Evolution Makes Sense of Homologies

Richard Owen (1848) introduced the term homology to refer to structural similarities among organisms.

To Owen, these similarities indicated that organisms were created following a common plan or archetype.

That is, although each species is unique, the plans for each might share many features, just as the design plans for a Honda Civic and a Honda Prelude might be similar.

Nevertheless, if every organism were created independently, it is unclear why there would be so many homologies among certain organisms, while so few among others.

It is also hard to make sense of the fact that homologous structures can be inefficient or even useless.

http://www.zoology.ubc.ca/~bio336/Bio336/Lectures/Lecture5/Overheads.html

Evolution Makes Sense of Homologies

Why would certain cave-dwelling fish have degenerate eyes that cannot see?

Darwin made sense of homologous structures by supplying an evolutionary explanation for them:

> A structure is similar among related organisms because those organisms have all descended from a common ancestor that had an equivalent trait.

Ridley uses a specific definition of homology: "A similarity between species that is not functionally necessary."

I interpret this as: "A similarity between species that exists despite several plausible alternative traits that would function equally well."

http://www.zoology.ubc.ca/~bio336/Bio336/Lectures/Lecture5/Overheads.html

The "Universal" Genetic Code

5'	T	C	A	G	3'
T	TTT Phe (F)	TCT Ser (S)	TAT Tyr (Y)	TGT Cys (C)	T
	TTC Phe (F)	TCC Ser (S)	TAC Tyr (Y)	TGC Cys (C)	C
	TTA Leu (L)	TCA Ser (S)	**TAA Stop**	**TGA Stop** [*Trp (W)*]	A
	TTG Leu (L)	TCG Ser (S)	**TAG Stop**	TGG Trp (W)	G
C	CTT Leu (L)	CCT Pro (P)	CAT His (H)	CGT Arg (R)	T
	CTC Leu (L)	CCC Pro (P)	CAC His (H)	CGC Arg (R)	C
	CTA Leu (L)	CCA Pro (P)	CAA Gln (Q)	CGA Arg (R)	A
	CTG Leu (L)	CCG Pro (P)	CAG Gln (Q)	CGG Arg (R)	G
A	ATT Ile (I)	ACT Thr (T)	AAT Asn (N)	AGT Ser (S)	T
	ATC Ile (I)	ACC Thr (T)	AAC Asn (N)	AGC Ser (S)	C
	ATA Ile (I) [*Met (M)*]	ACA Thr (T)	AAA Lys (K)	AGA Arg (R) [*Stop*]	A
	ATG Met (M)	ACG Thr (T)	AAG Lys (K)	AGG Arg (R) [*Stop*]	G
G	GTT Val (V)	GCT Ala (A)	GAT Asp (D)	GGT Gly (G)	T
	GTC Val (V)	GCC Ala (A)	GAC Asp (D)	GGC Gly (G)	C
	GTA Val (V)	GCA Ala (A)	GAA Glu (E)	GGA Gly (G)	A
	GTG Val (V)	GCG Ala (A)	GAG Glu (E)	GGG Gly (G)	G

http://www.zoology.ubc.ca/~bio336/Bio336/Lectures/Lecture5/Overheads.html

Evolution Makes Sense of Homologies

The genetic code for protein-coding genes is nearly universal in eukaryotes and prokaryotes.

The exceptions include most mitochondrial genomes and some nuclear ones (e.g. Mycoplasma and Tetrahymena).

Even in these cases, the genetic code is quite similar.

Millions of alternative genetic codes exist, so why do all organisms have nearly the same one?

Since the anti-codon is at the opposite end from the amino acid binding site of a tRNA and does not interact with the binding site, there is no chemical necessity for a codon to be assigned to a particular amino acid.

http://www.zoology.ubc.ca/~bio336/Bio336/Lectures/Lecture5/Overheads.html

Evolution Makes Sense of Homologies

The genetic code is homologous among living organisms: it is similar despite the fact that there exist many equally good genetic codes.

