Digestive anatomy and physiology of zoo mammals: *herbivores*

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University of Zurich[UZH]

Clinic of Zoo Animals, Exotic Pets and Wildlife

Herbivory

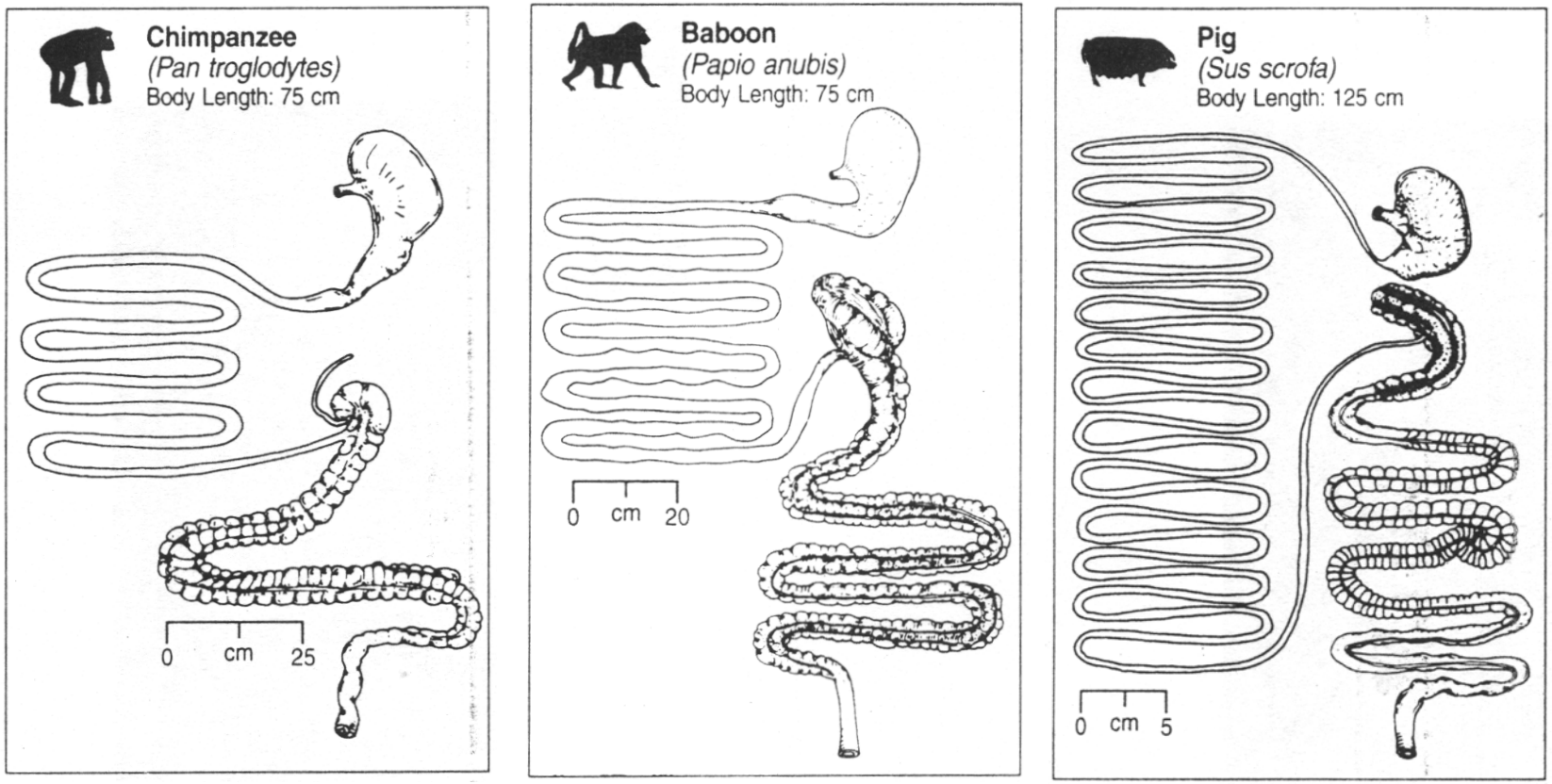
- Vertebrates cannot digest plant fibre by their own enzymes (aut-enzymatically); they have to rely on symbiotic gut microflora (allo-enzymatic digestion).
- Bacterial digestion = 'Fermentation'
- The host has to supply this microflora with a habitat (so-called 'fermentation chambers').

Herbivory ...

- *... is no logistical challenge*
- *... but a digestive one!*

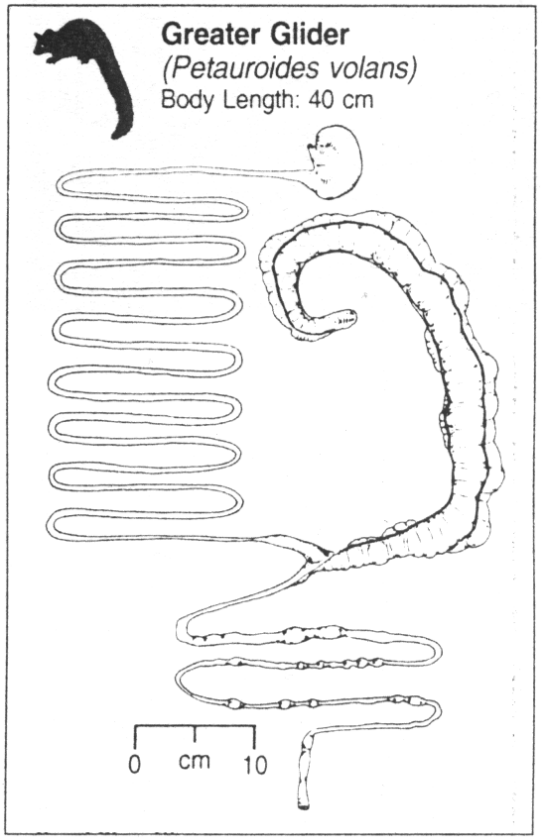
- ***Catching plants is easy - digesting plants is the hard part!***

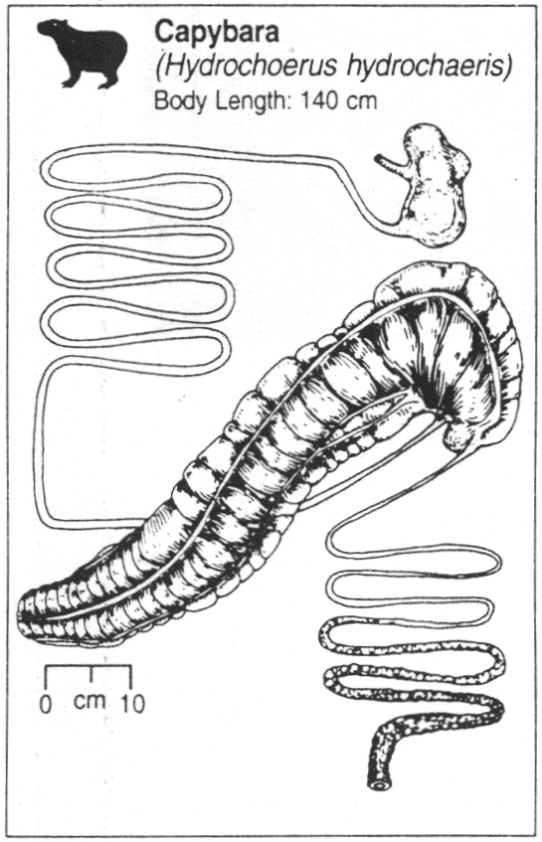
Omnivore

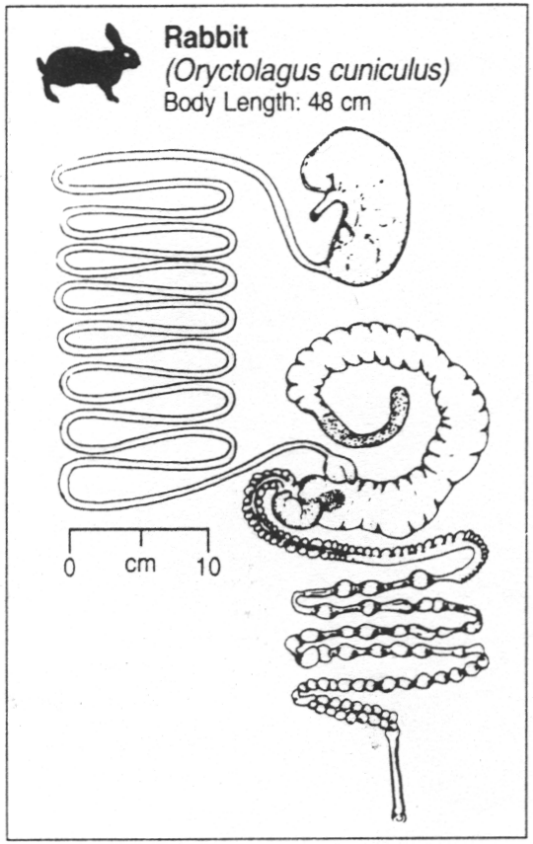


from Stevens & Hume (1995)

Hindgut Fermentation - Caecum







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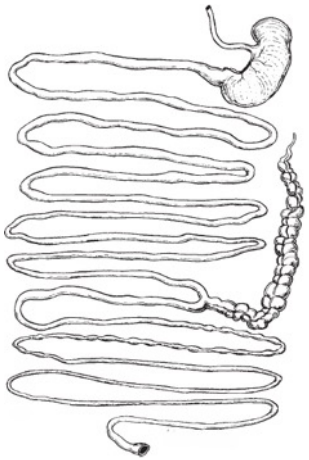
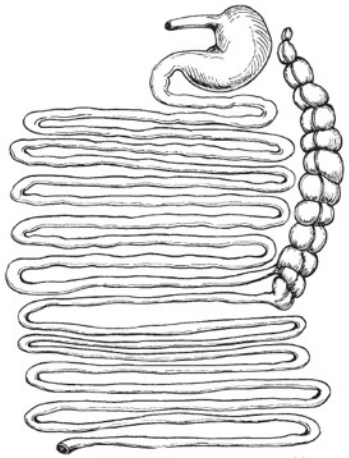
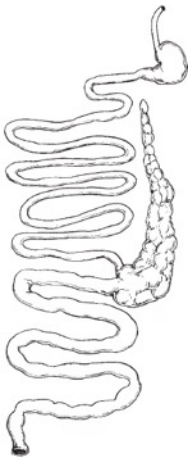
Hindgut Fermentation - Caecum



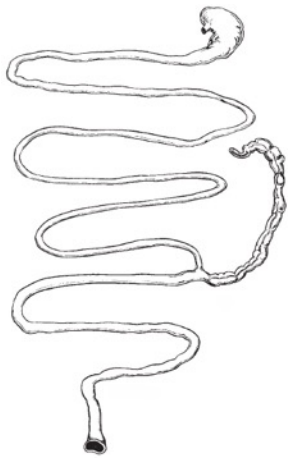
Propithecus tattersalli



Propithecus verreauxi



Lemur catta



Varecia variegata

Campbell et al. (2000)

