Introduction to comparative digestive physiology

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Wildlife Digestive Physiology Course Vienna 2013

University of Zurich[UZH]

Clinic of Zoo Animals, Exotic Pets and Wildlife

Digestive Physiology

- Food
- How animals get the food
- How animals digest the food
- How the animals metabolism deals with properties of the food

Digestive Physiology

- **Food**
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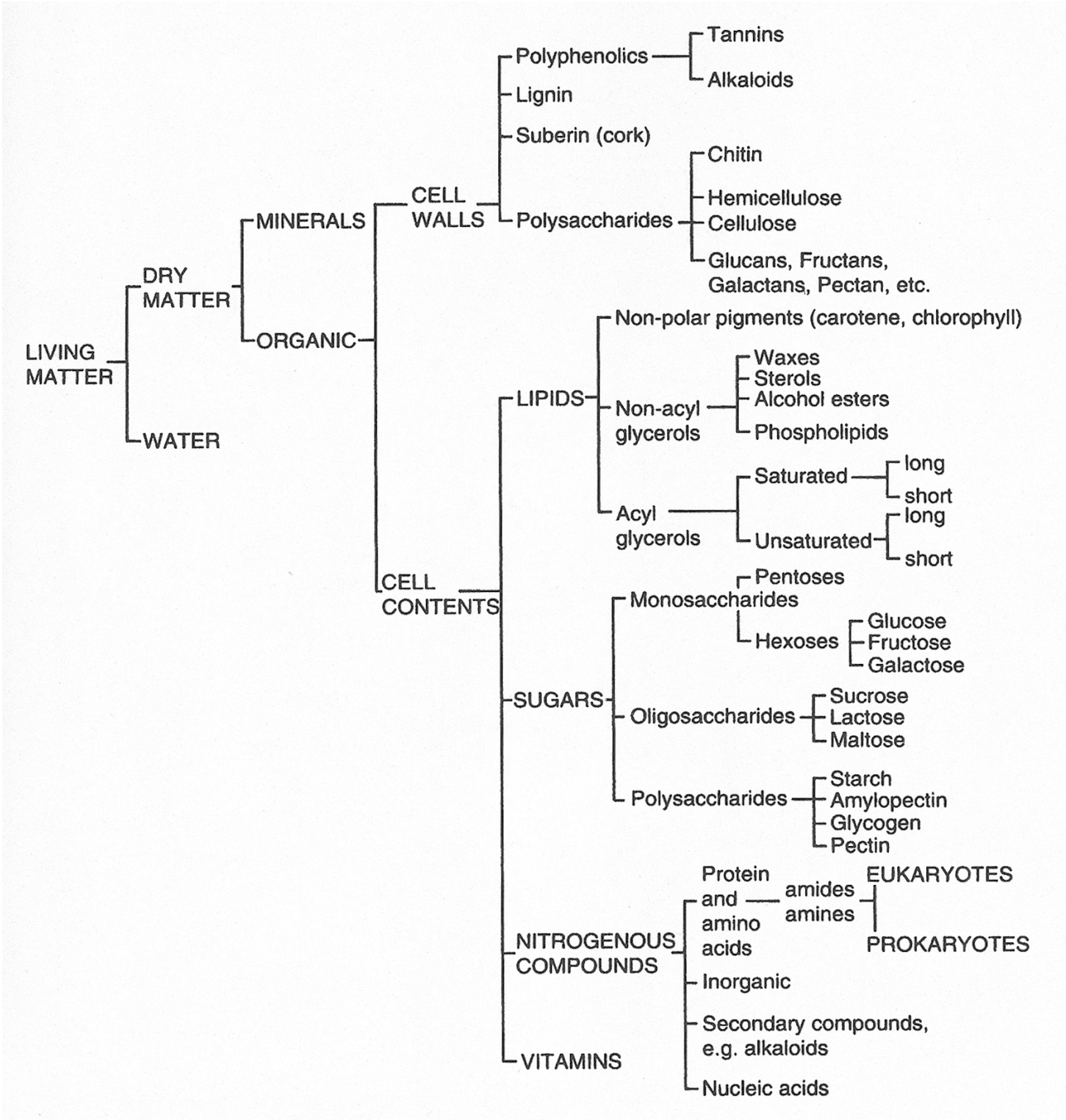
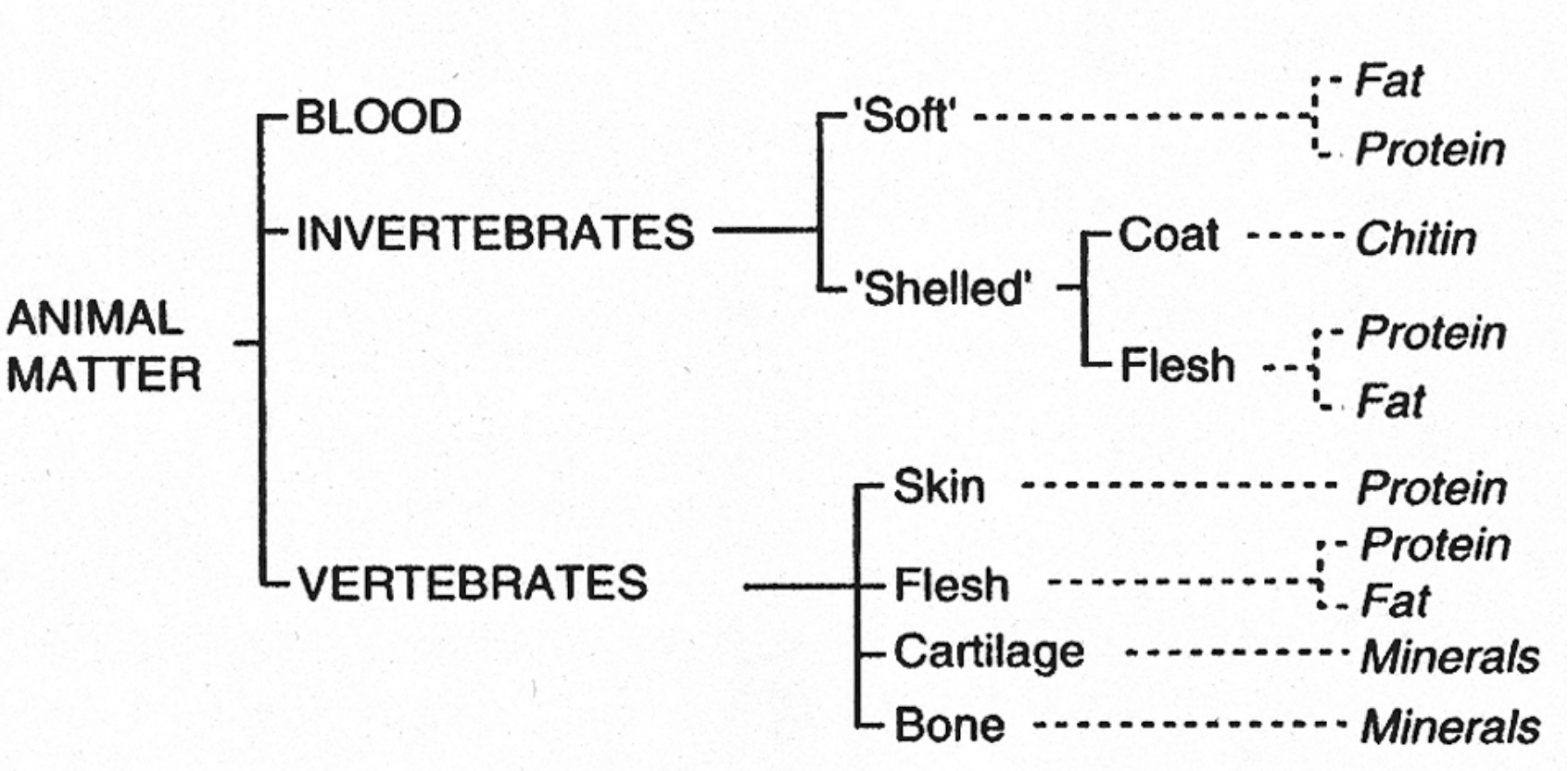
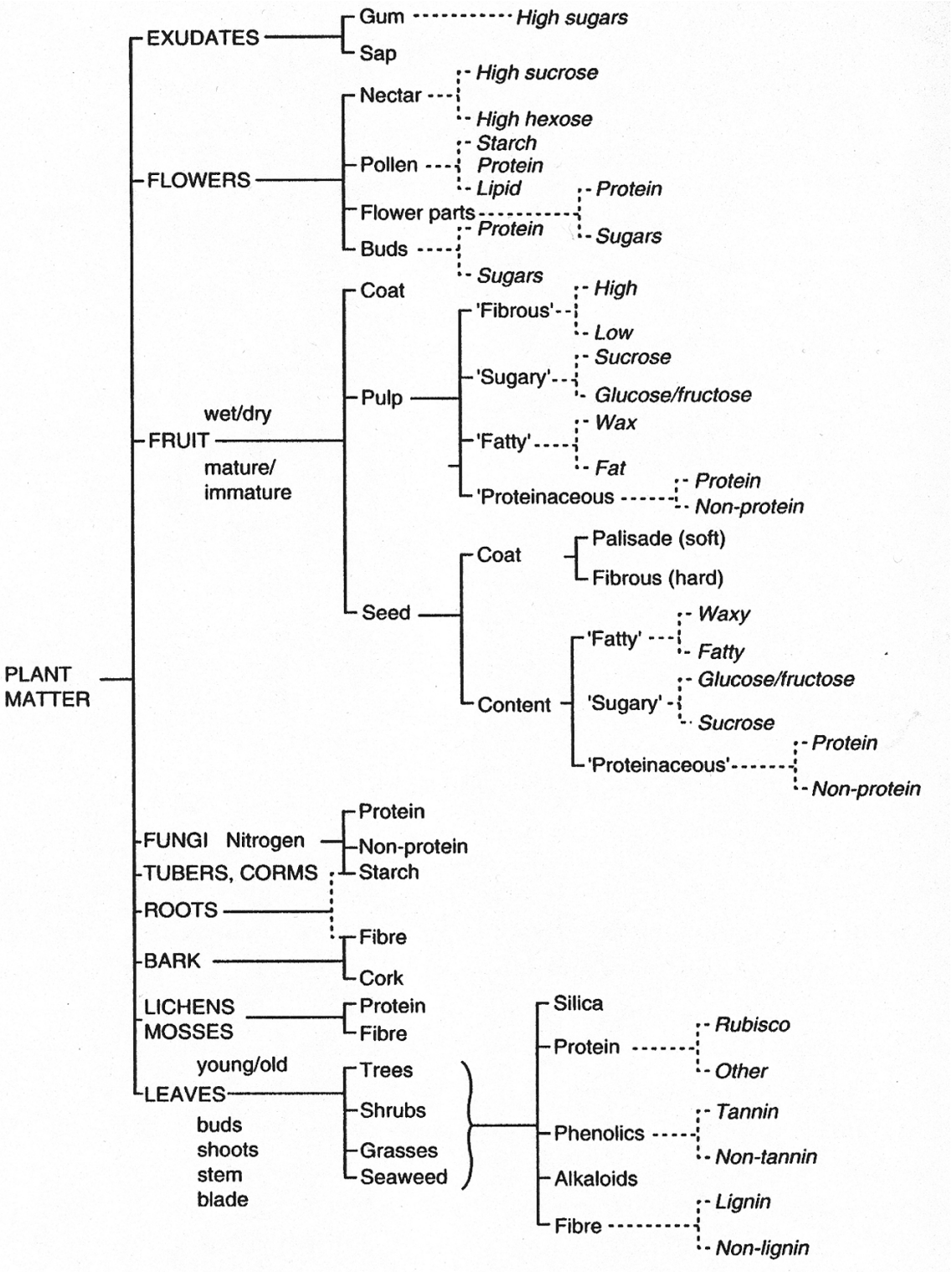

LIVING MATTER
DRY MATTER
WATER
MINERALS
ORGANIC
CELL WALLS
CELL CONTENTS
Polyphenolics
Tannins
Alkaloids
Lignin
Suberin (cork)
Polysaccharides
Chitin
Hemicellulose
Cellulose
Glucans, Fructans, Galactans, Pectan, etc.
LIPIDS
Non-polar pigments (carotene, chlorophyll)
Non-acyl glycerols
Waxes
Sterols
Alcohol esters
Phospholipids
Acyl glycerols
Saturated
long
short
Unsaturated
long
short
SUGARS
Monosaccharides
Pentoses
Hexoses
Glucose
Fructose
Galactose
Oligosaccharides
Sucrose
Lactose
Maltose
Polysaccharides
Starch
Amylopectin
Glycogen
Pectin
NITROGENOUS COMPOUNDS
Protein and amino acids
amides
amines
EUKARYOTES
PROKARYOTES
Inorganic
Secondary compounds, e.g. alkaloids
Nucleic acids
VITAMINS


ANIMAL MATTER
BLOOD
INVERTEBRATES
'Soft'
Fat
Protein
'Shelled'
Coat
Chitin
Flesh
Protein
Fat
VERTEBRATES
Skin
Protein
Flesh
Protein
Fat
Cartilage
Minerals
Bone
Minerals


PLANT MATTER
EXUDATES
Gum
High sugars
Sap
FLOWERS
Nectar
High sucrose
High hexose
Pollen
Starch
Protein
Lipid
Flower parts
Protein
Sugars
Buds
Protein
Sugars
FRUIT
wet/dry
mature/ immature
Coat
'Fibrous'
High
Low
'Sugary'
Sucrose
Glucose/fructose
'Fatty'
Wax
Fat
'Proteinaceous'
Protein
Non-protein
Pulp
Seed
Coat
Palisade (soft)
Fibrous (hard)
Content
'Fatty'
Waxy
Fatty
'Sugary'
Glucose/fructose
Sucrose
'Proteinaceous'
Protein
Non-protein
FUNGI Nitrogen
Protein
Non-protein
TUBERS, CORMS
Starch
ROOTS
Fibre
BARK
Cork
LICHENS
MOSSES
Protein
Fibre
LEAVES
young/old
buds
shoots
stem
blade
Trees
Shrubs
Grasses
Seaweed
Silica
Protein
Rubisco
Other
Phenolics
Tannin
Non-tannin
Alkaloids
Fibre
Lignin
Non-lignin

Food consists of …

Water

Protein

Fat

Fibre (Pectin, Hemicellulose, Cellulose, Lignin)
= 'indigestible or slowly digestible carbohydrates'

Sugar / Starch = easily digestible carbohydrates

Ash (Minerals)

Vitamins

Food consists of …

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Protein

Fat

Fibre (Pectin, Hemicellulose, Cellulose, Lignin)
= 'indigestible or slowly digestible carbohydrates'

Sugar / Starch = easily digestible carbohydrates

Energy

Ash (Minerals)

Vitamins

The Food Spectrum. The Composition of Some Foodstuffs eaten by Mammals

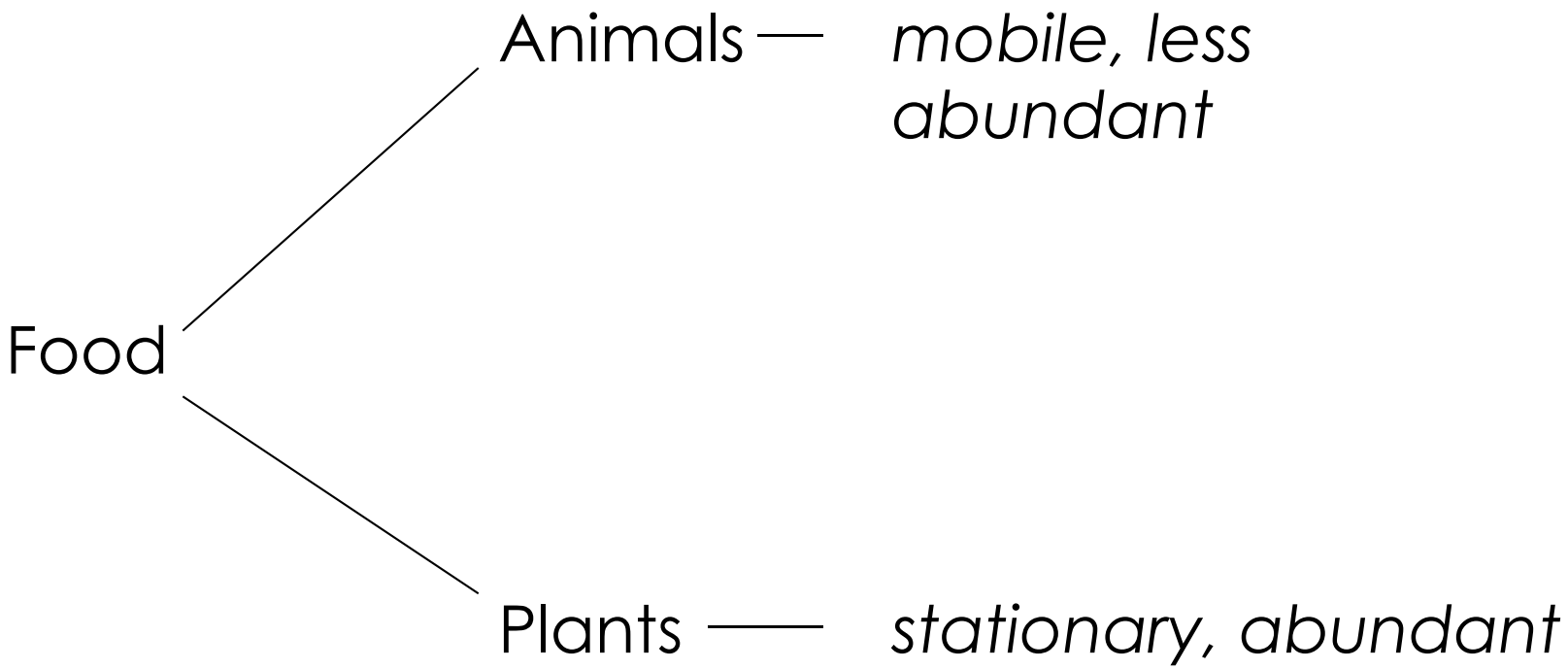
Food type	Example	kcal/100 g food	Gross constituents						
			Water	g/100 g dry matter					
				Protein	Oil	Oligosaccharide	Cellulose	Lignocellulose	Ash
Blood	(Pig)	61	84	88	2	3	0	0	7
Mammal	Muscle (Pig)	112	75	89	10	0	0	0	1
	Viscera (Pig)	117	75	65	23	0	0	0	12
	Whole body (Pig)	112	75	83	13	0	0	0	4
Other vertebrates	Whole body (Hen)	107	76	57	24	0	0	0	19
	Egg (Hen)	116	73	38	31	0	0	0	31
	Whole body (Cod)	81	75	70	4	2	0	0	24
Invertebrates	Snail/Cockle	46	79	52	1	0	0	0	47
	Prawn/Crab	126	26	33	2	9	0	0	56
Fruit, etc.	Honey	71	20	1	0	93	0	0	6
	Banana	77	71	4	0	66	11	1	18
	Brazil nut	629	9	15	68	5	8	2	2
	Barley	305	15	10	2	80	3	2	3
Fibrous plants	Broccoli flower	21	88	10	2	32	43	3	10
	Carrot	33	87	6	2	56	24	5	7
	Cabbage	39	85	12	4	46	22	5	11
Woody fibrous plants	Grass (Pasture)	44	80	13	6	30	34	9	8
	Leaves (Elm)	72	50	15	3	15	44	11	12

