The digestive anatomy and physiology of mammals

a comparative approach and comment upon wishful thinking in evolutionary biology

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Evolutionary Biology 2021

University of Zurich[UZH]

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wishful thinking:

where there is a special form,
there must be a special function

a non-primate example:

marine propulsion

Why the different modes of propulsion ?

wishful thinking:

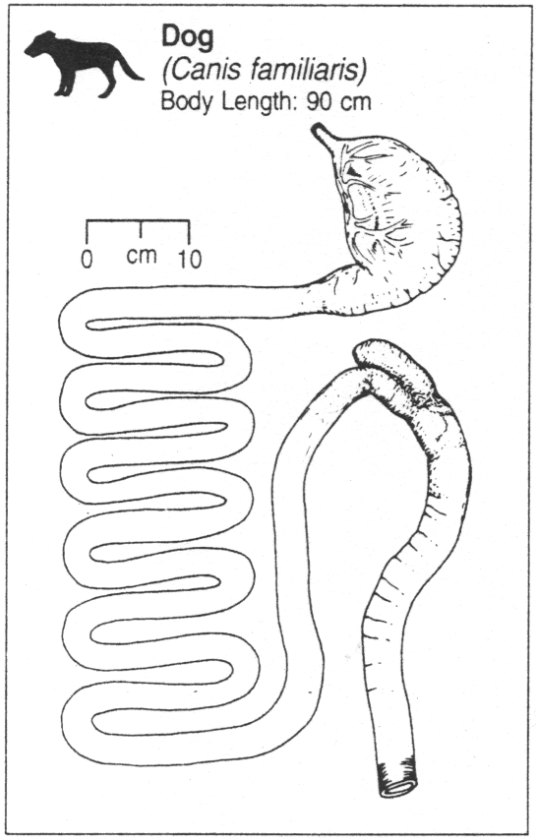
(where there is form,
there must be function)

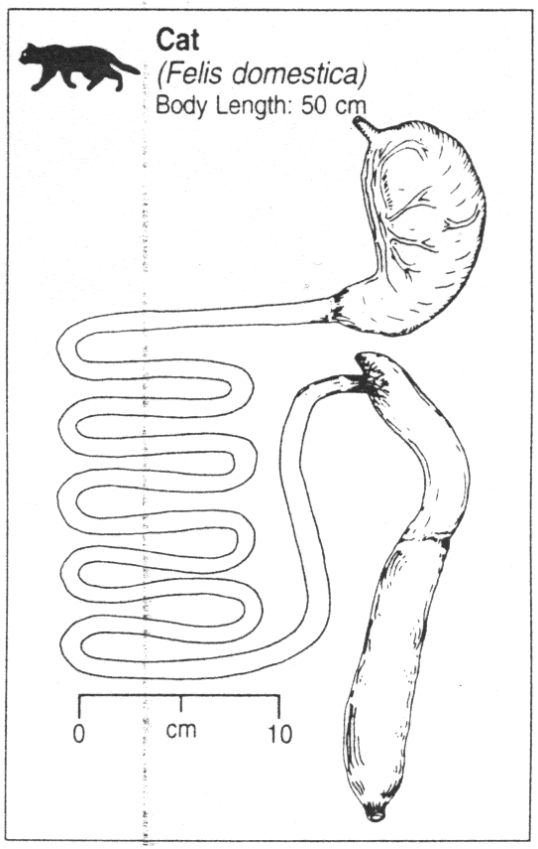
gastrointestinal tract and diet

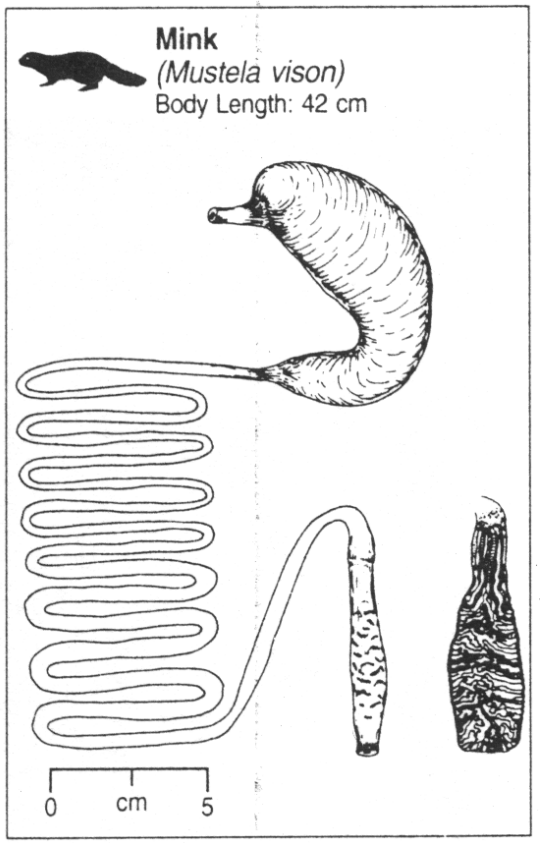
a simple story:

gastrointestinal complexity

Carnivore





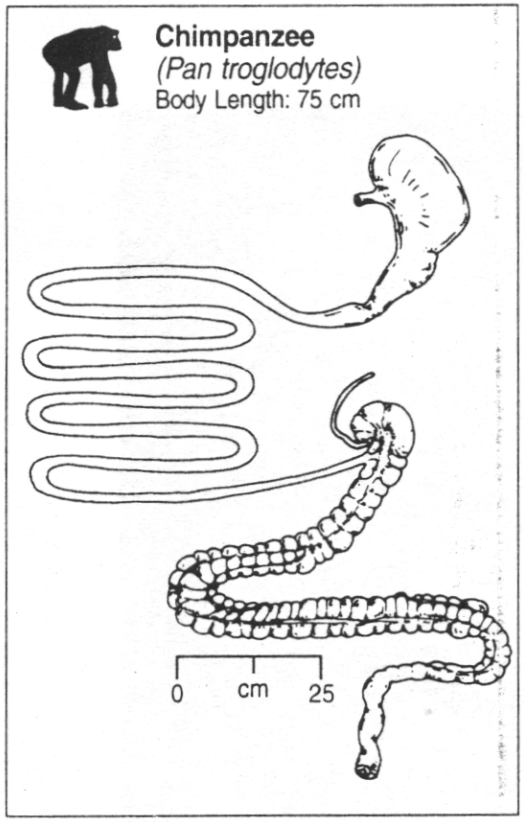


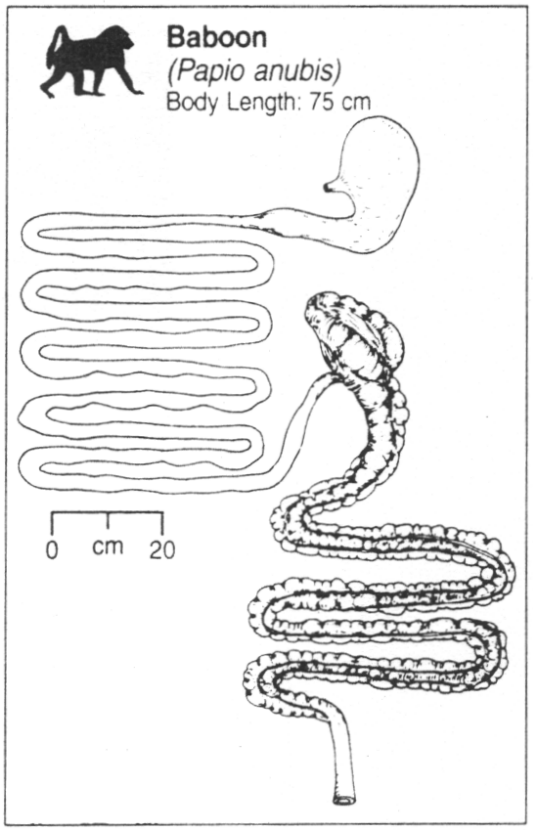
from Stevens und Hume (1995)