Under the hypothesis that evolution has occurred, however, the similarity among all genetic codes makes sense:

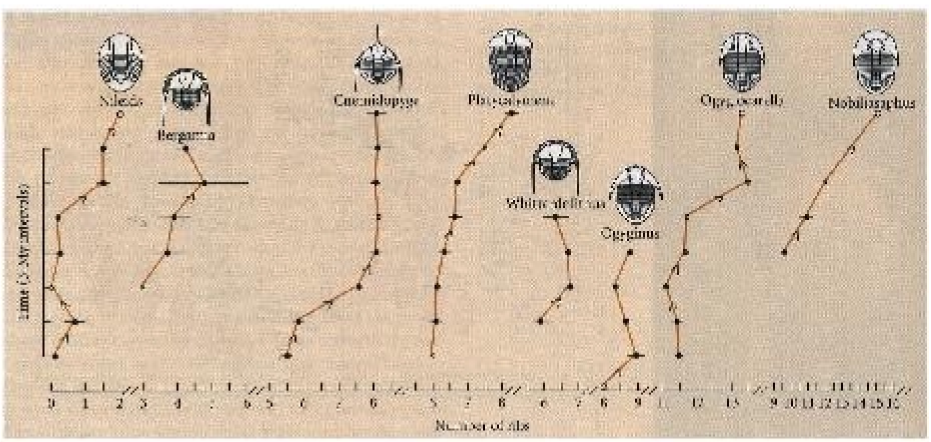
- The common ancestor to all known organisms had a genetic code similar to what we see today.
- Over the ages, the genetic code has passed unchanged (or nearly so) from parents to offspring, because mutations to the genetic code would have been disastrous (changing the amino acid sequence of all proteins produced).

(What would an evolutionist think if an organism were found today with an entirely different genetic code?)

http://www.zoology.ubc.ca/~bio336/Bio336/Lectures/Lecture5/Overheads.html

Trilobite Evolution

Although the fossil record is often poor and incomplete, there are certain deposits where sedimentary layers remain in a nearly continuous series. Fossils from these series provide direct evidence of evolutionary change. Sheldon (1987) examined a series of sedimentary layers from the Ordovician period (500 MYA) containing trilobite fossils (extinct marine arthropods).



Samples were obtained from every three million years. The number of ribs of each species of trilobite changed over time (=evolution).
Some of these changes over time were so large that the animals at the end of the series are assigned to a new genus!

http://www.zoology.ubc.ca/~bio336/Bio336/Lectures/Lecture5/Overheads.html

Foraminiferan Evolution

An even finer scale analysis was performed by Malmgren et al. (1983) on a species of foraminiferan (shell-bearing protozoans) from 10MYA to recent times.

[Three epochs are represented: Miocene (M; 23.8-5.2 MYA), Pliocene (P; 5.2-1.8 MYA) and Pleistocene (Q; 1.8 MYA - 10,000 YA)].

Over this period, the fossil shells evolved a larger, thicker shell, with a more pronounced ridge.

Although the fossil record demonstrates that change occurred in a continuous manner (=without breaks or jumps), the rate of change was not always the same: shape changed most around the Miocene/Pliocene boundary.

These changes were large enough that the lineage is assigned to the species Globorotalia plesiotumida in the Miocene, but to the species Globorotalia tumida afterwards.

http://www.zoology.ubc.ca/~bio336/Bio336/Lectures/Lecture5/Overheads.html

Foraminiferan Evolution

The fossil record demonstrates evolutionary changes do occur.

The disadvantage of the fossil record is that it is generally difficult to determine the selective forces that may have contributed to these changes.

The advantage of the fossil record over present-day observations of evolution is that higher order evolutionary changes may be tracked (e.g. the origin of new species,

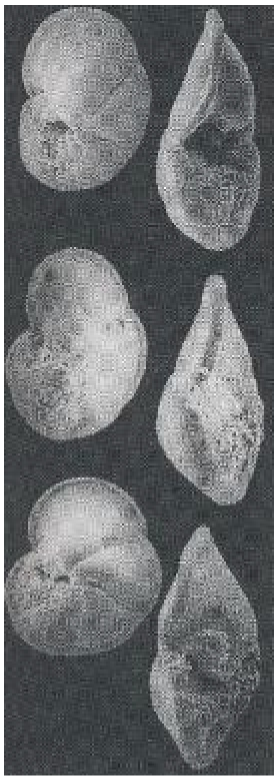
new genera, etc).

