Coprophagy

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Wildlife Digestive Physiology Course Vienna 2013

University of Zurich
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of Zoo Animals, Exotic Pets and Wildlife

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

C. A. Nalepa[1], D. E. Bignell[2] and C. Bandi[3]

Insectes soc. 48 (2001) 194–201

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ASOCIAL

DETRITIVORY,
GENERAL
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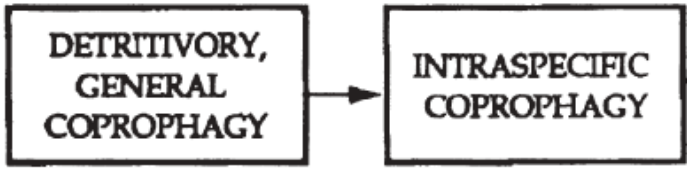

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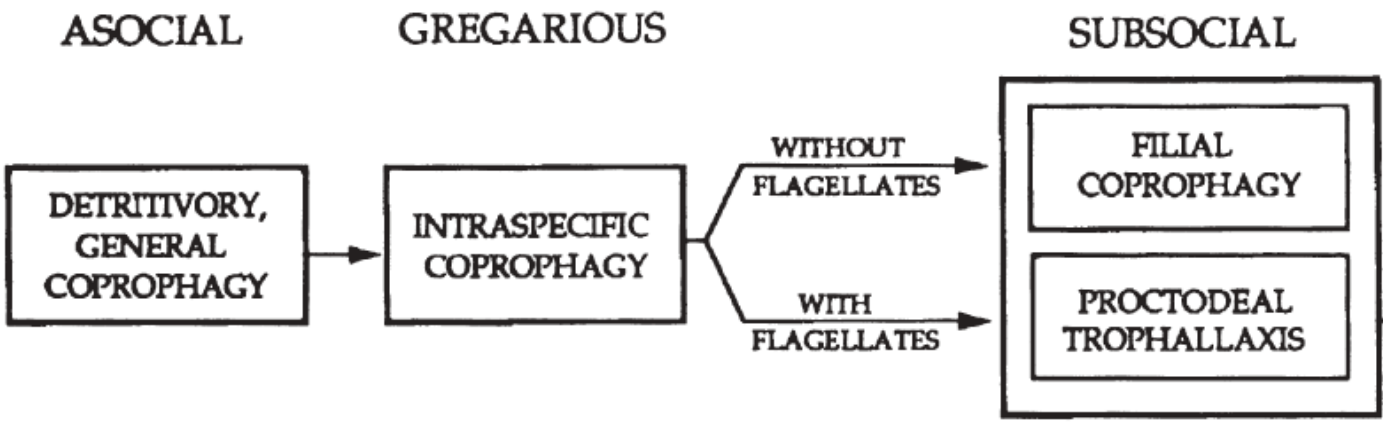

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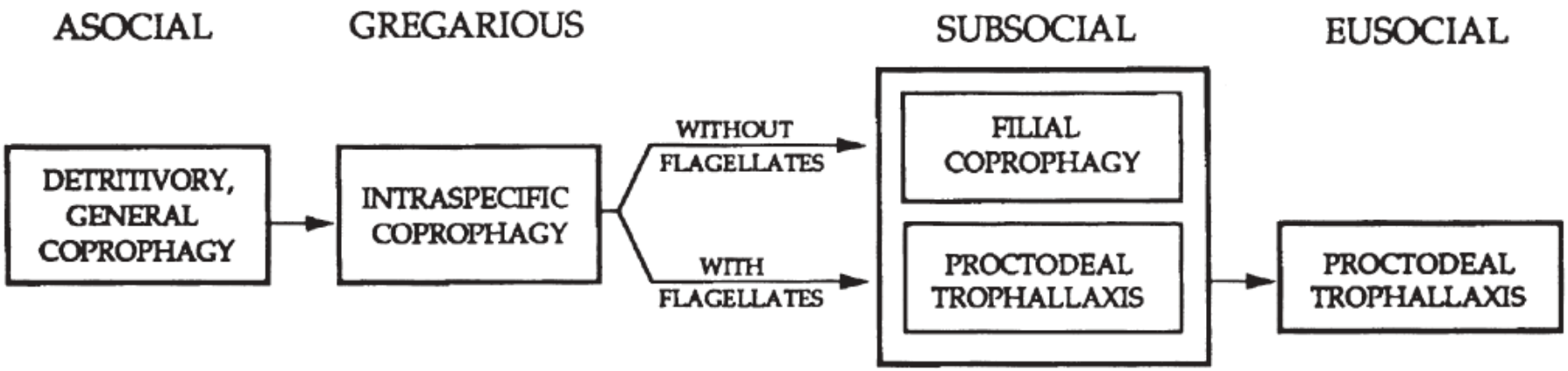
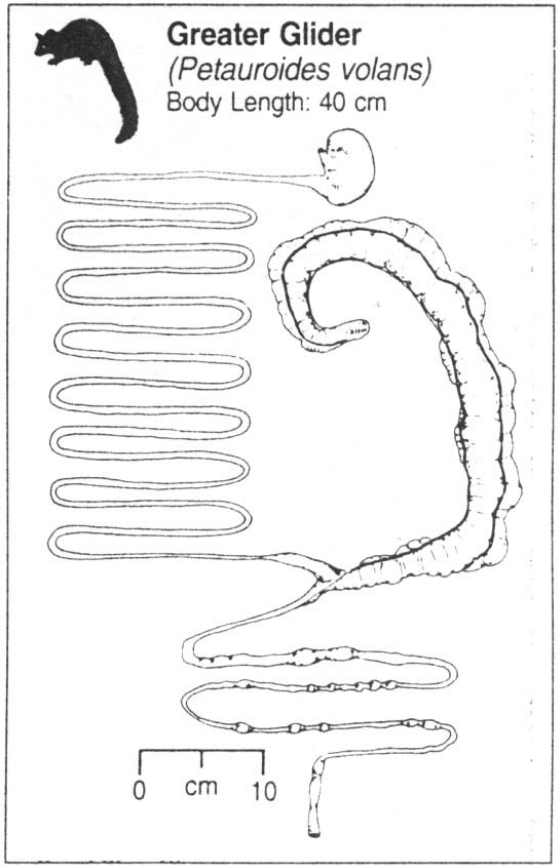
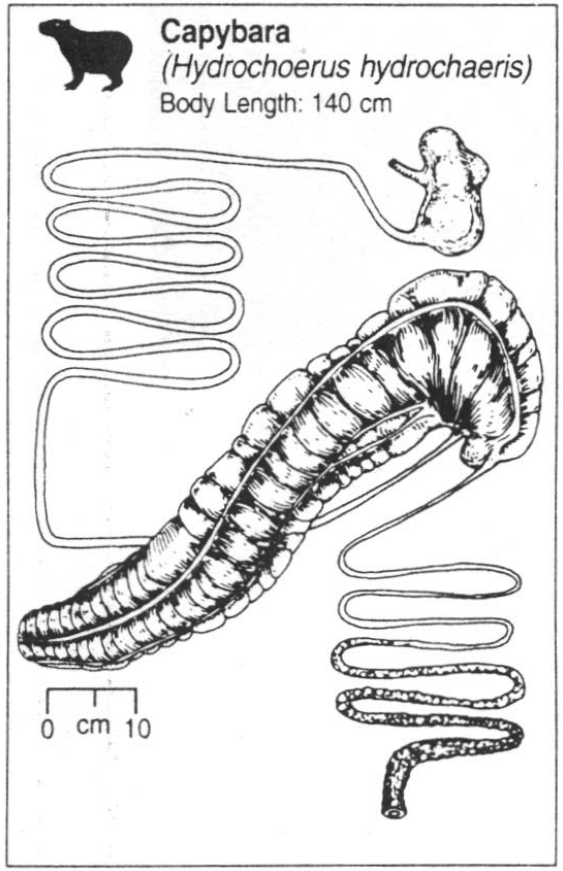
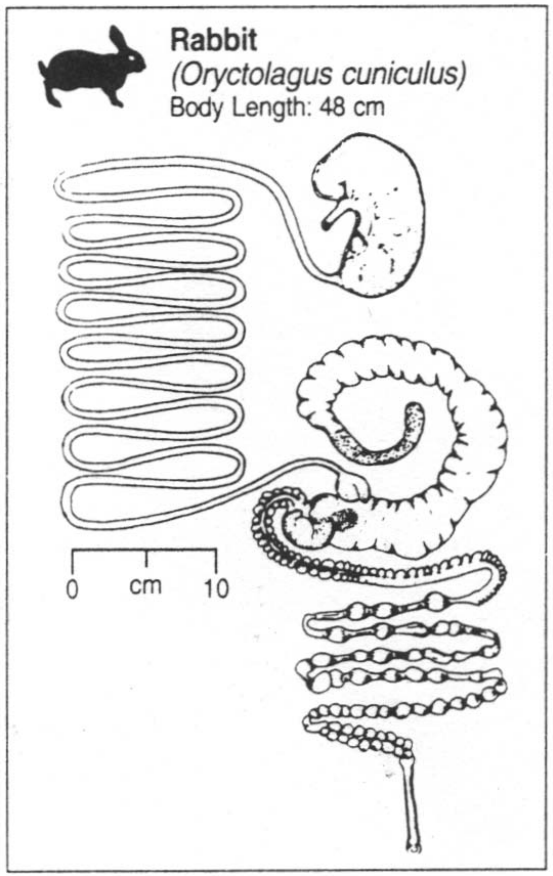


Caecum fermenters

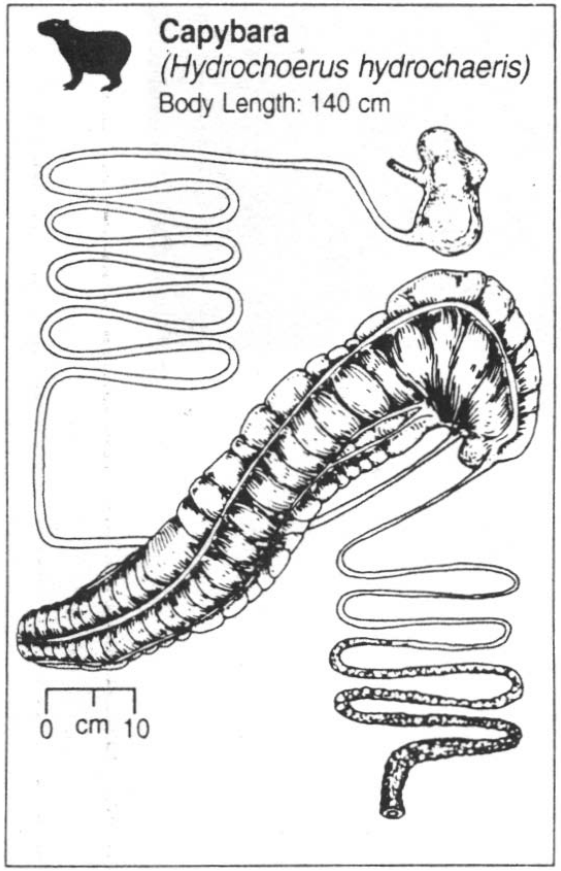


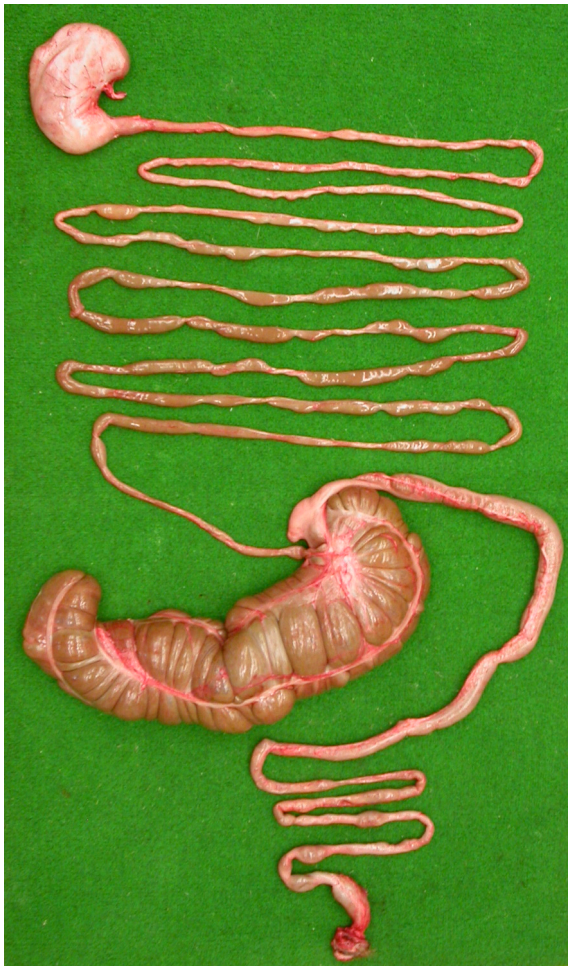




from Stevens und Hume (1995)

Caecum fermenters





from Stevens und Hume (1995)
Photo: M. Clauss

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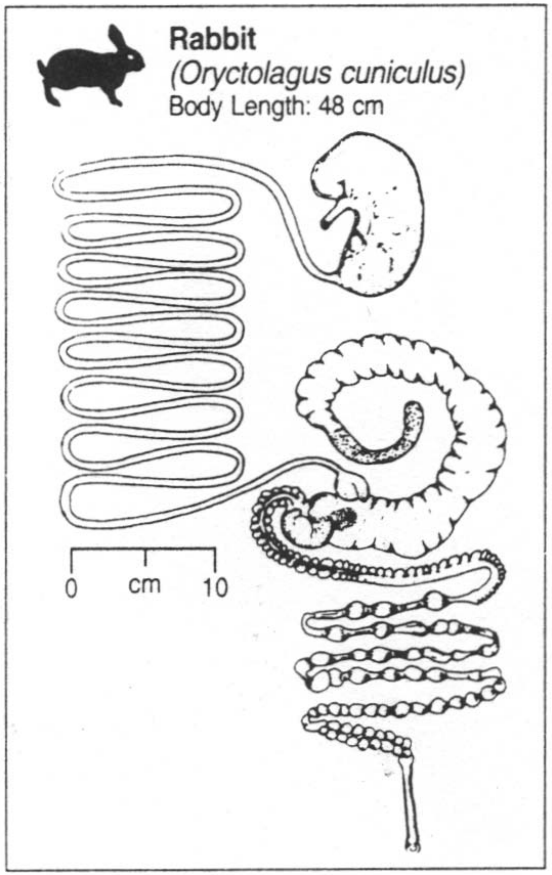

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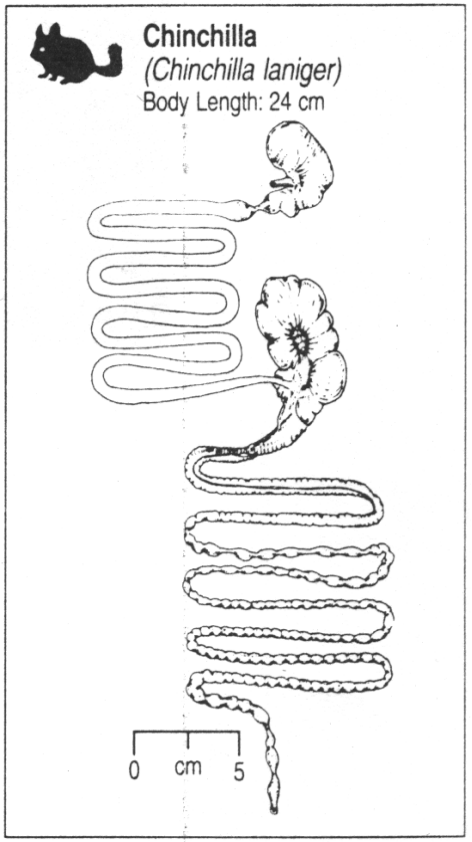

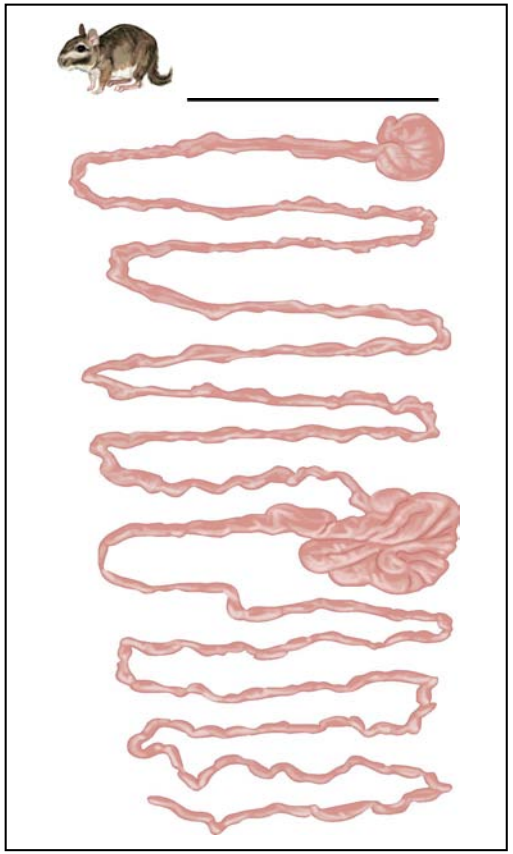

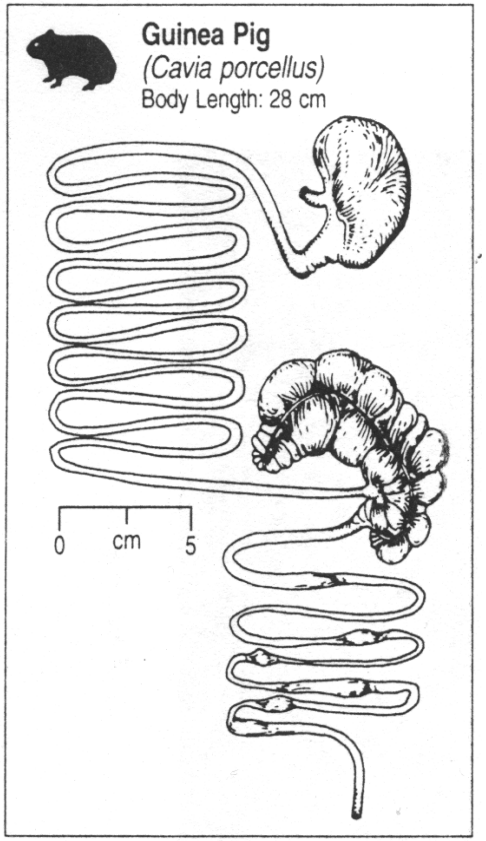

from Stevens und Hume (1995)
Besselmann (2005)

