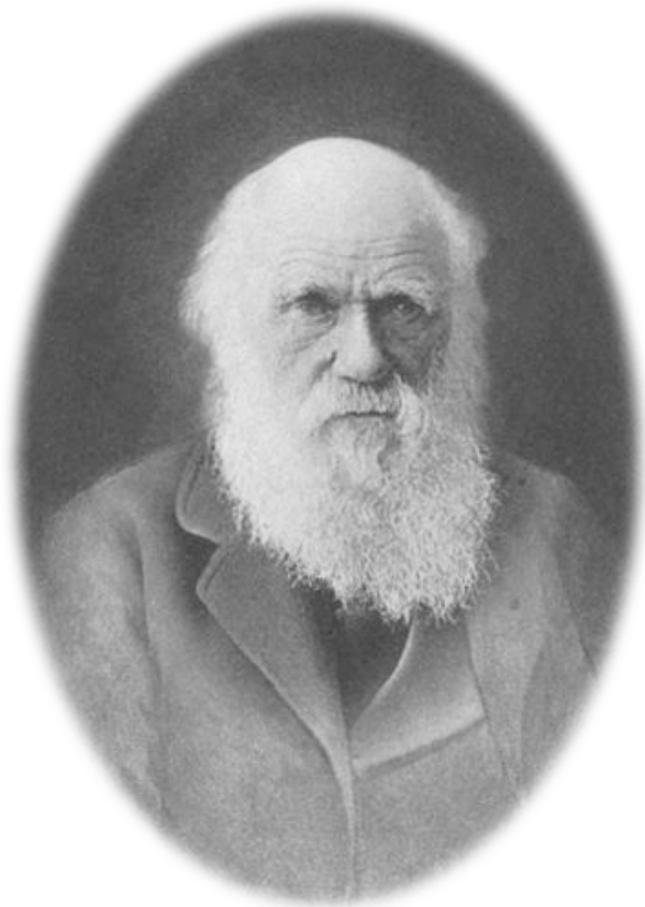


The Cambrian Explosion

Charles Darwin



“Consequently, if my theory be true, it is indisputable that before the lowest Silurian stratum was deposited, long periods elapsed, as long as, or probably far longer than, the whole interval from the Silurian age to the present day; and that during these vast, yet quite unknown periods of time, the world swarmed with living creatures. **To the question why we do not find records of these vast primordial periods, I can give no satisfactory answer.**”

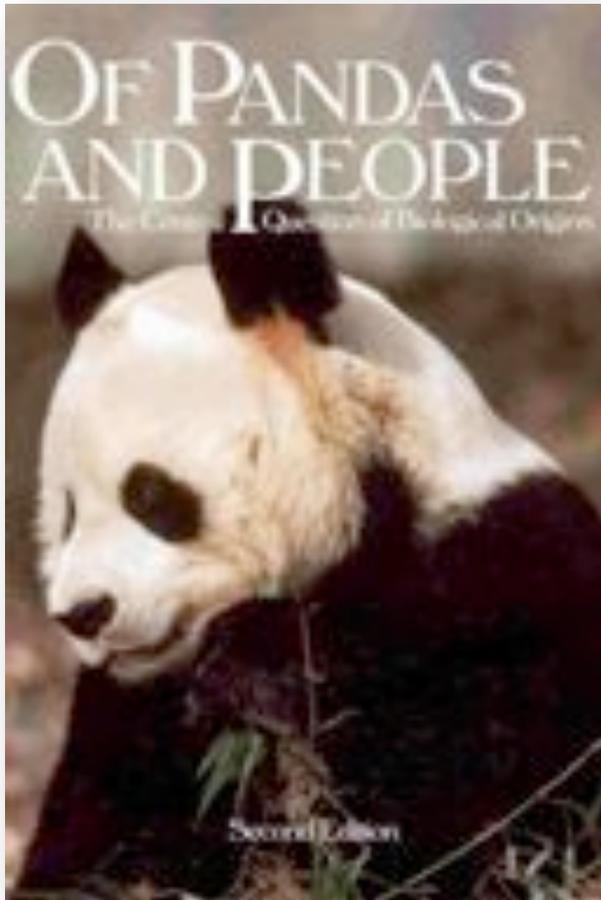
Origin of Species, 1859

Duane T. Gish (1974)

