Phylogenetic statistics and biological laws

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Research Unit 533 Sauropod Biology DFG

SAUROPOD NUTRITION SQUAD better late than never

University of Zurich[UZH]

Clinic of Zoo Animals, Exotic Pets and Wildlife

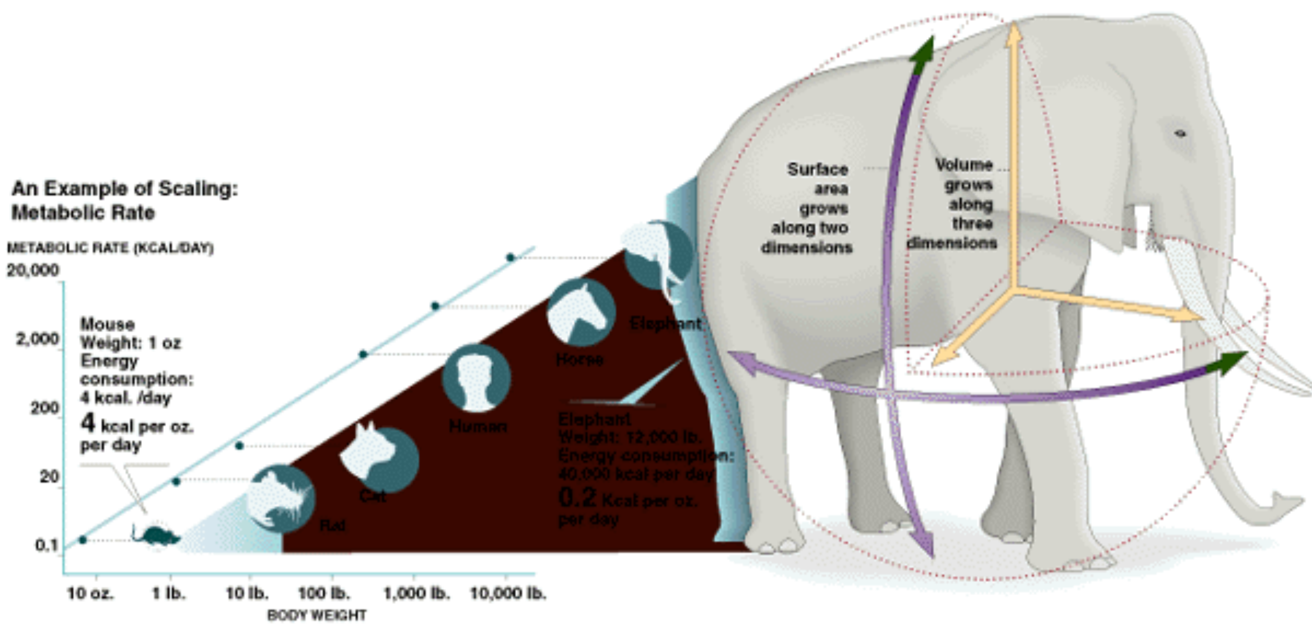
Allometry reminder

Scaling: fundamental (conceptual) relevance of body mass

Most biologists consider body mass the most important characteristic of an organism. It is also (mostly) easy to measure.

All morphological and physiological traits scale somehow with body mass.

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



Allometries

Morphological, physiological and life history variables scale with body mass.

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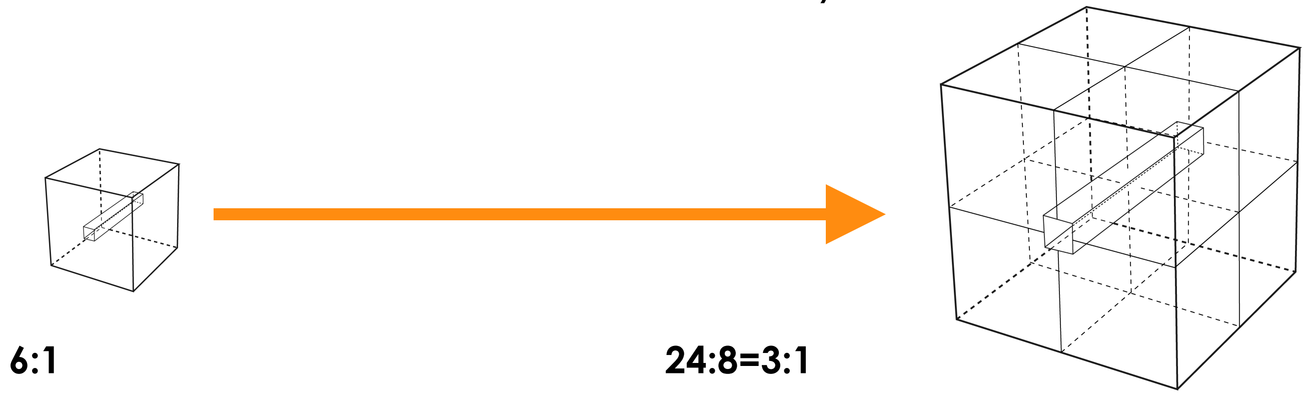
(allometric scaling mostly explained by geometry – e.g. surface-volume shifts, distribution networks etc.)



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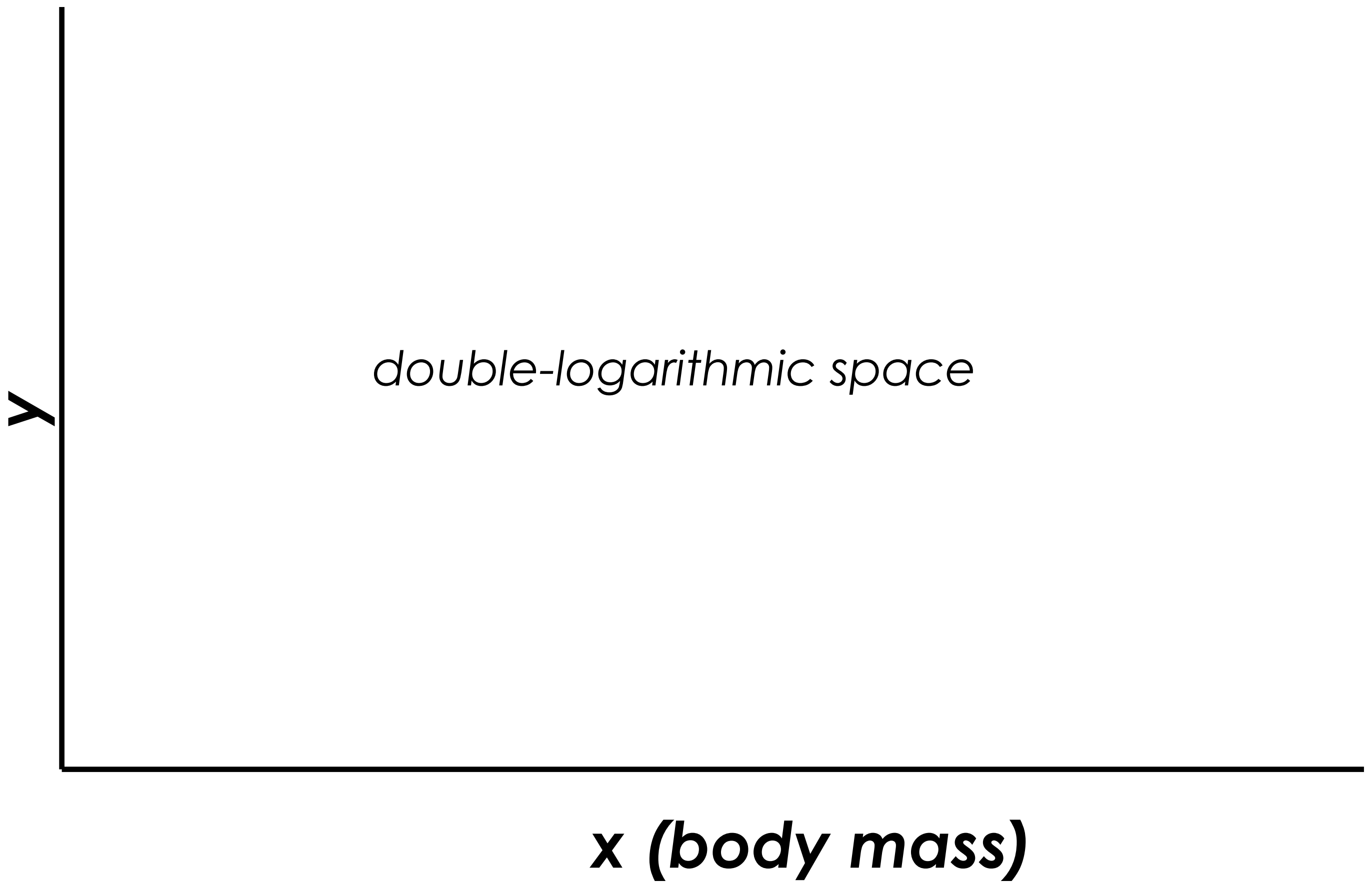

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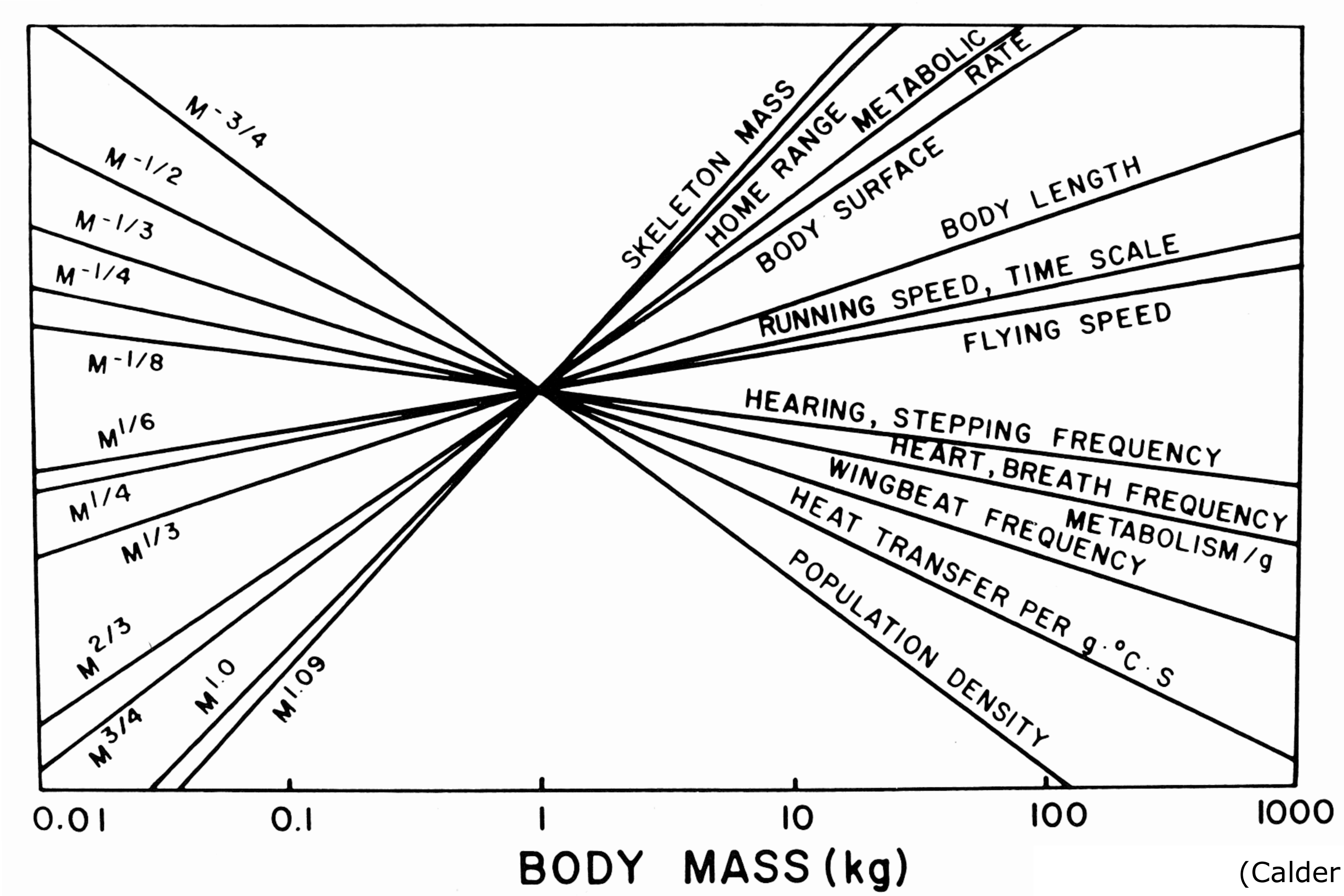

(Calder 1983)

Interpreting allometries

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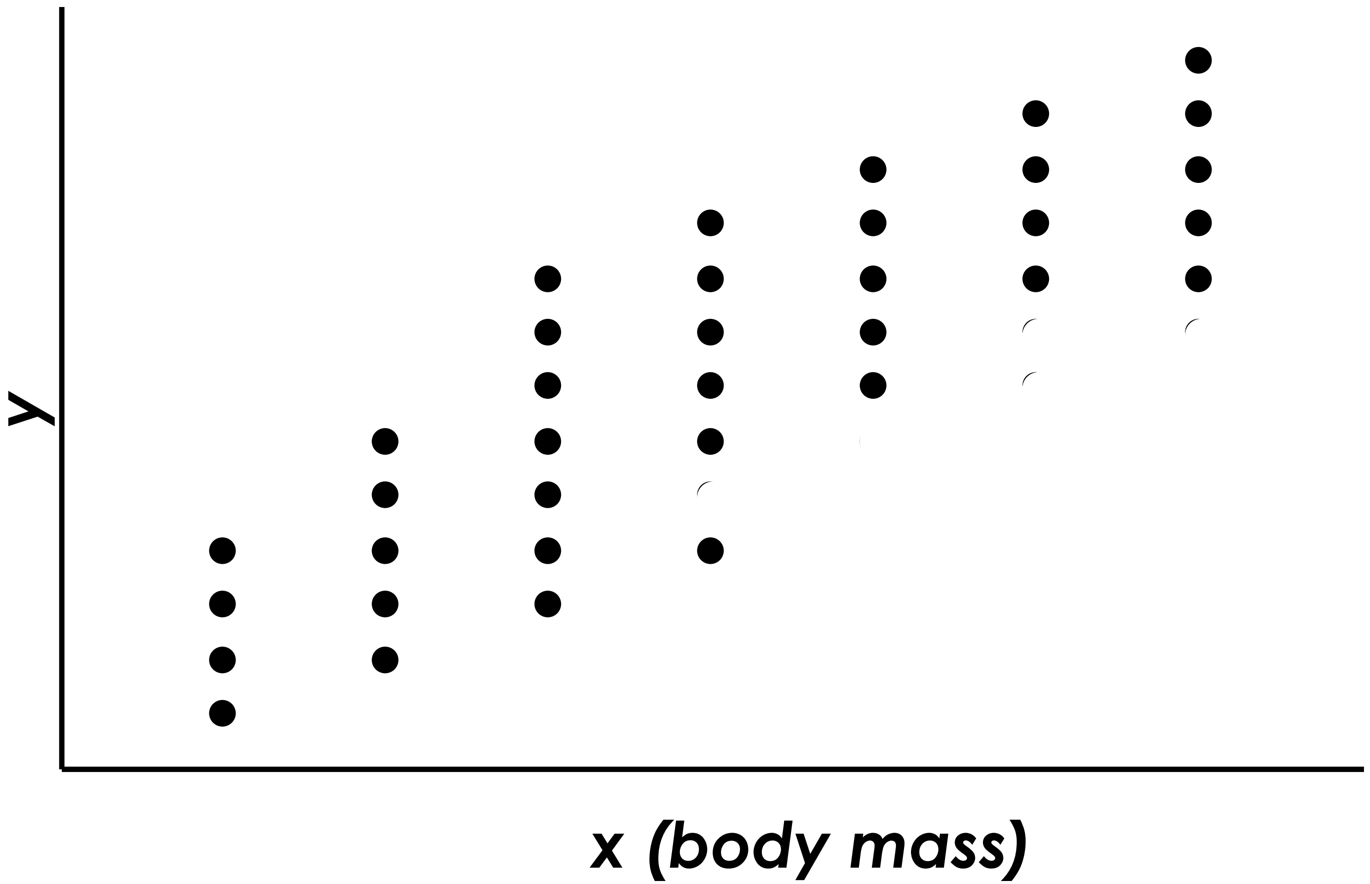

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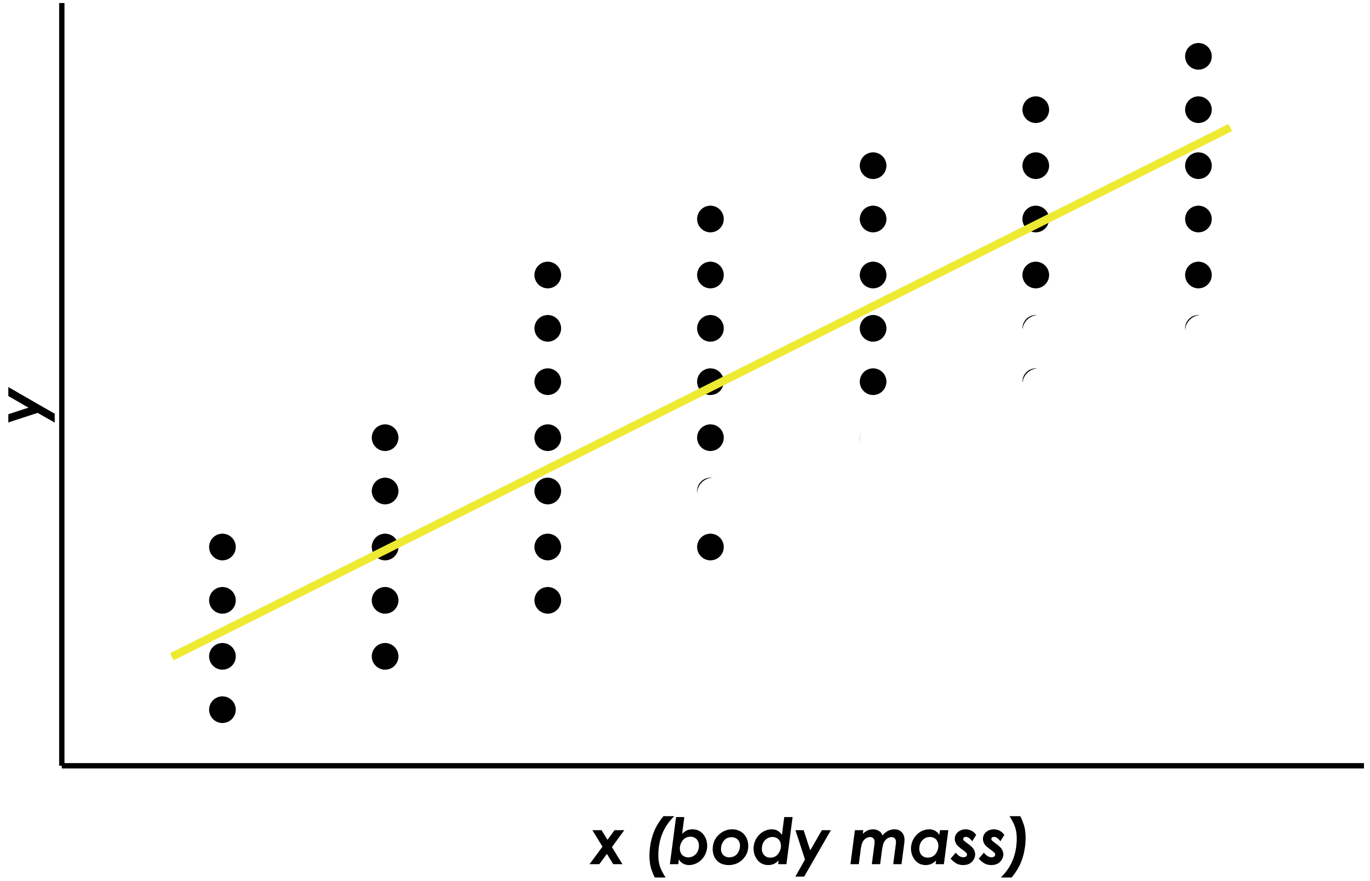

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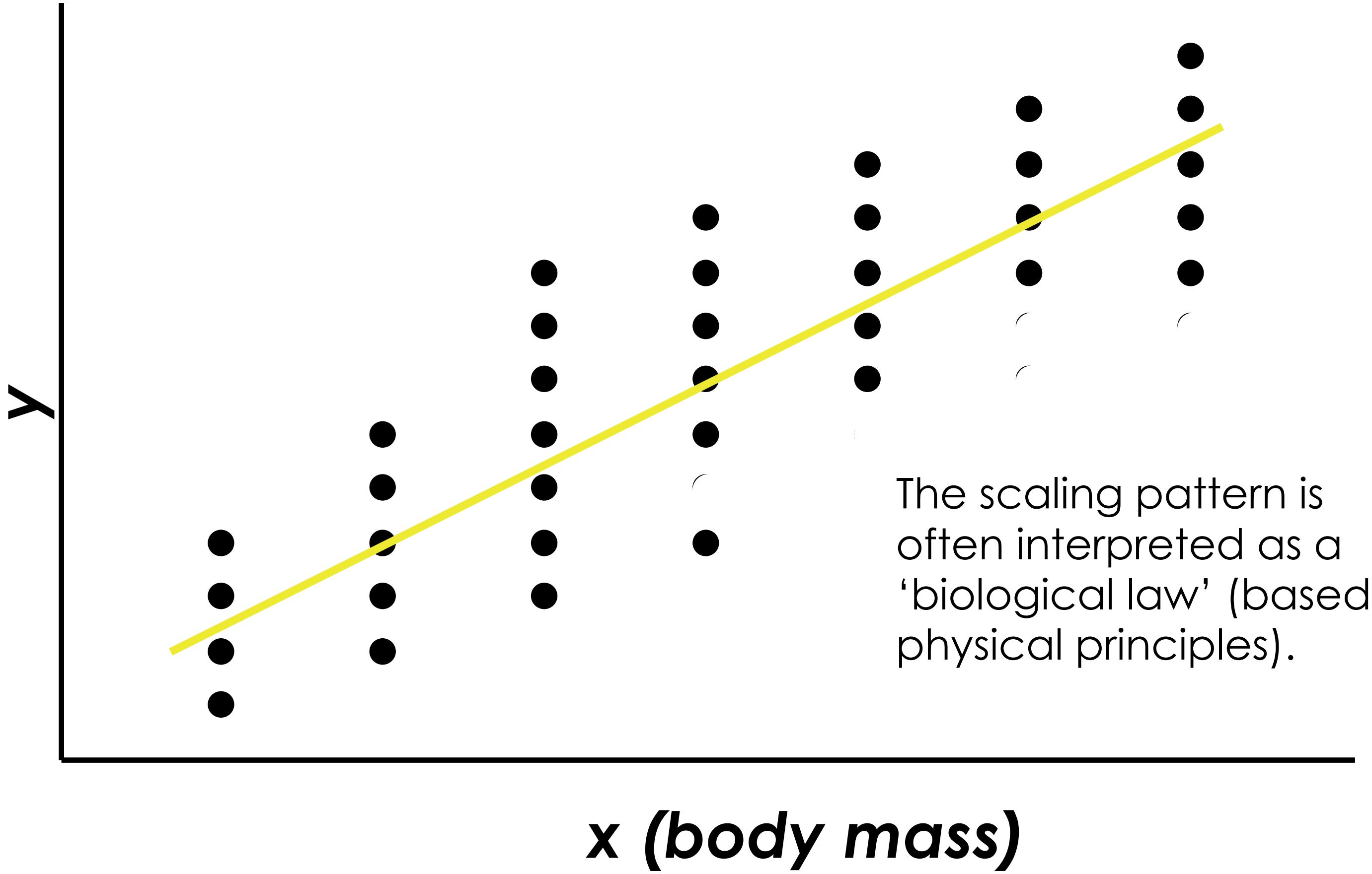

The scaling pattern is often interpreted as a 'biological law' (based on physical principles).

Testing for allometries

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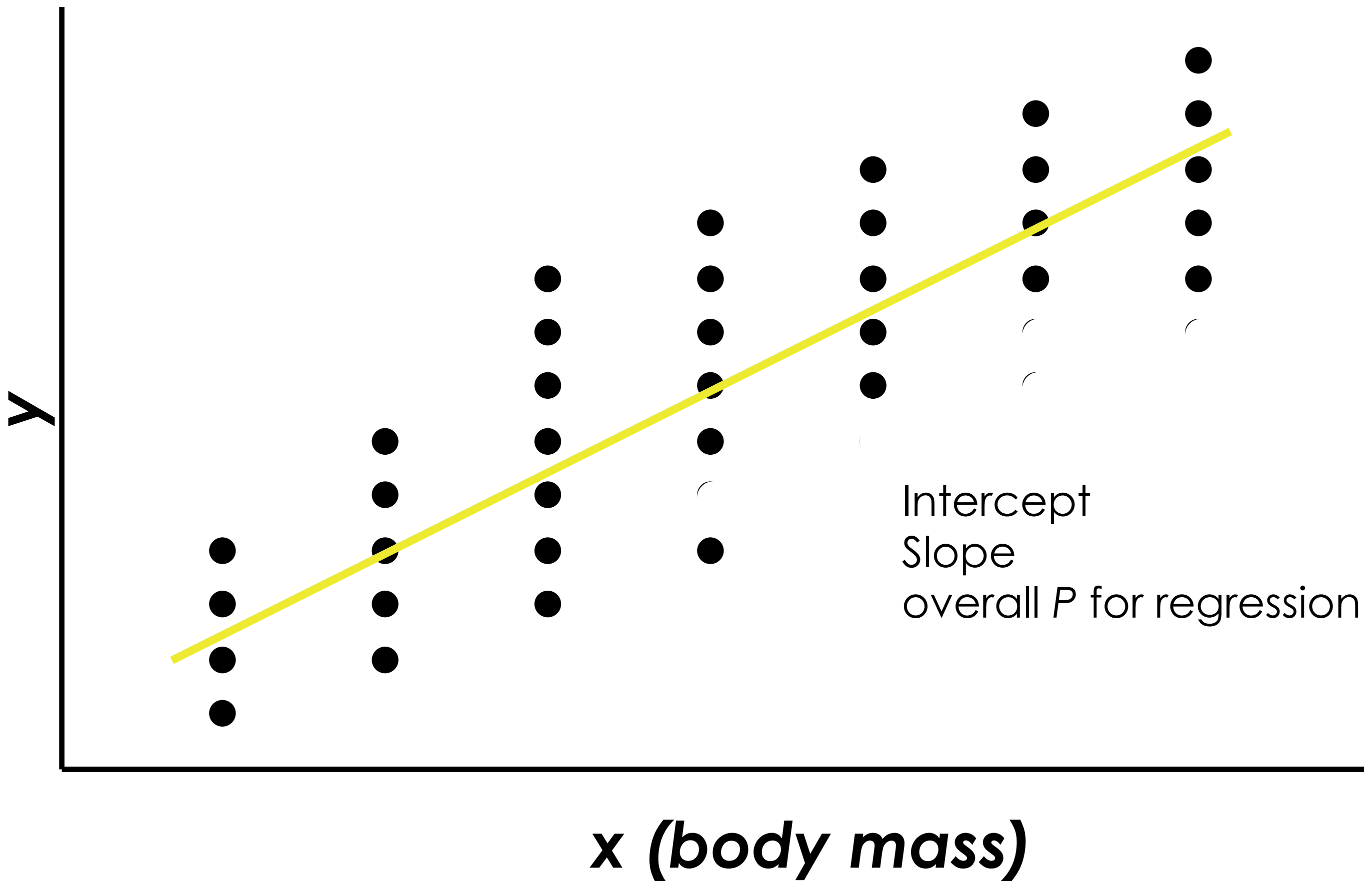

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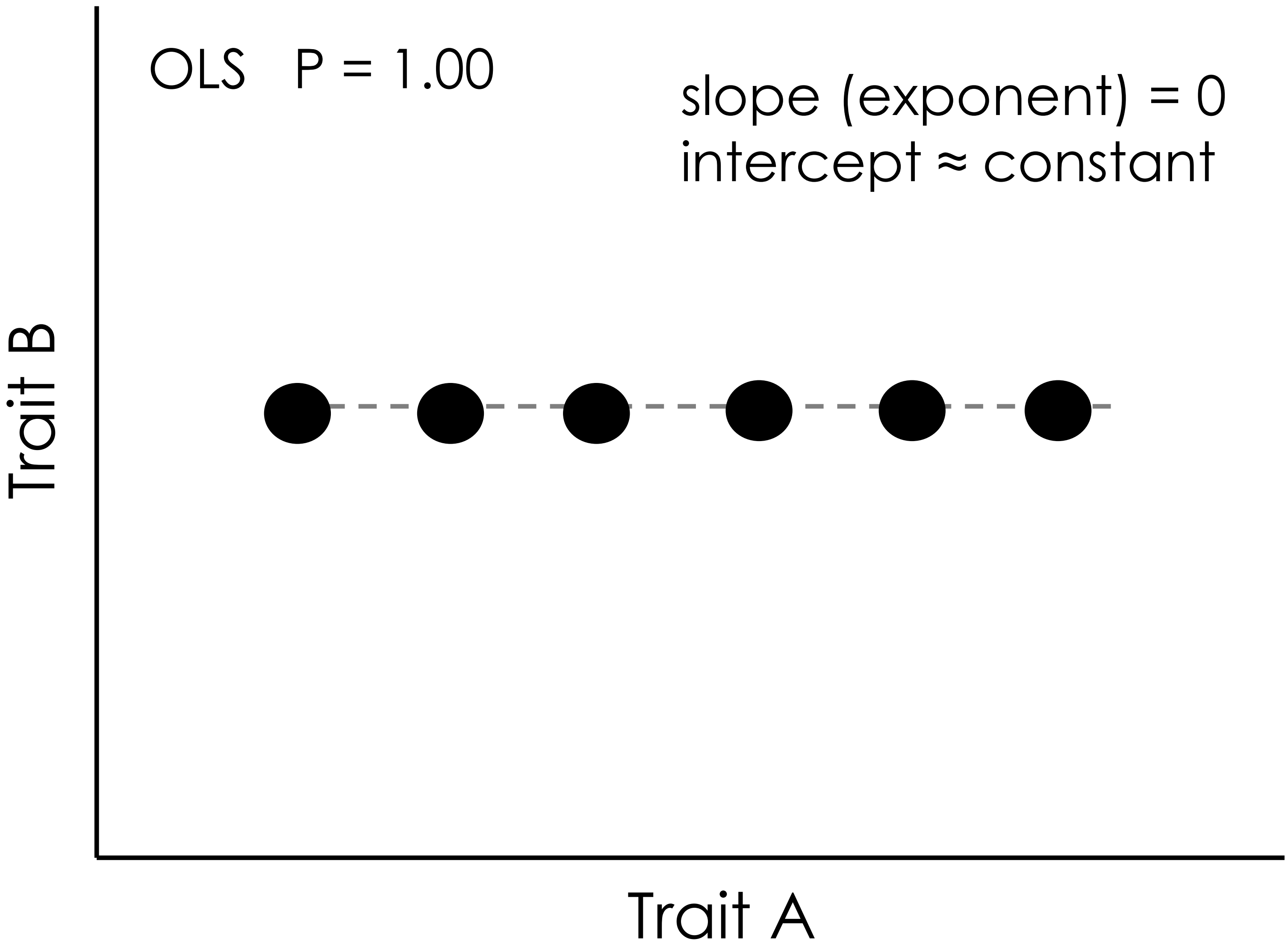
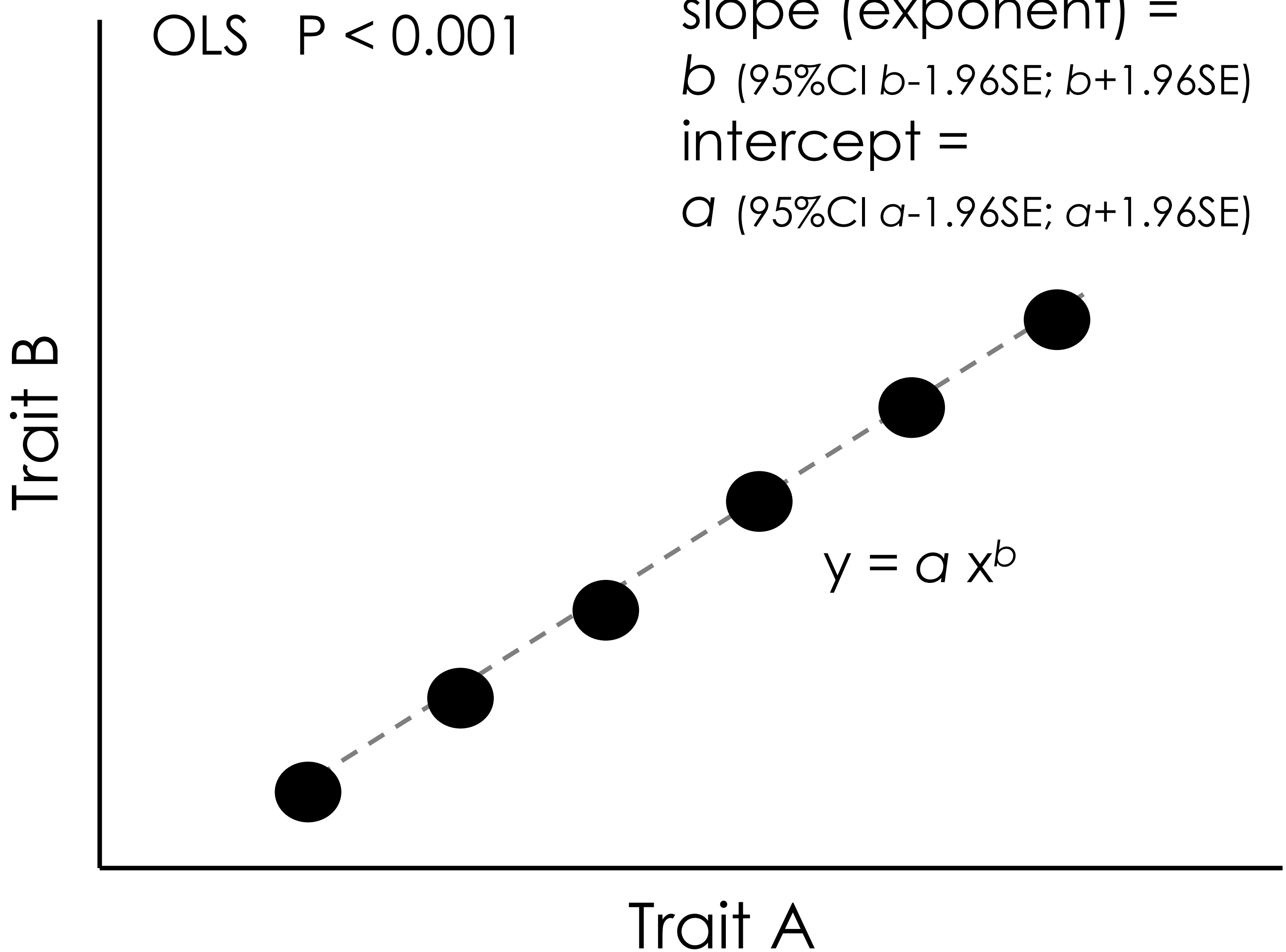


Testing for allometries

slope (exponent) =
b (95%CI *b*-1.96SE; *b*+1.96SE)
intercept =
a (95%CI *a*-1.96SE; *a*+1.96SE)



Using allometries

Using allometric relationships to extrapolate data for other species.

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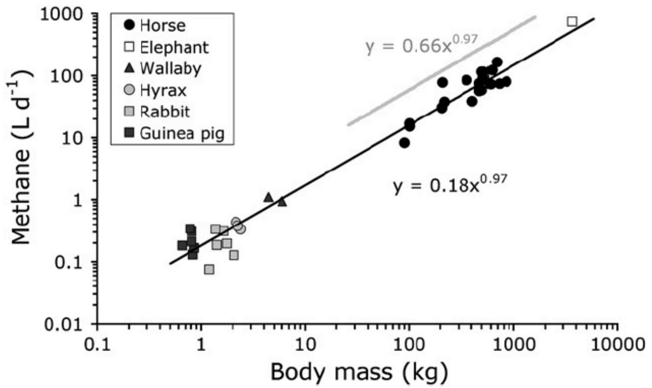
Methane output of rabbits (*Oryctolagus cuniculus*) and guinea pigs (*Cavia porcellus*) fed a hay-only diet: Implications for the scaling of methane production with body mass in non-ruminant mammalian herbivores

Ragna Franz [a], Carla R. Soliva [b], Michael Kreuzer [b], Jürgen Hummel [c], Marcus Clauss [a,*]

Comparative Biochemistry and Physiology, Part A 158 (2011) 177–181



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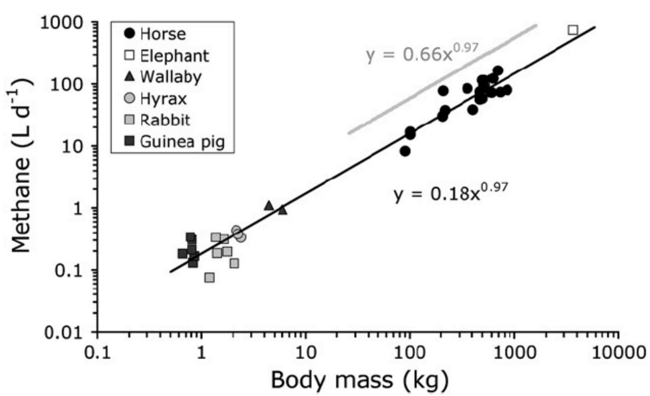

Could methane produced by sauropod dinosaurs have helped drive Mesozoic climate warmth?

David M. Wilkinson [1,*],
Euan G. Nisbet [2],
and Graeme D. Ruxton [3]

Current Biology Vol 22 No 9 R292

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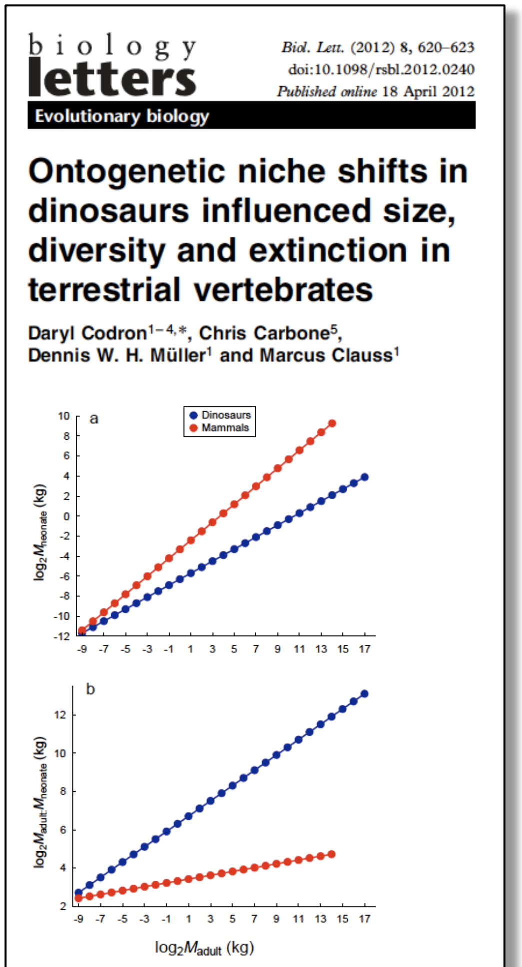
biology letters

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Evolutionary biology

Ontogenetic niche shifts in dinosaurs influenced size, diversity and extinction in terrestrial vertebrates

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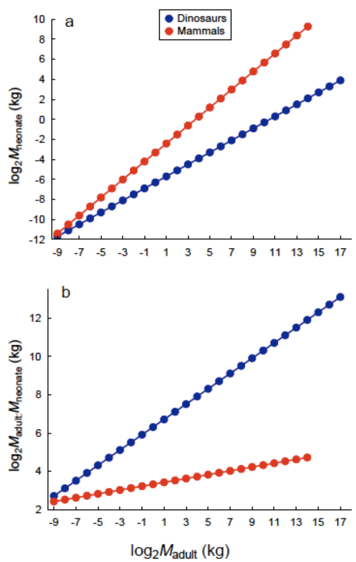

Ecological modelling, size distributions and taphonomic size bias in dinosaur faunas: a comment on Codron *et al.* (2012)

Caleb Marshall Brown[1], Nicolás E. Campione[1], Henrique Corrêa Giacomini[1], Lorna J. O'Brien[1], Matthew J. Vavrek[2] and David C. Evans[1,2]

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Phylogenetic statistics

Comparative statistics

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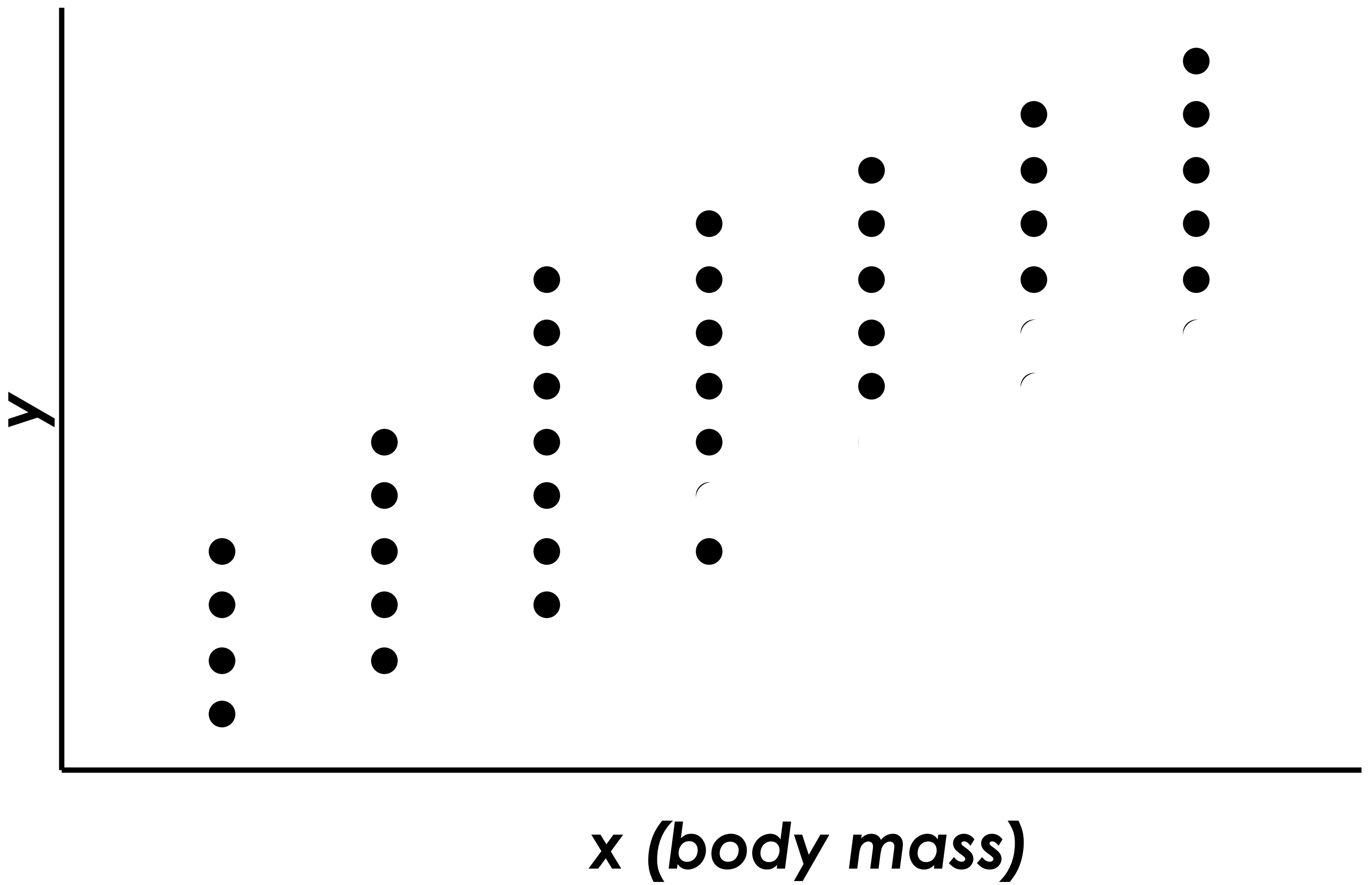

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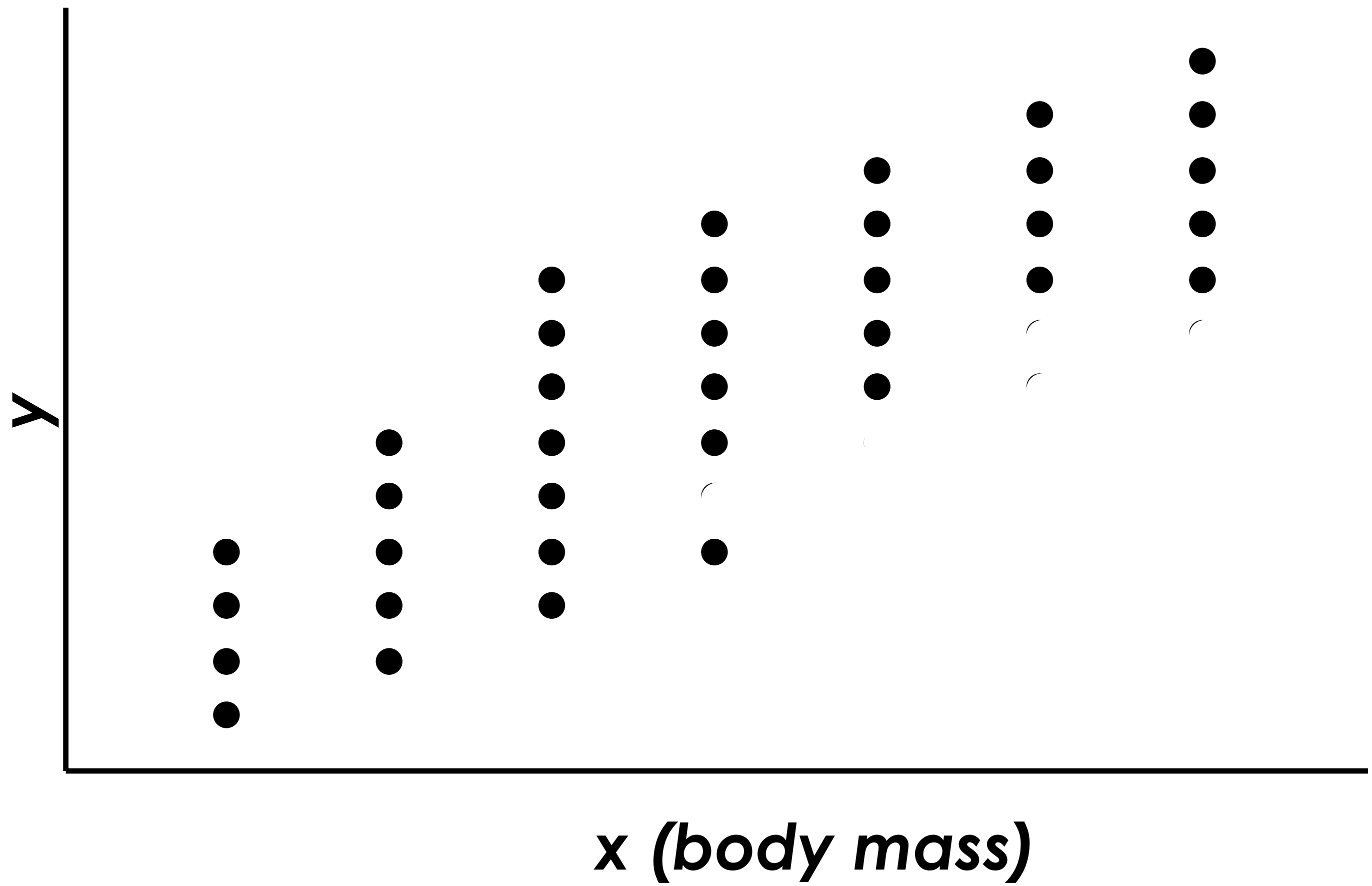

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Therefore, we perform allometric analyses also with accounting for phylogeny, using PGLS (Phylogenetic Generalized Least Squares).

Results mostly did not differ from conventional statistics in a relevant way, but the intensive use of comparative statistics (also with additional examples) led to formulation of some concepts new to ourselves.

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Pagel's lambdaλ: if 95%CI includes 0, then there is no phylogenetic structure in the dataset.
Does not decide whether the relationship is significant or not, but whether phylogenetic statistics need to be used or not.
Assumes Brownian motion; other measures of phylogenetic structure assuming other evolutionary scenarios exist.

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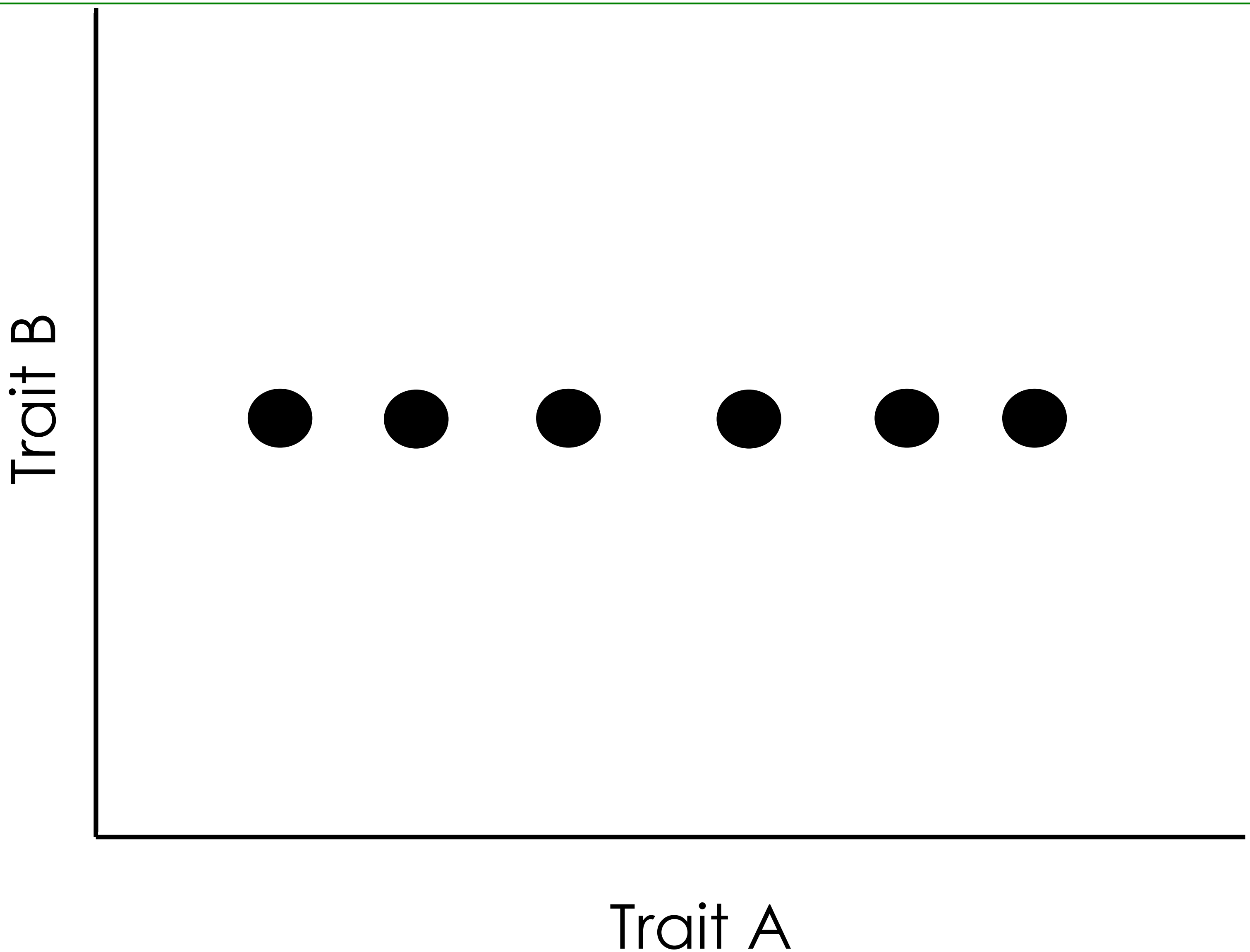
Type II error: you overlook a relationship where there is one (evident when you account for the phylogenetic structure of the data)

Just an error: you estimate a different parameter (e.g., allometric slope) depending on whether you account for phylogeny or not

Pagel‘s lambda(λ) examples

Accounting for phylogeny



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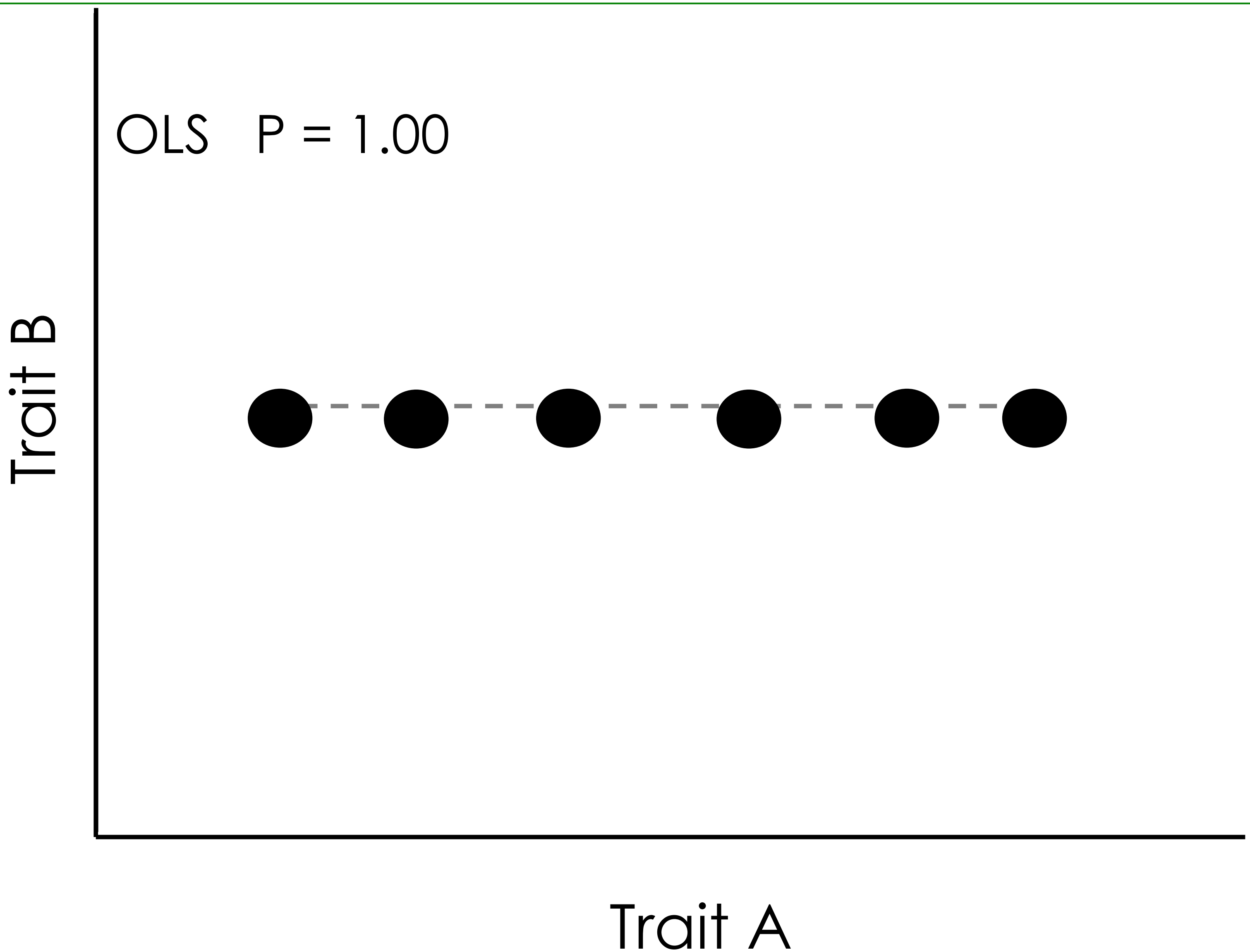

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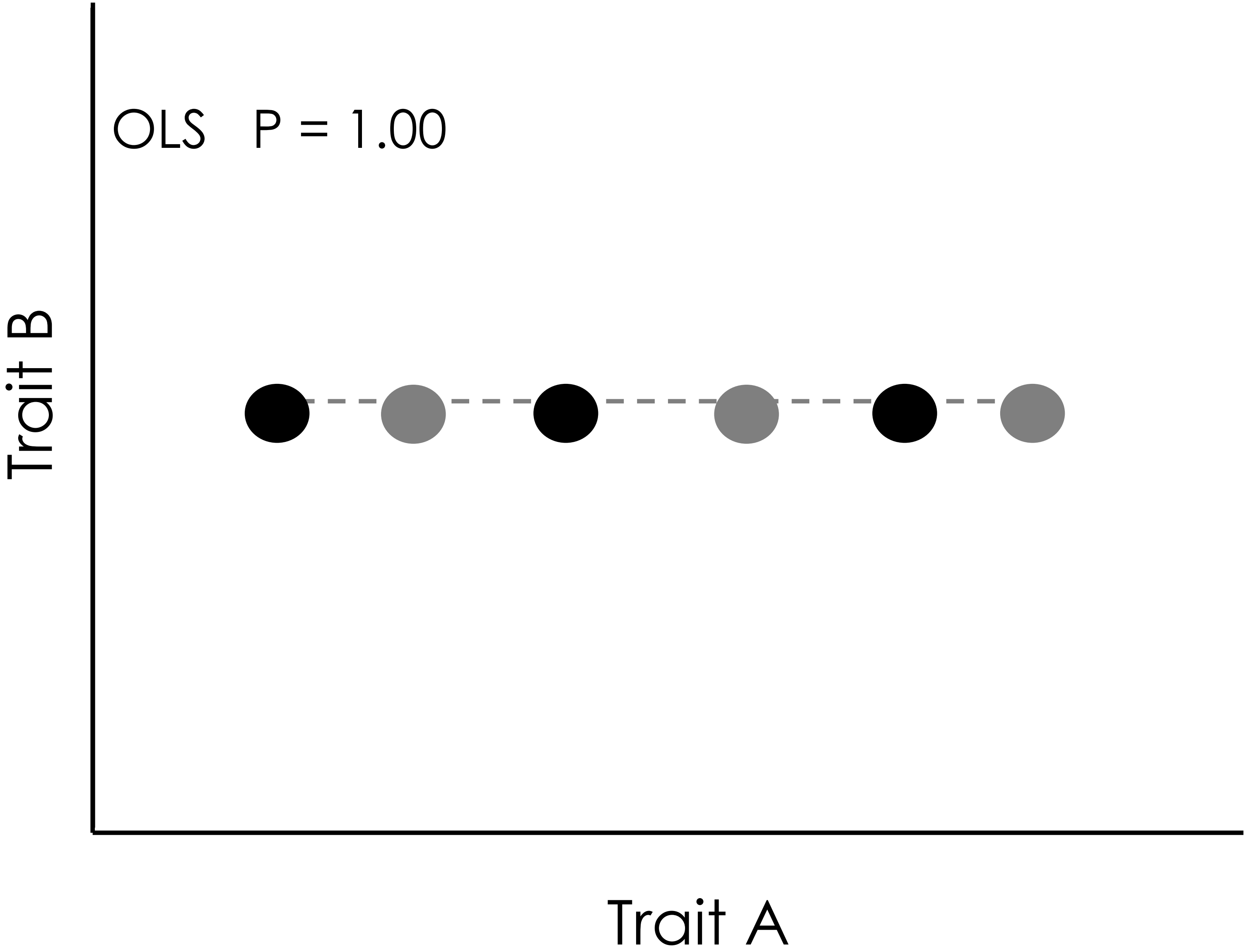

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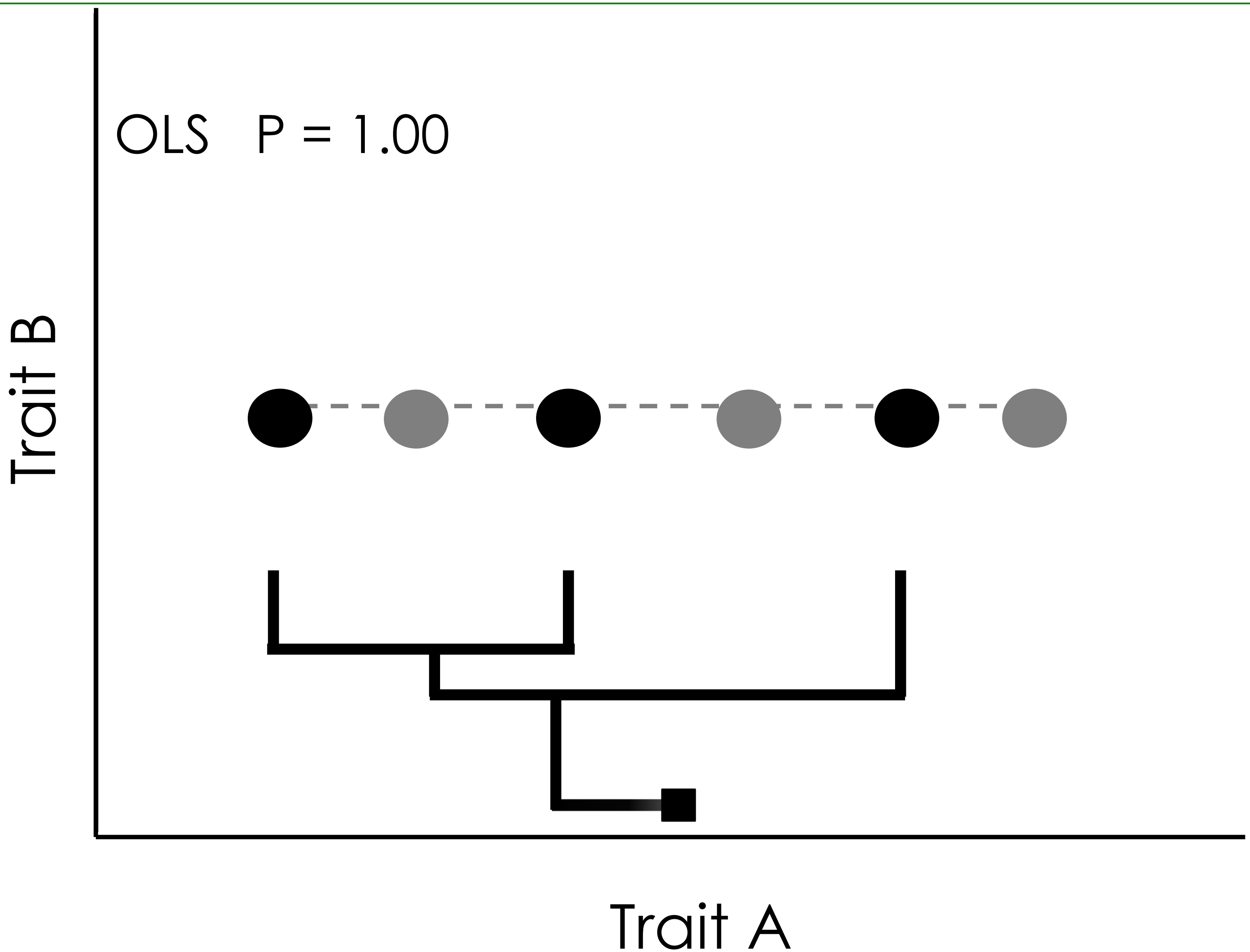

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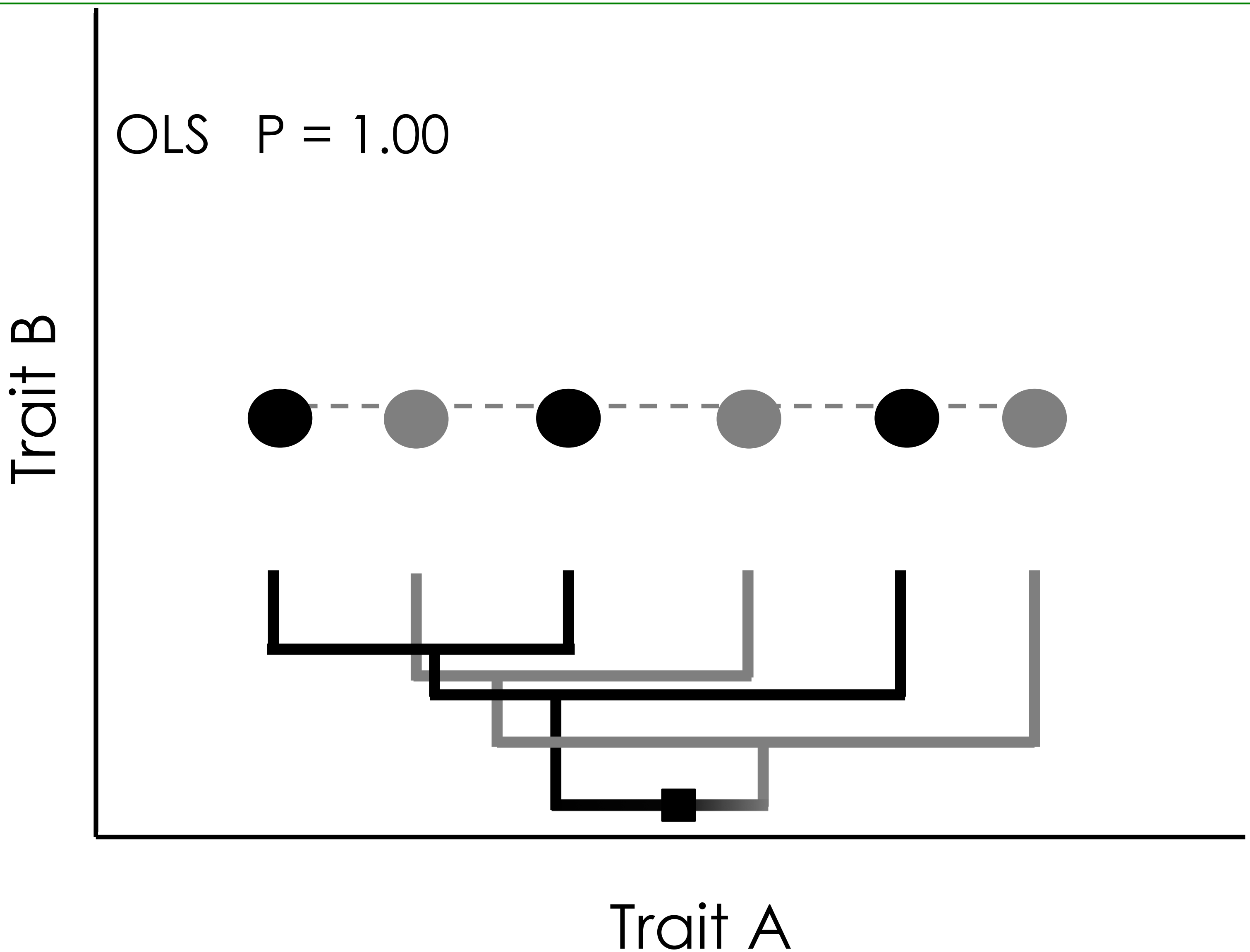

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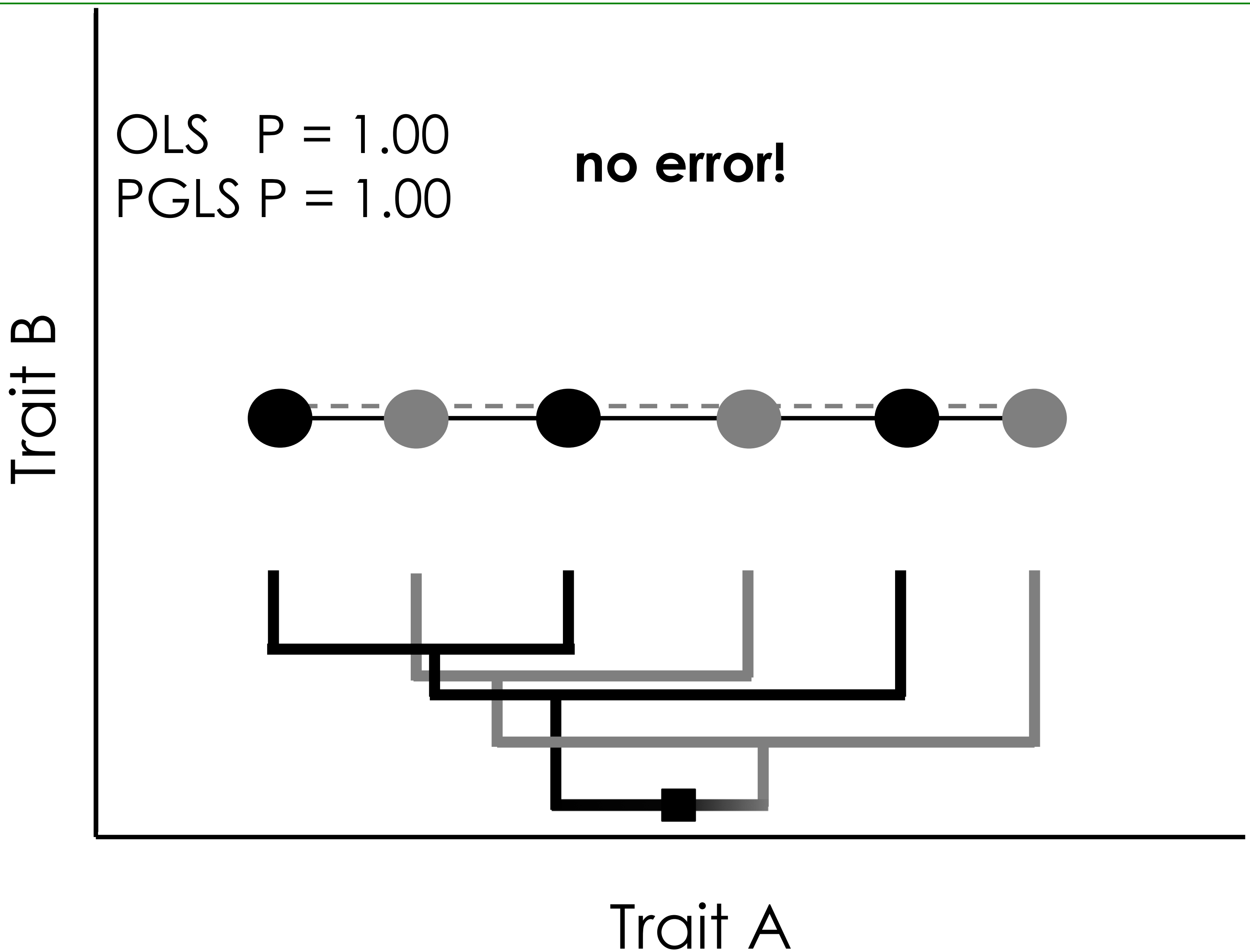

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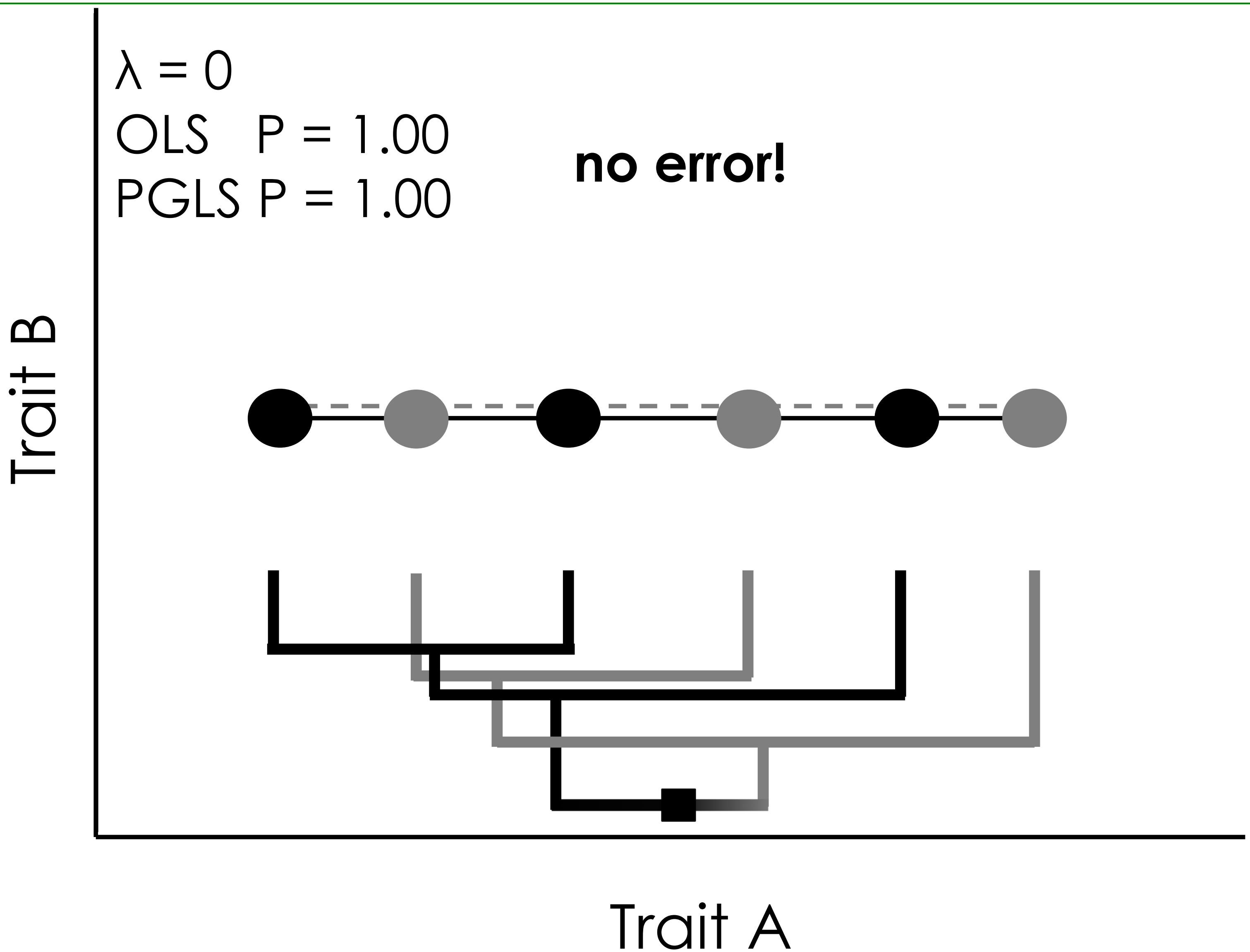

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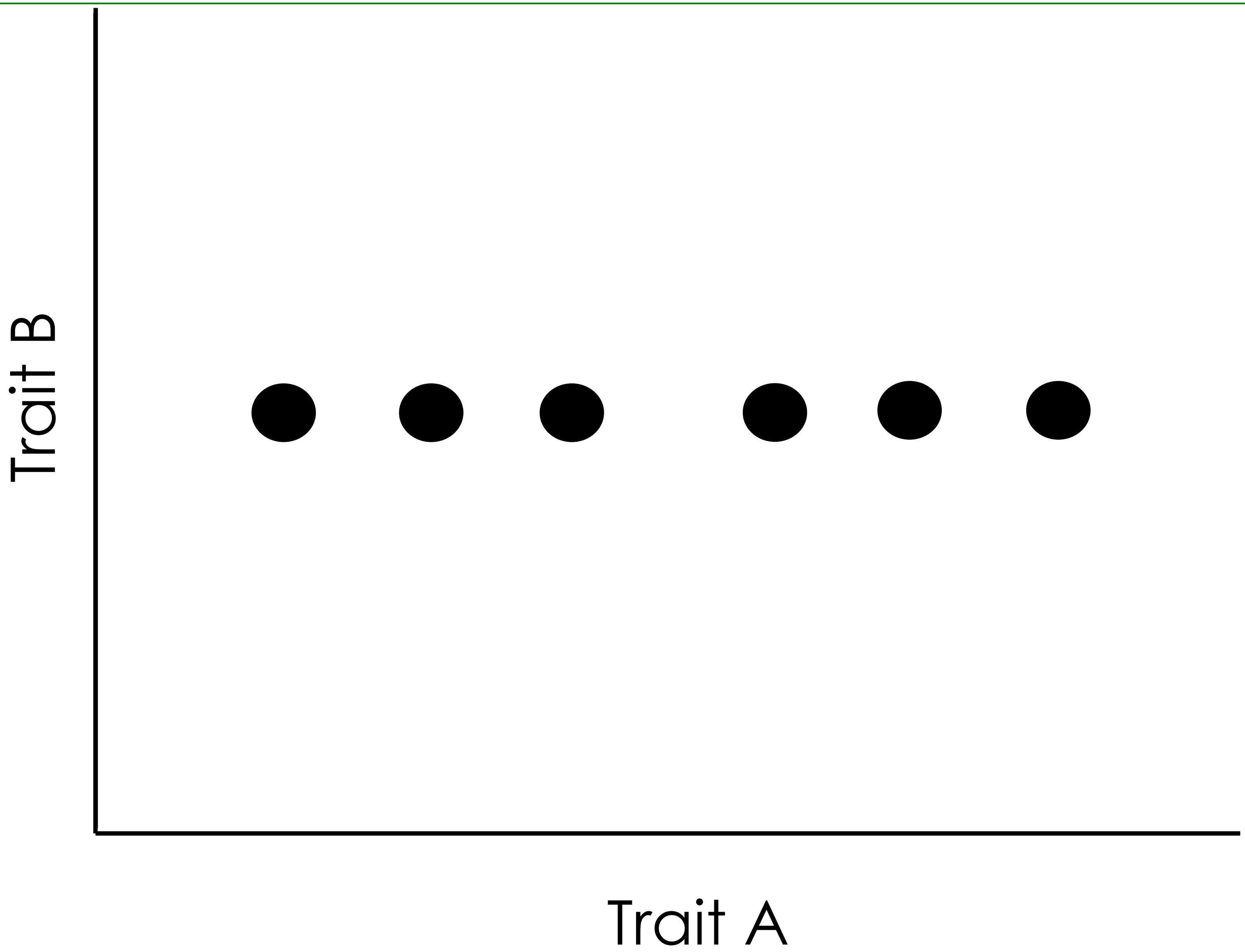

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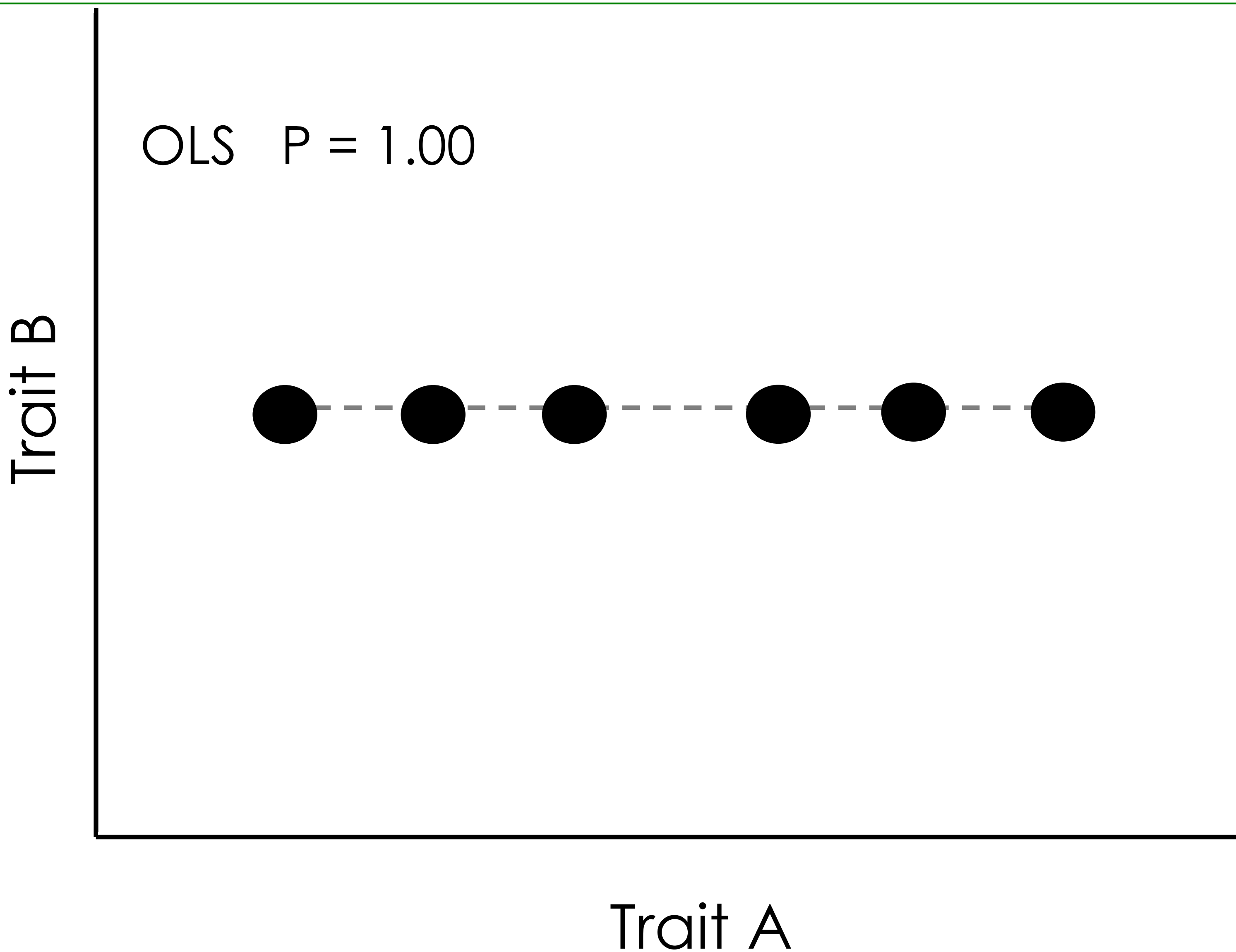

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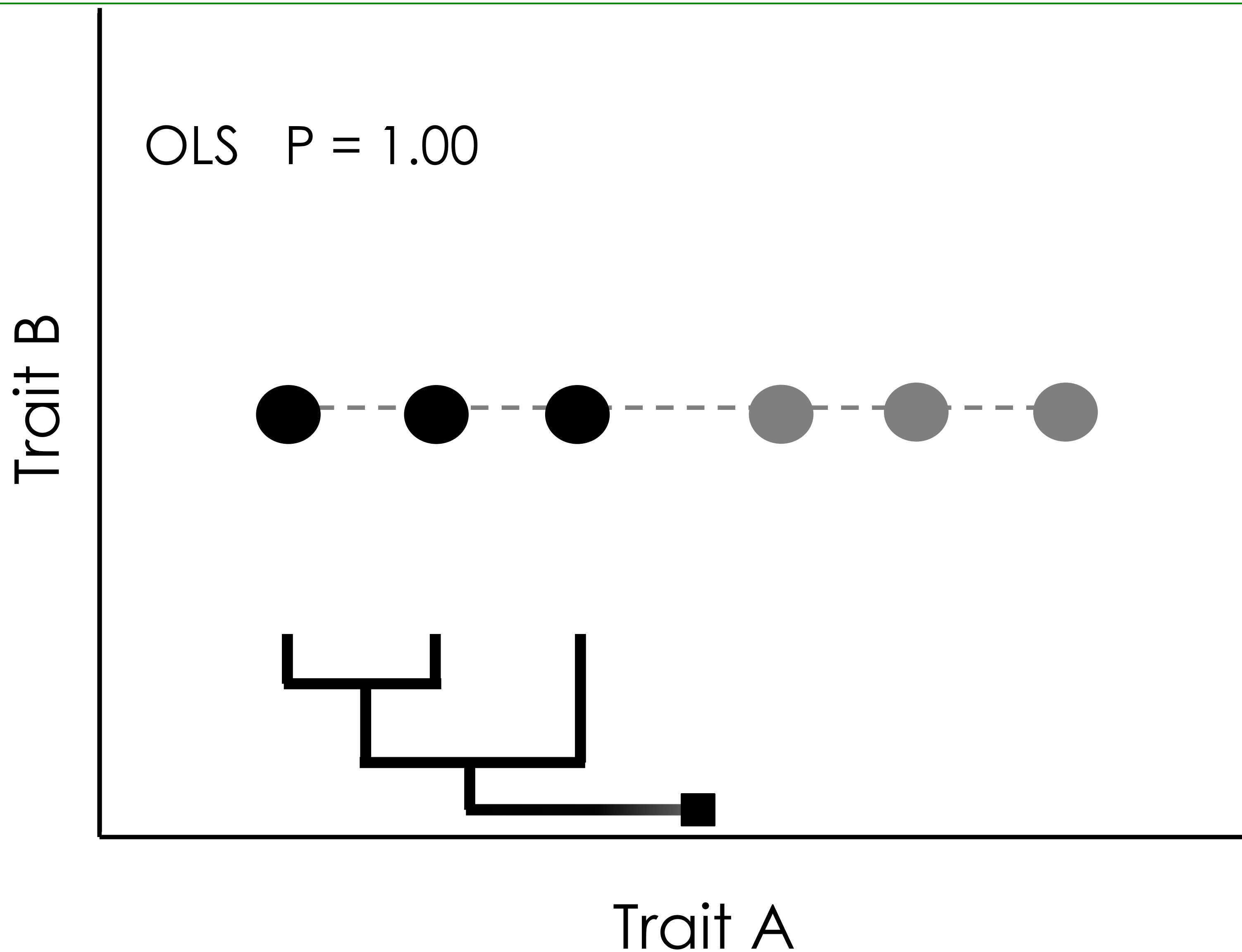

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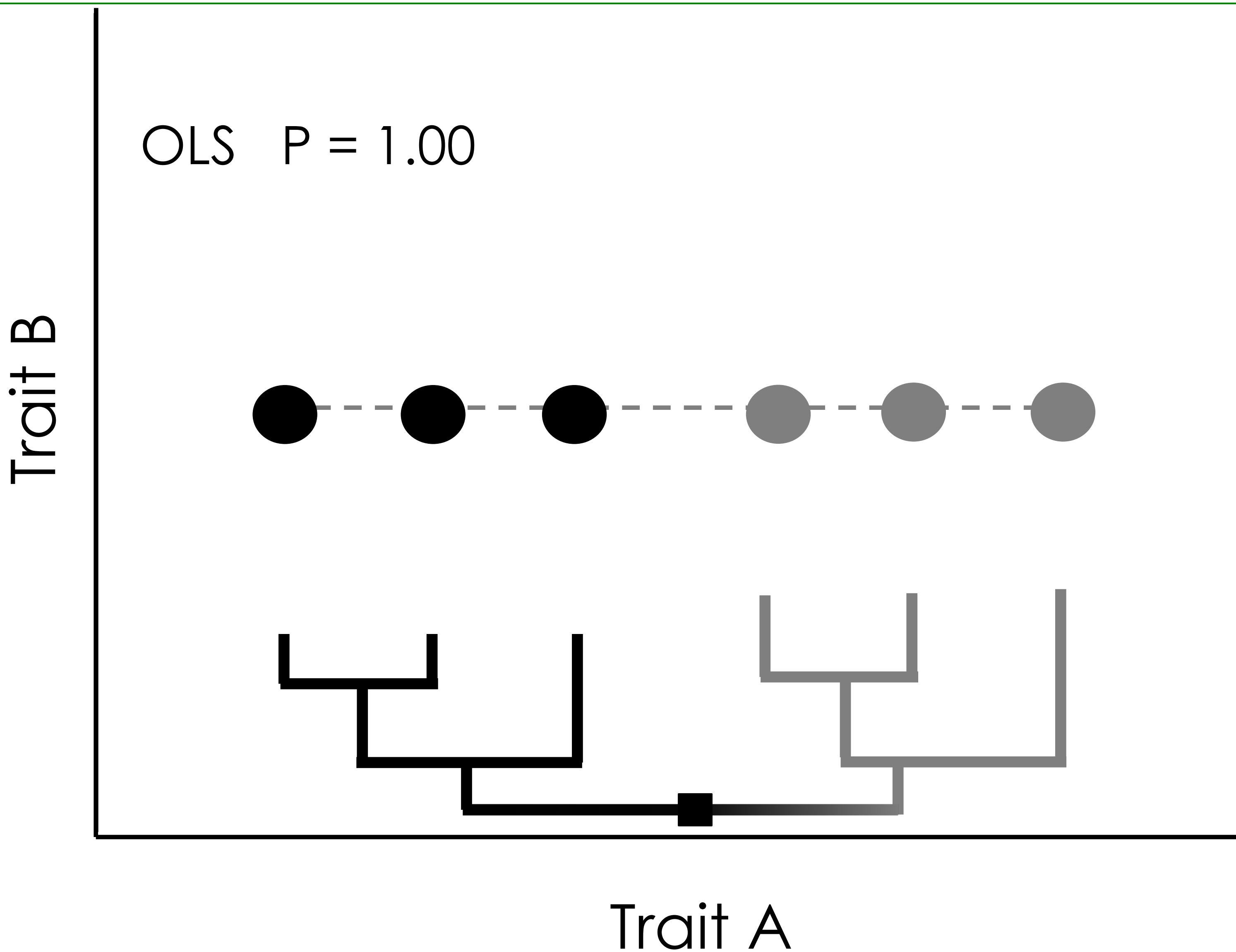

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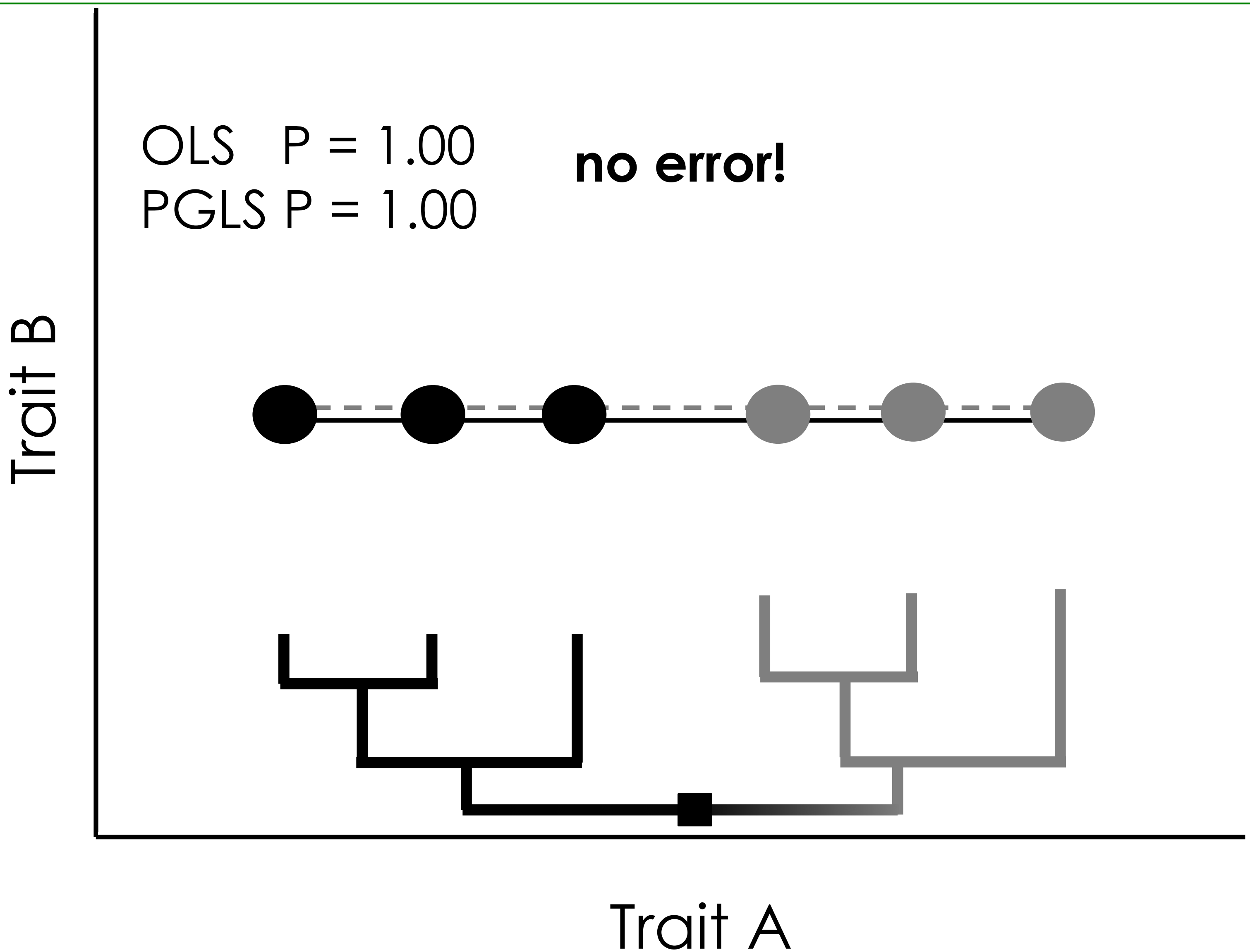

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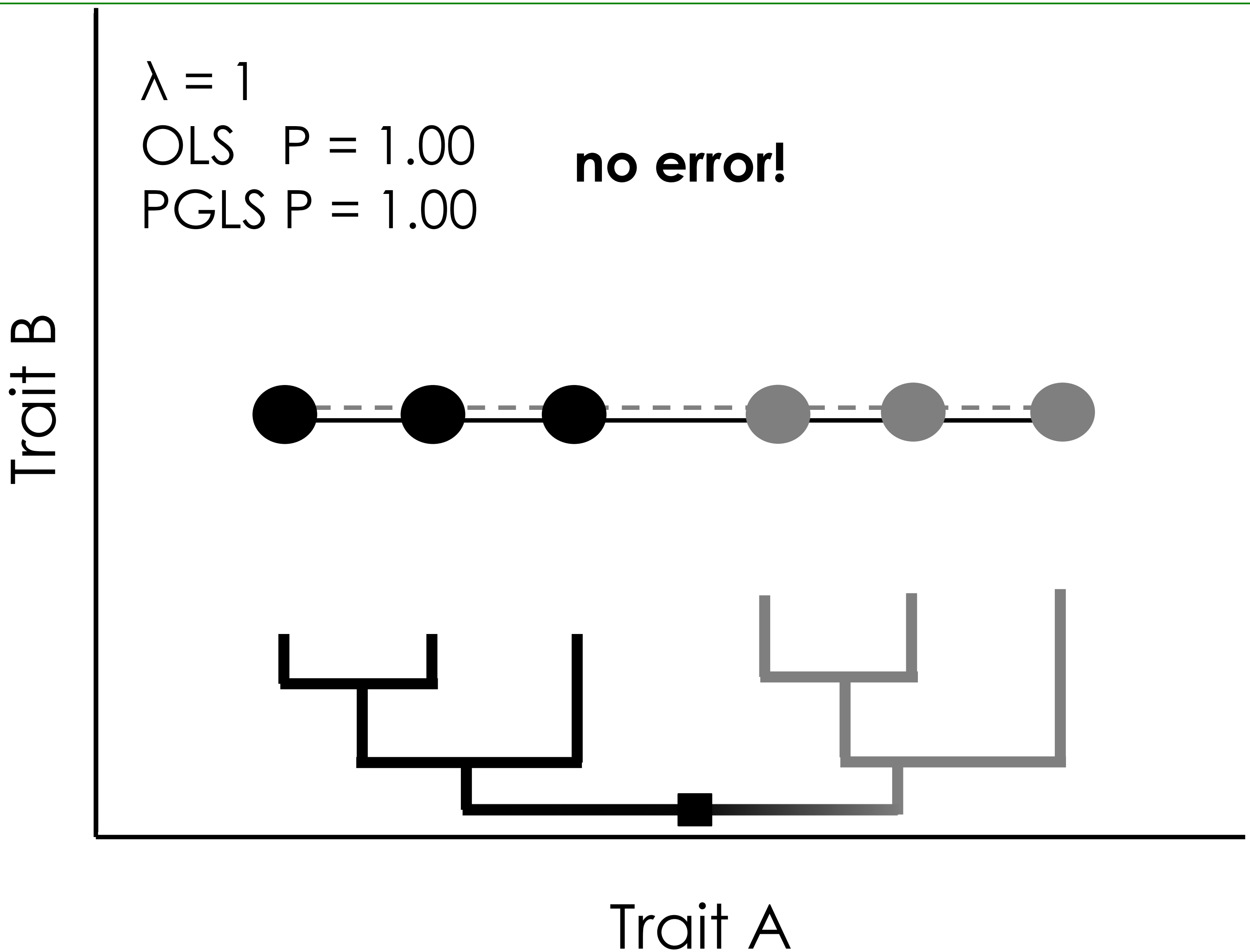

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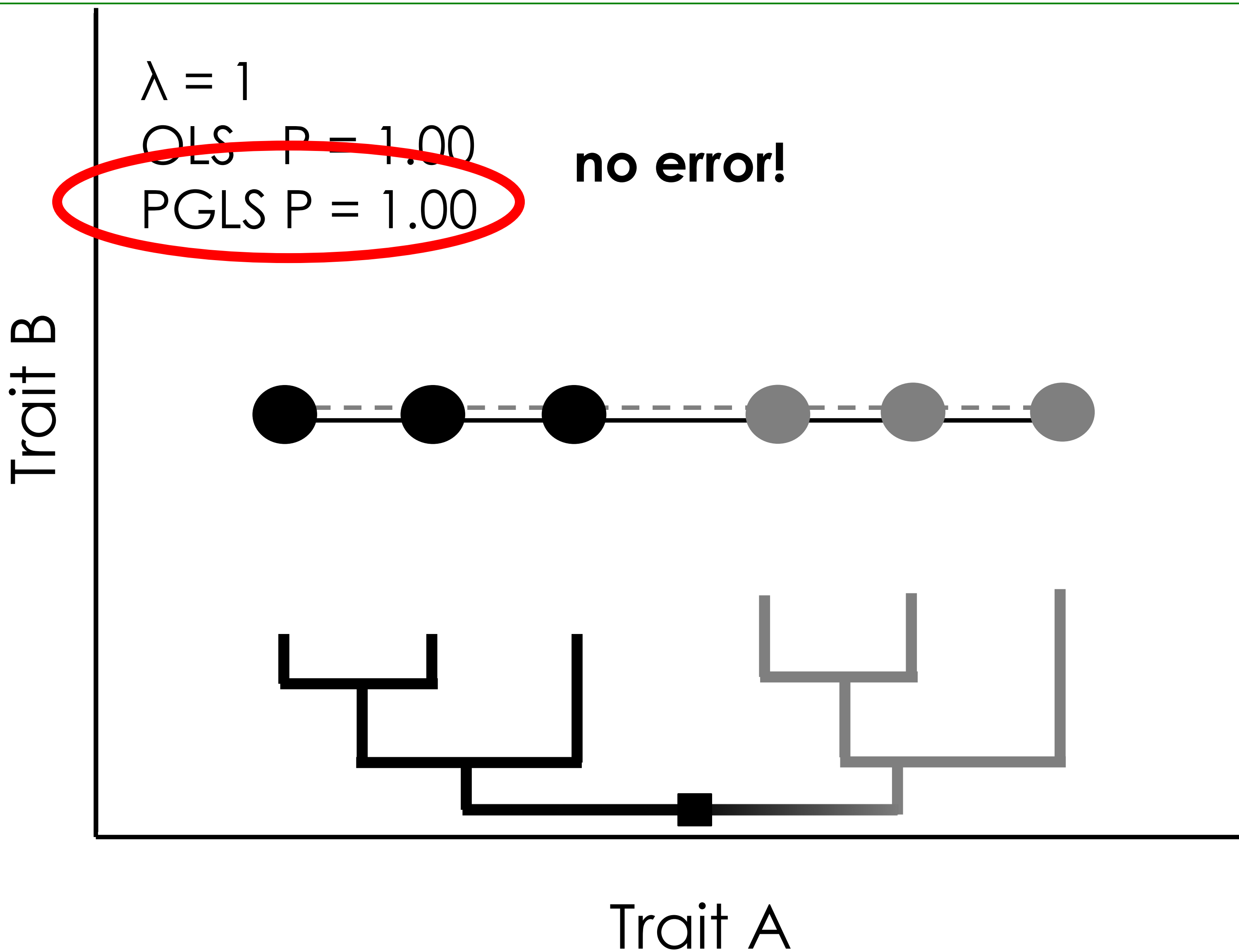

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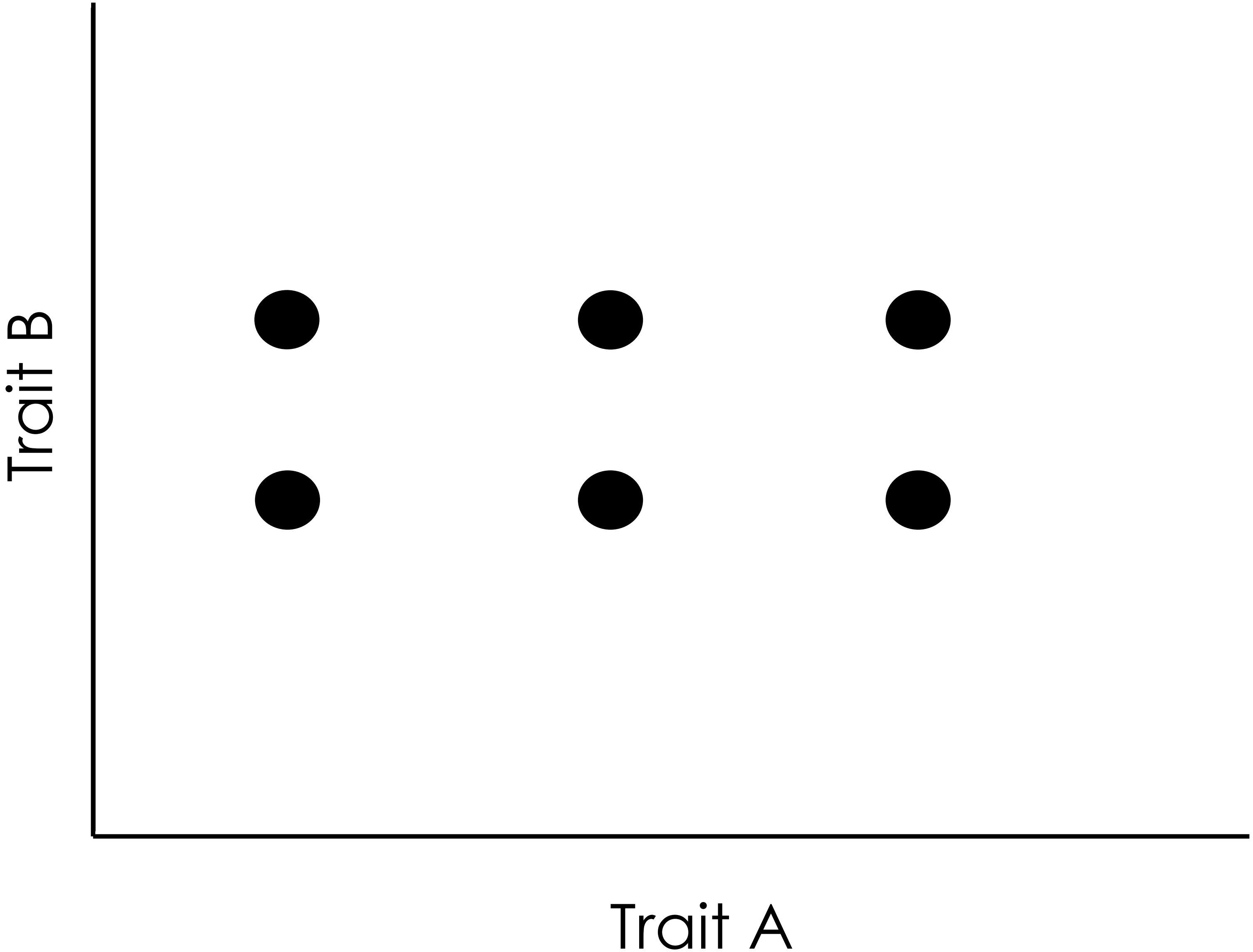