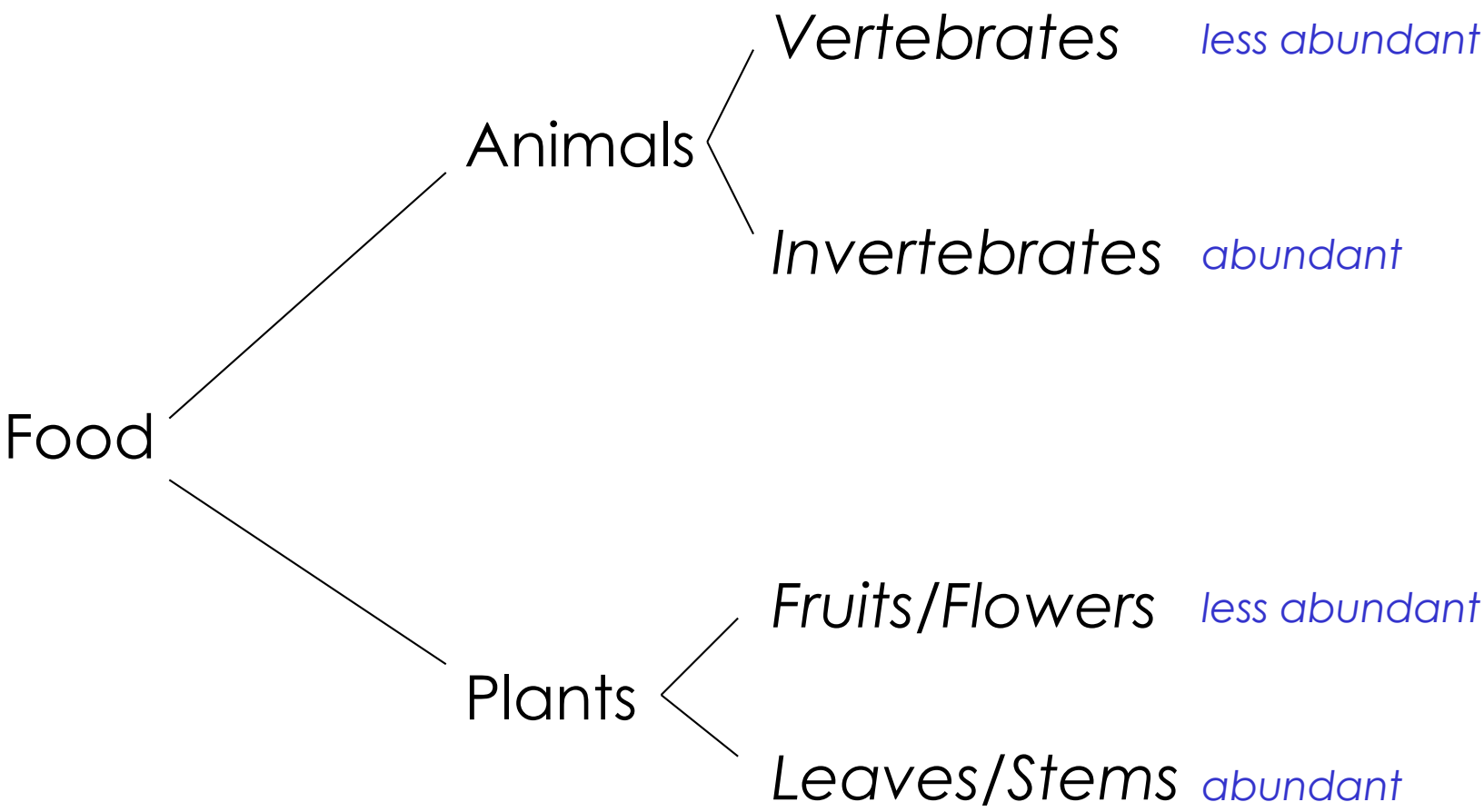
Water content

- Food intake is not related to fresh (wet) weight but to dry matter
- Dry matter content varies drastically between foods
- Always check the basis in food tables (wet weight vs. dry matter basis)

Water content

	DM content	Proportion of diet	
		wet weight	dry matter
Fruits	15 %	72 %	30 %
Pellets	90 %	28 %	70 %


Food
Animals
mobile, less abundant
Plants
stationary, abundant


Food
Animals
Vertebrates
less abundant
Invertebrates
abundant
Plants
Fruits/Flowers
less abundant
Leaves/Stems
abundant

Digestive Physiology

- Food
- **How animals get the food**
- How animals digest the food
- How the animals metabolism deals with properties of the food

