The everyday application of evolutionary concepts:

zoo medicine

Marcus Clauss

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Institute of Evolutionary Medicine, Zurich 2019

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Clinic of Zoo Animals, Exotic Pets and Wildlife

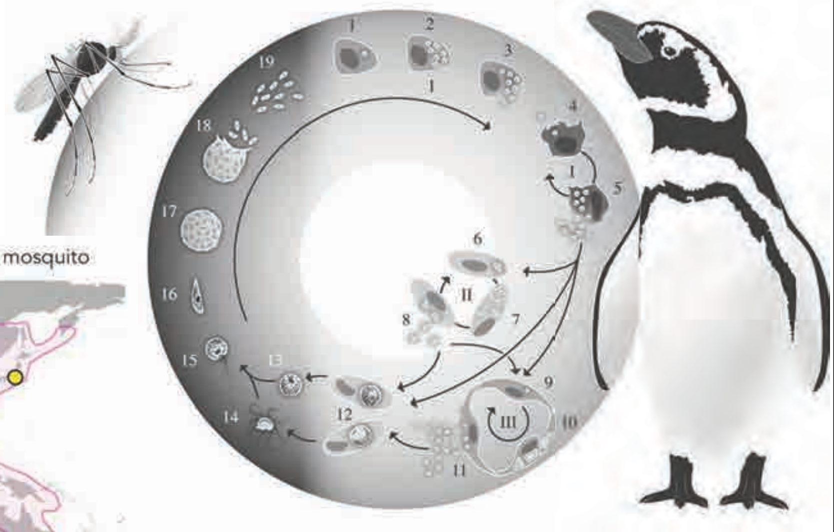
Penguin Malaria

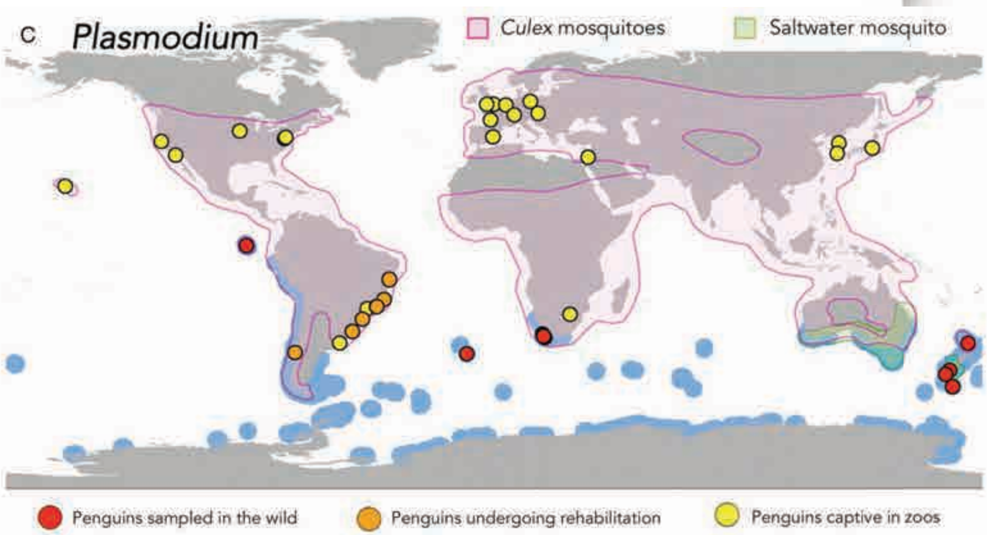
Malaria in penguins – current perceptions

AVIAN PATHOLOGY, 2016
VOL. 45, NO. 4, 393–407

M. L. Grilo[a,b], R. E. T. Vanstreels[c], R. Wallace[d], D. García-Párraga[e], É. M. Braga[f], J. Chitty[g], J. L. Catão-Dias[c] and L. M. Madeira de Carvalho[a]

Avian malaria is a mosquito-borne disease caused by protozoans of the genus *Plasmodium*, and it is considered one of the most important causes of morbidity and mortality in captive penguins, both in zoological gardens and rehabilitation centres. Penguins are known to be highly susceptible to this disease, and outbreaks have been associated with mortality as high as 50–80% of affected captive populations within a few weeks. The disease has also been





Pinniped ocular disease

Prevalence of ocular anterior segment disease in captive pinnipeds

A. G. Greenwood,

Aquatic Mammals 1985, **1**, 13–15

Table 3. Effect of environmental factors on eye disease

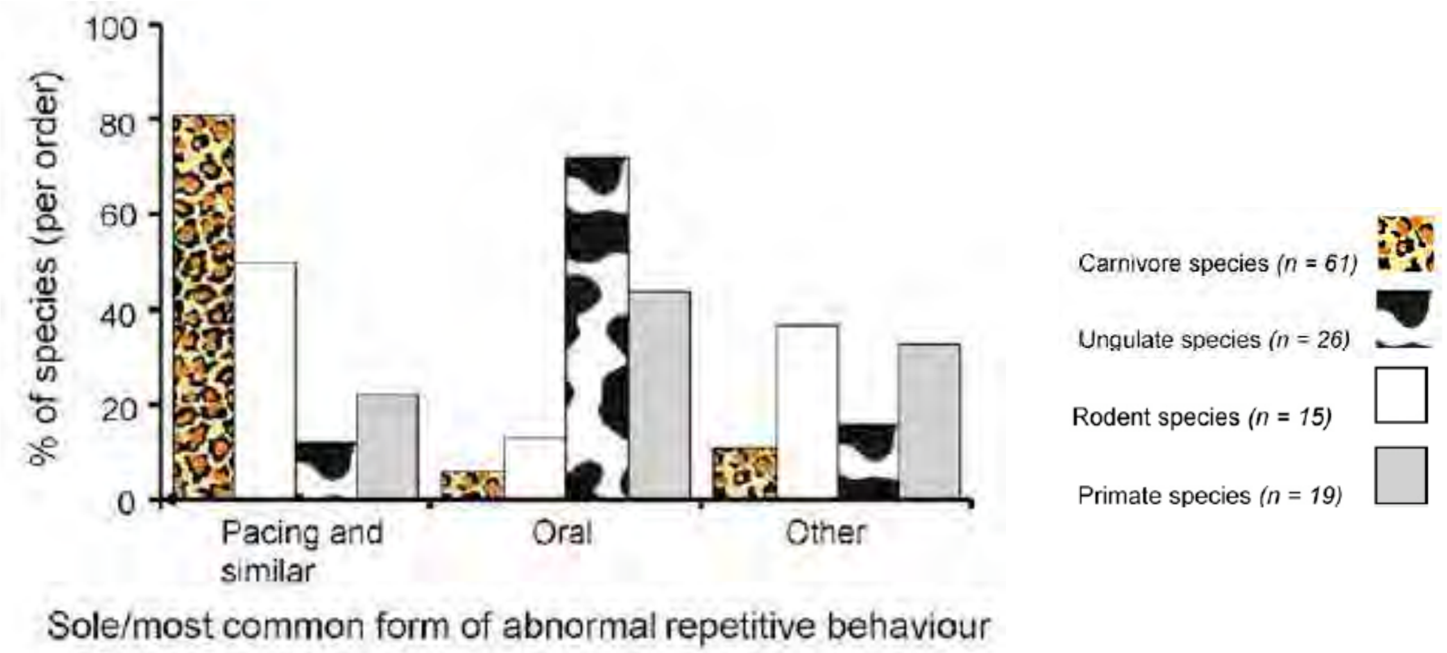
	Indoor	Outdoor	Fresh Water	Salt Water
Total	30	96	51	75
Number Affected	7	21	14	14
% Affected	23.33	21.9	27.45	18.66

Stereotypies

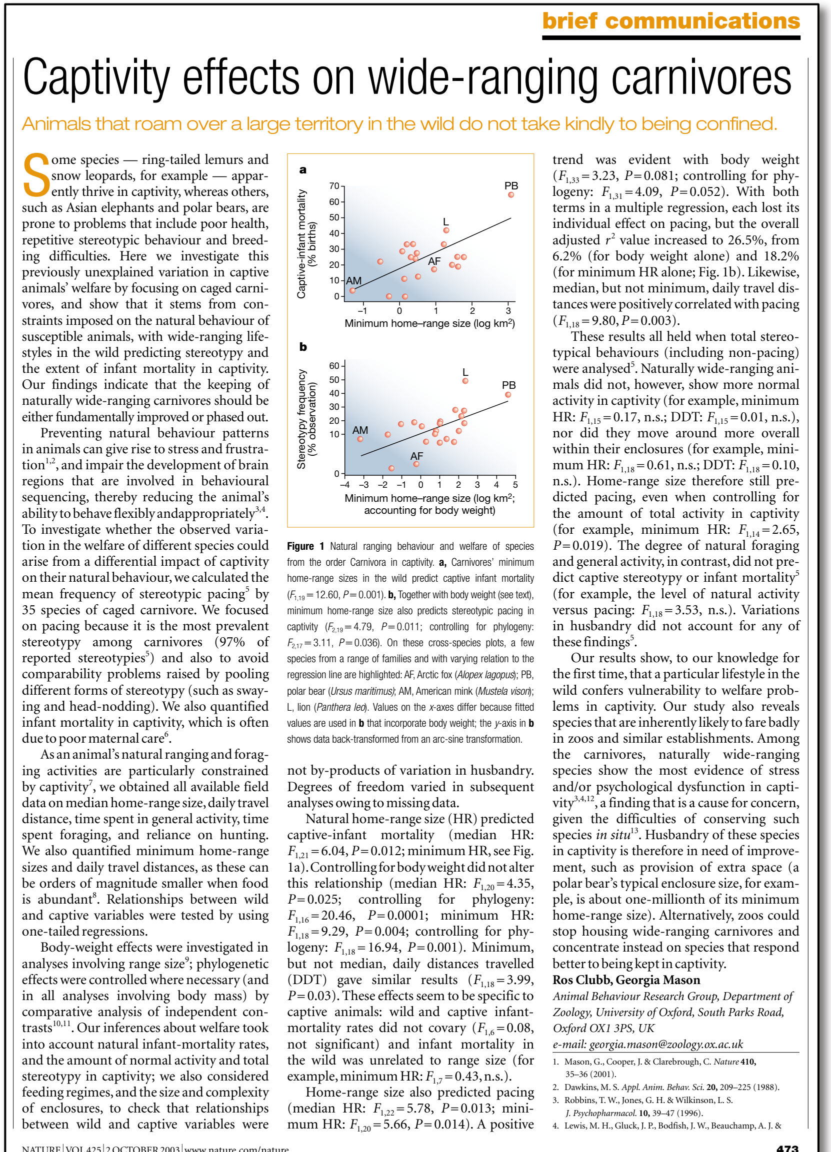
Why and how should we use environmental enrichment to tackle stereotypic behaviour?☆

G. Mason*, R. Clubb, N. Latham, S. Vickery

Applied Animal Behaviour Science 102 (2007) 163–188



Stereotypies



Captivity effects on wide-ranging carnivores

Animals that roam over a large territory in the wild do not take kindly to being confined.

Some species — ring-tailed lemurs and snow leopards, for example — apparently thrive in captivity, whereas others, such as Asian elephants and polar bears, are prone to problems that include poor health, repetitive stereotypic behaviour and breeding difficulties. Here we investigate this previously unexplained variation in captive animals' welfare by focusing on caged carnivores, and show that it stems from constraints imposed on the natural behaviour of susceptible animals, with wide-ranging lifestyles in the wild predicting stereotypy and the extent of infant mortality in captivity. Our findings indicate that the keeping of naturally wide-ranging carnivores should be either fundamentally improved or phased out.

Preventing natural behaviour patterns in animals can give rise to stress and frustration[1,2], and impair the development of brain regions that are involved in behavioural sequencing, thereby reducing the animal's ability to behave flexibly andappropriately[3,4]. To investigate whether the observed variation in the welfare of different species could arise from a differential impact of captivity on their natural behaviour, we calculated the mean frequency of stereotypic pacing[5] by 35 species of caged carnivore. We focused on pacing because it is the most prevalent stereotypy among carnivores (97% of reported stereotypies[5]) and also to avoid comparability problems raised by pooling different forms of stereotypy (such as swaying and head-nodding). We also quantified infant mortality in captivity, which is often due to poor maternal care[6].

As an animal's natural ranging and foraging activities are particularly constrained by captivity[7], we obtained all available field data on median home-range size, daily travel distance, time spent in general activity, time spent foraging, and reliance on hunting. We also quantified minimum home-range sizes and daily travel distances, as these can be orders of magnitude smaller when food is abundant[8]. Relationships between wild and captive variables were tested by using one-tailed regressions.

Body-weight effects were investigated in analyses involving range size[9]; phylogenetic effects were controlled where necessary (and in all analyses involving body mass) by comparative analysis of independent contrasts[10,11]. Our inferences about welfare took into account natural infant-mortality rates, and the amount of normal activity and total stereotypy in captivity; we also considered feeding regimes, and the size and complexity of enclosures, to check that relationships between wild and captive variables were not by-products of variation in husbandry. Degrees of freedom varied in subsequent analyses owing to missing data.

Figure 1 Natural ranging behaviour and welfare of species from the order Carnivora in captivity. **a,** Carnivores' minimum home-range sizes in the wild predict captive infant mortality ($F_{1,19}=12.60$, $P=0.001$). **b,** Together with body weight (see text), minimum home-range size also predicts stereotypic pacing in captivity ($F_{2,19}=4.79$, $P=0.011$; controlling for phylogeny: $F_{2,17}=3.11$, $P=0.036$). On these cross-species plots, a few species from a range of families and with varying relation to the regression line are highlighted: AF, Arctic fox (*Alopex lagopus*); PB, polar bear (*Ursus maritimus*); AM, American mink (*Mustela vison*); L, lion (*Panthera leo*). Values on the *x*-axes differ because fitted values are used in **b** that incorporate body weight; the *y*-axis in **b** shows data back-transformed from an arc-sine transformation.

Natural home-range size (HR) predicted captive-infant mortality (median HR: $F_{1,21}=6.04$, $P=0.012$; minimum HR, see Fig. 1a). Controlling for body weight did not alter this relationship (median HR: $F_{1,20}=4.35$, $P=0.025$; controlling for phylogeny: $F_{1,16}=20.46$, $P=0.0001$; minimum HR: $F_{1,18}=9.29$, $P=0.004$; controlling for phylogeny: $F_{1,18}=16.94$, $P=0.001$). Minimum, but not median, daily distances travelled (DDT) gave similar results ($F_{1,18}=3.99$, $P=0.03$). These effects seem to be specific to captive animals: wild and captive infant-mortality rates did not covary ($F_{1,6}=0.08$, not significant) and infant mortality in the wild was unrelated to range size (for example, minimum HR: $F_{1,7}=0.43$, n.s.).

Home-range size also predicted pacing (median HR: $F_{1,22}=5.78$, $P=0.013$; minimum HR: $F_{1,20}=5.66$, $P=0.014$). A positive trend was evident with body weight ($F_{1,33}=3.23$, $P=0.081$; controlling for phylogeny: $F_{1,31}=4.09$, $P=0.052$). With both terms in a multiple regression, each lost its individual effect on pacing, but the overall adjusted r^2 value increased to 26.5%, from 6.2% (for body weight alone) and 18.2% (for minimum HR alone; Fig. 1b). Likewise, median, but not minimum, daily travel distances were positively correlated with pacing ($F_{1,18}=9.80$, $P=0.003$).

These results all held when total stereotypical behaviours (including non-pacing) were analysed[5]. Naturally wide-ranging animals did not, however, show more normal activity in captivity (for example, minimum HR: $F_{1,15}=0.17$, n.s.; DDT: $F_{1,15}=0.01$, n.s.), nor did they move around more overall within their enclosures (for example, minimum HR: $F_{1,18}=0.61$, n.s.; DDT: $F_{1,18}=0.10$, n.s.). Home-range size therefore still predicted pacing, even when controlling for the amount of total activity in captivity (for example, minimum HR: $F_{1,14}=2.65$, $P=0.019$). The degree of natural foraging and general activity, in contrast, did not predict captive stereotypy or infant mortality[5] (for example, the level of natural activity versus pacing: $F_{1,18}=3.53$, n.s.). Variations in husbandry did not account for any of these findings[5].

Our results show, to our knowledge for the first time, that a particular lifestyle in the wild confers vulnerability to welfare problems in captivity. Our study also reveals species that are inherently likely to fare badly in zoos and similar establishments. Among the carnivores, naturally wide-ranging species show the most evidence of stress and/or psychological dysfunction in captivity[3,4,12], a finding that is a cause for concern, given the difficulties of conserving such species *in situ*[13]. Husbandry of these species in captivity is therefore in need of improvement, such as provision of extra space (a polar bear's typical enclosure size, for example, is about one-millionth of its minimum home-range size). Alternatively, zoos could stop housing wide-ranging carnivores and concentrate instead on species that respond better to being kept in captivity.

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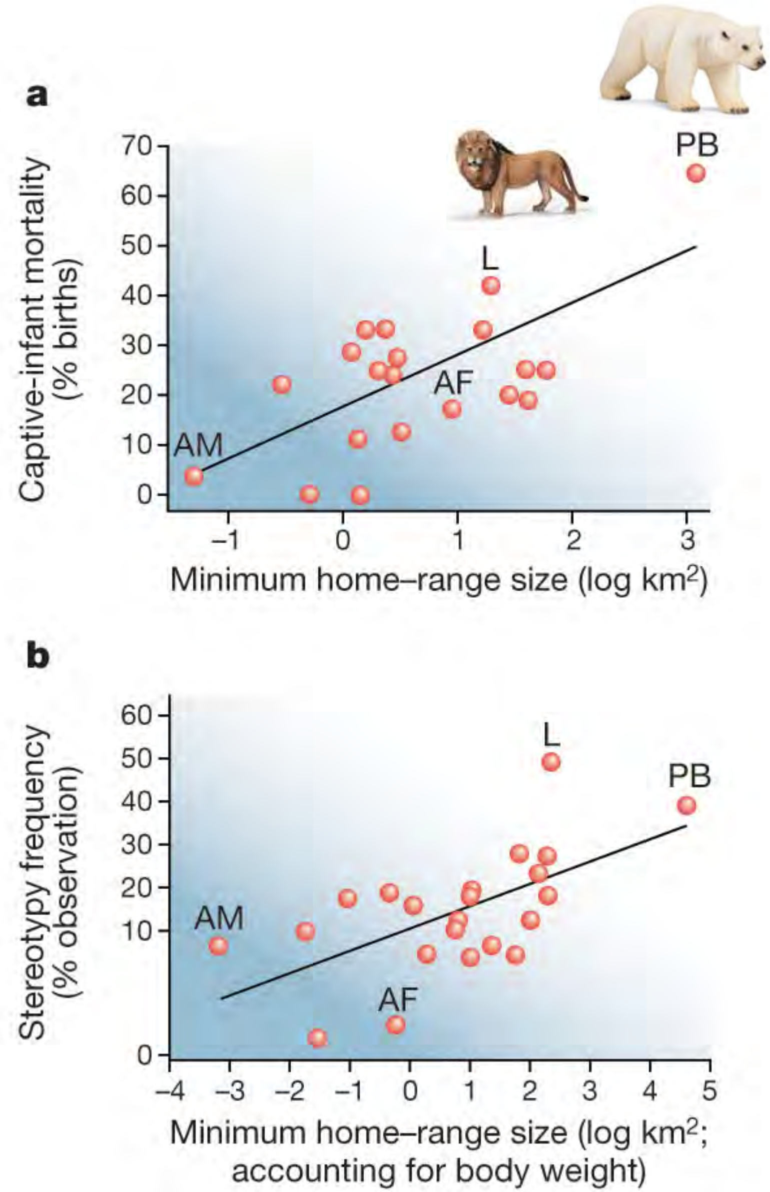
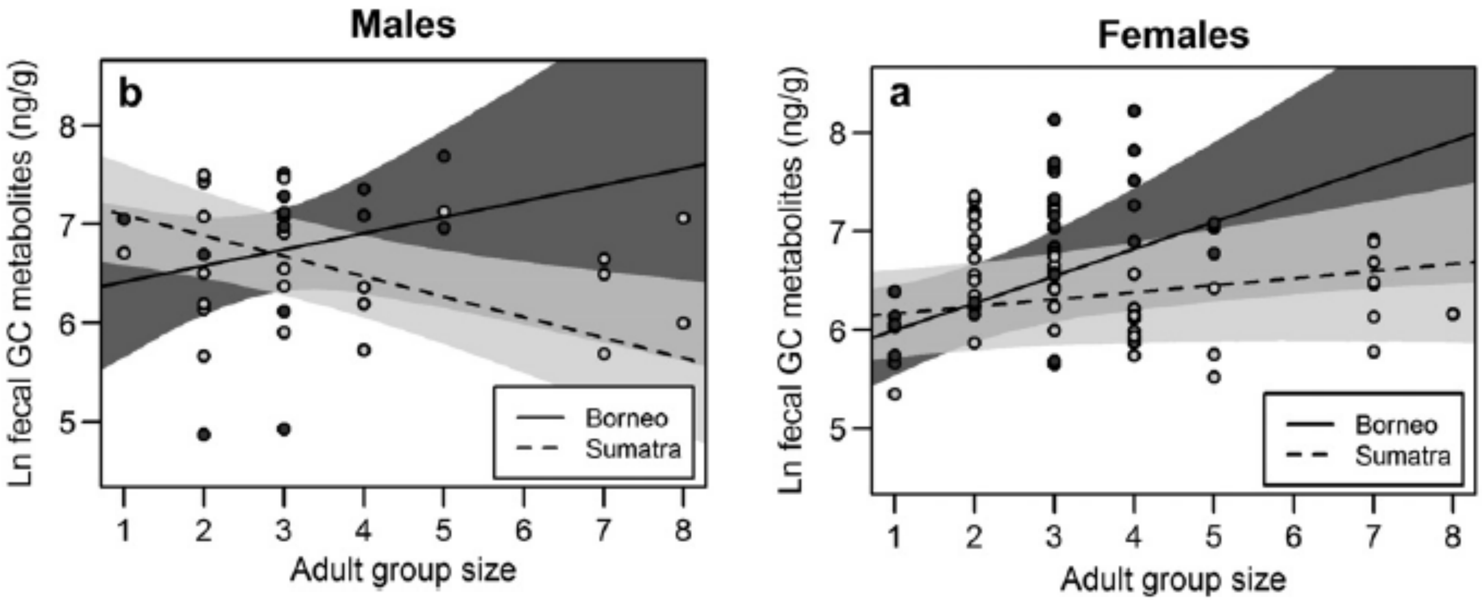


Sociality

Species-specific patterns in fecal glucocorticoid and androgen levels in zoo-living orangutans (*Pongo* spp.)

Tony Weingrill[a,*], Erik P. Willems[a], Nina Zimmermann[b], Hanspeter Steinmetz[c], Michael Heistermann[d]

General and Comparative Endocrinology 172 (2011) 446–457



Sociality

Upper respiratory tract disease in captive orangutans (*Pongo* sp.): prevalence in 20 European zoos and predisposing factors

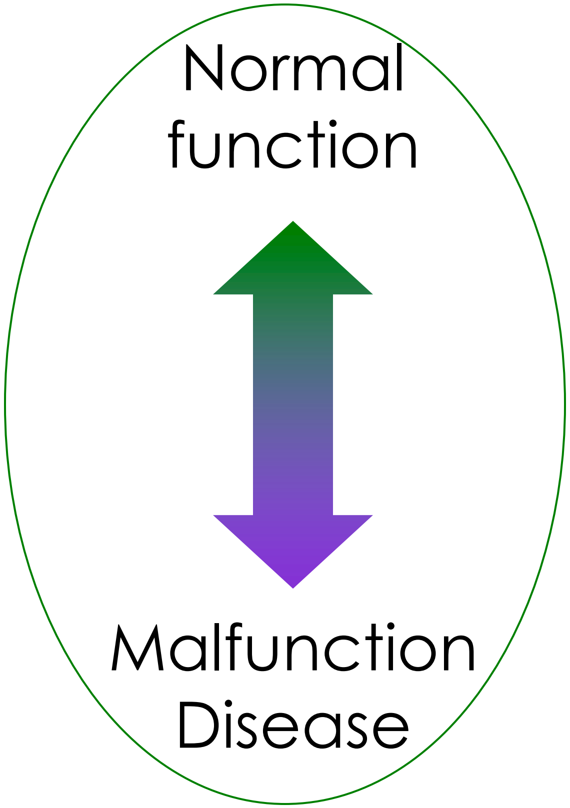
N. Zimmermann[1], M. Pirovino[1], R. Zingg[2], M. Clauss[1], F.J. Kaup[3], M. Heistermann[4], J.M. Hatt[1] & H.W. Steinmetz[1]

J Med Primatol **40** (2011) 365–375

Table 3 Individual factors possibly influencing the incidence of 'chronic respiratory signs only' (without air sacculitis) or 'air sacculitis' in captive orangutans (*Pongo pygmaeus, Pongo abelii*) (n = 170–201) of 20 European zoos, with respective data available from 1969 to 2009. Yates corrected chi-square test results for qualitative data are shown in (A), while *t*-test and Mann–Whitney *U*-test results for quantitative data are shown in (B)

		Animals (n)			*P*	
Individual factors	Total animals	Healthy	Chronic signs only	Air sacculitis	Chronic signs only	Air sacculitis
(A)						
Species						
P. pygmaeus	80	61	11	8	**0.026**	0.700
P. abelii	112	92	4	16		
Sex						
Male	76	53	12	11	**0.001**	0.489
Female	125	107	3	15		
Rearing						
Hand	100	73	6	21	0.883	**0.002**
Parent	101	87	9	5		

The simple vet's world view



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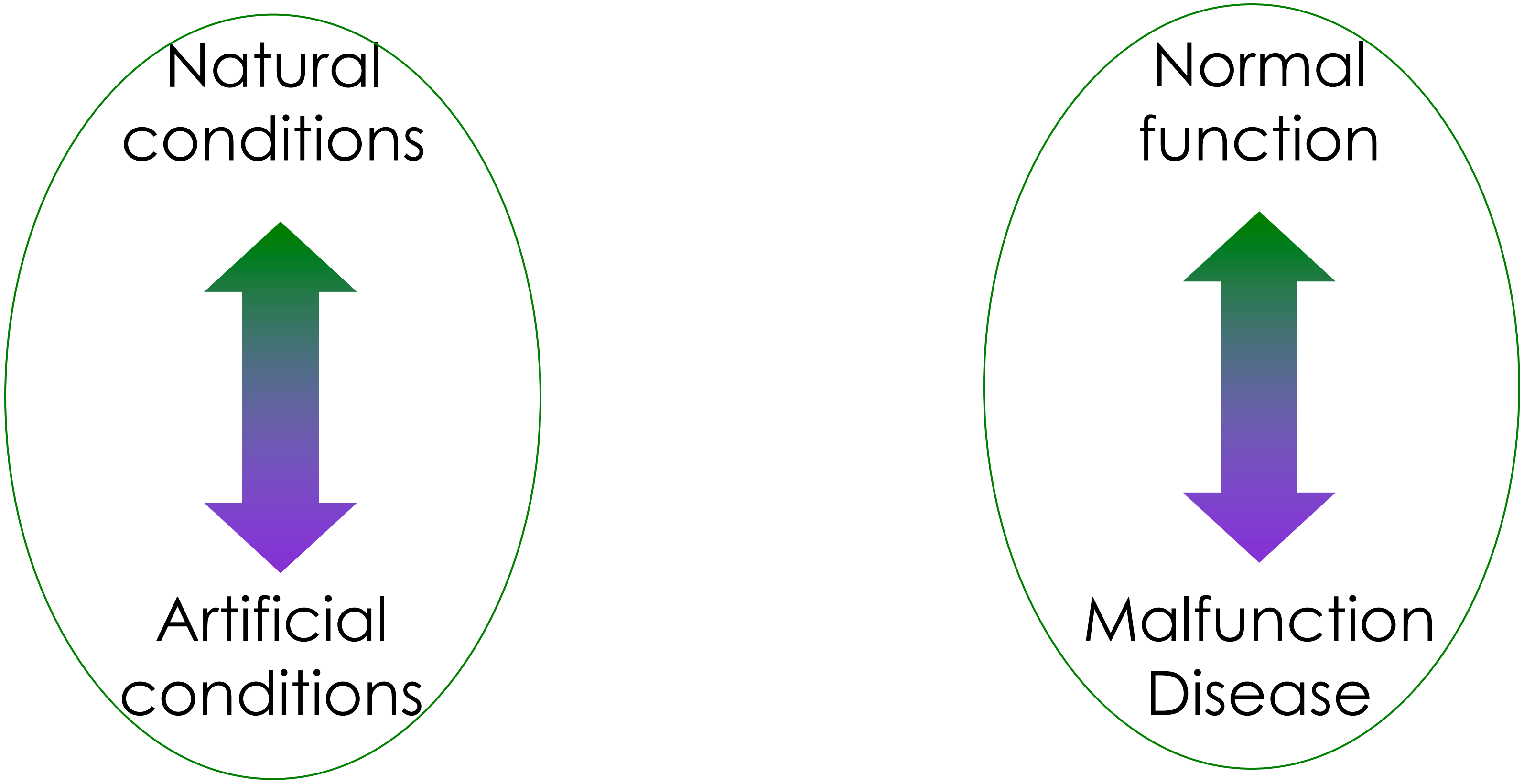

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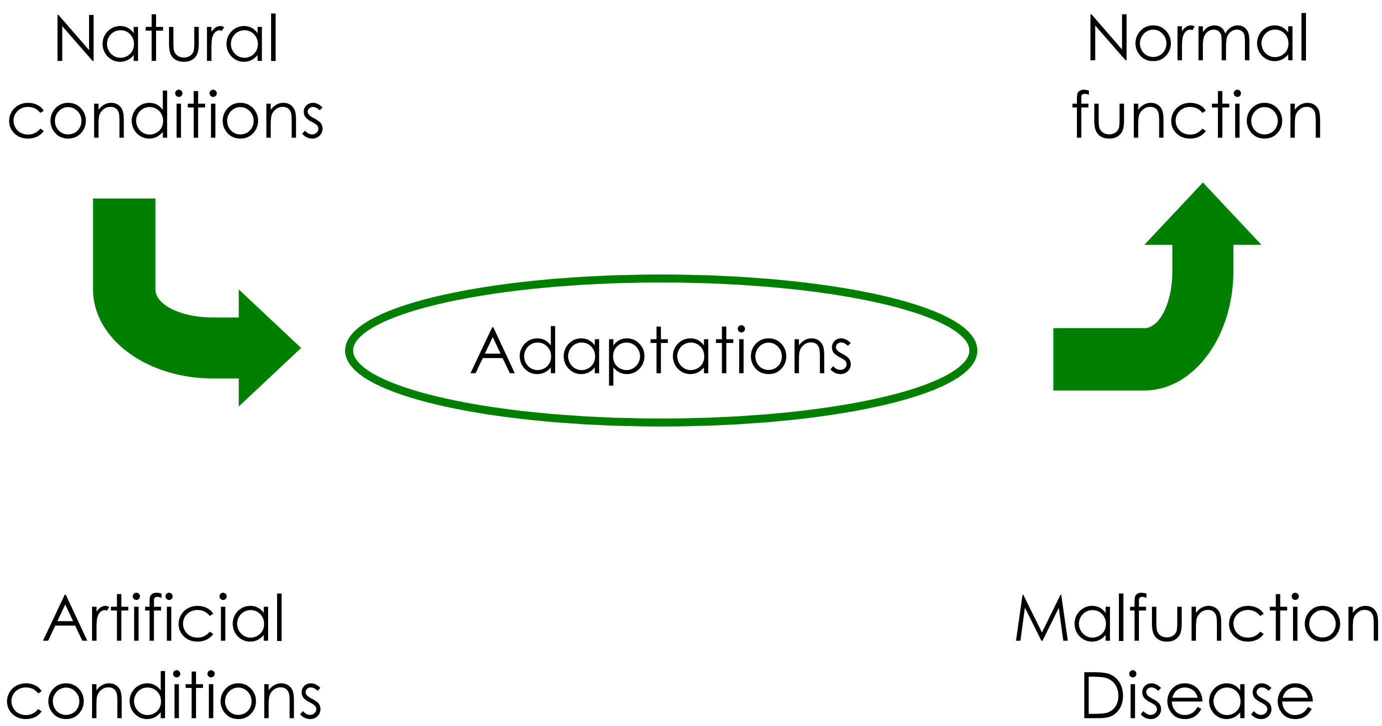

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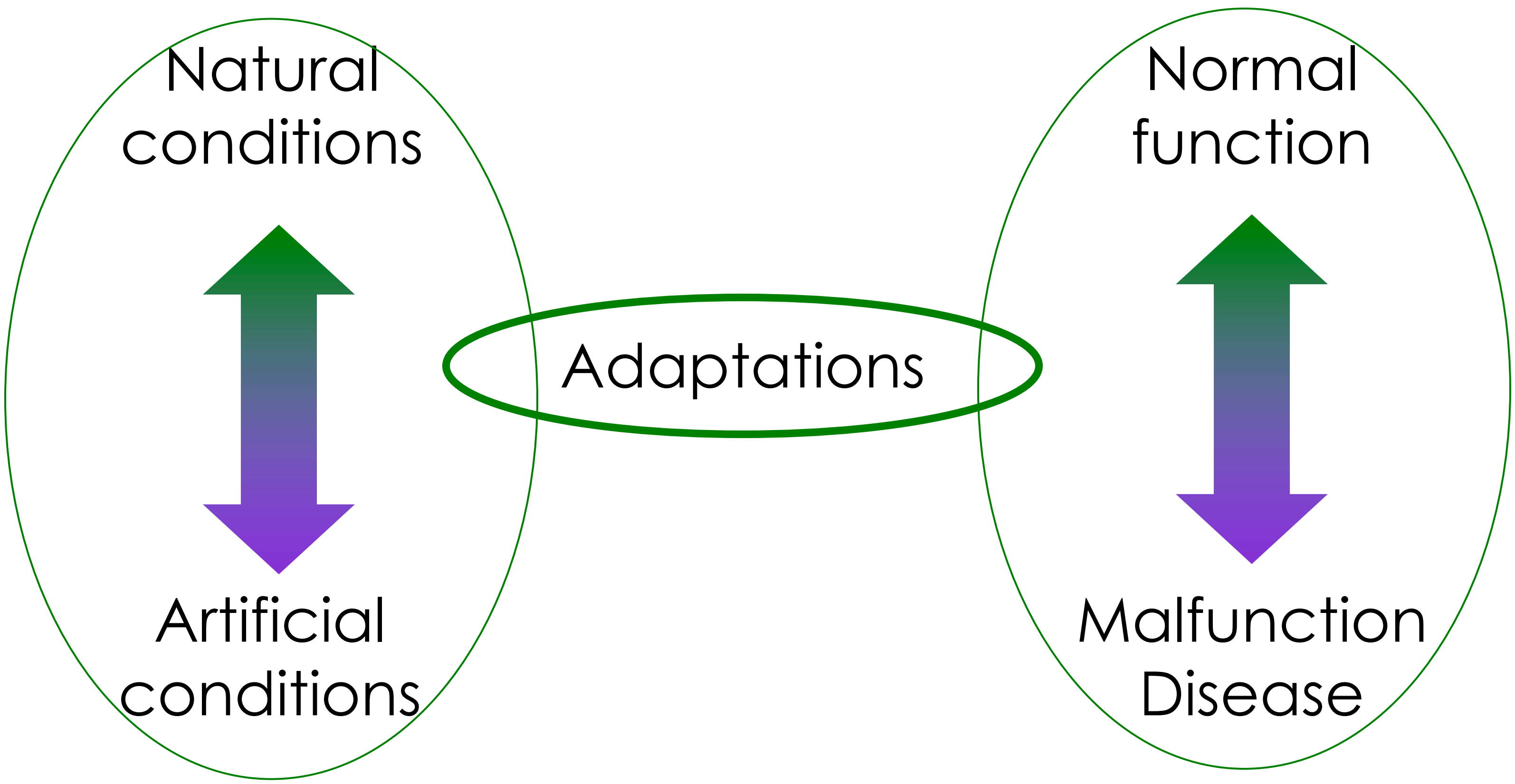

PALEOLITHIC NUTRITION

A Consideration of Its Nature and Current Implications

S. Boyd Eaton, M.D., and Melvin Konner, Ph.D.

THE NEW ENGLAND JOURNAL OF MEDICINE Jan. 31, 1985

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Paleolithic Nutrition

Nutrition in Clinical Practice
Volume 25 Number 6
December 2010 594-602

Twenty-Five Years Later

Melvin Konner, MD, PhD[1]; and S. Boyd Eaton, MD[2]

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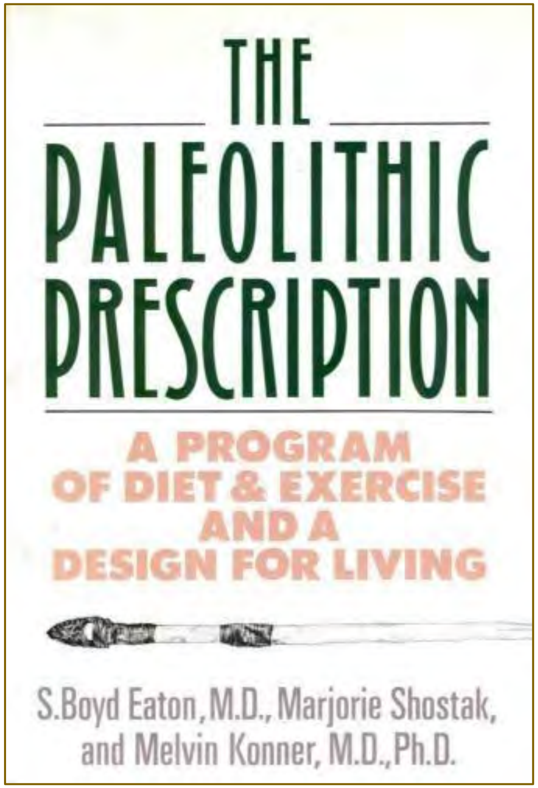

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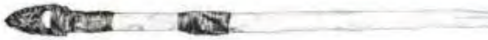
THE PALEOLITHIC PRESCRIPTION

A PROGRAM OF DIET & EXERCISE AND A DESIGN FOR LIVING



S.Boyd Eaton, M.D., Marjorie Shostak, and Melvin Konner, M.D., Ph.D.