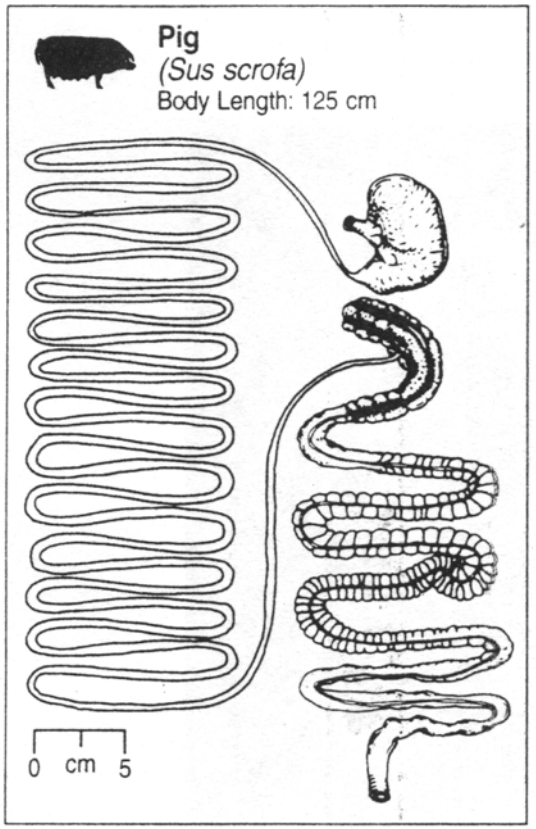
Carnivore

Photos Julia Fritz

Omnivore

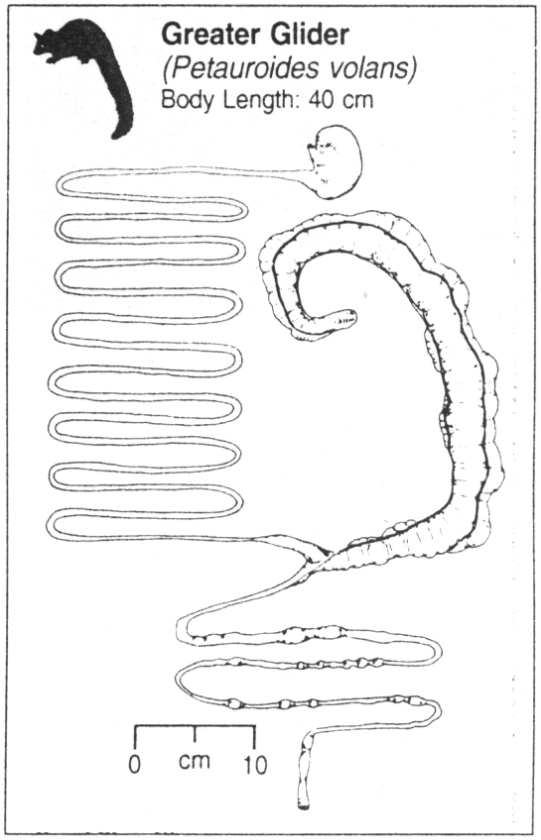


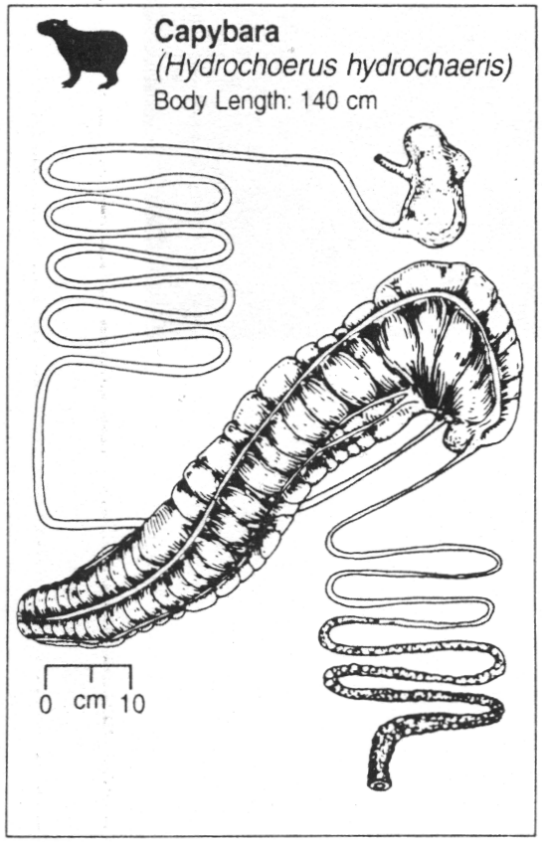


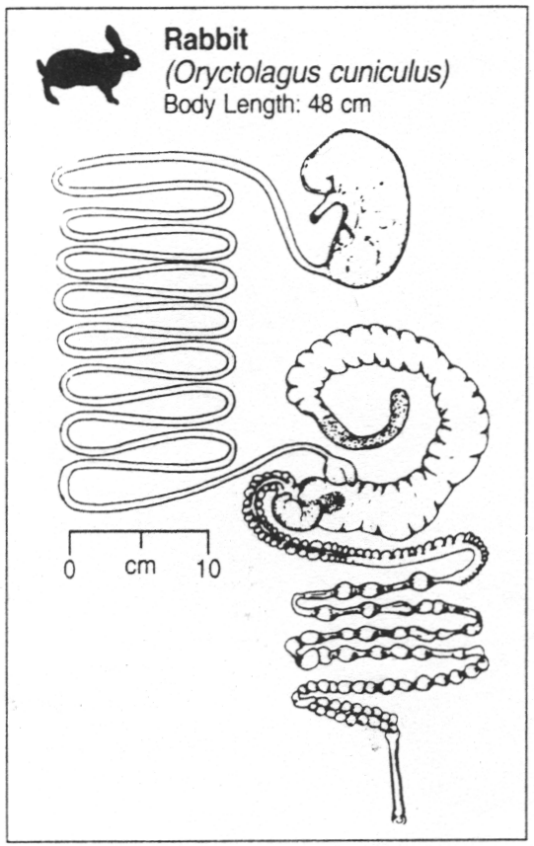


from Stevens und Hume (1995)

Hindgut fermenter - caecum

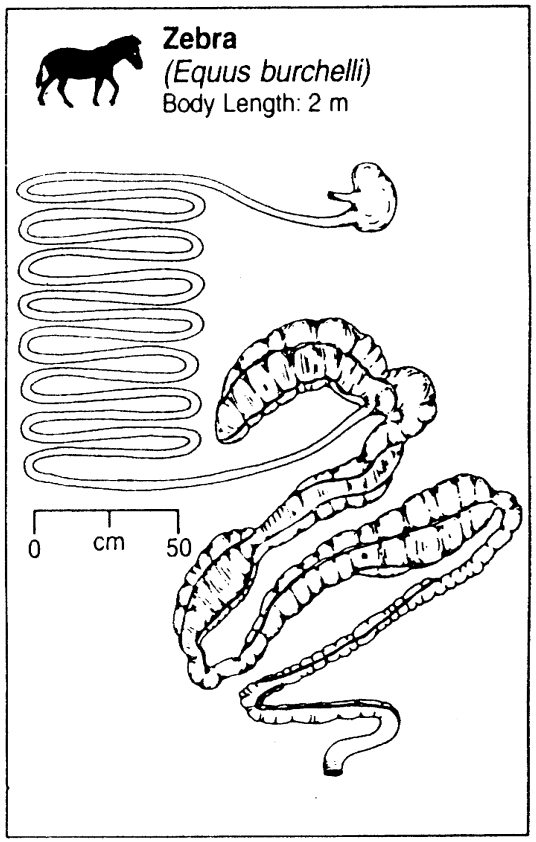


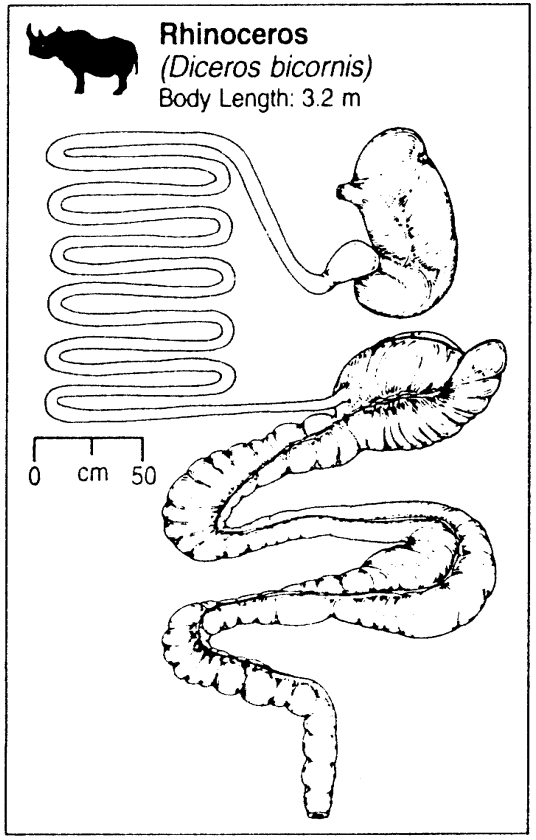


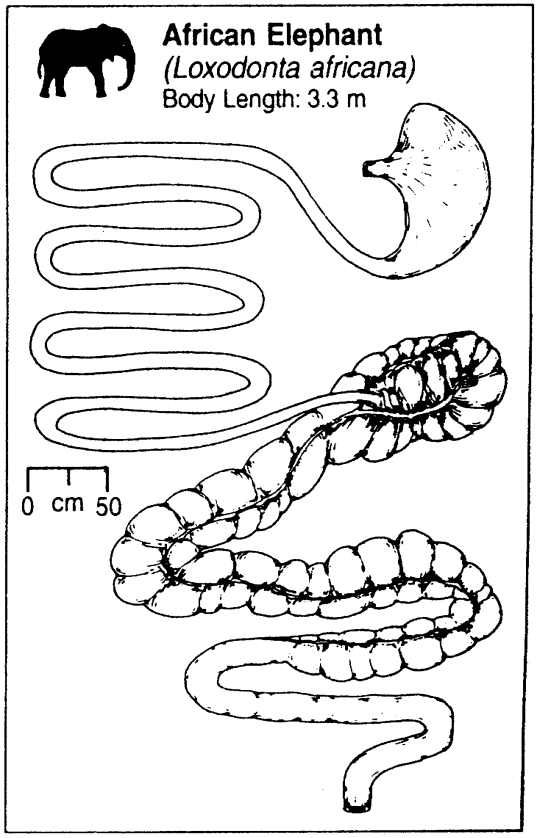


from Stevens und Hume (1995)