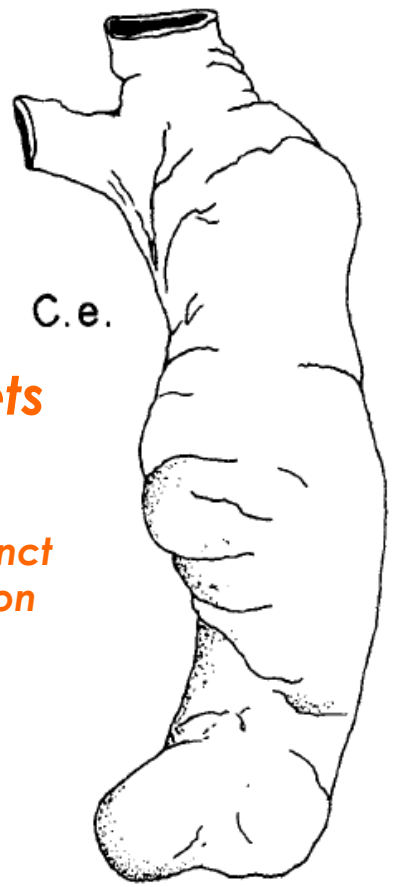
Caecum form and function: gummivory

Gums dominate, insects important, fruit can depend on location

Callithrix

Insects and fruit dominate, gums and nectar seasonally important

Saguinus



Marmosets

more efficienct gum digestion

Tamarins

1cm

Callithrix emiliae

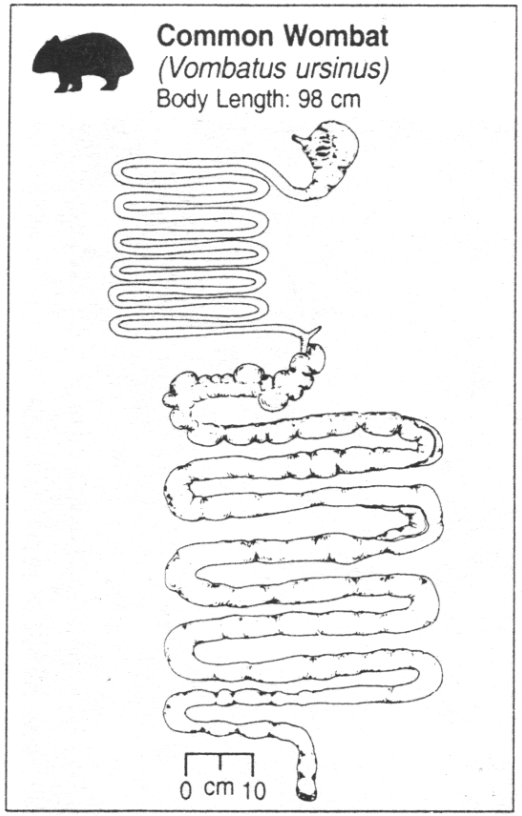
GUMMIVORE

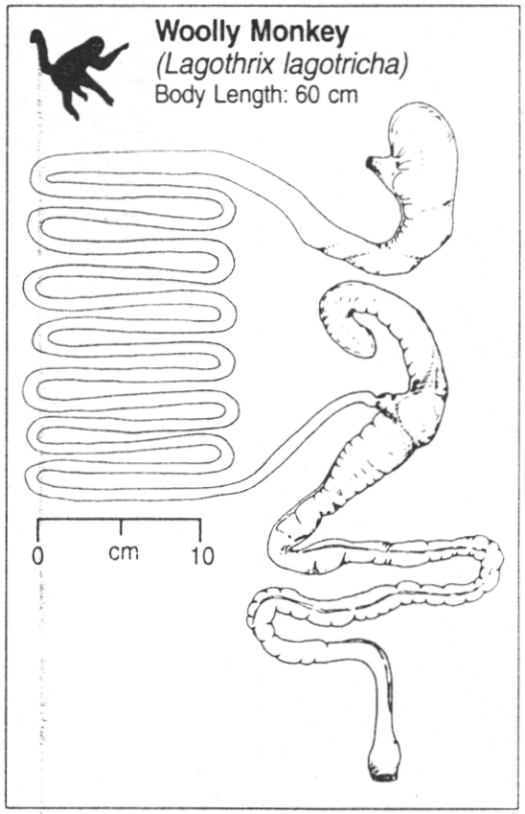
Saguinus fuscicollis

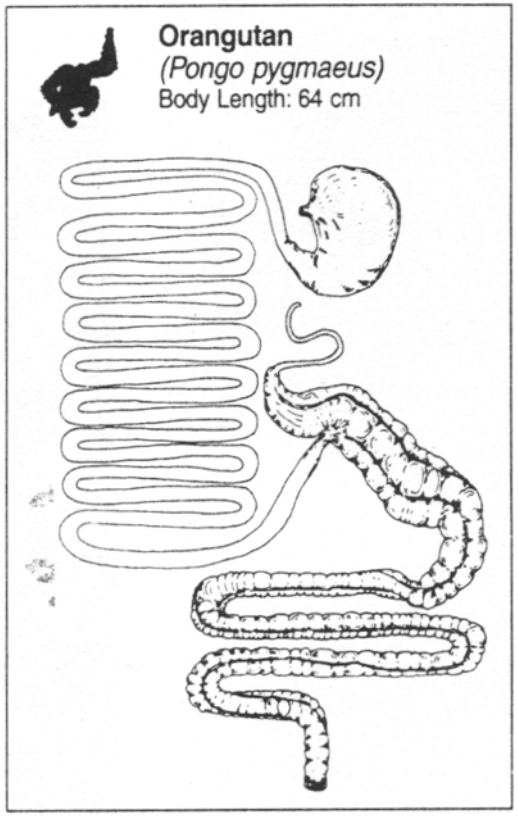
'OMNIVORE'

Power et al. (1990), Ferrari & Martins

Herbivores - Colon fermenters

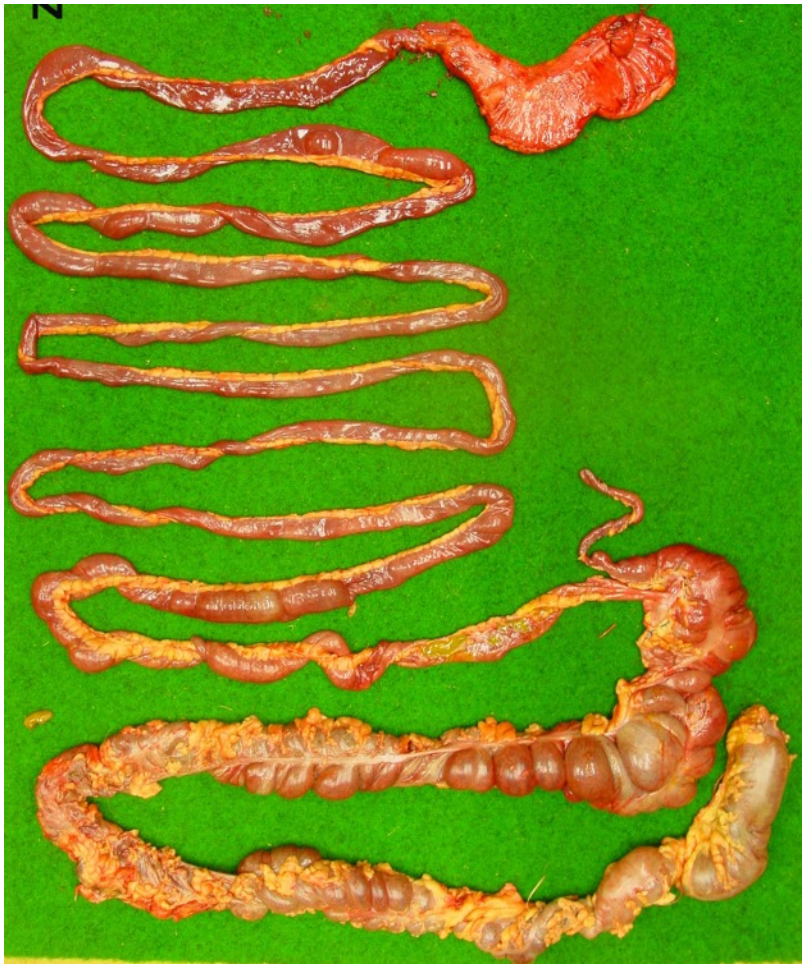






from Stevens und Hume (1995)

Herbivores - Colon fermenters

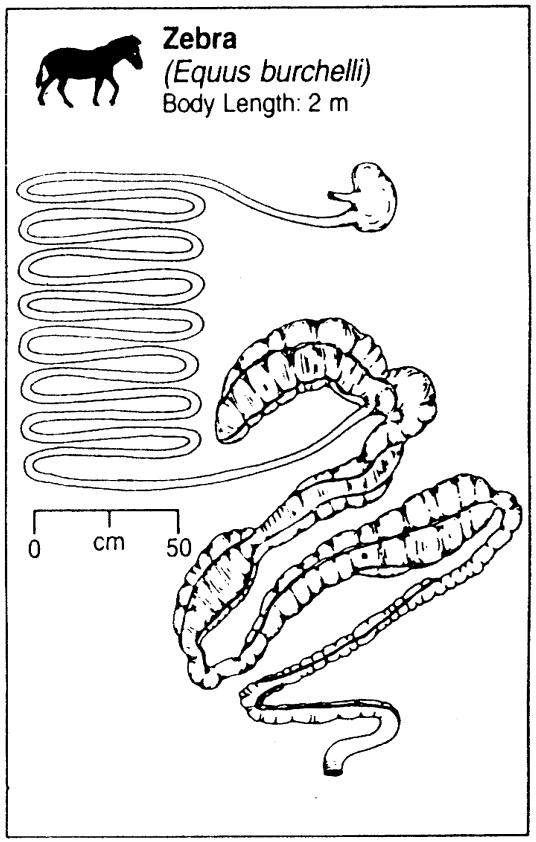


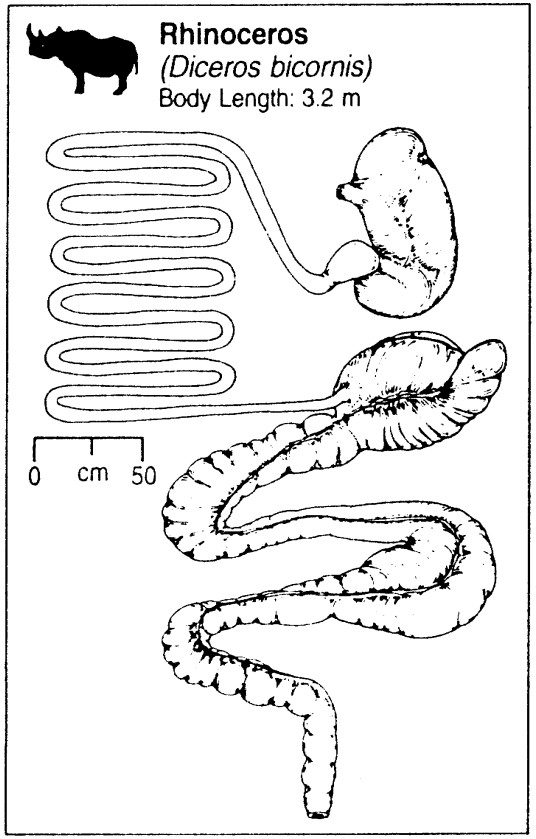
Pongo pygmaeus

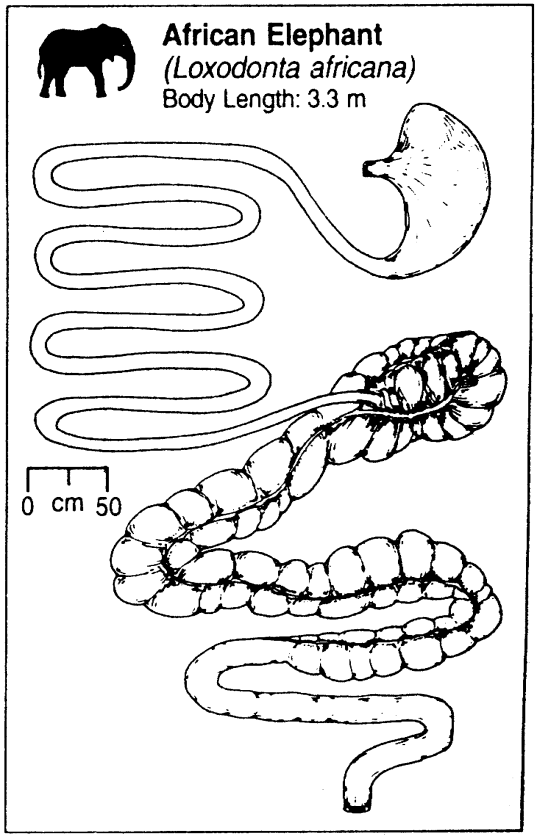
Gorilla gorilla

Photo: M. Clauss

Hindgut Fermentation - Colon

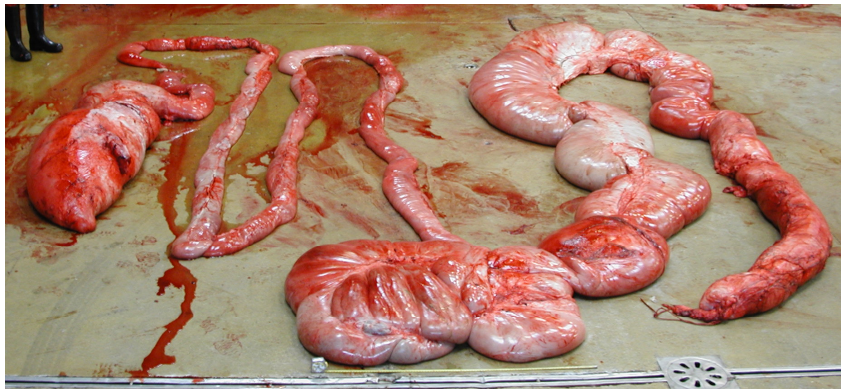






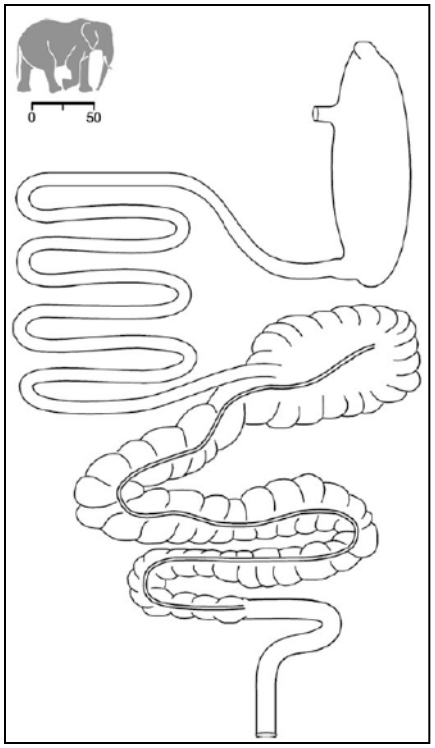
from Stevens & Hume (1995)

