Child of the wilderness ...

... or potato couch?

Feeding herbivores in zoos

Marcus Clauss

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Whose zoo animal's diet is this?

- strawberries
- mangos
- plums (w/o stones)
- apricots/peaches (w/o stones)
- apples
- pears
- ananas
- leek
- lettuce
- tomatoes
- cooked pasta/cooked rice with raisins
- oat flakes
- dry bread
- yoghurt
- minced meat (1x/week)

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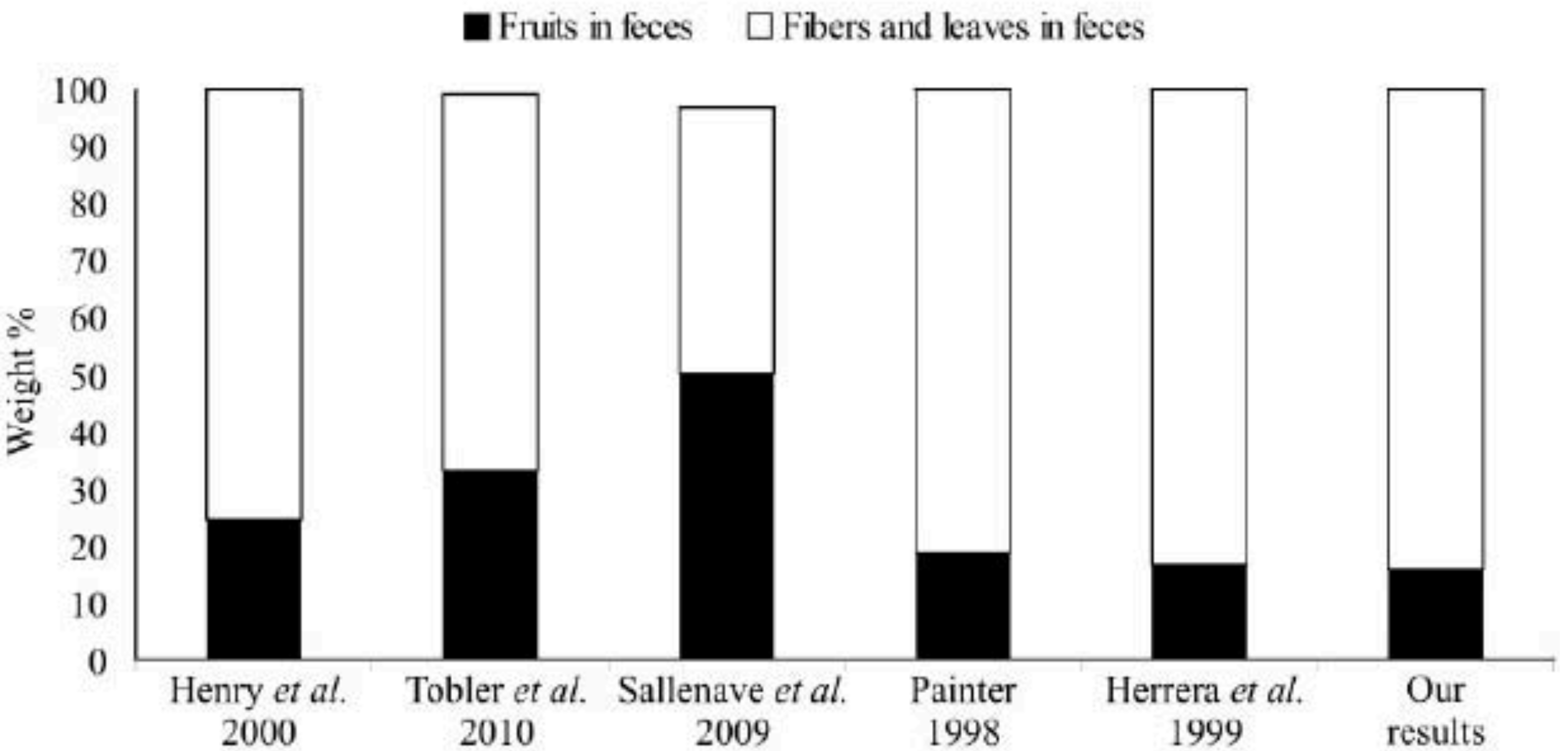
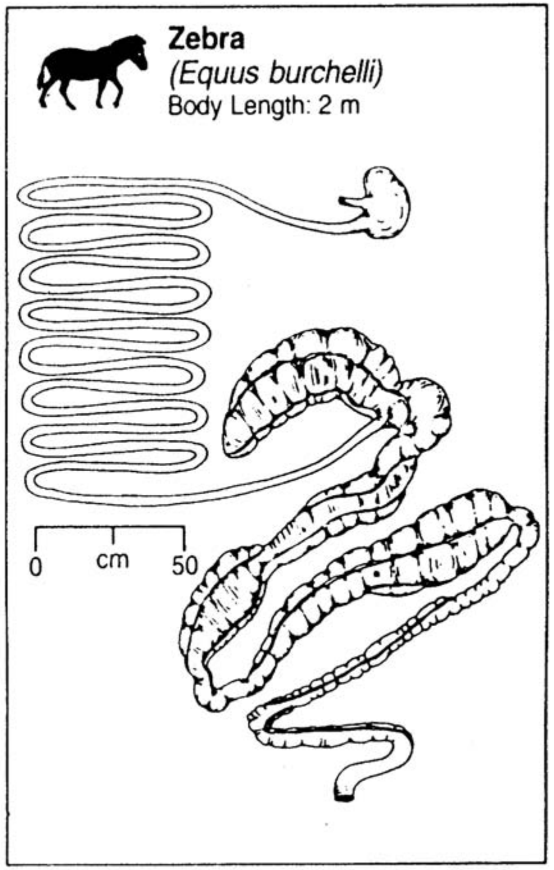
Diet of lowland tapir (*Tapirus terrestris*) in El Rey National Park, Salta, Argentina

Silvia C. CHALUKIAN,[1,4] M. Soledad de BUSTOS[2,4] and R. Leonidas LIZÁRRAGA[3,4]

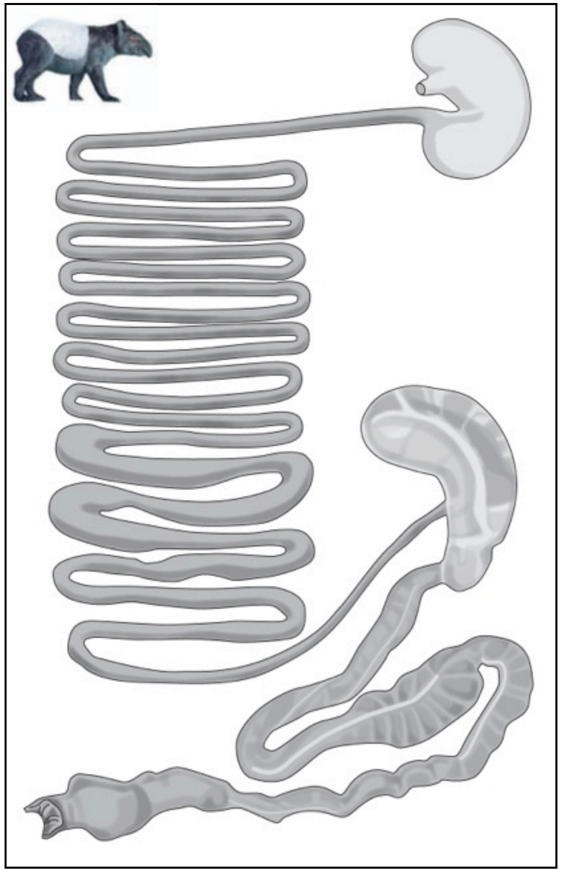
Integrative Zoology 2013; 8: 48–56



Tapir



from Stevens und Hume (1995)



Müller & Clauss (pers. obs.)

Development of zoo feeding regimes

concepts from agriculture
(production animals – use ***production*** potential)
human consumption habits

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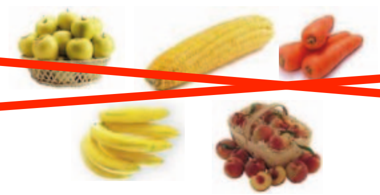

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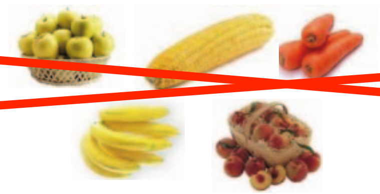


copying natural diets

avoid diseases – use ***adaptation*** potential – teaching biological knowledge



Example: rabbit feeds

	Crude fibre	NDF (total fibre)	Protein
	% DM	**% DM**	**% DM**
meat production	15	38	16
pet animal	15	37	14
in the wild	30	55	20

... pet rabbits are fed like meat-production animals but not like rabbits in their natural habitat!