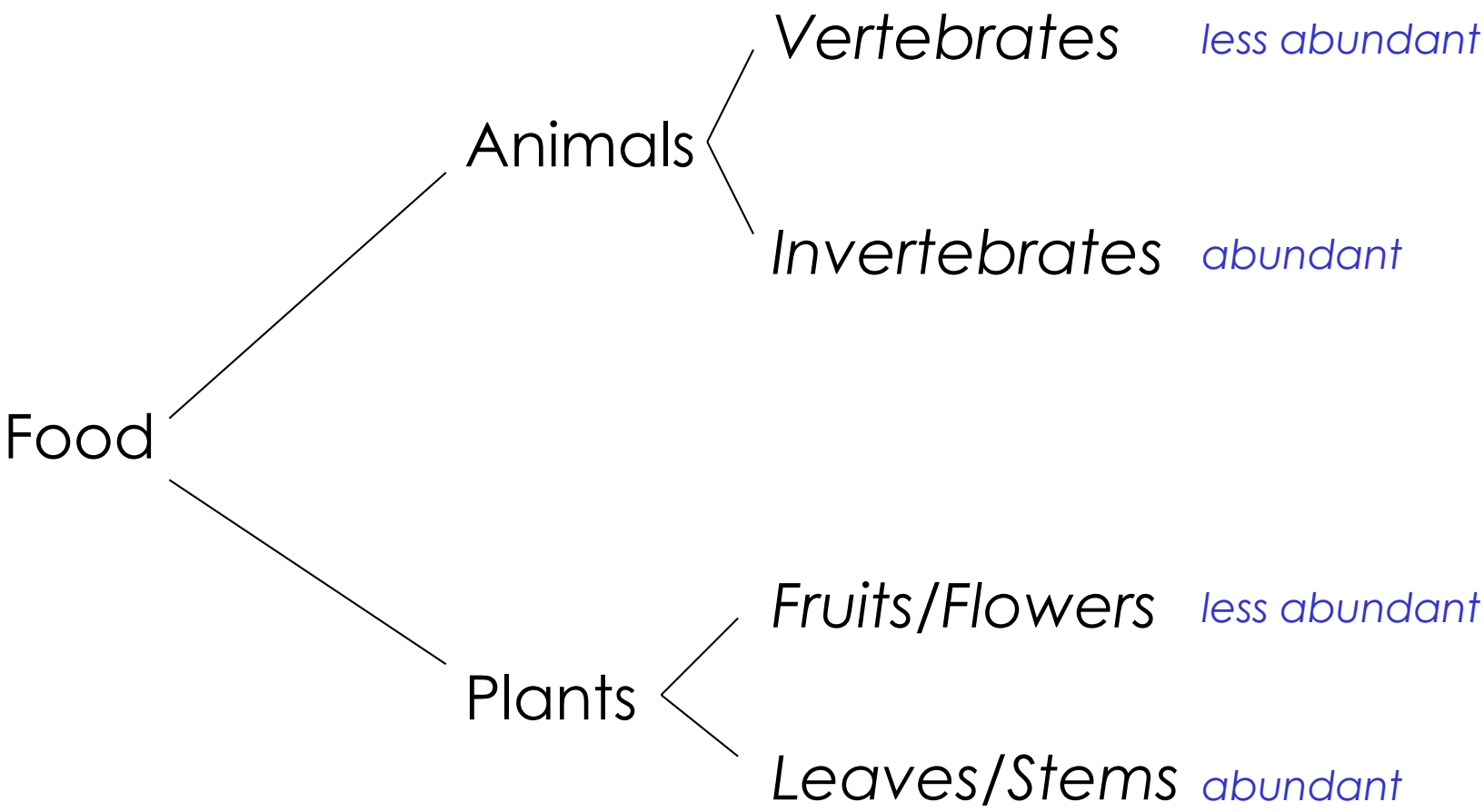
Getting the food

- *Catching prey is (often) the hard part!*



- *Catching plants is (mostly) easy!*

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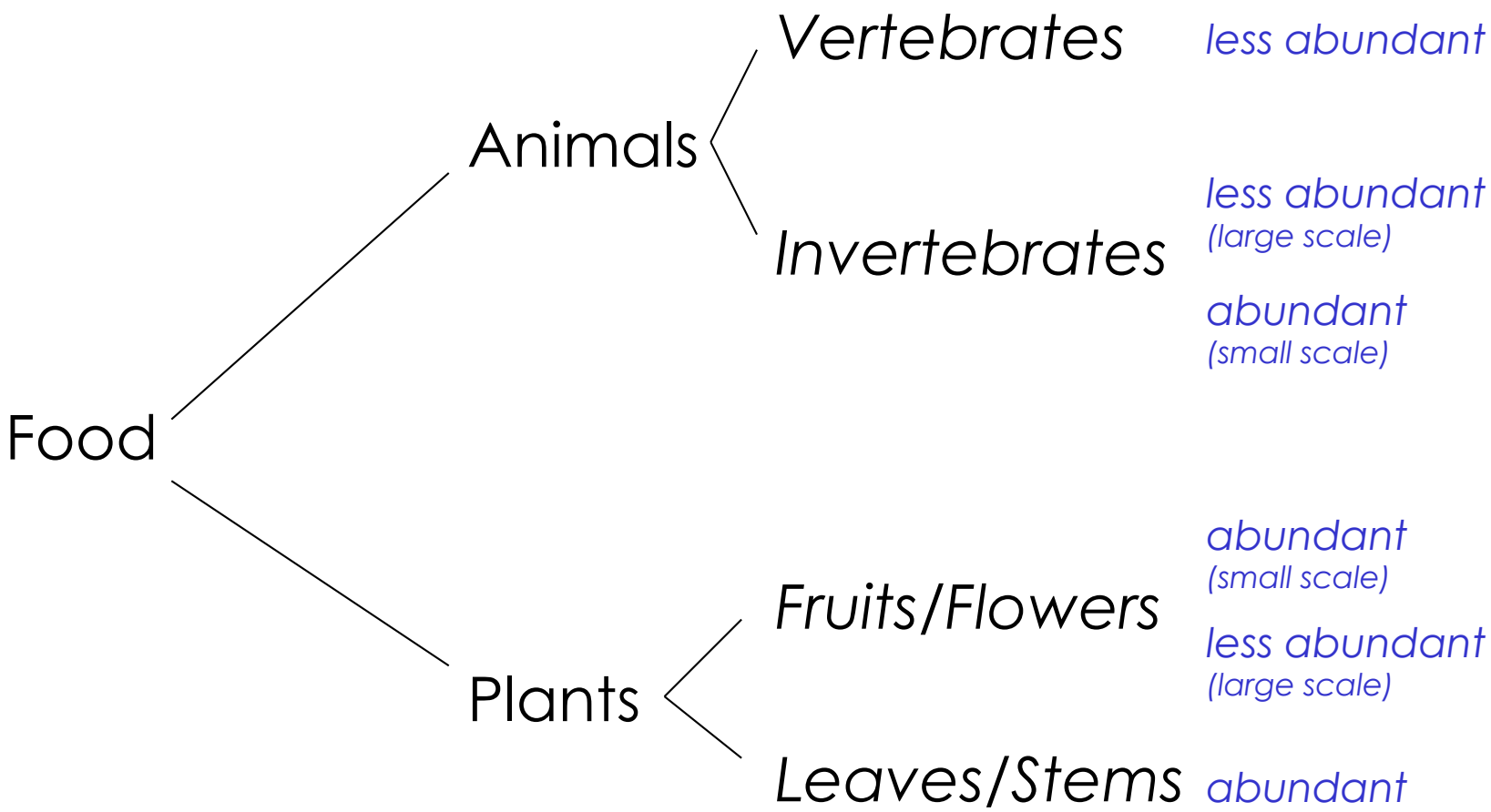
Food
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Invertebrates
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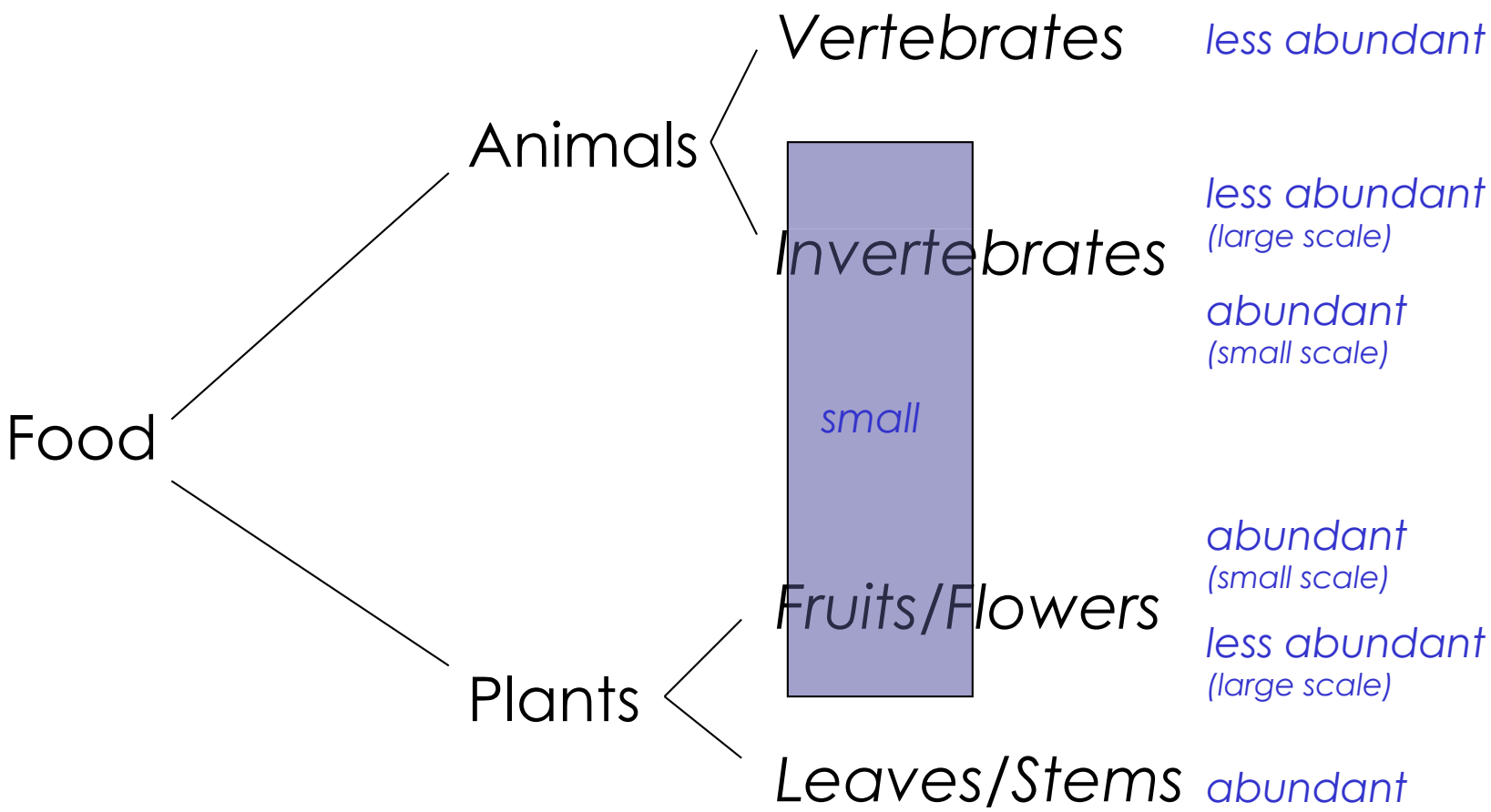
(large scale)
abundant
(small scale)
Plants
Fruits/Flowers
abundant
(small scale)
less abundant
(large scale)
Leaves/Stems
abundant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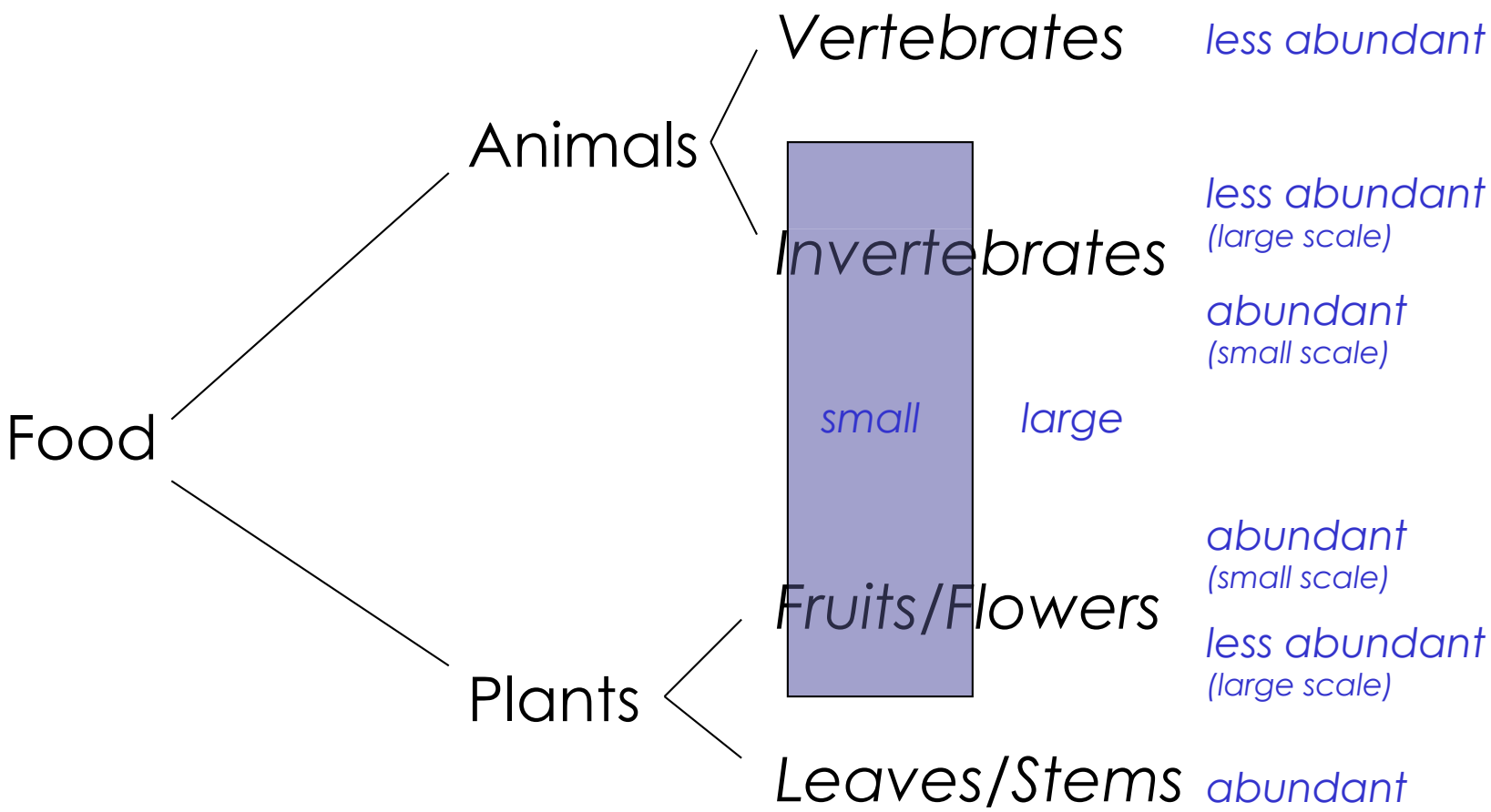
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Plants
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abundant
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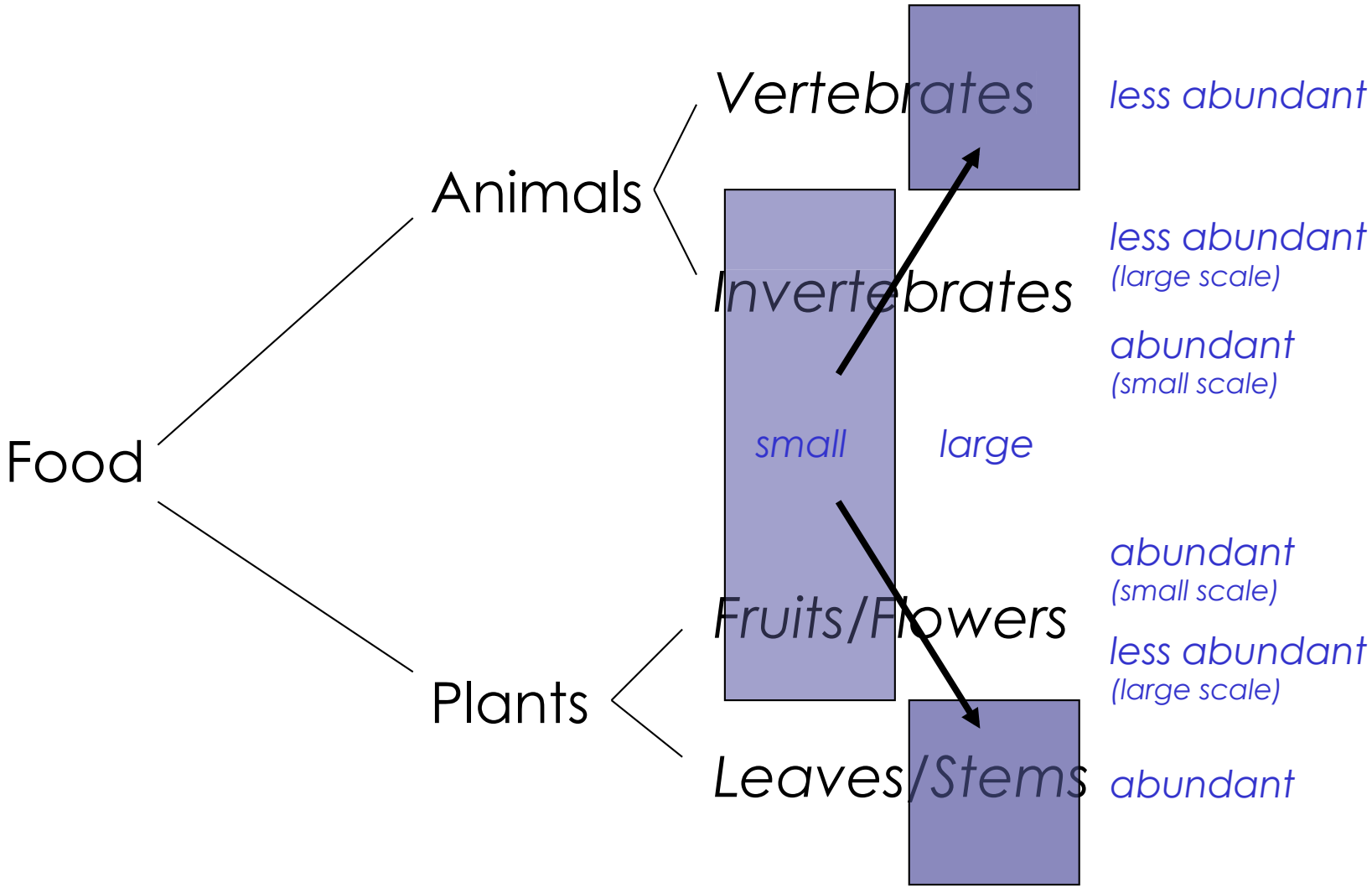
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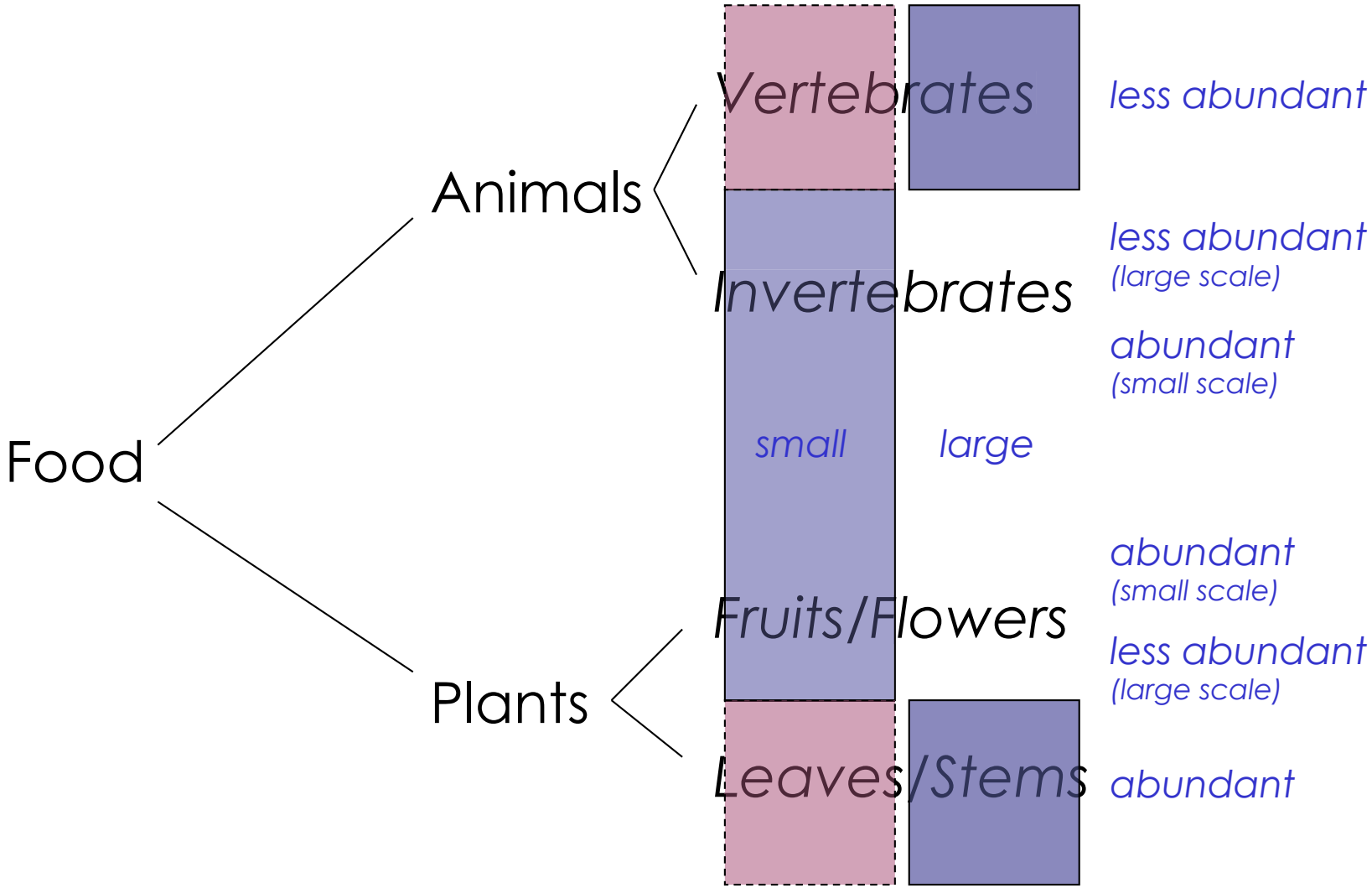
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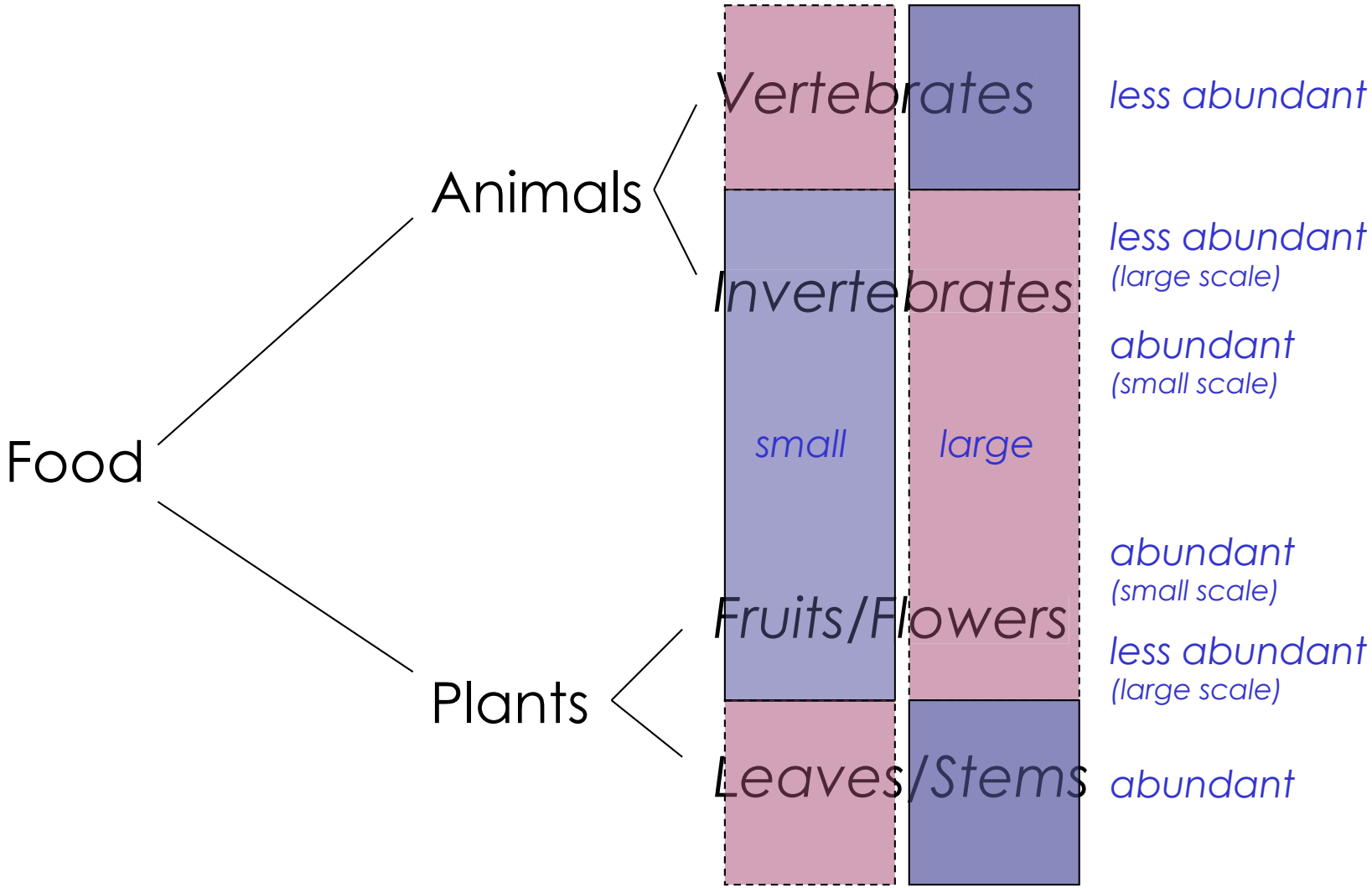
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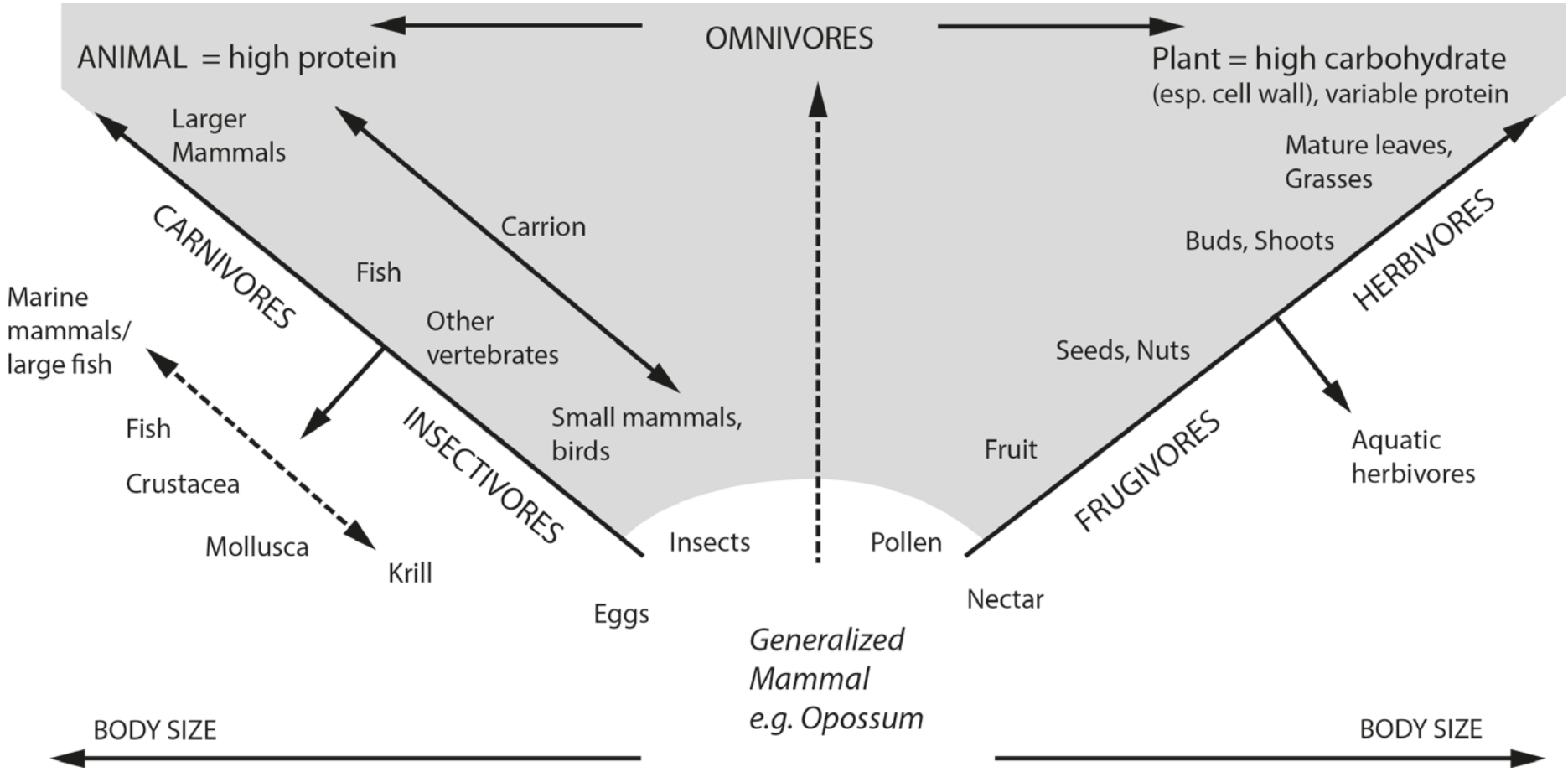
Sufficient amounts of available packages



from Hiiemae (2000)

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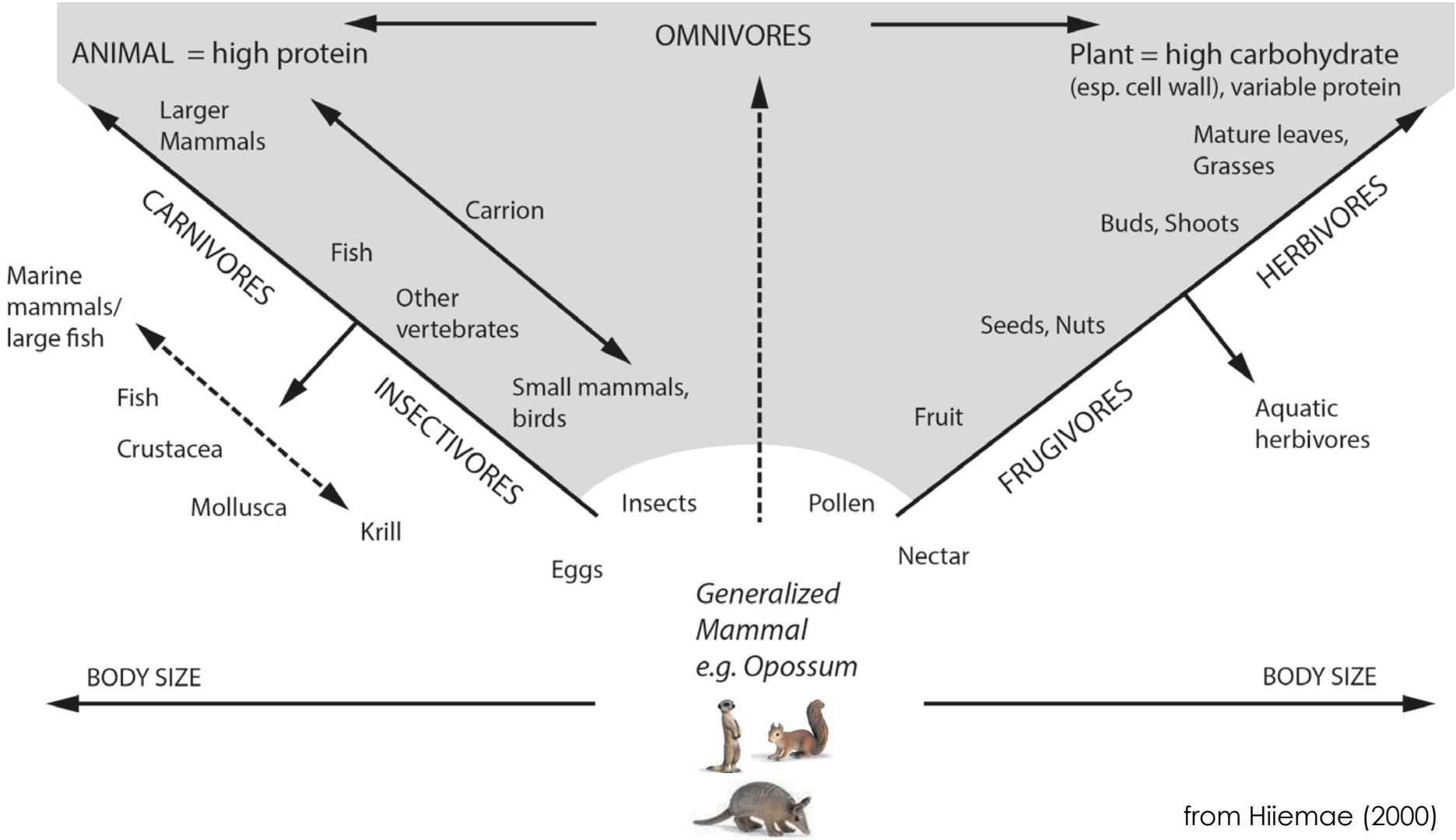

