



Feeding herbivorous reptiles and primates

I. Digestive anatomy/physiology & natural diet

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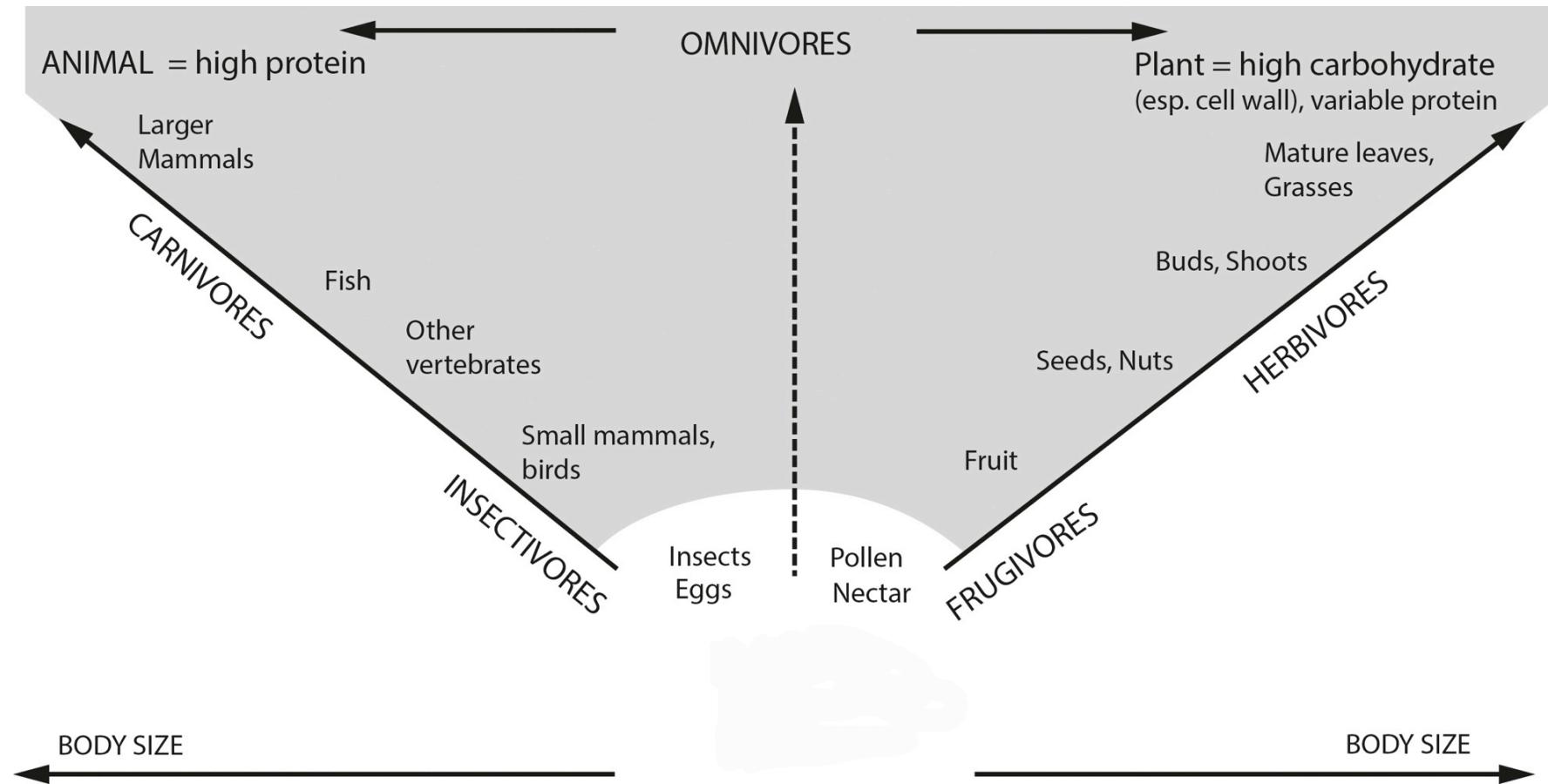


Structure

- Basic feeding ecology
- Basic digestive anatomy
 - Reptiles vs. mammals
 - Mammal herbivores
- Primate digestive anatomy
 - by phylogeny (=> balcony break)
- Primate feeding problems
 - Obesity
 - Dysbacteriosis
 - R/R
 - Faeces consistency
- Reptile feeding problems
 - Growth
 - Gout



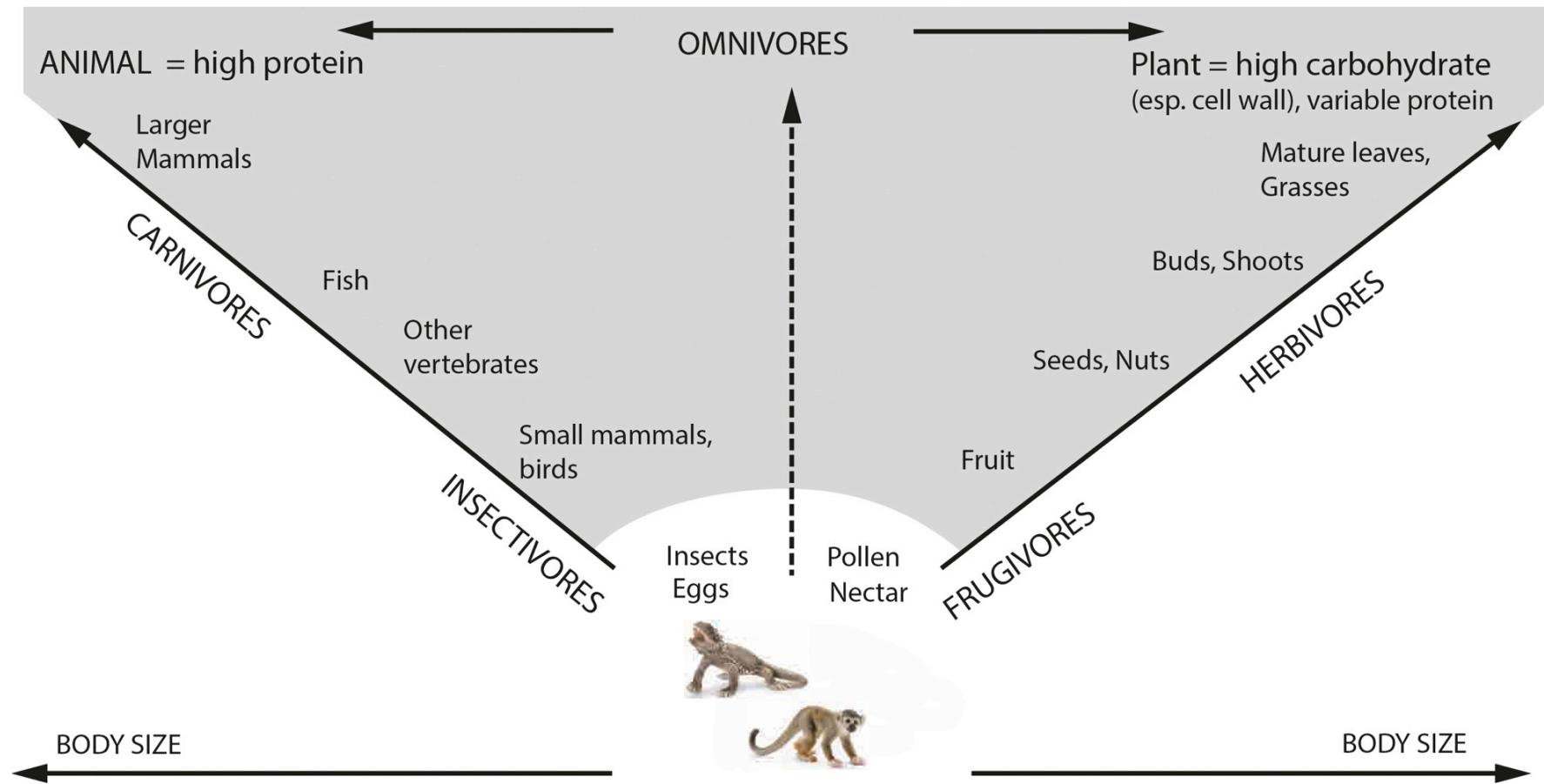
Sufficient amounts of available packages



from Hiiemae (2000)



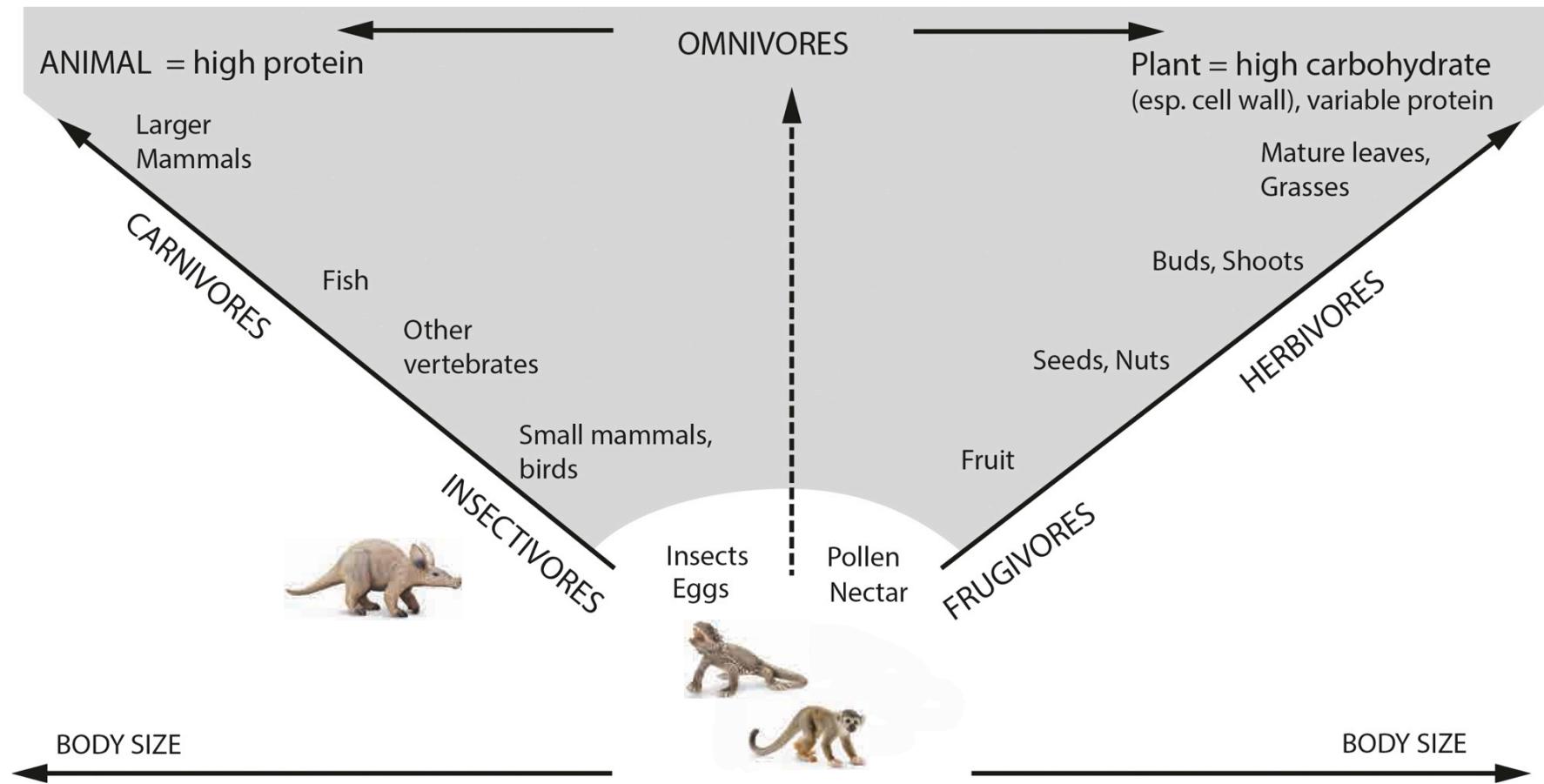
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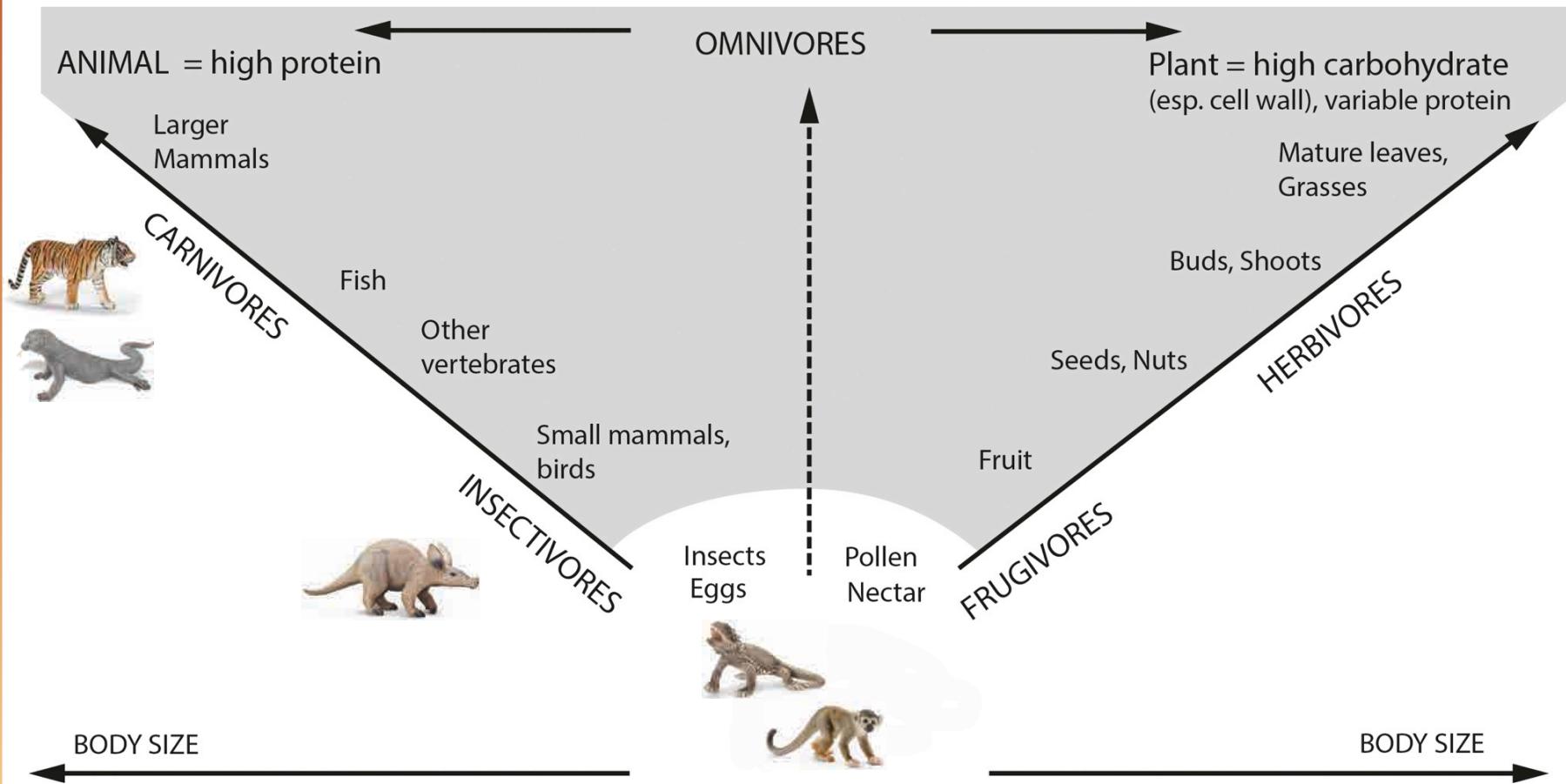
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from Hiiemae (2000)



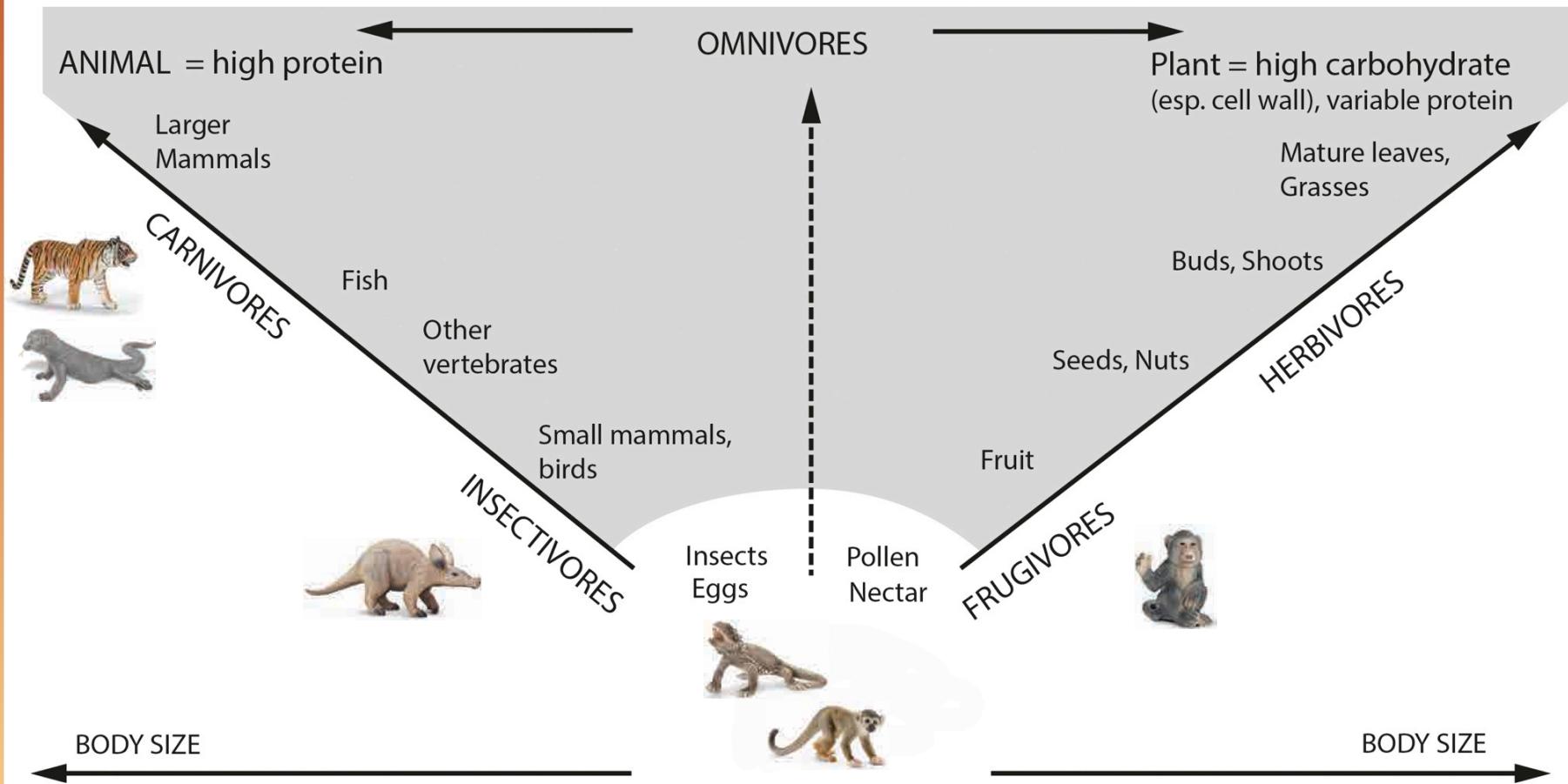
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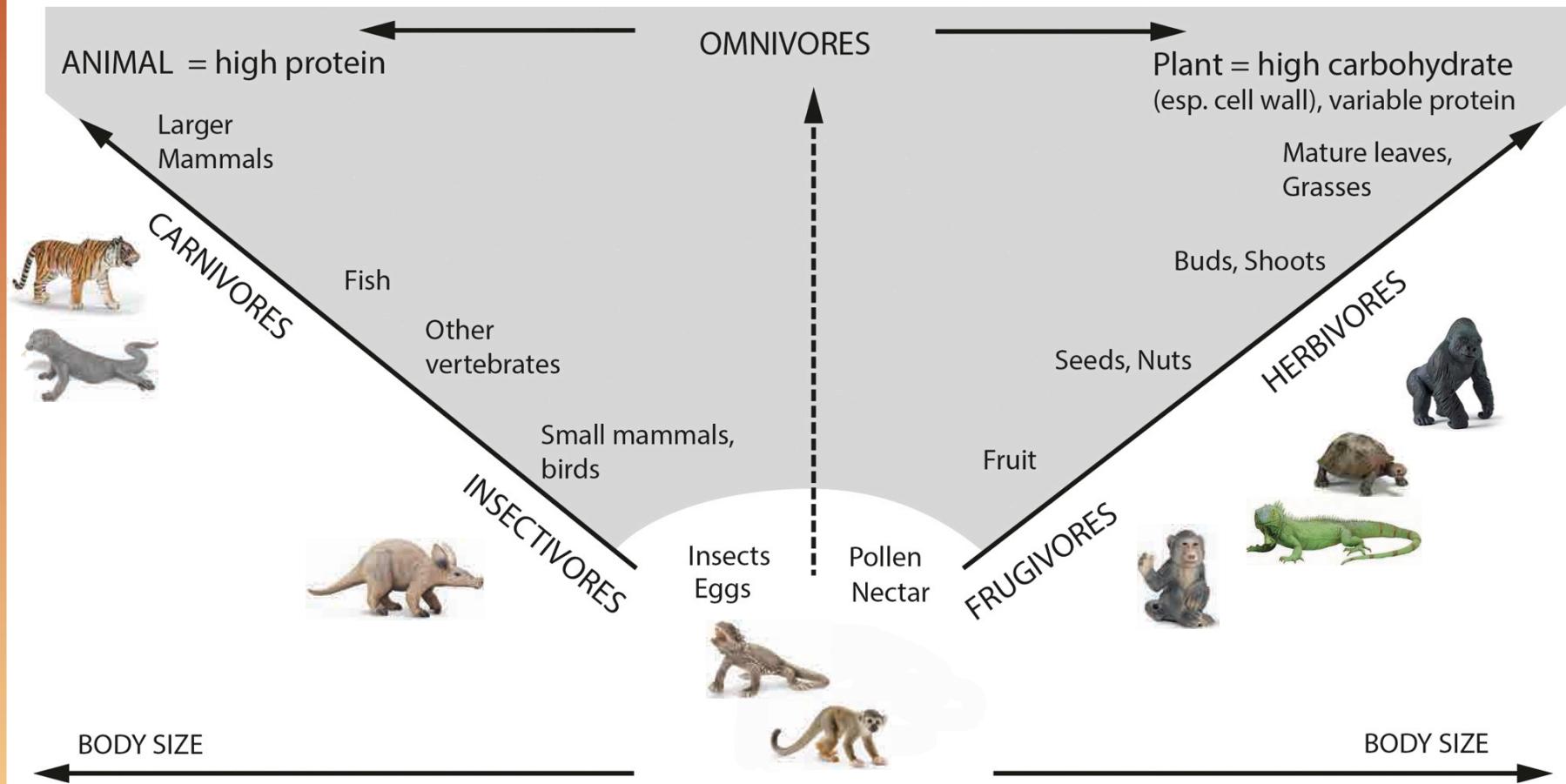
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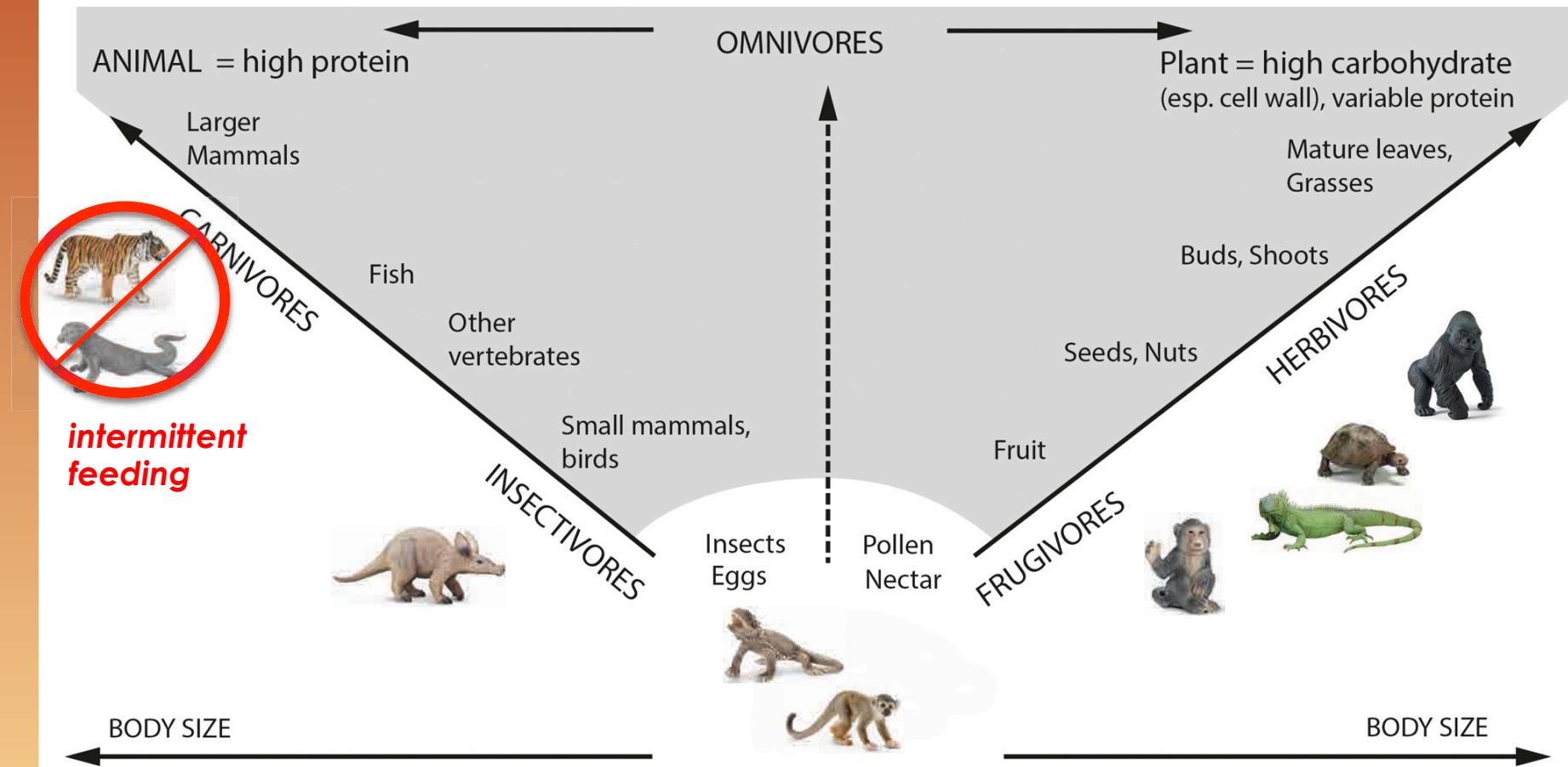
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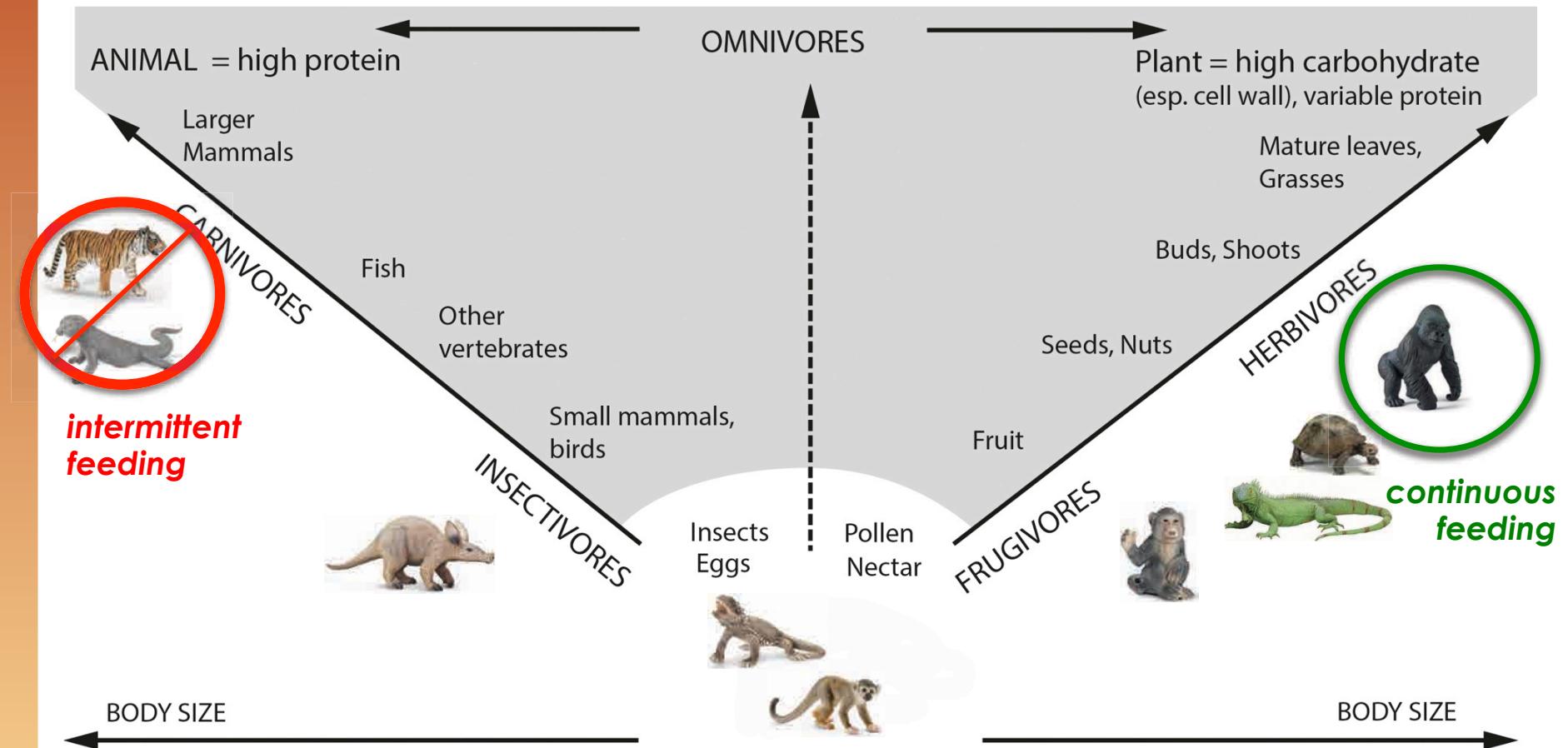
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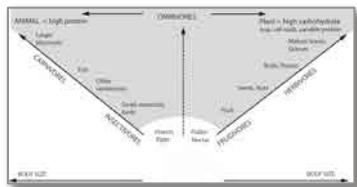
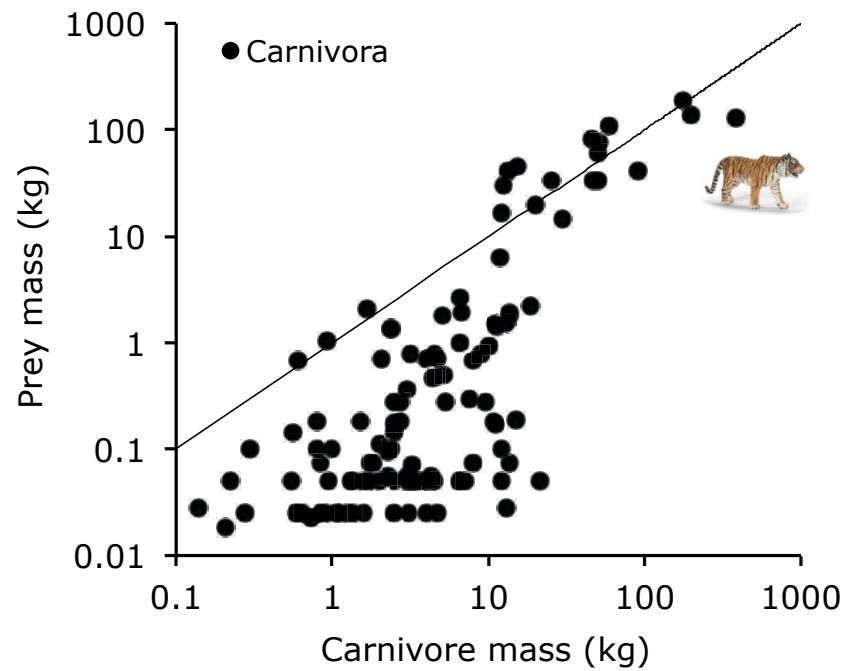
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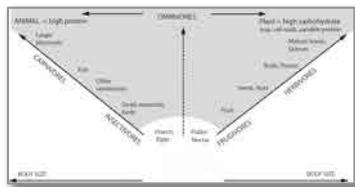
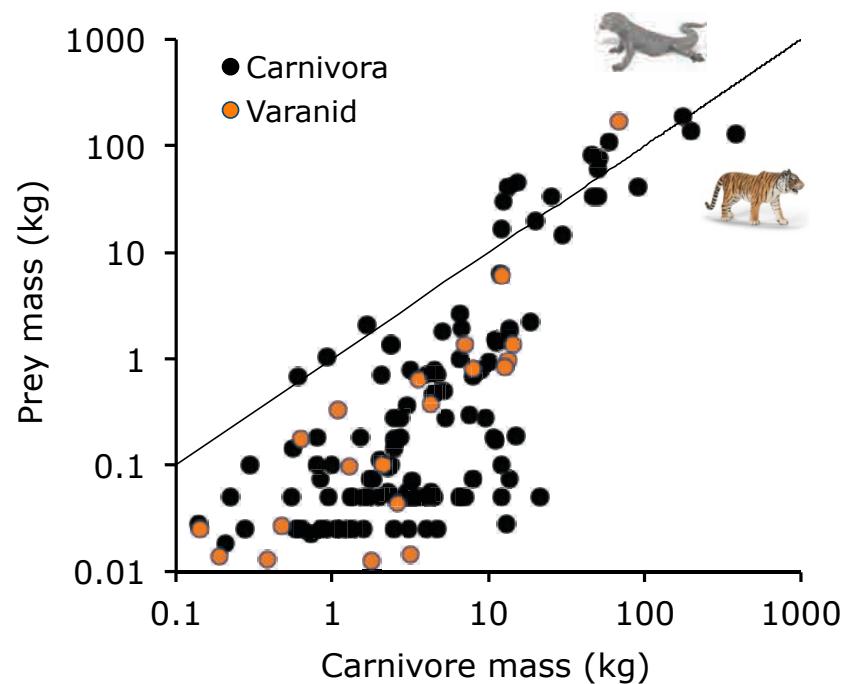
Prey size in carnivores