Hindgut fermenter - colon

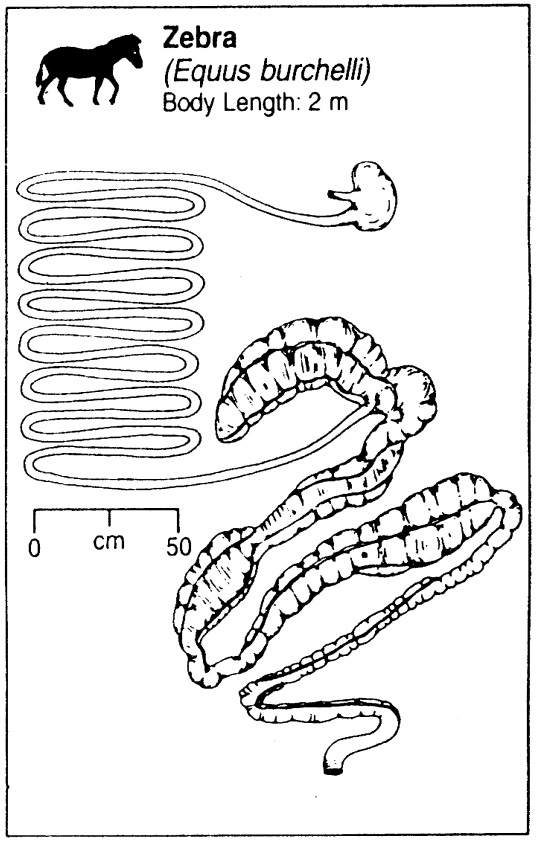






from Stevens und Hume (1995)

Hindgut fermenter - colon



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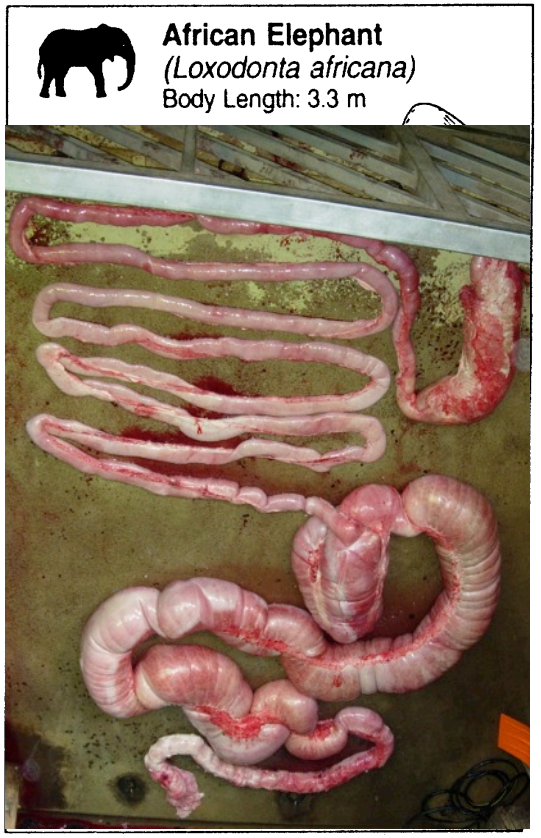
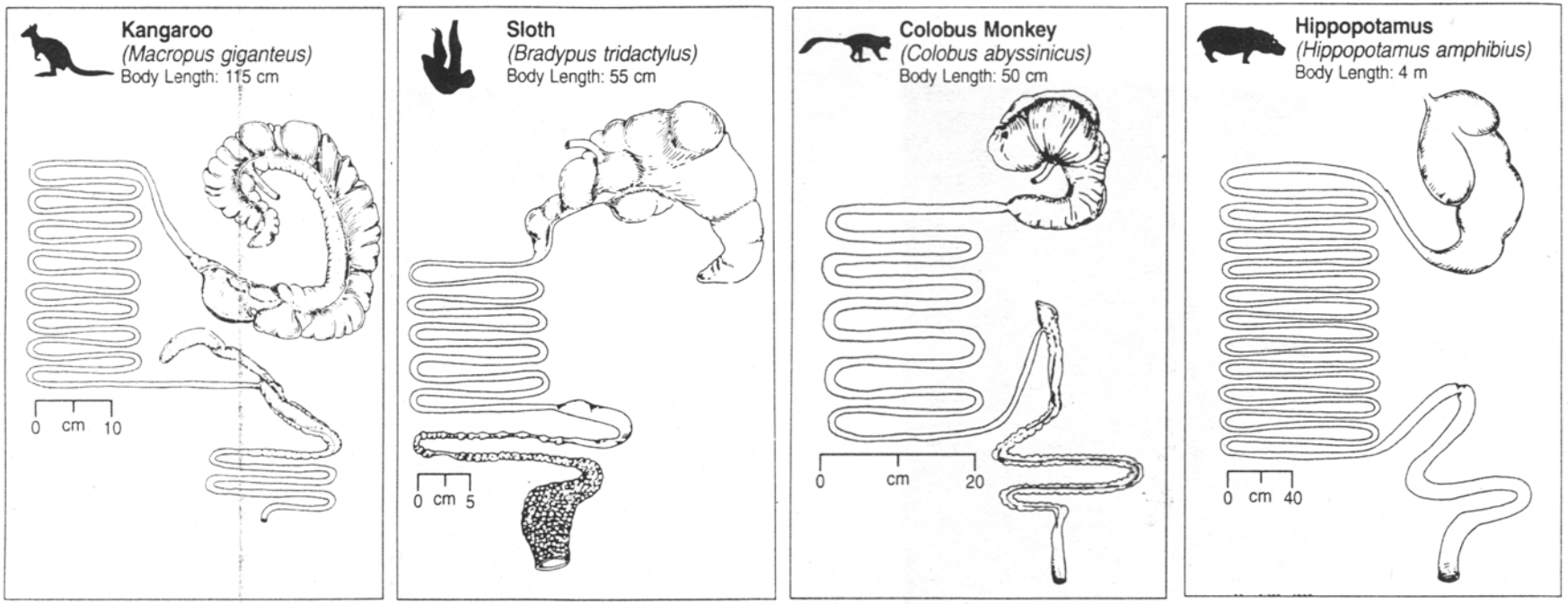


