4.0 Billion Years of Earth Environmental Change

Extinctions

General Observations About Extinctions

In a system, you cannot change one thing without causing something else to change, Sometimes with unintended consequences

We have seen many changes in Earth environments.

1. *Atmospheric evolution*
2. *Climate evolution*
3. *Land vs water evolution*

Life has three choices during such a crisis.

1. *Move to a safe environment – habitat tracking*
2. *Adapt to new conditions*
3. *Go extinct – a "choice" life has made with surprising regularity.*

The Abundance of Life On Earth

How many species have been named by science?

- *1.4 million - In his book, The Diversity of Life (1992), world-renowned biologist Edward O.Wilson says we know of approximately 1.4 million species on Earth — give or take 100,000.*
- *1.7 million - The World Biodiversity Database, which aims to document all living species on Earth today, puts the figure at 1.7 million.*

How many species are actually living on Earth right now?

- 3.6 million up to 117.7 million - Upper limit estimates, with 13 to 20 million being the most frequently cited range.

How many species have lived on Earth through its 4 billion years of history?

- Estimates range between 5 and 50 billion, although this is even more speculative than the number of living species.

The Abundance of Life On Earth

How many fossil species have been found and named by science?

- *About 150,000*

This means most species are extinct.

- *Likely 99.9999 % of all species are extinct.*
- *Less than 1/1000 of all species are alive today.*
- *Average species lasts about 4 million years.*
- *If 40 million species are alive today then 10 species become extinct in an average year.*

Then again, the fossil record is very biased, biased toward. . .

- *Organisms with skeletons*
- *Large organisms*

The Abundance of Life On Earth

Nonetheless, we have learned a tremendous amount from those fossil species.

- *Many fossil groups have no living forms; without fossils we would have no idea they exist.*

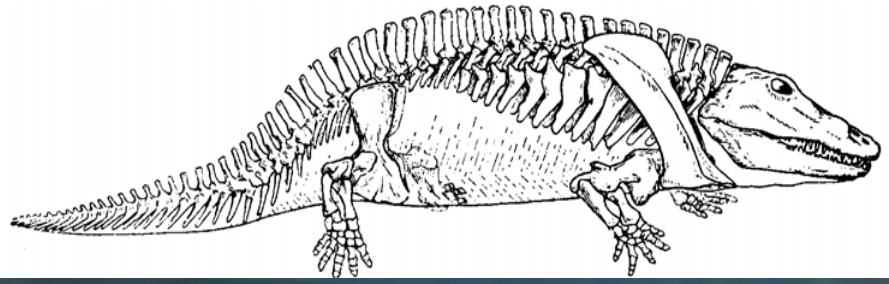
- *Many "missing links" or ancestor groups exist letting us deduce ancestor-descent relationships.*

For example . . .

Labrynthodont Amphibians

Eryops

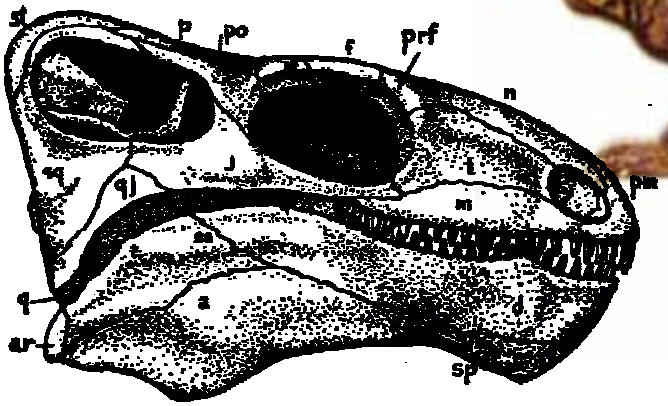
Labrynthodont



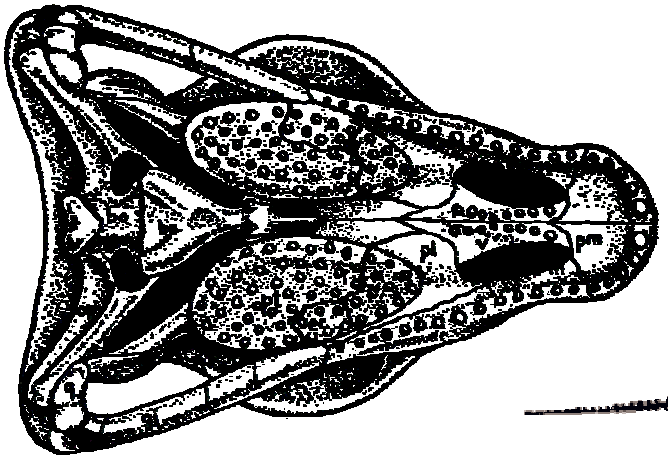
http://www.crummy.com/pix/2003/03-washington-dc/

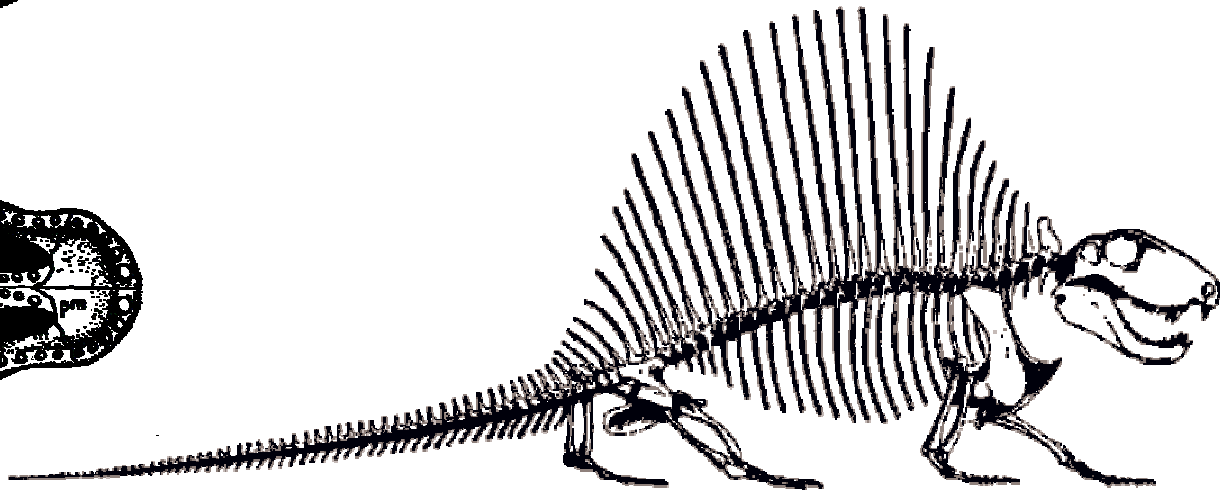
http://tolweb.org/tree?group=Temnospondyli&contgroup=Terrestrial_Vertebrates

Pelycosaur (mammal-like) Reptiles

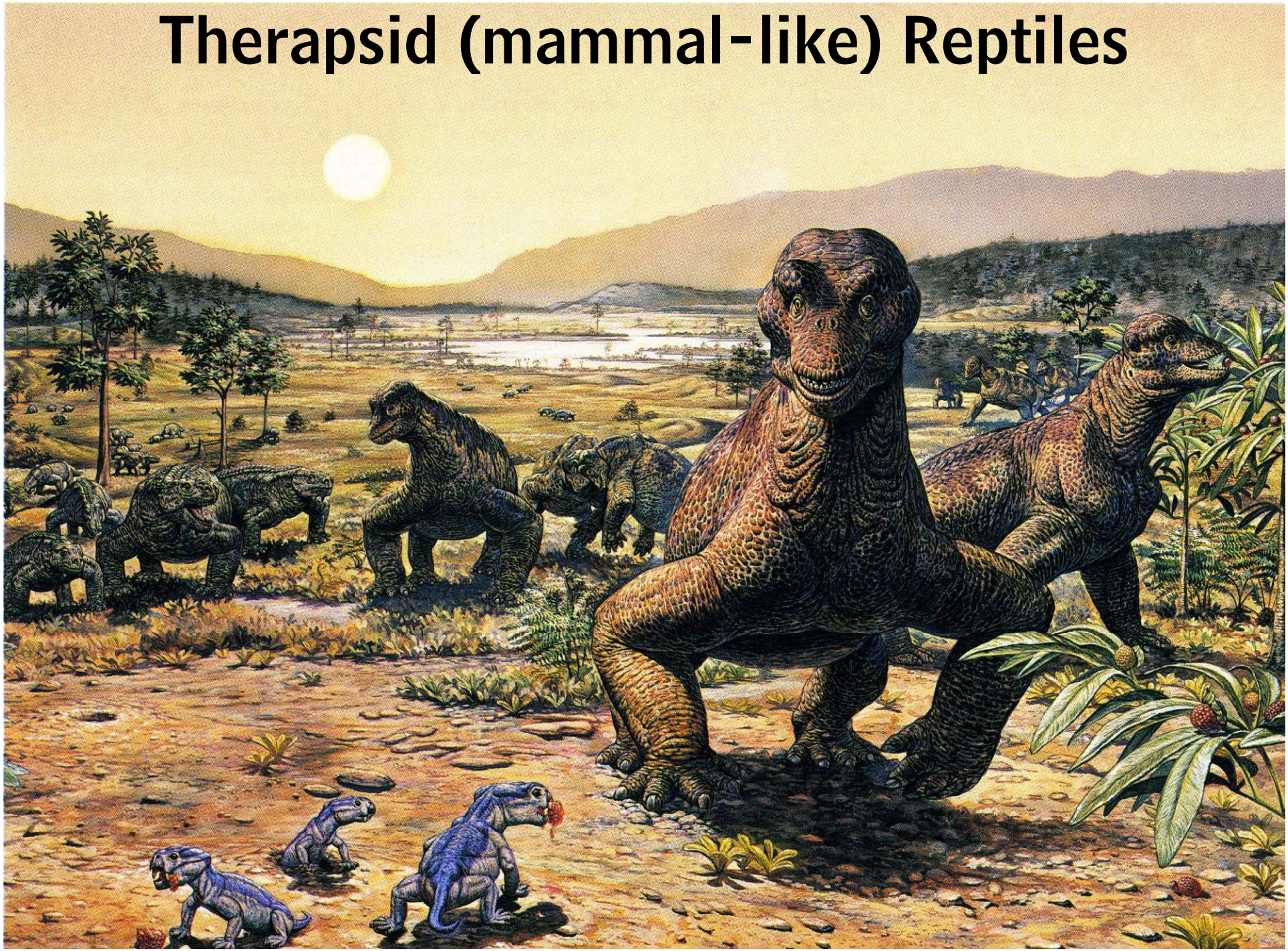


Edaphosaurus

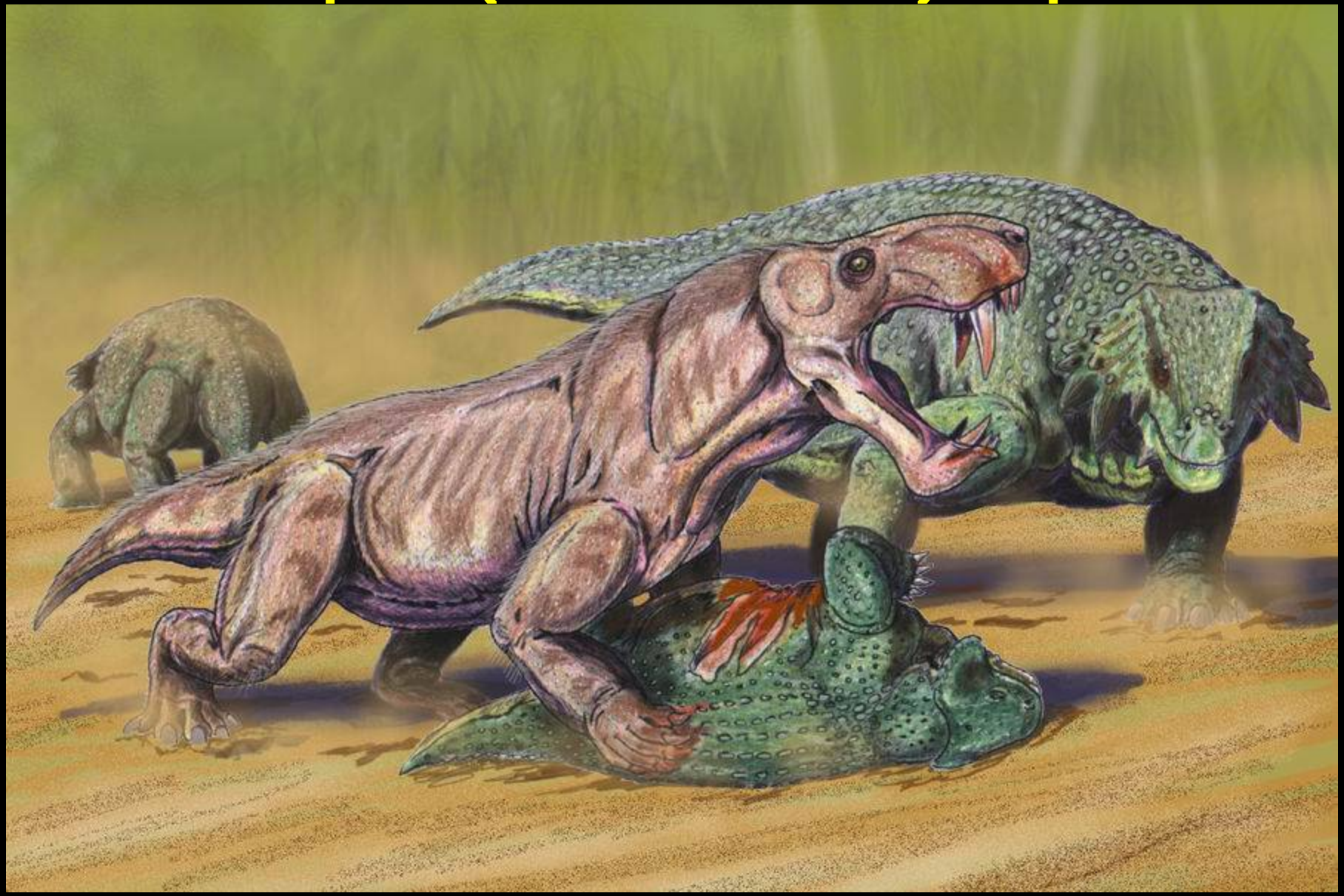




Therapsid (mammal-like) Reptiles



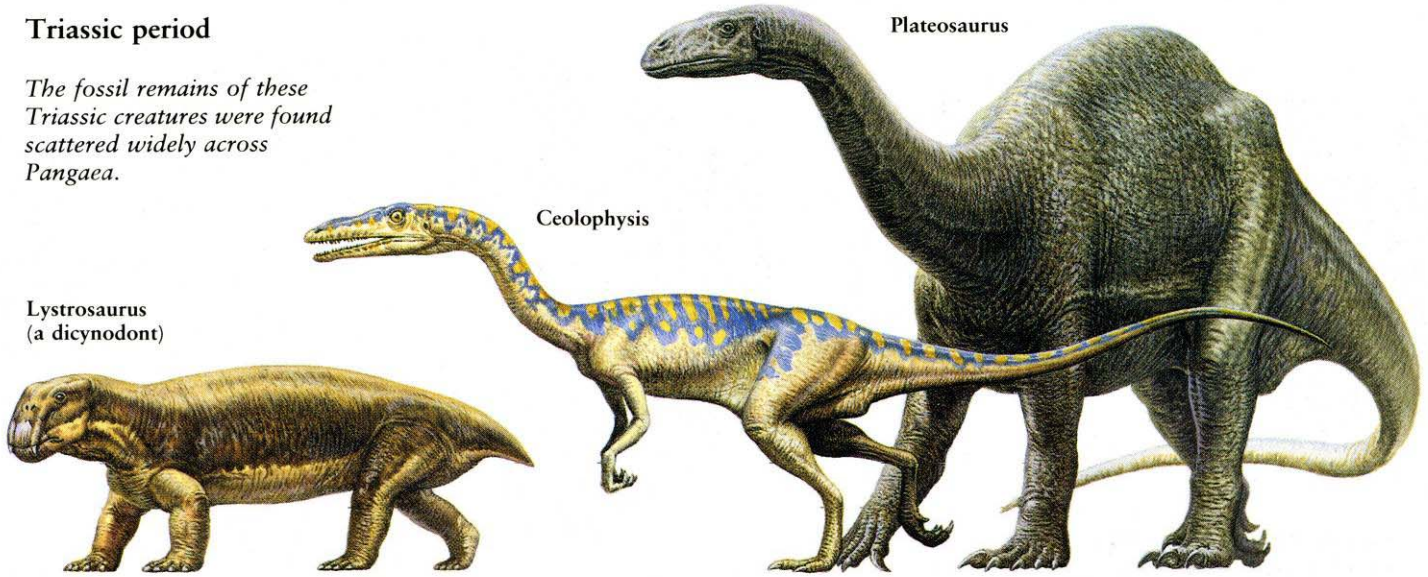
Therapsid (mammal-like) Reptiles



http://commons.wikimedia.org/wiki/Image:Inostrancevia_DB.jpg

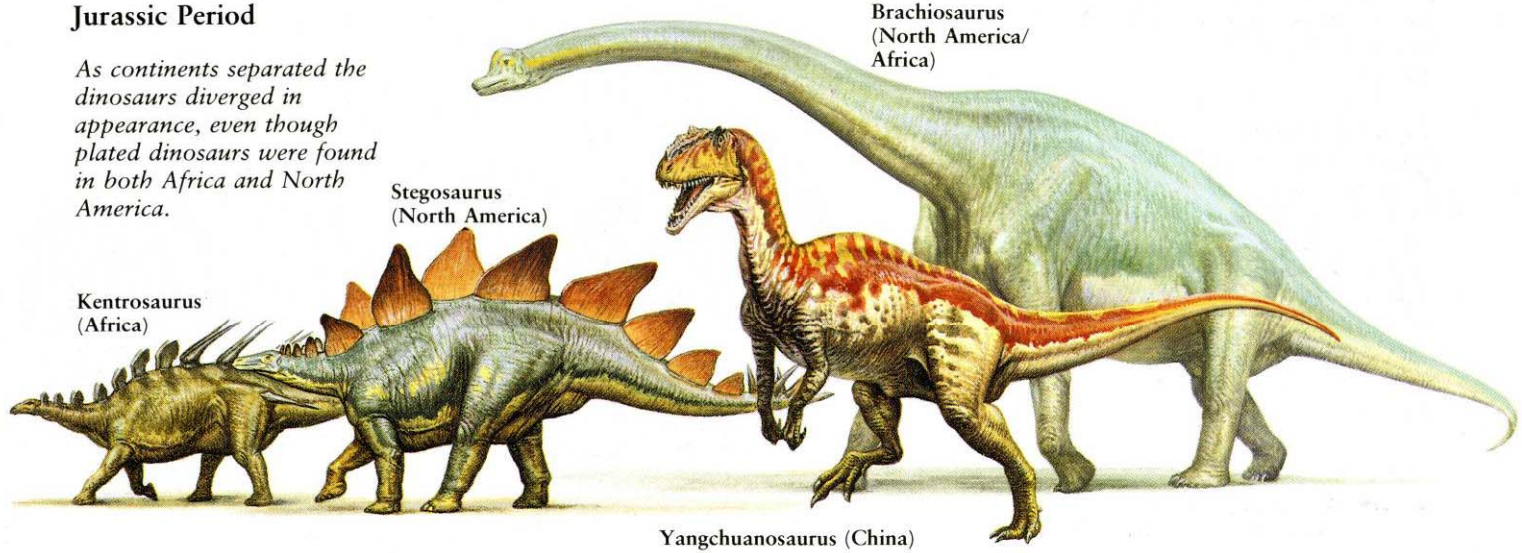
Triassic period

The fossil remains of these Triassic creatures were found scattered widely across Pangaea.



Jurassic Period

As continents separated the dinosaurs diverged in appearance, even though plated dinosaurs were found in both Africa and North America.



Cretaceous Period

As continents became more isolated, the dinosaurs of certain areas became more distinctive.

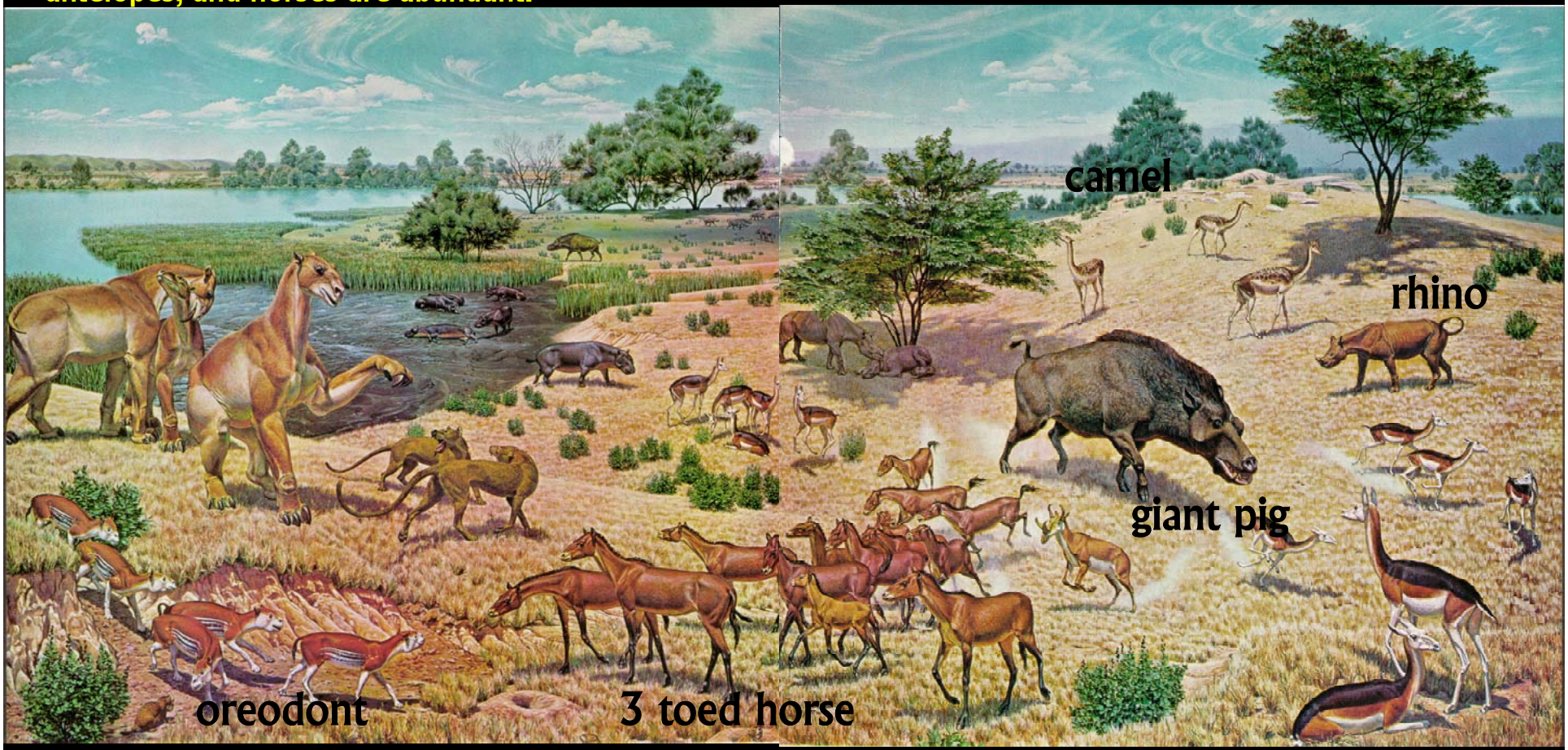
Feathered Dinosaurs

Feathered Dinosaurs

Strange North American Mammals

Early Miocene 25 – 20 mya

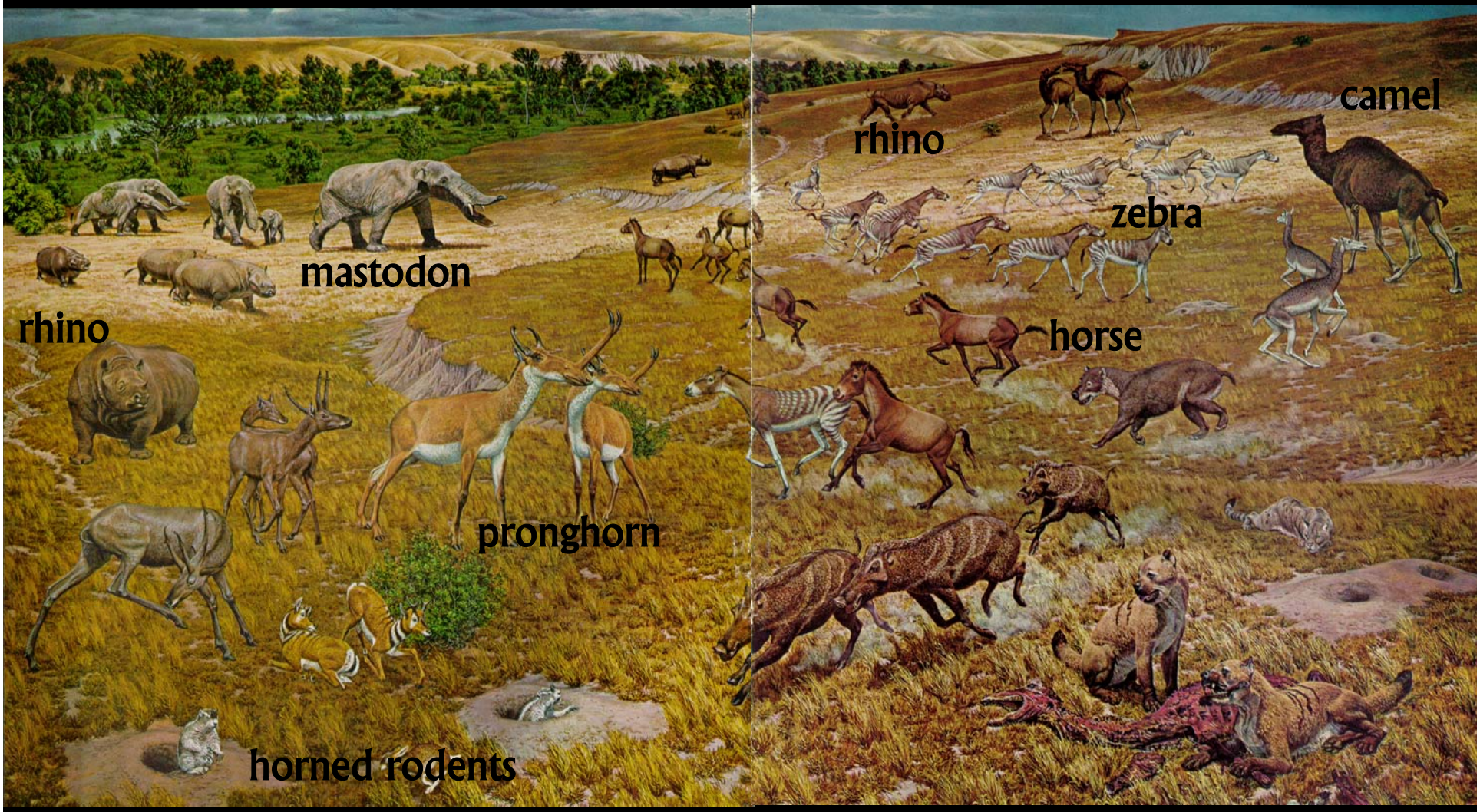
Grasses evolved and spread during this time leading to the rise of grassland animals with longer legs and faster running. Browsing dentition shifted to grazing dentition with higher crowns and resistance to the abrasion in the silica rich grasses. Giant animals such as Moropus and the giant (entelodon) pig. Camels, antelopes, and horses are abundant.



