



# Zoo Animal Nutrition Workshop



Marcus Clauss

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Kolmården 2022



**University of  
Zurich**<sup>UZH</sup>



**Clinic**  
of Zoo Animals, Exotic Pets and Wildlife



# Digstive anatomy



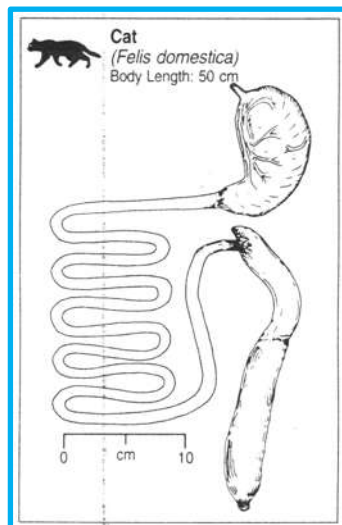
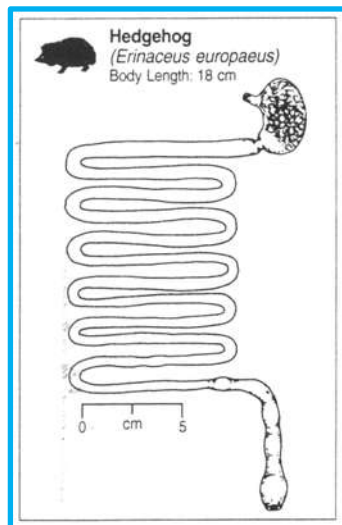
# Anatomy indicates diet - somehow



# Anatomy indicates diet - somehow

Faunivore

*with little fermentation*



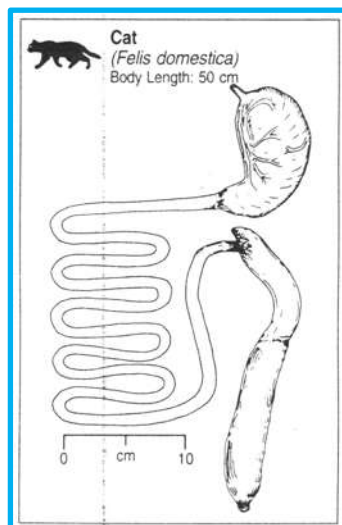
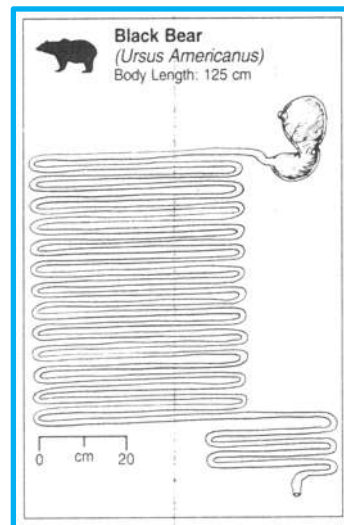
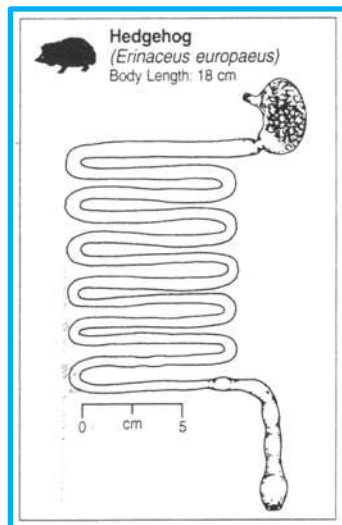


# Anatomy indicates diet - somehow

Faunivore

*with little fermentation*

Omnivore

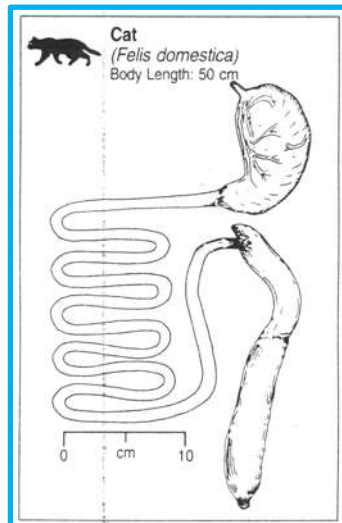
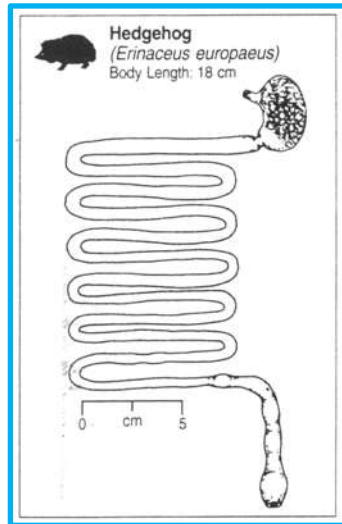




# Anatomy indicates diet - somehow

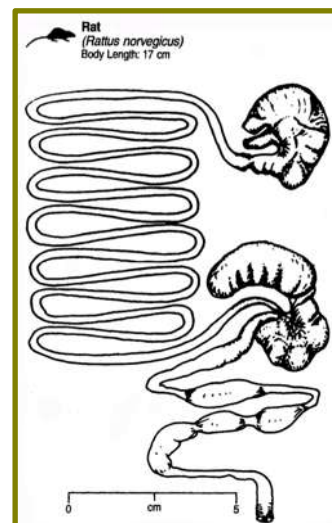
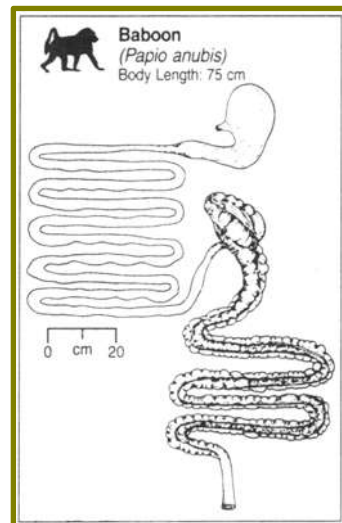
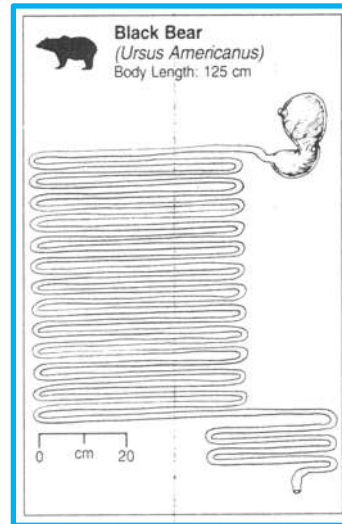
Faunivore

*with little fermentation*



Omnivore

*with relevant fermentation*



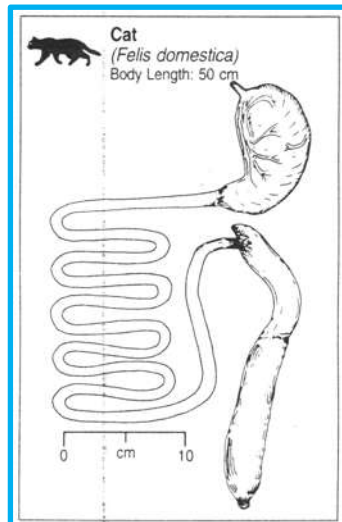
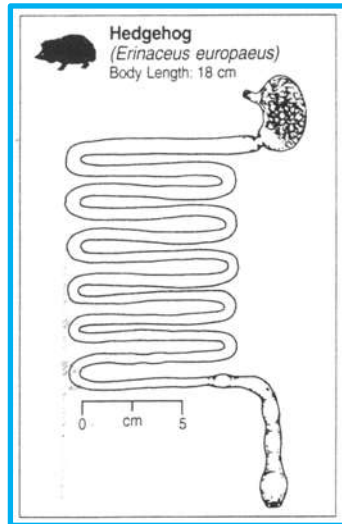




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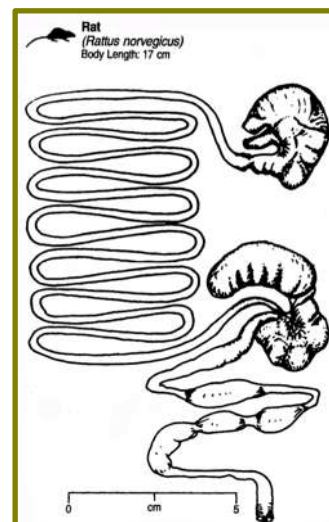
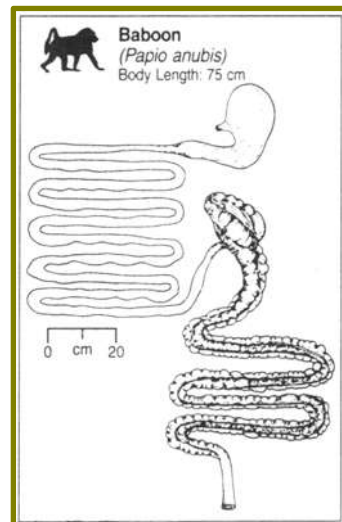
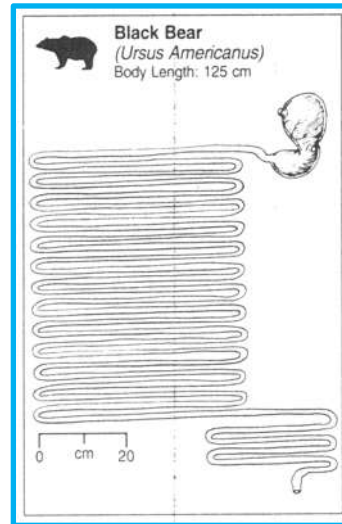
Faunivore