We Are The Founders of The Paleo Diet®

As a professor at Colorado State University, Dr. Loren Cordain developed The Paleo Diet® through decades of research and collaboration with fellow scientists around the world.

When Dr. Cordain began working on the concept of The Paleo Diet®, curiosity for the optimal human diet drove his research. He wasn't searching for opportunities to sell a product or promote a business.

His journey led to many years of collaboration with world-renowned scientists, including Dr. Boyd Eaton and Dr. Staffan Lindeberg. After 15 years of exploring all of the available research, The Paleo Diet® was born. Dr. Cordain coined the term "The Paleo Diet®" and wrote his first book to share their discovery with the world

THE LANCET JUNE 22, 1968

FATTY-ACID RATIOS IN FREE-LIVING AND DOMESTIC ANIMALS

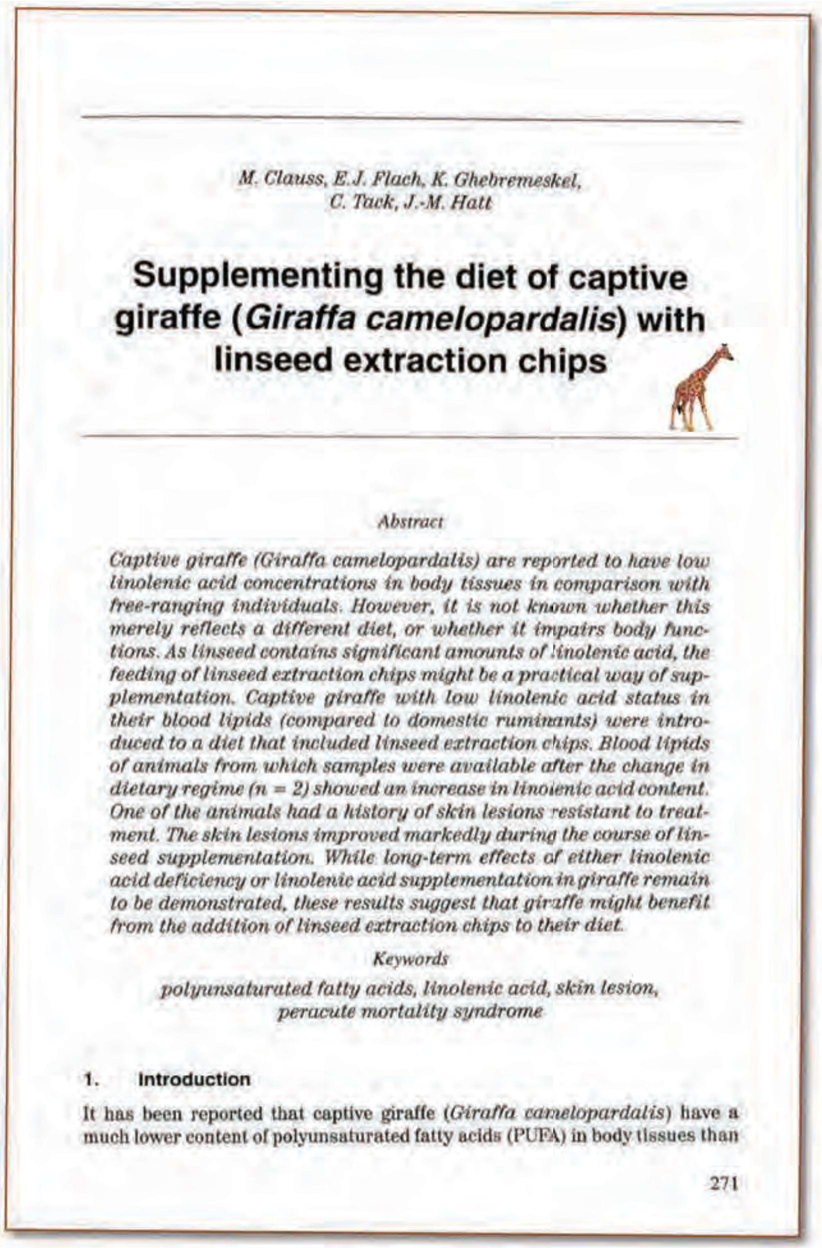
Possible Implications for Atheroma

M. A. CRAWFORD
B.Sc. Edin. Ph.D. Lond.

OF THE NUFFIELD INSTITUTE OF COMPARATIVE MEDICINE, ZOOLOGICAL SOCIETY OF LONDON, LONDON N.W.1

TABLE III—PROPORTIONS (*molecular equivalents*) OF POLYUNSATURATED FATTY ACIDS TO THE SATURATED AND MONOUNSATURATED FROM VARIOUS SOURCES

Source	Proportion	Source	Proportion
Wild African woodland/bushland:		*Captive and domestic:*	
Eland	35/65	Giraffe (mean of 2)	4/96
Hartebeest (1)	32/68	Somali fat-tailed sheep	4/96
Hartebeest (2)	29/71	Domestic pork	8/92
Topi	23/76	Man (Western)	4/96
Warthog	27/63	Beef	2/98
Giraffe	39/61	*Food sources (cattle products):*	
Plains, grassland:		Colostral milk †	3/97
Topi	8/92	Mature milk †	2/98
Uganda kob	2/98	Butter †	2/98
Birds:		*Human milk:*	
Wild grouse *	60/40	U.S.A.†	8/92
Domestic chicken	17/83	U.S.A.‡	11/89
		Japan §	20/80
		Japan §	25/75



M. Clauss, E.J. Flach, K. Ghebremeskel,
C. Tack, J.-M. Hatt

Supplementing the diet of captive giraffe (*Giraffa camelopardalis*) with linseed extraction chips

Abstract

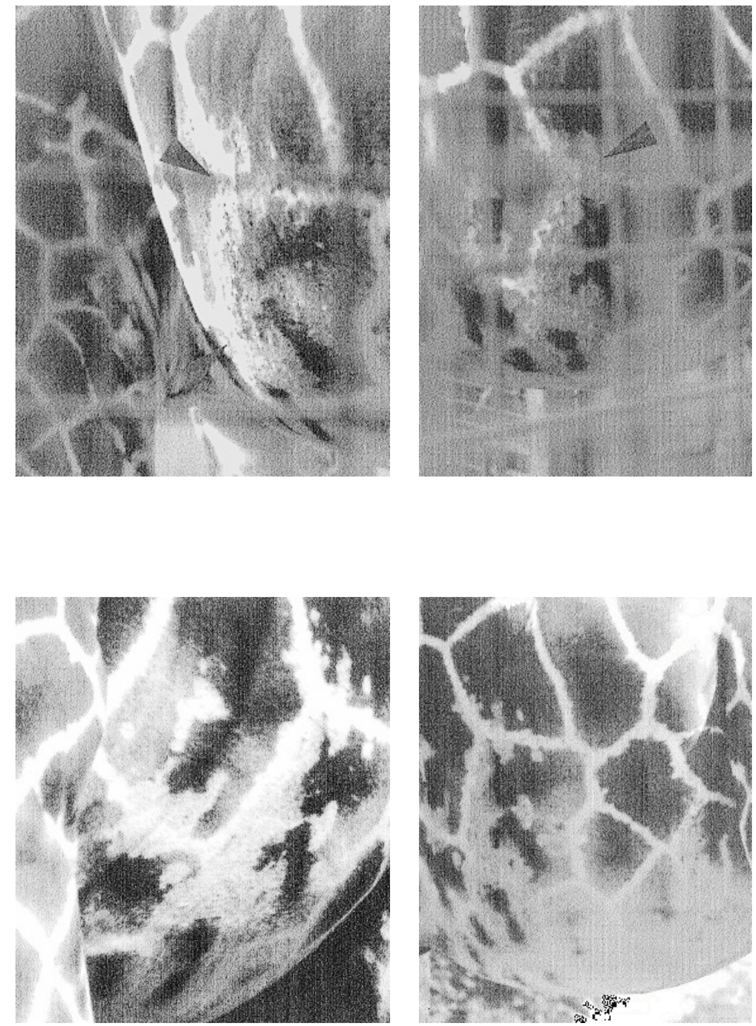
Captive giraffe (Giraffa camelopardalis) are reported to have low linolenic acid concentrations in body tissues in comparison with free-ranging individuals. However, it is not known whether this merely reflects a different diet, or whether it impairs body functions. As linseed contains significant amounts of linolenic acid, the feeding of linseed extraction chips might be a practical way of supplementation. Captive giraffe with low linolenic acid status in their blood lipids (compared to domestic ruminants) were introduced to a diet that included linseed extraction chips. Blood lipids of animals from which samples were available after the change in dietary regime (n = 2) showed an increase in linolenic acid content. One of the animals had a history of skin lesions resistant to treatment. The skin lesions improved markedly during the course of linseed supplementation. While long-term effects of either linolenic acid deficiency or linolenic acid supplementation in giraffe remain to be demonstrated, these results suggest that giraffe might benefit from the addition of linseed extraction chips to their diet.

Keywords

polyunsaturated fatty acids, linolenic acid, skin lesion, peracute mortality syndrome

1. Introduction

It has been reported that captive giraffe (*Giraffa camelopardalis*) have a much lower content of polyunsaturated fatty acids (PUFA) in body tissues than



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Zool. Garten N. F. 76 (2007) 5–6, S. 382–401
www.elsevier.de/zoolgart

DER ZOOLOGISCHE GARTEN

Fatty acid status of captive wild animals: a review

By Marcus Clauss, Christine Grum and Jean-Michel Hatt, Zurich

With 5 Figures and 4 Tables Eingeg. 10. August 2006

Zum Fettsäuren-Status von Wildtieren in Menschenobhut: ein Literaturüberblick

Abstract
The discrepancy in fatty acid (FA) status between a "natural" and a "civilized" environment, recognized as a major dietary phenomenon of clinical relevance in humans, was historically first described in the comparison of free-ranging and captive wild animals (Crawford 1968). Compared to their free-ranging counterparts, captive specimens seemed to have a lower polyunsaturated FA (PUFA) status, and in particular a lower omega(n)3/n6 PUFA ratio. However, a comprehensive evaluation of the available data on free-ranging and captive wild animals was missing so far. We collated data on the FA status of free-ranging and captive wild animals, comparing only data for the same body tissues and lipid fractions. In general, zoo-kept wild animals had a lower n3/n6 PUFA status; in particular, birds and mammalian herbivore species for which data were available consistently showed lower proportions of n3 PUFA and total PUFA in captivity. In zoo animals, this discrepancy has been repeatedly suspected to contribute to clinical problems, although conclusive studies are lacking. Should an adjustment of the FA status in captivity to the one in the wild be an objective in the dietary management of zoo animals, several strategies could be adopted: the feeding of horse or rabbit instead of ruminant meat; the use of food insects that are raised on green produce instead of grain products; the feeding of marine non-vertebrates such as shrimp or squid to animals specialized on these items but conventionally fed fish. In particular, a higher proportion of forage in general, the use of fresh or ensilaged forage instead of hay, a reduction of the use of grain-based concentrates, and an increased use of forage products (grass or lucerne meal) and linseed products in pelleted feeds, are measures that have been demonstrated in domestic herbivores to increase the n3/n6 PUFA status.

Key words
Fatty acid, wild animal, PUFA, n3/n6 ratio, zoo animal nutrition, feeding

Introduction

The fatty acid (FA) composition of the diet, and subsequently of different organ tissues, has received enormous attention in the literature on human medicine and nutrition. In particular, a low overall intake of polyunsaturated fatty acids (PUFA), and a drastic shift in the relation of omega(n)3 to n6 PUFA has been of concern (Simopou-

0044-5169/07/76/5–6–382 $ 30.00/0

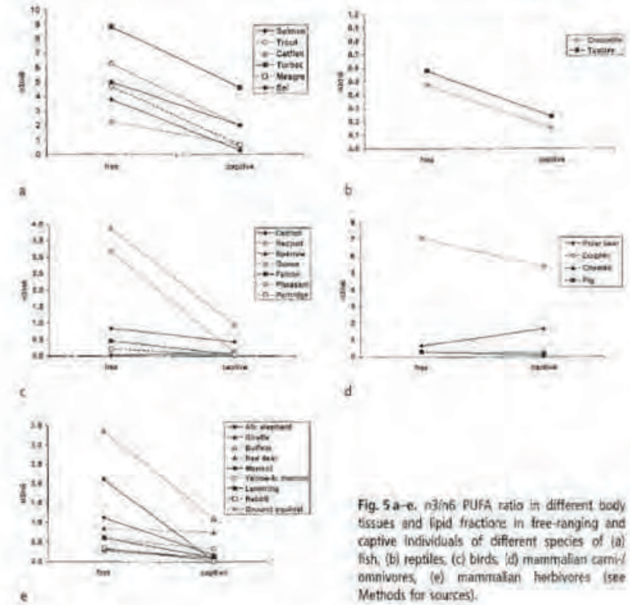

Fig. 5 a–e. n3/n6 PUFA ratio in different body tissues and lipid fractions in free-ranging and captive individuals of different species of (a) fish, (b) reptiles, (c) birds, (d) mammalian carni-/omnivores, (e) mammalian herbivores (see Methods for sources).

Discussion

The results support the concept of Crawford (1968), Crawford et al. (1991) and Clauss & Ghebremeskel (2001) that captive wild animals have lower proportions of PUFA, n3 PUFA, and in particular a lower n3/n6 PUFA ratio than free-ranging counterparts. It must be noted that these results should only be considered as general trends, and that exceptions can always occur. For example, the higher proportions of n3 PUFA in captive polar bears reported by Colay et al. (1993) were interpreted as the result of a peculiar captive feeding regime that included a high proportion of fresh green vegetables and horse meat. The data on these polar bears show higher n3 PUFA and total PUFA in captive specimens, but a lower UI, which means that in spite of higher proportions of linolenic acid (18:3n3), the proportions of highly unsaturated FA (eicosapentaenoic and docosahexaenoic acid) as occur in fish or pinniped tissue were actually lower in the captive specimens. This example indicates that the data compilation presented must be interpreted with caution. Nevertheless, the re-

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

Man-made diets: too little fibre

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Fibre in diet and intended use

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

*historical recommendations for ration design

Fibre in diet and 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

Nutrition Research Reviews (2002), **15**, 153–168
DOI: 10.1079/NRR200238
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Idiosyncratic nutrient requirements of cats appear to be diet-induced evolutionary adaptations*

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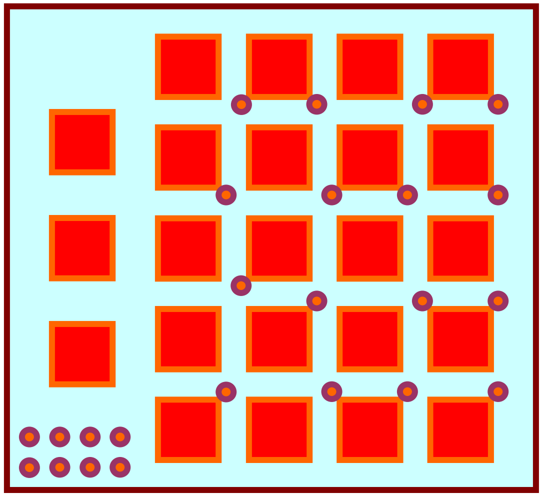
Organism



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Idiosyncratic nutrient requirements of cats appear to be diet-induced evolutionary adaptations*

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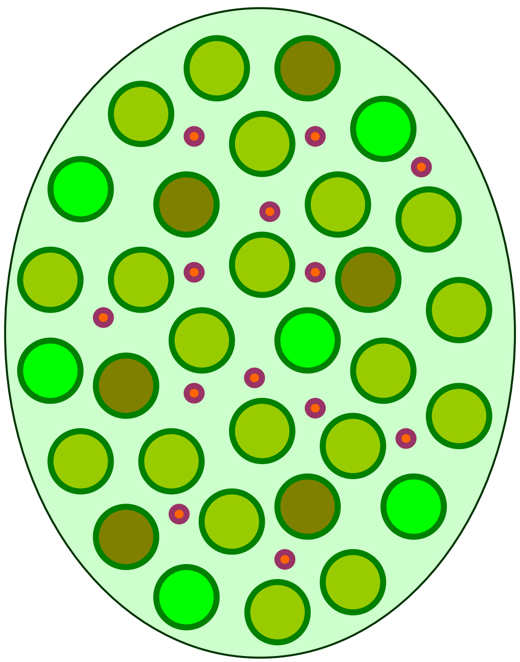
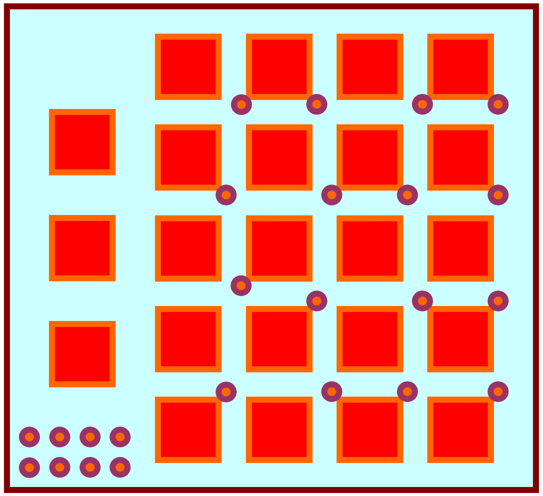
Food



Organism



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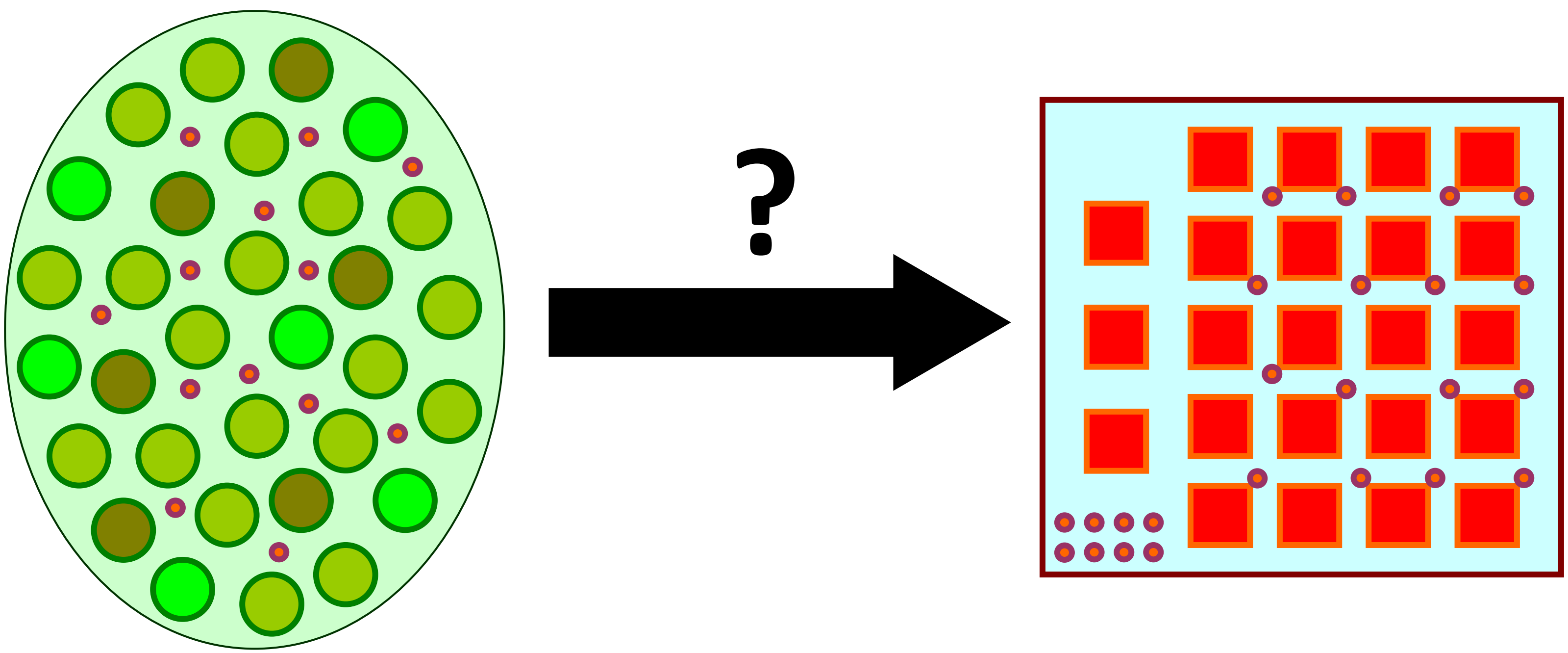
Food

Organism



Nutrition Research Reviews (2002), **15**, 153–168 DOI: 10.1079/NRR200238
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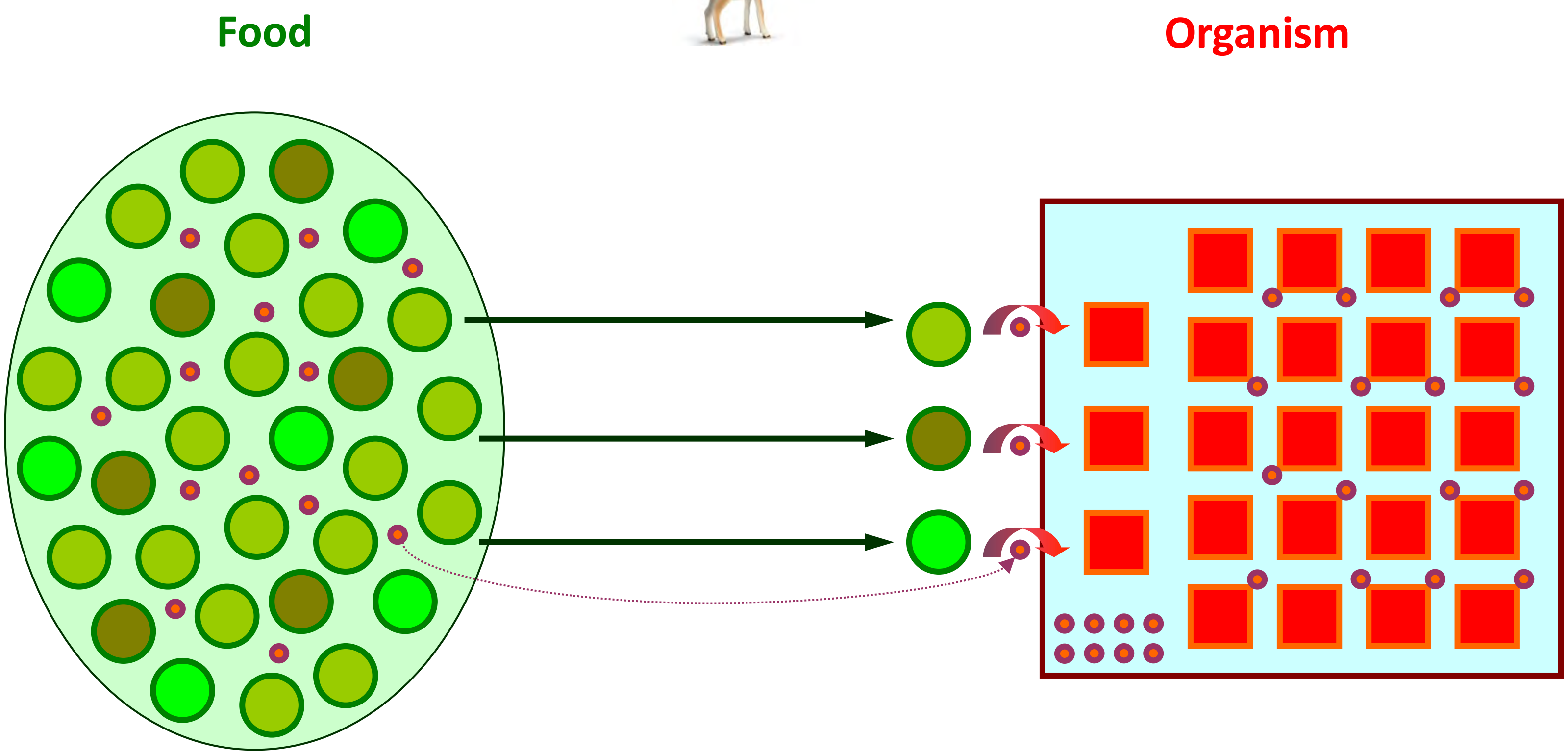
Idiosyncratic nutrient requirements of cats appear to be diet-induced evolutionary adaptations*

James G. Morris



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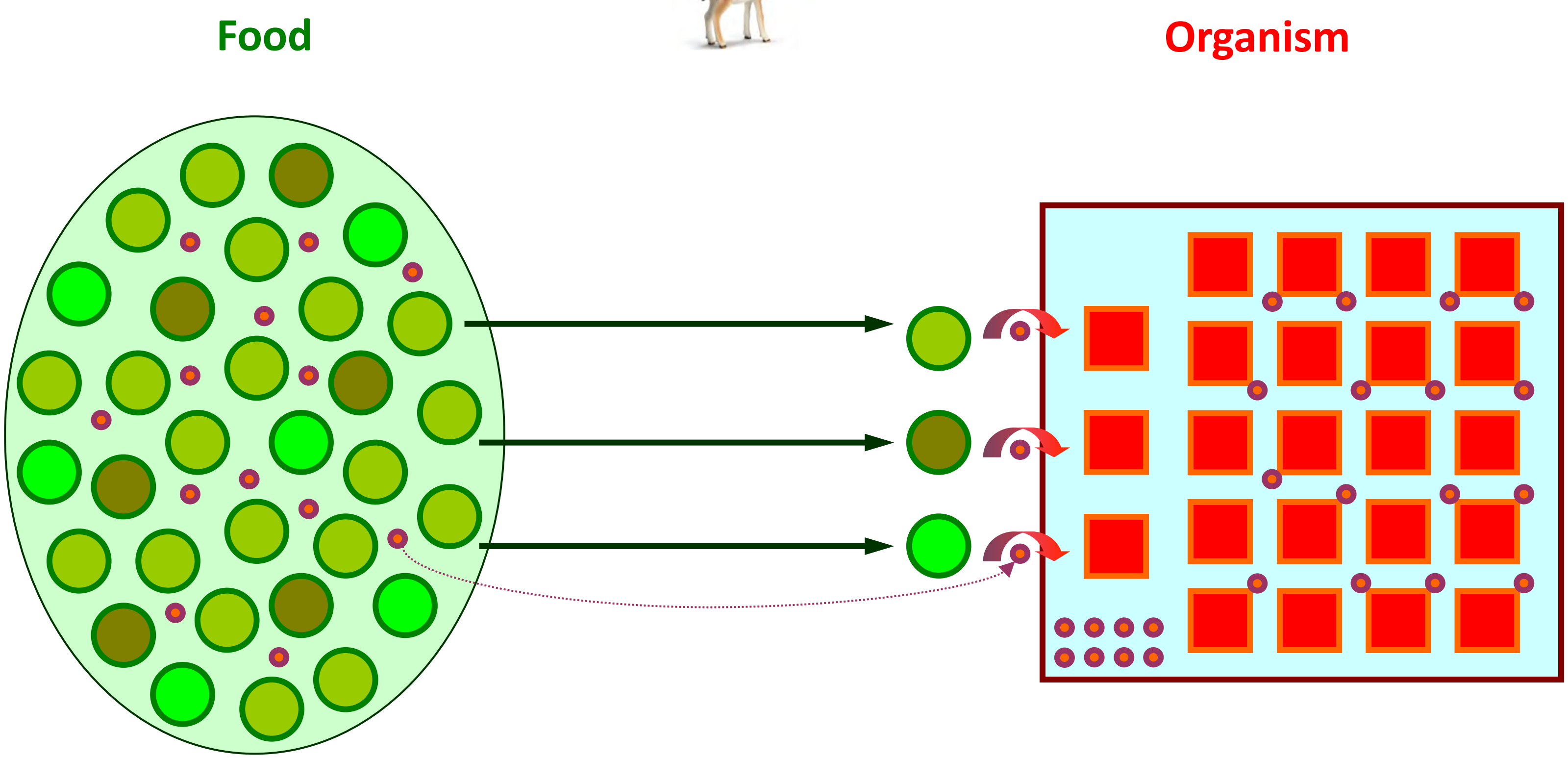

essential food components

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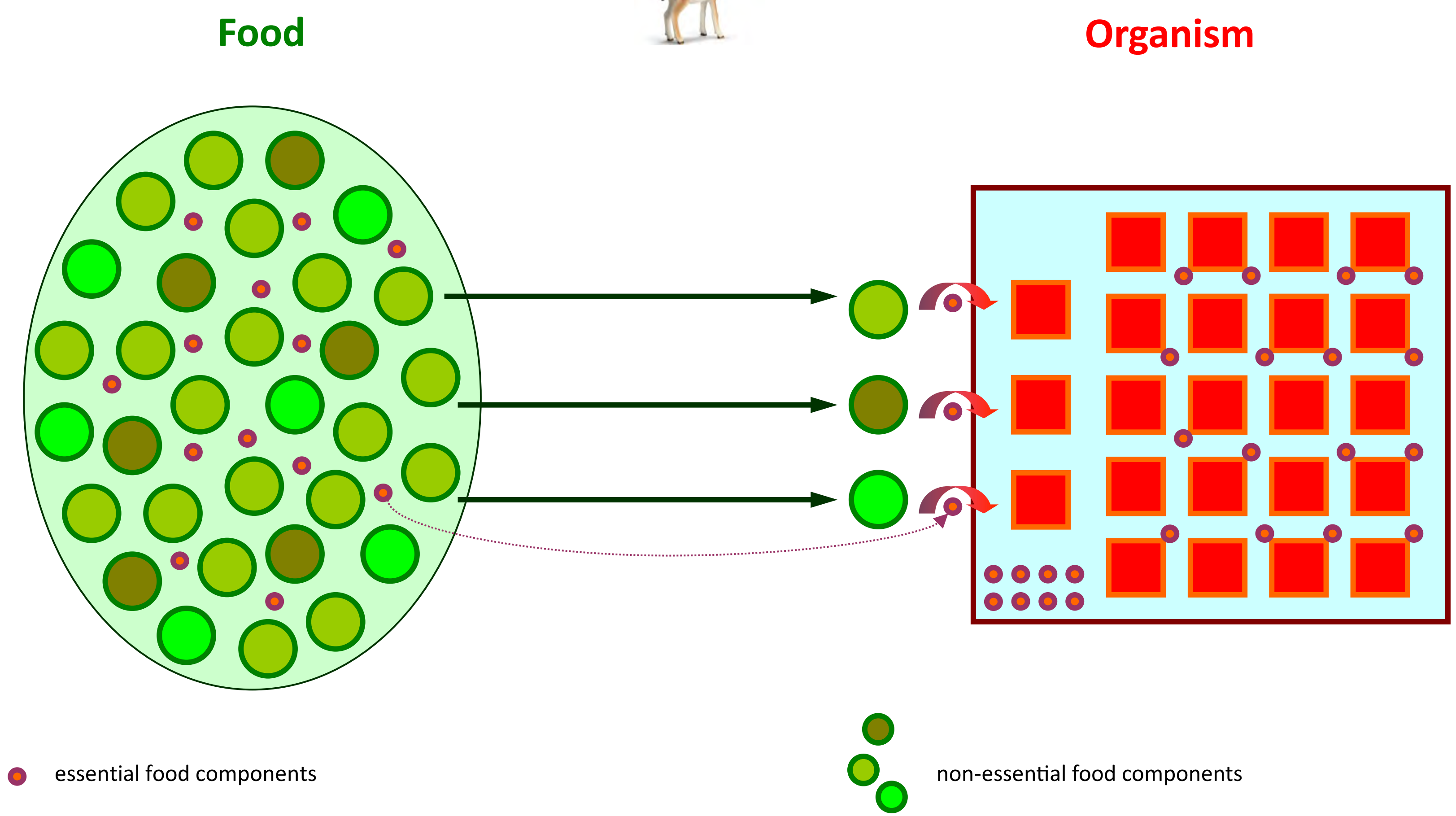

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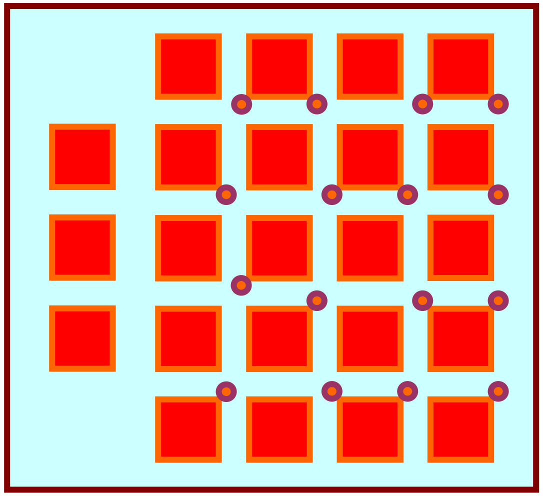
Organism



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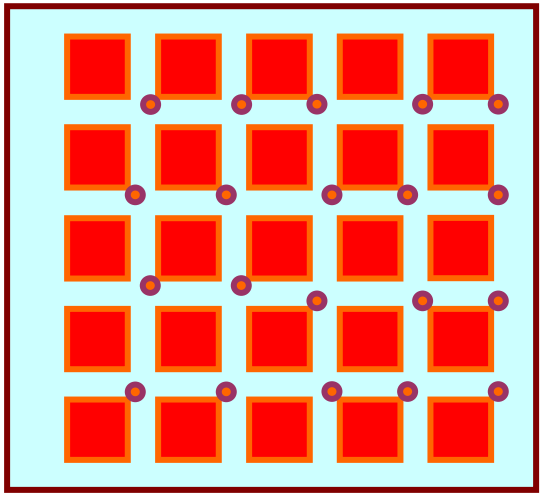
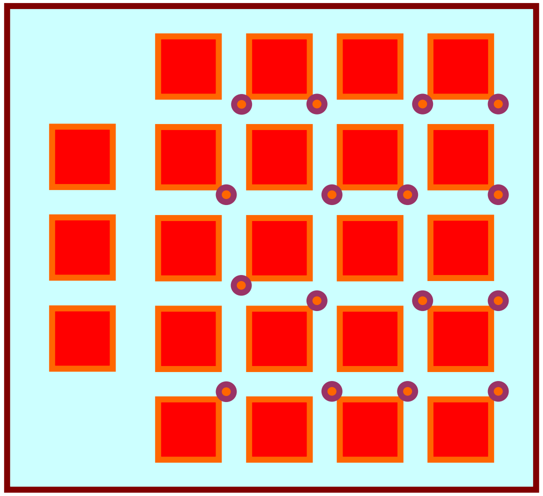
Food



