



Möglichst viel und sofort – oder wenig stetig?

# Lebenszyklus-Strategien bei Säugetieren



Marcus Clauss

*Zürich, Biologie und Erkrankungen der Wildtiere 2018*



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



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



# Mammal life history

- A principle of evolutionary theory
- Life history and the slow-fast continuum
- Evolution of life history strategies
- A set of tradeoffs
- Evolutionary theory and Creationism  
meet the **Red Queen** and the **Court Jester**
- A new view of life history evolution





# A principle of evolutionary theory: adaptation

# A principle of evolutionary theory

There is little or no development of the renal papilla in freshwater aquatic species. However,...

... the renal papilla is highly developed in species native to arid habitats, so much so that it often penetrates well into the ureter.

Aquatic species

Mesic species

Arid species



Aquatic mole  
(*Desmana moschata*)



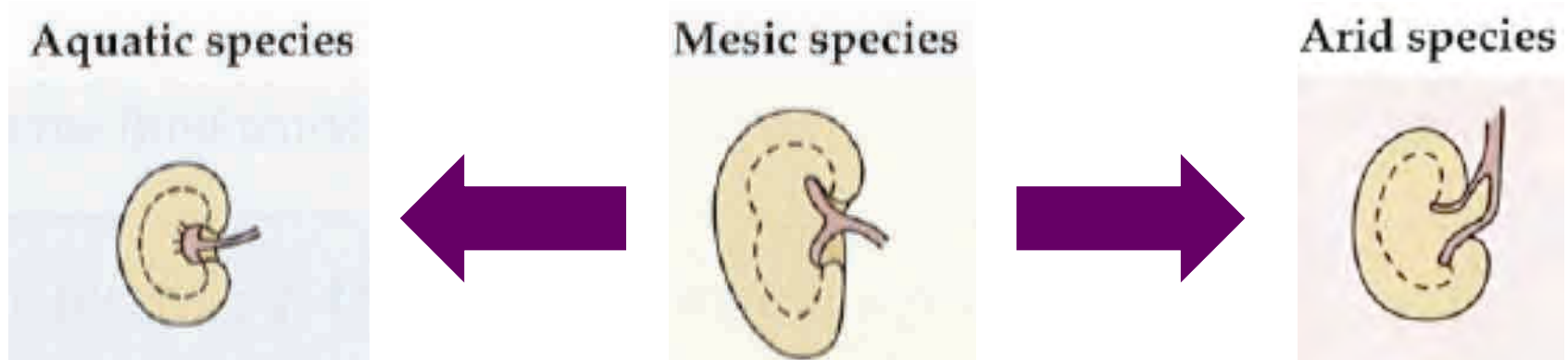
European hedgehog  
(*Erinaceus europaeus*)



Elephant shrew  
(*Macroscelides* sp.)

INSECTIVORES

# Two basic modes of adaptation



Ecological  
opportunity

- reduction (saving)

Ecological  
challenge

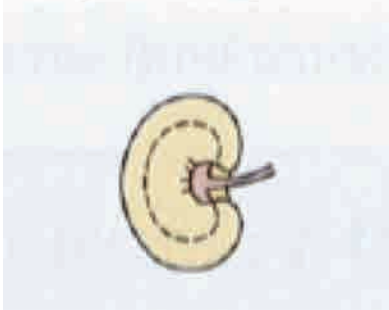
- addition (cost)



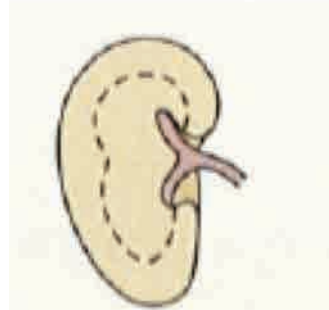
*high efficiency that is  
often not able to use  
high resource  
availability  
competitively*

# Two basic modes of adaptation

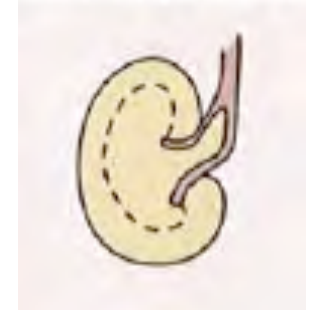
Aquatic species



Mesic species



Arid species



Ecological  
opportunity

- reduction (saving)



Ecological  
challenge

- addition (cost)





# Life history and the slow-fast continuum



# Mammal life history

## The Fast-Slow Continuum in Mammalian Life History: An Empirical Reevaluation

J. Bielby,<sup>1,2,\*</sup> G. M. Mace,<sup>2,†</sup> O. R. P. Bininda-Emonds,<sup>3,‡</sup> M. Cardillo,<sup>1,§</sup> J. L. Gittleman,<sup>4,||</sup> K. E. Jones,<sup>2,#</sup>  
C. D. L. Orme,<sup>1,\*\*</sup> and A. Purvis<sup>1,††</sup>

VOL. 169, NO. 6 THE AMERICAN NATURALIST JUNE 2007







# Mammal life history

**'fast'**

Pace of Life

**'slow'**

High

Metabolism

Low

Short

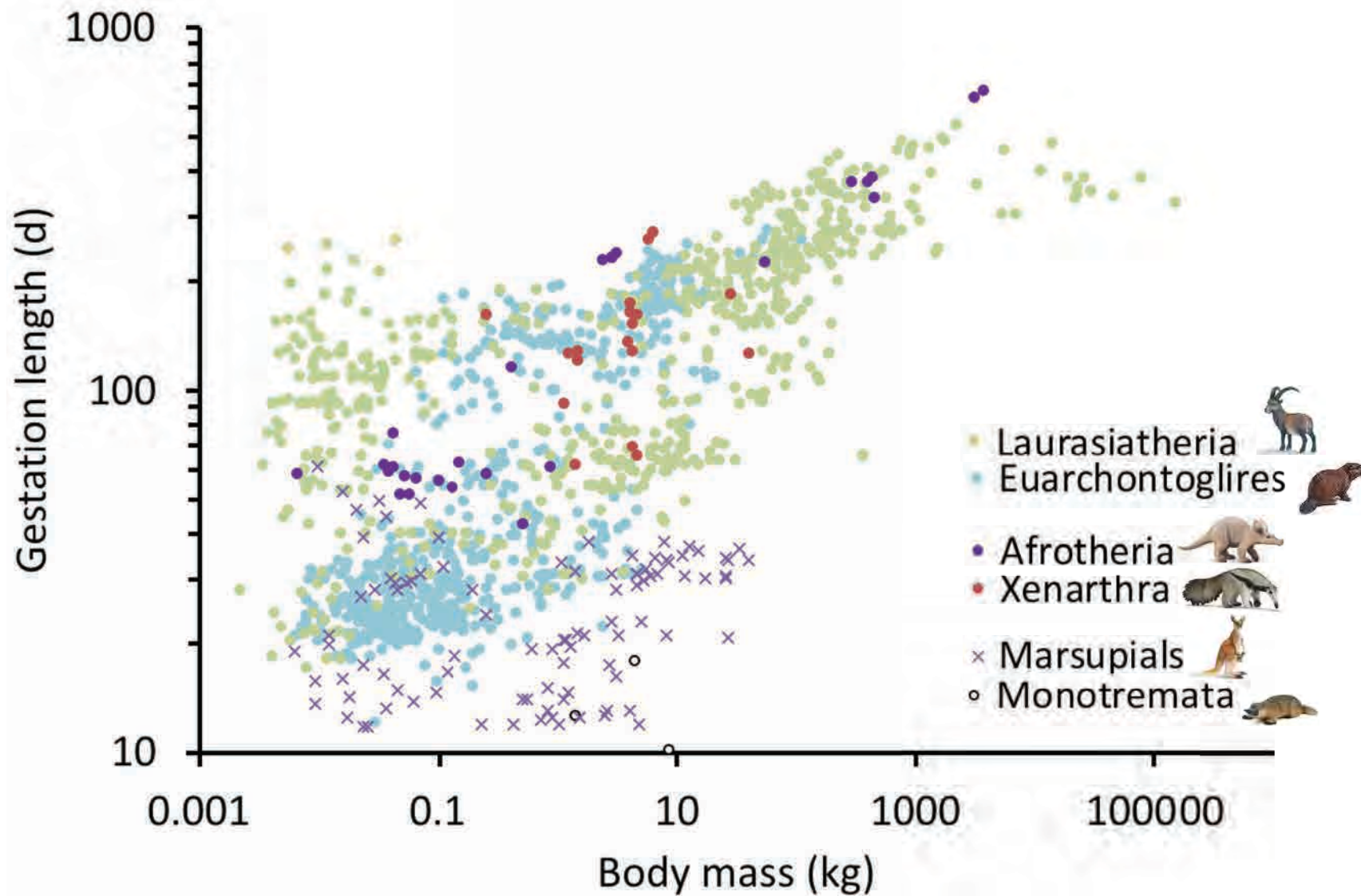
Times

Long

(gestation, longevity, growth,  
time to 1<sup>st</sup> reproduction)

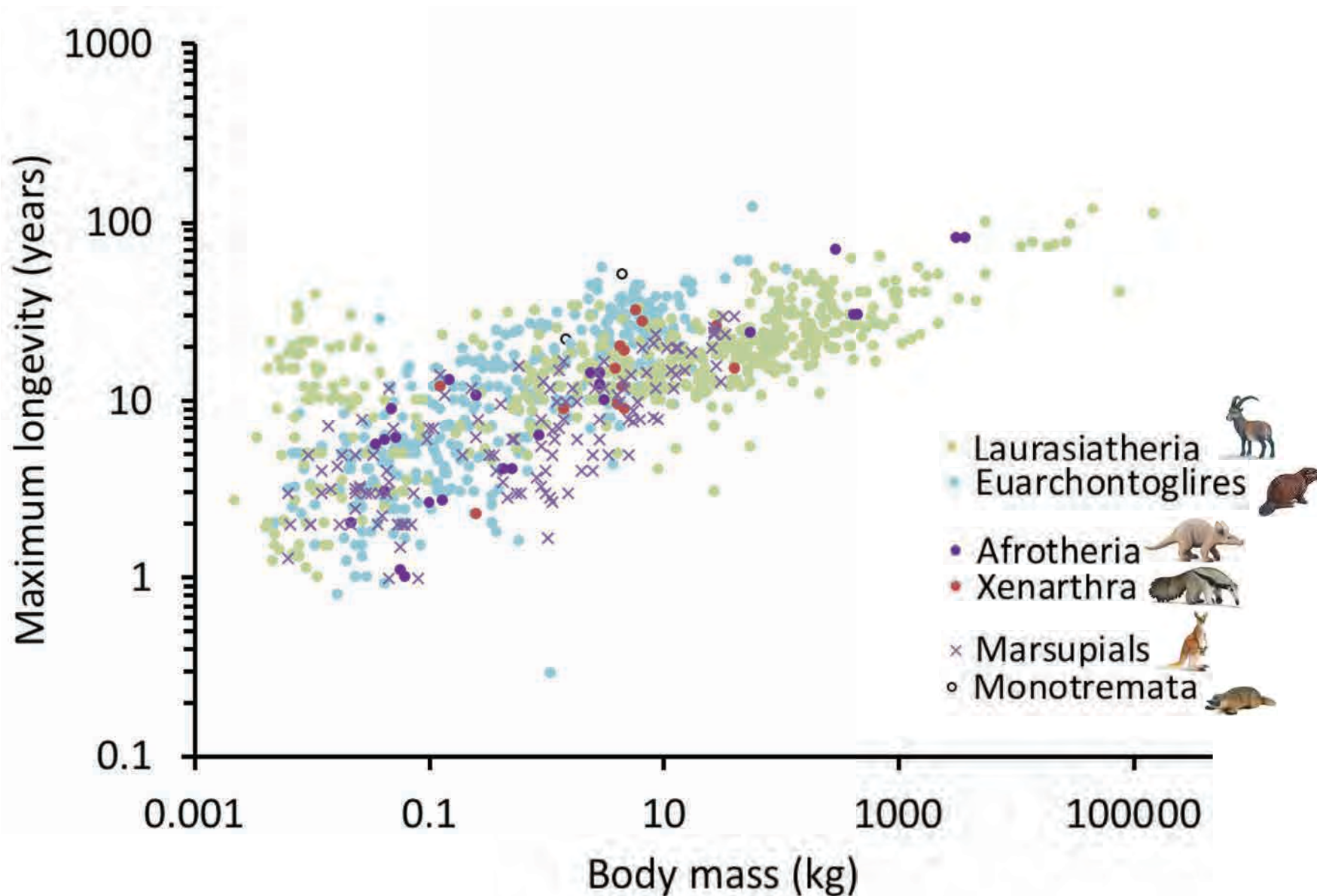


# Gestation length





# Maximum longevity





# Mammal life history

**'fast'**

Pace of Life

**'slow'**

High

Metabolism

Low

Short

Times

Long

(gestation, longevity, growth,  
time to 1<sup>st</sup> reproduction)

Many  
Altricial

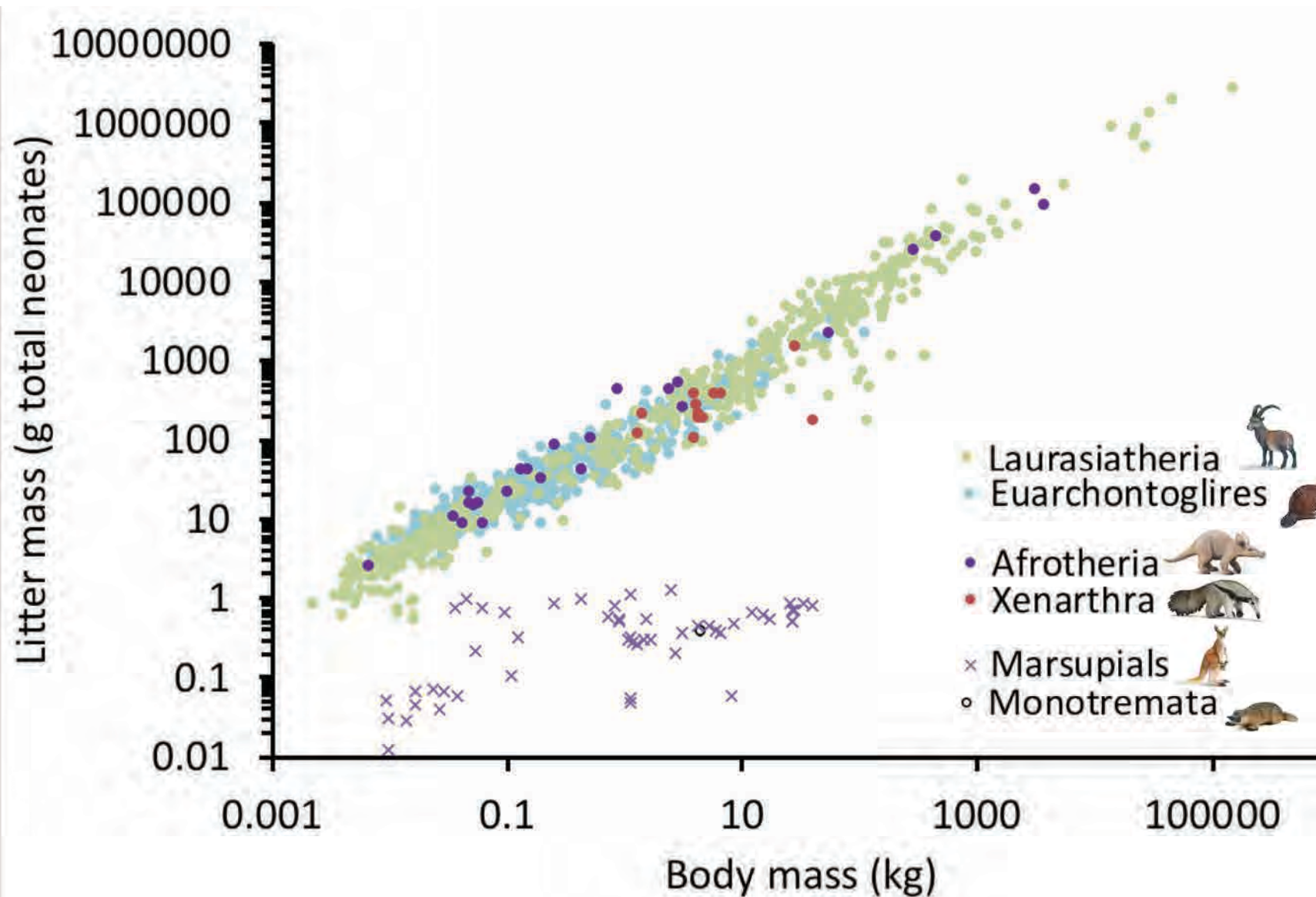
Offspring

Few  
Precocial



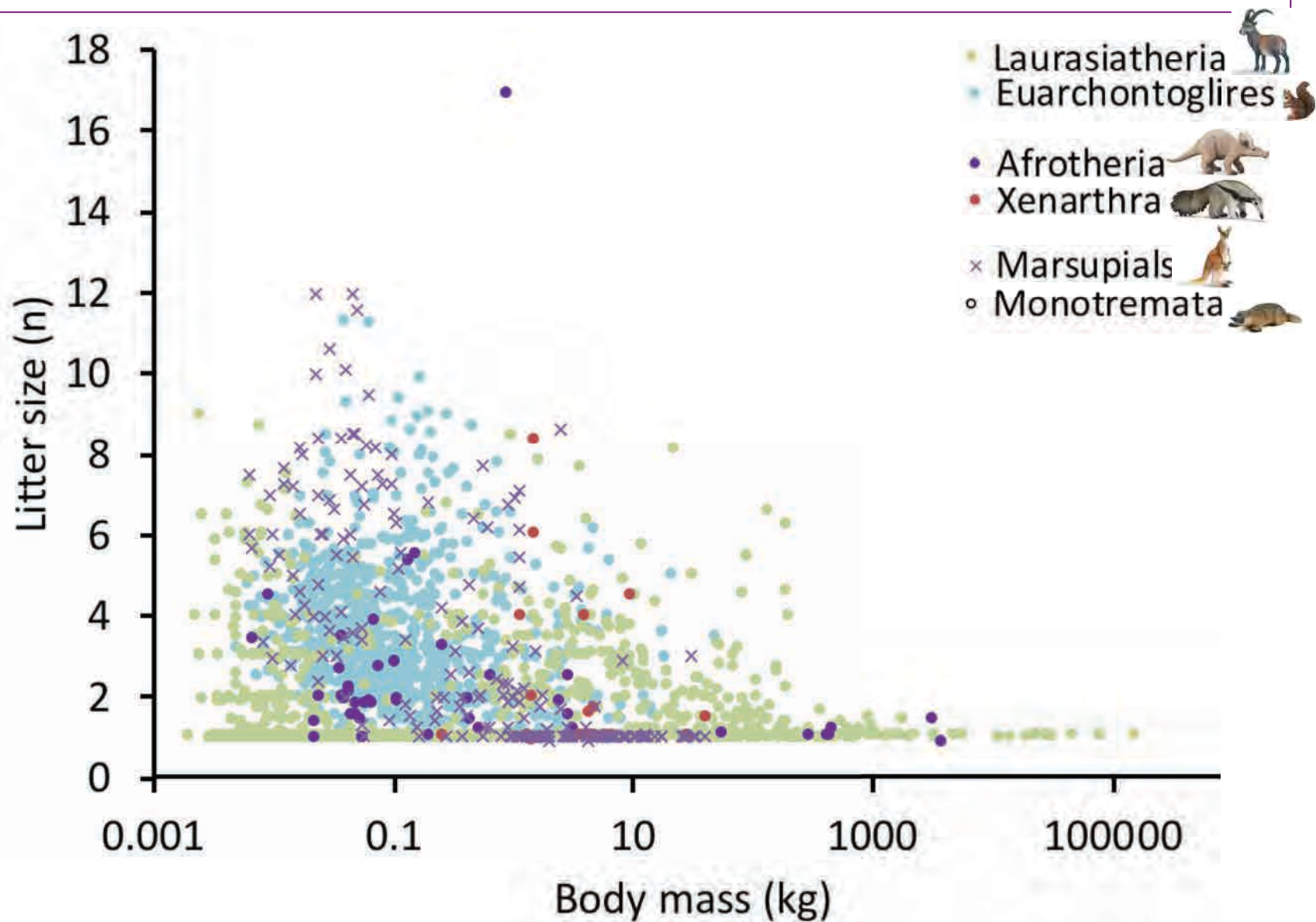


# Neonate (litter) mass

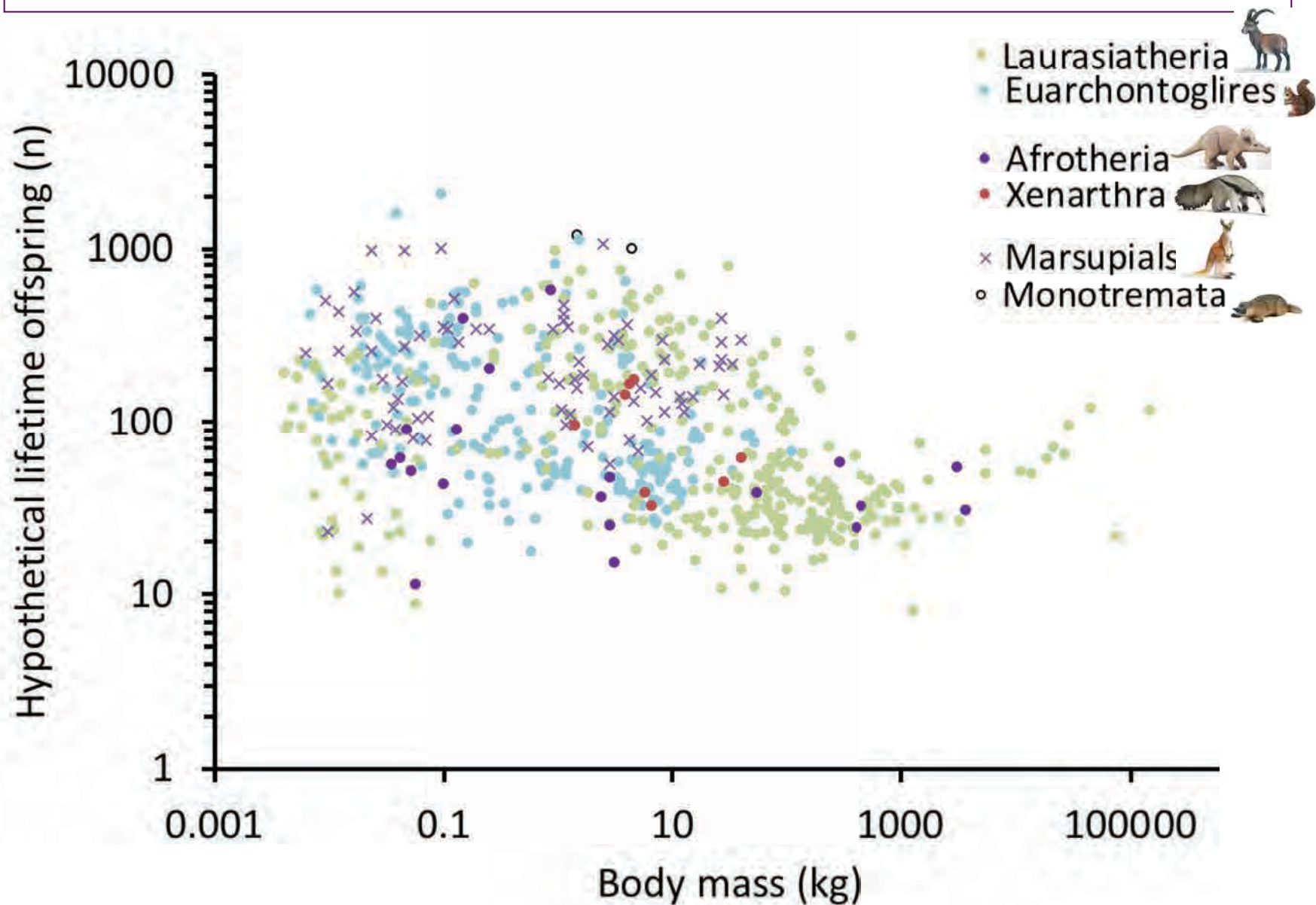




# Litter size



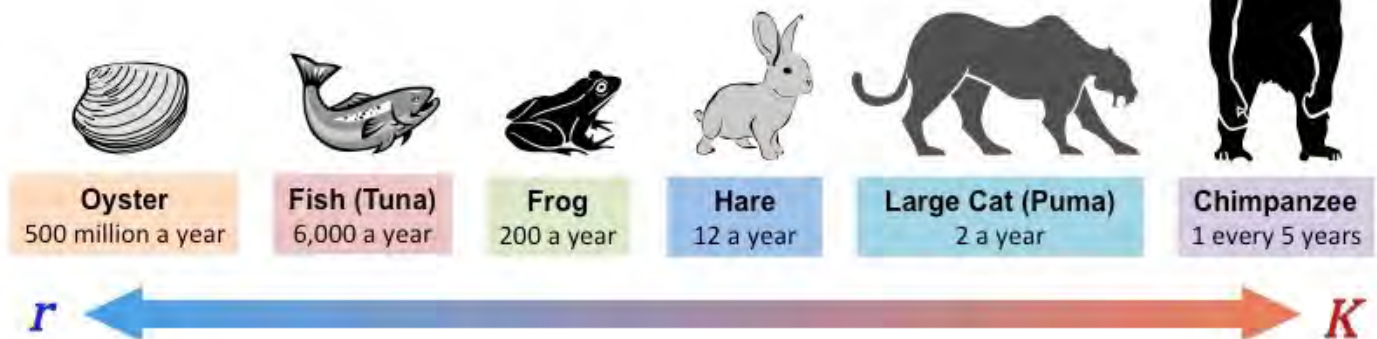
# Hypothetical lifetime offspring





# Mammal life history

<b>'fast'</b>	Pace of Life	<b>'slow'</b>
High	Metabolism	Low
Short	Times (gestation, longevity, growth, time to 1 <sup>st</sup> reproduction)	Long
Many Altricial	Offspring	Few Precocial
High	Mortality	Low





