



Comparative fibre digestion

Marcus Clauss¹ & Jürgen Hummel²

¹Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty, University of Zurich, Switzerland

²Animal Nutrition Group, Institute of Animal Science, University of Bonn, Germany

ESVCN Conference Zaragoza 2011



University of Zurich
Vetsuisse Faculty



Clinic
of Zoo Animals, Exotic Pets and Wildlife



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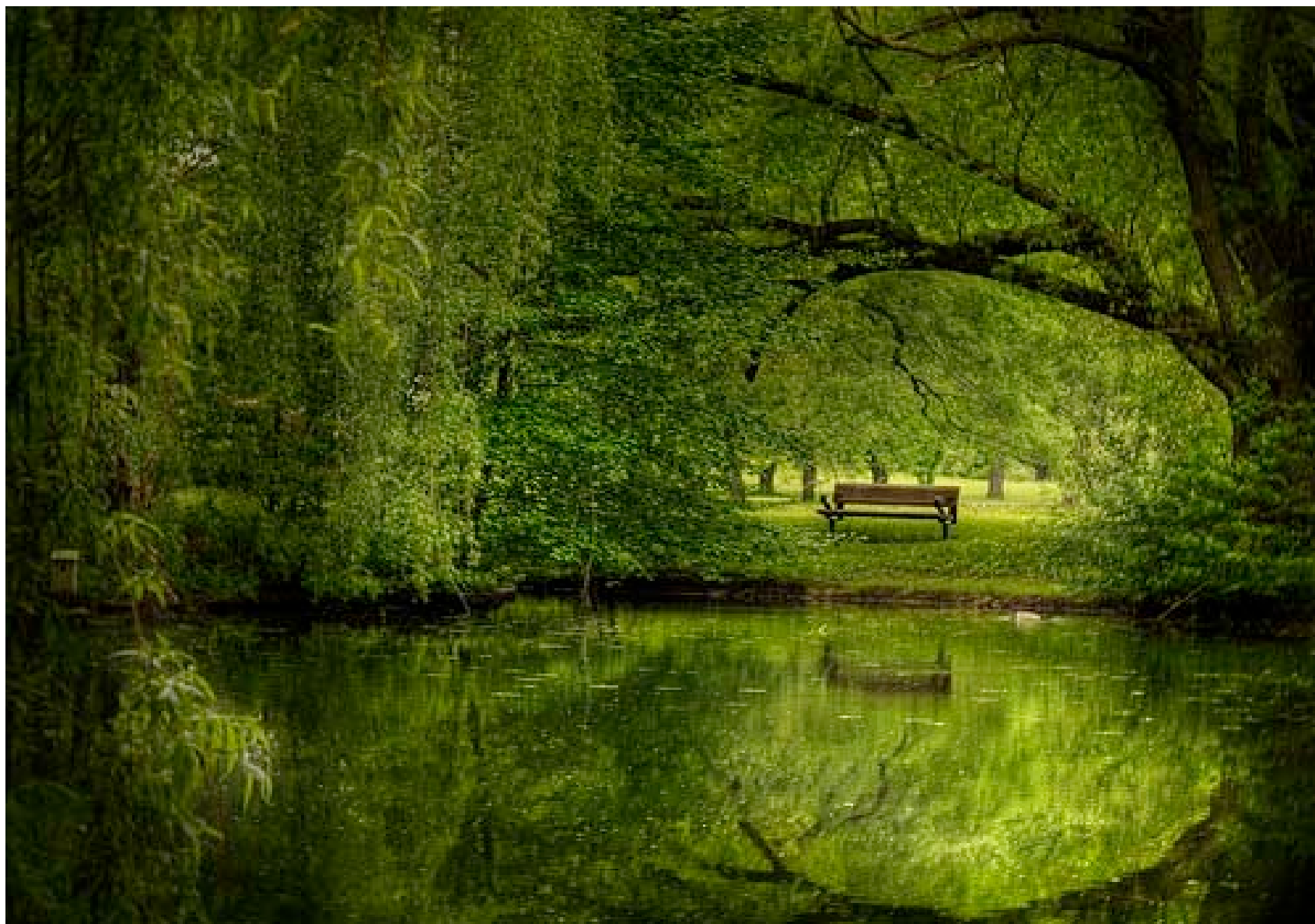
University of Zurich
Vetsuisse Faculty



Clinic
of Zoo Animals, Exotic Pets and Wildlife

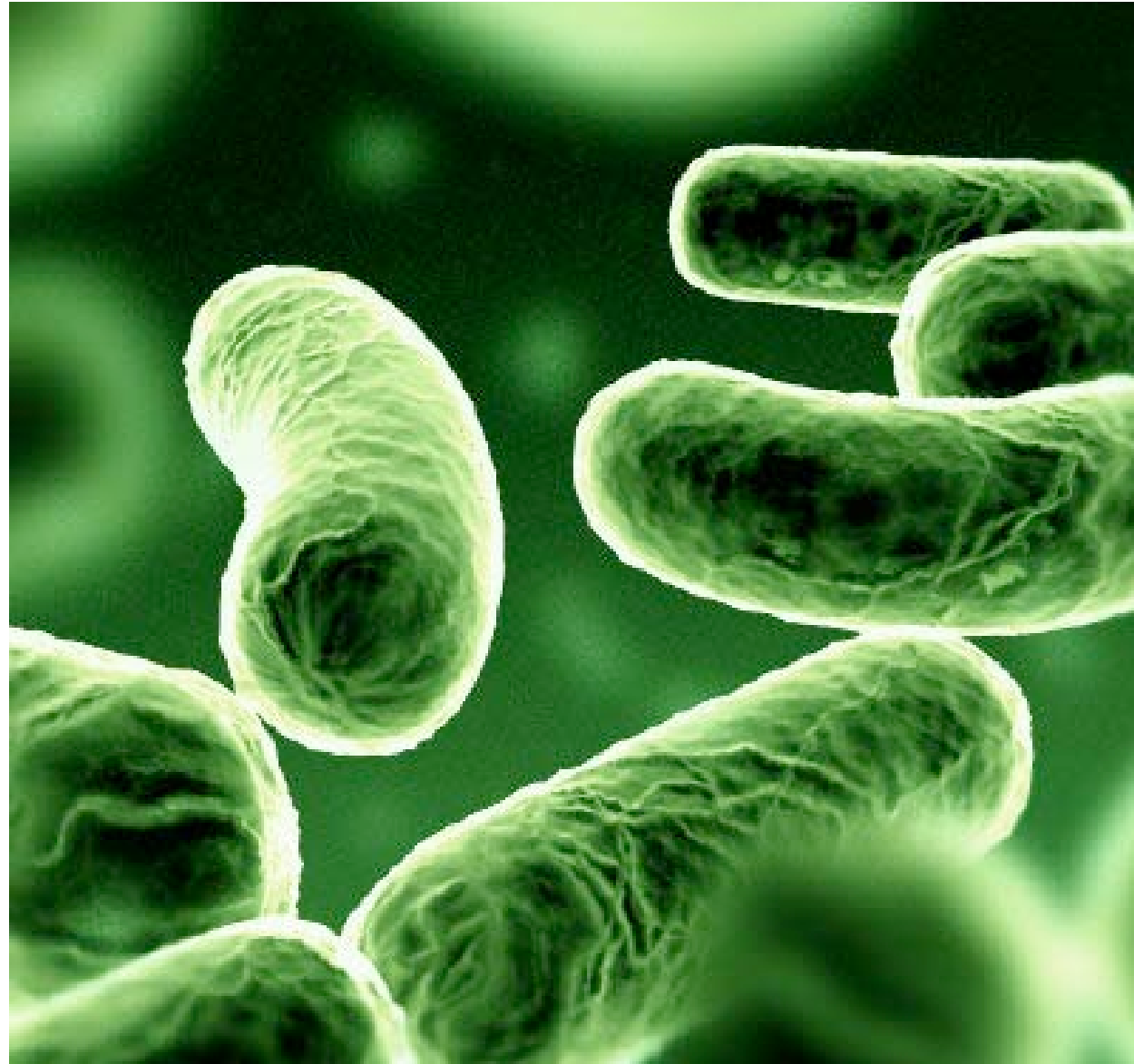


A green world





Primary consumers





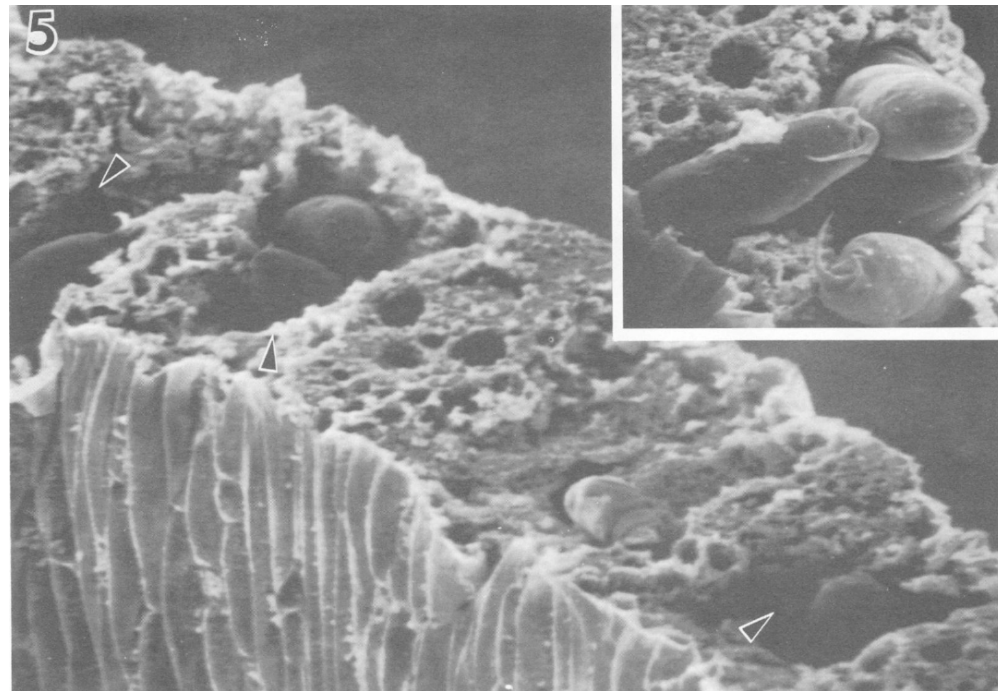
Primary consumers



from Akin & Amos (1975)



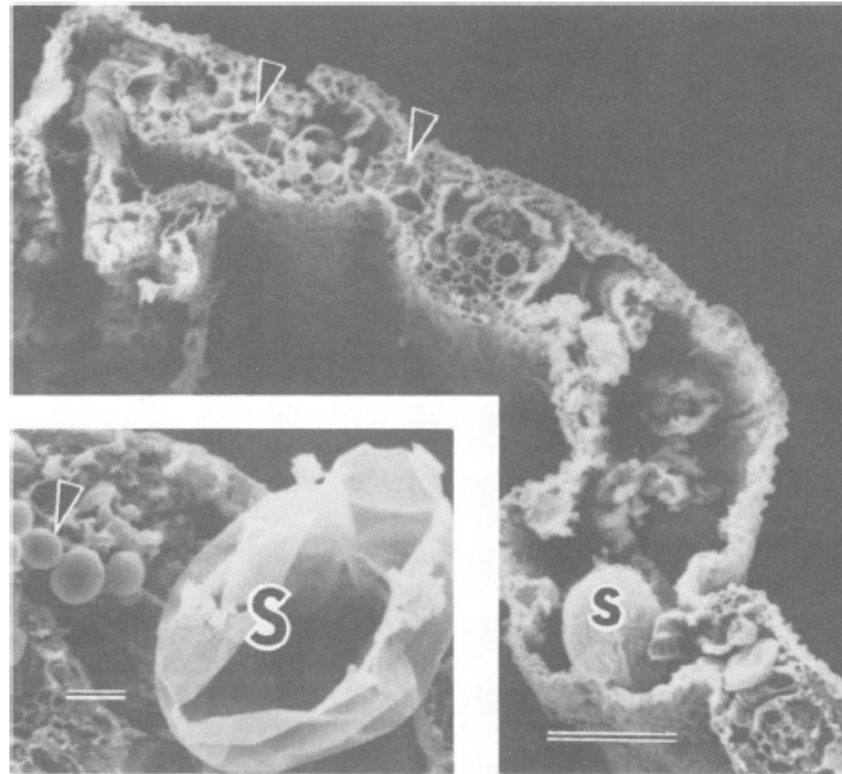
Primary consumers



from Amos & Akin (1978)



Primary consumers



from Akin & Benner (1988)



Primary consumers





Primary consumers





Primary consumers





Primary consumers





Primary consumers





Primary consumers





Primary consumers





Primary consumers





Primary consumers





Primary consumers





Primary consumers





Primary consumers





Primary consumers

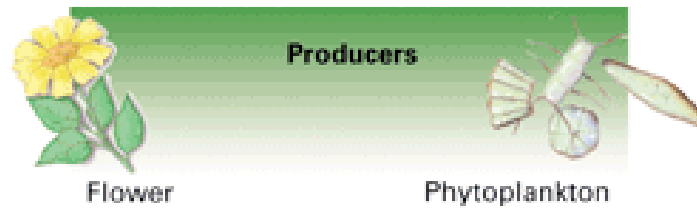




Food chains

**A terrestrial
food chain**

**A marine
food chain**

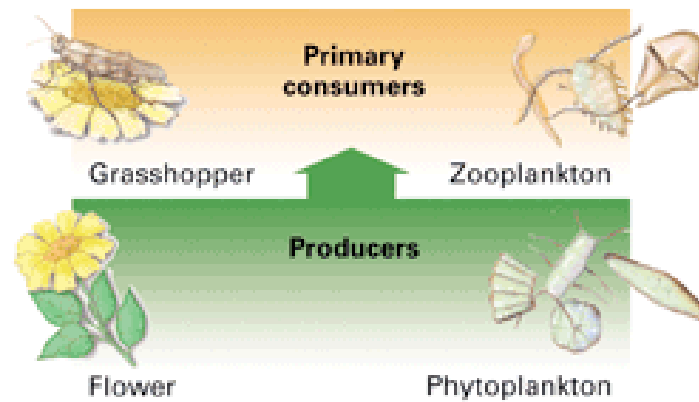




Food chains

A terrestrial
food chain

A marine
food chain

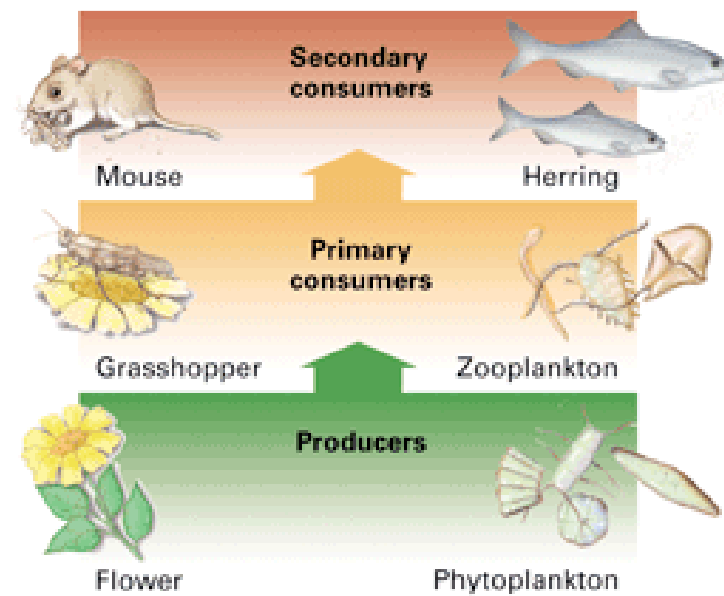




Food chains

A terrestrial
food chain

A marine
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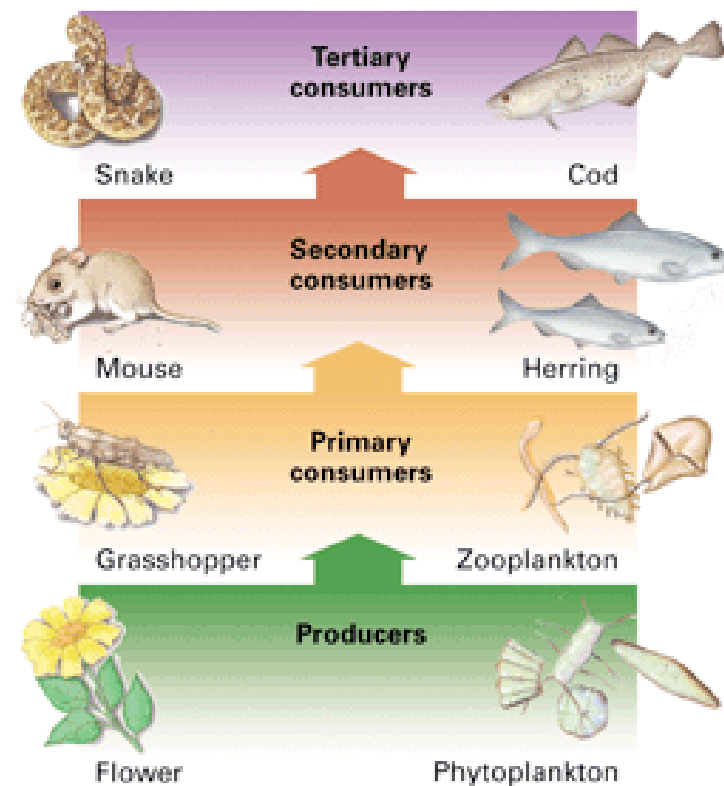




Food chains

A terrestrial
food chain

A marine
food chain

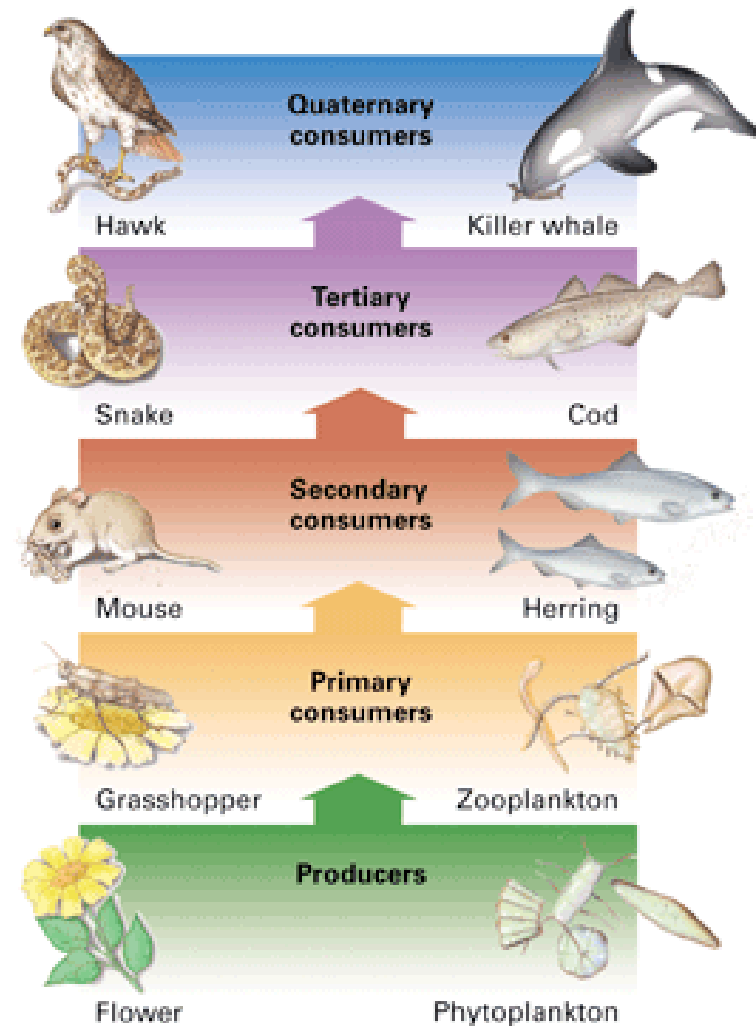




Food chains

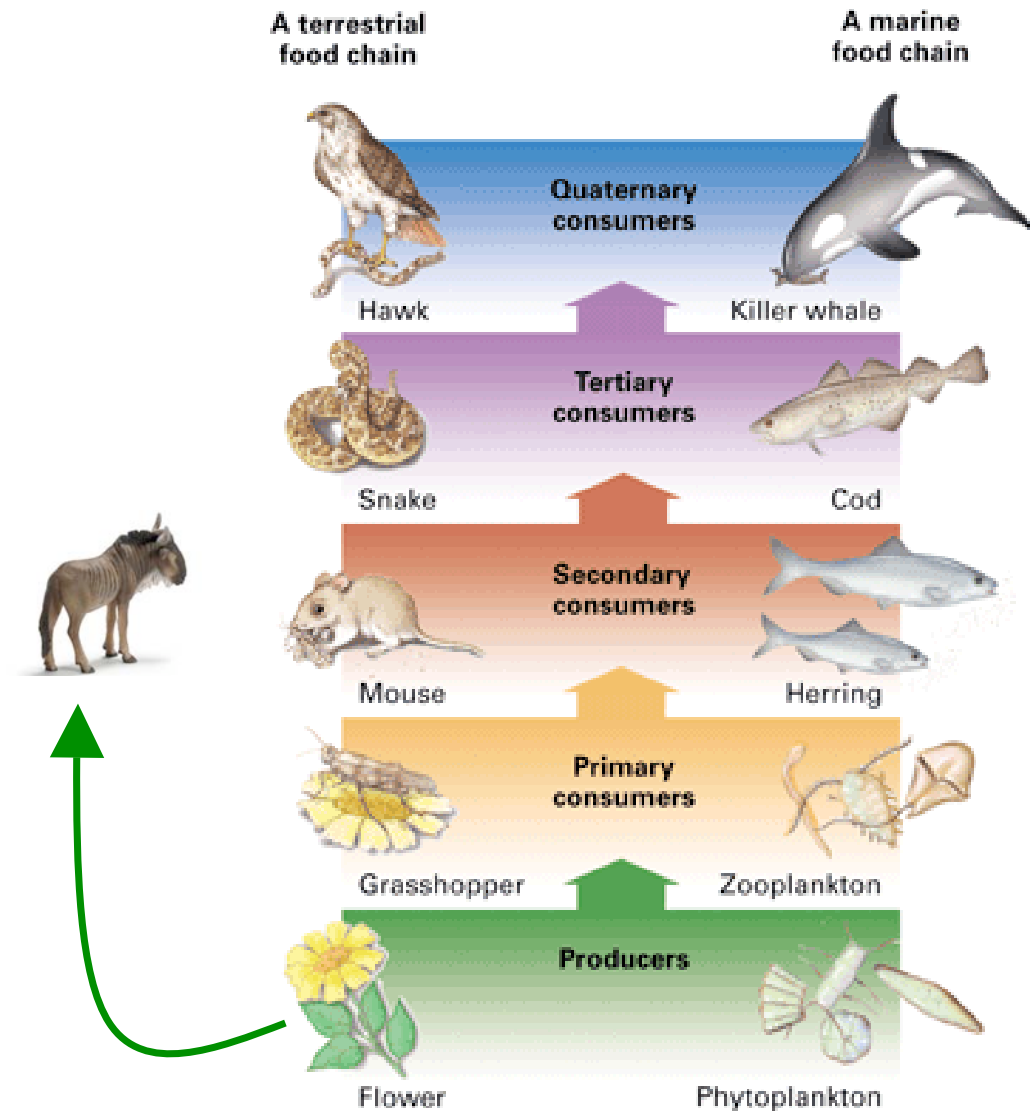
A terrestrial food chain

A marine food chain



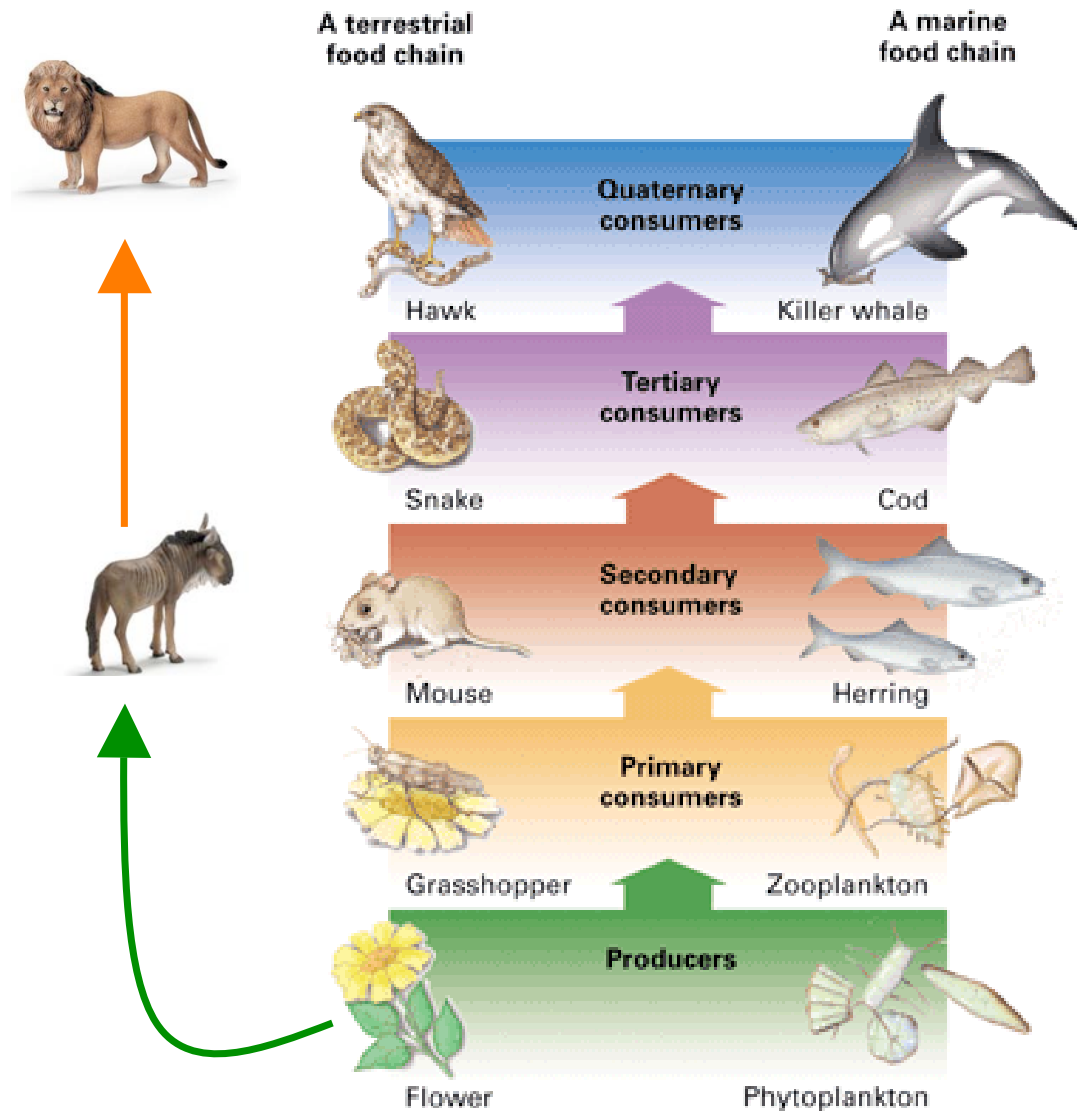


Food chains - and shortcuts



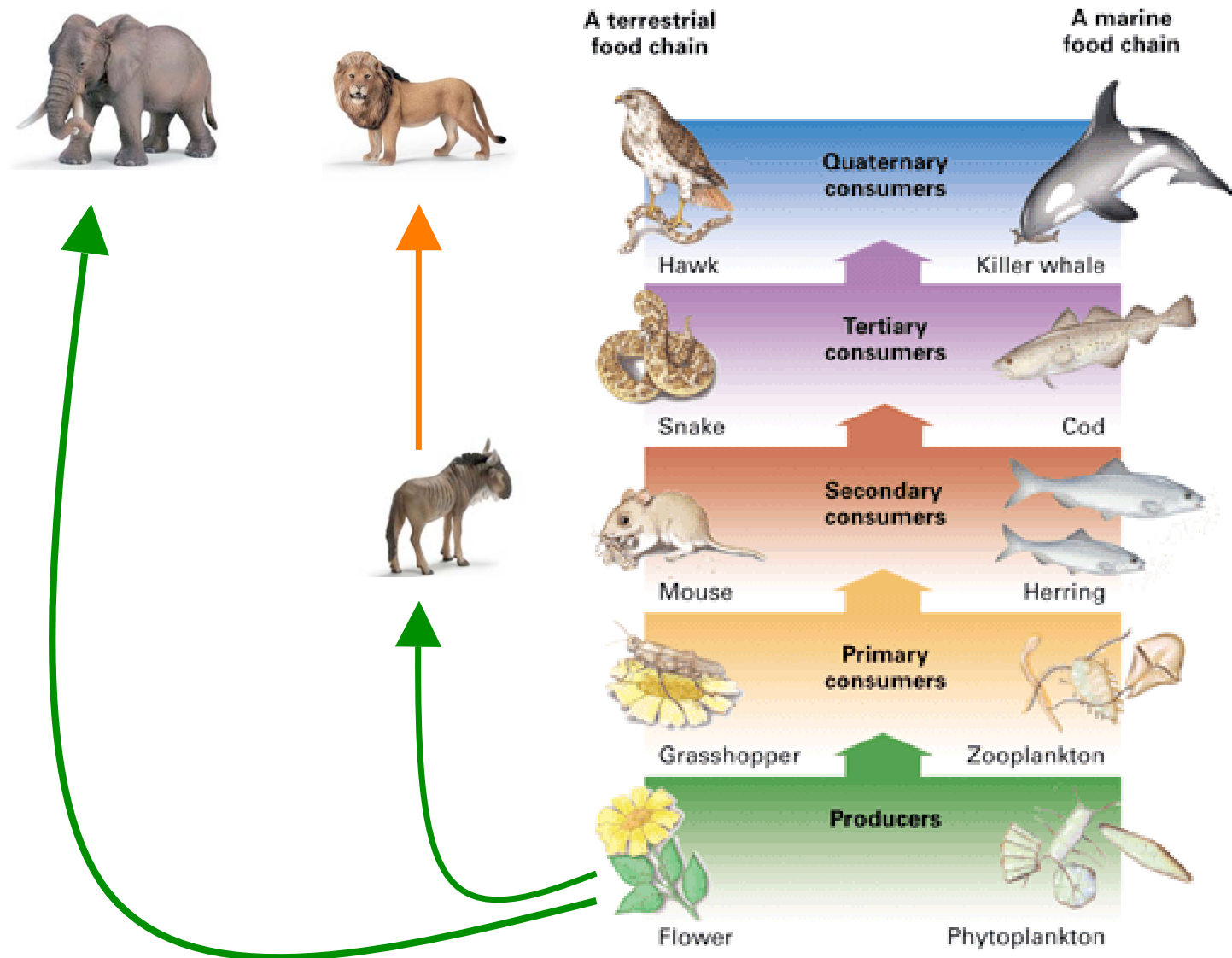


Food chains - and shortcuts





Food chains - and shortcuts





Ubiquitous dense large packages of plant food in terrestrial systems



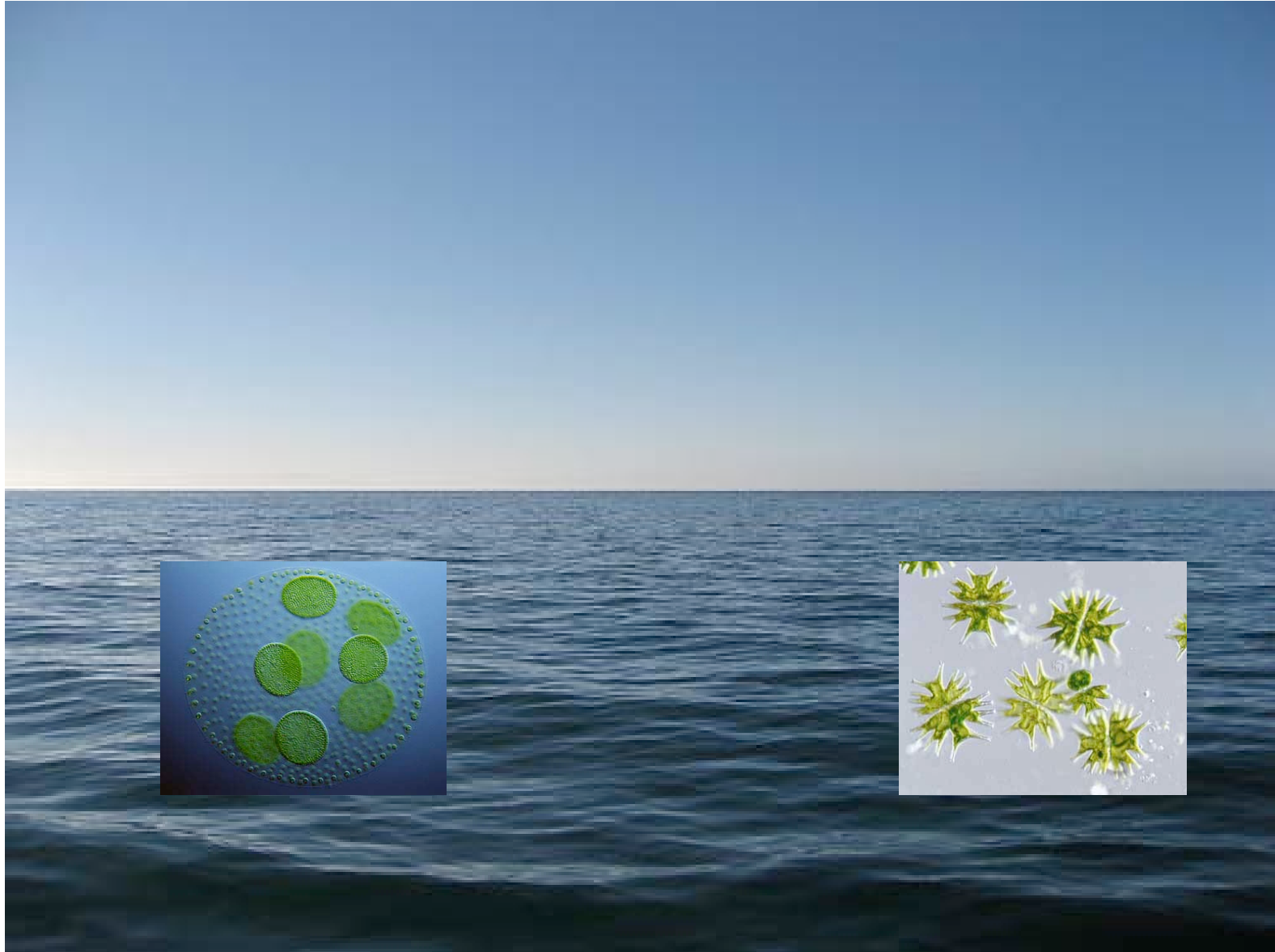


Productive yet minute packages of plant food in marine systems





Productive yet minute packages of plant food in marine systems





Rare large marine herbivores





Rare large marine herbivores



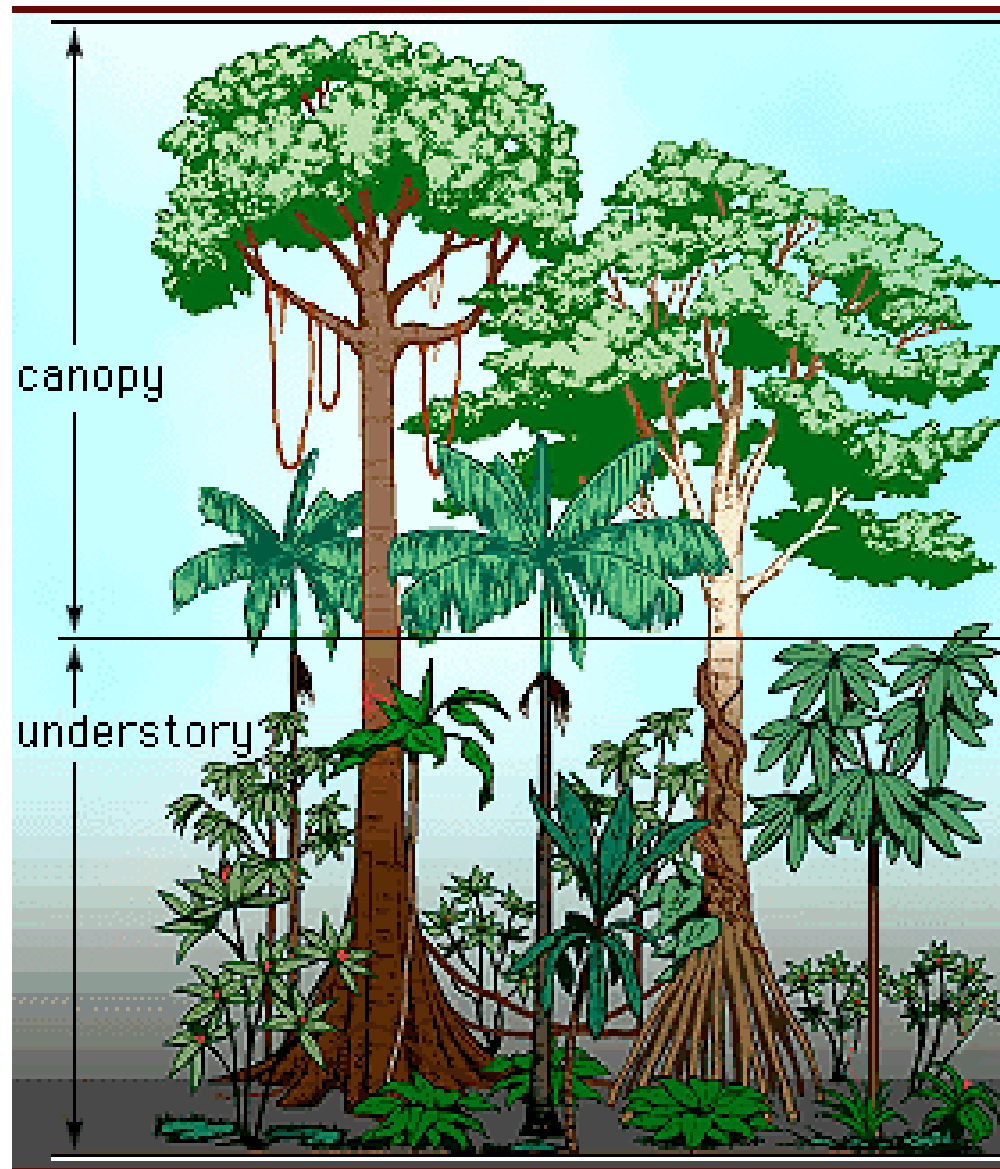


Competition for light ...



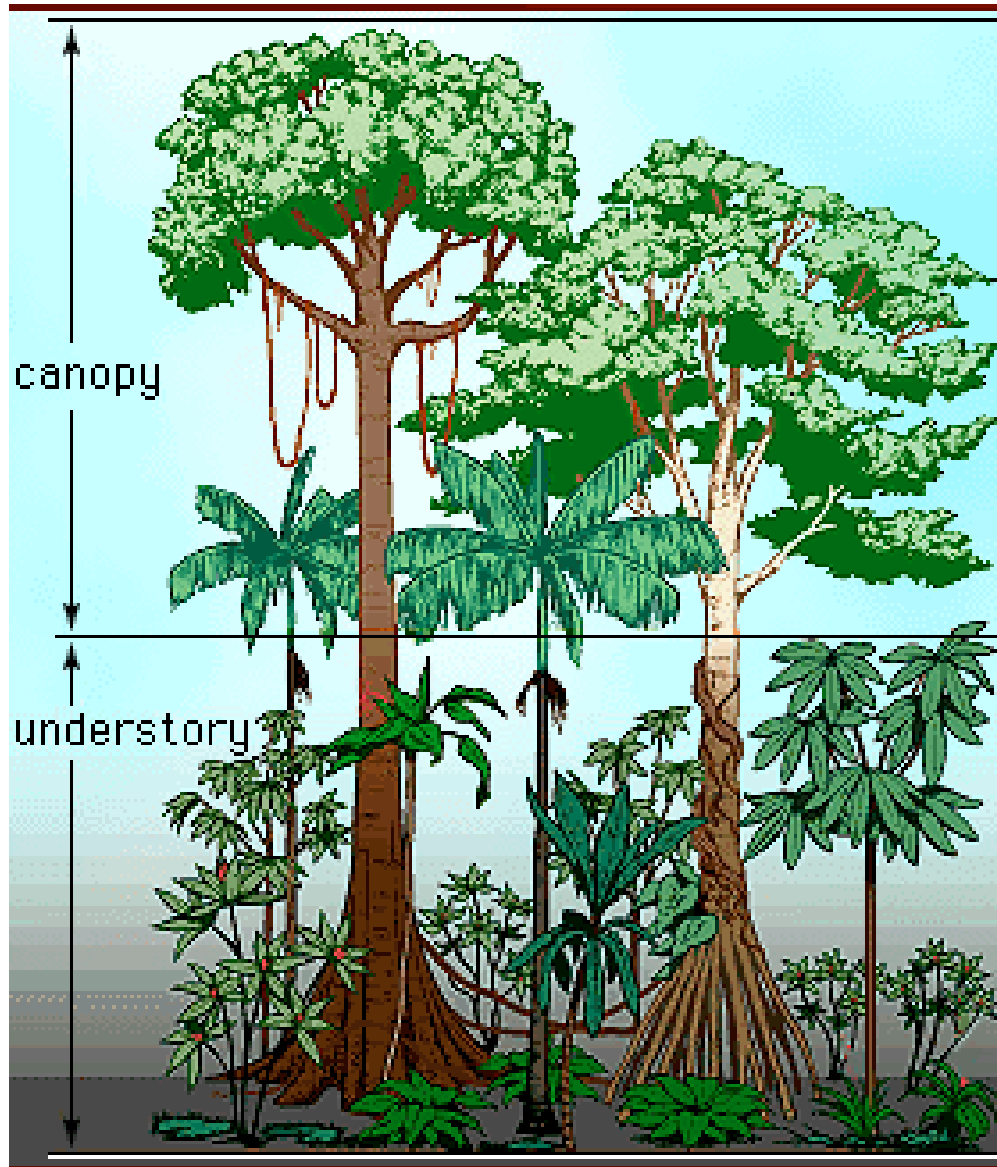


Competition for light ...





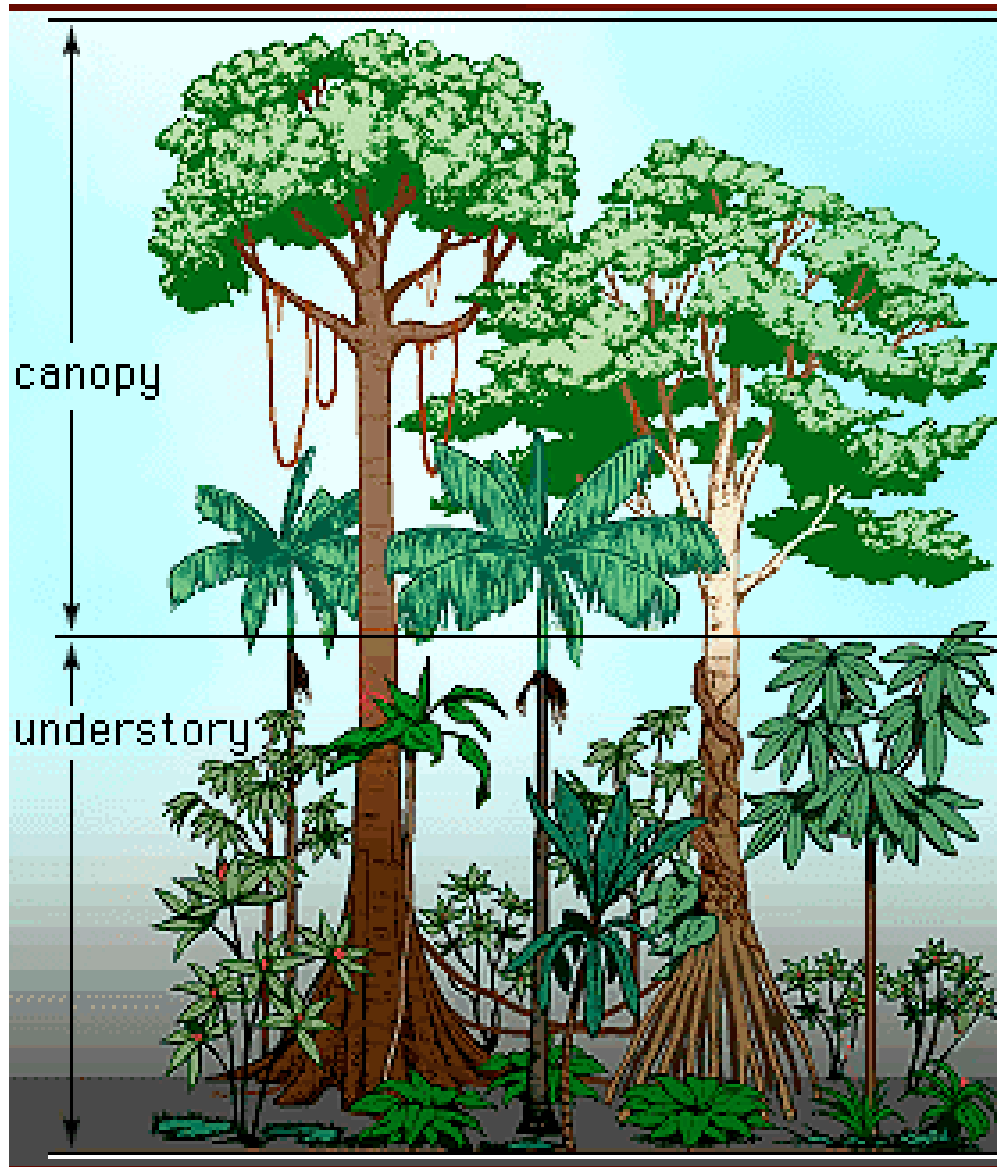
Competition for light ...



... results in a struggle against gravity in terrestrial systems:



Competition for light ...