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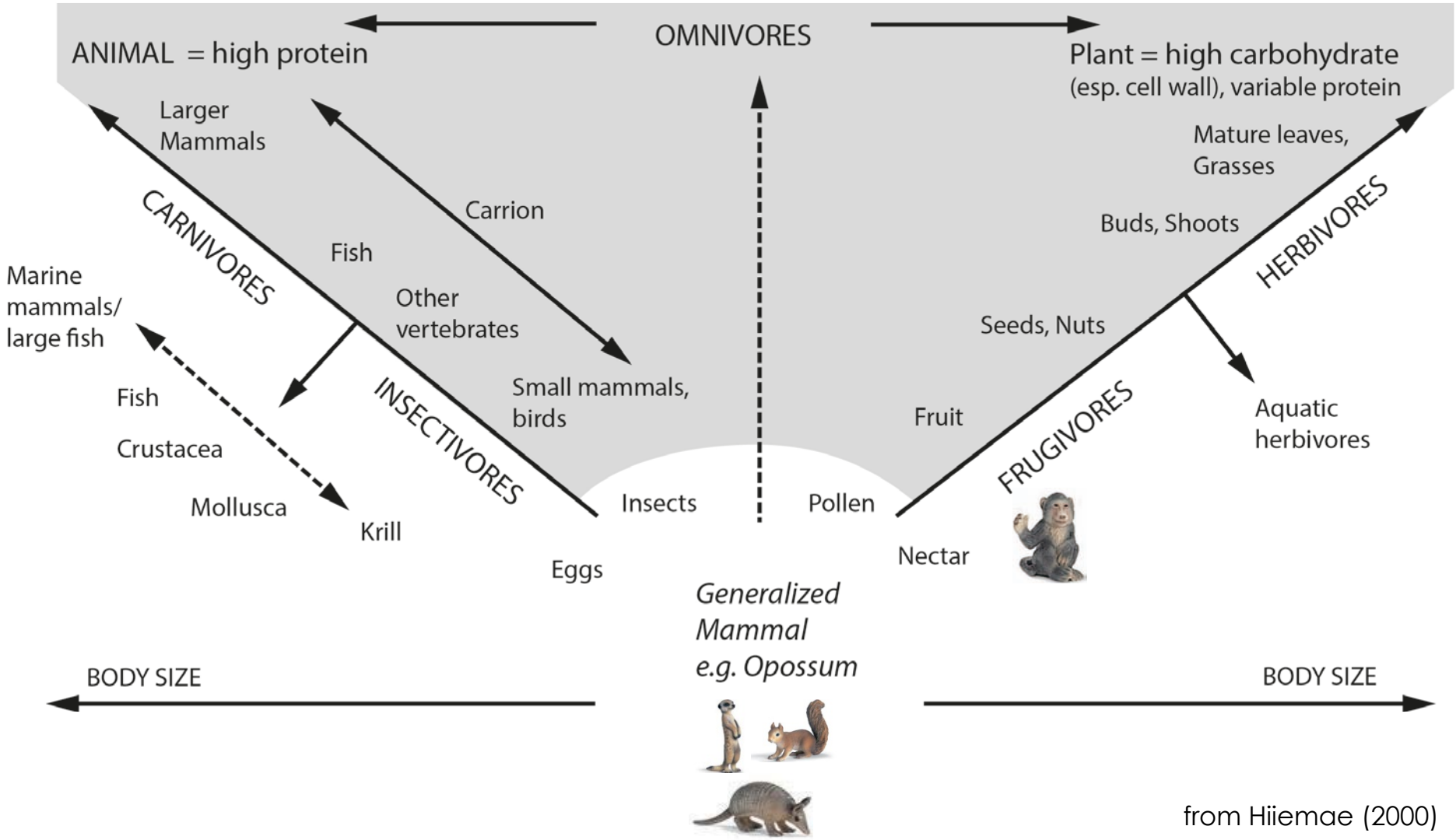

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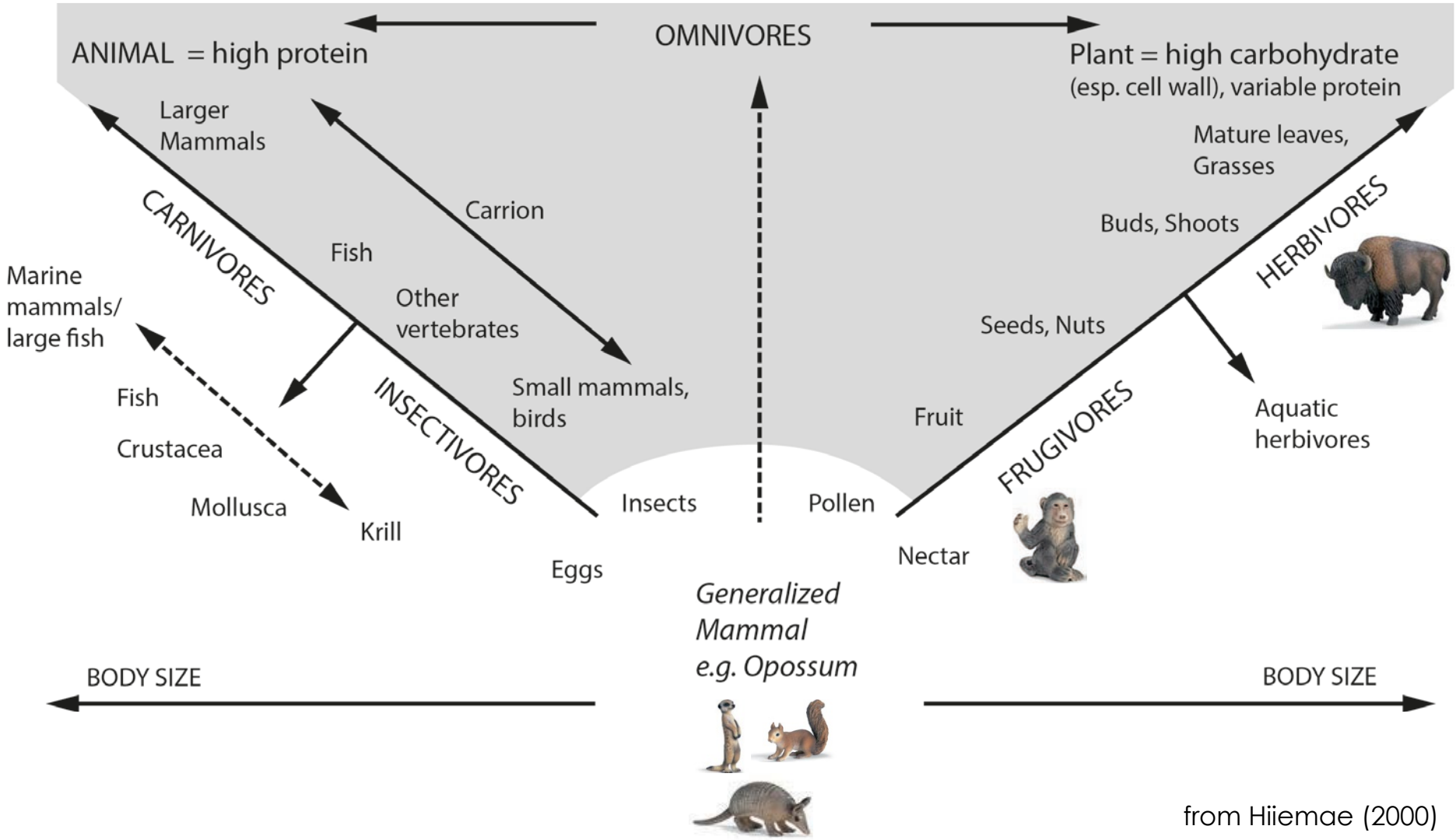

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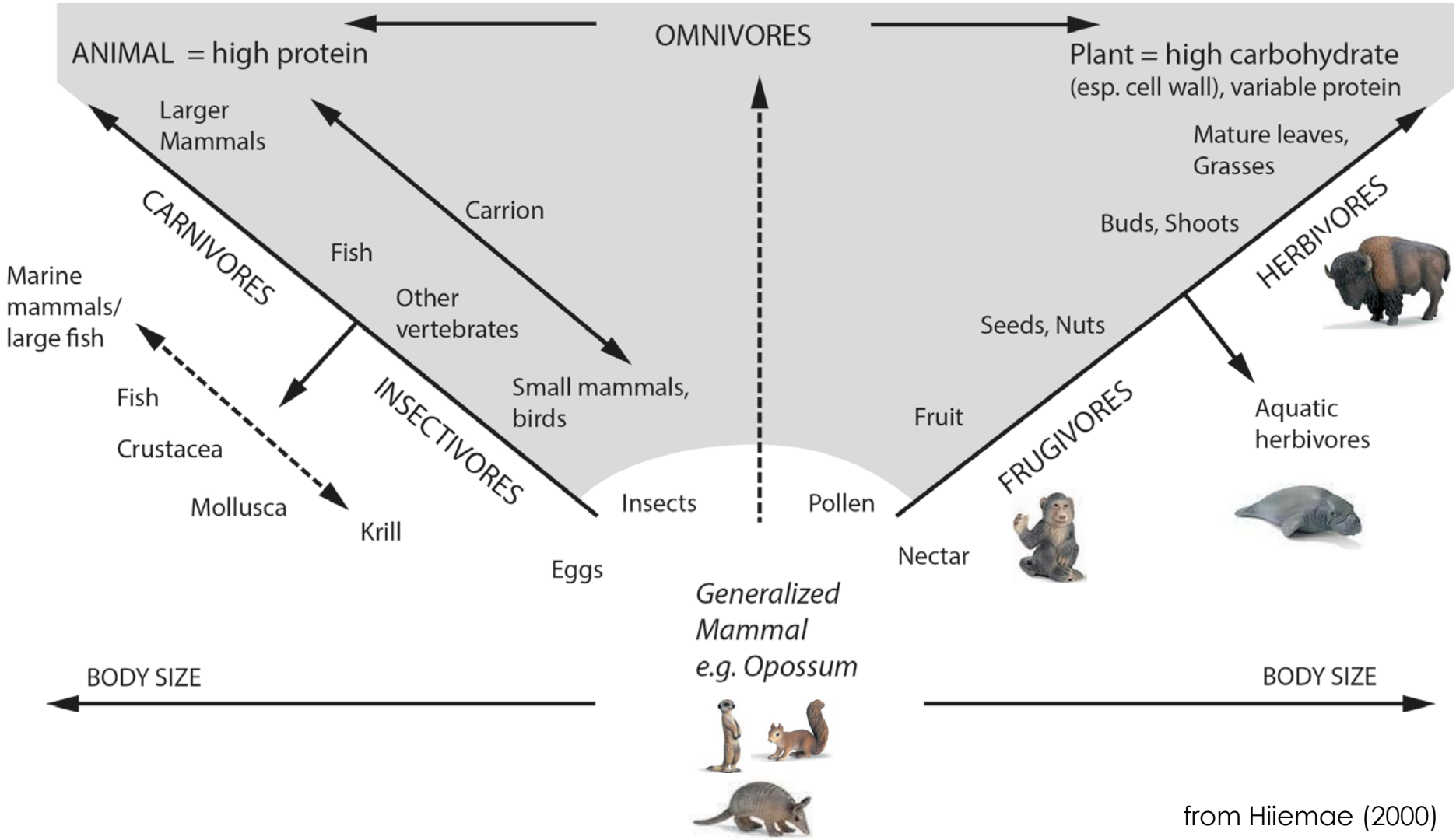

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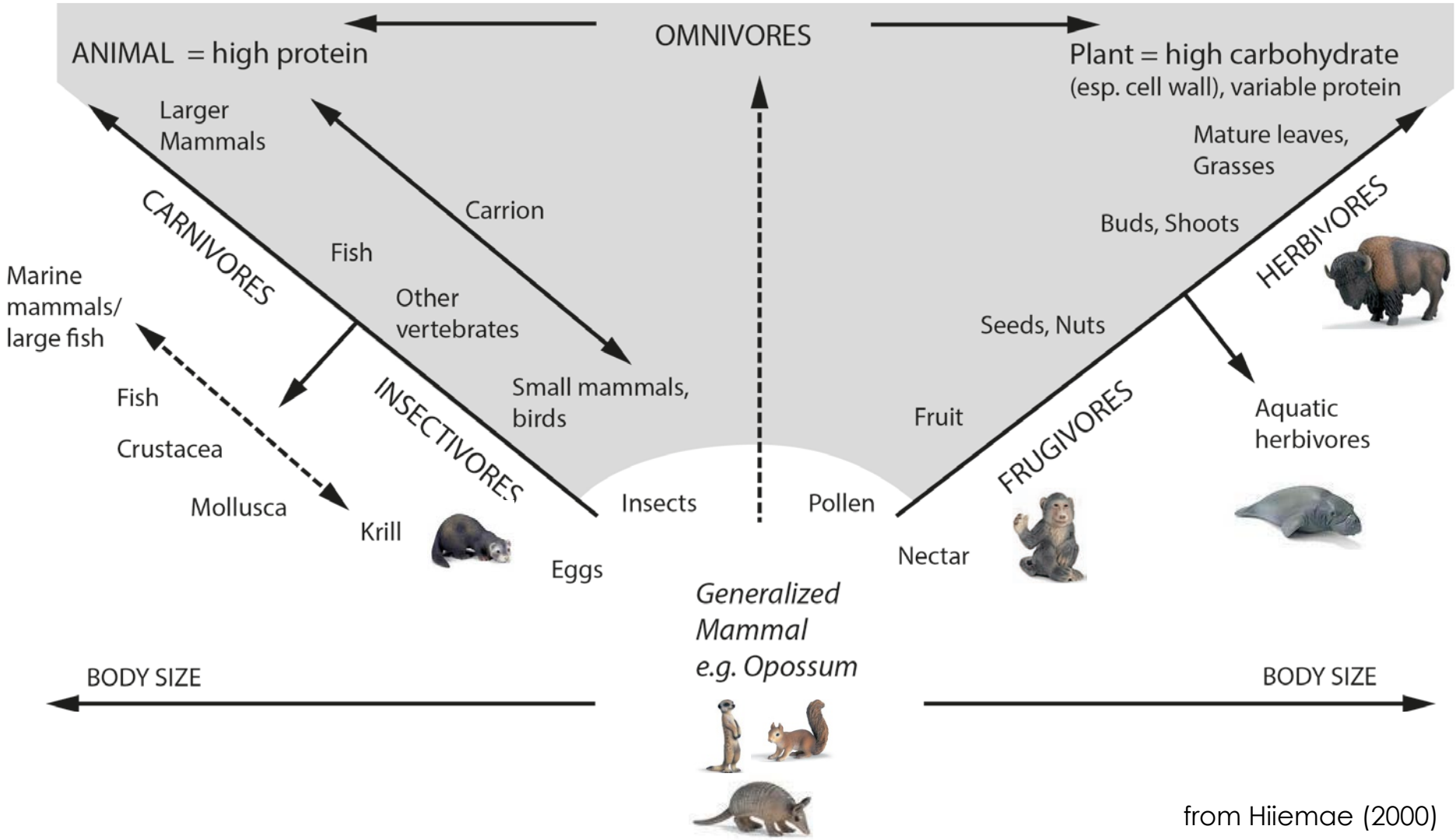

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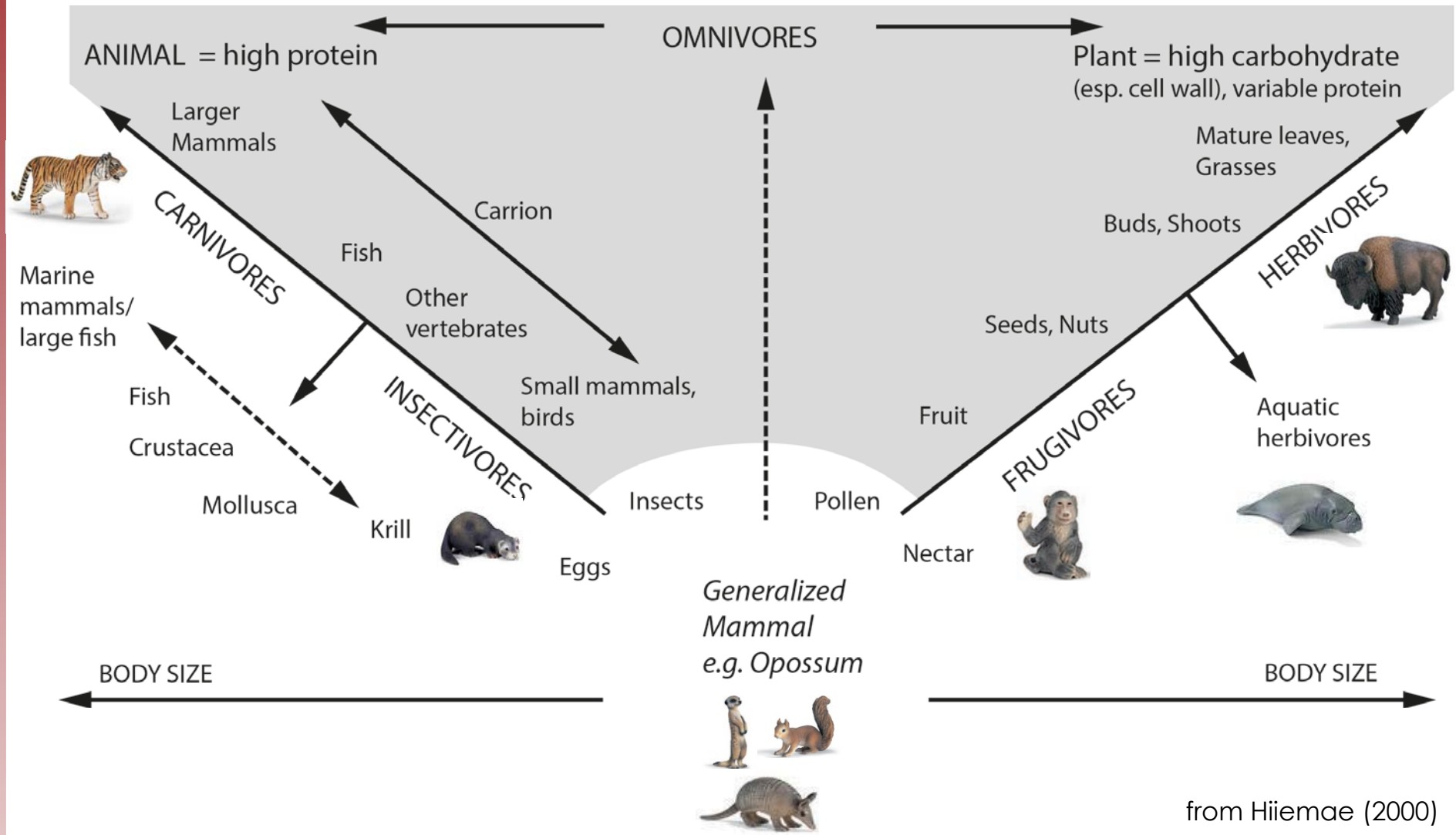

