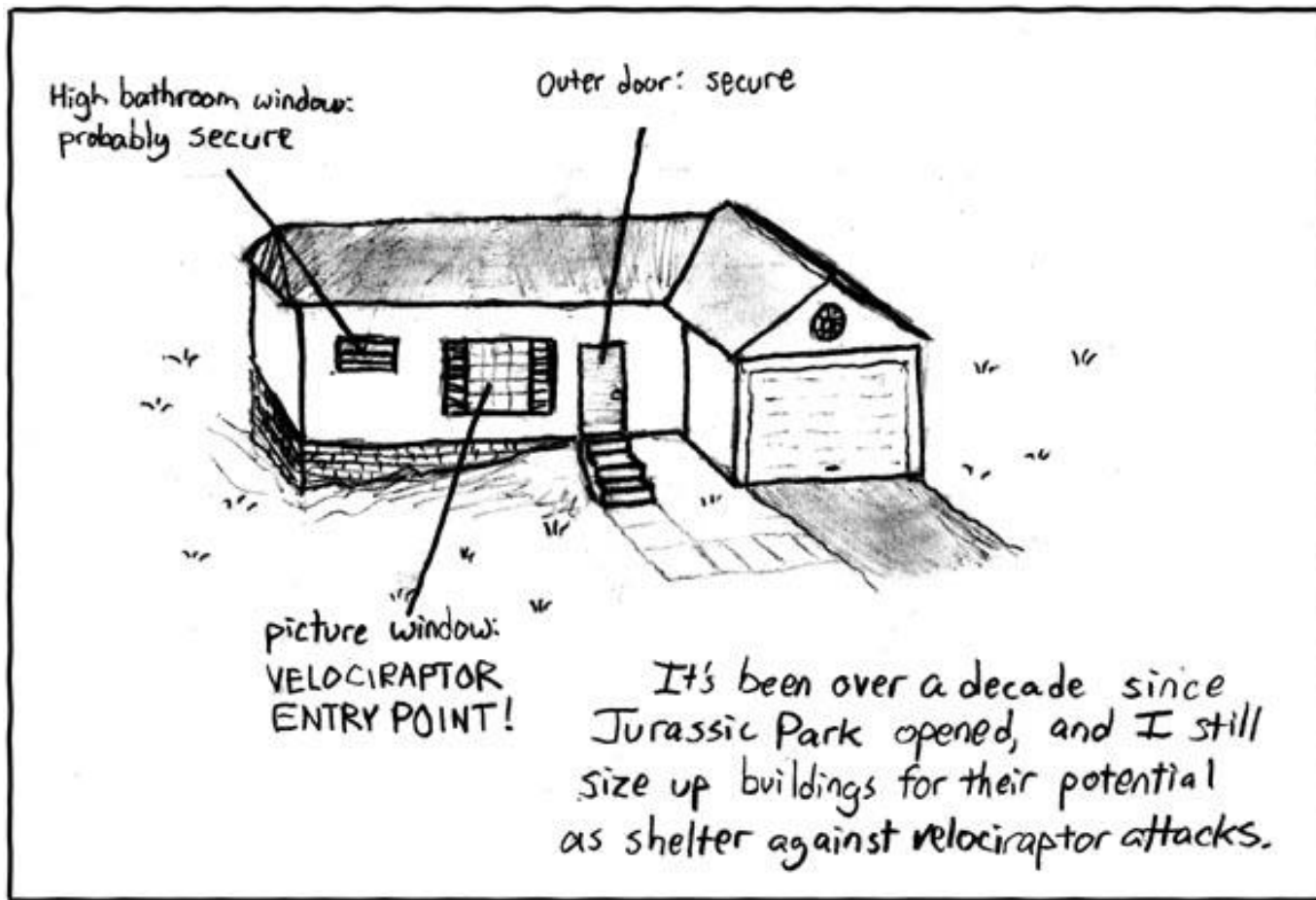


# LIVING IN A JURASSIC WORLD

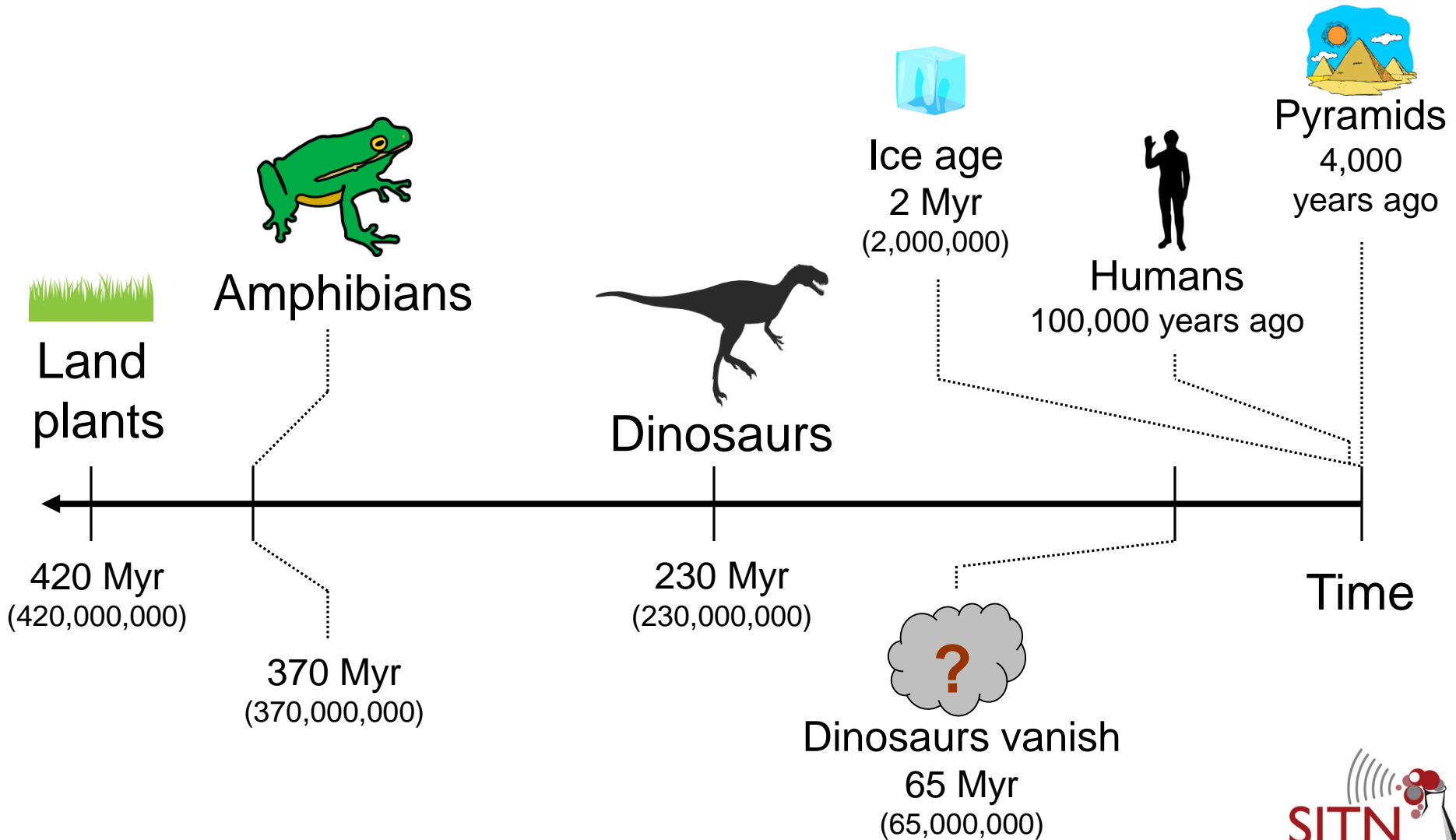
Could dinosaurs be  
lurking in our  
backyards?

Martin Fan  
Matt Schwartz

# Part 1: Dinosaur extinction



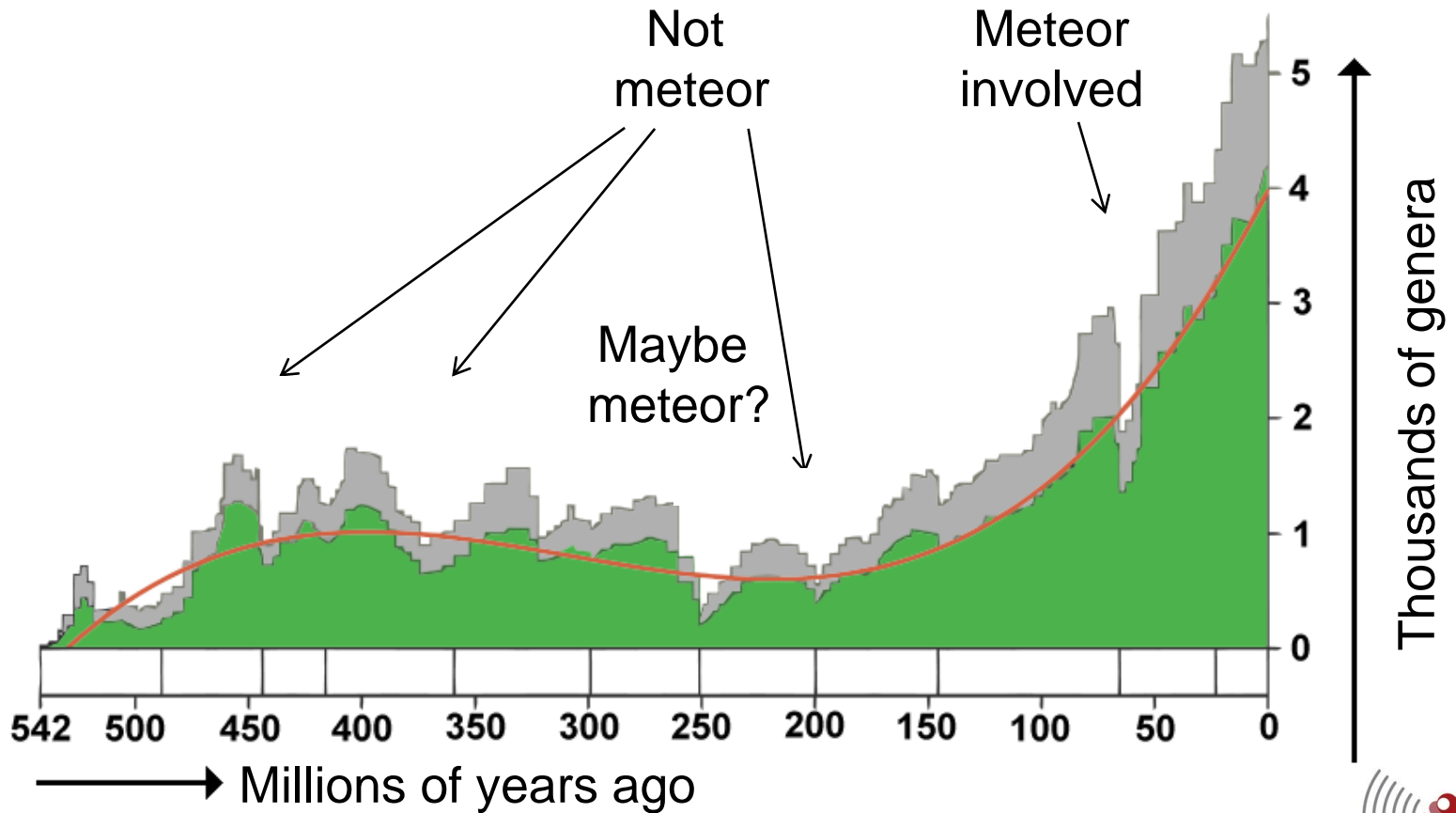
# Dinosaurs: a history



# The popular viewpoint



# Dinosaurs weren't the first, or the biggest, mass extinction



# How might it have happened?

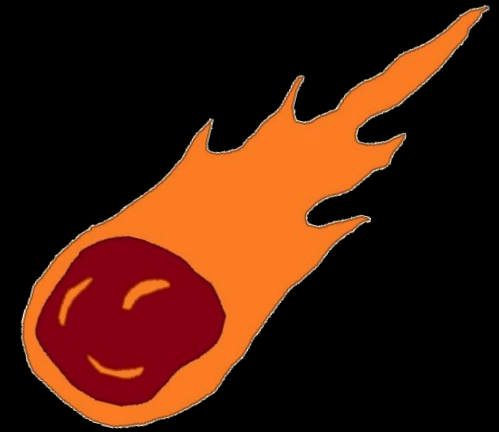
1) Supervolcanoes



4) Future



2) Meteor evidence



3) Meteor impact

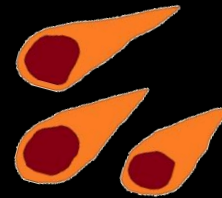




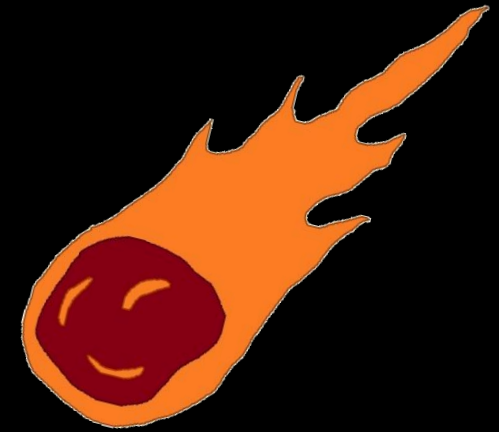
# How might it have happened?



