Παλαιός :

Palaeos

Χρόνος : **Time** — Cosmological Time – Geological Time – Quaternary Time		Βίος : **Life** — Cosmic Evolution (Matter – Life – Mind)	
Pre-nebular	Chaotian	Life on Earth	Life in the Cosmos
Hadean	Archean	Bacteria	Eukarya
Proterozoic	Paleozoic	Fungi	Plants
Mesozoic	Cenozoic	Invertebrates	Vertebrates
Quaternary	Historical	Future	Phylogeny

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Palaeos is currently undergoing a major revision (hence many links won't be working yet), but hopefully everything should be fixed and ready soon. As such the site administrators would request people who find these lines to keep quiet about the site until we are ready to announce it publicly. Thank you for your courtesy.

Archive of the old Palaeos

Palaeos wiki

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Page uploaded MAK111006; last modified MAK111013, RFVS111214; Palaeos logo by Renato Santos (RFVS); logo tagline by Réka Szabó; Ancient Greek orthography courtesy of the Perseus Digital Library.
Google search box courtesy of Ask Dave Taylor

Currently Palaeos is experiencing technical difficulties, but we will endeavour to have the site back to normal as soon as possible

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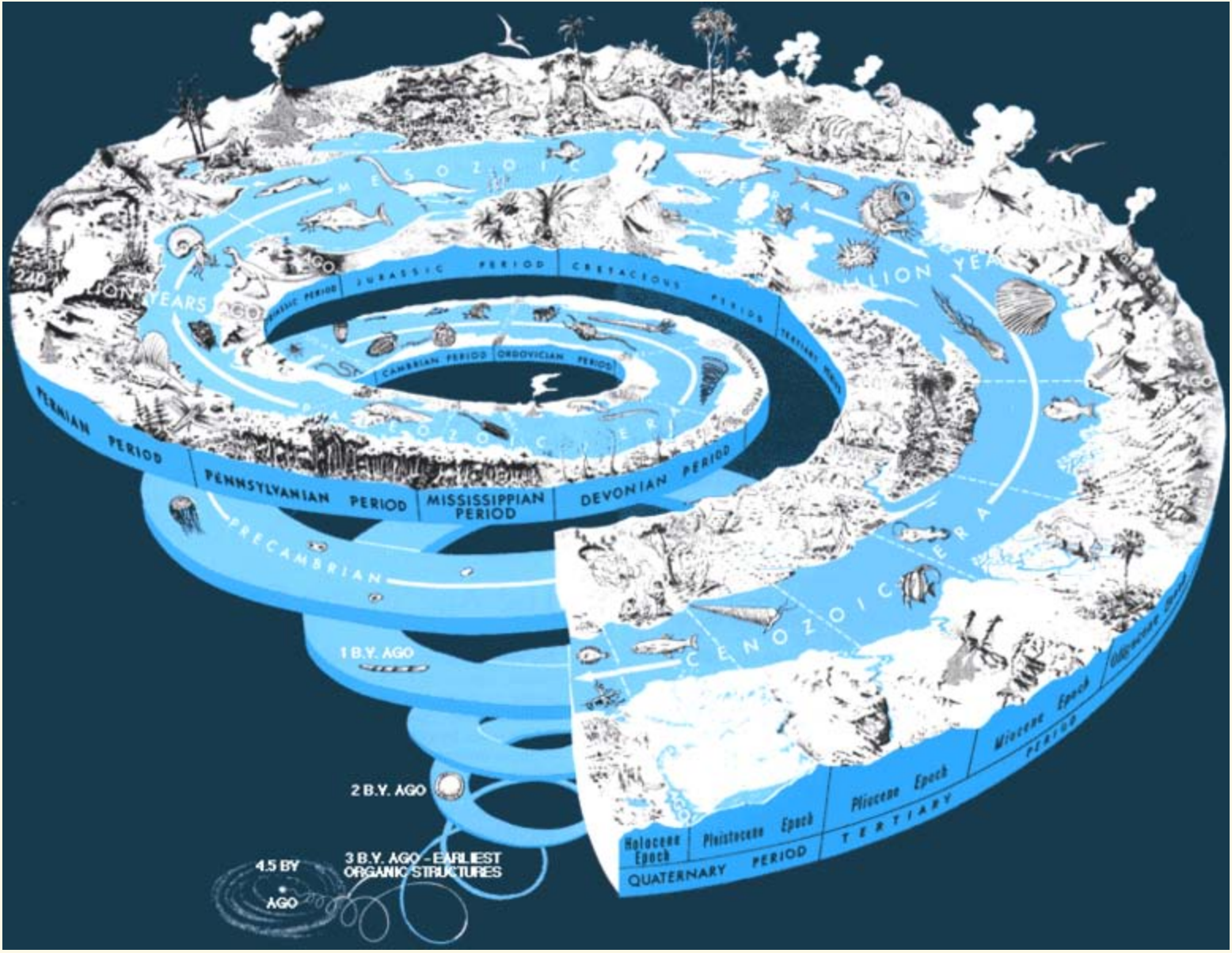
Palaeos: Overview



United States Geology Service drawing (public domain) of deep time, showing the history of life through geological time. In this diagram, one starts with the formation of the Earth, four and a half billion years ago (shown as the small dot at the lower left) and continue through the vast expanse of Precambrian time, before arriving at the Cambrian period, which marked the start of the Phanerozoic Eon and the appearance of complex life (although there is a tendency now to backdate this to the Ediacaran). Moving clockwise, through a succession of invertebrate types in the sea, we can follow the conquest of the land, the rise of insects and reptiles, and the dominance of the dinosaurs on land and marine reptiles in the sea. With the extinction of the Mesozoic megafauna (no asteroid is shown here, and the style of art predates the dinosaur renaissance of Ostrom and Bakker), there is a succession of primitive and then more advanced mammals, and finally paleolithic humans and modern towns and cities (these details are only visible in the large image).

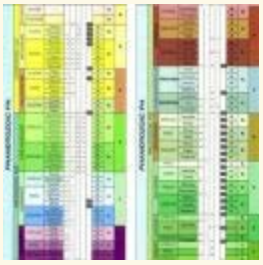
Overview

It is hard to provide an overview for a project as huge and rambling as **Palaeos**, so this page only some of the more basic categories and starting pages.

There are basically two orientations that can be taken here. One is to follow the sequence of ***Time***, the other ***Evolution***.

From the paleontological perspective of **Palaeos**, time is presented as the geological timescale, and life as the the evolutionary tree of life on Earth. These two pages can serve as starting points, from which other related and interrelated pages and topics can be explored. On the basis of the geological timescale there are seven major timescale units (eras and eons). Although in the above diagram there are seven major evolutionary categories (others have proposed similar or different classifications), as far as life on Earth goes we have arbitrarily divided our coverage into six main units (kingdoms and domains of life). Allowing

for the unevenness of coverage, **Palaeos** can be summarised as follows:



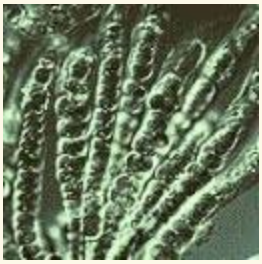
Time, or more specifically the geological time-scale is here used to define the major stages in the history of life on Earth. Here the four and a half billion year history of planet Earth is divided into seven segments, although once again this is semi-informal classification, mixing eons and eras. These are:

- the Chaotian, a new eon which was too good to leave out,. Why start with the origin of the Earth when you begin with the origin of the Solar System?
- the Hadean witnessed the formation of the Earth and, quite possibly, the origin of life
- the Archean was the age of early bacteria, Stromatolites, and the reducing atmosphere. For over a billion years in which the Earth was inhabited by nothing more advanced than algal mats.
- the Proterozoic was a dramatic time. There was the oxygen crisis—being a crisis for anaerobic bacteria, in that photosynthetic blue-green algae totally transformed the Earth by changing the atmosphere from reducing to oxygenating, thus paving the way for higher life. Other notable events were snowball earth, the rise of Eukarya, and the origin of multicellular life.
- The Phanerozoic, the fourth and most recent eon, the time of diverse life, complex ecosystems, and an oxygen-rich atmosphere. This is divided into:
    - the Paleozoic, the first and longest of the eras of complex life, which witnessed the Cambrian explosion, invertebrates, fish, and early land plants, amphibians and reptiles
    - the Mesozoic, the age of giant dinosaurs, marine reptiles, ammonites, gymnosperms, and primitive mammals
    - the Cenozoic, the age of mammals and birds, and modern taxa of plants and invertebrates, this being the era we are still in. Each of these eras is characterised by a mass-extinction, which in each case wiped out the dominant life-forms and paved the way for the next group of organisms. Unfortunately, human activities, overpopulation, and over-exploitation and degradation of the environment is currently bringing about a new mass-extinction, and as we enter a new, Anthropocene or Anthropozoic era, the future is very uncertain. I am intending to add a few pages here to cap off the grand narrative of the three and a half to four billion year history of life on Earth and possibilities of life, and human, future evolution.

Cosmic evolution includes everything from the Big Bang to the formation of galaxies and stars (which set the stage for the formation of the Solar System and the Earth (which goes under "Chaotian" and "Hadean" respectively) and to the evolution of minerals, the Earth, life, and mind. Most of these topics are very incomplete, nor is there currently any intention to describe them at length, as the focus of **Palaeos** is exploring the history and genealogy of life on Earth through time. Although the number and details of kingdoms of life differ, we have decided as far as main categories go to follow by default an informal approach that broadly follows the The Five Kingdom paradigm of Robert Whittaker and Lynn Margulis. Adding the now pretty much

meaningless (in terms of modern systematics) 19th Century distinction of vertebrates and invertebrates gives the following six categories:

- Bacteria the simplest and oldest forms of life, such as the various types of bacteria and blue-green algae, which don't have a distinct cellular nucleus. Included here are two distinct domains: Eubacteria and Archaea.
- Eukarya or eukaryotes are organisms with a complex cellular structure and distinct nucleus, the third domain of life. Here there are a huge diversity of unicellular forms, masking up the majority of the group. The remaining Eukarya (or Eucarya, depending on the spelling) make up the three kingdoms of multicellular life of the the Whittaker–Margulis scheme:
    - Plants, which need no introduction (our coverage of the more advanced taxa (gymnosperms and flowering plants) is still quite basic at the time of writing),
    - Fungi, not quite animals and not quite plants (again we don't have that much on them, though hopefully this will change),
    - and the Metazoa or animals. These are divided anthropocentrically and totally colloquially into Vertebrates and Invertebrates.
        - Invertebrates is another way of saying all metazoa (multicellular animals) except for higher chordates. That this outmoded classification is retained is because paleontology, biology, and popular understanding still refers to animal life in terms of vertebrate and invertebrate. Mostly small, they are often overlooked in favour of their backboned brethren, although a microscope or even a hand lens will reveal creatures as astonishing as those that one might imagine would inhabit an alien world. Marine forms with hard parts have a very good fossil record, and a few these groups are covered here.
        - Vertebrates include all those large charismatic animals. Much as **Palaeos** started out as Toby White's ***Vertebrate Notes***, and anyway who doesn't love ichthyosaurs, dinosaurs and other exotic prehistoric creatures? So not surprisingly this is the clade is given the most detailed coverage on these pages.



Finally there are a number of additional pages. Because the science featured in **Palaeos** doesn't come from nowhere, **Scientists** features a very incomplete alphabetical listing of (short biographies, along with occasional links) of paleontologists and other scientists who over the centuries have constructed, and continue to construct, the vast edifice of knowledge of the history of life on Earth (and related topics), whilst a **timeline** traces both the history of discoveries and their interplay with popular culture. **Resources** will, eventually, hopefully, include a directory of links to other paleo web sites and blogs, useful books, journals, and so on. **Authors** will give a very brief listing of contributers to **Palaeos**.

Navigating Palaeos

In keeping with Toby's original ***Vertebrate Notes***, **Palaeos** has a somewhat modular structure, being divided into "units". Therefore. in addition to the dual hierarchy of time and life, an attempt has been made to retain the modular and hierarchical approach here. Unfortunately it hasn't worked out as tidily as we would have liked, because each subject has so many ramifications and links to other topics in other hierarchies and units. Ideally, units are divided into pages, and also may have daughter units, which may in turn have subunits, and so on with maddening detail. The menu bars at the top and bottom of each page (including this one) present navigation options such as Page Back and Page Next, and Unit Up, Unit Down, Unit Back, Unit Next, and Unit Home. Page Back, Page Next, and Unit Home allow you to navigate "horizontally" (at the same hierarchical level) within the unit, and Unit Back and Unit Next between units of the same level. This may be through either similar or different (alternating life and time, e.g. Archean – Bacteria – Proterozoic – Eukarya – Paleozoic) units, or both. So on the Eukarya (or Eucarya) index page, Unit Back in the similar series goes to Bacteria and Unit Next to Plants, these all being on the same level. Whereas dissimilar (alternating) goes from Eukarya back to Proterozoic (when eukaryotes emerged and diversified) and next to Paleozoic (when they flourished beginning with the Cambrian explosion). As for the vertical button (which is always similar), Unit Up goes to the larger unit that includes Eukarya, which is Tellurobiota (Life on Earth). As with Unit Up, Unit Down navigate "vertically". Since each higher level unit will generally have several daughter units, Unit Down only goes to the first of these (according an arbitrary or non-arbitrary arrangement) after which Unit Next goes to the next unit in the group. So with for example the Palaeozoic index page, Unit Down goes to the Cambrian index page (the Cambrian being the first period of the Paleozoic era), and you need to click on Unit Next for the Ordovician (the next geological period in the sequence). Sometimes page and unit categories are the same, so on the page that follows the Unit index/home page, Page Back and Unit Home are the same, in which case there's some duplication, which is allowed for the sake of consistency of menu boxes. With the last page (usually a references page) of a unit, Page Next goes to the first page of the next unit, although Unit next goes to the similar page of the next unit (in this case the corresponding references page). Sometimes the units and pages are linked in a logical series, for example the sequence of the geological timescale, or the standard series of organisms in biology books (prokaryotes (bacteria), eukaryotes, plants, fungi, animals) or other phylogenetic listings. At other times the listing is more arbitrary. In addition to the usual unit and page next listing, there may be additional links to non-standard pages such as glossaries and notes.

In addition to the main menu bars at the top of the page, there is an abbreviated navigation bar at the bottom, and a listing of sub-topics and related topics under the main navigation bar.

Because of the scale of the task, it is likely that many menu links may not follow the right order. In such cases, please contact me (see email address at bottom of this page)

Types of pages

Palaeos includes several different types of pages, which together make up a Unit (although different units may include different types of pages).

Each unit starts with an ***index or home page***. This may give a brief overview or a detailed introduction, depending on the idiosyncrasy of the author and topic. Eventually there will be more standardisation here, with the detailed intro being moved to an ***overview page***.

Ordinary pages, such as this one, generally have a white background (apart from the geological timescale pages and some of the taxonomic pages). They follow after the index/home page of the unit.

Major Units may include a ***Glossary*** page or pages. These constitute an abbreviated coverage of each topic. Glossary listings will point to other listings, and where "more" appears it is to the main page on the topic. Sometimes there is also an external link or links, which are indicated as such

After the glossary page (if present) there is, in the case of the units on each of the groups of organisms, a ***Dendrogram (phylogenetic tree or, colloquially "cladogram") page***. This has a green background (symbolising the tree of life). Here the Page Back, Page Next, and Unit Home, refer to navigation within the dendrogram page's Unit; i.e. to a non-dendrogram page, whereas Unit Back, Unit Next, and Unit Up will take you to the corresponding dendrograms (evolutionary trees) for those Units. The only time Unit Home points to a dendrogram page is when it points back to the dendrogram index pages .

The ***Reference pages*** is, you guessed it, for the references for each unit. As with dendrogram menus,

Unit Back, Unit Next, and Unit Up will take you to the corresponding reference pages of those Units. The reference page is always at the end of a unit, so Page Next on a reference page always points to the Index page of the next unit.

Lists, of taxa or whatever, may be included as distinct pages or as part of the index/home page. So far there are not many of these due to the incompleteness of **Palaeos** and the usefulness of Google search. Notes, and Pieces are miscellaneous pages that don't fit in the above categories.

Currently the new **Palaeos** is still a work in progress, so if you would like to suggest or contribute material, please contact the editors at the email addresses provided below.

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page last modified MAK110902, MAK110914, edited RFVS111214
Google search box courtesy of Ask Dave Taylor

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6 October, 2011: Uploaded home page.

8 October, 2011: Uploaded Time and Evolution the big picture pages .

12 October, 2011: Uploaded more pages.

16 and 17 October, 2011: And still more.

23 November, 2011: And still more pages have been updated and uploaded, with a lot more being worked on. Because the current **Palaeos** site is still under construction, with so many pages are being worked on, it is inconvenient to list them all. Once we have the whole thing up then we'll be more systematic about announcements here. MAK111123

page uploaded MAK111007, revised MAK111123, edited RFVS111214
Google search box courtesy of Ask Dave Taylor

Palaeos: FAQs

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What's all this?

ATW (Toby White): My former site, the ***Vertebrate Notes***, began as a set of notes on vertebrate paleontology and biology kept for personal use, but the project got completely out of hand. At some point, I ran into Alan Kazlev, who has never been ***in*** hand. After a year of discussion, two weeks of serious thought, and no actual planning, we started **Palaeos**. I'm not sure what it is, but we spend a lot of time on it. I handle the vertebrates mostly. Alan was handling the rest of time and space.

MAK (M Alan Kazlev): I've added a few more comments in the About **Palaeos** page.

What's in Palaeos?

ATW: I have no idea. Ask Alan.

MAK: I suppose all I can say is that it's a work in progress, summed up by the motto: ***life through deep time***.

OK. What's in the Vertebrate Part?

ATW: All kinds of things: an alphabetical index of clades, cladograms showing the relationship of each group to the others, synapomorphies of the groups, other anatomical information, some images; often some quick information on ecological position, references and web links for further information, literature references; the names of typical or notable members of the taxon. Now and again, other material of interest in the form of notes or essays has been included in the entry. Another section takes a few vicious stabs at being an osteology of the vertebrates. There's a very home-grown glossary of vertebrate biology.

I've got some other sections in mind for later. In forming **Palaeos**, I've integrated most of Alan's vertebrate materials. Sometimes they complement the old material quite nicely. Then again, sometimes they don't. Some of the entries are, obviously, much more comprehensive than others. There is no real method to the selection. I've been trying to give a little coverage to all groups. So far the only group I find truly boring are the teleosts, and even they have their points.

Why?

ATW: Why not? Also because Fred Bervoets (DinoData) was kind enough to suggest and encourage it.

Are you one them cladists?

ATW: Yup – but I cheat sometimes.

Cheat?

ATW: The bane of cladograms are meaningless nodes and stem species. If you've ever tried to draw a cladogram, you'll know what I mean. When an important group starts to radiate, it often throws out a bunch of taxa early on that don't last long and leave no daughter clades. Their relationships are often poorly understood because only a few, isolated specimens are known. They tend to obscure the main lines of a cladogram. Worse, they require a lot of work for me because they often have some weird mix of characters that requires a great deal of explanation for not much learned—all of it for a group erected on 1 molar, half a vertebra and a burning to desire to finish the thesis before turning 30 (yes, I've been there). Sometimes the only solution is to erect a garbage taxon and throw the oddballs into it. Another approach is to allow nodes to include basal species. This would be ***wrong***. The practice has no theoretical justification. It undermines the whole theoretical foundation of cladistics. It is sheer sloppiness. But I'm going to do it anyway.

What are your sources?

ATW: The basic entries used to be drawn from RL Carroll (1988) ***Vertebrate Paleontology and Evolution***, Freeman & Co.; PJ Currie & K Padian (eds.) (1997) ***Encyclopedia of Dinosaurs***, Academic Press; JO Farlow & MK Brett-Surman (eds.) (1997), ***The Complete Dinosaur***, Indiana; P Janvier (1996), ***Early Vertebrates*** Oxford; FH Pough, CM Janis, & JB Heiser (1999) ***Vertebrate Life***, Prentice Hall (5^{th} ed.); the ***Encyclopedia Britannica***; as well as some marginally relevant professional experience long ago. As often as time permits, entries are revised from the primary literature, full citations to which are found on the References pages.

Why haven't you incorporated the findings of molecular phylogeny in your coverage of birds or mammals?

MAK: Originally **Palaeos** vertebrates mostly emphasised a cladistic morphology-based methodology. The current revision will use a "Total Evidence" approach, which incorporates and synthesises phylogenetic evidence from all possible sources: fossil record, gross morphology-based cladistics, molecular phylogeny, evo-devo, etc. However it will take time to revise all the pages (and many most likely won't be revised at all, generally because they are pretty good as they are!). Also some of the original pages from 10 or so years ago will be retained, but these will be supplemented with new pages and material.

Are you looking for additional authors, editors, artists, etc?

MAK: Yes, we would love to have your input and contributions! Especially a project as vast as **Palaeos** could not possibly be undertaken by only a couple of people.

Do you accept paid advertising?

MAK: At the moment, no.

I totally disagree with what you have said regarding [insert taxon, topic, or methodology].

MAK: In that case, please contact me and submit your counterargument. **Palaeos** is not intended to represent a single pov, least of all mine! As long as what you say is reasonably argued and backed up with a few references (or not, as the case may be), I would be happy to include it (though I do draw the line at

creationism, sorry).

How do I know the information is accurate?

ATW, MAK: You don't.

And just who the heck are you?

ATW: I have many years of experience as a vertebrate.

I used to leave it at that, but someone (correctly) thought I was being evasive. A resume is included for the hopelessly nosy.

MAK: Whereas I don't even have a resume, which should be enough to warn the unwary about the reliability or lack thereof of anything I've written. Other than that, there's a very brief bio here

Any restrictions on using this material?

ATW: I'm not sure. I used to have a "no copyright" policy except for attributed images. But Alan doesn't have this quirk, and he's trying out a Creative Commons licensing scheme. Myself, I tend to think that (a) no one could possibly make any commercial use out of my stuff and (b) they're welcome to try. Also: remember that the material found at any links contained in **Palaeos** is usually protected by copyrights belonging to the owners of those sites. All links in **Palaeos** are included purely by way of reference or citation. No claim is made to any material at those sites, nor does their citation in **Palaeos** constitute any form of license or permission, express or implied, to access, use or copy that material.

That's a pretty nifty disclaimer, can I use it?

ATW: For professional advice, my fee is $240 an hour.

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Palaeos: Main Glossary

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The following, inevitably incomplete, introductory glossary of terms and concepts links to other topics discussed elsewhere on this site, as well as including general topics of interest such as well-known prehistoric animals. It still needs to be modified more by removing some more technical terms, and adding more common terms. Inevitably there is some duplication with other glossaries.

Some of the references and source material used in compiling this list include Wesley R. Elsberry's talk.origins jargon FAQ (mirror as convenient single document text file and William Hudson's more readable glossary of terms, and also more relevant as a general evolution and science glossary (Talk Origins emphasises good and bad arguments, geek culture, etc.); the US Geological Survey Glossary of Terms, the Understanding Evolution Glossary, the PBS evolution Glossary, as well as Wikipedia: evolutionary biology topics, and other Wikipedia pages on evolution and Creation–evolution controversy; the EvoWiki Encyclopedia (including Geology, Paleontology, Paleontologists, EvoWiki: History of science, although more topics need to be added or listed, and some of my (MAK) own interests and definitions. Where an entry is taken from a single reference, the source is given; sometimes where there it integrates a number of references none is. Due to constraints of time, I have not hyperlinked the entries, nor is this listing complete. In addition, because of limitations of time and energy, or perhaps just sheer laziness and apathy, I have for the most part only included on-line references, which are easier to copy and paste ;-)

A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z

A

Abiotic evolution: Non-biological evolution, for example mineral evolution, stellar evolution, etc. (MAK) **More**

Abiotic factors: The non-biological environmental influences that affect organisms; for example, temperature, rainfall, and humidity. (Wikipedia glossary).

Absolute age: The age of an object as established by some precise dating method, such as radiometric dating. Compare with relative age. (Dinodata glossary by Fred Bervoets)

Absolute dating: A means of estimating the age of rocks with some degree of accuracy using measurements of radioactive isotopes. (Dinodata glossary by Fred Bervoets)

Acanthodians: A primitive group of Silurian to Permian jawed bony fishes, bearing bony spines in front of all but their caudal fins. (USGS Paleontology glossary)

Acritarch: microscopic organic structure from any of a number of organisms; common during the Proterozoic.

Adaptive radiation, evolutionary radiation: the rapid expansion and diversification of a group of organisms as they fill unoccupied ecological niches, evolving into new species.

Age of Mammals: term found in popular books on evolutionary systematics for the Cenozoic era, beginning with the Paleocene Epoch when following the K–T (end Cretaceous) mass extinction, mammals underwent a huge evolutionary radiation and thus replaced reptiles as the dominant life on Earth. Paleontologist Björn Kurtén wrote a popular intelligent layperson book with the same title. ***The Age of Mammals*** is also the name of a mural by Rudolph Zallinger for the Yale Peabody Museum (link), which follows his earlier and better known ***The Age of Reptiles***. The Age of Mammals has in turn been replaced by the Anthropocene or Age of Man, (Holocene) when humans dominate every conceivable environment and most other life forms (apart from weedy species) are suffering a mass extinction (Yes, I know humans are also mammals, so technically speaking this is still the Age of Mammals, but I tend to think of the Age of Mammals as a period of flourishing biodiversity). (MAK)

Age of Reptiles: term found in popular books on evolutionary systematics for the Permian through to Cretaceous periods (but obviously originating with Victorian discoveries of "antediluvian monsters"), when reptiles (first mammal-like reptiles, then archosaurs and marine reptiles) were the dominant life on Earth. Paleontologist Edwin Colbert wrote a popular intelligent layperson book with the same title. The Age of Reptiles was followed by the Age of Mammals. (MAK) ***The Age of Reptiles*** is also the title of a 110-foot (30 meter) mural painted by Rudolph Zallinger depicting the time from the Devonian to the Cretaceous and featuring dinosaurs and other prehistoric animals (His ***The Age of Mammals*** mural is similar and covers the Cenozoic). The fresco sits in the Yale Peabody Museum in New Haven, Connecticut, and was completed in 1947 after three years of work. ***The Age of Reptiles*** was at one time the largest painting in the world, and depicts a span of nearly 350 million years in Earth's history. Painted in the Renaissance fresco secco technique, ***The Age of Reptiles*** was an important cultural influence during the 1950s–60s, images of which are often found in earlier books on paleontology, and was also the model for dinosaur toys. Despite its somewhat outdated view of dinosaurs (presenting them as slow, sluggish creatures), ***The Age of Reptiles*** is still notable for its historical and artistic merit and as the largest natural history painting in the world. It has been an inspiration to many visitors including both Robert Bakker and Peter Dodson, who credit it with influencing them to become paleontologists. Dodson was nearly moved to tears upon first seeing it as a college senior. (Wikipedia). ***Editor's note***: In my own case (MAK), a photo of this mural in a book (I no longer remember which one) when I was still a young child (maybe 10 or so) exerted a huge influence on me, like a revelation, and for the first time gave me a visual appreciation of deep time in terms of succession and transformation of

various forms of plant and animal life. To this day, this mural, along with a spindle diagram of vertebrate evolution in G.G. Well's ***Science of Life***, have been the two central influences that determined the way I think about deep time and the evolution of life on Earth. I think of **Palaeos** as in many ways simply an extension, update (in keeping with more recent discoveries) and commentary on this magnificent work. (MAK) Link: Age of Reptiles at the Yale Peabody Museum

Agnatha: name given to what was previously considered a class of jawless fish, including both Paleozoic ostracoderms and extant lampreys and hagfish. With the cladistic revolution, the term has been replaced by more phylogenetically accurate terms such as "basal vertebrate". Armoured agnathans are called ostracoderms. (MAK)

Albian: geologic age of the latest Early Cretaceous (Middle Cretaceous), spanning the time between 107 and 95 million years ago. (USGS Paleontology glossary)

Algae: generic term for photosynthetic, almost exclusively aquatic, non-vascular plants; Precambrian to recent.

Algorithm: In mathematics and computer science, an effective method (a procedure that reduces the solution of some class of problems to a series of rote steps that give a specific and correct answer) expressed as a finite list of well-defined instructions for calculating a function. Algorithms are used for calculation, data processing, and automated reasoning. (Wikipedia)

Amino acid: The molecular building blocks of proteins. The properties of a protein are determined by its particular amino acid sequence. There are 20 amino acids in the proteins of life on Earth.

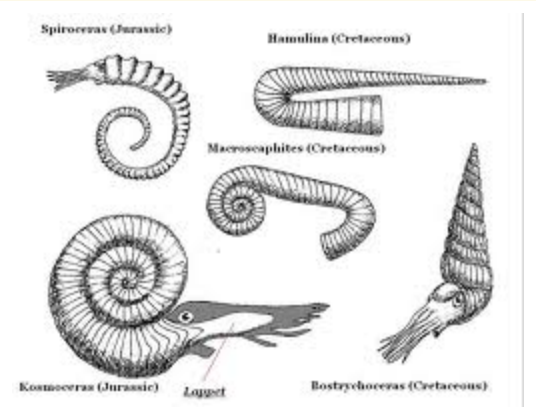


Figure: selected ammonites, from Phil Eyden, Ammonites: A General Overview.

Ammonite: A coiled, chambered fossil shell of a cephalopod mollusc of the extinct subclass Ammonoidea.

Amoeba: A microscopic, single celled protozoan consisting of a naked mass of protoplasm. Once considered the simplest form of animal life, they are now known to consist of several distinct and unrelated groups of protists. (USGS Paleontology glossary, MAK)

Amphibian: A class of vertebrates that have to return to water to lay their eggs. They are often equally at home on land and in water, hence the name "amphibian", derived from the Greek terms ἀμφίς (***amphis,*** "on both sides") and βίος (***bios***, "living"). Morphologically and ecologically diverse during the late Paleozoic era, including aquatic, semi-aquatic, and terrestrial newt, snake, crocodile, and frog analogues. The traditional term "amphibian" is disliked by cladists because it does not constitute a natural clade and so is considered phylogenetically meaningless. Hence instead terms like basal tetrapod or the names of individual clades and taxa (temnospondyls, lepidospondyls, Lissamphibia, etc), are used. Nevertheless, "amphibian" can still be used in a generic sense to refer to any non-amniotic tetrapod. (MAK, Perseus Digital Library)

Amniote: major tetrapod lade that reproduce by means of an external or internal egg in which the embryo or fetus is protected and nourished by several extensive membranes. Include reptiles, birds, and mammals. Middle Carboniferous to recent. **More**

Anagenesis: the evolutionary transformation of one species over time into another, resulting in the emergence of a new character or attribute (which in this case a new species) from an older one. Compare with cladogenesis and budding.

Ancestor: in this context, an organism, or more correctly a population, lineage, or species, that through evolution gives rise to one or more descendants that generally belong to a distinct species or lineage. See also common ancestor.

Ancient Astronaut theory: new age meme advocated by Erich Von Däniken, according to which extraterrestrials were involved in, or are responsible for, human evolution. A secular form of intelligent design. Generally does not try to explain where the rest of life (or the aliens themselves, for that matter!) comes from. A more recent iteration can be found in Ridley Scott's movie ***Prometheus***. Compare with

panspermia. (MAK)

Angiosperm: plants that possess true flowers with seeds enclosed in an ovary. (Bristol University: Palaeobiology and Biodiversity Research Group: Late Cretaceous Climate Change: Glossary)

Ankylosaur: herbivourous armoured mostly Cretaceous "bird hipped" dinosaurs with rows of bony plates protecting the sides and back, and armed with either spikes along the sides or a bony club at the end of the trail **More**

Anthropocene: informal geochronological term that serves to mark the evidence and extent of human activities that have had a significant global impact on the Earth's ecosystems. Compare with Holocene.

Anthropocentrism, anthropocentric: Centering on humans and considering or relating all other things to man; for example the biblical idea that only man has a divine soul, or the belief that humans are of greater moral worth than other species; the practice, conscious or otherwise, of regarding the existence and/or concerns of human beings as the central fact of the universe. CompareAscent, Creationism, Teleology. Contrast biocentrism. (MAK, Wikipedia glossary)

Apomorphy: In cladistics, a unique derived character trait found in a particular taxon, which is also possessed by a common ancestor. See also Synapomorphy. **More**

Aptian: geologic age of the Early Cretaceous, spanning the time between 114 and 107 million years ago. (USGS Paleontology glossary)

Archaea: one of the three domains of life in the molecular phylogeny described by Carl Woese (originally Archaeobacteria, renamed Archaea by Woese et al 1990), prokaryotes that are metabolically and morphologically distinct from Eubacteria; includes many types of extremophiles, remnants from the earlier history of the earth. Cavalier-Smith (Cavalier-Smith, T. 2010 and other refs) rejects ancient origin on morphological and paleontological grounds. Since each presents strong arguments, we defer trying to decide which paradigm is correct. (MAK) **More**

Archean: the second of the four eons of the geological timescale, characterised by a reducing (non-oxygen) atmosphere and the earliest prokaryote life. It lasted from about 3.9 to 2.5 billion years ago. **More**

Archaeopteryx: the earliest and most primitive known bird, most of whose fossil remains were recovered in the 19th century, from the Jurassic Solnhofen limestone in Bavaria. Perfectly intermediate between reptile (or more correctly, theropod dinosaur) and modern bird, its discovery was powerful evidence for Darwinian evolution. (MAK, Perseus Digital Library) Wikipedia page (detailed coverage)

Archosaur: derived from the Greek terms ἀρχός (***arkhos***, "ruling") and σαῦρος (***sauros***, "lizard"); it names any member of a major clade of tetrapods that includes birds, dinosaurs, pterosaurs, crocodiles, and their paraphyletic thecodont ancestors. Dominated terrestrial ecosystems for the entirety of the Mesozoic. (MAK, Perseus Digital Library, Wiktionary) **More**

Arthropoda: derived from the Greek terms ἄρθρον (***arthron***, "joint") and πόδα (***poda***, "foot"); it is a major phylum of segmented animals with an exoskeleton, includes trilobites, insects, spiders, crustacea, and others. An important component in marine and terrestrial ecosystems. Cambrian to recent. (Perseus Digital Library) **More**

Ascent: The premise that evolution directional, moving from primitive and less perfect to more complex and perfect forms, the whole constituting a sort of hierarchical gradation, usually with man at the top. Criticised by popular science writers like Stephen Jay Gould, but remains a very influential meme. Some popular thinkers, such as Teilhard de Chardin, have argued for an anthropocentric cosmology, culminating in a future omega point. (MAK)

ASCII phylogenetic tree: As here defined, an ***ASCII phylogeny***, or more correctly an ***ASCII phylogenetic tree***, is a dendrogram or tree diagram which uses ASCII text format to draw supertrees. Also informally be referred to as ***ASCII cladograms***.

Assemblage zone: An aggregation of fossils in a body of sedimentary rock. (Dinodata glossary by Fred Bervoets)

Australopithecus*, australopithecine**: derived from the Latin terms ***austrī ("south wind") and ***-alis*** (an adjective-forming suffix) and the Greek term πίθηκος (***pithēkos***, "ape"); it is a hominid predecessor of ***Homo***, known from the Plio-Pleistocene of Africa, first discovered by Raymond Dart. Mostly smaller than a modern human, walked erect, with a human-like body but ape-like skull, showing that brain size evolved late in evolution, rather than early, as the Piltdown forgery led early 20th century scientists to believe. The famous early hominid fossil "Lucy" is an example of an Australopithecine. (Perseus Digital Library, Wiktionary)

Astrobiology, also **Exobiology**: is the study of the origin, evolution, distribution, and future of life in the universe. This interdisciplinary field uses physics, chemistry, astronomy, biology, molecular biology, ecology, planetary science, geography, and geology to investigate the possibility of life on other worlds and help recognize biospheres that might be different from the biosphere on Earth. It includes the search for habitable environments in our Solar System and habitable planets outside our Solar System, the search for evidence of prebiotic chemistry, laboratory and field research into the origins and early evolution of life on Earth, and studies of the potential for life to adapt to challenges on Earth and in outer space. ***Astrobiology*** addresses the question of whether life exists beyond Earth, and how humans can detect it if it does. The term ***exobiology*** is similar but more specific — it covers the search for life beyond Earth, and the effects of extraterrestrial environments on living things. I have here used these two terms as synonyms. (Wikipedia, MAK) **More**

Autotroph: an organism which makes its own food from inorganic materials, using sunlight or chemical reactions for energy. (Wikipedia glossary, MAK)

B

Bakker, Robert T.: popular figure in dinosaur paleontology, largely credited with the "dinosaur renaissance" of the late 1960s and 1970s.