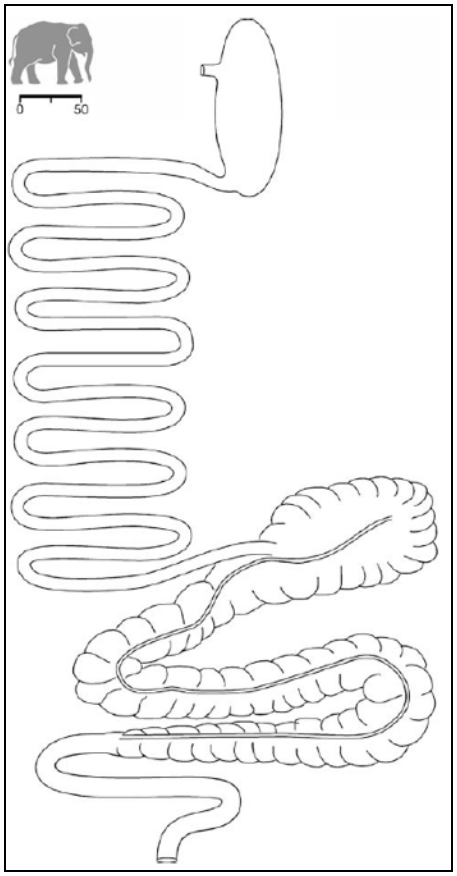
Digestive tract



from Clauss et al. (2007)

Digestive tract





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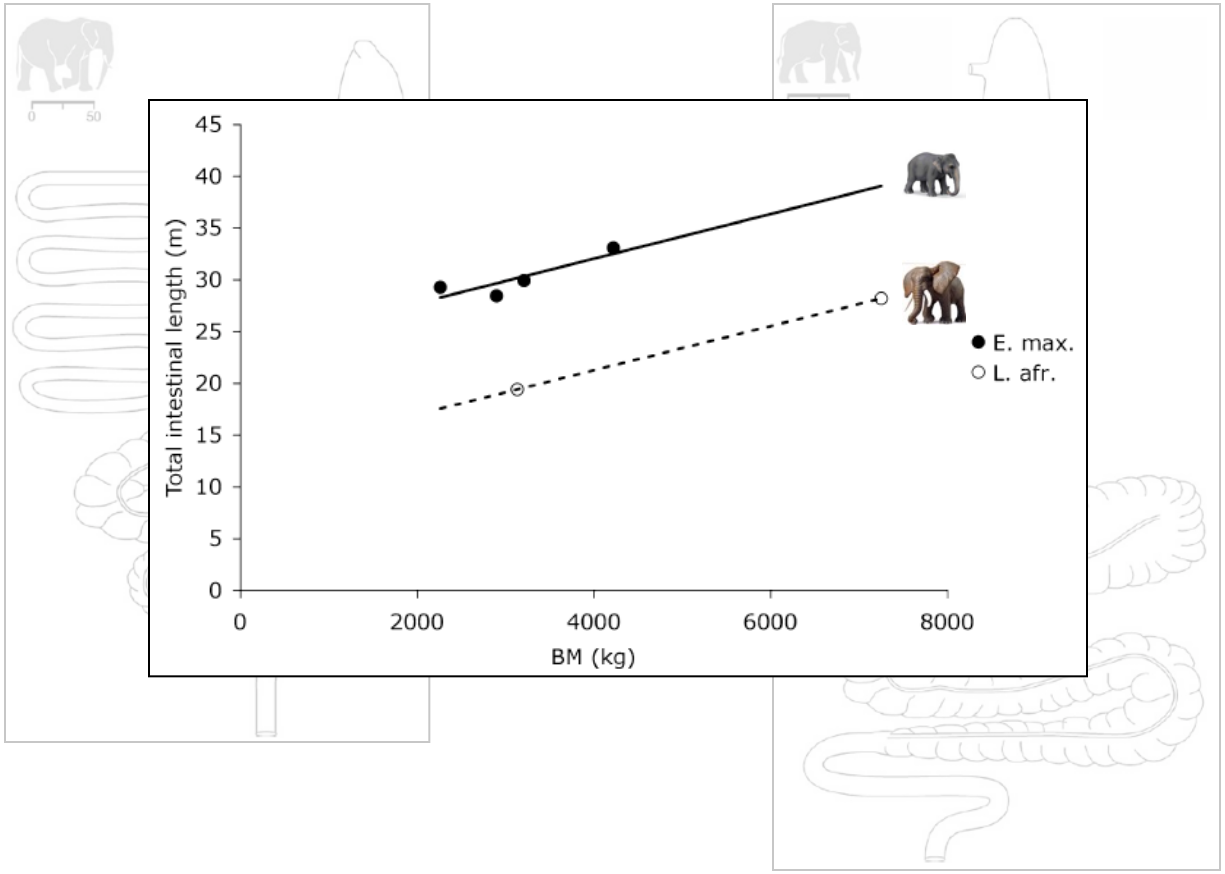
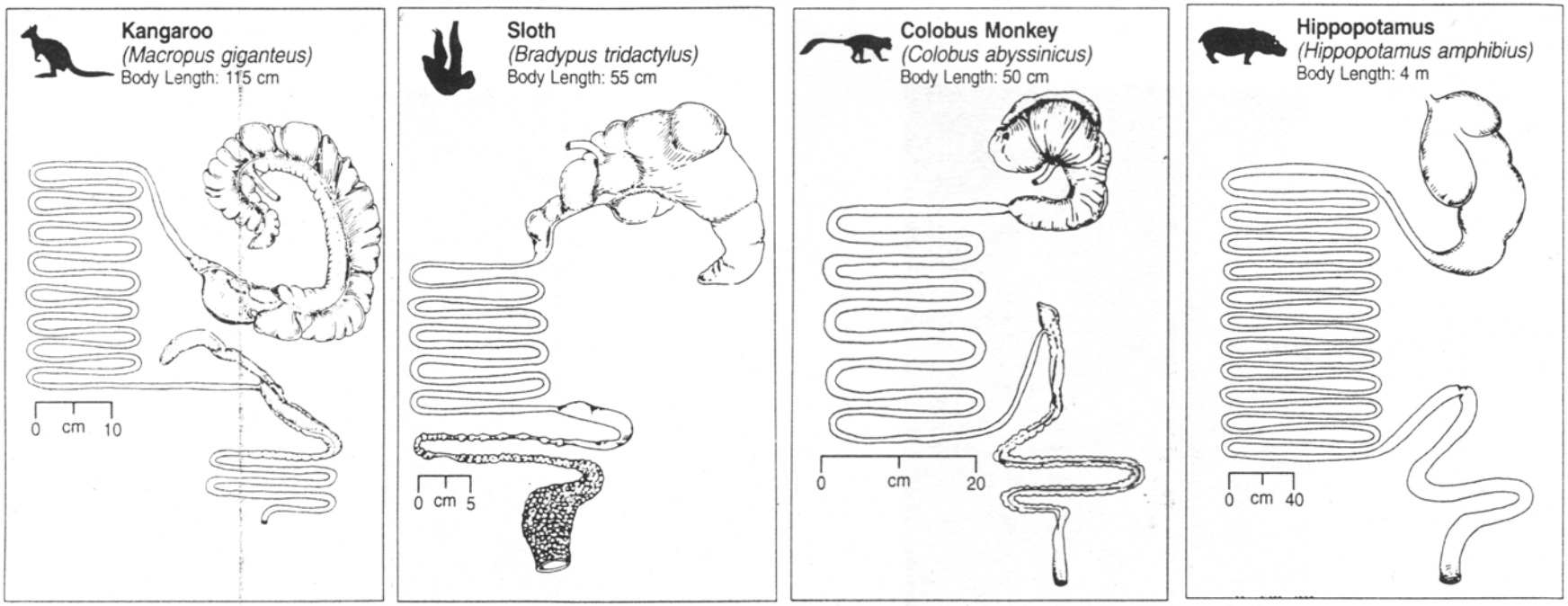


from Clauss et al. (2007)

Foregut Fermentation



from Stevens & Hume (1995)

Foregut Fermentation

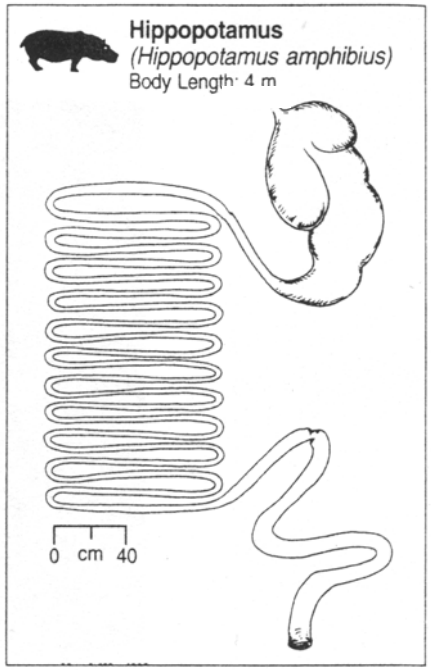
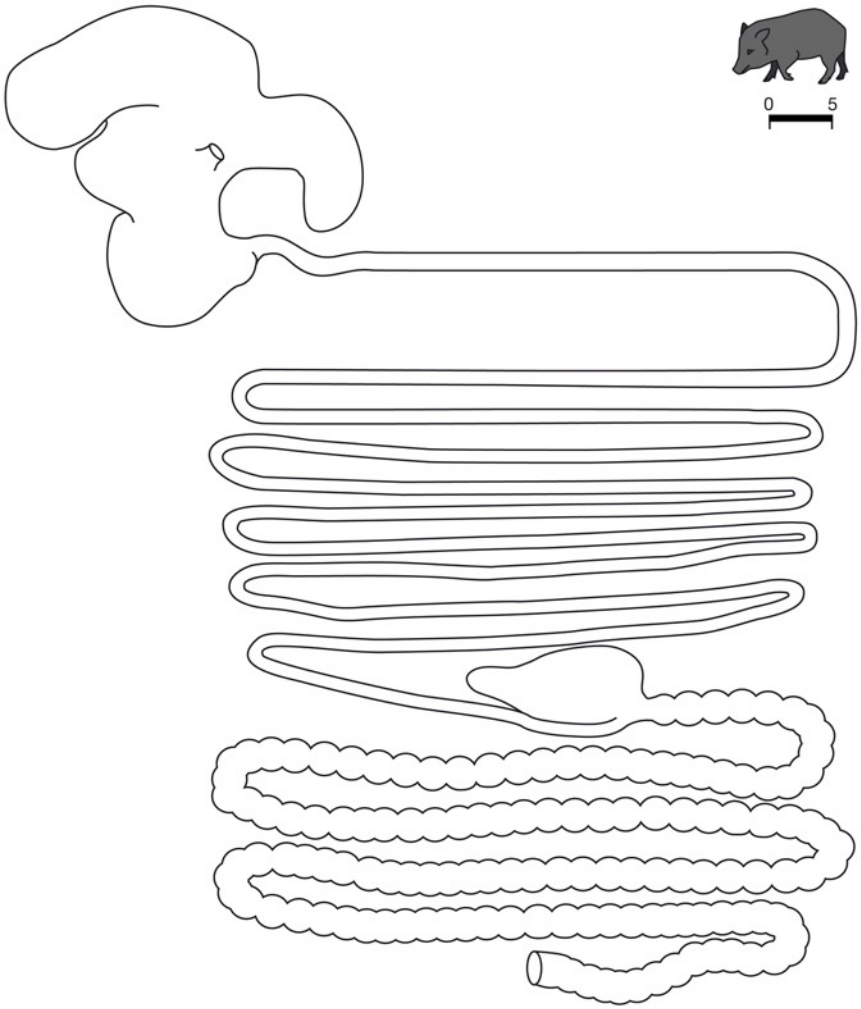