Example: rabbit feeds

Development of pet feeds

	Year°	CF %DM	NDF %DM	Prot %DM
Company A:				
Rabbit (Standard)	1982	8	26	13
Rabbit 4mm Pellet	1987	10	29	17
Supreme rabbit mix	2000	14	36	14
New Generation (Extrudate)	2006	21	47	16
Company B:				
Menu Thyme (Mix)	ca.1980	10	29	11
Rabbit Special Regular Pellet	2000	16	38	14
Emotion Beauty (Extrudate Mix)	2007	14	35	14
Emotion Sensitive (Extrudate Mix)	2007	17	40	14

Example: tortoises

Recommendations from successive editions of the same (German) textbook

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1999	Leafy green vegetables, vegetables, fruits (apple, banana, pear, grapes, kiwi), sometimes canned dog/cat food, grain products
2004-2009 	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

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Feeding herbivores

from Stevens und Hume (1995)

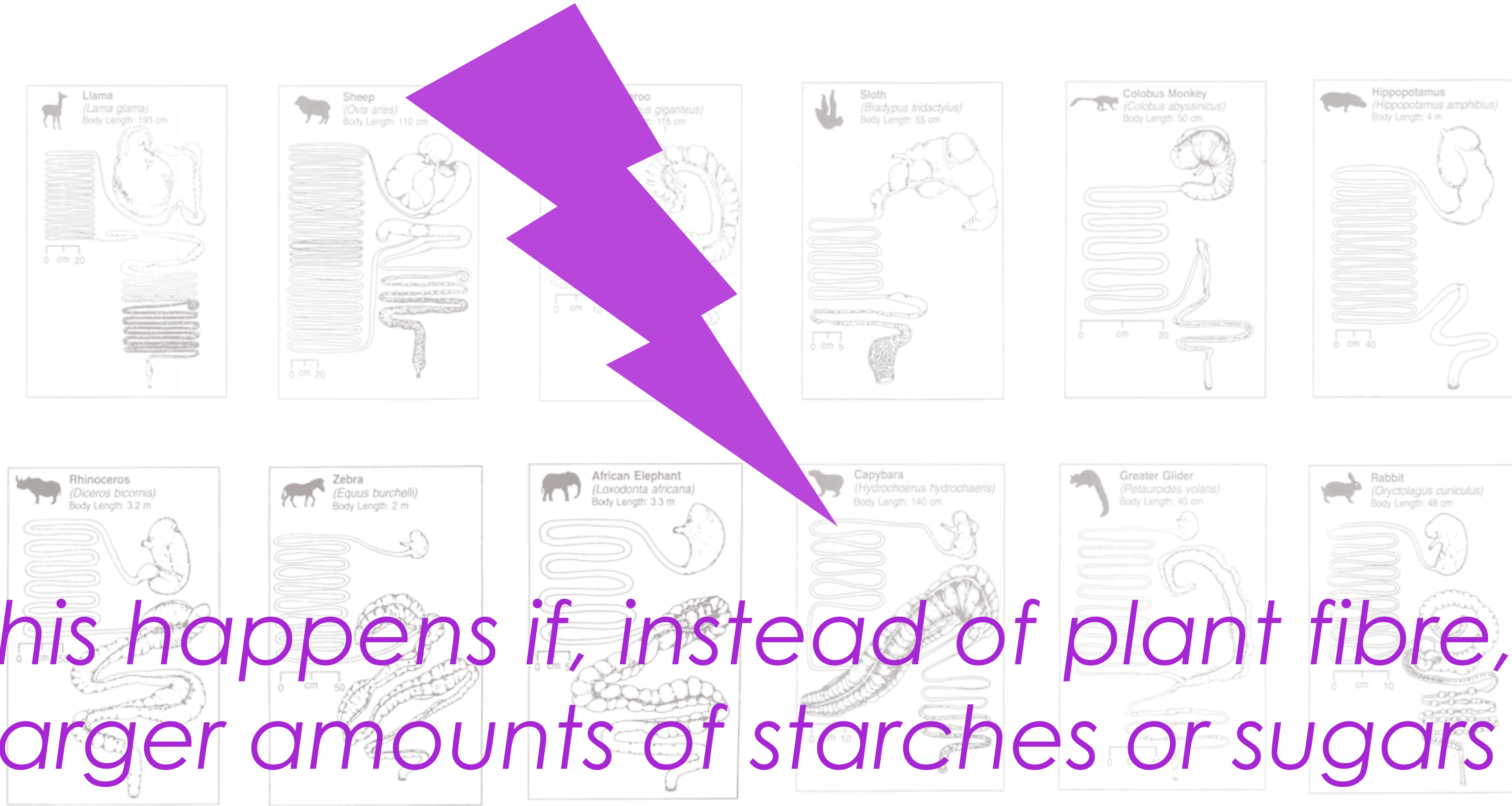
Feeding herbivores

Major goal of herbivore feeding:

Do not disturb the balance of the 'fermentation chamber'!

from Stevens und Hume (1995)

Feeding herbivores



This happens if, instead of plant fibre, larger amounts of starches or sugars enter into the fermentation chamber!

from Stevens und Hume (1995)

Bacteria ferment all carbohydrates into volatile fatty acids (VFA)

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▶ ▶ ▶ **ACIDOSis !**

Man-made diets: too little fibre

- Human nutrition
- Pigs
- Beef cattle/ Dairy cattle
- Riding horses
- Dogs/ Cats
- Zoo animals

Man-made diets: too little fibre

- Human nutrition → gut health
- Pigs → piglet diarrhoea
- Beef cattle/ Dairy cattle
- Riding horses → crib biting
- Dogs/ Cats → faeces consistency
- Zoo animals → obesity

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Fibre content depends on intended use

Use		Fibre content*
Beef cattle		12 %DM
Dairy cattle		18 %DM
Feral cattle		*30 %DM*

*historical recommendations for ration design

Fibre content depends on intended use

Use		Fibre content*	Longevity
Beef cattle		12 %DM	app. 2 years
Dairy cattle		18 %DM	app. 4 years
Feral cattle		*30 %DM*	*app. 25 years*

*historical recommendations for ration design

There are no secret, species-specific ingredients!

A simple way to pretend specialized nutritional knowledge is to produce a pellet, put it in bags of different colours and label (and price) these differently.

Complete feed for rabbits

- maintenance -

Protein	12 %
Fibre	18 %
Calcium	1.2 %

Ingredients: Lucerne meal, soy meal, wheat bran, oats, Calciummonophosphate

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Ingredients: Lucerne meal, soy meal, wheat bran, oats, Calciummonophosphate

Mandrill Special®

Supplement for Mandrills

Years of zoo experience!

Especially balanced nutrient composition for this critical species

Protein..........12 %
Fibre.............18 %
Calcium........1.2 %

Grazer-Pellet

Browser-Pellet

Camelid-Pellet

Rhino-Pellet

Elephanten-Pellet

Zebra-Pellet

Kangaroo-Pellet

Don't believe names, think for yourself

- 'Frugivores' are adapted to wild fruits but not to commercial produce that has been bred for centuries to please the human palate!

Species	Crude fiber (% dry matter)	NDF (% dry matter)
Duikers (various spp.)		
Forage	-	25-70
Fruits	-	30-60
Colobus monkeys (different species)		
Forages	-	30-70
Fruits	-	50-70
Howler monkey (*Alouatta aloutta*)		
Forages	-	20-80
Fruits	-	20-70

data collected in Clauss & Dierenfeld (2008)

Don't believe names, think for yourself

- A large number of nutritional analyses document that 'wild fruit' contain more fibre and less sugar than commercially available fruit (that is the product of selective breeding to please human taste).

What's in an apple?

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- **85 % water**
- **10 % sugar**

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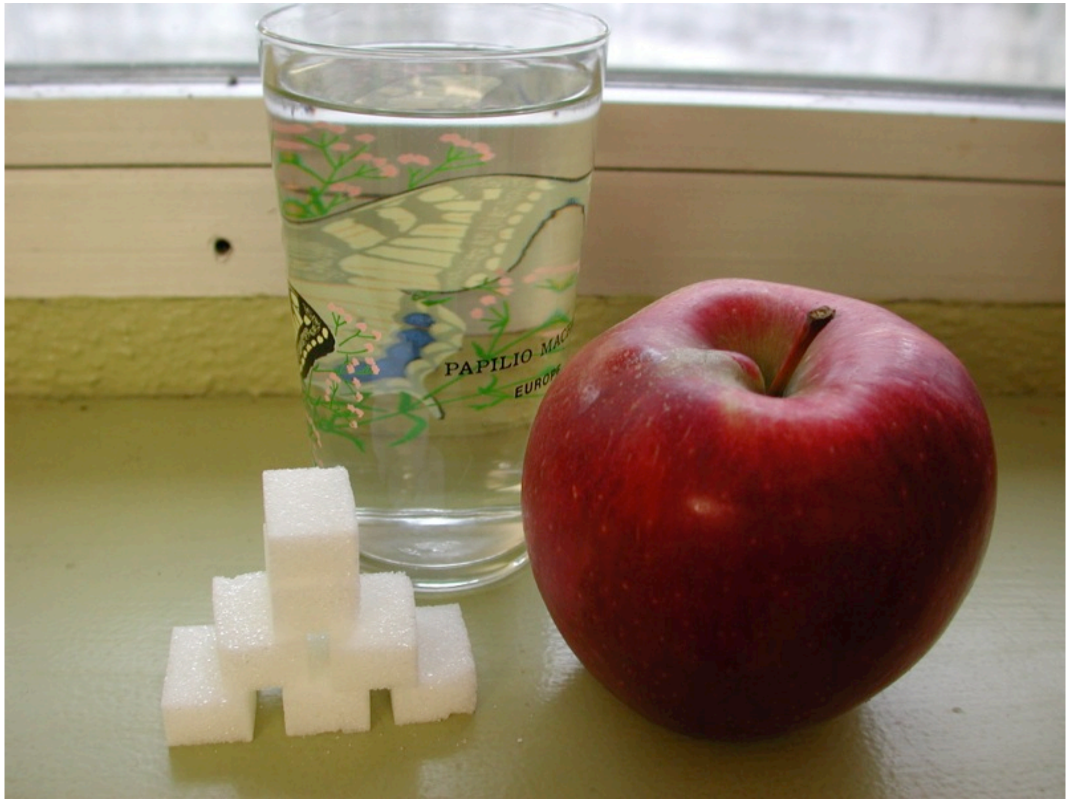