Organism



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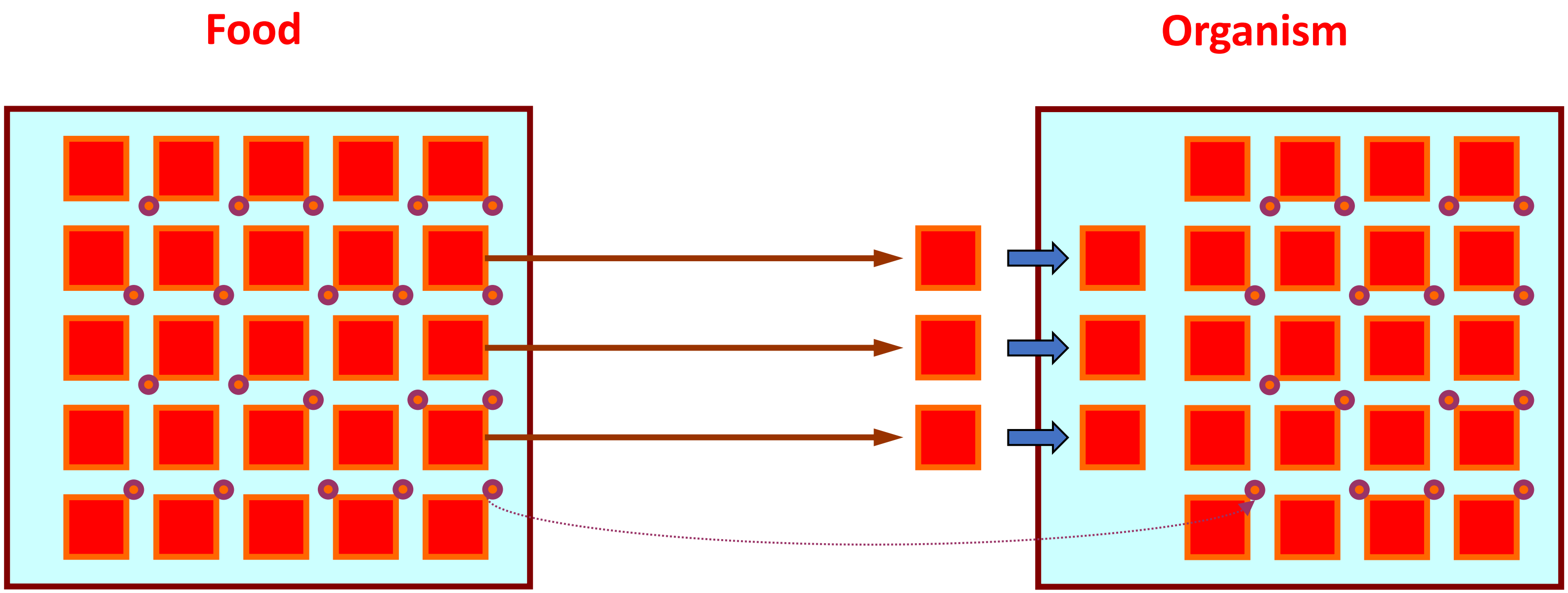

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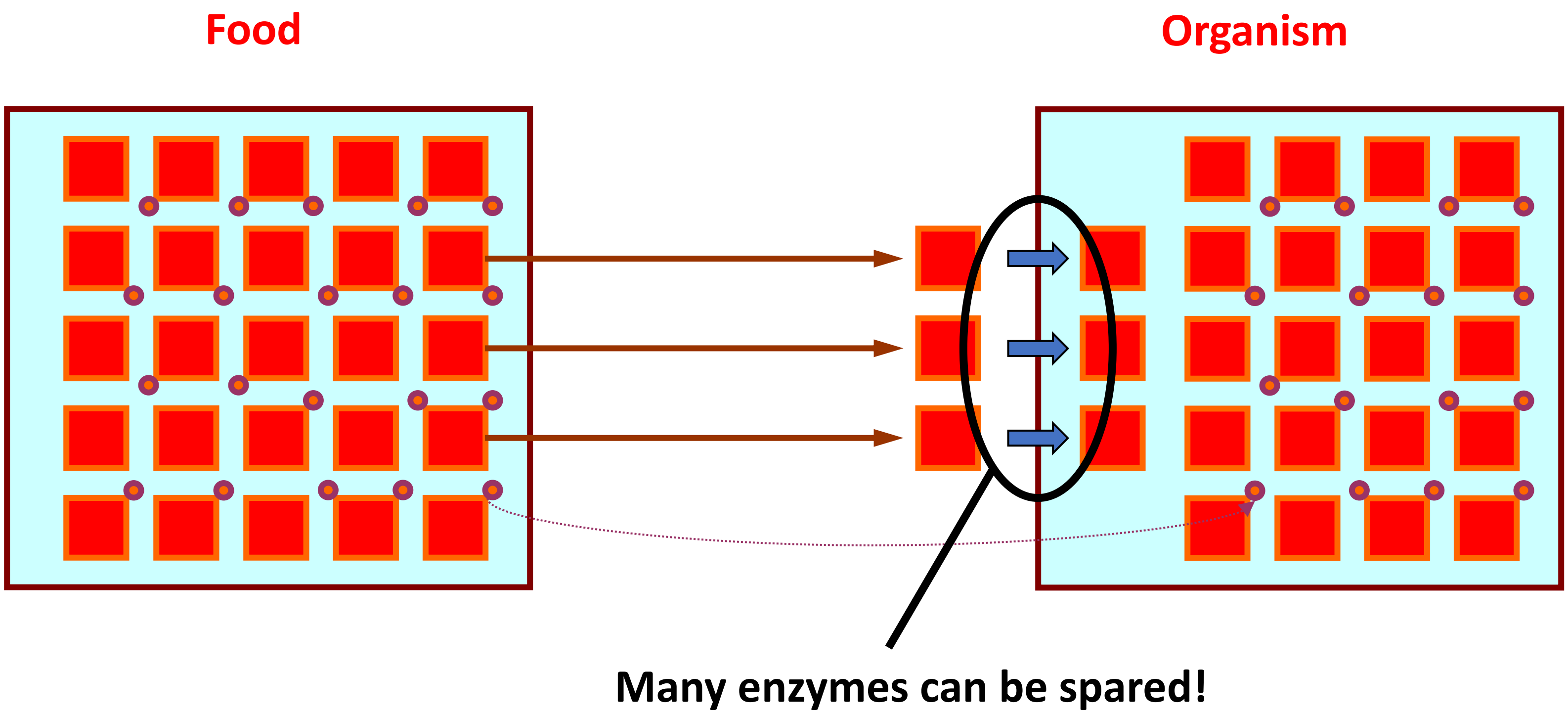

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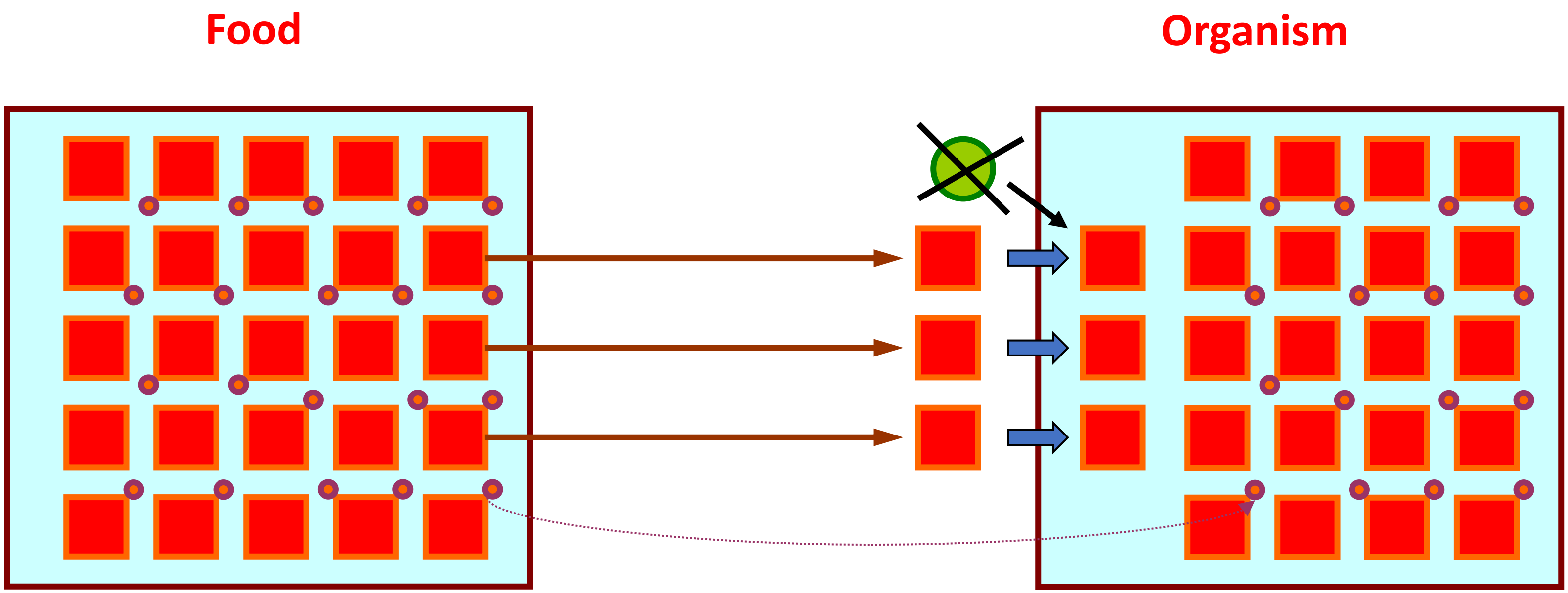

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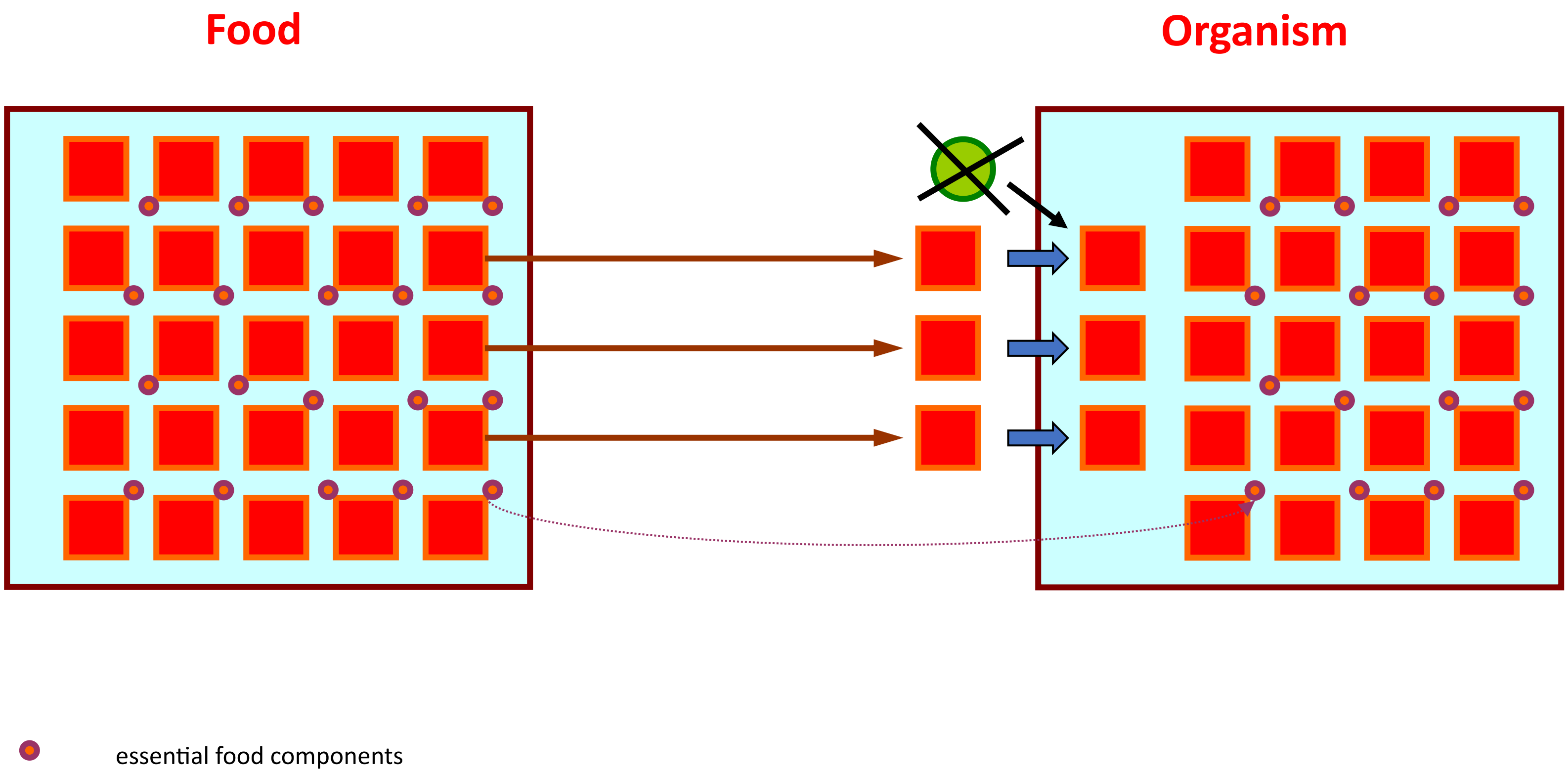

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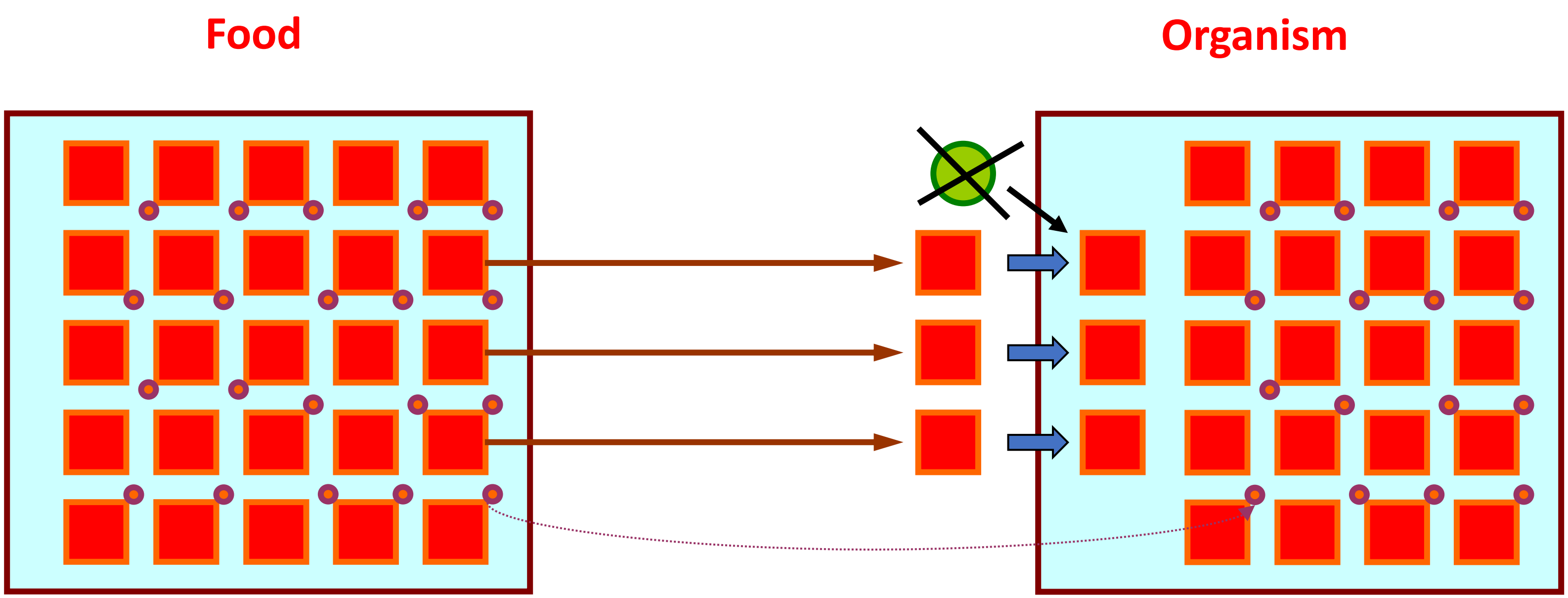

essential food components

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not essential for dogs

essential nutrients:

- high protein requirement
- amino acids taurine and arginine
- arachidonic acid
- vitamin A (β-carotine useless)
- vitamin D
- niacine

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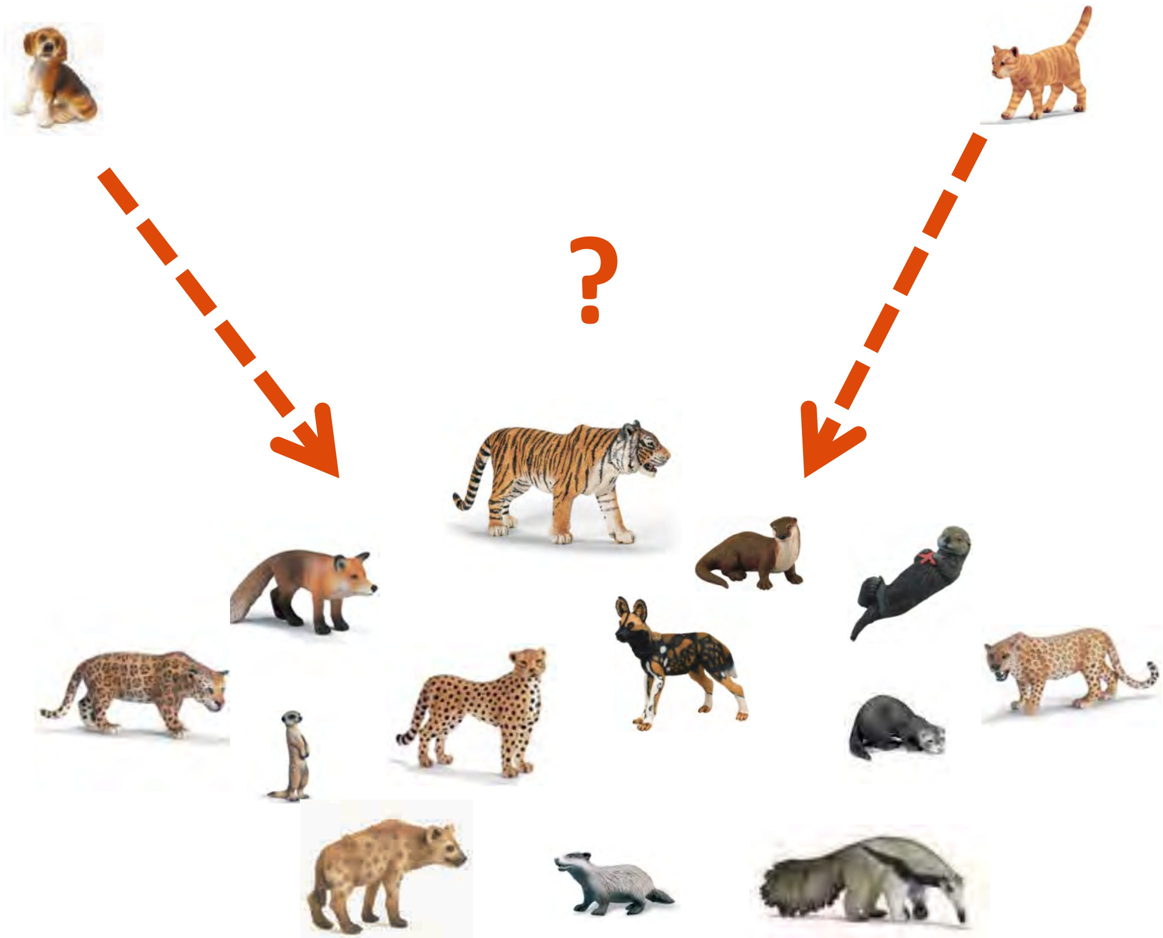

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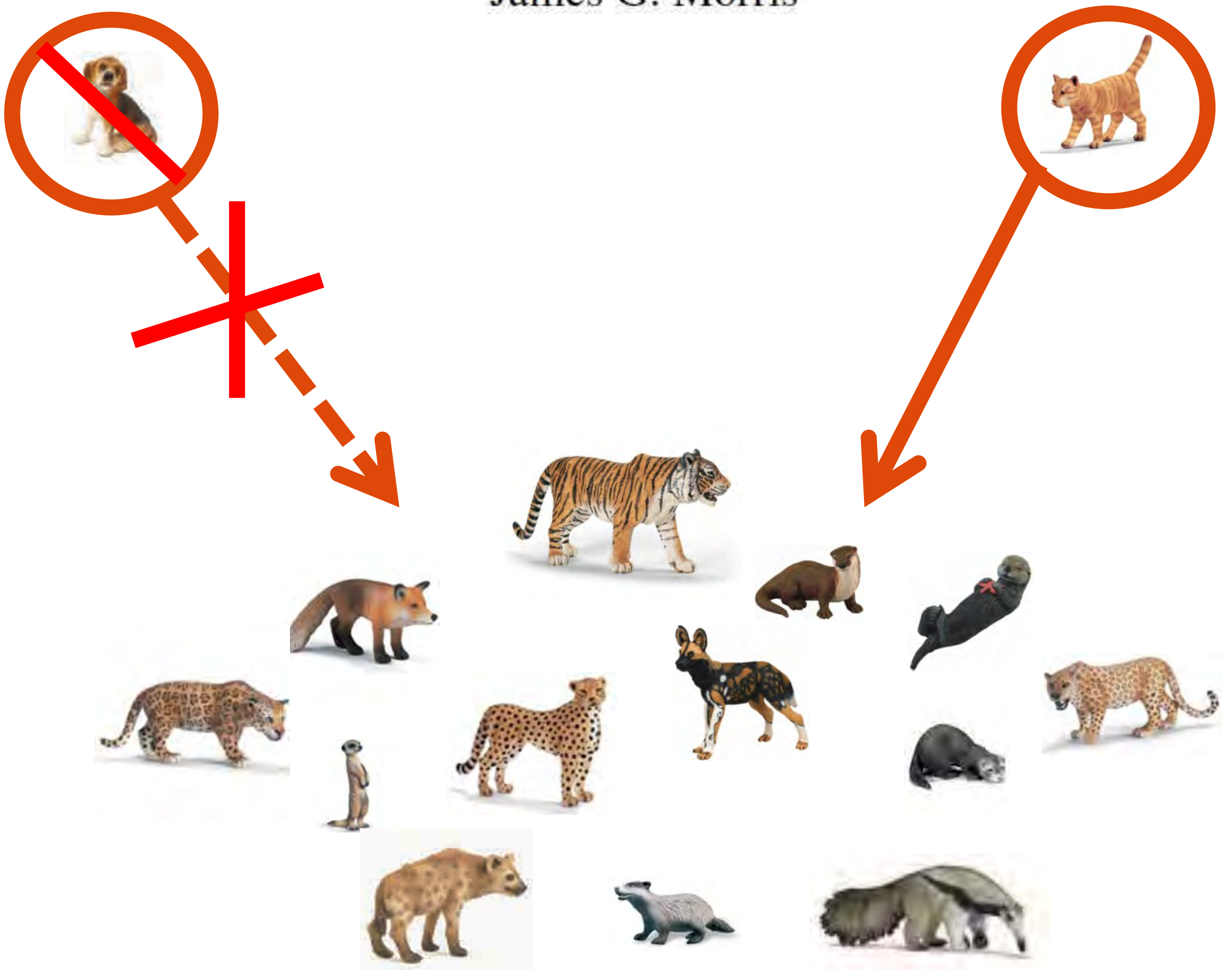
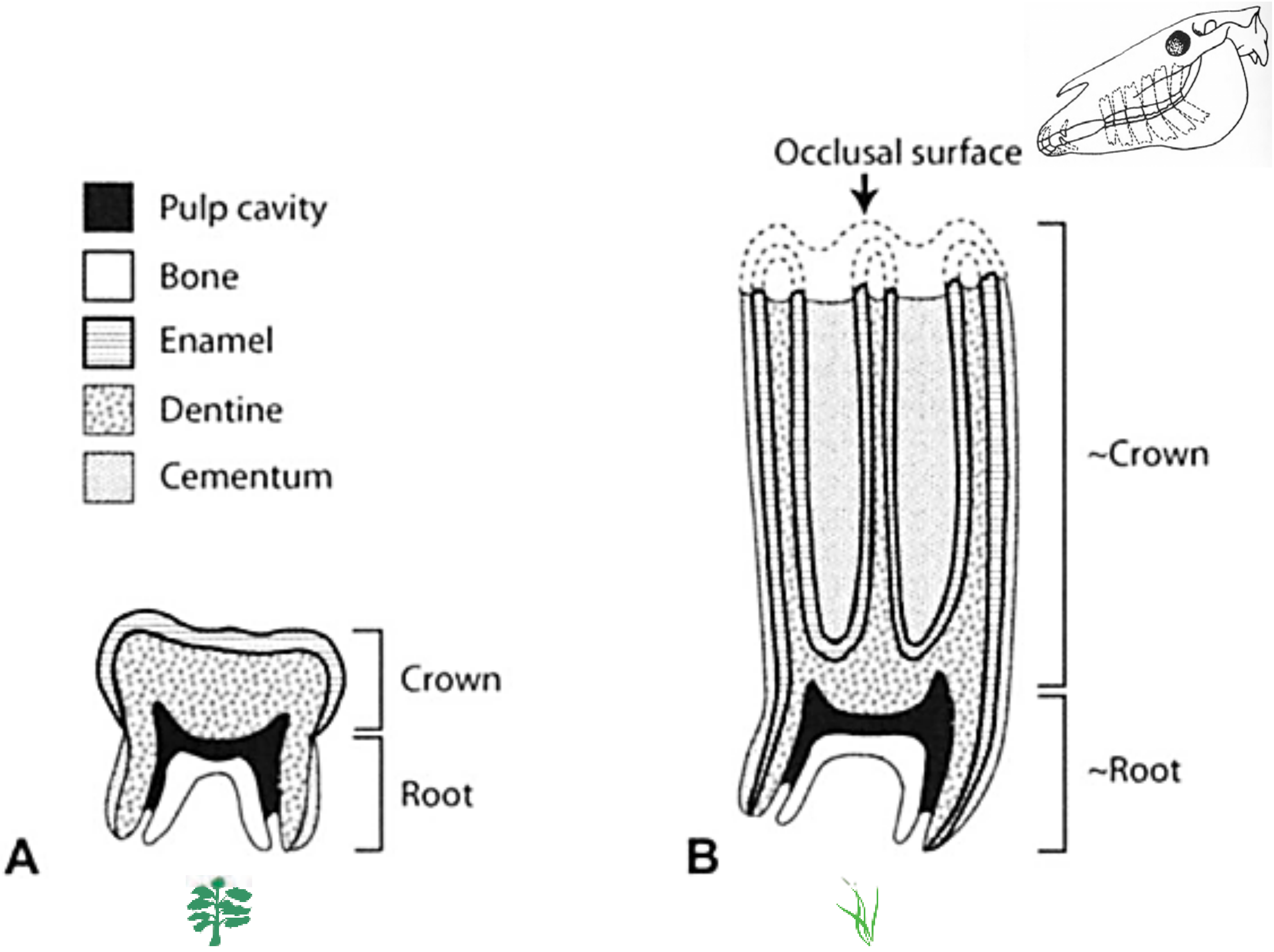


Hypsodonty



Occlusal surface
Pulp cavity
Bone
Enamel
Dentine
Cementum
Crown
Root
A
~Crown
~Root
B

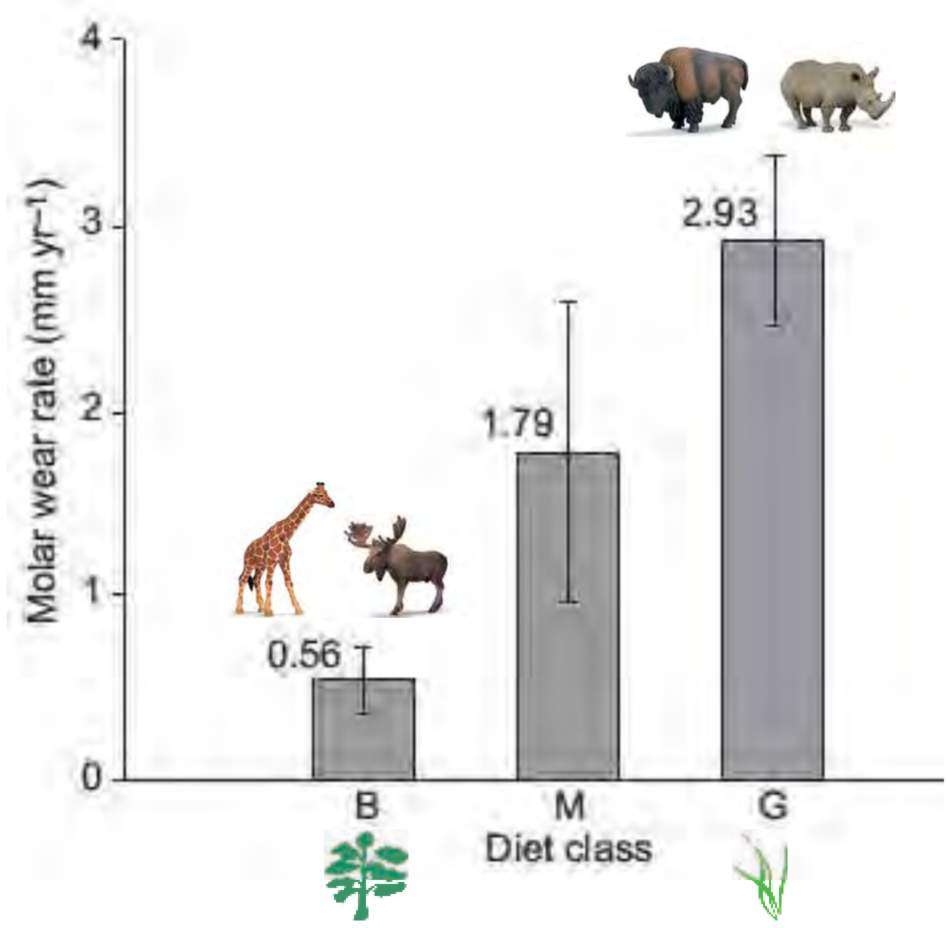
Hypsodonty

Hummel (unpubl.)

A comparison of observed molar wear rates in extant herbivorous mammals

John Damuth[1] & Christine M. Janis[2]

Ann. Zool. Fennici 51: 188–200
Helsinki 7 April 2014



Another one bites the dust: faecal silica levels in large herbivores correlate with high-crowned teeth

Jürgen Hummel[1,*], Eva Findeisen[1], Karl-Heinz Südekum[1], Irina Ruf[2], Thomas M. Kaiser[3], Martin Bucher[4], Marcus Clauss[5] and Daryl Codron[5]

Proc. R. Soc. B (2011) 278, 1742–1747

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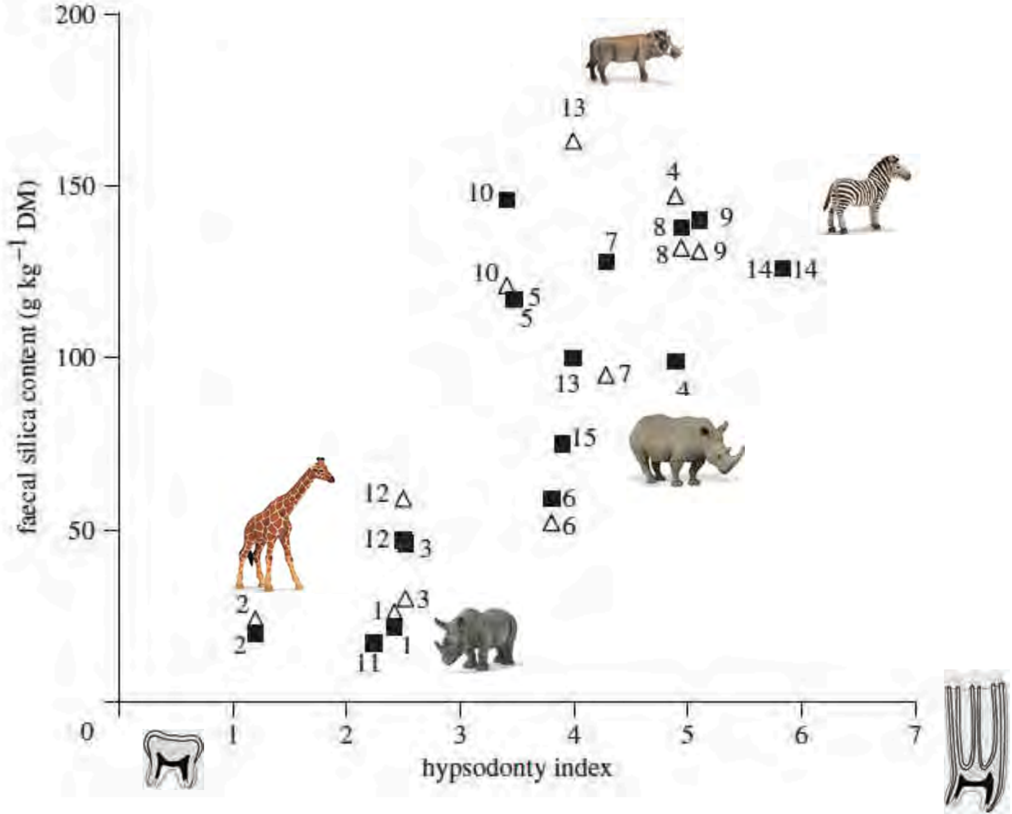
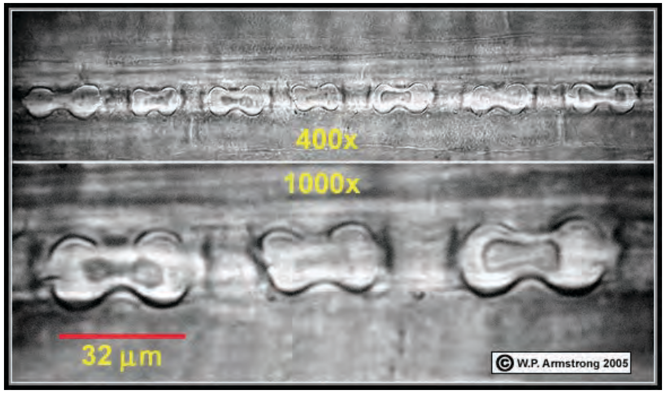


Where does the silica come from?

- grit/dust (external abrasives)?

- phytoliths (internal abrasives)?



Does it matter for zoos?

Food item	n	AIA (%DM) Mean	Range	Source
Temperate browse	1	0.0	—	Clauss et al.[6]
	6	0.2	0.0–0.4	Castell[4]
Alfalfa hay	1	0.2	—	Baer et al.[1]
	1	0.2	—	Clauss et al.[6]
	9	0.3	0.0–0.7	Castell[4]
Alfalfa meal pellet	1	0.5	—	Castell[4]
Grass hay	13	2.0	0.3–5.1	Castell[4]
Fresh grass	2	2.0	1.8–2.2	Castell[4]
Grass meal pellet[a]	1	6.4	—	Castell[4]
Pelleted compound feed	2	0.9	0.2–1.5	Baer et al.[1]
	3	0.8	0.7–1.0	Clauss et al.[6]
	24	1.5	0.5–3.1	Castell[4]

[a] Young grass cut low, dried artificially, ground and pelleted.

animals adapted to browse but eating grass products should experience more wear than they are naturally adapted to

Journal of Zoo and Wildlife Medicine 38(3): 433–445, 2007
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TOOTH WEAR IN CAPTIVE GIRAFFES (*GIRAFFA CAMELOPARDALIS*): MESOWEAR ANALYSIS CLASSIFIES FREE-RANGING SPECIMENS AS BROWSERS BUT CAPTIVE ONES AS GRAZERS

Marcus Clauss, M.Sc., Dr. Med. Vet., Dipl. E.C.V.C.N., Tamara A. Franz-Odendaal, Ph.D., Juliane Brasch, Johanna C. Castell, Dr. Med. Vet., and Thomas Kaiser, P.D. Dr. Rer. Nat.