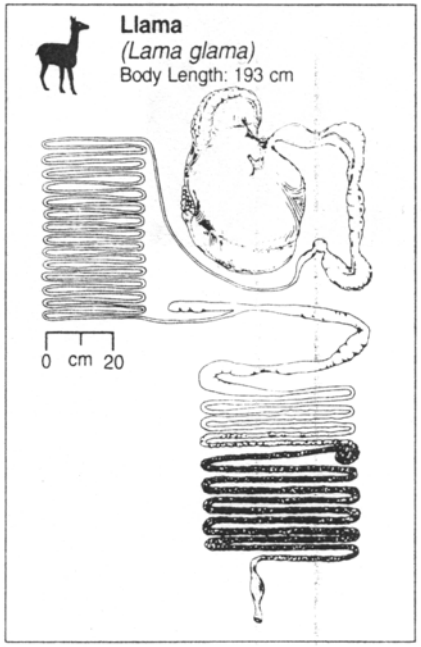
Photo M. Clauss

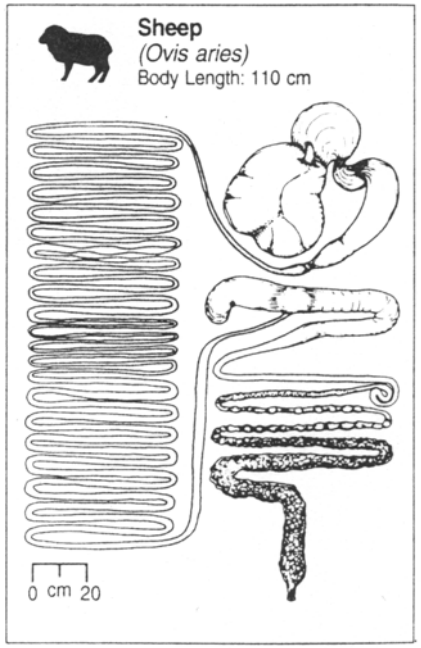
Herbivores - Foregut fermenters



from Schwarm et al. (2010)
Photo: A. Schwarm

Foregut Fermentation - Ruminant

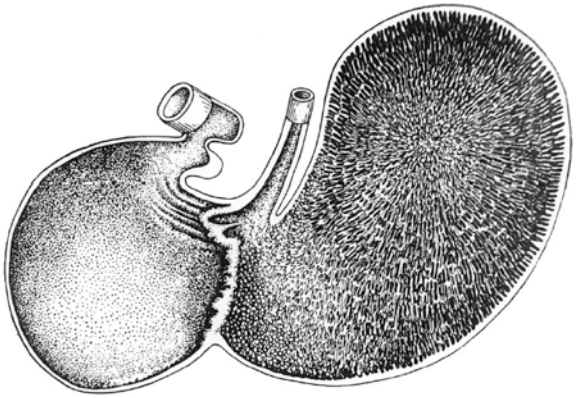




from Stevens & Hume (1995)
Photo: A. Riek, M. Clauss

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.



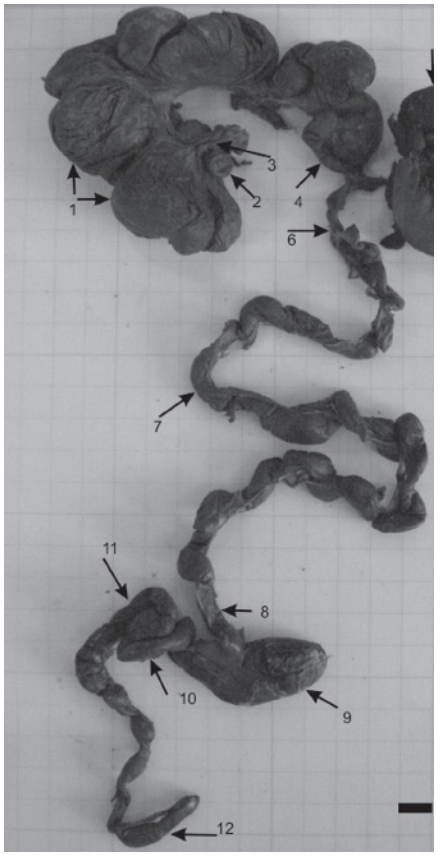
Demon mole rat
(*Tachyoryctes daemon*)
papillated forestomach

from Vrontsov (2003)

Foregut/Hindgut Fermenters

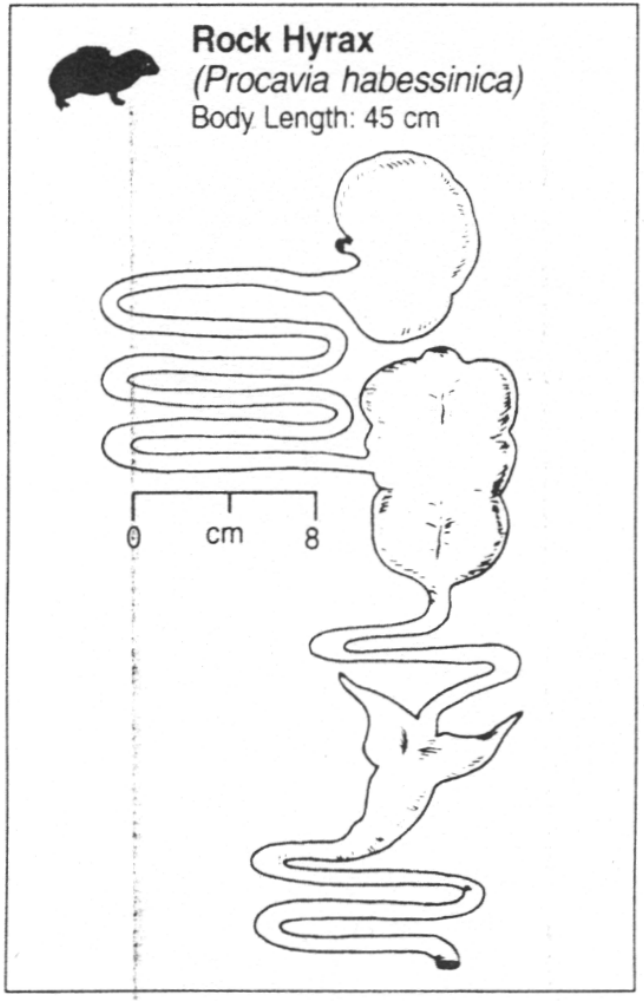
With the majority of rodent species un-studied, we have not grasped the variability, and adaptive significance, of foregut and hindgut fermentation yet.

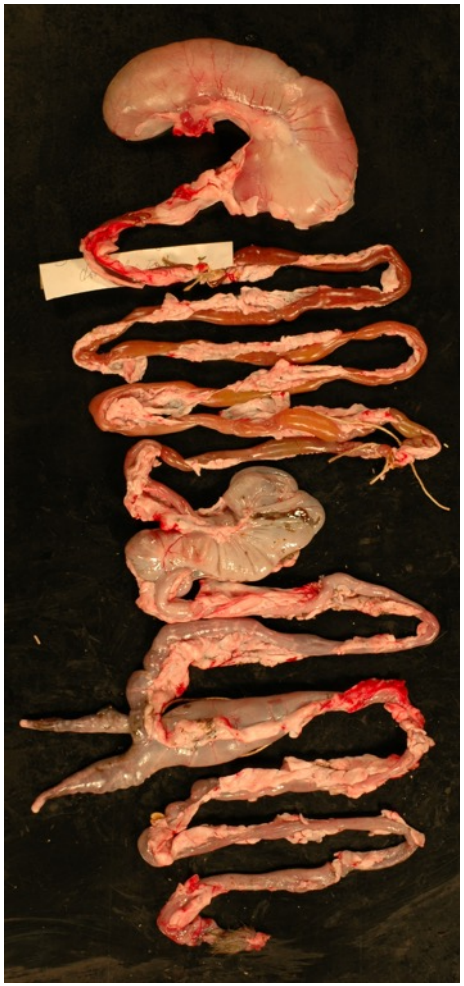
Laotian rock rat
(*Laonastes aenigmamus*)
kangoroo-like forestomach



from Scopin et al. (2011)

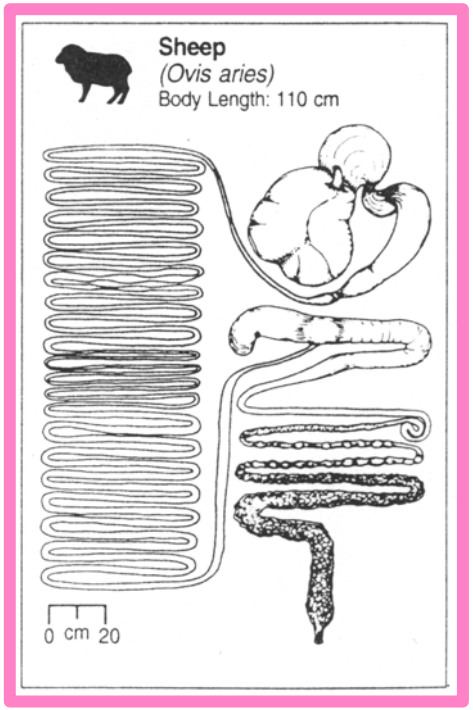
Herbivores - Hyrax

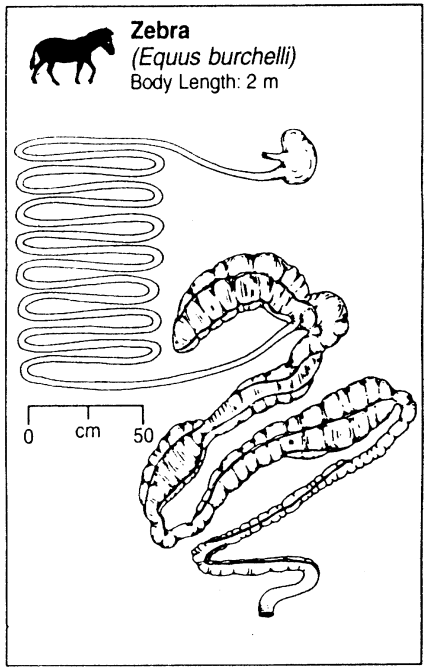




from Stevens und Hume (1995)

Which system is ‘more successful’ ?

