
Why are you waving?!?
RUN!!!

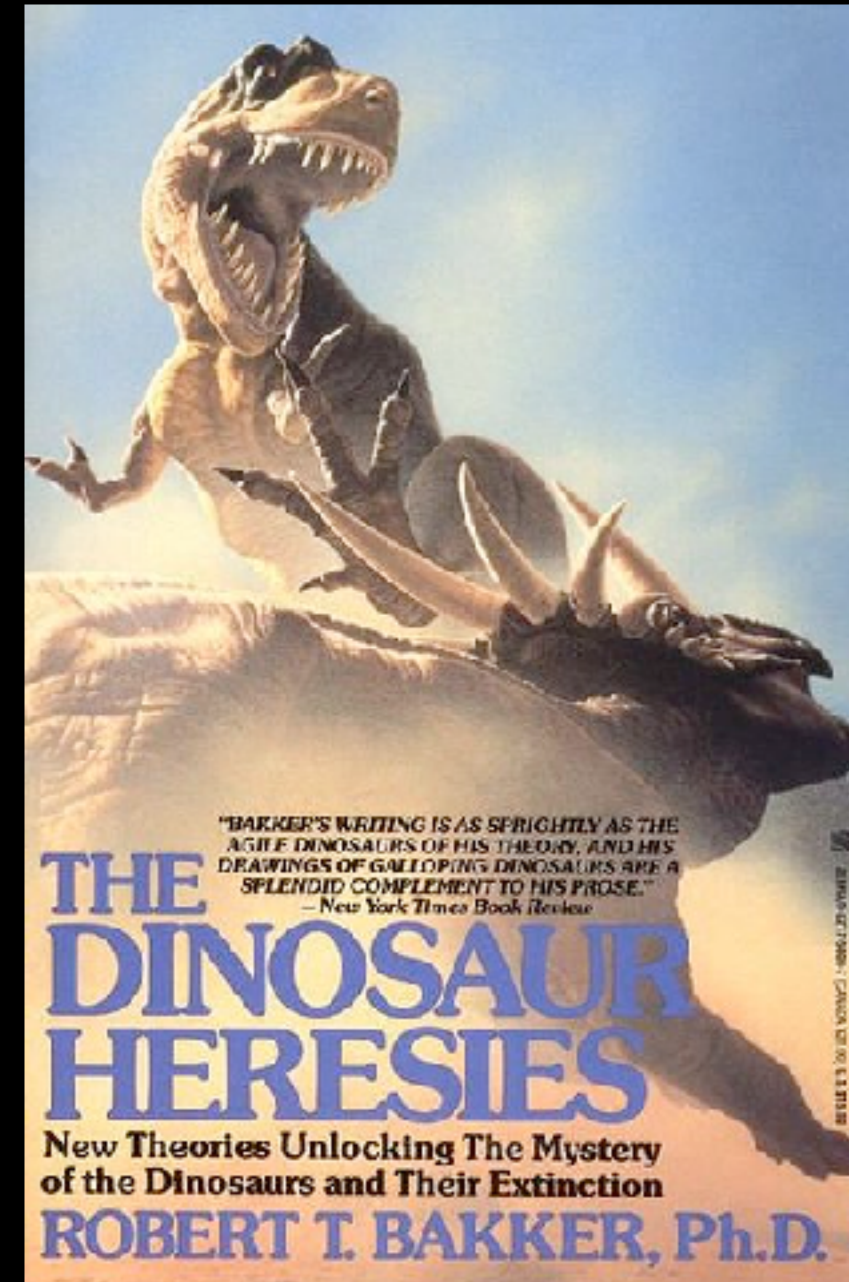
Dinosaur Thermoregulation: **hot or not?**

Dinosaur metabolism?

Cold-blooded?
Warm-blooded?
Different?

Early depiction of *Megalosaurus*

Charles Knight



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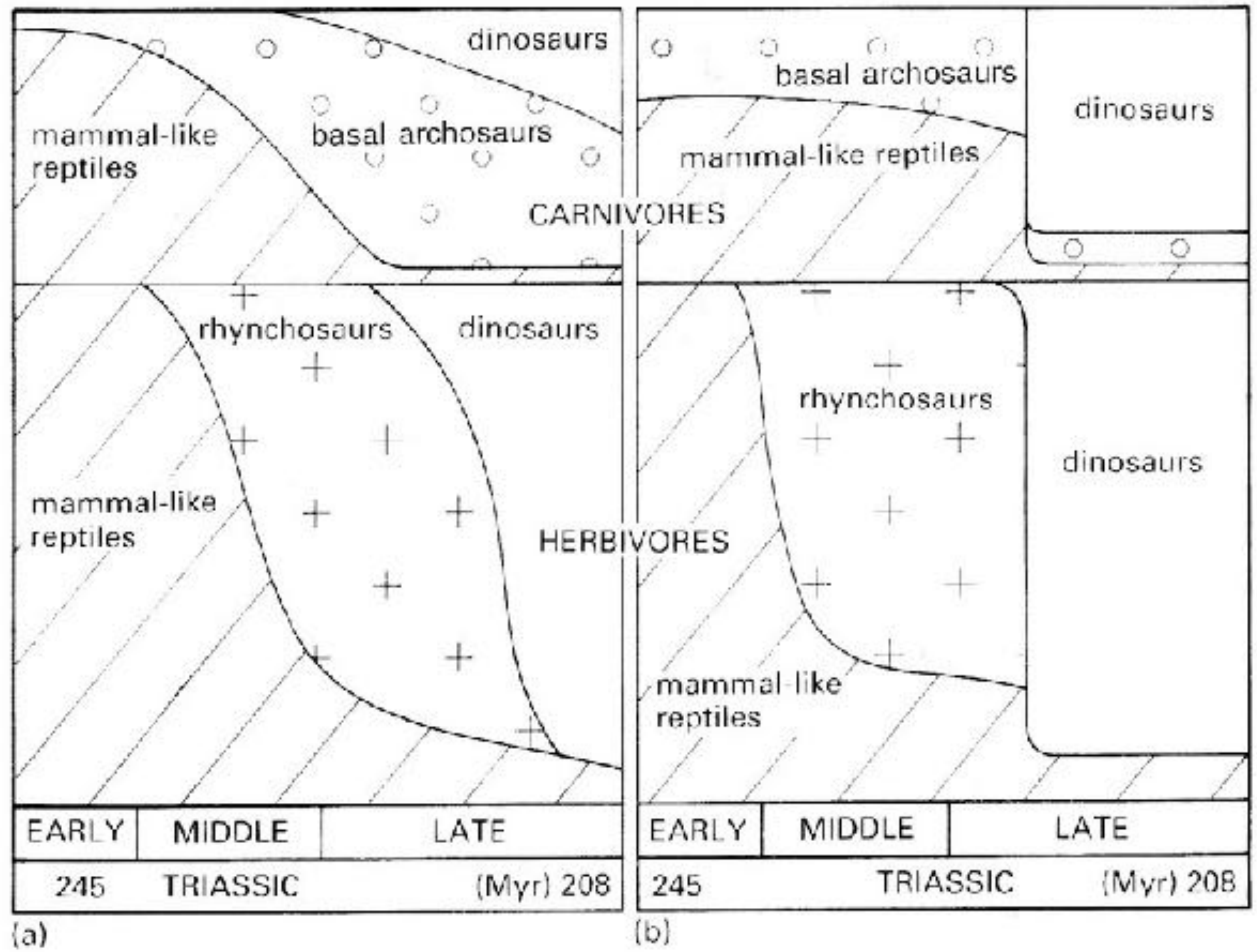


Fig. 6.10 Two models for the replacement of mammal-like reptiles, basal archosaurs, and rhynchosaurs by dinosaurs: (a) a competitive replacement scenario; (b) an opportunistic mass extinction replacement model.

Dinosaurs appeared at about the same time as mammals (160-170 Ma)
Dinosaurs took over at the start of the Mesozoic
Competitive Edge
vs.
Luck of the draw (Opportunistic)

Bakker argued that Dinosaurs were competitively superior to therapsids (including early mammals)
Therefore, they had to be warm-blooded animals
2 Major assumptions in this statement...

1) Dinos directly competed with mammals
2) Warm-bloodedness is competitively superior

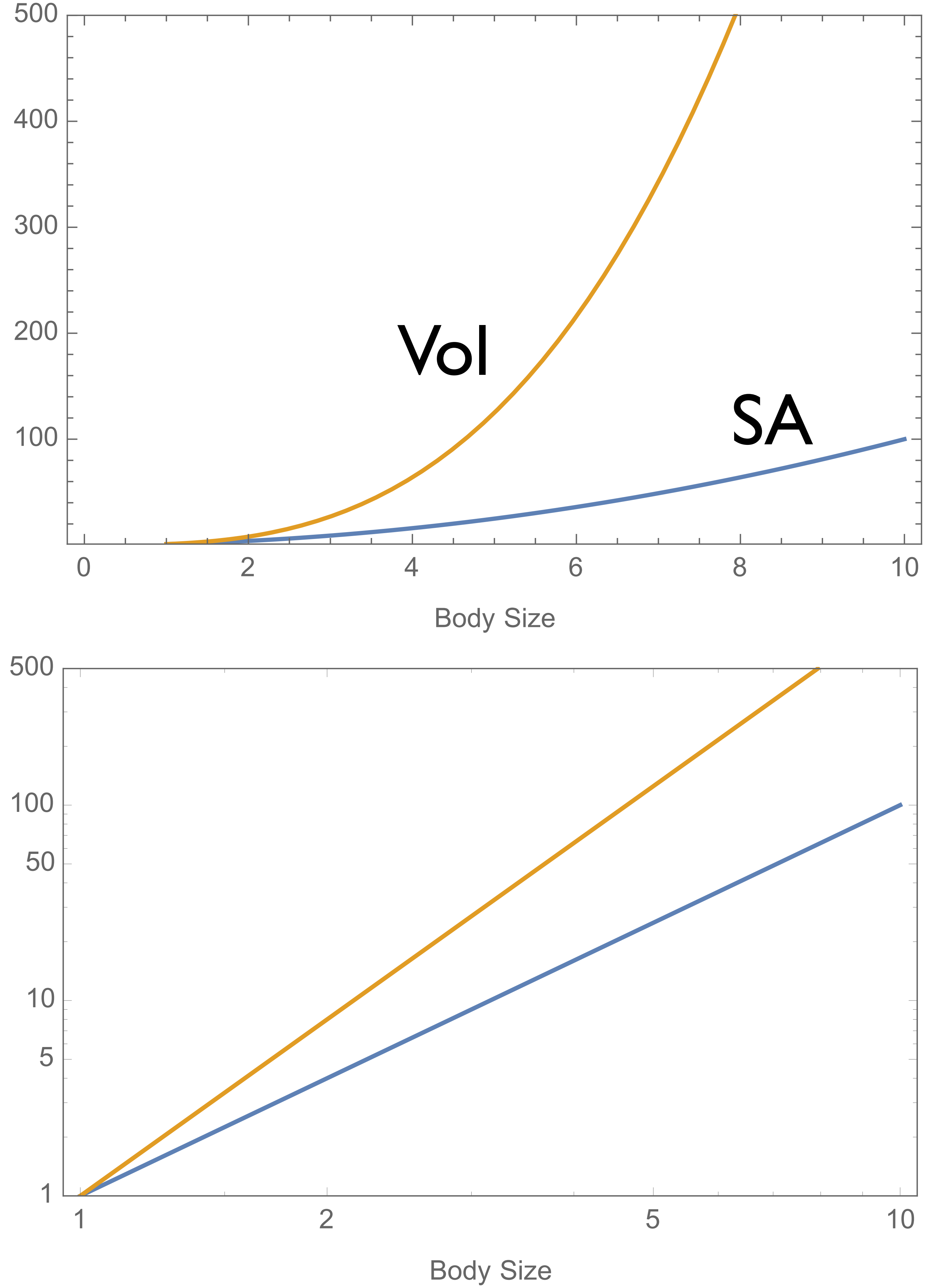
FOR

- Cold-blooded animals are restricted to 45˚ North and South of the equator
  - Even then, primarily 20˚ N & S
- Modern cold-blooded animals are small

AGAINST

- Most living vertebrates are coldblooded

SA => square function
Volume => cubed function


500
400
300
200
100
Vol
SA
0
2
4
6
8
10
Body Size
500
100
50
10
5
1
1
2
5
10
Body Size

