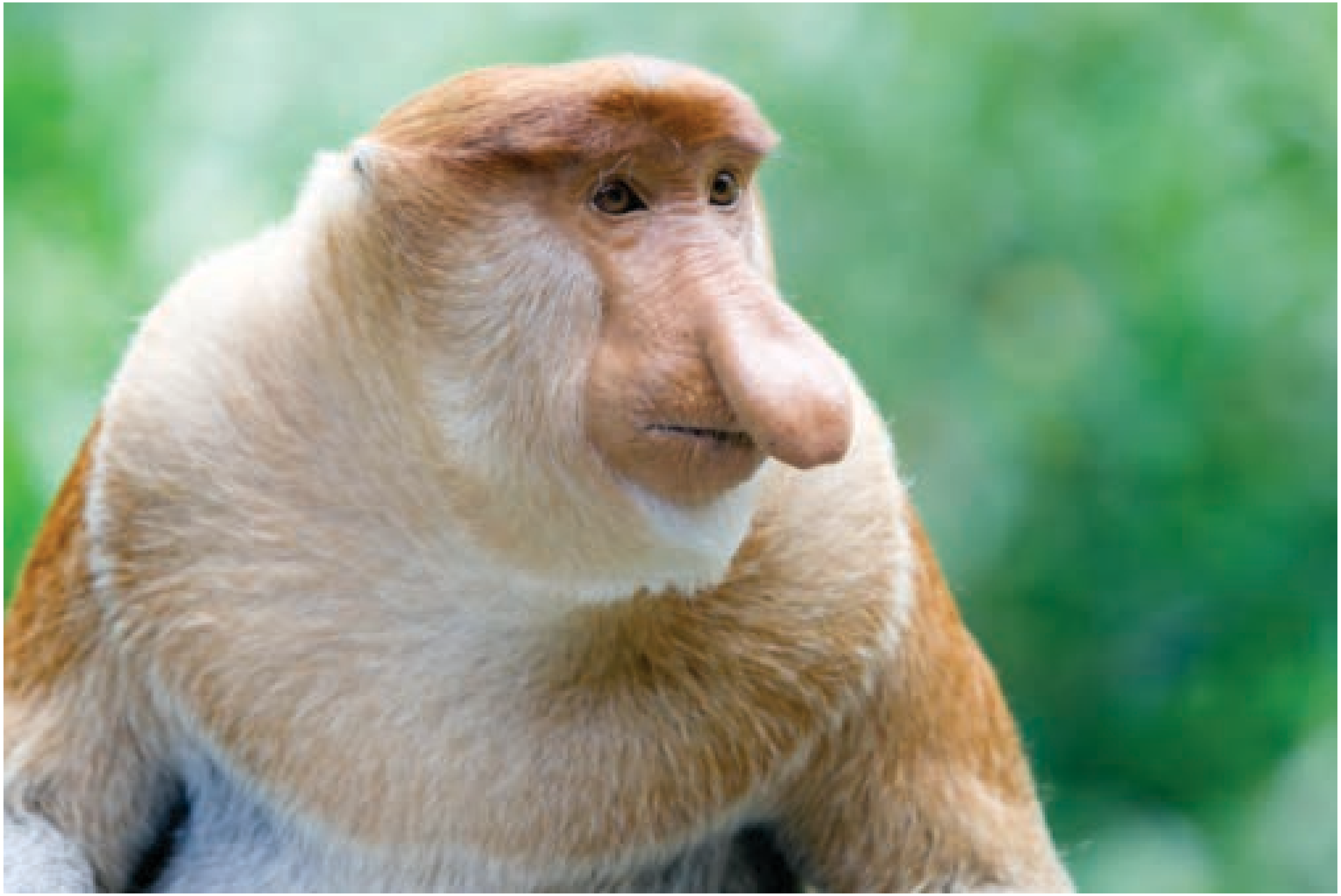
				
Low intake ⇒ long passage ⇒ ***low BMR***	✓	✓	✓	
High intake ⇒ differentiated passage ⇒ ***high BMR***	✓	✗	✓	

Conceptualizing herbivore diversity



from Clauss et al. (2010)

The case of the proboscis monkey



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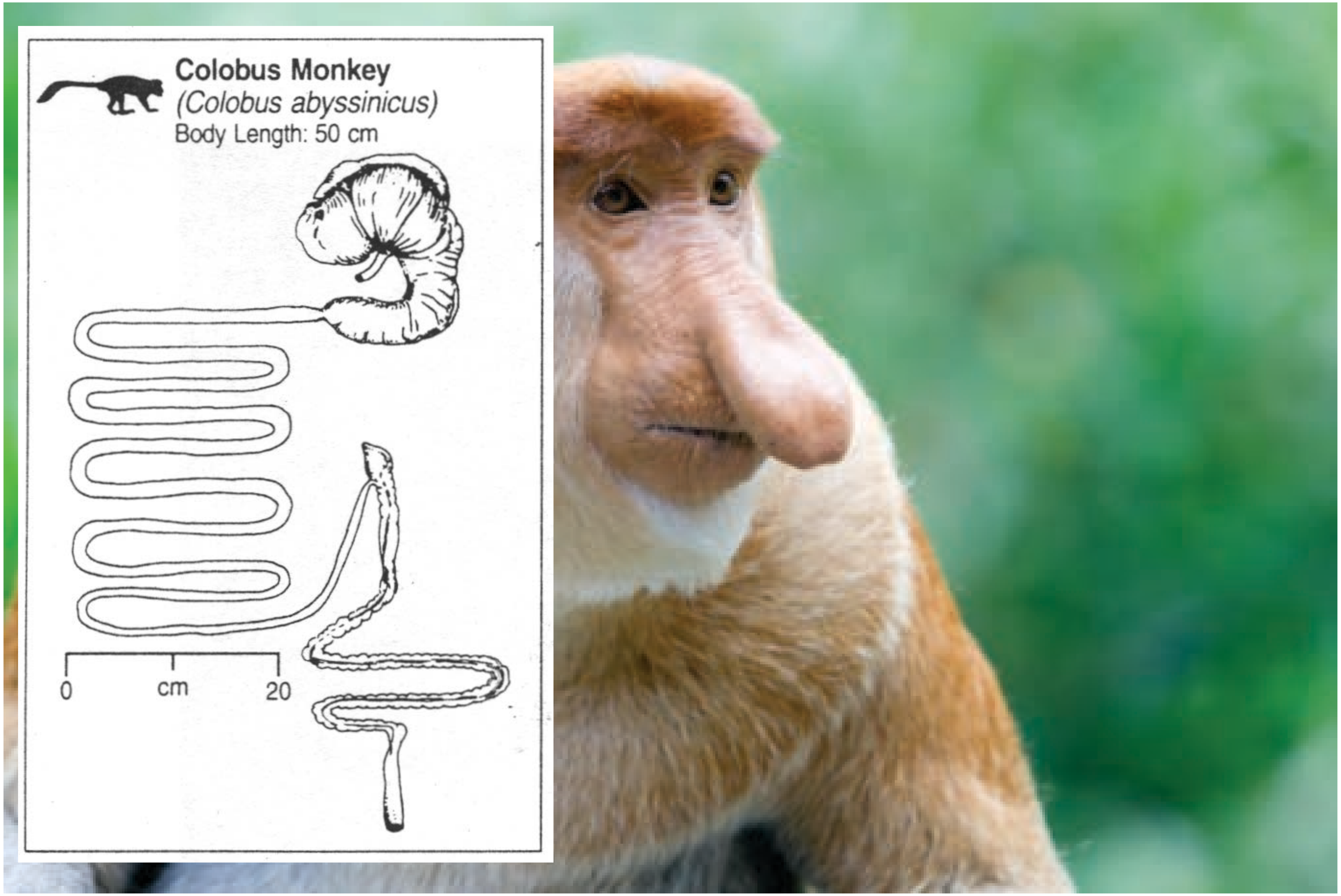


from Stevens und Hume (1995)

Matsuda et al. (2011)

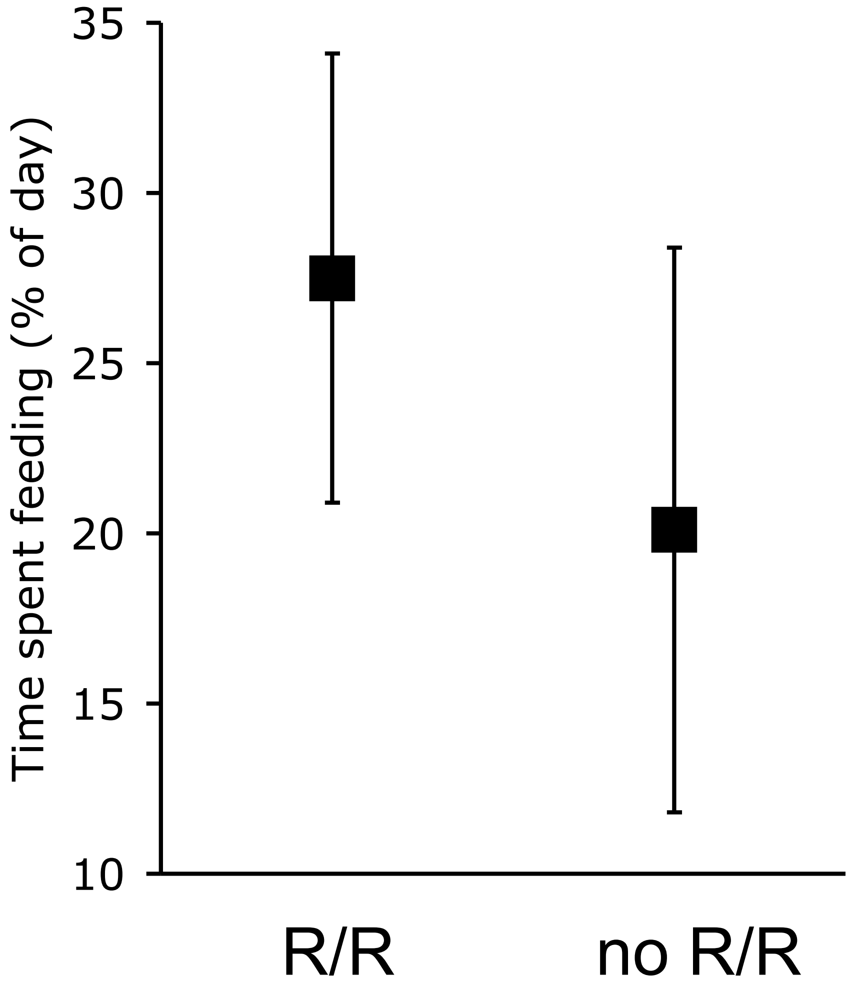
biology letters

Biol. Lett. (2011) 00, 1–4
doi:10.1098/rsbl.2011.0197
Published online 00 Month 0000