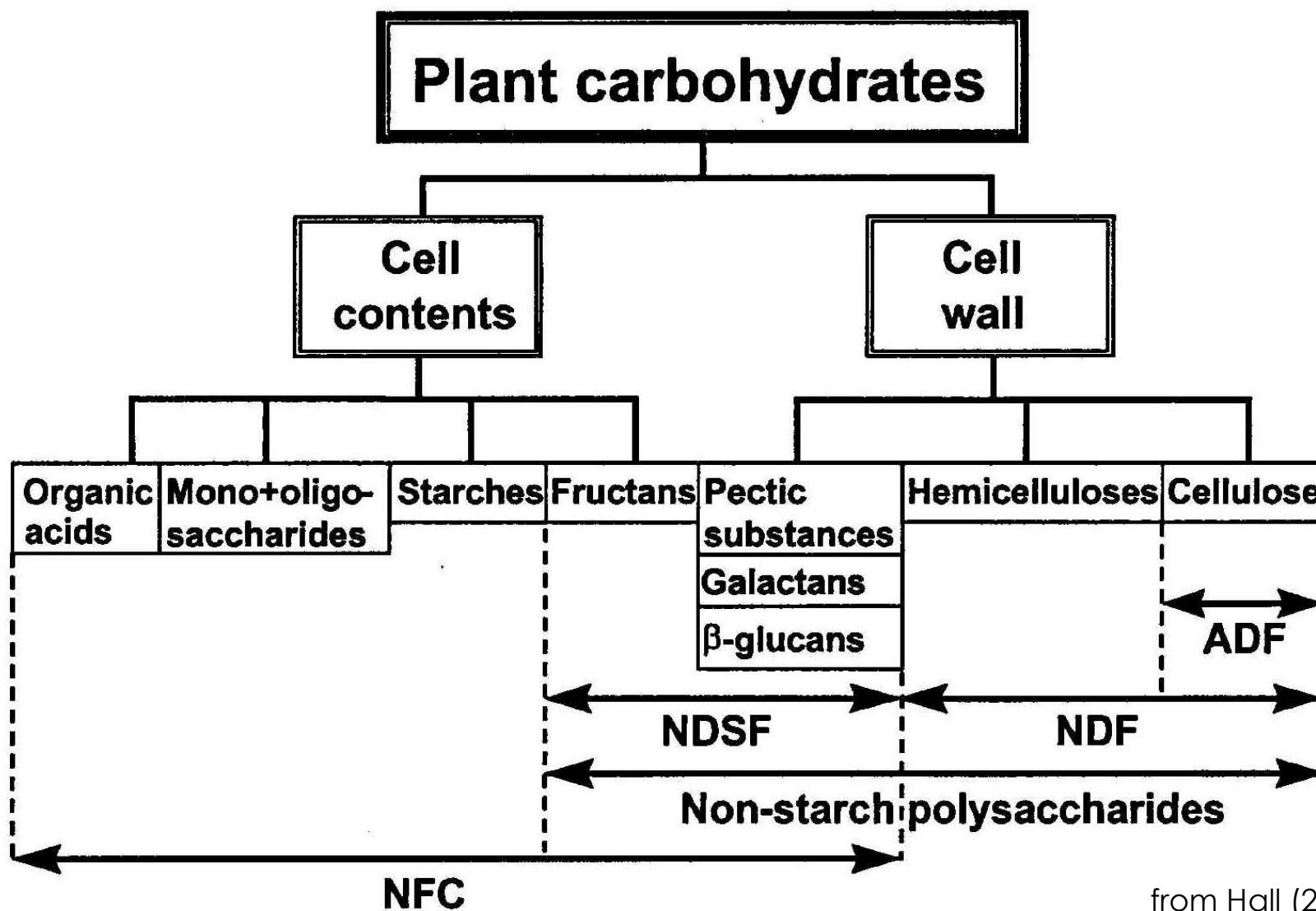


... results in a
struggle against
gravity in
terrestrial
systems:

the evolution of
'fibre'



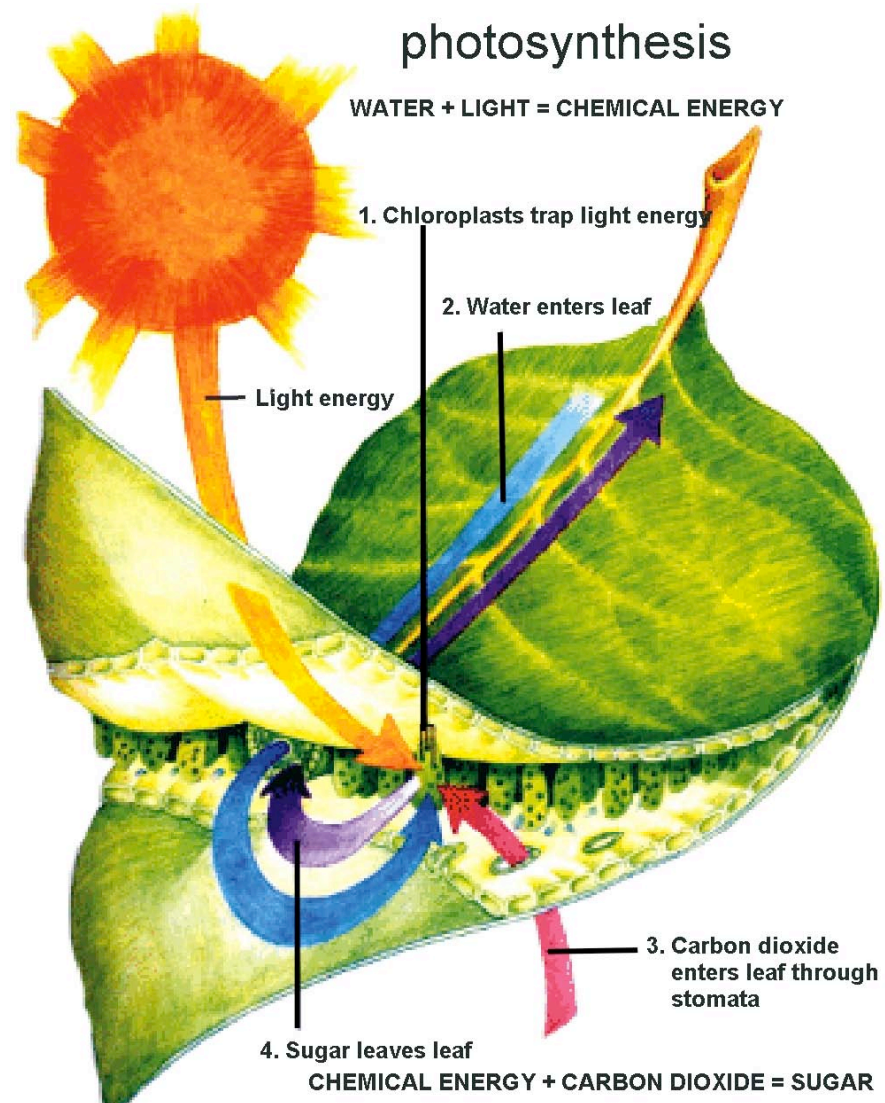
Fibre analysis



from Hall (2003)

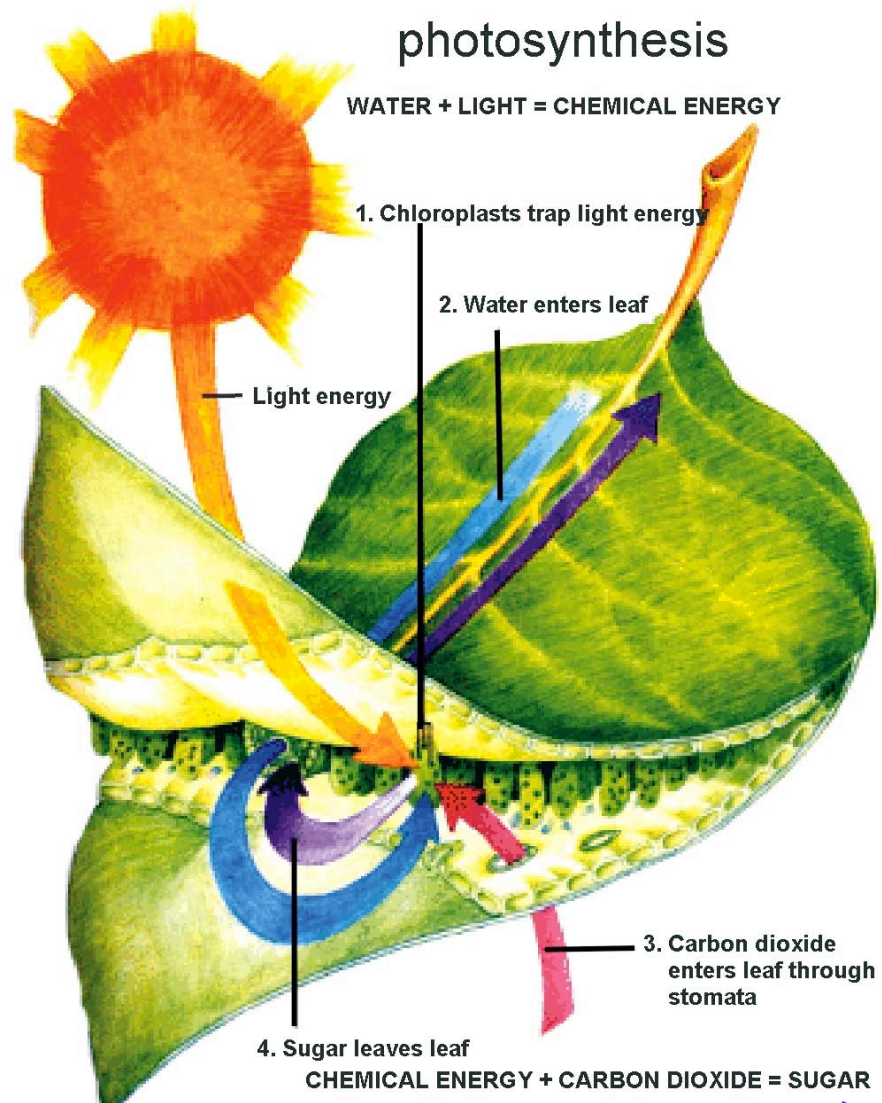


Photosynthesis





Photosynthesis



O_2



First fundamental question

Do you want to use plant fibre or only the plant cell contents?



First fundamental question

Do you want to use plant fibre or only the plant cell contents?





First fundamental question

Do you want to use plant fibre or only the plant cell contents?





Symbiotic Fermentation, Digesta Passage, and Gastrointestinal Morphology in Bullfrog Tadpoles (*Rana catesbeiana*)

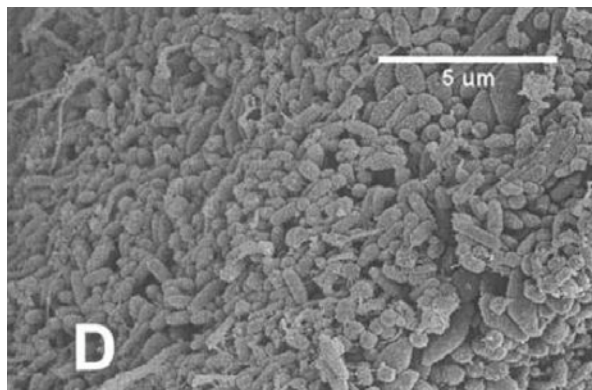


Gregory S. Pryor*

Karen A. Bjorndal†

Department of Zoology, 223 Bartram Hall, P.O. Box 118525,
University of Florida, Gainesville, Florida 32611-8525

Physiological and Biochemical Zoology 78(2):201–215. 2005.





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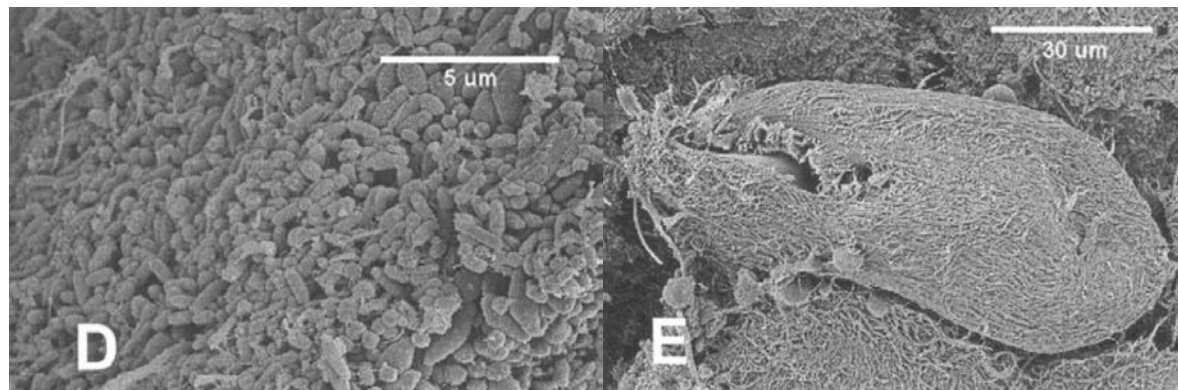


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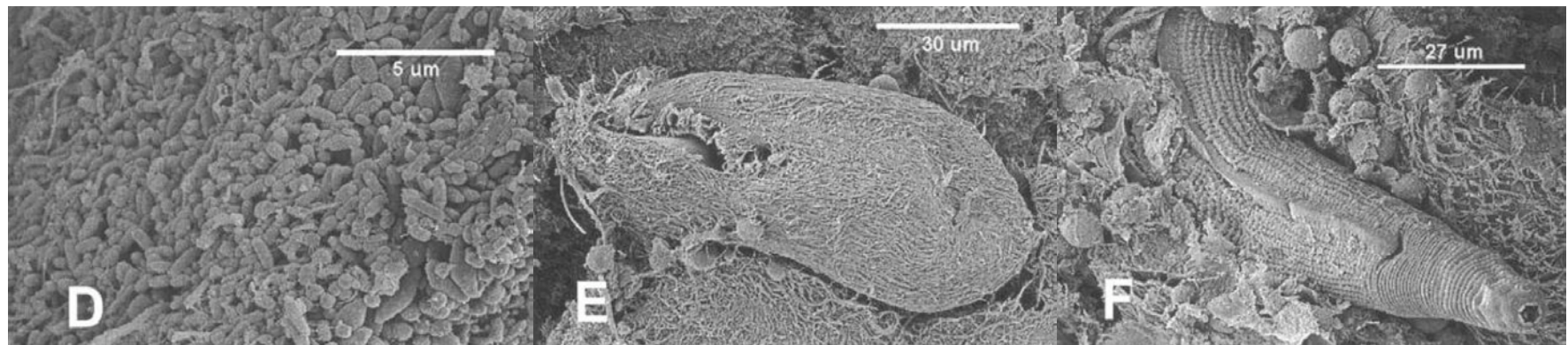


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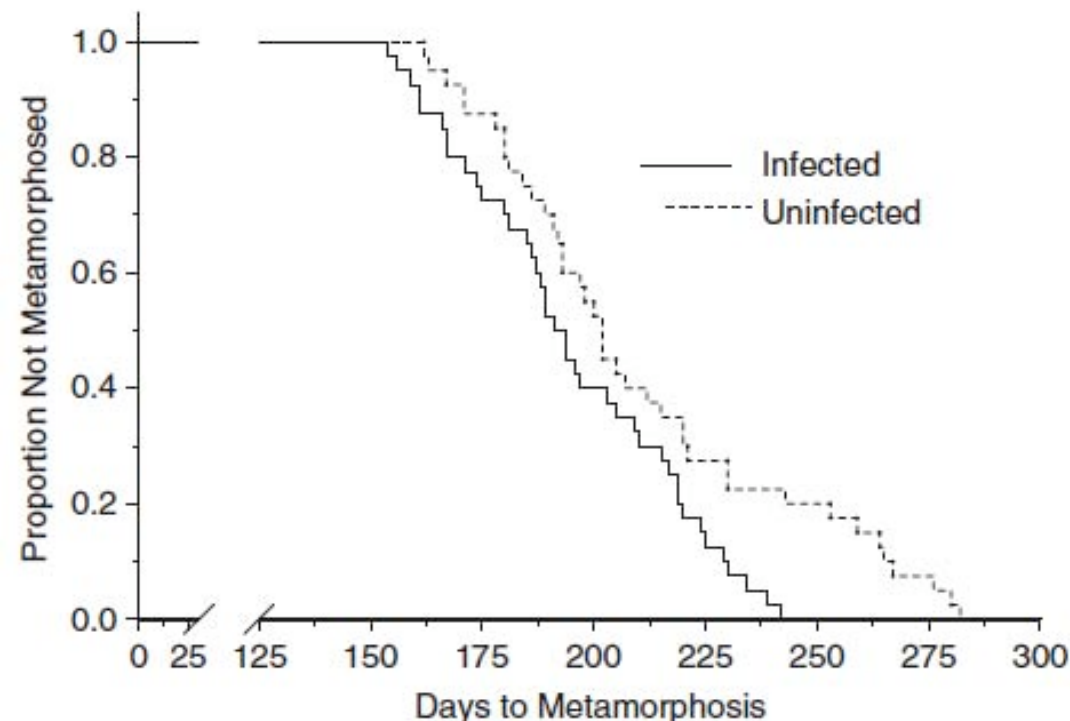
Effects of the Nematode *Gyrinicola batrachiensis* on Development, Gut Morphology, and Fermentation in Bullfrog Tadpoles (*Rana catesbeiana*): A Novel Mutualism



GREGORY S. PRYOR* AND KAREN A. BJORNDAL

Department of Zoology, University of Florida, Gainesville, Florida 32611-8525

JOURNAL OF EXPERIMENTAL ZOOLOGY 303A:704–712 (2005)





Evolution of Mammals and Their Gut Microbes

Ruth E. Ley,¹ Micah Hamady,² Catherine Lozupone,^{1,3} Peter J. Turnbaugh,¹
Rob Roy Ramey,⁴ J. Stephen Bircher,⁵ Michael L. Schlegel,⁶ Tammy A. Tucker,⁶
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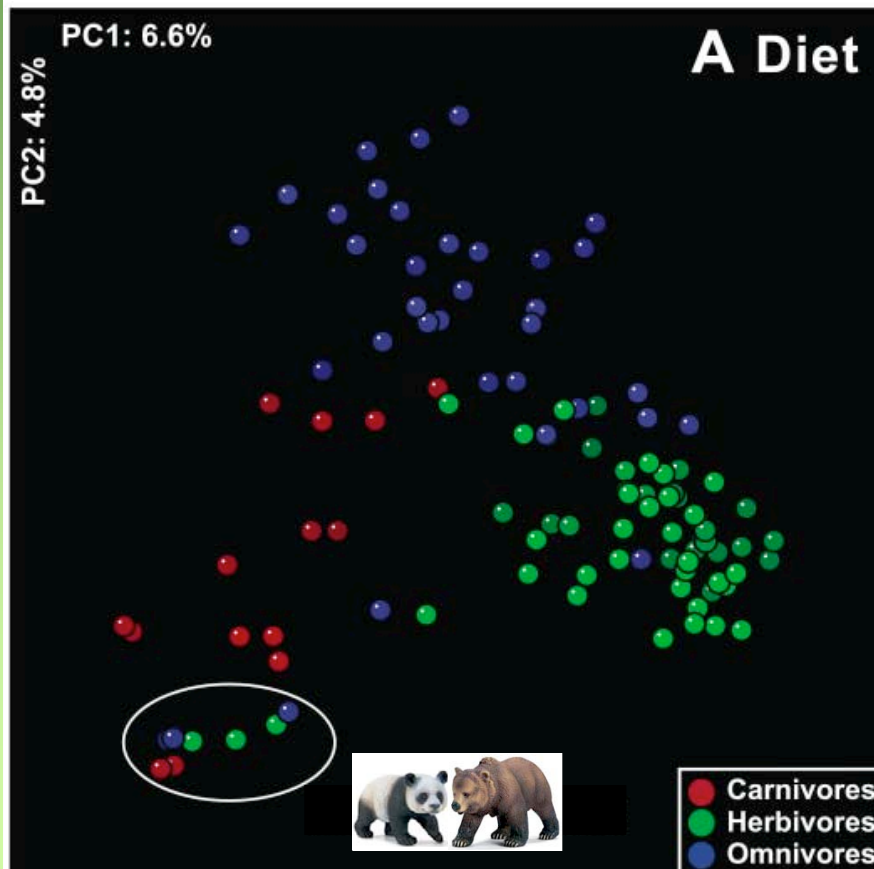
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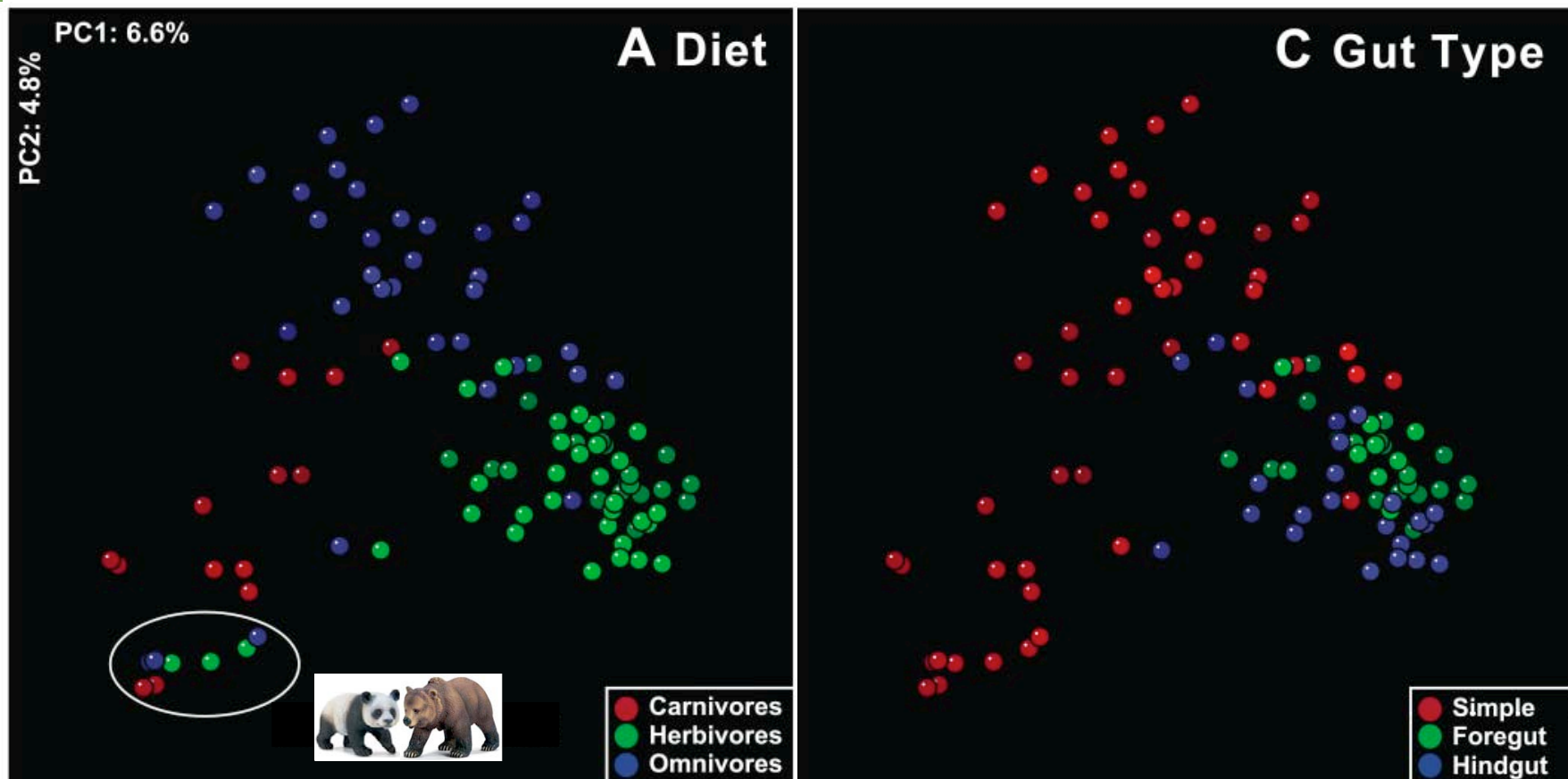




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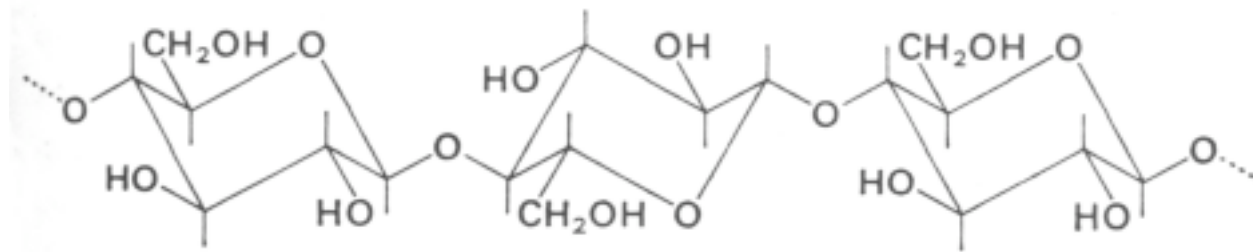
SCIENCE VOL 320 20 JUNE 2008





Fibre digestion

Organic polymers
(cellulose, hemicellulose)



from Karasov & Martinez del Rio (2007)



Fibre digestion

Organic polymers
(cellulose, hemicellulose)



Hydrolysis
(soluble sugars)



Fibre digestion

Organic polymers
(cellulose, hemicellulose)



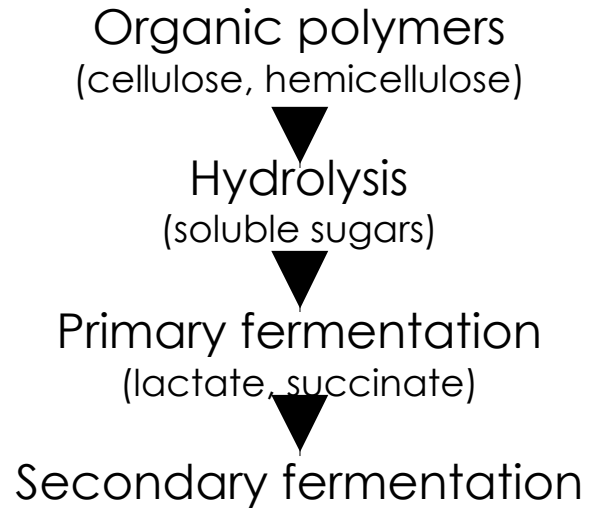
Hydrolysis
(soluble sugars)



Primary fermentation
(lactate, succinate)

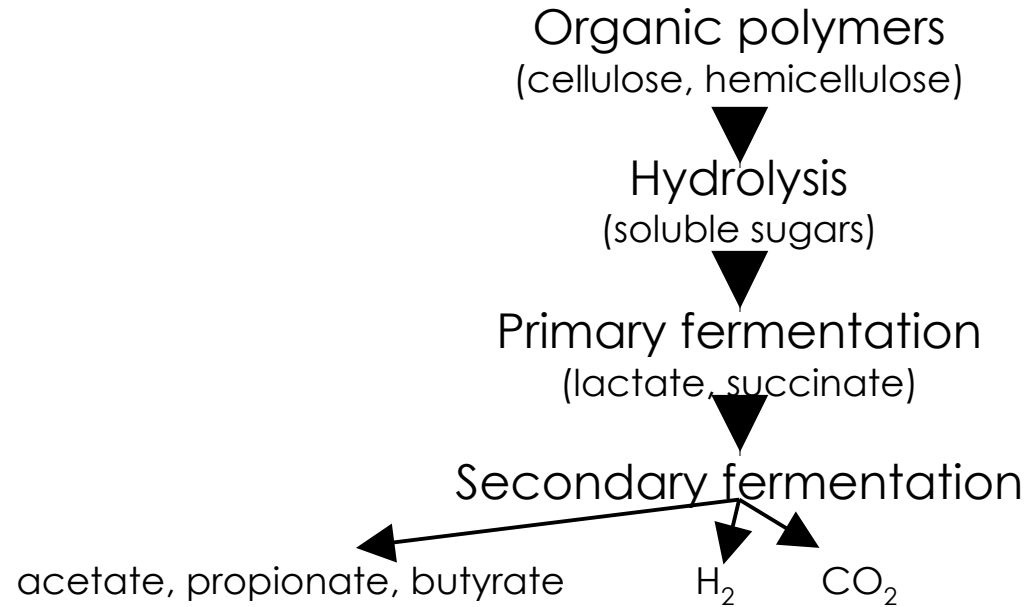


Fibre digestion



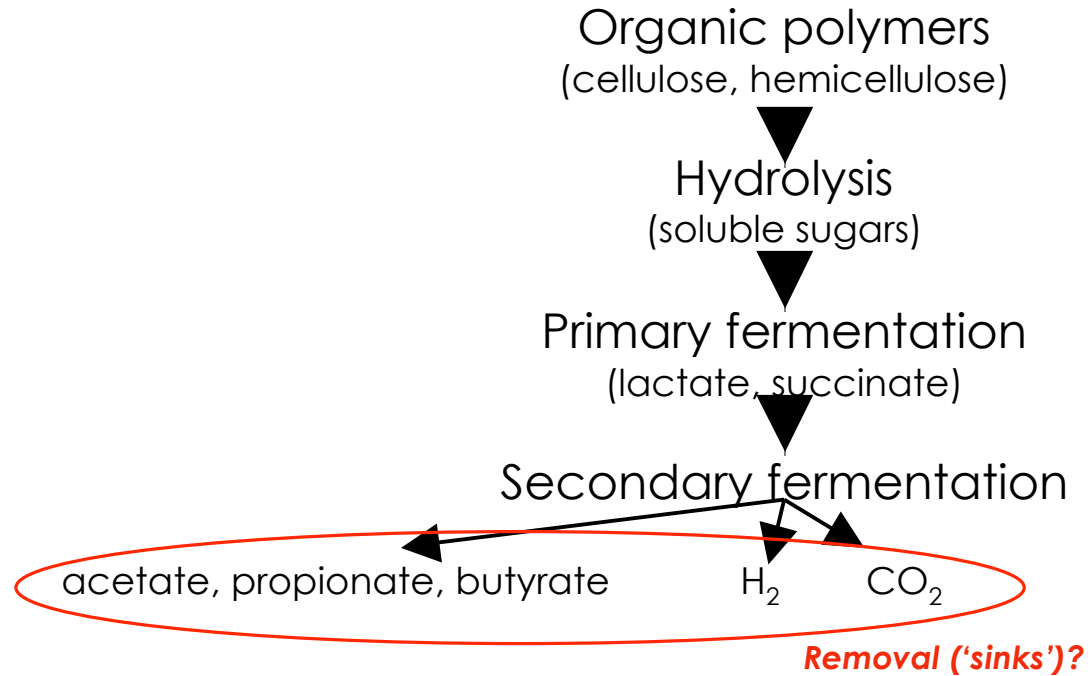


Fibre digestion



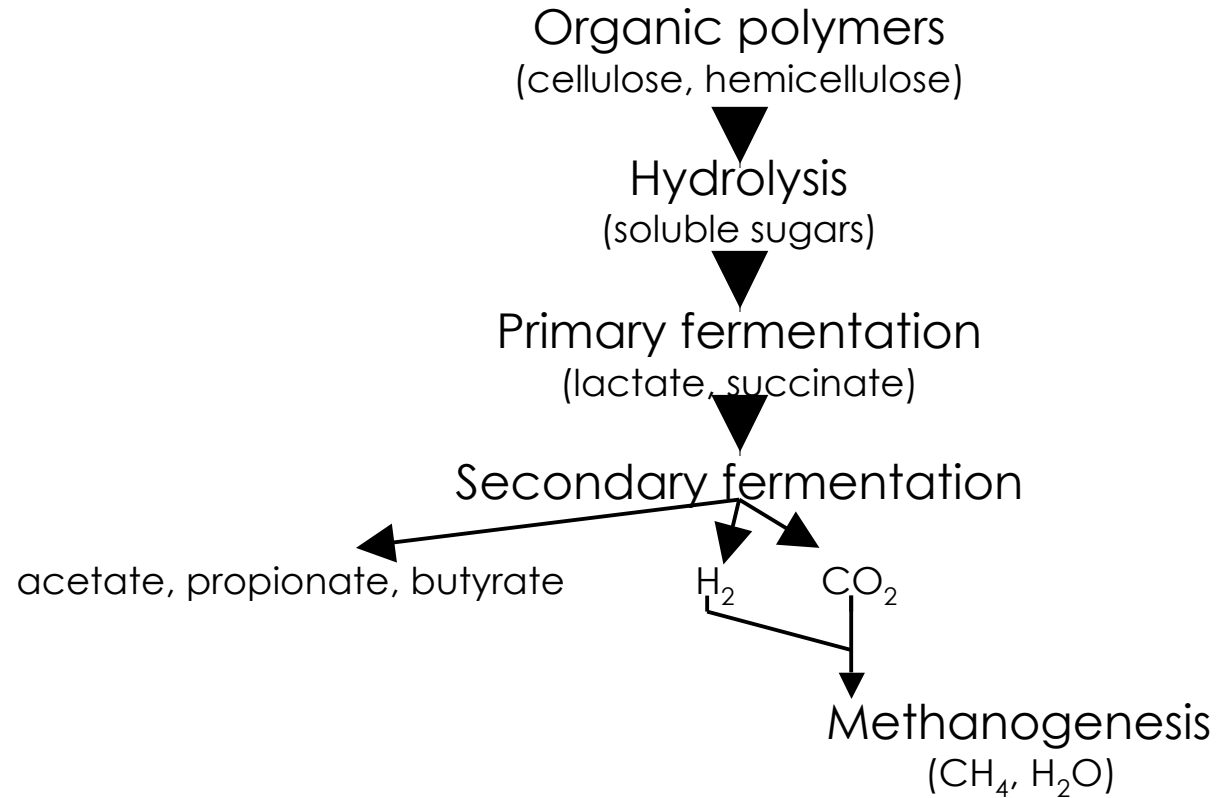


Fibre digestion



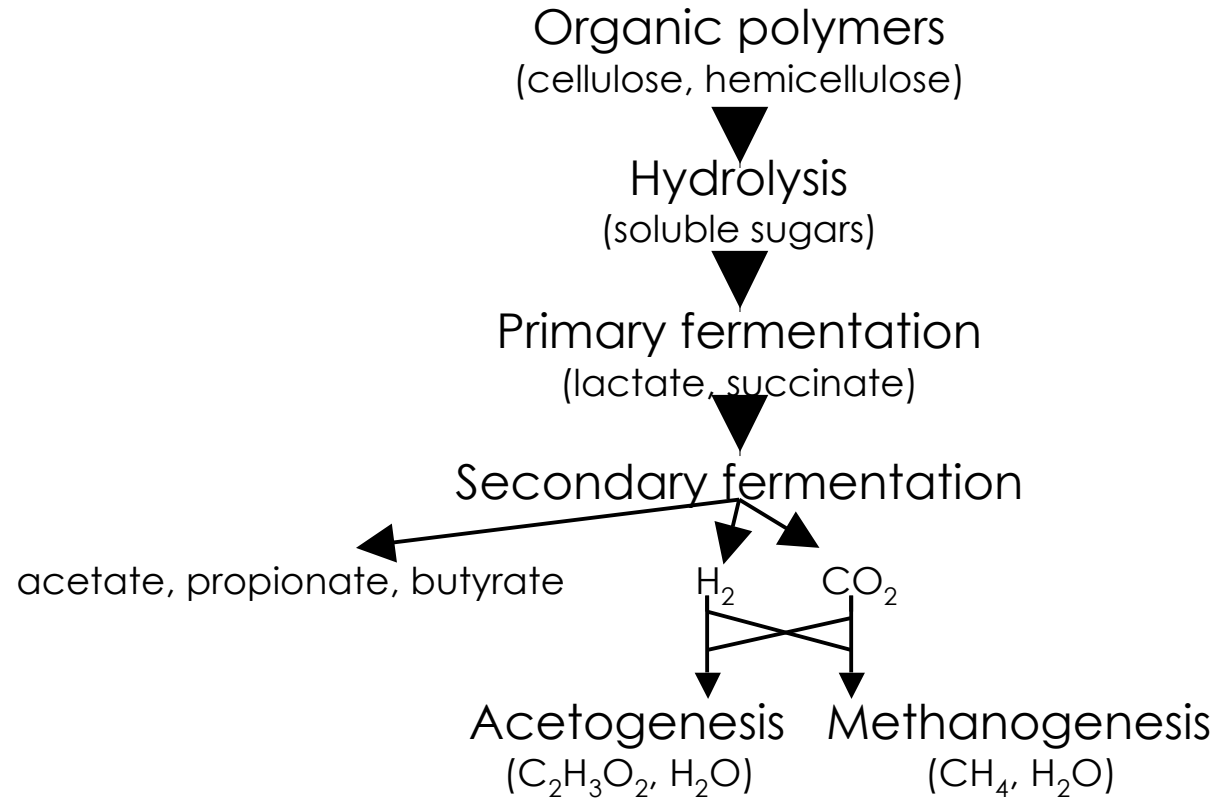


Fibre digestion



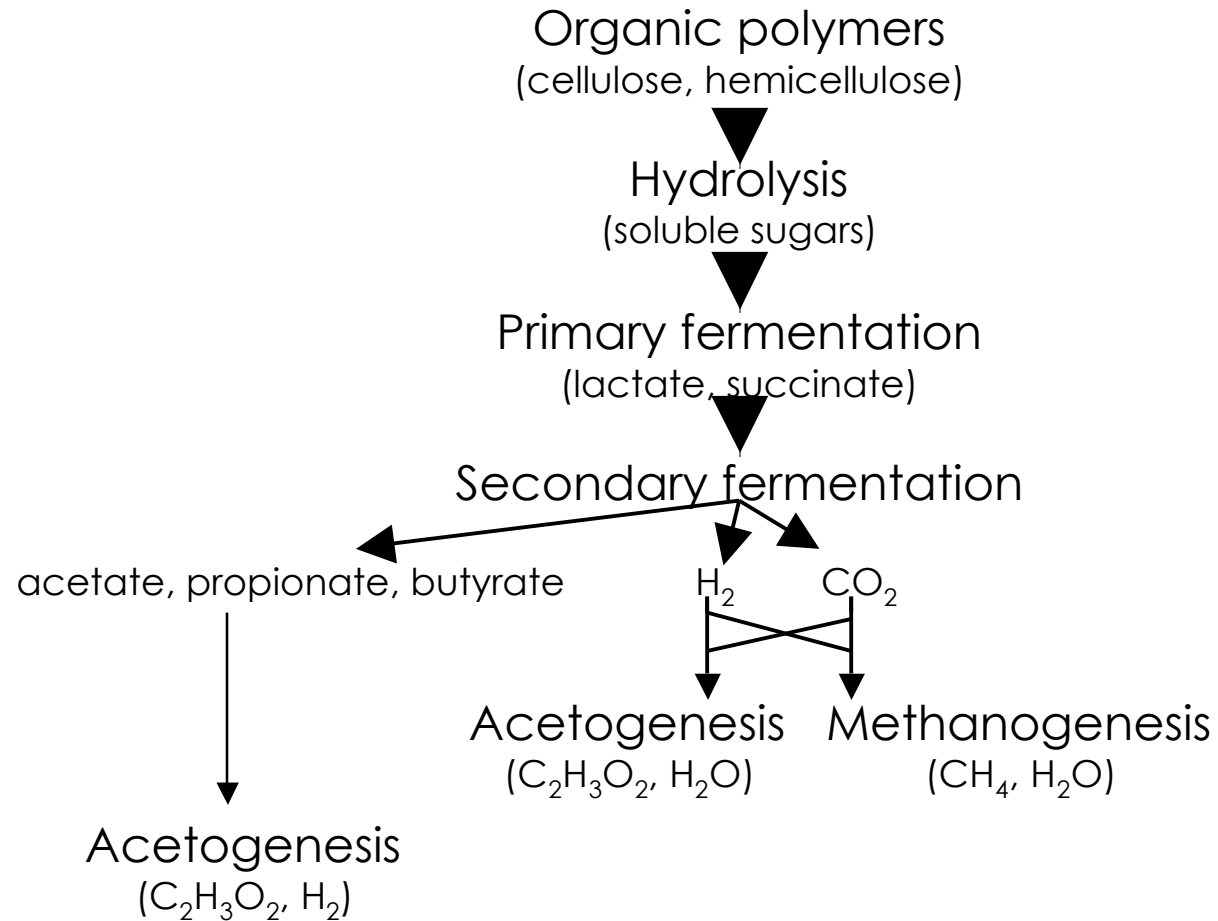


Fibre digestion



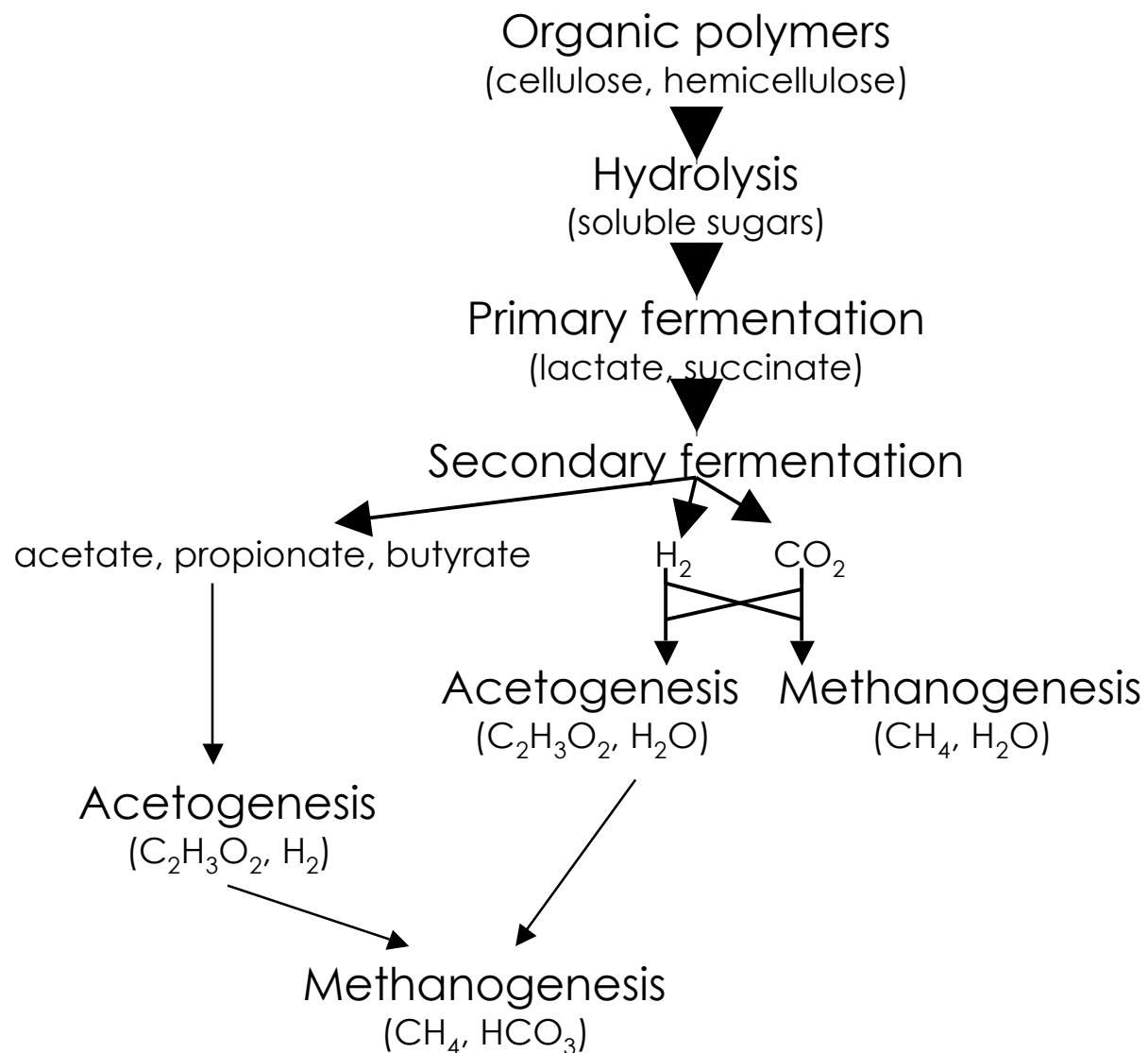


Fibre digestion





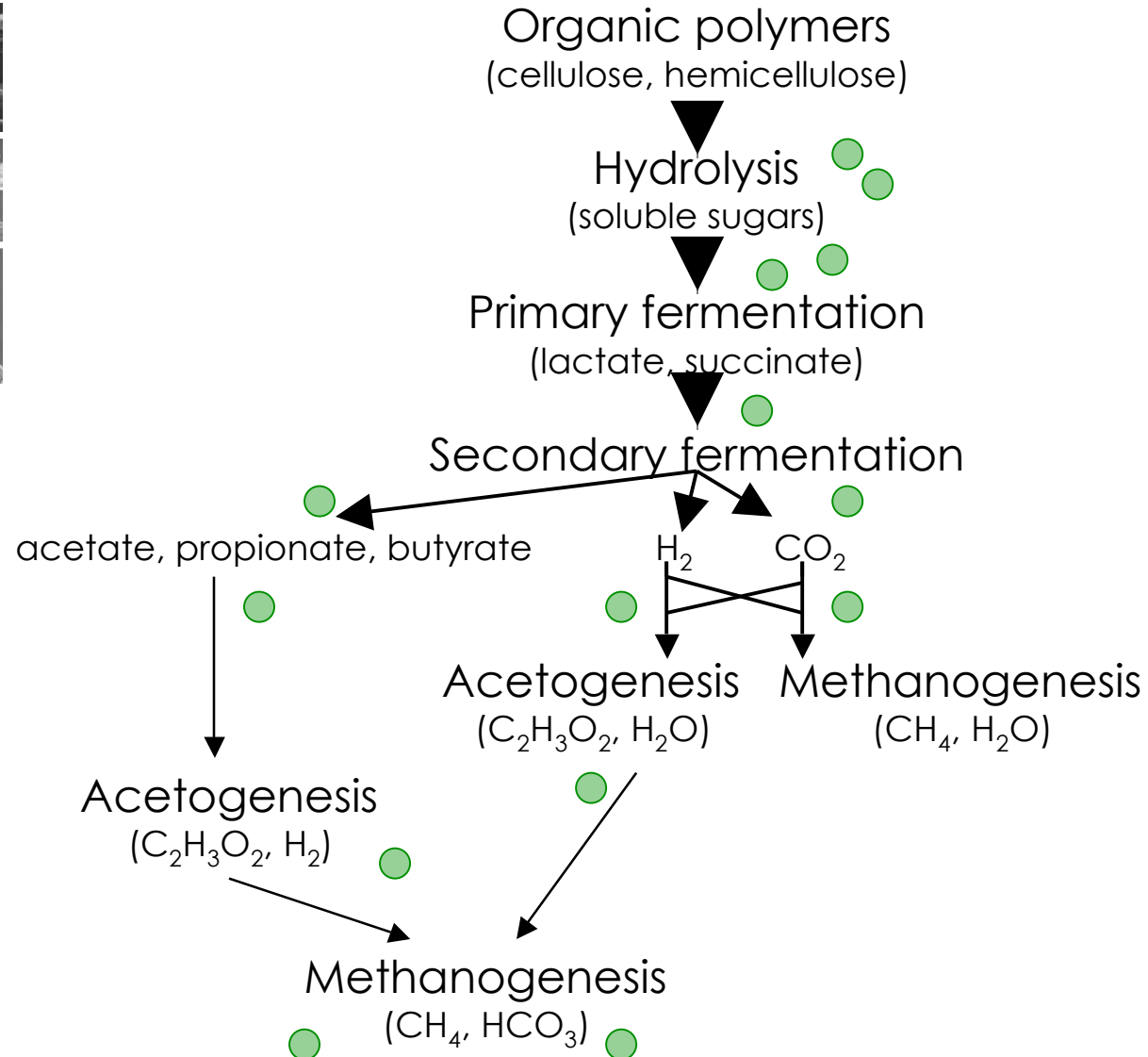
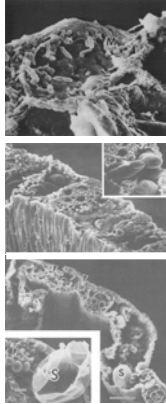
Fibre digestion



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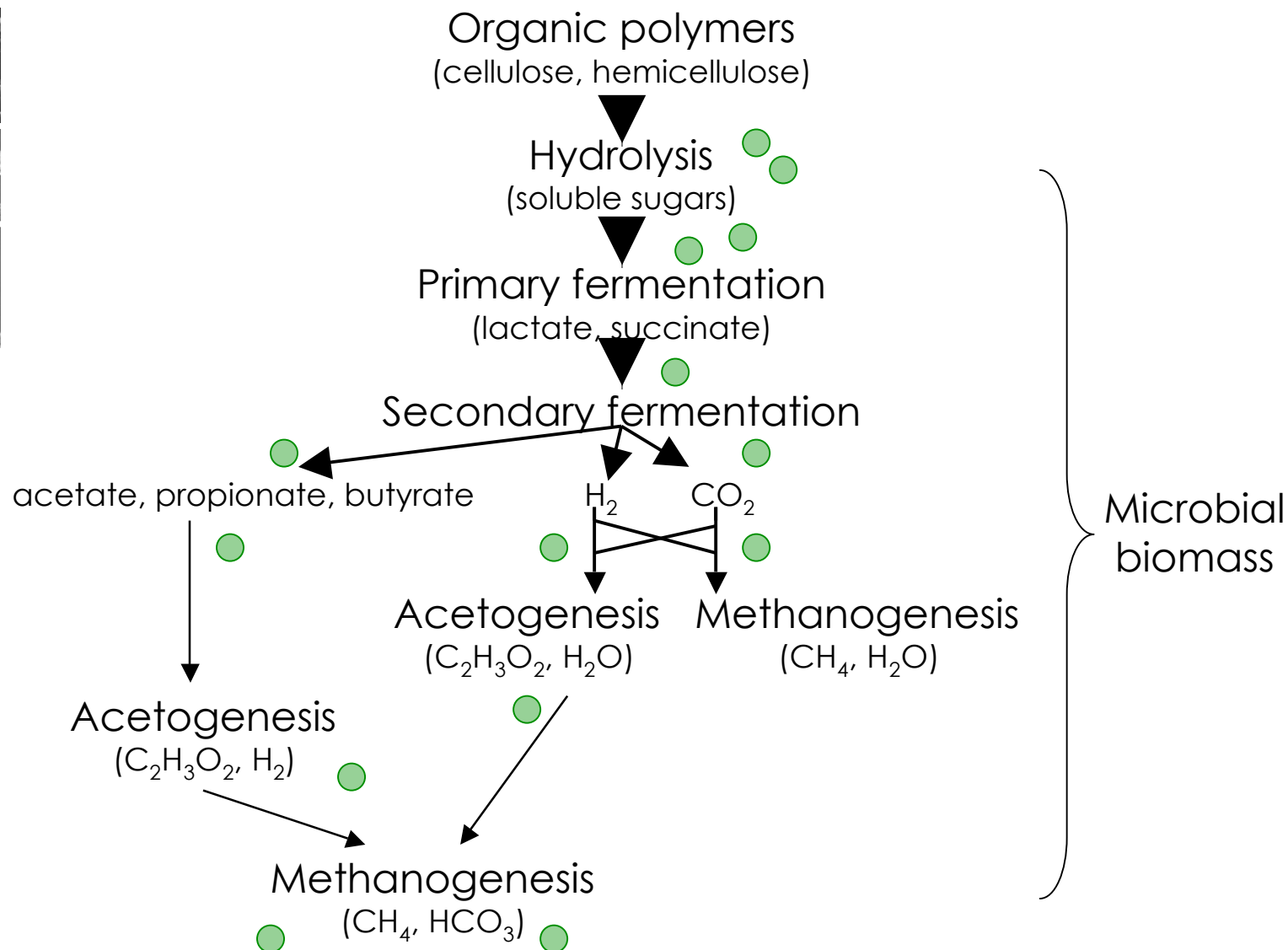
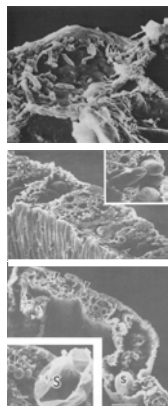
Fibre digestion



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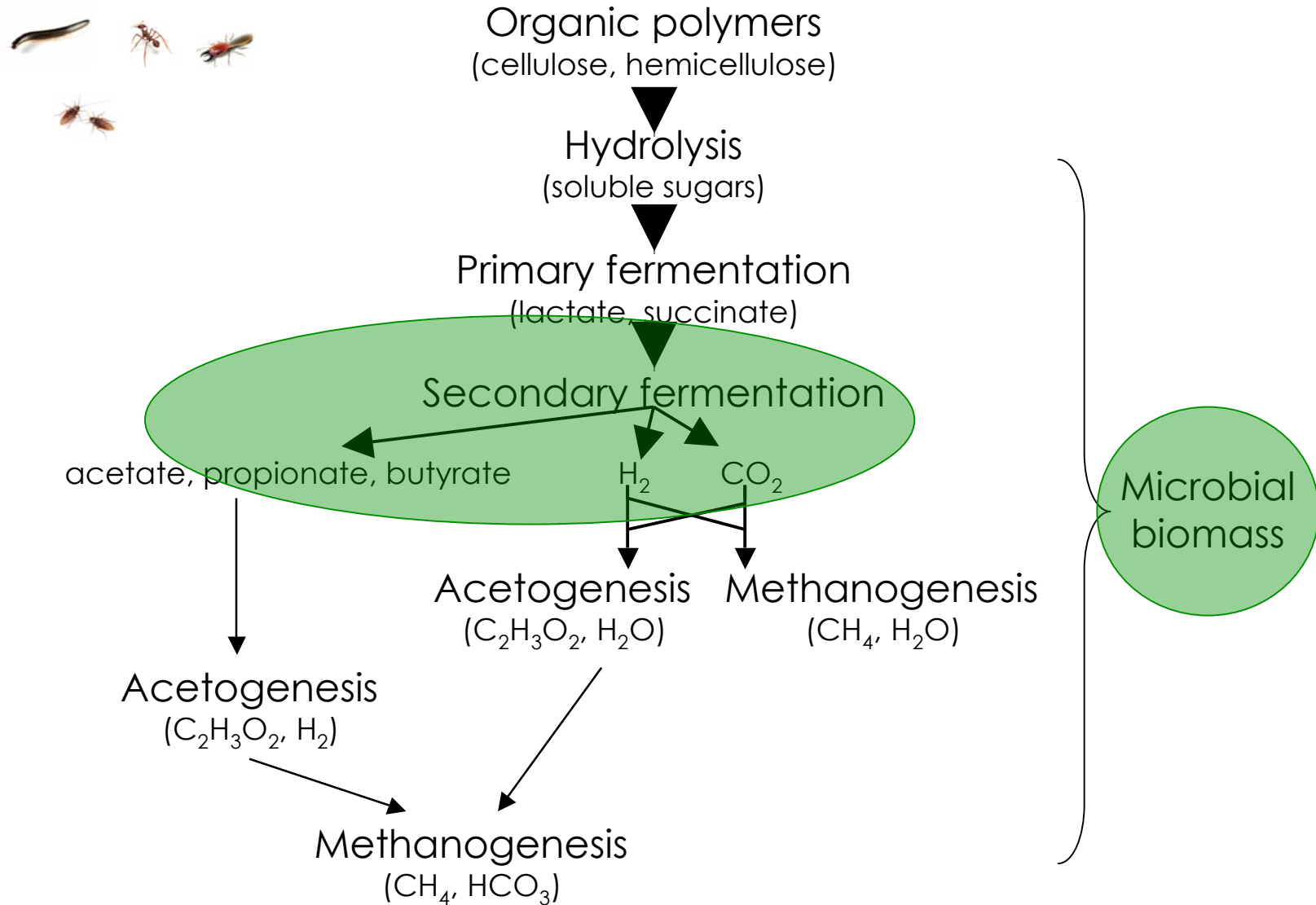
Fibre digestion