from Carbone et al. (1999)



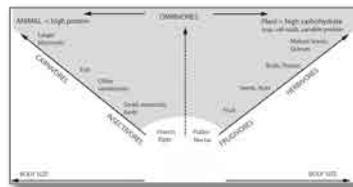
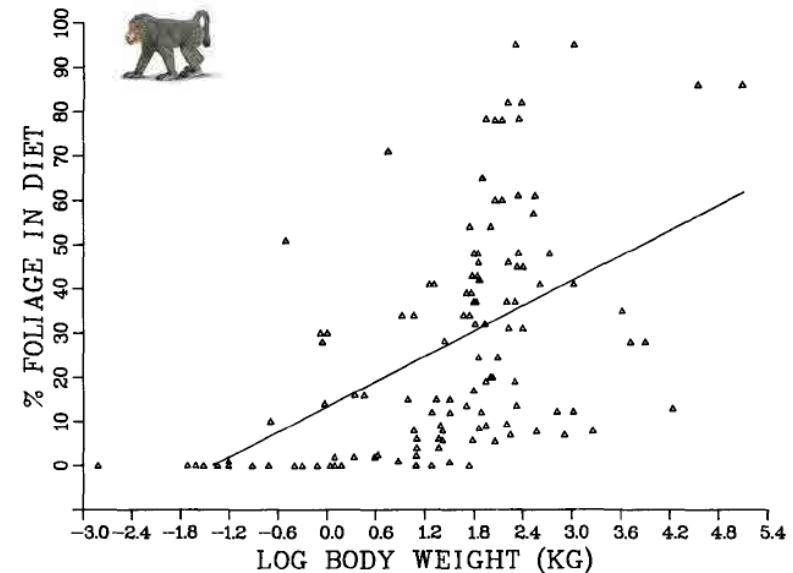
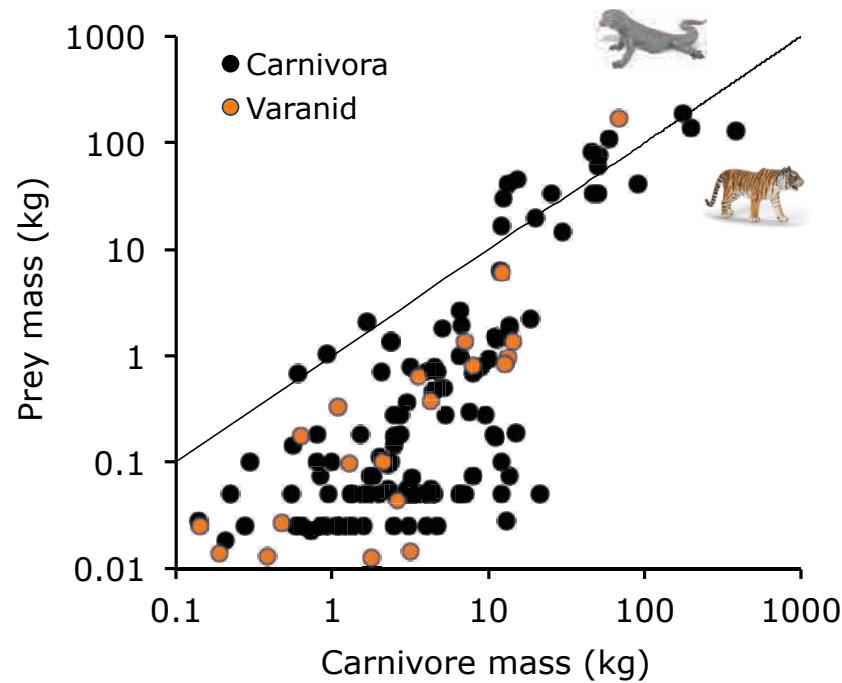
Prey size in carnivores



from Carbone et al. (1999), Losos and Greene (1988)



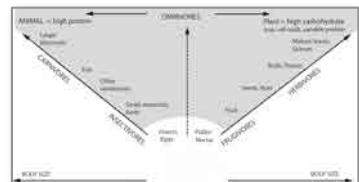
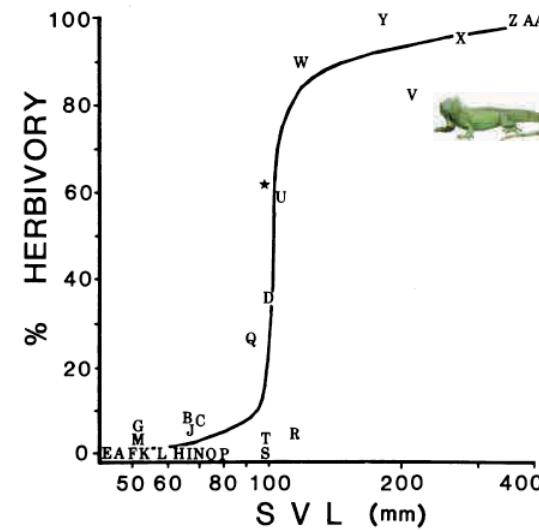
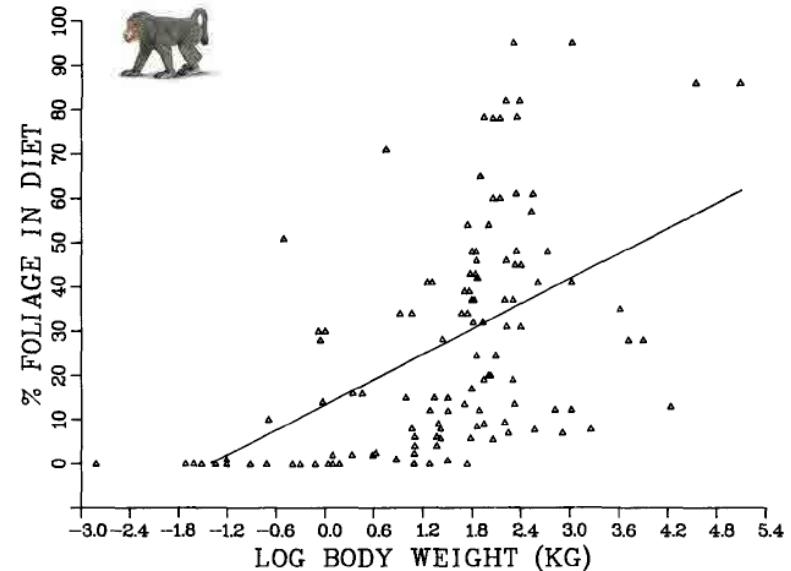
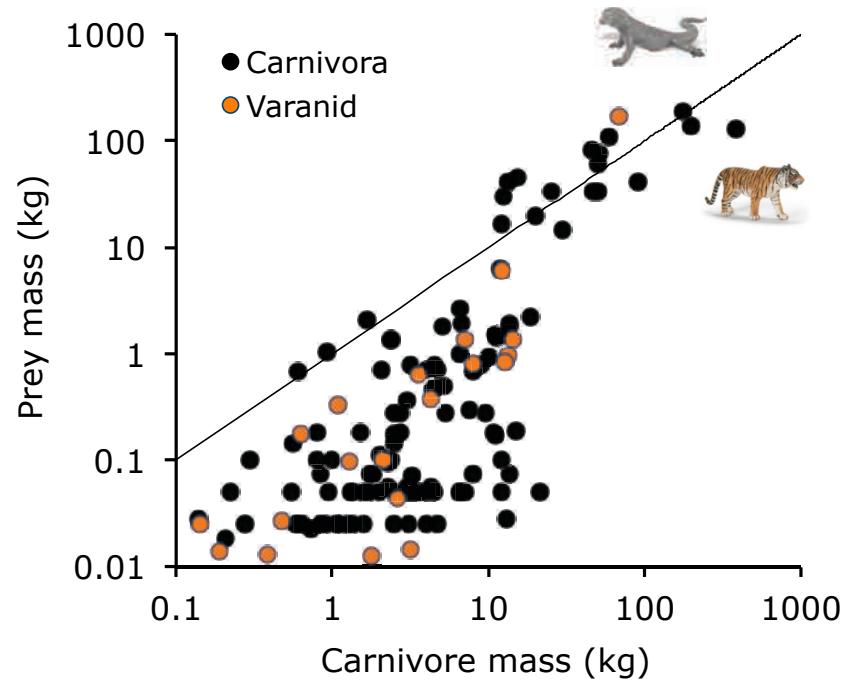
Prey size in carnivores/omnivores



from Carbone et al. (1999), Losos and Greene (1988), Sailer et al. (1985)



Prey size in carnivores/omnivores



from Carbone et al. (1999), Losos and Greene (1988), Sailer et al. (1985), Schluter (1984)

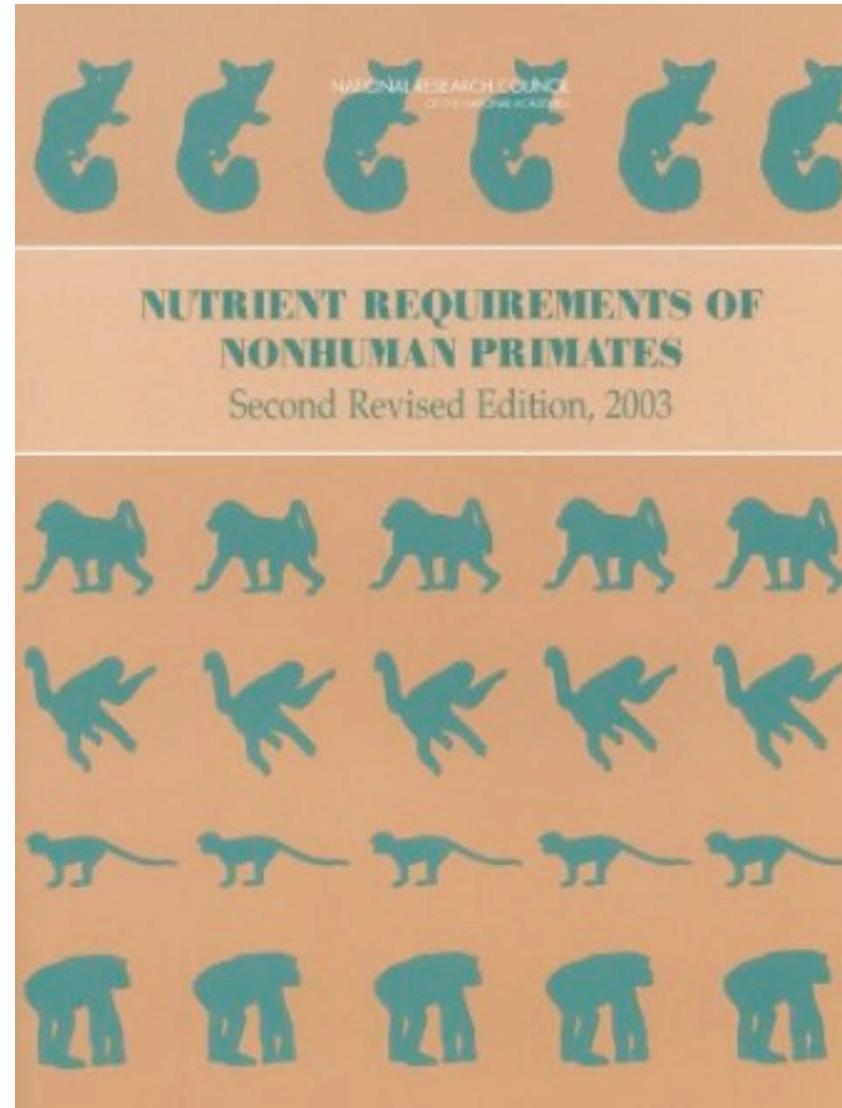


Natural diets

Schildkrötenarten	Insekten	Würmer, Schnecken	Blüten	Früchte	andere Pflanzen- teile
<i>Testudo graeca</i> Maurische Landschildkröte	•		×	×	×
<i>Testudo hermanni</i> Griechische Landschildkröte		×/×	×	×	×
<i>Testudo horsfieldii</i> Vierzehn Landschildkröten		×/-	•	•	×
<i>Testudo kleinmanni</i> Ägyptische Landschildkröte	•	•/-	×	×	×
<i>Testudo marginata</i> Breitbandschildkröte		•/-	×	×	×



Natural diets





Natural diets

1 Feeding Ecology, Digestive Strategies, and Implications for Feeding Programs in Captivity

The welfare of nonhuman primates in captivity depends heavily on meeting their nutrient needs in a manner that considers normal foraging and feeding behavior, structure and functions of the digestive system, and the options and constraints of captive dietary husbandry.

FEEDING ECOLOGY

In developing a system for the nourishment of captive nonhuman primates, it is helpful to examine the literature on the feeding ecology of primates in the wild. Several observational methods have been used to record foraging and feeding behavior in natural ecologic systems (Altman, 1974; Lehner, 1996), and data derived with these methods are summarized in Tables 1-1 through 1-6. To interpret the findings properly, the reader should have a background in the methods used, and a brief discussion of them follows.

Feeding-Ecology Methods Involving Visual Observations of Behavior

Data collected during visual observations of behavior typically include length of feeding bout, plant species eaten, plant parts eaten (for example, fruit and leaf), percentage of part eaten, feeding rate (for example, number of fruits consumed per minute), diameter and height of food plant, and food-plant location.

OBSERVATION OPTIONS

Choosing a data-collection method requires, as a first step, selection of one of two animal-observation options.

Focal-Animal Observation. One individual is observed during a given session of data collection (it can also be a pair or a small subgroup). Sessions can vary from 5 min to a whole day. This method is used to identify multiple behaviors in selected individuals. When sessions are only 5–10 min long, it is common to switch observations to another animal in the group for the next session.

All-Animal Observation. Primates that are naturally grouped are observed simultaneously. This method is feasible only when observing a few easy-to-see behaviors. It is not recommended for detailed feeding behaviors.

SAMPLING METHODS

After selection of an animal-observation option, the second step is to select a method of sampling foraging and feeding behavior.

Ad Libitum (or Periodic) Sampling. This is the classic pre-1970s field method, used before modern statistical techniques and advanced technologies were commonly applied. Today, it is recommended only for preliminary reconnaissance or the study of rare behaviors. This method is biased toward spectacular behaviors, like hunting, thus overestimating faunivory compared with herbivory.

Continuous-Recording Sampling Method. These sampling methods result in the most complete and accurate data. They are recommended for studying feeding ecology but are difficult to use with arboreal animals, such as primates.

- All-Occurrence Sampling. All occurrences of one or a few behaviors are recorded over an extended period.

6 Nutrient Requirements of Nonhuman Primates

TABLE 1-1 Prosimian Feeding Ecology

Scientific Name	Common Name	Diet*	Balance	Body Weight ^a	References
100% Insect/Vegetation					
<i>T. hamadryas</i>	Woolly center	Animal prey 20%, T. hamadryas sample, leaves 20%, seeds 23%, insects 18%, nectar 10%; carbohydrates 16%	Normal, arboreal, insect or fruits or nectar/parts, nectars, group size 2–6 individuals	27.5–137 g female, 27.5–134 g males	Chapman Jr & Atallah, 1995; Fegervold, 1974; Czarcik, 1990; Kappeler, 1993; MacKenna & MacKenna, 1980a; Novak, 1984; Novak & Novak, 2001; Tremble et al., 1991
<i>T. gelada</i>	Clan's center	Animal prey 20%, T. gelada sample, leaves 20%, seeds 23%, insects 18%, nectar 10%; carbohydrates 16%	Normal, arboreal, insect or fruits or nectar/parts, nectars, group size 2–6 individuals	27.5–137 g female, 27.5–134 g males	Chapman Jr & Atallah, 1995; Fegervold, 1974; Czarcik, 1990; Kappeler, 1993; MacKenna & MacKenna, 1980a; Novak, 1984; Novak & Novak, 2001; Tremble et al., 1991
<i>T. pygmaeus</i>	Pygmy center	Special center	Normal, arboreal, insect or fruits or nectar/parts, nectars, group size 2–6 individuals	27.5–137 g female, 27.5–134 g males	Chapman Jr & Atallah, 1995; Fegervold, 1974; Czarcik, 1990; Kappeler, 1993; MacKenna & MacKenna, 1980a; Novak, 1984; Novak & Novak, 2001; Tremble et al., 1991
<i>T. apertus</i>	Polygynous center	Normal, arboreal, insect or fruits or nectar/parts, nectars, group size 2–6 individuals	Normal, arboreal, insect or fruits or nectar/parts, nectars, group size 2–6 individuals	27.5–137 g female, 27.5–134 g males	Chapman Jr & Atallah, 1995; Fegervold, 1974; Czarcik, 1990; Kappeler, 1993; MacKenna & MacKenna, 1980a; Novak, 1984; Novak & Novak, 2001; Tremble et al., 1991
Mixed Insect/Vegetation					
<i>A. s. schmidti</i>	Malay-savanna deer/interior	In wild, omnivore, in captivity, insects 70%, nectars, tree fruits, fruits	Normal, arboreal, insect/nectar/parts, nectars, group size 2–6	70–90 g female, 75–80 g male	Altigard et al., 1991; Kappeler, 1993; Meier & Altigard, 1991; Minneboer et al., 1994
<i>A. senegalensis</i>	Senegal galago	Animal prey 70% (70–85%), fruits 15–18%, other vegetation 15%, prey, capuchins 75% (50–80%), insects, berries, ants	Normal, arboreal, insect/nectar/parts, nectars, group size 2–6	<i>A. senegalensis</i> 180–270 g; <i>A. m. mohamedii</i> 200–400 g	Breider, 1985; Charles-Dominique, 1974; Charles-Dominique & Römer, 1979; Gremmel, Kleinert, 1965; Silva & Downing, 1985; Wobwab, 1982
<i>C. demidoff</i>	Demidoff's bush baby	Animal prey 70% (70–85%), fruits 15–18%, other vegetation 15%, prey, capuchins 75% (50–80%), insects, berries, ants	Normal, arboreal, insect/nectar/parts, nectars, group size 2–6	<i>C. demidoff</i> 45–60 g; <i>C. a. aethiopicus</i> 35 g; <i>C. a. aethiopicus</i> 35–40 g; <i>C. a. aethiopicus</i> 40–140 g; <i>C. m. mohamedii</i> 110–170 g female, 130–175 g male	Charles-Dominique, 1974; Gremmel, Kleinert, 1965; Hassenauer & Baumberger, 1986; Hassenauer & Naef, 1986; Hofrik, 1970; Kappeler, 1991; Naef et al., 1984; Naef & Hassenauer, 1986; Sikes & Downing, 1985
<i>C. amederus</i>	Thomomys bush baby	Animal prey 70% (70–85%), fruits 15–18%, other vegetation 15%, prey, capuchins 75% (50–80%), insects, berries, ants	Normal, arboreal, insect/nectar/parts, nectars, group size 2–6	<i>C. amederus</i> 110–170 g female, 130–175 g male	Charles-Dominique, 1974; Gremmel, Kleinert, 1965; Hassenauer & Baumberger, 1986; Hassenauer & Naef, 1986; Hofrik, 1970; Kappeler, 1991; Naef et al., 1984; Naef & Hassenauer, 1986; Sikes & Downing, 1985
<i>L. senegalensis</i>	Savanna kudu	Alone or arboreally insects, seeds, tree fruits, leaves, flowers, eggs, small vertebrates, other insects, strong smelling	Normal, arboreal, insect/nectar/parts, nectars, group size 2–6	100–322 g	Reynolds, 1982; Pfeiffer & Hölzl, 1976; Silva & Downing, 1985; Wobwab, 1982
100% Plant Dominant					
<i>A. arctocephalus</i>	Rock hyrax/arboreal-climbing bush baby	Grass 50% (50–70%), animal prey 25% (insects, seeds, berries), fruits 25% (5–30%), nectars	Normal, arboreal, insect/nectar/parts, nectars, group size 2–6	271 g female, 275–306 g male	Breyne, 1982; Charles-Dominique, 1974, 1977; Charles-Dominique & Römer, 1979; Breider, 1985; Corcoran-Kleistner, 1985; Wobwab, 1982; Kappeler, 1991
<i>C. rufus</i>	Northern lesser bush baby	Grass (Africa) 40%, animal prey 35% (insects, seeds, berries), fruits 15–20%, nectars, no vegetation prey	Normal, arboreal, insect/nectar/parts, nectars, group size 2–6	<i>C. rufus</i> 120–180 g female, 125–180 g male; <i>C. r. rufus</i> 140–220 g female, 160–220 g male	Breider, 1985; Römer, 1977; Doyle, 1974; Römer & Charles-Dominique, 1979; Doyle & Römer, 1977; Hassenauer & Baumberger, 1986; Naef & Whiteman, 1984; Silva & Downing, 1985
<i>C. jacchus</i>	Southern lesser bush baby	Grass (Africa) 40%, animal prey 35% (insects, seeds, berries), fruits 15–20%, nectars, no vegetation prey	Normal, arboreal, insect/nectar/parts, nectars, group size 2–6	<i>C. jacchus</i> 120–180 g female, 125–180 g male; <i>C. j. jacchus</i> 140–220 g female, 160–220 g male	Breider, 1985; Römer, 1977; Doyle, 1974; Römer & Charles-Dominique, 1979; Doyle & Römer, 1977; Hassenauer & Baumberger, 1986; Naef & Whiteman, 1984; Silva & Downing, 1985
<i>C. mitis</i>	Eastern lesser bush baby	Grass (Africa) 40%, animal prey 35% (insects, seeds, berries), fruits 15–20%, nectars, no vegetation prey	Normal, arboreal, insect/nectar/parts, nectars, group size 2–6	<i>C. mitis</i> 120–180 g female, 125–180 g male; <i>C. m. mitis</i> 140–220 g female, 160–220 g male	Breider, 1985; Römer, 1977; Doyle, 1974; Römer & Charles-Dominique, 1979; Doyle & Römer, 1977; Hassenauer & Baumberger, 1986; Naef & Whiteman, 1984; Silva & Downing, 1985
<i>O. r. rufescens</i>	Tart-colored greater bush baby	Grass 44% (18–62%), fruits 27% (12–32%), animal prey 14% (11–27%) (insects, seeds, berries), nectars, no vegetation prey (0–9%), seeds 3% (0–7%), mix, vegetable matter 9% (0–15%)	Normal, arboreal, insect/nectar/parts, nectars, group size 2–6	1123–1497 g female, 1125–1750 g male	Roeke & Doyle, 1974; Breyne, 1982; Doyle & Römer, 1977; Kappeler, 1991; Minneboer et al., 1994
<i>O. r. rufescens</i>	White-eared greater bush baby	Tree gum (water) bark of tree, stems, leaf, cop, animal matter, fruits, flowers, seeds, nectars, remains of Hippocratea leaves	Normal, arboreal, insect/nectar/parts, nectars, group size 2–6	1120–1600 g	Charles-Dominique & Poer, 1985; Hölzl, 1976; Stark et al., 1984; Kappeler, 1991; Poer, 1974; Poer et al., 1991; Poer, 1993