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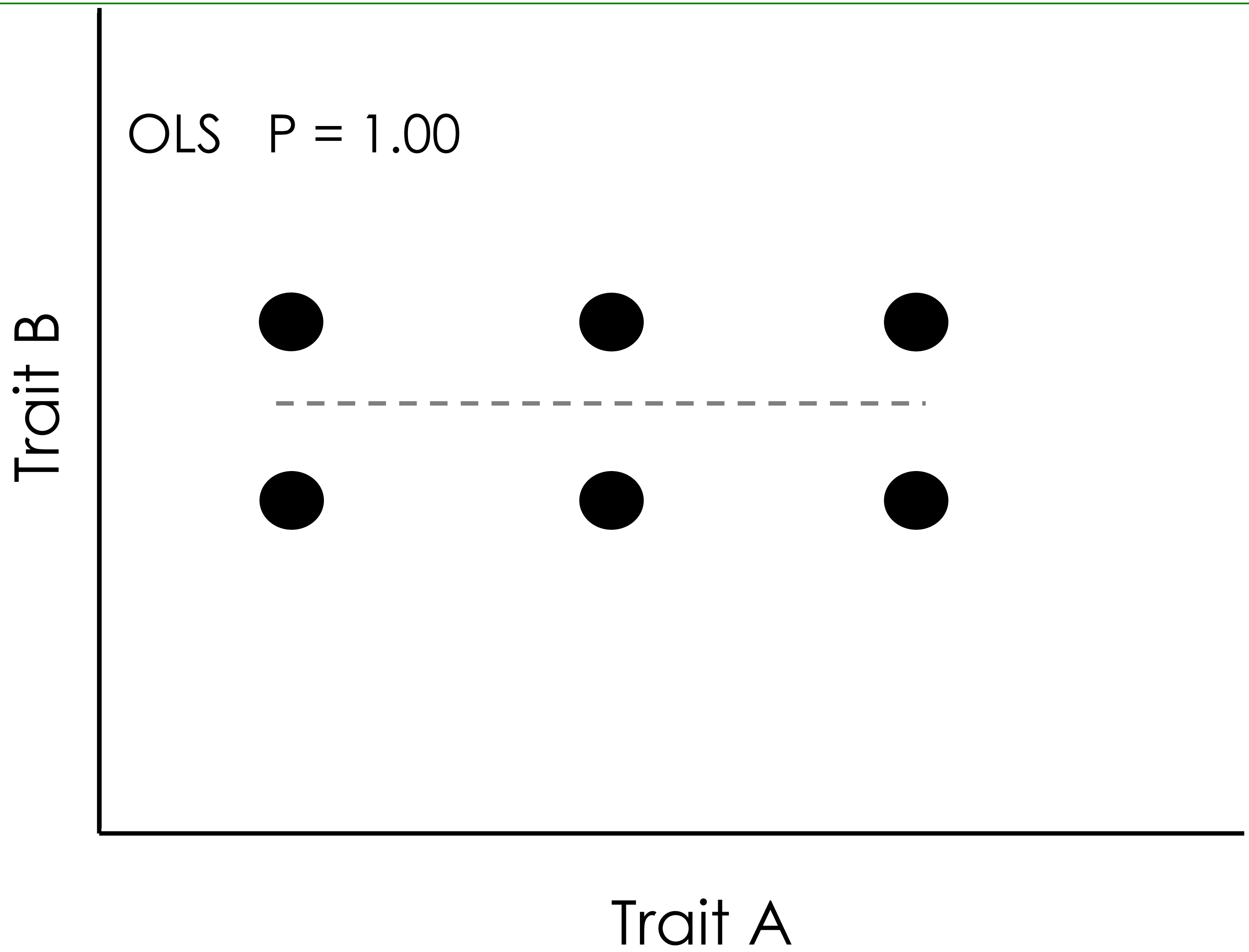

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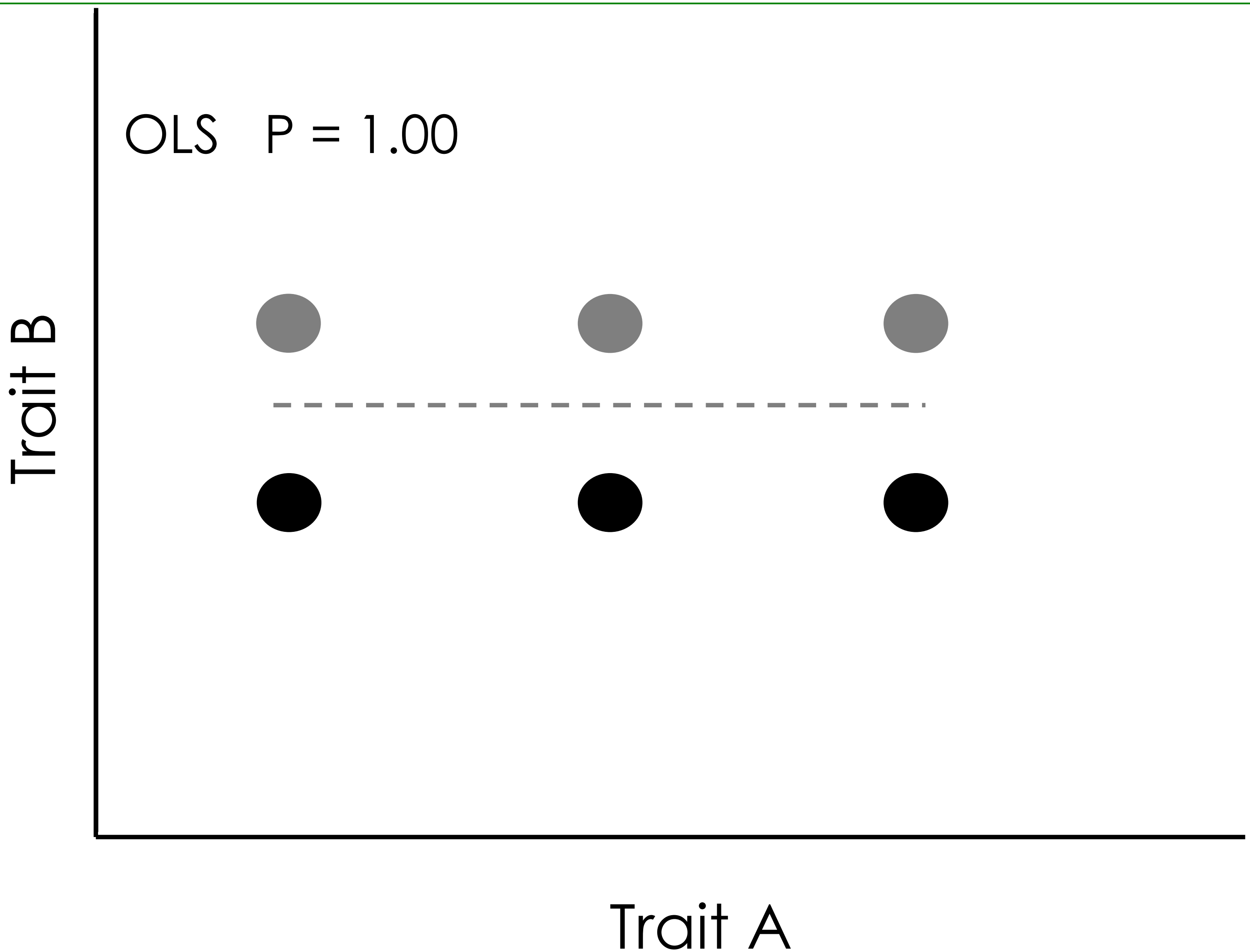

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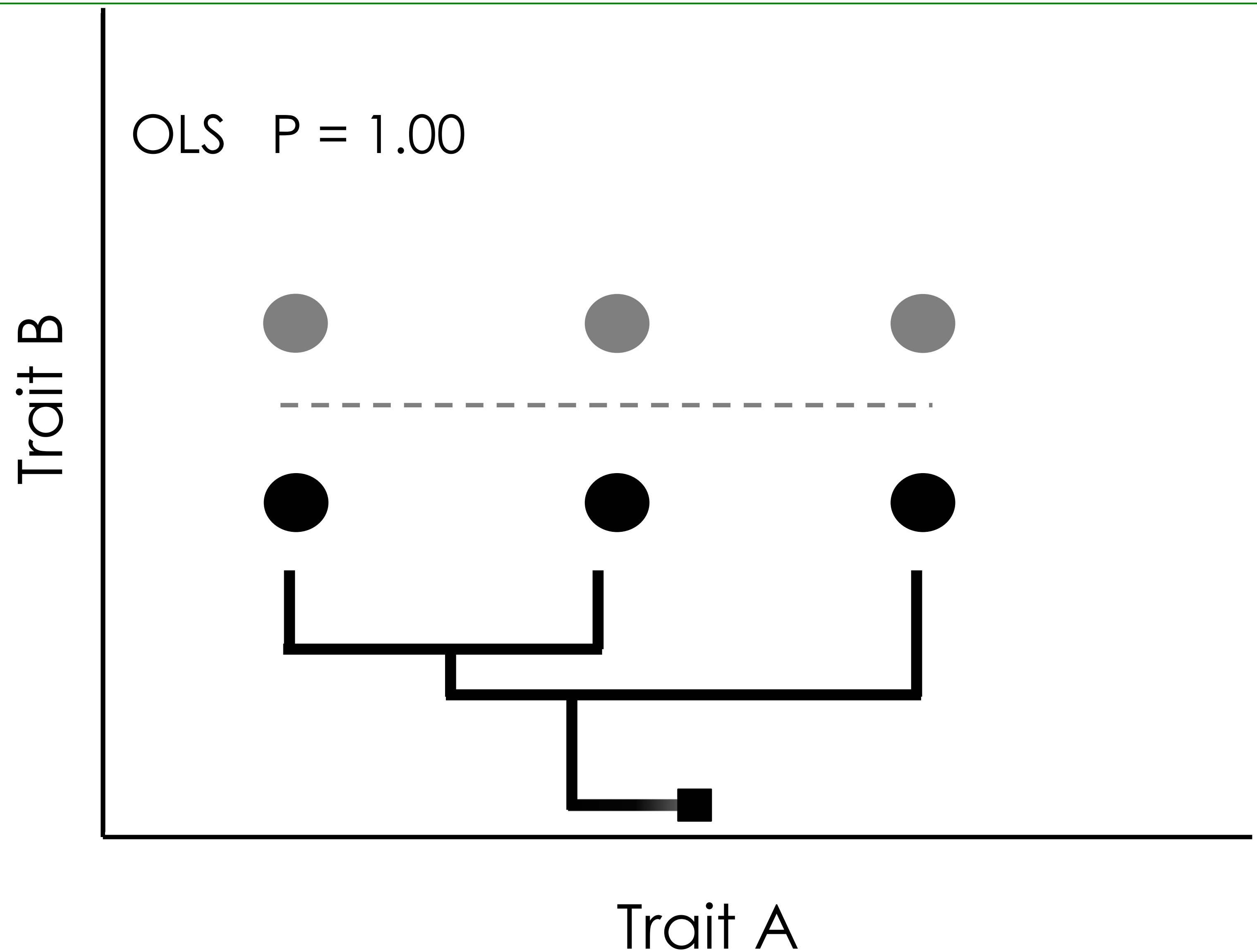

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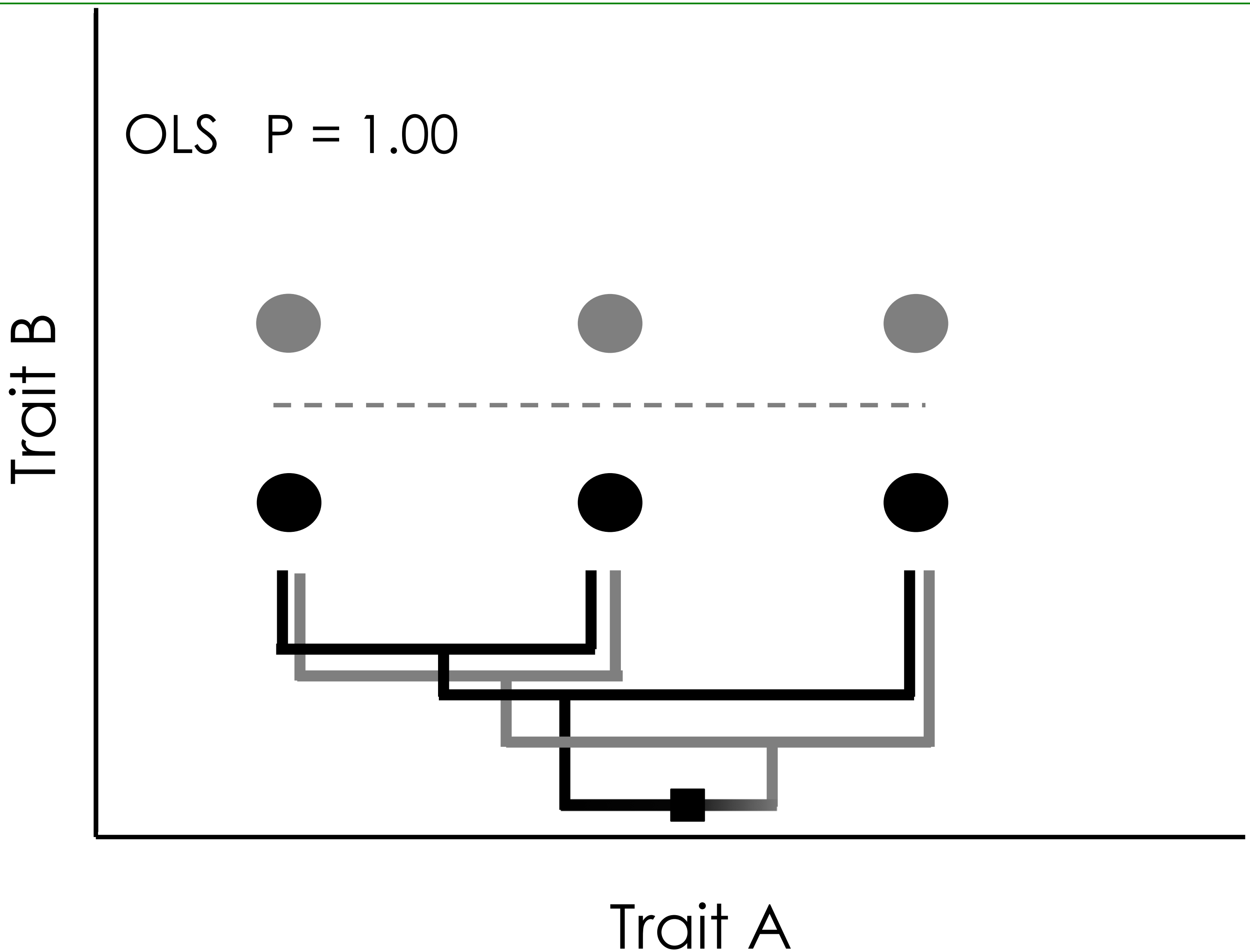

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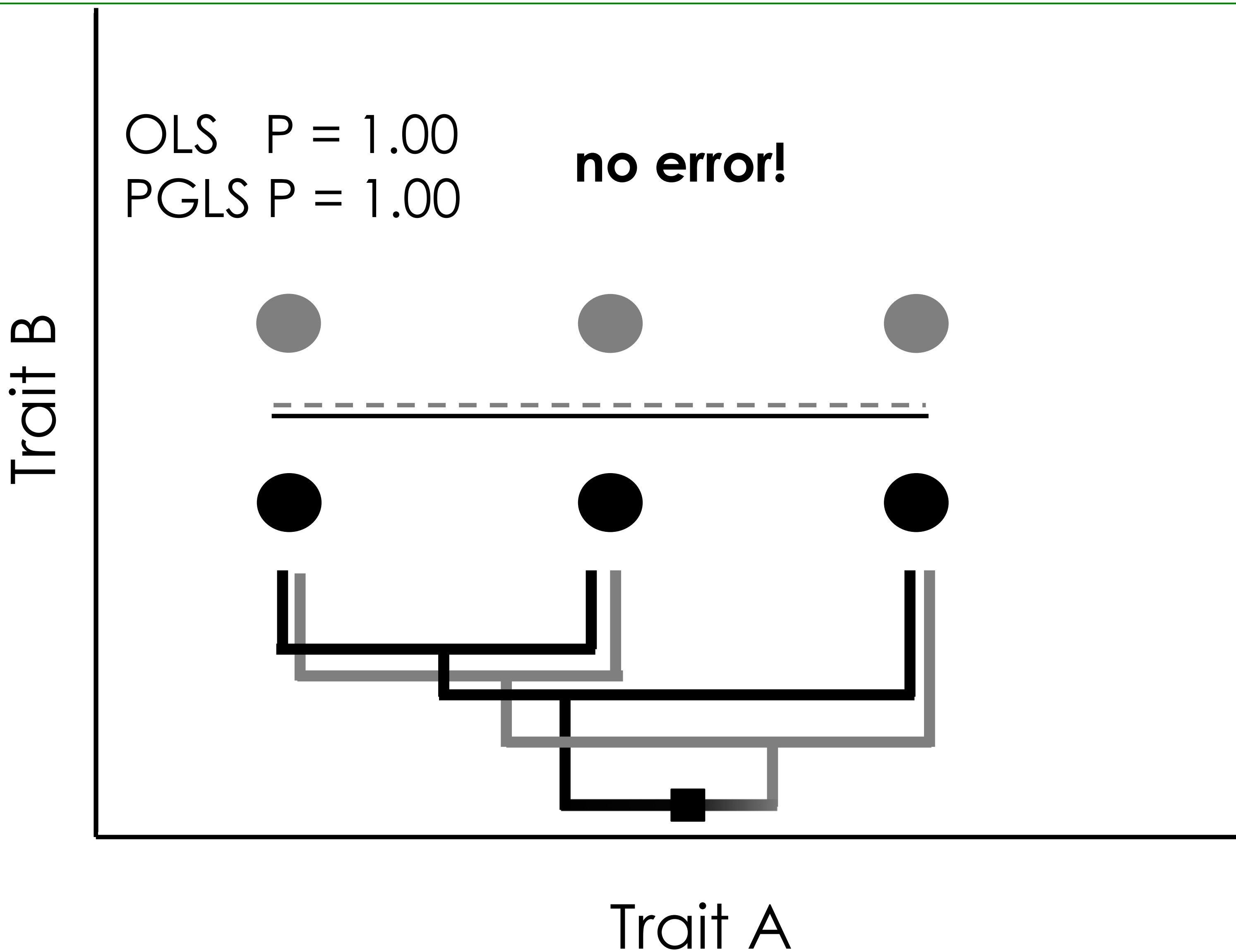

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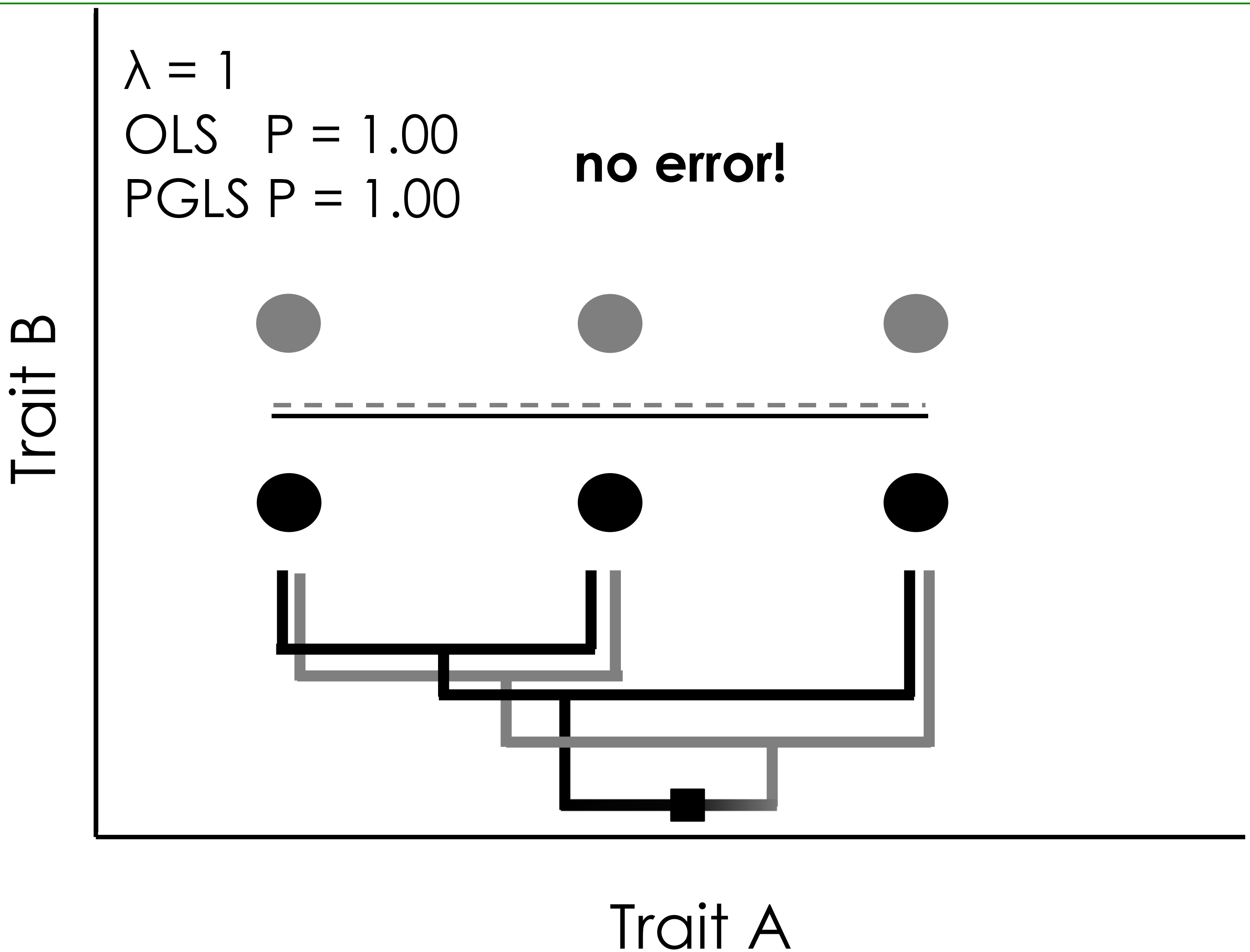

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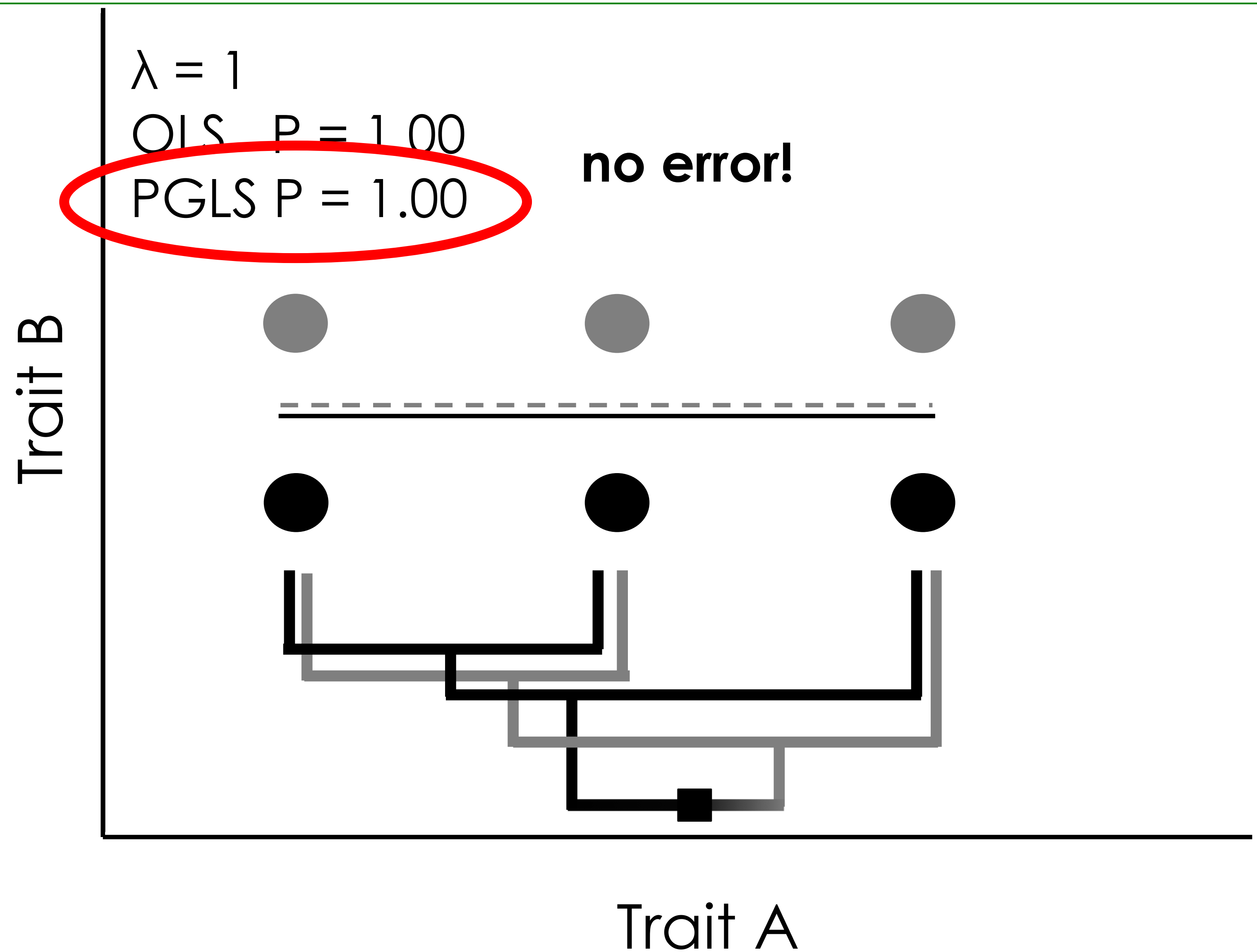

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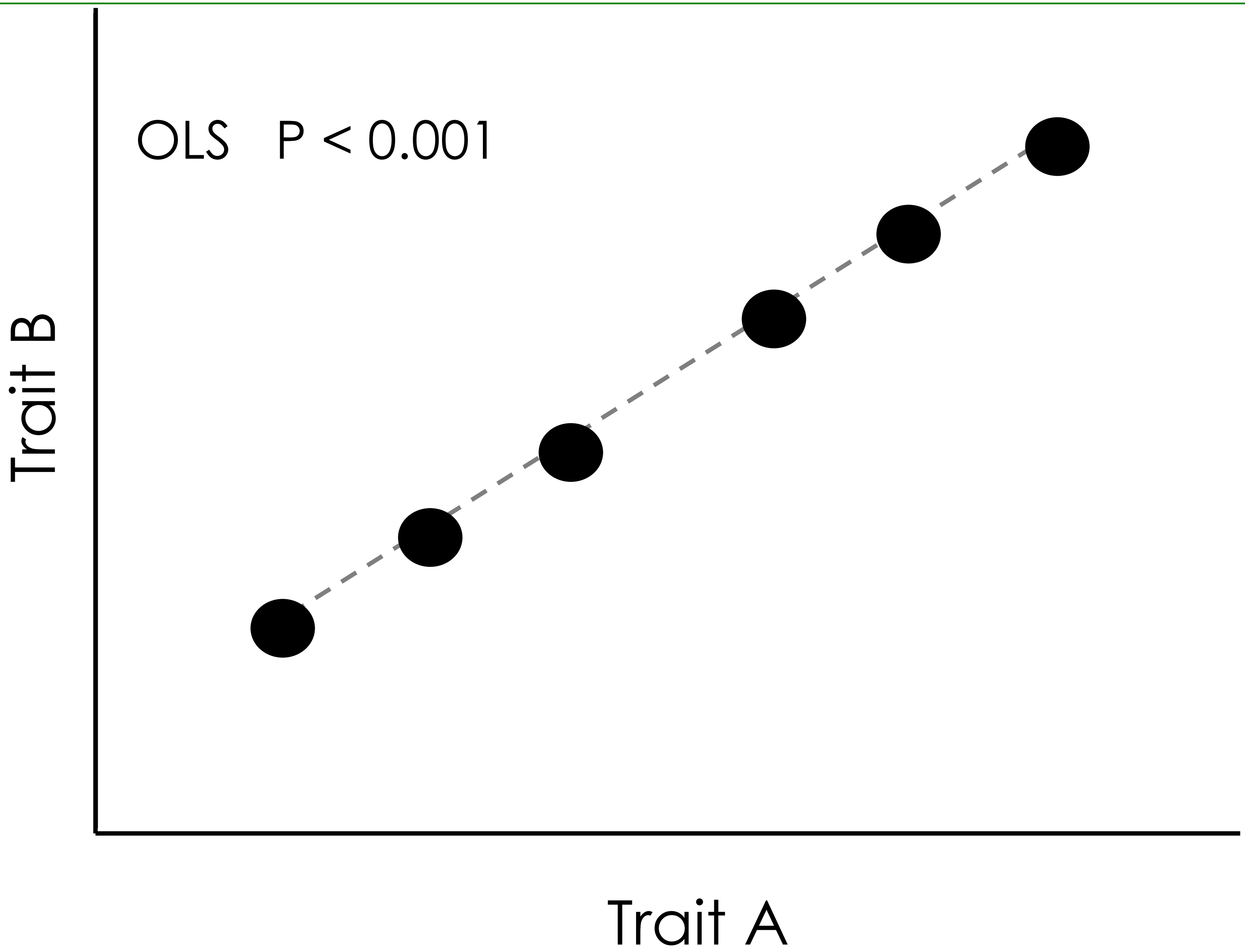

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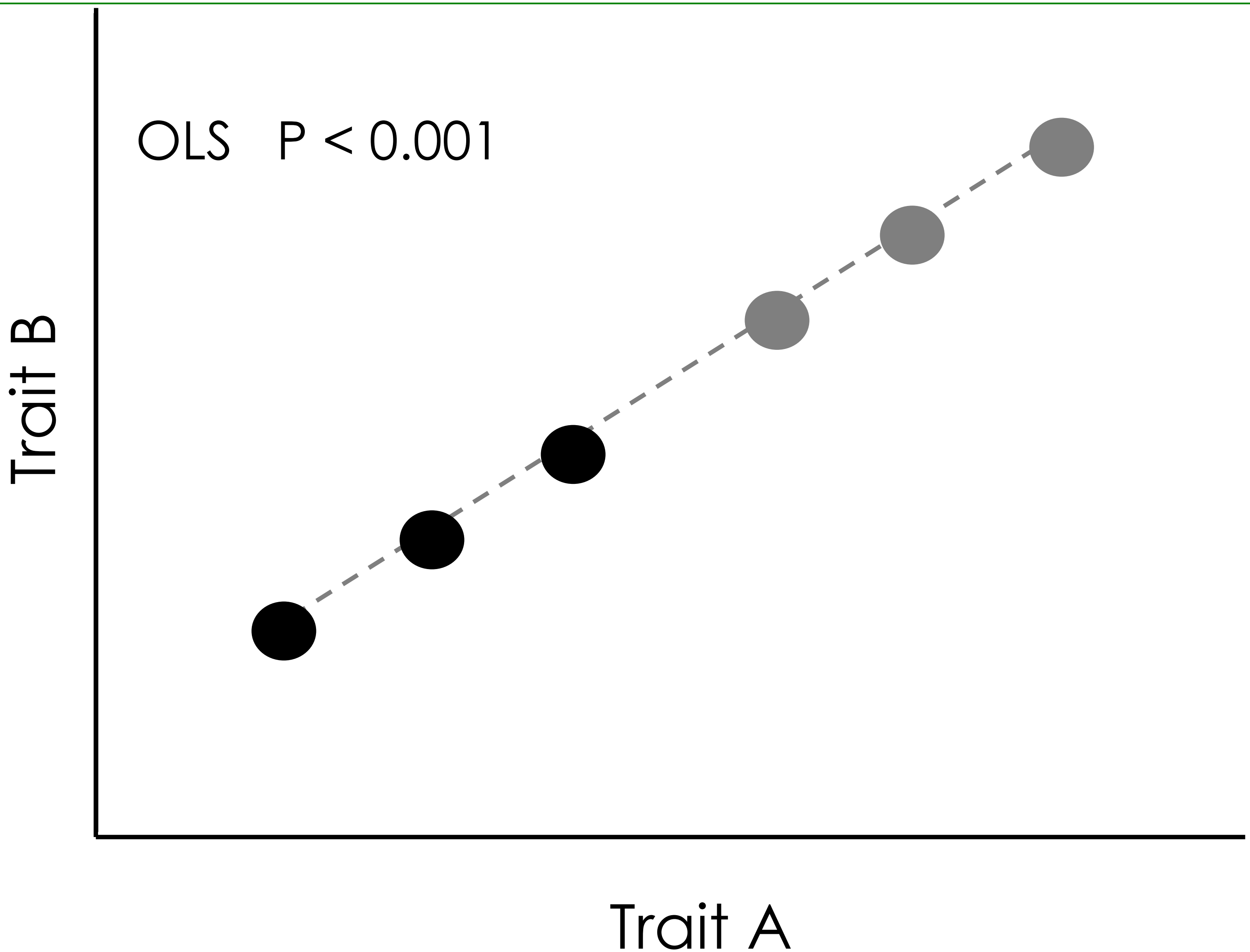

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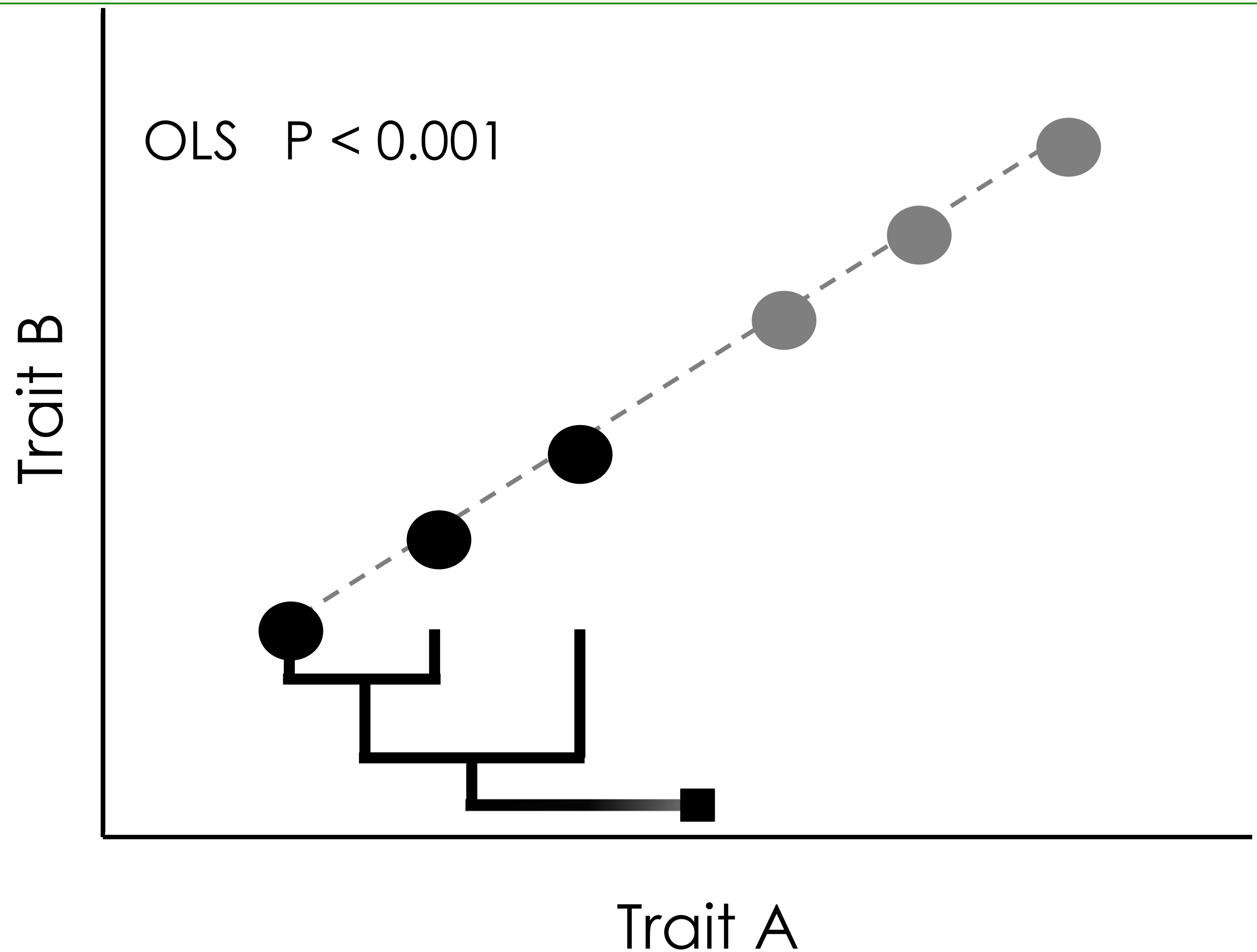

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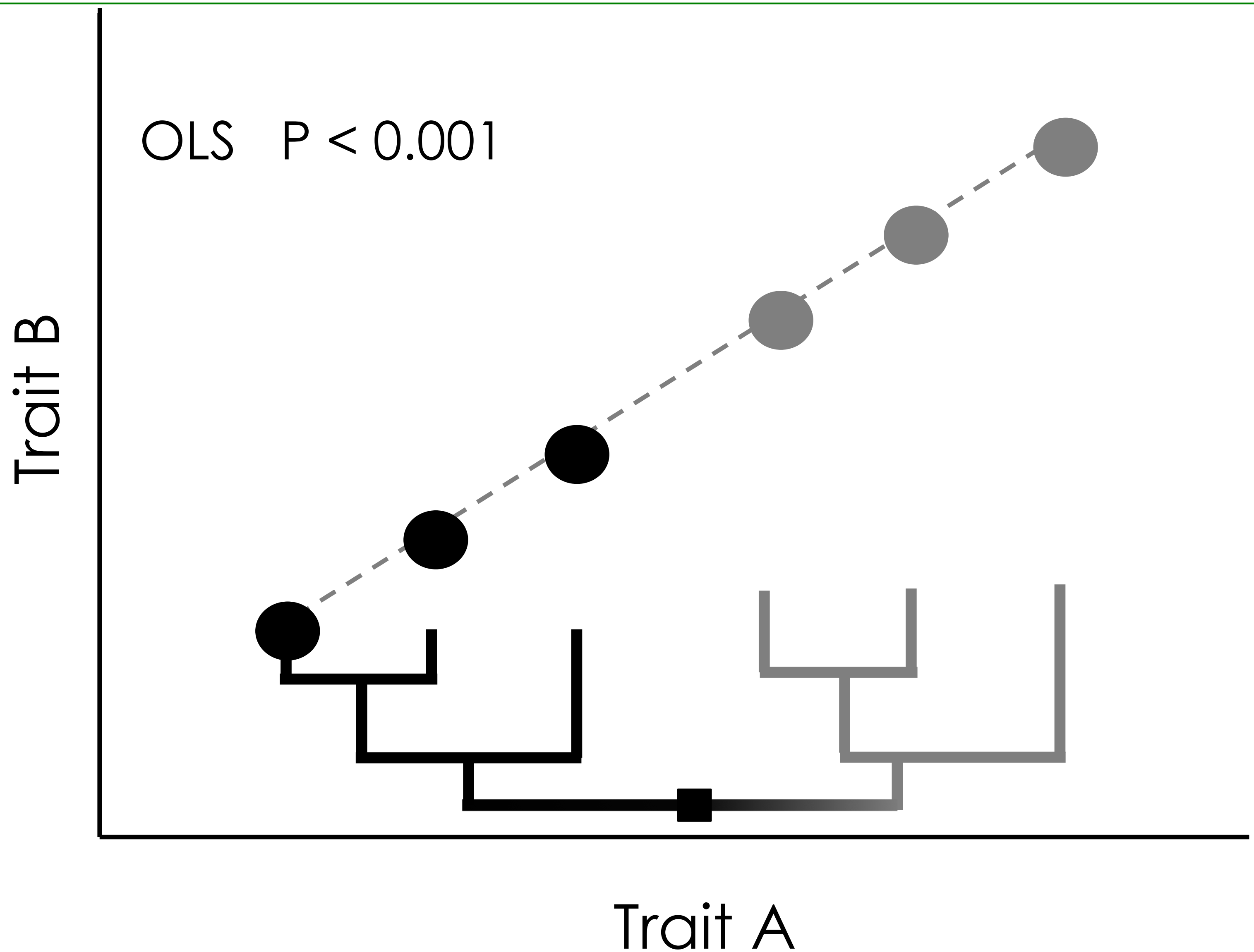

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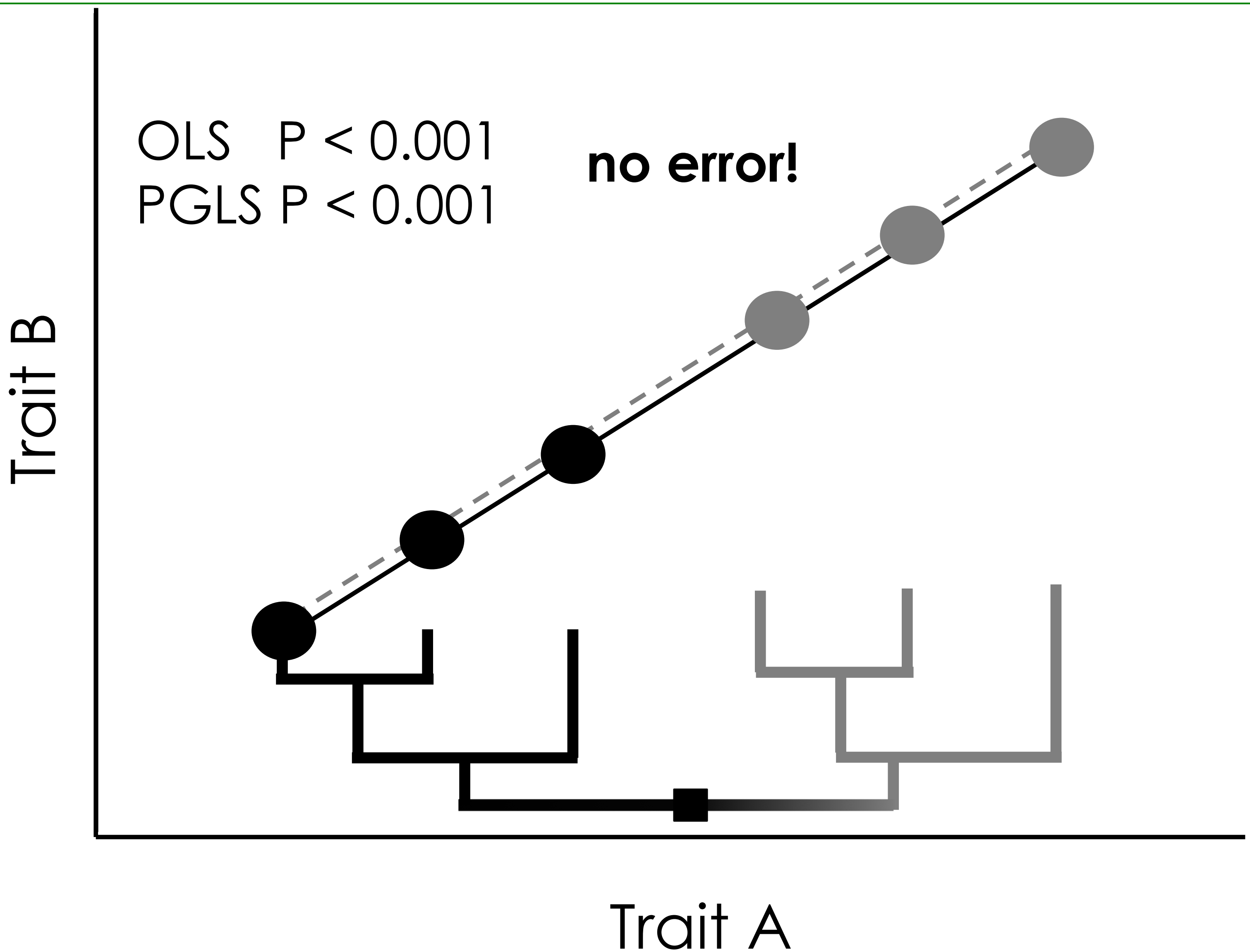

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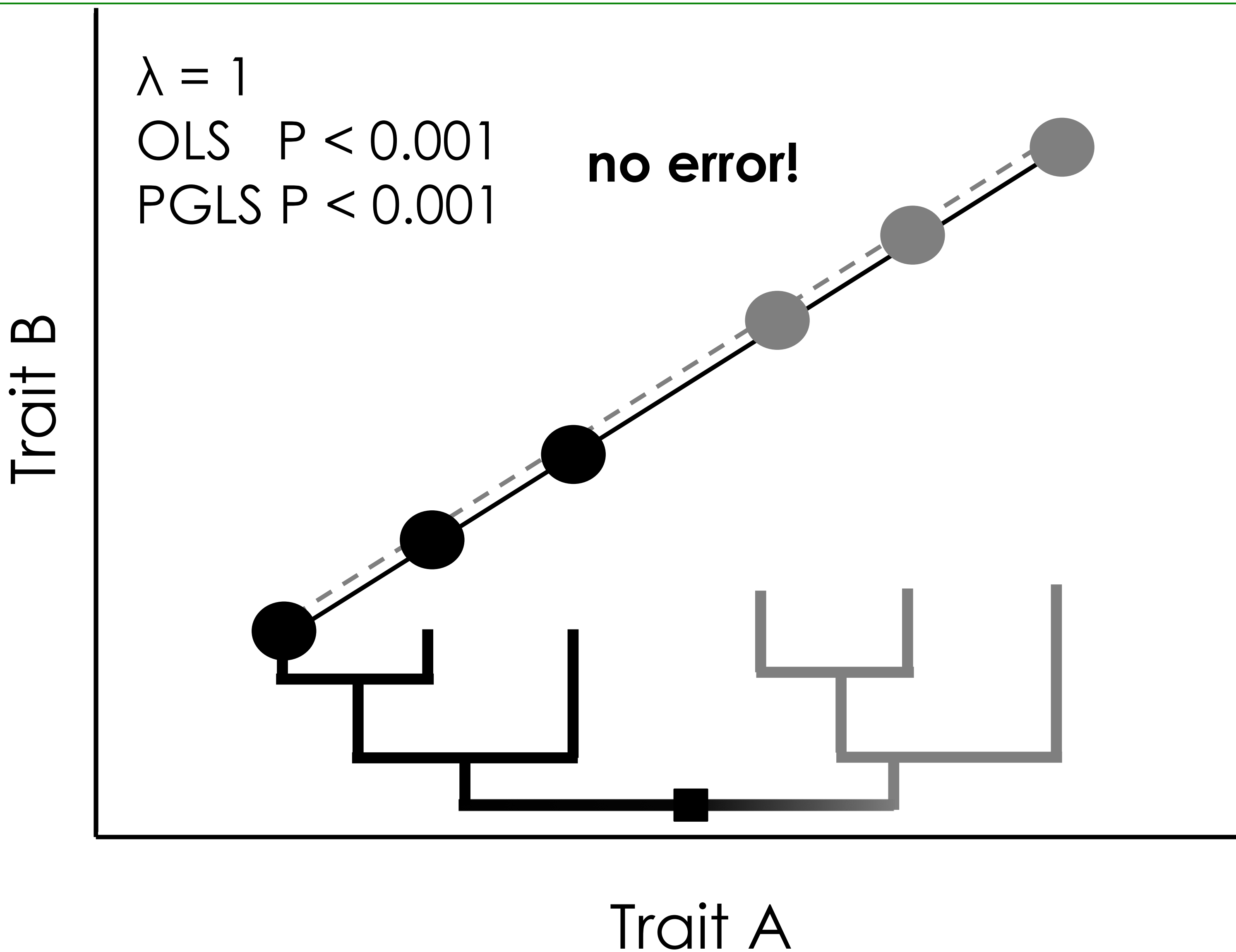

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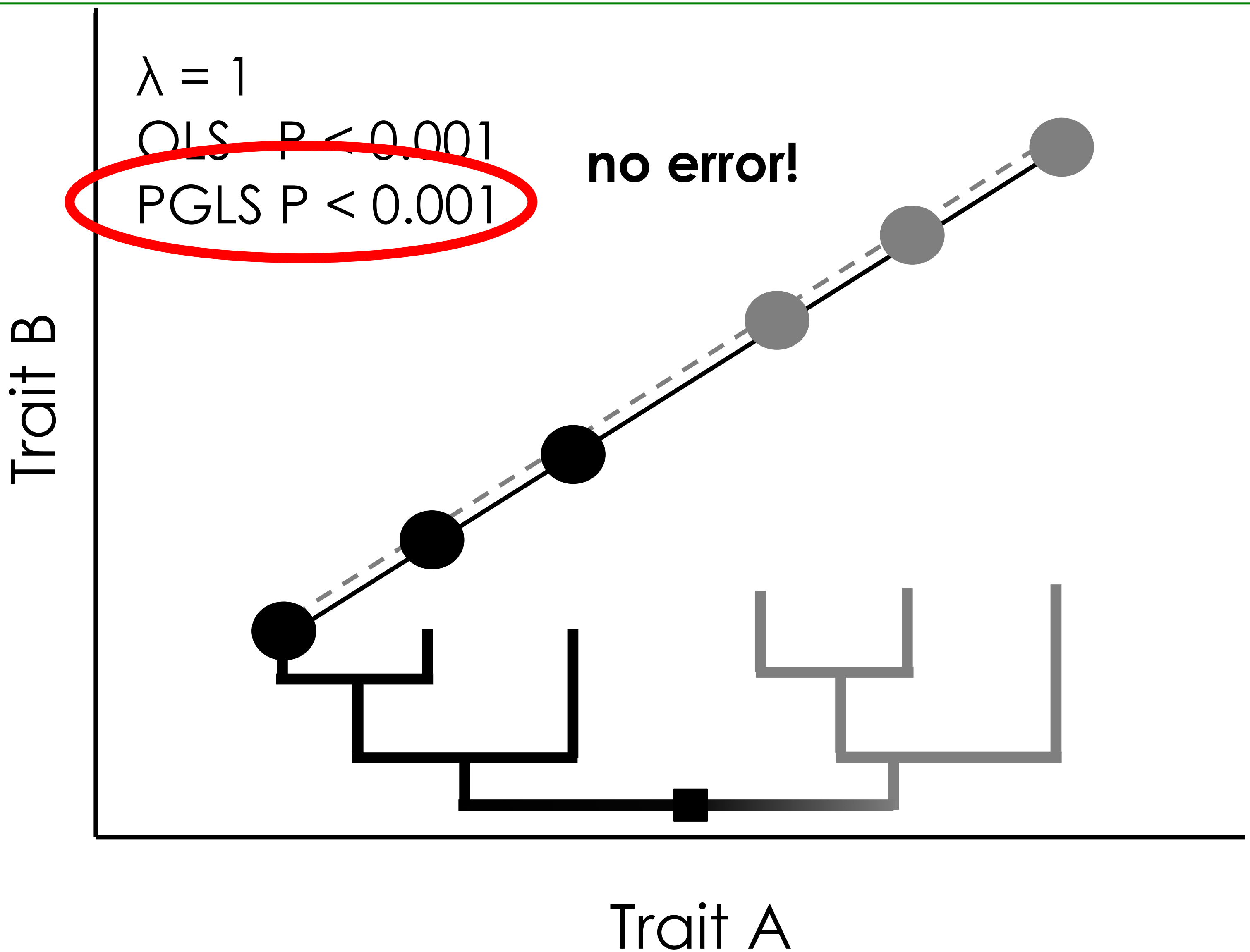

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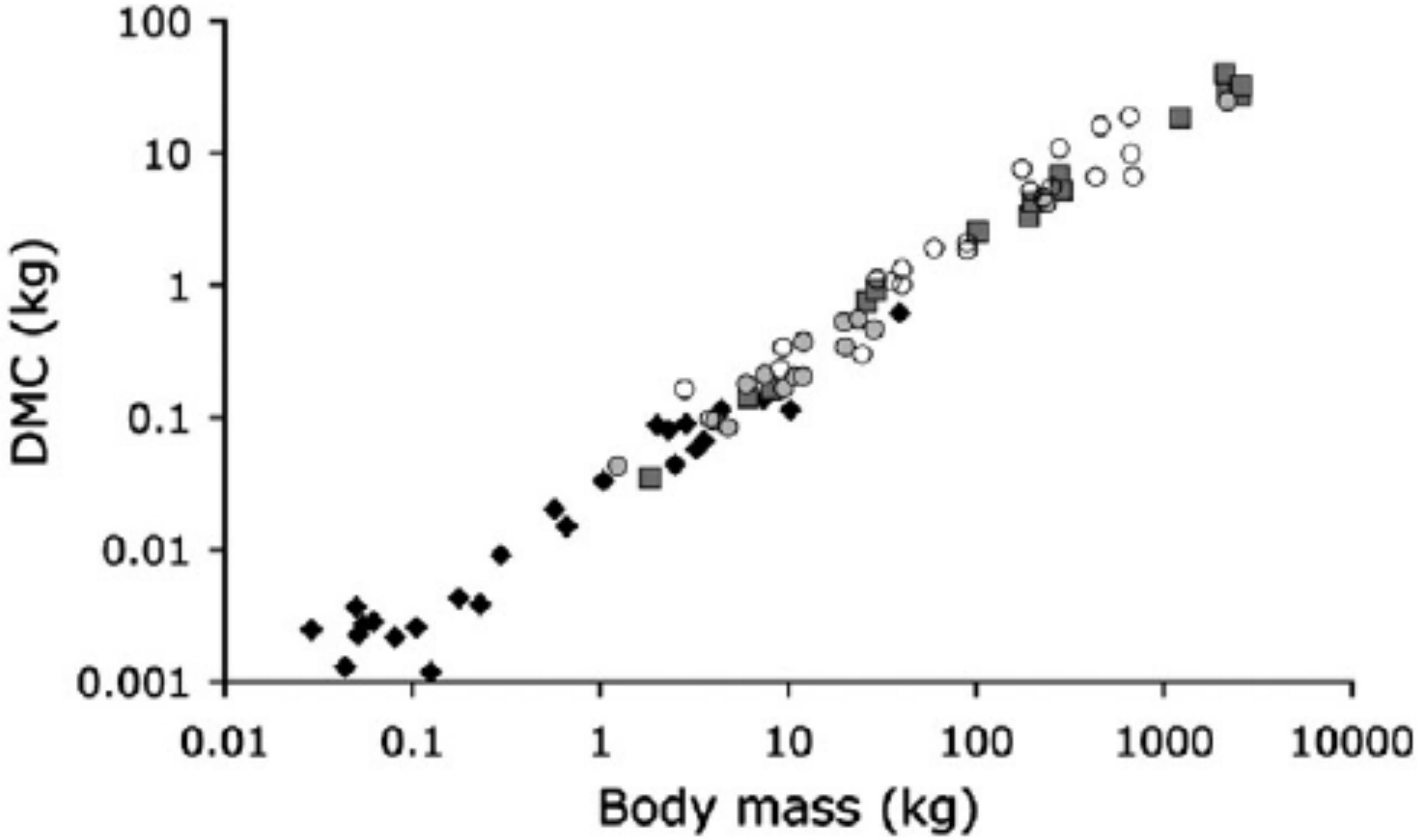
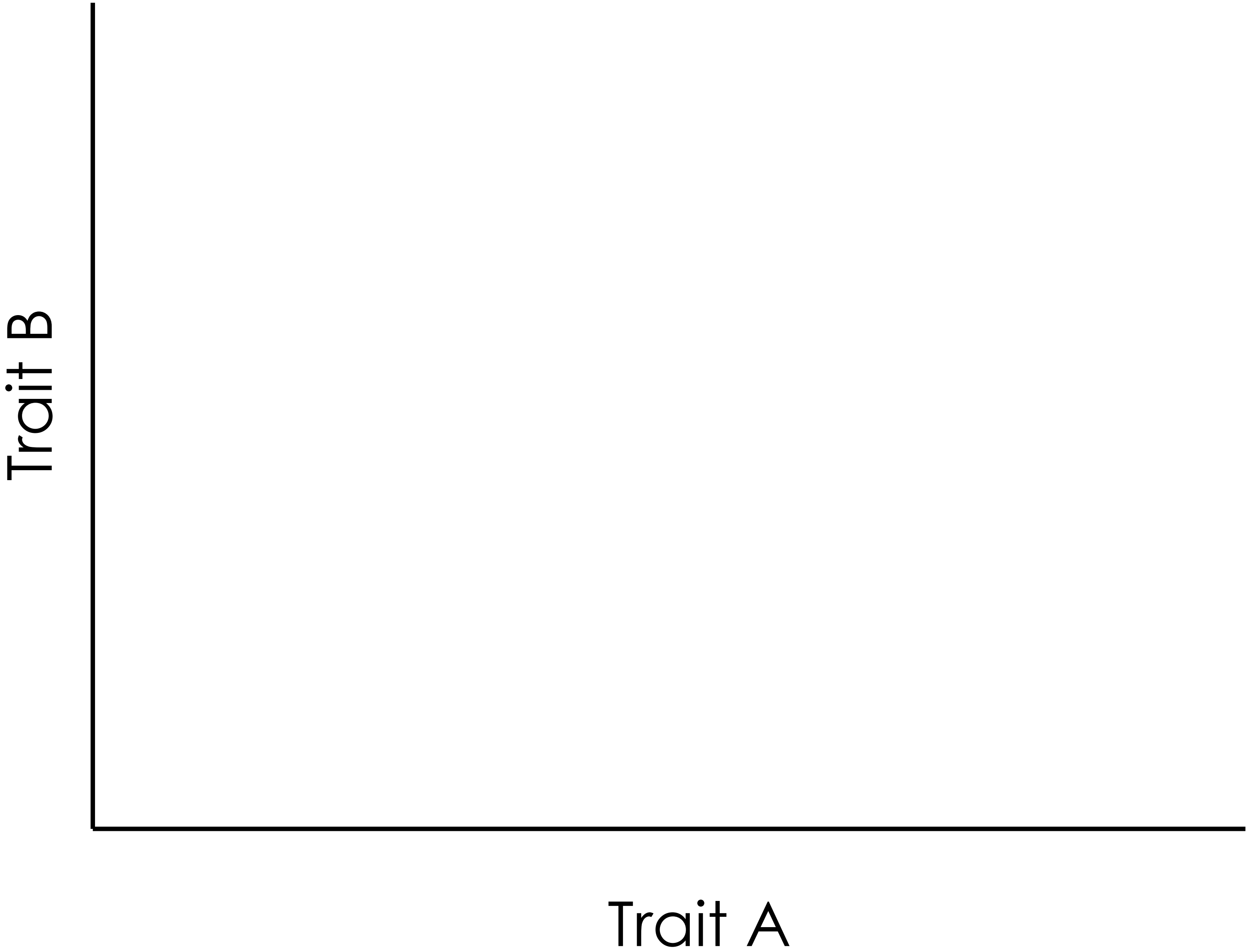
Example I: gut contents



from Müller et al. (2013) CBP A

Accounting for phylogeny



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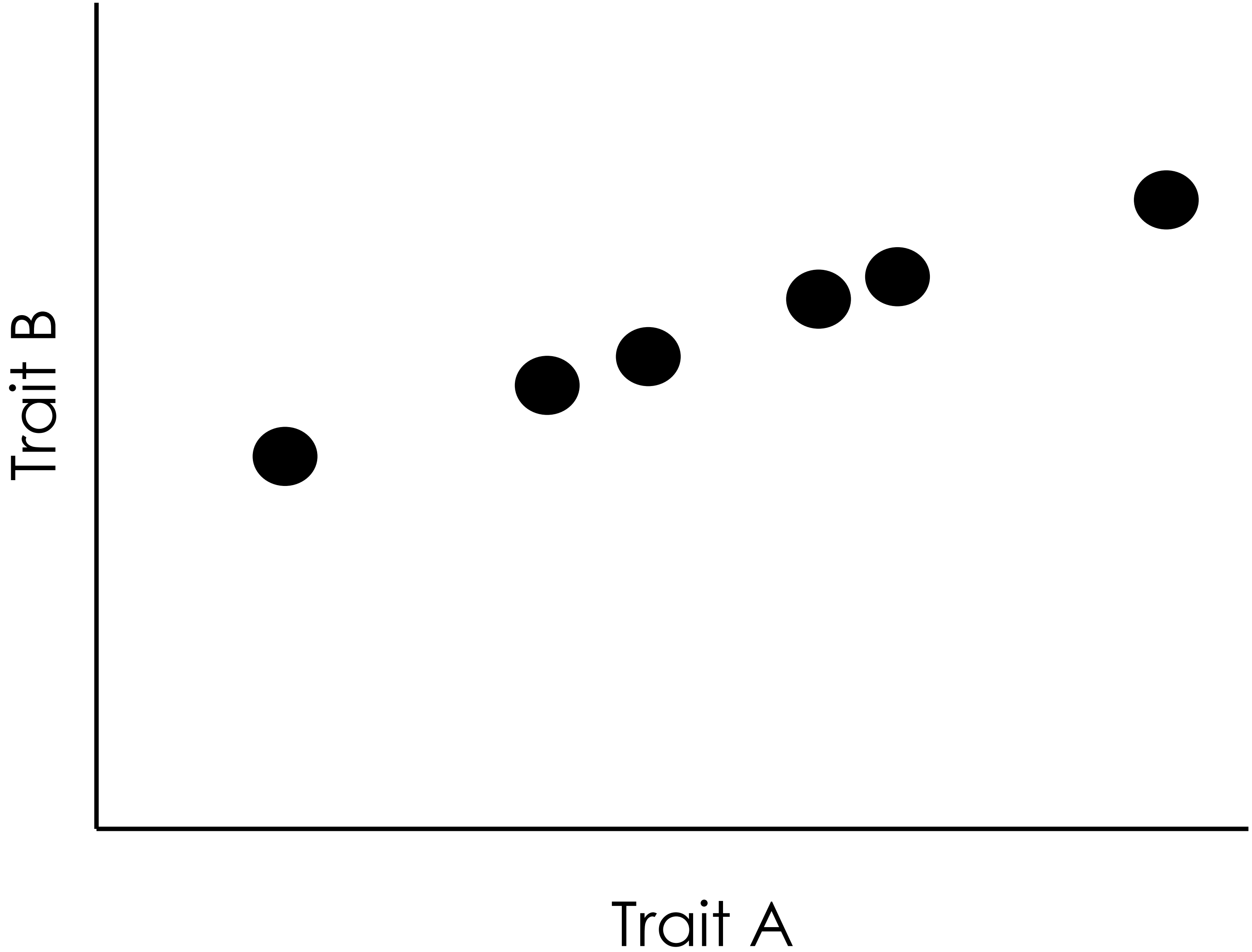

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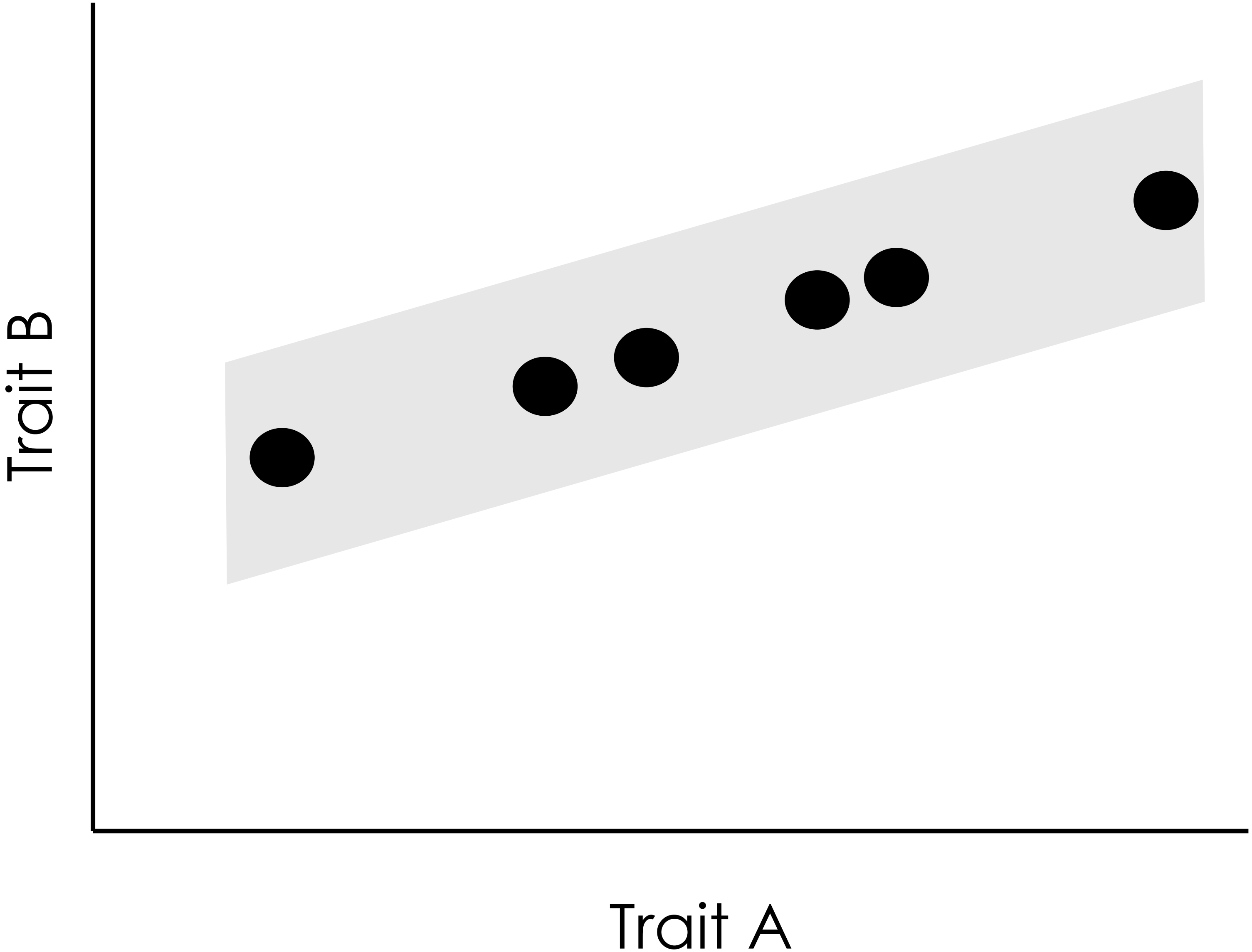

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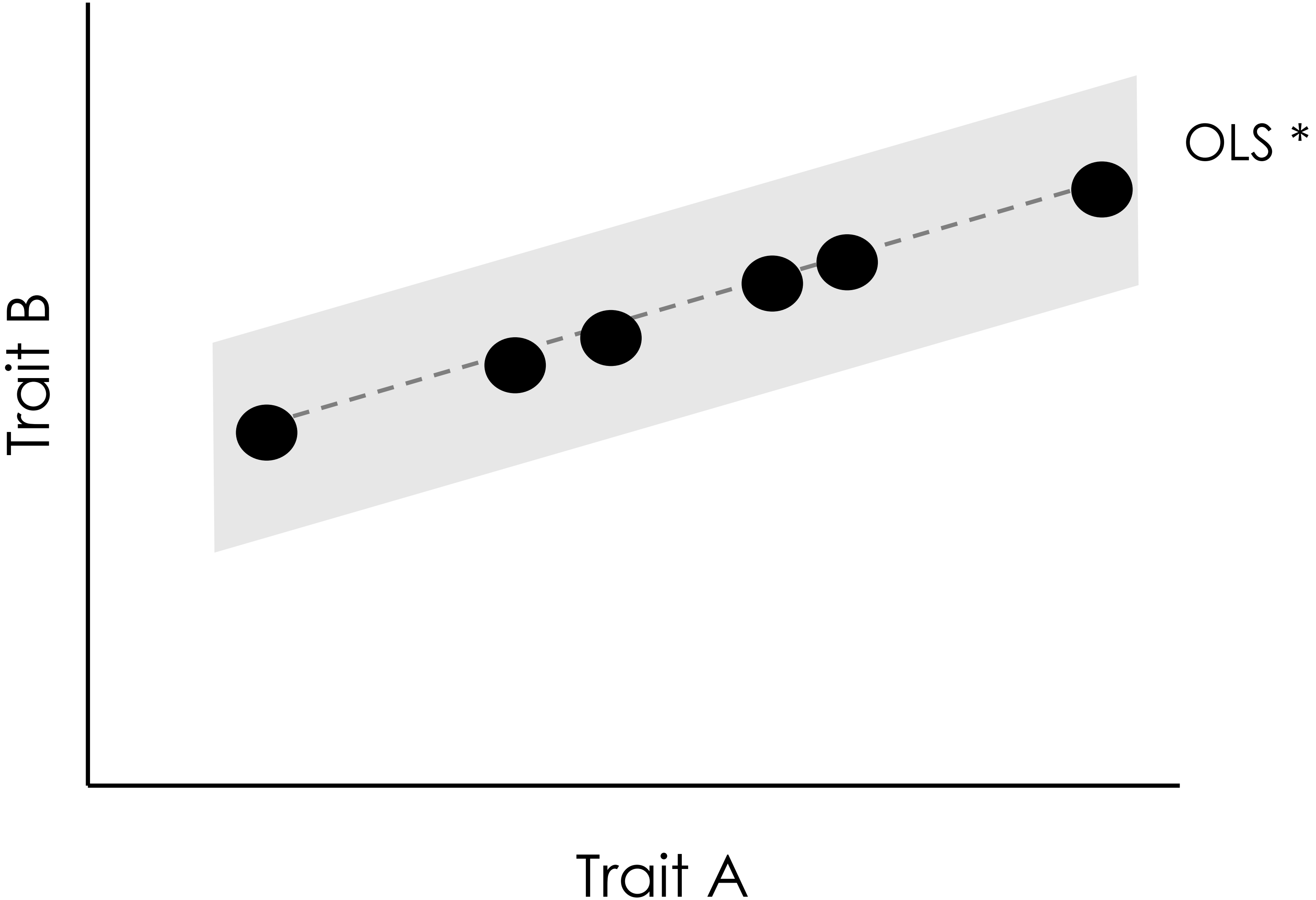
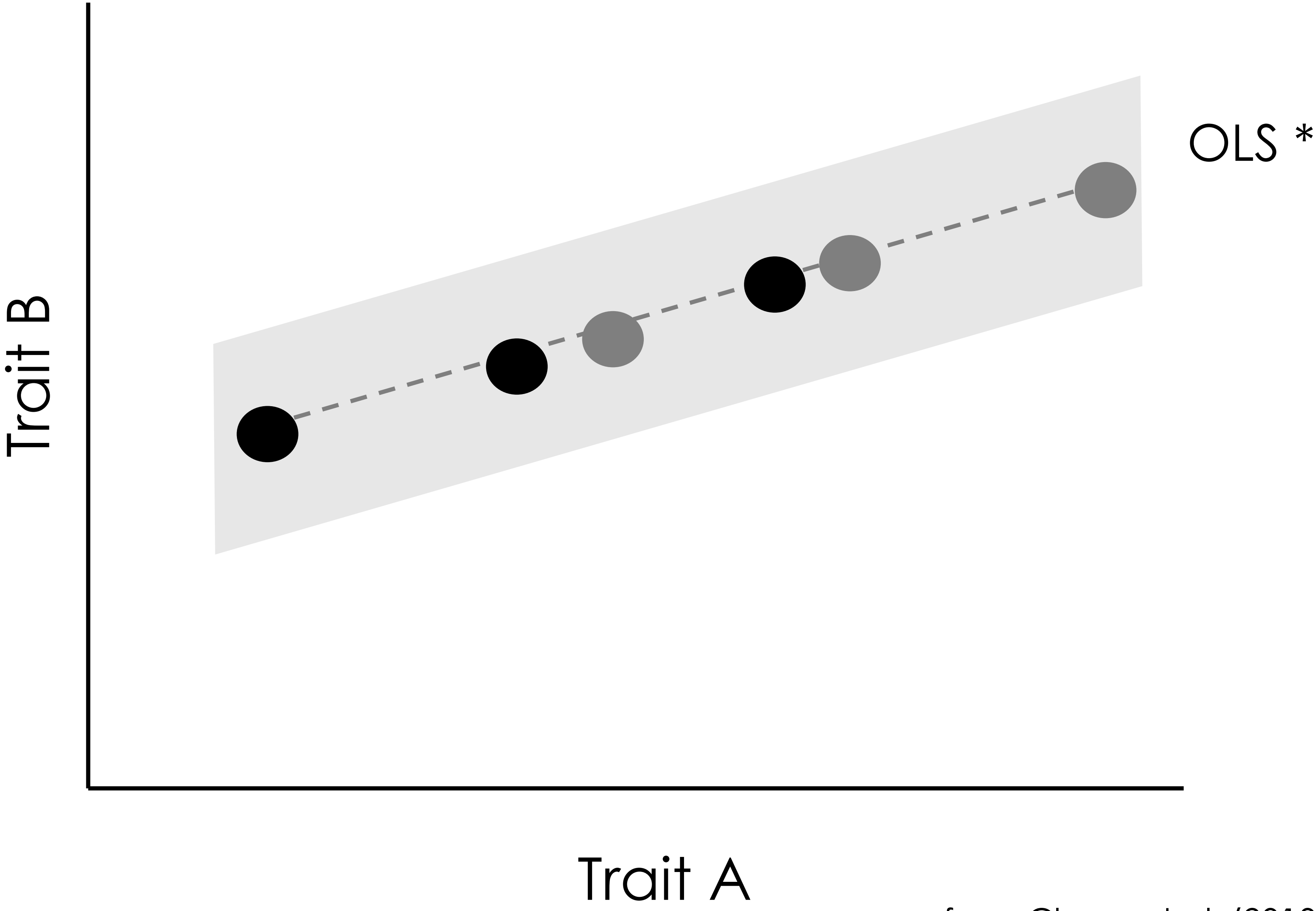


from Clauss et al. (2013)

Accounting for phylogeny



from Clauss et al. (2013)

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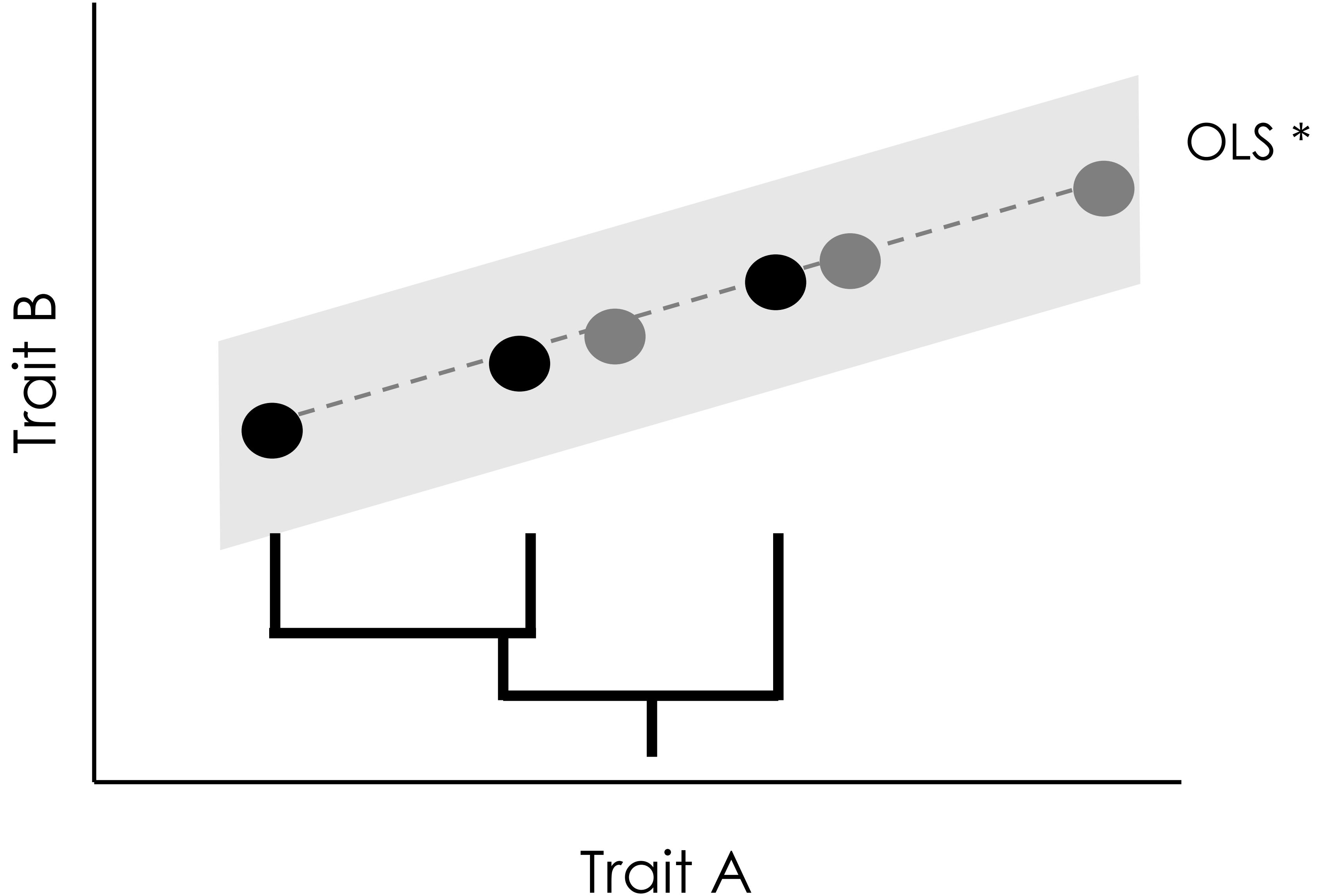

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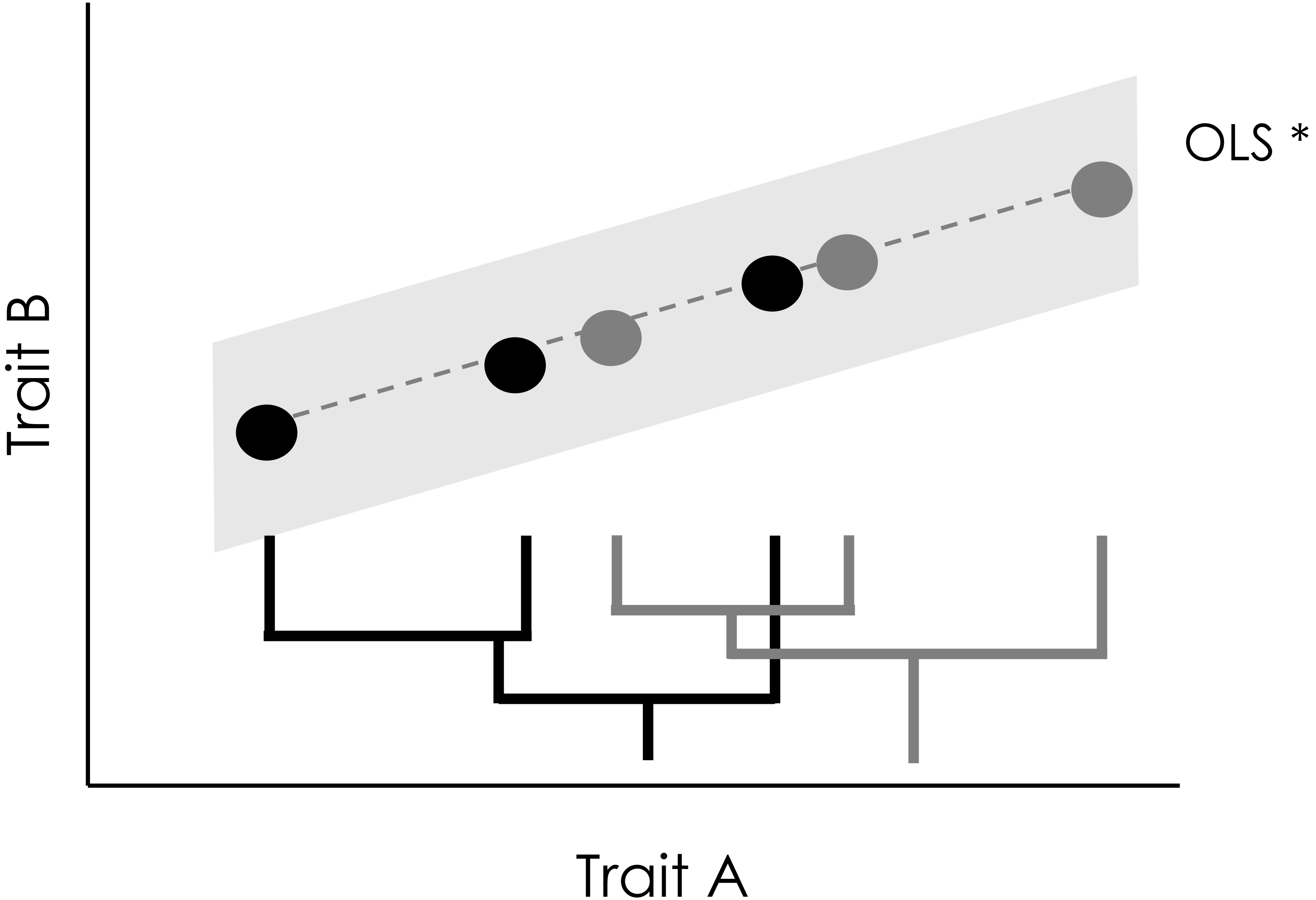
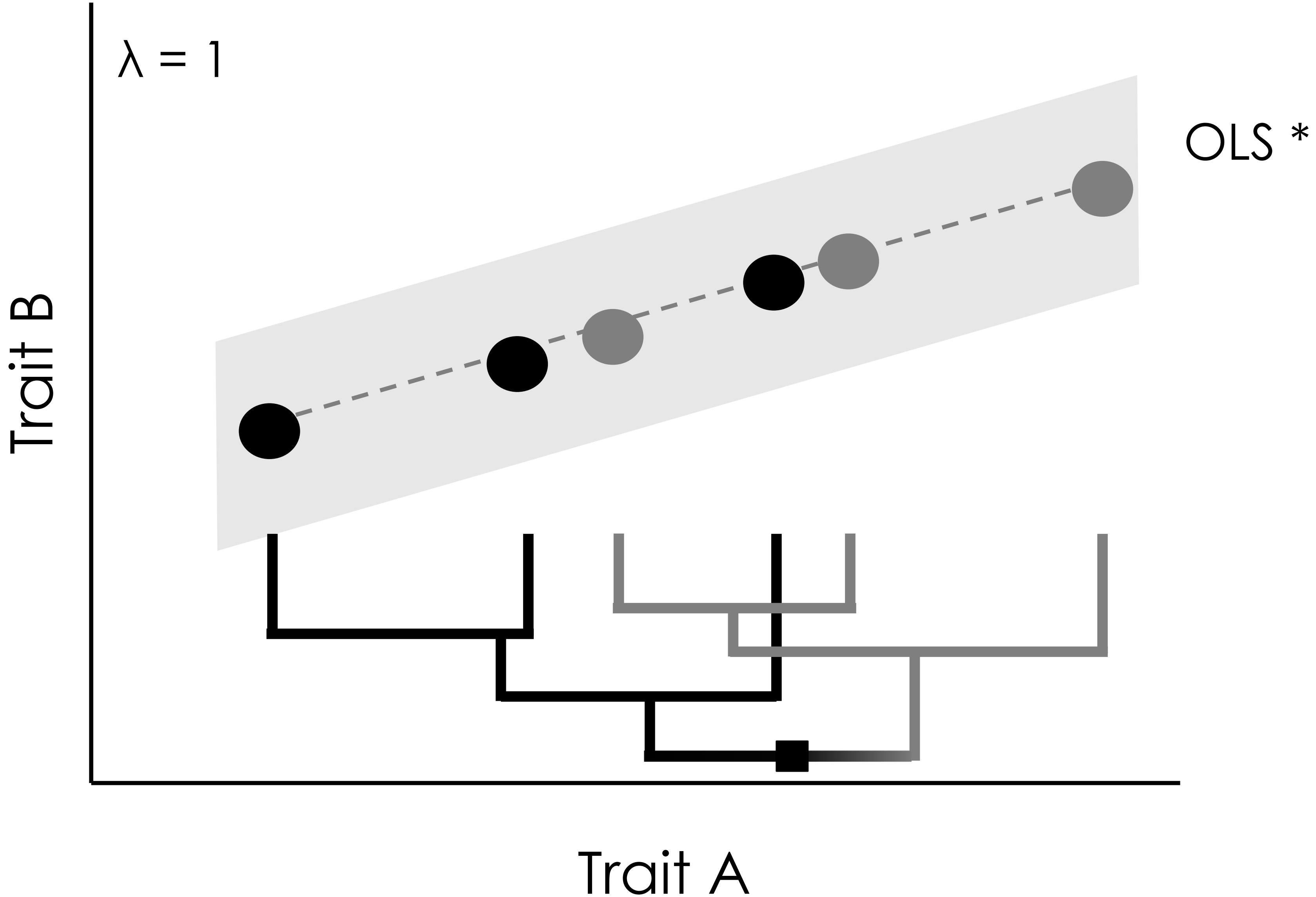


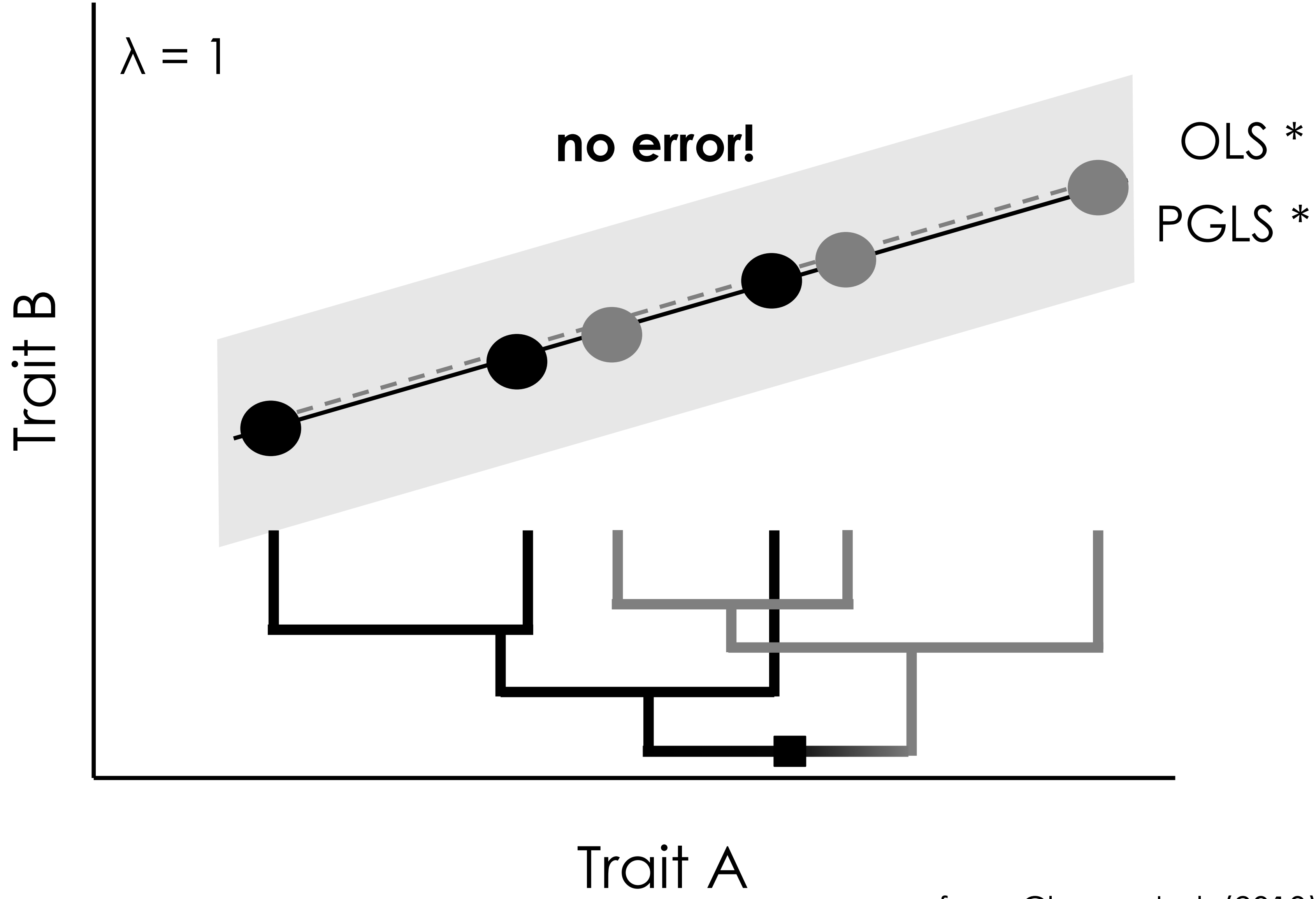
from Clauss et al. (2013)

Accounting for phylogeny



from Clauss et al. (2013)

Accounting for phylogeny



from Clauss et al. (2013)

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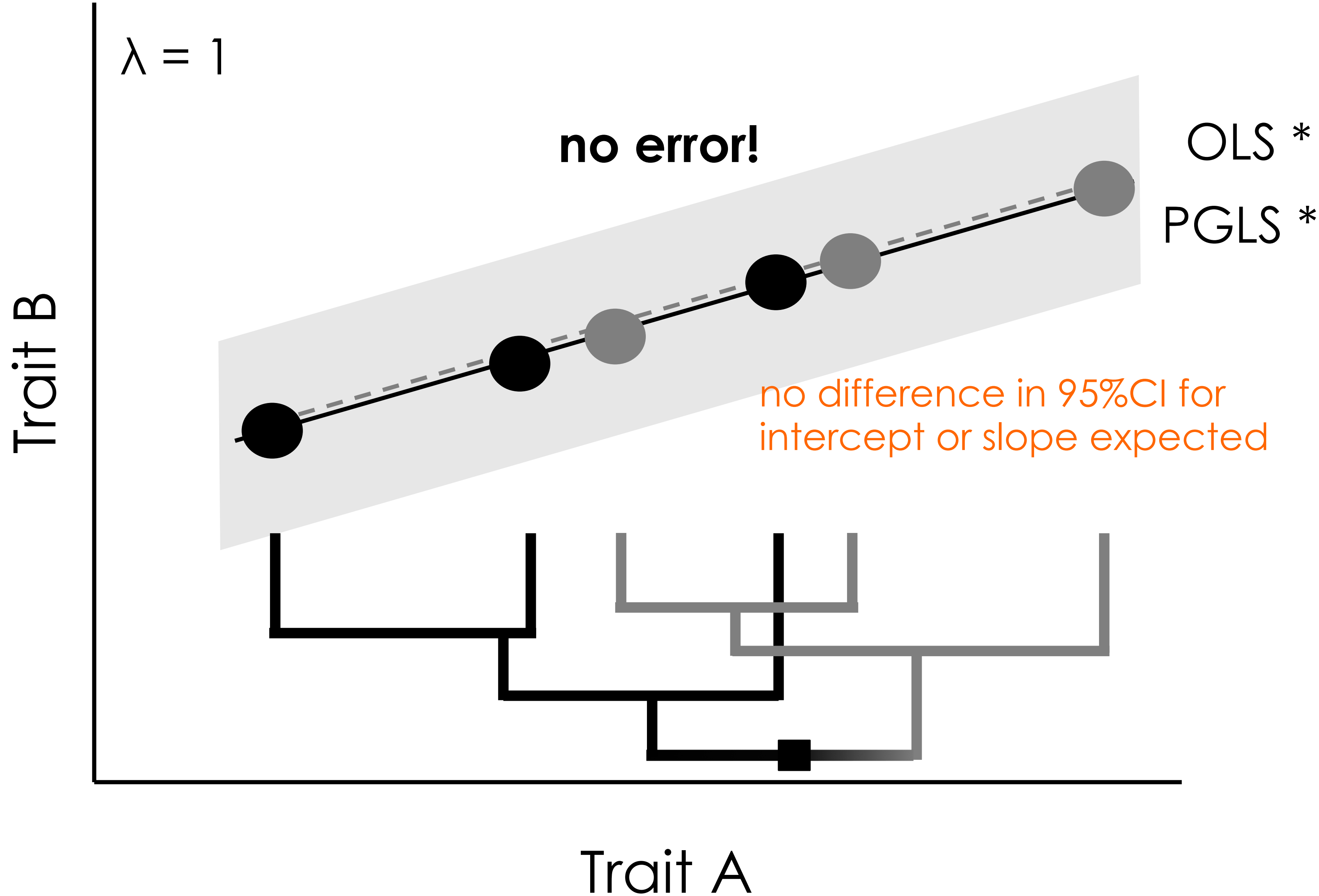
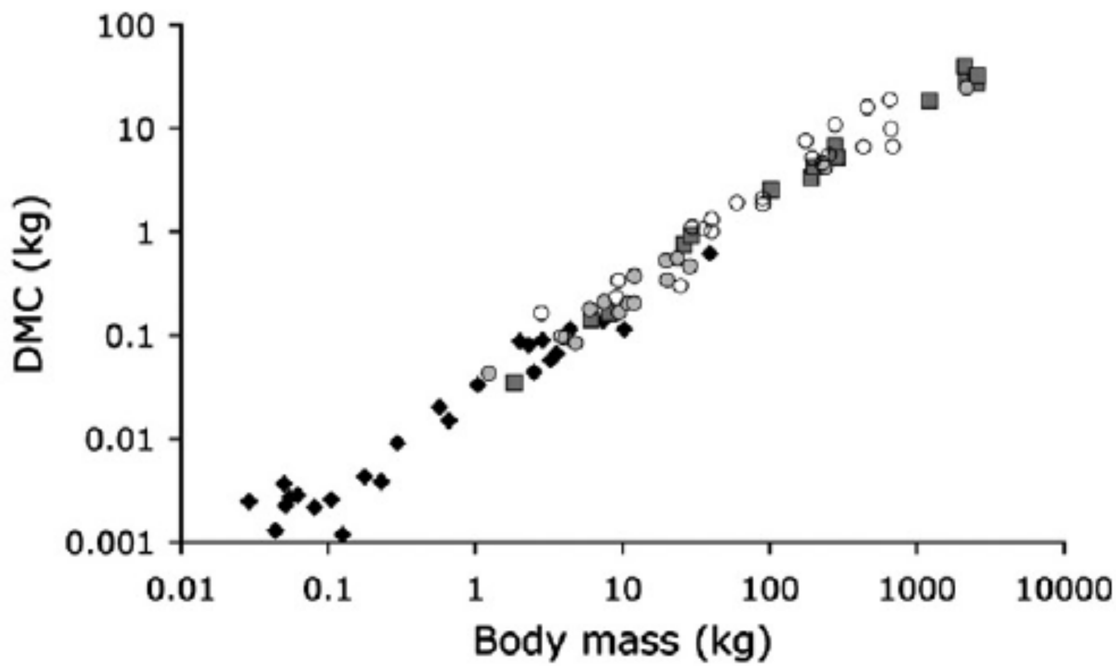


from Clauss et al. (2013)

Example I: gut contents

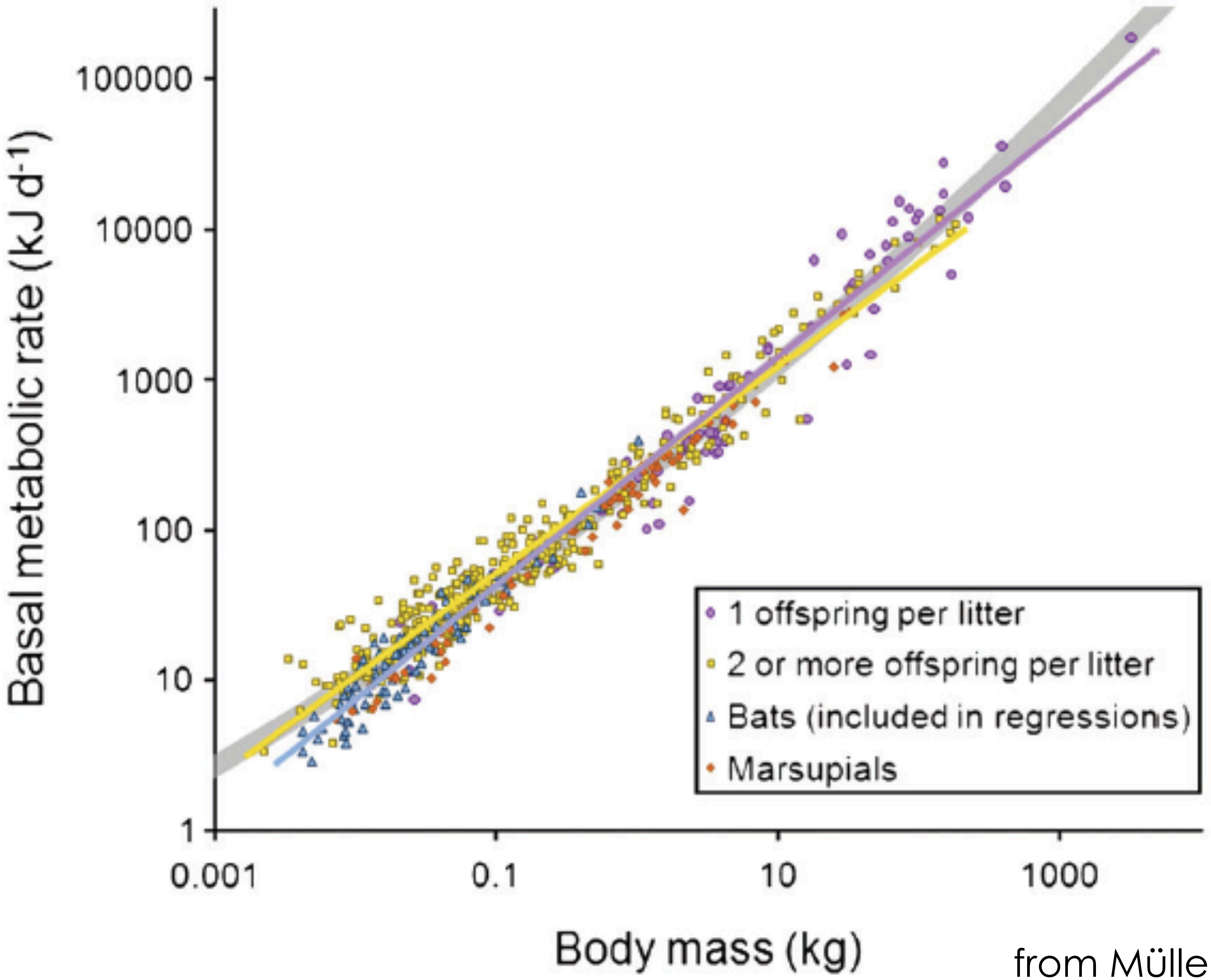
OLS: 0.03 (0.025-0.032) $BM^{0.93\ (0.90-0.96)}$

PGLS: 0.03 (0.010-0.075) $BM^{0.92\ (0.85-0.98)}$



from Müller et al. (2013)

Example II: basal metabolic rate

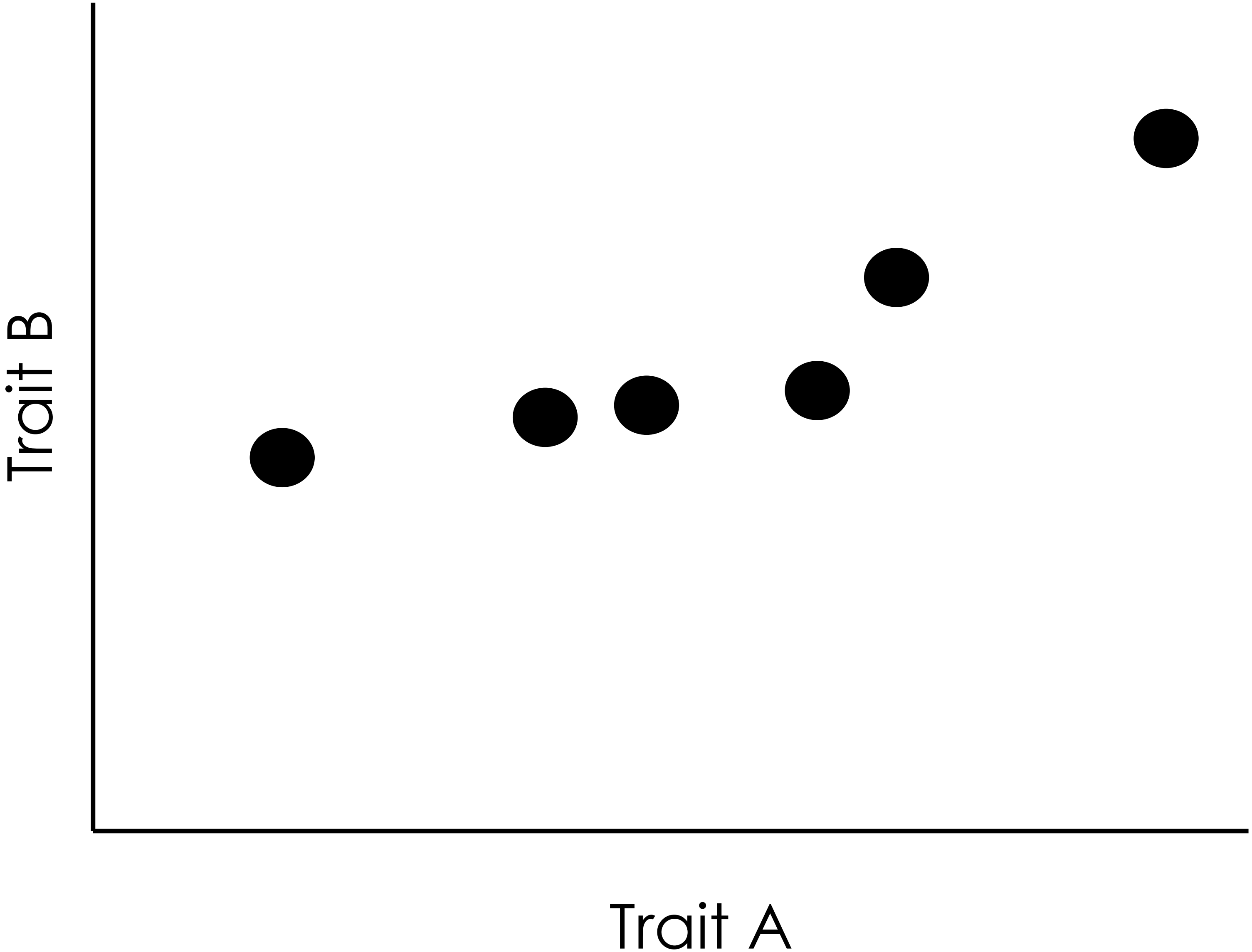


from Müller et al. (2012)