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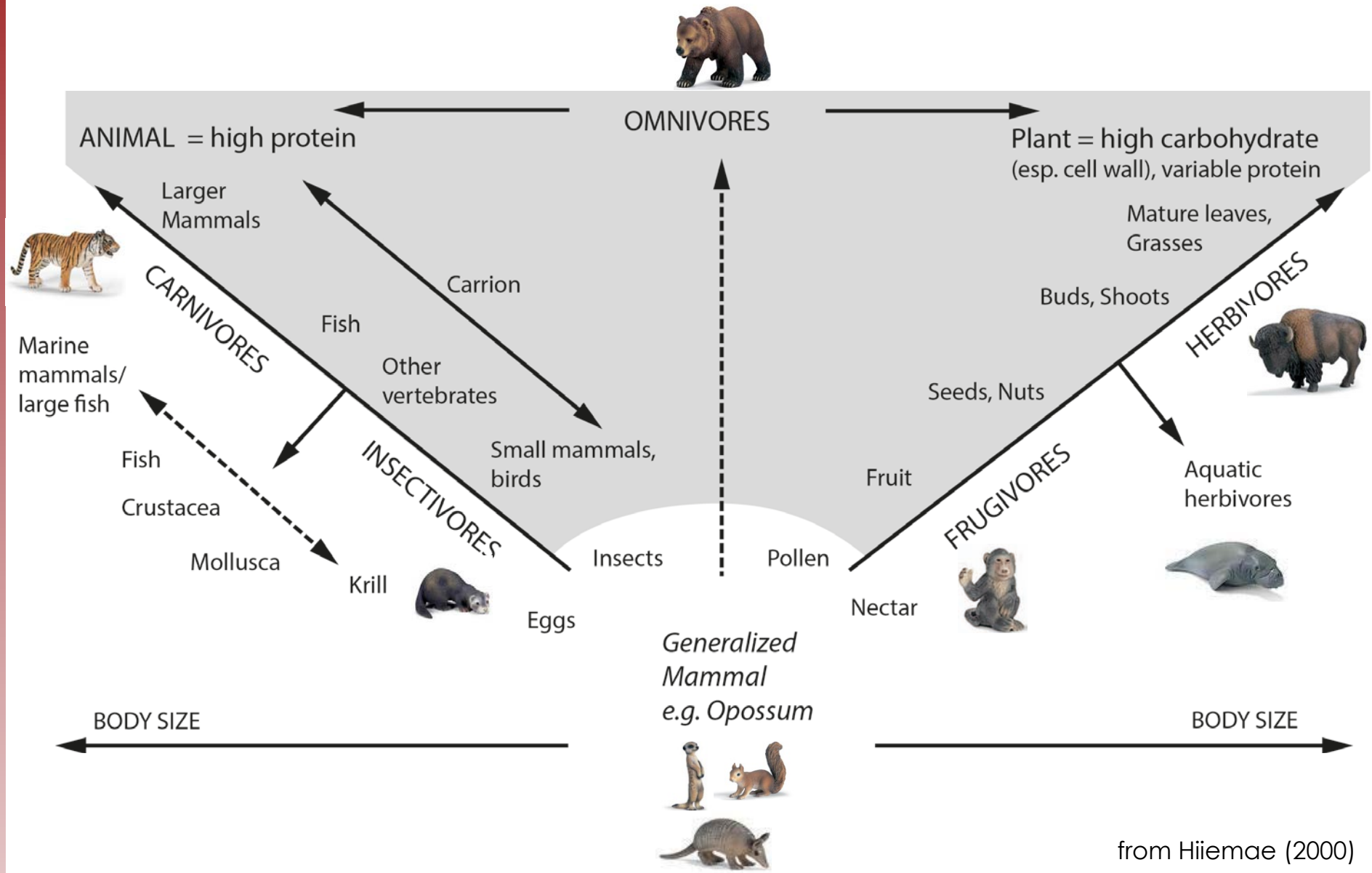

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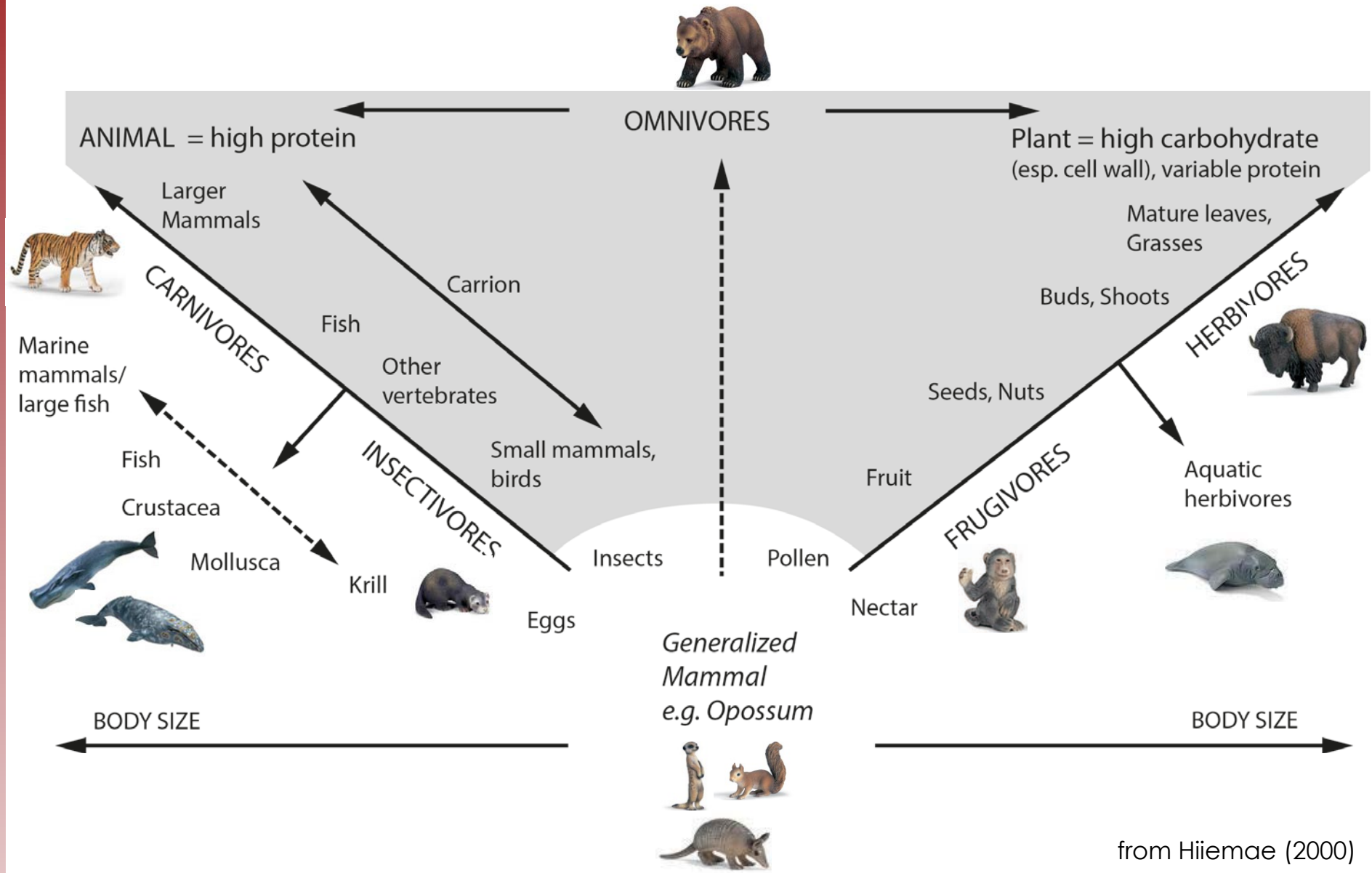

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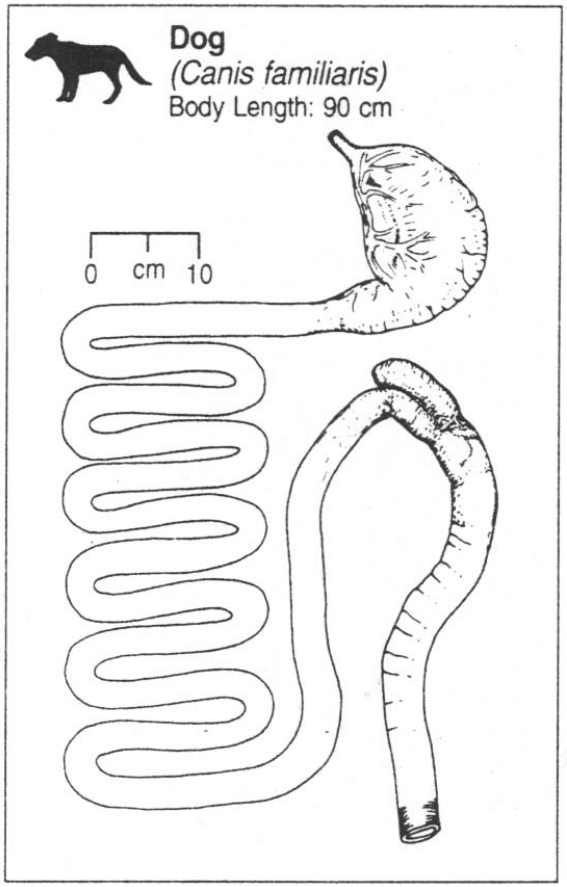
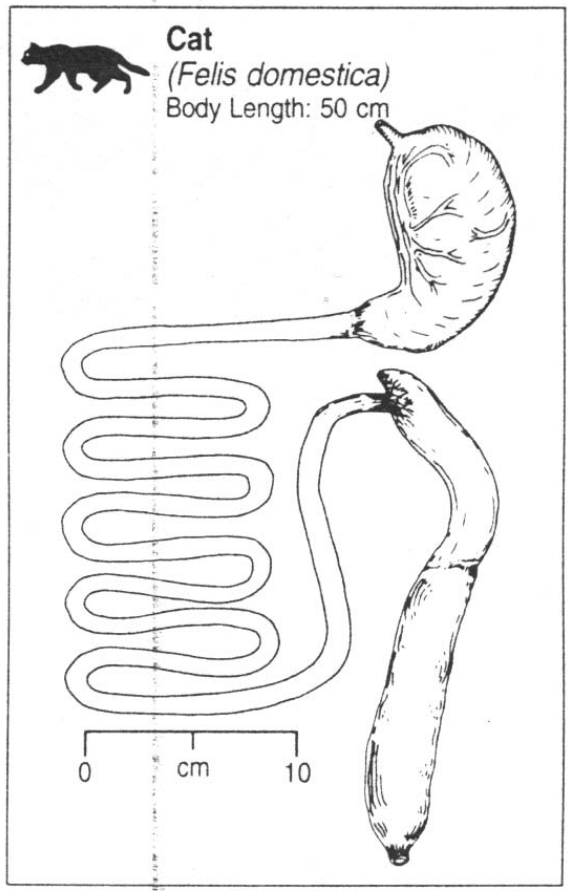
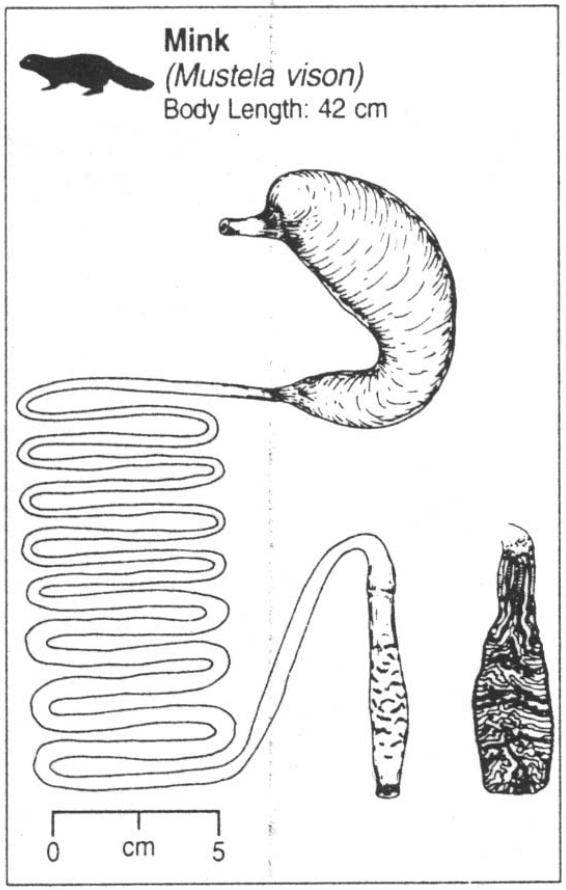
Carnivores - simple guts

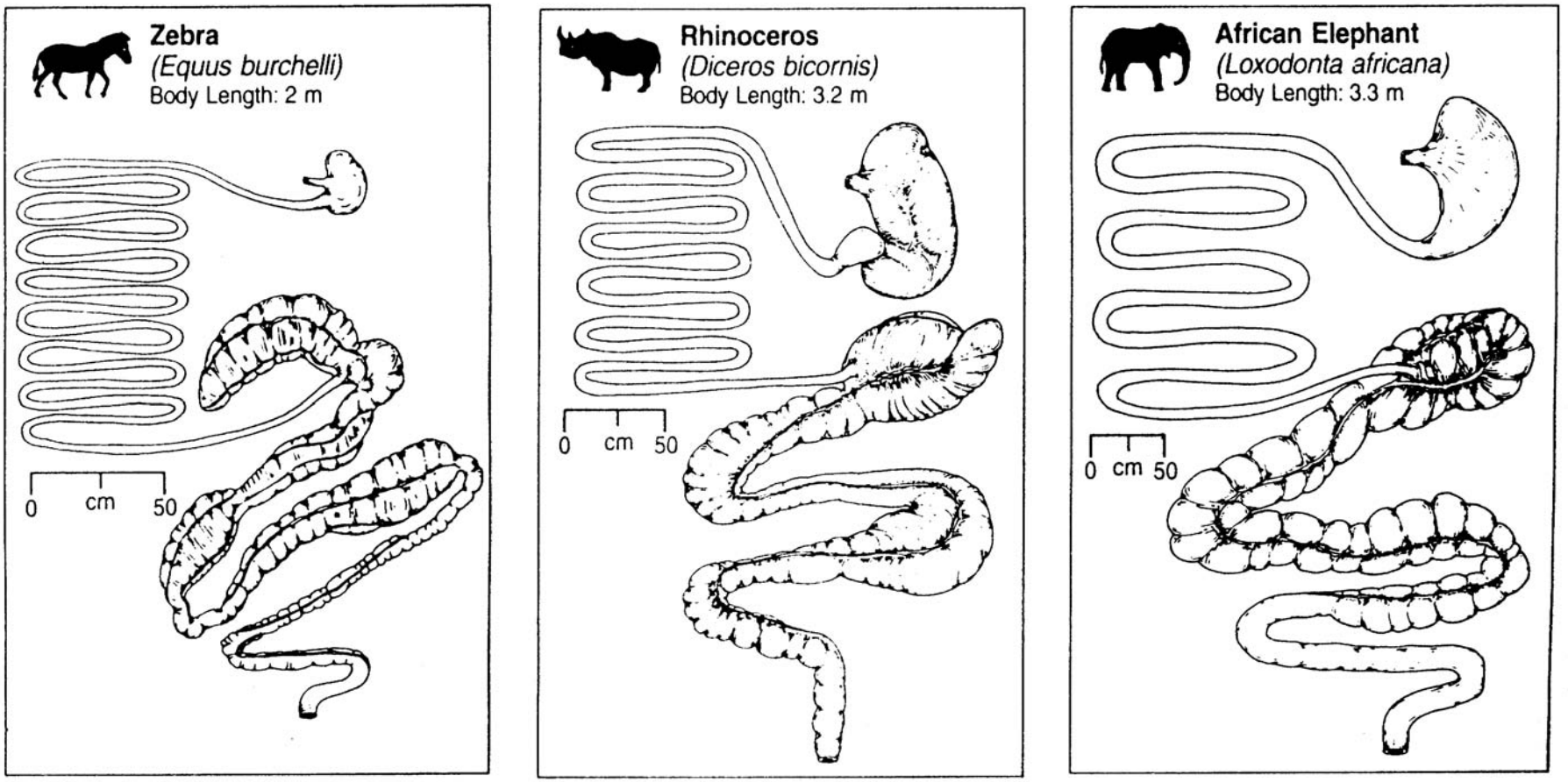






from Stevens und Hume (1995)

Herbivores- complex guts



from Stevens & Hume (1995)

Digestibility

Digestibility is the proportion of food that is apparently absorbed in the gut (in %)

$$\text{Digestibility} = \frac{(\text{Amount eaten} - \text{Amount defecated})}{\text{Amount eaten}} * 100$$

Digestibility is determined in animal experiments or by in vitro methods.

In order to estimate digestibility, one ALWAYS needs an estimation of the amounts eaten and defecated!

You cannot calculate a digestibility by the nutrient content of the food and the faeces !!!

Energy

Energy is measured as

Gross energy (GE) = combustion energy

Digestible energy (DE) = the amount of GE eaten minus GE excreted in faeces

Metabolizable energy (ME) = DE minus GE excreted via urine and digestion gases

It is NONSENSE to compare foods on the basis of GE.
Kerosene has a very very high GE, but you do not get fat when eating it.
GE content of foods is mainly influenced by content of ash (inorganic material).

DE content of foods is influenced by "digestibility" - e.g. fibre content

To determine DE, you need to perform a digestion trial and determine GE in feeds and faeces.

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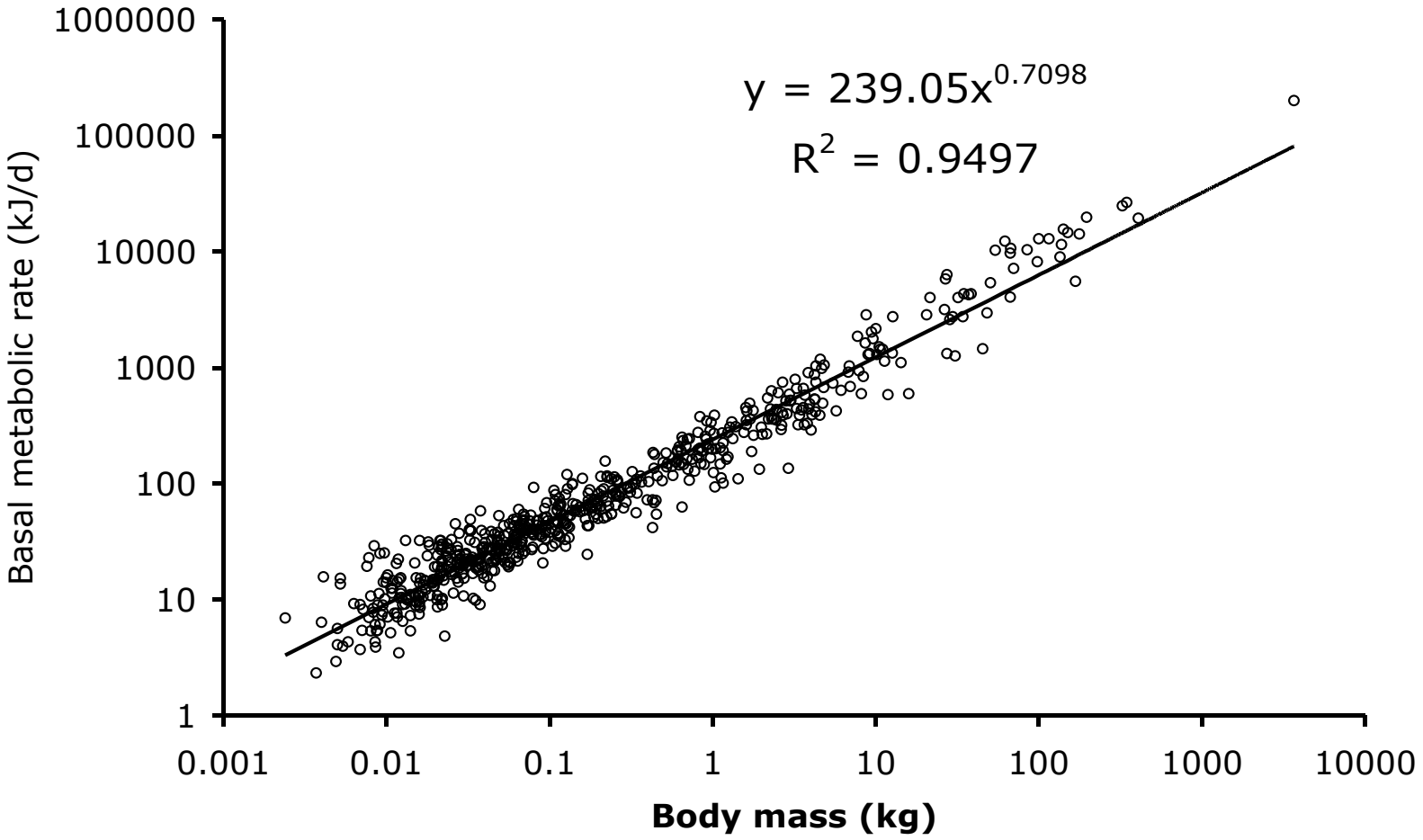
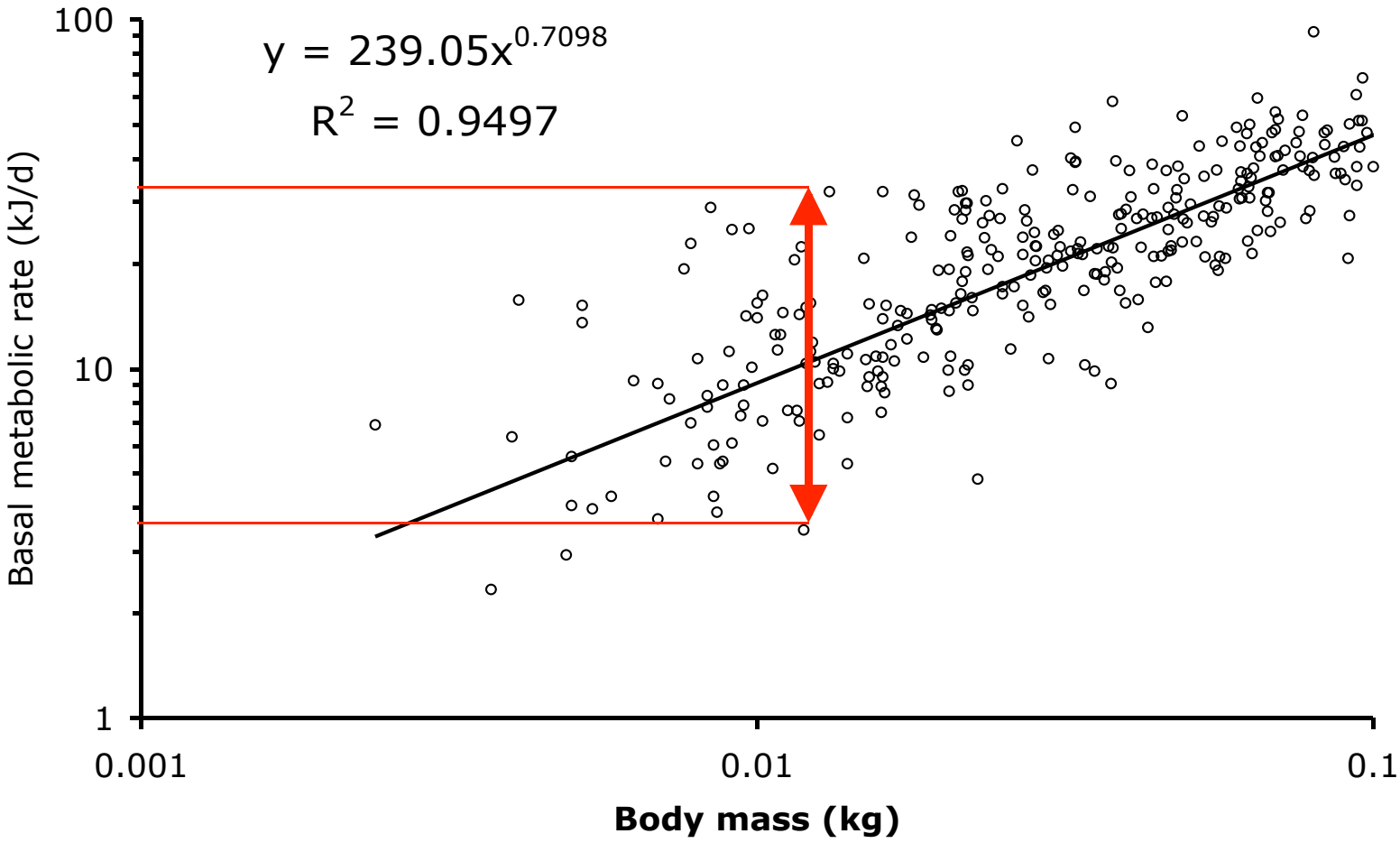
Mammalian metabolism