Physiology

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

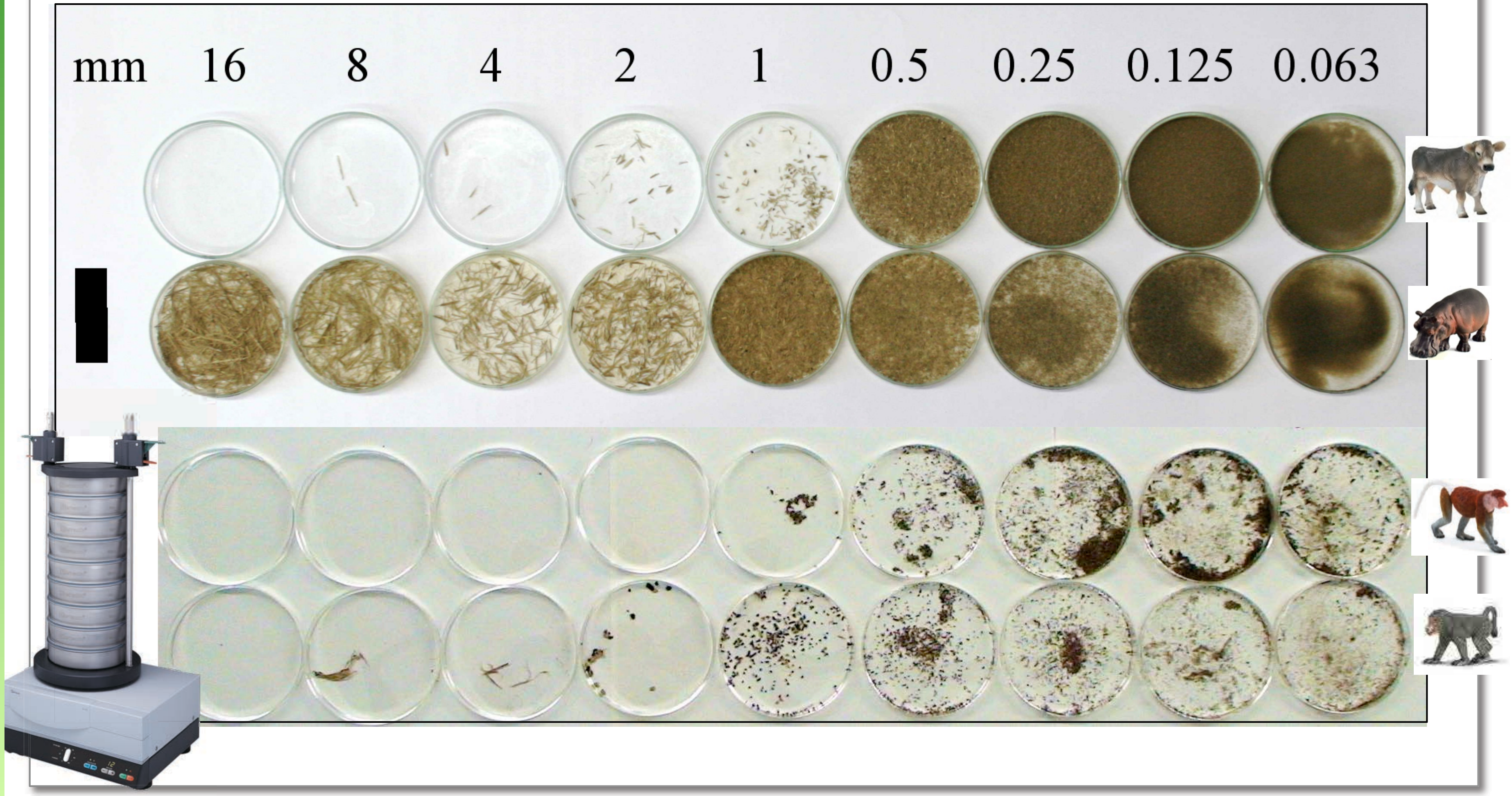
Ikki Matsuda[1,*], Tadahiro Murai[1], Marcus Clauss[2], Tomomi Yamada[3], Augustine Tuuga[4], Henry Bernard[5] and Seigo Higashi[6]



Faecal particle size in free-ranging primates supports a ‘rumination’ strategy in the proboscis monkey (*Nasalis larvatus*)

Ikki Matsuda · Augustine Tuuga · Chie Hashimoto · Henry Bernard · Juichi Yamagiwa · Julia Fritz · Keiko Tsubokawa · Masato Yayota · Tadahiro Murai · Yuji Iwata · Marcus Clauss

Oecologia
DOI 10.1007/s00442-013-2863-9



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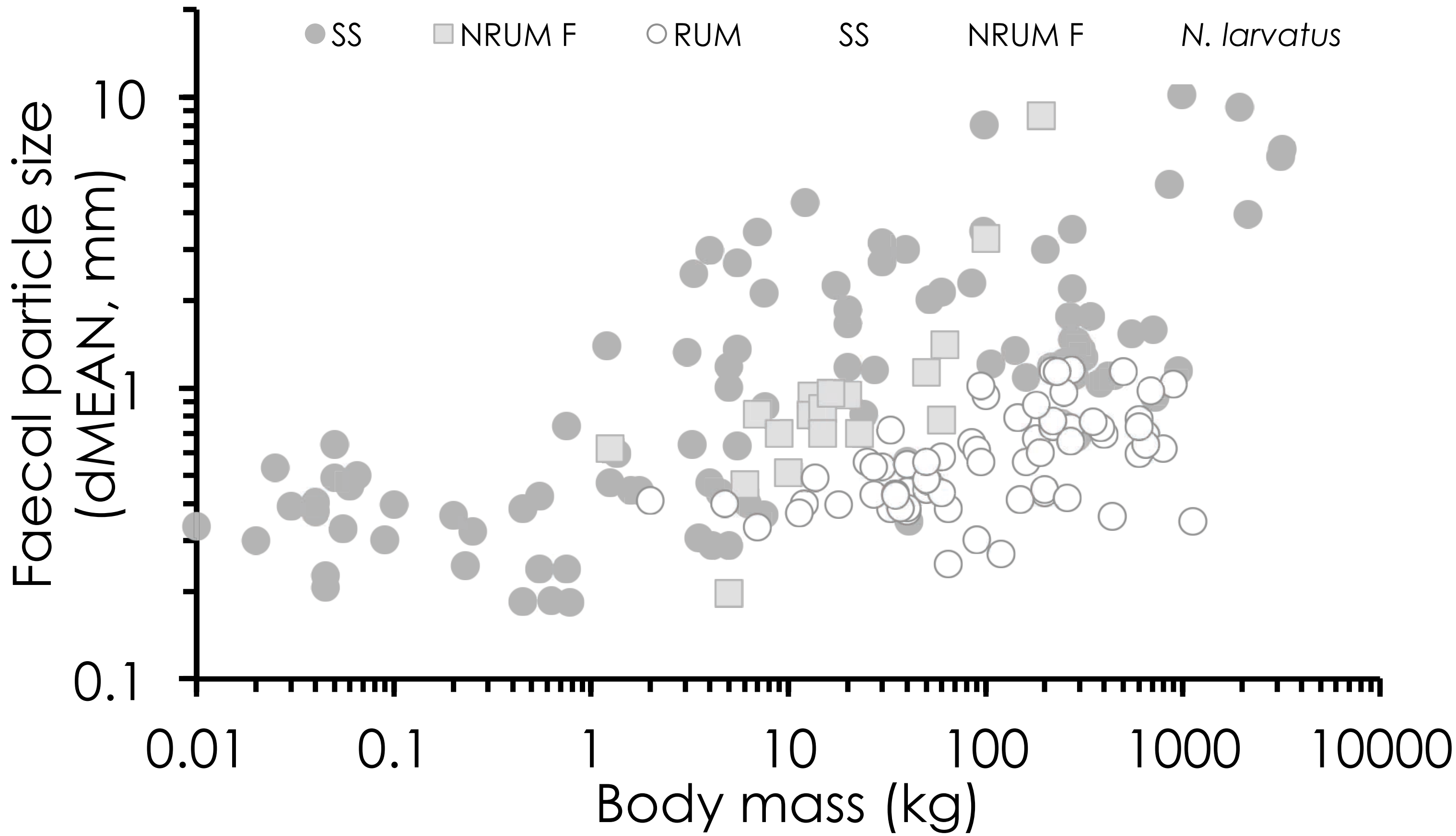