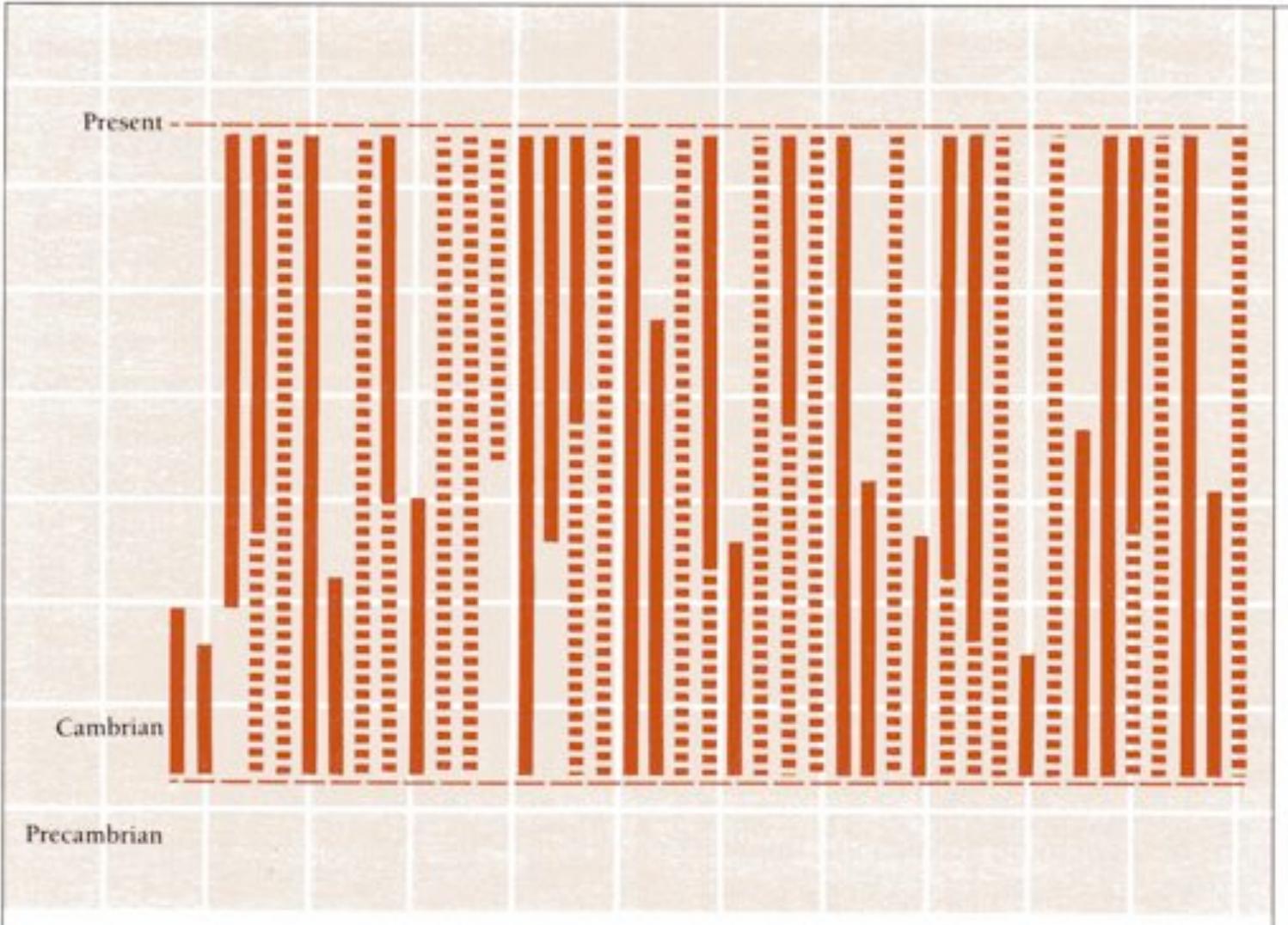
“In the Cambrian geological strata there occurs a sudden, great outburst of fossils of animals on a highly developed level of complexity. In the Cambrian rocks are found billions of fossils of animals so complex that the evolutionists estimate they would have required one and a half billion years to evolve. Trilobites, brachiopods, sponges, corals, jellyfish, in fact every one of the major invertebrate forms of life are found in the Cambrian. **What is found in rocks supposedly older than the Cambrian, that is in the so-called pre-Cambrian rocks? Not a single indisputable fossil!** Certainly it can be said without fear of contradiction, the evolutionary predecessors of the Cambrian fauna have never been found.”