with little fermentation

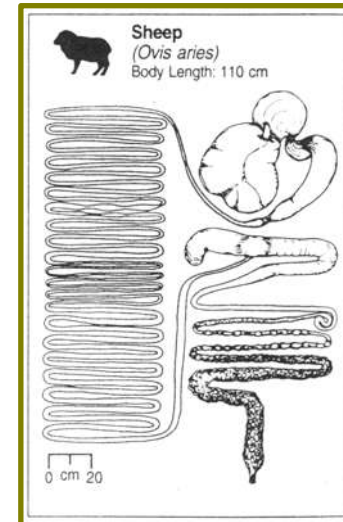
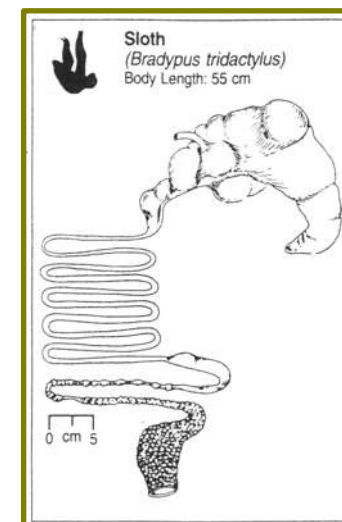
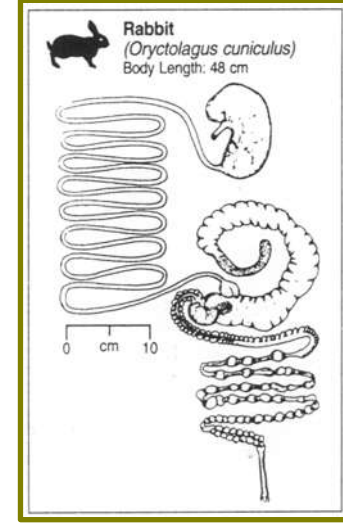
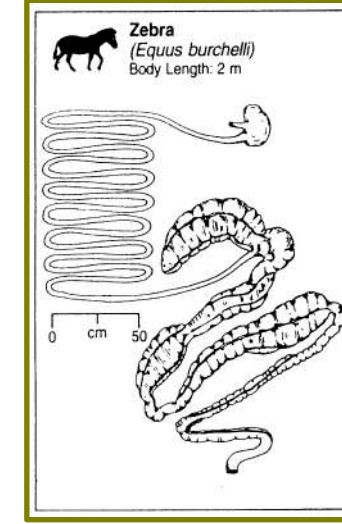


Omnivore

with relevant fermentation



Herbivore

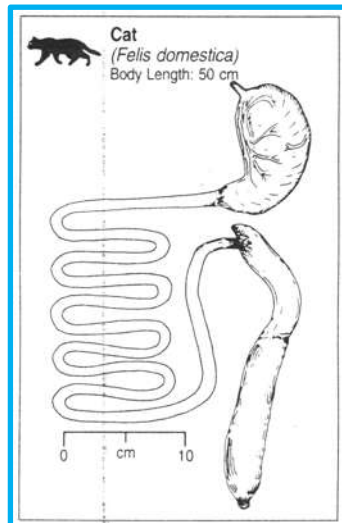
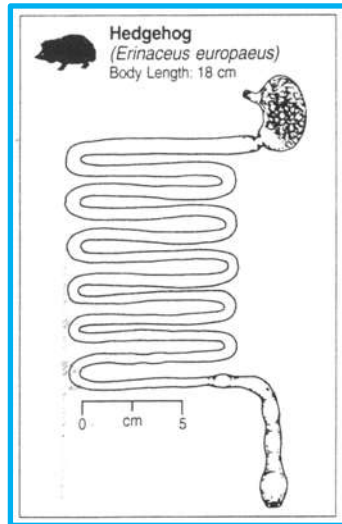




# Anatomy indicates diet - somehow

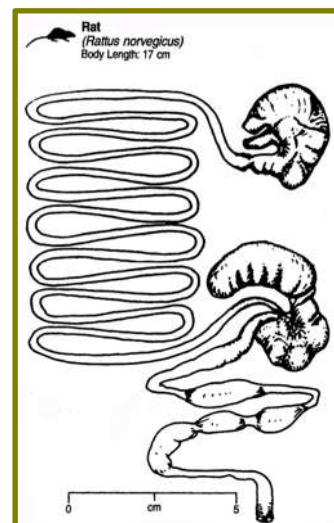
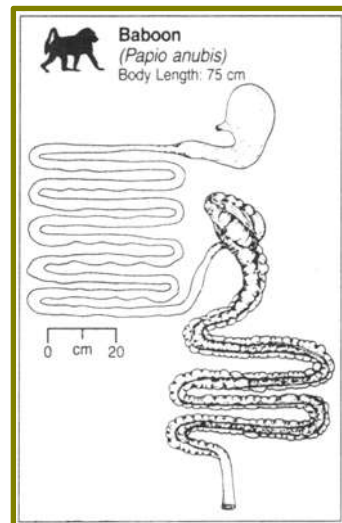
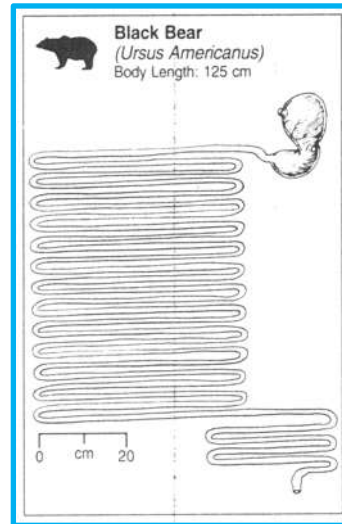
## Faunivore

with little fermentation



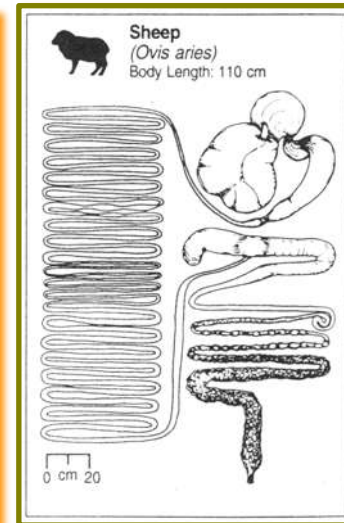
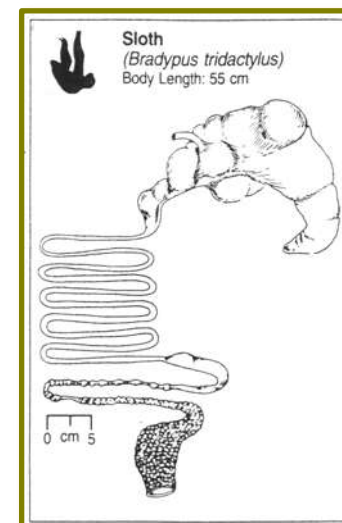
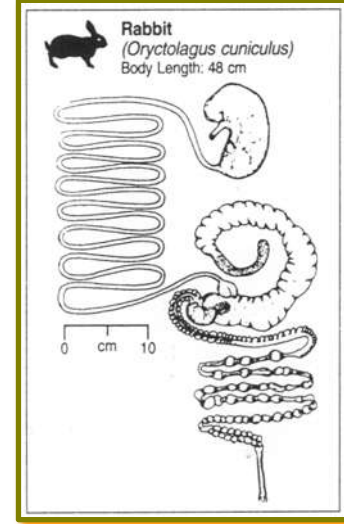
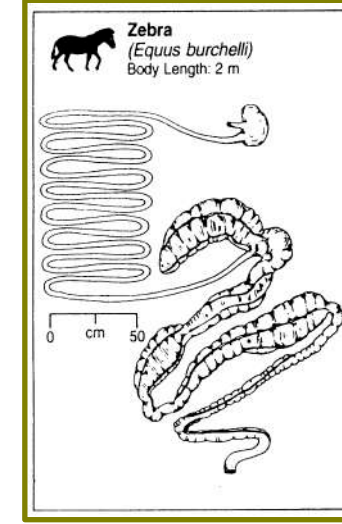
## Omnivore

with relevant fermentation



## Herbivore

with microbe farming







# Semantics

*words matter*



Don't believe names, think for yourself



# Don't believe names, think for yourself

What is an 'omnivore'?



# Don't believe names, think for yourself

What is an 'omnivore'?

## Mammal Review



Mammal Review ISSN 0305-1838

REVIEW



### **A review of wild boar *Sus scrofa* diet and factors affecting food selection in native and introduced ranges**

Sebastián A. BALLARI\* *Departamento de Diversidad Biológica y Ecología, Universidad Nacional de Córdoba-CONICET, Avenida Vélez Sársfield 299, 3er. Piso, Córdoba 5000, Argentina.*

The wild boar *Sus scrofa* is an omnivore



# Don't believe names, think for yourself

What is an 'omnivore'?

## Mammal Review



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REVIEW



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The wild boar *Sus scrofa* is an omnivore

Wild boar diet is dominated by plant material (~90%)





# Don't believe names, think for yourself

Sometimes we need generalisations



# Don't believe names, think for yourself

Sometimes we need generalisations  
- for large-scale comparative studies

**PROCEEDINGS B**  
royalsocietypublishing.org/journal/rspb

**Research**

**Mammalian intestinal allometry, phylogeny, trophic level and climate**

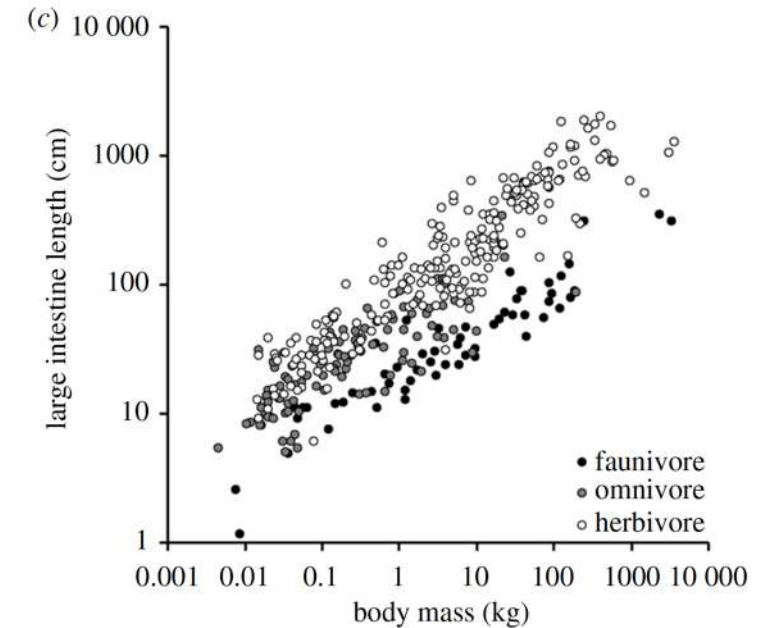
Maria J. Duque-Correa<sup>1</sup>, Daryl Codron<sup>2</sup>, Carlo Meloro<sup>3</sup>, Amanda McGrosky<sup>4</sup>, Christian Schiffmann<sup>1</sup>, Mark S. Edwards<sup>5</sup> and Marcus Clauss<sup>1</sup>