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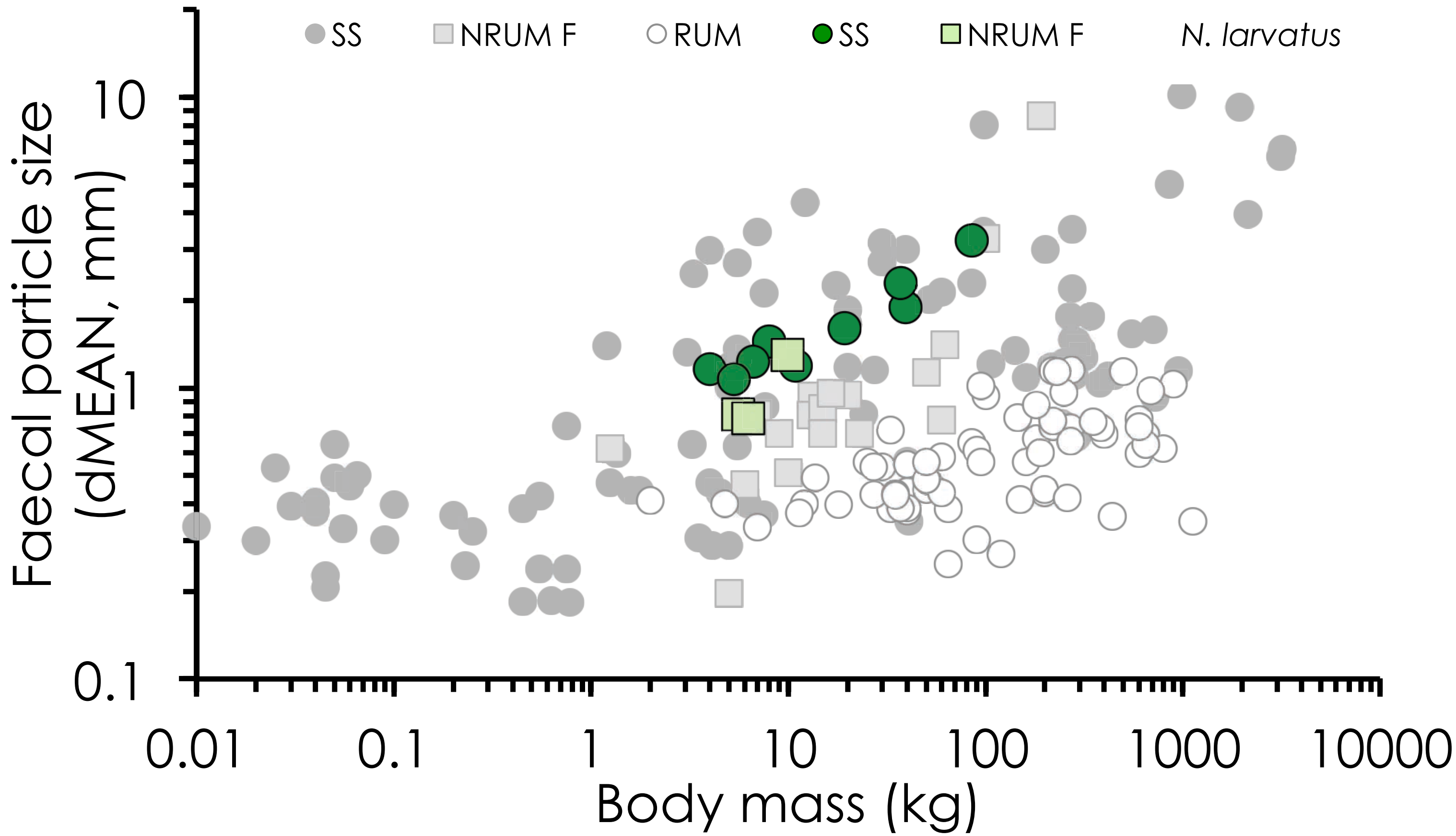

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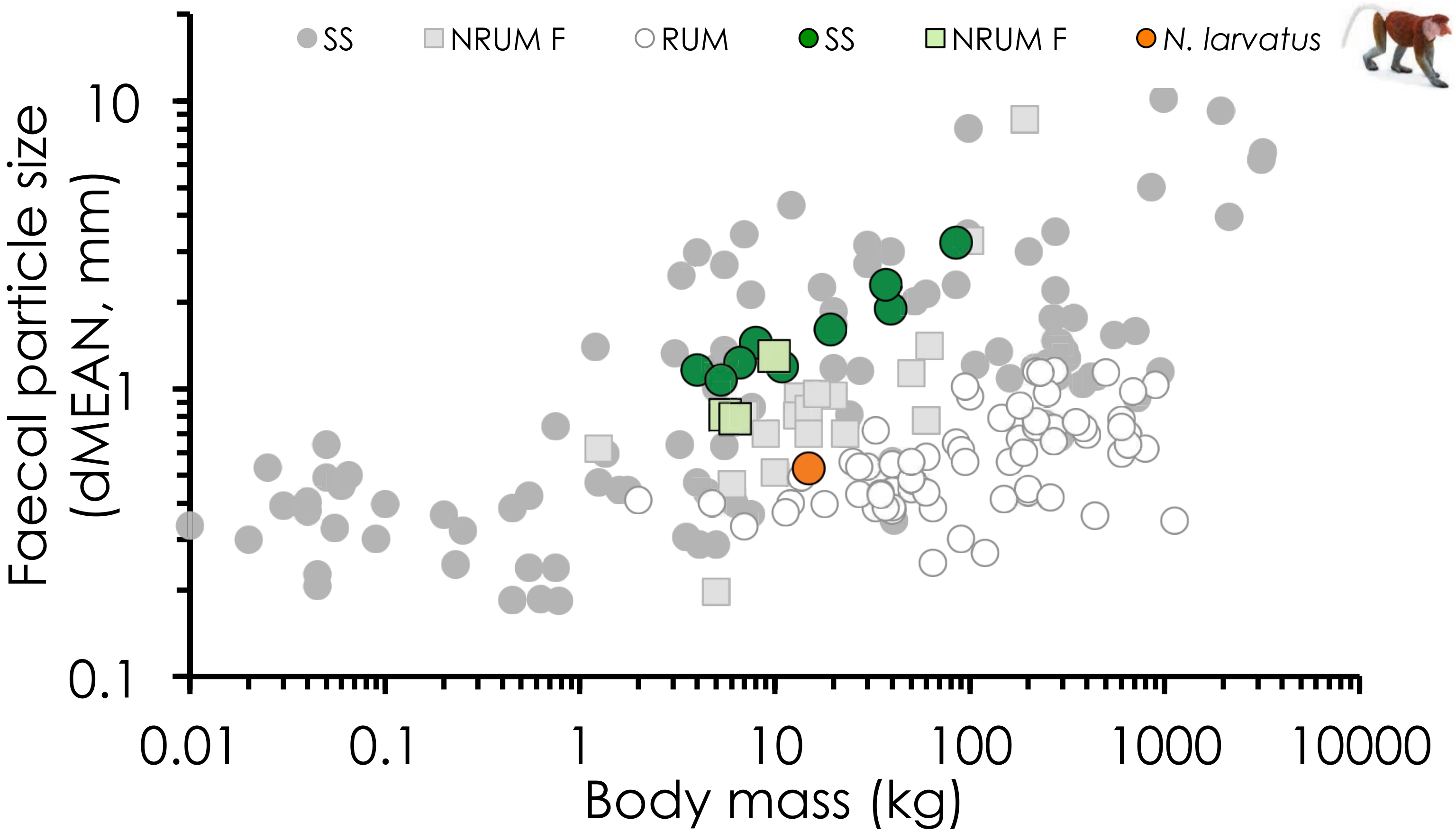
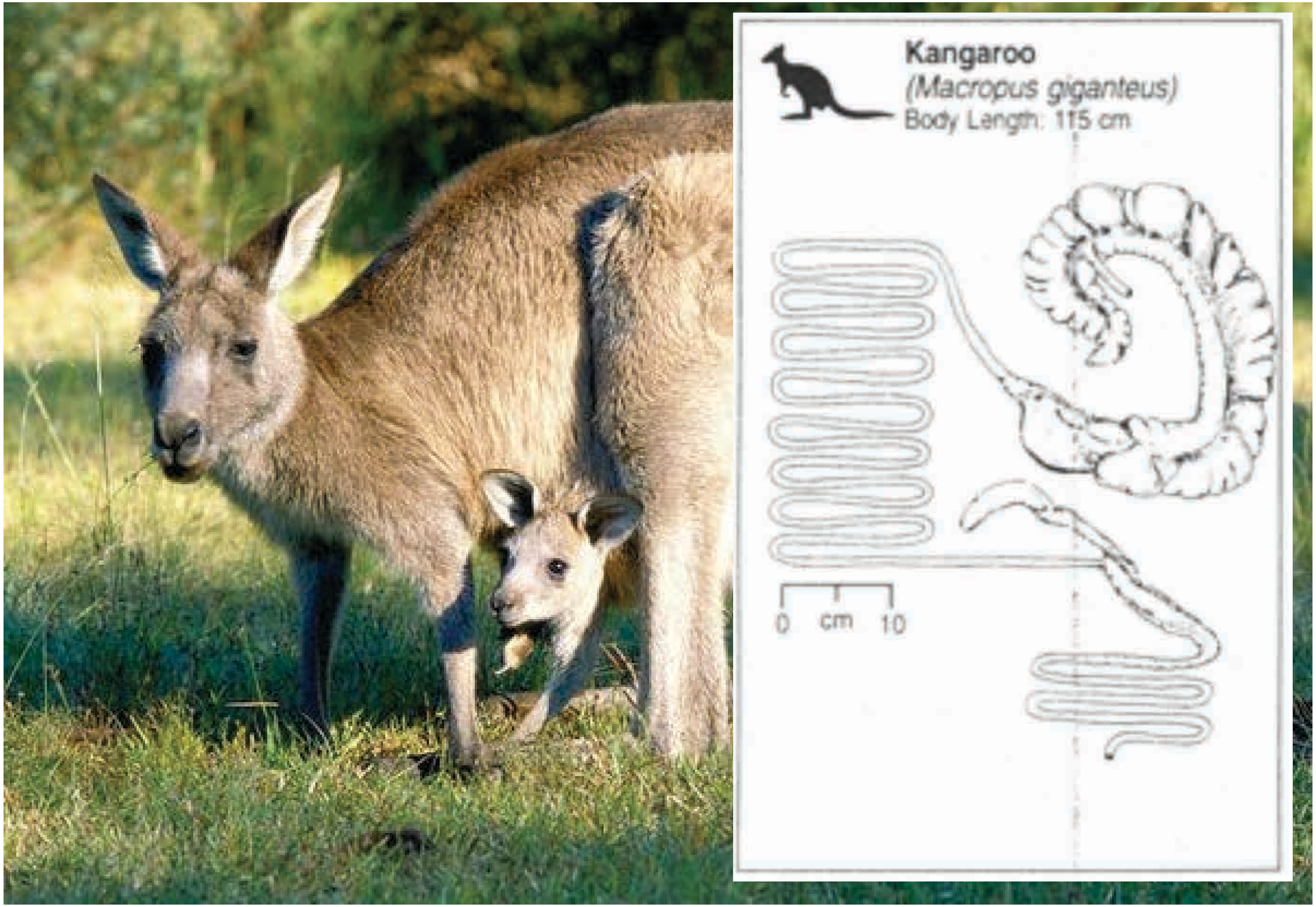