(ICR Impact 4)

Pandas and People



“[S]ome organisms appear with adaptational packages intact at the Cambrian boundary where multicellular life first “flowers,” **with no evidence whatsoever of fossil ancestors...** only an intelligent designer has the ability to coordinate the design requirements of multifunctional adaptational packages.” (71–72)



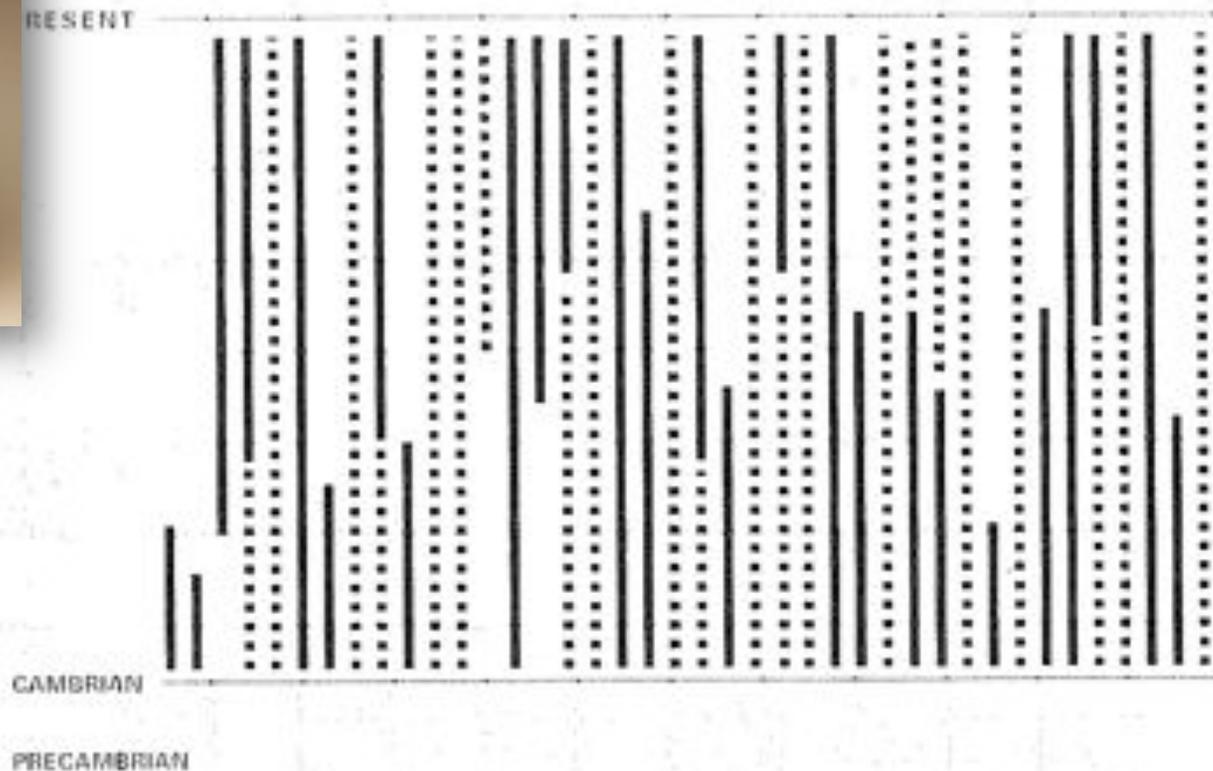
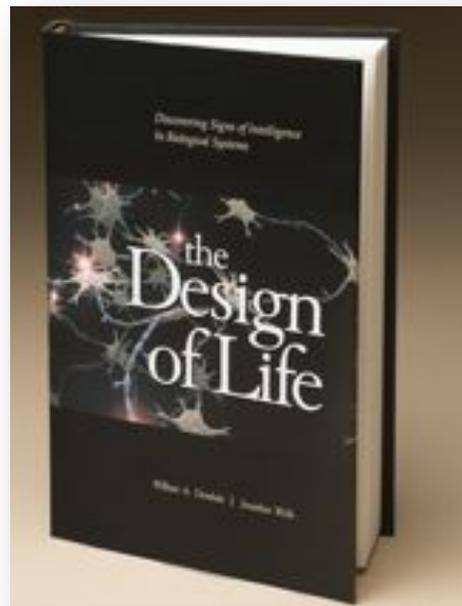
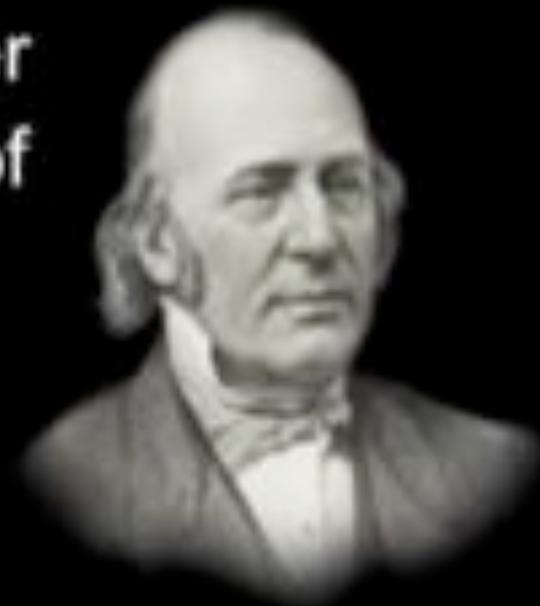
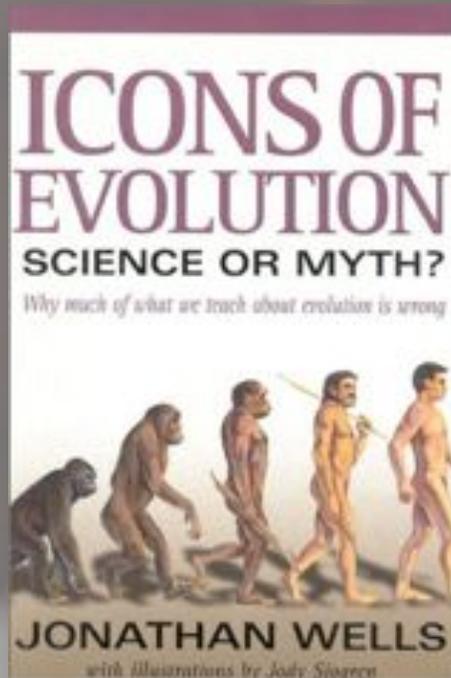