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<sup>2</sup>Department of Zoology and Entomology, University of the Free State, PO Box 339, 9300 Bloemfontein, South Africa  
<sup>3</sup>Research Centre in Evolutionary Anthropology and Palaeoecology, Liverpool John Moores University, Liverpool, UK  
<sup>4</sup>School of Human Evolution and Social Change, Arizona State University, Tempe, AZ, USA  
<sup>5</sup>California Polytechnic State University, San Luis Obispo, CA, USA

**Cite this article:** Duque-Correa MJ, Codron D, Meloro C, McGrosky A, Schiffmann C, Edwards MS, Clauss M. 2021 Mammalian intestinal allometry, phylogeny, trophic level and climate. *Proc. R. Soc. B* **288**: 20202888. <https://doi.org/10.1098/rspb.2020.2888>

Check for updates

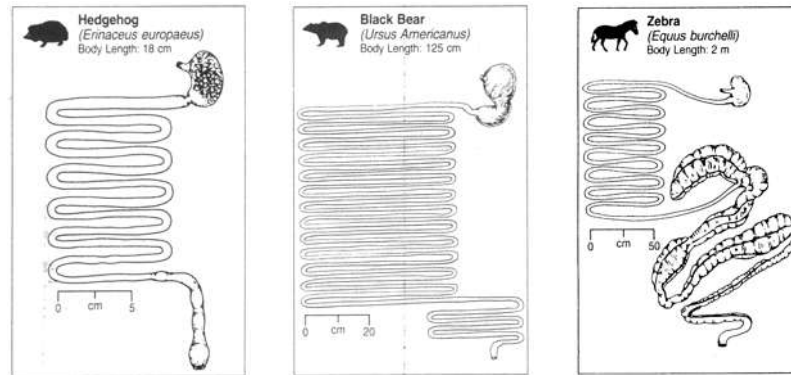
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# Don't believe names, think for yourself

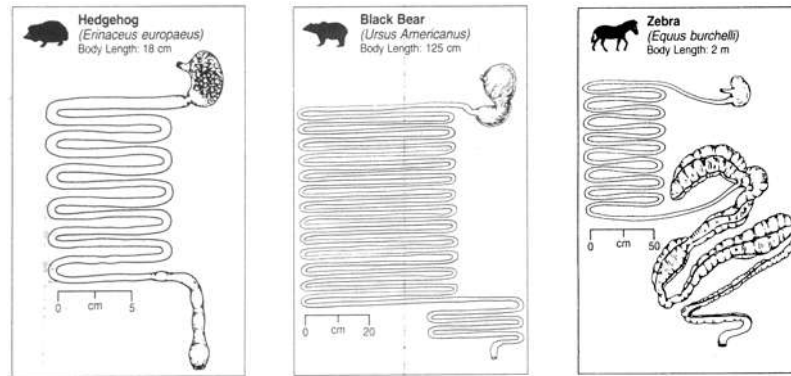
Sometimes we need generalisations  
- for large-scale comparative studies





# Don't believe names, think for yourself

Sometimes we need generalisations  
- for large-scale comparative studies

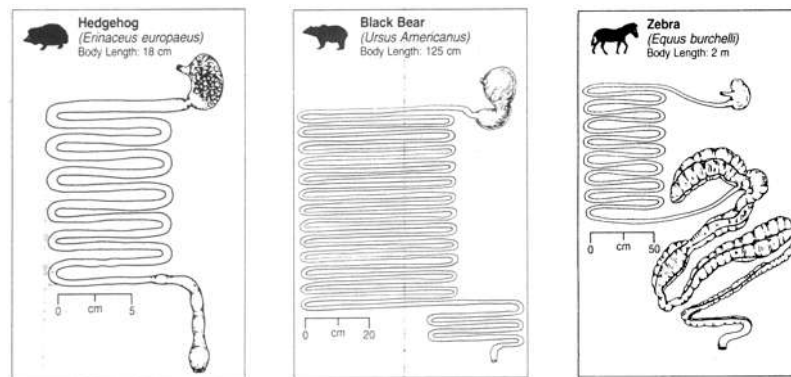


- but not for keeping a species over many years



# Don't believe names, think for yourself

Sometimes we need generalisations  
- for large-scale comparative studies



- but not for keeping a species over many years



*if you dedicate yourself to  
the husbandry of a species,  
you **MUST** be ready to read  
up on its specialities*





*Feeding has implications:*  
*why do we feed ...*  
*... and what happens when we feed*



# We feed zoo animals and we ...

meet energy requirements



# We feed zoo animals and we ...

meet energy requirements



(**any food** that is eaten)  
(enough)



# We feed zoo animals and we ...

meet energy requirements



(**any food** that is eaten)  
(enough)



imminent survival



# We feed zoo animals and we ...

meet energy requirements



(**any food** that is eaten)  
(enough)



imminent survival

meet nutrient requirements





# We feed zoo animals and we ...

meet energy requirements



(**any food** that is eaten)  
(enough)



imminent survival

meet nutrient requirements



(**any food** that is eaten)  
(**properly supplemented**)  
(enough)



# We feed zoo animals and we ...

meet energy requirements



(**any food** that is eaten)  
(enough)



imminent survival

meet nutrient requirements /  
avoid toxicity



(**any food** that is eaten)  
(**properly supplemented**)  
(enough)



# We feed zoo animals and we ...

meet energy requirements



(**any food** that is eaten)  
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imminent survival

meet nutrient requirements /  
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(**any food** that is eaten)  
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imminent health



# We feed zoo animals and we ...

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meet nutrient requirements /  
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imminent survival

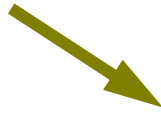


imminent health



# We feed zoo animals and we ...

meet energy requirements



meet nutrient requirements /  
avoid toxicity



meet physiological  
requirements

(**any food** that is eaten)  
(**properly supplemented**)  
(enough)



imminent survival



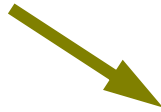
imminent health





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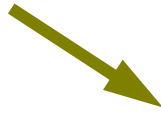
imminent survival

imminent health



# We feed zoo animals and we ...

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meet nutrient requirements /  
avoid toxicity



meet physiological  
requirements



(**any food** that is eaten)  
(**properly supplemented**)  
(enough)

(**species-appropriate food**)  
(**appropriate amount**)  
(**properly supplemented**)



imminent survival



imminent health



# We feed zoo animals and we ...

meet energy requirements



meet nutrient requirements /  
avoid toxicity



meet physiological  
requirements



(**any food** that is eaten)  
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imminent survival

imminent health

long-term  
physical health

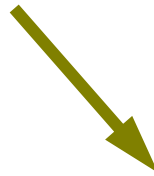


# We feed zoo animals and we ...

meet energy requirements

meet nutrient requirements /  
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**(species-appropriate food)**  
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imminent survival

imminent health

long-term  
physical health



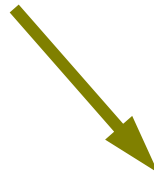
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meet physiological  
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influence behaviour /  
meet psychological  
requirements



**(species-appropriate food)**  
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imminent survival

imminent health

long-term  
physical health



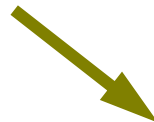
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imminent survival

imminent health

long-term  
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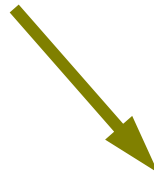
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**(species-appropriate food)**  
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**(properly supplemented)**  
**(properly presented)**



imminent survival

imminent health

long-term  
physical health



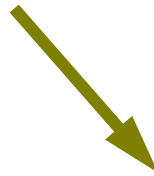
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**(properly presented)**



imminent survival

imminent health

long-term  
physical health

long-term  
psychological  
health





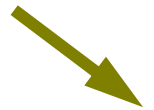
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imminent survival