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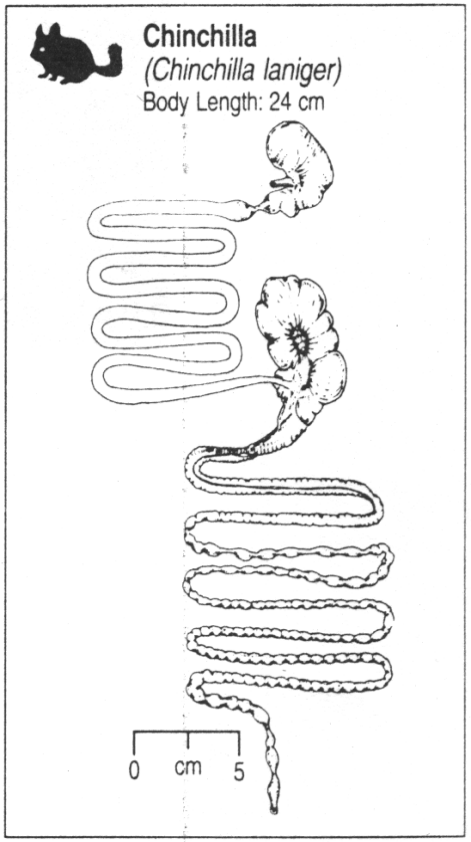
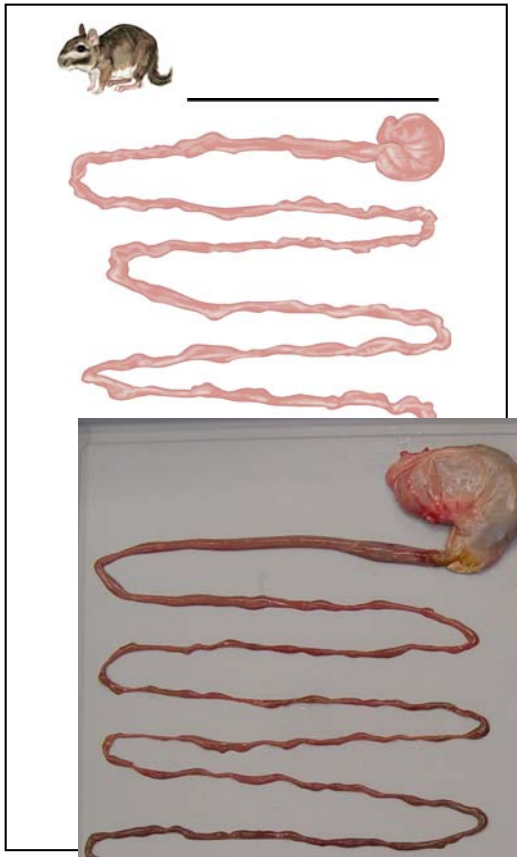
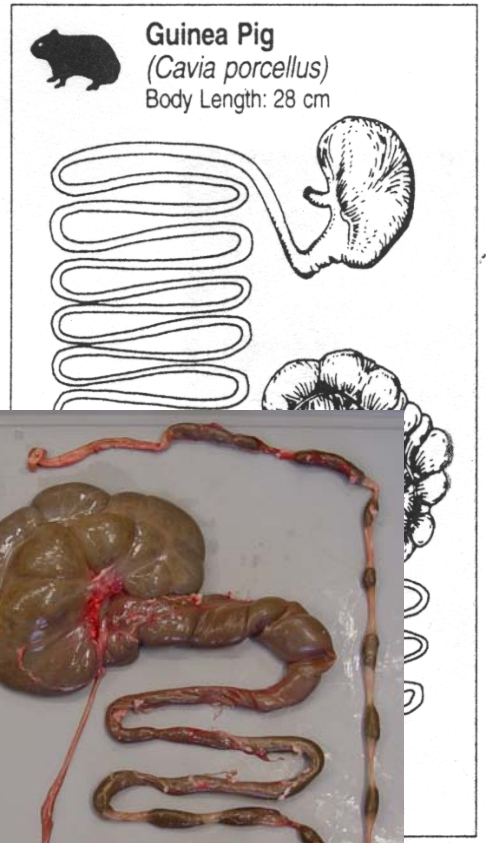
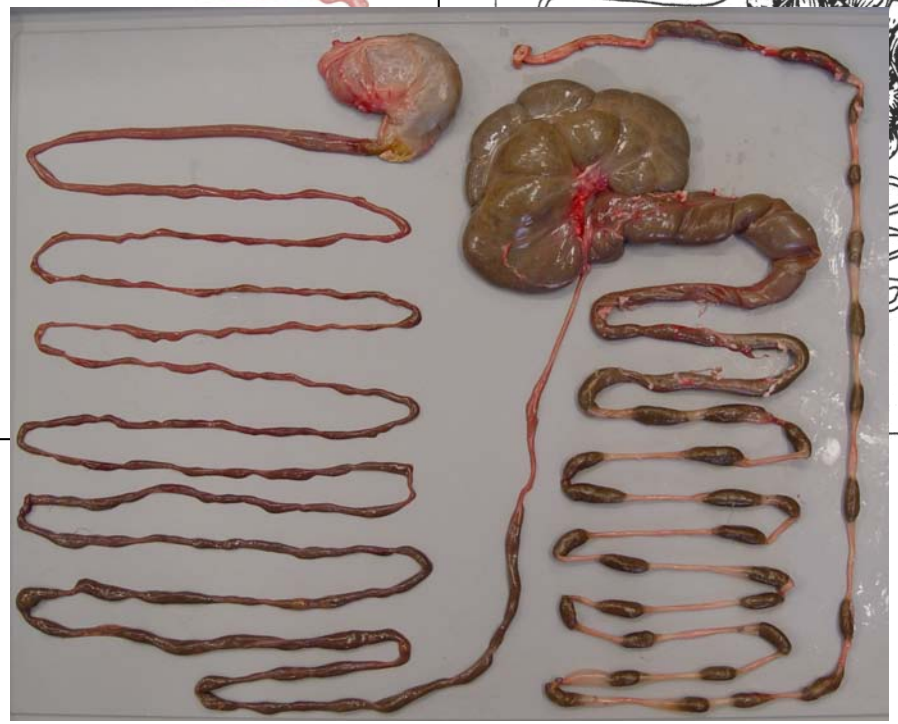








from Stevens und Hume (1995)
Besselmann (2005), Photo: A. Hug

Caecum fermenters

Agouti

Mara

Photo: D. Müller, M. Clauss

Caecum fermenters

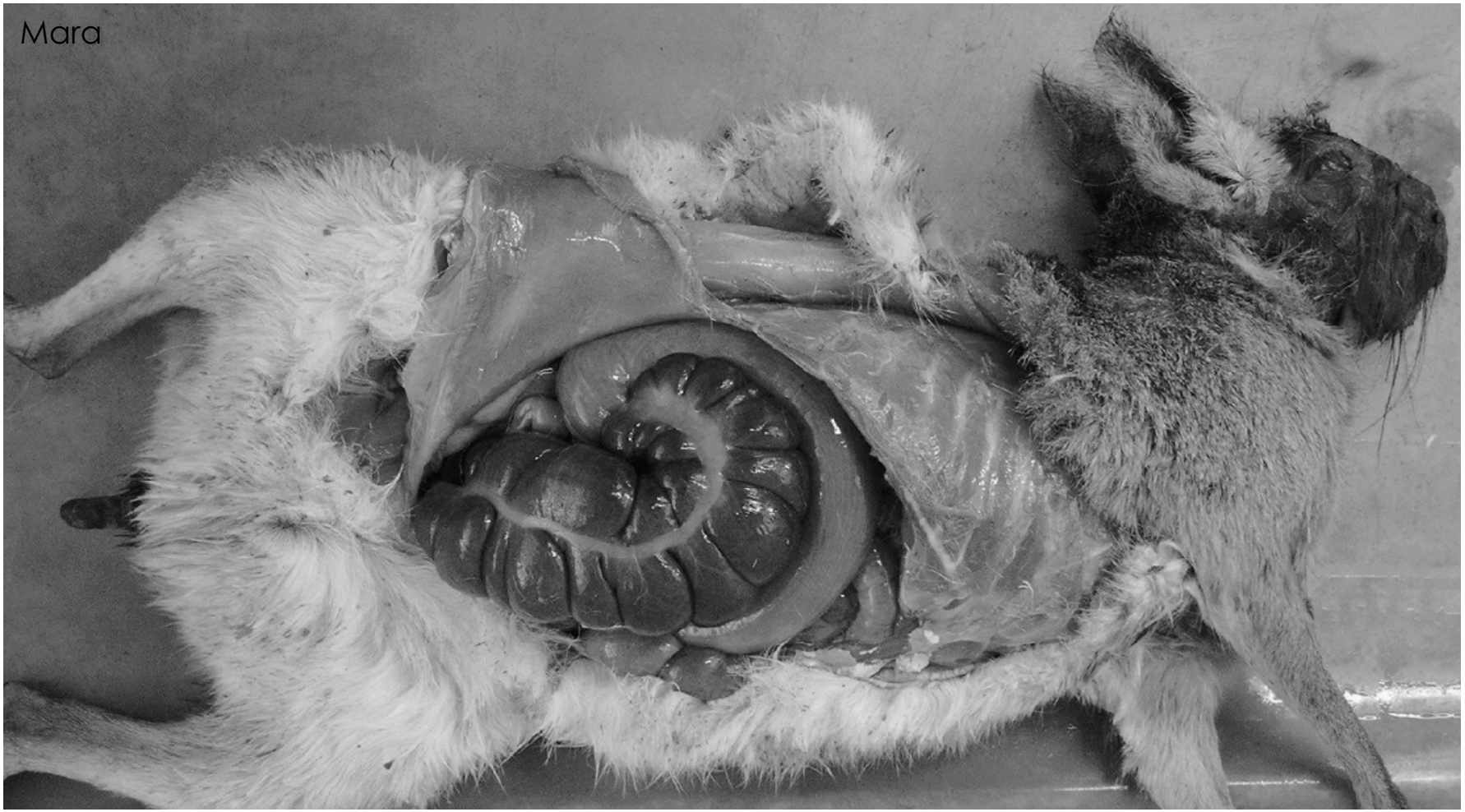
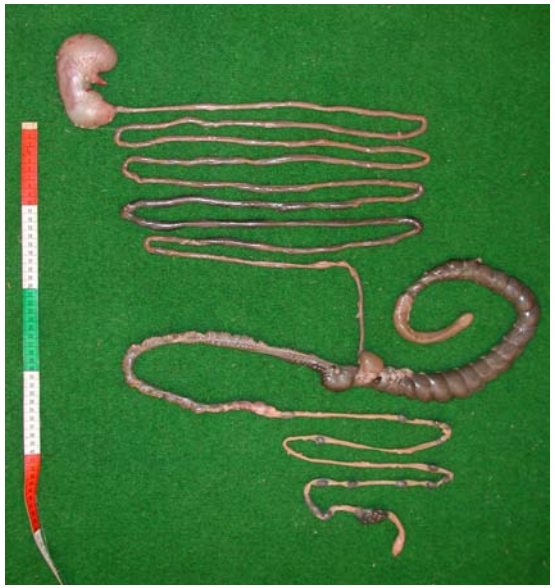
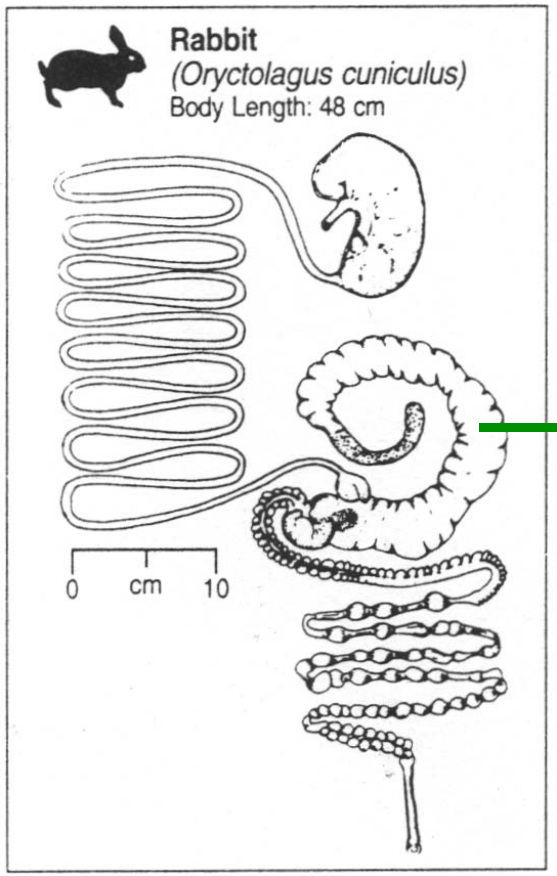


Photo: M. Clauss

Caecum fermenters



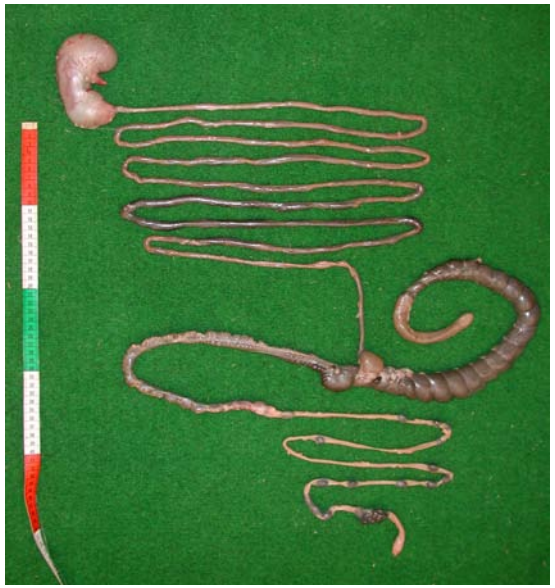


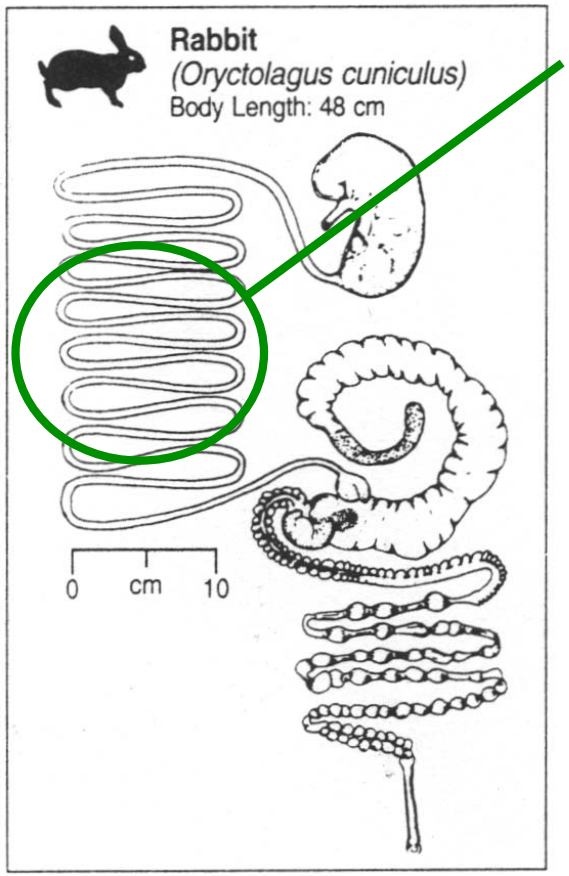
Fermentation:

Production of VFA
Acetate
Propionate
Butyrate

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

Caecum fermenters

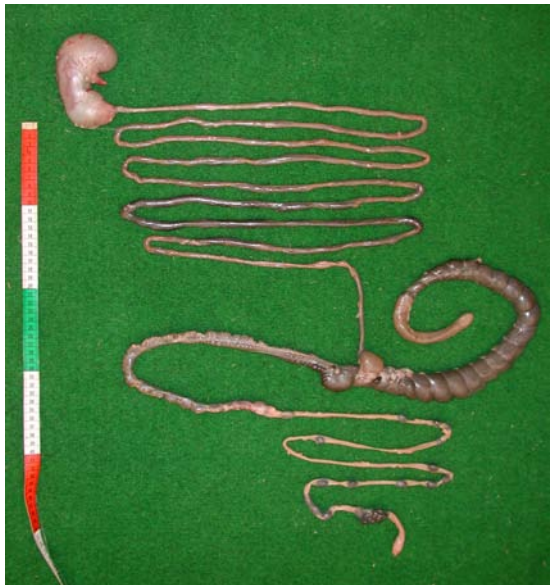


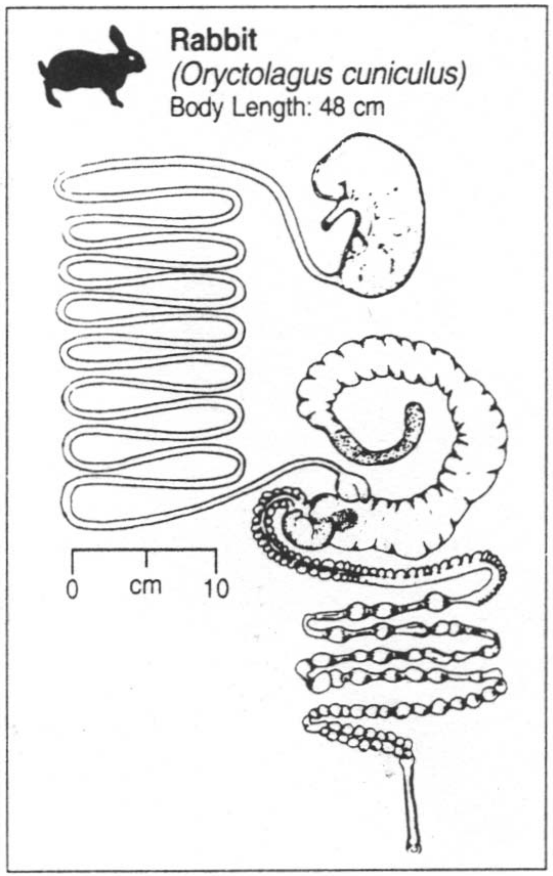


Fermentation after sites of aut-enzymatic digestion and absoprtion:

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

Caecum fermenters



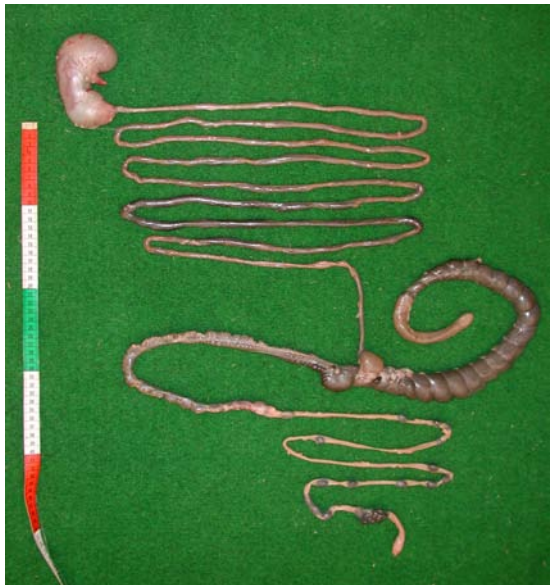


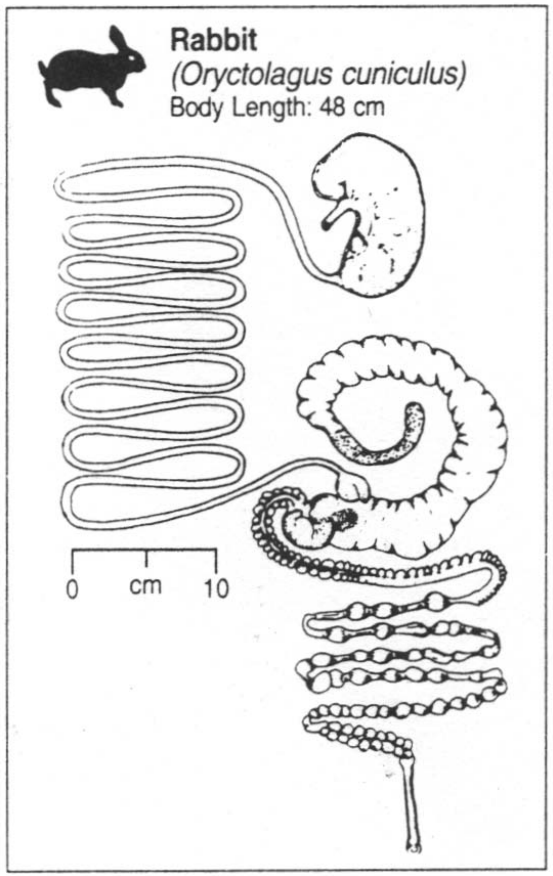
Fermentation <u>after</u> sites of aut-enzymatic digestion and absoprtion:

<u>Use</u> of easily digestible substances prior to fermentation

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

Caecum fermenters





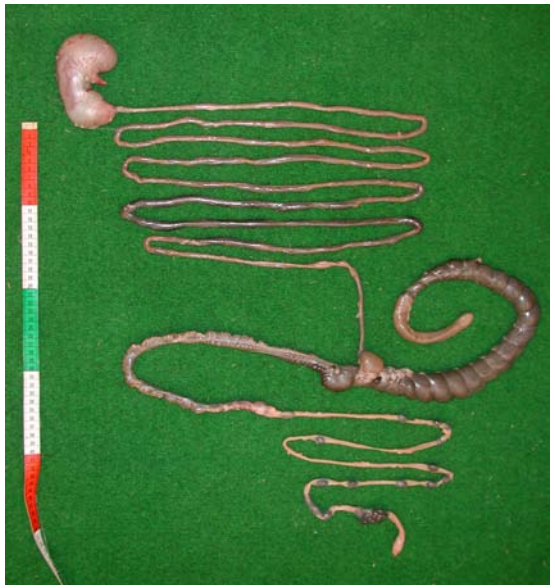
Fermentation <u>after</u> sites of aut-enzymatic digestion and absoprtion:

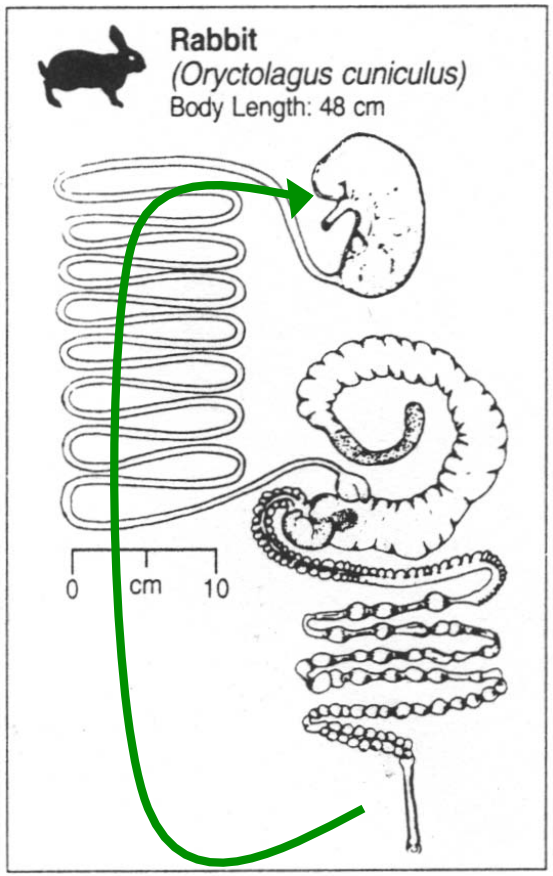
<u>Use</u> of easily digestible substances prior to fermentation

<u>Loss</u> of bacterial protein and bactrial products (B-Vitamins)

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

Caecum fermenters





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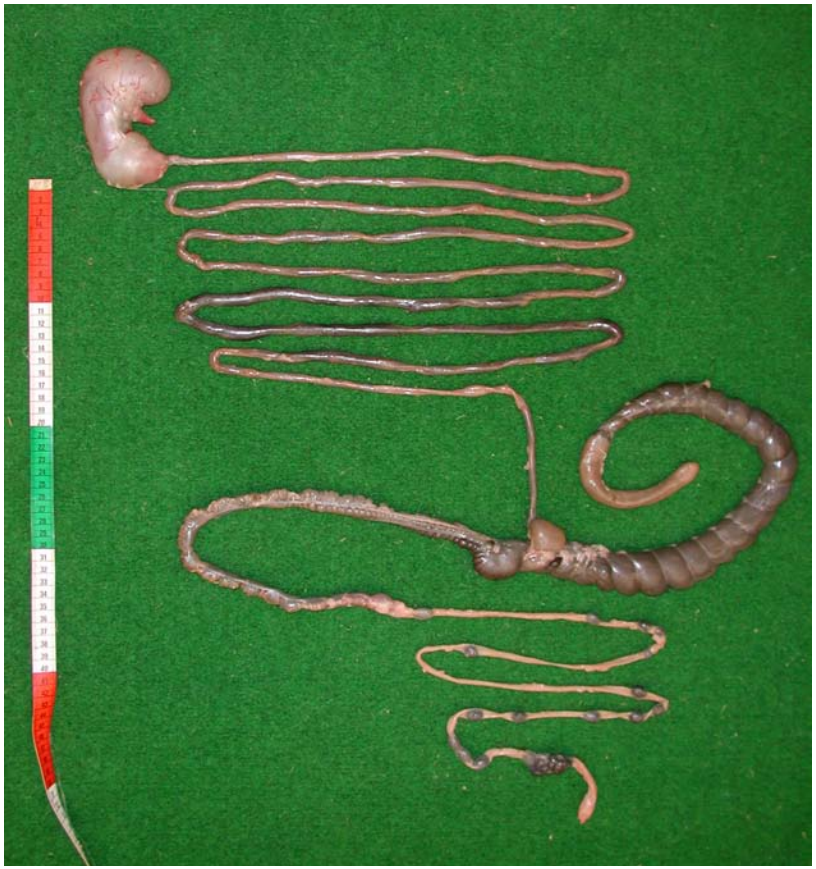
Coprophagy/ Caecotrphy

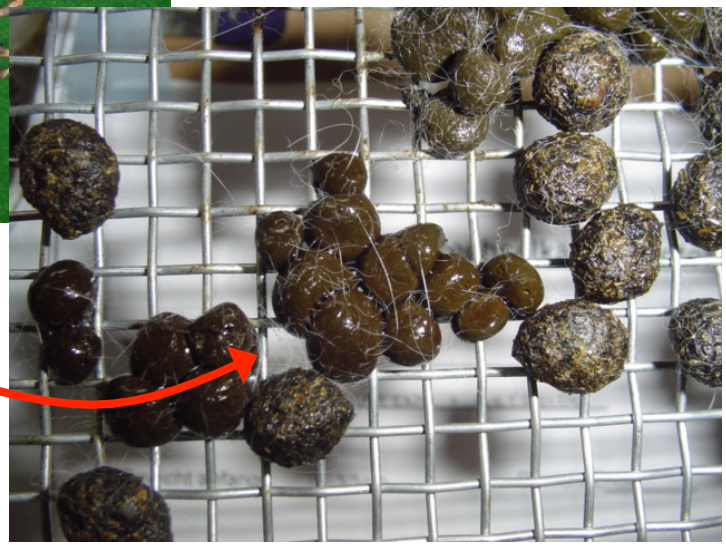
from Stevens und Hume (1995)
Photo: B. Burger

Coprophagy/Caecotrophy



Photos: B. Burger

Coprophagy/Caecotrophy



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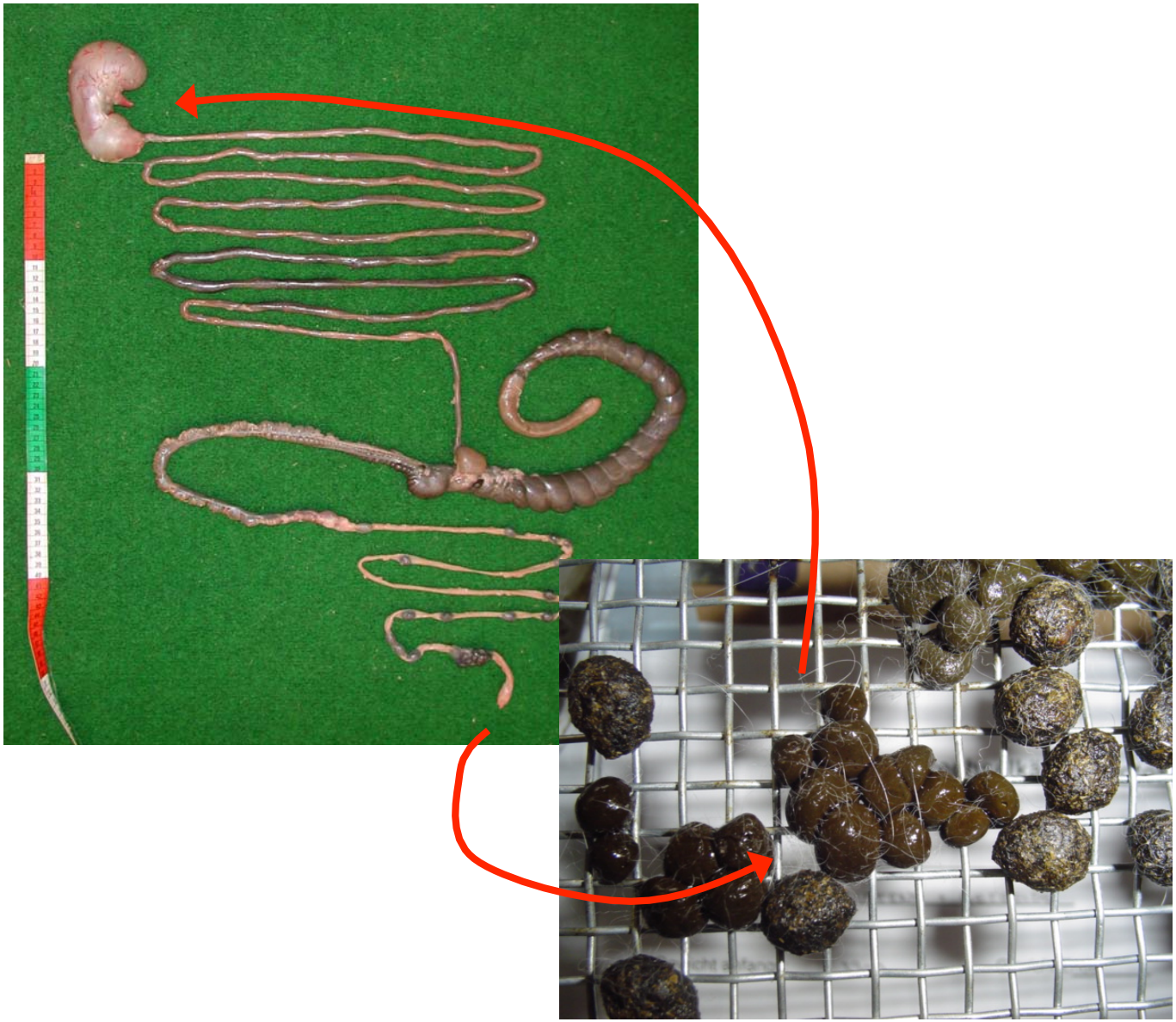
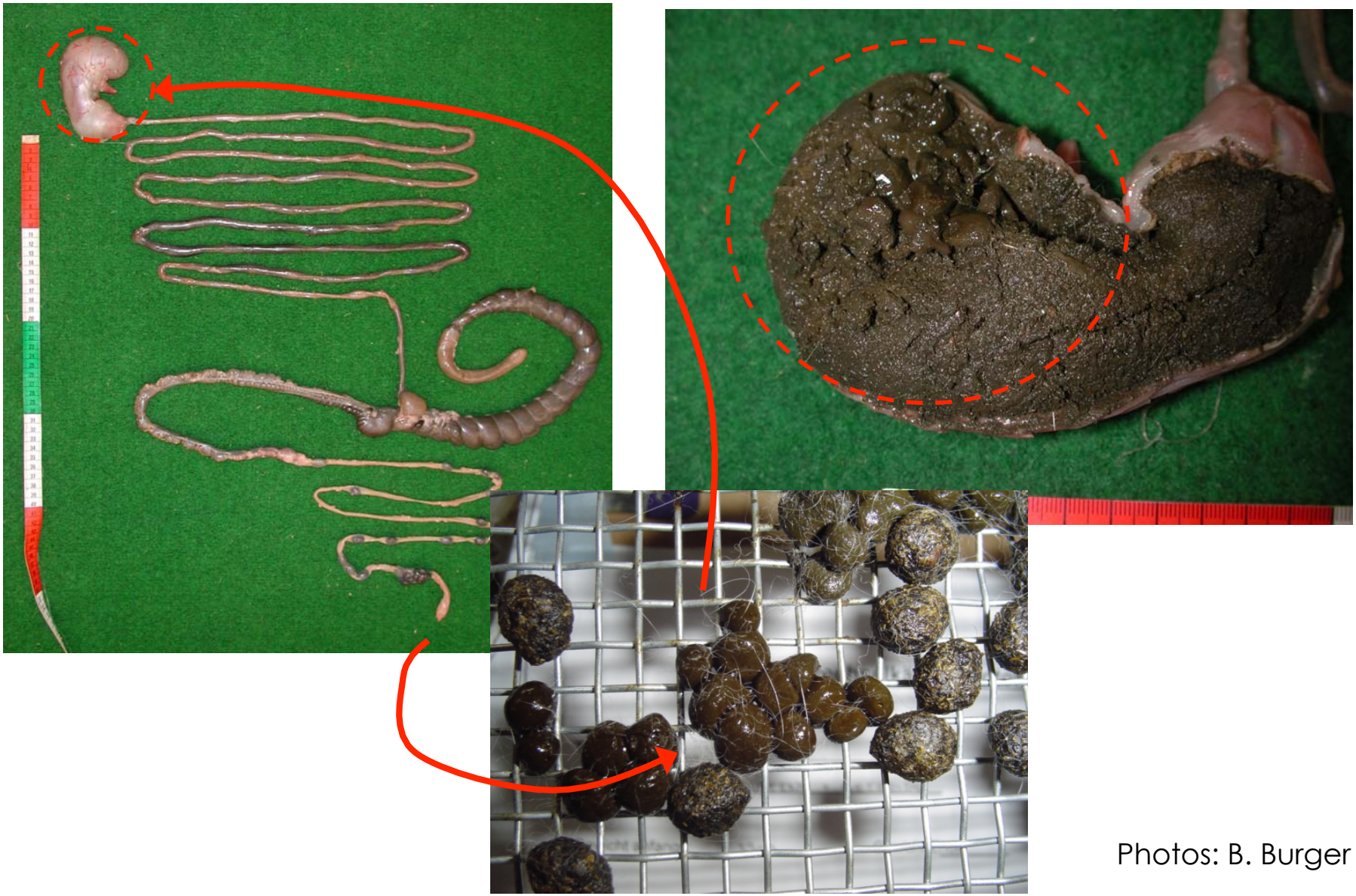
Coprophagy/Caecotrophy



Photos: B. Burger

Coprophagy/Caecotrophy



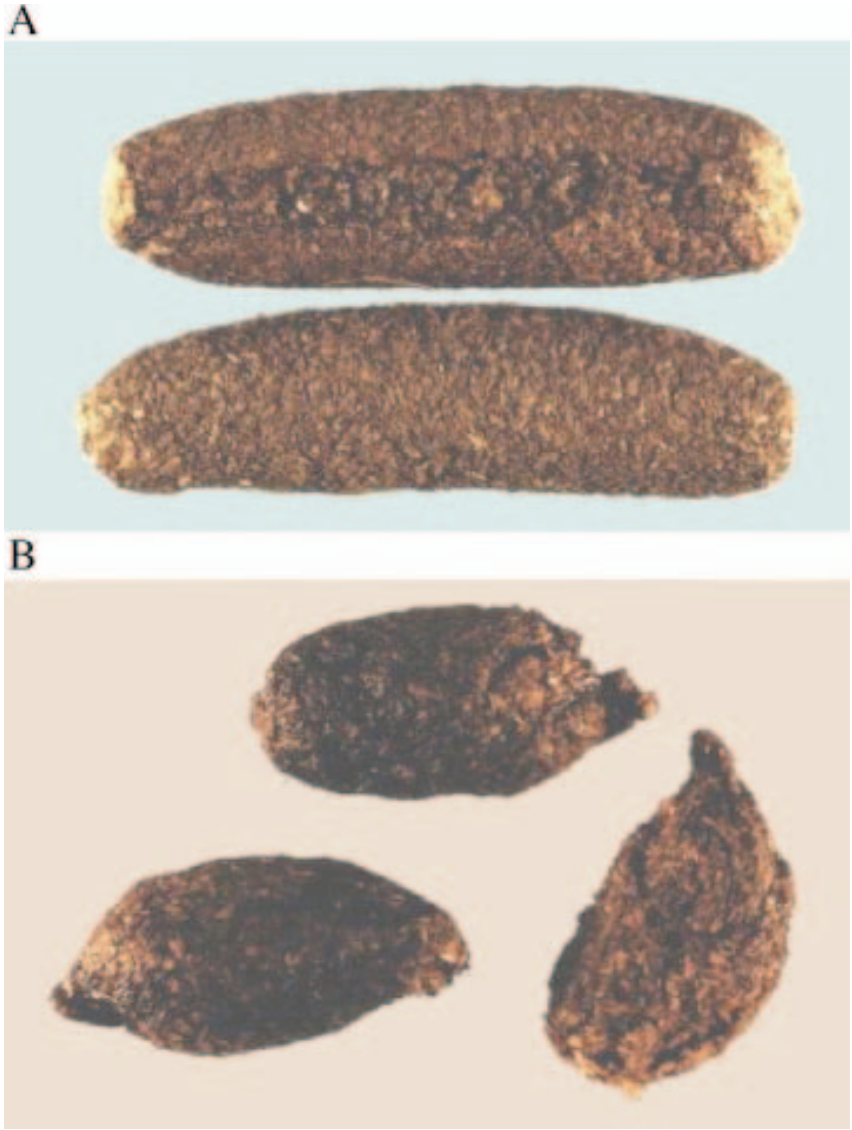
Photos: B. Burger

Coprophagy/Caecotrophy

Photos: B. Burger, M. Clauss

Coprophagy/Caecotrophy

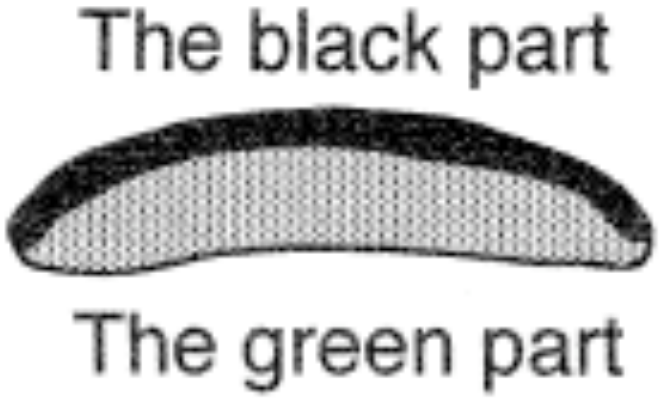
Ctenomys talarum



Martino et al. (2007)

Three kinds of faeces *(Myocastor coipus)*

Soft feces



Hard feces

from Takahashi & Sakaguchi (1998)