Photos Robert Zingg, Marcus Clauss

Foregut fermenter

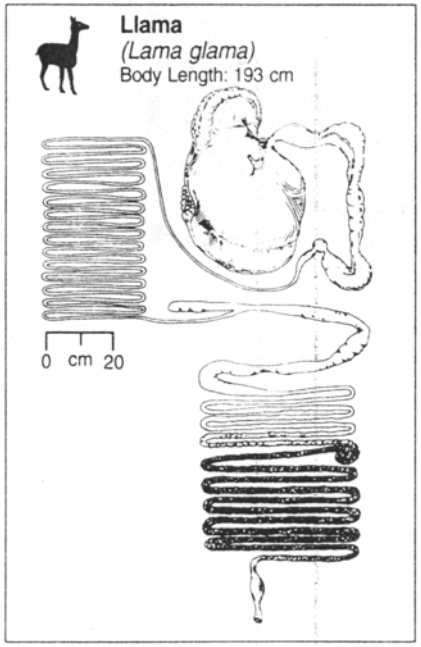


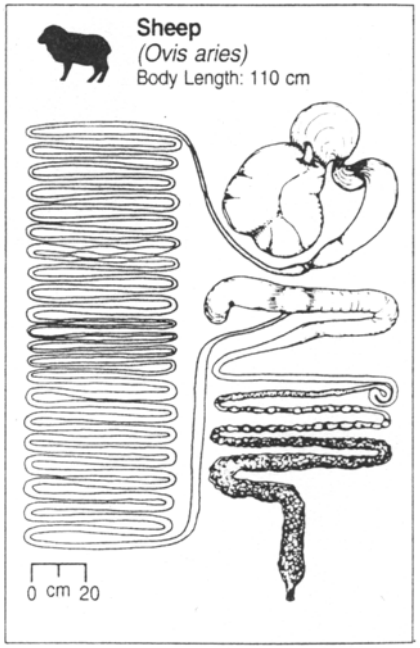
from Stevens und Hume (1995)

Foregut fermenter

Photos Angela Schwarm, Marcus Clauss

Foregut fermenter - Ruminant





from Stevens und Hume (1995)

Photos Alexander Riek, Marcus Clauss

A simple story: gastrointestinal complexity

1. Easily digestible diet = simple/ short gut

   Difficult-to-digest diet = complex/ long gut

2. Herbivores: foregut or hindgut fermenter?

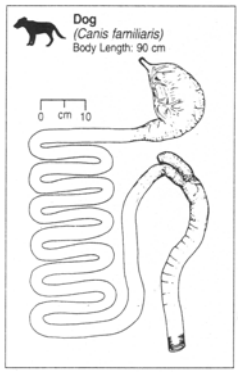
A simple story: gastrointestinal complexity

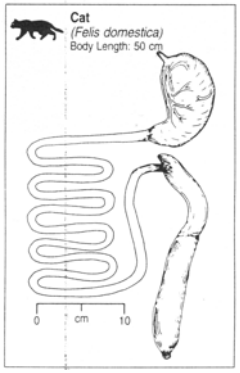
1. **Easily digestible diet = simple/ short gut**

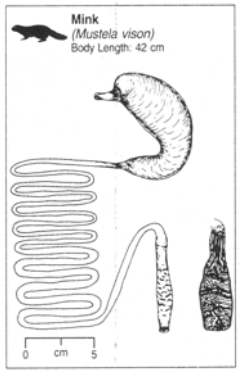
   Difficult-to-digest diet = complex/ long gut

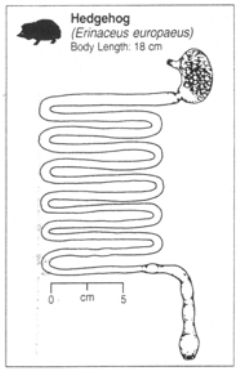
2. Herbivores: foregut or hindgut fermenter?

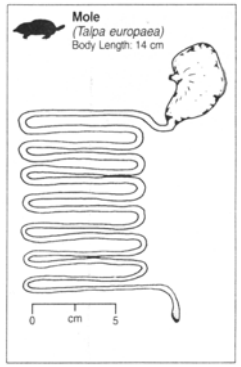
Carnivore vs. Herbivore

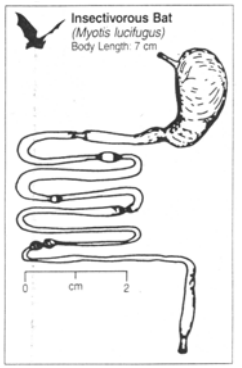




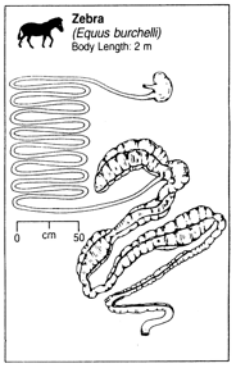


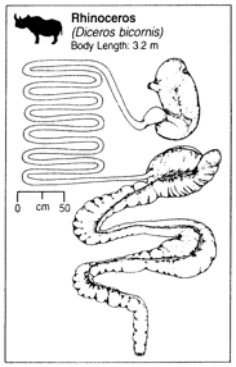


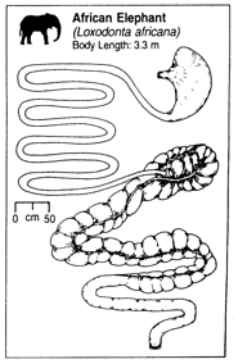


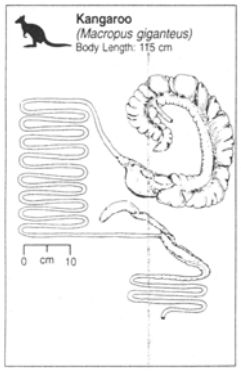


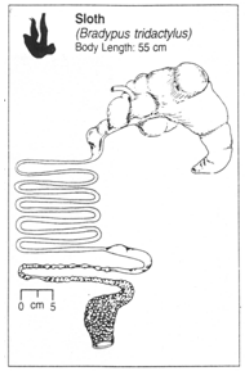
just pictures – no quantitative evidence