Bacteria: microscopic single-celled organism; the commonest and most ubiquitous form of life on Earth. Synonymous with prokaryote. Woese et al 1990 restrict the term "Bacteria" to Eubacteria only, and this practice has since been widely adopted, but in order to avoid confusing with the more general definition we have avoided following this course. (MAK)

Barremian: geologic age of the Early Cretaceous, spanning the time between 118 and 114 million years ago. (USGS Paleontology glossary)

Basal: Preferred cladistic substitute for "primitive", as it is felt the latter may carry false connotations of inferiority or a lack of complexity.

Basal node: the node or base of the cladogram, representing the hypothetical common ancestor of the entire clade

Basal taxon: general term in phylogenetic systematics for any terminal taxa that lie at the base of a cladogram, i.e., they are connected by, or else close to, the basal node, and their sister group is the sub-clade that constitutes the rest of the cladogram. Equivalent to primitive or ancestral (these terms not being used in cladistics). (MAK)

Bauplän: basic morphological body plan, involving the shared structural homologies of derived taxa, generally defines phyla or other major groups of organisms.

Belemnite: a Mesozoic to early Tertiary cephalopod mollusc with an internal cone-, bullet-, or cigar-shaped shell. In life a squid-like animal, along with their cousins the ammonites they were important members of the Mesozoic marine ecosystem.

Benthic: Used to describe aquatic organisms that are bottom dwelling. (USGS Paleontology glossary)

Benton, Michael J.: British paleontologist, professor of vertebrate palaeontology in the Department of Earth Sciences at the University of Bristol and author of many papers and several popular science books, as well as the palaeontology textbook ***Vertebrate Palaeontology***. **More**

Berriasian: geologic age of the earliest Cretaceous, spanning the time between 135 and 131 million years ago. (USGS Paleontology glossary)

Big Five: five mass extinctions identified by Jack Sepkoski and David M. Raup in a paper published in 1982. These are:

- ***Ordovician–Silurian extinction event***
- ***Late Devonian extinction event***.
- ***Permian–Triassic, or End Permian extinction event, aka the Great Dying.***
- ***Triassic–Jurassic extinction event*** (apparently two, the End-Carnian and the End-Triassic, not as large as the others).
- ***Cretaceous–Tertiary (K–T) extinction event***.

Big History: history not just on the human scale, but also Earth and cosmic history. In a sense, the **Palaeos** website is concerned with Big History. Compare Deep Time, Universe Story. (Wikipedia) **More**

Bilateral symmetry: Symmetry in only one plane, called the sagittal plane, that divides an organism into roughly mirror image halves. Contrast radial symmetry. (Wikipedia)

Binomial nomenclature: Linnaean universal standard of biological scientific notation, according to which every species is given a distinct two-part name. The first part, think of it as like the surname, is the genus, which is capitalised, the second part the species, written completely in lower case, is like the given name. Both names are by convention written in ***italics***.

Biocentrism: Centered on life as a whole, rejecting the idea that man is the summit of creation, or has greater moral worth or ontological value than other species. Contrast anthropocentrism. (MAK, Wikipedia glossary)

Biodiversity: In biology, the degree of variety of the Earth's animal, plant, and microbial lineages within a given ecosystem, biome, or an entire planet. Used to describe species richness, ecosystem complexity, and genetic variation.

m

Biogeography: the study of the distribution of organisms and species, past and present, and of diverse processes that underlie their distribution patterns.

Biome: The total complex of biotic communities occupying and characterizing a particular area or zone, classified according to its climate and type of vegetation. (Wikipedia glossary) **More**

Biosphere: life as a planetary phenomenon, the global ecosystem, the totality of life on Earth, or on other planets in the universe.

Biostratigraphy: dating rock layers according to the fossils they contain. Provides information on the relative age of the rocks, in contrast to radiometric dating, which gives data for the absolute age. Also, more informally, using the fossil record in Deep Time to understanding the evolution of life. Evolutionary Systematics, which developed from paleontology, utilises biostratigraphy, whereas cladistics, which is based much more on neontology, totally rejects it in favour of morphological similarity alone, on the grounds that the fossil record is incomplete.

Biota: The plants and animals of a specific region or time period. **More**

Bird (Aves): A class of intelligent, feathered, flying, warm-blooded vertebrates that first evolved during the late Jurassic period, along with mammals they constitute the predominant vertebrates of the Cenozoic. Birds also are instructive as regards competing systematics paradigms: in evolutionary systematics they are a distinct taxon that evolved from dinosaurian ancestors (birds ***evolved from*** dinosaurs) whereas cladistically speaking they are simply a clade of highly derived dinosaurs (birds ***are*** dinosaurs). Despite its counter-intuitive aspects, cladistics has been almost universally adopted in vertebrate paleontology, so the second position is the official one. **More**

Bivalve: names any a mollusc that is a member of Class Bivalvia, a clade characterised by having two shells hinged together, as the

oyster, clam, scallop, or mussel. The term is sometimes also used to refer to any animal with two halves to its shell such as an ostracod or brachiopod. Here ***bivalve*** is used to refer specifically to the molluscan class. In contrast to brachiopods, the plane of symmetry is primitively between the valves (the two shells), although many types, for example oysters, developed different sized valves. The second largest class of mollusc, after gastropods. Common as fossils, especially during the Mesozoic and Cenozoic, and these animals remain an important element in marine ecologies, especially in the littoral region. (MAK)

A variety of fossil bivalves, after C. L. Fenton and M. A. Fenton, *The Fossil Book*, Doubleday, 1958., original URL)

Bony Fishes: Fish of the class Osteichthyes, characterized by a skeleton composed of bone in addition to cartilage, gill covers, and an air bladder. (USGS Paleontology glossary)

Brachiopod: derived from the Greek terms βραχίων (***brakhiōn,*** "arm") and πόδα (***poda***, "foot"); it names any member of a major phylum of marine organisms with bivalved shell, in contrast to molluscan bivalves the plane of symmetry is through the mid-line of the shell, not between the valves. Filter feeding by means of a specialised organ called a lophophore. Abundant during the Paleozoic (most especially from the Ordovician to the Devonian), where, along with corals, they make up the majority of invertebrate fossils. Less common in the Mesozoic, and even less frequent in the Cenozoic. Cambrian–Recent. (MAK, Perseus Digital Library)

Brachiosaurus: gigantic Late Jurassic to Early Cretaceous sauropod with sloping back and forearms longer than hindlimbs, include some of the largest land animals ever to walk the Earth. Originally applied to a number of such animals, there is a tendency now to include each species in a separate genus, as some of these animals differ in many details. However, dinosaur genera are certainly oversplit. During the mid Cretaceous, brachiosaurs were replaced by the equally huge titanosaurs. (MAK)

Branching: for the sake of convenience I use this term as the counterpole to anagenesis. See also Multiplication of species.

Bryozoa: derived from the Greek terms βρύον (***bruon,*** "moss") and ζῷα (***zōa***, "animal"); is a phylum of exclusively aquatic and mostly marine colonial organisms. At one time thought to be related to brachiopods because of the common possession of a lophophore, this is now considered the result of convergence. Ordovician–Recent. (MAK, Perseus Digital Library)

Budding: in a phylogenetic context, a new species that splits from the parental taxon which remains unchanged. Contrast anagenesis, cladogenesis.

Burgess Shale: ***Konservat-Lagerstätten*** from the Middle Cambrian of British Columbia, preserves carbonised films which give a unique preservation of soft-bodied organisms and soft parts of hard-shelled organisms, provides an important window on the Cambrian explosion. The inspiration for Stephen Jay Gould's book ***Wonderful Life***.

Burian, Zdenek (1905–1981): Czech painter and book illustrator whose work played a central role in the development of palaeontological reconstructions.

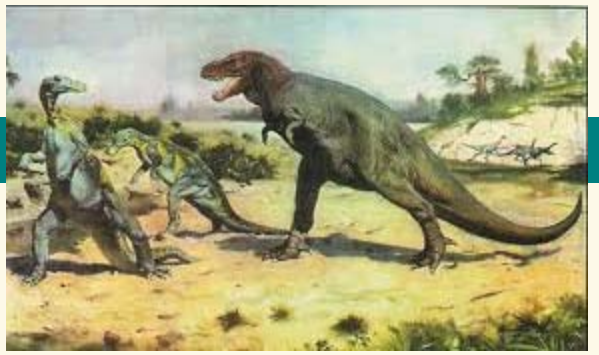


Figure: *Tyrannosaurus rex* charges the "duck billed" herbivore *Trachodon* (later renamed *Anatotitan* and *Edmontosaurus*).

C

Cambrian: The earliest period of the Paleozoic era, spanning the time between 544 and 505 million years ago. Its name derives from Cambria, the Roman name for Wales, where rocks of this age were first studied. (USGS Paleontology glossary) Major diversification of life in the Cambrian Explosion. Numerous fossils; most modern animal phyla appear. First chordates appear, along with a number of extinct, problematic phyla. Reef-building Archaeocyatha abundant; then vanish.

Trilobites, priapulid worms, sponges, inarticulate brachiopods, and many other animals numerous. Anomalocarids are giant predators, while many Ediacaran fauna die out. Prokaryotes, protists (e.g., forams), fungi and algae continue to present day. Gondwana emerges. Petermann Orogeny on the Australian Continent tapers off (550–535 Ma). Ross Orogeny in Antarctica. Adelaide Geosyncline (Delamerian Orogeny), majority of orogenic activity from 514–500 Ma. Lachlan Orogeny on Australian Continent, c. 540–440 Ma. Atmospheric CO2 content roughly 20–35 times present-day (Holocene) levels (6000 ppmv compared to today's 385 ppmv). (Wikipedia) **More**

Cambrian explosion, Cambrian radiation: The abrupt appearance of a diverse and highly derived fauna in the brief Tommotian and Atdabanian Stages of the Early Cambrian, one of the most, if not ***the*** most, dramatic evolutionary radiations in the history of life. Although that particular phrase only came into common usage in the early to mid 1970s, the event itself has long been recognized as a phenomenon demanding some accommodation from evolutionary theory. As early as 1859, Charles Darwin drew attention to the matter in ***Origin of Species***, and it is probable he had considered the matter for many years prior to that. (Chris Clowes 2002–2003)

Campanian: geologic age of the Late Cretaceous, spanning the time between 84 and 72 million years ago. (USGS Paleontology glossary)

Carboniferous: A period of time in the Paleozoic era that includes the Mississippian and Pennsylvanian subperiods and extended from 360 to 286 million years ago. The later Carboniferous was the time of great Coal Swamps. (USGS Paleontology glossary) **More**

Cartilaginous fishes: Class Chondrichthyes; fish having a skeleton composed mostly of cartilage, as sharks and rays. Cartilage, aka gristle, is a firm, elastic, flexible type of connective tissue. (USGS Paleontology glossary)

Catastrophism: the theory that the Earth's geological landscape is the result of violent cataclysmic events. It was used by George Cuvier to explain the extinction of species. Contrast with uniformitarianism; the two opposed each other during the late 18th and 19th centuries. Young Earth Creationism uses a modified from of Catastrophism, employing the Biblical Flood to explain the fossil record.

Cell: The basic structural and functional unit of living organisms, differentiated into cytoplasm and nucleoplasm, which contains DNA, and enclosed by a cell membrane, which in the cells of plants, fungi, algae, and bacteria is surrounded by a cell wall.

Cenomanian: geologic age of the earliest Late Cretaceous (middle Cretaceous), spanning the time between 95 and 91 million years ago. (USGS Paleontology glossary)

Cenozoic: derived from the Greek terms καινός (***kainos,*** "new"), ζωή (***zōē,*** "animal life") and -ικός, (***-ikos***, an adjective-forming suffix); is the current of the three Phanerozoic eras in the geological timescale. It began 65.5 million years ago. The era when the modern continents formed, mammals and birds filled the ecological niches vacated by dinosaurs, and modern taxa of plants and invertebrates evolved. The later part of the Cenozoic was marked by a pronounced cooling, culminating in the Pleistocene ice age. Includes two periods, the Tertiary and Quaternary, and seven epochs, the Paleocene, Eocene, Oligocene, Miocene, Pliocene, Pleistocene, and Holocene. **More**

Cephalopod: derived from the Greek terms κεφαλή (***kephalē,*** "head") and πόδα (***poda***, "foot"); names any member of Class Cephalopoda, a clade of highly intelligent molluscs, primitive types with shells, shells reduced and internal or lost altogether with more advanced members of the group. Shelled forms common in the fossil record. Includes nautiloids, ammonoids, belemnites, squid, octopi, and cuttlefish. Late Cambrian to Recent. (Perseus Digital Library)

Chalk: soft, earthy, fine-grained white to greyish limestone of marine origin. It is composed almost entirely of by shallow-water accumulations of coccoliths and other microscopic organisms and forms in a sea predominantly free from terrestrial sediment. (Bristol University: Palaeobiology and Biodiversity Research Group: Late Cretaceous Climate Change: Glossary)

Chaotian: a recently proposed addition to the geologic time scale in Goldblatt et al. 2010, it is an eon spanning the indeterminate amount of time between the collapse of the solar nebula and the collisional formation of the Earth–Moon system. The major subdivisions are the Eochaotian and Neochaotian eras with the start of the latter marked by the Sun's thermonuclear ignition. (RFVS) **More**

Character: In cladistics, any recognizable trait, feature, or property of an organism, used to reconstruct an evolutionary tree. Characters may be morphological, behavioral, physiological, or molecular. ***Character states*** the mutually exclusive conditions of a character (one of the possible alternative conditions of the character): for example, "present" and "absent" are two states of the character "hair" in mammals.

Chelicerate: Arthropod subphylum characterized by have chelicera (a pair of pre-oral appendages), including arachnids (spiders, mites, etc), horseshoe crabs, scorpions and eurypterids ("sea scorpions").

Chloroplast: plastid organelles found in plant cells and other eukaryotes (some protists) that conduct photosynthesis. Thought to have originated from cyanobacteria through endosymbiosis. (Wikipedia)

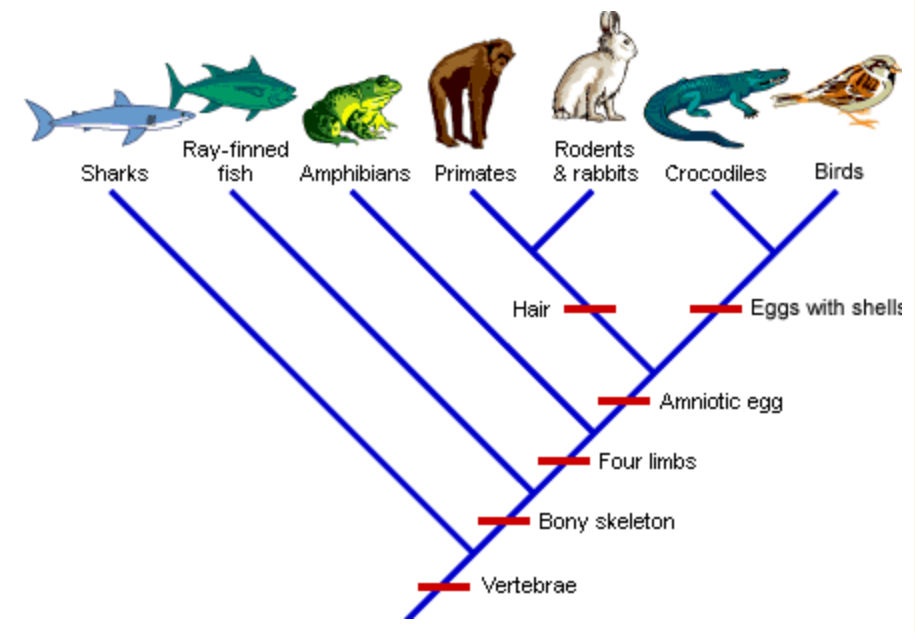
Chordate: organism having a notochord at some stage of development: a rigid cartilaginous rod in the back extending from anterior to posterior; includes the vertebrates along with several lesser known groups. (based on Curtis Loer & students)

Chronogram: phylogenetic tree (which or may not also be a cladogram) that explicitly represents evolutionary time through its branch lengths. (Wikipedia)

Chronospecies: One or more species which continually changes from an ancestral form along an evolutionary scale. This sequence of alterations eventually produces a population which is physically, morphologically, and/or genetically distinct from the original ancestors. Throughout this change, there is only one species in the lineage at any point in time, as opposed to cases where divergent evolution produces contemporary species with a common ancestor. Relies on an extensive fossil record, since morphological changes accumulate over time and two very different organisms could be connected by a series of intermediaries. The related term ***paleospecies*** indicates an extinct species only identified with fossil material. To avoid unnecessary multiplication of terminology (and paleontology–neontological distinctions) these terms are here synonymised. For example, changes in the Permian lepospondyl amphibian ***Diplocaulus*** over time may imply a chronospecies (= paleospecies). (MAK, Wikipedia)

Clade: the set of all organisms descended from a particular common ancestor. See also monophyly, contrast grade. (MAK)

Cladistics: more correctly but less commonly known as ***Phylogenetic Systematics***. Rigorous methodology first developed by Wili Hennig, which uses a logical empirical approach to reconstruct phylogeny, often represented in the form of a branching diagram, called a cladogram or tree. In contrast to evolutionary systematics, phylogenetic systematics collects character data only from the taxa being studied, and does not consider the inferred characters of ancestors, or the transformation from one species to another, nor does it consider deep time or the sequence of appearance of fossils to be of relevance, only shared morphological features. Cladistic methodology is very popular with vertebrate paleontologists and paleo geeks. In the march of paradigms, cladistics supplanted evolutionary systematics in the 1980s and 90s, but has since been pushed aside by molecular phylogeny, which ignores gross morphology altogether. Nowadays there is the tendency to combine both under the heading of phylogenetics



Simple cladogram classifying vertebrates according to their synapomorphies (shared unique characteristics). Most cladograms involve many hundreds of characteristics

Cladogenesis (also called **Splitting**): The division of an ancestral or parental lineage into two or more daughter lineages or species. Contrast with anagenesis, budding.

Cladogram: A diagram used in cladistics to shows the family relationship between organisms, in the form

of a tree. Cladograms reveal the branching order of lineages but not the amount of evolutionary change (for which see phylogram). Originally cladograms were drawn on the basis of well-known morphological characters, but more recently are based on large data matrixes that include not just morphological but also molecular sequencing data (see computational phylogenetics and total evidence). Contrary to popular belief, cladogram nodes do not represent actual ancestral taxa. Were an actual ancestor to be included it would ideally appear as the sister taxon of the sub-clade that includes all its descendants. Informal cladograms are probably better referred to as dendrograms. (MAK)

Class: In the Linnaean classification the taxonomic rank between phylum and order, used to define major sub-group within a phylum. Classes are used in the taxonomic series of evolutionary systematics but are not used in cladistic analysis. **More**

Cnidaria: derived from the Greek term κνίδη (***knidē***, "nettle") and the Latin ***-aria*** (nominal form of an adjective-forming suffix); is a phylum of solitary or colonial, sessile or free-living, predatory organisms with specialized stinging cells called ***nematocytes*** (or ***cnidoblasts***), and frequently having distinctive morphologies for asexual and sexual reproduction. Cnidarians include jellyfish, corals, hydrozoans and others. In older books the name ***coelenterate*** is used instead. (University of Arizona Geosciences 308 Paleontology glossary, Perseus Digital Library, Wiktionary) **More**

Coal swamp: name given to the vast equatorial tropical forests and swamplands of the late Carboniferous, from which most modern black coal comes from (brown coal in contrast is Tertiary in age). Despite the name, coal swamps did not themselves contain any coal. Page with links to dioramas. (MAK)

Coccoliths: Microscopic structures of varying shape and size that are made of calcite, are secreted by calcareous nanoplankton, and are found in marine deposits from the Triassic period to the Recent. Coccoliths range in size from one to thirty-five micrometers in size. (USGS Paleontology glossary), found only in warm, low-latitude waters and hence useful for understanding ancient climates. (Bristol University: Palaeobiology and Biodiversity Research Group: Late Cretaceous Climate Change: Glossary)

Co-evolution: Evolution in two or more species, such as predator and its prey or a parasite and its host, in which evolutionary changes in one species influence the evolution of the other species. (PBS evolution Glossary). See also evolutionary arms race

Co-extinction: the loss of one species due to the extinction of another; for example, the extinction of parasitic insects following the loss of their hosts. Co-extinction can also occur when a flowering plant loses its pollinator, or through the disruption of a food chain. (Wikipedia)

Common ancestor: The ancestral species that gave rise to two or more descendant lineages, and thus represents the ancestor they have in common. Contrary to popular opinion, cladograms do not actually show the common ancestor; in this context, see basal taxon, hypothetical common ancestor.

Common descent. This is the theory that every group of organisms descended from a common ancestor, and that all groups of organisms, including animals, plants, and microorganisms, ultimately go back to a single origin of life on earth. (W.J. Hudson)

Community: Any grouping of populations of different organisms that live together in a particular environment (Allaby 1998), including plants, animals, micro-organisms.

Complexity: A systemic characteristic that stands for a large number of densely connected parts and multiple levels of embeddedness and entanglement. Not to be confused with complicatedness, which denotes a situation or event that is not easy to understand, regardless of its degree of complexity. (Wikipedia glossary)

Computational phylogenetics: the application of computational algorithms, methods and programs to phylogenetic analyses. The goal is to assemble a phylogenetic tree representing a hypothesis about the evolutionary ancestry of a set of genes, species, or other taxa. A central element in modern cladistics and phylogenetics. (MAK, Wikipedia)

Condylarth: Order Condylartha. Evolutionary systematic term for a broad assemblage of primitive, mostly Paleocene and Eocene, hoofed mammals, not used in cladistic systematics.

Coniacian: geologic age of the Late Cretaceous, spanning the time between 90 and 88 million years ago. (USGS Paleontology glossary)

Conodont: derived from the Greek terms κῶνος (***kōnos,*** "cone") and ὀδόντος (***odontos***, "tooth"); designates microscopic tooth-shaped skeletal elements for a long time of unknown origin, now known to be the feeding apparatus of planktonic eel-like primitive/basal vertebrates . Important in biostratigraphy. Ordovician to Triassic. About 230 genera. (University of Arizona Geosciences 308 Paleontology glossary, Fossil Mall glossary, (Perseus Digital Library, Memidex) **More**

Continental drift: the movement of the Earth's continents relative to each other. The hypothesis was proposed by Alfred Wegener in 1912, but it was not until an understanding of plate tectonics in the 1960s, that an actual geological explanation of that movement was found. There is considerable paleontological and geological evidence in favour of continental drift. (based on Wikipedia)

Convergent evolution, Convergence: process in which two or more distinct lineages independently evolve similar characteristics of one another. In other words, there is an evolutionary convergence between two unrelated or only distantly related types. This often occurs because both lineages face similar environmental challenges and selective pressures. A form of homoplasy. Compare Parallel Evolution

Cope, Edward Drinker(1840–1897): important American paleontologist and comparative anatomist, whose competition with Othniel Charles Marsh for the discovery of new fossils became known as the "Bone Wars". **More**

Coral: Class Anthozoa, sessile Cnidaria, solitary or colonial polyp-like animals, may be soft-bodied (sea anemone) or secret a stony skeleton (this is the familiar coral). Often reef-building organisms. Include the Paleozoic Rugose and Tabulate corals, both common or very common as fossils in rocks of Ordovician to Permian age, and the Mesozoic to Recent Scleractinian corals. **More**

Core: A cylindrical section of rock, usually 2–4 inches in diameter and up to several feet long, that is the result of coring into the earth. Individual cores are brought to the surface for geologic examination and/or laboratory analysis. (USGS Paleontology glossary)

Cosmology: the study of the nature and structure of the universe, either from the standpoint of science (specifically physics and astrophysics), philosophy, esotericism, mythology, or religion. Generally a distinction is made cosmogony which refers to the study of origins of the Universe, but in practice the two are usually considered together. From a science perspective, cosmology and cosmogony include the Big Bang theory and hypotheses on the early history of the universe and the formation of galaxies and stars. (MAK) **More**

Counter-intuitive: going against the most familiar or seemingly obvious interpretation. Science is often counter-intuitive. (MAK)

Craton: The stable portions of the continents that have escaped orogenic activity for the last 2 billion years. Made predominantly of granite and metamorphic rocks. ***compare*** orogen. (S.M. Richardson)

Creationism: The belief in the universe and life on Earth as having a supernatural origin, creator, or designer. Assumes a static (non-evolving) universe. Based on the premise that science and religion are mutually incompatible and that only a literal belief in scripture is justified. Creationist arguments are easily refuted by science (see e.g. the Talk Origin archives). See also Intelligent Design. Creationists generally accept microevolution but not macroevolution. **More**

Cretaceous: The final period of the Mesozoic era, spanning the time between 145 and 65 million years ago. The name is derived from the Latin ***crēta*** ("chalk", "earth from Crete") and was first applied to extensive deposits of this age that form white cliffs along the English Channel between Great Britain and France. (USGS Paleontology glossary) Flowering plants proliferate, along with new types of insects. More modern teleost fish begin to appear. Ammonites, belemnites, rudist bivalves, echinoids and sponges all common. Many new types of dinosaurs (e.g. tyrannosaurs, titanosaurs, duck bills, and horned dinosaurs) evolve on land, as do Eusuchia (modern crocodilians); and mosasaurs and modern sharks appear in the sea. Primitive birds gradually replace pterosaurs. Monotremes, marsupials and placental mammals appear. Break up of Gondwana. Beginning of Laramide and Sevier Orogenies of the Rocky Mountains. Atmospheric CO2 close to present-day levels. (Wikipedia, Perseus Digital Library, Dictionary of Botanical Epithets by Chuck Griffith) **More**

Crinoid: sea lily, (Subphylum Crinozoa, Class Crinoidea) a type stalked and filter-feeding echinoderm that was very common during the Paleozoic, especially the early Carboniferous, and continues to flourish today,

mostly in deep sea environments

Crustacean: Subphylum Crustacea. Large group of mostly marine arthropods (although there are also some freshwater types and even a few terrestrial ones). Include shrimps, lobsters, crabs, barnacles, krill, ostracods, and terrestrial slaters and pillbugs. Morphologically distinct from other arthropods (hence given their own subphylum), but according to molecular phylogeny closely related to insects. Cambrian to recent.

Culture: The result of individual learning processes that distinguish one social group of higher animals from another. In humans culture is the set of products and activities through which humans express themselves and become aware of themselves and the world around them. (Wikipedia glossary)

Cyanobacteria: common name "blue-green algae", a type of photosynthetic Eubacteria, one of the most primitive forms of life on Earth. Form stromatolites, and the "scum" on rocks and in showers. Archean to recent.

Cynodont: mostly Triassic mammal-like reptiles, from which true mammals evolved. (MAK) **More**

D

Darwin, Charles: 19th-century naturalist and father of the theory of evolution. His landmark work, ***On the Origin of Species***, published in 1859, presented a wealth of facts explaining how evolution occurs, via the mechanism he called 'natural selection. **More**

Darwinism: see Natural selection

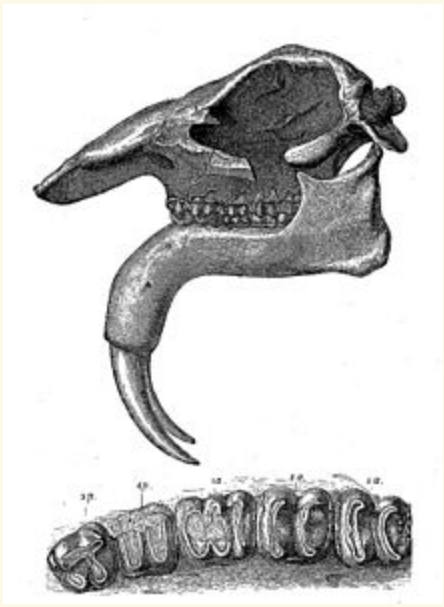
Dawkins, Richard: English evolutionary biologist who has taught zoology and is the author of several books on evolution and science, including ***The Selfish Gene*** (1976) and ***The Blind Watchmaker*** (1986). He is known for his popularization of Darwinian ideas, as well as for original thinking on evolutionary theory. A committed atheist, he strongly argues for metaphysical naturalism. (PBS evolution Glossary, MAK)

Daughter group: see Sister group

Deep Time: time that can only be thought of or measured in terms of geological processes (erosion, mountain building, glaciation, etc). Time that involves millions of years, as opposed to mere decades or centuries as in human history. (MAK) **More**

Deinonychus: derived from the Greek terms δεινός (***deinos,*** "mighty") and ὄνυχος (***onukhos***, "claw"); is a sickle-clawed feathered Middle Cretaceous theropod that was a bird "uncle" (close to the ancestry of birds, but living later than Archaeopteryx); a member of the family Dromaeosauridae. (Perseus Digital Library)

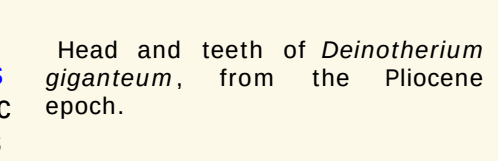
Deinotherium: derived from the Greek terms δεινός (***deinos***, "mighty") and θηρίον (***thērion***, "beast"); is a huge prehistoric proboscidean, Miocene to Early Pleistocene, distinguished by no upper tusks, downward curving lower tusks, and a shorter trunk than elephants. One of the first types of prehistoric animal to be discovered. (Perseus Digital Library) **More**



Dendrogram: Any branching diagram or tree, such as a cladogram. Also used here to refer to tree diagrams that include phylogeny, speciation, and time. (MAK)

Derived: technical cladistic term for advanced or specialised. (MAK)

Deuterostome: broad classification of triploblastic animals including echinoderms and chordates that tend to share certain embryological traits; among these the formation of the "mouth second" (hence the name) during gastrulation, after the future anus, which is comes from the blastopore, the site of gastrulation initiation. Contrast with protostome. (Developmental Biology 376 Glossary) **More**



Head and teeth of *Deinotherium giganteum*, from the Pliocene epoch.

Developmental biology: study of the process by which organisms grow and develop. Modern developmental biology studies the genetic control of cell growth, differentiation and morphogenesis. Includes embryology (originally a more descriptive science until the 20th century). The related field of evolutionary developmental biology was formed largely in the 1990s and is a synthesis of findings from molecular developmental biology and evolutionary biology which considers the diversity of organismal form in an evolutionary context. (Wikipedia)

Devonian: A period of the Paleozoic era, spanning the time between 410 and 360 million years ago. It is named after Devonshire, England, where rocks of this age were first studied. (USGS Paleontology glossary) First clubmosses, horsetails and ferns appear, as do the first seed-bearing plants (progymnosperms), first trees (the progymnosperm ***Archaeopteris***), and first (wingless) insects. Strophomenid and atrypid brachiopod, rugose and tabulate corals, and crinoids are all abundant in the oceans. Goniatite ammonoids are plentiful, while squid-like coleoids arise. Trilobites and armoured agnathans decline, while jawed fishes (placoderms, lobe-finned and ray-finned fish, and early sharks) rule the seas. First amphibians still aquatic. "Old Red Continent" of Euramerica. Beginning of Acadian Orogeny for Anti-Atlas Mountains of North Africa, and Appalachian Mountains of North America, also the Antler, Variscan, and Tuhua Orogeny in New Zealand. (Wikipedia) **More**

Dinoflagellate: Small organisms with both plant-like and animal-like characteristics, in earlier taxonomies usually classified as algae (plants). The name is derived from the Greek δῖνος (***dinos***, "whirling") and the Latin ***flăgellum*** ("whip") due to the dinoflagellates' twirling motion and their whip-like flagella. (USGS Paleontology glossary, Perseus Digital Library)

Dinosaur: any of a diverse and successful group, Superorder Dinosauria, of mostly large to huge terrestrial archosaurian reptiles that dominated much of the Mesozoic, and gave rise to birds. Children and paleo geeks (who are kids who never grew up) seem to have a particular love of dinosaurs, because they represent all the things that make a creature cool: big, strange, and dead (extinct). All of which tends to overshadow the fact that these were among the most successful land animals that ever lived, their reign two and a half times longer than that of mammals. Because cladistics does not accept the validity of ancestral (paraphyletic) groups, the definition of dinosaur has been expanded to include their descendants, the birds. The Dinosauria were first described and named by Richard Owen. Three main monophyletic sub-groups: Theropoda, Sauropodomorpha, and Ornithischia. (MAK) **More**

Dinosaur renaissance: term coined by paleontologist Robert T. Bakker (Bakker, 1975) referring to the academic and popular/lay paradigm shift in thinking about dinosaurs, of the late 1960s onwards, sparked by new discoveries and research indicating that dinosaurs may have been active andwarm-blooded animals, rather than cold-blooded and sluggish as had been the prevailing view and description during the first half of the twentieth century. Championed by John Ostrom, who argued that birds evolved from coelurosaurian dinosaurs, by Ostrom's student Bakker, who argued that dinosaurs were warm-blooded not as gigantotherms but in the same way that mammals and birds are, and paleo-artist Greg Paul for example in his 1988 book on theropod dinosaurs. Led to a profound shift in thinking on nearly all aspects of dinosaur biology, including physiology, evolution, behaviour, ecology and extinction, as well as change in depictions of dinosaurs in popular culture (e.g. ***Jurassic Park, Walking with Dinosaurs***), which have dominated all thinking about dinosaurs since. (MAK, Wikipedia).

Directionality (in evolution): as here defined, the premise that evolution begins with simple or primitive structures or forms of life and moves to greater complexity or perfection; hence some forms of life are more complex, advanced, or evolved relative to others. Whilst the emergence of complexity in the universe is a self-evident fact, philosophers and scientists are divided over whether evolution itself is directional. (MAK)

Distance: phylogenetic or evolutionary divergence. Distances are usually expressed pair-wise among terminal taxa, and can be calculated based on a specified evolutionary model; the model specifies the probabilities of character-state changes through evolutionary time. Distances are popular for building phylogenetic trees from molecular sequence data Compare with maximum likelihood, parsimony. (Introductory glossary of cladistic terms by Michael D. Crisp)

Diversity: the variation of genomes, populations, species, families, or whatever, within a lineage

DNA: Deoxyribonucleic acid, the molecule that contains genetic information.