(continued)



Phylogeny is no reliable clue

Mostly insectivorous

Galagoides

G. demidoff
G. thomasi
G. zanzibaricus

Demidoff's bush baby
Thomas's bush baby
Zanzibar bush baby

Animal prey 75% (70-81%),
fruit 17% (4-30%), gums/
resins 5% (0-18%), leaves,
buds; prey: moths, beetles,
grasshoppers, ants, some birds

Nocturnal, arboreal
(mostly), forage
solitary, sleep
(females) 1-10

G. demidoff 46-69 g
females, 78-85 g
males; *G. thomasi* 55-
149 g; *G. zanzibaricus*
118-155 g females,
130-183 g males

Charles-Dominique, 1974;
Gonzalez-Kirchner, 1995;
Harcourt & Bearder, 1989;
Harcourt & Nash, 1986;
Hladik, 1979; Kappeler, 1991;
Nash et al., 1989; Nash &
Harcourt, 1986; Silva &
Downing, 1995

Omnivorous, gums dominate

Euoticus

E. elegantulus
(*Galago elegantulus*)
E. pallidus

Southern needle-clawed
bush baby
Northern needle-clawed
bush baby

Gums 55% (35-75%), animal
prey 32% (20-44%), fruit 12%
(5-20%), birds

Nocturnal, arboreal,
forage solitary, sleep
1-7

271 g female, 270-360
g males

Butynski, 1982; Charles-
Dominique, 1974, 1977;
Charles-Dominique &
Bearder, 1979; Gonzalez-
Kirchner, 1995; Hladik, 1979;
Kappeler 1991

Galago

G. senegalensis
G. moholi

Northern lesser bush baby
Southern lesser bush baby

Gums (Acacia) 48%, animal
prey 52% (butterflies, moths,
beetles), gums from 2 tree
species, no vertebrate prey

Nocturnal, arboreal,
forage solitary, sleep
1-3

G. senegalensis 126-
193 g females, 125-
212 g males; *G.
moholi* 140-229 g
females, 160-255 g
males

Bearder, 1987; Bearder &
Doyle, 1974; Bearder &
Martin, 1979; Doyle, 1979;
Doyle & Bearder, 1977;
Harcourt & Bearder, 1989;
Nash & Whitten, 1989; Silva
& Downing, 1995

Otolemur

O. crassicaudatus
(*Galago
crassicaudatus*)

Thick-tailed greater bush
baby

Gums 44% (18-62%), fruit
27% (21-33%), animal prey
14% (1-27%) (invertebrates
and vertebrates), nectar 4%
(0-8%), seeds 3% (0-7%),
misc. vegetable matter 8% (0-
16%)

Nocturnal, arboreal,
male solitary, female
and offspring forage
together, sleep 1-6

1122-1497 g females,
1126-1750 g males

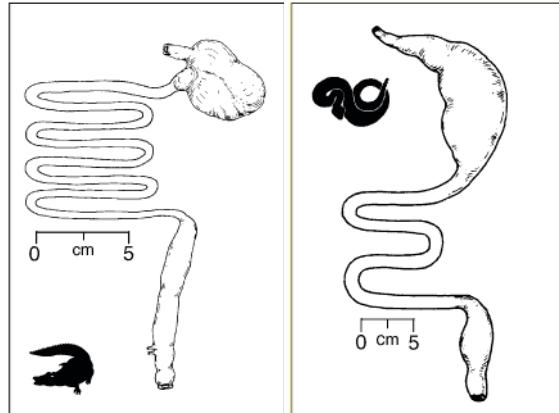
Bearder & Doyle, 1974;
Butynski, 1982; Doyle &
Bearder, 1977; Kappeler,
1991; Masters et al., 1988



Basic gut anatomy



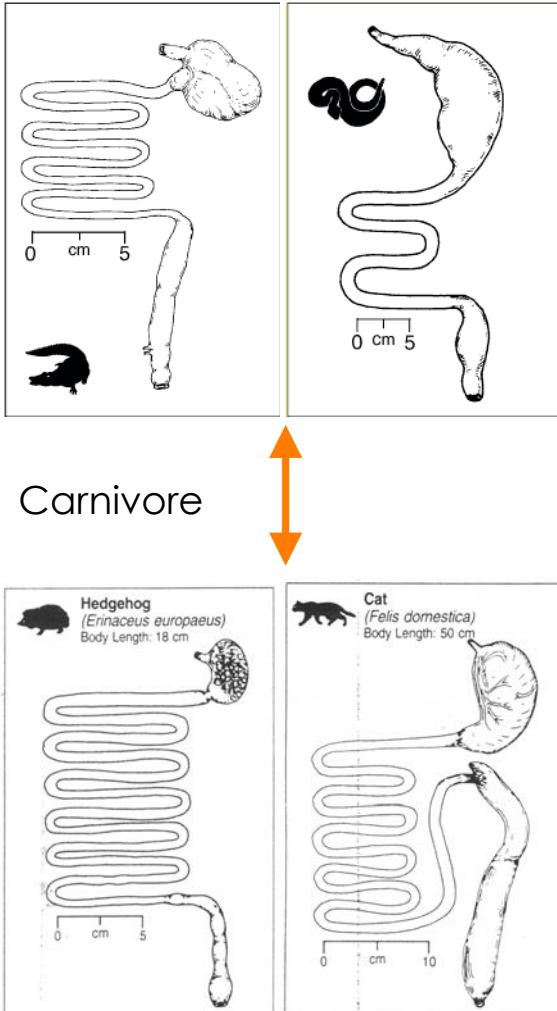
Basic gut anatomy



Carnivore

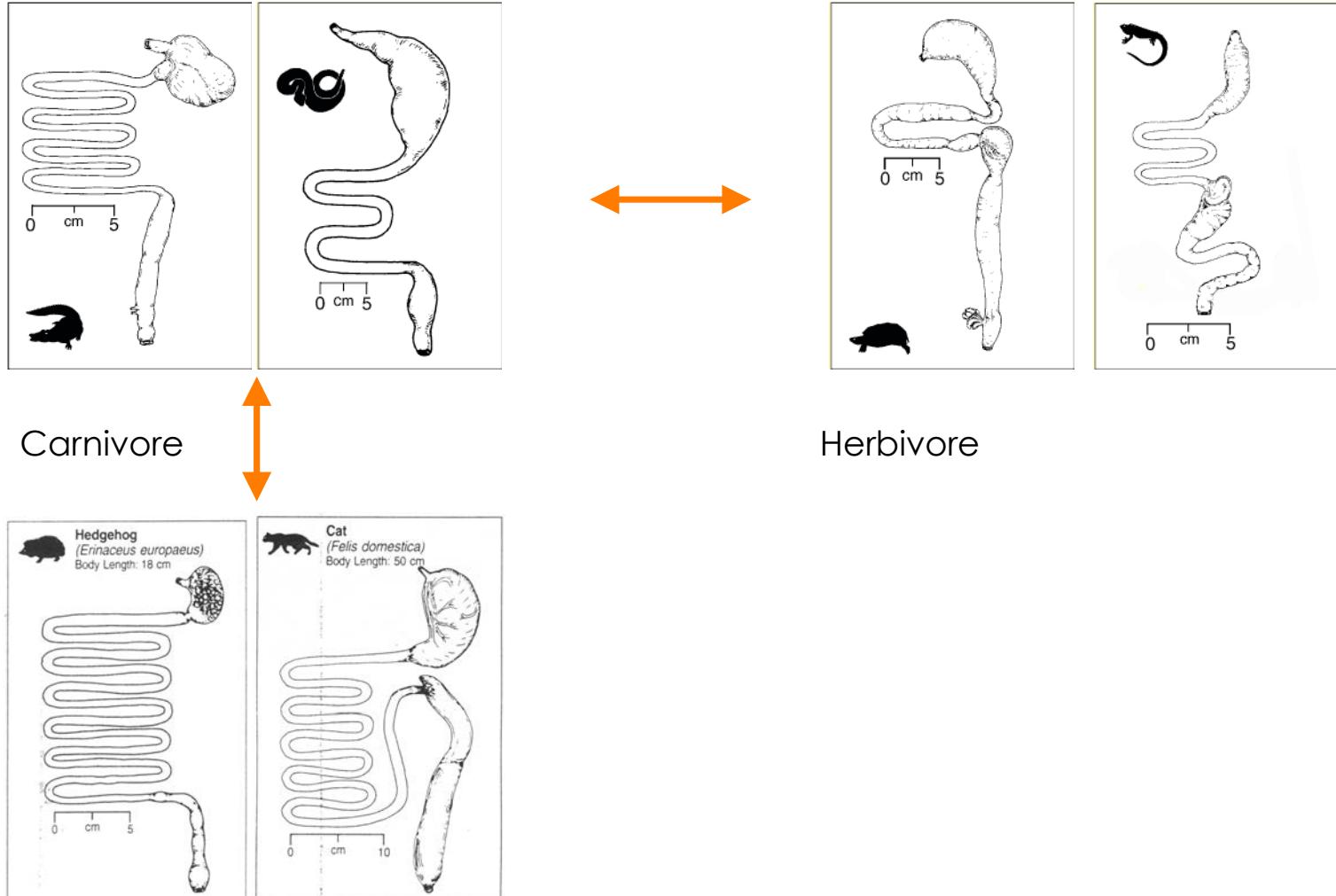


Basic gut anatomy





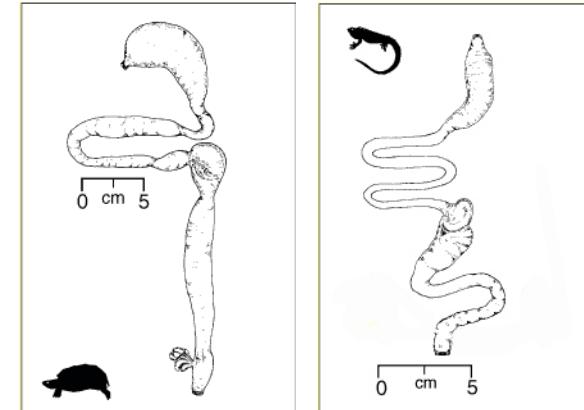
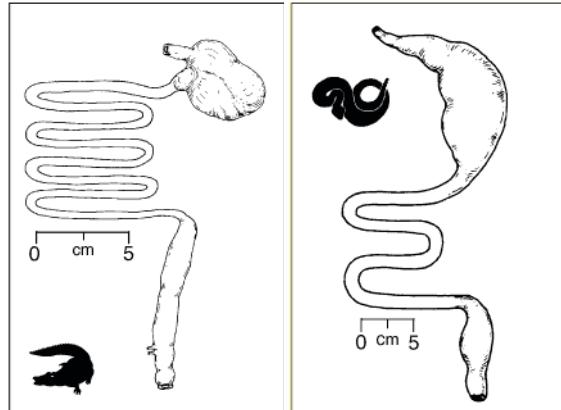
Basic gut anatomy



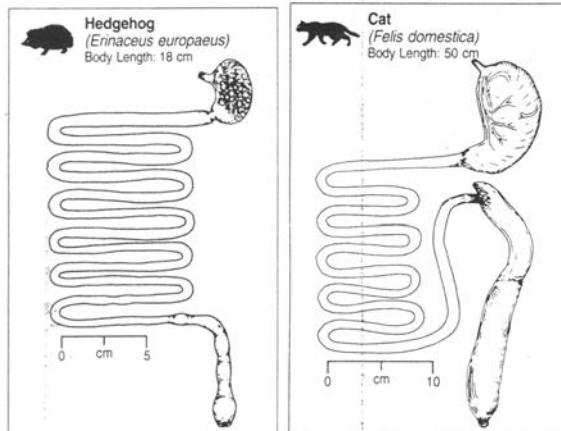
Stevens & Hume (1995)



Basic gut anatomy



Carnivore



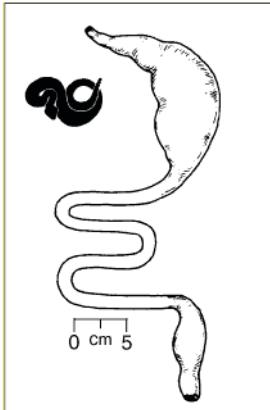
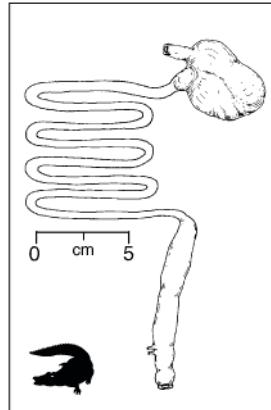
Herbivore



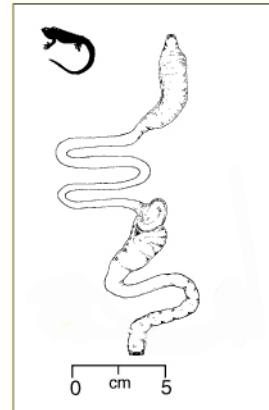
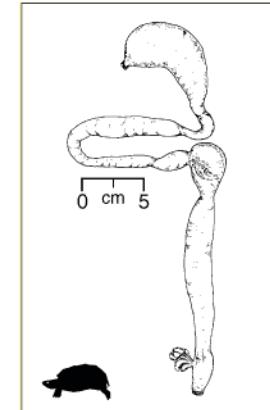
Stevens & Hume (1995), Fritz pers. comm.



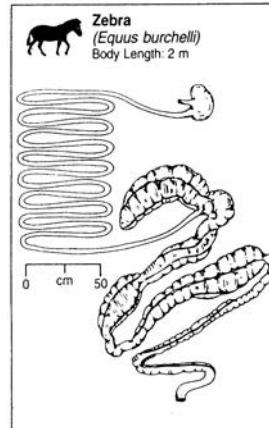
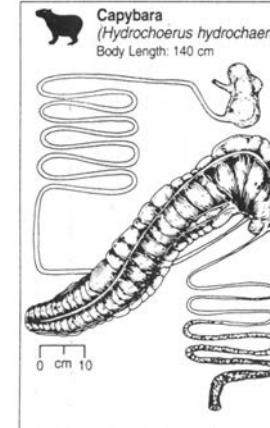
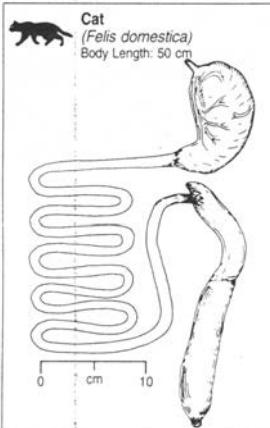
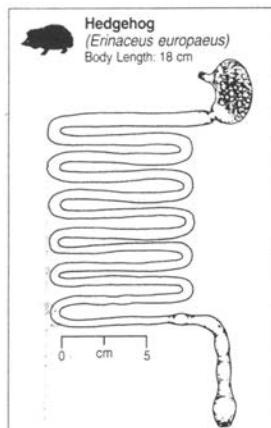
Basic gut anatomy



Carnivore

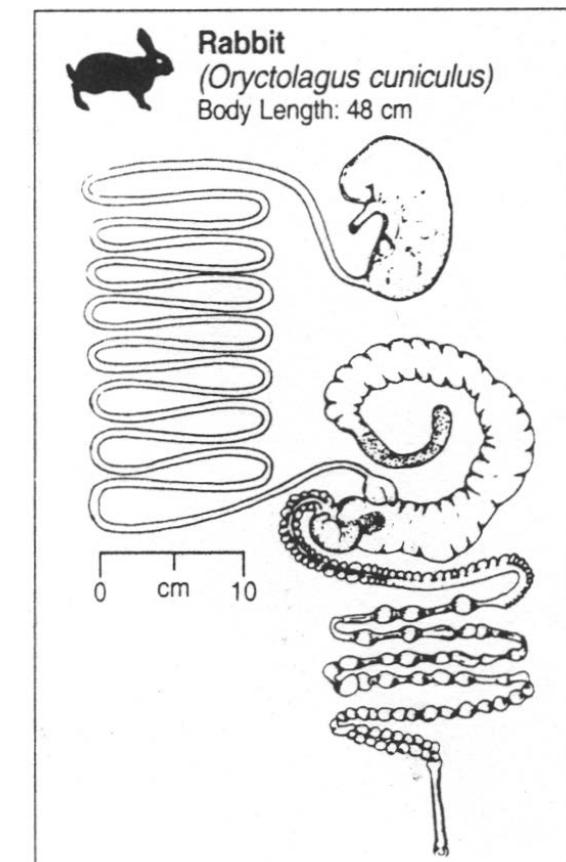
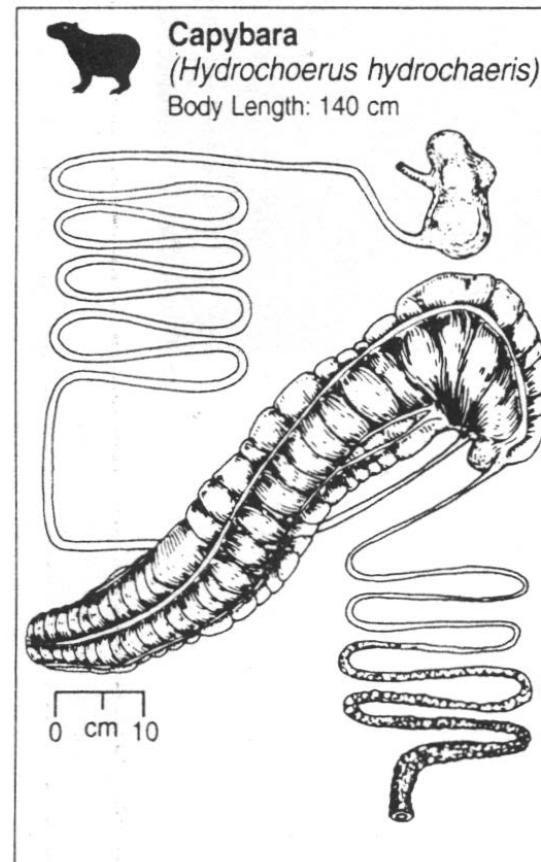
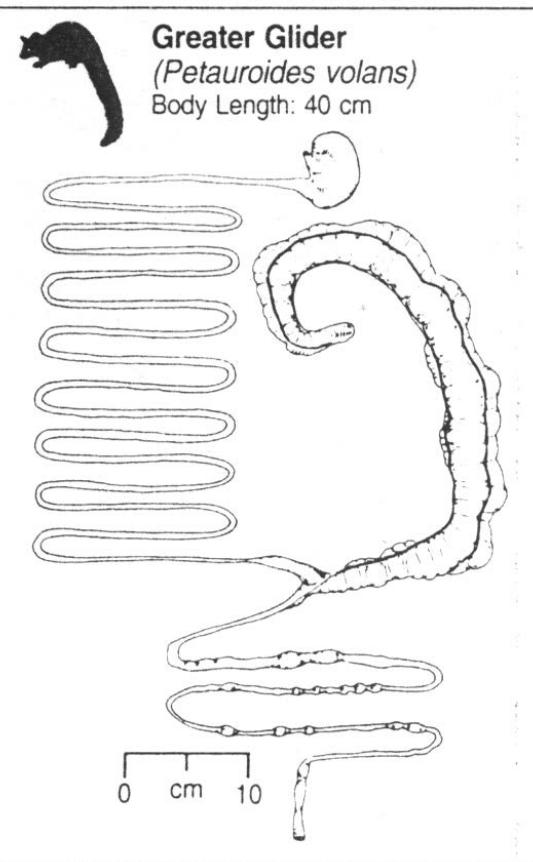


Herbivore





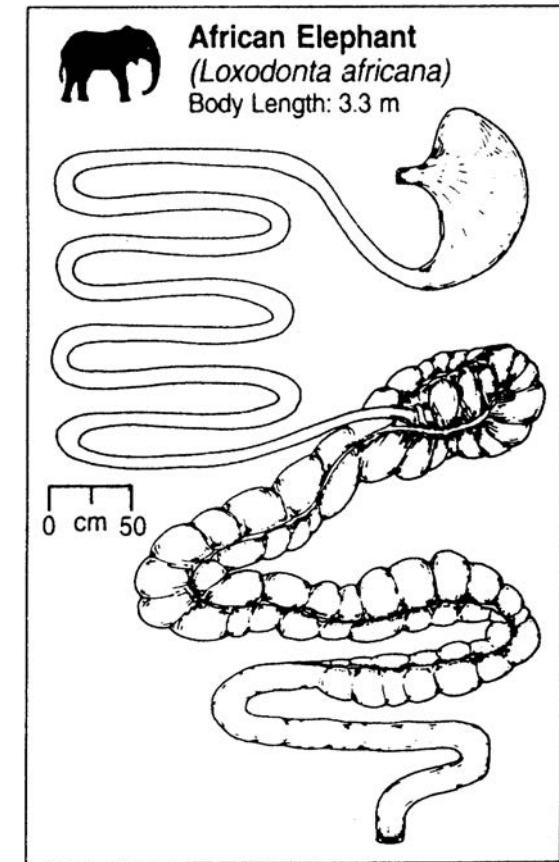
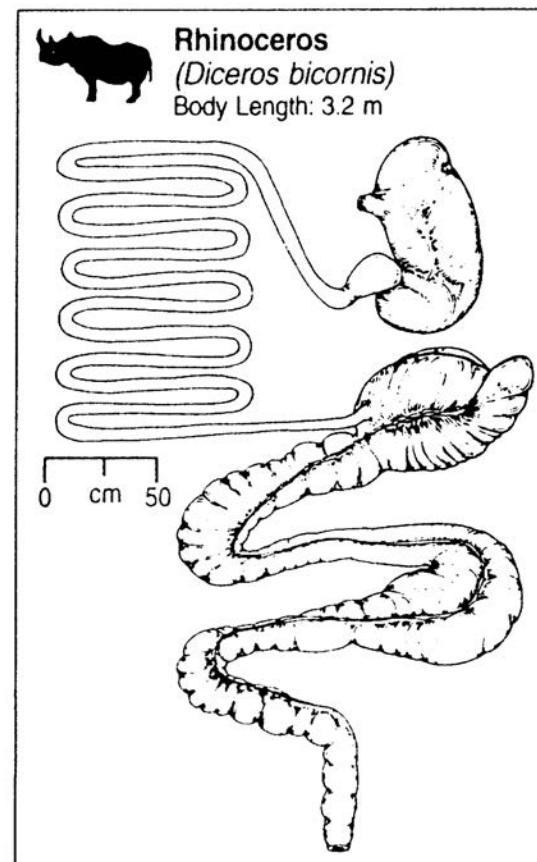
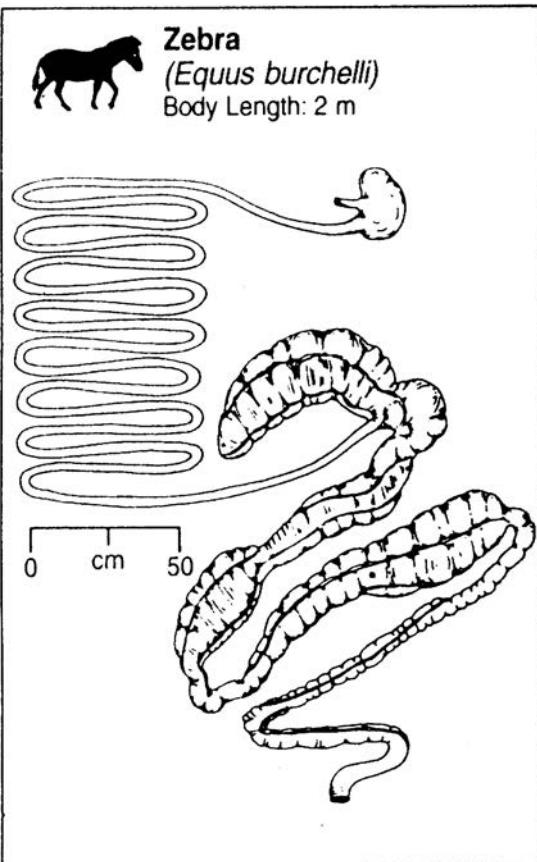
Hindgut Fermentation - Caecum



Stevens & Hume (1995)