Data from Savage et al. (2004)

Mammalian metabolism



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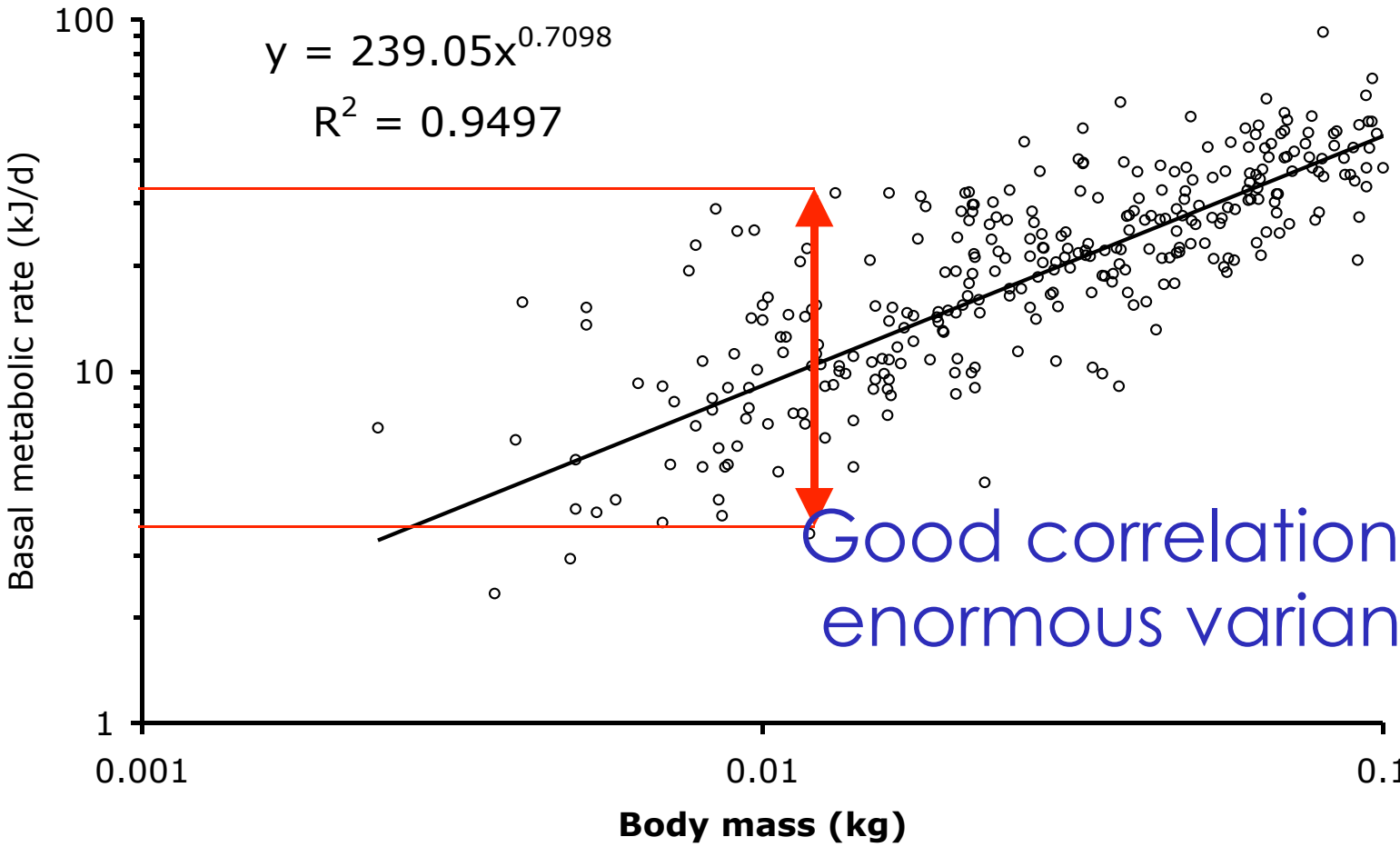

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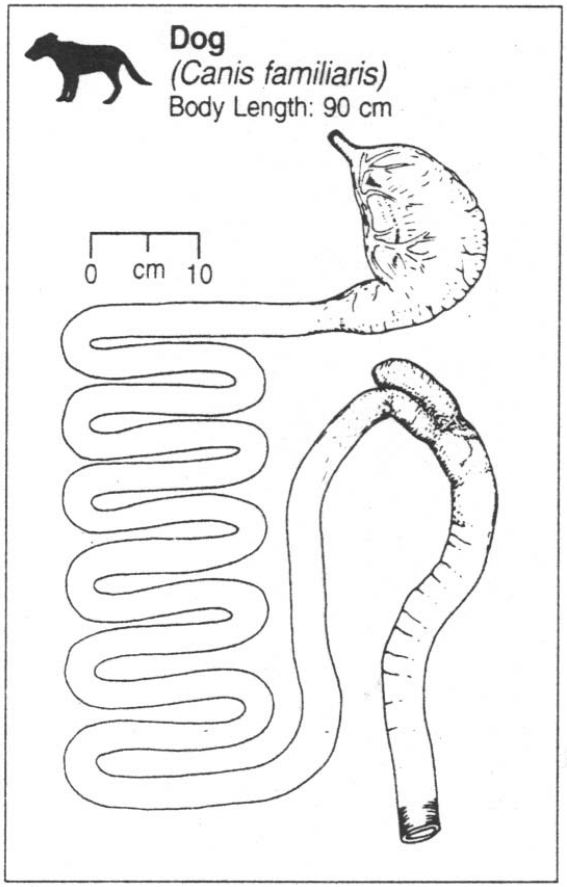
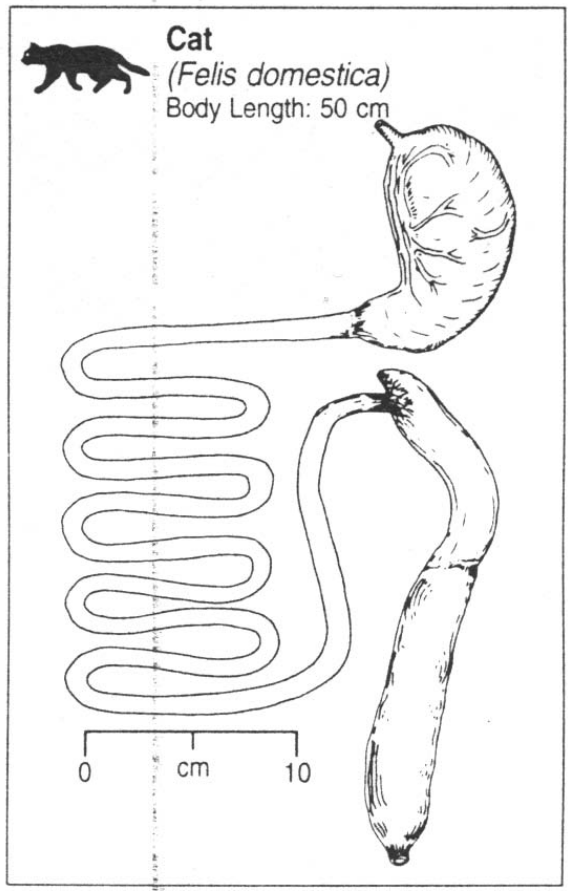
The comparative method

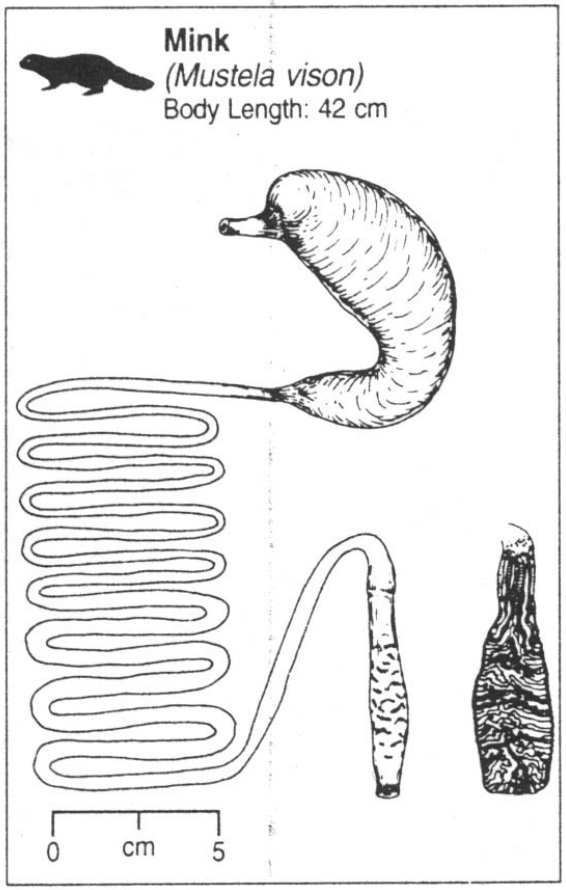
- **A certain type of food is, in many different species, associated with a certain set of adaptations**

  (i.e. we determine convergence)

Carnivores - simple guts







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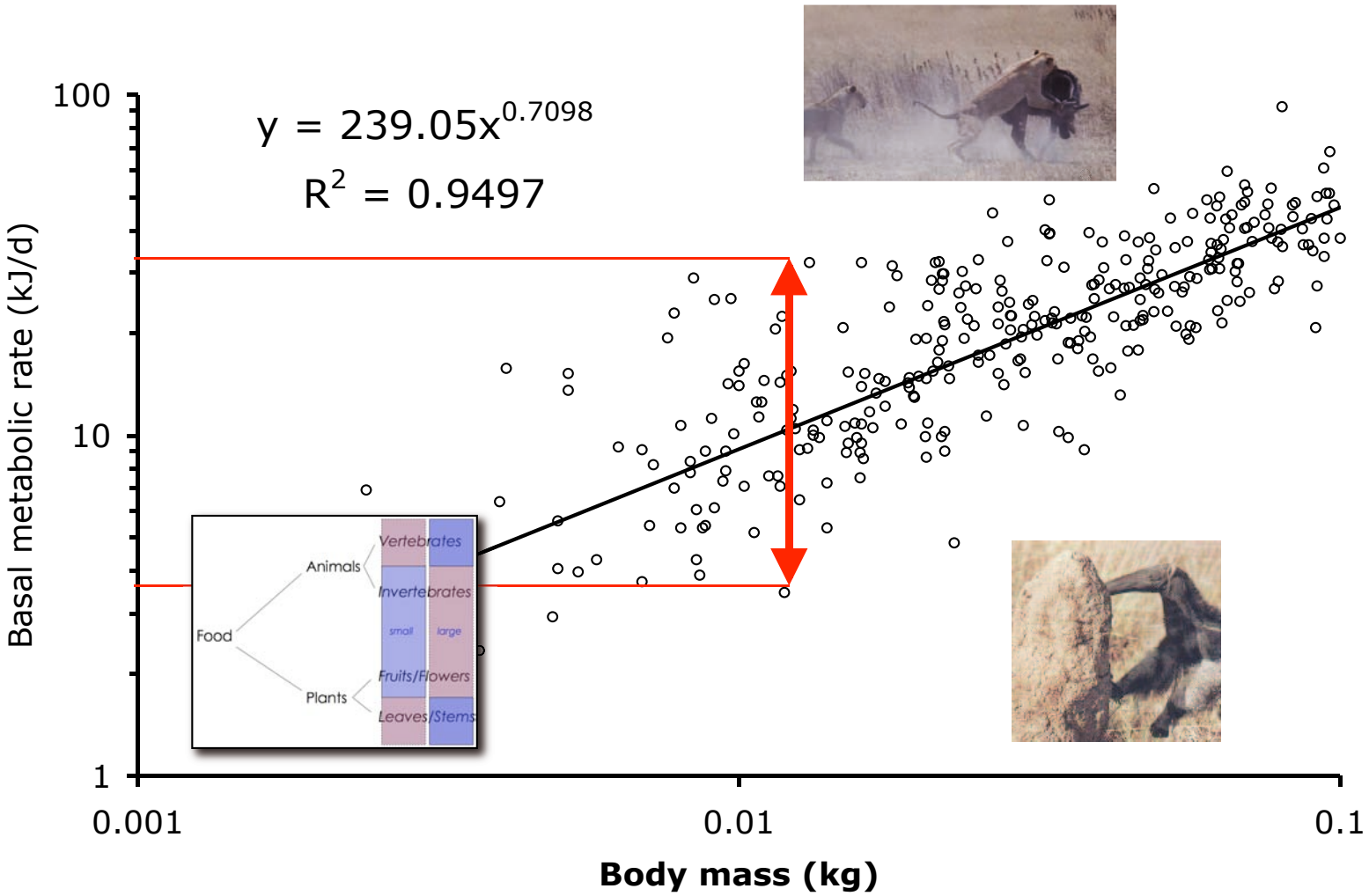

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- **'*because* ...'**

The comparative method

- **A certain type of food is, in many different species, associated with a certain set of adaptations**

  (i.e. we determine convergence)
- **'*because* ...'**

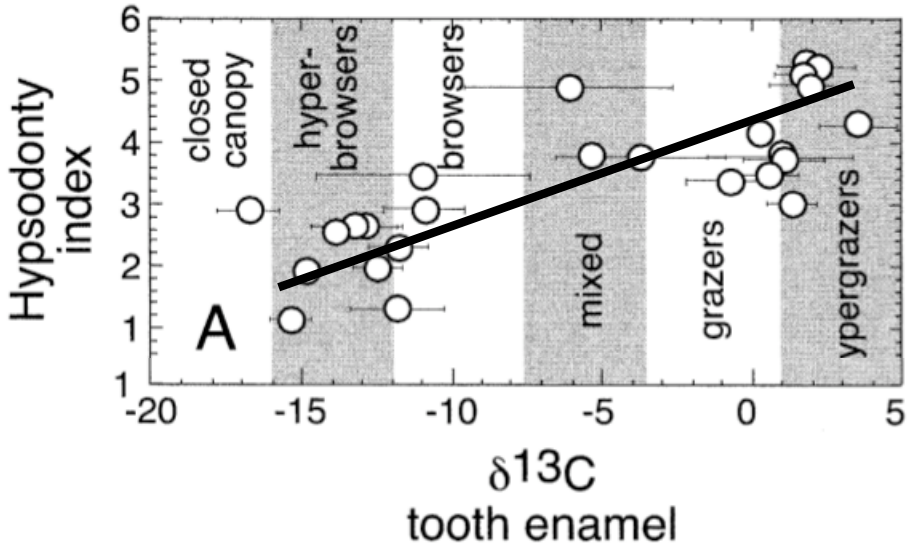
  ... and we assume a function

Form &Function

- the probably oldest approach to biology: linking form and function

Form &Function

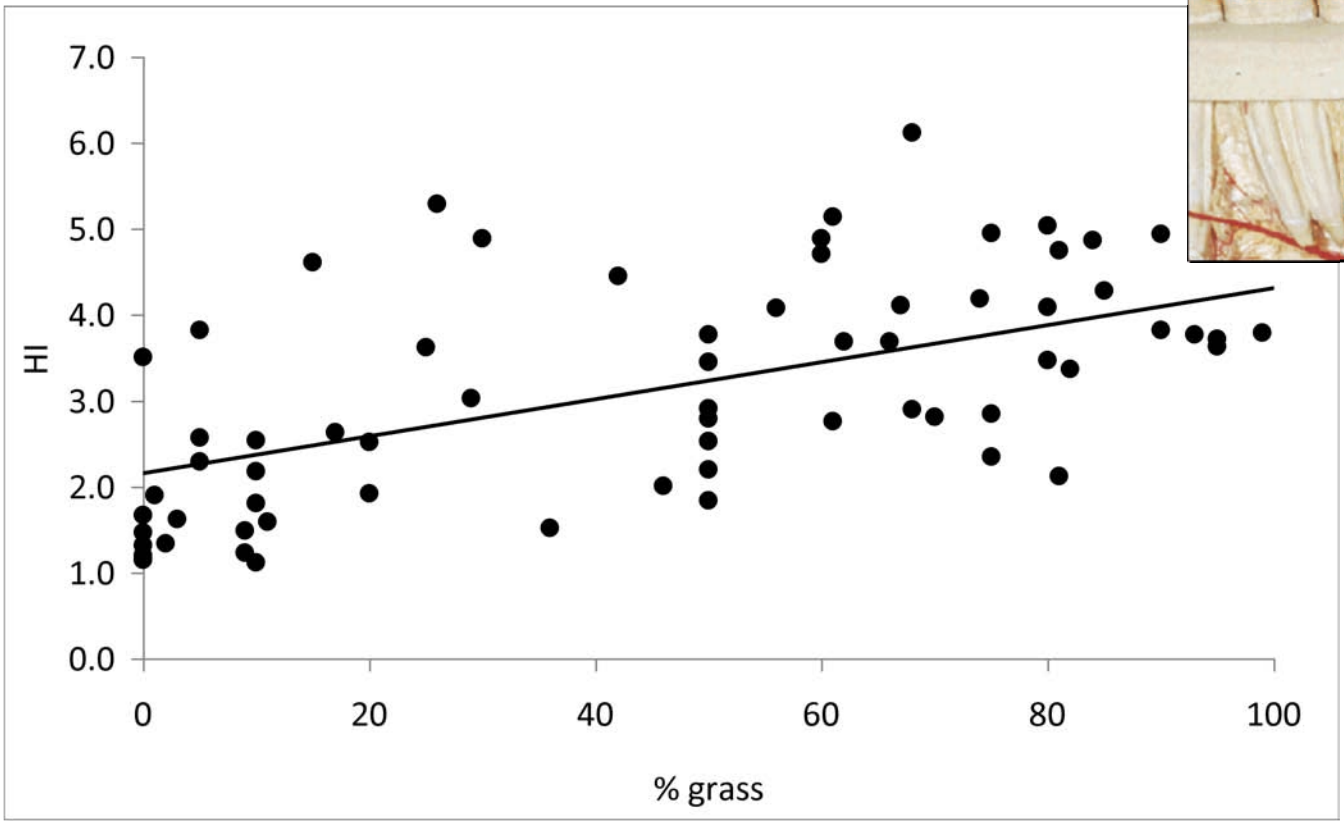
- An evident link: hypsodonty index and grass consumption



from Cerling et al. (2003)