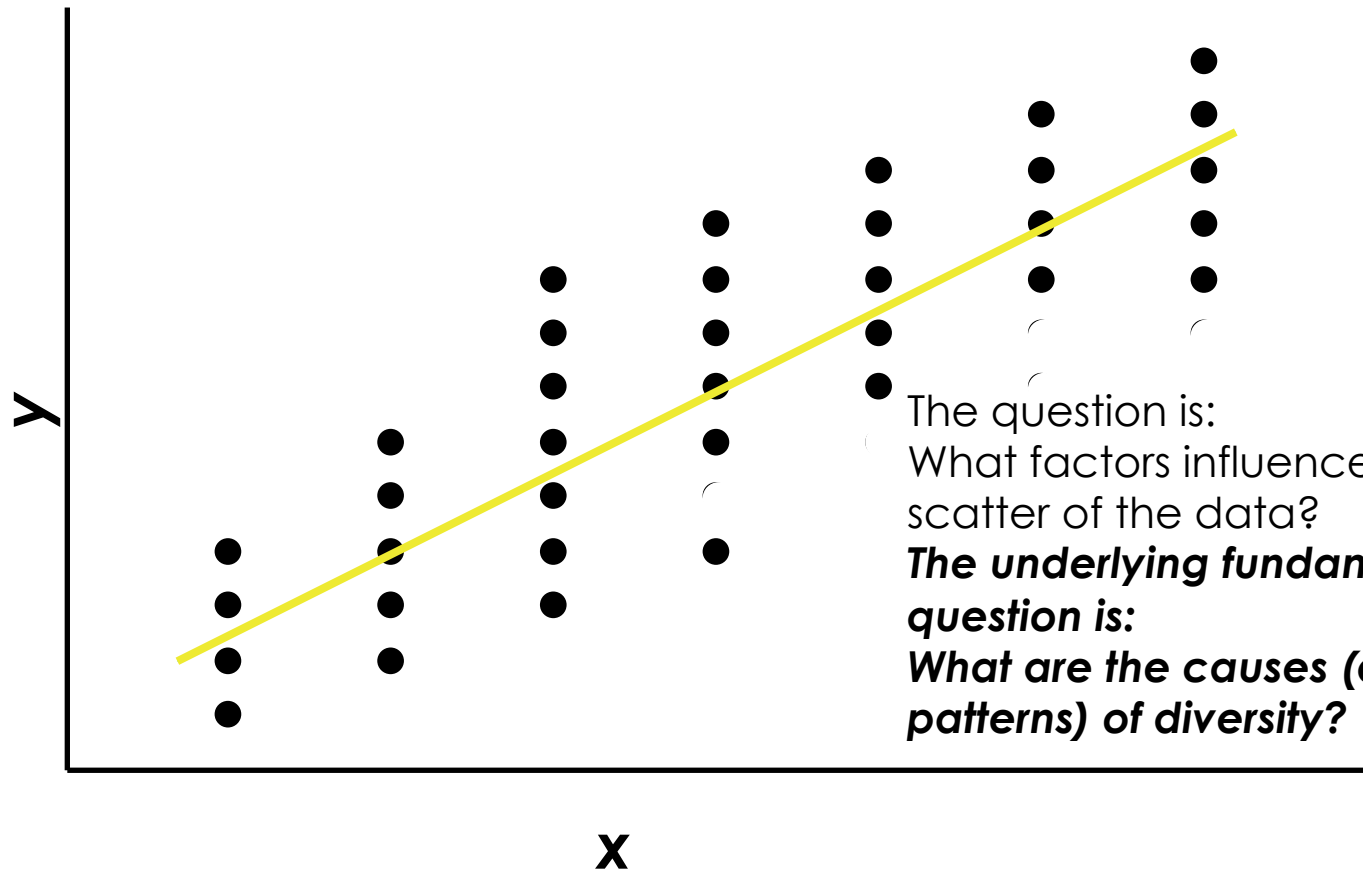


# Evolution of life history strategies



# Interpreting scaling

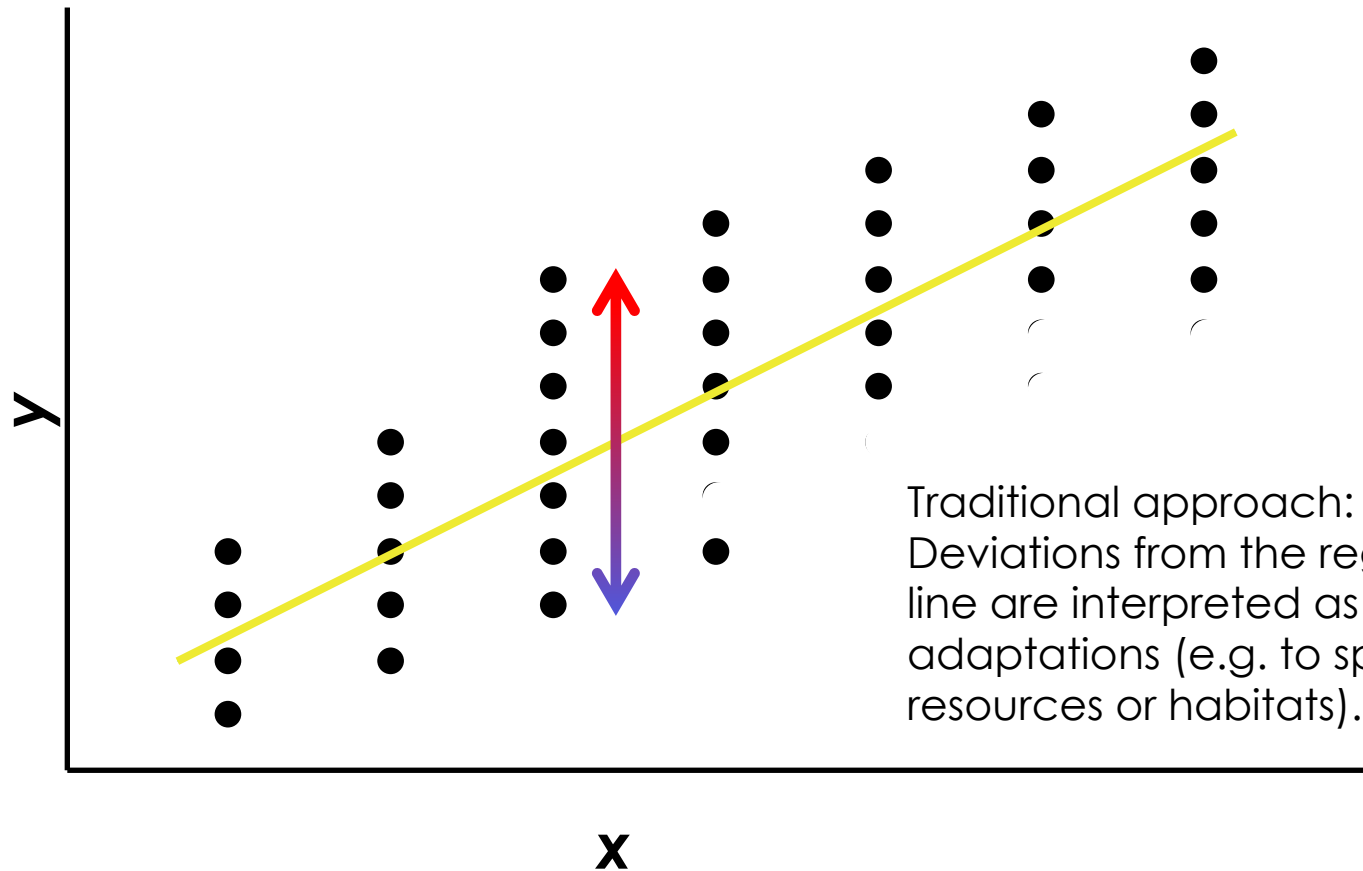
Morphological, physiological and life history variables scale.





# Interpreting scaling

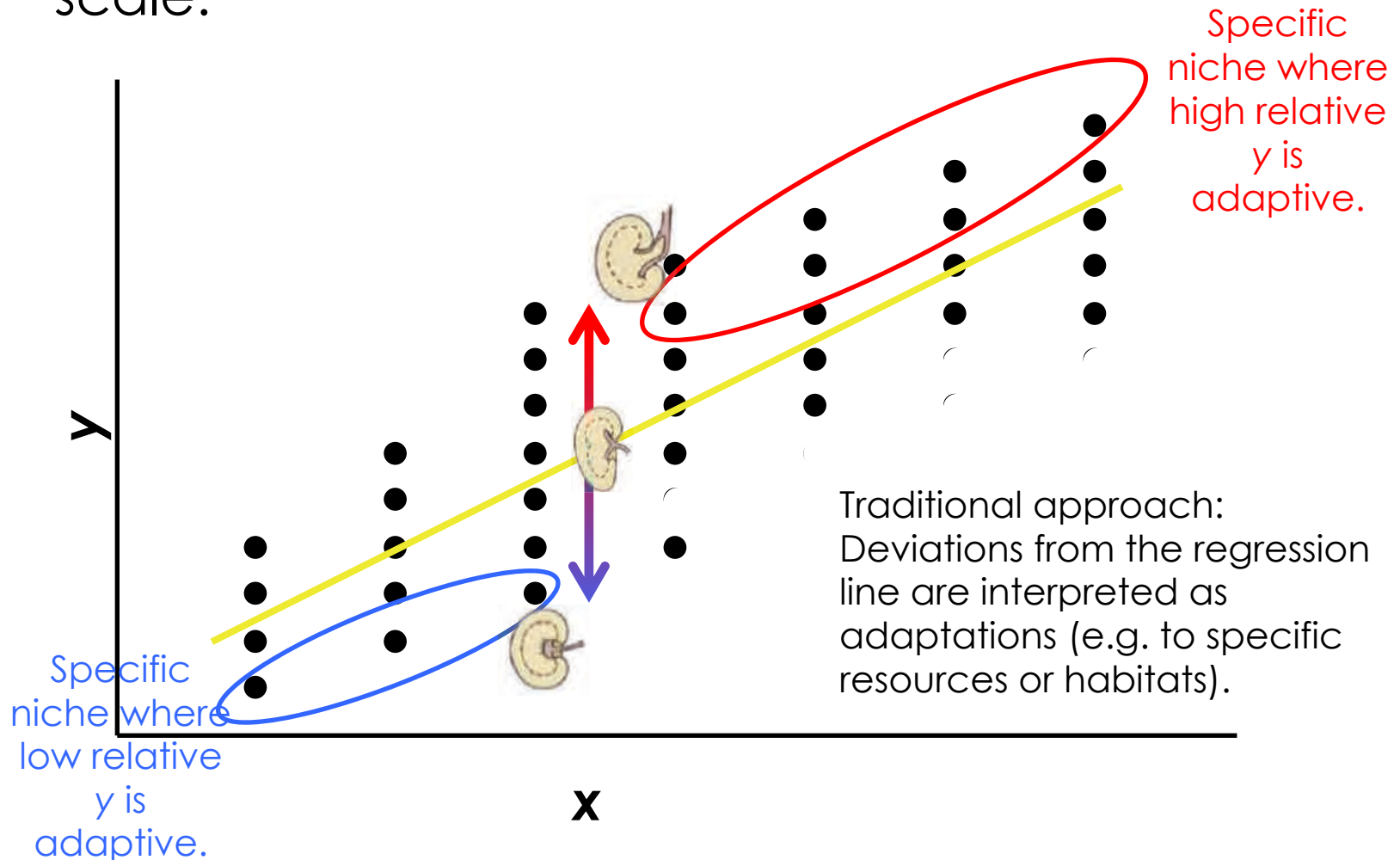
Morphological, physiological and life history variables scale.





# Interpreting scaling

Morphological, physiological and life history variables scale.



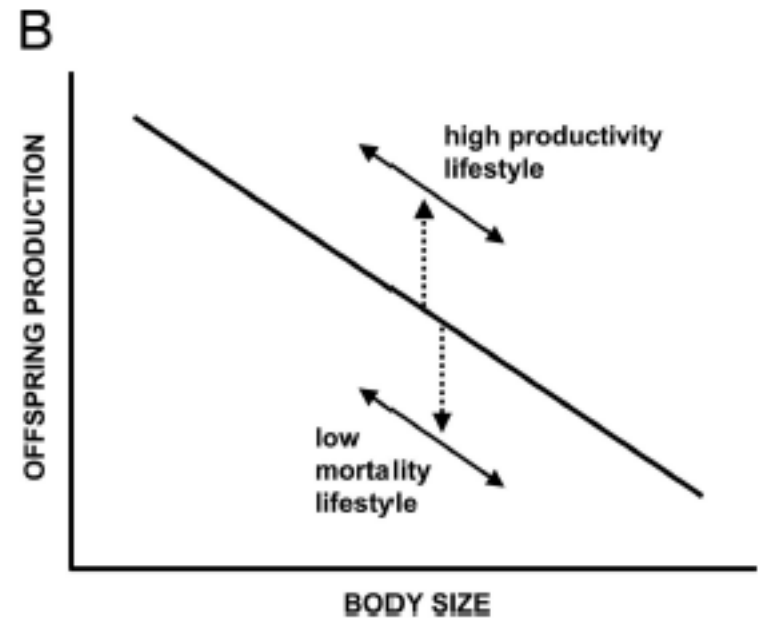
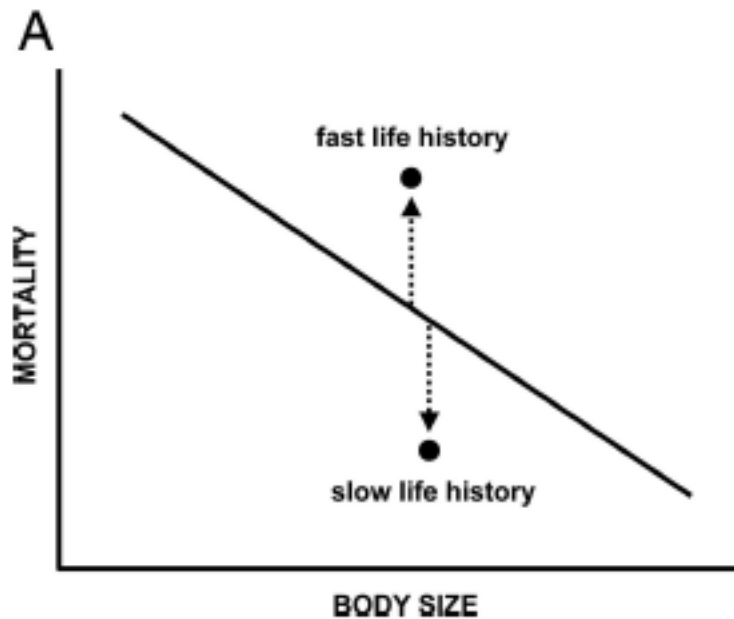


# Life history scaling

## 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\*<sup>†‡</sup> and James H. Brown<sup>‡§¶</sup>

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

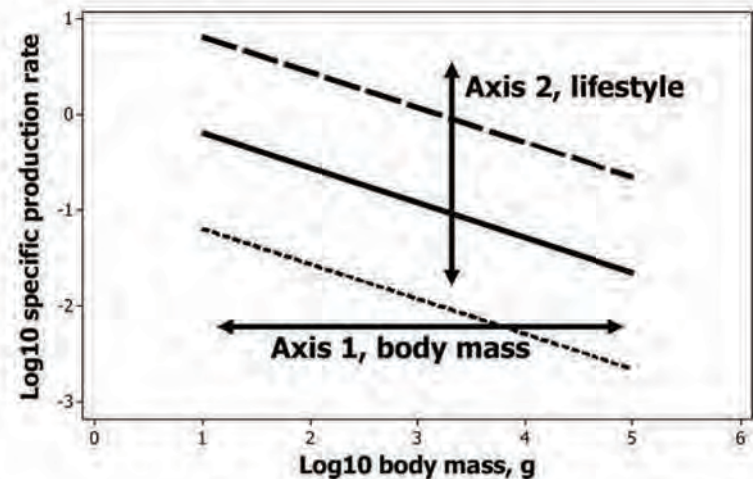
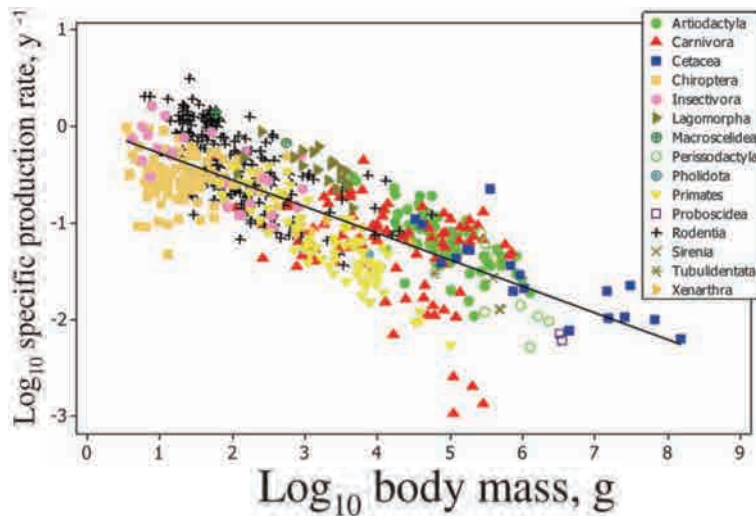


Fig. 4. The two major axes of the slow-fast life-history continuum, body mass, and lifestyle. To the well known axis of allometric variation due to body size, we have added a second orthogonal axis based on ecological lifestyle. Here the solid line represents an unspecialized ancestral condition, the 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.





# Living fast and dying young: A comparative analysis of life-history variation among mammals

D. E. L. PROMISLOW AND P. H. HARVEY

*J. Zool., Lond.* (1990) **220**, 417–437

*Correlations of life-history traits with juvenile and adult mortality after removing adult body weight using partial correlation*

Life-history variable	Juvenile mortality	Adult mortality
Juvenile mortality	—	0.794***
Litter size	0.69***	0.556**
Neonatal weight	−0.46*	−0.199
Litter weight	−0.141	0.095
Gestation length	−0.78***	−0.602**
Duration of lactation	−0.321	−0.392 ( $P < 0.1$ )
Maternal investment (days)	−0.609**	−0.574**
Inter-litter interval	−0.509*	−0.582**
Adolescence	−0.599**	−0.699***
Age of maturity	−0.598***	−0.721***
Maximum lifespan	−0.43 ( $P < 0.1$ )	−0.434 ( $P < 0.1$ )
Reproductive lifespan	−0.186	−0.192
Growth rate (gestation vs. litter weight)	−0.723**	−0.644**
Offspring per year	0.737***	0.663**
Litter weight per year	0.267	0.48*
Lifetime output: no offspring	0.762***	0.716**
Lifetime output: total litter weight	0.182	0.527*
Altricial vs. precocial (2-tailed $t$ )	2.78*	1.54

\*  $P < 0.05$ ; \*\*  $P < 0.01$ ; \*\*\*  $P < 0.001$



# Tradeoffs



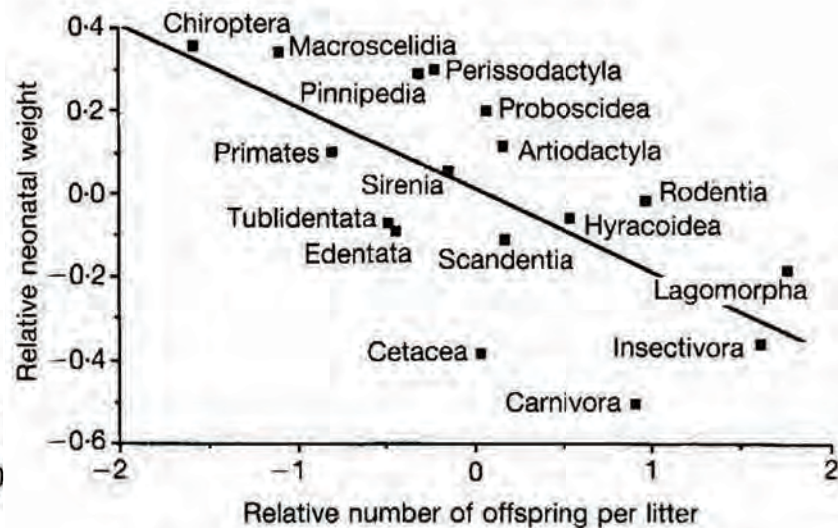
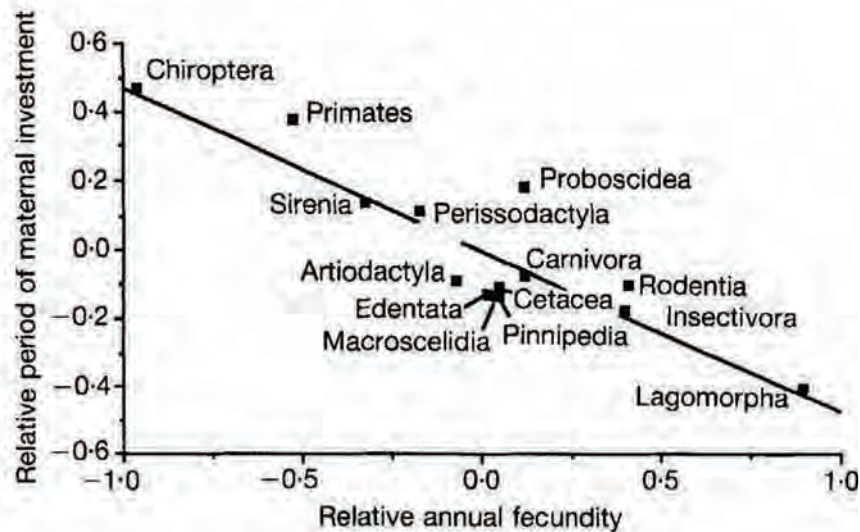


# Tradeoffs

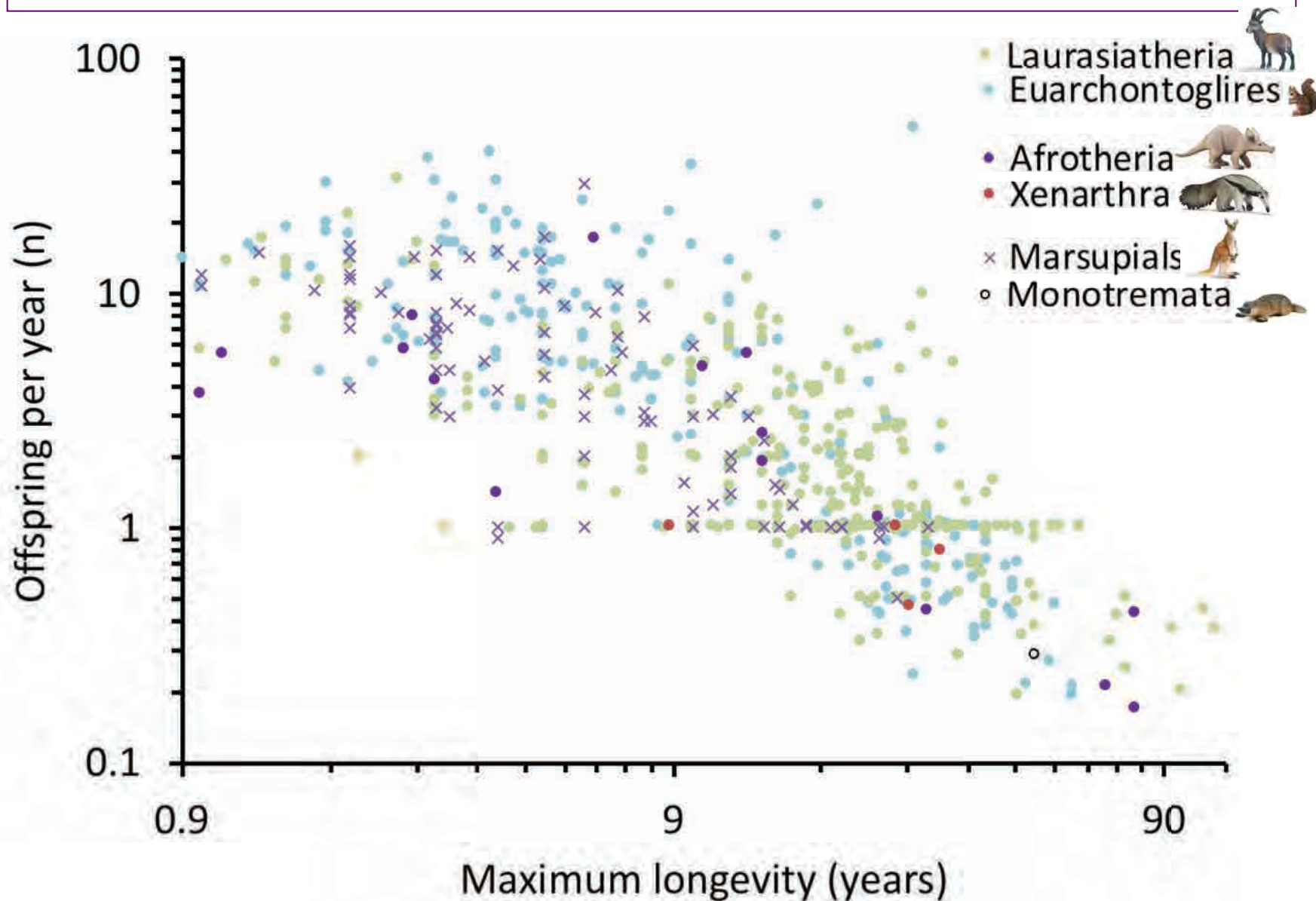
## Life history differences among the eutherian radiations