The case of the kangaroos

The case of the kangaroos



from Stevens und Hume (1995)

The case of the kangaroos

430 THE AUSTRALIAN JOURNAL OF SCIENCE APRIL

Food Regurgitation in the Macropodidae

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

BIOLOGISCHES ZENTRALBLATT

Band 84 November–Dezember 1965 Heft 6

Vergleichende Untersuchung des Wiederkauverhaltens

Von HUBERT HENDRICHS[1])

Dagegen sah ich folgende Marsupialier wiederkauen:

Thylogale eugenii (DESMAREST, 1817)
Setonix brachyurus (QOUY et GAIMARD, 1830)
Dendrolagus ursinus (TEMMINCK, 1836)
Dendrolagus ursinus inustus (MÜLLER, 1840)
Protemnodon agilis (GOULD, 1842)
Protemnodon rufogrisea (DESMAREST, 1817)
Macropus gigantea (ZIMMERMANN, 1777)
Macropus (Megaleia) rufus (DESMAREST, 1822)
Macropus (Osphranter) robustus (GOULD, 1841).

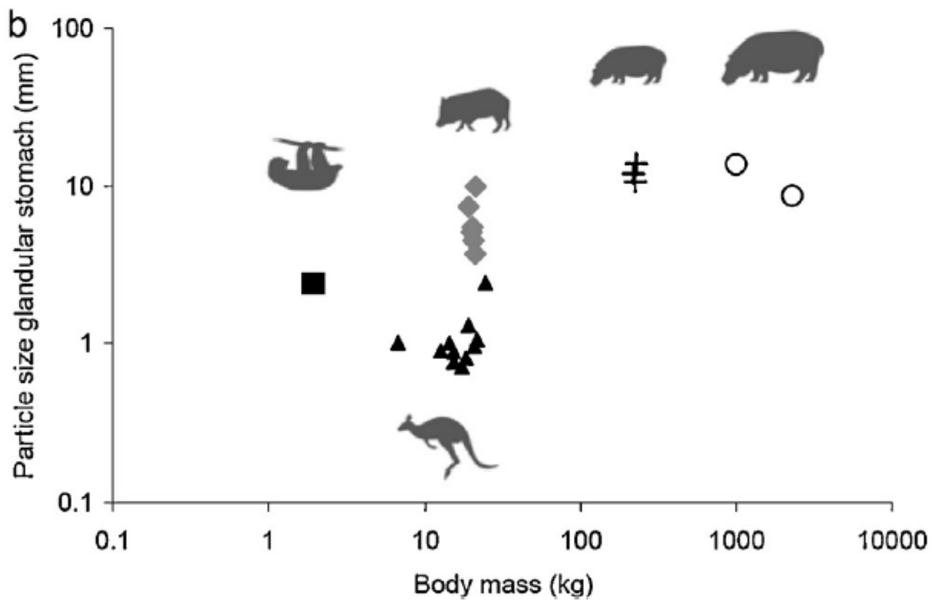
The case of the kangaroos

The case of the kangaroos

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

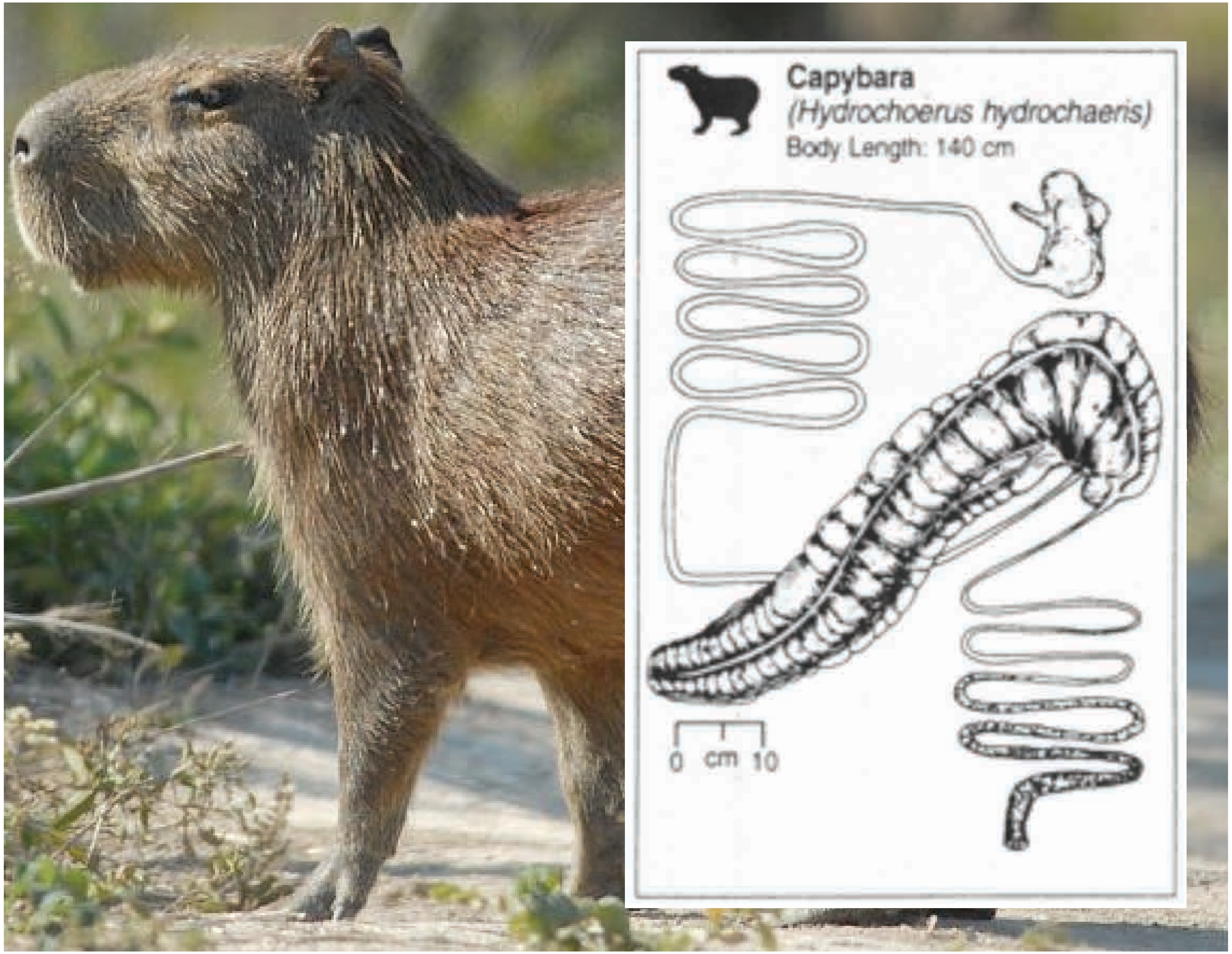
Angela Schwarm[a,b,*], Sylvia Ortmann[a], Julia Fritz[c], Edmund Flach[d], Wolfram Rietschel[e], Marcus Clauss[f]

Mammalian Biology 78 (2013) 412–421



The case of the capybara

The case of the capybara



from Stevens und Hume (1995)