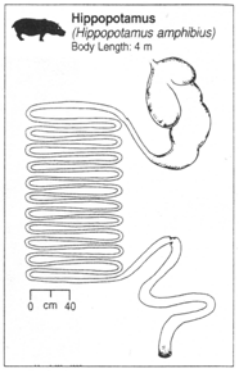






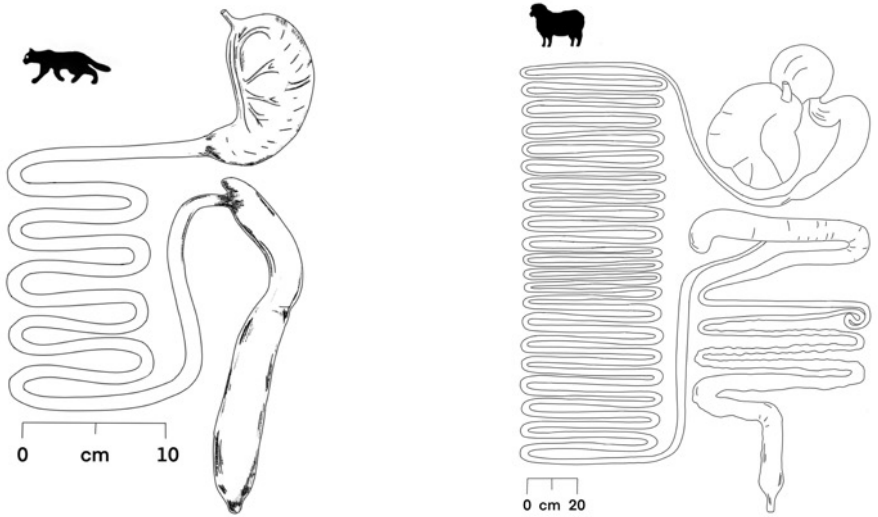






from Stevens und Hume (1995)

Carnivore vs. Herbivore



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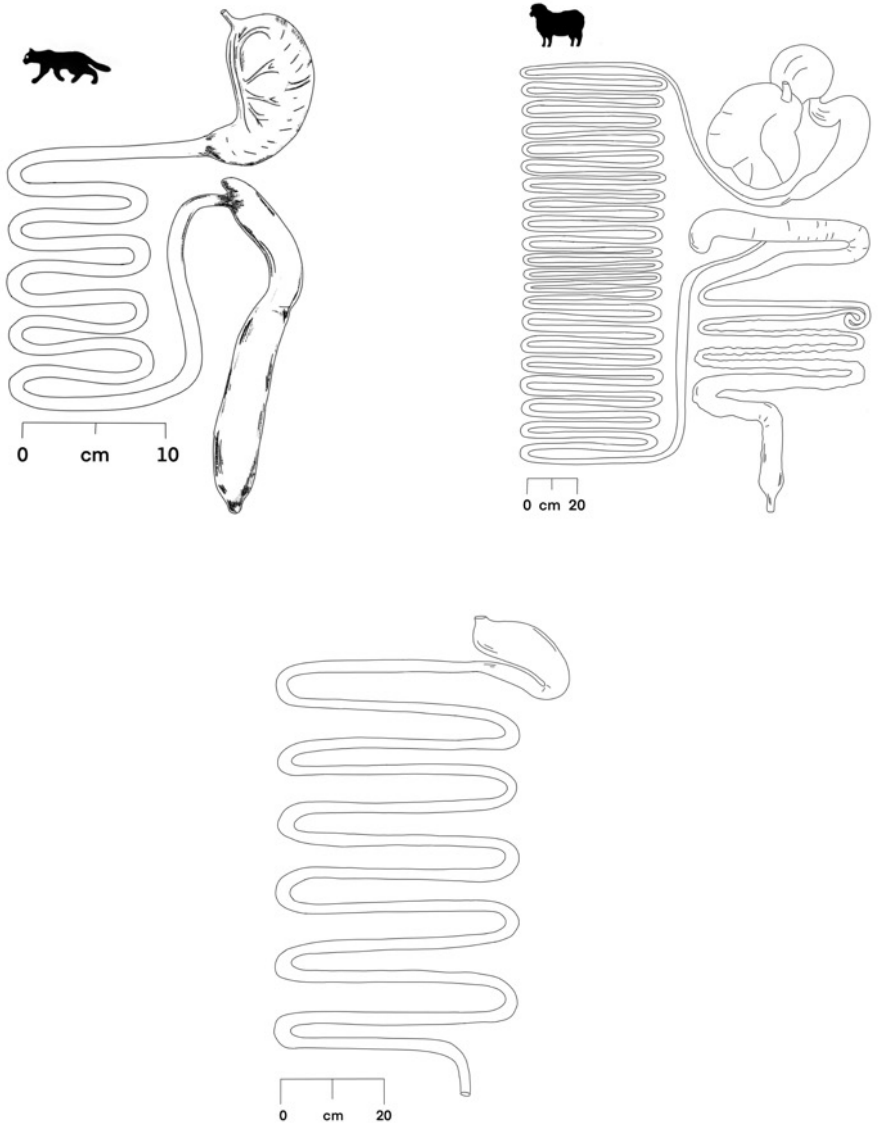