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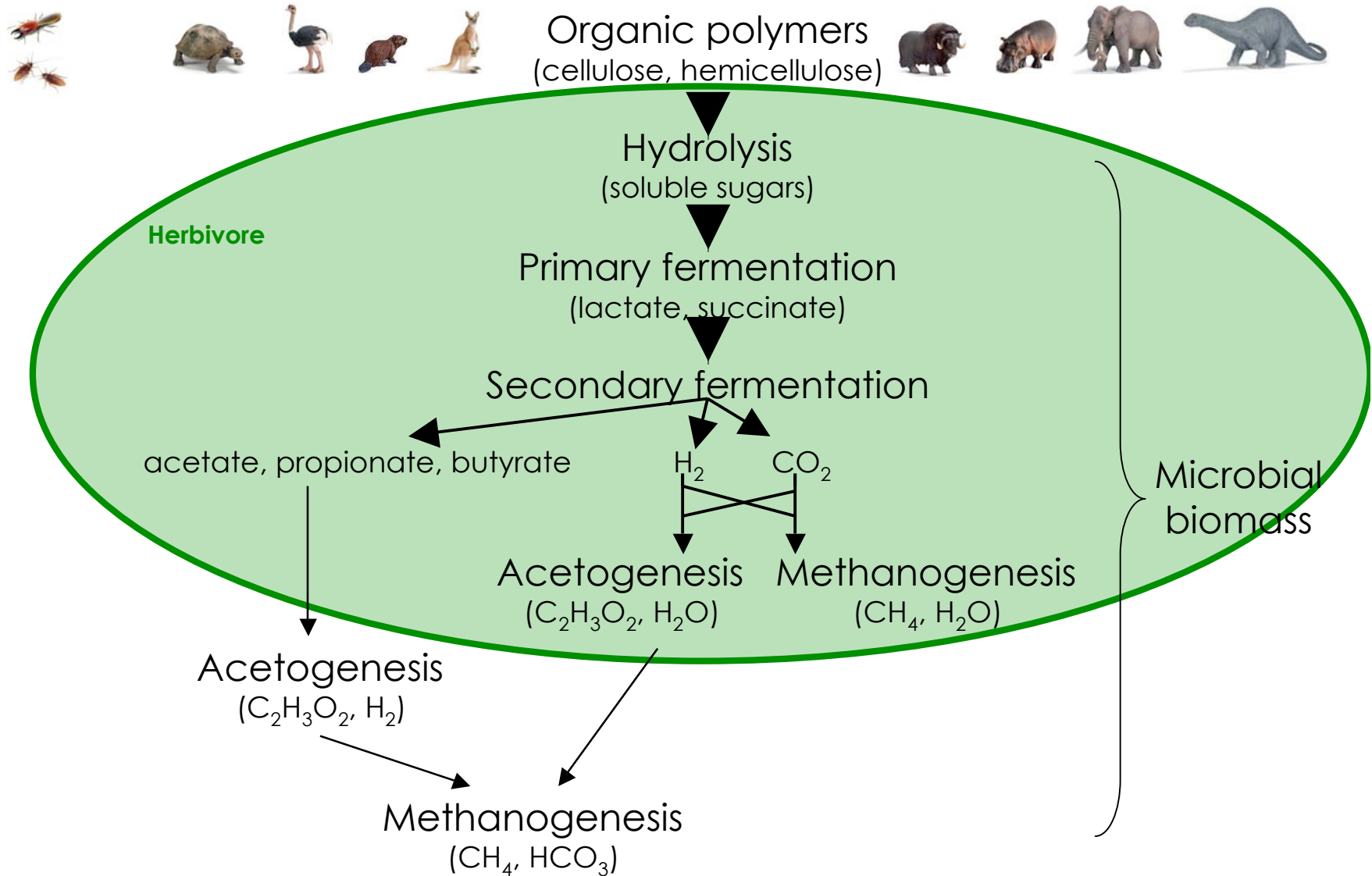
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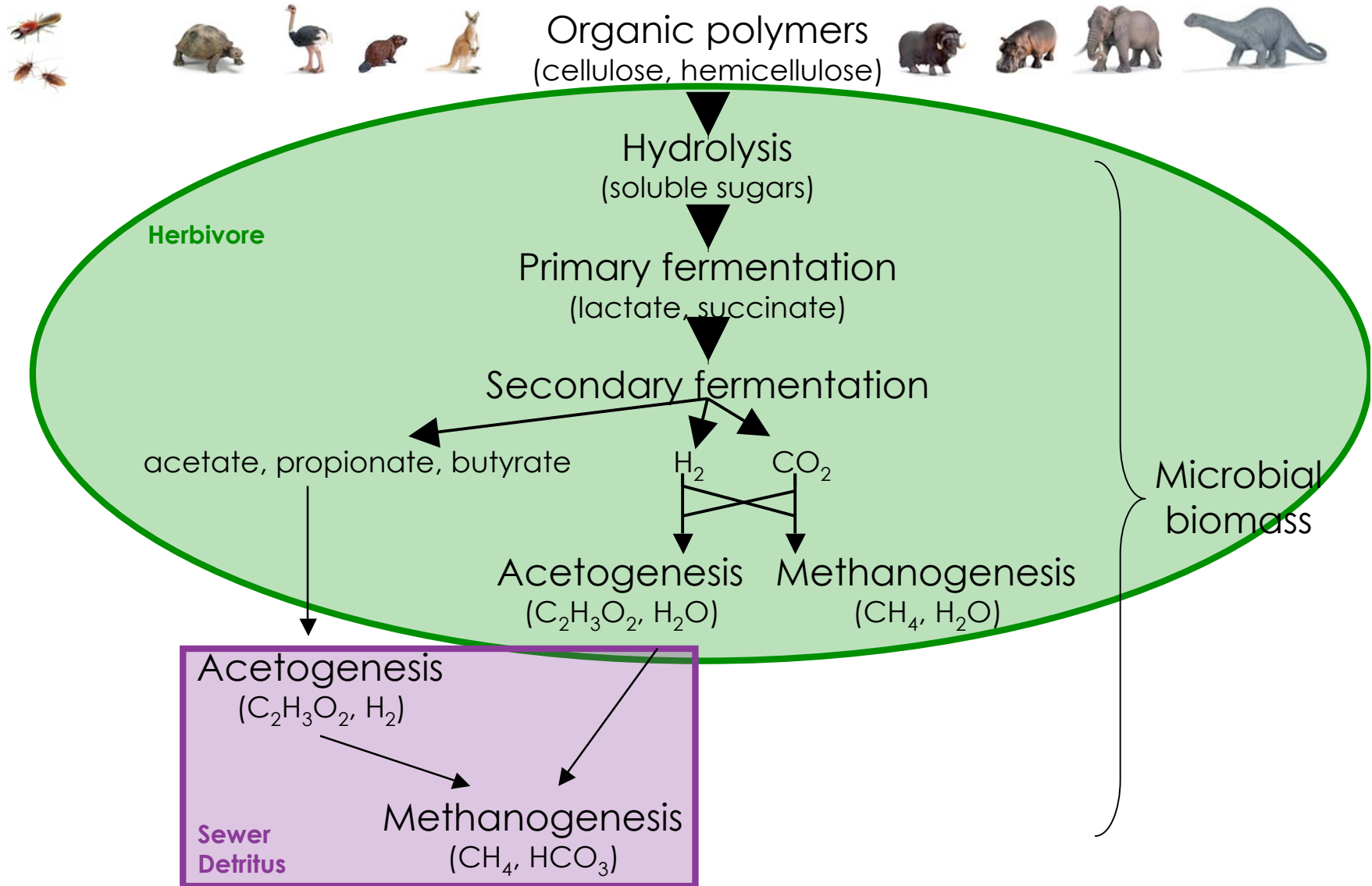
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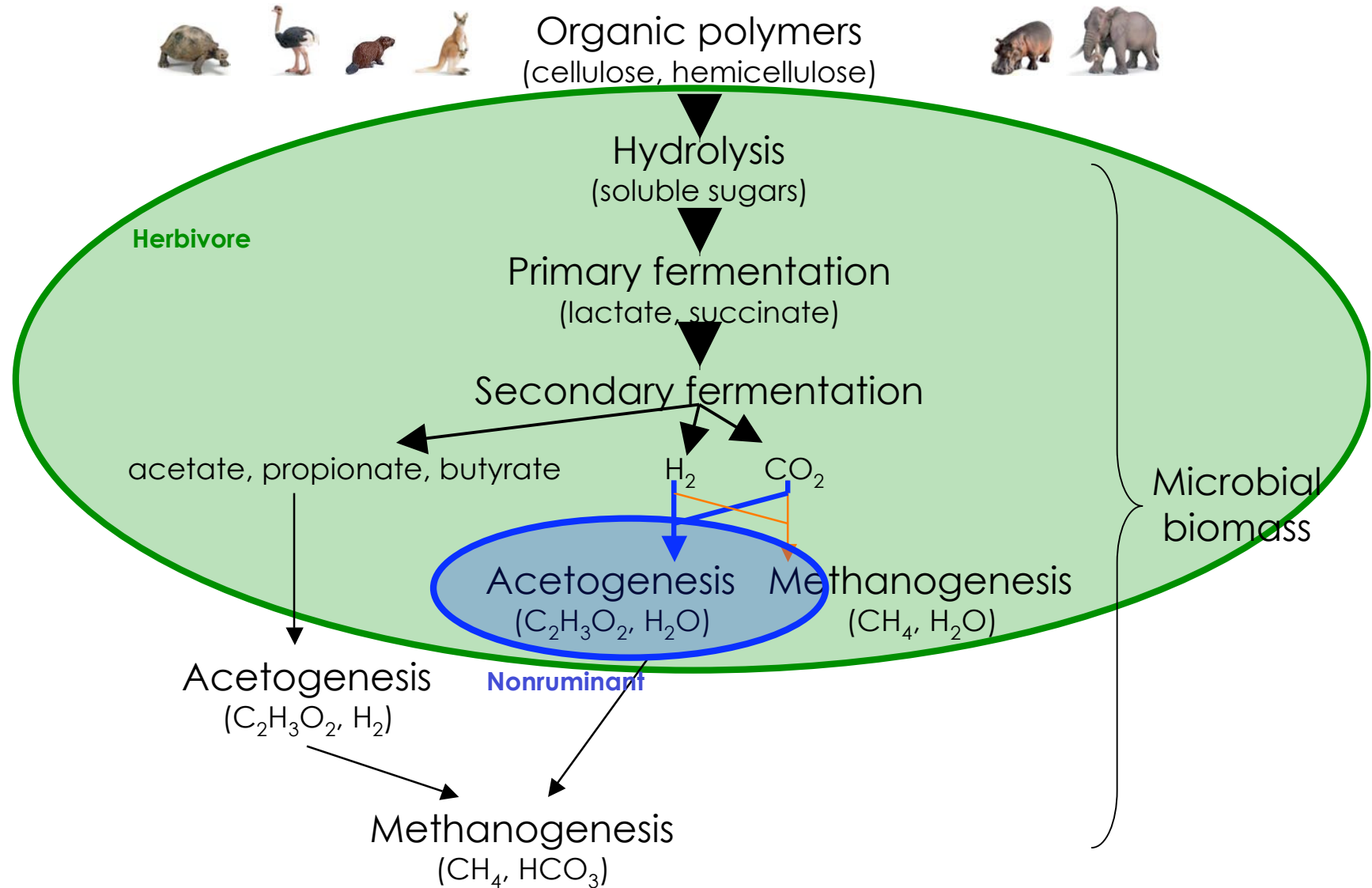
Fibre digestion



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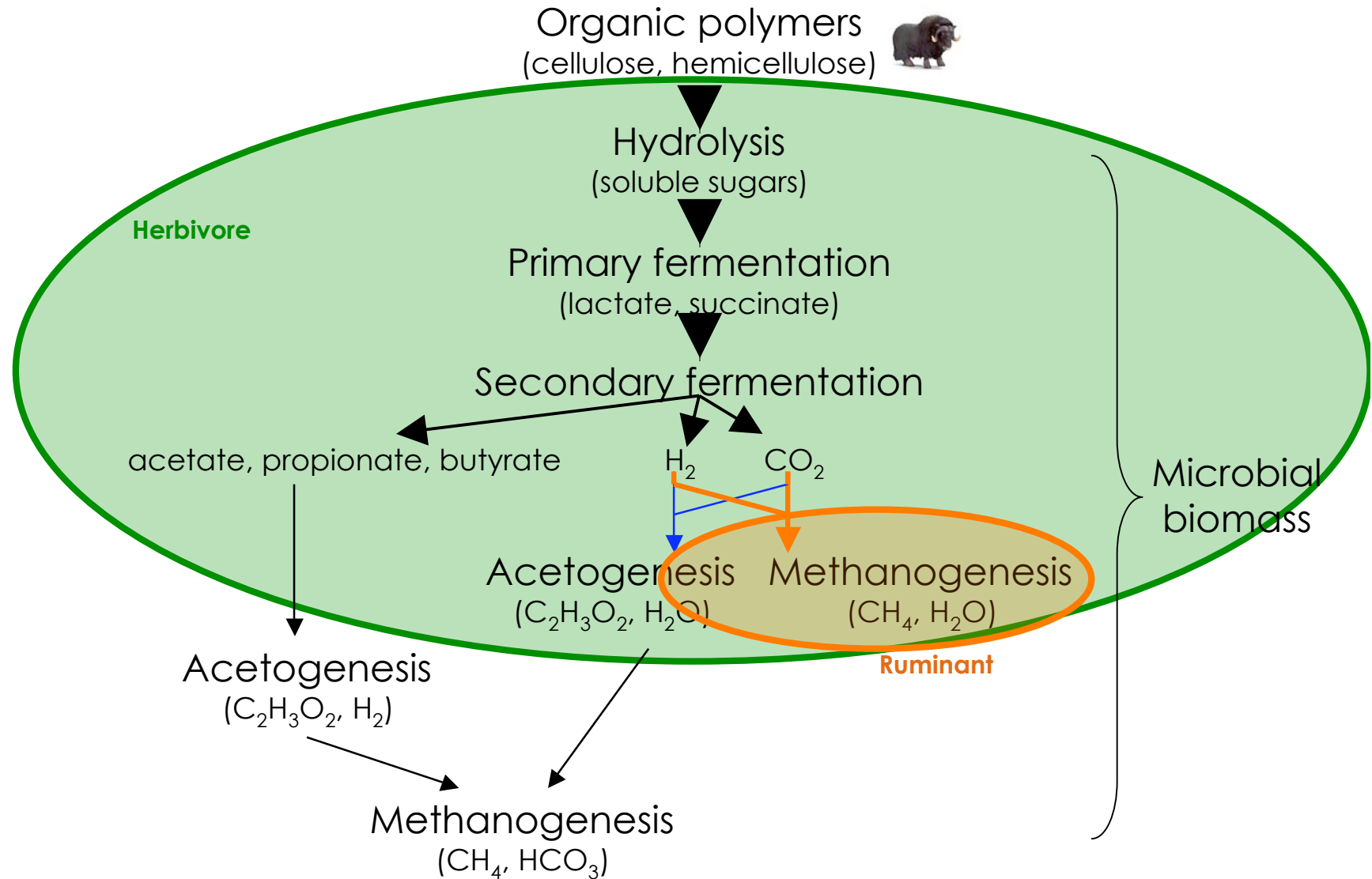
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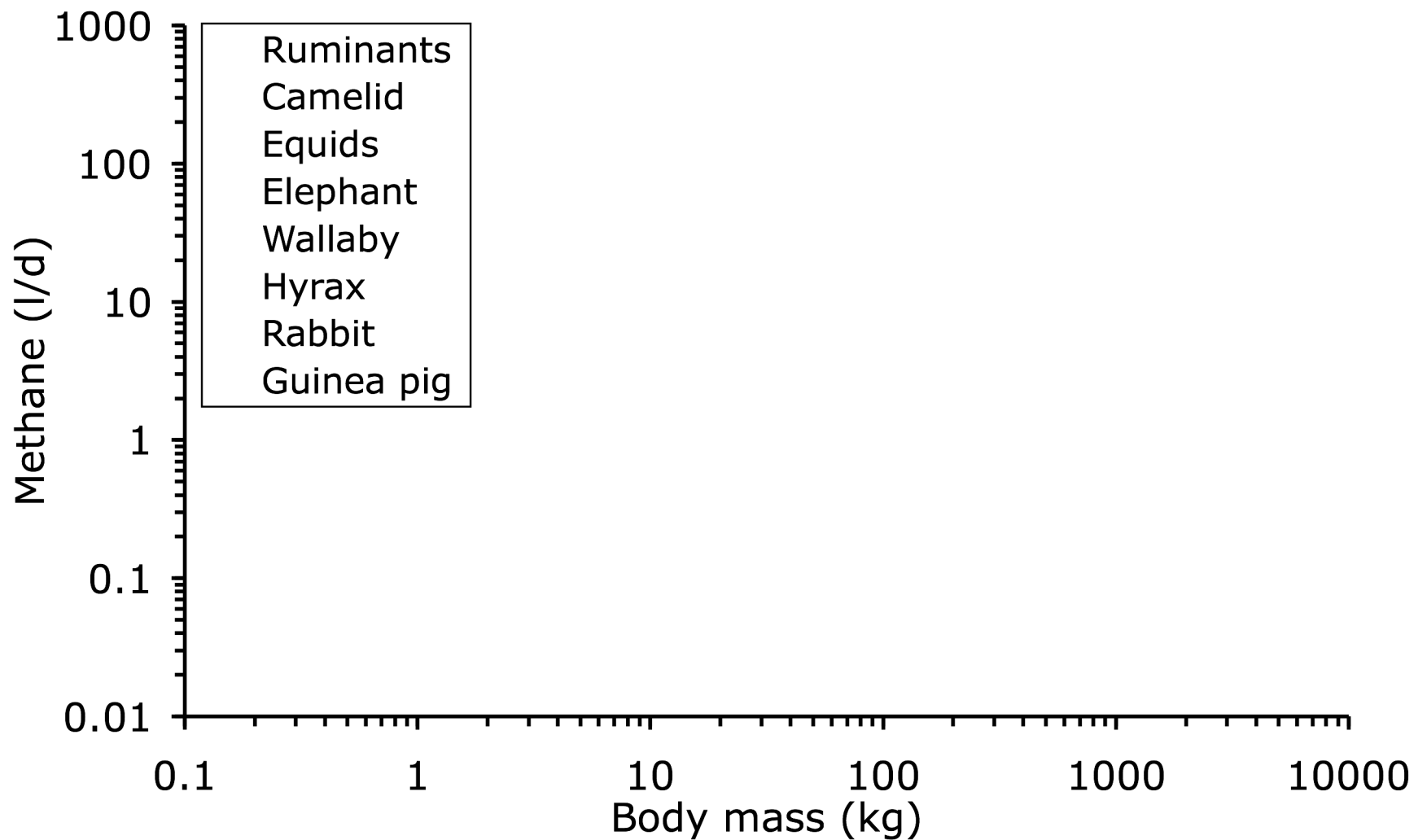
Fibre digestion



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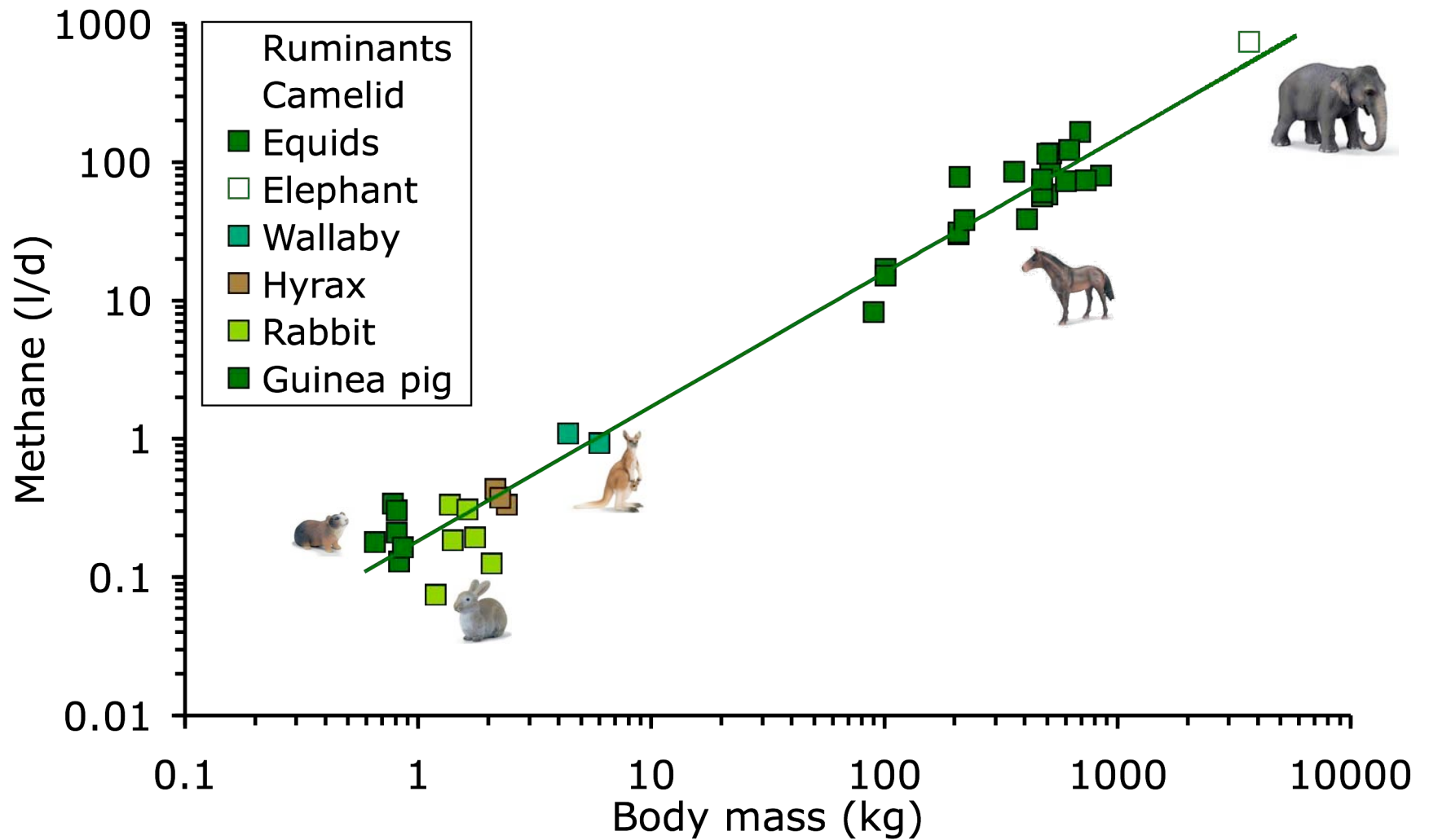
Methane allometry in herbivores



from Franz et al. (2011)

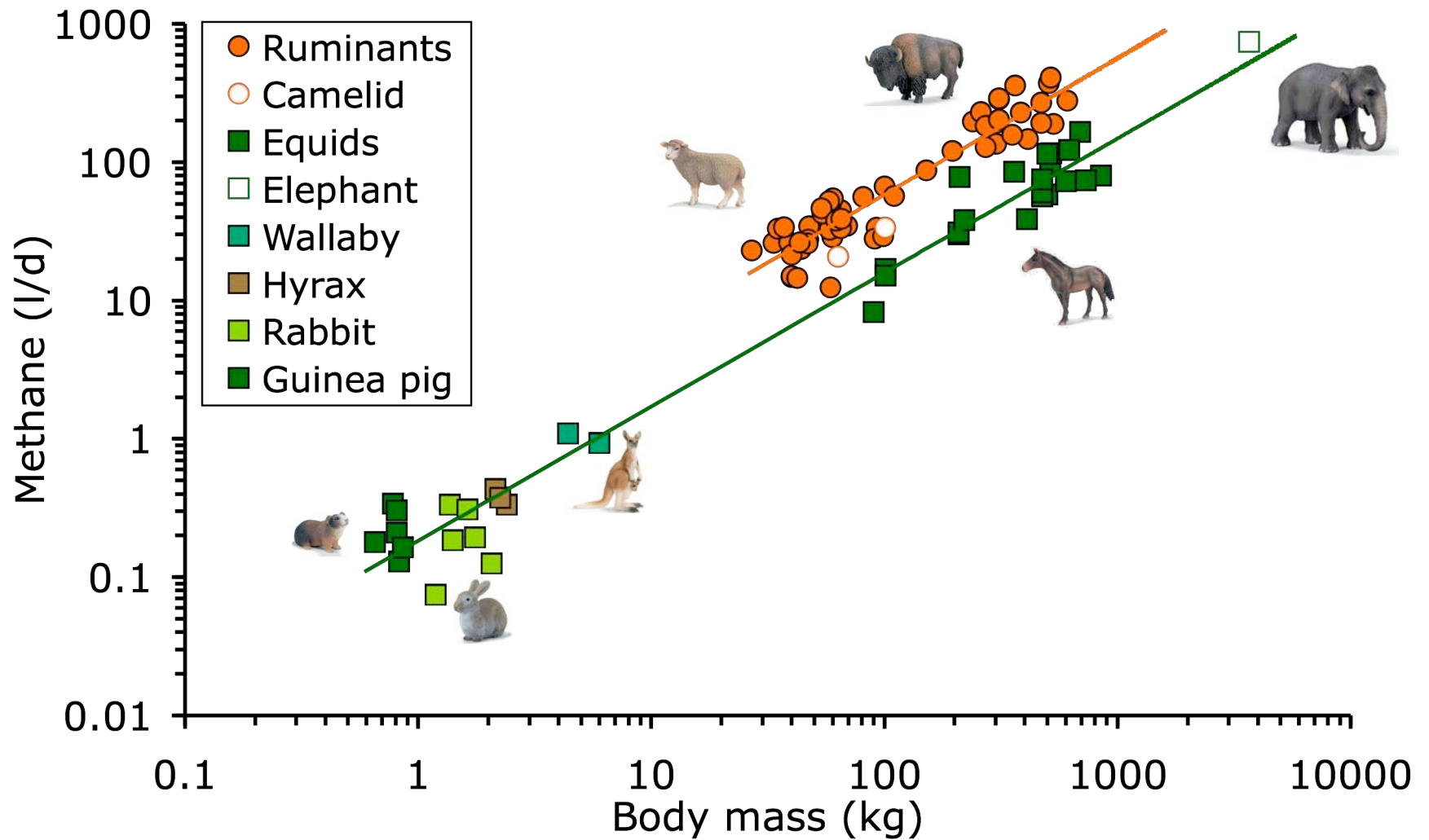


Methane allometry in herbivores





Methane allometry in herbivores



from Franz et al. (2011)



Two fundamental questions

1. 'In-house' or outsourcing of fibre digestion?

'In-house' fibre digestion necessitates anatomical and physiological adaptations that might be costly in some circumstances.

2. What sequence of fibre digestion and auto-enzymatic digestion?

- fibre digestion **prior** to auto-enzymatic digestion allows the use of bacterial biomass*
- bacterial digestion **after** auto-enzymatic digestion allows more efficient use of those substrates that can be digested auto-enzymatically*



Detritivory, coprophagy, and the evolution of digestive mutualisms in Dictyoptera

C.A. Nalepa¹, D.E. Bignell² and C. Bandi³

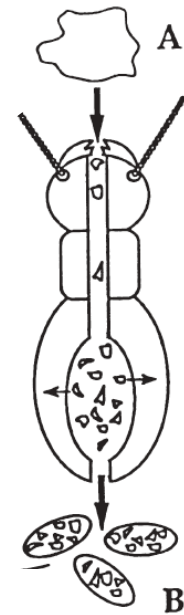
Insectes soc. 48 (2001) 194–201



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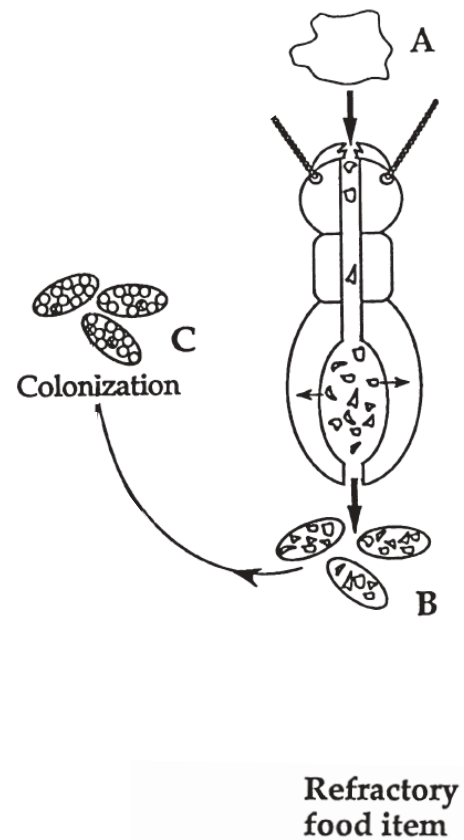
Refractory
food item



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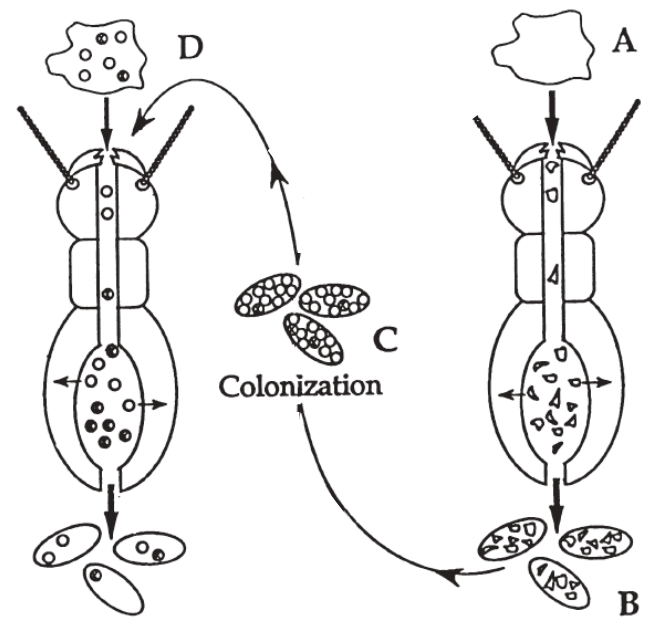




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Microbes

◦ transient or digested

• gut fauna

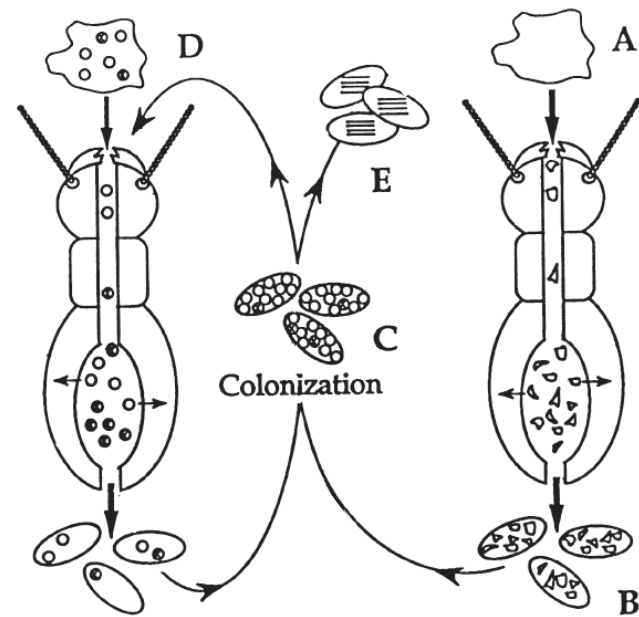
**Refractory
food item**



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Insectes soc. 48 (2001) 194–201



Microbes

◦ transient or digested

• gut fauna

**Refractory
food item**

**Metabolites,
exoenzymes**

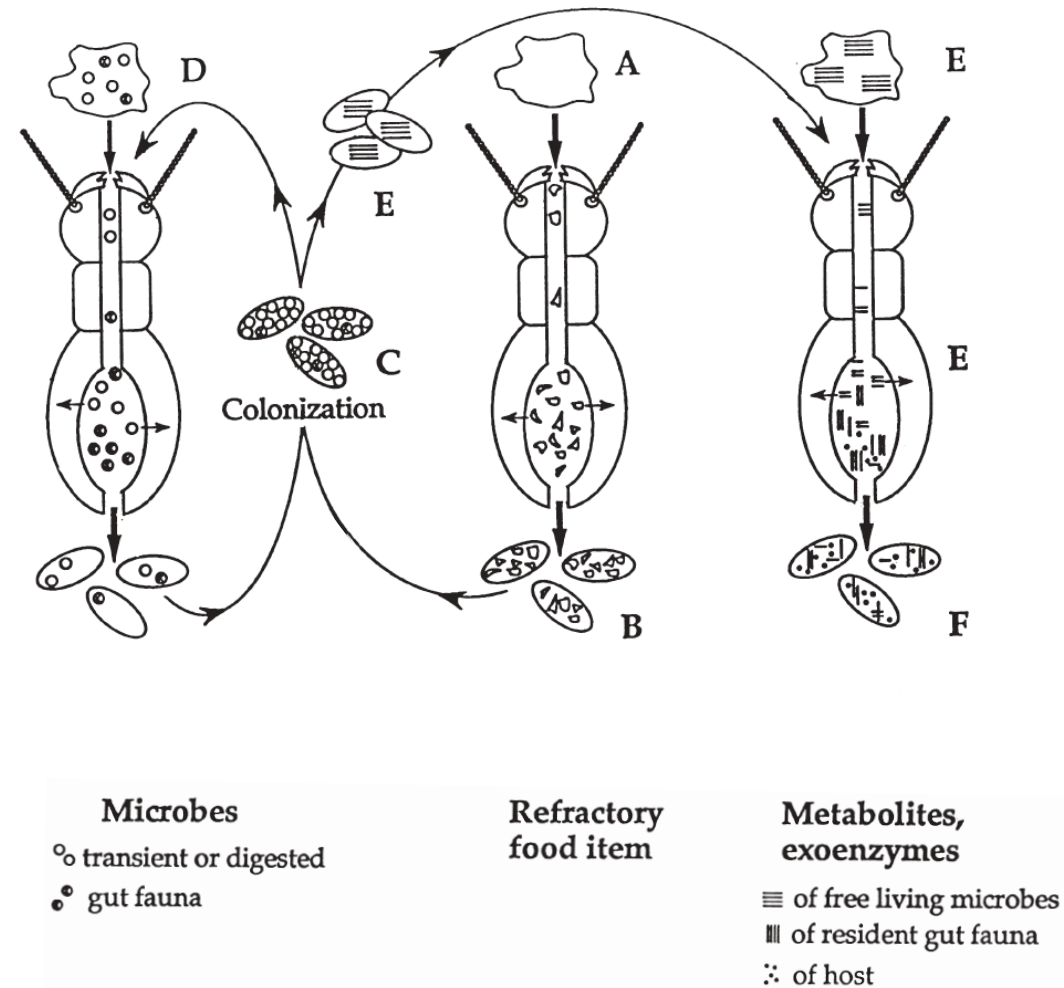
≡ of free living microbes



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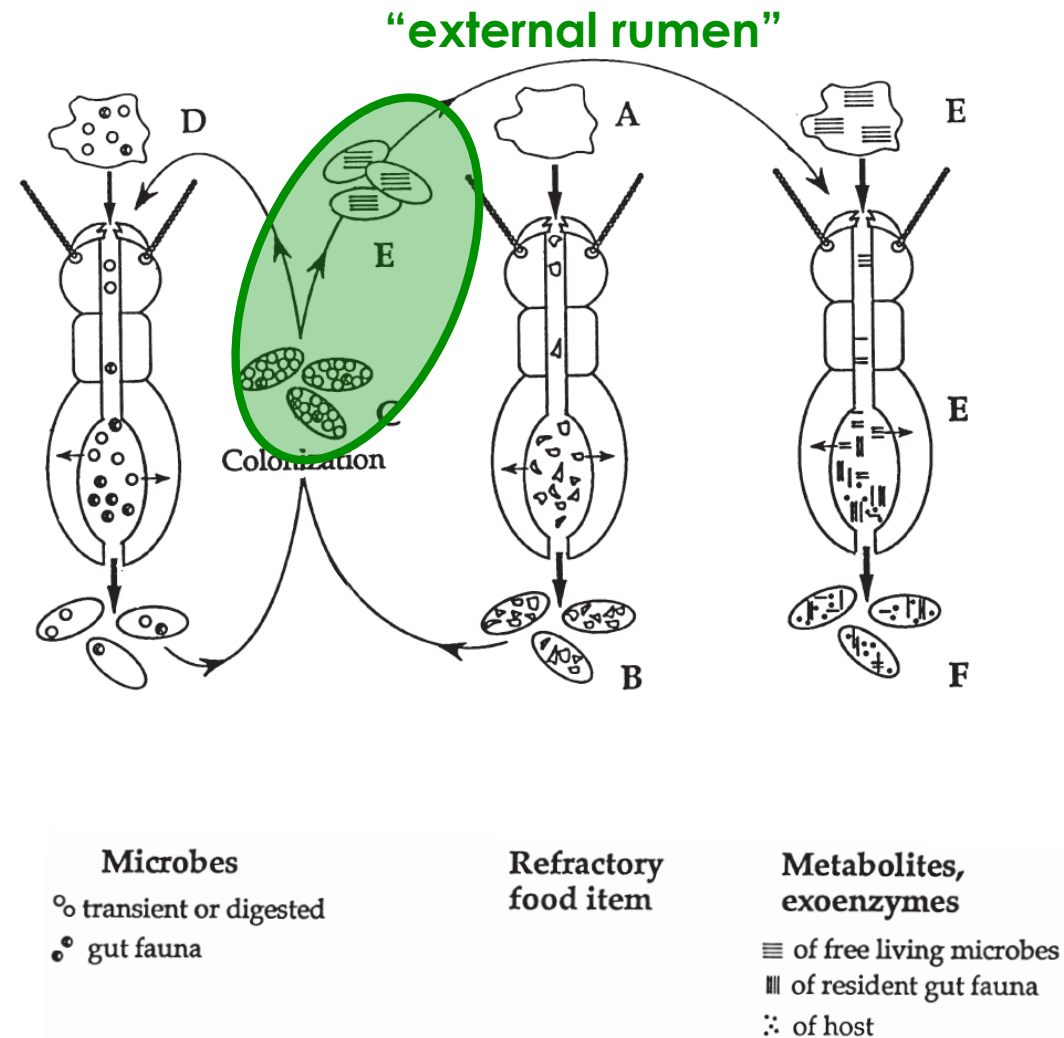




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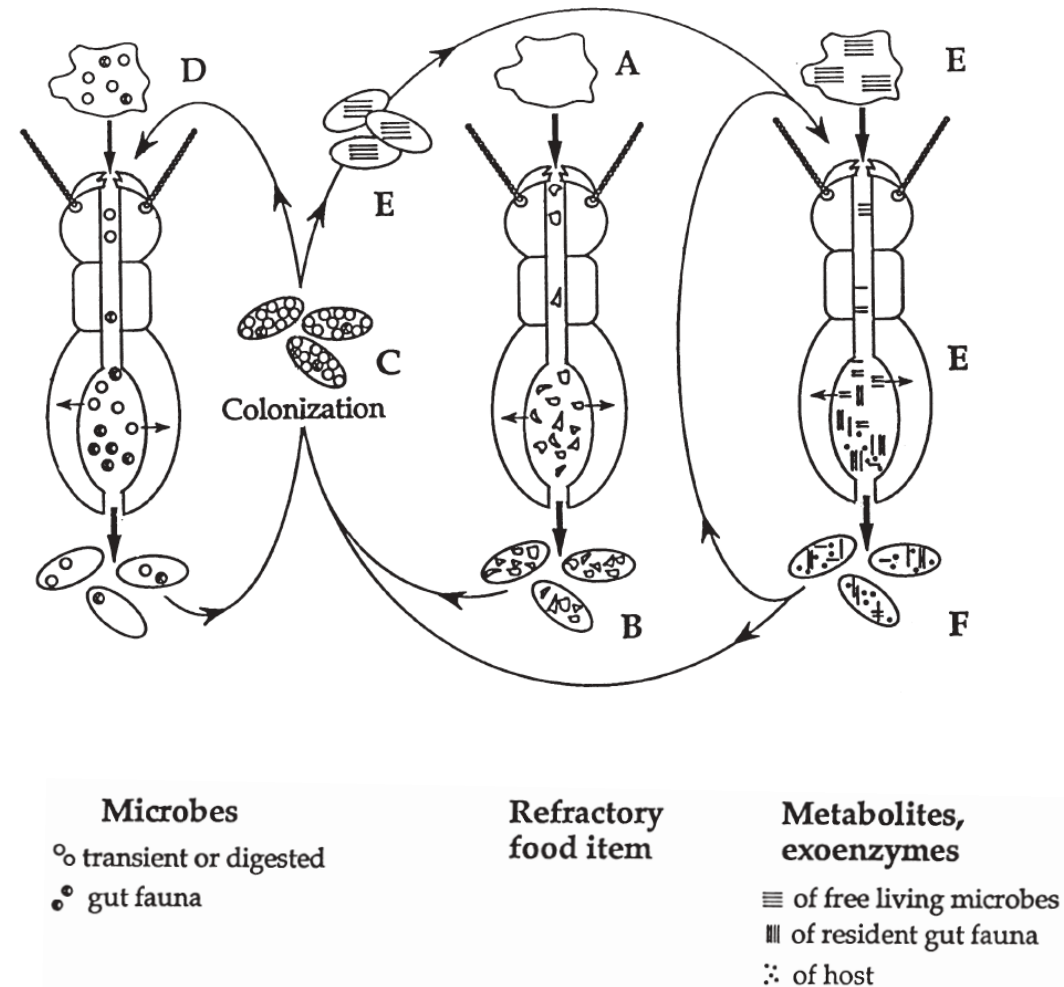




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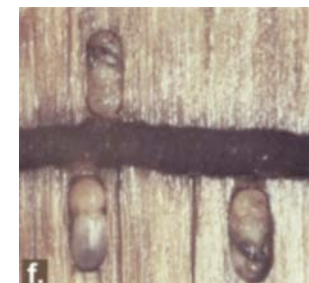
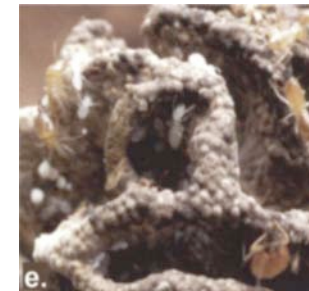
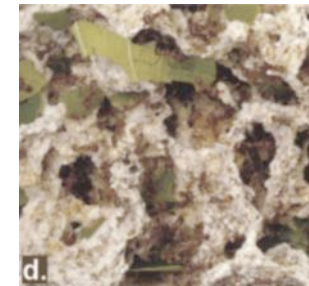
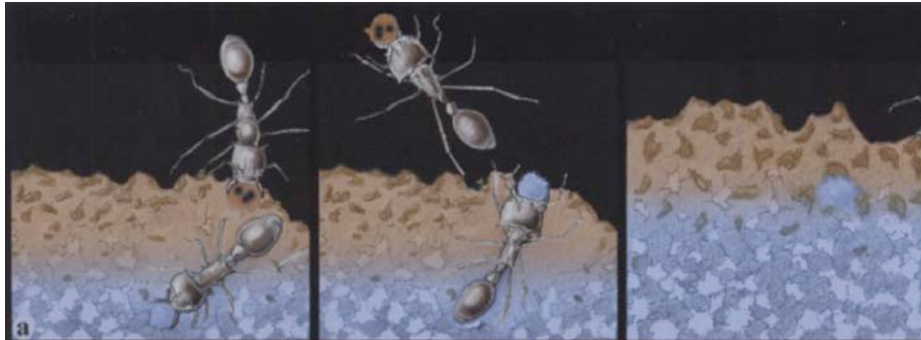
Insectes soc. 48 (2001) 194–201





THE EVOLUTION OF AGRICULTURE IN INSECTS

Ulrich G. Mueller,^{1,2} Nicole M. Gerardo,^{1,2,3}
Duur K. Aanen,⁴ Diana L. Six,⁵ and Ted R. Schultz⁶
Annu. Rev. Ecol. Evol. Syst. 2005. 36:563–95





Body size

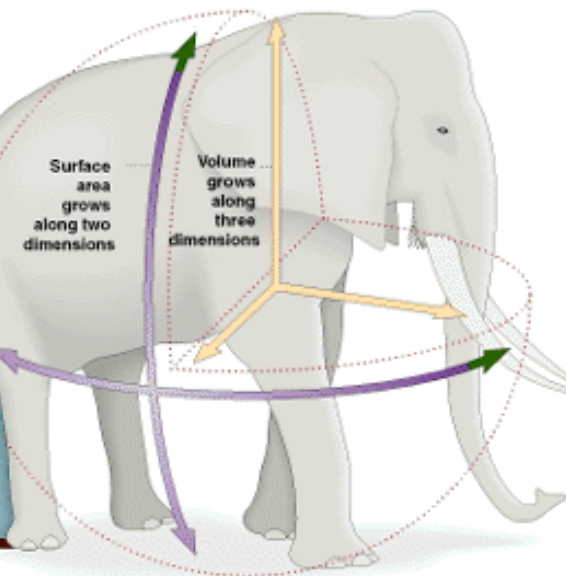
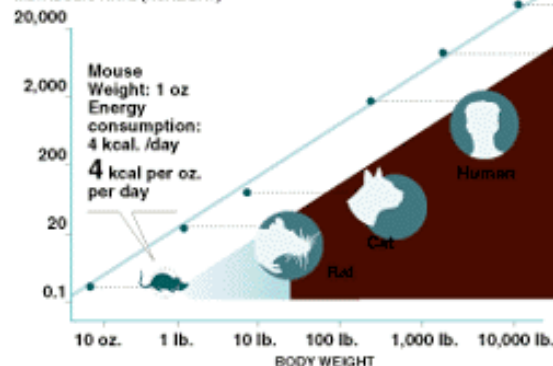
Most biologists consider body mass the most important characteristic of an organism. It is also (mostly) easy to measure.

All morphological and physiological traits scale somehow with body mass.

"Scaling is interesting because, aside from natural selection, it is one of the few laws we really have in biology." John Gittleman

An Example of Scaling:
Metabolic Rate

METABOLIC RATE (KCAL/DAY)





Two fundamental questions

1. 'In-house' or outsourcing of fibre digestion?

'In-house' fibre digestion necessitates anatomical and physiological adaptations that might be costly in some circumstances.

Outsourcing is only feasible at small body sizes where you have high encounter rates with nutritionally relevant amounts of microorganisms.