Form &Function

- An evident link: hypsodonty index and grass consumption



Own evaluation

Form &Function

- Conclusion: diets of grazers must be more abrasive

Form &Function

- Conclusion: diets of grazers must be more abrasive - ***but this has never been tested!***

Form &Function

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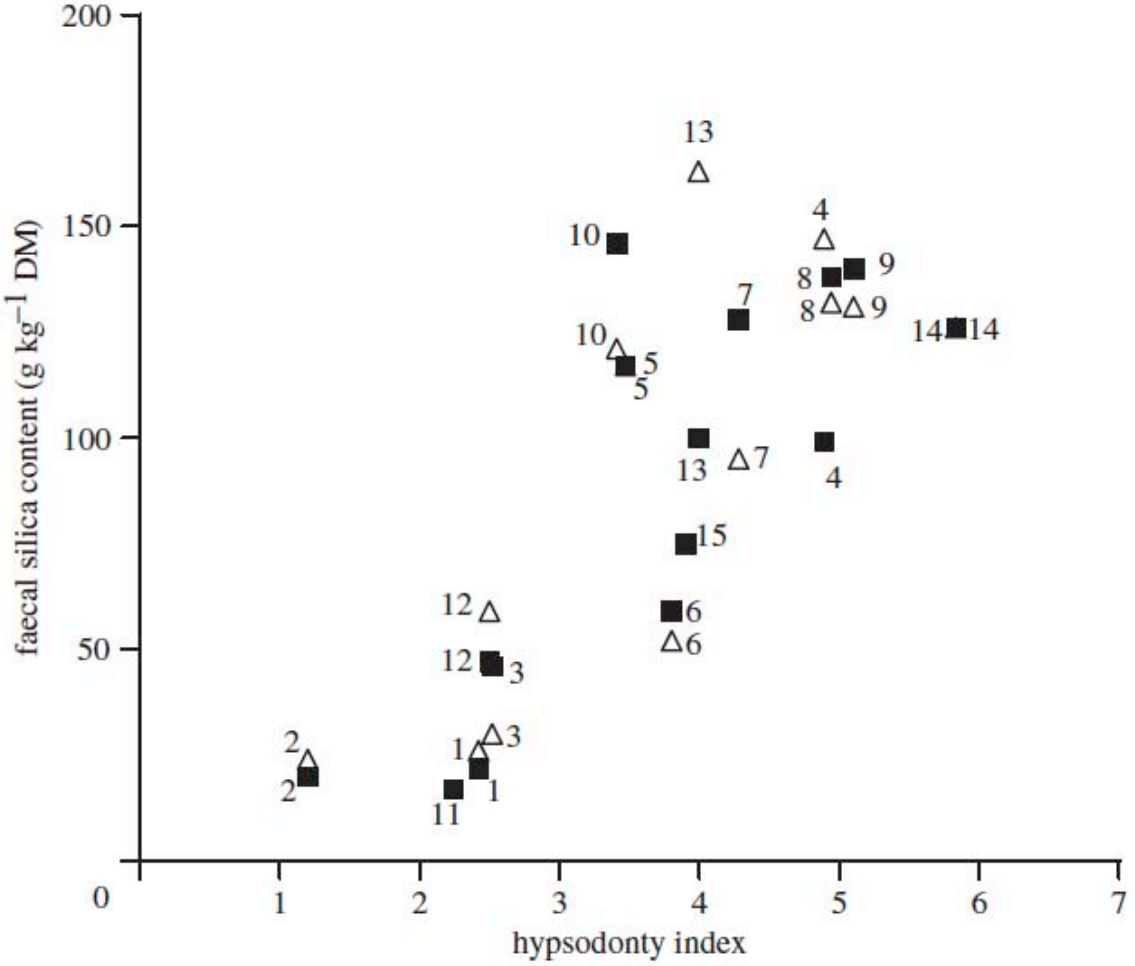
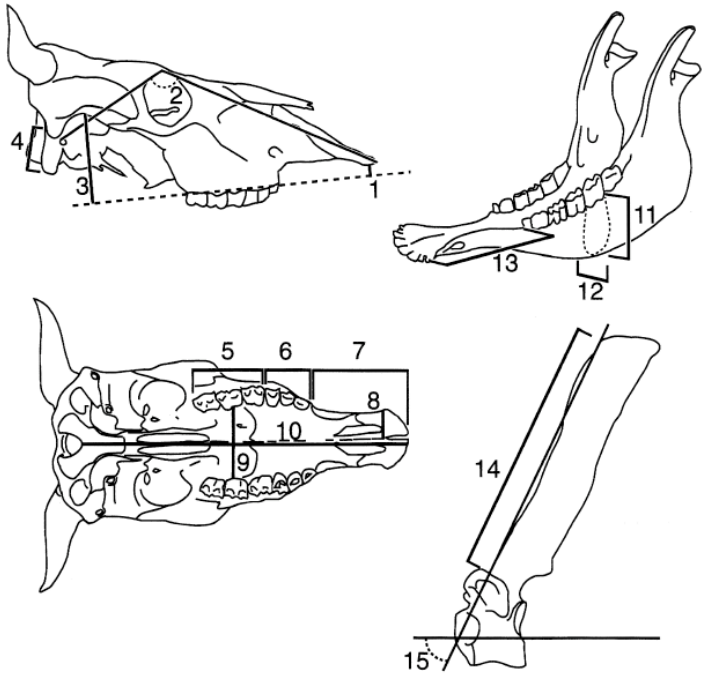
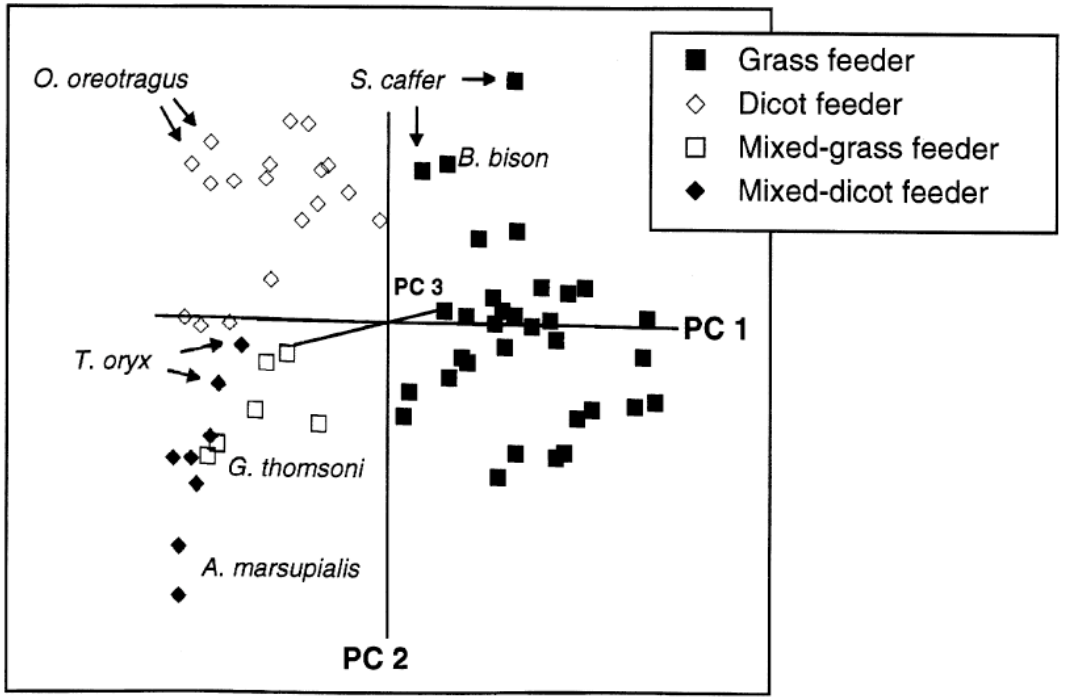


Hummel et al. (2011)

Form &Function

- Often, the pattern may be obvious but the underlying cause (function) is not





from Spencer (1995)

The comparative method

- **A certain type of food is, in many different species, associated with a certain set of adaptations**

  (i.e. we determine convergence)
- **‘*because* …’**

  … and we assume a function

  … and we use words to label our findings

Don't believe names, think for yourself!

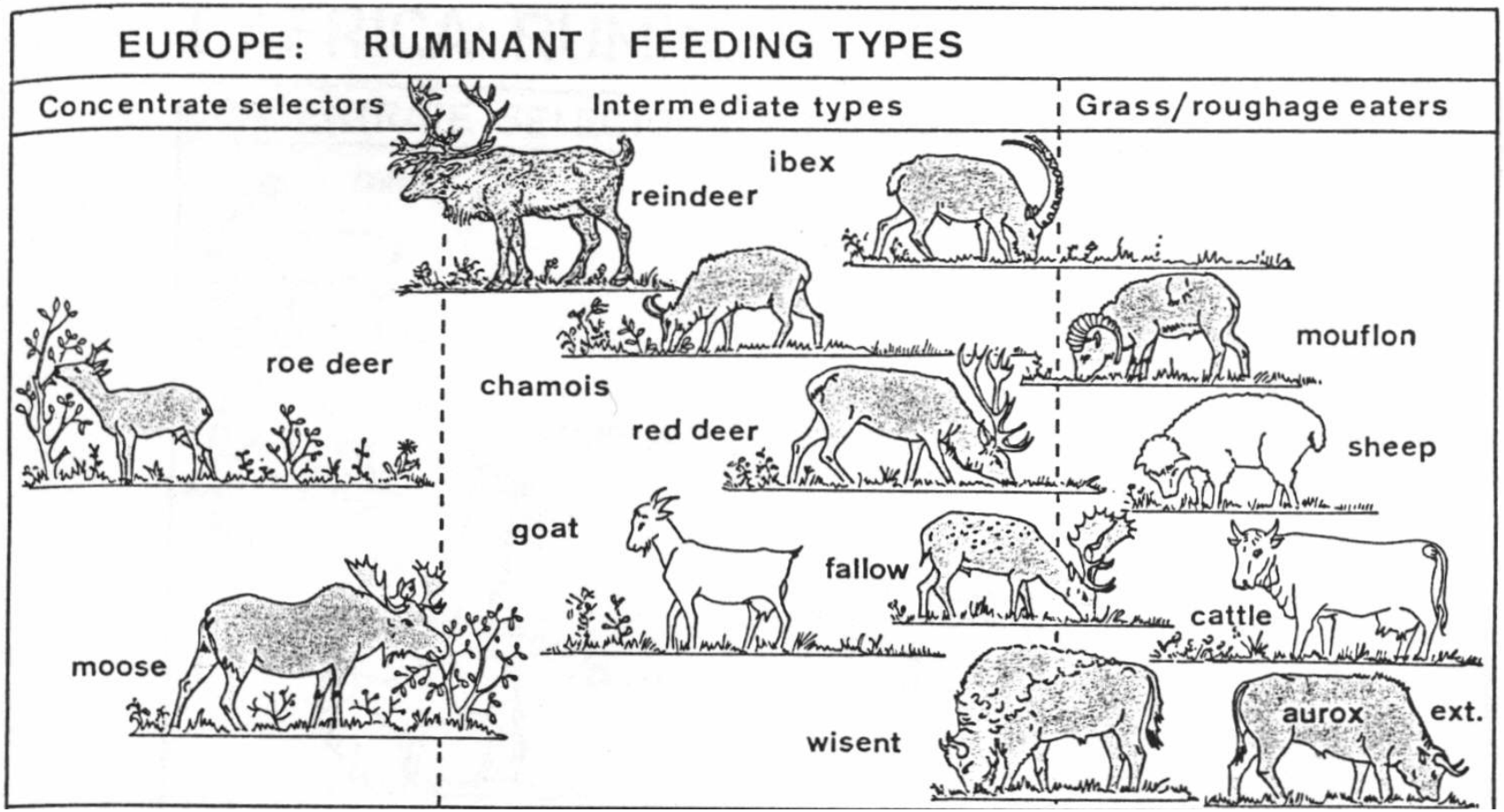
- **Because an animal is a 'frugivore' this does not mean it eats highly digestible, low-fibre food**

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!

- **What is a ‘concentrate selector’?**



from Hofmann (1989)

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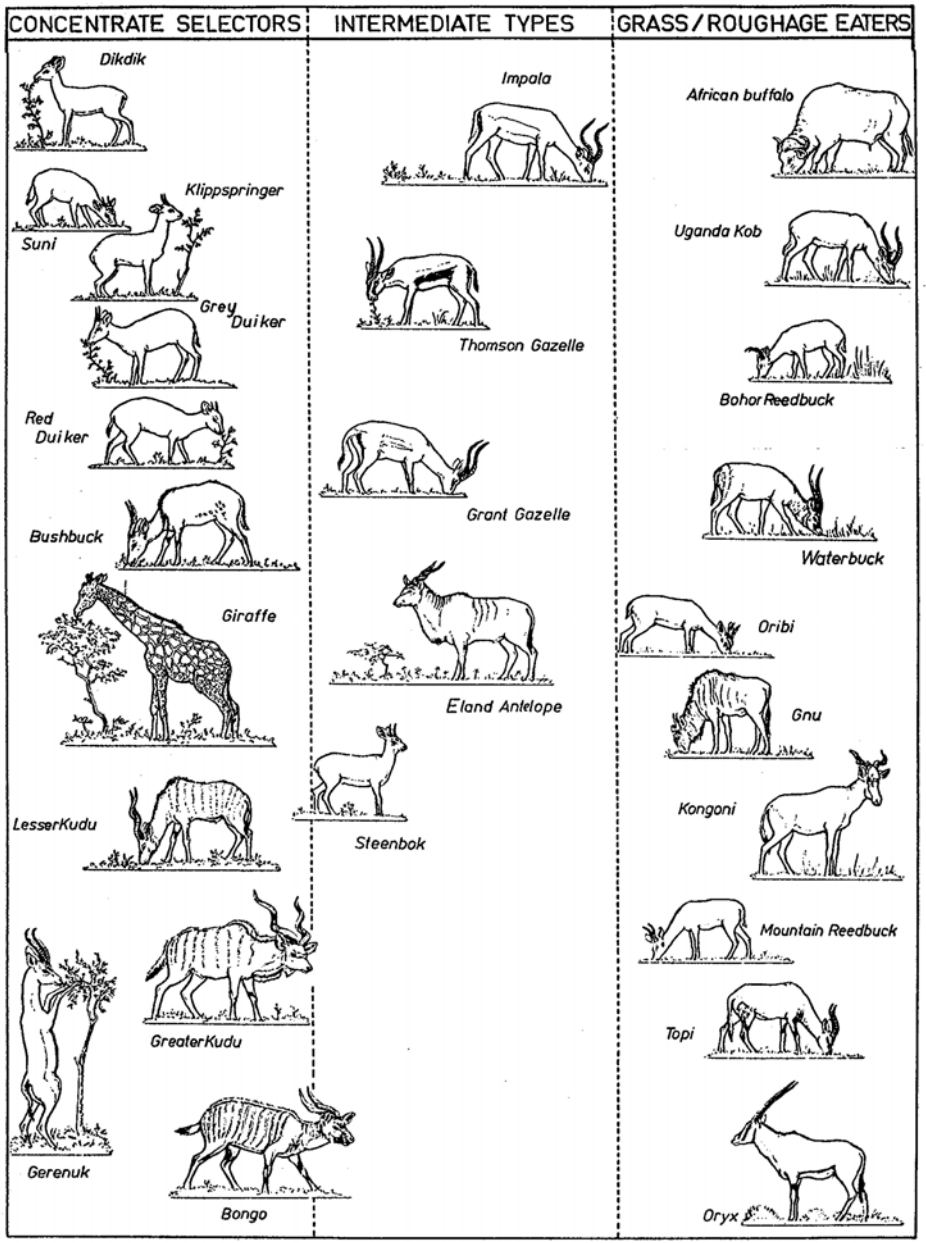

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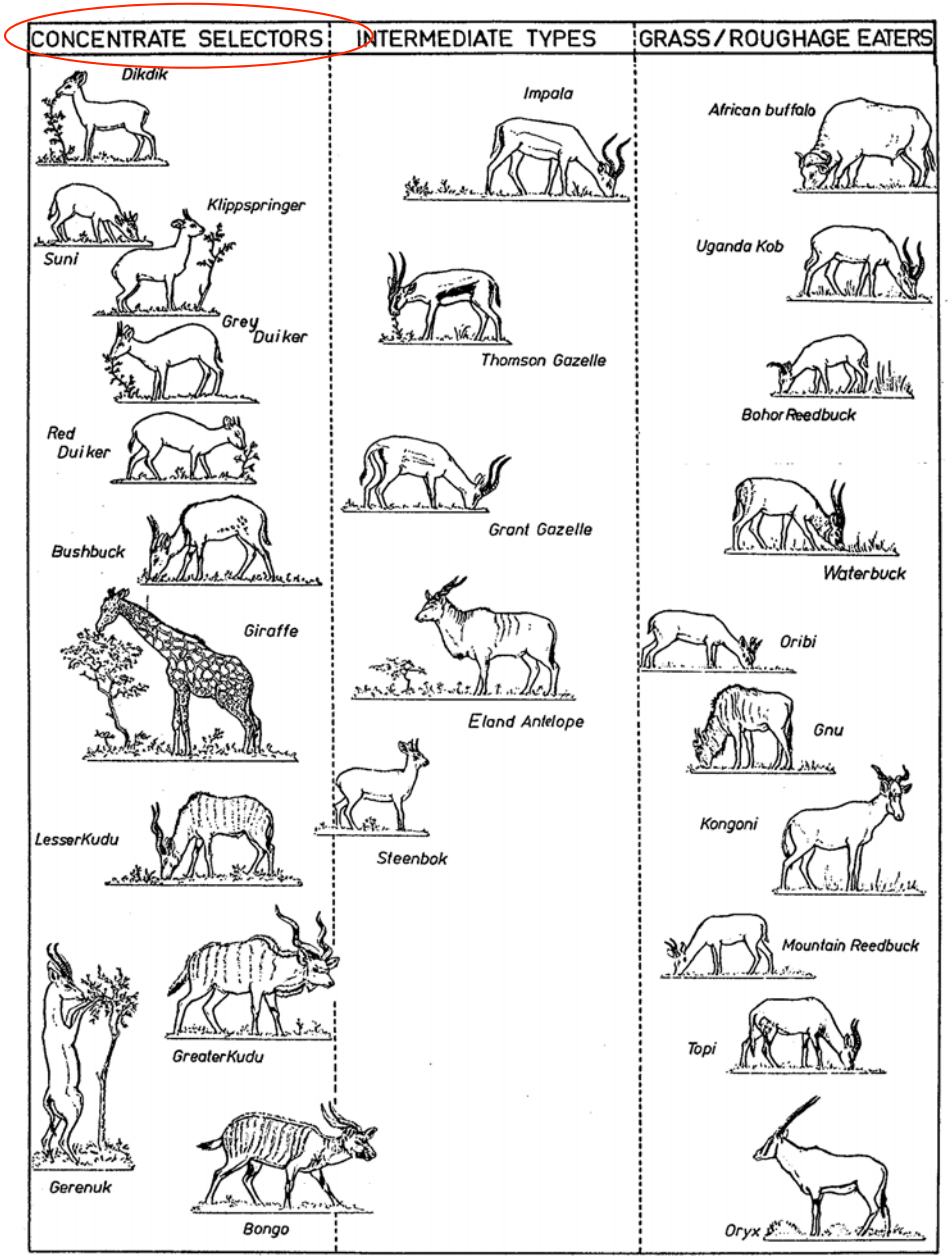