1) Supervolcanoes



4) Future



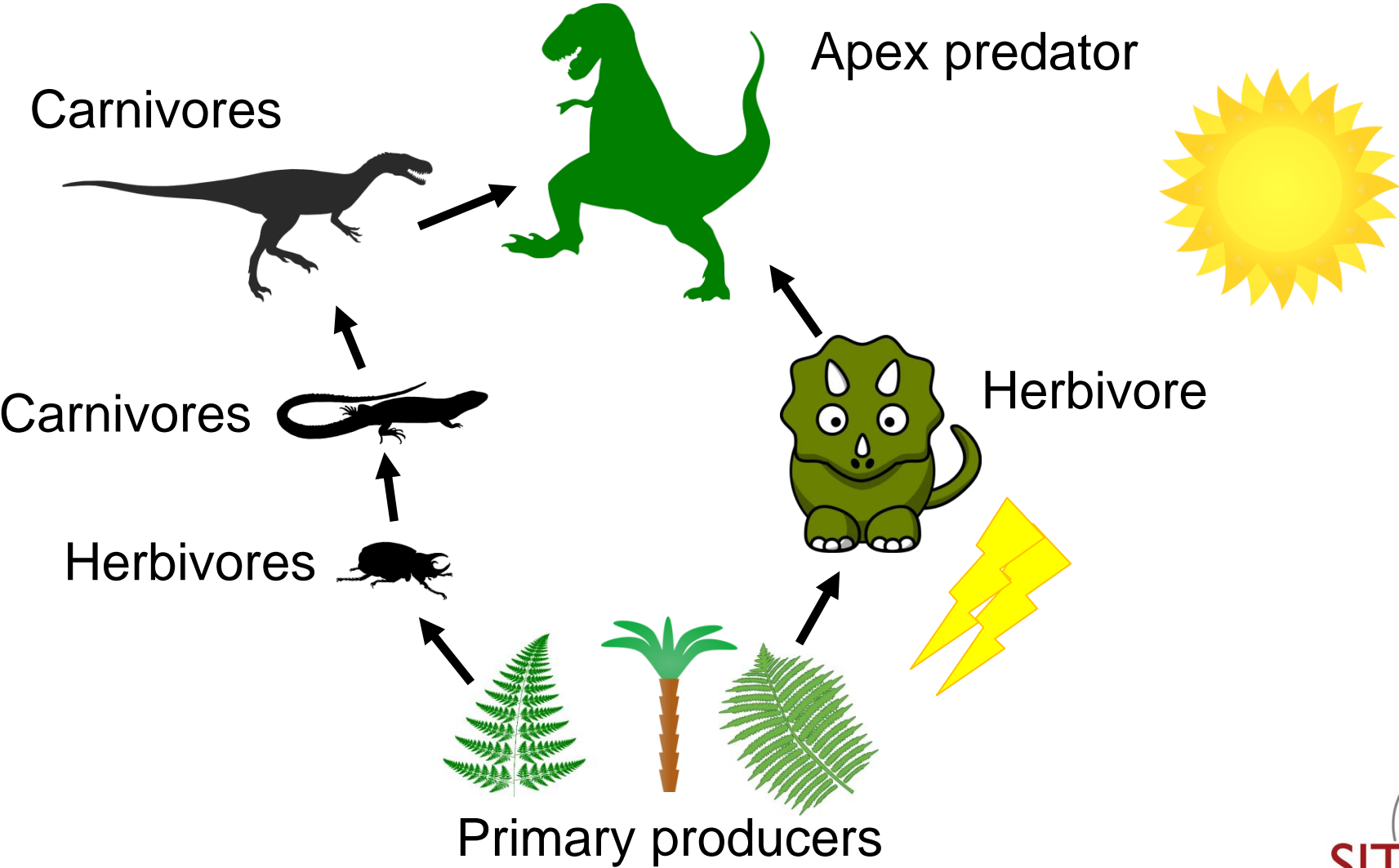
2) Meteor evidence



3) Meteor impact



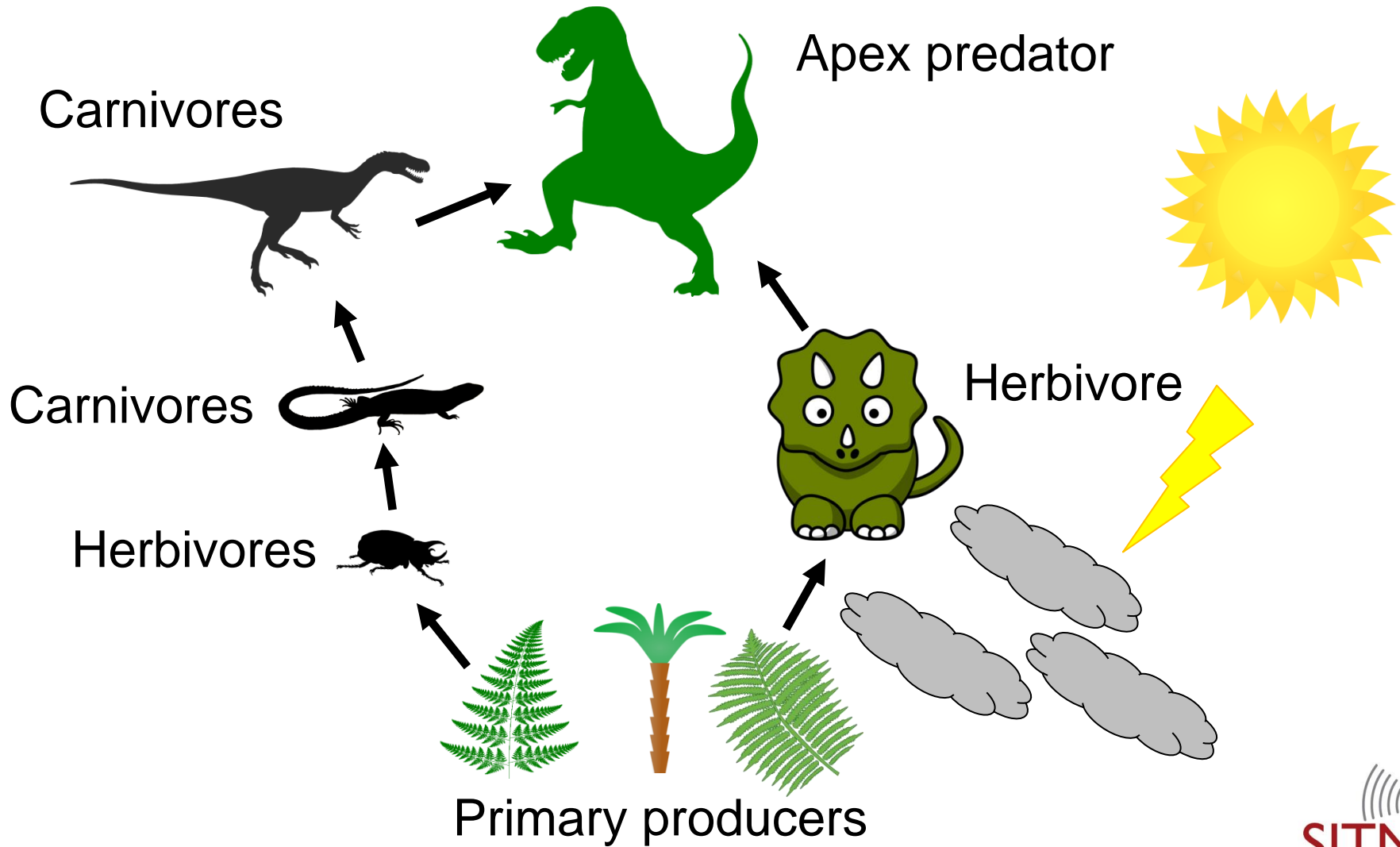
# Food chains



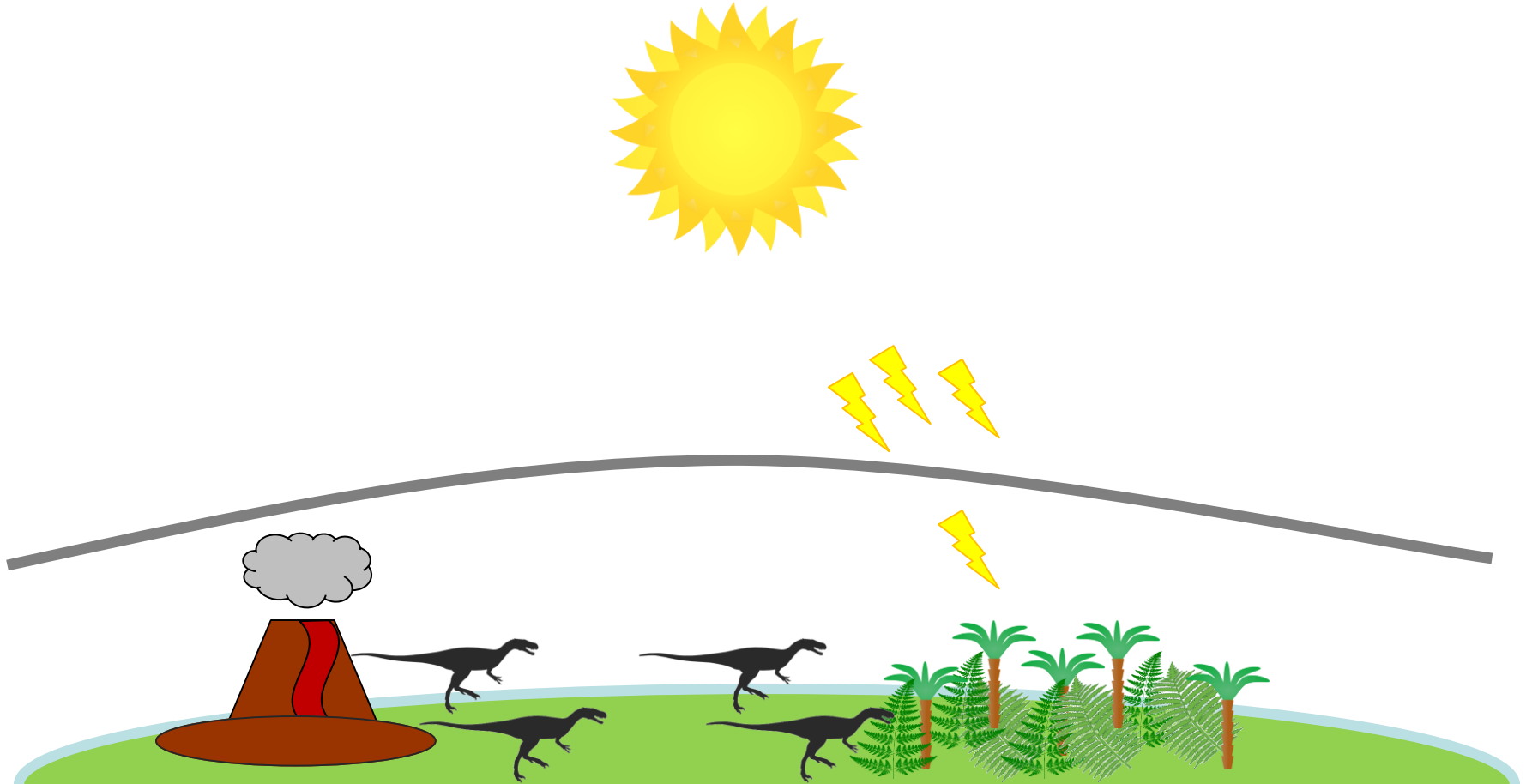
Images from Microsoft ClipArt



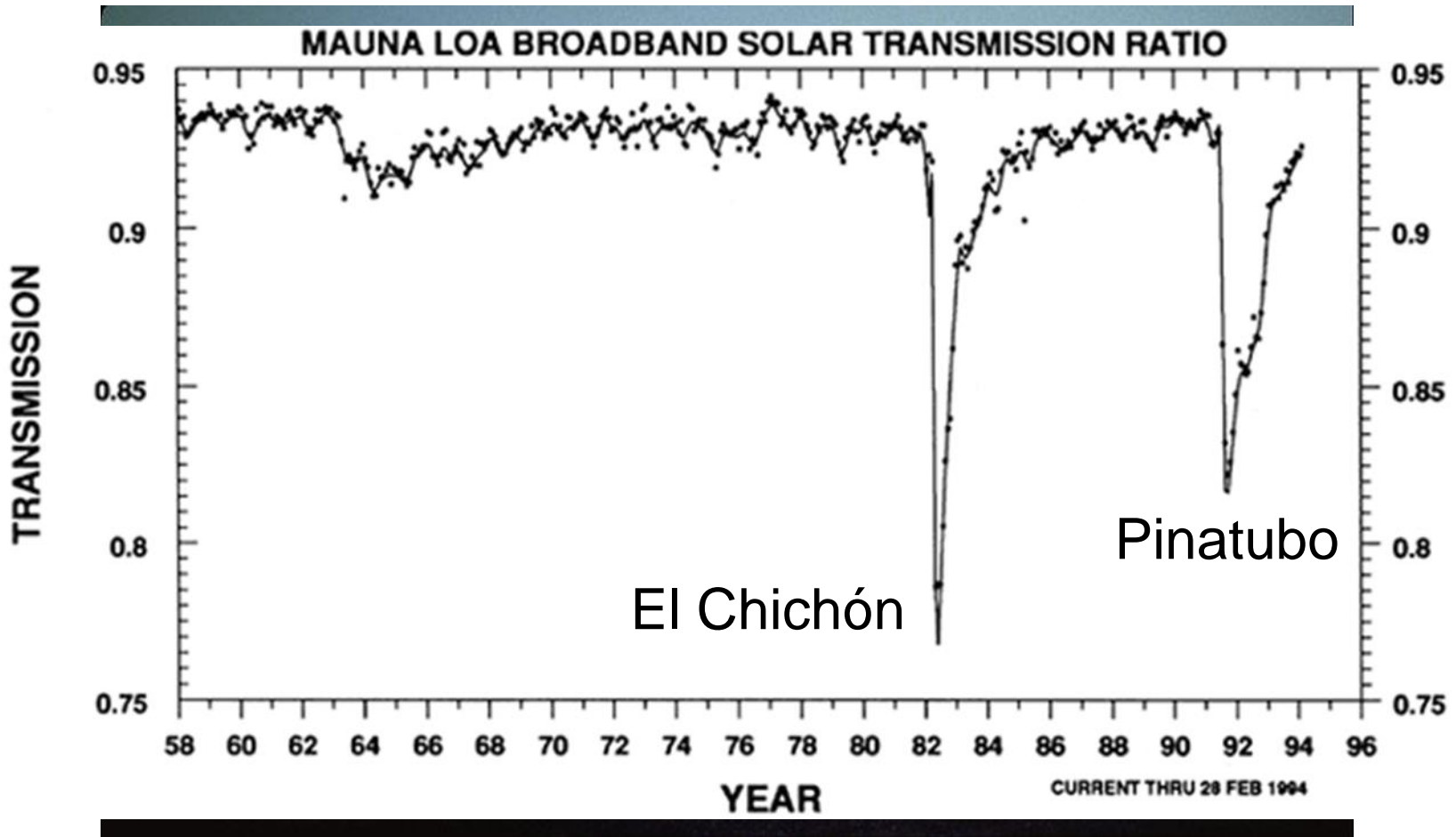
# Food chain collapse



# Volcanic winter



# Mount Pinatubo

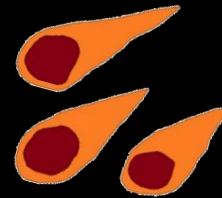


# Why do we think it was a meteor?

1) Supervolcanoes



4) Future



2) Meteor evidence



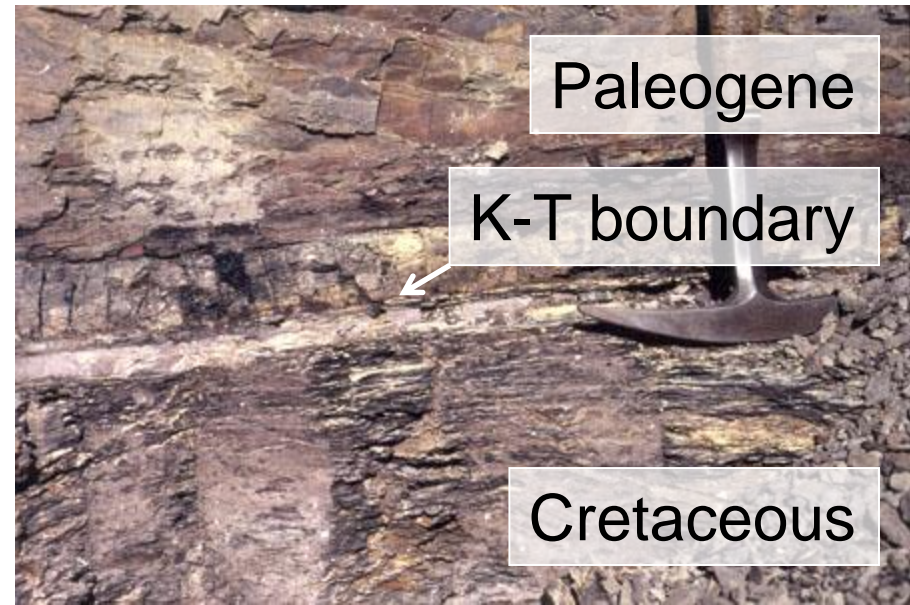
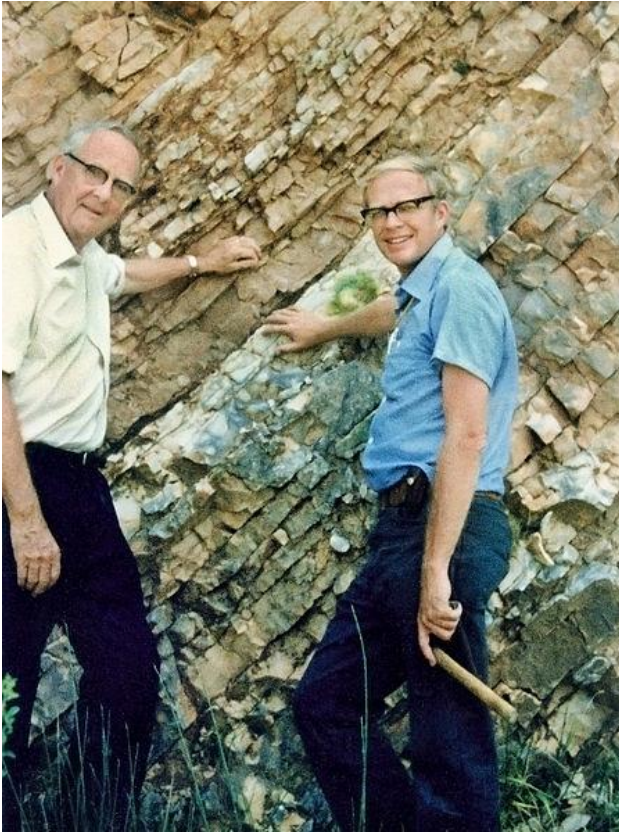
3) Meteor impact