Duck-billed dinosaur: common name for ***hadrosaurs***, a type of ornithopod dinosaur that were the most common large herbivores of the late Cretaceous northern hemisphere (in the southern hemisphere sauropods still predominated). So called because in some advanced forms such as ***Edmontosaurus*** the front of skull and jaws are wide and flattened, superficially resembling a duck's bill. Prior to the dinosaur renaissance, artists drew them like huge ducks. It is now known that in life the sides of the jaws were covered by cheeks, and looked nothing like a duck's bill. (MAK) **More**

E

Early: In the geological timescale, the chronological equivalent to Lower. Often refers to a subdivision or epoch of a period, especially when the period is divided into three; e.g. "Early Jurassic". (MAK)

Ecdysozoa: Clade of animals that grow by periodically moulting or shedding their skin or exoskeleton (timed by steroid hormone signals); share a unique pattern of HOX genes, lack cilia; have separate sexes that copulate to achieve egg fertilization. (Fossil Mall glossary)

Echinoderm: derived from the Greek terms ἐχῖνος (***ekhinos,*** "hedgehog, sea urchin") and δέρμα (***derma***, "skin"); names any member of Phylum Echinodermata; a large group of primarily pentamerally radially symmetrical exclusively marine metazoans with internal calcite skeletons and hydrostatic vascular system. Includes crinoids (sea lilies), echinoids (sea urchins, sand dollars, sea biscuits), holothurians (sea cucumbers), asteroids (starfish), ophiuroids (brittle star), and many exclusively Paleozoic groups such as blastoids, edrioasteroids, carpoids, and others. (University of Arizona Geosciences 308 Paleontology glossary, Perseus Digital Library) **More**

Echinoid: Subphylum Echinozoa, Class Echinoidea. Sea urchins and their relatives. Echinoderms with spherical or flattened bodies, often protected by long spines, like starfish they move about on tube feet. Very common as fossils, especially in the Cretaceous and Tertiary. Ordovician–Recent (rare prior to the Jurassic). (MAK)

Ecology: The study of the interactions of organisms with their environment and with each other. Wikipedia glossary

Ecosystem: A discrete unit, or community of organisms and their physical environment (living and non-living parts), that interact to form a stable system. (A Glossary of Terms Related to Basic Ecology)

Ectotherm: derived from the Greek terms ἐκτός (***ektos,*** "outside") and θέρμη (***thermē***, "heat"), colloquially intended as "cold blooded"; is an animal that regulates body temperature through external means; e.g. basking in the sun to become warmer, or sitting in the shade to become cooler. (Perseus Digital Library)

Ediacaran: most recent period of the Proterozoic era, characterised by the appearance of both enigmatic Vendobionta and trace fossils that seem to pertain to more conventional organisms. The term Ediacaran was replaced for a while by Vendian, but now it seems that Ediacaran is back in fashion. (MAK)

Ediacaran biota: enigmatic life forms from the Ediacaran period; the first large to appear. Their affinities remain highly controversial; they have been interpreted as the first representatives of current animal phyla (Cnidaria, Annelida, Arthropoda, etc), as sister group to all Metazoa more derived than sponges, as a totally distinct kingdom (Vendobionta, Vendozoa), and even as marine fungi and giant Rhizarian protists. Each hypothesis has advantages and disadvantages going for it. (MAK)

Electrophoresis: The method of distinguishing entities according to their motility in an electric field. In evolutionary biology, it has been mainly used to distinguish different forms of proteins. The electrophoretic motility of a molecule is influenced by its size and electric charge. (PBS evolution Glossary)

Embryo: An early stage of animal development that begins after division of the zygote (the earliest stage, in which joined egg and sperm have not yet divided). (PBS evolution Glossary)

Embryology: study of embryogenesis, the development of animals and plants from fertilization to birth/hatching. (Developmental Biology 376 Glossary)

Emergence: also Spontaneous order, self-organization. The appearance of novel characteristics exhibited on the level of the whole ensemble, but not by the components in isolation. (Wikipedia glossary). ***Strong emergence*** is a type of emergence in which the emergent property is irreducible to its individual constituents. See also Evolutionary directionality. (from Wikipedia)

Empiricism: understanding the natural world by means of verifiable observation via the senses and scientific instruments; an essential component of scientific method and naturalism in general.

Endotherm: derived from the Greek terms ἔνδον (***endon,*** "within") and θέρμη (***thermē***, "heat"), colloquially intended as "warm blooded"; is an animal that regulates and maintains a constant body temperature and can generate internal heat for maximal metabolic efficiency, regardless of external (environmental, ambient) temperature. (Perseus Digital Library)

Endosymbiosis: A relationship in which one organism lives inside another, to the mutual benefit of both (these are called ***endosymbionts***). Examples are nitrogen-fixing bacteria (called rhizobia) which live in root nodules on legume roots, single-celled algae inside reef-building corals, and bacterial endosymbionts that provide essential nutrients to about 10%–15% of insects. It is generally accepted that early in the evolutionary history of Eukarya, eukaryote cells engulfed bacteria, forming a symbiotic relationship, which became so mutually interdependent, that they behaved as a single organism; these include mitochondria and chloroplasts. (from Wikipedia and UCMP Understanding Evolution Glossary)

Eocene: An epoch of the early Tertiary period, spanning the time between 55.5 and 33.7 million years ago. Its name is derived from the Greek words ἠώς (***eos,*** "dawn") and καινός (***kainos***, "new"). It was a period of global greenhouse climate and lush forests, in which small to large archaic mammals, large reptiles, and giant flightless birds all flourished. (USGS Paleontology glossary, MAK, Perseus Digital Library) Moderate, cooling climate. Archaic mammals (e.g. Creodonts, Condylarths, Uintatheres, etc) flourish and continue to develop during the epoch. Appearance of several "modern" mammal families. Primitive whales diversify. First grasses. Reglaciation of Antarctica and formation of its ice cap; ***Azolla*** event triggers ice age, and the Icehouse Earth climate that would follow it to this day, from the settlement and decay of seafloor algae drawing in massive amounts of atmospheric carbon dioxide, lowering it from 3800 ppmv down to 650 ppmv. End of Laramide and Sevier Orogenies of the Rocky Mountains in North America. Orogeny of the Alps in Europe begins. Hellenic Orogeny begins in Greece and Aegean Sea. (Wikipedia) **More**

Eon: The largest division of geologic time in the geological timescale, embracing several Eras (for example, the Phanerozoic, 540 m.y. ago to present); also any span of one billion years. (Geotech.org) **More**

Epoch: A division of the geologic time shorter than a period. Epochs are further divided into several ages. Generally, the geological timescale and the history of life is described in terms of periods, but in the case of the 65 million year long Cenozoic era, epoches are used instead (Paleocene, Eocene, etc). With most earlier periods, epoches are often equivalent to the Early, Middle, and Late part of the period. (MAK)

Era: A division of the geologic time shorter than an eon, and measuring major stages in the evolution of life—e.g. Paleozoic, Mesozoic, Cenozoic. Eras are further divided into periods. (MAK)

Erosion: The transportation of material by a mobile agent, i.e., water, wind or ice. (C Simoneau, Wikiversity)

Eubacteria: the majority of extant bacteria; one of the three domains of life on Earth, prokaryotes that are metabolically and morphologically distinct from Archaea. Woese et al 1990 replaced "Eubacteria" with "Bacteria " as the taxon name; in order to avoid ambiguity we have avoided following this course. **More**

Eukarya, eukaryote: an organism whose cells contain complex structures enclosed within membranes (called organelles), and in which genetic material is contained within a nucleus, in contrast to prokaryotes. Generally reproduce through sexual rather than asexual means. Include all living organisms except bacteria **More**

Eurypterid: colloquially known as "sea scorpions", these were medium-sized to gigantic, marine to freshwater to amphibious Paleozoic chelicerates, include the largest arthropods ever to live (up to 2.5 meters long). Most common during the late Silurian and early Devonian, although also flourished in Carboniferous swamps. (MAK) **More**

Evo-Devo: the informal name for ***Evolutionary developmental biology***, a new

branch of evolutionary studies that compares the developmental processes of different organisms to determine the ancestral relationship between them, and to discover how developmental processes evolved; incorporating insights from genetics, embryology and microbiology. It addresses the origin and evolution of embryonic development; how modifications of development and developmental processes lead to the production of novel features, such as the evolution of feathers in birds and the shell in turtles; the role of developmental plasticity in evolution; how ecology impacts in development and evolutionary change; and the developmental basis of homoplasy and homology. Answers many problems regarding the origin of new structures, and early development, raised by Creationism (e.g. the evolution of feathers in reptilian ancestors), Intelligent Design, and Vitalism. (Wikipedia, PBS evolution Glossary, MAK)

Evolution: In ***Biology*** refers to change in the gene pool of a population over time. The process of evolution can be summarized in three sentences: Genes mutate. Individuals are selected. Populations evolve. (W.J. Hudson). In ***Systems Theory***, evolution is the tendency toward greater structural complexity, ecological and/or organizational simplicity, more efficient modes of operation, and greater dynamic harmony. It is not limited to the domain of biological phenomena, but extends to include all aspects of change in open dynamic systems with a throughput of information and energy. In other words, evolution relates to the formation of stars from atoms, of ***Homo sapiens*** from the anthropoid apes, and the formation of complex societies from rudimentary social systems. (Wikipedia glossary) **More on Evolutionary Theory** (biology). **More on Cosmic Evolution** (systems theory).

Evolutionary classification: see Evolutionary systematics

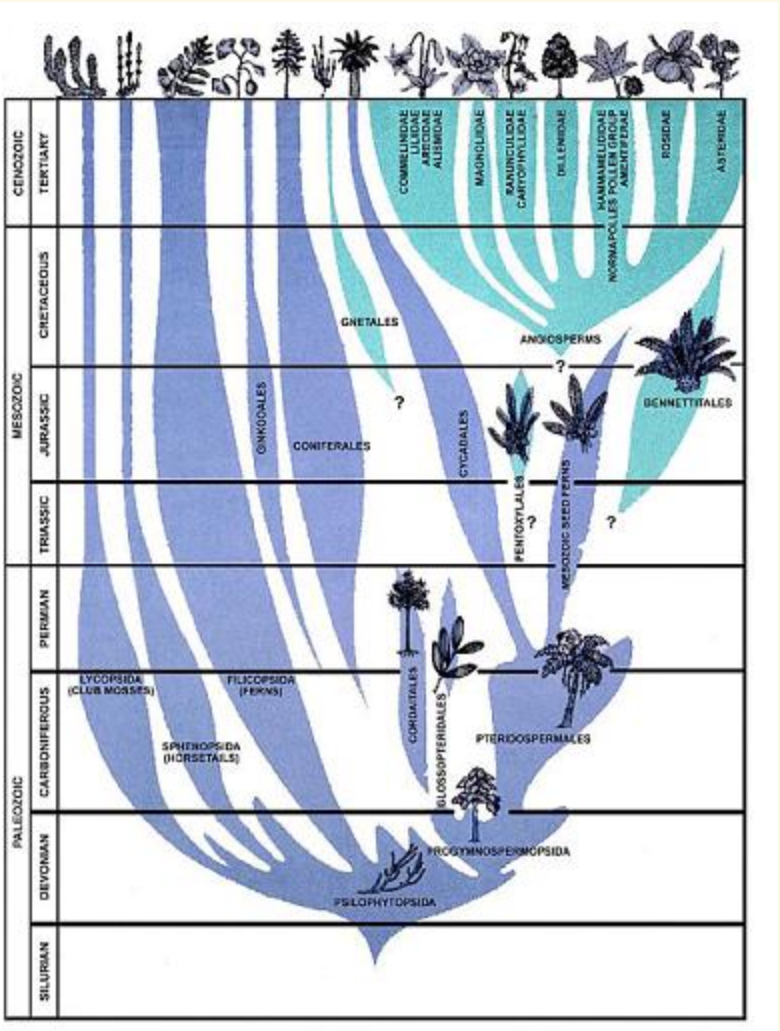
Evolutionary clock: see Molecular clock

Evolutionary creationism: See Theistic evolution

Evolutionary radiation: see Adaptive radiation

Evolutionary synthesis: see Modern Synthesis

Evolutionary systematics, evolutionary classification: evolutionary classification that integrates Linnaean classification with the Darwin-Mendel evolutionary Modern Synthesis. It classifies organisms using a combination of phylogenetic relationship and overall similarity. Emphasises fossils and life through time, and includes both higher and ancestral taxa (often represented in the form of a spindle diagram) and speciation. Linnaean rank is determined by similarity and diversity, and matches the rank of ancestral and sister taxa (hence Class reptilia give rise to classes Aves and Mammalia). Evolutionary systematics remained the standard paradigm in paleontology and evolution until the 1980s and 90s, when it was supplanted and eventually replaced by cladistics and phylogenetic nomenclature. (MAK) **More**



Evolution of Plants. Appeared in a special Scientific American issue devoted to the evolution of life (*ed. note: need to find citation*). This Evolutionary systematics spindle diagram plots

Extremophile: an organism that favours extreme conditions (relative to what is optimal to

most life on Earth), such as very high or very low temperature, or lack of oxygen. Most life in the universe would almost certainly be extremophile.

generic diversity (width) against time (vertical axis). In contrast to cladistics, the tree is rooted in ancestral groups and paraphyletic taxa. Angiosperms are related forms are shown in turquoise, gymnosperms in darker blue.

F

Family: In the Linnaean classification the taxonomic rank between order and genus, or order and tribe, used to define group of related organisms. Used in evolutionary systematics but only informerly in phylogenetics. (MAK) **More**

Feathered dinosaur: any of a large number of feathered, bird-like theropod dinosaurs that represent transitional stages between "ordinary" dinosaurs and birds. The discovery of numerous fossils of dinosaur skeletons complete with feathers, in China, and the realisation (thanks to the dinosaur renaissance) that even many other dinosaurs thought to naked and scaly actually had feathers and a bird-like physiology, provide proof that birds are descended from (in cladistic-speak, are a derived clade of) theropod dinosaurs. (MAK)

Fish: Generally, the lower vertebrates, a taxonomically meaningless assemblage of vertebrates defined only by their non-tetrapod nature.

Five Kingdoms: evolutionary classification of life developed by Robert Whittaker and Lynn Margulis, according to which organisms are divided into five kingdoms: Monera, Protist, Plants, Fungi, and Animals. **More**

Food chain: a group of organisms interrelated by the fact that each member of the group feeds upon on the one below it. Wikipedia glossary

Food web: a set of interconnected food chains by which energy and materials circulate within an ecosystem. Wikipedia glossary

Foraminifera: Amoeboid protozoans traditionally included under the subclass Sarcodina, order Foraminifera, but more recently reclassified as Rhizaria. They have a test (shell) of one to many chambers composed of secreted calcite or agglutinated particles. They have a comprehensive fossil record, and are very important in stratigraphy. (USGS Paleontology glossary)

Nummulitid foraminiferans from the Eocene near Al Ain, United Arab Emirates. Microspheric and megalospheric specimens shown. Scale in mm. Photo by Mark A. Wilson, Wikipedia.

Fossil: mineralized or otherwise preserved remains or traces (such as footprints) or impressions of animals, plants, and other organisms. (from Wikipedia glossary); Evidence of past life on earth. Can include the preserved hard and soft parts of plants and animals, tracks and burrows, whole organisms preserved intact in amber or tar, and fossilized dung. ***Any*** evidence of life constitutes a fossil. (GeoMan)

Fossil record: the history of life on Earth through geological time, as preserved through fossil remains in sedimentary rock (sometimes referred to poetically in older books as the record of the rocks). Also the fossil history of any particular group

Fossilization: All the processes that involve the burial of a plant or animal in sediment and the eventual preservation of all, part, or a trace of it. (USGS Paleontology glossary)

Fungi: Moulds and mushrooms. Not quite animals and not quite plants (though phylogenetically more closely related to the former than the latter). One of the threekingdoms of multicellular life in the Whittaker–Margulis classification scheme. **More**

G

Gametes: The specialized cells produced by organisms for sexual reproduction. In isogamous species, the gametes produced by the sexes are of equal size; in anisogamous species, the gametes are of different sizes (with the producers of smaller gametes considered as male). In most metazoan animals, gametes are produced by meiosis and are haploid. (W.J. Hudson)

Gastrulation: stage in animal development following cleavage characterized by extensive cell movement and rearrangement to form a "three-layered" embryo of ectoderm, mesoderm and endoderm. (Developmental Biology 376 Glossary)

Gauthier, Jacques: American vertebrate paleontologist, comparative morphologist, and systematist, and one of the founders of the use of cladistics in biology and paleontology. **More**

Gene: The fundamental physical and functional unit of heredity which carries information from generation to the next. (W. R. Elsberry ***in*** talk.origins ***via*** W. J. Hudson)

Gene pool: The set of all genes in a species or population. (W.J. Hudson)

Genetic algorithms: Computational systems based upon an implementation of natural selection as an algorithm for classification or optimization. (W. R. Elsberry ***in*** talk.origins)

Genetic drift: Random changes in the frequency of genes in the population that are not due to selective pressure. This may occur because the different genotypes do not have a noticeable effect on the relative fitness of individuals (such as different mitochondrial haplotypes), or selection may not be strong enough to affect transmission of the genotype (for instance, on a recently-colonised island without predators). Genetic drift is a factor in neutral evolution. The significance of genetic drift in evolution is uncertain. In a large population, most of the factors affected by genetic drift will be minor, and drift is probably not significant over the population as a whole. However, in a small, isolated population drift may have a significant effect on the makeup of the population. (CKT061201)

Genetics: The branch of science which deals with elucidating the attributes and mechanisms of heredity in living systems. On Earth, this involves research into RNA and DNA. (W. R. Elsberry ***in*** talk.origins)

Genome: complete haploid complement of DNA (including all genes) from the chromosomes of the nucleus of an organism. (Developmental Biology 376 Glossary)

Genus: In the Linnaean classification the taxonomic rank between family or tribe and species, and used to define group of closely related organisms that differ in only very minor ways. In the Linnaean system of binomial nomenclature, the genus is written in italics, with a capital letter, in front of the species name, or on its own. e.g. with ***Tyrannosaurus rex***, the name ***Tyrannosaurus*** is the genus, and ***T. rex*** (no hyphen!) is the species. Used in evolutionary systematics; in cladistic classification every genus is only allowed two species (because of excessive formalism regarding cladogenesis), and Linnaean genera are always oversplit and new names created, resulting in much taxonomic confusion (for example in paleontology the established dinosaur genus ***Iguanodon*** has been split into about a dozen different monospecific genera (link). See also the discussion at Sauropod Vertebra Picture of the Week. It may be that the Phylocode will discard binomial nomenclature altogether (although there is obvious resistance to this) . (MAK) **More**

Geochemistry: The science that deals with chemical changes in and composition of the earth's crust. (USGS Paleontology glossary)

Geologic(al) timescale: Standardised system of chronological measurement and dating, first developed during the early 19th century and revised ever since, which relates stratigraphy to time. It is used by geologists, paleontologists and other scientists to describe the timing of events that occurred during the history of the Earth, for example the age of particular rock strata, mountain building, or evolutionary radiation. The entire geological timescale consists of four eons, each divided into a number of eras. Each era is in turn divided into periods. Periods are further divided into epochs, which in turn are divided into ages. The regulatory scientific body that deals with this subject, the International Commission on Stratigraphy, uses an arbitrary colour code which nevertheless allows us to make **Palaeos** very colourful. The basic geological table is shown below; in keeping with stratigraphic and geological formalism, the oldest eras are at the bottom, the youngest at the top.

Eon	Era	Period	begin–end (Mya)
	Cenozoic Era: CZ	**Neogene N**	**23.0–**
		Paleogene E	**65.5–23.0**
		Cretaceous K	**146–65.5**

Phanerozoic Eon: PH	Mesozoic Era: MZ	Jurassic J	200–146
		Triassic T	251–200
	Paleozoic Era: PZ	Permian P	299–251
		Carboniferous C	359–299
		Devonian D	416–359
		Silurian S	444–416
		Ordovician O	488–444
		Cambrian Є	542–488
Proterozoic PR			2500–542
Archean AR			3800–2500
Hadean* HA			3850–4500
Chaotian* CH			–4500

Geology: The science that deals with the study of the planet Earth—the materials of which it is made, the processes that act to change these materials from one form to another, and the history recorded by these materials; the forces acting to deform the outer layers of the Earth and create ocean basins and continents; the processes that modify the Earth's surface; the application of geologic knowledge to the search for useful materials and the understanding of the relationship of geologic processes to people. (S.M. Richardson). Physical Geology includes processes that affect the earth's internal and external structure, composition and other natural functions. Historical Geology is the study of Earth history and the evolution of life on earth, especially the past life forms that are preserved as fossils. (J. Wittstrom, Wikiversity)

Ghost lineage: in cladistics, a phylogenetic lineage that is inferred to exist, for example by matching a cladogram against geological time, but is not known from the fossil record. **Links:** UCMP, Evowiki, Dave Hone's Archosaur Musings. (MAK)

Glaciation: The formation, advance and retreat of glaciers and the results of these activities. (S.M. Richardson)

Gondwana: The southern land mass derived from the supercontinent of Pangea, which continued until its break-up during the Cretaceous and early Tertiary. It comprised of Antarctica, Africa, South America, Australia and India. The term is also used to describe these same continents when connected as a supercontinent in the Paleozoic, prior to Pangea. Gondwana means "Land of the Gonds" (a tribe from the Indian subcontinent). Note, the popular term Gondwana***land*** is therefore redundant. **More**

Gorgonopsid (**gorgon** for short): a type of medium to large carnivorous therapsid common during the late Permian period, characterised by very large canine teeth (convergent with sabre tooth cats). **More**

Gould, Stephen Jay (1941–2002): American paleontologist, evolutionary biologist, historian of science, and popular science writer who spent most of his career at Harvard University. With Niles Eldredge he formulated the theory of punctuated equilibrium in 1972. Gould was very critical of the idea of evolutionary ascent, arguing that this is a misinterpretation of Darwinism. In ***Wonderful Life*** (a study of the Burgess Shale) he argued that the Cambrian explosion involved a large number of organisms totally unrelated to extant phyla, and hence that evolution does not have any direction, and that the rise of intelligence on Earth was purely accidental. Some of his paleontological interpretations here have since been refuted, as taxa such as ***Hallucigenia*** have been slotted in or related to current phyla. **More**

Grade: As here defined, an evolutionary or developmental grade or stage at a particular time, a horizontal taxon, consisting of transitional forms between two other taxa. Not allowed in cladistics (as they would be considered paraphyletic) . (MAK). In alpha taxonomy, a grade refers to a taxon united by a level of morphological and/or physiological complexity. The term was coined by British biologist Julian Huxley, to contrast with clade, a strictly phylogenetic unit. (Wikipedia)

Gradualism or **phyletic gradualism**: evolutionary mechanism theory, based on the premise that evolutionary change takes place through the gradual change of populations and not by the sudden

(saltational) production of new individuals that represent a new type. This view is wrongly attributed to Darwin by Eldredge and Gould, who favoured Punctuated Equilibria. Richard Dawkins explained that gradualism is not present in the professional literature, and only serves as a straw-man for punctuated equilibrium advocates.

Graptolite: derived from the Greek terms γραπτός (***graptos,*** "written") and λίθος (***lithos***, "stone"); are mostly planktonic, Paleozoic, colonial hemichordates with a chitinous skeleton (periderm), commonly preserved as carbon films in black shales, common during the Ordovician, Silurian, and early Devonian, important as index fossils 240 genera are known. (MAK, University of Arizona Geosciences 308 Paleontology glossary, Perseus Digital Library, Memidex)

Great chain of being: term coined by historian of ideas Arthur O. Lovejoy for the historical idea that all beings constitute a continuous series of forms an unbroken gradation from the Absolute (later, God) down through intermediate spiritual and material stages to formless matter. The premise was developed by Greek philosophers such as Plato (transcendent ideas), Aristotle (***scala naturae***), and Plotinus. In the Middle Ages it was the basis for both scholastic theology (ranking all of creation from dirt through to humans to angels) and feudal social stratification; it formed a central element in the Elizabethan understanding of the world still evident in Shakespeare's plays. It continued through 17th, 18th and 19th century Europe and North America, in an understanding of the universe as the highest good, complete and full (Lovejoy refers to this belief as "the Principle of Plenitude") in which every species of being has its perfect place and no species can ever become extinct (to do so would result in a gap in God's creation), and understanding this harmonious linear order of nature as a product of God's benign creative activity was a meaningful pursuit. From the end of the 18th century, with the "temporalization of the great chain of being" the meme persisted in evolutionary form (now as ascent rather than descent) through 19th century German Idealism and Naturphilosophie. Despite the rise of Darwinian evolution and a branching tree of life, the idea of a single line of ascent continued through mid 19th to early 20th century ideas of sociological evolution and social darwinism, and early to mid 20th century psychology and the meme is still strongly held (see for example March of Progress. (MAK) **More**

Guild: Group of organisms having a similar morphology, and exploiting the same food resources, living the same life-style and in the same environment, but which are not necessary related. Because no two types of organisms can occupy the same ecological niche (one will inevitably outcompete the other, and push it aside), comparable guilds have to be separated by geographical or chronological distance. A good example of the same guild is the modern crocodile and the phytosaurian thecodont (Parasuchia) of the late Triassic. Both are astonishingly similar in size, appearance, and life-style, and indeed modern crocodiles only appeared after the phytosaurs had become extinct. But they are only distantly related (both are archosaurian reptiles, but their common ancestor lived millions of years before the first phytosaur appeared). (MAK)

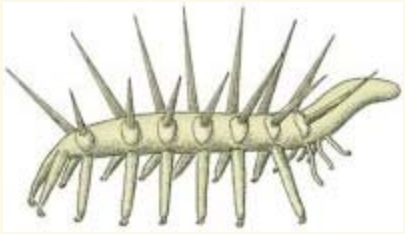
Gymnosperm: derived from the Greek terms γυμνός (***gumnos,*** "naked") and σπέρμα (***sperma***, "seed") due the unenclosed condition of their seeds (called ovules in their unfertilized state). Their naked condition stands in contrast to the seeds or ovules of flowering plants (angiosperms) which are enclosed during pollination. Includes conifers, cycads, Ginkgo, Gnetales, and extinct groups such as "seed ferns". (Wikipedia, Perseus Digital Library)

H

Habitat: The environment, including physical and biotic conditions, where a plant or an animal usually occurs, physical conditions that surround a species or population

Hadean: First of the four eons of the geological timescale, the earliest subdivision of the Precambrian, spanning the time between the formation of the Earth, about 4.5 billion years ago, and the start of the Archaean era, 3.8 billion years ago. This interval predates the period of true geologic time since no rocks of this age are known on Earth, with the exception of a few meteorites. . Except possibly for the very end of the Hadean, conditions were too harsh to support life (hence the name, after the underworld of Greek mythology). (USGS Paleontology glossary, MAK) **More**.

Hallucigenia: A Cambrian lobopod (proto-arthropod) known from the Burgess Shale, and related to the modern ***Peripatus***. When fossils were first discovered they were reconstructed upside down, resulting in a truly bizarre creature (hence the name). It was later shown that the stilt like "legs" were



actually protective spines, and the row of "mouths" or feeding tubes along the back were in fact legs. (MAK) **More**.

Haploid: having only half the normal complement of chromosomes. (W.J. Hudson)

Haeckel, Ernst (1834–1919): eminent German zoologist, naturalist, philosopher, physician, professor of comparative anatomy and artist who discovered, described and named thousands of new species, mapped a genealogical tree relating all life forms, and coined many terms in biology, including anthropogeny, ecology, phylum, phylogeny, and the kingdom Protista. His chief interests lay in evolution and life development processes in general, including development of nonrandom form. **More**

Hauterivian: geologic age of the Early Cretaceous, spanning the time between 122 and 118 million years ago. (USGS Paleontology glossary)

Heredity: the passing of traits to offspring (from its parent or ancestors). Through heredity, variations exhibited by individuals can accumulate and cause some species to evolve. **More**

Hiatus: A gap or interruption in the continuity of the geologic record either because the record was never formed or because it was destroyed by erosion. It represents the time interval spanned by an unconformity. (S.M. Richardson)

Higher: In biology, an informal, "great chain of being" like term for more developed representatives of a particular taxon or lineage, e.g. "the higher primates". Terms like "ascent", "lower" and "higher", and "primitive" and "advanced" are discouraged by phylogeneticists because they impose subjective value judgments on the natural world. (MAK)

Holism: A non-reductionist descriptive and investigative strategy for generating explanatory principles of whole systems. Attention is focused on the emergent properties of the whole rather than on the reductionist behavior of the isolated parts. The approach typically involves and generates empathetic, experiential, and intuitive understanding, not merely analytic understanding, since by the definition of the approach, these forms are not truly separable. (Wikipedia glossary)

Holocene: An epoch of the Quaternary period, spanning the time from the end of the Pleistocene (10,000 years ago) to the present. The most recent period of geologic history, which extends from 10,000 years ago to the present. It is named after the Greek words ὅλος (***holos***, "entire") and καινός (***kainos***, "new"). See also Anthropocene. (MAK, USGS Paleontology glossary, Perseus Digital Library) The last glacial period ends; rise of human civilization. Quaternary Ice Age recedes, and the current interglacial begins. Younger Dryas cold spell occurs, Sahara forms from savannah, and agriculture begins, allowing humans to build cities. Paleolithic/Neolithic (Stone Age) cultures begin around 10000 BC, giving way to Copper Age (3500 BC) and Bronze Age (2500 BC). Cultures continue to grow in complexity and technical advancement through the Iron Age (1200 BC), giving rise to many pre-historic cultures throughout the world, eventually leading into Classical Antiquity, such as the Roman Empire and even to the Middle Ages and present day. Little Ice Age (stadial) causes brief cooling in Northern Hemisphere from 1400 to 1850. Also refer to the List of archaeological periods for clarification on early cultures and ages. Mount Tambora erupts in 1815, causing the Year Without a Summer (1816) in Europe and North America from a volcanic winter. Following the Industrial Revolution, Atmospheric CO2 levels rise from around 280 parts per million volume (ppmv) to the current level of 390 ppmv, due to anthropogenic emissions, very likely causing global warming and climate change. (Wikipedia) **More**

Homeobox genes: "Homeobox genes" are genes that contain "homeoboxes" (relatively short sequences of DNA which play a central role in controlling body development), and can regulate the expression of other genes. There are at least 24 homeobox genes, some but not all of which are also homeotic in their effect. In general, "homeotic" genes are genes that control the identity of body parts. They are active in the early stages of embryonic development of organisms. Some, but not all, homeotic genes are homeobox genes. "Hox" genes are a subgroup of homeotic homeobox genes that determine positional cell differentiation and development. They lay out the head to tail body pattern in very early embryos. The Hox genes are very ancient and widely shared among bilateral animals. After the head to tail pattern is

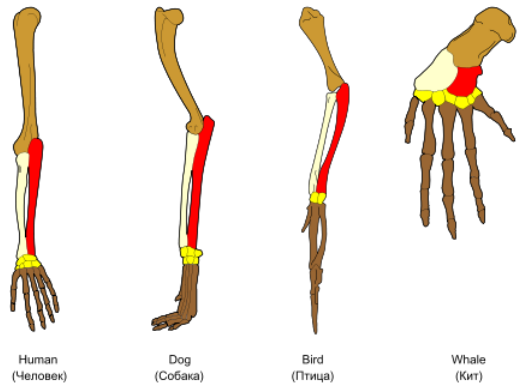
established, homeotic genes direct the developmental fates of particular groups of cells. (PBS evolution Glossary)

Homeostasis: the property by which a system, especially a living organism, regulates its internal environment so as to maintain a stable, constant condition. According to James Lovelock, the planet Earth as a whole is homeostatic system (Gaia Hypothesis). (MAK, Wikipedia glossary)

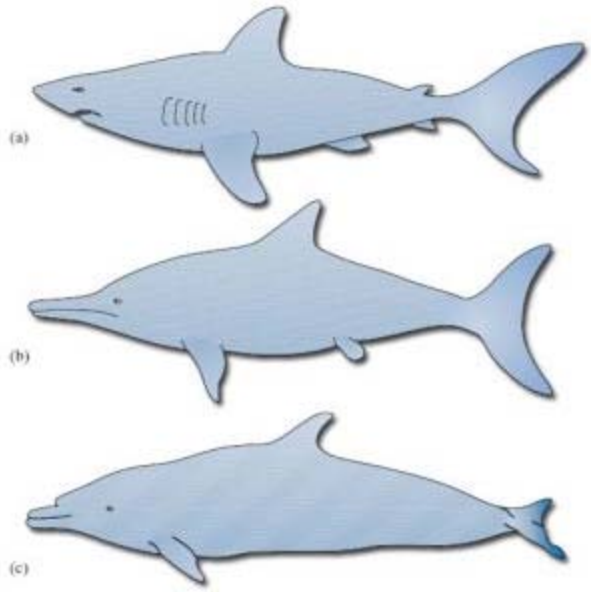
Hominid: family Hominidae; in evolutionary systematics, refers to early humans (genus ***Homo***) and their Australopithecine ancestors, as opposed to the great apes. In molecular phylogeny-based phylogenetic nomenclature the subtribe ***Hominina*** is used instead, reflecting the topology of the anthropoid primate tree. (MAK)

Homology / homologous structure: a character shared by a set of species and present in inherited, with or without modification, from their common ancestor. For example, the bones in a bat's wing, a dog's front leg, and a human arm, are the same, although modified to serve different functions (see following diagram). Contrast with homoplasious.

Homoplasy: Features that are similar but have an independent (or ***convergent***) evolutionary origin, the opposite of homology; for example the streamlined shape and dorsal fin of a shark, ichthyosaur, and dolphin (ichthyosaurs and dolphins descended from land animals), or the wing of a pterosaur, bird, and bat (each evolved from distinct flightless ancestors).



The principle of homology: the common derivation (shown by colors) of the various bones in the forelimbs of a human, dog, bird, and whale. All four descended from a common ancestor (a basal amniote) who likewise had that particular type of forelimb. (From Wikipedia under Creative Commons/Public Domain.



The streamlined bodies of (a) a shark, (b) an ichthyosaur and (c) a dolphin, an example of homoplasy. Despite the superficial similarity, each descended from very different ancestors; the shark from an earlier fish-like form, the ichthyosaur from a diapsid reptile of lizard-like appearance, and the dolphin from a somewhat dog like ungulate. Diagram from Open University: Studying mammals: Return to the water under Creative Commons Attribution License.

Hopeful monster: termed coined by the German-born geneticist Richard Goldschmidt, who thought that small gradual changes could not bridge the divide between microevolution and macroevolution. In ***The Material Basis of Evolution*** (1940), Goldschmidt wrote "the change from species to species is not a change involving more and more additional atomistic changes, but a complete change of the primary pattern or reaction system into a new one, which afterwards may again produce intraspecific variation by micromutation." His thesis however was universally rejected and has been widely ridiculed within the biological community, which favored the neo-Darwinian explanations of R.A. Fisher, J. B. S. Haldane and Sewall Wright. (Wikipedia) **More**

Host: organism that serves as a habitat for another organism. A host may provide nutrition for a parasite, alternatively with mutualism the host benefits. (from UCMP Understanding Evolution Glossary)

Hox genes: A particular subgroup of homeobox genes that function to pattern the axis of an organism's body and determine where limbs and other body segments will grow as the embryo develops. (PBS evolution Glossary)

Human: big-brained erect hairless primate, the dominant form of life on Earth during the Holocene/Anthropocene epoch. Can refer either to ***Homo sapiens*** (anatomically modern man), genus ***Homo***, or hominids (***sensu*** evolutionary classification; = Hominina ***sensu*** phylogenetic classification) in general. (MAK)

Hybrid: an offspring resulting from cross-breeding between two different species. **More**

Hydrogeology: The science that deals with subsurface waters and geologic aspects of surface waters. (USGS Paleontology glossary)

Hypothetical common ancestor: it is necessary to distinguish between cladistics and evolutionary systematics, as the two tend to confused in a sort of mishmash in the popular imagination and some Wikipedia diagrams. In contrast to the evolution trees (spindle diagrams, dendrograms, and so on) that evolutionary taxonomists use, cladograms are not intended to portray ***actual*** phylogeny. i.e. a cladogram does not have a time axis, and it does not portray ancestors, but only hypotheses of branching patterns, that is, sister relationships between terminal taxa and other nodes. This means that the internal nodes that lie at the base of each nested clade do not represent an actual species which can be described in terms of traits and characters, but rather a hypothetical and abstract representation of the common ancestor of that particular clade. (MAK)

Ice Age: period of earth history subject to lowered temperatures and high and medium latitude glaciation. There have been a number of ice ages in the Earth's history, of which the Pleistocene ice age was only the most recent. See also snowball earth. (MAK)

Ichnology: branch of paleontology that deals with traces of organismal behavior, such as burrows and footprints. (Wikipedia).

Ichnotaxon: defined by the International Code of Zoological Nomenclature as "a taxon based on the fossilized work of an organism". Ichnotaxa are names used to identify and distinguish morphologically distinctive ichnofossils, more commonly known as trace fossils. They are assigned genus and species ranks by ichnologists, much like organisms in Linnaean taxonomy. These are known as ***ichnogenera*** and ***ichnospecies***, respectively. Ichnotaxa include trace fossils such as burrows, borings and etchings, tracks and trackways, coprolites, gastroliths, regurgitaliths, nests, leaf mines, bite and gnaw structures, secretions modified by organismal activity, such as cocoons, pupal cases, spider webs, embedment structures and plant galls. (Wikipedia).

Dinosaur footprints, preserved at Dinosaur Ridge, Morrison Formation (late Jurassic), Colorado

Ichthyosaur: group of mesozoic marine reptiles (Order Ichthyosauria / Ichthyopterygia) characterised by superficially dolphin-like appearance. The largest (***Shonisaurus***) grew to the size of whales. **More**

Index fossil: A fossil species that identifies and dates the strata in which it is typically found. To be most useful, an index fossil must have broad, even worldwide distribution and must be restricted to a narrow stratigraphic range. (S.M. Richardson)

Individual evolution: Common cultural, spiritual, and New Age belief that evolution occurs on an individual level. Also used by Creationists to attack evolutionary science (presumably as an example of the arrogance of man in thinking he can get to higher state without God's help). In fact evolutionary science

does not recognise individual evolution, but instead only refers to the evolution of populations via selection of randomly occurring mutations. (MAK)

Inheritance of acquired characteristics: theory proposed by Jean Baptiste Lamarck, according to whom evolution occurs through the inheritance of traits or abilities an organism acquires in life. For example, the ancestral giraffe stretched its neck to reach the leaves of trees, and as a result passed on a slightly longer neck and legs to its offspring. Also referred to as the "use–disuse theory." Despited being rejected by Weismannian Neo-Darwinism, Lamarckism remained popular well into the early twentieth century, especially in France, but was supplanted by the synthesis of Darwinian and Mendelian theory.