Tooth wear in captive wild ruminant species differs from that of free-ranging conspecifics

Mamm. biol. 74 (2009) 425–437

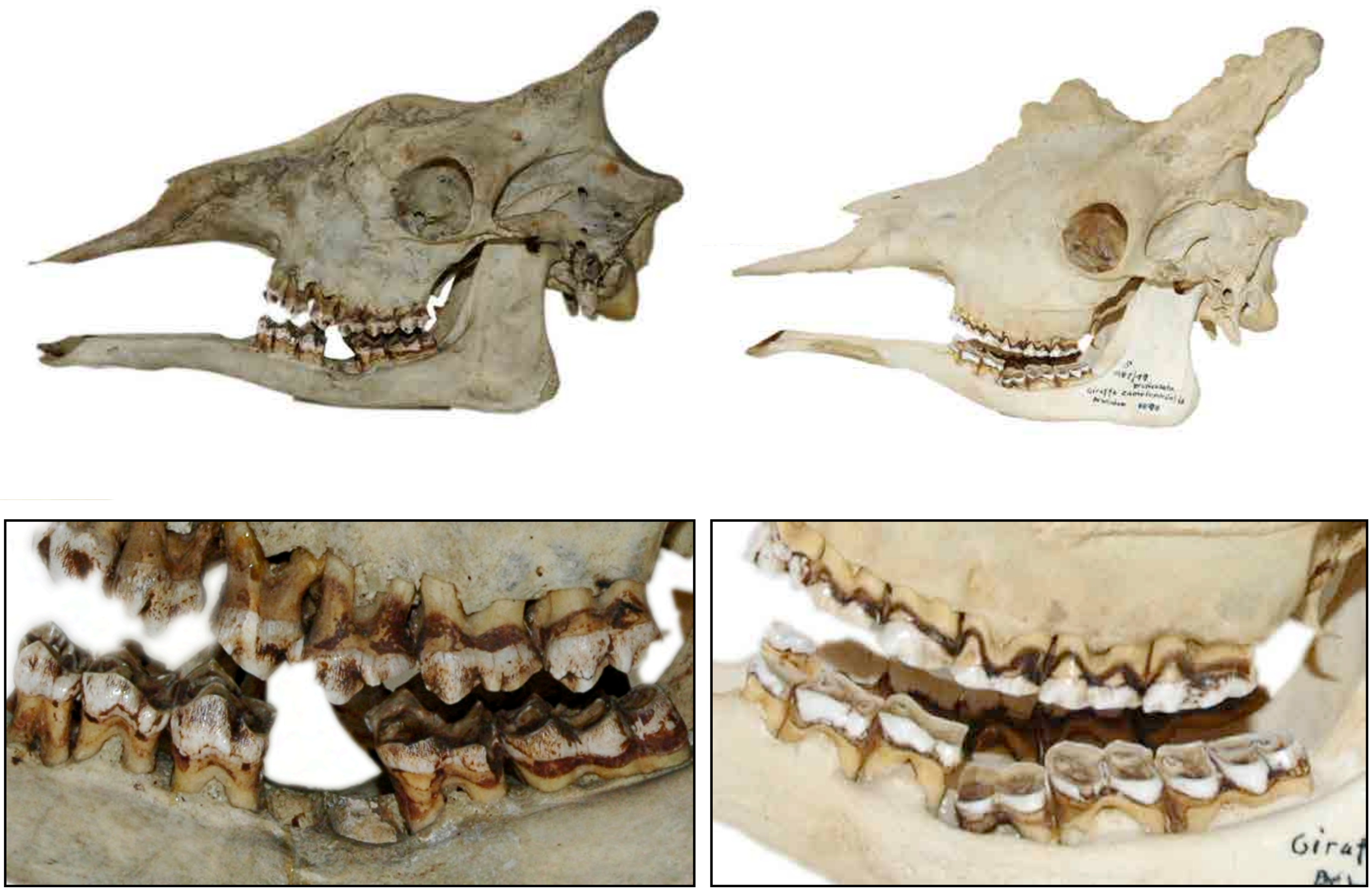
Thomas M. Kaiser[a,*], Juliane Brasch[b], Johanna C. Castell[c], Ellen Schulz[a], Marcus Clauss[d]

Contributions to Zoology, 83 (2) 107-117 (2014)

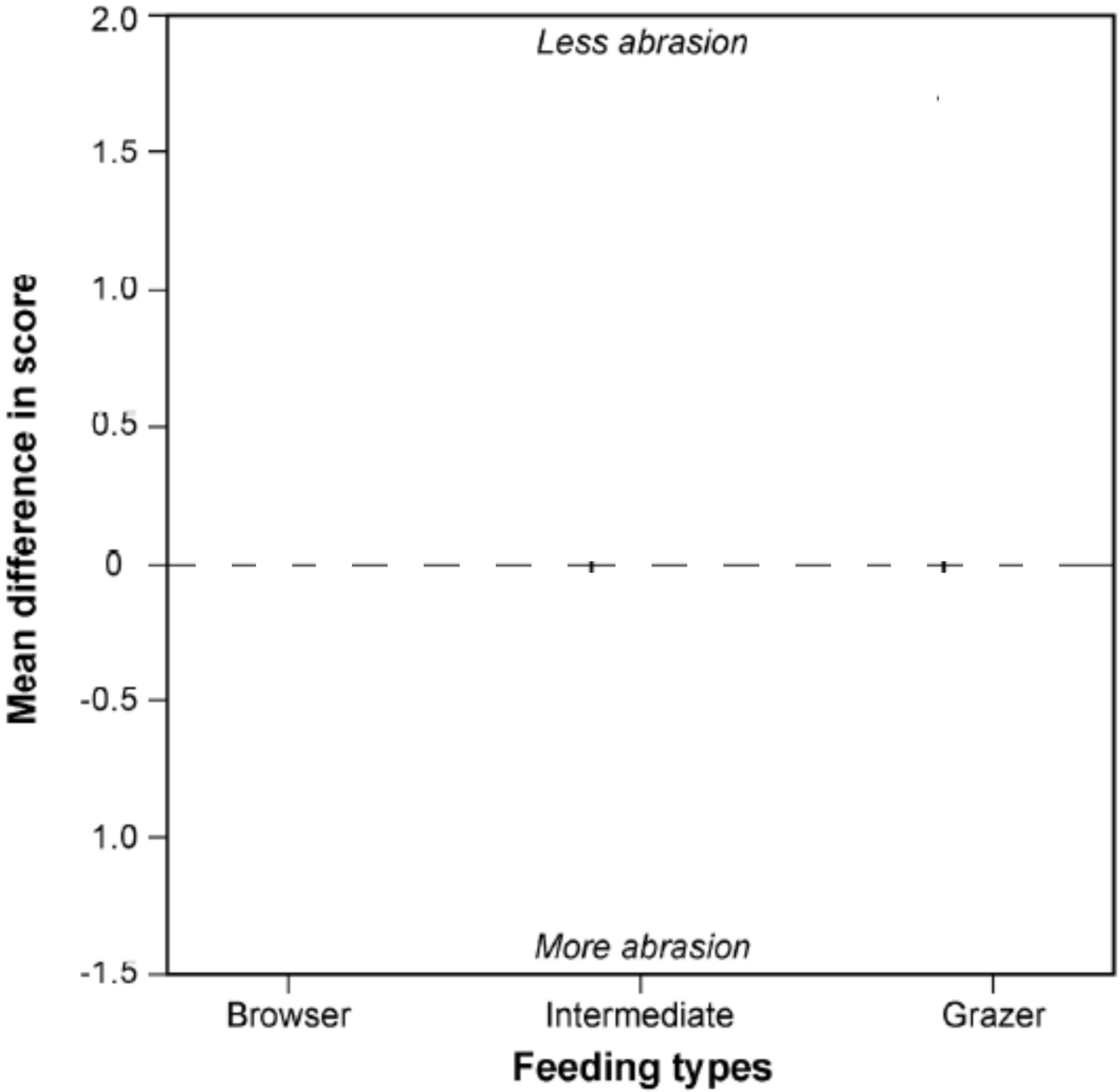
Tooth wear in captive rhinoceroses (*Diceros*, *Rhinoceros*, *Ceratotherium*: Perissodactyla) differs from that of free-ranging conspecifics

Lucy A. Taylor[1,2], Dennis W.H. Müller[3,4], Christoph Schwitzer[1], Thomas M. Kaiser[5], Daryl Codron[3,6], Ellen Schulz[5], Marcus Clauss[3,7]

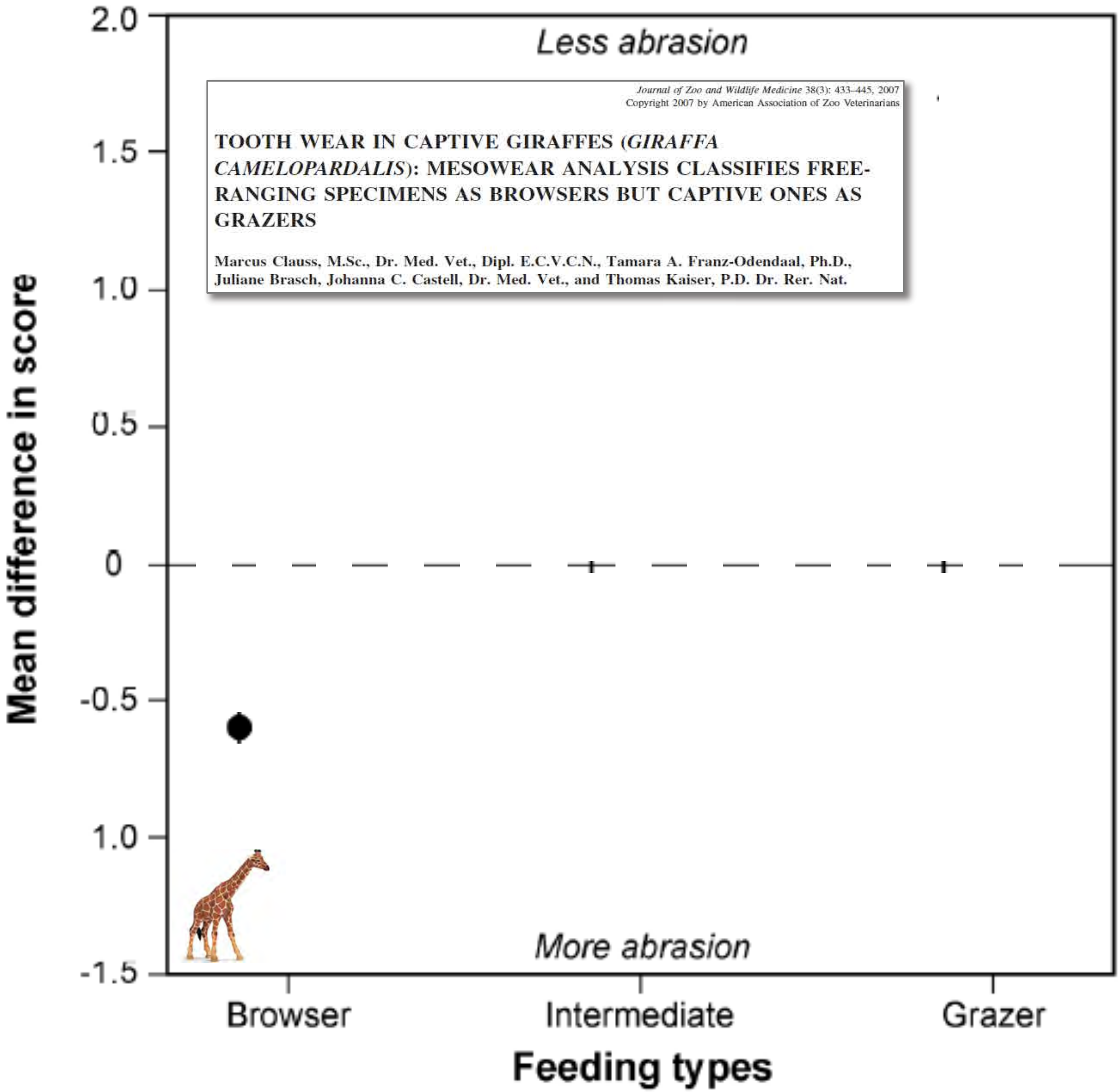
Free-ranging vs. captive giraffes



from Clauss et al. (2007)



Less abrasion
More abrasion
Mean difference in score
2.0
1.5
1.0
0.5
0
-0.5
1.0
-1.5
Browser
Intermediate
Grazer
Feeding types



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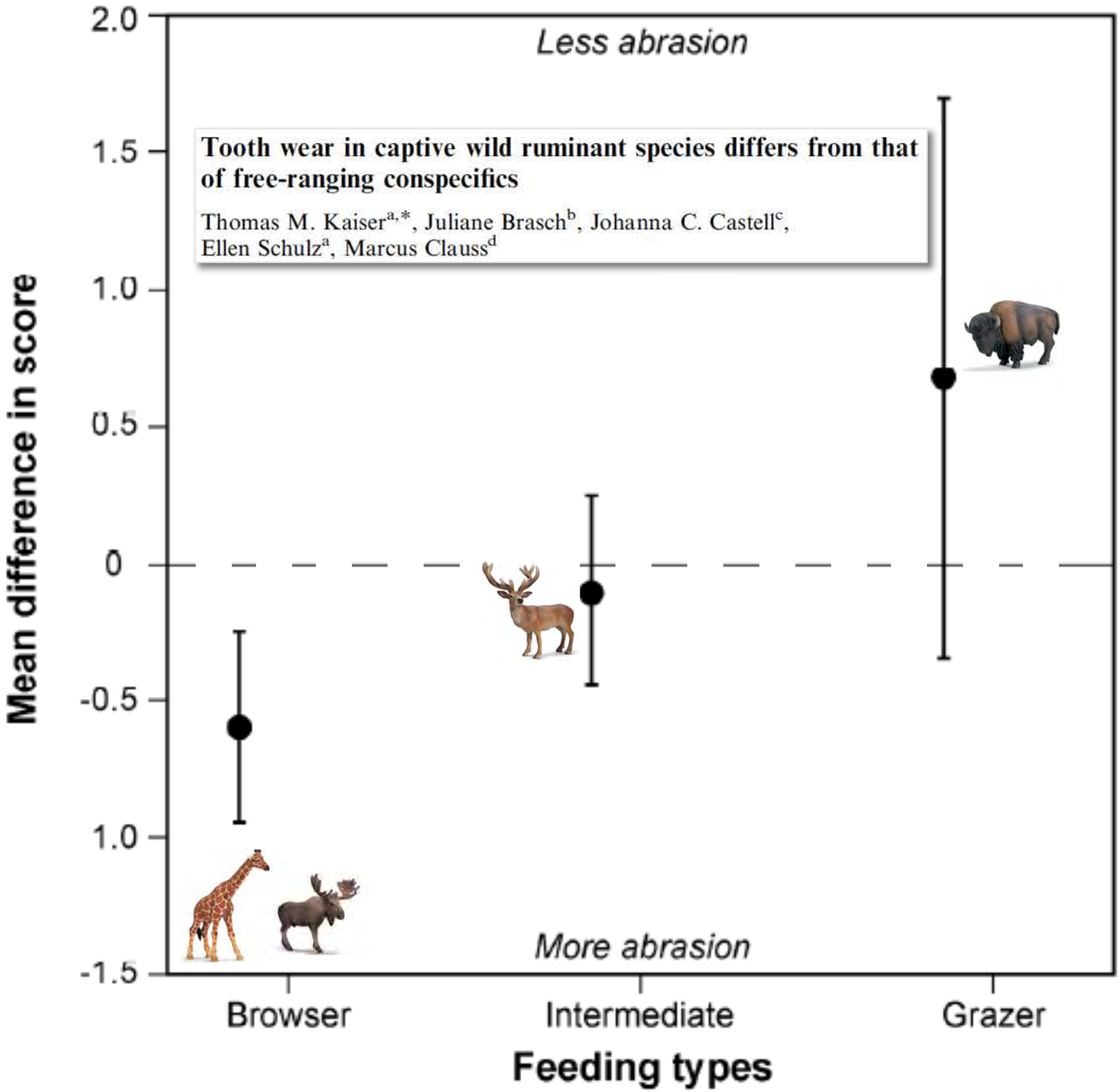
Less abrasion
Tooth wear in captive wild ruminant species differs from that of free-ranging conspecifics
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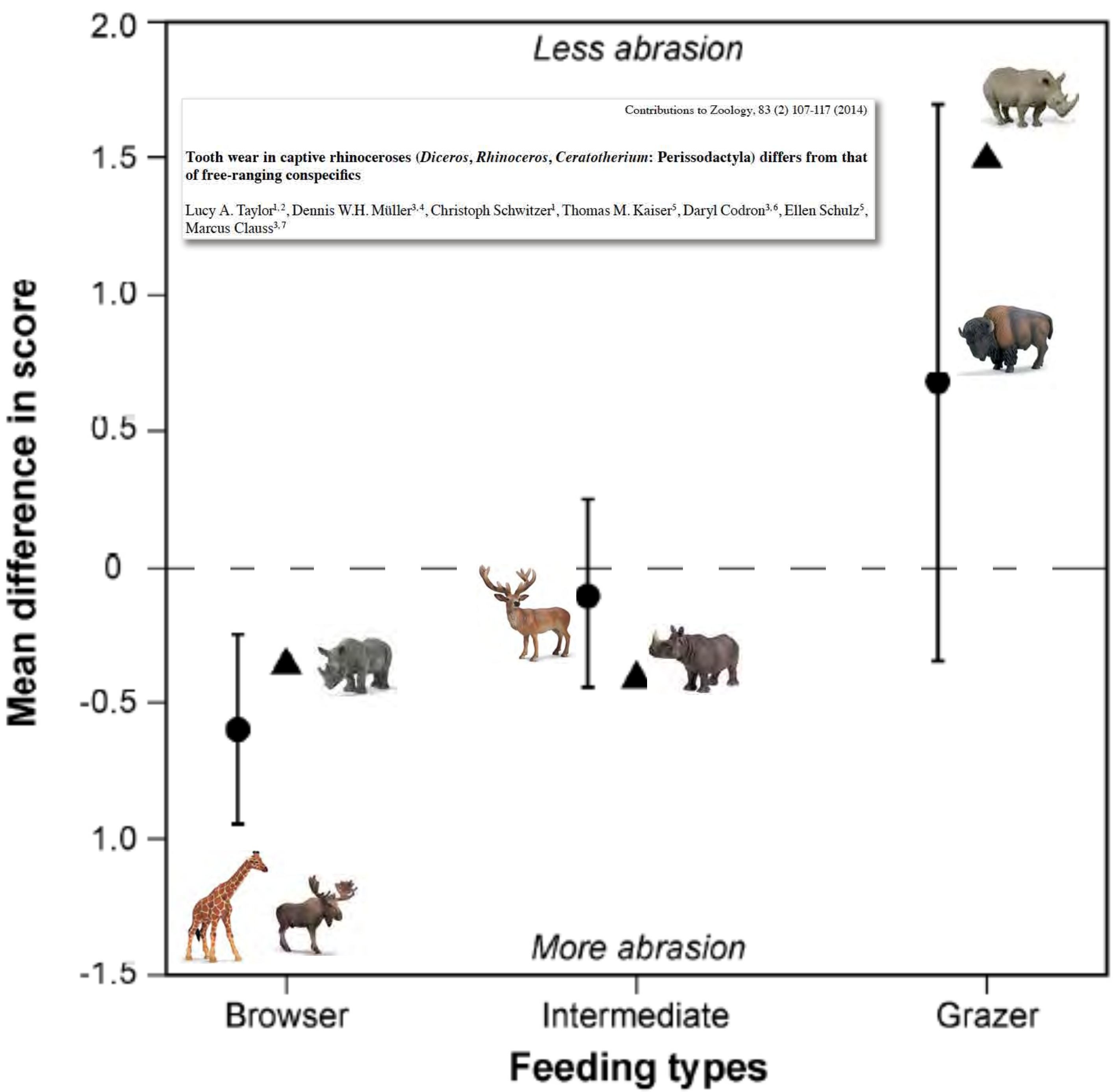
2.0
1.5
1.0
0.5
0
-0.5
1.0
-1.5
Mean difference in score
More abrasion
Browser
Intermediate
Grazer
Feeding types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Contributions to Zoology, 83 (2) 107-117 (2014)
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Feeding types

The simple zoo vet's world view

The simple zoo vet‘s world view

Adaptations

The simple zoo vet's world view

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

Adaptations

The simple zoo vet's world view

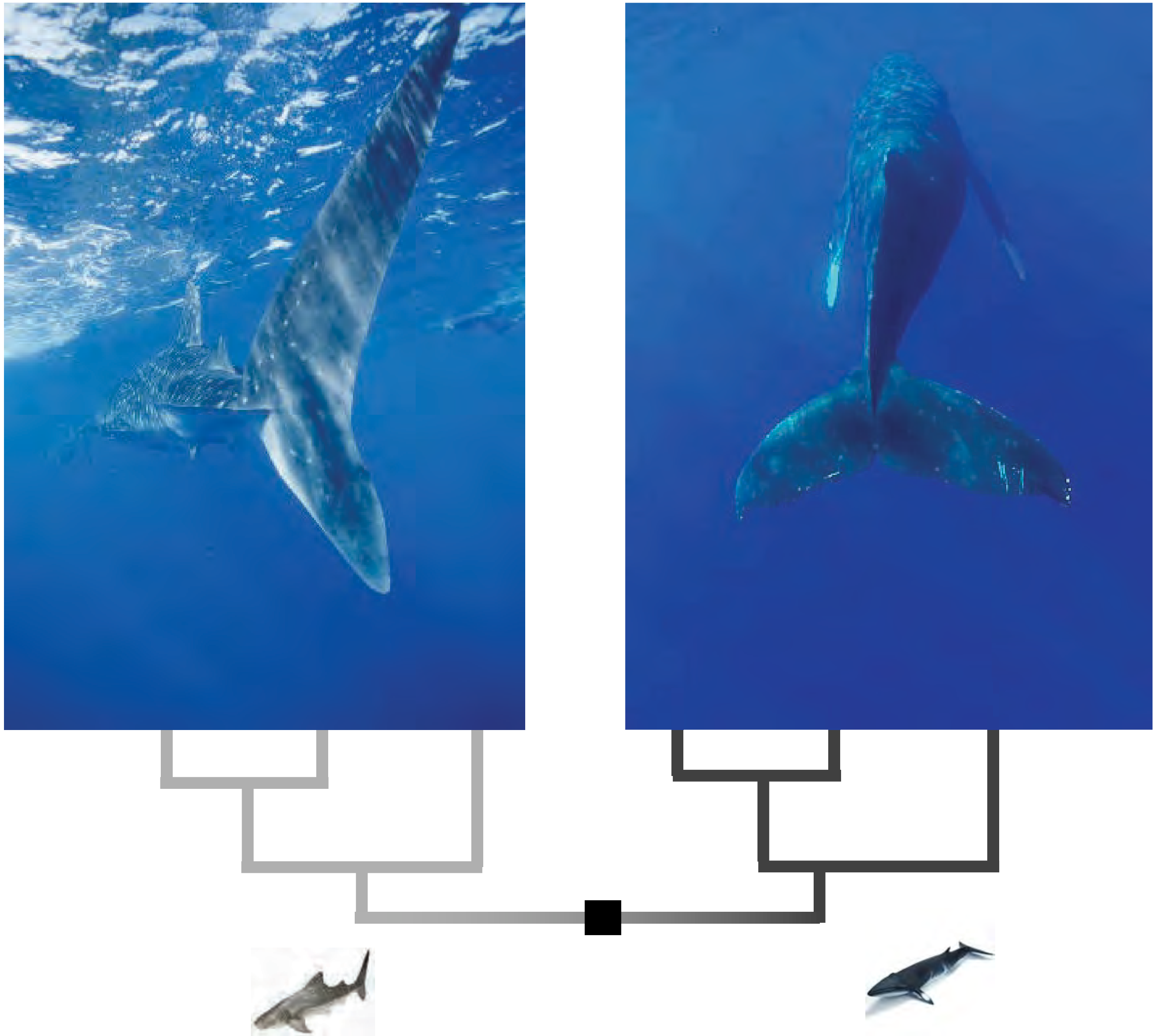
careful evaluation of concepts, size of effect, functional logic, functional relevance

Adaptations

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

but might be a part of the evolutionary history

Detailed function: constraints by evolutionary history ('contingency')



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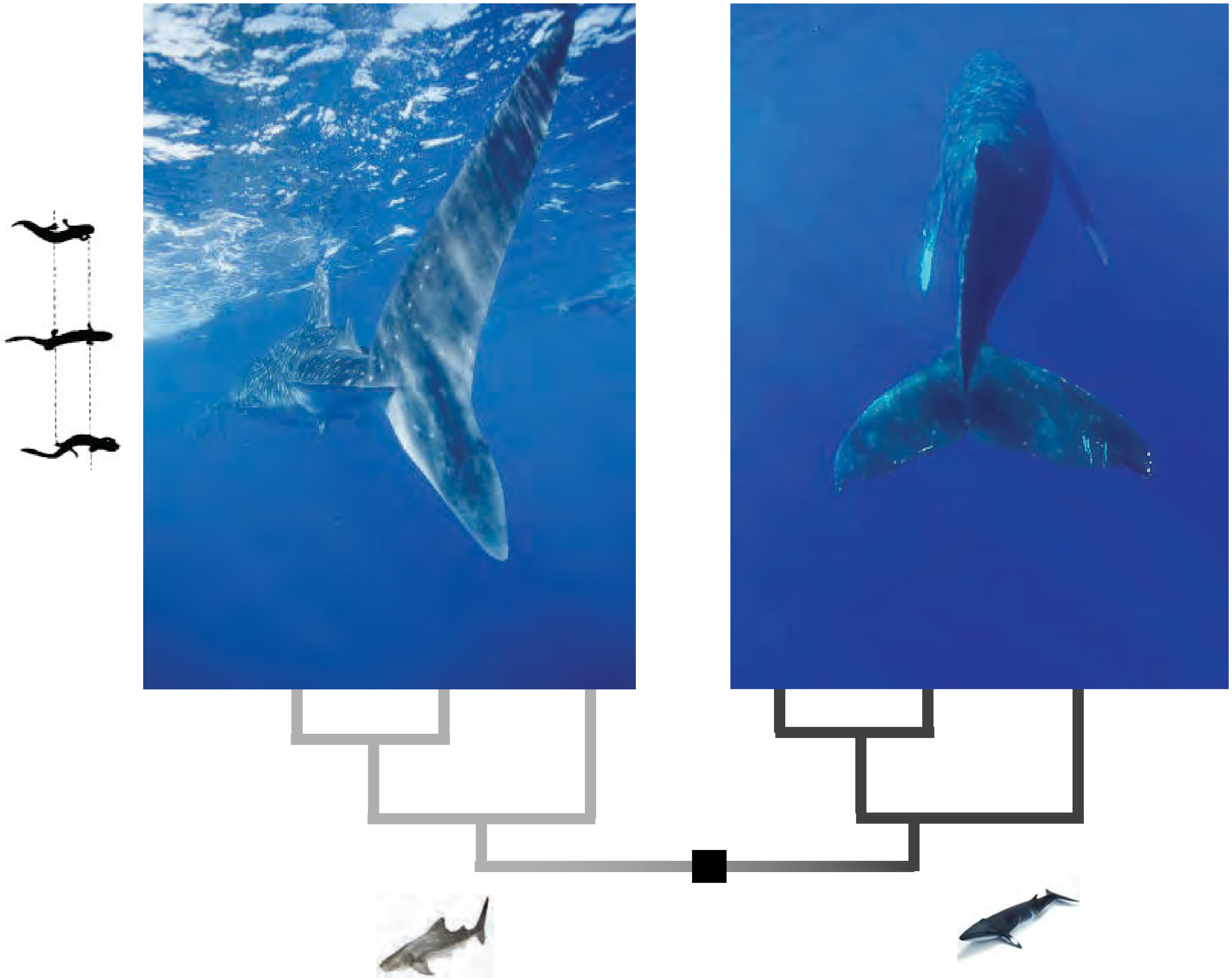

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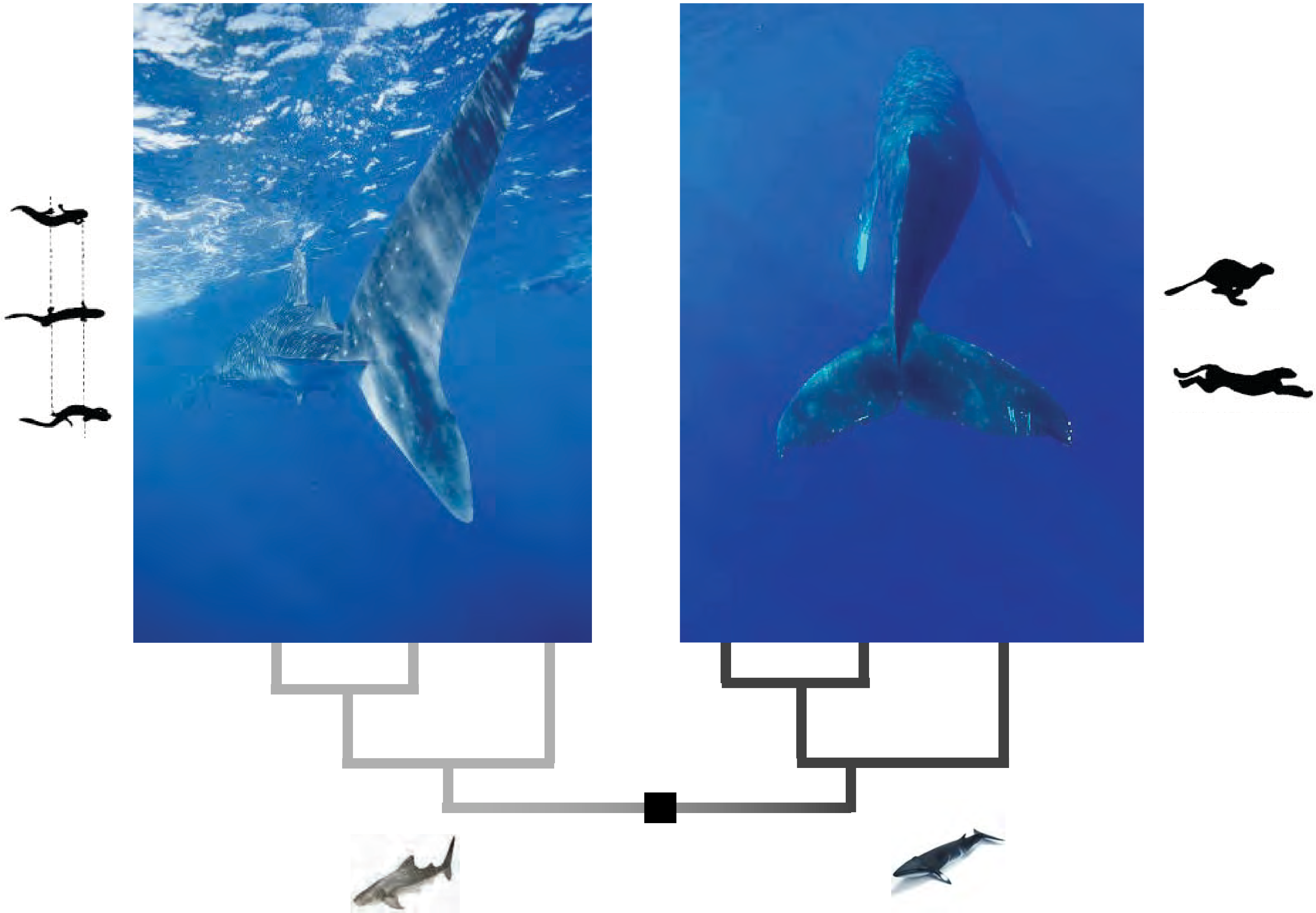
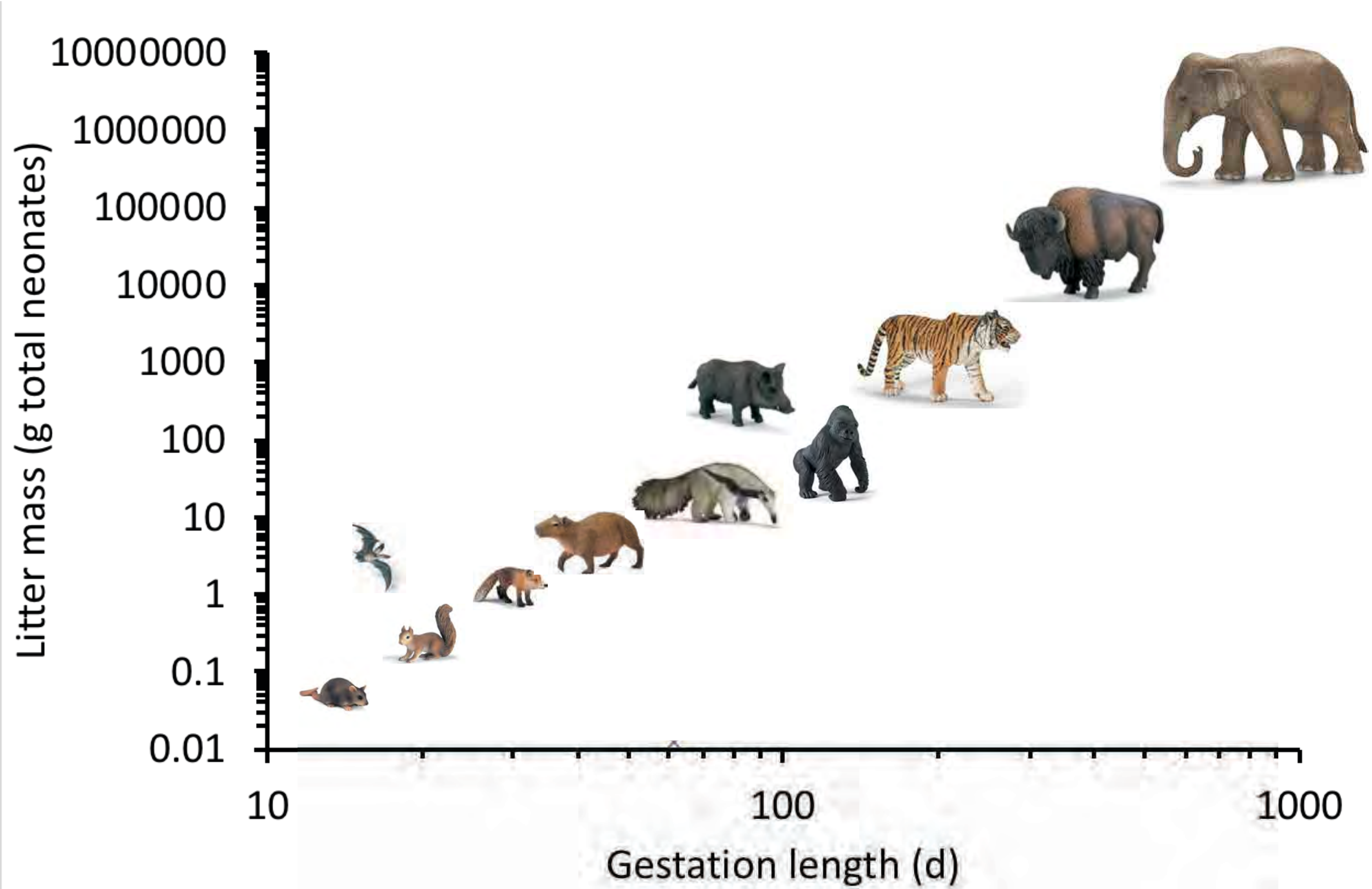


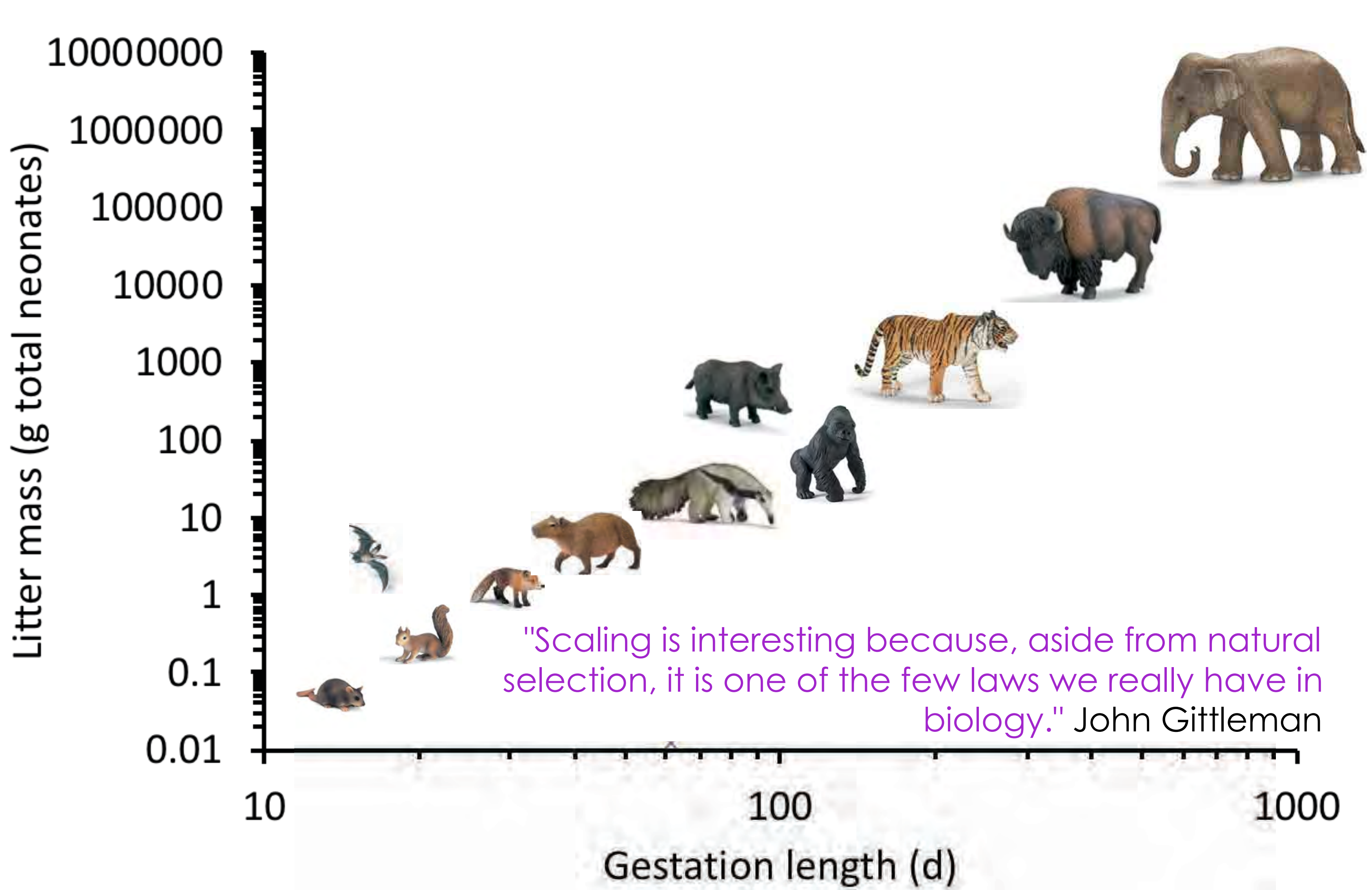
Directionality in Evolution:

Allometries as snapshots in evolutionary time

Biology: fixed laws ?