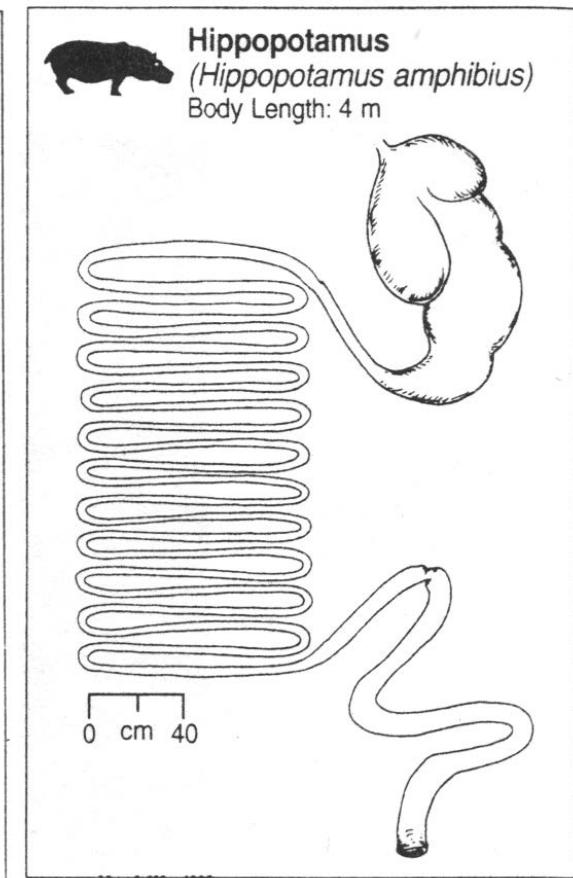
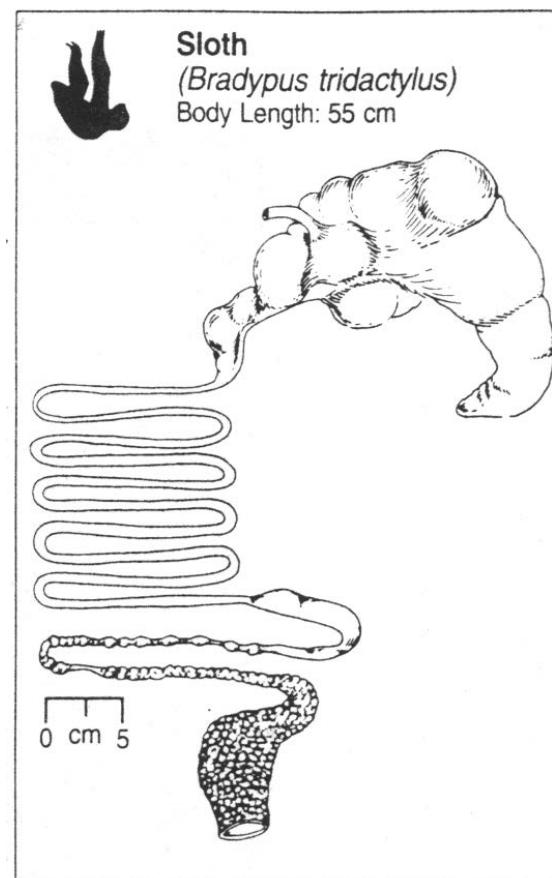
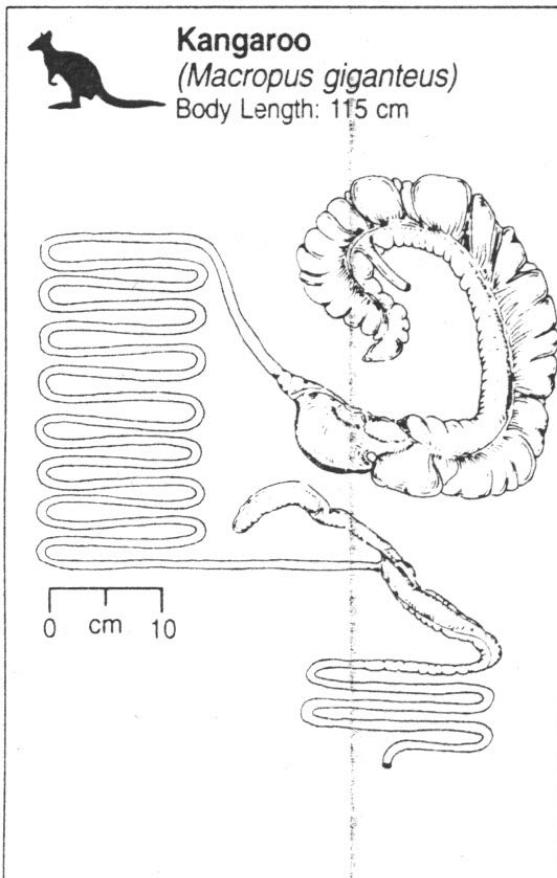
Hindgut Fermentation - Colon



from Stevens & Hume (1995)



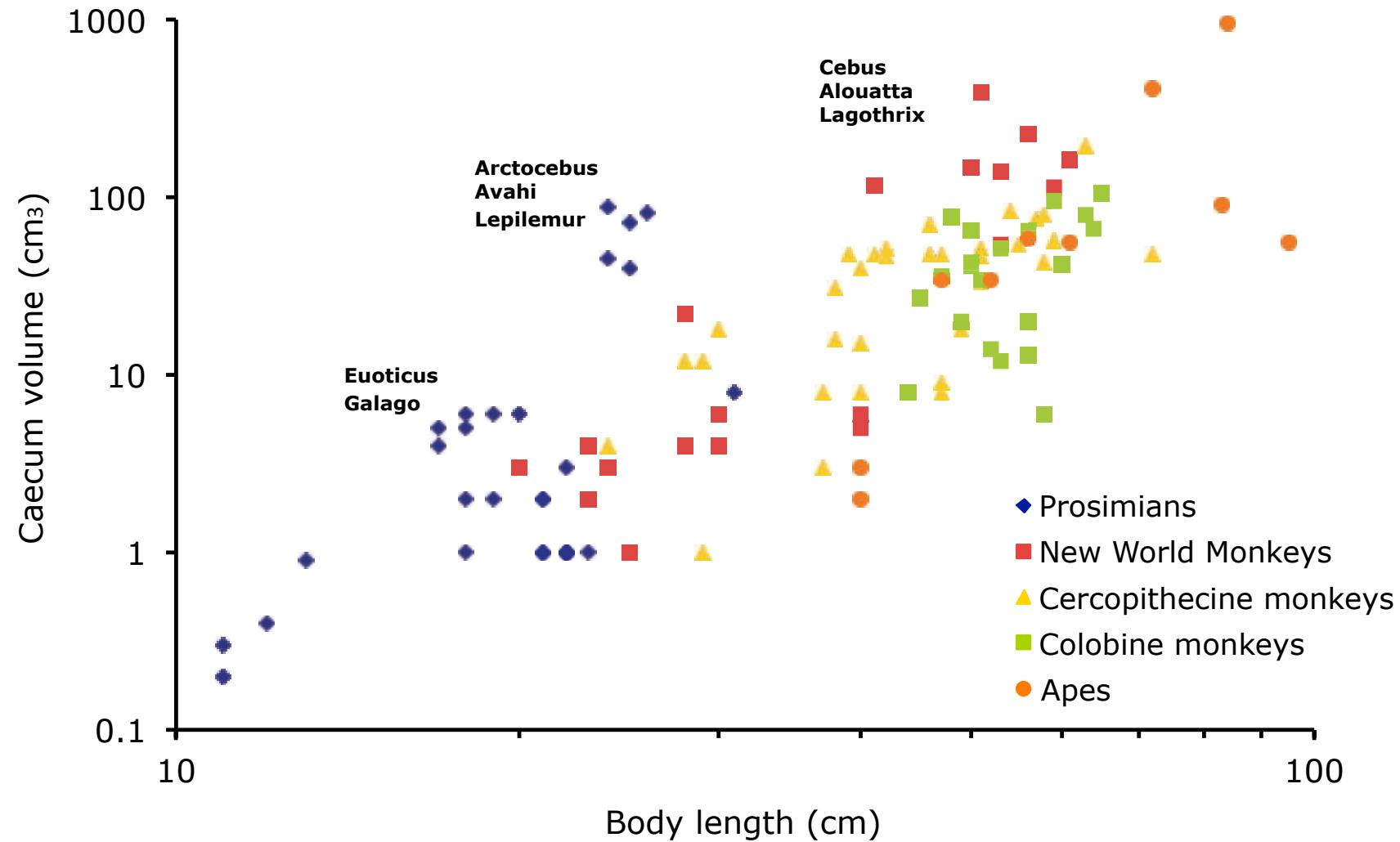
Foregut Fermentation



from Stevens & Hume (1995)



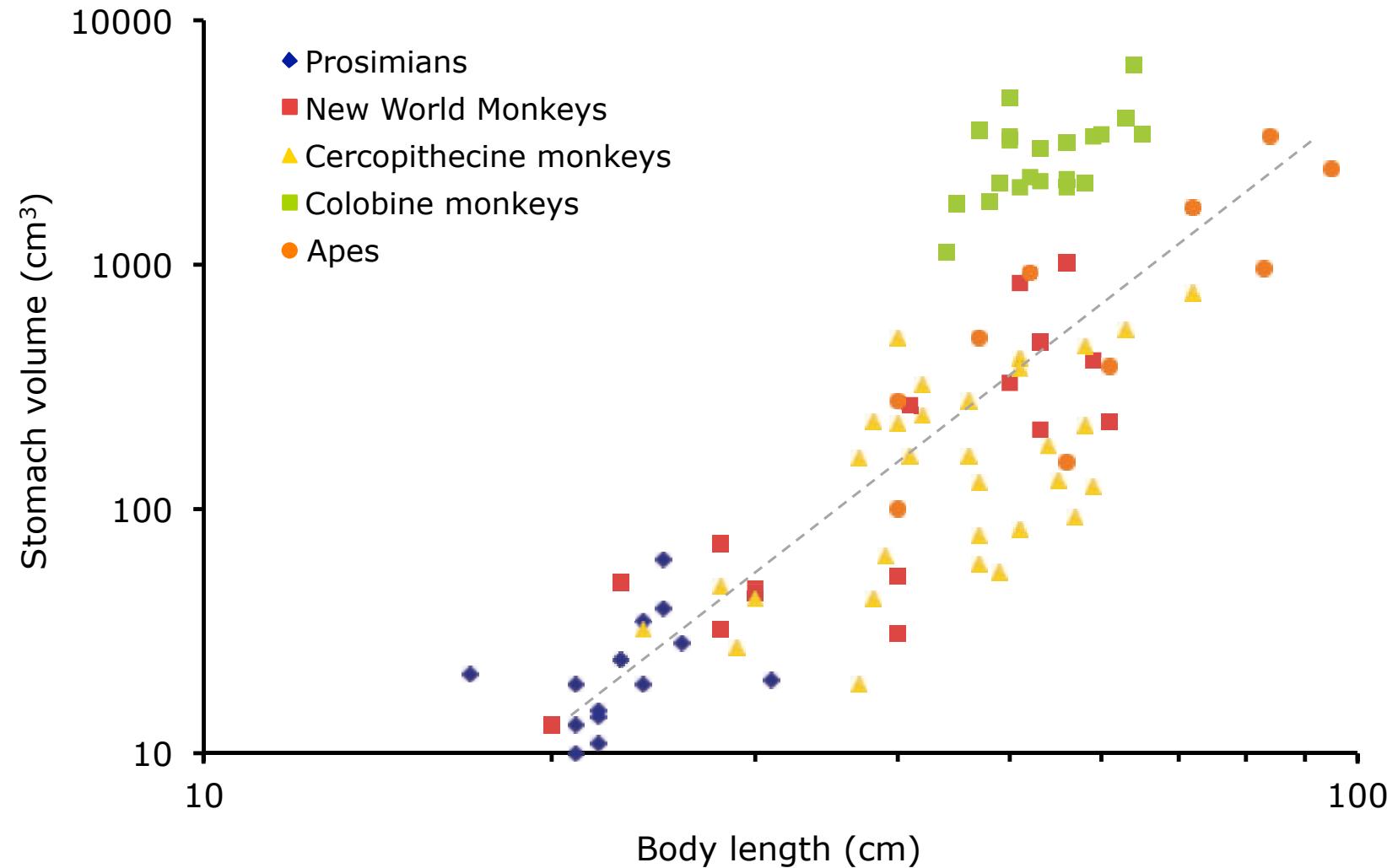
Caecum volume in primates



Data from Chivers & Hladik (1980)



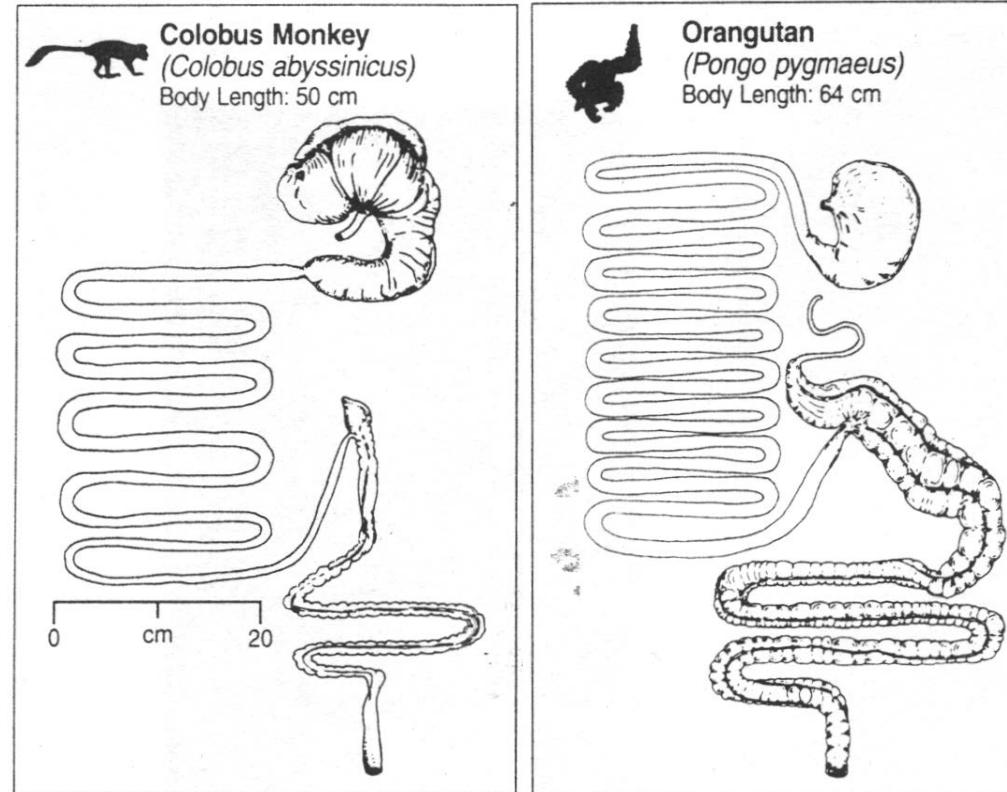
Stomach volume in primates



Data from Chivers & Hladik (1980)



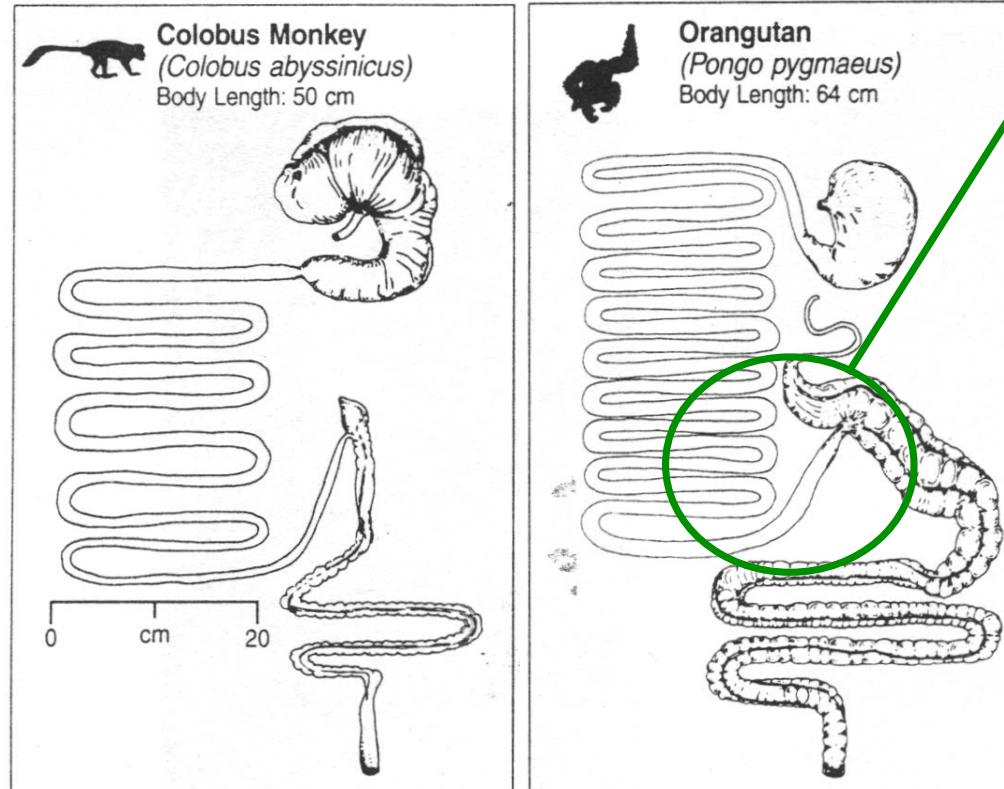
Foregut vs. Hindgut Fermentation



from Stevens & Hume (1995)



Foregut vs. Hindgut Fermentation

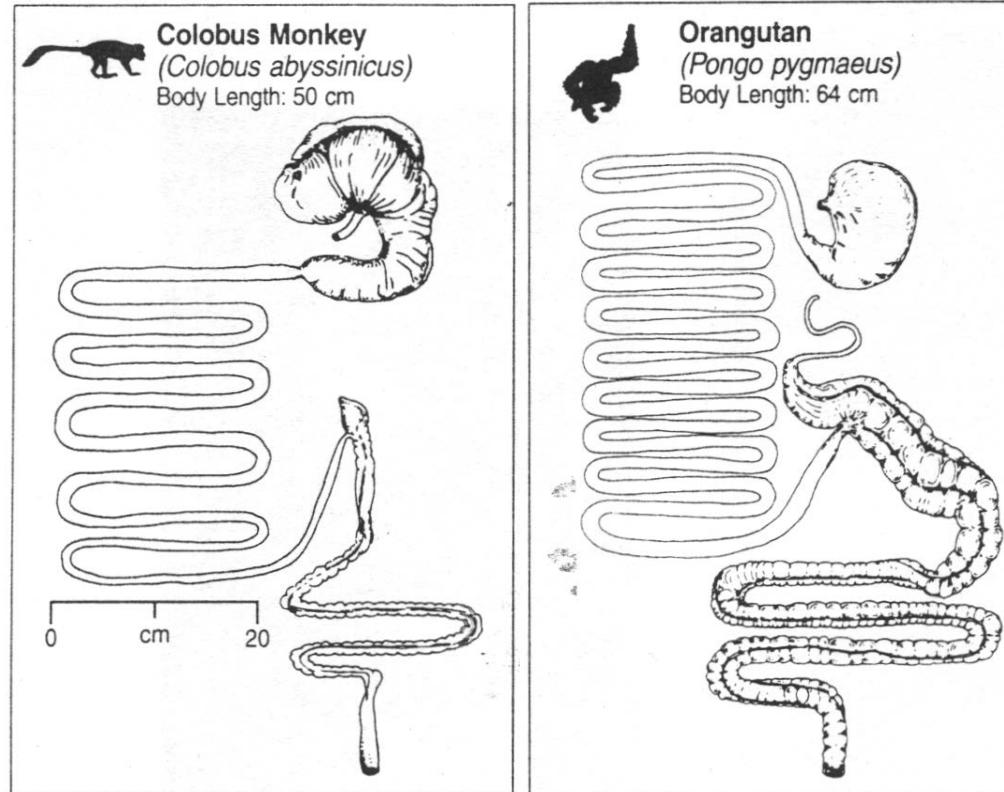


Fermentation
after
enzymatic
digestion and
absorption:

from Stevens & Hume (1995)



Foregut vs. Hindgut Fermentation



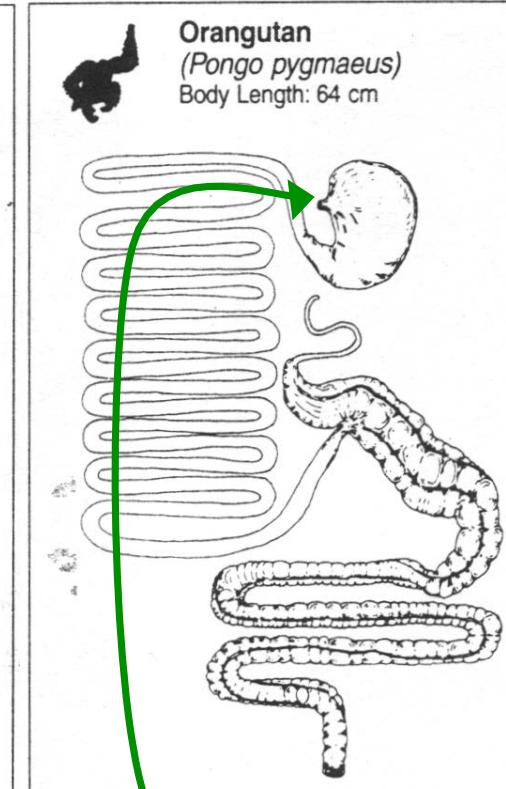
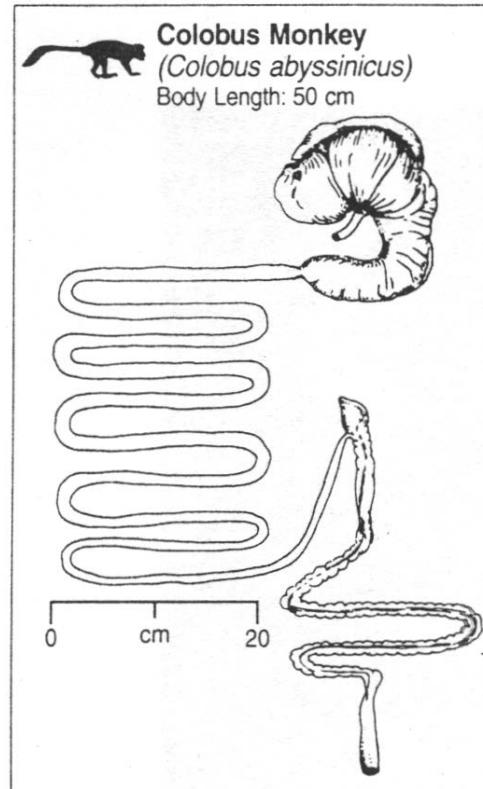
Fermentation
after
enzymatic
digestion and
absorption:

'Loss' of
bacterial
protein,
bacterial
products (B-
Vitamins?)?

from Stevens & Hume (1995)



Foregut vs. Hindgut Fermentation



Fermentation
after
enzymatic
digestion and
absorption:

'Loss' of
bacterial
protein,
bacterial
products (B-
Vitamins?)?
(coprophagy)

from Stevens & Hume (1995)