Strange North American Mammals

Early Pliocene 12 – 9 mya

The American grasslands support a variety of plains animals, including horses of many kinds, but also rhinos (dying out), camels, pronghorn antelopes, giant pigs, peccarys and shovel tusked mastodons.



The Abundance of Life On Earth

Nonetheless, we have learned a tremendous amount from those fossil species.

- *Many fossil groups have no living forms; without fossils we would have no idea they exist.*

- *Many "missing links" or ancestor groups exist letting us deduce ancestor-descent relationships.*

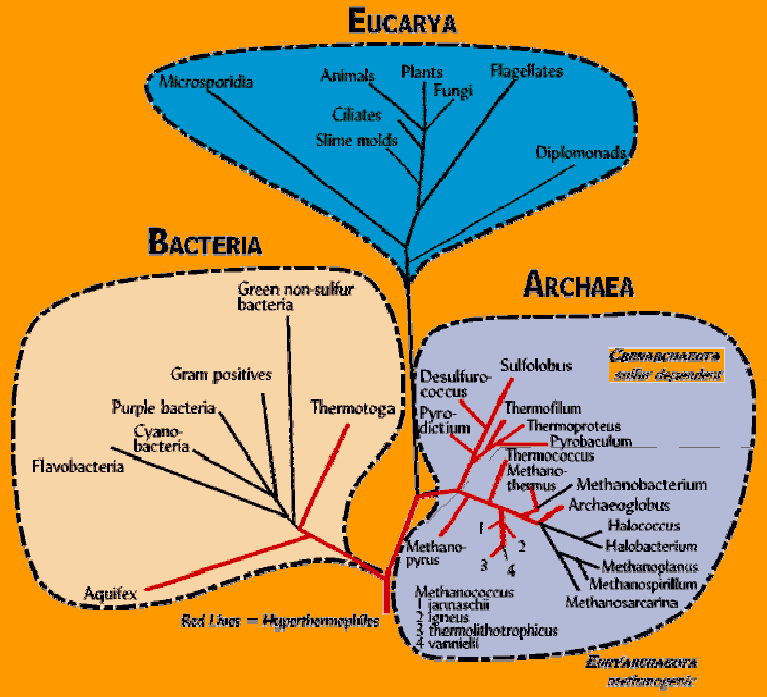
Then Again.....

- *There are organisms that have been with us for a long time we are just discovering are strange.*

Extremophile Archaebacteria

Have been here all along, and it was not until about ten years ago we recognized they are a whole separate branch of life.

Boiling hot springs in Yellowstone National Park are colored by colonies of thermophilic cyanobacteria, eubacteria and archaebacteria. Thermus aquaticus survives in temperatures too high for photosynthetic bacteria, up to 80 degrees Celsius (176 degrees F). Thermus aquaticus is heterotrophic and survives on minute amounts of organic matter in the water.

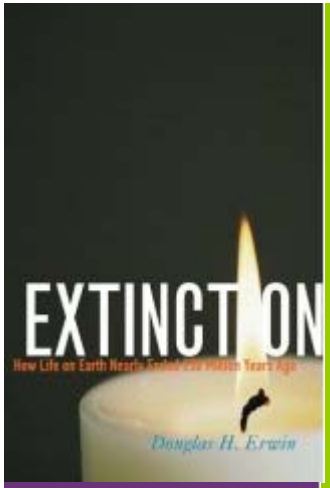


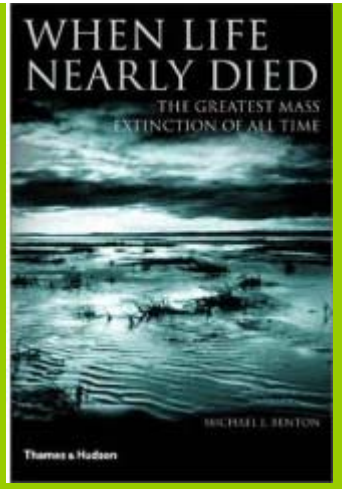
But, the truth is . . .

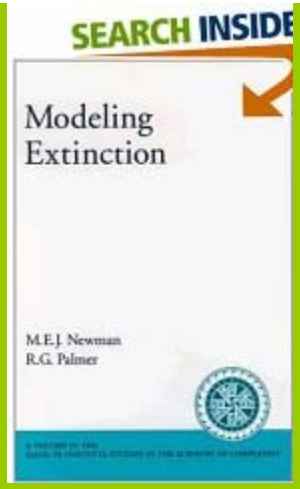
Most life is extinctly dead

Why ?

Extinction


EXTINCTION
Douglas H. Erwin


WHEN LIFE NEARLY DIED
THE GREATEST MASS EXTINCTION OF ALL TIME
MICHAEL J. BENTON
Thames & Hudson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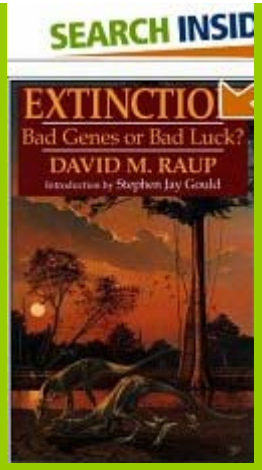
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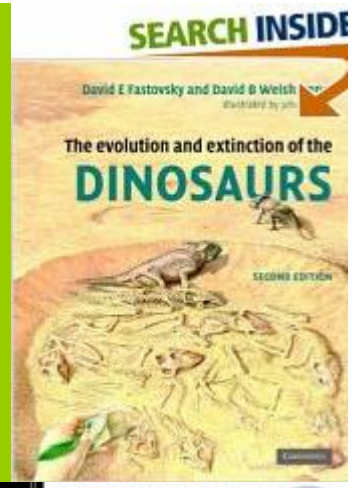
Bad Genes or Bad Luck?
DAVID M. RAUP
Introduction by Stephen Jay Gould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The evolution and extinction of the
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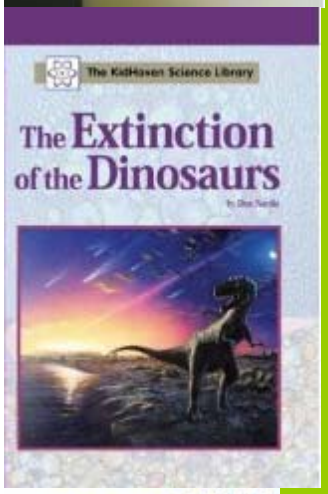
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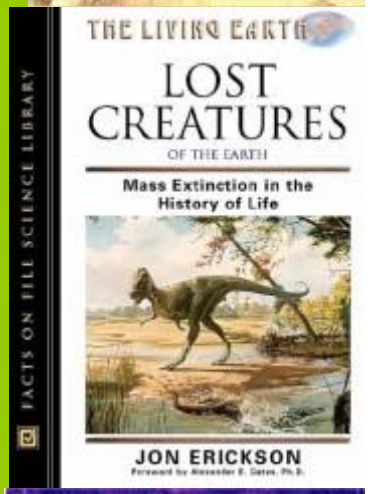
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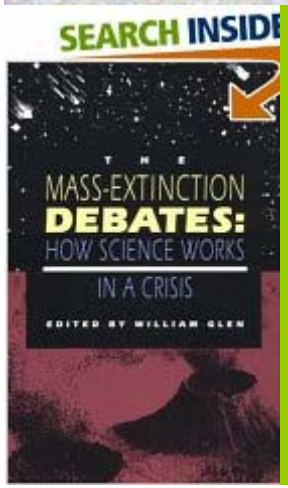
Mass Extinction in the History of Life
JON ERICKSON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THE MASS-EXTINCTION DEBATES:
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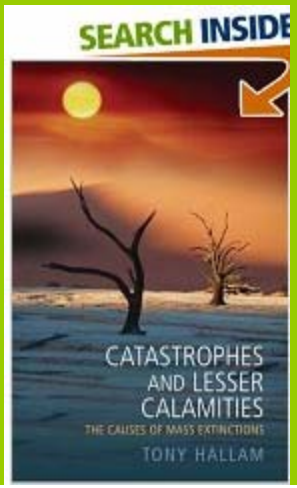
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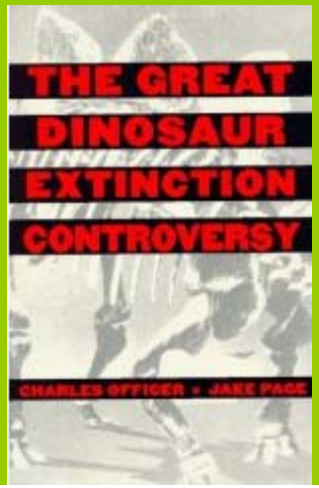
THE CAUSES OF MASS EXTINCTIONS
TONY HALLAM


THE GREAT DINOSAUR EXTINCTION CONTROVERSY
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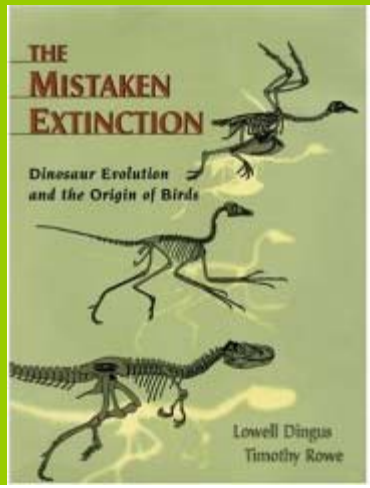
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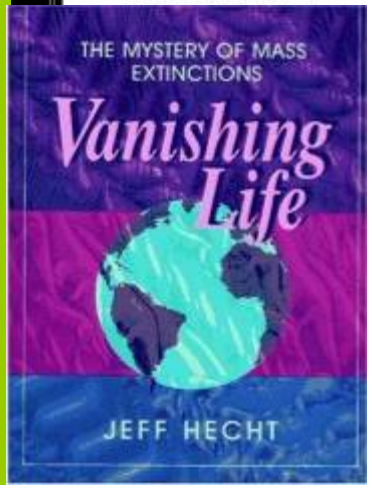
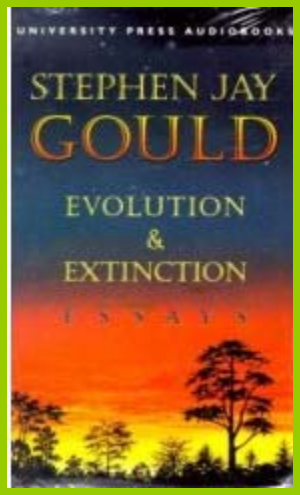
Dinosaur Evolution and the Origin of Birds
Lowell Dingus
Timothy Rowe


THE MYSTERY OF MASS EXTINCTIONS
Vanishing Life
JEFF HECHT

Extinction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EVOLUTION
&
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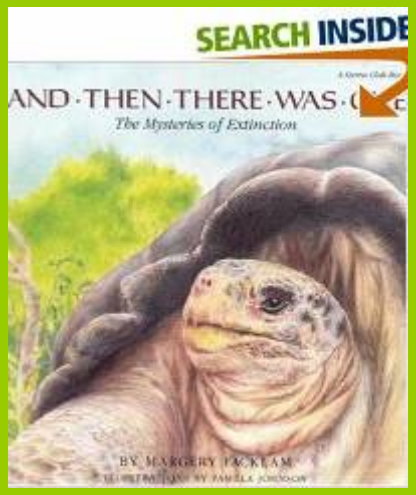
ESSAYS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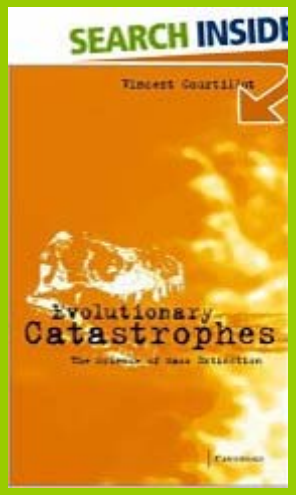
AND THEN THERE WAS
The Mysteries of Extinction
BY MARGERY FACKLAM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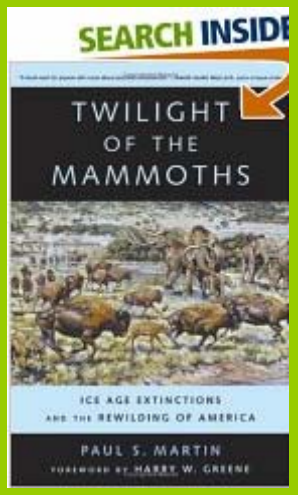
Catastrophes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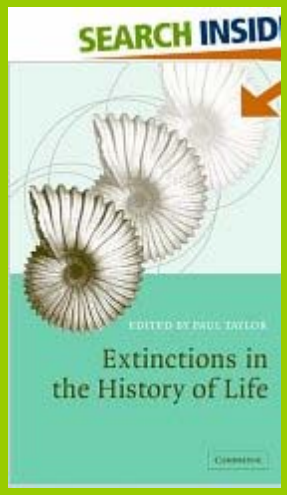
ICE AGE EXTINCTIONS
AND THE REWILDING OF AMERICA
PAUL S. MARTIN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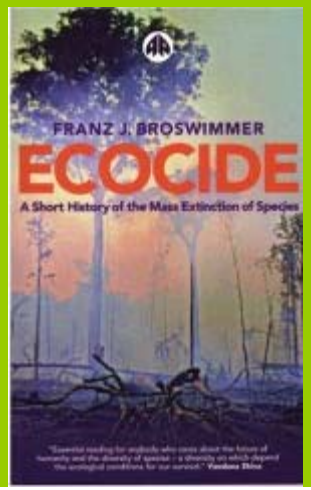
Extinctions in
the History of Life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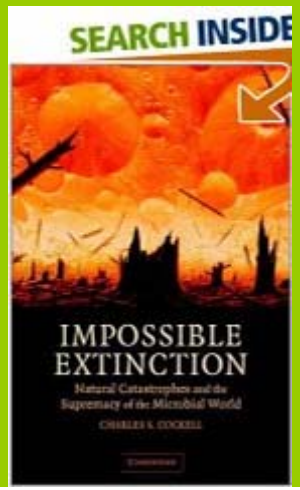
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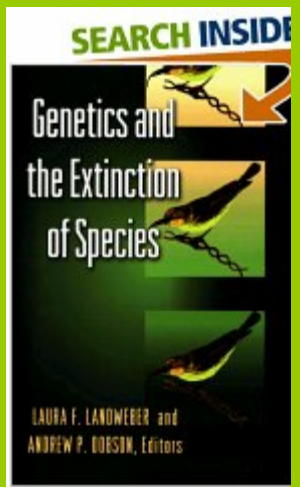
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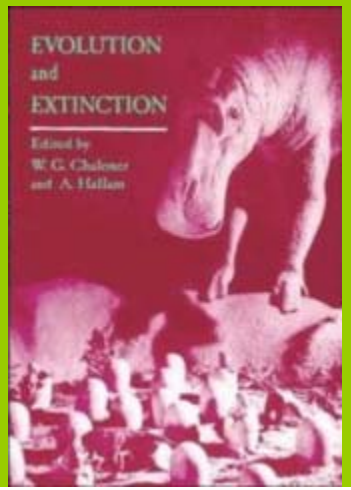
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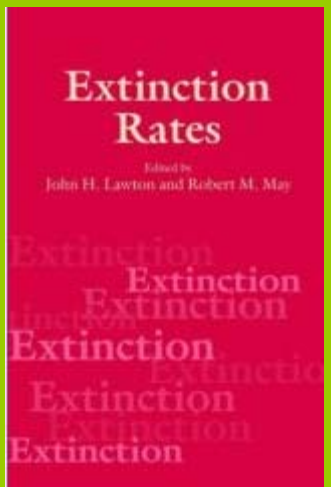
Extinction
Rates
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Extinction
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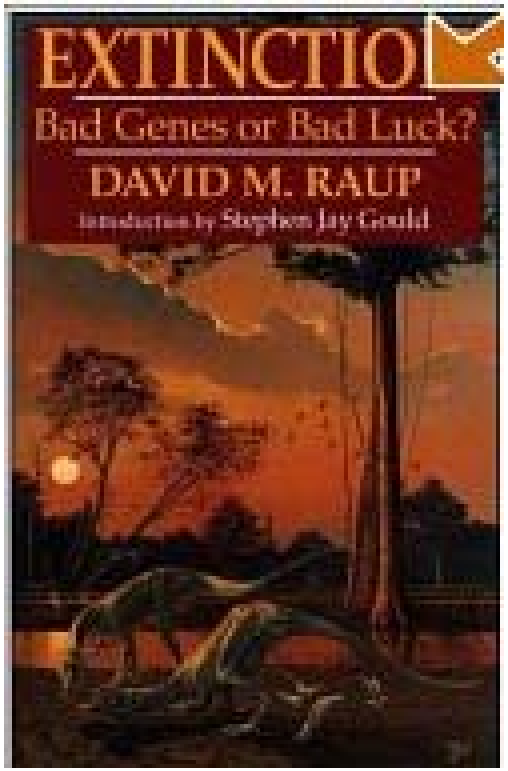
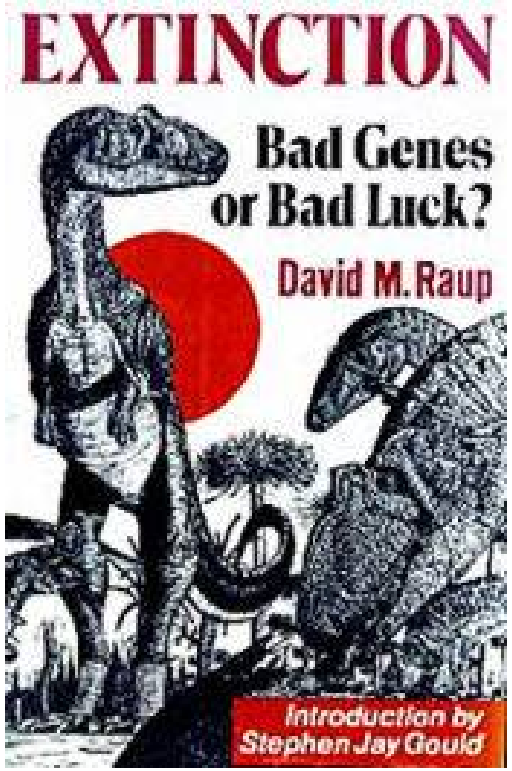
Extinction

The Varieties of Extinction





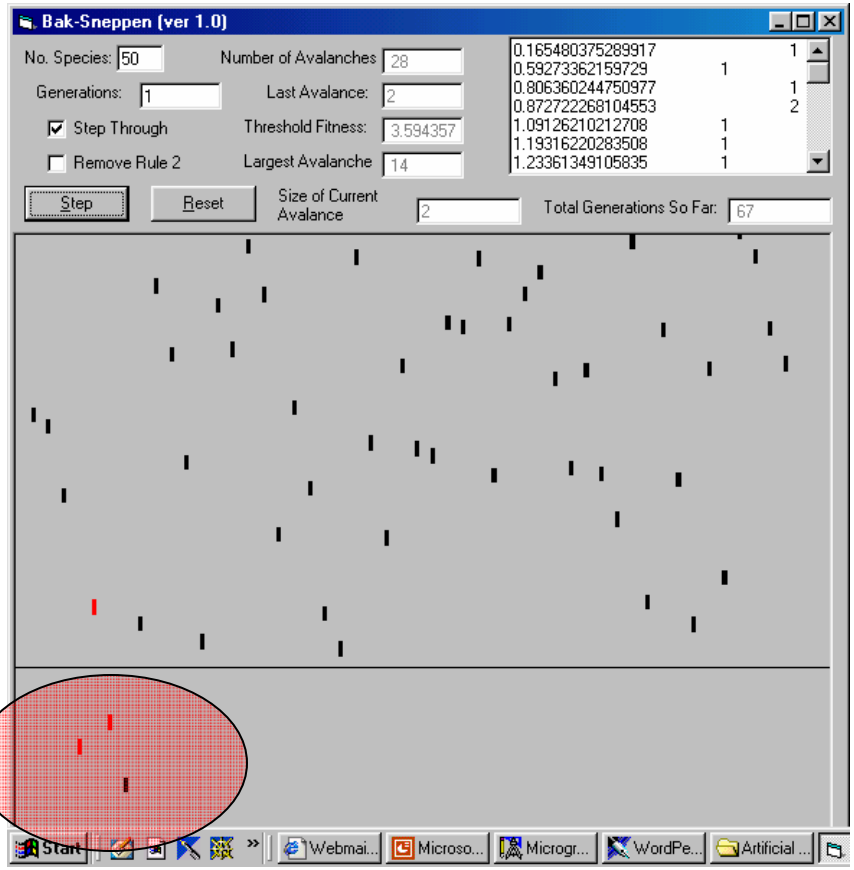
Are all extinctions the same?

The Varieties of Extinction

Fair Game – Bad Genes scenario

Selective extinction in a Darwinian sense, leading to survival of the most fit or best adapted species

Modeling an Evolutionary System



Rule One - find the species with the lowest fitness and randomly change its fitness.

Rule Two - at the same time the lowest fit species is changed, also randomly change the fitness of the species to the immediate left and right.

Low fitness species go extinct.

And some unlucky species next to low fitness species go extinct.

The Varieties of Extinction

Fair Game – Bad Genes scenario

Selective extinction in a Darwinian sense, leading to survival of the most fit or best adapted species

Field of Bullets – Bad Luck scenario

Random extinction without regard to differences of fitness

Wanton Extinction – Bad Luck scenario

Extinction is selective but not in ways related to the ability of organism to adapt in normal times.
Accidents of evolutionary history that make some kinds of organisms more susceptible than others to rare stresses. For example, if the Earth were suddenly subjected to a heavy dose of ionising radiation from space, all exposed mammals might die from radiation sickness, but all insects might survive because insects are less affected by high energy radiation.

Proposed Causes of Bad Luck Extinctions

Proximal vs Exotic

Proximal – those that represent everyday sources of mortality, but some how at times become accentuated.