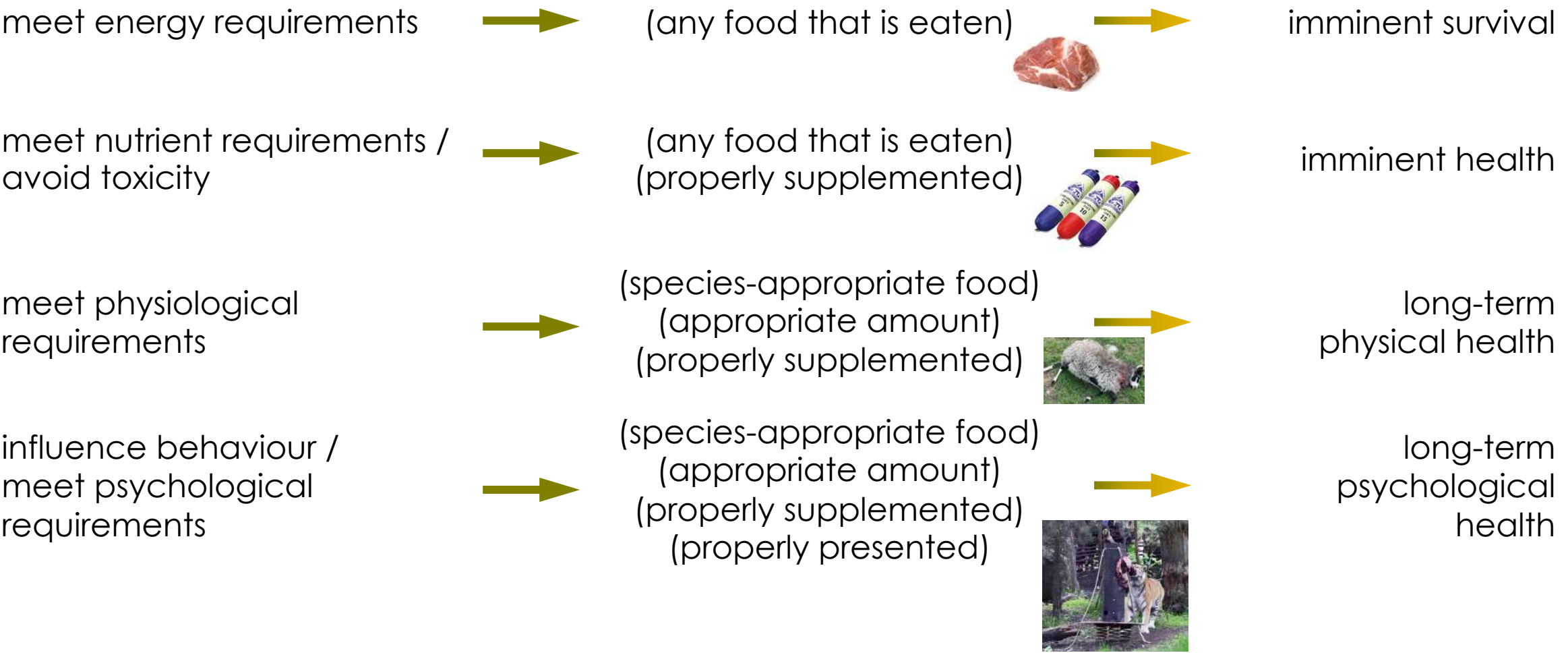
imminent health

long-term  
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long-term  
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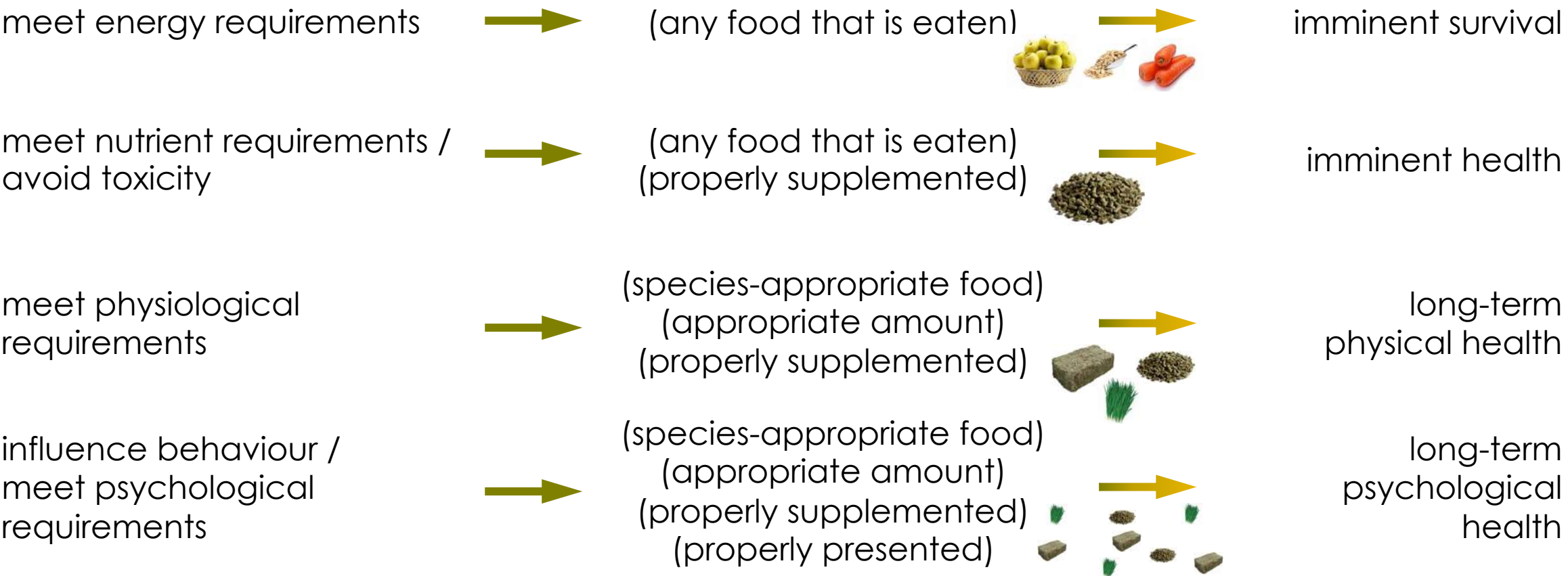


# We feed zoo animals and we ...





# We feed zoo animals and we ...





# *Superfast zoo animal nutrition history*



# The classic problem repertoire

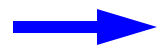
Carnivore





# The classic problem repertoire

Carnivore



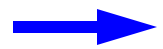
Red meat





# The classic problem repertoire

Carnivore



Red meat

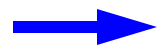


Calcium deficiency



# The classic problem repertoire

Carnivore



Red meat



+



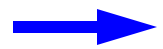
~~Calcium deficiency~~





# The classic problem repertoire

Carnivore



Red meat



+



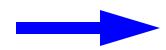
~~Calcium deficiency~~





# The classic problem repertoire

Carnivore



Red meat



+



~~Calcium deficiency~~



+



Dental calculus,  
obesity,  
behavioural  
deficiencies

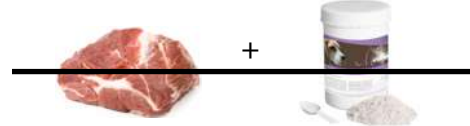


# The classic problem repertoire

Carnivore



→ Red meat



→ ~~Calcium deficiency~~



→ ~~Dental calculus,  
obesity,  
behavioural  
deficiencies~~



# The classic problem repertoire

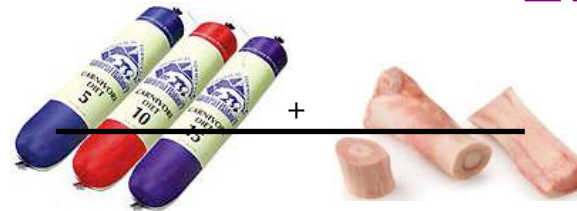
Carnivore



→ Red meat



→ ~~Calcium deficiency~~



→ ~~Dental calculus,  
obesity,  
behavioural  
deficiencies~~





# The classic problem repertoire

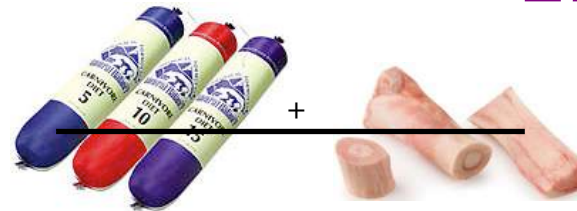
Carnivore



→ Red meat



→ ~~Calcium deficiency~~



→ ~~Dental calculus,~~  
~~obesity,~~  
~~behavioural~~  
~~deficiencies~~



+

adequate  
presentation



# The classic problem repertoire

Carnivore



→ Red meat



→ ~~Calcium deficiency~~



→ ~~Dental calculus,  
obesity,  
behavioural  
deficiencies~~



+

adequate  
presentation =  
**enrichment !!**



# The classic problem repertoire

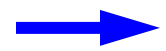
Primate





# The classic problem repertoire

Primate



Fruits & vegetables

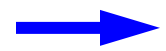






# The classic problem repertoire

Primate



Fruits & vegetables



Calcium deficiency





# The classic problem repertoire

Primate



Fruits & vegetables



~~Calcium deficiency~~



+





# The classic problem repertoire

Primate



→ Fruits & vegetables → ~~Calcium deficiency~~



Obesity, caries,  
aggression,  
abnormal  
behaviour

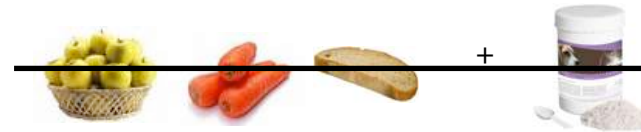


# The classic problem repertoire

Primate



→ Fruits & vegetables → ~~Calcium deficiency~~



~~Obesity, caries,  
aggression,  
abnormal  
behaviour~~



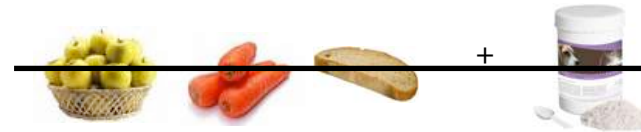


# The classic problem repertoire

Primate



→ Fruits & vegetables → ~~Calcium deficiency~~



~~Obesity, caries,  
aggression,  
abnormal  
behaviour~~



+

adequate  
presentation

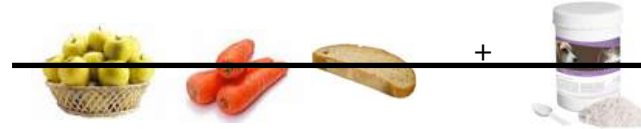


# The classic problem repertoire

Primate



→ Fruits & vegetables → ~~Calcium deficiency~~



~~Obesity, caries,  
aggression,  
abnormal  
behaviour~~



+

adequate  
presentation =  
**enrichment !!**



# The classic problem repertoire

Insectivore





# The classic problem repertoire

Insectivore



Meat, fruit, insects

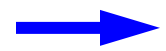






# The classic problem repertoire

Insectivore



Meat, fruit, insects



Calcium and  
Vitamin A deficiency



# The classic problem repertoire

Insectivore



Meat, fruit, insects



+



~~Calcium and  
Vitamin A deficiency~~



# The classic problem repertoire

Insectivore



Meat, fruit, insects



+



~~Calcium and  
Vitamin A deficiency~~



Obesity,  
aggression,  
abnormal behavior



# The classic problem repertoire

Insectivore



→ Meat, fruit, insects →



~~Calcium and  
Vitamin A deficiency~~



Obesity, dental calculus,  
aggression,  
abnormal behavior





# The classic problem repertoire

Insectivore



→ Meat, fruit, insects →



~~Calcium and  
Vitamin A deficiency~~



Obesity, ~~dental calculus~~,  
aggression,  
abnormal behavior





# The classic problem repertoire

Insectivore



→ Meat, fruit, insects →



~~Calcium and  
Vitamin A deficiency~~

→

~~Obesity, dental calculus,  
aggression,  
abnormal behavior~~



+

adequate  
presentation



# The classic problem repertoire

Insectivore



→ Meat, fruit, insects →



~~Calcium and  
Vitamin A deficiency~~



~~Obesity, dental calculus,  
aggression,  
abnormal behavior~~



+

adequate  
presentation =  
**enrichment !!**



# The classic problem repertoire

Fish-Eater







# The classic problem repertoire

Fish-Eater



Thawed fish





# The classic problem repertoire

Fish-Eater



Thawed fish



Sodium- and vitamin B  
deficiency



# The classic problem repertoire

Fish-Eater



Thawed fish



+



+

adequate thawing  
regime



~~Sodium and vitamin B  
deficiency~~



# The classic problem repertoire

Fish-Eater



Thawed fish



+



+

adequate thawing  
regime



~~Sodium and vitamin B  
deficiency~~



abnormal behavior,  
skin/eye problems



# The classic problem repertoire

Fish-Eater



Thawed fish



+



+

adequate thawing  
regime



~~Sodium and vitamin B  
deficiency~~



~~abnormal behavior,  
skin/eye problems~~

+

adequate  
presentation



# The classic problem repertoire

Fish-Eater



Thawed fish



+



+

adequate thawing  
regime



~~Sodium and vitamin B  
deficiency~~



~~abnormal behavior,  
skin/eye problems~~

+

adequate  
presentation =  
**enrichment !!**



# The classic problem repertoire

Fish-Eater



Thawed fish



+



+

adequate thawing  
regime



~~Sodium and vitamin B  
deficiency~~



~~abnormal behavior,  
skin/eye problems~~

+

adequate  
presentation =  
**enrichment !!**

+

salt water bath  
(e.g. 1x/week)