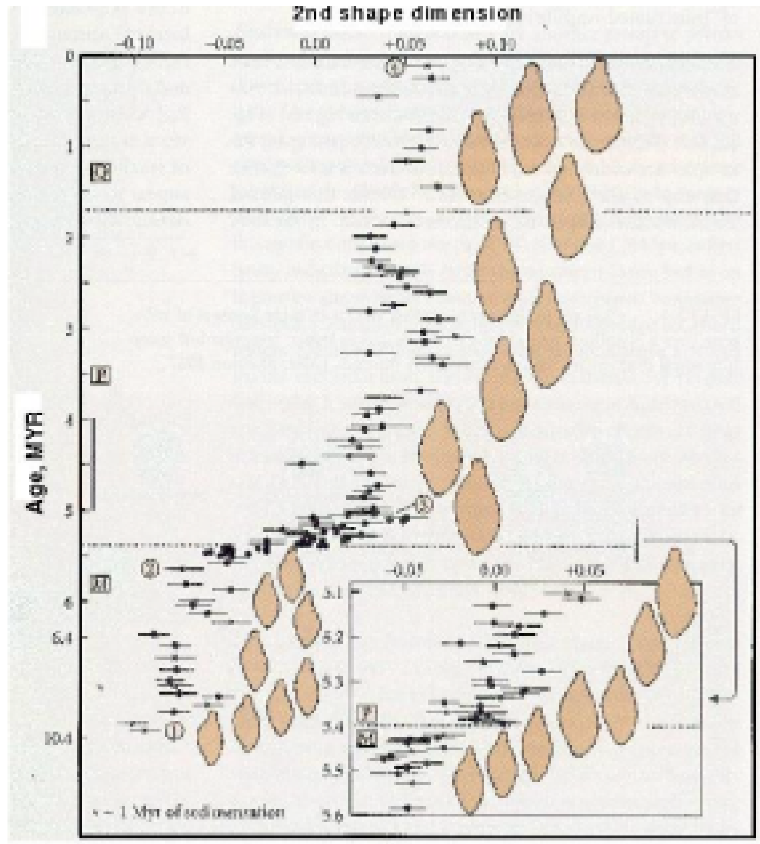
SOURCES:

- Pentadactyl limbs: Ridley (1997) Evolution.
- Whale, salamander, primate trees: Freeman and Herron (1998) Evolutionary Analysis.
- Membrane photo: Wessells and Hopson (1988) Biology.
- Dinosaur information: UC Museum of Paleontology.
- Trilobite and foraminiferan fossil record: Futuyma (1998) Evolutionary Biology.