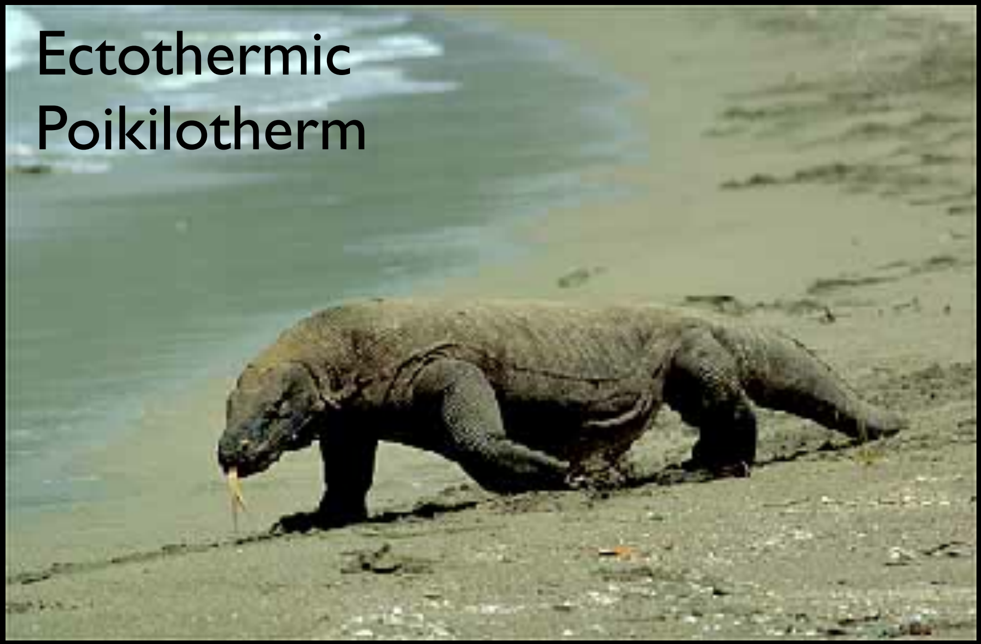
Some Terminology... all animals regulate temperature; it's just a matter of HOW

Ectotherms = animals whose temperature is regulated by external temperature
Endotherms = Animals whose temperature is not regulated by external temperature

EITHER/OR

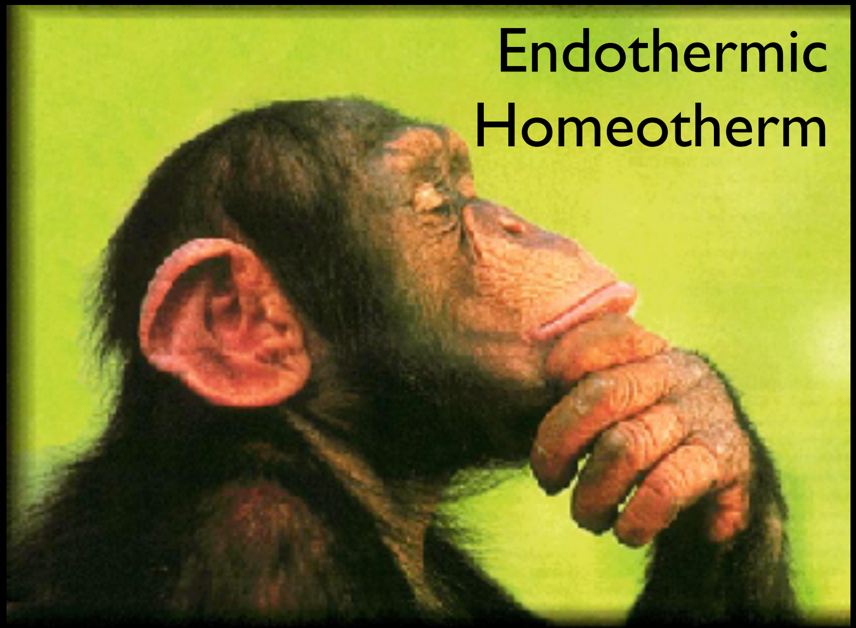
Poikilotherms = Animals whose temperatures fluctuate
Homeotherms = Animals whose temperatures are constant

SPECTRUM



FUNCTIONALLY
homeothermic

Ectothermic Homeotherm



Endothermic Poikilotherm

Regulating your temperature - not just mammals

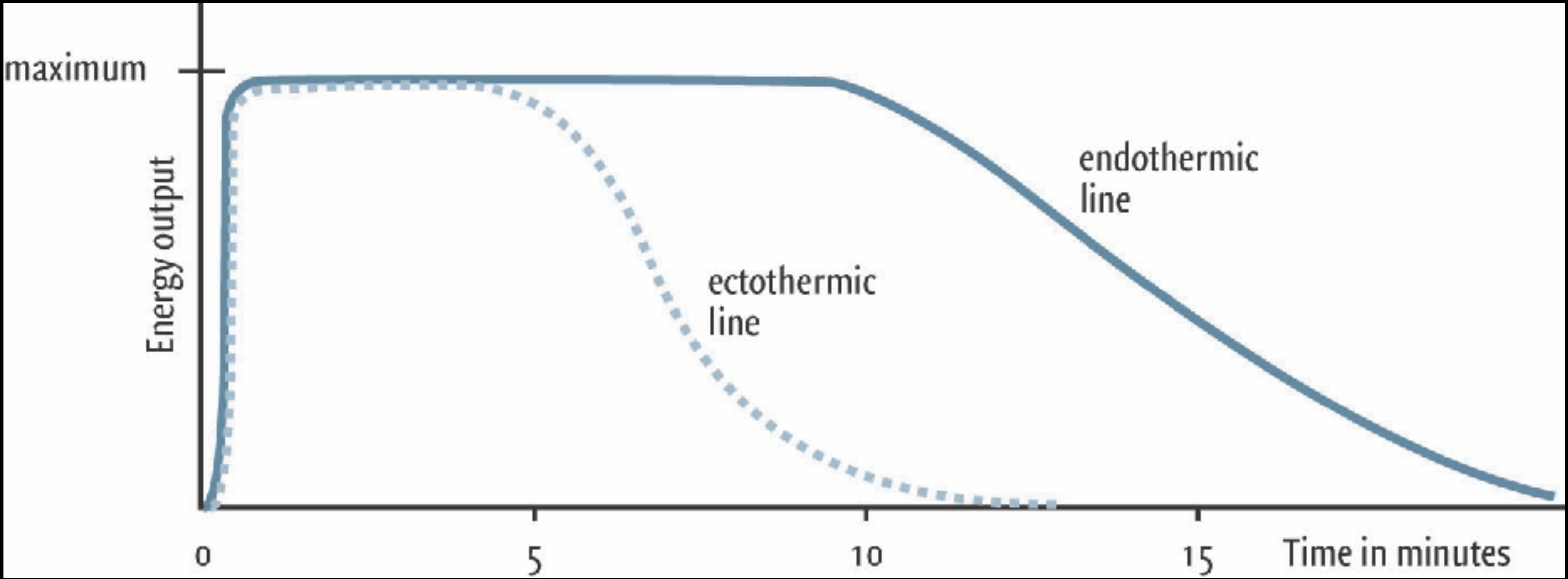
Regulating your temperature - not just animals

Eastern skunk cabbage

Dead horse arum lily

Carrion flower

Not just Temperature control; these ‘lifestyles’ describe the whole of metabolic processes.



Endothermy vs. Ectothermy: both have different metabolic consequences...

For a given activity, the Energy that is required for an ectotherm and an endotherm is the same, but:

1) an ectotherm produces less energy before it hit’s the ‘wall’ (where anaerobic respiration begins ~ lactic acid buildup)

2) an endotherm can produce energy for a longer period of time before it hit’s the ‘wall’. (It can produce the same amount of energy LONGER) This is partly because an endotherm’s resting metabolic rate is HIGHER than an ectotherms

It's good to be an ectotherm because:

1) Energetically cheaper
   Lower resting metabolic rate
2) Potentially higher quick bursts of energy

Costs:
Cannot expend a lot of energy for a long period of time

It's good to be an endotherm because

1) You can expend more energy for a longer period of time

Costs:
Energetically EXPENSIVE

Consequences:

For a given 'energy landscape'
You can support more ectotherms
b/c they are more economical

Conclusion:

Endothermy is not superior.
It is just another lifestyle

Deciding Factor:
What is the best strategy for survival in a given ecological scenario? Varies from scenario to scenario

The Million Dollar Question: Were dinosaurs endothermic or ectothermic or something else entirely???

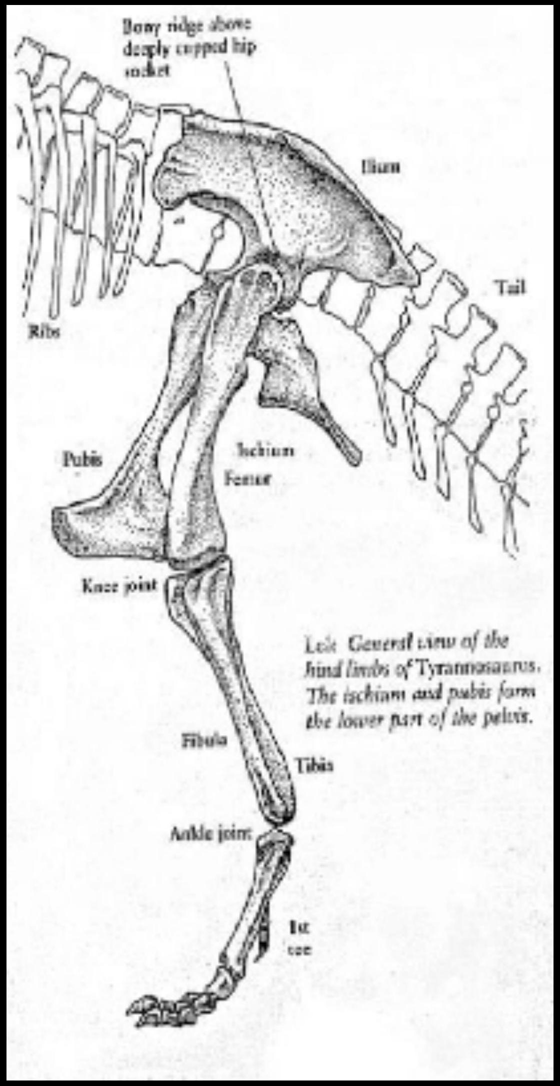
Dinosaur Metabolism: The evidence

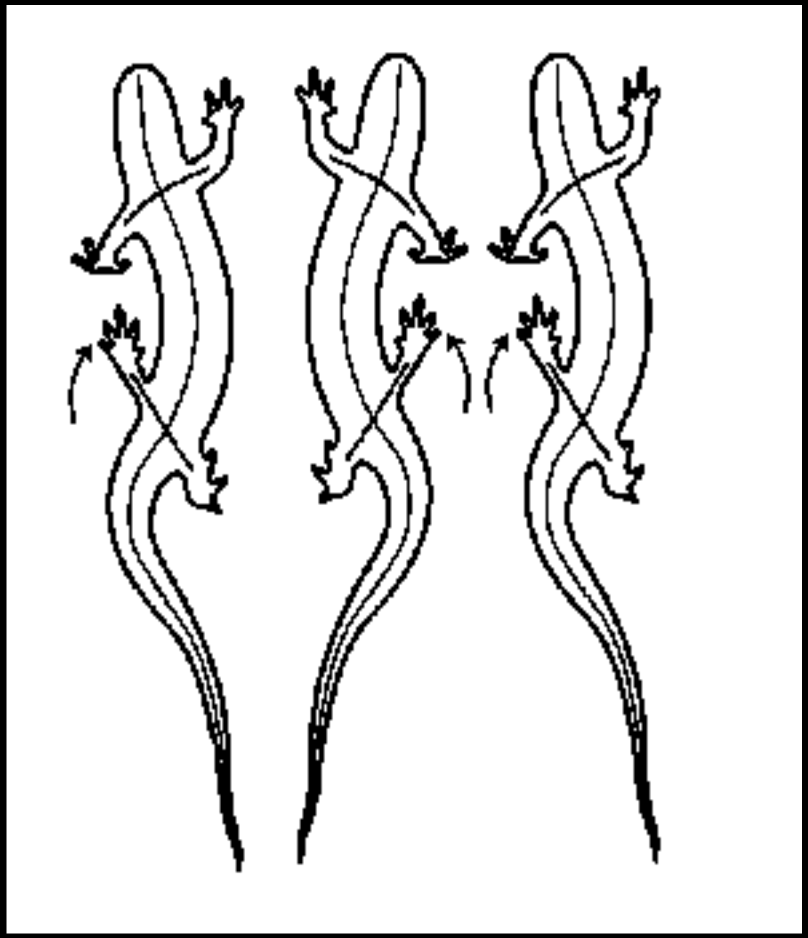
1) Anatomy
2) Diet
3) Hearts
4) Brains
5) Bone Histology
6) Growth and LAGS
7) Plumage
8) Ecology / Zoogeography
9) Chemistry
10) Noses