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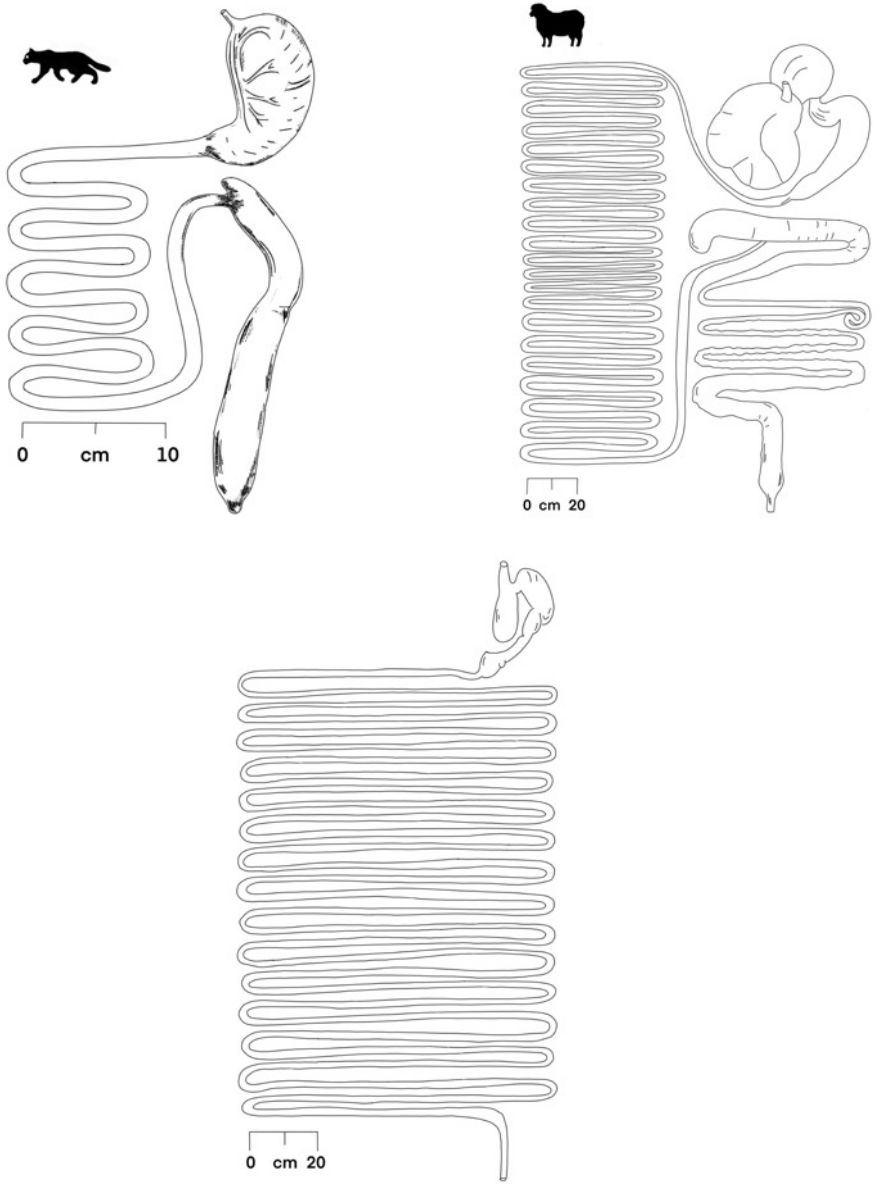

Morphology of the Gastrointestinal Tract in Primates: Comparisons With Other Mammals in Relation to Diet

DAVID J. CHIVERS AND C.M. HLADIK

JOURNAL OF MORPHOLOGY 166:337–386 (1980)

Morphology of the Gastrointestinal Tract in Primates: Comparisons With Other Mammals in Relation to Diet

DAVID J. CHIVERS AND C.M. HLADIK
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ABSTRACT Three categories of dietary adaptation are recognized—*faunivory, frugivory,* and *folivory*—according to the distinctive structural and biochemical features of animal matter, fruit, and leaves respectively, and the predominance of only one in the diets of most species.

Mammals subsisting mainly on animal matter have a simple stomach and colon and a long small intestine, whereas folivorous species have a complex stomach and/or an enlarged caecum and colon; mammals eating mostly fruit have an intermediate morphology, according to the nature of the fruit and their tendency to supplement this diet with either animal matter or leaves. The frugivorous group are mostly primates: 50 of the 78 mammalian species, and 117 of the 180 individuals included in this analysis are primates.

Coefficients of gut differentiation, the ratio of stomach and large intestine to small intestine (by area, weight, and volume), are low in faunivores and high in folivores; the continuous spread of coefficients reflects the different degrees of adaptation to these two dietary extremes.

Interspecific comparisons are developed by allowing for allometric factors. In faunivores, in which fermentation is minimal, the volume of stomach and large intestine is related to actual body size, whereas these chambers are more voluminous in larger frugivores and mid-gut fermenting folivores; fore-gut fermenters show a marked decrease in capacity with increasing body size. Surface areas for absorption are related to metabolic body size, directly so in frugivores; area for absorption is relatively less in larger faunivores and more in larger folivores, especially those with large stomachs.

Indices of gut specialization are derived from these regressions by nonlinear transformation, with references to the main functional features of capacity for fermentation and surface area for absorption.

These are directly comparable with the *dietary index,* derived from quantitative feeding data displayed on a three-dimensional graph, with all species within a crescentic path from 100% faunivory through 55–80% frugivory to 100% folivory, perhaps illustrating, at least for primates, the evolutionary path from primitive insectivorous forms through three major ecological grades.

Recent field studies of primates have produced major advances in our understanding of their feeding behaviour and diet (Clutton-Brock, '77; Chivers and Herbert, '78; Hladik, '75). The introduction of quantitative assessments of diet in these field studies allows precise comparisons between food intake and the morphology of the gastro-intestinal tract.

Detailed descriptions of gut morphology in mammals (Mitchell, '05; Bolk et al., '39; Grassé, '55; Hill, '58) have also lacked effective quantification. The first quantitative effort at comparing gut morphology with diet (Cuvier, 1805) produced no obvious correlations. Magnan ('12), however, working with areas rather than lengths, demonstrated a correlation between structure and diet (in general terms), but data are not presented so that his conclusions can be verified. Preliminary efforts at a more critical analysis (Fooden, '64; Hladik,

0362-2525/80/1663-0337$08.00

Morphometrics of the Avian Small Intestine Compared with That of Nonflying Mammals: A Phylogenetic Approach

Shana R. Lavin[1]
William H. Karasov[1,*]
Anthony R. Ives[2]
Kevin M. Middleton[3,†]
Theodore Garland Jr.[3]