Figure 3.7 A generalized schematic of the fossil record, showing the Cambrian origins of nearly all animal phyla in relation to the overall time scale of the history of animal organisms. Solid lines represent phyla confirmed in the fossil record. Dotted lines represent the presumed existence of phyla yet to be confirmed in the fossil record.

Louis Agassiz (1807-1873): Design Theorist

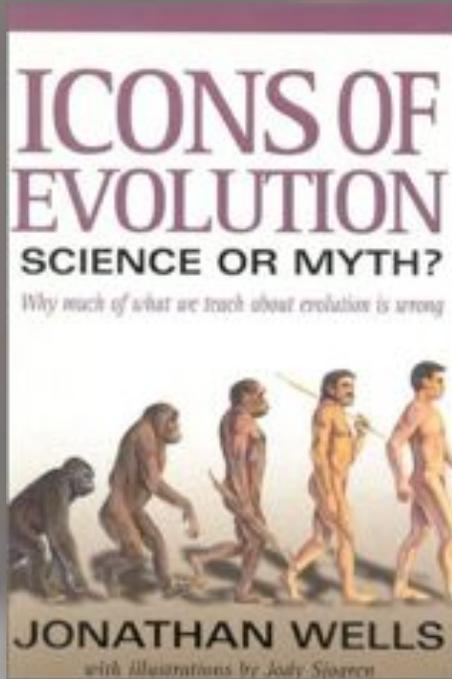
- Leading paleontologist-biologist
- Agassiz, "more than any other single man," was "the voice of science in America" in the mid-19th century





The Cambrian Explosion
“presents a serious
challenge to Darwinian
evolution”

Jonathan Wells



“From nothing, we have almost everything, almost overnight.”