http://www.zoology.ubc.ca/~bio336/Bio336/Lectures/Lecture5/Overheads.html

Foraminiferan Evolution





http://www.zoology.ubc.ca/~bio336/Bio336/Lectures/Lecture5/Overheads.html

Whale Evolution
The evidence

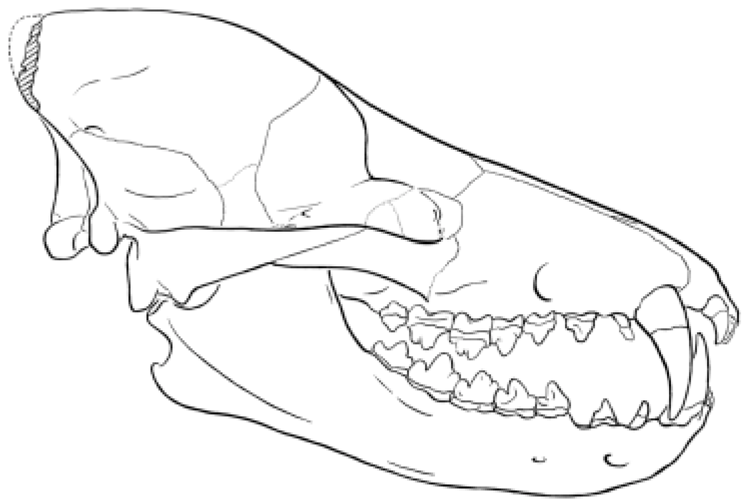
Paleontological evidence

- Sinonyx
- Pakicetus
- Ambulocetus
- Rodhocetus
- Basilosaurus
- Dorudon

http://www.talkorigins.org/features/whales/

Whale Evolution

Sinonyx jiashanensi skull reconstruction



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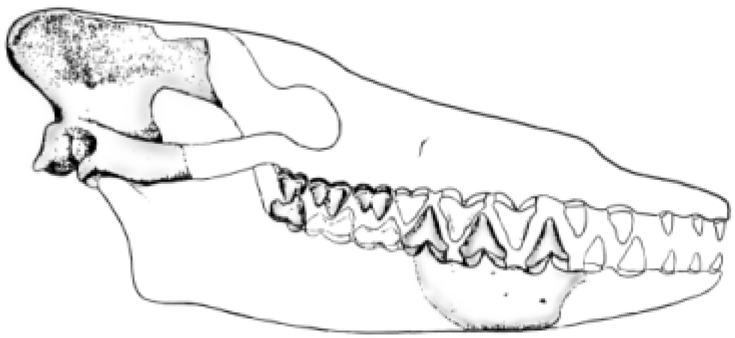
Whale Evolution

Pakicetus skull reconstruction



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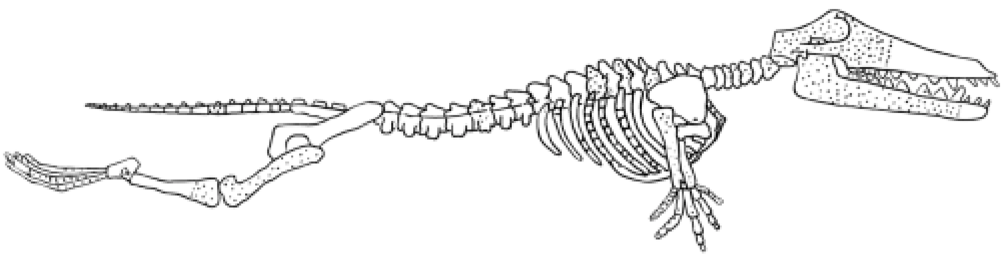
Whale Evolution

Ambulocetans natans



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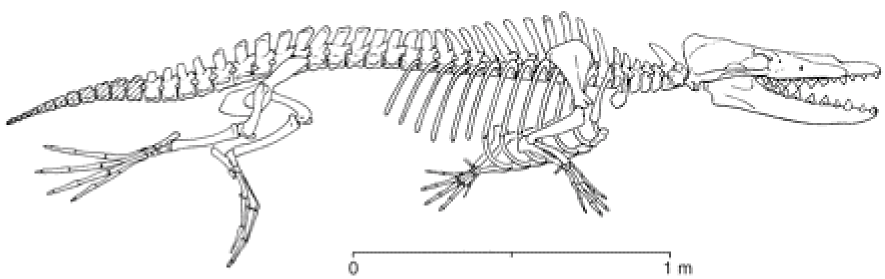
Whale Evolution