Intelligence: difficult to define quality associated with developed consciousness. Considered to include the abilities for abstract thought, understanding, communication, reasoning, learning, planning, emotional intelligence and problem solving. Intelligence is most widely studied in humans, but has also been observed in animals and plants. Artificial intelligence is the intelligence of machines or the simulation of intelligence in machines. (Wikipedia)

Intelligent design: is the proposition that "certain features of the universe and of living things are best explained by an intelligent cause, not an undirected process such as natural selection." Usually a form of creationism restated in non-religious terms, retaining the idea of deity while seeking to embrace scientific method, although there are also non-religious versions of intelligent design, such as the "ancient astronaut" and panspermia memes.

International Code of Zoological Nomenclature: widely accepted convention in zoology that rules the formal scientific naming of organisms treated as animals. The rules principally regulate:

1. how names are correctly established in the frame of binomial nomenclature,
2. which name has to be used in case of conflicts among various names,
3. how names are to be cited in the scientific literature.

The rules and recommendations have one fundamental aim: to provide the maximum universality and continuity in the scientific naming of animals. The code is published by the ***International Commission on Zoological Nomenclature*** (ICZN), an organization dedicated to "achieving stability and sense in the scientific naming of animals". The rules in the Code determine what names are valid for any taxon in the family group, genus group, and species group. It has additional (but more limited) provisions on names in higher ranks. Several cladists have argued that the Linnaean-based ICZN code needs to be replaced by a new cladistically-based system, the Phylocode. (Wikipedia)

Interspecific relations: interactions between different species. **More**

Intraspecific relations: relations which are established between individuals of the same species, forming a population.

Invertebrate: all metazoa except for higher chordates. That this outmoded classification is retained is because paleontology, biology, and popular understanding still refers to animal life in terms of vertebrate and invertebrate. Mostly small, they are often overlooked in favour of their backboned brethren, although a microscope or even a hand lens will reveal creatures as astonishing as those that one might imagine would inhabit an alien world. Marine forms with hard parts have a very good fossil record, and help us understand the history of phanerozoic biodiversity, as well as the dynamics of macroevolution and phylogeny in general. **More**

Island arc: A curved chain of islands that rise from the sea floor, usually near a continent. The convex side usually faces the open ocean, while the concave side usually faces the continent, e.g., the Aleutian Islands in Alaska; volcanic arc (UCMP); chain of volcanic islands or mountains formed by plate tectonics as an oceanic tectonic plate subducts under another tectonic plate and produces magma. (Wikipedia glossary)

Isochron dating: A self-checking method of dating used with several radioisotopes. This mechanism compares ratios of radioactive isotopes to their decay products. (W. R. Elsberry ***in*** talk.origins ***via*** W. J. Hudson)

Isotopic dating: Radiometric dating; all methods of age determination based on nuclear decay of naturally occurring radioactive isotopes. Age in years for geologic materials are calculated by measuring the presence of a short-life radioactive element, e.g. carbon-14, or by measuring the presence of a long-life radioactive element plus its decay product, e.g. potassium-40/argon-40. (USGS Paleontology glossary)

J

Junior synonym: a new name for a species, supra-specific taxon, or clade which already has a scientific name. Junior synonyms are redundant and hence usually rejected in scientific nomenclature; the exception being when the more recent name is so well known that to change it would cause confusion. For example, the first named fossil which can be attributed to ***Tyrannosaurus rex*** consists of two partial vertebrae found by Edward Drinker Cope in 1892 and named ***Manospondylus gigas***. It was only later realised that they belong to the same animal. In this case, the newer name, ***Tyrannosaurus rex*** (named by Henry Fairfield Osborn in 1905) was retained, and the older one ***Manospondylus gigas***, rejected. (MAK, Wikipedia)

Jurassic: The middle period of the Mesozoic era, spanning the time between 213 and 145 million years ago. It is named after the Jura Mountains between France and Switzerland, where rocks of this age were first studied. (USGS Paleontology glossary). The classic age of dinosaurs, featuring such familiar types as sauropods, ***Allosaurus***, and ***Stegosaurus***. Their counterparts in the sea were the ichthyosaurs and plesiosaurs. Regarding smaller animals, mammals were common, and the first birds (***Archaeopteryx***) and lizards evolved. Bivalves, Ammonites and belemnites abundant. Sea urchins very common, along with crinoids, starfish, sponges, and terebratulid and rhynchonellid brachiopod. Gymnosperms (especially conifers, Bennettitales and cycads) and ferns common. Breakup of Pangaea into Gondwana and Laurasia. Nevadan orogeny in North America. Rantigata and Cimmerian Orogenies taper off. Atmospheric CO2 levels 4–5 times the present day levels (1200–1500 ppmv, compared to today's 385 ppmv). (Wikipedia) **More**

Jurassic Park: 1990 science fiction thriller novel by Michael Crichton, which became the basis for a very successful Steven Spielberg 1993 movie of the same name, and eventually an entire franchise of books, films and video games centered on a fictional theme park full of cloned and revived dinosaurs. Crichton either imitated, or independently arrived at a very similar premise, to John Brosnan's ***Carnosaur***, a 1984 horror novel about theropod dinosaurs running amok. The science of ***Jurassic Park*** was actually based on a very plausible hypothesis of the time—that dinosaurs could be cloned from their DNA in the stomachs of gnats and mosquitos embedded in amber, although it was discovered that DNA quickly degrades in amber so the hard science premise is nonviable (there are also inaccuracies regarding the way the dinosaurs are described). The story not unexpectedly centered on theropod dinosaurs, especially overgrown velociraptors, as scary monsters chasing the protagonists around the theme park, turning door knobs and opening doors. Nevertheless, the movie served to help popularise dinosaurs among the general public. Incorporated now refuted ideas from Bob Bakker's dinosaur renaissance, such as a 60 kph ***Tyrannosaurus***. (MAK)

K

K-selection, K-selected species: species that produce fewer but stronger offspring and dedicate more care to their upbringing. K-selected species are better suited for, and better able to compete with strong competitors in a crowded environment. (Wikipedia glossary)

Keystone species: keystone species is a species that has a disproportionate effect on its environment relative to its abundance. Such species affect many other organisms in an ecosystem and help to determine the types and numbers of various others species in a community. (Wikipedia glossary)

Kingdom: In the Linnaean classification the highest taxonomic rank. Traditionally only included plants and animals; Whittaker–Margulis classification scheme adds three more kingdoms, and other researchers such as Thomas Cavalier-Smith have added additional kingdoms.

Knight, Charles R. (1874–1953): American artist best known for his highly influential paintings of dinosaurs and other prehistoric animals. His works have been reproduced in many books and are currently on display at several major museums in the United States. Examples of his work frequently appeared in dinosaur and paleontology books published in the US during the first half of the twentieth century. While some of his works depicted the dinosaurs as slow and sluggish, such as the iconic ***Brontosaurus*** grazing in a swamp, others, such as the ***Laelaps*** featured here prefigure the later dinosaur renaissance (although perhaps going to the opposite extreme, as Bakker's and Paul's fully endothermic dinosaurs

also do). Knight was most active during the 1890s–1940s, and his work exerted a strong influence on popular culture, including both toys and movies such as the stop motion dinosaurs in Harry Hoyt's ***The Lost World*** (1925) and Ray Harryhausen's magnificent special effects (***One Million Years B.C***. (1966), ***The Valley of Gwangi*** (1969)). (MAK, Wikipedia)

Konservat-Lagerstätten: see Lagerstätten.

L

Labyrinthodont: Small to very large, primitive Paleozoic to Mesozoic amphibians defined by the complex maze-like infolding of their enamel, a feature inhereted from their lobe-finned fish ancestors. As with thecodont, this term is disliked by cladists because it does not constitute a natural clade.

Lagerstätten (more correctly called **Konservat-Lagerstätten**): a term coined by German paleontologists for exceptionally preserved fossil assemblages. Most contain direct evidence of soft part morphology. Examples include Mazon Creek (concretions, Carboniferous, Illinois), Solnhofen Limestone (extremely fine grained (lithographic) limestone, Jurassic, Germany), La Brea (tar pits, Pleistocene, California), Burgess Shale (carbonization, Cambrian, Canada). (University of Arizona Geosciences 308 Paleontology glossary)

Late: In the geological timescale, the chronological equivalent to Upper. Often refers to a subdivision or epoch of a period, especially when the period is divided into three; e.g. "Late Jurassic". (MAK)

Laurasia: the Mesozoic northern supercontinent that was derived from Pangea. It comprised of North America, Eurasia (exclusive of India) and Greenland. Most of the famous Cretaceous dinosaurs are from Laurasia; Laurasia's sister continent Gondwana being inhabited by different types of animals. (Bristol University: Palaeobiology and Biodiversity Research Group: Late Cretaceous Climate Change: Glossary; MAK) **More**

Lazarus taxon: a taxon that disappears from one or more periods of the fossil record, only to appear again later. **More**

Life: characteristic that distinguishes objects that have signaling and self-sustaining processes (i. e., living organisms, but could also apply to virtual life, artificial or machine life, etc) from those that do not. Living organisms undergo metabolism, maintain homeostasis, possess a capacity to grow, respond to stimuli, reproduce and, through natural selection, adapt to their environment in successive generations. There is no reason why life should only be limited to Earth; it is certain that suitable planets elsewhere in the universe would also contain evolving life. The totality of life on Earth (or any planet or self-contained ecosystem, e.g. a future base on Mars) at any moment is called the biosphere. (MAK, Wikipedia). **More**

Limestone: the most abundant of the non-clastic sedimentary rocks that is produced from the mineral calcite (calcium carbonate) and sediment. The main source of limestone is the limy ooze formed in the ocean. The calcium carbonate can be precipitated from ocean water or it can be formed from sea creatures that secrete lime such as algae and coral. (Fossil Mall)

Lineage: in this context, an evolutionary lineage, a sequence of ancestors and descendants (which may be cells, genes, populations, species) that evolve through time.

Linnaean classification: hierarchical taxonomy developed by the 18th century Swedish botanist Carl von Linné, (Linnaeus). It was the first systematic classification of life on Earth, in which every species is given it's own binomial designation. So for example anatomically modern human beings are ***Homo sapiens***, genus (the "family name") ***Homo*** and species (the specific name) ***sapiens***. In contrast, Neanderthal man is ***Homo neanderthalensis***. Linnaean classification provides a nested hierarchy of levels, each with its own specific characteristics. In this way any organism or species is grouped more and more specifically within the hierarchy. The Linnaean system was originally static, being based on creationism. In the 19th century, applied to the evolution of life and the modern synthesis it became evolutionary systematics, and was used to construct phylogenetic trees. Still foundational to modern biology, Linnaean classification is in the process of being superseded by cladistic systematics. Unfortunately, this latter, with its indefinite series of nested clades, lacks the categorical simplicity and ease of use of the old Linnaean system. **More**

Lissamphibia: refers to the amphibian crown group clade, that is, all living amphibians (frogs, newts, salamanders, etc) and their shared ancestors, as opposed to diverse earlier forms. Lissamphibia first

appeared during the Triassic, and have been an important part of the terrestrial ecosystem from the Late Jurassic till now. (MAK)

Lithologic unit or **Lithostratigraphic unit**: a body of rock that is consistently dominated by a certain lithology or similar color, mineralogical composition, and grain size. It may be igneous, sedimentary, or metamorphic and may or may not be consolidated. (USGS Paleontology glossary)

Lithosphere: located above the asthenosphere, the lithosphere consists of the outer layer of earth's crust and upper mantle. The lithosphere also contains the Moho boundary. (H. Redoble, Wikiversity)

Living fossil: informal term for any living species (or genus or clade) of organism which appears to be the same as a species otherwise only known from fossils and which has no close living relatives. Examples include the brachiopod ***Lingula*** and the coelacanth.

Lobe-finned fish: subclass Sarcopterygii, includes lung fish, coelocanths, and their ancient ancestors and relatives. Common and diverse in the Paleozoic (especially the Devonian and Carboniferous) and Mesozoic. Instead of a normal fin, the lobe fins have a fleshy base, hence the name. These fins evolved into the limbs of amphibians, and the same bones that make up tetrapod limbs, including our own, can be recognised in these Paleozoic fossil fish. **More**

Long branch attraction (LBA): A phenomenon in cladistic and especially molecular phylogenetic analyses, in which unrelated species or lineages which may be highly derived or share rapid evolutionary rates are grouped together and hence considered closely related, regardless of their true evolutionary relationships. **More**

Lower: In geology, refers to lower, older strata. In the geological timescale, refers to the older rocks of a period, especially when the period is divided into three; e.g. "Lower Jurassic". Apart from specific geological contexts, this usage is now generally replaced by the more chronological descriptive term Early. In biology, an informal, "ladder of nature" like term for more primitive representatives of a particular taxon, e.g. "the lower vertebrates"; contrast with "higher". (MAK)

LUCA (Last Universal Common Ancestor), also **Universal Common Ancestor**: The postulated most recent common ancestor of every living thing on Earth; the root of the tree of life. According to Carl Woese, horizontal gene transfer between the three domains early in the history of life makes the idea of a single common ancestor meaningless. **More**

Lyell, Charles: A 19th-century scientist, principal architect of uniformitarianism and a founding father of modern geology, helping to transform the discipline into an empirical, testable science. **More**

M

Maastrichtian: geologic age of the Latest Cretaceous, spanning the time between 72 and 66 million years ago. The time of the last but also some of the greatest dinosaurs, such as ***Tyrannosaurus*** and ***Triceratops*** (whose battles are immortalised in the artwork of Charles R. Knight). Flowering plants, and some marine reptiles like mosasaurs, flourish. (USGS Paleontology glossary, MAK)

Macroevolution: Evolution at or above the species level. The boundary between macro- and micro- is fuzzy, as some researchers prefer to include speciation in micro- and others reason that the only macro-process that gives distinctive events is speciation. Speciation events are thus, to many scientists, examples of macroevolution. Another definition is evolution too imperceptible to be observed within the lifetime of one researcher. Link: Macroevolution Its Definition, Philosophy and History by John Wilkins. (W. R. Elsberry ***in*** talk.origins ***via*** W. J. Hudson)

Macrofossil: A fossil that is large enough to be studied without a microscope. (USGS Paleontology glossary)

Mammal: A class (and monophyletic clade) of of intelligent (big-brained), warm-blooded vertebrates that give birth to and suckle live young. Also distinguished by possession of hair, three middle ear bones, a single dentary (lower jaw bone), sweat glands and several different types of teeth. Late Triassic to Recent. Dominant land animals of the Cenozoic era (which is not surprisingly therefore called the Age of Mammals). **More**

Mammal-like reptile: in evolutionary taxonomy, Subclass Synapsida, Class Reptilia. consisting of the orders Pelycosauria and Therapsida, which dominated terrestrial ecosystems from the early Permian through to the late Triassic. Form a gradation of transitional forms ancestral and leading to the mammals. One of the classic instances where the fossil record shows the detailed stages in the transformation from one major taxon to another (good for refuting creationist claims). The cladistic paradigm shift means that the term "Mammal-like reptile" can not be used because it is a paraphyletic group. But since I consider evolutionary and phylogenetic systematics to be complementary rather than contradictory, I am not buying into this argument, and so will use paraphyletic terms when appropriate. (MAK)

Graphic (right), skull of *Cynognathus*, an Early Triassic mammal-like reptile (Therapsida: Cynodontia), combining reptile and mammal features. Karoo of South Africa. Wikipedia, photo by Ghedoghedo

Mammoth: large to gigantic prehistoric proboscidean, abundant during the Pleistocene.

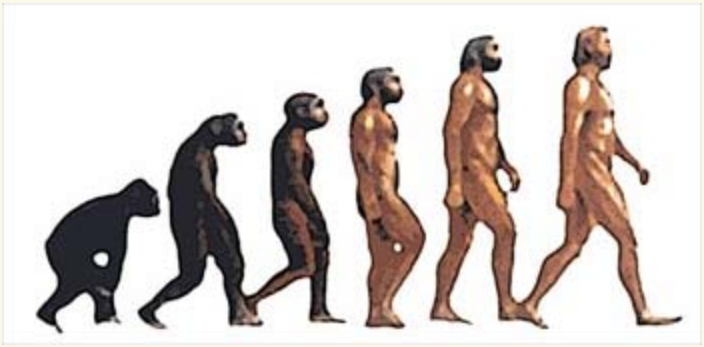


Image from Free Clip Art.

The March of Progress: one of the most recognizable and misinterpreted scientific illustrations ever produced, drawn by Rudolph Zallinger, depicting a line of human evolutionary forebears lined up as if marching in a parade from left to right, and copied and parodied countless times (most often with only six hominids rather than the original fifteen). The artist never intended to portray human evolution as a single unbranched line. **More**

Marsh, Othniel C. (1831–1899): of Yale University, was perhaps the single most influential American vertebrate paleontologist of the 19th Century. Life-long rivalry with Edward Drinker Cope over the hunt for new fossils became known as the "Bone Wars". **More**

Mass extinction: Event involving higher extinction rates than the usual degree of background extinction. See Big Five for diagram of extinction rates, and synopsis of five major extinctions

Mastodon: large prehistoric browsing proboscidean known from the Pleistocene of North America; the term mastodon is also applied to other species, some of which (such as Gomphotheres) were unrelated.

Megafauna: animal life, generally specifically applied to terrestrial vertebrate, of exceptionally large size. Dinosaurs and large mammals such as proboscideans (mastodons, elephants, etc), rhinos, and so on are classic examples. Because they are so striking and charismatic, megafauna often feature in nature documentaries, books and artwork on the history of life, and so on.

Meme: controversial concept proposed by Richard Dawkins. A meme is a "a unit of cultural inheritance, hypothesized as analogous to the particulate gene and as naturally selected by virtue of its 'phenotypic' consequences on its own survival and replication in the cultural environment." A meme can be an idea, skill, story, or custom, which is passed from one person to another by imitation or teaching. Some theorists argue that memes are the cultural equivalent of genes, and reproduce, mutate, are selected, and evolve in a similar way. The study of memes is called ***memetics***. (Mavericks of the Mind; PBS evolution Glossary)

Mendel, Gregor Johann (1822–1884): Austrian monk whose study of the inheritance of certain traits in pea plants, led to insights into the mechanisms of heredity that are the foundation of genetics today.

Mendelian inheritance: The mode of genetic inheritance of all diploid species, and therefore of nearly all multicellular organisms. more

Mesozoic: the second of the three Phanerozoic eras of the geological timescale, between the Paleozoic and the Cenozoic, and lasting from 251 to 65.5 million ago. More or less equivalent (especially in the popular imagination) to the "age of reptiles". Dinosaurs, pterosaurs, marine reptiles, ammonites, gymnosperms, and primitive mammals and birds all flourished. The word Mesozoic is derived from the reek terms μέσος (***mesos***, "middle"), ζωή (***zōē***, "animal life") and -ικός, (***-ikos***, an adjective-forming suffix). Includes three periods: the Triassic, Jurassic, and Cretaceous. (MAK, USGS Paleontology glossary, Perseus Digital

Library, Wiktionary) **More**

Metazoa: a multicellular animal, whose cells are organized into tissues and organs. One of the three kingdoms of multicellular life in the Whittaker–Margulis classification scheme. They are rather anthropocentrically divided into Vertebrates and Invertebrates. **More**

Microevolution: Evolution within the species level, or a change in allele frequency in a population over time. (W. R. Elsberry ***in*** talk.origins ***via*** W. J. Hudson)

Microfossil: A fossil so small that it must be studied with a microscope. (USGS Paleontology glossary)

Micron: Micrometer, a unit of measure, used for example when describing protists and microfossils. There are one million micrometers in one meter. (MAK, USGS Paleontology glossary)

Middle: In the geological timescale, the middle of the three subdivisions or epochs of a period; e.g. "Middle Jurassic". (MAK)

Mimicry: imitative behavior, one species resembling one another, and gaining advantages as a result. For example harmless flies that have the same colouration as bees and wasps. Because predators know that wasps sting they tend to avoid anything that looks like them. See Batesian mimicry and Müllerian mimicry. (Wikipedia glossary)

Miocene: A epoch of the late Tertiary period, spanning the time between 23.8 and 5.3 million years ago. It is named after the Greek words μείων (***meion,*** "less") and καινός (***kainos***, "new"). (USGS Paleontology glossary, Perseus Digital Library) Moderate Icehouse climate, punctuated by ice ages; Orogeny in northern hemisphere. Modern mammal and bird families become recognizable. Horses and mastodons diverse. Grasses become ubiquitous. First apes appear (for reference see the article: "Sahelanthropus tchadensis"). Kaikoura Orogeny forms Southern Alps in New Zealand, continues today. Orogeny of the Alps in Europe slows, but continues to this day. Carpathian orogeny forms Carpathian Mountains in Central and Eastern Europe. Hellenic orogeny in Greece and Aegean Sea slows, but continues to this day. Middle Miocene Disruption occurs. Widespread forests slowly draw in massive amounts of CO2, gradually lowering the level of atmospheric CO2 from 650 ppmv down to around 100 ppmv. (Wikipedia) **More**

Mississippian: A subperiod of the Paleozoic era, spanning the time between 360 and 325 million years ago. It is named after the Mississippi River valley, which contains good exposures of rocks of this age. The term is used by American geologists as a period ranking of geological time, but not European ones, who refer instead to the "Lower Carboniferous". The Mississippian has since been standardised as subperiod of the Carboniferous. (MAK, USGS Paleontology glossary) Large primitive trees, first land vertebrates, and amphibious sea-scorpions live amid coal-forming coastal swamps. Lobe-finned rhizodonts are dominant big fresh-water predators. In the oceans, early sharks are common and quite diverse; echinoderms (especially crinoids and blastoids) abundant. Corals, bryozoa, goniatites and brachiopod (Productida, Spiriferida, etc.) very common, but trilobites and nautiloids decline. Glaciation in East Gondwana. Tuhua Orogeny in New Zealand tapers off. Variscan orogeny occurs towards middle and late Mississippian Periods. (Wikipedia) **More**

Mitochondria (sing. **mitochondrion**): A a small round organelle found in most cells in nearly all eukaryotes; produce enzymes that convert food to energy. Because mitochondria are generally carried in egg cells but not in sperm, mitochondrial DNA is inherited from mothers but not fathers. Hence it is possible to trace ancestry through the mother's line (see also mitochondrial Eve).

Mitosis: Cell division. All cell division in multicellular organisms occurs by mitosis except for the special division called meiosis that generates the gametes. (PBS evolution Glossary)

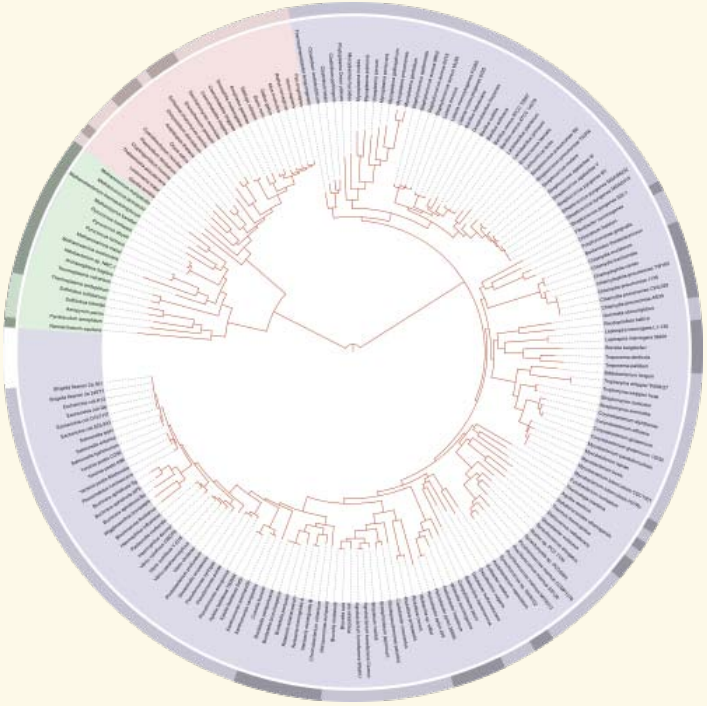
Modern Synthesis: synthesis of Darwin's theory of natural selection and Mendelian genetics, the basis of modern evolutionary theory. **More**

Mold: fossilised impression of organism preserved in rock.

Molecular clock: the premise that the rate at which mutational changes accumulate is constant over time.

Molecular phylogeny, molecular systematics: Use

of molecular data as characters for phylogenetic analyses. Generally speaking, the more closely related two organisms are, the more similar their gene sequences will be. By statistically comparing the similarities and differences in the sequence between the same gene from various organisms, we can deduce the pattern of how those organisms are related, and shown in a phylogram.



Mollusca: also ***mollusk*** (American spelling) major phylum of invertebrate animals distinguished by a shell-secreting mantle and radula teeth. Includes chitons, bivalves, gastropods, cephalopods, and various minor groups. An important component in marine ecosystems, also many freshwater and terrestrial forms. Cambrian to recent. **More**

Monophyletic group, monophyly: in cladistics refers to those phylogenetic groups in which no descendent is a part of any other group; also called a clade.

Monospecific: a higher taxon (family, genus, etc) that contains only a single species.

Moore, Raymond C. (1892–1974): American paleontologist, co-author (with Lalicker and Fischer) of ***Invertebrate Fossils*** (1952) and founder and first editor of the multi-volume ***Treatise on invertebrate paleontology*** (1953–ongoing). He was also a talented artist who illustrated the book ***Invertebrate Fossils***. (MAK)

Morphogenesis : biological process that causes an organism to develop tissues, organs and shape.

Morphology: The study of the form and structure of organisms, such as animals and plants and their fossil remains.

Morphospace: a representation of the possible shape, structure, or form of an organism, usually with two or three variables plotted on a grid or diagram.

Mosaic evolution: tendency of transitional organisms to have a mosaic of different characteristics, so that both primitive/basal and specialised/derived characters occur together. So for example early tetrapods had both fish-like and amphibian features, and ***Archaeopteryx*** possessed both dinosaur and bird-like features. (MAK)

Mosasaur: giant marine reptiles, probably related to the ancestors of snakes. They dominated the seas during the late Cretaceous. (MAK)

Mountain building: see Orogeny.

Mutation: An error in duplication of genetic material which results in a different sequence of and/or a different number of base pairs in the copy than were in the original. Mutation creates new alleles. (W. R. Elsberry ***in*** talk.origins ***via*** W. J. Hudson)

N

Natural selection: The differential reproduction and, thereby, transmission of alleles between generations, of individuals in a population, due to heritable variation in a trait or traits which they possess. This is one mechanism by which evolution can occur. (W. R. Elsberry ***in*** talk.origins ***via*** W. J. Hudson)

Darwin's theory of evolution through natural selection can be summarised by means of three principles:

1. ***Principle of variation***. Among individuals within any population, there is variation in

morphology, physiology, and behavior.
2. ***Principle of heredity***. Offspring resemble their parents more than they resemble unrelated individuals.
3. ***Principle of selection***. Some forms are more successful at surviving and reproducing than other forms in a given environment.

(Griffiths AJF, Miller JH, Suzuki DT, et al. "Introduction", in ***An Introduction to Genetic Analysis***. 7th edition. New York: W. H. Freeman; 2000)

Conceived independently and then jointly published by Darwin and Wallace, and substantially elaborated upon in the early part of the twentieth century with the rediscovery of Mendelian genetics and then advances in population genetics.

Naturalism: any of several philosophical stances, typically those descended from materialism and pragmatism, that interpret the world and consciousness in such a way that does not require a supernatural explanation. **More**

Nautiloid: the pearly nautilus and its ancestors. Include a large assemblage of mostly Paleozoic cephalopods with straight, curved, loosely or tightly coiled shells and simple sutures. Common and most diverse from the Ordovician to the Devonian, after which time they were increasingly supplanted by ammonoids. Nevertheless, nautiloids much like the modern Nautilus continued virtually unscathed even when the various groups (goniatite, ceratite, ammonite) of their advanced ammonoid cousins died out, perhaps because they inhabited deeper water and were not so dependent on the plankton-based food chain. The largest Paleozoic nautiloids had straight shells several meters or more in length, but most species were of more modest proportions. (MAK)

Nekton: Used to describe aquatic organisms that swim, as opposed to plankton which drift. (USGS Paleontology glossary)

Neogene: A subperiod of the Tertiary period of the Cenozoic era, Includes the Miocene and Pliocene epochs. A move to have the Paleogene and Neogene replace the Tertiary was not successful, and they now seem to have become subperiods. (MAK) **More**

Neomura: derived from the Greek νέος (***neos***, "new") and the Latin ***mūrus*** ("wall") in reference to the distinct cell membrane; in Thomas Cavalier-Smith's evolutionary model, the clade including Archaea and Eukarya. Contrast with Three Domains. (Perseus Digital Library)

Neontology: those aspects of biology that, in contrast to paleontology, deal with now living or extant organisms. (MAK)

Niche: In ecology, the role the species plays in the functioning of the ecosystem.

Nondirectionality (in evolution): as here defined, the premise that evolution does not have a direction, that nature does not tend towards greater complexity, that it is misleading to speak of "lower", "simpler", or "primitive" or "higher" or "advanced". Contrast with directionality. (MAK)

Non-missing link: Although creationists often claim that no transitional forms are known in the fossil record, in fact the reverse is the case. As it would be oxymoronic to refer to these intermediate species by their popular moniker as "missing link", Note that even though, in view of the vagaries of the fossil record, the non-missing link may not necessarily be the actual, literal, common ancestor of all later species in that lineage (although in some cases where stratigraphic preservation is very good it might),it would certainly be a closely related type. I have coined the informal term "non-missing link". See also transitional forms. (MAK)

Noosphere (sometimes spelt **noösphere**): thesis developed, either independently or jointly, by Édouard Le Roy (French mathematician and Bergsonian philosopher), Pierre Teilhard de Chardin, and Vladimir Vernadsky in the 1920s, to describe the "sphere of human thought" (Greek νόος, ***noos***, mind), by analogy with "geosphere", "atmosphere", "biosphere", etc. The Noosphere is considered the latest sphere of earth evolution, but is interpreted differently by Teilhard, Vernadsky, and modern authors. For example today it is frequently identified with the Internet. (MAK, Wikipedia, Perseus Digital Library)

Notochord: A rodlike cord of cells in lower chordates that forms the main lengthwise support structure of the body. (USGS Paleontology glossary)

Nucleus: a membrane-enclosed central region of the eukaryotic cell, which contains the genetic material.

O

Oligocene: An epoch of the early Tertiary period, spanning the time between 33.7 and 23.8 million years ago. It is named after the Greek words ὀλίγος (***oligos***, "little", "few") and καινός (***kainos***, "new"). (USGS Paleontology glossary, Perseus Digital Library) Warm but cooling climate, moving towards Icehouse; Rapid evolution and diversification of fauna, especially mammals. Major evolution and dispersal of modern types of flowering plants. (Wikipedia) **More**

Order: In the Linnaean classification the taxonomic rank between class and family, used to define middle-level sub-group. Generally includes a number of similar families. Orders are often used in evolutionary systematics (and may represent monophyletic or paraphyletic taxa) but not cladistics. (MAK) **More**

Ordovician: The second earliest period of the Paleozoic era, spanning the time between 505 and 440 million years ago. It is named after a Celtic tribe called the Ordovices. (USGS Paleontology glossary) Invertebrates diversify into many new types (e.g., long straight-shelled cephalopods). Early corals, articulate brachiopod (Orthida, Strophomenida, etc.), bivalves, nautiloids, trilobites, ostracods, bryozoa, many types of echinoderms (crinoids, cystoids, starfish, etc.), branched graptolites, and other taxa all common. Conodonts (early planktonic vertebrates) appear. First green plants and fungi on land. Ice age at end of period. (Wikipedia) **More**

Organelle: a specialized subunit within a cell that has a specific function, and is usually separately enclosed within a double membrane (or lipid bilayer). (from Wikipedia)

Organism: individual member of a species, that is, a single biological entity, either unicellular (single-celled) or multicellular (many-celled).

Ornithischian: derived from the Greek terms ὄρνιθος (***ornithos***, "bird"), ἰσχίον (***iskhion***, "haunches") and -ἰα (***-ia***, nominal form of an adjective-forming suffix); names any member of one of the three main clades of dinosaurs, this diverse group included plated (stegosaur), armoured (ankylosaur), generalised herbivores (iguanodonts and "duck billed" hadrosaurs) and head-butting and horned (ceratopsian) dinosaurs. Rare during the Triassic, they were most abundant during the Cretaceous. (MAK, Perseus Digital Library, Wiktionary) **More**

Orogeny: The tectonic process in which large areas are folded, thrust-faulted, metamorphosed, and subjected to plutonism. The cycle ends with uplift and the formation of mountains. (Geowords glossary)

Osteology: derived from the Greek terms ὀστέον (***osteon***, "bone") and λόγος (***logos***, "explanation"); the study of the various parts of the vertebrate skull and skeleton. Regardless of how much neontology and soft-part morphology, paleobiological reconstruction (especially popularised by the dinosaur renaissance of Ostrom, Bakker, and Paul), developmental biology, and molecular phylogeny increase in importance in studying the evolution of vertebrates, along with trace fossils and footprints, the study of the most durable and commonly preserved parts of the organism, the teeth (in small delicate animals such as Mesozoic mammals) and bones will always remain an essential element in any analysis of vertebrate phylogeny and paleontology. Classic vertebrate paleontology textbooks and papers such as the works of Zittel, Romer and Carroll are full of dense descriptions on the skeletal and cranial minutiae of various extant and extinct taxa, and even more so this is the case with technical journals. Thus material, essential for listing traits for cladistic analysis, makes up a large part of the "Vertebrates" section of **Palaeos** (originally, "Vertebrate Notes"). (MAK, Perseus Digital Library)

Ostracod: names any member of Class Ostracoda, small crustaceans with dorsally located bivalved carapace which is commonly heavily calcified, common as microfossils and very useful for biostratigraphy. (University of Arizona Geosciences 308 Paleontology glossary, MAK)

Ostracoderm: name given to a diverse assemblage of highly distinctive armoured jawless fish from the Ordovician, Silurian and Devonian periods. The term is now rarely used in scientific literature, as they are now known to consist of a number of different lineages, representing a paraphyletic or polyphyletic grouping. Nevertheless it is a useful label for referring to these bizarre creatures from the early days of vertebrate evolution. (MAK)

Oxygen crisis: being a crisis for the earlier mentioned Archaea (one of the three domains of life), in that photosynthetic blue-green algae totally transformed the Earth by changing the atmosphere from reducing to oxygenating, thus paving the way for eukaryote life.

P

Paleo geek, paleo nerd: what you and I are; someone with a disproportionate interest in, and knowledge concerning, the history of life on Earth. (MAK)

Paleoanthropology: the study of fossil hominids, especially human ancestors.

Paleoart: informal term first coined by Mark Hallett for art that depicts subjects related to paleontology. These may be representations of fossil remains or depictions of the living creatures and their ecosystems. (Wikipedia). Paleo artists therefore are any of those wonderfully talented people who produce those beautiful reconstructions of prehistoric organisms that help to brighten up the web (and **Palaeos** too!). (MAK)

Paleobiology: The study and understanding of fossil organisms from a biological perspective. Whereas paleontology looks at the fossil bone, shell, or leaf for its own sake, paleobiology seeks to understand the organism that produced those remains.