Fruits

	Water	Rest	protein	available carbohydrates	calcium	phosphorus
		"dry matter"	%		‰	
	%	%	-------------------- dry matter --------------------			
Honey	18.6	81.4	0.5	92.3	0.1	0.2
Rock melon	87.0	13.0	6.9	92.5*	0.5	1.6
Water melon	93.2	6.8	8.8	90.5*	1.5	1.6
Ananas	85.3	14.7	3.1	89.3	1.1	0.6
Grapes	81.1	18.9	3.6	85.2	1.0	1.1
Apple	85.3	14.7	2.3	84.3	0.5	0.8
Dried dates	20.2	79.8	2.3	83.1	0.8	0.7
Cherry	82.8	17.2	5.2	82.6	1.0	1.2
Banana	73.9	26.1	4.4	82.0	0.3	1.1
Grapefruit	89.0	11.0	5.5	81.4	1.6	1.5
Pear	84.3	15.7	3.0	80.6	0.6	1.0
Peach	87.5	12.5	6.1	75.5	0.6	1.8
Mango	82.0	18.0	3.3	71.1	0.7	0.7
Plum	83.7	16.3	3.7	70.0	0.9	1.1
Apricot	85.3	14.7	6.1	67.6	1.1	1.4
Gooseberry	87.3	12.7	6.3	66.9	2.3	2.4
Kiwi	83.8	16.2	6.2	66.5	2.3	1.9
Fig	80.2	19.8	6.6	65.2	2.7	1.6
Orange	85.7	14.3	7.0	64.3	2.9	1.6
Strawberry	89.5	10.5	7.8	61.4	2.5	2.8
Black currant	81.3	18.7	6.8	53.3	2.5	2.1
Red currant	84.7	15.3	7.4	48.6	1.9	1.8
Blueberry	84.6	15.4	3.9	47.8	0.6	0.8
Blackberry	84.7	15.3	7.8	46.7	2.9	2.0
Raspberry	84.5	15.5	8.4	44.6	2.6	2.8
Guava	83.5	16.5	5.5	40.6	1.0	1.9
Papaya	87.9	12.1	4.3	19.8	1.7	1.4
Avocado	68.0	32.0	5.9	1.3 (due to high fat content)	0.3	1.2

*minimum

Source: Souci/Fachmann/Kraut „Die Zusammensetzung der Lebensmittel – Nährwert-Tabellen 1989/90". 4. Auflage, Wiss. Verlagsgesellschaft Stuttgart

Vegetables

	Water	Rest	protein	available carbohydrates	calcium	phosphorus
		"dry matter"	%		‰	
	%	%	-------------------- dry matter --------------------			
Sweet potato	69.2	30.8	5.3	94.0*	1.1	1.5
Manioc/Tapioca	63.1	36.9	2.7	86.9	1.0	1.0
Beetroot	88.8	11.2	13.7	76.9	2.6	4.0
Potato raw/cooked	77.8	22.2	9.2	69.4	0.4	2.3
Cucumber	96.8	3.2	18.8	64.7	4.7	7.2
Tomato	94.2	5.8	16.4	59.5	2.4	4.5
Pumpkin	91.3	8.7	12.6	54.9	2.5	5.1
Green beans	90.3	9.7	24.6	54.5	5.9	3.9
Onion	87.6	12.4	10.1	46.7	2.5	3.4
Kohlrabi	91.6	8.4	23.1	45.8	8.1	5.9
Carrot	88.2	11.8	8.3	41.8	3.5	3.0
Chicoree	94.4	5.6	23.2	41.4	4.6	4.6
Squash	88.7	11.3	12.4	40.6	2.4	3.8
Radish	94.4	5.6	18.8	39.6	6.1	4.7
Aubergine	92.6	7.4	16.8	35.9	1.8	2.9
Sweet pepper	91.0	9.0	13.0	35.7	1.2	3.2
Celery stalks	92.9	7.1	16.9	30.7	11.3	6.8
Cauliflower	91.6	8.4	29.3	30.2	2.4	6.4
Chinese cabbage	95.4	4.6	25.9	29.1	8.7	6.5
Leek	89.0	11.0	20.4	29.0	7.9	4.2
Broccoli	89.7	10.3	32.0	27.4	10.2	8.0
Zucchini	92.2	7.8	20.5	25.6	3.8	2.9
Brussels sprouts	85.0	15.0	29.7	25.1	2.1	5.6
Savoy cabbage	90.0	10.0	29.5	24.1	4.7	5.6
Lettuce	95.0	5.0	25.0	22.0	7.4	6.6
Kale/Green cabbage	86.3	13.7	31.4	21.7	15.5	6.4
Fennel	86.0	14.0	17.4	20.1	7.8	3.6
Celery root	88.6	11.4	13.6	19.7	6.0	7.0
Girasole	78.9	21.1	11.6	19.0	0.5	3.7
Artichoke	82.5	17.5	13.7	16.6	3.0	7.4
Field salad/Lamb's lettuce	93.4	6.6	27.9	10.6	5.3	7.4
Mangold	92.2	7.8	27.3	8.8	12.8	5.0
Spinach	91.6	8.4	30.0	7.3	15.0	6.5
Parsley	81.9	18.1	24.5	7.2	13.5	7.1
Endive	94.3	5.7	30.7	5.3	9.5	9.5

*minimum

Source: Souci/Fachmann/Kraut „Die Zusammensetzung der Lebensmittel – Nährwert-Tabellen 1989/90". 4. Auflage, Wiss. Verlagsgesellschaft Stuttgart

courtesy Tjalling Huisman

... is healthy?

... is healthier than ...

... is healthier than ...

... is healthier than ...

Variety

Samuel Clauss (2005) Int J Desper Parents Res 1: 2-7

Variety

Samuel Clauss (2005) Int J Desper Parents Res 1: 2-7

Variety


Katjes
Saure Heringe
Jogger Gums
Rock'n Gums
Frucht Pfötchen
Frucht Katzen
Neu
Yoghurt Tropicale
Tropen-Früchte
Yoghurt-Gums

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BUNNY BROME
ALFALFA NIBBLES
OAT HAY
ORCHARD GRASS
WESTERN TIMOTHY
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Variety

There are no studies to date corroborating a positive effect of dietary variety on animal welfare!

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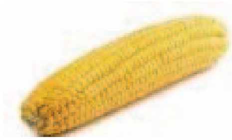
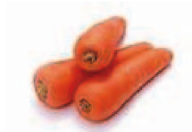
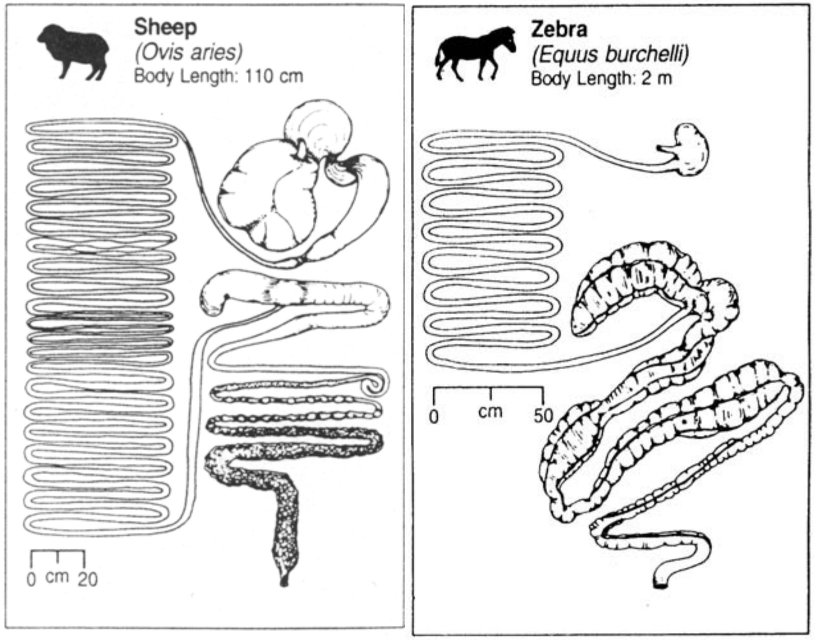
Feeding high-sugar/starch diets







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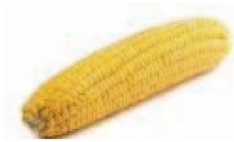