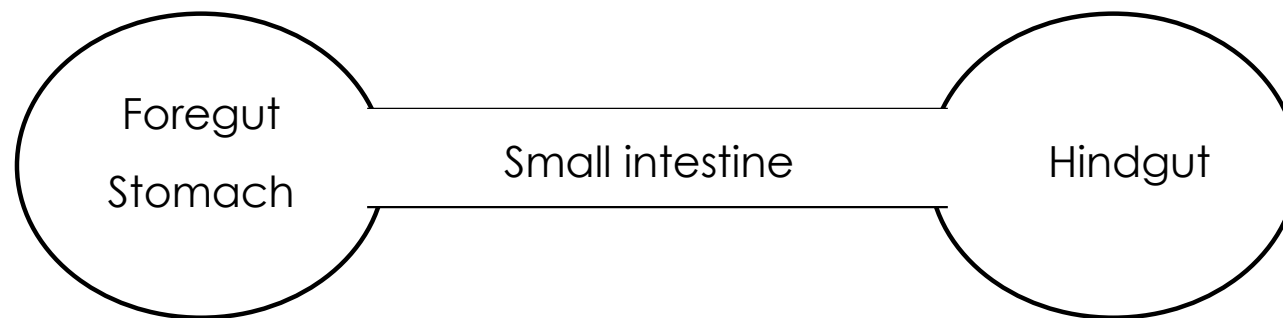
(although there are billions of microorganisms in this room, their mass is not enough to meet the daily energy requirements of a single member of the audience)



Two fundamental questions

2. What sequence of fibre digestion and auto-enzymatic digestion?

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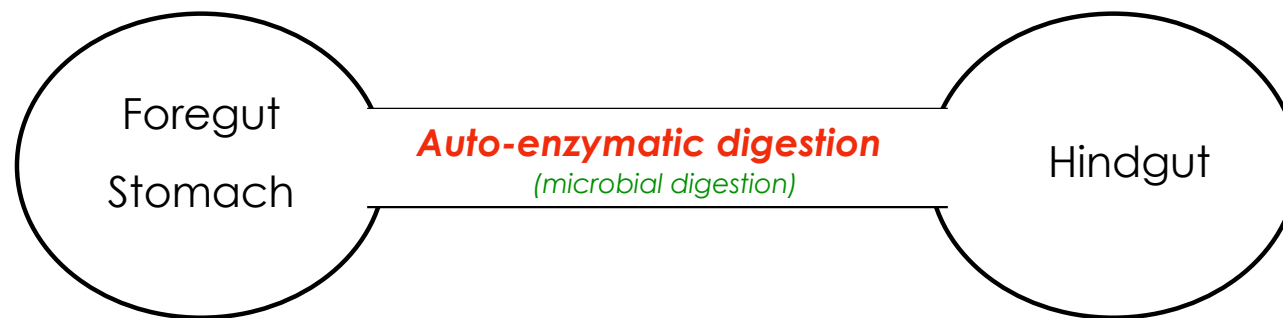




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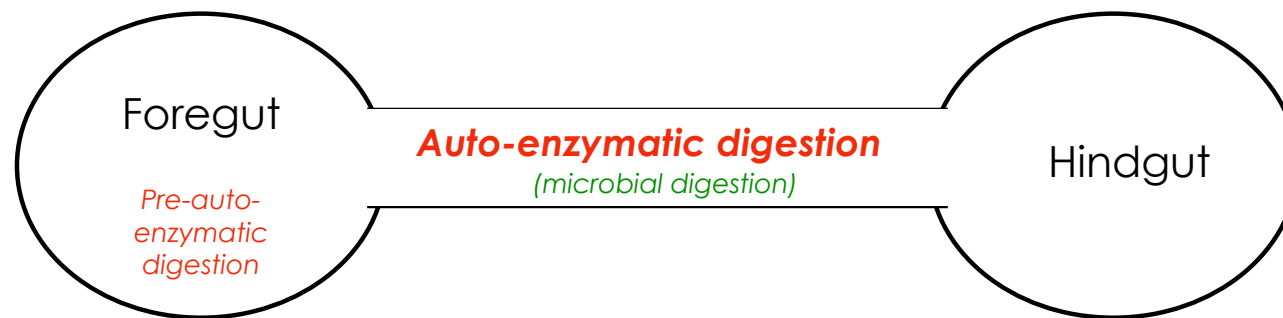




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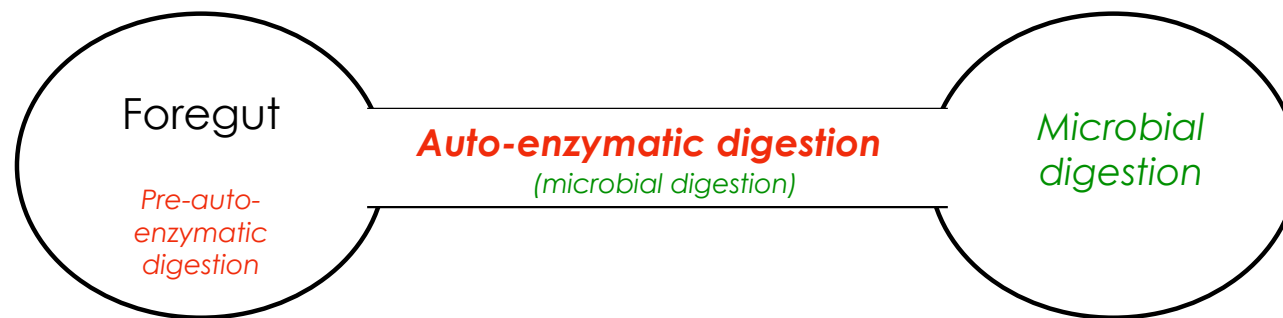




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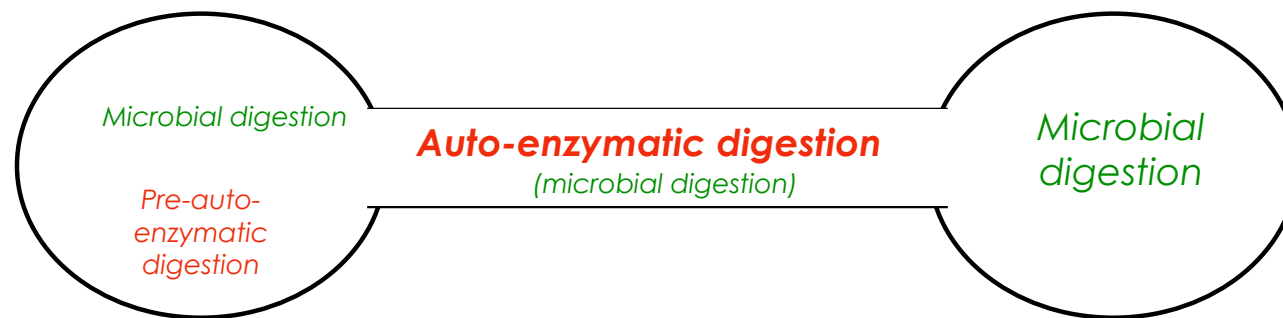




Two fundamental questions

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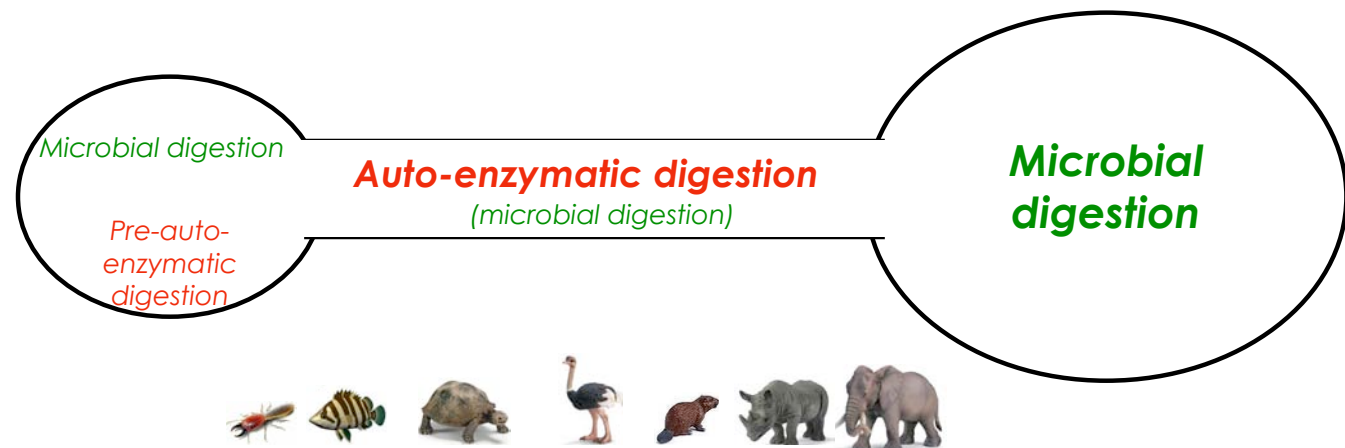




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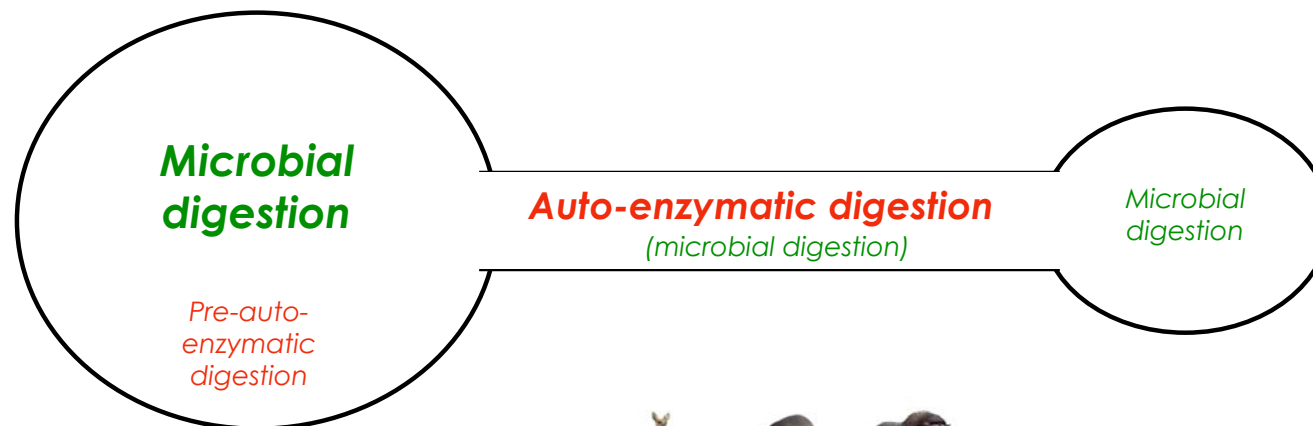




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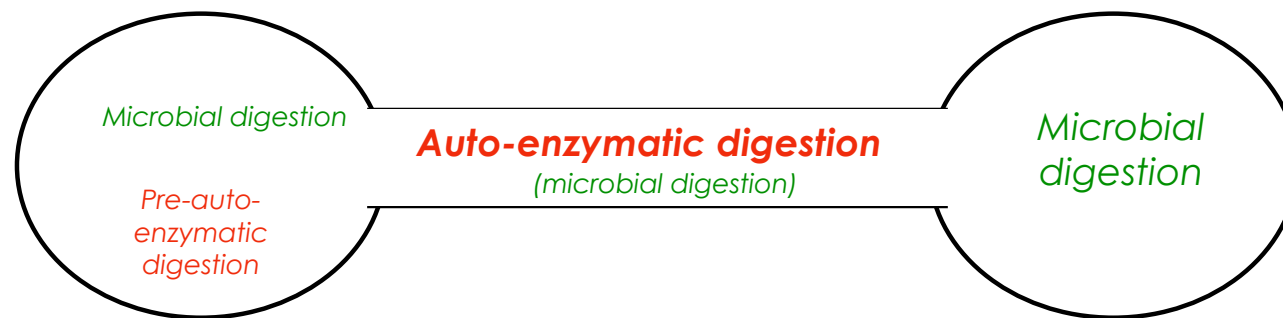




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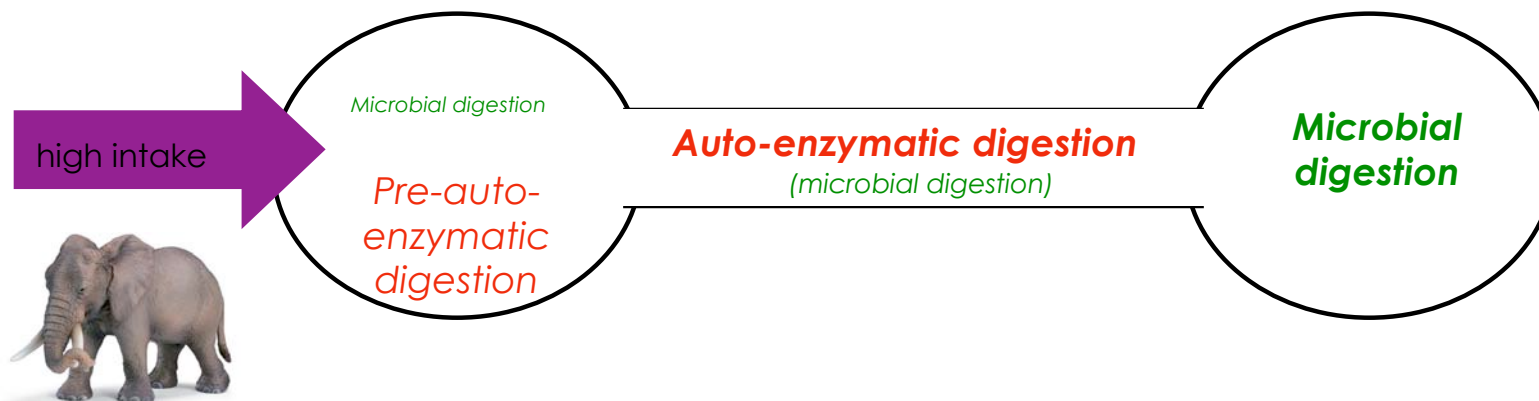




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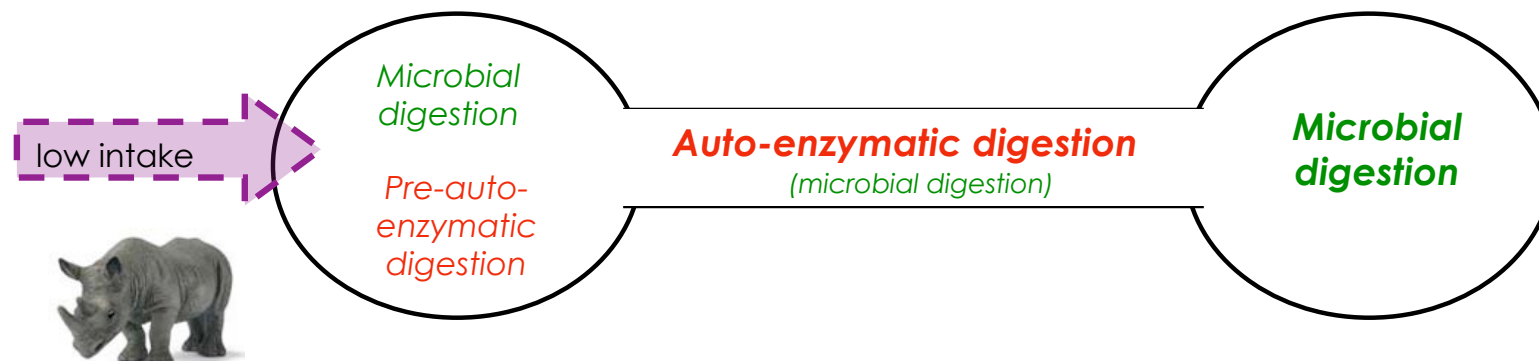




Two fundamental questions

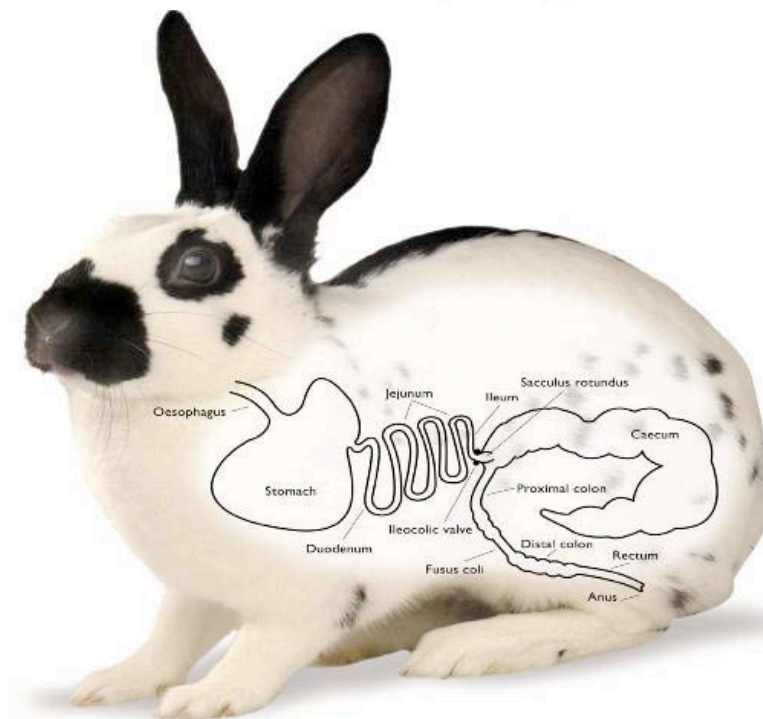
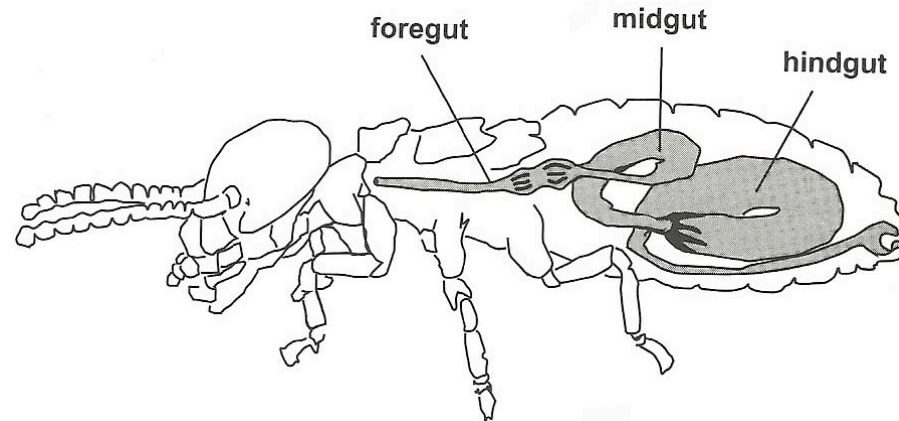
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Hindgut fermentation - 'the conventional approach'

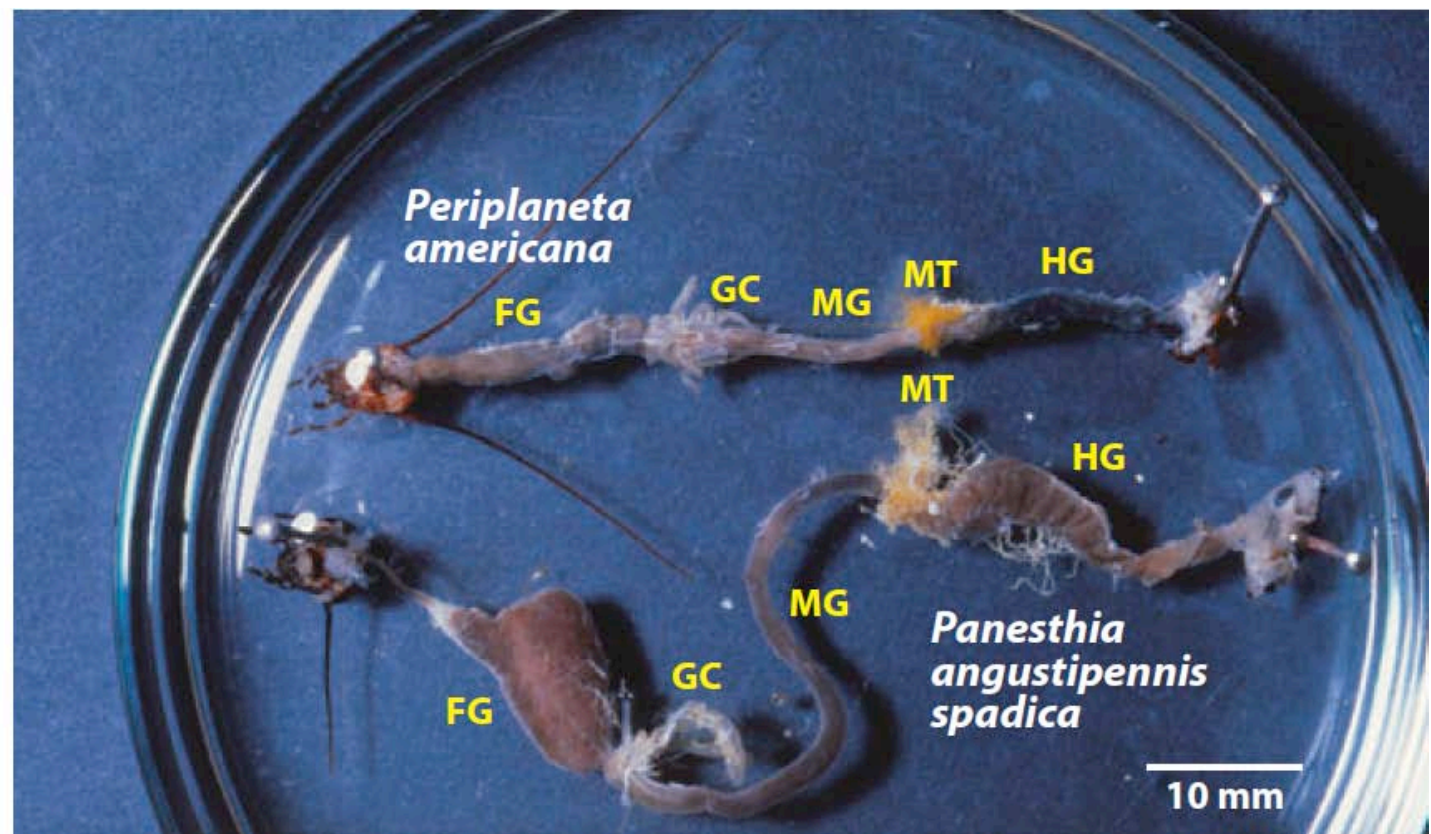




Cellulolytic Systems in Insects

Hirofumi Watanabe¹ and Gaku Tokuda²

Annu. Rev. Entomol. 2010. 55:609–32

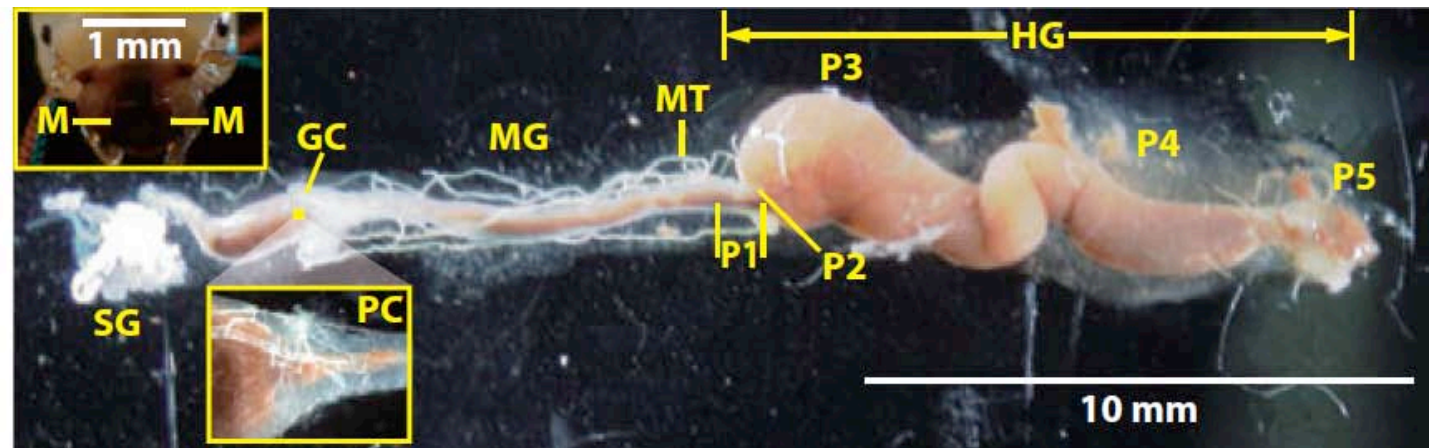
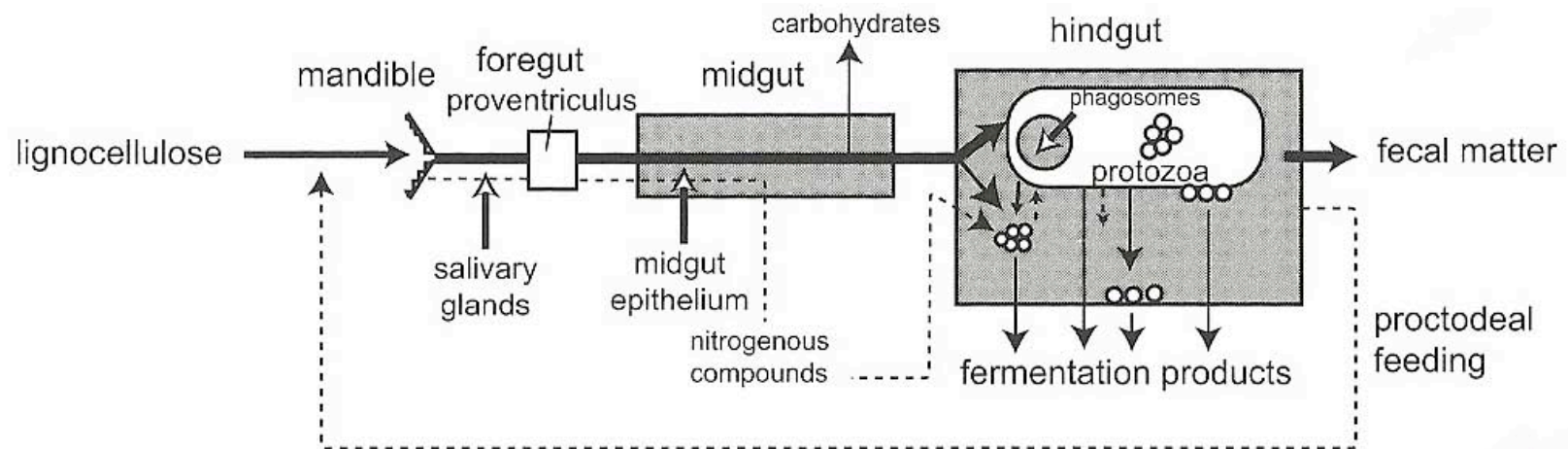




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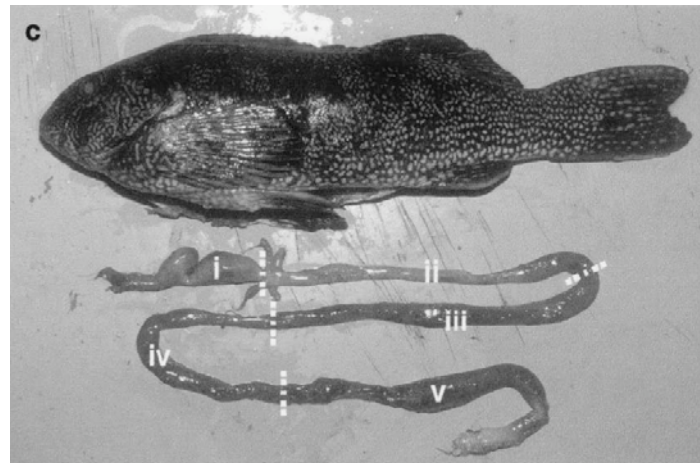
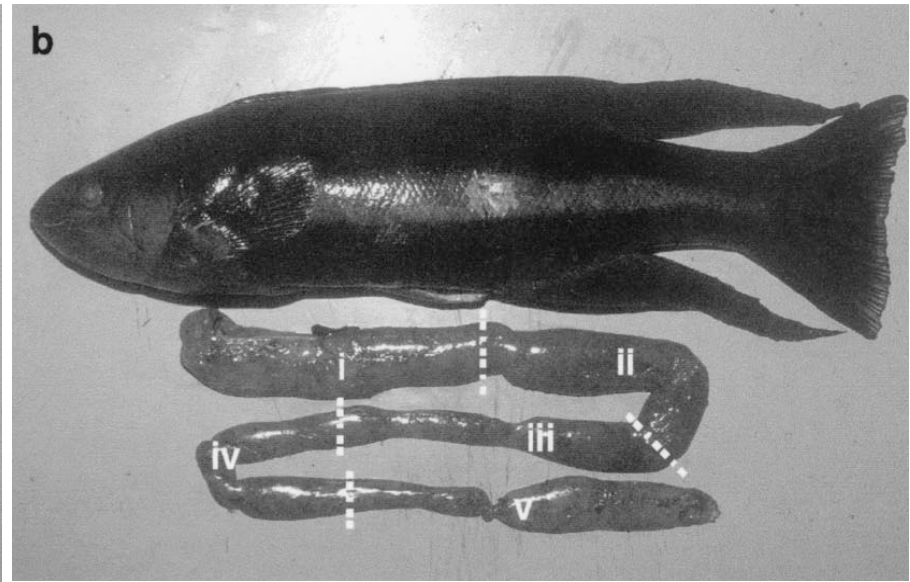
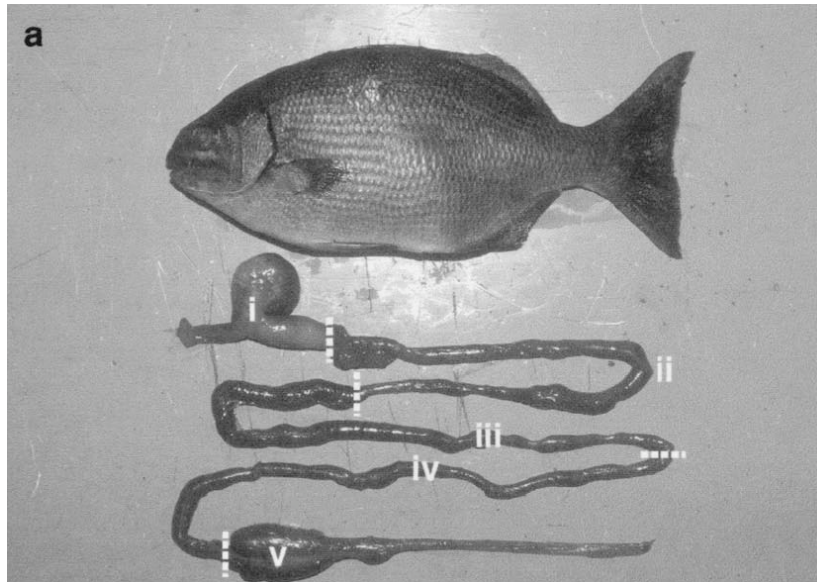
scheme from Karasov & Martinez del Rio (2007)



Hindgut Fermentation in Three Species of Marine Herbivorous Fish

Douglas O. Mountfort,^{1*} Jane Campbell,² and Kendall D. Clements²

APPLIED AND ENVIRONMENTAL MICROBIOLOGY, Mar. 2002, p. 1374–1380



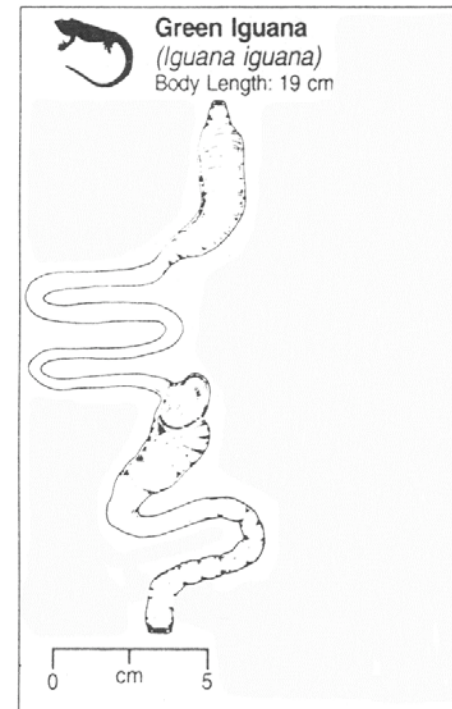
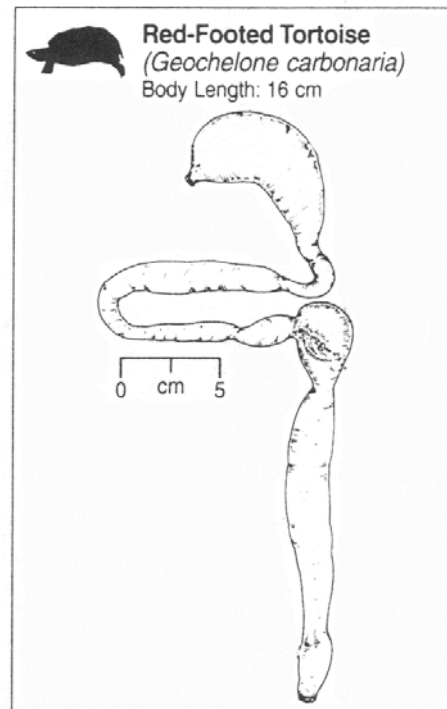


Herbivorous fish





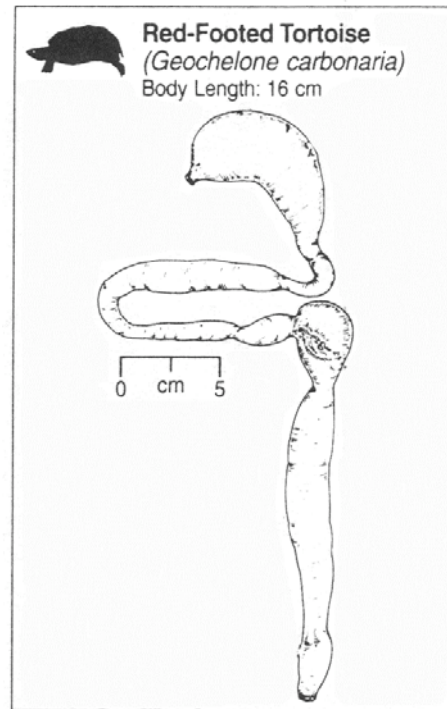
Hindgut Fermentation - Reptiles



from Stevens & Hume (1995)



Hindgut Fermentation - Reptiles



from Stevens & Hume (1995)

Photo: J. Fritz



Hindgut Fermentation - Birds



Hindgut Fermentation - Birds

15th ESVCN Zaragoza – 15th Sept. 2011



**Passage kinetics,
digestibility and faecal
particle size of
ostriches (*Struthio
camelus*) at different
levels of feed intake**

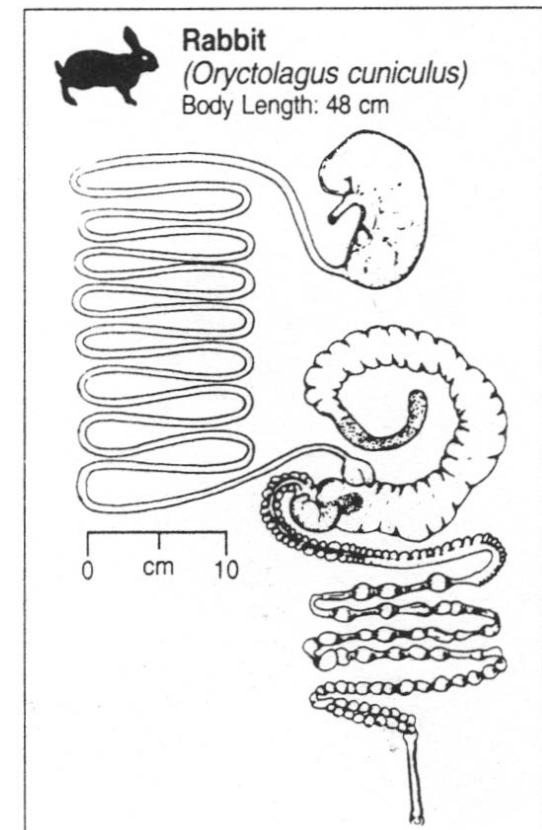
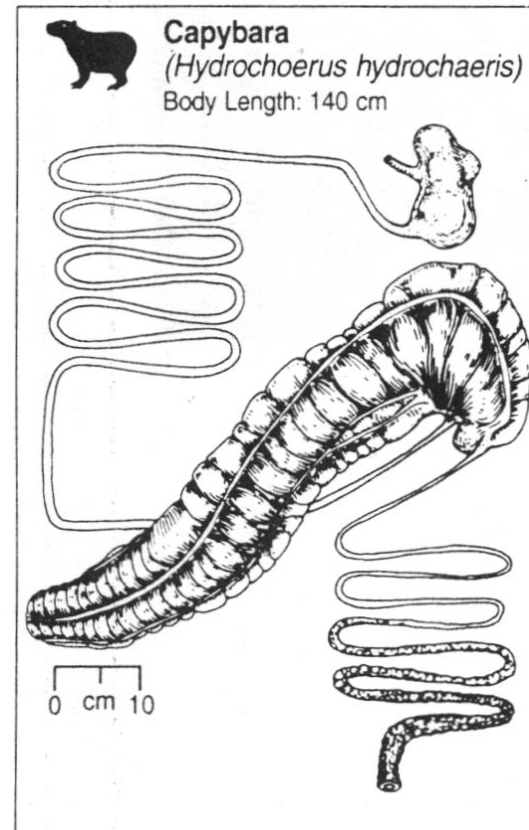
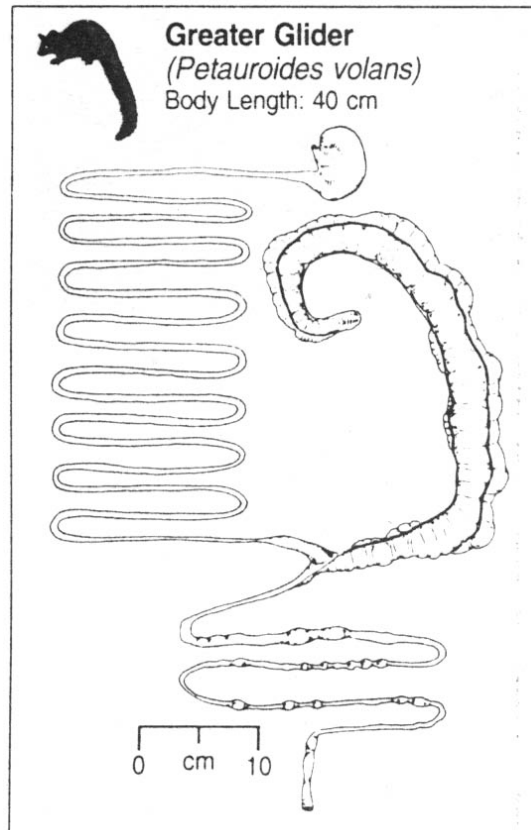
J. Fritz, S. Hammer, C. Hebel,
B. Michalke, W.J. Streich, M. Clauss



Alwabra
HelmholtzZentrum münchen



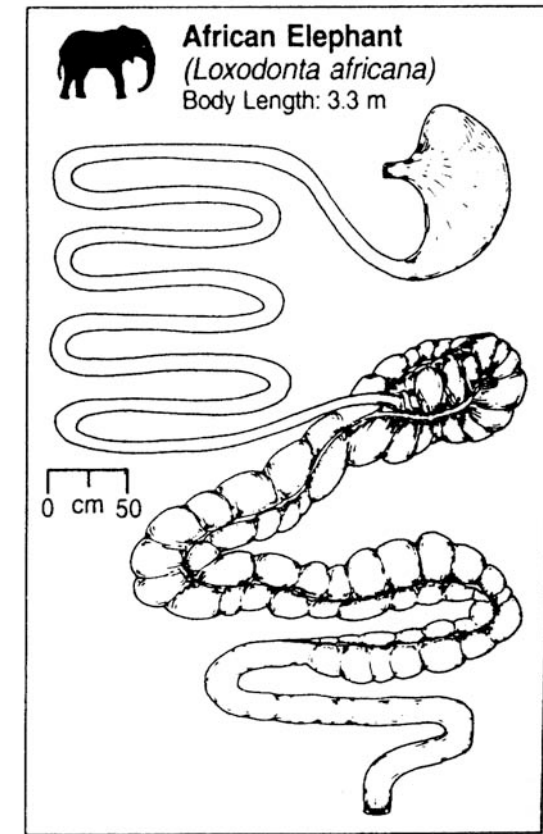
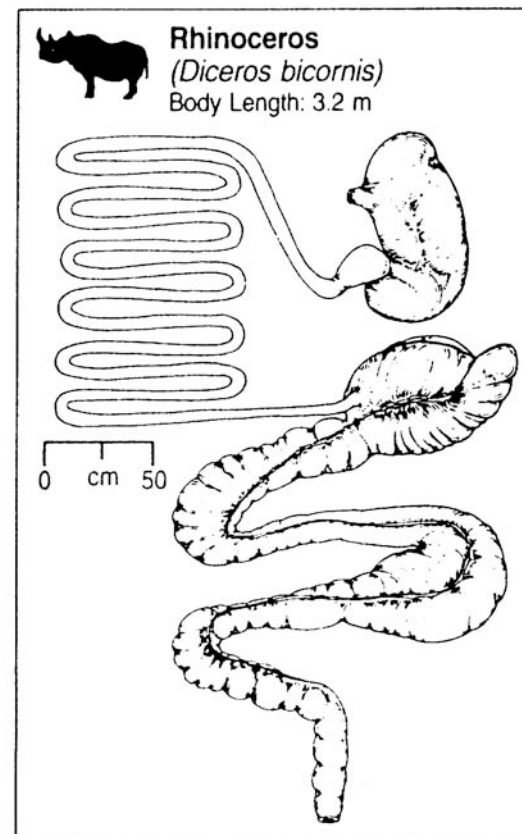
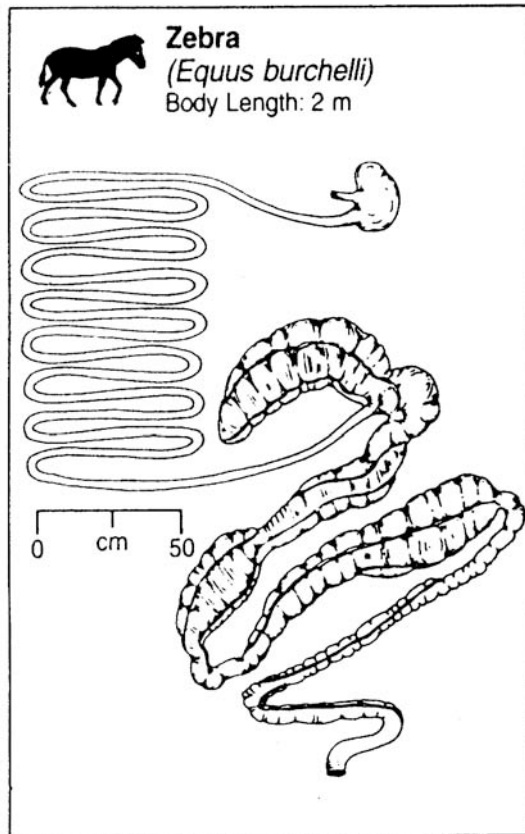
Hindgut Fermentation - Caecum



from Stevens & Hume (1995)



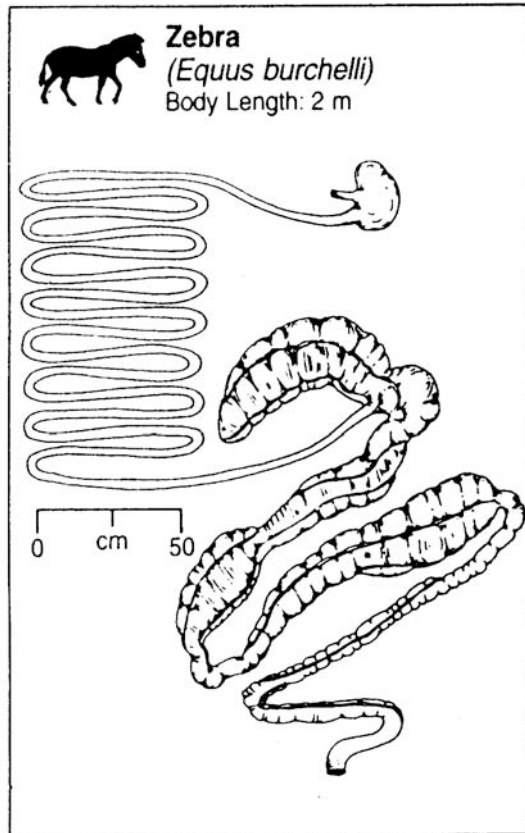
Hindgut Fermentation - Colon



from Stevens & Hume (1995)



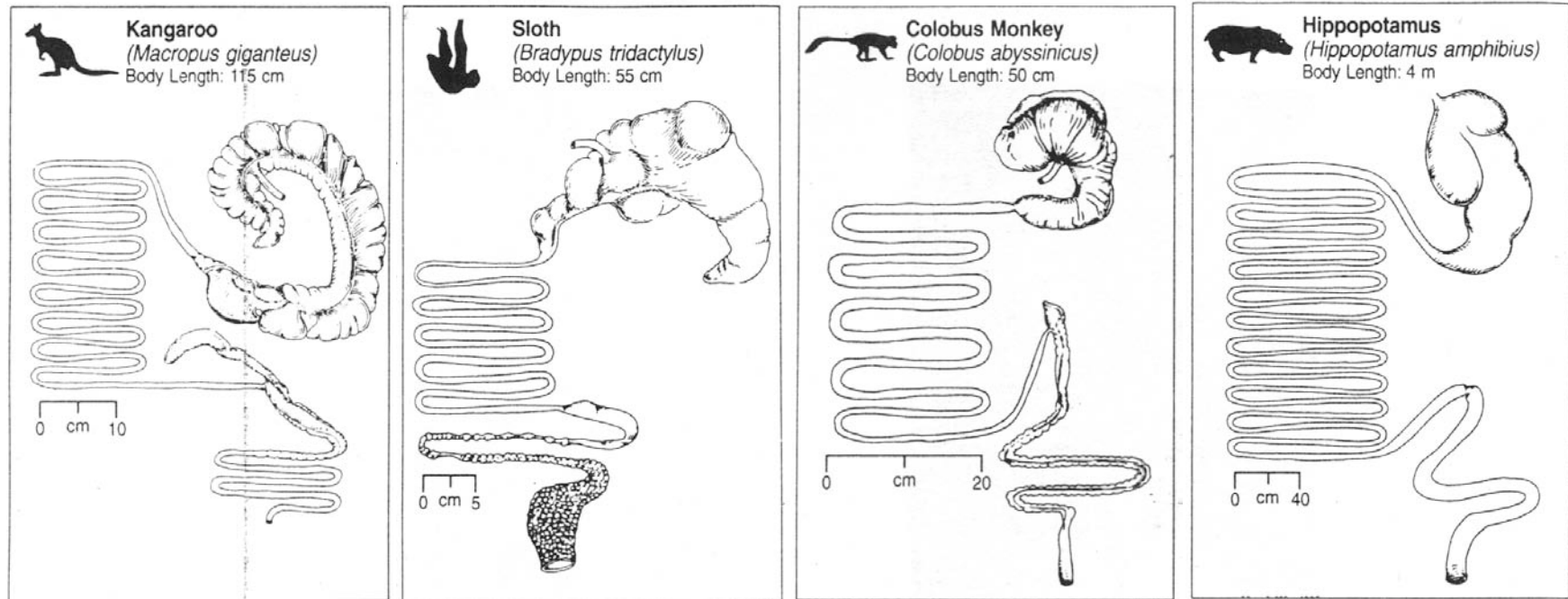
Hindgut Fermentation - Colon



from Stevens & Hume (1995)



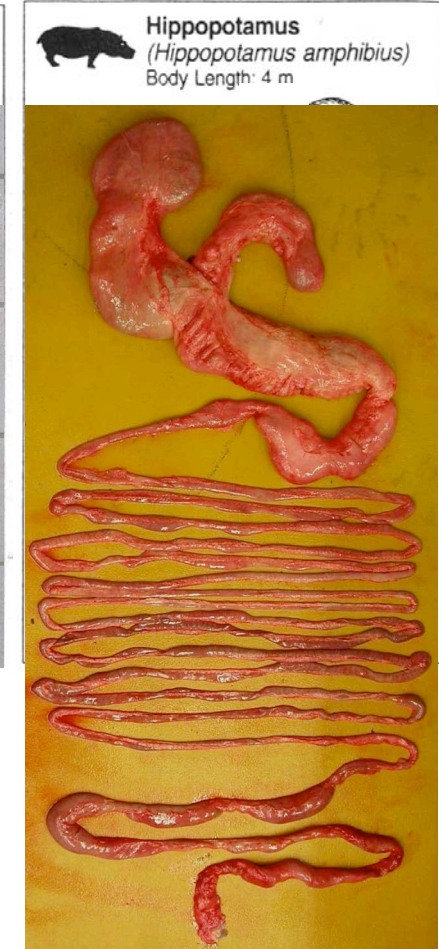
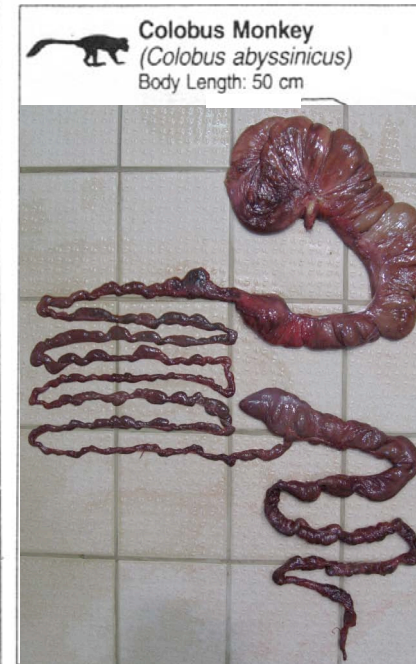
Foregut Fermentation



from Stevens & Hume (1995)



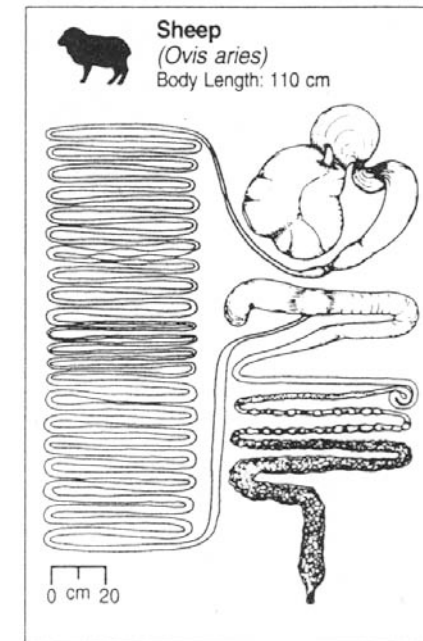
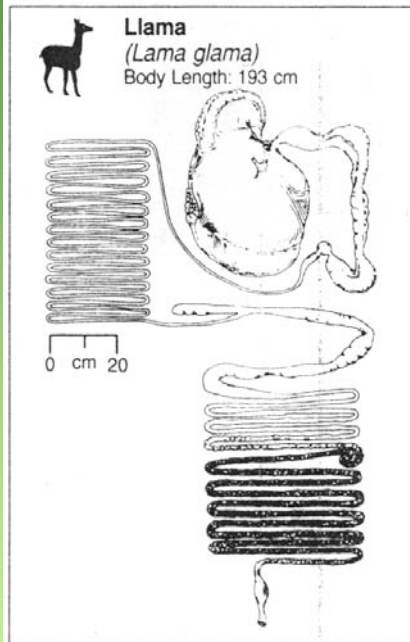
Foregut Fermentation



Photos A. Schwarm/
M. Clauss



Foregut Fermentation - Ruminant

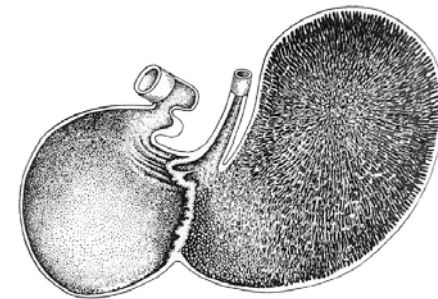


aus Stevens & Hume (1995)
Photo Llama: A. Riek



Foregut/Hindgut Fermenters

With the majority of rodent species un-studied, we have not grasped the variability, and adaptive significance, of foregut and hindgut fermentation yet.