Coprophagy/Caecotrophy

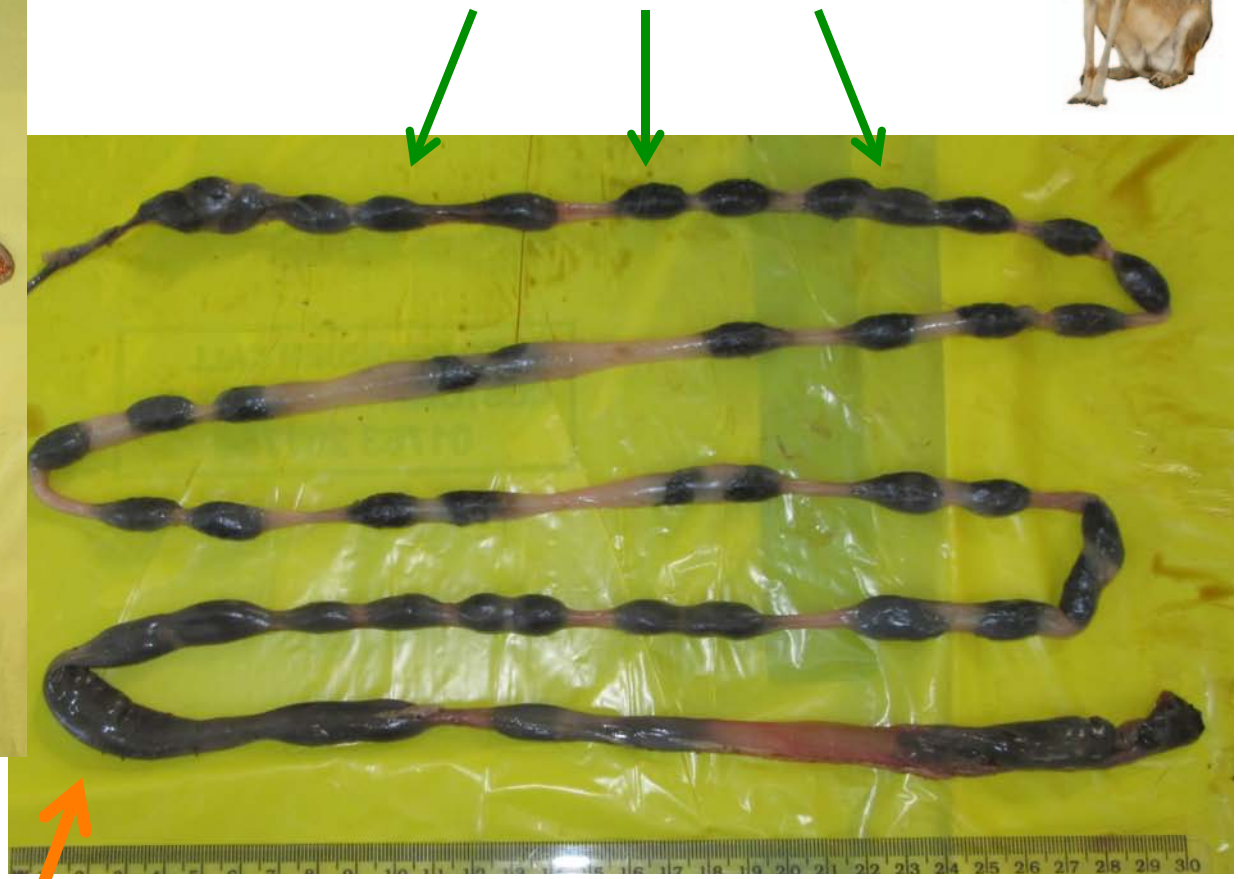
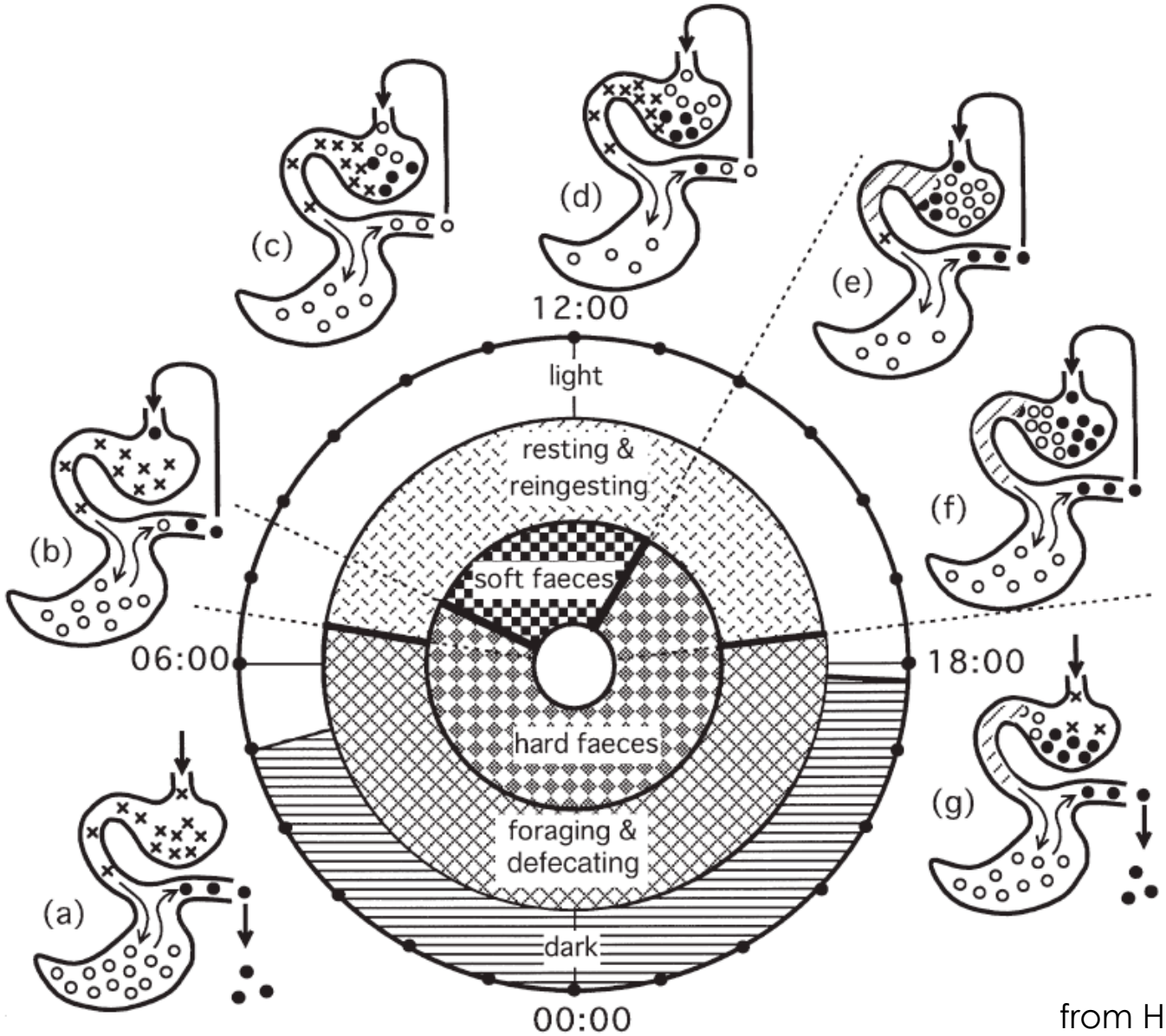


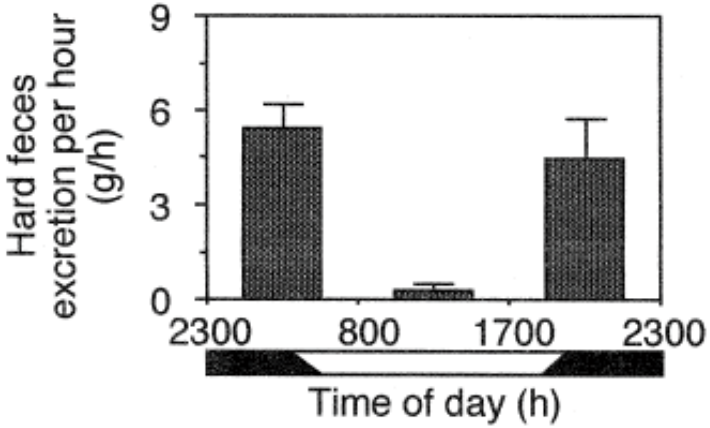
Photo: Pablo Rodríguez López del Río

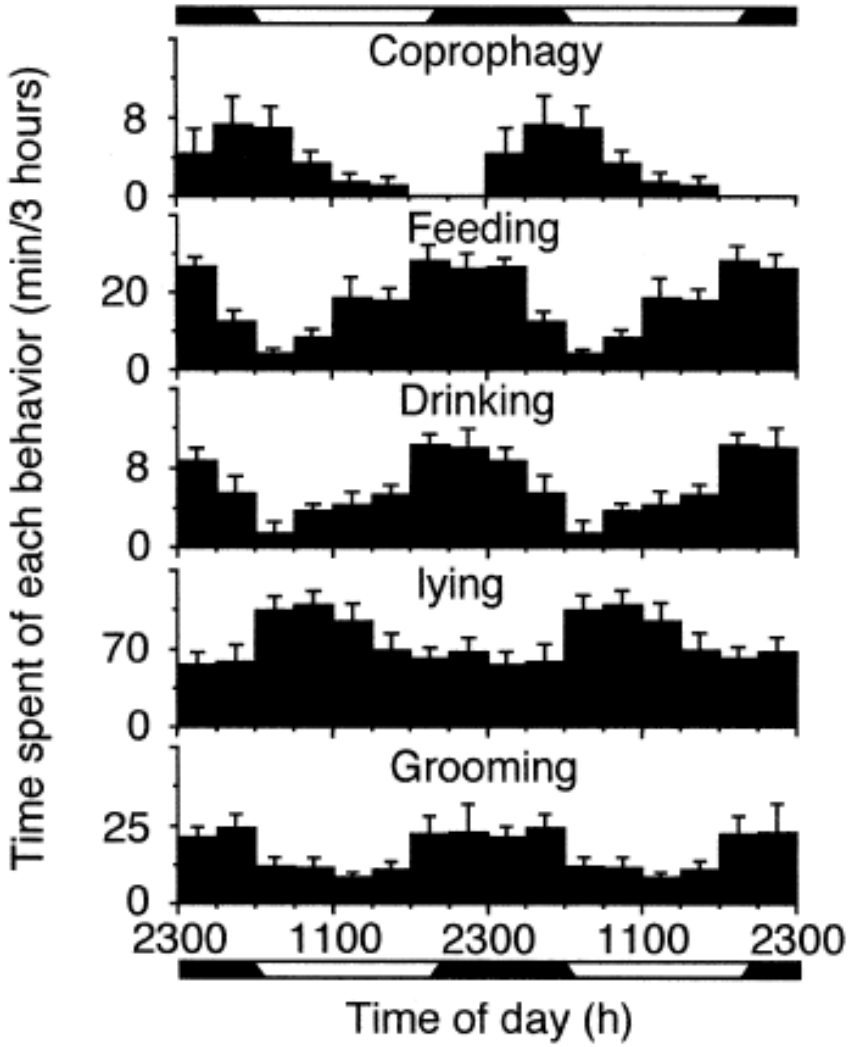
Coprophagy/Caecotrophy



from Hirakawa (2001)

Coprophagy/Caecotrophy





from Takahashi & Sakaguchi (1998)

Coprophagy/Caecotrophy

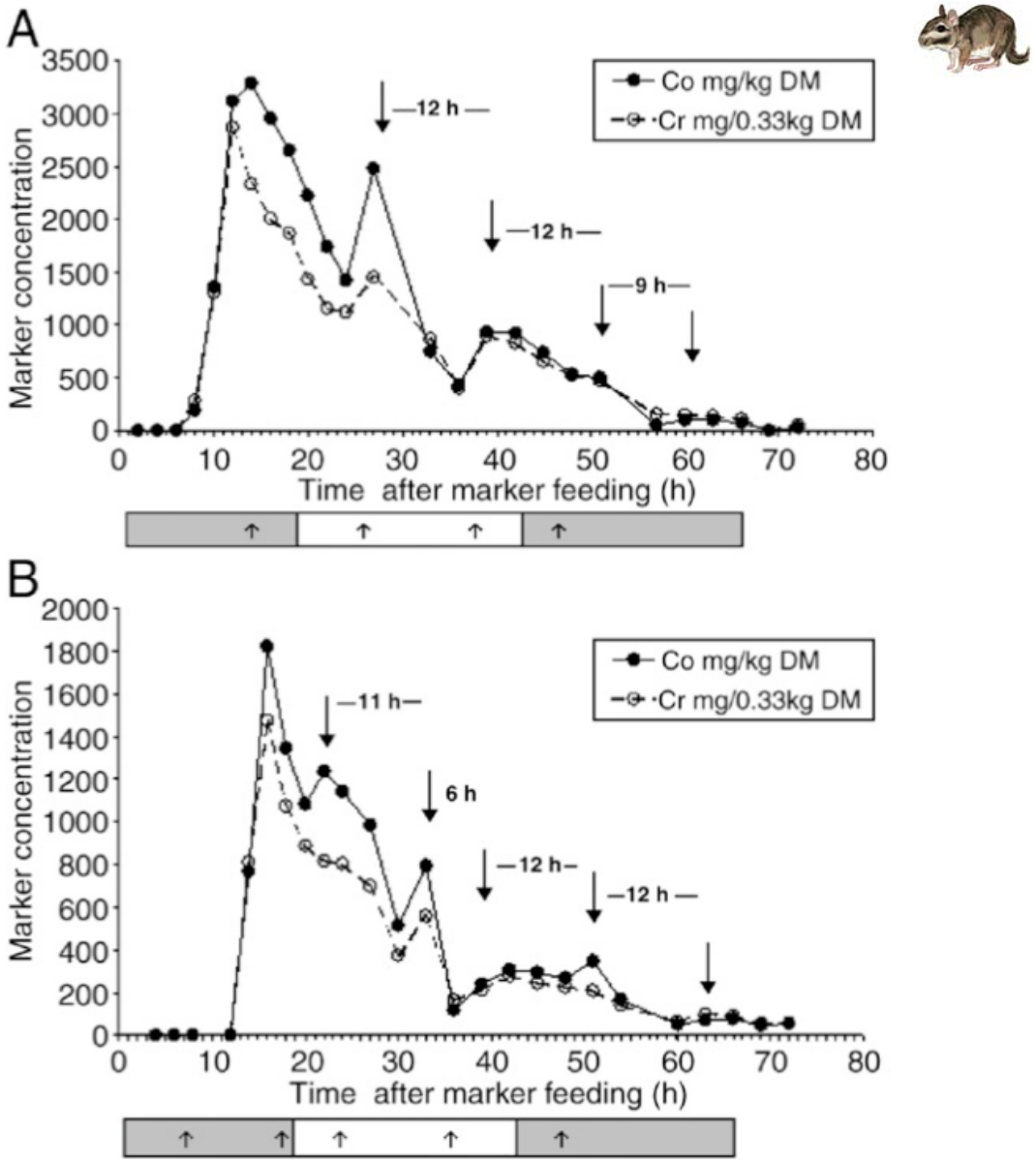
Photo: A. Tschudin

Coprophagy/Caecotrophy

Photo: D. Besselmann

Coprophagy/Caecotrophy

Coprophagy and ingesta passage patterns



from Clauss et al. (2007)

Why coprophagy?

Comparative Composition of Hard Feces and Cecotropes

Constituent (%)	Hard feces	Cecotropes	References
Crude protein	9.2	28.5	Eden (1940)
Ether extract	1.7	1.1	
Crude fiber	28.9	15.5	
Nitrogen free extract	52.0	43.7	
Ash	8.2	11.2	
Phosphorus	1.3	2.2	
Sodium	0.11	0.22	
Potassium	0.57	1.80	
Dry matter	52.7	38.6	Fekete and Bokori (1985)
Ash	13.7	15.2	
Crude fiber	30.0	17.8	
Crude protein	15.4	25.7	
Gross energy (kcal/kg)	4350	4540	
Crude protein	14.8	37.8	Huang *et al.* (1954)
Fat	1.8	1.5	
Ash	14.8	14.3	
Crude fiber	27.8	14.3	
Crude protein	18.7	37.4	Thacker and Brandt (1955)
Ether extract	4.3	3.5	
Ash	13.2	13.1	
Lignin	12.3	7.5	
Cellulose	46.6	27.2	
Other carbohydrates	4.9	11.3	
Cell wall constituents	78.1	45.1	Uden and Van Soest (1982)
Cellulose	35.8	20.3	
Hemicellulose	31.1	19.1	
Acid detergent fiber	47.0	26.0	
Lignin	11.0	5.8	

Table 1: **The concentrations of nitrogen (% in dry matter) in food, caecal contents, caecotrophes, and faeces of nine hindgut fermentors**

	Food	Caecal contents	Faeces	Caeco-trophes
Scandinavian lemming *Lemmus lemmus*	1.8	5.2	1.7	nm
Water vole *Arvicola terrestris*	nm	6.0	1.9	6.3
Rat *Rattus norvegicus*	2.1	3.1	1.9	3.5
Guinea pig *Cavia porcellus*	1.9	3.1	1.7	4.7
Chincilla *Chincilla laniger*	2.0	2.7	1.8	3.4
Nutria *Myocaster coypus*	2.7	3.3	2.7	nm
Rabbit *Oryctolagus cuniculus*	2.4	4.2	1.5	4.6
Common ringtail possum *Pseudocheirus peregrinus*	1.3	3.9	1.2	4.6
Donkey *Equus asinus*	1.3	1.2	0.9	–

nm = not measured

Effect of coprophagy on fibre digestion

Diet	Coprophagy[a]	Digestibility (%) DM	Digestibility (%) ADF	References
High-alfalfa pellets	+	48.3	13.1	Robinson *et al.* (1985)
High-alfalfa pellets	−	45.3	14.2	
Fresh grass	+	49.8	20.4	Robinson *et al.* (1985)
Fresh grass	−	52.6	8.7	
Laboratory diet	+	60.8	15.7	Stephens (1976)
Laboratory diet	−	58.2	12.1	

[a] +, Coprophagy permitted; −, coprophagy prevented.

Effect of coprophagy on protein digestion

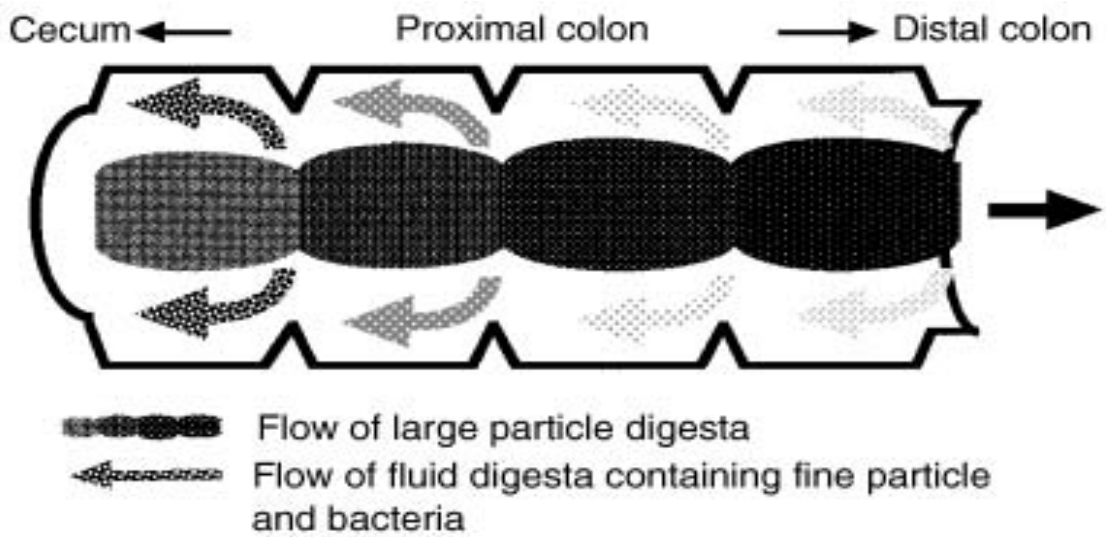
Dietary protein source	Coprophagy[b]	Nitrogen digestibility (%)	Nitrogen retention (g/day)
Alfalfa meal	+	64.9	1.10
Alfalfa meal	−	50.8	0.93
Soybean meal	+	76.9	0.78
Soybean meal	−	64.0	0.65
Fresh grass	+	77.6	0.78
Fresh grass	−	67.6	0.44

[a] From Robinson *et al.* (1985).