Accounting for phylogeny

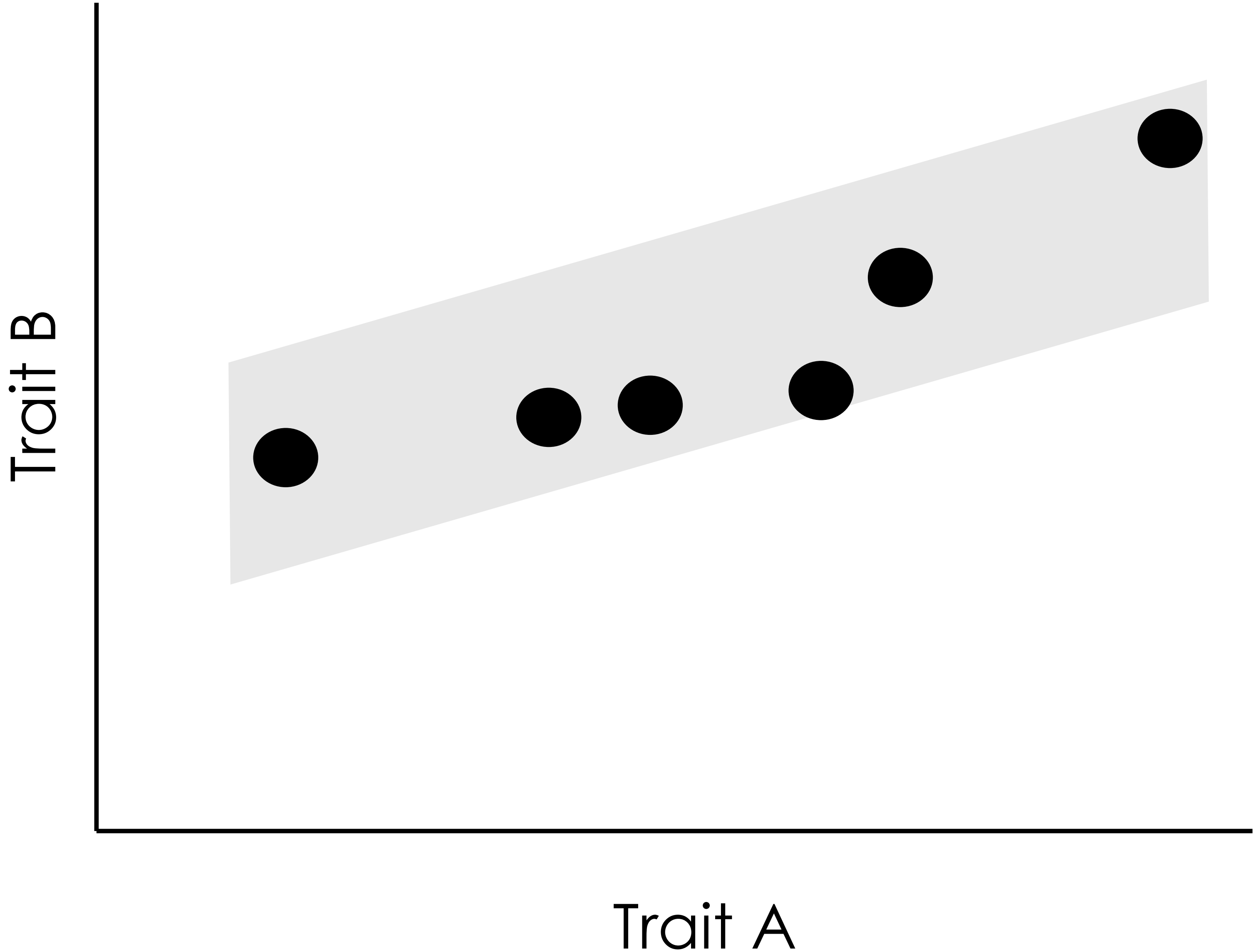
from Clauss et al. (2013)

Accounting for phylogeny



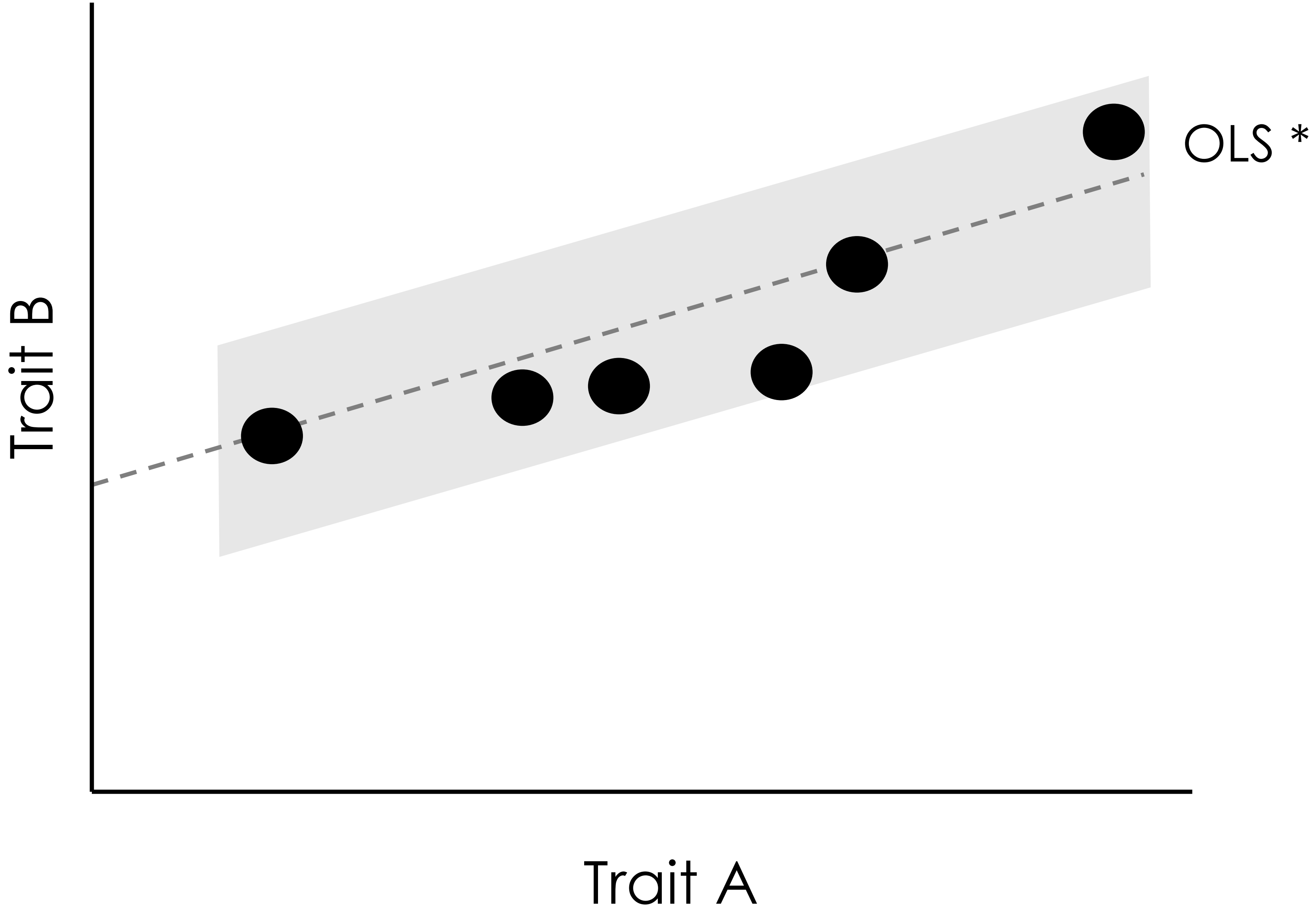
from Clauss et al. (2013)

Accounting for phylogeny



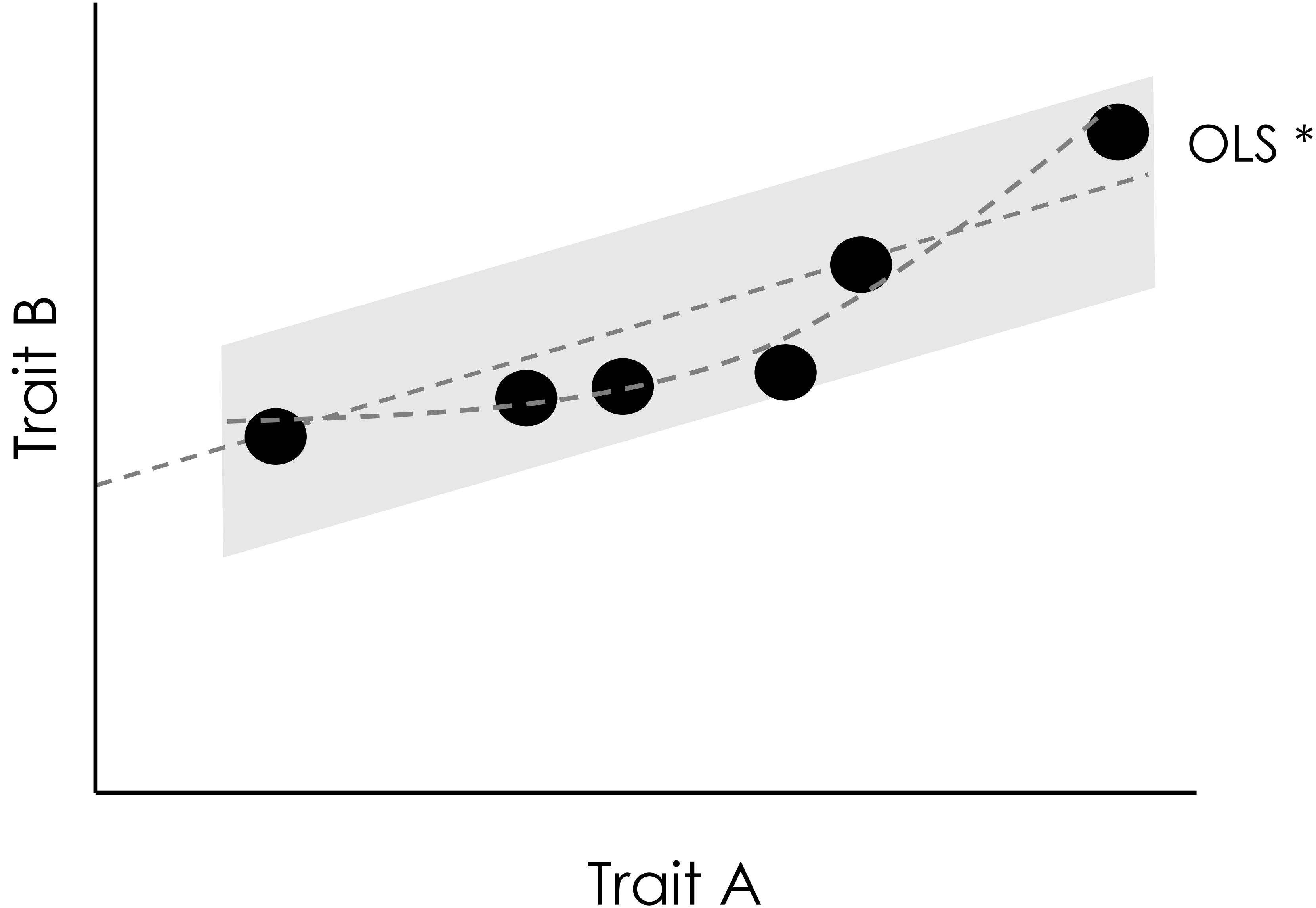
from Clauss et al. (2013)

Accounting for phylogeny



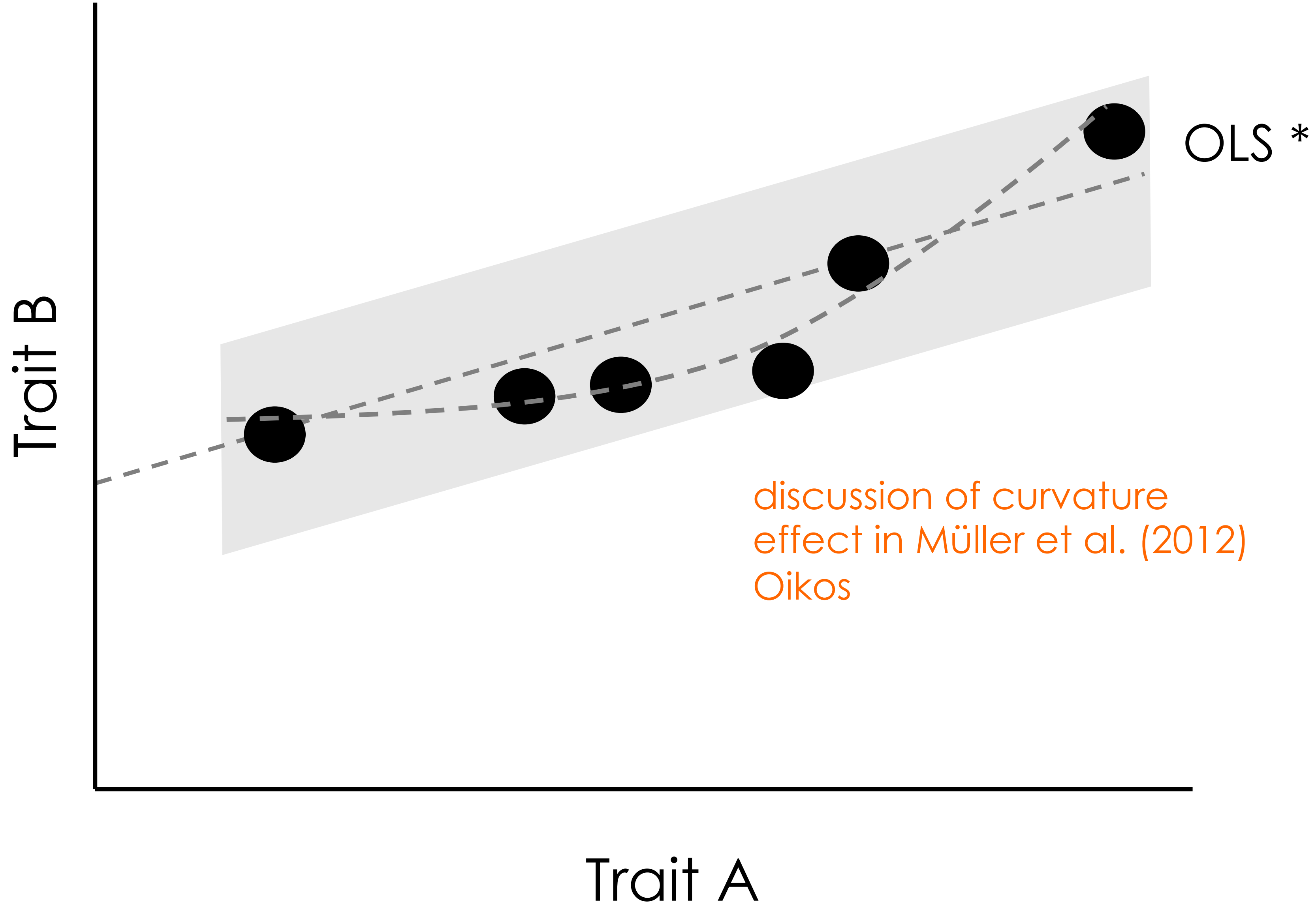
from Clauss et al. (2013)

Accounting for phylogeny



from Clauss et al. (2013)

Accounting for phylogeny



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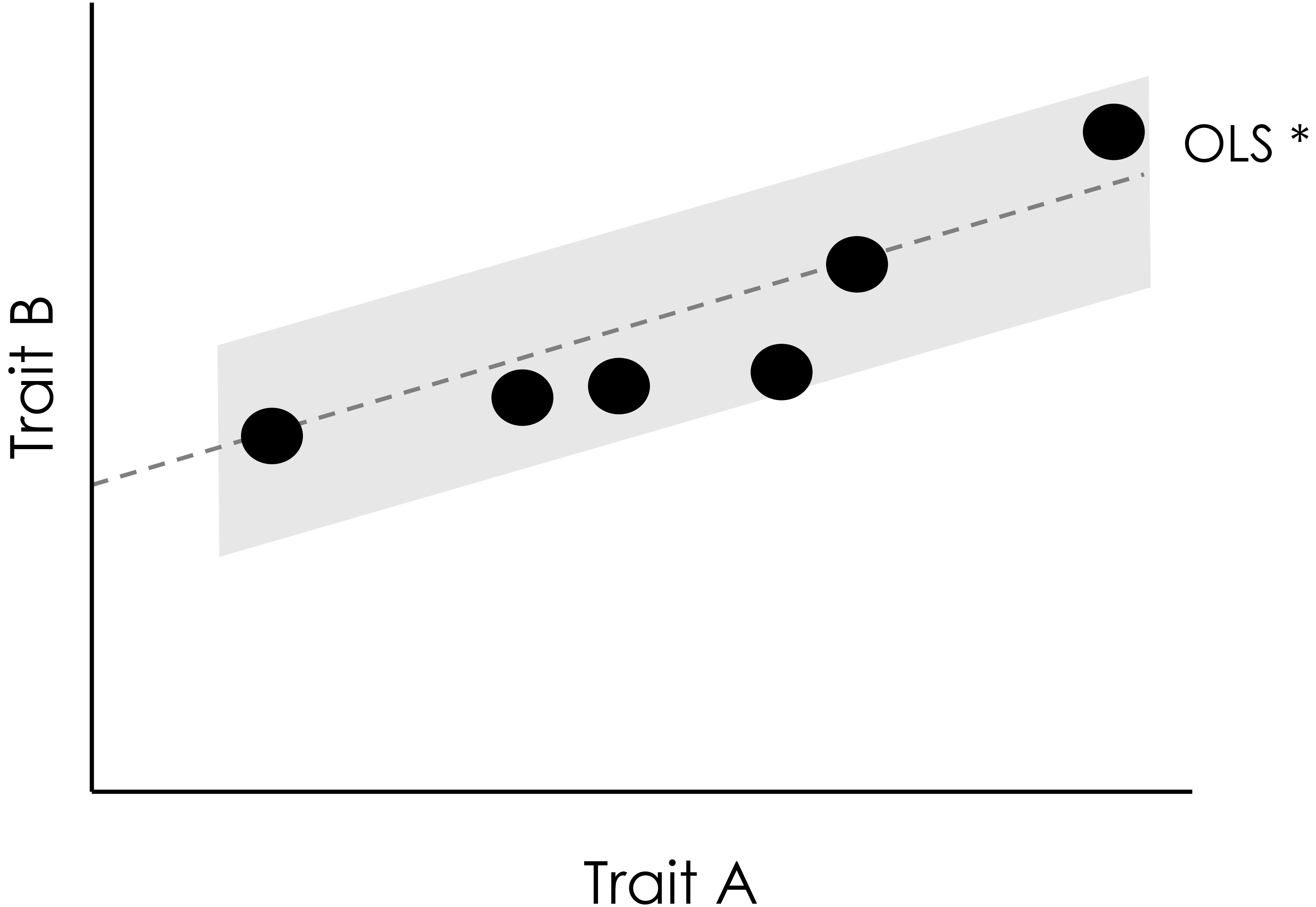

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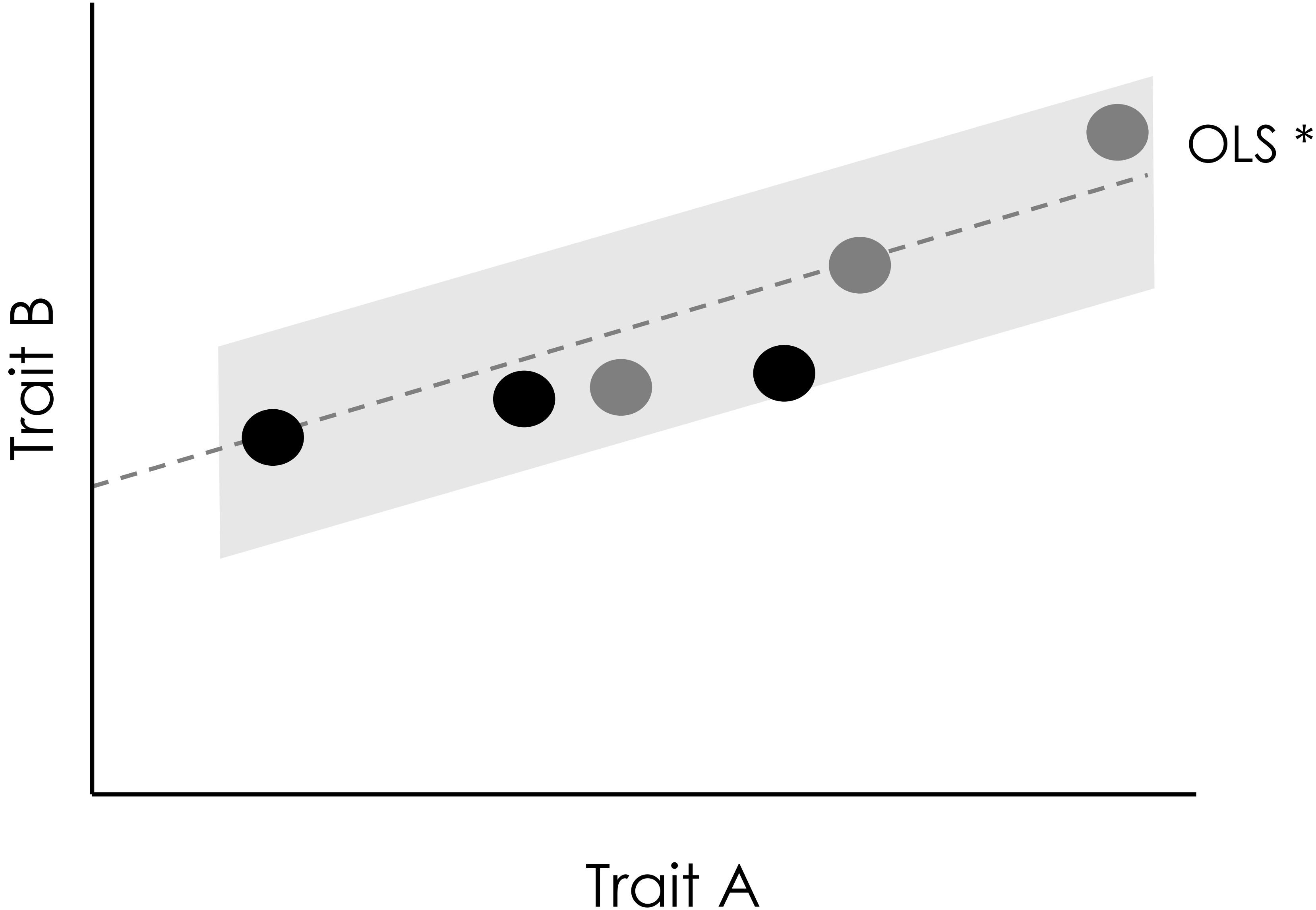
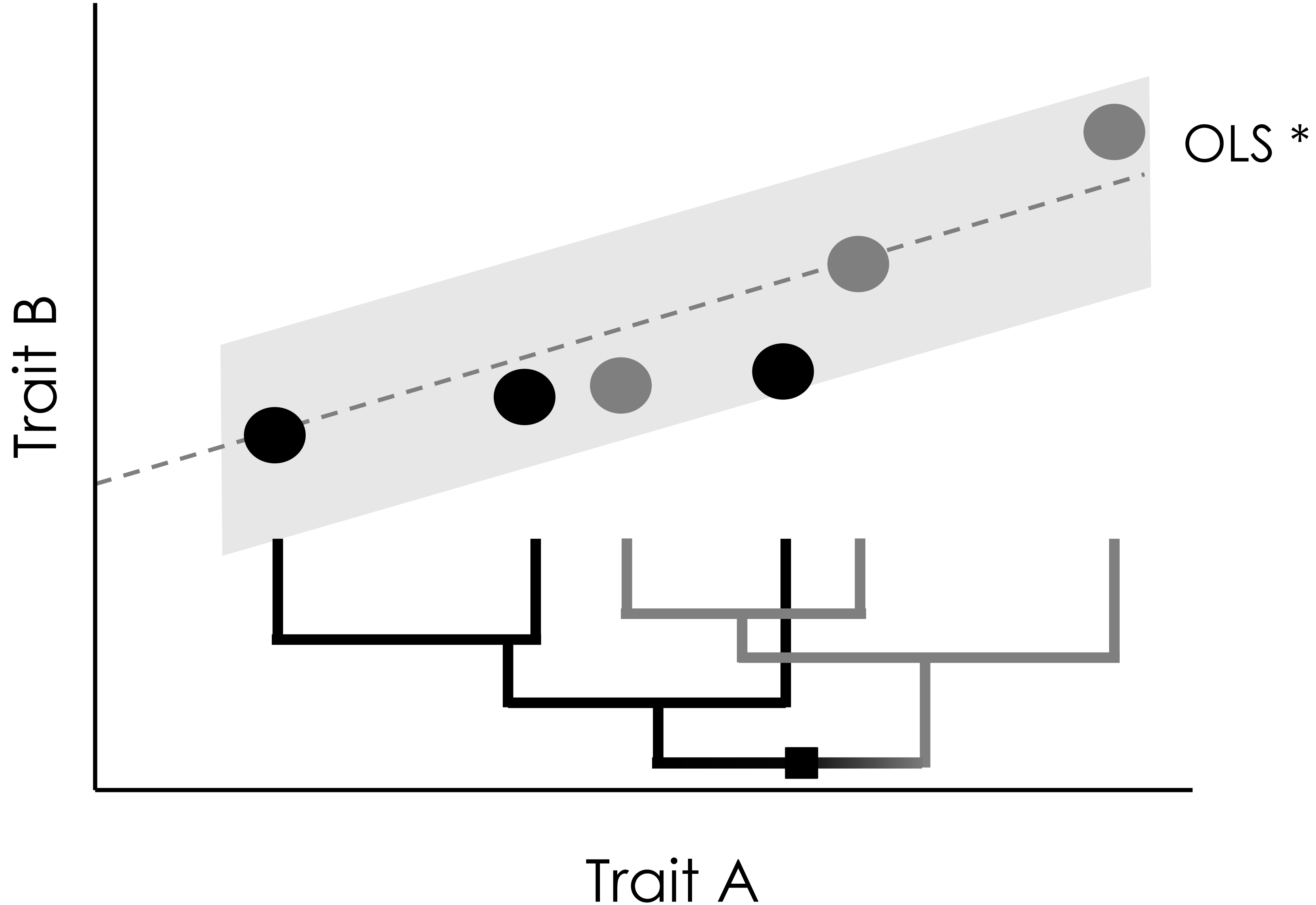
Accounting for phylogeny



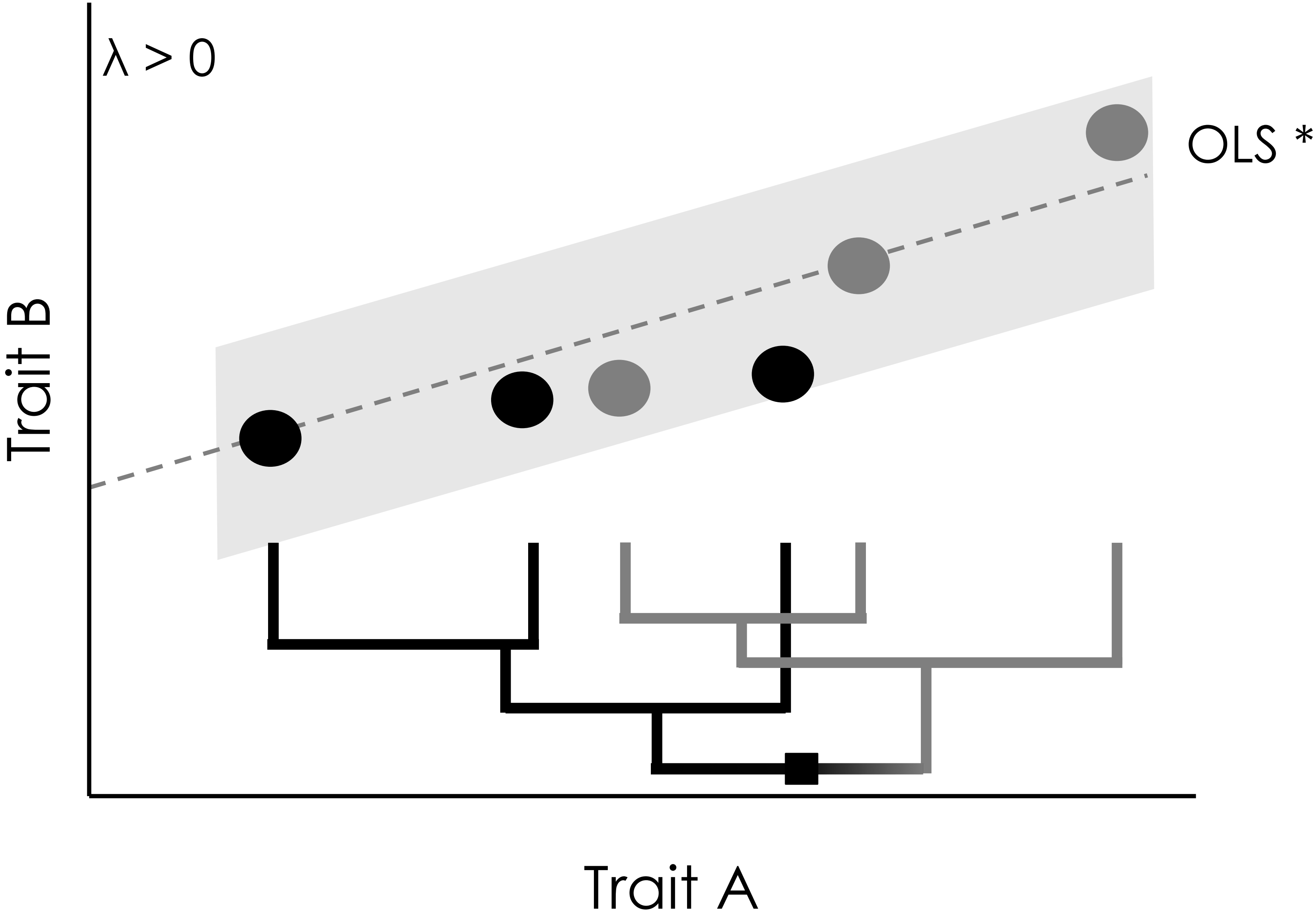
from Clauss et al. (2013)

Accounting for phylogeny



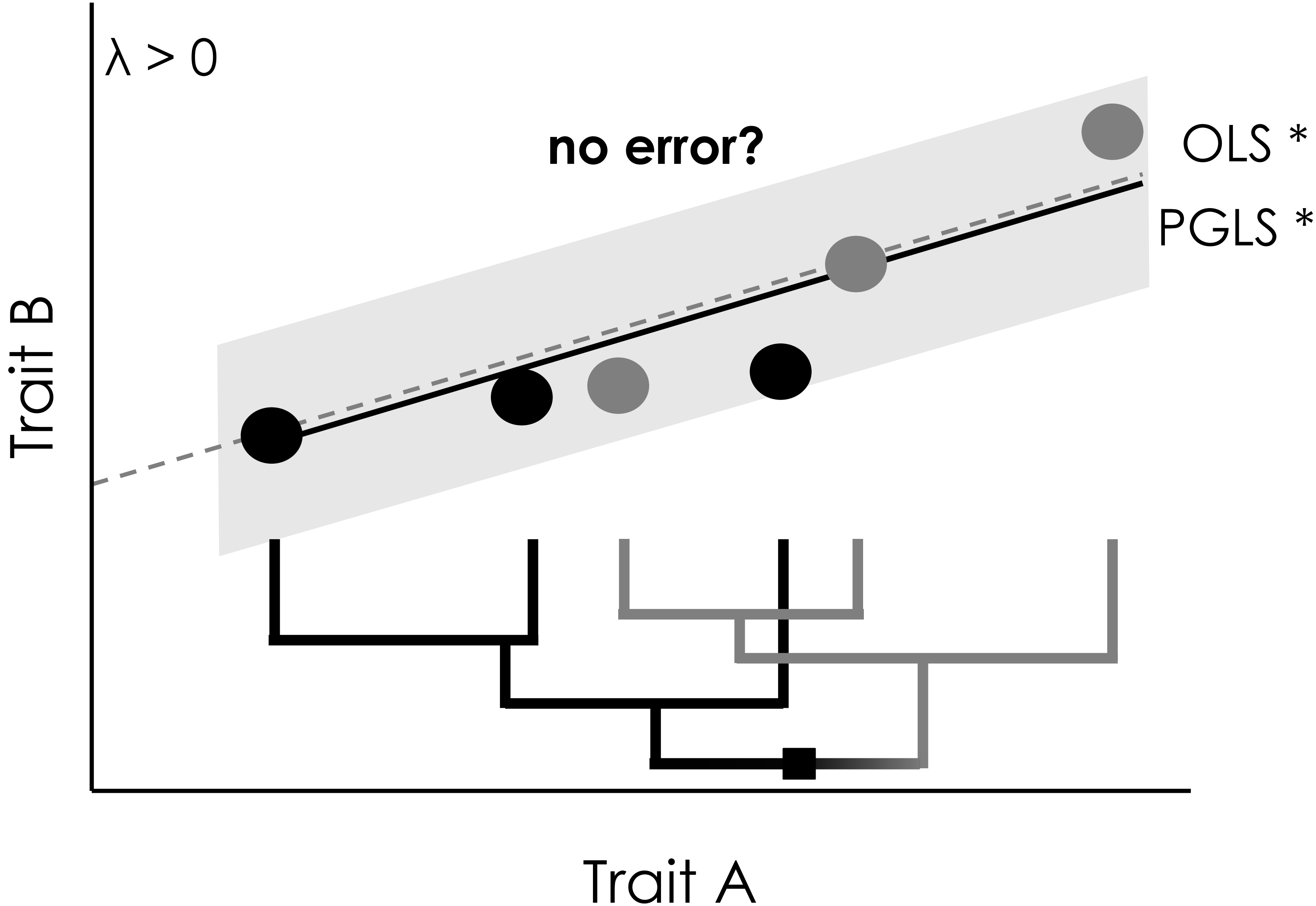
from Clauss et al. (2013)

Accounting for phylogeny



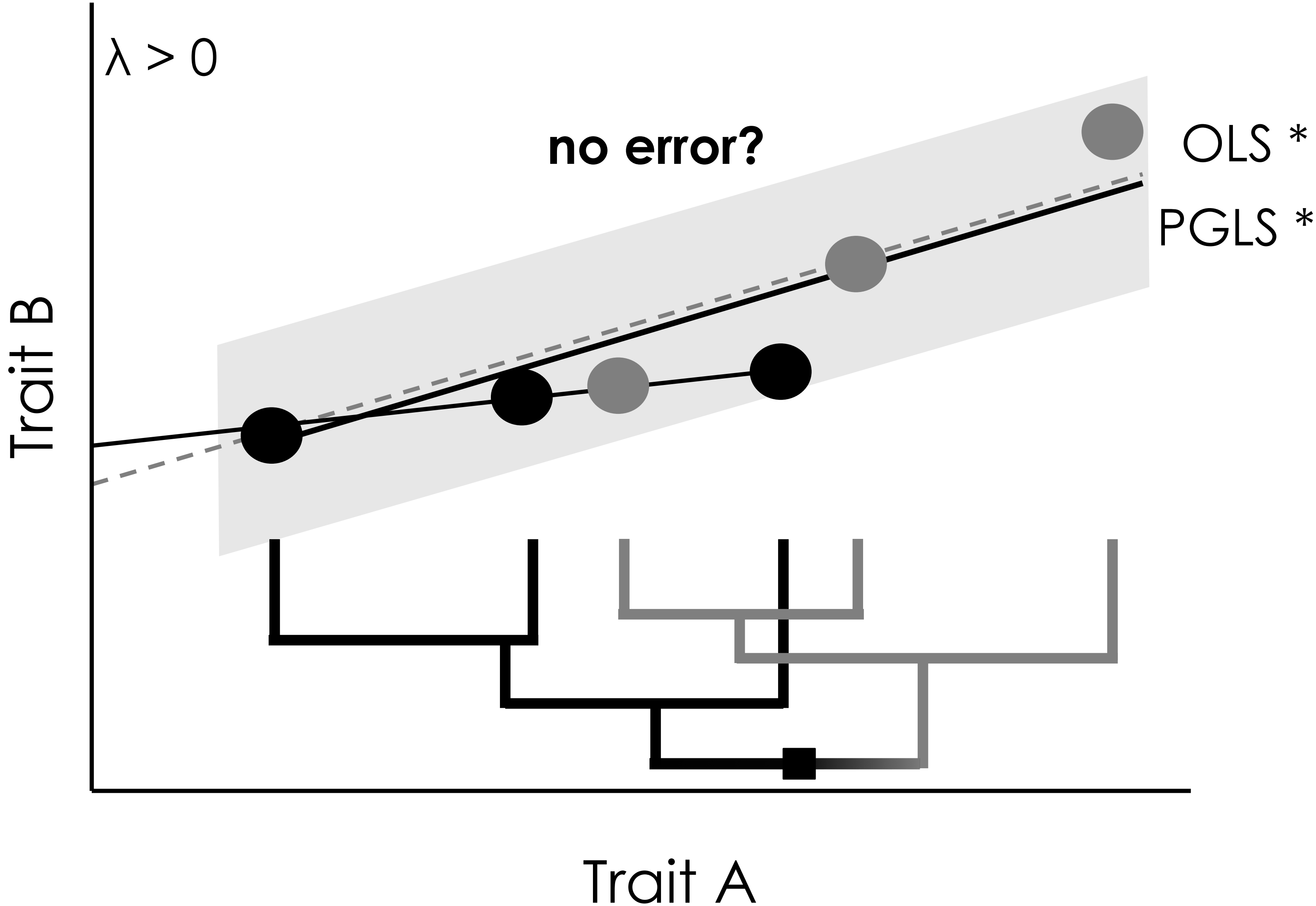
from Clauss et al. (2013)

Accounting for phylogeny



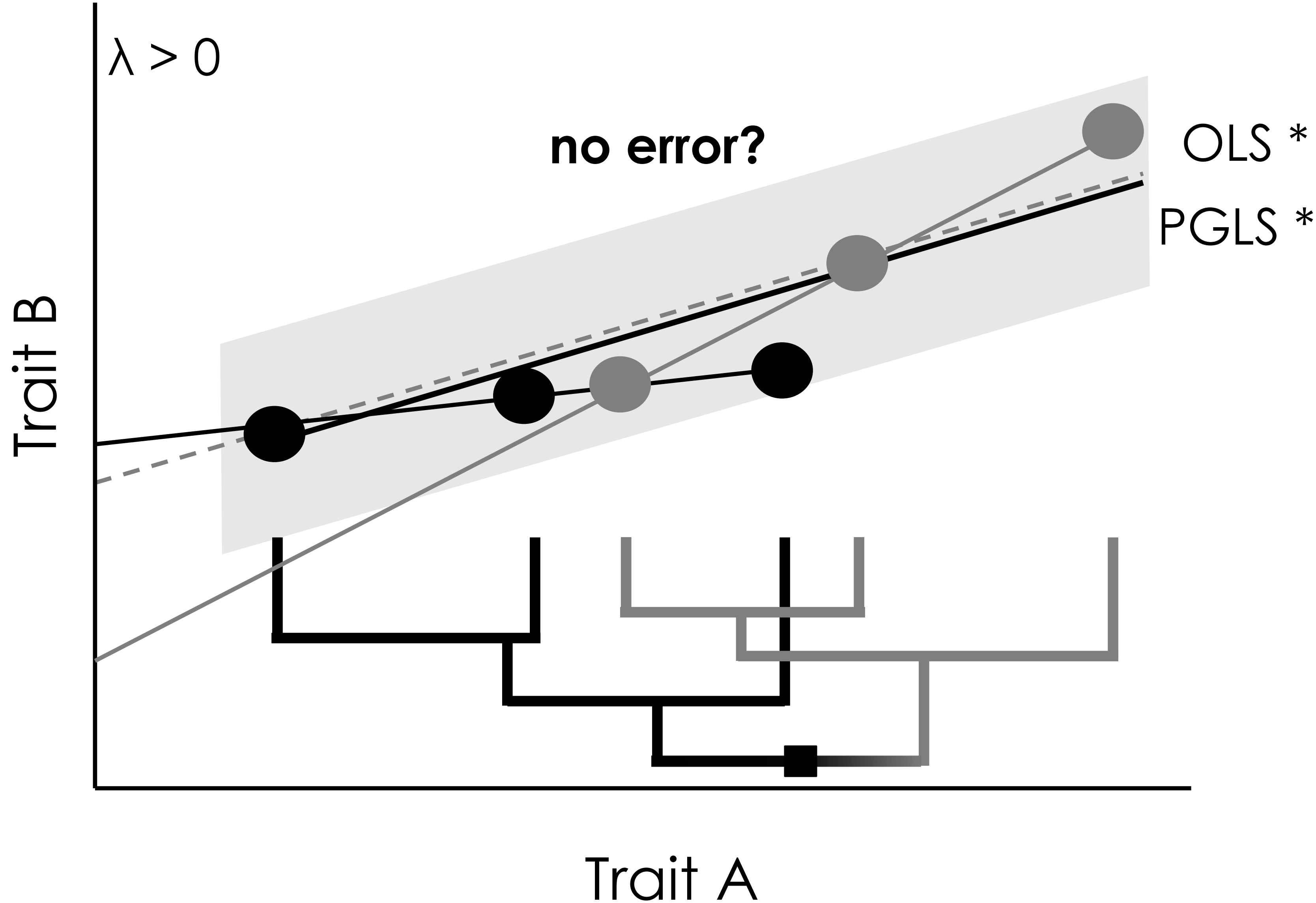
from Clauss et al. (2013)

Accounting for phylogeny



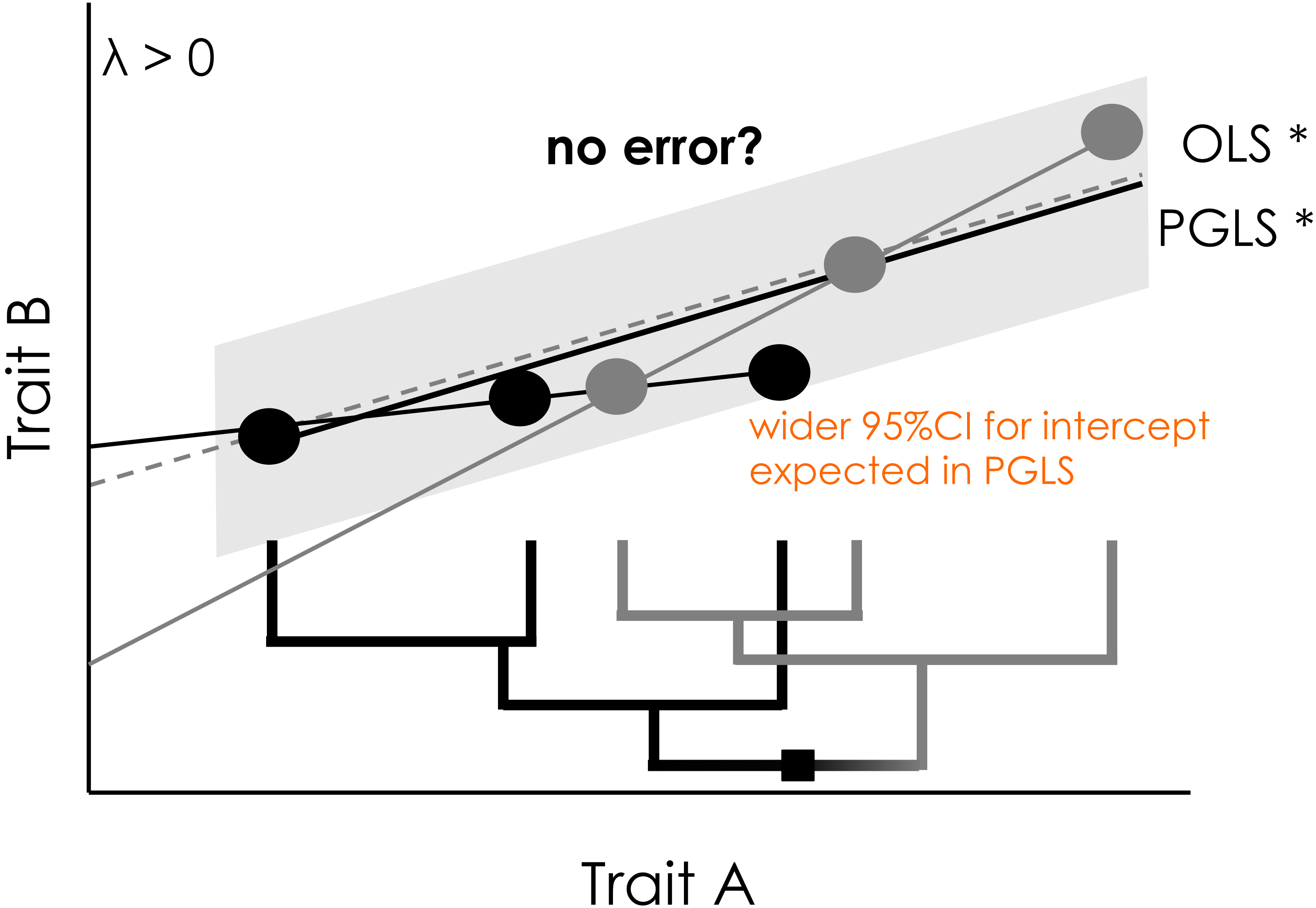
from Clauss et al. (2013)

Accounting for phylogeny



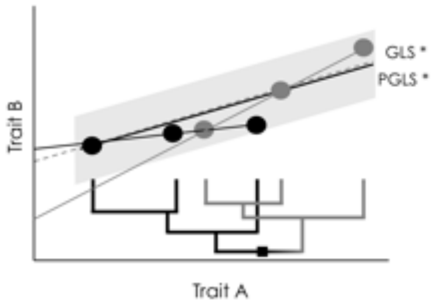
from Clauss et al. (2013)

Accounting for phylogeny



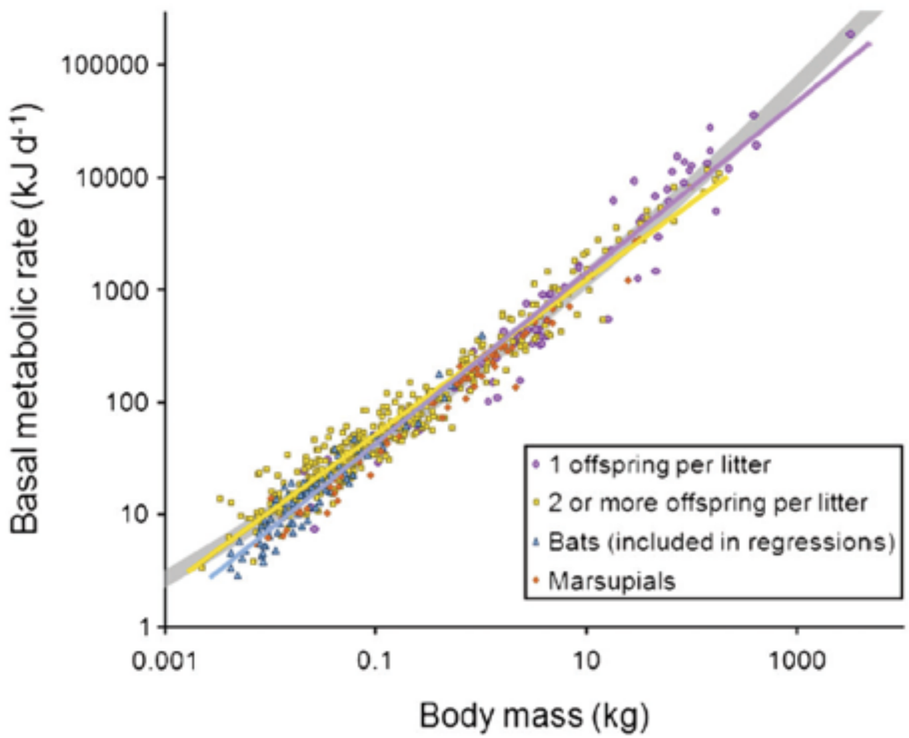
from Clauss et al. (2013)

Example II: basal metabolic rate



OLS: 2.38 (2.37-2.40) $BM^{0.72\ (0.71-0.73)}$

PGLS: 2.25 (2.05-2.44) $BM^{0.73\ (0.71-0.75)}$



from Müller et al. (2012)

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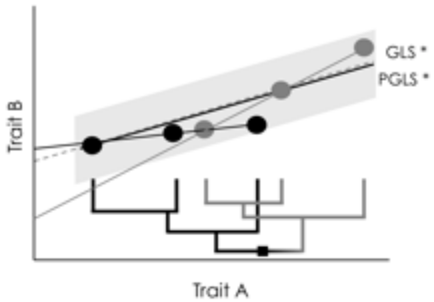

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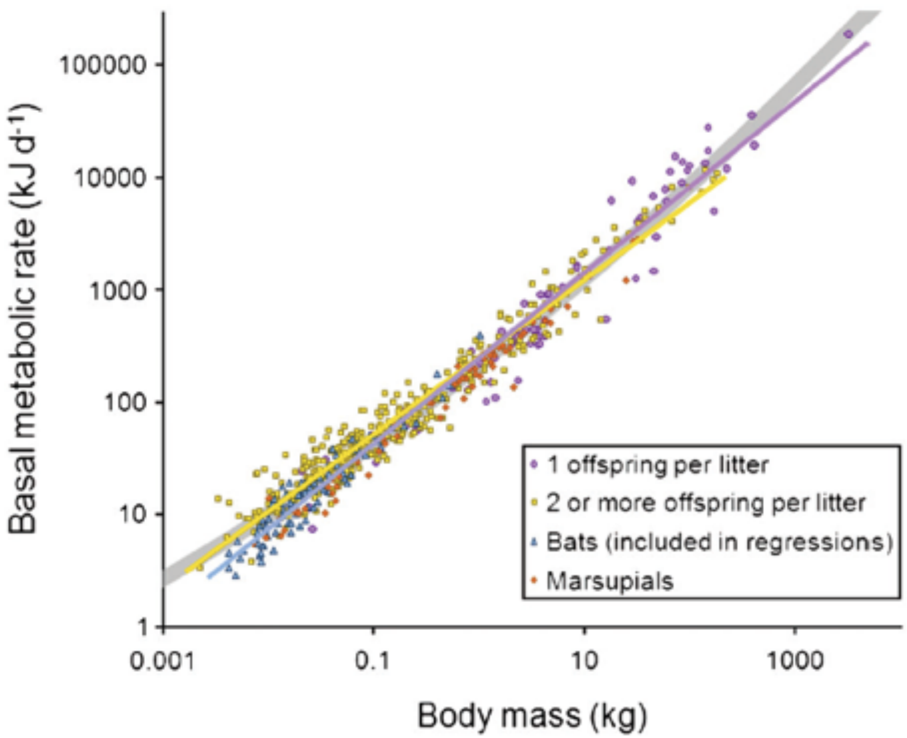
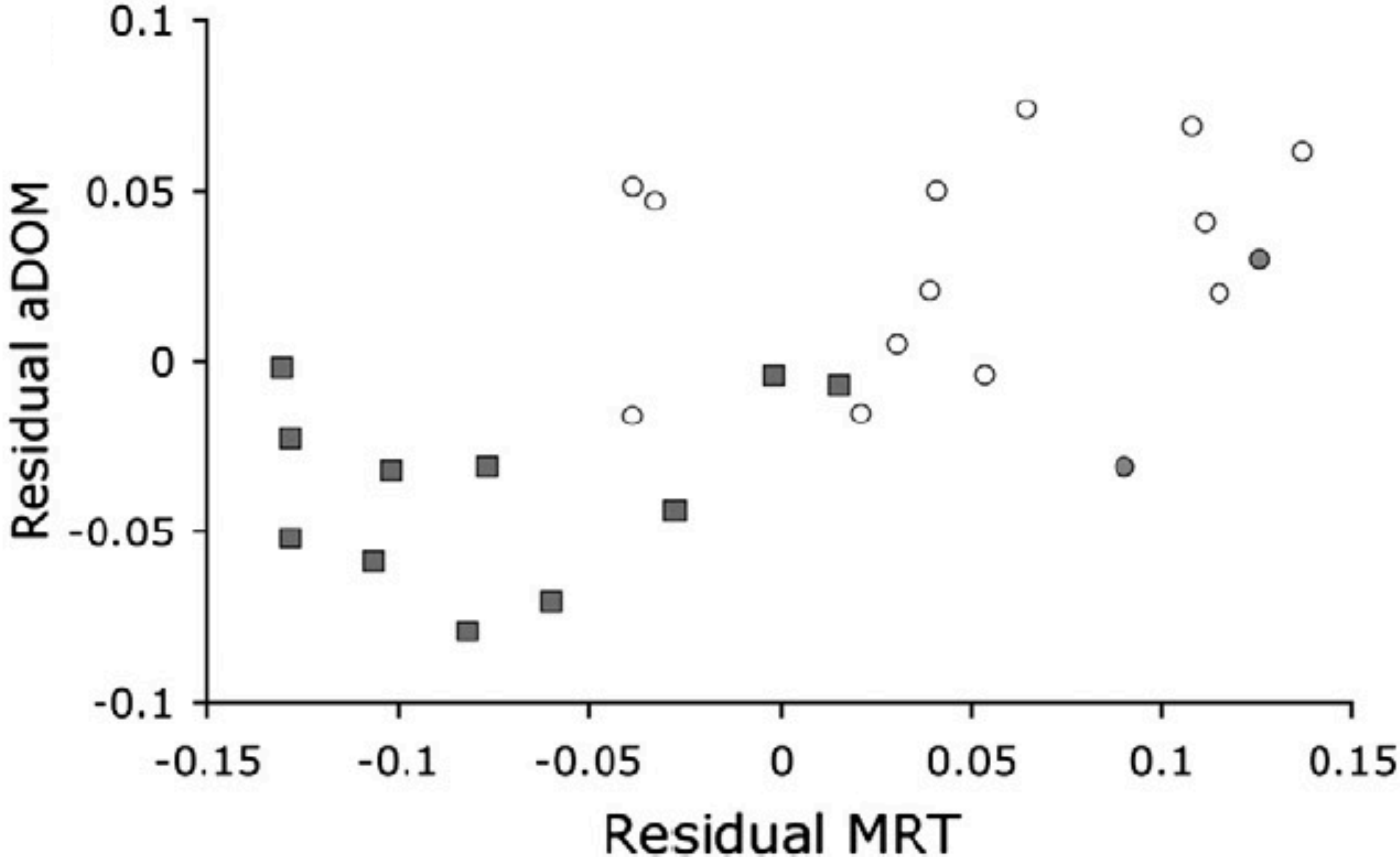
PGLS: 2.25 (2.05-2.44) $BM^{0.73\ (0.71\text{-}0.75)}$



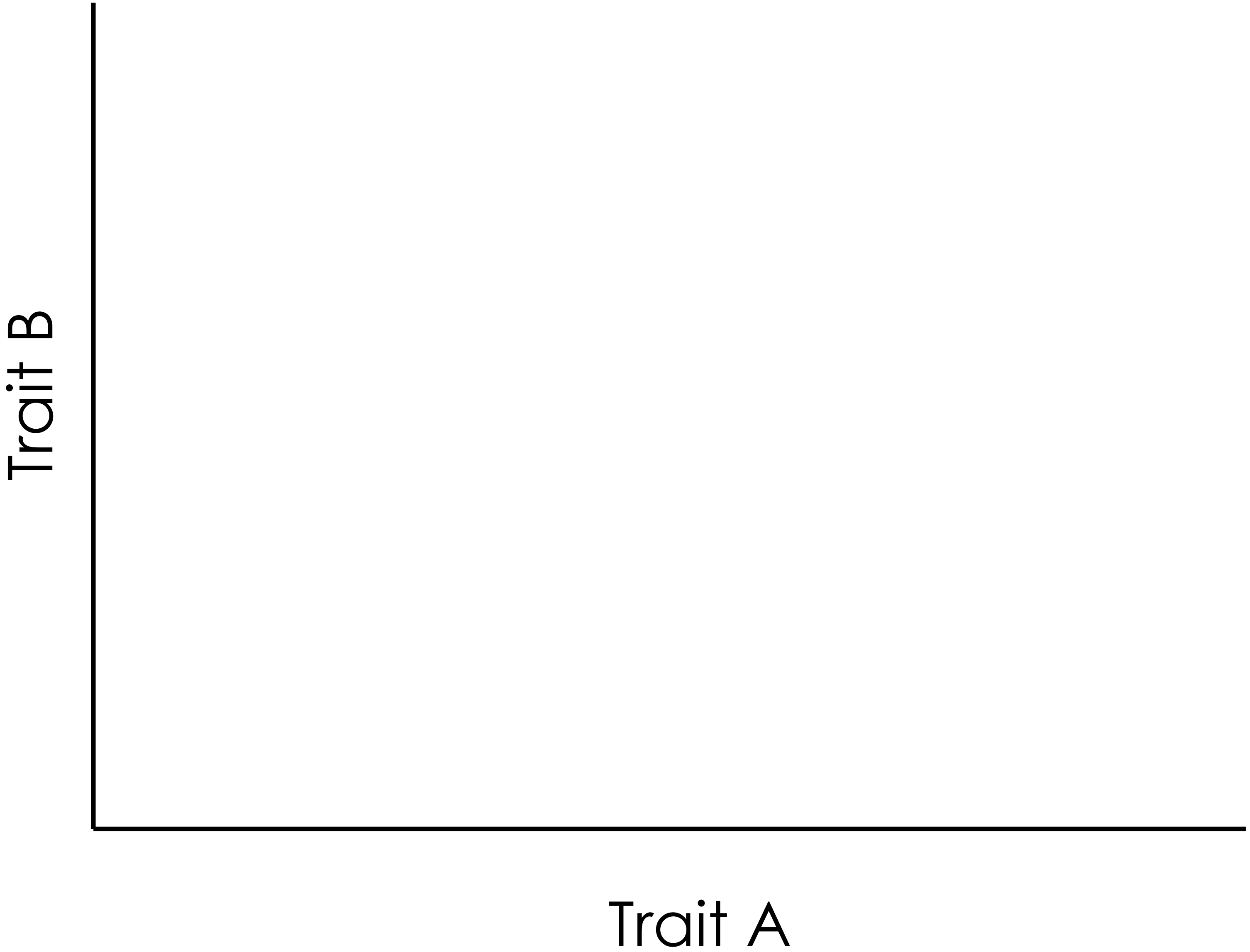
from Müller et al. (2012)

Example III: retention/digestibility



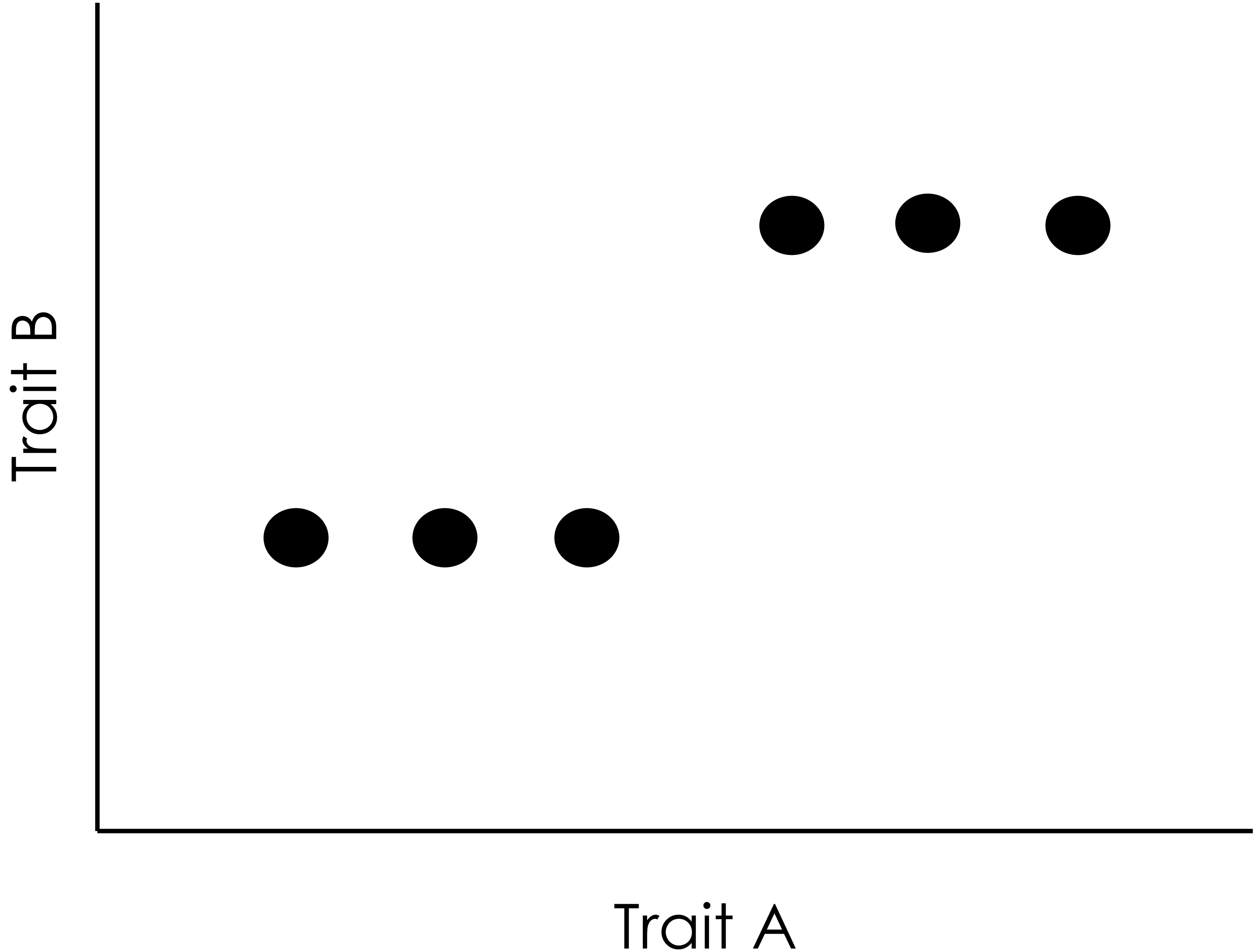
from Müller et al. (2013)

Accounting for phylogeny



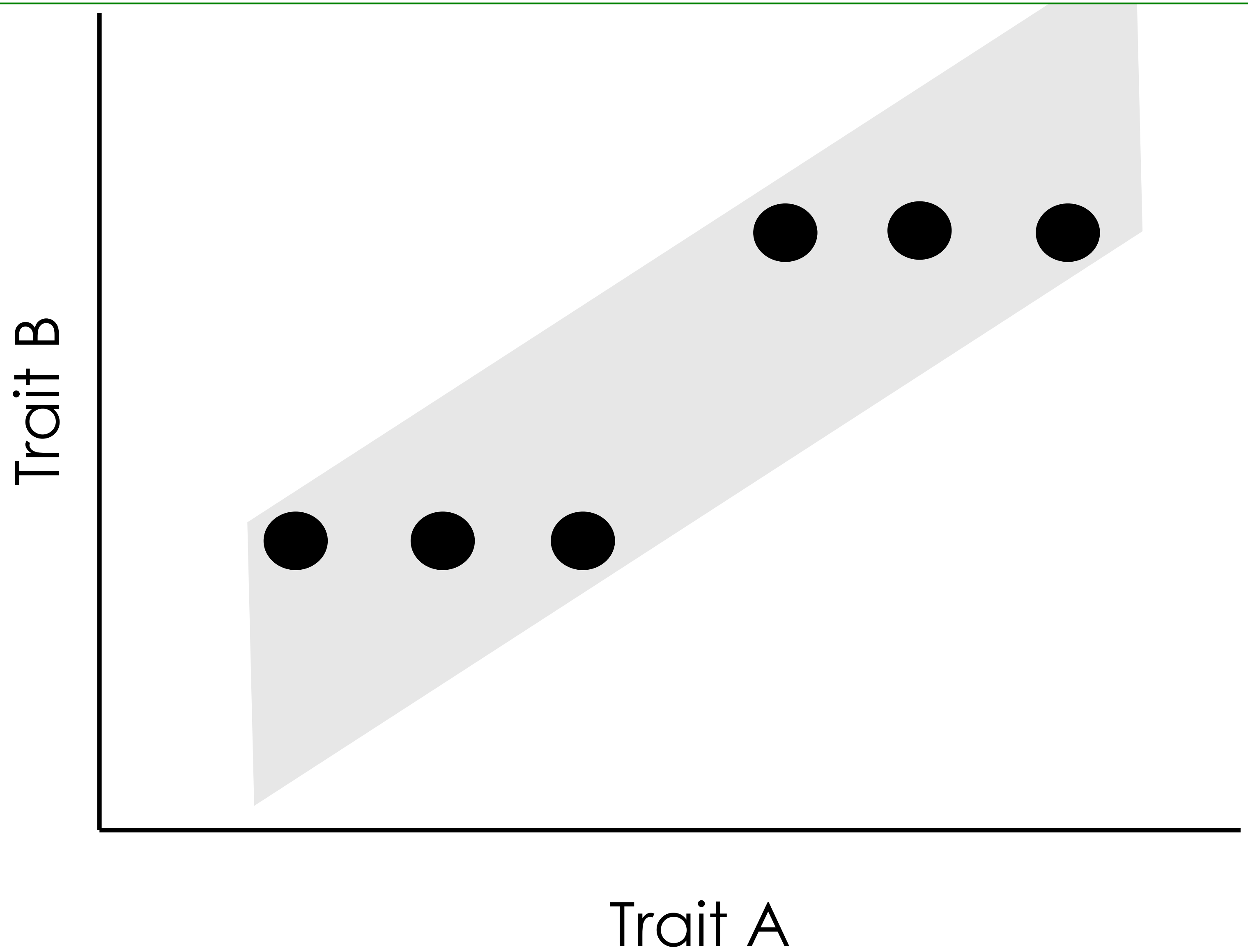
from Clauss et al. (2013)

Accounting for phylogeny



from Clauss et al. (2013)

Accounting for phylogeny



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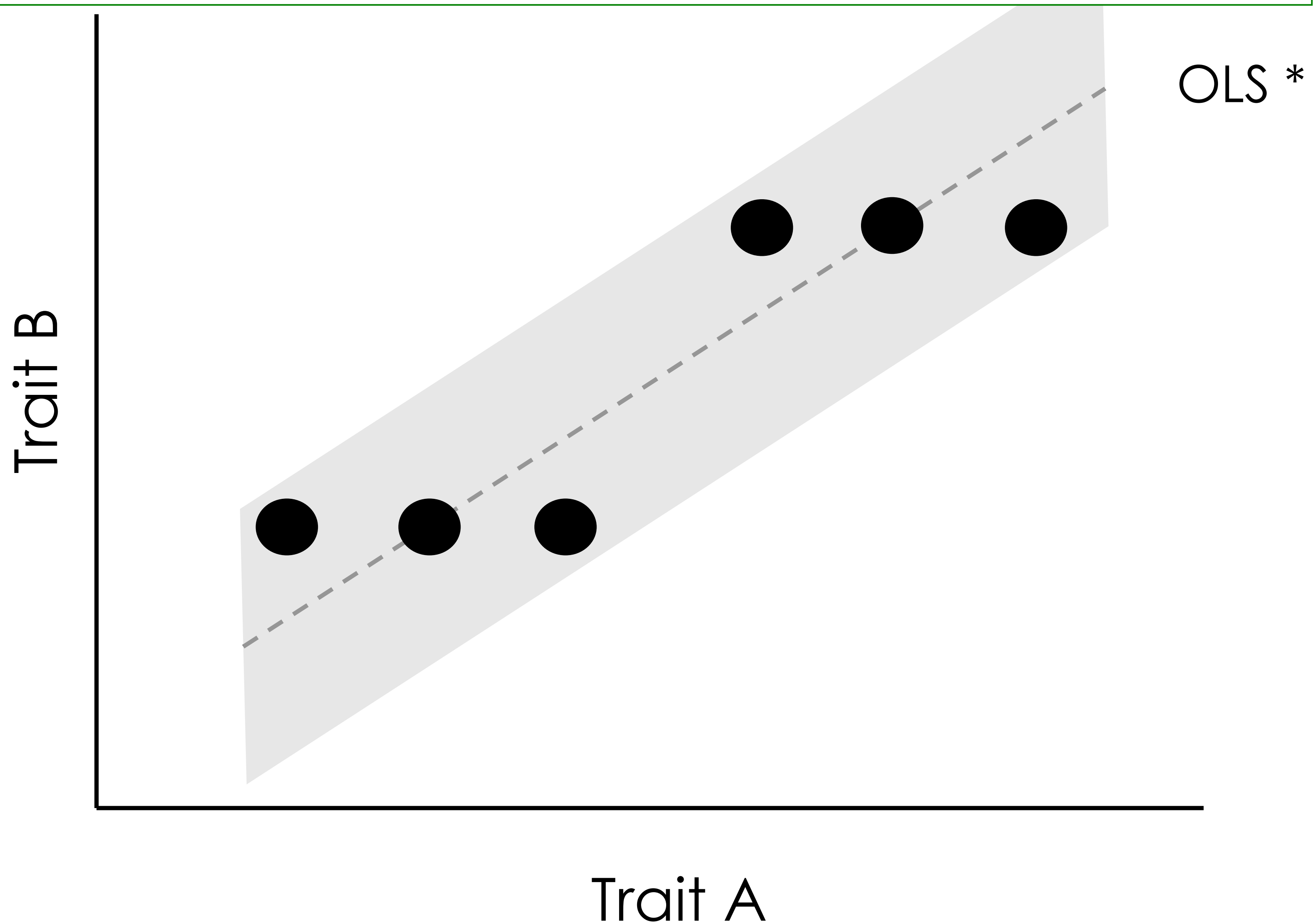
Accounting for phylogeny



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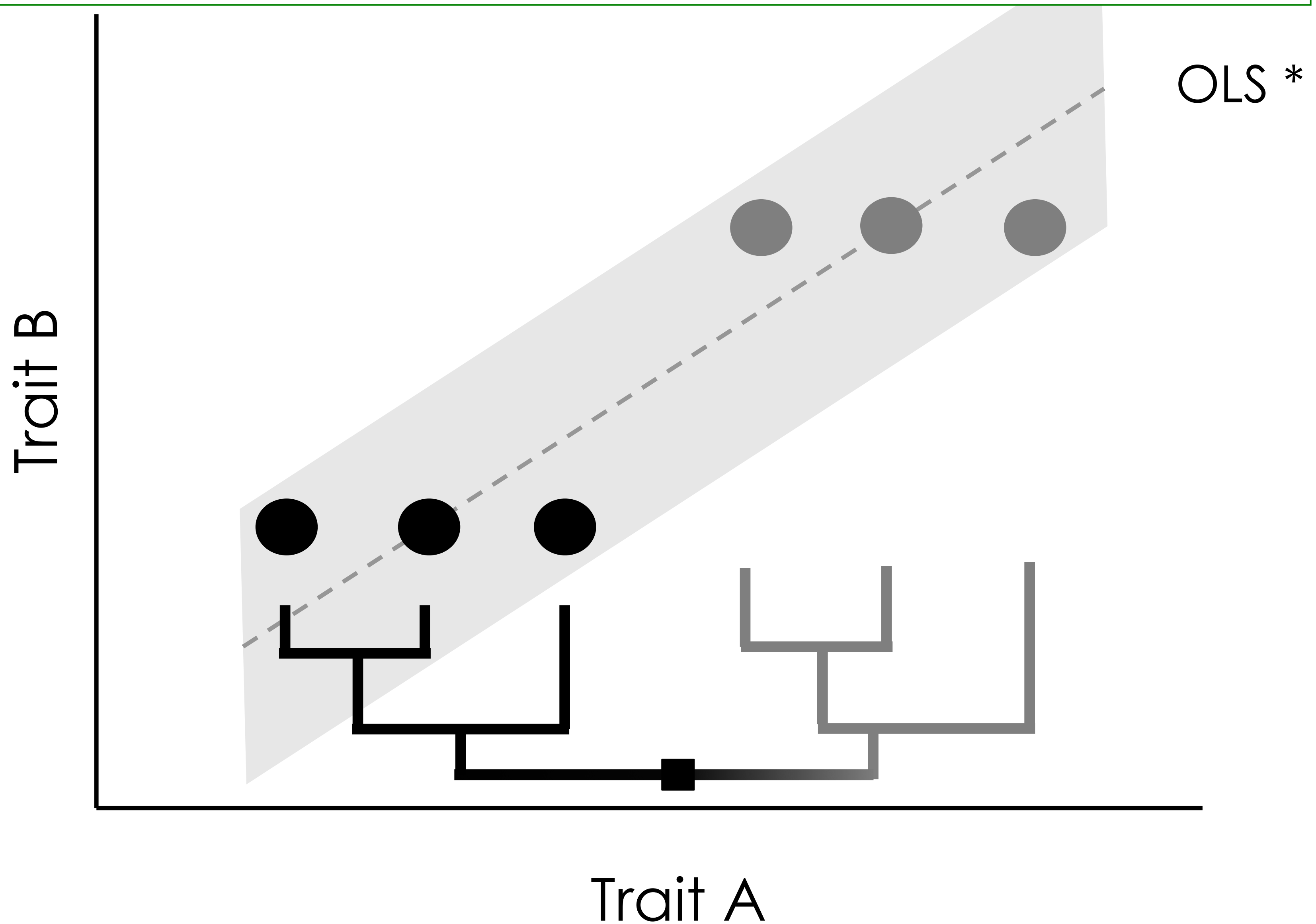
Accounting for phylogeny



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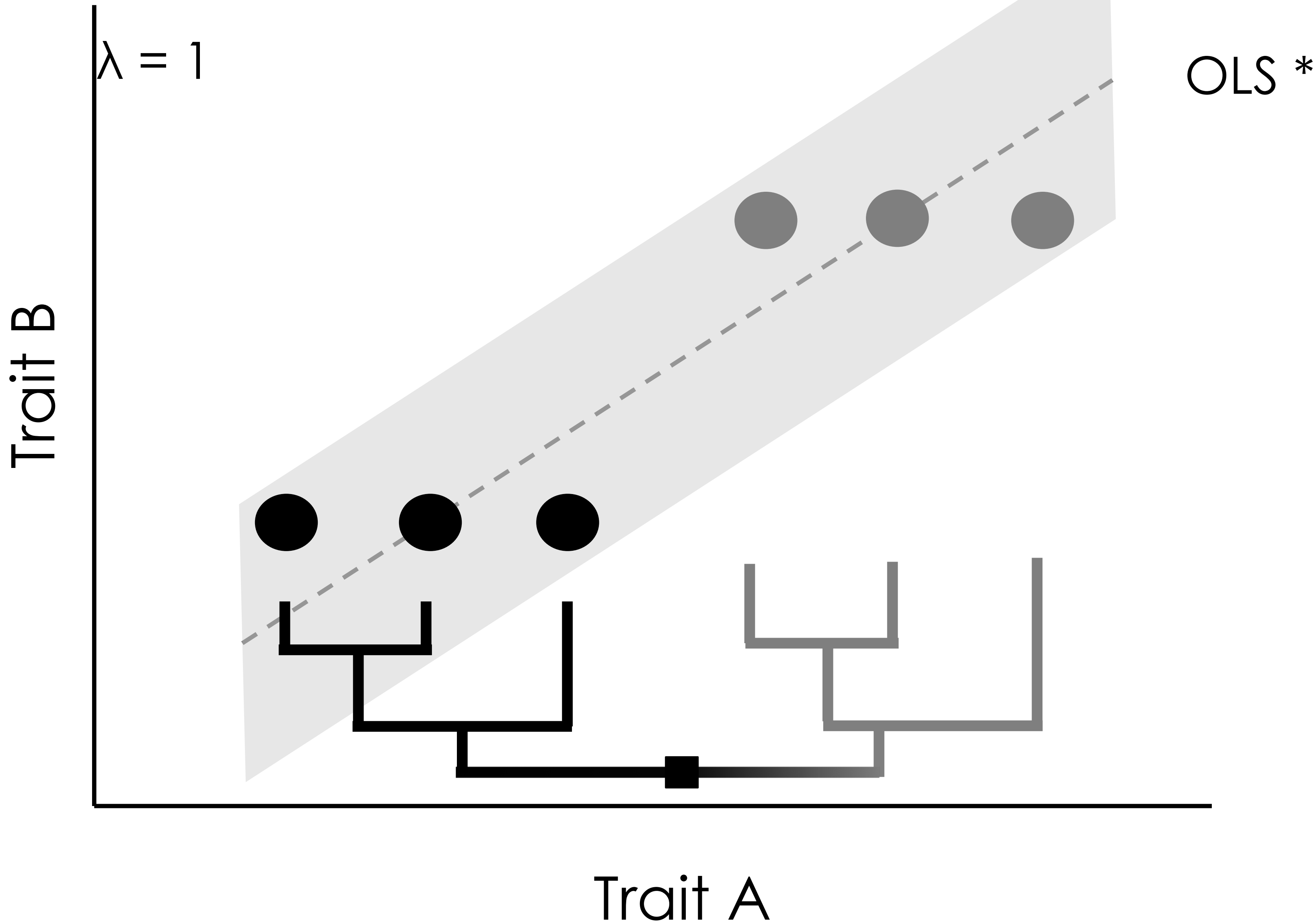
Accounting for phylogeny



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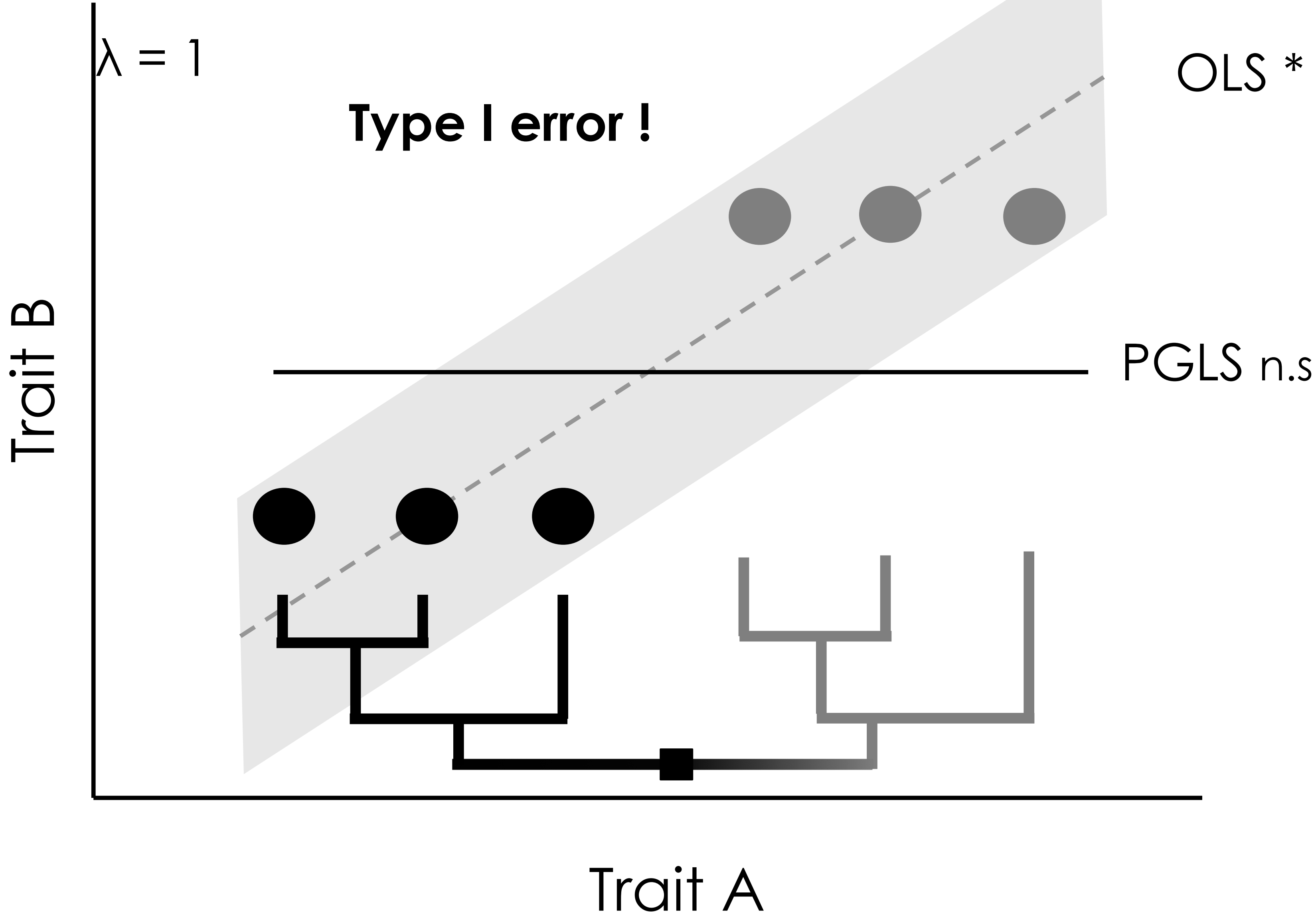
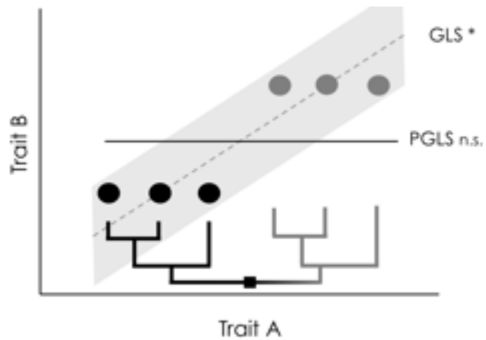
Accounting for phylogeny



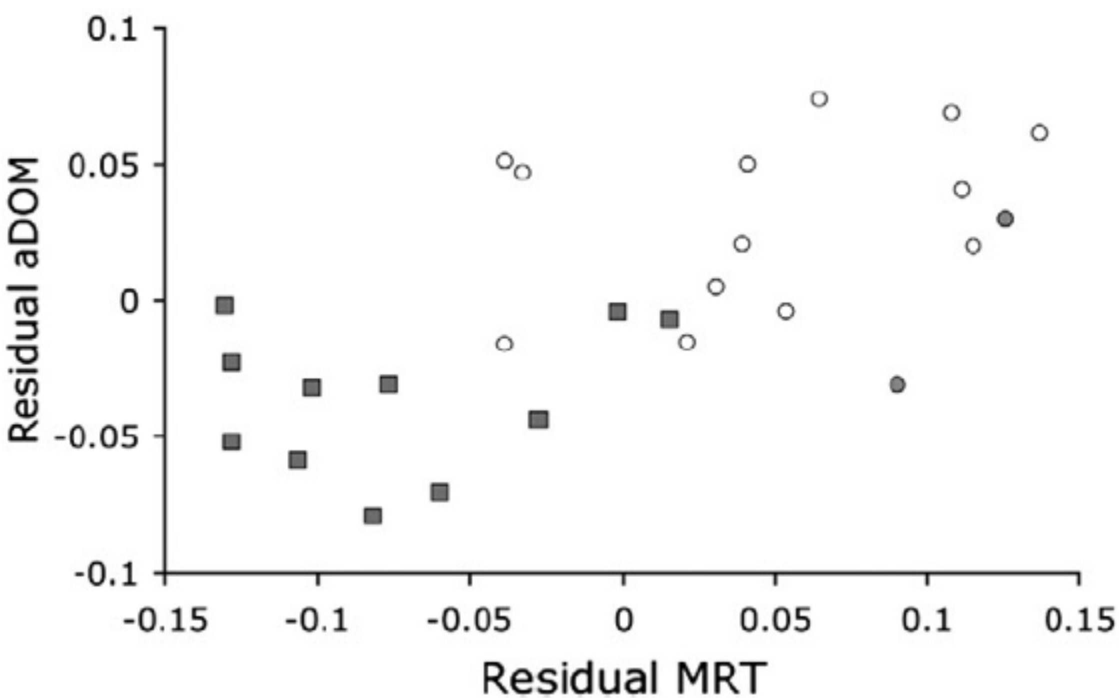
from Clauss et al. (2013)

Example IIIa: retention/digestibility



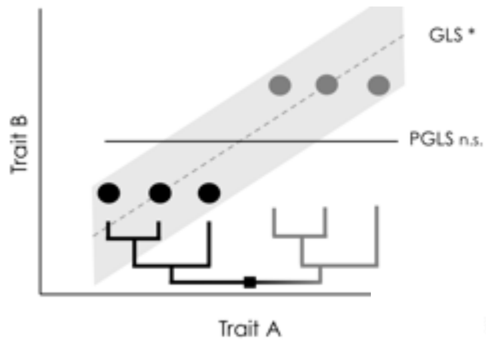
OLS: significant

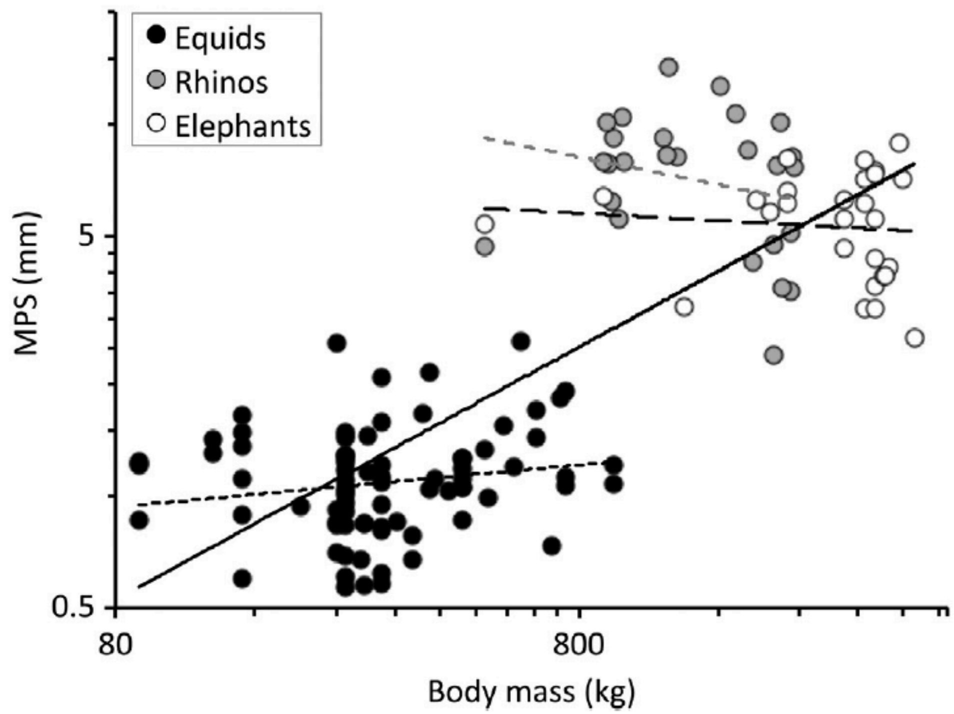
PGLS: not significant



from Müller et al. (2013)

Example IIIb: fecal particle size





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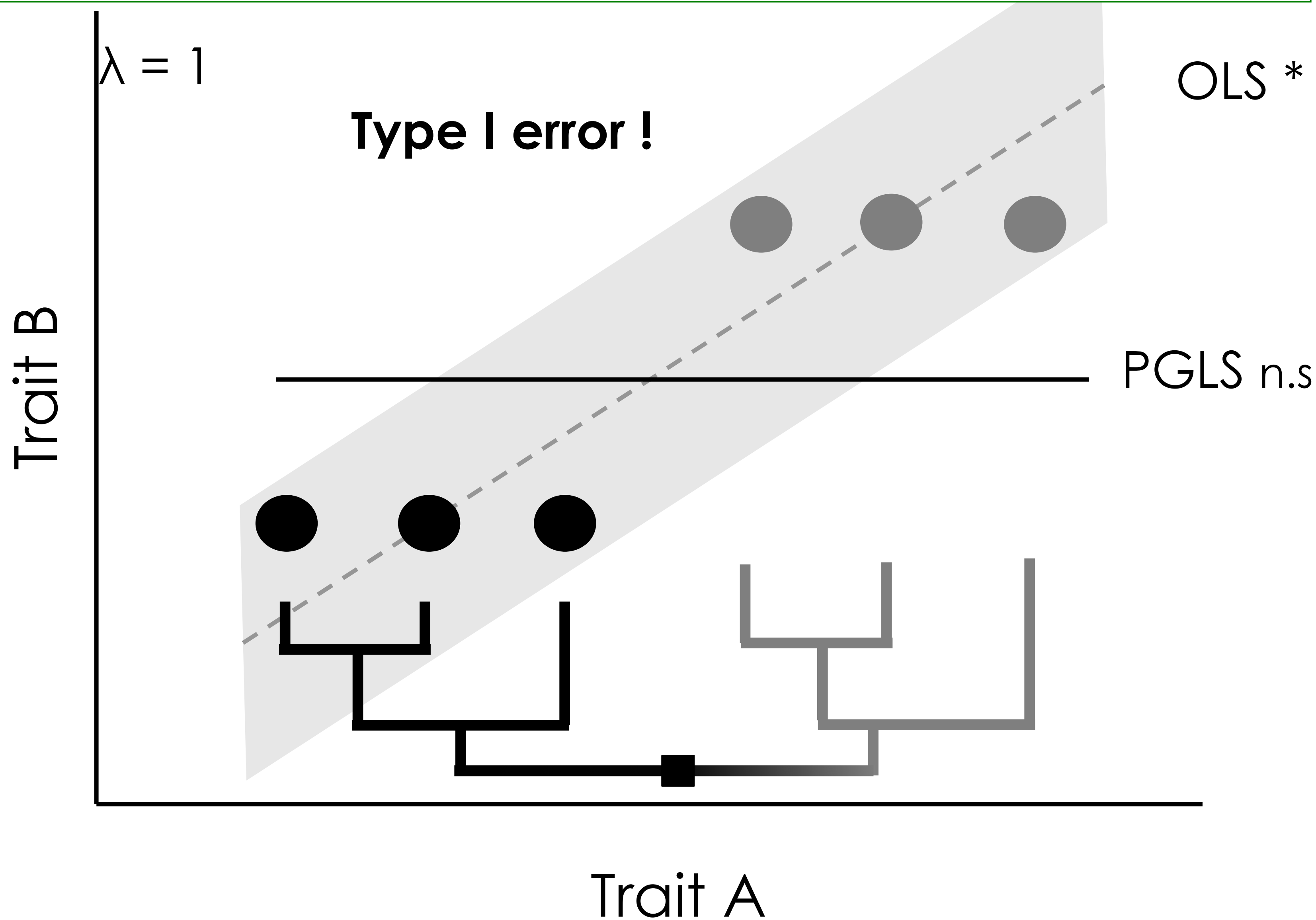
Accounting for phylogeny

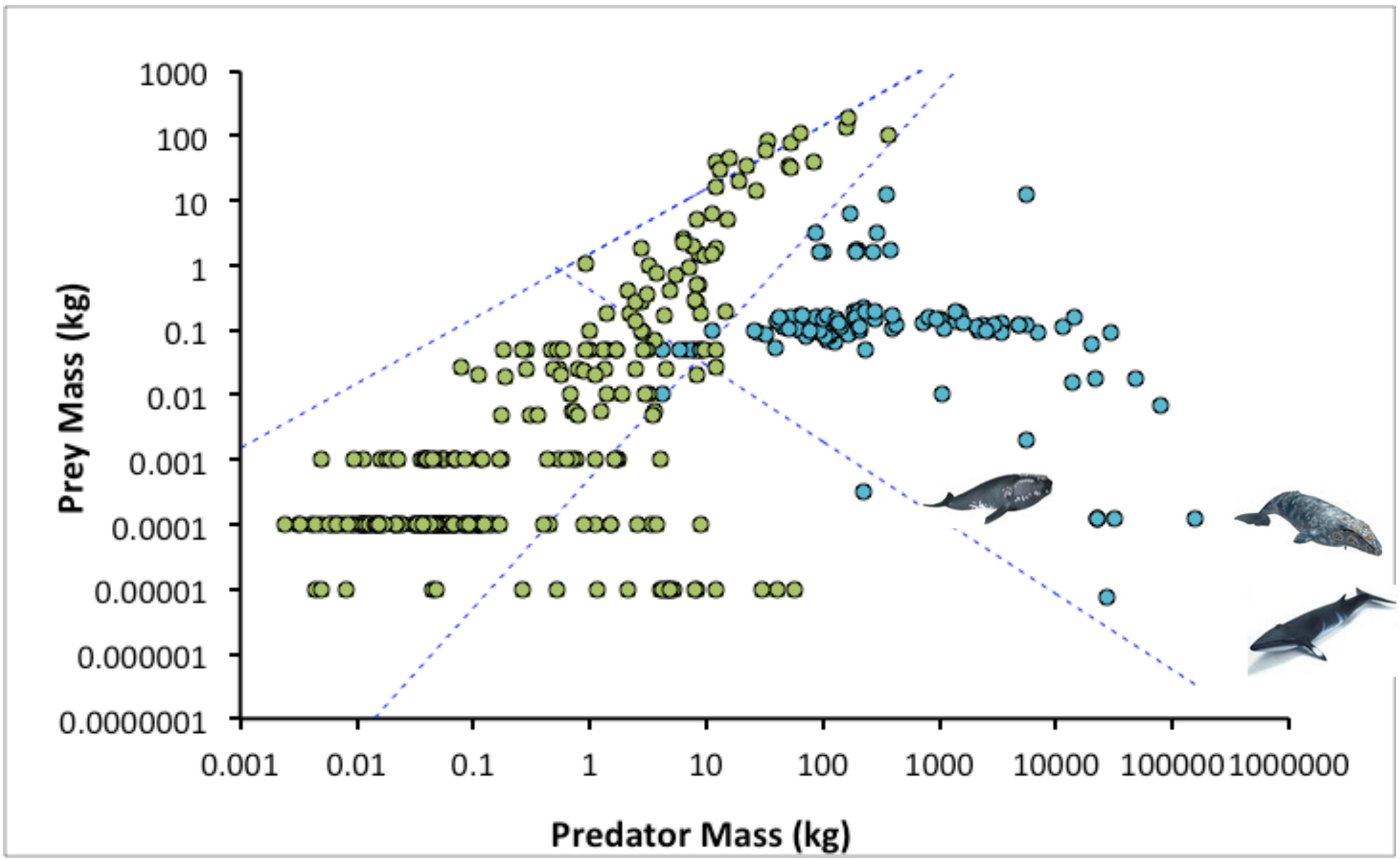


from Clauss et al. (2013)

Ecology Letters, (2014) **17**: 1553–1559 doi: 10.1111/ele.12375

Geometric factors influencing the diet of vertebrate predators in marine and terrestrial environments

Chris Carbone,[1]* Daryl Codron,[2,3]
Conrad Scofield,[1] Marcus Clauss[3]
and Jon Bielby[1]



from Carbone et al. (2014)

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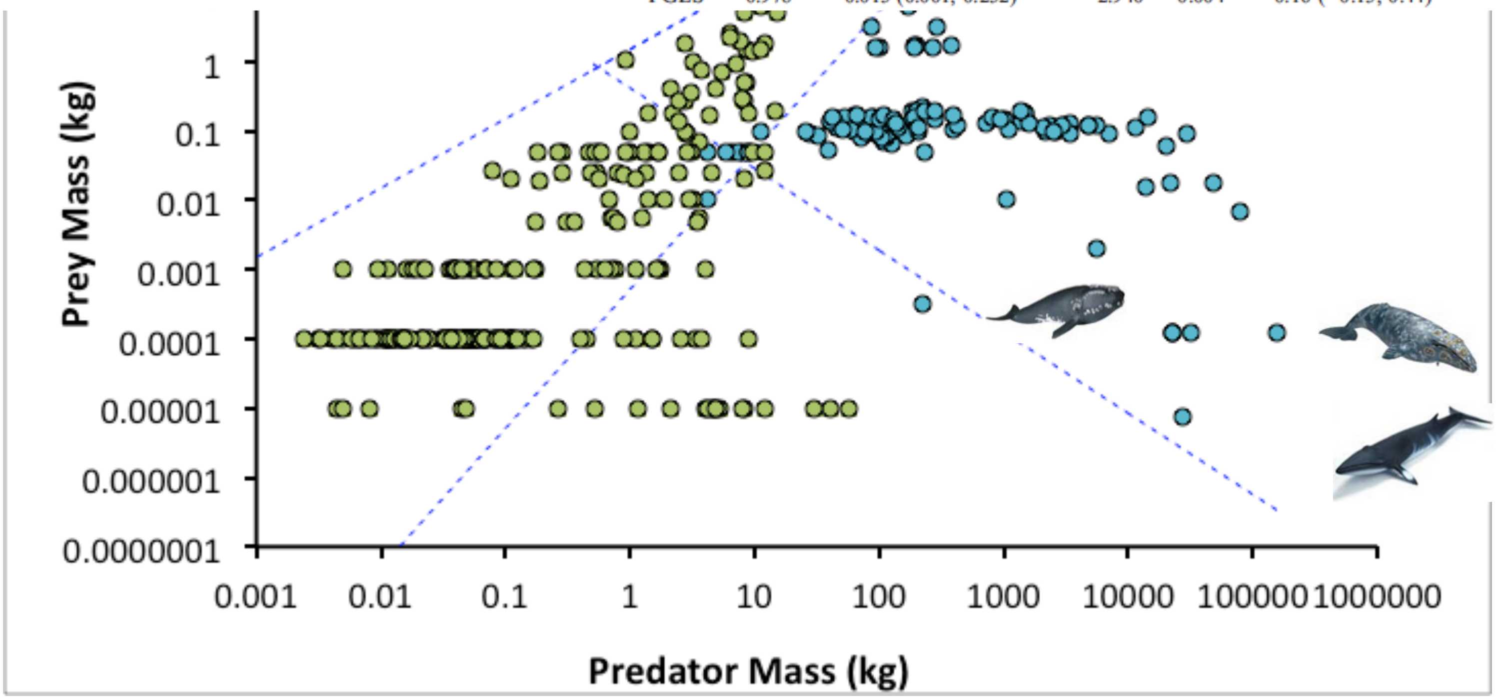
Table 2 Result of comparative analyses of how minimum prey size varies as a function of predator size

Taxonomic group/biome	*n*	Body mass (kg, mode, range) Predator	Prey	Stat	λ*	a (95% CI)	*t*	*P*	b (95% CI)	*t*	*P*
Terrestrial mammals	270	0.112 (0.002–371)	0.0001 (0.000001–189)	OLS	(0)	0.007 (0.004; 0.010)	−22.456	0.000	1.05 (0.90; 1.20)	13.709	0.000
				PGLS§	0.929‡	0.0003 (0.00001; 0.013)	−4.276	0.000	0.82 (0.60; 1.03)	7.381	0.000
				PGLS¶	1.0†	0.0001 (0.00001; 0.001)	−7.923	0.000	0.36 (0.15; 0.57)	3.293	0.001
Marine Mammals	126	23000 (4–154160)	0.100 (0.00003–12)	OLS	(0)	0.546 (0.215; 1.386)	−1.274	0.205	−0.30 (−0.45; −0.15)	−3.975	0.000
				PGLS¶	0.978†	0.013 (0.001; 0.232)	−2.940	0.004	0.16 (−0.13; 0.44)	1.054	0.294



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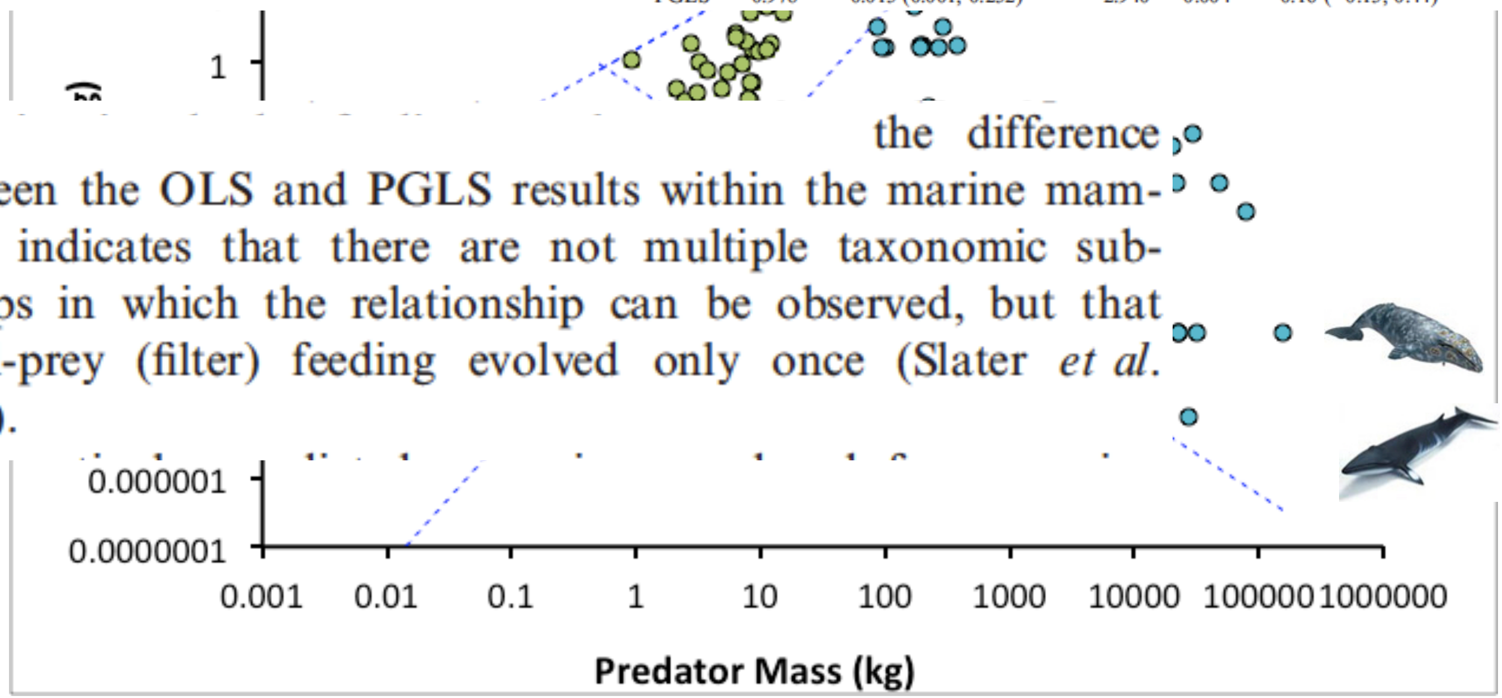
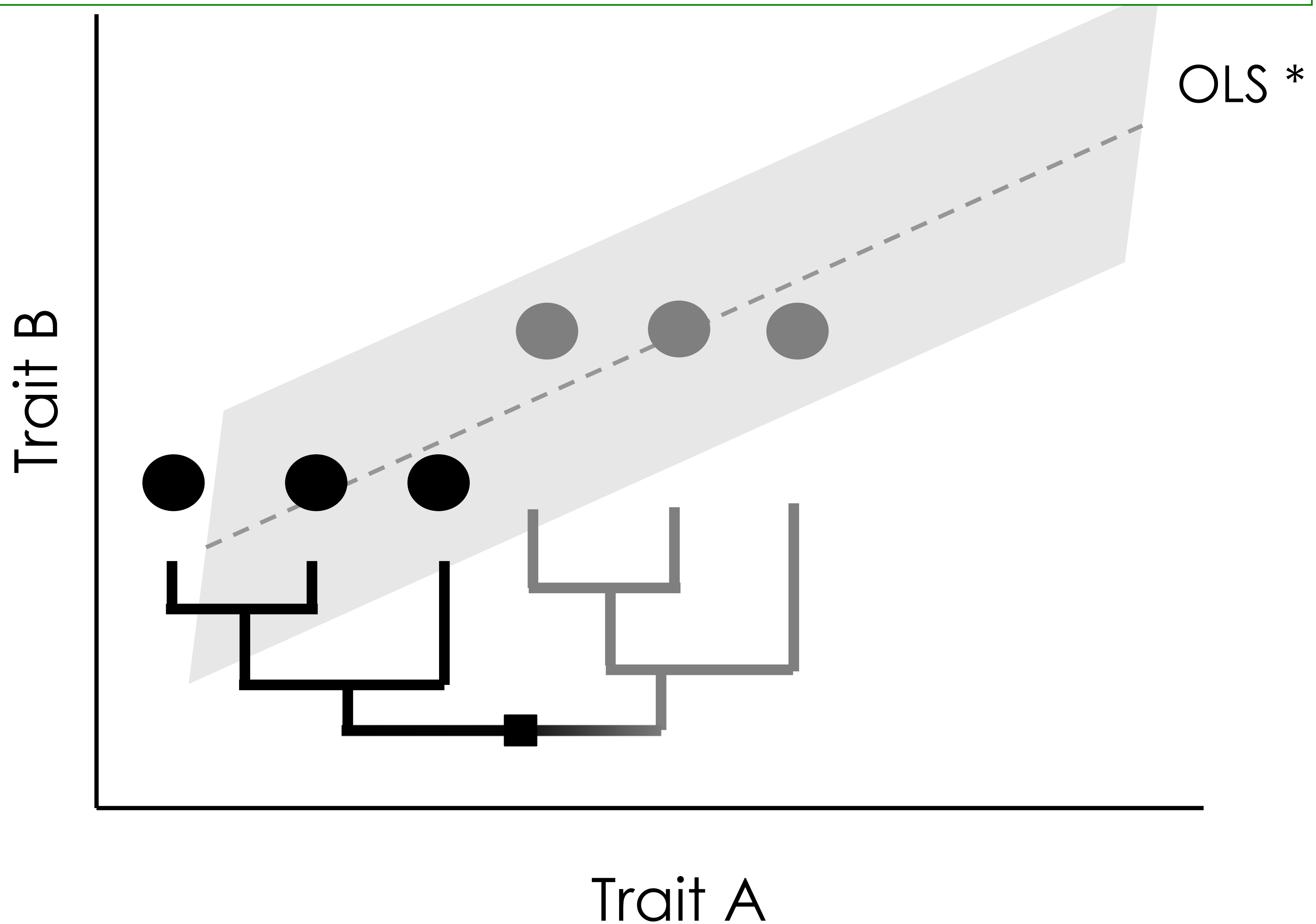


the difference between the OLS and PGLS results within the marine mammals indicates that there are not multiple taxonomic subgroups in which the relationship can be observed, but that small-prey (filter) feeding evolved only once (Slater *et al.* 2010).