Exotic – do not kill off individuals and species under normal circumstances, but only during mass extinctions.

Proposed PROXIMAL Causes

1. Global climate change, especially drying and cooling.
2. Sea level rises, or falls – changing the area of shallow marine environments or land areas.
3. Predation.
4. Epidemic disease (a kind of predation).
5. Competition with other species.

- Brachiopods replaced by clams?
- Dinosaurs replaced by mammals?
- Synapsids (mammal-like reptiles) replaced by dinosaurs?

Proposed EXOTIC Causes

EARTH BOUND

1. Changes in oxygen concentration or other atmospheric chemistry.
2. Disruptions of supplies of food and nutrients.
3. Changes in ocean salinity.
4. Spread of turbidity.
5. Sudden volcanic emissions of either poisonous gasses or darkening dust clouds.

Proposed EXOTIC Causes

EXTRATERRESTRIAL

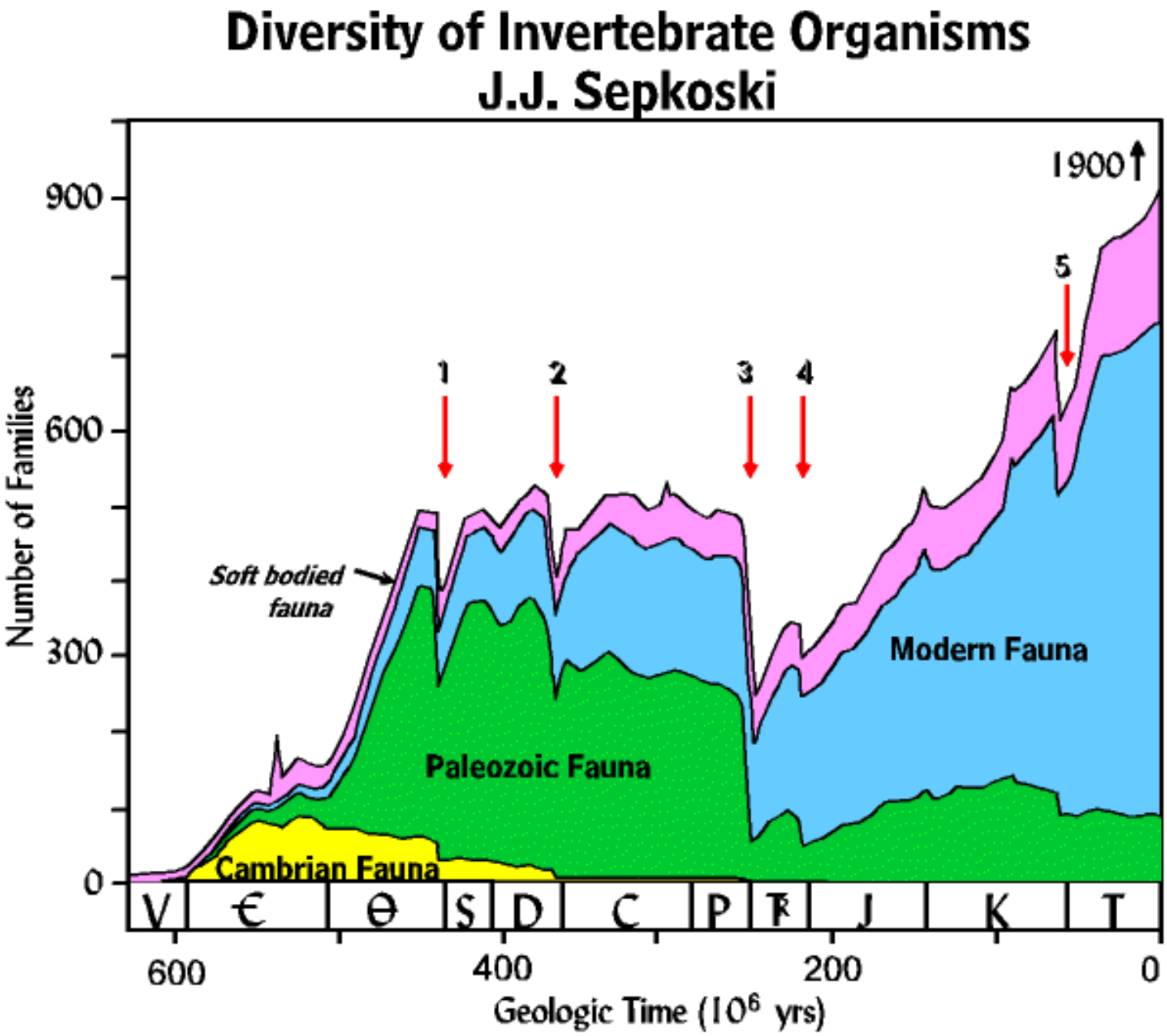
1. Supernova ionizing radiation.
2. Intense cosmic radiation triggered by weakening of the earth's magnetic field.
3. Asteroid impacts.
4. Invasions from outer space.

Strategy for Exploring Extinction Causes

1. Get an answer to the question of whether all extinctions are the same, with just natural variations in intensity.
2. Then, if all extinctions are not all equivalent:
   - Which ones are background extinctions - those that go on all the time.
   - Which ones are unusual, above background – so called mass extinctions?

Then of the unusual ones we must ask why they are unusual?

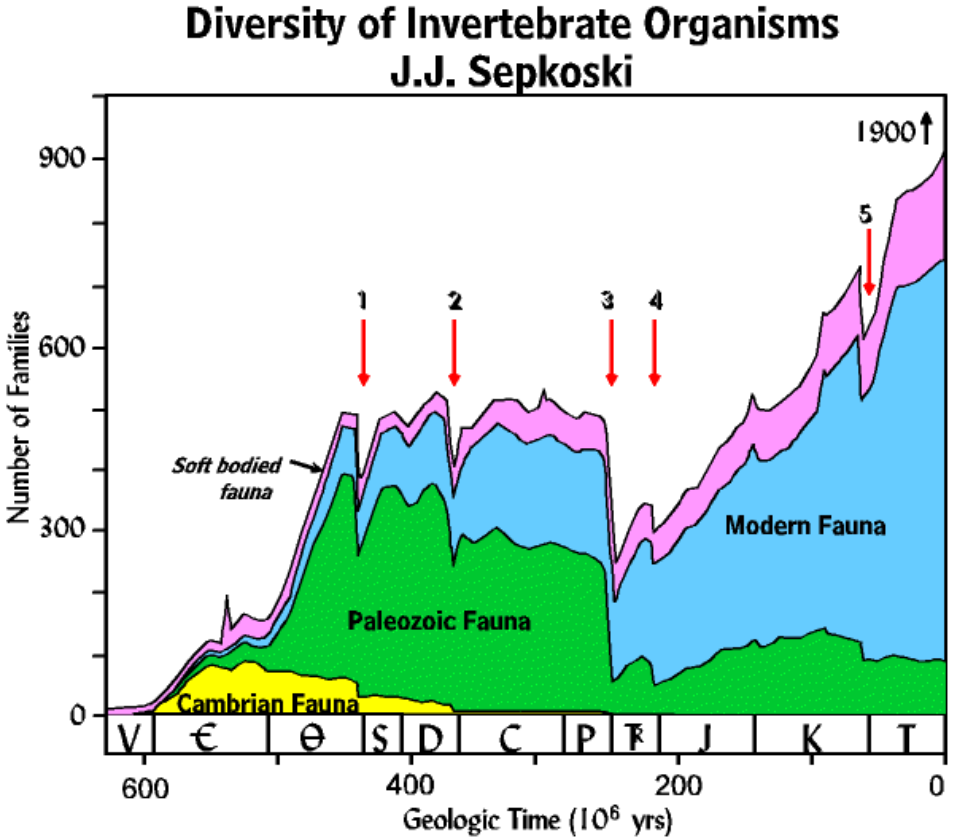
And, are they fundamentally different from other extinction events?

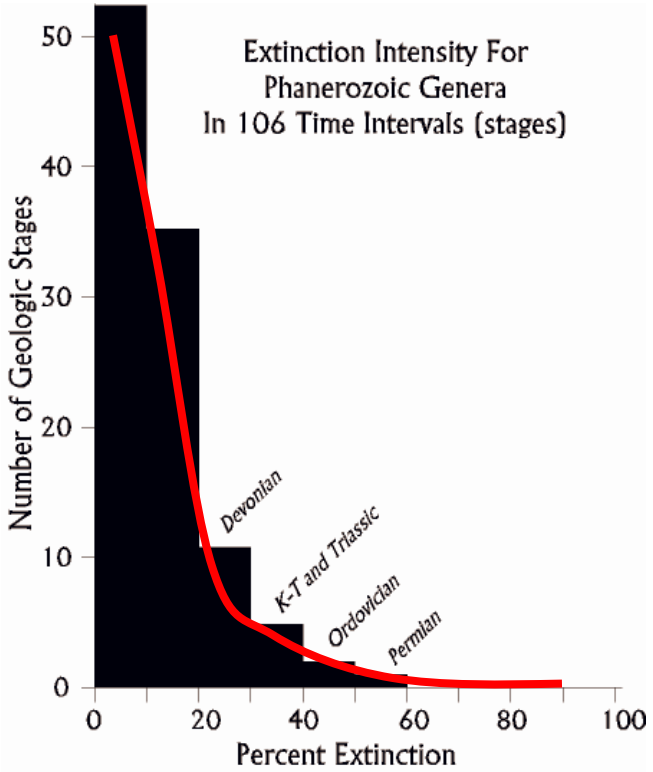

Diversity of Invertebrate Organisms
J.J. Sepkoski
Number of Families
900
600
300
0
1900
5
1
2
3
4
Soft bodied fauna
Modern Fauna
Paleozoic Fauna
Cambrian Fauna
V
€
Θ
S
D
C
P
Tr
J
K
T
600
400
200
0
Geologic Time (10⁶ yrs)

Is there a Difference
Background vs Major Extinction

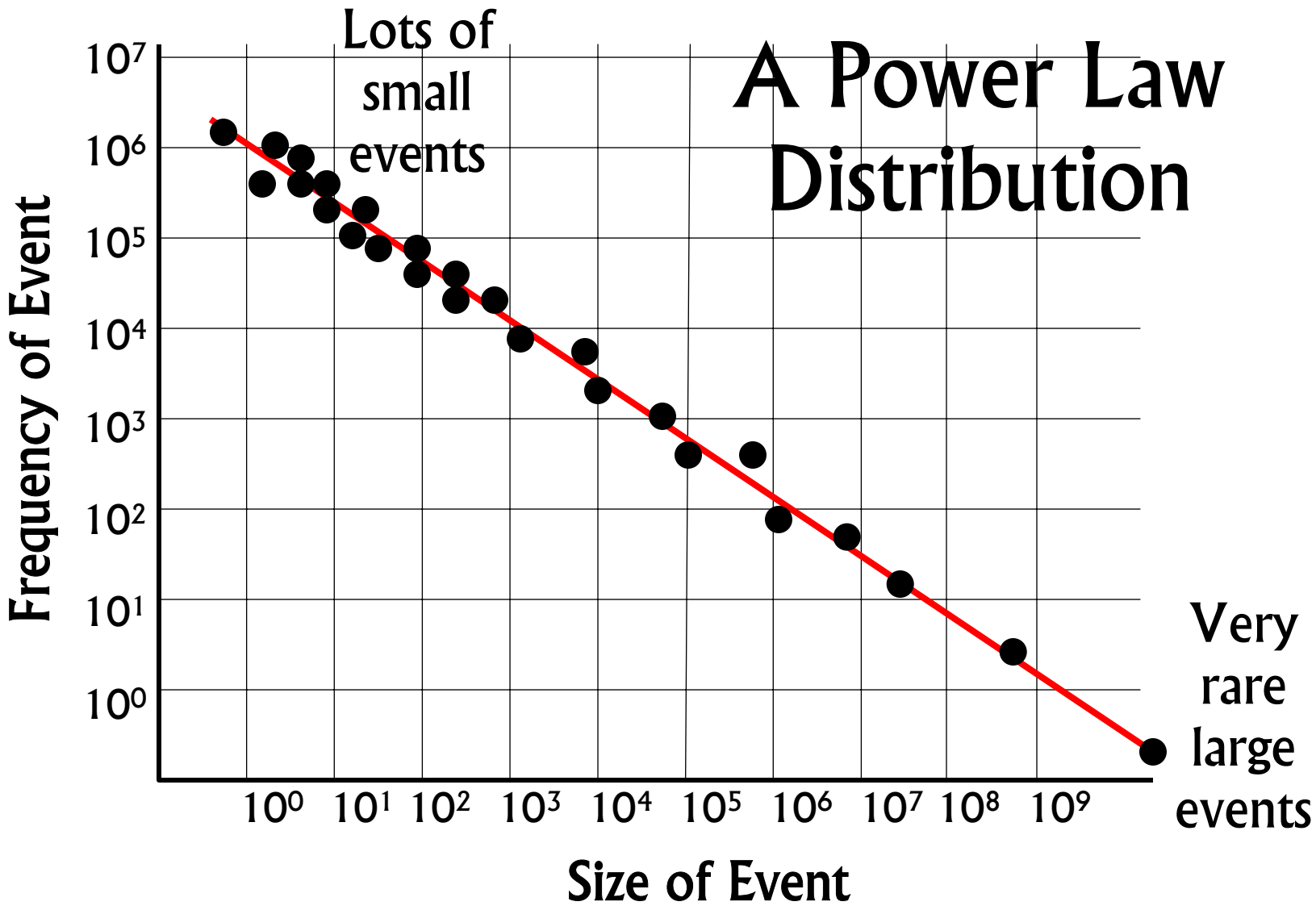
The Big Five Extinctions

And, . . . these real extinction events do not follow a normal distribution but a power-law distribution, and so cannot be understood with normal statistics.



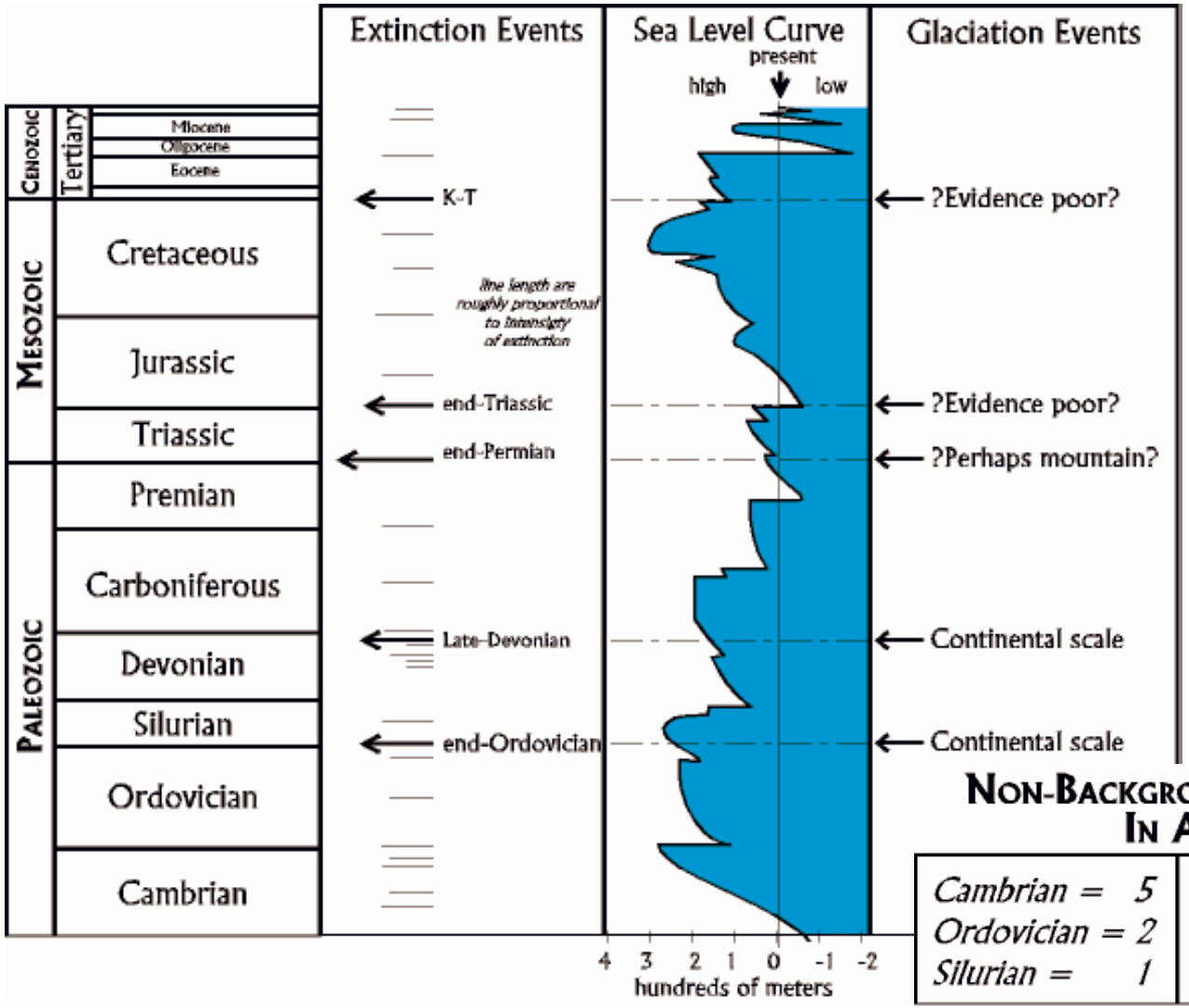


Extinction Events Follow a Power Law Distribution



Are Mass Extinctions Different or Just Above Average?

. . . But it is easy to lose site of the fact there are many other extinction events of intermediate size.

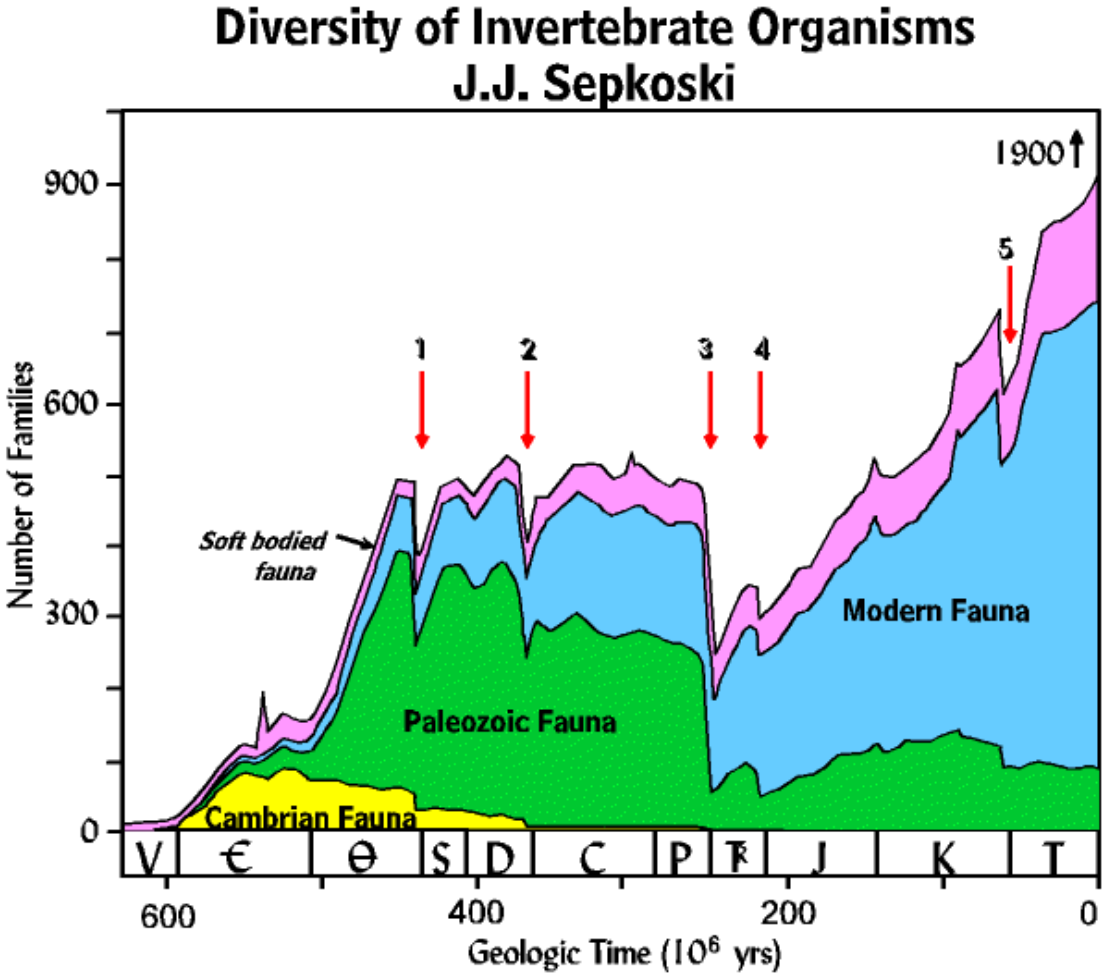


Non-Background Phanerozoic Extinctions In Addition to the Big 5

Cambrian = 5	*Devonian = 5*	*Cretaceous = 2*
Ordovician = 2	*Carboniferous = 2*	*Cenozoic = 3*
Silurian = 1	*Jurassic = 2*	

Mass Extinctions Are Not Above Average
Because in a Power-Law there is no Average

The biggest, easiest to see extinction events, commonly called mass extinctions, are the Big-5, . . .

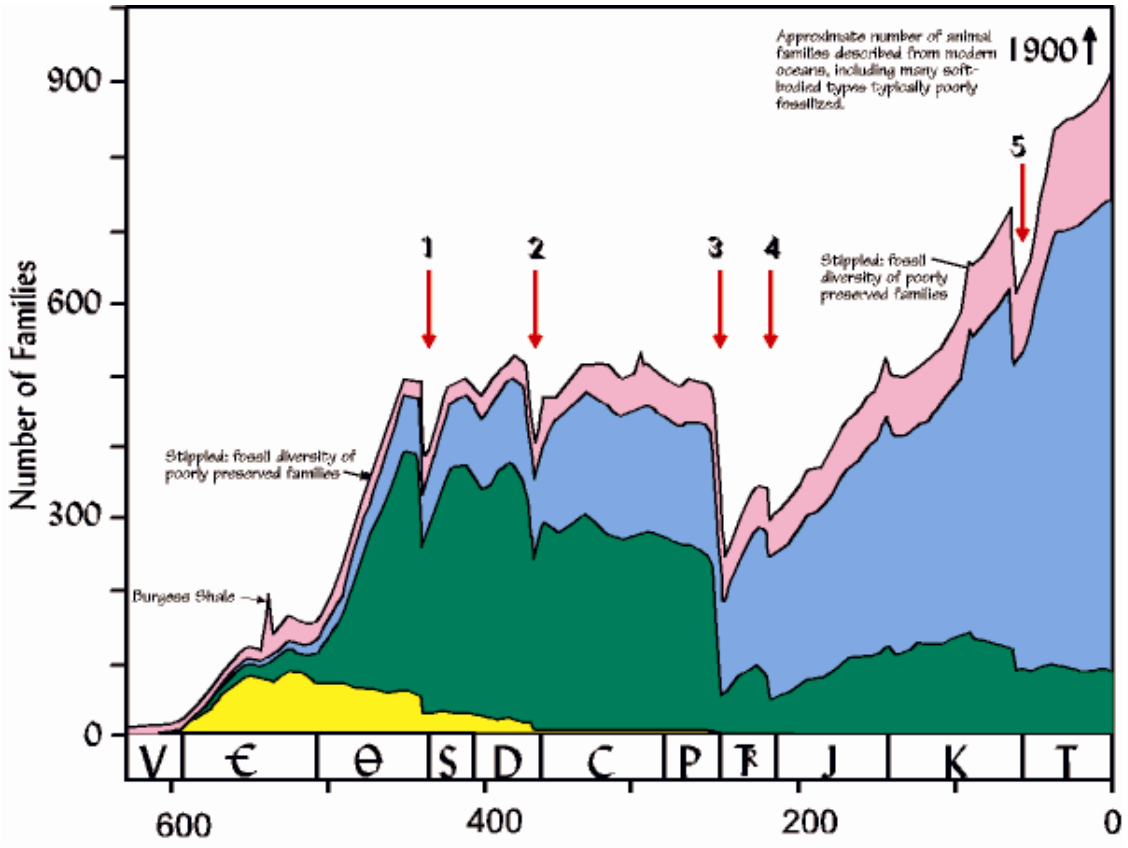


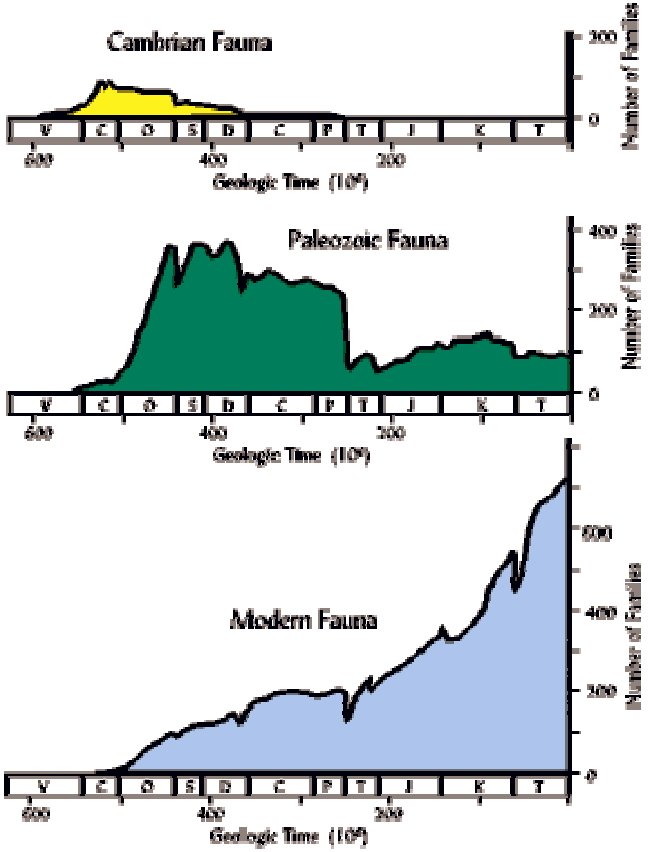
Are Mass Extinctions Different From Background Extinctions?