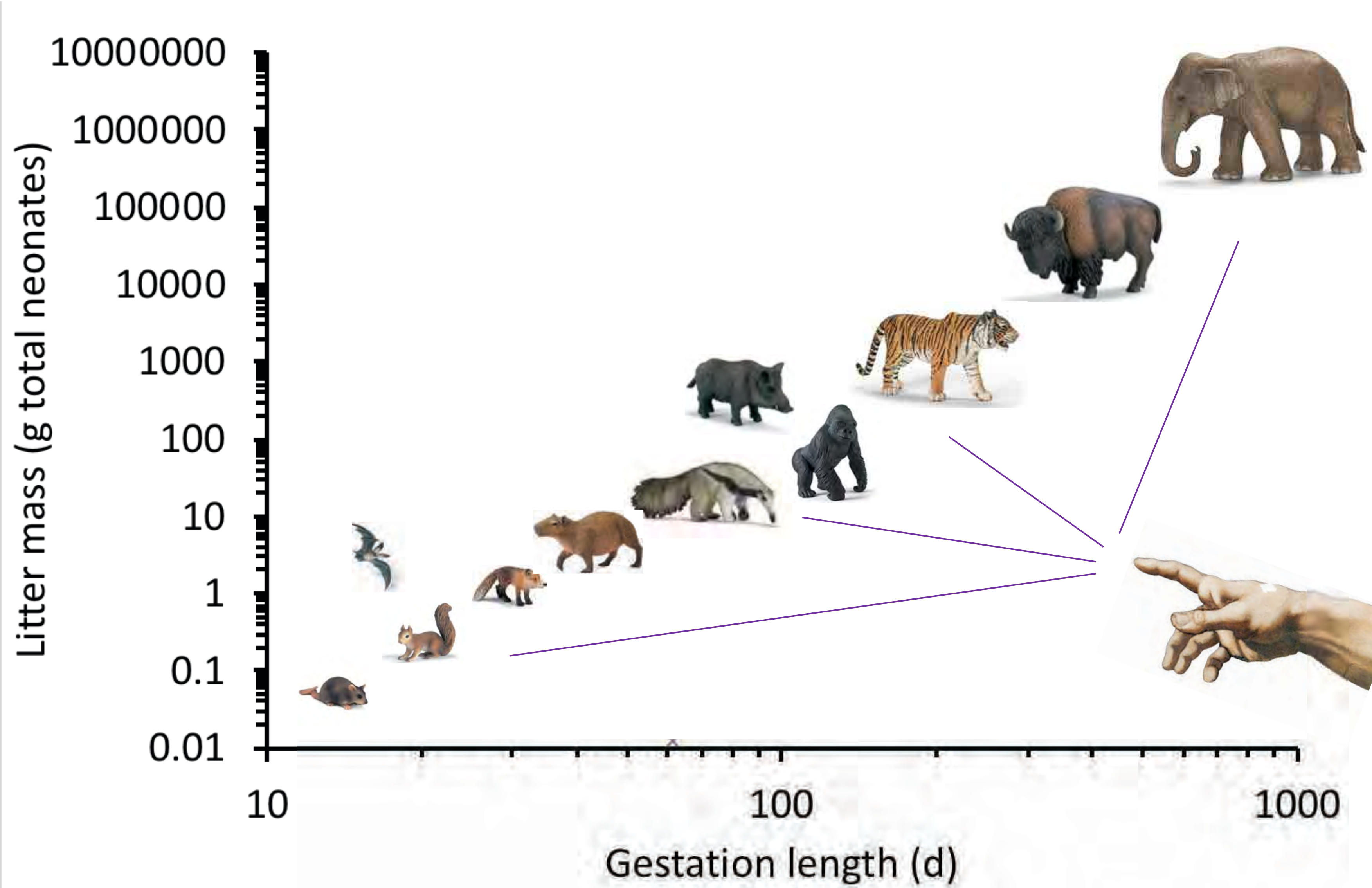


Biology: fixed laws ?



"Scaling is interesting because, aside from natural selection, it is one of the few laws we really have in biology." John Gittleman

Biology: fixed laws ?



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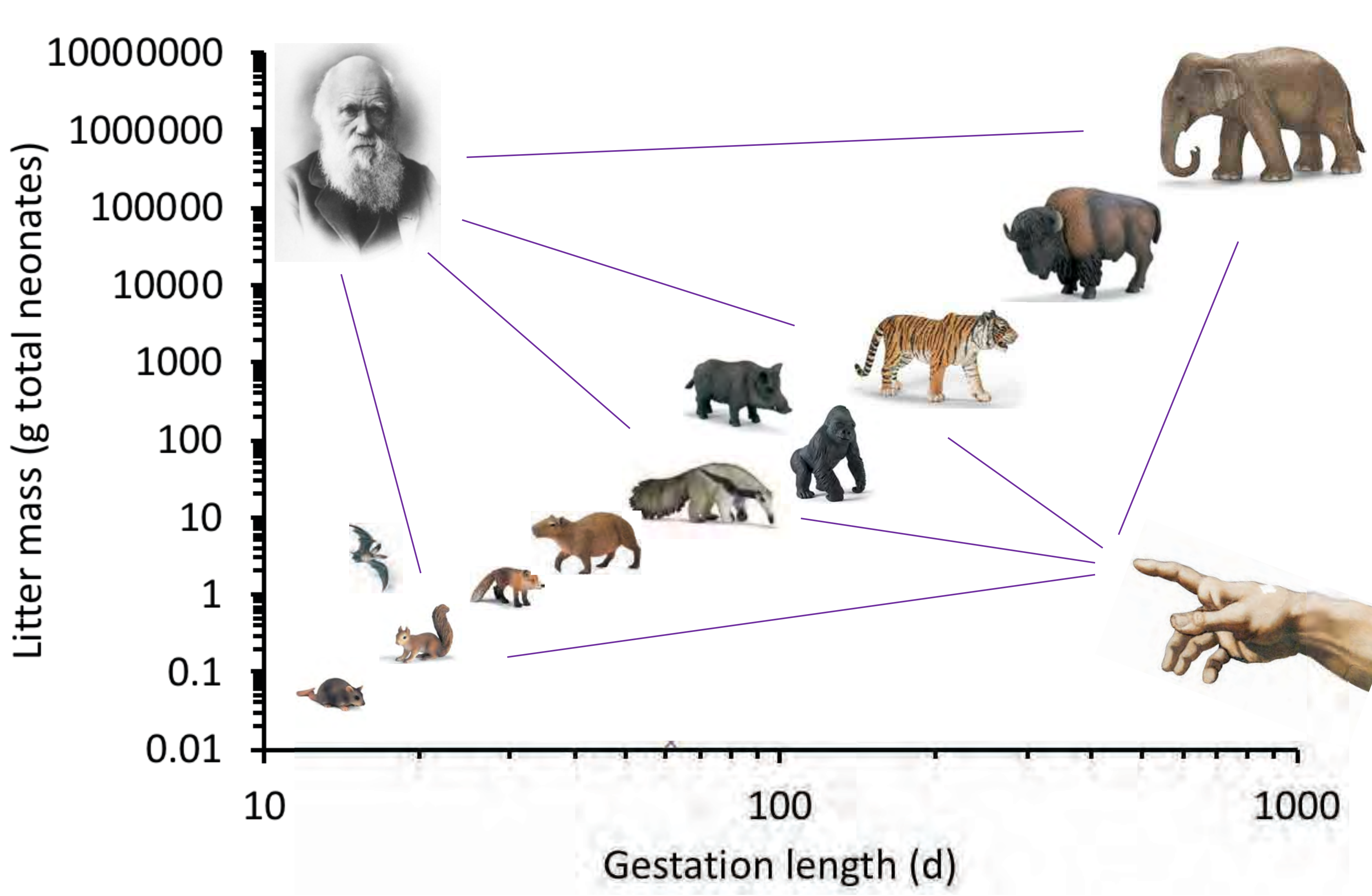
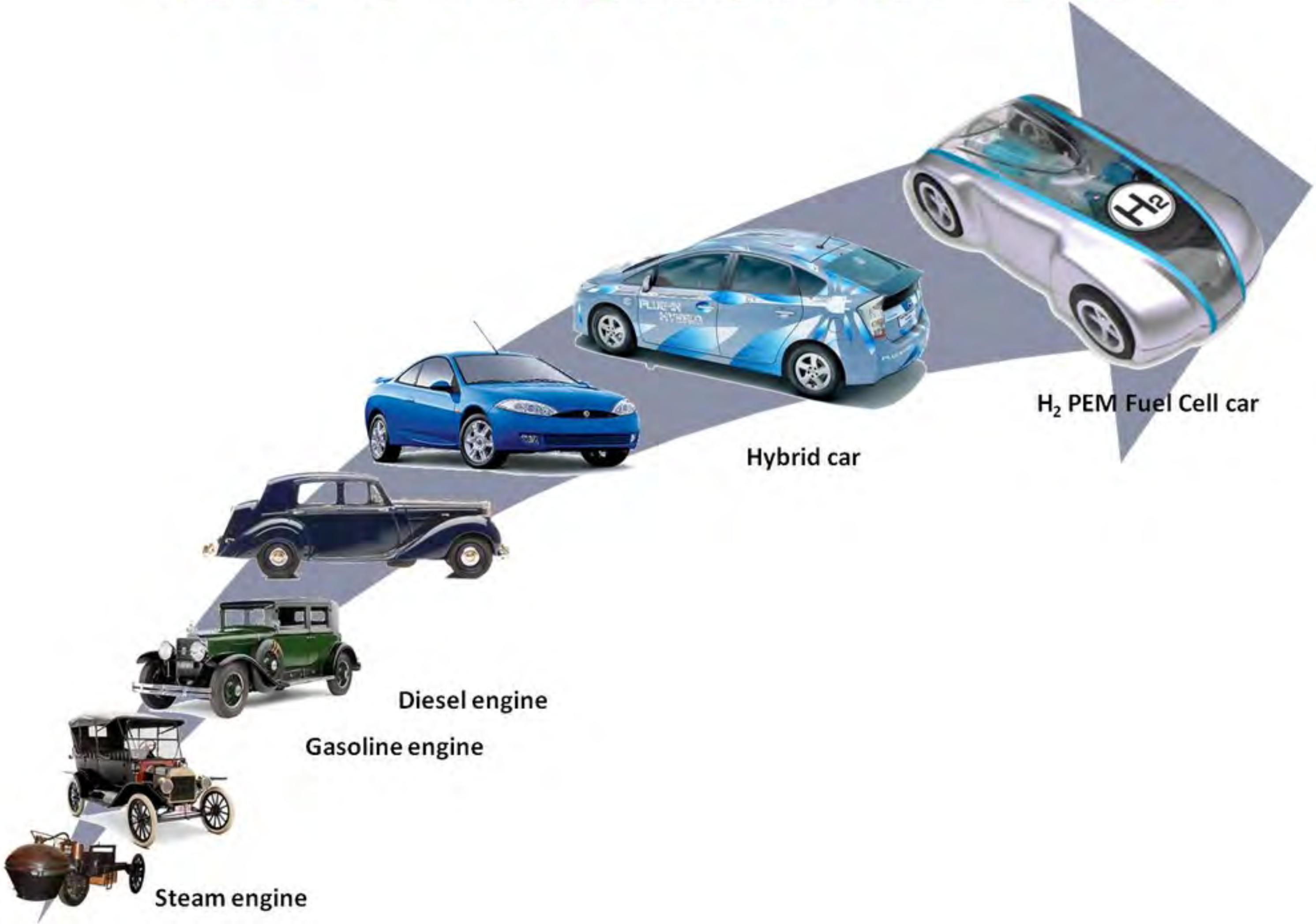


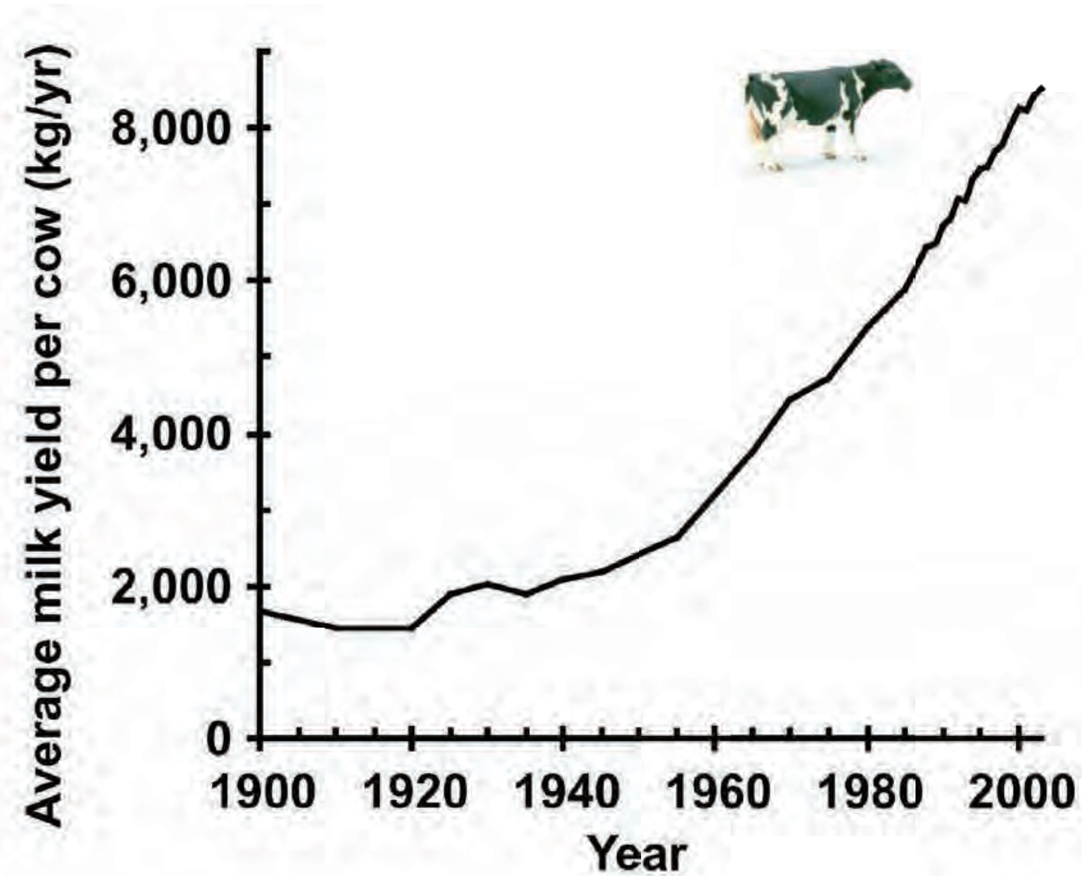
The evolution of cars

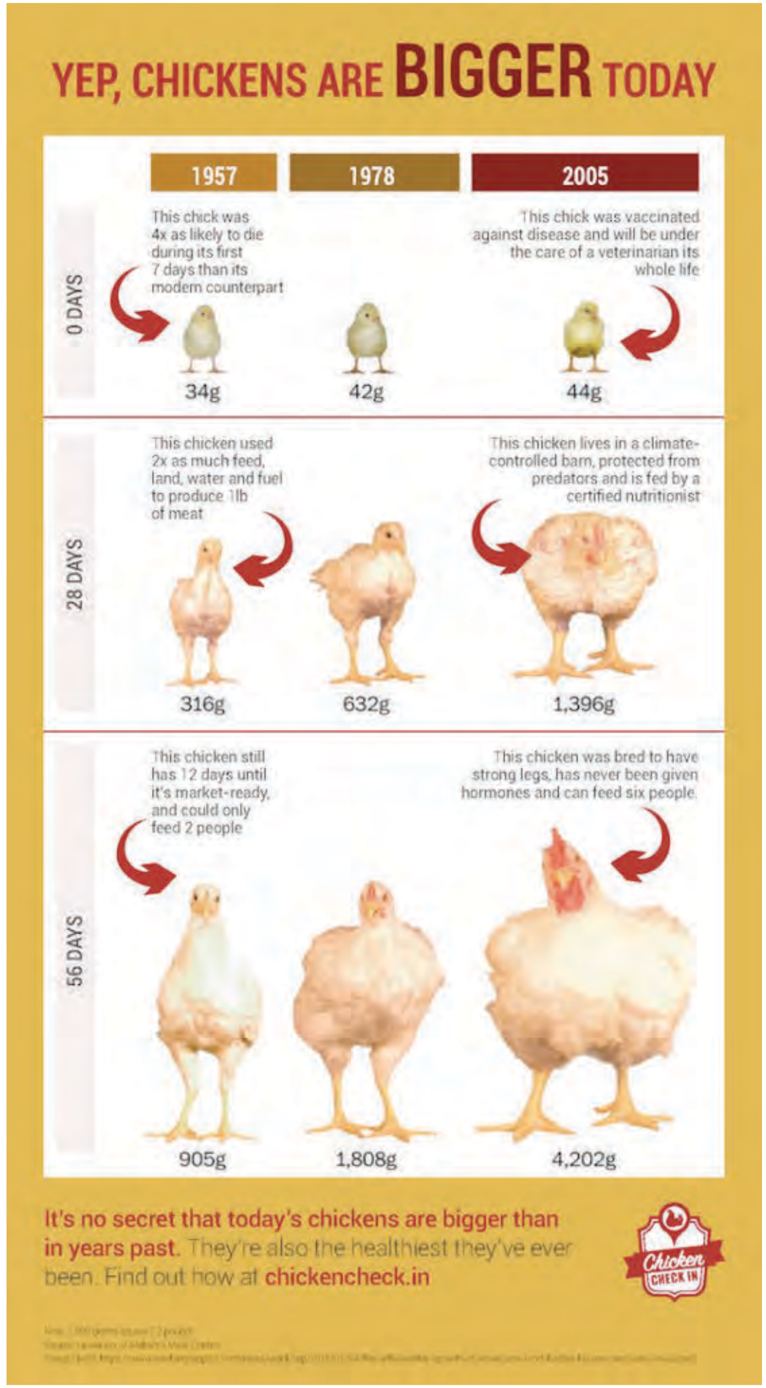


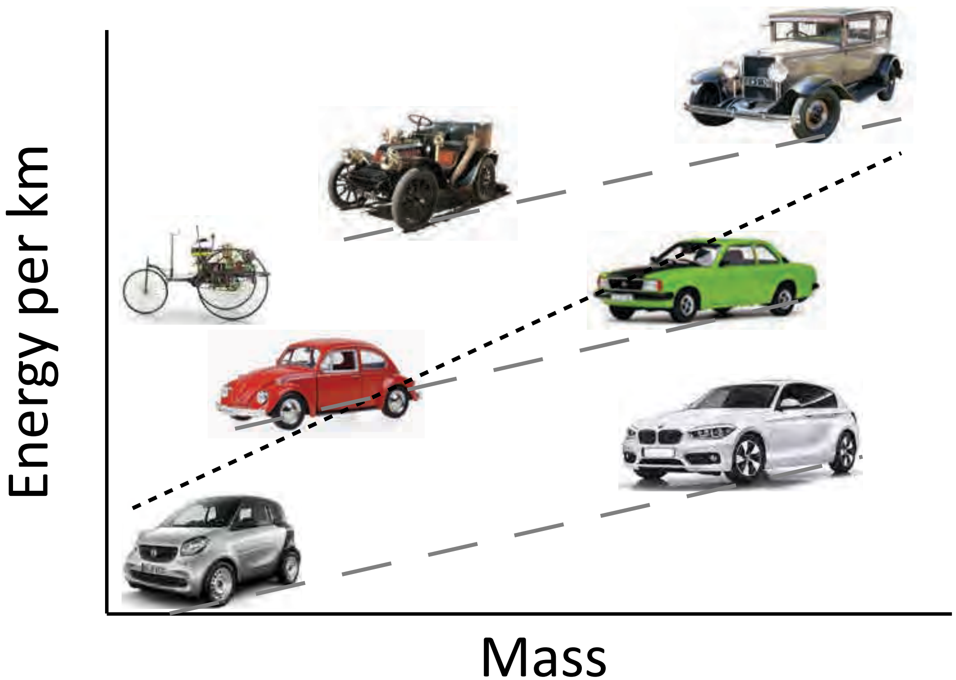
J. Dairy Sci. 89:1280–1291
© American Dairy Science Association, 2006.

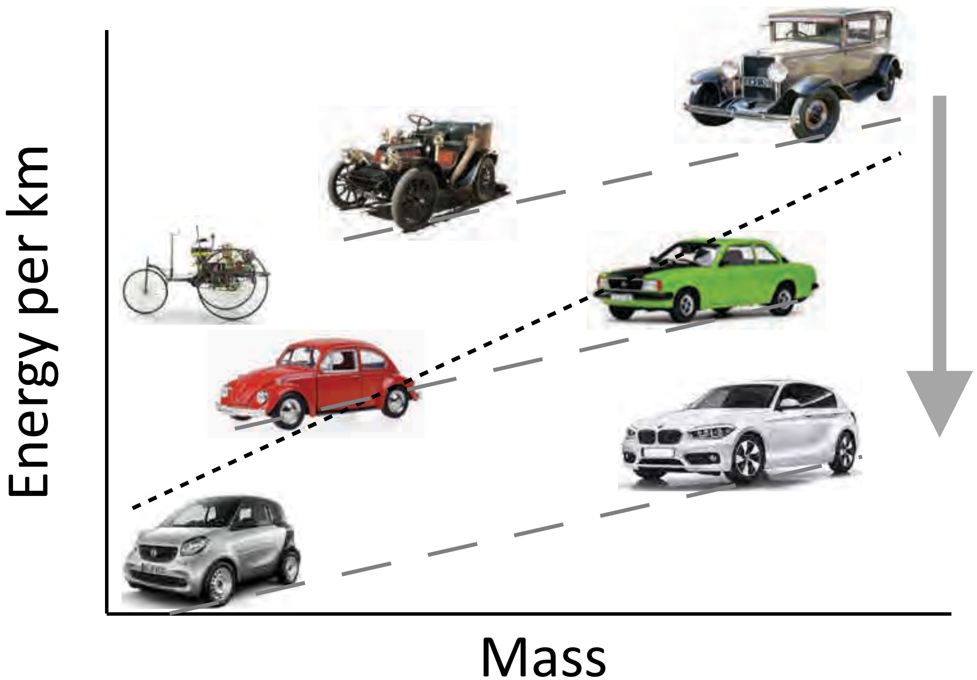
Major Advances in Nutrition: Relevance to the Sustainability of the Dairy Industry

M. J. VandeHaar*[1] and N. St-Pierre†

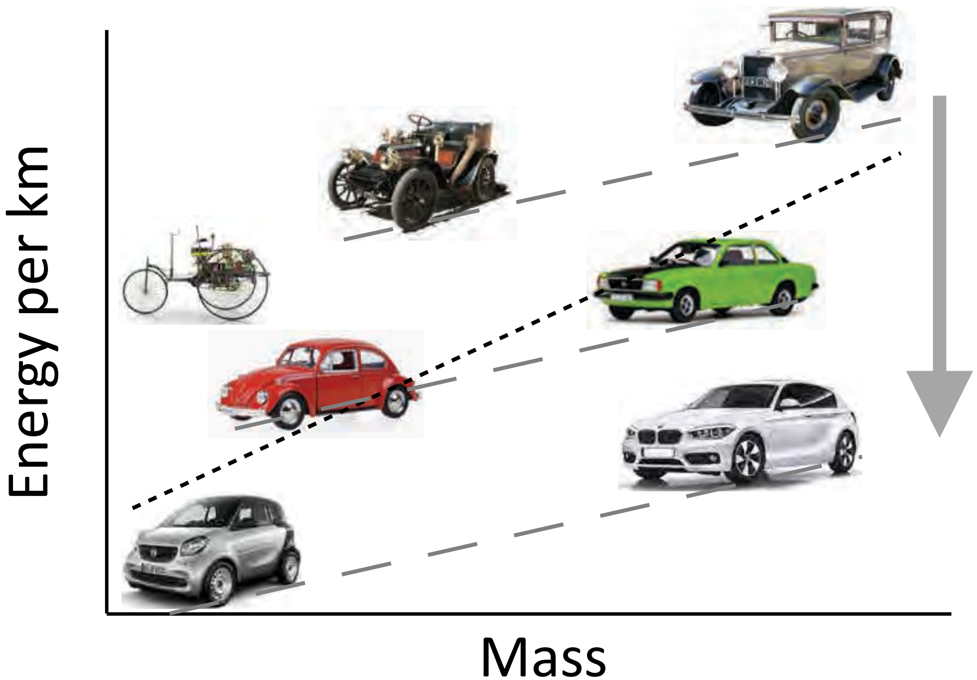


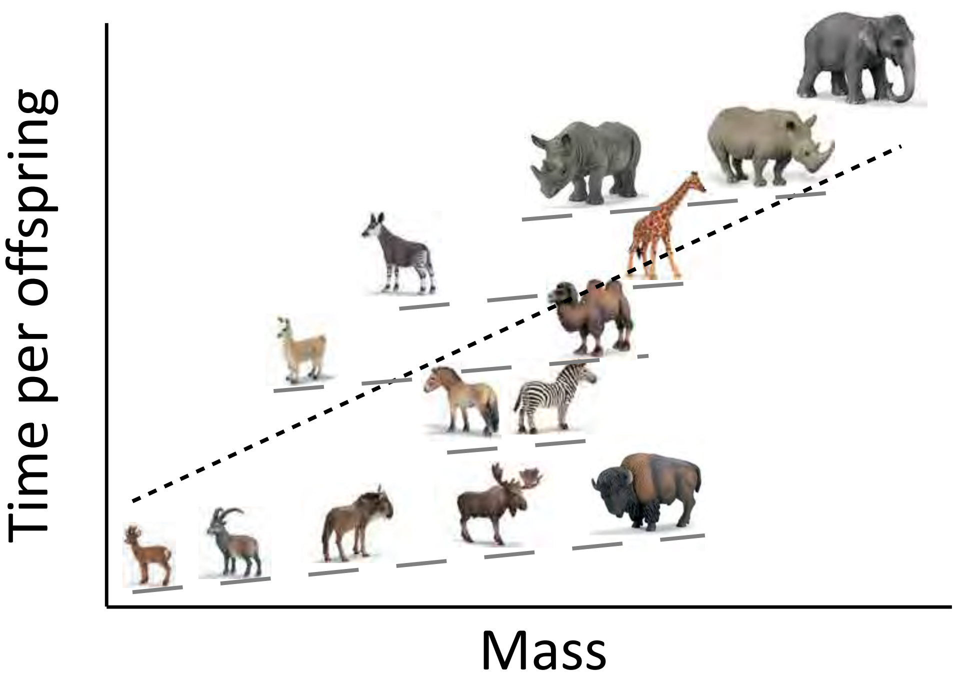

YEP, CHICKENS ARE BIGGER TODAY
1957
1978
2005
0 DAYS
This chick was 4x as likely to die during its first 7 days than its modern counterpart
This chick was vaccinated against disease and will be under the care of a veterinarian its whole life
34g
42g
44g
28 DAYS
This chicken used 2x as much feed, land, water and fuel to produce 1lb of meat
This chicken lives in a climate-controlled barn, protected from predators and is fed by a certified nutritionist
316g
632g
1,396g
56 DAYS
This chicken still has 12 days until it's market-ready, and could only feed 2 people
This chicken was bred to have strong legs, has never been given hormones and can feed six people
905g
1,808g
4,202g
It's no secret that today's chickens are bigger than in years past. They're also the healthiest they've ever been. Find out how at chickencheck.in
Chicken CHECK IN


Energy per km
Mass



You would not consider the overall pattern a fixed law, but consider it with respect to technical progress.





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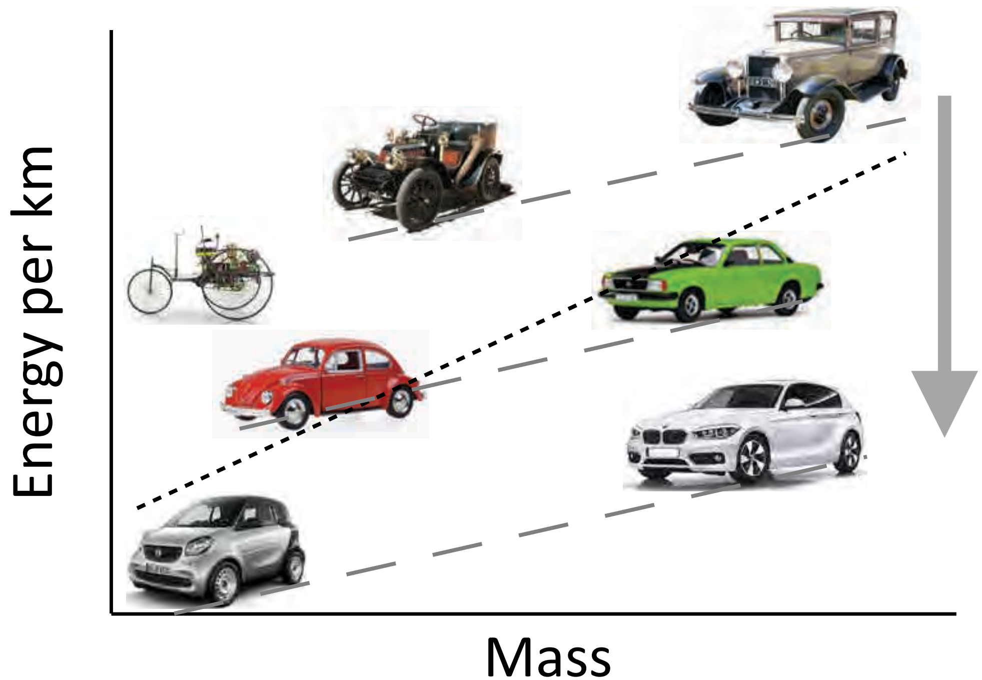

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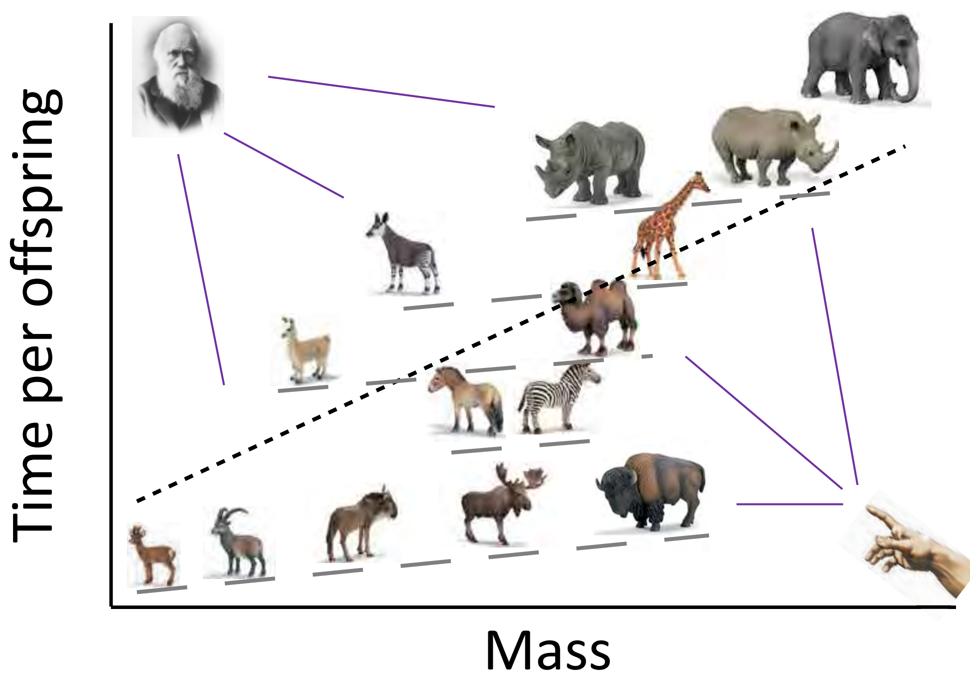
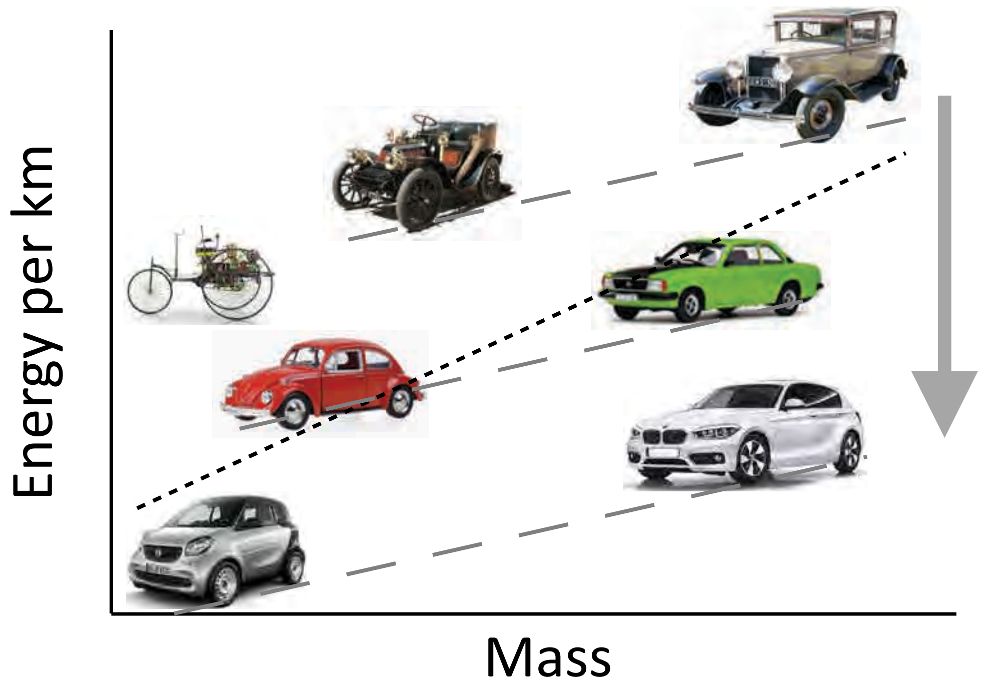


Why would you consider this a pattern due to fixed life history tradeoff laws?



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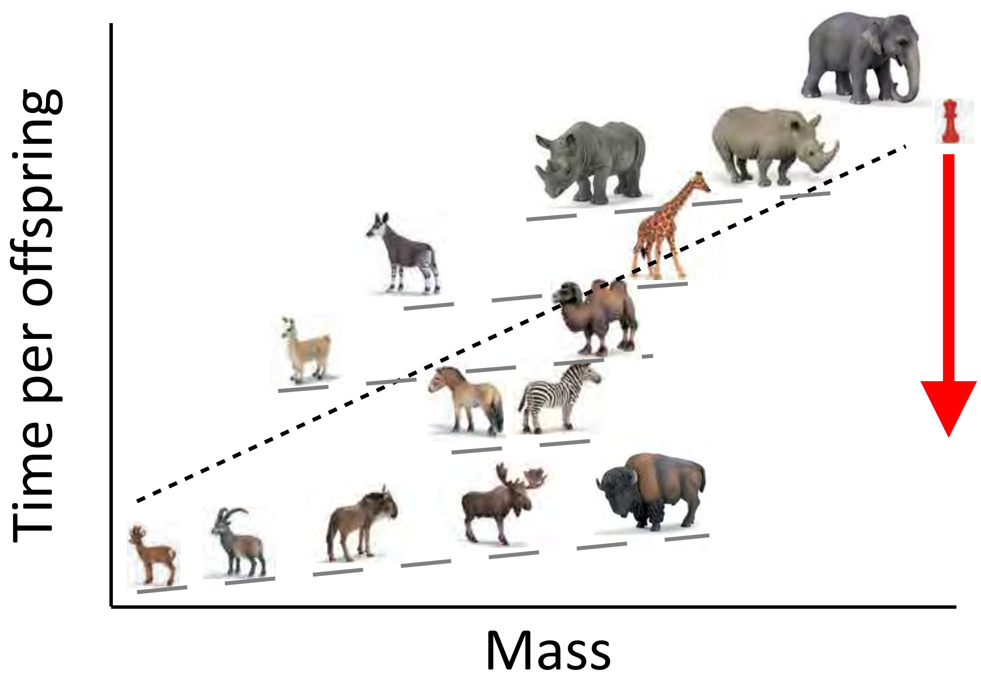

Why would you consider this a pattern due to fixed life history tradeoff laws, and not rather a snapshot in a process of optimization?

Some simple a priori assumptions and their consequences

A priori conditions and their consequences

Life requires input of resources.

A priori conditions and their consequences

Life requires input of resources.

Life starts simple (non-complex).

A priori conditions and their consequences

Life requires input of resources.

Life starts simple (non-complex).

Life means reproduction.

A *priori* conditions and their consequences

Life requires input of resources.