from Carbone et al. (2014)

Accounting for phylogeny



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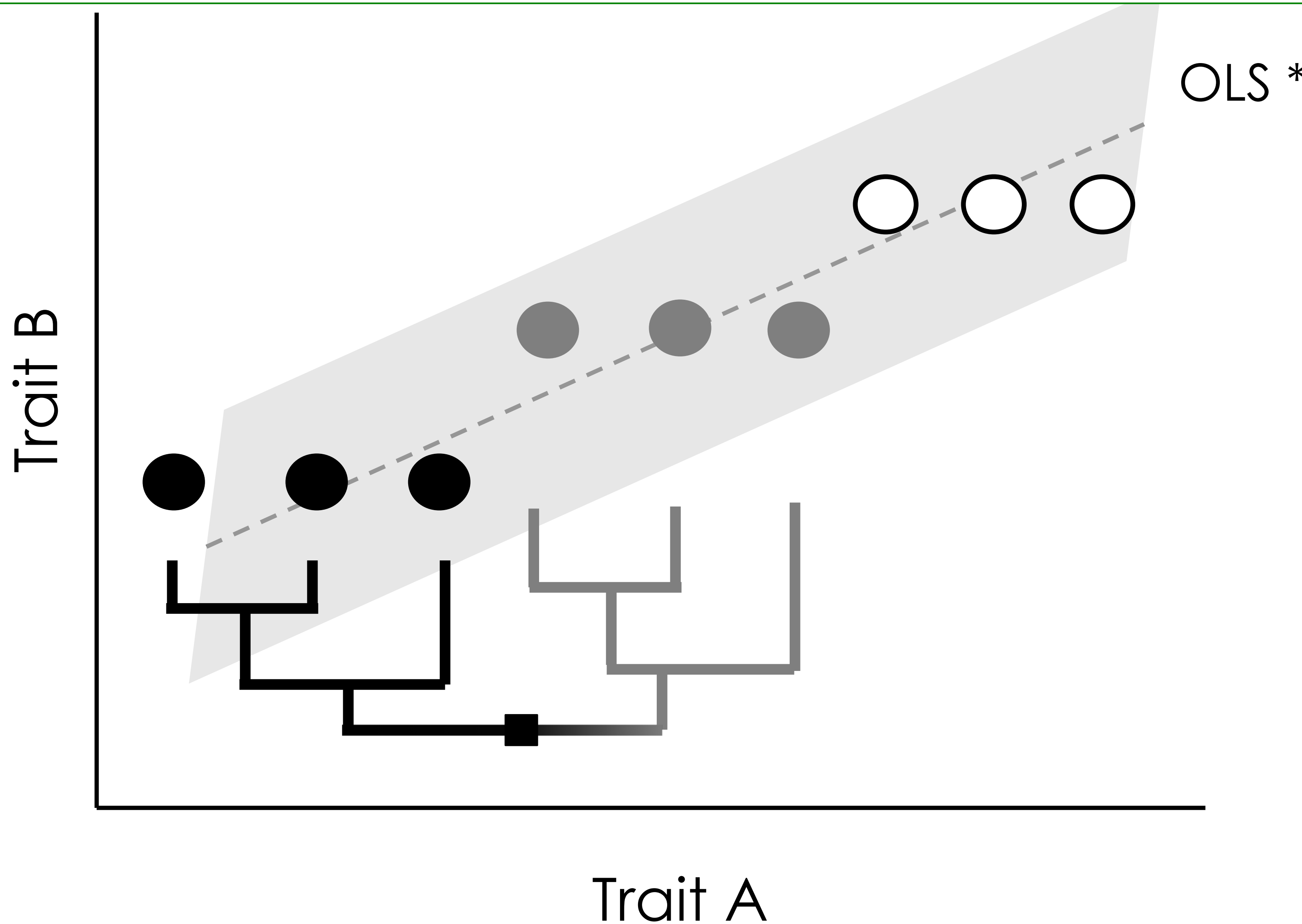

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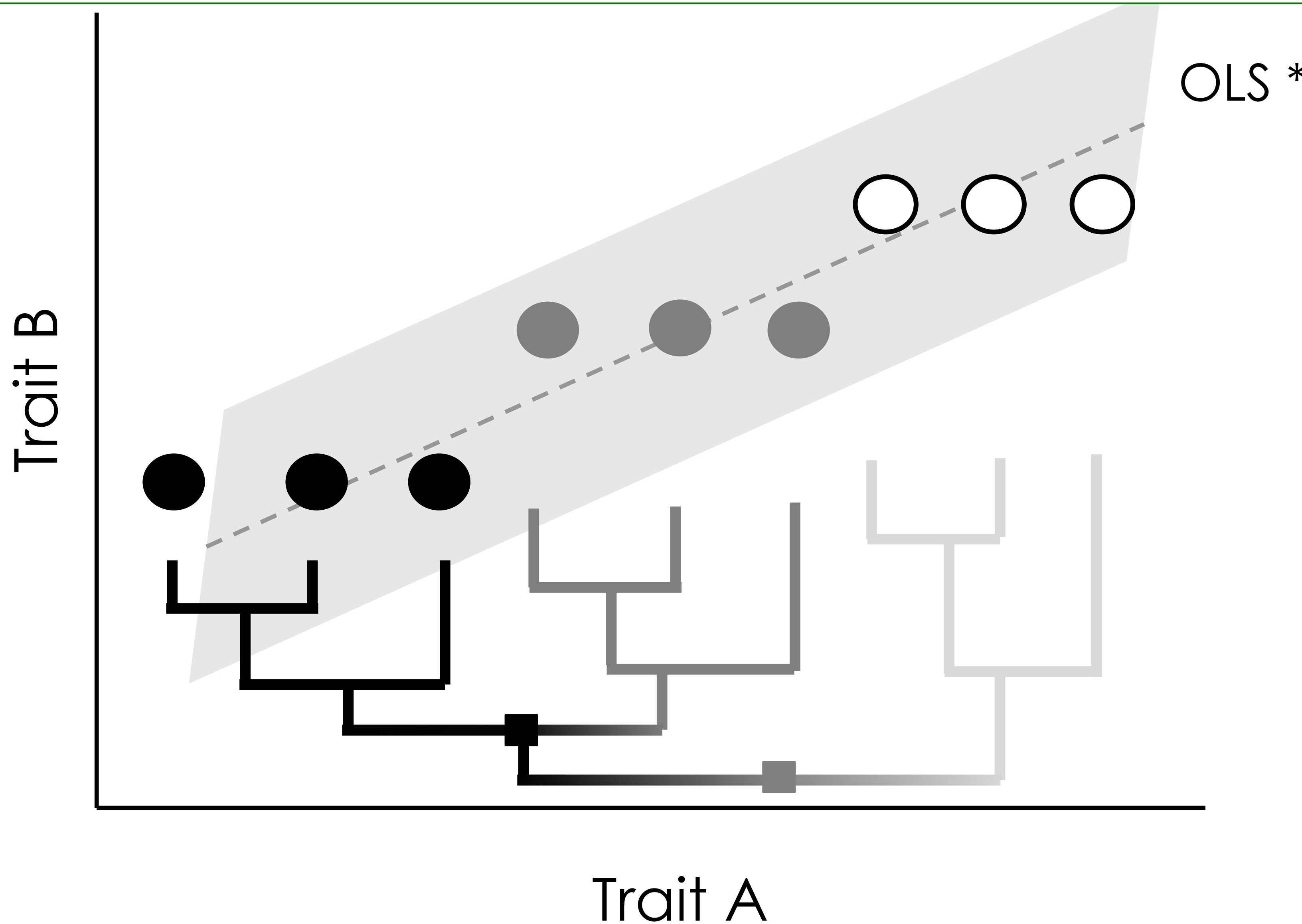

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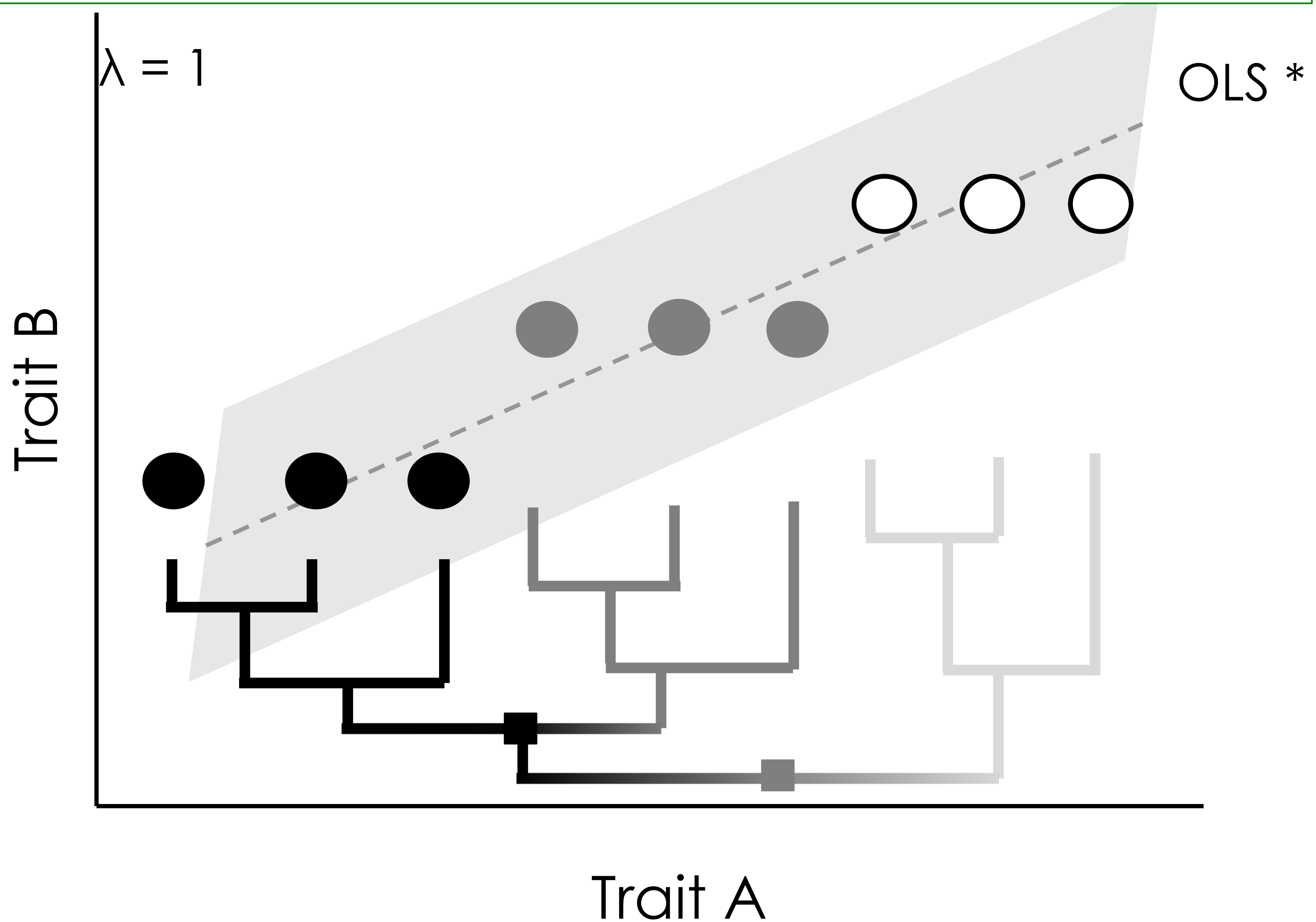

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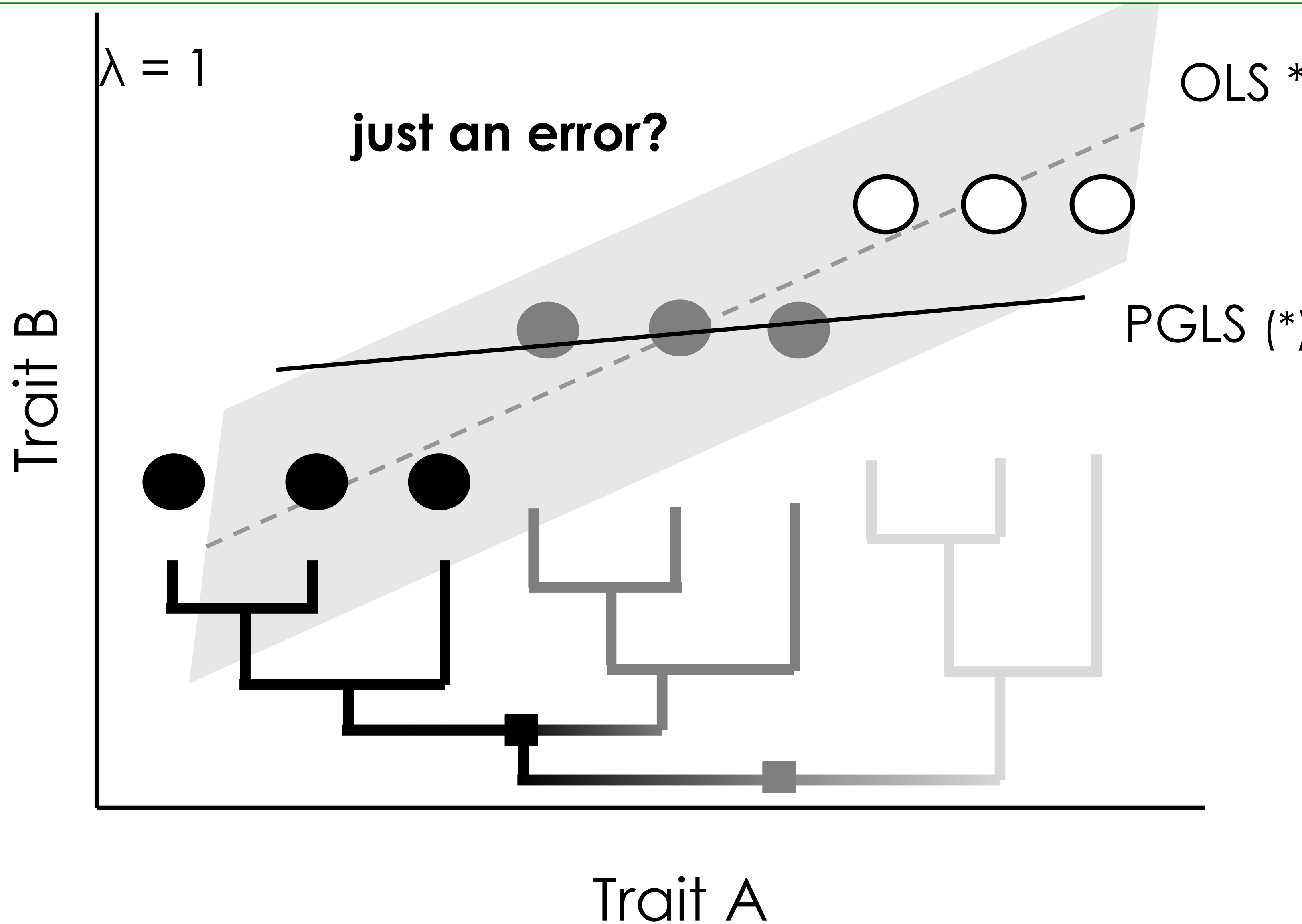
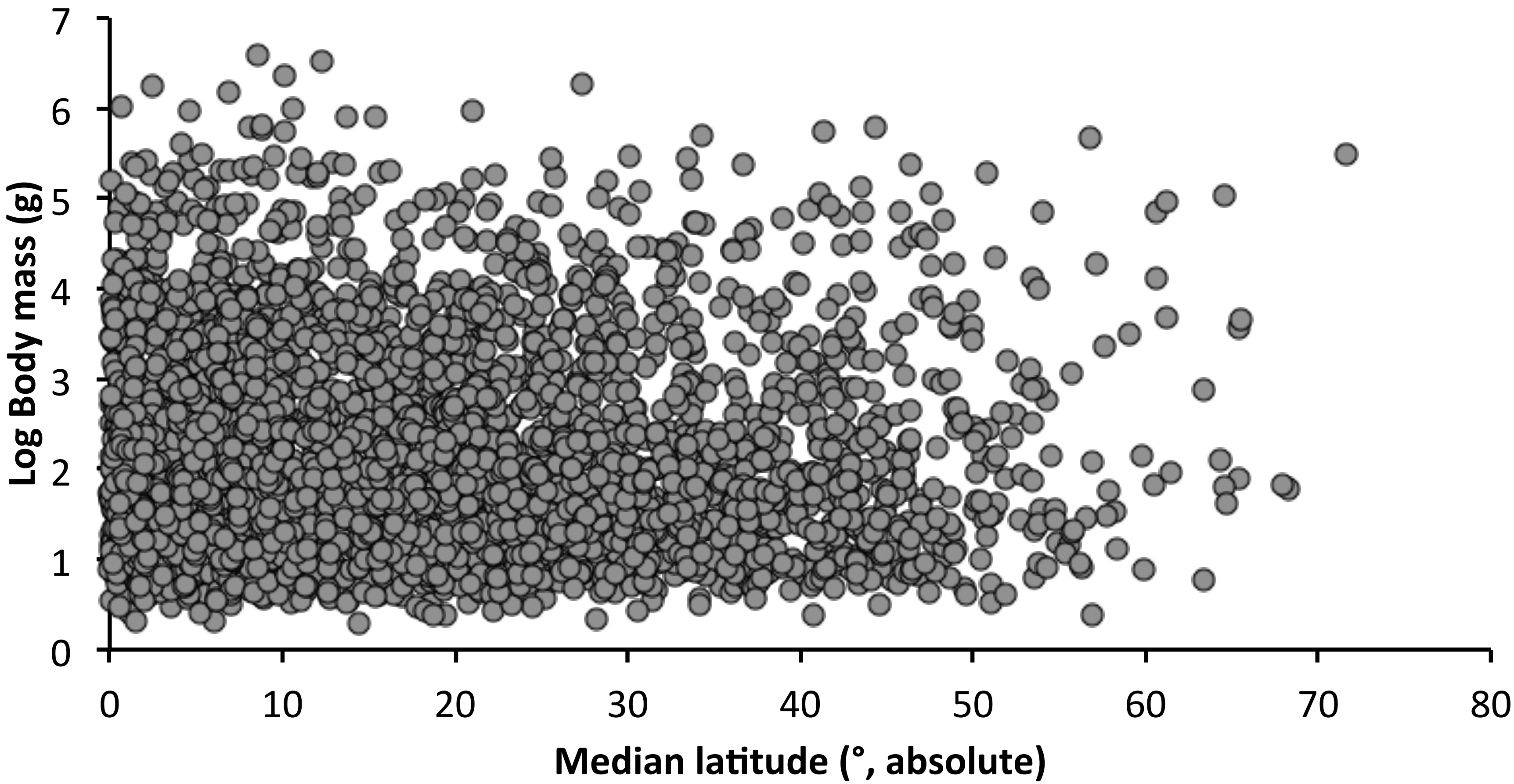


from Clauss et al. (2013)

Example IV: Bergmann's rule



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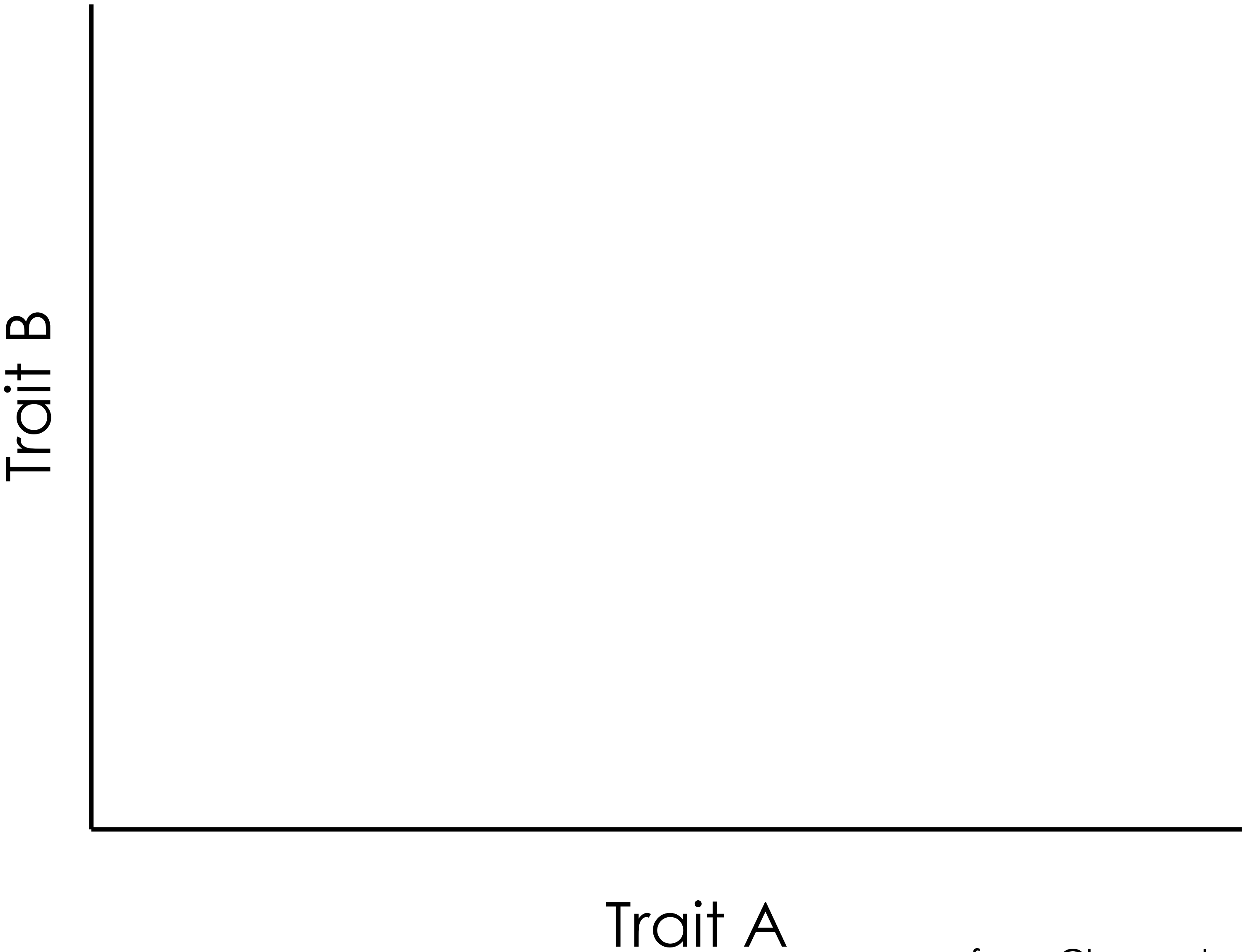
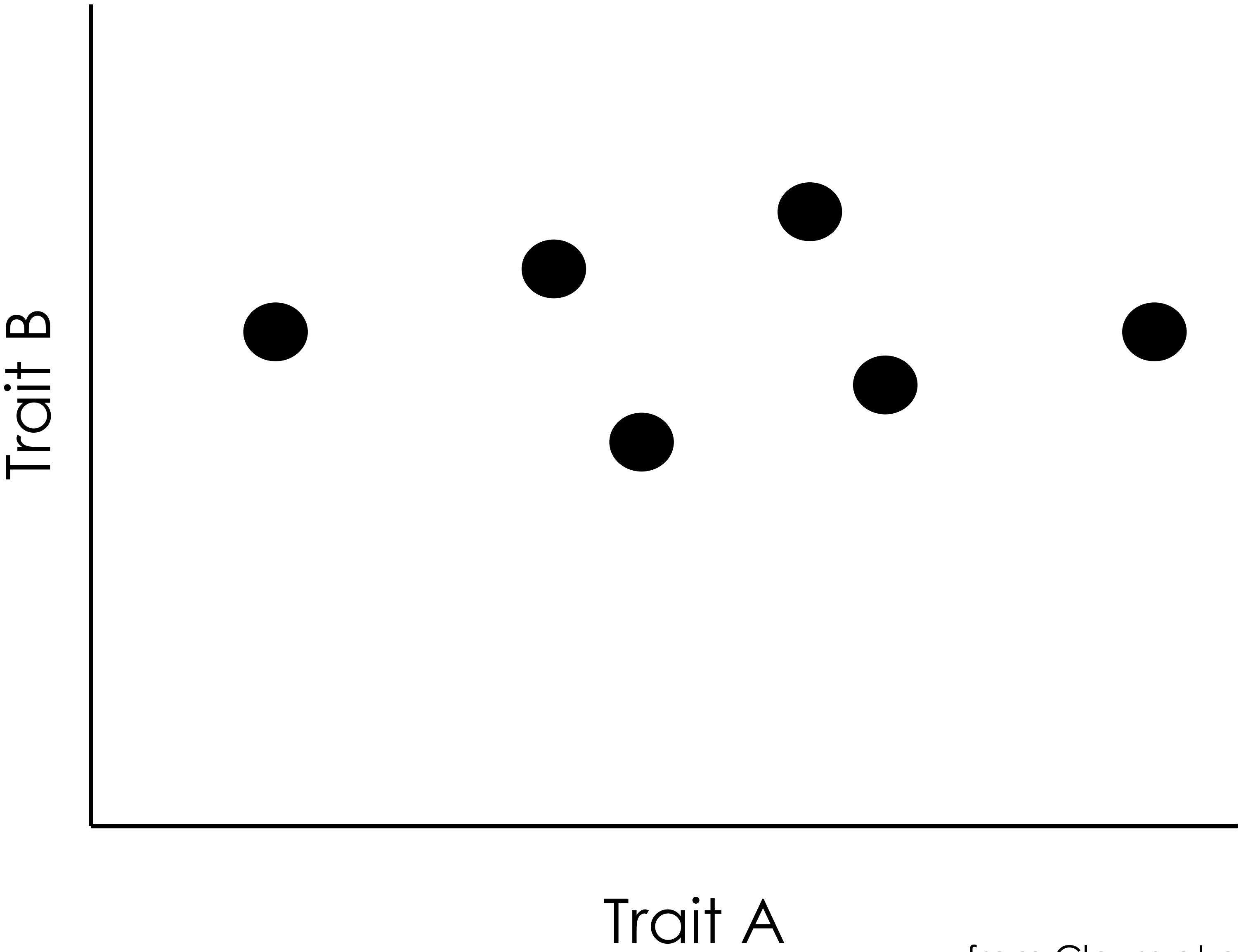


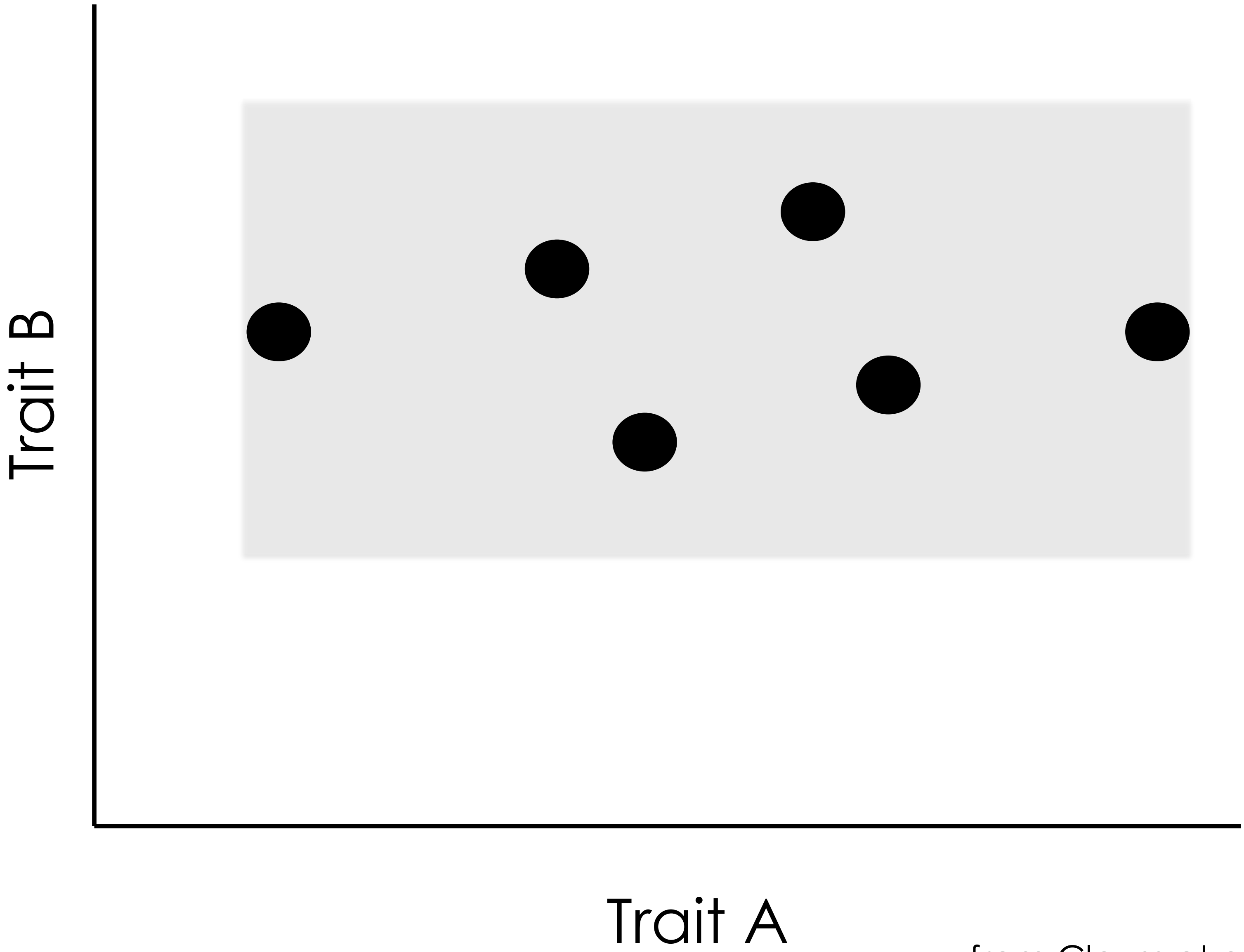
from Clauss et al. (2013)

Accounting for phylogeny



from Clauss et al. (2013)

Accounting for phylogeny



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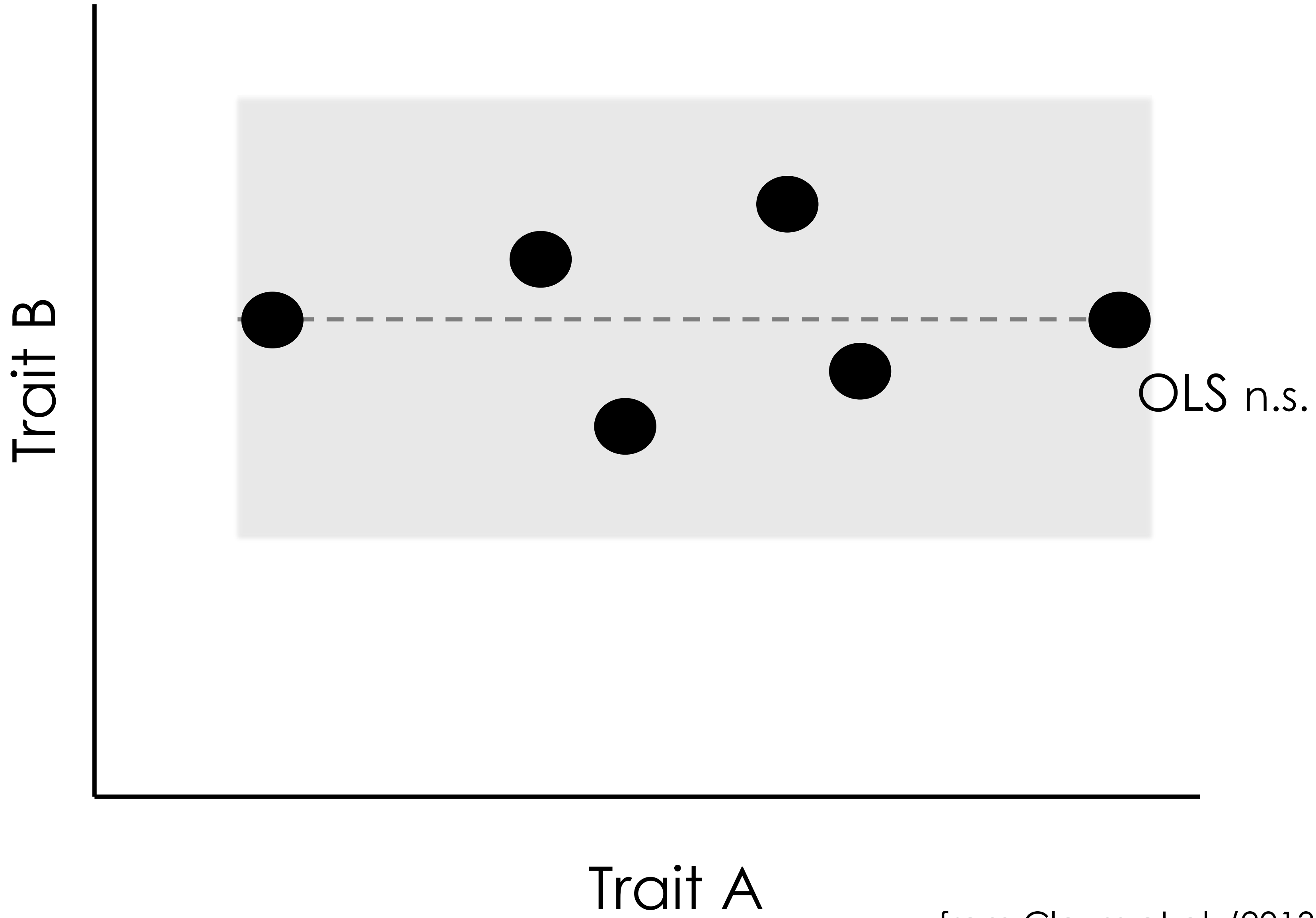

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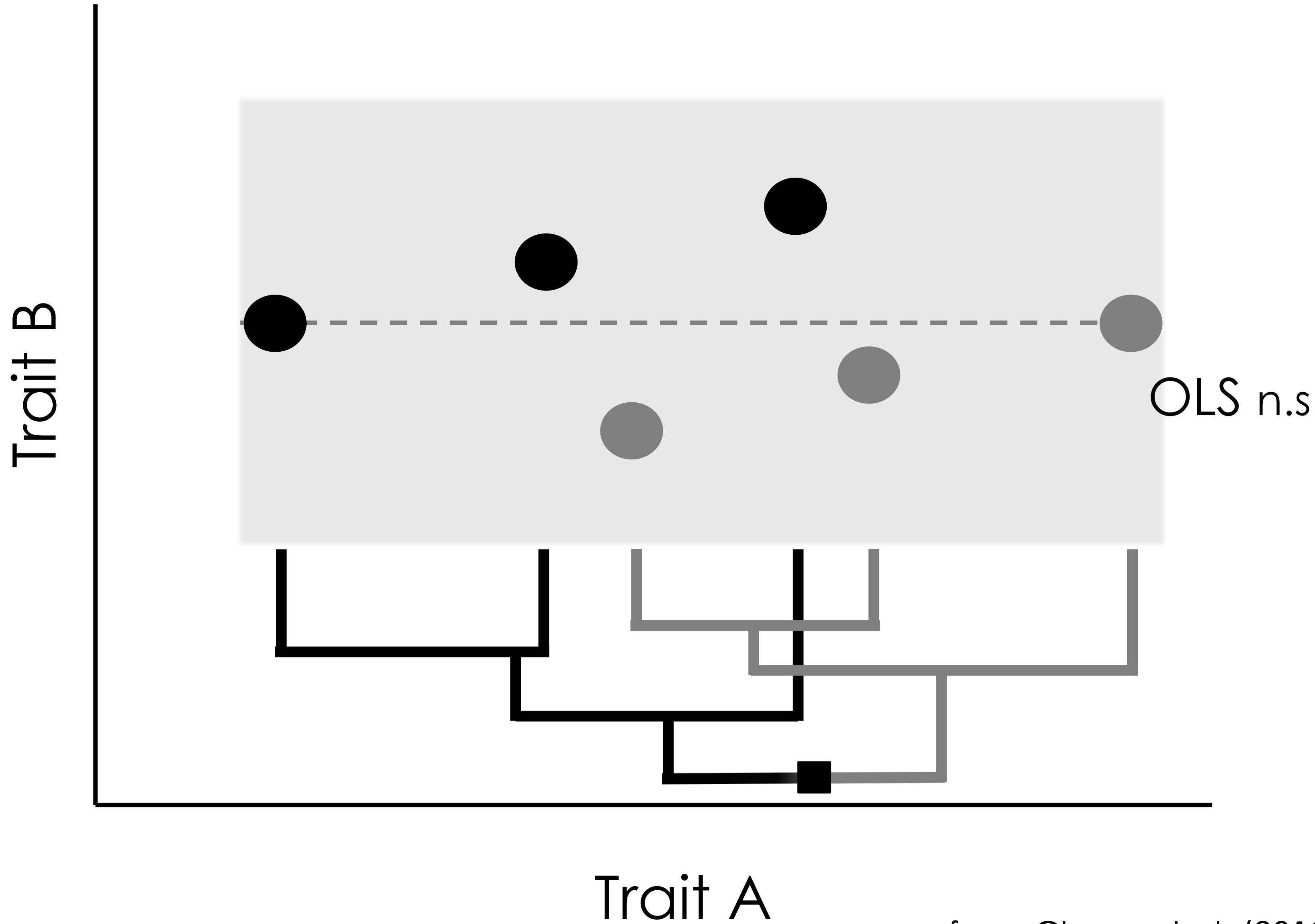

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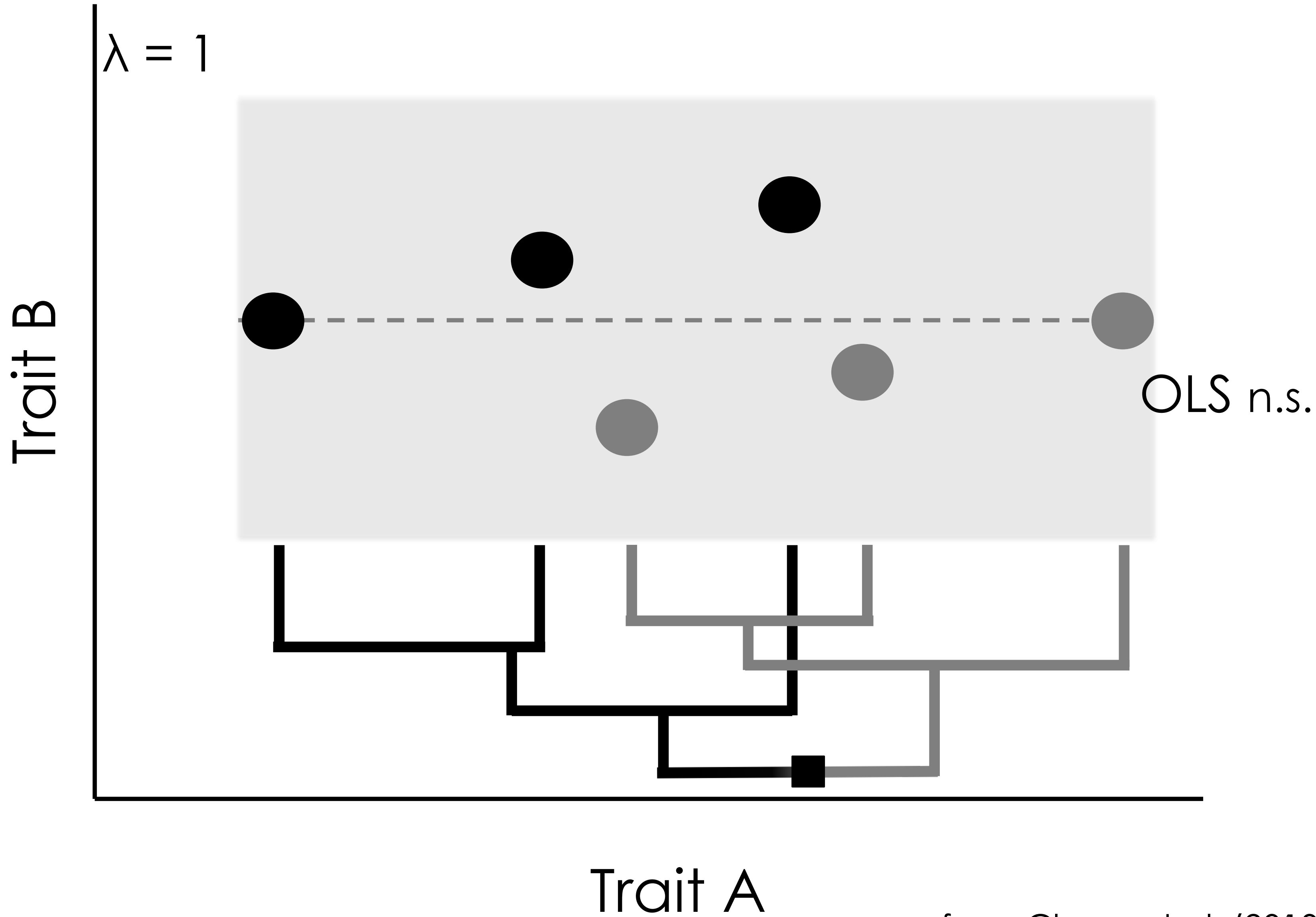

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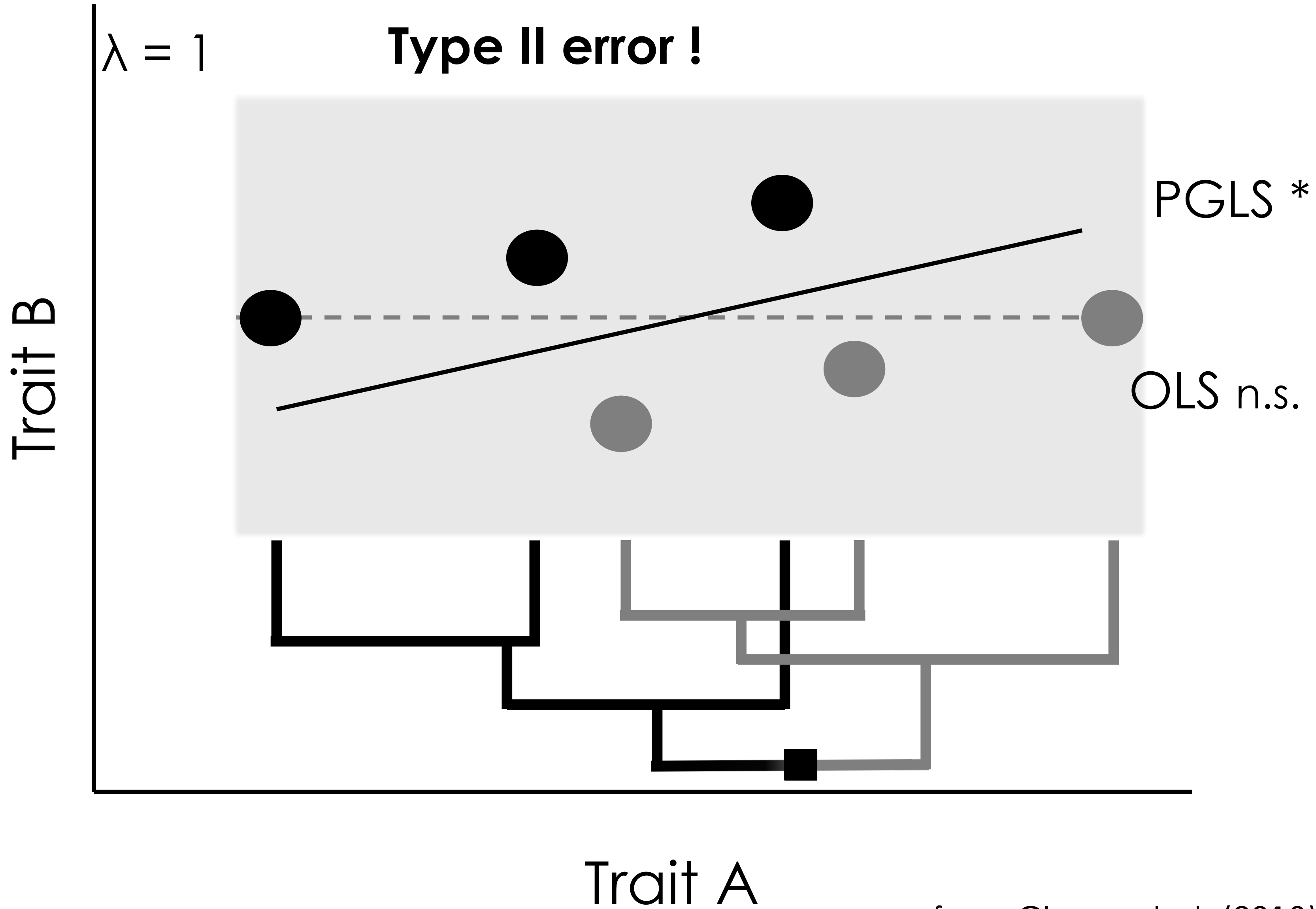

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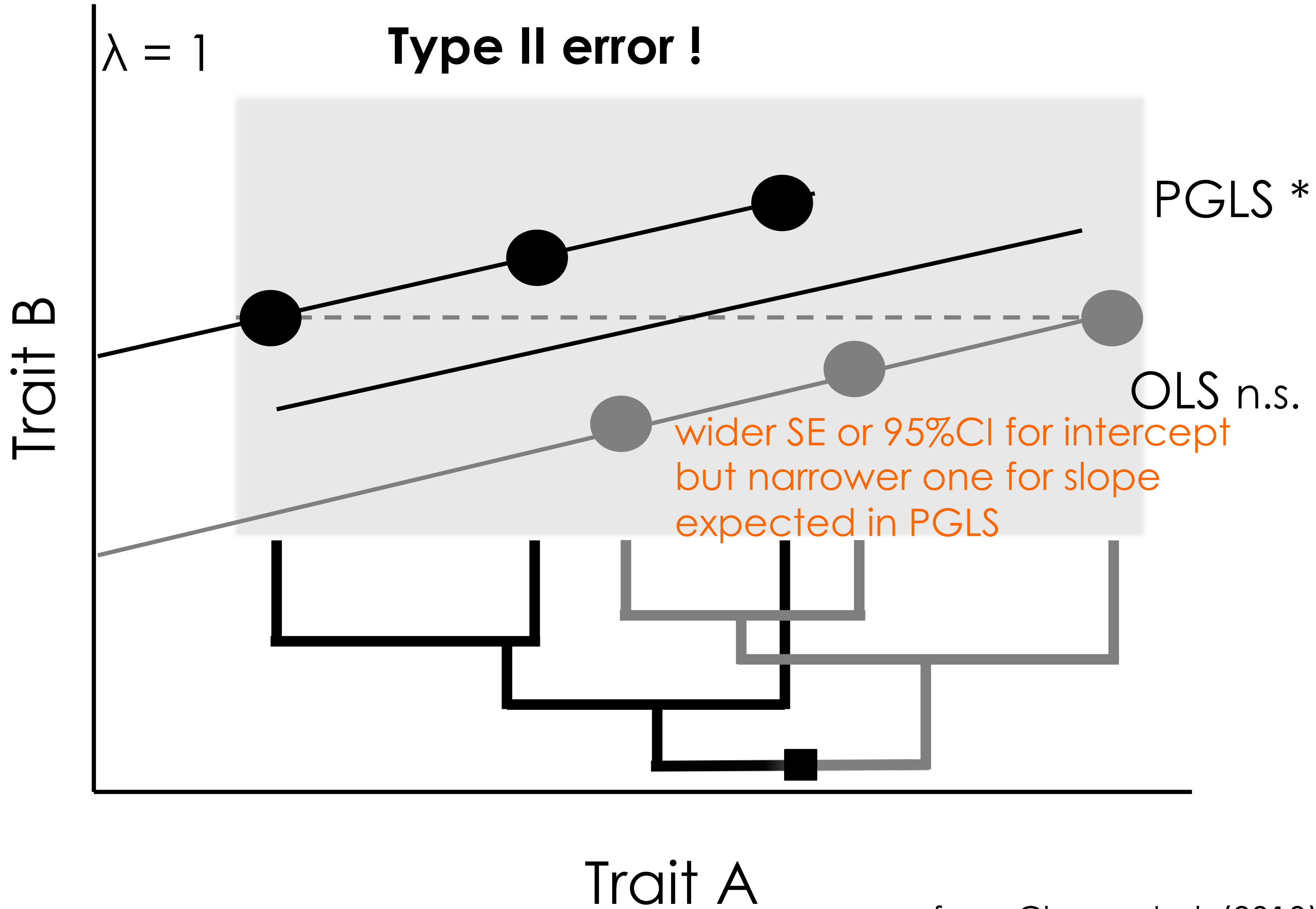

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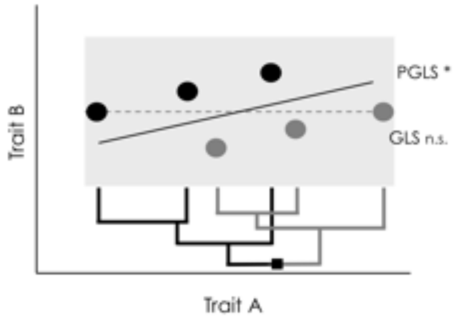
Example IV: Bergmann's rule



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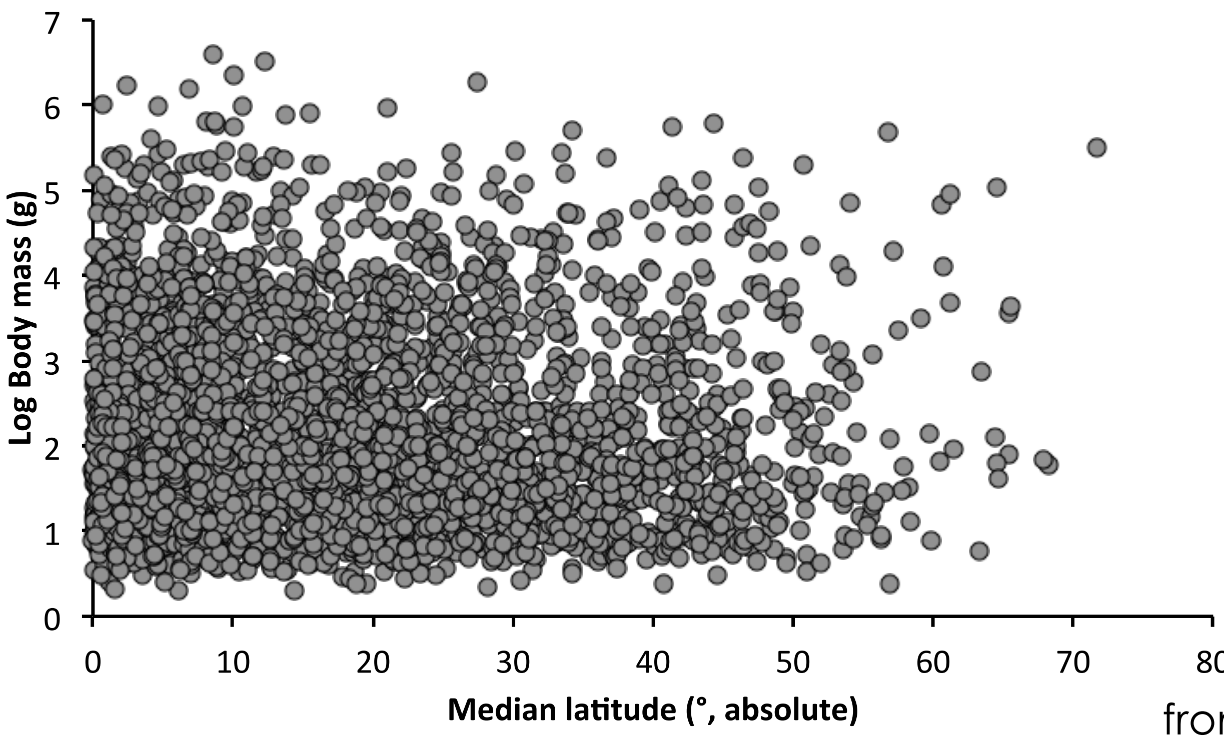
PGLS: 2.79 (±0.47) + 0.0016 (±0.0005) Lat.



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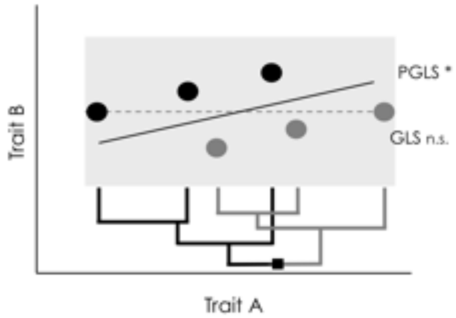

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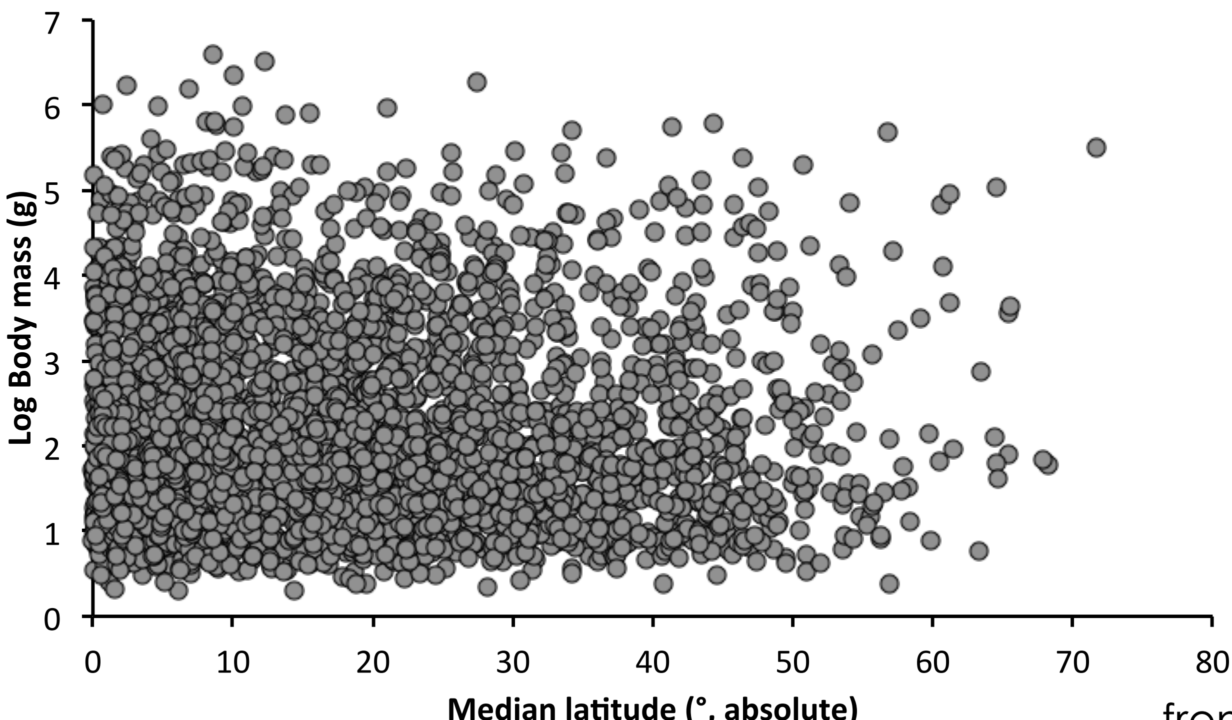

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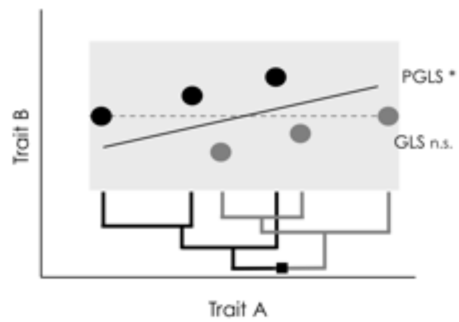

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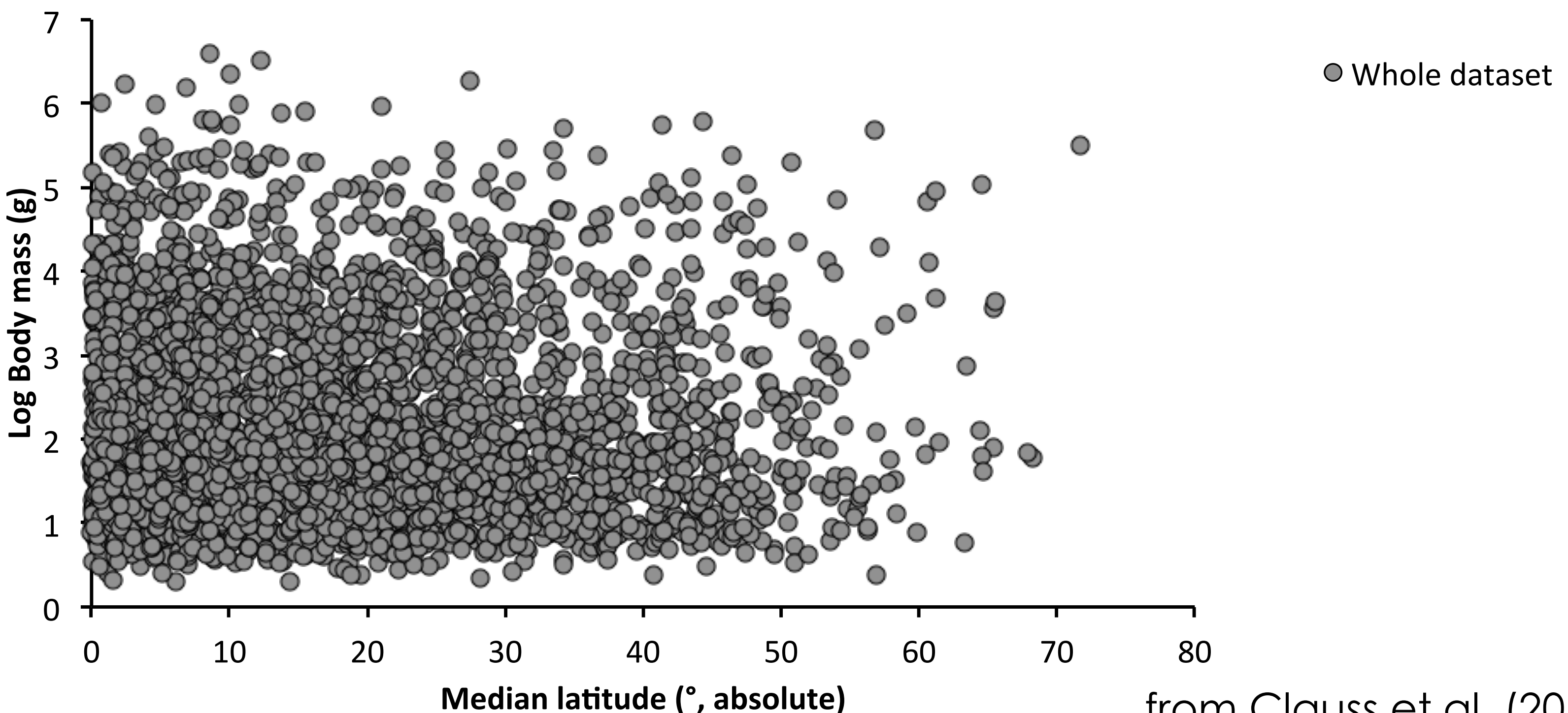

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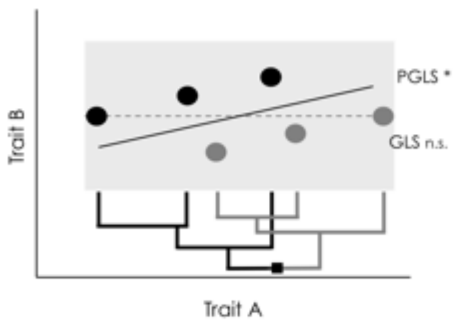

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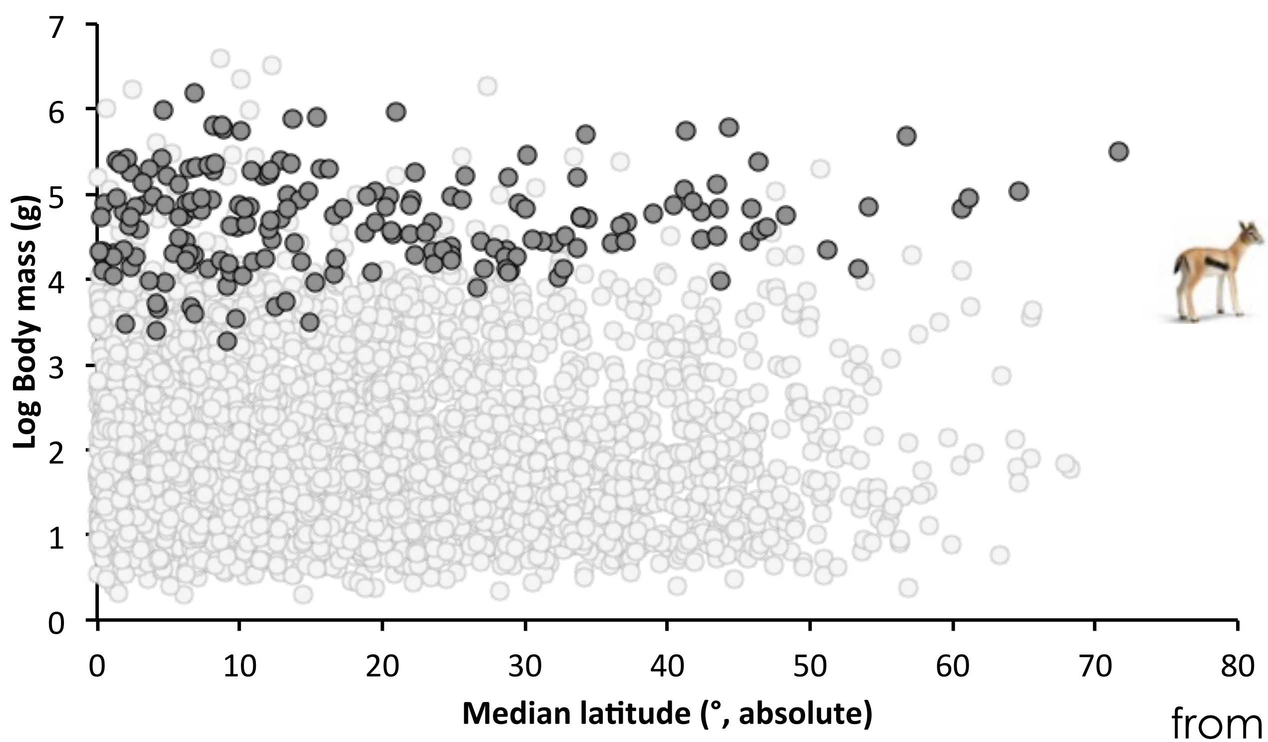

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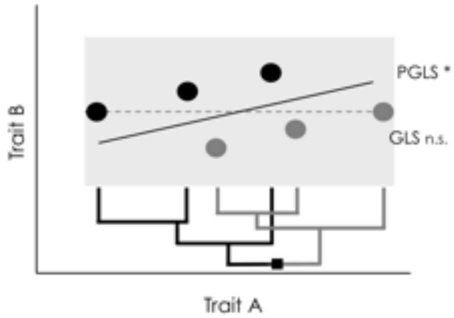

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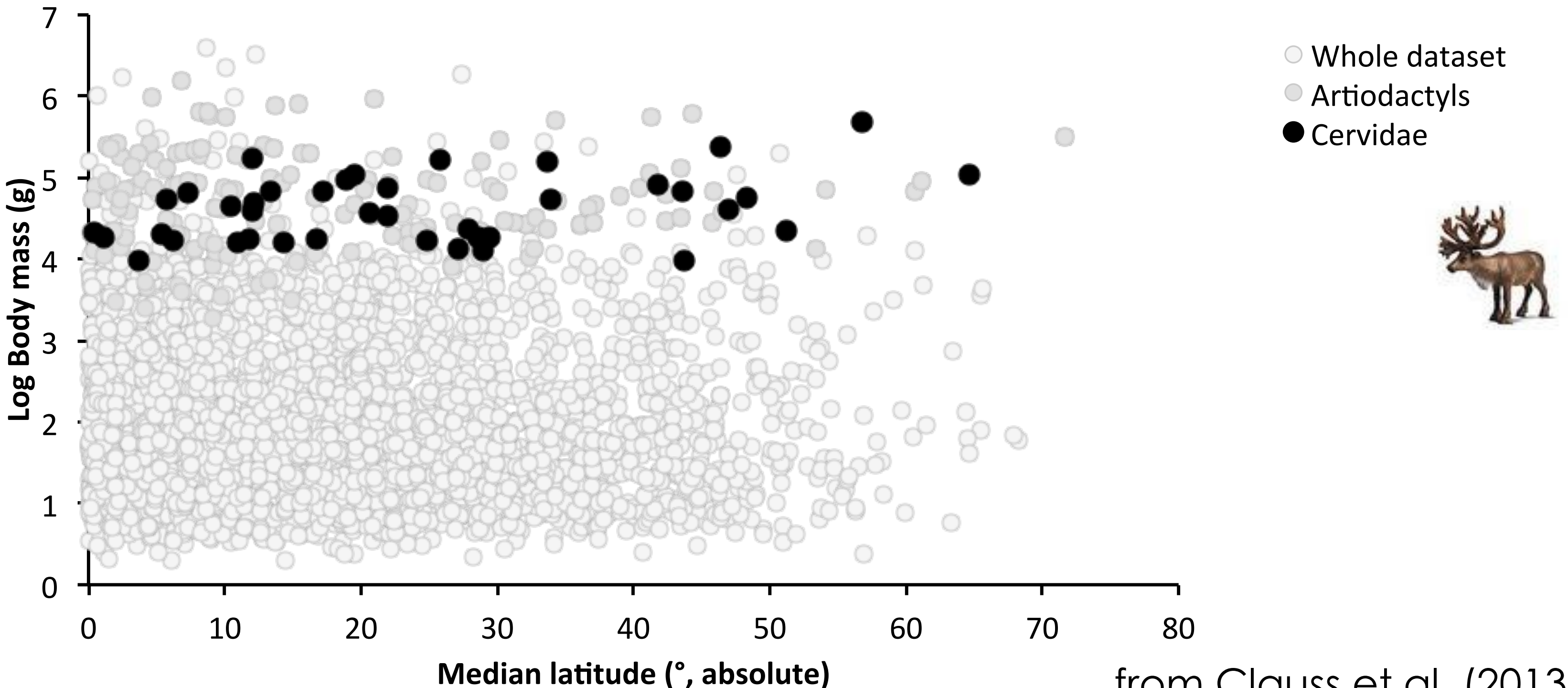

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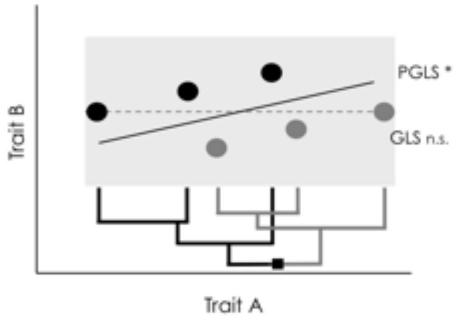

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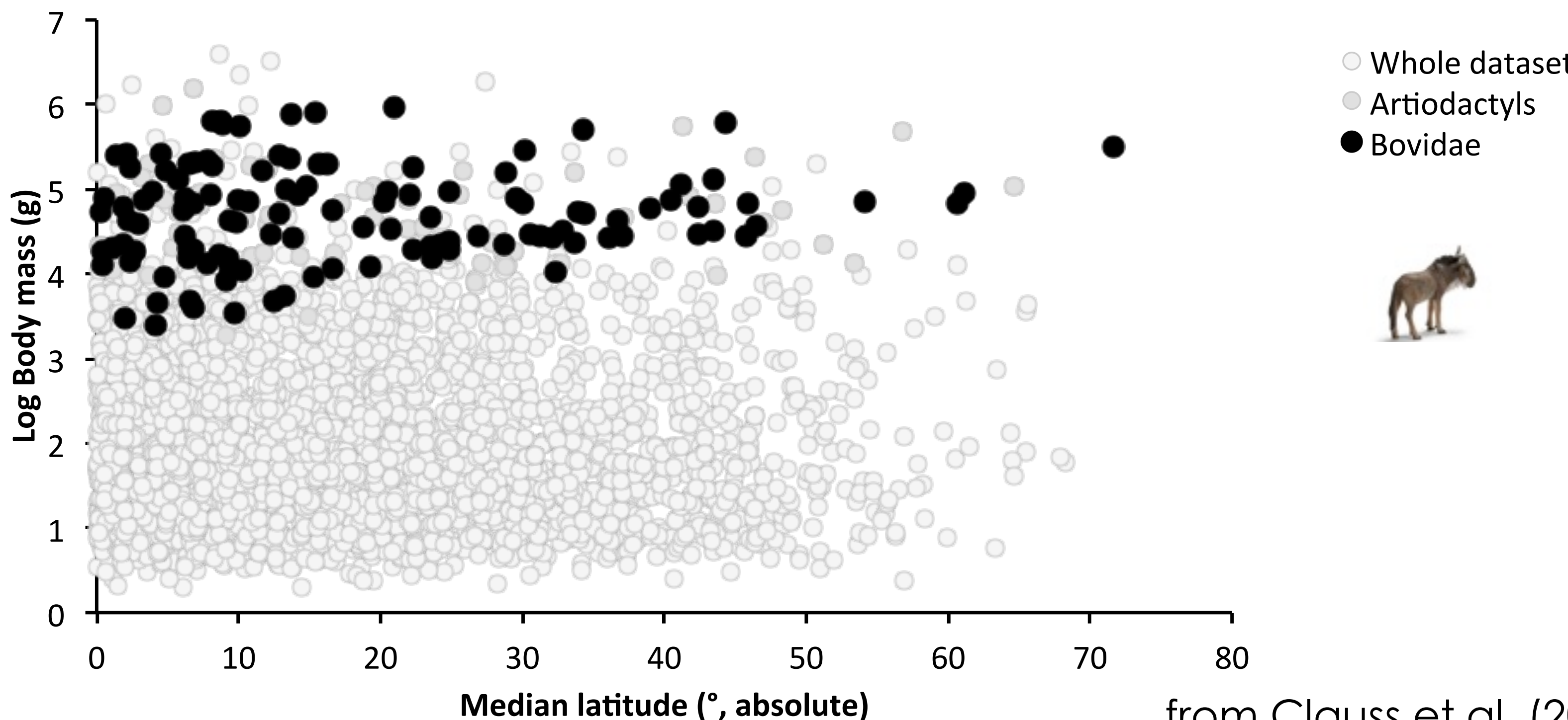

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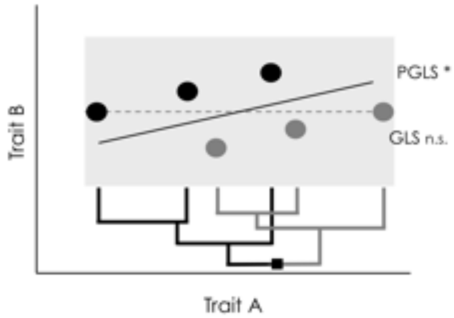

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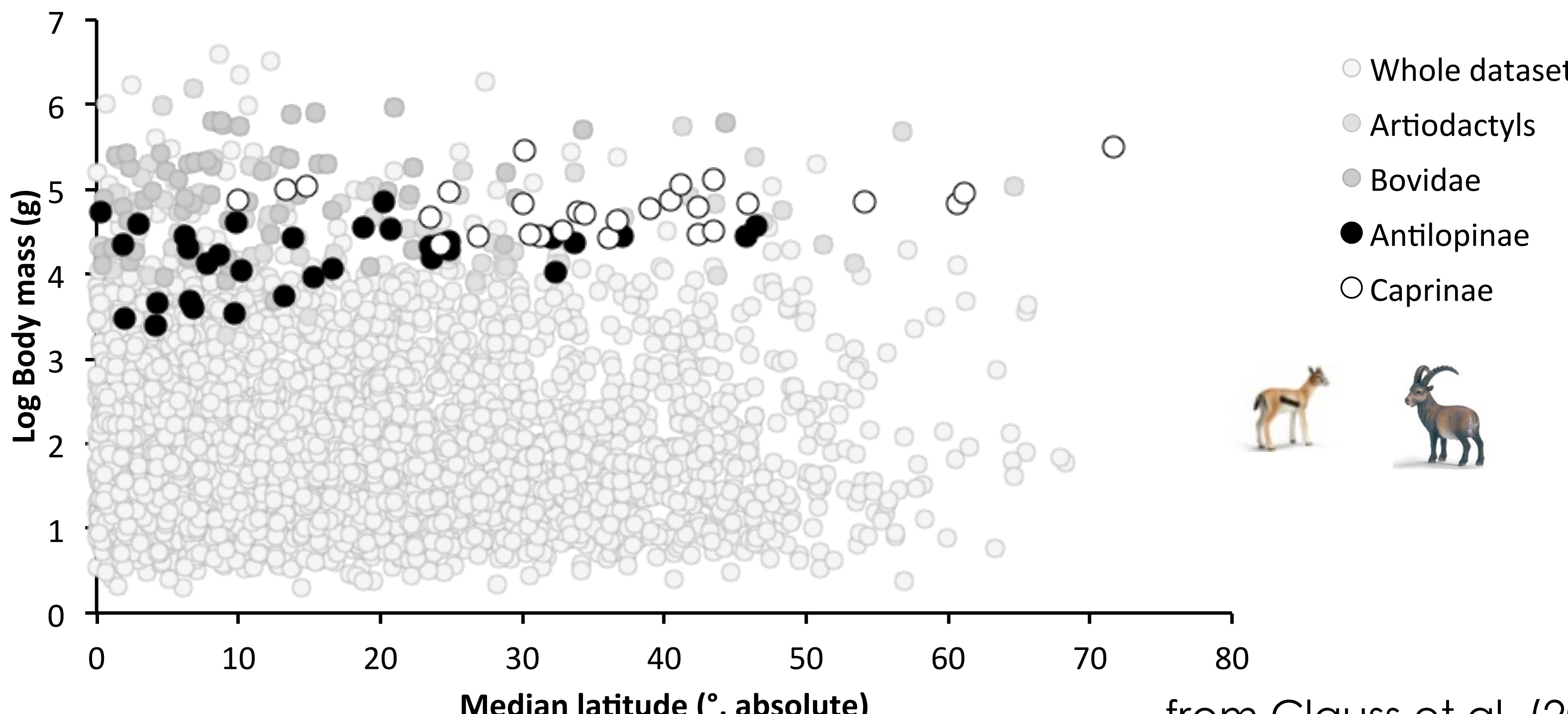

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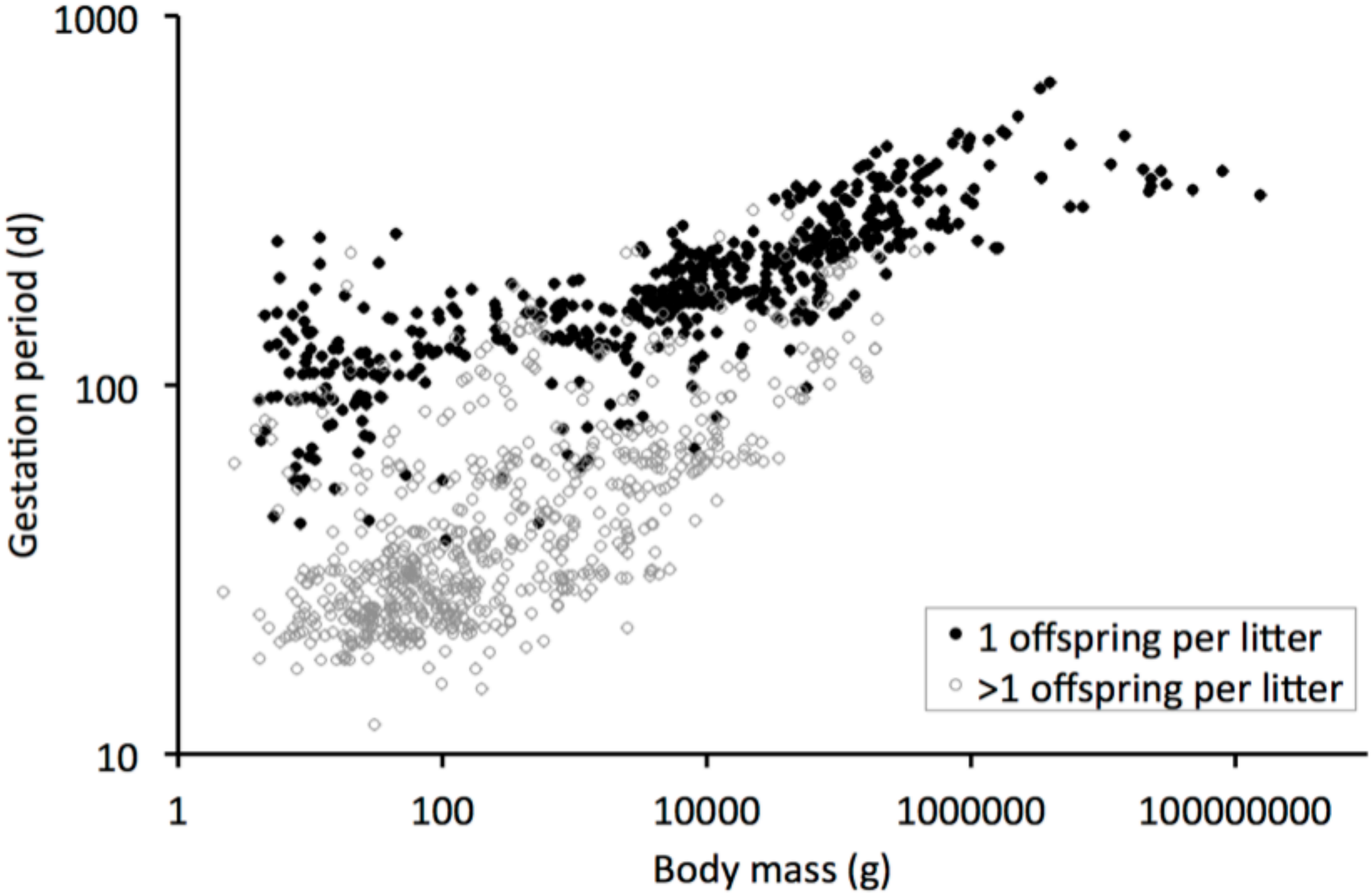
Example V: Gestation time



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Accounting for phylogeny

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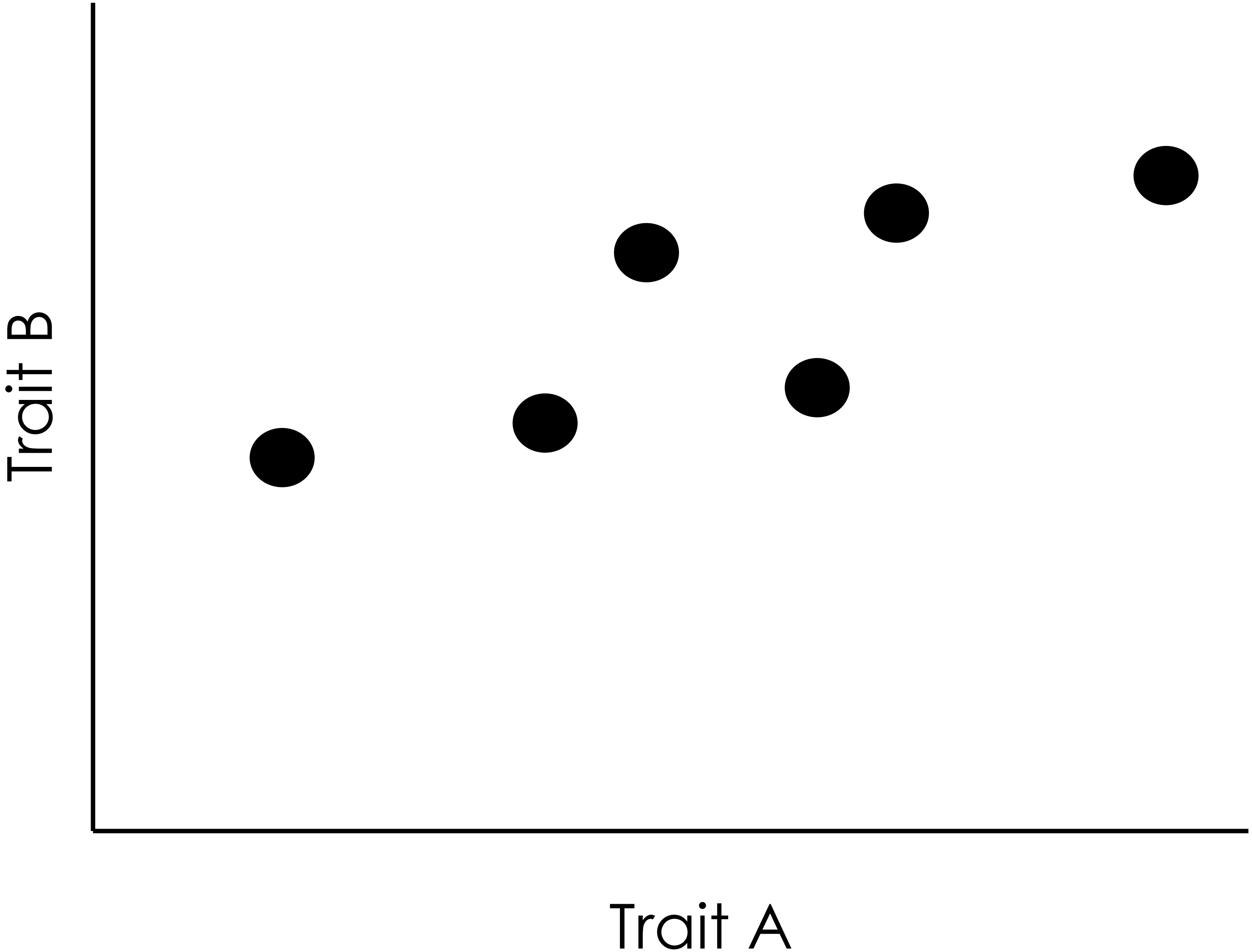

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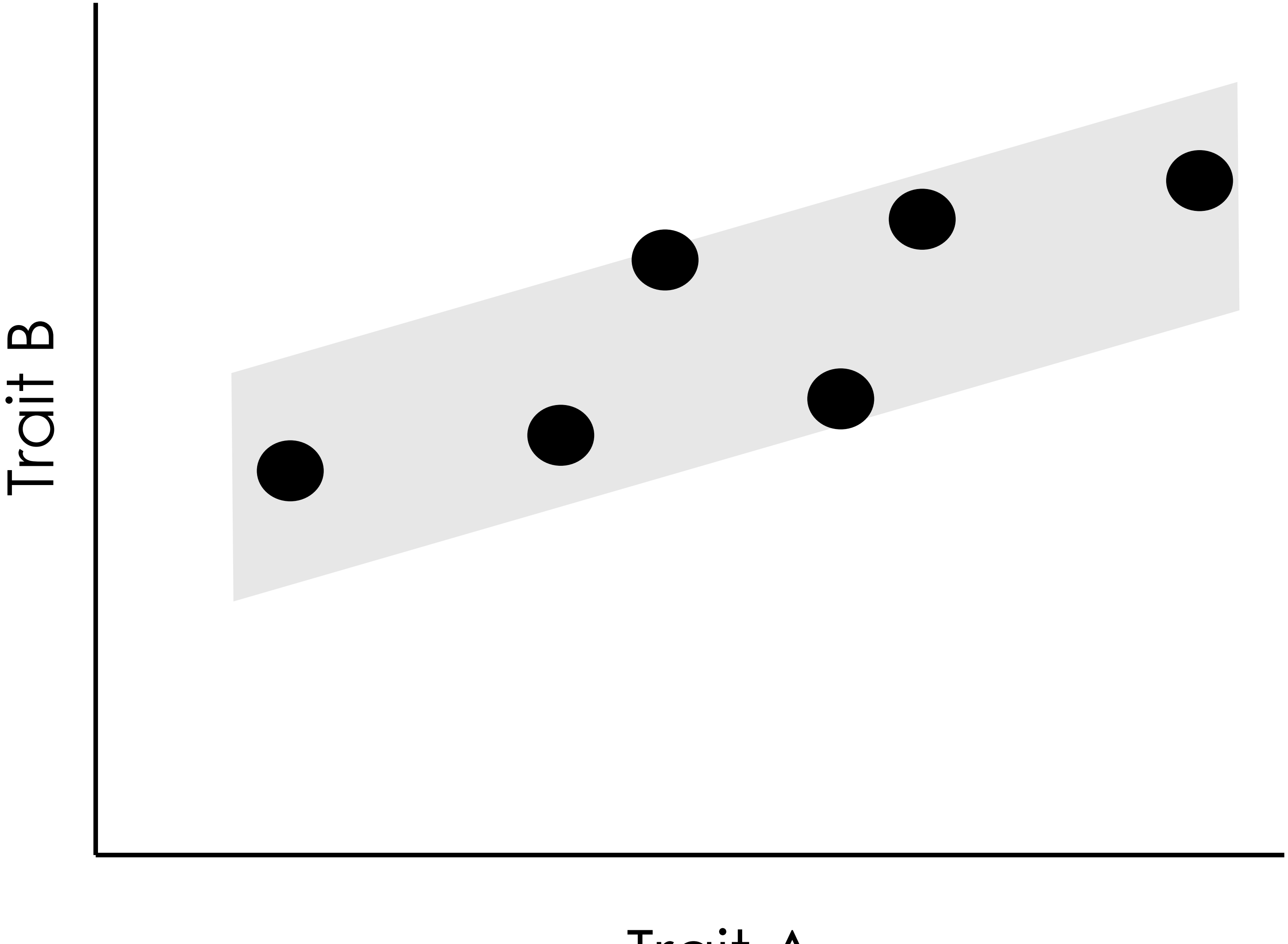

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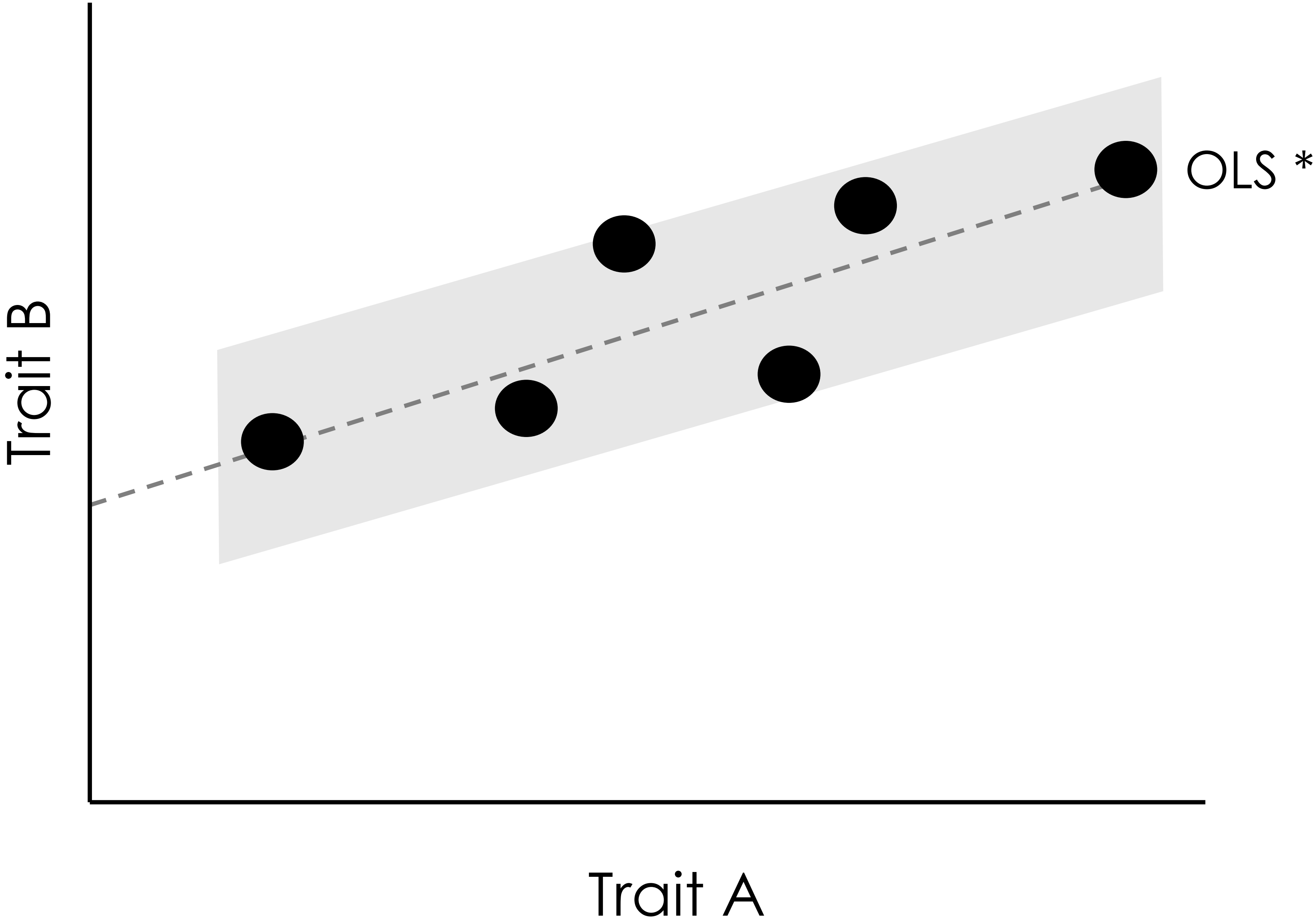

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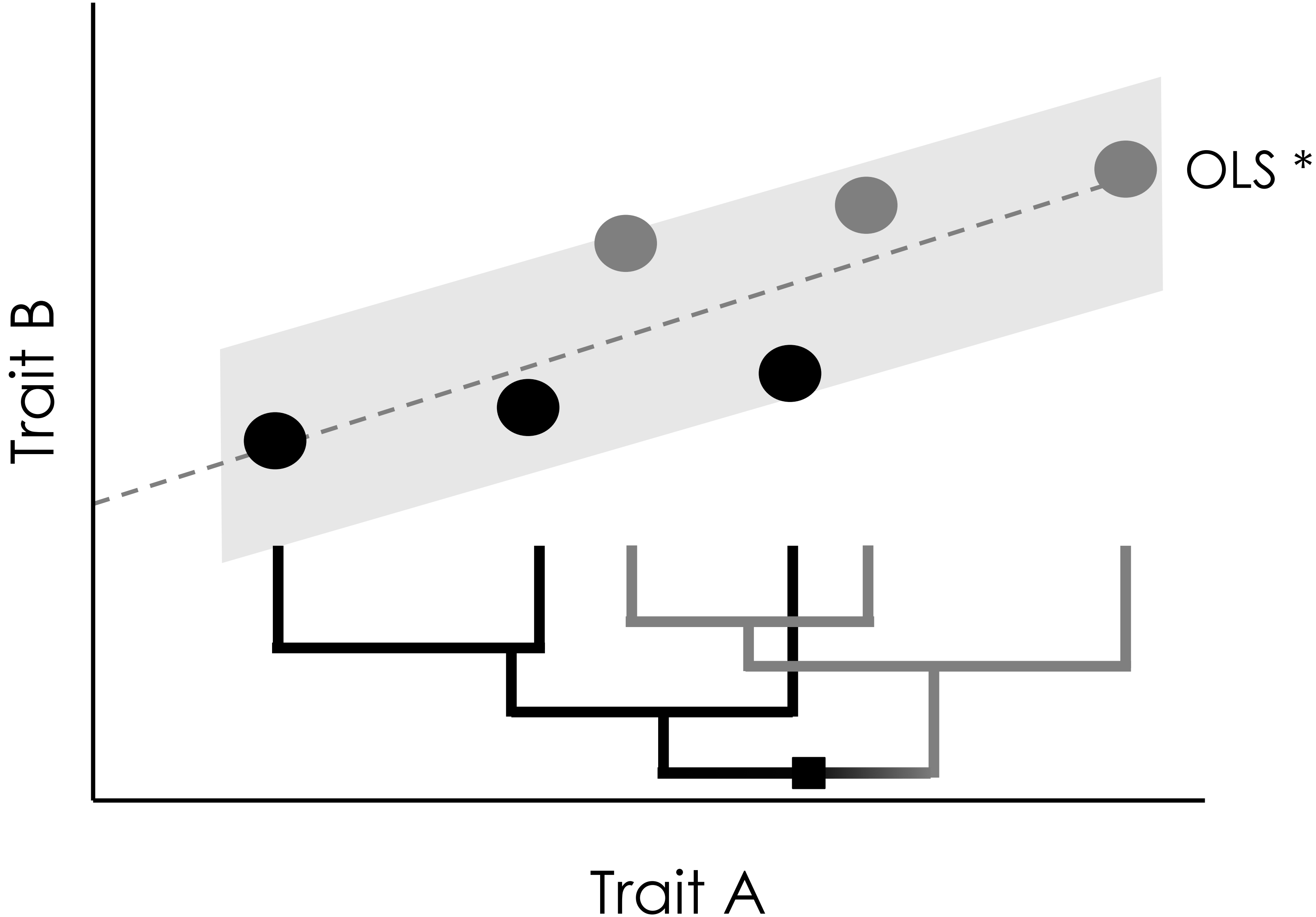

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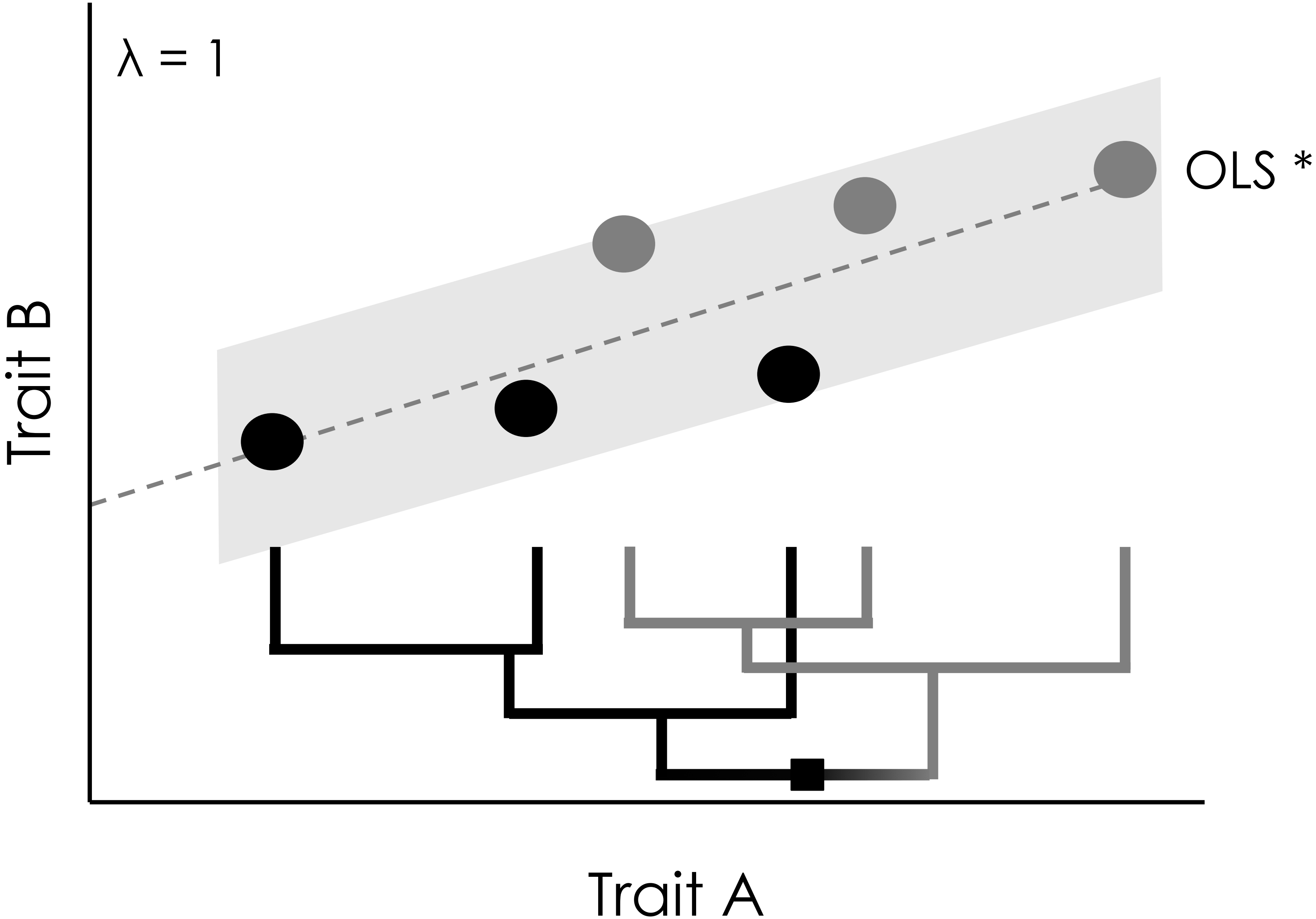

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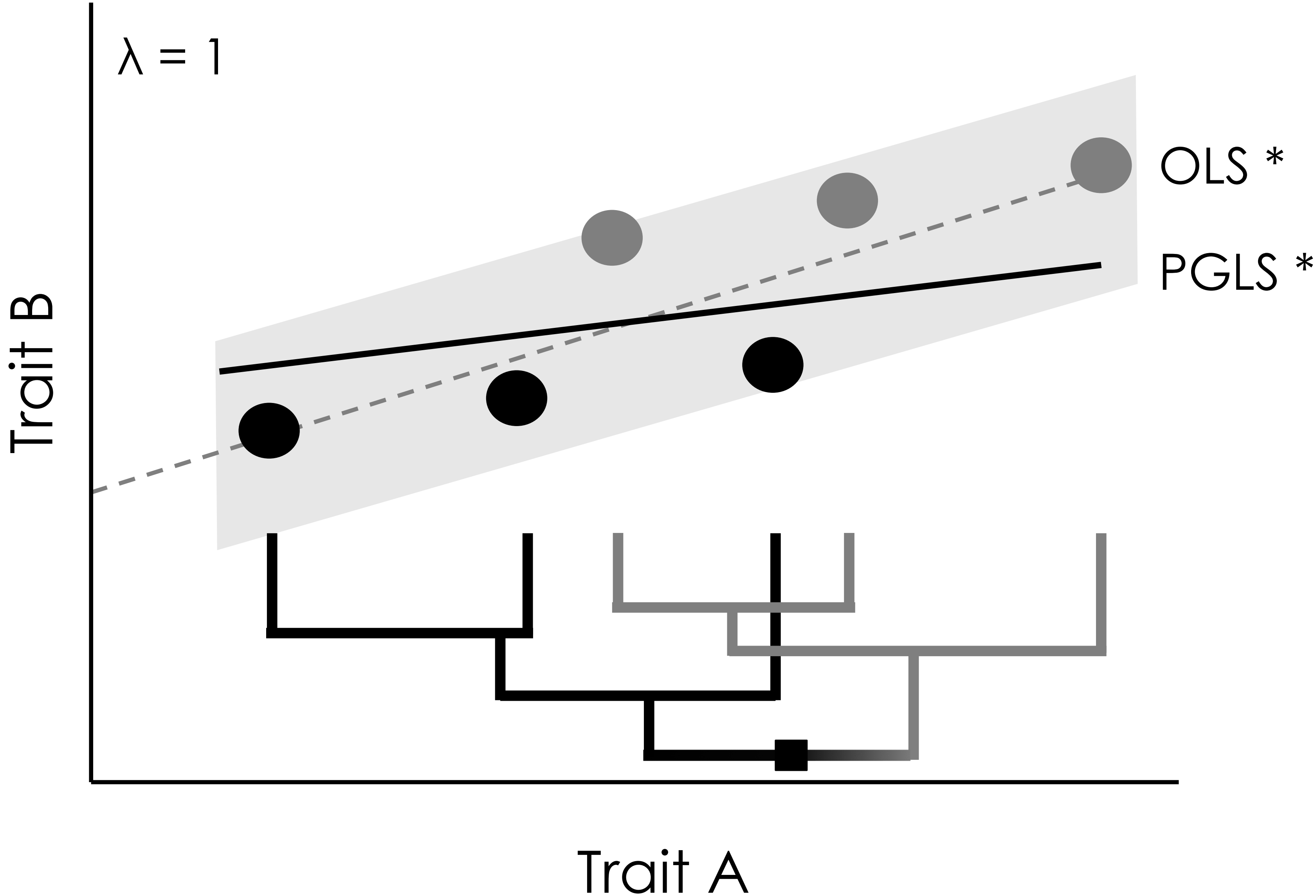