Extinction Events

Cretaceous Extinction

Cretaceous Extinction – 5th of the Big Five

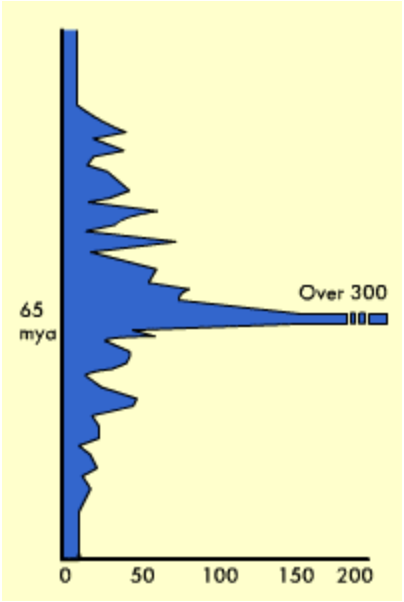




http://www.student.oulu.fi/~jkorteni/space/boundary/

"Key Beds"

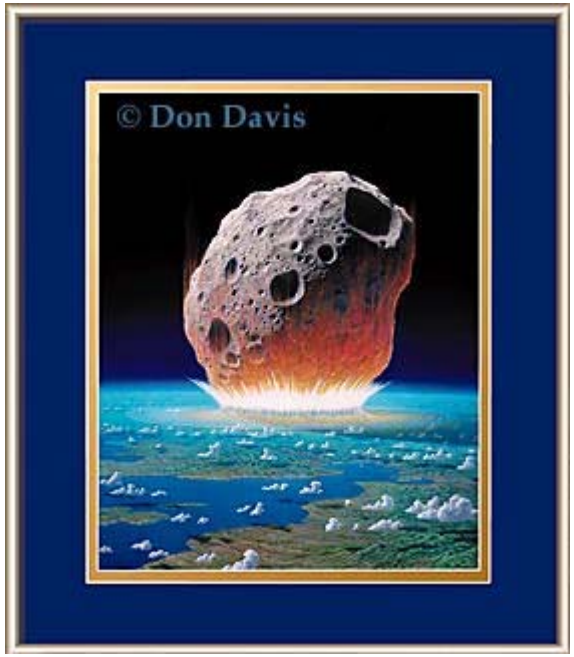
The iridium layer at the K-T boundary



An analysis of the chemical composition of this clay layer shows that it contains a relatively high concentration of an element called iridium. Iridium is rare in the Earth's crust, but more common towards the Earth's centre, and in space. It continually filters down to earth from outer space, and so a high concentration of iridium is usually an indication that the sediment was deposited very slowly, absorbing lots of iridium over time.

http://www.bbc.co.uk/beasts/whatkilled/evidence/analyse1.shtml

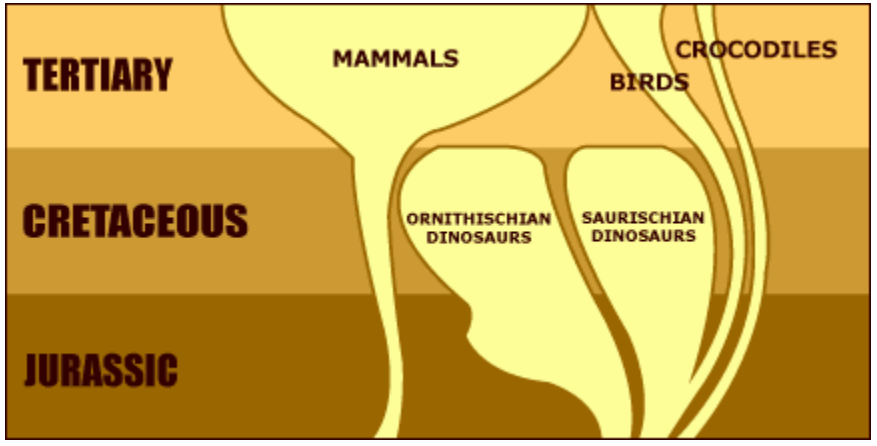
http://c3po.barnesos.net/homepage/lpl/fieldtrips/K-T/day3/day3.html



http://www.novaspace.com/DIGI/KT.html

http://www.uhaul.com/supergraphics/crater/what-is-it2.html

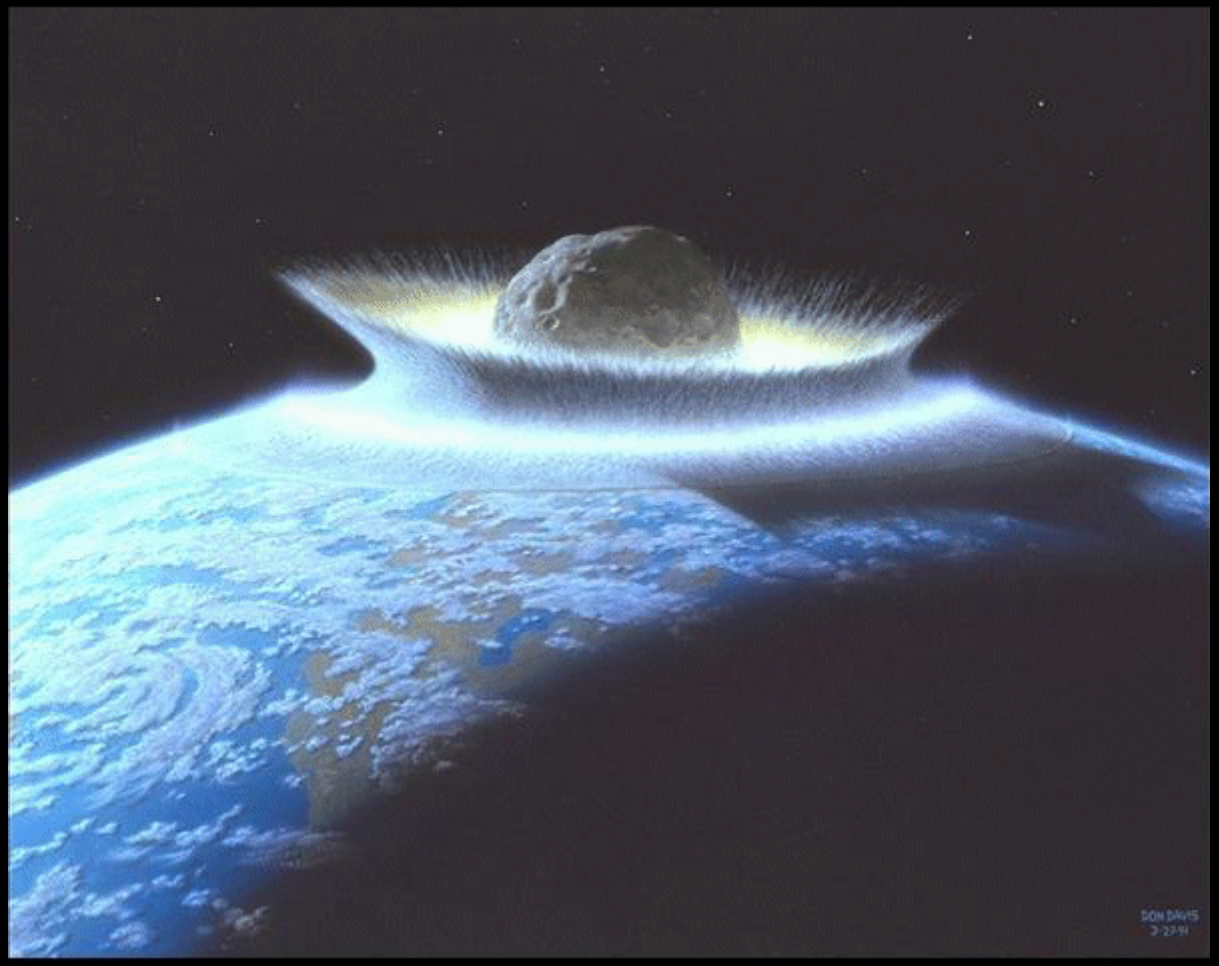
http://filebox.vt.edu/artsci/geology/mclean/Dinosaur_Volcano_Extinction/



http://evolution.berkeley.edu/evosite/evo101/VIIB1aAdaptiveRadiation.shtml

Extinction Because of Bad Luck
Species Area Effects

Asteroid Impacts

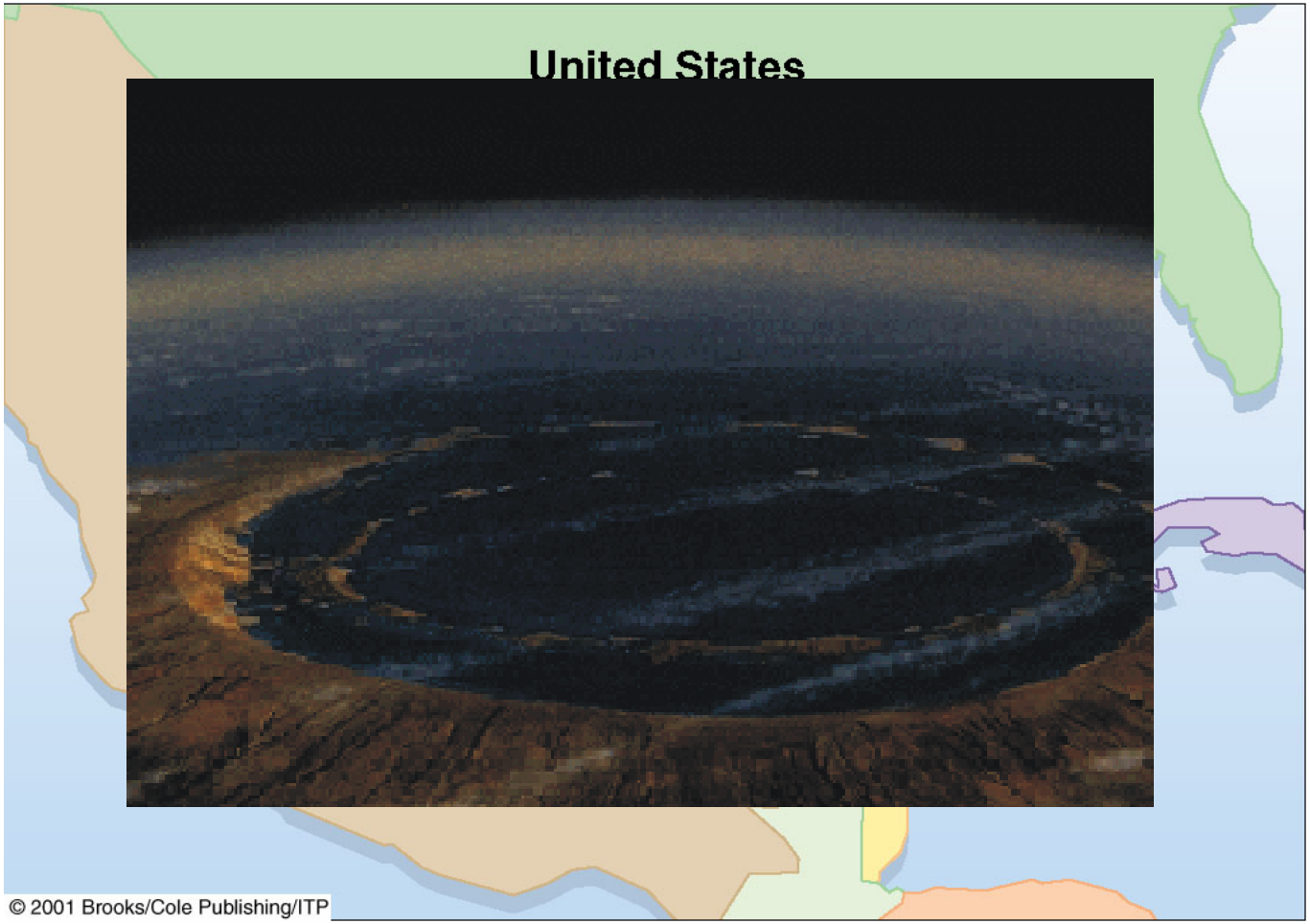


http://www.igeofcu.unam.mx/chicxulub/main.html

Extinction Because of Bad Luck
Species Area Effects
Asteroid Destructive Power

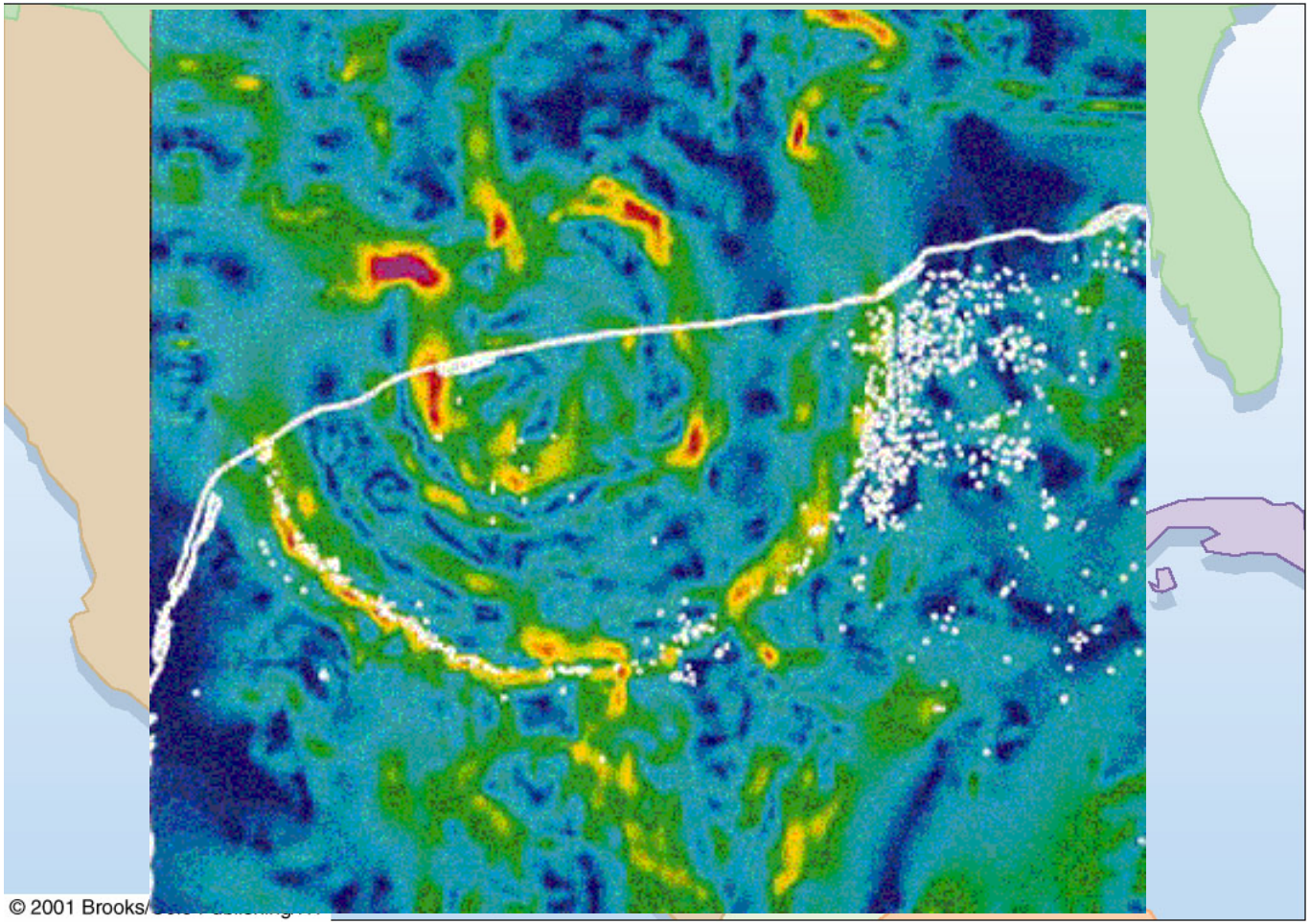
http://www.physics.uc.edu/~hanson/ASTRO/LECTURENOTES/F04/OUTERDEBRIS/Page11.html

Extinction Because of Bad Luck
Species Area Effects
Asteroid Destructive Power



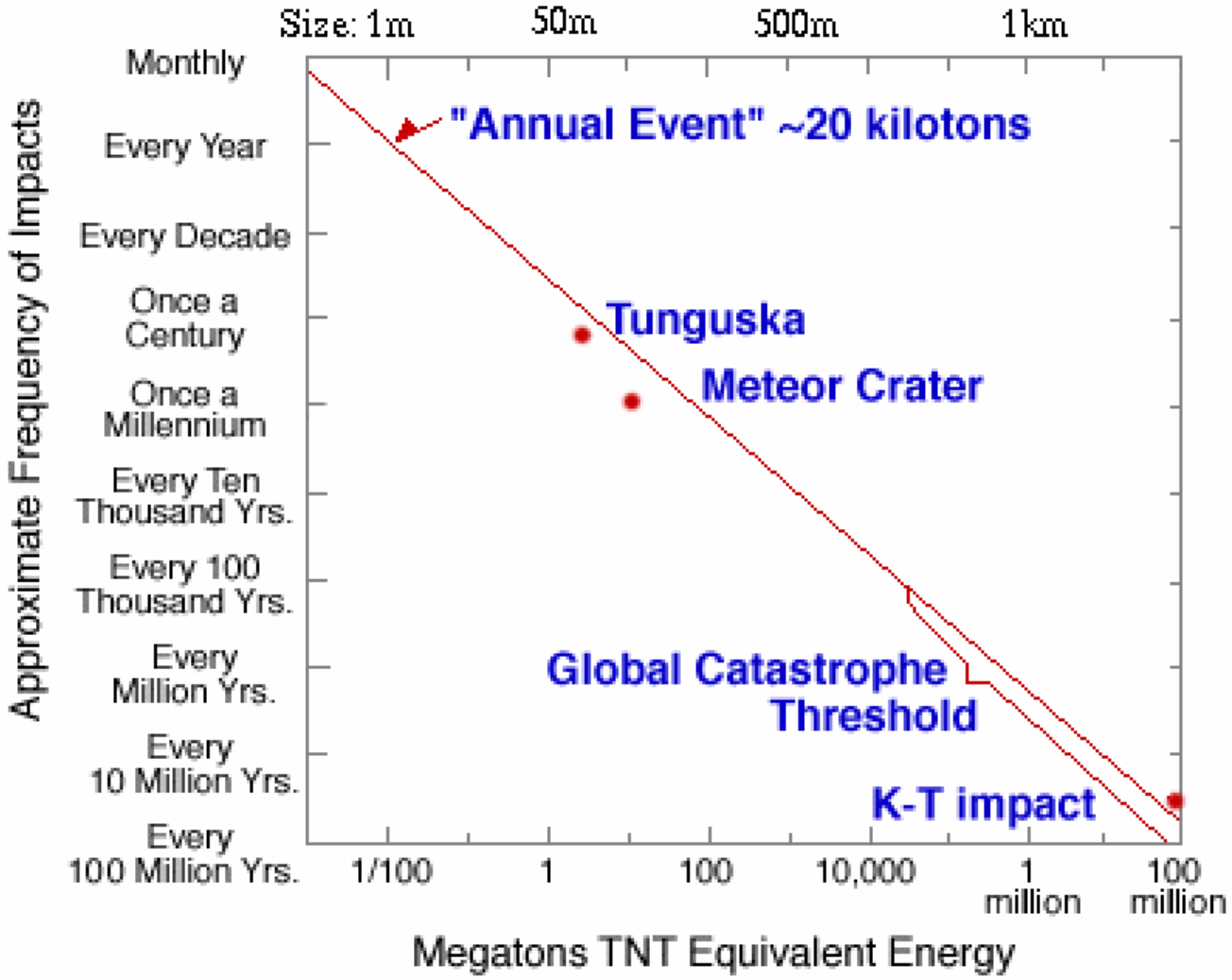
http://www.physics.uc.edu/~hanson/ASTRO/LECTURENOTES/F04/OUTERDEBRIS/Page11.html