# The classic problem repertoire

Herbivore







# The classic problem repertoire

Herbivore



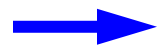
Hay, fruits & grains





# The classic problem repertoire

Herbivore



Hay, fruits & grains



Vitamin E- and calcium  
deficiency



# The classic problem repertoire

Herbivore



Hay, fruits & grains



~~Vitamin E and calcium  
deficiency~~



# The classic problem repertoire

Herbivore



Hay, fruits & grains



+



~~Vitamin E and calcium  
deficiency~~



Obesity,  
malfermentation  
(acidosis),  
abnormal  
behaviour

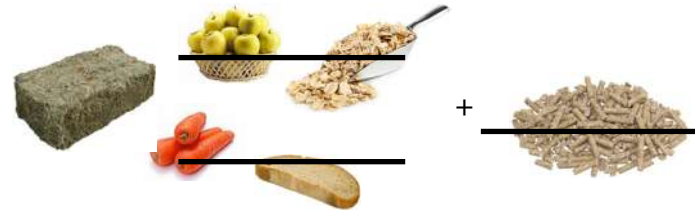


# The classic problem repertoire

Herbivore



Hay, fruits & grains



~~Vitamin E and calcium deficiency~~



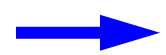
~~Obesity,  
malfermentation  
(acidosis),  
abnormal  
behaviour~~