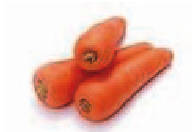

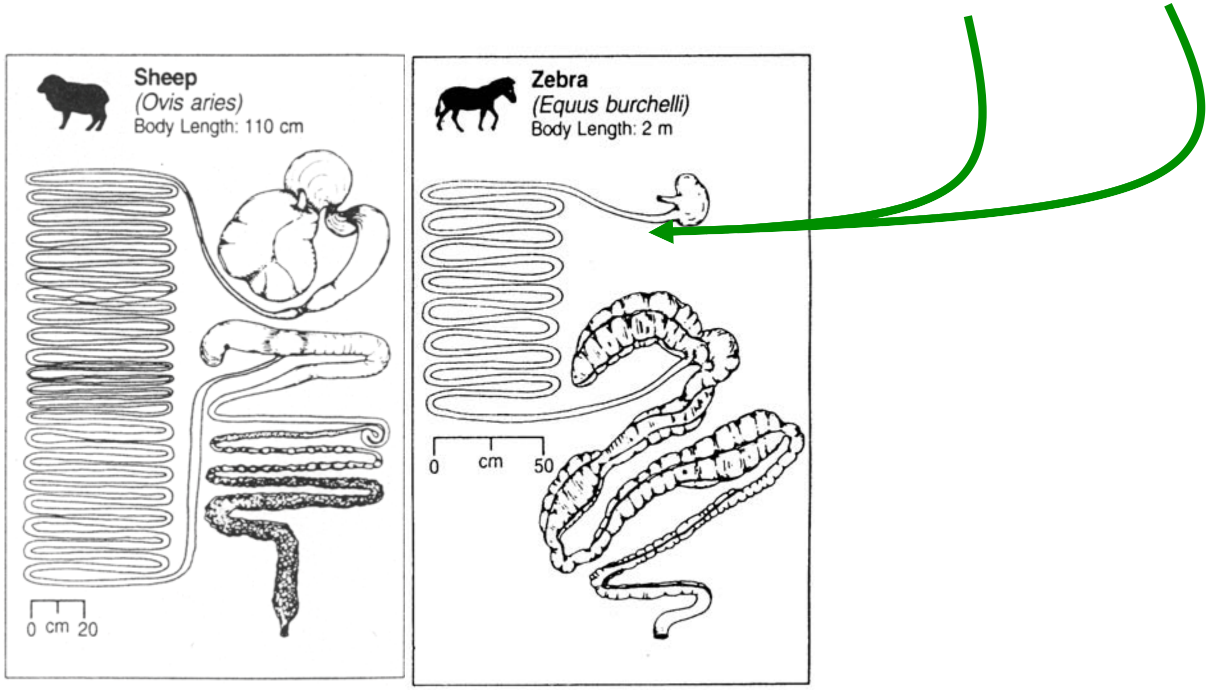

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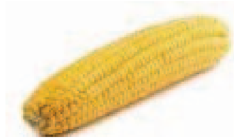
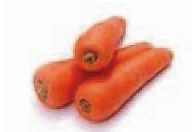
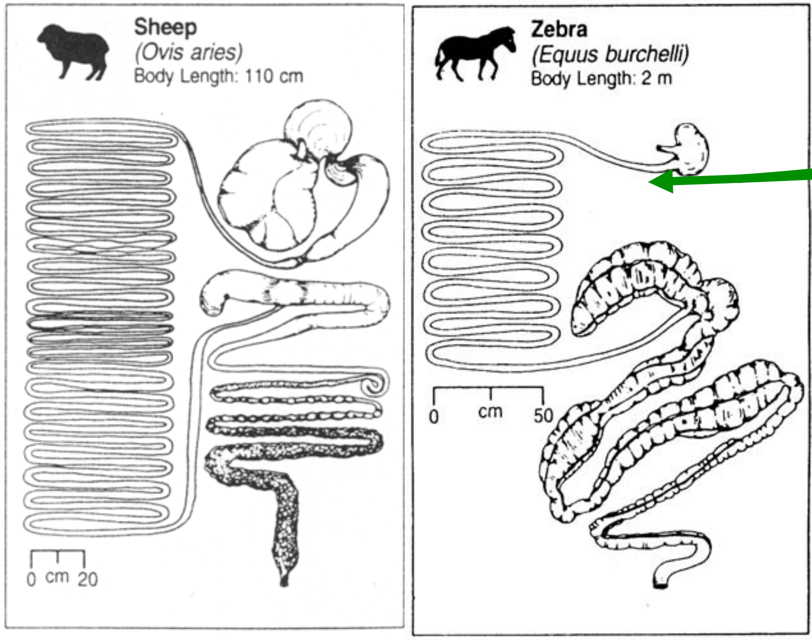
  



Easily digestible nutrients absorbed in small intestine
=> obesity


Photo Jean-Michel Hatt

Free-range vs. zoo

from Hatt & Clauss (2006)

A survey of African (*Loxodonta africana*) and Asian (*Elephas maximus*) elephant diets and measured body dimensions compared to their estimated nutrient requirements

K. Ange, S.D. Crissey, C. Doyle, K. Lance, H. Hintz

Proceedings of the 2001 Conference of the AZA Nutrition Advisory Group 4:5-14

Mean adult female body mass (kg)

Free-range	2720	2800
Zoo	3453	3375

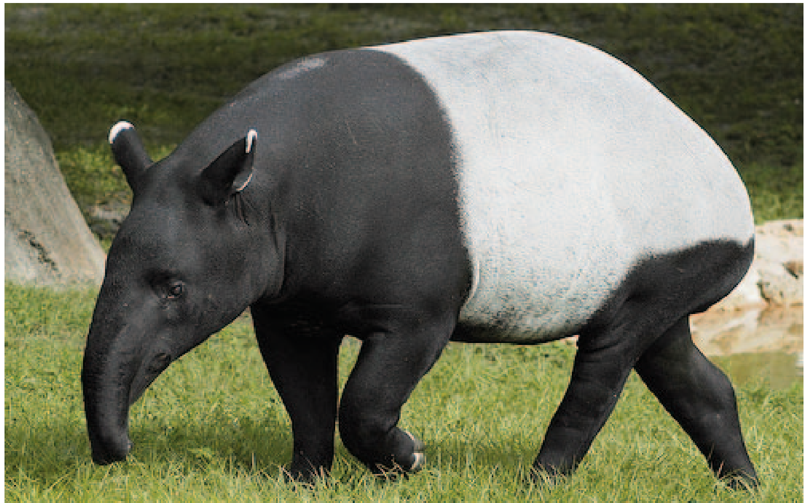
Fecundity and population viability in female zoo elephants: problems and possible solutions

R Clubb[†], M Rowcliffe[‡], P Lee[§#], KU Mar[¶], C Moss[#] and GJ Mason[¥]*

Animal Welfare 2009, 18: 237-247

Group/measure	**Population**		**Population difference**	**Data source/notes**
	In situ	**Zoo**		
Birth weight	89.5 (± 6.3) kg (n = 5)	102.1 (± 9.6) kg (n = 63)	$F_{1,66} = 8.32$, $P = 0.005$	Hayssen *et al* 1993
	74.0 kg (n = 6)	105.6 kg (n = 40)	Reported in paper as significant	Kurt & Mar 1996 (sexes pooled)
	–	118.8 kg (n = 7)	n/a	ISIS 2002 (females only)

Free-range vs. zoo



from various internet sources and own photo

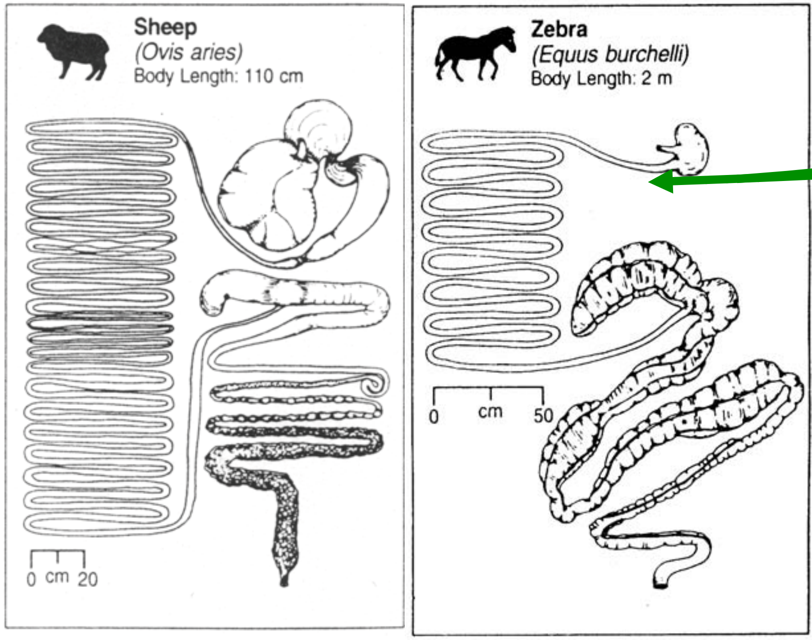
Free-range vs. zoo

from Clauss & Hatt (2006)

(from Von Houwald 2001)

Gabrisch & Zwart (2005)