A. F. READ AND P. H. HARVEY

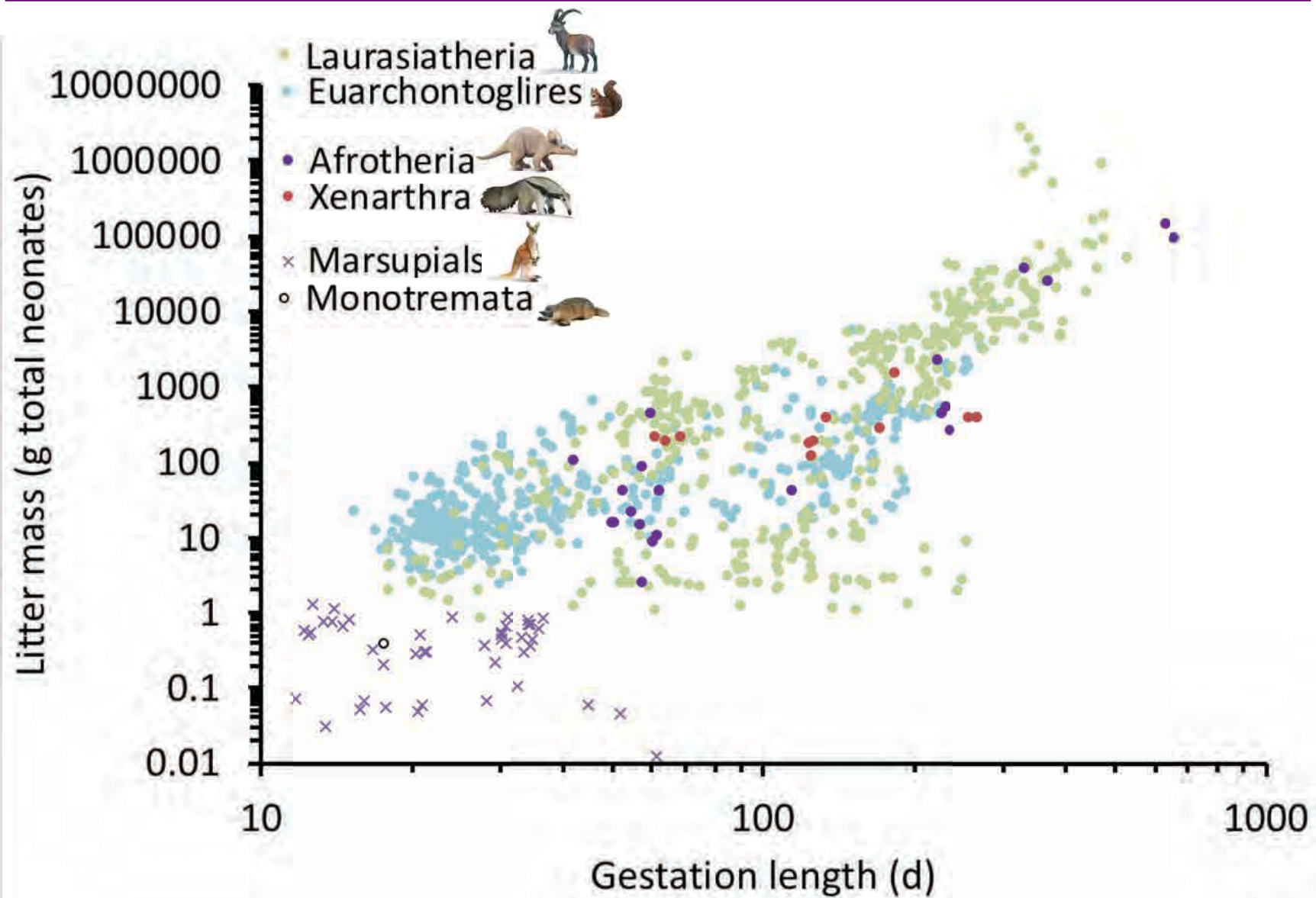
*J. Zool., Lond.* (1989) **219**, 329–353



# Longevity – Reproduction tradeoff



# Gestation – Neonate mass tradeoff

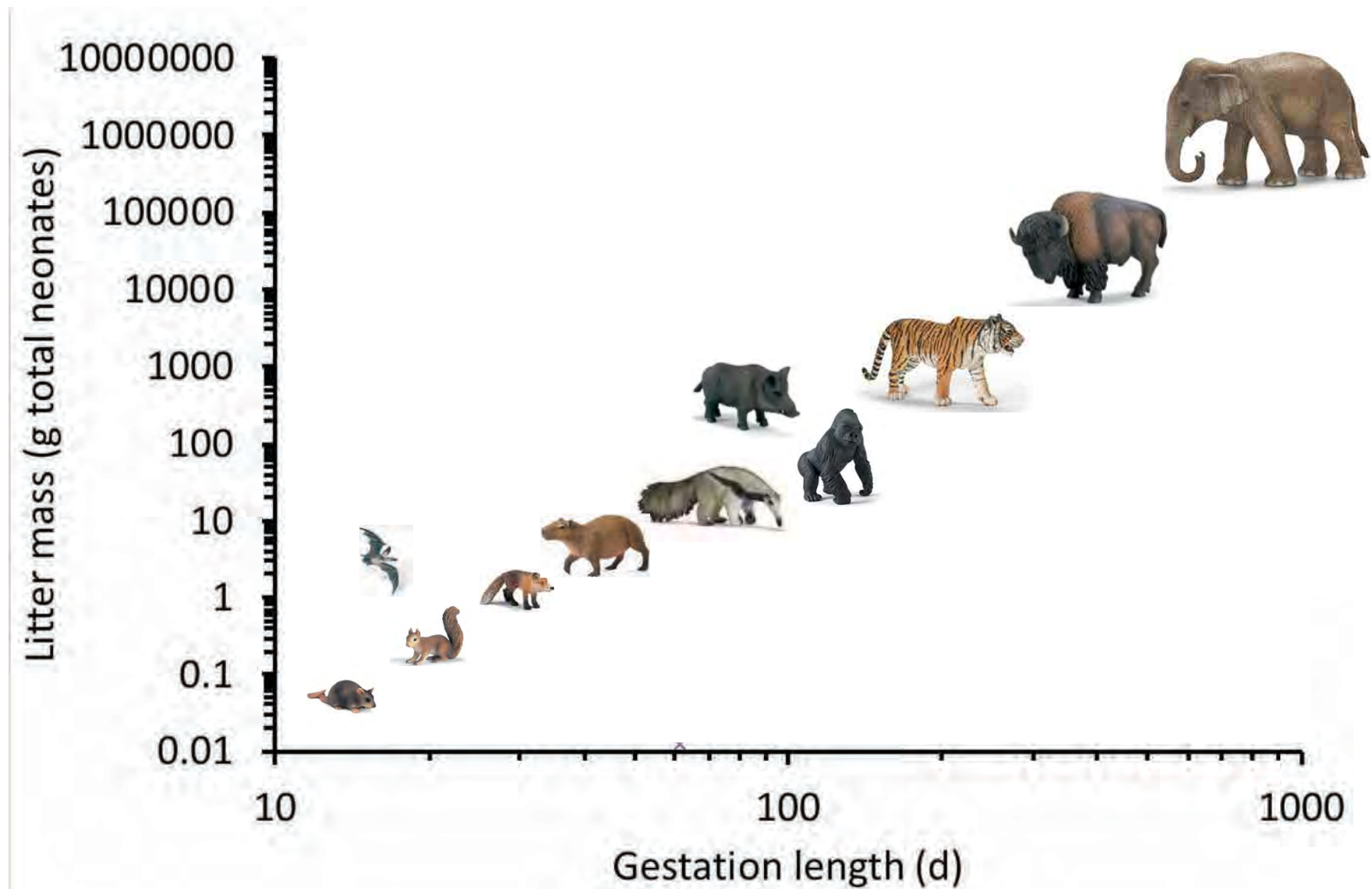




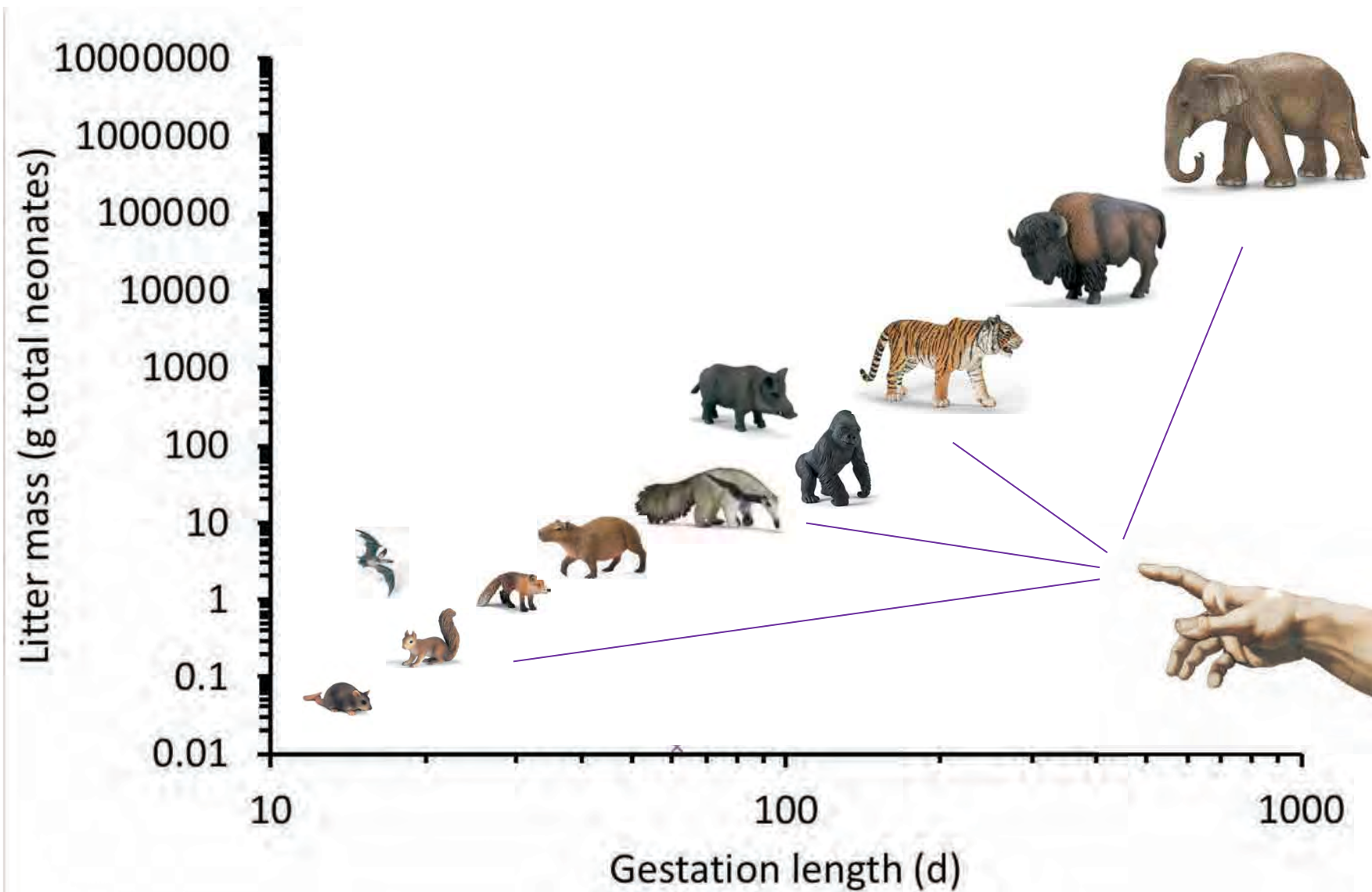
# Evolutionary theory, Creationism, the Red Queen and the Court Jester



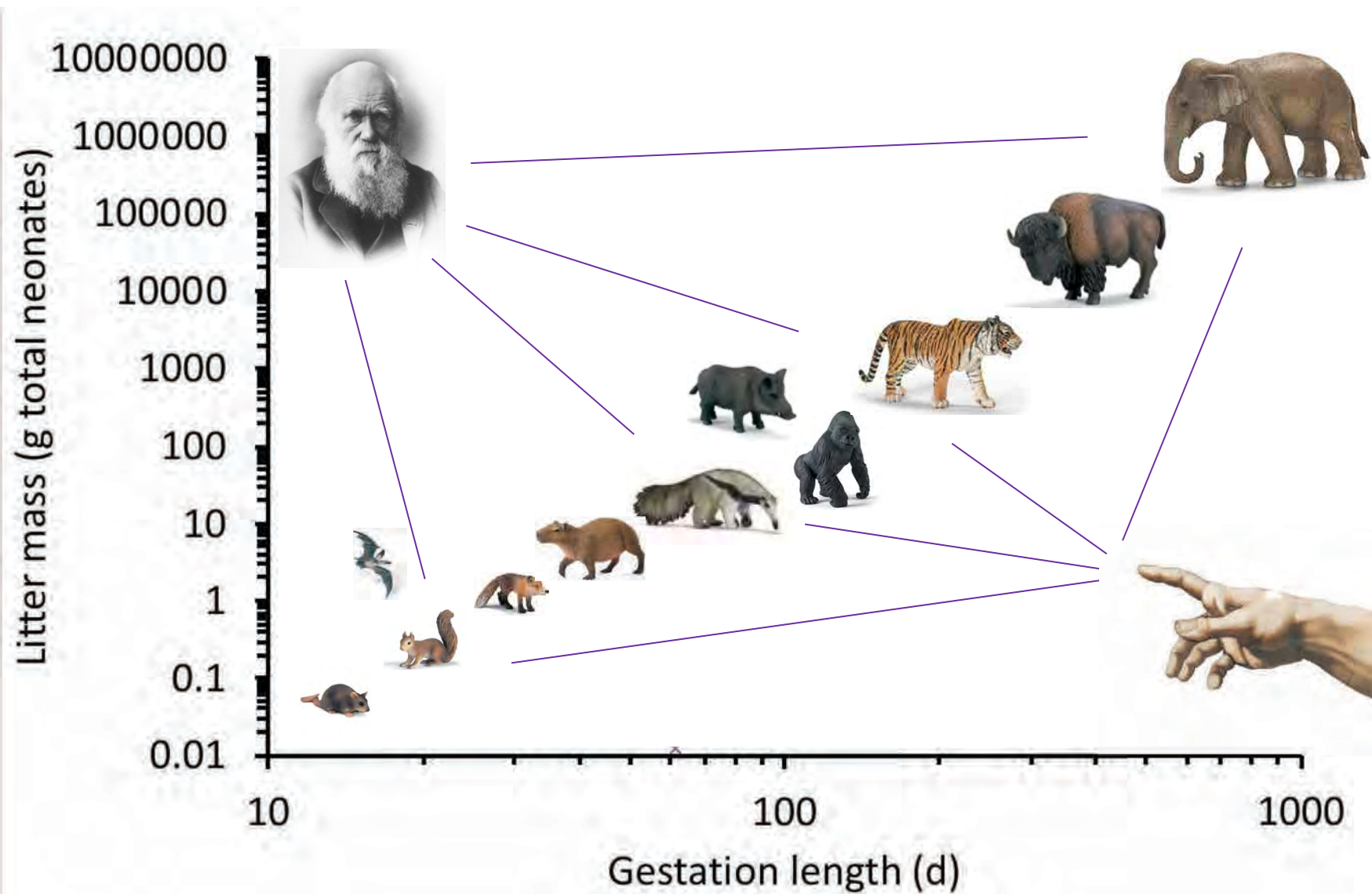
# Tradeoffs: fixed laws ?



# Tradeoffs: fixed laws ?

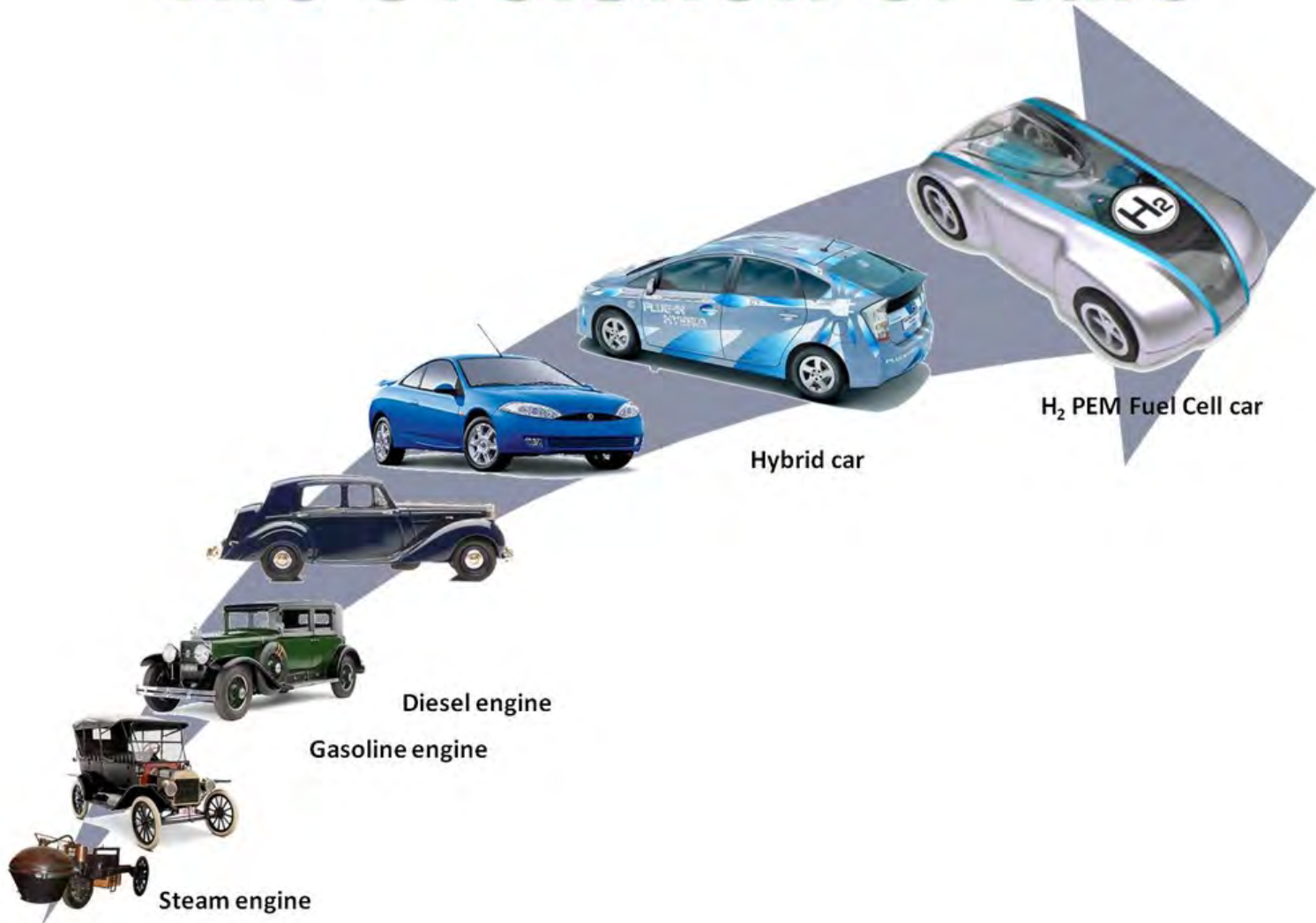


# Tradeoffs: fixed laws ?





# The evolution of cars



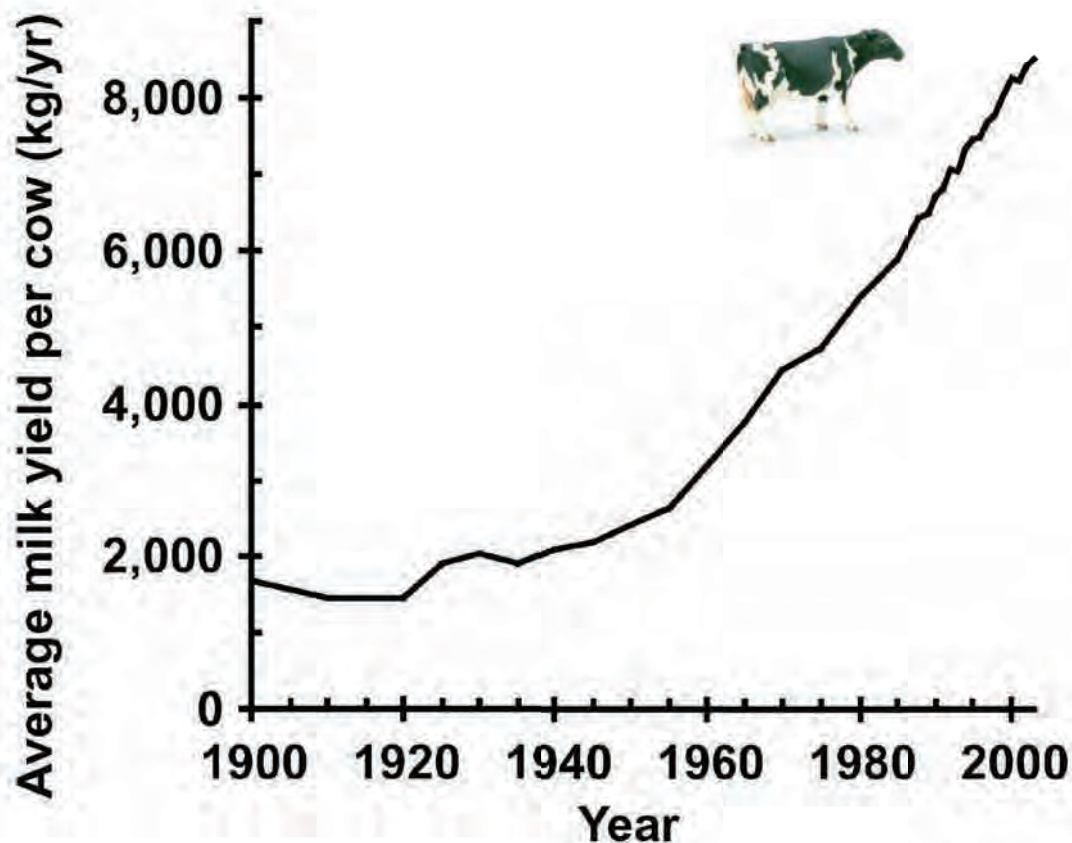


**J. Dairy Sci. 89:1280–1291**

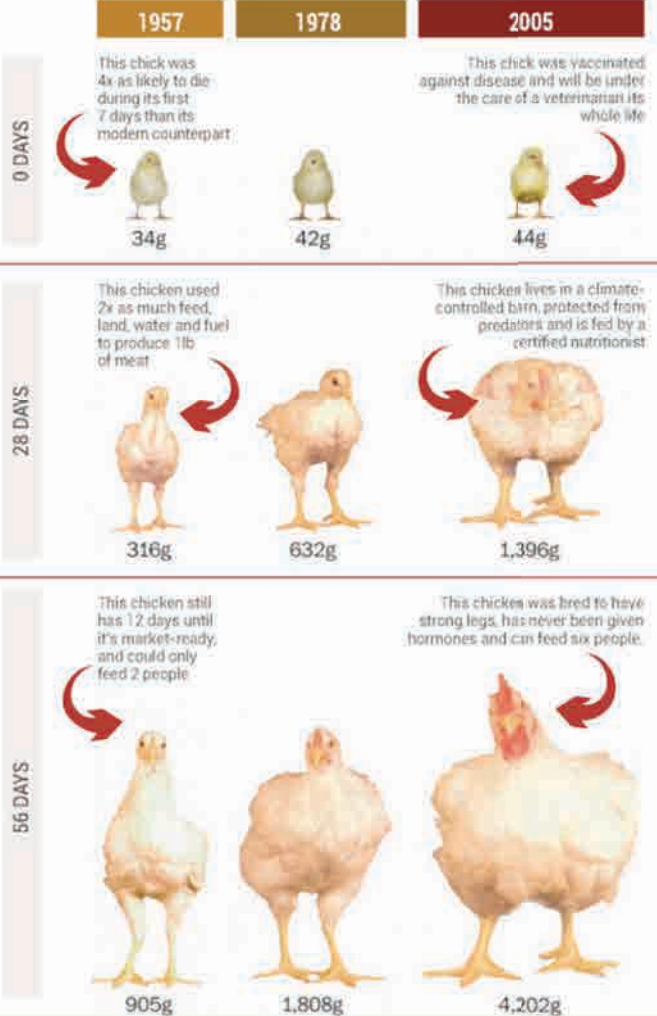
© American Dairy Science Association, 2006.