[b] +, Coprophagy allowed; −, coprophagy prevented by a collar.

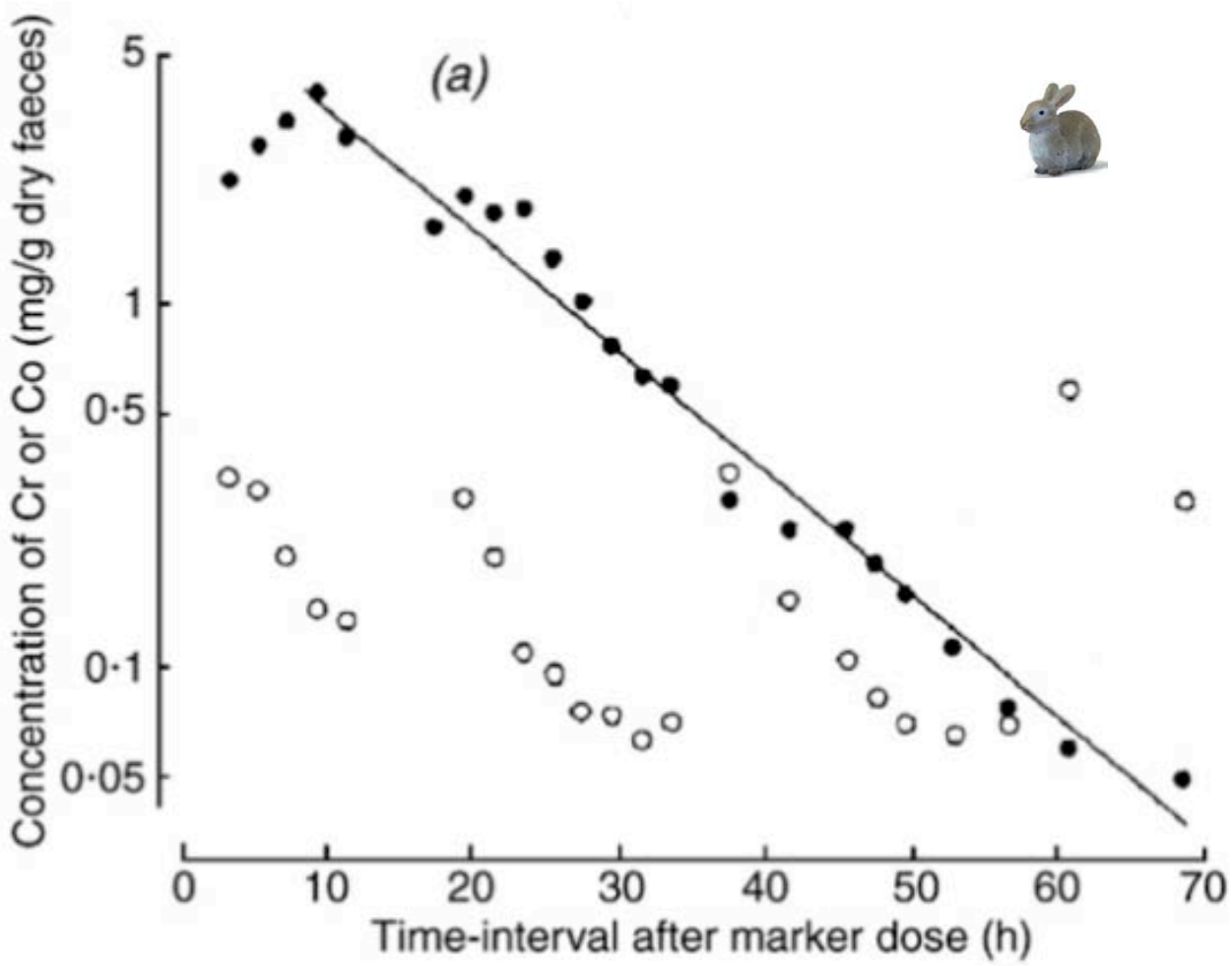
Sorting of ingesta for caecotroph formation

Wash back mechanism
(Rabbit)



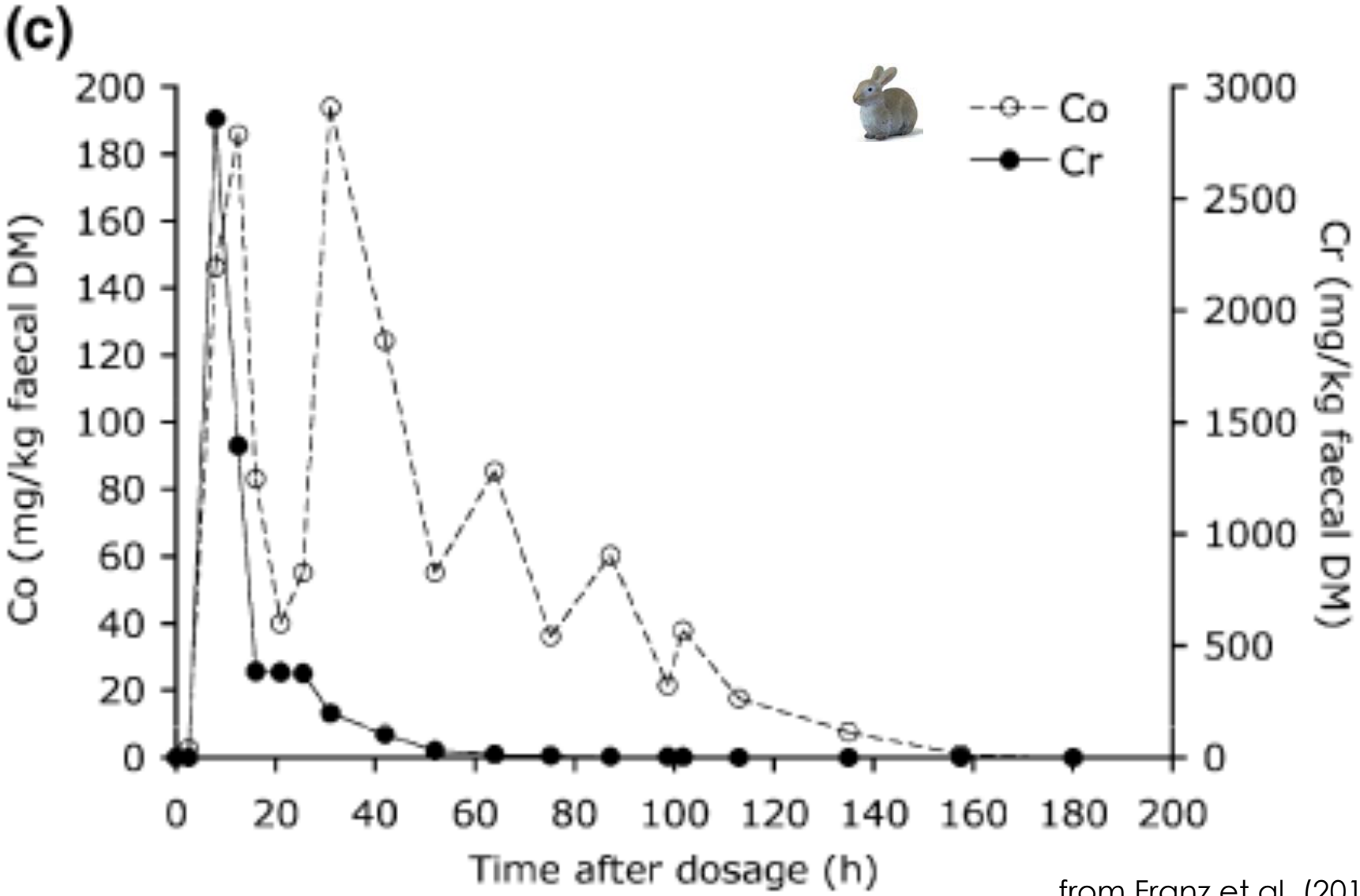
from Sakaguchi (2003)

Coprophagy and ingesta passage patterns



from Sakaguchi et al. (1987)

Coprophagy and ingesta passage patterns



from Franz et al. (2011)

Sorting of ingesta for caecotroph formation

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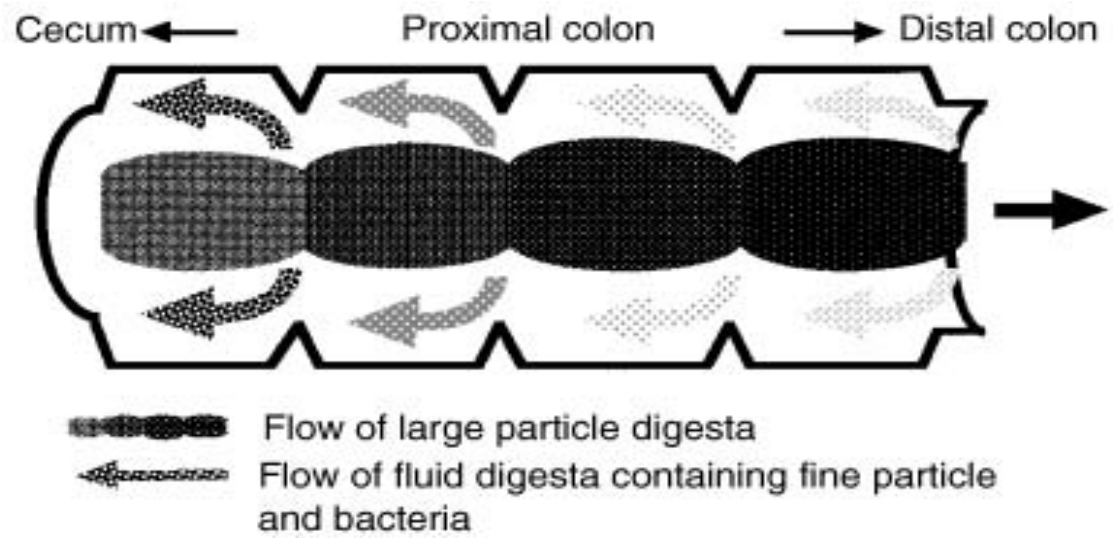
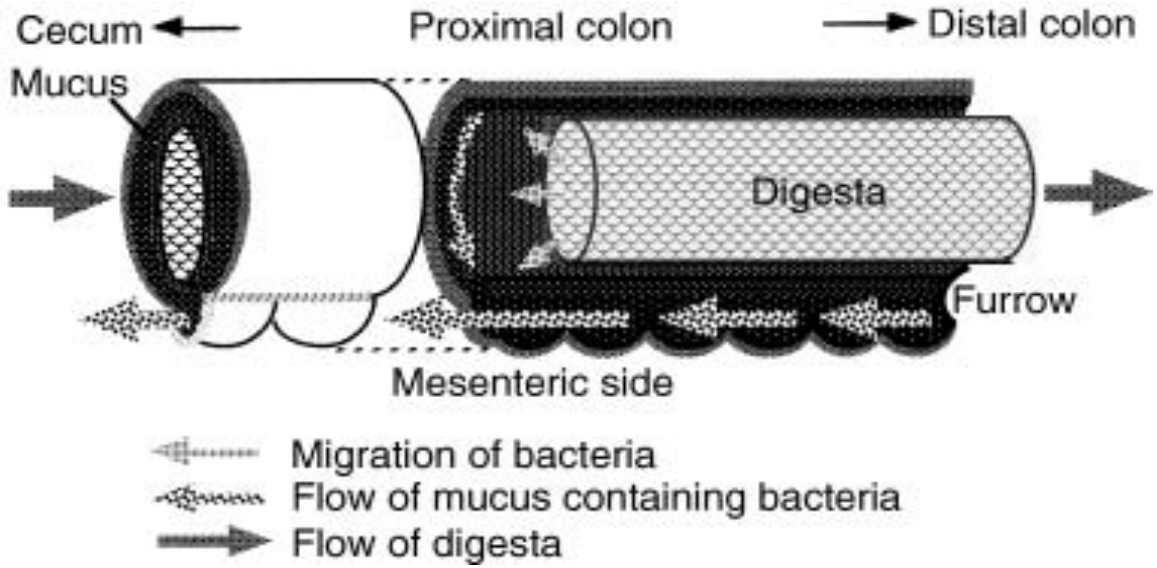


Mucus trap mechanism
(Guniea pig, Chinchilla)



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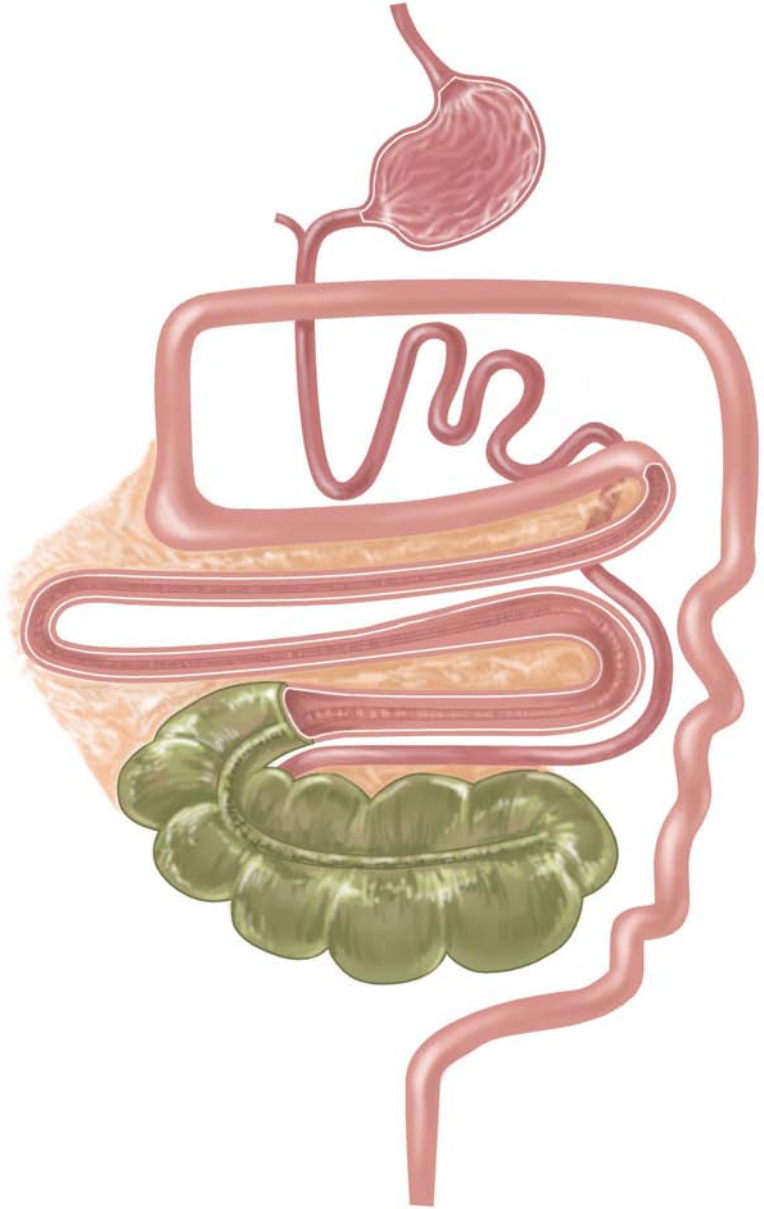
The colonic groove / furrow



from Besselmann (2005)

The colonic groove / furrow

from Besselmann (2005)