Extinction Because of Bad Luck
Species Area Effects
Asteroid Destructive Power



http://www.physics.uc.edu/~hanson/ASTRO/LECTURENOTES/F04/OUTERDEBRIS/Page11.html

Extinction Because of Bad Luck
Species Area Effects
Asteroid Destructive Power

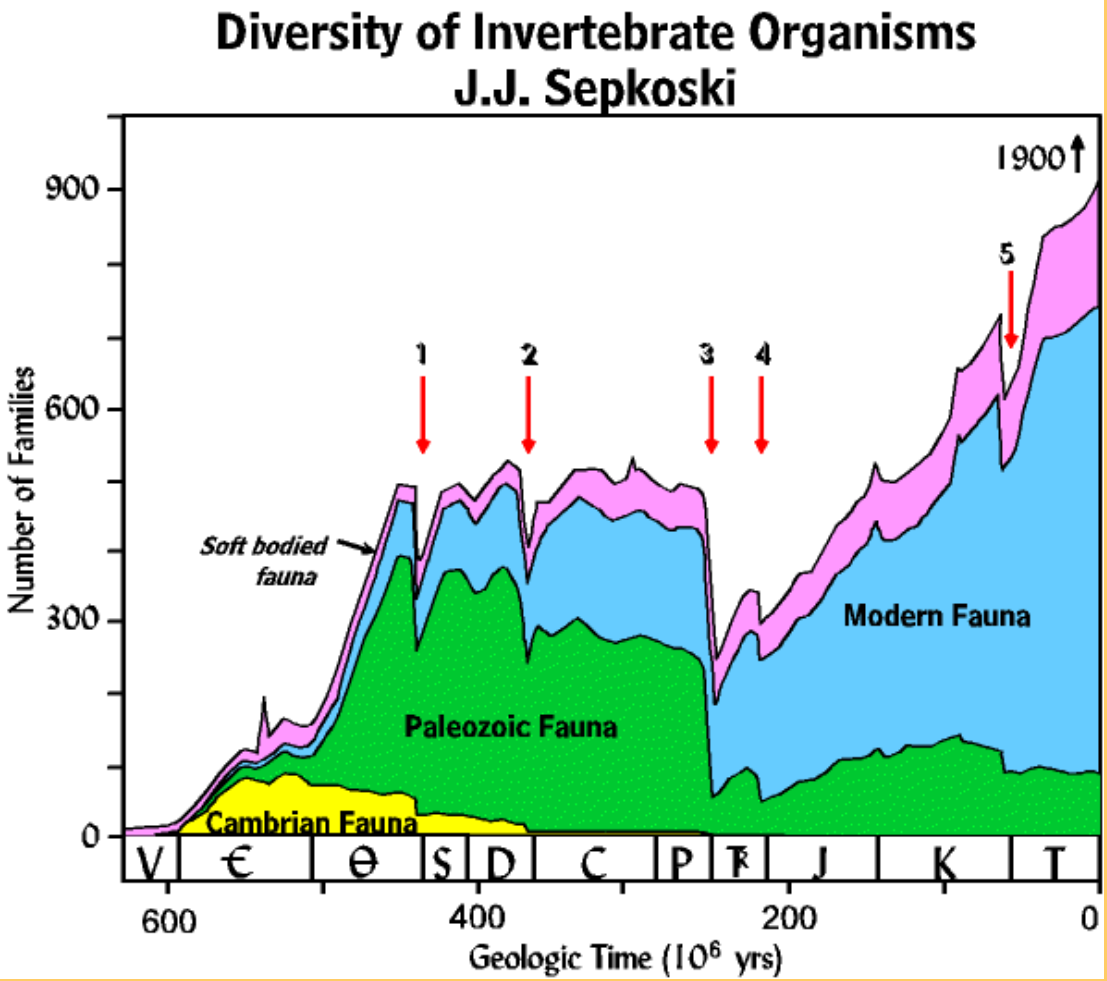


/OUTERDEBRIS/Page11.html

Permian Extinction

Extinction Because of Bad Luck

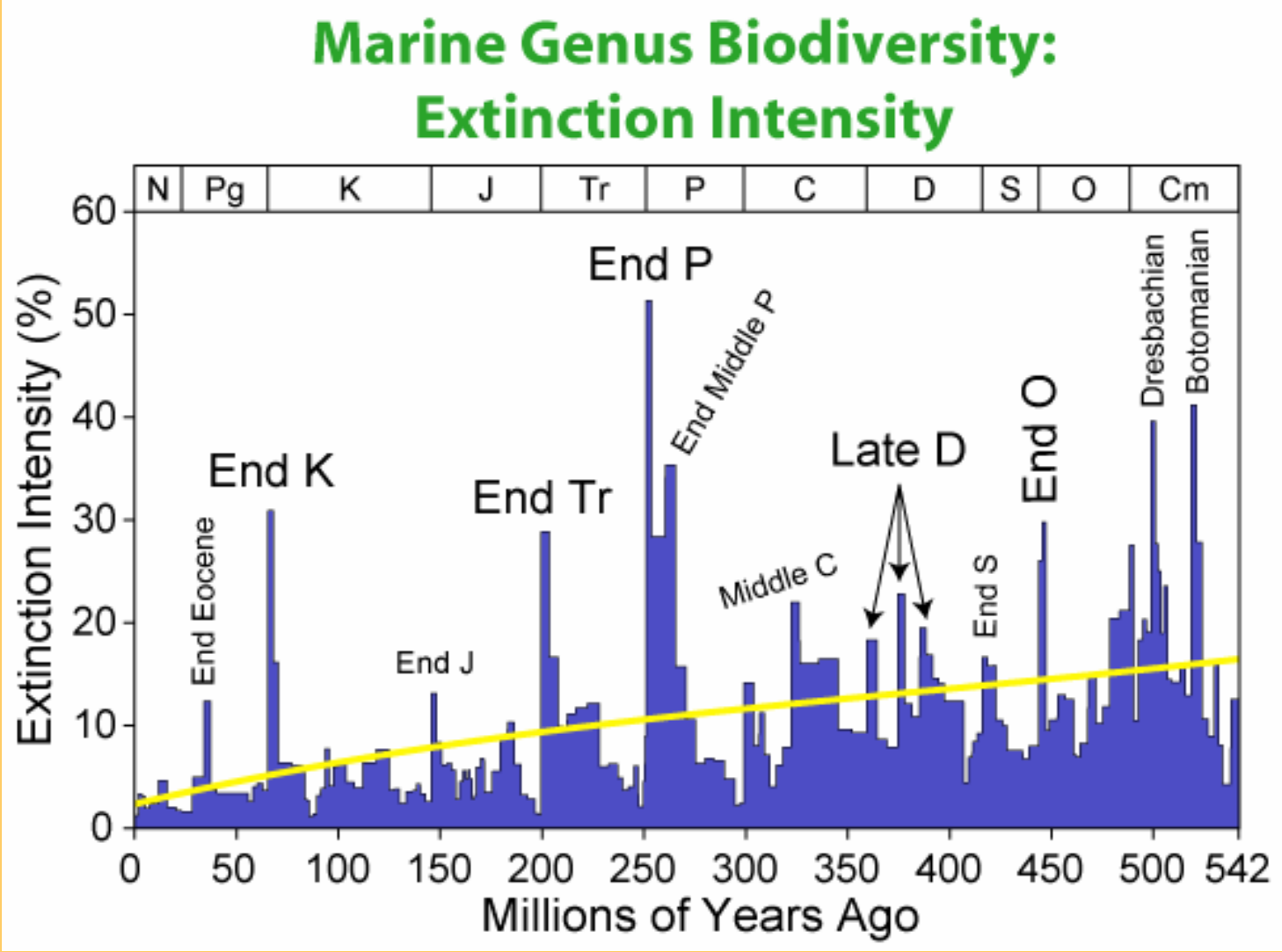
The Permian Extinction



More than 90 percent of all species on Earth mysteriously perished during a mass extinction, perhaps within just a few thousand years. Trilobites became extinct; coral, bryozoan, and brachiopod species diminished. Land plants and animals were also impacted; amphibian species dwindled and fungi dominated some ecosystems.

Extinction Because of Bad Luck

The Permian Extinction

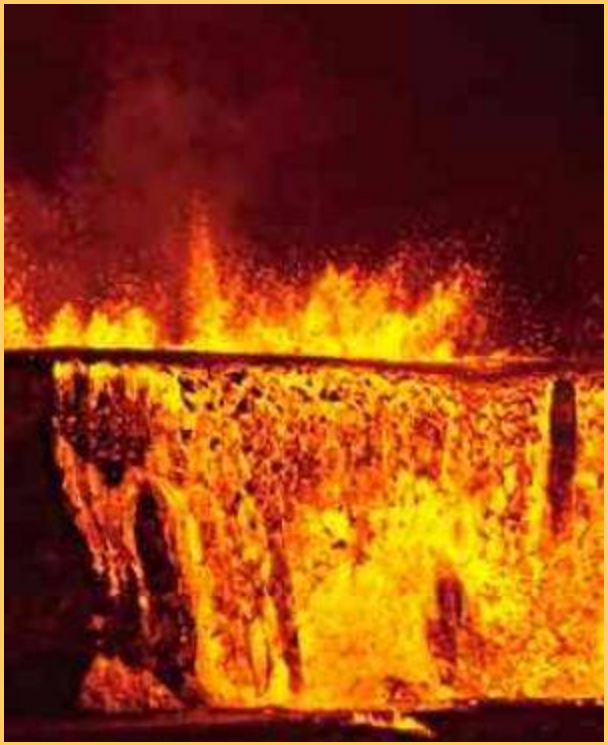


http://en.wikipedia.org/wiki/Image:Extinction_Intensity.png

Extinction Because of Bad Luck

The Permian Extinction

The extinction began with a massive volcanic eruption in Siberia that covered an area the size of Europe



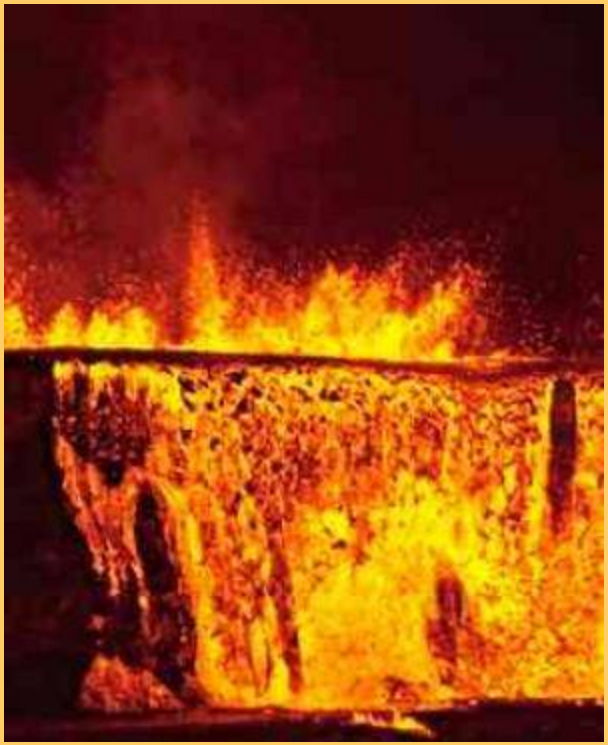
EUROPE
EUROPEAN UNION
EU Member States
EU New Members 2004
EU Candidates
EFTA Member States
© Nations Online Project
Greenland Sea
ICELAND
Norwegian Sea
Faroe Islands (DENMARK)
NORGE NORWAY
SVERIGE SWEDEN
SUOMI FINLAND
Gulf of Bothnia
Baltic Sea
RUSSIA
Moscow
St. Petersburg
ESTONIA
LATVIA
LITHUANIA
BELARUS
Minsk
North Sea
Atlantic Ocean
ÉIRE IRELAND
UNITED KINGDOM
DANMARK DENMARK
DEUTSCHLAND GERMANY
NETHERLANDS
BELGIUM
POLAND
UKRAINE
Kiev
Celtic Sea
English Channel
FRANCE
CZECH REPUBLIC
SLOVAKIA
Österreich Austria
HUNGARY
ROMANIA
Switzerland
Bay of Biscay
Black Sea
BULGARIA
SERBIA AND MONTENEGRO
BOSNIA AND HERZEGOVINA
CROATIA
SLOVENIA
Adriatic Sea
ITALIA ITALY
PORTUGAL
ESPAÑA SPAIN
Tyrrhenian Sea
Ionian Sea
Aegean Sea
Ελλάς GREECE
ALBANIA
TURKEY
ASIA
Mediterranean Sea
AFRICA
MALTA
CRETE
CYPRUS
250 Km
250 Mi

Extinction Because of Bad Luck

The Permian Extinction

The extinction began with a massive volcanic eruption in Siberia that covered an area the size of Europe

This put large amounts of carbon dioxide into the atmosphere creating a greenhouse warming effect.



Extinction Because of Bad Luck

The Permian Extinction

The greenhouse warming warmed the ocean waters, triggering a release of methane hydrate from the ocean floor.

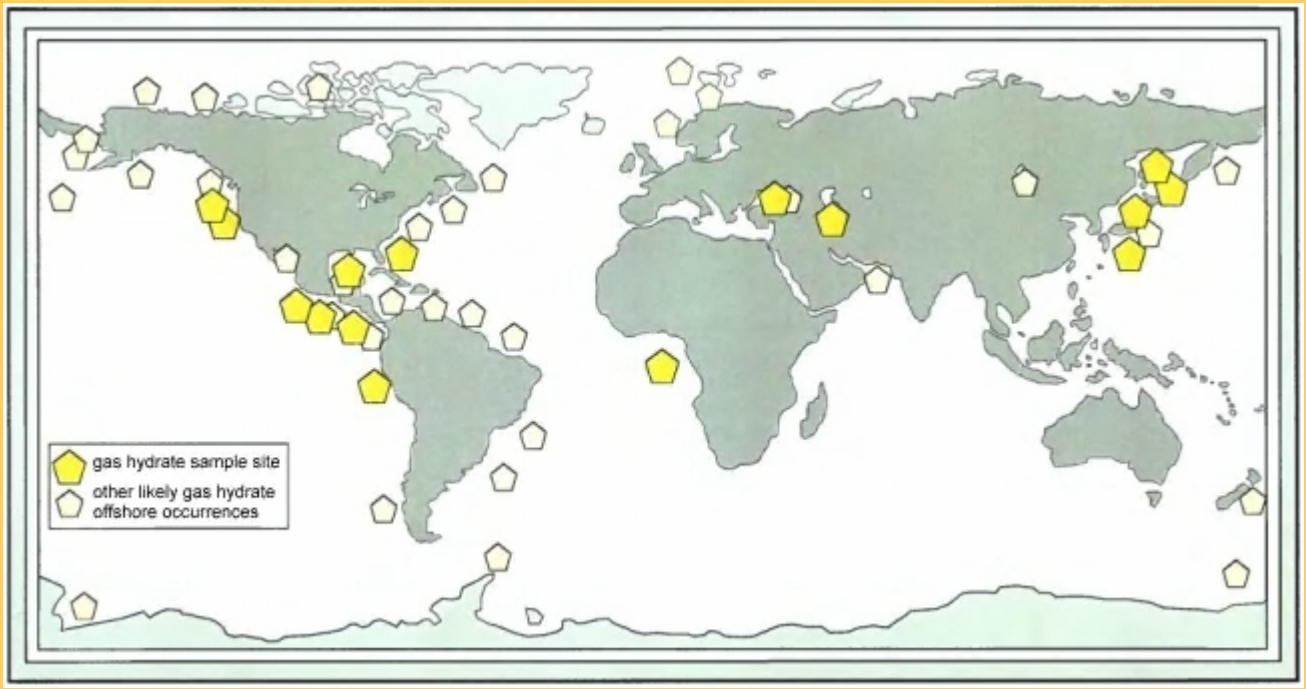
Extinction Because of Bad Luck

The Permian Extinction

Tubeworms and mussels on top of a hydrate mound. The yellowish methane hydrate provides a source of methane for the mussels living on top of them. A little further from the hydrate, we see lots of tubeworms growing. They may be connected to the hydrate too, since the microbes in the sediment that turn seawater sulfate into sulfide need methane for energy.

Extinction Because of Bad Luck

The Permian Extinction



Methane Hydrate Production

Extinction Because of Bad Luck

The Permian Extinction

As a greenhouse gas methane is 20 times more effective than carbon dioxide.

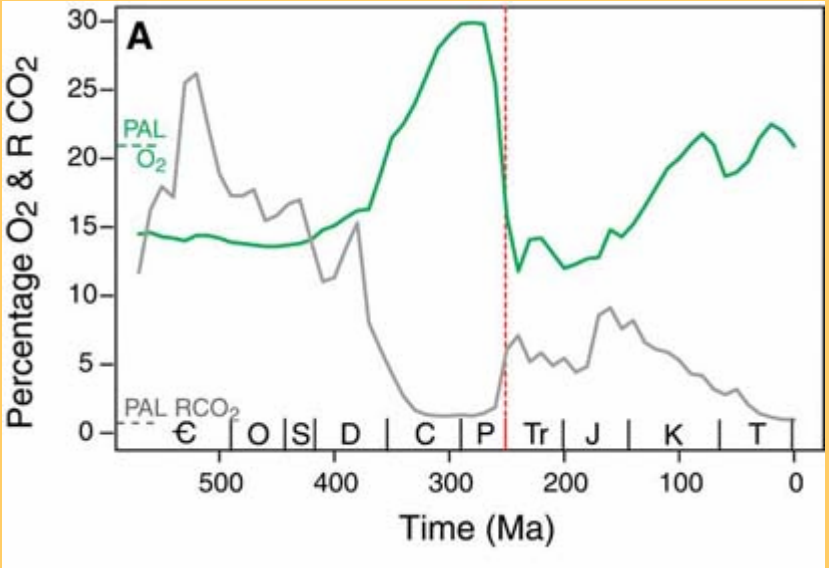
Runaway Greenhouse effect by positive feedback processes

- CO_2 release heats atmosphere and oceans.
- Heating of oceans releases methane hydrate.
- Greenhouse effect of methane raises temperature of oceans even more, which leads to release of even more methane – RUNAWAY GREENHOUSE

Extinction Because of Bad Luck

The Permian Extinction

Atmospheric methane reacts with oxygen, leading to a rapid decline of oxygen concentration from about 30 percent to 10 percent



The vertical, dashed red line marks the Permian-Triassic boundary. The green line indicates the level of oxygen; the dashed green line at left, its present atmospheric level (PAL). The grey line indicates the level of carbon dioxide; the dashed grey line, its present atmospheric level. Note how the level of atmospheric carbon dioxide declines, and the level of oxygen increases, with the rise of the forests during the Devonian, Carboniferous, and Permian. Note also how the level of carbon dioxide abruptly increases, and that of oxygen abruptly declines, at the end of the Permian and into the Triassic.

http://www.killerinourmidst.com/grafix/PhanerozoicOxygen.jpg

Extinction Because of Bad Luck

The Permian Extinction

More than 90 percent of all species on Earth mysteriously perished during a mass extinction, perhaps within just a few thousand years. Trilobites became extinct; coral, bryozoan, and brachiopod species diminished. Land plants and animals were also impacted; amphibian species dwindled and fungi dominated some ecosystems.

http://www.killerinourmidst.com/grafix/PhanerozoicOxygen.jpg

Extinction Because of Bad Luck

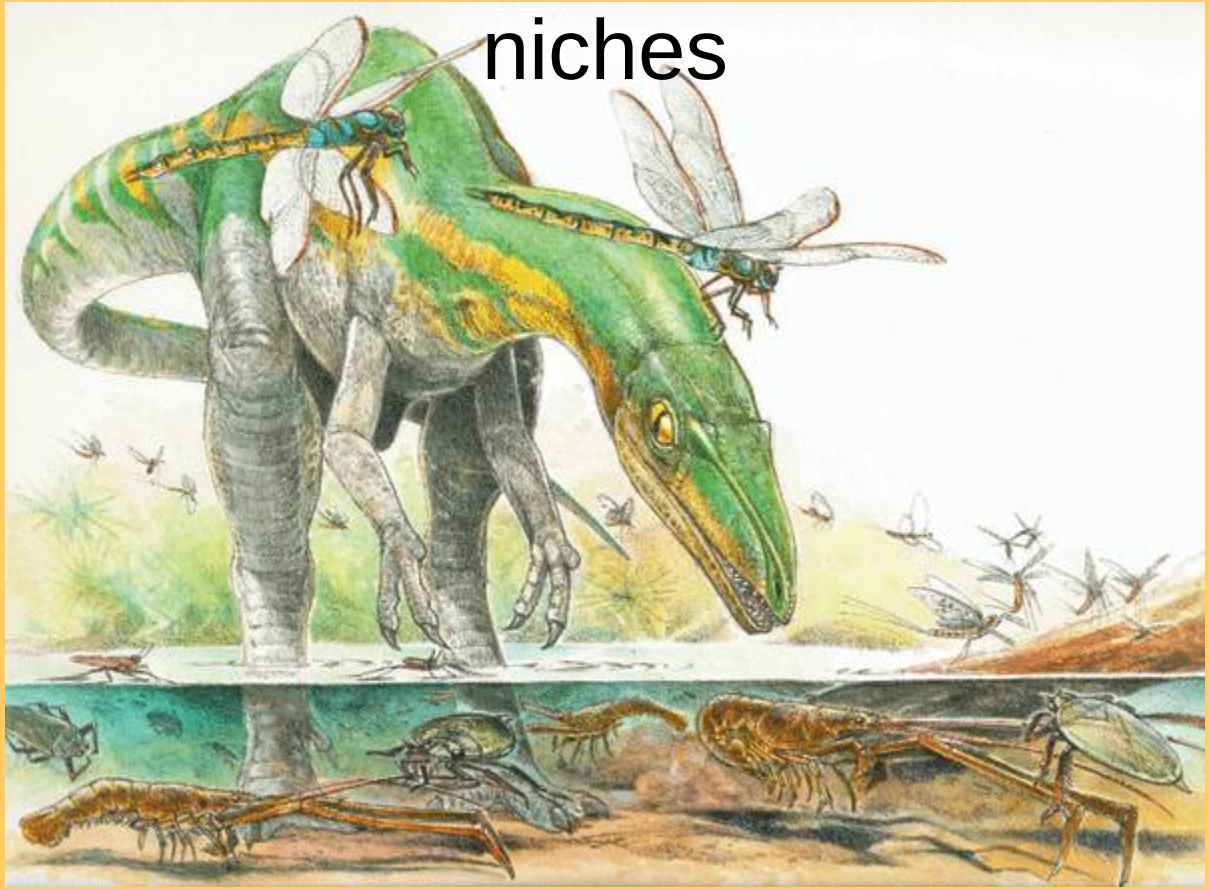
The Permian Extinction

Marine ecosystems collapse

http://cas.bellarmine.edu/tietjen/Evolution/permia10.jpg

After the Permian Extinction

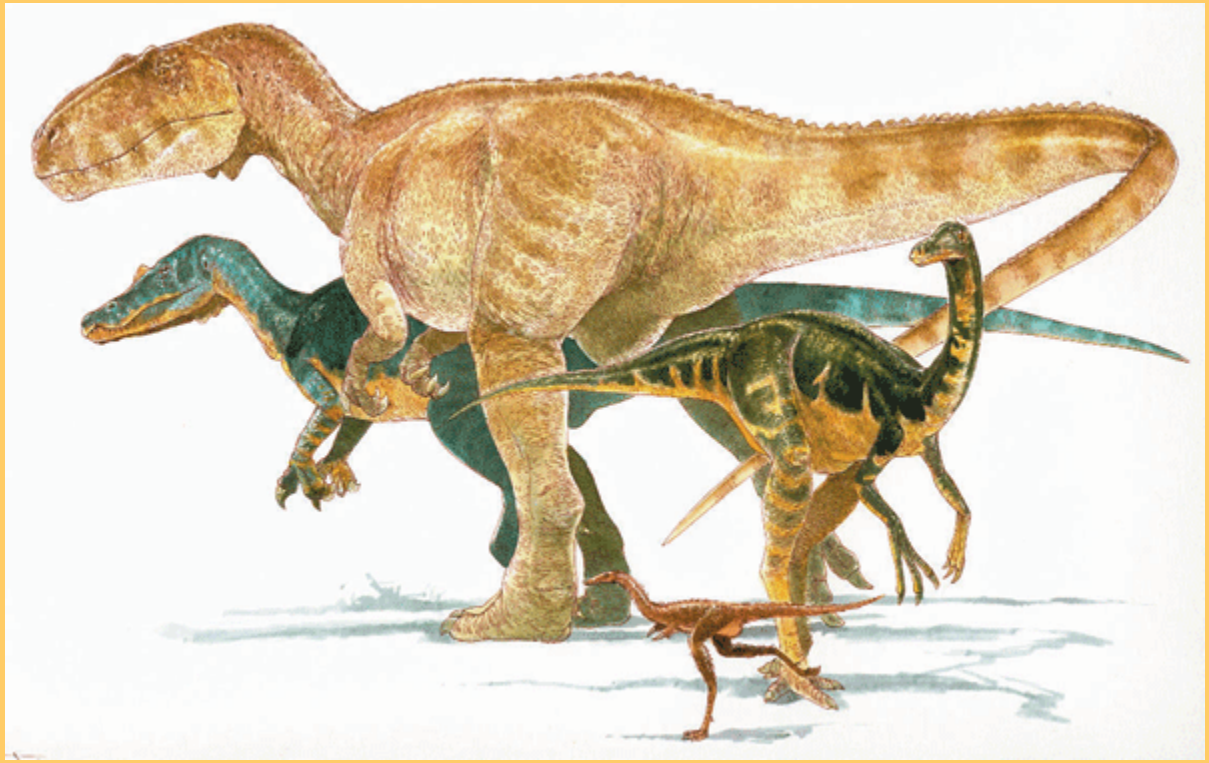
But, some groups expanded into the vacant niches



http://www.dinoruss.org/art.html

After the Permian Extinction

Like Dinosaurs



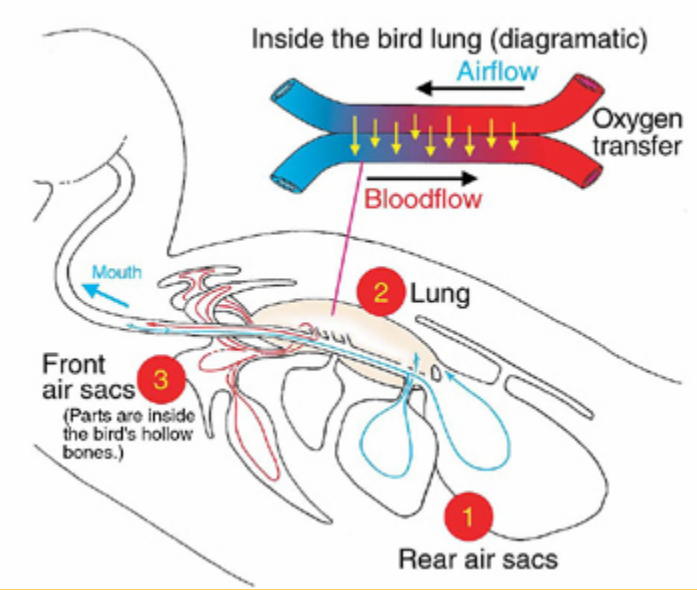
Why did these animals thrive after the extinction?

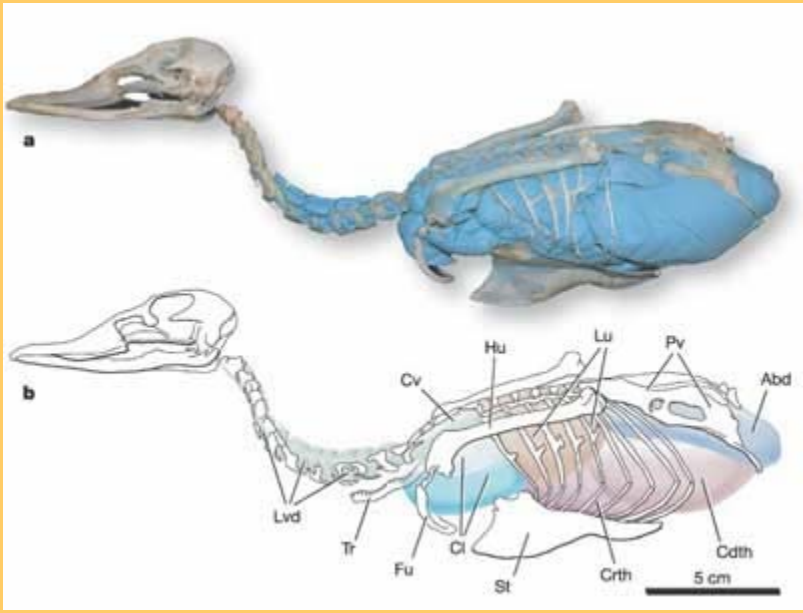
http://www.dinoruss.org/art.html

After the Permian Extinction

We can get some idea by looking at the only living dinosaur representatives . . .