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

M. J. VandeHaar\*<sup>1</sup> and N. St-Pierre†



# YEP, CHICKENS ARE BIGGER TODAY

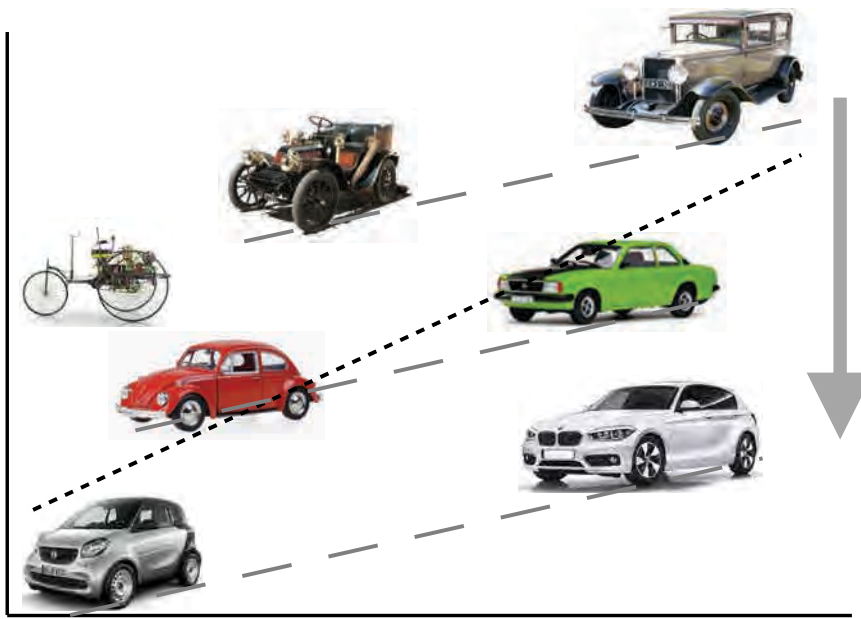


It's no secret that today's chickens are bigger than in years past. They're also the healthiest they've ever been. Find out how at [chickencheck.in](http://chickencheck.in)



Source: USDA, National Chicken Council, 2005. 1.25 lbs (568g) per dozen (12) chickens.  
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Energy per km

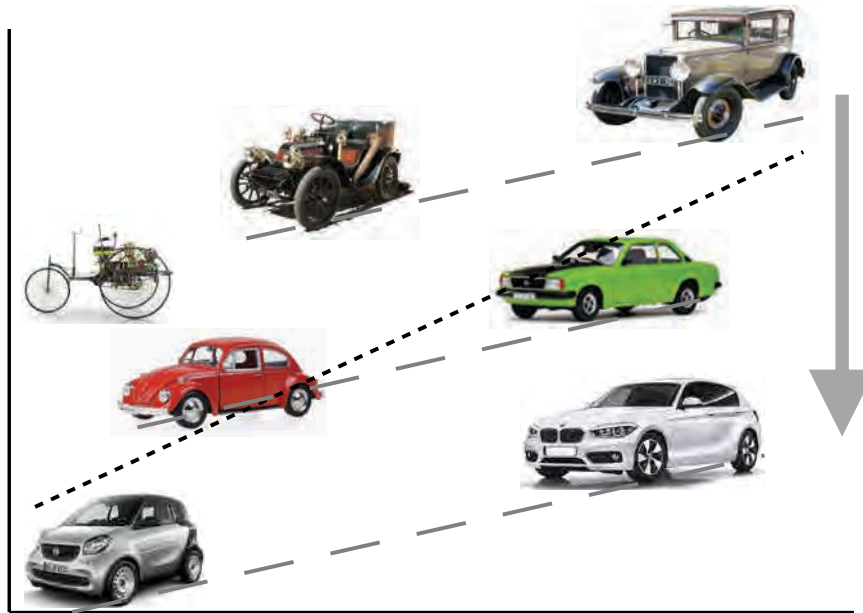


Mass

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



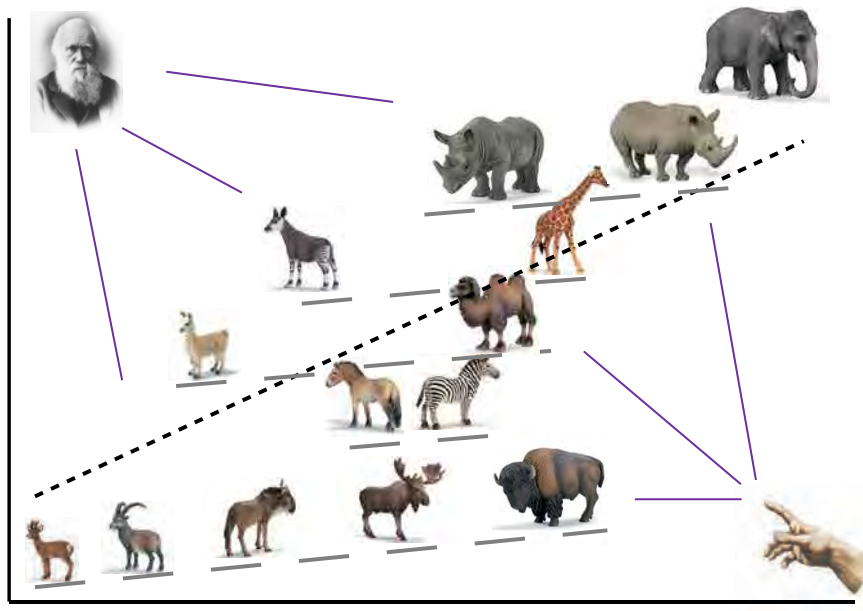
Energy per km



Mass

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

Time per offspring

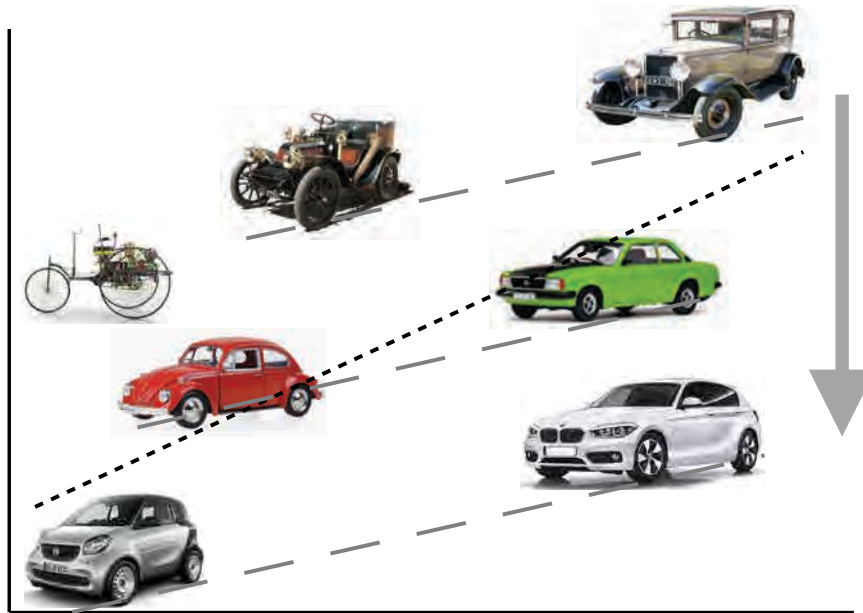


Mass

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



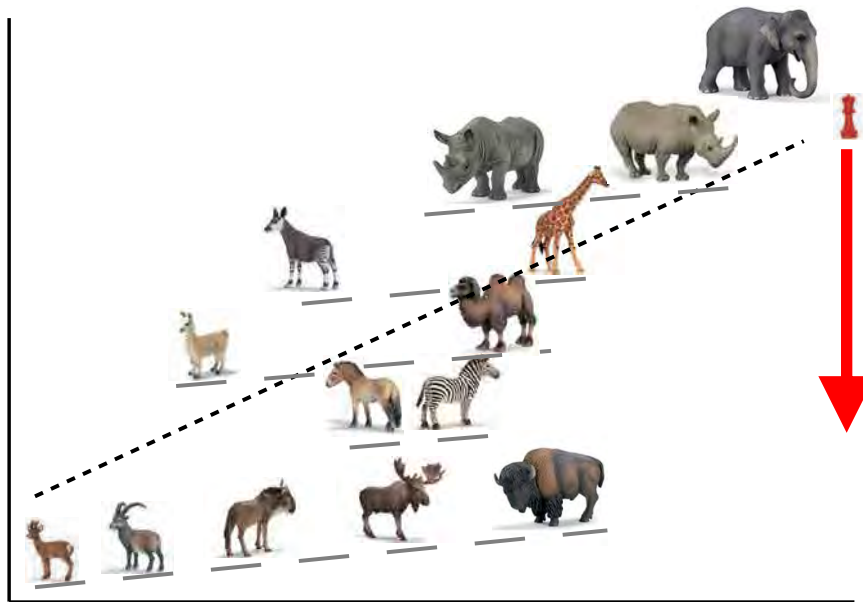
Energy per km



Mass

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

Time per offspring



Mass

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

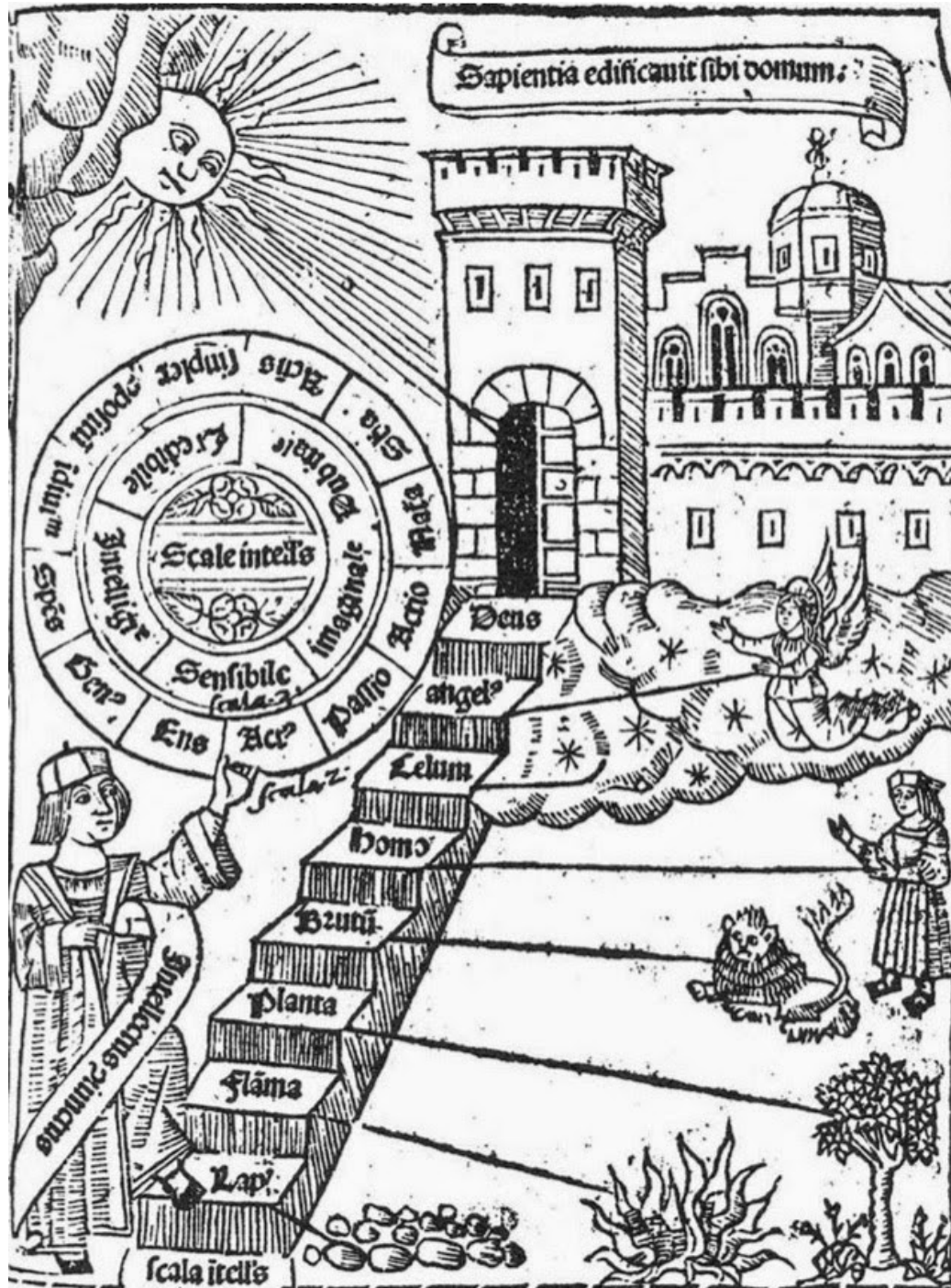




*Many evolutionary biologists abhor the concept of 'progress'.*



Sapientia edificavit sibi domum.



# PHILOSOPHIE ZOOLOGIQUE, ou EXPOSITION

Des Considérations relatives à l'histoire naturelle des Animaux ; à la diversité de leur organisation ; et des facultés qu'ils en obtiennent ; aux causes physiques qui maintiennent en eux la vie et donnent lieu aux mouvemens qu'ils exécutent ; enfin , à celles qui produisent , les unes le sentiment , et les autres l'intelligence de ceux qui en sont doués ;

PAR J.-B.-P.-A. LAMARCK ,

TOME PREMIER.

A PARIS,

{DENTU, Libraire, rue du Pont de Lodi, N°. 3;  
Chez L'AUTEUR, au Muséum d'Histoire Naturelle (Jardin  
des Plantes).

M. DCCC. IX.

## IDÉE D'UNE ÉCHELLE DES ÊTRES NATURELS.

L'HOMME.
Orang-Outang.
Singe.
QUADRUPÈDES.
Écureuil volant.
Chauve-souris.
Autruche.
OISEAUX.
Oiseaux aquatiques.
Oiseaux amphibies.
Poissons volans.
POISSONS.
Poissons rampans.
Anguilles.
Serpens d'eau.
SERPENS.
Limaces.
Limaçons.
COQUILLAGES.
Vers à tuyau.
Teignes.
INSECTES.
Gallinules.
Ténia, ou Solitaire.
Polypes
Orties de Mer.
Sensitive.
PLANTES.

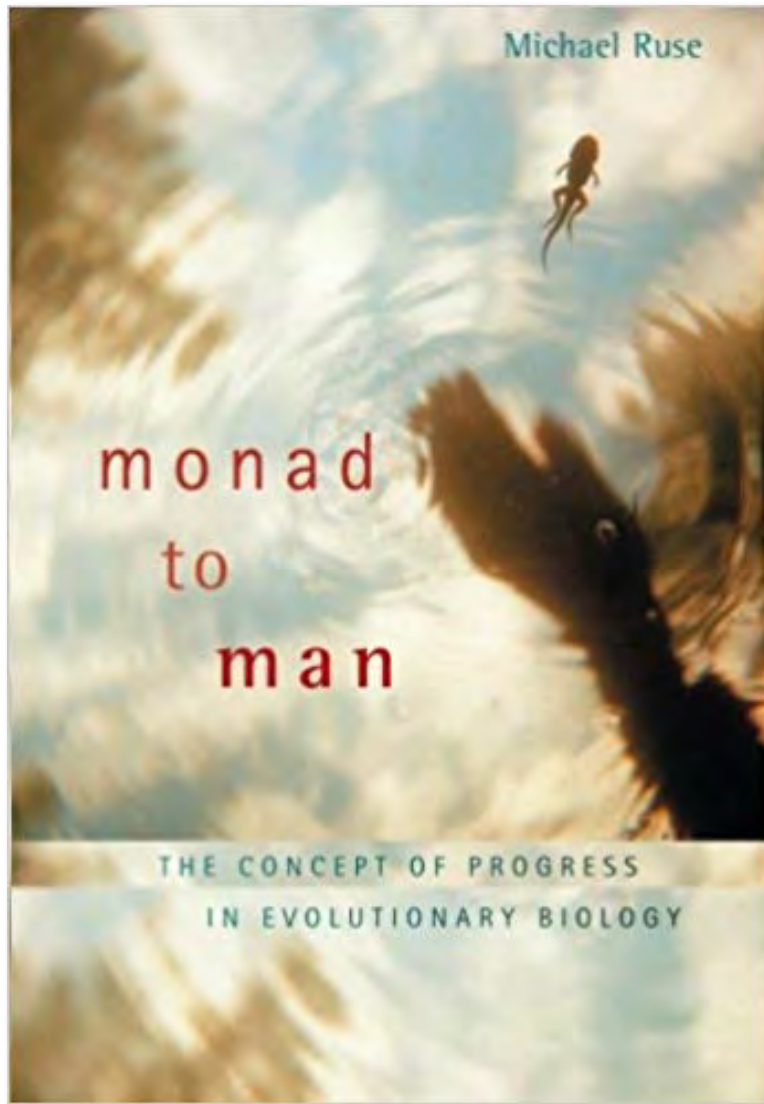
*Evolutionary Ecology Research*, 2013, 15: 747–756

## Cope's Law of the Unspecialized, Cope's Rule, and weak directionality in evolution

Pasquale Raia<sup>1</sup> and Mikael Fortelius<sup>2</sup>

Understanding of directionality was akin to Lamarck's concept of linear progress up life's ladder, and ever since the many evils of social Darwinism were recognized and abandoned, evolutionary biologists have been extremely cautious about considering evolutionary progress of any sort.





Stephen Gould



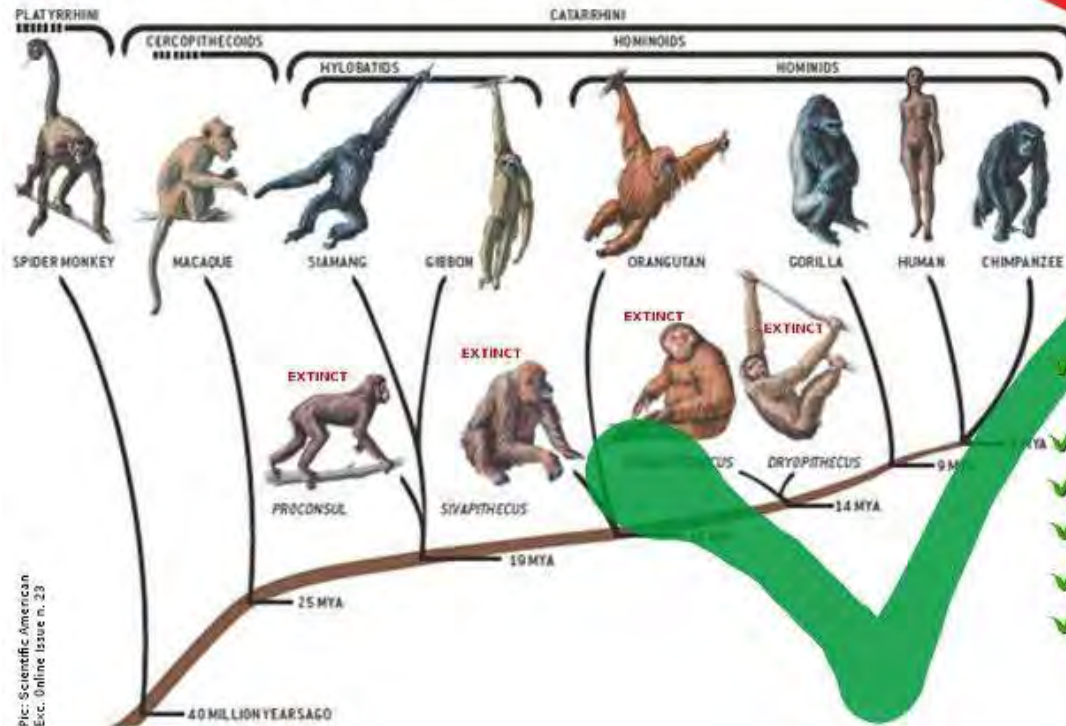
*... my favourite theme that Darwinian evolution cannot be read as a theory of progress, but only as a mechanism for building better adaptation to changing local environments - and that the equation of evolution with progress represents our strongest cultural impediment to a proper understanding of evolution*



*Our failure to find any clear vector of [...] accumulating progress [...] represents our greatest dilemma for a study of patterns in life's history.*

# THIS IS NOT EVOLUTION

- This is *Scala Naturae*, an incorrect pre-evolutionary concept
- ✗ Suggests progress, not adaptation
- ✗ Human is a target, superior being
- ✗ Ancestor being resembles a chimp
- ✗ No branches or extinctions



# THIS IS EVOLUTION

- ✓ Humans are not special. Just a species, not superior, "more evolved" or a target.
- ✓ Some species become extinct (99% of them)
- ✓ Chimps are not portrayed as ancestors
- ✓ Individual beings do not change. Populations do
- ✓ Ancestor species branches into other species
- ✓ Adaptations might lead to smaller size, loss of unused features and extinction

# 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



The crab is the natural predator of the snail.



Natural selection favors snails with thicker shells and spines.



Through natural selection, crabs evolve more powerful claws that can pierce the snails' thick, spiny shells.



In response, natural selection favors snails with even thicker shells and spines.





# ‘Evolutionary progress’ – directional evolution

*Proc. R. Soc. Lond. B* **205**, 489–511 (1979)

489

*Printed in Great Britain*

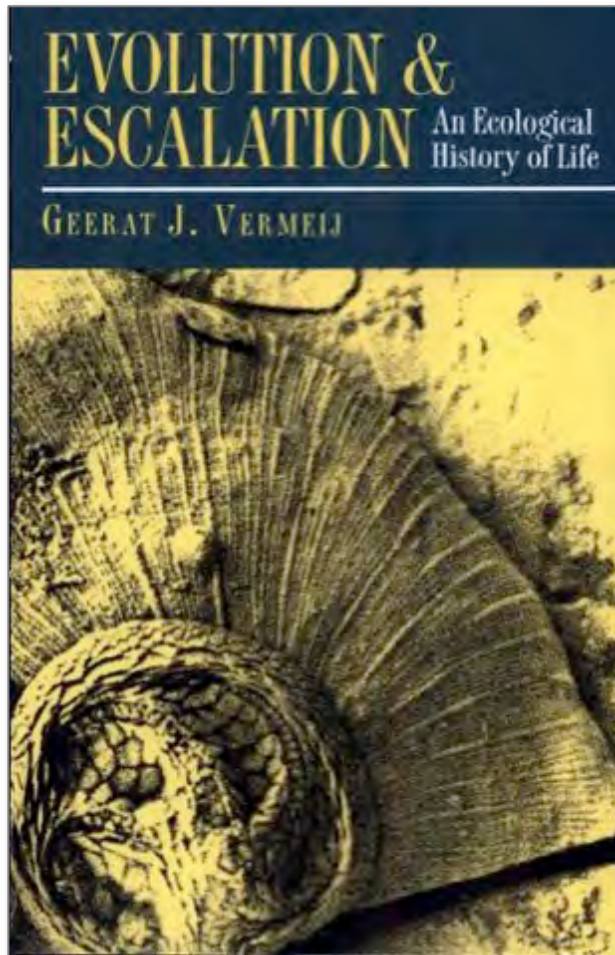
## Arms races between and within species

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





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## On Escalation

**Geerat J. Vermeij**  
Department of Geology, University of California, Davis, California 95616;  
email: [gjvermeij@ucdavis.edu](mailto:gjvermeij@ucdavis.edu)



*Anna. Rev. Earth Planet. Sci.* 2013. 41:1–19  
The *Annual Review of Earth and Planetary Sciences* is online at [earth.annualreviews.org](http://earth.annualreviews.org)  
This article's doi: 10.1146/annurev-earth-050212-124123  
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### 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.





*'Arms races' do not only occur between predator and prey.*







**BE NICE TO FAT PEOPLE**

ONE DAY THEY MAY SAVE YOUR LIFE

The best way to survive a polar bear attack is to go for a walk with a friend that you can outrun!



your eCards  
someecards.com

You don't have to outrun the bear—  
you just have to outrun the other campers.



**SPIRIVA<sup>®</sup> RESPIMAT<sup>™</sup>**  
(tiotropium bromide) INHALATION SPRAY

**SPIRIVA.  
DON'T BECOME  
BEAR FOOD**

**ALWAYS HIKE WITH SOMEONE  
IN WORSE SHAPE THAN YOU.**



**THERE'S BEARS OUT  
THERE YOU KNOW.**



**lifetips**

You don't need to run  
faster than the bear,  
you just need to run  
faster than the other  
guy running from the  
bear

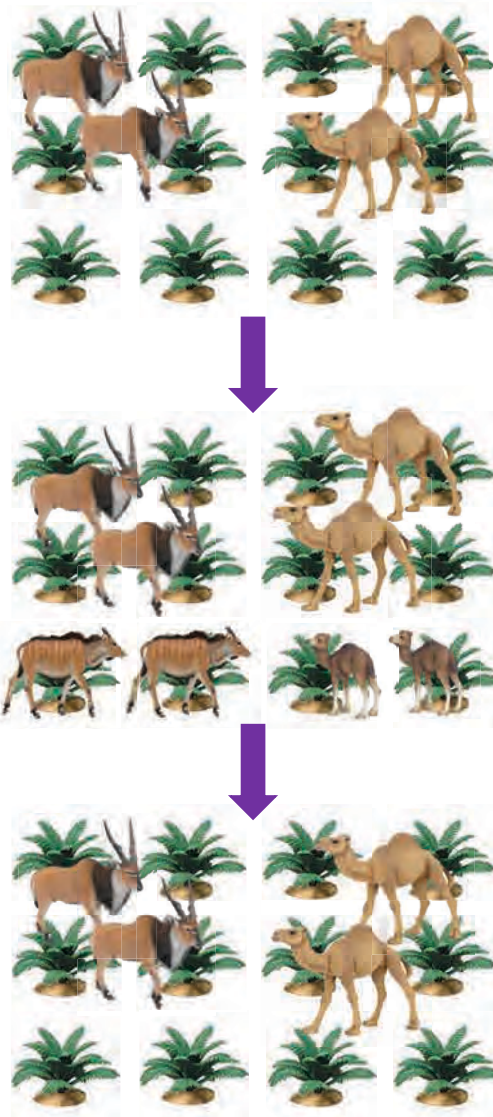
**TRAIN SMART, NOT HARD:  
YOU DON'T HAVE TO  
OUTRUN THE  
BEAR.  
YOU JUST HAVE TO  
OUTRUN YOUR  
BUDDIES.**

imgflip.com



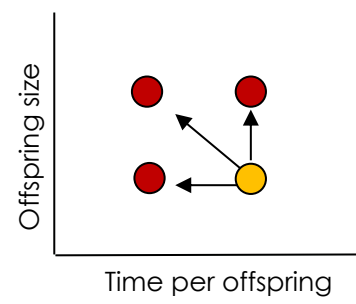
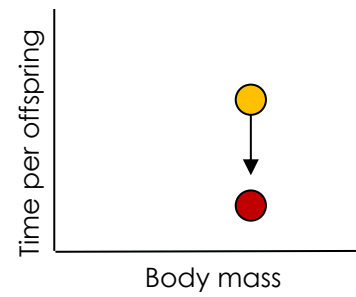
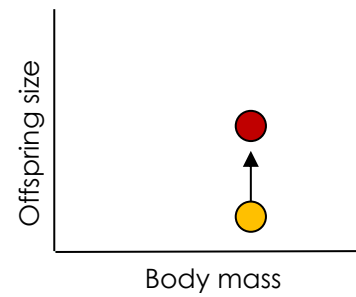


# Stasis





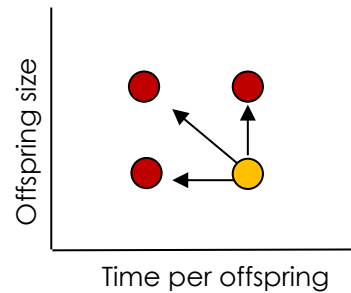
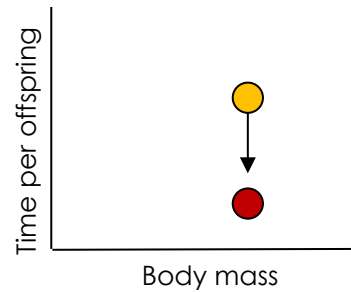
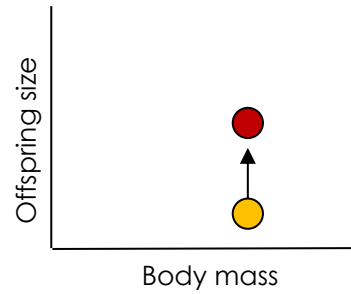
# Competition for limited resources