Paleoceanography: The study of oceans in the geologic past, including its physical, chemical, biologic, and geologic aspects. (USGS Paleontology glossary)

Paleocene: Earliest epoch of the Tertiary period, spanning the time between 65 and 55.5 million years ago. It is named after the Greek words παλαιός (***palaios,*** "old") and καινός (***kainos***, "new"). (USGS Paleontology glossary, Perseus Digital Library) Climate tropical. Modern plants appear; mammals diversify into a number of primitive lineages following the extinction of the dinosaurs. First large mammals (up to bear or small hippo size). Alpine orogeny in Europe and Asia begins. Indian Subcontinent collides with Asia 55 Ma, Himalayan Orogeny starts between 52 and 48 Ma. (Wikipedia) **More**

Paleoclimate: The climate of a given period of time in the geologic past. (USGS Paleontology glossary)

Paleoecology: the study of the relationships between species in fossil assemblages.

Paleogene: A subperiod of the Tertiary period of the Cenozoic era, Includes the Paleocene, Eocene, and Oligocene epochs. A move to have the Paleogene and Neogene replace the Tertiary was not successful, and they now seem to have become subperiods. (MAK) **More**

Paleomagnetism: Refers to the study of the magnetic properties of rocks and minerals. This demonstrates to us that both the strength and direction of Earths magnetic field is not constant. Each rock and mineral tells its own story at a particular moment in time. (A. Atwal, Wikiversity)

Paleontology. The scientific study of ancient life (***palaeos*** = ancient, ***ontos*** = being, ***logos*** = speech, reason, hence study of), through examination of fossil remains and the fossil record. Includes subdivisions such as Vertebrate, Invertebrate, and Micro- paleontology. Contrast with neontology. Paleontologists have access to many extinct forms of life, including many transitional and ancestral forms, and information regarding their stratigraphic or temporal position in the geological timescale, paleobiology, paleoecology, paleoclimatology, etc extend this to environmental, geographic, and other areas to provide a comprehensive history of the Earth. Because of the fragmentary or partial nature of many fossils, reconstructing extinct life and extinct environments is often more like forensic science than biology or ecology. (MAK) **More**

Paleozoic: the first and longest of the three Phanerozoic eras of the geological timescale, lasting from 542 to 251 million years ago. Characterised by the emergence and dominance of multicellular life in the Cambrian explosion, and the succession of invertebrates, fish, and early land plants, amphibians and reptiles. Includes six periods: the Cambrian, Ordovician, Silurian, Devonian, Carboniferous, and Permian. The word Paleozoic is derived from the Greek terms παλαιός (***palaios,*** old), ζωή (***zōē***, "animal life") and -ικός (***-ikos***, an adjective-forming suffix). (Perseus Digital Library, Wiktionary) **More**

Palynology: The study of pollen, living and fossil. (Amateur Geologist Glossary)

Pangea, **Pangaea**: derived from the Greek terms πᾶν (***pan,*** "all") and γαῖα (***gaia***, "earth"); is a supercontinent that existed during the Permian and Triassic, and included most of the Earth's continental crust. During this time, terrestrial faunas were often quite uniform, as there were few geographic barriers, although there were distinct vegetation zones (biomes). Beginning in the Jurassic, Pangea divided into Laurasia in the north and Gondwana in the south. (Perseus Digital Library, Wiktionary) **More**

Panspermia: the theory that life on Earth was seeded from other planets, whether accidentally (through microbes floating on comets or carried in meteorites) or deliberately (through intelligent extraterrestrials - see intelligent design). The version of panspermia that only considers human beings is called the Ancient Astronaut hypothesis. (MAK)

Paradigm: the set of practices and methodologies that define a scientific discipline at any particular period of time. **More**

Parallel evolution: the development of a similar trait or traits in related, but distinct, species descending from the same ancestor, but from different clades or lineages.

Paraphyly, paraphyletic group: a technical term in Cladism, used to refer to groups that have a common ancestry but which do not include all descendents. e.g. reptile is a paraphyletic group because reptiles evolved into mammals and birds. Evolutionary systematics regards paraphyletic groups as valid, whereas cladistics does not. Contrast with monophyly. **More**

Parareptile: mostly Permian (with some Triassic) reptiles that may or may not have given rise to turtles. They include small lizard-like and large armoured forms. **More**

Parsimony: Also known as Occam's Razor, the principle that recommends choosing the simplest of two competing hypotheses. A central premise in cladistics, where computer algorithms routinely generate huge numbers of cladistic trees. When reconstructing the phylogenetic relationships, parsimony implies that we should prefer the branching pattern that requires the fewest number evolutionary changes. Unfortunately, the picture becomes more complex when homoplasy is taken into account. (MAK)

Paul, Gregory S.: paleo artist and author of several popular books, whose work played a major role in defining the way we think of dinosaurs.

Pelagic: Referring to open water marine habitats free of direct influence of the shore or ocean bottom. Pelagic organisms are generally free-swimming (nektonic) or floating (planktonic). (USGS Paleontology glossary)

Pelycosaur Synapsid reptiles common during the early Permian, include distinctive fin-back carnivorous ***Dimetrodon*** and herbivorous ***Edaphosaurus*** (the fin serving for thermoregulation), as well as more conventionally looking animals. **More**

Pennsylvanian: A subperiod of the Carboniferous period of the Paleozoic era, spanning the time between 325 and 286 million years ago. It is named after the state of Pennsylvania where rocks of this age are widespread. (USGS Paleontology glossary) Winged insects radiate suddenly; some (esp. Protodonata and Palaeodictyoptera) are quite large. Amphibians common and diverse. First reptiles and coal forests (scale trees, ferns, club trees, giant horsetails, ***Cordaites***, etc.). Highest-ever atmospheric oxygen levels. Goniatites, brachiopod, bryozoa, bivalves, and corals plentiful in the seas and oceans. Testate forams proliferate. Uralian orogeny in Europe and Asia. (Wikipedia) **More**

Period: a unit or division of geological time, usually lasting several tens of millions of years, and hence intermediate in duration between era and epoch. By convention, each period is divided into two or more epochs. In terms of geological strata, rather than time, the word "system" is traditionally used, although this now seems to be falling out of favour, and only found in older books. (MAK)

Permian: The final period of the Paleozoic era. Landmasses unite into supercontinent Pangaea, creating the Appalachians. End of Permo-Carboniferous glaciation. Synapsid reptiles (pelycosaurs and therapsids) become plentiful, while parareptiles and temnospondyl amphibians remain common. In the mid-Permian, coal-age flora are replaced by cone-bearing gymnosperms (the first true seed plants) and by the first true mosses. Beetles and flies evolve. Marine life flourishes in warm shallow reefs; productid and spiriferid brachiopod, bivalves, forams, and ammonoids all abundant. Permian–Triassic extinction

event occurs 251 Ma: 95% of life on Earth becomes extinct, including all trilobites, graptoloids, and blastoids. Ouachita and Innuitian orogenies in North America. Uralian orogeny in Europe/Asia tapers off. Altaid orogeny in Asia. Hunter-Bowen Orogeny on Australian Continent begins (c. 260–225 Ma), forming the MacDonnell Ranges. (Wikipedia) **More**

Permo-Carboniferous: informal period of time encompassing the Carboniferous and Permian periods, or alternatively the latter parts of the Carboniferous and early part of the Permian period. Important in considering late Paleozoic geology, global climate change (glaciation), and plant, invertebrate, and tetrapod ecology and evolution. (MAK)

Phanerozoic: the most recent, and current, of the four eons of the geological timescale, the time of diverse and complex life, complex ecosystems, and an oxygen-rich atmosphere. Divided into Paleozoic, Mesozoic, and Cenozoic. The Phanerozoic begins with the start of the Cambrian period, and continues to today. **More**

Pheromone: A chemical substance produced by some organisms and emitted into the environment to communicate with others of the same species; play an important role in the social behavior of certain species.

Phylogenetic: a rather ambiguous adjective that may refer to phylogeny or evolutionary relations in general, the phylogenetic systematics (Hennigian) school of cladistics, cladistics in general, or phylogenetics

Phylogenetic nomenclature: classification and taxonomy based on cladistic phylogenetic principles, accepting only monophyletic clades, and proposed as a rank-free alternative to the Linnaean system of classification. Sometimes informerly use Linnaean ranks and suffixes, especially from superfamily down, but in contrast to evolutionary systematics, supra-specific taxa are based solely on branching sequence (tree topology) rather than similarity or diversity, so the earlier branches have higher ranks. See also Hominidae vs Hominina (MAK)

Phylogenetic systematics: cladistics as developed by Hennig, which uses recognisable synapomorphies to determine natural groups (clades), and emphasises phylogeny (as opposed to pattern cladistics which claimed that phylogeny is impractical). More recently has been subsumed under phylogenetics. **More**

Phylogenetic tree: See Tree.

Phylogenetics: the synthesis of cladistics and molecular phylogeny. The current phylogenetic paradigm. **More**

Phylogeny: the field of study—established by Ernst Haeckel—of evolutionary relationships among groups of organisms, often illustrated with a branching diagram called a tree. Included under the heading of systematics. **More**

Phylogram: evolutionary tree diagram used in molecular phylogeny, in which evolutionary change is shown by the length of each branch. (MAK)

Phylum: In the Linnaean classification the taxonomic rank between kingdom and class, and hence one of the highest levels of taxonomic classification, used to define major groups of organisms; e.g. molluscs, arthropods, echinoderms, chordates s based on a shared general body plan. **More**

Placoderms: A peculiar group of primitive armored jawed fish, superficially similar to Ostracoderms, and found almost exclusively in rocks from the Devonian Period. (USGS Paleontology glossary, MAK)

Plankton: Aquatic organisms that drift, or swim weakly. Hence ***Planktonic*** describing aquatic organisms that float. (USGS Paleontology glossary)

Plant: traditionally and taxonomically meaninglessly used to include all photosynthetic organisms and fungi. In the Whittaker–Margulis scheme one of the three kingdoms of multicellular life, include the land plants and (in later classifications) green algae. **More**

Plate tectonics: The theory, proposed by Alfred Wegener, that the surface of Earth is made of a number of plates, which have moved throughout geological time to create the present-day positions of the

continents. Plate tectonics explains the location of mountain building, as well as earthquakes and volcanoes. The rigid plates consist of continental and oceanic crust together with the upper mantle, which "float" on the semi-molten layer of the mantle beneath them, and move relative to each other across the planet. Six major plates (Eurasian, American, African, Pacific, Indian, and Antarctic) are recognized, together with a number of smaller ones. The plate margins coincide with zones of seismic and volcanic activity. (PBS evolution Glossary)

Plesiomorphy: in cladistic analysis, an ancestral character state present before the last common ancestor of the clade in question evolved, and hence not unique to it. Contrast with synapomorphy.

Plesiosaur: group of mesozoic marine fish-eating reptiles (Plesiosauria/Plesiosauroidea) characterised by a long flexible neck, small head, and broad, turtle-like body. The closely related pliosaurs had a large head and short neck **More**

Pleistocene: An epoch of the Quaternary period, spanning the time between 1.8 million years ago and the beginning of the Holocene at 8,000 years ago. The period of the last ice age, characterised by many large mammals (Pleistocene megafauna), as well as modern plants and invertebrates. Evolution of anatomically modern humans. Dawn of human stone-age cultures, with increasing technical complexity relative to previous ice age cultures, such as engravings and clay statues (e.g. Venus of Lespugue), particularly in the Mediterranean and Europe. Lake Toba supervolcano erupts 75000 years before present, causing a volcanic winter that pushes humanity to the brink of extinction. Ends with Oldest Dryas, Older Dryas/Allerød and Younger Dryas climate events, with Younger Dryas forming the boundary with the Holocene. (Wikipedia) **More**

Pliocene: Final epoch of the Tertiary period, spanning the time between 5.3 and 1.8 million years ago. It is named after the Greek words πλεῖον (***pleion,*** "more") and καινός (***kainos***, "new"). The Miocene and Pliocene represented the time of greatest abundance and diversity of the mammals. Characterised by a cooling climate and ice sheets in Antarctica. (USGS Paleontology glossary, MAK, Perseus Digital Library) Intensification of present Icehouse conditions, present (Quaternary) ice age begins roughly 2.58 Ma; cool and dry climate. Australopithecines, many of the existing genera of mammals, and recent mollusks appear. ***Homo habilis*** appears. (Wikipedia) **More**

Plio-Pleistocene: informal period of time encompassing the Pliocene and Pleistocene epochs, but not the Holocene. Important in considering late Cenozoic climate change, the evolution of hominids and mammals in general. (MAK)

Pliosaur: group of mesozoic marine apex predators related to plesiosaurs but with a large head and streamlined body. The mesozoic equivalent of toothed whales **More**

Polyphyly, polyphyletic group: A group that does not share a common ancestor, but is defined on the basis of independently acquired or convergent (non-homologous) character states. Examples for polyphyletic groups would be the old taxon Pachydermata which includes the thick-skinned hippos, rhinos and elephants,

Polytomy: in cladistics, a node where more than two lineages descend from a single ancestral lineage. This indicates either that we don't know how the descendent lineages are related or the descendent lineages speciated simultaneously.

Population: A group of potentially inter-breeding individuals of the same species found in the same place at the same time (Booth et al. 2003). A group of organisms, typically a single species, and typically isolated from other members of its species in some manner. (W.J. Hudson)

Population ecology: major subfield of ecology that deals with the dynamics of species populations and how these populations interact with the environment.

Precambrian: older term, now rarely used, to refer to the expanse of geological time prior to the Cambrian period. Because the Cambrian was when animal fossils first appear, it, and the following periods to the present, were called the Phanerozoic, and was contrasted with earlier ages and their corresponding rock strata, often highly metamorphised, and devoid of fossils (or characterised only by stromatolites). The Precambrian was also known as the Cryptozoic (hidden life), and originally referred to as "Primary" strata. Current understanding and research has revealed the Precambrian to be a time of diverse geological, climatological, and microbiological activity and evolution. Current usage replaces "Precambrian eon" with

three distinct eons, Hadean, Archean, and Proterozoic, with complex life forms only appearing at the end of the latter, during the Edicaran period. (MAK) **More**

Primary producer: an autotroph that obtains energy directly from the nonliving environment through photosynthesis (e.g. a plant) or less commonly through chemosynthesis (some types of bacteria). (Wikipedia glossary)

Proboscidean: elephants and their extinct relatives, including mammoths, mastodonts, and deinotheres. **More**

Productid: spiny brachiopods very common during the Carboniferous and Permian.

Prokaryote: unicellular organisms that lack a cell nucleus, bacteria. **More**

Proterozoic: the most recent, and current, of the four eons of the geological timescale, during which occurred the oxygen crisis, snowball earth, the rise of Eukarya, and the origin of multicellular life. It followed the Archean, and lasted from around 2.5 to half a billion years. **More**

Protist, protoctist: kingdom (in the Linnaean classification of mostly unicellular organisms, which do not fit into either the categories of animal or plant. For now, protist is retained as a generic term for (mostly) unicellular eukaryotes, but it is not considered a taxon or kingdom, more a sort of wastebasket taxon, for which "unicellular eukaryote" can usually be substituted. **More**

Protozoa: originally "protist" or wastebasket taxon for animal-like (motile, heterotrophic) unicellular eukaryotes; Cavalier-Smith's system one of the six kingdoms of life, including the first eukaryotes, flagellate, and amoeboid forms.

Reconstruction of *Sordes pilosus*, a Jurassic pterosaur. Fossils show that these animals had a furry coating, which implies they were warm-blooded like birds and mammals.

Pterosaur: derived from the Greek terms πτερόω (***pteroō***, "winged") and σαῦρος (***sauros***, "lizard"); names any member of a group of Mesozoic flying reptiles characterised by a greatly elongated fourth finger that supported a membranous wing (in contrast to bats in which all five digits are elongated; artwork and movies that give pterosaurs bat-like wings are inaccurate) thus the moniker "pterodactyl", derived from the Greek terms πτερόω (***pteroō,*** "winged") and δάκτυλος (***daktulos***, "finger"). They include the largest animals ever to fly, although others were of more modest proportions. Not dinosaurs, but closely related. (MAK, Fossil Mall glossary, Perseus Digital Library, Wiktionary) **More**

Punctuated Equilibria; more commonly known an Punctuated evolution, and evolutionary theory by Eldredge & Gould 1972 that argues that new species evolve suddenly and in geographically isolated areas, where it is rarely observed. For the rest of the time, species change slowly, if at all

Q

Quaternary: The second period of the Cenozoic era (following the Tertiary), spanning the time between 1.8 million years ago and the present (in terms of duration, this is the shortest period, equivalent to a standard age). It contains two epochs: the Pleistocene and the Holocene. It is named after the Latin words ***quăternĭo*** ("number four") and ***-ārius*** (nominal form of an adjective-forming suffix), and refers to the earliest (19th century) stratigraphic systems (Primary, Secondary, Tertiary, and Quaternary). Although there was a movement to scrap both Tertiary and Quaternary in favour of more modern terms such as Paleogene and Neogene, this was not successful, and in current geological timescales the Quaternary has been restored or retained. The Quaternary includes both the Ice Age with its distinctive megafauna, and the modern, human-dominated period of Earth history. (USGS Paleontology glossary, MAK, Perseus Digital Library, Wiktionary) **More**

R

r-selection, r-selected species: A species that produces a large number of off-spring, each of which receives little care (quantity rather than quality). R-selected species are better suited for variable or unpredictable environments. (Wikipedia glossary)

Radial symmetry: An organism (or any object) that can be divided into two matching halves by many different lines, which all intersect one another at a single point in the center.These organisms resemble a pie where several cutting planes produce roughly identical pieces. An organism with radial symmetry exhibits no left or right sides, or specific front or rear. They have a top and a bottom (dorsal and ventral surface) only. Examples include plants, sponges, Cnidaria (corals, jellyfish, etc), and echinoderms. Contrast bilateral symmetry. (Wikipedia, UCMP Understanding Evolution Glossary)

Random: Unpredictable in some way. Mutations are "random" in the sense that the sort of mutation that occurs cannot generally be predicted based upon the needs of the organism. However, this does not imply that all mutations are equally likely to occur or that mutations happen without any physical cause. Indeed, some regions of the genome are more likely to sustain mutations than others, and various physical causes (e.g., radiation) are known to cause particular types of mutations. (UCMP Understanding Evolution Glossary)

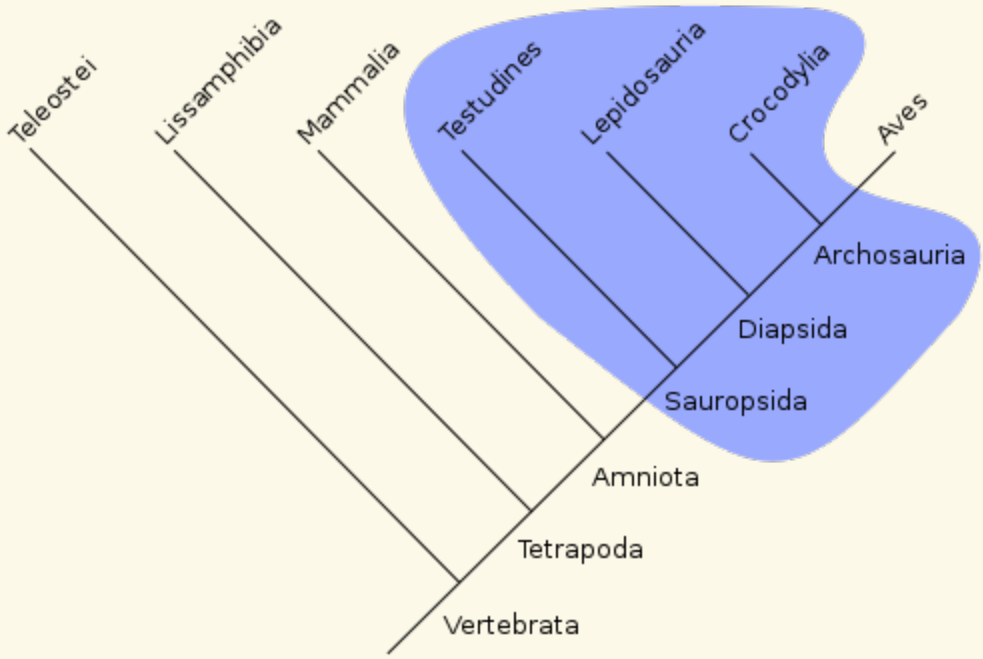
Random drift: See genetic drift.

Rank: the hierarchical level of a supra-specific taxon, according to the Linnaean approach to classification. The eight ranks are kingdom, phylum (added by Haeckel), class, order, family, tribe (used mostly in botany, much more rarely in zoology and paleontology), genus, and species, plus optional intermediate grades represented by the suffixes ***super***-, ***sub***- and ***infra***-. Ranks are rejected by most cladists. (MAK)

Recapitulation: The hypothesis, argued by Ernst Haeckel, that in developing from embryo to adult, animals go through stages resembling or representing successive stages in the evolution of their remote ancestors. Refuted by von Baer. (W. R. Elsberry ***in*** talk.origins, Wikipedia)

Relative age, relative time: A statement of the approximate age of an object or feature in comparison with some other object or feature, rather than in terms of its age in years. (Dinodata glossary by Fred Bervoets) Dating of rocks and geologic events by their positions in chronological order without reference to number of years before the present. Compare with Absolute age. (Glossary of Geologic Terms by S. M. Richardson)

Reproductive isolation: Isolation of one species or population from another species or population by differences in reproductive traits or habits. The two species or populations may or may not share the same environmental range. An example of two species being reproductively isolated are similar species of animals that breed at different times of the year. (W.J. Hudson)



Reptile: A diverse class of vertebrates, constituting all amniotic egg-laying tetrapods that are not birds or mammals. Far more diverse in past ages; the late Paleozoic and the Mesozoic are collectively referred to as

the "Age of Reptiles". The traditional term "reptile" is disliked by cladists because it does not constitute a natural clade, but rather constitutes a paraphyletic taxon distinguished only by shared primitive features (see diagram).

Ribonucleic acid (**RNA**): A molecule similar to DNA, but with only a single strand, by which the genetic code of DNA is converted into proteins in cells. It has three forms: ***Messenger RNA***, ***ribosomal RNA***, and ***transfer RNA***. Some viruses carry RNA as their genetic material instead of DNA. There has been speculation that an "RNA world" preceded current life on Earth.

Rudist: A type of extinct bivalve mollusk from the Jurassic and especially the Cretaceous that had two different sized and shaped shells; they usually were attached to the substrate and were either solitary or in reef-like masses. (USGS Paleontology glossary)

Rugose: derived from the Latin term ***rūgōsus*** ("wrinkled"); names any member of Order Rugosa, Paleozoic group of mostly solitary, but some colonial, stony corals; 800 genera known. Common as fossils. (adapted from University of Arizona Geosciences 308 Paleontology glossary)

S

Sabre-tooth cat: commonly but misleadingly called "sabre-tooth tiger" (tigers are members of the true cat group), a type of extinct big cat of the subfamily Machairodontinae, characterised by the greatly elongated canine teeth. This feature evolved independently at least three times among cat-like mammals, as well as twice among marsupials and twice (gorgonopsids and therocephalia) among mammal-like reptiles. The best known species is ***Smilodon fatalis***, a stocky, lion-sized beast known from hundreds of skeletons of animals that became trapped in the La Brea Tar Pits. **More**

Santonian: geologic age of the Late Cretaceous, spanning the time between 88 and 84 million years ago. (USGS Paleontology glossary)

Sauropod, sauropodomorph: derived from the Greek terms σαῦρος (***sauros***, "lizard"), πόδα (***poda***, "foot") and μορφή (***morphē***, "form"); a misleading name for these giant creatures with their compact short-toed feet. One of the three main clades of dinosaurs, the other two being theropods and ornithischians. Early sauropodomorphs, called ***prosauropods***, were small to medium sized animals, but they quickly grew to become ***sauropods*** proper, the largest animals to walk the Earth. Sauropods are characterised by very small heads (relative to the overall body), long to very long necks and tails, solid pillar-like legs, and massive dorsal vertebrae. At one time they were believed to be sluggish semi-aquatic wallowers in swamps, unable to walk on land. It is now known that they were active and fully terrestrial animals, much like elephants. Adults were so large they were immune to predation even from the biggest theropods. (MAK, Perseus Digital Library) **More**

Scala Naturae: meaning "natural ladder" in Latin, is a sort of proto-taxonomy first developed by Aristotle, according to which the natural world can be arranged in a single linear series from inanimate matter through plants, invertebrates, higher vertebrates, and finally man. Overlaps and sometimes synonymous with the great chain of being. Remained a central idea in natural philosophy until the early or mid 19th century. **More**

Science: a methodical and naturalist approach to the acquisition of knowledge, by means of empirical method, hypothesis, experiment, and conformation or refutation. Science does not offer absolute answers, but rather increasingly refined insights regarding the nature of the material world, on the basis of available evidence.

Sediment: Solid unconsolidated rock and mineral fragments that come from the weathering of rocks and are transported by water, air, or ice and form layers on the Earth's surface. Sediments can also result from chemical precipitation or secretion by organisms. (USGS Paleontology glossary)

Sedimentary Rock: A rock that is the result of consolidation of sediments. (USGS Paleontology glossary)

Selection: see natural selection.

Selective pressure: any environmental factors such as scarcity of food or extreme temperatures that favour the survival of only those organisms with characteristics that provide resistance or adaptability. (PBS evolution Glossary)

Self-organization: process in which the internal organization of a system, normally an open system, increases in complexity without being guided or managed by an outside source. Self-organizing systems typically (though not always) display emergent properties. See also Directional Evolution. (Wikipedia glossary)

Sequencing: any of several methods and technologies that are used for determining the order of proteins in a cell, or nucleotide bases (adenine, guanine, cytosine, and thymine) in a molecule of RNA or DNA. An essential element in molecular phylogeny.

Shale: a fine-grained sedimentary rock formed by the compaction of silt, clay, or sand that accumulates in deltas and on lake and ocean bottoms. (Bristol University: Palaeobiology and Biodiversity Research Group: Late Cretaceous Climate Change: Glossary)

Silurian: A period of the Paleozoic, spanning the time between 440 and 410 million years ago. It is named after a Celtic tribe called the Silures. (USGS Paleontology glossary) First Vascular plants (the rhyniophytes and their relatives), first millipedes and arthropleurids on land. First jawed fishes, as well as many armoured jawless fish, populate the seas. Sea-scorpions reach large size. Tabulate and rugose corals, brachiopod (Pentamerida, Rhynchonellida, etc.), and crinoids all abundant. Trilobites and mollusks diverse; graptolites not as varied. Beginning of Caledonian Orogeny for hills in England, Ireland, Wales, Scotland, and the Scandinavian Mountains. Also continued into Devonian period as the Acadian Orogeny, above. Taconic Orogeny tapers off. Lachlan Orogeny on Australian Continent tapers off. (Wikipedia) **More**

Singularity: In mathematics, a point at which a given mathematical object is not defined or not well-behaved, for example infinite or not differentiable. In the natural sciences, a point in spacetime where the laws of physics break down, for example where gravitational forces cause matter to have an infinite density and zero volume (as in a Black Hole). In transhumanism and futurism, the end of history as we know it, the point (***Technological singularity***) at which accelerating change and technological progress becomes so rapid, or alternatively that an exponential growth of artificial intelligence surpasses human levels of intelligence, so that it becomes impossible to predict the nature of any post-singularity intelligence or technological civilization. See also posthuman. Link: Acceleration Watch. (MAK)

Similarity: the degree to which two or more species or other taxa resemble each other. Similarity could be the result of common descent and divergence (homology) or convergence (homoplasy).

Sister group: Cladistic term for any of the descendant branches from a node on a cladogram.

Sixth extinction: the on-going anthropogenic mass-extinction, so called because it is comparable in impact to the preceding big five. The term was coined or popularised by Richard Leakey and Roger Lewin in their 1996 book ***The Sixth Extinction: Patterns of Life and the Future of Humankind***. In his book ***The Future of Life*** (2002), E.O. Wilson calculated that, if the current rate of human disruption of the biosphere continues, one-half of Earth's higher lifeforms will be extinct by 2100. (MAK, Wikipedia)

Snowball Earth: hypothesis that the Earth's surface became entirely or nearly entirely frozen one or more times during the Precambrian. The most recent snowball was about or earlier than 650 million years ago (Neoproterozoic era, during the appropriately named Cryogenian period). Evidence includes glacial deposits found at what at the time were tropical paleolatitudes, It is not known whether the Earth was a full snowball, or a "slushball" with a thin equatorial band of open (or seasonally open) water. (MAK, Wikipedia) **More**

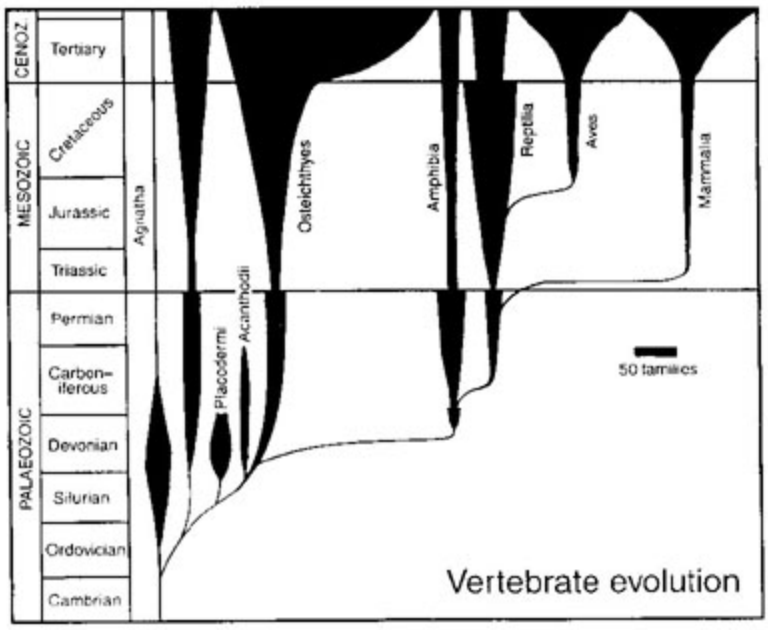
Sociobiology: scientific study that explains and examine social behavior within an evolutionary that context. Often considered a branch of biology and sociology, it also draws from ethology, anthropology, evolution, zoology, archaeology, population genetics, and other disciplines. Popularised in 1975 with the publication of Edward O. Wilson's book, ***Sociobiology: The New Synthesis***.

Species: Highly controversial term given a variety of definitions by biologists. Currently, the Biological Species Concept (BSC) is widely popular: Groups of actually or potentially interbreeding populations, which are reproductively isolated from other such groups (Mayr, 1963, ***Animal Species and Evolution***). See other species definitions. (W. R. Elsberry ***in*** talk.origins ***via*** W. J. Hudson) **More**

Speciation: The the basic process of evolution by which new species appear. ***Allopatric speciation*** is supposed to be caused by the physical separation of specimens of what was one and the same species. The classical example is Darwin's work on the finches of the Galapagos Islands. ***Peripatric speciation*** is taken to occur in the same geographic area—without severance of the gene flow—due to ecological differences, e.g. the existence of two different ecological niches into which an existing species can specialize. (Jcwf100131)

Spiriferid: brachiopods with spiral shaped lophophores, abundant during the Carboniferous and Permian.

Spindle diagram: Also called Romerogram; an evolution tree that maps lineage diversity or abundance against geologic time. Spindle diagrams are employed in evolutionary systematics. They frequently emphasise ancestral groups, transitional forms, and transformation of one lineage into another. Note the way the various more recent spindles emerge from earlier lineages.



Spindle Diagram, showing evolution of the vertebrates, showing the relative importance of the major groups through time. The vertical axis represents geological time, and the horizontal axis represents the diversity of each group, in terms of number of families. Include both monophyletic clades, such as Chondrichthyes, Placodermi, Acanthodii, Aves, and Mammalia, and paraphyletic groups such as Agnatha, Amphibia, and Reptilia. Diagram from Michael Benton, The quality of the fossil record of vertebrates. Wikipedia version

Splitting: see cladogenesis.

Stegosaur: herbivourous armoured mostly Jurassic "bird hipped" dinosaurs equipped with two rows of upright bony plates along the back and spines on the tail and, in some species, also the hips **More**

Stratigraphy: Branch of geology concerned with the formation, composition, ordering in time, and arrangement in space of sedimentary rocks. (USGS Paleontology glossary) **More**

Stromatolite: algae mats, formed in shallow water by microorganisms, especially cyanobacteria accreting grains in layers. Rare now, but common during the Proterozoic. The oldest stromatolites are known from the Archean, they are among the oldest records of life on Earth. Image (right) Wikipedia. (MAK)

Subperiod: optional unit of geological time intermediate between period and epoch. (MAK)

Subspecies: A grouping of organisms less inclusive than a species, and often capable of interbreeding with other subspecies of the same species.

Subtropical: Bordering on the tropics or nearly tropical. (USGS Paleontology glossary)

Superorganism: an organism consisting of many (sometimes thousand, in some cases even millions) individuals working together as a single functional somatic or social unit, e.g. a jellyfish (where individual organisms fulfill the role of different organs) or an ant colony (where the superorganism is more dispersed in space, but also more intelligent). (MAK)

Superposition A statement of relative age in layered rocks: In a series of sedimentary rocks that has not been overturned, the topmost layer is always the youngest and the bottommost layer is always the oldest. (S.M. Richardson)

Supertree: the synthesis of a number of distinct cladograms, combining morphological, molecular, and other data from the different individual phylogenies in a single, more comprehensive dendrogram.

Supra-specific taxon: a taxon above the species level: anything from subgenus and genus upwards (family, order, etc). Useful for understanding biotic diversity through time and large scale patterns of evolution. (MAK)

Suspension feeder: aquatic or marine organisms which capture food suspended in the water column. Suspension feeders that use a filter to capture food (e.g. brachiopods, crinoids, etc.) are called ***filter feeders***. Suspension feeders were more predominant in Paleozoic ecosystems, where they often would form tiers. (MAK, University of Arizona Geosciences 308 Paleontology glossary)

Suture: the line of partition between gas-filled chambers in shelled cephalopods. Sutures can only be seen when the outside of the shell has been removed, and suture pattern is used to characterize many ammonoid groups. Nautiloids have simple sutures, ammonites more complex ones. (MAK, University of Arizona Geosciences 308 Paleontology glossary)

Symplesiomorphy: see plesiomorphy.

Synapomorphy: An character trait or "apomorphy" ***shared by*** (syn-) several taxa, where the trait in question originates in their last common ancestor. Being shared by multiple taxa, synapomorphies can be used to diagnose (describe) a clade (a monophyletic group). Compare with homology. **More**

Synapsid: in older books, refers to a subclass of reptiles related to and ancestral to mammals, also known as "mammal-like reptiles", and consisting of the orders Pelycosauria and Therapsida, which flourished during the early Permian, and Middle Permian to Late Triassic periods respectively. Because this is a paraphyletic definition, in cladistics it is expanded to include mammals as well. (MAK) **More**

Systematics, Systematic Biology: the study of the diversification of life on the planet Earth, both past and present, and the relationships among living things through time. Includes taxonomy and phylogeny. **More**

Systems theory: the study of systems in general, with the goal of elucidating principles that can be applied to all types of systems in all fields of research. The term originates from Ludwig von Bertalanffy's General System Theory (GST). See also complex system, emergence. (Wikipedia)

T

Tabulate: Order Tabulata. Paleozoic group of exclusively colonial organisms traditionally classified as stony corals, although other interpretations have been suggested (e.g. sponges). Common as fossils, 280 genera known. (adapted from University of Arizona Geosciences 308 Paleontology glossary)

Taxon (plural: **taxa**): a group of organisms, considered to be a unit, and which generally has been formally named with a scientific (Latin or Greek) proper name and a rank. Whether or not clades are acceptable as taxons is a matter of dispute

Taxonomy: the practice and science of classification. In evolutionary theory this is a branch of systematics

Teleology: the philosophical supposition that there is design, purpose, directive principle, or final causes in the works and processes of nature. Rejected by metaphysical naturalism

"Tellurobiota": our term for life or living organisms that evolved on Earth, as distinct from extraterrestrial life.

Temnospondyl: highly diverse Carboniferous to Cretaceous labyrinthodont amphibians, most common during the Permian and Triassic; may or may not include the ancestors of some or all modern amphibians

Tethys: during the time of Pangea (Permian and Triassic) this was the sea that separated the northern half (Laurasia) of the supercontinent from the southern (Gondwana). If Pangea can be imagined in the shape of a giant "pac-man", then the Tethys is the "mouth". During the Triassic especially, the borders of the Tethys were populated by unique animals, such as the walrus and turtle like placodonts. (MAK) **More**

Tetrapod: four-legged, land-living vertebrate, or any secondarily limbless (e.g. snakes) or aquatic (e.g.

whales) descendants of such. Cladistic terminology disagrees over whether "tetrapod" should be used to include all four-legged animals (stem-based definition) or only those that include the common ancestor of all living tetrapods and its descendants (crown-based definition). **More**

Terrane (microplate): A fragment of the lithosphere, smaller than a plate, that forms a portion of an accreted terrane margin. (S.M. Richardson)

Terrestrial: organisms living mostly or entirely on dry land, in contrast to aquatic or marine; land habitats as distinction from aquatic habitats.