BIRDS

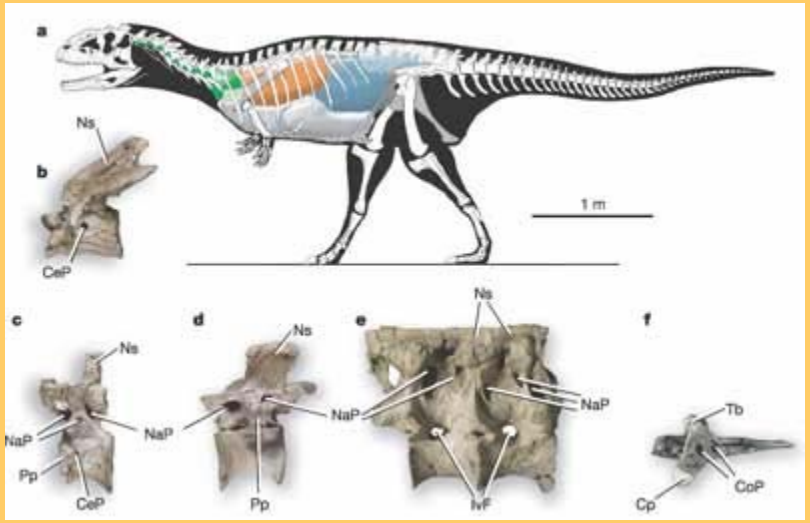


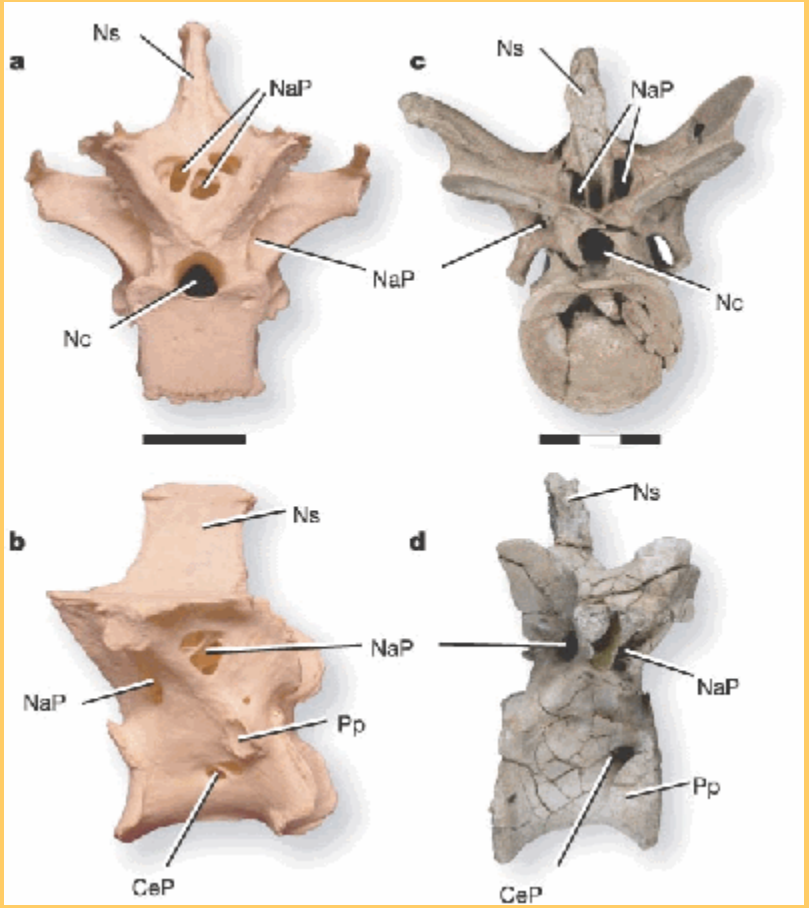


Latex injection (blue) of the pulmonary system in a duck (Anas crecca), highlighting the extent of air sacs throughout the body.

http://pharyngula.org/index/weblog/comments/dino_lungs/

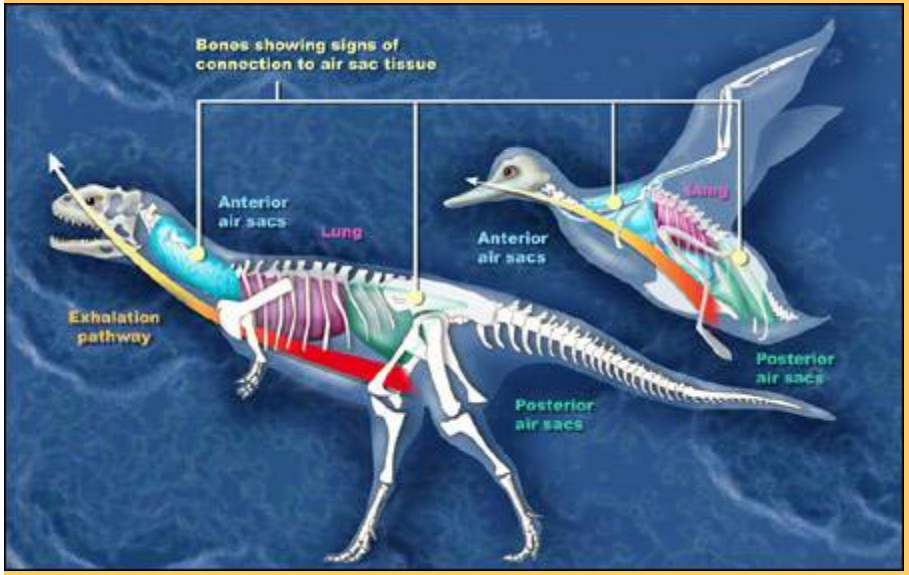
After the Permian Extinction



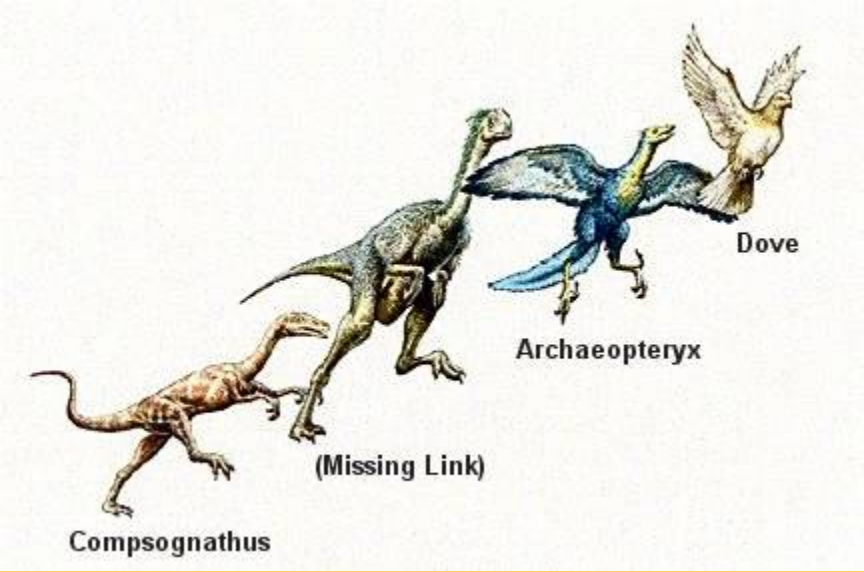


http://pharyngula.org/index/weblog/comments/dino_lungs/

After the Permian Extinction



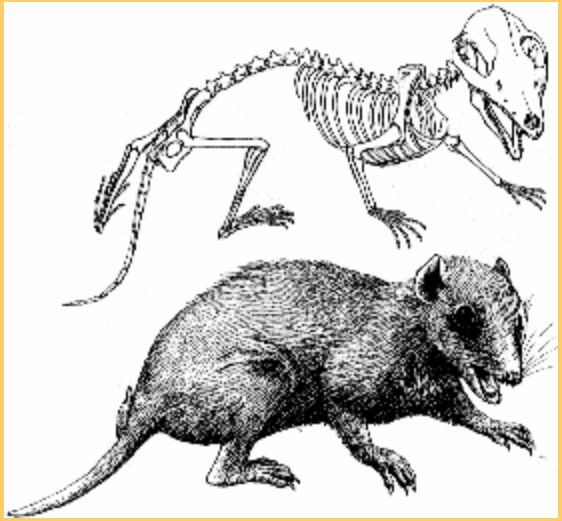
http://www.news.harvard.edu/gazette/2005/07.21/photos/13-dino_2.jpg

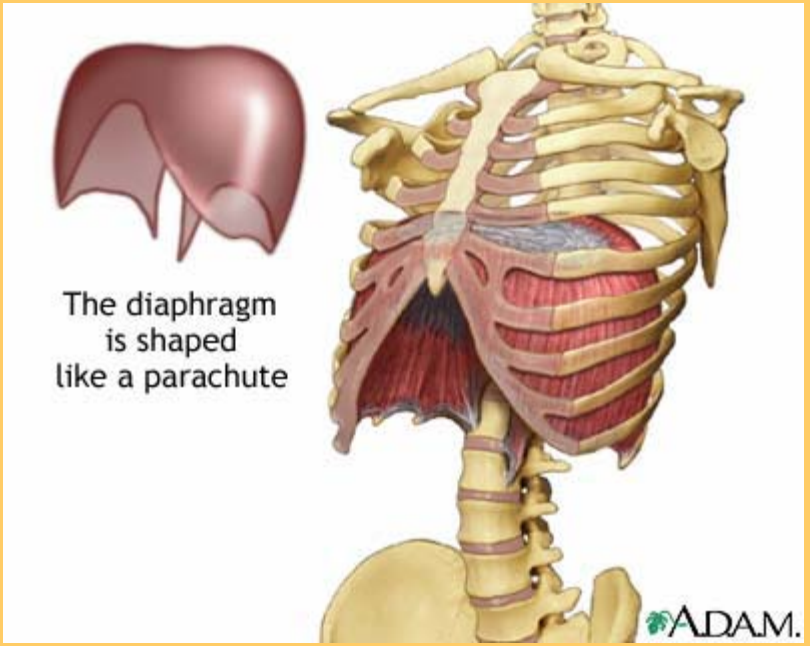


http://universe-review.ca/I10-72-flyingreptiles.jpg

After the Permian Extinction

But, why then did mammals also do so well after the extinction.





http://earth.usc.edu/~stott/Catalina/Mesozoic.html

After the Permian Extinction

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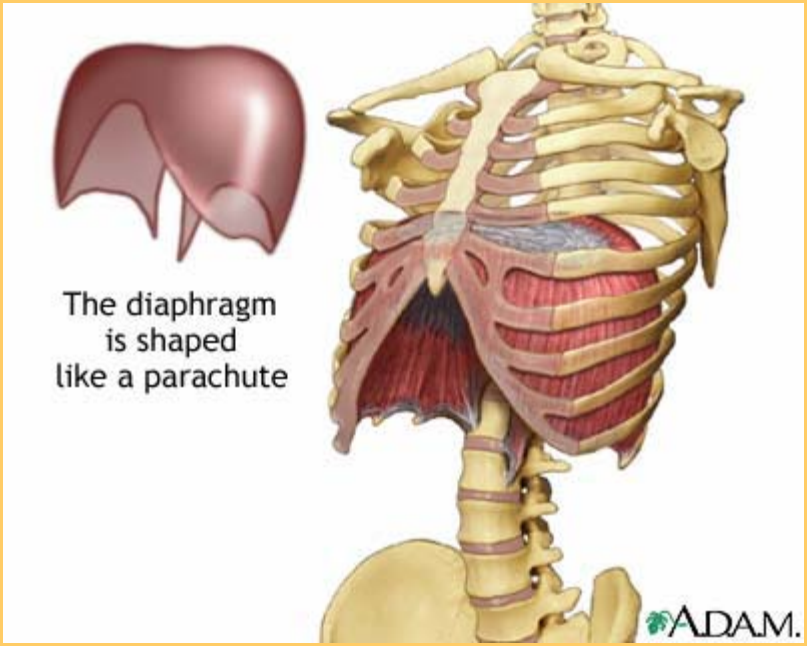


http://earth.usc.edu/~stott/Catalina/Mesozoic.html

Pleistocene Megafauna Extinction

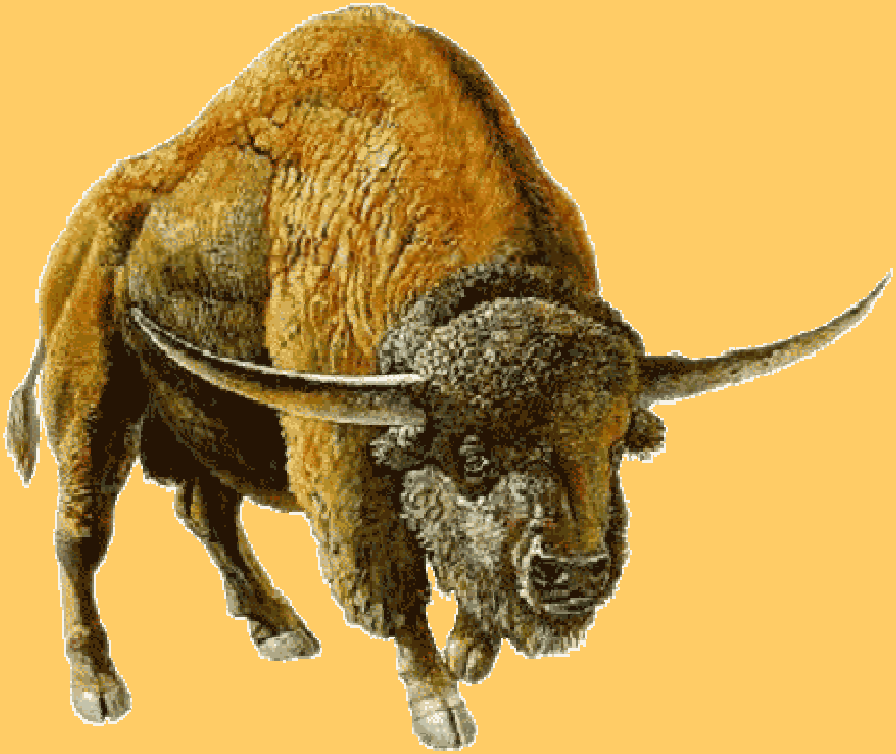
Ice Age Mammals

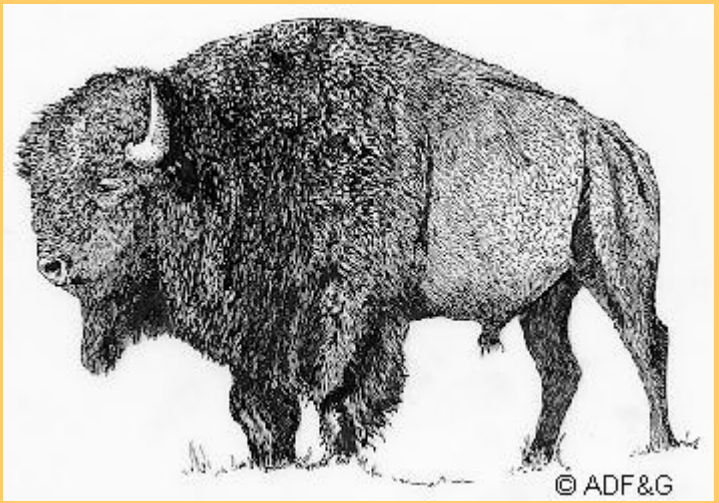
Pleistocene Mega Fauna. Large mammals were more susceptible to extinction at the end of the last ice age.

	Number Before Extinction	Number Dying	Percent Dying
Small Mammals			
Species	**211**	**21**	**10%**
Genera	**83**	**4**	**5%**
Large Mammals			
Species	**79**	**57**	**72%**
Genera	**51**	**33**	**65%**

Pleistocene Mega Fauna

Bison latifrons





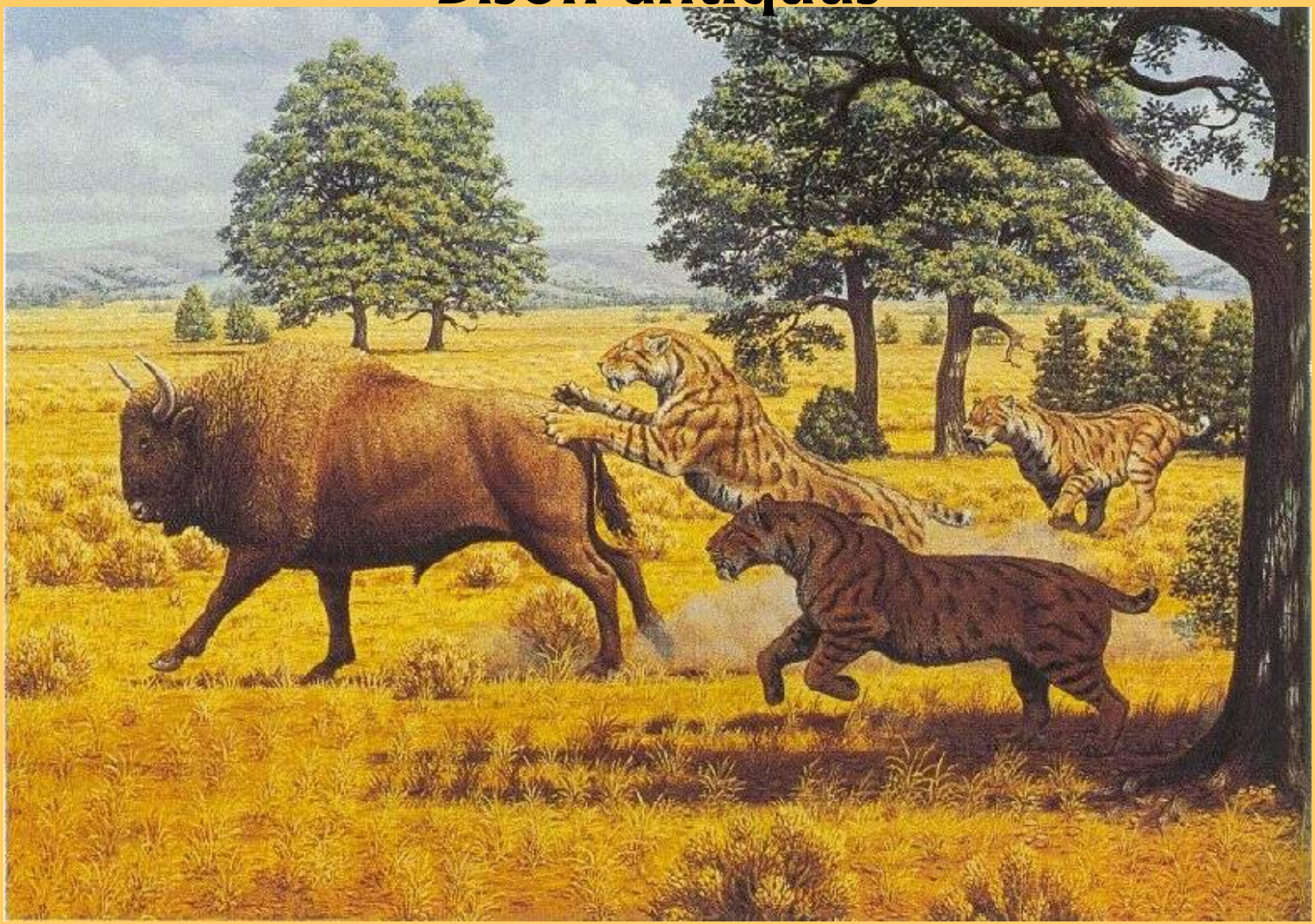
Ice-age bison, such as this long-horned *Bison latifrons*, were twice as big as the bison (*Bison bison*) that live in South Dakota today. They died out about seven thousand years ago. Smaller bison took their place.

Pleistocene Mega Fauna

Bison antiquus

Pleistocene Mega Fauna

Bison antiquus



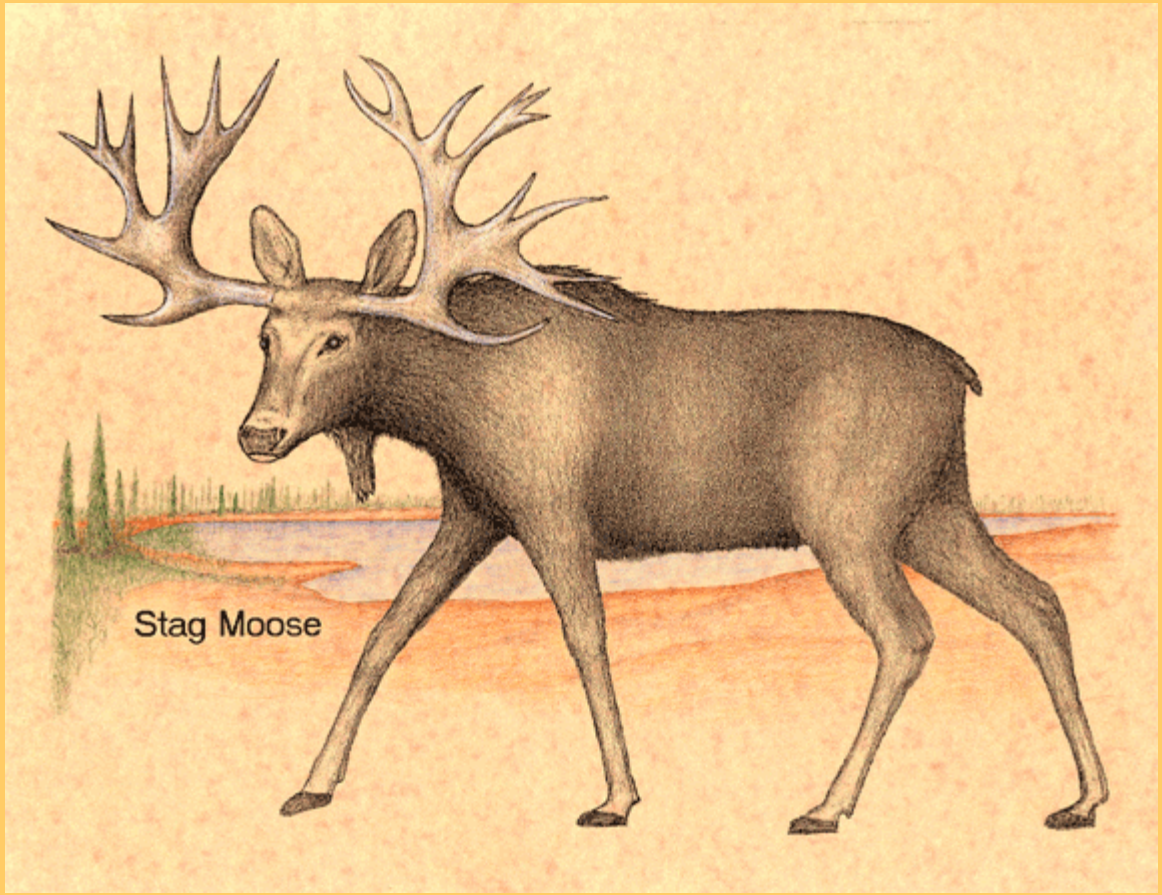
Sabre-tooth Cats (*Smilodon fatalis*) hunting bison (*Bison antiquus*) near Rancho La Brea, California, late Pleistocene