Dinosaur Metabolism: The evidence

1) Anatomy

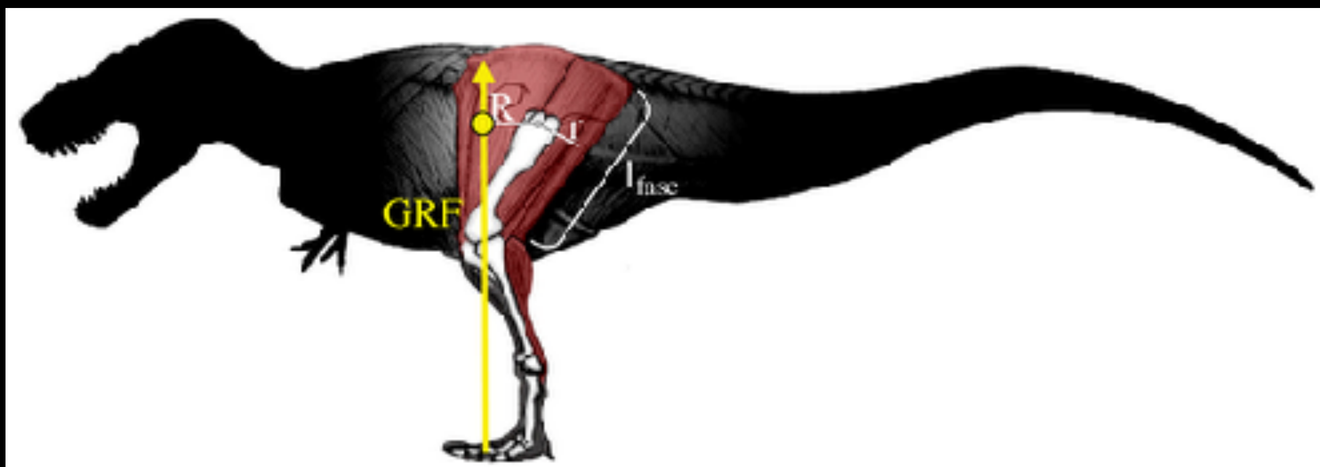
1) Among modern animals, all animals with erect stances are endotherms
2) Sprawling animals have limited O2 intake while moving quickly; parasagittal stance evolved to overcome this? Upright stance may be a prerequisite for endothermy
3) Trackways: indicates slow animals (compared to quadrupedal mammals)



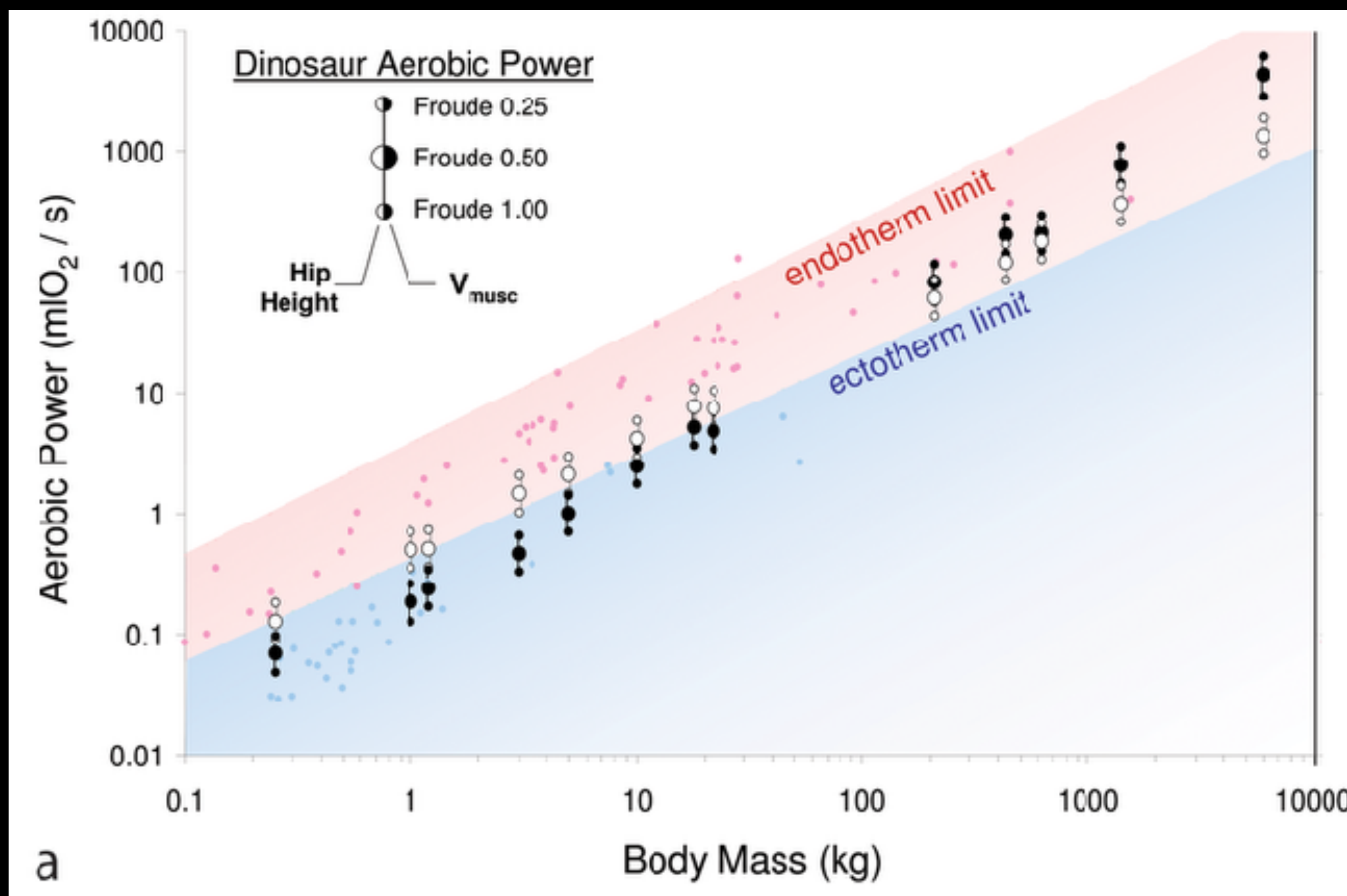


Dinosaur Metabolism: The evidence

1) Anatomy



Limb & muscle proportions
=> estimate aerobic power



Dinosaur Metabolism: The evidence

2) Diet

1) If Dinos required a lot of food, endothermy might be implied (more energetically expensive)
    Chewing dinos: Ornithopods, ceratopsians
2) If Dinos had secondary palates, endothermy might be implied
    Ankylosaurs
    Maybe stegosaurs
    Hadrosaurids

This isn't clear. Birds don't have these things and they're endotherms!

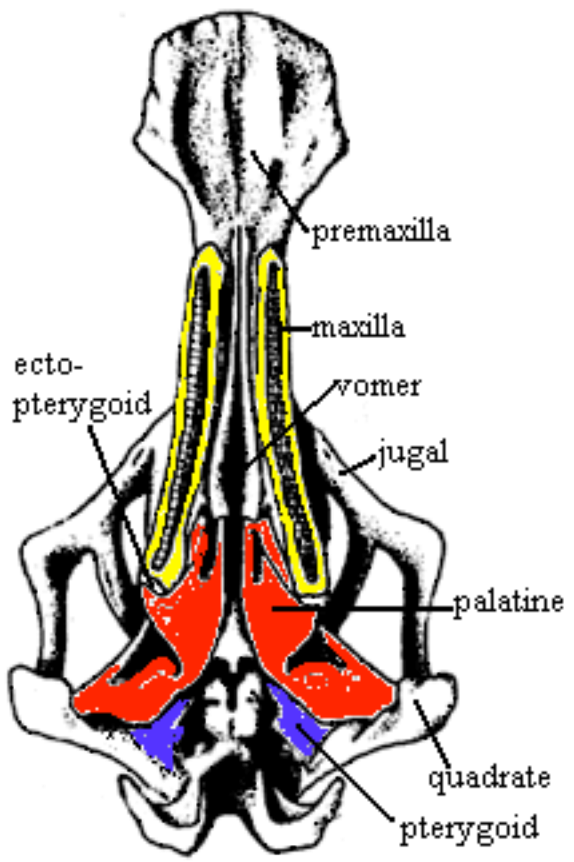


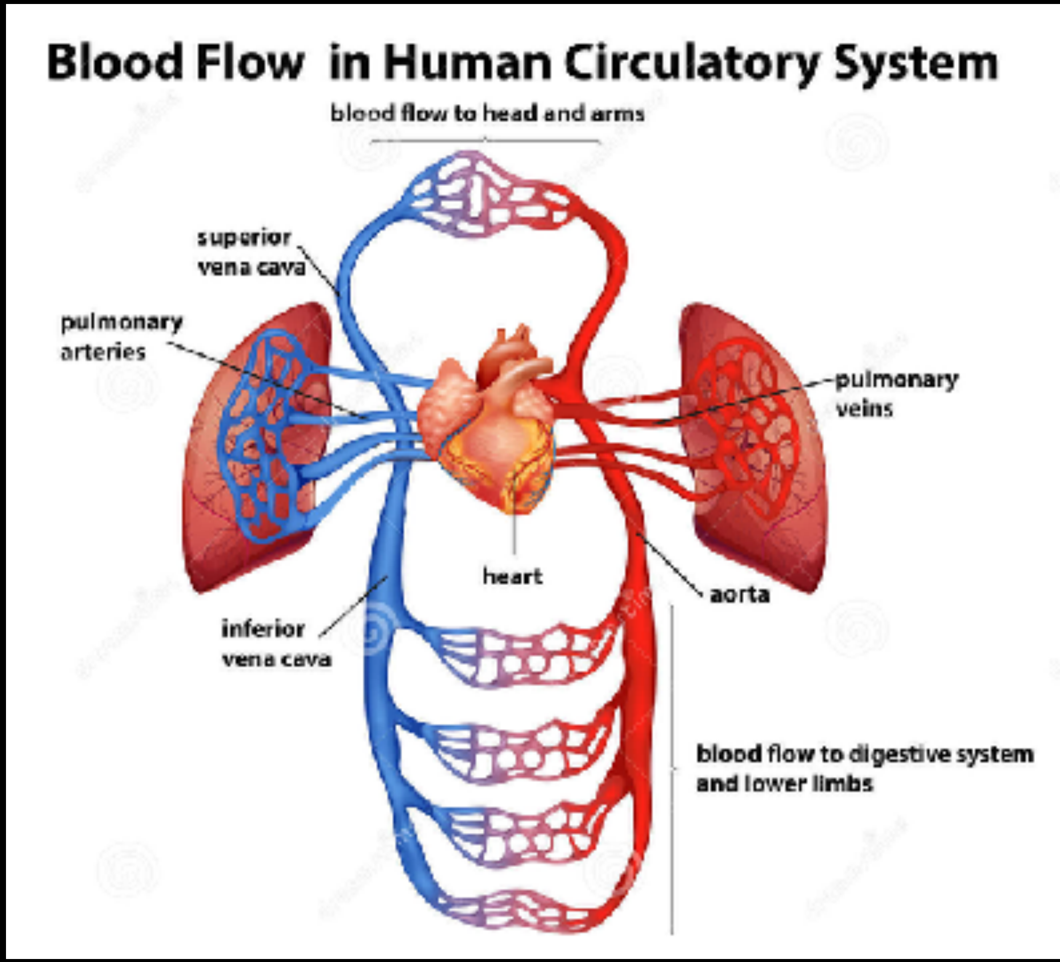
Figure 5. Brachylophosaurus in palatal view. Modified from Weishampel & Horner (1990)