Feeding high-sugar/starch diets



Easily digestible nutrients absorbed in small intestine => obesity

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


Photo: Patricia Medici

Tapir faeces

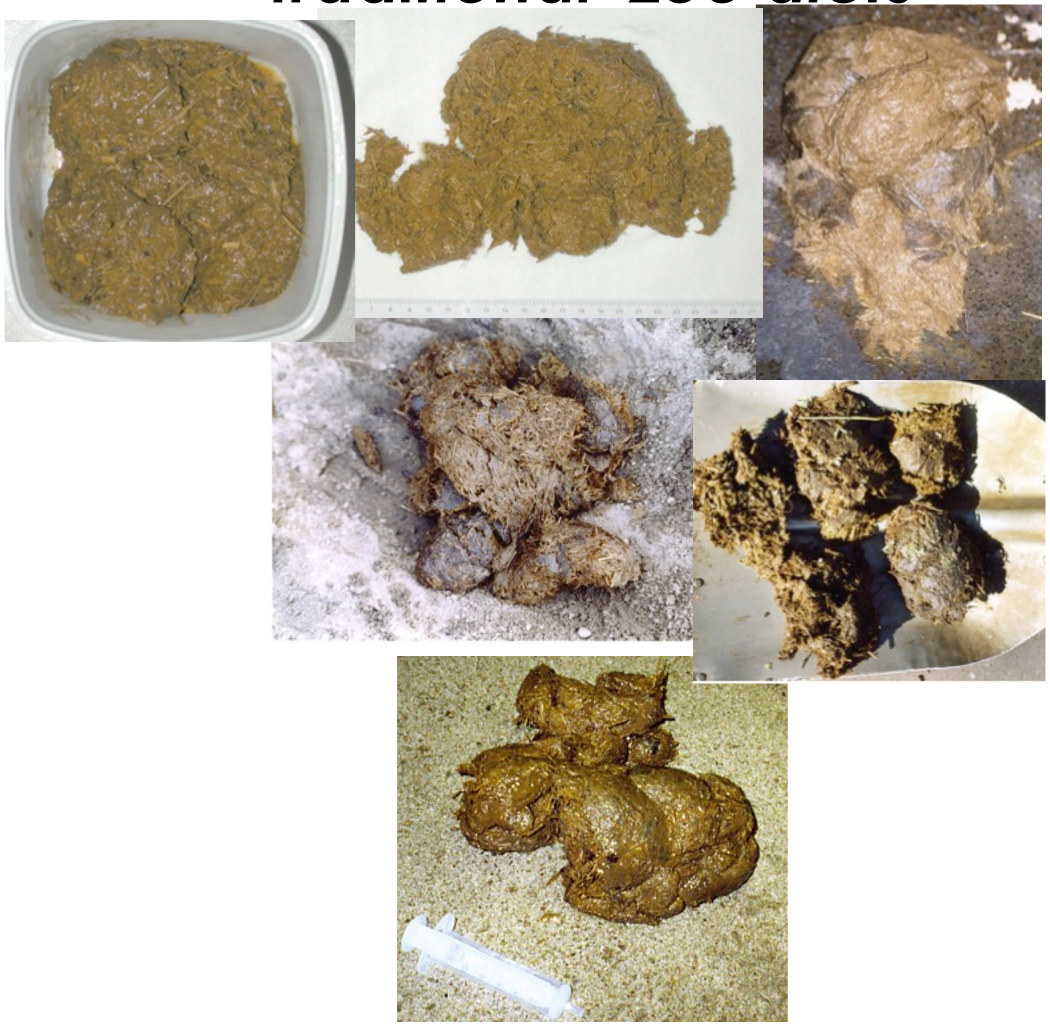
Free range

Photo: Patricia Medici

Tapir faeces

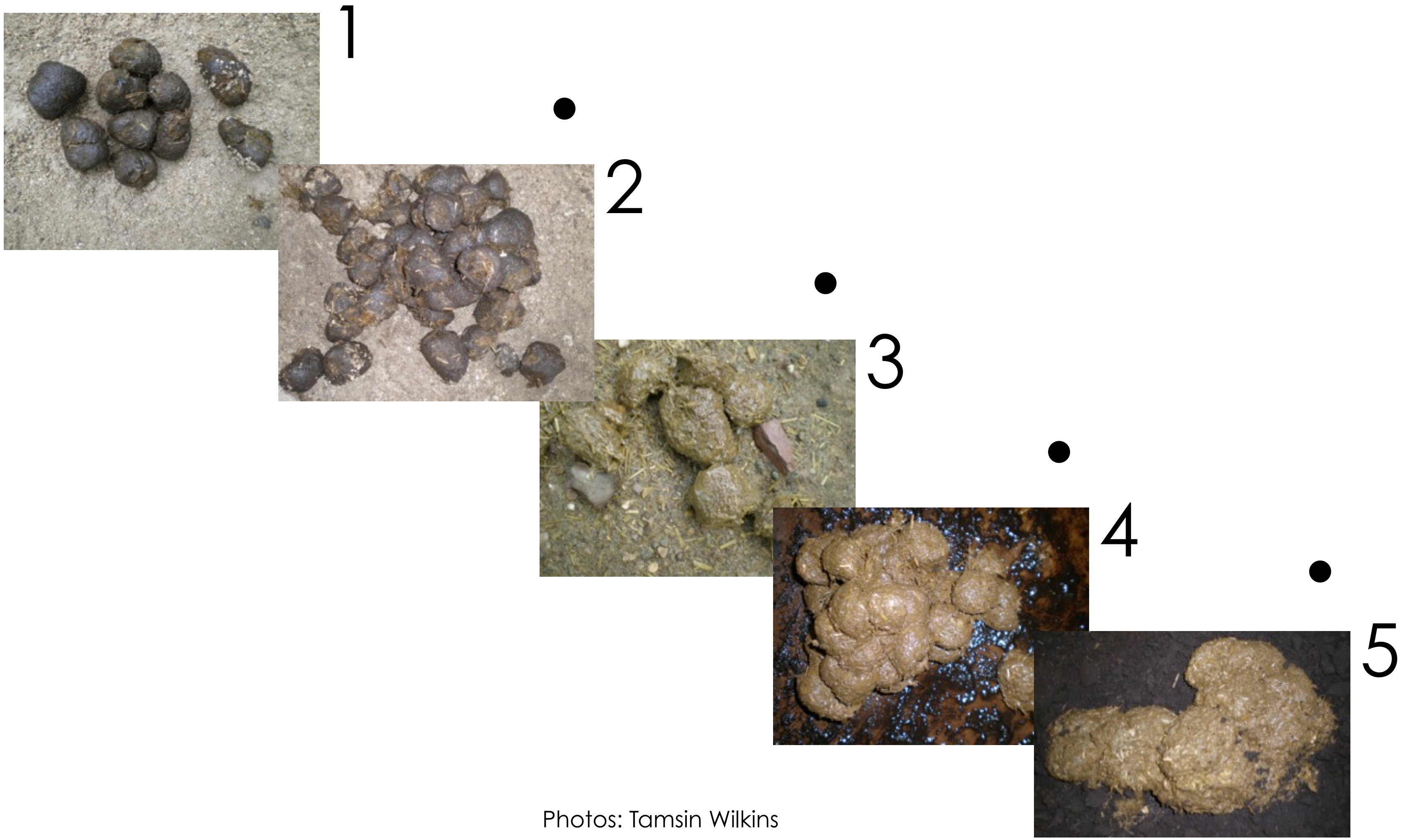
Free range

'traditional' zoo diets



Photos: Patricia Medici, Stefanie Lang-Deuerlein, J.-M. Hatt, M. Clauss

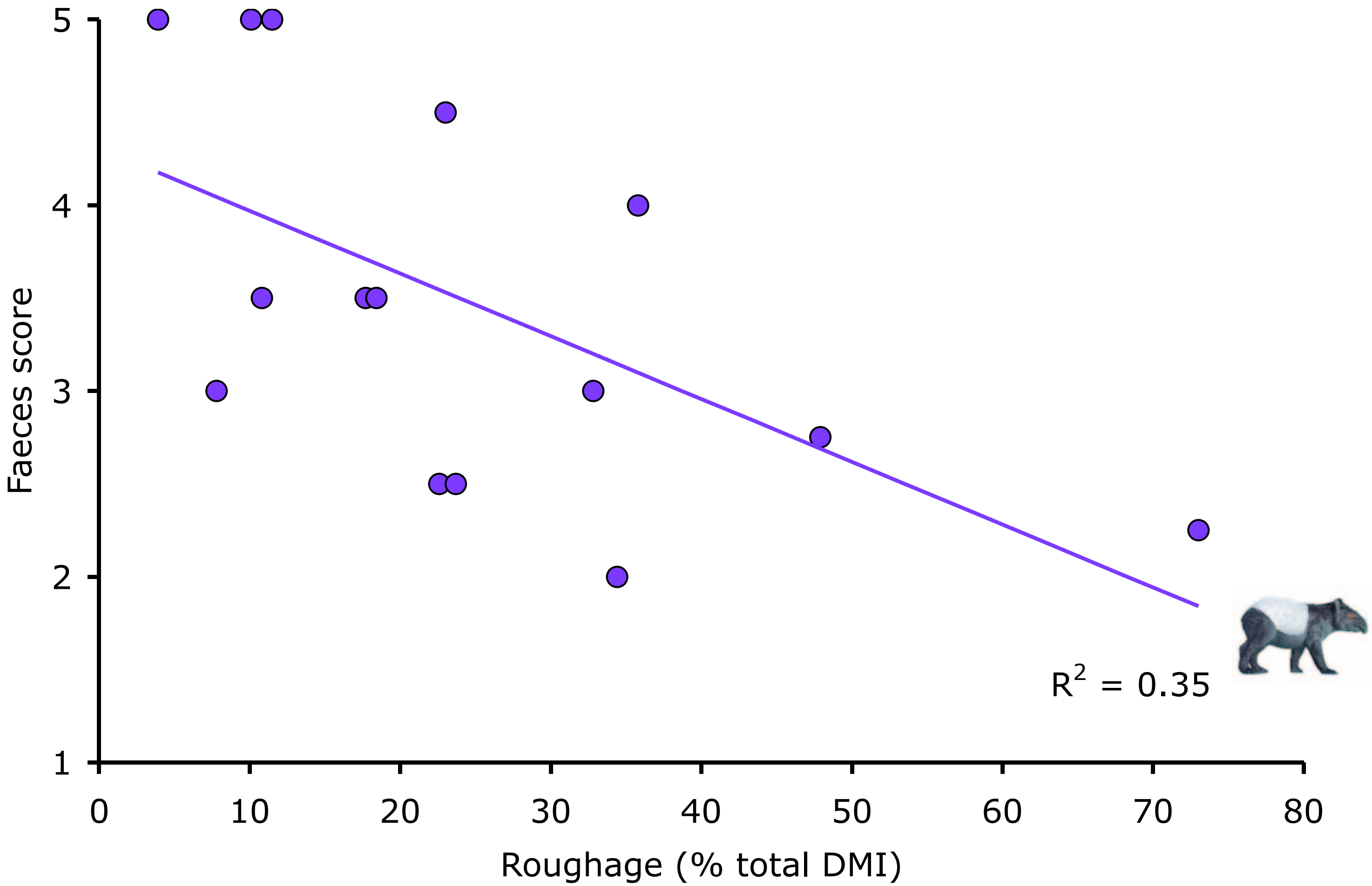
Faecal scores in tapirs



Photos: Tamsin Wilkins

from Clauss et al. (2008)

Faecal scores in tapirs



from Clauss et al. (2008)

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

Shiho Fujita[1] & Takashi Kageyama[2]

J Med Primatol **36** (2007) 25–32

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

Subject	Sex	Age	Birth	No. of samples tested	First PCR	Nested PCR	Not detected
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)

[1]Ai and Ayumu are a mother–infant pair.
[2]Japan Monkey Center.
[3]Primate Research Institute.
[4]Parc Zoologique de Paris.

Table 3 Detection of *Clostridium perfringens* in feces of wild 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)

[1]The values in parentheses show percentages.

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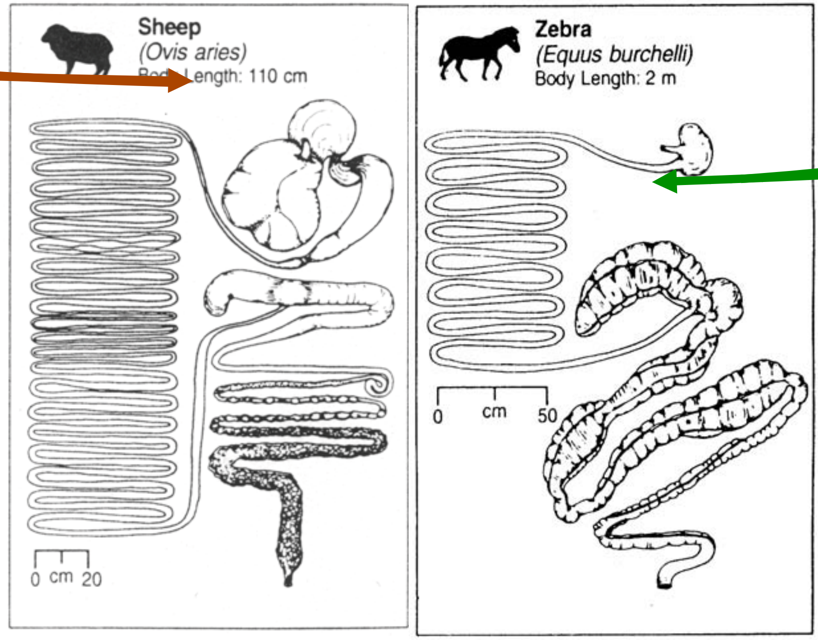
Feeding high-sugar/starch diets