Tertiary: The first period of the Cenozoic era (after the Mesozoic era and before the Quaternary period), spanning the time between 65 and 1.8 million years ago. This was the Age of Mammals proper, before the rise of man. It is divided into two subperiods, Paleogene and Neogene, and five epochs, Paleocene, Eocene, Oligocene, Miocene, and Pliocene. (USGS Paleontology glossary)

Thecodont: in evolutionary systematics, (Romer, Carroll) an order of Triassic archosaurs, morphologically similar to each other, and ancestral to several later groups. Originally usually interpreted as mostly small bipedal forms. In cladistics, a paraphyletic assemblage of basal or stem archosaurs, which became a wastebasket taxon for any non-crocodilian, non-pterosaurian, non-dinosaurian archosaurs. It includes the includes the Triassic members of two different archosaurian clades, Ornithodira and Crurotarsi. On **Palaeos** used in lower case, rather than as a formal taxon. (MAK, EvoWiki)

Theistic evolution: the view that some or all classical religious teachings about God and creation are compatible with some or all of modern scientific theory, including, specifically, evolution. Most adherents consider that the first chapters of Genesis should not be interpreted as a "literal" description, but rather as a literary framework or allegory. Theistic evolutionists have frequently been prominent in opposing creationism.

Thermoregulation: the ability of an organism to keep its body temperature within certain boundaries, even when the surrounding temperature is very different. This process is one aspect of homeostasis: a dynamic state of stability between an animal's internal environment and its external environment. See also ectotherm, endotherm, gigantothermy. (Wikipedia)

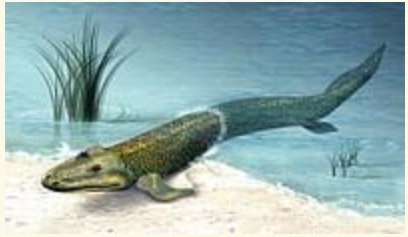
Therapsid: Synapsid mammal-like reptiles common during the Permian and Triassic, include the ancestors of mammals (cynodonts). **More**

Theropod: derived from the Greek terms θηρός (***thēros***, "beast") and πόδα (***poda***, "foot"). Rather misleadingly named because these dinosaurs were distinguished by their bird-like appearance and, yes, bird-like feet. In fact, birds evolved from theropods (or in cladistic methodology birds are a derived clade of theropods). Theropods are one of the three main clades of dinosaurs, the other two being sauropodomorphs and ornithischians. They also include the only meat-eating dinosaurs (all other groups were herbivores). These diverse, impressive, and highly successful animals evolved into a number of small and large to gigantic types, as well as becoming increasingly more bird-like. During the Cretaceous, there was a spectrum of animals from primitive yet successful hold-overs like the abelisaurs, through allosaurs to advanced, feathered, and bird-like coelurosaurs, to true birds of several types. Well known types include ***Coelophysis***, ***Allosaurus***, ***Velociraptor***, and ***Tyrannosaurus***. (MAK, Perseus Digital Library) **More**

Three-domain system: biological classification introduced by Carl Woese that rejects the old prokaryote-eukaryote distinction and divides cellular life forms into Archaea, Bacteria, and Eukarya domains.

Tiktaalik: late Devonian animal transitional between sarcopterygian lobe-finned fish and tetrapod amphibians. The stout, fleshy pectoral fins have a joint corresponding to the elbow in higher tetrapods, and, unlike all other fish, there is a mobile neck and separate shoulder girdle. (Wikipedia).

Titanosaur: large clade of medium-sized to gigantic Cretaceous sauropod



dinosaurs, which included some of the largest animals that ever lived. Advanced forms, such as ***Saltasaurus***, were medium-sized, with armour protection. (MAK) **More**

Topology: in this context a technical term that refers to the particular shape or arrangement or branching order of the branches of a cladogram or phylogram

Total evidence: the philosophical principle that the best hypothesis is the one derived from all the available data. In phylogenetics it is associated with supermatrixes and usually incorporates morphological, molecular, and other data. **More**

Trace fossil: fossil not of an organism itself (e.g. shell, bone, mold, carbonised impression) but of the traces and impressions it left behind while alive (footprints, burrows, resting traces, etc. The study of trace fossils is called Ichnology. (MAK) **More**

Trait: a characteristic or condition or attribute of an organism, which may be morphological, developmental, molecular (protein, RNA or DNA), behavioural, or anything else. See also character.

Transitional form, or **transitional fossil**: A fossil or group of organisms that are intermediate and a link between a more primitive or ancestral group and a more advanced or specialised one, possessing characteristics or traits of both (see Mosaic evolution).

Treatise on Invertebrate Paleontology: massive multi-authored multi-authored work-in-progress (beginning 1953 and still ongoing), with contributions by more than 300 paleontologists, and covering every phylum, class, order, family, and genus of fossil and extant invertebrates.

Tree, **phylogenetic tree**: a tree-like, diagrammatic representation of the evolutionary relationships and patterns of branching in the history of the organisms being considered. One type of tree, called a cladogram, is central to cladistics. Dendrogram can be used to refer either to a more informal diagram, or to one that emphasises phylogeny, speciation, time, etc . (MAK) **More**

Tree of Life: poetic term for an evolutionary tree that (ideally) includes all life on Earth.

Triassic: The earliest period of the Mesozoic era, spanning the time between 248 and 213 million years ago. The name Triassic refers to the threefold division of rocks of this age in Germany. (USGS Paleontology glossary) Archosaurs dominant on land as dinosaurs, in the oceans as ichthyosaurs and nothosaurs, and in the air as pterosaurs. Cynodonts become smaller and more mammal-like, while first mammals and crocodilians appear. ***Dicroidium*** flora common on land. Many large aquatic temnospondyl amphibians. Ceratitic ammonoids extremely common. Modern corals and teleost fish appear, as do many modern insect clades. Andean Orogeny in South America. Cimmerian Orogeny in Asia. Rangitata Orogeny begins in New Zealand. Hunter-Bowen Orogeny in Northern Australia, Queensland and New South Wales ends, (c. 260–225 Ma). (Wikipedia) **More**

Tribe: In the Linnaean classification the taxonomic rank between family and genus, a mostly botanical rank, used to define group of closely related organisms. Used frequently but informerly in phylogenetics, where repeated branchings generate a large number of hierarchical nodes, for which the standard Linnaean ranking does not have enough divisions. (MAK) **More**

Trilobite: important class of Paleozoic marine arthropods, distinguished by a three-fold division of the exoskeleton. Most were small (a few centimeters) although a few giants reached half a meter or so. Abundant during the Cambrian, where they make up the majority of invertebrate fossils. Also very common during the Ordovician to the Devonian, but declined thereafter. Their exquisite forms and great variety of species make them a favourite o\f most fossil collectors. Morphologically distinct; relationships with other arthropods unclear,

hence included in a distinct subphylum, the ***Trilobitomorpha***. Cambrian–Permian. (MAK)

Tropical: Referring to climatic conditions like those found in the region on the earth today between the tropic of Cancer and the tropic of Capricorn; it includes high temperature and humidity and abundant rainfall. (USGS Paleontology glossary)

Tyrannosaurus rex: elephant-sized theropod dinosaur from the latest Cretaceous, perhaps the best known superpredator of the Earth's past. More heavily built than other similar sized giant theropods. The last and largest representative of the family Tyrannosauridae, often (and often inaccurately) portrayed in popular culture (e.g. ***King Kong***, ***Jurassic Park***, etc). It is also the only prehistoric animal correctly represented by its binomial, rather than genus only. **More**

Photo (right): *Olenoides serratus* from the Mt. Stephen Trilobite Beds (Middle Cambrian) near Field, British Columbia, Canada. photo by Mark A. Wilson, Wikipedia

Turonian: geologic age of the Late Cretaceous, spanning the time between 91 and 90 million years ago. (USGS Paleontology glossary)

U

Unconformity: A buried erosion surface separating two rock masses. (S.M. Richardson)

Unicellular organism: a living system consisting of only a single cell. May be simple, as with bacteria, or complex, as with protists. In the case of protists, different parts of the cell takes on the functions that organs and other systems fulfill in multicellular (many-celled) organisms. (MAK)

Uniformitarianism: Assumption that processes acting in the past are the same as those acting in the present. proposed the late 18th century theory of James Hutton that the natural forces now changing the shape of the earth's surface have been operating in the past much in the same way. The most important implication is that the earth is very old (deep time) and that the present is the key to understanding the past. Developed by Charles Lyell in the 19th century, who in turn influenced Darwin. Contrast with catastrophism, punctuated equilibrium.

Upper: In geology, refers to the upper, and therefore younger or more recent strata. In the geological timescale, refers to the younger rocks of a period, especially when the period is divided into three; e.g. "Upper Jurassic". This usage is now generally replaced by the more chronological descriptive term Late. (MAK)

V

Valanginian: geologic age of the Early Cretaceous, spanning the time between 131 and 122 million years ago. (USGS Paleontology glossary)

Variation: differences between individual organisms, or populations.

Vendian: The latest period of the Proterozoic era, spanning the time between 650 and 544 million years ago. Also referred to as the Ediacaran period, the Vendian is distinguished by fossils representing a characteristic collection of complex soft-bodied organisms found at several localities around the world. (USGS Paleontology glossary) After Vendian replaced Edicaran it seems the pendulum has now swung the other way, with Edicaran the preferred term for this period. (MAK)

Vestigial, vestigial structure: A non-functional anatomical component retained merely as a matter of contingent history. (W. R. Elsberry ***in*** talk.origins)

Victorian age: in Britain and the British colonies, the period of Queen Victoria's reign (from 1837 to 1901). A long and prosperous period, and also a time of great scientific, technological, and social advancement. Evolutionary thinking and the science of paleontology are among the developments that stem from this period (and also from equivalent contemporary developments in France, Germany, and the United States).

Vertebrate Notes: the phylogenetic paleontology website developed by ATW, which formed the central element of **Palaeos**. As the name indicates, it is about Vertebrates, including many fossil forms. The Vertebrate Notes are currently been revised and upgraded, but all of the original material will be retained.

Vertebrates: animals with backbones. Include all those large charismatic animals, as well as many smaller ones, that one often finds in popular books on prehistoric animals. **More**

von Baer, Karl Ernst (1792–1876): Baltic German naturalist, a founding father of embryology, formulated what would later be called ***von Baer's laws***, which refuted and replaced Haeckel's Recapitulation theory.

W

Wastebasket taxon: a taxon that includes all species or groups that cannot be easily or conveniently placed elsewhere. e.g. for a while all large theropod dinosaurs that could not be included under the Ceratosauridae, Allosauridae or Tyrannosauridae were named "Megalosaurus".

Web of life: conventionally refers to the food chain or trophic network, describes the feeding relationships between different species in an ecosystem. However, in reference to horizontal gene transfer can also refer to genetic transfer and evolution by non-hereditary means; especially common among bacteria.

Wegener, Alfred (1880–1930): A German climatologist and geophysicist whose book, ***The Origins of Continents and Oceans***, was the first to propose the concept of continental drift (the forerunner to the theory of plate tectonics), as well as to suggest a supercontinent called Pangaea, which Wegener suggested had fragmented into the continents as we know them today. His ideas remained controversial until the 1960s, when they became widely accepted as new evidence led to the development of the concept of plate tectonics. (PBS evolution Glossary)

Woese, Carl Richard (b. 1928): American microbiologist and physicist who developed the three-domain system, based upon genetic relationships rather than obvious morphological similarities, with divided life into three domains: Bacteria, Archaea, and Eukarya.. His ideas and techniques, at first resisted by many, now form the basis of much of our understanding of the relationship of life on Earth. **More**

X

Y

Young Earth creationism: the belief that the Earth along with the entire cosmos was created by a supernatural God within the last 10,000 years, or even 6000 or so years ago, as described literally in Genesis. The most common form of creationism.

Z

Zallinger, Rudolph F. (1919–1995): Russian-born American paleo artist, notable for two immensely influential representations of evolution: the ***The Age of Reptiles*** mural (1947) (his ***The Age of Mammals*** follows a similar theme) and the popular illustration known as ***March of Progress*** (1965), one of the world's most recognizable scientific images. (Wikipedia)

Zygote: The cell formed by the fertilization of male and female gametes. (PBS evolution Glossary)

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About Palaeos

Google Search

only search Palaeos.com

The History of Palaeos

Palaeos was originally two separate projects. On the one hand there were my paleo pages originally appeared on my Kheper net site in the late 1990s. These were very incomplete, and organised along Linnaean based evolutionary systematic lines. My interest, then as now, was with bestiaries of weird and wonderful prehistoric critters and how they come together in ecological communities and dynasties that rise and fall over millions of years. I was however greatly impressed by online resources, such as the UCMP website, the Tree of Life, and the Dinosauricon.

A little later, Toby White began working on a parallel but quite different project called ***Vertebrate Notes***, to form Palaeos.com. He was concerned less with bestiaries and more with delving into osteological and morphological minutiae and phylogenic controversies, and used a cladistic approach. Toby had been working with Fred Bervoets of the DinoData site where the vertebrate notes were briefly being hosted, before being transferred to a separate server for practical reasons.

At some point, Toby contacted me by email, as he had seen my Sauropterygia pages, one of the very few topics where I had taken the trouble to delve into osteology and proper science (albeit on a layman level), and gave these the coveted "best of the web" award. After corresponding and continuing to work on separate but parallel, overlapping, and interlinked projects, Toby and I decided to in 2002 to merge our two sites, the result being the original Palaeos.com.

After a few years, I was distracted by other projects, leaving Toby, the senior and without doubt the more talented of the two of us, as the main and basically the only author. After a while it became too much work to check and update all the links, and in 2006 the site was dropped and went off line.

I started networking and we restored the site and set up a wiki, which is still running and which was to be the replacement to the static site. However transferring everything over from html to wiki mark up was too tedious, and the wiki never replaced Palaeos.com. I occasionally updated the static web site, as did Toby. The problem came in late 2009 when I was trying to do a major upgrade of the turtles, which led to an upgrade of other groups as well, and the realisation that it was very hard to incorporate major updates,

because of the linear presentation of the Vertebrate Notes and early Palaeos.com, which really form an integral unit. Then in 2010, Paleos.com once again went off the air.

The present iteration represents a major revision relative to the earlier Palaeos.com. As I now find myself in the rather dubious and unsavoury position of senior author, I decided to radically overhaul the site, making it more open-ended to allow incorporation of blog pages, pertinent Wikipedia/Wikimedia material, and other material, and reorganising the directories, to allow easier phylogenetic revision and updating. I would also like to get more people involved in contributing to the site, so that Palaeos becomes a truly collaborative venture.

The pages you see on this site are a dedication to the love of knowledge for its own sake, and a desire to present information to the world free of charge. MAK110419, MAK110902

Subject matter

The Palaeos website is organised along two themes; ***time***, being the geological timescale, deep time, which spans not the mere centuries or millennia of world history, but millions or even billions of years, and mapping out the ***evolution***, specifically the evolution of life on Earth; the diversity of organisms that constitute the tree of life, beginning with simple bacteria and proceeding to ever more complex forms from there, as well as the interrelations between them. There is no reason to doubt that life could also have evolved elsewhere in the cosmos, and we also explore this topic. However, most of Palaeos is devoted to a detailed consideration of the history of life on Earth. MAK110914

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Note that while the site is ostensibly in construction using these contacts to report errors is unnecessary as they will probably be noted and corrected in due time. When we've announced the site's uploading and revision as complete feel free to come over, test it and report your results.

We are not perfect: mistakes of varied nature **will** crop up while editing **Palaeos** for any number of reasons which are neither here nor there. If the perceptive, knowledgeable reader wishes to do so he or she has listed below the contacts of the site editors to which their query can be sent. The query should include a link to the offending page and a succinct description of the issue. If it deals with matters of Science please include the pertinent reference(s). Note that an editor may at their discretion forward your query to the other editors.

- M. Alan Kazlev: **akazlev *(at)* mail *(dot)* com**
- Renato Santos: **dracontes *(at)* gmail *(dot)* com**
- Roger Perkins: **rgperkins *(at)* att *(dot)* net**

Thank you very much for your interest in keeping us honest!

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It's impossible, or at least totally impractical, to put up a proper site map. So the following is just a bare bones coverage, which only includes the main pages of the various sections. With time, more pages may be listed.

Abbreviated Index

(Stubby units and placeholder sections are marked with an asterix)

(Click for more detailed index)

- **Palaeos Main/Home/Root** (the present pages which introduce the whole thing; click on the Palaeos trilobite logo to return to the index page)
- **Deep Time** (being one of the main parameters of Palaeos, Deep Time (geological and cosmic) is distinguished from ordinary human scale time)
    - Cosmic Time
    - Geological Timescale (one of the two central themes of Palaeos)
        - Chaotian
        - Hadean
        - Archean
        - Proterozoic
        - Paleozoic

Main Index

Palaeos Main / Home / Root

- **Palaeos** Home Page (top level / root / home / intro: divides into Deep Time, Cosmic Evolution, Science, Resources, and Site authors)
    - About Palaeos
    - New & Revised Pages
    - Overview
    - FAQs
    - Glossary
    - Sitemap (you are here)

The Big Picture

- Time (i.e Deep Time, one of the primary subdivisions of **Palaeos**: divides into Cosmic Time, Geological Timescale, Quaternary Time, Historical Time, and Future Time—History having nothing to do with Deep Time and only included so that everything can be neatly organised)
    - Deep Time
    - Logarithmic Timescale

        - Cosmic Calendar
        - Timescales
- Evolution: the Big Picture (aka Cosmic Evolution) (one of the primary subdivisions of **Palaeos**: divides into Cosmos, Abiotic evolution, Life, Mind, and Singularity)
        - Complexity
        - The Self-Organizing Universe
        - Big History Deep Time
        - Cosmic Evolution
        - Glossary
        - References

Cosmic Timescale

- Cosmos (the pre-Solar System period, one of the primary subdivisions of time, no further major subcategories as yet (for those you need to go to NASA or similar websites)
        - Cosmology
        - Time
            - Five ages of the Universe
        - The Primordial Era
            - Very Early Universe
            - Early Universe
            - References
        - The Stelliferous Era
            - Structure formation: Galaxies and Stars
            - The Elements
        - Glossary

Geological Timescale

- Geological Timescale (one of the primary subdivisions of Deep Time and major **Palaeos** topic: divides into Chaotian, Hadean, Archean, Proterozoic, Paleozoic, Mesozoic, and Cenozoic)
        - The Discovery of Deep Time
            - Pre-modern concepts of Time
            - Geology and the discovery of Deep Time
            - Reading List
        - Geological Timescale
            - Stratigraphy
            - Radiometric dating
            - Detailed Geological Timescale
                - Precambrian Time
                - Phanerozoic Eon
            - Geological Time Units
            - Geon
            - Glossary
            - References
        - Other Planetary Timescales
            - Lunar Geological timescale
            - Martian Geological timescale
- Chaotian (subdivision of Geological Timescale)
        - Earth's forgotten youth, and beyond
        - Eochaotian
        - Neochaotian
        - References
- Hadean (subdivision of Geological Timescale)
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        - Paleohadean

        - Mesohadean
        - Neohadean
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- Archean (subdivision of Geological Timescale)
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    - Proterozoic 3
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    - Paleoproterozoic
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        - Ediacaran
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            - Ediacaran 3
            - Ediacaran 4
            - References
- Paleozoic (subdivision of Geological Timescale)
- Mesozoic (subdivision of Geological Timescale)
- Cenozoic (subdivision of Geological Timescale)
- Quaternary (subdivision of Time)

(the above entries will be filled out in due course)

Historical and Future Time

- History (subdivision of Time)
- Some Possible Futures (subdivision of time)
    - Possible Futures subdivision:
        - Extinction (Post-apocalypse)
        - Impoverishment (Suburban sprawl and monoculture)
        - Diversity (Ecotopia)

Abiotic evolution

- Abiotic evolution (major subdivision of Cosmic Evolution, includes Earth)
    - Quantum physical
    - Stars and Galaxies
    - Chemical Elements
    - Mineral evolution
- Earth (subdivision of Abiotic evolution)

    - Geology
    - Plate tectonics
    - Oceanography
    - Paleogeography (many pages)
    - Climate
    - Glossary

Life and the evolution of life on Earth

- Life (major subdivision of Cosmic Evolution, includes Taxonomy, Paleontology, Evolution, Phylogeny, Ecology, Astrobiology, and Life on Earth)
    - Glossary
- Evolution (subdivision of Life)
    - Evolution
    - Glossary
    - References
- Paleontology (subdivision of Life)
- Systematics (subdivision of Life)
    - Overview of Systematics
    - "The Great Chain of Being"
    - Linnaean taxonomy
    - Evolutionary Tree
    - Evolutionary systematics
    - Phylogenetic systematics (Cladistics)
    - Molecular phylogeny
    - Stratigraphy and phylogeny
    - Phylogenetics
    - Taxonomy
    - Glossary
    - References
- Ecology
- Astrobiology (subdivision of Life)
- Life on Earth (= "Tellurobiota") (subdivision of Life and major **Palaeos** topic: divides into Bacteria, Eukarya, Plants, Fungi, Invertebrates, and Vertebrates)
    - Life
    - Kingdoms of Life
    - Tree of Life
- Bacteria (subdivision of Life on Earth)
    - Bacteria
    - Eubacteria
    - Glossary
    - Pieces
    - Dendrograms
    - References
- Archaea (subdivision of Life on Earth)
- Eukarya (subdivision of Life on Earth)
- Plants (subdivision of Life on Earth)
- Fungi (subdivision of Life on Earth)
- Metazoa: Invertebrates (subdivision of Life on Earth)
- Metazoa: Vertebrates (subdivision of Life on Earth)

(the above entries will be expanded in due course)

The human condition and beyond

- Sociocultural (subdivision of Cosmic Evolution)

- Singularity (Posthuman transcension) (subdivision of Cosmic Evolution)
    - Posthuman subdivision:
    - Singularity (Posthuman transcension)
    - Glossary
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Science, Biographies, Resources, etc

- Science (one of the primary subdivisions of **Palaeos**, includes biographies and Historical timeline of discoveries)
    - Scientists, etc
        - (Alphabetical listing)
            - Lamarck
            - Darwin
        - References
        - Timeline
            - Timeline of discoveries and popular culture
    - References
- Resources (one of the primary subdivisions of **Palaeos**: no further major subcategories)
    - Book reviews
    - Paleo web sites and wikis
    - Paleo blogs
    - PDF resources
- **Palaeos** authors and contributors (one of the primary subdivisions of **Palaeos**: no further major subcategories)

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Palaeos is currently undergoing a major overhaul. For this reason, the old links aren't working, and many of the replacement pages and directories—including ones linked to from pages already on the site—haven't been posted yet. However we are working very hard at upgrading the site, and everything should be ready soon.

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Books

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

By Author

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Walker, Gabrielle (2003), **Snowball Earth**. Crown Group: 269 pp. ISBN 0-7475-6433-7. (Earth systems)

Wallace, David R. (2004), **Beasts of Eden: Walking Whales, Dawn Horses, and Other Enigmas of Mammal Evolution**. U. Calif. Press, 340 pp. (History, Paleontology)

Whittington, HB, BDE Chatterton, SE Speyer, RA Fortey, RM Owens, WT Chang, WT Dean, PA Jell, JR Laurie, AR Palmer, LN Repina, AWA Rushton, JH Shergold, ENK Clarkson, NV Wilmot, & SRA Kelly (1997), **Treatise on Invertebrate Paleontology, Part O (Revised) Arthropoda 1, vol. 1: Trilobita: Introduction, Order Agnostida, Order Redlichiida.** RA Kaesler [ed.]. Geol. Soc. Amer. & Univ. Kan., 530+ pp. (Systematics)

Zimmer, Carl (1998), **At the Water's Edge: Fish with Fingers, Whales with Legs, and How they Came Ashore, but Then Went Back to Sea**. Free Press, 290 pp. ISBN 0-684-83490-1. (evolution)

By Subject

Anatomy

Romer, Alfred S (1956), **Osteology of the Reptiles**. 1997 reprint ed. Krieger Publ. Co., 772 pp. ISBN 0-89464-985-X (anatomy)

Evolution

Conway Morris, S (1998), **The Crucible of Creation**. Oxford Univ. Press, 266 pp. (Evolution)

Fortey, Richard A (2000), **Trilobite! Eyewitness to Evolution**. HarperCollins, 269 pp. ISBN 0-00-257012-2, 0375406255? (evolution, paleontology)

McMenanin, Mark AS (1998), **The Garden of Ediacara: Discovering the First Complex Life**. Columbia Univ. Press, 295 pp. ISBN 0-231-10558-4 (evolution)

Prothero, Donald R & RM Schoch (2002), **Horns, Tusks, and Flippers: The Evolution of Hoofed Mammals**. Johns Hopkins Univ. Press., 311 pp. ISBN 0-8018-7135-2 (evolution, zoology)

Zimmer, Carl (1998), **At the Water's Edge: Fish with Fingers, Whales with Legs, and How they Came Ashore, but Then Went Back to Sea**. Free Press, 290 pp. ISBN 0-684-83490-1. (evolution)

General

Dixon, Douglas, B Gardiner, D Palmer, B Cox, & RJ Savage (1999), **The Simon and Schuster Encyclopedia of Dinosaurs and Prehistoric Creatures : A Visual Who's Who of Prehistoric Life**. Simon & Schuster, 312 pp. ISBN: 0684864118 (general)

Gould, Stephen J [ed.] (2001), **The Book of Life: An Illustrated History of the Evolution of Life on Earth, 2nd ed.** Norton: 256 pp. (General)

Geology & Earth Systems

Benton, Michael J. (2003), **When Life Nearly Died: the Greatest Mass Extinction of all Time**. Thames & Hudson, 336 pp. (paleoecology, geology)

Walker, Gabrielle (2003), **Snowball Earth**. Crown Group: 269 pp. ISBN 0-7475-6433-7. (Earth systems)

History

Wallace, David R. (2004), **Beasts of Eden: Walking Whales, Dawn Horses, and Other Enigmas of Mammal Evolution**. U. Calif. Press, 340 pp.

Paleobiology

Parker, Andrew (2003), **In the Blink of an Eye**. Perseus Publishing, 316 pp. ISBN 0-7382-0607-5 (paleobiology)

Paleoecology

Behrensmeyer, Anna K, JD Damuth, WA DiMichele, R Potts, H-D Sues & SL Wing [eds.] (1992), **Terrestrial Ecosystems through Time: the Evolutionary Paleoecology of Terrestrial Plants and Animals**. Univ. Chicago Press, 568 pp. Collective author, the Evolution of Terrestrial Ecosystems Consortium. (paleoecology)

Benchley, Peter J & DAT Harper (1998), **Palaeoecology: Ecosystems, Environments and Evolution**. Chapman & Hall. (paleoecology)

Benton, Michael J. (2003), **When Life Nearly Died: the Greatest Mass Extinction of all Time**. Thames & Hudson, 336 pp. (paleoecology, geology)

Paleontology

Clack, Jennifer A (2002), **Gaining Ground: the Origin and Evolution of Tetrapods**. Indiana Univ. Press, 369 pp. ISBN 0-253-34054-3. (paleontology, systematics)

Currie, Phillip J & K Padian [eds.] (1997), **Encyclopedia of Dinosaurs**. Academic Press, 869 pp. (Paleontology)

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Vickers Rich, Patricia, TH Rich, MA Fenton, & CL Fenton (1997), **The Fossil Book : A Record of Prehistoric Life**. Dover Publ., 760 pp. ISBN: 0486293718 (Paleontology)

Wallace, David R. (2004), **Beasts of Eden: Walking Whales, Dawn Horses, and Other Enigmas of Mammal Evolution**. U. Calif. Press, 340 pp.

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Systematics

Clack, Jennifer A (2002), **Gaining Ground: the Origin and Evolution of Tetrapods**. Indiana Univ. Press, 369 pp. ISBN 0-253-34054-3. (paleontology, systematics)

Rose, Kenneth D & J David Archibald [eds.] (2005), **The Rise of Placental Mammals: Origins and Relationships of the Major Extant Clades**. Johns Hopkins University Press, 259 pp. (systematics)

Whittington, HB, BDE Chatterton, SE Speyer, RA Fortey, RM Owens, WT Chang, WT Dean, PA Jell, JR Laurie, AR Palmer, LN Repina, AWA Rushton, JH Shergold, ENK Clarkson, NV Wilmot, & SRA Kelly (1997), **Treatise on Invertebrate Paleontology, Part O (Revised) Arthropoda 1, vol. 1: Trilobita: Introduction, Order Agnostida, Order Redlichiida.** RA Kaesler [ed.]. Geol. Soc. Amer. & Univ. Kan., 530+ pp. (Paleontology, Systematics)

Zoology

Prothero, Donald R & RM Schoch (2002), **Horns, Tusks, and Flippers: The Evolution of Hoofed Mammals**. Johns Hopkins Univ. Press., 311 pp. ISBN 0-8018-7135-2 (evolution, zoology)

By Taxon (in more or less phylogenetic order)

Ediacaran ?Fauna

McMenanin, MAS (1998), **The Garden of Ediacara: Discovering the First Complex Life**. Columbia Univ. Press, 295 pp. ISBN 0-231-10558-4

Trilobita

Fortey, Richard A (2000), **Trilobite! Eyewitness to Evolution**. HarperCollins, 269 pp. ISBN 0-00-257012-2, 0375406255? (evolution, paleontology)

Whittington, HB, BDE Chatterton, SE Speyer, RA Fortey, RM Owens, WT Chang, WT Dean, PA Jell, JR Laurie, AR Palmer, LN Repina, AWA Rushton, JH Shergold, ENK Clarkson, NV Wilmot, & SRA Kelly (1997), **Treatise on Invertebrate Paleontology, Part O (Revised) Arthropoda 1, vol. 1: Trilobita: Introduction, Order Agnostida, Order Redlichiida.** RA Kaesler [ed.]. Geol. Soc. Amer. & Univ. Kan., 530+ pp. (Systematics)

Tetrapoda

Clack, Jennifer A (2002), **Gaining Ground: the Origin and Evolution of Tetrapods**. Indiana Univ. Press, 369 pp. ISBN 0-253-34054-3. (paleontology, systematics)

Zimmer, Carl (1998), **At the Water's Edge: Fish with Fingers, Whales with Legs, and How they Came Ashore, but Then Went Back to Sea**. Free Press, 290 pp. ISBN 0-684-83490-1. (evolution)

Amniota

Romer, Alfred S (1956), **Osteology of the Reptiles**. 1997 reprint ed. Krieger Publ. Co., 772 pp. ISBN 0-89464-985-X (anatomy)

Dinosauria

Currie, Phillip J & K Padian [eds.] (1997), **Encyclopedia of Dinosaurs**. Academic Press, 869 pp. (Paleontology)

Theropoda

Paul, Gregory S (1988), **Predatory Dinosaurs of the World**. Simon & Schuster. (paleontology, paleobiology)

Mammalia

Wallace, David R. (2004), **Beasts of Eden: Walking Whales, Dawn Horses, and Other Enigmas of Mammal Evolution**. U. Calif. Press, 340 pp.

Eutheria

Rose, Kenneth D & J David Archibald [eds.] (2005), **The Rise of Placental Mammals: Origins and Relationships of the Major Extant Clades**. Johns Hopkins University Press, 259 pp. (systematics)

Ungulata

Prothero, Donald R & RM Schoch (2002), **Horns, Tusks, and Flippers: The Evolution of Hoofed Mammals**. Johns Hopkins Univ. Press., 311 pp. ISBN 0-8018-7135-2 (evolution, zoology)

Cetacea

Zimmer, Carl (1998), **At the Water's Edge: Fish with Fingers, Whales with Legs, and How they Came Ashore, but Then Went Back to Sea**. Free Press, 290 pp. ISBN 0-684-83490-1. (evolution)

By Time Period

Neoproterozoic

Walker, Gabrielle (2003), **Snowball Earth**. Crown Group: 269 pp. ISBN 0-7475-6433-7. (Earth systems)

Ediacaran

McMenanin, MAS (1998), **The Garden of Ediacara: Discovering the First Complex Life**. Columbia Univ. Press, 295 pp. ISBN 0-231-10558-4

Cambrian

Conway Morris, S (1998), **The Crucible of Creation**. Oxford Univ. Press, 266 pp. (Evolution)

Parker, Andrew (2003), **In the Blink of an Eye**. Perseus Publishing, 316 pp. ISBN 0-7382-0607-5 (paleobiology)

Devonian

Clack, Jennifer A (2002), **Gaining Ground: the Origin and Evolution of Tetrapods**. Indiana Univ. Press, 369 pp. ISBN 0-253-34054-3. (paleontology, systematics)

Zimmer, Carl (1998), **At the Water's Edge: Fish with Fingers, Whales with Legs, and How they Came Ashore, but Then Went Back to Sea**. Free Press, 290 pp. ISBN 0-684-83490-1. (evolution)

Carboniferous

Clack, Jennifer A (2002), **Gaining Ground: the Origin and Evolution of Tetrapods**. Indiana Univ. Press, 369 pp. ISBN 0-253-34054-3. (paleontology, systematics)

Permian

Benton, Michael J. (2003), **When Life Nearly Died: the Greatest Mass Extinction of all Time**. Thames & Hudson, 336 pp. (paleoecology, geology)

Mesozoic

Currie, Phillip J & K Padian [eds.] (1997), **Encyclopedia of Dinosaurs**. Academic Press, 869 pp. (Paleontology)

Triassic

Benton, Michael J. (2003), **When Life Nearly Died: the Greatest Mass Extinction of all Time**. Thames & Hudson, 336 pp. (paleoecology, geology)

Cenozoic

Prothero, Donald R & RM Schoch (2002), **Horns, Tusks, and Flippers: The Evolution of Hoofed Mammals**. Johns Hopkins Univ. Press., 311 pp. ISBN 0-8018-7135-2 (evolution, zoology)

Rose, Kenneth D & J David Archibald [eds.] (2005), **The Rise of Placental Mammals: Origins and Relationships of the Major Extant Clades**. Johns Hopkins University Press, 259 pp. (systematics) (with some discussion of Cretaceous mammals)

Eocene

Zimmer, Carl (1998), **At the Water's Edge: Fish with Fingers, Whales with Legs, and How they Came Ashore, but Then Went Back to Sea**. Free Press, 290 pp. ISBN 0-684-83490-1. (evolution)

By Title

At the Water's Edge: Fish with Fingers, Whales with Legs, and How they Came Ashore, but Then Went Back to Sea. Zimmer, Carl (1998), Free Press, 290 pp. ISBN 0-684-83490-1. (evolution)

Beasts of Eden: Walking Whales, Dawn Horses, and Other Enigmas of Mammal Evolution. Wallace, David R. (2004), U. Calif. Press, 340 pp. (History, Paleontology)

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Gaining Ground: the Origin and Evolution of Tetrapods. Clack, Jennifer A (2002), Indiana Univ. Press, 369 pp. ISBN 0-253-34054-3. (paleontology, systematics)

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Osteology of the Reptiles. Romer, Alfred S (1956), 1997 reprint ed. Krieger Publ. Co., 772 pp. ISBN 0-89464-985-X (anatomy)

Palaeoecology: Ecosystems, Environments and Evolution. Benchley, Peter J & DAT Harper (1998), Chapman & Hall. (paleoecology)

Rise of Placental Mammals: Origins and Relationships of the Major Extant Clades. Rose, Kenneth D & J David Archibald [eds.] (2005), Johns Hopkins University Press, 259 pp. (systematics)

Simon and Schuster Encyclopedia of Dinosaurs and Prehistoric Creatures : A Visual Who's Who of Prehistoric Life. Dixon, Douglas, B Gardiner, D Palmer, B Cox, & RJ Savage (1999), Simon & Schuster, 312 pp. ISBN: 0684864118 (general)

Snowball Earth. Walker, Gabrielle (2003), Crown Group: 269 pp. ISBN 0-7475-6433-7. (Earth systems)

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Trilobite! Eyewitness to Evolution. Fortey, Richard A (2000), HarperCollins, 269 pp. ISBN 000-257012-2, 0375406255? (evolution, paleontology)

When Life Nearly Died: the Greatest Mass Extinction of all Time. Benton, Michael J. (2003). Thames & Hudson, 336 pp. (paleoecology, geology).