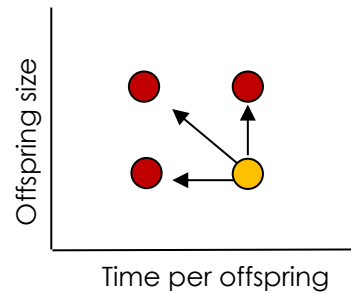
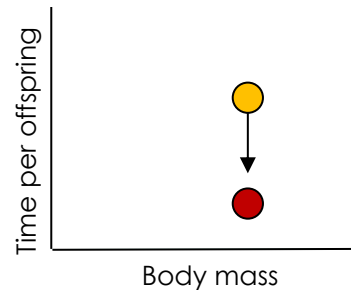
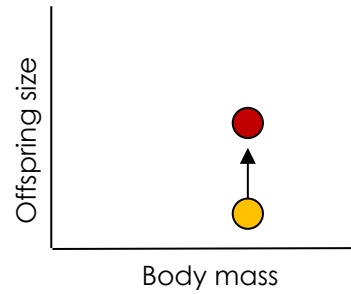


# Competition for limited resources





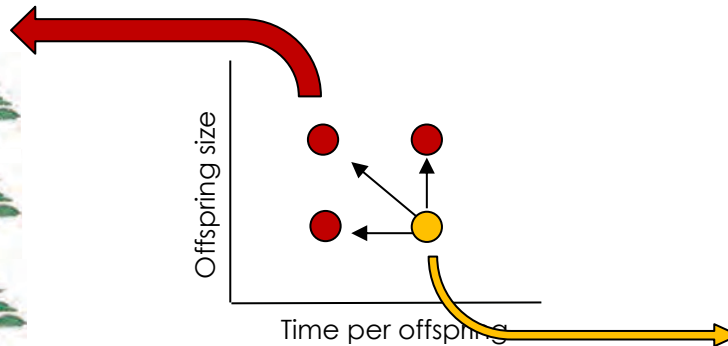
# Competition for limited resources







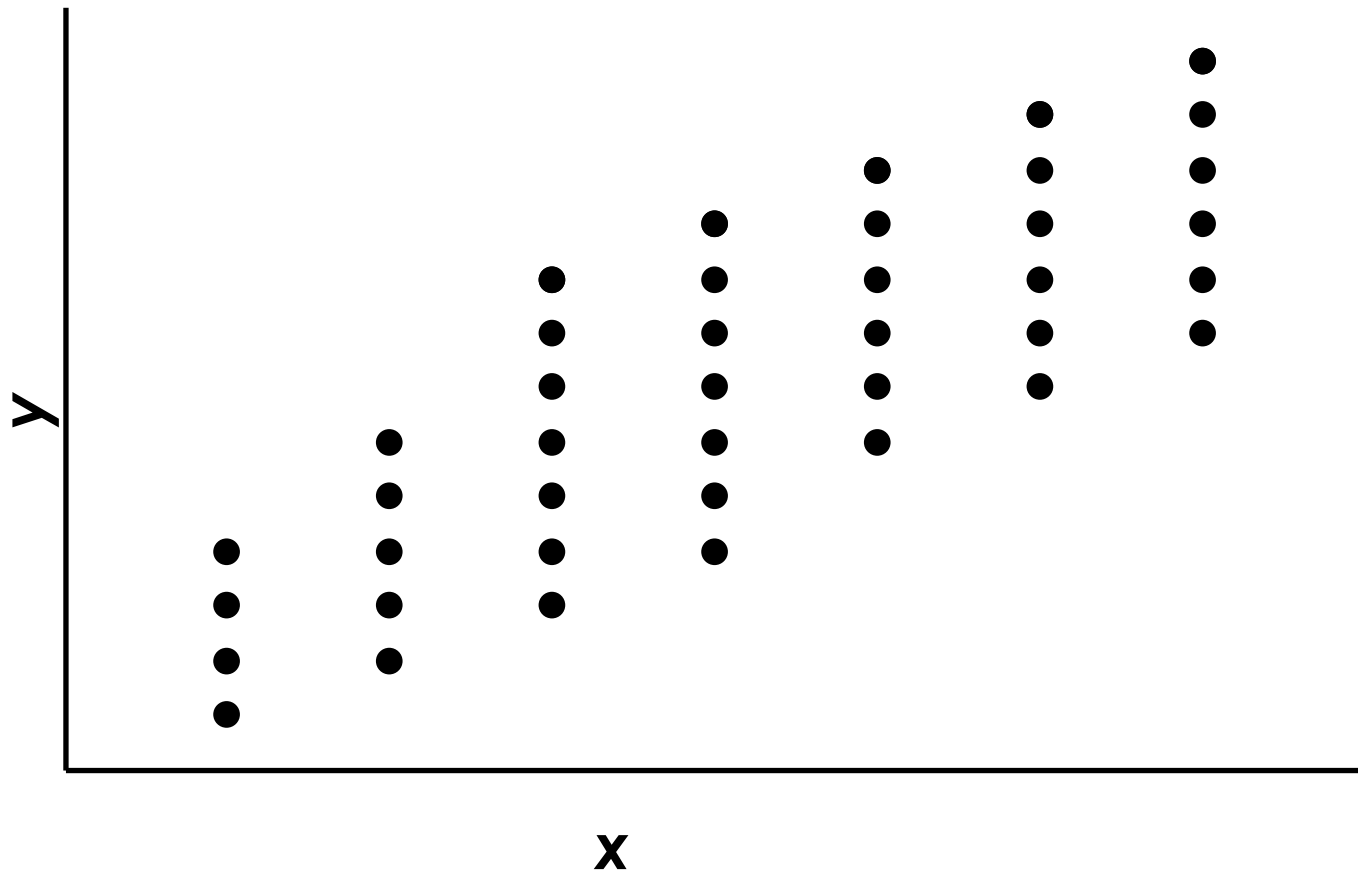
# Competition for limited resources





# Interpreting scaling

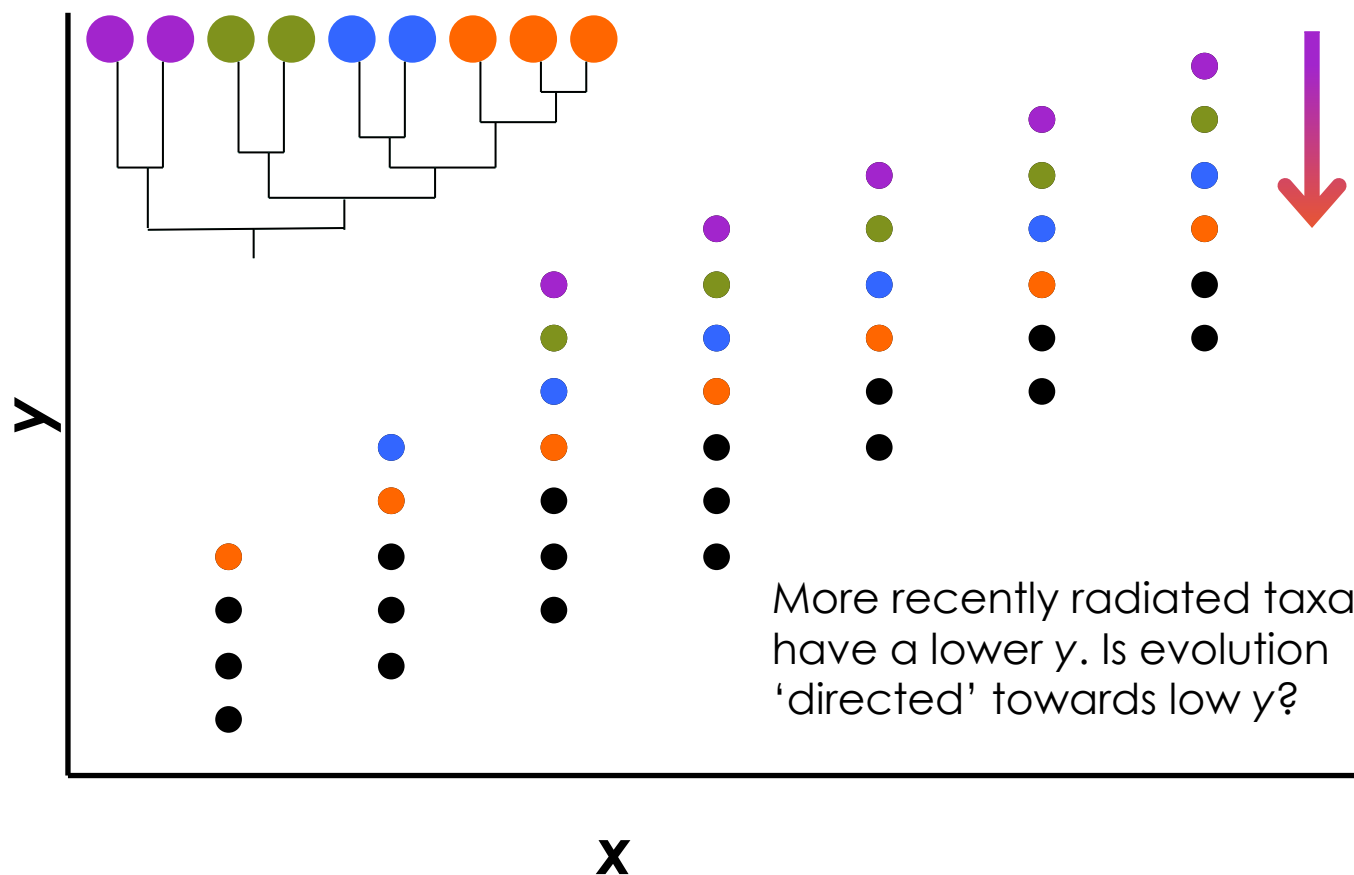
Are scaling relationships 'laws' around which adaptation works?





# Interpreting scaling

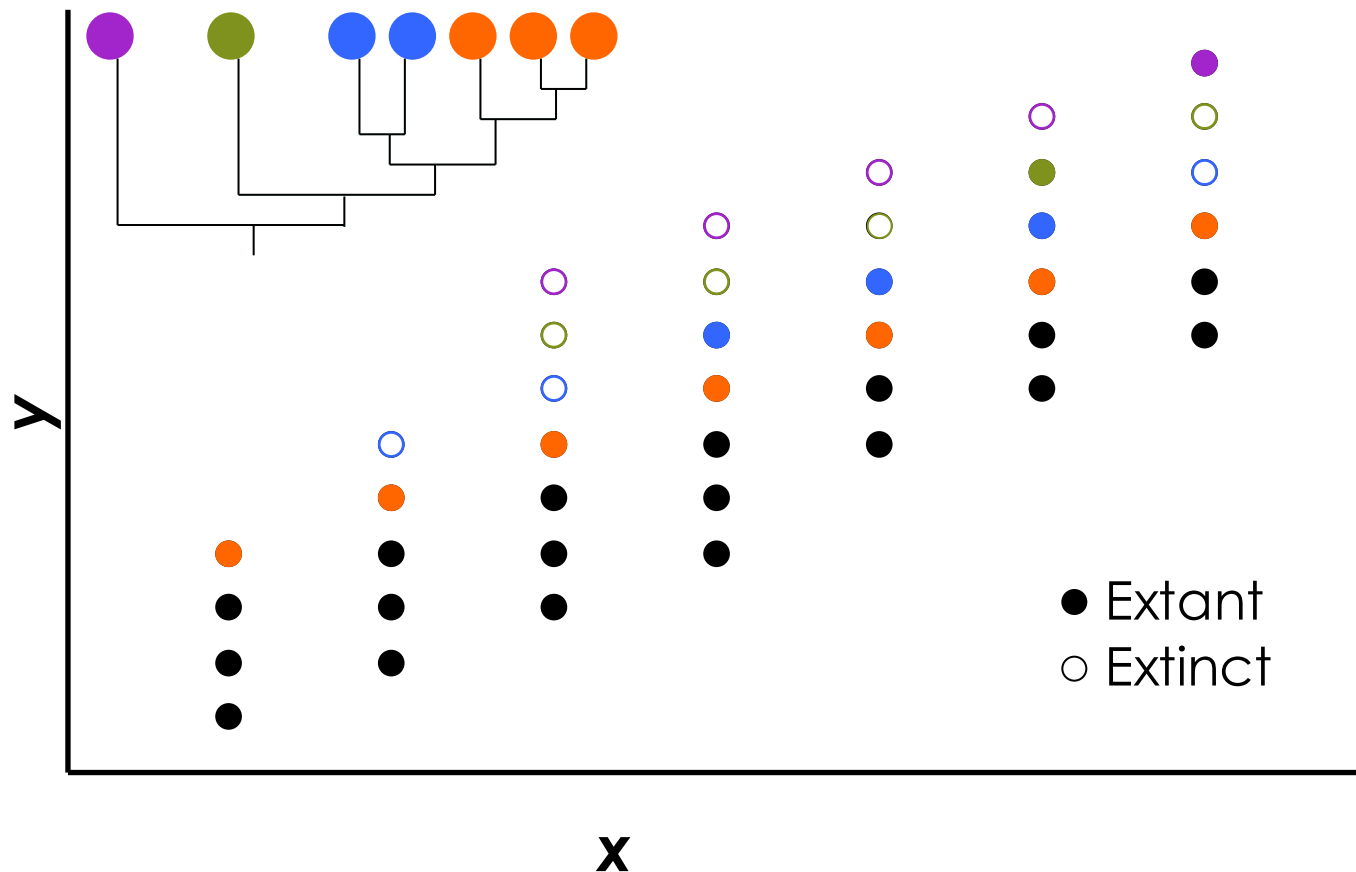
Is there a systematic phylogenetic structure in the dataset?





# Interpreting scaling

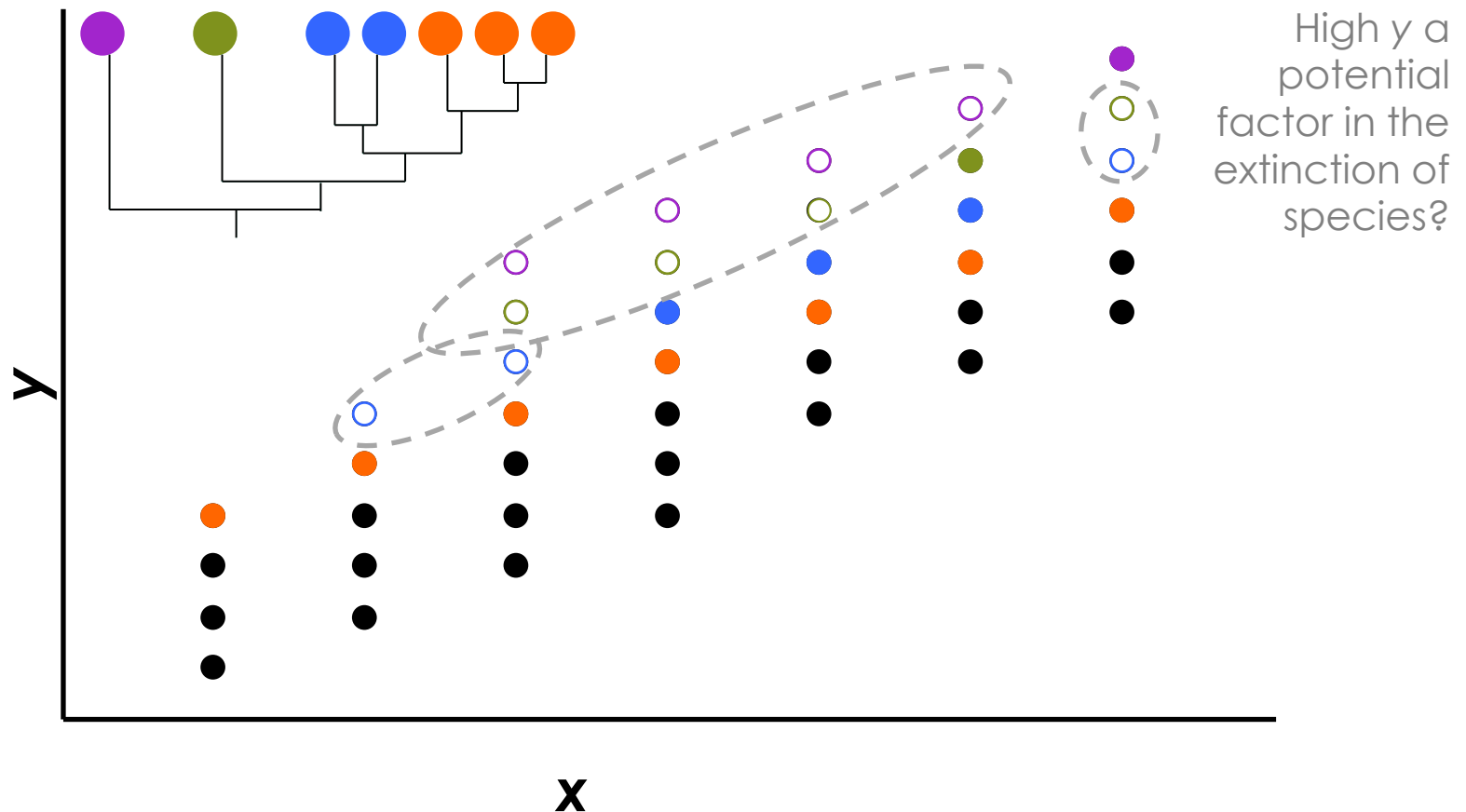
Is there a systematic phylogenetic structure in the dataset?





# Interpreting scaling

Is there a systematic phylogenetic structure in the dataset?

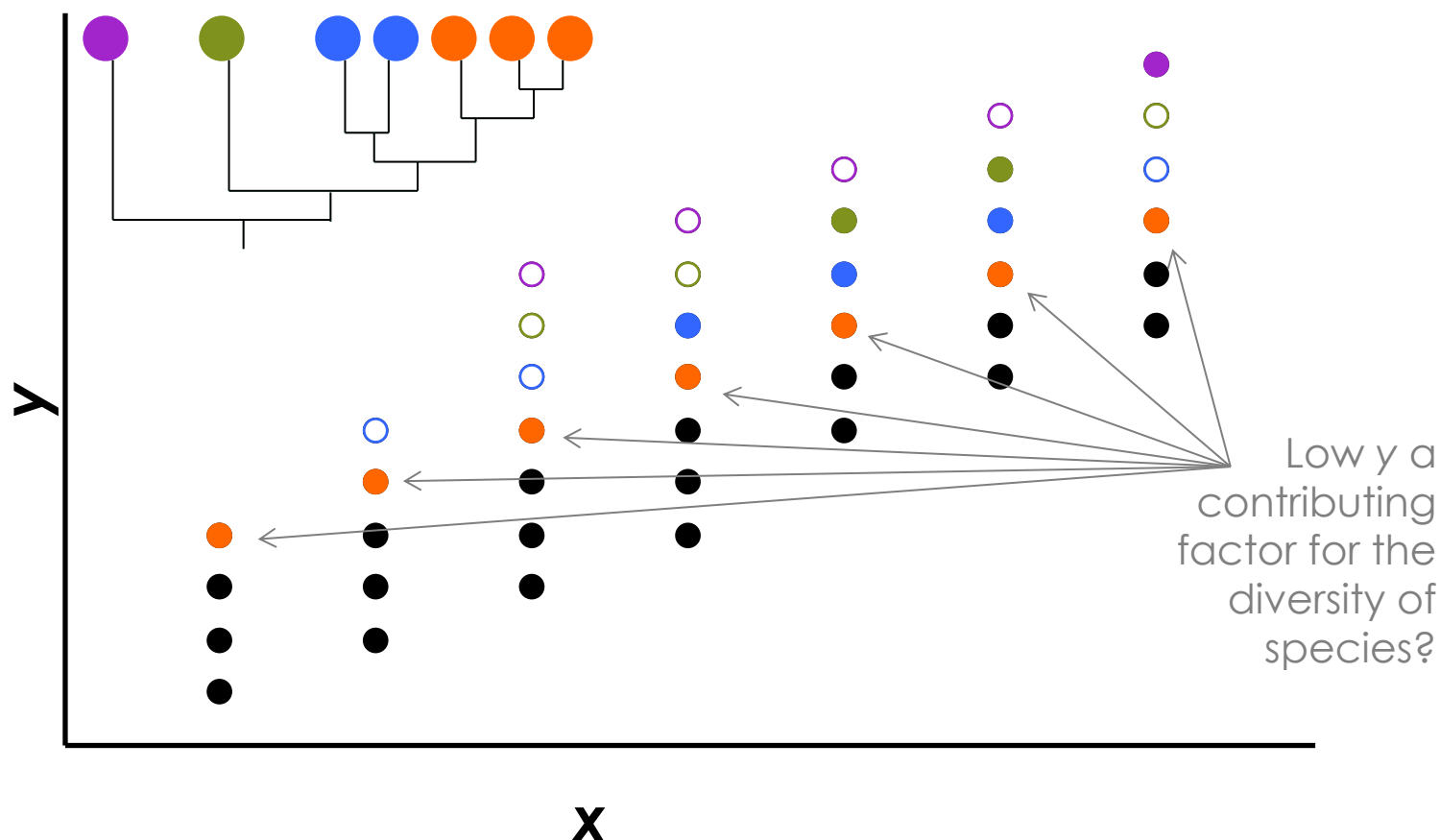






# Interpreting scaling

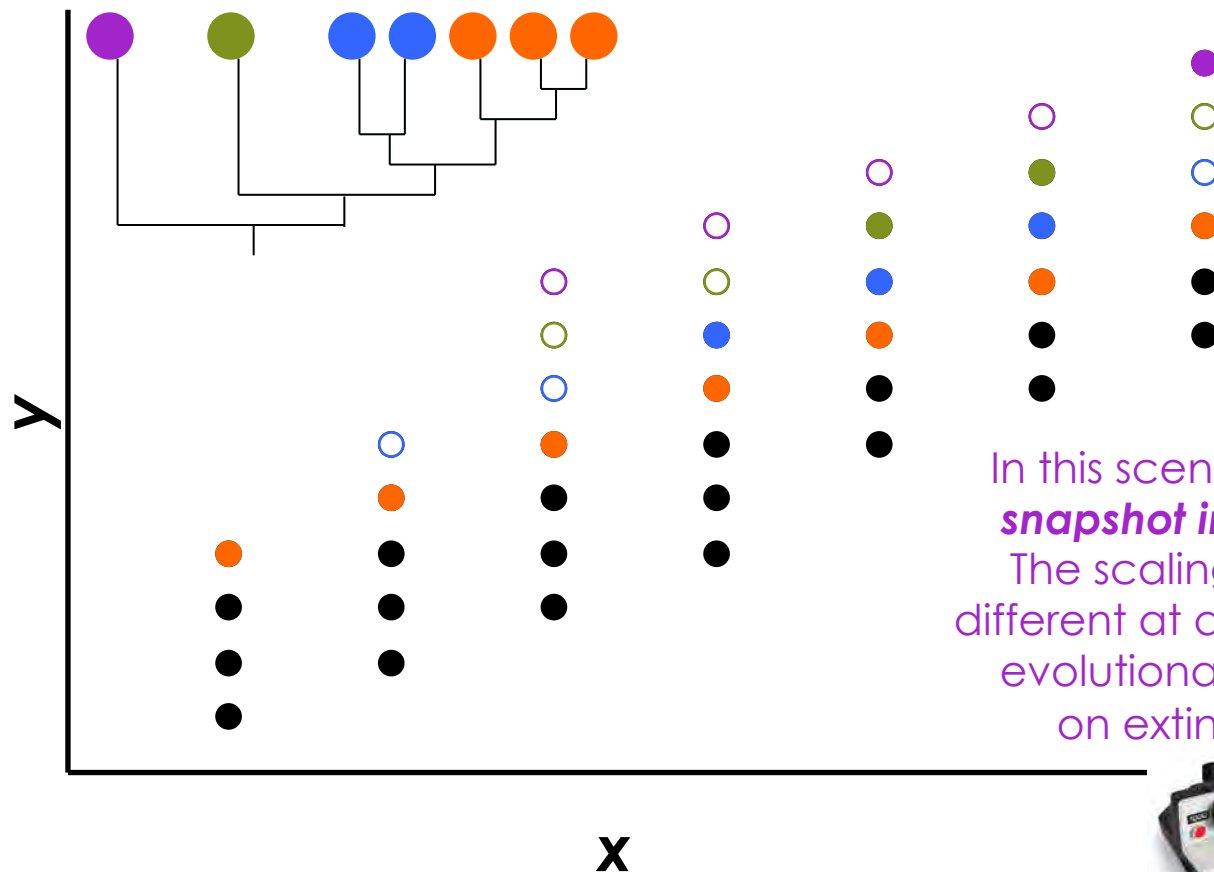
Is there a systematic phylogenetic structure in the dataset?





# Interpreting scaling: snapshots

Is there a systematic phylogenetic structure in the dataset?