The case of the capybara

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

A Descriptive Account of Capybara Behaviour

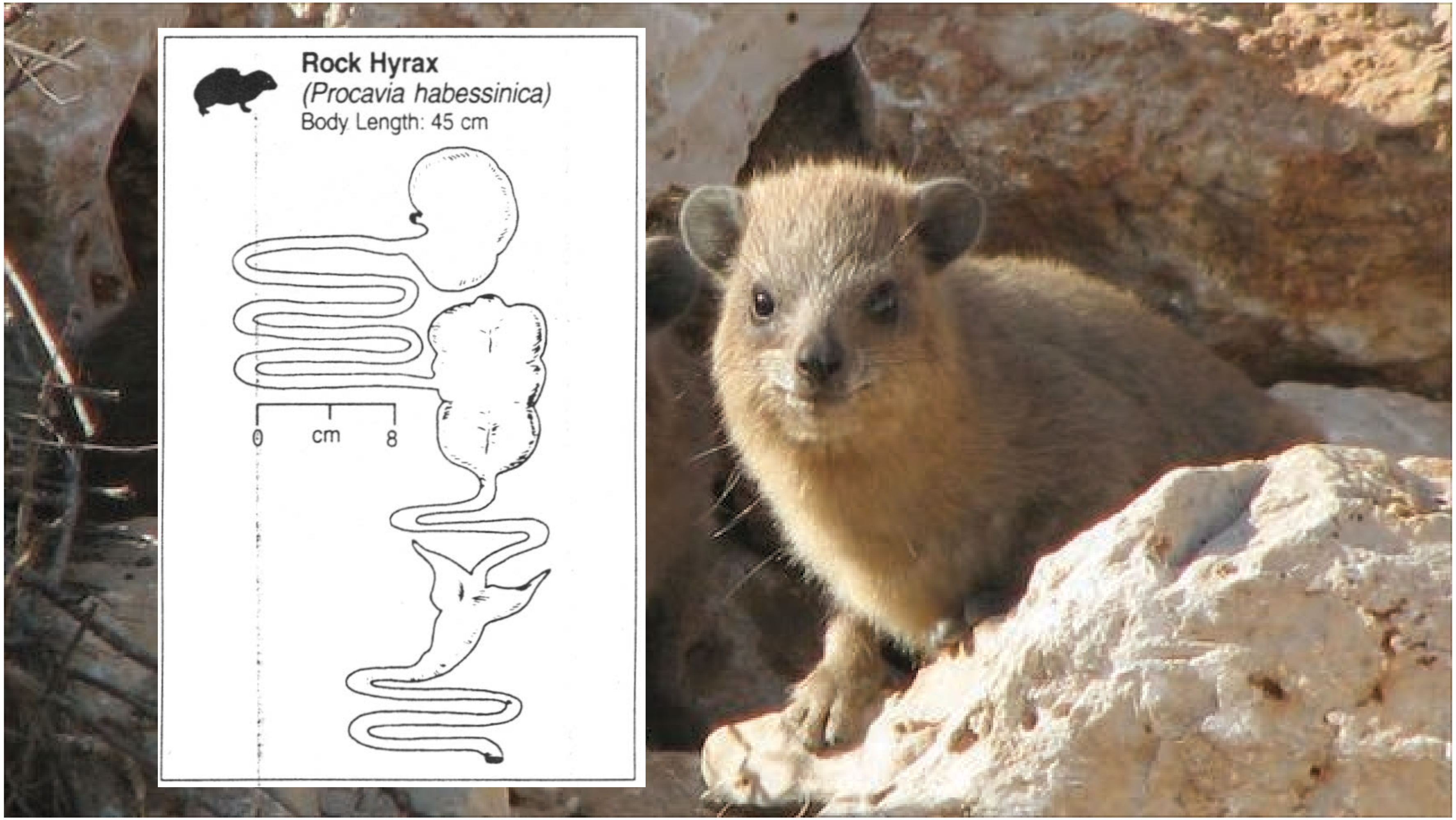
Rexford D. LORD

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

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

The case of the hyrax

The case of the hyrax



from Stevens und Hume (1995)

The case of the hyrax

The case of the hyrax

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

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

The case of the hyrax

BIOLOGISCHES ZENTRALBLATT

Band 84 November–Dezember 1965 Heft 6

Vergleichende Untersuchung des Wiederkauverhaltens

Von Hubert Hendrichs[1])

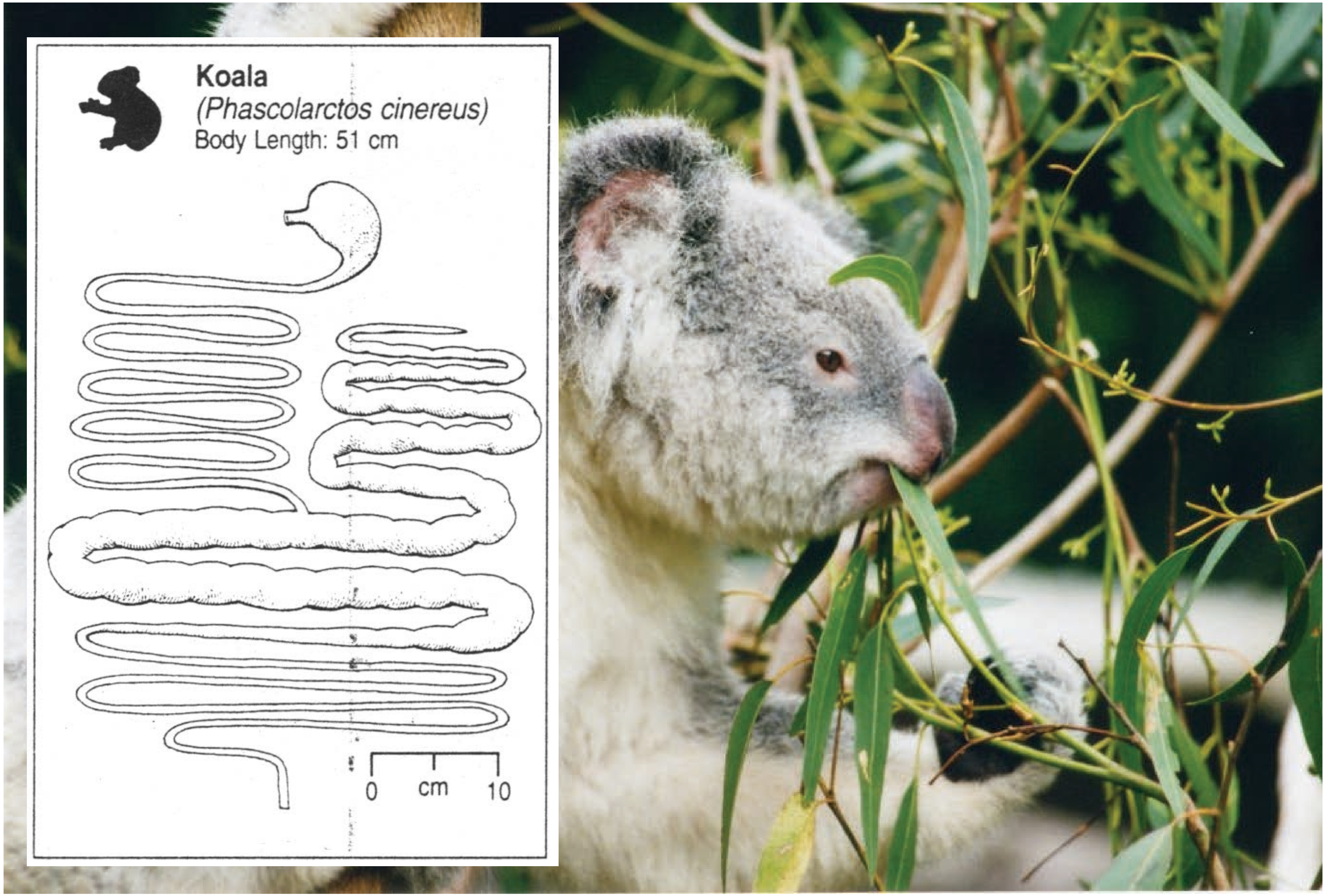
VI. Entdeckung von Wiederkauen bei einer Säugetierordnung

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

The case of the hyrax

The case of the koala

The case of the koala



from Stevens und Hume (1995)

The case of the koala

J. Zool., Lond. (2001) **255**, 83–87 Printed in the United Kingdom

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

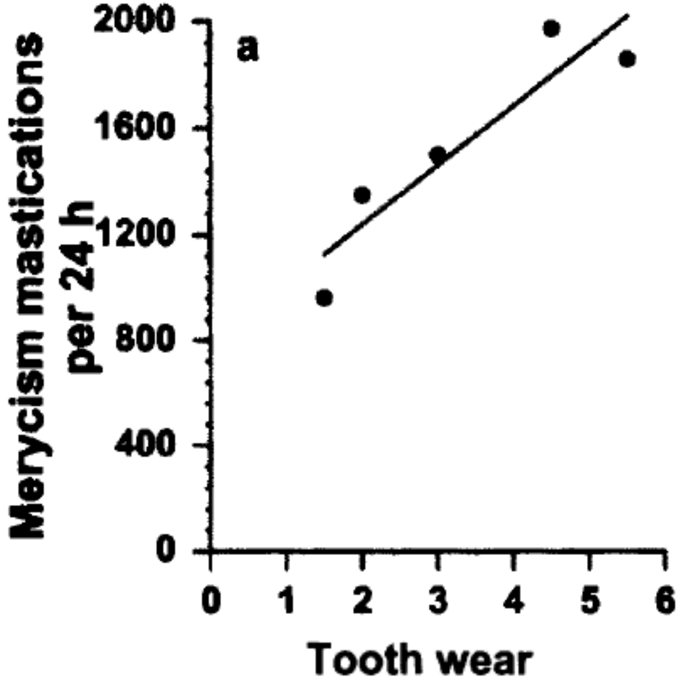
M. Logan

The case of the koala

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

M. LOGAN*

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

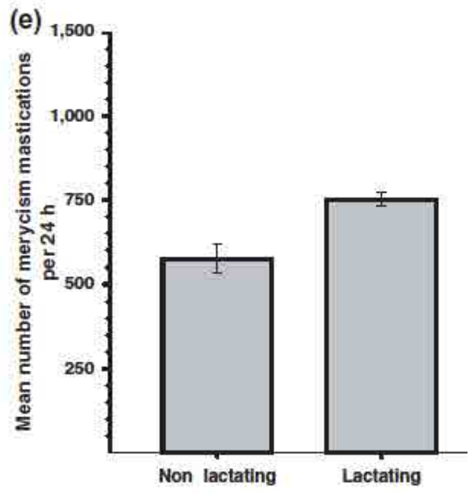


The case of the koala

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

The effects of lactation on the feeding behaviour and activity patterns of free-ranging female koalas (*Phascolarctos cinereus* Goldfuss)