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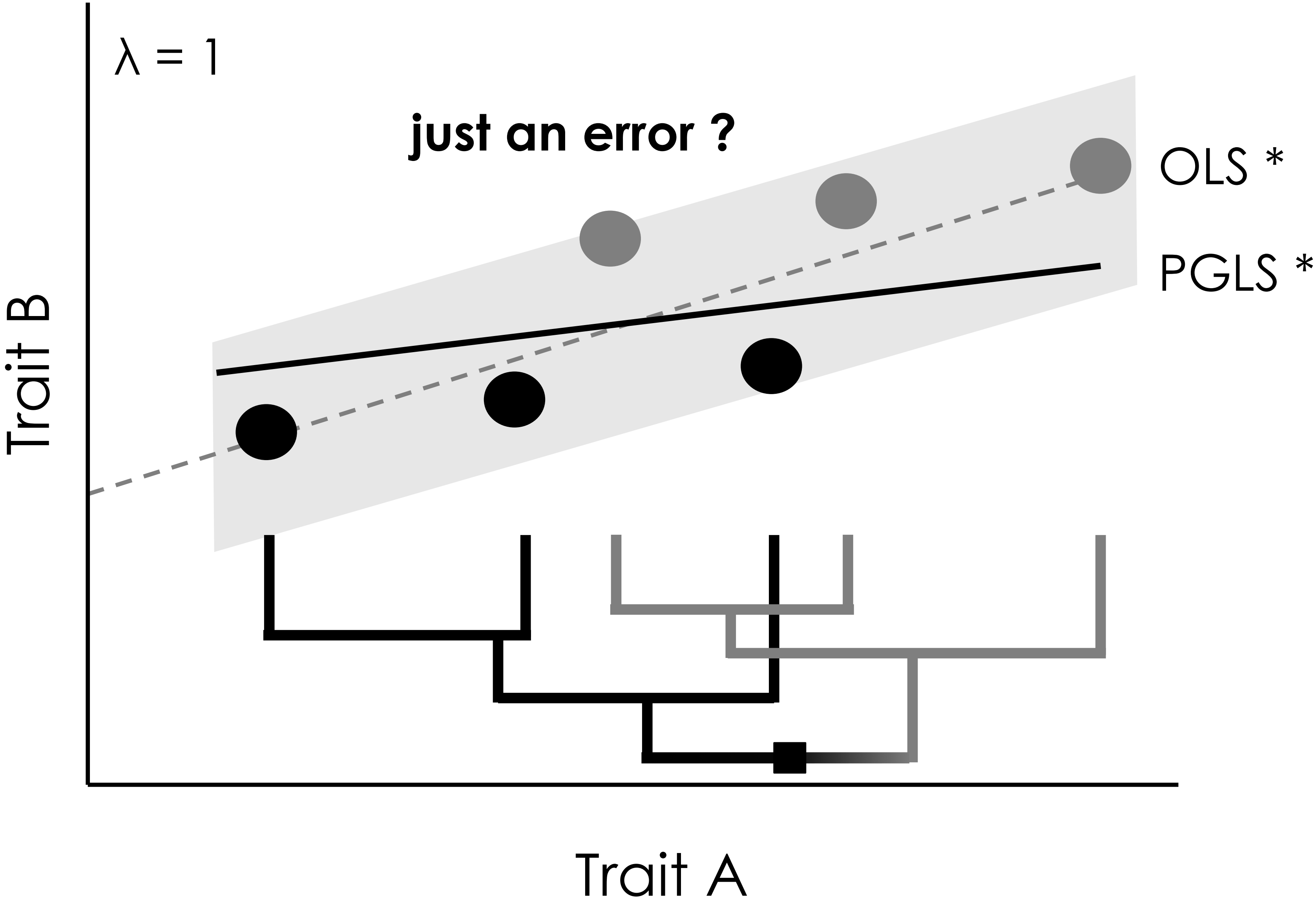

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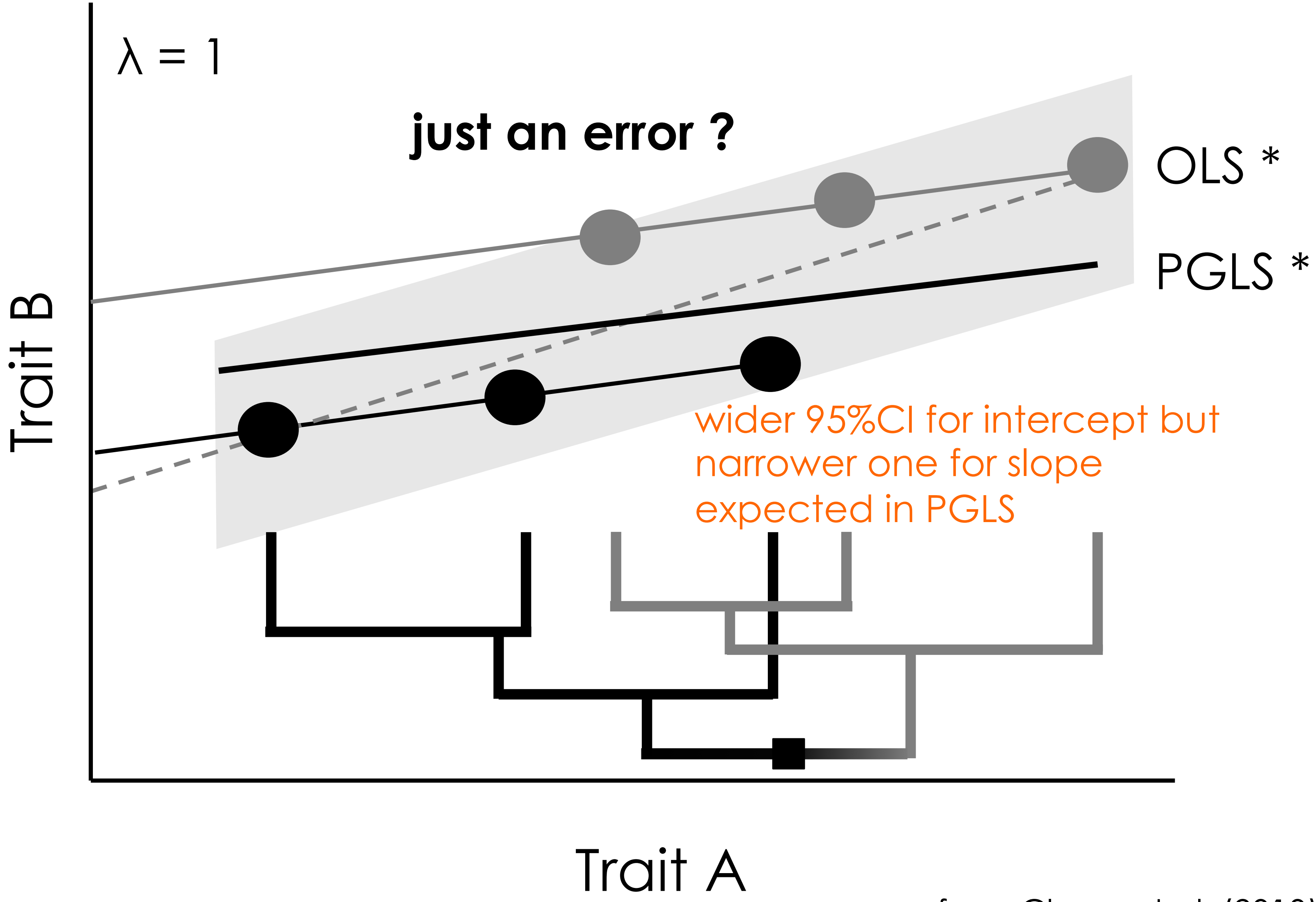

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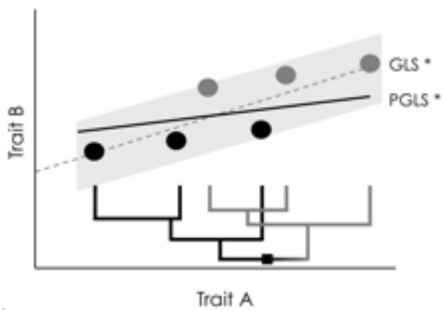

OLS: 21.5 (19.9-23.3) $BM^{0.19\ (0.18-0.20)}$

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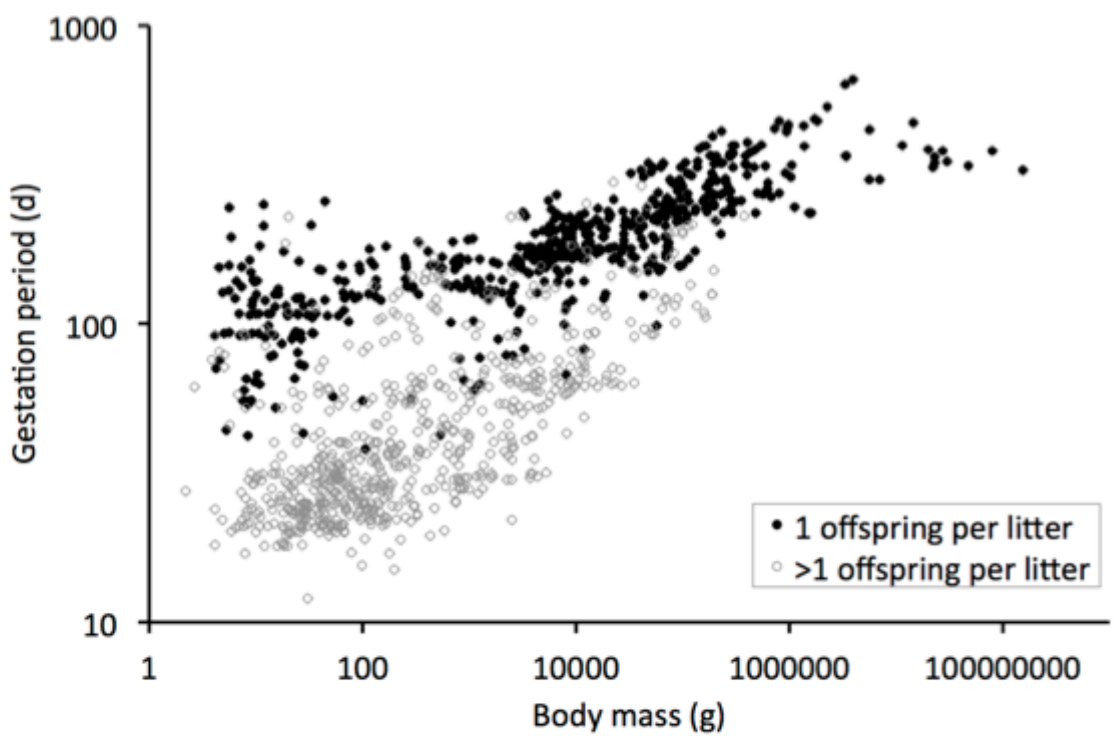

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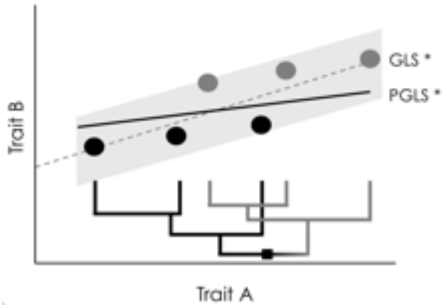

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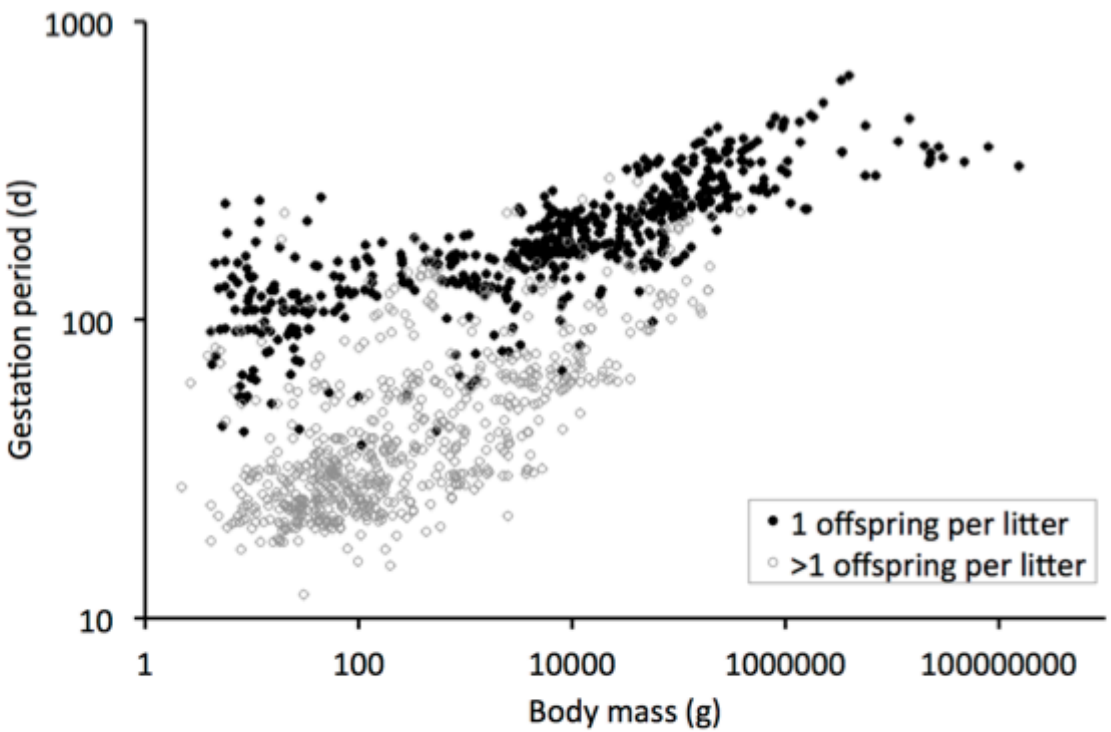

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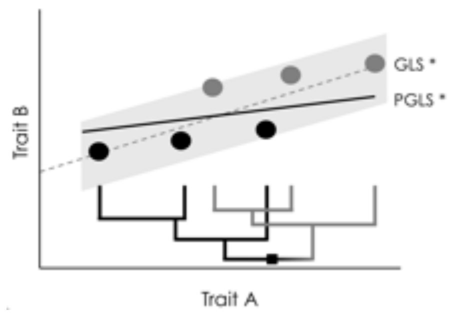

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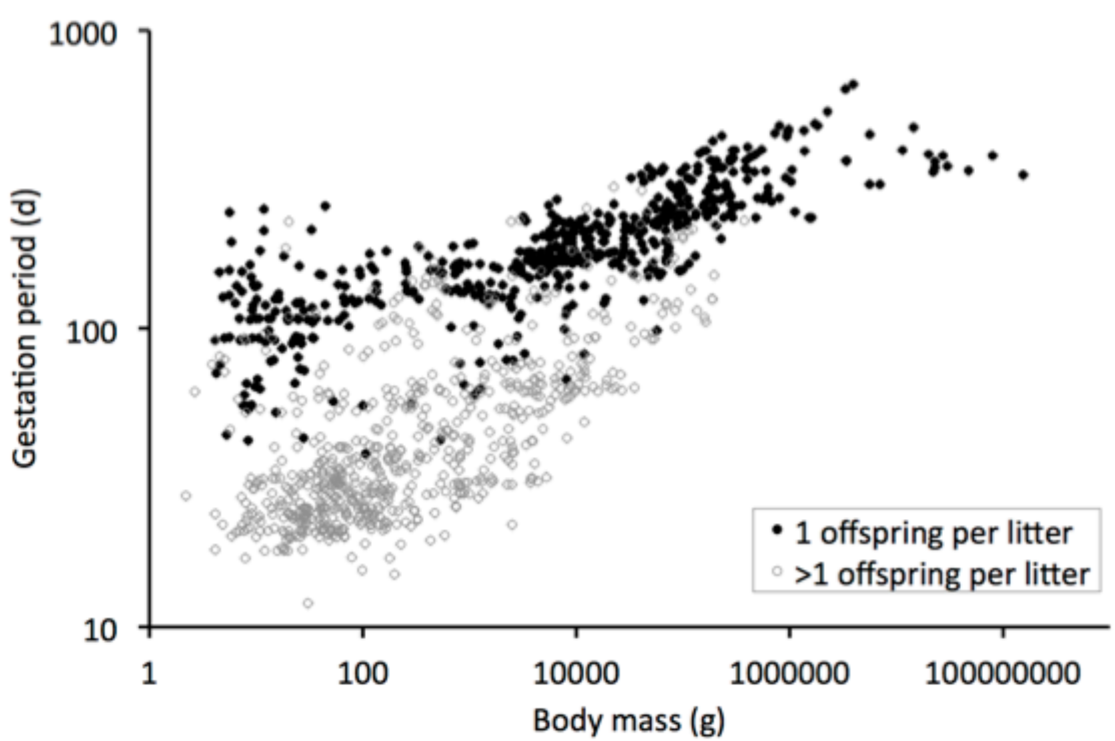

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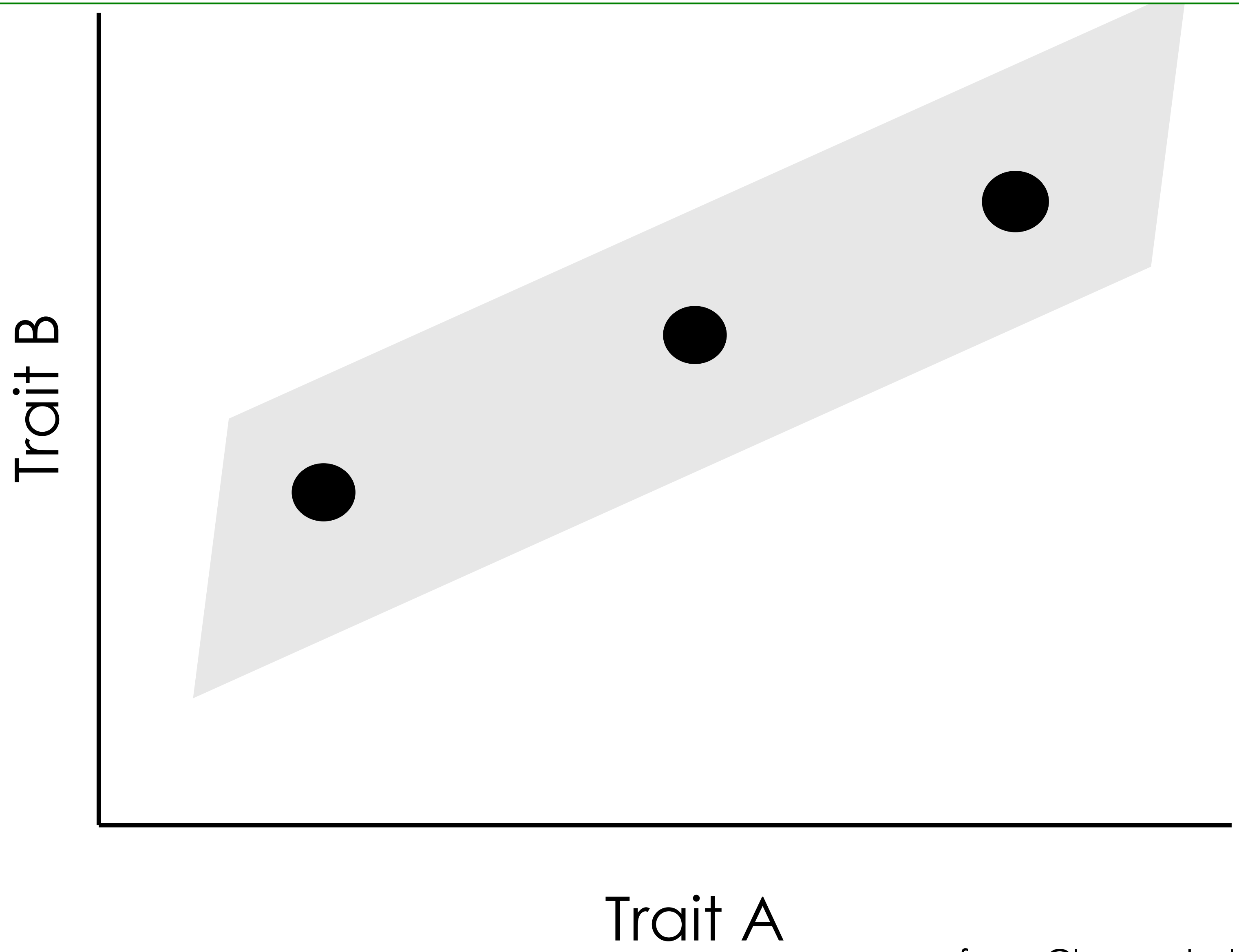

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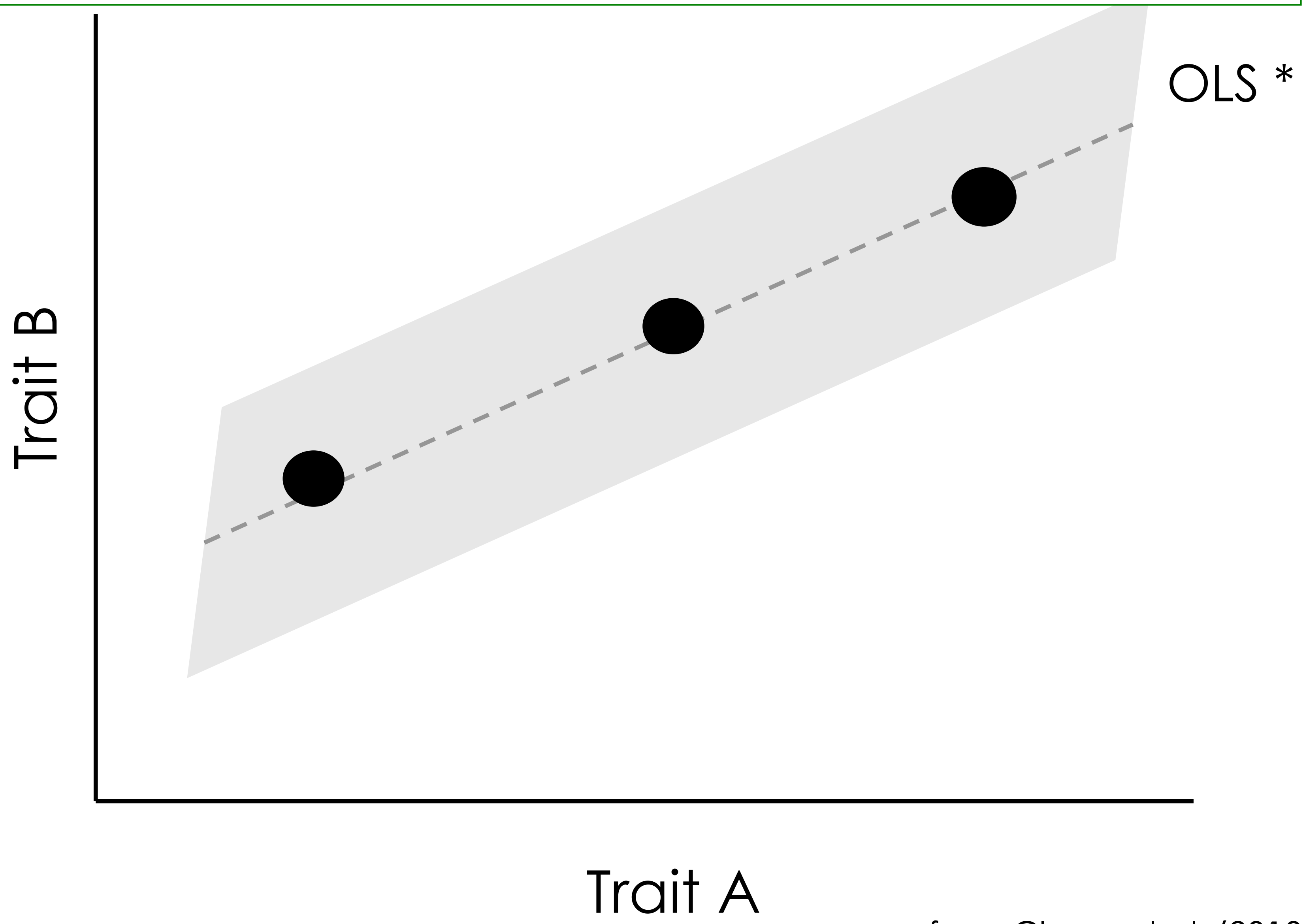

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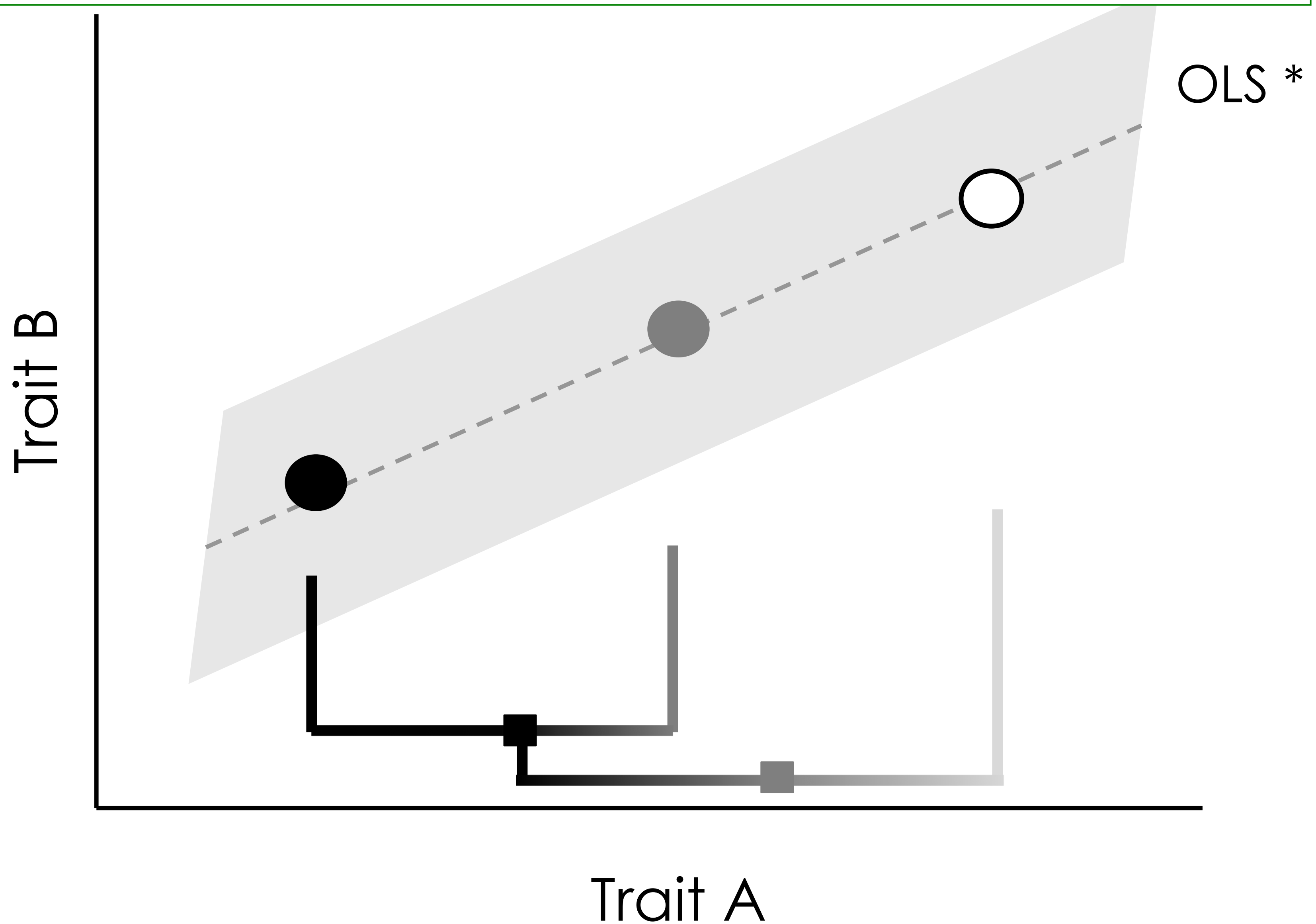

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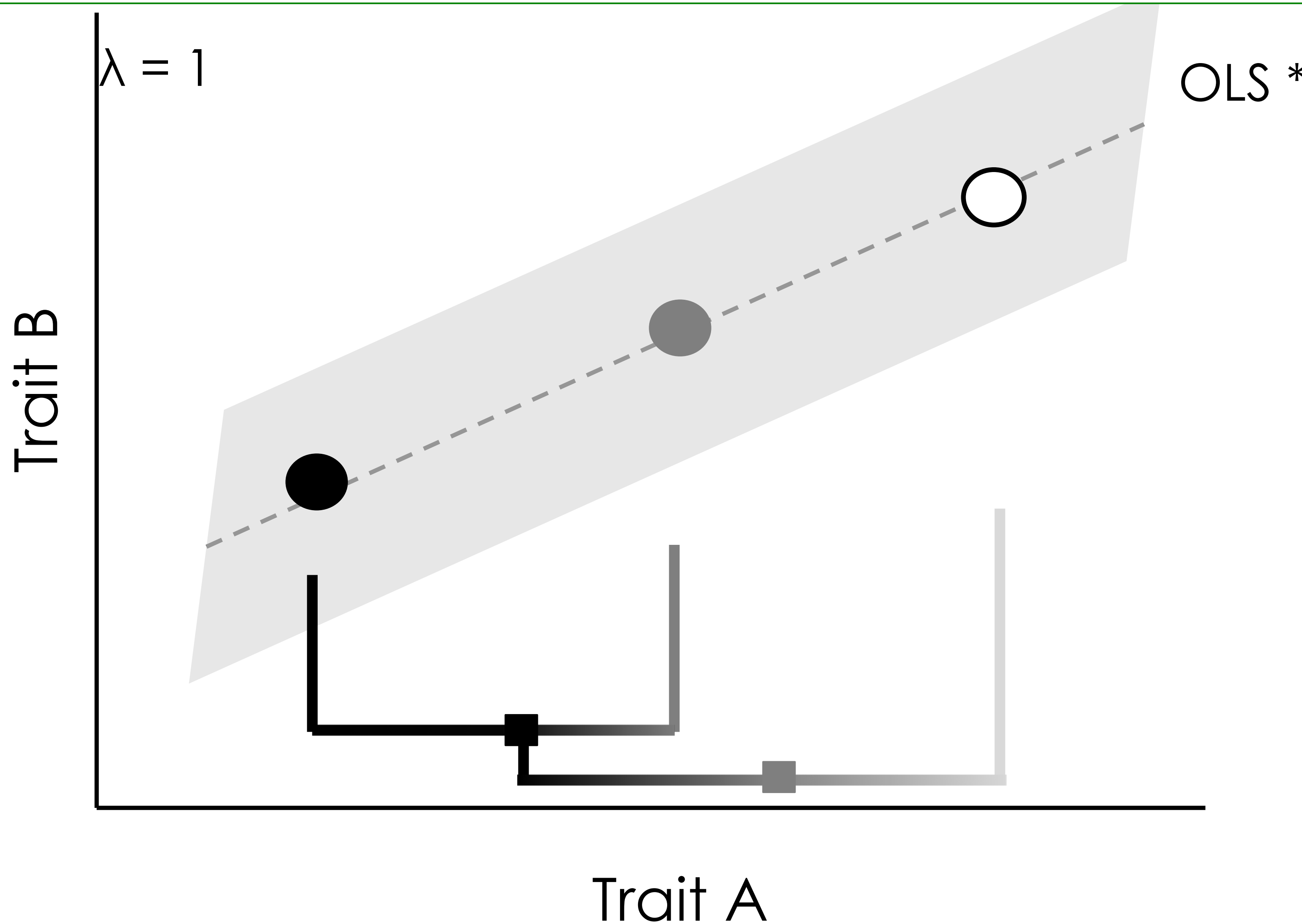

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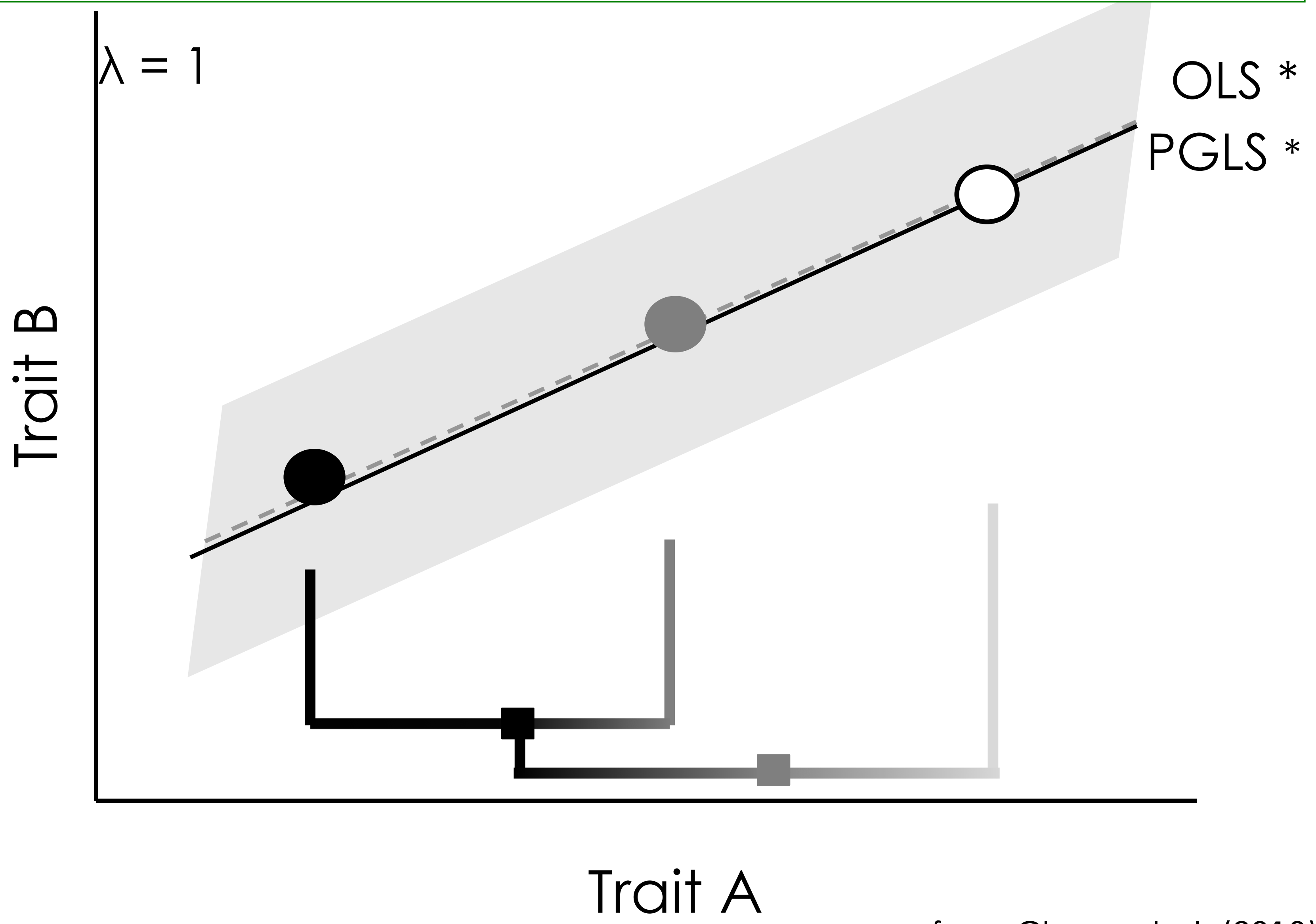

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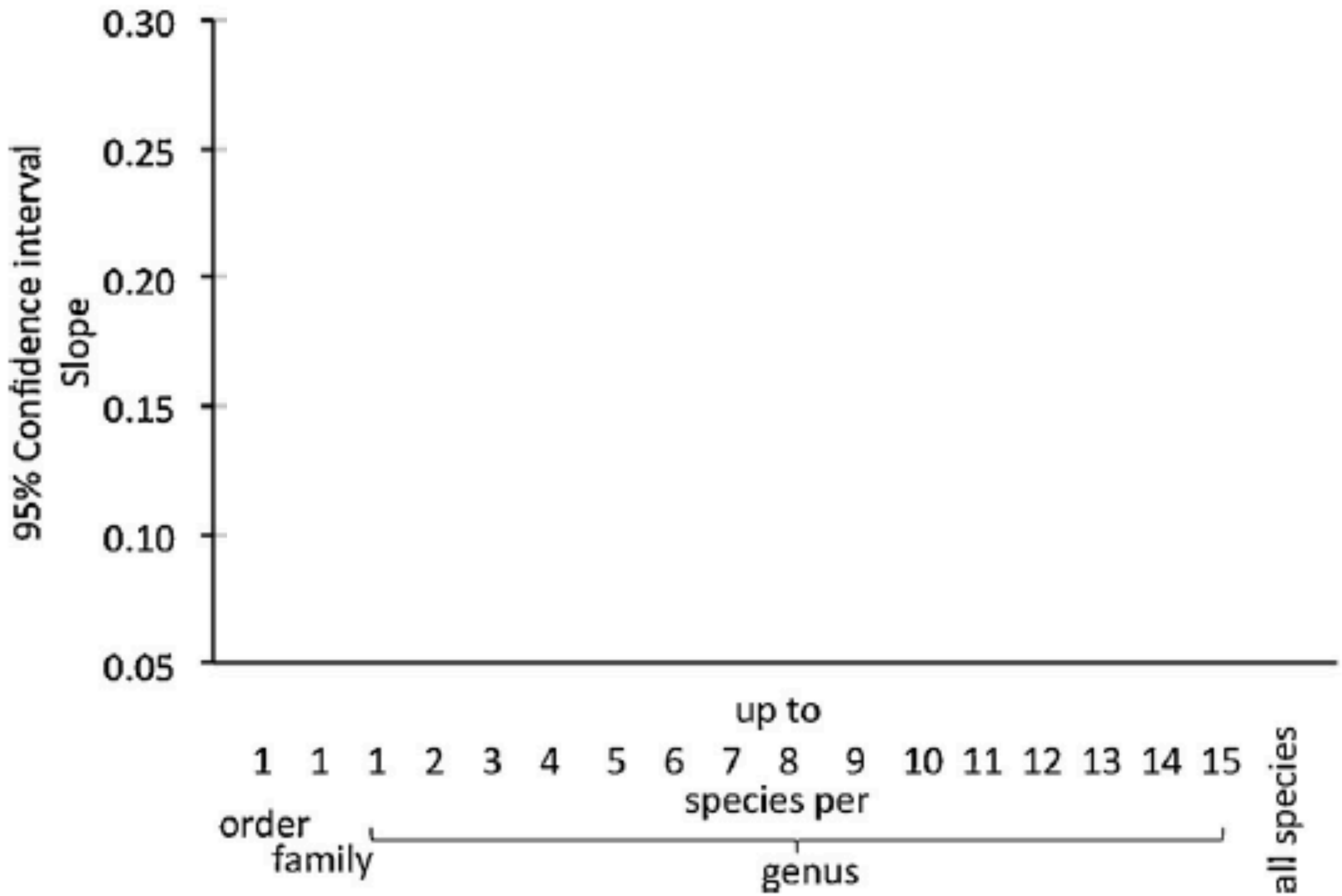
Low scaling of a life history variable: Analysing eutherian gestation periods with and without phylogeny-informed statistics

Marcus Clauss[a,*], Marie T. Dittmann[b], Dennis W.H. Müller[a,c], Philipp Zerbe[a,d], Daryl Codron[a,e]

Mammalian Biology 79 (2014) 9–16



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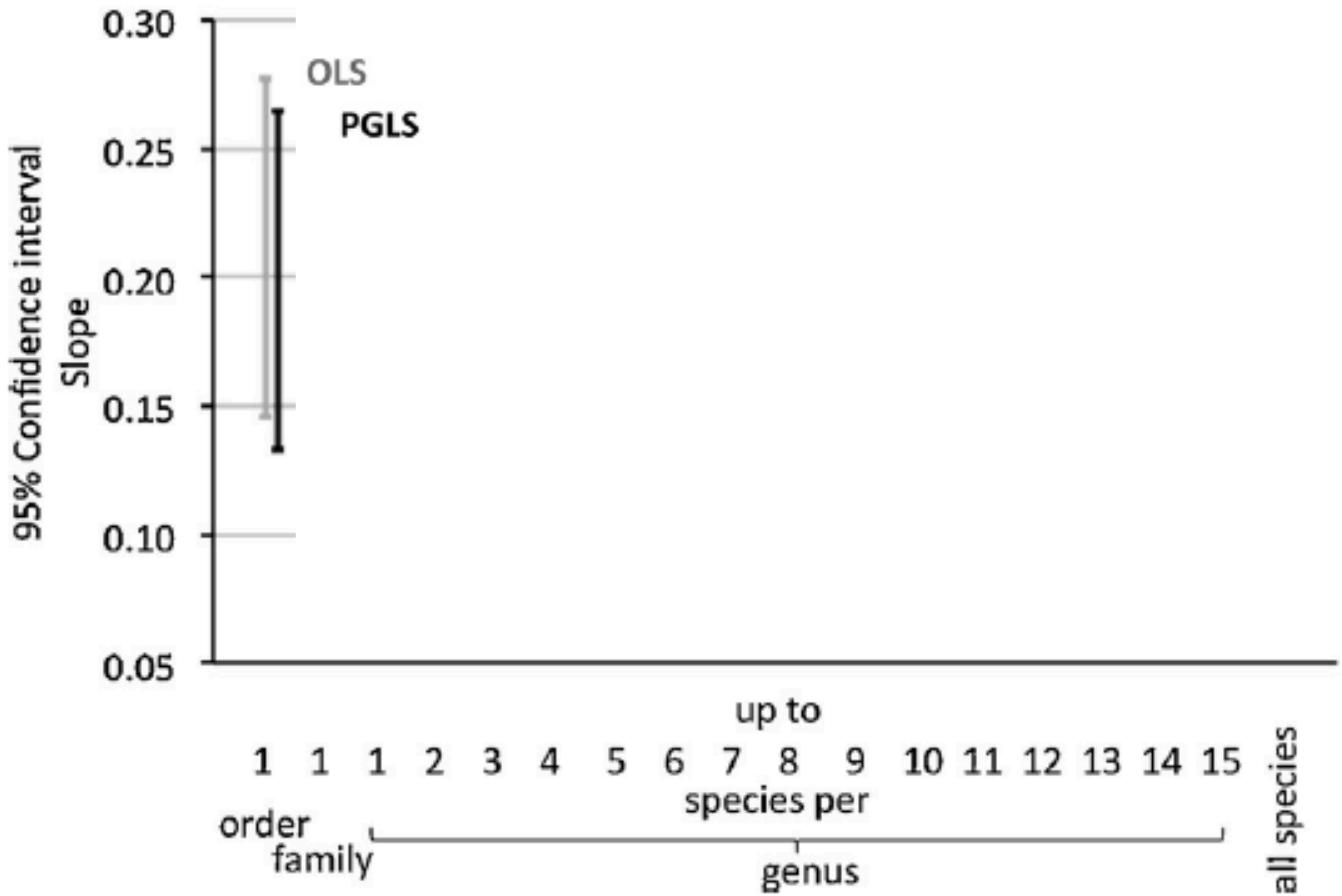

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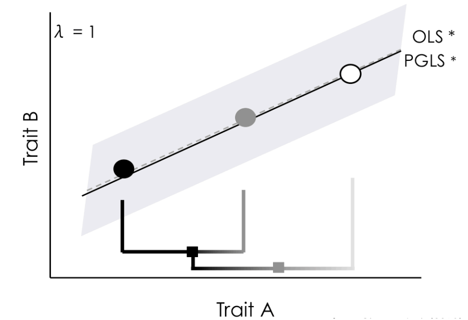

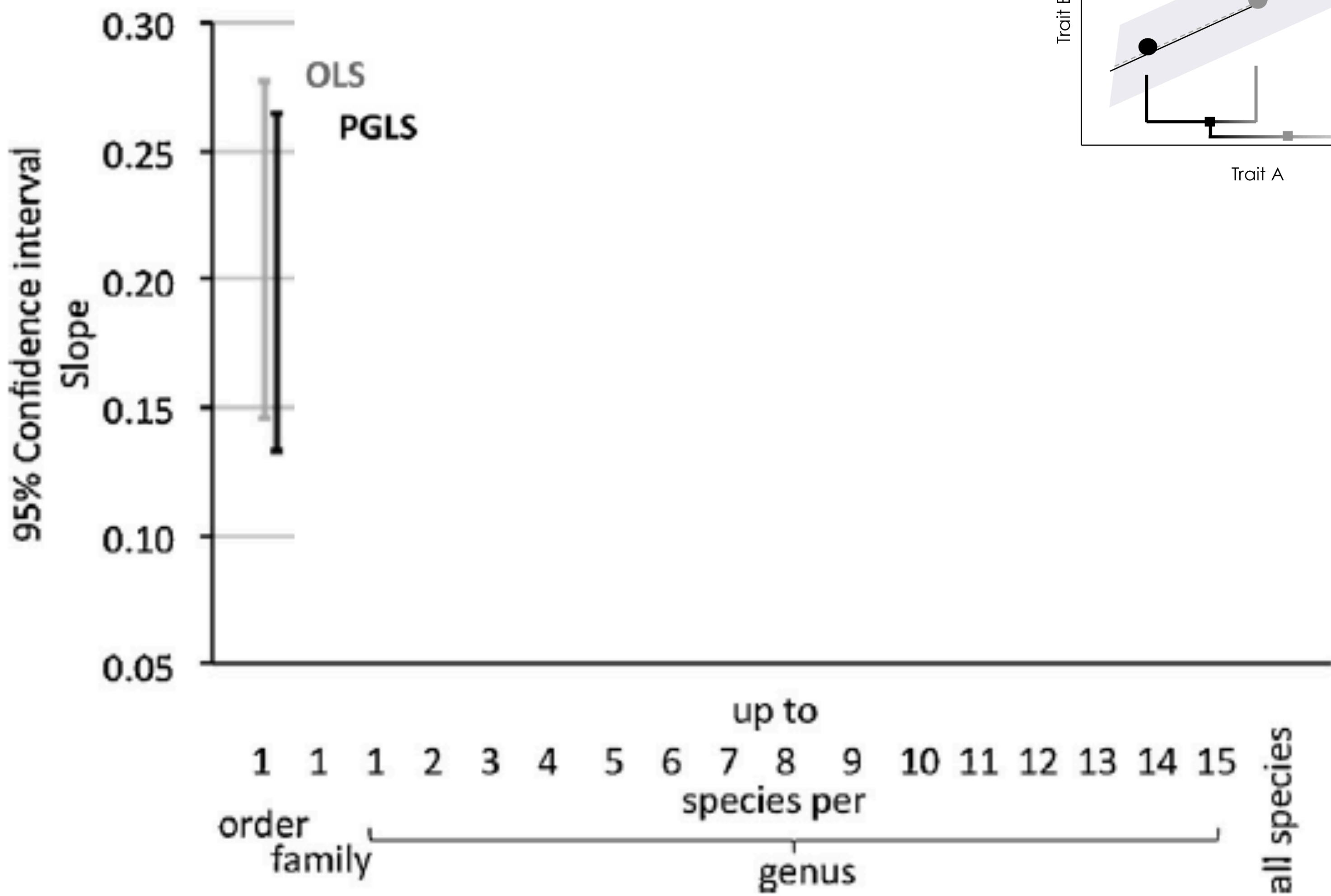

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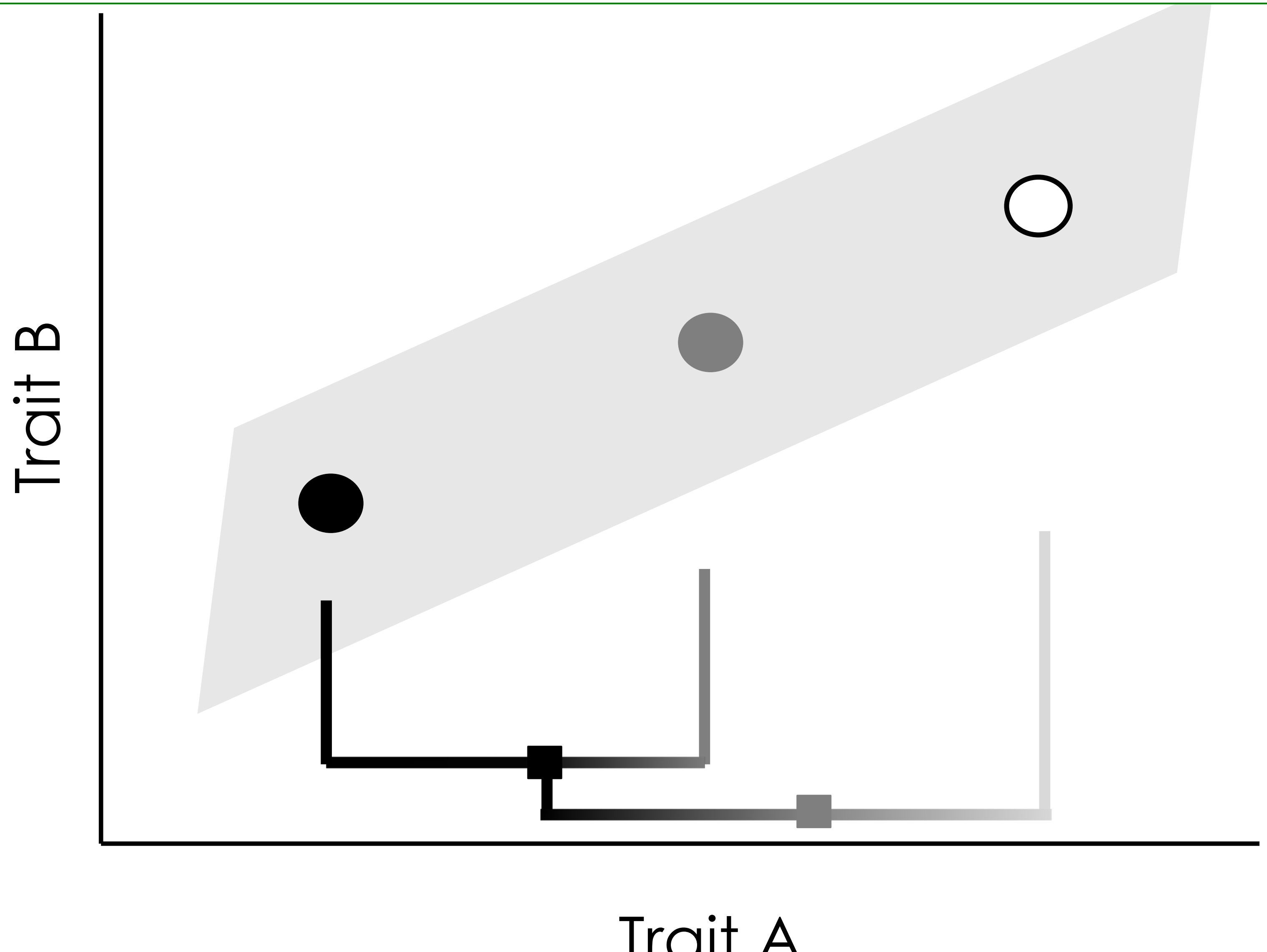

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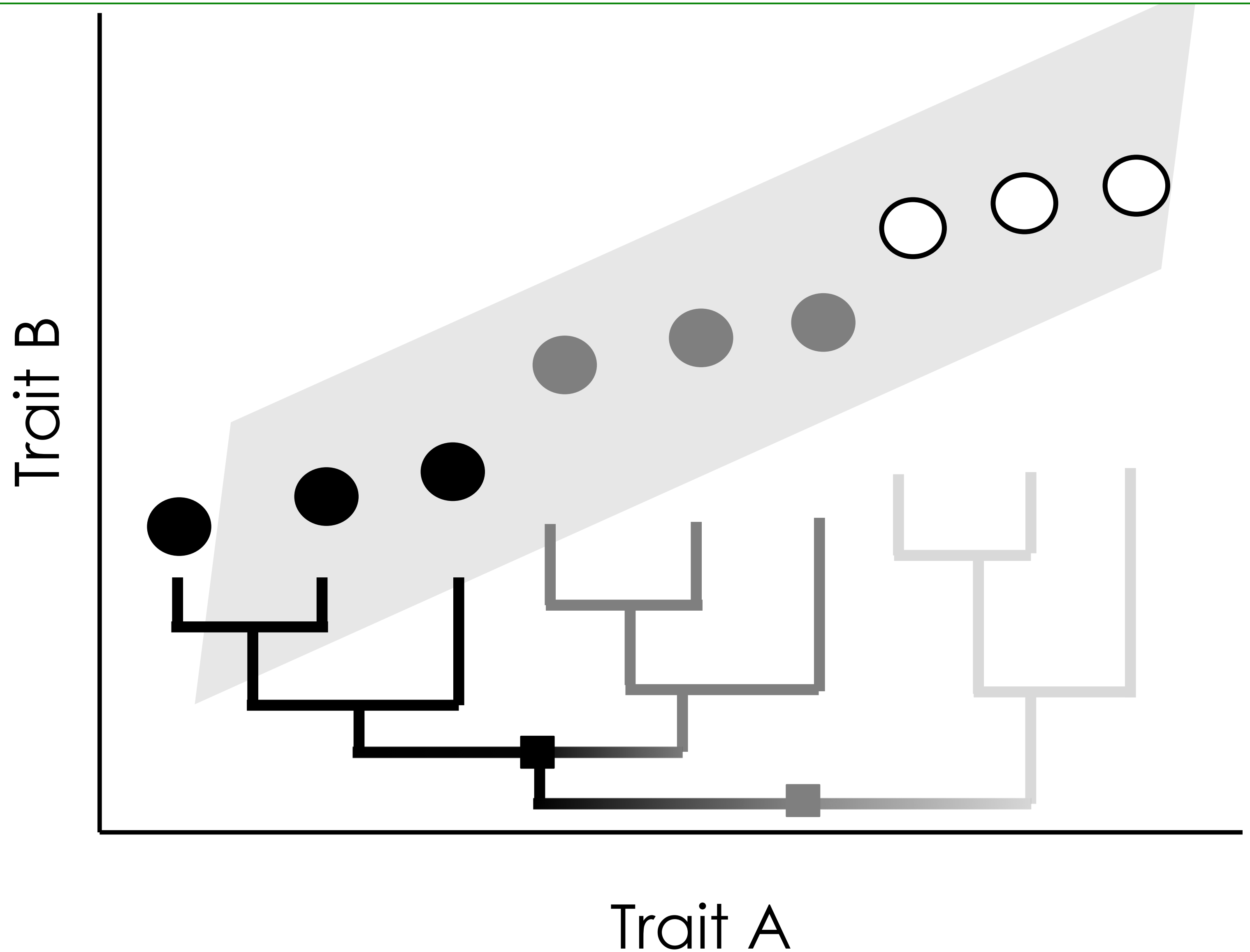

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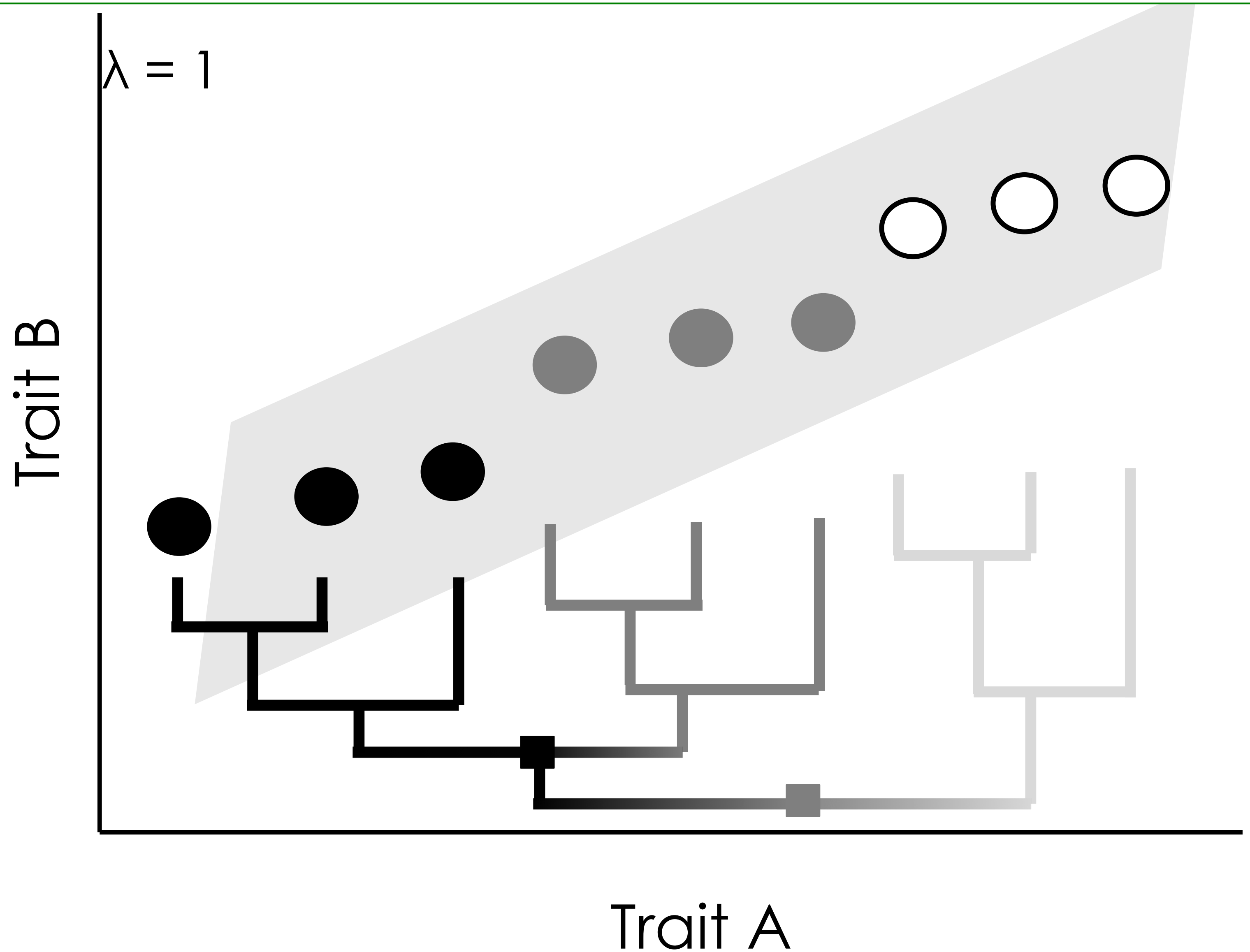

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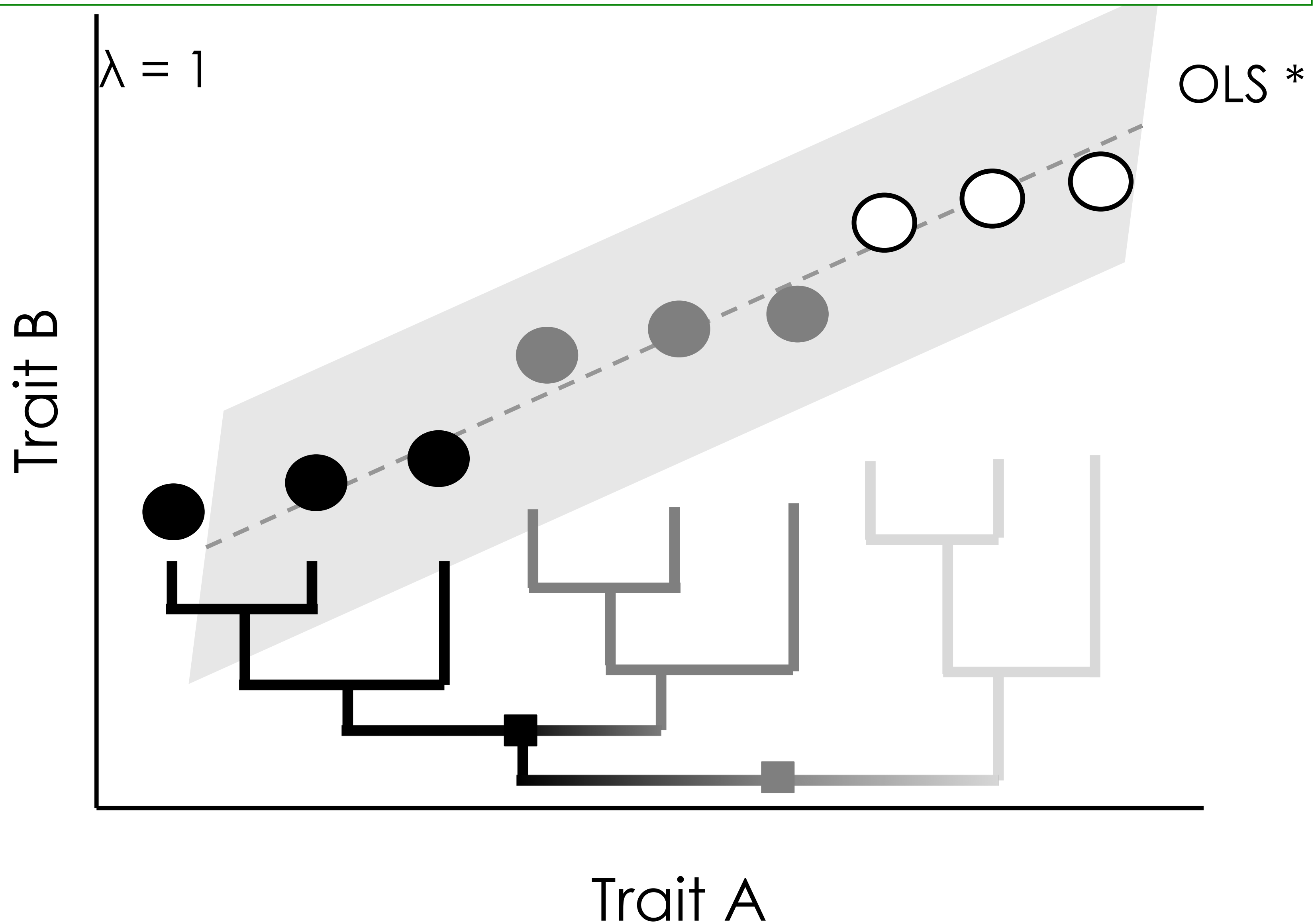

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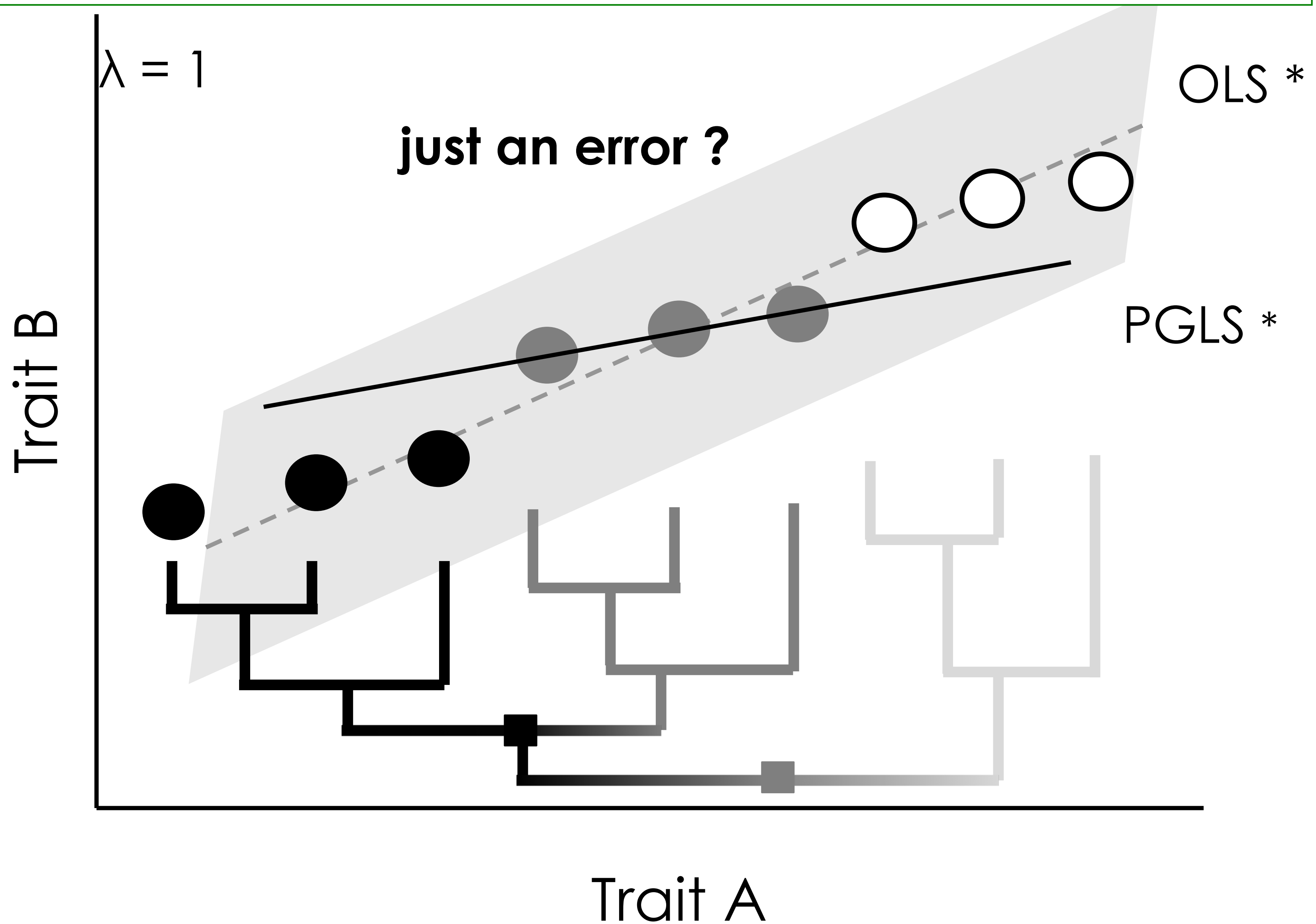

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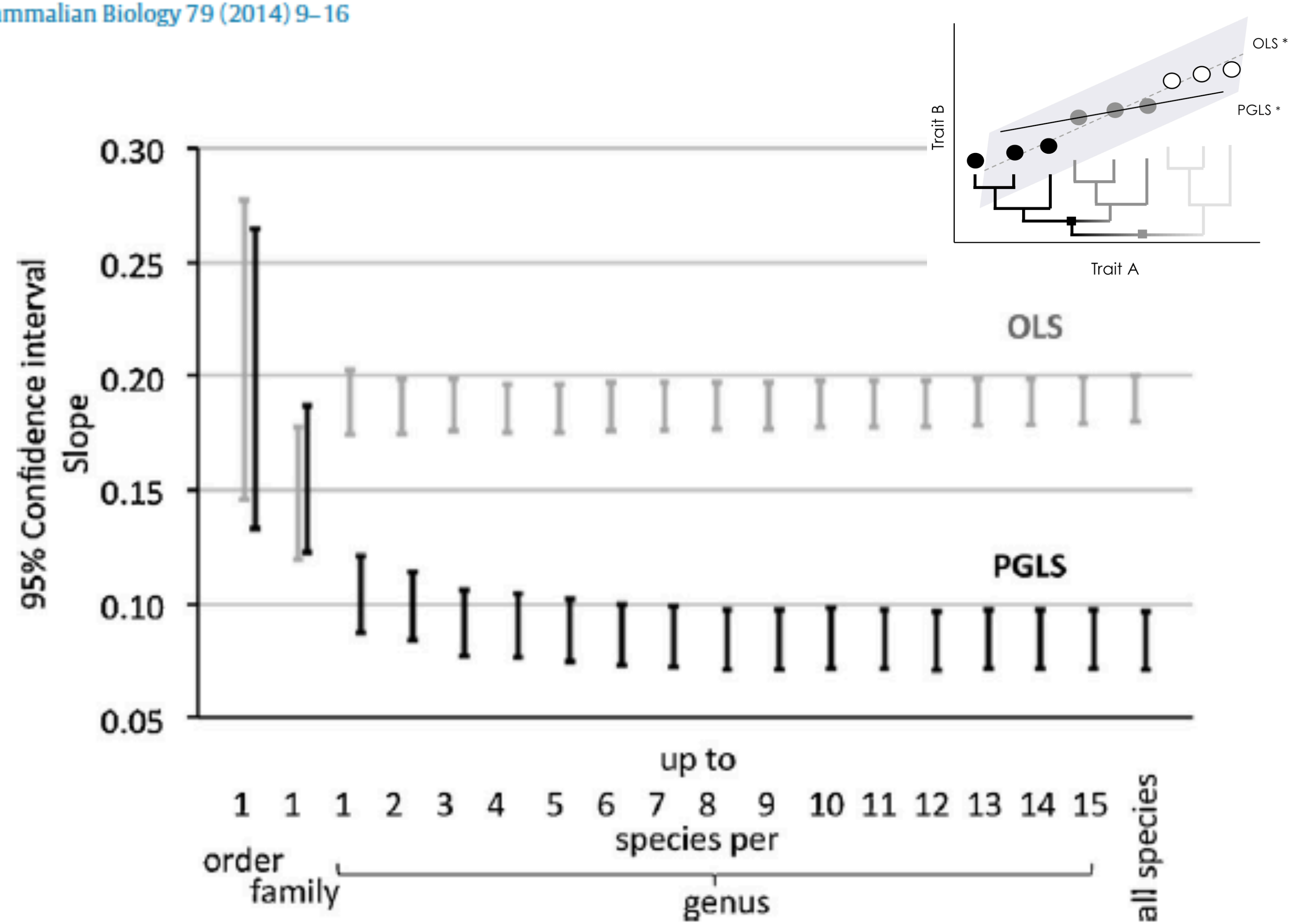

A deadly sin ?

REVIEW

The seven deadly sins of comparative analysis

R. P. FRECKLETON

J. EVOL. BIOL. **22** (2009) 1367–1375

Reporting both PI and PC analyses

Frequently, both across-species and phylogenetically corrected analyses of the same data are reported simultaneously. This is despite the fact that the two forms of analysis make very different assumptions about the distribution of the data.

A deadly sin ? – ***No !***

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Reporting both PI and PC analyses

~~Frequently, both across-species and phylogenetically corrected analyses of the same data are reported simultaneously. This is despite the fact that the two forms of analysis make very different assumptions about the distribution of the data.~~

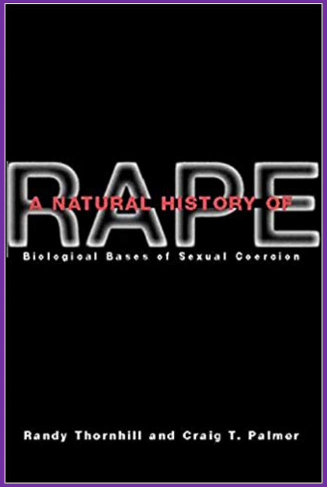
A comparison of OLS and PGLS results is an important tool for understanding the structure of the data! (irrespective of which is the ‘correct’ one) ***because the two make very different assumptions about the data***

Directionality in Evolution:

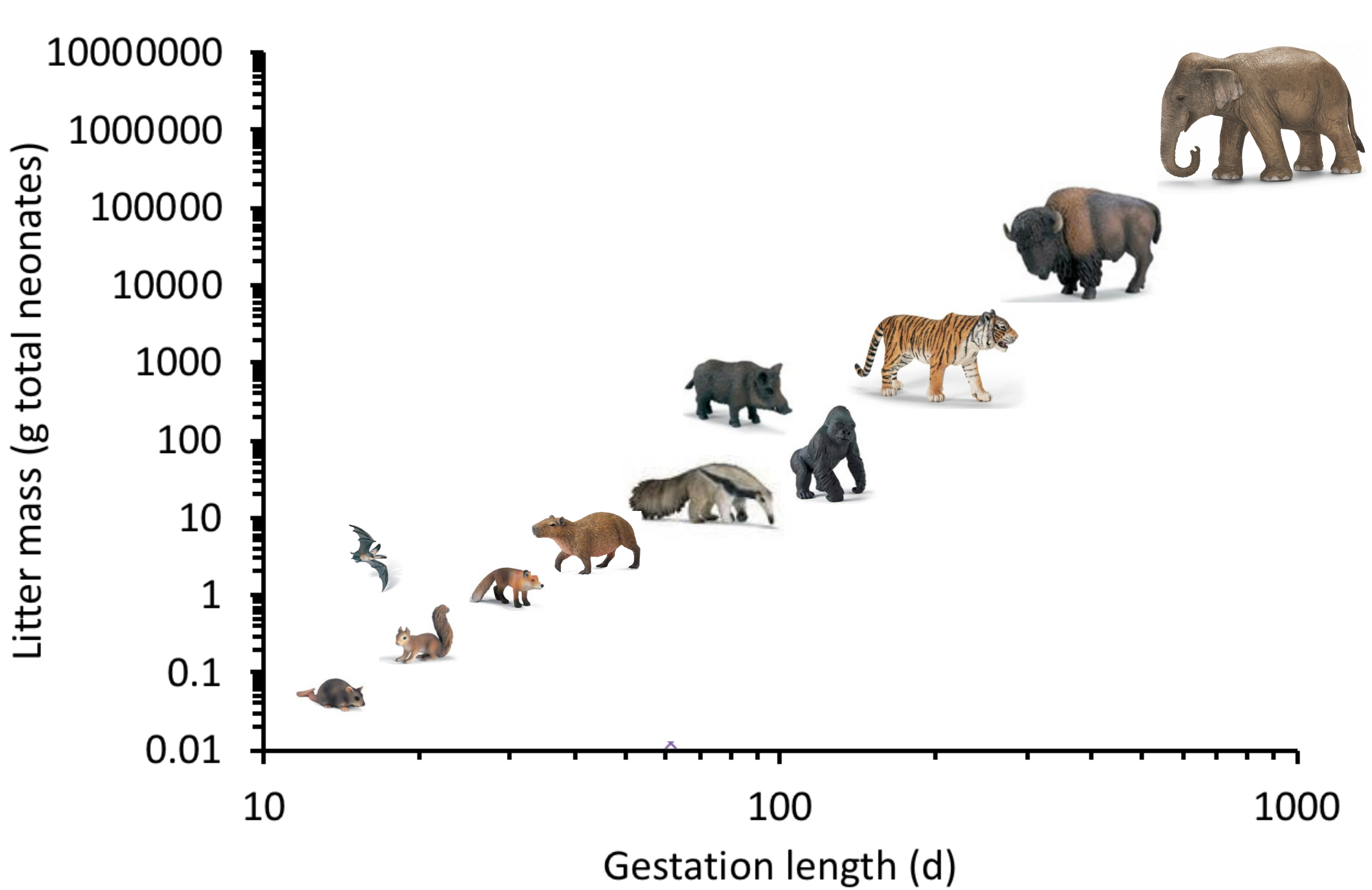
Allometries as snapshots in evolutionary time

Directionality in Evolution:

beware of the *natural fallacy*



Biology: fixed laws ?



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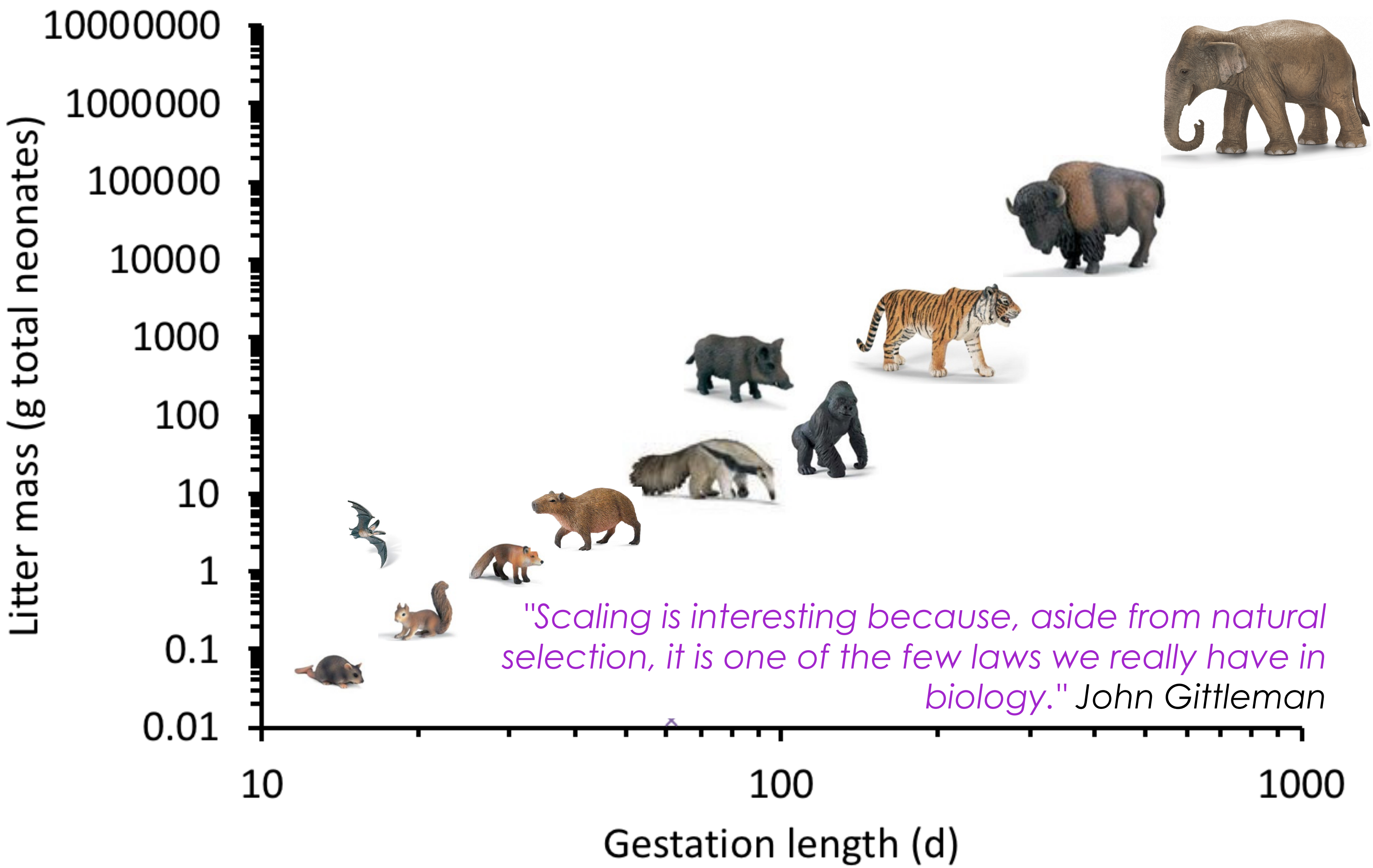
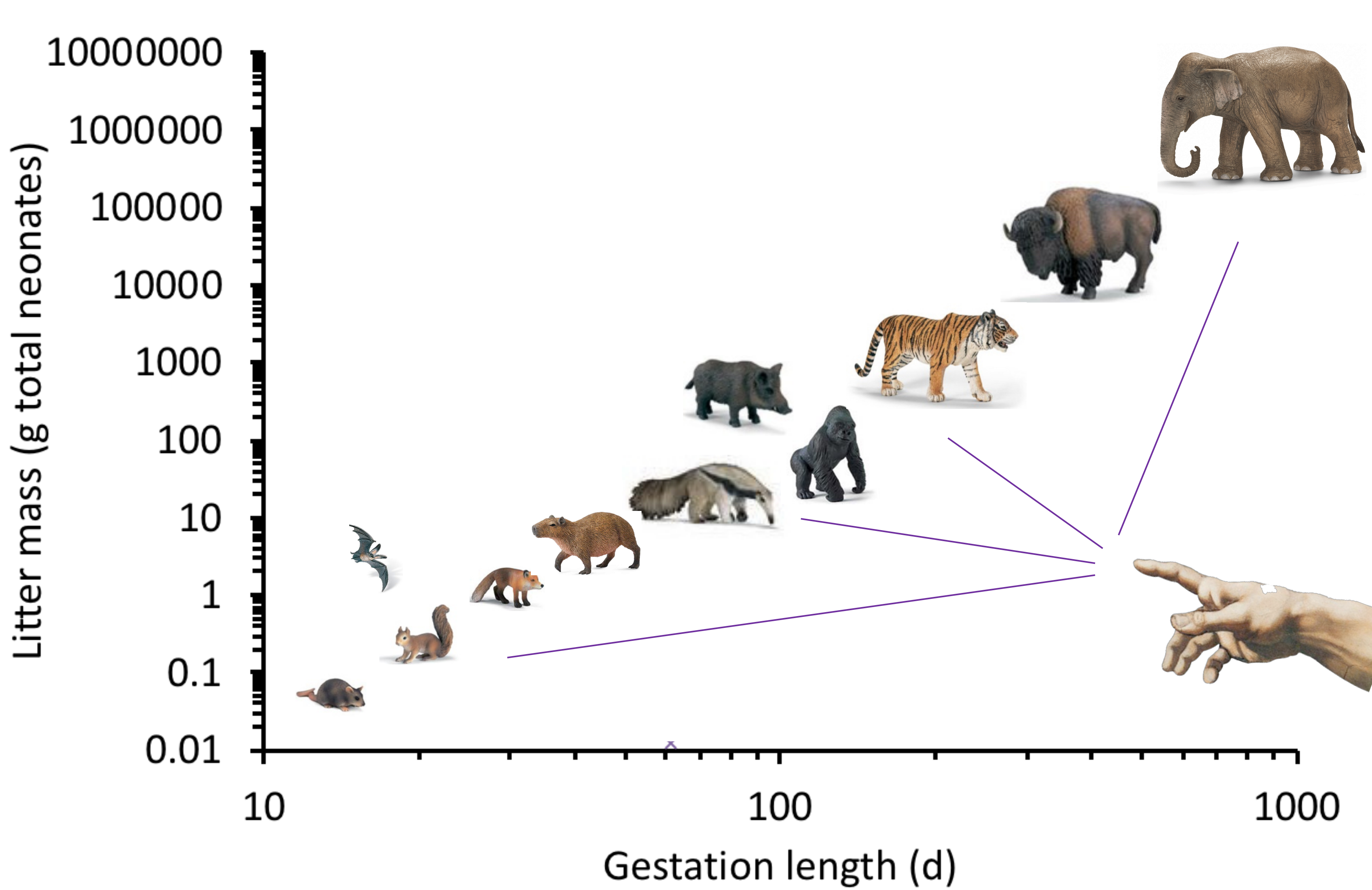


"Scaling is interesting because, aside from natural selection, it is one of the few laws we really have in biology." John Gittleman

Biology: fixed laws ?



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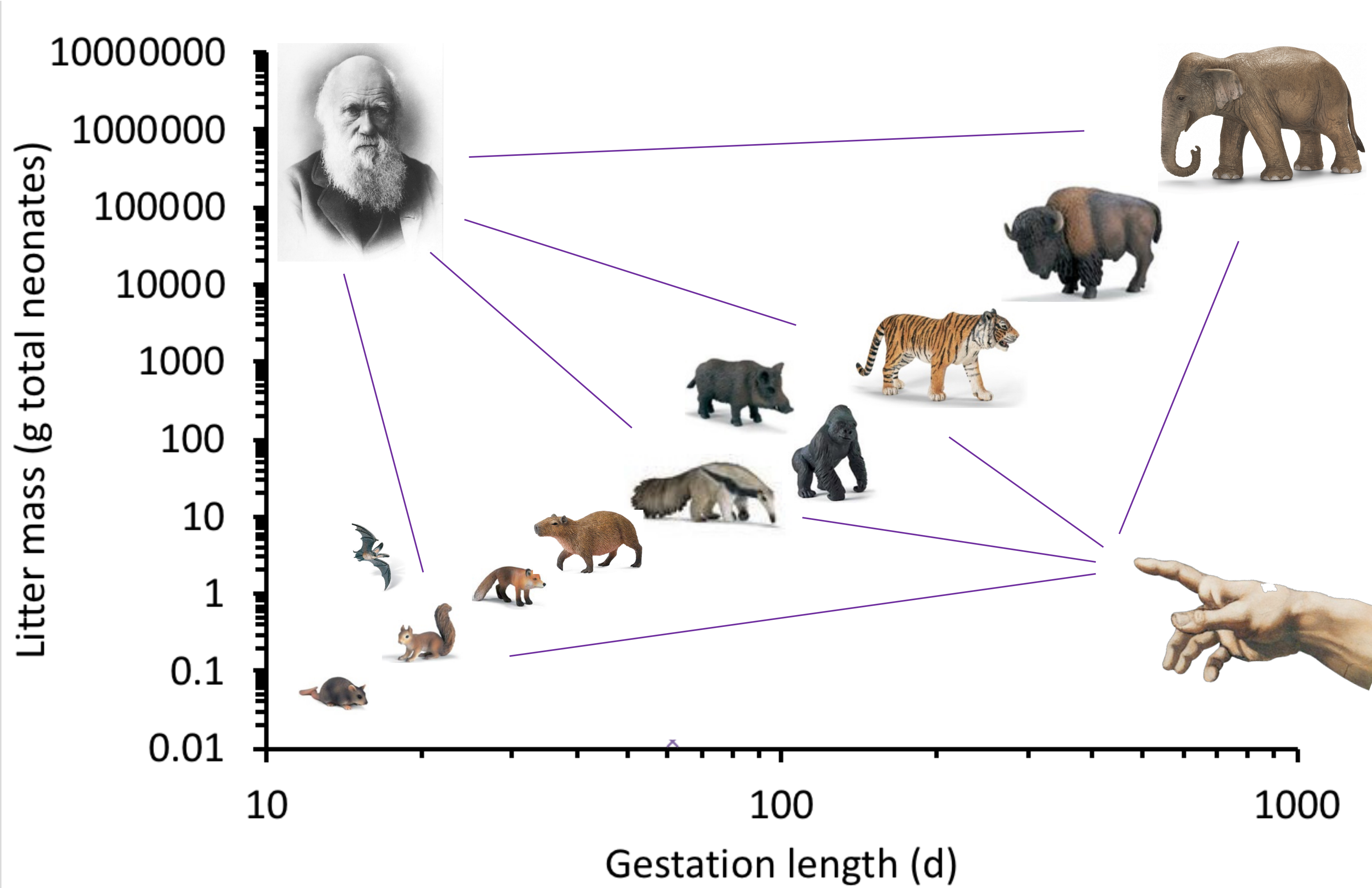
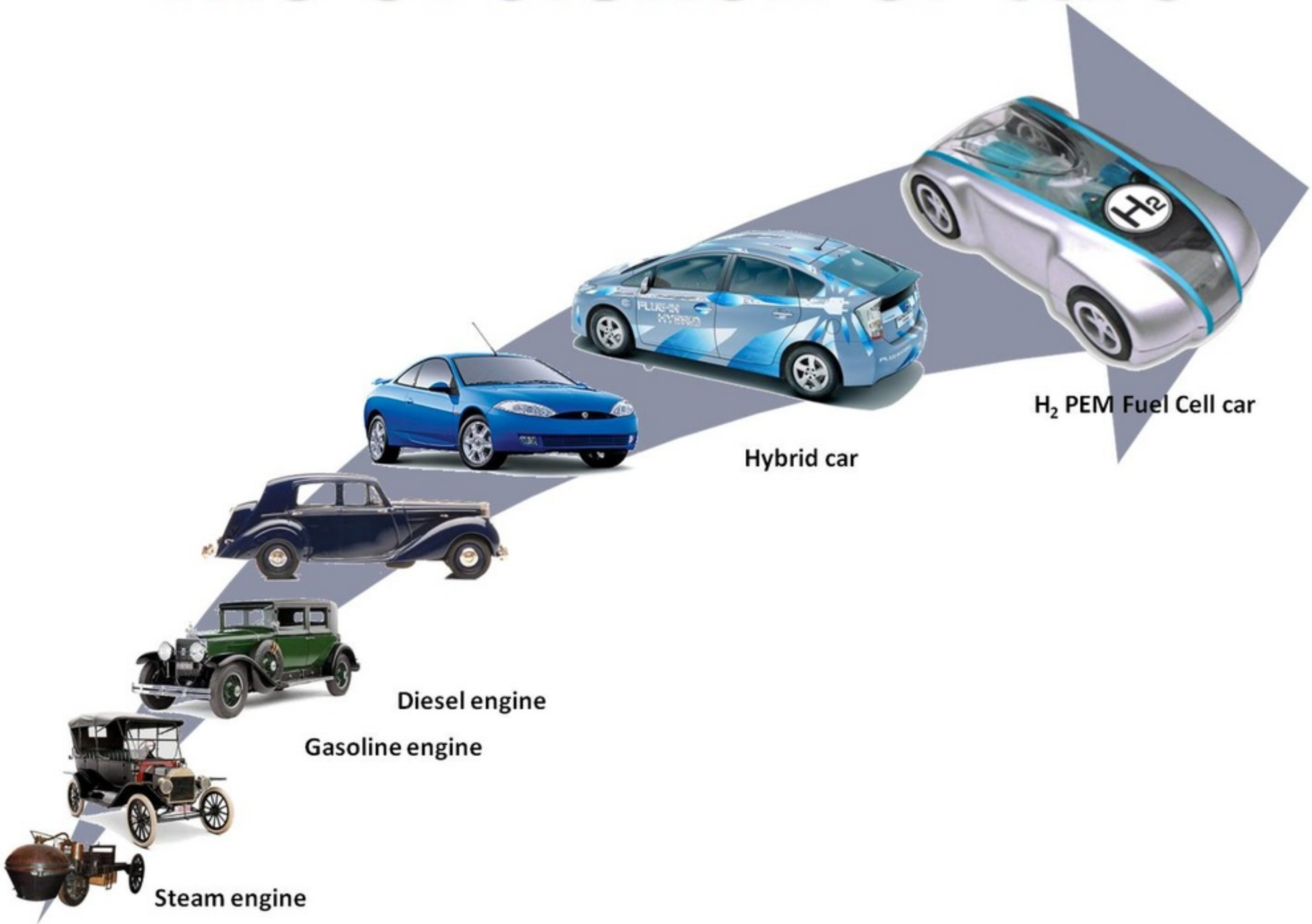


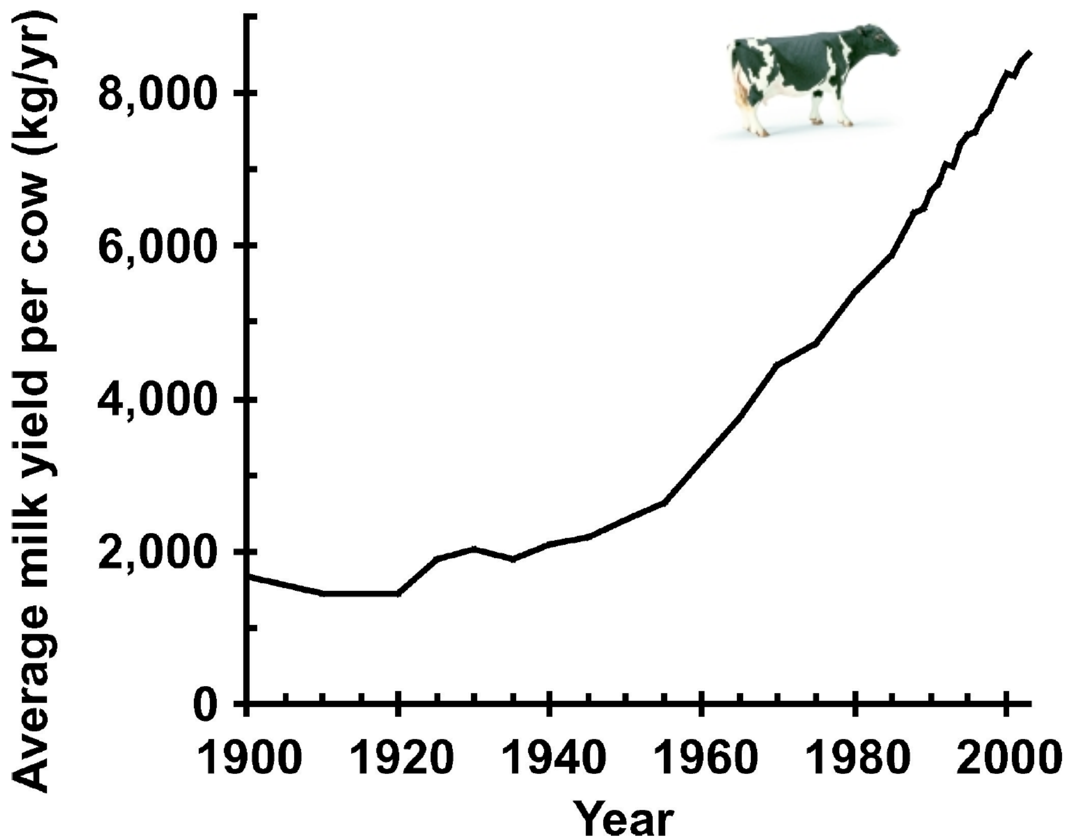
The evolution of cars

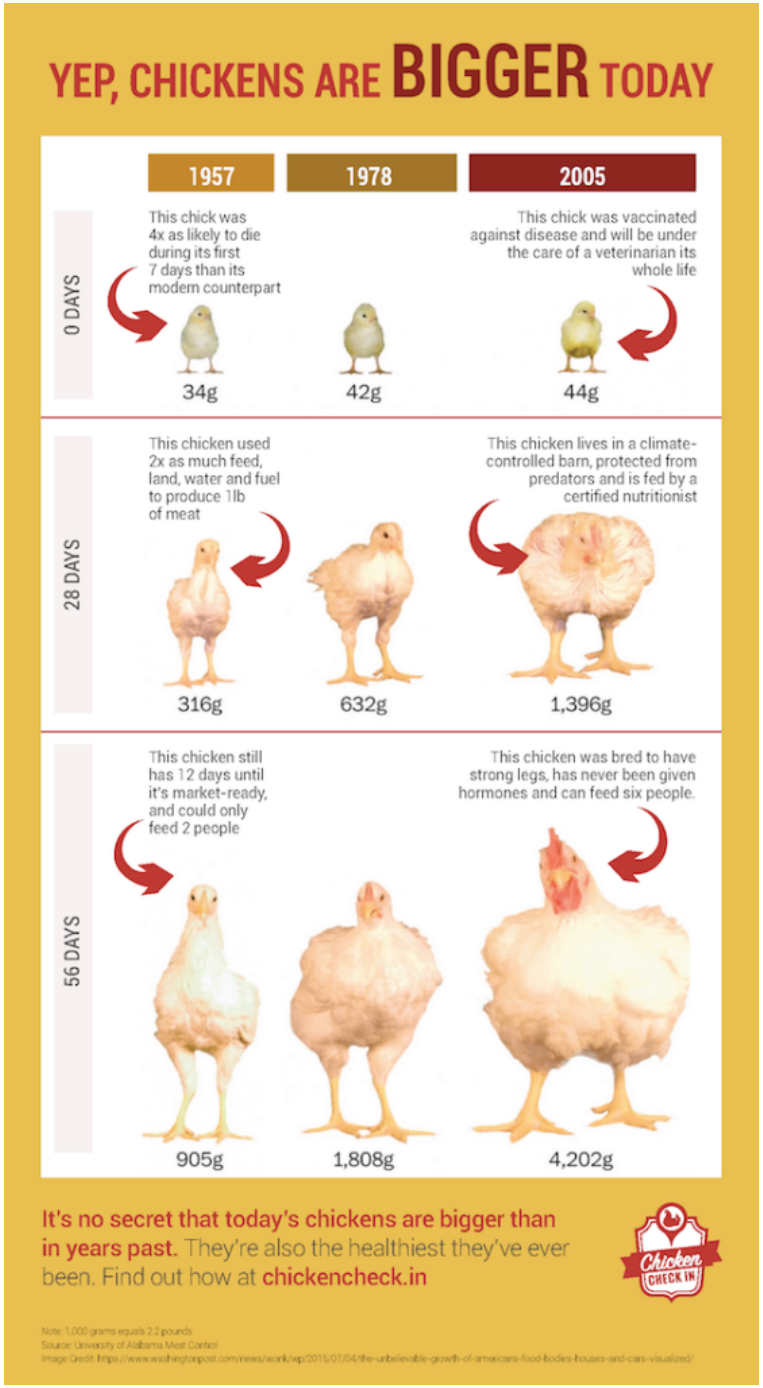


J. Dairy Sci. 89:1280–1291

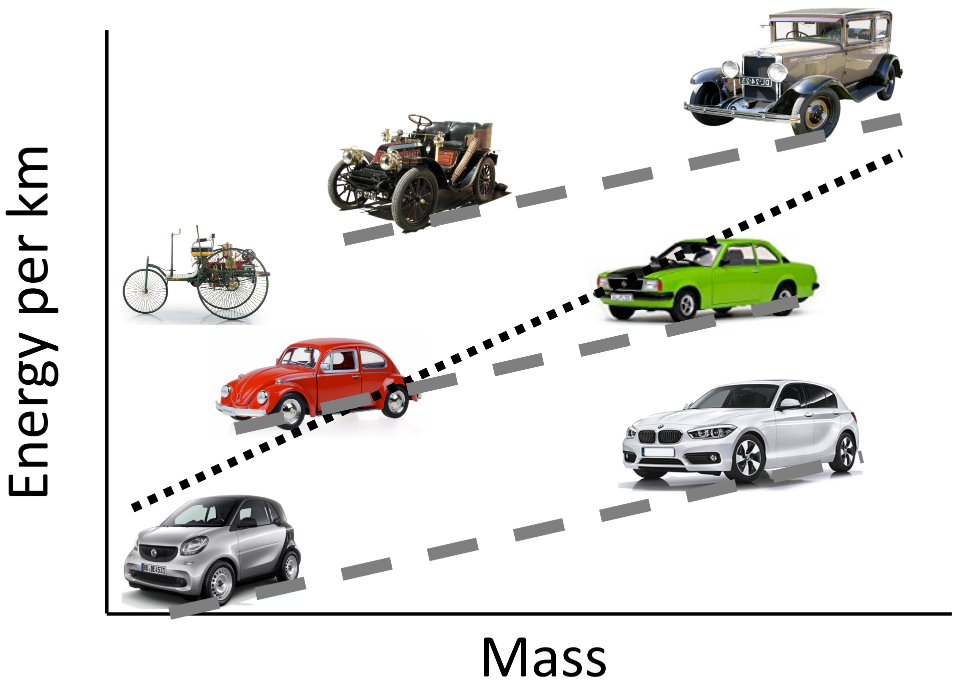
Major Advances in Nutrition: Relevance to the Sustainability of the Dairy Industry

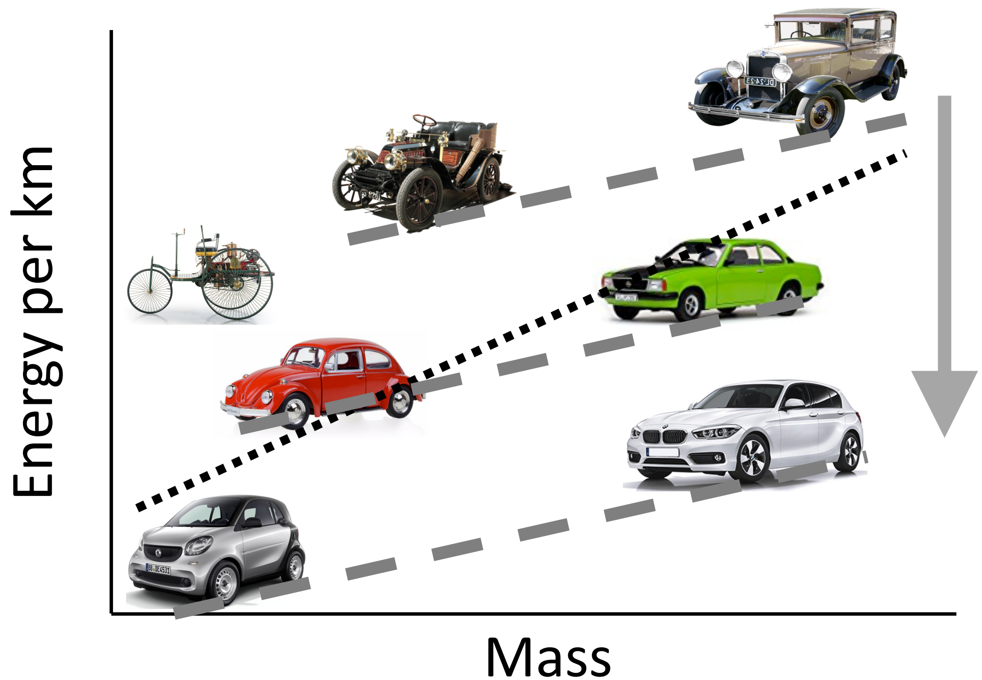
M. J. VandeHaar*[1] and N. St-Pierre†



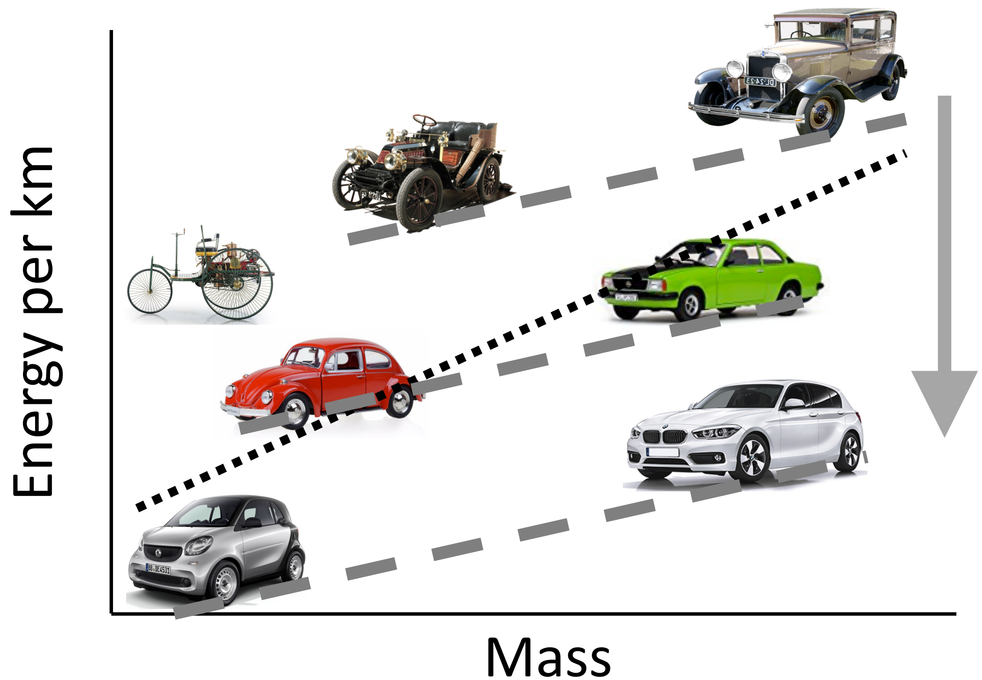


YEP, CHICKENS ARE BIGGER TODAY
1957
1978
2005
0 DAYS
This chick was 4x as likely to die during its first 7 days than its modern counterpart
This chick was vaccinated against disease and will be under the care of a veterinarian its whole life
34g
42g
44g
28 DAYS
This chicken used 2x as much feed, land, 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
Note: 1,000 grams equals 2.2 pounds
Source: University of Alabama Meat Control
Image Credit: https://www.washingtonpost.com/news/wonk/wp/2015/07/04/the-unbelievable-growth-of-americans-food-bodies-houses-and-cars-visualized/


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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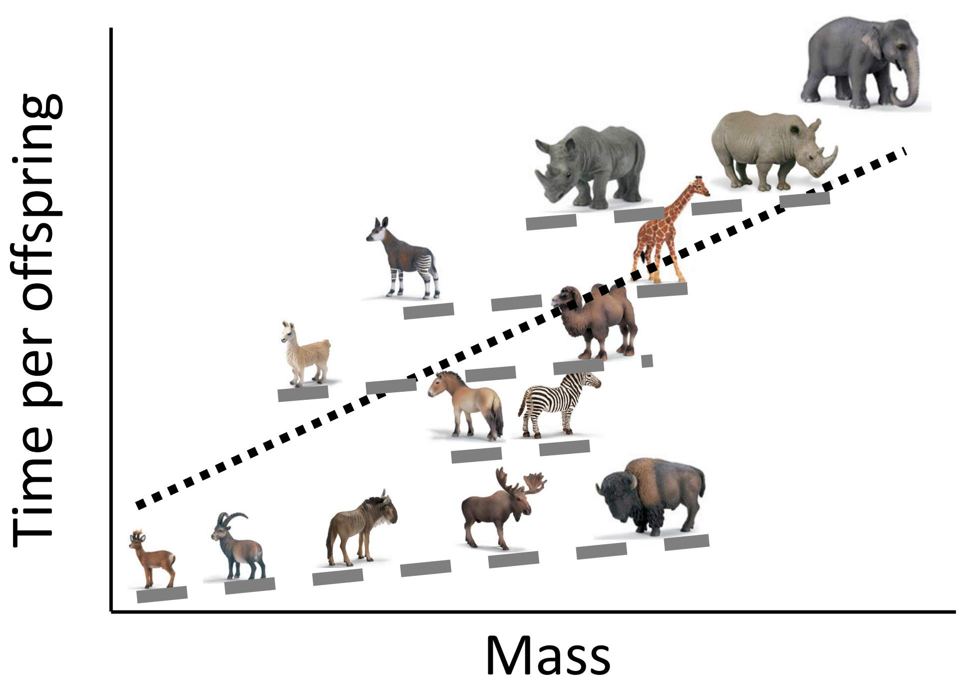

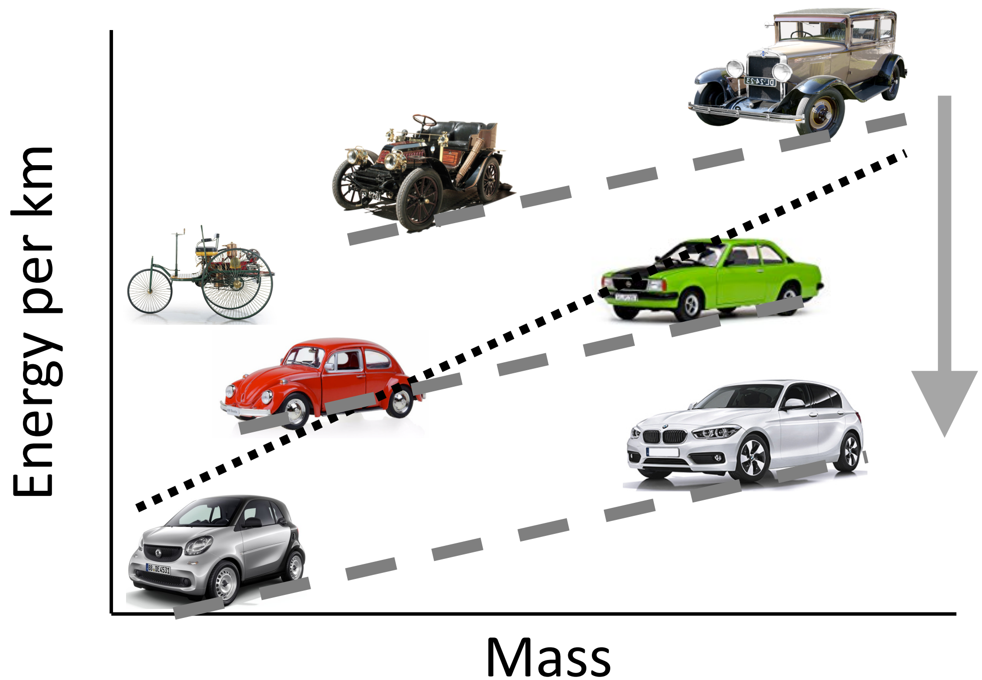

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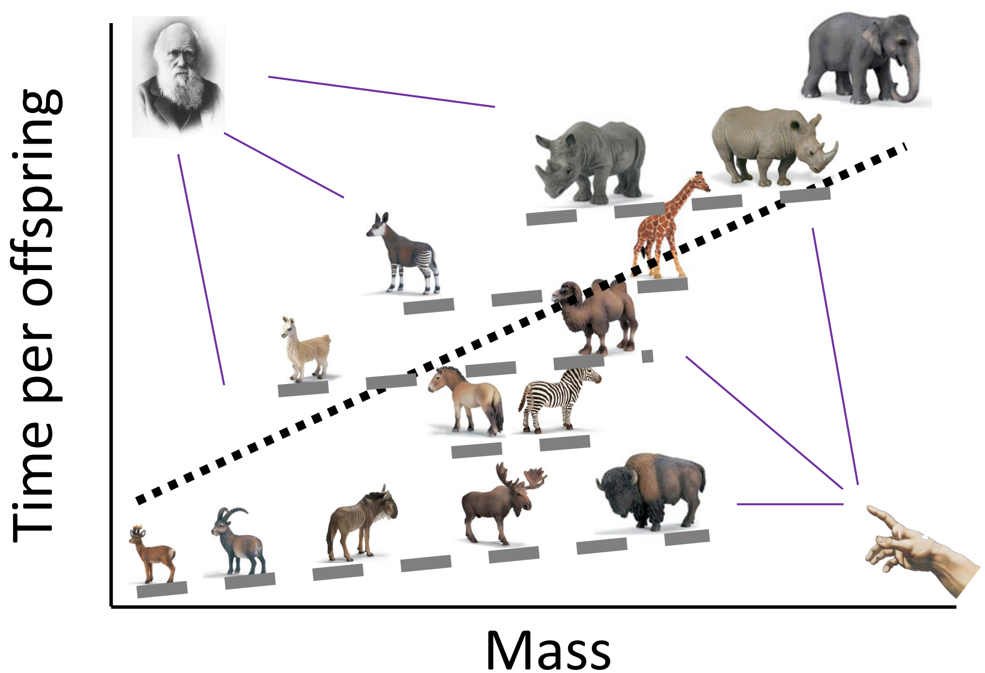
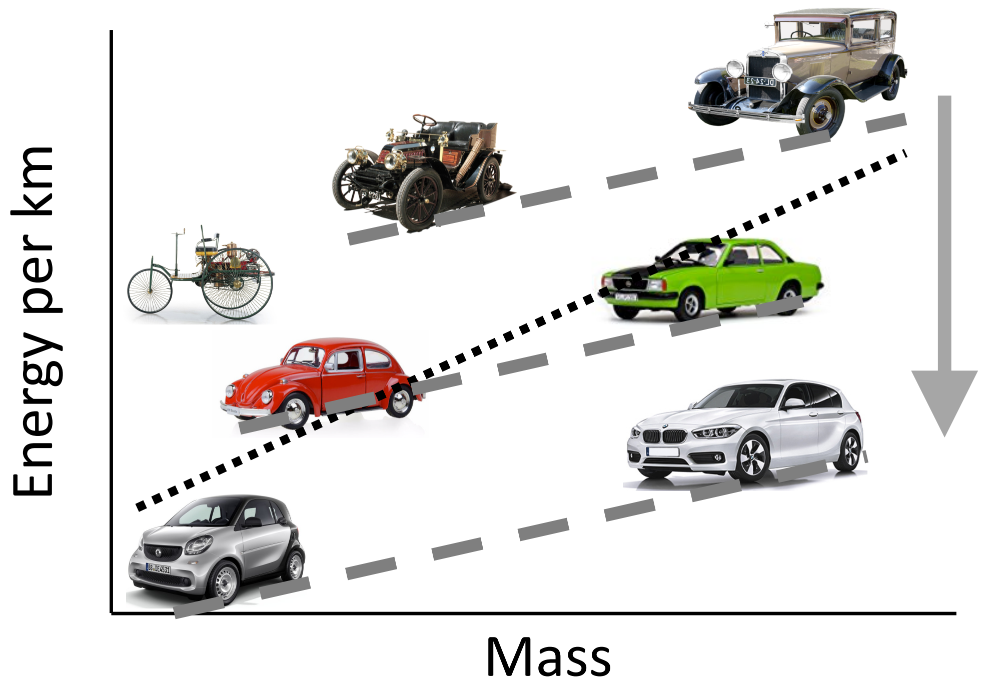


Why would you consider this a pattern due to fixed life history tradeoff laws?