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)





*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'.*

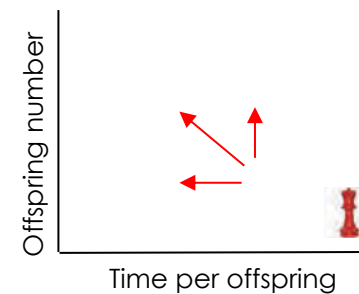
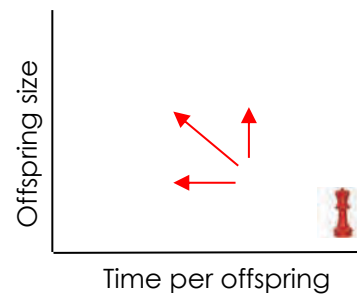
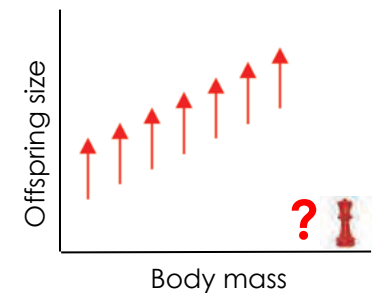
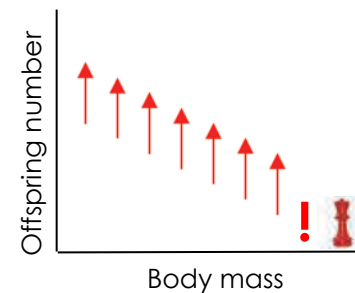
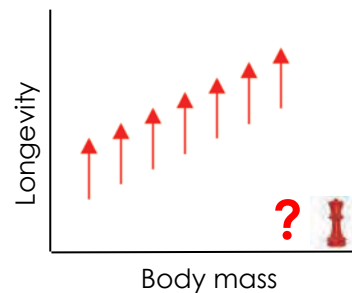
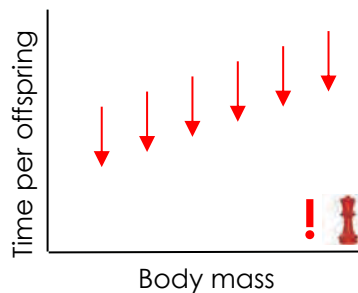




# Darwinian demon



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





*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



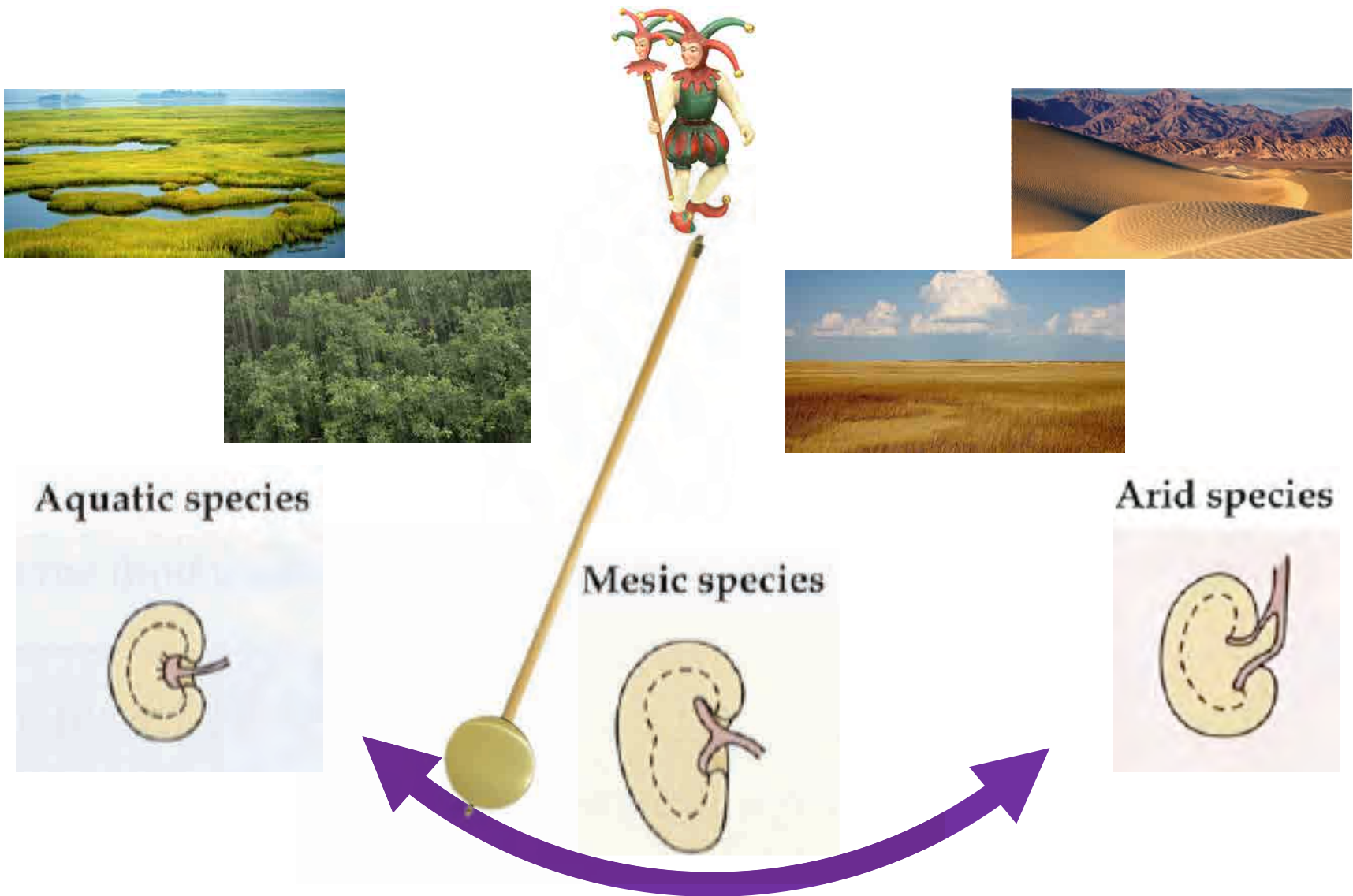


# The Court Jester's pendulum





# The Court Jester's pendulum





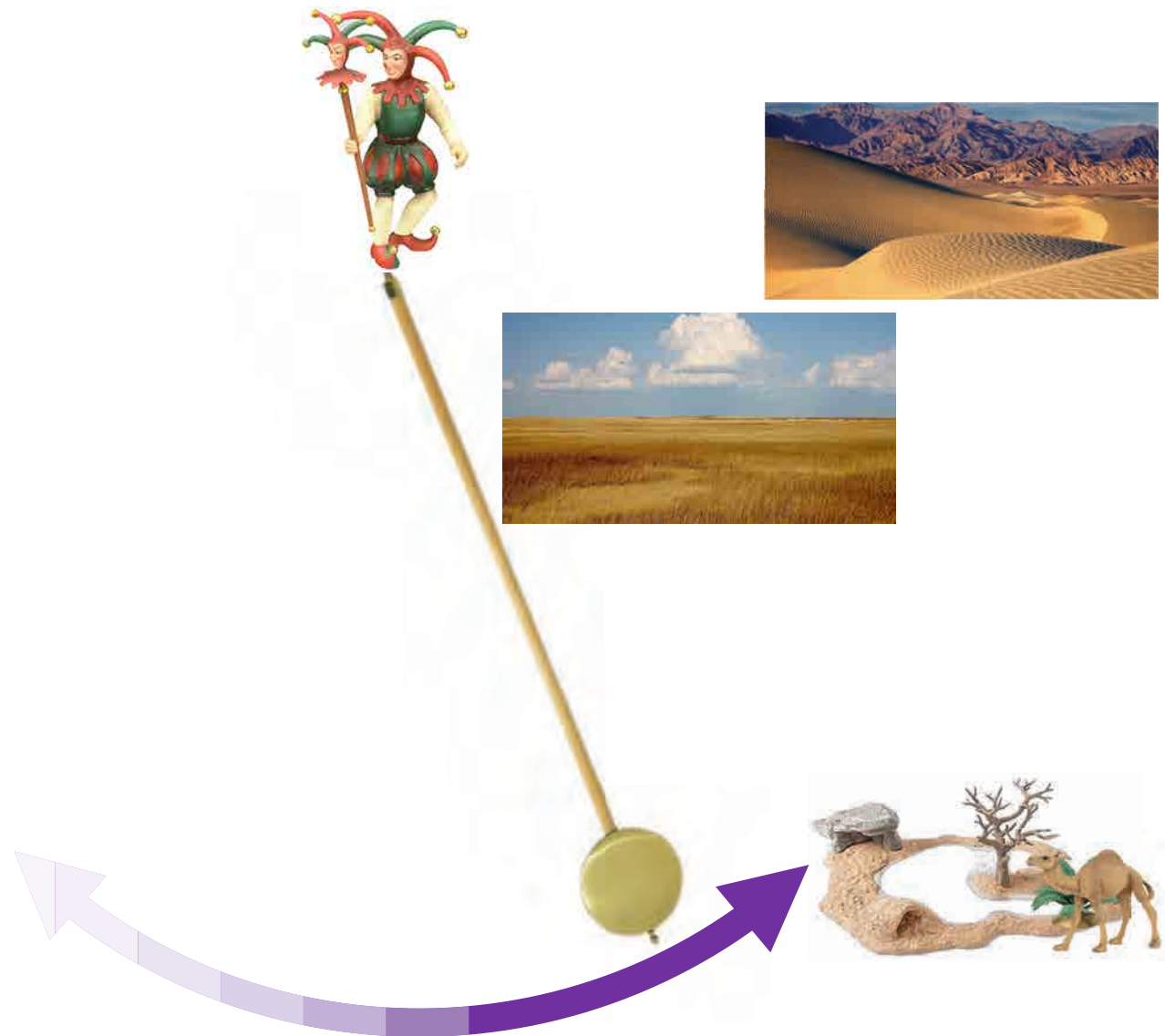
# The Court Jester's pendulum







# The Court Jester's pendulum





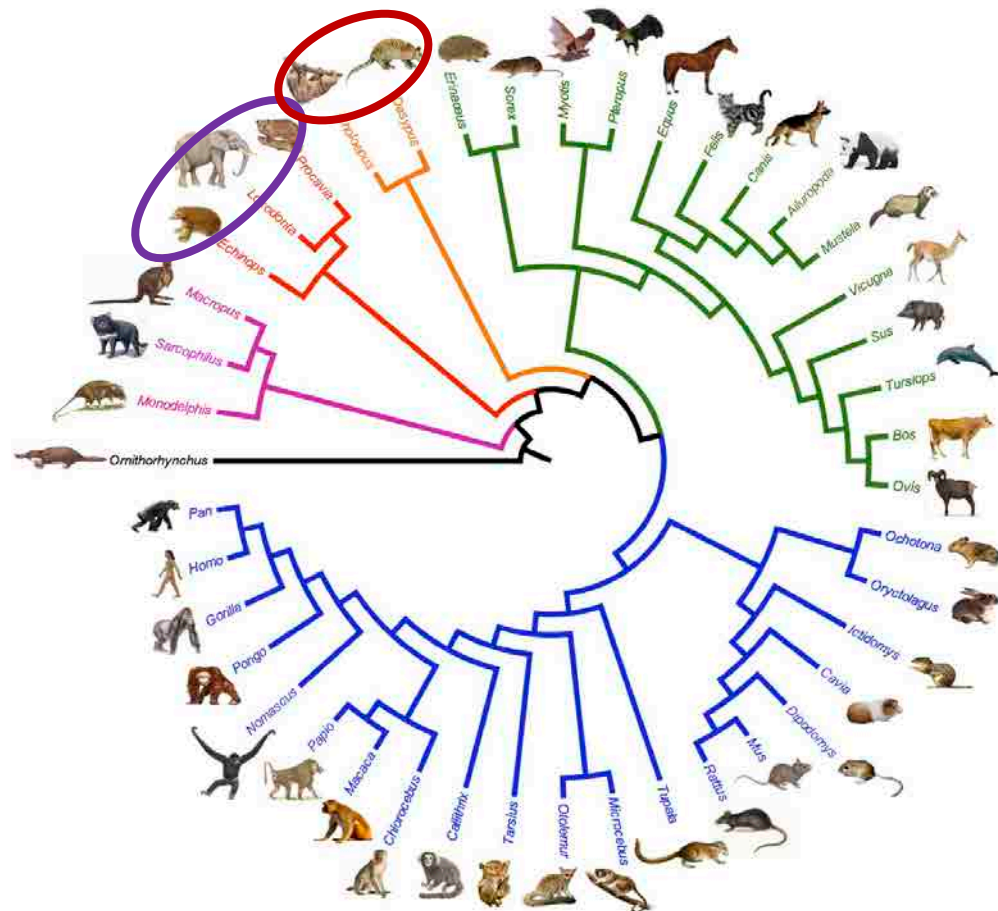
# Assessing 'direction' / *Red Queen* / escalation / progress in life history

using the PanTheria dataset  
(Jones et al. 2009)

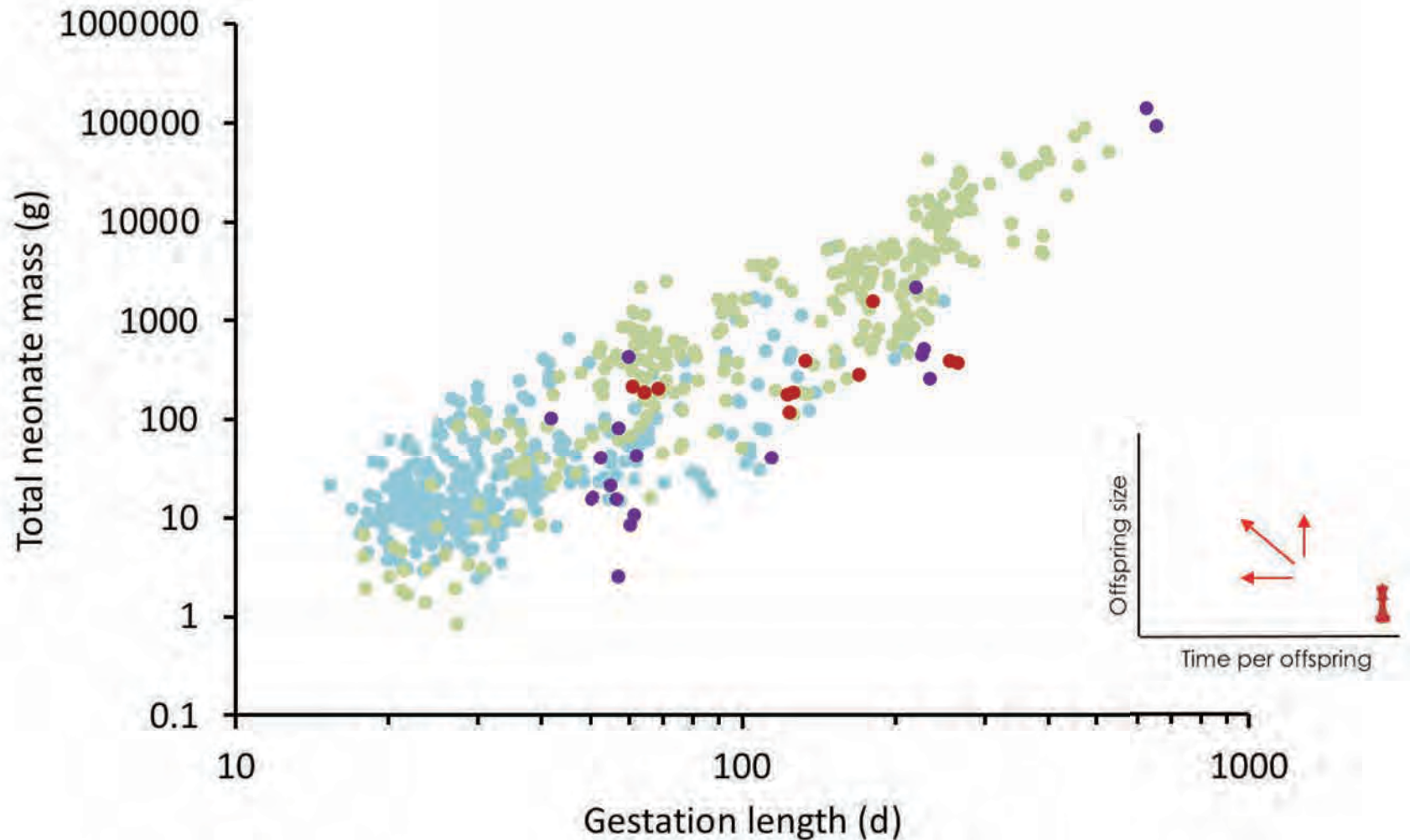




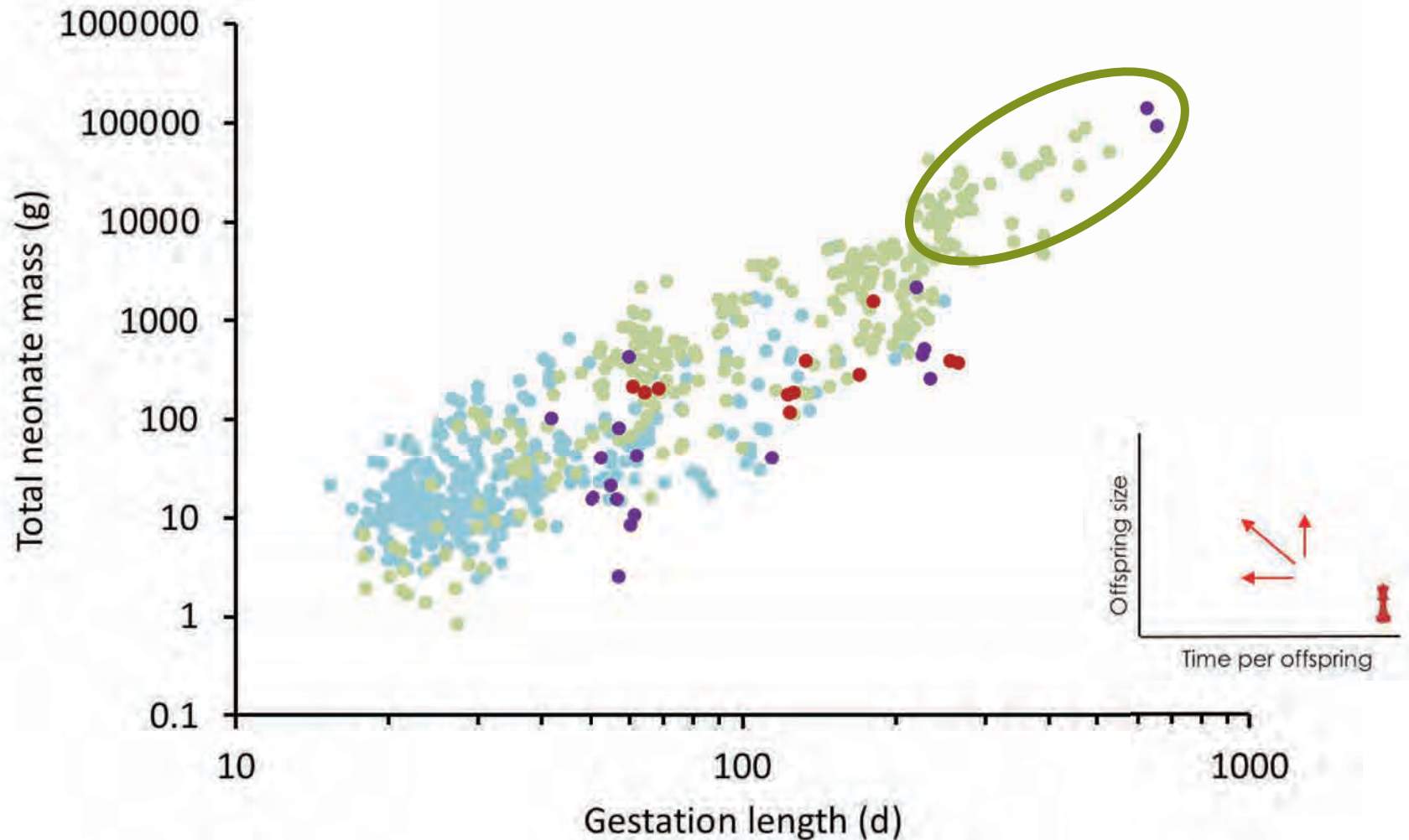
The eutherian superorders of Afrotheria and Xenarthra are not particularly speciose and could serve as a test case for clades that produced low extant diversity.



# A clear picture for gestation length?

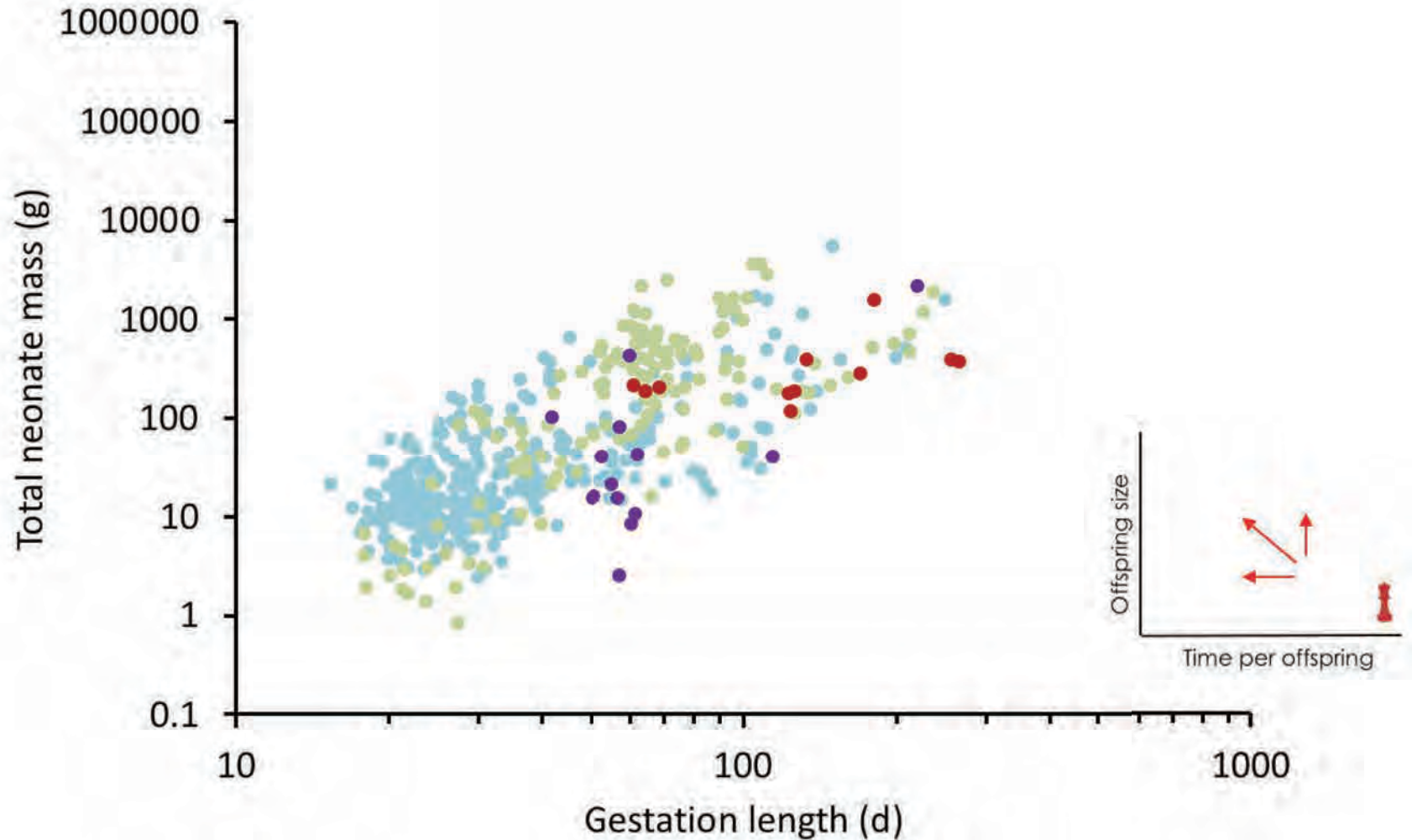


# A clear picture for gestation length?



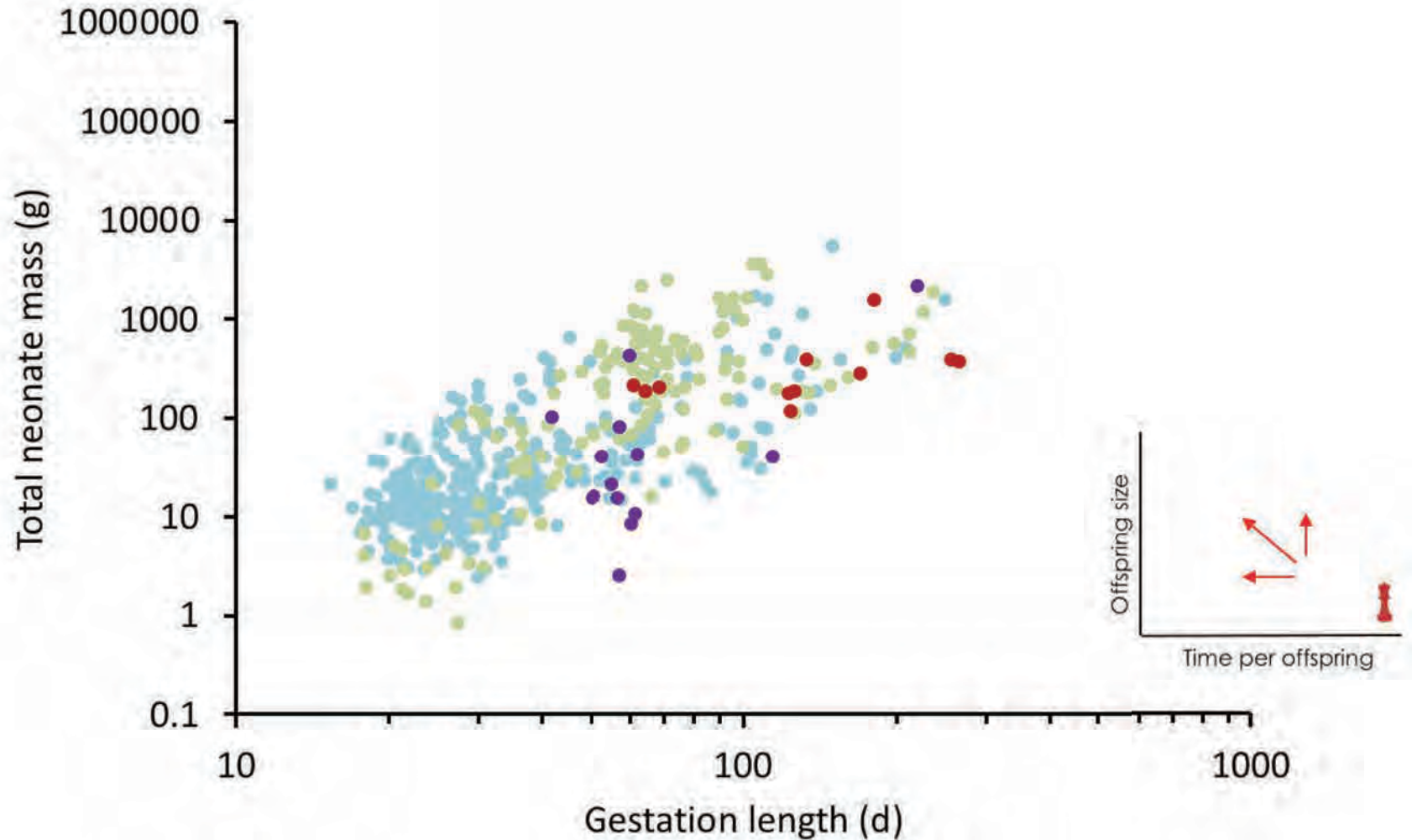
# A clear picture for gestation length?