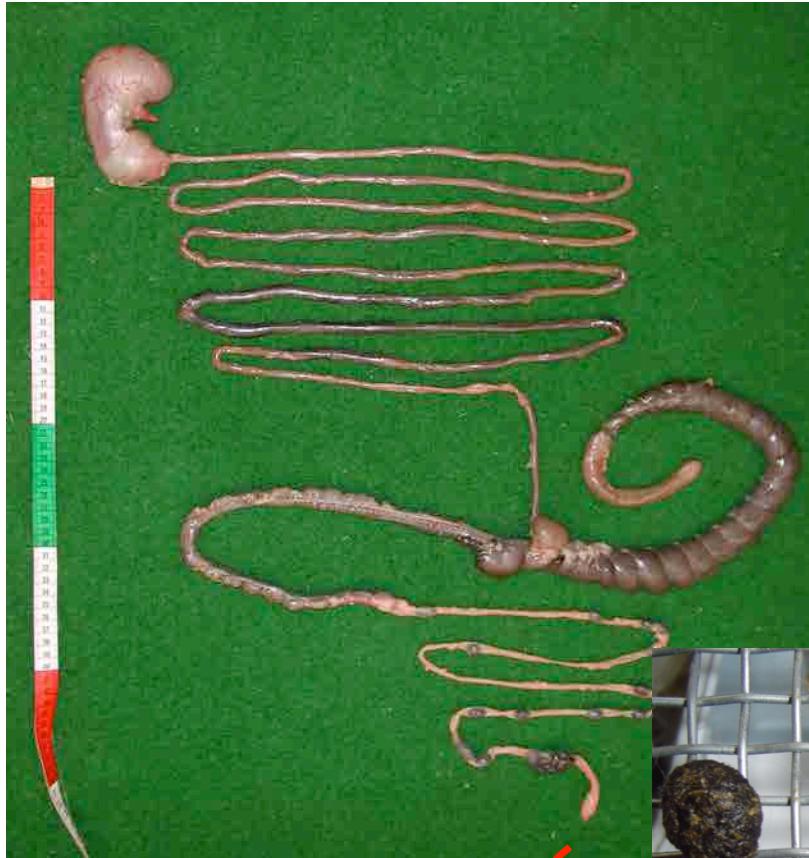
Coprophagy/Caecotrophy



Photos: B. Burger



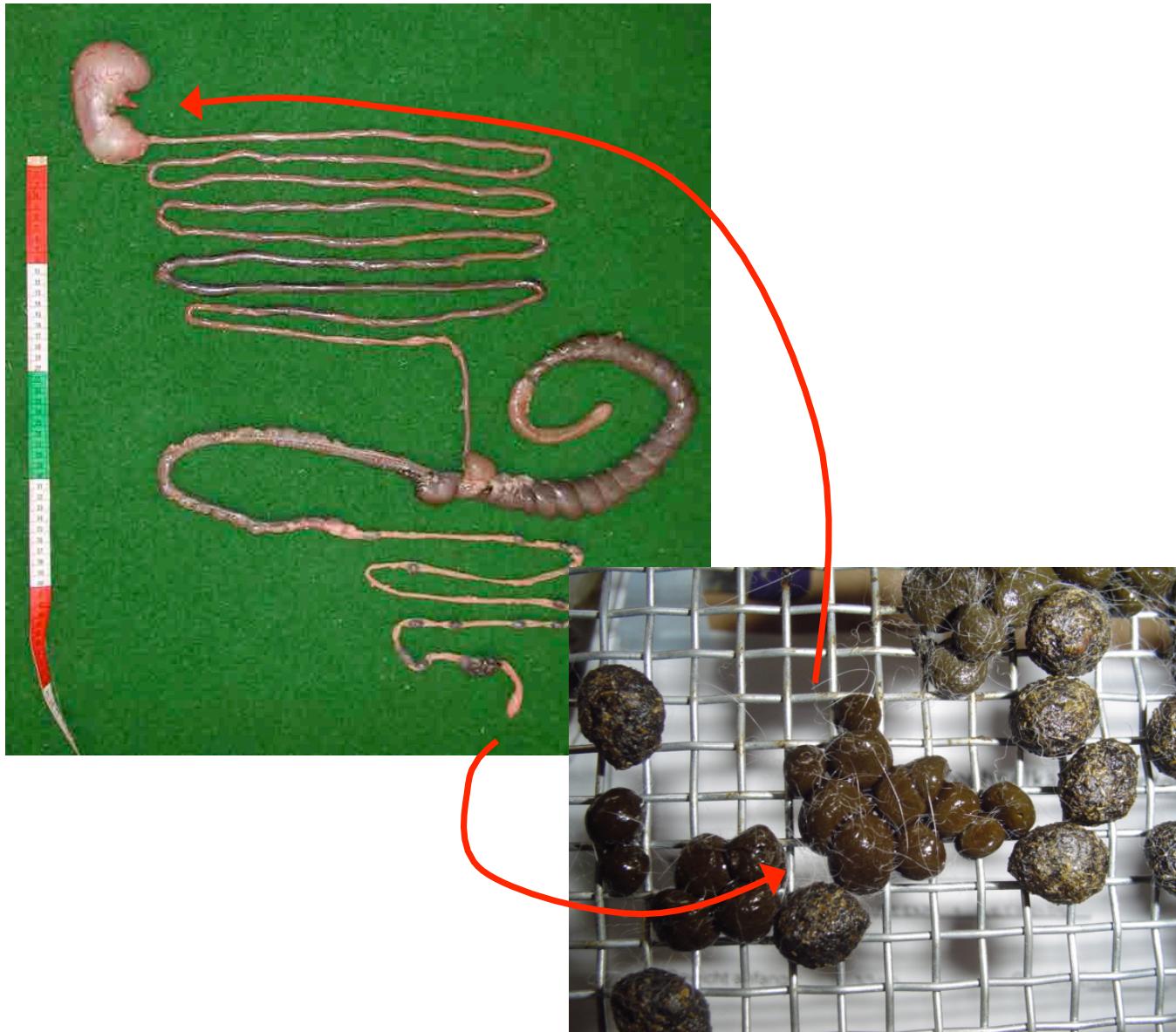
Coprophagy/Caecotrophy



Photos: B. Burger



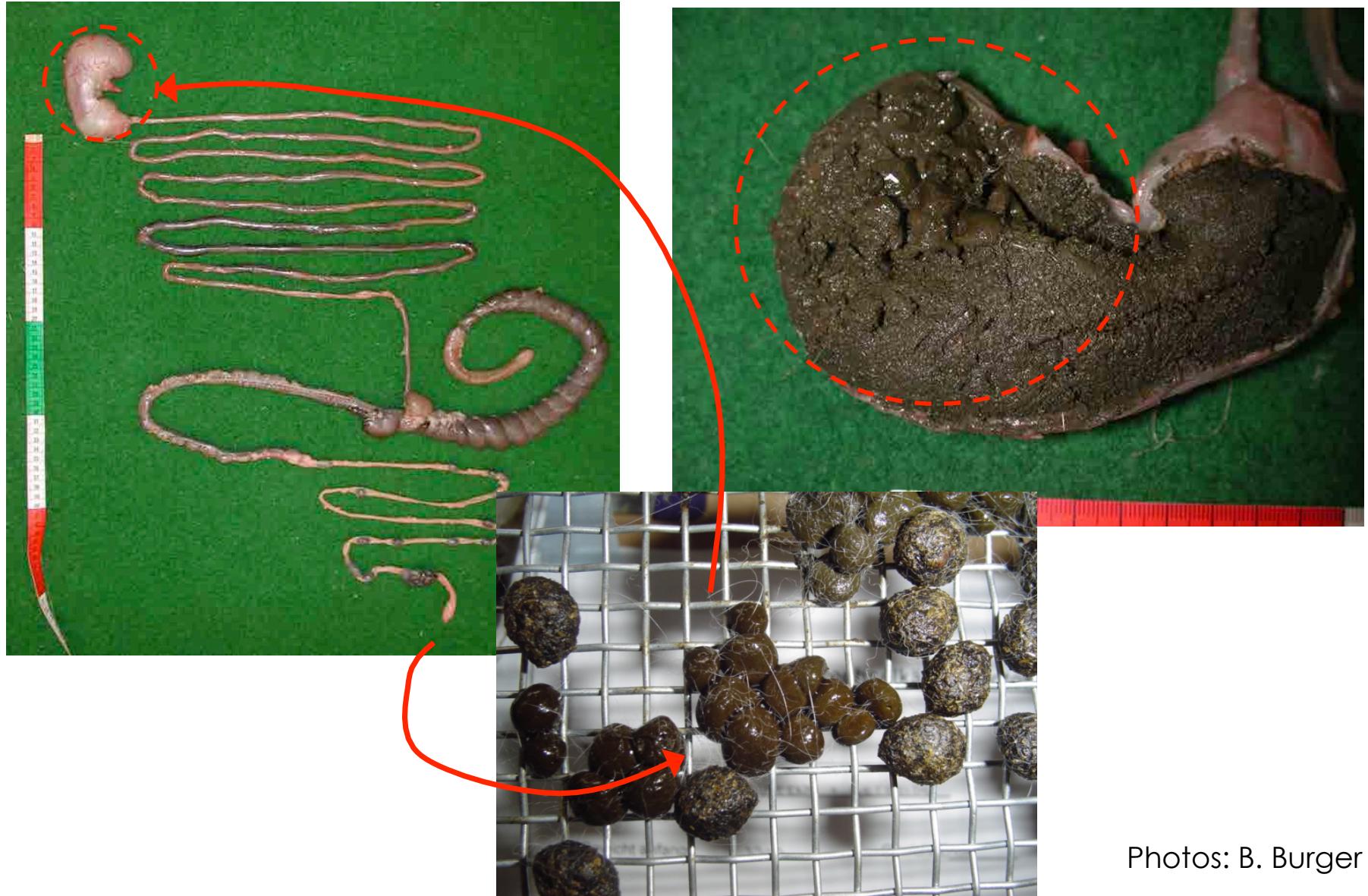
Coprophagy/Caecotrophy



Photos: B. Burger



Coprophagy/Caecotrophy



Photos: B. Burger



Coprophagy/Caecotrophy



Photos: B. Burger, M. Clauss



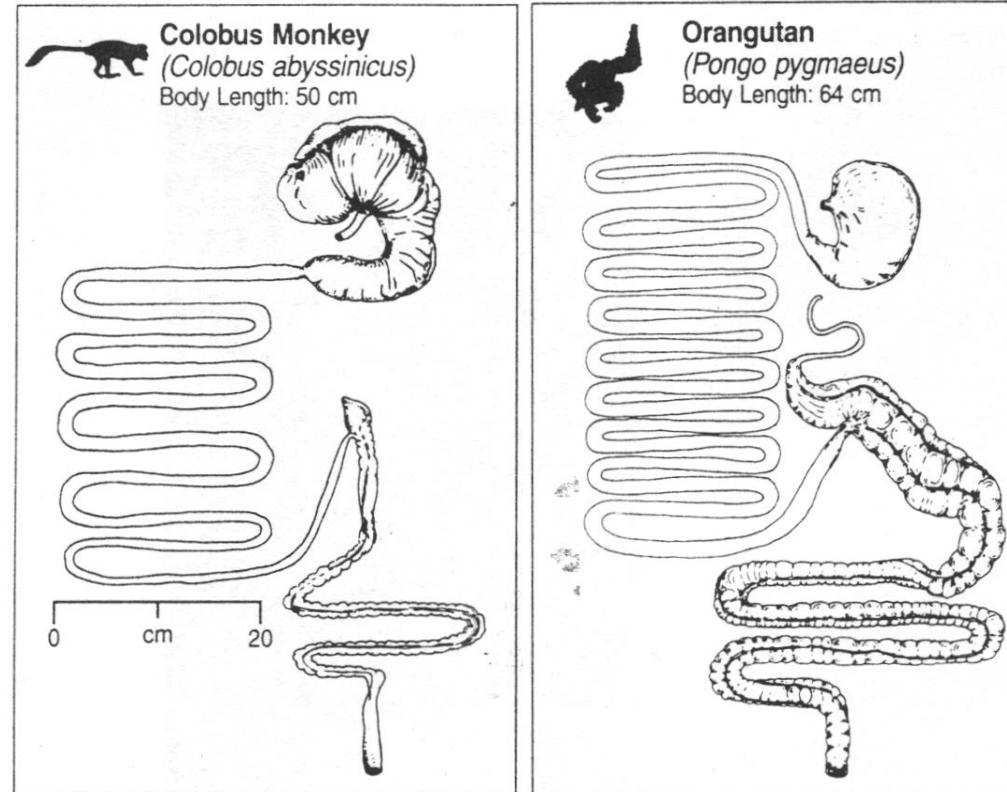
Coprophagy/Caecotrophy



Photo: A. Tschudin



Foregut vs. Hindgut Fermentation



Fermentation
after
enzymatic
digestion and
absorption:

'Loss' of
bacterial
protein,
bacterial
products (B-
Vitamins?)?
(coprophagy)

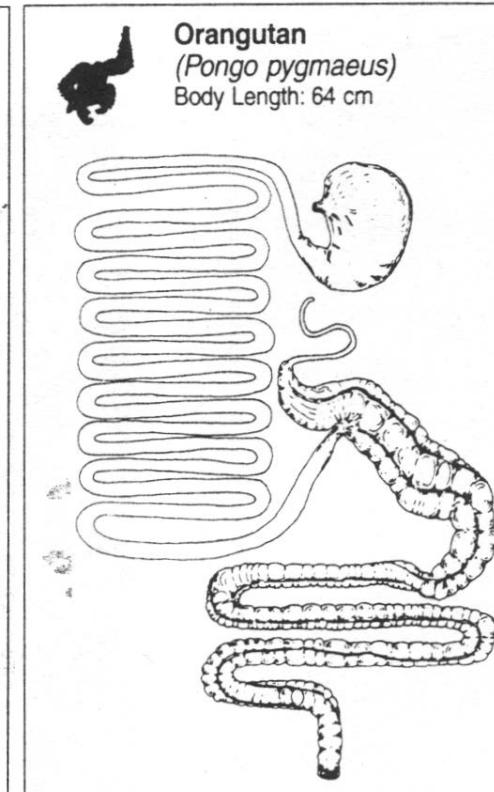
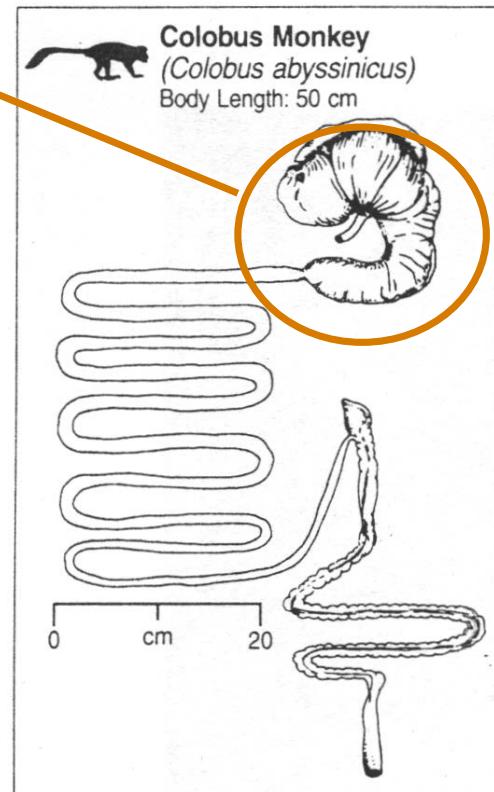
Use of easily
digestible
substrates

from Stevens & Hume (1995)



Foregut vs. Hindgut Fermentation

Fermentation prior to enzymatic digestion and absorption:



Fermentation after enzymatic digestion and absorption:

'Loss' of bacterial protein, bacterial products (B-Vitamins?)?
(coprophagy)

Use of easily digestible substrates

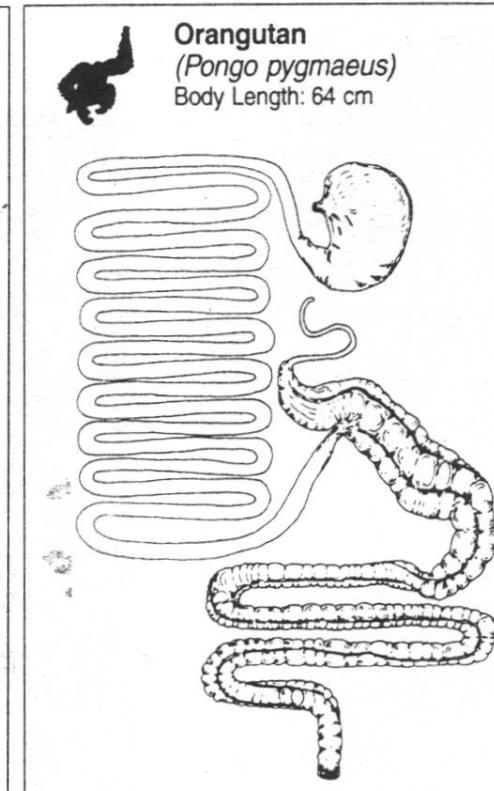
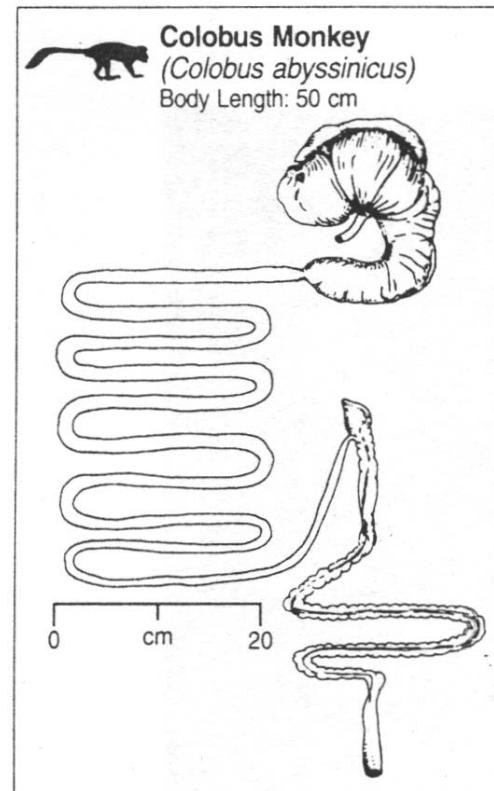
from Stevens & Hume (1995)



Foregut vs. Hindgut Fermentation

Fermentation prior to enzymatic digestion and absorption:

Use of bacterial protein, bacterial products (B-Vitamins)



Fermentation after enzymatic digestion and absorption:

'Loss' of bacterial protein, bacterial products (B-Vitamins?)?
(coprophagy)

Use of easily digestible substrates

from Stevens & Hume (1995)

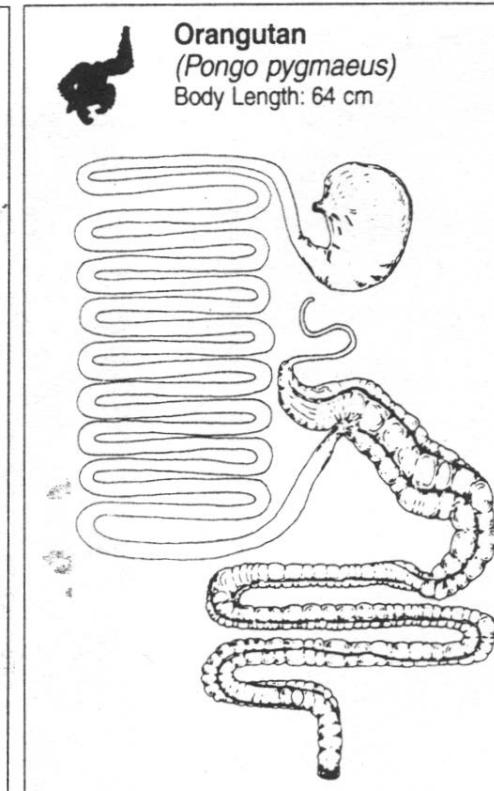
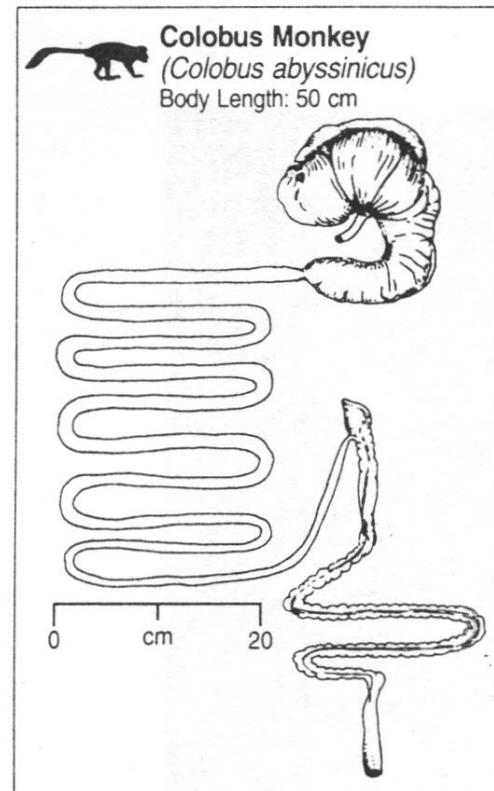


Foregut vs. Hindgut Fermentation

Fermentation prior to enzymatic digestion and absorption:

Use of bacterial protein, bacterial products (B-Vitamins)

Bacterial detoxification?



Fermentation after enzymatic digestion and absorption:

'Loss' of bacterial protein, bacterial products (B-Vitamins?)?
(coprophagy)

Use of easily digestible substrates

from Stevens & Hume (1995)



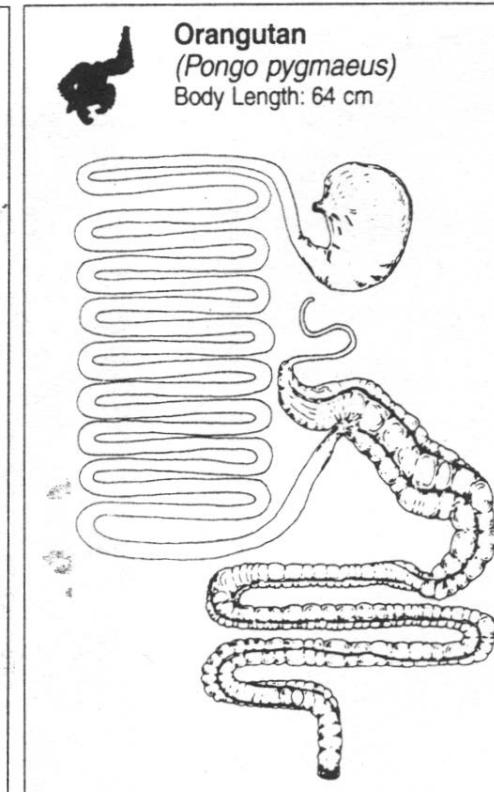
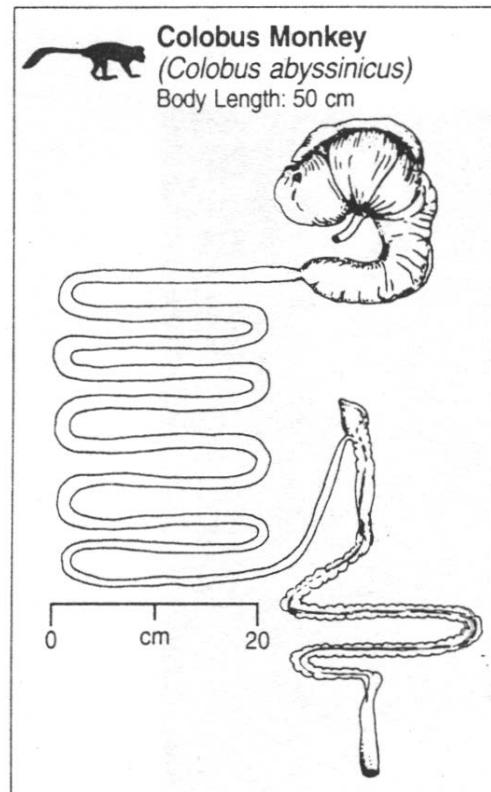
Foregut vs. Hindgut Fermentation

Fermentation prior to enzymatic digestion and absorption:

Use of bacterial protein, bacterial products (B-Vitamins)

Bacterial detoxification?

'Loss' of easily digestible substrates and bacterial modification



Fermentation after enzymatic digestion and absorption:

'Loss' of bacterial protein, bacterial products (B-Vitamins?)?
(coprophagy)

Use of easily digestible substrates

from Stevens & Hume (1995)



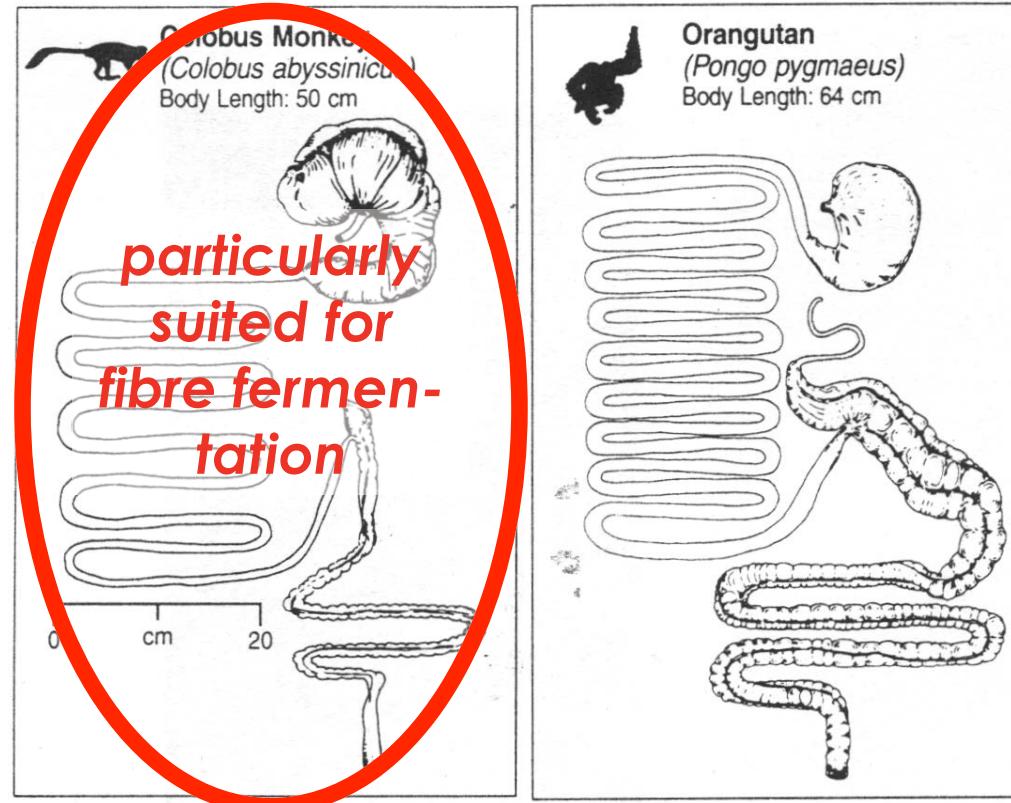
Foregut vs. Hindgut Fermentation

Fermentation prior to enzymatic digestion and absorption:

Use of bacterial protein, bacterial products (B-Vitamins)

Bacterial detoxification?

'Loss' of easily digestible substrates



Fermentation after enzymatic digestion and absorption:

'Loss' of bacterial protein, bacterial products (B-Vitamins?)

(coprophagy)

Use of easily digestible substrates

from Stevens und Hume (1995)



Digestive tract: galagos



Euoticus elegantulus

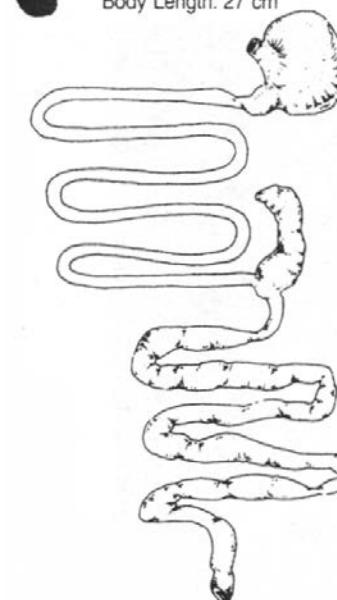
Euoticus

E. elegantulus
(*Galago elegantulus*)
E. pallidus

Southern needle-clawed
bush baby
Northern needle-clawed
bush baby

Gums 55% (35-75%), animal
prey 32% (20-44%), fruit 12%
(5-20%), birds

Bush baby
(*Galago crassicaudatus*)
Body Length: 27 cm



Otolemur crassicaudatus

Otolemur

O. crassicaudatus
(*Galago*
crassicaudatus)

Thick-tailed greater bush
baby

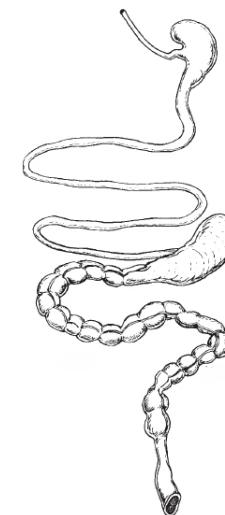
Gums 44% (18-62%), fruit
27% (21-33%), animal prey
14% (1-27%) (invertebrates)



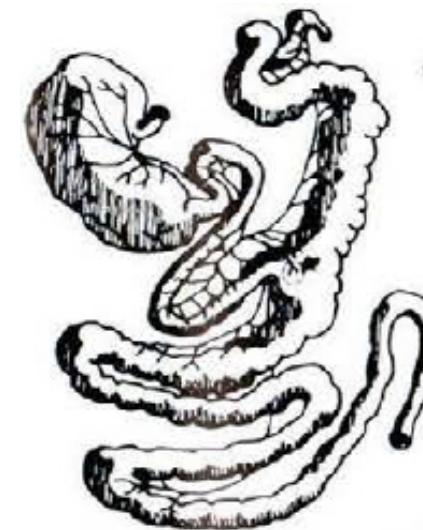
Digestive tract: lemurs



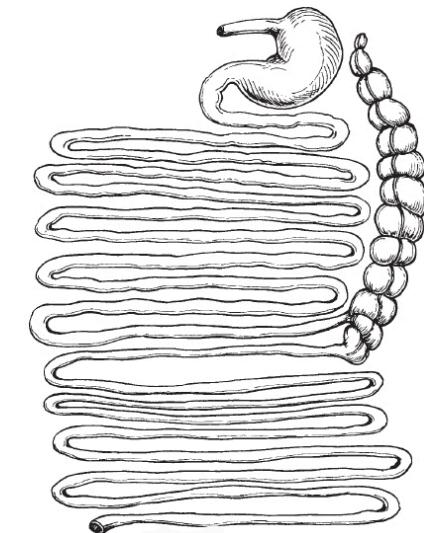
Eulemur macaco



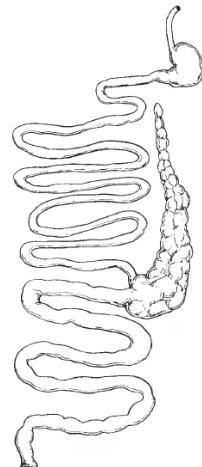
Hapalemur griseus



Lepilemur leucopus



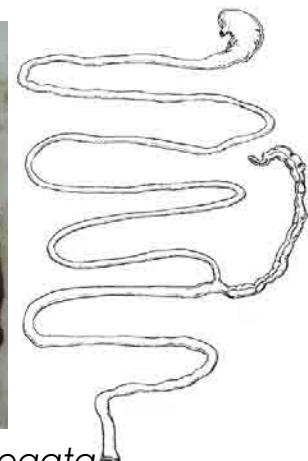
Propithecus verreauxi



Lemur catta



Varecia variegata

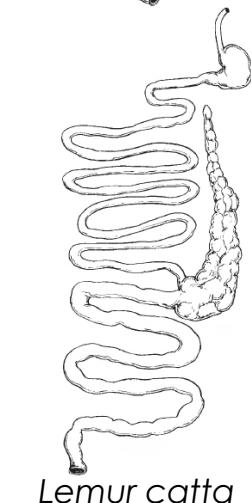
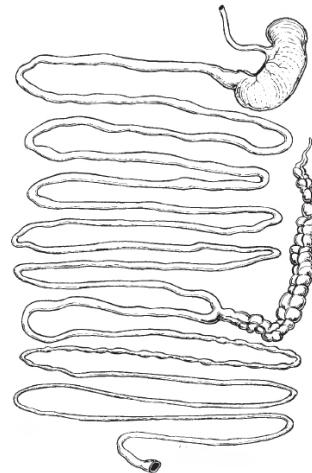


Chivers & Hladik (1980), Campbell et al. (2000), Navarrete pers.