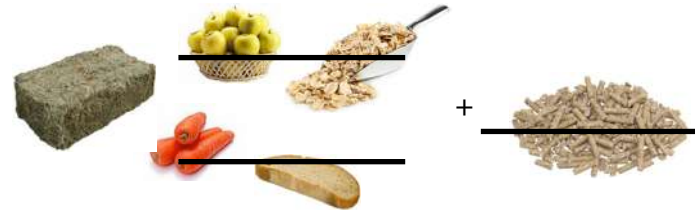


# The classic problem repertoire

Herbivore



Hay, fruits & grains



~~Vitamin E and calcium deficiency~~



~~Obesity,  
malfermentation  
(acidosis),  
abnormal  
behaviour~~



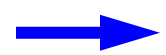
+

adequate  
presentation

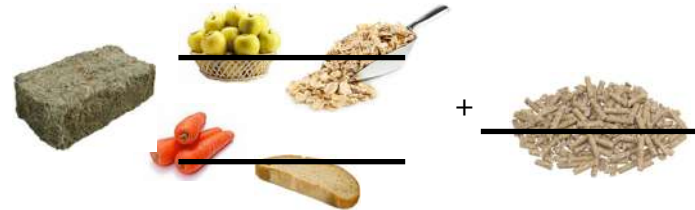


# The classic problem repertoire

Herbivore



Hay, fruits & grains



+



~~Vitamin E and calcium deficiency~~



~~Obesity,  
malfermentation  
(acidosis),  
abnormal  
behaviour~~



+

adequate  
presentation =  
**enrichment !!**



# The basic feeding approach

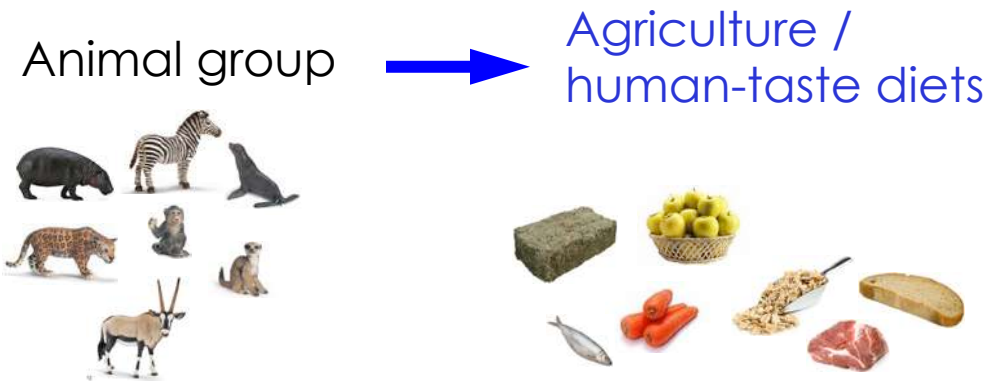
Animal group







# The basic feeding approach





# The basic feeding approach





# The basic feeding approach



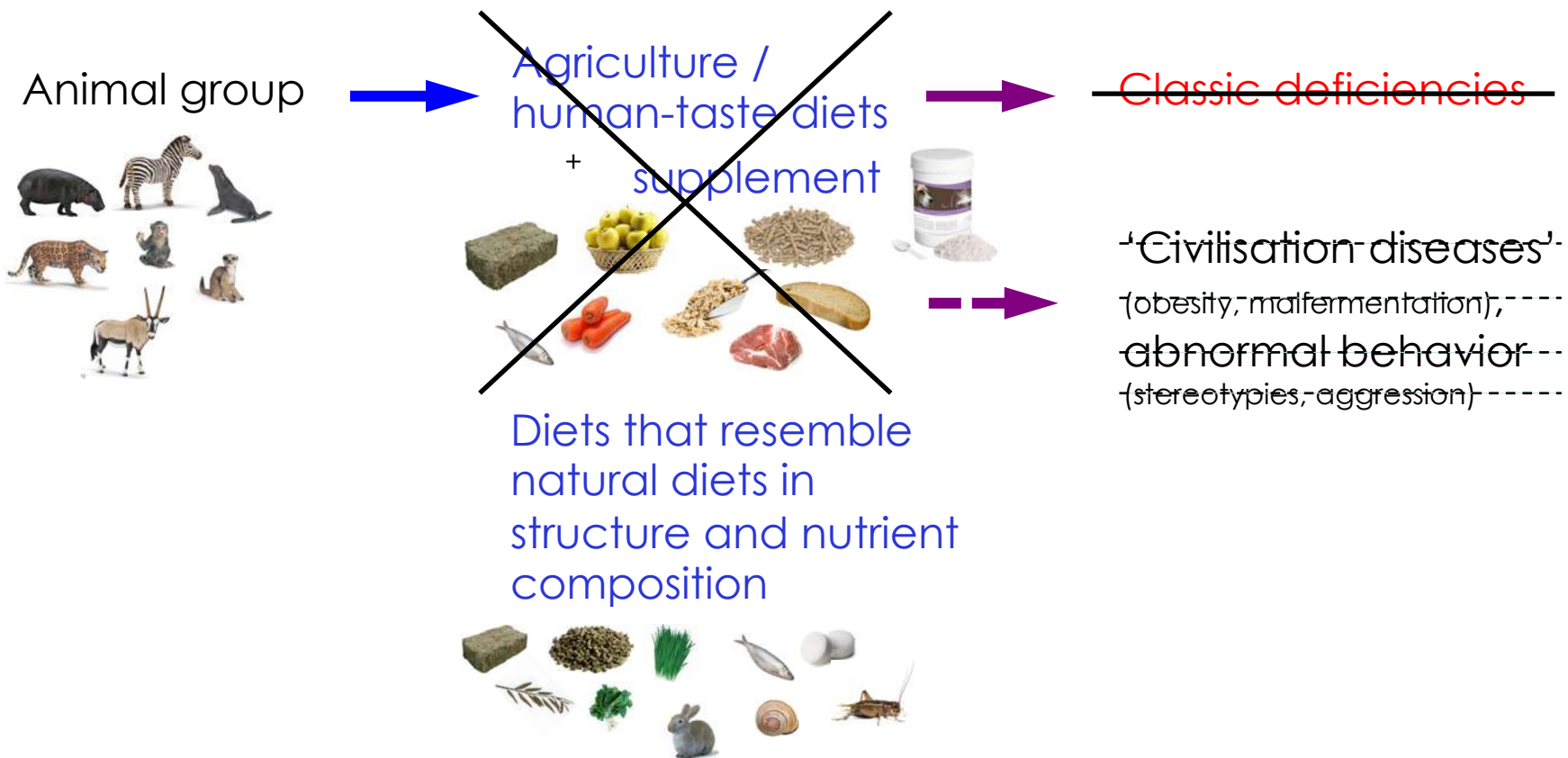


# The basic feeding approach



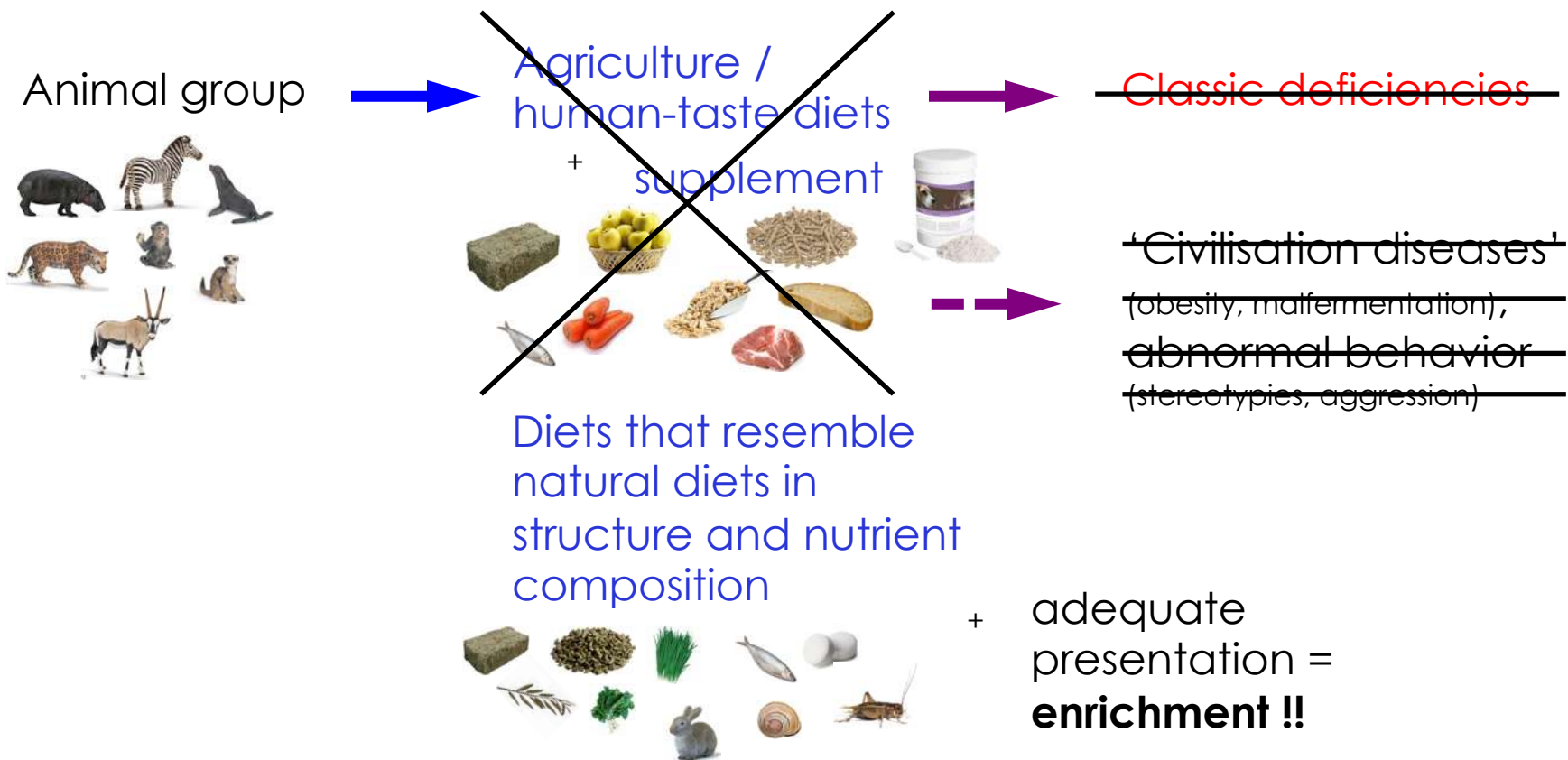


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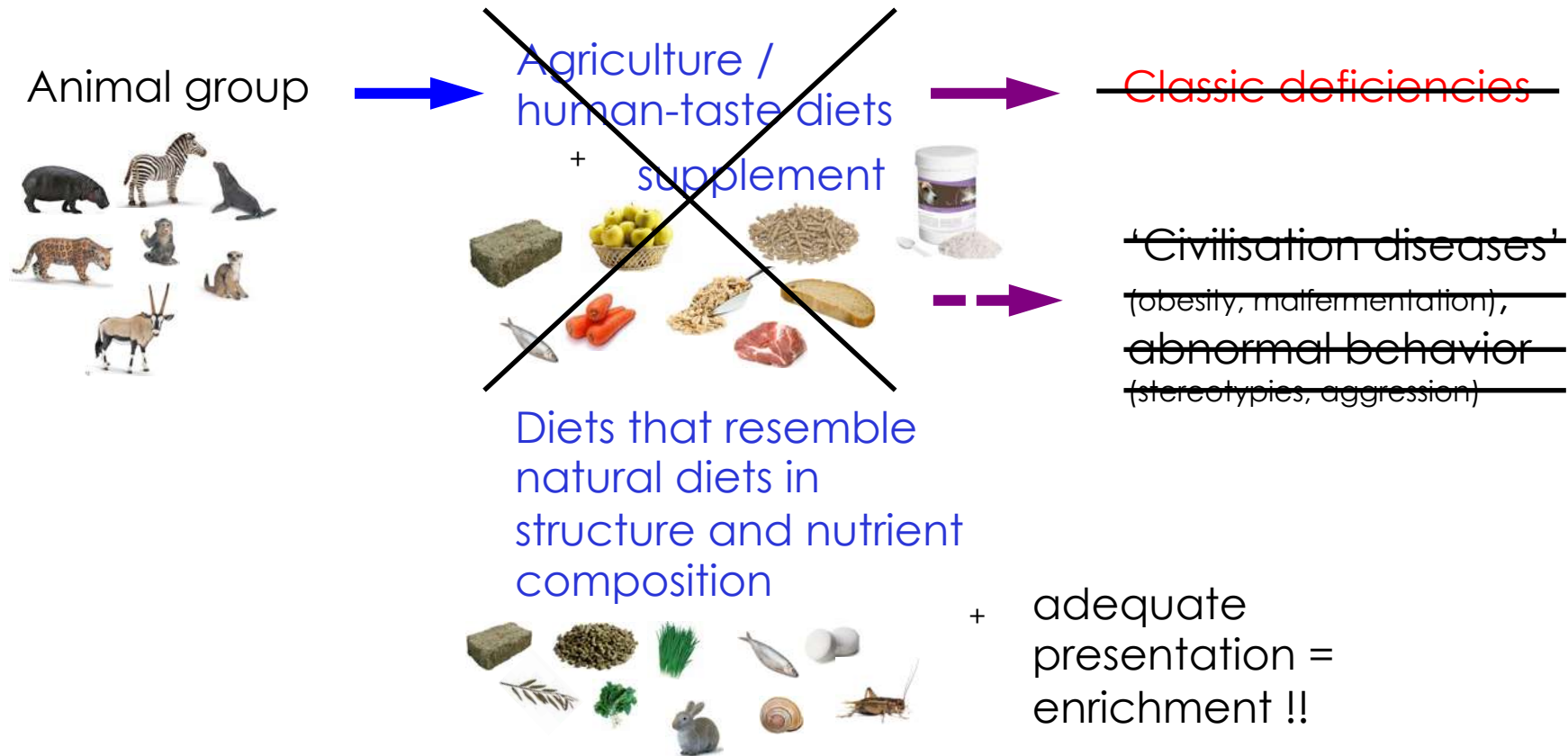


# The basic feeding approach





# The basic feeding approach



Enrichment should **not** be the **addition** of something (like human-taste items) but **the presentation of the diet in a challenging and meaningful way !**



# *Feeding and behaviour*





# Rabbit feeding



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# Rabbit feeding



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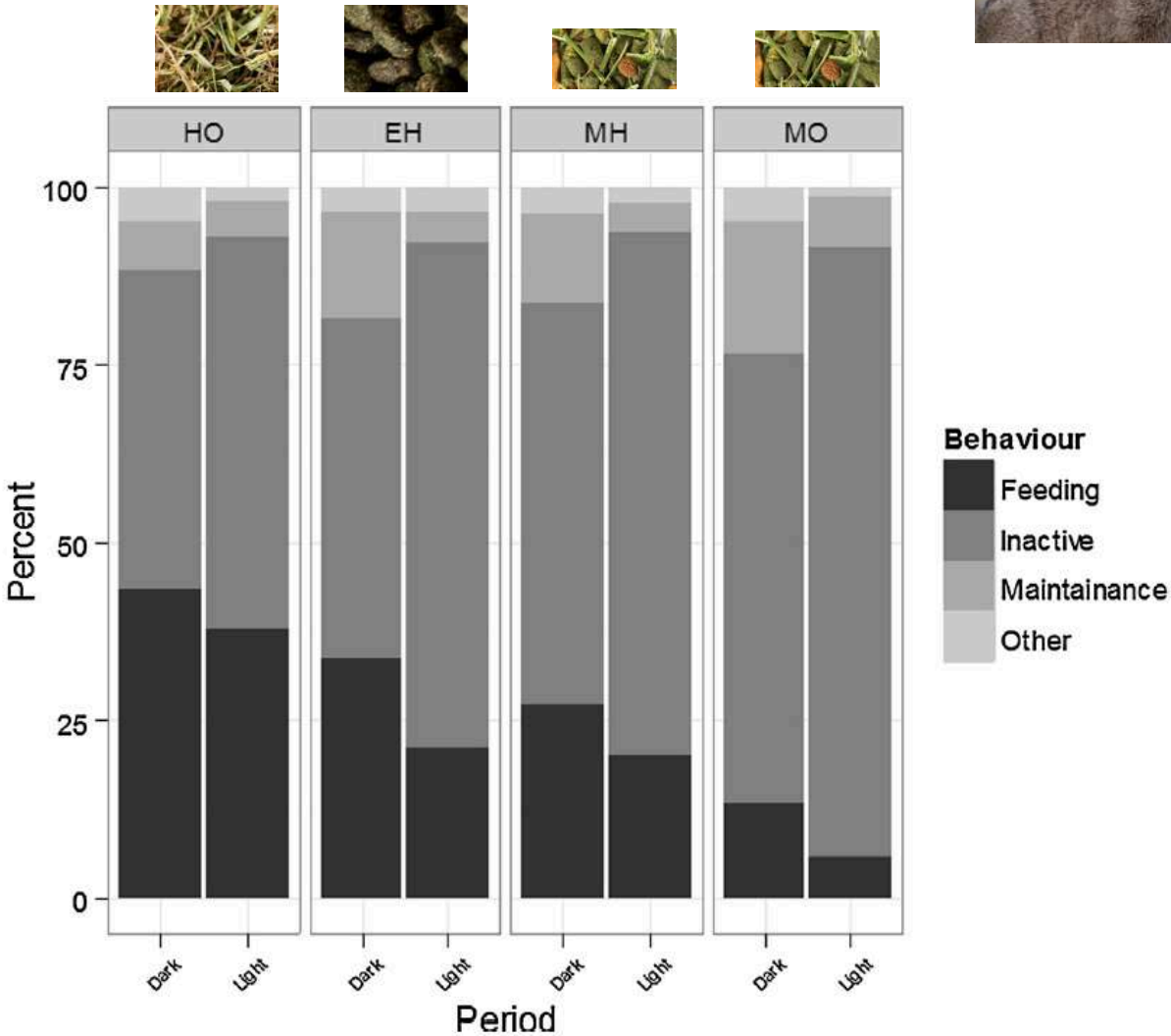
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# Rabbit feeding



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8-10 h eating  
10 h 'inactive'



2 h eating  
15-18 h 'inactive'

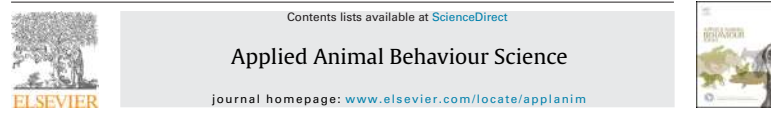
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### 1. Introduction

As herbivores, wild rabbits consume relatively large amounts of a high fibre diet of low nutritional quality (Williams and Wells, 1974). This requires them to apportion a large amount of their time budget to grazing. Rabbits spend 30–70% of time outside the burrow grazing, pausing occasionally to groom (Mykytowycz, 1958; Myers and Poole, 1961; Myers and Mykytowycz, 1958; Lockley, 1961). Time spent eating varies with age, sex and social status within the group and has also been shown to increase when food availability falls during drought (Myers and Mykytowycz, 1958; Mykytowycz, 1958). Grazing occurs mainly during late afternoon and throughout the night and daylight hours are spent underground in warrens (Myers and Mykytowycz, 1958; Mykytowycz, 1958; Lockley, 1961, 1962). Caecotrophy is performed while underground (Southern, 1942). Domestic rabbits kept in free range conditions exhibit a similar feeding pattern to their wild counterparts (Vastrade, 1987; Lehmann, 1991). In contrast, many pet rabbits are housed in small hutches with limited exercise opportunities

(Mullan and Main, 2006; PDSA, 2011) and a diet consisting largely of concentrates (mono-component nugget or muesli mixes) (PDSA, 2011) which can be consumed rapidly (Lidfors, 1997), with limited or no access to hay or grass (Mullan and Main, 2006; PDSA, 2011).