terrestrial, no primates/bats, no large herbivores



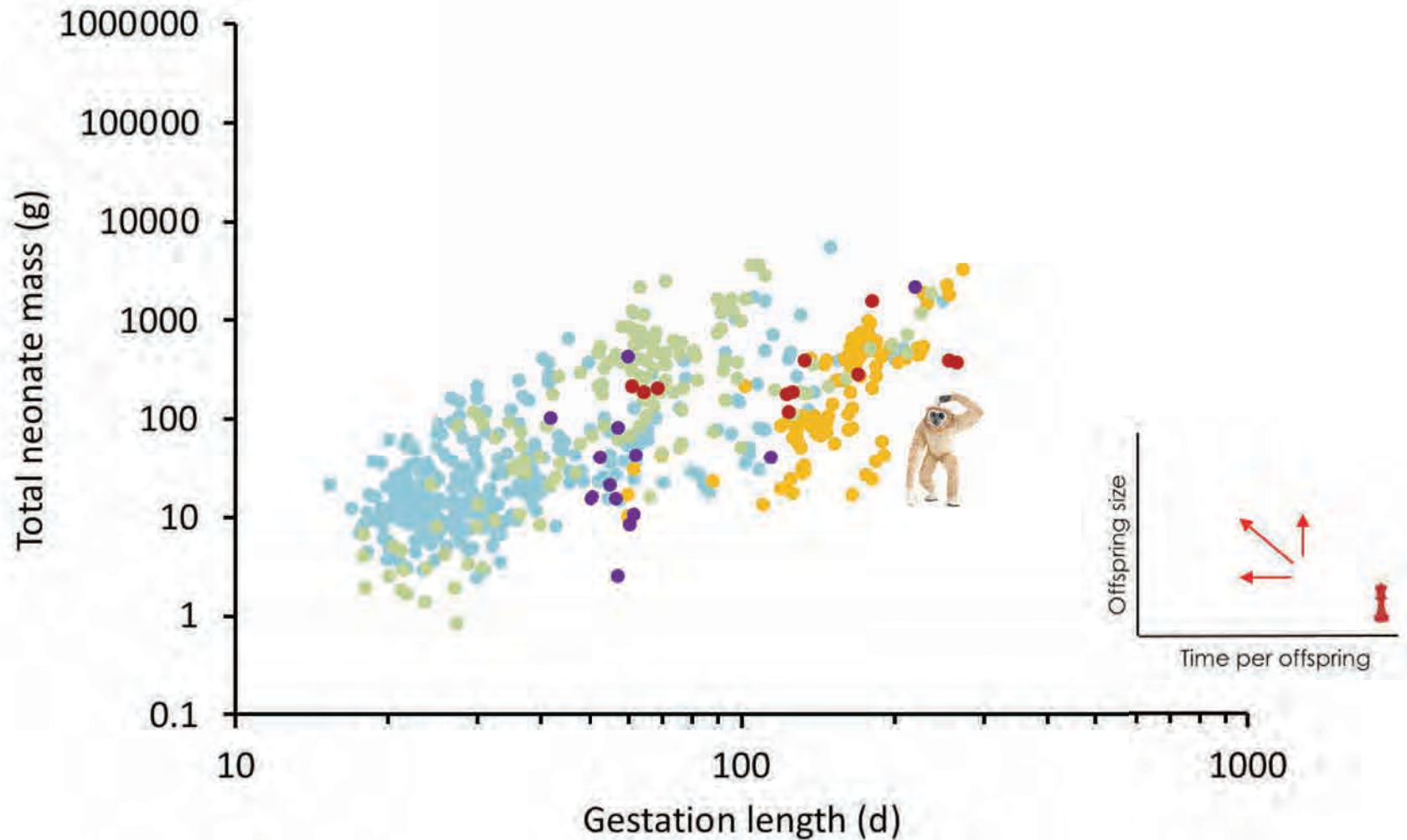
# A clear picture for gestation length?

terrestrial, no primates/bats, no large herbivores





# A clear picture for gestation length?

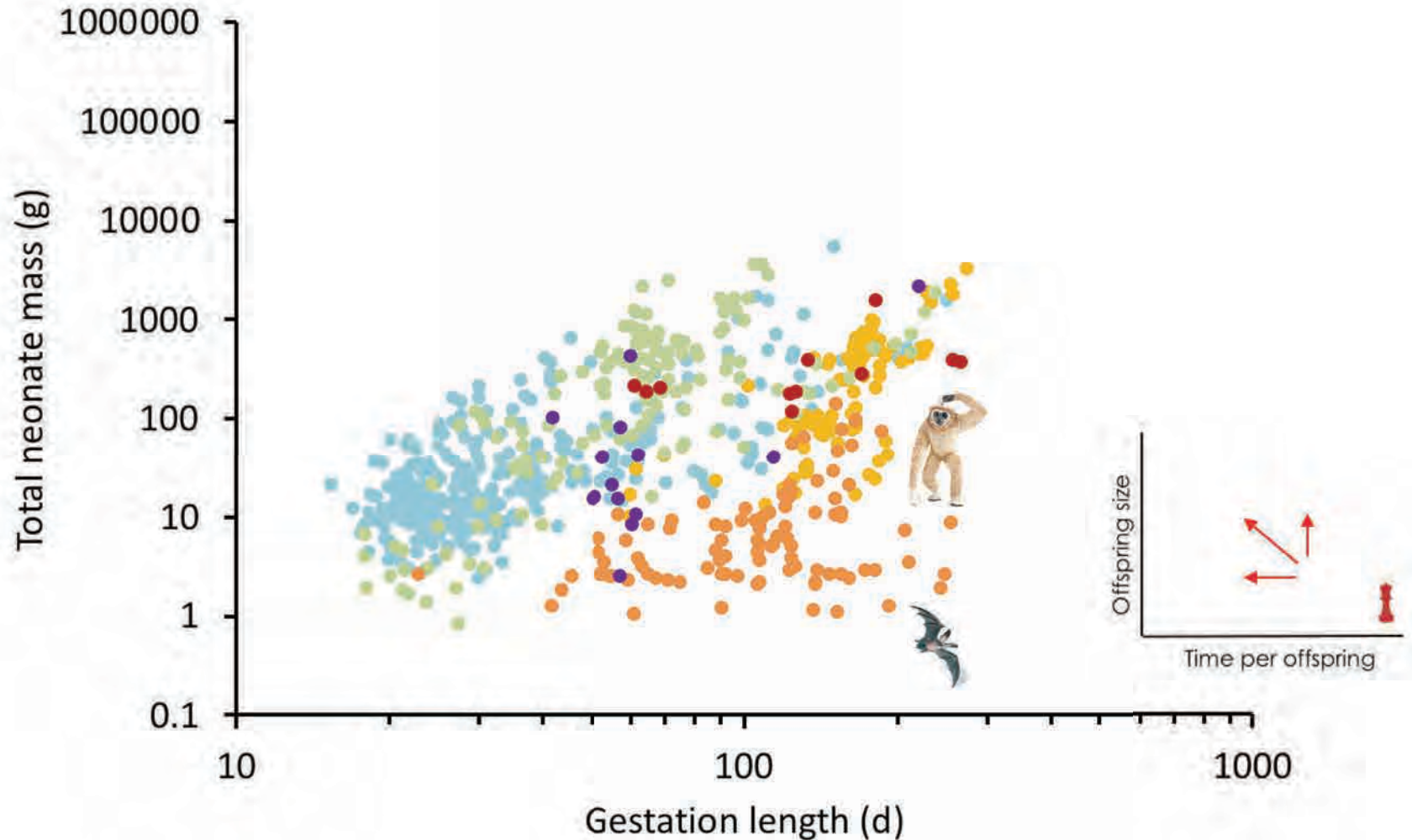


terrestrial, no bats, no large herbivores





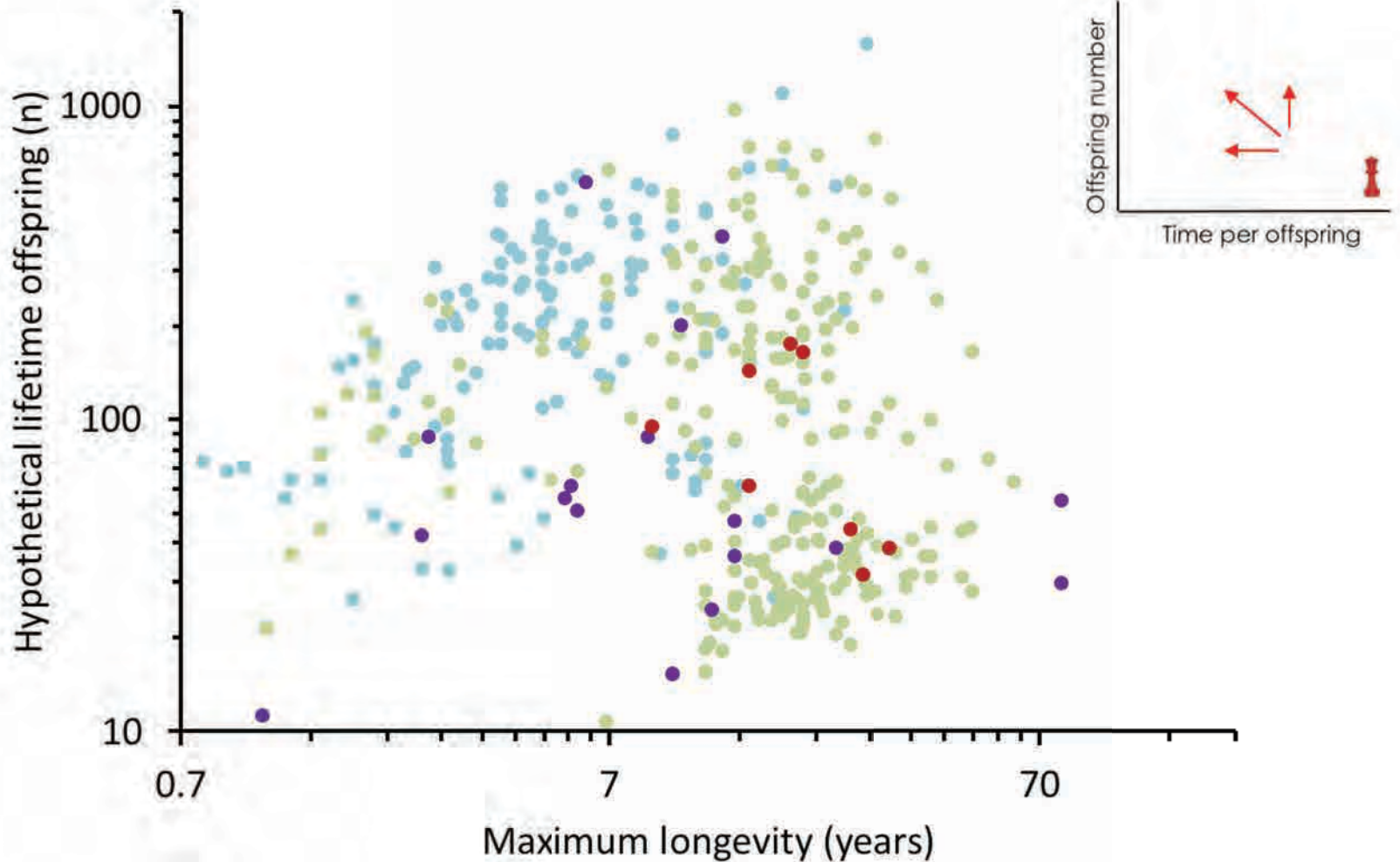
# A clear picture for gestation length?



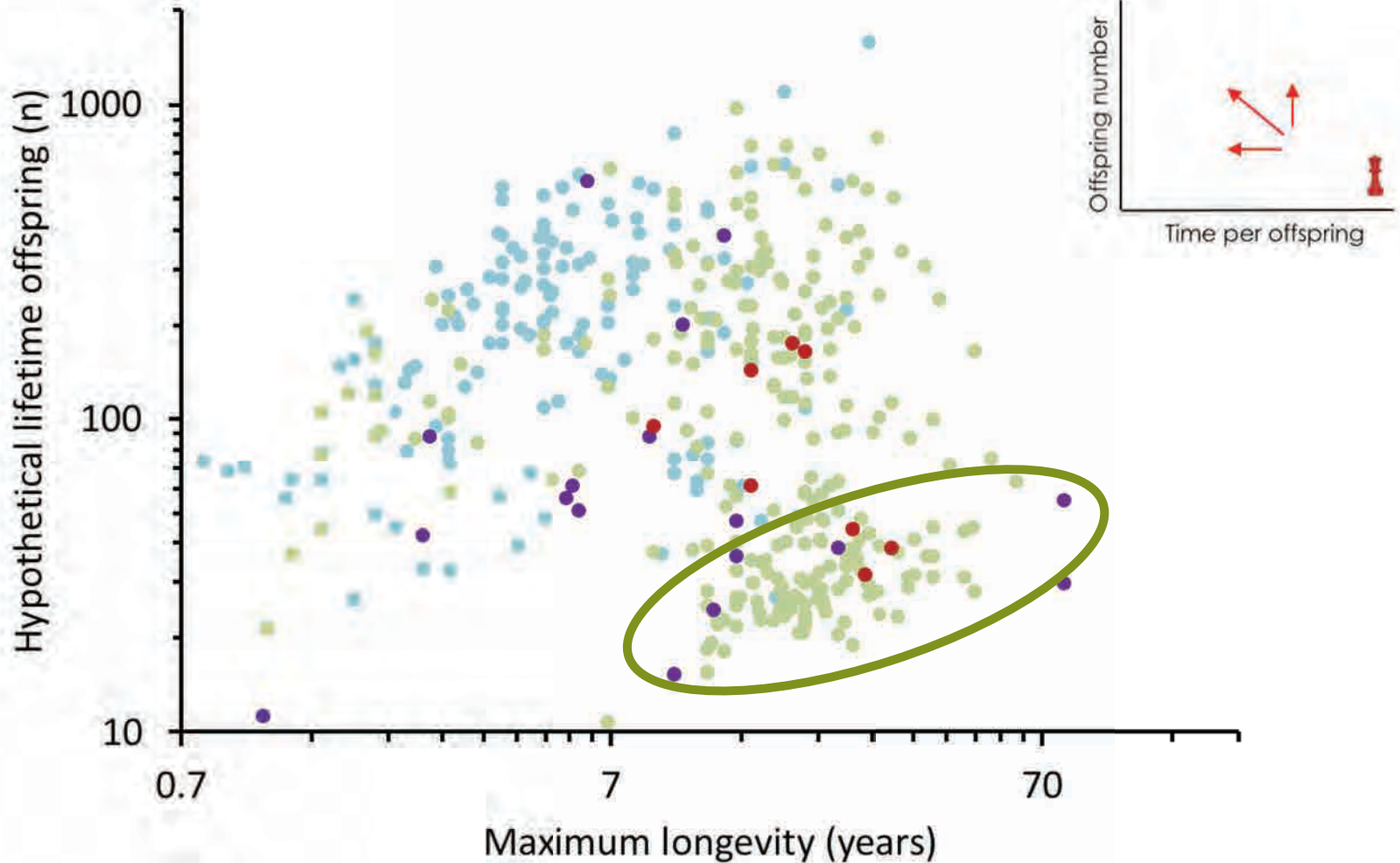
terrestrial, no large herbivores



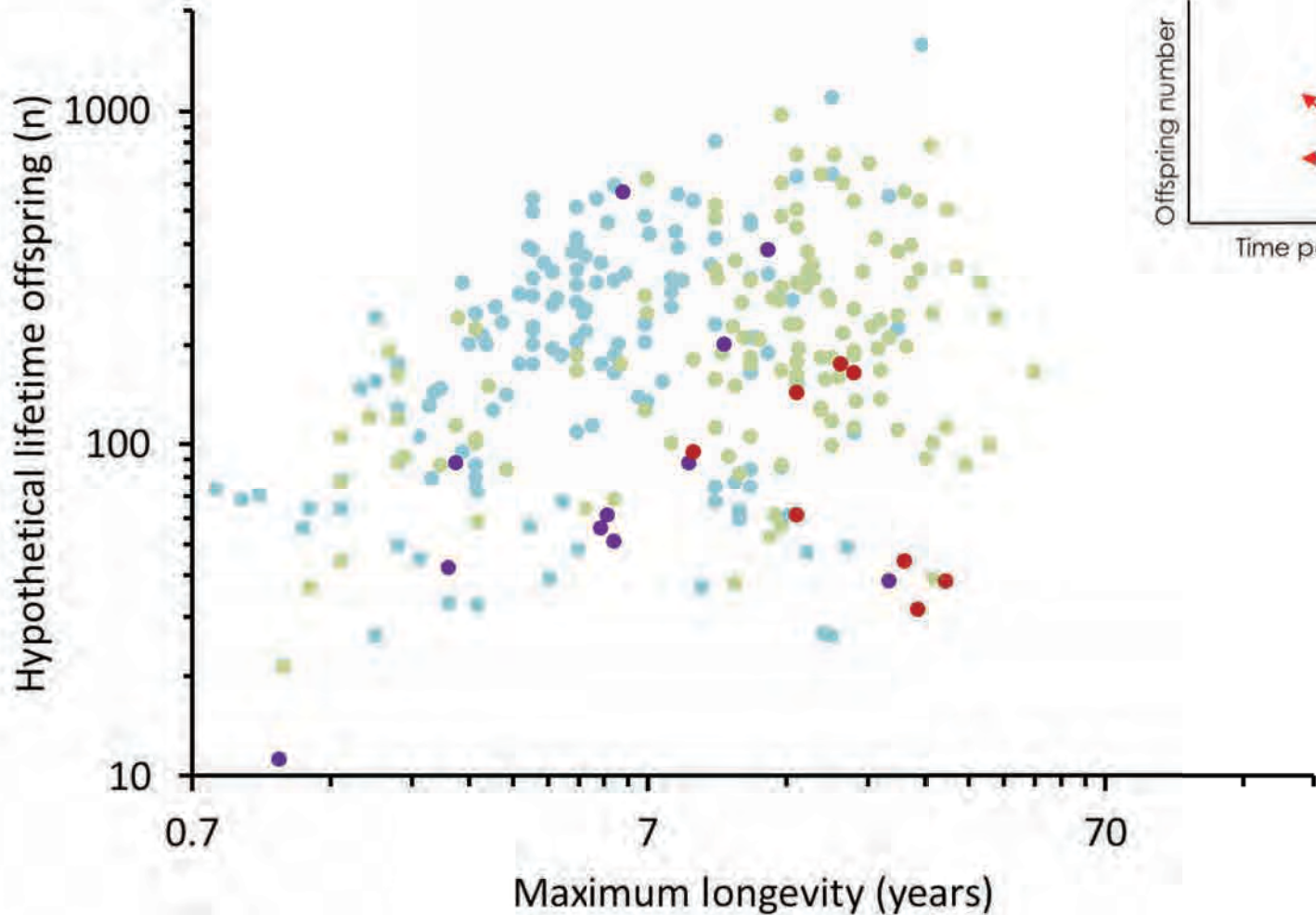
# A clear picture for lifetime offspring output?



# A clear picture for lifetime offspring output?



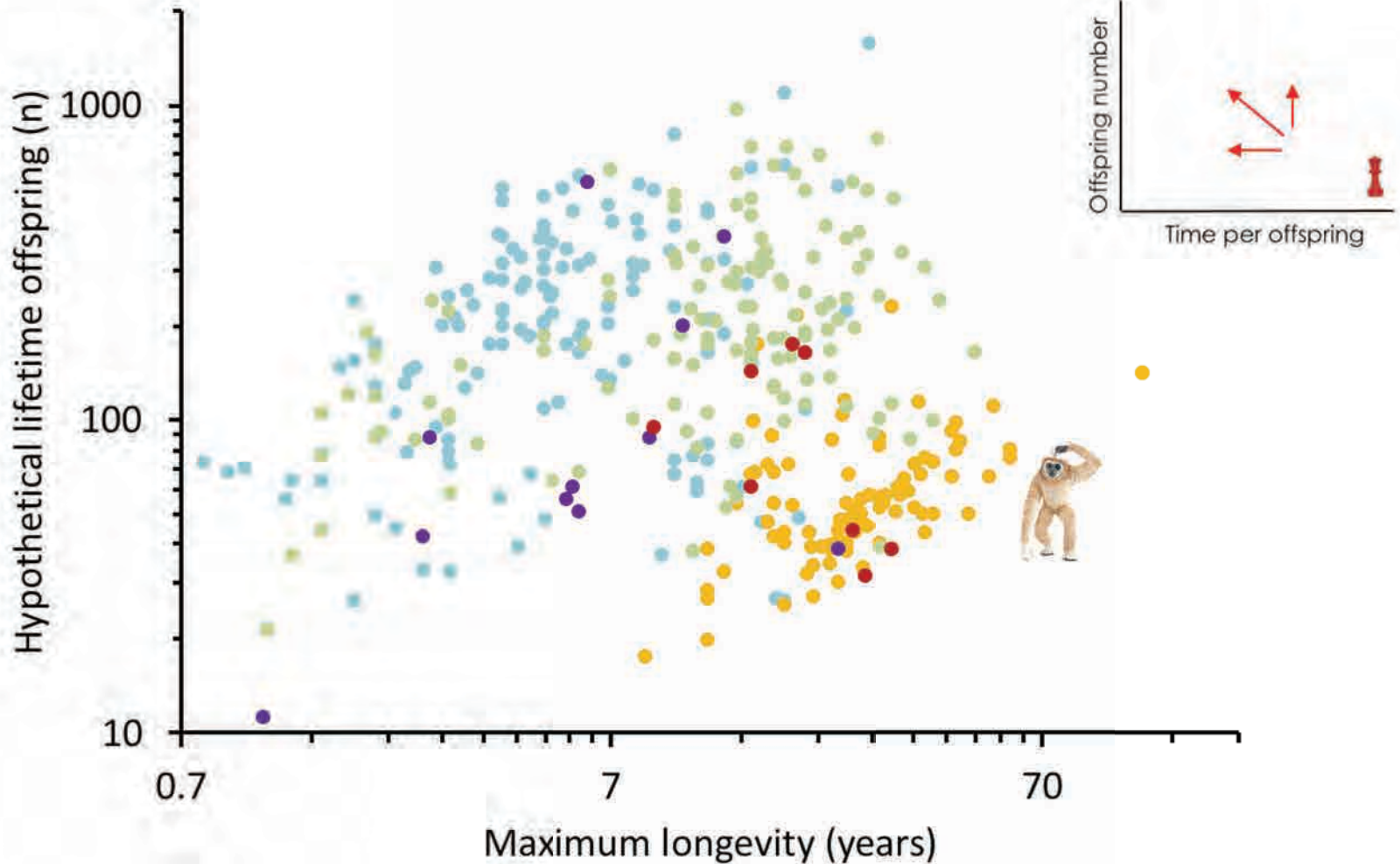
# A clear picture for lifetime offspring output?