# A clay layer all over the world

Luis  
Alvarez

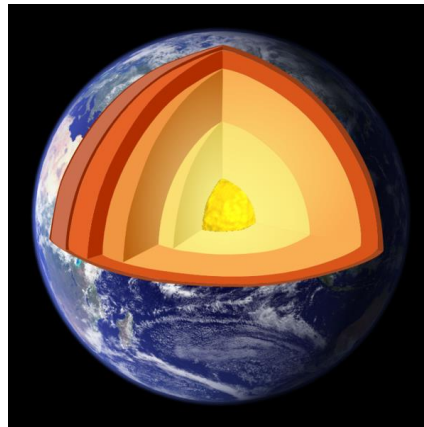
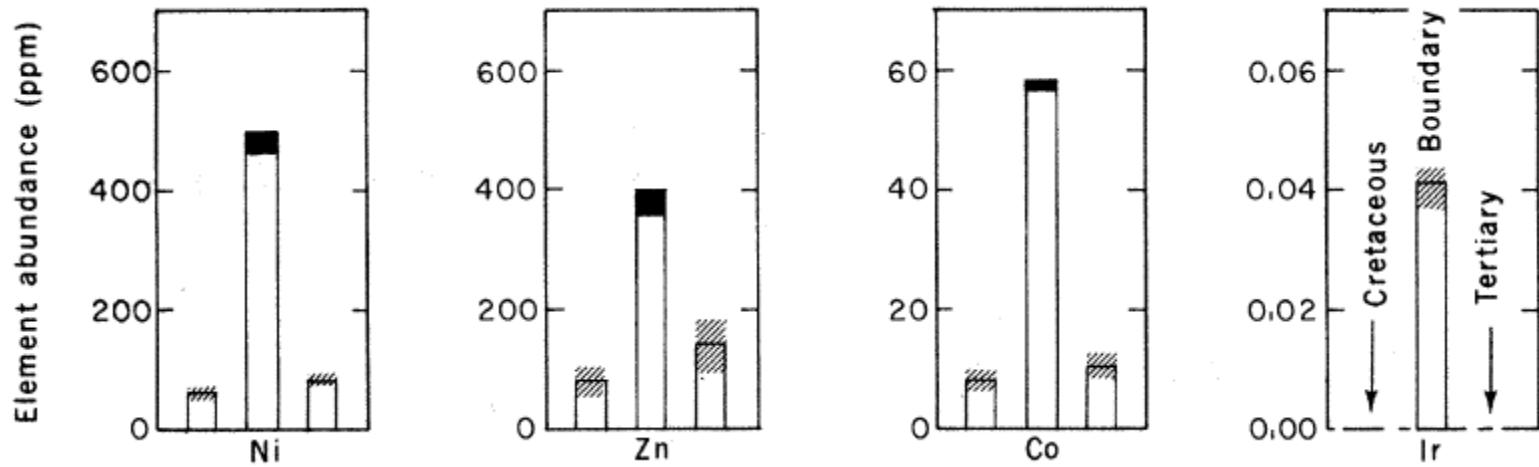
Walter  
Alvarez



[https://en.wikipedia.org/wiki/File:LWA\\_with\\_Walt.JPG](https://en.wikipedia.org/wiki/File:LWA_with_Walt.JPG)

[https://commons.wikimedia.org/wiki/File:K-T\\_boundary\\_at\\_Starkville\\_South.jpg](https://commons.wikimedia.org/wiki/File:K-T_boundary_at_Starkville_South.jpg)

# Iridium at the boundary



From Alvarez, Science 1980. Reprinted with permission from AAAS.  
[https://commons.wikimedia.org/wiki/File:Earth\\_cutaway.png](https://commons.wikimedia.org/wiki/File:Earth_cutaway.png)

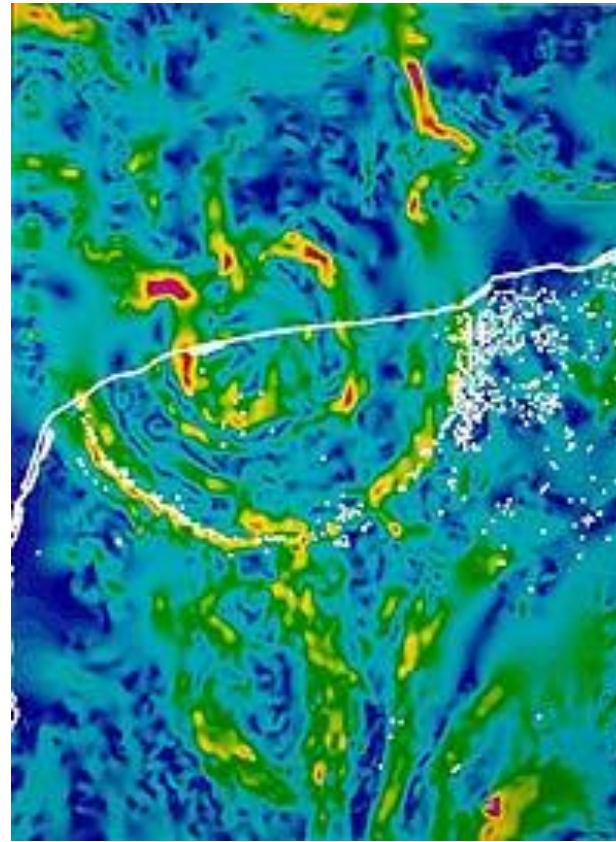


# The smoking gun...or crater

Regular map



Gravity anomaly map

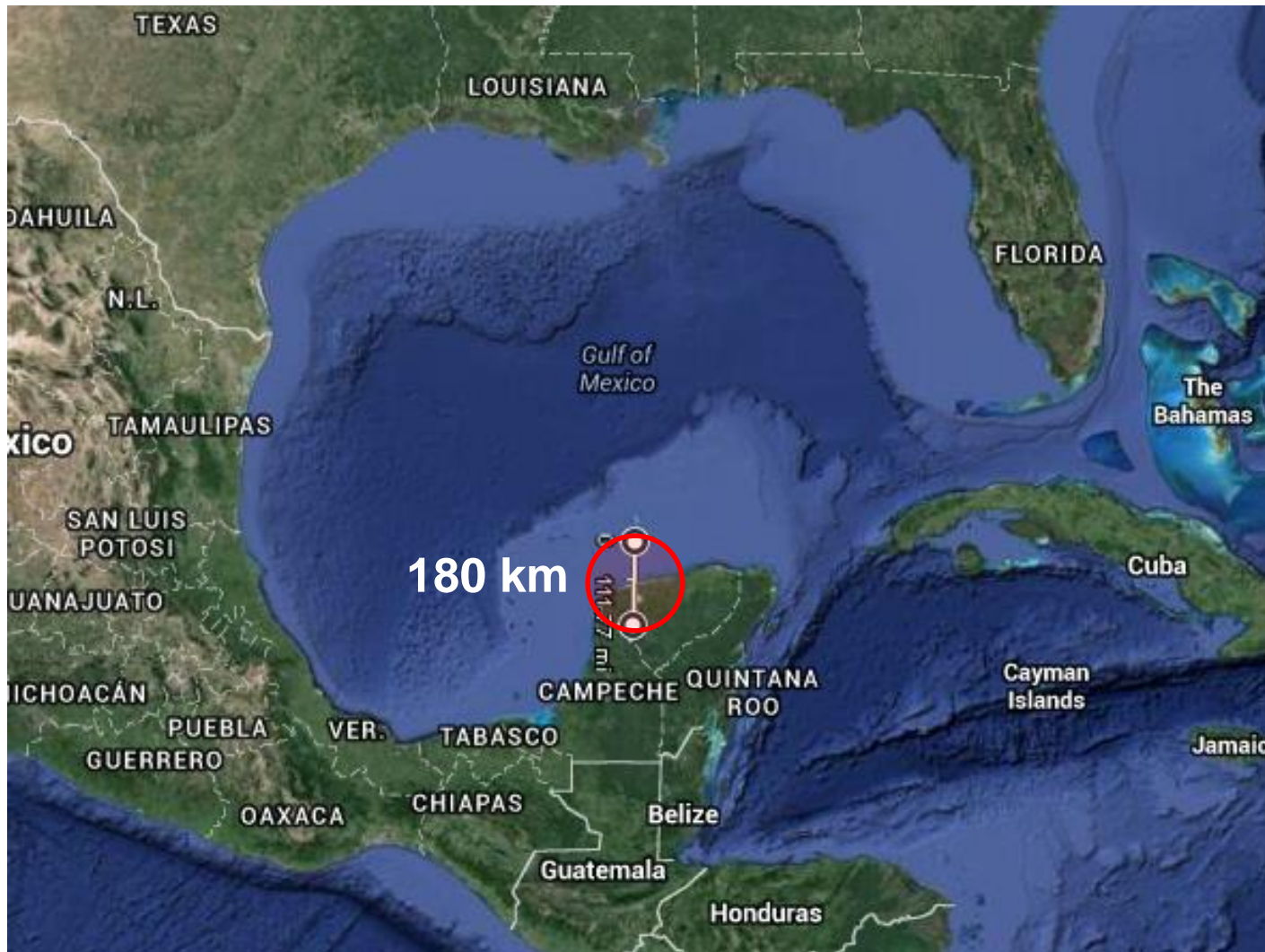


More dense



Less dense

# Crater size



# Summary – Part 1

- Multiple extinction events happened during the reign of the dinosaurs
- Most weren't due to meteors, but more likely supervolcanism and climate change
- We have solid evidence for a meteor impact
  - Iridium all over the world
  - Chicxulub crater in Mexico

# Pause for questions

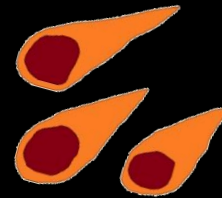
SPEED		
kph	m/s	
5	1.5	WALKING
13	3.5	JOGGING
25	7	SPRINTING
35	10	FASTEST HUMAN
45	13	HOUSECAT
55	15	RABBIT
75	20	RAPTOR
100	25	SLOW HIGHWAY
110	30	INTERSTATE (65 MPH)
120	35	SPEED YOU ACTUALLY GO WHEN IT SAYS "65"
140	40	RAPTOR ON HOVERBOARD