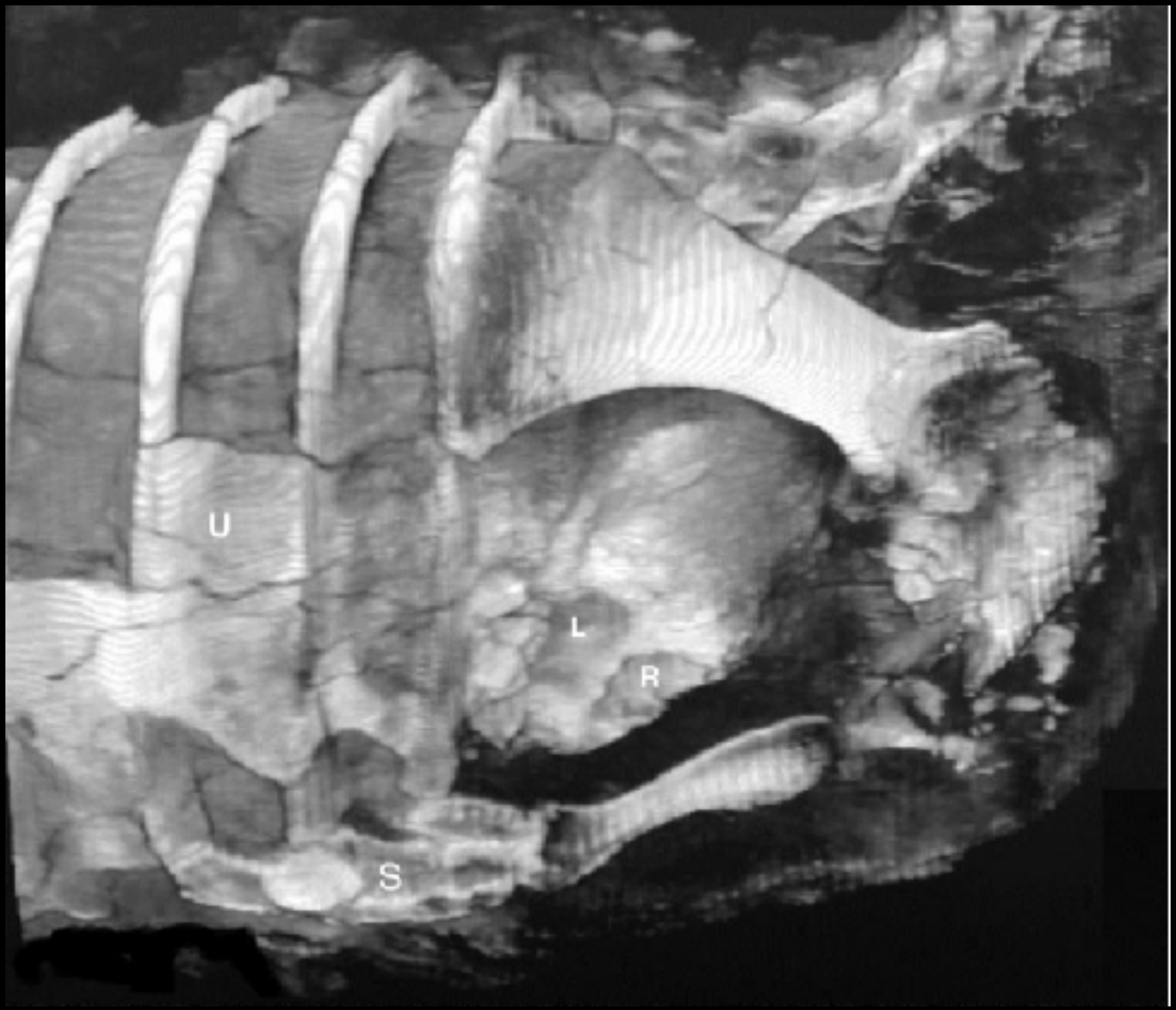
Dinosaur Metabolism: The evidence

3) Hearts

1) All endotherms have a 4 chambered heart (prerequisite?)
   Endothermy require high blood pressure to infuse tissues with O2
   But, this would destroy lung tissue
   So you isolate blood flow to lungs from blood flow to body = 4 chambered

   Sauropods (requirement?)
   Crocs and birds have it => phylogenetically reasonable
   Heart Stone Brewhaha (2000)



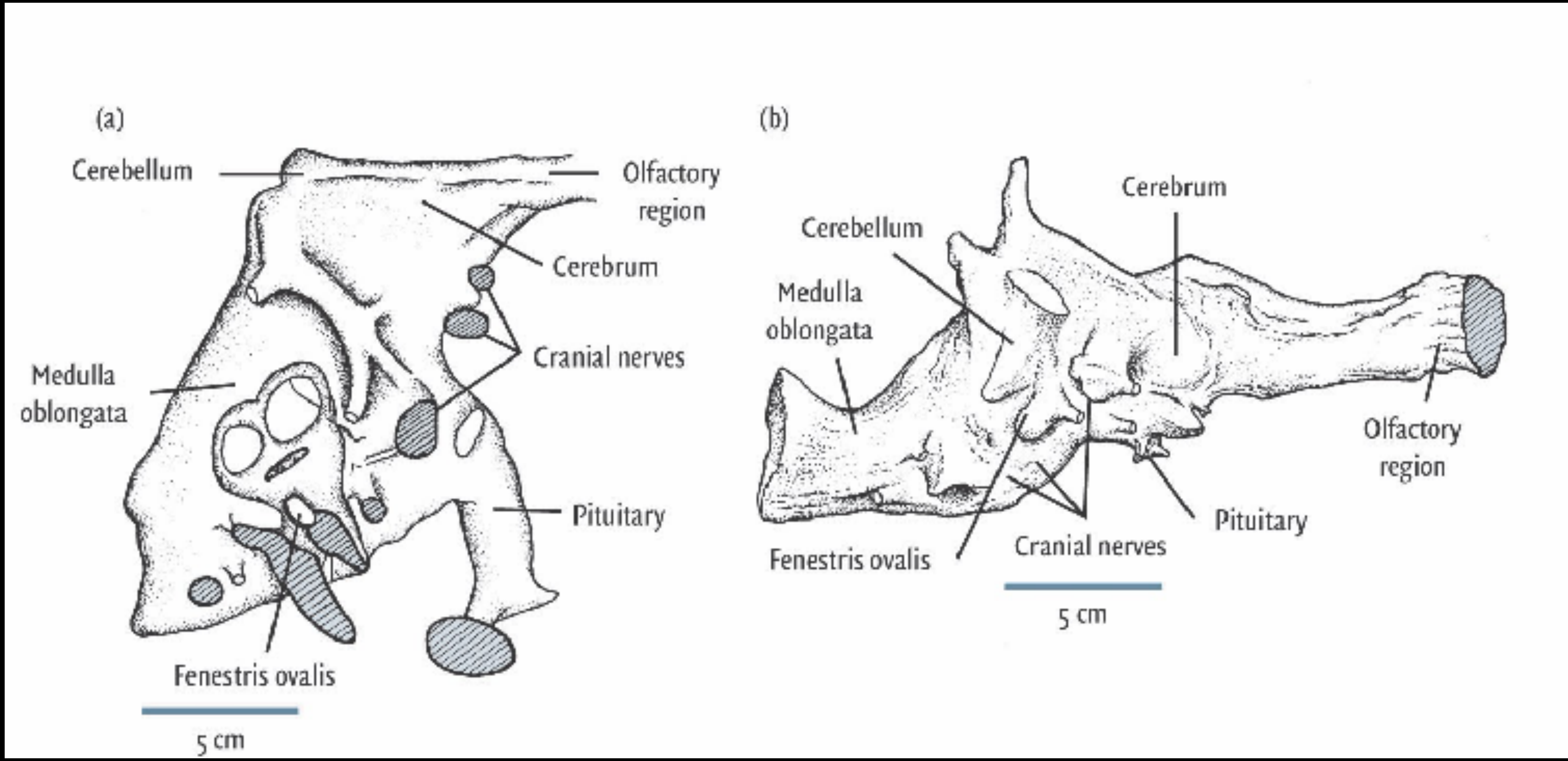


Dinosaur Metabolism: The evidence

4) Brains

1) Some people think brain size is indicative of total activity level
   Some dinos have a high EQ... suggesting higher activity? Does that indicate endothermy?

2) Upright stance (in some dinos) might indicate high neuromuscular control

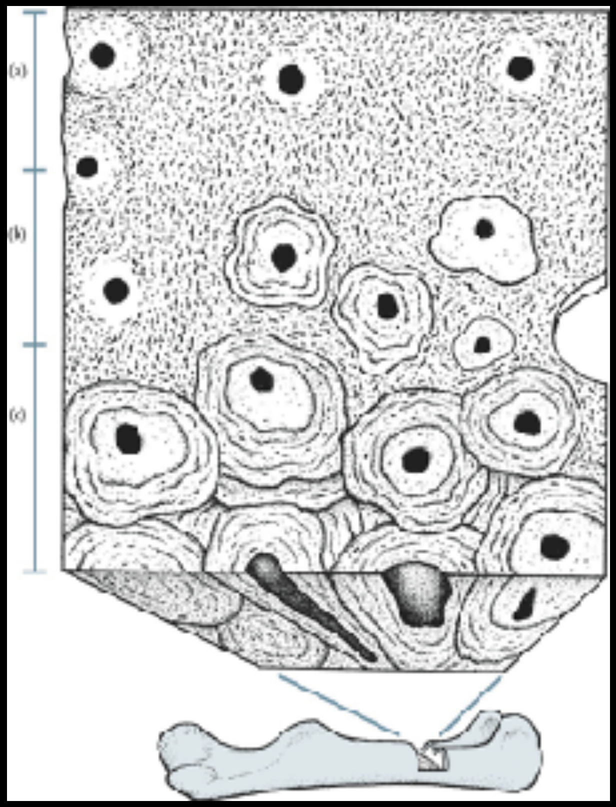


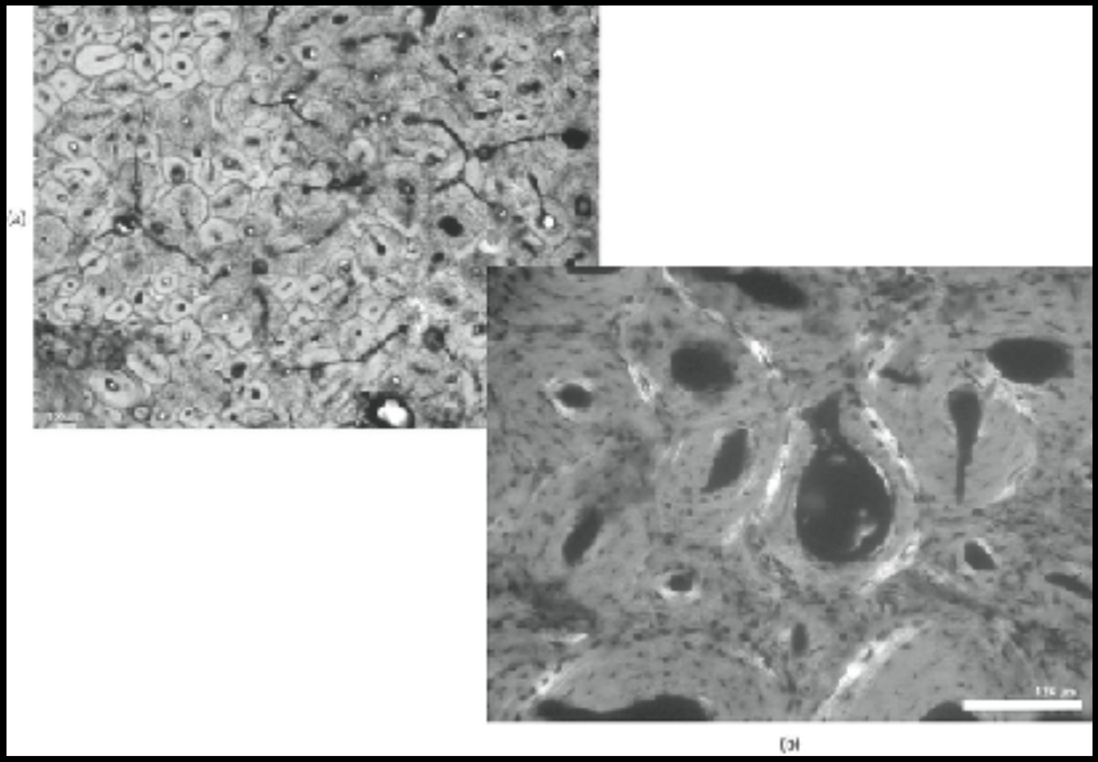
Dinosaur Metabolism: The evidence

5) Bone histology

1) Bone remodels over time, forms Dense Haversian Bone (DHB)
   Large degree of remodeling may imply endothermy ~ Large amount of DHB
2) It's true that bone replacement is related to metabolism
   But this may or may not be reflected in the DHB

3) IF DHB formed similarly in Dinos as it does mammals, it is in agreement with Endothermy
   Dino DHB certainly different than reptiles (both modern and fossil)