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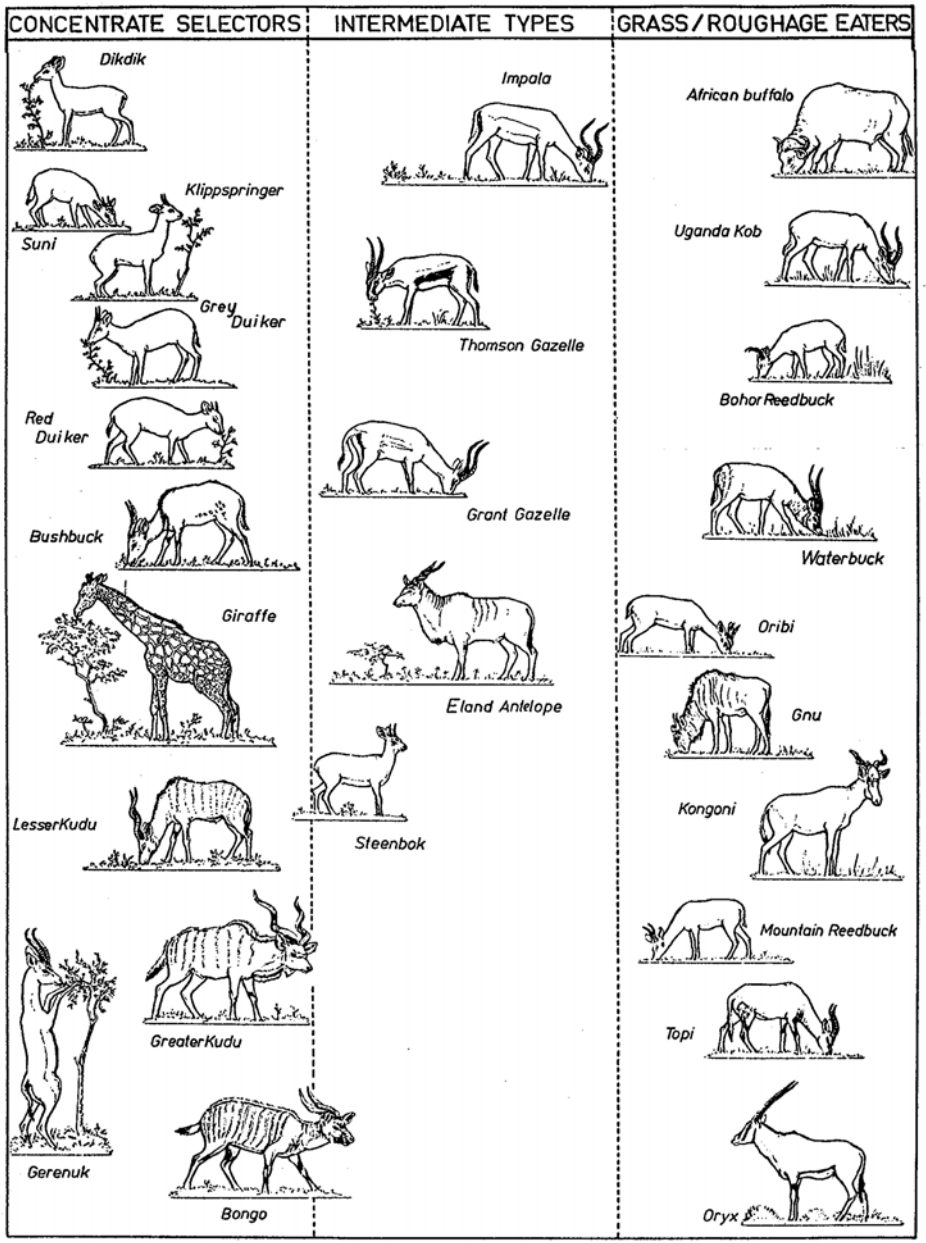
Crude fibre in rumen contents (%DM)



from Hofmann (1989) and Woodall (1992)

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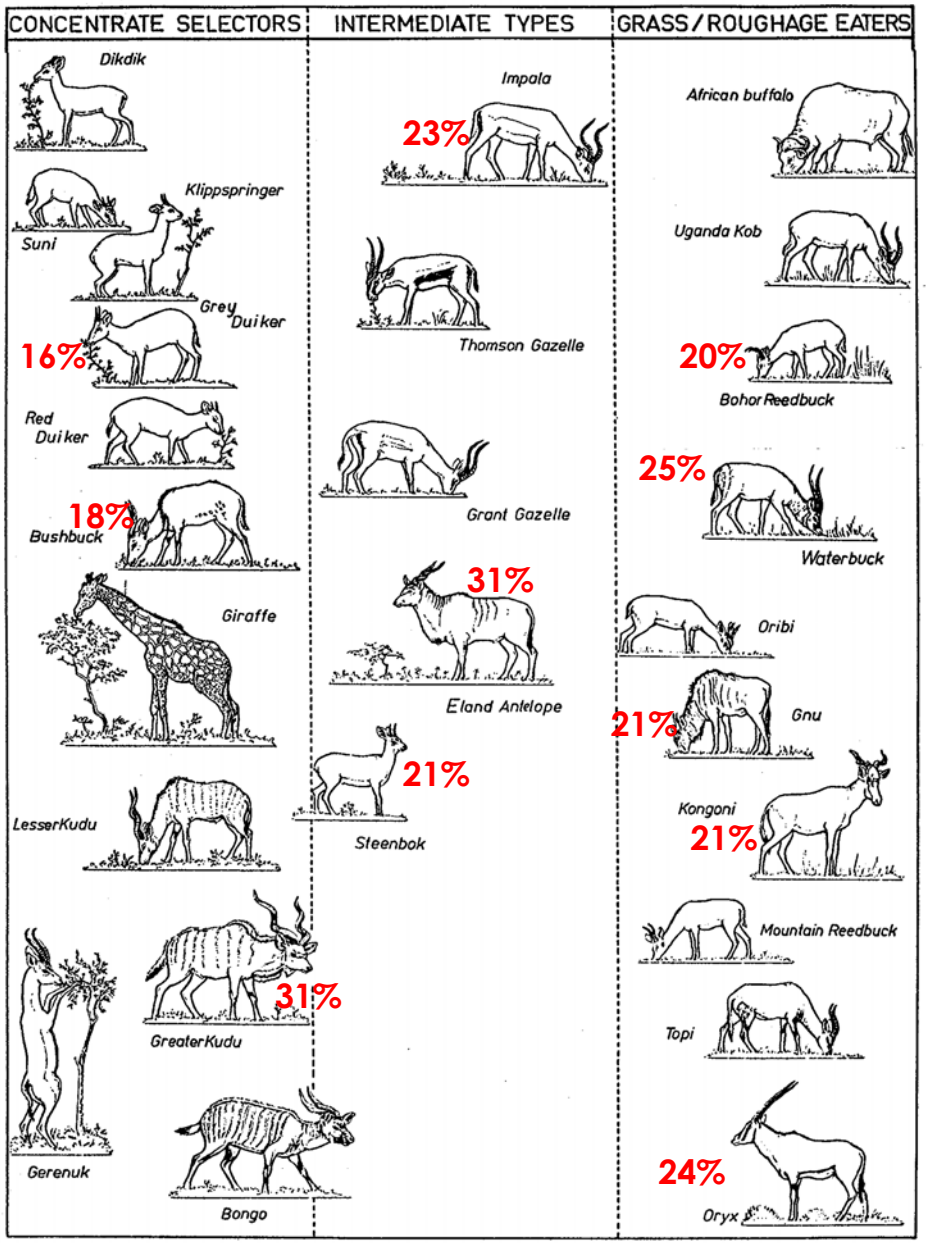

from Hofmann (1989) and Woodall (1992)

The comparative method

- **A certain type of food is, in many different species, associated with a certain set of adaptations**

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Convergence is not a proof of function (only circumstantial evidence).

Comparative digestive physiology

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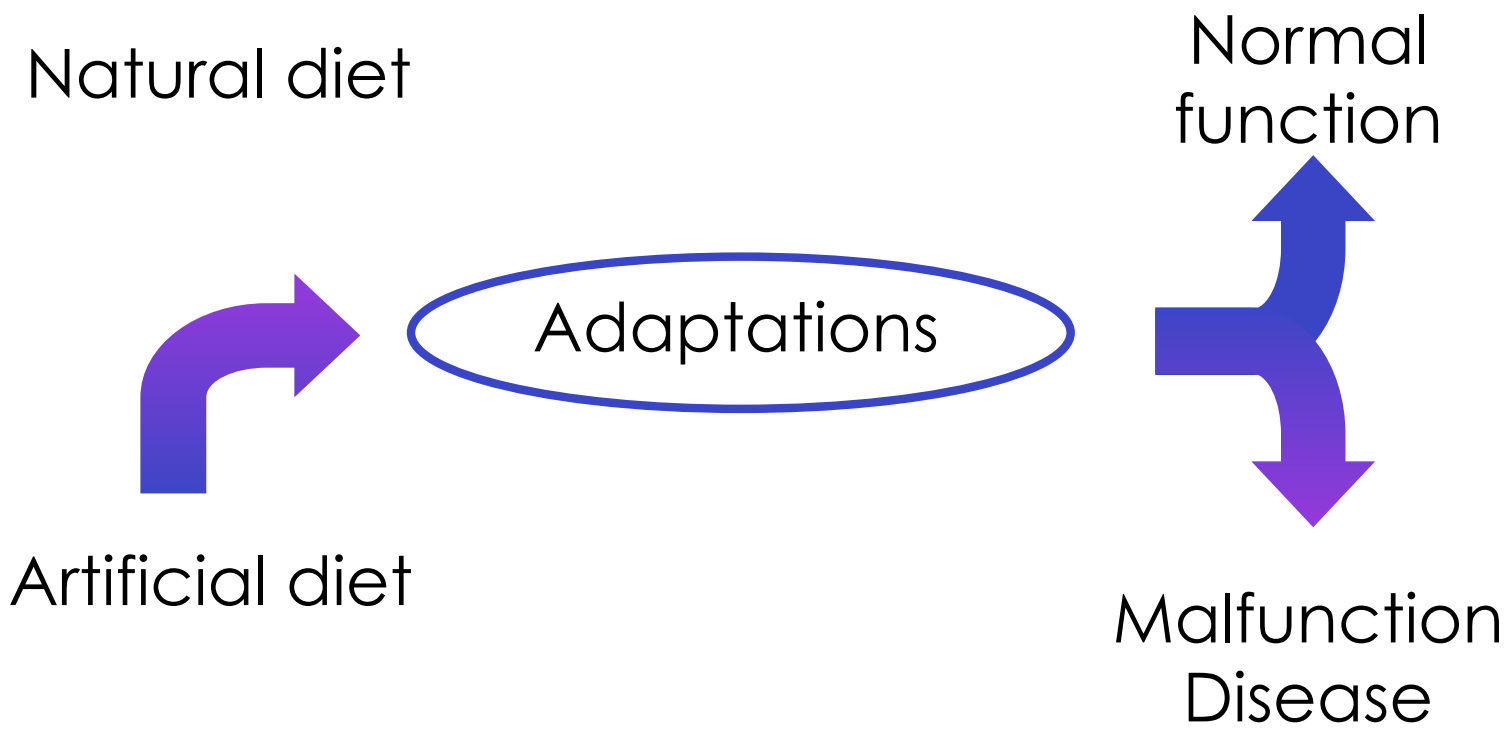
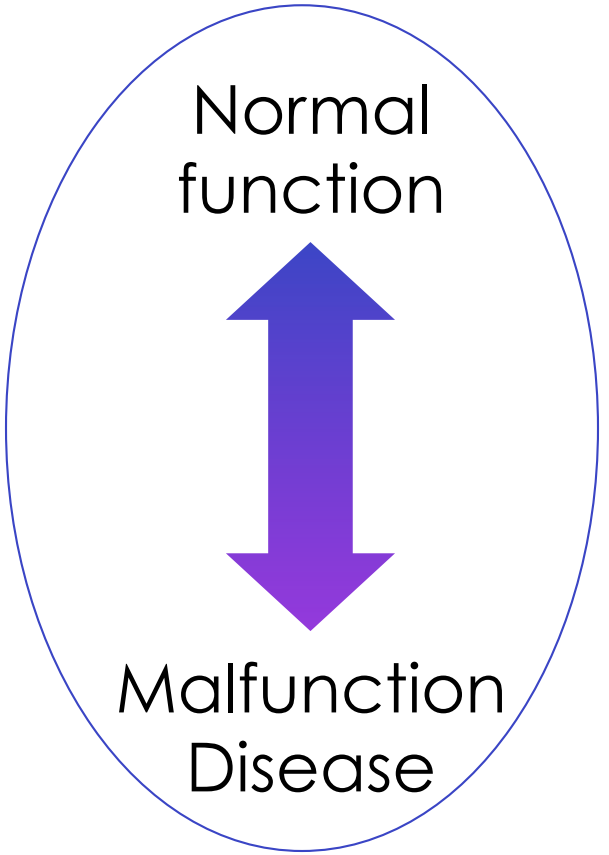


Comparative digestive physiology

Natural diet

Adaptations

Artificial diet



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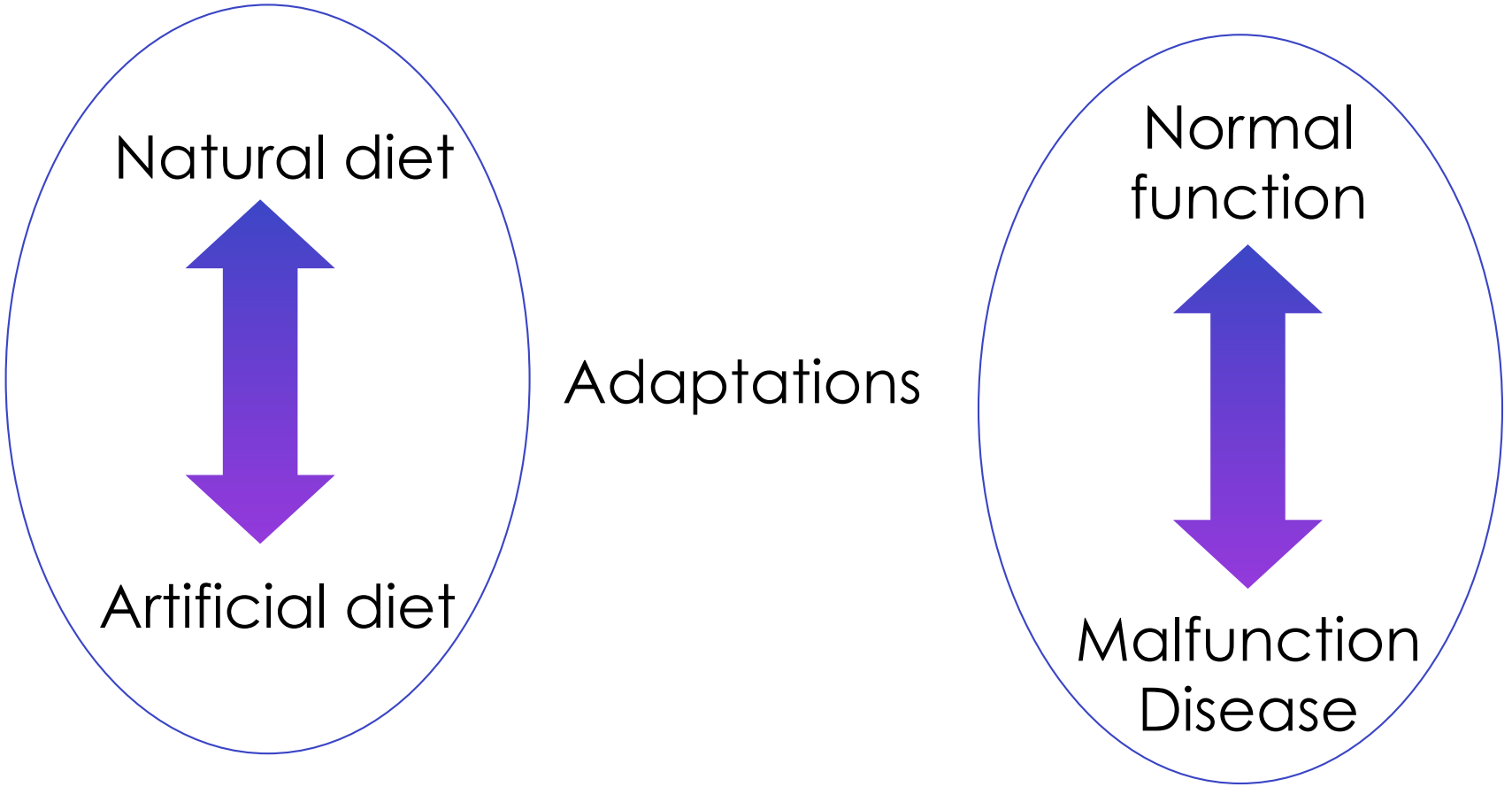

Comparative digestive physiology

Adaptations

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careful evaluation of concepts, size of effect, functional logic, functional relevance

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... but not everything that is exists must therefore be adaptive

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careful evaluation of concepts, size of effect, functional logic, functional relevance

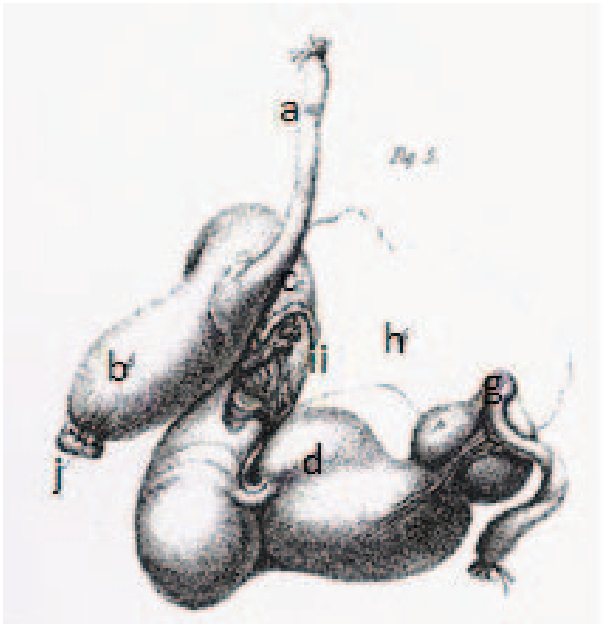
Adaptations

... but not everything that is exists must therefore be adaptive

but might be a part of the evolutionary history

Form & Function

Baleen whales, with their complex stomach system, feed on the same resource as whale sharks with a simple stomach-system



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