# What would be the effects of a meteor impact?

1) Supervolcanoes



4) Future



2) Meteor evidence



3) Meteor impact





# The popular viewpoint

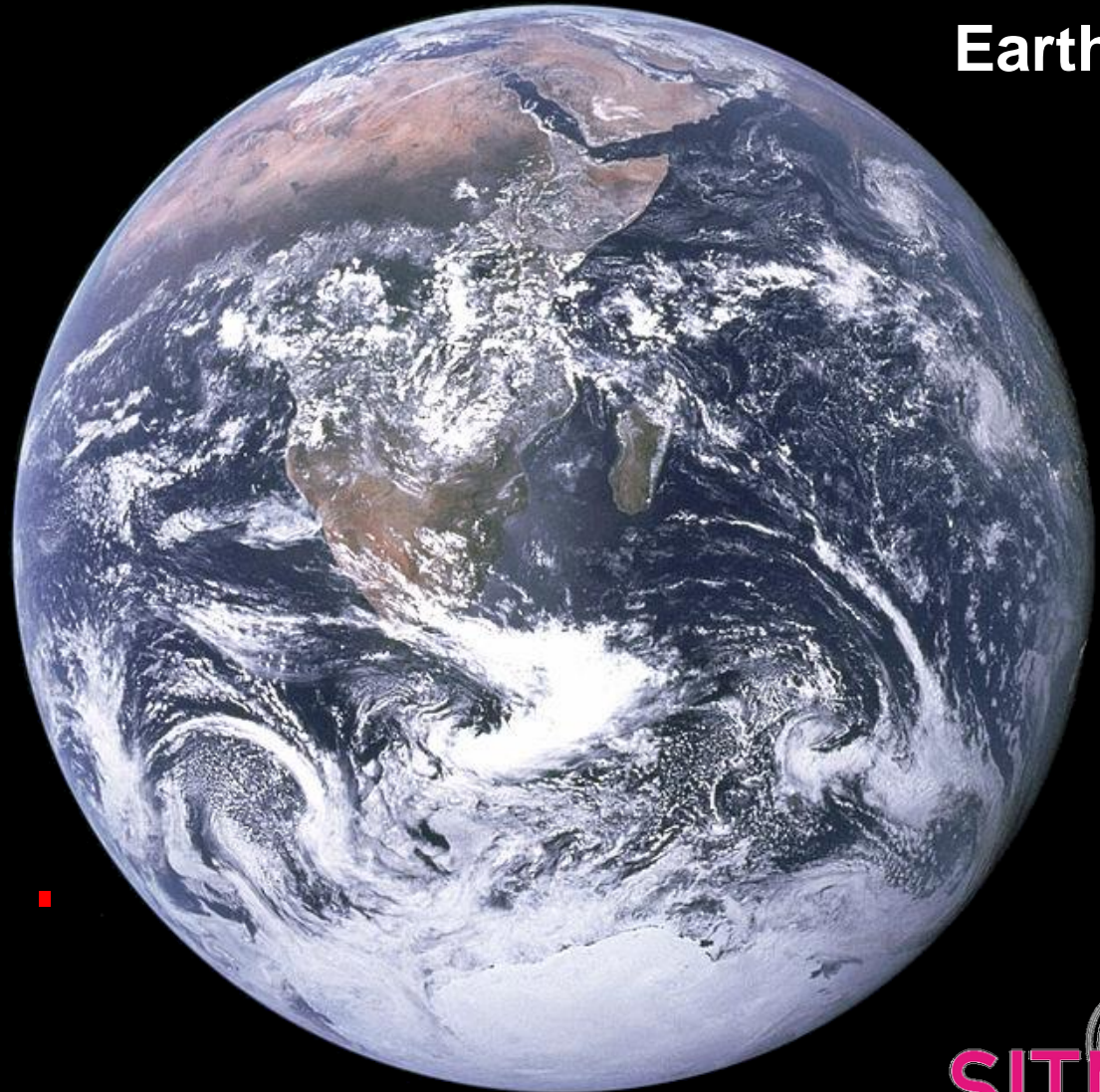




# Realistic asteroid size



**Moon**

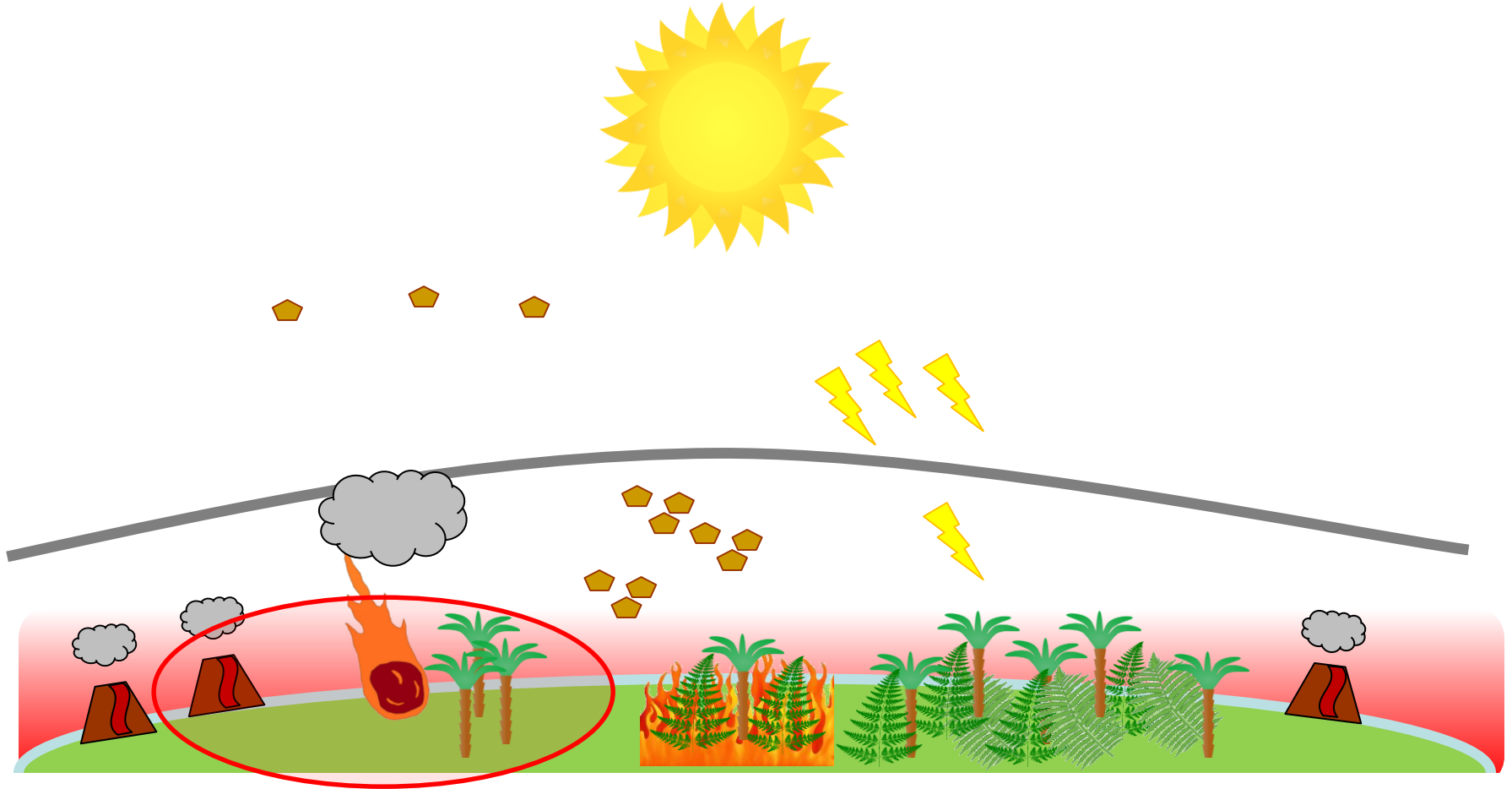


**Earth**

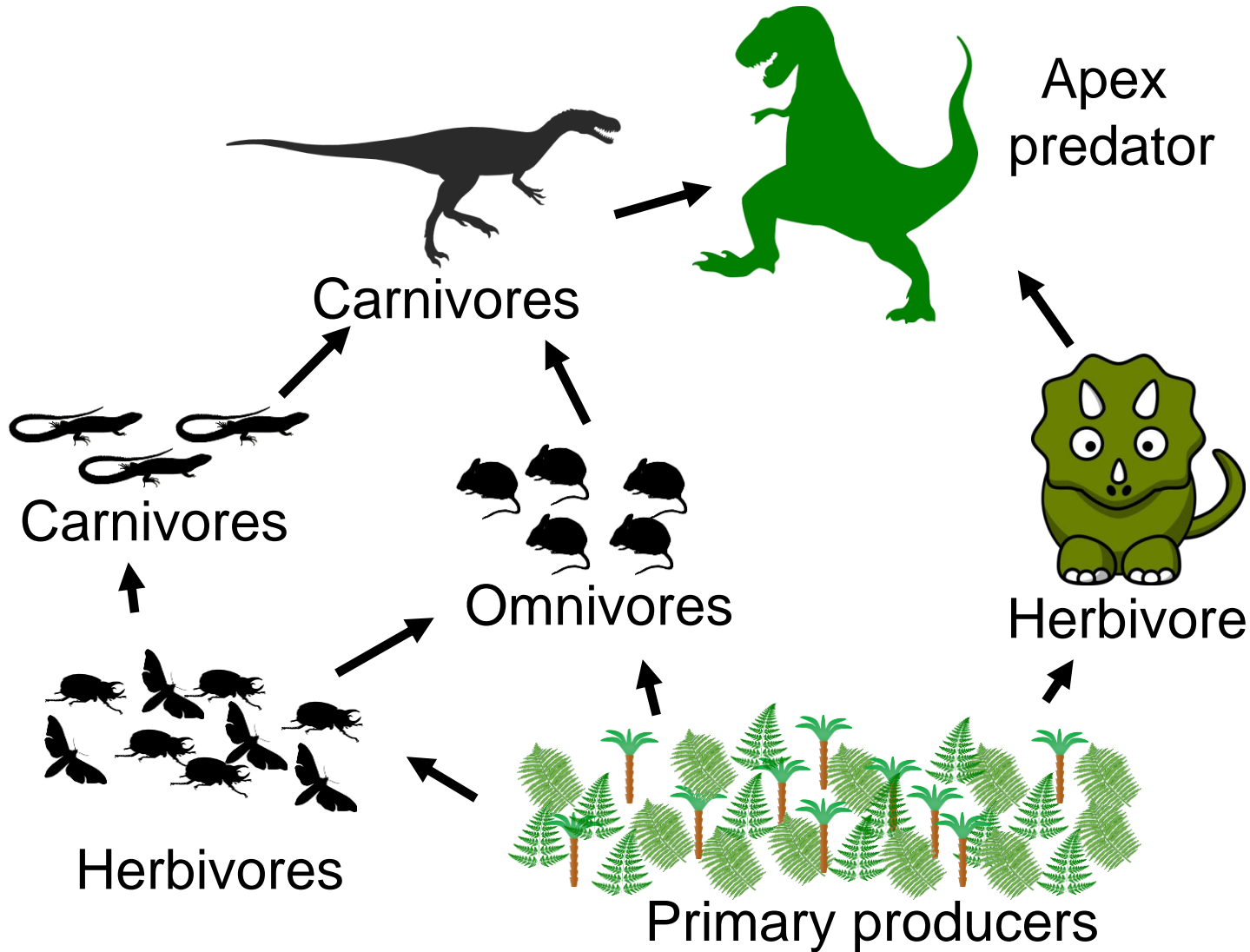


Adapted from  
[https://en.wikipedia.org/wiki/Ceres\\_%28dwarf\\_planet%29](https://en.wikipedia.org/wiki/Ceres_%28dwarf_planet%29)