Dinosaur Metabolism: The evidence

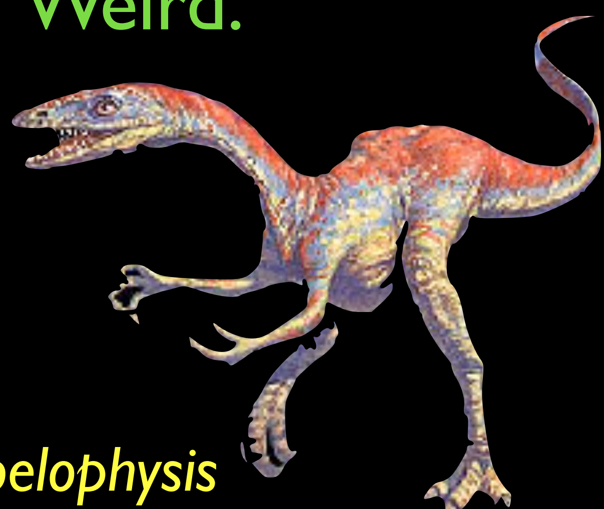
6) Growth and LAGS

1) Reconstructed growth rates are high, vascularized ~ birdlike
2) LAGs = Lines of Arrested bone Growth
   Found in ectotherms that slow growing during cold snaps

Growth rates slower than birds

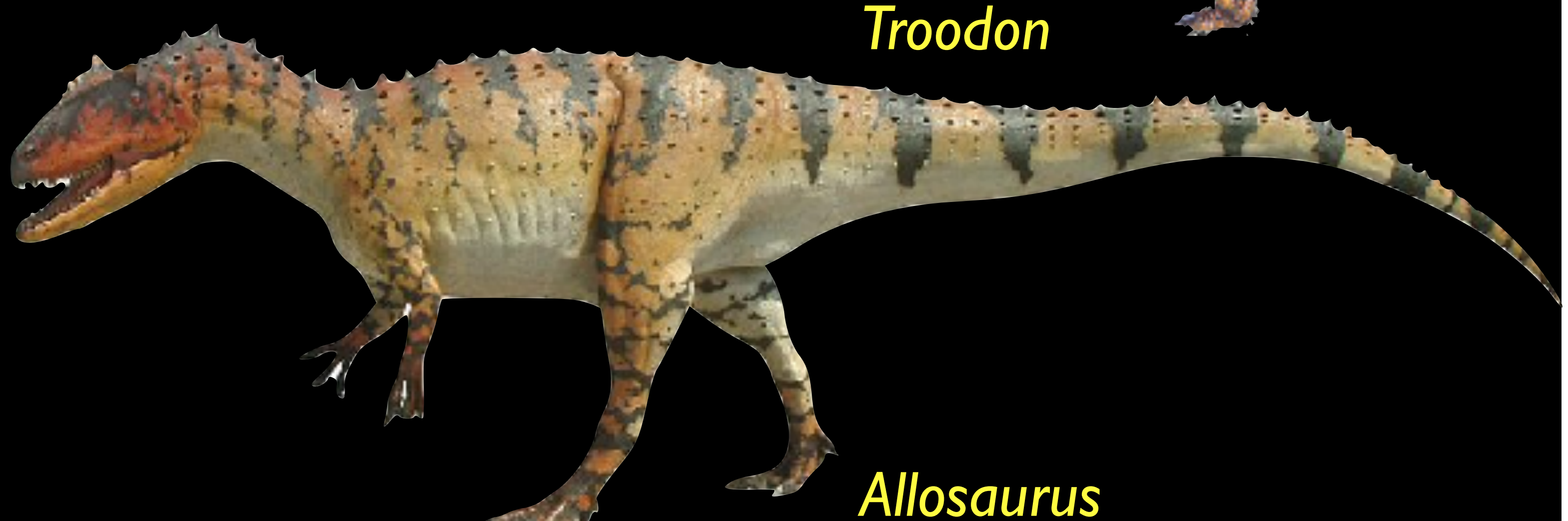
Some Dinos have LAGs (even most active)
LAGs found in early birds

Weird.

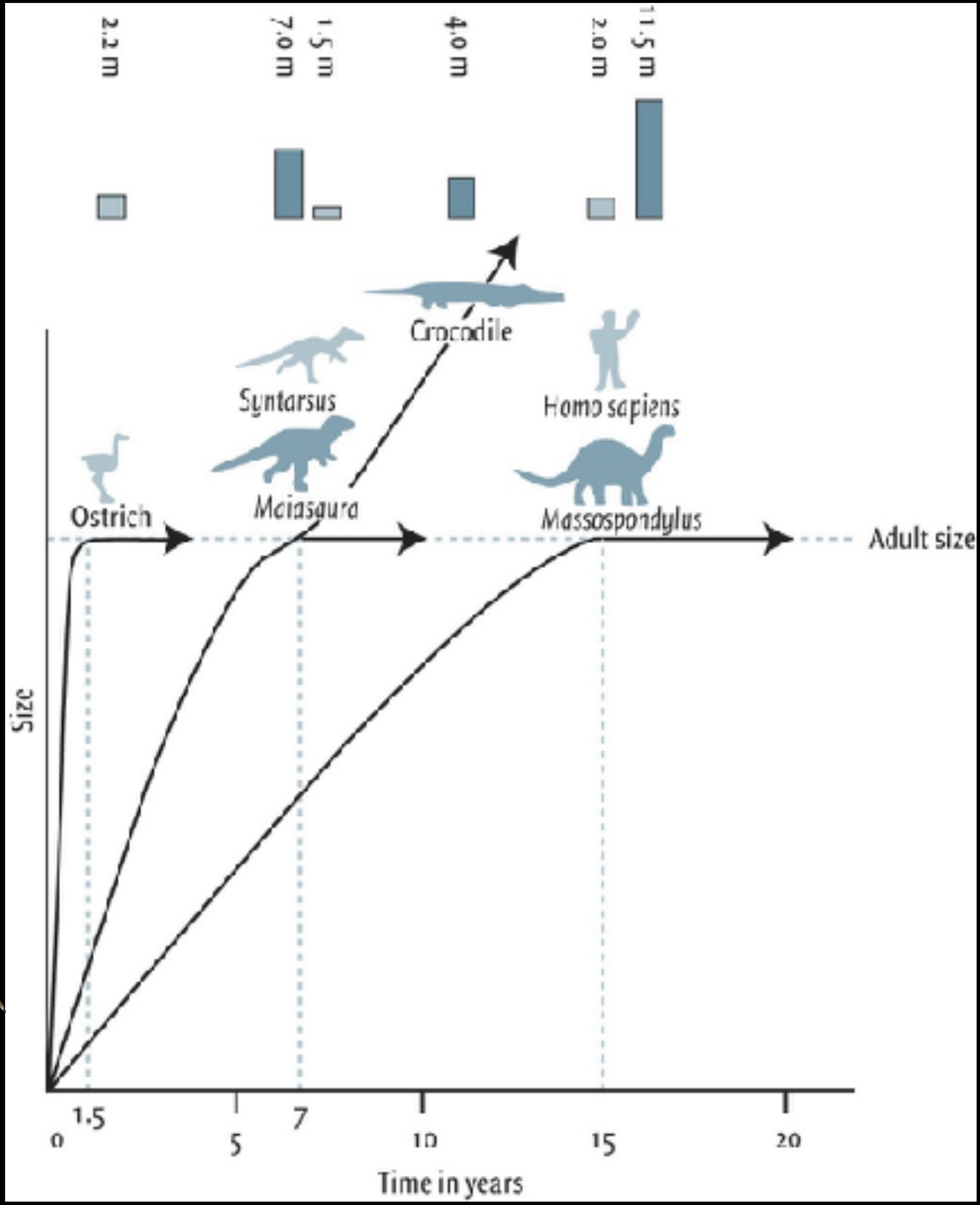


Coelophysis

Troodon



Allosaurus

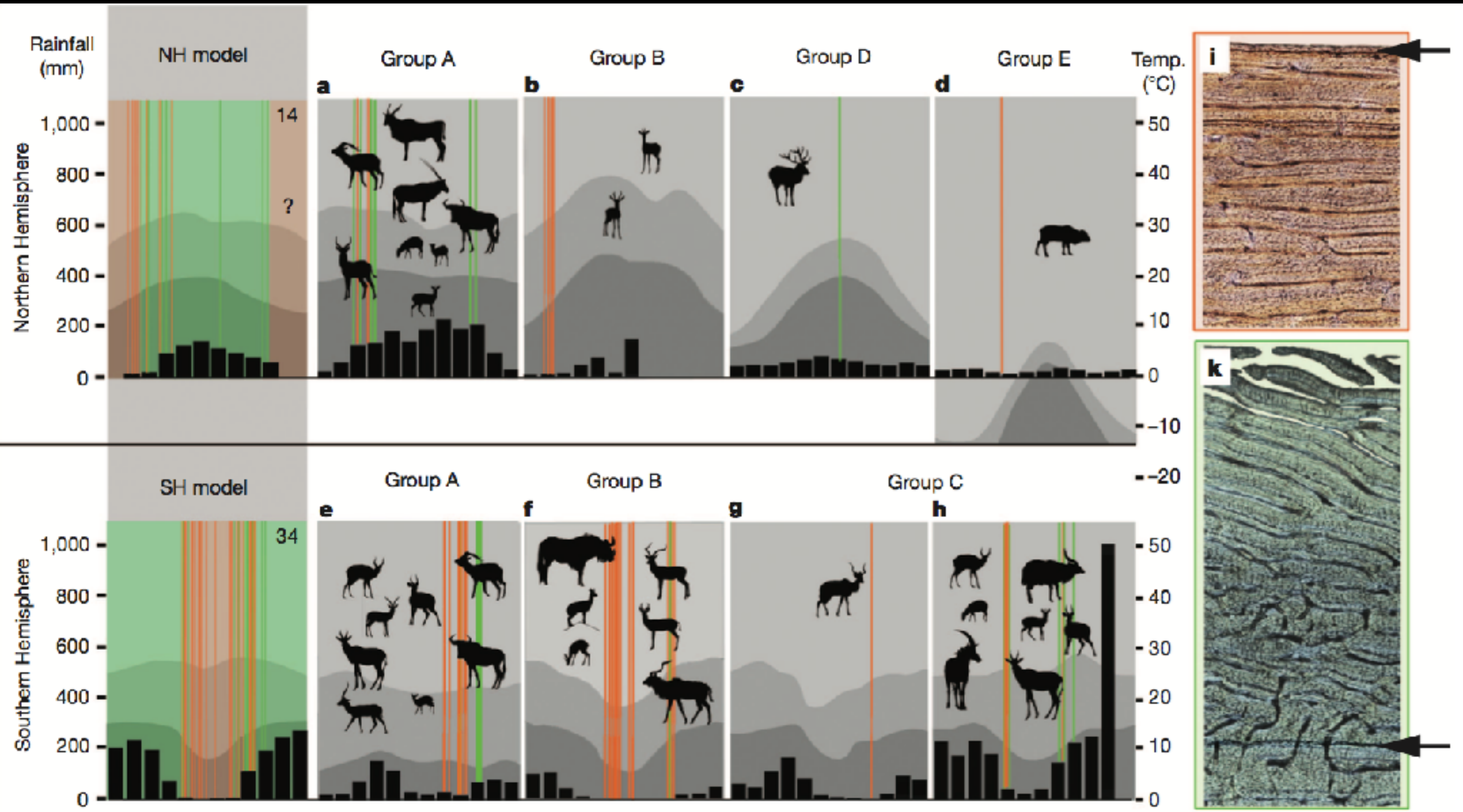


Dinosaur Metabolism: The evidence

6) Growth and LAGS

Problem: Modern endotherms all have LAGs…

arrest



active growth

Dinosaur Metabolism: The evidence

7) Plummage

If an ectotherm is warmed up by the environment, why slow this down by having plumage?