Life starts simple (non-complex).

Life means reproduction.

- spontaneously occurring yet heritable variability

A priori conditions and their consequences

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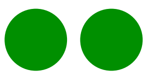

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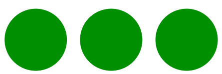

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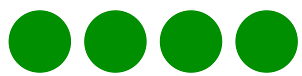

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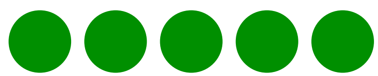

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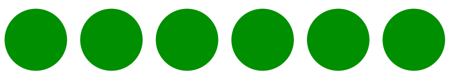

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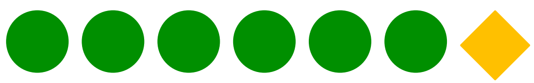

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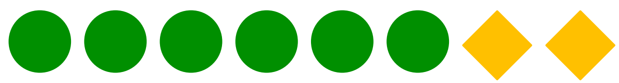

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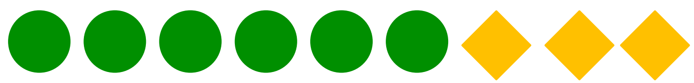

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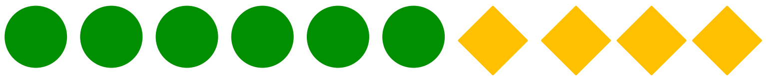

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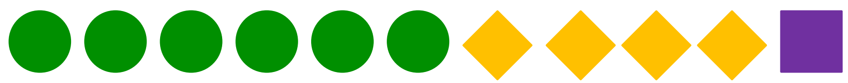

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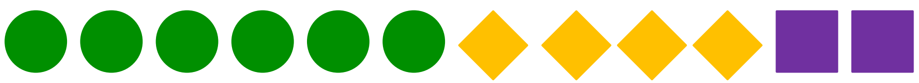

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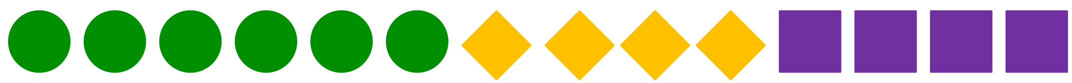

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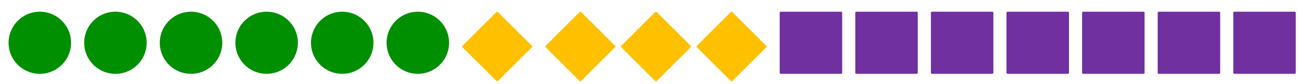

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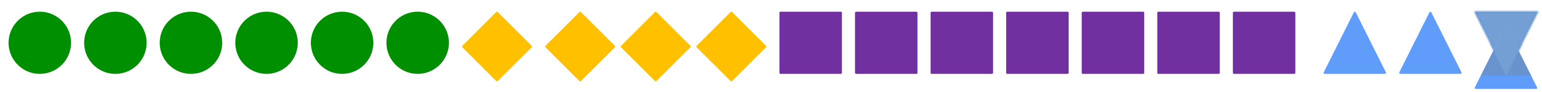

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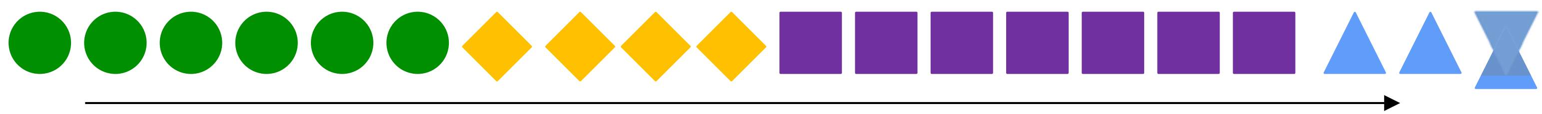

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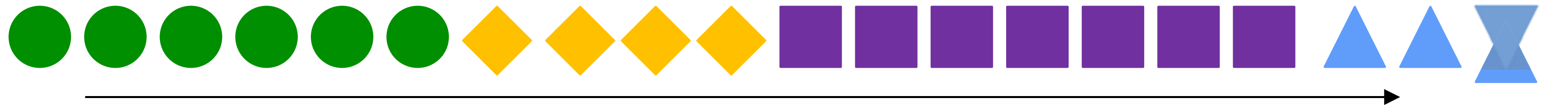

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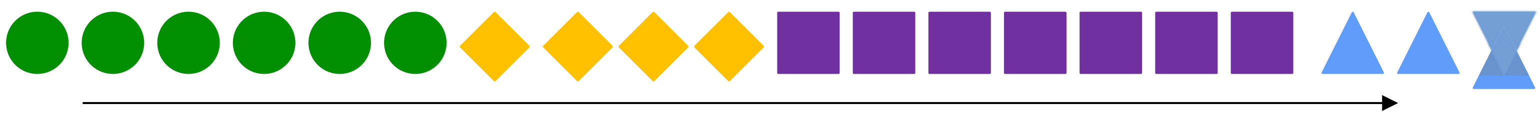

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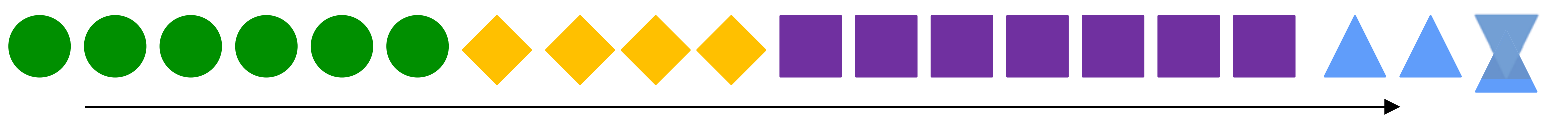

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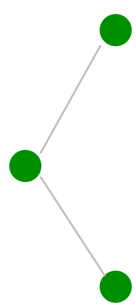

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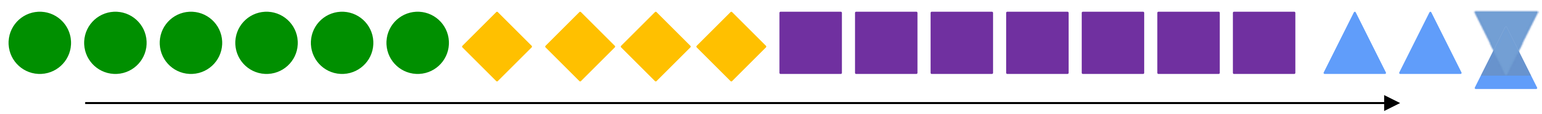

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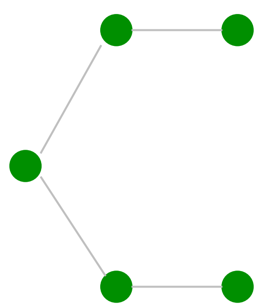

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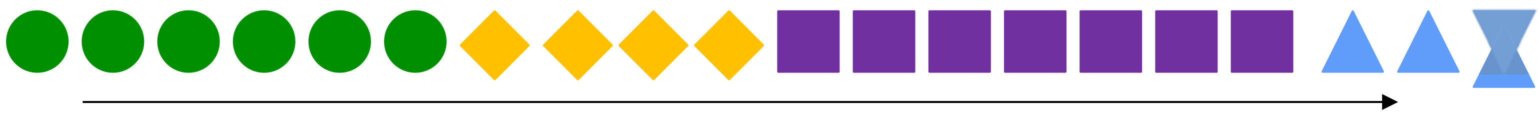

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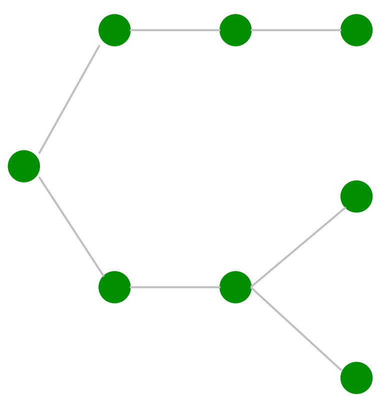

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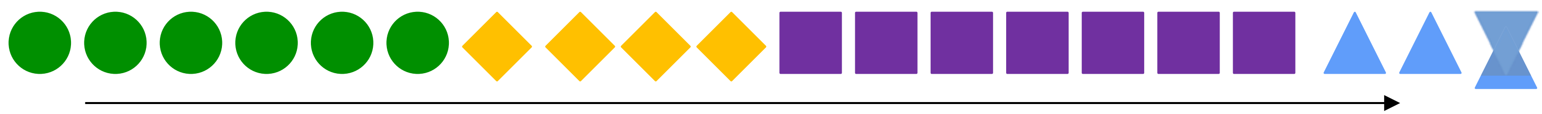

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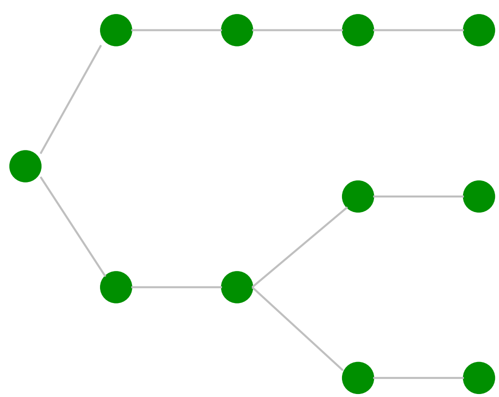

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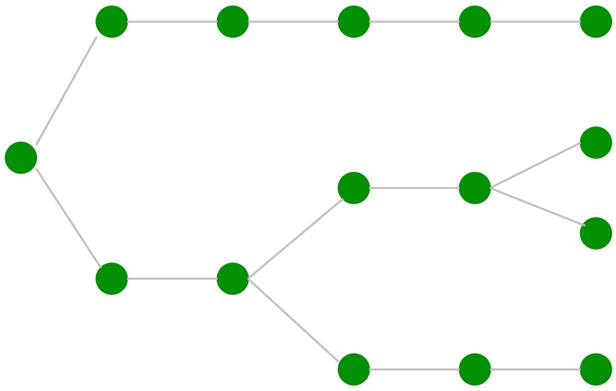

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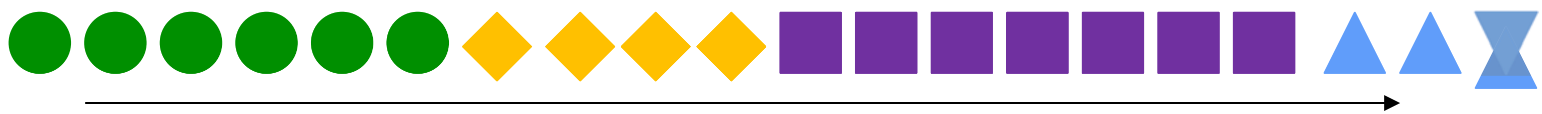

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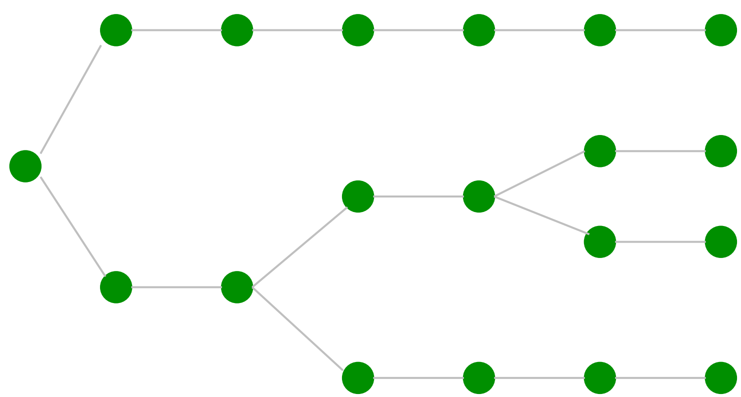

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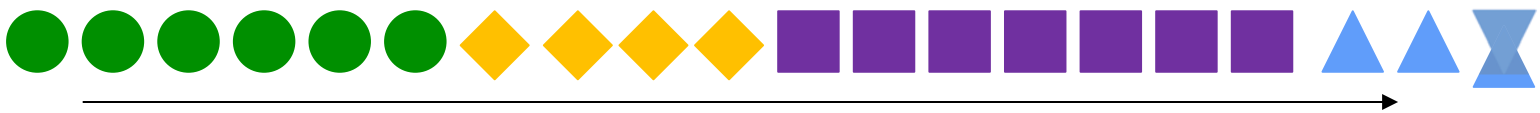

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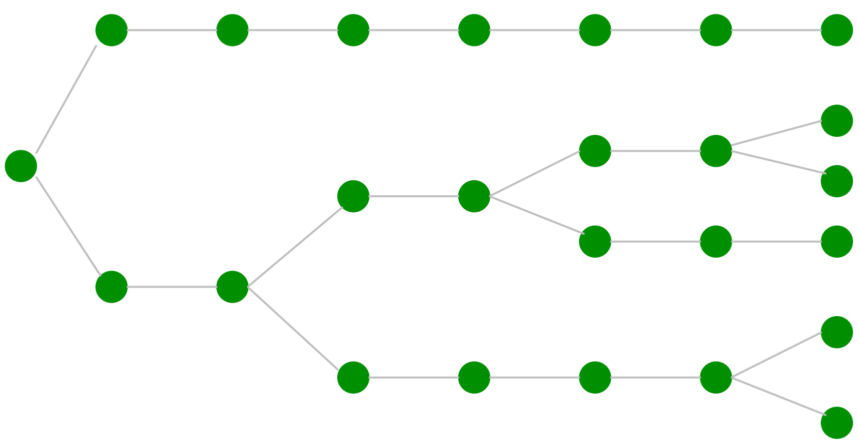

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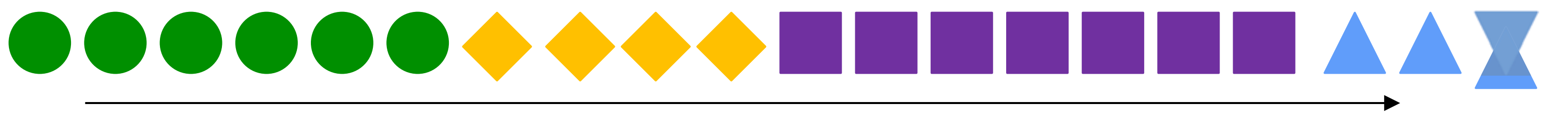

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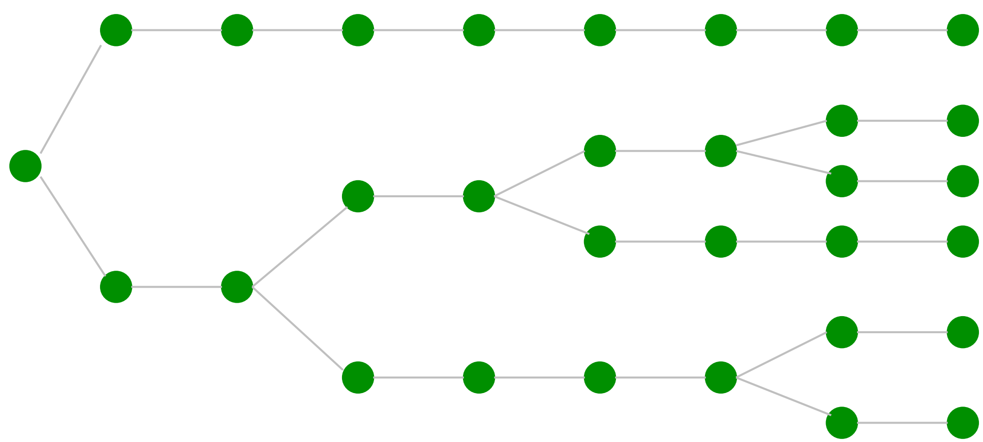

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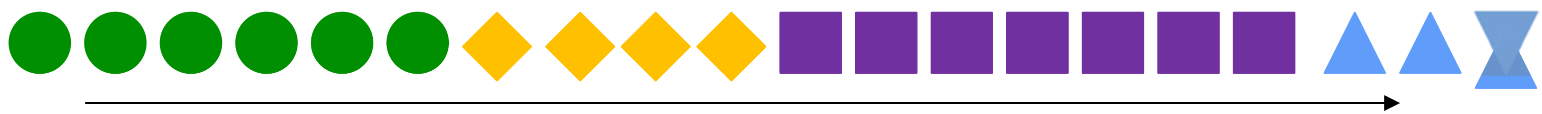

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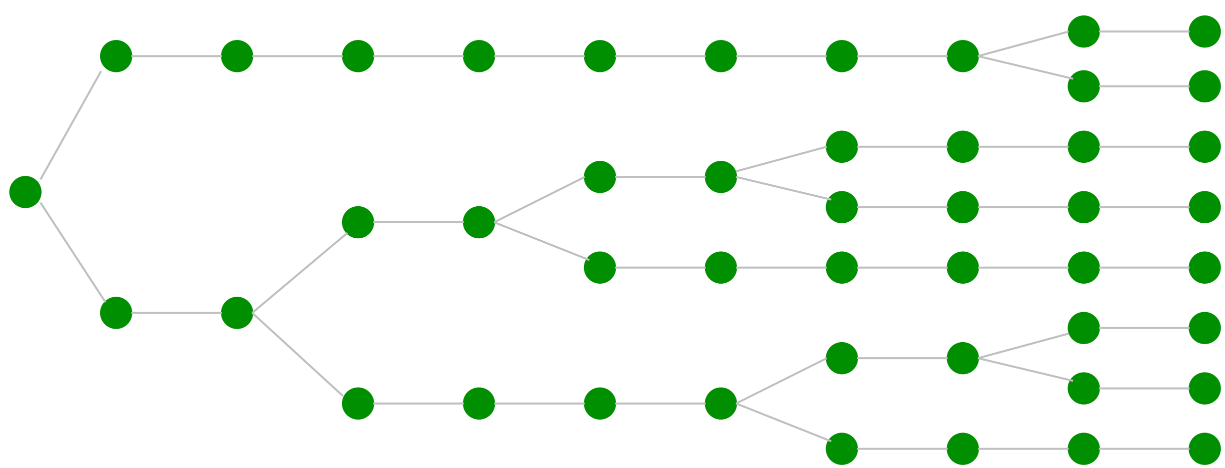

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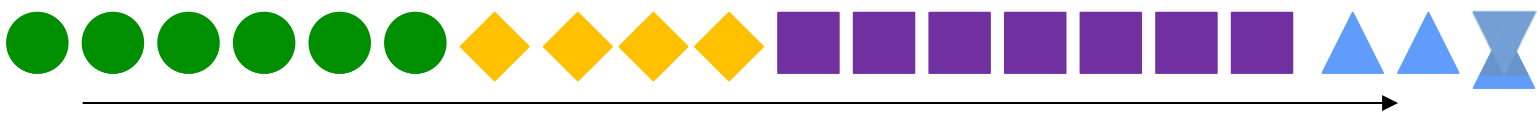

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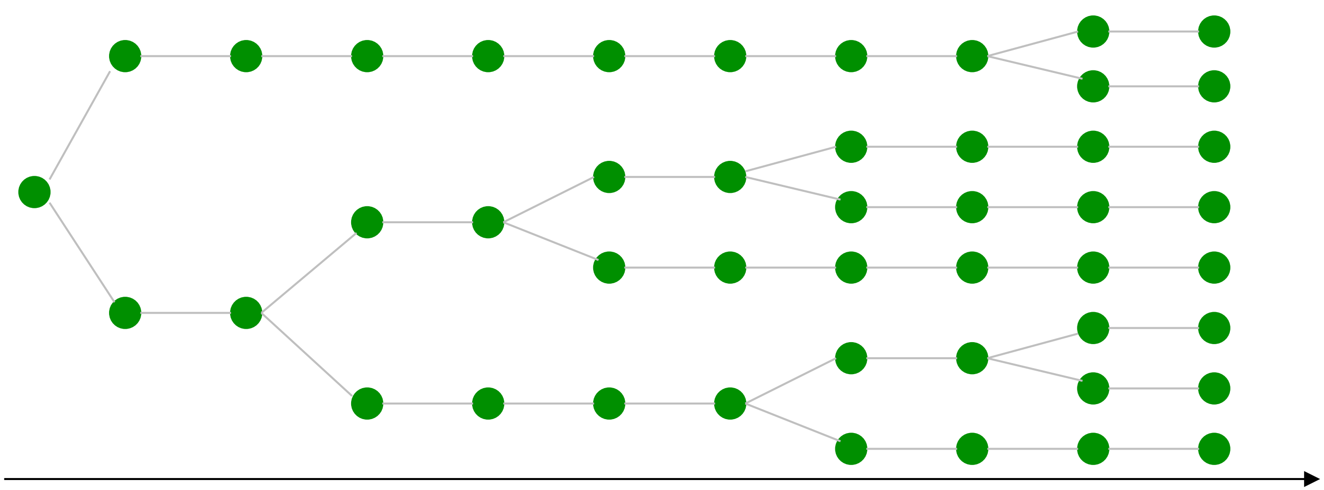

Probabilistic directionality II: more

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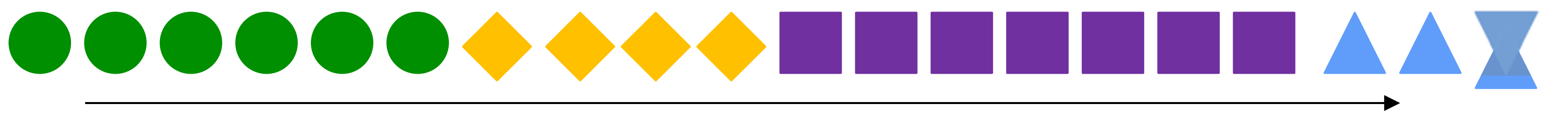

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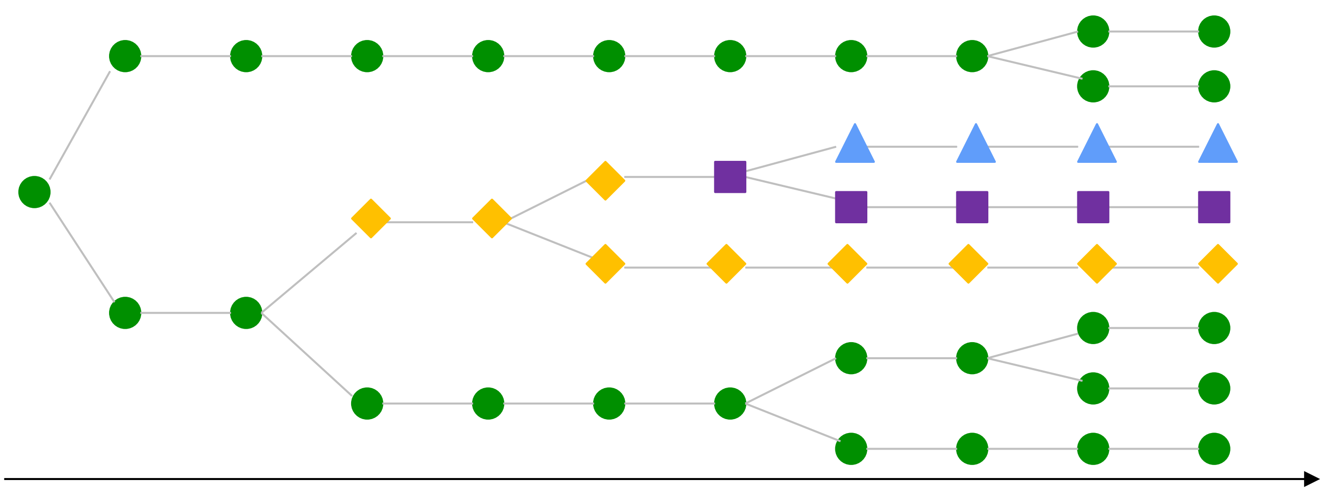

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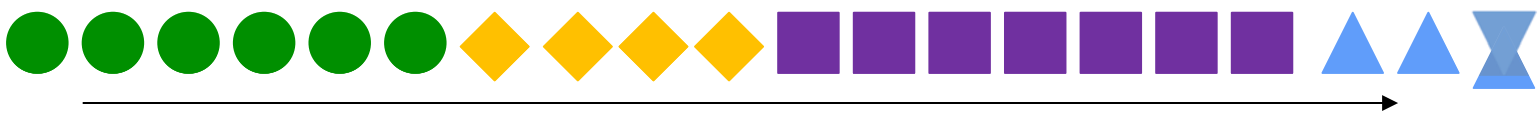

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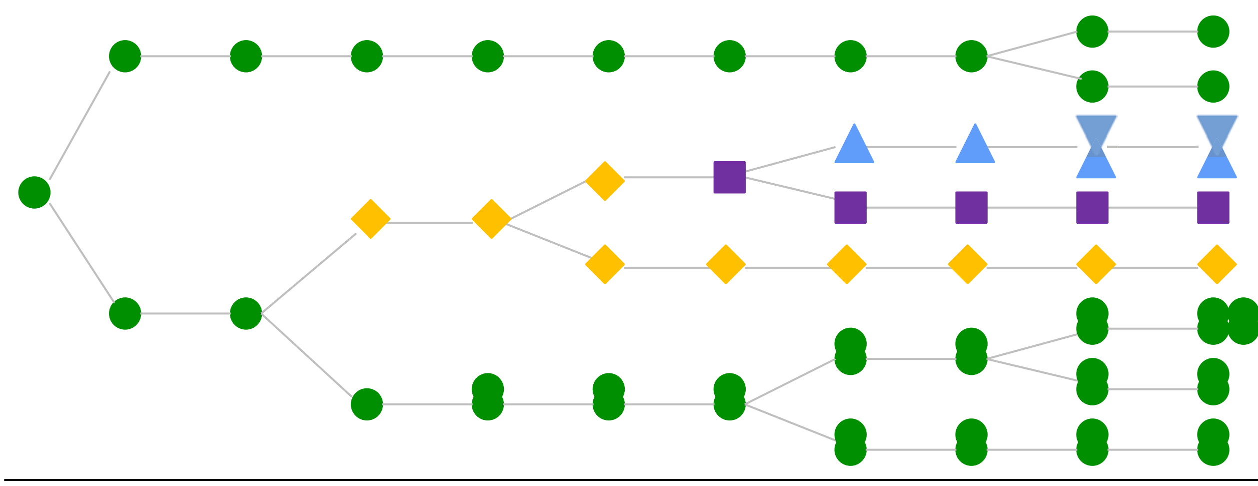
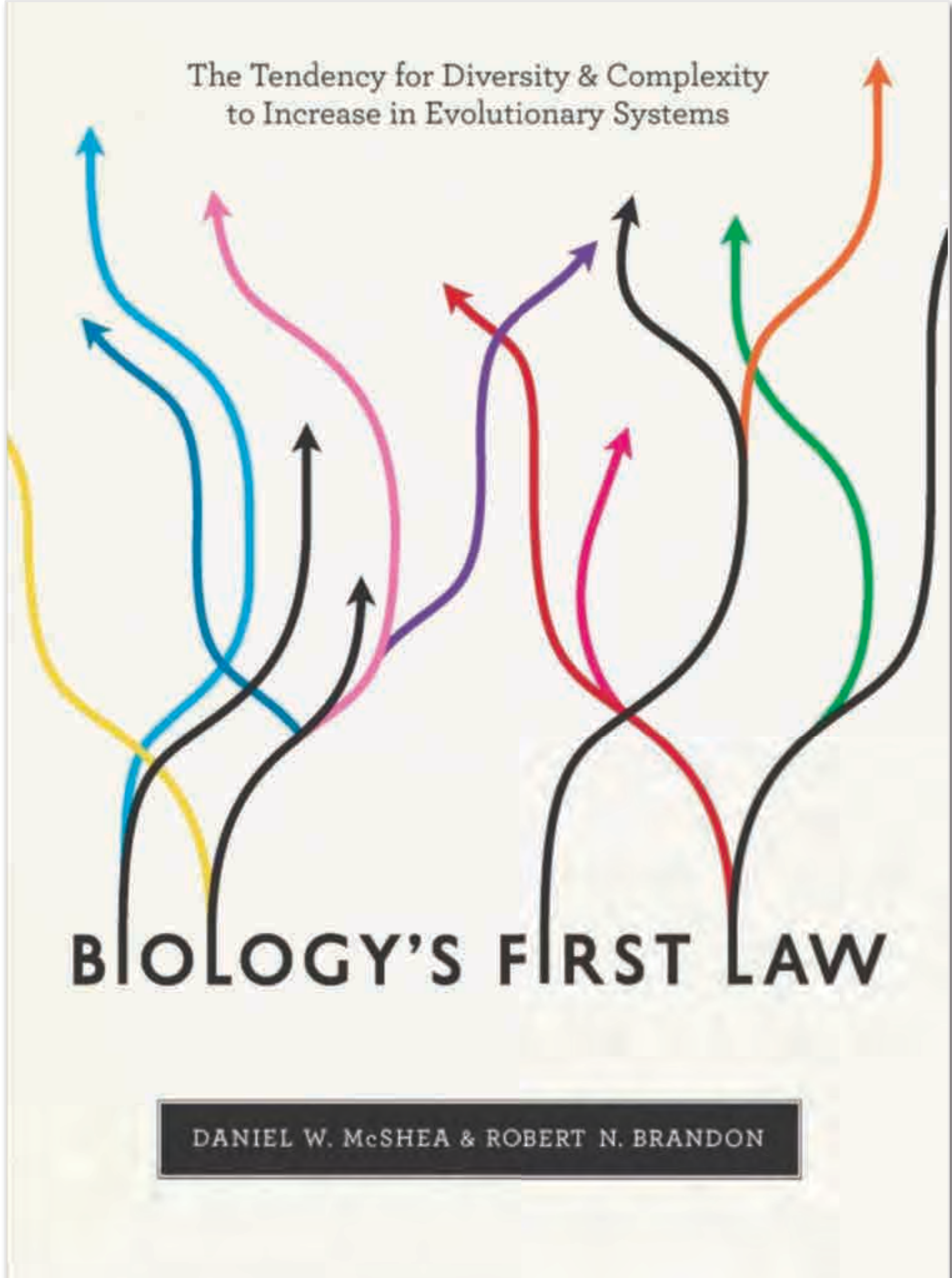


Probabilistic directionality II: more diversity & complexity


The Tendency for Diversity & Complexity
to Increase in Evolutionary Systems
BIOLOGY'S FIRST LAW
DANIEL W. McSHEA & ROBERT N. BRANDON

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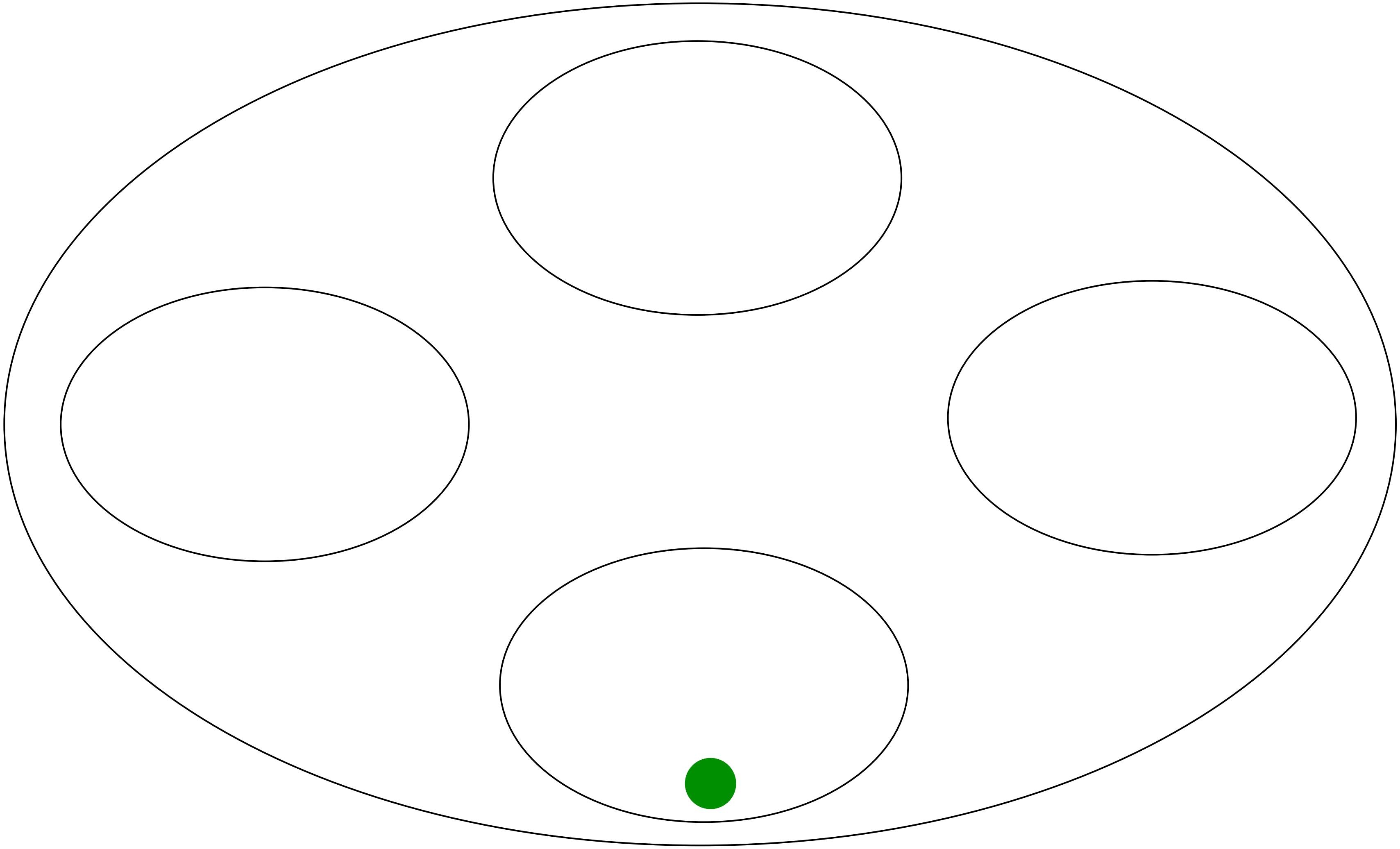
Resources are finite.