M. Logan and G. D. Sanson



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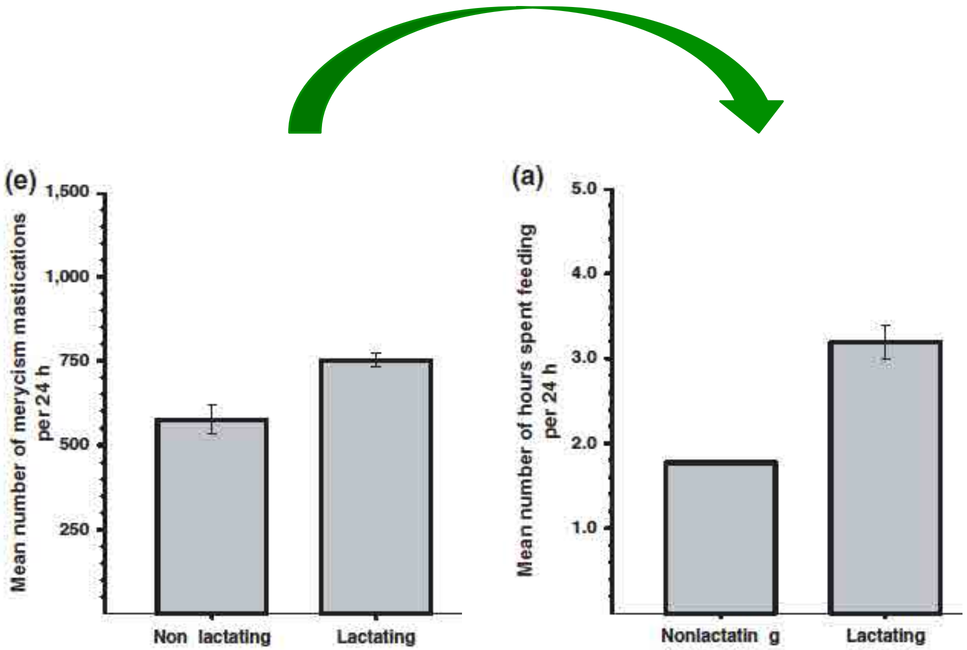

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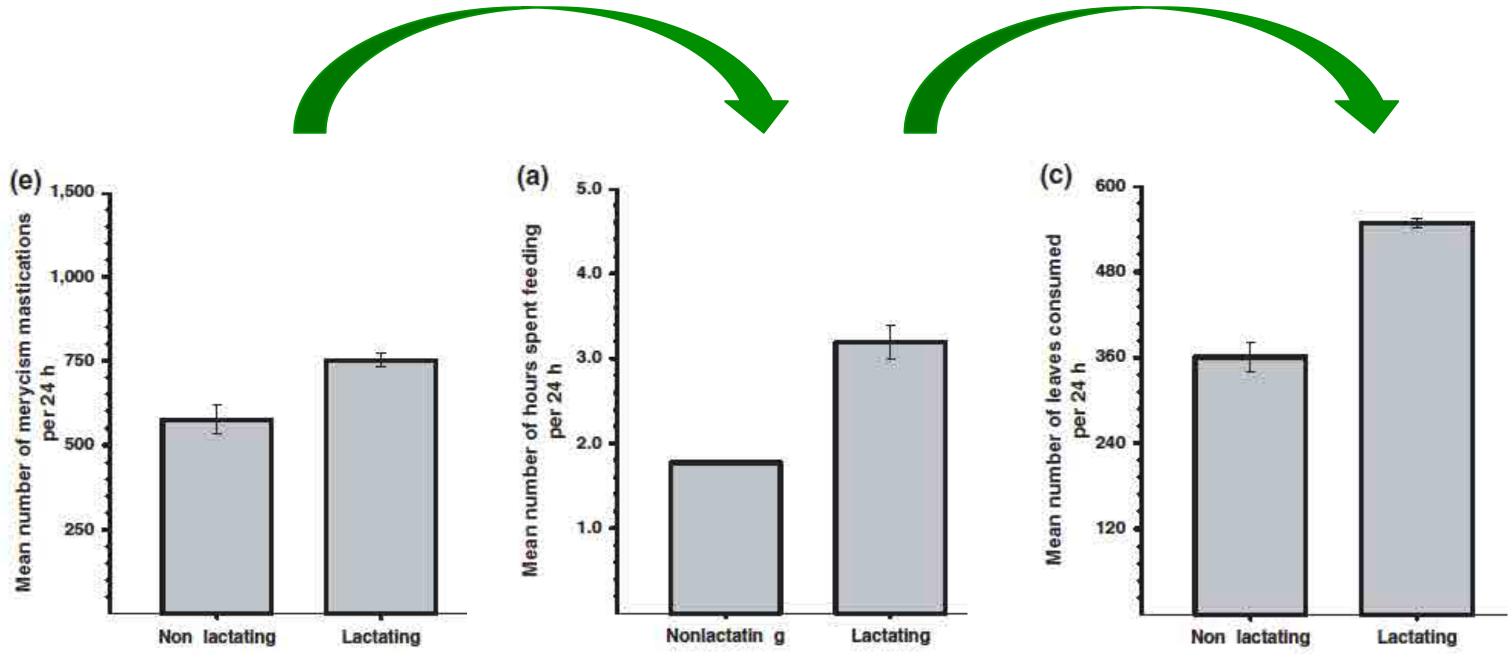


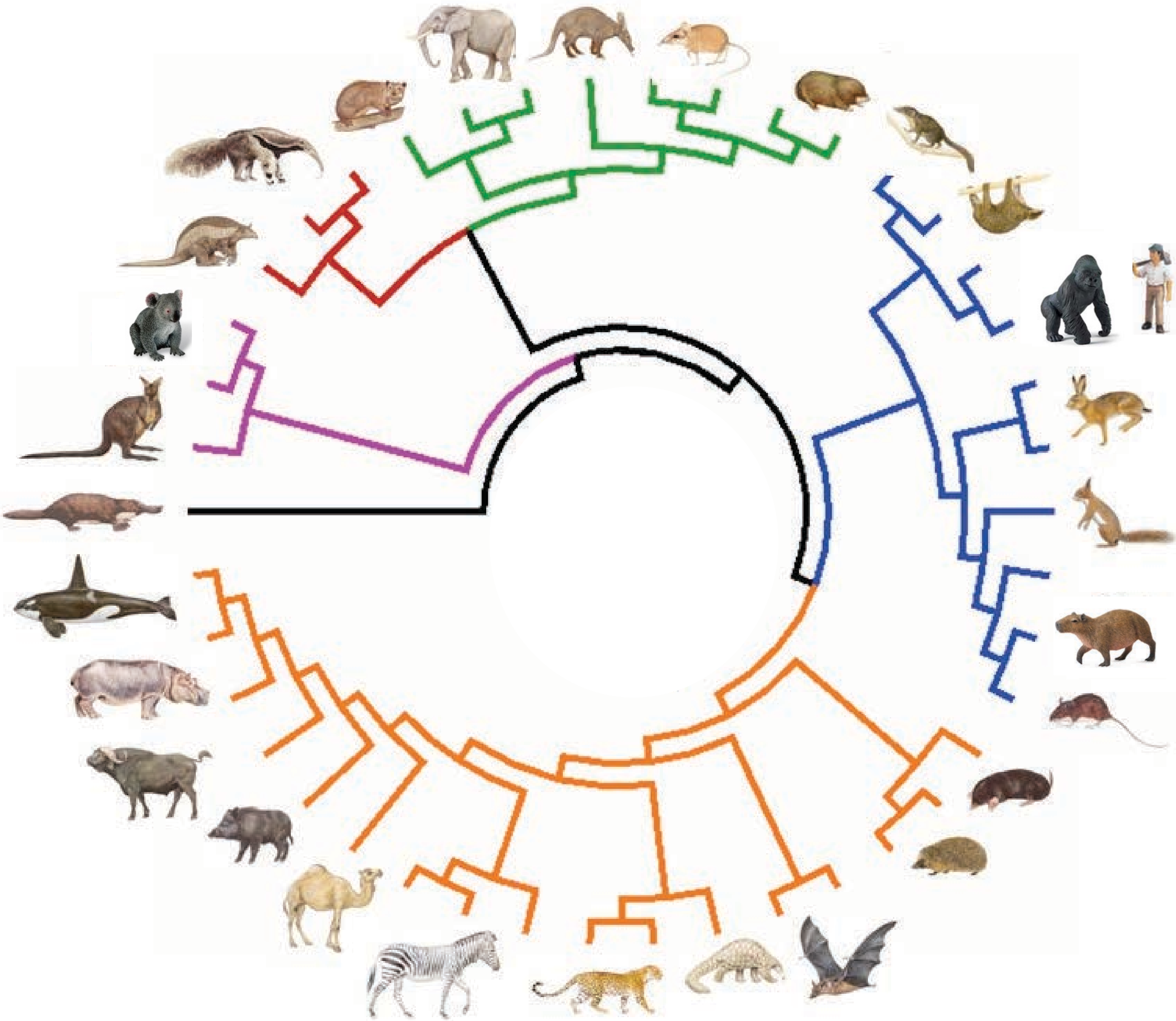
Why rumination?