Archaeopteryx

Dinosaur Metabolism: The evidence

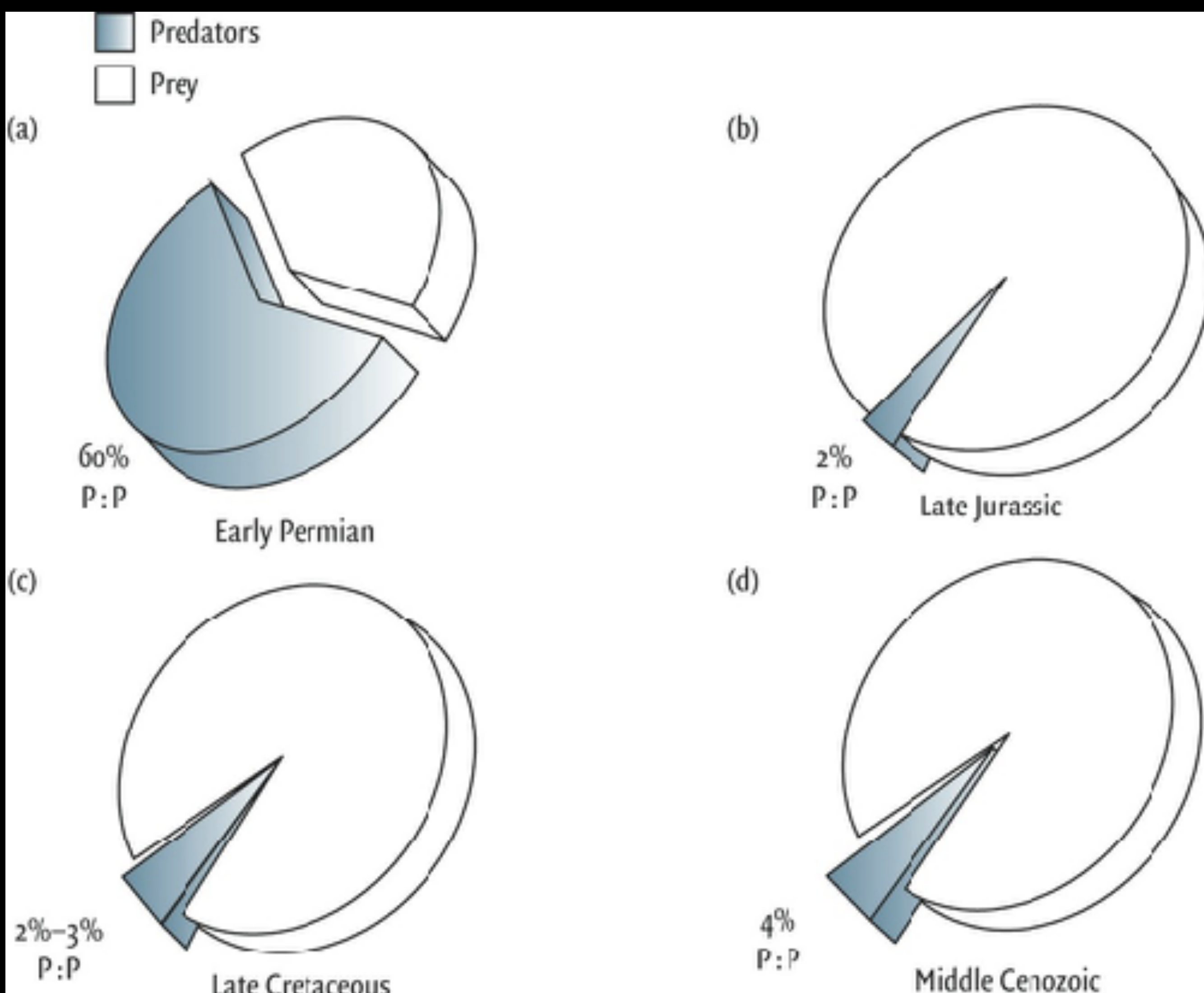
8) Ecology and Zoogeography

1) Endotherm predators require more energy; therefore endotherm ecosystems should support fewer predators per prey (measured in biomass)

  Endotherm systems: 1-3% predators

  Ectotherm systems: 40% predators!

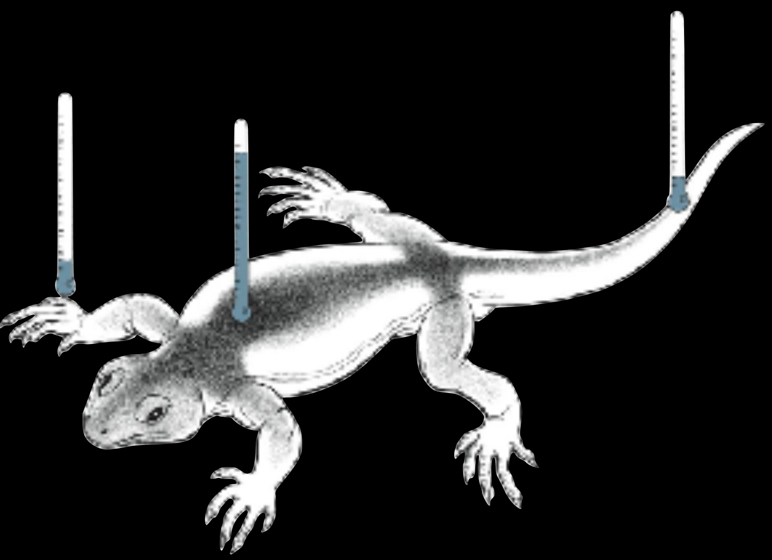
2) Dinosaur geographical ranges exceed those of living ectotherms

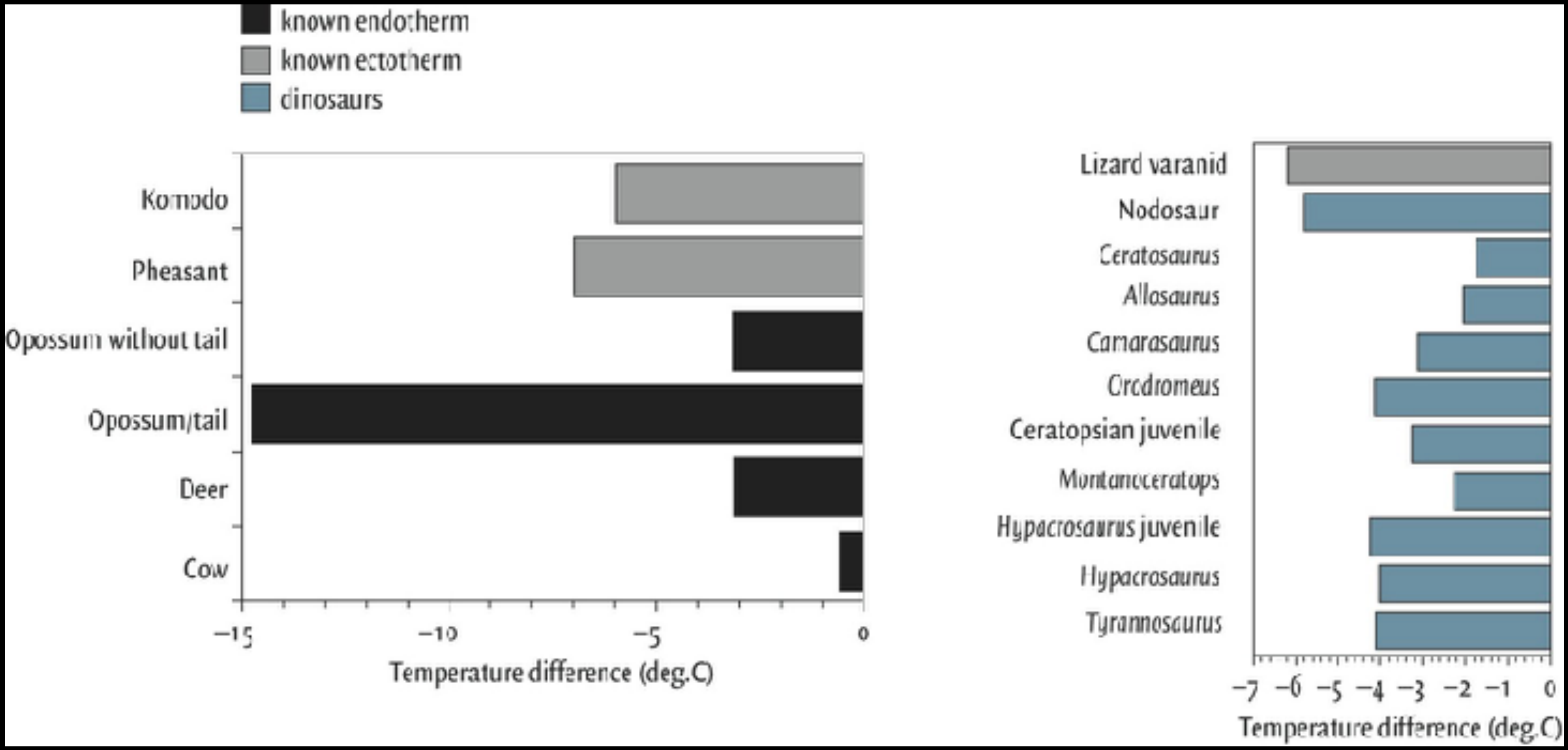


Dinosaur Metabolism: The evidence

9) Chemistry

1) Oxygen isotopes record the temperature during tissue formation
Measure oxygen isotopes in bone phosphate of both externally and internally situated bones; ectotherms should have different temperatures for core/extremities (LARGE DIFFERENCES), while endotherm tissues should all have grown at the same temperatures! (SMALL DIFFERENCES)