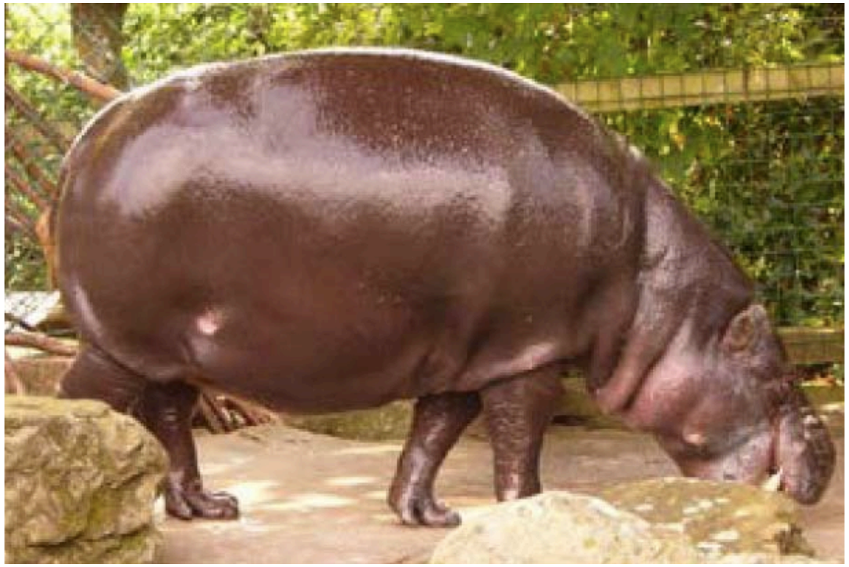
(obesity)



Easily digestible nutrients absorbed in small intestine => obesity

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

Free-range vs. zoo



from Collen et al. (2011)

from Taylor et al. (2013)

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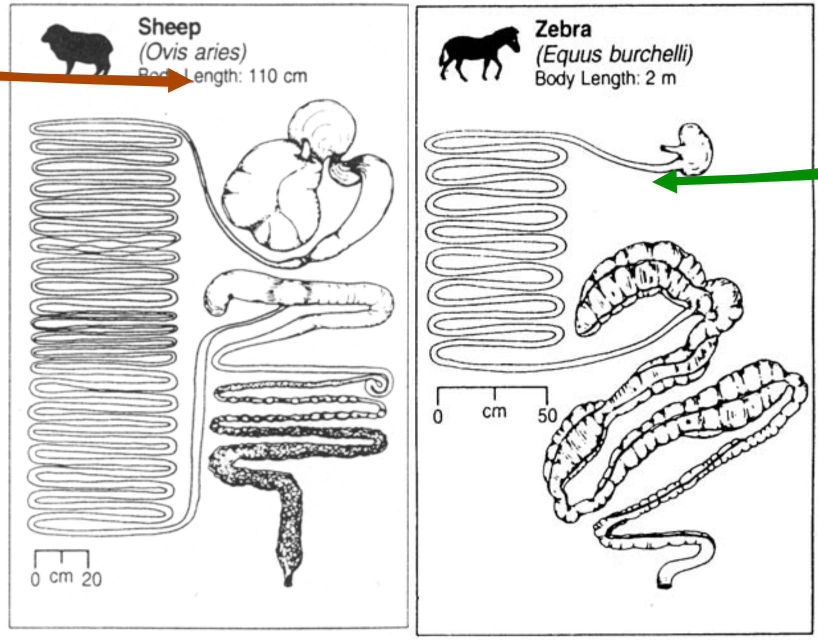

(obesity)

Easily digestible nutrients enter the fermentation chamber
⇒'malfermentation'

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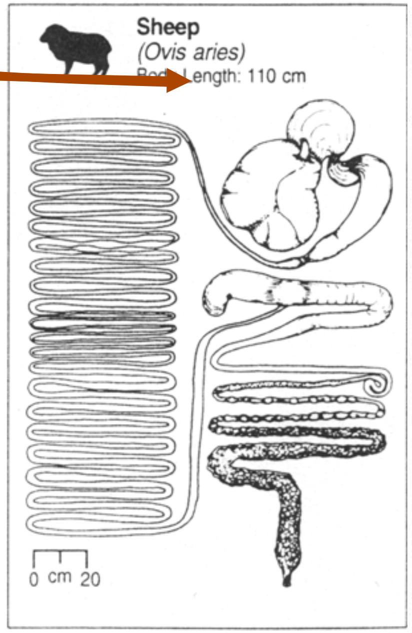
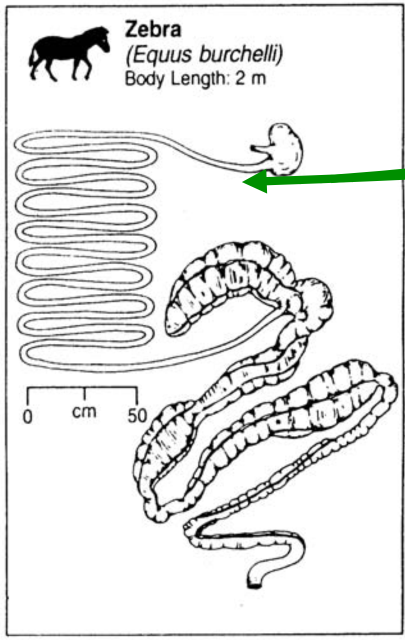
Feeding high-sugar/starch diets





(obesity)

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

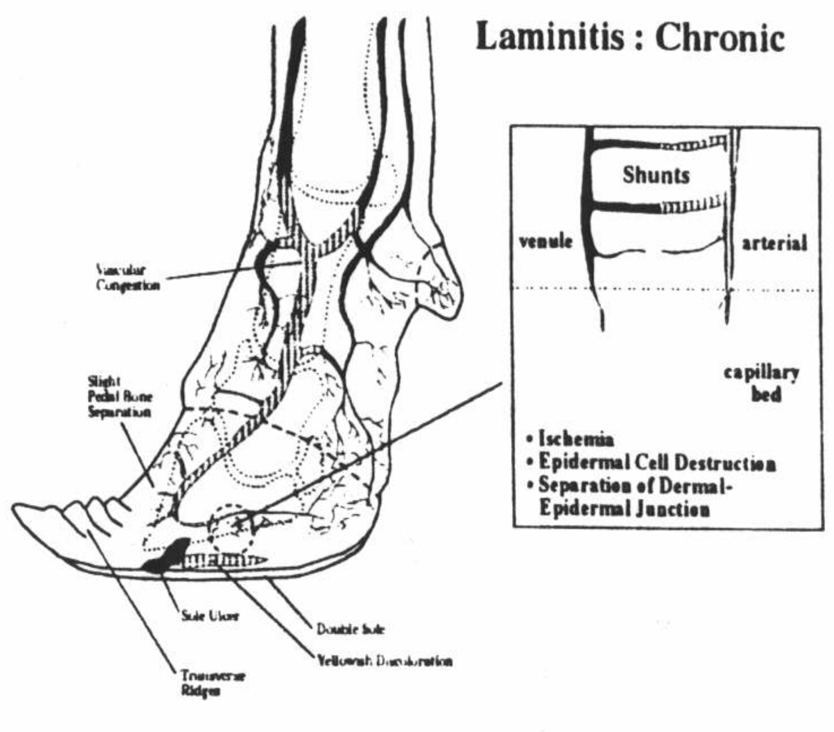
Only at very excessive amounts: 'caecum acidosis', diarrhoea, laminitis


Foto: Marcus Clauss

Oral Stereotypies in Giraffe

Photo: Daniela Schaub

Laminitis

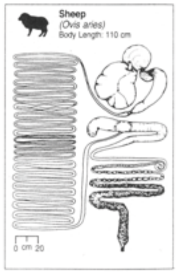


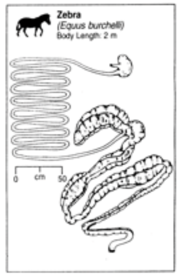
from Nocek (1997)

Photos: M. Clauss, W. Zenker

Feeding-related problems - rule of thumb for high-energy feeds

Digestive upset/wasting ——— **Obesity**





langurs

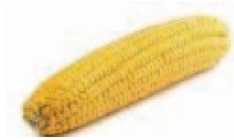
sloths
small ruminants
browsing ruminants

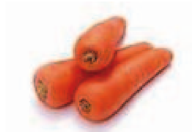
elephants
rhinos
tapirs
lemurs
great apes

large grazing ruminants

hippos

Primates as a prime example

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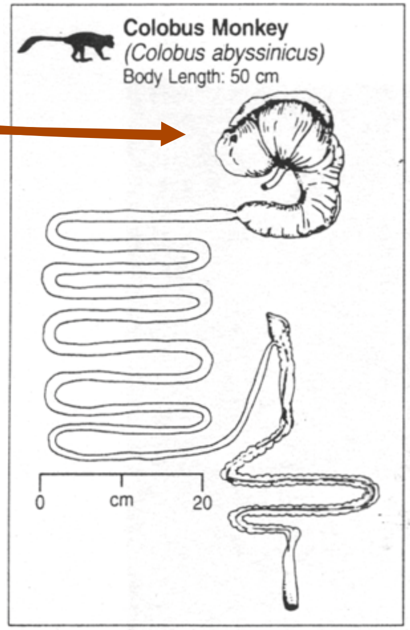
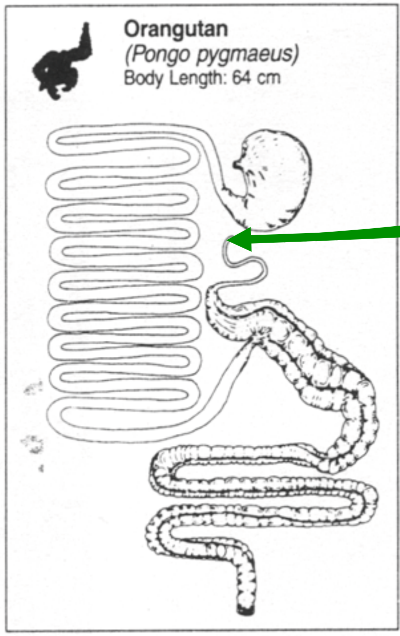
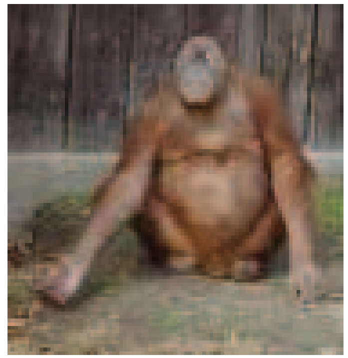