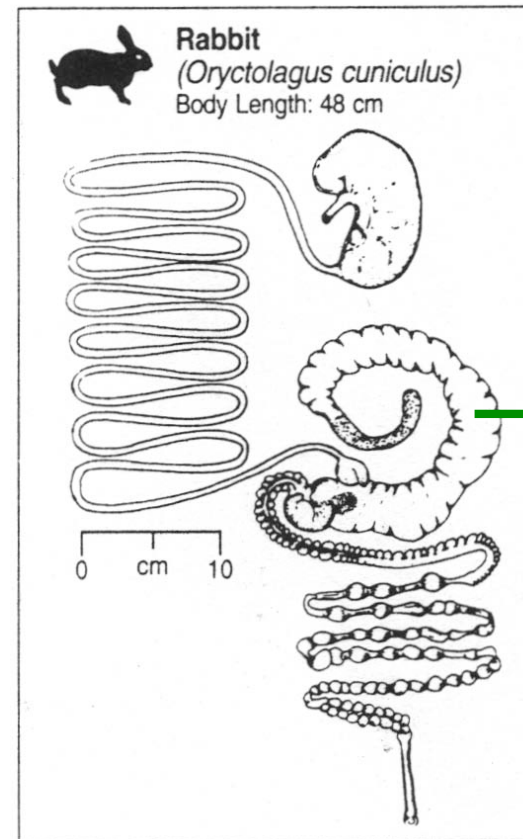
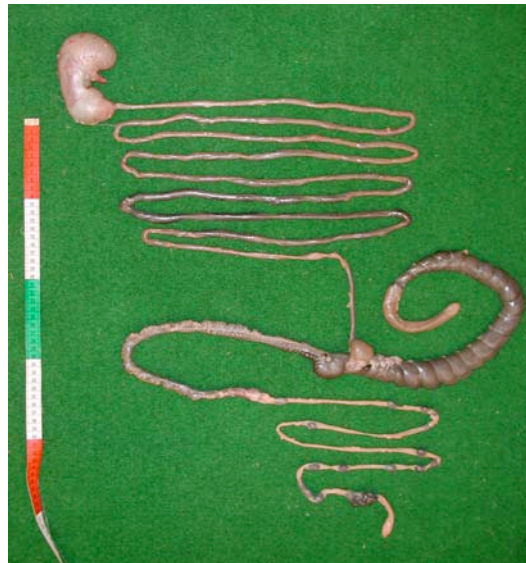


Demon mole rat
(*Tachyoryctes daemon*)
papillated forestomach

from Vrontsov (2003)



Hindgut fermenters



Fermentation:

Production of VFA

Acetate

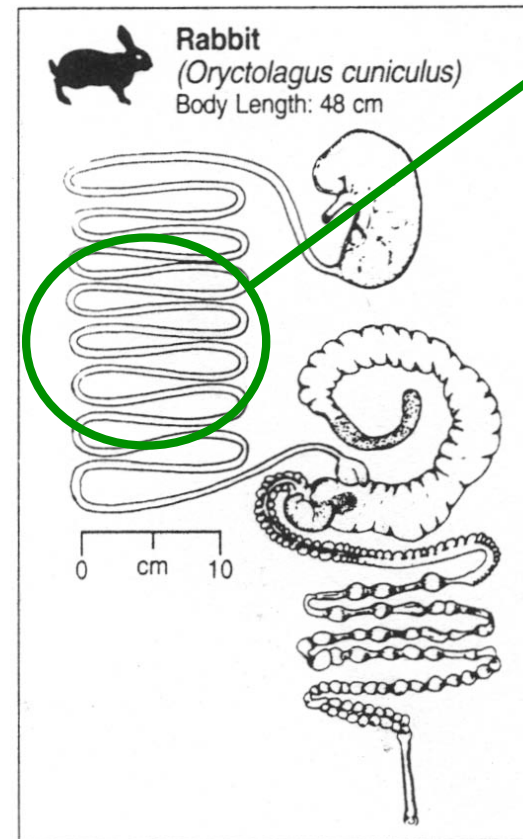
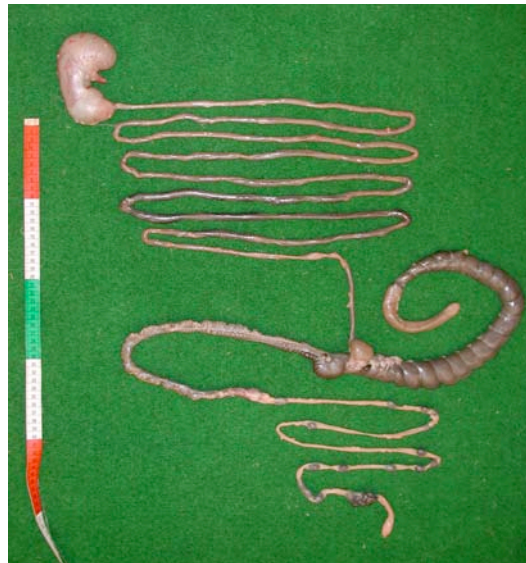
Propionate

Butyrate

from Stevens und Hume (1995)
Photo: B. Burger



Hindgut fermenters

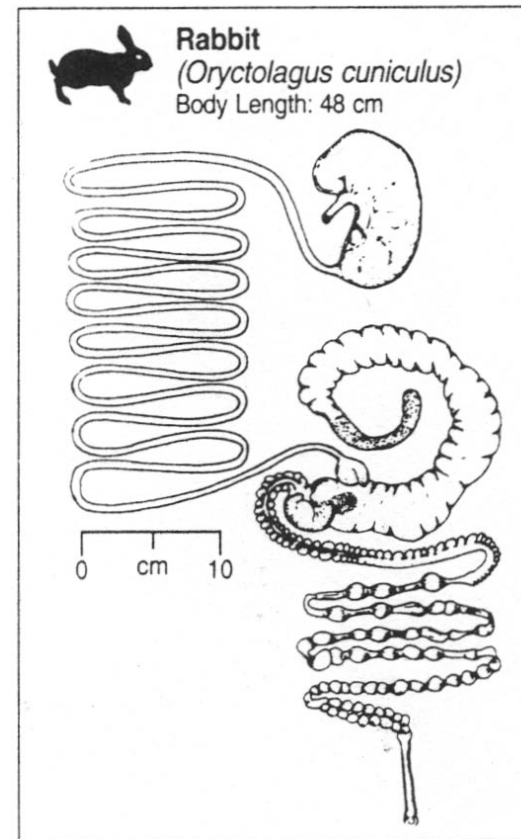
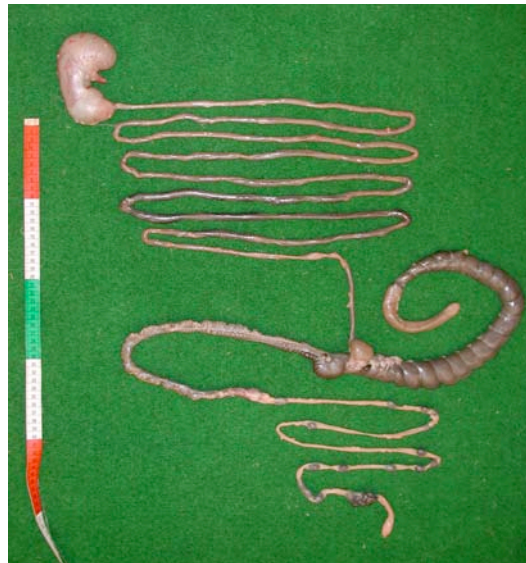


Fermentation after
sites of aut-
enzymatic digestion
and absorption:

from Stevens und Hume (1995)
Photo: B. Burger



Hindgut fermenters



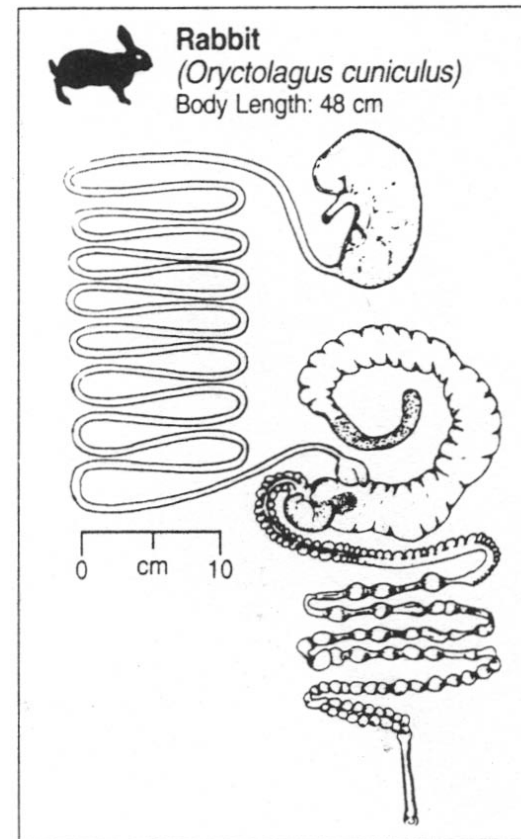
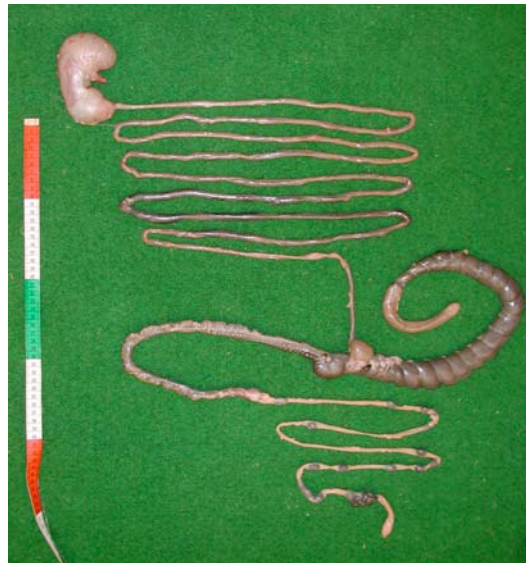
Fermentation after sites of aut-enzymatic digestion and absorption:

Use of easily digestible substances prior to fermentation

from Stevens und Hume (1995)
Photo: B. Burger



Hindgut fermenters



Fermentation after sites of aut-enzymatic digestion and absorption:

Use of easily digestible substances prior to fermentation

Loss of bacterial protein

from Stevens und Hume (1995)
Photo: B. Burger



... but remember





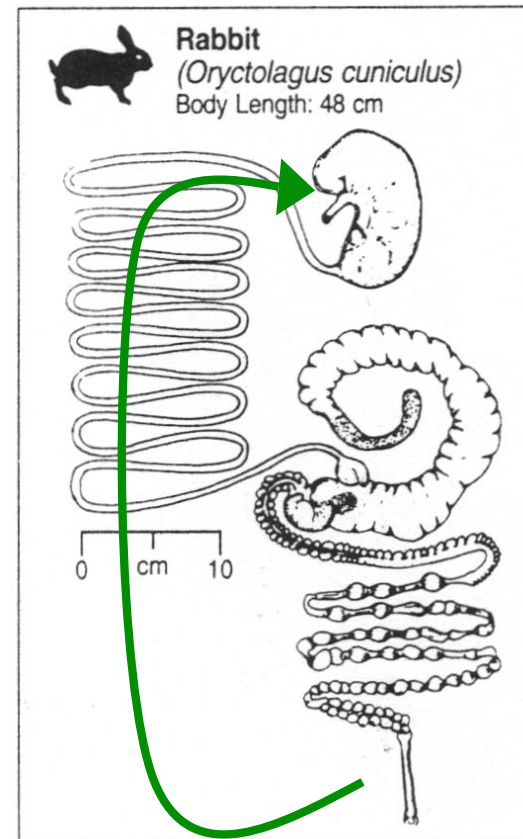
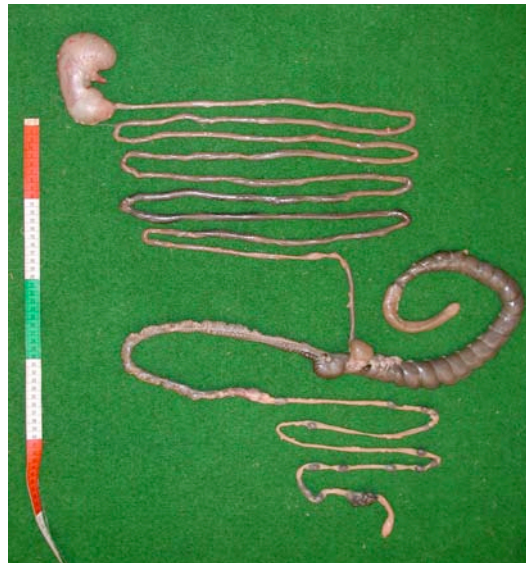
... but remember

After the game is before the game.





'Backward pass'



Fermentation after sites of aut-enzymatic digestion and absorption:

Use of easily digestible substances prior to fermentation

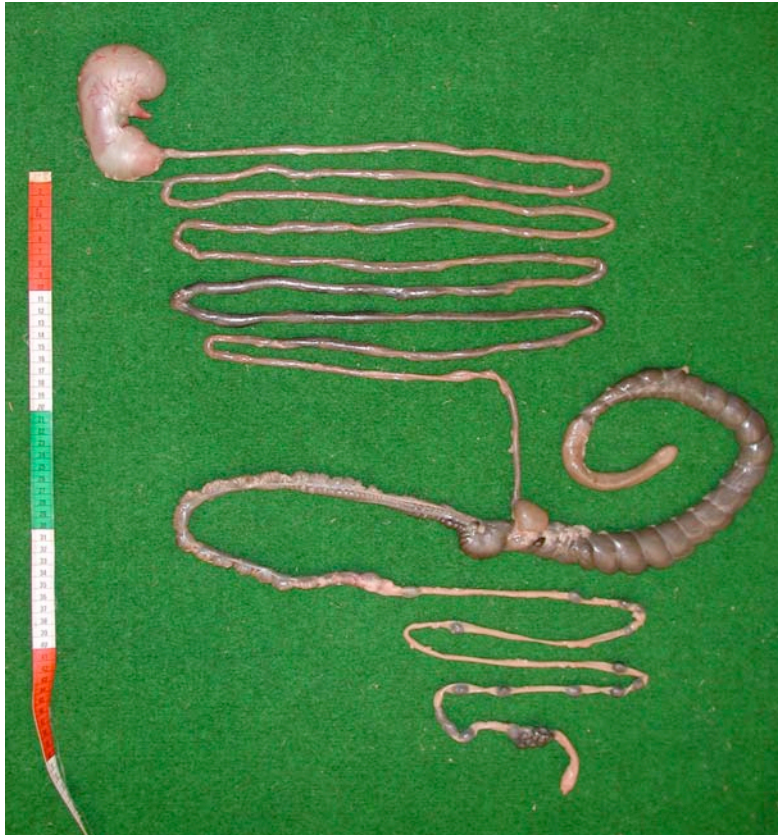
Loss of bacterial protein

**Coprophagy/
Caecotrophy**

from Stevens und Hume (1995)
Photo: B. Burger



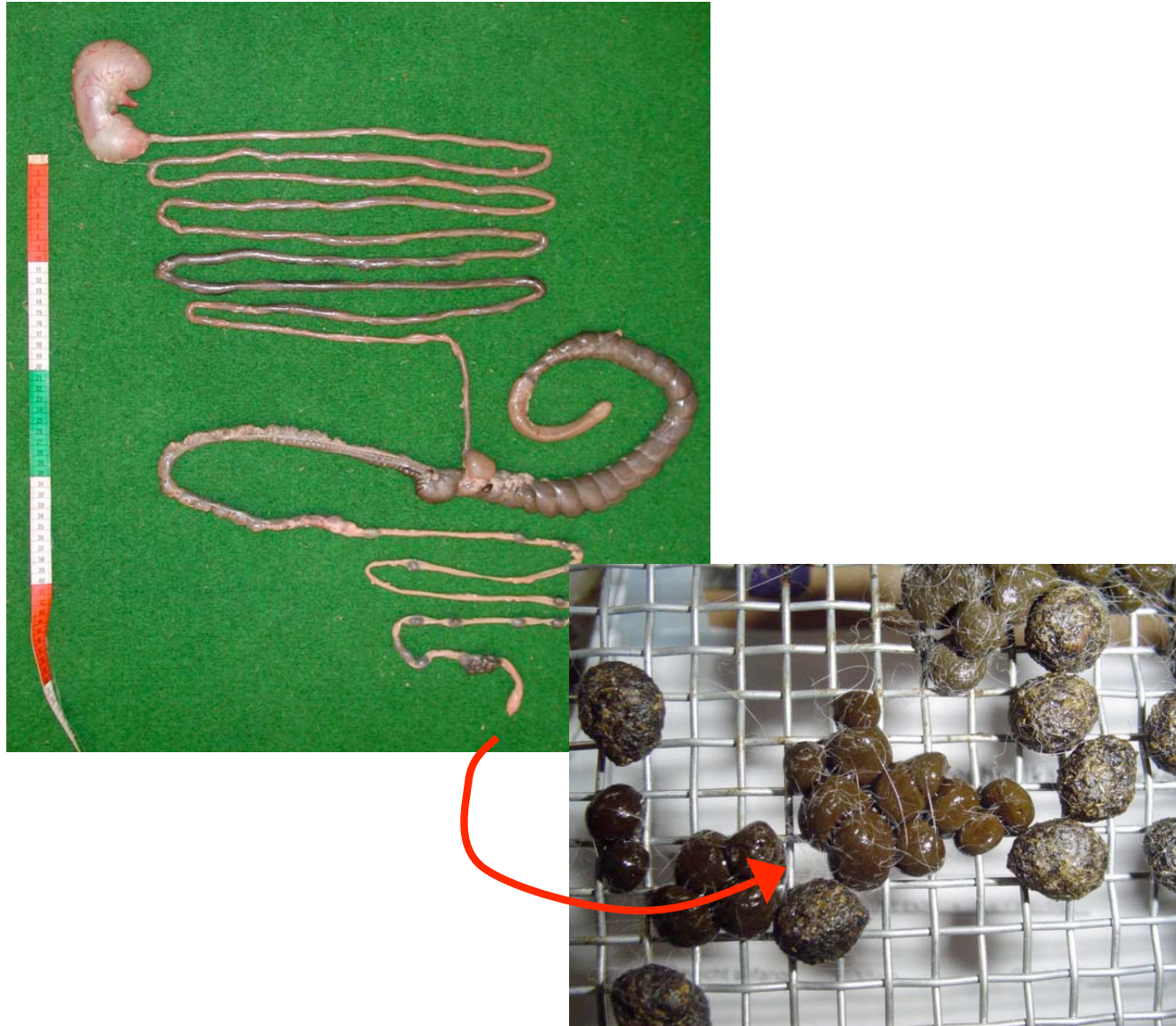
Coprophagy/Caecotrophy



Photos: B. Burger



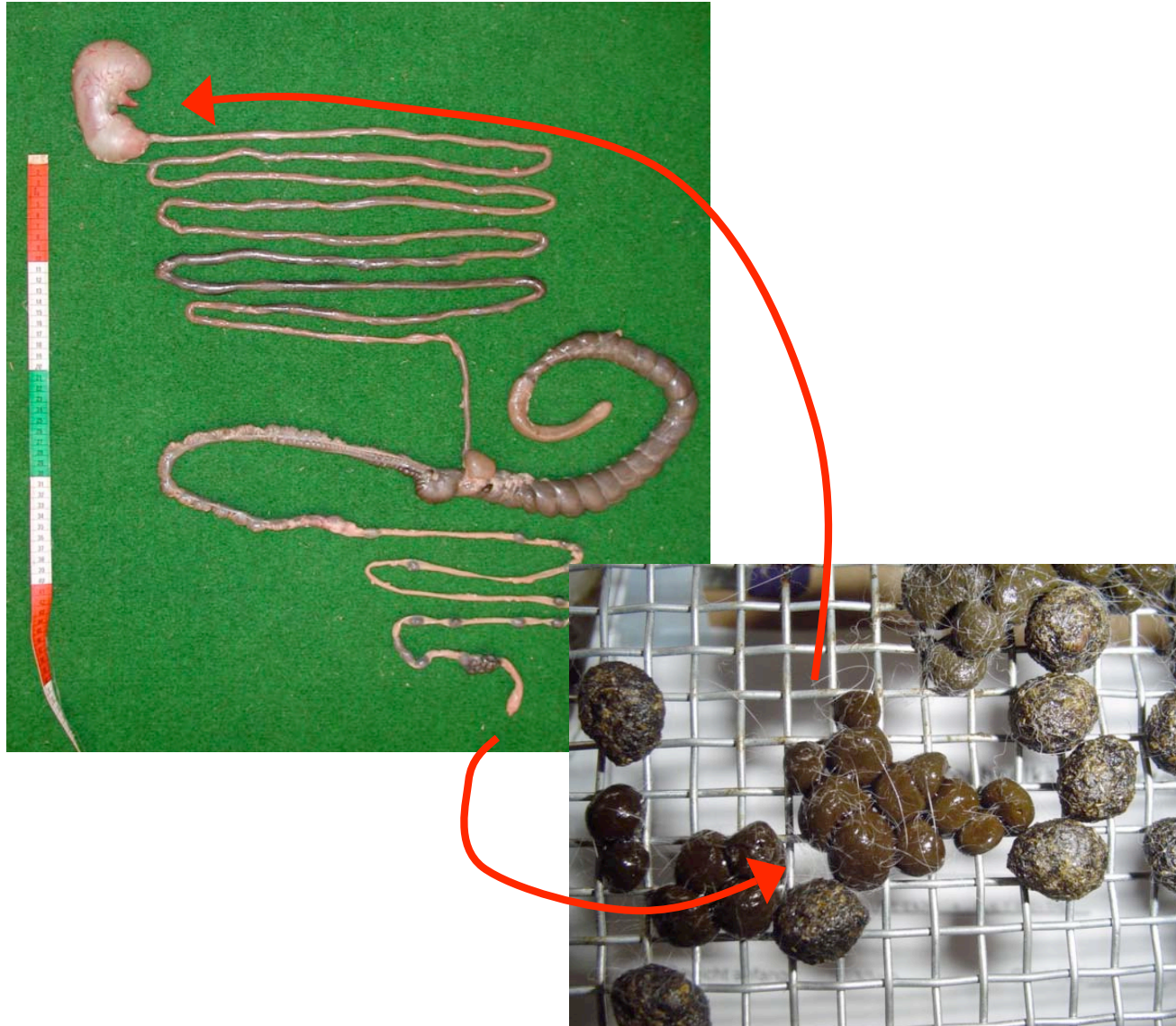
Coprophagy/Caecotrophy



Photos: B. Burger



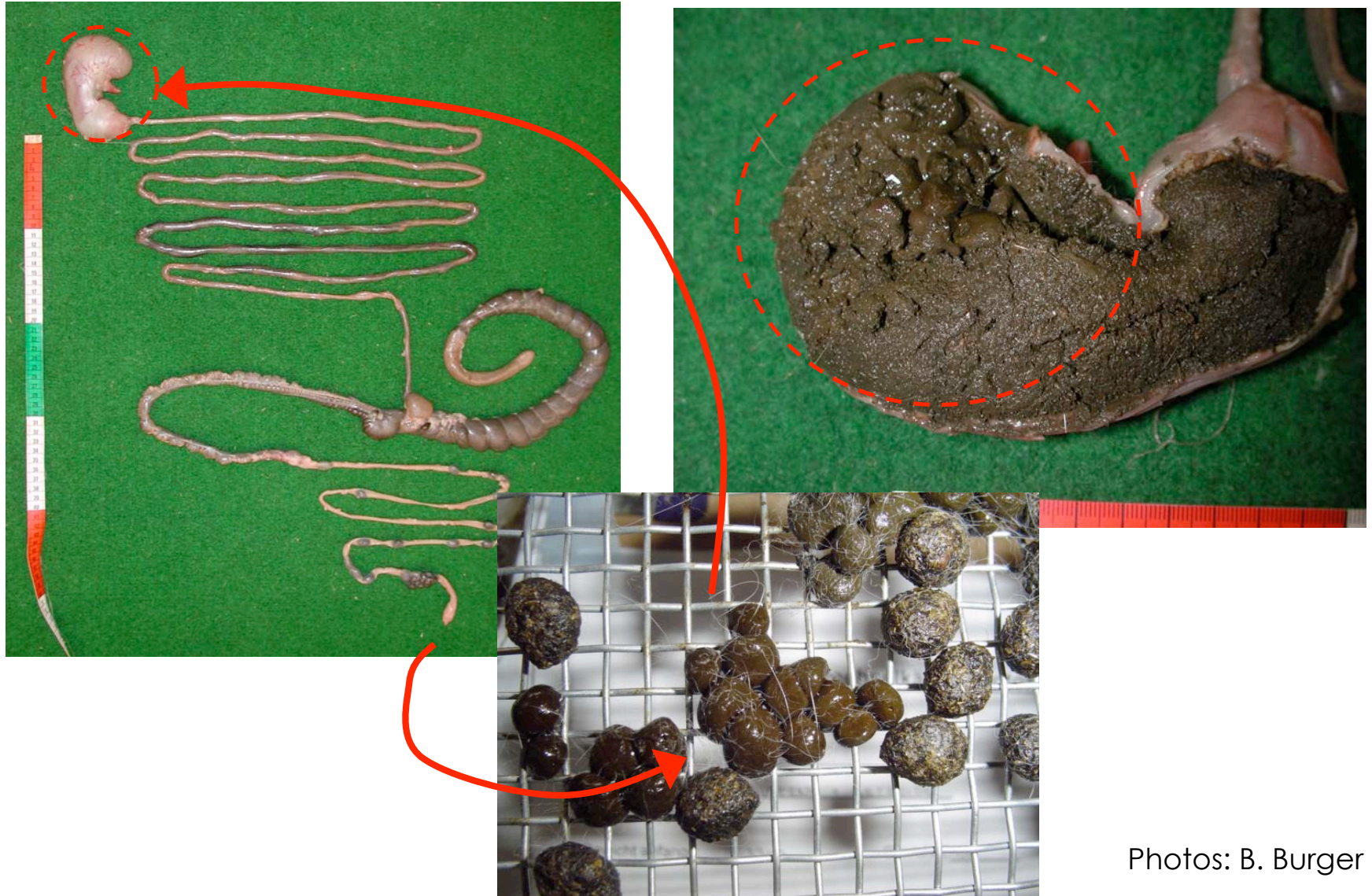
Coprophagy/Caecotrophy



Photos: B. Burger



Coprophagy/Caecotrophy



Photos: B. Burger



Coprophagy/Caecotrophy



Photos: B. Burger, M. Clauss



Coprophagy/Caecotrophy



Photo: A. Tschudin



Detritivory, coprophagy, and the evolution of digestive mutualisms in Dictyoptera

C.A. Nalepa¹, D.E. Bignell² and C. Bandi³

Insectes soc. 48 (2001) 194–201



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ASOCIAL

DETRITIVORY,
GENERAL
COPROPHAGY





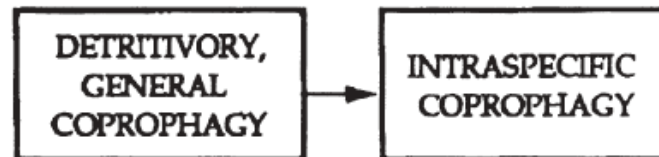
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ASOCIAL

GREGARIOUS

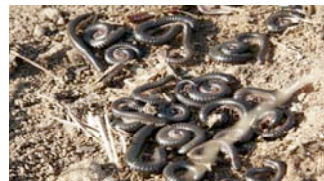
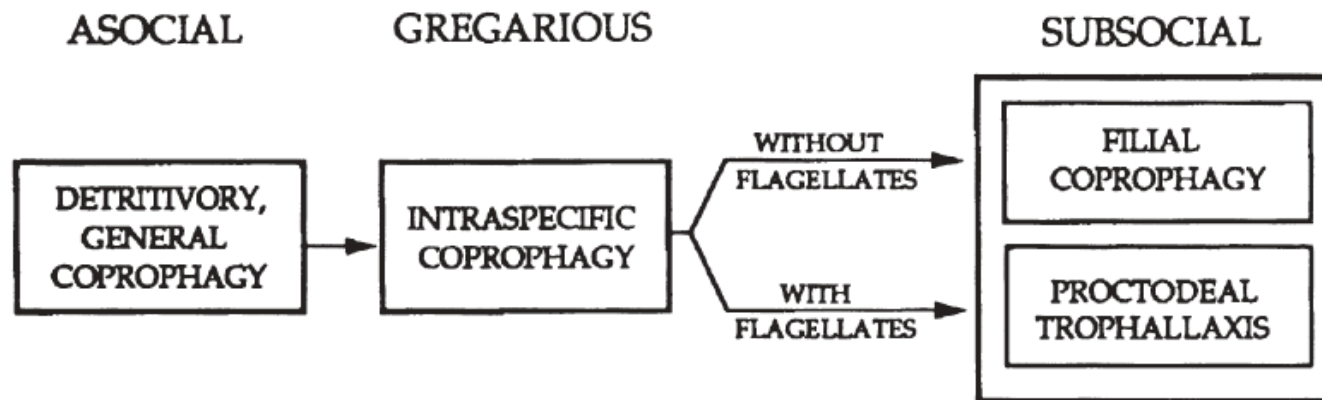




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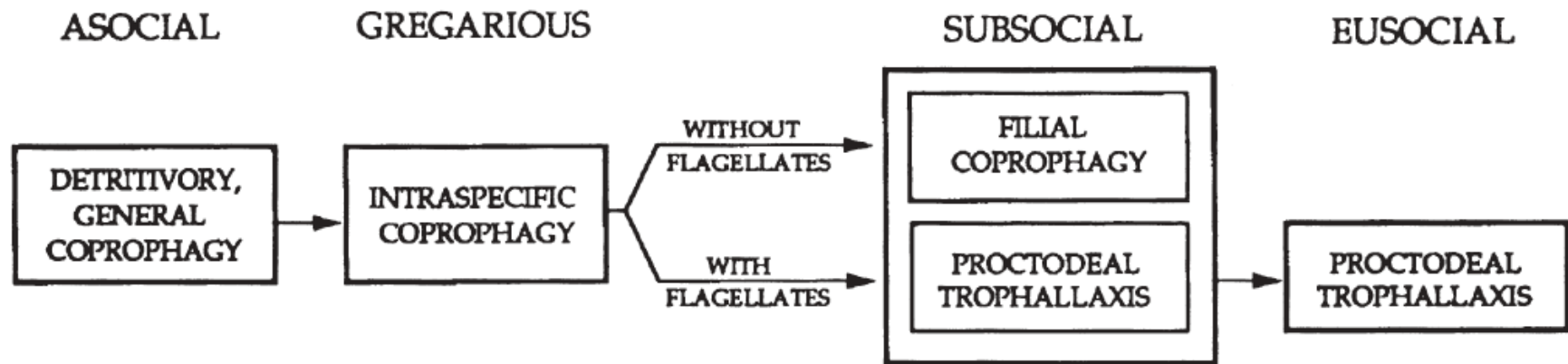




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Insectes soc. 48 (2001) 194–201





Coprophagy / Trophallaxis

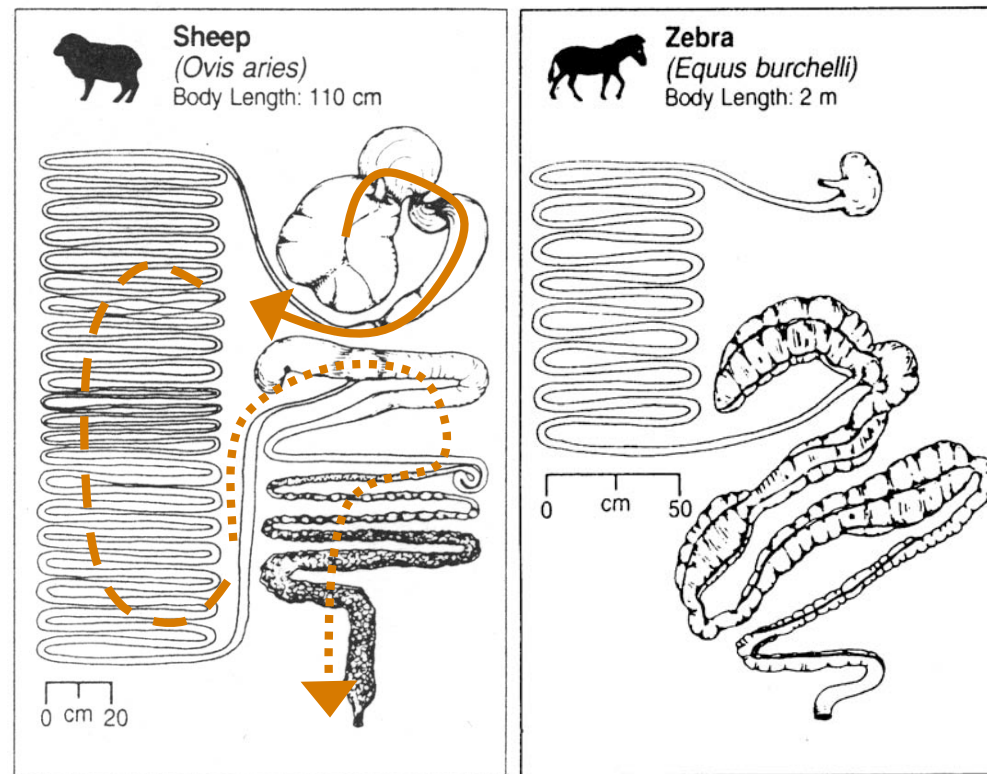
The question is not so much
why such a large variety of hindgut fermenters
practice coprophagy,
but rather
why there is a certain group
of large hindgut fermenters
that does not.





Foregut vs. Hindgut Fermentation

Lower
bacterial
nitrogen losses
in the faeces?

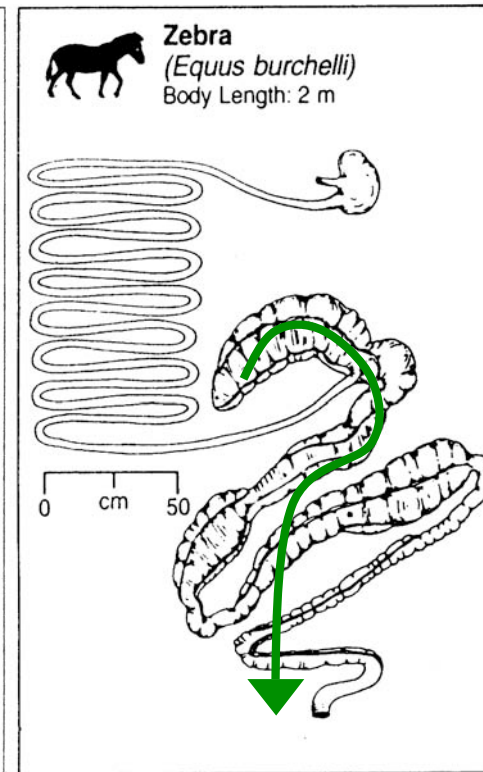
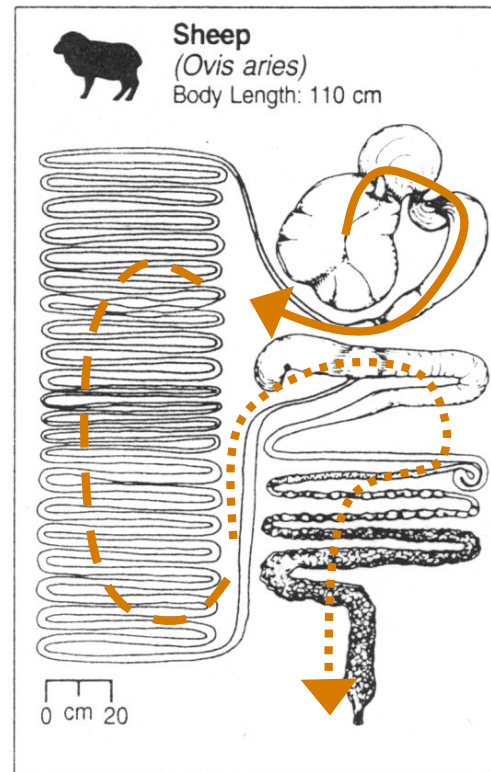


from Stevens & Hume (1995)



Foregut vs. Hindgut Fermentation

Lower
bacterial
nitrogen losses
in the faeces?



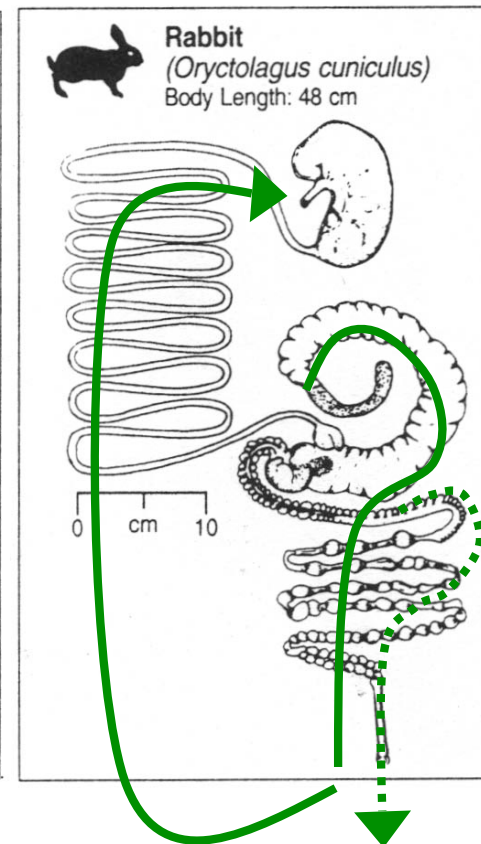
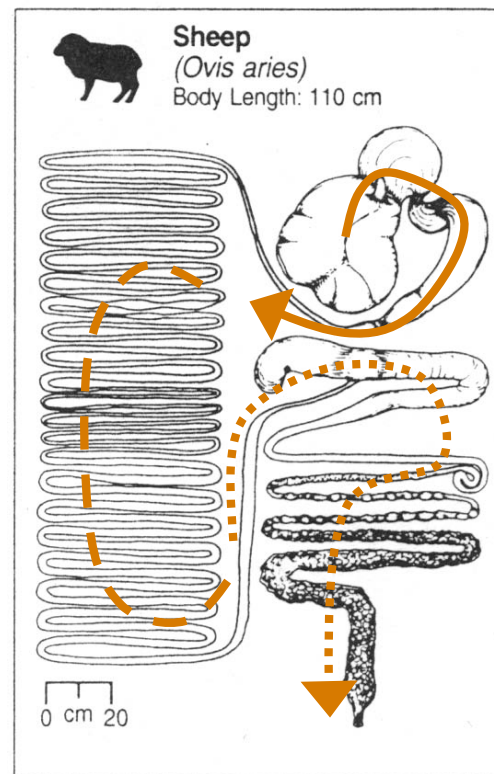
Higher
bacterial
nitrogen
losses in the
faeces?

from Stevens & Hume (1995)



Foregut vs. Hindgut Fermentation

Lower
bacterial
nitrogen losses
in the faeces?

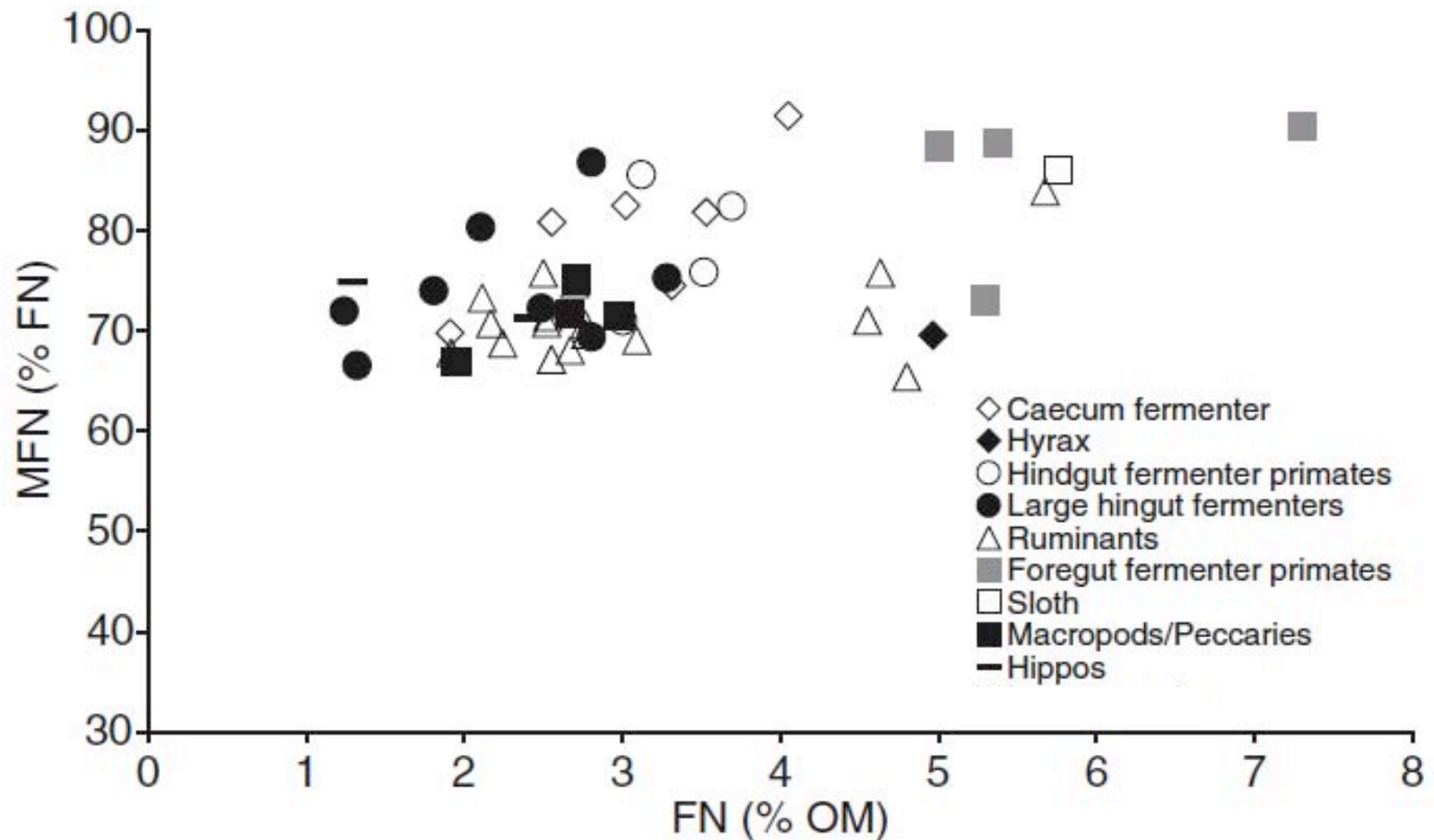


Lower
bacterial
nitrogen
losses in hard
faeces in
coprophagic
hindgut
fermenters
due to
bacterial
accumulation
in
caecotrophs?

from Stevens & Hume (1995)



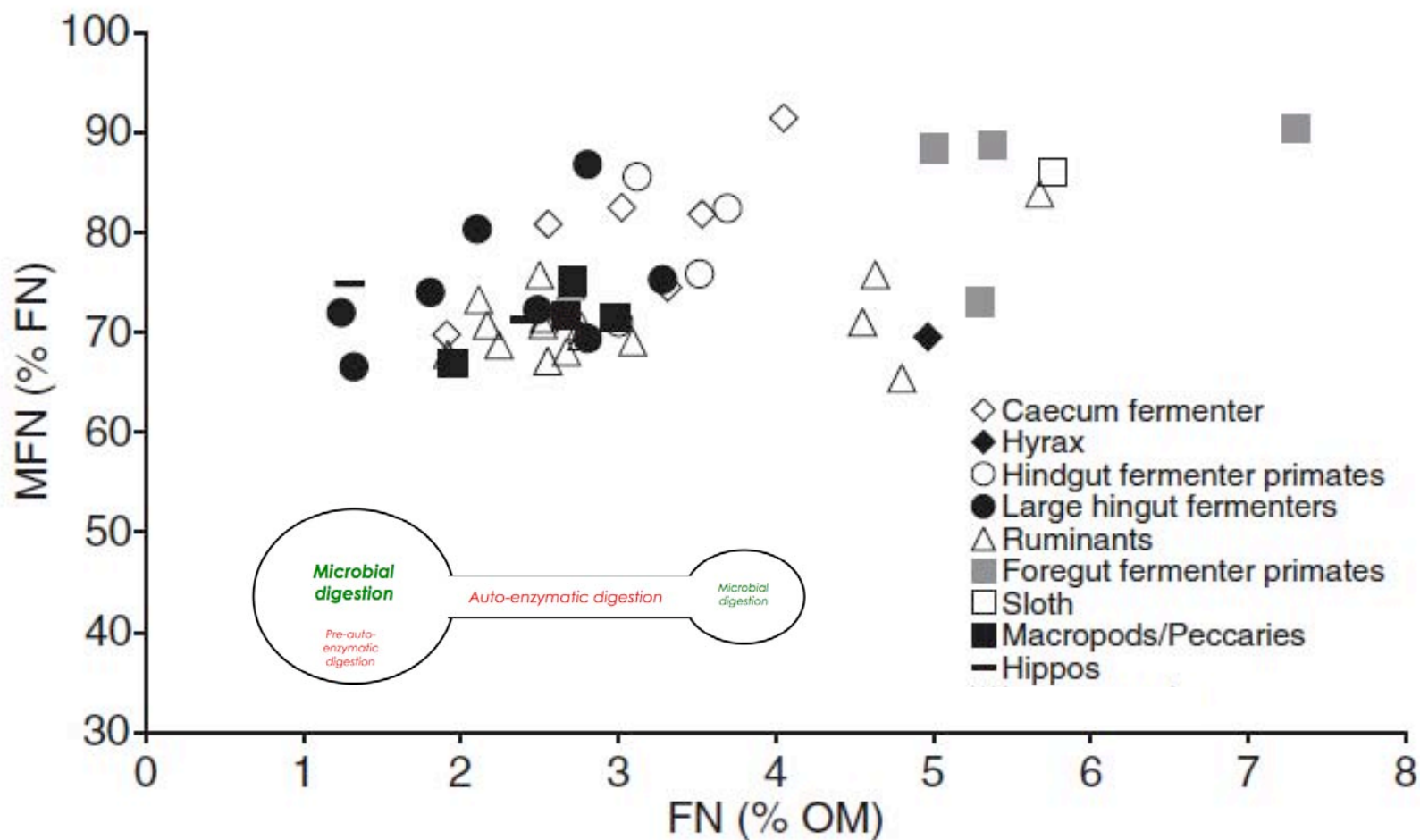
Metabolic faecal nitrogen in zoo herbivores



from Schwarm et al. (2009)



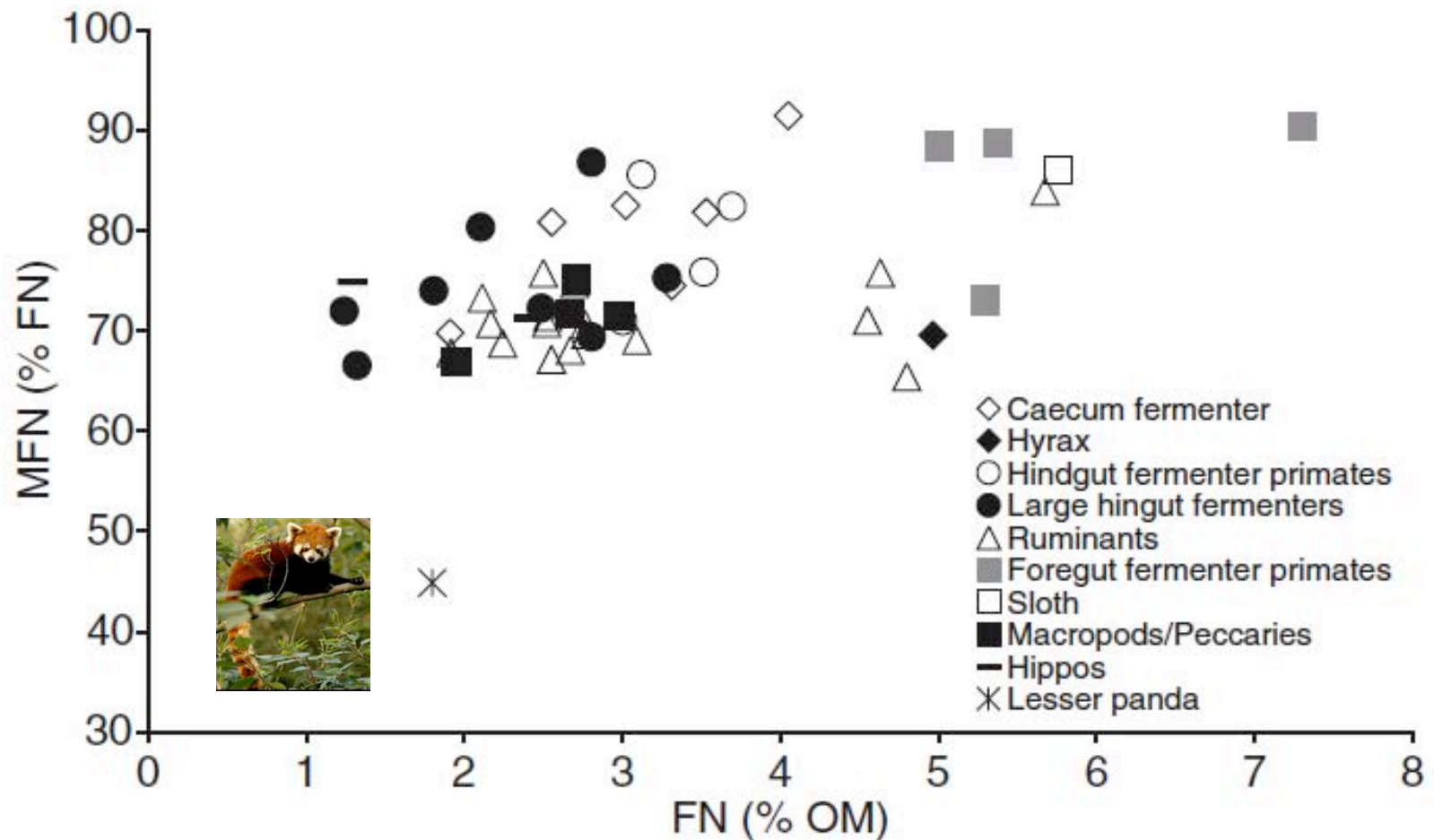
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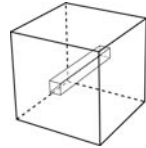
Metabolic faecal nitrogen in zoo herbivores