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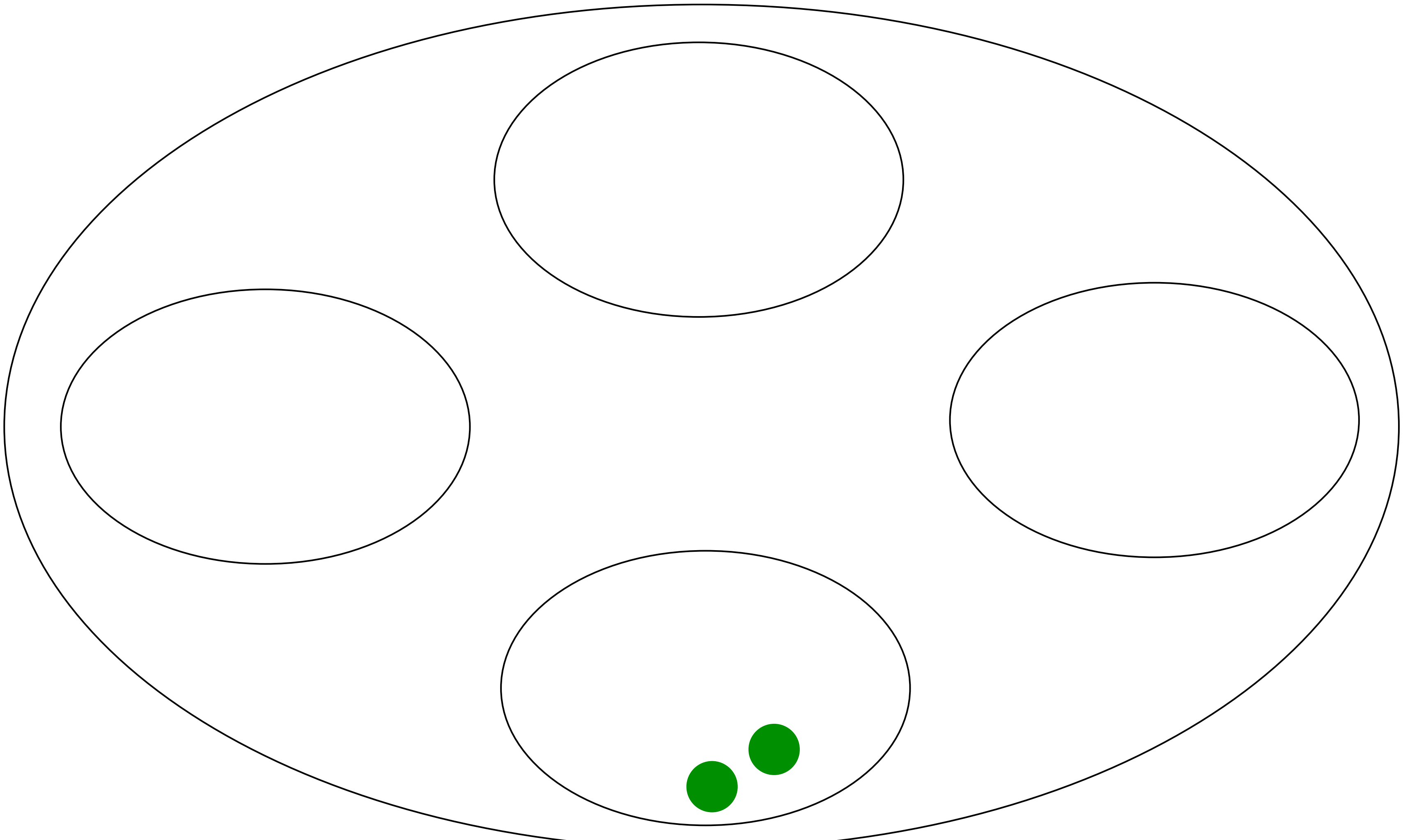

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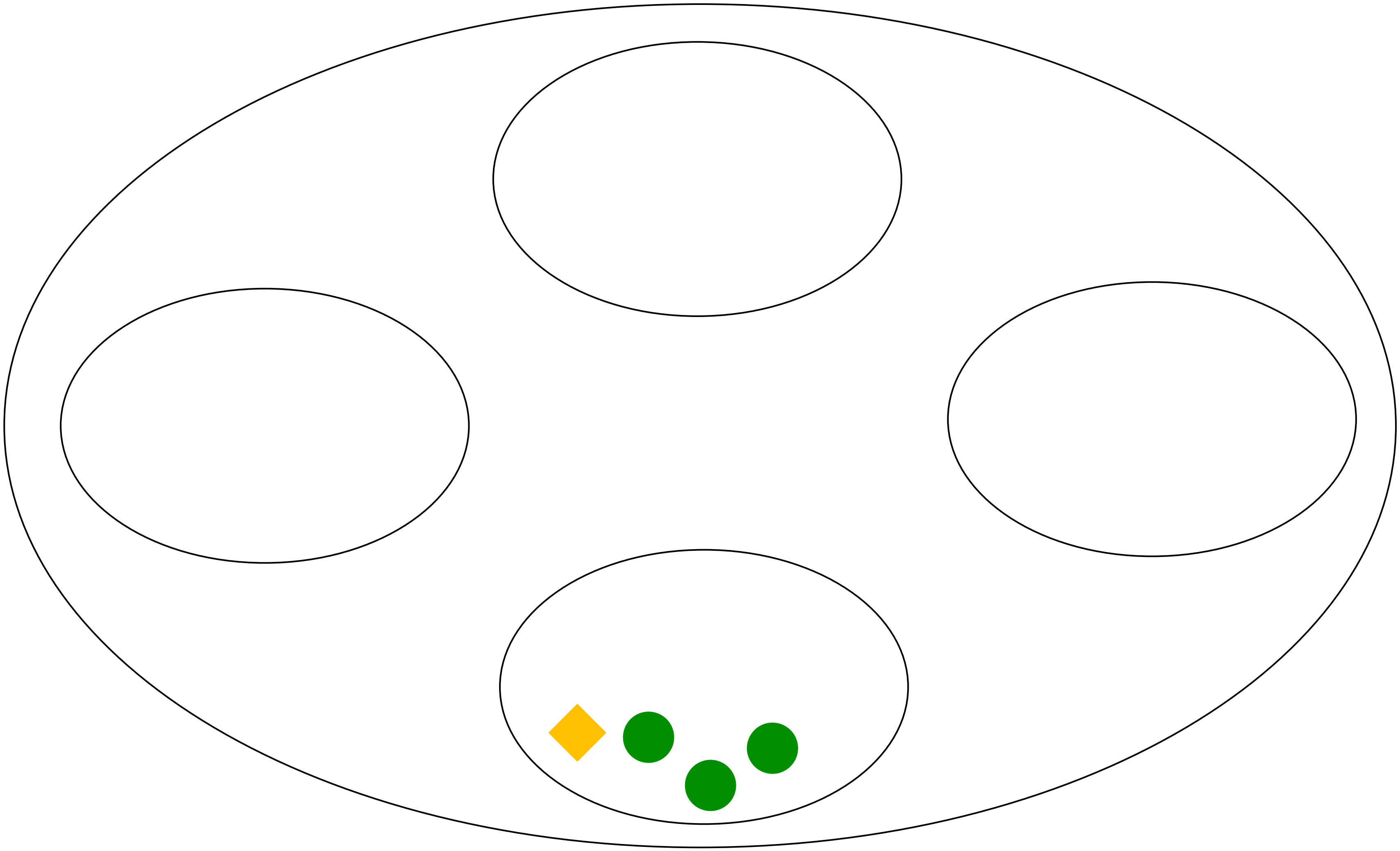

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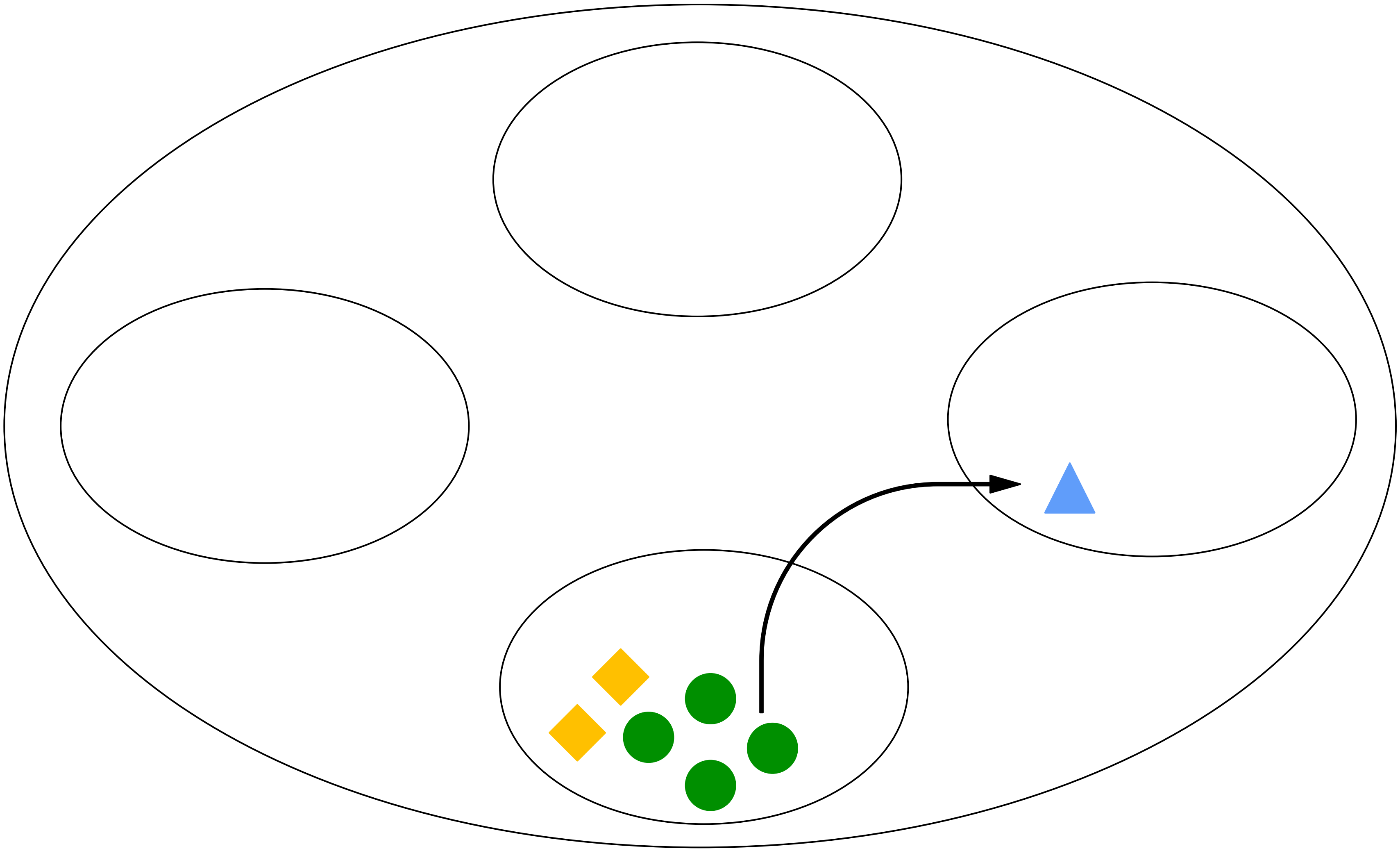

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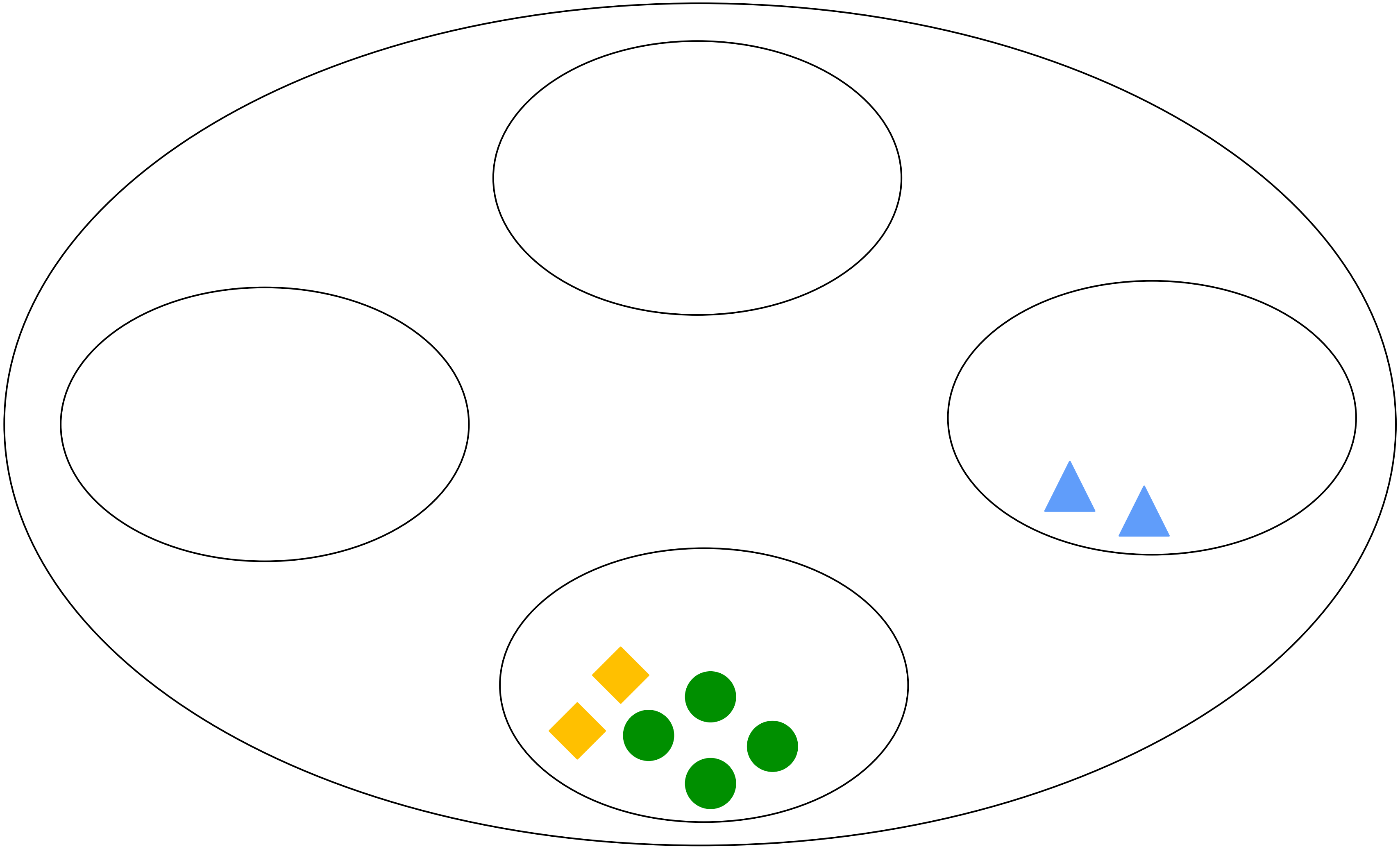

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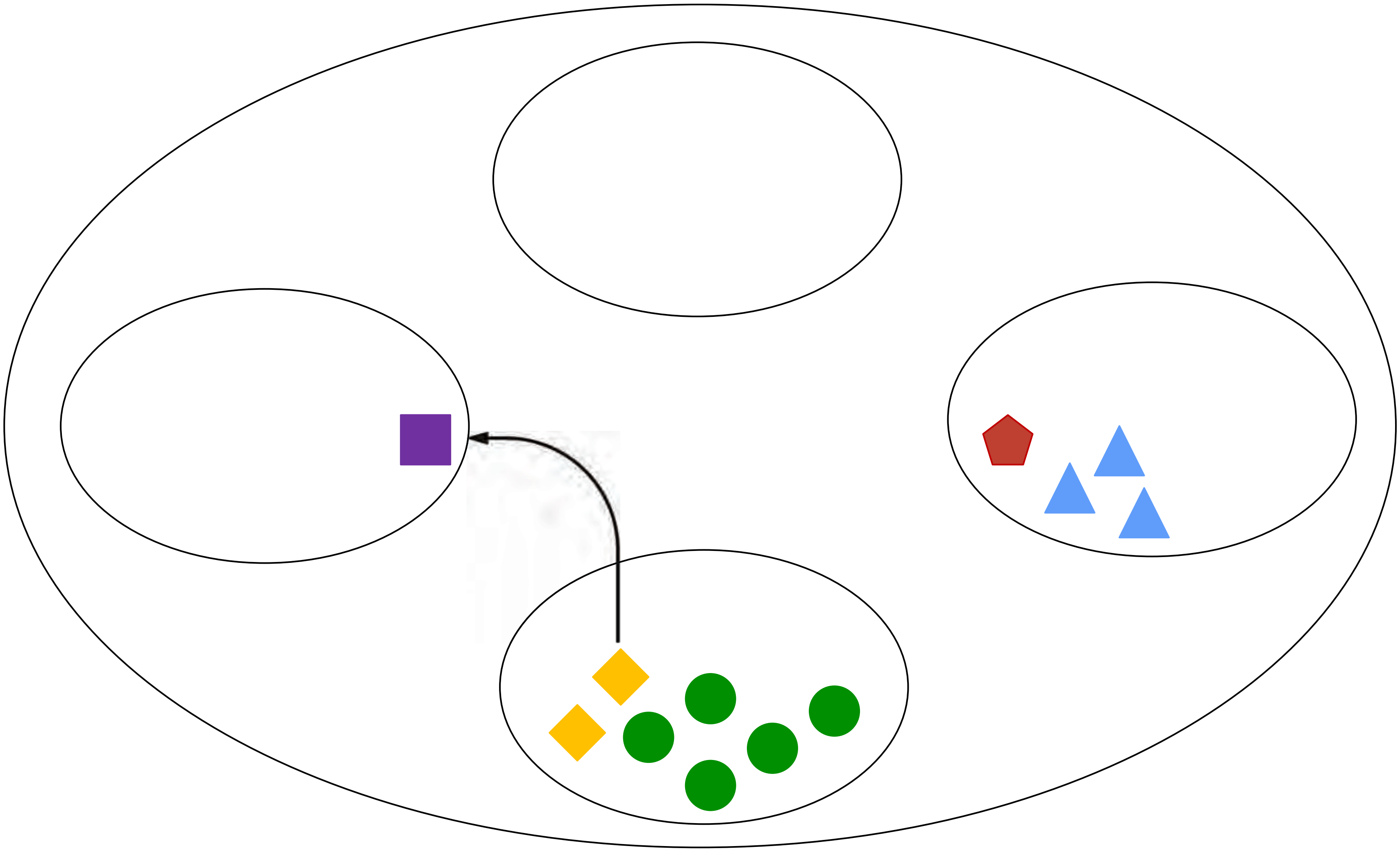

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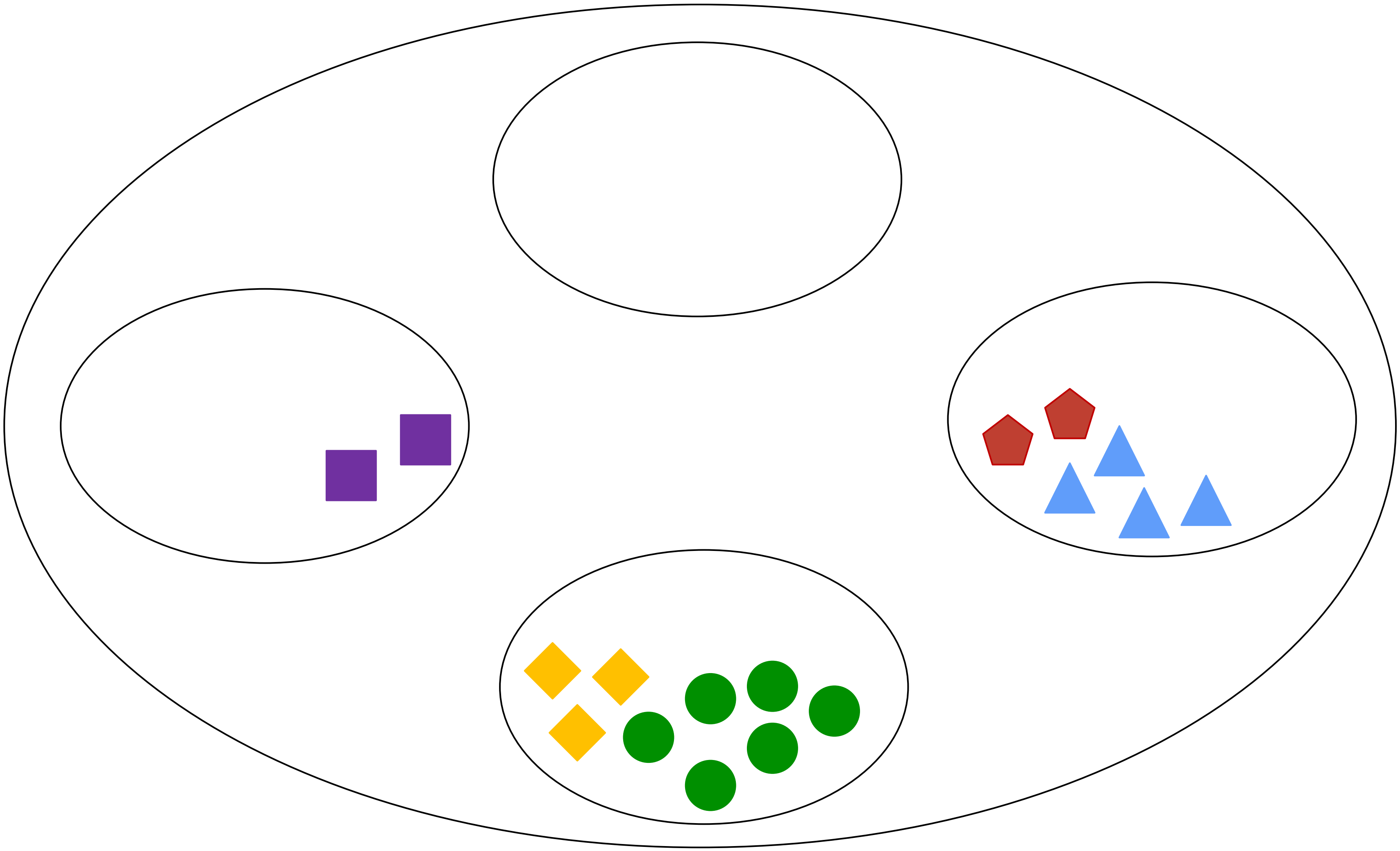

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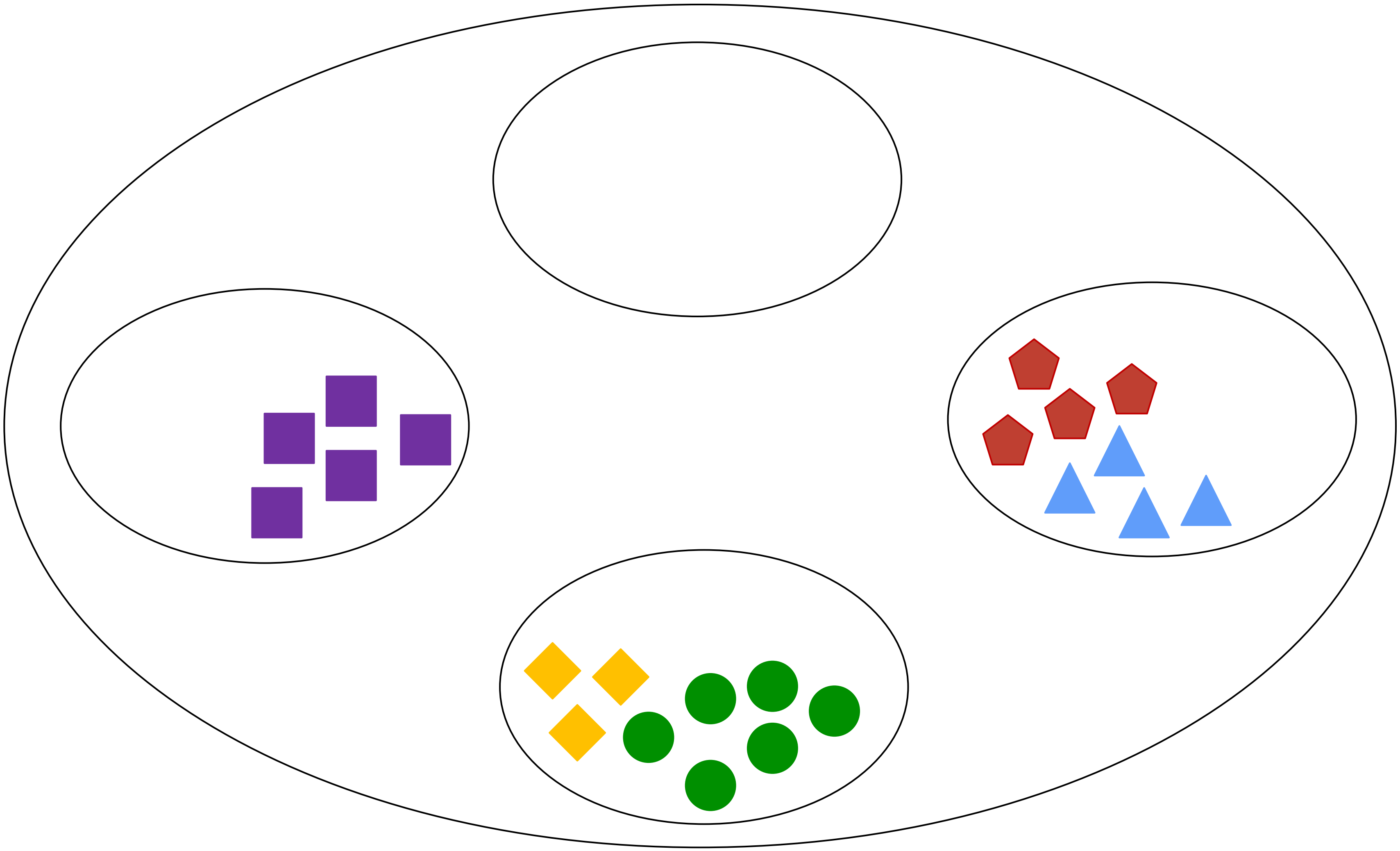

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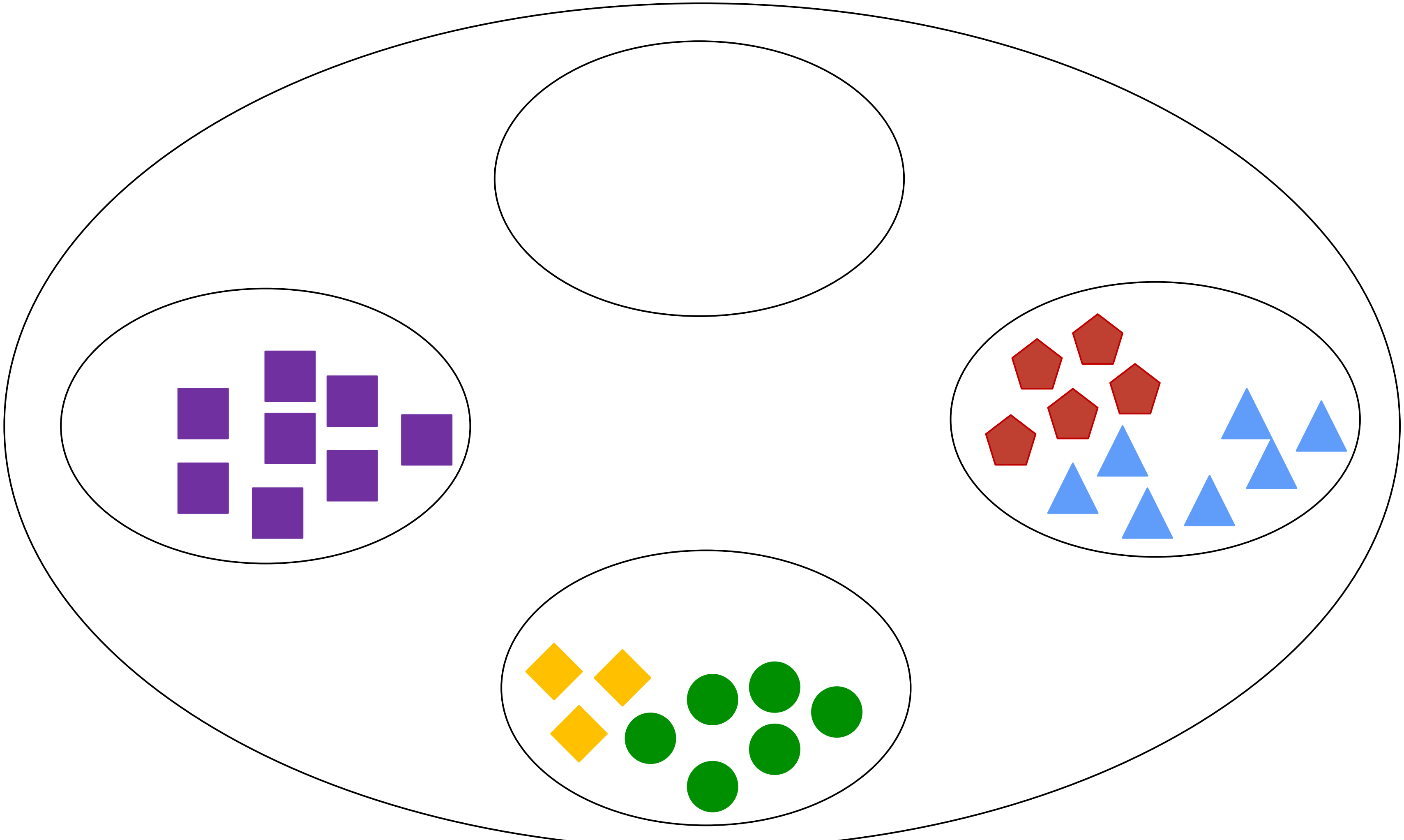

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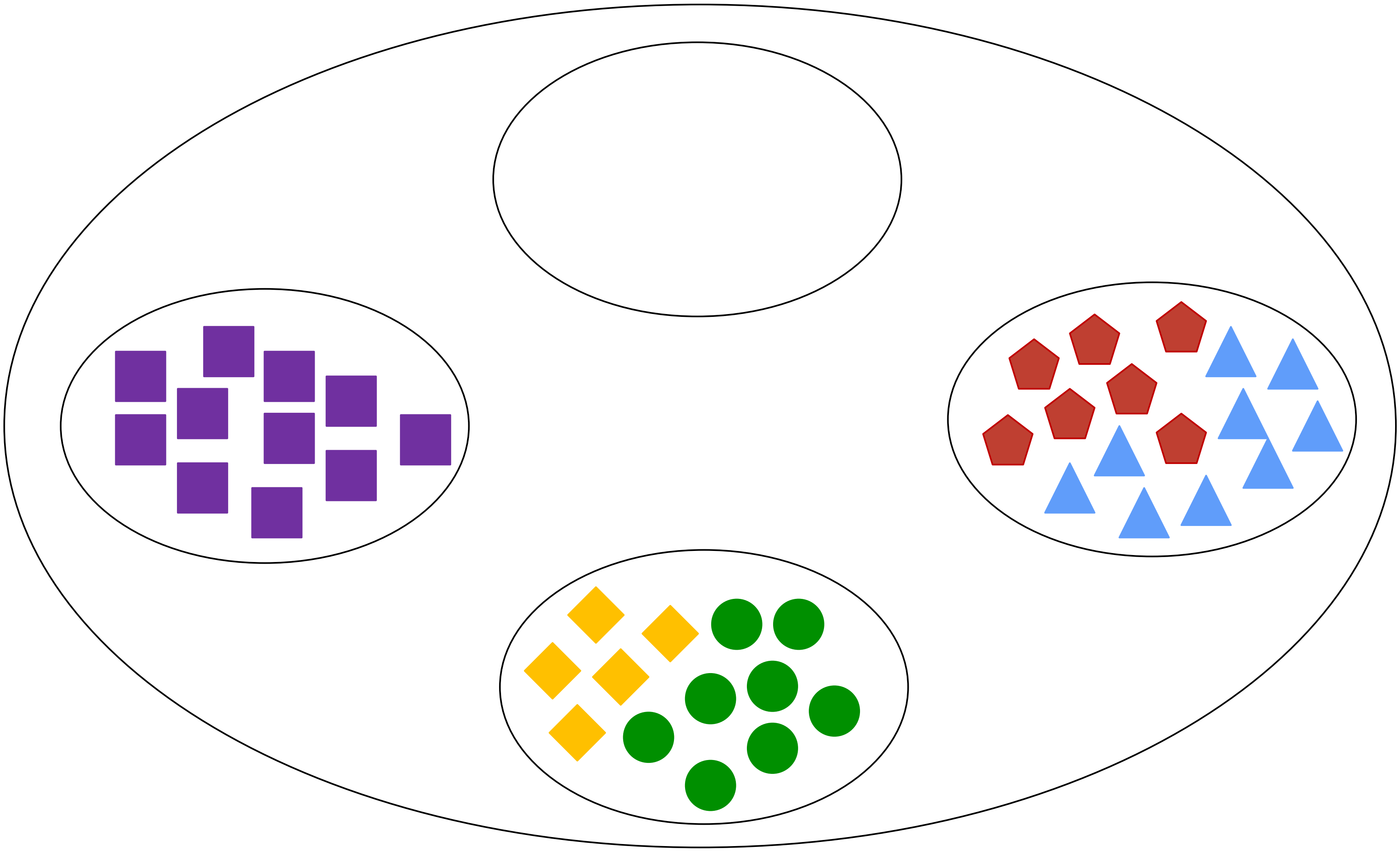

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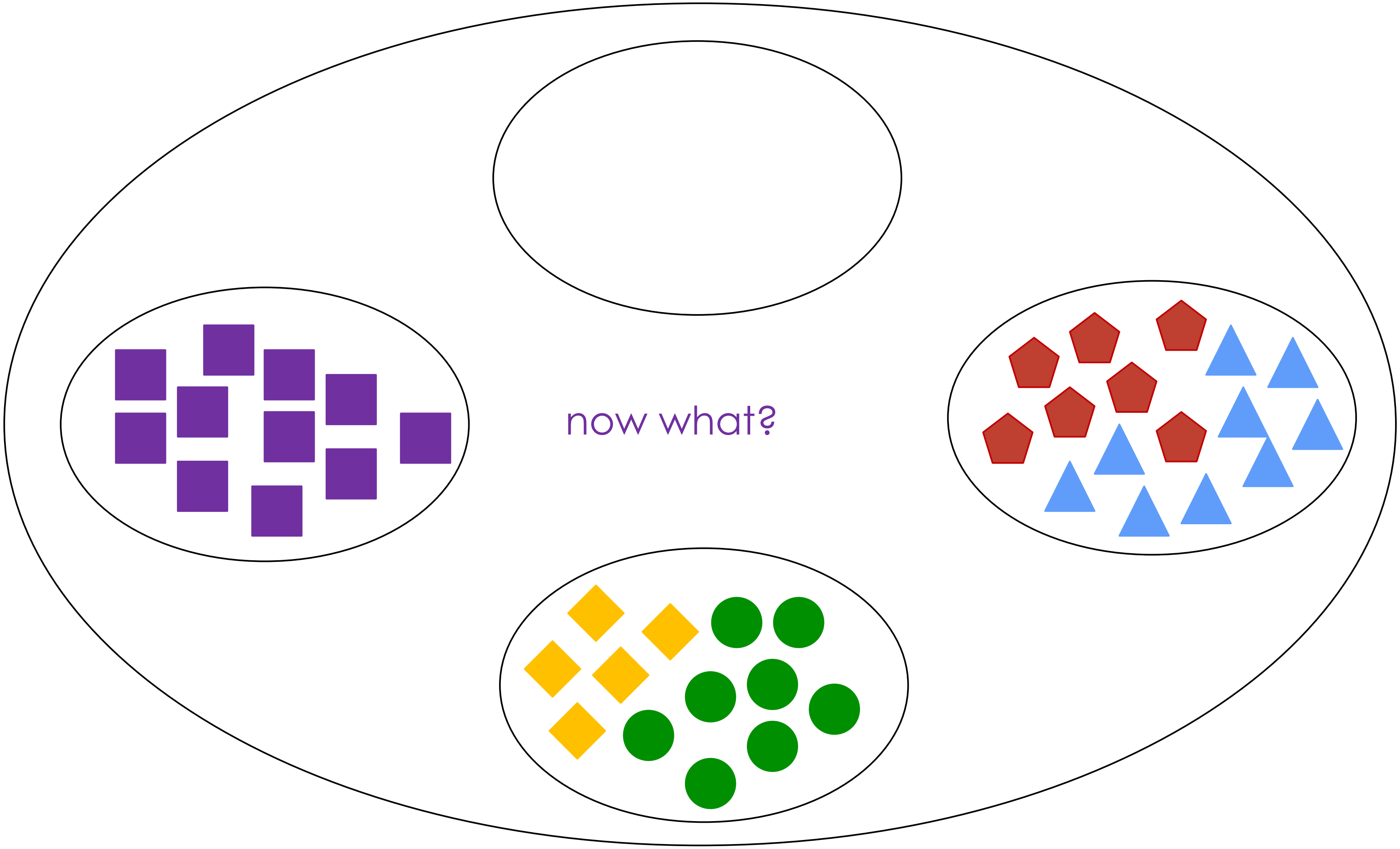

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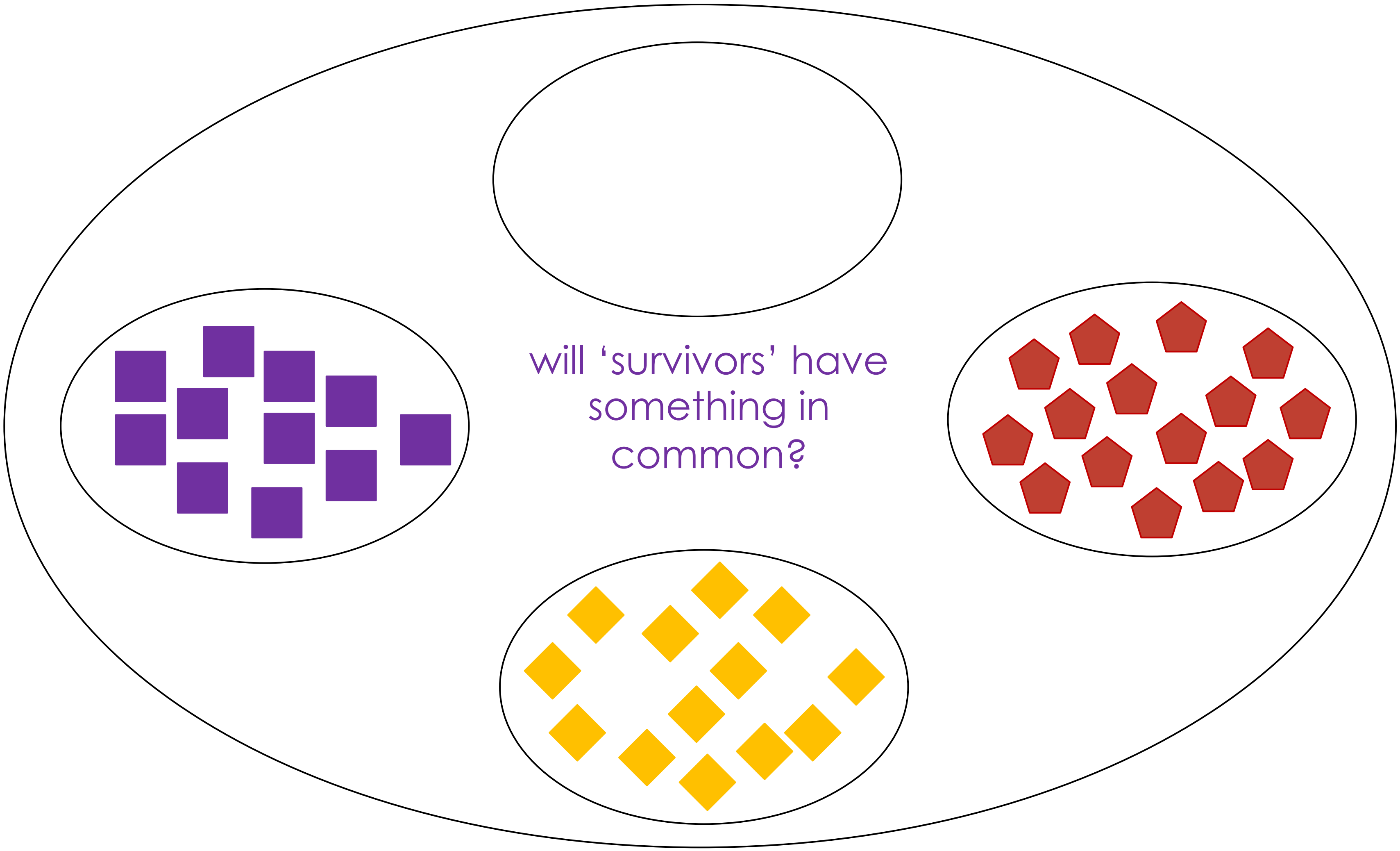

‘Evolutionary progress’ – directional evolution

Biol. Rev. (1987), **62**, *pp.* 305–338

PROGRESS AND COMPETITION IN MACROEVOLUTION

BY MICHAEL J. BENTON

It is merely a tautology to identify the later animal (the ‘winner’) as a ‘superior competitor’ in the absence of any other evidence (Schopf, 1979).