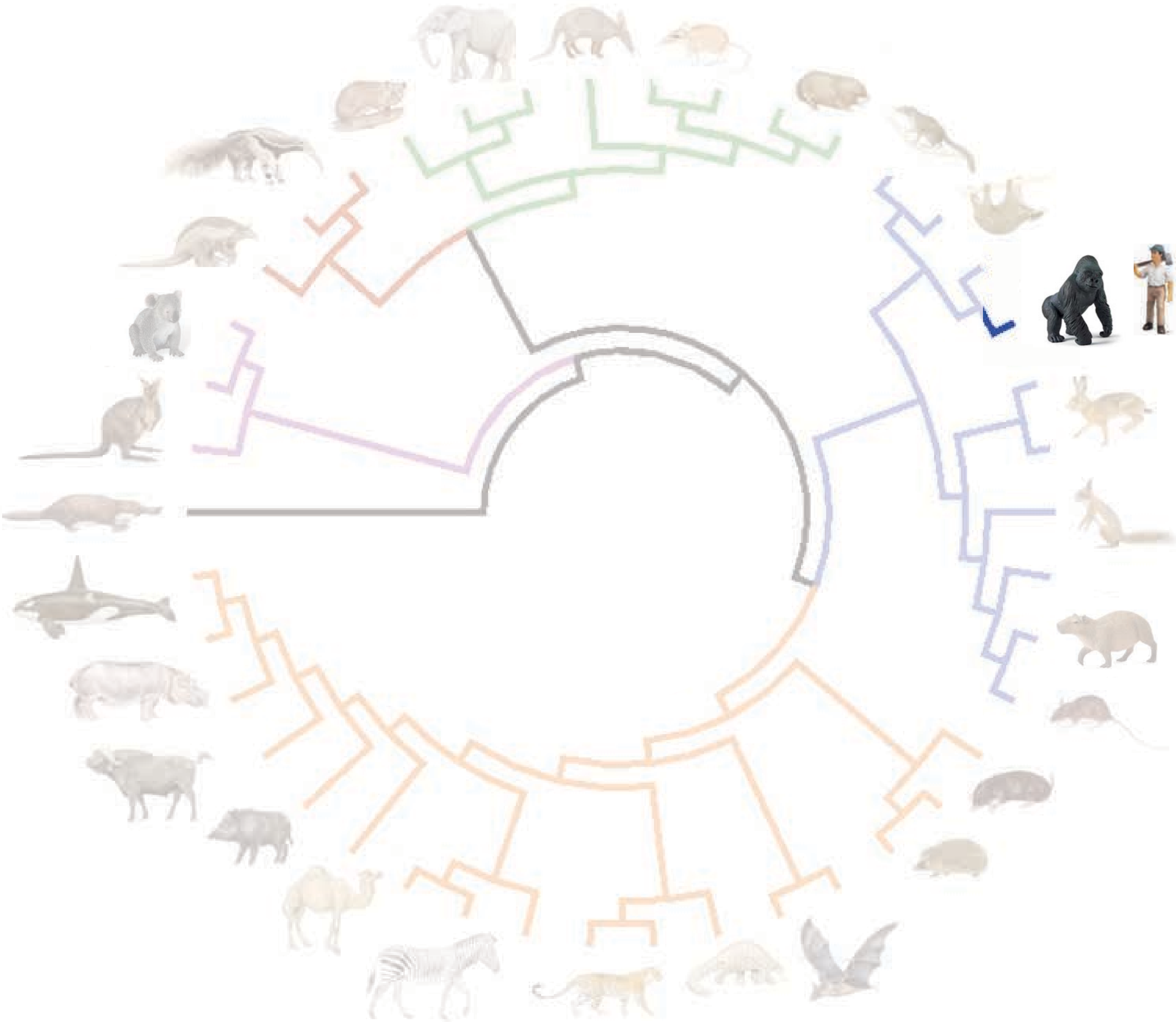
- Anti-predation strategy
  - *"Rumination seems to allow herbivores to ingest in haste and masticate at leisure"* (Karasov & Del Rio 2007)

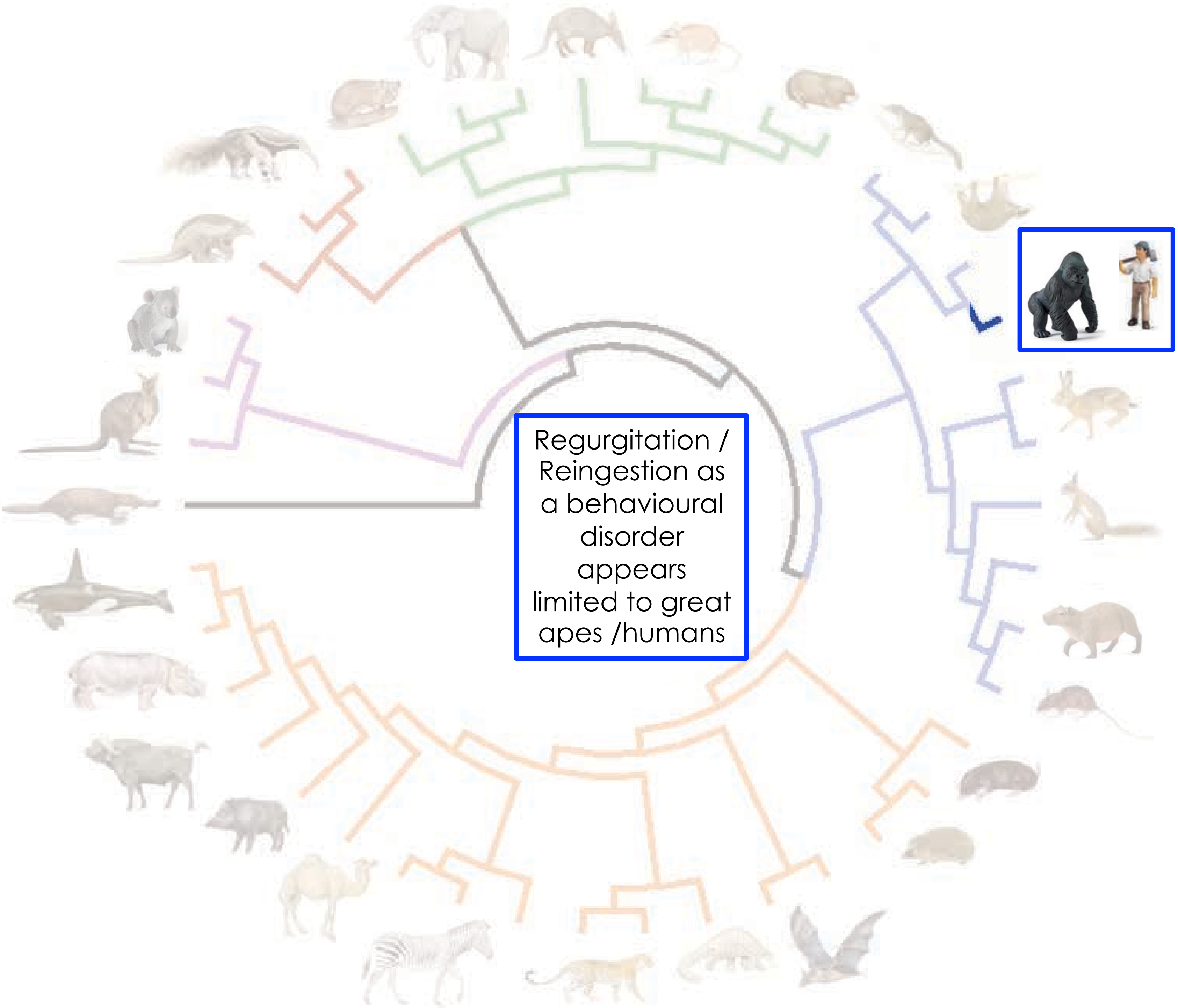
    => Ruminants should ingest similar amounts of food as other herbivores and just 'chew later' - or become time-constrained in intake
- Energy-saving mechanism
  - Rumination occurs in a state of 'drowsiness' similar to rest; may represent an energy-saving strategy - less time spent 'wide awake' (Gordon 1968)

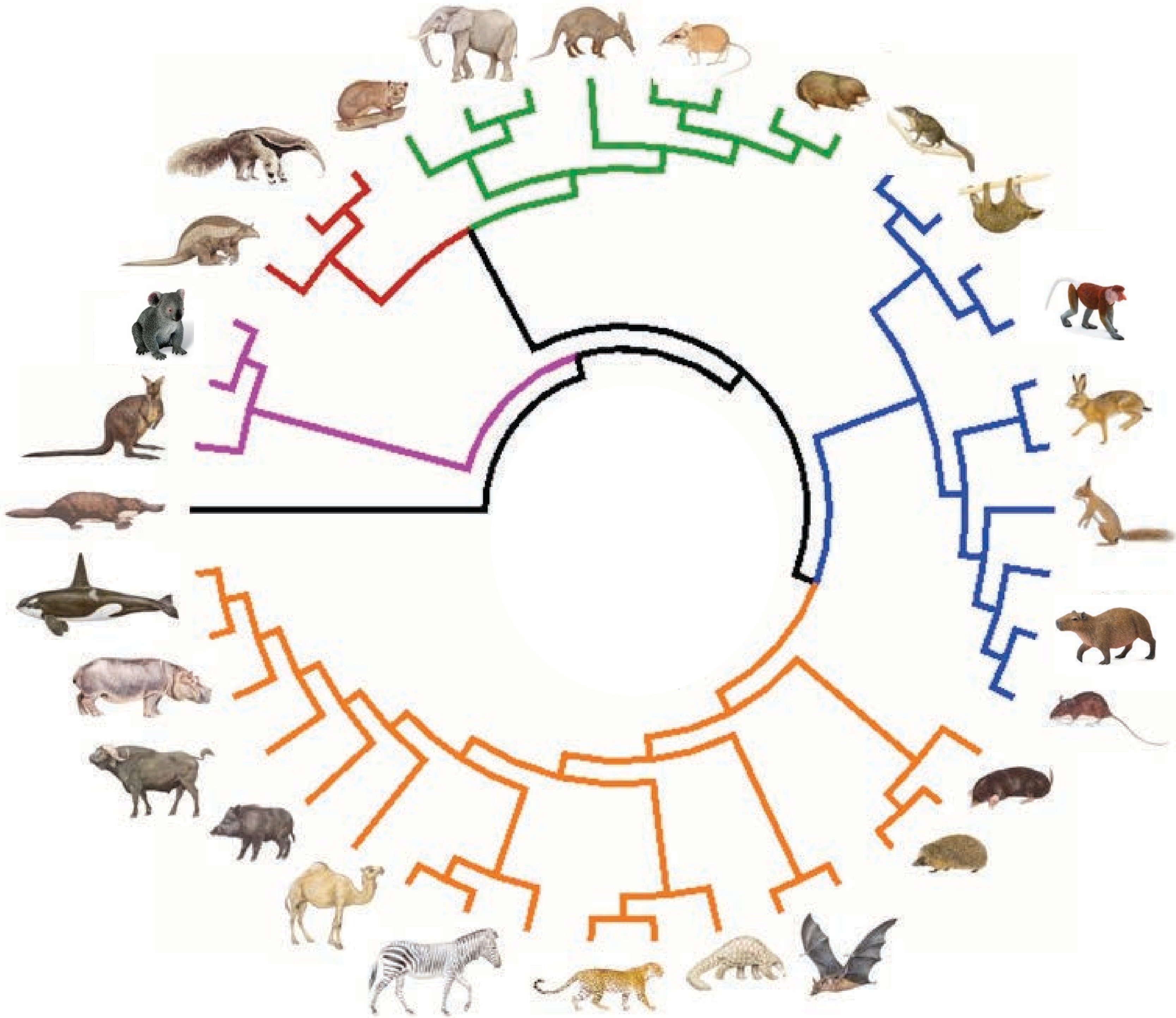
    => Ruminants should have lower energy requirements/higher productivity than other herbivores
- Enhancement of digestive efficiency
  - Rumination reduces particle size and hence allows faster digestion at constant intake