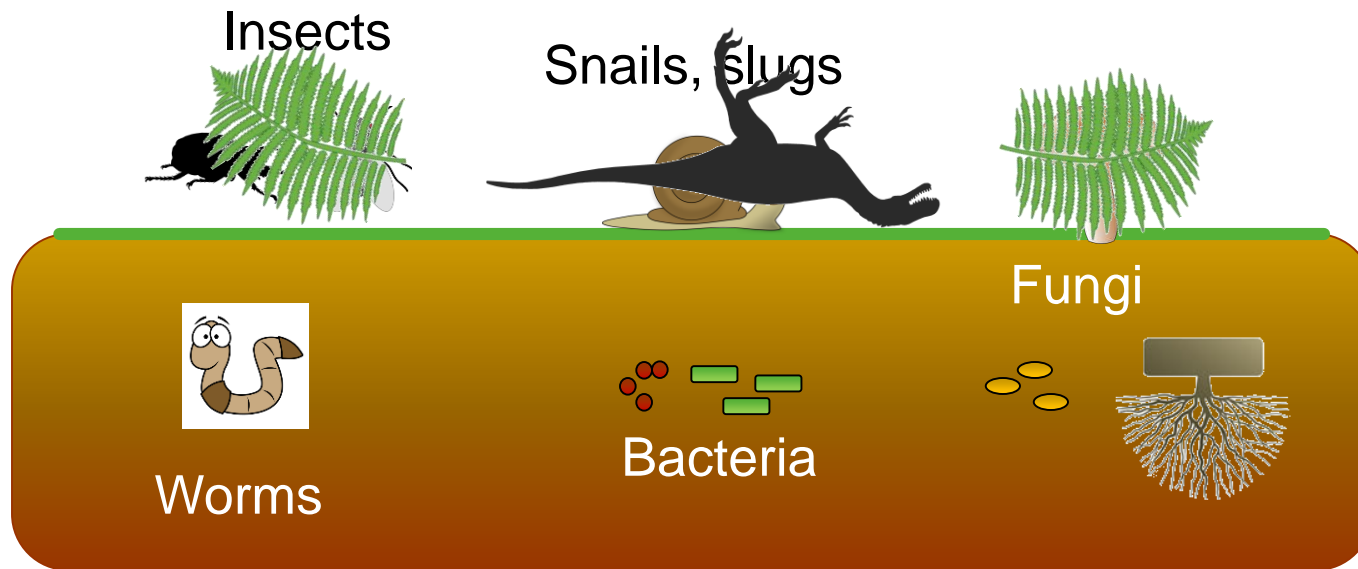
# Effects of impact



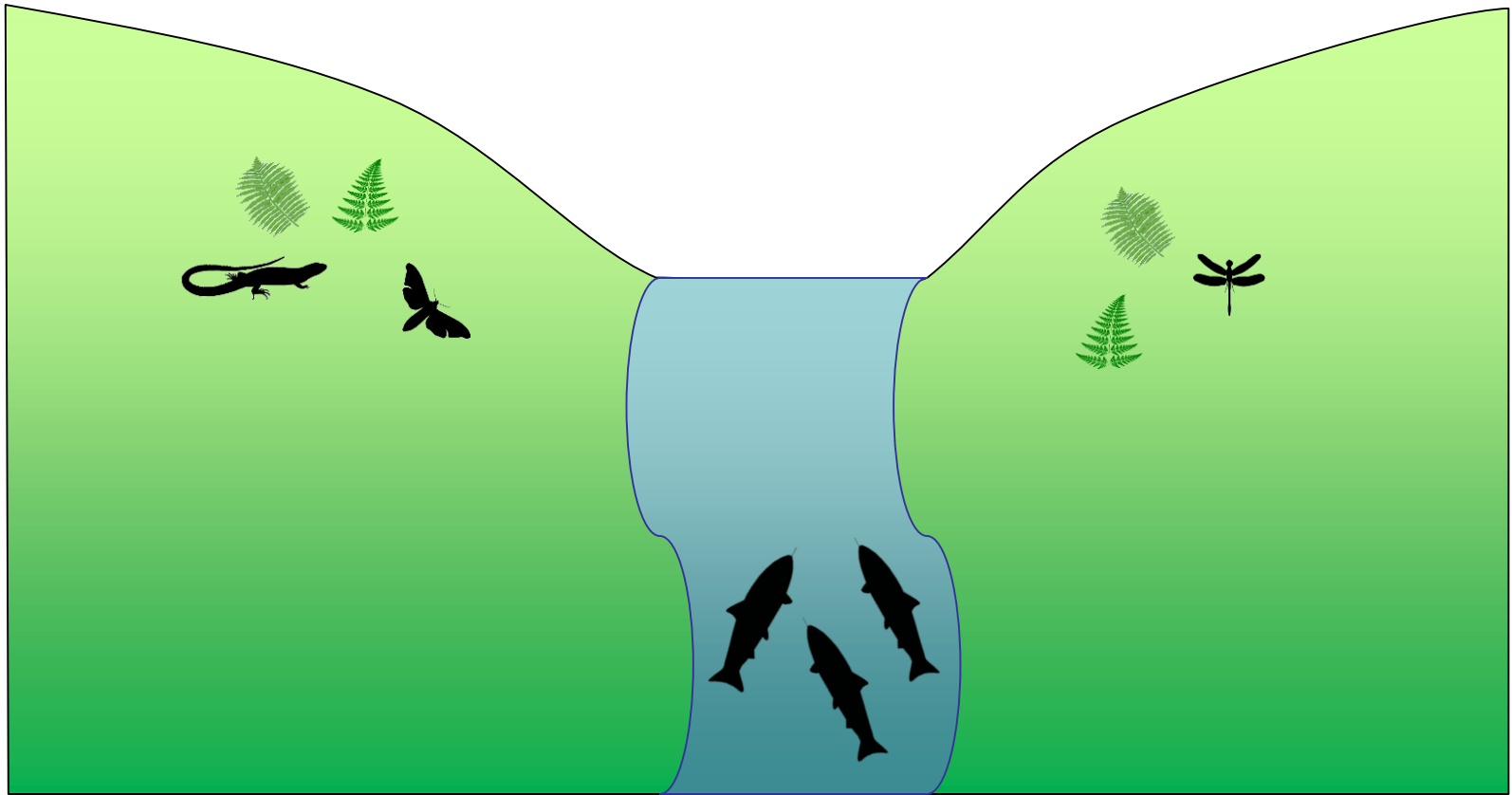
# Survivors: smaller animals



# Winners 1: Decomposers



# Winners 2: Stream communities



# Could this happen again?

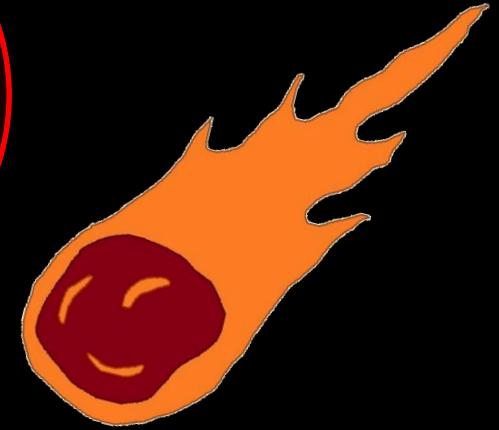
1) Supervolcanoes



4) Future



2) Meteor evidence

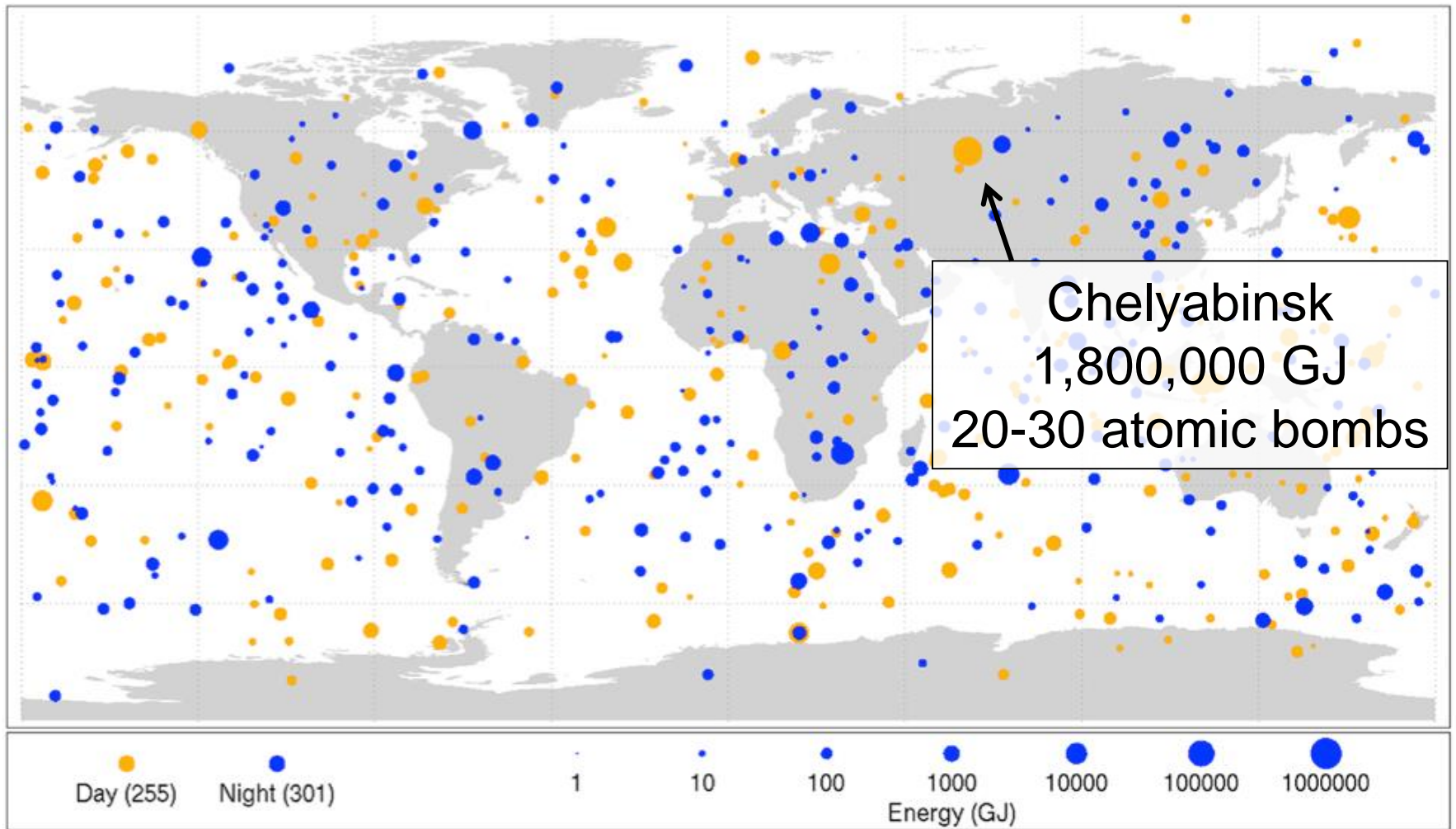


3) Meteor impact





# Asteroid events 1994-2013

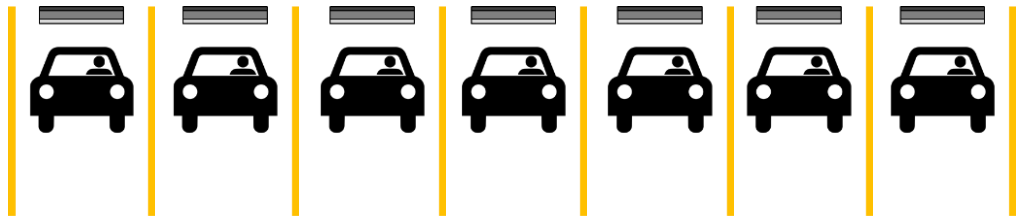
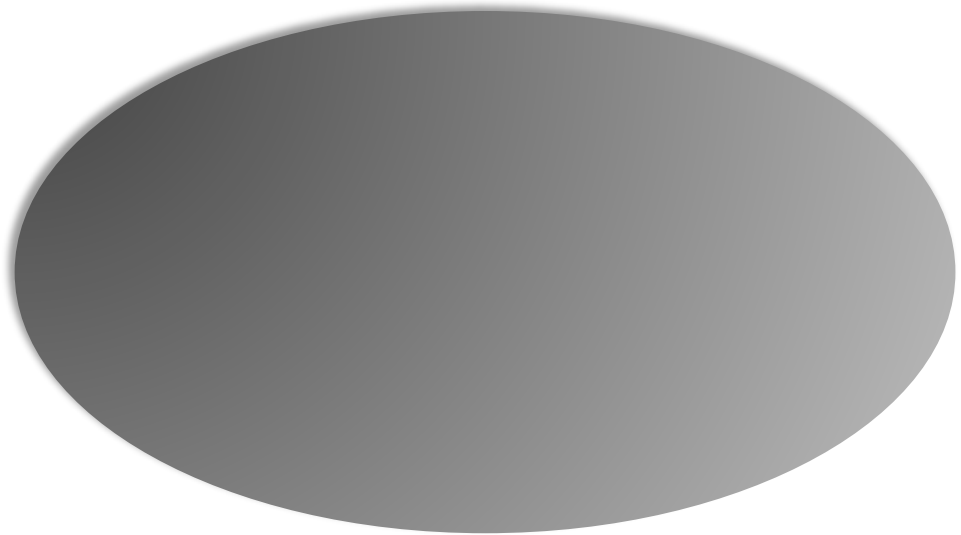