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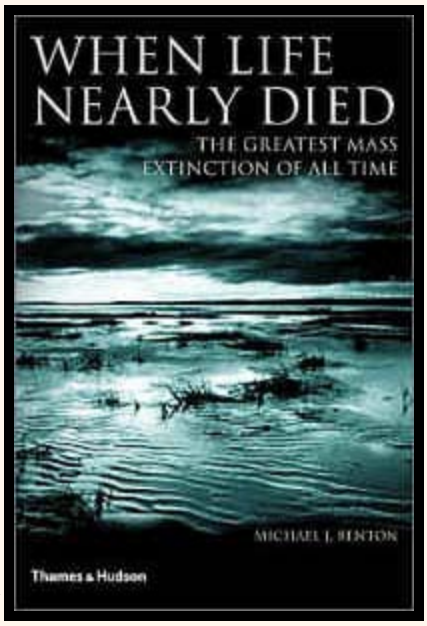
Book Reviews & Descriptions (A-L)

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

-B-

Benchley, PJ & DAT Harper (1998), **Palaeoecology: Ecosystems, Environments and Evolution**. Chapman & Hall

Very highly recommended, an excellent and comprehensive introduction to palaeoecology in all its facets. Many references for those who wish to explore the subject further.



Benton, Michael J. (2003), **When Life Nearly Died: the Greatest Mass Extinction of all Time**. Thames & Hudson, 336 pp. ISBN 0-500-05116-X

Michael Benton's latest book is a semi-popular explanation of the end-Permian extinction. Over the last two decades, paleontologists have reached consensus that the end-Permian ("PT") event was the greatest biotic disaster of the Phanerozoic, and possibly of all time. It is hard to know how seriously to take figures of this sort, but Benton cites species extinction rates of 95% and more. Even this figure, he suggests, is conservative because it does not take into account additional pulses of extinction, including a slightly later Olenekian event. He describes the PT devastation as world-wide, non-selective, and so thorough that ten million years were required to recover to more or less normal levels of biodiversity.

Explaining why and how the PT extinction happened is a difficult task, but Benton does it very well indeed. More than half of the book is history and background. Normally, this would be irritating, but Benton covers it so fluidly that one doesn't really mind. The heart of the PT problem is stratigraphy -- both the science of stratigraphy and the philosophical bias of the stratigraphic community. Benton has an almost unmatched ability to tell the science part of any paleontological tale in plain, straightforward

prose. In this book, Benton shows us that he can also produce, at the same time, a well-structured story about the interaction between philosophy and science in the geological community, as well as the interplay between geologists, paleontologists, and others. In short, this is that rare book, a really balanced and compelling study of a scientific idea, including both its content and its history.

Personally, I am perhaps even more impressed with Benton the historian than with Benton the writer or Benton the paleontologist. He never bogs down in personalities. He tries to understand both Victorian Englishmen and Soviet apparatchiks on their own terms and usually succeeds. True, he inserts the conventional reminder that the former were arrogant imperialists, and he does gloss over some uncomfortable truths about Soviet science -- all according to the latest academic fashion. However, Benton's writing is too clear and honest to allow even self-deceptions to cloud the facts.

If there is any disappointment in the book, it is on the science side. However, this was intended to be a semi-popular book, and it would be churlish to expect too much. Benton concludes that the Siberian Traps were responsible for the PT extinction. If his marshalling of the evidence for this hypothesis is less than compelling, it is probably only because the evidence itself is still less than compelling.

He is probably correct, but there are aspects of the PT event which are still very unclear. Unfortunately, most of these issues remain unresolved due to the same problems which have bedeviled the PT question from the very beginning -- the intractable issues of dating and stratigraphy around the PT boundary. We just don't know, not even to an order of magnitude, how long the die-off took. Our knowledge of the recovery phase is just as bad. Everyone agrees that the recovery took a long time. Certainly it took over a million years, but whether it was 1, 5, 10, or 20 My depends on what one's criteria are and on the uncertainties of Early Triassic stratigraphy.

A few examples will suffice. The Induan Age, the first age of Triassic, has been shrinking. Not very long ago, it was supposed to have lasted about 5 My. Now, the best estimate is 1.3 My and possibly as little as 0.2 My. Obviously this makes a huge difference in how one views the initial post-PT world. Another problem is the supposed Late Olenekian extinction. Benton views it as a mass extinction. Others see it (as Benton is fair enough to state) as faunal turnover connected with recovery, much like a succession series in any ecological recovery (see our discussion at Olenekian). Which view is correct depends critically on what organisms were where and at what time. The issue simply cannot be resolved without a much finer parsing of the stratigraphic record.

But enough of that sort of thing. The scientific issues are sometimes frustrating and difficult. The book, on the other hand, is simply a really good book. At the moment, its US$30 price is a bit steep for many of us; but, by all means, get it when you can. ATW040209.

Postscript: very recent dating of the Siberian flood vulcanism places this series of events at about 251.3 Mya, with most locations dating between 251.7 and 251.1 Mya (all dates ±0.3 My), resulting in the extrusion of 2-4 million cubic *kilometers* of volcanic material. Kamo *et al*. (2003). This is extremely close to the currently accepted date for the end-Paleozoic of 251.0. Unfortunately, the Permo-Triassic boundary is placed about 1My *after* the main pulse of extinction. So we still have a small, but annoying gap, with the extinctions taking place slightly *before* Central Siberia turned into an incandescent mud bath. In addition, the figures sound large, but amount to no more than a single Krakatoa-size (20 km³ ejecta) event every 4 years, on the average. Maybe enough to threaten the existence of life, but maybe not. Once again, we just don't have the temporal resolution down fine enough to tell. If, for example, 100 Krakatoas, had exploded during even one of those 500-600 ky, we might well not be around today to discuss the matter today. The odds are that no more than 10-15 or so would have occurred in even the worst year, if the distribution were random. [Check my math: I make it 3,000,000 km³/ 20 km³ = 150,000 Krakatoa-equivalents. 150,000 Keq / 600,000 yr = 0.25 Keq/yr on the average. The chance of 10 in any given year is then $(0.25)^{10} = 9.54 \times 10^{-7}$. The chance of ten *not* happening at all in 600,000 years is $(1 - 9.54 \times 10^{-7})^{600,000} = 0.564$] However this assumes that the rate of vulcanism was randomly distributed, which is a very, very bad assumption.

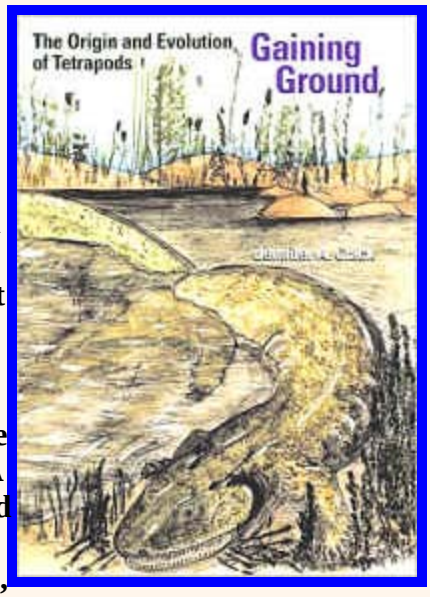
Kamo, SL, GK Czamanske, Y Amelin, VA Fedorenko, DW Davis & VR Trofmov (2003), *Rapid eruption of Siberian flood-volcanic rocks and evidence for coincidence with the Permian-Triassic boundary and mass extinction at 251 Ma*. **Earth & Planet. Sci. Lett.** 214: 75-91.

Vertebrate Palaeontology by Michael J. Benton, illustr. by John Sibbick - more readable than Carroll's masterwork, a good basic-level textbook

-C-

Vertebrate Paleontology and Evolution **- by Robert L. Carroll. - rather dated now, but in many ways still the classic work on the subject. Covers everything from jawless fish to dinosaurs to mammals. Quite technical for the beginner, but worth persevering if this is your interest. An invaluable reference work. One of the last non-cladistic books on vertebrate paleontrology**

Clack, Jennifer A (2002), Gaining Ground: the Origin and Evolution of Tetrapods. Indiana Univ. Press, 369 pp. ISBN 0-253-34054-3.



Gaining Ground **is about the evolution of terrestriality in the tetrapods; not a topic about which a great deal is presently accessible to the layman. The book is written by someone currently active in the field, and so possesses the greatest possible authority and currency.**

However, I feel *GG* falls between audiences. The book probably amounts to little more than a review for the specialist, yet it is vastly over-whelming for the layman and too poorly organised to provide much value to serious students. A comment like that requires an explanation or, rather, two. First, the poor old layman (and, in the field of vertebrate paleontology, I am as good an example as any) is presented with the obligatory 20 pages or so explaining what is a fossil, what is the geological timescale, what is phylogeny, and so on, gratuitously pausing to mention that "birds *are* dinosaurs" (definitely a red rag to *this* bull - read why). This is all rather mundane stuff, which any layman interested in paleontology will have read dozens of times. The next nine pages, however, are a very different story. Here is a sample:

> **'The appendicular skeleton comprises the limbs and girdles, at the front the shoulder or pectoral set, and at the back, the hip or pelvic set. Figure 2.5 shows views of the shoulder and Figure 2.6 the hip girdles of *Eusthenopteron* and a tetrapod. The pectoral girdle is a mixture of elements, consisting of dermal bones such as the cleithrum, clavicle, and interclavicle and the endochondral scapulocoracoid. It is this latter bone that provides the articulatory socket, or glenoid, for the pectoral appendages, and it fits within and behind the sheathing series of dermal bones.' — p. 29**

Wow, what a transition! But this is not simply a case of picking up the pace: actually understanding much of the subsequent text requires one to have learned (or at least remembered the names of) these bones from this whirlwind tour. I venture to suggest this material is simply too densely-written for a lay audience; I expect many a second-year vertebrate zoology student would struggle with it.

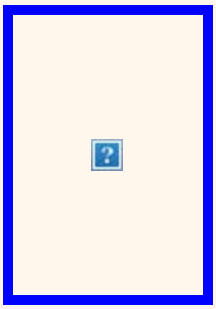
Which brings us to my second point, really a generalisation of the first. The organisation of the book is not really conducive to learning. For one example, it is set out geochronologically rather than by smaller-scale evolutionary themes (more interesting for the layman, perhaps, but unhelpful to the struggling student). Another example, which particularly nagged me, is the inconsistent use of various taxonomic ranks. One minute we're talking about lysorophids, the next microsaurs, then lepospondyls. It was only once I took out a notebook and began sytematically tracking all these names down in the text that I discovered that a lysorophid is a kind of microsaur, which in turn is a kind of lepospondyl, except it might not be. It shouldn't require detective work to learn the sense of a textbook. Incidentally, I was prompted to undertake this exercise in order to compare the cladograms which fill the book from page 271 onwards, and are the worst example of this problem. Without your own "systematic index" these will be a complete mystery to even an advanced student, who, gazing at fig. 10.3 for example, is otherwise unlikely to realise that *Paleothyris* is included as a proxy for the Diapsida.

One aspect that particularly impressed me and which, to be fair, may have been impossibleto achieve with a different structure, was the breadth adopted at the beginning of several chapters, to place the "action" in a meaningful ecological context. These small vignettes paint a reasonable picture of the life and times of *Acanthostega* et al., and alone are worth the price of the book.

Recommendation: **Recommended, though with the provision mentioned above.**

Look and Feel: **A good-quality hardback. Photographs are matt b&w, and the reproduction somewhat variable. The many line drawings are mostly very good.**

Conway Morris, S (1998), The Crucible of Creation. Oxford Univ. Press, 266 pp.



This book is straight from the horse's mouth, so to speak. Conway Morris was one of the original team involved in the massive effort of re-examining and re-interpreting the Burgess Shale collections from Walcott's Quarry and nearby.

The book begins with a rather strange discussion about evolution – presumably motivated by a desire to bury the tosh that Stephen J. Gould tossed up in his book, *Wonderful Life* [® sidebar] – before moving on to setting the scene; both in terms of the history of life (there is a page or two about the Ediacaran biota) and of the locality itself.

Next the author describes some of the organisms in more detail, beginning with *Hallucinigenia* which he originally misinterpreted. The main taxonomic section of the book is organized into chapters corresponding to ecological, rather than phylogenetic groupings: mud-dwellers, mud-stickers, walkers and crawlers, and swimmers.

The next chapters compare the Burgess Shale Lagerstätten with similar faunas elsewhere in the world, including the Sirius Passet locality which Conway Morris was instrumental in bringing to world attention. The author then essays a synthesis of these faunas and an interpretation their evolutionary significance. This provides him with another opportunity to debunk Gould and offer less dramatic explanations on the Cambrian "explosion," the genetic underpinning of evolution, animal architecture, and more.

This book, as a whole, is rather idiosyncratic – though amusingly so – combining quirky metaphors with hard science. It is an easy read for anyone who knows a bit about geology and I would guess that anybody who had a mind to could get through it and understand everything.

Recommendation: **Recommended.**

He is taken to task for this criticism by Richard Fortey, in the latter's book, *Trilobite* (see also London Review of Books).

> 'I have never encountered such spleen in a book by a professional; I was taken aback. ... It is, of course, perfectly legitimate to have differences of scientific opinion, – in fact, it is an essential ingredient of progress. But what surprised me here was the unwonted explosiveness.... The detail of the attempt to cast Gould in a poor light extended into the depths of footnotes.' – p. 136

He goes on to speculate:

> '[Gould's book] *Wonderful Life* was such a global success. There, preserved in the aspic of a print that could never be unprinted, was ... the Conway Morris of the early 1980s. The nineties version disowned the ideas of the earlier one, and quite right, too: scientists are supposed to move with the times. ... [T]he root cause of Simon's explosion was not envy of Gould, but resentment of the hold he had on the past.' – p. 138

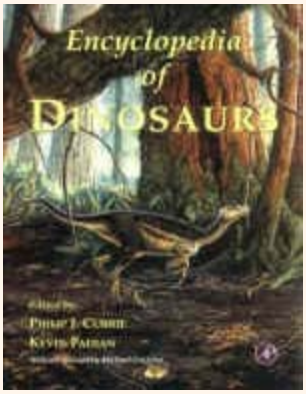
Fortey *may* have the right of it, but I think he has taken pop psychology just a tad too far and overlooked the obvious. I think it's more likely that Conway Morris (and others) are simply pissed off with Gould's chest-thumping brand of self aggrandizement.

Look and Feel: **Hardback; good quality paper with high resolution b&w photographs and some colour plates, extensive reading lists, and a good index, but by no means a text book.**

Other reviews: **Book Review - Crucible of Creation- The Burgess Shale and the ...; OUP- Crucible of Creation- Conway Morris (publisher's blurb); The Crucible of Creation- The Burgess Shale and the Rise of ... (extended excerpt); Book Reviews- Morris (extensive discussion); Jack's Stacks- January, 1999; The Eagle 1999 - Book reviews; The Crucible of Creation.**

> And who wouldn't be? Gould takes a self-evident proposition – that Cambrian animals were a diverse and unfamiliar lot – and over-blows it into yet another one of his grandiose 'pattern of nature' theories. And, of course, only our Stephen is clever enough to have realized the *real* significance of the work Whittington, Conway Morris and Briggs have been slaving over for years. Not only that, he makes his pitch direct to the public in a popular book.
>
> Blurrgh!

Currie, PJ & K Padian [eds.] (1997), Encyclopedia of Dinosaurs. Academic Press, 869 pp.



ISBN 0-1222-6810-5

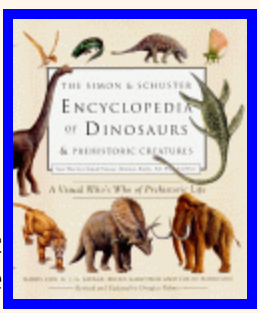
A landmark book, collecting together a huge range of information about dinosaurs which would ordinarily only be available to those with access to a professional research library. The writing is generally dispassionate, the information generally balanced and well-presented.

Recommendation: **Recommended, but don't make it your only reference.**

Look and Feel: **Good quality hardback. Photographs and good diagrams are plentiful. The few coloured plates could have been put to better use than reproducing various artists' impressions of what dinosaurs may have looked like.**

-D-

Dixon, D, B Gardiner, D Palmer, B Cox, & RJ Savage (1999), The Simon and Schuster Encyclopedia of Dinosaurs and Prehistoric Creatures : A Visual Who's Who of Prehistoric Life. Simon & Schuster, 312 pp. ISBN: 0684864118



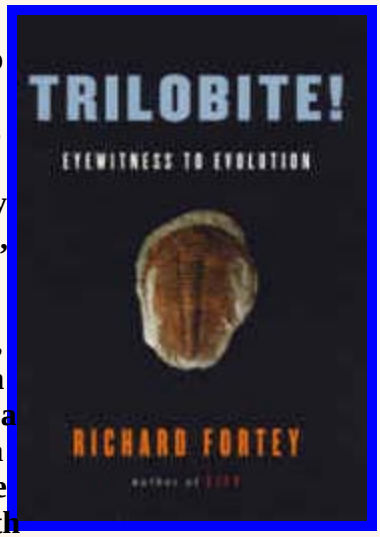
This is a very good non-technical introduction to prehistoric vertebrates. Although there is a brief coverage of basic background topics - how fossils form, continental drift, etc - by the far the most interesting, and indeed the bulk, of the book is the coverage it gives to a large number of individual genera (more than 600 altogether, from primitive fish to Pleistocene mammals), each of which is illustrated by a specially commissioned full-colour painting. It is the sheer number and diversity of creatures covered here, that makes this book so interesting. (But even that diversity is just a tiny fraction of all the types of prehistoric creatures that are known to science). The realism of the art work tends to vary - some drawings seem to me more realistic than others, but I suppose that's just personal taste. The art work is still of good quality throughout though, and often represents the only life-reconstructions available

for creatures otherwise shown only as drawings of skeletons in palaeontological textbooks. Obviously, the colour schemes are speculative, since it is not known what these animals really looked like. The accompanying text is brief and non-technical but still clear and informative, and gives a basic introduction to that type of animal. The best thing about this book is that it's not just about dinosaurs (although these are covered in detail) but also deals with many other types of vertebrate creatures as well. My only real criticism is that despite the title - "animals" - no invertebrate animals were included, no trilobites, eurypterids, nautiloids etc. Still, you can only cover so much in the space available, and this book does a pretty good job.

M. Alan Kazlev 2001.

-F-

Fortey, Richard A (2000), Trilobite! Eyewitness to Evolution. HarperCollins, 269 pp. ISBN 0-00-257012-2, 0375406255?



When I read the introduction to one of Fortey's earlier books, Hidden Landscape, I immediately realized that here was someone who truly understands how it feels to hammer open a rock and discover some treasure within. However, the introductory chapter of Trilobite!, which involves an over-extended parable about some Thomas Hardy character, exceeded some kind of threshold in my mind and became, simply, florid. Fortunately, the introduction is soon over and we jump into some very lightly technical details about the beasts themselves: a field in which Fortey is, justly, considered pre-eminent.

> **"So in just eight technical terms – cephalon, thorax, pygidium, segment, axis, pleura, glabella, eyes – it is possible to begin to embrace the form of these strange animals. To be able to name the parts introduces a certain familiarity. Further, to be competent to recognize the glabella for what it is means that it does not take long to see that one trilobite has a glabella which is quite different from that of another. With language comes discrimination." – p. 29**

Three of the early chapters are organized along morphological lines – Shells, Legs, and Crystal Eyes – each describing important parts of the creatures' anatomy. It is in the legs chapter, perhaps appropriately, that Fortey really hits his straps with a 'parade' of common trilobites, lasting a few pages, from the most ancient to the last of their kind. Each is summed up in a few (too few, for me) sentences, sketching the history of their discovery and a quirky description, of sorts. To give you a taste of what you're in for, here's *Olenellus*:

> **"The widest part of the animal is at the head end where there are prominent spines at either corner, behind which the body tapers gradually backwards along a thorax comprising many, rather flat segments with prominently spiny tips. … Somehow this *looks* like a primitive trilobite. It has not yet developed the sutures crossing the headshield that helped its relatives during molting." – pp. 69-70**

The eyes chapter begins with the brief exposition of a highly unlikely notion – some bizarre spin-off of Gould's "re-played tape" nonsense – to the effect that, but for historical accident, the sense of sight might not have evolved: "the inevitability of vision is … uncertain" (p. 79). Well, I think that's just bunk and Fortey should stick to trilobites. There is zero likelihood of a world ruled by, say, smell because – moths notwithstanding – it just isn't a very useful sense. I could go on about the relationship between wavelength and resolution, but the reader would be better served by Richard Feynman; try The Character of Physical Law for an excellent starter. (Hint: The wavelength of some aromatic molecule with an atomic weight in the bazillions, wafting around in the atmosphere, is not small.) Fortunately one has to endure only a page of this crap before the author is back among the fields he knows – *Hox* genes, in this particular instance.

Next appears a rather exotic chapter, Exploding Trilobites, dealing ostensibly with the Cambrian explosion but in actuality with several of the personalities involved in the debate – Gould, the McMenamins … – and includes his now, surely, infamous denunciation of Simon Conway Morris (read more). Disappointingly, there is only a passing reference to the Ediacaran biota, which struck me as rather strange since I'd expect this topic to be of acute relevance to any discussion on the origins of metazoans.

The second half of the book, which I will skip over much more briefly, provides a quirky though fascinating insight into some of the actual daily work of a researcher like Fortey; an anthropic but useful discussion of stratigraphy and, unusually in a book like this, extinction. This is followed up by a rare and interesting look at the difficulties of paleogeography in a chapter called Possible Worlds. Finally, oddly cheek-by-jowl in the penultimate chapter, we are treated to a discussion of ontogeny – how little trilobites grew up into big trilobites – and a chronologically arranged review of trilobite evolution.

On balance, I have to admit to some disappointment though. Having read 250-odd pages, ostensibly all about trilobites, by one of the world's foremost authorities on the subject, I feel no better equipped to tackle the professional literature (*e.g.* the updated Treatise) than when I started. I guess I just didn't *learn* as much as I'd have expected to.

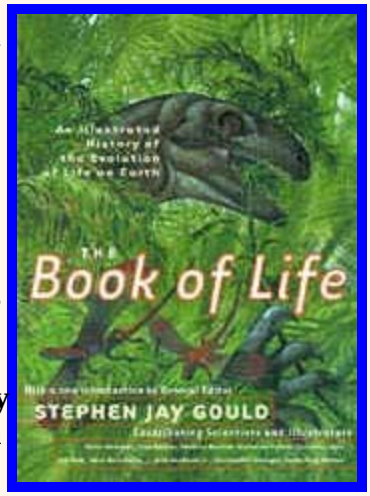
Recommendation: **Eccentric, but highly readable.**

Look and Feel: **Hardback; good quality paper with high resolution b&w photographs on the pages and some b&w plates; indexed. Authoritative, and with the weight and feel of a good text book, but by no means written like one.**

Links: Trilobite- Eyewitness to Evolution by Richard Fortey (Sam Gon); Trilobite by Fortey, RA, FORTEY, RICHARD; Jack's Stack- April 2001; Rocks & Minerals- Trilobite! Eyewitness to Evolution (book review ...; Sharp Blue- Trilobite!; Trilobite Eyewitness to Evolution.

-G-

Gould, SJ [ed.] (2001), The Book of Life: An Illustrated History of the Evolution of Life on Earth, 2nd ed. Norton: 256 pp.



Excellent introductory coverage of the evolution of life on Earth. Unfortunately little emphasis given to invertebrates in the later chapters (a fact Gould himself points out in his extended and very readable preface). Contributed articles by Peter Andrews, John Barber, and Michael Benton. Illustrated by Jean-Paul Tibbles.

This book has not done as well as it might have, and bookstores have deeply discounted the price. Currently (12/03), it's a steal, but may become unavailable in the near future.

Difficulty: Easy/Non-technical

Rating: recommended

Links: Book of Life (hardcover) (the publisher's description); Book of Life (a moderately favorable review from Prof. Phil Adds); A mini book review The Book of Life Stephen Jay Gould, General ... (another favorable review); The Secular Web - infidels.org (two reviews, one with the usual carping about Gould's personality).

-J-

Early Vertebrates, **Philippe Janvier, 1996,** *(Clarendon Press, Oxford) absolute masterwork on early vertebrates*

-K-

Vertebrates: Comparative Anatomy, Function, Evolution by Kenneth V. Kardong - a good textbook on vertebrate comparative anatomy. Not suitable for the beginner

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

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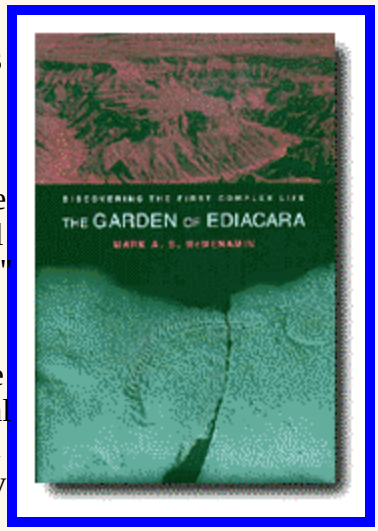
Book Reviews & Descriptions (M-Z)

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

-M-

McMenanin, MAS (1998), **The Garden of Ediacara: Discovering the First Complex Life**. Columbia Univ. Press, 295 pp. ISBN 0-231-10558-4



This book both chronicles the author's search for Ediacaran fossils and attempts to interpret the biota and its significance to evolutionary biology. McMenamin recounts his searches in Mexico, Namibia, and Australia, and includes a few drawings and photographs of specimens and the locales in which they were collected.

There is some interesting information here, but to get to it though, you have to wade through a lot of personal anecdotes in tedious detail and other interjections of minimal relevance. On the Amazon site, an equally frustrated "reader from Boise, Idaho," concludes:

> 'I have read the book nearly twice and each time close it with a deep sense of disappointment. The problem I have with the story is the personal observation and biographical material. I wanted to read about Ediacaran animals not the Namibian airport, recalcitrant gatekeepers and inane diary entries about who the author had dinner with. Some of the book could have been taken up with more photos and perhaps professional sketches [rather than] crayon drawings from Mrs. Thompson's second grade class.
>
> 'The ideas the author presents on the fauna are what made me get through the book at all. Those were great but occupy very little of the book.'

A similar criticism is logged by professional paleontologist, Ben Waggoner (Department of Biology, University of Central Arkansas): "Scientists and laymen alike will be turned off by the book's jagged organization, stylistic weaknesses, constant horn-blowing, and endless speculation." (Waggoner's full review here.)

This book features far too much author. In my experience, most scientists are a modest lot but, unfortunately, some of their popularist representatives seem to have an ego the

Extrapolating wildly from little or no evidence is not atypical of McMenamin. But don't take my word for

size of all outdoors, and this guy is clearly one of them. However, ego is not the book's foremost defect: There are two other, and rather more serious, shortcomings.

The first is one of veracity. Waggoner again: "[A] serious flaw is the relatively small number of photos of the Ediacaran fossils. Most of its illustrations are fairly simple, unshaded line drawings, which aren't always accurate – I know that *Bomakellia* doesn't have the ornamented glabella-like thingamajig that figure 5.7 illustrates. A book that purports to solve the Mystery of Ediacaran Life really ought to include more photographs, camera lucida drawings, and professional-quality reconstructions of the specimens...." The diagram Waggoner refers to is minimalist – almost child-like in its simplicity. The lines drawn on the boss at the top of the figure cannot be misinterpreted for shading or anything else: So, if they are not present on the original specimen, what can we believe except that McMenamin is making it up? On page 35 (reference to note 67) McMenamin refers to the Middle Cambrian arthropod "*Marella*" as "a true soft-bodied trilobite." Indeed? In fact, *Marrella* (with two 'r's) is neither soft-bodied, nor a trilobite.

it; here's what the Richard Fortey has to say:

> '[In *The Emergence of Animals*, Mark and Dianna McMenamin] claimed up to a hundred [most modern textbooks list about thirty] animal phyla 'exploding' into life in the Cambrian; most of them are also claimed to have died out, leaving no progeny. ... This view out-Goulded Gould ten-fold. The extraordinary thing to an objective reader is that there is no attempt to justify why these hundred or so 'Cambrian phyla' should be recognized. ... Not a word. ... One is driven to the conclusion that these particular writers regard it as only necessary to appear on the Cambrian stage dressed in any sort of odd costume to be called a phylum.' – Richard Fortey, *Trilobite*, pp. 134-135

I don't think I'll trouble to read *The Emergence of Animals*.

Second, McMenamin presents extraordinary interpretations based upon – as far as I can see – no evidence at all, let alone the very strong evidence normally expected when advancing any radical idea [® sidebar]. As another Amazon commentator opined, the author advances hypotheses without any "real scientific test of these ideas" relying instead upon "over extended analogies and conjecture." Quite so. For example, McMenamin concludes – on the basis of what evidence eludes me – that although they were related to animals, Ediacarans were not animals in the strict sense, because they never passed through an embryonic blastula stage (which is peculiar to animal life forms, as far as we know). He believes they developed a central nervous system and a brain independent from animal evolution. Well, I guess that's fine but, for all the evidence McMenamin provides, he might equally well have suggested they beamed down from Mars.

Recommendation: If you ignore the unsubstantiated conjecture, and have the patience to battle your way through the author's *I said..., I did..., I am...*, then McMenamin's book contains a few interesting snippets for anyone interested in the Ediacaran biota: Half a star.

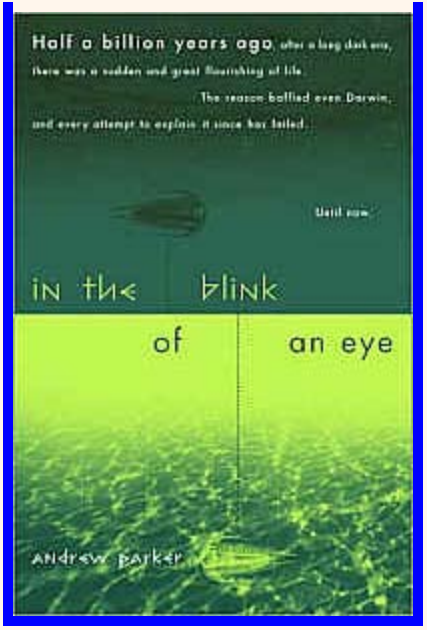
A better read is Chapter 3 of "Major Events in the History of Life" (J. William Schopf ed.) in which Bruce Runnegar writes about the fossils (rather than about Bruce Runnegar).

Look and Feel: Hardback; good paper; indifferent line drawings; good resolution b&w photographs; variable colour plates (and, of 18 plates, only five depict fossils! Plate 1 illustrates McMenamin's Mexican identity card, plate 4 depicts a packet of *Lithops* seeds....)

-P-

Parker, Andrew (2003), **In the Blink of an Eye** . Perseus Publishing, 316 pp. ISBN 0-7382-0607-5

To be fair, this is not the kind of book I like. These sorts of popularizations are often



the elevator music of science: banal, dumbed down, and deliberately designed as distractions from the real business of the reader's day. Often, they are also what I'm always afraid **Palæos** will turn into: a sort of self-absorbed, "Look how smart I am!" technoblog, full of monomanias and crackpot analysis. The world is full of smart people with ideas. Most of these ideas are, inevitablty, completely daft. A reasonable percentage of the people who have them write competently, as Parker certainly does. That is not reason enough to write a book or – for that matter – to put up a gigantic web site. So reviewing these books also makes me nervous, because I'm not sure exactly who should be casting the first stone at whom. Accordingly, I've read it twice. I'm glad I did. The book is much better than it seems on first reading.

Make no mistake. Parker's idea *is* daft. He believes that the Cambrian explosion was driven by the development of vision in several animal groups, particularly the trilobites. Read the book critically, and you'll see why he's wrong. On the other hand, this is the kind of book one *can* read critically. Parker lays out his evidence and thought process carefully and non-technically. He doesn't spend much space talking about himself, or waste the reader's time with personalities. His paleontology is not completely up to date, but he's not a paleontologist. He's a zoologist and vision physiologist. More importantly, his method is impressive, even if he ultimately gets the wrong result. His work exemplifies what we all must do, more and more: follow the truth of an idea wherever it may lead, without regard to traditional academic and scientific borders. His willingness to explore the paleontological evidence, as well as ideas from other disciplines, is what makes the book worth reading. More science ought to be done this way.

While it is hard to accept Parker's specific conclusions, his general concept is worth some thought as well. For example, one could make a very strong case that the Triassic "explosion" of new tetrapod forms was associated with the independent acquisition, in at least four separate lineages, of acute, pitch-sensitive hearing. In each case, the engineering innovation involved very similar anatomical changes. We need not leap to the conclusion that advanced hearing *caused* the faunal turnover of the Triassic. Manifestly, it did not. But Parker's book validly teaches us that that matters of this type are worth a much closer look.

Other reviews: In the Blink of an Eye (relatively uninformative reviews), Bookslut- In the Blink of an Eye by Andrew Parker; In the Blink of an Eye - www.smh.com.au; Parker, Andrew- In the Blink of an Eye; American Scientist Online - On the First Day, God Said . . . (Conway Morris doesn't like it much); In the Blink of an Eye. Andrew Parker. Review. (excellent, detailed review). ATW040101.

Vertebrate Life by F. Harvey Pough, Christine M. Janis, John B. Heiser - basic level textbook, a very good and readable overview of vertebrate physiology, evolution, etc. Technical concepts all well explained

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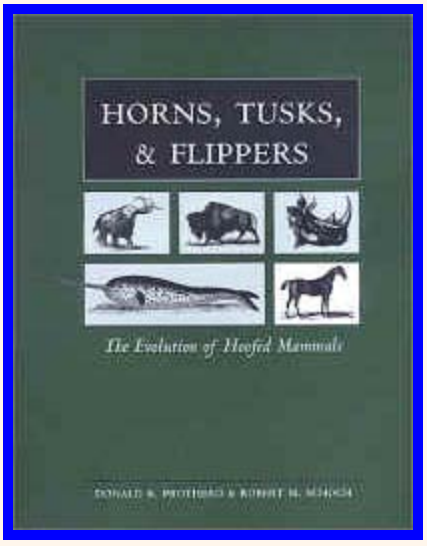


Prothero, Donald R & RM Schoch (2002), **Horns, Tusks, and Flippers: The Evolution of Hoofed Mammals**. Johns Hopkins Univ. Press., 311 pp. ISBN 0-8018-7135-2

I wanted a book which surveyed the ungulates. This book does that. I wanted one with literature references. It has them. I wanted a book with a phylogenetic perspective, sampling extinct, as well as living groups. Yes, it has that, too. I even wanted a book with lots of brontotheres, just because I happen to like them. It has a whole chapter on brontotheres. So why am I not satisfied?

First, let's be clear about the verdict. This is a good book. If you want something

with ungulates, references, evolution, and, of course, brontotheres, by all means purchase the book. The investment will be a wise one, and the book will probably remain a useful reference for a decade or two -- well past the shelf life of most things that live on shelves. The book is solid, if about five years out of date on some phylogenetic matters, clearly written, and remarkably comprehensive for so short a book on so large a topic.

But therein lies the rub. This is a truly fantastic and exciting topic. The ungulates are as unique and successful among mammals as dinosaurs are among reptiles. The Cenozoic is sometimes called the Age of Mammals. It might more aptly be called the Age of Rodents and Ungulates. The rest of us hairy folk have only bit parts in a story starring these two great therian clades.

However, **Horns, Tusks, & Flippers** is not fantastic or exciting. Its more like a set of course notes for a good, solid, if slightly stodgy, course at a liberal arts college, retooled for the interested general reader. Perhaps that's what it is. The difficulty is that a book, unlike a course, has to have thematic content. Zoology 205, *Evolution of the Ungulates*, must have at least a paragraph on every last tiresome deer family because Zoology 205 is a survey course. A book for the general reader doesn't have to do that, and shouldn't. What it *must* have is an explanation of why we should care. The usual technique, and the one which works the best, is simply for the author to tell us the reasons why *he* cares.