Stereotypic behaviours are described as behaviours that are relatively invariant, regularly repeated and without an obvious function (Mason, 1991). Stereotypic behaviours reported to occur in laboratory rabbits include excessive grooming, sham chewing (chewing with nothing in mouth), bar biting, licking parts of cage, digging against cage, biting water nipple, sliding nose against bars, head pressing and running repeatedly in a defined pattern (Gunn and Morton, 1995; Lidfors, 1997). An apathetic state of inactivity and boredom has also been reported by Gunn and Morton (1995). Stereotypic behaviours occur most frequently during the night (Gunn and Morton, 1995) when rabbits are naturally at their most active (Mykytowycz, 1958).

Whilst not studied in pet rabbits, the beneficial impact of providing hay to laboratory rabbits has been demonstrated (Lidfors, 1997; Berthelsen and Hansen, 1999). The provision of hay to individually housed laboratory rabbits has proved effective at reducing the expression of abnormal behaviours (Lidfors, 1997; Berthelsen and Hansen, 1999).

Rabbits can consume pelleted feeds rapidly (Lidfors, 1997) and, whilst they may provide adequate nutrition for the maintenance of the rabbit, foraging behaviour is limited. If fed in limited amounts the rapid consumption of the daily ration may leave the rabbit in a state of hunger for a considerable portion of the day (Lidfors, 1997). It has been suggested that stereotypes in pigs and broiler

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8-10 h eating  
10 h 'inactive'



as described for  
wild rabbits



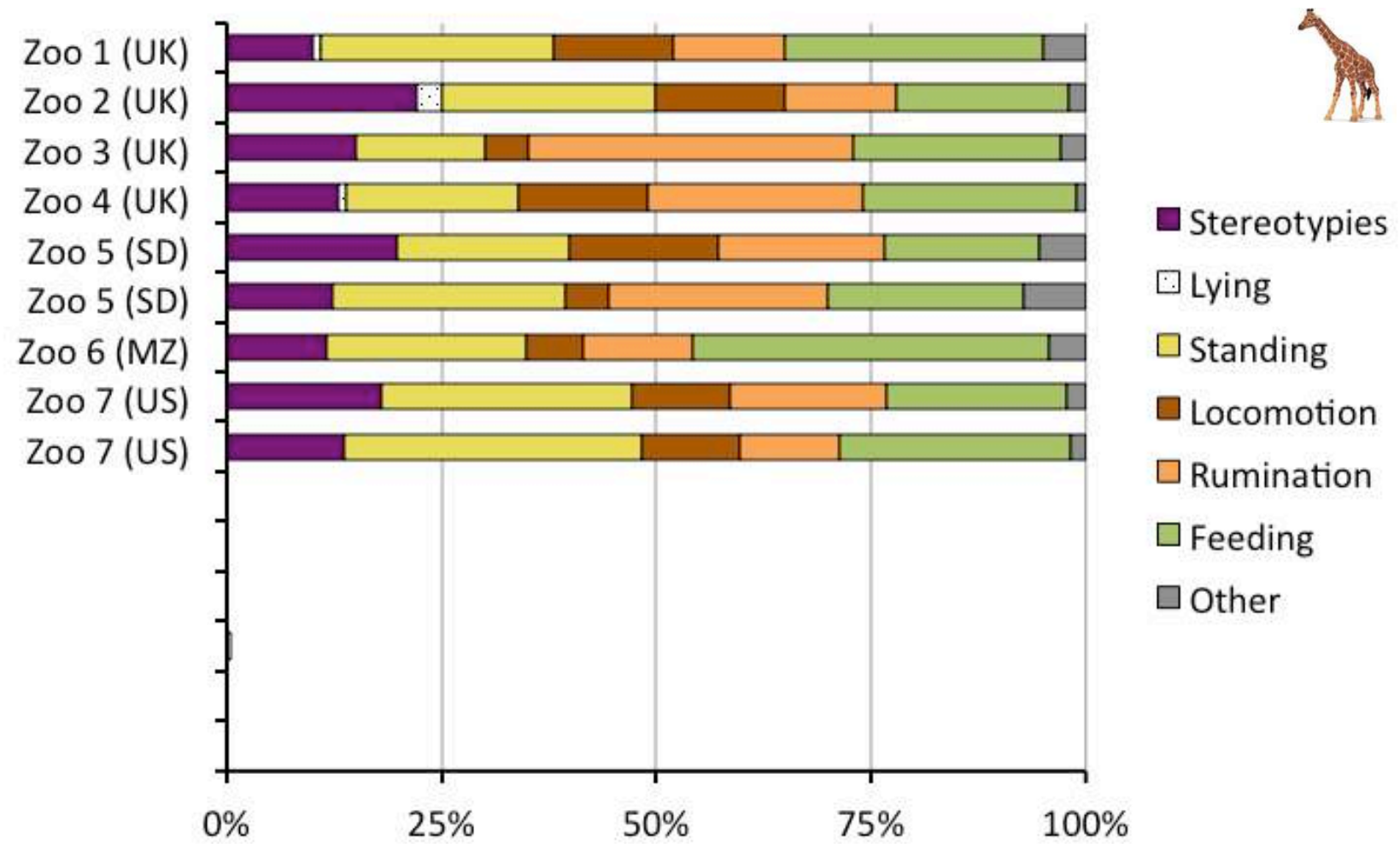
2 h eating  
15-18 h 'inactive'



as described for  
lab rabbits



# Giraffe activity budgets

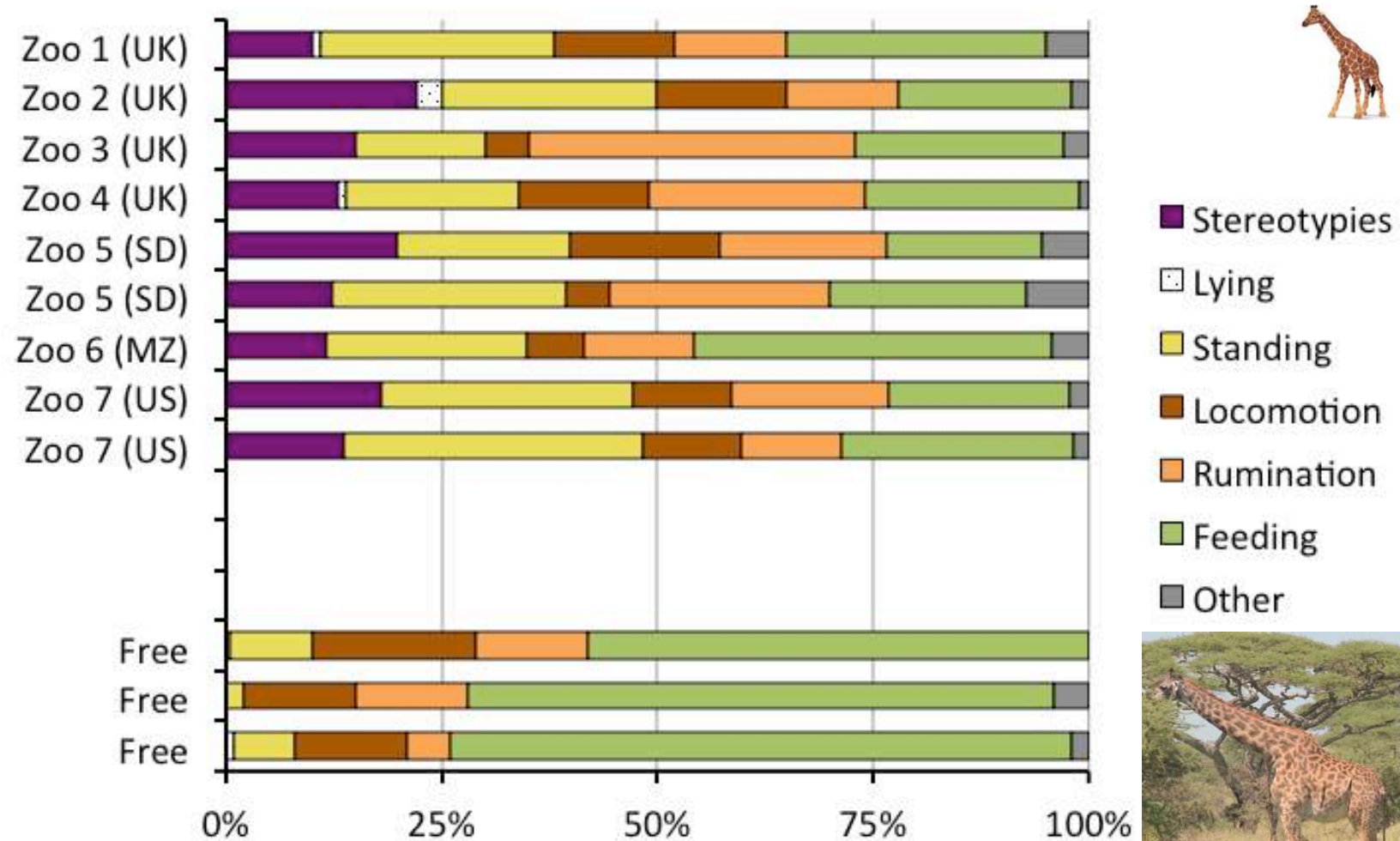


Veasey et al. (1996), del Castillo et al. (2005), Bashaw (2011), Orban et al. (2016)