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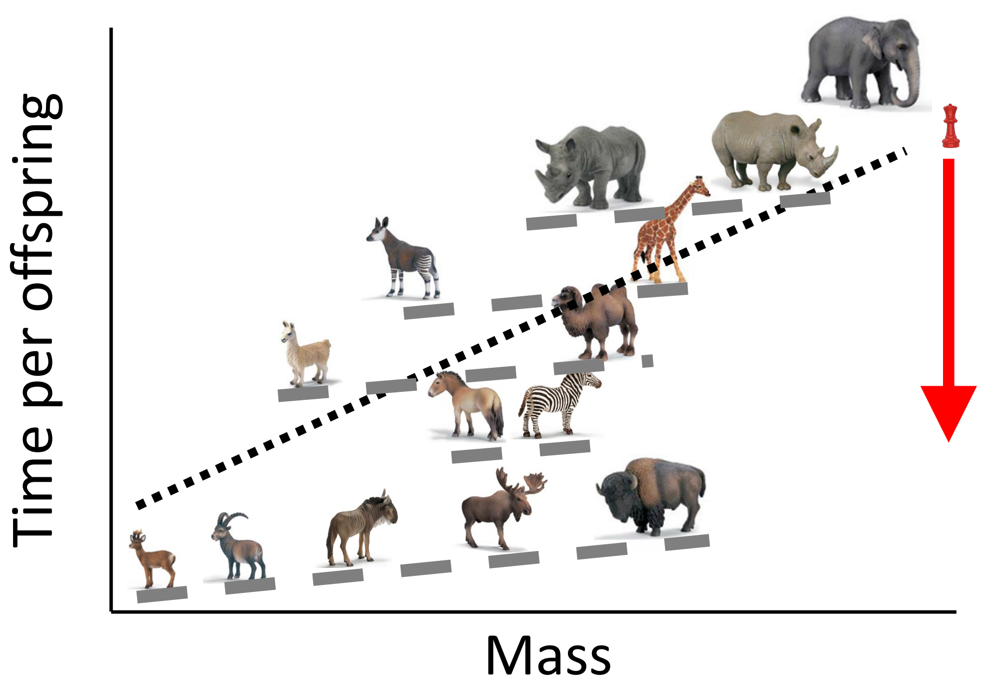
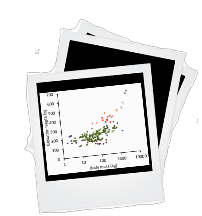


*Why would you consider this a pattern due to fixed life history tradeoff laws, and not rather a **snapshot** in a process of optimization?*



Some simple *a priori* assumptions and their consequences

A priori conditions and their consequences

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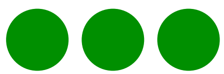

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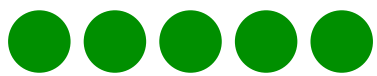

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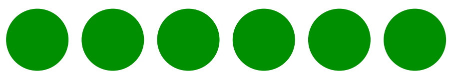

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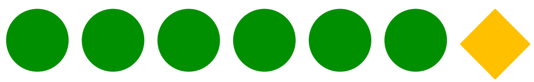

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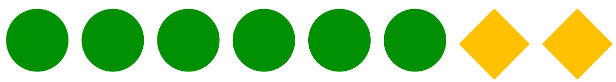

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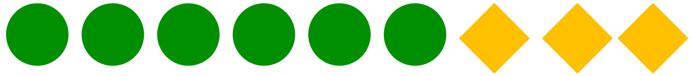

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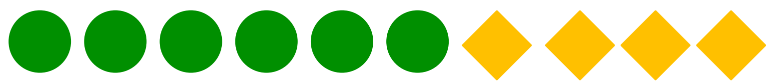

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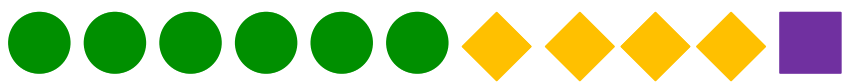

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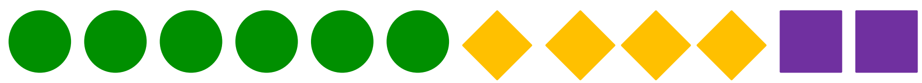

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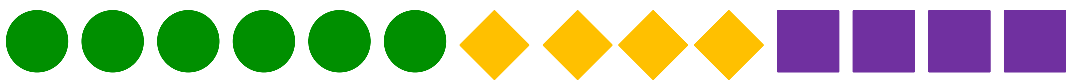

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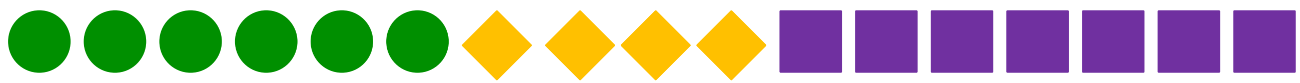

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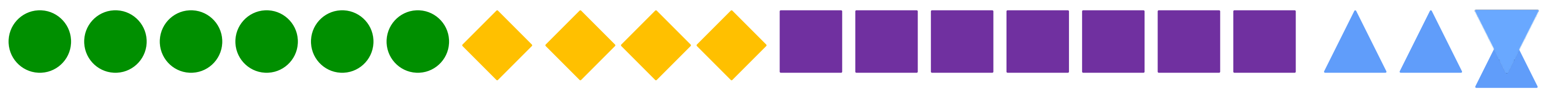

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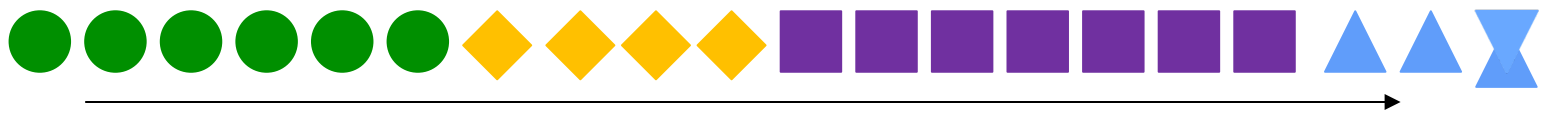

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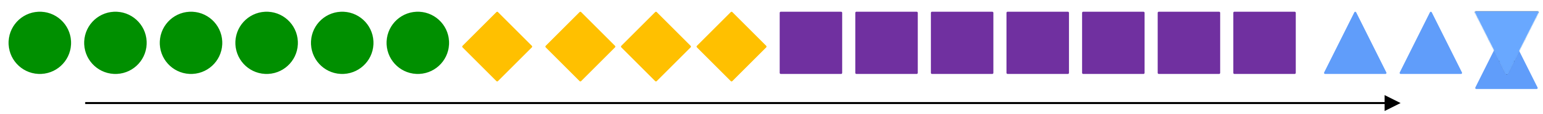

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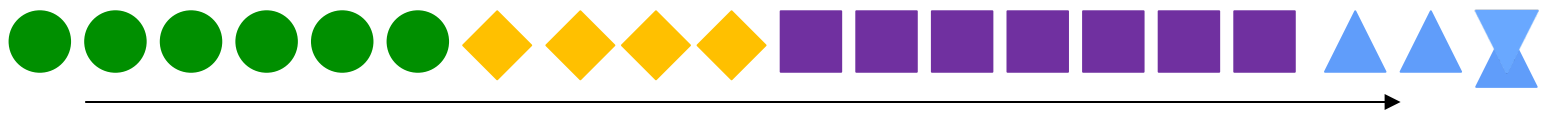

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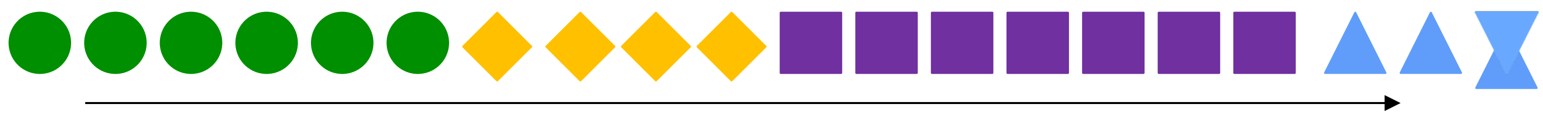

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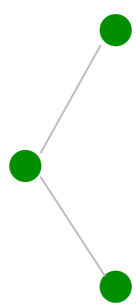

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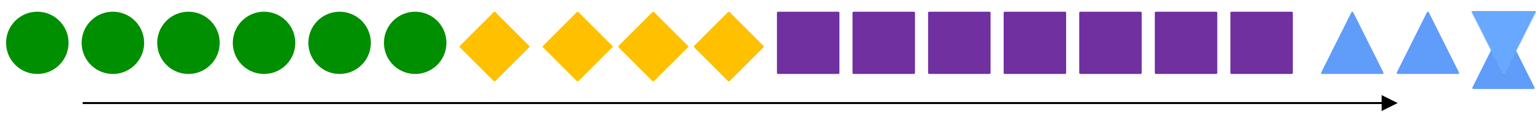

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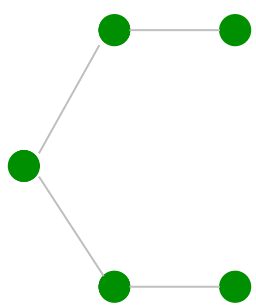

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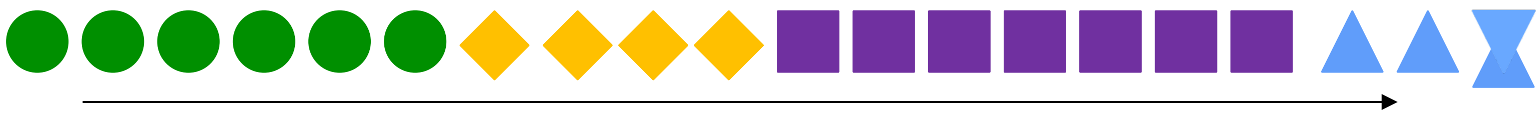

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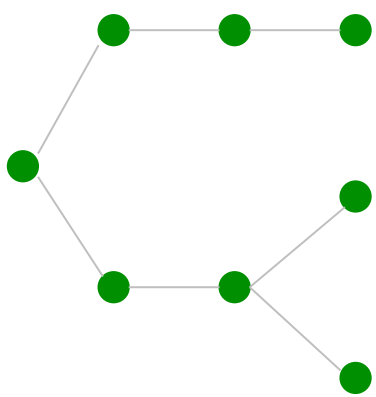

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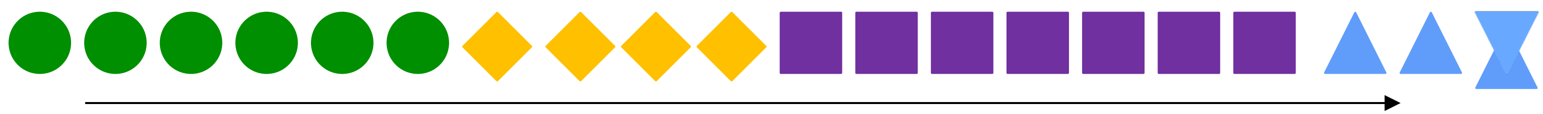

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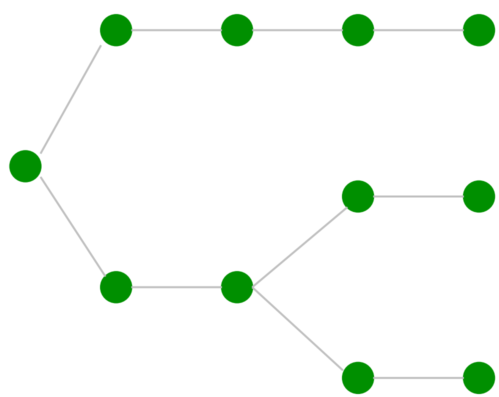

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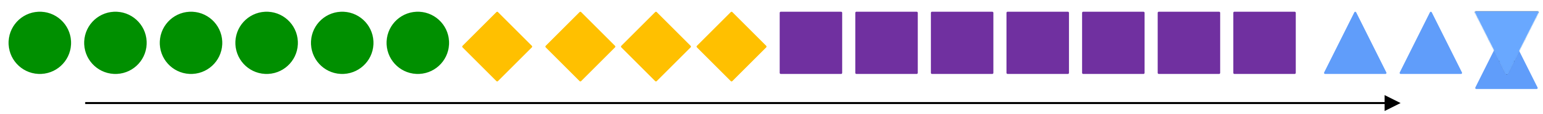

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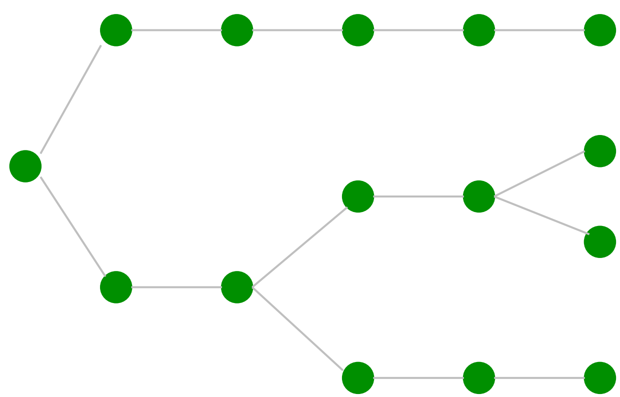

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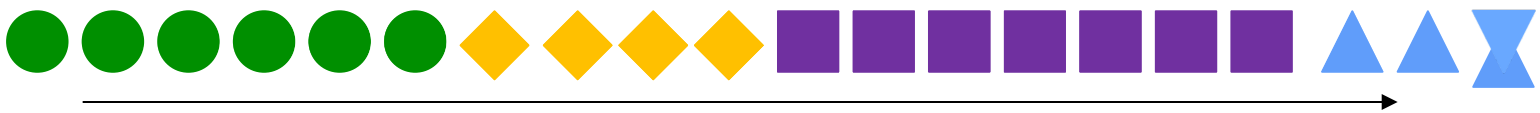

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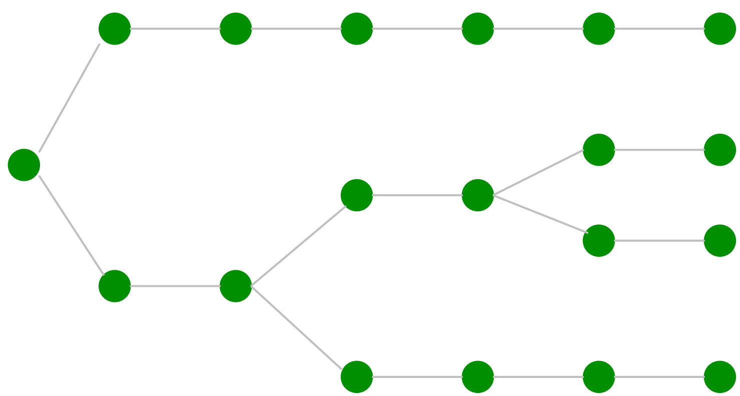

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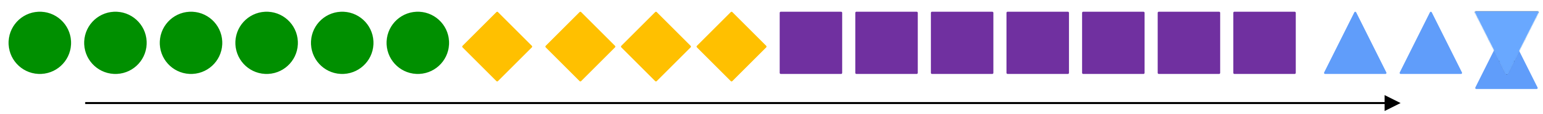

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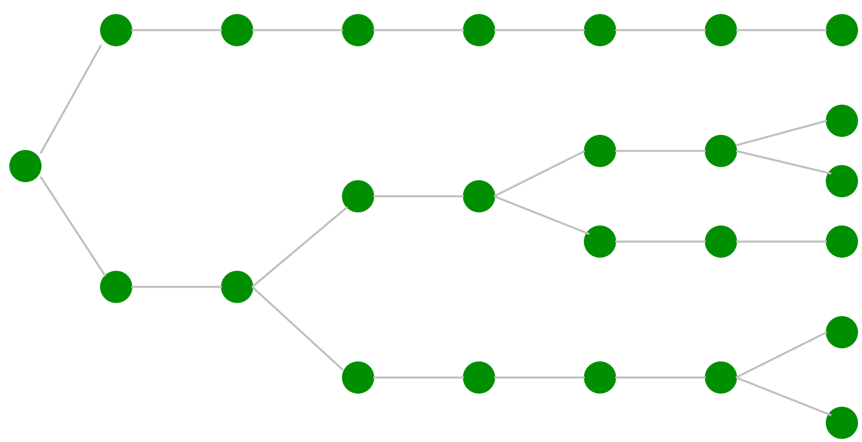

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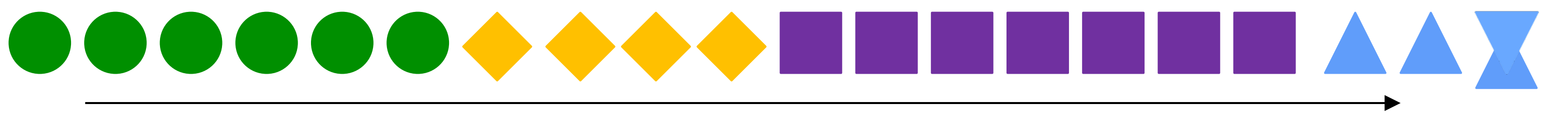

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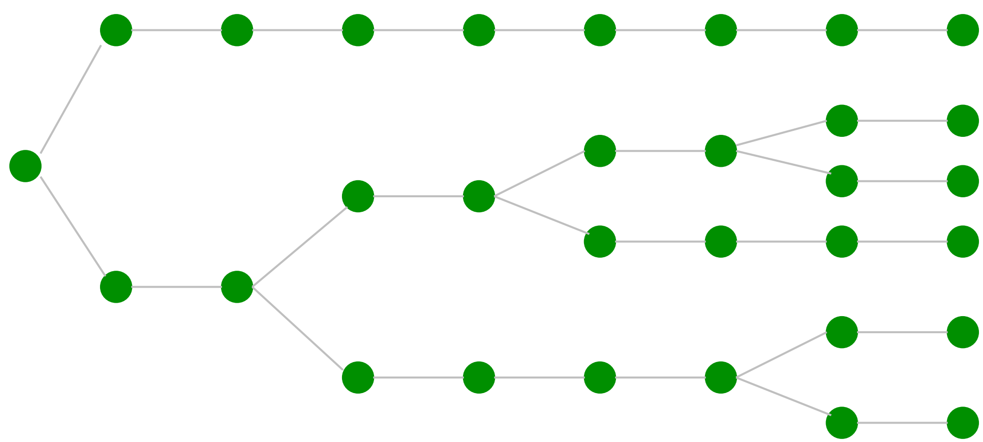

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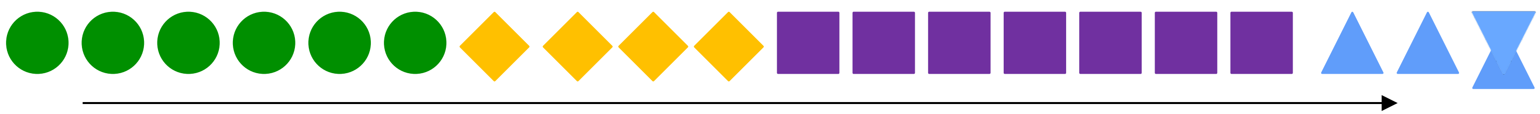

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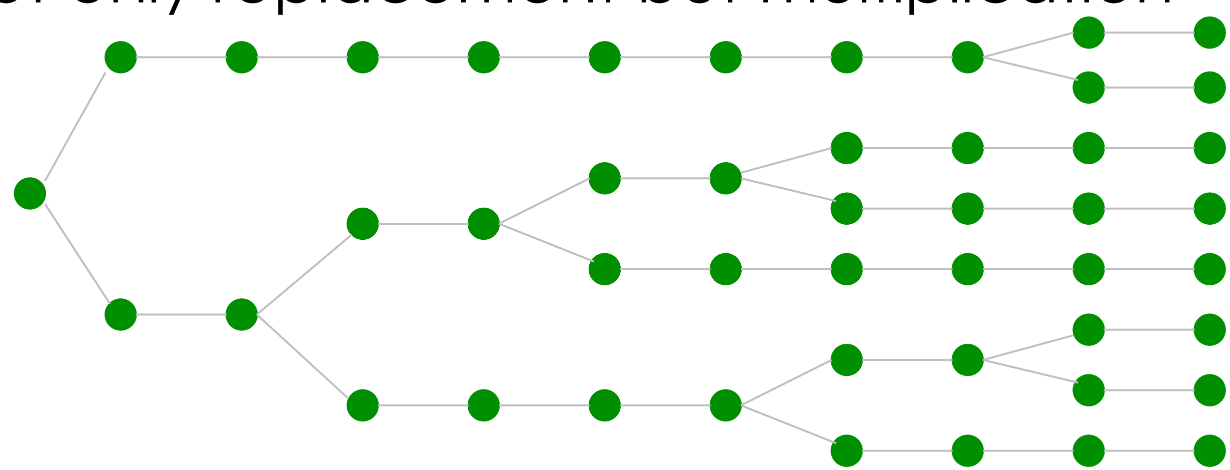

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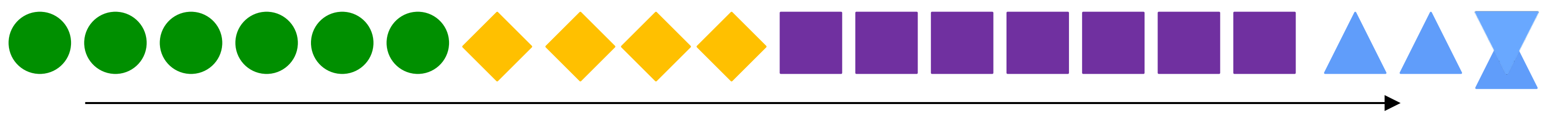

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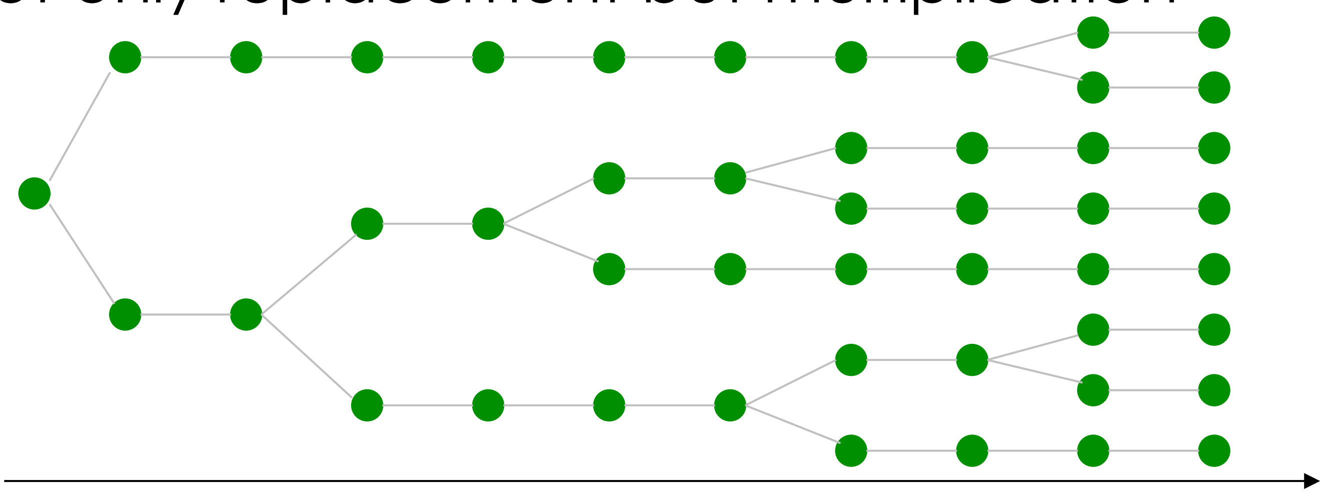

Probabilistic directionality II: more

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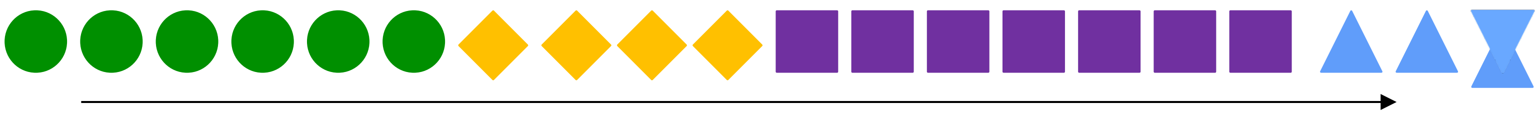

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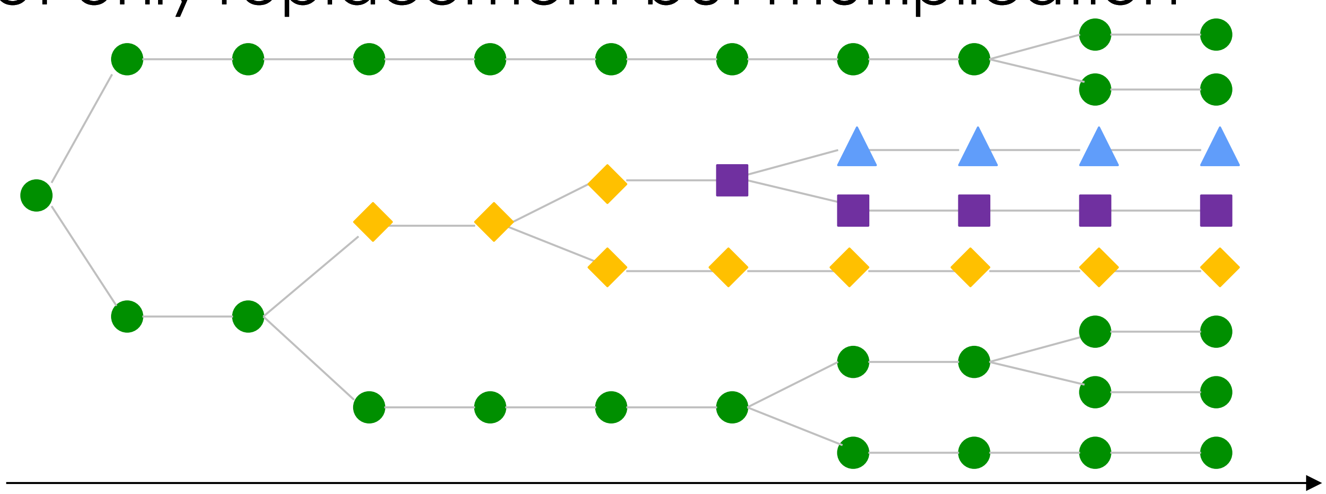

Probabilistic directionality II: more diversity

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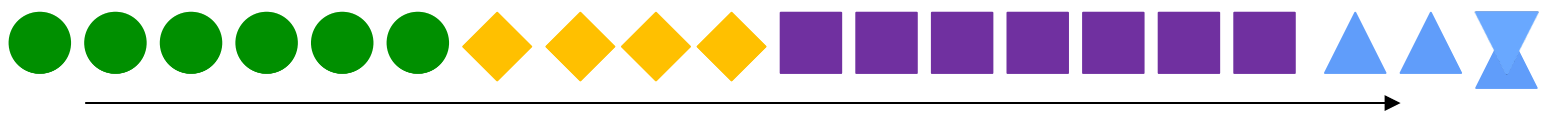

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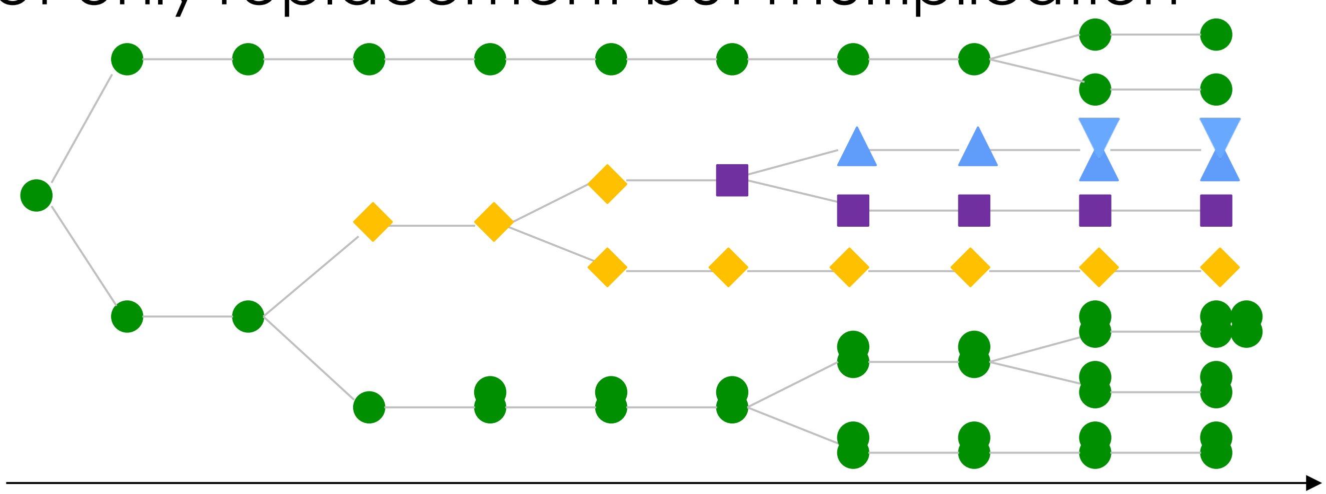
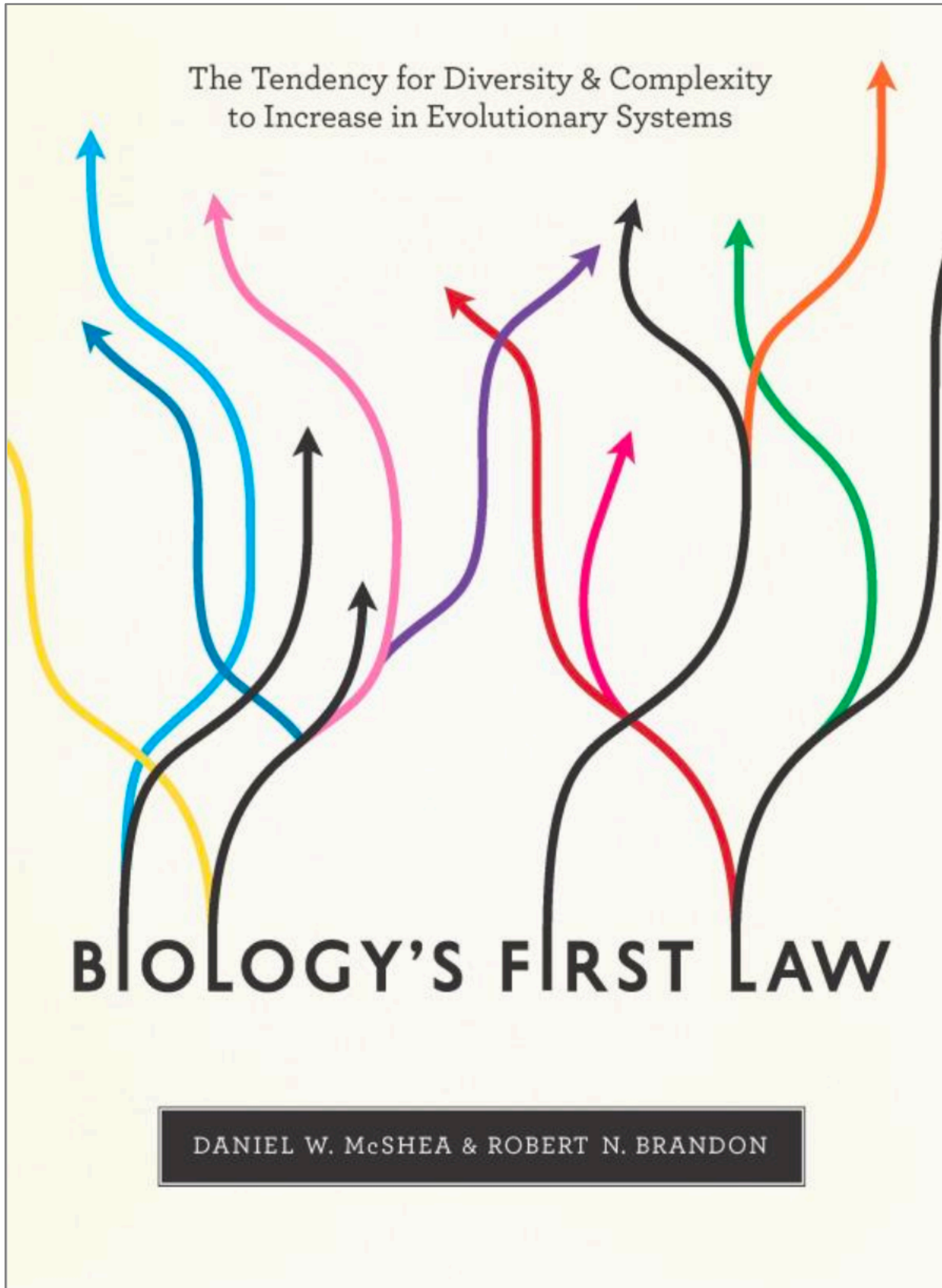


Probabilistic directionality II: more diversity & complexity


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

A priori conditions and their consequences

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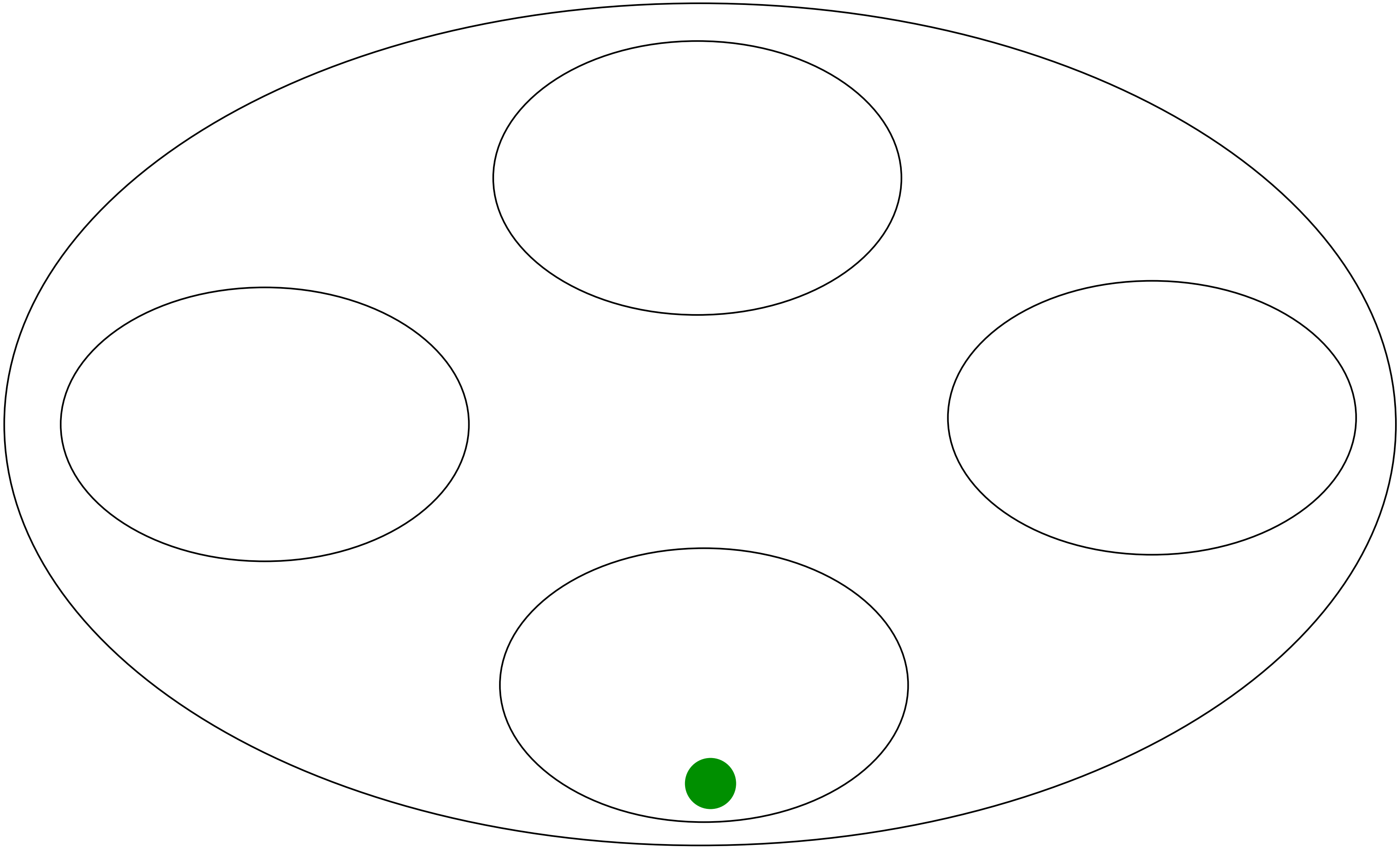

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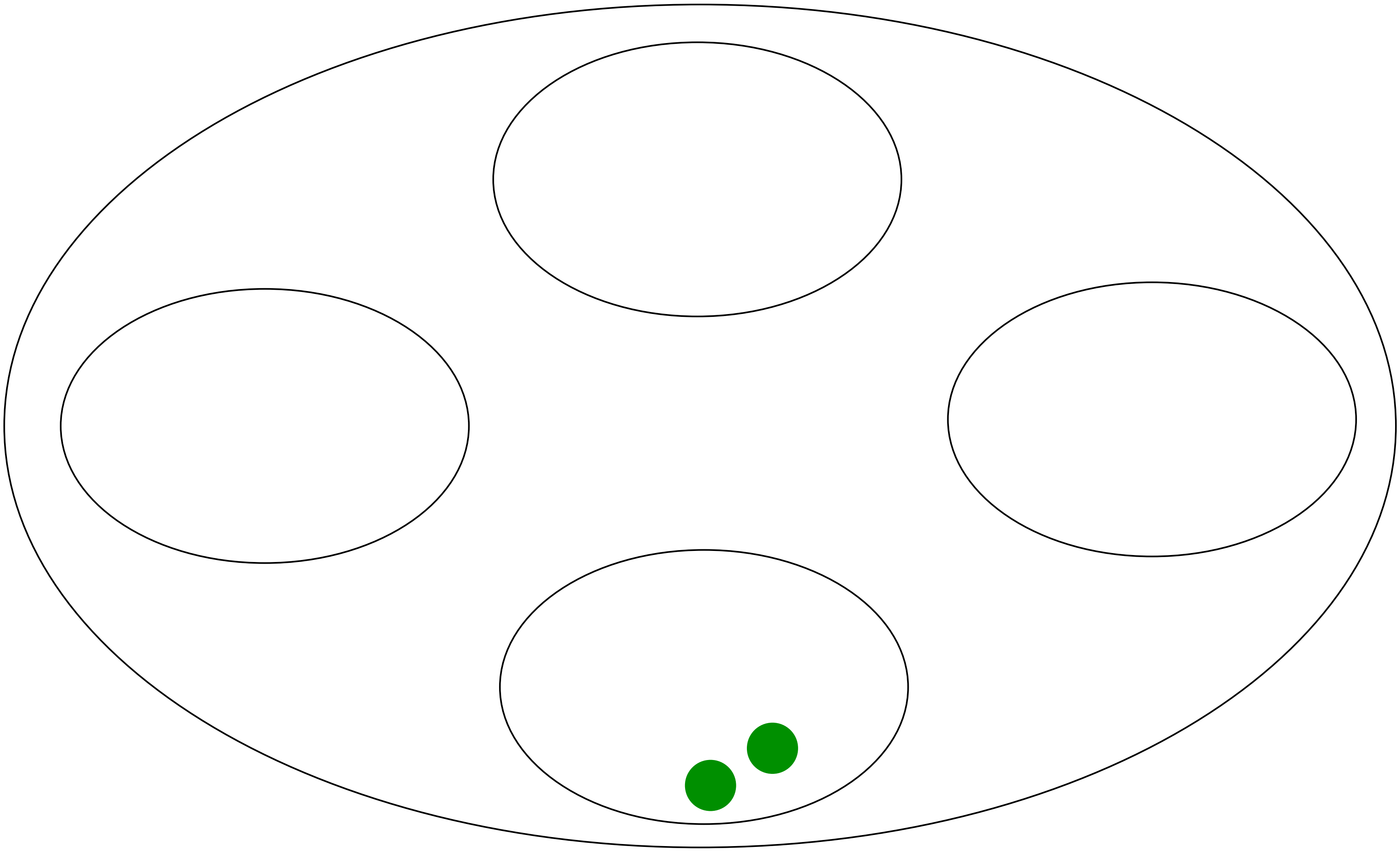

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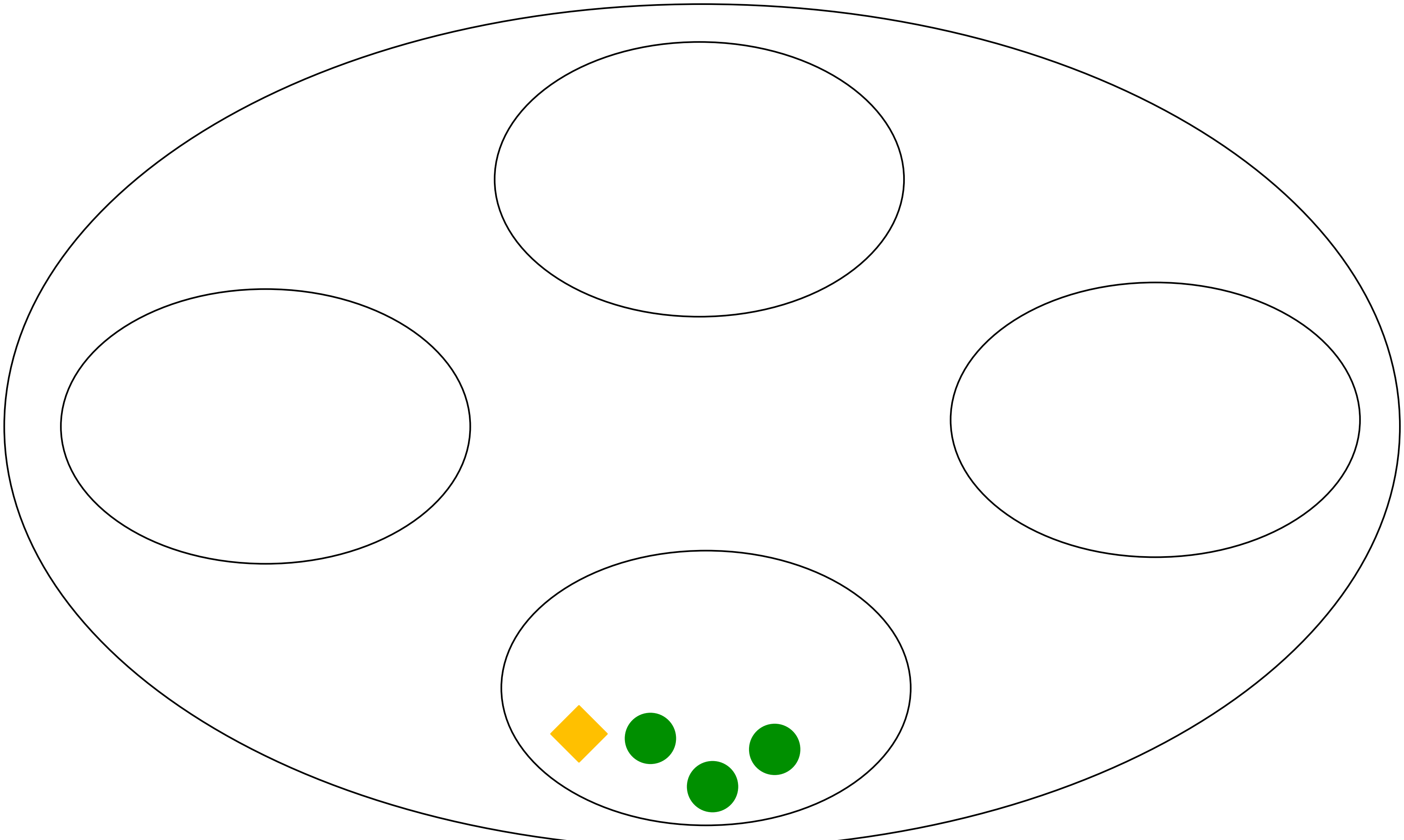

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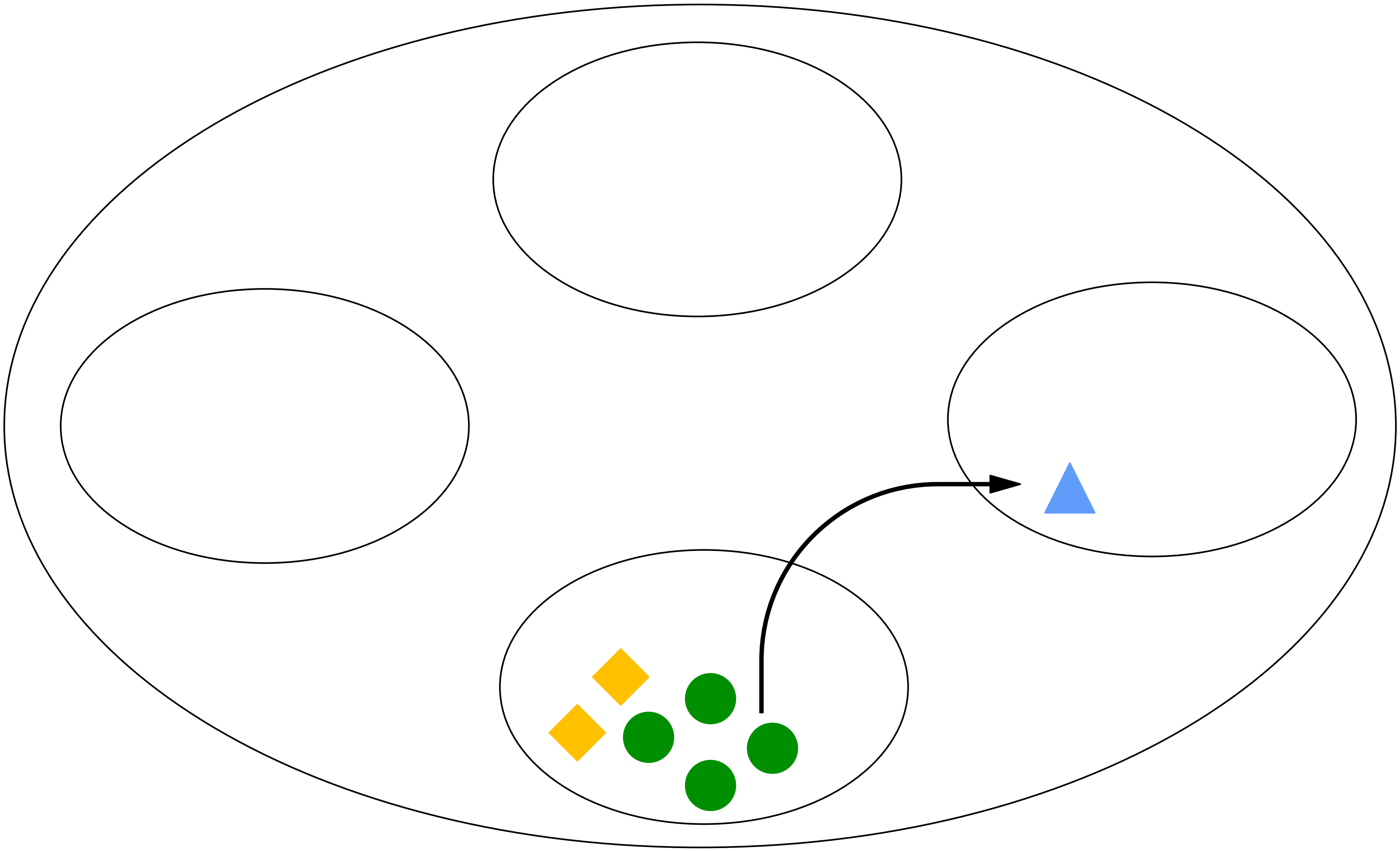

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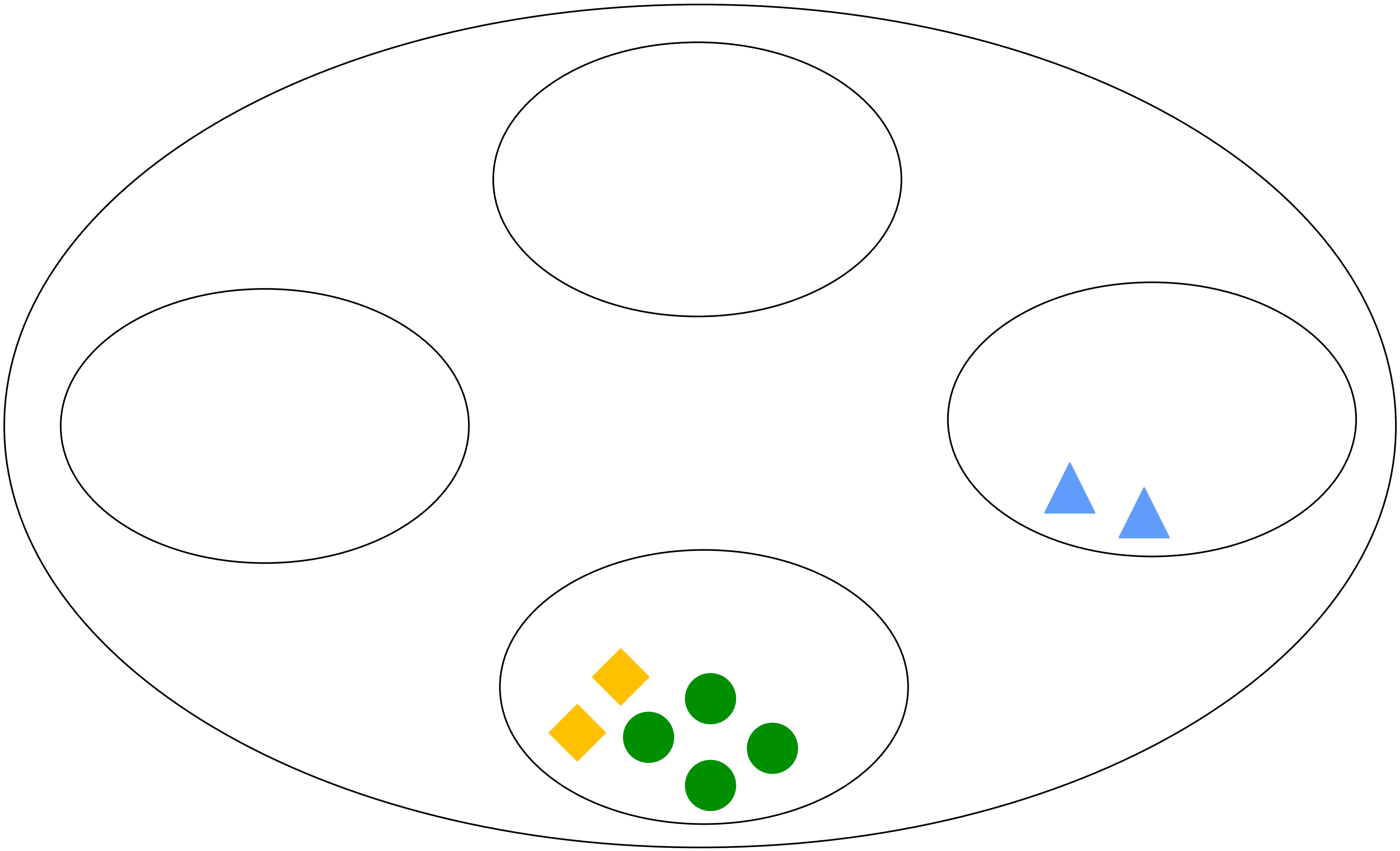

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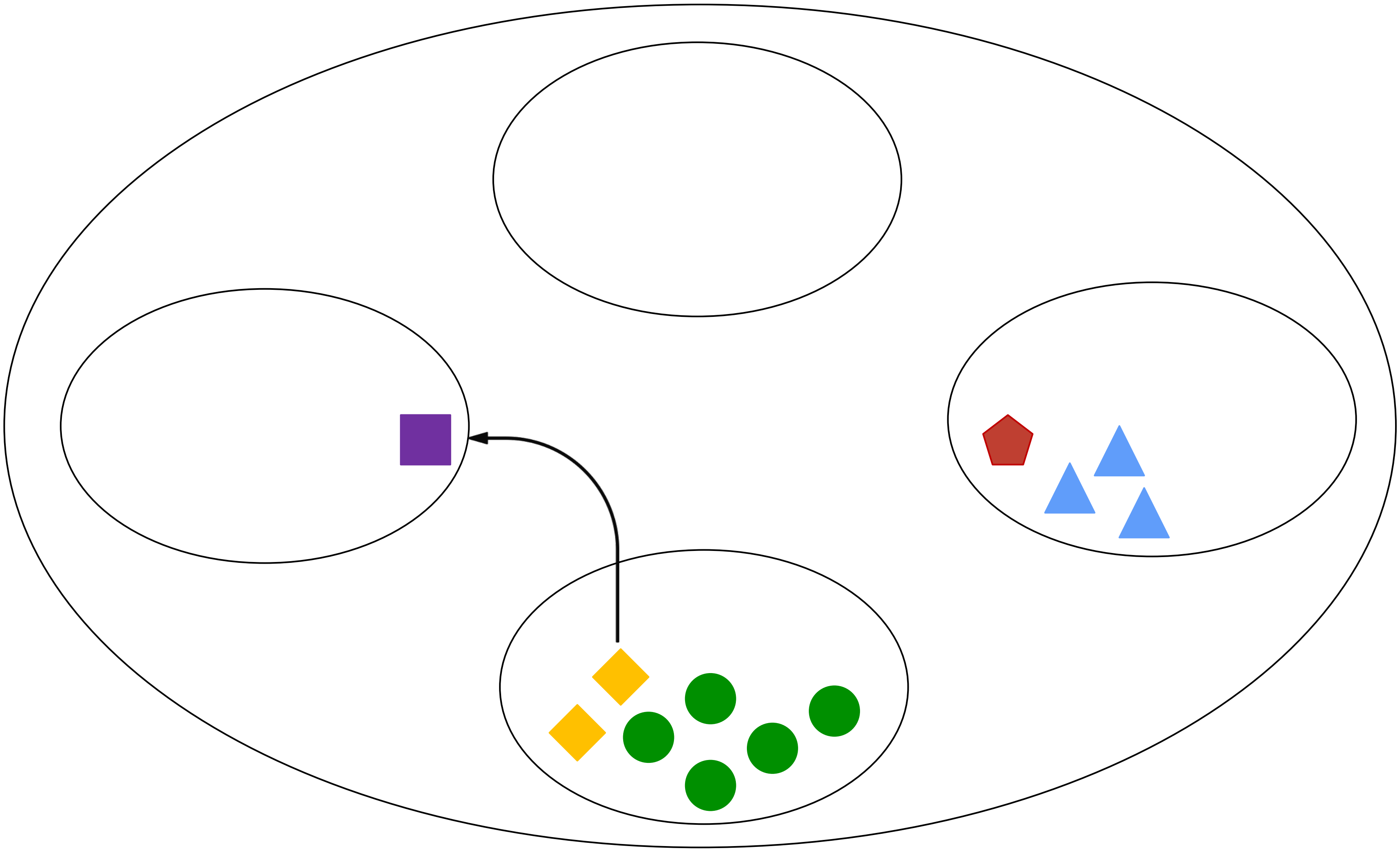

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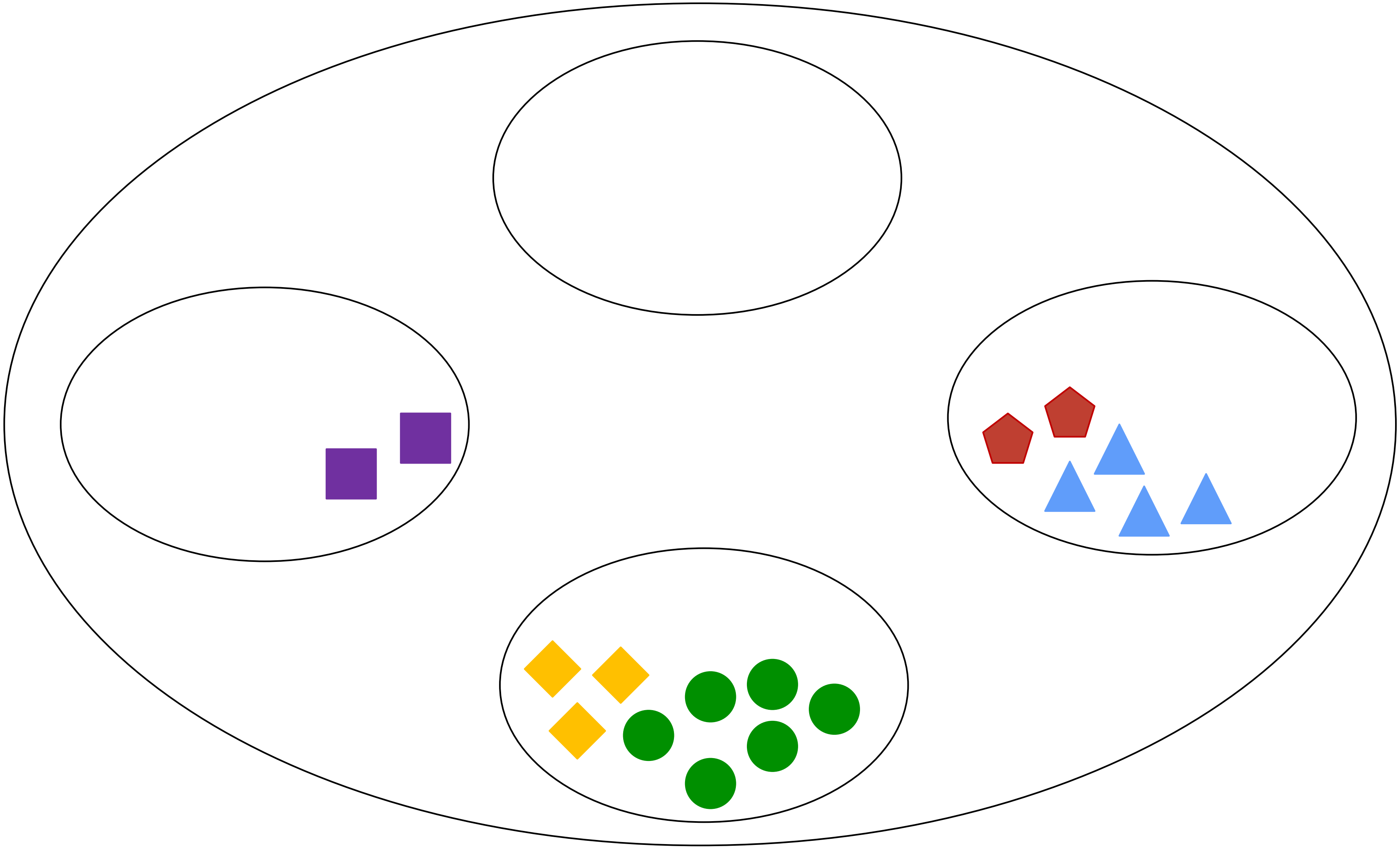

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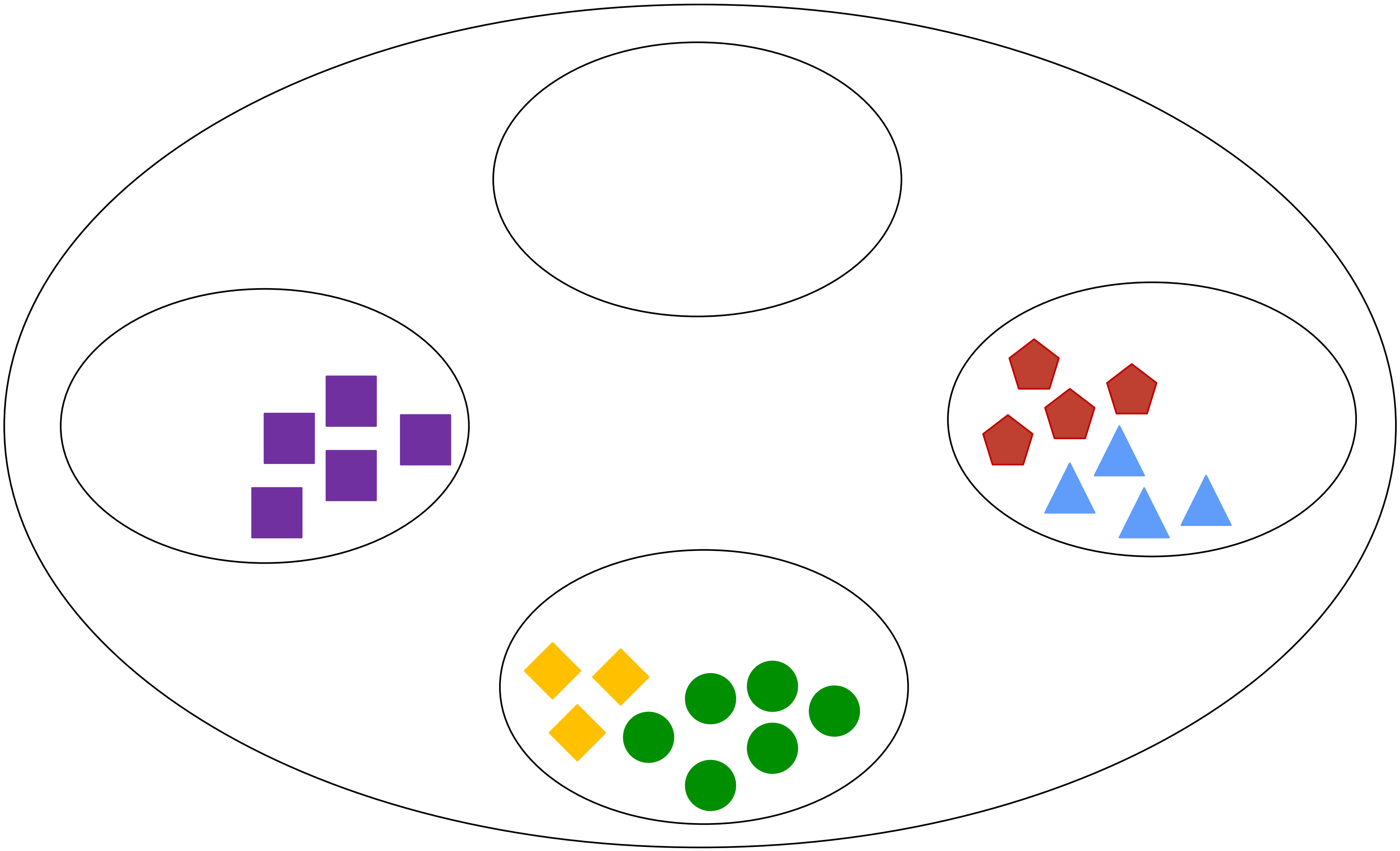

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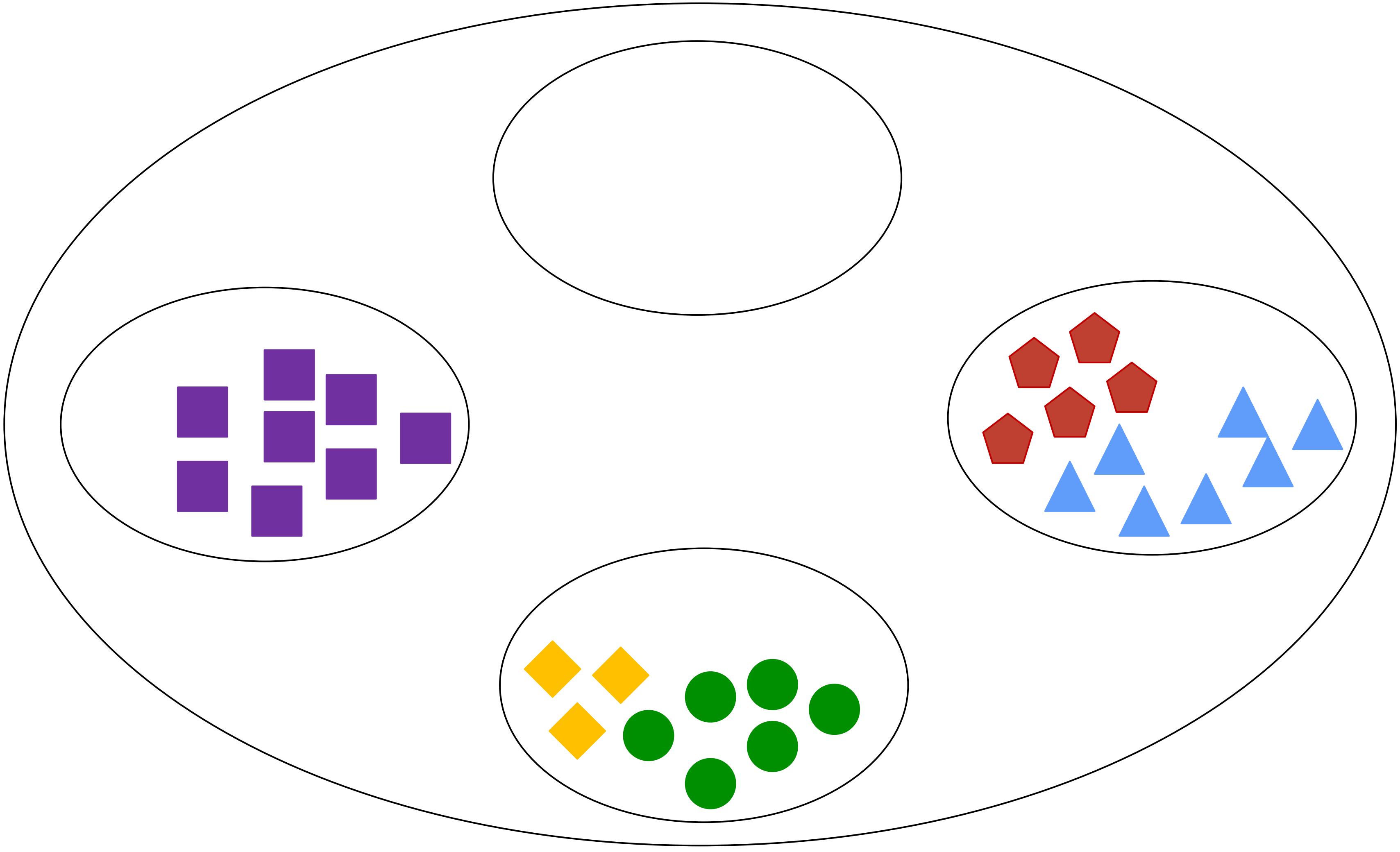

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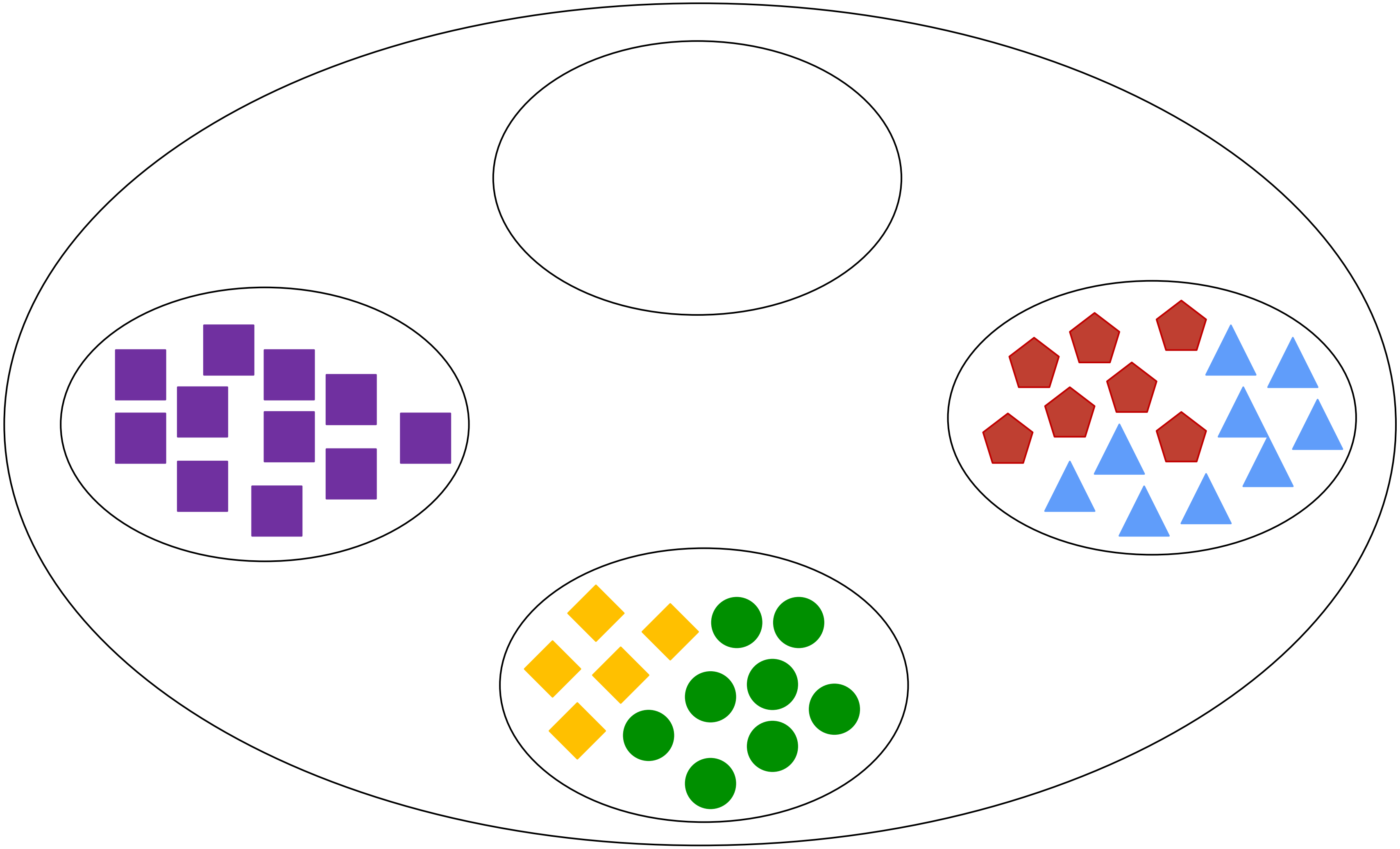

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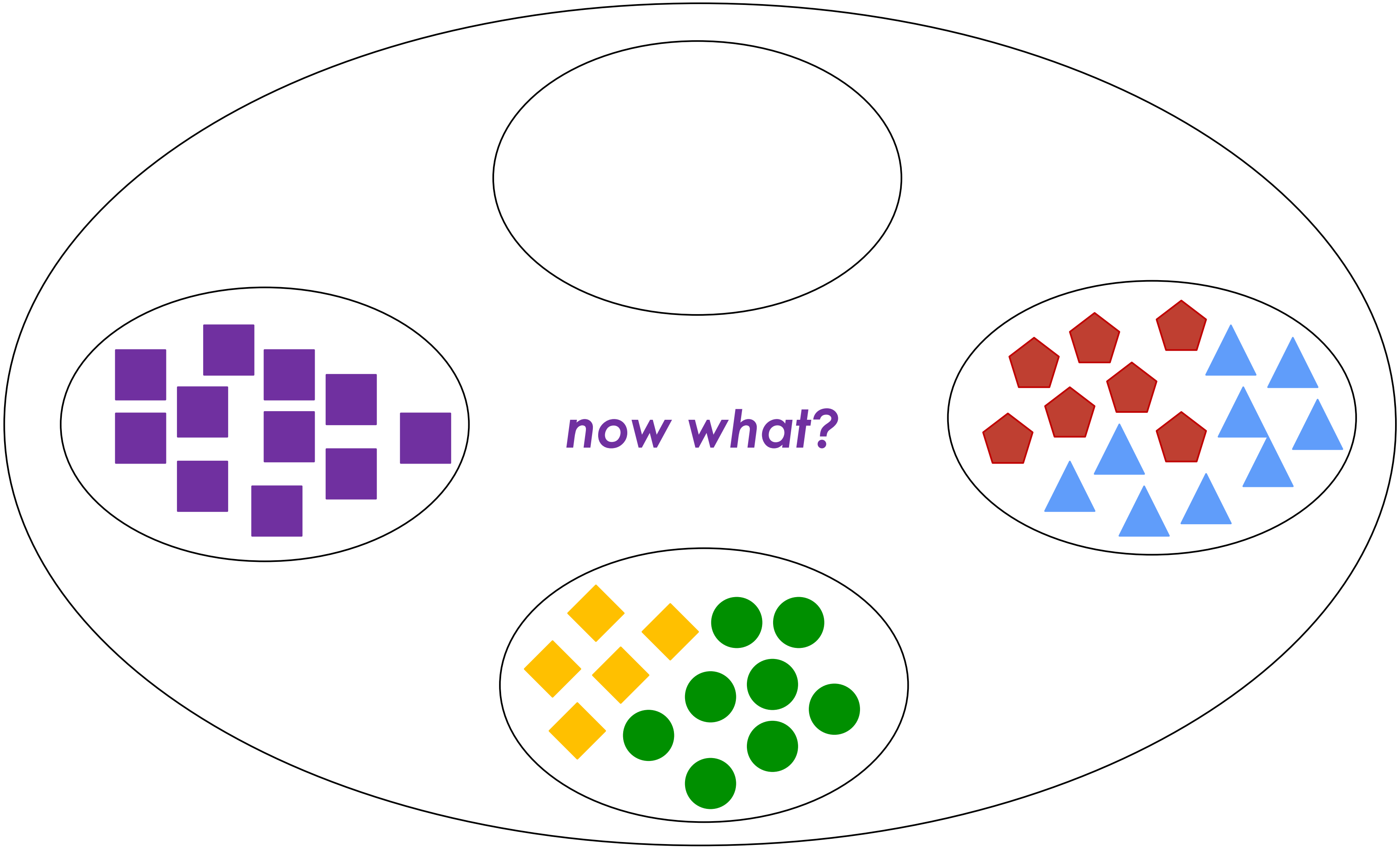


A NEW EVOLUTIONARY LAW

Leigh Van Valen

The Red Queen's Hypothesis (32)

Evol. Theory 1:1-30 (July 1973)

A NEW EVOLUTIONARY LAW

Leigh Van Valen

The Red Queen's Hypothesis (32)

(32). "Now here, you see, it takes all the running you can do, to keep in the same place." (L. Carroll, Through the Looking Glass.)

Evol. Theory 1:1-30 (July 1973)

‘Evolutionary progress’ – directional evolution

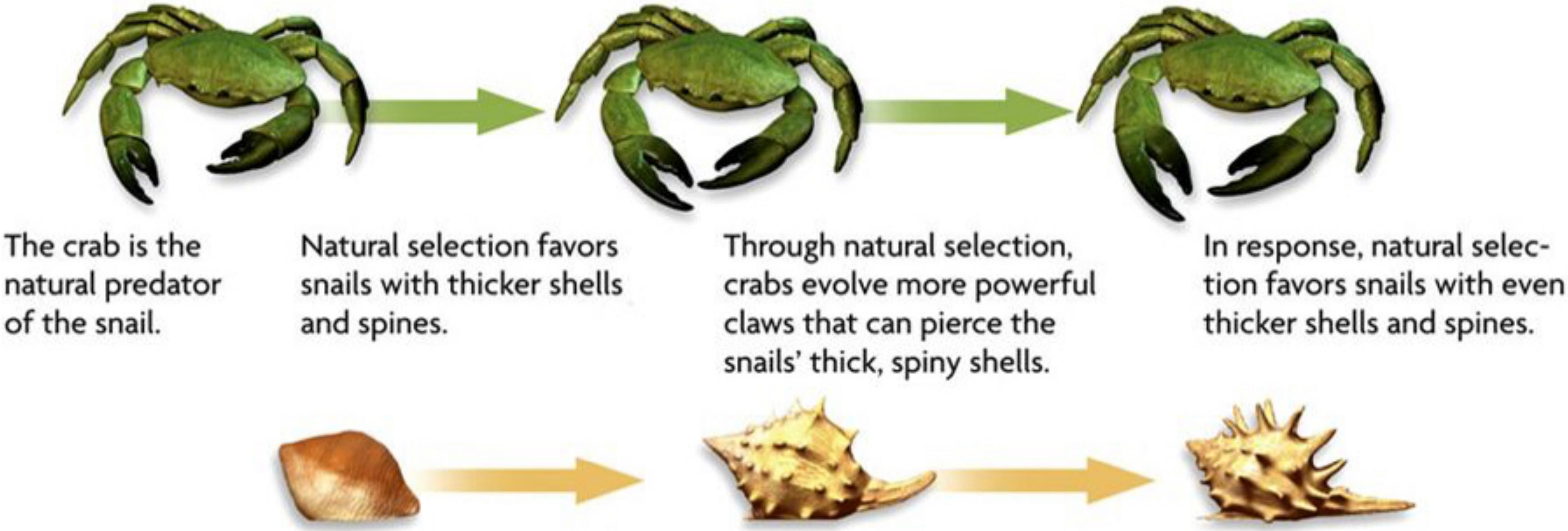
Proc. R. Soc. Lond. B **205**, 489–511 (1979) 489
Printed in Great Britain

Arms races between and within species

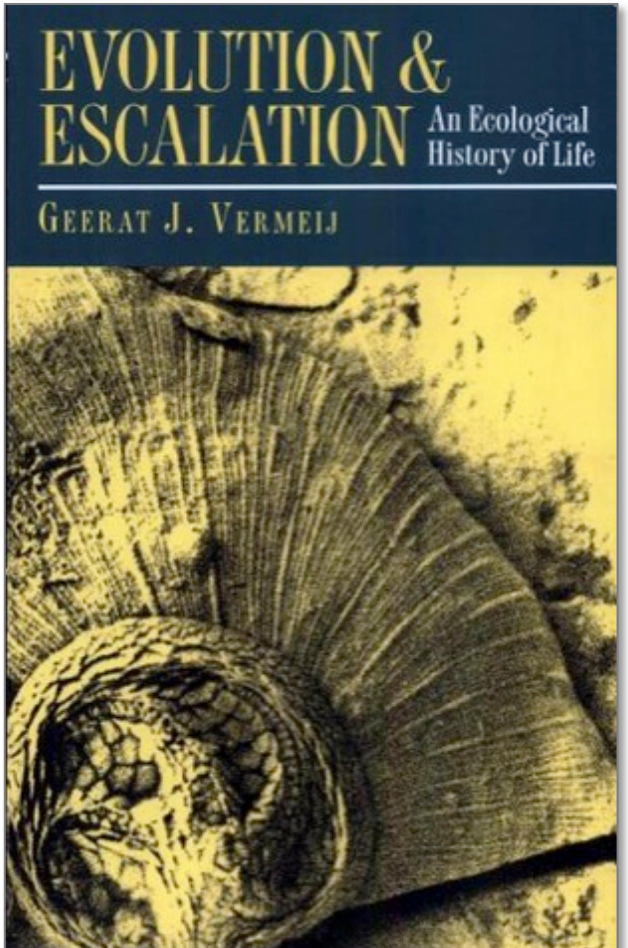
By R. Dawkins and J. R. Krebs

reverse as to continue the previous one. But in fact consistent directionality is introduced because the environment of any one evolving lineage includes other evolving lineages. Above all, it is because adaptations in one lineage call forth counter-adaptations in others, setting in motion the unstable evolutionary progressions we call arms races.

‘Evolutionary progress’ – directional evolution



‘Evolutionary progress’ – directional evolution



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On Escalation

Geerat J. Vermeij

Department of Geology, University of California, Davis, California 95616; email: gjvermeij@ucdavis.edu

Annu. Rev. Earth Planet. Sci. 2013. 41:1–19

The *Annual Review of Earth and Planetary Sciences* is online at earth.annualreviews.org

This article's doi: 10.1146/annurev-earth-050212-124123

Keywords

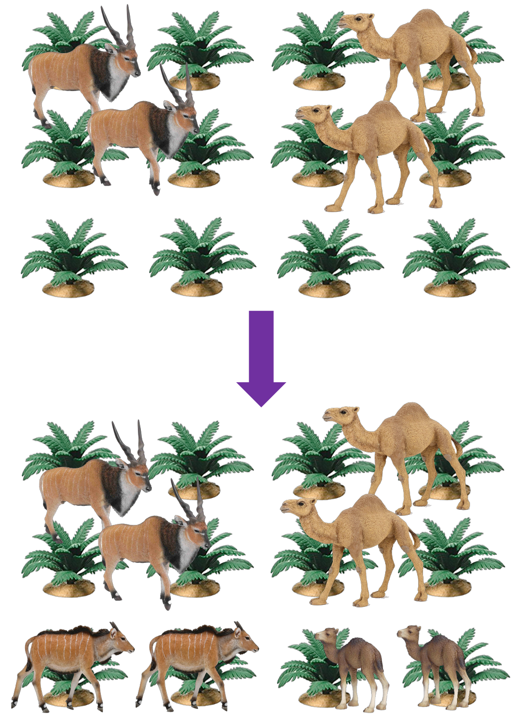
Red Queen, coevolution, Phanerozoic, enabling factors, predation, competition

Abstract

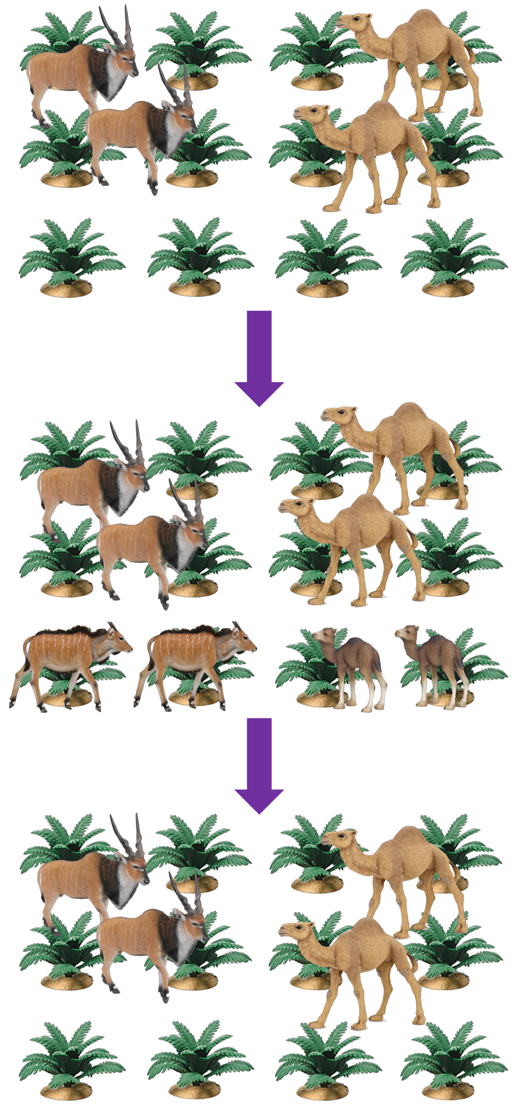
Organisms have been important agents of selection throughout the history of life. The processes and outcomes of this selection are the subject of this review. Among these, escalation is the most widespread. The primary selective agents are powerful competitors and consumers, which together push many populations toward higher performance in acquiring and defending resources while relegating less competitive species to physiologically marginal settings, where escalation also ensues. The extent to which performance standards rise depends on enabling factors, which control availability of and access to resources. By establishing positive feedbacks between species and enabling factors, effective competitors regulate and enhance resource supply. The pace of escalation toward greater power and reach is dictated by geological factors as well as by growing interdependencies between species and their resources. Evolutionary events on land related to the production of oxygen may have been instrumental in triggering the major episodes of escalation.

Equivalent use of limited resources

Stasis



Stasis



Competition for limited resources

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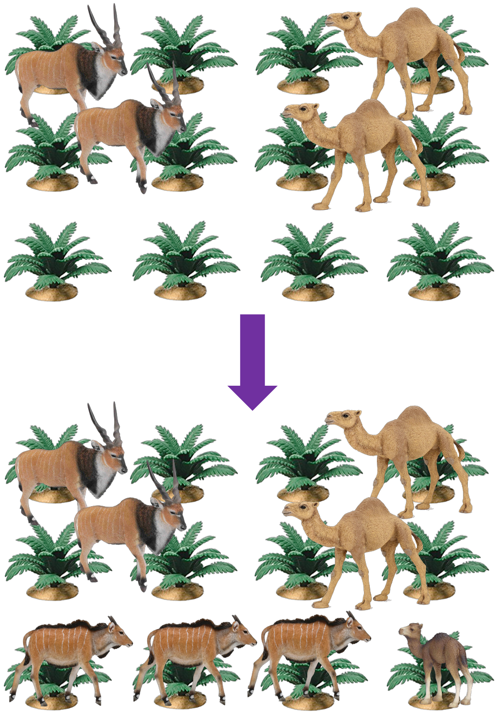
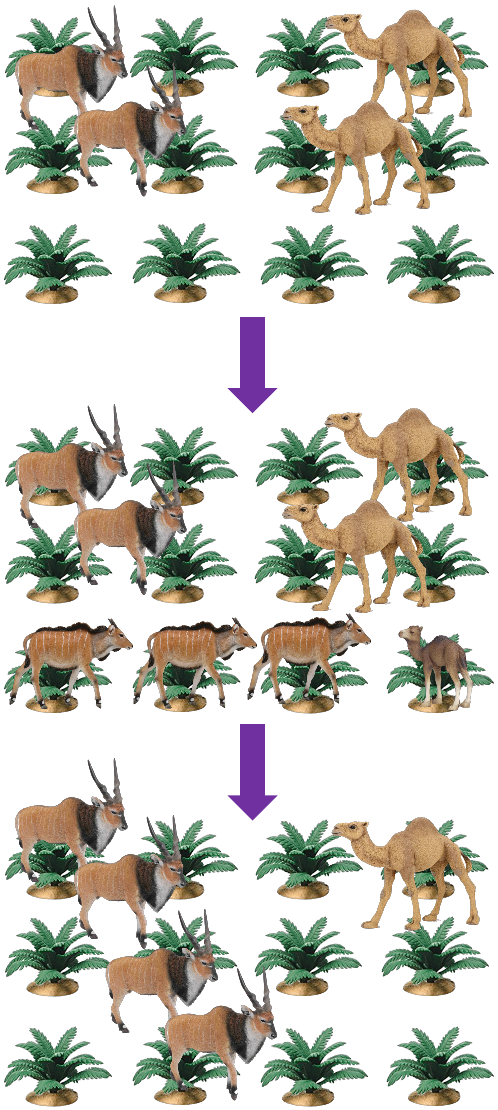


Competition for limited resources



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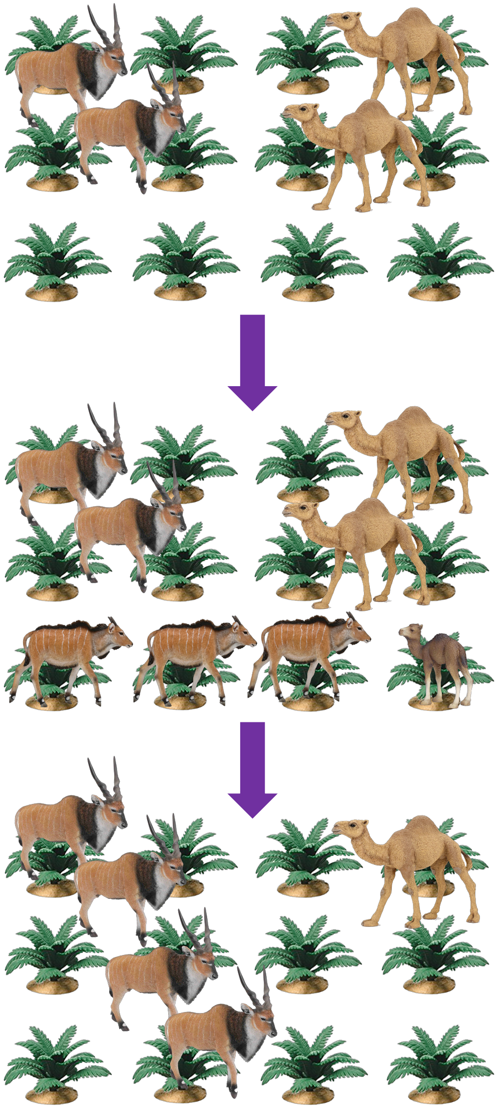

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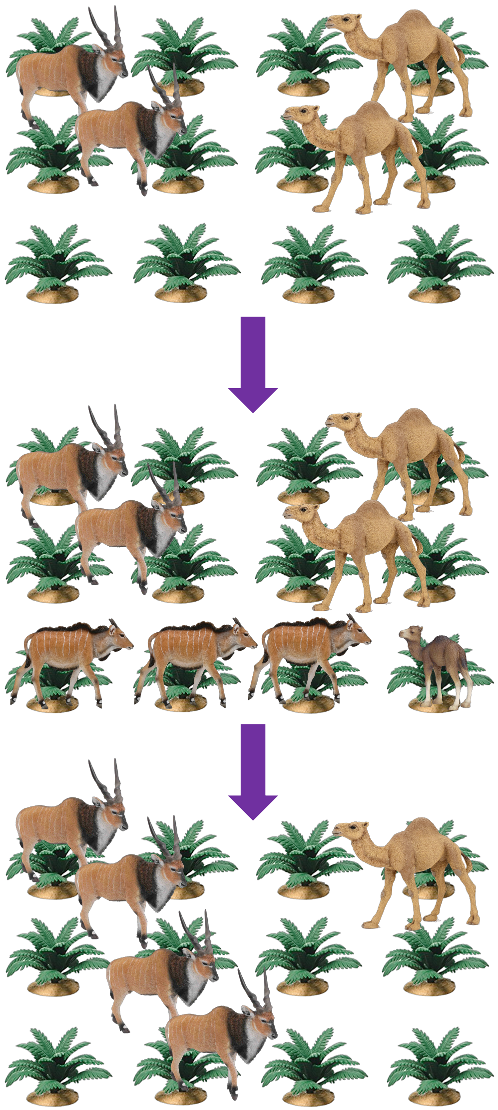

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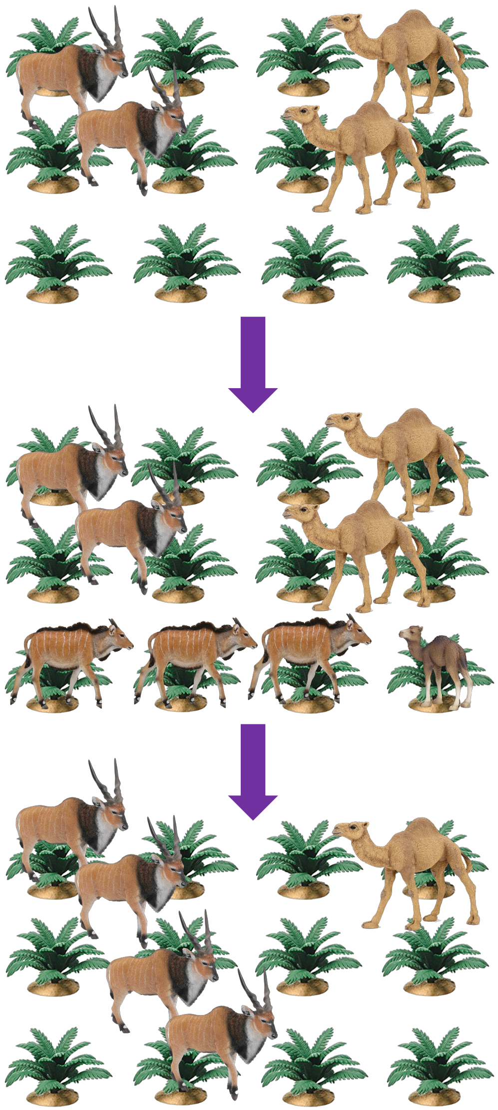
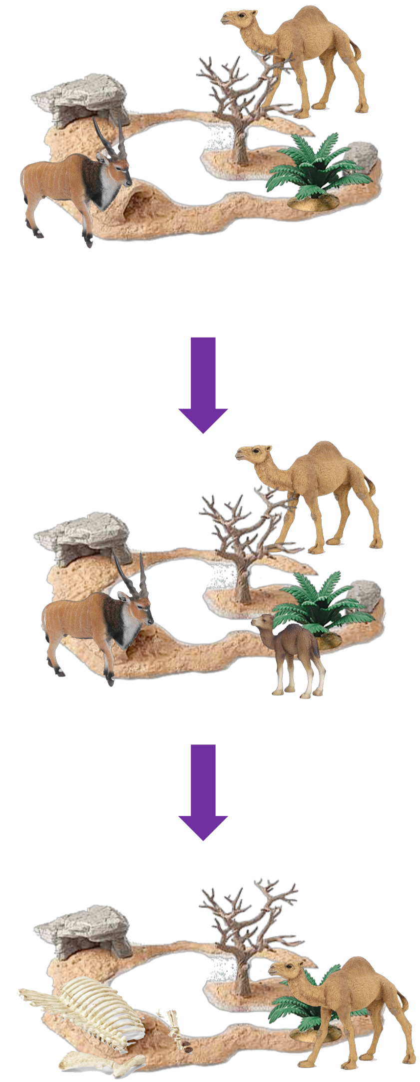




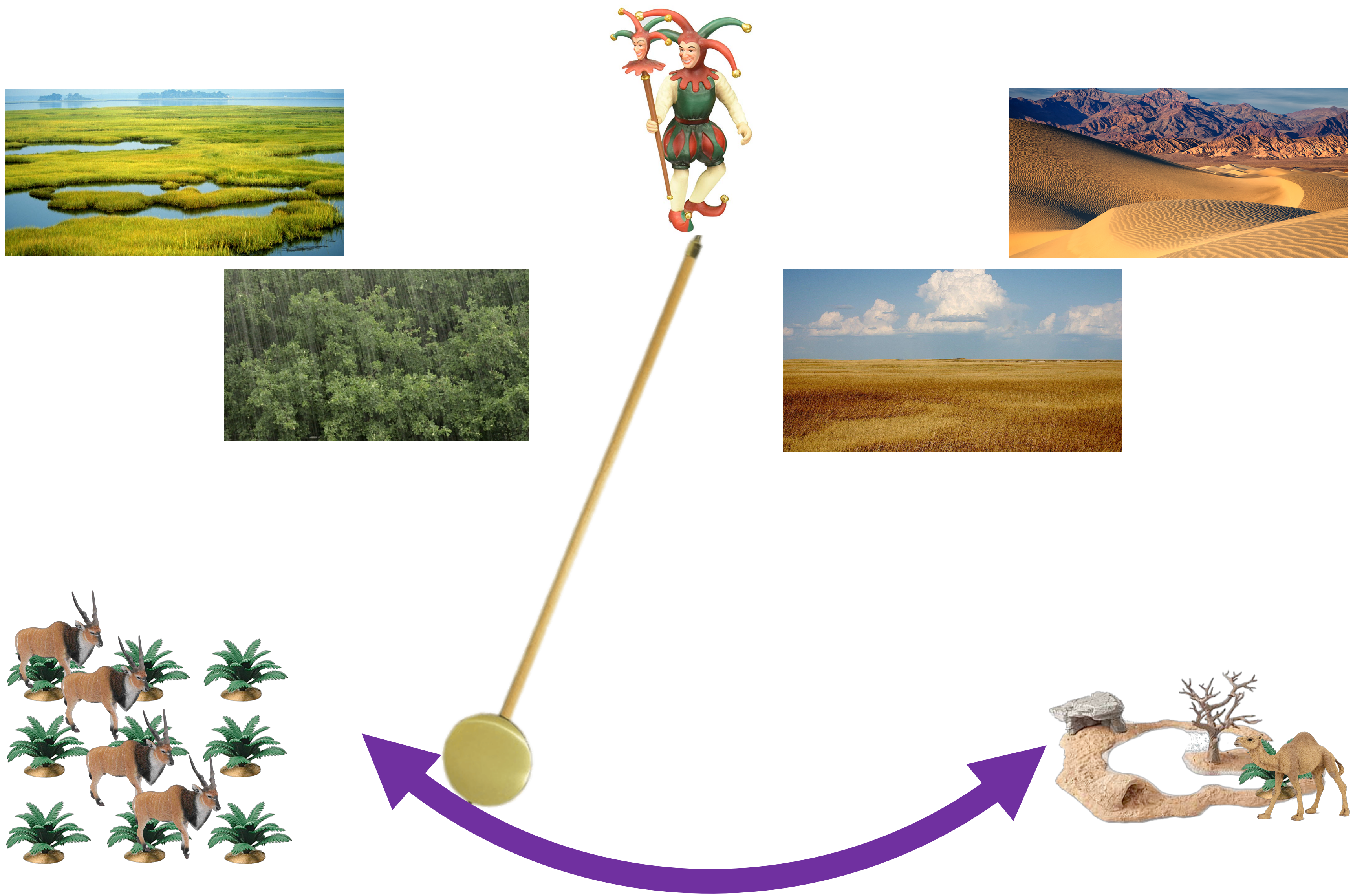
Are conditions stable enough so that the direction of a Darwinian Demon is always the same?