The colonic groove / furrow

Mara

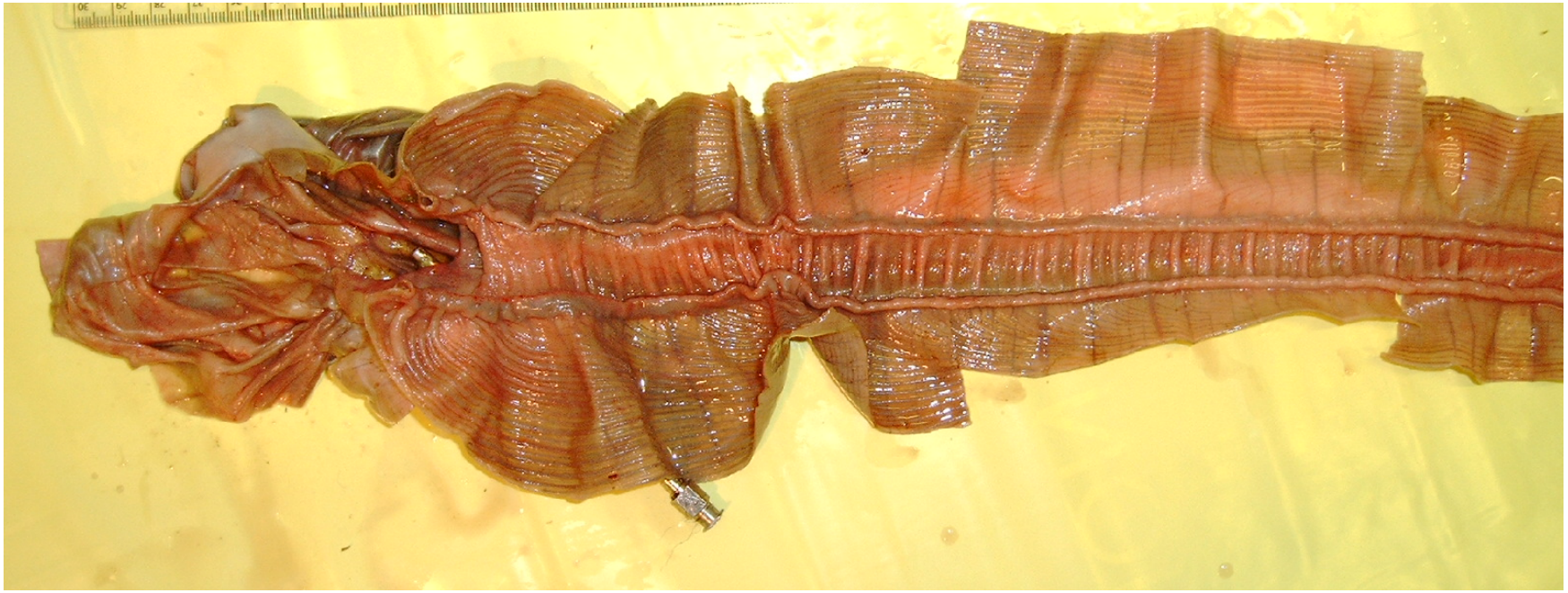


Photo: M. Clauss

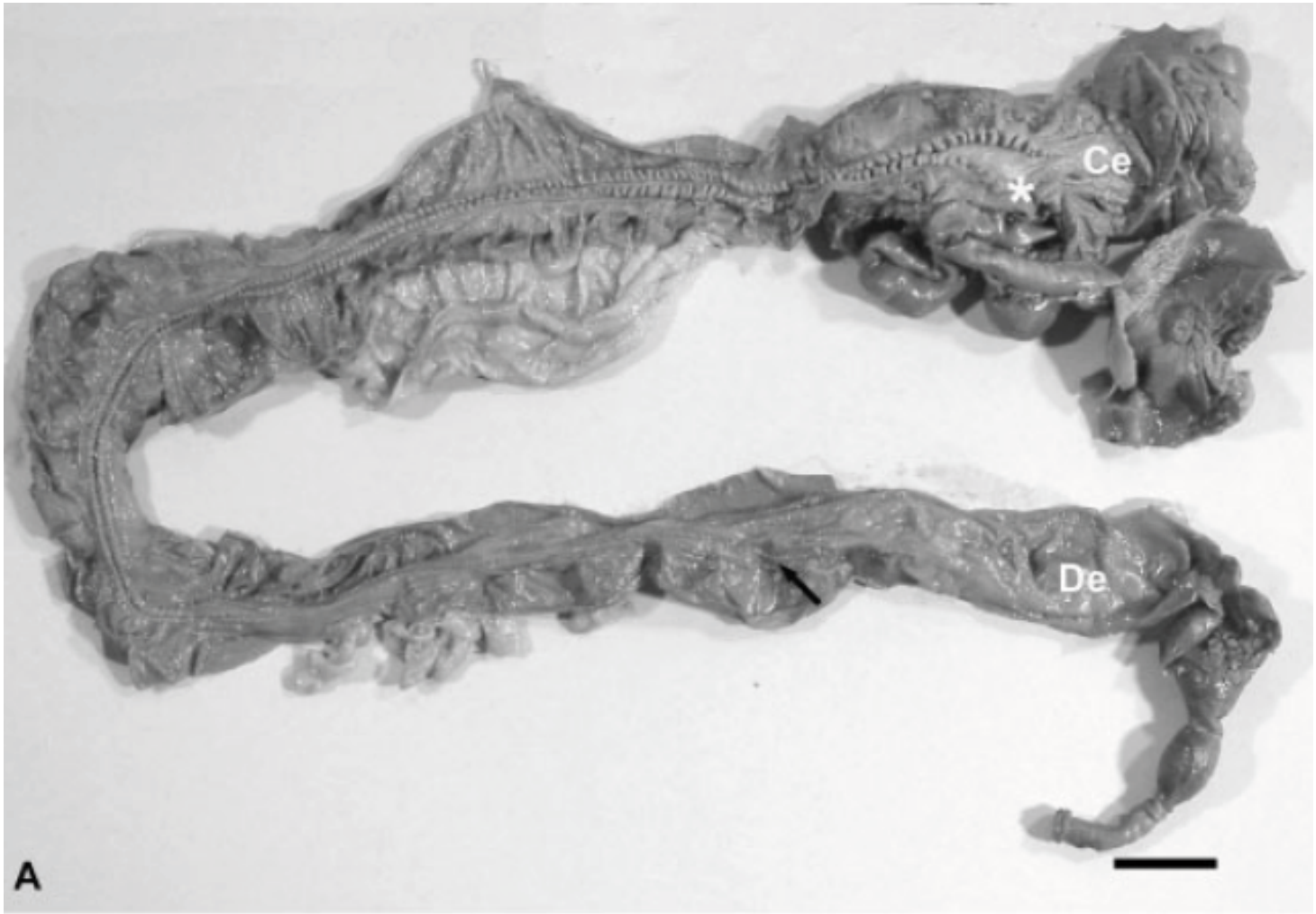
The colonic groove / furrow

Capybara

Photo: M. Clauss

The colonic groove / furrow

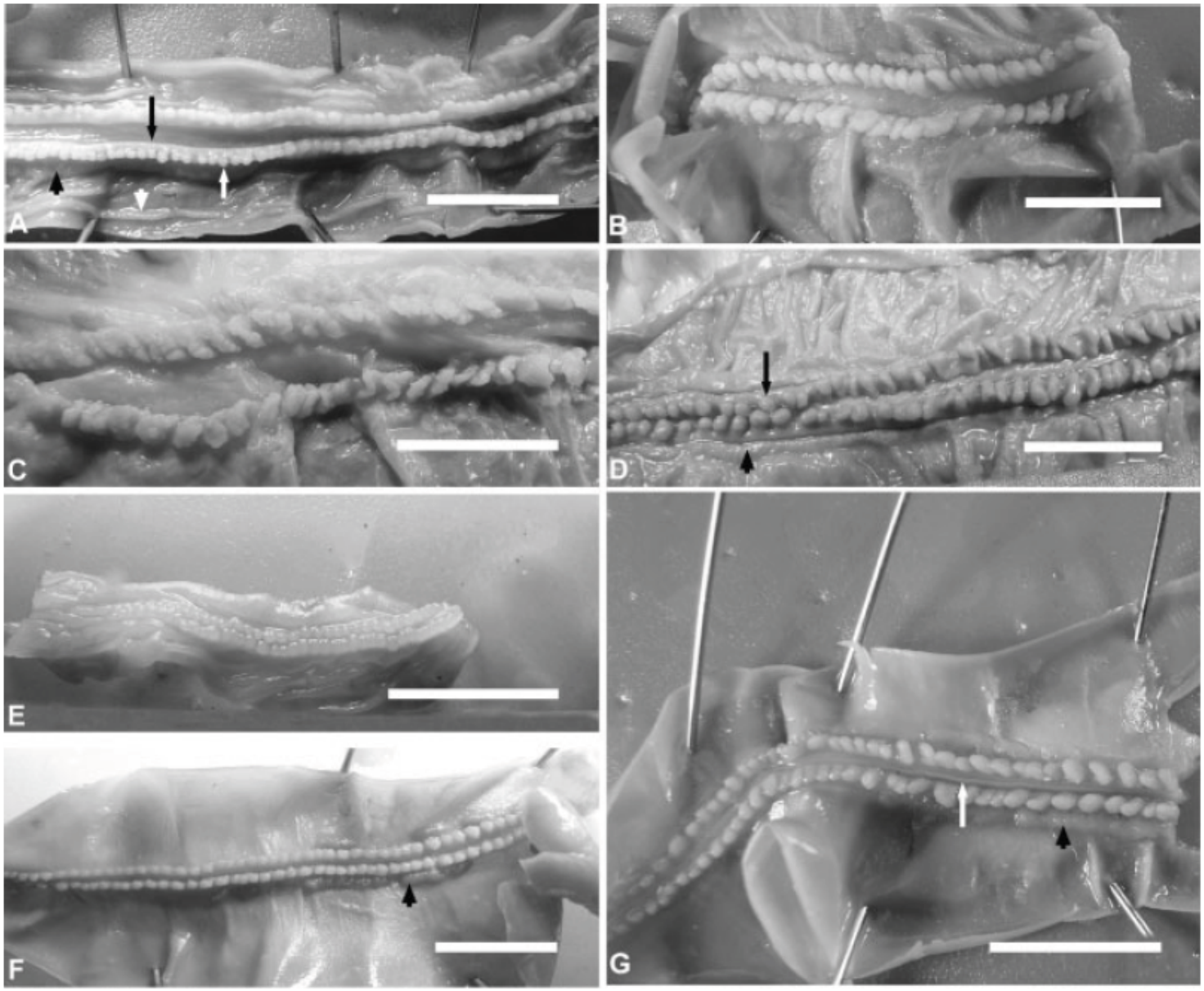
Mole-rat (*Bathyergus suillus*)



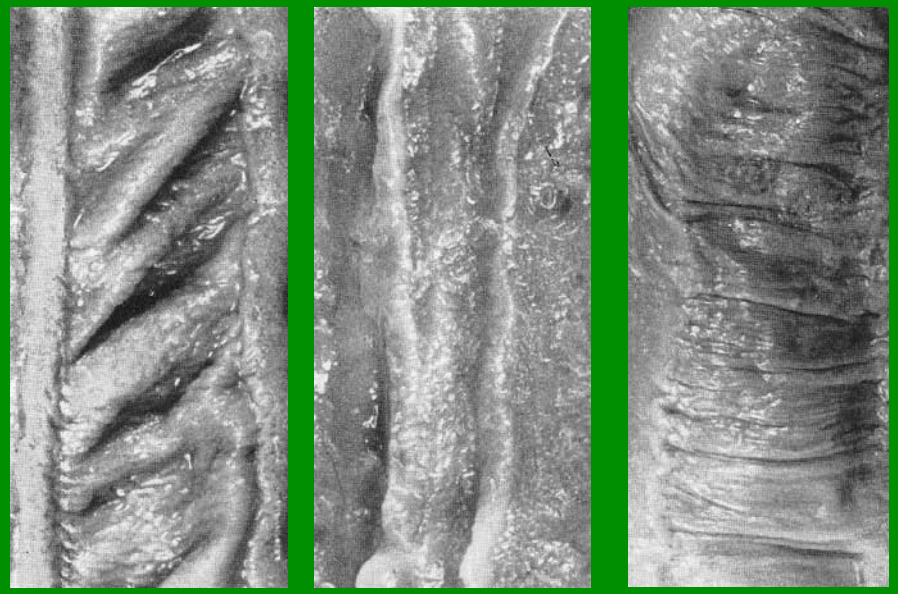
from Kotze et al. (2009)

The colonic groove / furrow

Mole-rats



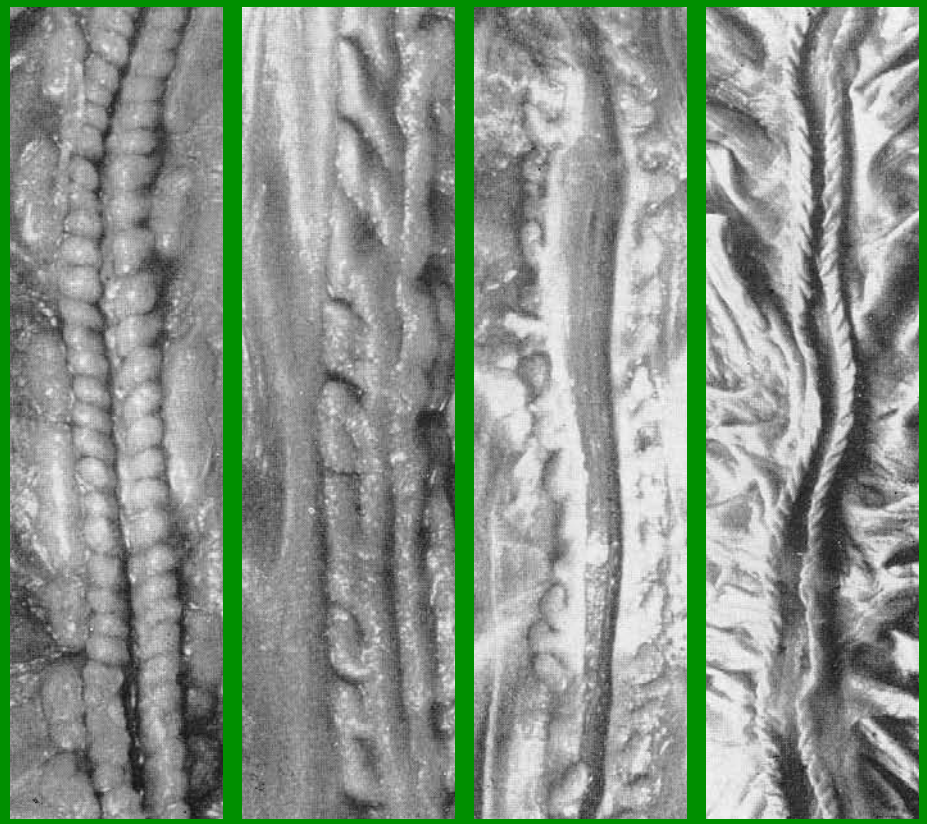
from Kotze et al. (2009)



Nutria (*Myocastor coypus*)

Brush-tailed procupine (*Atherurus africanus*)

Springhare (*Pedetes capensis*)



Bocage□s mole rat (*Cryptomys bocagei*)

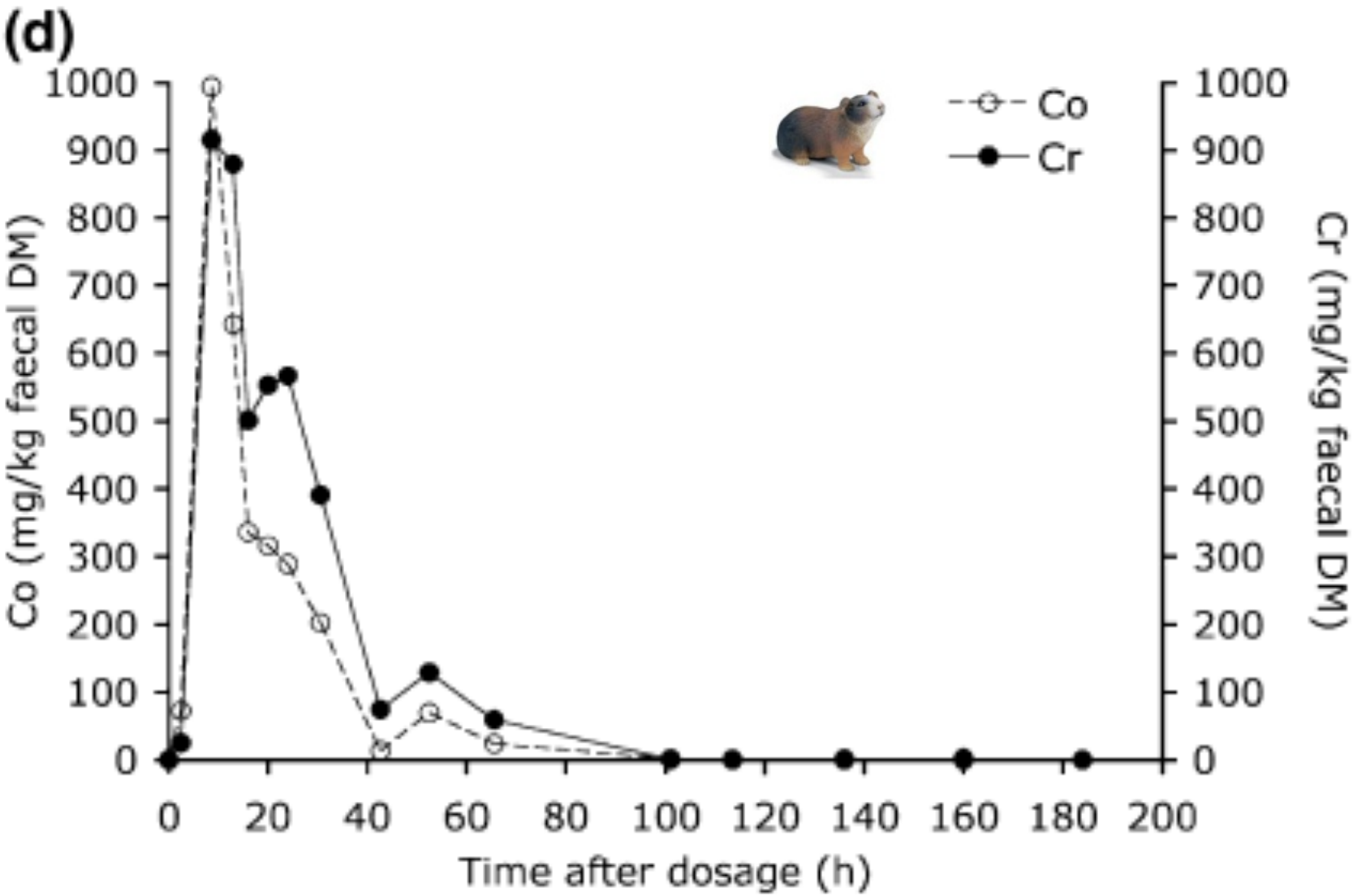
Hutia (*Capromys prehensilis*)

Cape mole rat (*Goerychus capensis*)

Grasscutter (*Thryonomys swinderinus*)

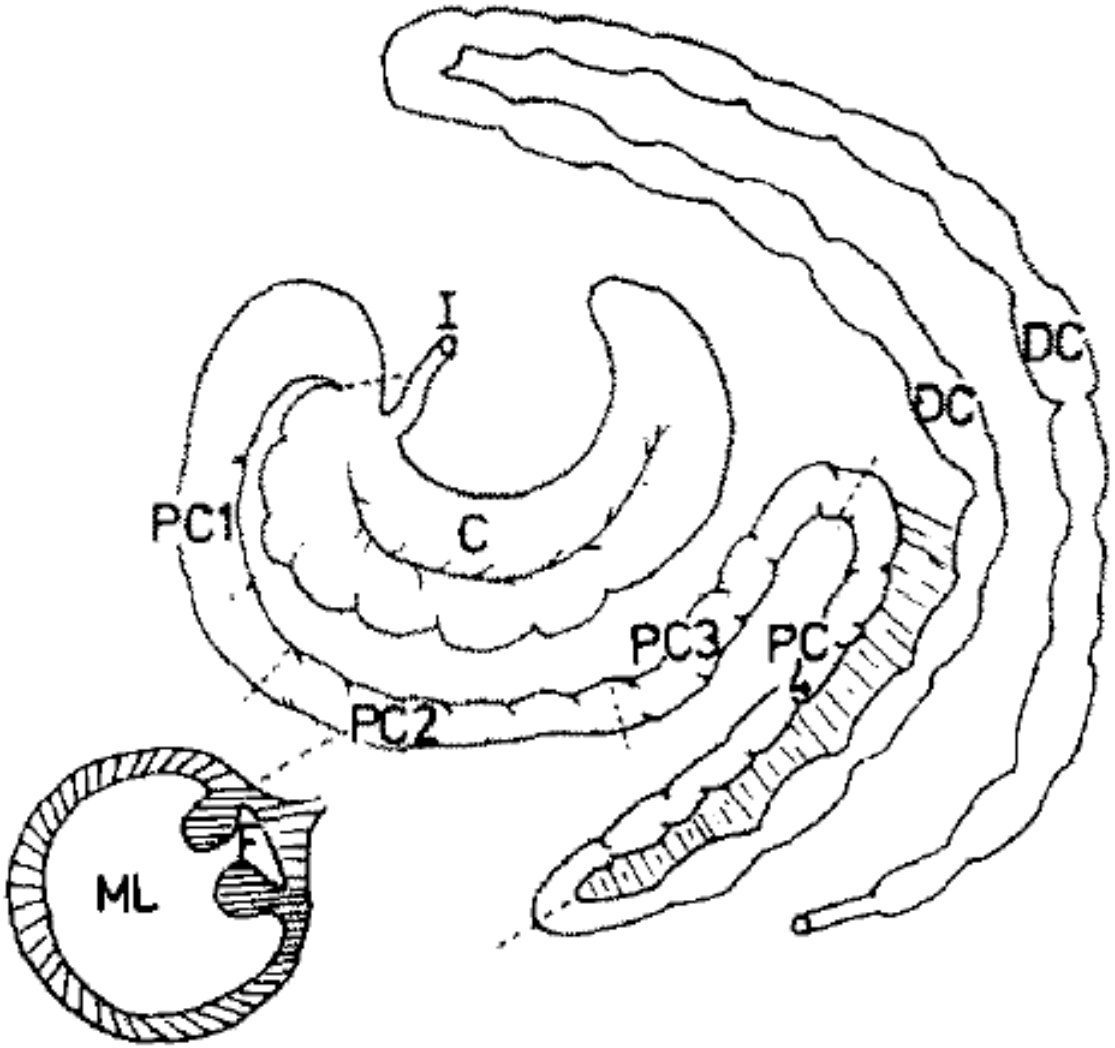
from Gorgas (1967)

Coprophagy and ingesta passage patterns



from Franz et al. (2011)

The colonic groove / furrow



from Holtenius & Björnhag (1985)