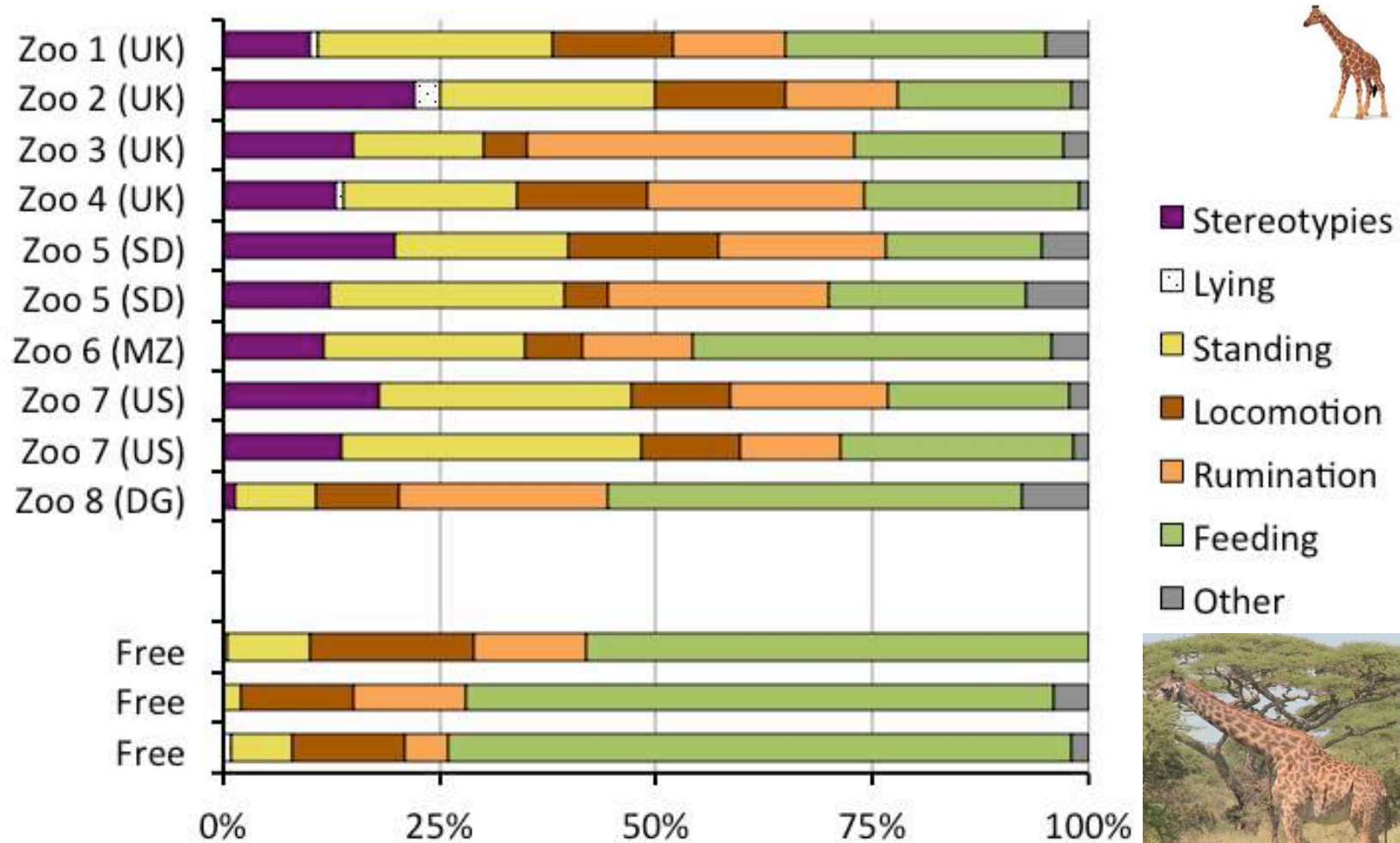
# Giraffe activity budgets



Veasey et al. (1996), del Castillo et al. (2005), Bashaw (2011), Orban et al. (2016); du Toit & Yetman (2005), Pellew (1984)



# Giraffe activity budgets



Veasey et al. (1996), del Castillo et al. (2005), Bashaw (2011), Orban et al. (2016); du Toit & Yetman (2005), Pellew (1984), Schüssler et al. (2015)





*What do we need to achieve our  
aims ?*



# We feed zoo animals and we need ...

to meet energy requirements



# We feed zoo animals and we need ...

to meet energy requirements → info on what others did



# We feed zoo animals and we need ...

to meet energy requirements



info on what others did



old school



# We feed zoo animals and we need ...

to meet energy requirements → info on what others did → old school

to meet nutrient requirements /  
avoid toxicity



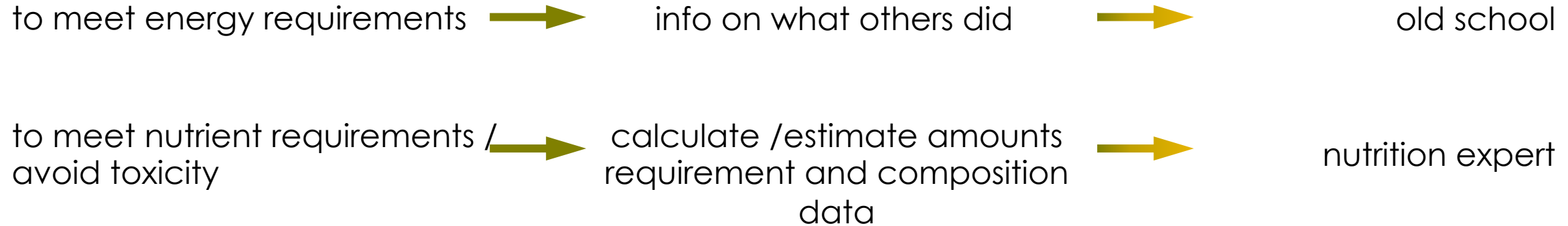
# We feed zoo animals and we need ...

to meet energy requirements → info on what others did → old school

to meet nutrient requirements /  
avoid toxicity → calculate /estimate amounts  
requirement and composition  
data



# We feed zoo animals and we need ...



Nutrient	Quality Prime <sup>a</sup> Alfalfa	Quality 1 <sup>a</sup> Alfalfa	Quality 3-4 <sup>ab</sup> Grass	Low Fiber Herbivore Pellet
Moisture, %	9.0-10.7	8.2-9.6	7.4-10.0	10.6
Crude protein, %	18.0-21.8	15.9-17.0	9.8-11.2	17.4
Neutral detergent fiber, %	29.1-36.5	37.2-42.8	51.0-67.4	29.3
Acid detergent fiber, %	24.6-27.3	25.3-33.5	31.2-36.3	17.3
Vitamin A, IU/g <sup>c</sup>	*	*	*	5
Vitamin D, IU/g <sup>c</sup>	*	*	*	1.2
Vitamin E, IU/kg <sup>c</sup>	*	*	*	400
Calcium, %	1.13-1.33	1.2-1.5	0.41-0.67	0.88
Phosphorus, %	0.26-0.27	0.26-0.27	0.19-0.38	0.64
Sodium, %	0.057-0.53	0.014-0.08	0.003-0.03	0.4
Magnesium, %	0.27-0.28	0.24-0.31	0.15-0.21	0.29
Potassium, %	2.1-2.2	1.4-1.7	1.9-2.4	1.5
Copper, mg/kg	7-12	5-9	5-11	23
Iron, mg/kg	166-240	106-138	69-85	394
Manganese, mg/kg	28-38	25-33	25-36	120
Zinc, mg/kg	25-29	17-20	15-31	136

<sup>a</sup> These are classifications of the Hay Market Task Force of the American Forage and Grassland Council (see NAG Fact Sheet 001).

<sup>b</sup> Grasses include timothy, coastal bermudagrass, and sudan.

<sup>c</sup> The vitamin levels in hays are variable; values in pellets were specified concentrations.

\* Value not determined.

Body Size	Concentrate Selectors	Medium Large Browsers	Medium Intermediate Browsers	Medium Intermediate Grassers	Medium Large Grassers
Ruminant/Nonruminant	Ruminant	Ruminant	Nonruminant	Ruminant	Ruminant
Species	Bongo, Kipspringer	Giraffe, Kudu, Sitatunga, Grevy's, Reindeer, Okapi	Lepus, Bb. Rhino, Pigmy Hippo	Goats, Ibex, Eland, Springbok, Dama Gazelle	Sheep, Addax, Pere David's Deer
	Waterbuck, Topi, Llama, Camel, Cape Buffalo, Haring	Zebra, White Rhino	Nile Hippo		
Suggested Diet, % <sup>a</sup>	50-75P 25-50AHP	30-40P 60-70AHP	30P 40-50AHPQ1 20-30GH	30-40P 60-70AHPQ1 30GH	30-40P 60-70GH
Intake as %DMI	3-4%	2%	1.5%	2-3.5%	2-3.5%
	1.5-2.9%	1.5-2.9%	1.5-3.0%	1.5%	
Nutrient	Protein, %	15-18	15-19	15-18	14-17
	NDF, %	23-33	25-34	31-37	25-36
	Vitamin A, IU/g	2.5-3.8	1.5-2.2	1.5	1.5-2.0
	Vitamin D, IU/g	0.6-0.9	0.4-0.5	0.4	0.4-0.5
	Vitamin E, IU/kg	200-300	120-178	120	120-160
	Thiamin, mg/kg	-	-	2.4	-
	Riboflavin, mg/kg	-	-	2.7	-
	Calcium, %	0.65-0.87	0.70-0.97	0.80-0.90	0.90-1.10
	Phosphorus, %	0.44-0.54	0.36-0.40	0.35-0.40	0.35-0.40
	Magnesium, %	0.18-0.22	0.18-0.24	0.20-0.22	0.21-0.22
	Potassium, %	1.3-1.5	1.6-1.8	1.5-1.7	1.2-1.8
	Sodium, %	0.16-0.39	0.10-0.44	0.09-0.36	0.10-0.44
	Iron, mg/kg	107-125	126-139	82-126	98-139
	Zinc, mg/kg	77-106	54-68	52-58	51-67
	Copper, mg/kg	13-16	10-12	10-12	11-13
	Manganese, mg/kg	57-75	54-57	45-51	44-57
	Selenium, mg/kg	0.20-0.30	0.12-0.18	0.12	0.12-0.16
	Iodine, mg/kg	0.5-0.8	0.3-0.4	0.3	0.3-0.4

<sup>a</sup> P = Low Fiber Pellets; AHP = alfalfa hay quality prime; AHPQ1 = alfalfa hay quality grade 1; GH = grass hay.



*Marcus:*  
*rough Intro to calculation*





*Anja Tschudin:  
how to do a calculation*



*Anouk Fens:  
how to do a calculation*