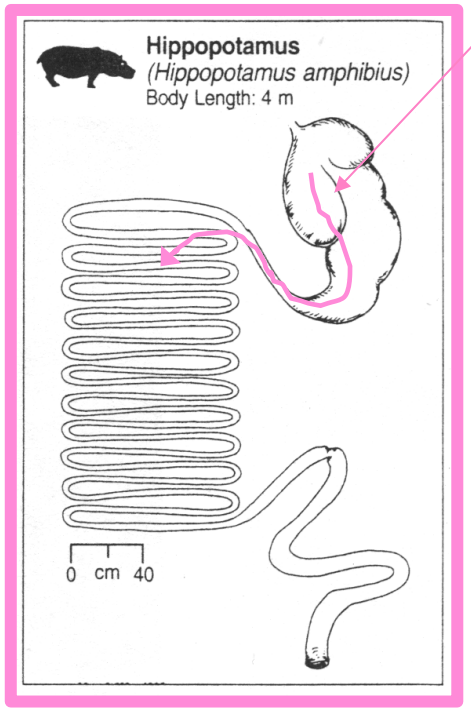


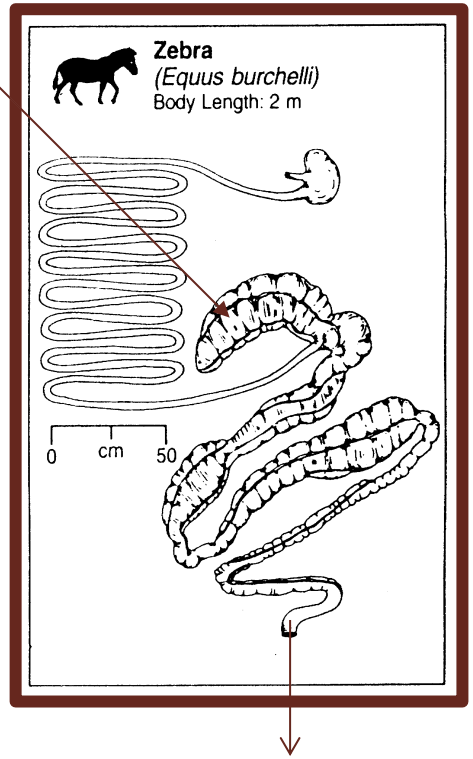


from Stevens und Hume (1995)

Function

Bacteria ferment the
diet (rest) ...
... and produce
volatile fatty acids





(from Stevens & Hume 1995)

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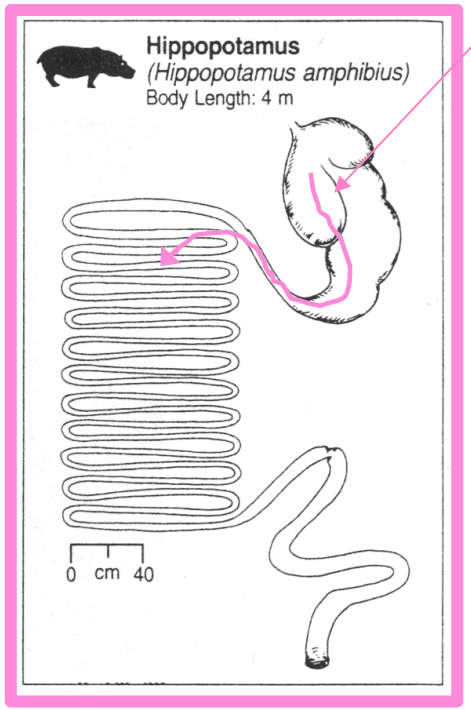
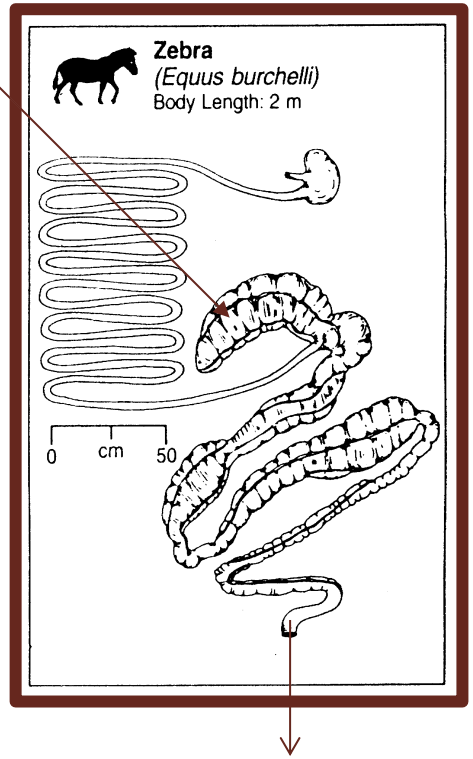
Bacteria ferment the diet (rest) ...



... **prior to** small intestine

... **after** small intestine



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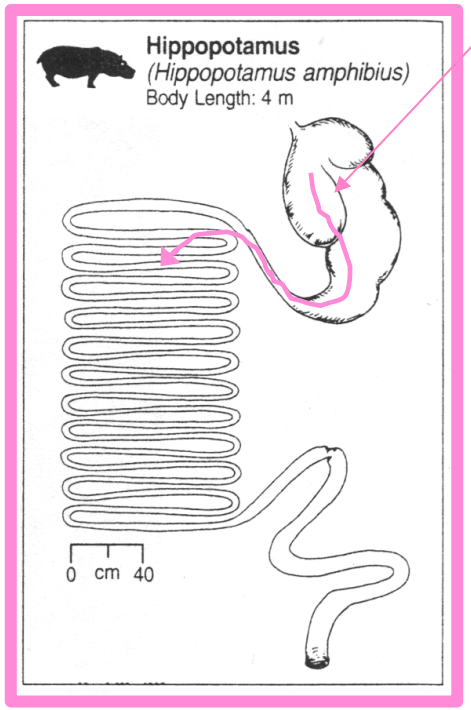
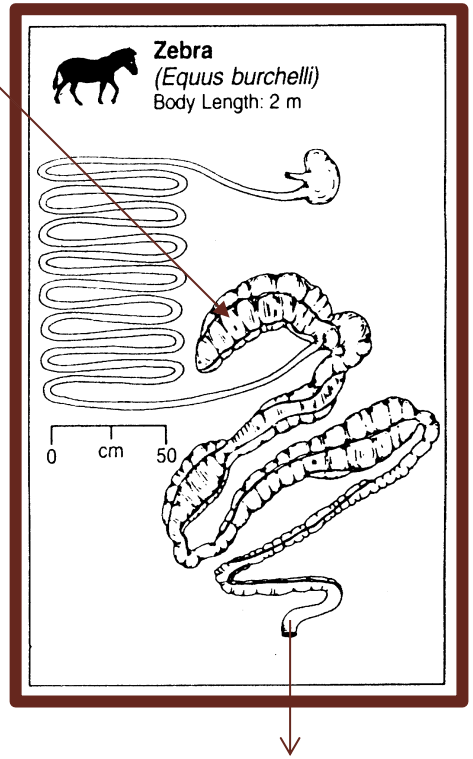


... and modify it before own digestion

... after diet has been digested un-modified



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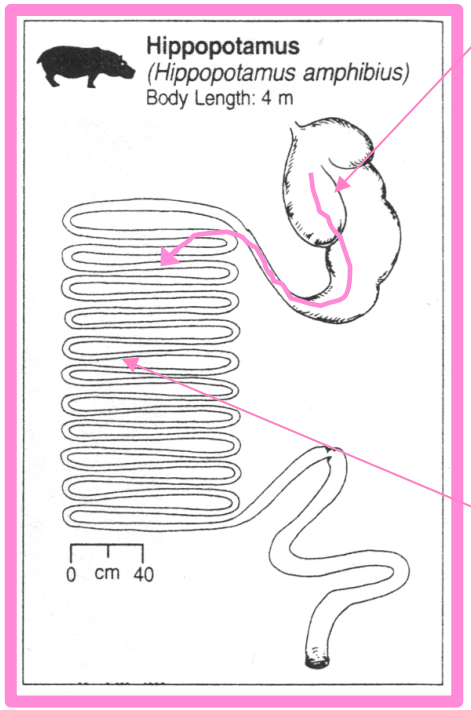
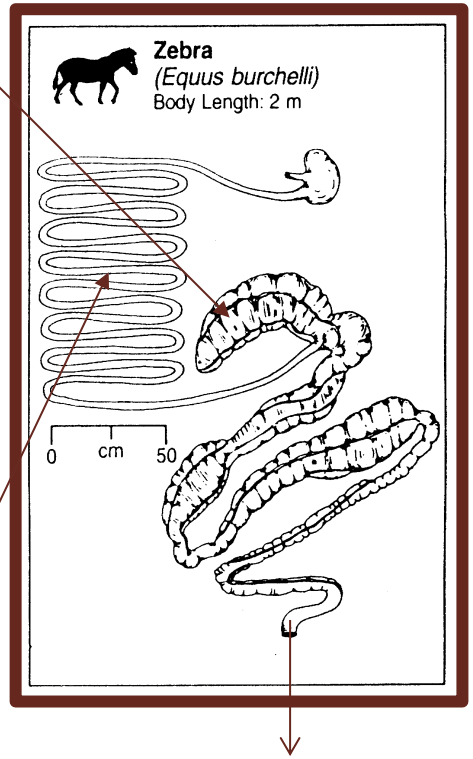


... and modify it before own digestion

enzymatic digestion of processed material

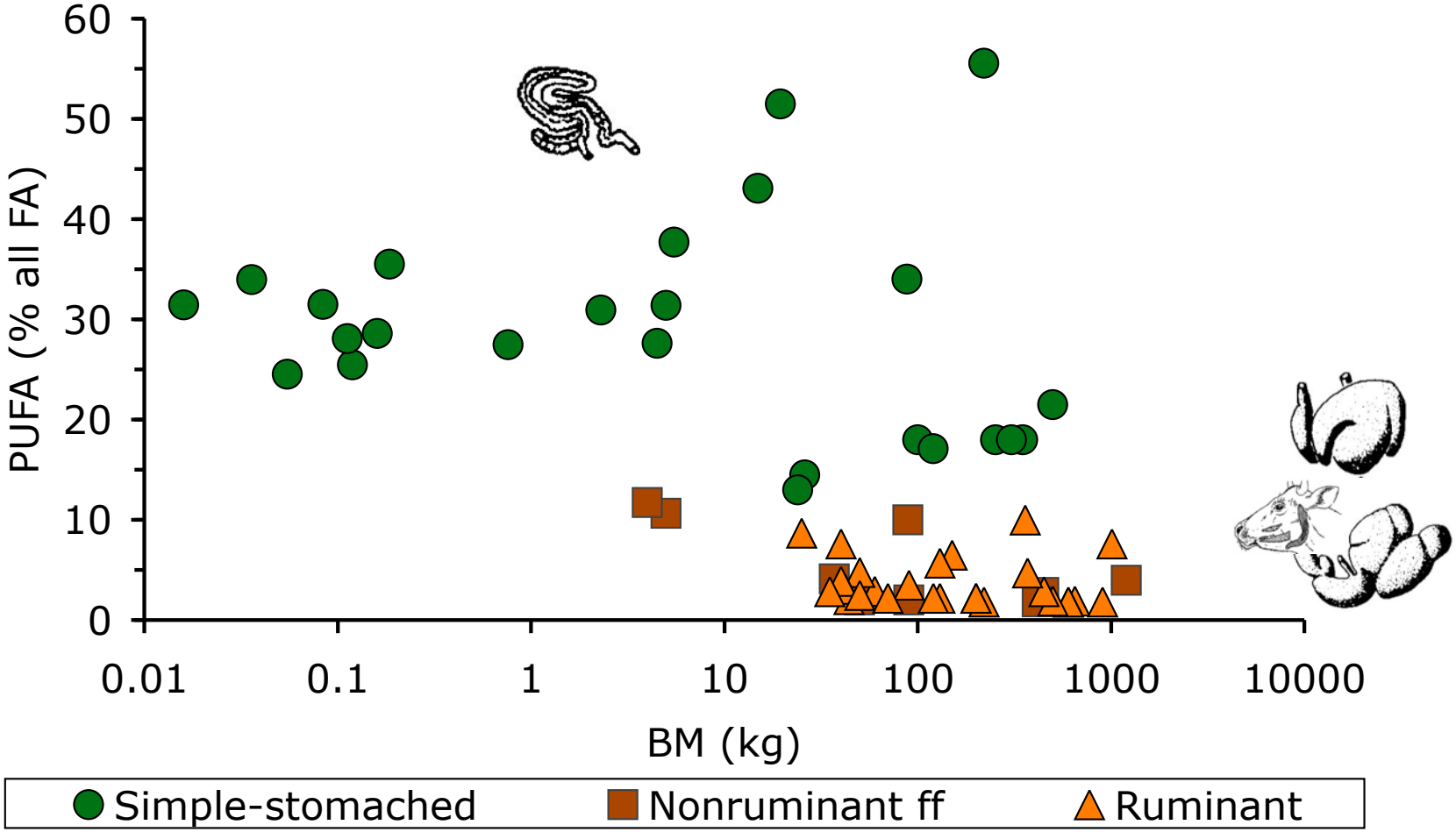
... after diet has been digested un-modified

enzymatic digestion of diet



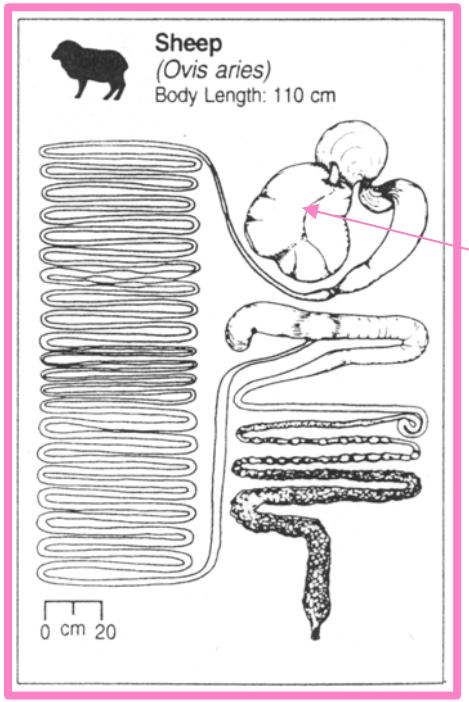
(from Stevens & Hume 1995)