# Chelyabinsk vs Chicxulub

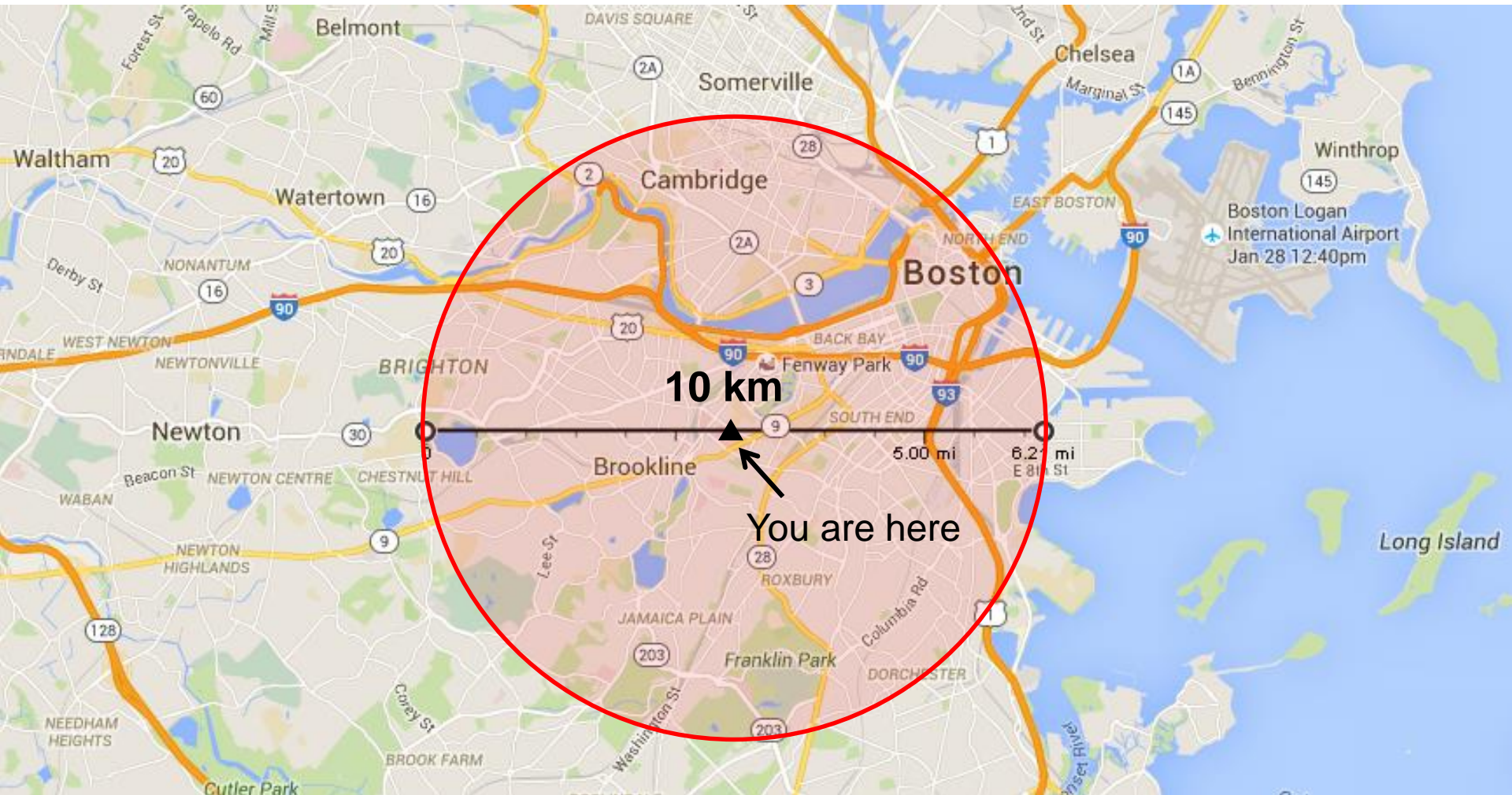
Parking space  
~2.3 meters



Chelyabinsk object  
~15 meters, or 6 ½ parking spaces

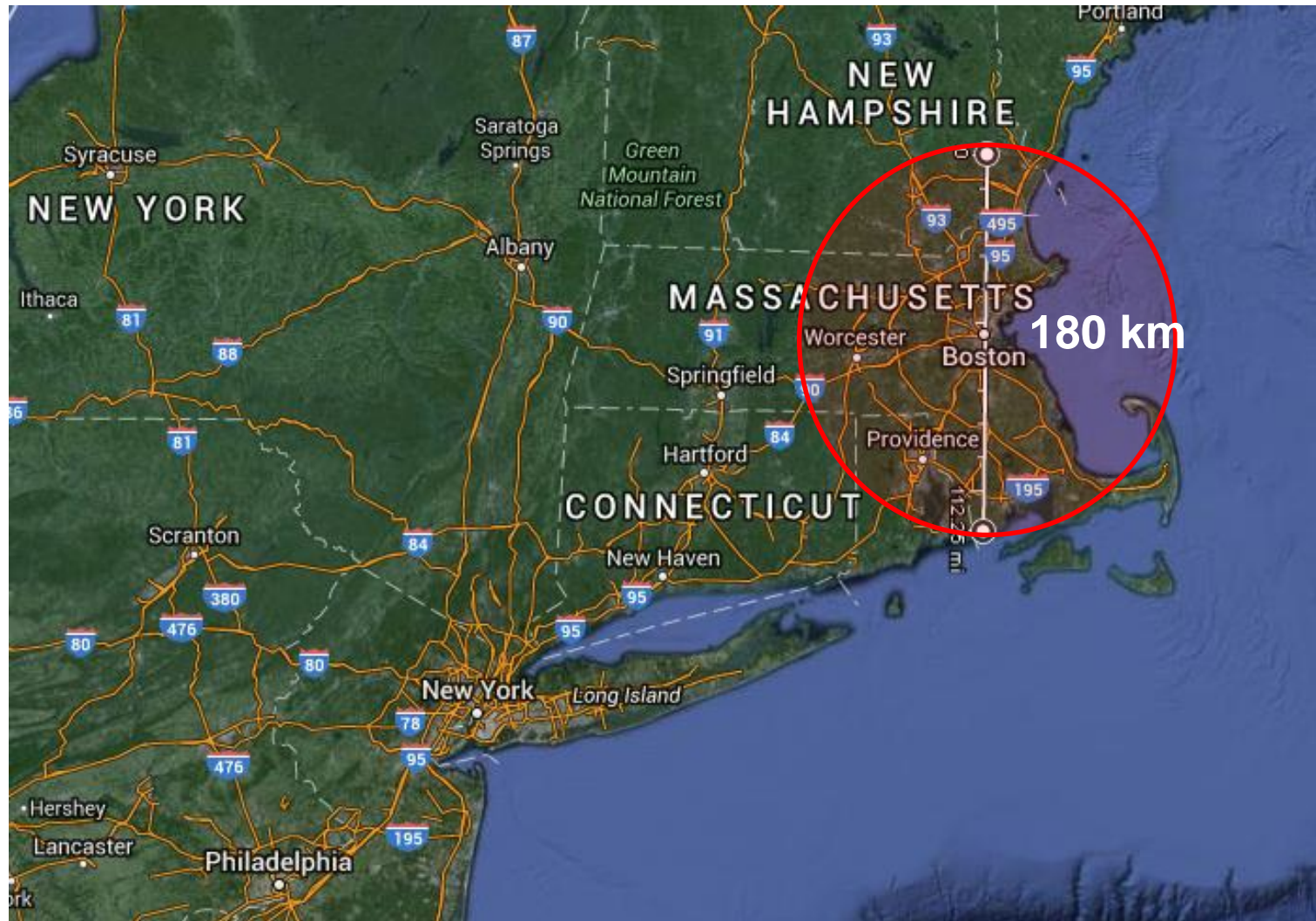


# Chelyabinsk vs Chicxulub

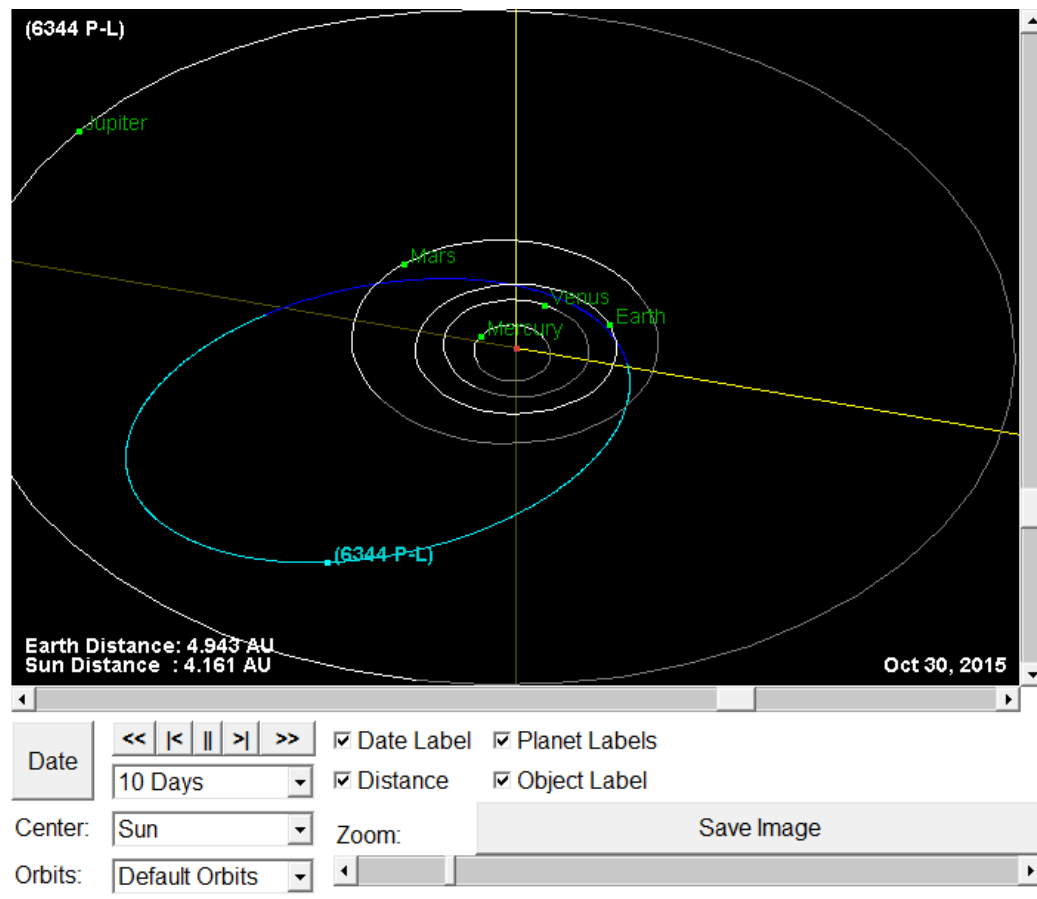




# Crater size



# Monitoring efforts

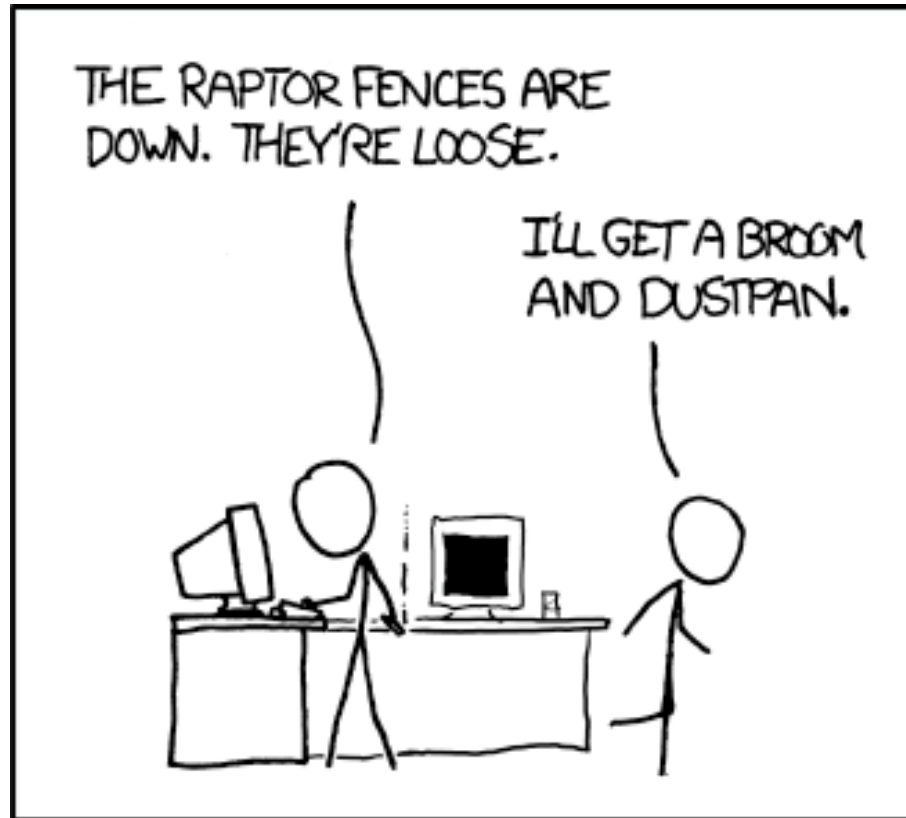


# Summary – Part 2

- It was ash, not the shock or the heat of the impact, that killed off the dinosaurs
- Volcanoes were important too - it was both the meteor and volcanoes!
- Smaller animals and omnivores were best able to survive on limited food
- Some communities had an abundance of food during the extinction



# Final questions



JURASSIC PARK GOT A LOT LESS SCARY WHEN THE RESEARCHERS DISCOVERED THEY COULD ACTIVATE THE GENE FOR EXTREME DWARFISM.

# Part II: What is a Dinosaur?



(Hic et nunc, Didier Descouens)

# What is a Dinosaur?

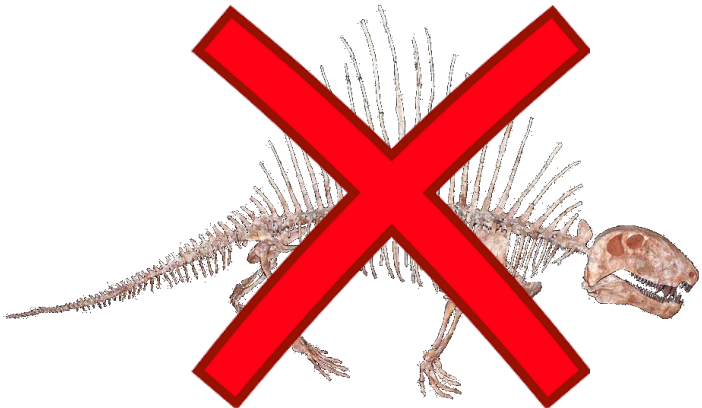
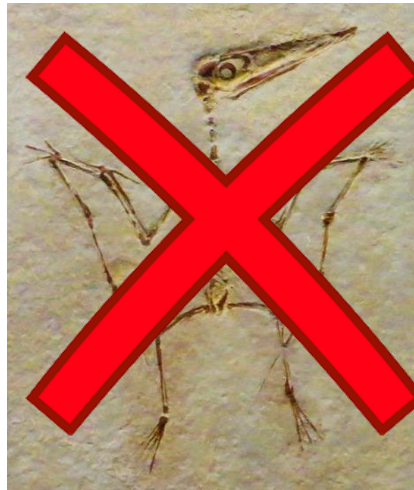
- What is a dinosaur
- How birds might have survived extinction
- Anatomical evidence birds evolved from dinosaurs
- Behavioral evidence birds evolved from dinosaurs

# Traditional Vertebrate Classifications

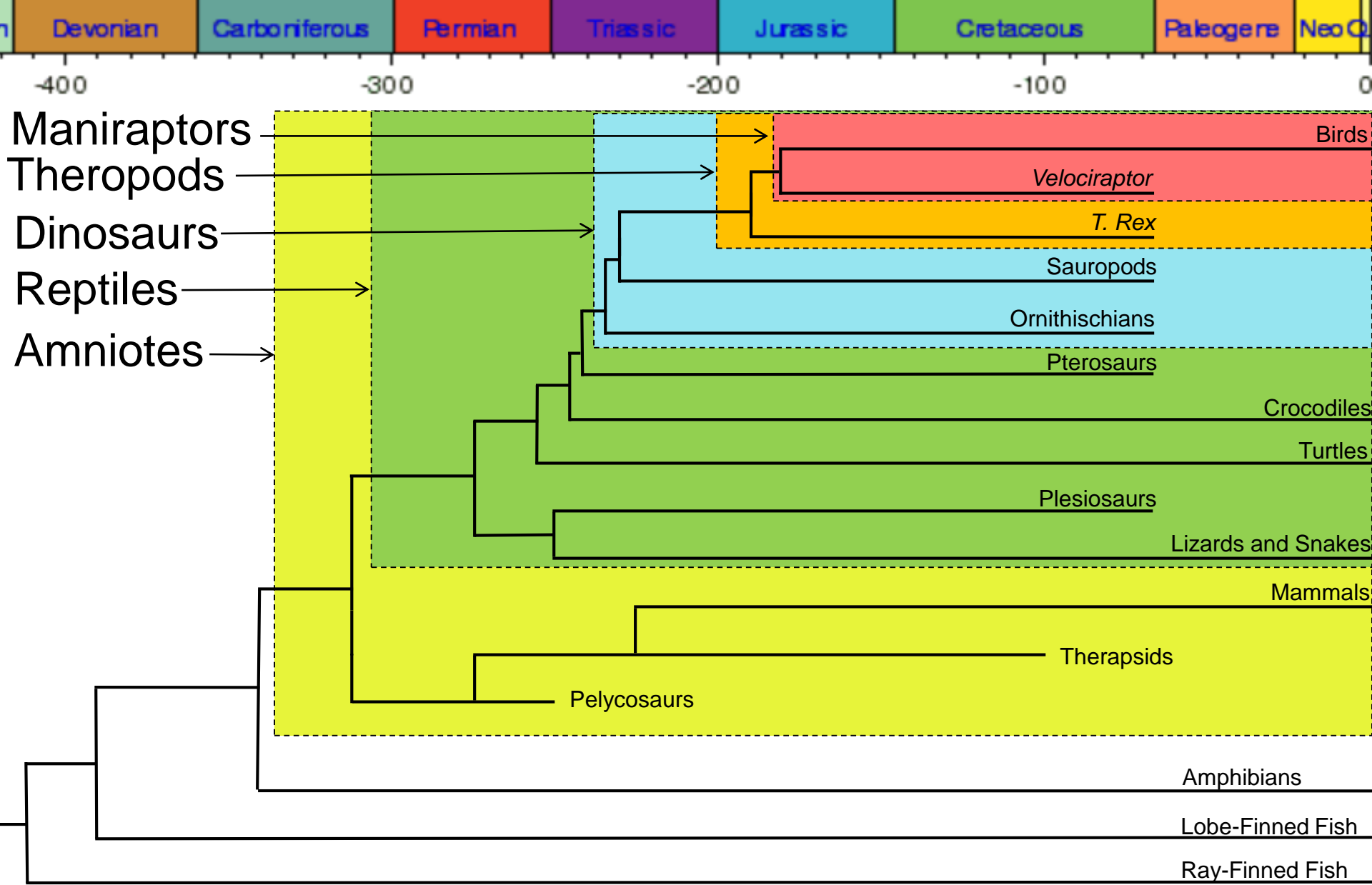
- Fish
- Amphibians
- Reptiles
- Birds
- Mammals
- Dinosaurs?



# Are these Dinosaurs?

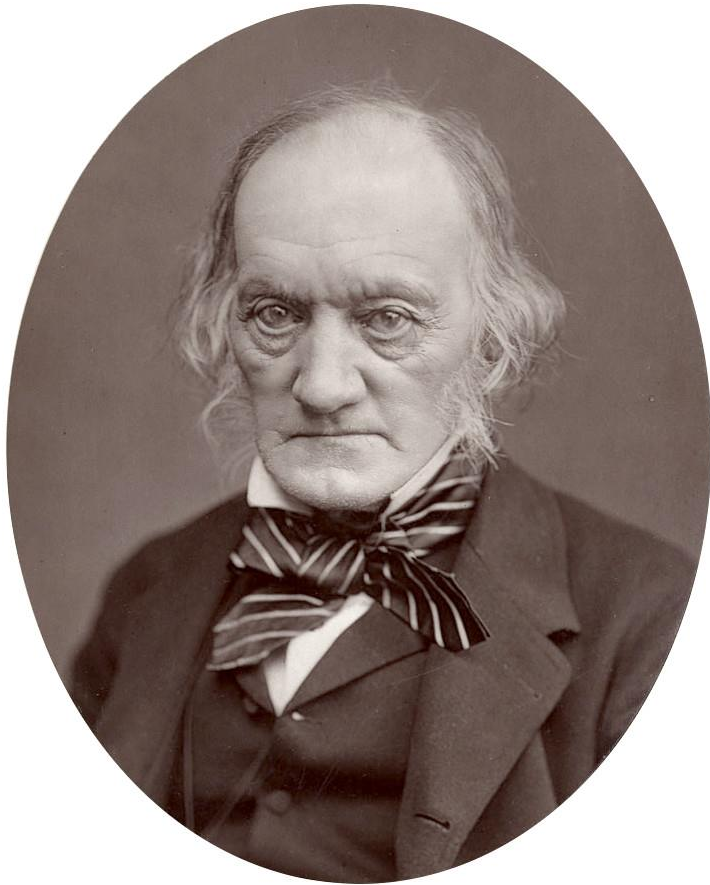


(Hic et nunc, H Zell, plesiosauria.com, Ghedoghedo, Didier Descouens)



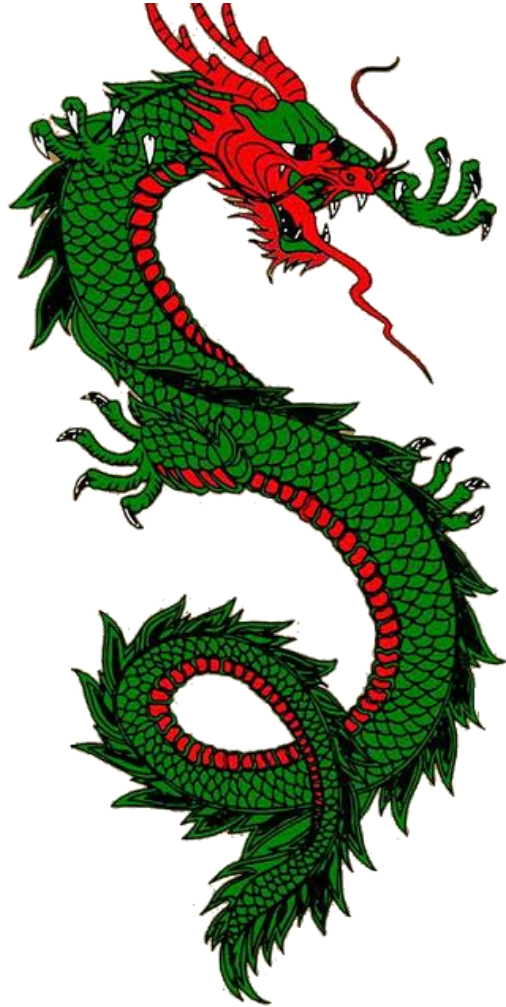


# Dinosaurs Defined



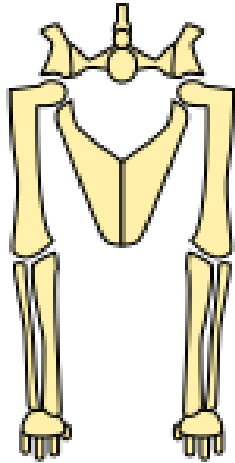
- Named by Paleontologist Sir Richard Owen in 1842
- Derived from Greek *deinos* “terrible” *sauros* “lizard”
- Name intended to evoke size and majesty
- Three previously scientifically described dinosaurs:  
Megalosaurus (1824), Iguanodon (1825), and Hylaeosaurus (1833)