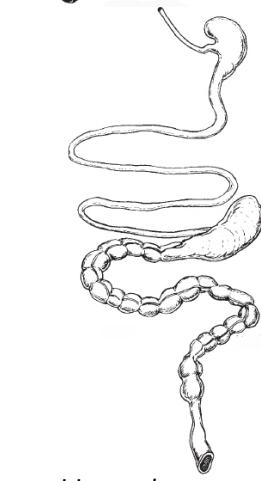
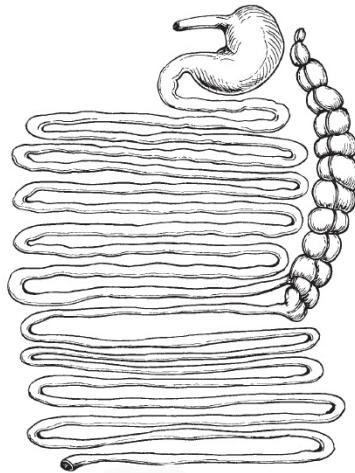


Digestive tract form and function: lemurs

Propithecus tattersalli *Propithecus verreauxi*



Lemur catta



Hapalemur griseus

FOLIVORE

digesta retention



fibre digestibility



Varecia variegata

FRUGIVORE

Campbell et al. (2000, 2004ab)



Digestive tract: Callitrichids



Callithrix jacchus



Leontopithecus chrysomelas



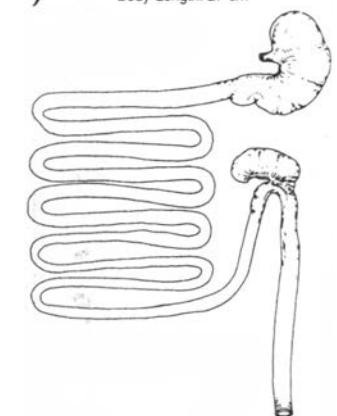
Saguinus oedipus



Saimiri sciurus



Squirrel Monkey
(*Saimiri sciureus*)
Body Length: 27 cm





Caecum form and function: gummivory

Gums dominate, insects important, fruit can depend on location

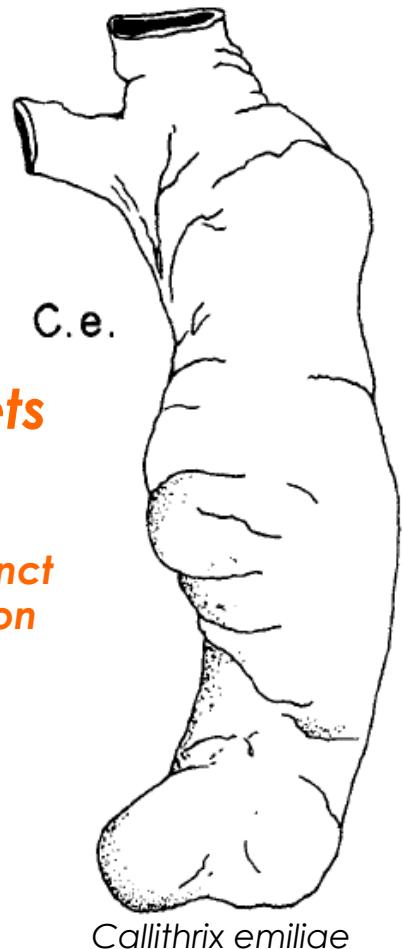
Callithrix

Insects and fruit dominate, gums and nectar seasonally important

Saguinus

Marmosets

more efficient
gum digestion



GUMMIVORE

Saguinus fuscicollis

'OMNIVORE'

1cm



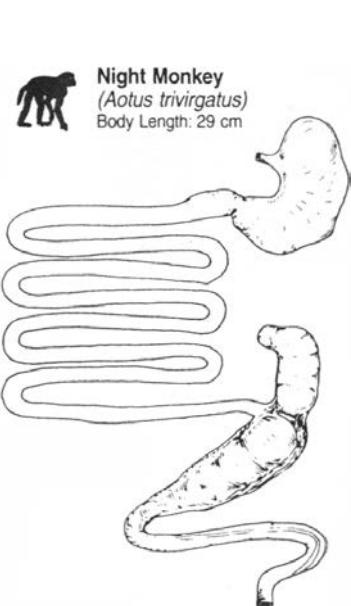
Power et al. (1990), Ferrari & Martins



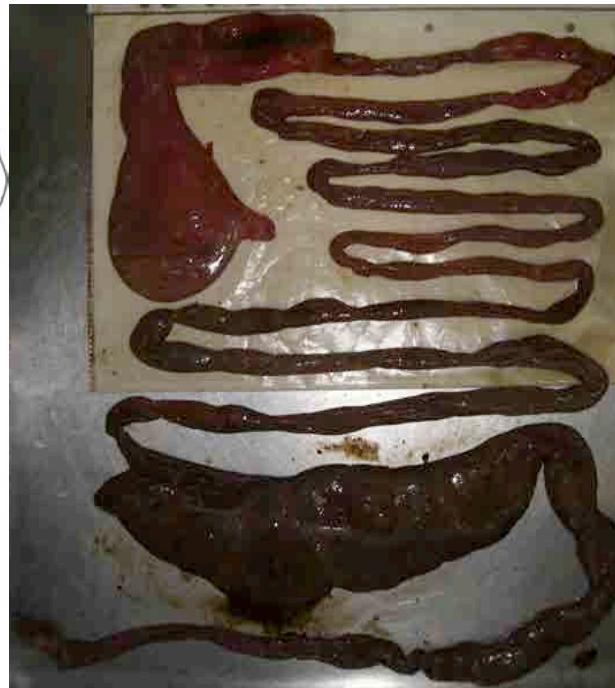
Digestive tract: Cebidae, Aotidae, Atelidae



Cebus apella



Night Monkey
(*Aotus trivirgatus*)
Body Length: 29 cm



Ateles paniscus



Alouatta sara

Primarily frugivorous, seasonally seeds or leaves important

<i>A. trivirgatus</i>	Northern gray-necked owl monkey	Fruit (soft) 44% (16-75%), leaves 32% (5-46%), insects 13% (5-15%), other (especially flowers) 11%;
<i>C. albifrons</i>	White-fronted capuchin	Fruit 55% (10-95%), of which seeds are 8% (0-39%); leaves (mostly young) 8% (0-39%); insects 33% (2-100%);
<i>C. apella</i>	Tufted or brown capuchin	
<i>C. capucinus</i>	White-throated capuchin	
<i>C. olivaceus</i>	Weeper or wedge-capped	

Primarily frugivorous

Ateles

<i>A. belzebuth</i>	White-bellied spider monkey	Total fruit 78% (18-100%), including unripe fruit 6%; seed 5% (0-19%); total leaves 16% (0-38%), including mature leaves 3%; flowers 3%
<i>A. chamek</i>	Black-faced black spider monkey	
<i>A. paniscus</i>	Black spider monkey	

Primarily folivorous, some fruit, no animal prey

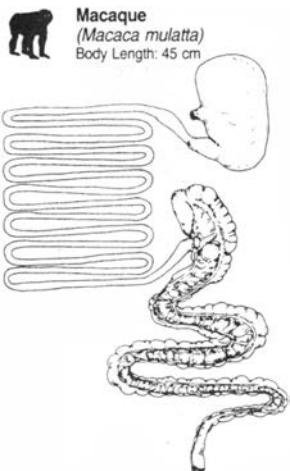
<i>Alouatta</i>		
<i>A. belzebul</i>	Red-handed howler	
<i>A. caraya</i>	Black-and-gold howler	
<i>A. colibensis</i> ^c	Colba Island howler	
<i>A. fusca</i>	Brown howler	
<i>A. palliata</i>	Mantled howler	
<i>A. pigra</i>	Black howler	
<i>A. sara</i> ^c	Bolivian red howler	

A. palliata, *A. seniculus*, *A. pigra*: total leaves 54% (20-100%), including 38% young, 16% mature leaf; total fruit, especially figs, 39% (0-80%), including 34% ripe, 5% unripe; flowers 9% (0-90%);

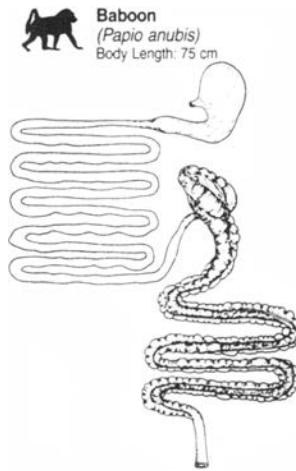
Navarrete pers.
comm., Stevens &
Hume (1995)



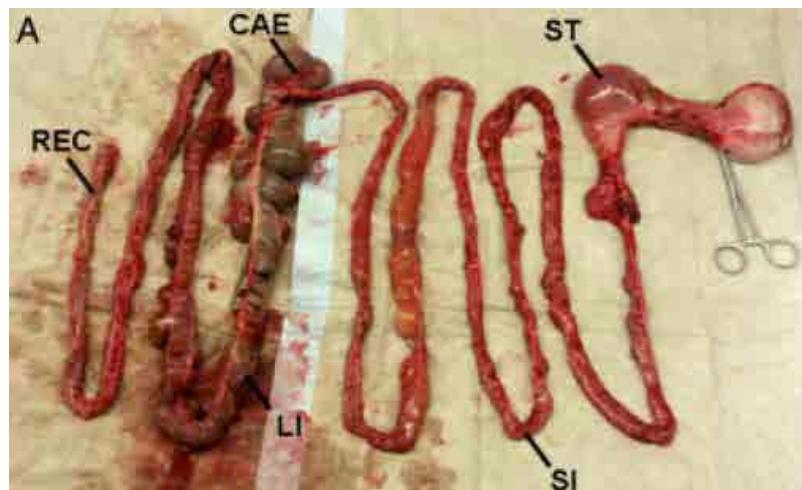
Digestive tract: Papionini



Macaca mulatta



Papio anubis



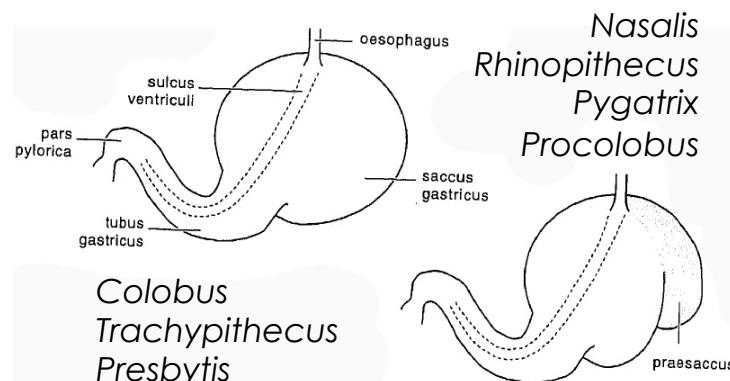
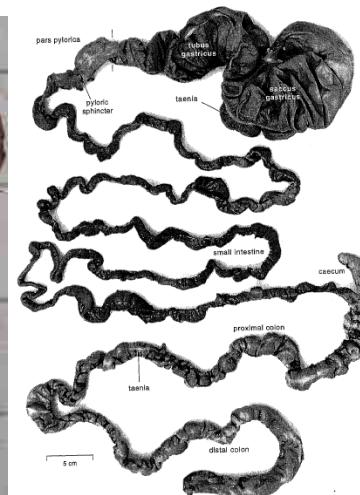
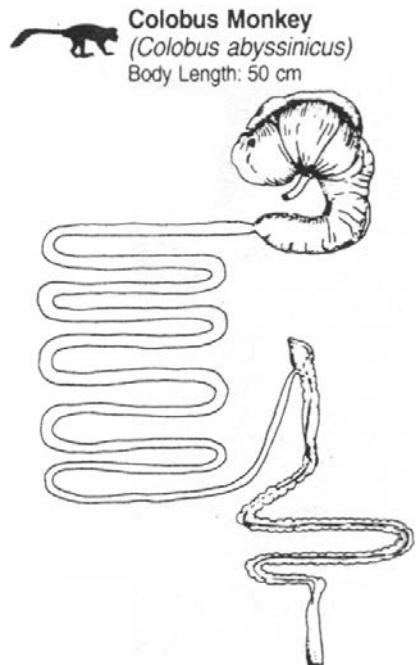
*Theropithecus
gelada*



Navarrete pers. comm., Stevens & Hume (1995),
Mau et al. (2011)



Digestive tract: Colobinae





Digestive tract: Hominoidea



Hylobatus concolor



Hylobatus syndactylus

H. (Nomascus) concolor

Black gibbon

Fruits 21%, flowers 7%, leaves 11%, leaf buds and shoots 61%, bamboo

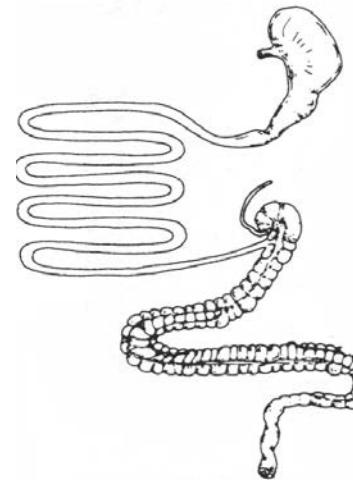
H. (Symphalangus) syndactylus

Siamang

Fruit 40% (6-59%) (figs are 28%), flowers 6% (0-32%), leaves 49% (24-70%) (42% young leaves), prey 5%



Chimpanzee
(*Pan troglodytes*)
Body Length: 75 cm



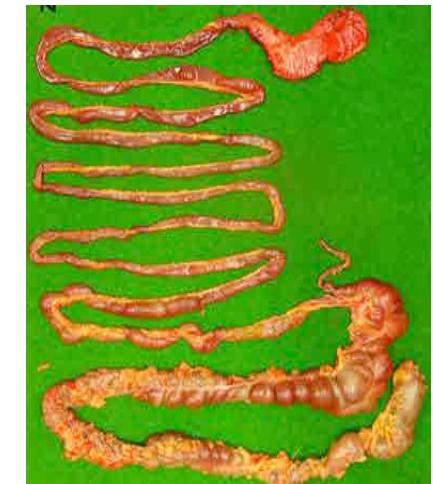
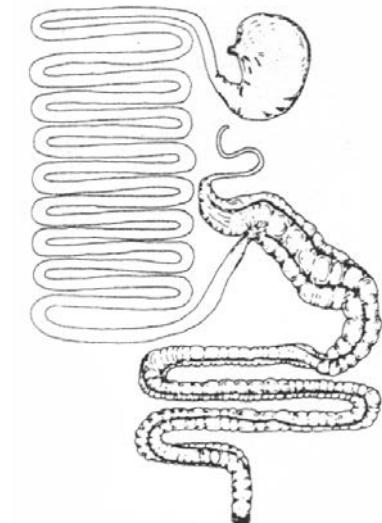
Pan troglodytes



Gorilla gorilla



Orangutan
(*Pongo pygmaeus*)
Body Length: 64 cm



Pongo pygmaeus

Stevens & Hume (1995), Navarrete pers. comm., Clauss pers. obs.



traditional primtae feeding
(mistakes)



Monkey zoo diet 1878

- Milk, sugar and soft bread
- Cooked rice, potatoes, carrots
- Fruits, nuts, almonds
- Tea, coffee, beer, wine
- Fried meat should be investigated!
- 1 cigar

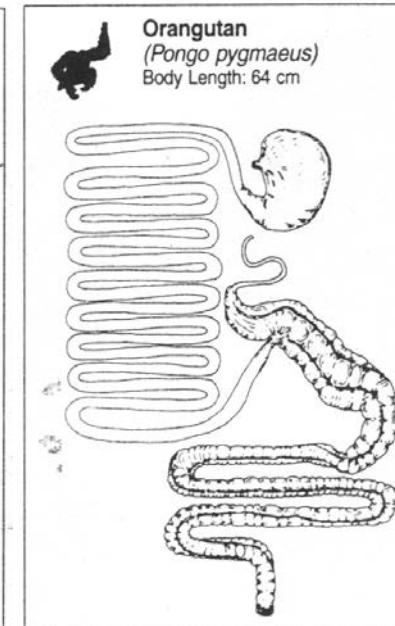
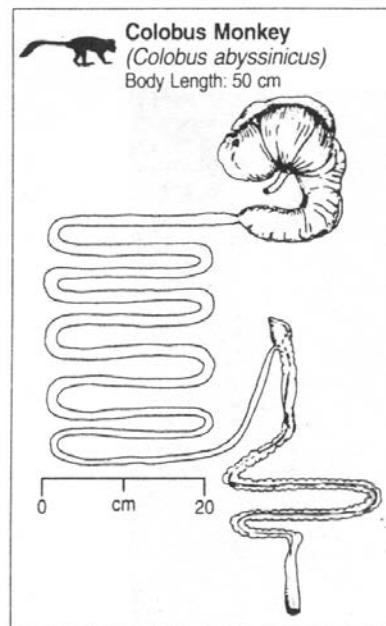


Major limitation: diets used in digestion studies



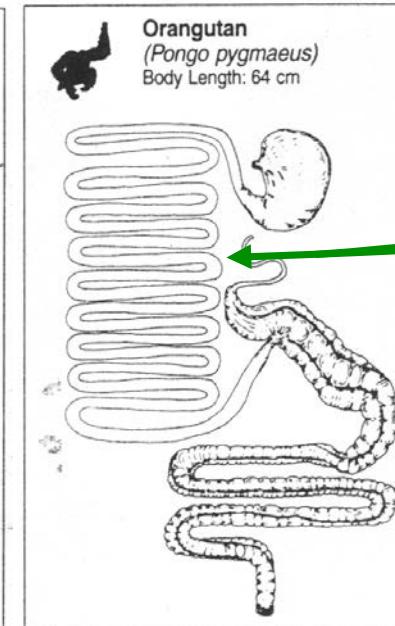
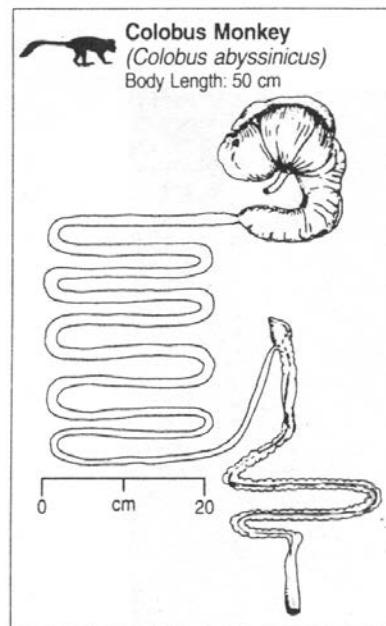


Feeding high-sugar/starch diets



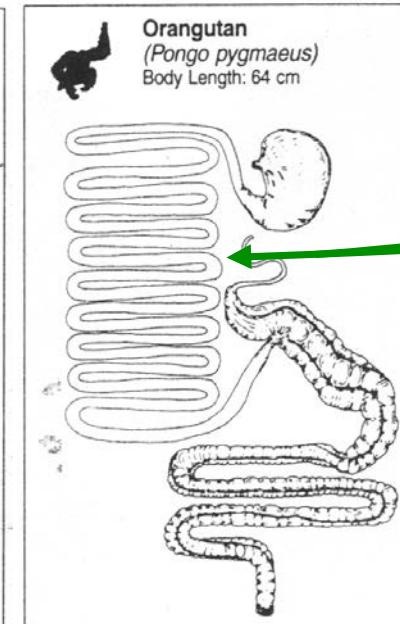
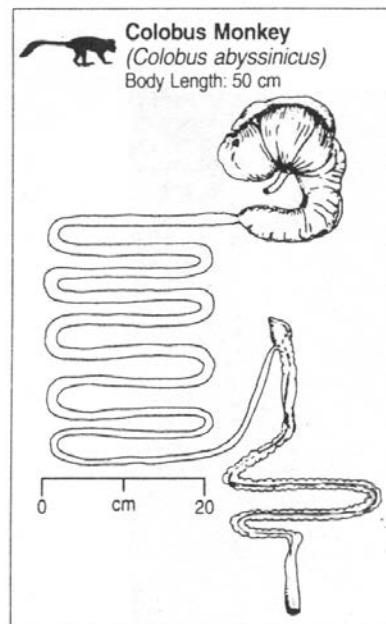


Feeding high-sugar/starch diets





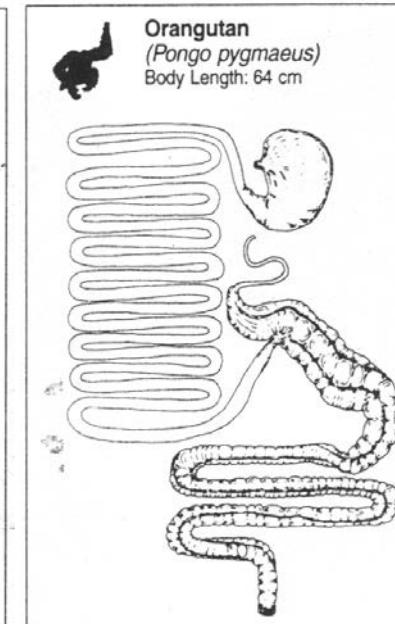
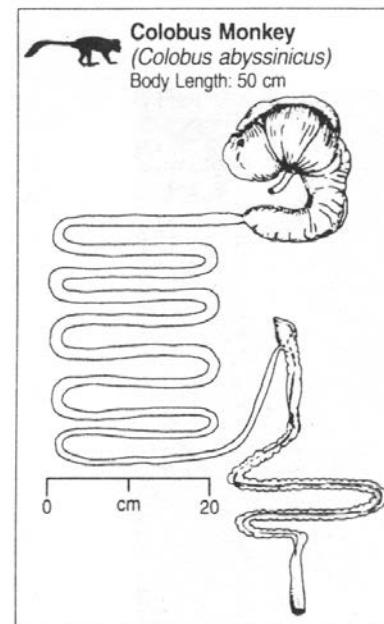
Feeding high-sugar/starch diets



Easily digestible
nutrients absorbed
in small intestine
=> obesity



Feeding high-sugar/starch diets



cf. Schwitzer & Kaumanns (2001)



Obesity in primates



- Gorillas (Cousins 1972, Leigh 1992)
- Orangutans: wild ♀ 38.7 kg, ♂ 86.3 kg
zoo ♀ up to 81 kg, ♂ up to 189 kg;
(Schmidt 2004)
- Chimpanzees: 10.5% ♀♀ obese
(Videan et al. 2007)
- Macaques: 7-23% obese
(Walike et al. 1977, Schwartz et al. 1993, Chen et al. 2002)
- Marmosets
(Savage et al. 1993, Encarnación & Heymann 1998, Araújo et al. 2000)
- Lemurs (Schaaf & Stuart 1983, Schwitzer & Kaumanns 2001, Taylor et al. 2012)





Obesity in primates

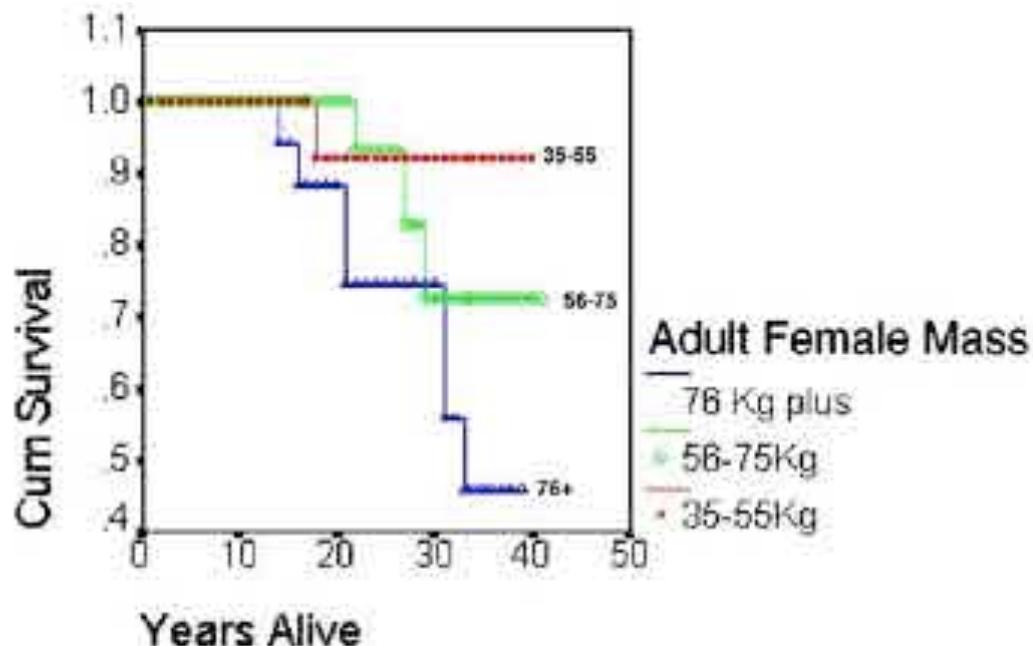
Int J Primatol (2007) 28:429–440
DOI 10.1007/s10764-007-9117-9

Factors Influencing the Well-Being and Longevity of Captive Female Orangutans



Leif Cocks

Fig. 12 Survival vs.
female weight.





A Survey of Diabetes Prevalence in Zoo-housed Primates

C. W. Kuhar,* G. A. Fuller, and P. M. Dennis

Zoo Biology 32: 63–69 (2013)

Nearly 30% of responding institutions reported at least one diabetic primate in their current collection. Although the majority of reported cases were in Old World Monkeys (51%), all major taxonomic groups were represented. Females represented nearly 80% of the diagnosed cases. A wide variety of diagnosing, monitoring, and treatment techniques were reported. It is clear from these results diabetes should be considered prominently in decisions relating to diet, weight and activity levels in zoo-housed primates, as well as discussions surrounding animal health and welfare.

Hypertension Increases With Aging and Obesity in Chimpanzees (*Pan troglodytes*)

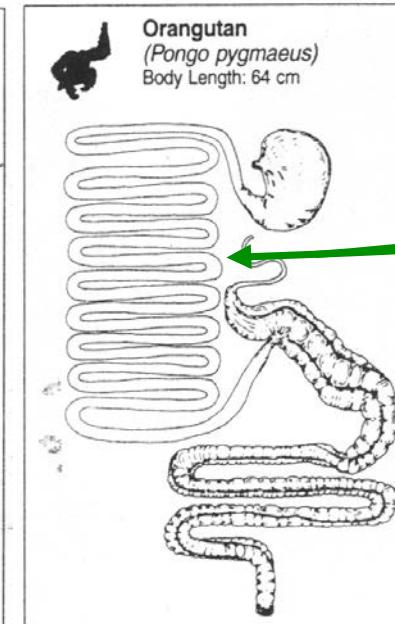
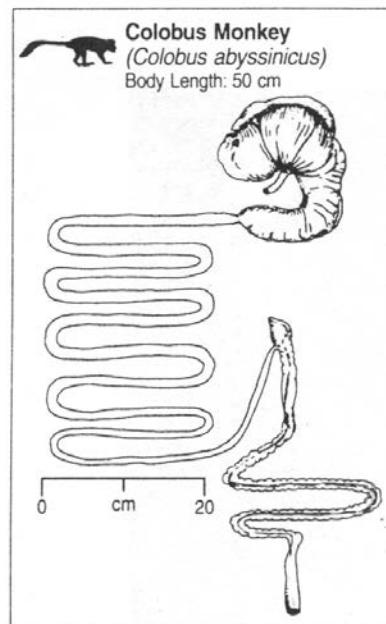
John J. Ely,* Tony Zavaskis, and Michael L. Lammy

Zoo Biology 32: 79–87 (2013)

Cardiovascular disease is a primary cause of morbidity and mortality in captive chimpanzees. For females, obesity was a significant determinant of BP.



Feeding high-sugar/starch diets



Easily digestible
nutrients absorbed
in small intestine
=> obesity

Only at very
excessive amounts:
'caecum acidosis',
diarrhoea, laminitis



Polymerase chain reaction detection of *Clostridium perfringens* in feces from captive and wild chimpanzees, *Pan troglodytes*

Shiho Fujita¹ & Takashi Kageyama²

J Med Primatol 36 (2007) 25–32

Subject	Sex	Age	Birth	No. of samples tested			Not detected
					First PCR	Nested PCR	
Ai ¹	Female	24 years	Wild	1	1	0	0
Pendesa	Female	23 years	Captive ²	1	0	0	1
Chloé	Female	19 years	Captive ⁴	4	3	1	0
Reo	Male	18 years	Captive ³	2	0	1	1
Ayumu ¹	Male	5 months	Captive ³	2	1	1	0
Total (%)				10	5 (50)	3 (30)	2 (20)

¹Ai and Ayumu are a mother–infant pair.

²Japan Monkey Center.

³Primate Research Institute.

⁴Parc Zoologique de Paris.

Table 2 Detection of *Clostridium perfringens* in feces of captive chimpanzees

Site	Season	No. of samples tested	First PCR	Nested PCR	Not detected
Mahale	Dry	16	0 (0.0) ¹	1 (6.3)	15 (93.7)
	Wet (I and II)	65	0 (0.0)	0 (0.0)	65 (100.0)
	Total	81	0 (0.0)	1 (1.3)	80 (98.7)
Bossou	Dry	23	1 (4.3)	2 (8.7)	20 (87.0)
	Wet	30	5 (16.7)	4 (13.3)	21 (70.0)
	Total	53	6 (11.3)	6 (11.3)	41 (77.4)

¹The values in parentheses show percentages.