Saturation of body fat



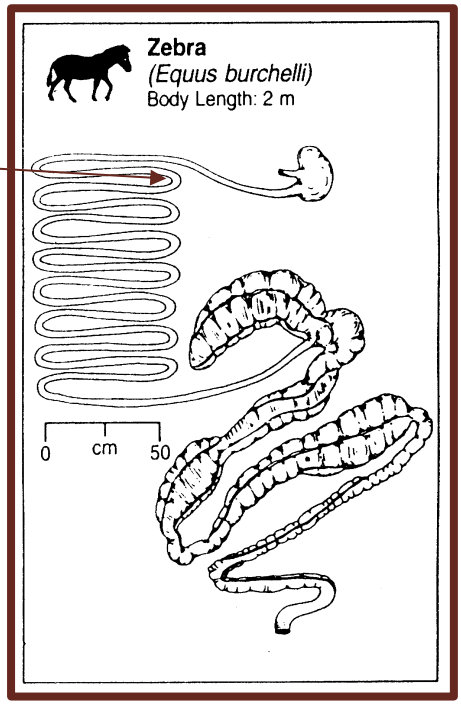
from Clauss et al. (2008)

A forestomach has a problem: *no milk must get in !*



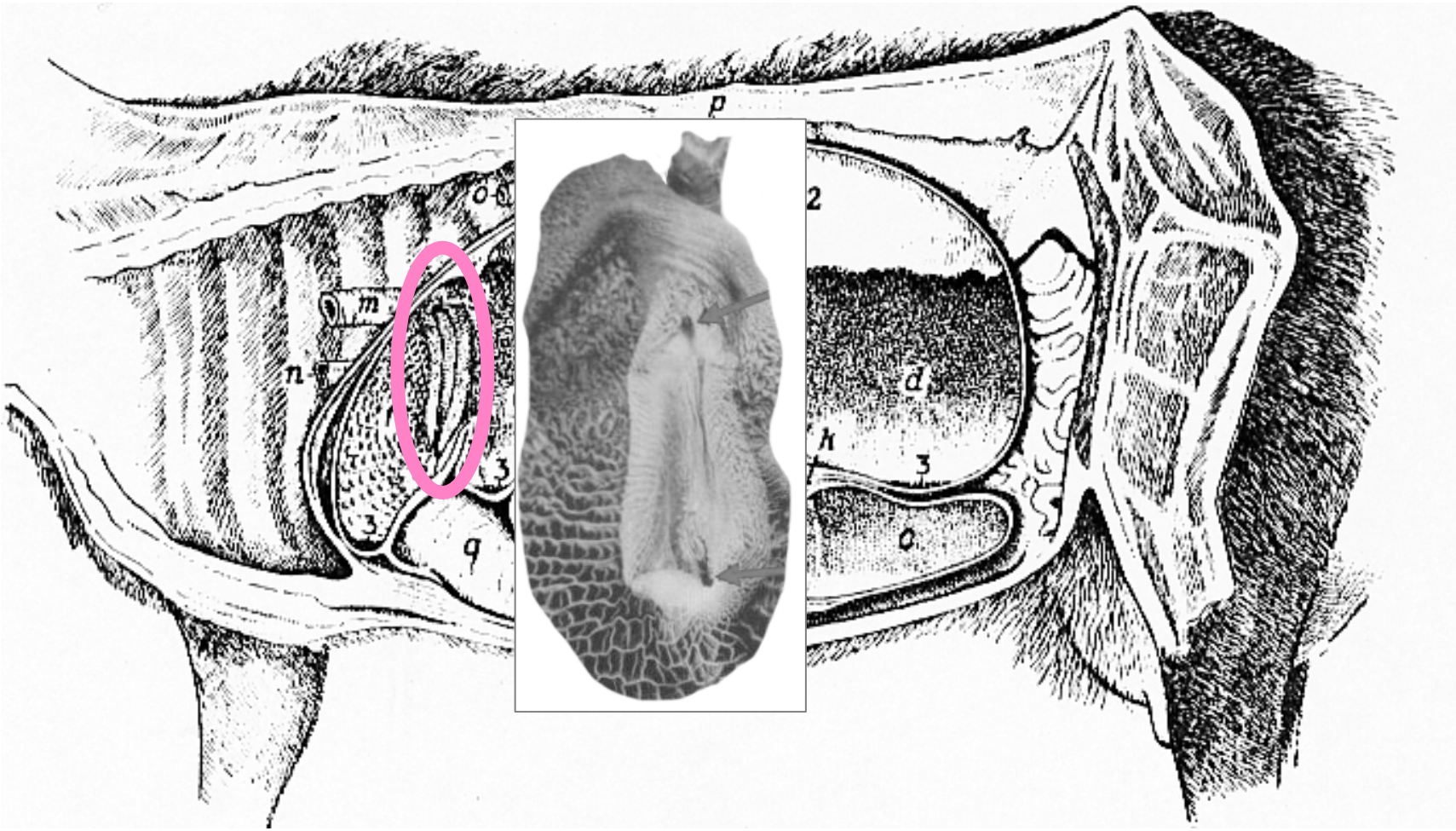
milk is fermented by bacteria – ***acidosis***

milk is digested directly



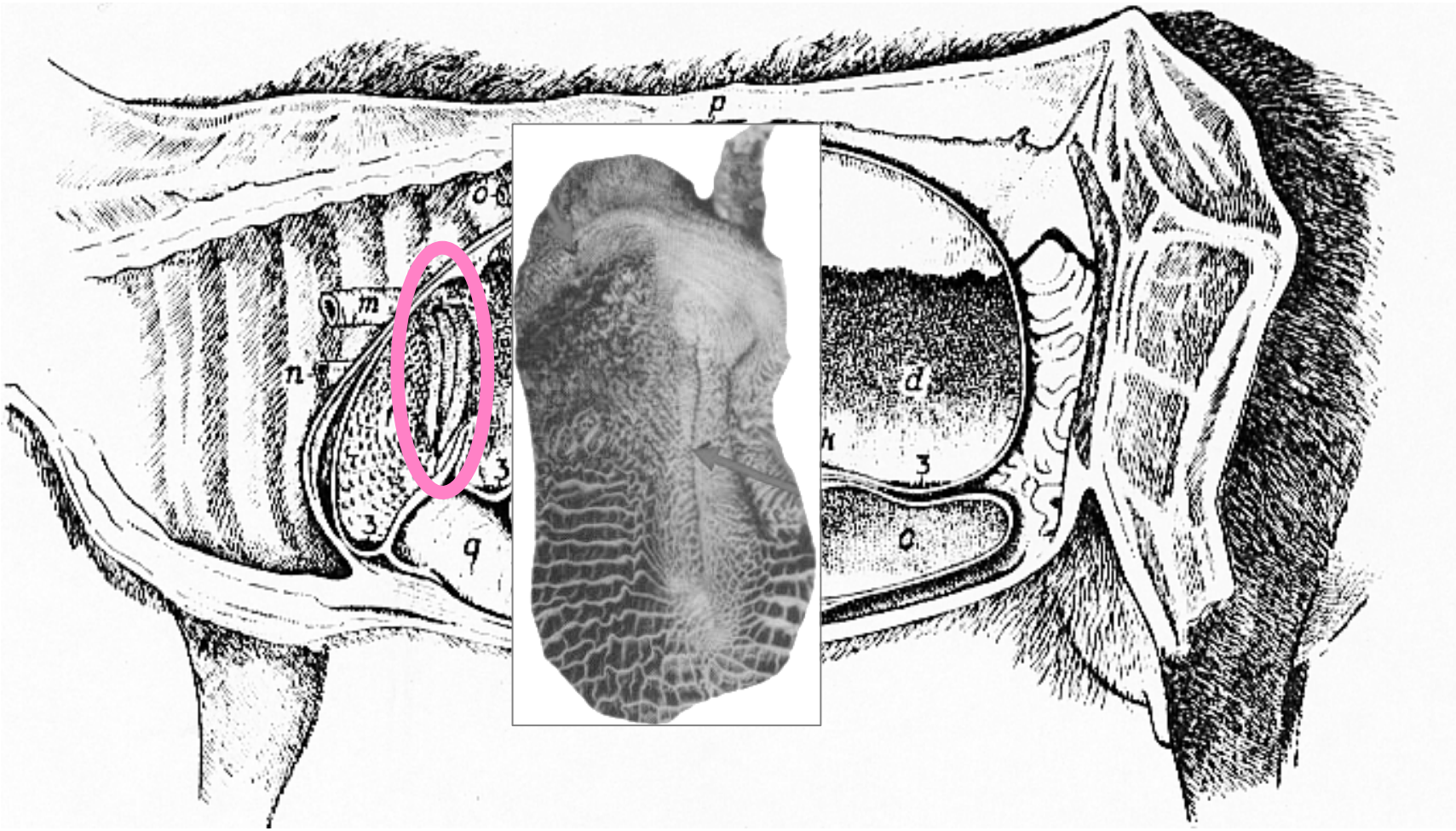
(from Stevens & Hume 1995)

Deviation for milk



(fom Grau 1955)