# Misattributed Dinosaur Discoveries

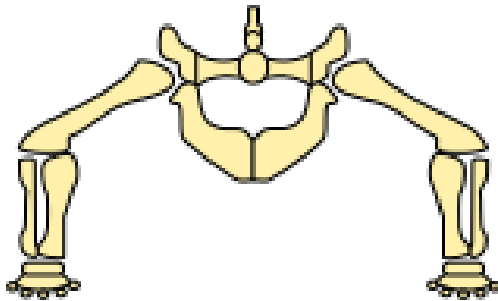


- “Dragon” fossil from 4<sup>th</sup> century BC Chinese historian Chang Qu

# What makes a dinosaur?

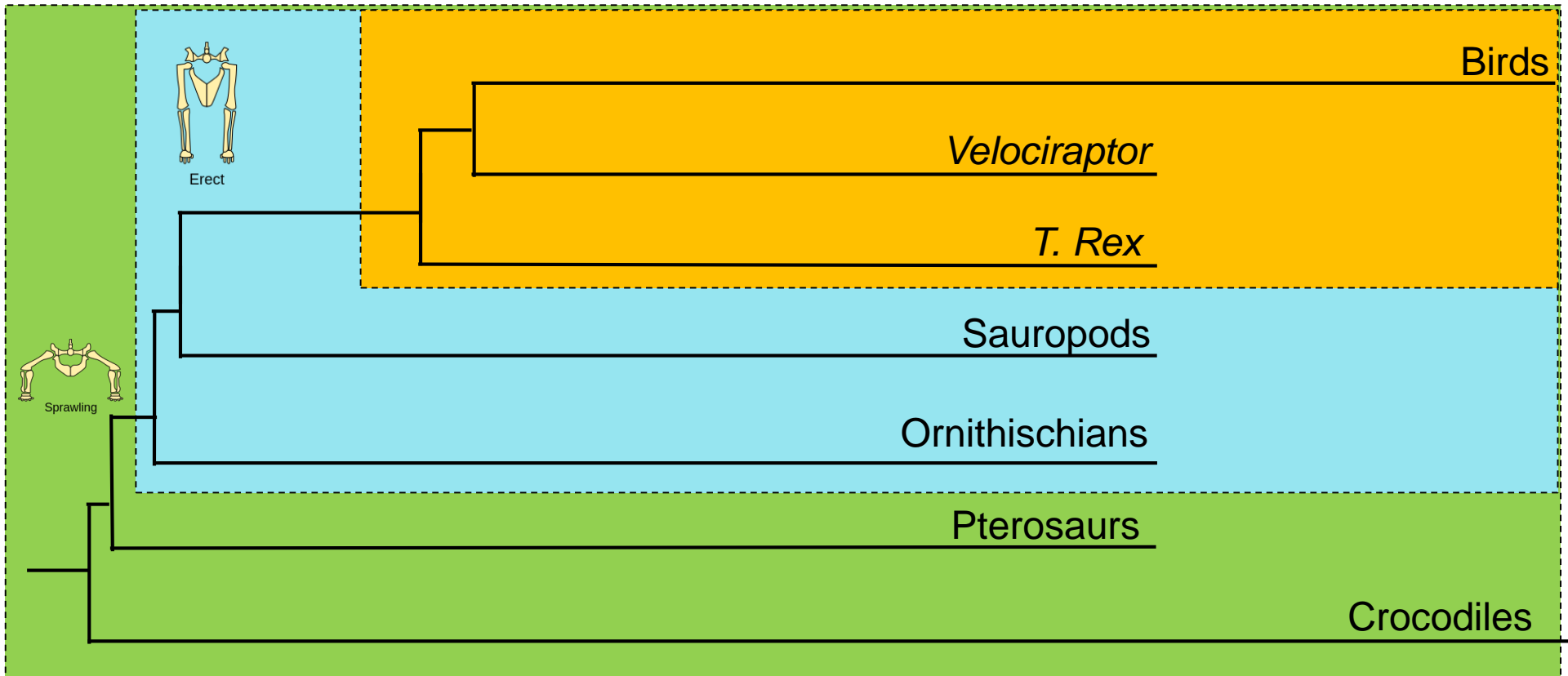
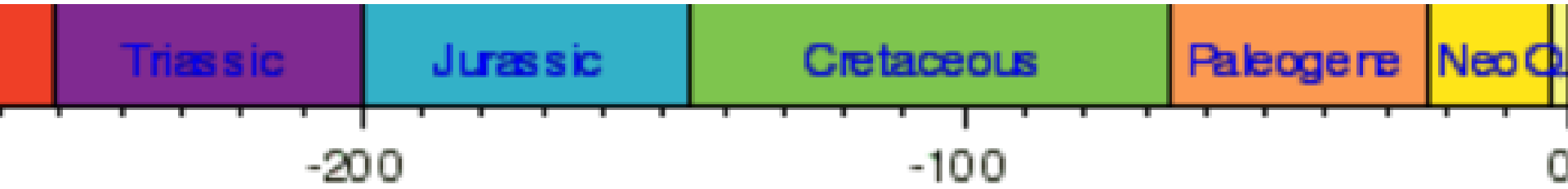


Erect

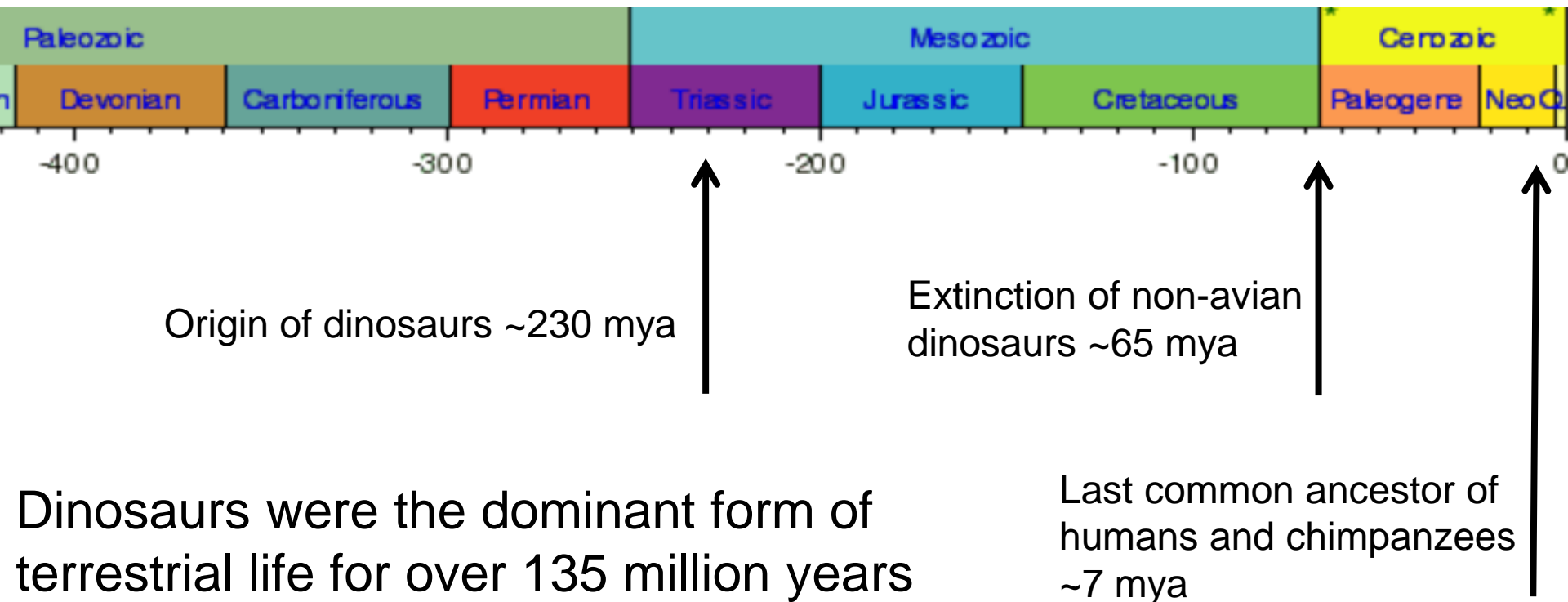


Sprawling

- Erect posture due to hip socket
- Easier breathing while moving, higher activity
- Supports more weight, reduced bending stress



# Dinosaurs: By the Numbers



Dinosaurs were the dominant form of terrestrial life for over 135 million years

- >19x longer than the time since the last common ancestor between humans and chimpanzee

# What is a Dinosaur?

- What is a dinosaur
- How birds might have survived extinction
- Anatomical evidence birds evolved from dinosaurs
- Behavioral evidence birds evolved from dinosaurs



# Dinosaur Size Comparison

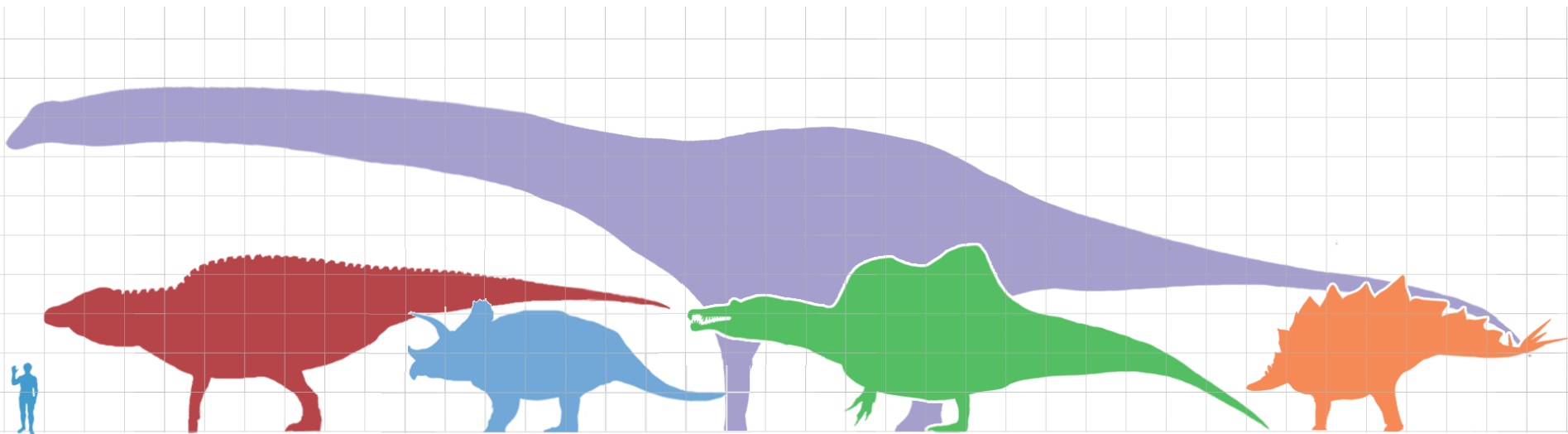
■ *Argentinosaurus huinculensis* - 39 m

■ *Shantungosaurus giganteus* - 15 m

■ *Spinosaurus aegyptiacus* - 15 m

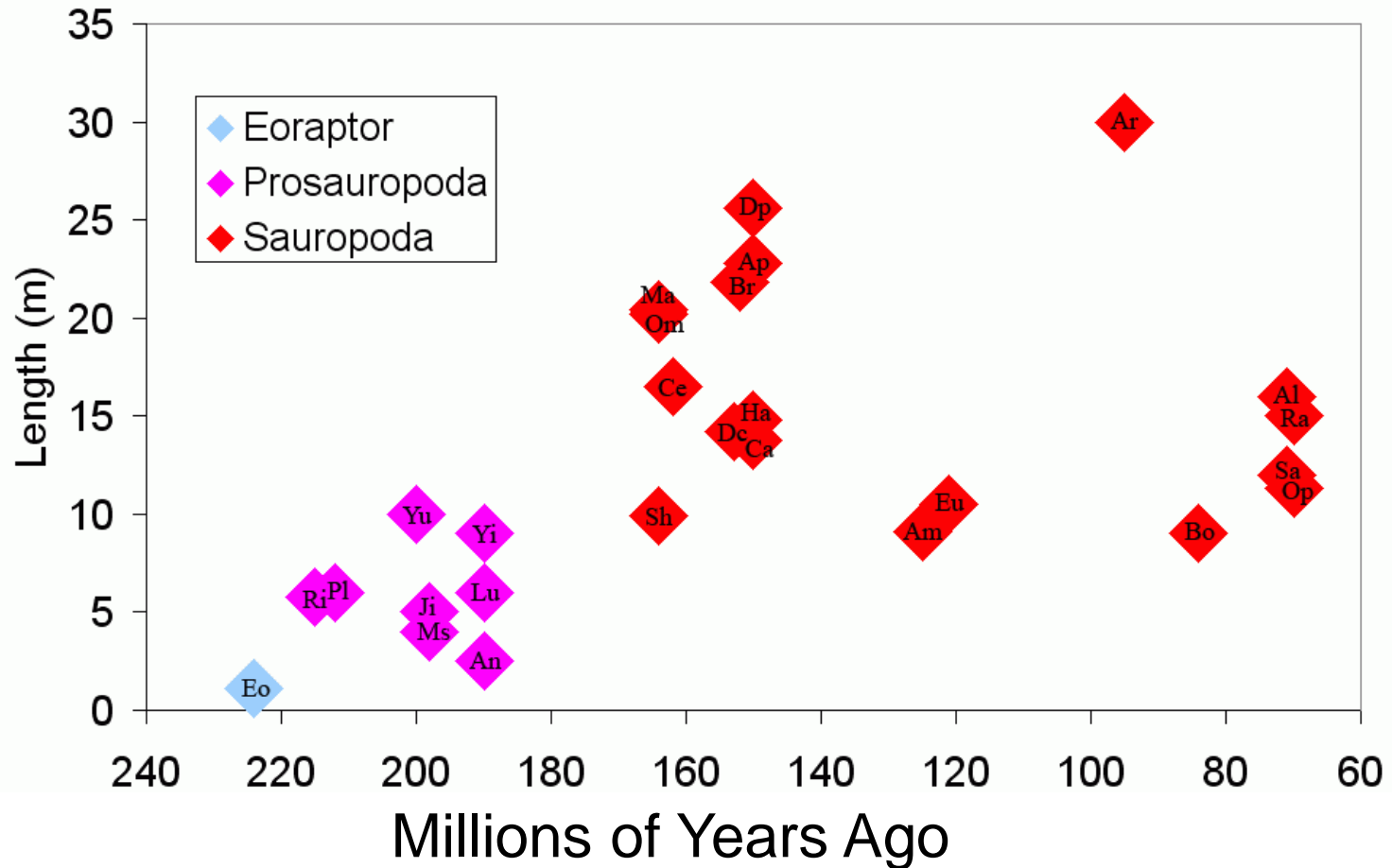
■ *Stegosaurus armatus* - 9 m

■ *Triceratops prorsus* - 8 m



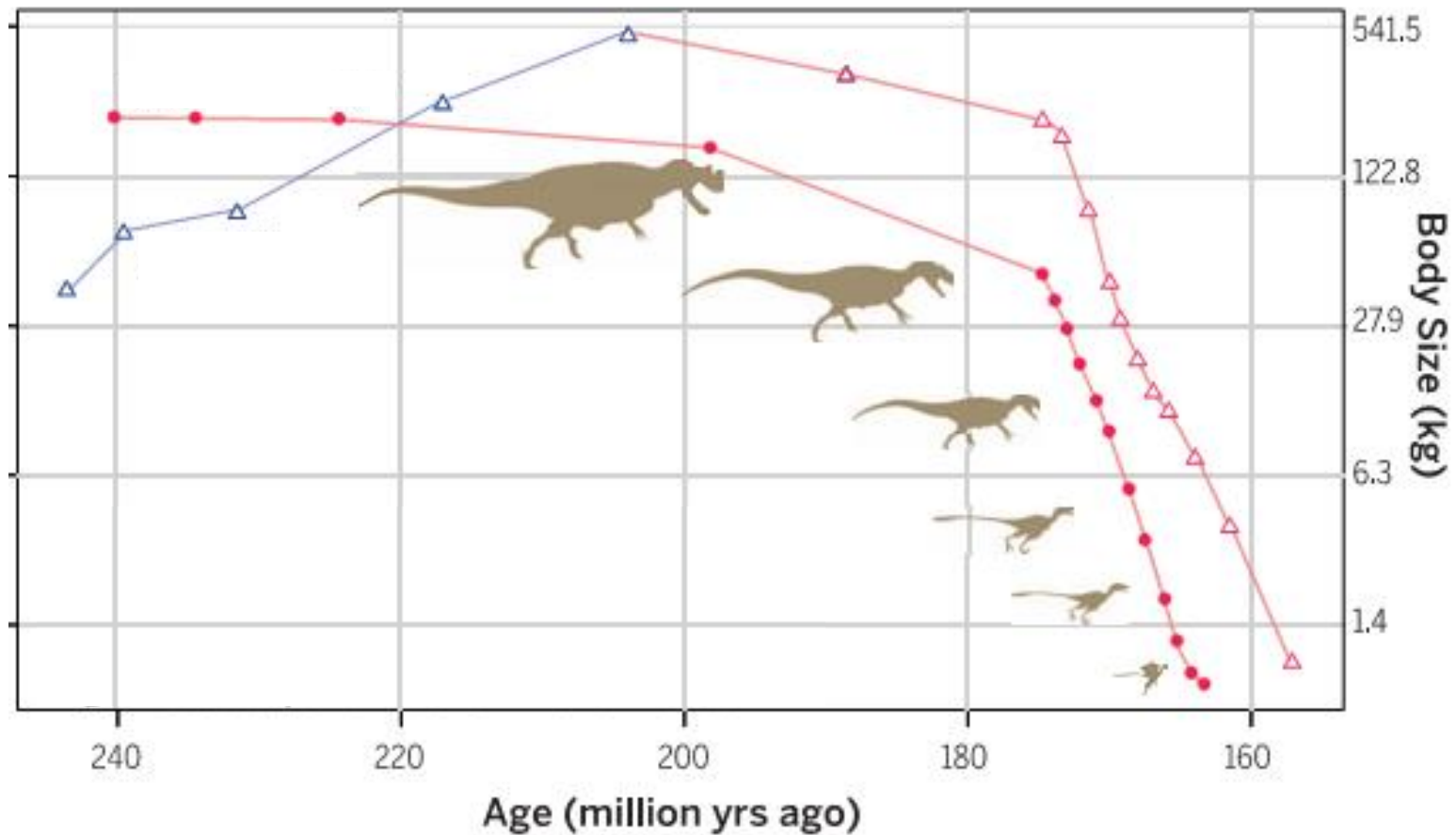
(Modified from Matt Martyniuk)