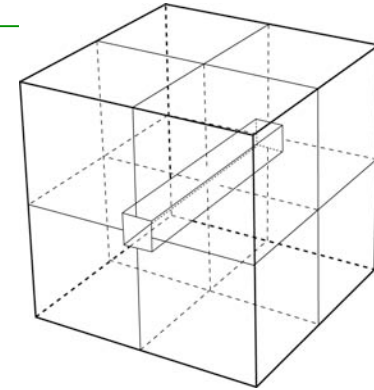
from Schwarm et al. (2009)



Surface/volume geometry



6:1



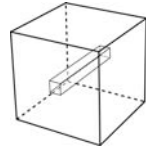
24:8=3:1

... affects all surface-related processes

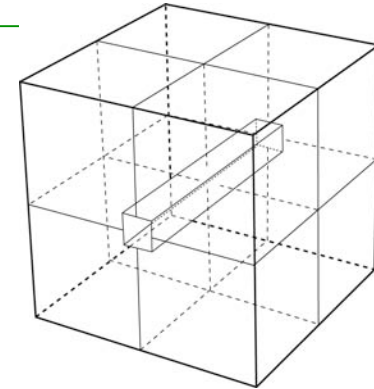
heat loss **---** ➔ **energy requirements** **---** ➔ **food intake**



Surface/volume geometry

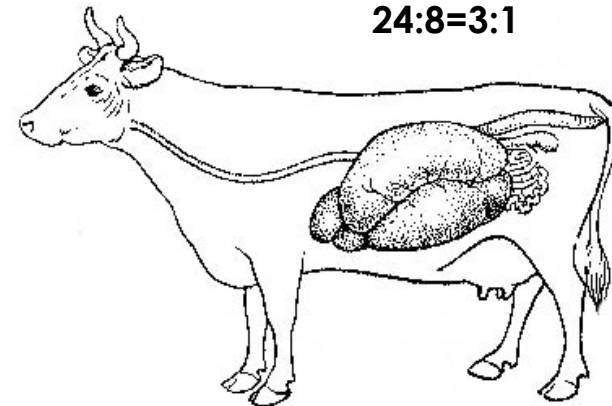
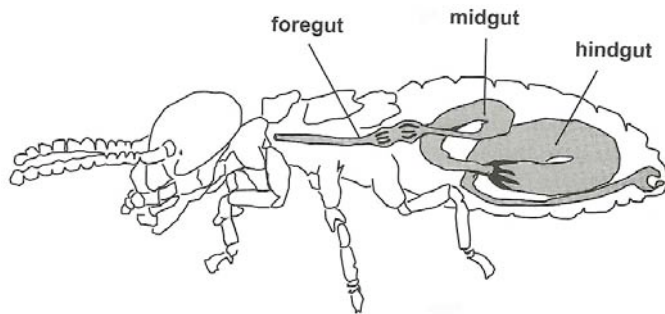


6:1



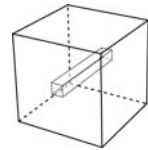
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... affects all surface-related processes

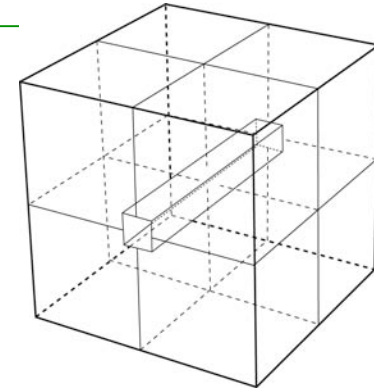




Surface/volume geometry

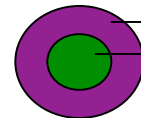
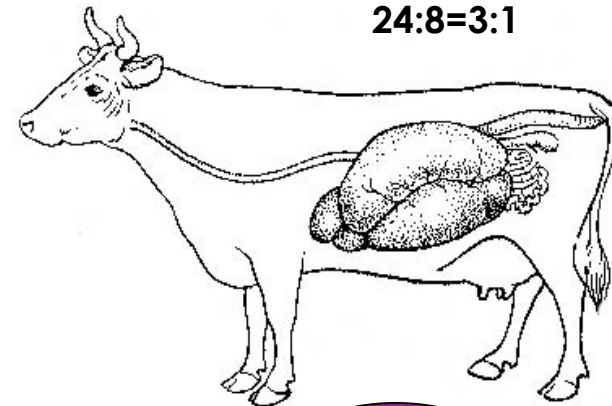
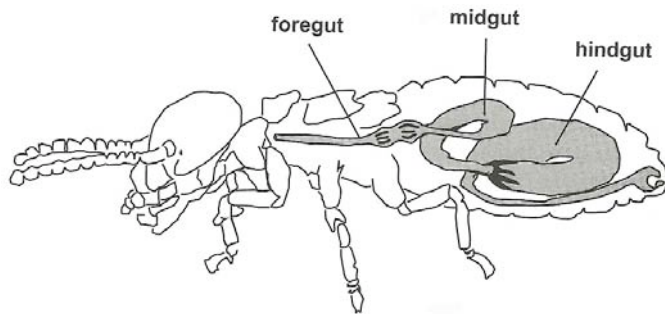


6:1



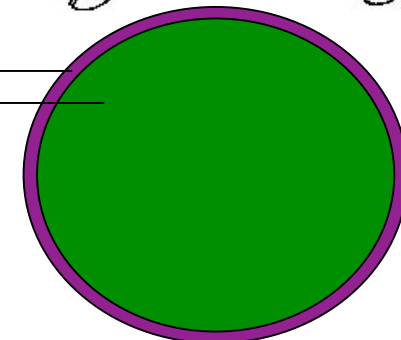
24:8=3:1

... affects all surface-related processes



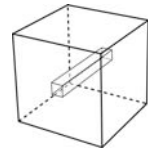
oxic
anoxic

gut contents

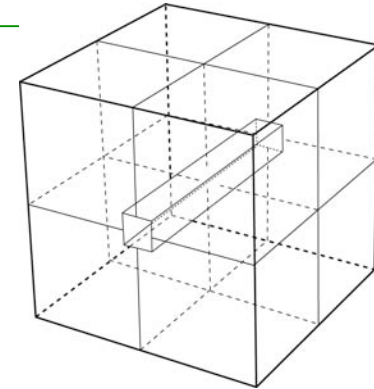




Surface/volume geometry

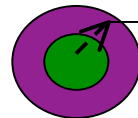
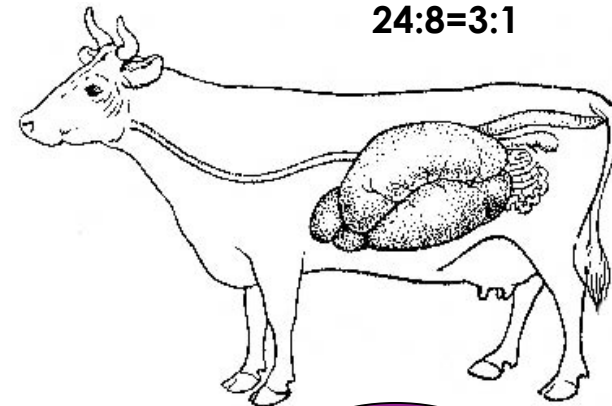
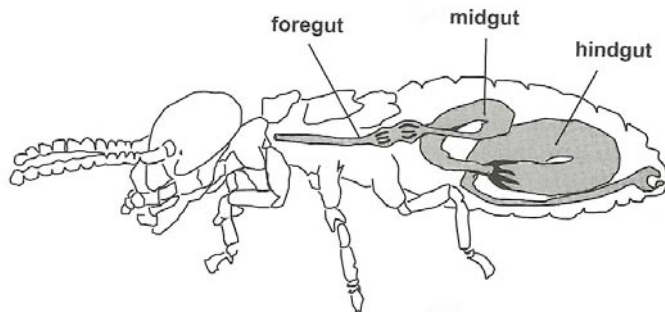


6:1



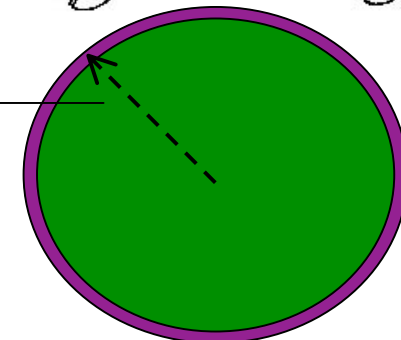
24:8=3:1

... affects all surface-related processes



short
long

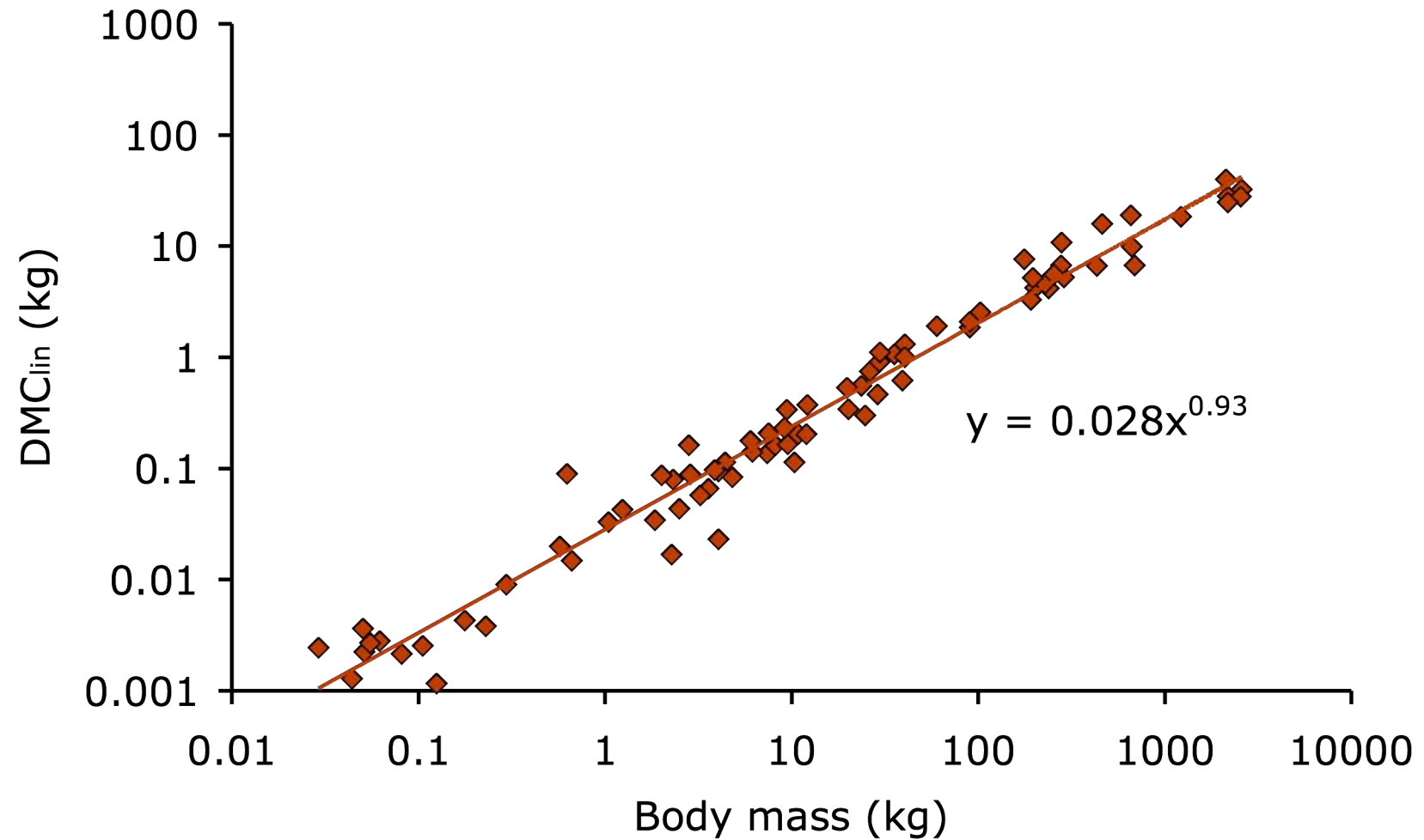
diffusion ways



from Karasov & Martinez del Rio (2007)

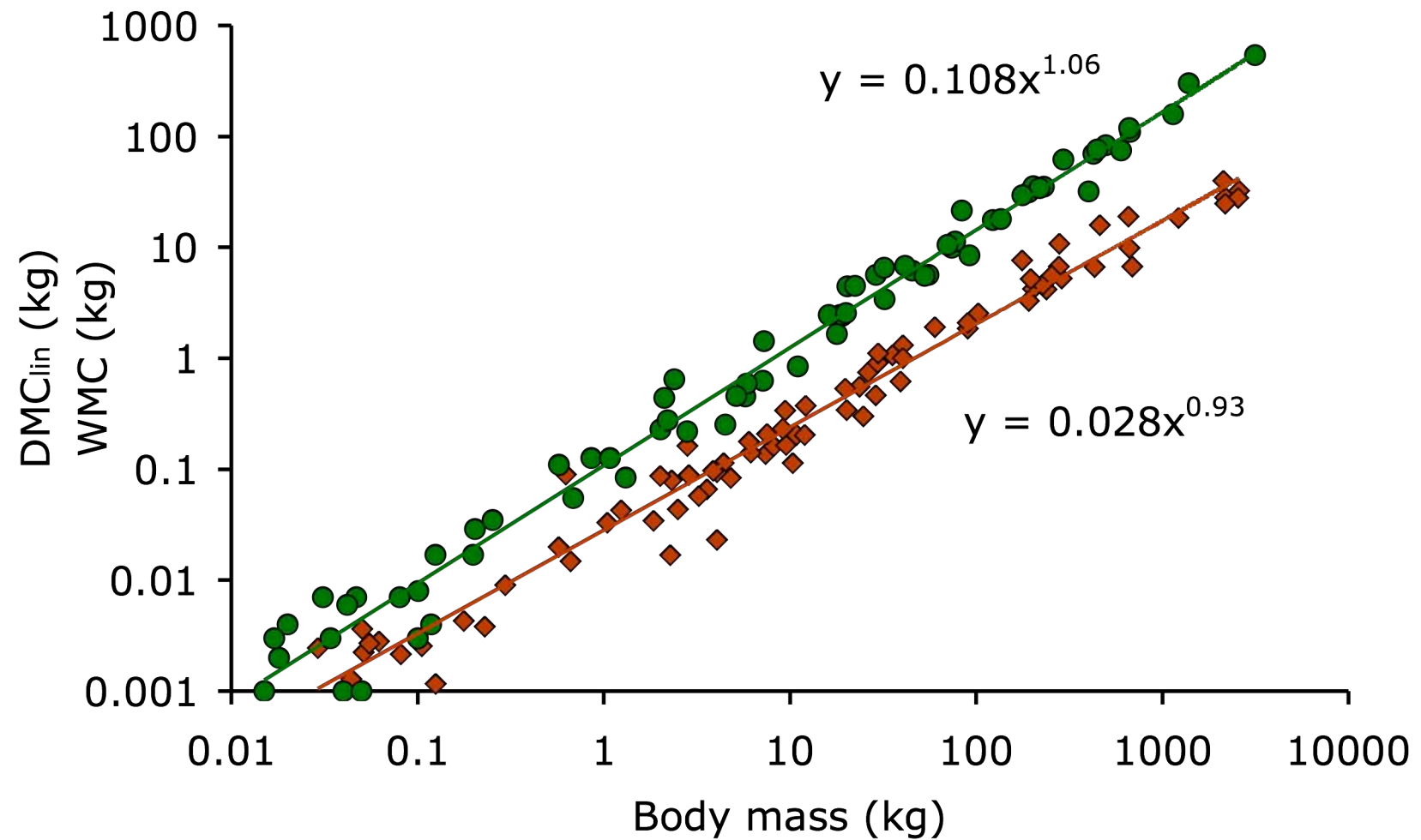


Gut moisture content



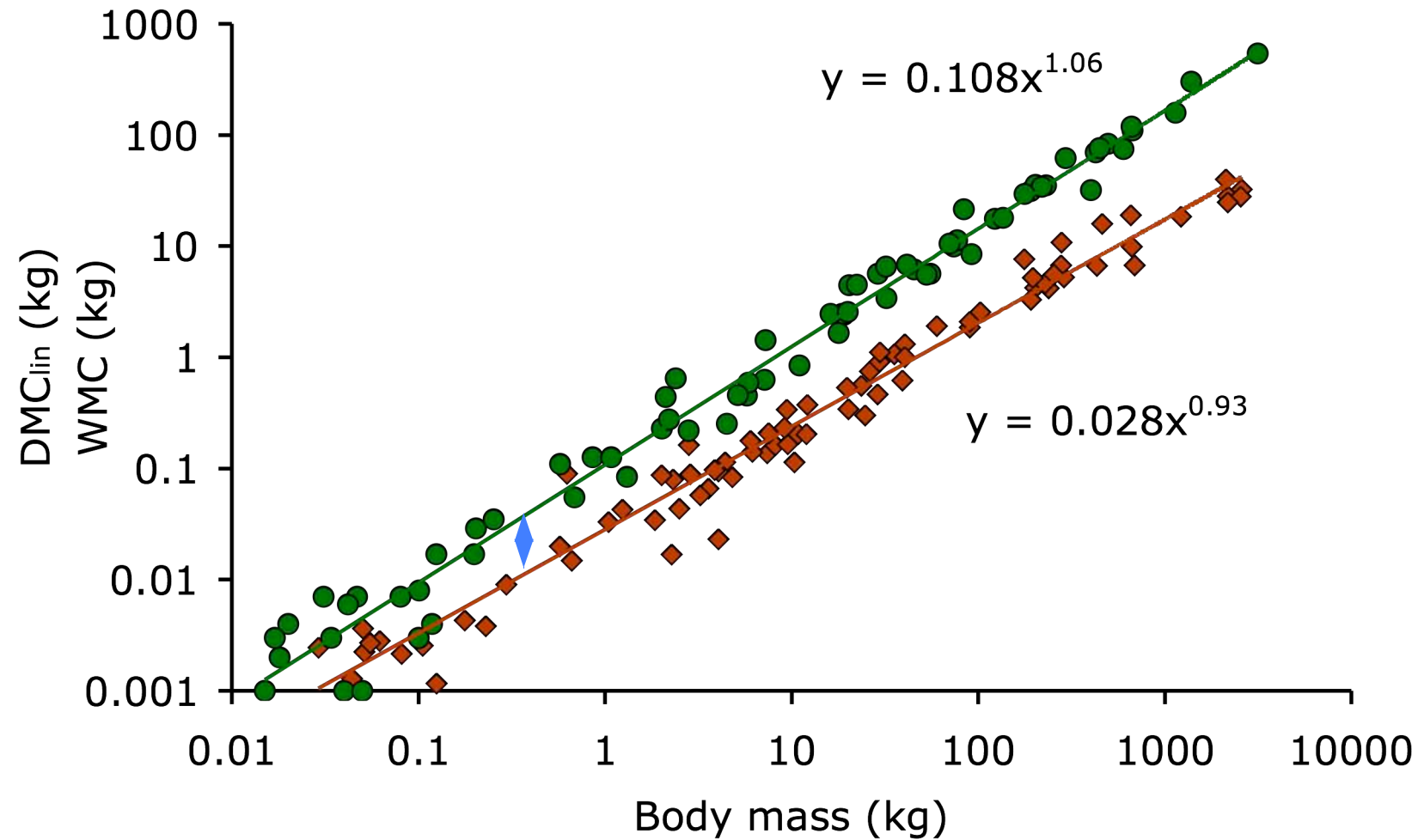


Gut moisture content



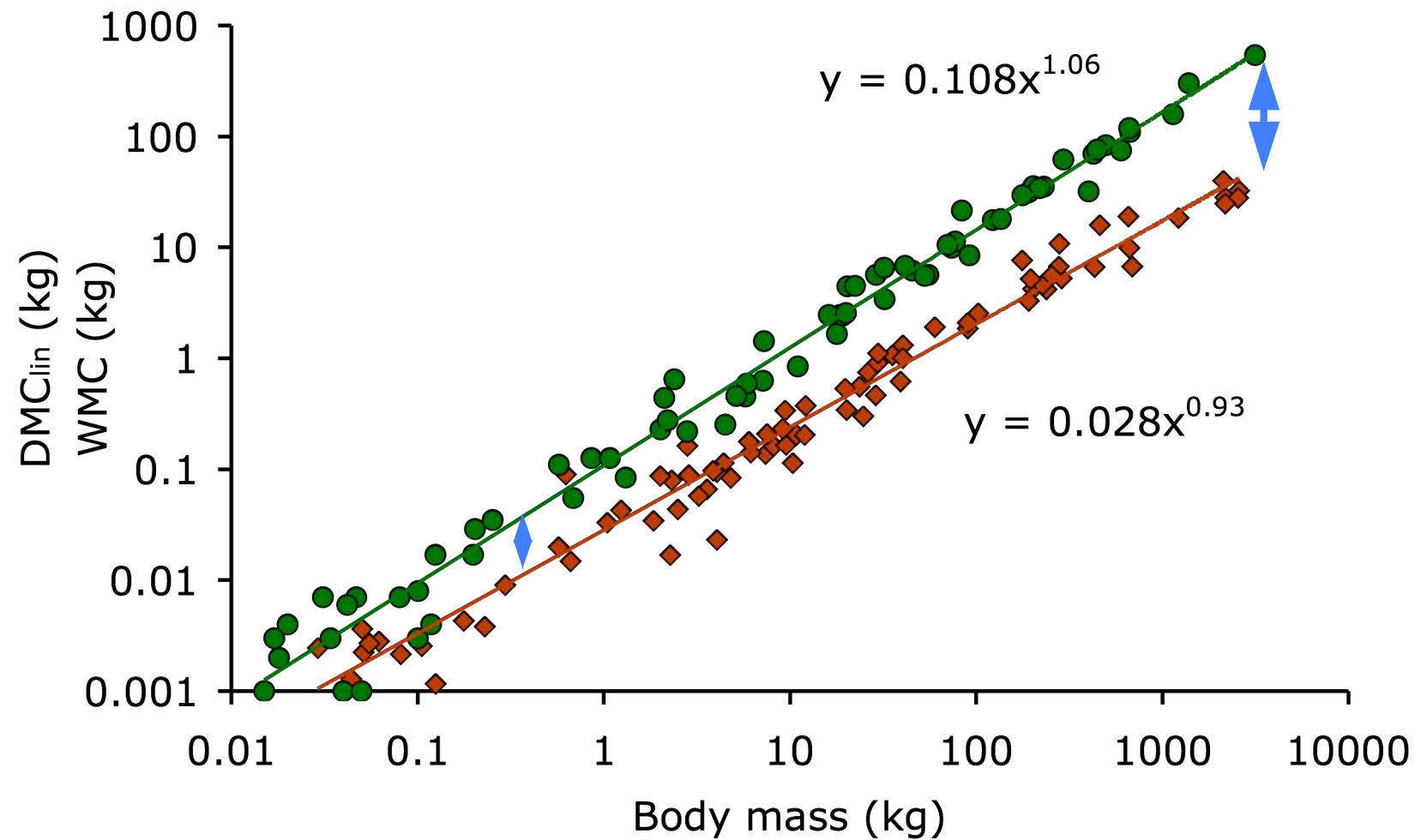


Gut moisture content





Gut moisture content



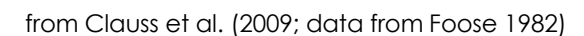


Conceptualizing herbivore diversity

Traditionally, body size is considered the major driver of herbivore diversity (in the sense that larger animals achieve longer retention times and higher digestibilities).



However, empirical data does not indicate a relevant scaling of digestibility ...

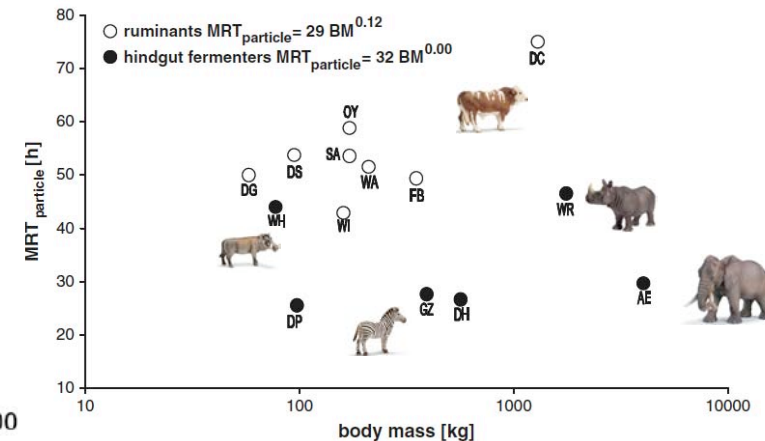
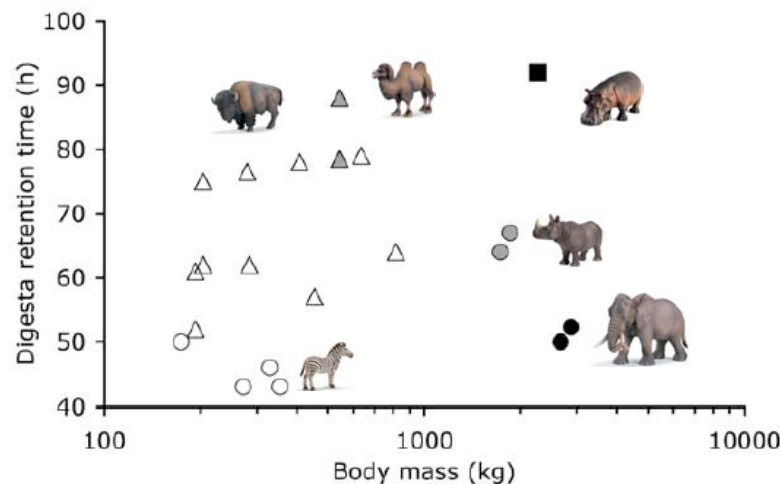




Conceptualizing herbivore diversity

Traditionally, body size is considered the major driver of herbivore diversity (in the sense that larger animals achieve longer retention times and higher digestibilities).

However, empirical data does not indicate a relevant scaling of digestibility or digesta retention times with body mass.



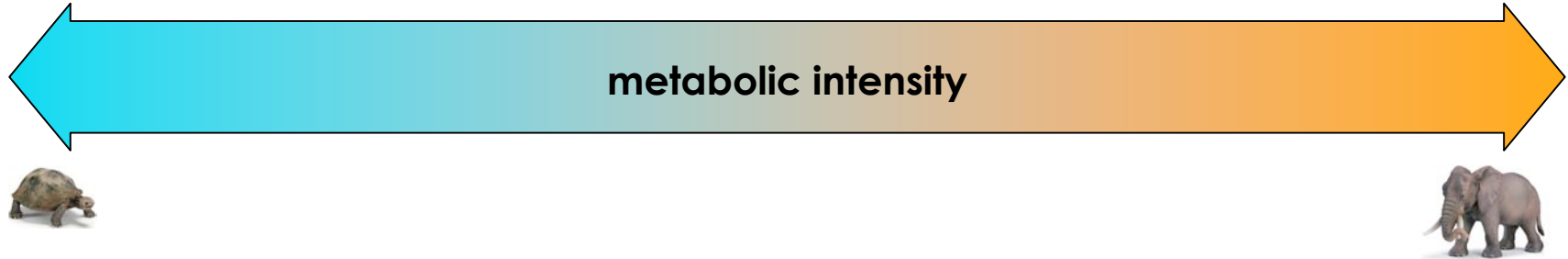


Conceptualizing herbivore diversity





Conceptualizing herbivore diversity





Conceptualizing herbivore diversity



To achieve a high metabolic intensity, you need





Conceptualizing herbivore diversity



To achieve a high metabolic intensity, you need

- *a high food intake*



Conceptualizing herbivore diversity



To achieve a high metabolic intensity, you need

- *a high food intake*
- *a high digestive efficiency*



Conceptualizing herbivore diversity



To achieve a high metabolic intensity, you need

- *a high food intake*
- *a high digestive efficiency*
 - *long retention times*
 - *intensive particle size reduction*
 - *(high feeding selectivity)*



Conceptualizing herbivore diversity



To achieve a high metabolic intensity, you need

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- *a high digestive efficiency*
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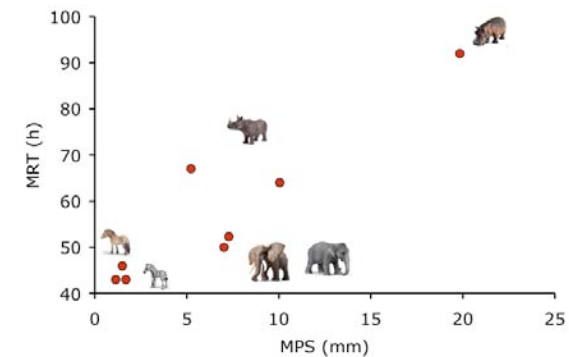


Conceptualizing herbivore diversity



To achieve a high metabolic intensity, you need

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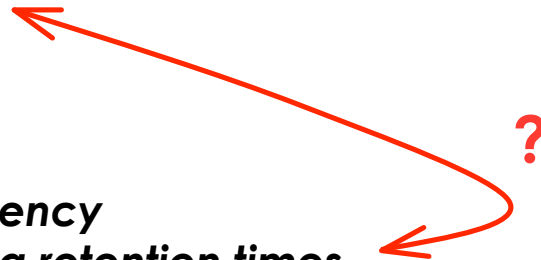


Conceptualizing herbivore diversity



To achieve a high metabolic intensity, you need

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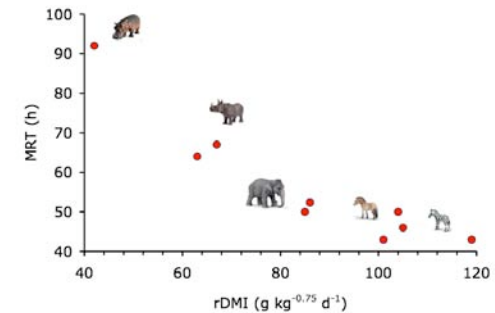
Conceptualizing herbivore diversity



To achieve a high metabolic intensity, you need



- *a high food intake*
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 - *long retention times*
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Conceptualizing herbivore diversity



To achieve a high metabolic intensity, you need

- *a high food intake*
- *a high digestive efficiency*
 - *long retention times*
 - *intensive particle size reduction*
 - *(high feeding selectivity)*

*Compensation via
gut capacity?*





Conceptualizing herbivore diversity



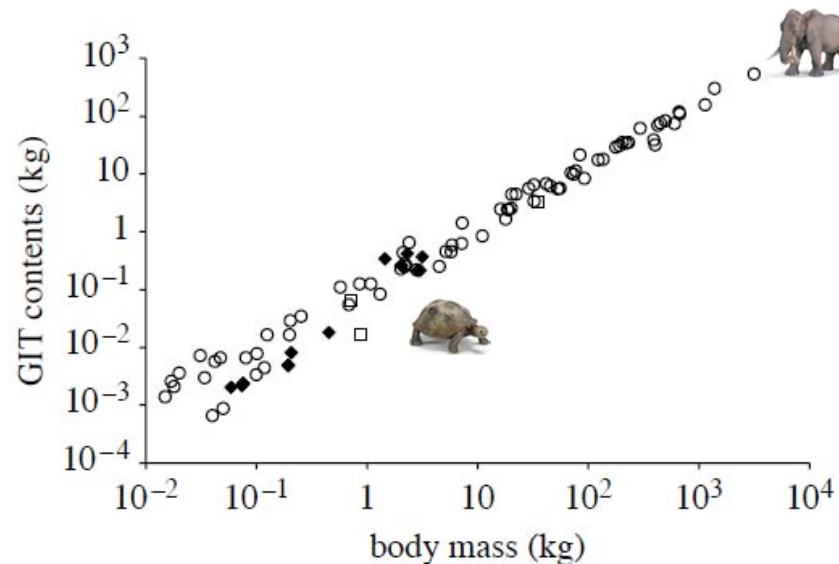
*Gut capacity is relatively constant across
metabolic intensities*



Conceptualizing herbivore diversity



Gut capacity is relatively constant across metabolic intensities

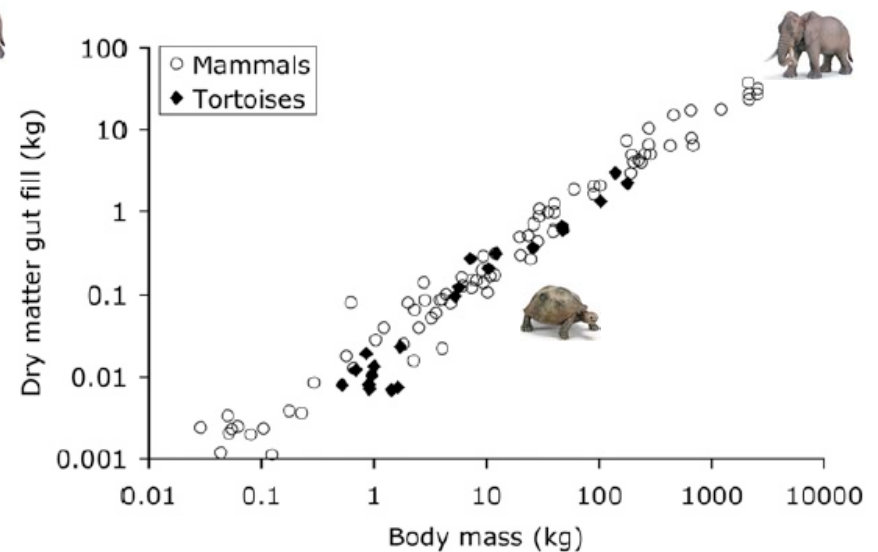
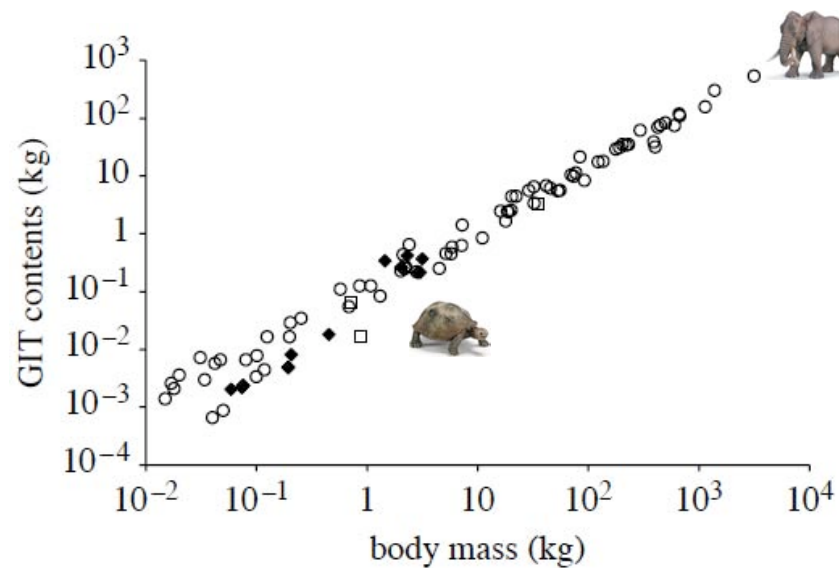




Conceptualizing herbivore diversity

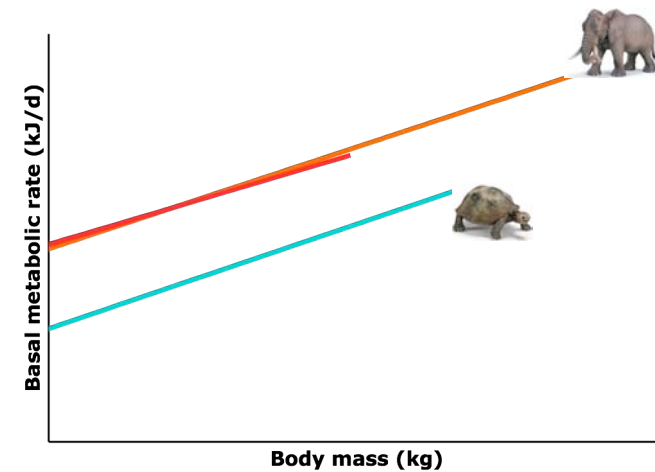
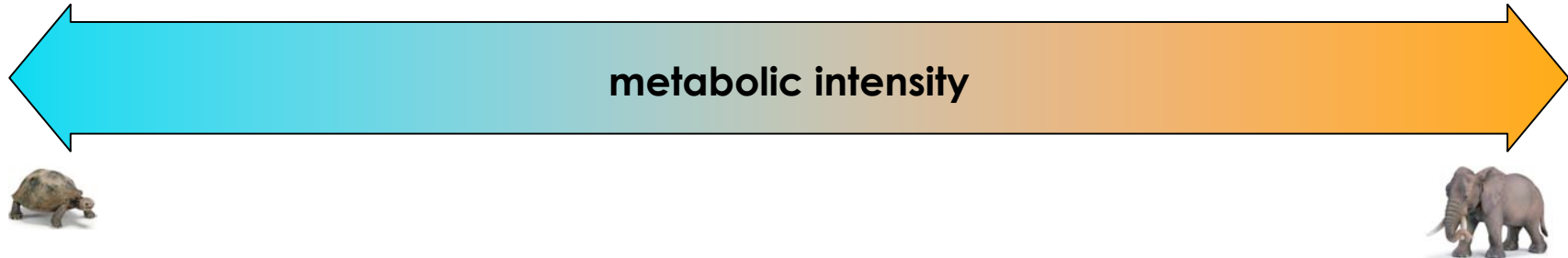


Gut capacity is relatively constant across metabolic intensities



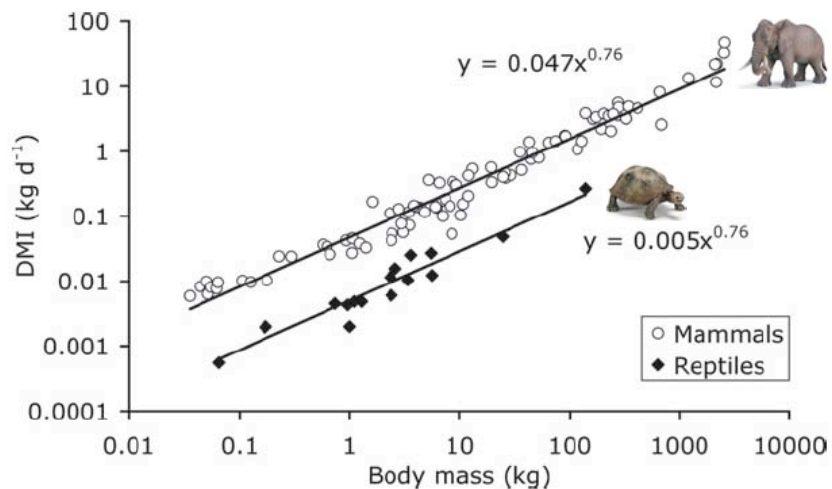
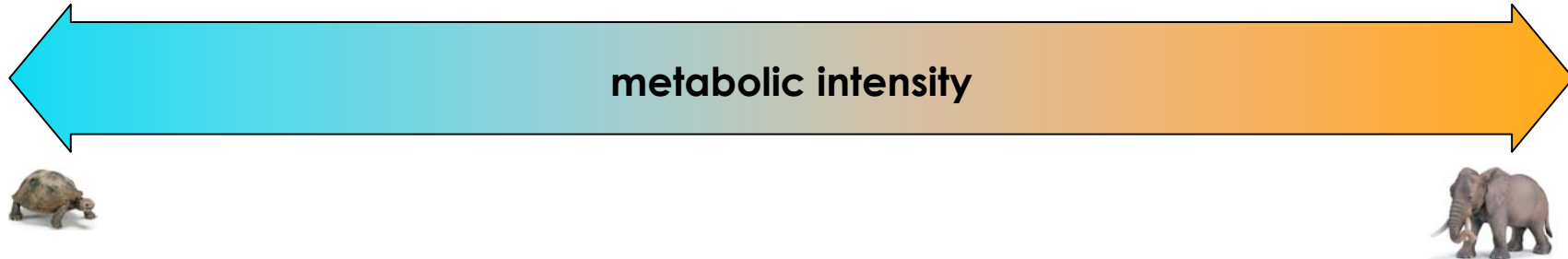


Conceptualizing herbivore diversity



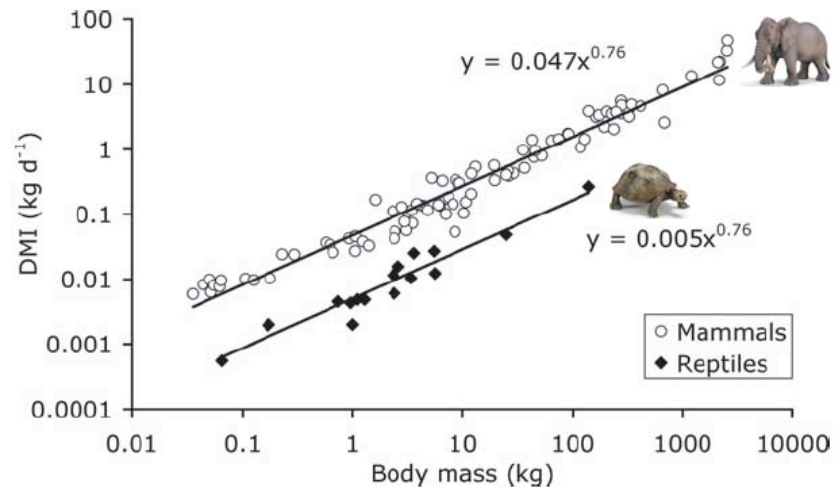
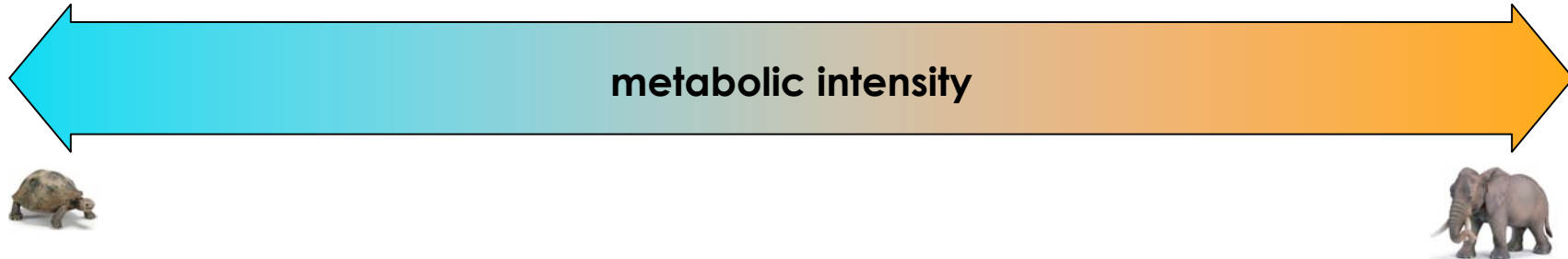


Conceptualizing herbivore diversity





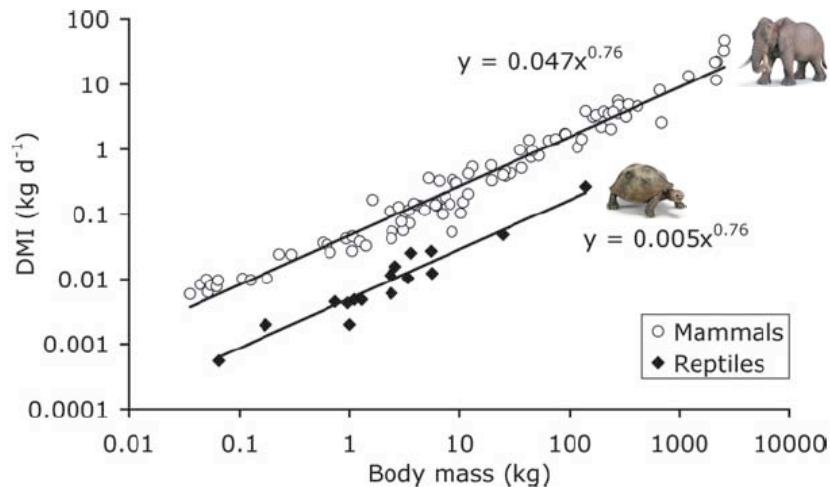
Conceptualizing herbivore diversity



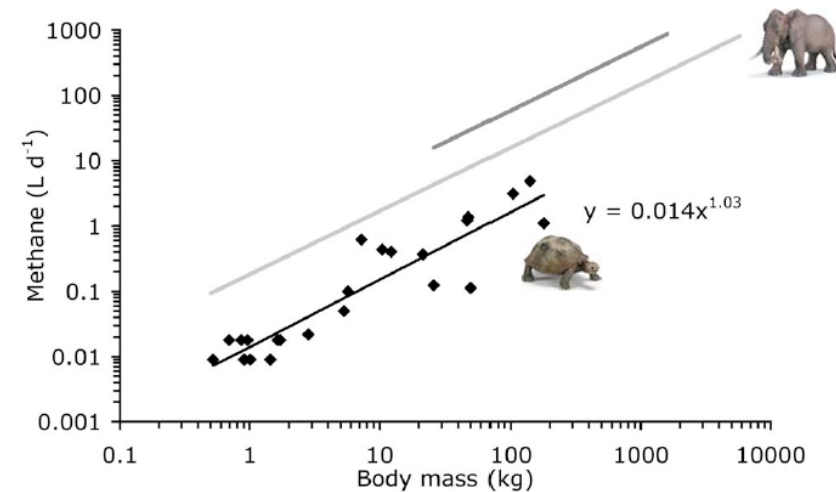
from Franz et al. (2011)



Conceptualizing herbivore diversity



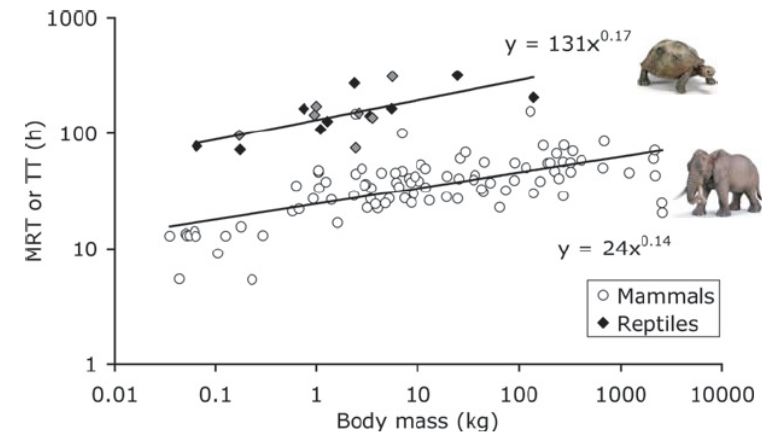
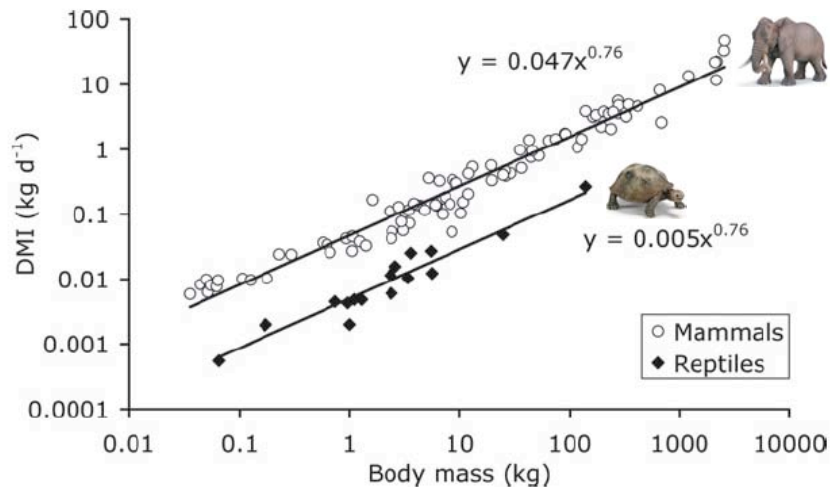
from Franz et al. (2011a)



from Franz et al. (2011b)