Deviation for milk



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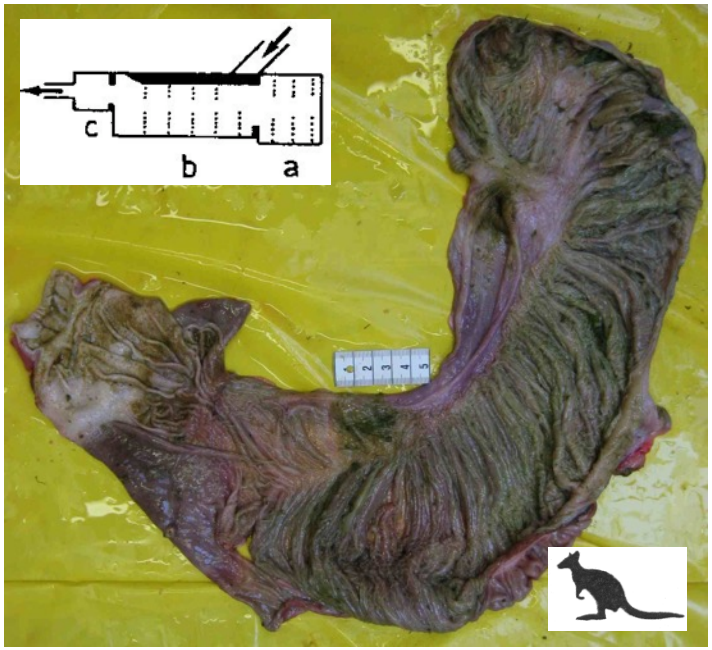
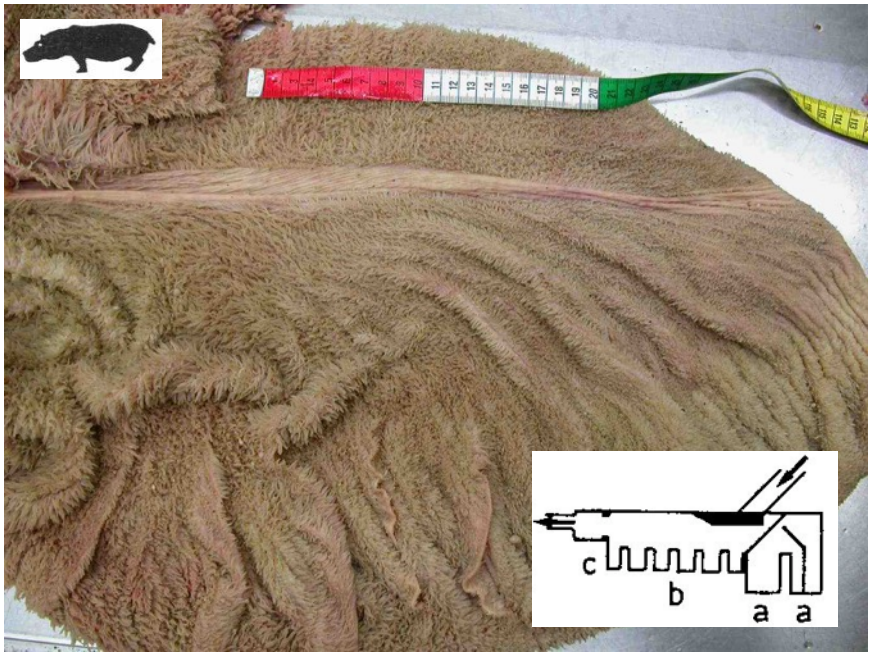
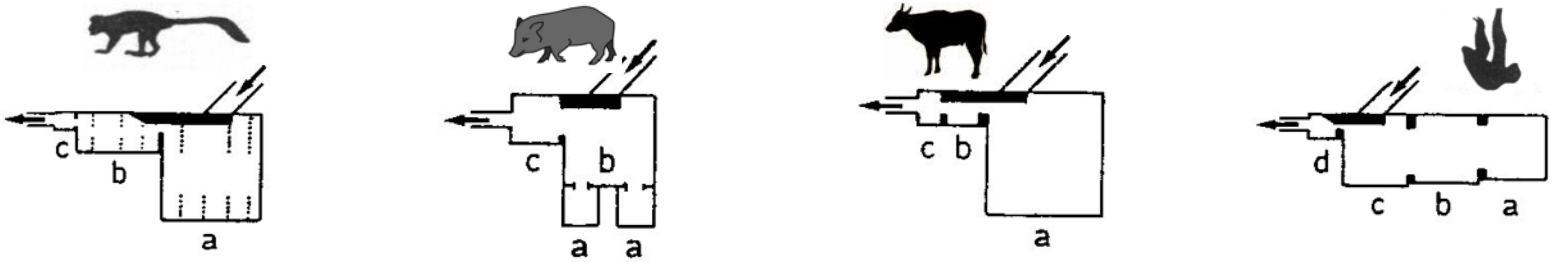
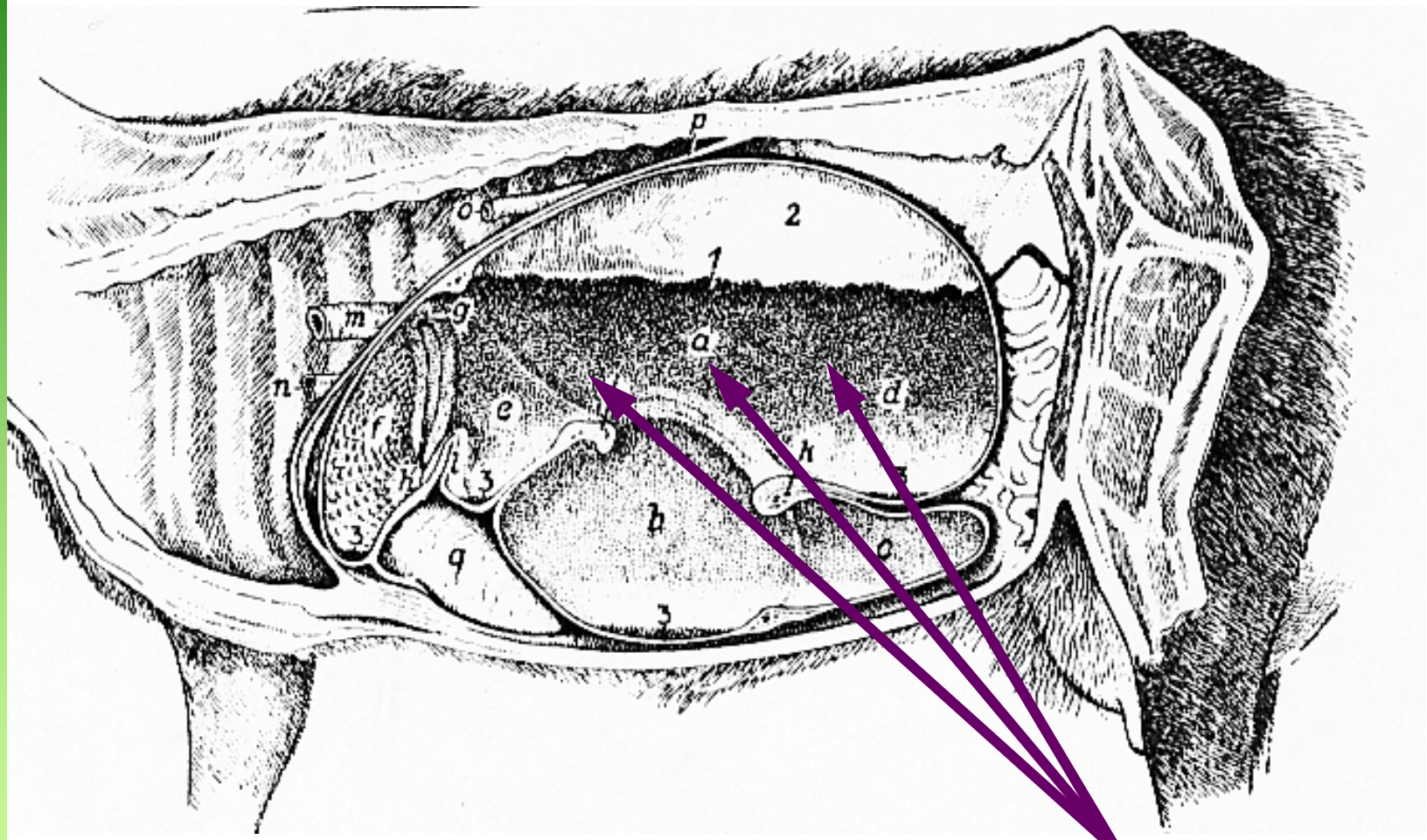






from Langer (1988)
Photos A. Schwarm

Digestion

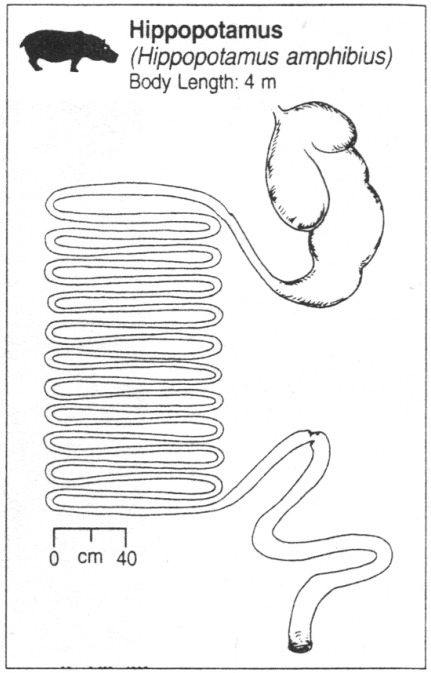


Forestomach: Bacteria digest

(from Grau 1955)

Functions of any forestomach

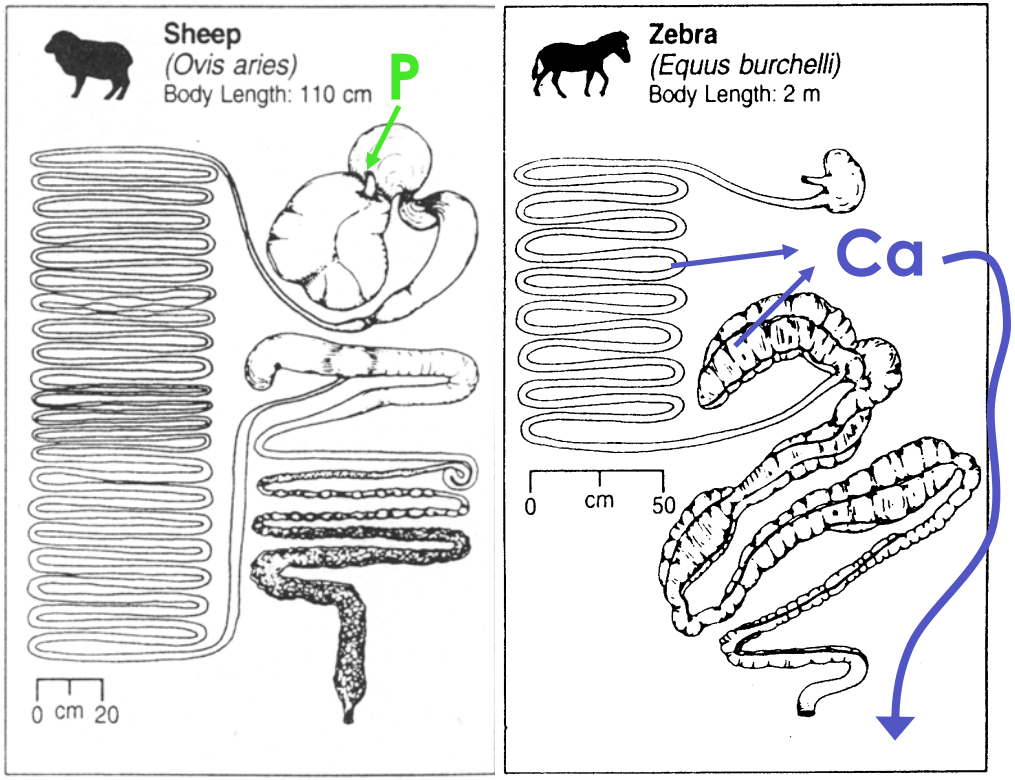
1. Fermentation of plant fibre by bacteria



from Stevens und Hume (1995)

Foregut vs. Hindgut: Calcium

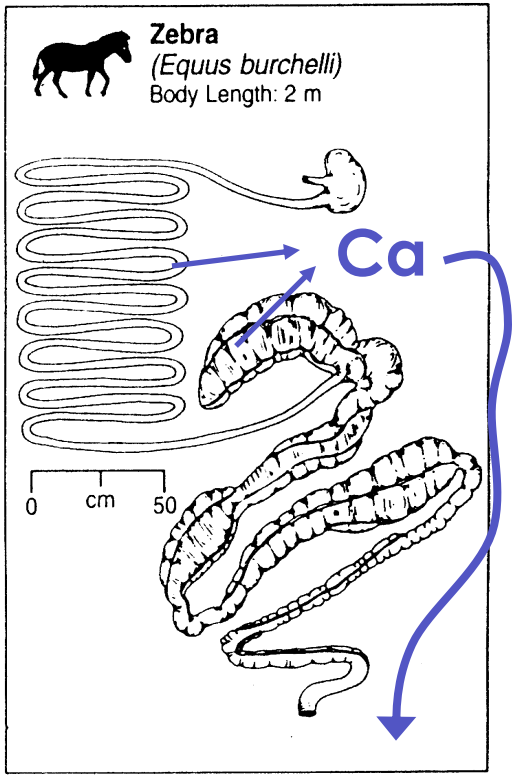
Phosphorus is supplied directly to microbes via saliva



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

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

Foregut vs. Hindgut: Calcium



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Function

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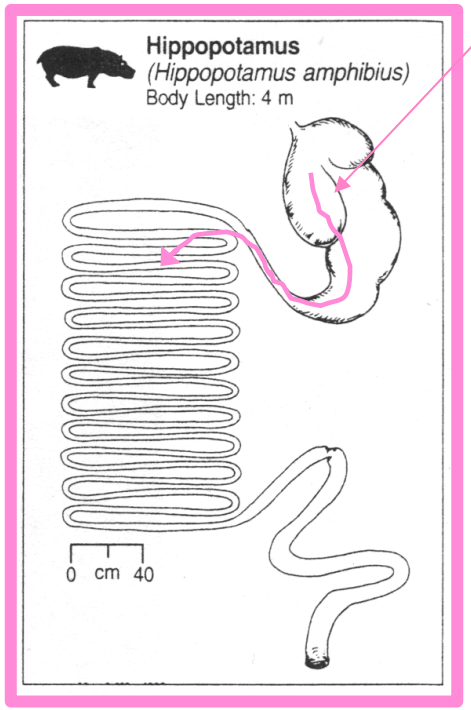
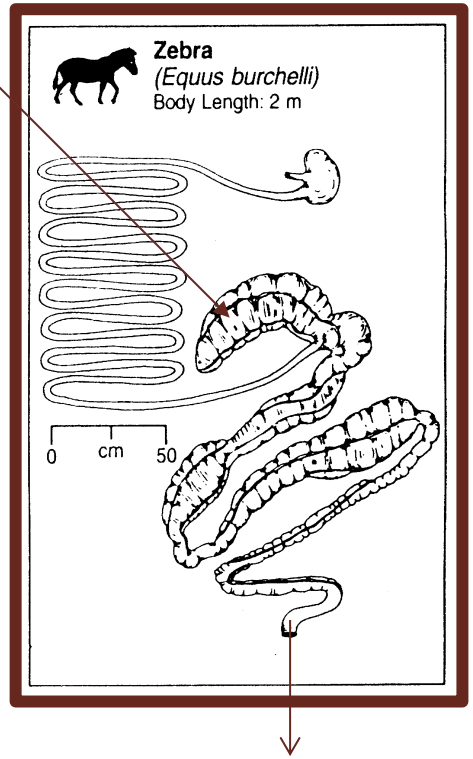