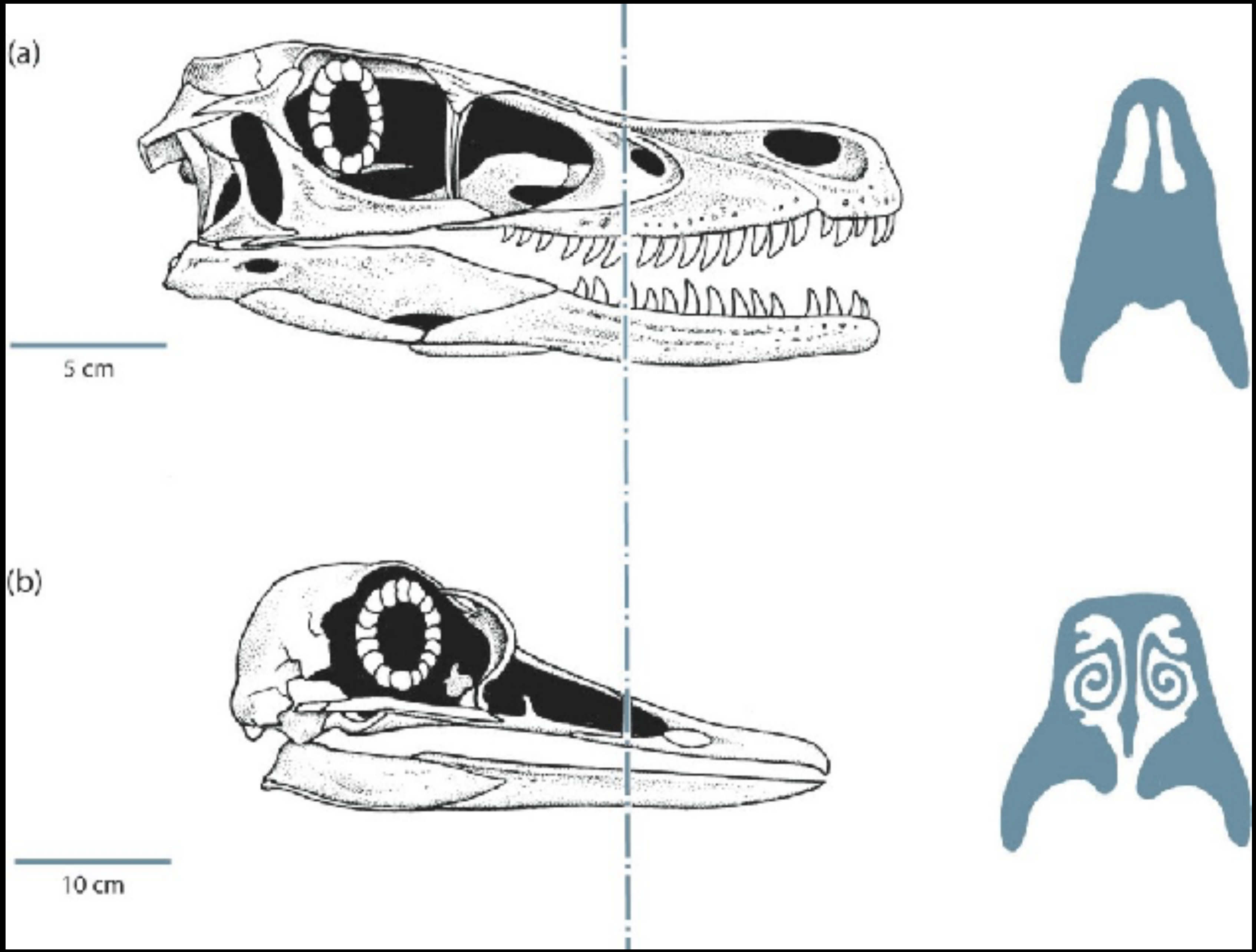




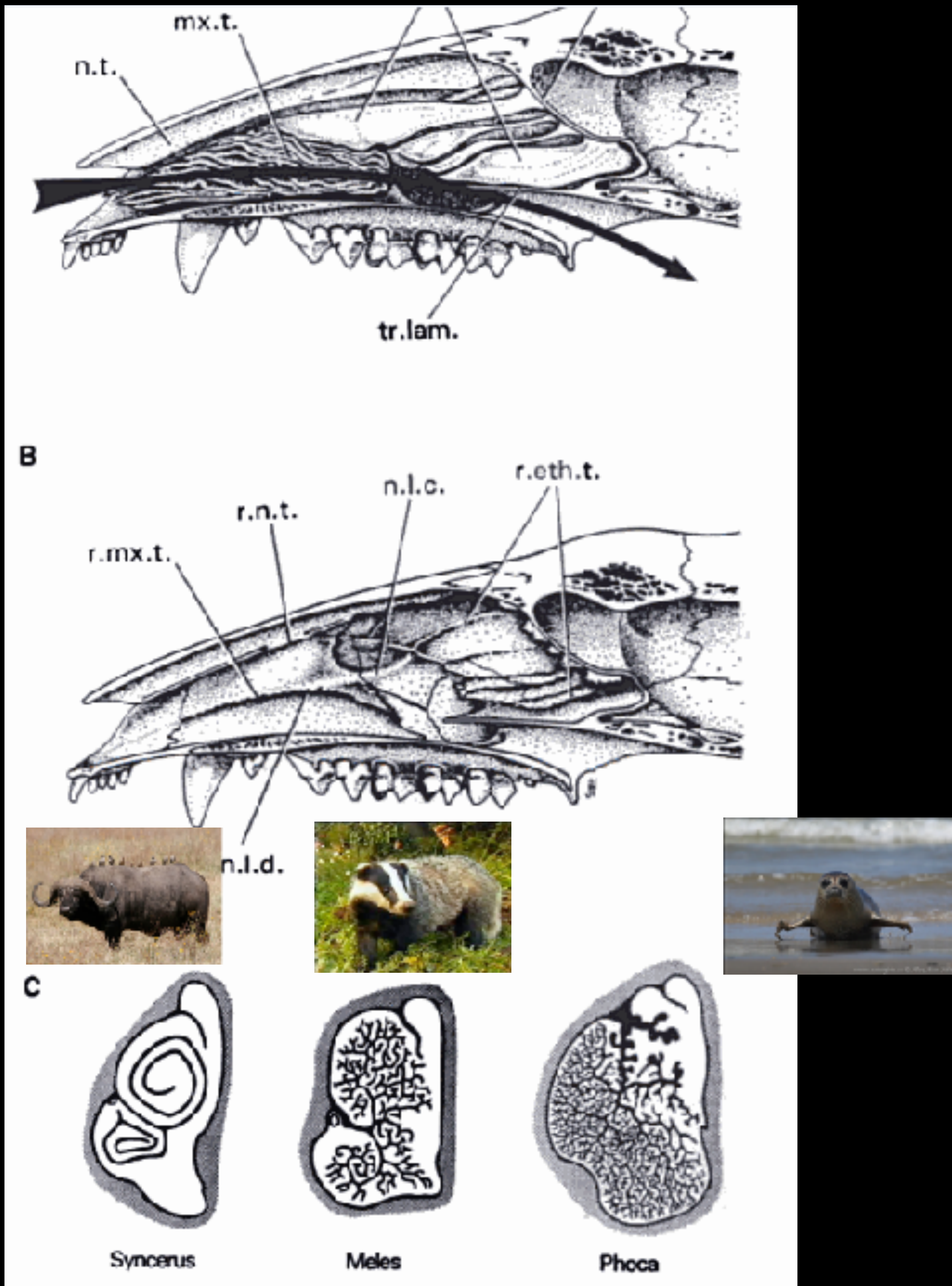
Dinosaur Metabolism: The evidence

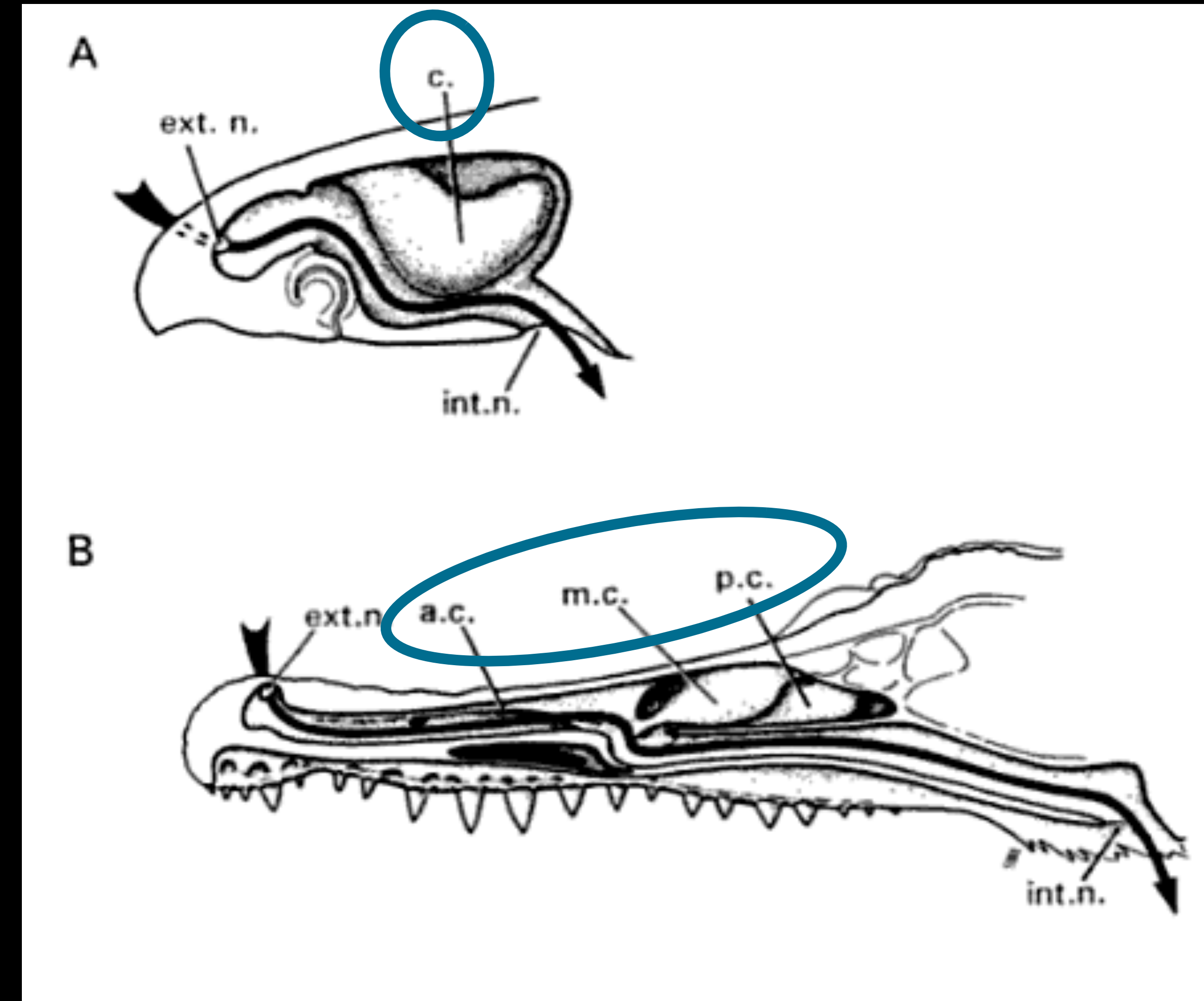
10) Noses

1) Endotherms require lungs to replenish air at a high rate
   - Leads to high water loss
   - Respiratory turbinates resorb water
   - Respiratory turbinates may indicate endothermy indirectly
   - No respiratory turbinates in Dinosaurs