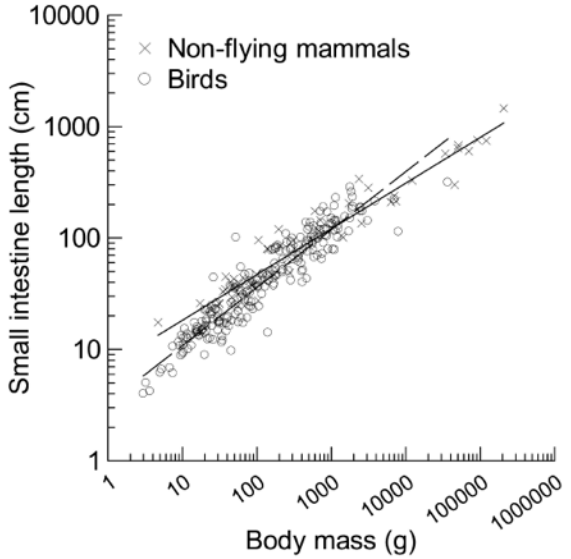
Physiological and Biochemical Zoology 81(5):526–550. 2008.

ANCOVA with Same Slope but Different Intercepts (Diet)

Model	*d*	ln Maximum Likelihood	AIC	χ^2 for LRT vs. Simple Allometry	*P* for LRT (df = 3)	Partial *F* for Diet	*P* for Partial *F* (df = 3, 59)
OLS		−9.4	30.8	3.78	.2863	1.20	.3190
PGLS		−22.2	56.4	3.16	.3680	.99	.4017
RegOU	.213	−8.6	31.2	2.67	.4452	.79	.5058

ANCOVA with Different Slopes (Diet × Mass) and Intercepts (Diet)

Model	*d*	ln Maximum Likelihood	AIC	χ^2 for LRT vs. Different Intercepts	*P* for LRT (df = 3)	Partial *F* for Diet and Diet × Mass Interaction	*P* for Partial *F* (df = 6, 56)
OLS		−5.3	28.5	8.28	.0405[b]	1.94	.0909[c]
PGLS		−17.3	52.7	9.74	.0209[b]	2.08	.0696[c]
RegOU	.140	−5.1	30.2	7.05	.0702[b]	1.43	.2210[c]

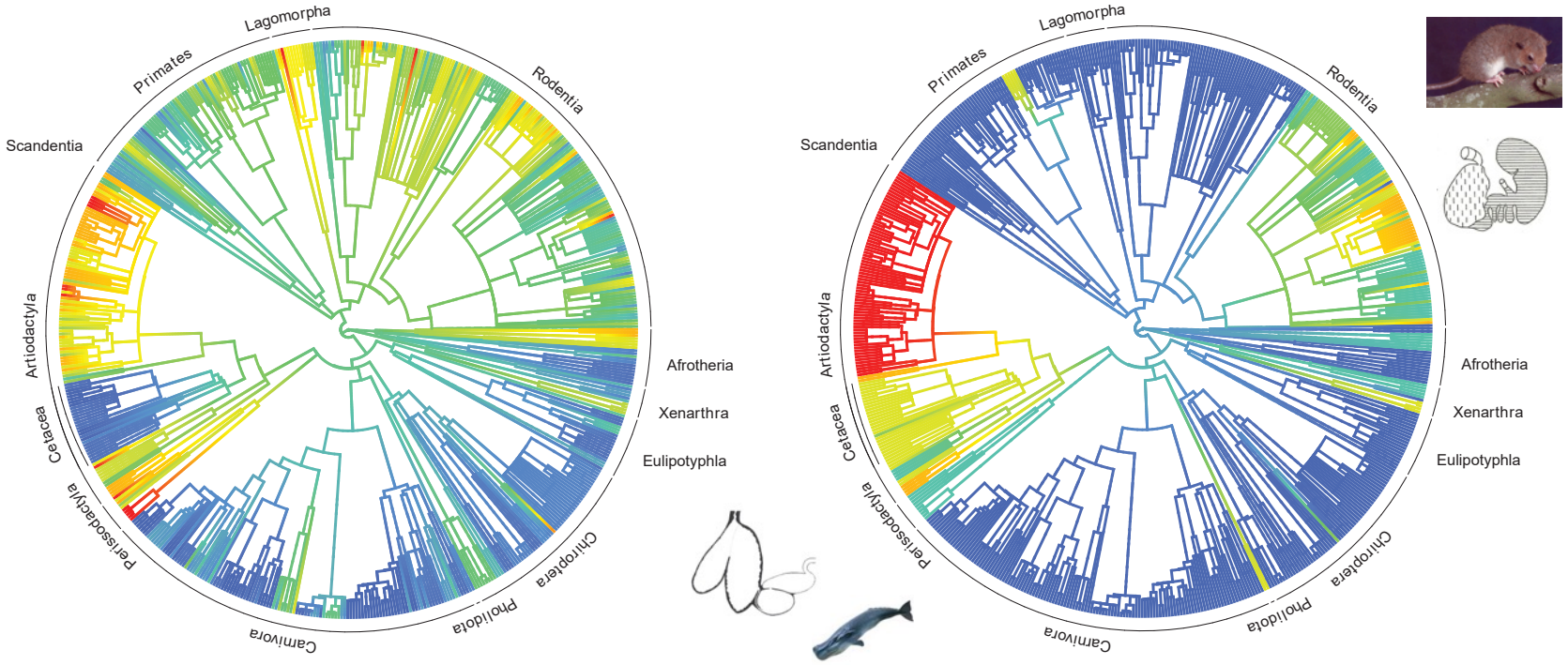


In mammals, the best-fitting model was again simple allometry by RegOU (Table 4), and LRTs and partial *F*-tests indicated that diet did not significantly affect small intestine length.

Morphological adaptation of the eutherian gastro-intestinal tract to diet

VERTEBRATE ZOOLOGY 68 (3): 237 – 252
20.11.2018

Peter Langer[1], Marcus Clauss[2]



no correlation of dietary fibre and **stomach complexity** when controlling for body mass (also not in primates)

high fibre — low fibre
high GIT complexity — low GIT complexity

Although GIT anatomy appears to correlate with diet in comparisons with limited numbers of species, it does not seem to correlate well with diet in larger-scale comparisons.

Let‘s test this with really large datasets.