. it is hard to envisage a constant competitive advantage that lasted so long and persistently favoured all of the species of one large taxon against all of the species of another in all environments.

Darwinian demon

An organism that starts reproducing directly after birth, producing a large number of surviving offspring at extreme speed without ever dying.

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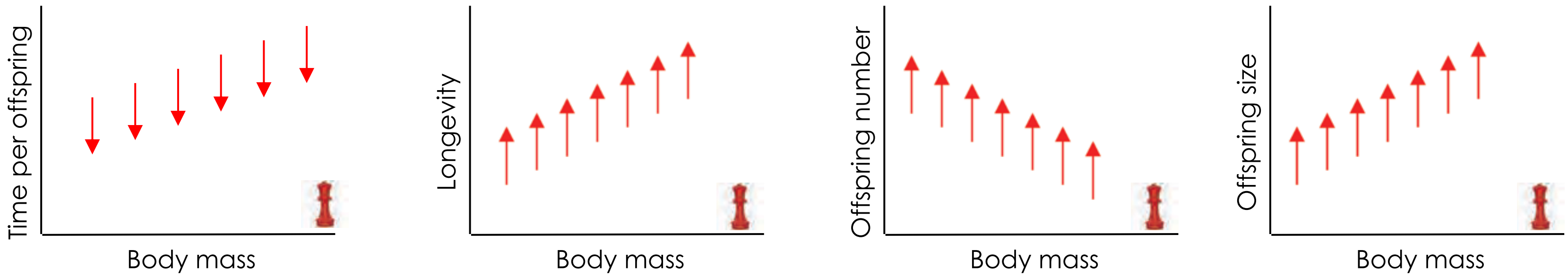

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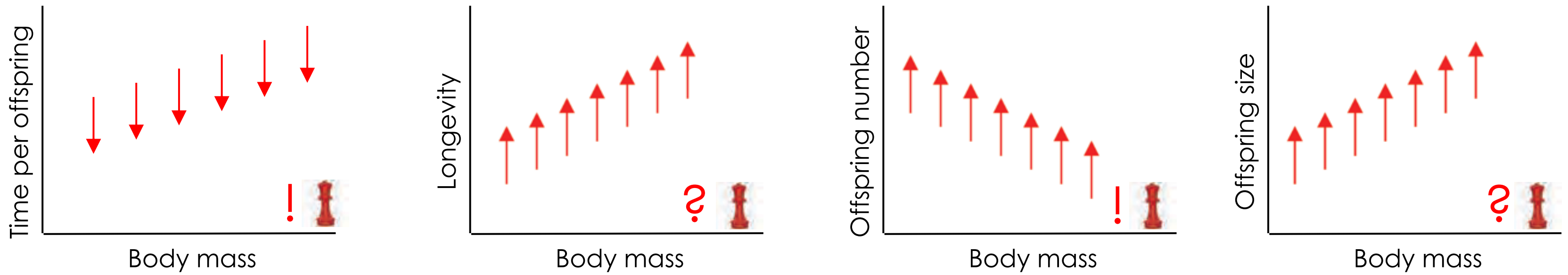

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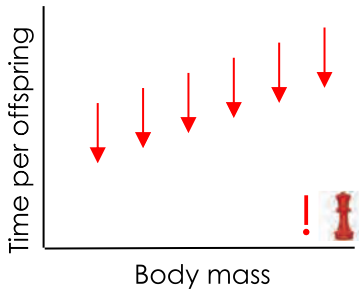
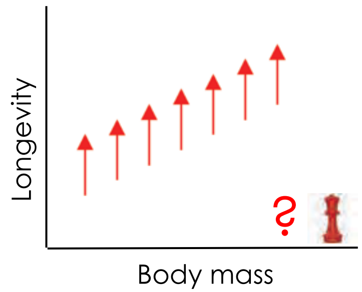
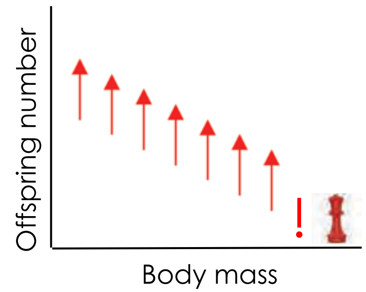
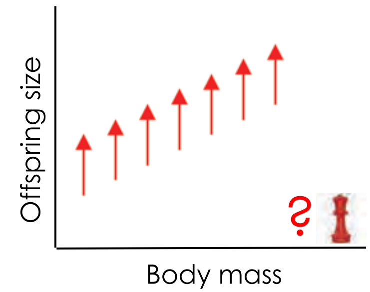
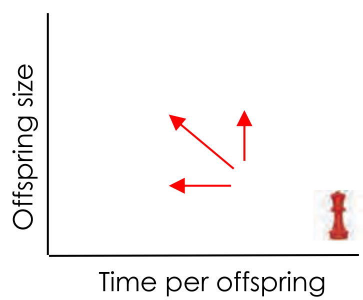
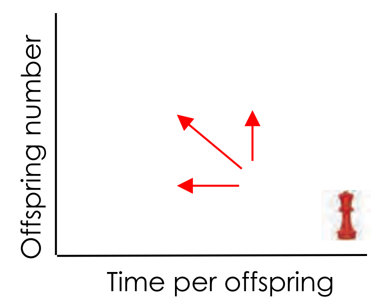






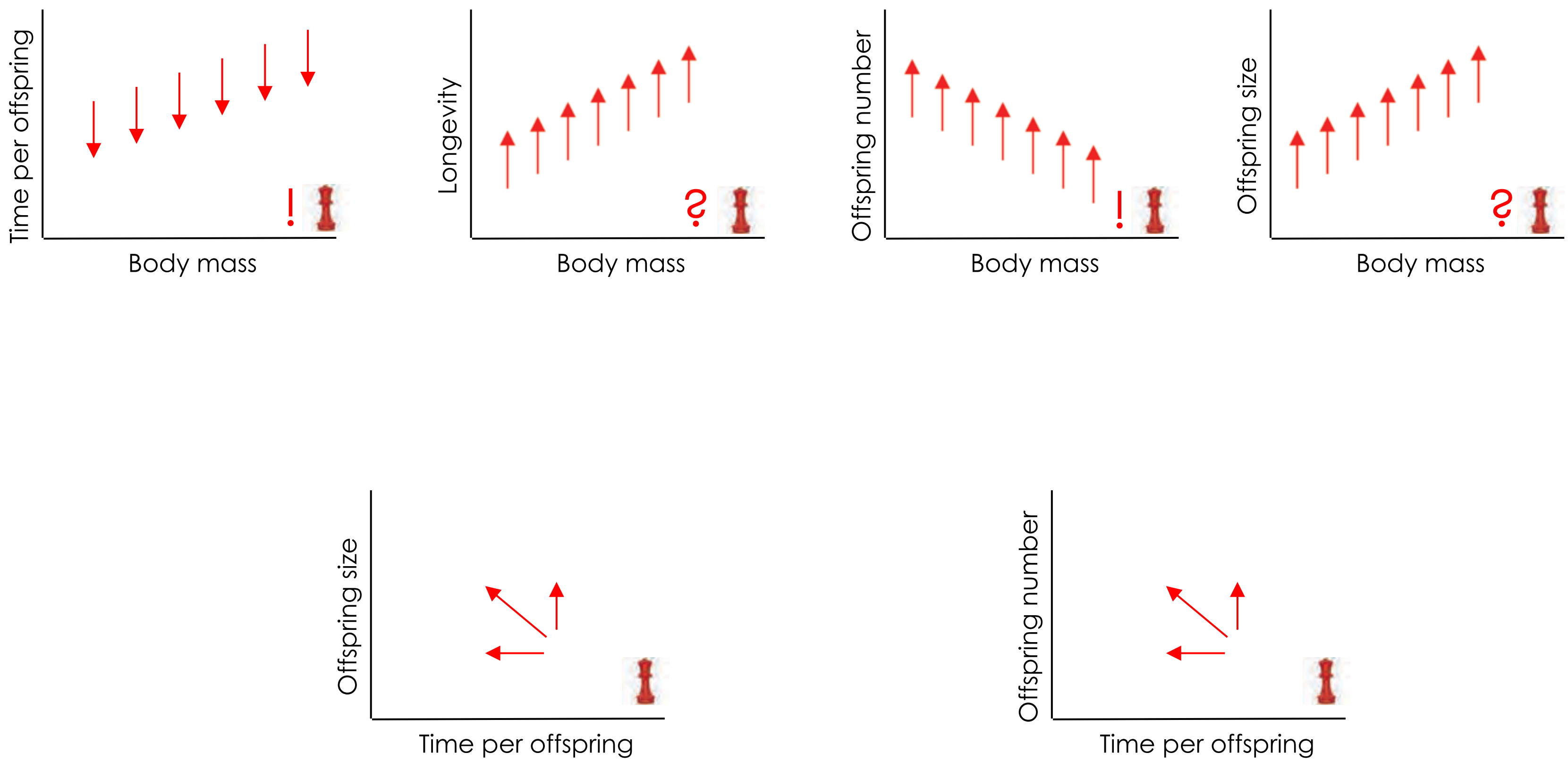






Darwinian demon

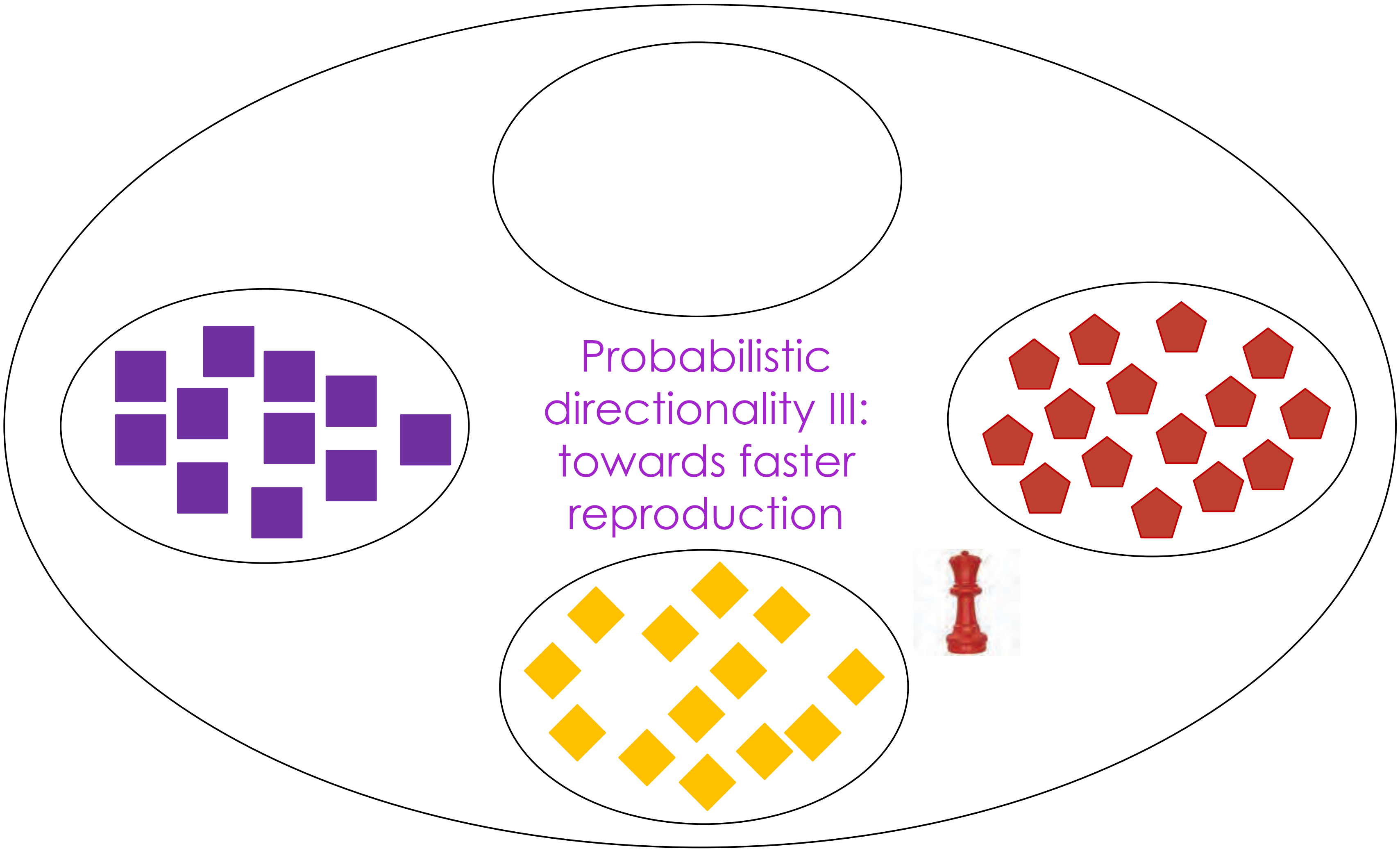
An organism that starts reproducing directly after birth, producing a large number of surviving offspring at extreme speed without ever dying.

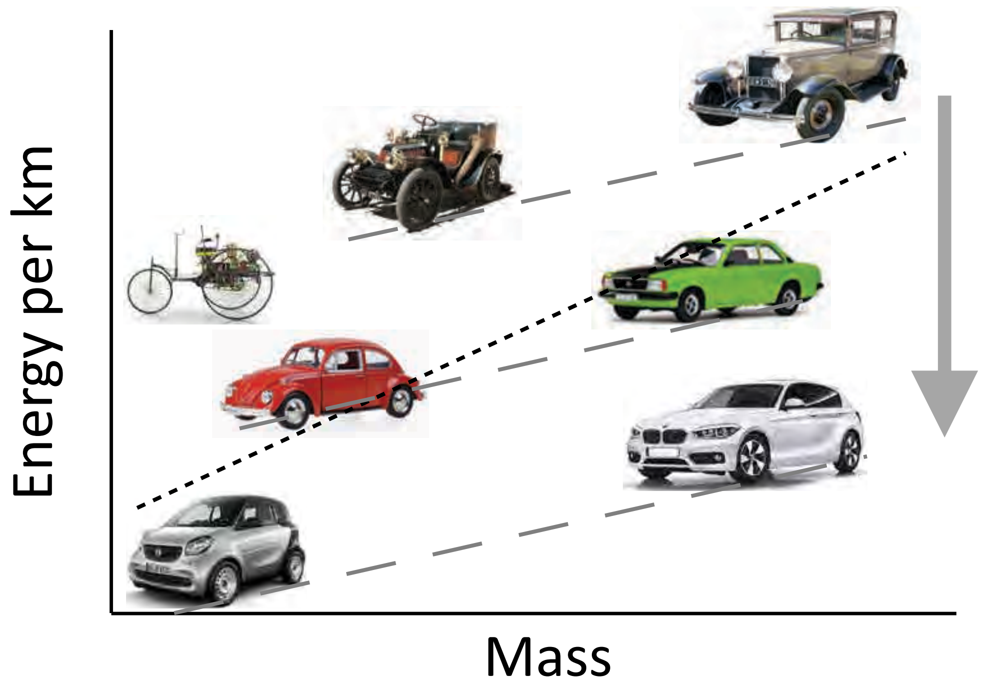


FASTER

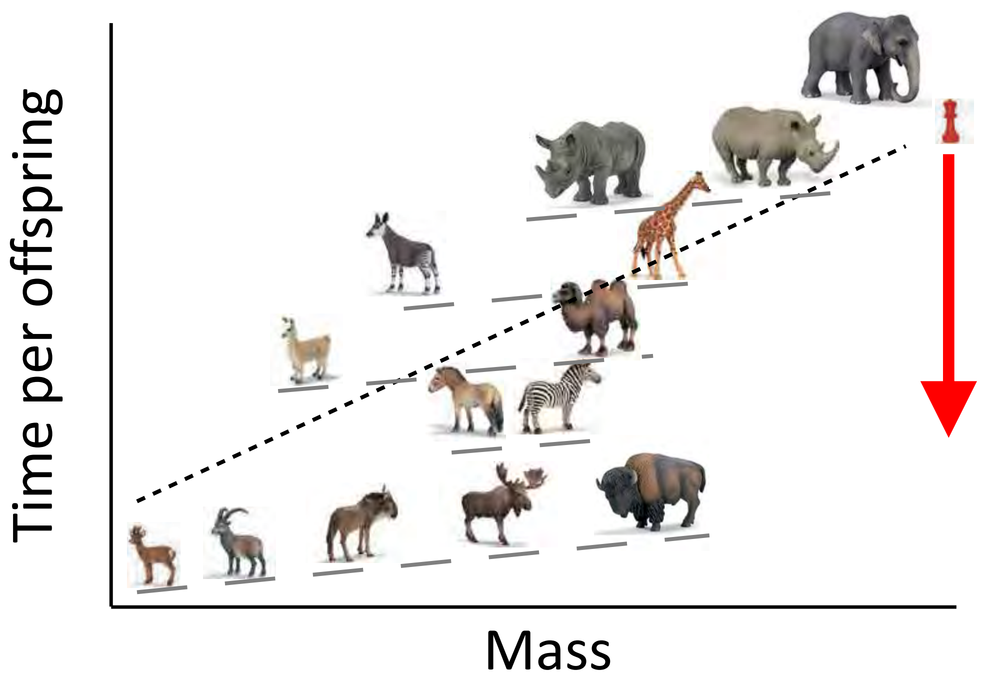
A priori conditions and their consequences

Resources are finite.





You would not consider the overall pattern a fixed law, but consider it with respect to technical progress.



Why would you consider this a pattern due to fixed life history tradeoff laws, and not rather a snapshot in a process of optimization?

Assessing
‘direction’/Red Queen/escalation/progress
in life history

using the PanTheria dataset
(Jones et al. 2009)

Niche-specific assessment

Because niche space is less diverse at larger body sizes, large herbivores may be a particularly fruitful area of research for ‘directed evolution’.

Herbivore basic™

Herbivore 2.0™

Herbivore professional™

Herbivore ultimate™

?

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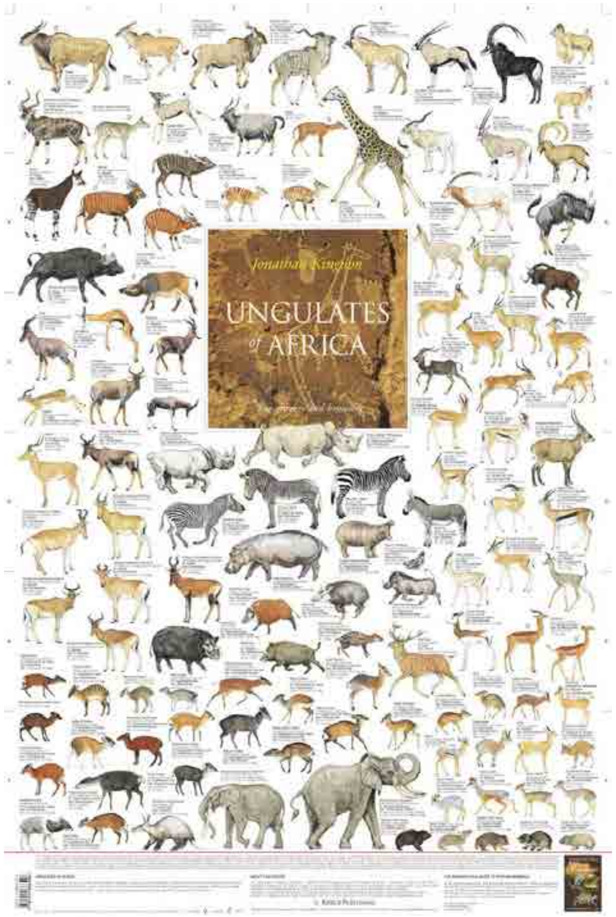
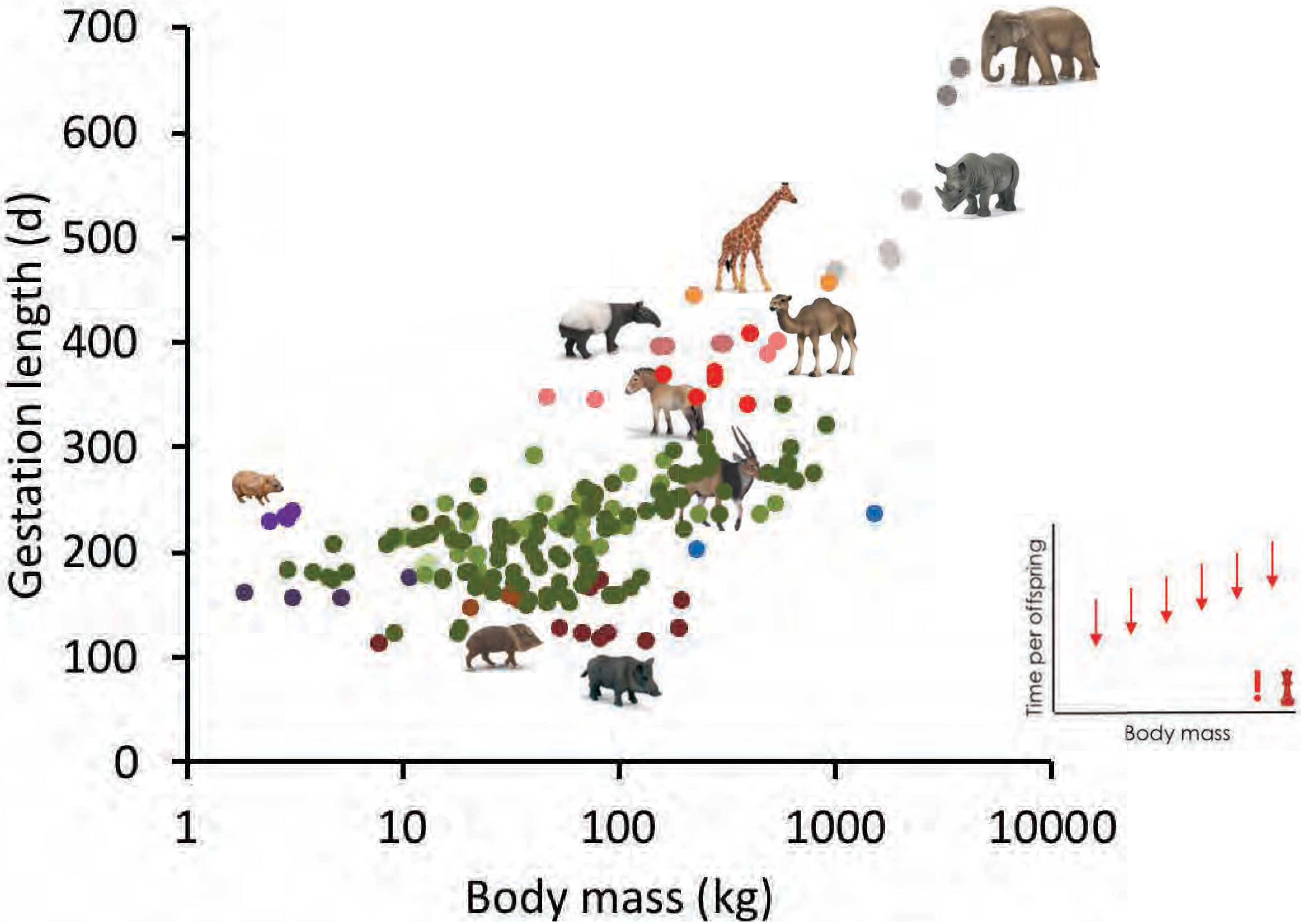


A clear picture for gestation length



(Precocial) Mammal gestation period

For any mammal, achieving the same degree of neonatal development in a shorter gestation period – if not associated with higher costs – should be advantageous (higher fecundity due to shorter generation times).

Days of gestation period (to apparently similar level of precociality)

Cattle:	app. 280 days
Horse:	app. 340 days
Dromedary:	app. 390 days
Okapi:	app. 440 days

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The difference cannot be due to body size!

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nearly extinct in a very limited geographical range

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only in extreme, resource-poor habitats

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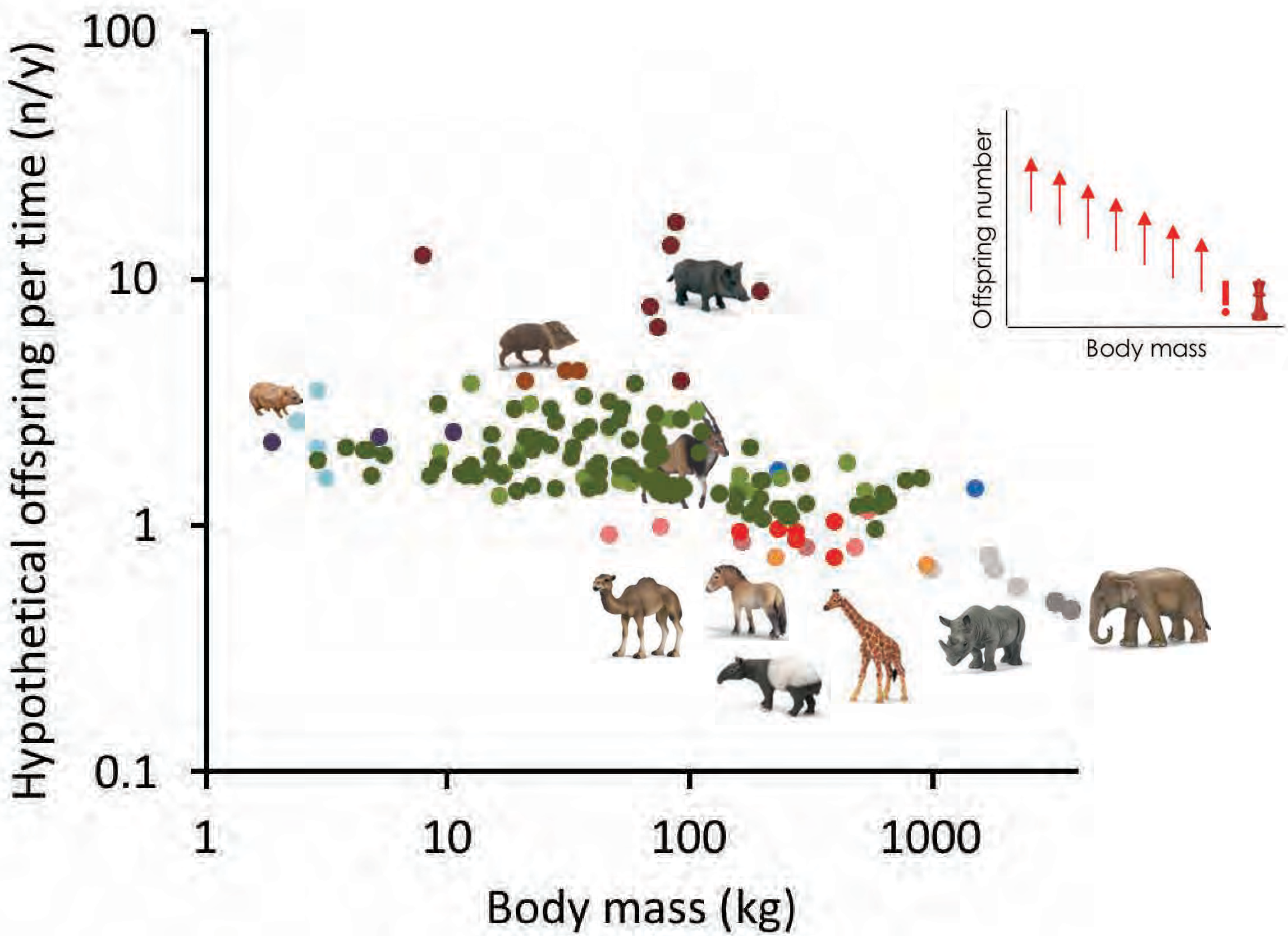
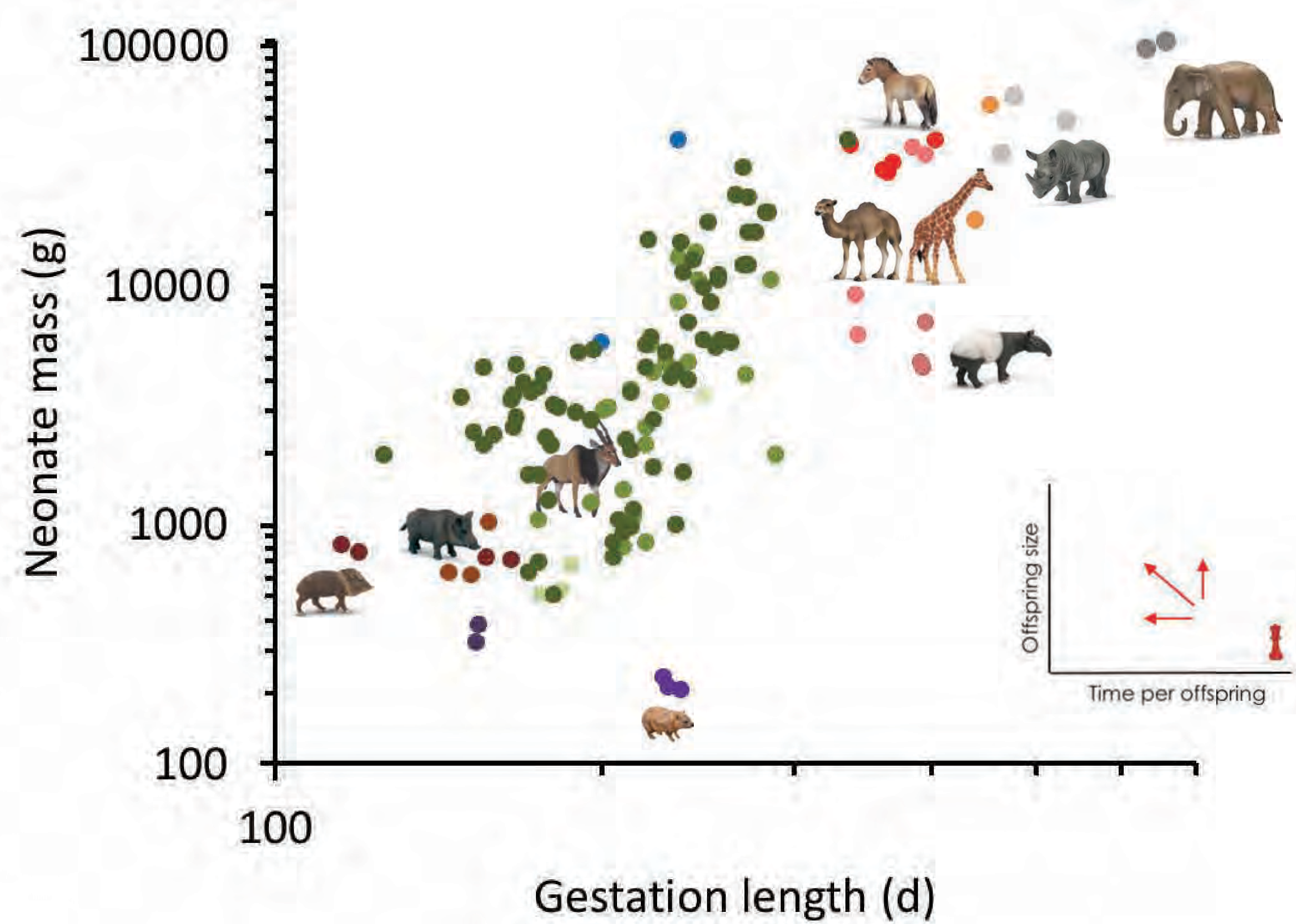
rule the world !!

Clear effect for yearly offspring

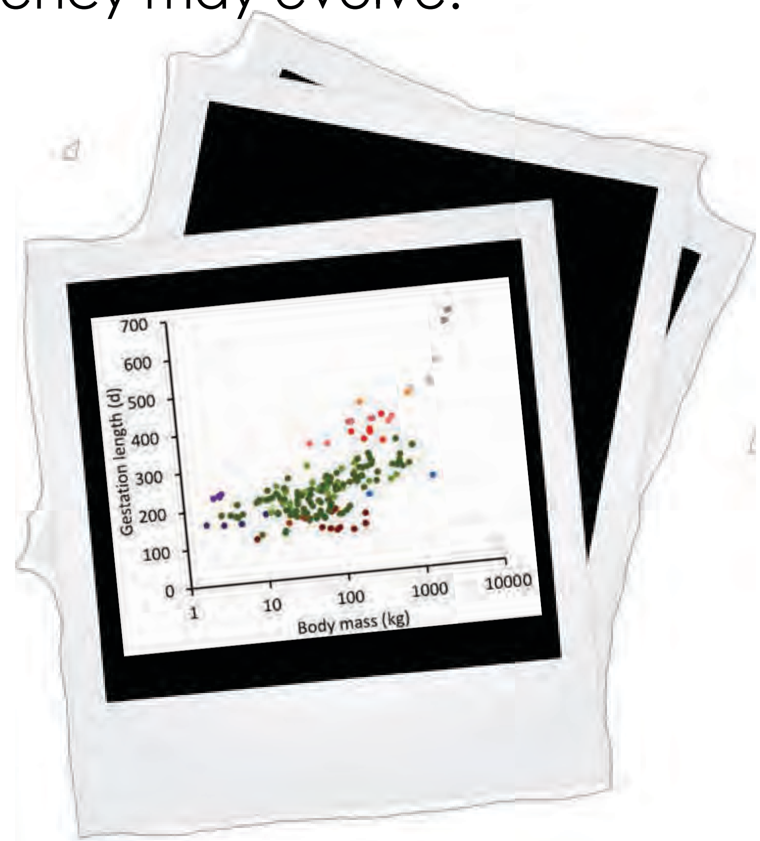


A clear picture for intrauterine growth



Summary, Conclusions & Outlook

Rather than understanding tradeoffs along the fast-slow continuum as fixed physical laws, they can be considered as representing the efficiency of the organisms from which the data was taken – and that efficiency may evolve.



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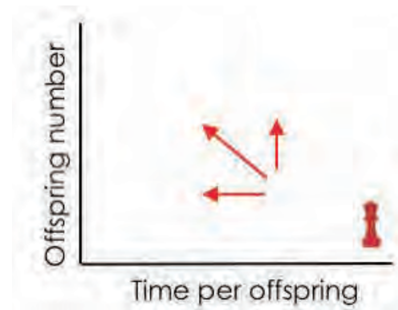
Rather than understanding tradeoffs along the fast-slow continuum as fixed physical laws, they can be considered as representing the efficiency of the organisms from which the data was taken – and that efficiency may evolve.

Within the boundaries of a specific niche, taxa possibly compete by demographic means: by evolving a faster reproduction.



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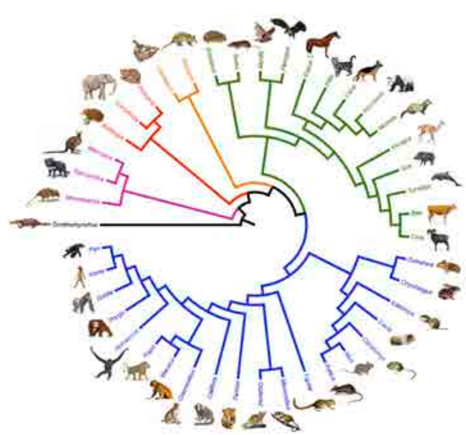

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Life history characteristics appear to be linked to taxonomic groups.

We would predict that during earth history, 'faster' taxa were not replaced by 'slower' taxa.

The physiological means by which taxa differ in their life history are not well explored.

thank you for your attention

Anpassen, Dominieren, Kontrollieren

Überleben durch Ressourcen-Kontrolle

Marcus Clauss

Zürich, Biologie und Erkrankungen der Wildtiere 2019

University of Zurich[UZH]

Clinic of Zoo Animals, Exotic Pets and Wildlife