... and are digested

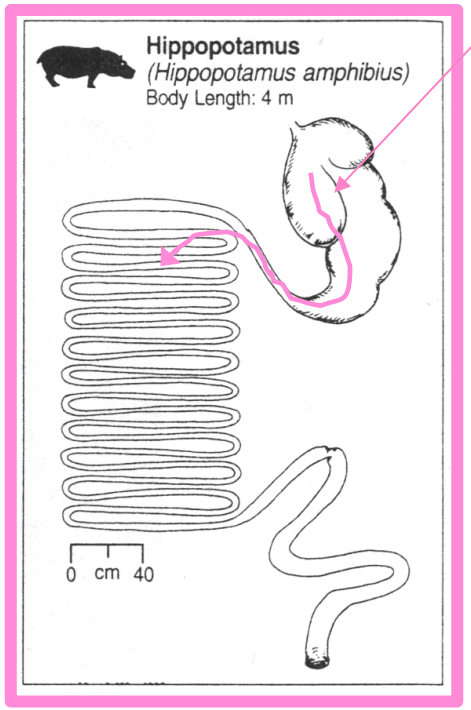
... and are excreted



(from Stevens & Hume 1995)

Function

Bacteria digest the diet (rest) ...



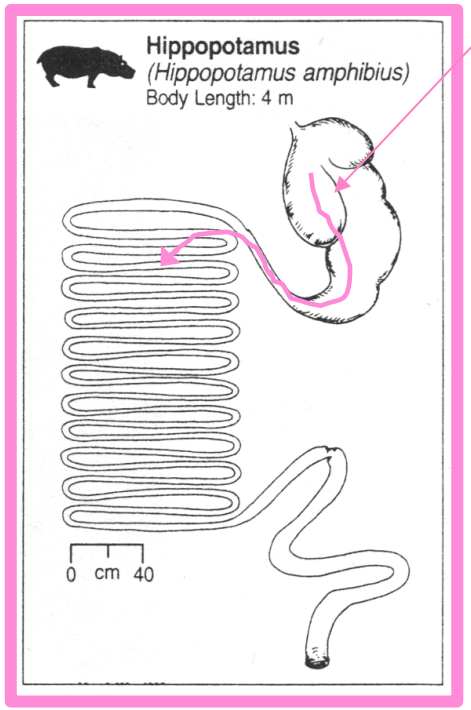
... and are digested

Foregut fermenters are 'bacteria farmers'.

(from Stevens & Hume 1995)

Function

Bacteria digest the diet (rest) ...



... and are digested

Foregut fermenters are 'bacteria farmers'.

How can you maximise bacteria harvest?

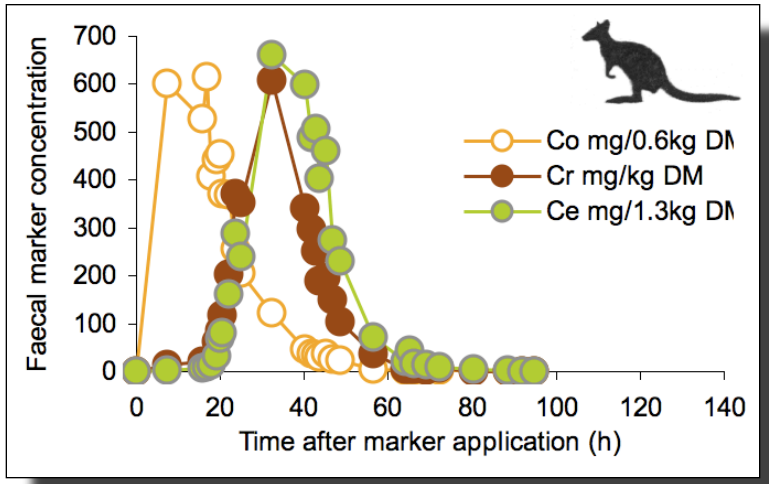
Flush!

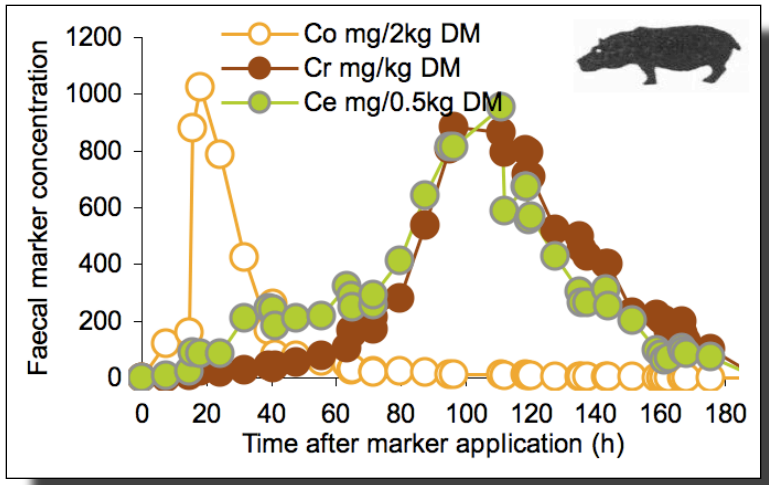
Where do you get the fluid from?

Saliva!

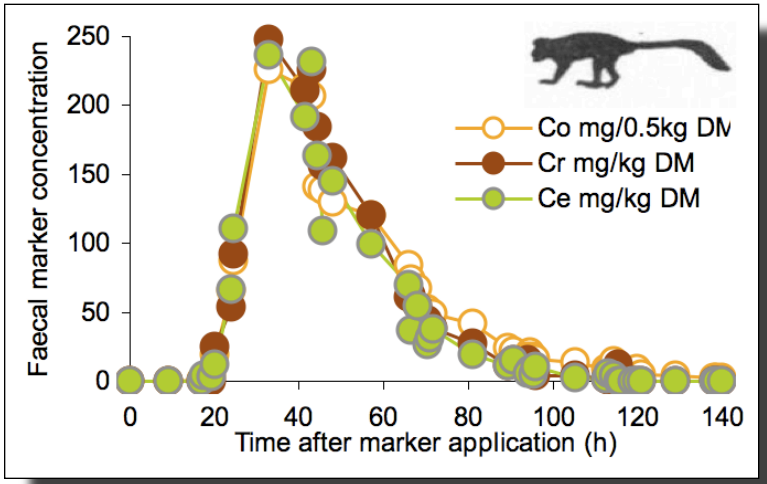
(from Stevens & Hume 1995)

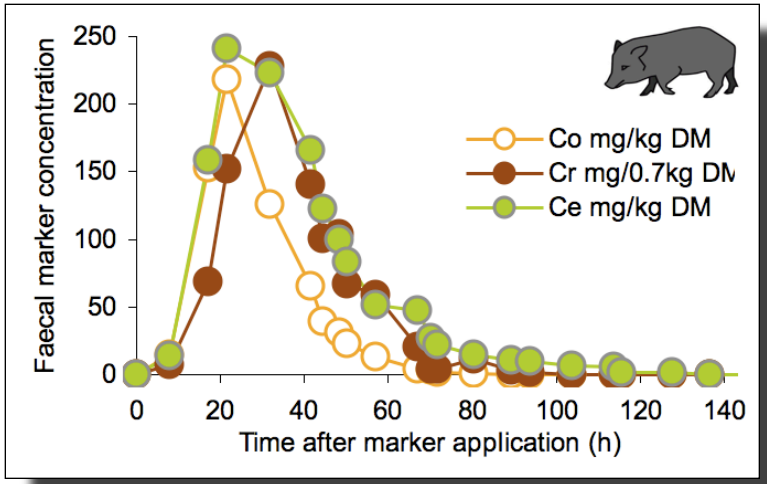
Flushing the forestomach





Schwarm et al. (2008,2009)

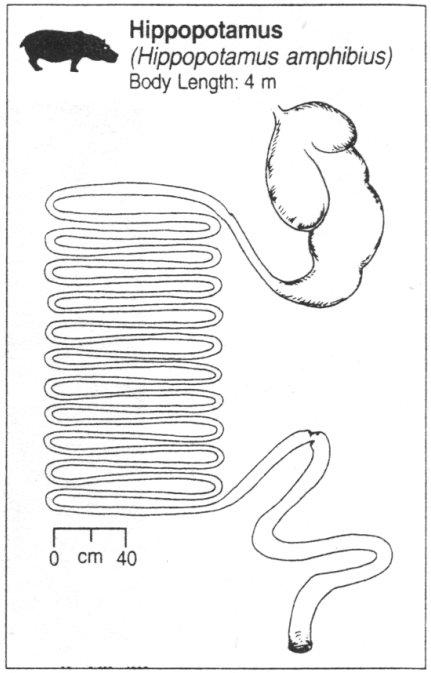




Functions of any forestomach

1. Fermentation of plant fibre by bacteria

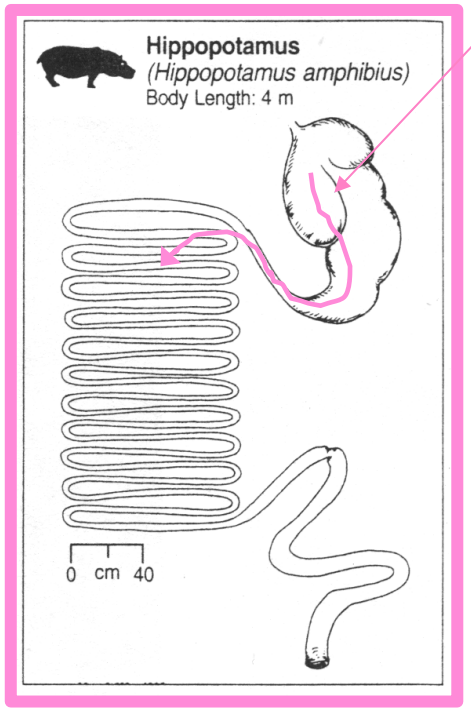
2. 'Bacteria farm' with constant harvest mechanism by flushing (except primates)



from Stevens und Hume (1995)

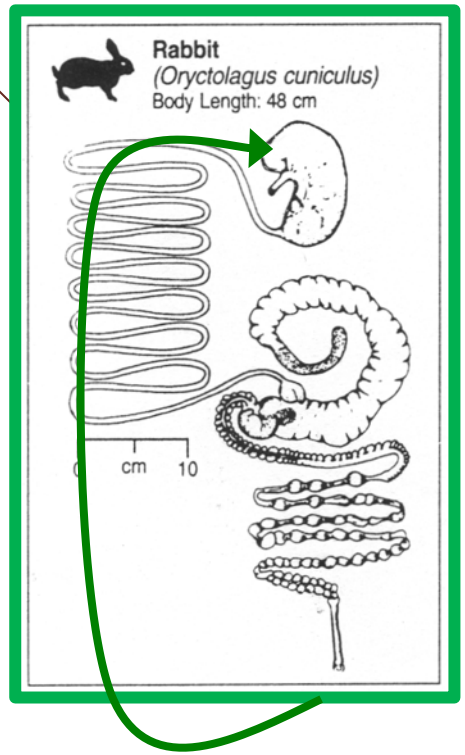
Function

Bacteria digest the diet (rest) ...



... and are digested

... or re-ingested and digested



(aus Stevens & Hume 1995)

Coprophagy