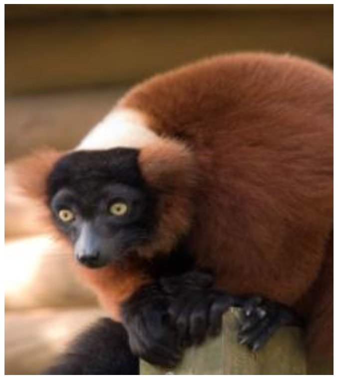






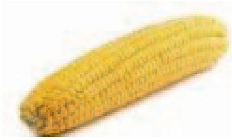
Low food intake
Laminitis
Liver abscess
Reduced lifespan?
Diarrhoea
Oral stereotypies

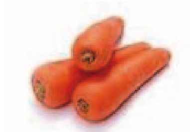
Obesity in primates

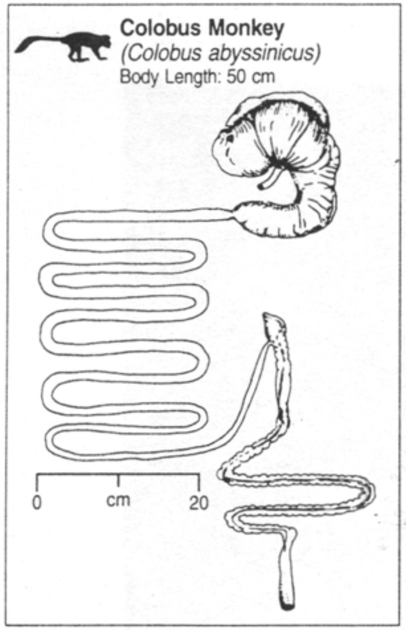


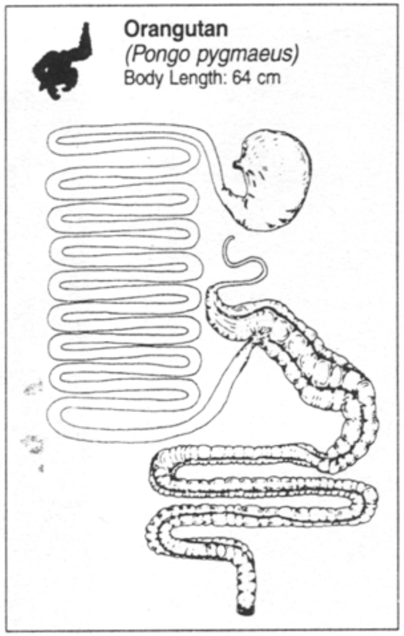
- Gorillas (Cousins 1972, Leigh 1992)
- Orangutans: wild ♀ 38.7 kg, ♂ 86.3 kg
  zoo ♀ up to 81 kg, ♂ up to 189 kg;
  (Schmidt 2004)
- Chimpanzees: 10.5% ♀♀ obese
  (Videan et al. 2007)
- Macaques: 7-23% obese
  (Walike et al. 1977, Schwartz et al. 1993, Chen at al. 2002)
- Marmosets
  (Savage et al.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

Primates as a prime example



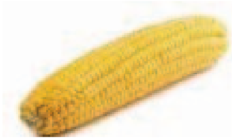


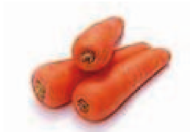




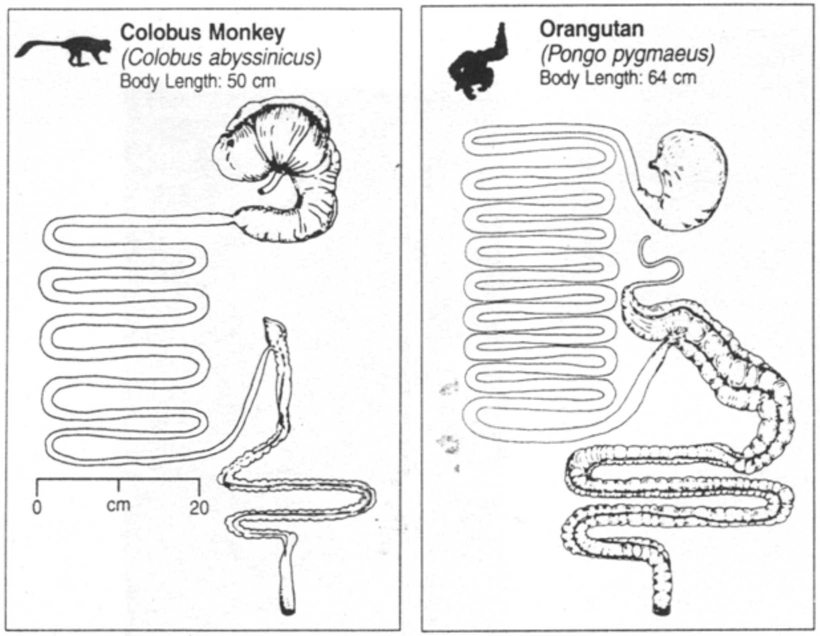
obese lemurs

Primates as a prime example

langurs with bad condition, diarrhoea, short lifespan



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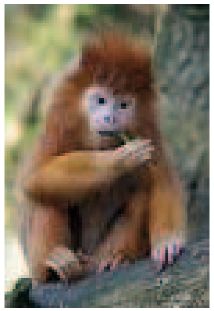


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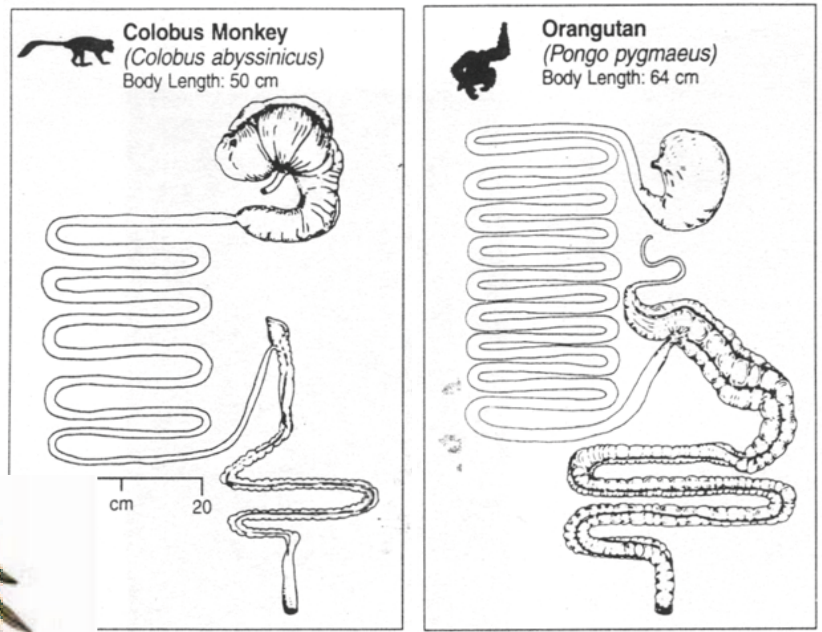

Does it matter?

Indigestion / Unthriftiness - Wasting	Obesity
	Elephant/ Rhino/ Tapir
Langurs	Lemurs
Sloths	
	Rodents
Small ruminants/	(Carnivores, Bears)
Browsing ruminants	

	(large ruminants/ grazing ruminants/ hippos)

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Health problems	

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Indigestion /
Unthriftiness - Wasting

Langurs
Sloths

Small ruminants/
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Health problems

Obesity

Elephant/ Rhino/ Tapir

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Rodents
(Carnivores, Bears)

(large ruminants/
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hippos)

Obesity in orangutans

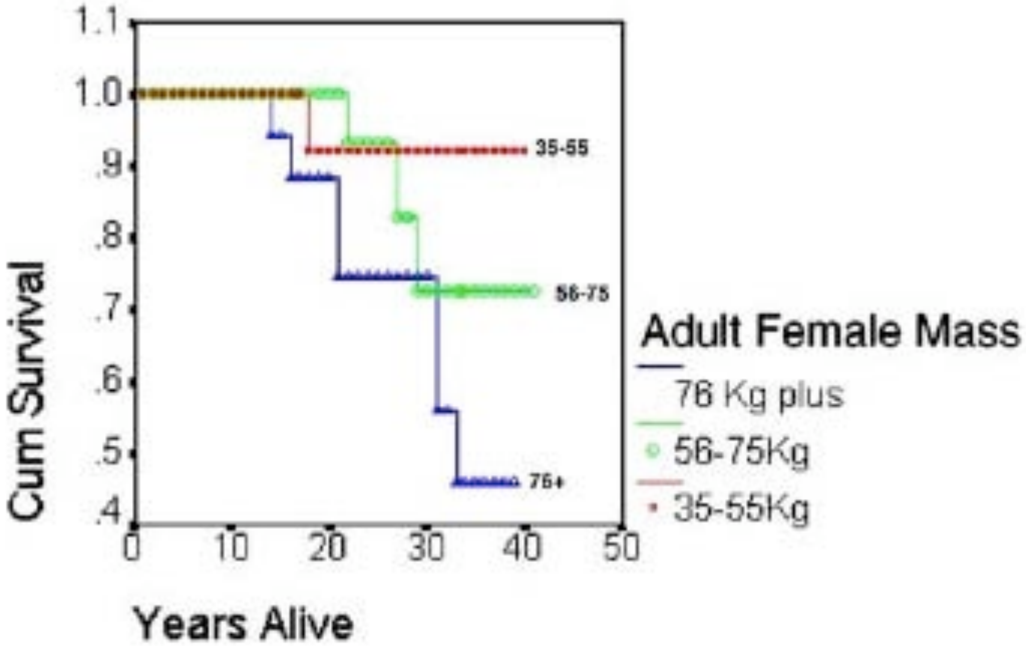
Int J Primatol (2007) 28:429–440
DOI 10.1007/s10764-007-9117-9

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

VIVAMUS

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. Lammey

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.