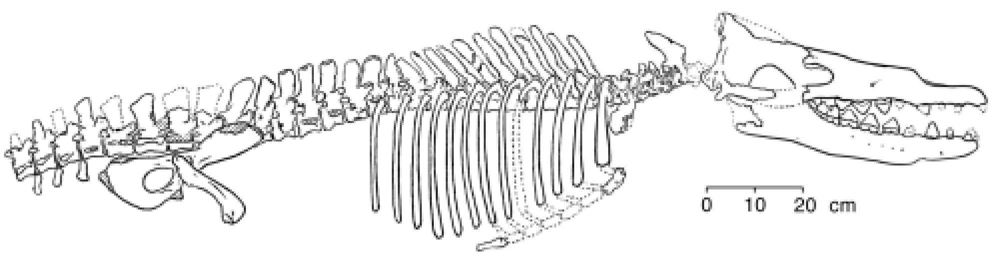
Rodhocetus kasrani



Science, Vol. 293, Issue 5538, 2239-2242, September 21, 2001

Whale Evolution

Rodhocetus kasrani reconstruction



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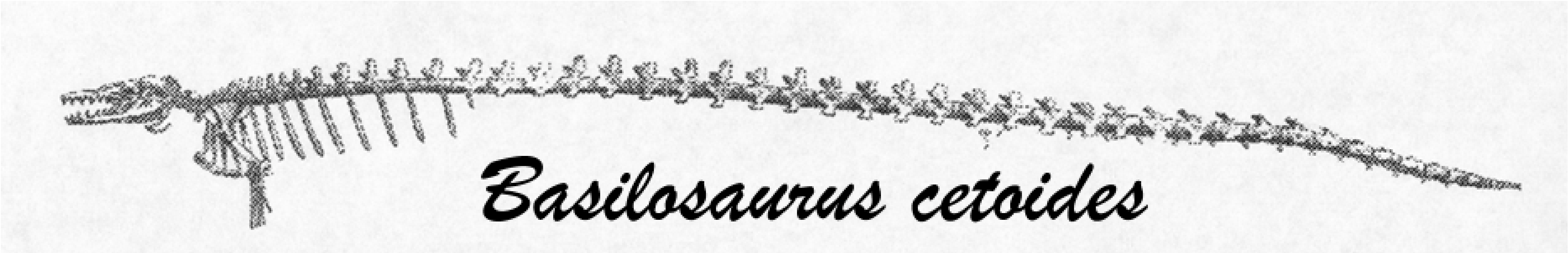
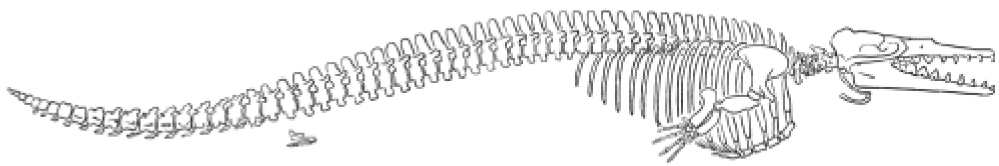
Whale Evolution



http://www-dept.usm.edu/~bsclabs/museum_brochure.htm

Whale Evolution

Dorudon atrox



http://www.talkorigins.org/features/whales/

Whale Evolution
The evidence

Morphological evidence

The examination of the morphological characteristics shared by the fossil whales and living ungulates makes their common ancestry even clearer.

For example, the anatomy of the foot of Basilosaurus allies whales with artiodactyls (Gingerich and others 1990). The axis of foot symmetry in these fossil whales falls between the 3rd and 4th digits. This arrangement is called paraxonic and is characteristic of the artiodactyls, whales, and condylarths, and is rarely found in other groups (Wyss 1990).

Another example involves the incus (the "anvil" of the middle ear). The incus of Pakicetus, preserved in at least one specimen, is morphologically intermediate in all characters between the incus of modern whales and that of modern artiodactyls (Thewissen and Hussain 1993).

http://www.talkorigins.org/features/whales/

Whale Evolution
The evidence

Morphological evidence

Additionally, the joint between the malleus (hammer) and incus of most mammals is oriented at an angle between the middle and the front of the animal (rostromedially), while in modern whales and in ungulates, it is oriented at an angle between the side and the front (rostrolaterally).

In Pakicetus, the first fossil cetacean, the joint is oriented rostrally (intermediate in position between the ancestral and derived conditions).

Thus the joint has clearly rotated toward the middle from the ancestral condition in terrestrial mammals (Thewissen and Hussain 1993); Pakicetus provides us with a snapshot of the transition.

http://www.talkorigins.org/features/whales/

Whale Evolution
The evidence

Molecular biological evidence

The hypothesis that whales are descended from terrestrial mammals predicts that living whales and closely related living terrestrial mammals should show similarities in their molecular biology roughly in proportion to the recency of their common ancestor.

In contrast, creationism lacks any scientific basis for predicting what the patterns of similarity should be…

Molecular studies by Goodman and others (1985) show that whales are more closely related to the ungulates than they are to all other mammals...

These studies examined myoglobin, lens alpha-crystallin A, and cytochrome c in a study of 46 different species of mammals. Miyamoto and Goodman (1986) later expanded the number of protein sequences by including alpha- and beta-hemoglobins and ribonuclease; they also increased the number of mammals included in the study to 72.