# Most Dinosaurs Getting Larger



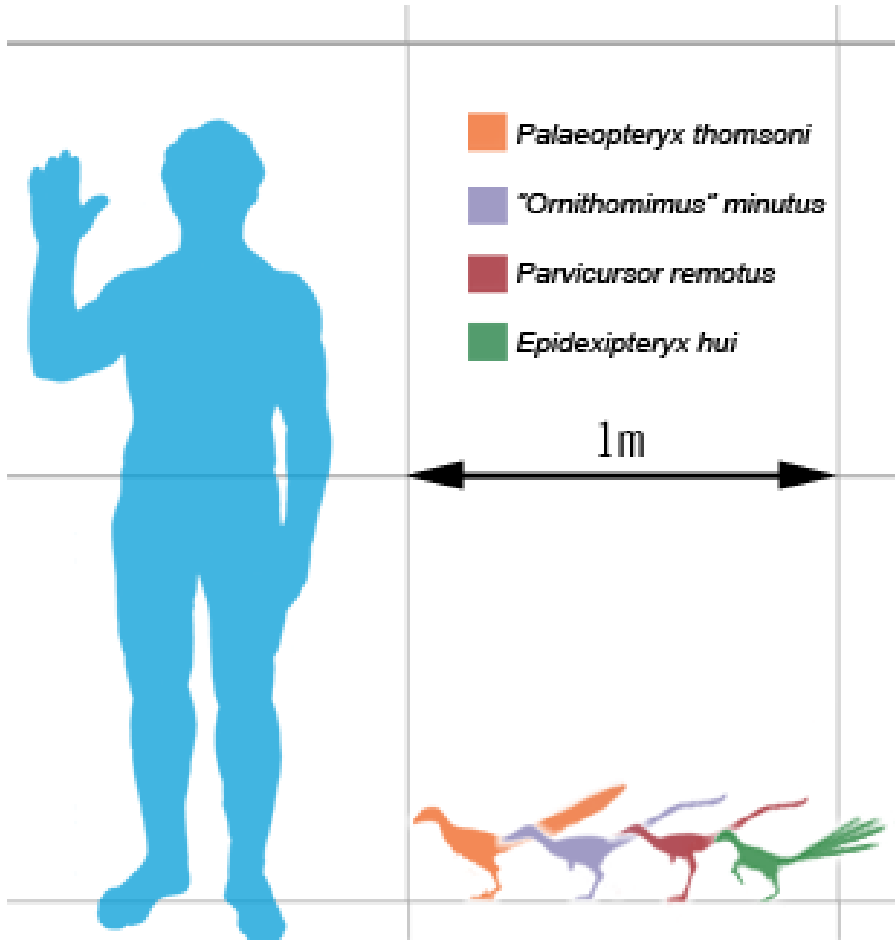
(Modified from Mollwoolfunmble)

# Theropods Shrinking!



(Modified from Lee MSY et al., 2014)







# Size Does Matter



- Avian dinosaur lineages decreasing in size 160 times faster than other dinosaurs increasing
- Avian dinosaurs survived the K-T extinction, diversified 66 mya

(Modified from Matt Martyniuk)

# Paedomorphic Skulls

	Juvenile	Adult
Alligator		
Coelophysis		
Archaeopteryx		

- An evolutionary process by which a species evolves so an adult resembles an ancestor's juvenile stage
- Stalling embryonic development at an earlier phase
- Adult bird skulls resemble juvenile dinosaur skulls

# Avian Intelligence



(Weir and Kacelnik, 2006)



# Summary

- Dinosaurs are vertebrates which evolved an erect hip stance with pelvic sockets from a common archosaur ancestor
- Most dinosaurs were increasing in size while the ancestors of birds were shrinking
- Birds have paedomorphic skulls, possibly increasing their intelligence

# Questions?

# What is a Dinosaur?

- What is a dinosaur
- How birds might have survived extinction
- Anatomical evidence birds evolved from dinosaurs
- Behavioral evidence birds evolved from dinosaurs

# Discovery of *Archaeopteryx* - 1861



- Avian Features:
  - Wings
  - Feathers
- Reptilian Features:
  - Tail
  - Claws
  - Teeth
- Birds share over 100 anatomical features with dinosaurs

# Discovery of *Deinonychus* - 1964

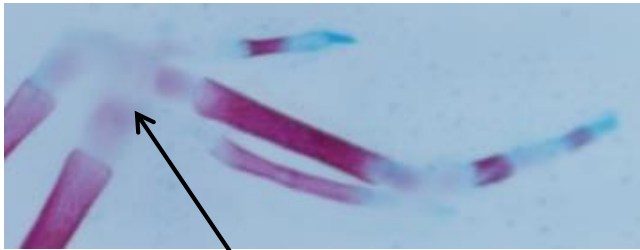


- John Ostrom's discovery sparked a dinosaur renaissance
- Discovery of this agile active predator suggests that dinosaurs were warm-blooded



# Discovery of *Deinonychus* - 1964

Chicken



Semilunate carpal

*Archaeopteryx*



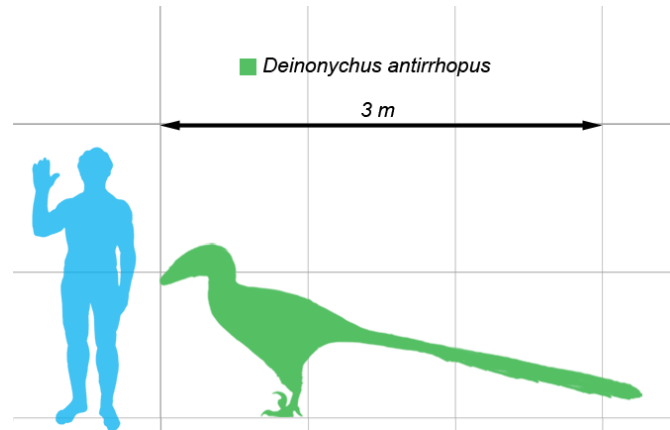
Semilunate carpal

*Deinonychus*



Semilunate carpal

- Maniraptorian Dinosaurs have bird-like forelimbs





# Dinosaurs Evolved Feathers

- Over 40 theropod dinosaur fossils discovered since the 1990s with feathers
- Some evidence of proto-feathers in three ornithischians
- Pycnofibers in pterosaurs may be homologous to feathers



*Microraptor gui*

(Hone et al 2010; Dinoguy2)



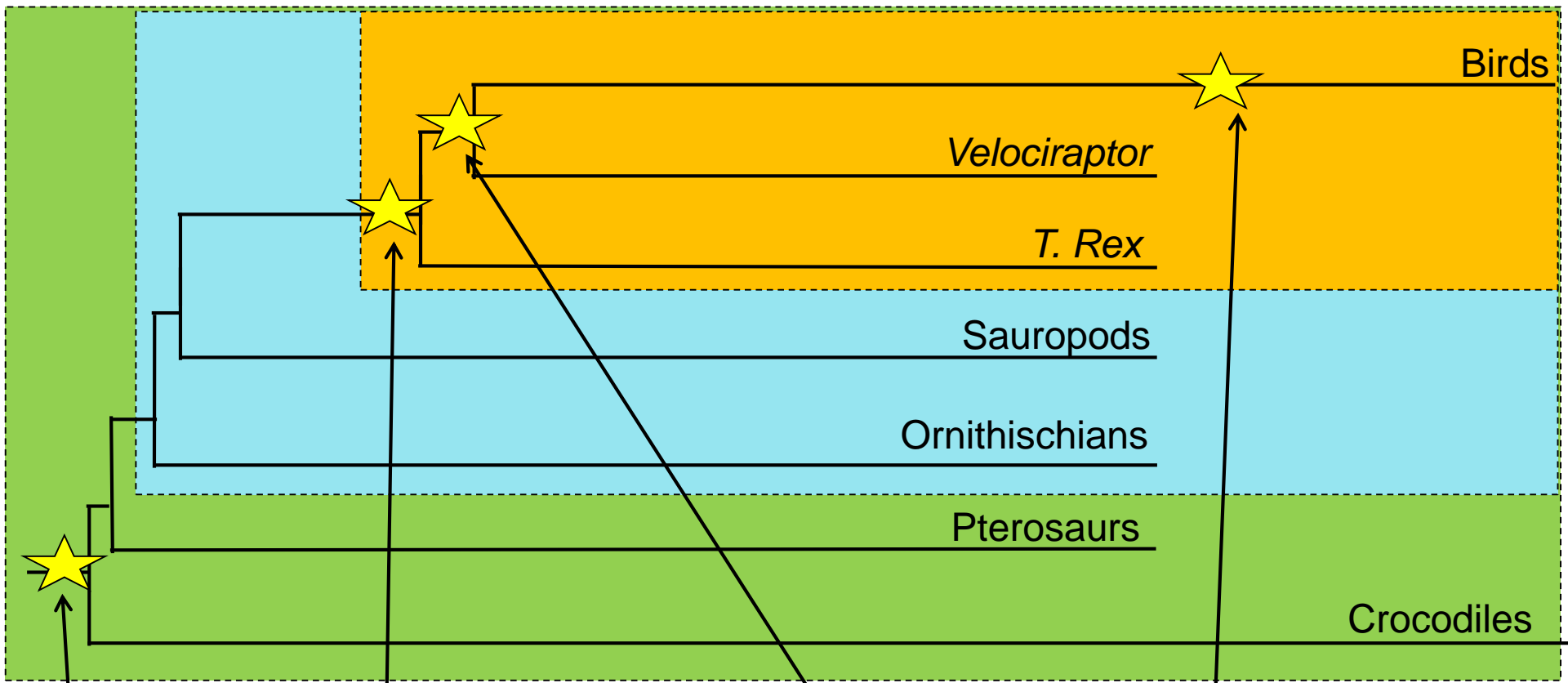
*Sinornithosaurus millenii*



-200

-100

0



5 Digits

3 Digits in hands,  
Feathers,  
Hollow bones, Wishbone

Semilunate  
Carpal Bone,  
Enlarged Keel

Toothless beak,  
Short tail,  
Fused digits II + III



# What is a Dinosaur?

- What is a dinosaur
- How birds might have survived extinction
- Anatomical evidence birds evolved from dinosaurs
- Behavioral evidence birds evolved from dinosaurs

# Brooding Behavior



- Several *Citipati* fossils are preserved resting over nests with outstretched arms
- Reminiscent of brooding behavior unique to birds



# Parental Care



- Extensive *Maiasaura* colony in Egg Mountain, Montana, 1977
- Nested in large colonies of herds
- Found regurgitated vegetation in nests
- Young lived in nests for up to two months



# Gastroliths



*Psittacosaurus* fossil

- Rocks held or passed through the gastrointestinal tract to aid in digestion
- Commonly found in birds



# Summary

- Anatomical evidence from fossils that birds evolved from dinosaurs such as digit reduction, semilunate carpal bones, and feathers
- Behavioral evidence from fossils that birds evolved from dinosaurs such as brooding, parental care, and gastroliths
- Many avian traits evolved slowly over time in non-Avian dinosaurs



(Thord Daniel Hedengren)

# Questions?

# Thank you!

*SITN would like to acknowledge the following organizations for their generous support.*

## **Harvard Medical School**

Office of Communications and External Relations  
Division of Medical Sciences

## **The Harvard Graduate School of Arts and Sciences (GSAS)**

## **The Harvard Graduate Student Council (GSC)**

## **The Harvard Biomedical Graduate Students Organization (BGSO)**

## **The Harvard/MIT COOP**



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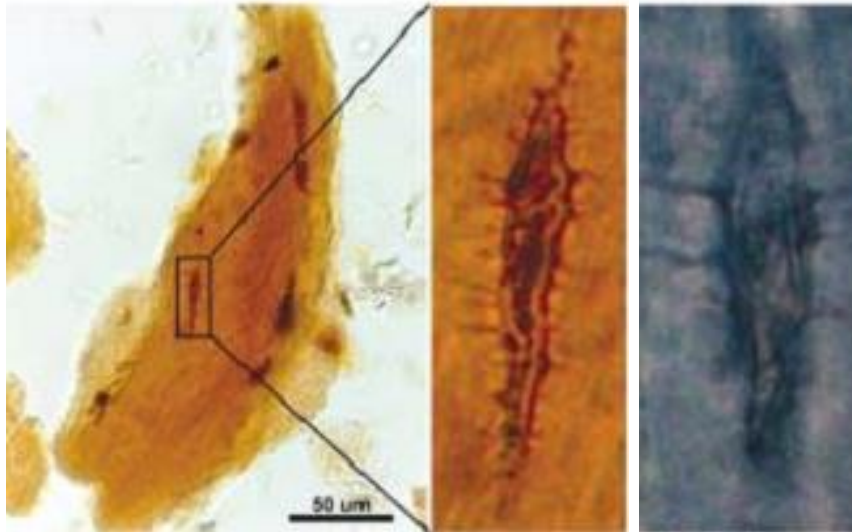
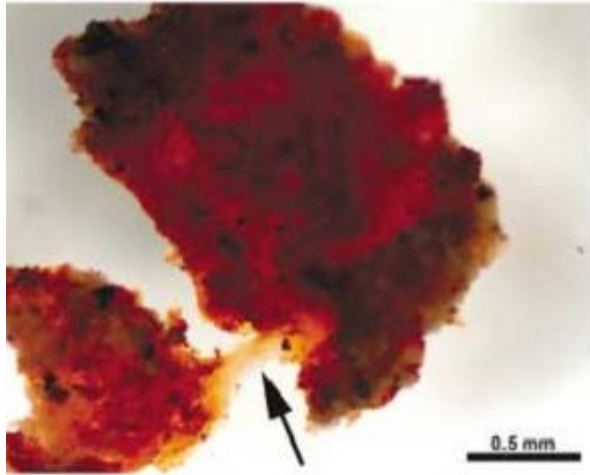
Like

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# Soft Tissue



- Soft Tissue found in *T. rex* femur in 2005 by Mary Schweitzer following bone demineralization
- Collagen elemental composition similar to birds
- Osteocytes present