http://www.mun.ca/biology/scarr/Smilodon.htm

Pleistocene Mega Fauna

Cervalces scotti

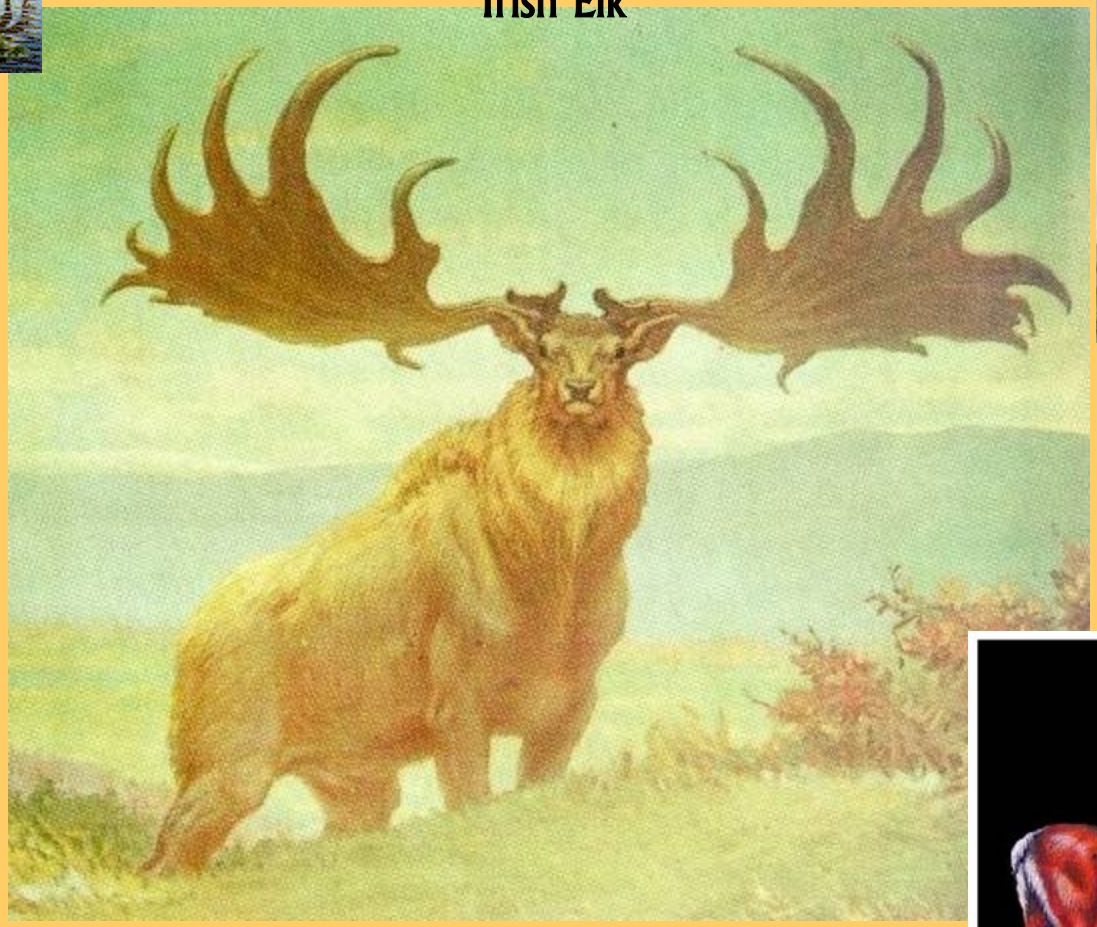
Stag moose

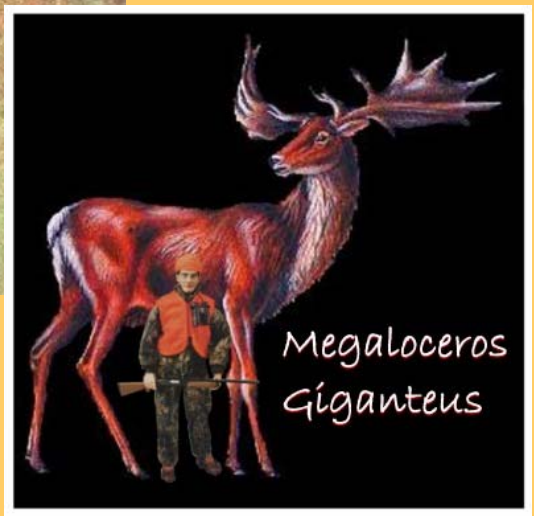


Pleistocene Mega Fauna

Megaloceras giganteus

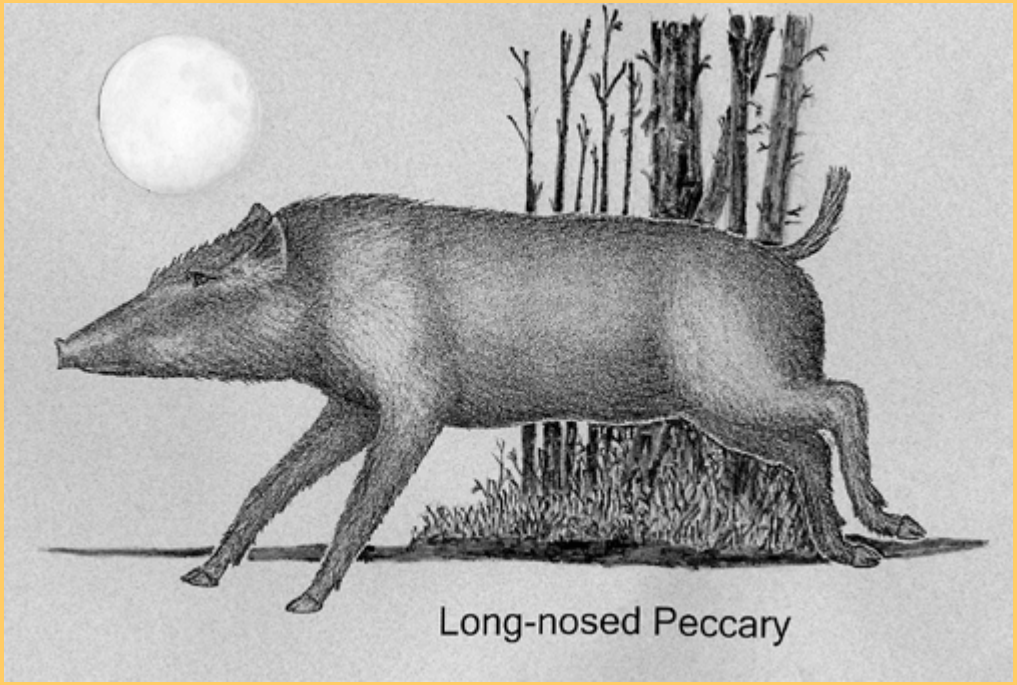
Irish Elk





Pleistocene Mega Fauna

Mylohyus nasutus



Up to three feet tall, this swift long-legged peccary lived in Illinois long before the Ice Age and eventually was contemporary with early humans, possibly as late as 9,000 years ago.

http://www.isgs.uiuc.edu/quaternary/peccary.htm

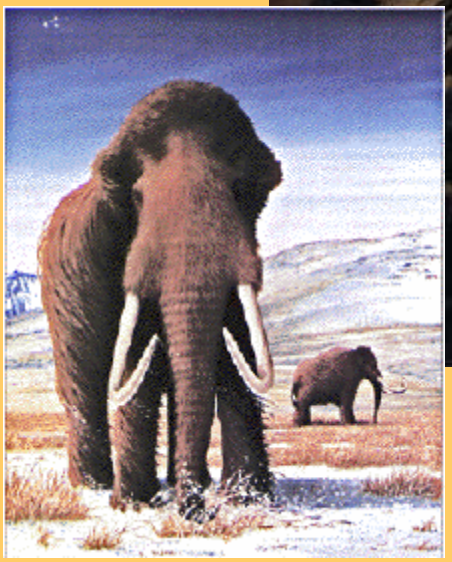
Pleistocene Mega Fauna

Camelops hesternus

http://www.geol.umd.edu/~jmerck/geol100/lectures/36.html

Pleistocene Mega Fauna

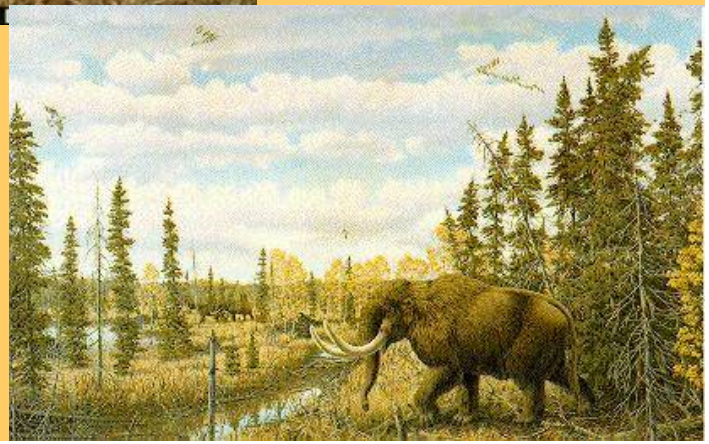
Mammuthus - mammoth



http://www.vs-durach.de/projekte/landschaft/Eiszeit%20Mammut.JPG

Pleistocene Mega Fauna

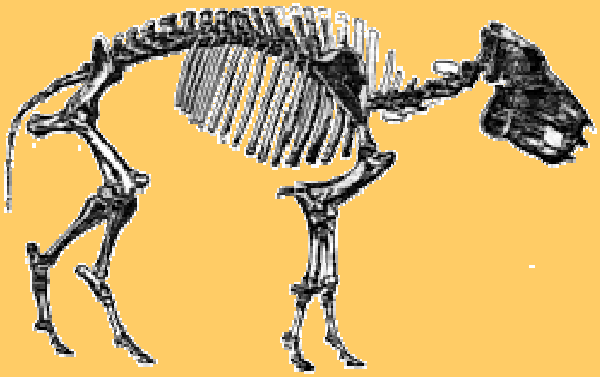
Mastodon



Pleistocene Mega Fauna

Platygonus compressus

Flat Headed Peccary



http://www.bbc.co.uk/beasts/evidence/prog6/page2.shtml

Pleistocene Mega Fauna

Castoroides

Giant beaver

Pleistocene Mega Fauna

Tapirus terrestrius

Giant beaver

Pleistocene Mega Fauna

Megalonyx jeffersonii

Jefferson ground sloth

Pleistocene Mega Fauna

Paramylodon harlani

Harlan's ground sloth

http://www.tarpits.org/education/guide/flora/sloth.html

Pleistocene Mega Fauna

Nothrotheriops shastensis

Shasta ground sloth

http://www.tarpits.org/education/guide/flora/sloth.html

Pleistocene Megagauna

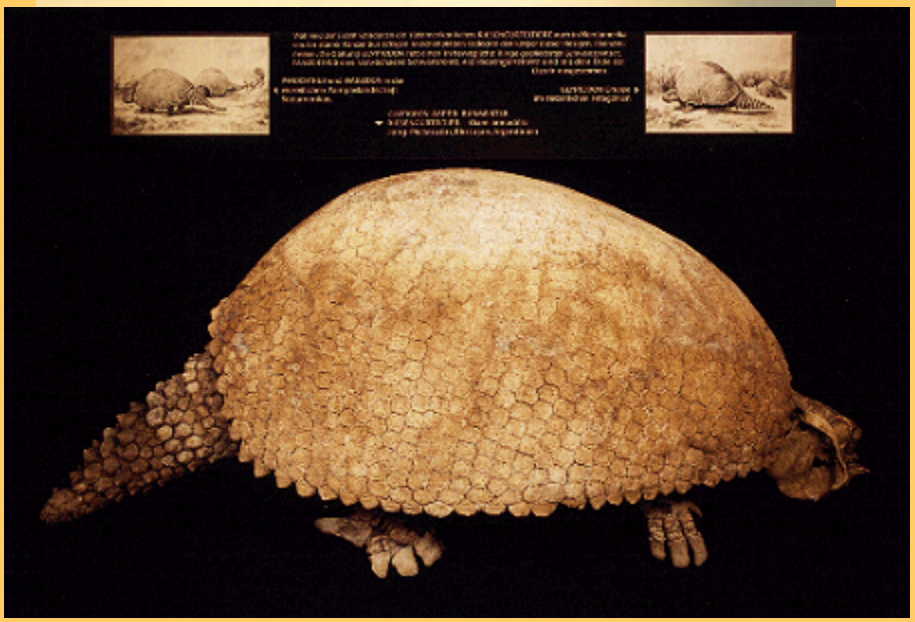
Eremotherium laurillardi

Laurillard's ground sloth

http://www.beringia.com/01/01maina1.html

Pleistocene Megagauna

Glyptodon



Pleistocene Megagauna

Rhinoceros antiquitatis

Woolly rhino: Europe and Asia but not North America

Pleistocene Mega Fauna

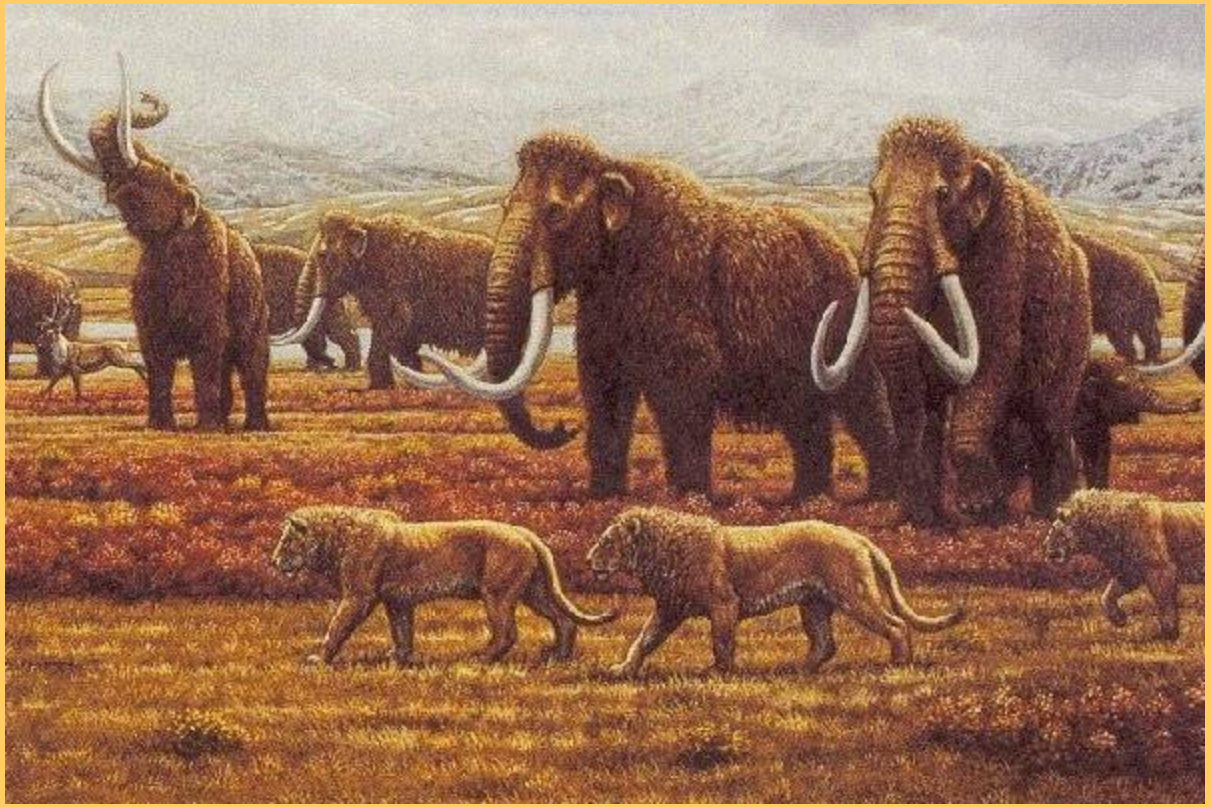
Felis atrox – American Lion

http://www.beringia.com/01/01maina1.html

Pleistocene Mega Fauna

Felis atrox – American Lion

With Mammuthus



Mammoths (*Mammuthus*) and American Lions (*Felis atrox*) in the late Pleistocene of Alaska

http://www.mun.ca/biology/scarr/Pleistocene_megafauna.htm

Pleistocene Mega Fauna

Ursus

Giant short faced bear

http://www.joevenusartist.com/Utah%20Ice%20Age.htm

Pleistocene Mega Fauna

Ursus

Giant short faced bear

Pleistocene Mega Fauna

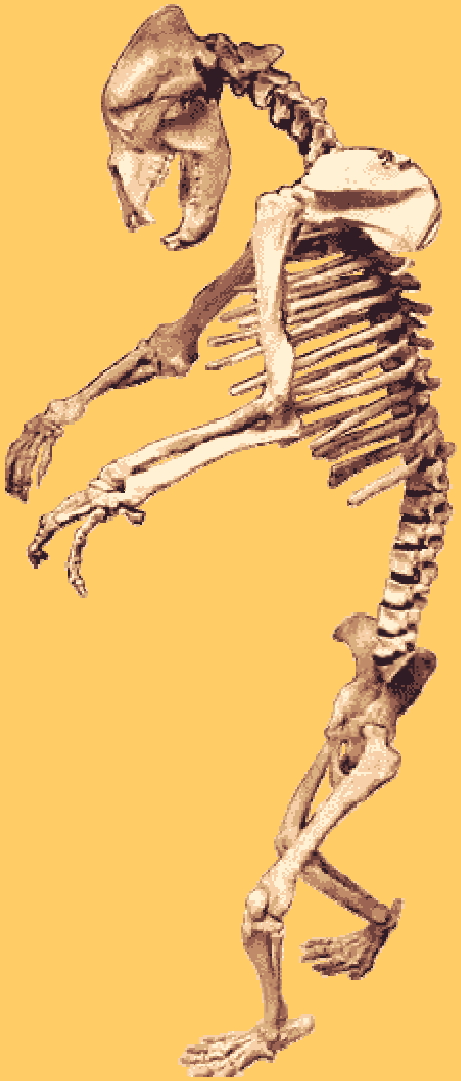
Ursus arctos

Grizzly bear

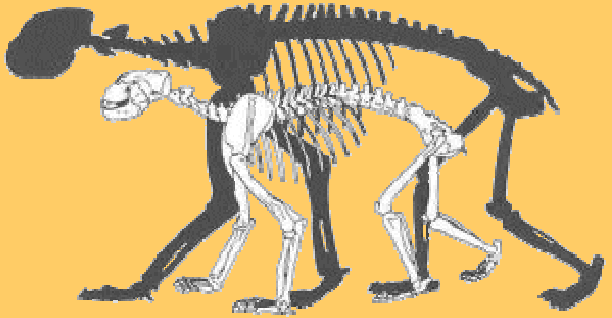
Pleistocene Mega Fauna

Ursus spelaeus

Cave Bear



fierce, 20-foot long versions of Grizzly bears with huge teeth and razor sharp claws

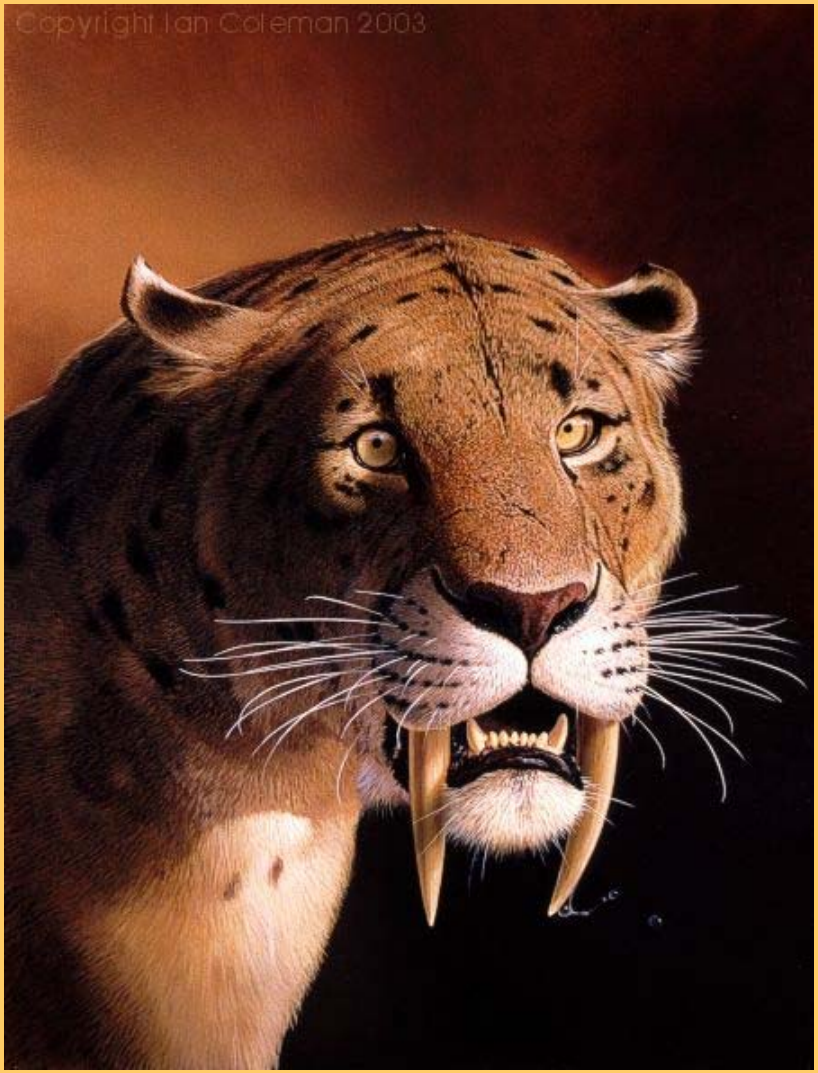


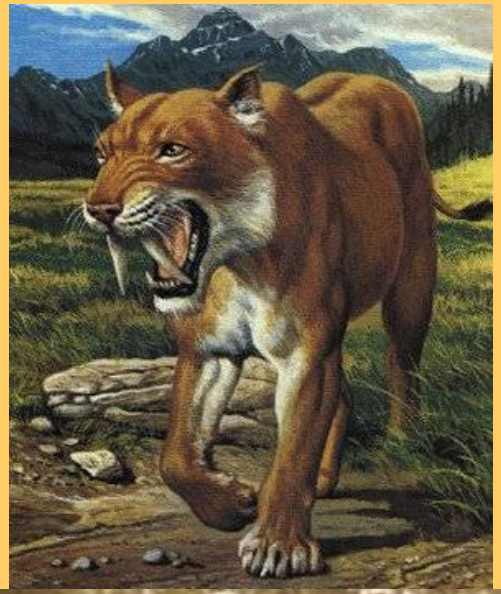
http://www.personal.psu.edu/users/w/x/wxk116/cavebears/

Pleistocene Mega Fauna

Smilodon

Saber toothed cat



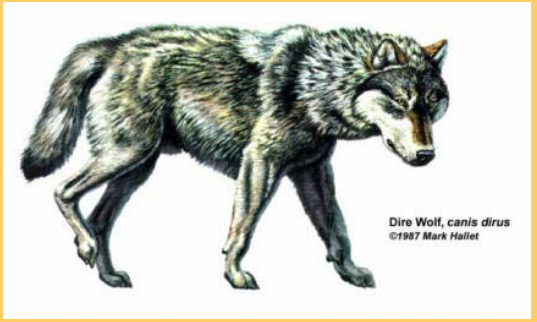


http://www.colemangallery.com/Portfolio_pages/L26F_Sabre_Toothed_Cat_Full.htmlhttp://www.mun.ca/biology/scarr/Smilodon.htm

Pleistocene Mega Fauna

Canis diris

Dire wolf



Pleistocene MegaFauna Extinction

Proposed Causes:

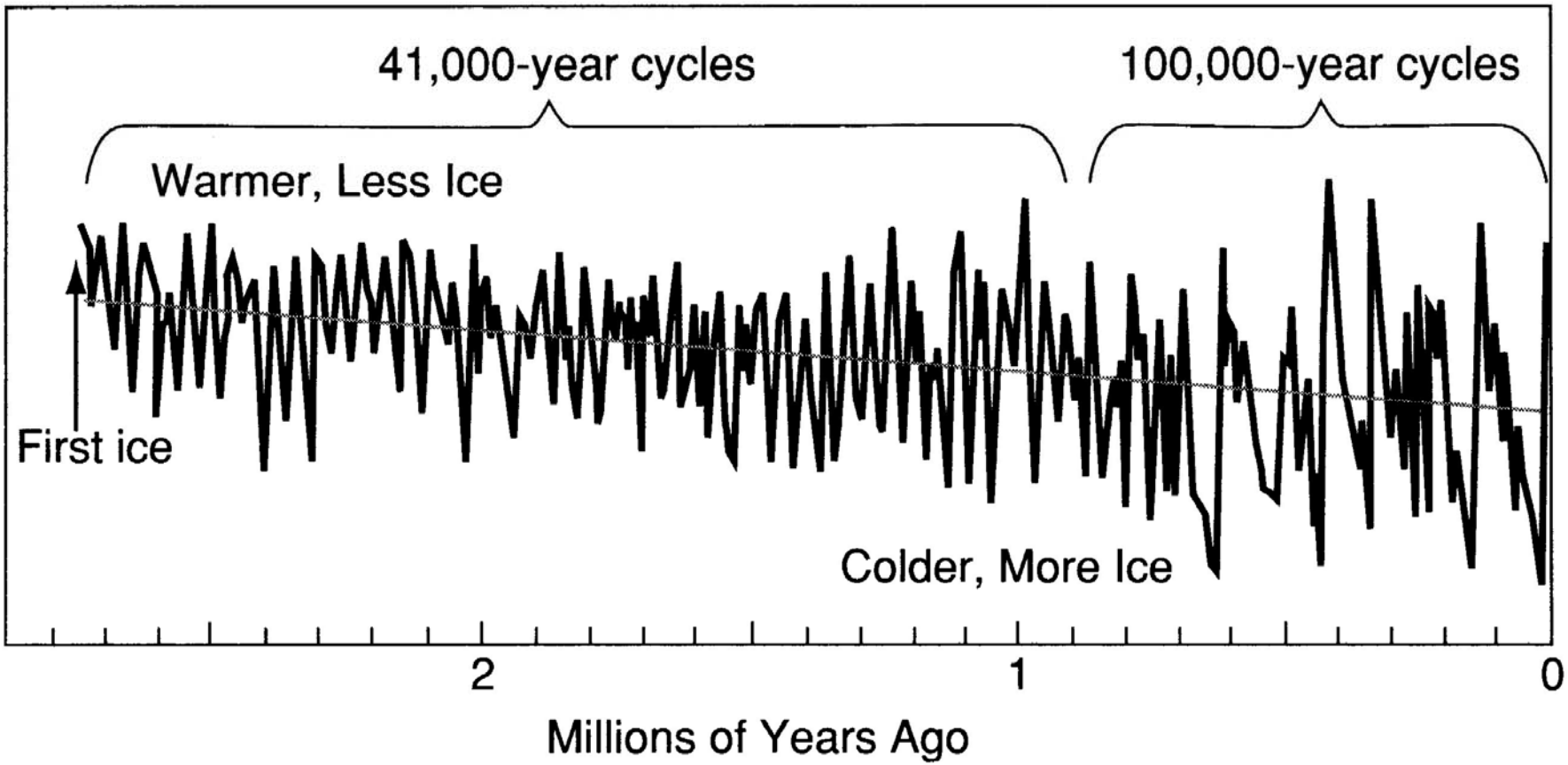
Climate Change

Between about 18,000 and 11,500 years ago the climate and environments of North America were changing rapidly. Temperatures were warming. Rainfall patterns were changing. The glaciers were melting. The seasonal difference in temperatures was increasing.