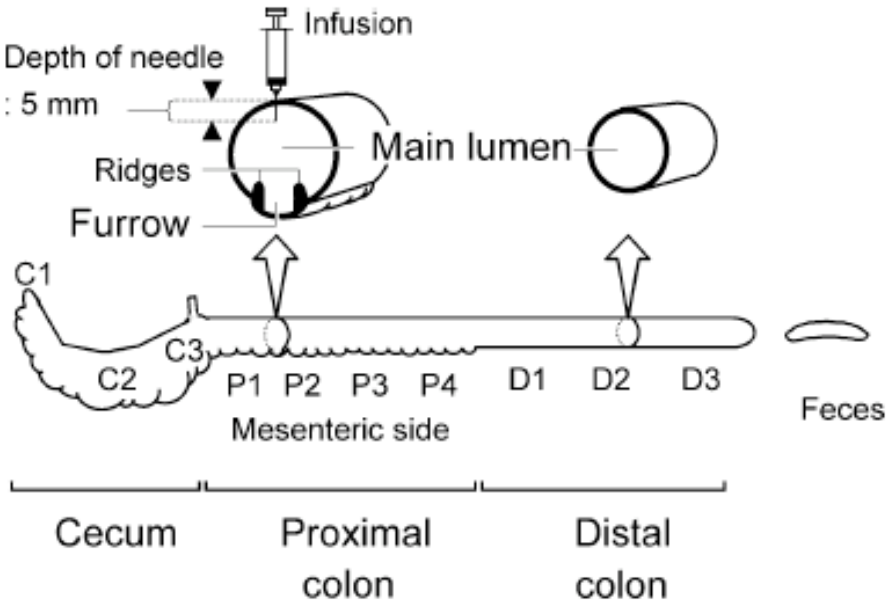
The colonic groove / furrow

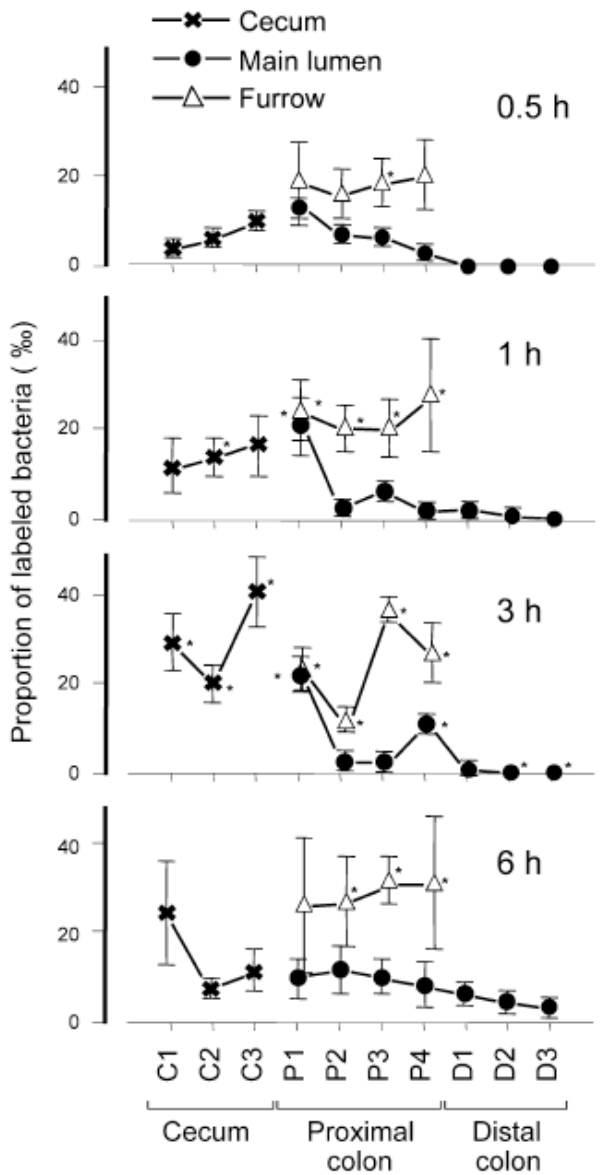
Table 2. The concentration of nitrogen, ATP and dry matter (DM) in contents of the main lumen and of the furrow in proximal colon of guinea-pigs

	Main lumen		Furrow		
	Mean	SD	Mean	SD	
Nitrogen mg/g DM, $N = 39$					
Colon, proximal part 1	30.3	6.3	43.0	11.9	$P < 0.001$
Colon, proximal part 2	25.9	6.2	43.4	11.2	$P < 0.001$
Colon, proximal part 3	23.8	5.7	39.3	9.4	$P < 0.001$
ATP μg/g DM, $N = 22$					
Colon, proximal part 1	298	188	512	300	$P < 0.001$
Colon, proximal part 2	194	144	270	148	$P < 0.001$
Colon, proximal part 3	88	56	165	66	$P < 0.005$
Dry matter %, $N = 43$					
Colon, proximal part 1	18.3	2.0	19.2	4.7	$P < 0.05$
Colon, proximal part 2	19.9	2.4	22.8	4.8	$P < 0.001$
Colon, proximal part 3	20.7	2.1	23.2	4.4	$P < 0.001$

from Holtenius & Björnhag (1985)

The colonic groove / furrow





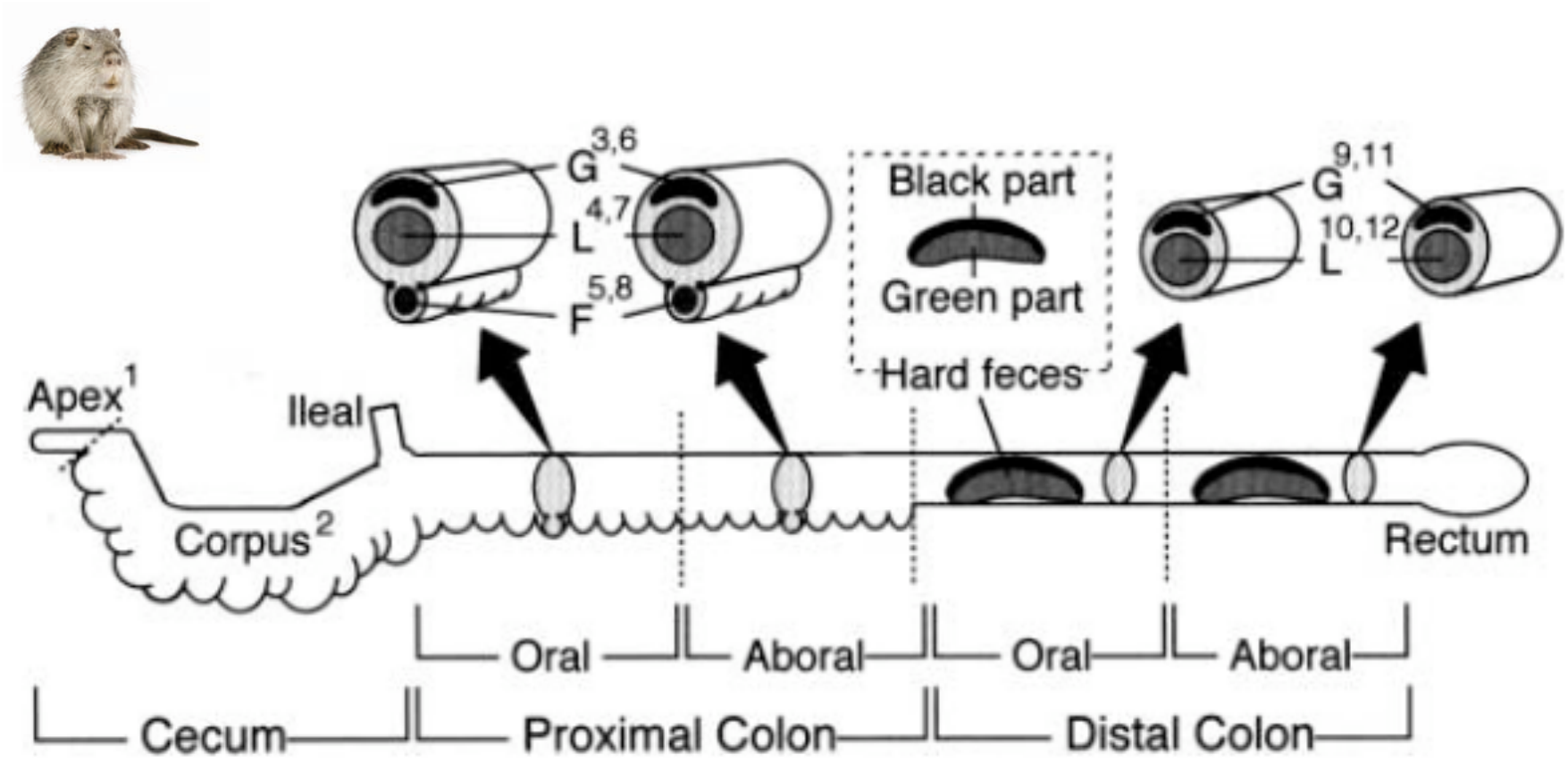
from Takahashi & Sakaguchi (2006)

Three kinds of faeces *(Myocastor coipus)*

	Type of feces			Part of hard feces		
	Soft	Hard	SE	Black[a]	Green	SE
Moisture (% of fresh feces)	67.4*	59.3	2.0	61.9	58.7	1.9
Organic matter	85.3	85.1	1.1	84.0	87.0	1.2
Crude protein (n × 6.25)	19.1**	13.4	0.8	18.0††	10.9	1.1
Ether extracts	3.55*	2.77	0.20	3.05†	2.45	0.15
NEE[b]	23.5**	25.8	0.4	26.4	27.3	1.4
ADF	29.5**	33.6	0.7	26.6††	36.7	0.8
Crude ash	14.7	14.9	1.1	16.0	13.0	1.2

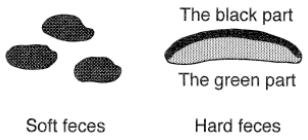
from Takahashi & Sakaguchi (1998)

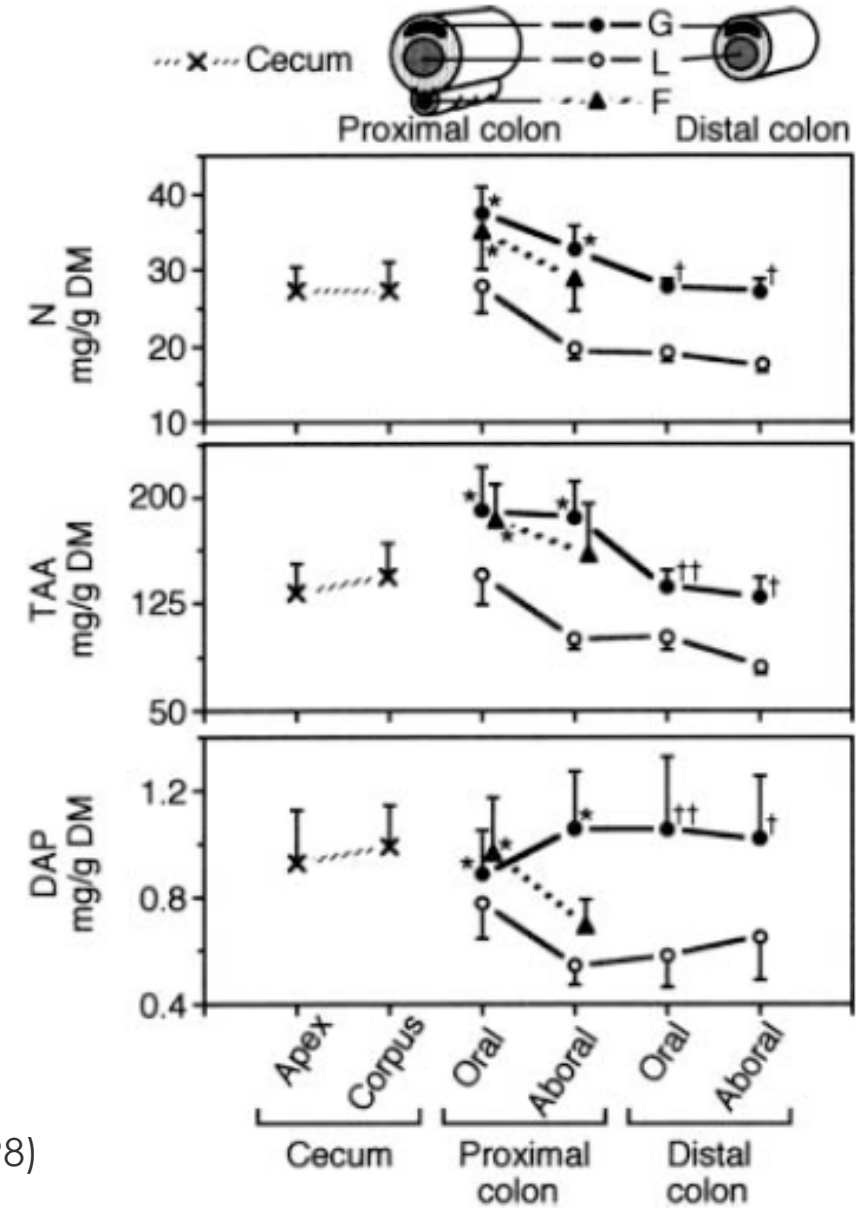
The colonic groove / furrow *(Myocastor coipus)*



from Takahashi & Sakaguchi (2000)

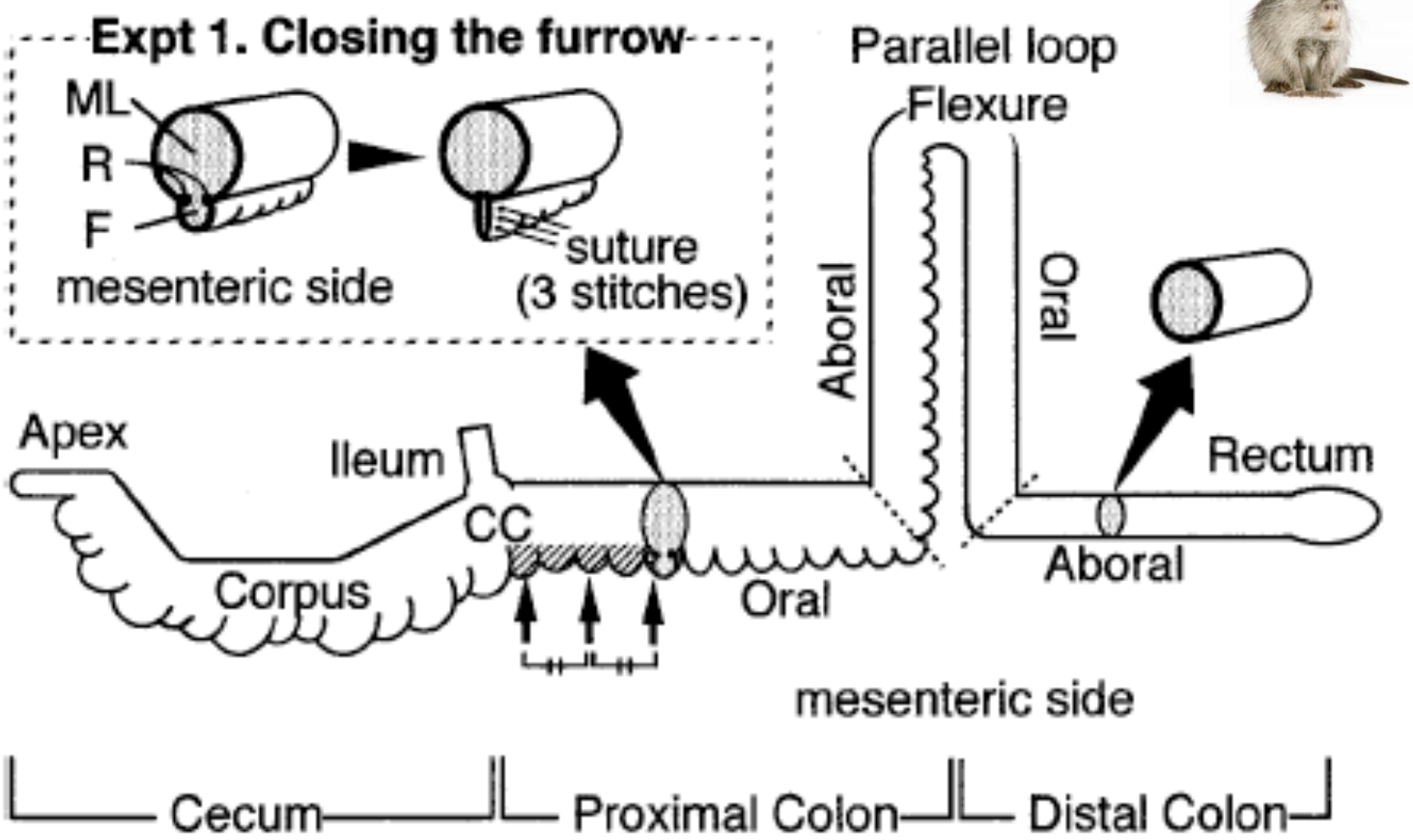
Three kinds of faeces *(Myocastor coipus)*





from Takahashi & Sakaguchi (1998)

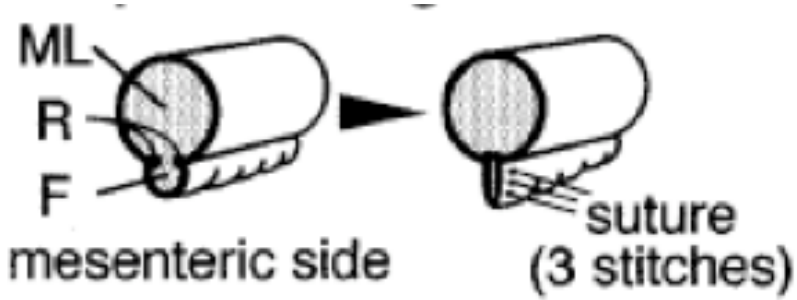
The colonic groove / furrow *(Myocastor coipus)*



from Takahashi & Sakaguchi (2000)

The colonic groove / furrow *(Myocastor coipus)*

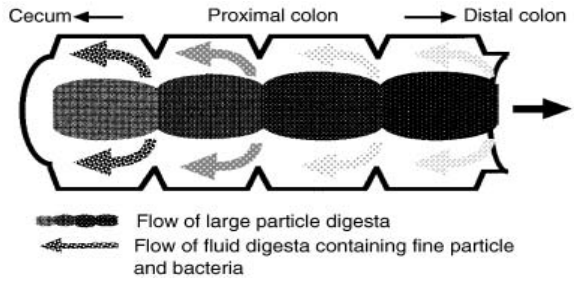
	Intact (n = 5)		Sutured (n = 3)		Sham (n = 3)	
	Soft	Hard	Soft	Hard	Soft	Hard
N	30.6^{a}	21.4^{b}	25.2^{b}	24.3^{b}	38.8^{a}	25.4^{b}
TAA	150.8^{a}	76.9^{b}	109.7^{b}	104.8^{b}	148.0^{a}	76.4^{b}
DAP	0.92^{a}	$0.62^{a,b}$	0.80^{a}	0.74^{a}	1.03^{a}	0.58^{b}



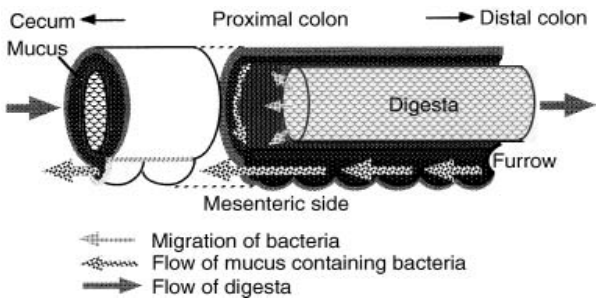
from Takahashi & Sakaguchi (2000)