The Red Queen and the Court Jester: Species Diversity and the Role of Biotic and Abiotic Factors Through Time

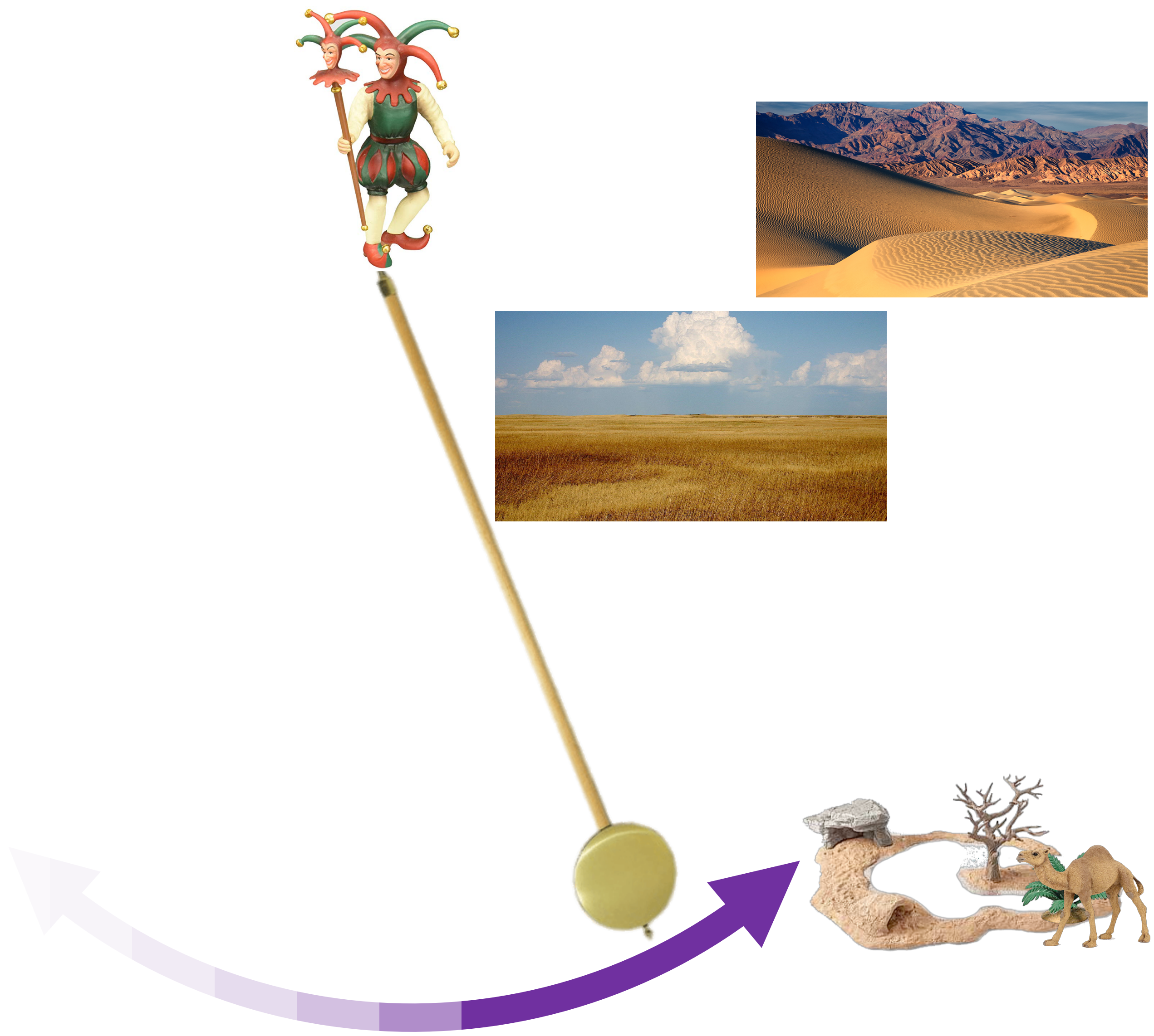
Michael J. Benton FEBRUARY 2009 VOL 323 **SCIENCE**

The Court Jester's pendulum

The Court Jester's pendulum

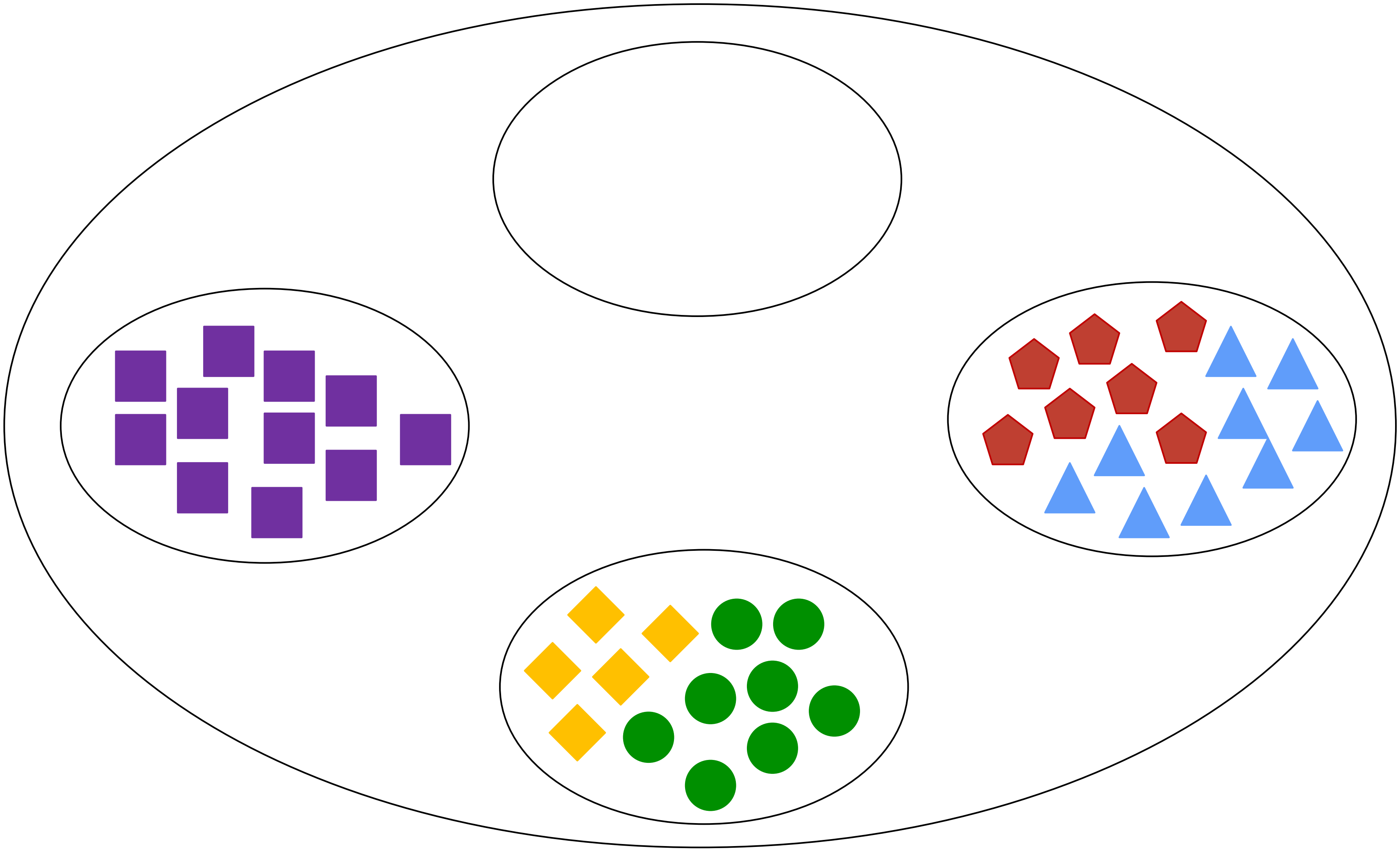


The Court Jester's pendulum



A priori conditions and their consequences

Resources are finite.



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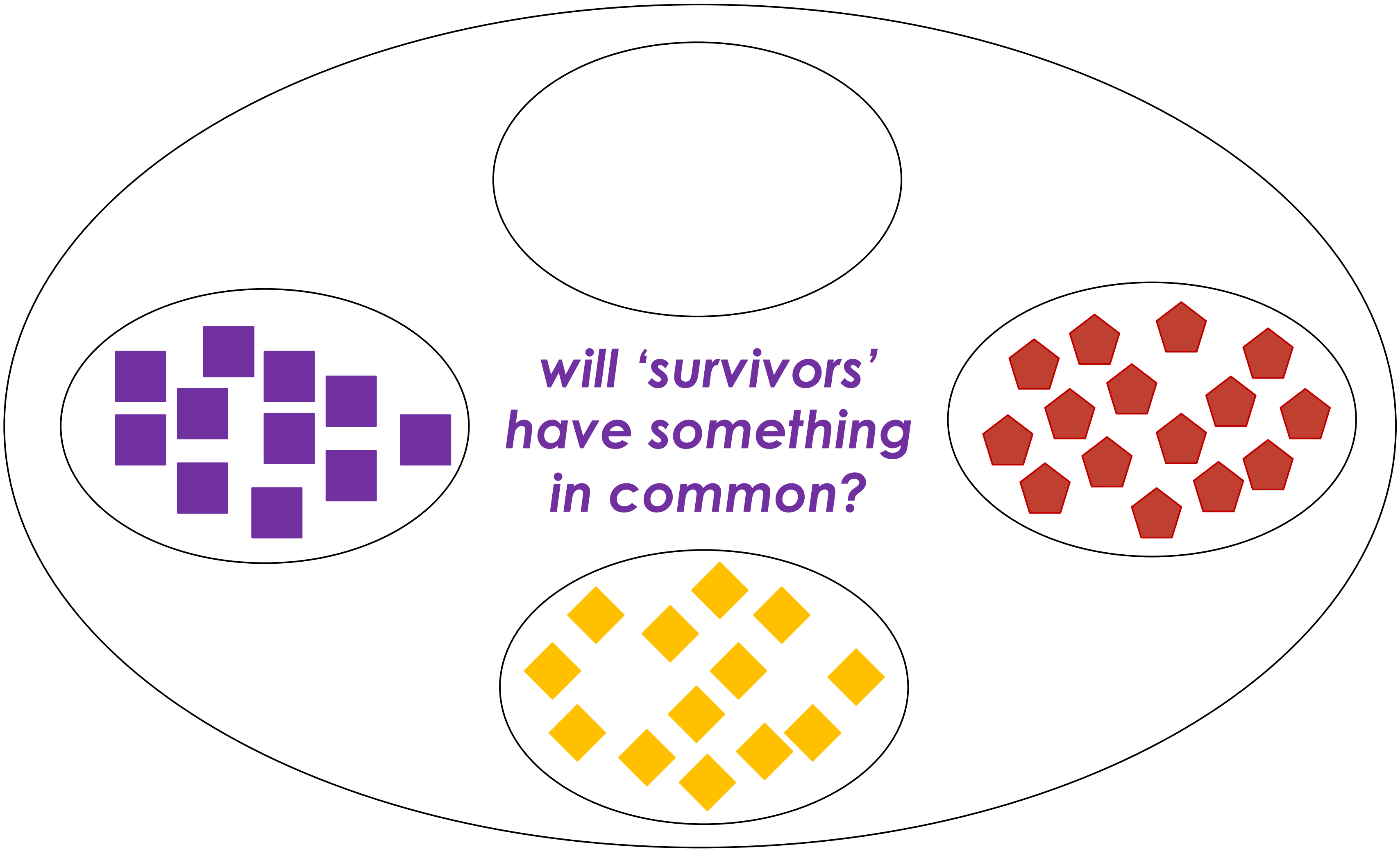

‘Evolutionary progress’ – directional evolution

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 evolution is a set of rules where the one constant (demographic) selective pressure is to outreproduce competitors.

In the presence of competitors, Darwinian selection should always go in the ***direction*** *of a 'Darwinian Demon'.*

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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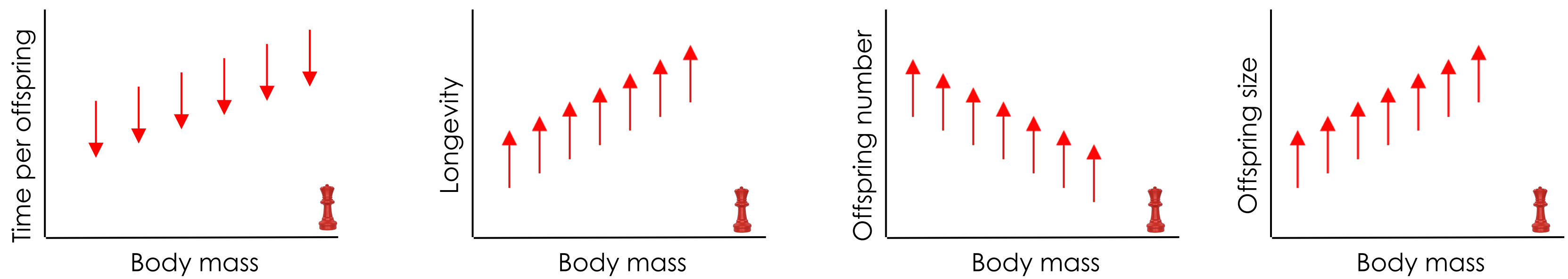

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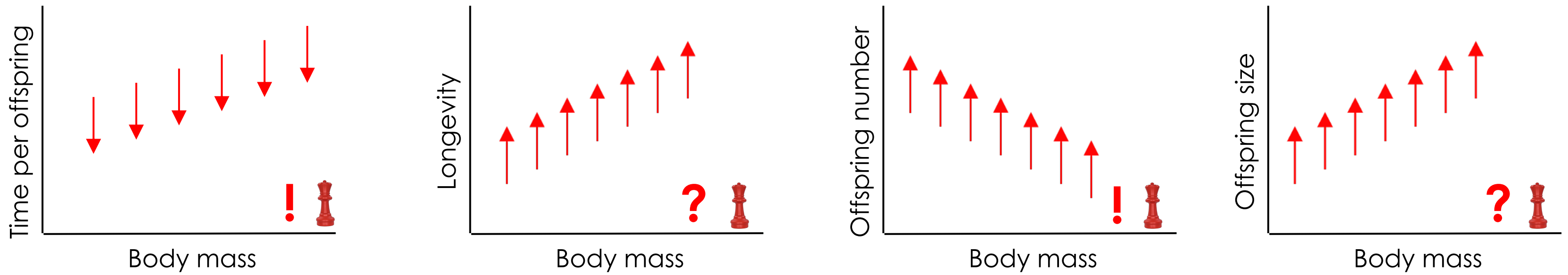

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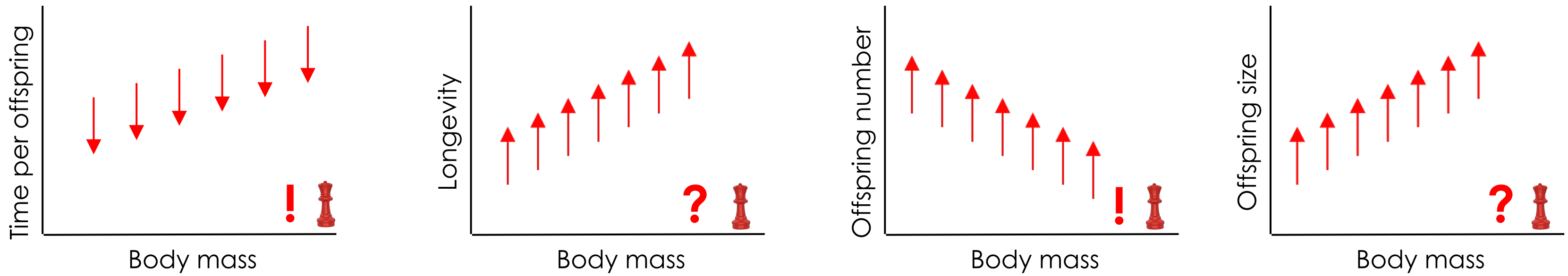

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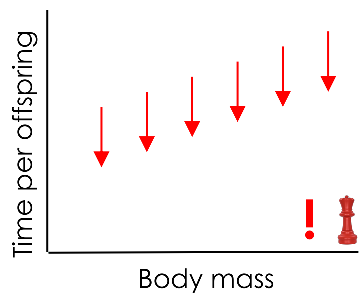

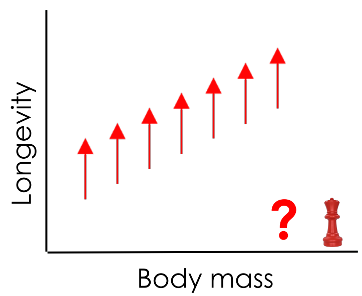

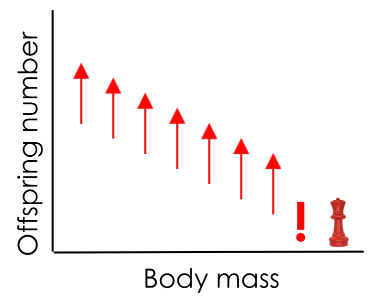

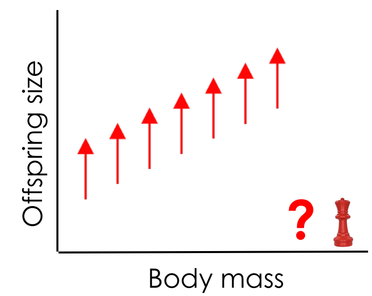

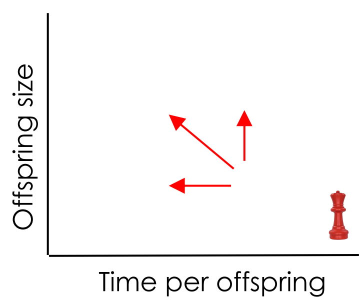

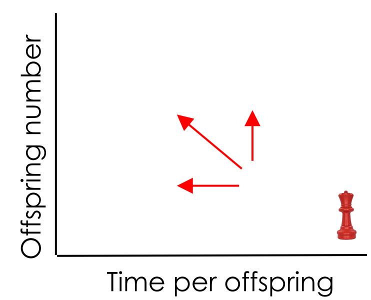

FASTER

A priori conditions and their consequences

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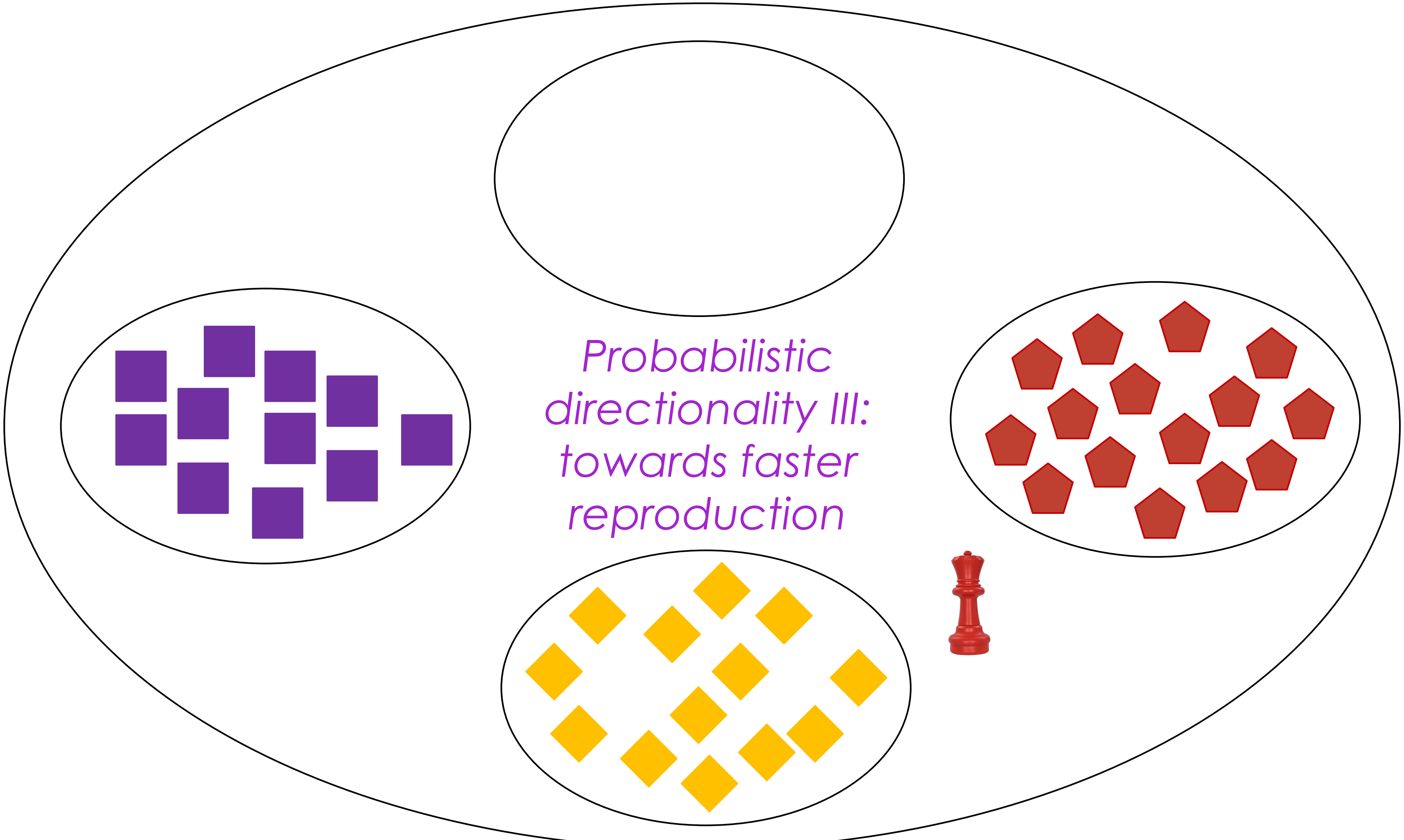
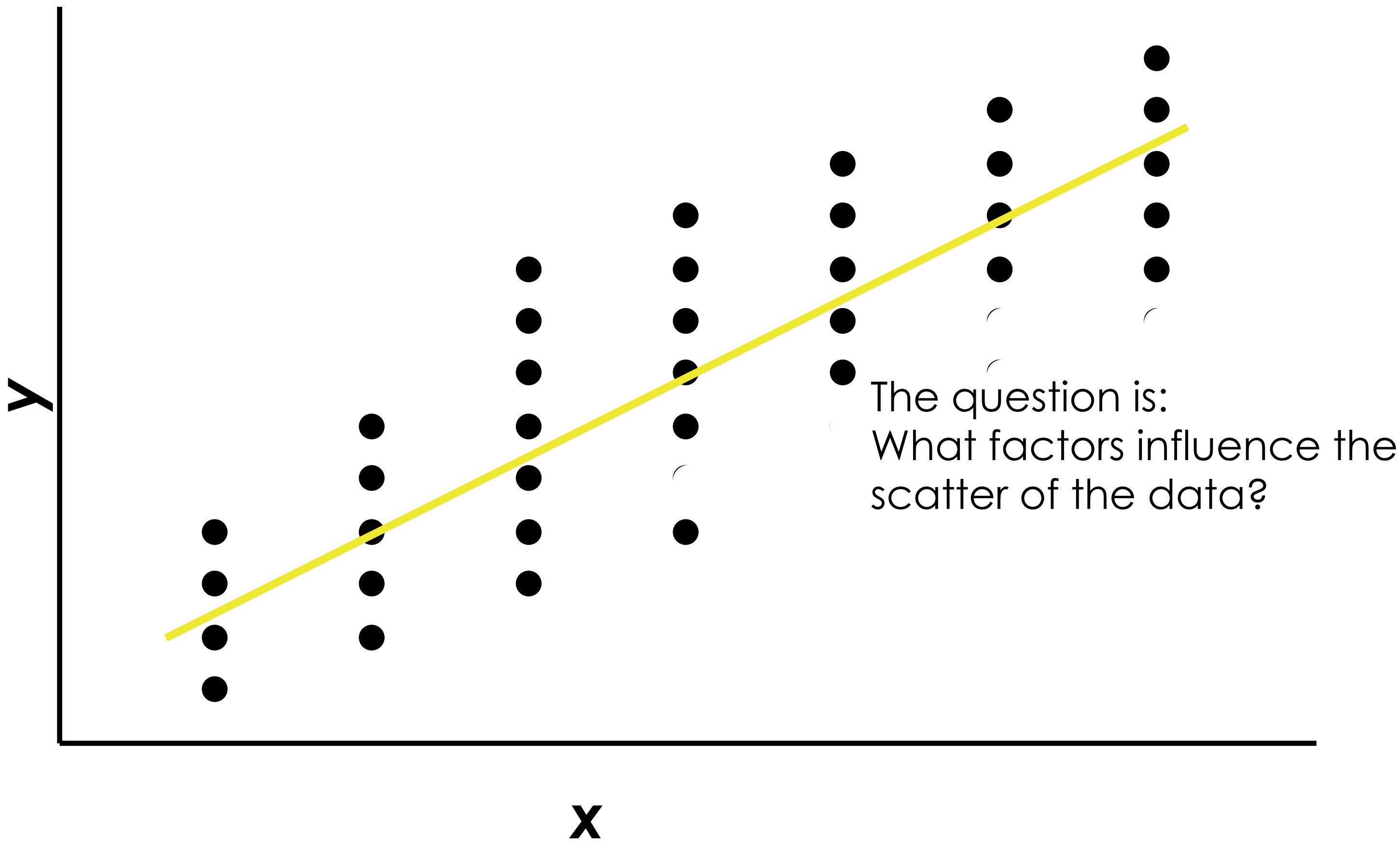


Interpreting scaling

Morphological, physiological and life history variables scale.



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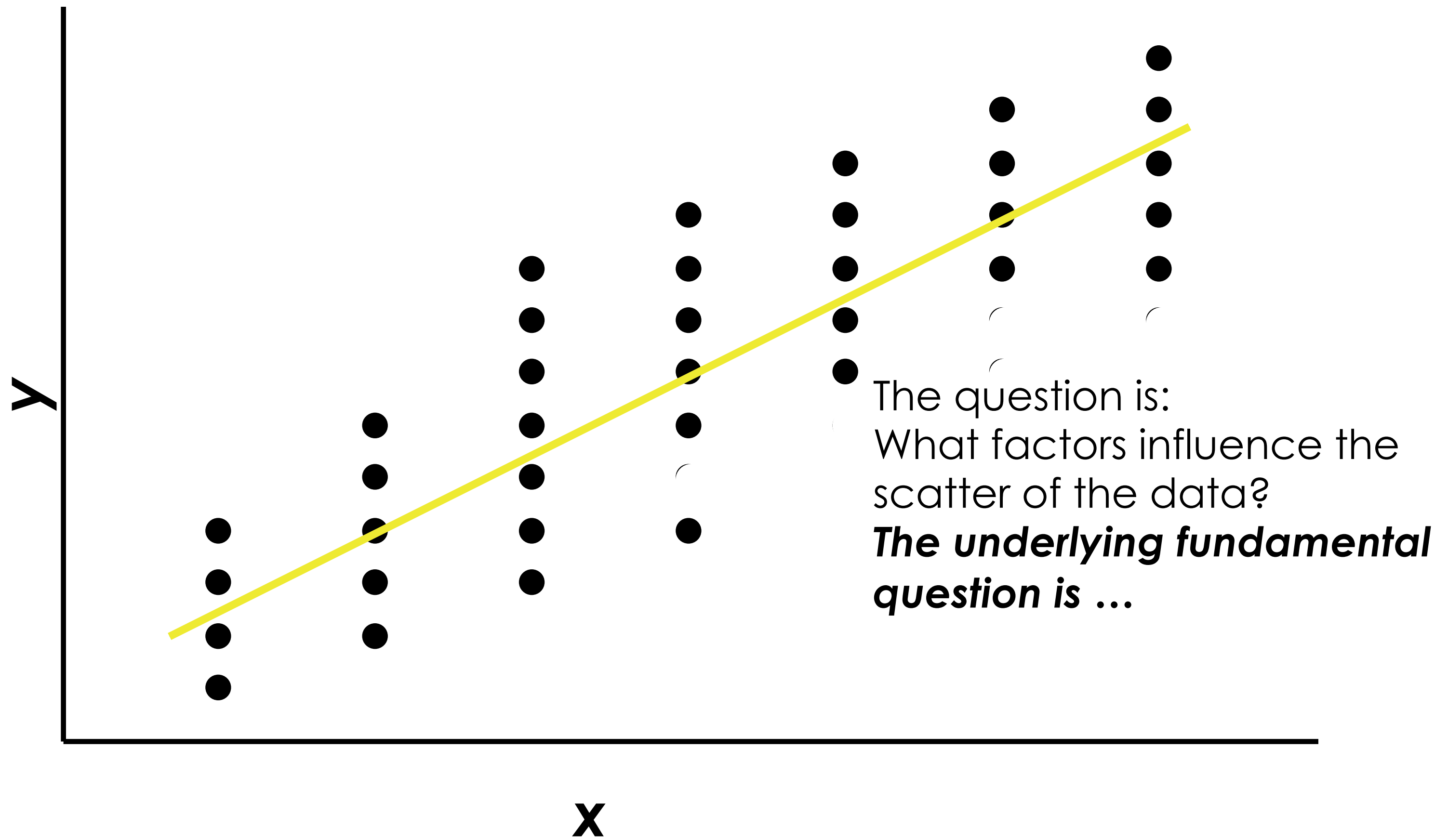

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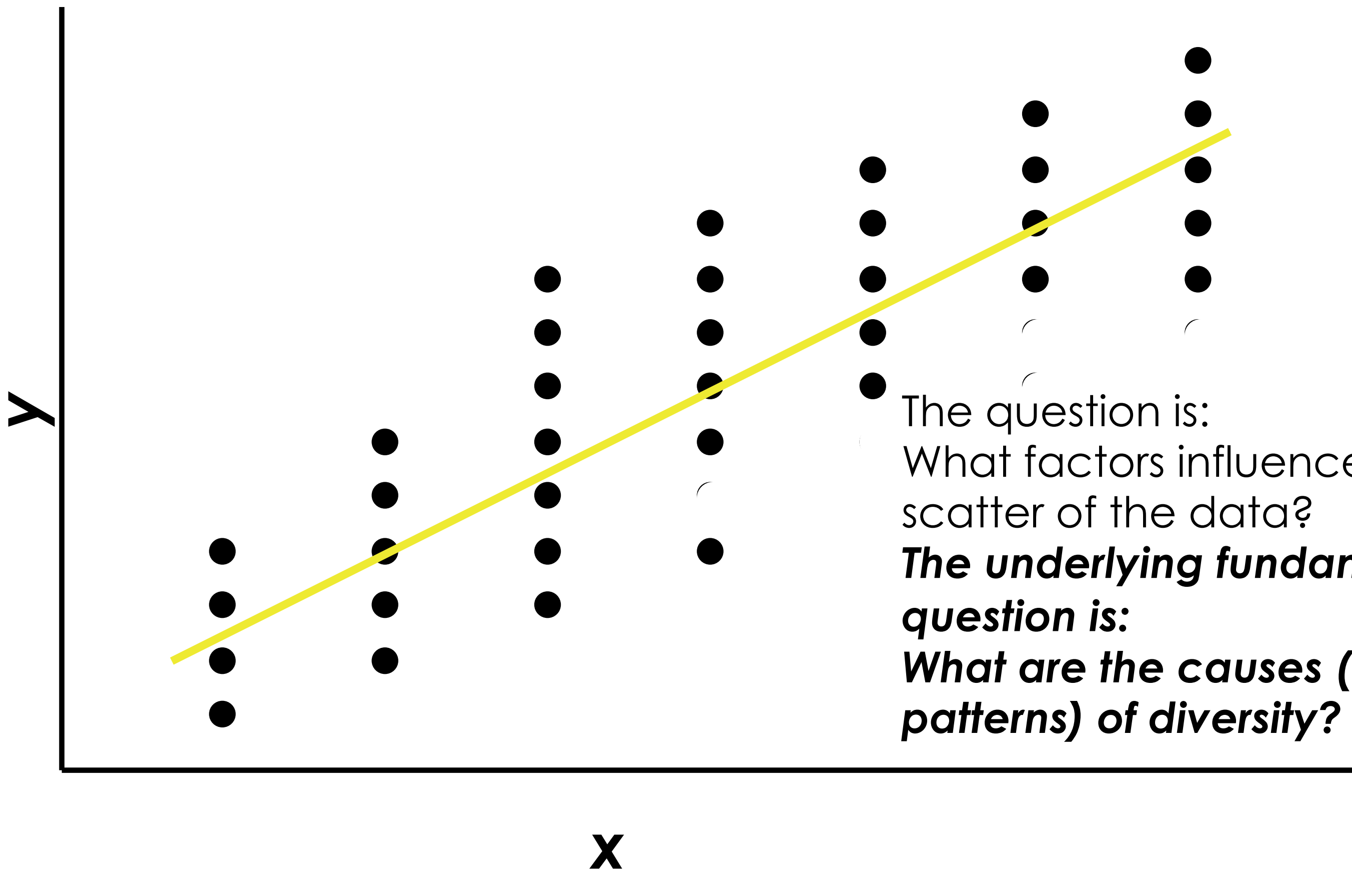
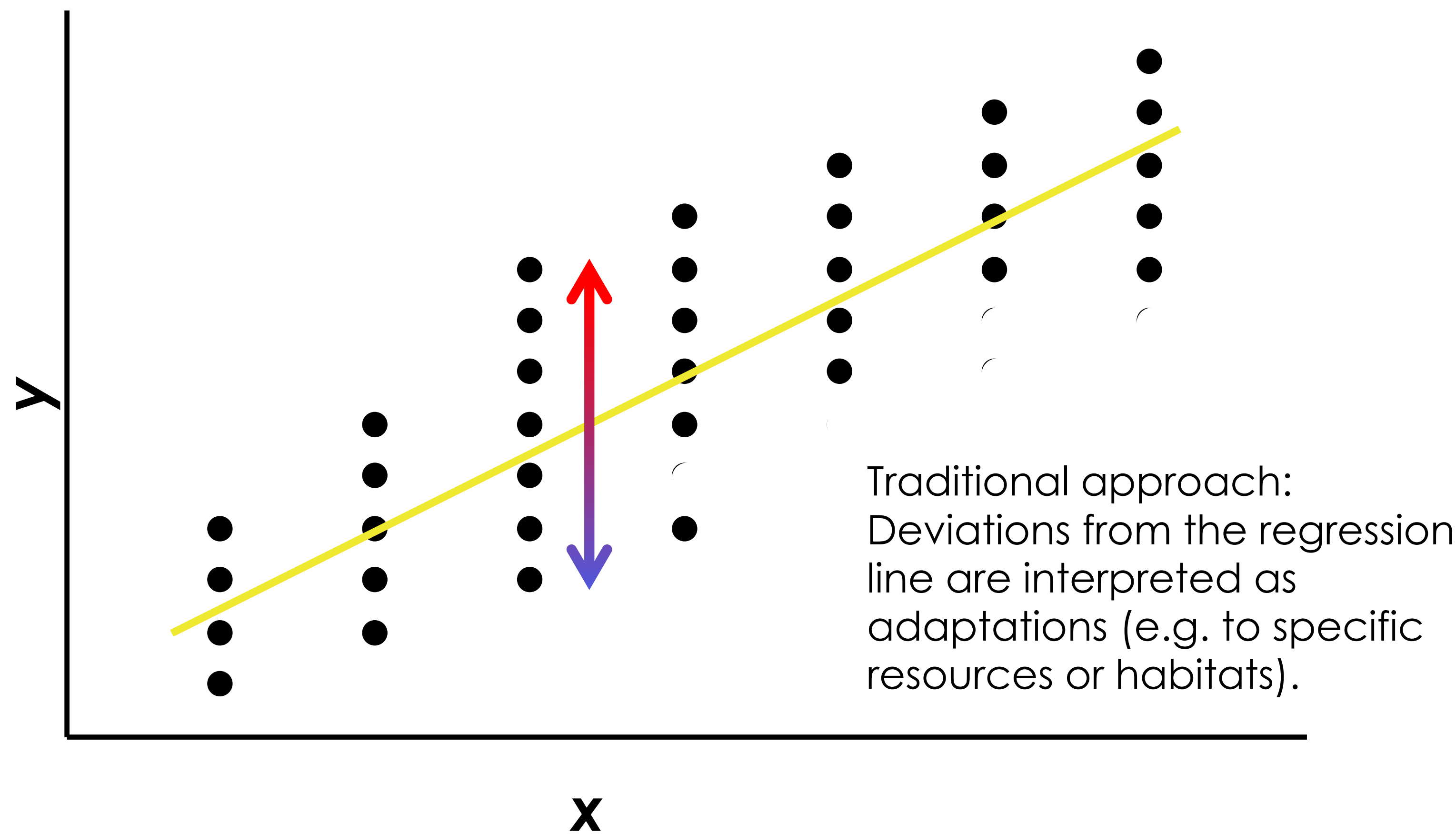


The question is:
What factors influence the scatter of the data?
The underlying fundamental question is:
What are the causes (and patterns) of diversity?

Interpreting scaling

Morphological, physiological and life history variables scale.



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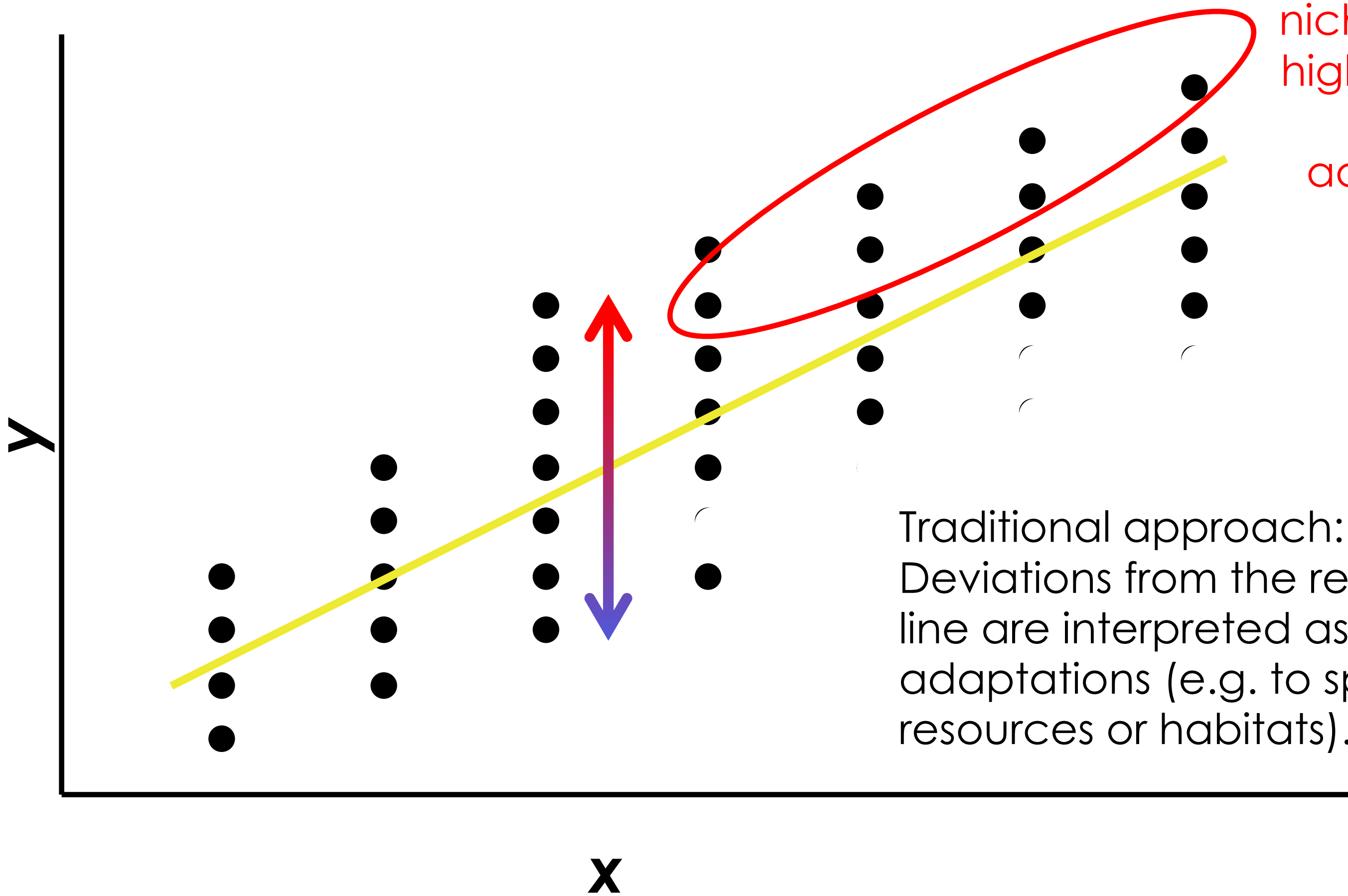
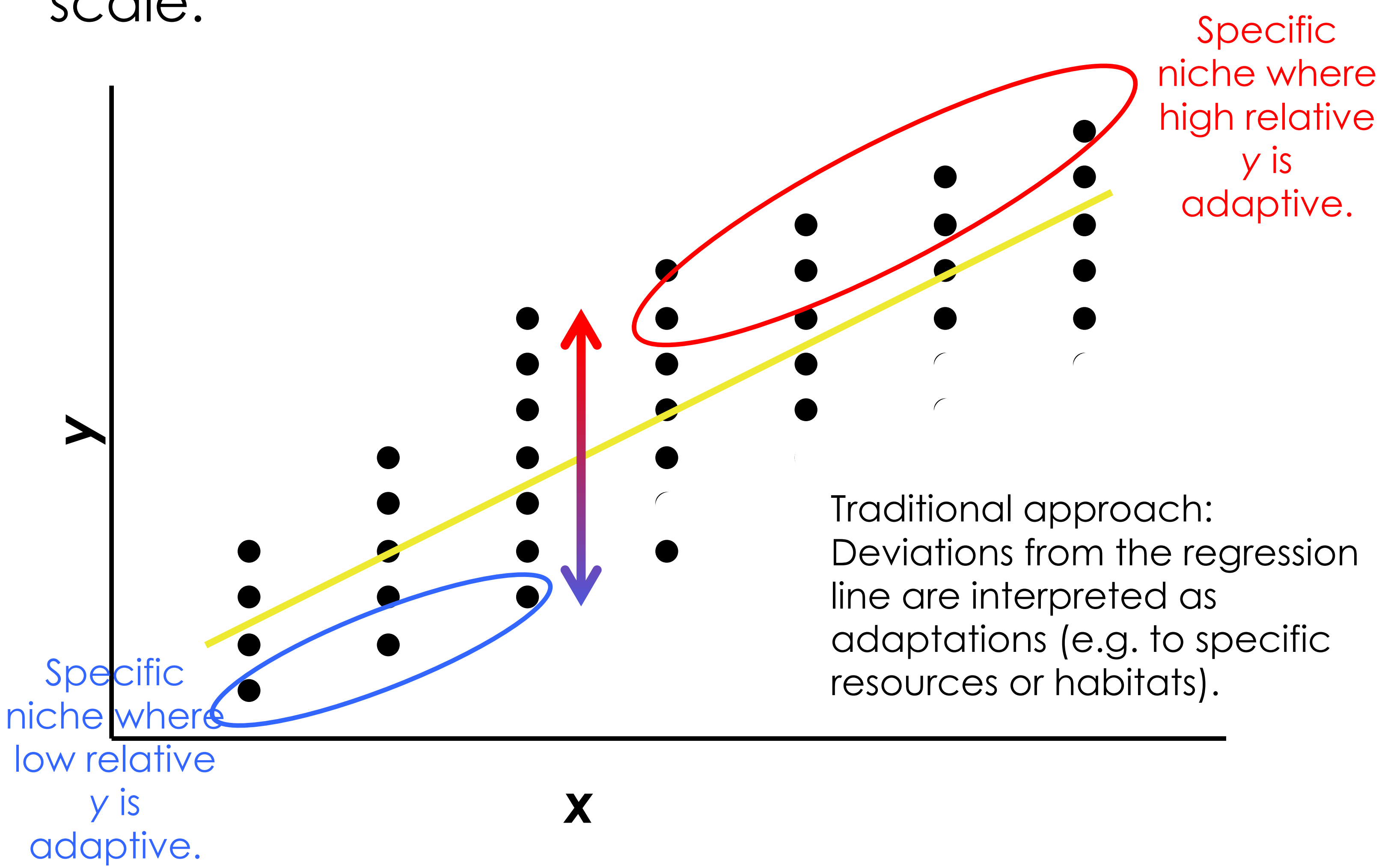


Specific niche where high relative y is adaptive.

Traditional approach: Deviations from the regression line are interpreted as adaptations (e.g. to specific resources or habitats).

Interpreting scaling

Morphological, physiological and life history variables scale.

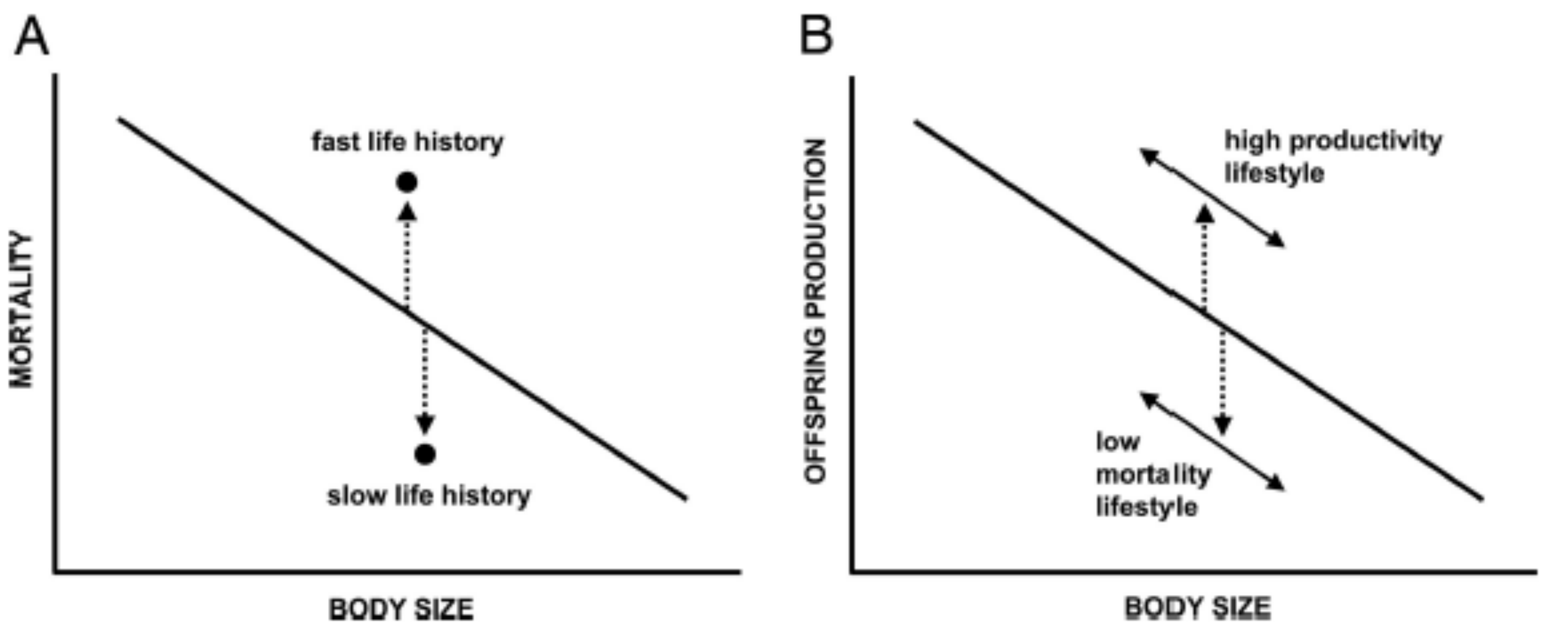


Life history scaling

A lifestyle view of life-history evolution

F. Stephen Dobson*

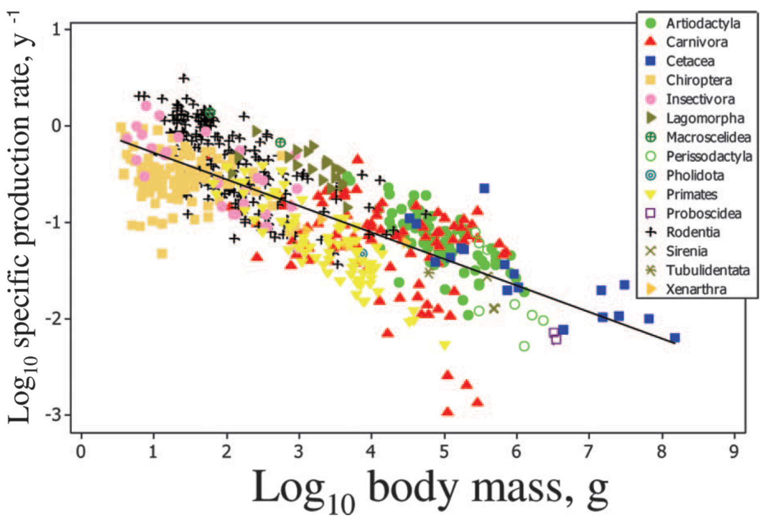
PNAS | November 6, 2007 | vol. 104 | no. 45 | 17565–17566



Effects of body size and lifestyle on evolution of mammal life histories

Richard M. Sibly*[†‡] and James H. Brown[‡§¶]

PNAS | November 6, 2007 | vol. 104 | no. 45 | 17707–17712



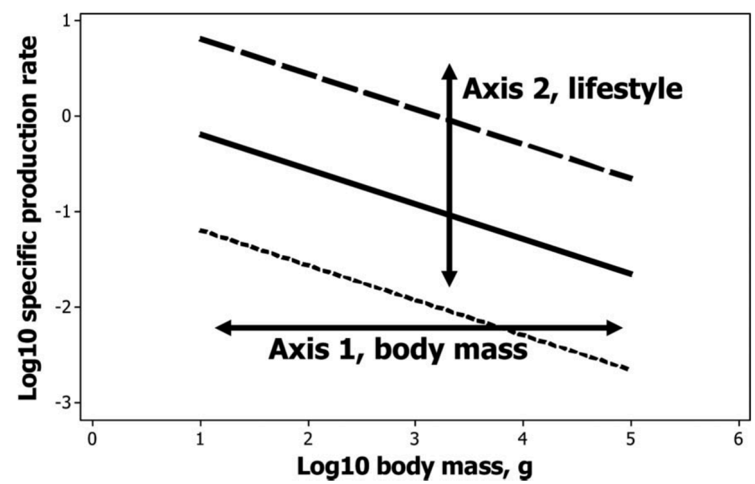
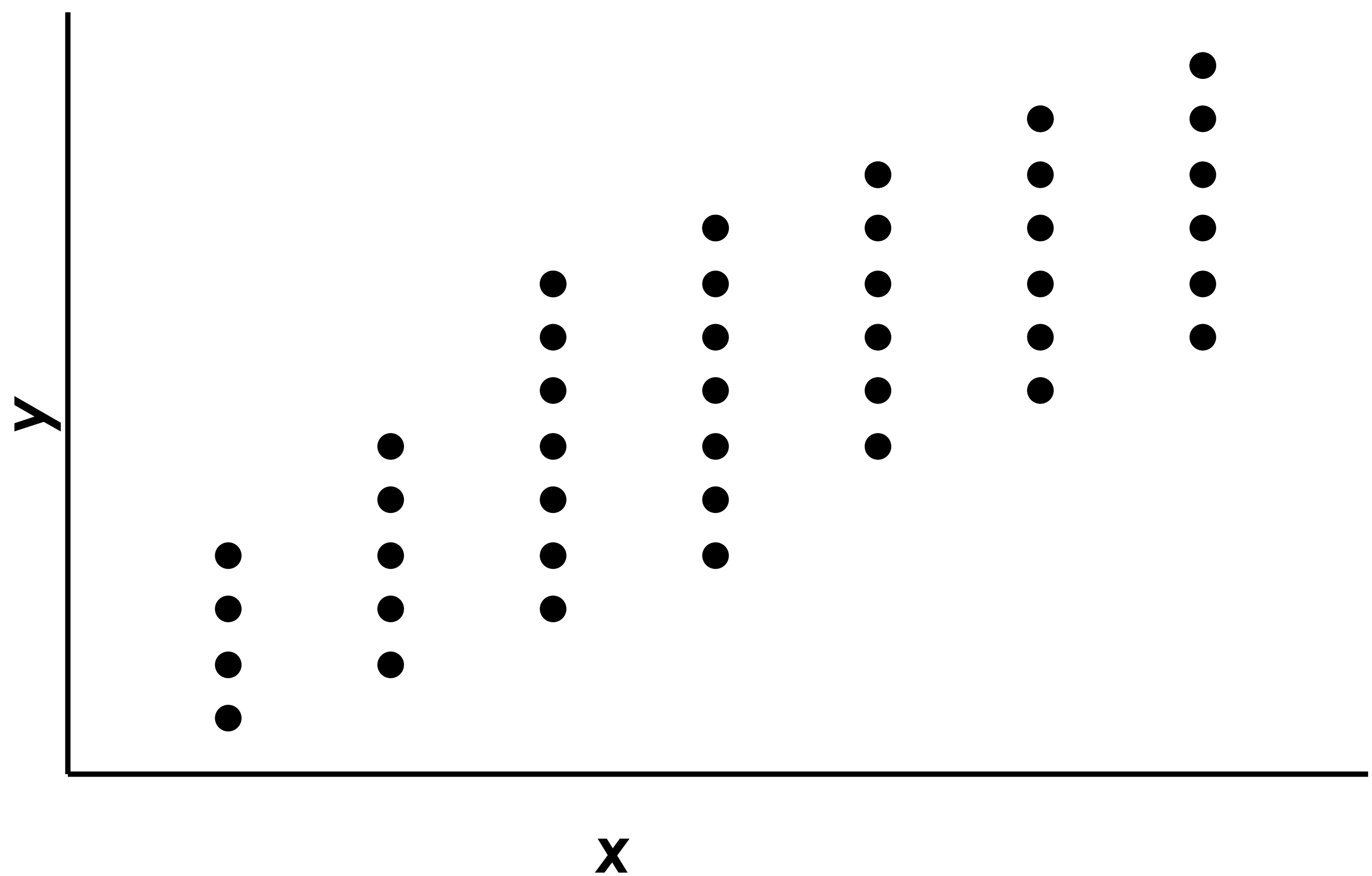


Fig. 4. The two major axes of the slow–fast life-history continuum, body mass, and lifestyle. To the well known axis of allometric variation due to body size, we have added a second orthogonal axis based on ecological lifestyle. Here the solid line represents an unspecialized ancestral condition, the dashed line depicts a more productive ''live fast die young'' lifestyle, and the dotted line shows a lifestyle with a lower death rate, slower life history, and consequently lower production.

Interpreting scaling

Is there a systematic phylogenetic structure in the dataset?



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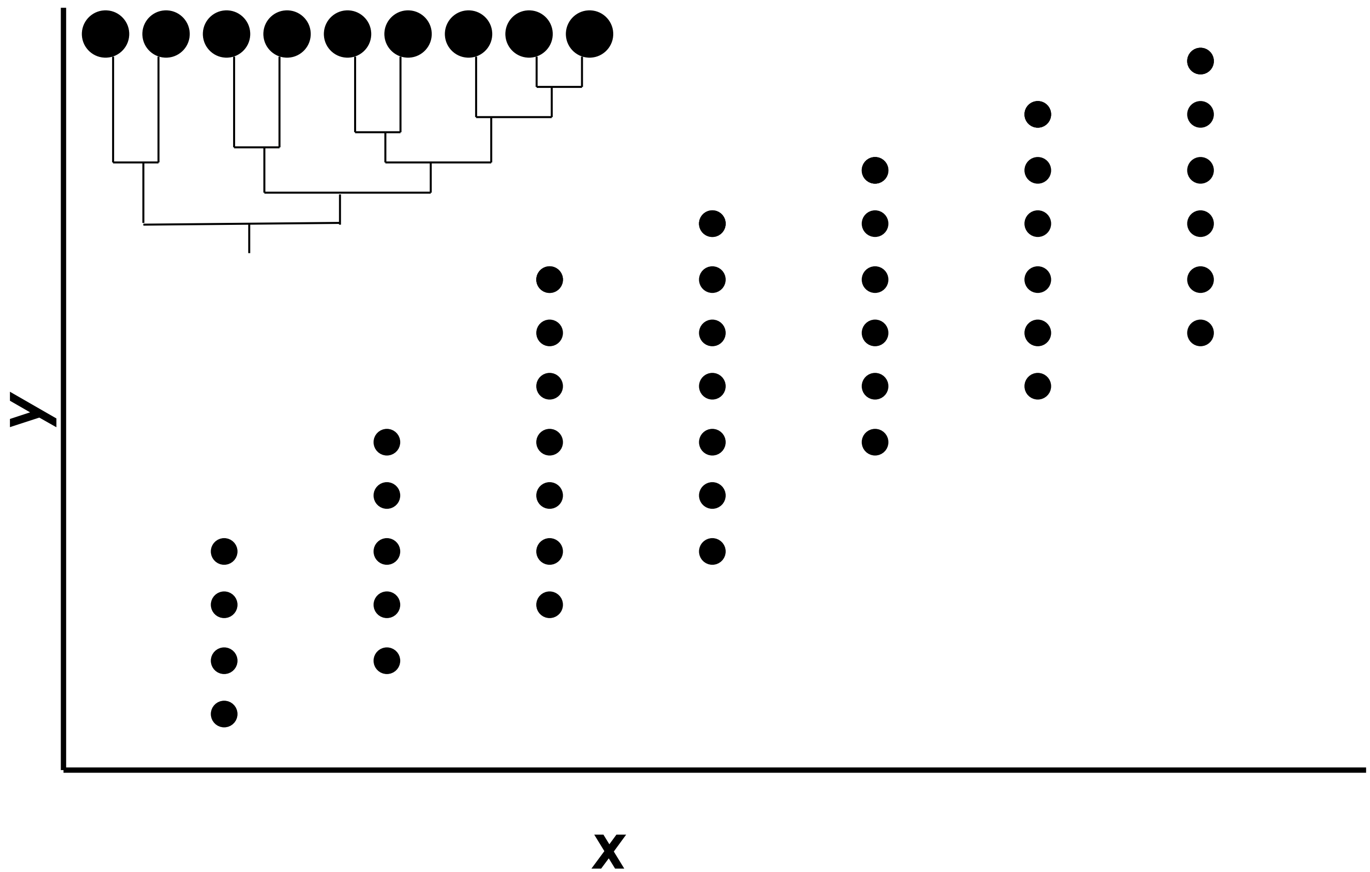

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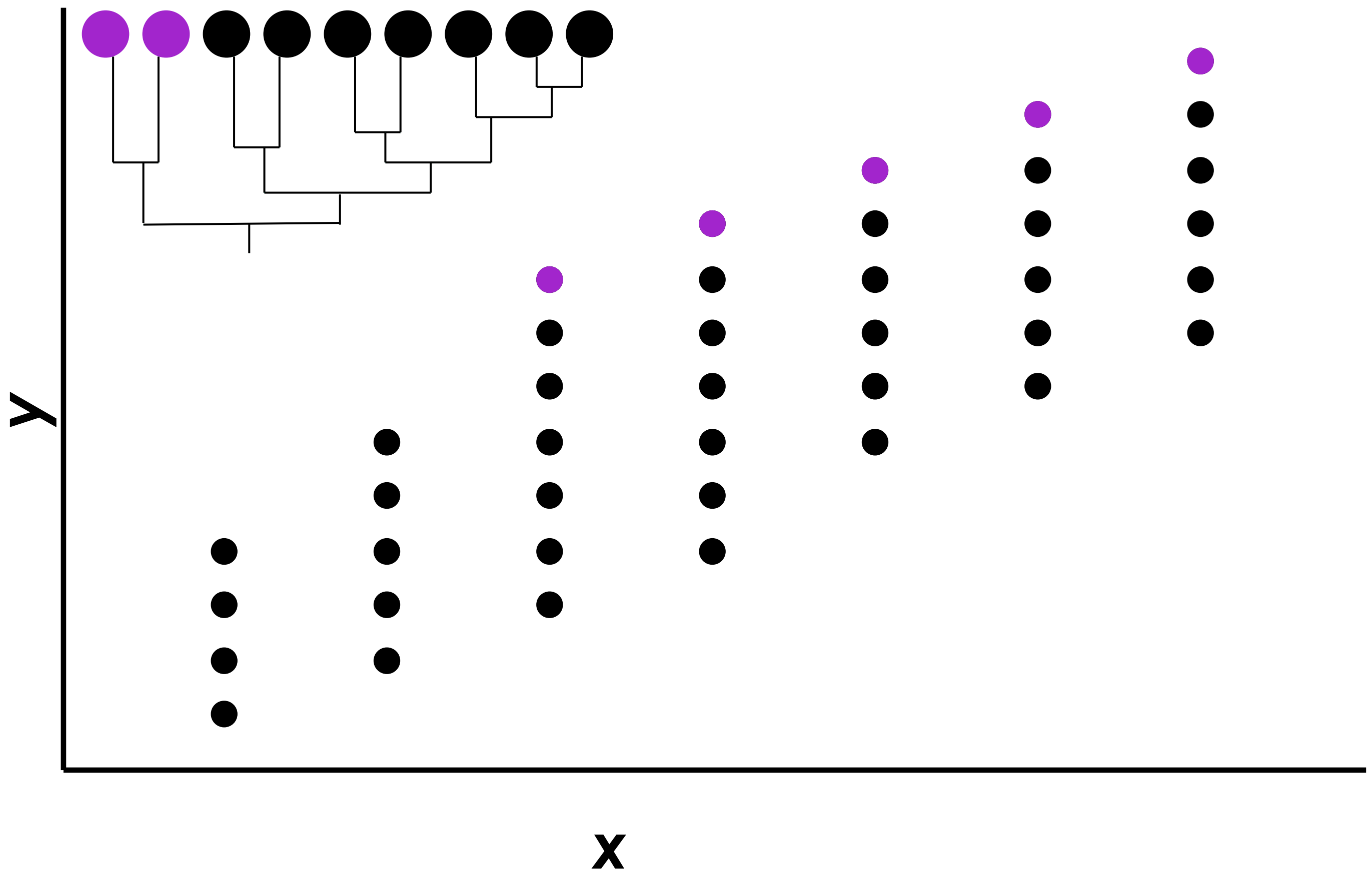

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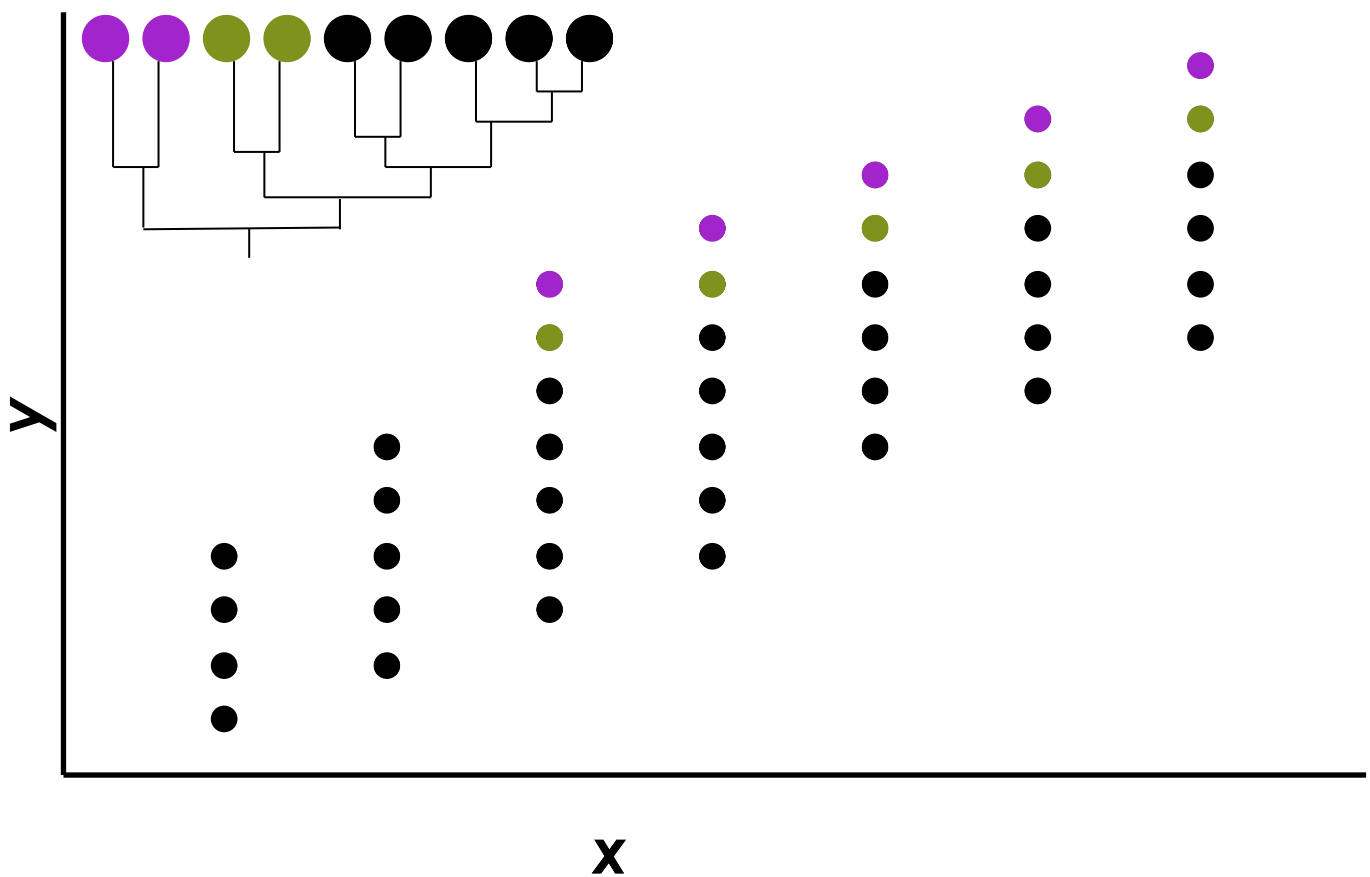

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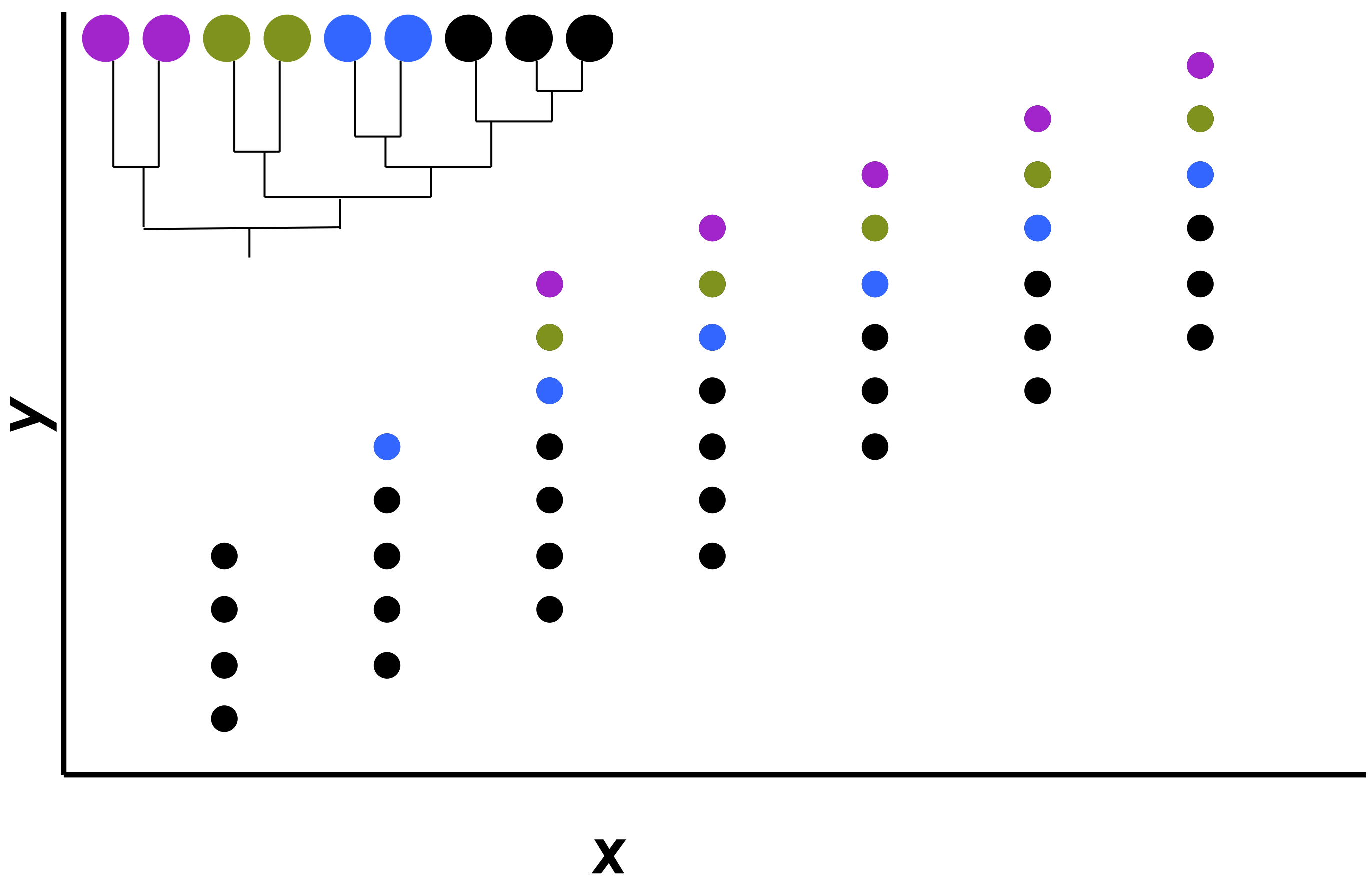

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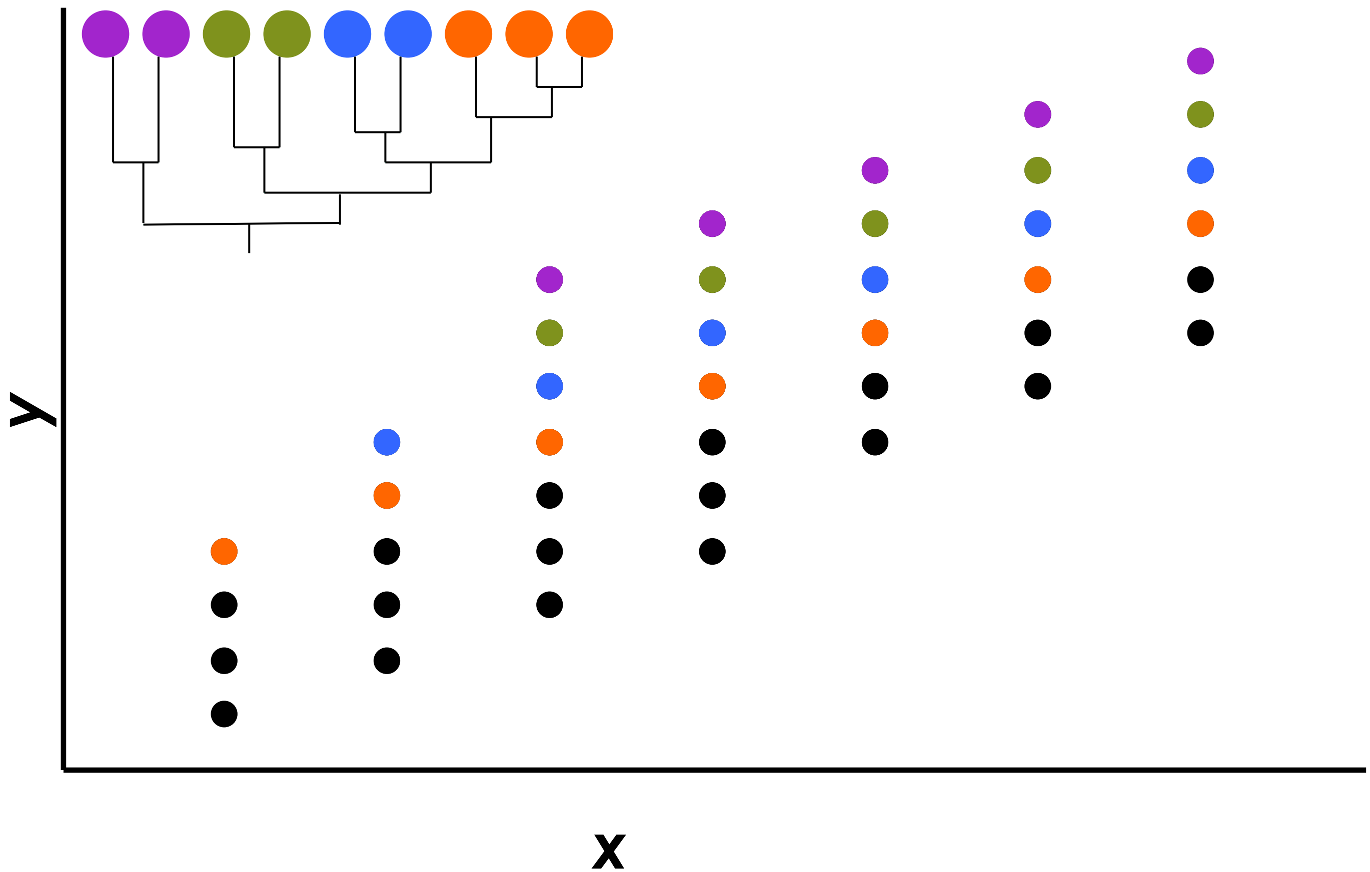

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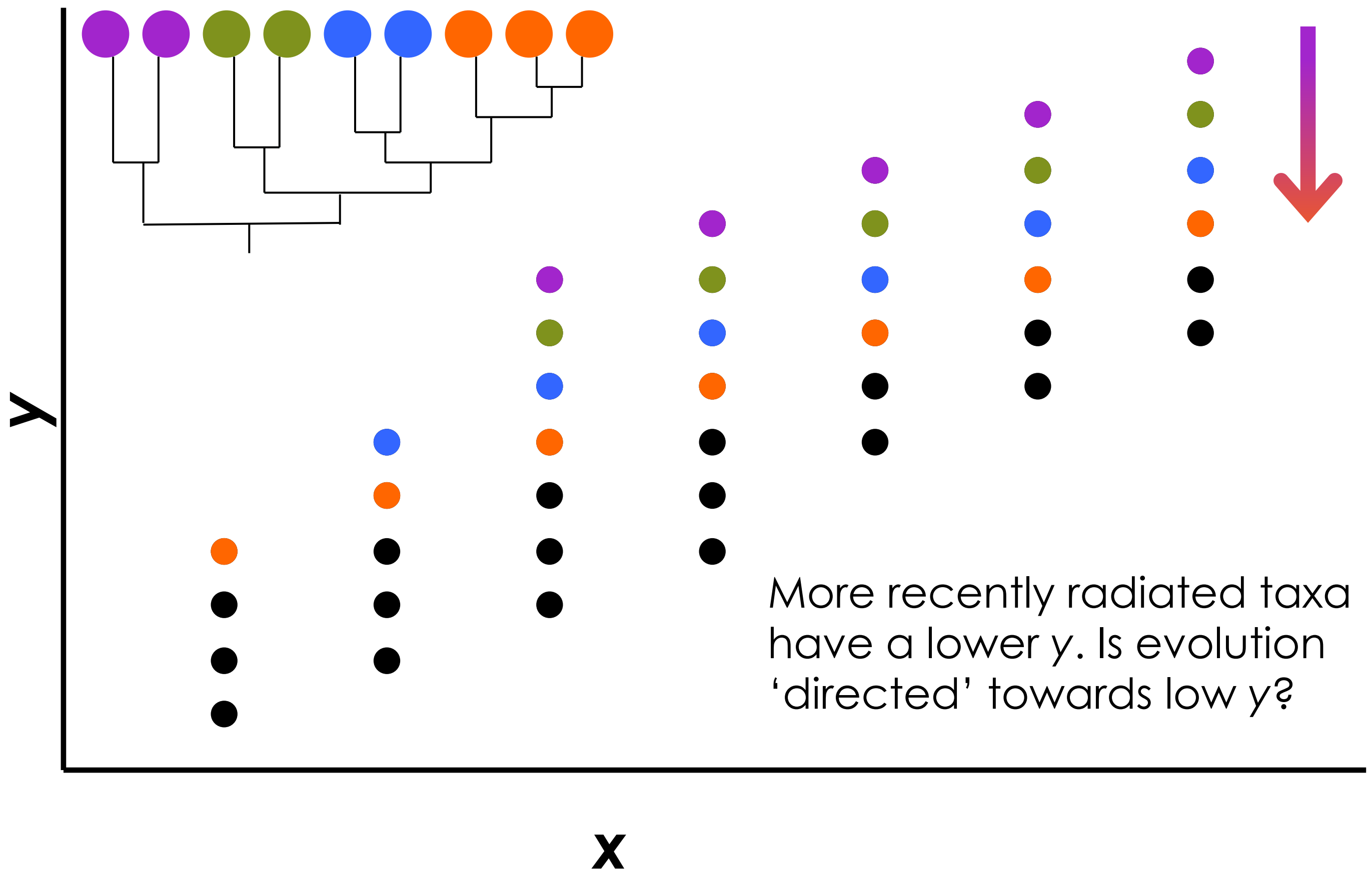

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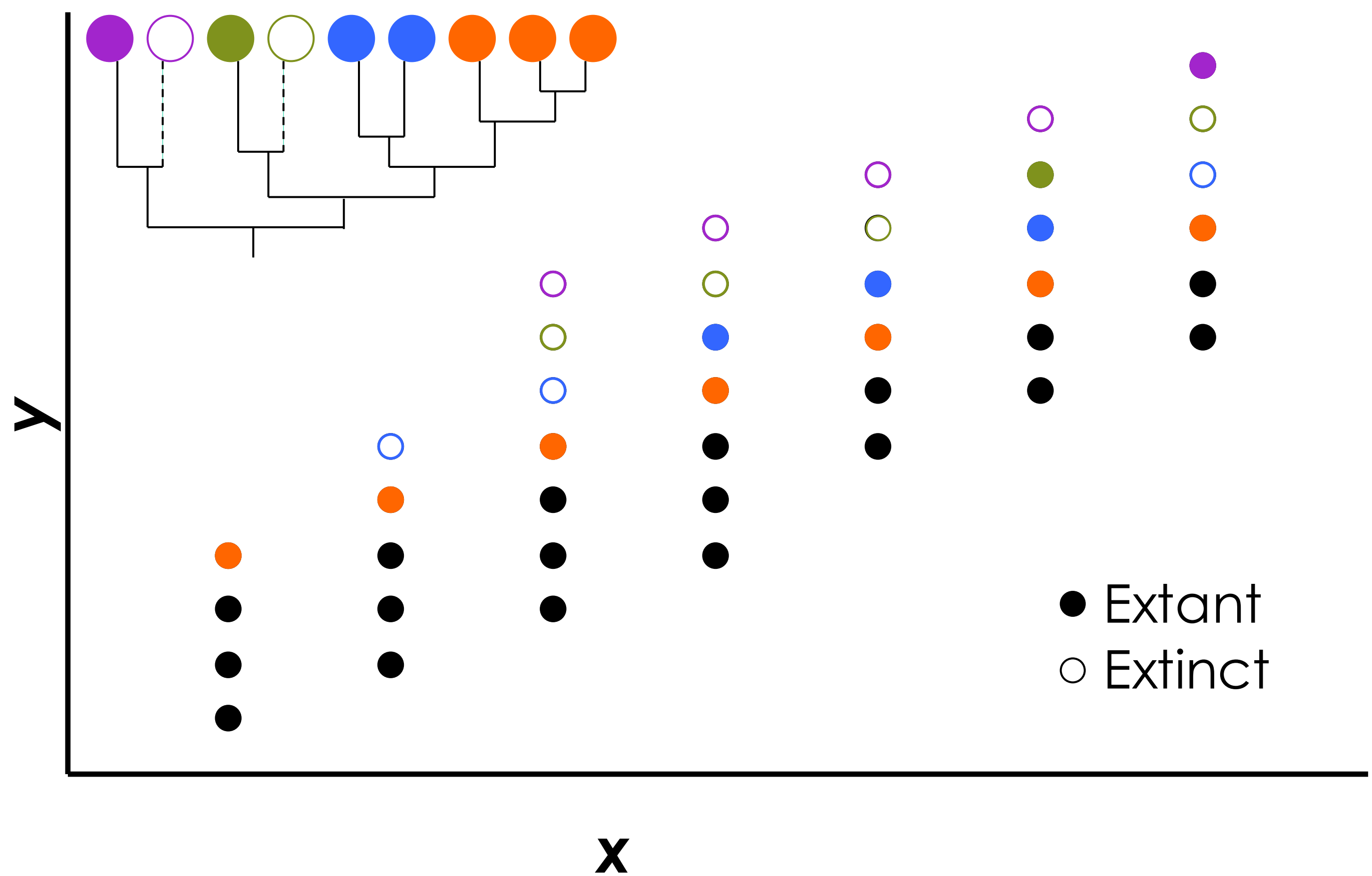

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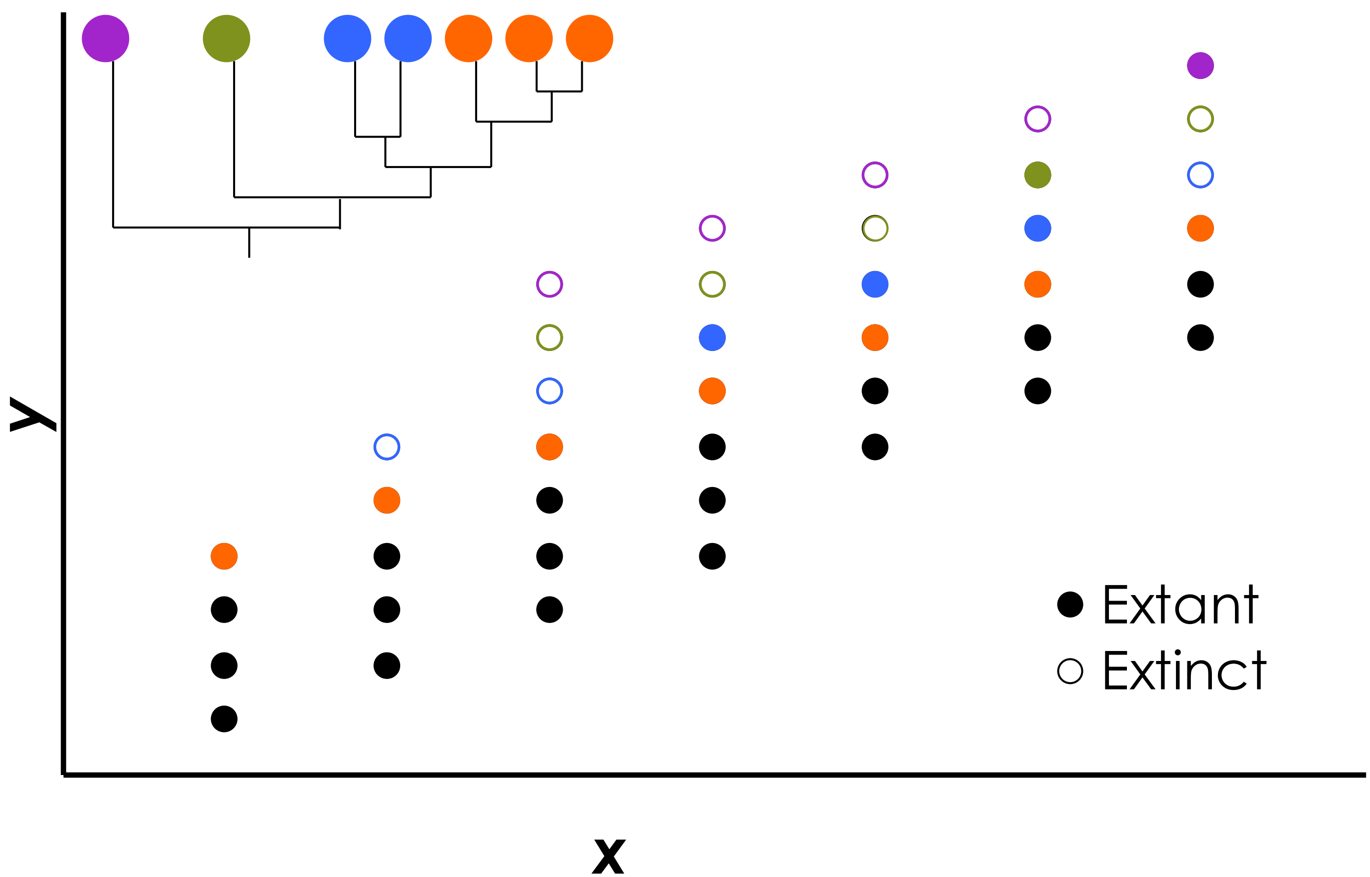

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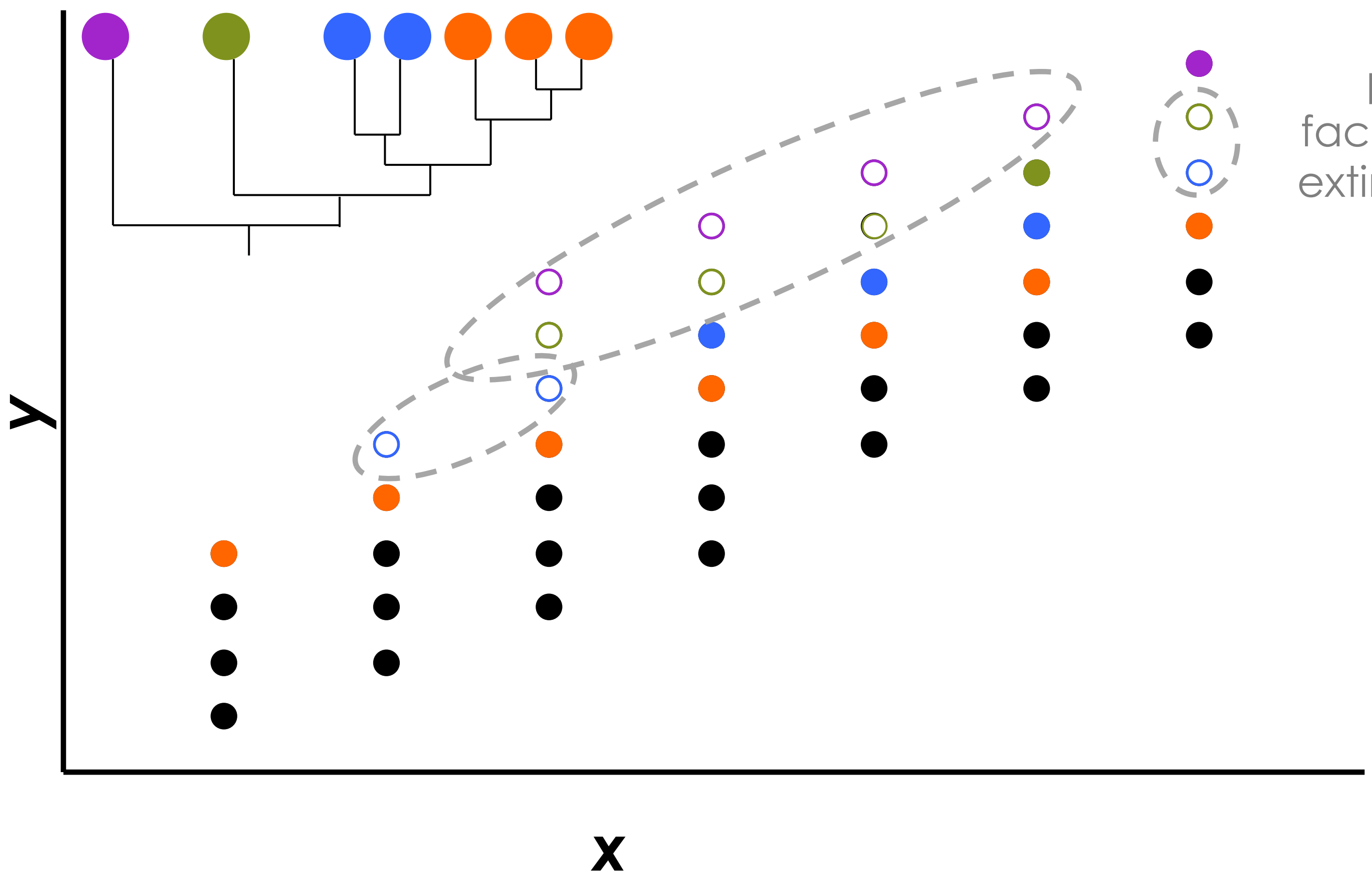

High y a potential factor in the extinction of species?