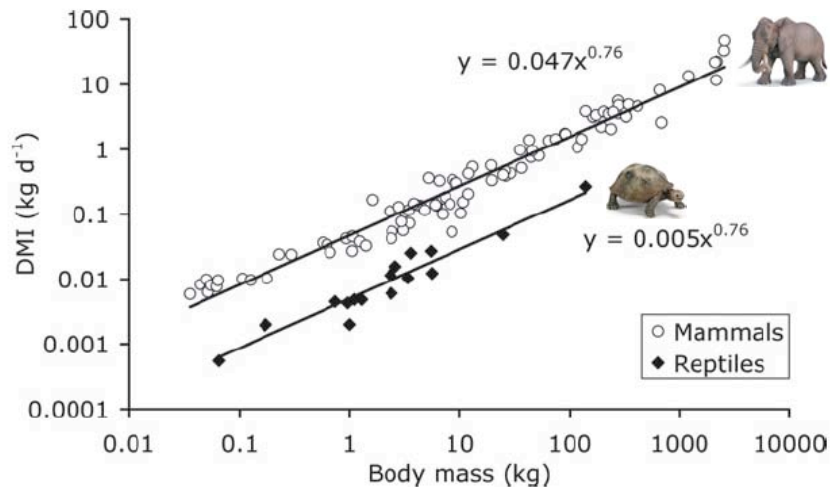
Conceptualizing herbivore diversity



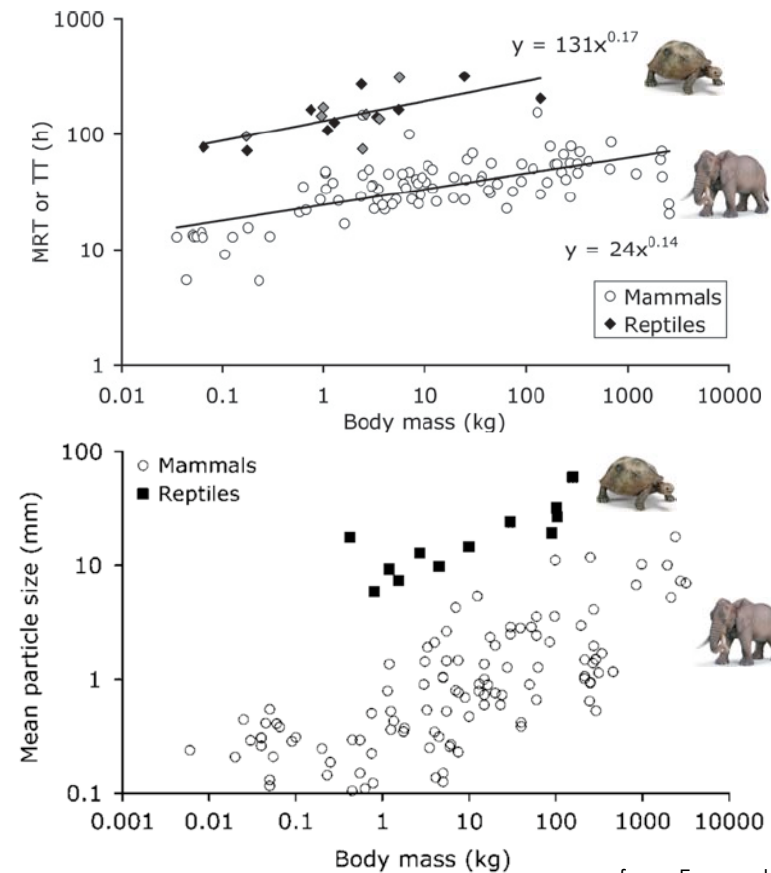


Conceptualizing herbivore diversity

metabolic intensity



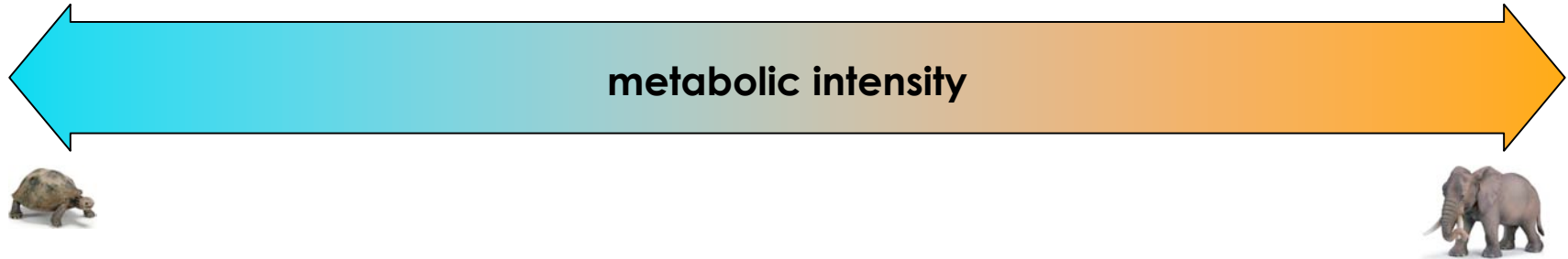
from Franz et al. (2011)



from Franz et al. (2011)
and Fritz et al. (2010)

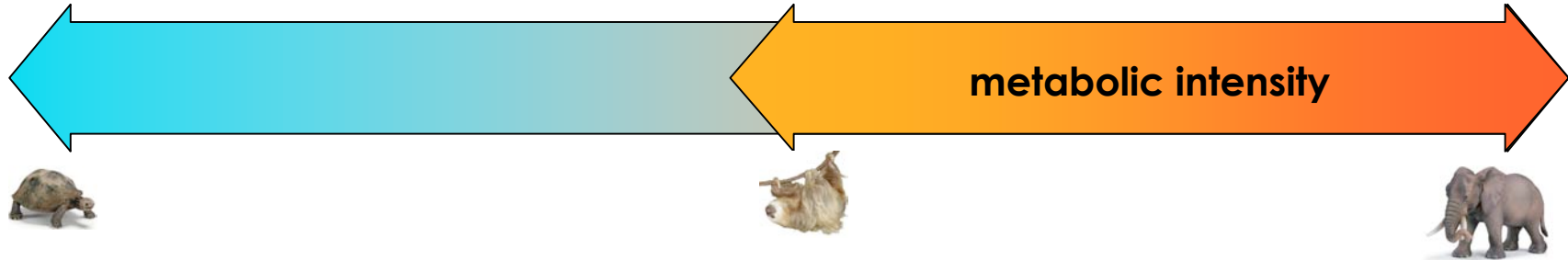


Conceptualizing herbivore diversity



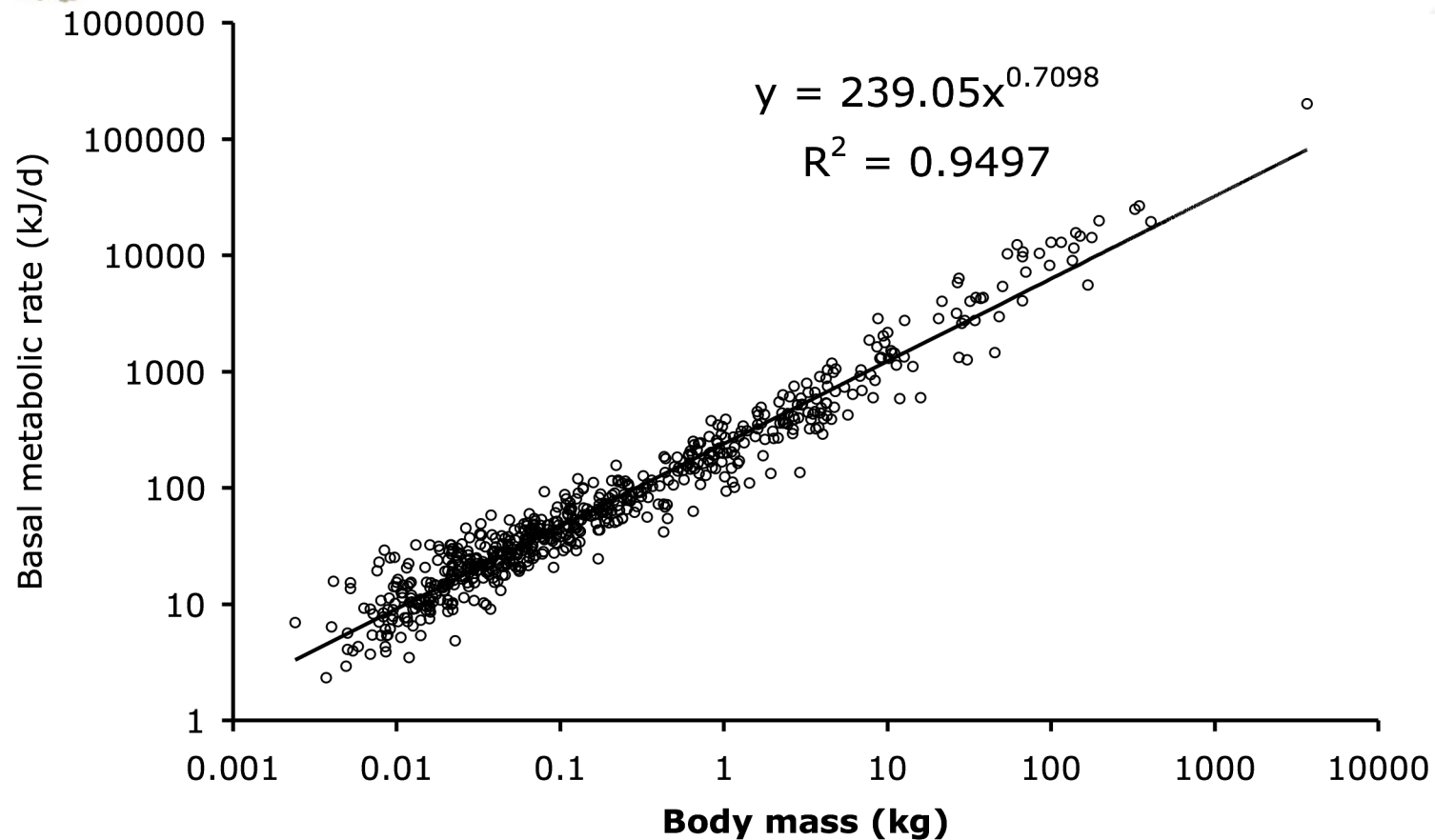


Conceptualizing herbivore diversity





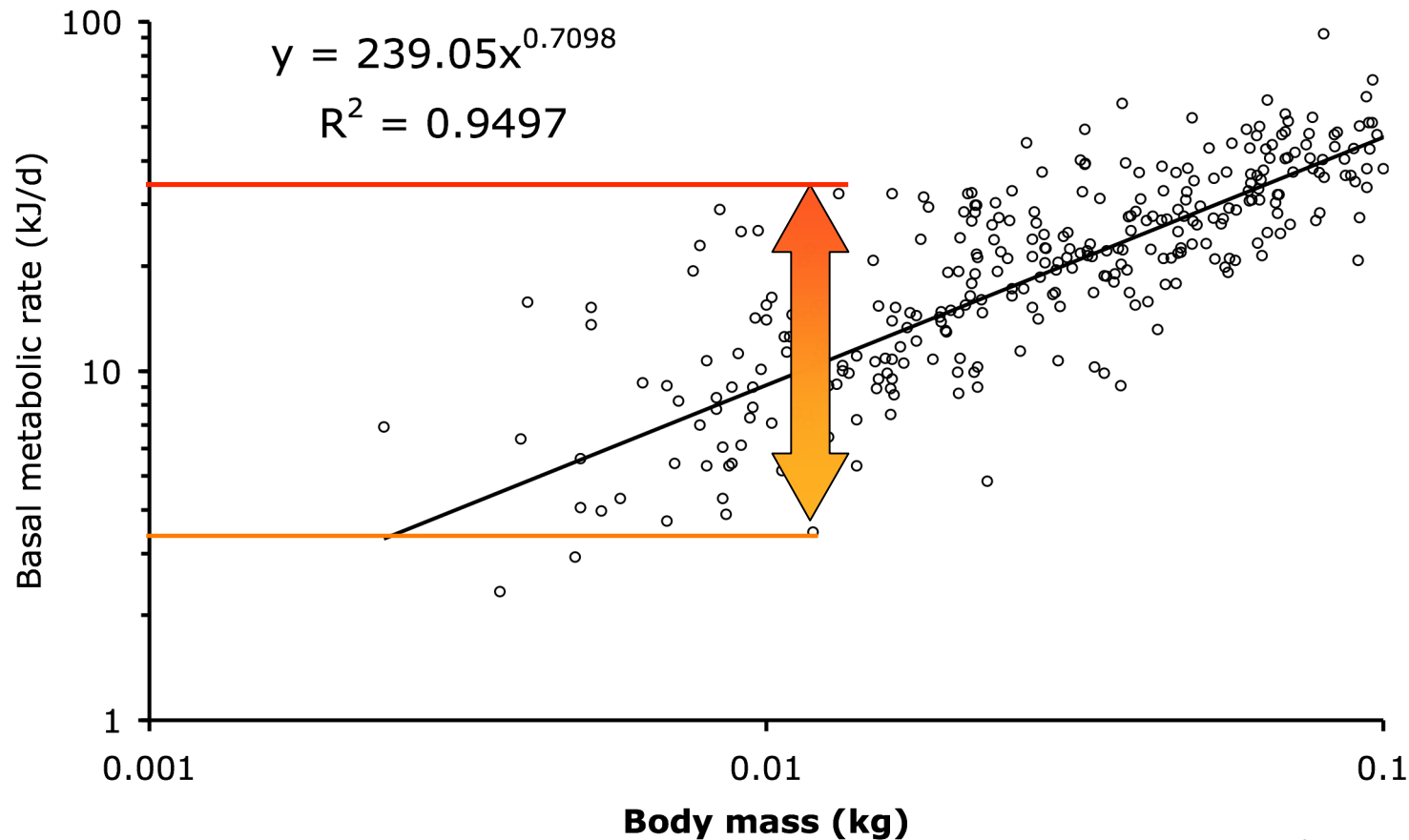
Conceptualizing herbivore diversity



Data from Savage et al. (2004)



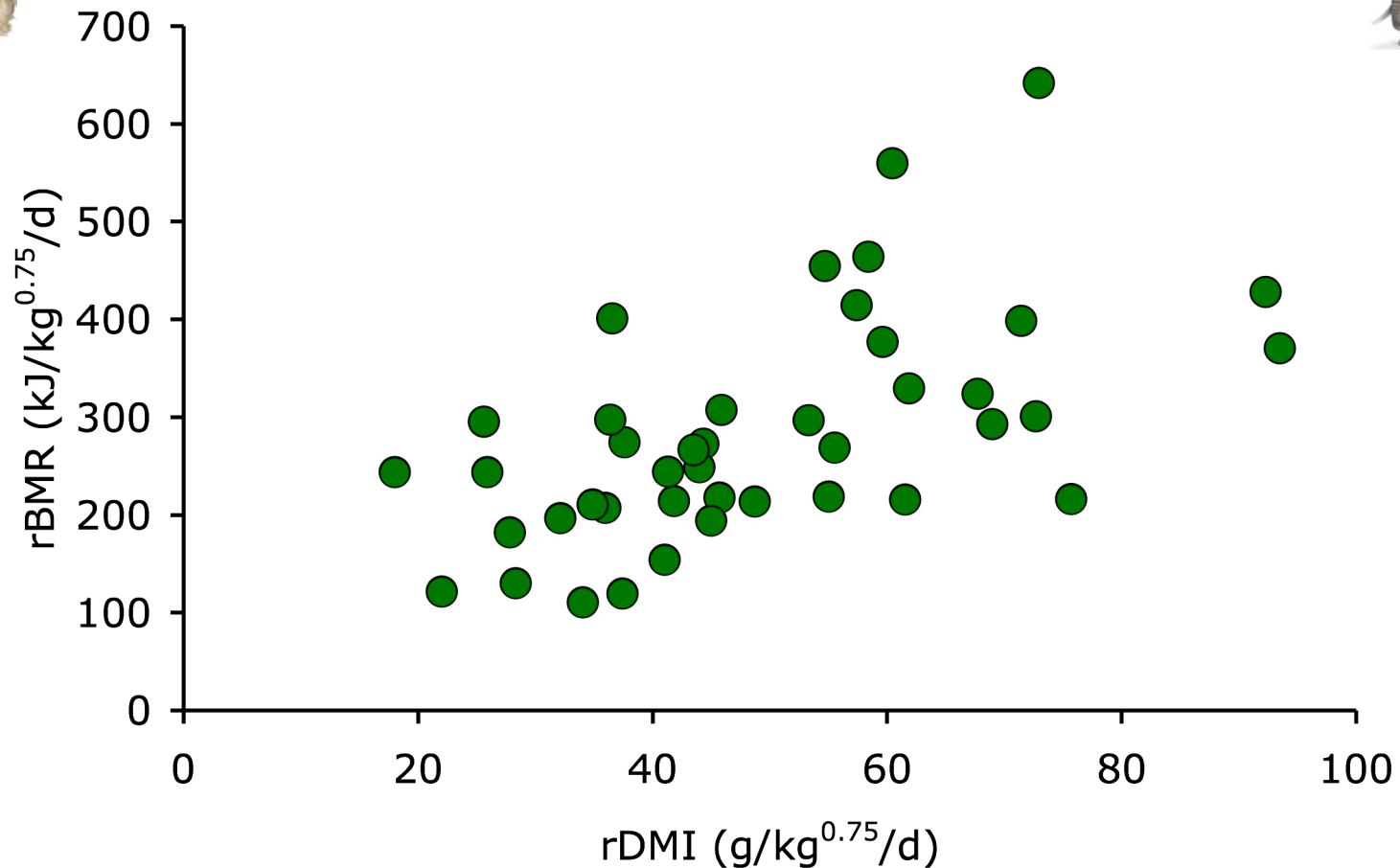
Conceptualizing herbivore diversity



Data from Savage et al. (2004)



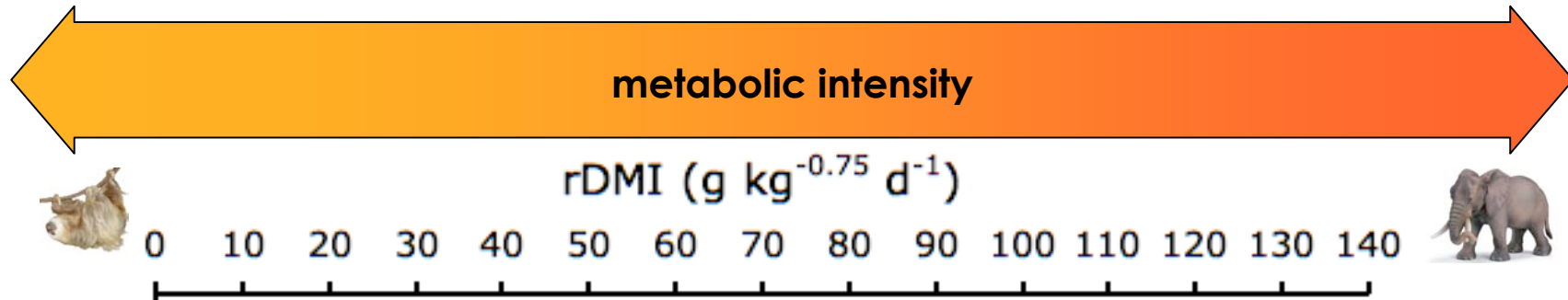
Conceptualizing herbivore diversity



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

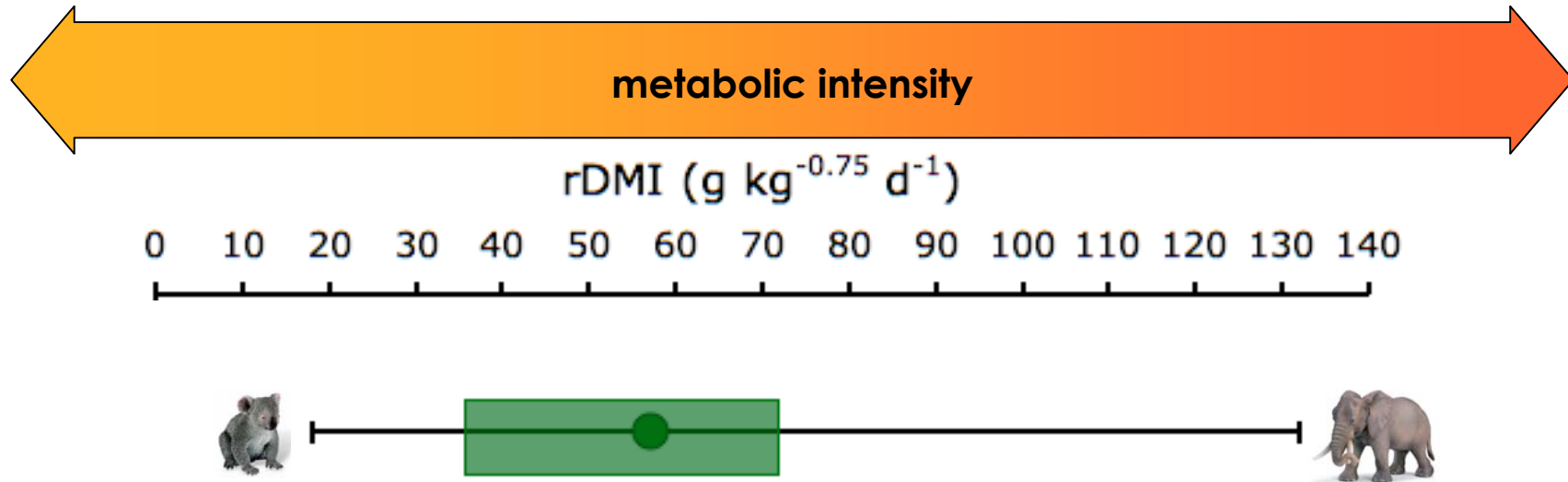


Conceptualizing herbivore diversity



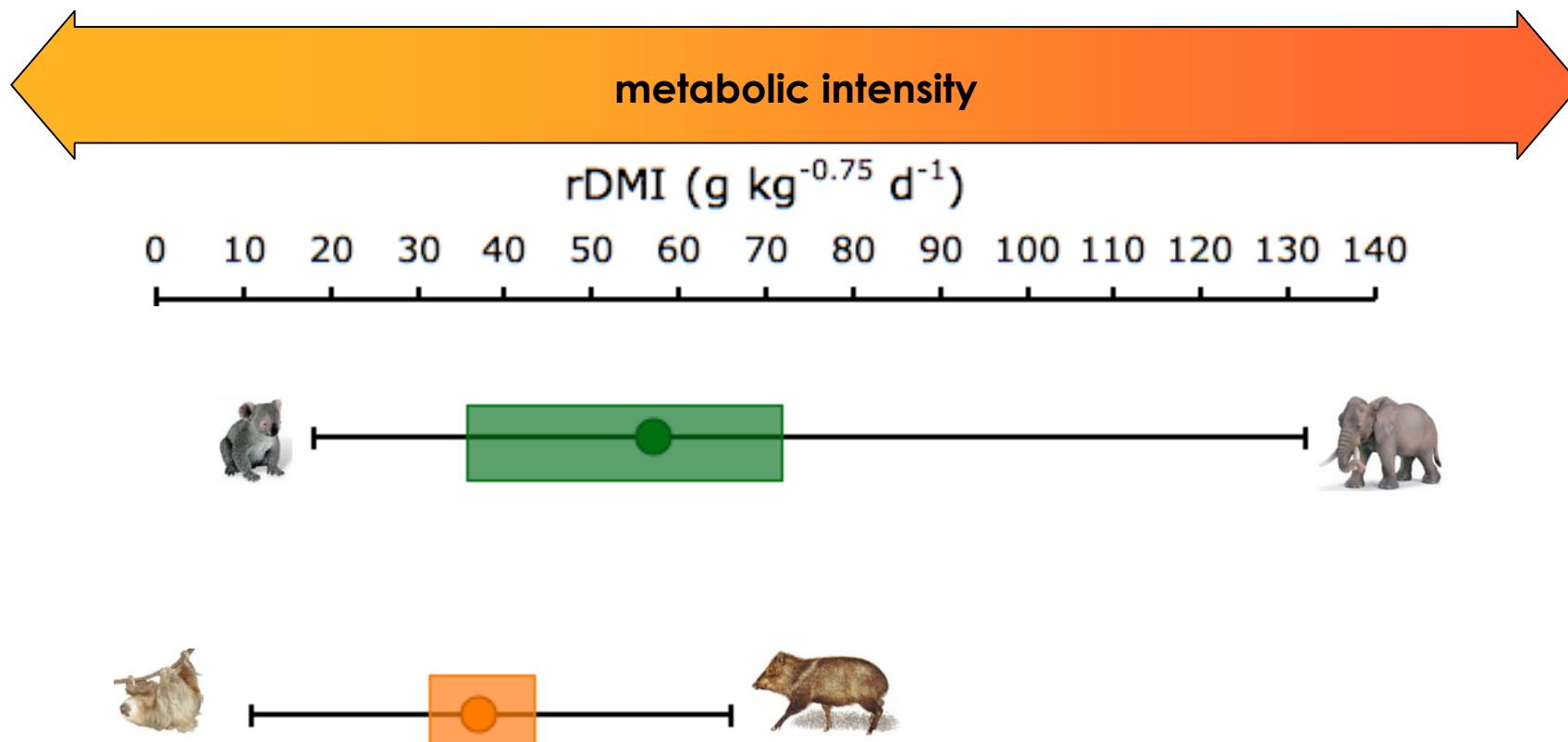


Conceptualizing herbivore diversity





Conceptualizing herbivore diversity





Conceptualizing herbivore diversity



rDMI ($\text{g kg}^{-0.75} \text{ d}^{-1}$)

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140



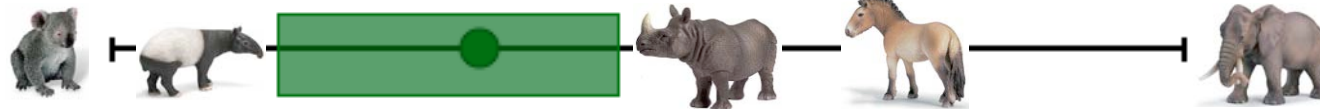


Conceptualizing herbivore diversity



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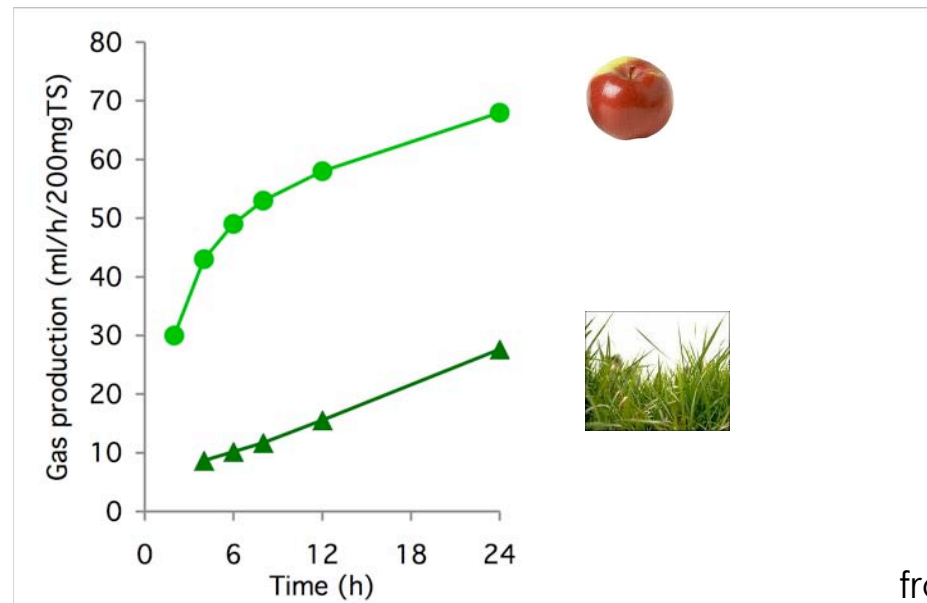
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140





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
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Digestive Strategies



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⇒ long passage

Autoenzymatic
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High intake
⇒ short passage

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digestion followed
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*Cursory fermentative
digestion mainly of
autoenzymatically
digestible components
followed by ineffective
autoenzymatic digestion
of undigested fiber?*



Digestive Strategies



Low intake
⇒ long passage

Autoenzymatic
digestion followed
by thorough
fermentative
digestion ✓

Fermentative digestion
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High intake
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~~Cursory fermentative
digestion mainly of
autoenzymatically
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autoenzymatic digestion
of undigested fiber?~~



From Digestive to Metabolic Strategies



Low intake
⇒ long passage
⇒ **low BMR**

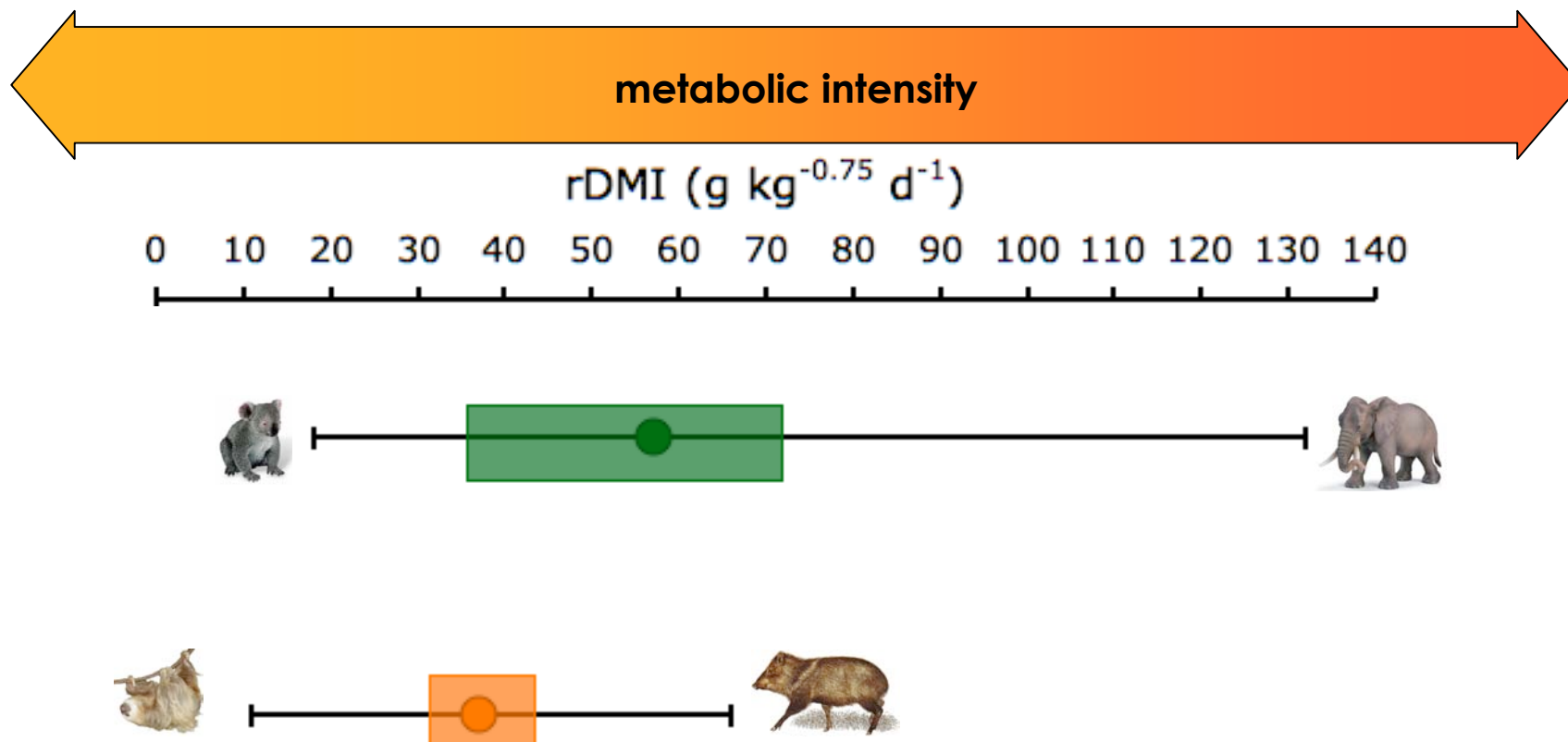


High intake
⇒ short passage
⇒ **high BMR**





Conceptualizing herbivore diversity



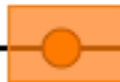


Conceptualizing herbivore diversity



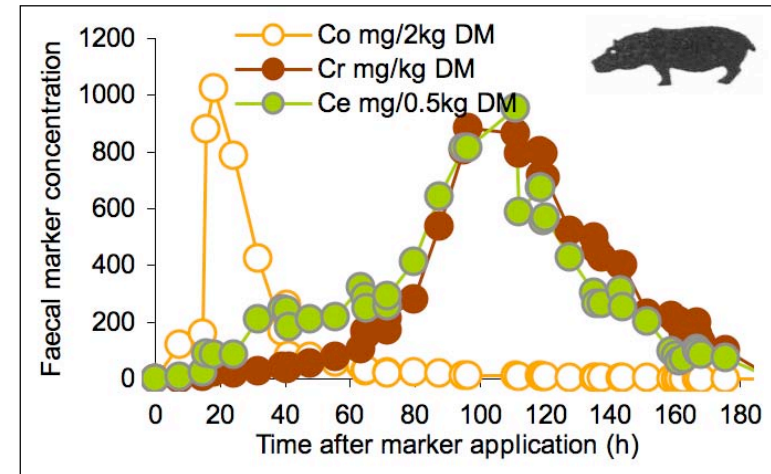
rDMI ($\text{g kg}^{-0.75} \text{ d}^{-1}$)

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140





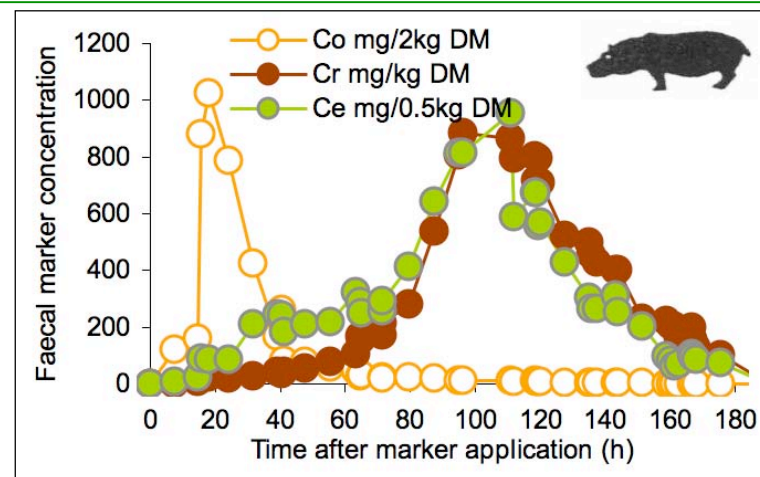
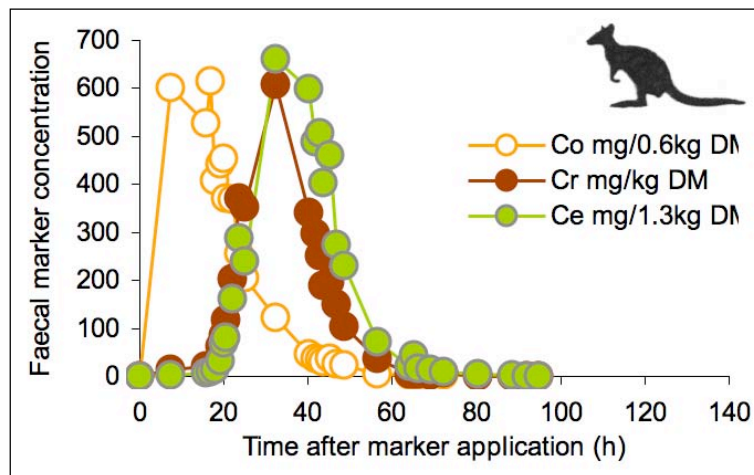
Ruminant vs. Nonruminant Foregut Fermentation



Schwarm et al. (2008)



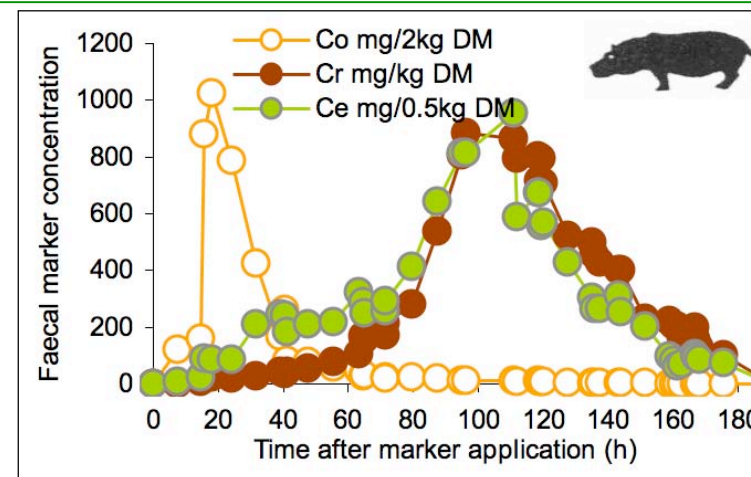
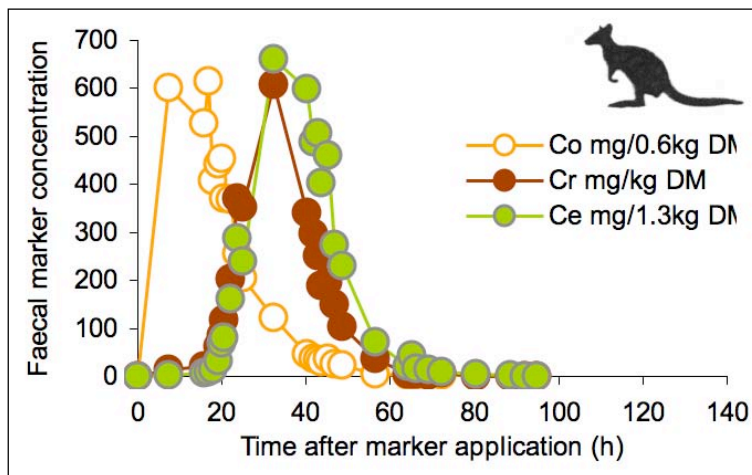
Ruminant vs. Nonruminant Foregut Fermentation



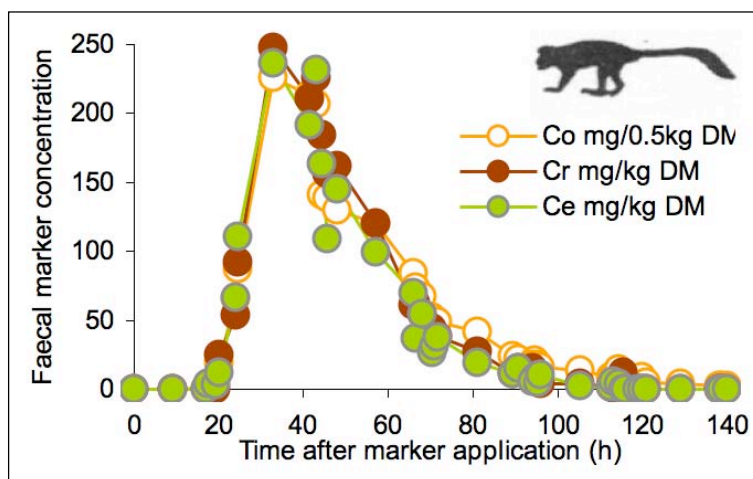
Schwarm et al. (2008,2009)



Ruminant vs. Nonruminant Foregut Fermentation

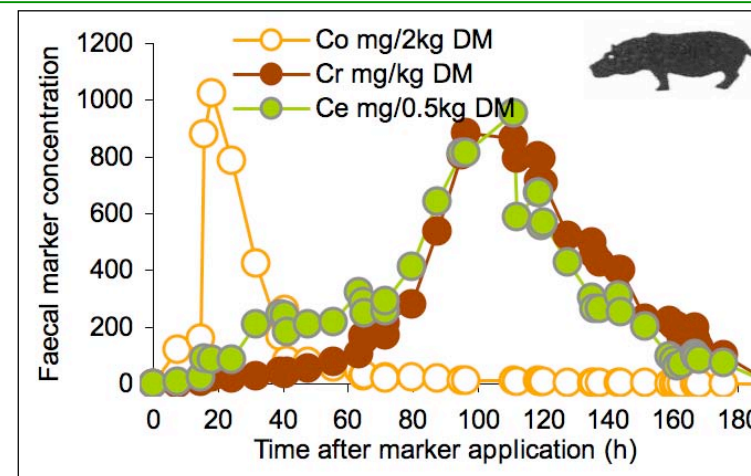
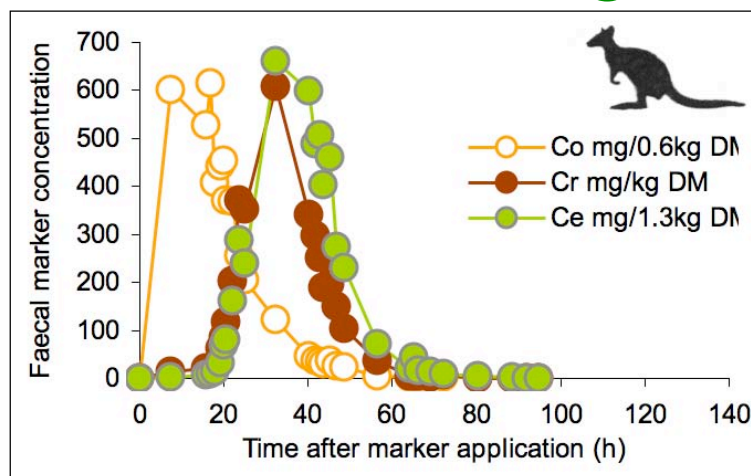


Schwarm et al. (2008,2009)

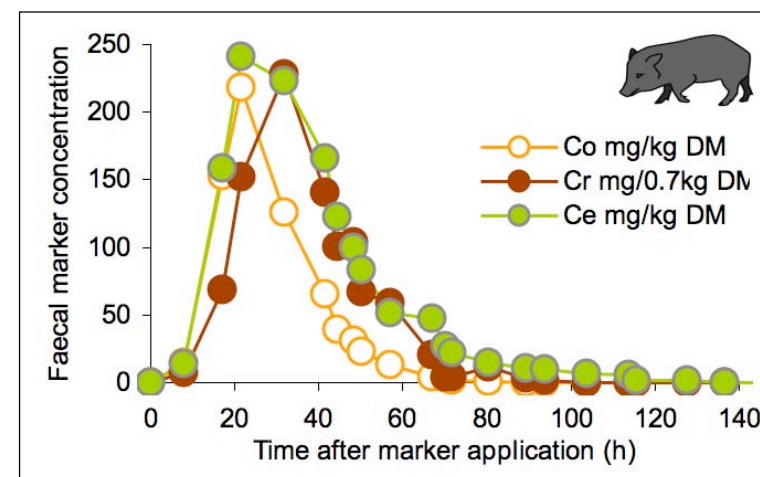
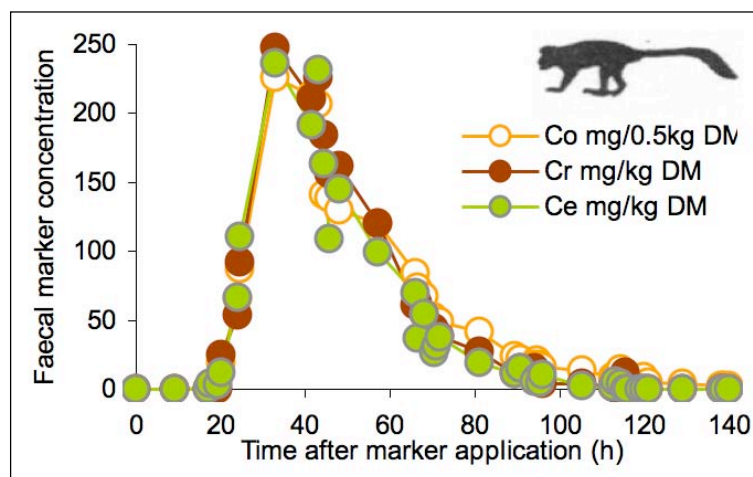




Ruminant vs. Nonruminant Foregut Fermentation

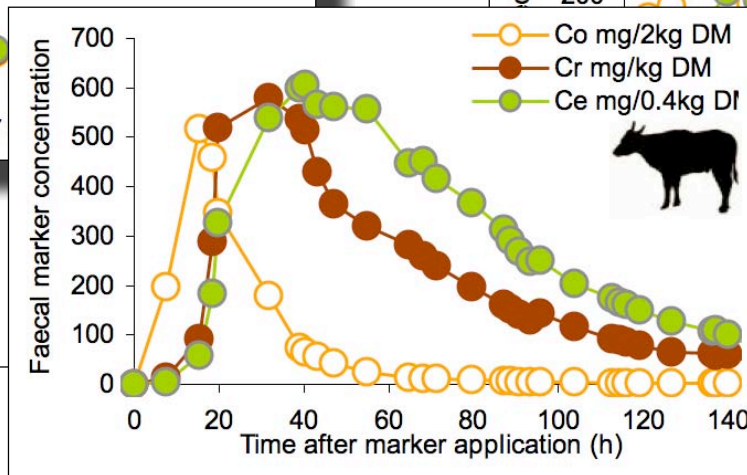
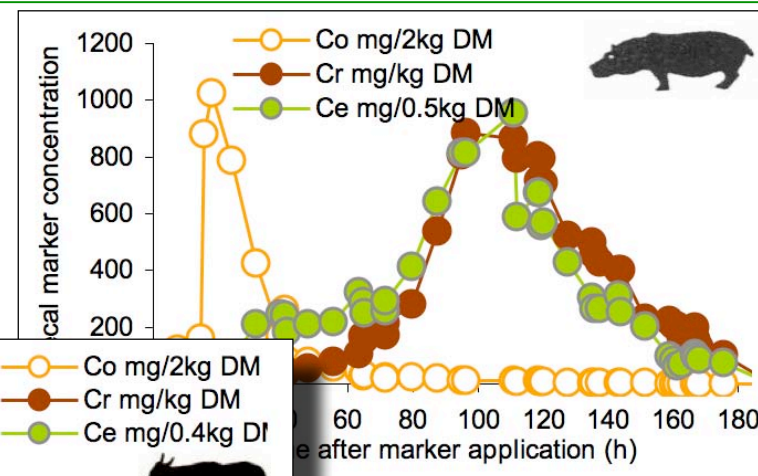
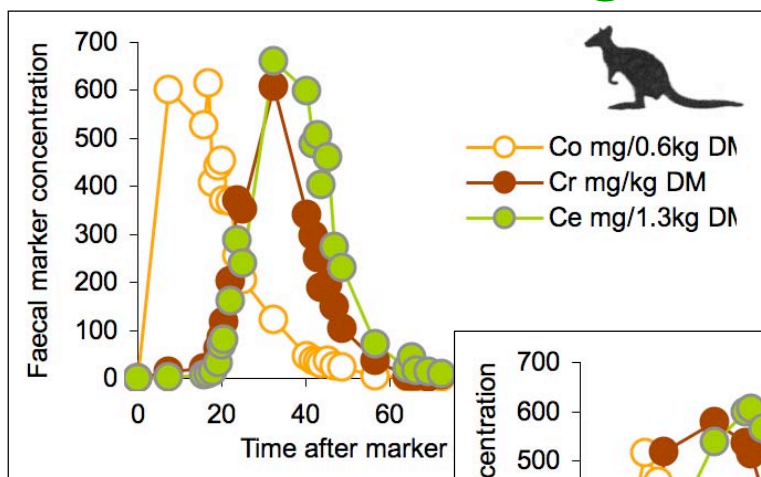


Schwarm et al. (2008,2009)

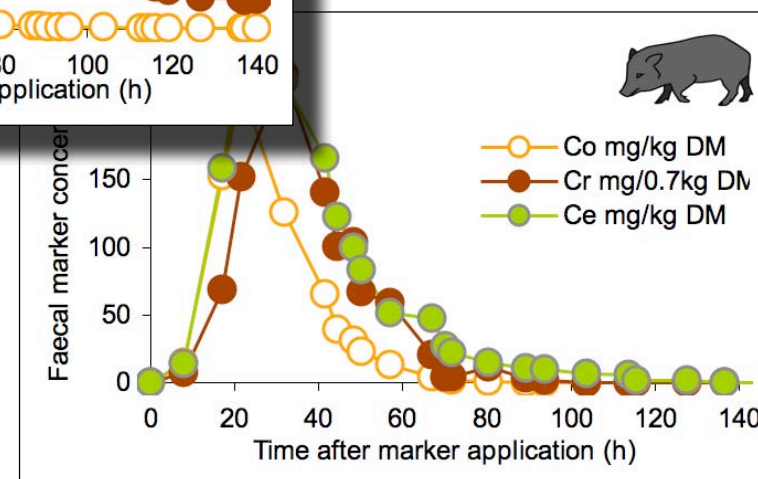
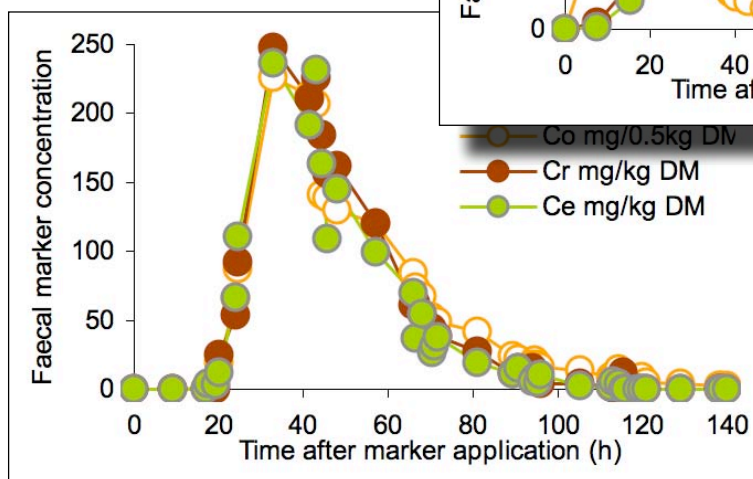




Ruminant vs. Nonruminant Foregut Fermentation

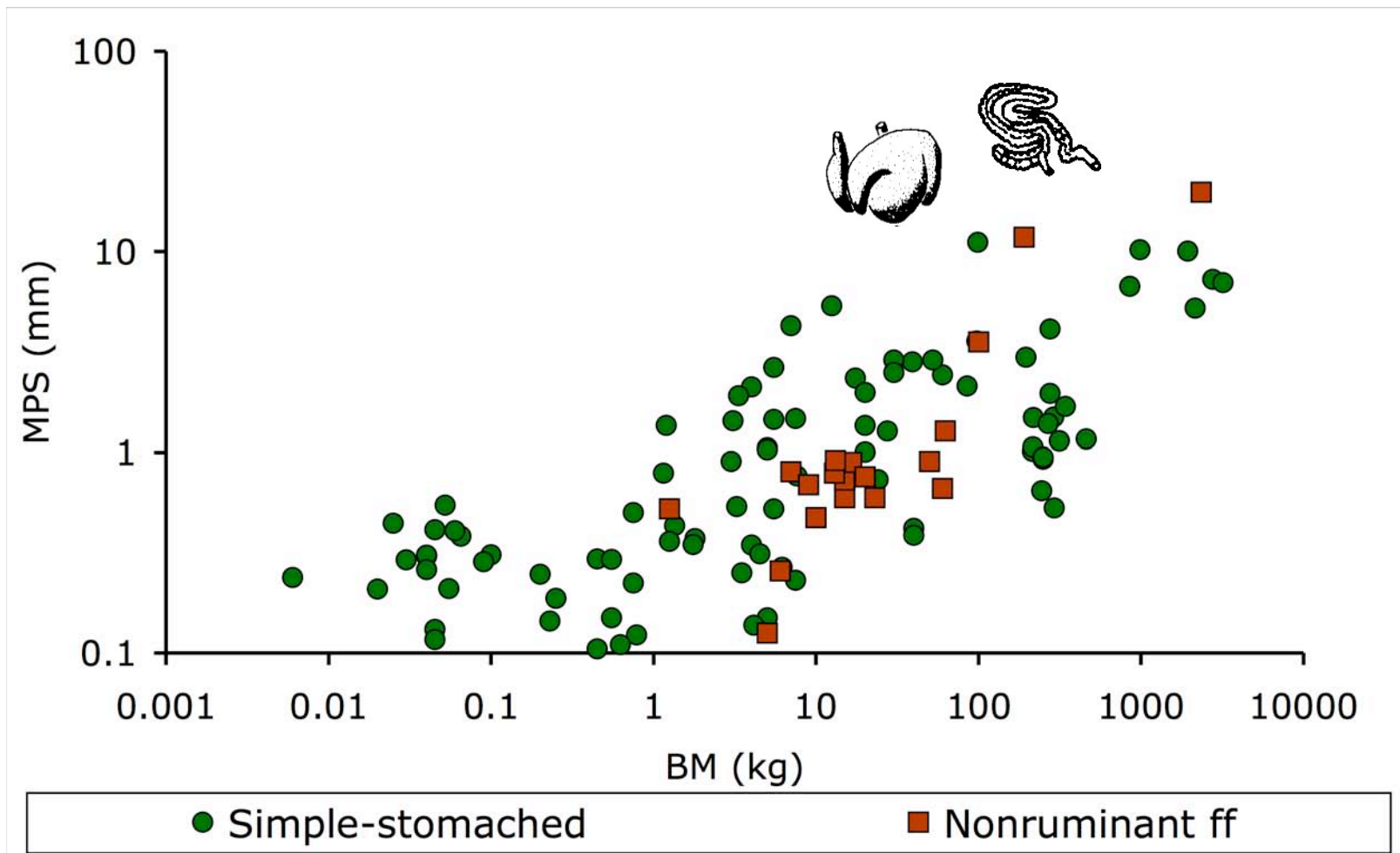


Schwarm et al. (2008,2009)