These climate changes were causing fundamental changes in the ecosystems of North America. Plants and animals were moving out of areas they had lived in and into new areas. Communities were coming apart and reorganizing.

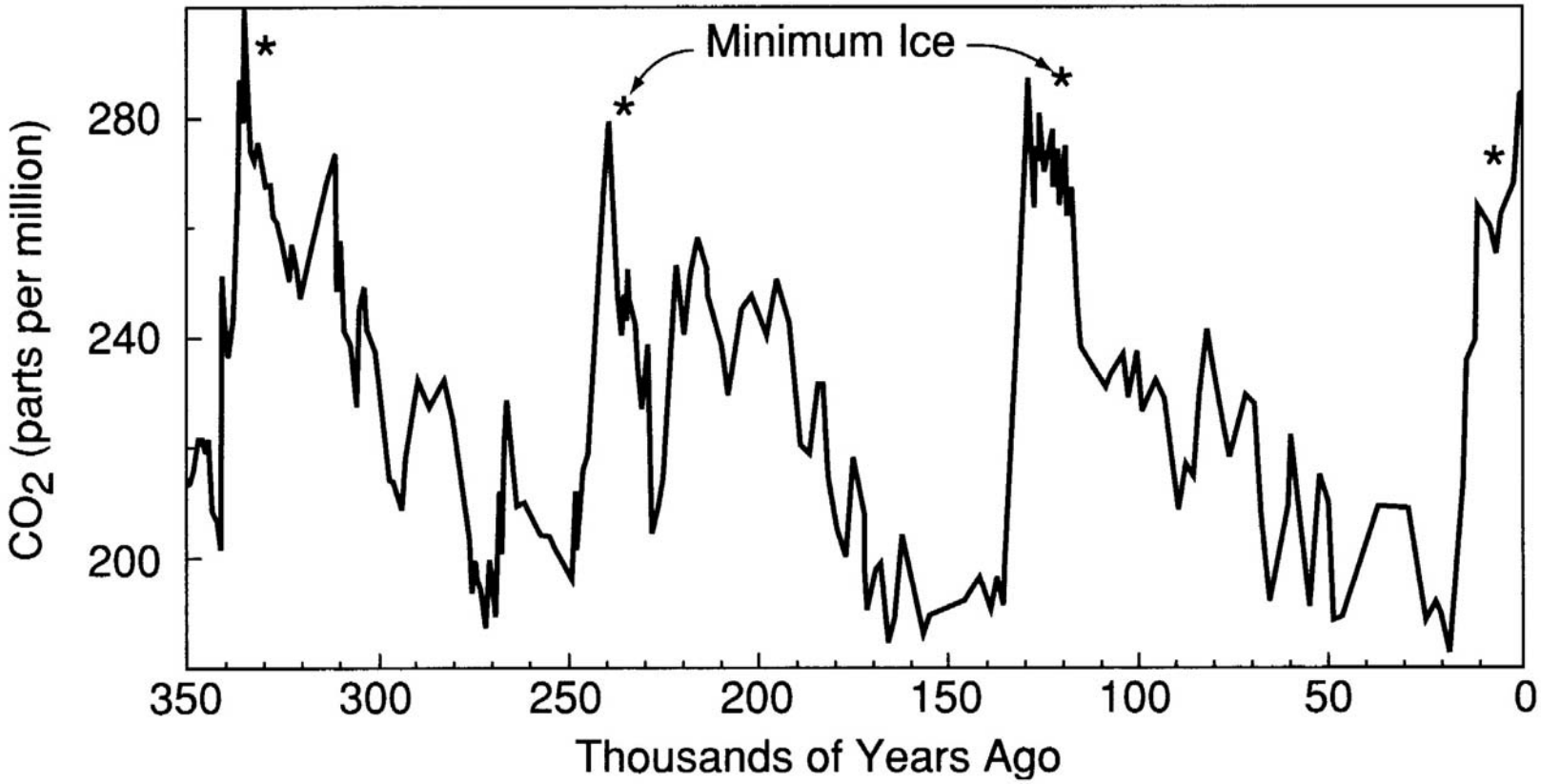
Many scientists think that these climatic and ecosystem changes caused the extinctions at the end of the Pleistocene. The environmental changes might have caused extinction by eliminating food sources, disrupting birth schedules, or exposing animals to climatic conditions to which they were not adapted.

However, similar climate changes have occurred at the end of each glacial event, of which there have been many dozens, and the megafauna survived all of those.



4.2. Large ice sheets first appeared in the Northern Hemisphere nearly 2.75 million years ago and grew and melted at the 41,000-year cycle of orbital tilt until about 0.9 million years ago. Since that time, the major cycle of ice-sheet changes has been at a cycle of 100,000 years.

Ice Advances and Retreats in the Past 350,000 Years



9.1. CO_2 concentrations in the atmosphere vary naturally at a cycle of 100,000 years, with peak values occurring a few thousand years before the ice sheets reach minimum (interglacial) size.

Pleistocene MegaFauna Extinction

Proposed Causes:

Hyper Diseases

This theory was most recently proposed by Dr. Ross MacPhee of the American Museum of Natural History and Dr. Preston Marx of the Aaron Diamond AIDS Research Center. It supposes that as human populations expanded into new areas during the Pleistocene, for example, into North America approximately 14,000 years ago, they brought with them one or more disease-causing agents. These diseases, new to the New World, jumped from human or animal carriers (for example, their dogs) to the highly susceptible large native fauna. These diseases, according to this theory, were sufficieintly lethal to wipe out the native animals.

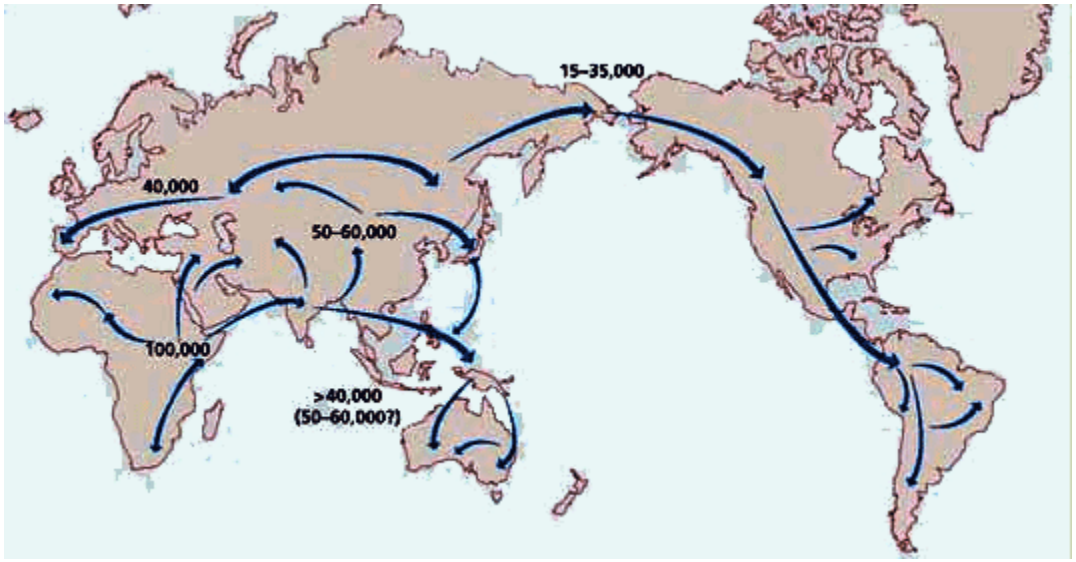
Pleistocene MegaFauna Extinction

Proposed Causes:

Human Hunting

Just after 14,000 years ago human migrants from Asia entered the New World. They may have been the first people to set foot in North America. They are known as the Clovis people. Their sites and artifacts, including distinctive projectile points, are found over much of North America.

These people hunted and gathered wild animals and plants. The animals they hunted included many that became extinct. However, they also hunted numerous animals that survived.



Pleistocene MegaFauna Extinction

Proposed Causes:

Human Hunting Clovis spear points

Just after 14,000 years ago human migrants from Asia entered the New World. They may have been the first people to set foot in North America. They are known as the Clovis people. Their sites and artifacts, including distinctive projectile points, are found over much of North America.

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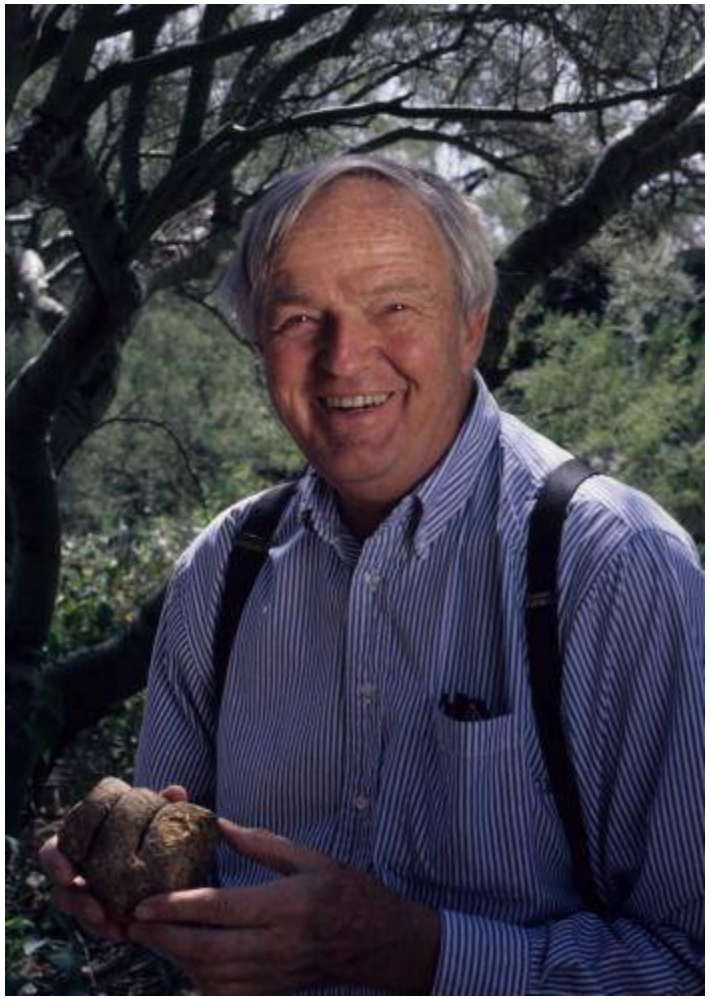
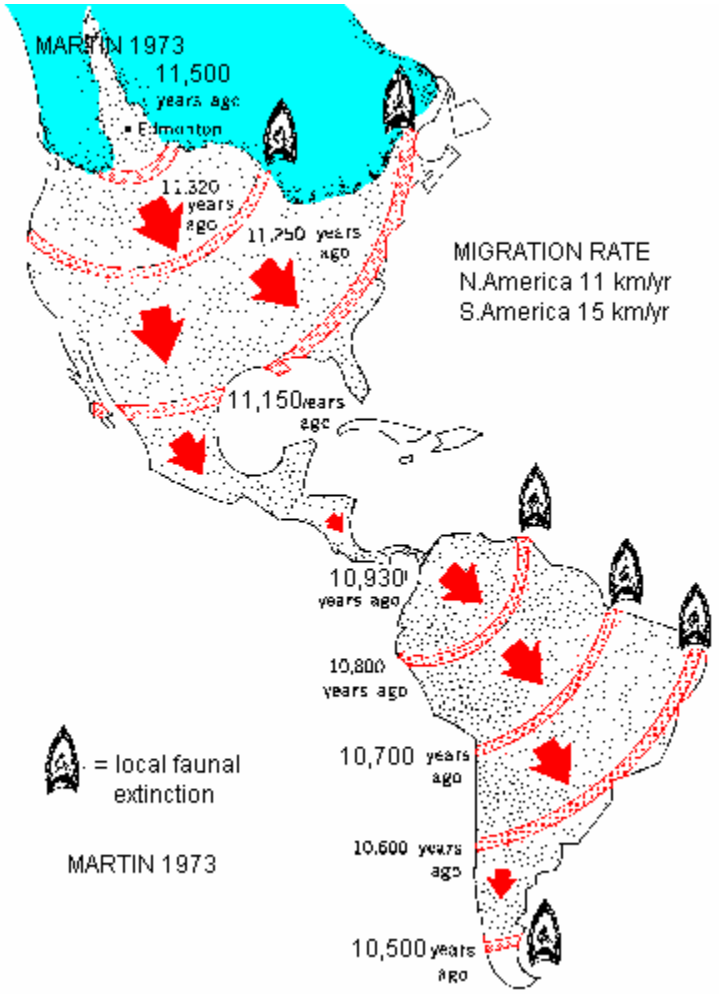
Paul Martin and the Overkill Hypothesis





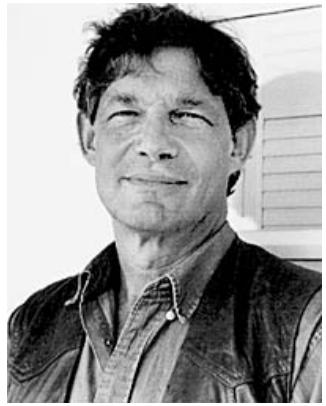
Late Pleistocene

Mural of Utah: 10,000 B.C.

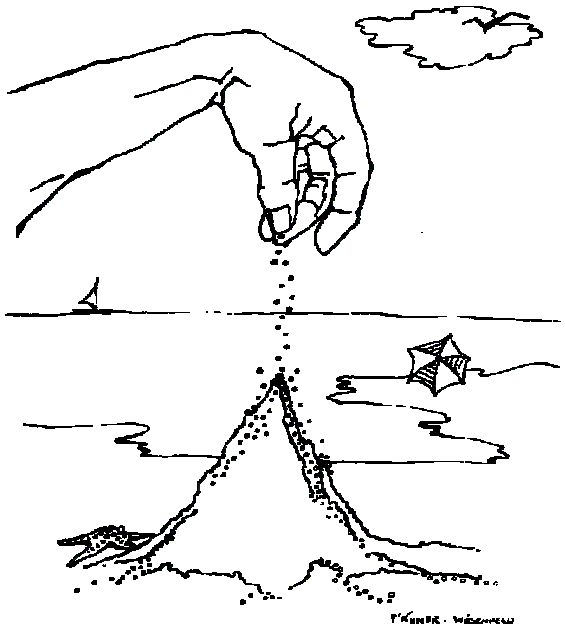
College of Eastern Utah Museum

http://museum.ceu.edu/animal.htm

Stuart Kauffman



"The critical point is not, as Stuart Kauffman once described it, "a nice place to be." So "survival of the fittest" does not imply evolution to a state where everybody is well off. On the contrary, individual species are barely able to hang on - like the grains of sand in the critical sand pile."



Maybe there is no "cause" to extinctions

Maybe extinctions (avalanches) are just part of the dynamic of evolution.

Modern Extinction

Holocene Extinction

Holocene extinction event is the widespread, ongoing mass extinction of species during the past several thousand years.

The large number of extinctions span numerous families of plants and animals including mammals, birds, amphibians, reptiles and arthropods; a sizeable fraction of these extinctions are occurring in the rainforests.

Since 1500 CE, 784 extinctions have been documented by the International Union for Conservation of Nature and Natural Resources.[1] However, since most extinctions are likely to go undocumented, scientists estimate that during the last century, between 20,000 and two million species have become extinct, but the precise total cannot be determined more accurately within the limits of present knowledge.

Up to 140,000 species per year (based on Species-area theory)[2] may be the present rate of extinction based upon upper bound estimating.

The observed rate of extinction has accelerated dramatically in the last 50 years. There is no general agreement on whether to consider more recent extinctions as a distinct event or merely part of a single escalating process. Only during these most recent parts of the extinction have plants also suffered large losses.

Overall, the Holocene extinction event is most significantly characterized by the presence of man-made driving factors and its very short geological timescale (tens to thousands of years) compared to most other extinction events.

Slash and Burn Agriculture

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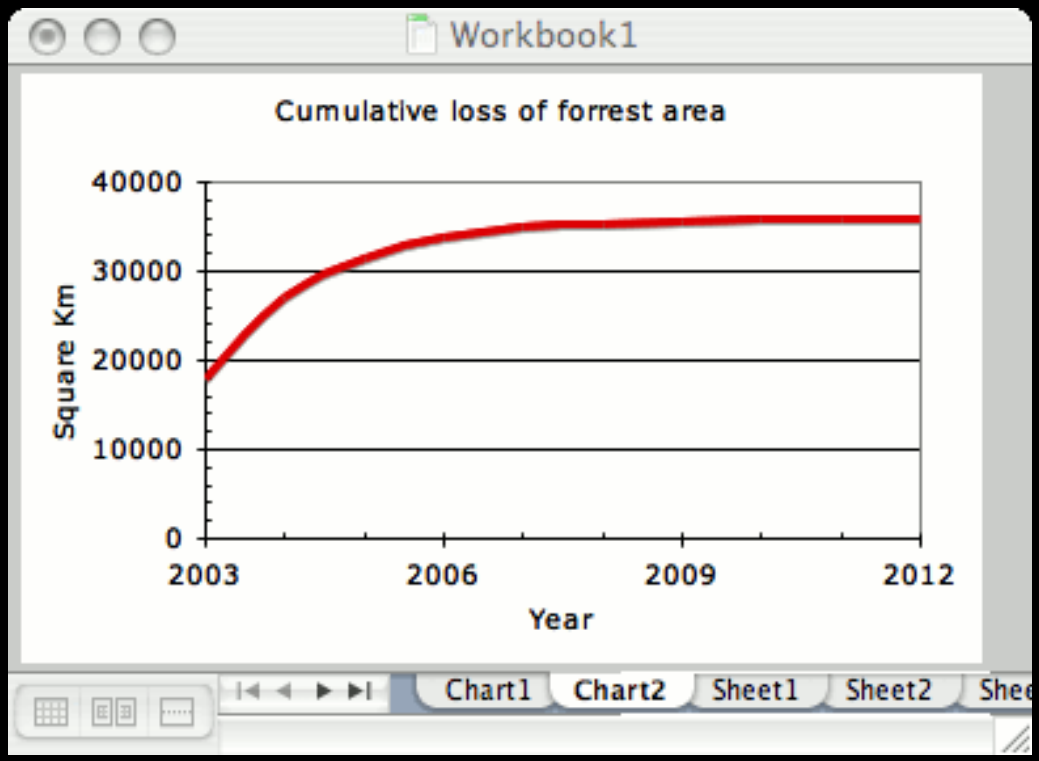
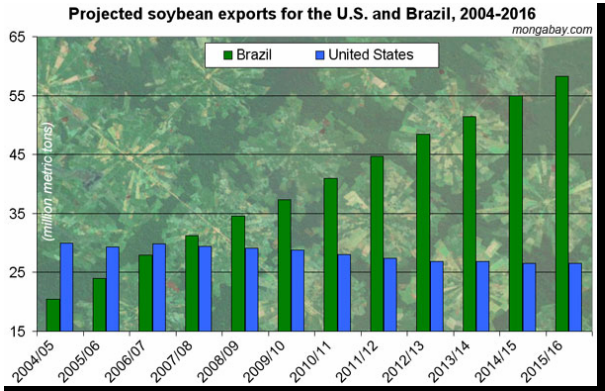


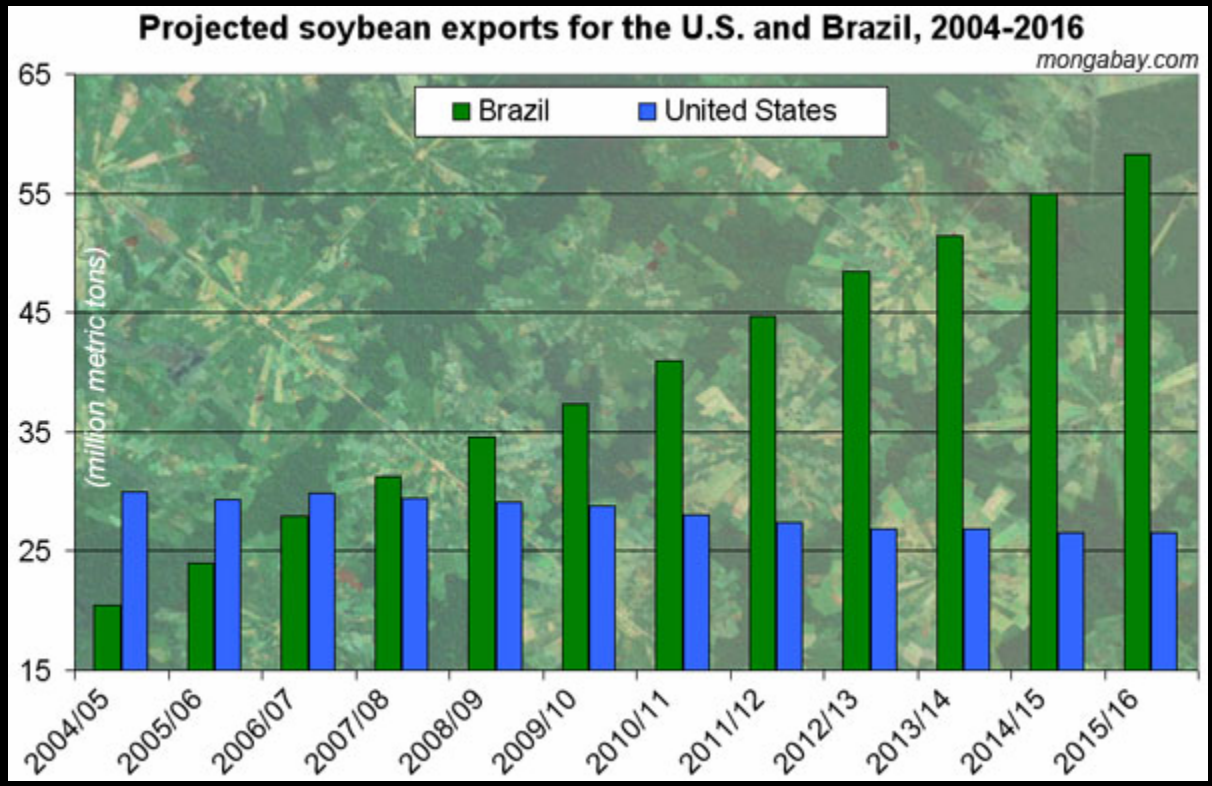


Deforestation

U.S. ethanol may drive Amazon deforestation

(5/17/2007) Ethanol production in the United States may be contributing to deforestation in the Brazilian rainforest said a leading expert on the Amazon. Dr. Daniel Nepstad of the Woods Hole Research Center said the growing demand for corn ethanol means that more corn and less soy is being planted in the United States. Brazil, the world's largest producer of soybeans, is more than making up for shortfall, by clearing new land for soy cultivation. While only a fraction of this cultivation currently occurs in the Amazon rainforest, production in neighboring areas like the cerrado grassland helps drive deforestation by displacing small farmers and cattle producers, who then clear rainforest land for subsistence agriculture and pasture.

Slash and Burn Agriculture



We have met the enemy, and (s)he is us