Interpreting scaling

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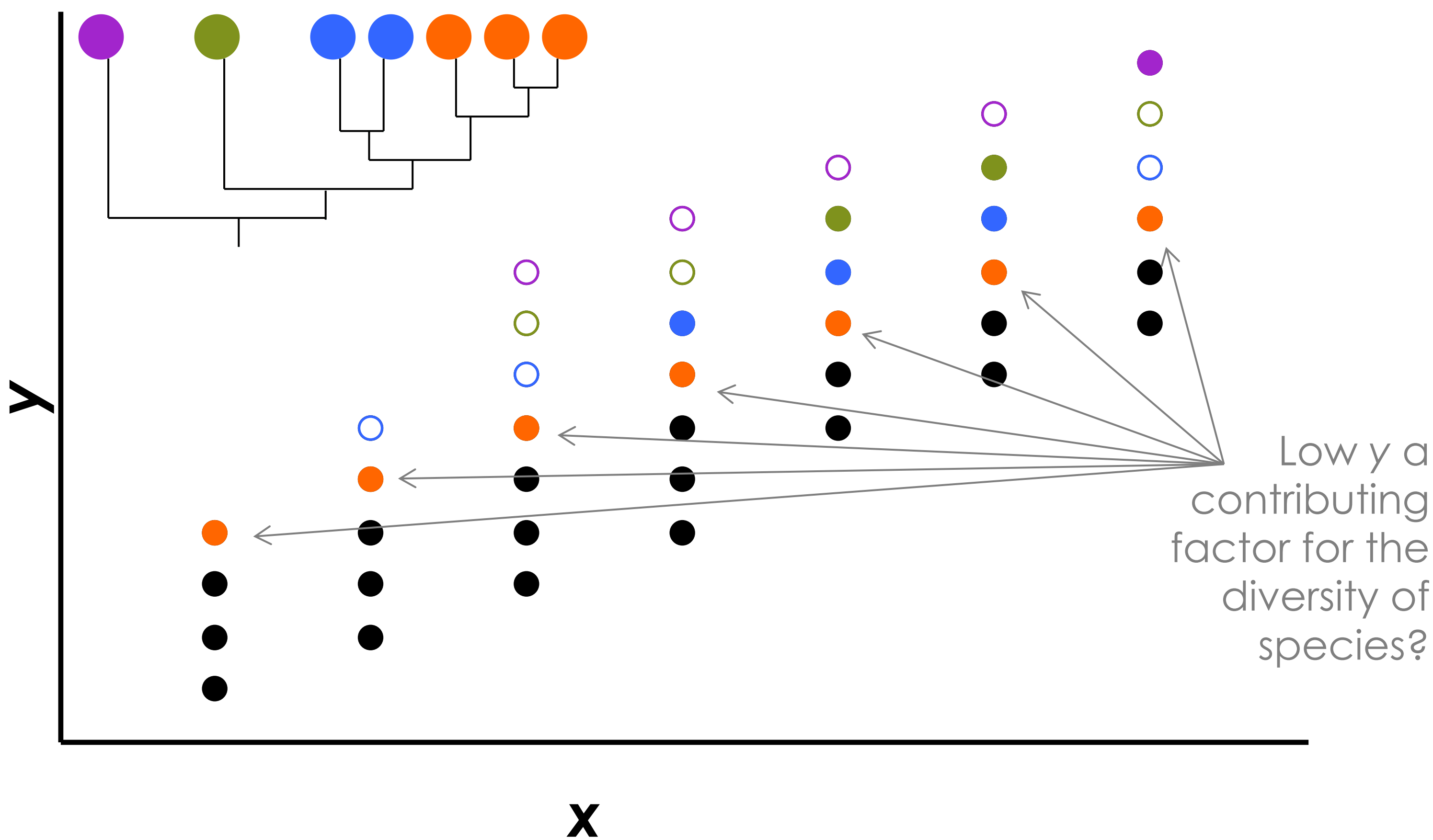

Interpreting scaling: snapshots

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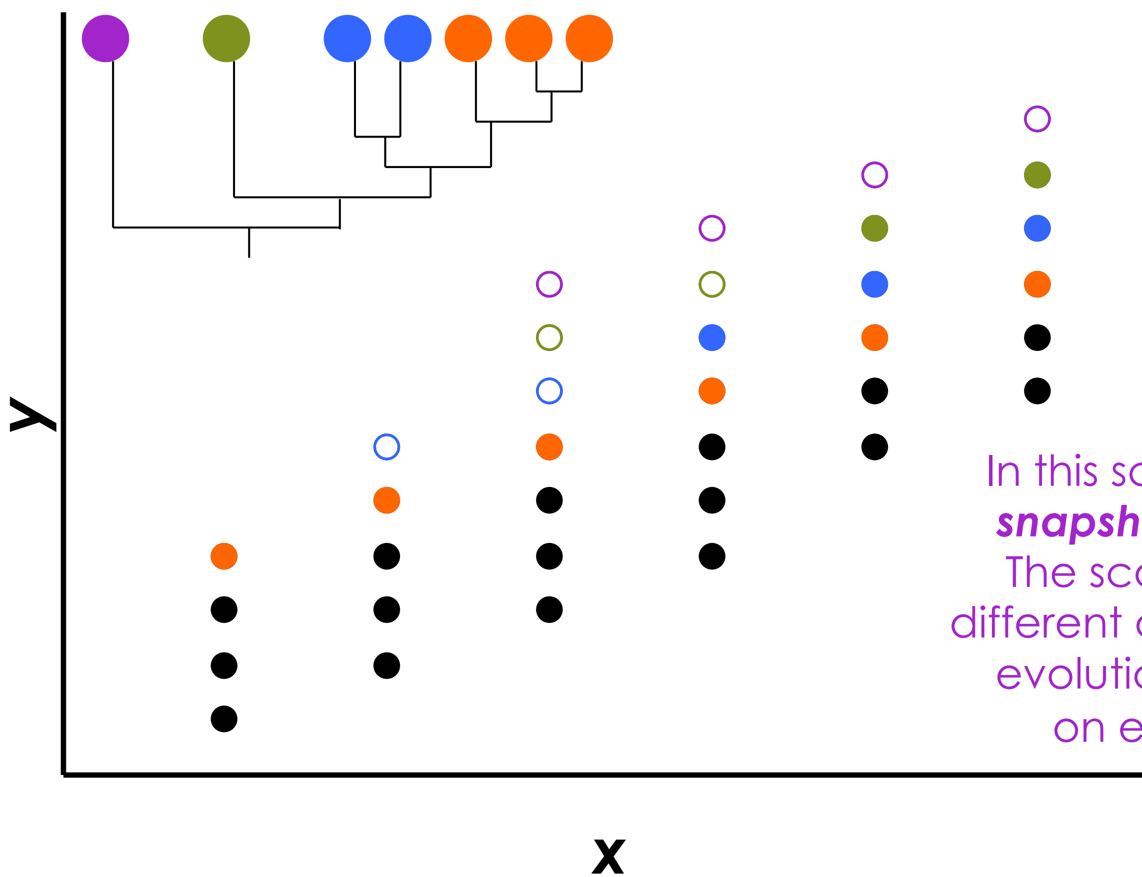
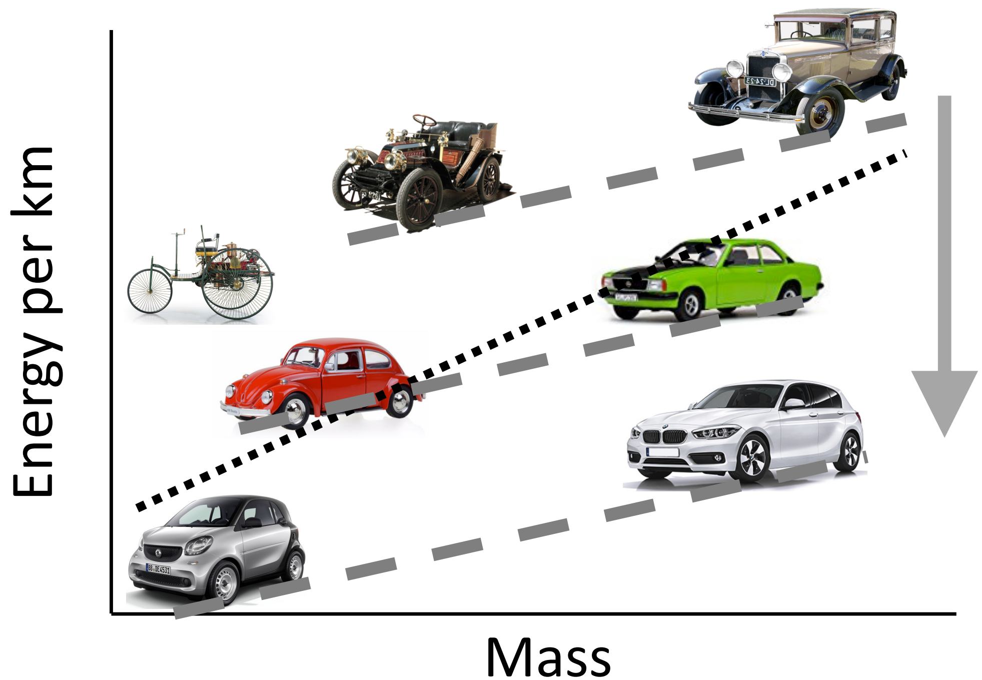
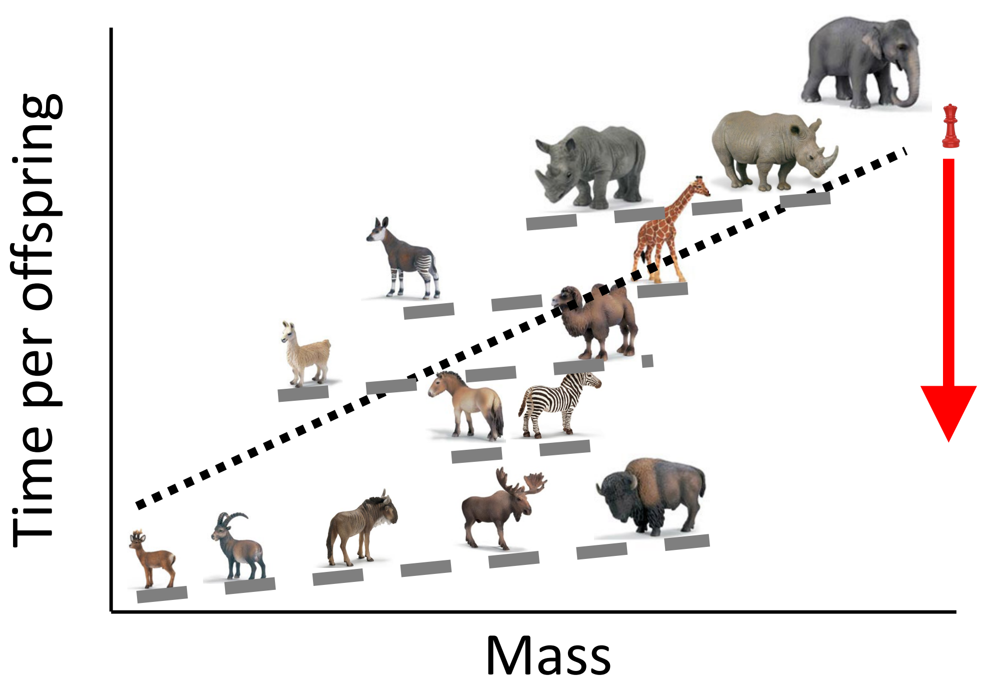


In this scenario, the scaling is a ***snapshot in evolutionary time***. The scaling would have been different at different moments in evolutionary time (depending on extinction and radiation events)



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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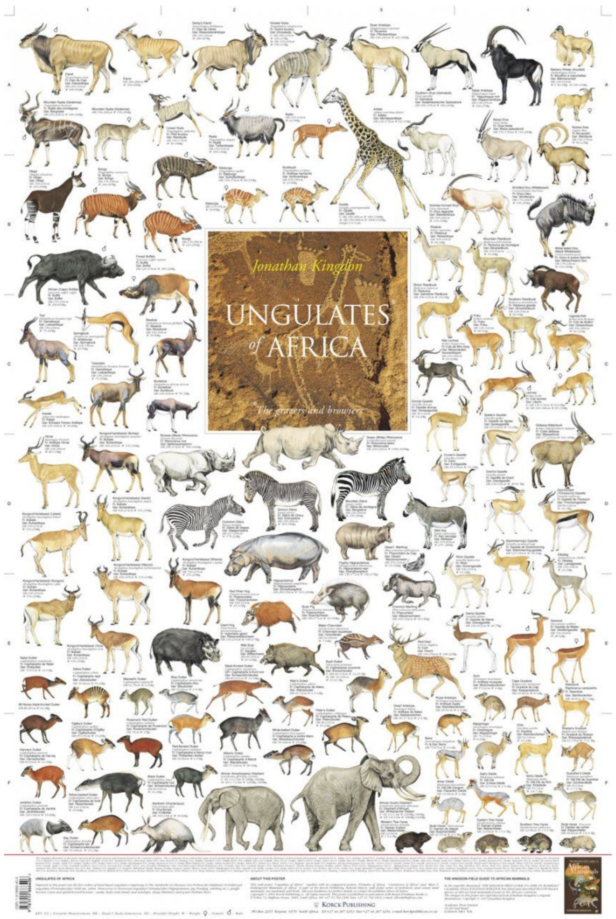
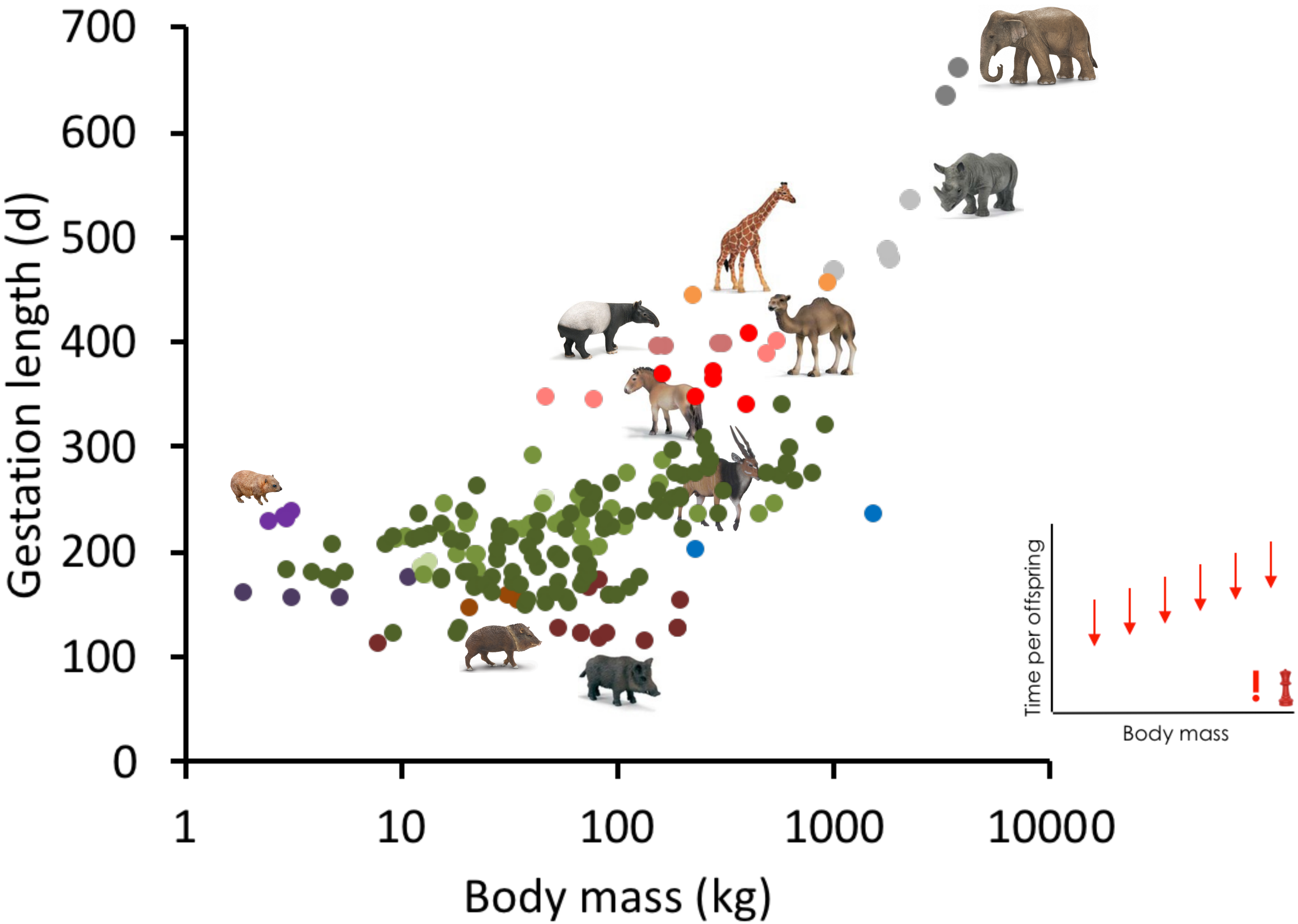


A clear picture for gestation length



(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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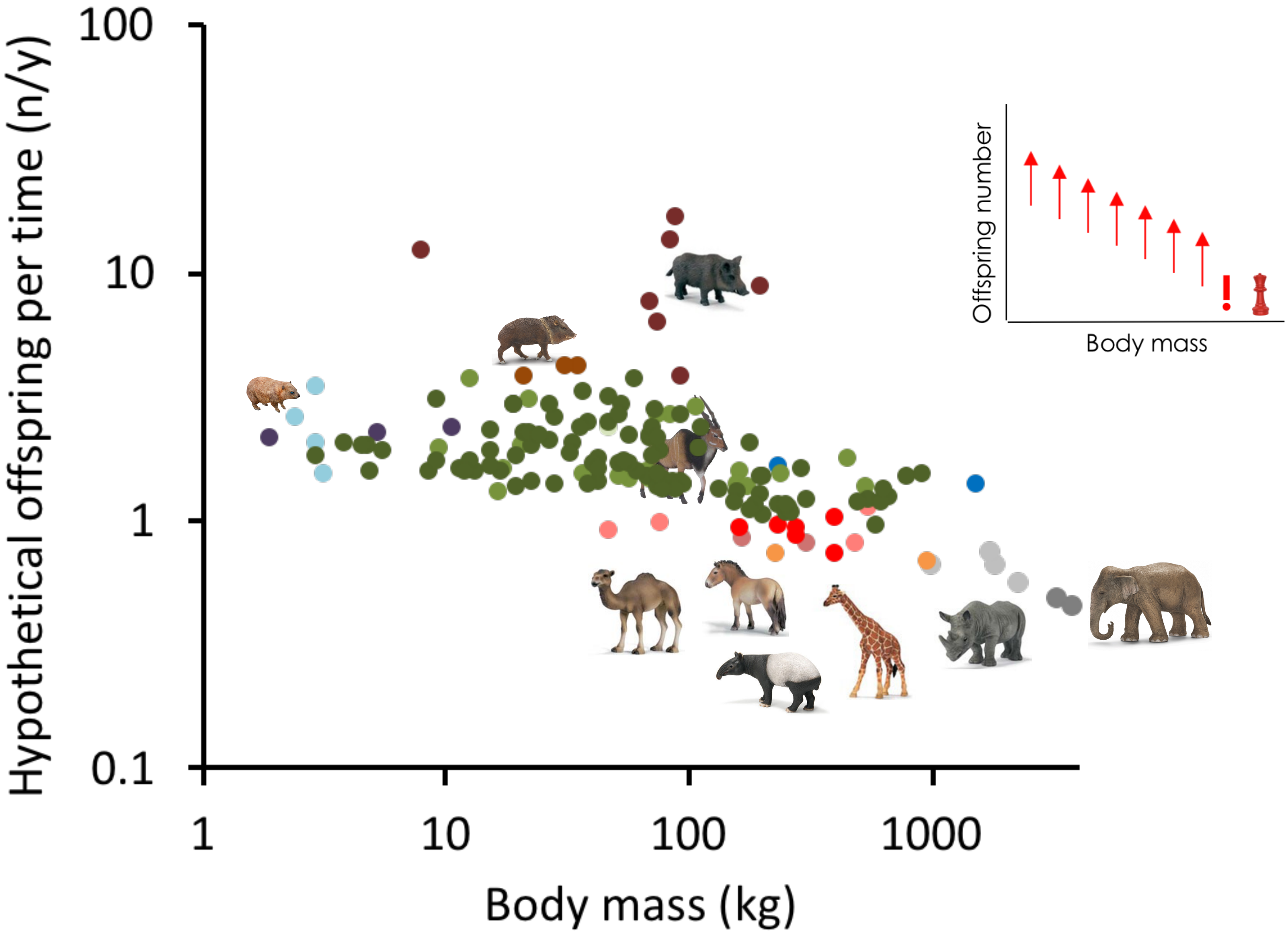
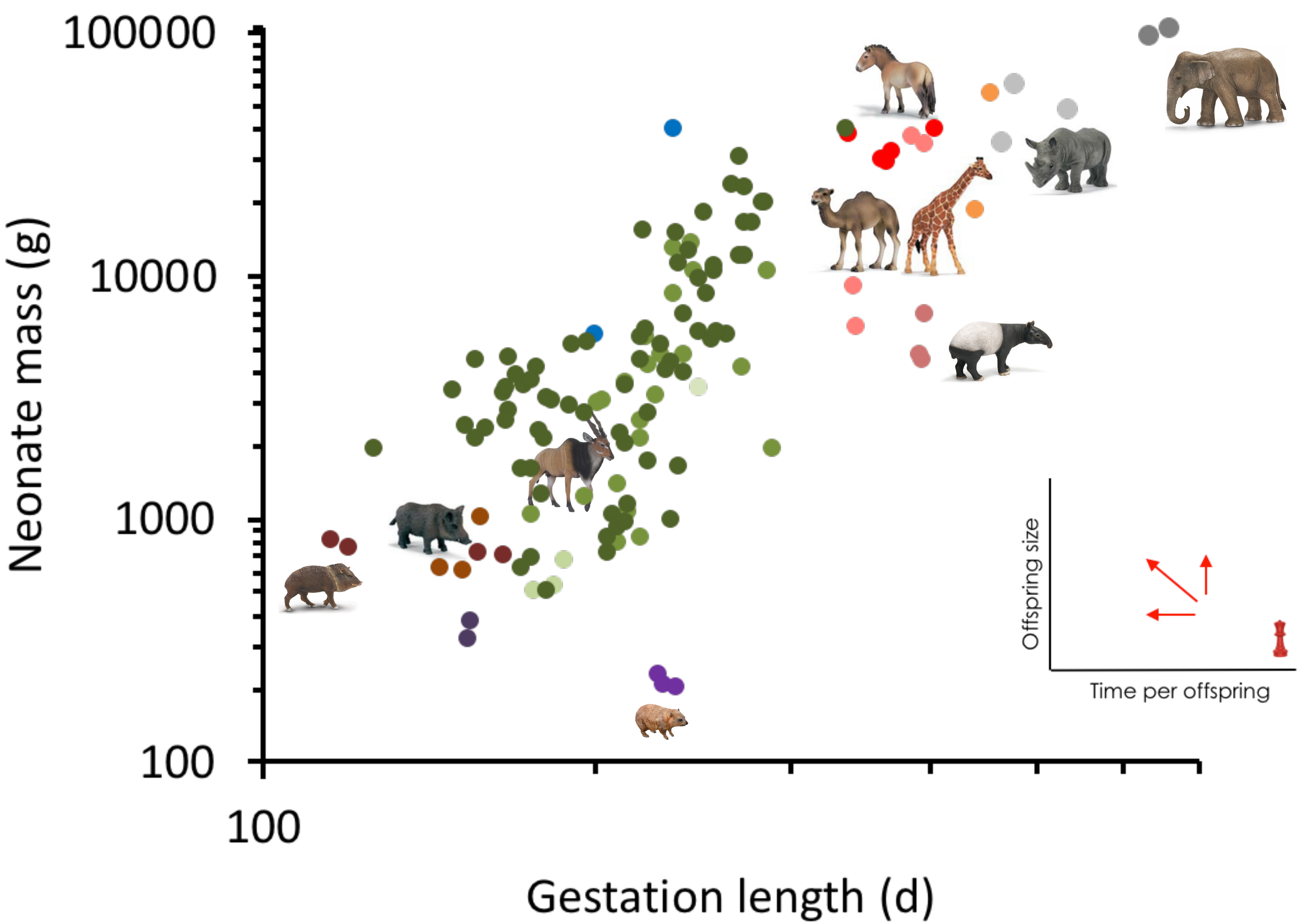
rule the world !!

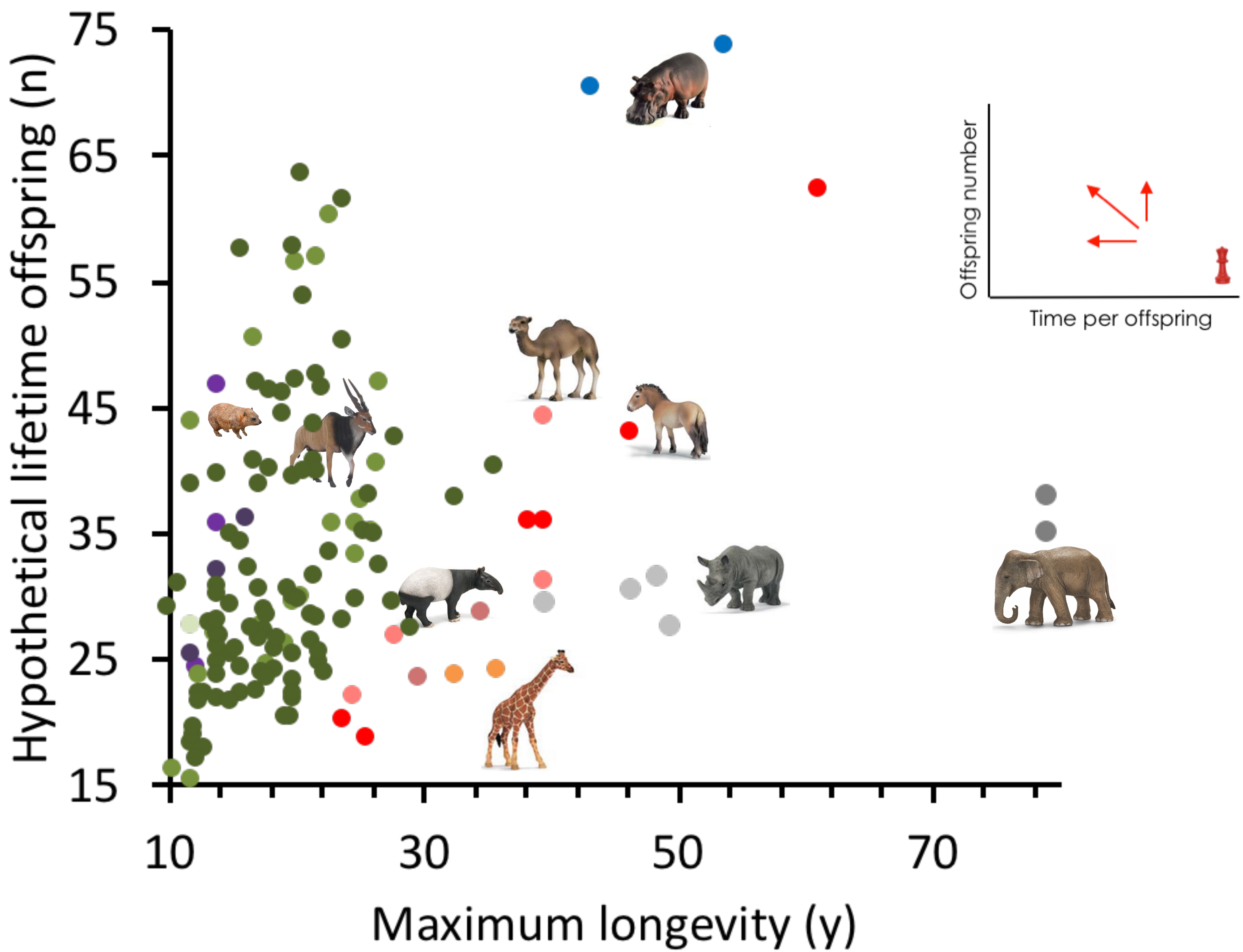
Clear effect for yearly offspring



A clear picture for intrauterine growth

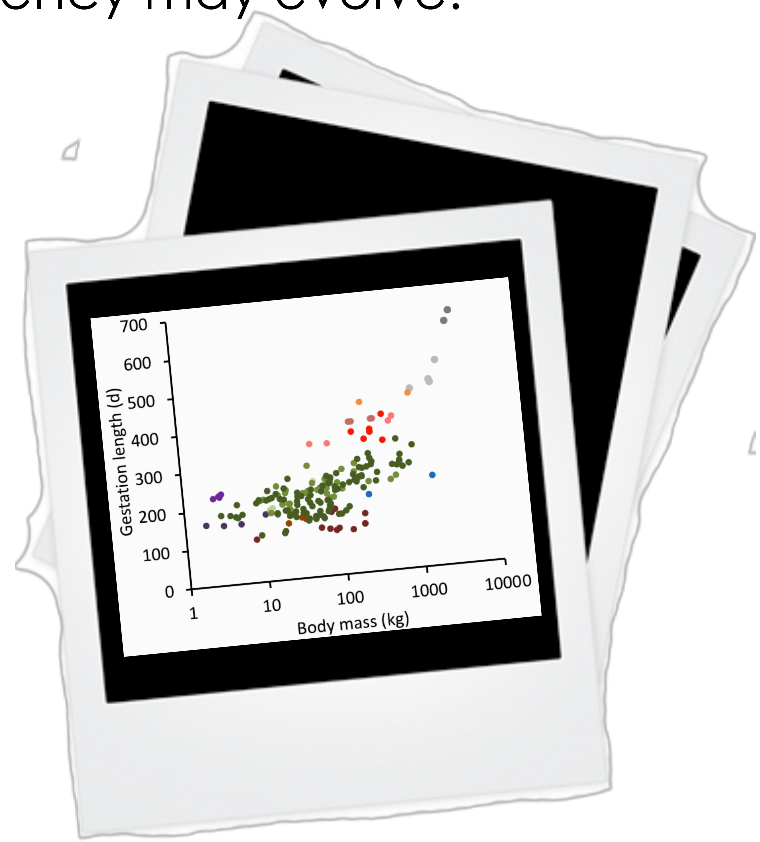


A clear picture for lifetime offspring production



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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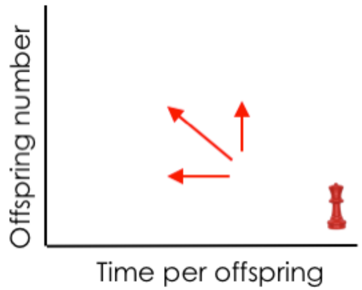

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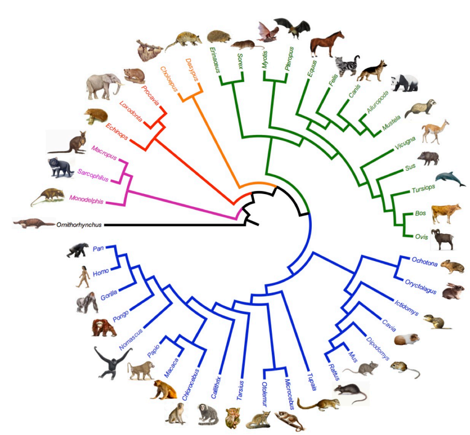
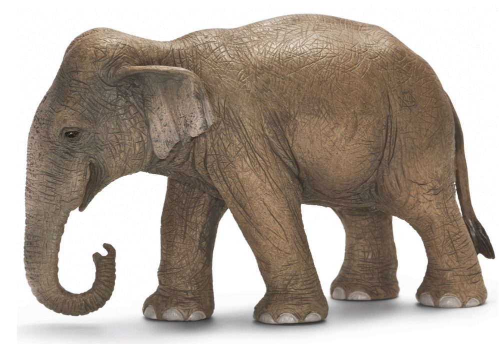


The interesting question …

… what allowed the remaining extant species of the ‘slower’ taxa to survive?





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Life history characteristics appear to be linked to taxonomic groups.

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

Application: large herbivore diversity through time

Historical Biology, 1994, Vol. 8, pp. 15–29
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MODELLING EQUID/RUMINANT COMPETITION IN THE FOSSIL RECORD

CHRISTINE M. JANIS[1], IAIN J. GORDON[2] and ANDREW W. ILLIUS[3]

[1]*Department of Ecology and Evolutionary Biology, Brown University, Providence, Rhode Island 02912, USA*
[2]*Macaulay Land Use Research Institute, Craigiebuckler, Aberdeen AB9 2QY, UK*
[3]*School of Agriculture, University of Edinburgh, West Mains Road, Edinburgh EH9, 3JG, UK*

(Received November 2, 1993)

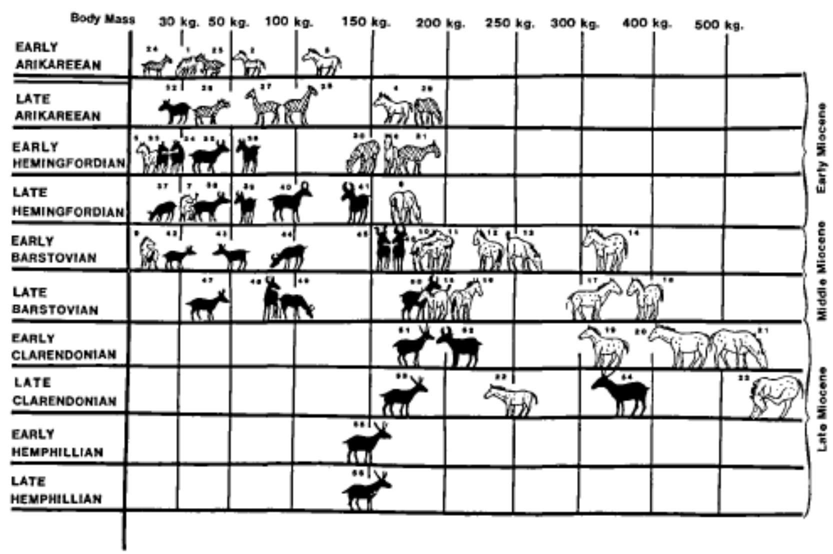

Figure 3 Body size distribution of browsing Miocene equids and ruminants. Key to ungulate taxa: A. Color of taxon: Striped horses=Mesohippines; white horses=Anchitherines; spotted horses=Hypohippines; black artiodactyls=Pecorans; cross-hatched artiodactyls=Tylopods.

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Body Mass	30kg.	50kg.	100kg.	150kg.	200.kg.	250kg.	300kg.	400kg.	500kg.	
EARLY ARIKAREEAN										
LATE ARIKAREEAN										EARLY MIOCENE
EARLY HEMINGFORDIAN										EARLY MIOCENE
LATE HEMINGFORDIAN										EARLY MIOCENE
EARLY BARSTOVIAN										MIDDLE MIOCENE
LATE BARSTOVIAN										MIDDLE MIOCENE
EARLY CLARENDONIAN										LATE MIOCENE
LATE CLARENDONIAN										LATE MIOCENE
EARLY HEMPHILLIAN										LATE MIOCENE
LATE HEMPHILLIAN										LATE MIOCENE

from Janis et al. (1994)

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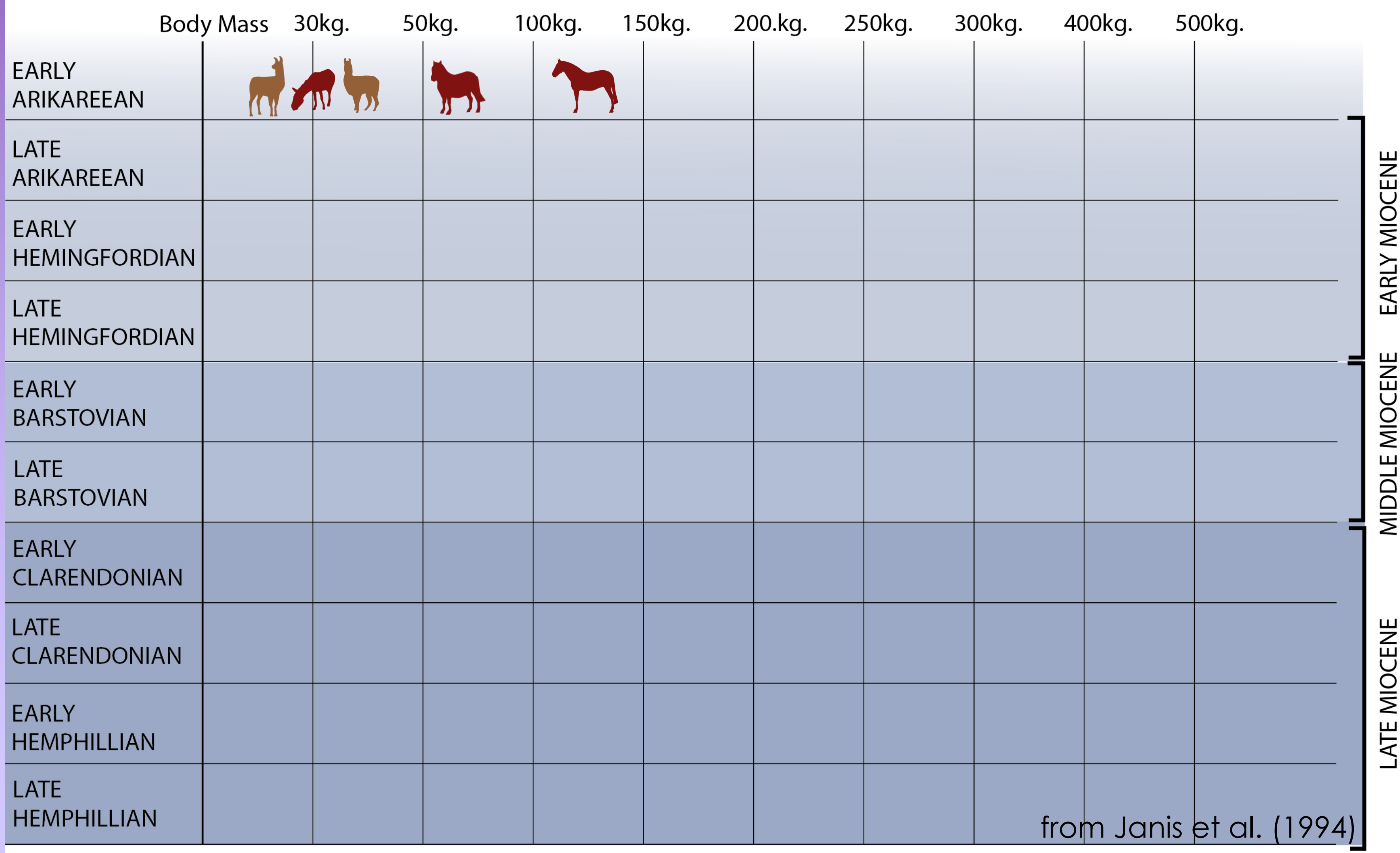

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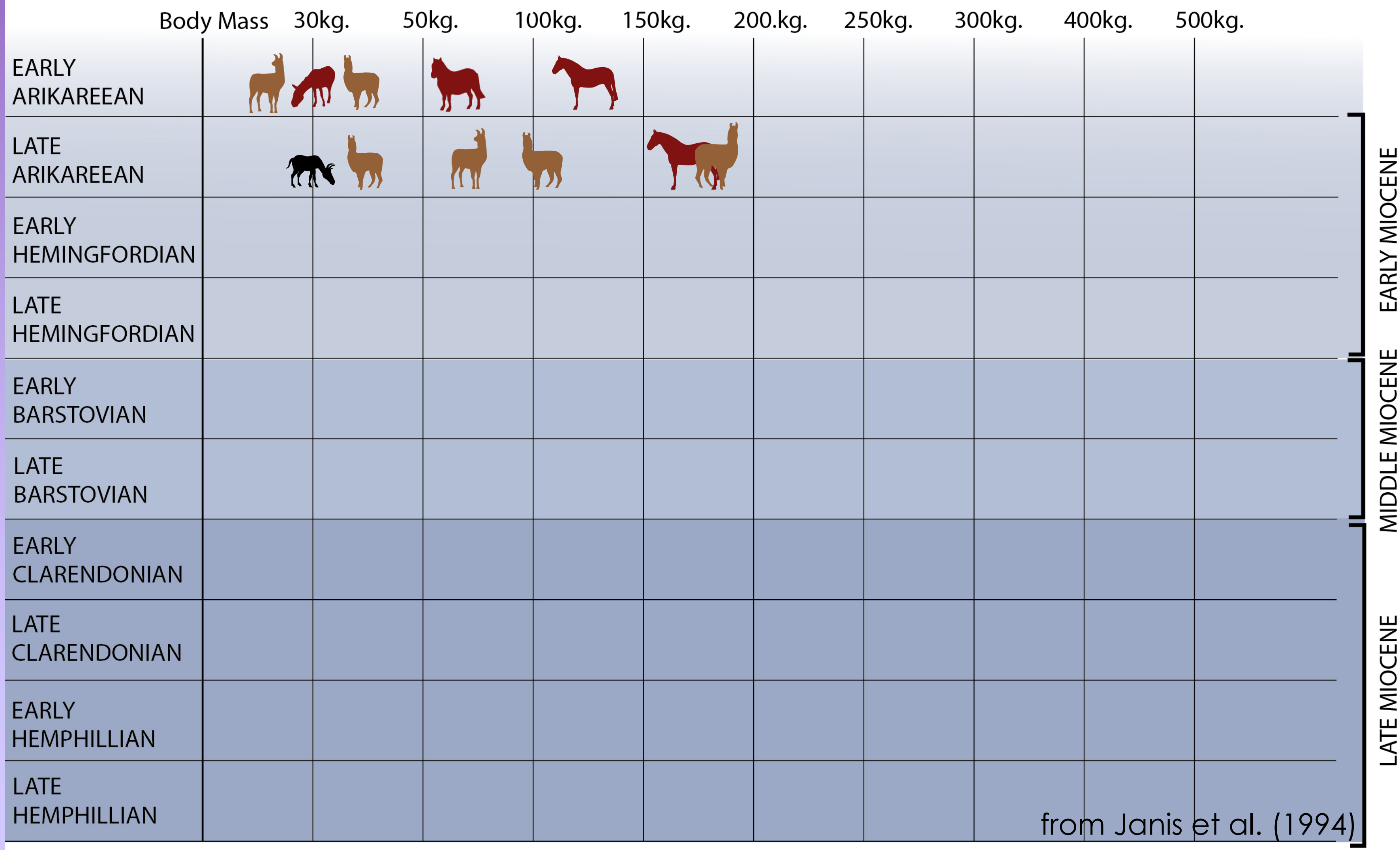

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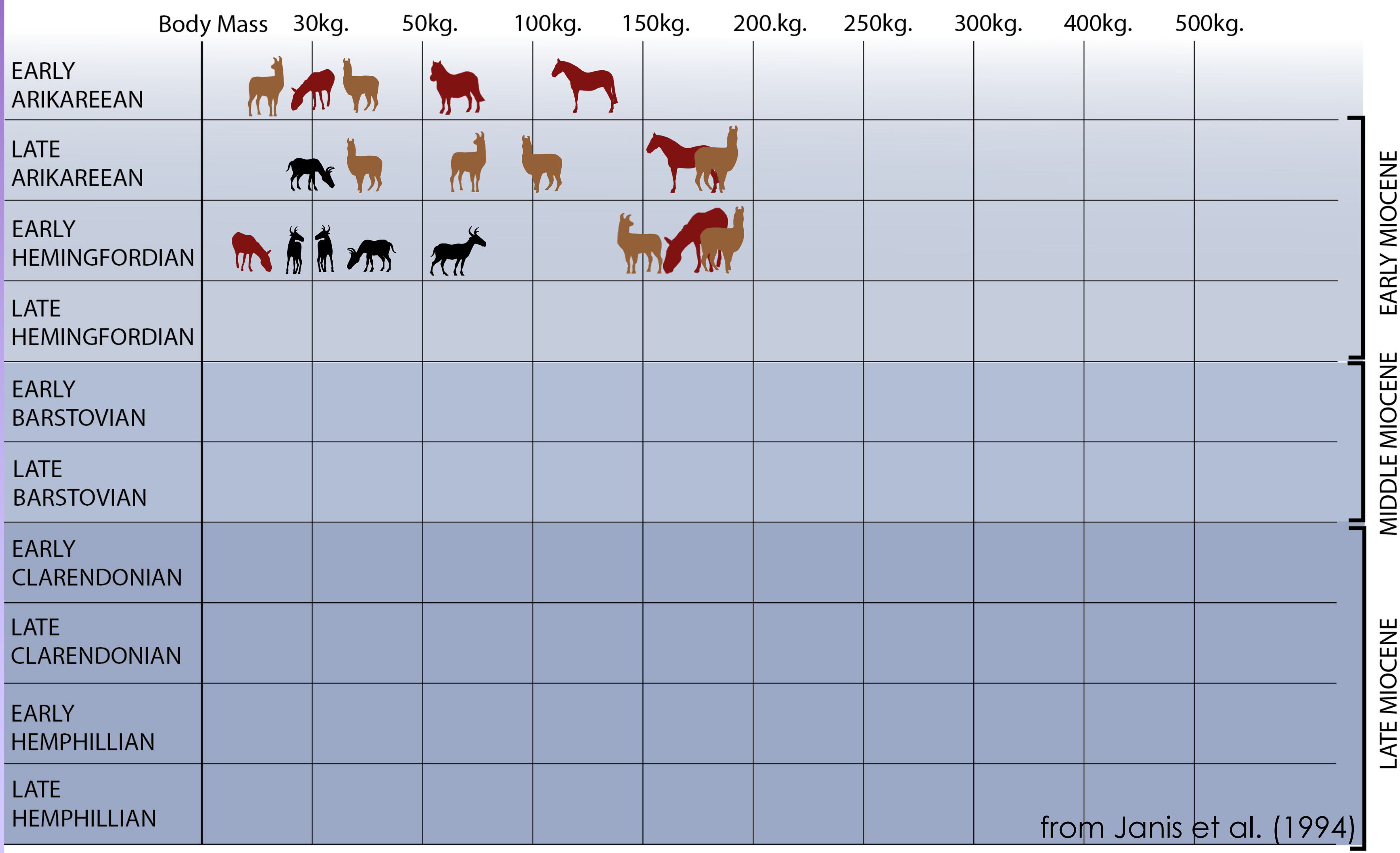

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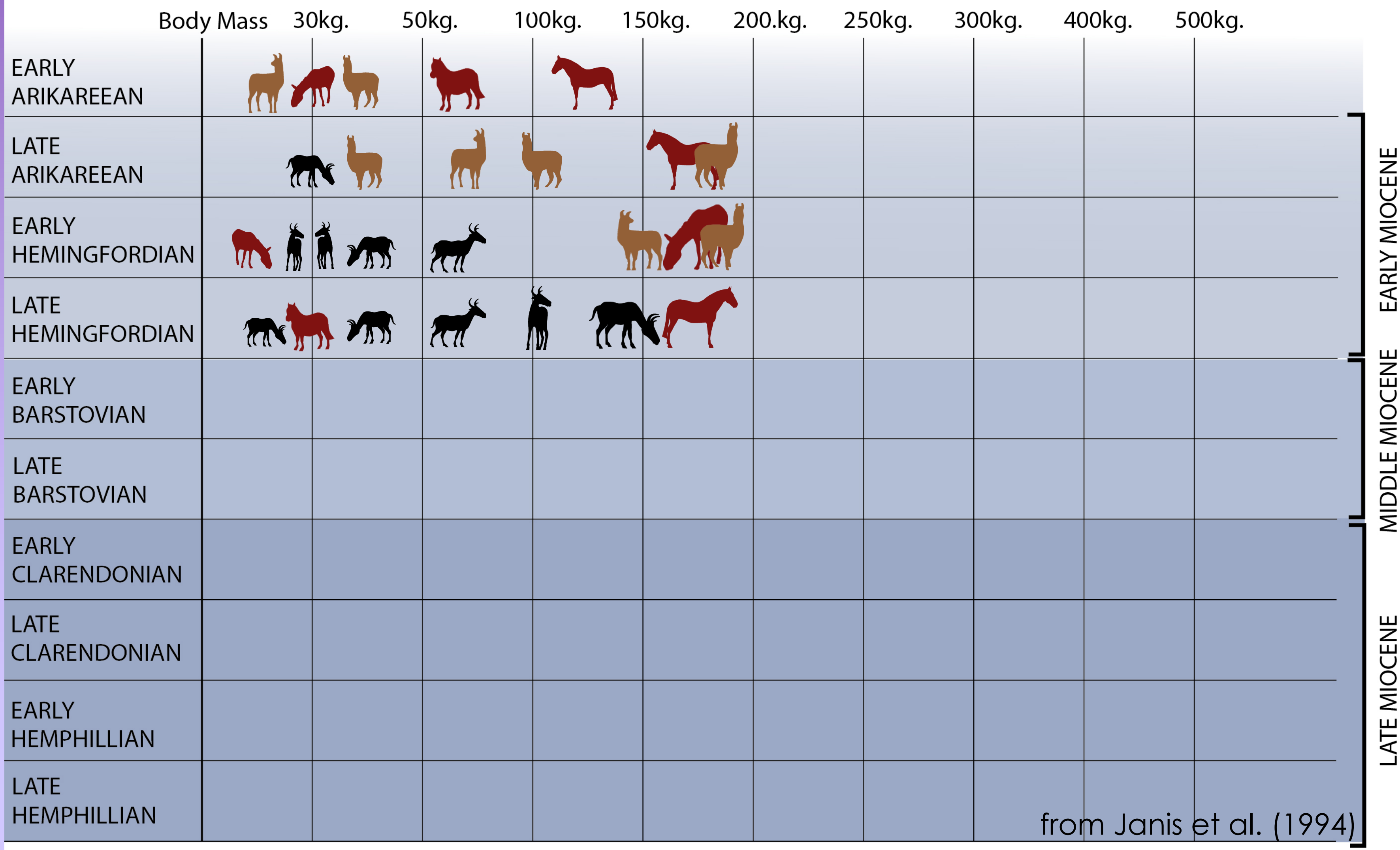

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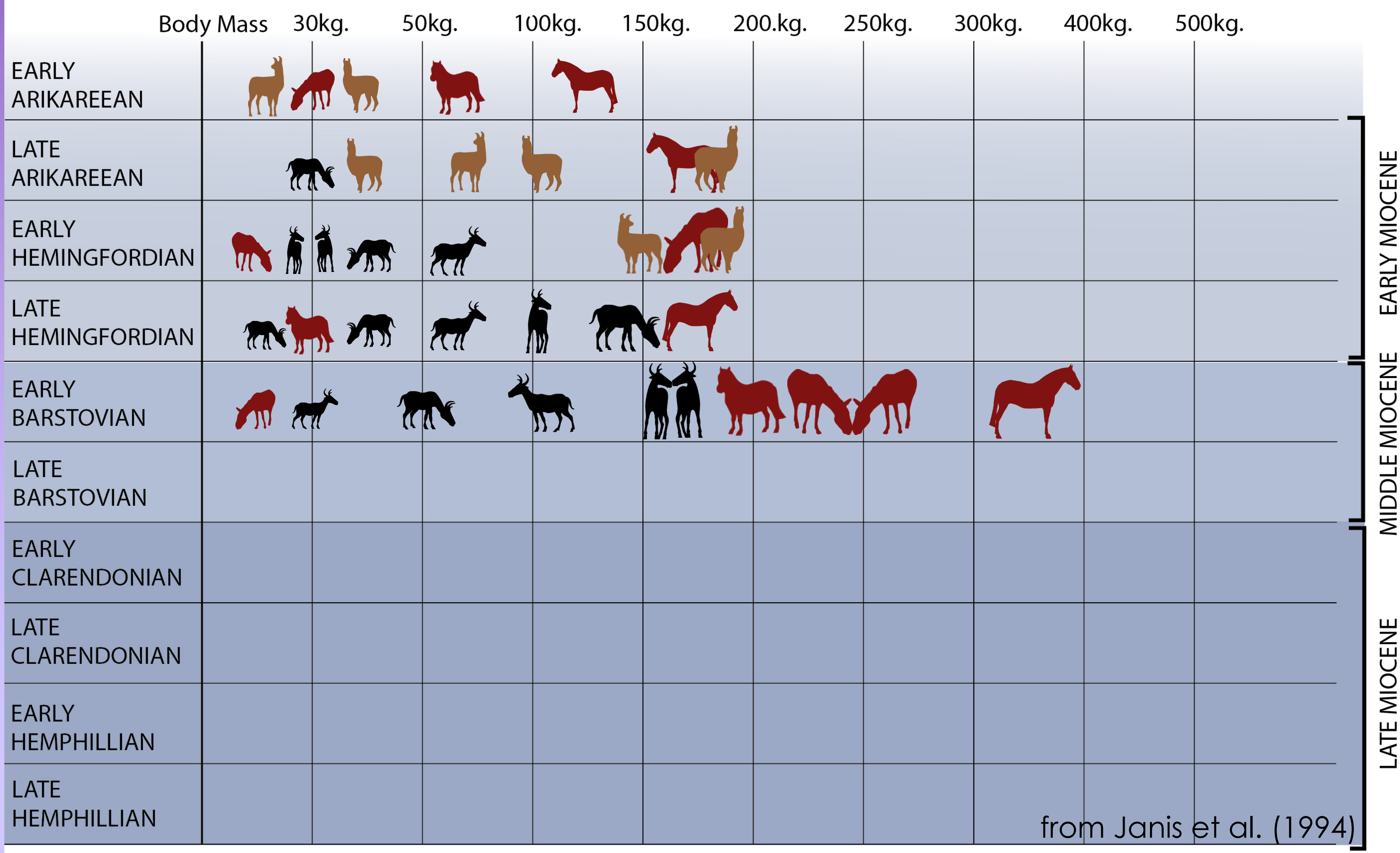

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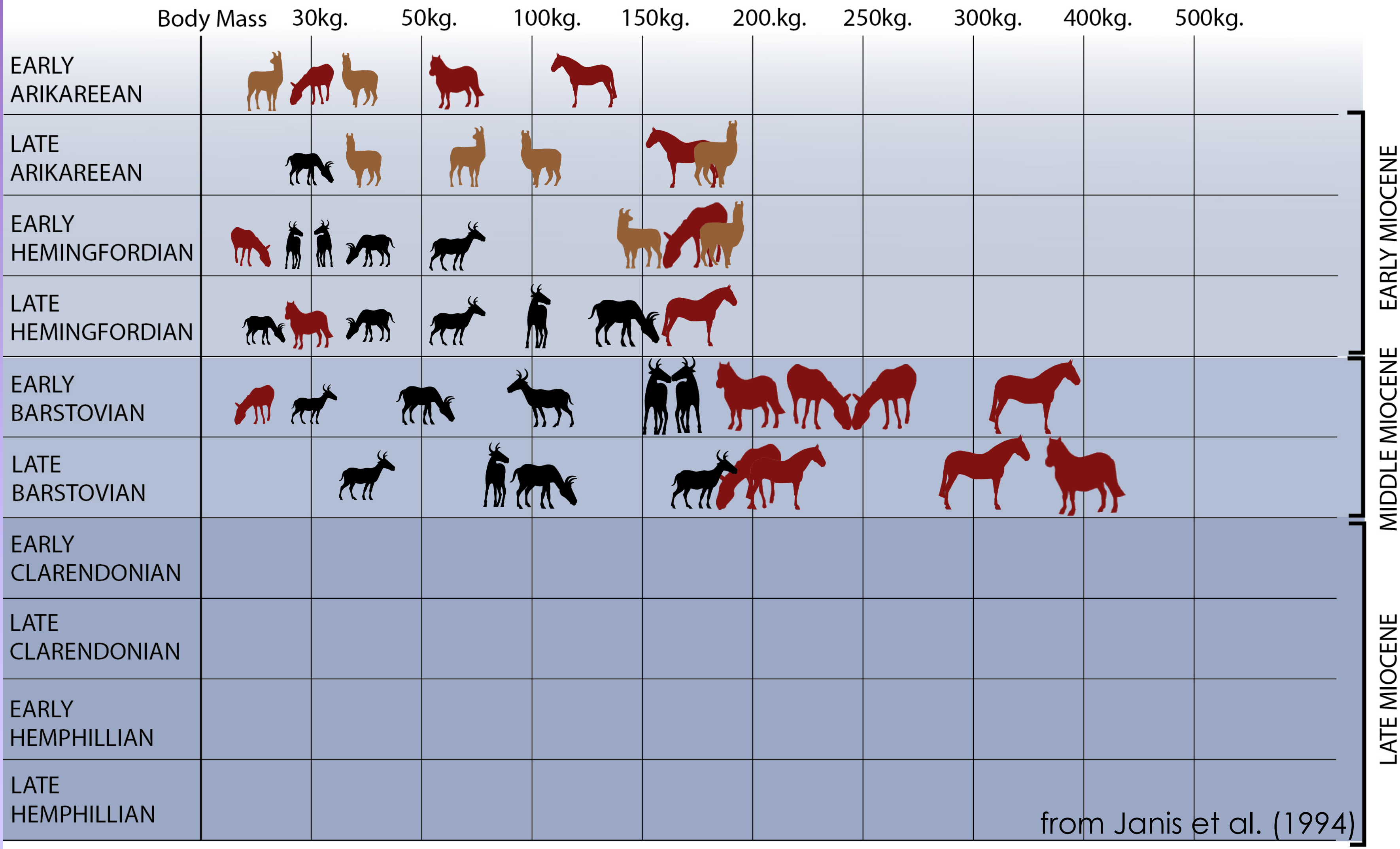

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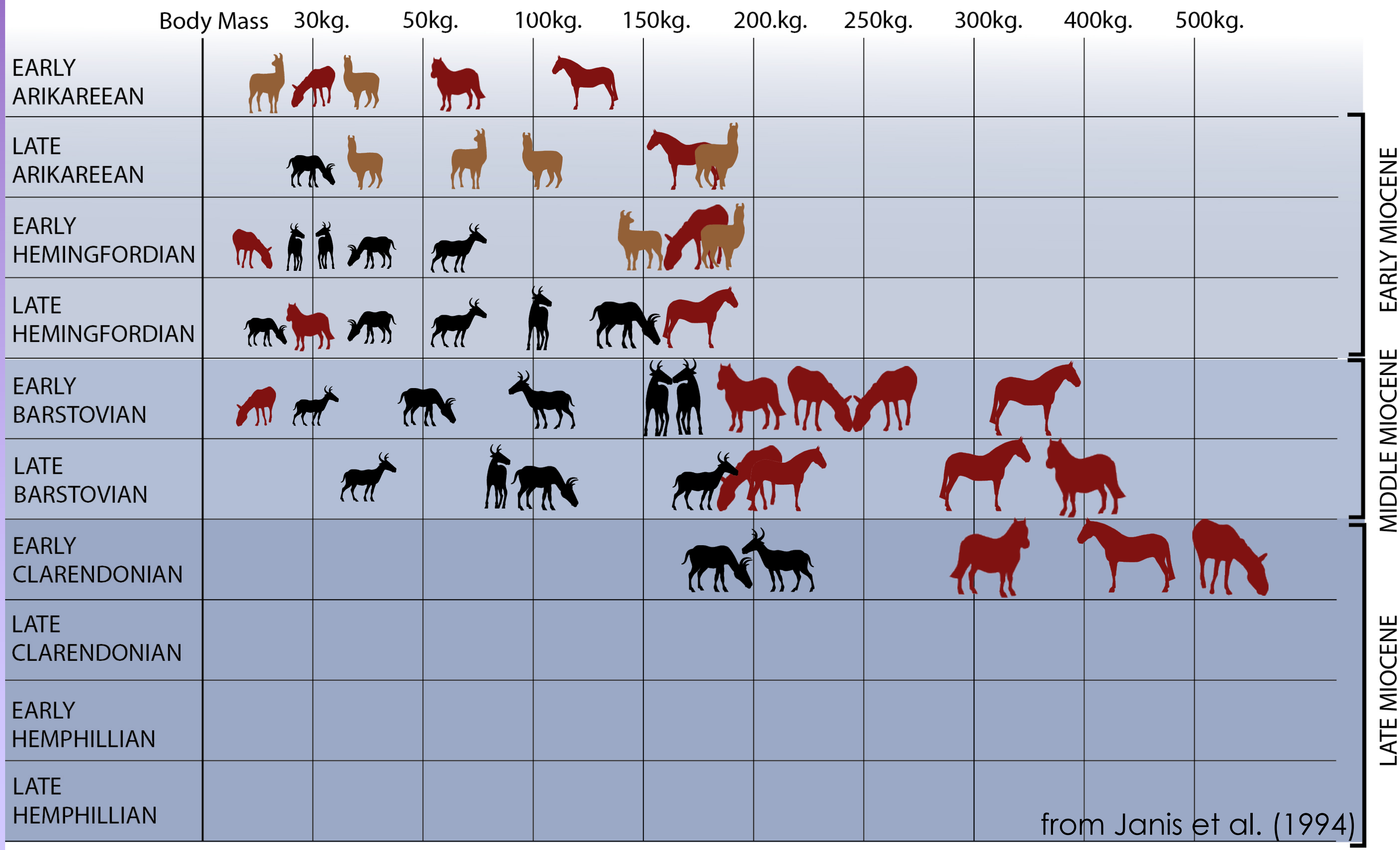

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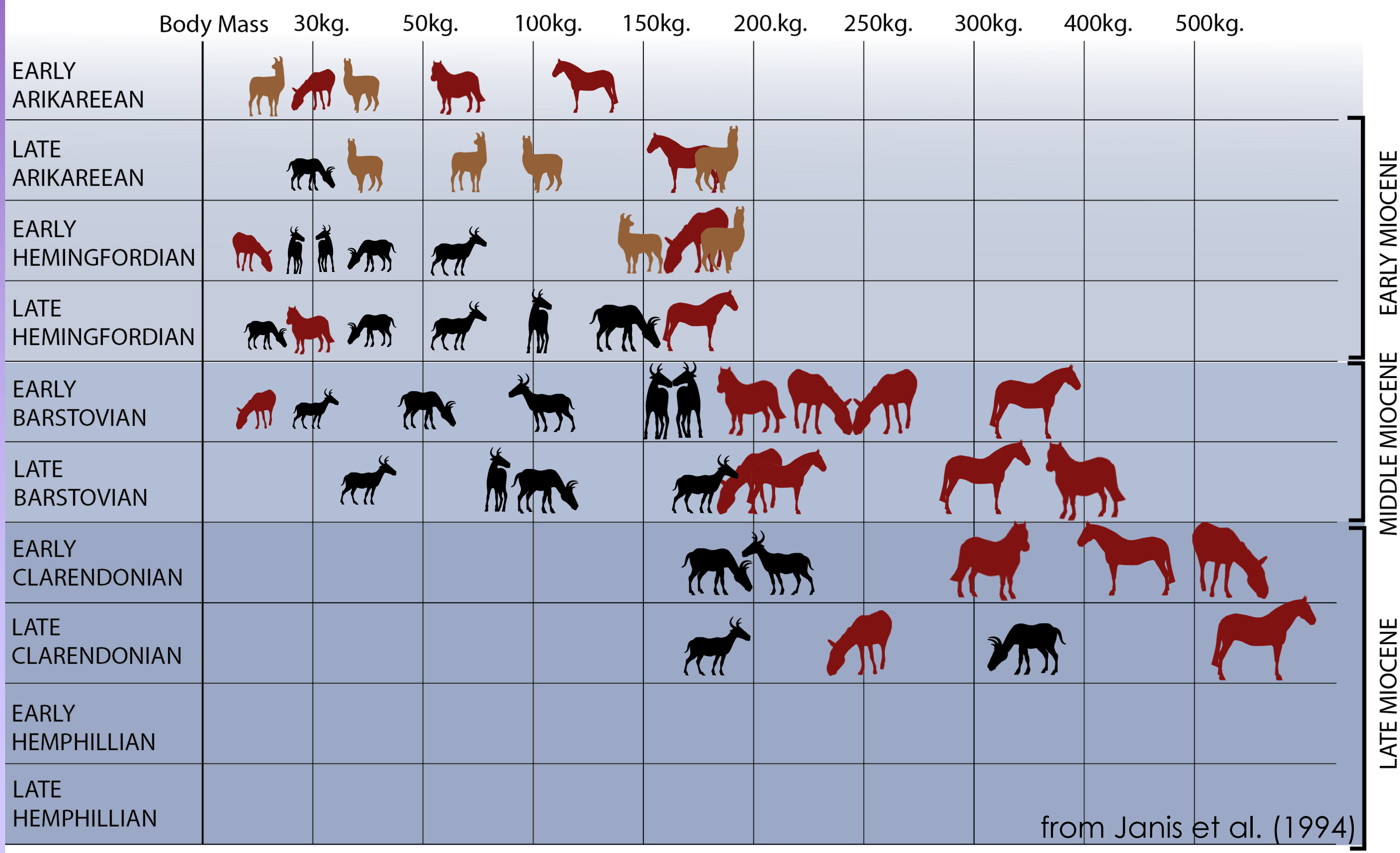

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We would predict that during geological history, 'faster' species were not replaced by 'slower' species.

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

By what means do cattle achieve faster intrauterine growth than horses?

A priori conditions and their consequences

By which means can organisms become more efficient?

A priori conditions and their consequences

By which means can organisms become more efficient?

adapting to optimal resource use

A priori conditions and their consequences

By which means can organisms become more efficient?

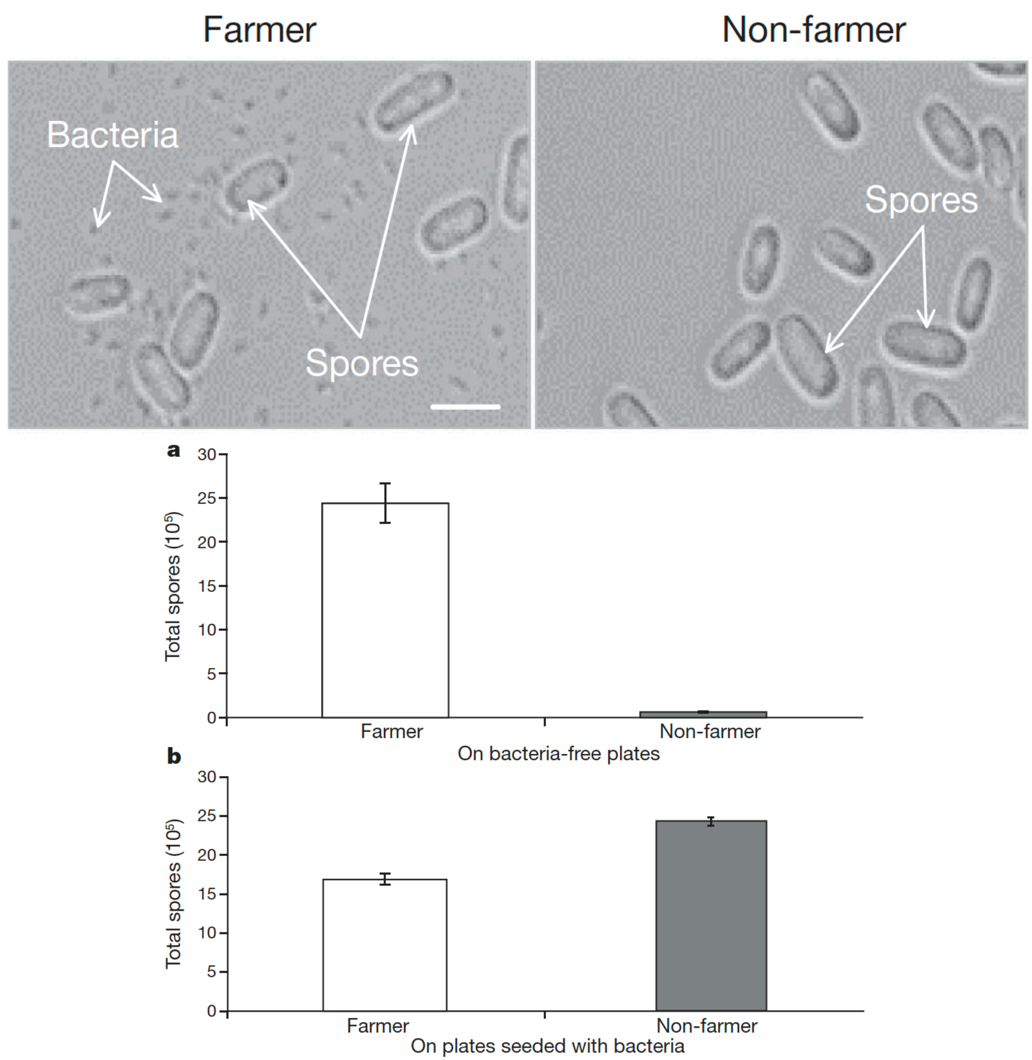
adapting to optimal resource use

controlling resources

Primitive agriculture in a social amoeba

Debra A. Brock[1], Tracy E. Douglas[1], David C. Queller[1] & Joan E. Strassmann[1]

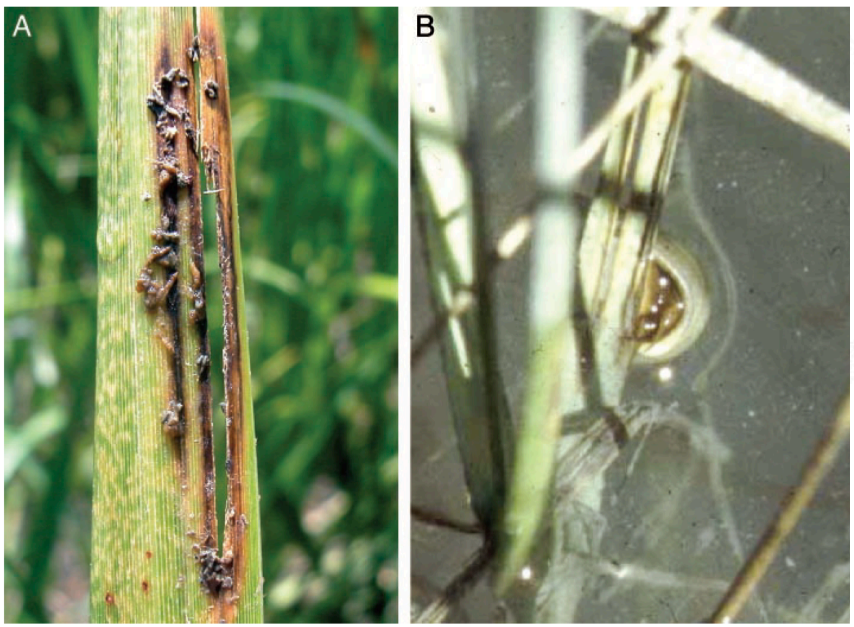
20 JANUARY 2011 | VOL 469 | NATURE | 393

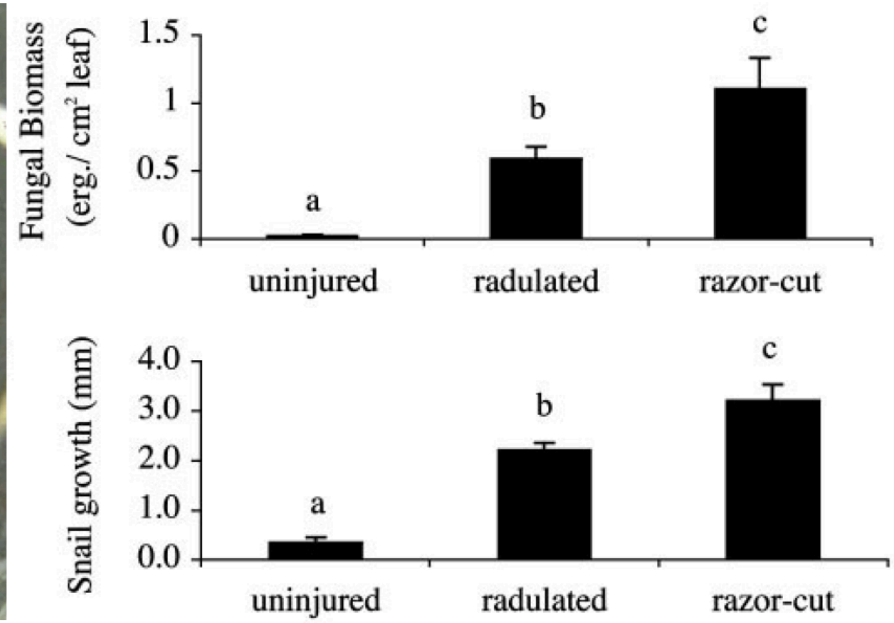


Fungal farming in a snail

Brian R. Silliman*† and Steven Y. Newell‡

PNAS | December 23, 2003 | vol. 100 | no. 26 | 15643–15648

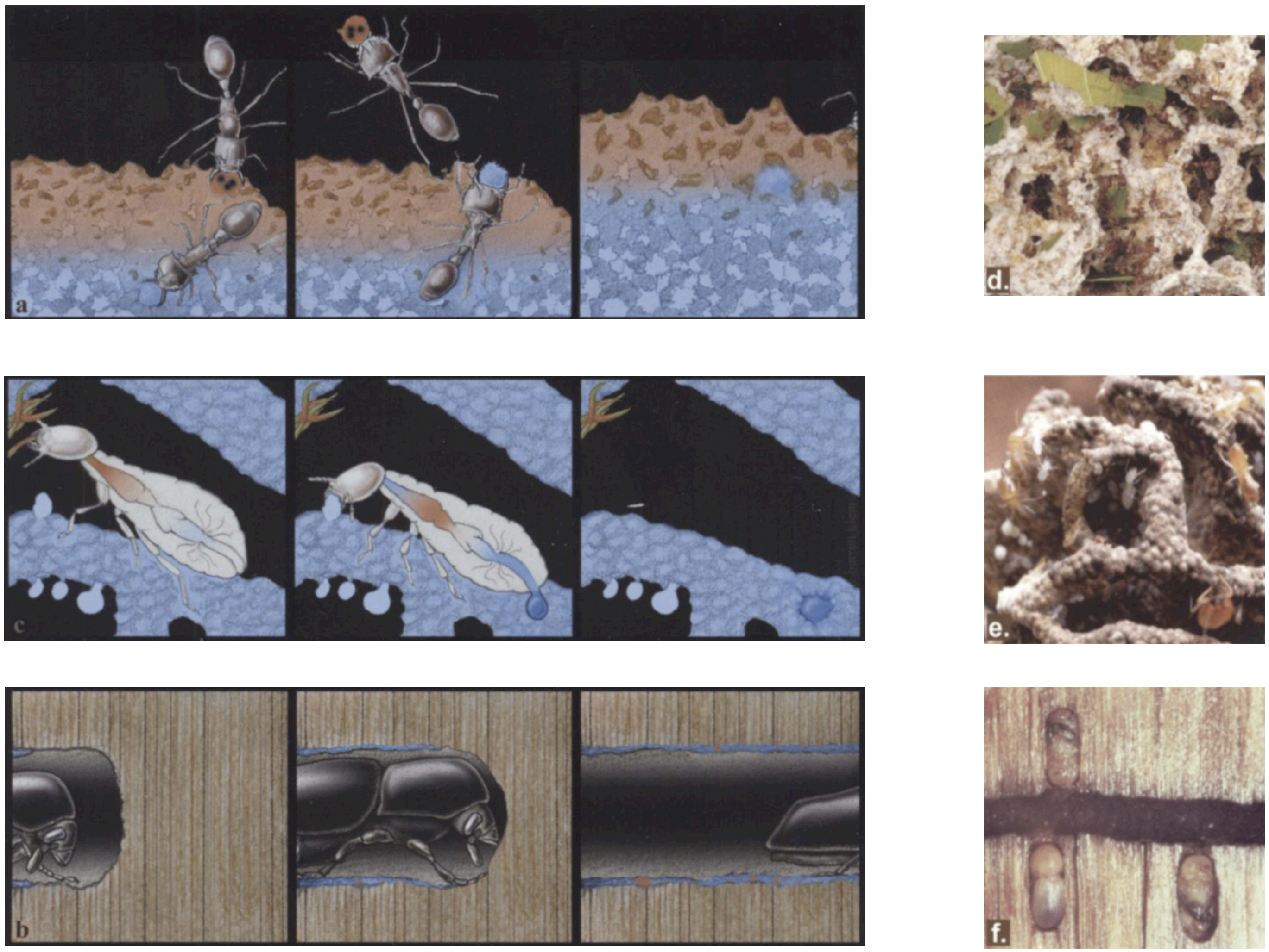




The Evolution of Agriculture in Insects

Ulrich G. Mueller,[1,2] Nicole M. Gerardo,[1,2,3]
Duur K. Aanen,[4] Diana L. Six,[5] and Ted R. Schultz[6]

Annu. Rev. Ecol. Evol. Syst. 2005. 36:563–95

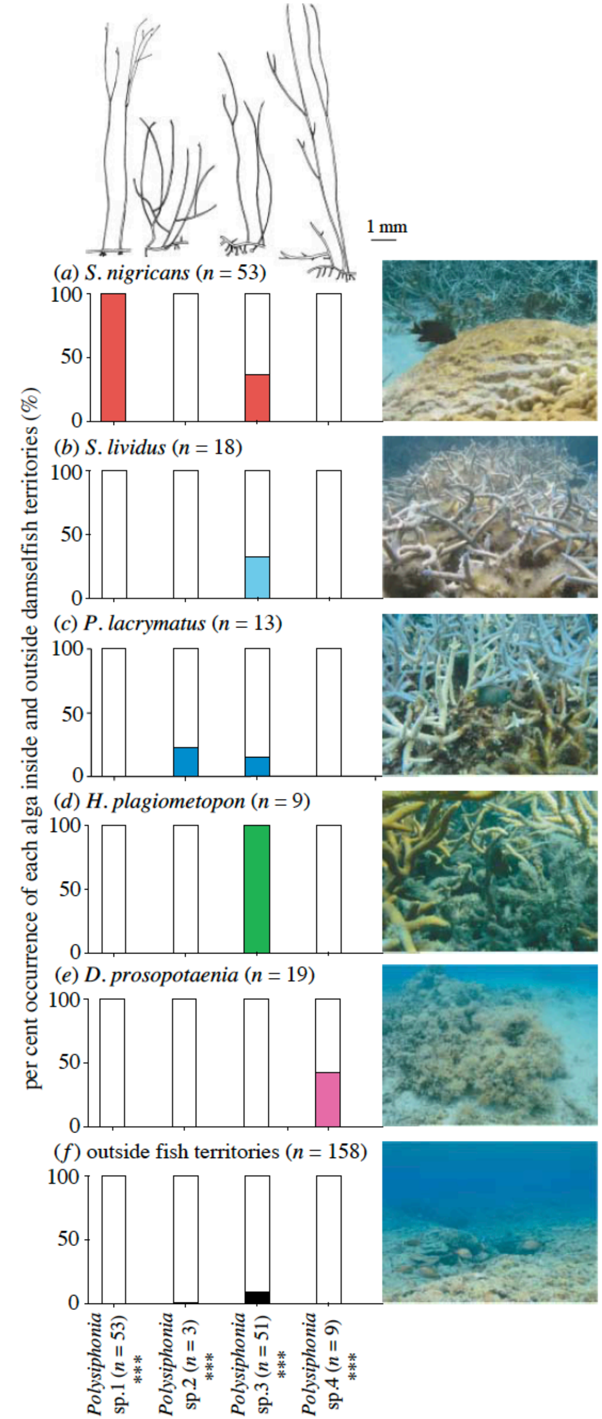


biology
letters

Biol. Lett. (2006) **2**, 593–596
doi:10.1098/rsbl.2006.0528
Published online 7 August 2006

A novel obligate cultivation mutualism between damselfish and *Polysiphonia* algae

Hiroki Hata[†,*] and Makoto Kato



A priori conditions and their consequences

By which means can organisms become more efficient?

adapting to
optimal
resource use

controlling
a broad set of resources

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adapting to
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resource use
(niche specificity)

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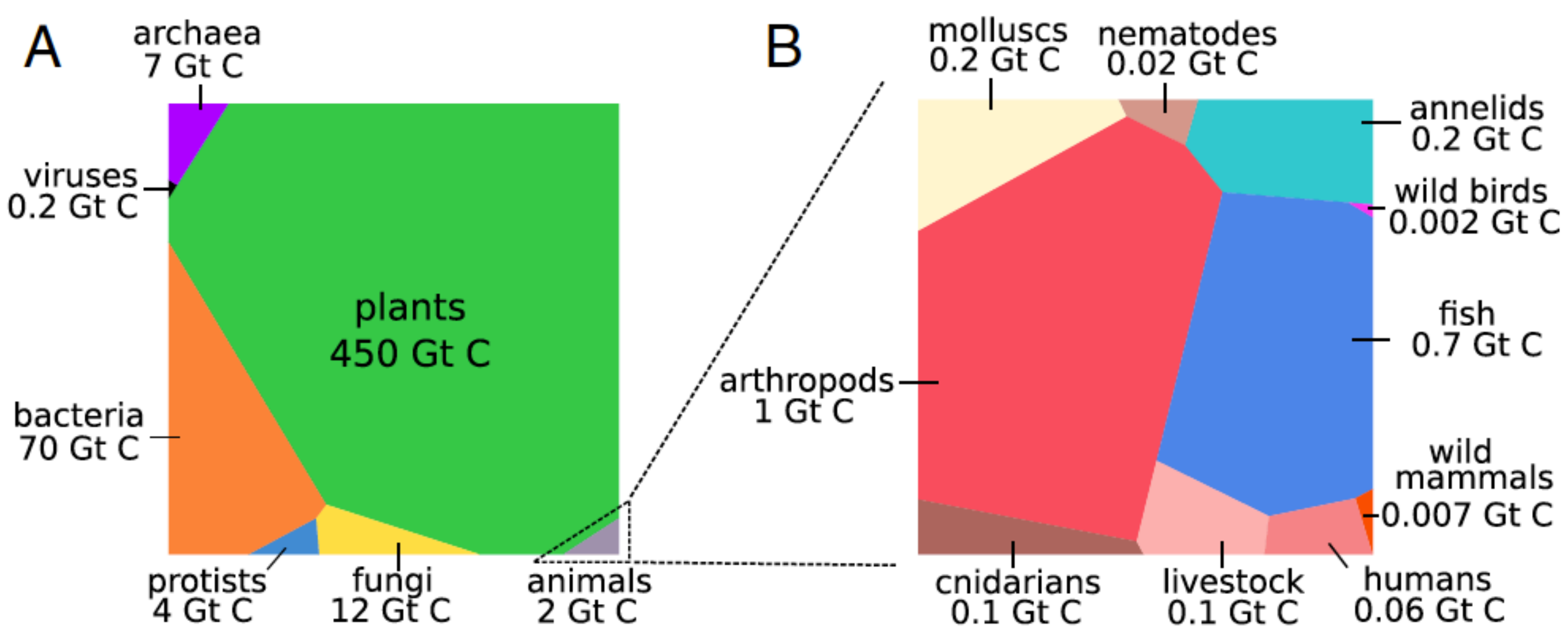
"In the course of the process described by Darwinian evolution, which includes a not-so-sharply-defined relationship between specific niches and more-or-less specific adaptations to them, including arms races and directionality of reproductive efficiency, evolution might (but does not have to), helped by its probabilistic directionality of increasing variability and complexity, evolve an organism whose adaptations are of such a general application that its existence changes the basic, probabilistic rules of evolution."

The state of the planet

The biomass distribution on Earth

Yinon M. Bar-On[a], Rob Phillips[b,c], and Ron Milo[a,1]

www.pnas.org/cgi/doi/10.1073/pnas.1711842115



estimate for reptiles similar magnitude as wild birds (but more assumptions; estimate for amphibians not possible)

The state of the plane

The biomass distribution on Earth

Yinon M. Bar-On[a], Rob Phillips[b,c], and Ron Milo[a,1]

www.pnas.org/cgi/doi/10.1073/pnas.1711842115

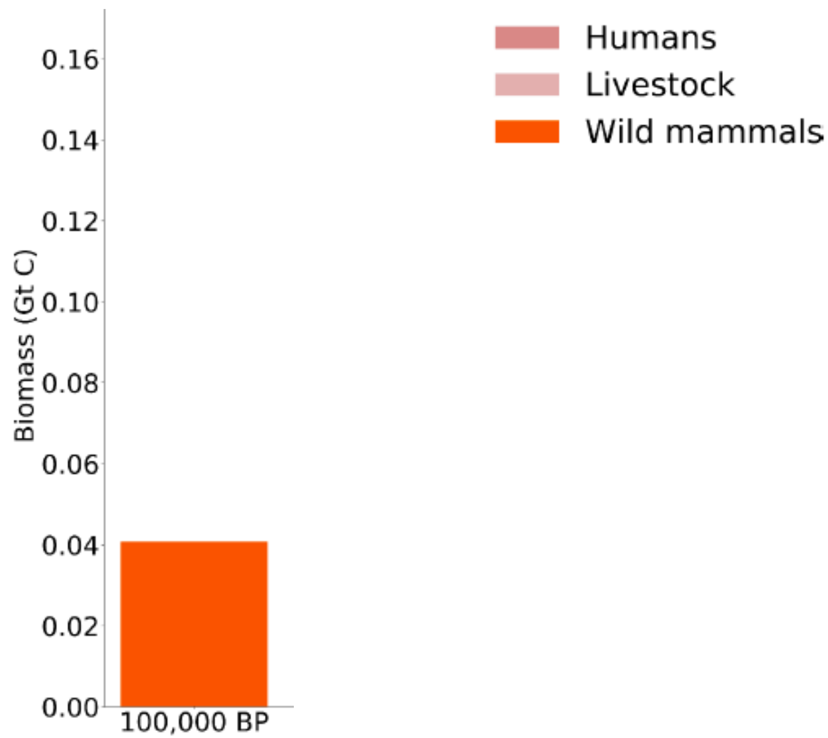


Fig. S5. The impact of human civilization on the biomass of mammals.

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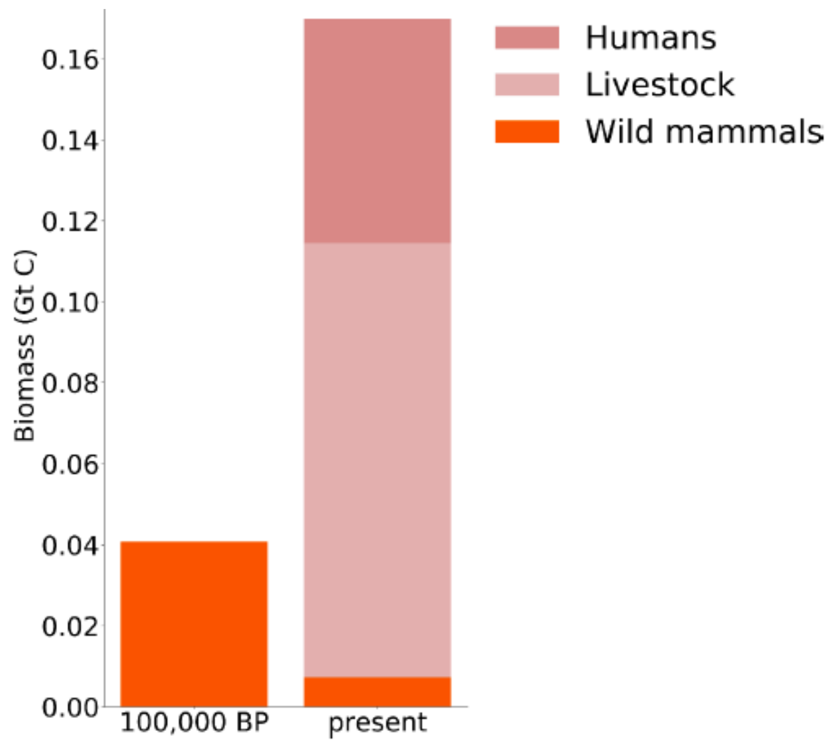

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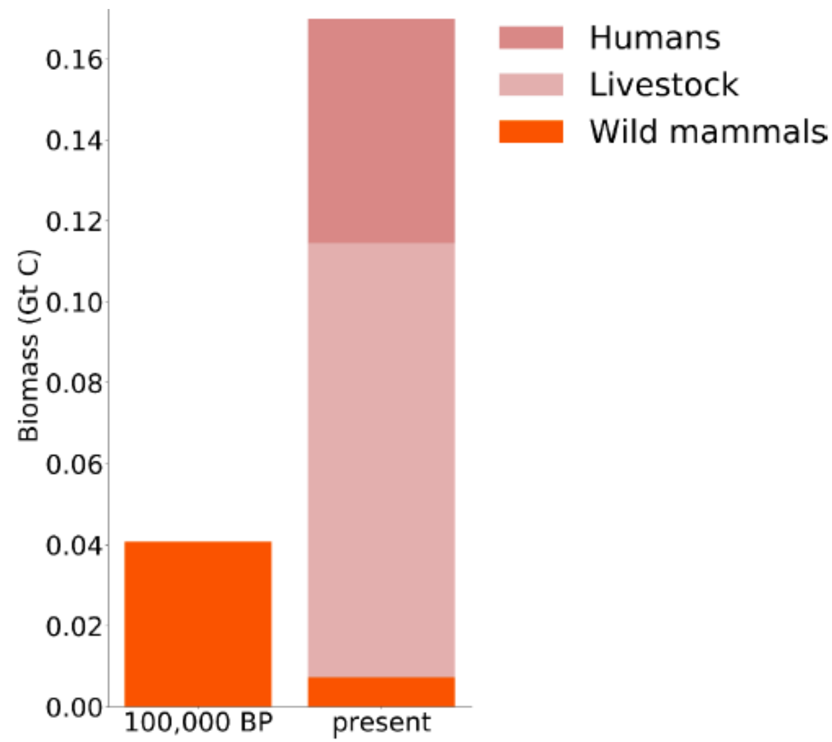

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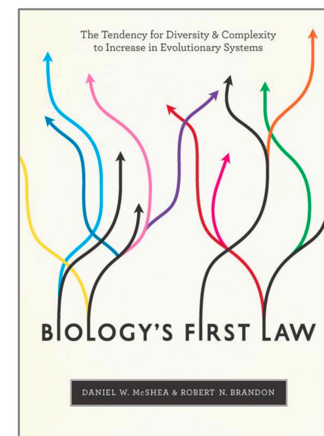

?

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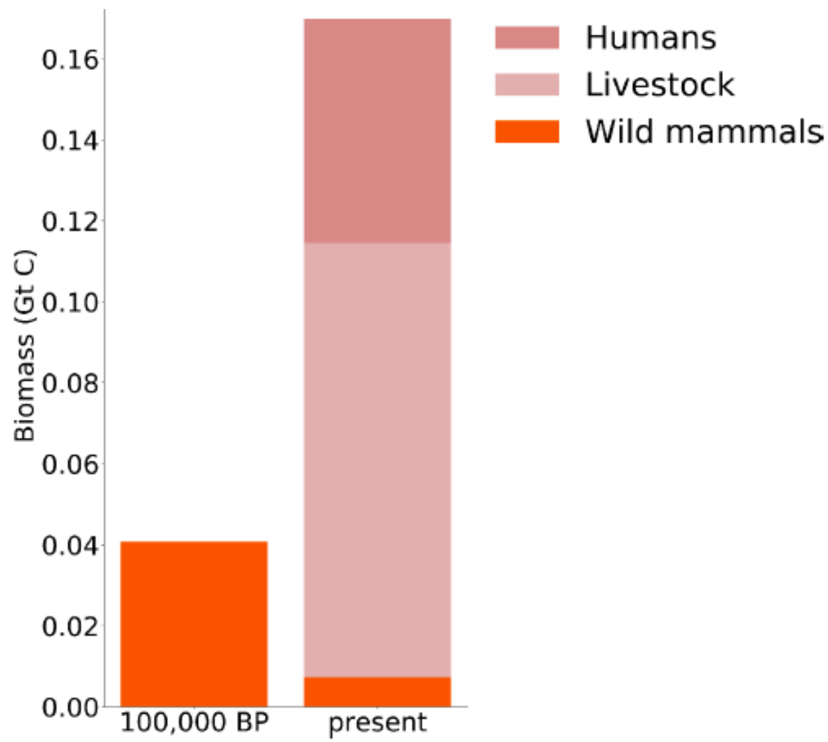

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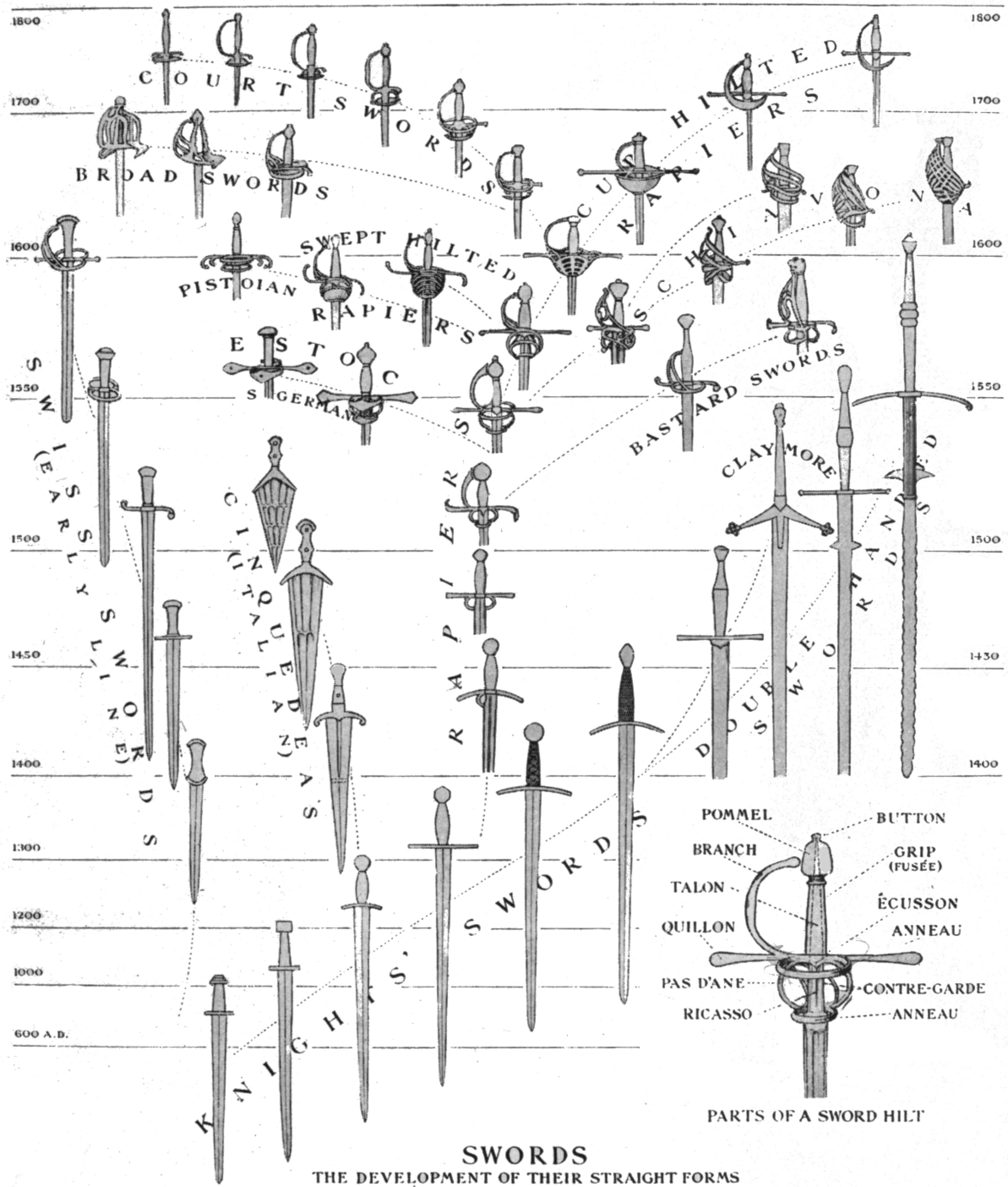


SWORDS
THE DEVELOPMENT OF THEIR STRAIGHT FORMS
DURING THE CENTURIES

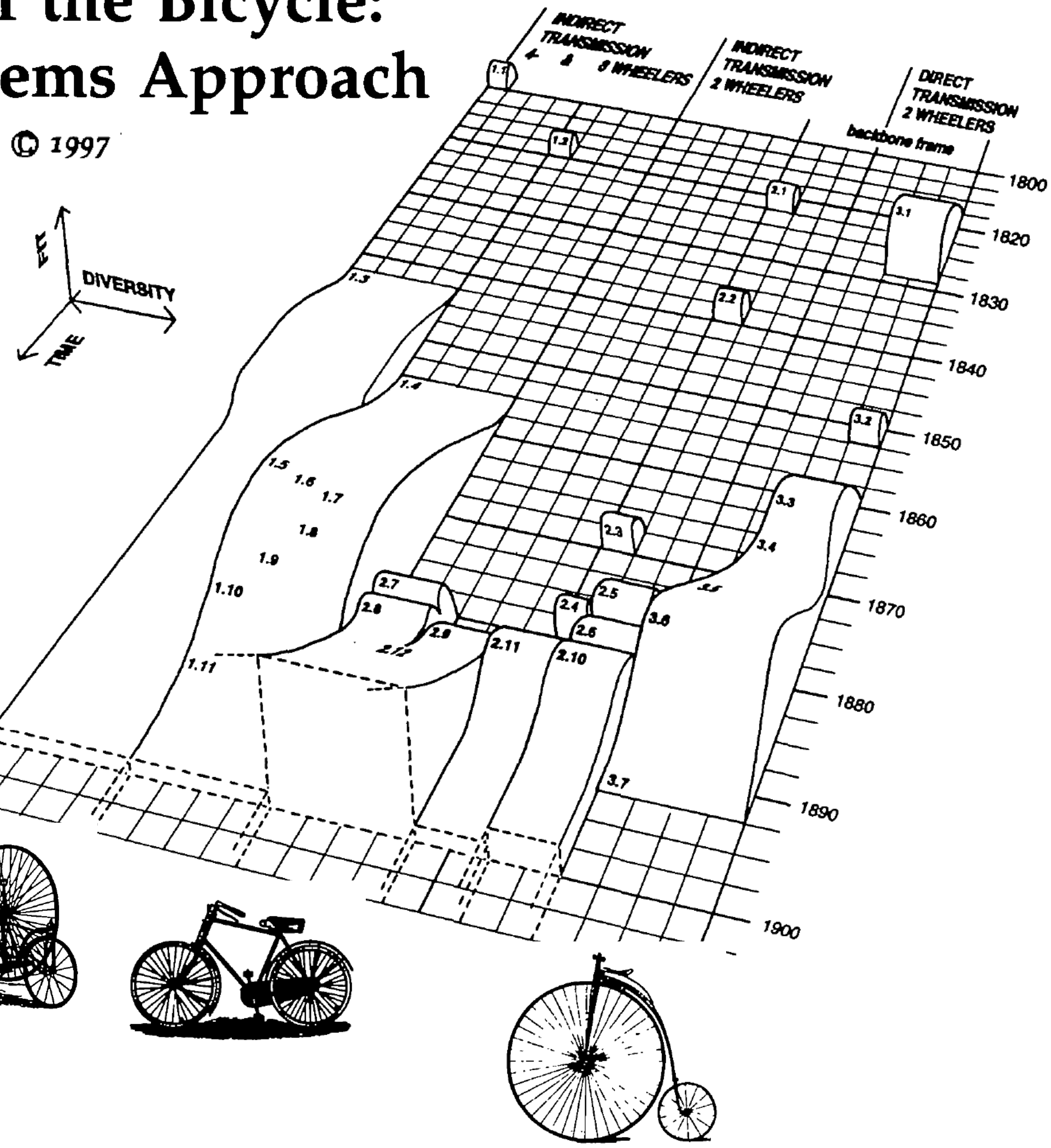
BASHFORD DEAN DIR.

STANLEY J. ROWLAND, DEL.

O. A. van Nierop, A. C. M. Blankendaal, and C. J. Overbeeke

The Evolution of the Bicycle: A Dynamic Systems Approach

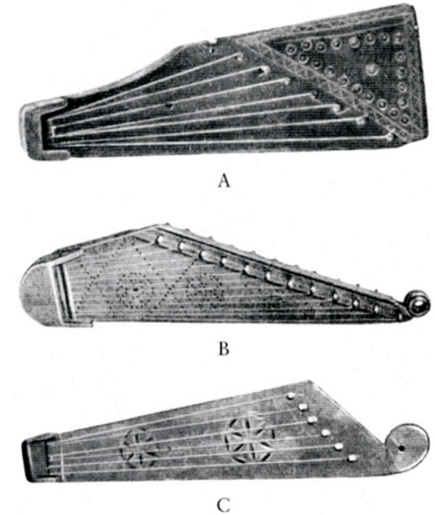
Journal of Design History Vol. 10 No. 3 © 1997

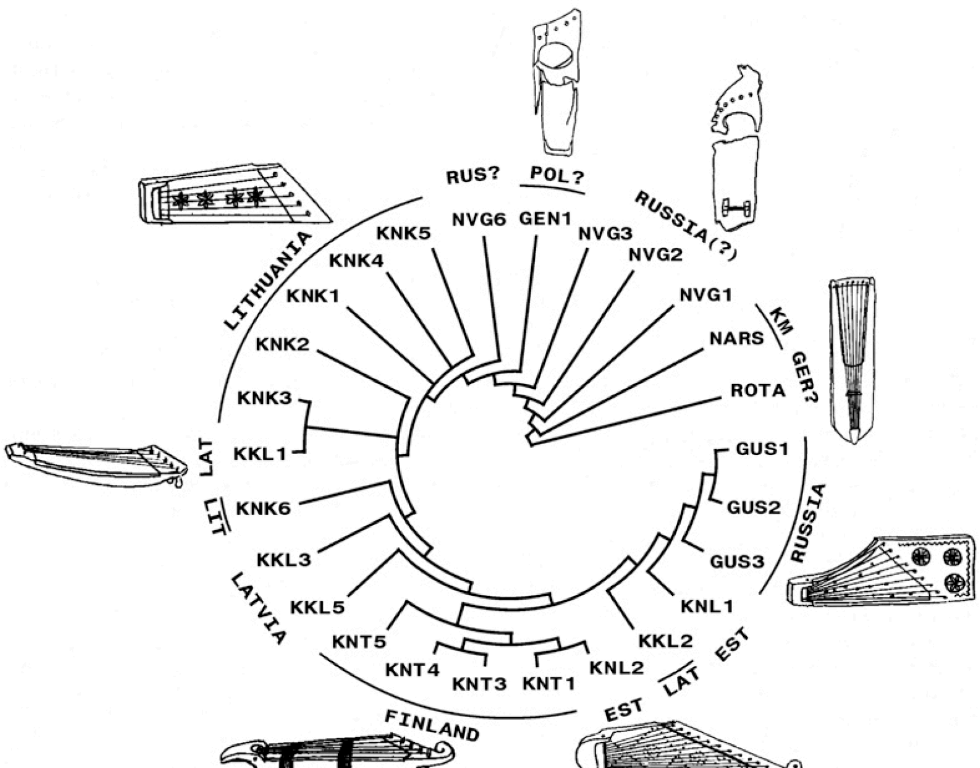


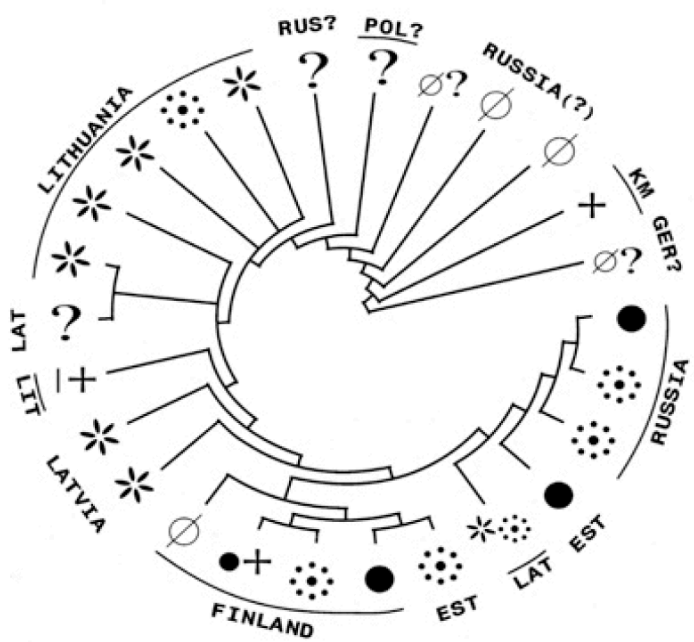
ILYA TËMKIN

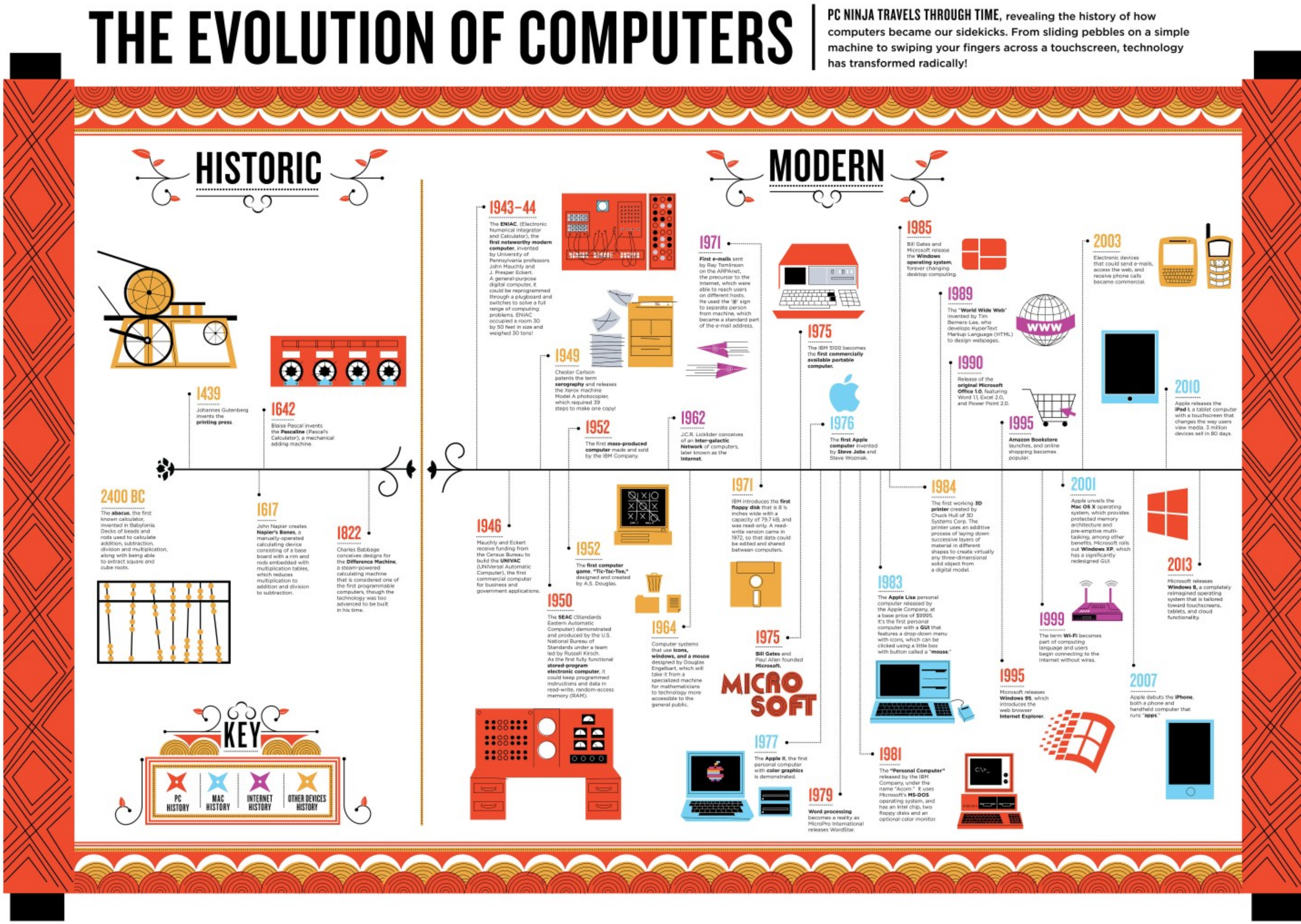
The Evolution of The Baltic Psaltery: A Case for Phyloorganology

The Galpin Society Journal MAY 2004








THE EVOLUTION OF COMPUTERS
PC NINJA TRAVELS THROUGH TIME, revealing the history of how computers became our sidekicks. From sliding pebbles on a simple machine to swiping your fingers across a touchscreen, technology has transformed radically!
HISTORIC
2400 BC
The abacus, the first known calculator, invented in Babylonia. Decks of beads and rods used to calculate addition, subtraction, division and multiplication, along with being able to extract square and cube roots.
1439
Johannes Gutenberg invents the printing press.
1617
John Napier creates Napier's Bones, a manually-operated calculating device consisting of a base board with a rim and rods embedded with multiplication tables, which reduces multiplication to addition and division to subtraction.
1642
Blaise Pascal invents the Pascaline (Pascal's Calculator), a mechanical adding machine.
1822
Charles Babbage conceives designs for the Difference Machine, a steam-powered calculating machine that is considered one of the first programmable computers, though the technology was too advanced to be built in his time.
KEY
PC HISTORY
MAC HISTORY
INTERNET HISTORY
OTHER DEVICES HISTORY
MODERN
1943–44
The ENIAC, (Electronic Numerical Integrator and Calculator), the first noteworthy modern computer, invented by University of Pennsylvania professors John Mauchly and J. Presper Eckert. A general-purpose digital computer, it could be reprogrammed through a plugboard and switches to solve a full range of computing problems. ENIAC occupied a room 30 by 50 feet in size and weighed 30 tons!
1946
Mauchly and Eckert receive funding from the Census Bureau to build the UNIVAC (UNIVersal Automatic Computer), the first commercial computer for business and government applications.
1949
Chester Carlson patents the term xerography and releases the Xerox machine Model A photocopier, which required 39 steps to make one copy!
1950
The SEAC (Standards Eastern Automatic Computer) demonstrated and produced by the U.S. National Bureau of Standards under a team led by Russell Kirsch. As the first fully functional stored-program electronic computer, it could keep programmed instructions and data in read-write, random-access memory (RAM).
1952
The first mass-produced computer made and sold by the IBM Company.
1952
The first computer game, "Tic-Tac-Toe," designed and created by A.S. Douglas.
1962
J.C.R. Licklider conceives of an Inter-galactic Network of computers, later known as the Internet.
1964
Computer systems that use icons, windows, and a mouse designed by Douglas Engelbart, which will take it from a specialized machine for mathematicians to technology more accessible to the general public.
1971
First e-mails sent by Ray Tomlinson on the ARPAnet, the precursor to the Internet, which were able to reach users on different hosts. He used the '@' sign to separate person from machine, which became a standard part of the e-mail address.
1971
IBM introduces the first floppy disk that is 8 ½ inches wide with a capacity of 79.7 kB, and was read-only. A read-write version came in 1972, so that data could be edited and shared between computers.
1975
The IBM 5100 becomes the first commercially available portable computer.
1975
Bill Gates and Paul Allen founded Microsoft.
MICRO SOFT
1976
The first Apple computer invented by Steve Jobs and Steve Wozniak.
1977
The Apple II, the first personal computer with color graphics is demonstrated.
1979
Word processing becomes a reality as MicroPro International releases WordStar.
1981
The "Personal Computer" released by the IBM Company, under the name "Acorn." It uses Microsoft's MS-DOS operating system, and has an Intel chip, two floppy disks and an optional color monitor.
C:\>_
1983
The Apple Lisa personal computer released by the Apple Company, at a base price of $9995. It's the first personal computer with a GUI that features a drop-down menu with icons, which can be clicked using a little box with button called a "mouse."
1984
The first working 3D printer created by Chuck Hull of 3D Systems Corp. The printer uses an additive process of laying down successive layers of material in different shapes to create virtually any three-dimensional solid object from a digital model.
1985
Bill Gates and Microsoft release the Windows operating system, forever changing desktop computing.
1989
The "World Wide Web" invented by Tim Berners-Lee, who develops HyperText Markup Language (HTML) to design webpages.
WWW
1990
Release of the original Microsoft Office 1.0, featuring Word 1.1, Excel 2.0, and Power Point 2.0.
1995
Amazon Bookstore launches, and online shopping becomes popular.
1995
Microsoft releases Windows 95, which introduces the web browser Internet Explorer.
1999
The term Wi-Fi becomes part of computing language and users begin connecting to the Internet without wires.
2001
Apple unveils the Mac OS X operating system, which provides protected memory architecture and pre-emptive multi-tasking, among other benefits. Microsoft rolls out Windows XP, which has a significantly redesigned GUI.
2003
Electronic devices that could send e-mails, access the web, and receive phone calls became commercial.
2007
Apple debuts the iPhone, both a phone and handheld computer that runs "apps."
2010
Apple releases the iPad I, a tablet computer with a touchscreen that changes the way users view media. 3 million devices sell in 80 days.
2013
Microsoft releases Windows 8, a completely reimagined operating system that is tailored toward touchscreens, tablets, and cloud functionality.

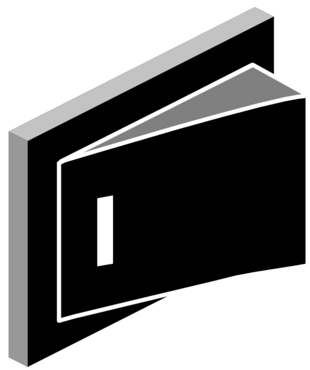
Directionality in Evolution:

beware of the *natural fallacy*

A priori conditions and their consequences

By which means can organisms become more efficient?

adapting to optimal resource use



controlling a broad set of resources

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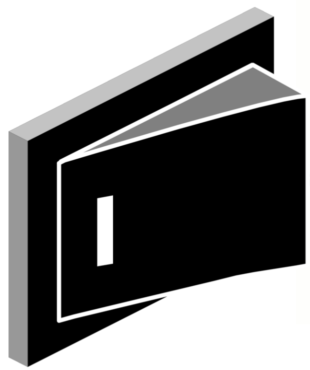

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