Prothero and Schoch sometimes hint at those reasons. For example, no matter how diverse the ungulates, the terrestrial forms generally fall into certain specific guilds, with very similar body plans. In Holocene terms, these are the horse, antelope, giraffe, hippo, elephant, pig, camel, and ox types. I've probably missed a few, and doubled up on others. These keep reappearing, and lineages tend to split along these lines. However, not all the jobs are always filled. There were no "hippo" types in North America between the Oligocene and the Middle Miocene. Today, we're short on a sort of small grazer niche that ungulates have often filled. What about the converse? Is the collection of known ungulate guilds a complete description of herbivore ecospace? In other words, are there herbivore jobs out there that are never filled by ungulates? How has any of this changed over time and phylospace?

The trouble is that one has to extract these meaty issues from stacked bales of naturalistic fodder. The questions are not asked, much less answered, in the book. A central theme of that type (and there are many others in this remarkable area) would do much to turn this good and solid book into a compelling read. A bit more anatomy wouldn't hurt; but, for a chapter on brontotheres, I will forgive much.

So, read the book for what it is. Even if it is not quite all it could be, it's a worthy volume.

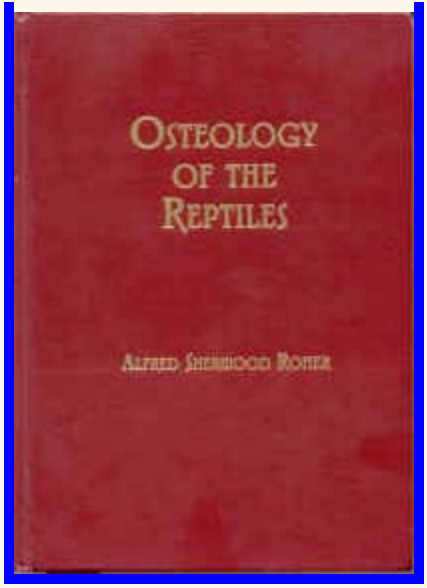
ATW040221

-R-

Romer, Alfred S (1956), **Osteology of the Reptiles** . 1997 reprint ed. Krieger Publ. Co., 772 pp. ISBN 0-89464-985-X

This is the 1997 reprint edition of Romer's 1956 treatise. The style is hopelessly dated. The phylogeny is so obsolete as to be, at times, incomprehensible. There are no references to speak of. The illustrations, for an anatomy reference, are few and crude. Yet, this book is indispensable. No one who is serious about Mesozoic vertebrate paleontology keeps this book far beyond arm's reach. Although it is 50 years old, no one has even tried to update or edit Romer's text. Some have added glosses or exegesis, like Vedic commentaries. The text itself is inviolate, and simply part of the received wisdom of the profession.

The **Osteology** is not just an anatomy text. In fact, as an anatomy text, it is not that complete. No one, even Romer, could really cover this topic in one volume, and certainly not at the level of anatomical detail at which things are done today. However, this book is still the voice of perhaps the most influential vertebrate

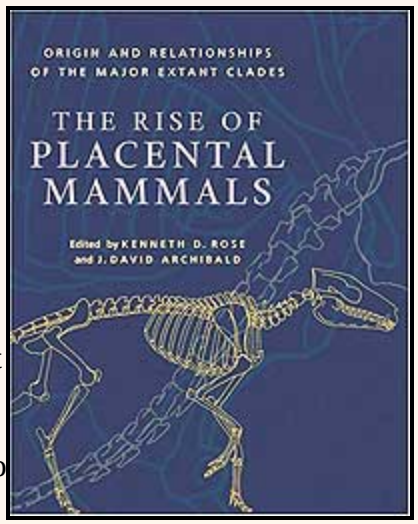


anatomist of the last century, writing at the height of his powers. So, the **Osteology** is not really a complete text. It is best understood as a comprehensive distillation of anatomical *ideas* -- many original to Romer -- which are still the conceptual background against which almost all subsequent work has been done.

It is difficult to convey to someone who has not done much anatomy exactly what, and how much, this means. Some examples may help: (a) the idea that the humerus should be analyzed as having 4 triangular sides, (b) the idea that *Sphenodon* and basal amniotes (that's right, even our own *Bob* is due to Romer) should be used as two important reference points for reptile anatomy, (c) the way in which embryonic germ layers are used to understand homology among vertebrate groups, (d) the concept that muscle actions can be analyzed in terms of the basic dorsoventral organization of trunk muscles in fish; and (e) our fundamental understanding of the relationships between locomotion and limb posture -- in fact the whole approach which was taken towards structure-function relationships until very recently.

The last two examples raise a different issue. Inevitably, there is some dead weight after 50 years. For example, the recent work of locomotion anatomists like Gatesy, Blob and Hutchinson rests squarely on the foundation of structural concepts embodied in Romer's **Osteology**. However, their work also suggests that Romer's approach to muscle action was not only inadequate, but perhaps headed us off in the wrong direction. The modern mode of analysis differs qualitatively from Romer's dorsoventral patterning. Instead, the analysis is essentially radial. Each major joint is treated as a hub, and one works in a circle around that hub, identifying the muscle actions which are effective over various portions of its range of motion. Romer stresses embryology and focuses on position. The current view emphasizes mechanics and focuses on kinetics. Even so, the **Osteology** is the baseline from which the newer understanding departed, and it would be difficult to appreciate the importance of what the current lot of locomotion anatomists are doing without a clear appreciation of their point of departure.

It would be pointless for us to "recommend" this book. One does not recommend a copy of the tax code to an accountant. Either she already has a copy, or she is not an accountant. When you have reached a certain point in your studies, you, likewise, will find that you have already acquired this book. ATW031223.



Rose, Kenneth D & J David Archibald [eds.] (2005), **The Rise of Placental Mammals: Origins and Relationships of the Major Extant Clades**. Johns Hopkins University Press, 259 pp.

We apologize in advance for a short and hurried review. Difficult as it is to conceive, this rather pricey ($95.00) volume is probably worth the money. Rose and Archibald must surely have someone on the payroll who leaves the skulls of (formerly) extant mammals where, as in the famous horse head scene in The Godfather, they send an unmistakable message to contributing authors. At any rate, Rose and Archibald have succeeded in getting a large number of busy and well-known paleomammal folks to toe the line in remarkable fashion, producing 15 chapters of high and level quality. The content is not formulaic, but each of the 11 chapters devoted to particular clades covers the same essential topics

relating to its allotted taxon, including both molecular and morphological evidence with a fairly even hand.

But wait! There's more! The best news is that the focus of the book is largely on developments above the level of the traditional mammalian orders. Thus, there is extensive discussion of Altungulata, Euarchonta, Afrotheria, and others that are frequently mentioned, but rarely discussed. Its a pity that a separate chapter was not devoted to Afrotheria -- although, admittedly, we don't personally believe that this is a clade. Nevertheless, there's plenty of discussion at various different points in the extensive text. Don't let the seemingly paltry page count fool you. The pages are large. The print size is small. The text is dense. As usual with JHU Press, the illustrations are relatively few and of low quality. However, the real point is the cladograms, which fortunately don't demand too much of this publisher.

If you are a regular reader of **Palaeos**, you may well question the viability of our occasional anti-molecular rants by the time you finish the book. (Actually, you may well question the viability of *any* of our opinion pieces, whether or not you read this book). We have resolved to be less strident in future. Molecules have come a long way in a very short time. The naive studies that placed rabbits as the closest relatives of mankind have generally been succeeded by far more sophisticated stuff that now often makes sense. Frankly, we still do not understand why phylogenetics doesn't take the obvious step of treating molecules as morphological entities, not just sequences of amino acids or nucleotides **[1]**. This step is *very slowly* being taken by a few molecular types, who are realizing the enormous value of rare genetic events. These are still being dealt with as sequence issues, largely insertions and deletions. Perhaps good tertiary structure information is still too sparse for broad scale phylogenetic studies. However, it would not be too surprising to see molecules and morphology merge in the next 10-20 years.

One serious methodological disappointment may be found in the chapter by Robert Asher on Insectivora. Asher attempts to combine molecular and morphological data using Bayesian methods. This ought to work. It has to work. But it hasn't worked so far. Asher recovers a tree rooted in a paraphyletic rodent group, the infamous man/rabbit relationship, and other unlikely combinations. However, its early days yet for this complicated technique.

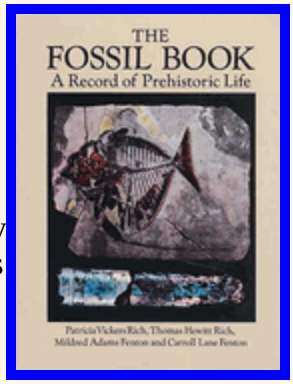
Altogether, an excellent book. ATW050713.

[1] *C.f.* Carroll (2005), a well-argued review by Sean Carroll, a molecule guy, who has a related complaint about the field's inexplicable obsession with sequence over function.

-S-

-V-

Vickers Rich, P, TH Rich, MA Fenton, & CL Fenton (1997), **The Fossil Book : A Record of Prehistoric Life**. Dover Publ., 760 pp. ISBN: 0486293718

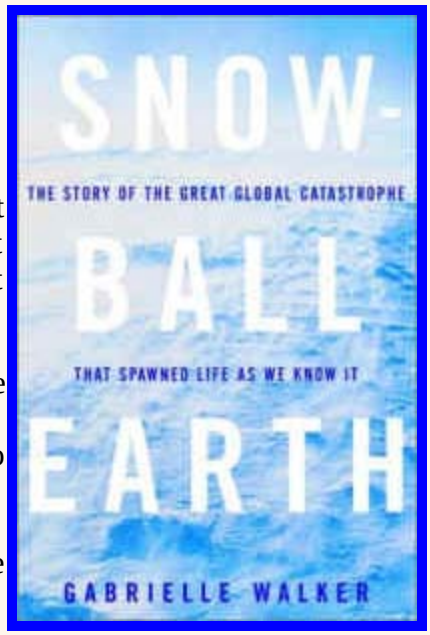


I only have the original (1958) edition by Fenton and Fenton. Sorta folksy style, but very readable. A good introduction to the various invertebrate groups, plants, fish and land animals from Earth's past. Includes a number of Paleozoic species. It may be out of date but still covers topics (e.g. plants, invertebrates) many other books ignore. MAK.

Links: The Fossil Book - A Record of Prehistoric Life (customer reviews -- and one anti-Creationist rant); ? Reviews for Rich,_Thomas_Hewitt. But seriously, who needs a review of a book which has been a continuously updated classic for almost half a century?

-W-

Walker, Gabrielle (2003), **Snowball Earth** . Crown Group: 269 pp. ISBN 0-7475-6433-7.



When I first picked up *Snowball Earth*, I thought I'd somehow gotten hold of a large print copy or something: the text is huge and widely spaced. Although this format makes it particularly easy for somebody in their dotage, like me, to read the thing, it also spins the book out to a somewhat misleading 269 pages. There simply isn't that much content in here.

Sadly, that was only the first of several disappointments awaiting me between the covers. Perhaps most irritating, the book is constructed like a work of fiction. Points of interest are introduced only with the greatest circumspection. Of this there is no better example than the Preface: Six pages of gassing with nothing - *nothing* - relevant to the topic. Paul Hoffman used to be a marathon runner. Ok, fine; now let's get on with it. Then on to chapter one and another four-and-a-half pages of waffle between "Shark Bay" and the first occurrence of the word "stromatolite."

Worse is to follow: Almost as soon as this first point of interest finally is made, the chapter ends and we're off talking about something else! The entire narrative flip-flops back and forth between ideas, apparently deliberately, as if attempting to build suspense. It made me think of Tolkein's *The Two Towers*, in which the author employs the same technique, though rather more proficiently, and with the happy advantage of doing so for a reason. No sooner are we actually given some morsel of information to think about, than we are whisked off to elsewhere and elsewhen. Frankly, it's all completely tedious and, worse than that, it makes the book impossible to use as a reference. Because there is no logical structure to it, you can't find anything unless there is an (obvious) index entry to exactly what you are looking for.

As for the science itself, this book is extremely superficial. Not only that, but the instant we're off the main topic, the science becomes pretty suspect, also. Some statements, such as "there were no worms in the Precambrian" (p. 116), or that the bizarre progeny of the 'Cambrian Explosion' date "from the beginning of the Cambrian period, around 545 million years ago" (p. 203), are simply incorrect. But more often Walker's pronouncements are not exactly *wrong*, factually; they're just distinctly misleading. For example, p. 159 claims that paleomagnetic polarity reversals occur "roughly once every few hundred thousand years" which is only true for some periods of the planet's history and conspicuously ignores the Cretaceous "quiet periods" when the polarity appears to have remained constant for millions of years. An even better example is the *non sequitur* "By finding [paleomagnetic] reversals in the Flinders ice rocks, Linda confirmed Joe's discovery that ice had been present near the equator" (p. 160). Oh, yes; we're all on first name terms here. The final few nails in the coffin are the several references - at least one rather florid - to the dinosaurs being wiped out by an asteroid. (Yes, a bolide of some sort almost certainly did strike the Earth at the end of the Cretaceous. Did it wipe out the dinosaurs? Sorry to ruin a good story, but nobody knows to what extent it may have contributed to their demise. Taking a broader view of mass extinction events throughout the Phanerozoic, *volcanism alone* shows a good correlation with observed extinctions - read more.)

Further Reading

Palaeos Cryogenian: Snowball Scenarios
Palaeos Cryogenian

By the Same Author

- None; *Snowball Earth* is Walker's first book.

Similar Writing

- *At the Waters Edge* - Carl Zimmer
- *The Crucible of Creation* - Simon Conway Morris
- *Wonderful Life* - Stephen Jay Gould

The unfortunate conclusion is that Walker simply doesn't know her stuff.

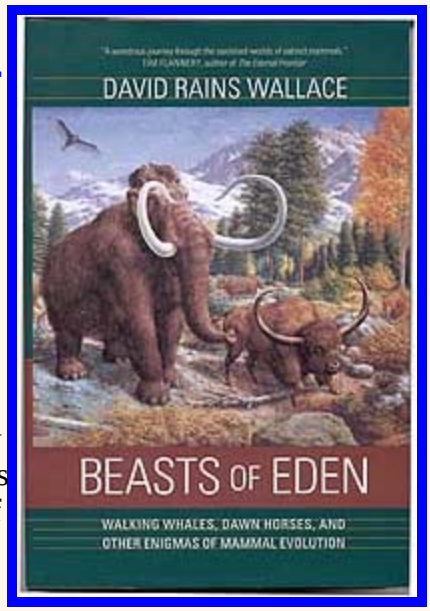
To judge from the descriptions of interviews and excursions, a great number of eminent and busy scientists gave a great deal of their time to the author and authoring of this ... novel. It is hard to imagine they'd be willing to do it again, even for a more accomplished practitioner, which is perhaps the saddest indictment of this effort. Even weighted up against some undoubted public-educational benefit, it seems to me this effort will have done more harm than good, in the long term.

Recommendation: Barely recommended; strictly for a light read, and only if you're feeling particularly indulgent. Otherwise I'd have to say it's crap.

Look and Feel: My edition is the usual matt-finish paperback. There are no photographs, though some would have been beneficial. There are good index and references sections.

Chris Clowes 0305xx

Wallace, David R. (2004), **Beasts of Eden: Walking Whales, Dawn Horses, and Other Enigmas of Mammal Evolution** . U. Calif. Press, 340 pp.



The title of this book is more or less unrelated to its content. The book is a brief and anecdotal history of mammal paleontology by someone who doesn't seem to care much for paleontologists. Almost everyone comes off looking like a lazy, self-absorbed, megalomaniac -- except living paleontologists. Wallace even finds mean-spirited things to say about Simpson, which isn't easy.

The book is not completely useless, because the history of mammalian paleontology is an interesting subject, and there are few other sources. Wallace also writes reasonably well -- although his heart just doesn't seem to be in the subject matter of this book. Wallace is primarily known as a naturalist and conservationist. I understand that some of his books in that area are considered among the best of their kind. However, he has little ability as either historian or paleontologist.

His history is a history of individuals. As we go back further in time in this history, these individuals seem more and more like two-dimensional caricatures who behave in sundry irrational and amusing ways. That's usually a sign that the writer is not making a serious attempt to understand a person or an era on its own terms. Rather, he has subsumed the real person into a modern stereotype, or simply accepted myth as history. That's perhaps a bit unfair. Wallace briefly discusses aspects of Darwin and Huxley, for example, which were interesting and certainly new to me. However, almost everyone comes off as selfish and conceited in their later careers. Racial senescence, no doubt ...

Wallace does have one genuine theme worthy of the history of ideas -- sort of. Unfortunately, he never really tells us what it is. It appears that he sees paleontology as constantly in tension between the proponents of Darwinian selection and those favoring some sort of teleological development. The problem is that this model, and Wallace's discussion, breaks down after the early Twentieth Century. Since 1950, most of the challenges to natural selection as the principal engine of evolution have come from the other side: the radical indeterminism of Gould's punctuated equilibrium, the proponents of random genetic drift as the prime mover, studies of apparently pathological sexual selection (e.g. the peacock). These critiques of natural selection are quite the opposite of teleological. Their fundamental criticism of Darwinian natural selection is that things are more random and unpredictable than can be accounted for by gradual, incremental, selection for fitness.

There isn't a great deal of science in the book. Wallace deals very competently with the "Modern synthesis" and some other "big" ideas. He gets into trouble, sometimes very serious trouble, over the details. For example, this wonderful pronouncement from p. 230: "It is less well known that, when modern grazers were evolving, many grasses underwent a major biochemical shift, metabolizing a different carbon isotope, C_4, than most plants, which use the isotope C_3." How did this get past the editor? Almost every word is wrong. C_4 plants use the same carbon isotopes as every other plant. However the initial carbon fixation step in photosynthesis differs. In C_3 plants, carbon dioxide is added

to form a three-carbon carboxylic acid. In C_4 plants, it forms a four-carbon carboxylate. Because of the differing chemistry, there is a tiny difference in the relative rates at which the naturally occurring carbon isotopes ^{13}C and ^{12}C are incorporated, and thus a corresponding difference in the isotopic composition of the plant material remaining in fossils. This so-called $d^{13}C$ value can be used to determine whether the predominant vegetation was C_4 or C_3. C_4 plants evolved many times independently, probably beginning in the Oligocene. However, they were relatively rare until the very end of the Miocene. The same dry, highly seasonal conditions which drove the evolution of modern grazers at that time also favored C_4 grasses. **[1]**

It's fairly hard to talk about mammal paleontology without at least touching on the intricacies of molar cusp patterns, the energetics of warm-blooded animals, the wonderful interplay of jaw, ear and brain, and a host of similar subjects. These, like C_4 grasses, are sometimes tough and dry, but ultimately well worth adapting to. This book doesn't cover any of these matters. On the whole, we'd encourage you to graze elsewhere. ATW040518.

[1] Our explanation may also have its flaws, but we don't charge you $25+ for our errors.

Whittington, HB, BDE Chatterton, SE Speyer, RA Fortey, RM Owens, WT Chang, WT Dean, PA Jell, JR Laurie, AR Palmer, LN Repina, AWA Rushton, JH Shergold, ENK Clarkson, NV Wilmot, & SRA Kelly (1997), **Treatise on Invertebrate Paleontology, Part O (Revised) Arthropoda 1, vol. 1: Trilobita: Introduction, Order Agnostida, Order Redlichiida.** RA Kaesler [ed.]. Geol. Soc. Amer. & Univ. Kan., 530+ pp.

ISBN 0-8137-3115-1

At last, volume one of the long-awaited update to Moore's 1959 epic. It is difficult to understand the monumental amount of work in one of these volumes of the Treatise without reading through it. Take the chapter on ontogeny, for example. How do we know how a trilobite developed? After all, we can hardly watch one. Only by collecting dozens or hundreds of fossils of each – at first, no doubt, misidentified as different species – and comparing them, across collection, institution, and probably national boundaries: work which may take multiple workers decades. The 530 pages of this volume represents whole lifetimes of dedicated research.

The Treatise is a technical reference for professional palaeontologists so you will want to be a very enthusiastic amateur before you consider buying it. If you are, though, then this is definitely *the* definitive word on trilobite morphology, habit, ontogeny, evolution and classification available today. It is not a complete systematic review of the whole class, however: This is the first volume of a work which is expected to stretch to three. Systematic descriptions are given for the Agnostida and Redlichiida only.

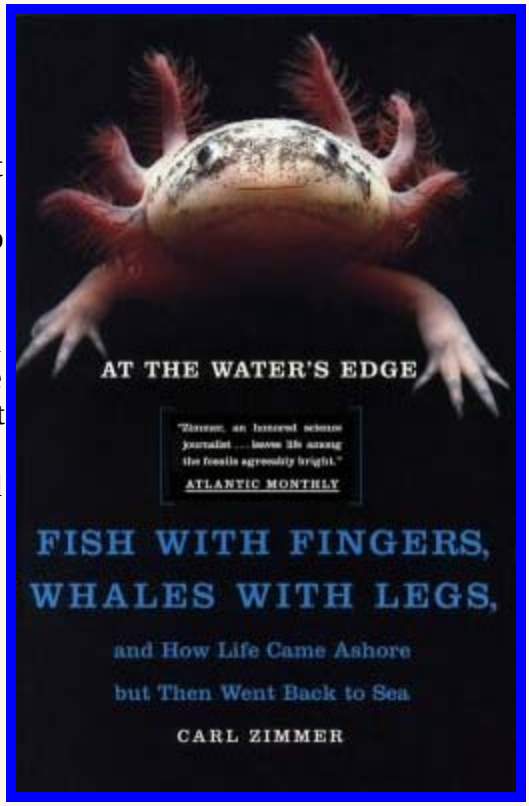
Readers familiar with the 1959 version will first notice that the familiar line drawings have been almost totally replaced by excellent (at least 600 dpi) photographs of actual fossils. As before, taxonomic descriptions are provided down to generic level, providing authorship, synonymy, diagnostic morphology, type species and provenance.

Recommendation: Recommended.

Look and Feel: Hardcover textbook.

-Z-

Zimmer, Carl (1998), **At the Water's Edge: Fish with Fingers, Whales with Legs, and How they Came Ashore, but Then Went Back to Sea** Free Press, 290 pp. ISBN 0-684-83490-1.



The original subtitle – Macroevolution and the Transformation of Life – was perhaps a little too sweeping in scope, but does give a feel for the subject matter. This is a book about some of the important macroevolutionary events in vertebrate evolution: breathing air, adapting limbs to terrestrial life and, unusually, the cetacean transition back to water again. There are diversionary discussions about genetic phylogeny, cladograms, etc. as well as the compulsory hox gene discussion, to bring the lay reader up to speed, but they are well-handled and do not detract too badly from the main thread.

Like most of these lay audience type books, it is all wrapped up with the usual annoying human interest stories about the careers of some of the more notable scientists working in the particular field, and the usual titillating hints about professional rivalries which, in my experience, simply don't exist (or at least no more than in ordinary life). That said, the book is accessible, well-written and informative: Recommended.

Links: CarlZimmer.com; Review of At the Water's Edge by Carl Zimmer; The Politburo Forum - Mini-Review- "At the Water's Edge"; IW Books - At the Water's Edge; Everybody Out of the Pool (review by Philip Gingerich).

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

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Terrestrial Ecosystems Through Time

Evolutionary Paleoecology of Terrrrestrial Plants and Animals

Edited by Anna K. Behrensmeyer, John D. Damuth, William A. DiMichele, Richard Potts, Hans-Dieter Sues, and Scott L. Wing
The Evolution of Terrestrial Ecosystems Consortium; 1992, The University of Chicago Press, Chicago and London, 568 pp.

This is one of my all-time favourite paleobiology books, and an invaluable resource. Although it only deals with terrestrial ecosystems it does so in a very all-enclusive way. For the indepth scholar and armnchair enthusiast of Earth History I can certainly recommend it. I only wish there were more books like this

From the back cover:

> *Evolutionary Paleoecology of Terrrrestrial Plants and Animals* presents an ambitious new approach to the historv of life on land, from the earliest traces of terrestrial organisms over 410 million years a go to the beginning of human agriculture. By stressing how the "ecological theater" of evolution changed through geo- logical time, this landmark book provides access to a wealth of unique and thought-provoking ecological information contained in the fossil record. A joint undertaking of the Evolution of Terrestrial Ecosystems Consortium at the National Museum of Natural History, Smithsonian Institution, and twenty-six additional researchers, the book begins by laying out the theoretical background and methodology of evolutionary paleoccology. Included are a comprehensive review of the taphonomy and palcoenvironmental settings of fossil deposits and guidelines for developing ecological characterizations of extinct organisms and communities. The authors then treat the history of terrestrial ecosystems through time, emphasizing the tempo of ecosystem change, the role of exogenous forcing factors" in generating ecological change, and the effect of ecological setting on major radiations of land organisms. A central theme is that understanding the patterns that occur in associ- ations of fossil land plants and animals is essential to a broader macro-synthesis. and microevolutionary Despite short-term fluctuations, many terrestrial fossil-bearing sequences record ecological stasis over millions of years. When climatic or other environmental perturb3tions termi- nate periods of stasis, ecological reorganization cannot be predicted; new dominants arise and former ones become subordinate or extinct. The book also offers a unique view of the impact of *Homo sapiens* from the perspective of 300 million years of relative stability in the basic structure of land ecosystems.
>
> Anna K. Behrensmeyer, William A. DiMichele, and Scott L. Wing are research curators in the Department of Paleobiology, and Richard Potts is research curator in the Department of Anthropology, at the National Museum of Natural History, Smithsonian Institution. John D. Damuth is research biologist in the Department of Biological Sciences at the Universitv of California at Santa Barbara and research associate in the Department of Paleobiology at the National Museum of Natural History, Smithsonian Institution. Hans-Dieter Sues is associate curator in the Department of Vertebrate Paleontology at the Royal Ontario Museum, Toronto.

Books and Links

The ETE Consortium. The Evolution of Terrestrial Ecosystems Consortium The ETE Consortium was established in 1988 by a group of professional paleontologists associated with the Evolution of Terrestrial Ecosystems which they had initiated the year before at the National Museum of Natural History, Smithsonian Institution. These researchers shared common interests and perspectives in the study of terrestrial paleoecology, and felt a coordinated effort to investigate long-term patterns in the history of terrestrial biotas and paleocommunities was overdue. Such an approach is needed to augment the traditional foci of paleobiology -- species-level adaptations and phylogenetic relationships -- in order to address questions about coevolution, the relationship of environmental factors to evolutionary change, the nature of ecological associations and the factors that influence their stability or transformation, and the effects of major global environmental changes on the Earth's biota. The ETE Consortium oversees all aspects of the ETE Database, a computerized database for research in evolutionary paleoecology.

Terrestrial Ecosystems Through Time : Evolutionary Paleoecology of Terrestrial Plants and Animals, by Anna K. Behrensmeyer, John D. Damuth, William A. Dimichele, and Hans-Dieter Sues - Paperback - **Hardcover**

Books

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content by M.Alan Kazlev
most recent update 28 April 2001

Authors

Chris Clowes: a number of book reviews, much of the Precambrian material & whatever else we can steal from his personal site, **Peripatus**.

Christopher Taylor: Bacteria, many basal deuterostomes, and some Eukarya. Discoverer of ***Pantopsalis phocator***.

Jcwf: a few entries.

Mikko Haaramo: almost all of the cladograms except vertebrates.

M. Alan Kazlev: almost everything, particularly invertebrates and the time pages; design & layout.

Renato Filipe Vidal Santos: cleaning up, sourcing, streamlining and general niggling.

Roger Perkins: really too soon to tell, but I'll probably start with the Cambrian Explosion and provide a lot of pretty pictures.

Toby White: vertebrates, a few time pages, Eukarya; editing, previously updating & maintenance.

page uploaded on Palaeos Site 22 April 2002
Last revised ATW060902, MAK110731 , RGP111022, RFVS111209
checked ATW030726

Original FAQs page has been relocated

Resume

AUGUSTUS T. WHITE

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Houston, Texas 77096
Phone: 713-667-7002
augwhite@sbcglobal.net

Legal Practice:

Augustus T. White
2004 - present: Private practice of commercial and employment law. In recent years, my practice has tended to emphasize ERISA litigation, litigation relating to trade secrets and covenants not to compete, employment discrimination claims, and arbitration.

Chamberlain, Hrdlicka, White, Williams & Martin
1986-1989 & 1997-2004: Shareholder: 1200 Smith, Suite 1400, Houston, Texas, 77002. Private practice of employment law.

Youngblood & White
1995-1997: Partner. 1800 West Loop South, Suite 1800, Houston, Texas. Private practice of employment law, medical malpractice and benefit claims.

Keck, Mahin & Cate
1989-1994: Partner: 1001 Main, Suite 2400, Houston, Texas 77002. Private practice of employment law.

Vinson & Elkins

1981-1986: Associate: 1001 Main, Houston, Texas 77002. Private practice of employment law.

Arbitration:

American Arbitration Association
1992- Current: AAA employment panel. Approximately 12 arbitrations, including benefit disputes, discrimination claims, non-subscriber personal injuries, and employment contracts

National Arbitration and Mediation
2004-Current: NAM employment panel. Two arbitrations relating to claims of discrimination and wrongful discharge.

Scientific:

Palaeos
Owner & Co-author: **Palaeos.com**. Palaeos is a large (1000+ pp.), web site concerned with phylogeny, paleontology, evolution, and earth history. It is frequently used as a supplemental resource for university courses related to these fields.

- Palaeos was selected by the National Institute of Biotechnical Information (NIH) as one of its core taxonomy providers for the MEDLINE/PUBMED Taxonomy Browser.

- The site is used as supplementary course material at colleges and universities including Cambridge University (UK), the University of Helsinki (Fin.), the University of Washington (USA), Heidelberg University (Ger.), and the Universidad de Granada (Spain), as well as numerous smaller colleges, universities and high schools throughout the world.

- During the 2002-03 year, the site was large part of the core curriculum at a paleontology course taught at the University of Helsinki.

Education:

Yale Law School
J.D. 1981, Yale Law School, New Haven, Connecticut.

Johns Hopkins University
Ph.D. (Biology) 1980, Johns Hopkins University, Baltimore, Maryland. National Institutes of Health Pre-doctoral Fellow and Johns Hopkins Fellow. My graduate work related to DNA cloning experiments and gene isolation, a field which was then in its infancy.

New College
B.A. (Biology) 1973 New College, Sarasota, Florida.

Selected Publications and Media:

White, A.T. & M.A. Kazlev (2002-present), **Palaeos**, http://www.Palaeos.com/

White, A.T. (2000), *Would you, could you in a box?: Hox genes and the rhythm of evolution*. Lecture: Fla. Gulf Coast Univ.

White, A.T. (1999-2002), **The Vertebrate Notes** (former site)

White, A.T. (1998), *The Boston fee party: **Beck** rights and project labor agreements*, 19 **J. Lab. Res.** 89.

White, A.T. (1997), *Litigation: Where has it been and where is it going?* 18 **J. Lab. Res.** 65.

Northrup, H.C. & A.T. White (1996), *Subsidizing contractors to gain employment: Construction union "job*

targeting", 17 **Berkeley J. Employ. & Lab. Law** 62

Northrup, H.C. & A.T. White, (1995), *Construction union use of environmental regulation to win jobs: Cases, impact and legal challenges*, 19 **Harv. J. Law & Public Policy** 55.

White, A.T., *Employment arbitration in the non-union workplace*, in **Dispute Resolution at Work**, Texas Employment Law Council Annual Meeting, June 29, 1994, Houston, Texas

White, A.T., *Employment arbitration in the non-union workplace*, in **Fifth Annual ADR Institute**, State Bar of Texas, September 30, 1993, Houston, Texas

Ono, M., M.D. Cole, A.T. White, & R.-C. Huang (1980), *Sequence organization of cloned intracisternal **a** particle genes*. **Cell** 21: 465.

Brade, W.P., A.T. White & L.S. Hnilica (1974), *Early acetylation of mouse kidney histones after injection of folic acid*. **Deutsche Pharm. Gesell.** 282 supp.: R12 (abstr.)

References: available on request.

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checked ATW030726, edited RFVS111016

M. Alan Kazlev

I've got a few got a few bios and other stuff scattered around, including on my website Kheper.net, my Wikipedia user page (and list of pages, including Paleo pages, I wrote for Wikipedia; mostly in 2005), Facebook, Google+, and Academia.edu. How I came to be the senior editor and contributor to the Palaeos.com website is explained here.

email: **akazlev *(at)* mail *(dot)* com**

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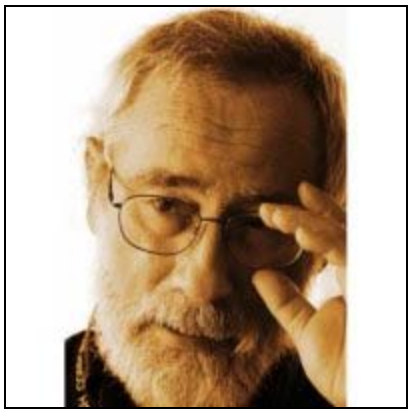
content by M. Alan Kazlev
checked ATW031218, edited RFVS111016, last modified MAK121220

Roger Perkins



I still have a day job. Working chronologically since university, I've been a nuclear reactor physicist and supercomputer center director. Then, on a lark, realizing that biologists are often mathematically challenged, I switched to biomedical research. I keep a list of publications here so I don't lose them.

Having made that switch, I found myself biologically challenged, and had to switch to autodidactic mode. Where to start? Evolution, of course, the organizing principle of all biology, which led to the Virtual Fossil Museum that has been online since 1999. The journal ***Science*** called it "Life's Family Album". As they say, the rest is history, since anything worth doing is worth overdoing, is it not? I'm also webmaster for the Western Trilobites Association, and now a Palaeos contributor. Fortunately, the Palaeos cohort, comprising an open minded lot with eclectic interests and multidisciplinary skills, did not check my creds.

email: **rgperkins *(at)* att *(dot)* net**

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content by Me
not checked, last modified RGP111022, not edited

Renato Filipe Vidal Santos

Short resumé

Portuguese. Atheist. 28 years old. Degree: major in Biology with a minor in Earth Science at Universidade do Algarve. Moderately accomplished amateur artist. Currently working as a research assistant at the university where I graduated. Pretty much a confirmed nerd!

You can find out more on the deviantART page mentioned above, Wikipedia, Twitter, Facebook and Google+. Finally, my e-mail address:

dracontes *(at)* gmail *(dot)* com

A bit of a history

I'm not even sure when I first found **Palaeos**.

I do remember long hours at an Internet terminal in a local library writing down the explicit or implicit phylogenetic trees available on the Web in the earliest noughties, including one of **Palaeos**' predecessors, the evolution section on Kheper.

Fast forward a few years to 2004 and I'm in college but still plying the routes of the information superhighway. Imagine the dismay at finding one of my sources, **Palaeos**, at the risk of disappearing for good. So, even knowing I might not be the best choice of editor, I offer myself for the position. Unfortunatelly, it wasn't a success: at the time I didn't have the skills or infrastructure (read "computer") to be of much help, besides being a soundboard for ideas regarding the reorganization of the site.

I did my bit adding content to Palaeos.org in 2006 but, as was the case for its parent, finishing college took precedence.

In 2011, with college near finished and a job more or less secured I found **Palaeos** down... again. As before, I wouldn't have any of that, so I contacted Alan and we got the ball rolling.

My job here

I'm basically taking over Toby's maintenance position and see if I can get some content in edgewise at the same time. I will (or have, depending on when you're reading this) be revising the site's style and illustrations.

I've got my job cut out for me ;-)

Jcwf

(From Palaeos.org)

In a better universe I would have been a paleontologist or so. In this one I am a Solid State Chemist. But I like dabbling in what I am not an expert in. The origins of birds (I'm a birder), mammals mostly. It has its advantages: I have no self-interest in this and no axe to grind. If I make mistakes: I assure you they are honest ones that can be reverted. Please do give me a reason though. I like to know more. I have been with Wikipedia (mostly nl.wiki and nl.wikt) for far too long. I'm still admin at nl.wikt, af.wikt and af.wiki, but I like it here.

Jwcf100110, edited RFVS111016

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uploaded on 30 April 2003
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Palaeos: Resources (similar sites)

Sitemap (incomplete) Life Time	Main Menu About Palaeos New & Revised Pages Overview FAQs

There isn't much in the way of FAQs to include here, so I've added a few genuine requests and queries, and some I made up to pad out the page. See also Toby White's FAQ page

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