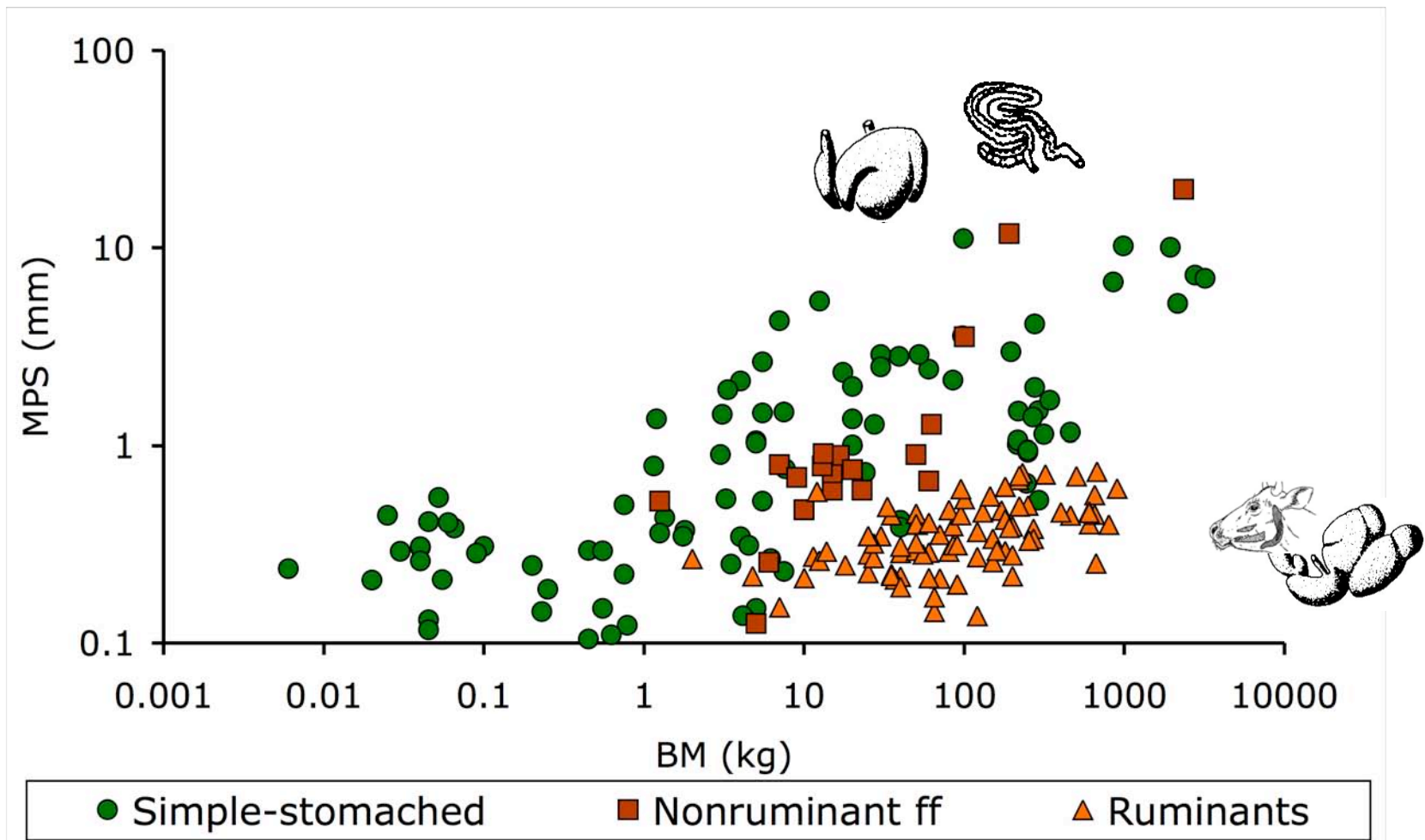
Ingesta particle size (chewing efficiency)



from Fritz et al. (2009)



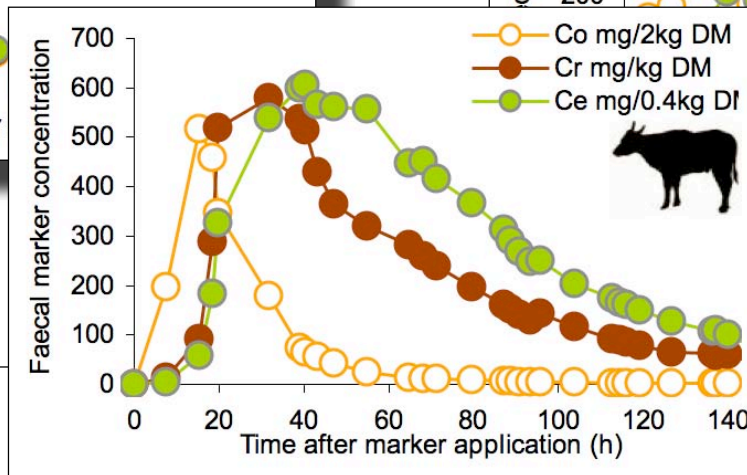
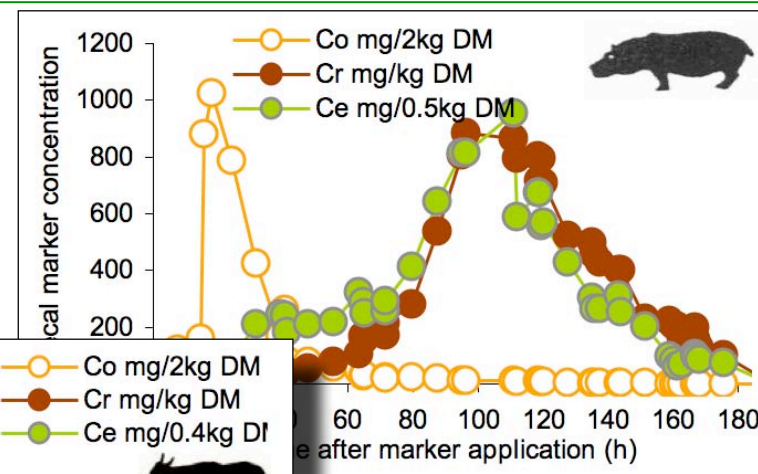
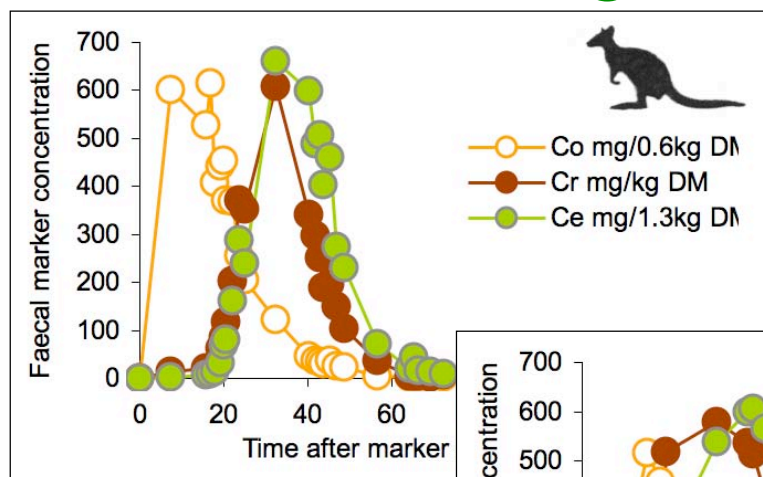
Ingesta particle size (chewing efficiency)



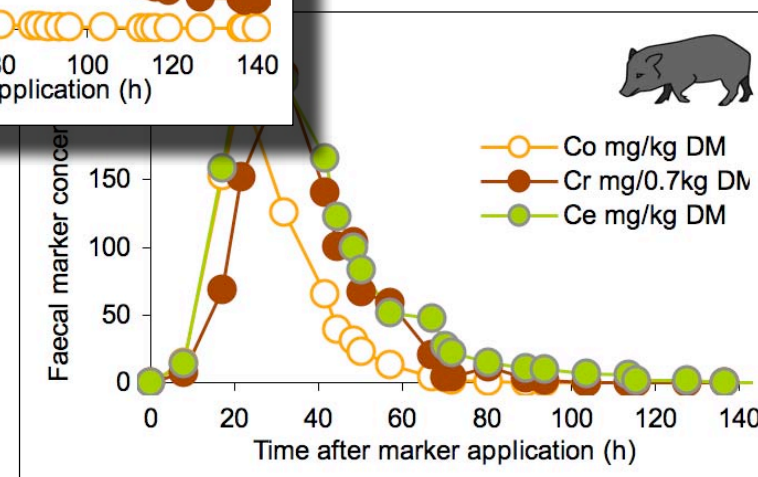
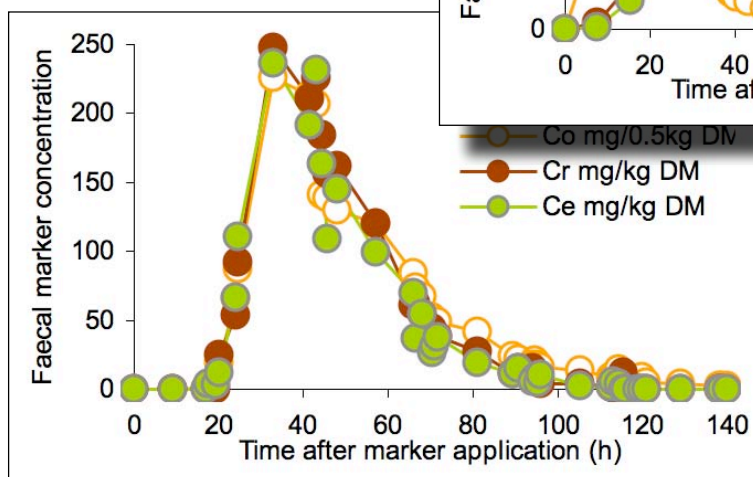
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Ruminant vs. Nonruminant Foregut Fermentation



Schwarm et al. (2008,2009)



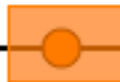


Conceptualizing herbivore diversity



rDMI ($\text{g kg}^{-0.75} \text{d}^{-1}$)

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140





Digestive and Metabolic Strategies



Low intake
⇒ long passage
⇒ **low BMR**



High intake
⇒ **differentiated**
passage
⇒ **high BMR**





Digestive and Metabolic Strategies



Low intake
⇒ long passage
⇒ **low BMR**



High intake
⇒ **differentiated**
passage
⇒ **high BMR**





Digestive and Metabolic Strategies



Low intake
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High intake
⇒ **differentiated**
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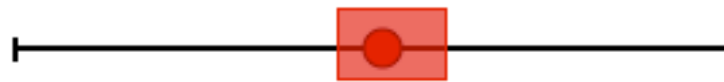
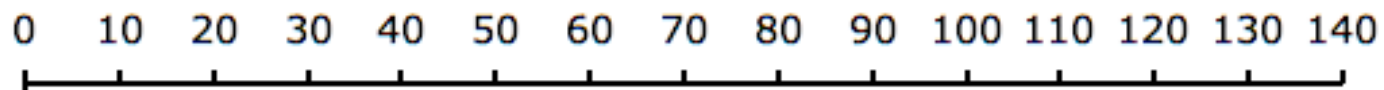




Conceptualizing herbivore diversity



rDMI ($\text{g kg}^{-0.75} \text{ d}^{-1}$)

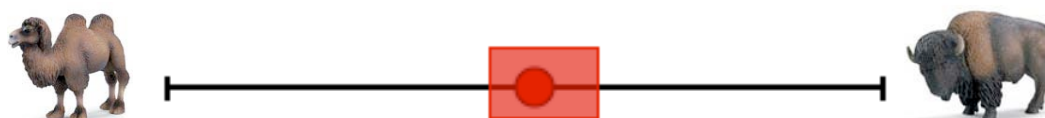
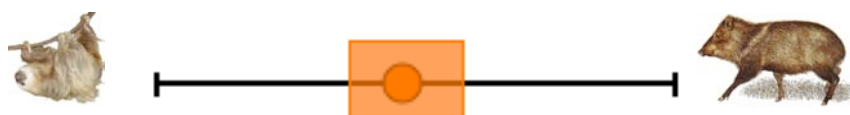
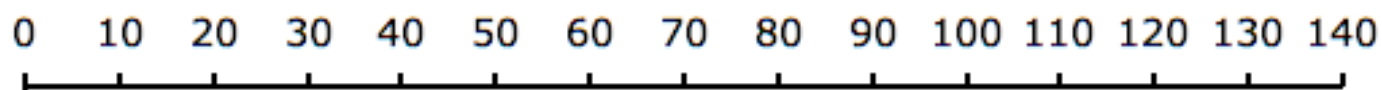




Conceptualizing herbivore diversity



rDMI ($\text{g kg}^{-0.75} \text{d}^{-1}$)

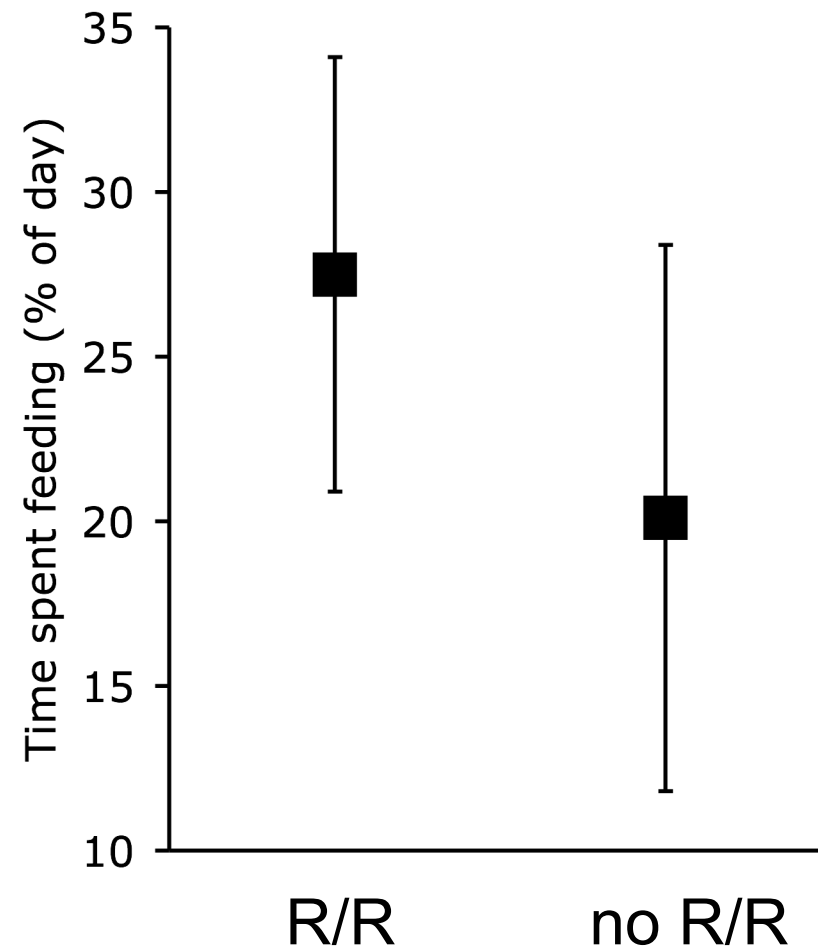
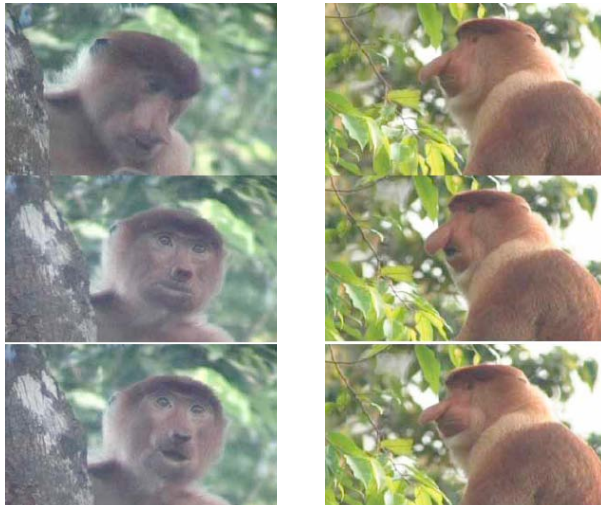






Regurgitation and remastication in the foregut-fermenting proboscis monkey (*Nasalis larvatus*)

Ikki Matsuda^{1,*}, Tadahiro Murai¹,
Marcus Clauss², Tomomi Yamada³,
Augustine Tuuga⁴, Henry Bernard⁵
and Seigo Higashi⁶



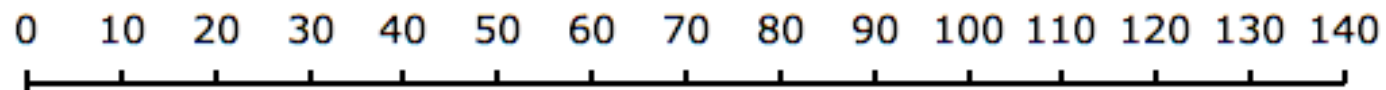
Matsuda et al. (2011)



What does metabolic intensity determine?



rDMI ($\text{g kg}^{-0.75} \text{ d}^{-1}$)





What does metabolic intensity determine?



rDMI ($\text{g kg}^{-0.75} \text{ d}^{-1}$)

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140





What does metabolic intensity determine?



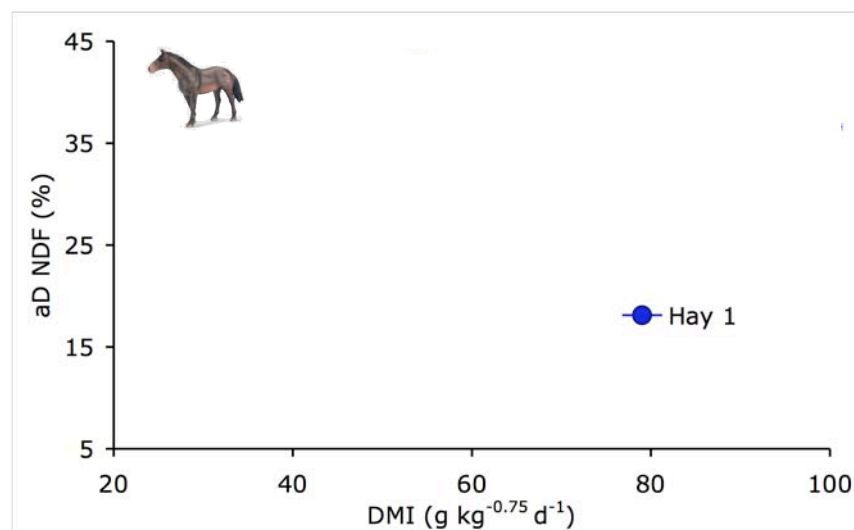
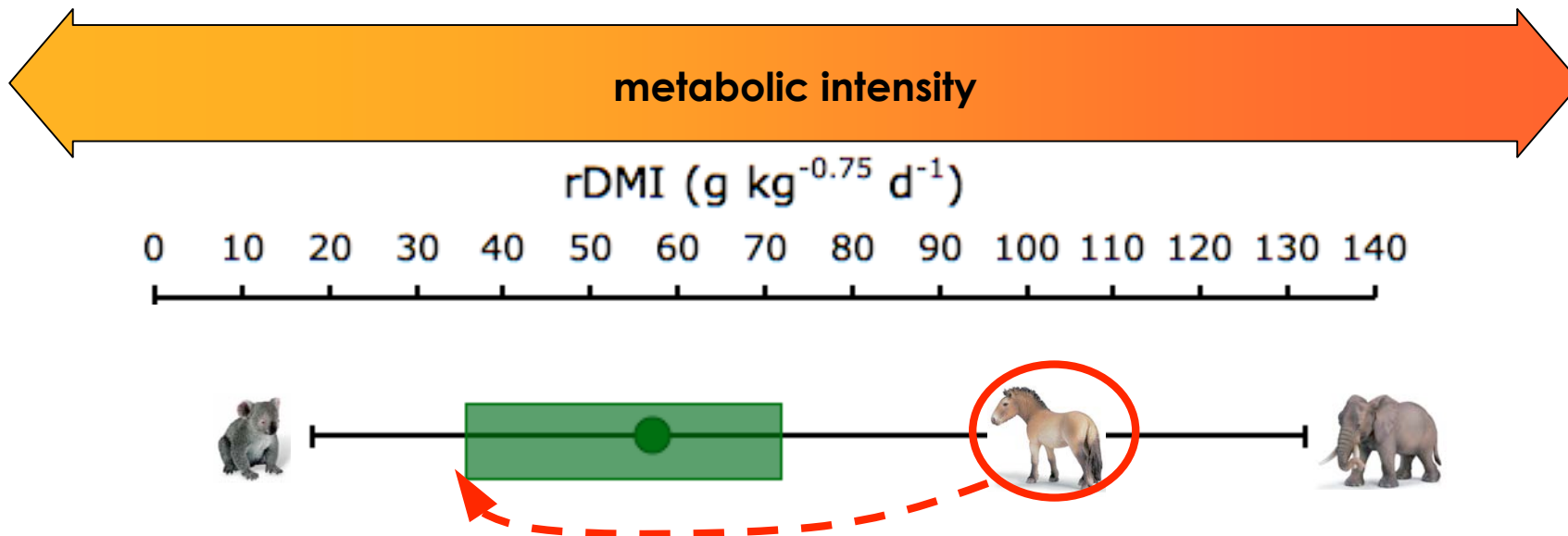
rDMI ($\text{g kg}^{-0.75} \text{ d}^{-1}$)

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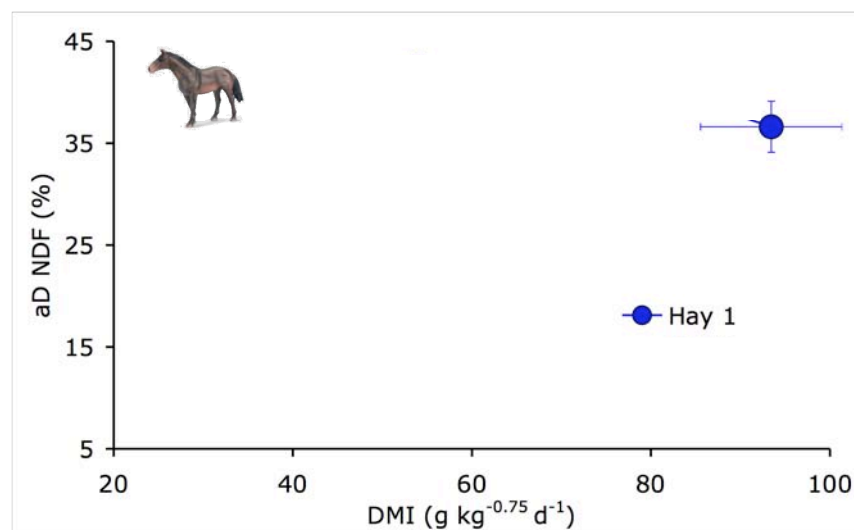
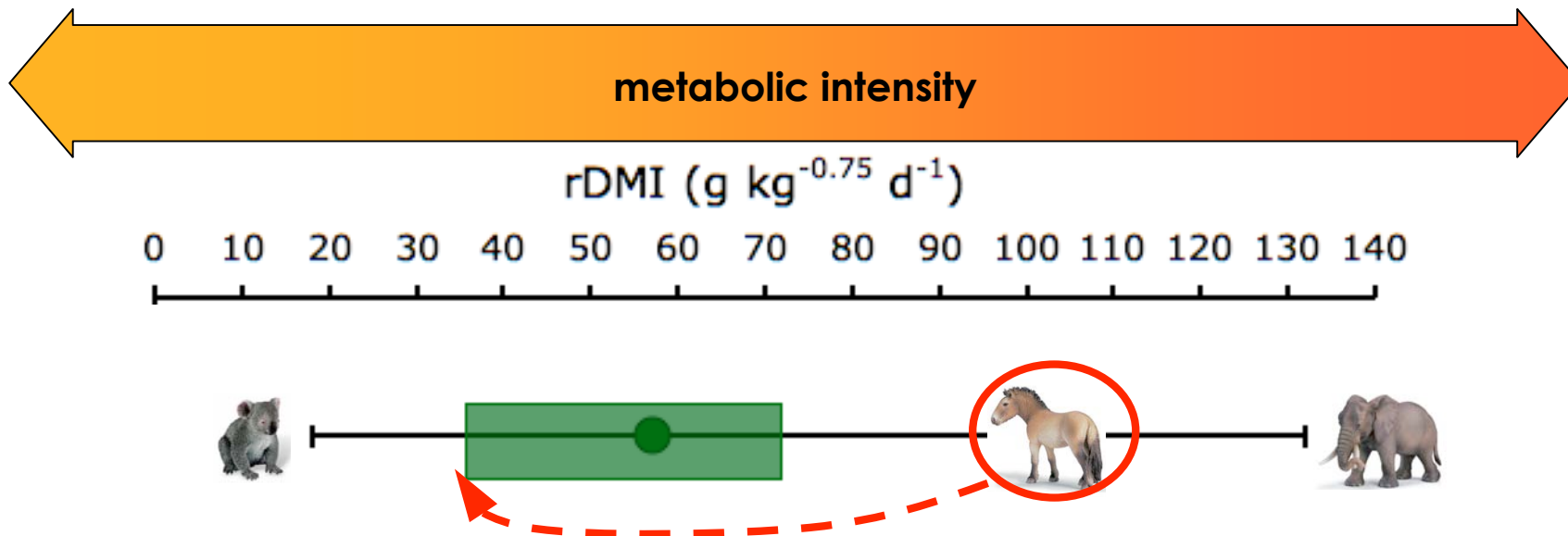


What does metabolic intensity determine?



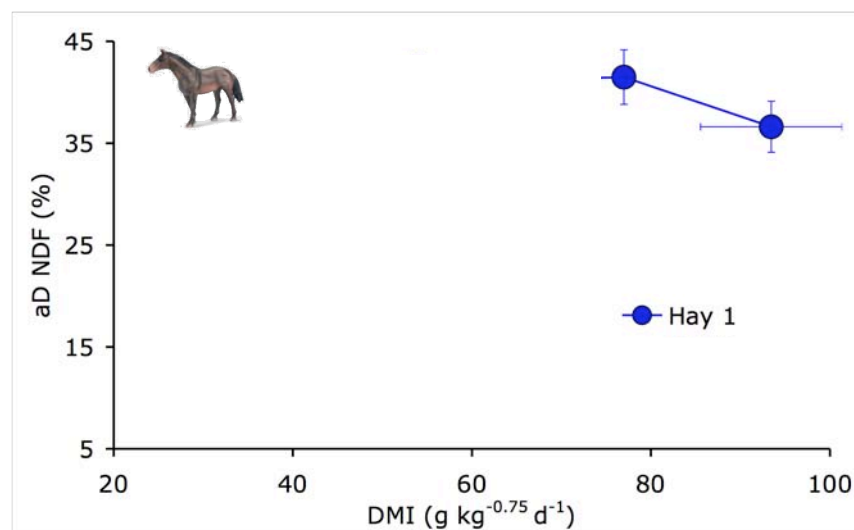
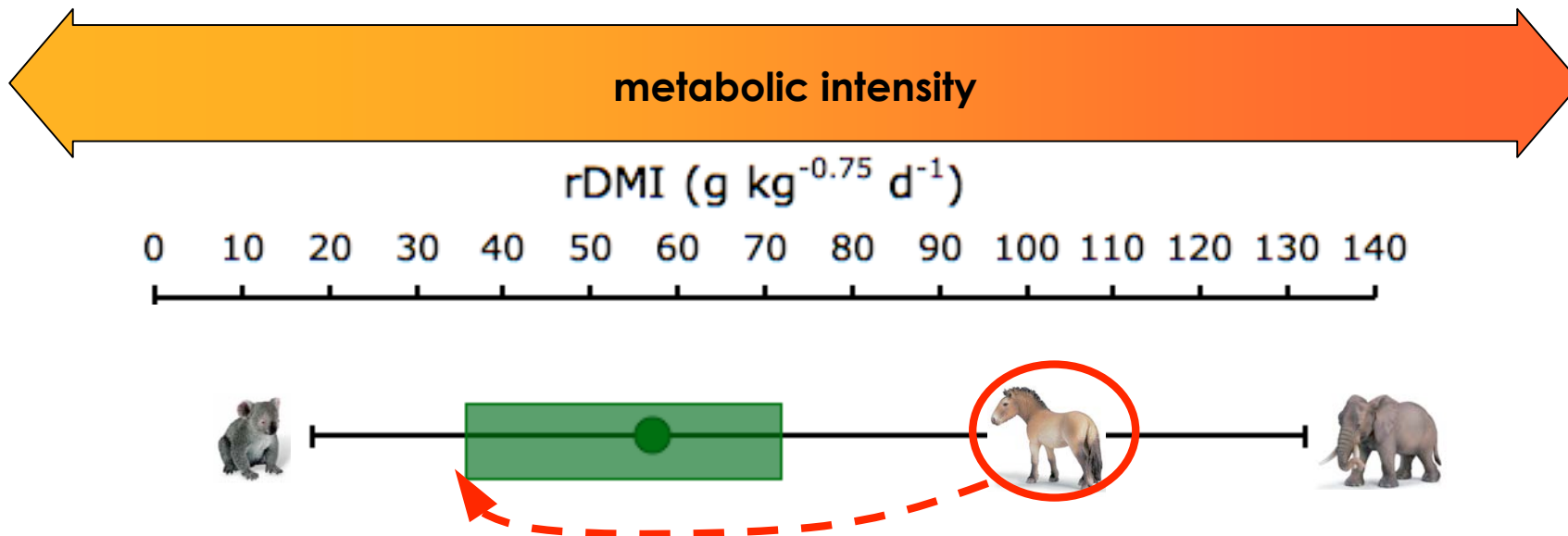


What does metabolic intensity determine?



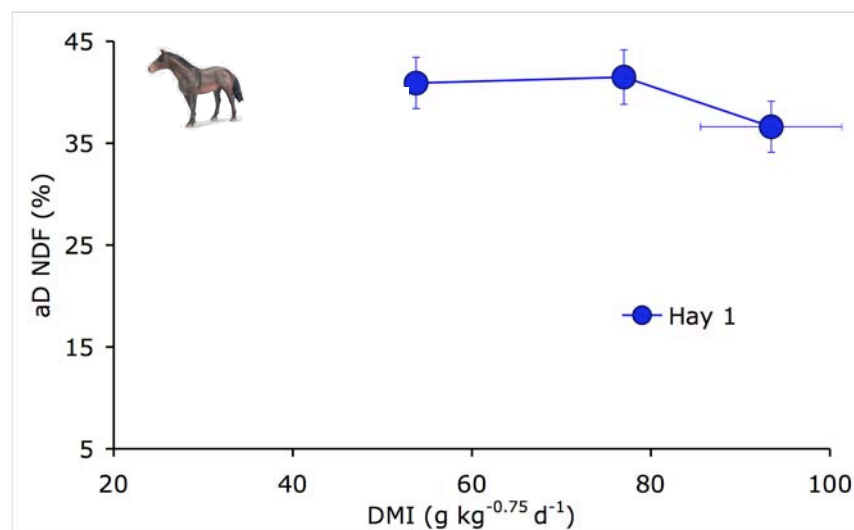
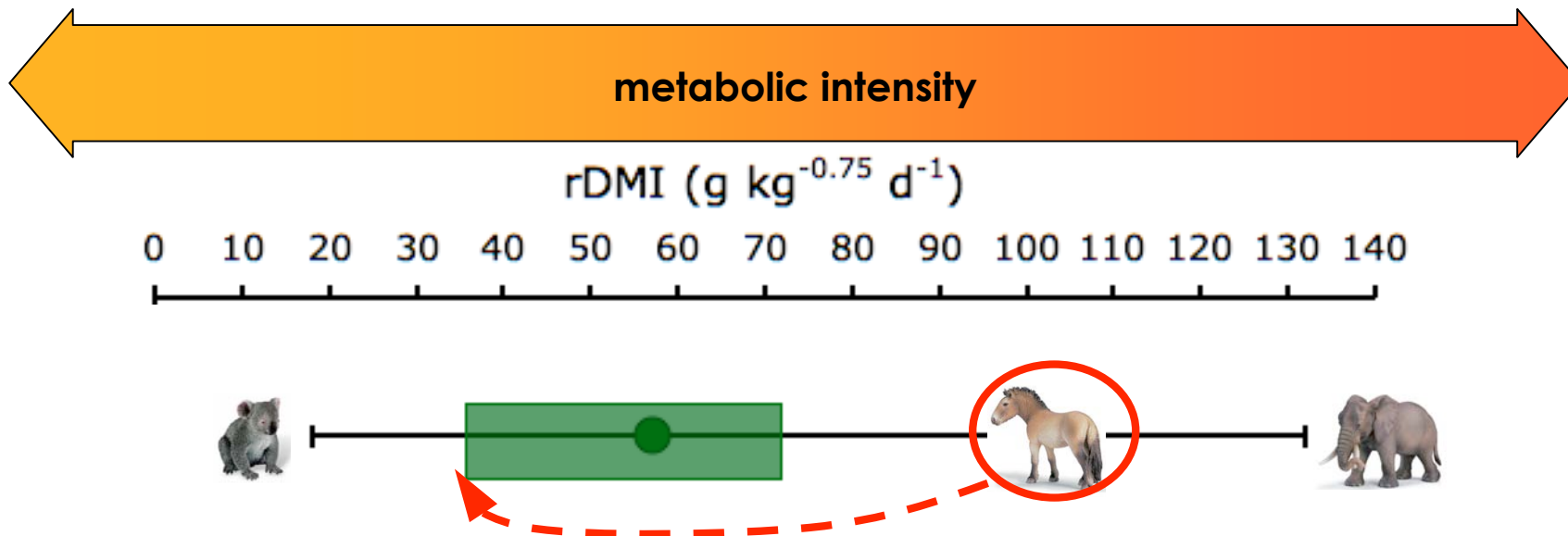


What does metabolic intensity determine?



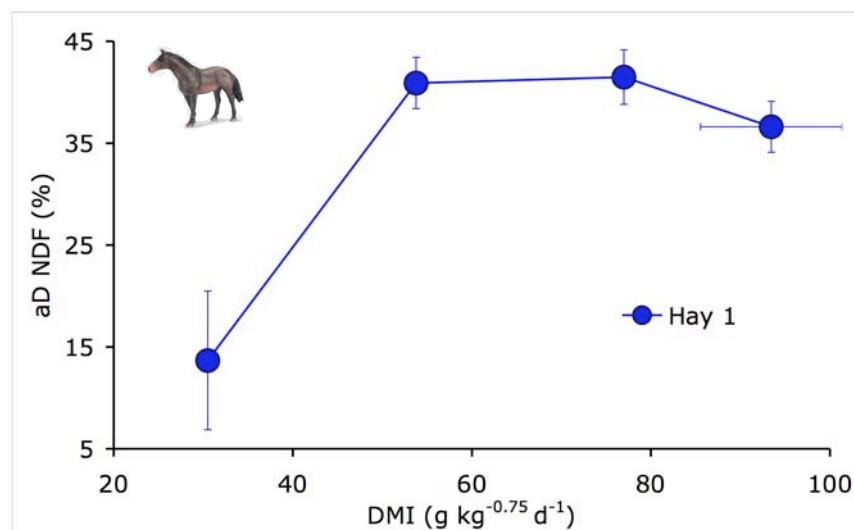
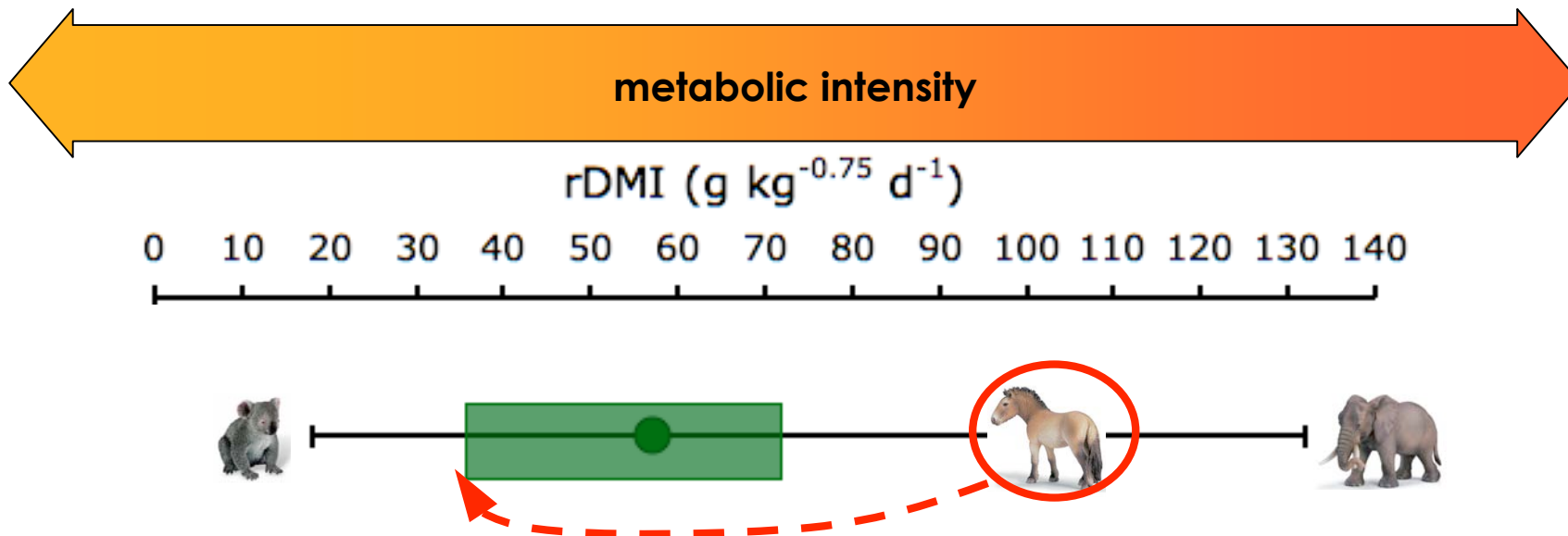


What does metabolic intensity determine?





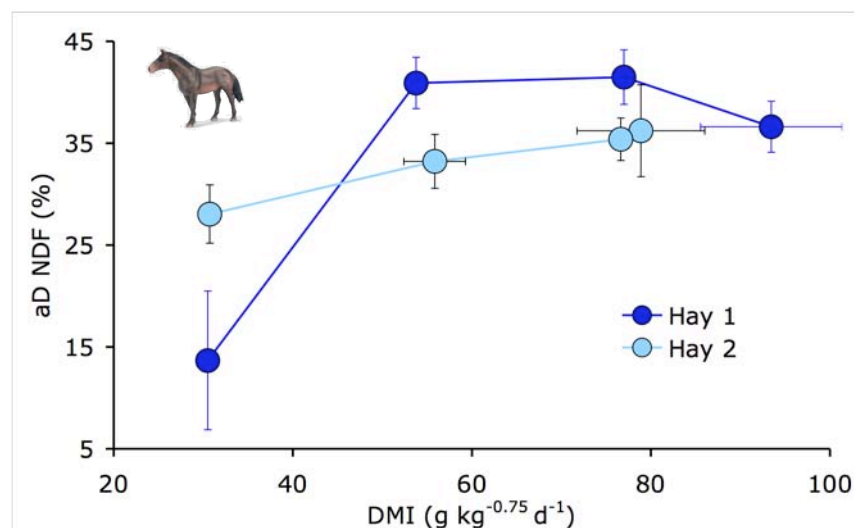
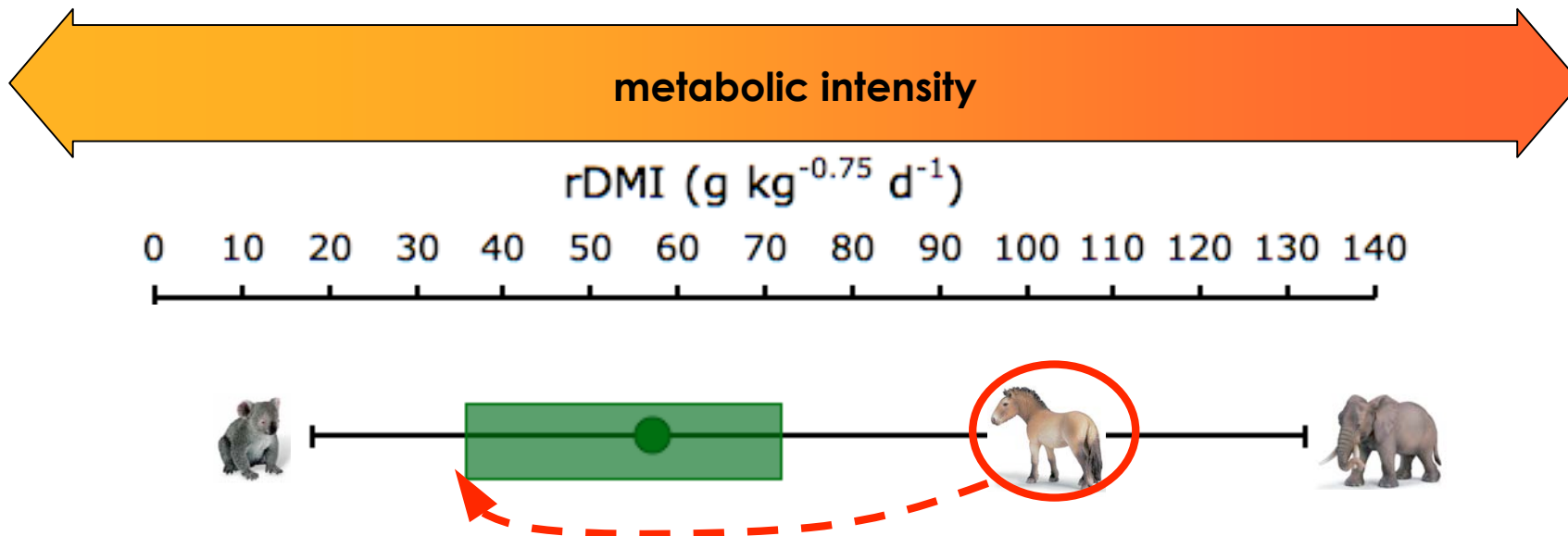
What does metabolic intensity determine?



from Clauss et al. (2008, 2010)



What does metabolic intensity determine?



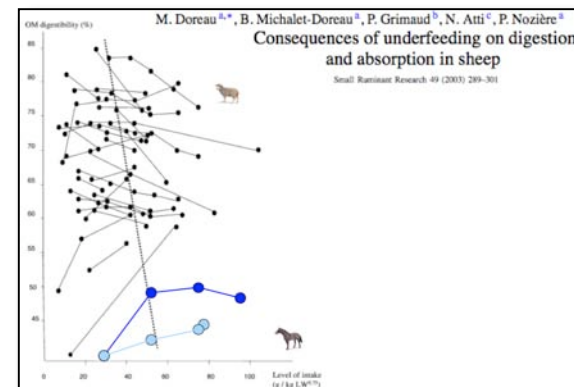
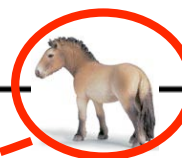
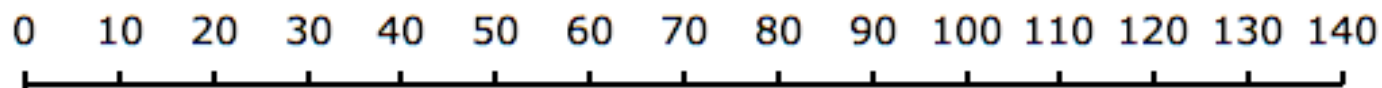
from Clauss et al. (2008, 2010)



What does metabolic intensity determine?



rDMI ($\text{g kg}^{-0.75} \text{ d}^{-1}$)





Summary I

1. Fibre digestion with the help of symbiotic microbes is widespread in the animal kingdom
2. So is the direct use of microbial biomass - either via coprophagy, farming, or foregut fermentation
3. Reasons for different proportions of acetogenic and methanogenic hydrogen sinks in ruminants and nonruminants remain unclear
4. Due to its relevance for food encounter rates, harvesting mechanisms and surface/volume geometry, body size has an important influence on foraging strategies and digestive morphophysiology



Summary II

6. Different merits of foregut and hindgut fermentation (at similar metabolic intensity) remain to be fully elucidated
7. Rather than classifying herbivores according to body size or digestion type, classifying herbivores according to metabolic intensity is a promising novel approach
8. Whereas the hindgut fermenter system allows a large range of metabolic intensities, the (nonruminant) foregut fermenter system appears to restrict animals to the low metabolic intensity side of the spectrum



Summary III

9. Findings on reduced digestibilities (incl. that of fibre fractions) in low food intake-scenarios with high-metabolic intensity species suggest that hitherto unknown microbial and endogenous properties exist that are linked to metabolic intensity



Thanks to

Daryl Codron

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Julia Fritz

Jean-Michel Hatt

Ian Hume

Ellen Kienzle

Michael Kreuzer

Ikki Matsuda

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Charles Nunn

Sylvia Ortmann

Kristina Schiele

Angela Schwarm

Carla Soliva

Patrick Steuer

Jürgen Streich

Karl-Heinz Südekum



*thank you
for your attention*



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2-Day-seminar

For an example of a 2-day seminar on the digestive physiology of wild animals

General Introduction	↓ 1.1.10 (PDF, 578 KB)
Food Intake	↓ 1a.1.10 (PDF, 2205 KB)
Allometric principles	↓ 2.1.10 (PDF, 3855 KB)
Carnivory	↓ 3.1.10 (PDF, 6661 KB)
Herbivory Introduction	↓ 4.1.10 (PDF, 3936 KB)
Herbivore Allometry	↓ 5.1.10 (PDF, 6100 KB)
Coprophagy	↓ 6.1.10 (PDF, 3603 KB)
Hindgut and Foregut	↓ 7.1.10 (PDF, 6684 KB)
Browser and Grazer	↓ 8.1.10 (PDF, 15194 KB)
Applications	↓ 9.1.10 (PDF, 4570 KB)
Digestive physiology suids	↓ 10.1.10 (PDF, 1355 KB)
Desert adaptations english	↓ 12.1.10 (PDF, 4237 KB)
Digestive physiology primates	↓ 13.1.10 (PDF, 3394 KB)





7th European Zoo Nutrition Conference University of Zurich, 27-30 January 2012

Workshop

27.01. 900-1700

Feeding herbivores: forage quality evaluation, roughage hygiene, and herbivore diet formulation and assessment

Conference

27 Jan 1800

Icebreaker

28 Jan 0900-1700 Scientific and practical sessions (incl. topics 1,2,3)

29 Jan 0900-1700 Practical sessions incl. demonstrations, Question/Answer session, 'Round table' poster sessions (incl. topic 4)

30 Jan 0900-1200 Scientific sessions (incl. topic 5)

Specific topics:

- (1) Diet imprinting and diet changes
- (2) Feeding of primates
- (3) Feeding of amphibians
- (4) Feeding of bears
- (5) Feeding of elephants ... and free topics

Oral presentations (10 or 20 minutes, 5 minutes discussion)

Poster presentations

Q/A-sessions (for question/answer sessions, participants can send their questions to the organizers in advance in PowerPoint format including - if available - photos)

Podium discussions on the specific topics (and on free topics if several submissions are made that relate to each other)

Demonstrations (body condition and faecal scoring, food presentation, intake measurements, commissary organisation)

Submission deadlines

Oral presentation/poster abstracts: 30 September 2011

Questions for Q/A session: 31 December 2011

(email to mclaus@vetclinics.uzh.ch)

The conference, including dinners, will be held at the Irchel Campus of the University of Zurich, with ample space for interactions and networking.

Registration fees (Euros)*

Type	until 30 Sept 2011	after 30 Sept 2011
Workshop	80	110
Workshop (student)	50	80
Conference	280	310
Conference (student)	250	280

*registration fees include

- for the workshop: coffee breaks and a lunchbag

- for the conference: icebreaker, coffee breaks, lunchbags on all three days, dinner on Saturday and Sunday, 4-day public transport ticket, abstract book

Hotel Reservation

We recommend to book rooms (share a double room) at the

Hotel Ibis Zurich Messe Airport

Heidi Abel Weg 5, 8050 Zürich

Tel: 044 307 47 00, Fax: 044 307 47 47,

Email: H2980@accor.com, Homepage: www.ibishotel.com

When booking a room, indicate you come for

"European Zoo Nutrition"

Prices (per night, including breakfast)

26 - 27.01.2012 Double bedroom CHF 116.30

Single bedroom CHF 103.30

27 - 30.01.2012 Double bedroom CHF 95.30

Single bedroom CHF 82.30

Parking CHF 16.00 per night

The hotel is in walking distance to the conference site.

Check also regularly <http://www.eaza.net/activities/Pages/NutritionConference.aspx> for updates

Registration for the conference starts July 2011 through the website