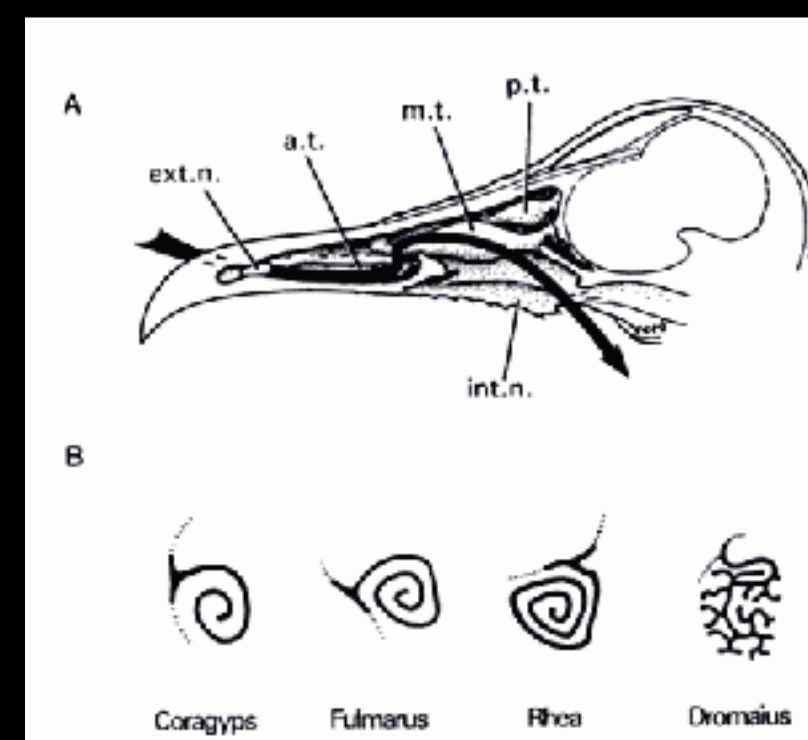


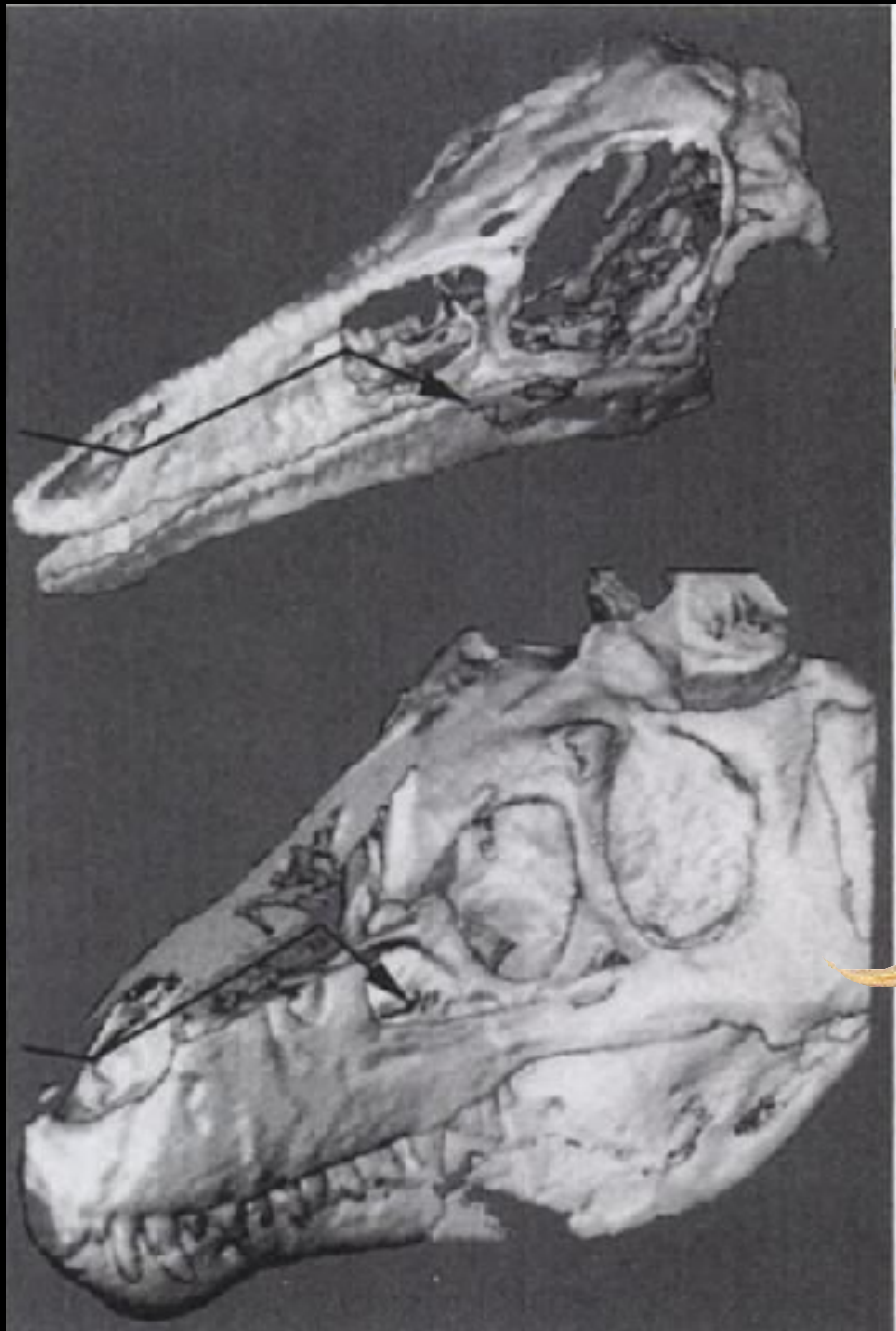
Mammal turbinates



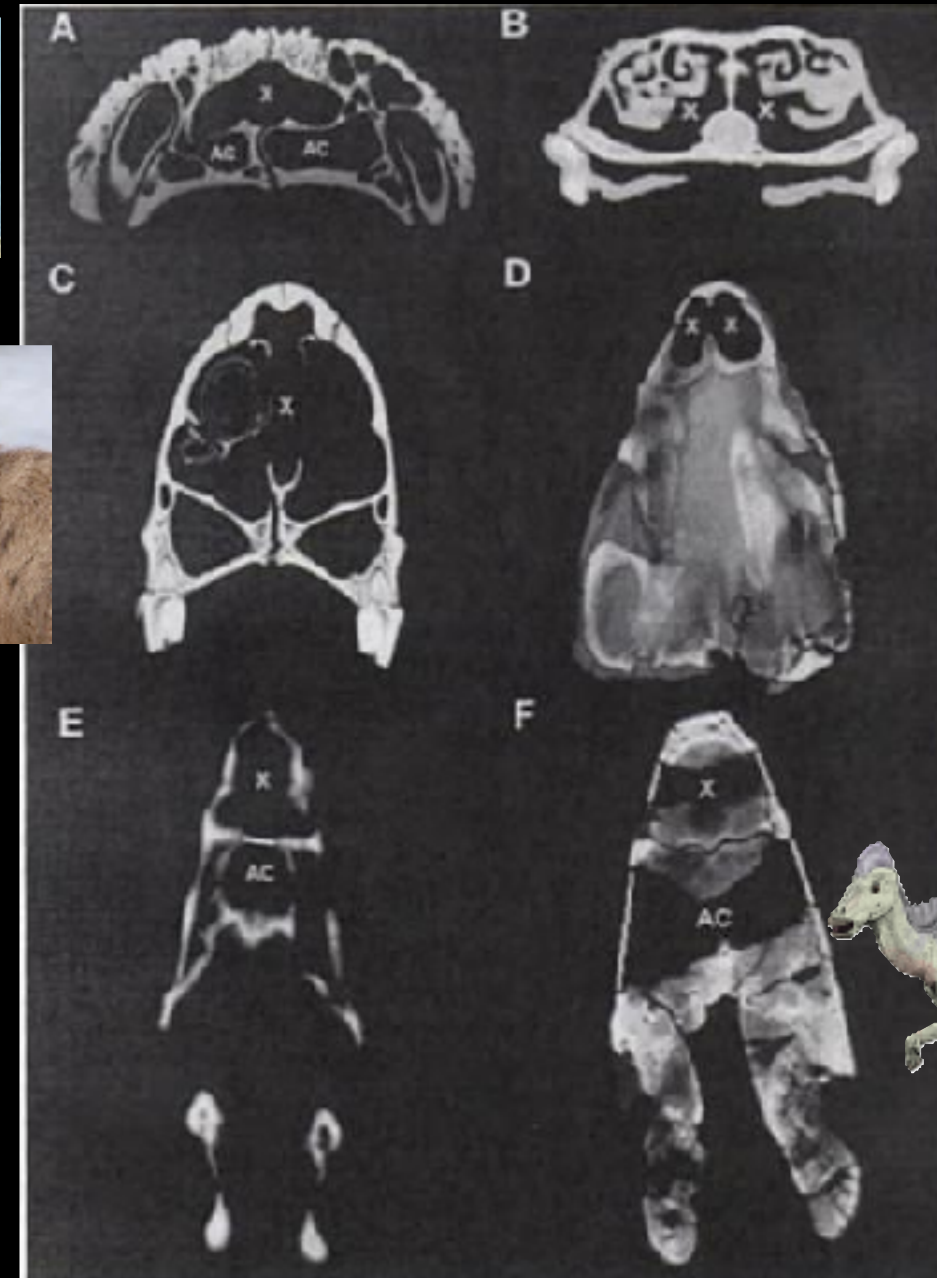


Reptilian turbinates: Exclusively olfactory in function



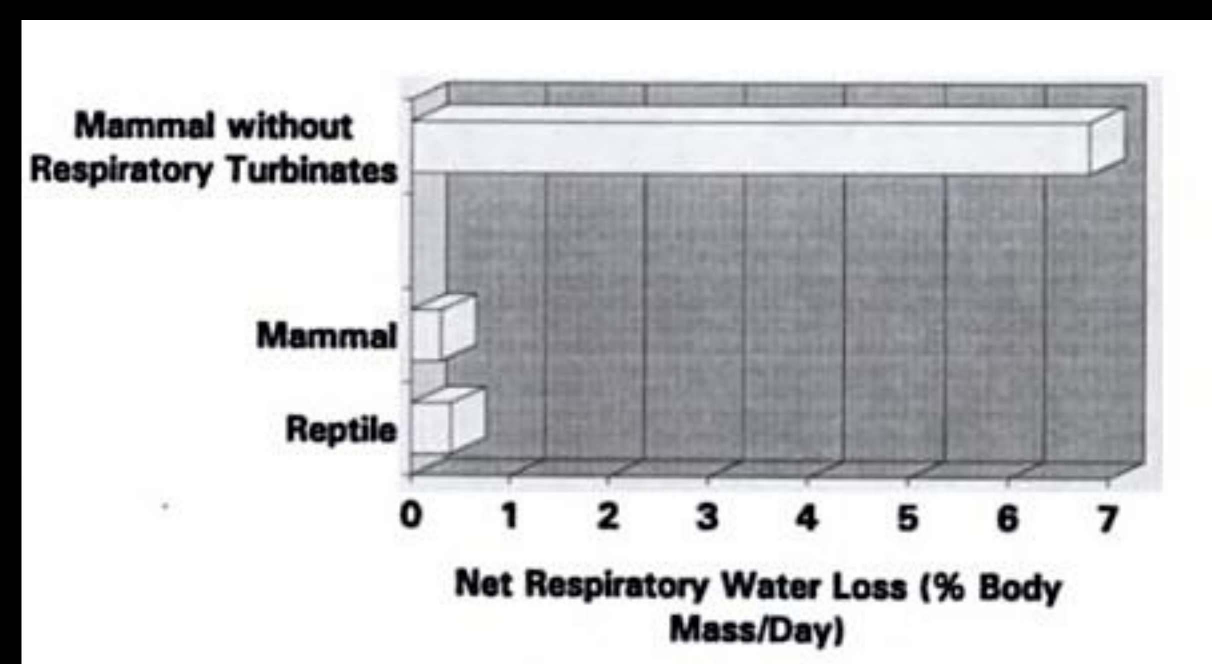


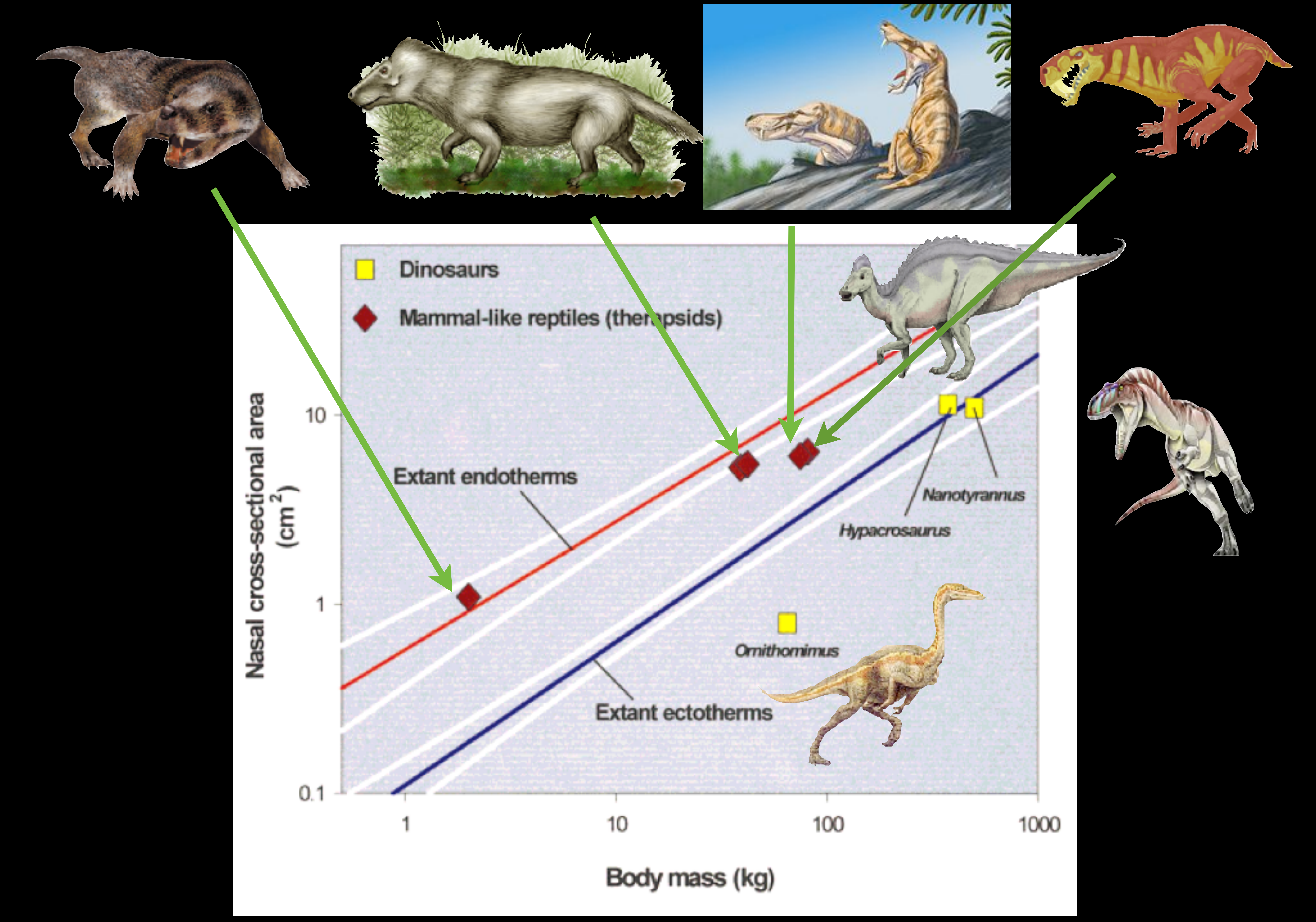
Ornithomimus



Nanotyrannus

Hypacrosaurus





Dinosaurs
Mammal-like reptiles (therapsids)
Extant endotherms
Extant ectotherms
Nanotyrannus
Hypacrosaurus
Ornithomimus
Nasal cross-sectional area (cm^2)
Body mass (kg)
0.1
1
10
100
1000

Dinosaur Metabolism: Conclusions

Dinosaurs were unlike modern endotherms or modern ectotherms! Oh great!

1) Dinosaurs seem to be a mixed bag
2) Large ornithopods and theropods were likely homeothermic endotherms as juveniles, and more like homeothermic ectotherms as adults
3) Sauropods were likely gigantotherms ~ their large size retained core heat (small SA:V); homeothermic without the cost of endothermy
4) Small ornithopods and theropods were likely homeothermic endotherms throughout lives
5) Some large slow-moving ornithischians were likely more ectothermic, and perhaps poikilothermic