Sorting of ingesta for caecotroph formation

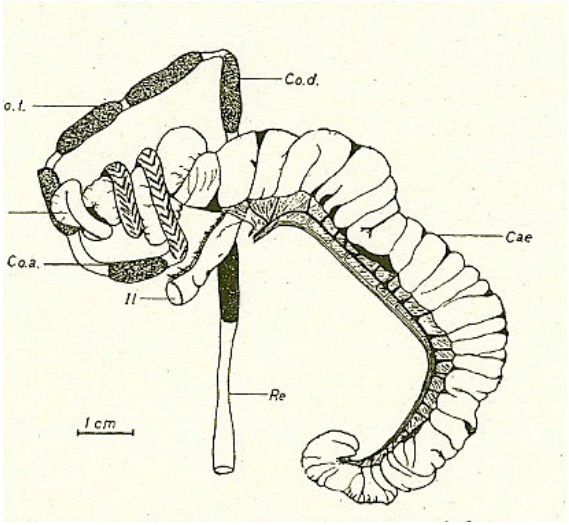
Wash back mechanism
(Lagomorphs)



Mucus trap mechanism
(Hystricomorph rodents)



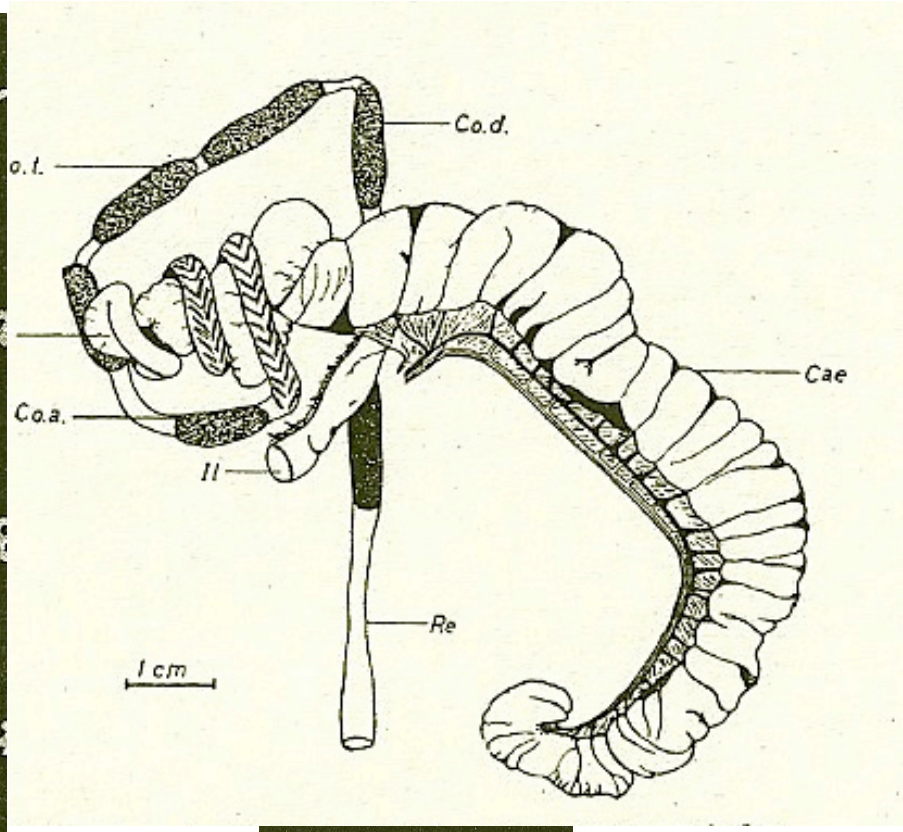
Mucus trap mechanism ?
(Myomorph rodents)

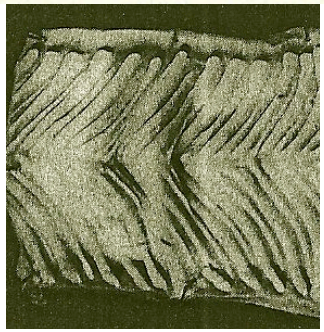


from Sakaguchi (2003) & Behmann (1972)

Sorting of ingesta for caecotroph formation

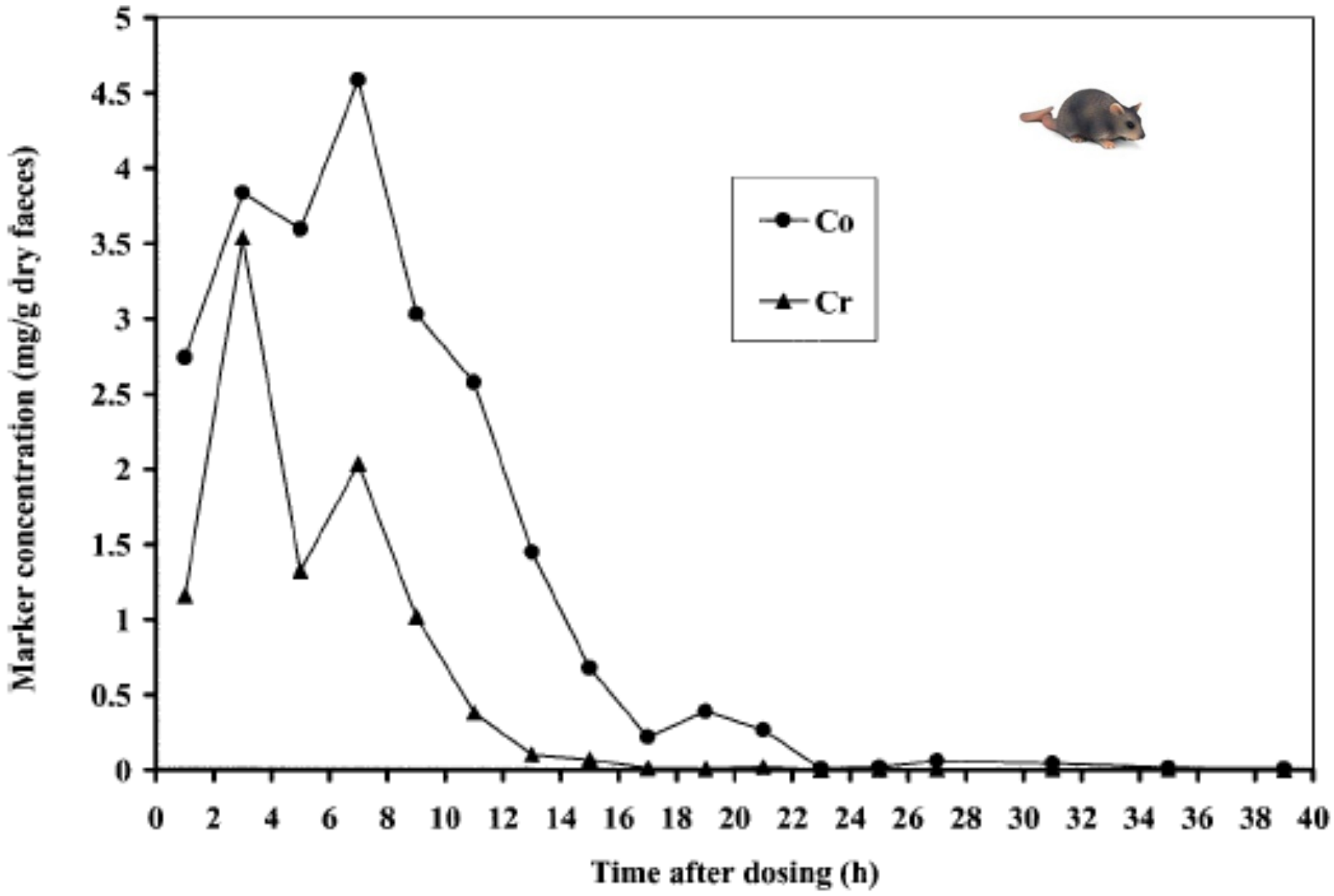
Mucus trap mechanism ?
(Myomorph rodents)





from Behmann (1972)

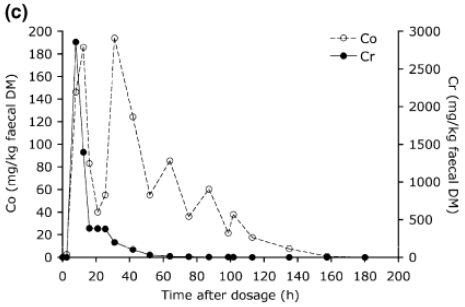
Coprophagy and ingesta passage patterns

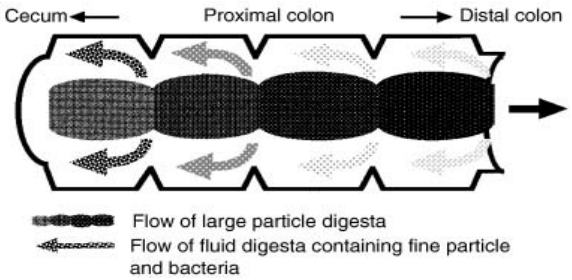


from Pei et al. (2001)

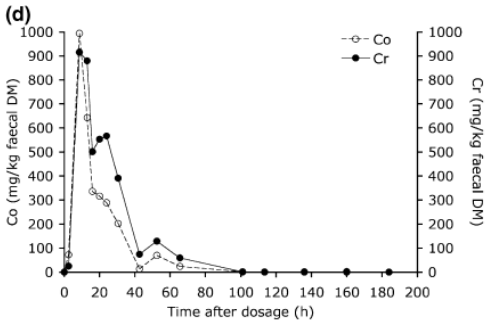
Sorting of ingesta for caecotroph formation

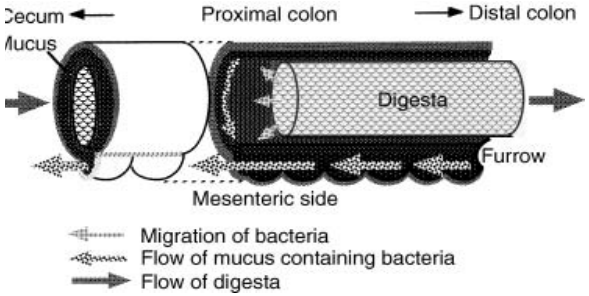
Wash back mechanism
(Lagomorphs)



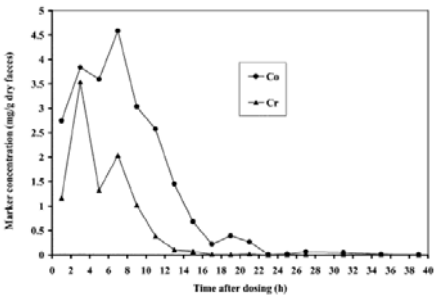


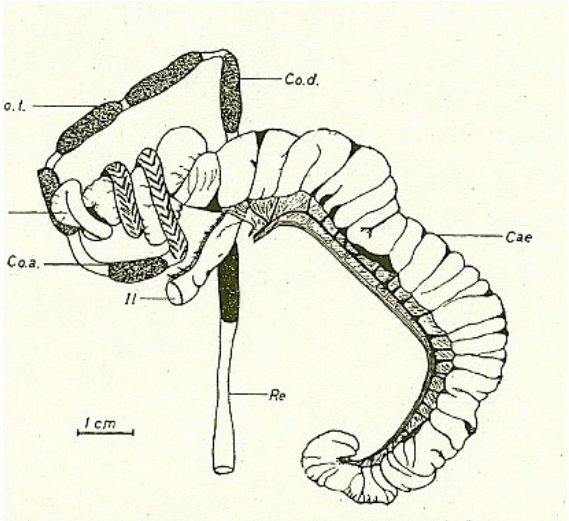
Mucus trap mechanism
(Hystricomorph rodents)





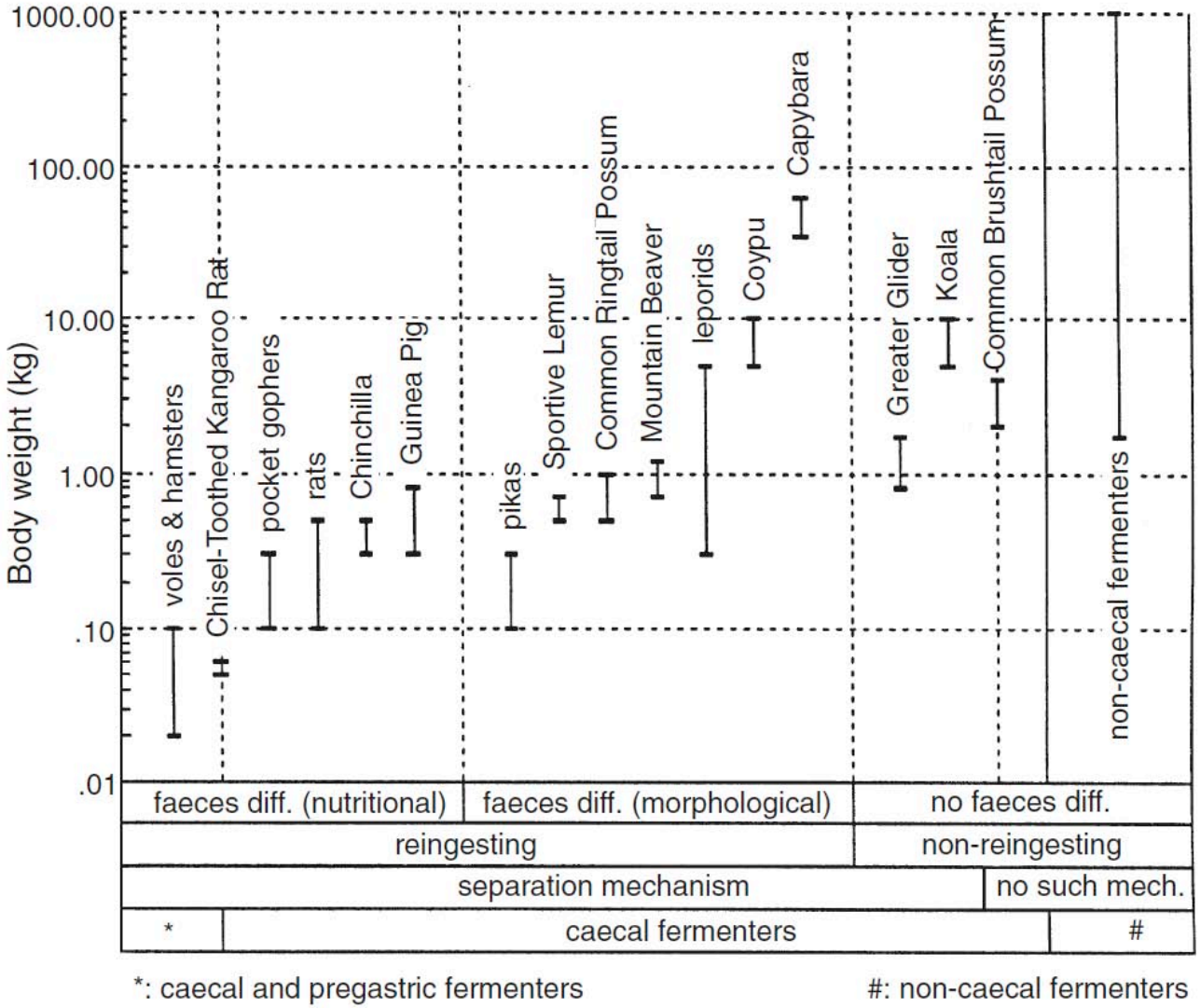
Mucus trap mechanism ?
(Myomorph rodents)





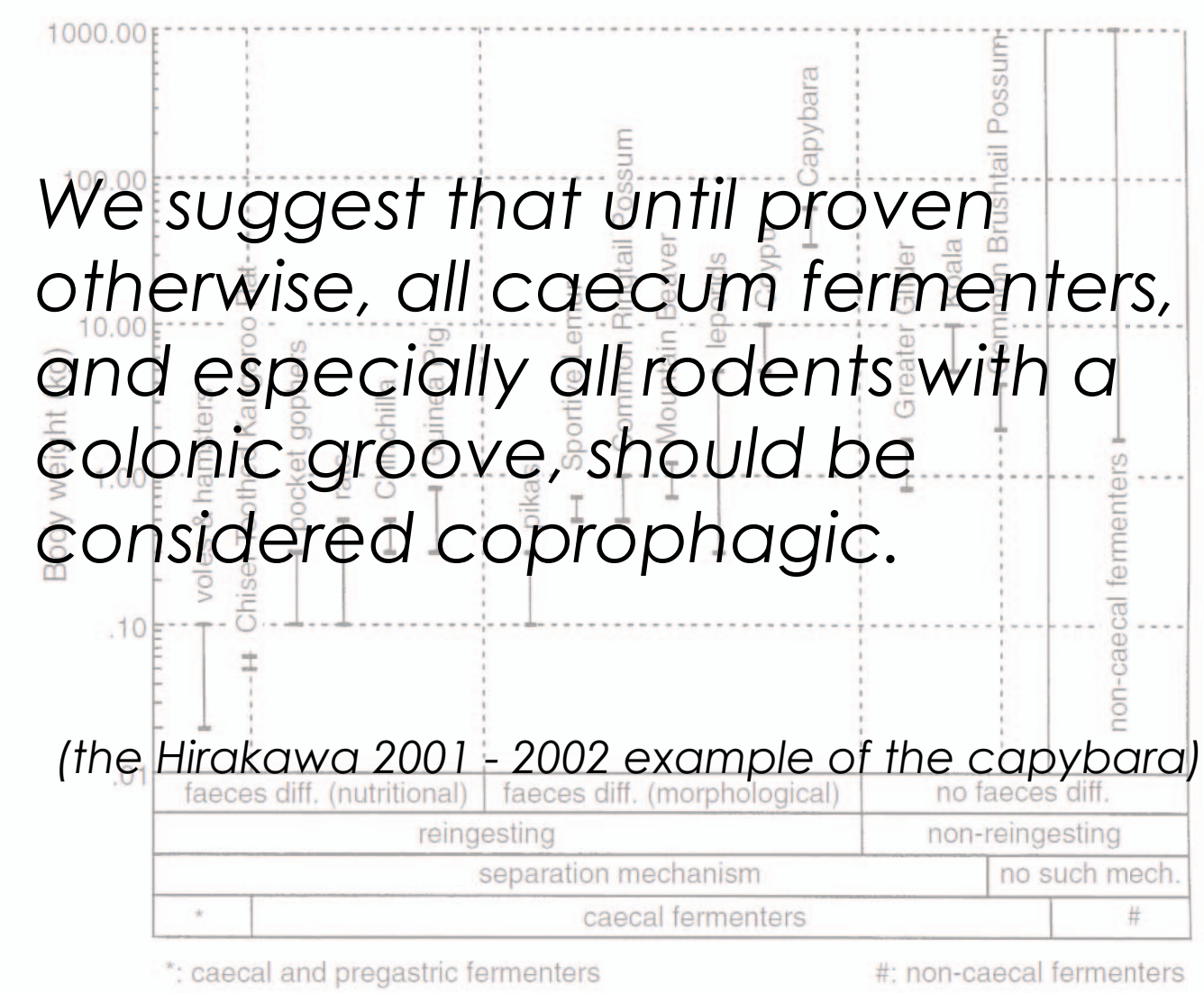
from Sakaguchi (2003) & Behmann (1972)

Who practices coprophagy?



from Hirakawa (2002)

Who practices coprophagy?



We suggest that until proven otherwise, all caecum fermenters, and especially all rodents with a colonic groove, should be considered coprophagic.

(the Hirakawa 2001 - 2002 example of the capybara)

from Hirakawa (2002), Clauss et al. (2007)

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.