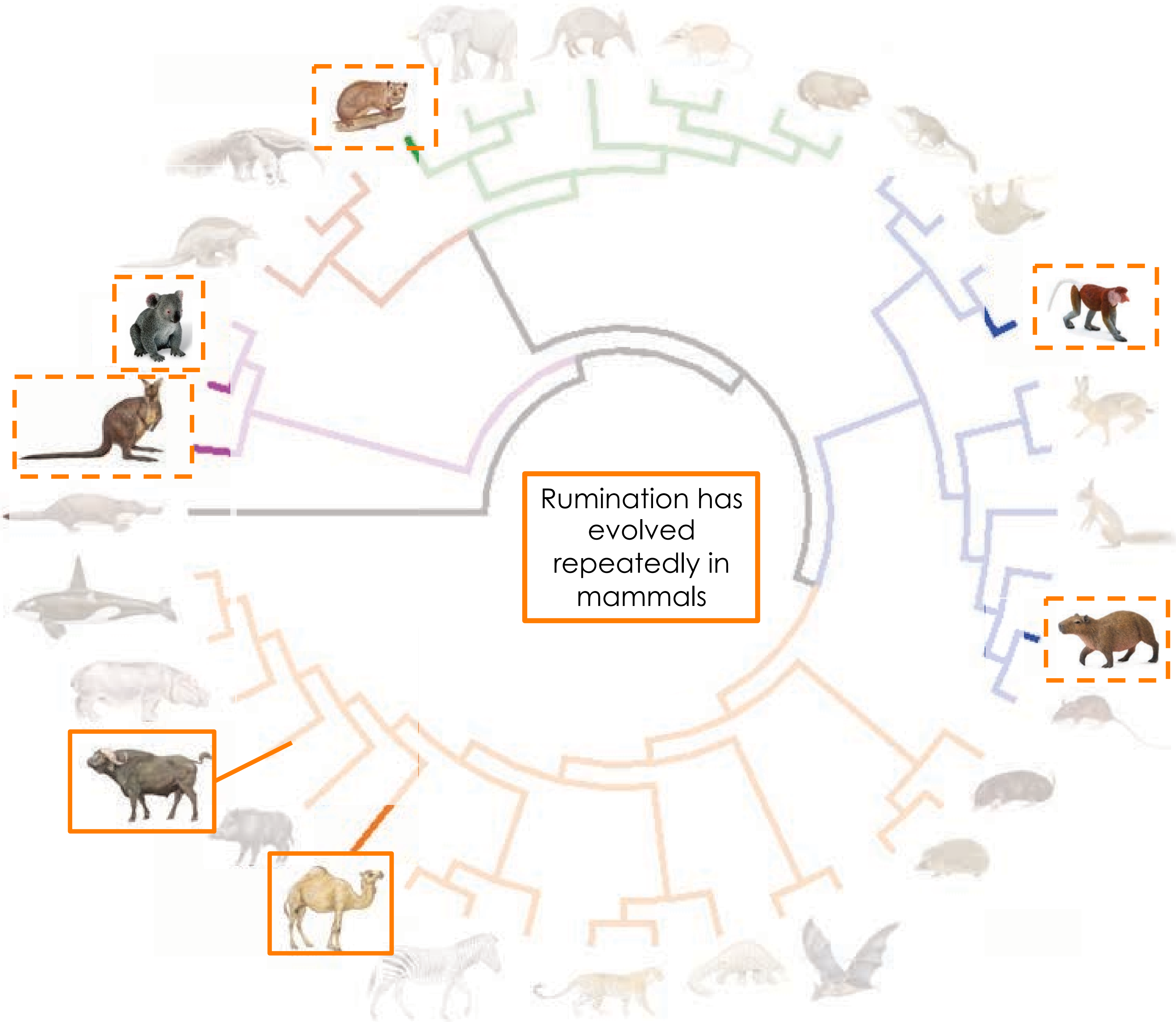
    => Ruminants should have smaller digesta particle sizes (and higher intakes) than other herbivores



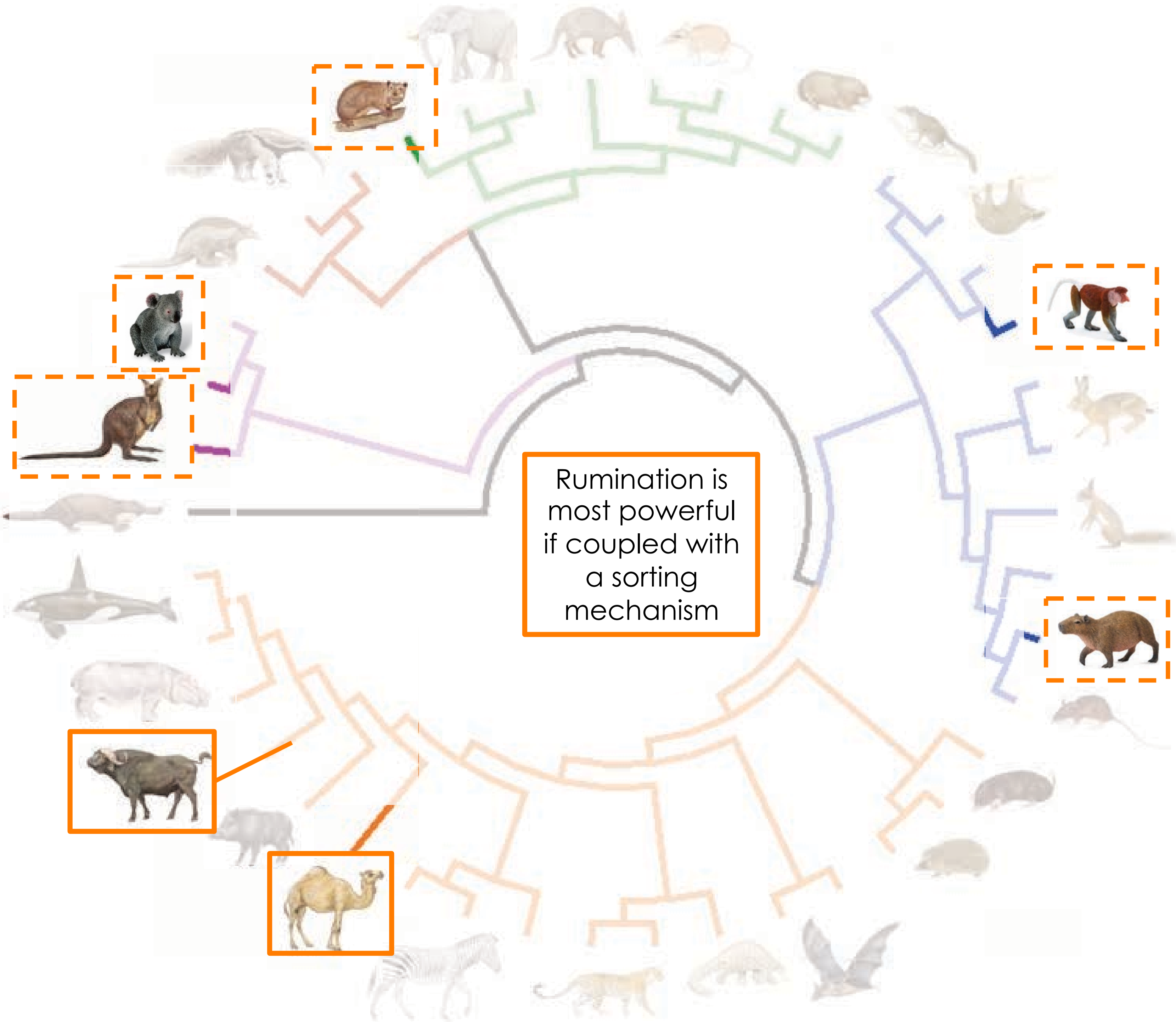



Regurgitation / Reingestion as a behavioural disorder appears limited to great apes /humans





Rumination has evolved repeatedly in mammals



Rumination is most powerful if coupled with a sorting mechanism

thank you
for your attention

outlook: cheek pouches // coprophagy