The results were the same: the whales clearly are included among the ungulates.

http://www.talkorigins.org/features/whales/

Whale Evolution
The evidence

- Vestigial evidence
- Embryological evidence
- Geochemical evidence
- Paleoenvironmental evidence
- Paleobiogeographic evidence
- Chronological evidence

http://www.talkorigins.org/features/whales/

Cross bedding

http://agcwww.bio.ns.ca/schools/EarthNet/english/glossary/c/cross_bedding.html

Geologic Time

CENOZOIC ERA (Age of Recent Life)	Quaternary Period	The several geologic eras were originally named Primary, Secondary, Tertiary, and Quaternary. The first two names are no longer used. Tertiary and Quaternary have been retained but used as period designations.
	Tertiary Period	
MESOZOIC ERA (Age of Medieval Life)	Cretaceous Period	Derived from Latin word for chalk (creta) and first applied to extensive deposits that form white cliffs along the English Channel.
	Jurassic Period	Named for the Jura Mountains, located between France and Switzerland, where rocks of this age were first studied.
	Triassic Period	Taken from the word "trias" in recognition of the threefold character of these rocks in Europe.
PALEOZOIC ERA (Age of Ancient Life)	Permian Period	Named after the province of Perm, U.S.S.R., where these rocks were first studied.
	Pennsylvanian Period	Named for the State of Pennsylvania where these rocks have produced much coal.
	Mississippian Period	Named for the Mississippi River Valley where these rocks are well exposed.
	Devonian Period	Named after Devonshire, England, where these rocks were first studied.
	Silurian Period	Named after Celtic tribes, the Silures and the Ordovices, that lived in Wales during the Roman Conquest.
	Ordovician Period	
	Cambrian Period	Taken from the Roman name for Wales (Cambria) where rocks containing the earliest evidence of complex forms of life were first studied.
PRECAMBRIAN	---------	The time between the birth of the planet and the appearance of complex forms of life. More than 80 percent of the Earth's estimated 4-1/2 billion years falls within this era.

http://pubs.usgs.gov/gip/geotime/divisions.html

Whale Evolution

Sinonyx jiashanensi skull reconstruction

John Klausmeyer with part of the Sinonyx skull that he has constructed. Photo by Joanne Nesbit

After nearly 200 hours of concentrated effort, John Klausmeyer just about has the 60-piece, 3-D jigsaw puzzle completed. Using a heat gun, leather gloves, drills and bits, oil and acrylic paints, and various size brushes, sponges, and rags, the medical illustrator has just about finished part of the puzzle that will be featured in "Back to the Sea: The Evolution of Whales." The exhibition is slated for an October opening at the Exhibit Museum.

http://www.umich.edu/~urecord/9697/Mar25_97/artcl01.htm

References

- http://agcwww.bio.ns.ca/schools/EarthNet/english/glossary/c/cross_bedding.html
- http://www.ge-at.iastate.edu/courses/Geol_100/angular.html
- http://www.hartwick.edu/geology/work/VFT-so-far/glaciers/glacier1.html
- http://www.glossary.oilfield.slb.com/DisplayImage.cfm?ID=59
- http://www.seismo.unr.edu/ftp/pub/louie/papers/dome/fig2.pdf
- http://www.dgi.com/earthvision/sol_diapir.shtml
- http://agcwww.bio.ns.ca/schools/EarthNet/english/glossary/d/diapir.html
- http://woodshole.er.usgs.gov/operations/obs/Images/BlakeRidge/Figure7.html
- Originally published in Science Express as 10.1126/science.1063902 on September 19, 2001 Science, Vol. 293, Issue 5538, 2239-2242, September 21, 2001
- Originally published in Science Express as 10.1126/science.1065305 on September 19, 2001 Science, Vol. 293, Issue 5538, 2216-2217, September 21, 2001
- http://www.brookes.ac.uk/geology/8361/1998/kirsty/trilo.html
- http://www.aloha.net/~smgon/ordersoftrilobites.htm
- http://www.zoology.ubc.ca/~bio336/Bio336/Lectures/Lecture5/Overheads.html

References

- http://faculty.uca.edu/~benw/debate/whale/sld001.htm
- http://www.gsa.state.al.us/gsa/Paleoweb/palpage_statefos2.html