terrestrial, no bats/primates, no large herbivores



# A clear picture for lifetime offspring output?

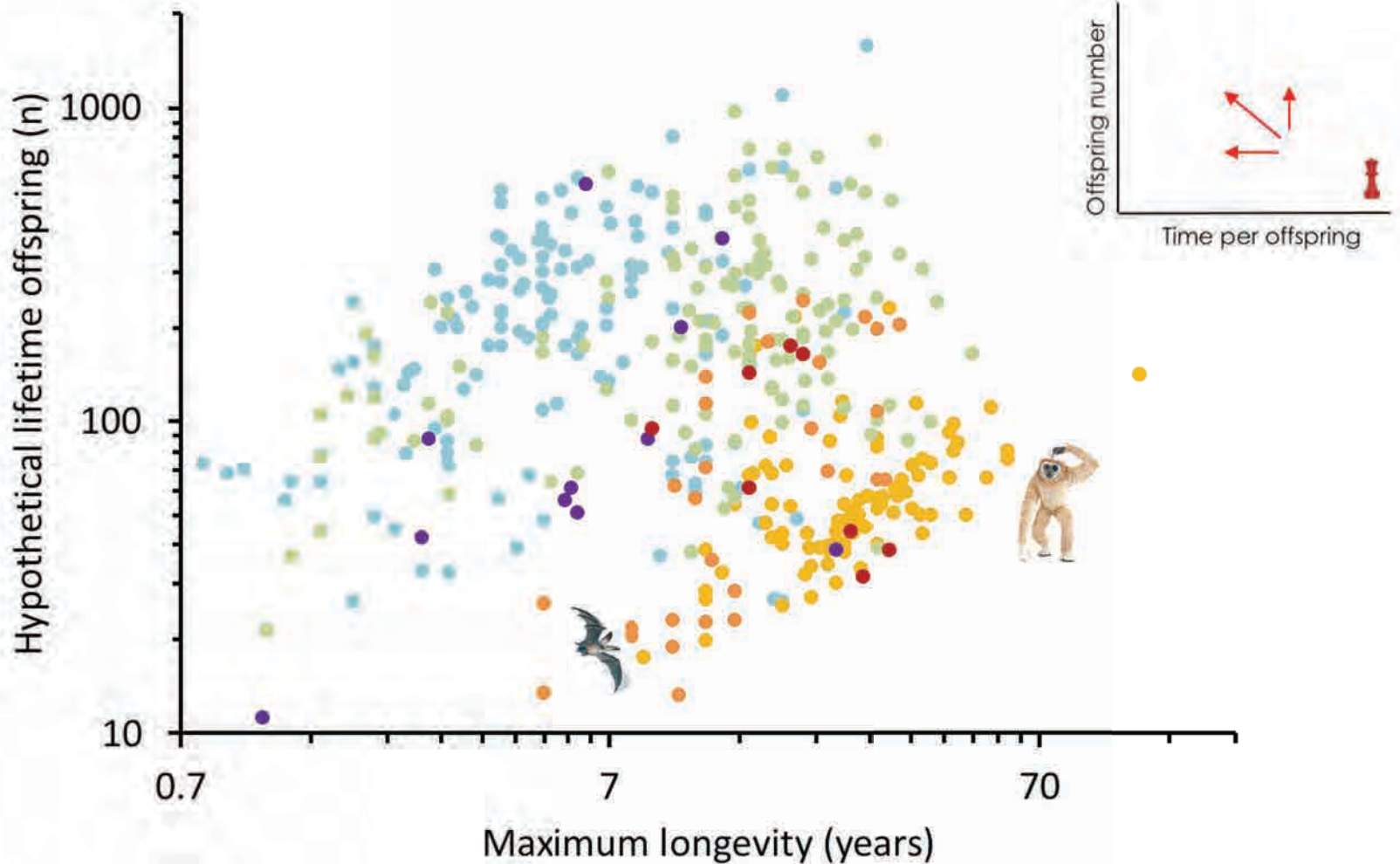


terrestrial, no bats, no large herbivores





# A clear picture for lifetime offspring output?



terrestrial, no large herbivores





# 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™



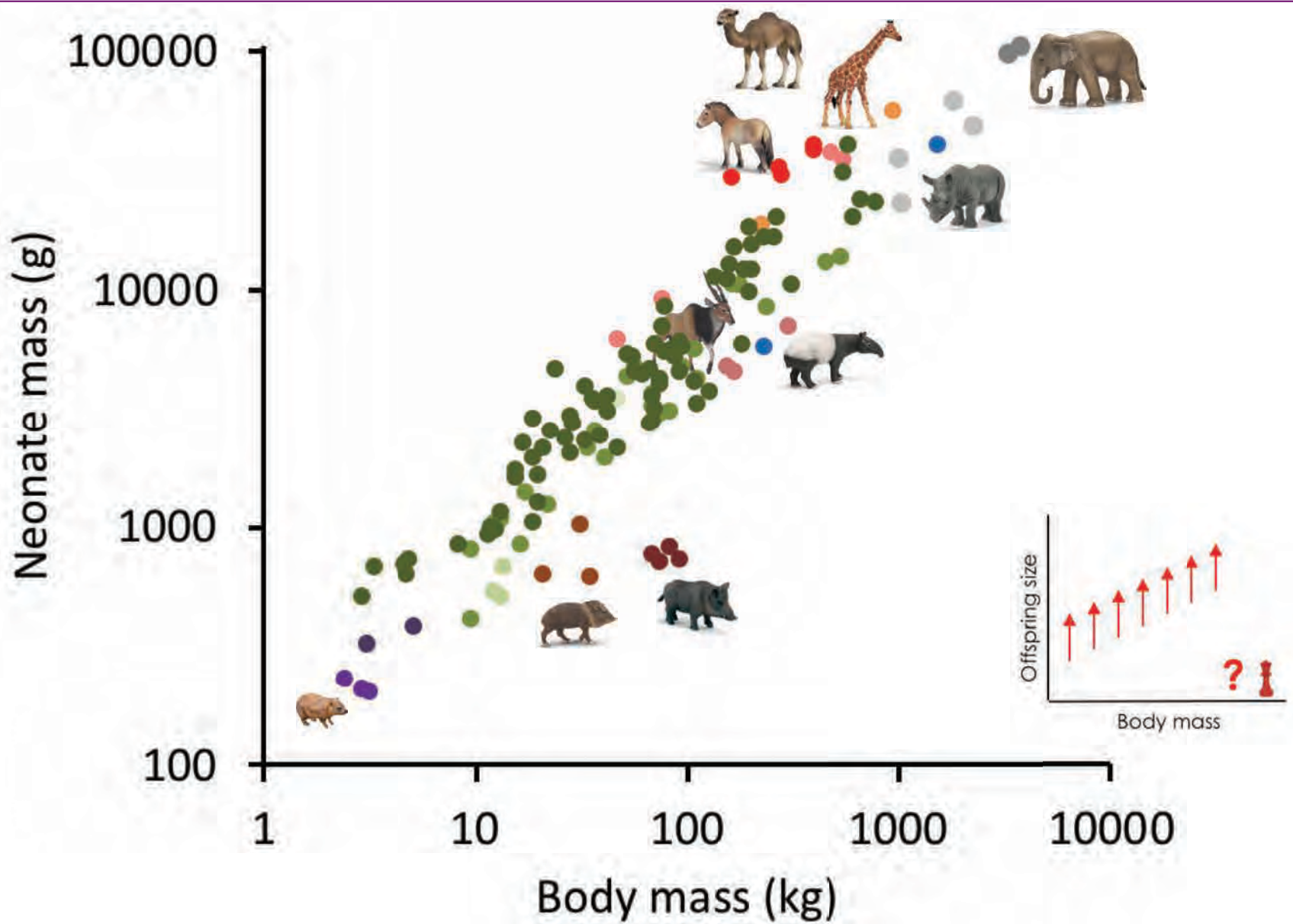


# Niche-specific assessment

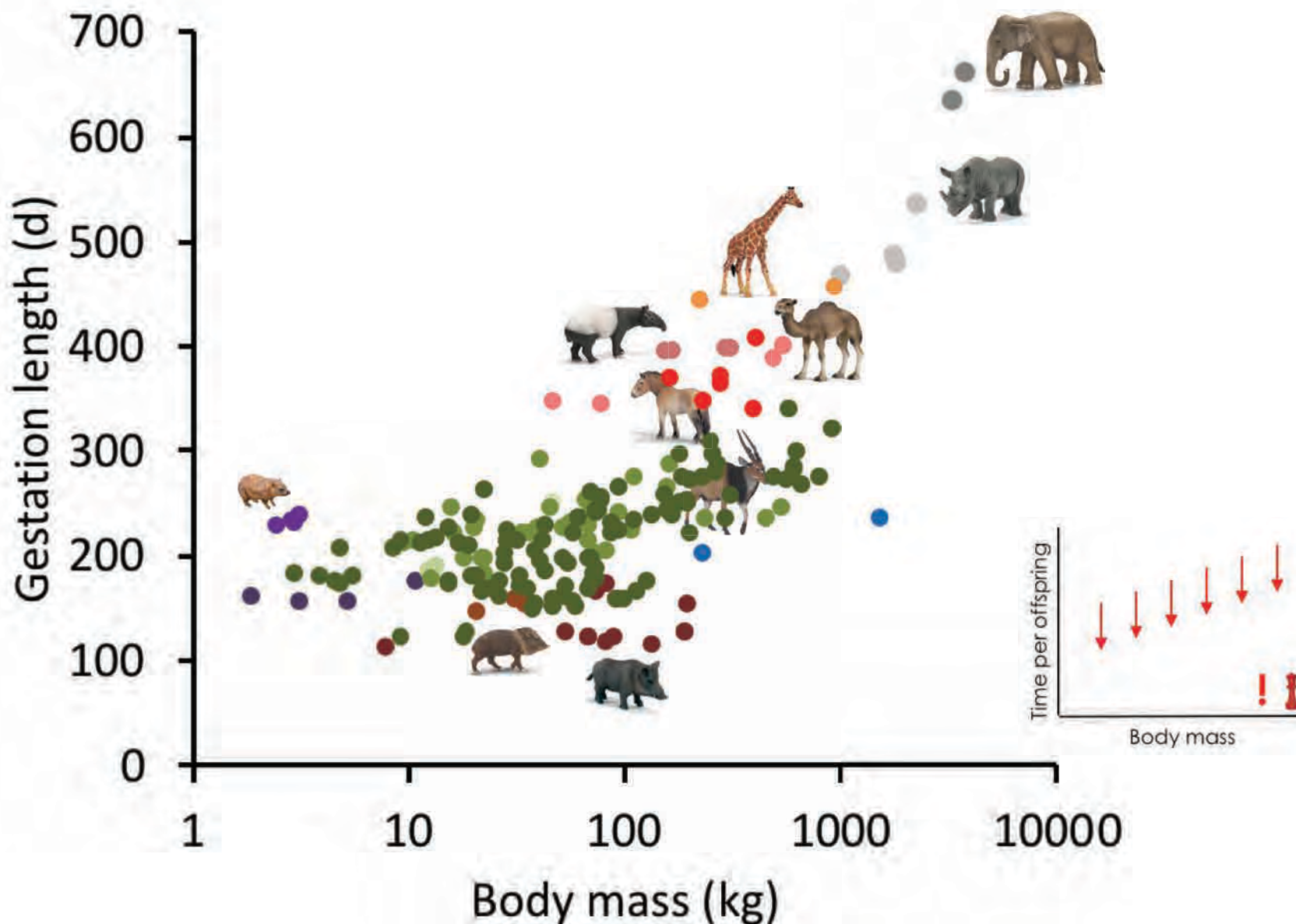
Because niche space is less diverse at larger body sizes, large herbivores may be a particularly fruitful area of research for 'directed evolution'.



# No clear picture for neonate mass

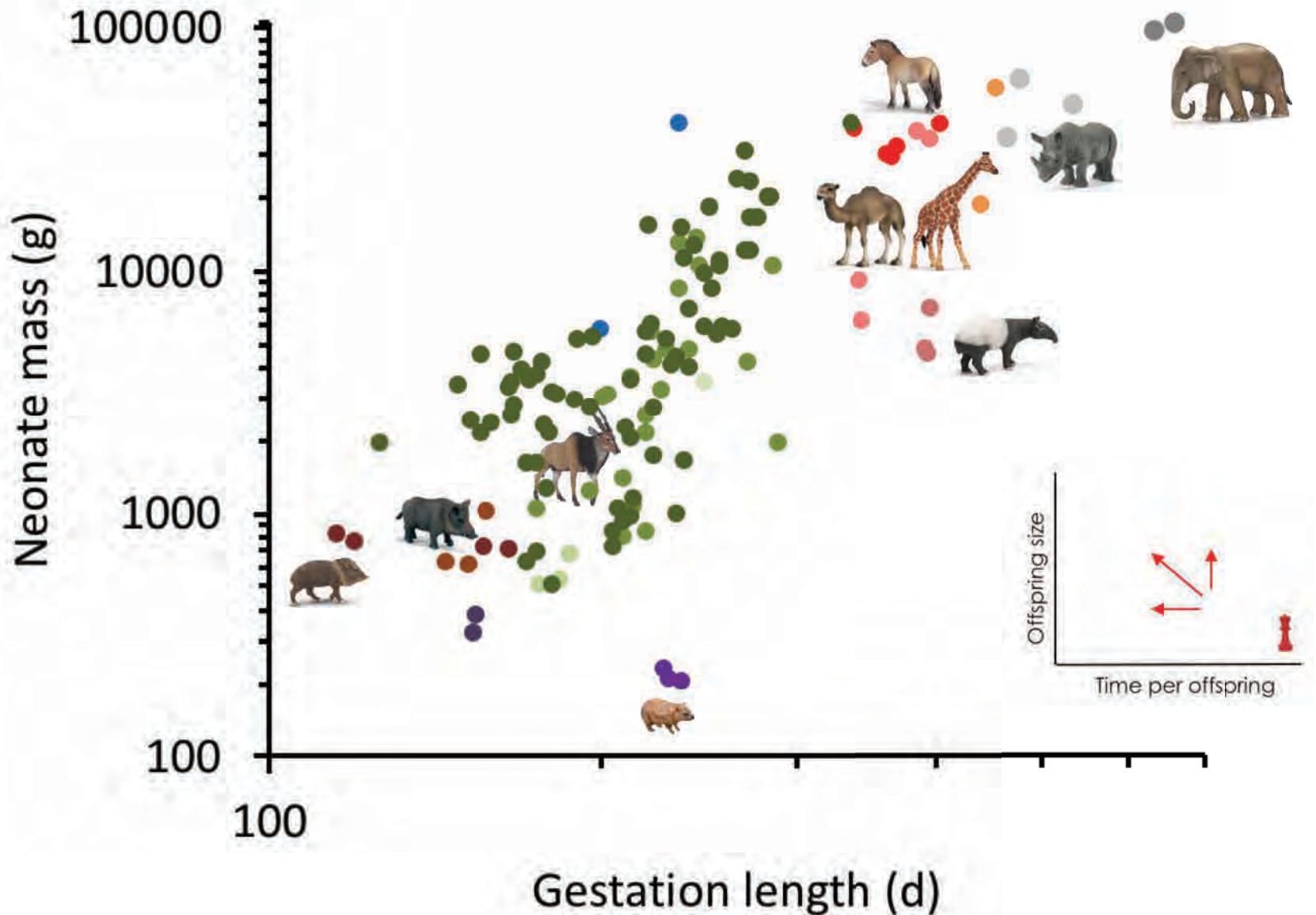




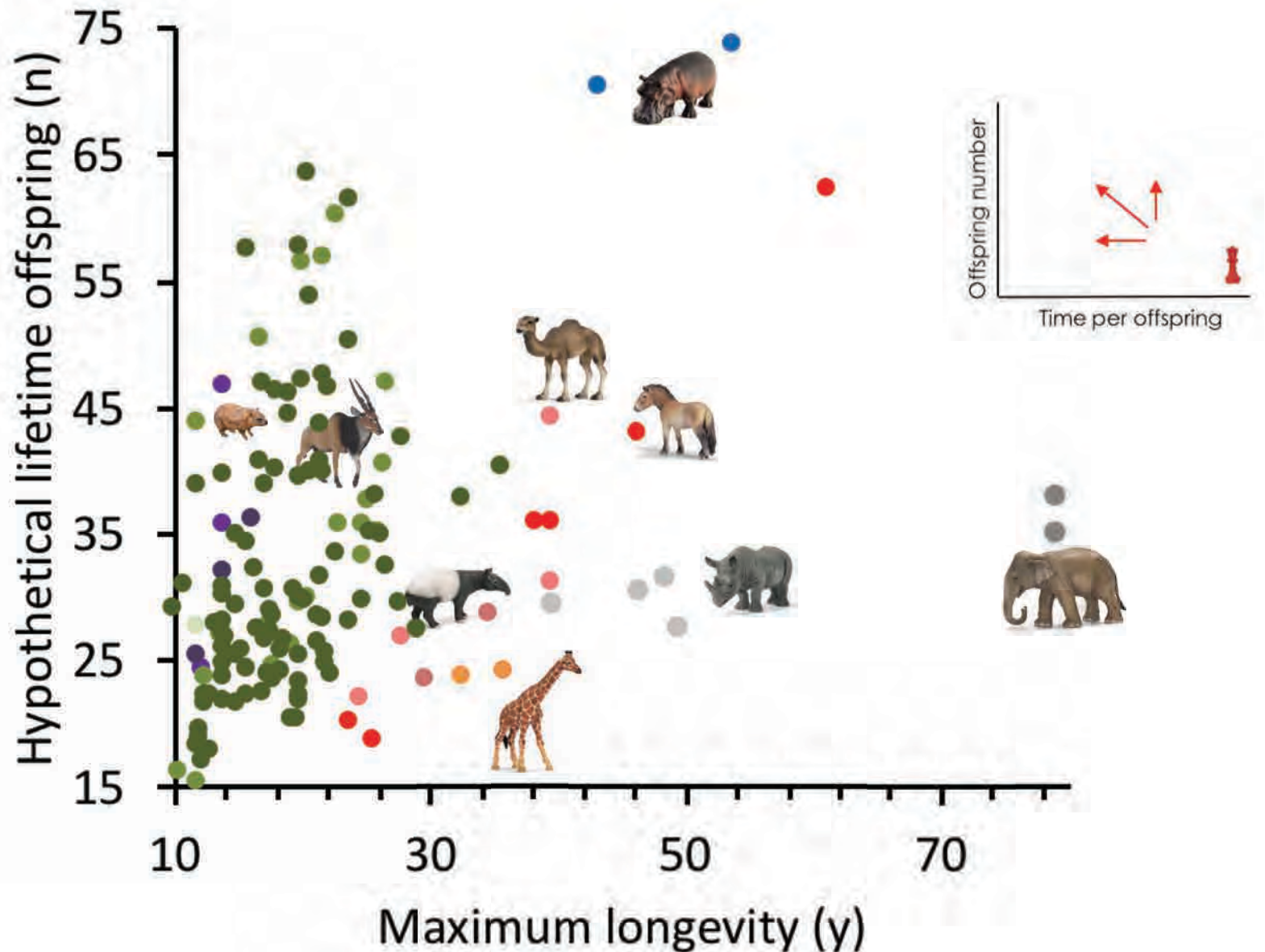




# A clear picture for intrauterine growth



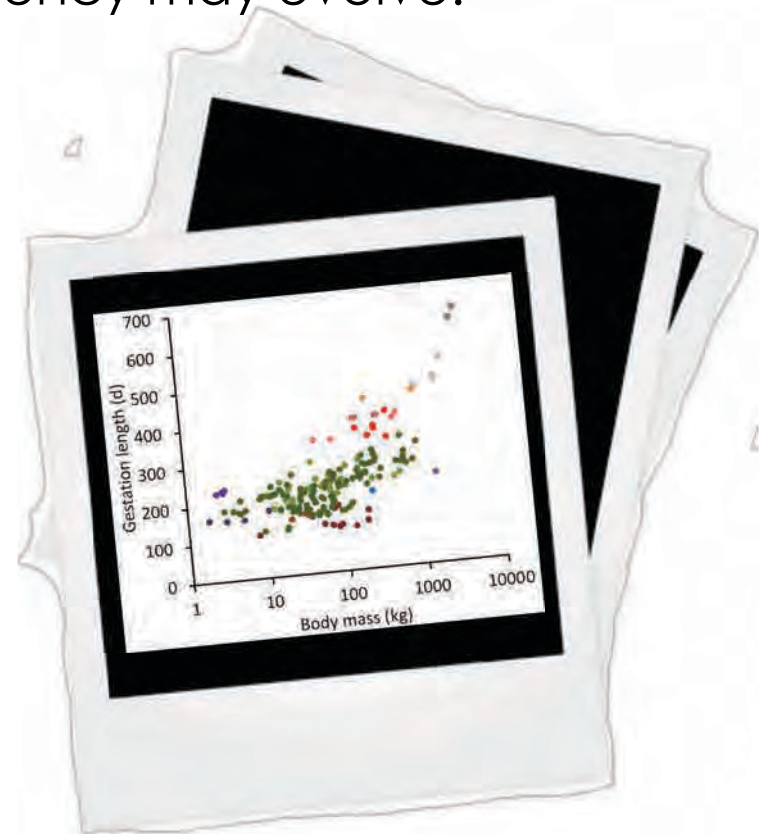
# A clear picture for lifetime offspring production





# 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.

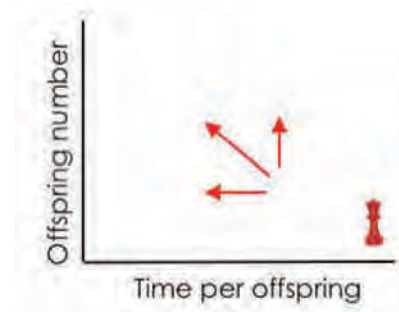




# Summary, Conclusions & Outlook

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.

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



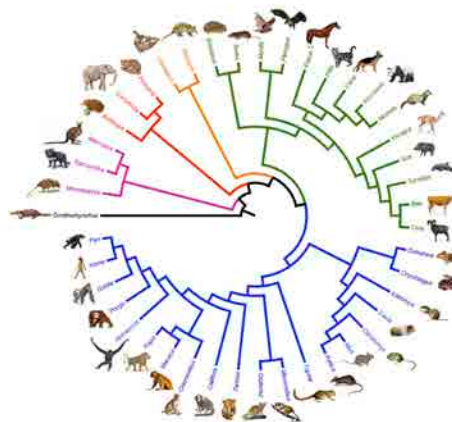


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Rather than understanding tradeoffs along the fast-slow continuum as fixed physical laws, they can be considered as representing the efficiency of the organisms from which the data was taken – and that efficiency may evolve.

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

Life history characteristics appear to be linked to taxonomic groups.

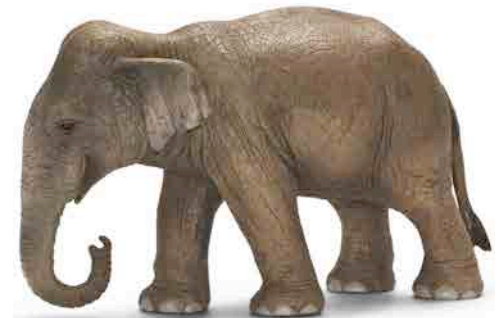






## The interesting question ...

*... what allowed the remaining extant species of the 'slower' taxa to survive?*





# 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.

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

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

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<sup>3</sup>*School of Agriculture, University of Edinburgh, West Mains Road, Edinburgh EH9, 3JG, UK*

(Received November 2, 1993)

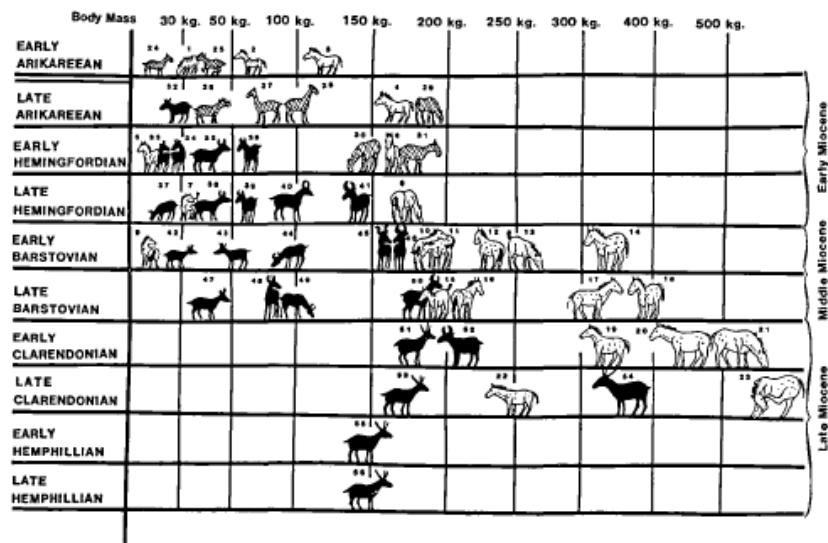


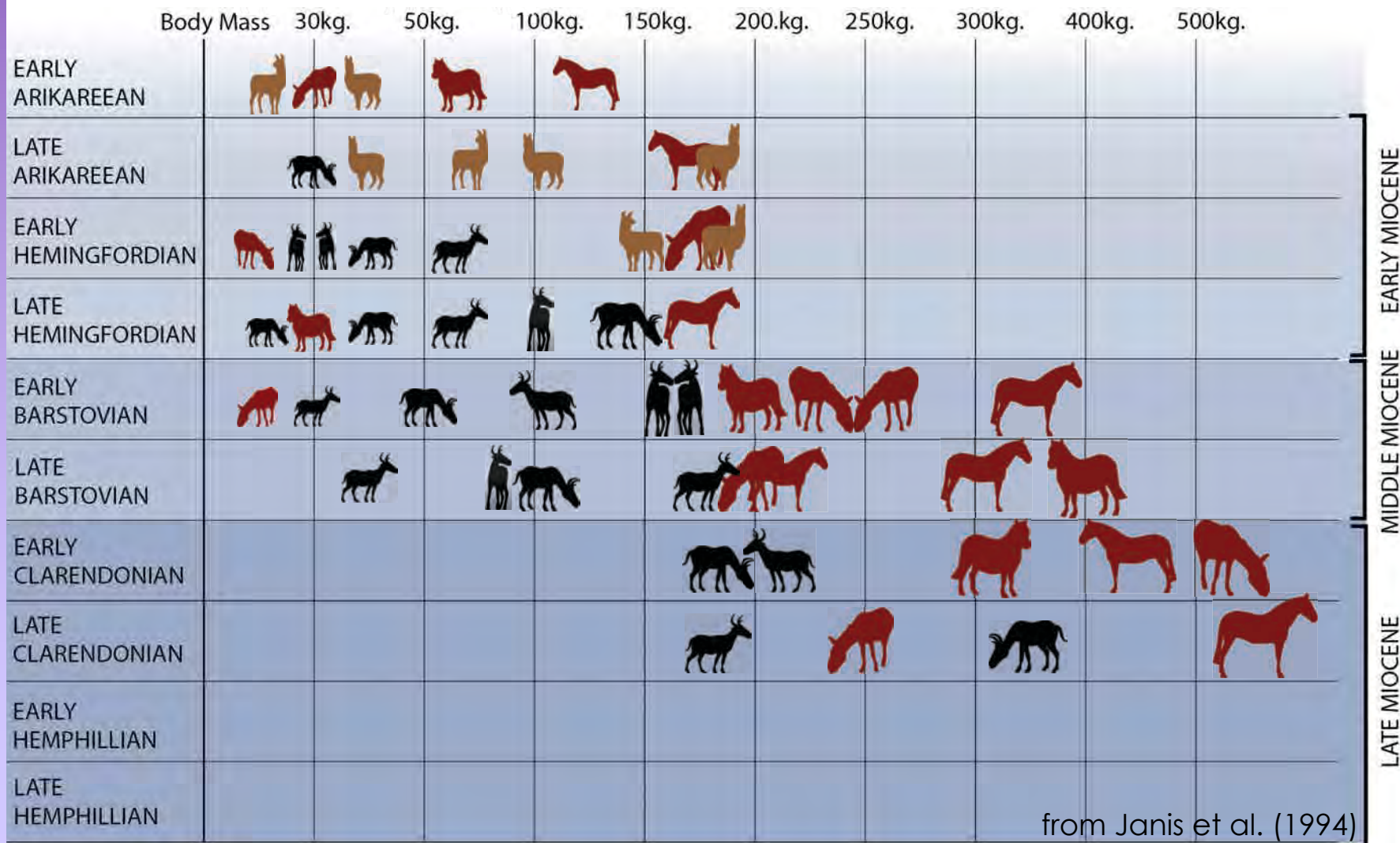
Figure 3 Body size distribution of browsing Miocene equids and ruminants. Key to ungulate taxa:  
A. Color of taxon: Striped horses=Mesohippines; white horses=Anchitherines; spotted horses=Hypohippines;  
black artiodactyls=Pecorans; cross-hatched artiodactyls=Tylopods.



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# 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.

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

Life history characteristics appear to be linked to taxonomic groups.

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?





*thank you for your attention*