Social Factors Influence Ovarian Acyclicity in Captive African Elephants (*Loxodonta africana*)

Elizabeth W. Freeman,[1,2*] Greg Guagnano,[2] Deborah Olson,[3] Mike Keele,[4] and Janine L. Brown[1]

Zoo Biology 28:1–15 (2009)

to ovarian acyclicity. Females more likely to be acyclic had a larger body mass index and had resided longer at a facility with the same herdmates. Results suggest that controlling the weight of an elephant might be a first step to helping mitigate estrous cycle problems.

let‘s show what they evolved to cope with (not what they can stand)

from Stevens und Hume (1995)

Feeding captive herbivores

- no commercial fruits (they resemble nothing in the wild!)
- wild fruits = green leafy vegetables !
- starch(grain)-based pellets only very limited amounts (better: beet pulp and lucerne meal-based)

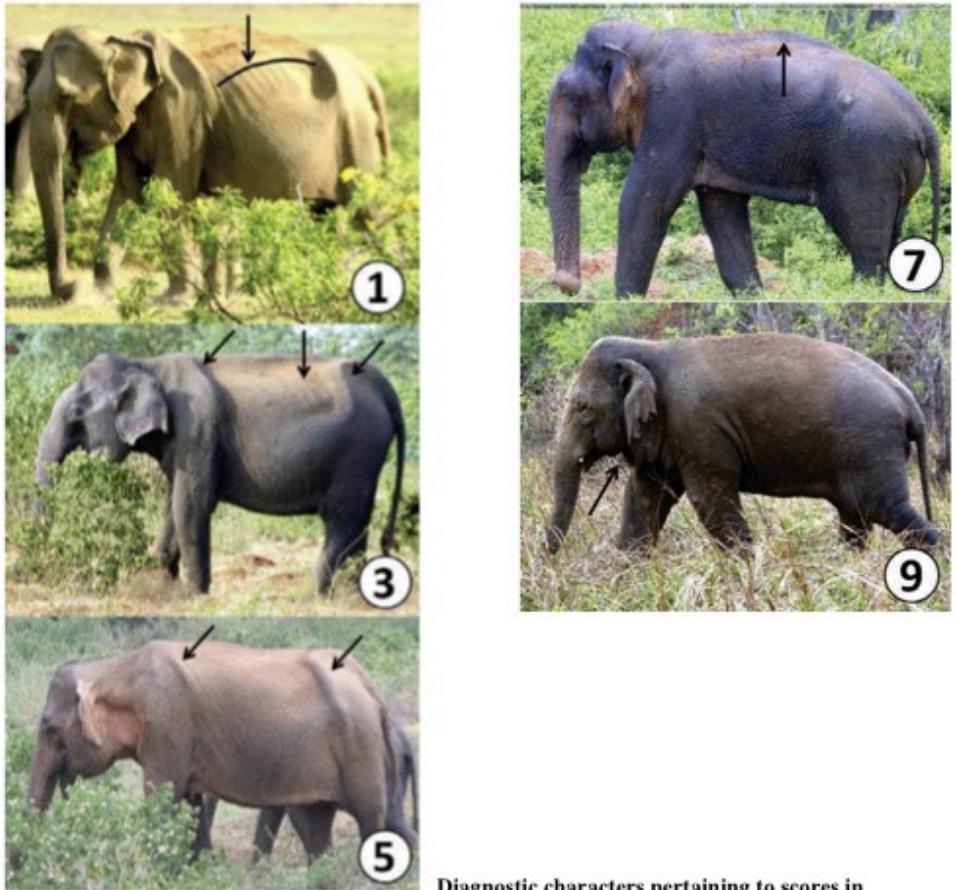
- roughage or a variety of roughages (grass hay, lucerne hay, browse, fresh grass, fresh lucerne, silages incl. browse silage)

- minerals (mineralised pelleted feed)

- weight control (scales, body condition score)

Check weight / body condition

Body Condition Index Scores



Diagnostic characters pertaining to scores in photographic scale.

1	All ribs (shoulder to pelvis) visible, some ribs prominent (spaces in between sunken in)
3	Some ribs visible (spaces in between not sunken in), shoulder and pelvic girdles prominent
5	Ribs not visible, shoulder and pelvic girdles visible
7	Backbone visible as a ridge, shoulder and pelvic girdles not visible
9	Back rounded, thick rolls of fat under neck

If it is difficult to decide between two points on the scale, as the scale is composed of odd numbers, the score represented by the intervening even number is assigned.

Feeding captive herbivores

- Roughages of medium or low feeding value (i.e. ‘rough cuts’) are suitable for many large zoo herbivores

- hygienic status has to be impeccable

  (feeding value ≠ hygienic status)

Feeding herbivores

- If variety is an aim, achieve it by offering different roughages

Feeding herbivores

- in situations of increasing energy/nutrient requirements (e.g. lactation)?

Feeding herbivores

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'concentrates'?

Feeding herbivores

- in situations of increasing energy/nutrient requirements (e.g. lactation)?

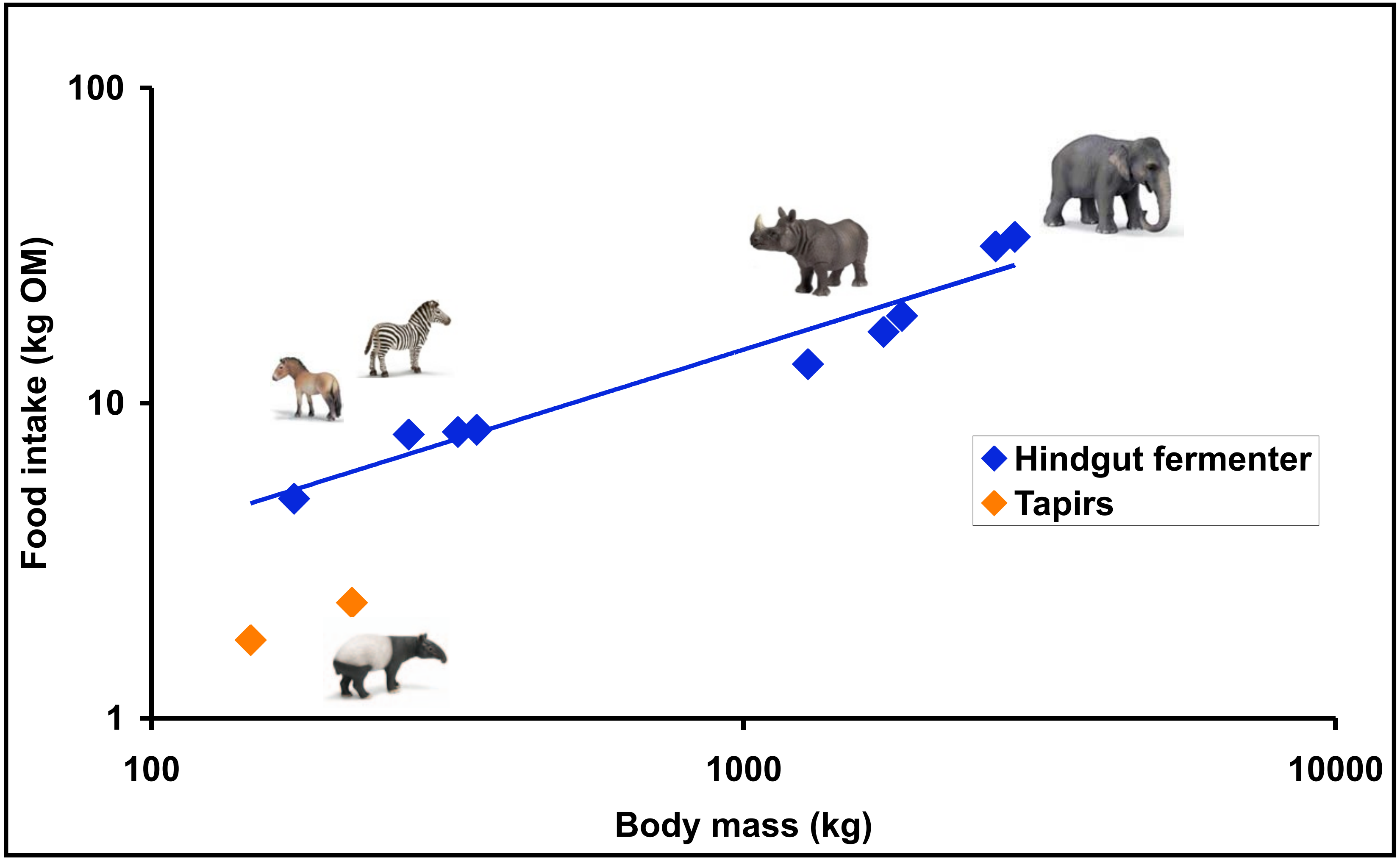
‘concentrates’?

roughage of a higher feeding value

Feeding by weight

- visually estimating amounts often leads to errors

Not every herbivore likes grass hay



from Foose (1982)

Changing a tapir diet I

- strawberries
- mangos
- plums (w/o stones)
- apricots/peaches (w/o stones)
- apples
- pears
- ananas
- leek
- lettuce
- tomatoes
- cooked pasta/cooked rice with raisins
- oat flakes
- dry bread
- yoghurt
- minced meat (1x/week)
- ... and grass hay ad libitum (is hardly eaten)

Changing a tapir diet II

- morning:
  Lucerne hay *ad libitum* (for the whole day)
  and one lettuce, one bunch of leek, one bunch of celery stalks
  handful of pelleted feed (for minerals)

- afternoon (alterating):
  20 carrots *or*
  2 pieces of barley sprouts *or*
  2 cucumbers

- always fresh browse (twigs with leaves)

from Clauss et al. (2008)

Changing a tapir diet III

- <u>Alfred Brehm (1864)</u>:
  „It always costs them quite an effort to rise up from their inactivity and phlegm."

Changing a tapir diet III

- <u>Alfred Brehm (1864)</u>:

  „It always costs them quite an effort to rise up from their inactivity and phlegm."

- <u>one year after the diet change</u>:

  animals did not starve!

  animals are more active, alert, lively, ingest food (lucerne hay) throughout the day, easier to handle for keepers (more responsive)

  animals are less obsese

from Clauss et al. (2008)


Foto: Jean-Michel Hatt