Polymerase chain reaction detection of *Clostridium perfringens* in feces from captive and wild chimpanzees, *Pan troglodytes*

Shiho Fujita¹ & Takashi Kageyama²

J Med Primatol 36 (2007) 25–32

Subject	Sex	Age	Birth	No. of samples tested			Not detected
				First PCR	Nested PCR		
Ai ¹	Female	24 years	Wild	1	1	0	0
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Table 3 Detection of *Clostridium perfringens* in feces of wild chimpanzees

Site	Season	No. of samples tested	First PCR	Nested PCR	Not detected
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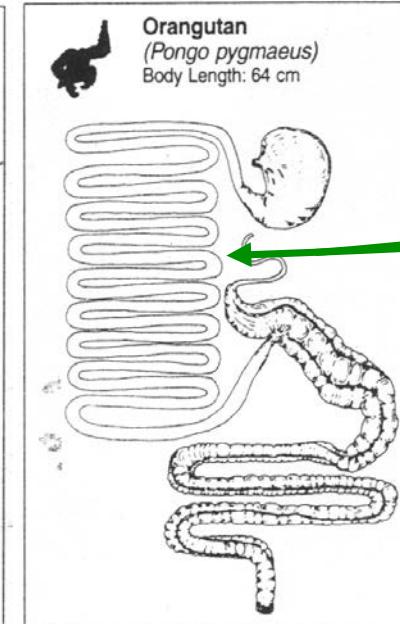
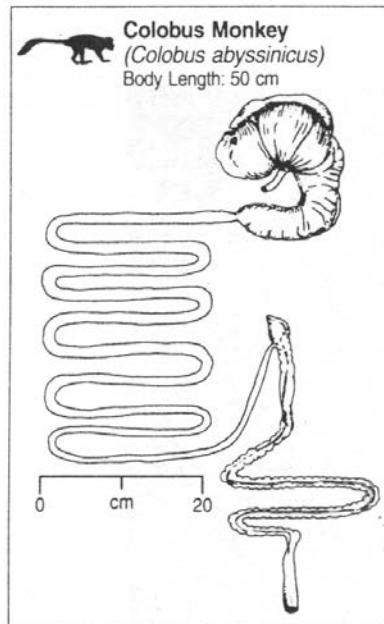
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Feeding high-sugar/starch diets

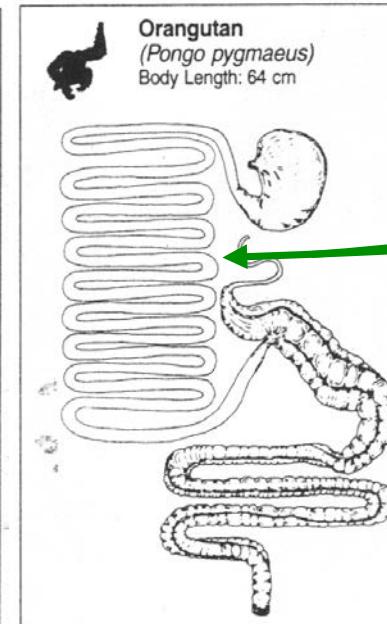
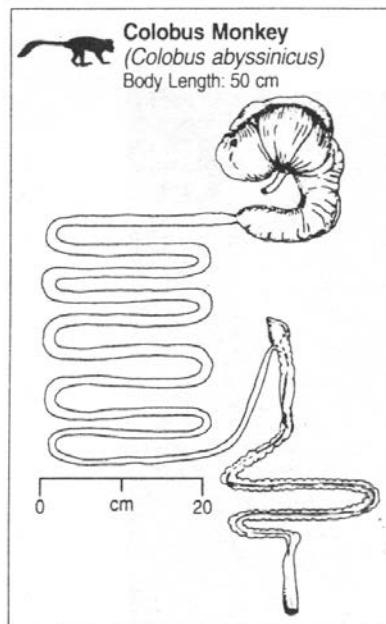


Easily digestible
nutrients absorbed
in small intestine
=> obesity

Only at very
excessive amounts:
'caecum acidosis',
diarrhoea, laminitis

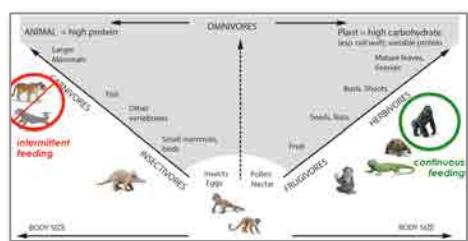


Feeding high-sugar/starch diets



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Stevens & Hume (1995)



Gorilla R/R





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

Kristen E. Lukas *

Applied Animal Behaviour Science 63 (1999) 237–249

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



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

Kristen E. Lukas,^{1,2,3*} Gloria Hamor,³ Mollie A. Bloomsmith,^{2,3}

Charles L. Horton,³ and Terry L. Maple^{2,3}

Zoo Biology 18:515 - 528 (1999)

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

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



Chimpanzee R/R





An analysis of regurgitation and reingestion in captive chimpanzees

Kate C. Baker ^{a,*}, Stephen Phillip Easley ^b

Applied Animal Behaviour Science 49 (1996) 403–415

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

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



Orangutan R/R

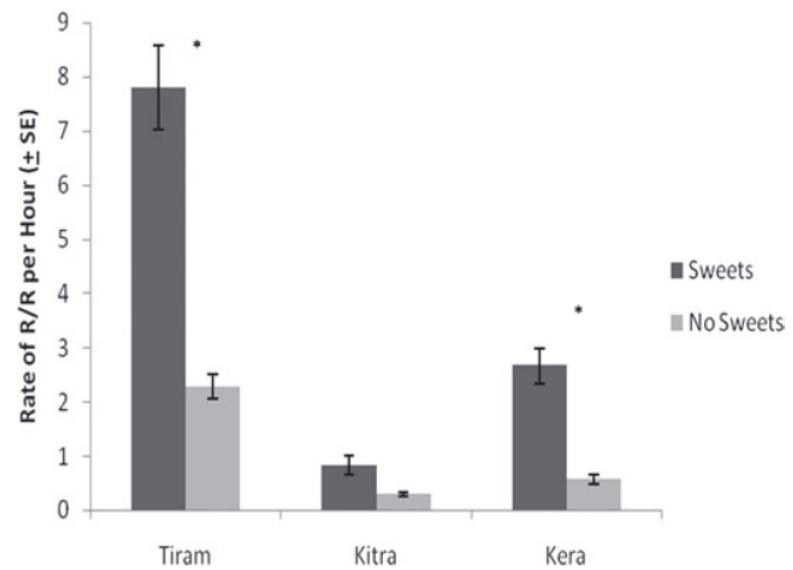
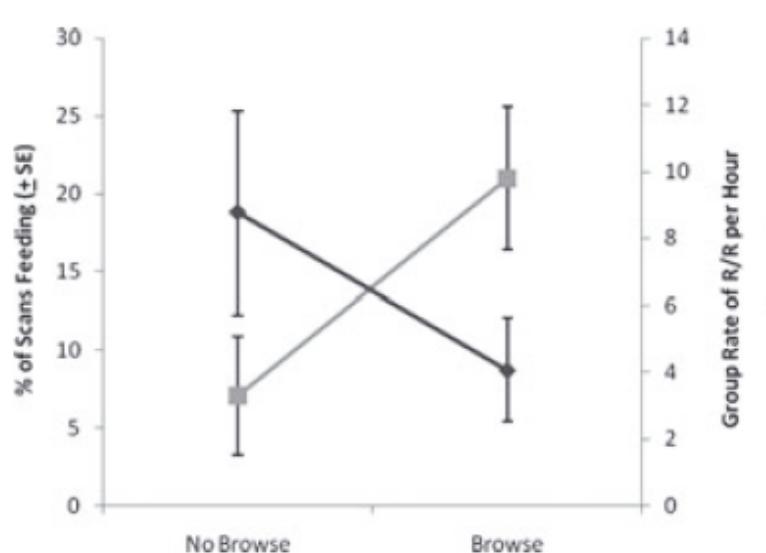




Prevalence of Regurgitation and Reingestion in Orangutans Housed in North American Zoos and an Examination of Factors Influencing its Occurrence in a Single Group of Bornean Orangutans

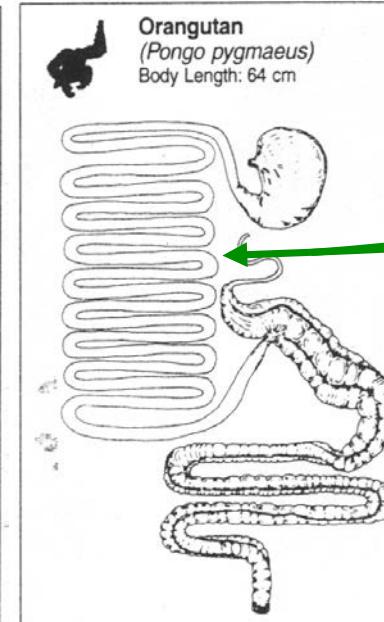
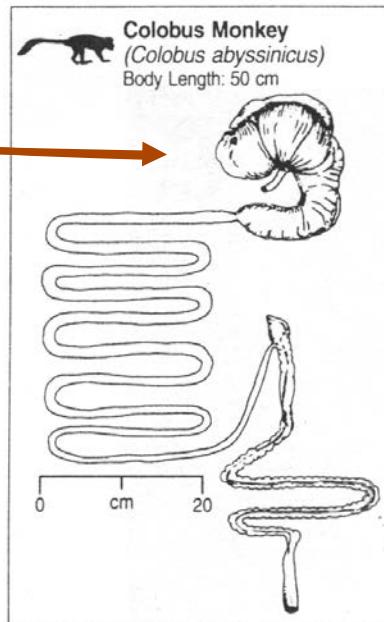
Zoo Biology 31: 609–620 (2012)

Christine M. Cassella,^{1,2*} Alyssa Mills,¹ and Kristen E. Lukas^{1,2}





Feeding high-sugar/starch diets



Easily digestible
nutrients absorbed
in small intestine
=> obesity

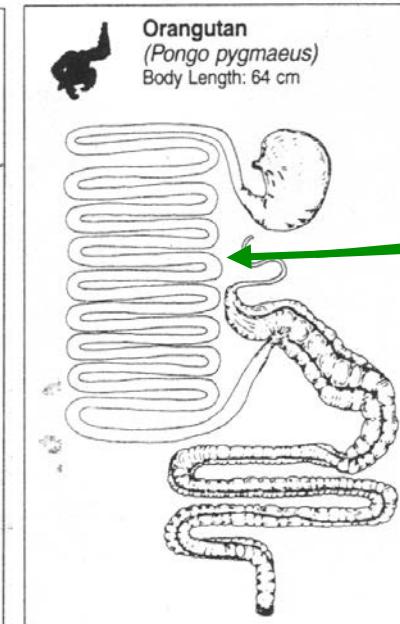
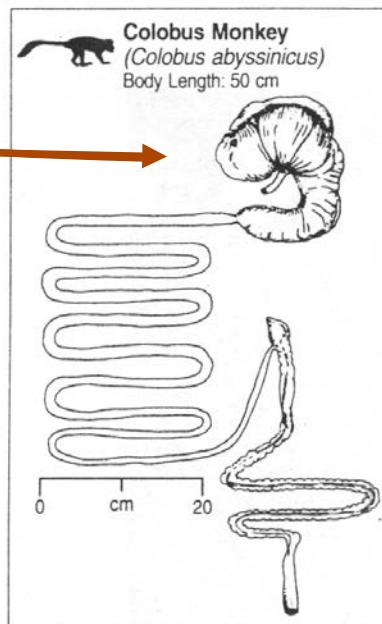
Only at very
excessive amounts:
'caecum acidosis',
diarrhoea, laminitis



Feeding high-sugar/starch diets



Easily digestible
nutrients enter the
fermentation
chamber
⇒ 'malfermentation'



Easily digestible
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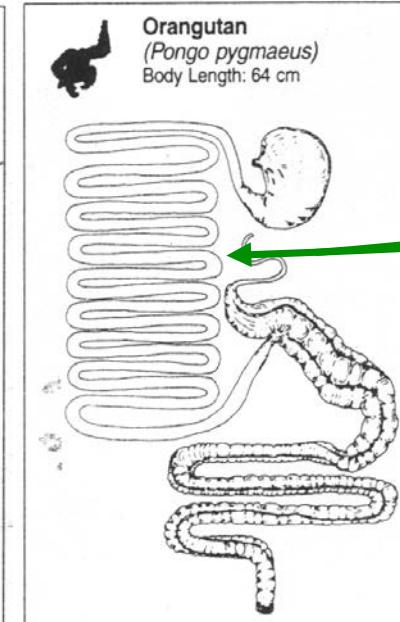
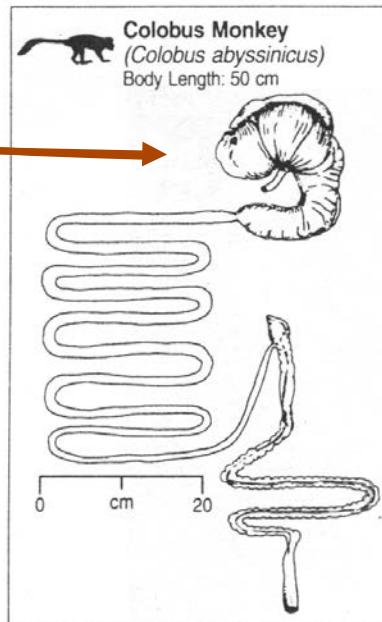


Feeding high-sugar/starch diets



Easily digestible nutrients enter the fermentation chamber
⇒ 'malfermentation'

Low food intake
Laminitis
Liver abscess
Reduced lifespan?
Diarrhoea
Oral stereotypies

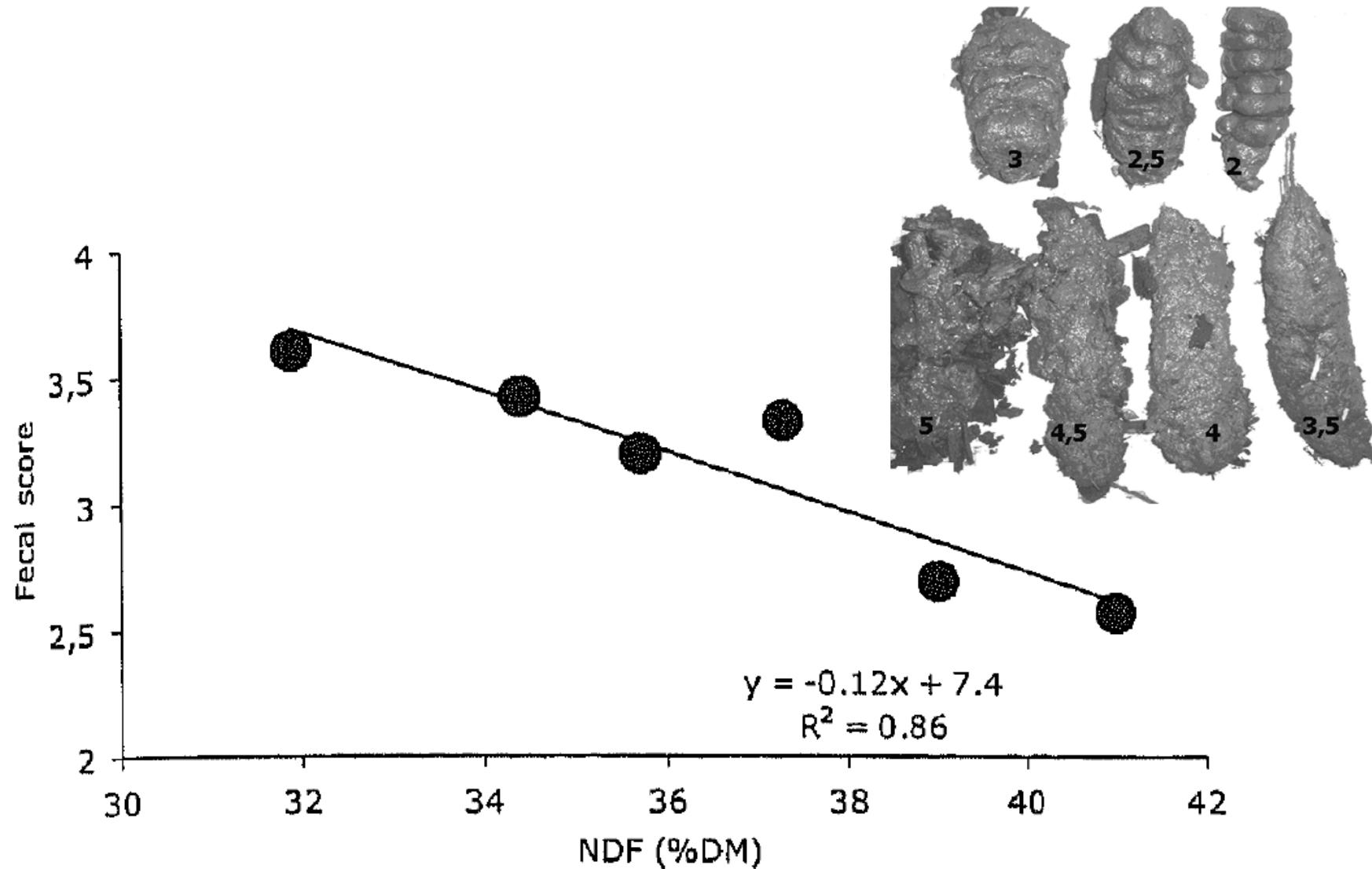


Easily digestible nutrients absorbed in small intestine
=> obesity

Only at very excessive amounts:
'caecum acidosis', diarrhoea, laminitis



Fibre and faeces consistency in langurs



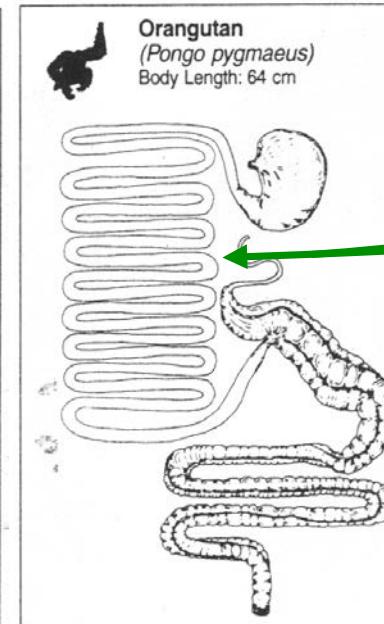
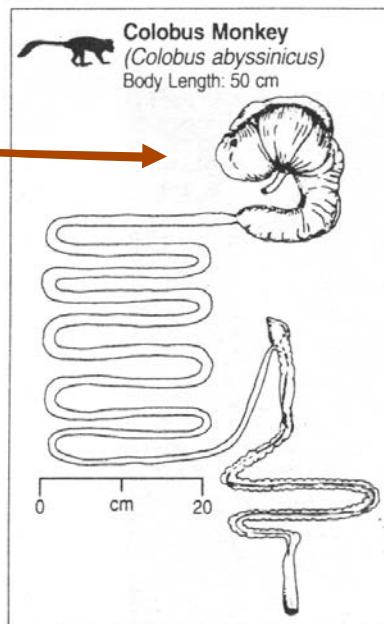
Nijboer et al. (2006)



Feeding high-sugar/starch diets



Easily digestible
nutrients enter the
fermentation
chamber
=>
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Easily digestible
nutrients absorbed
in small intestine
=> obesity

Thin, unthrifty langurs



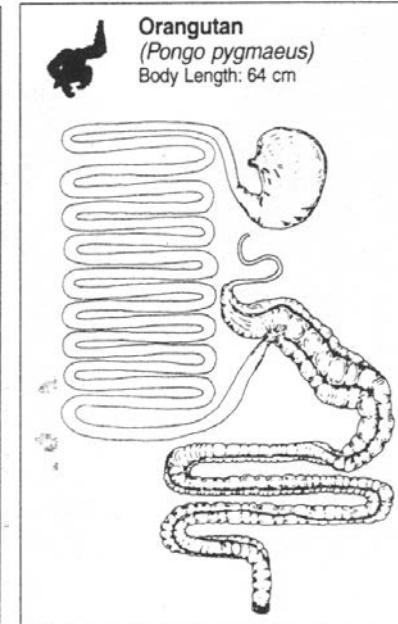
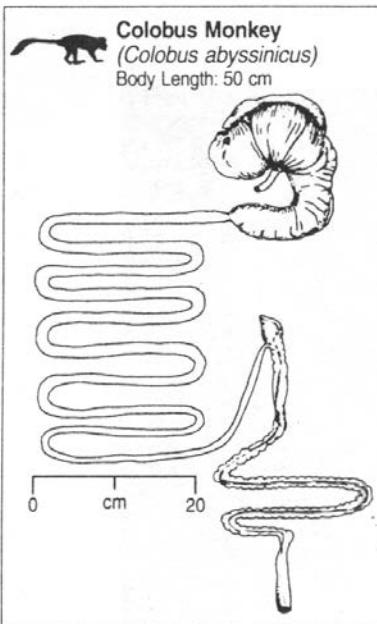
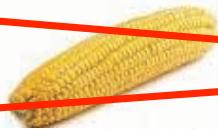
Obese lemurs



cf. Edwards (1995), Schwitzer & Kaumanns (2001)



Feeding high-sugar/starch diets





traditional reptile feeding (mistakes)



Historical tortoise diets

Recommendations from successive editions of the same
(German) textbook



Historical tortoise diets

Recommendations from successive editions of the same
(German) textbook

Year	Recommendation
1980-1993	<p>80% fruits, 19% meat, 1% minerals</p> <p>Fruits: apple, pear, orange, banana, tomato, greens (grass, clover, salad)</p> <p>Meat: muscle, heart – finely cut – also canned dog/cat food</p> <p>If fruits not available: oat flakes, rice, dry dog food, cooked potato</p> 



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1999	<p>Leafy green vegetables, vegetables, fruits (apple, banana, pear, grapes, kiwi), sometimes canned dog/cat food, grain products</p>
2004-2009	<p>Greens (herbs, low proportion of salad/vegetables), low amounts of fruits (lead to malfermentation and diarrhoea), canned dog/cat food should not be main component (cause gout), milk and grain products only in small amounts, hay always ad libitum, cuttlefish bone/egg shells</p> 



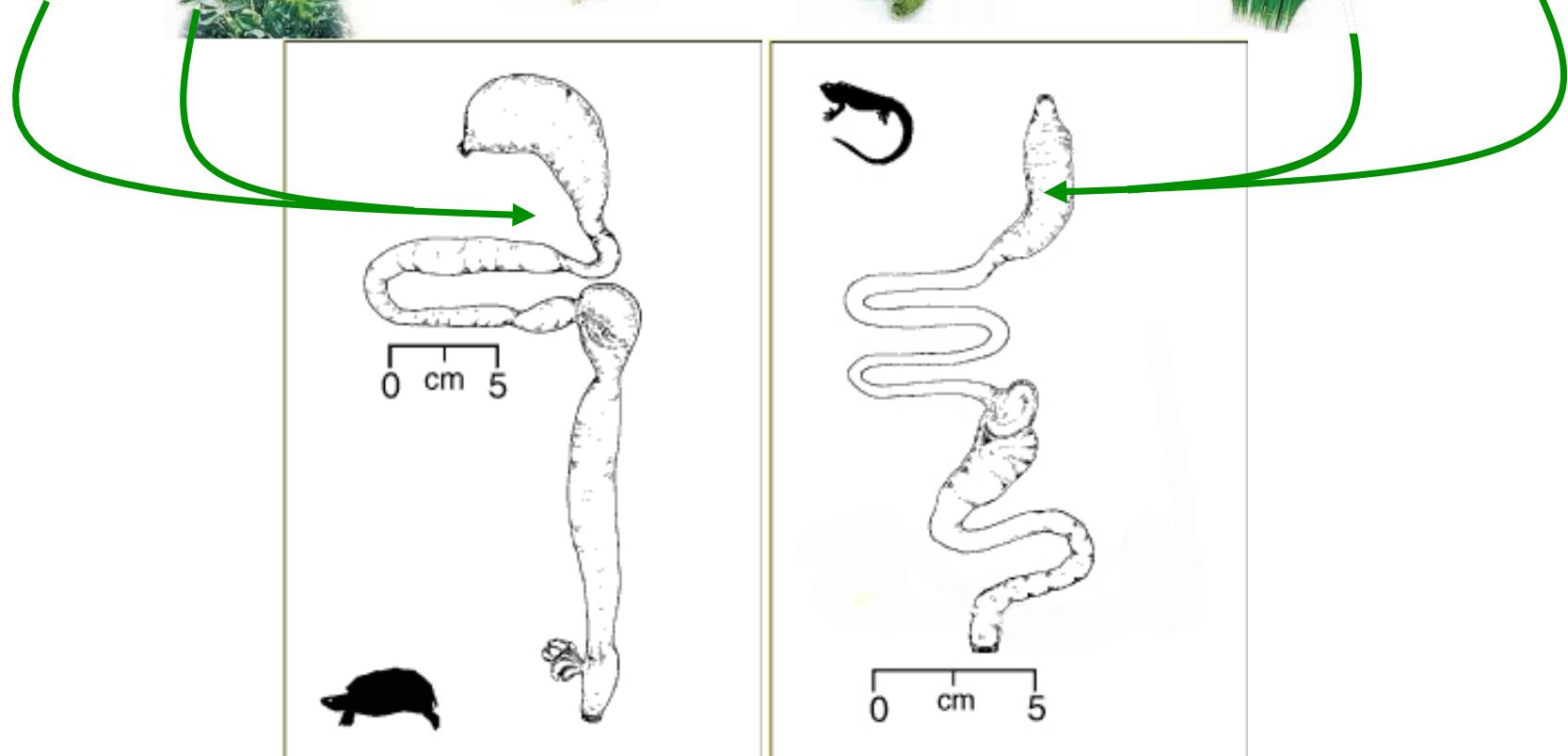
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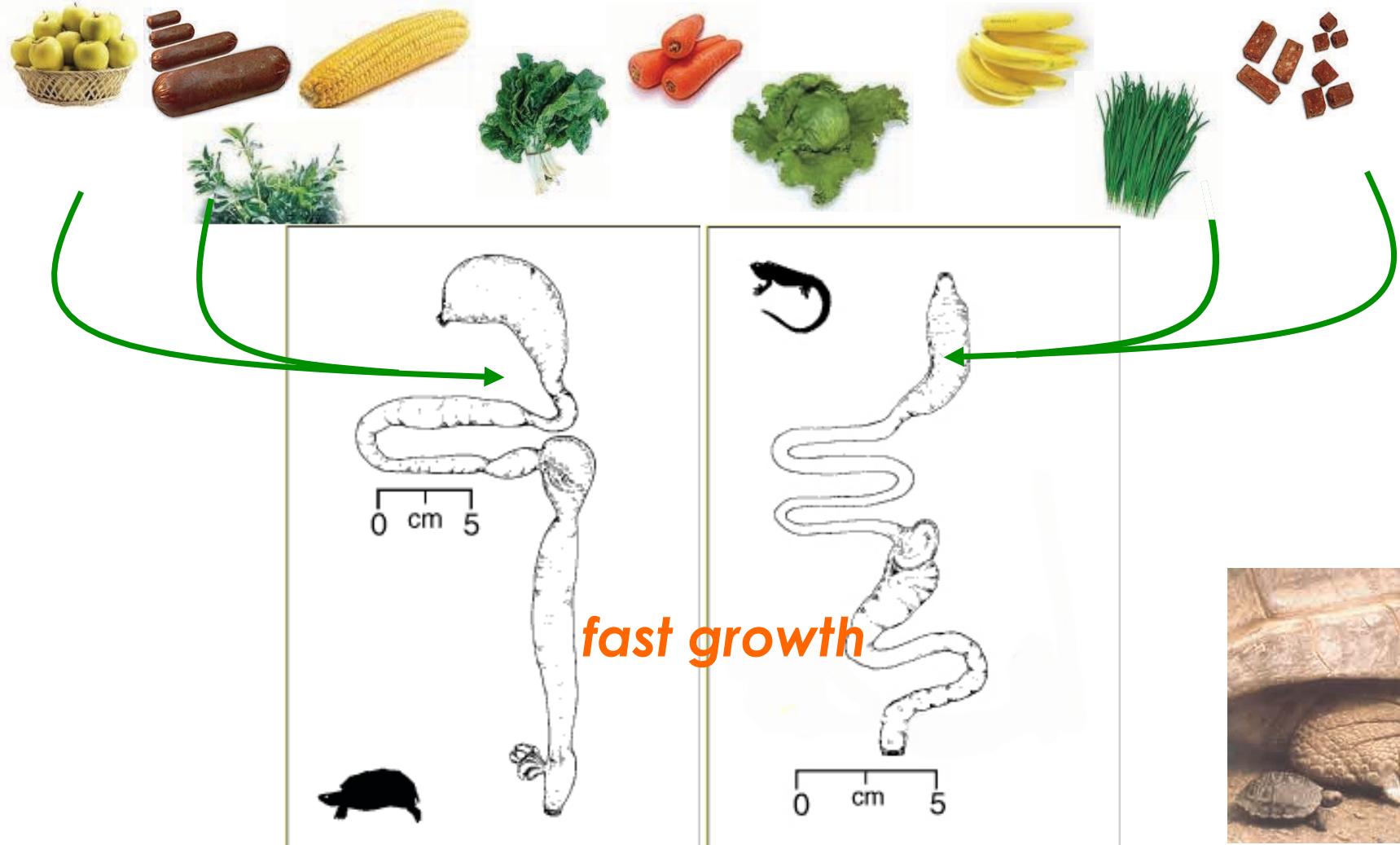


Feeding high-energy diets (sugar/starch/meat or just a lot)





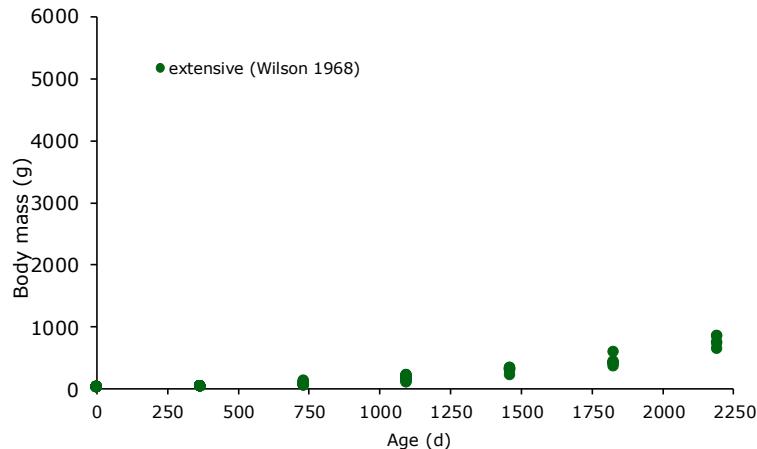
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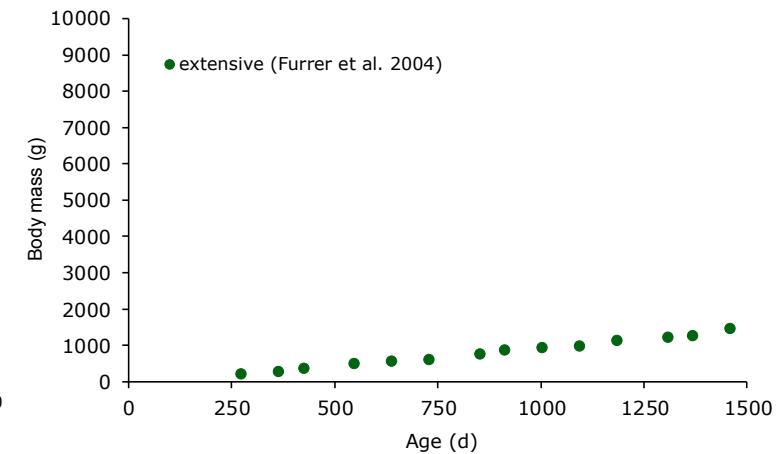


Tortoise growth

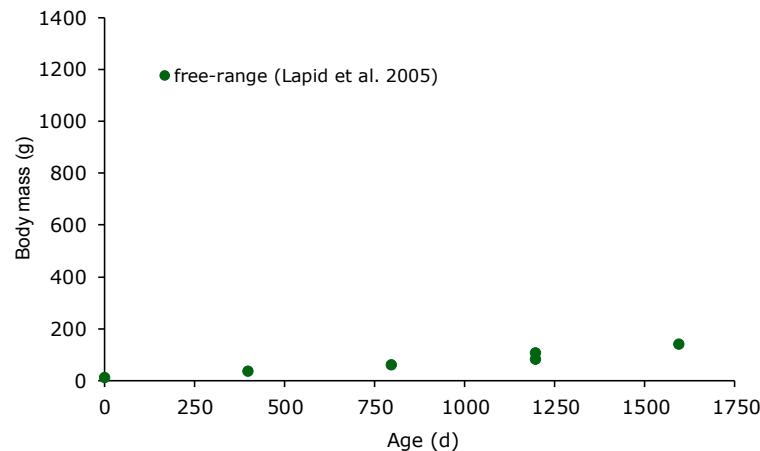
Geochelone pardalis



Geochelone nigra



Testudo graeca

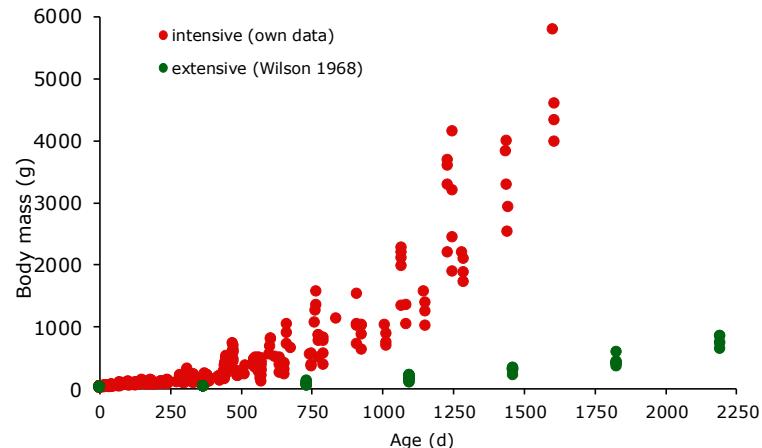


- extensive or free-range
- intensive

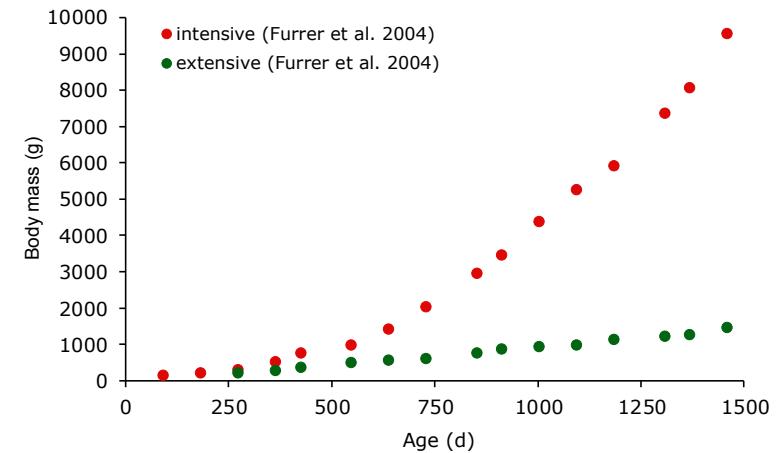


Tortoise growth

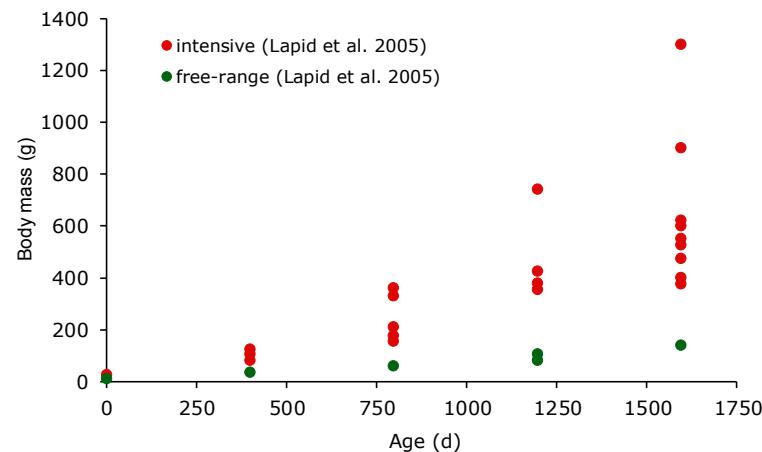
Geochelone pardalis



Geochelone nigra



Testudo graeca

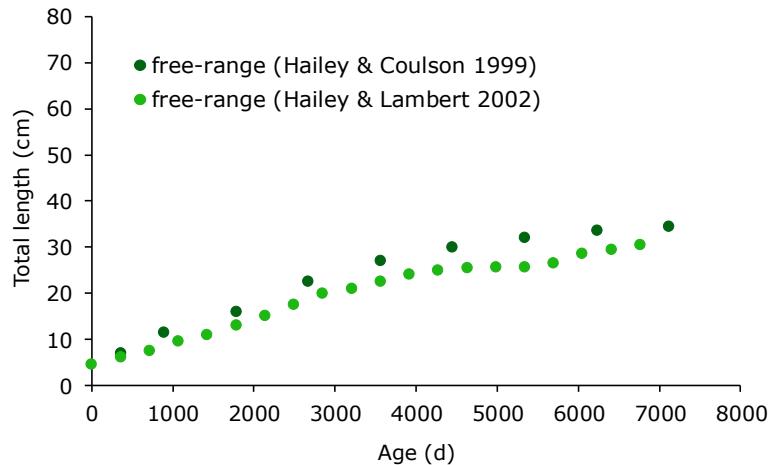


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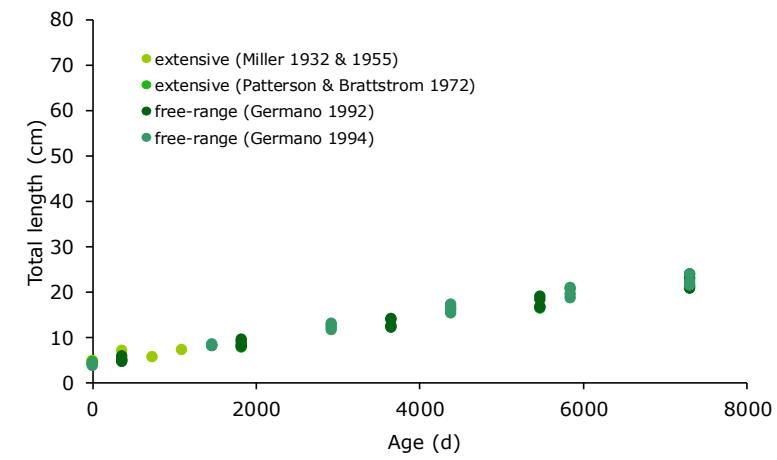


Tortoise growth

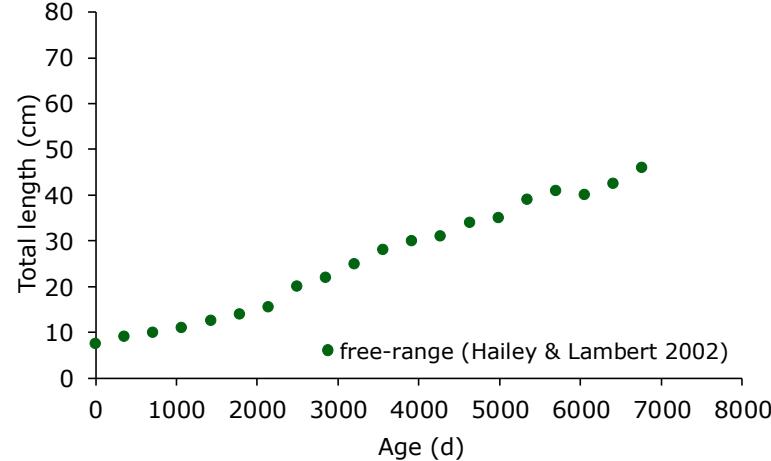
Geochelone pardalis



Gopherus agassizi



Geochelone sulcata

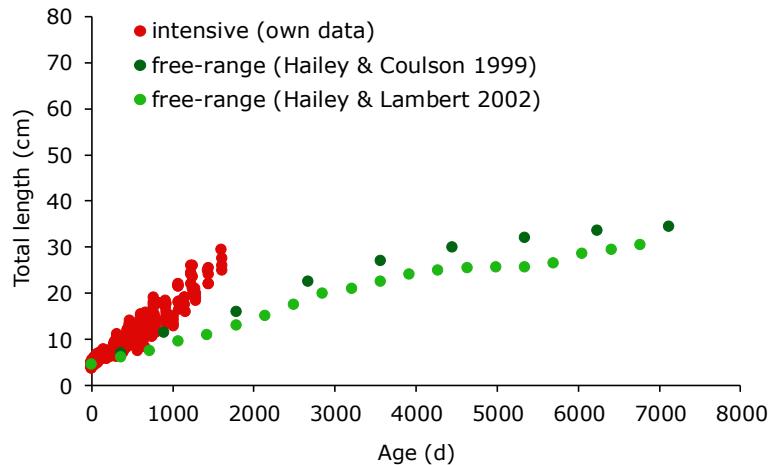


- extensive or free-range
- intensive

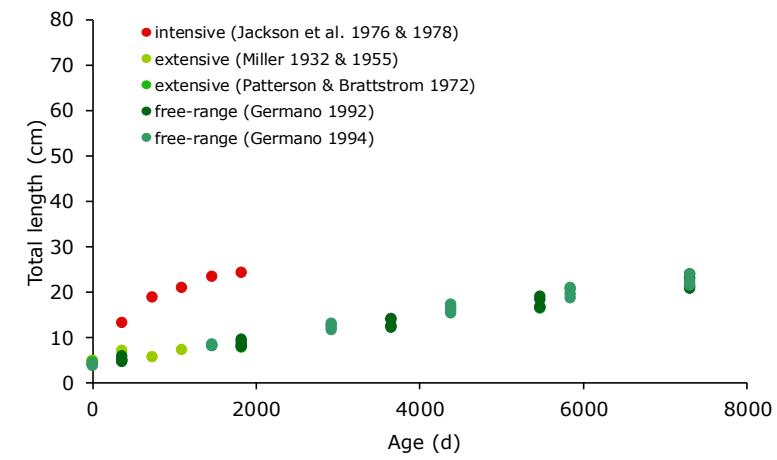


Tortoise growth

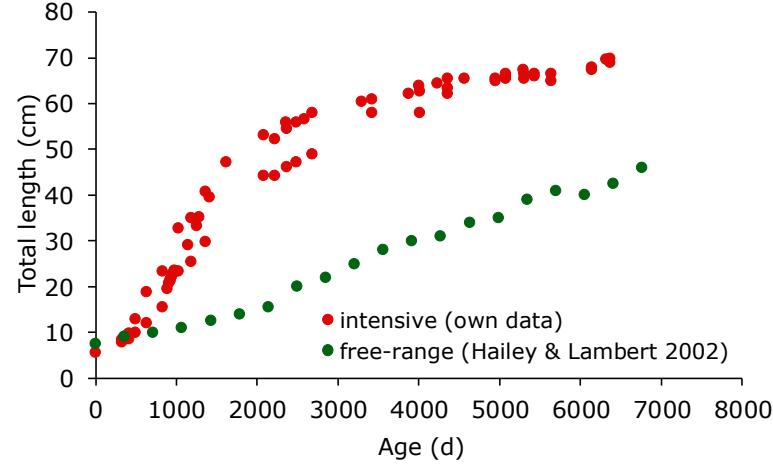
Geochelone pardalis



Gopherus agassizi



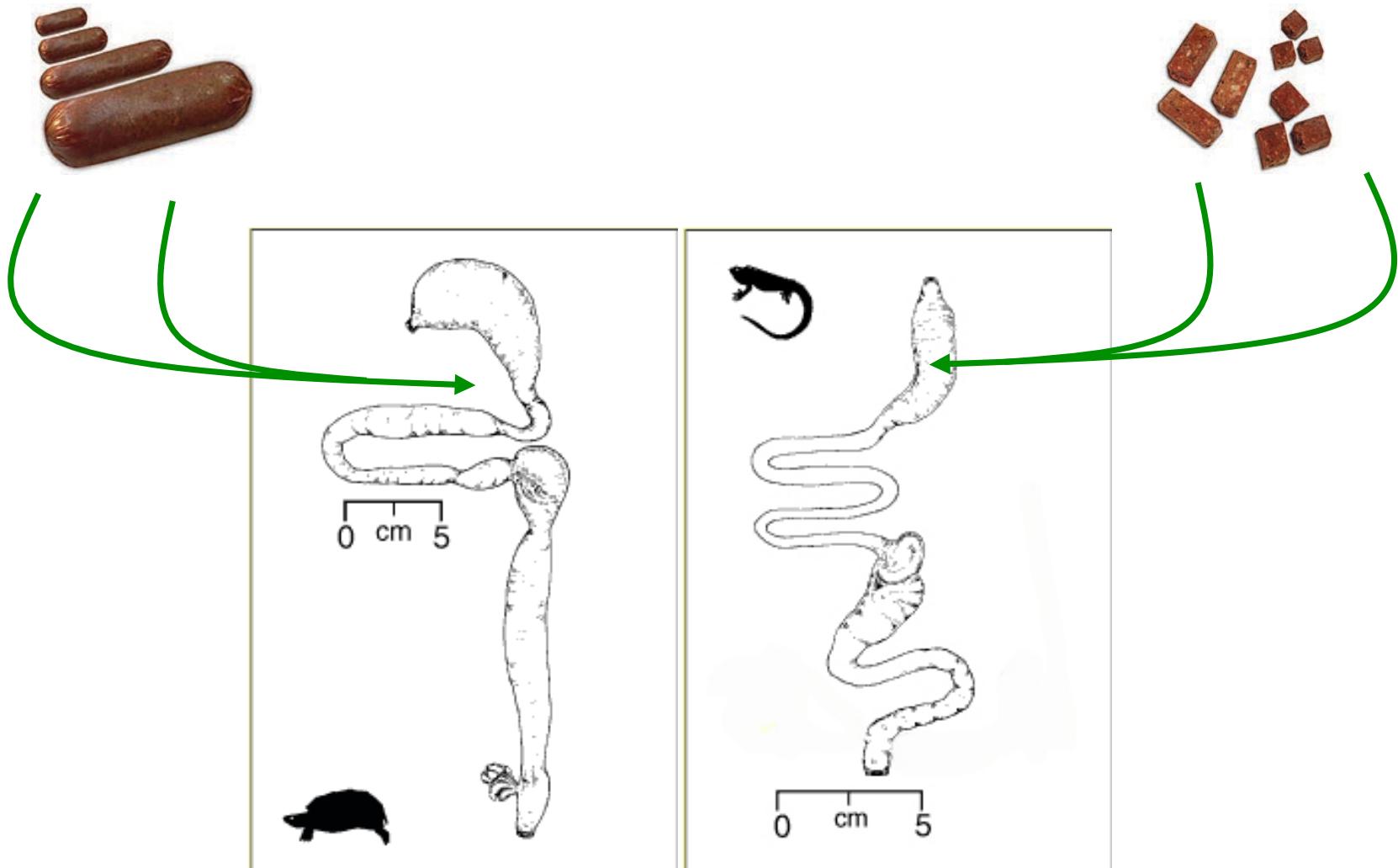
Geochelone sulcata



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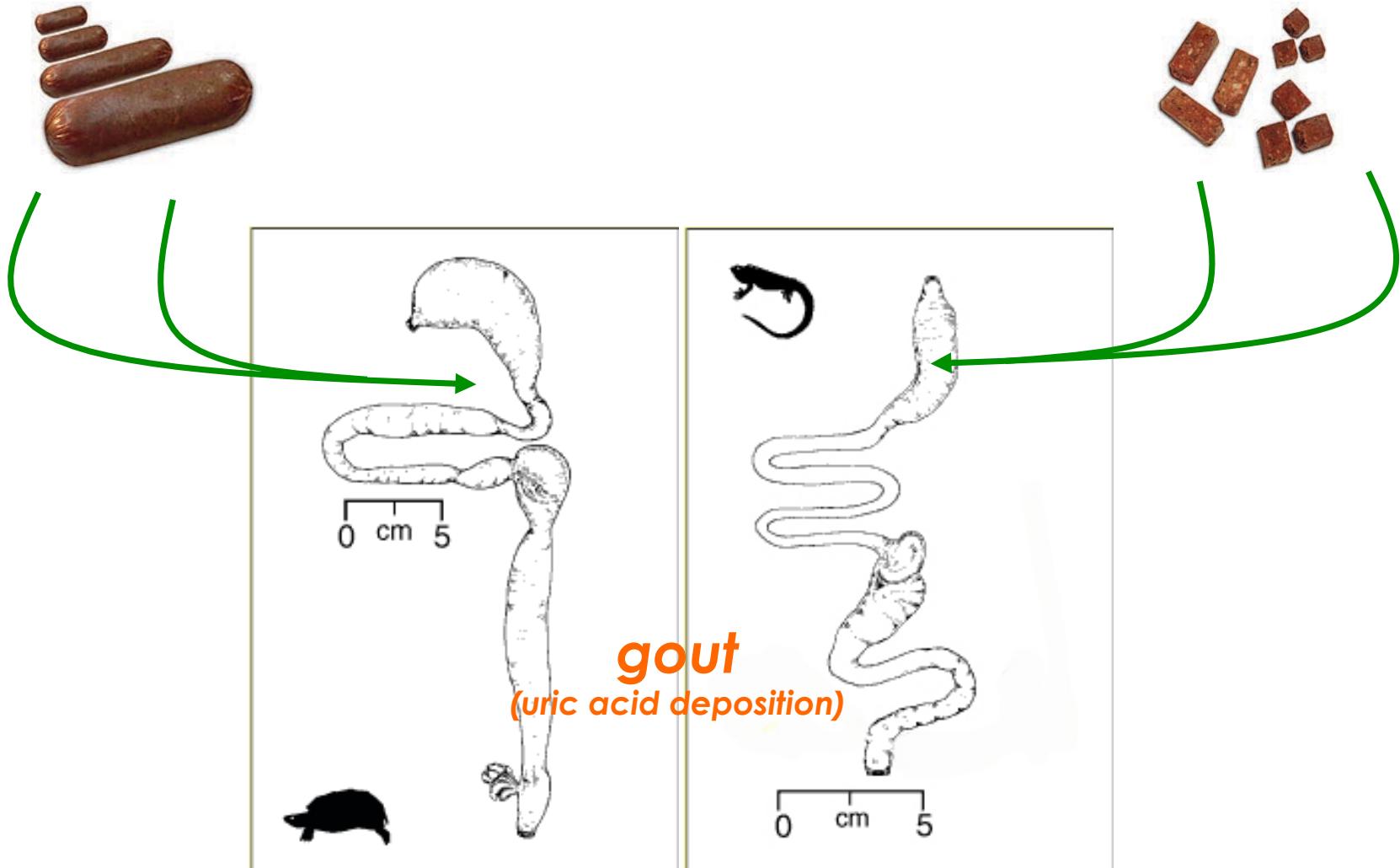
Feeding meat



Stevens & Hume (1995)

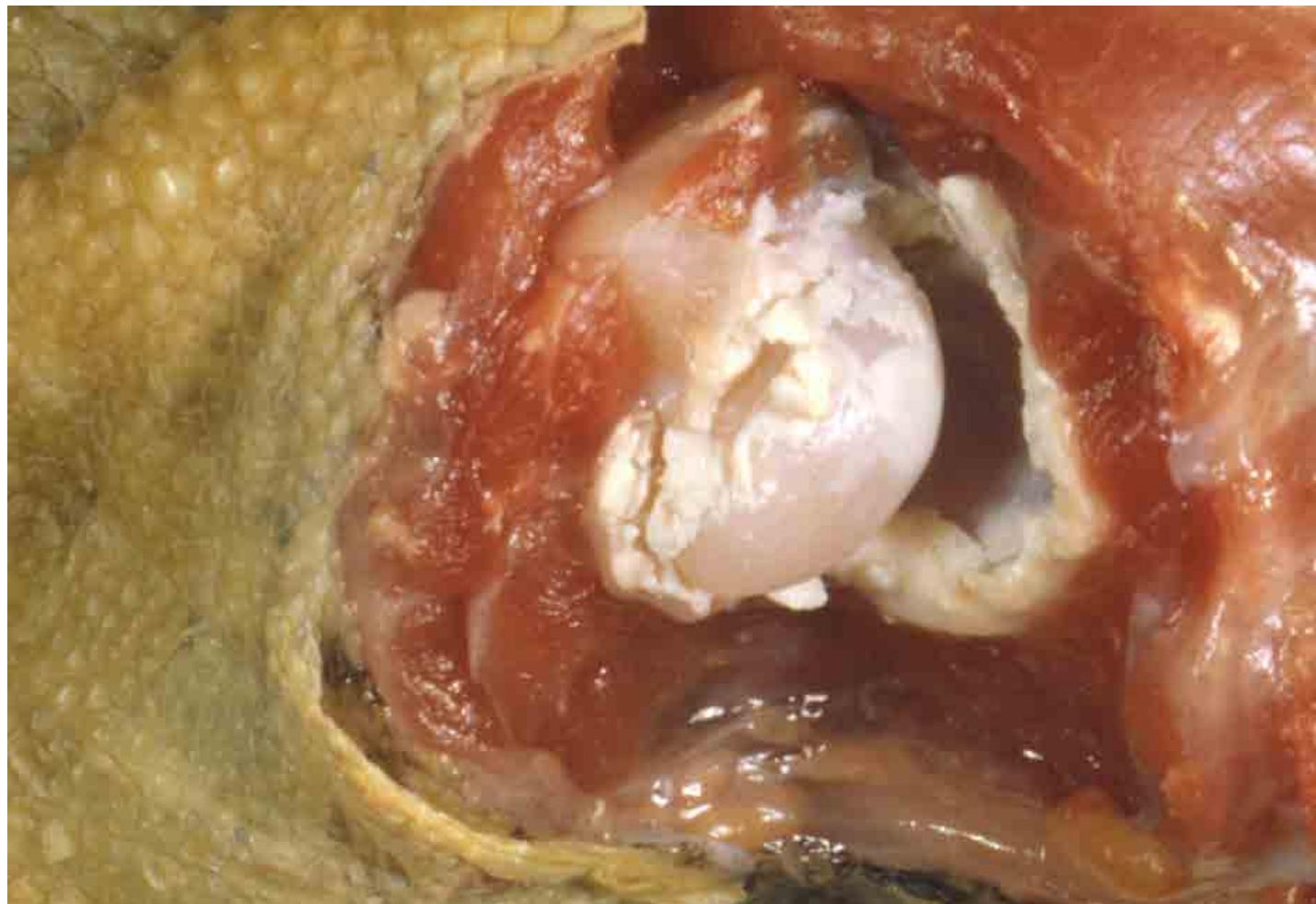


Feeding meat





Gout in reptiles



Hatt pers. comm.



Gout in reptiles



Hatt pers. comm.



Gout in reptiles



Hatt pers. comm.



Gout in reptiles



Hatt pers. comm.



*thank you
for your attention*