Jonathan Wells

Kansas State Board of Education Testimony

Topeka, KS, May 2005

Scientific Evidence

Supporting Proposed Revisions to

12th Grade Standard 3, Benchmark 3
of the

Kansas Science Standards

Jonathan Wells

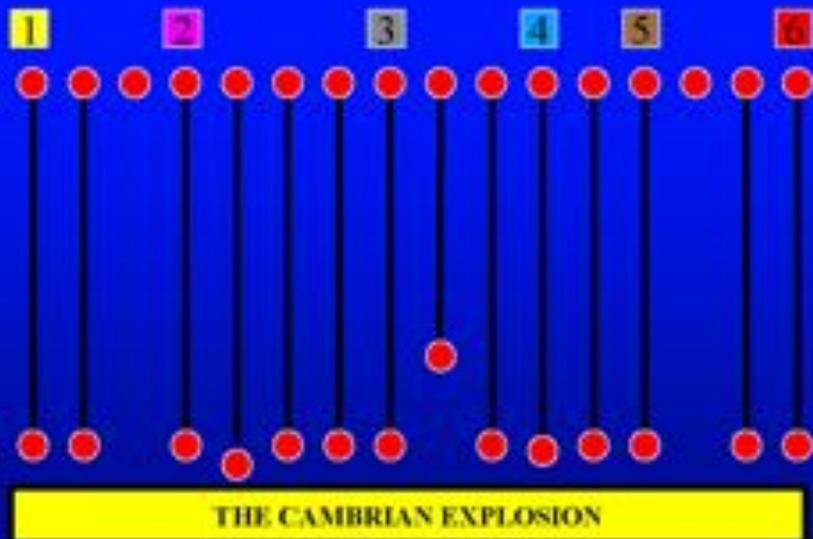
Ph.D., Theology (Yale University)

Ph.D., Biology (University of California at Berkeley)

Senior Fellow, Discovery Institute, Seattle



Darwin's Theory



Fossil Evidence

The Cambrian explosion has turned out to be even more dramatic and extensive than Darwin realized.

Clearly, Darwin's tree of life does not fit the fossil evidence for the origin of the major groups of animals.

PROCEEDINGS OF THE BIOLOGICAL SOCIETY OF WASHINGTON
117(2):213-239, 2004.

The origin of biological information and the higher taxonomic categories

Stephen C. Meyer

Palm Beach Atlantic University, 901 S. Flagler Dr., West Palm Beach, Florida 33401
e-mail: stevemeyer@discovery.org



Introduction

In a recent volume of the Vienna Series in Theoretical Biology (2003), Gerd B. Müller and Stuart Newman argue that what they call the "origination of organismal form" remains an unsolved problem. In making this claim, Müller and Newman (2003:3-10) distinguish two distinct issues, namely, (1) the causes of form generation in the individual organism during embryological development and (2) the causes responsible for the production of novel organismal forms in the first place during the

have proven adequate for mapping and understanding quantitative variability and populational changes in organisms. Yet Müller and Newman insist that population genetics, and thus evolutionary biology, has not identified a specifically causal explanation for the origin of true morphological novelty during the history of life. Central to their concern is what they see as the inadequacy of the variation of genetic traits as a source of new form and structure. They note, following Darwin himself, that the sources of new form and structure must precede the action of natural selection (2003:



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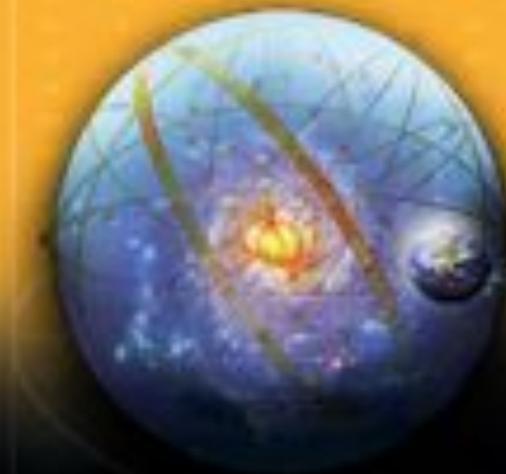
[id & the future of science 2004 conference](#)

[conference speakers](#)

[conference sessions](#)

[conference schedule](#)

[contact info](#)



INTELLIGENT DESIGN

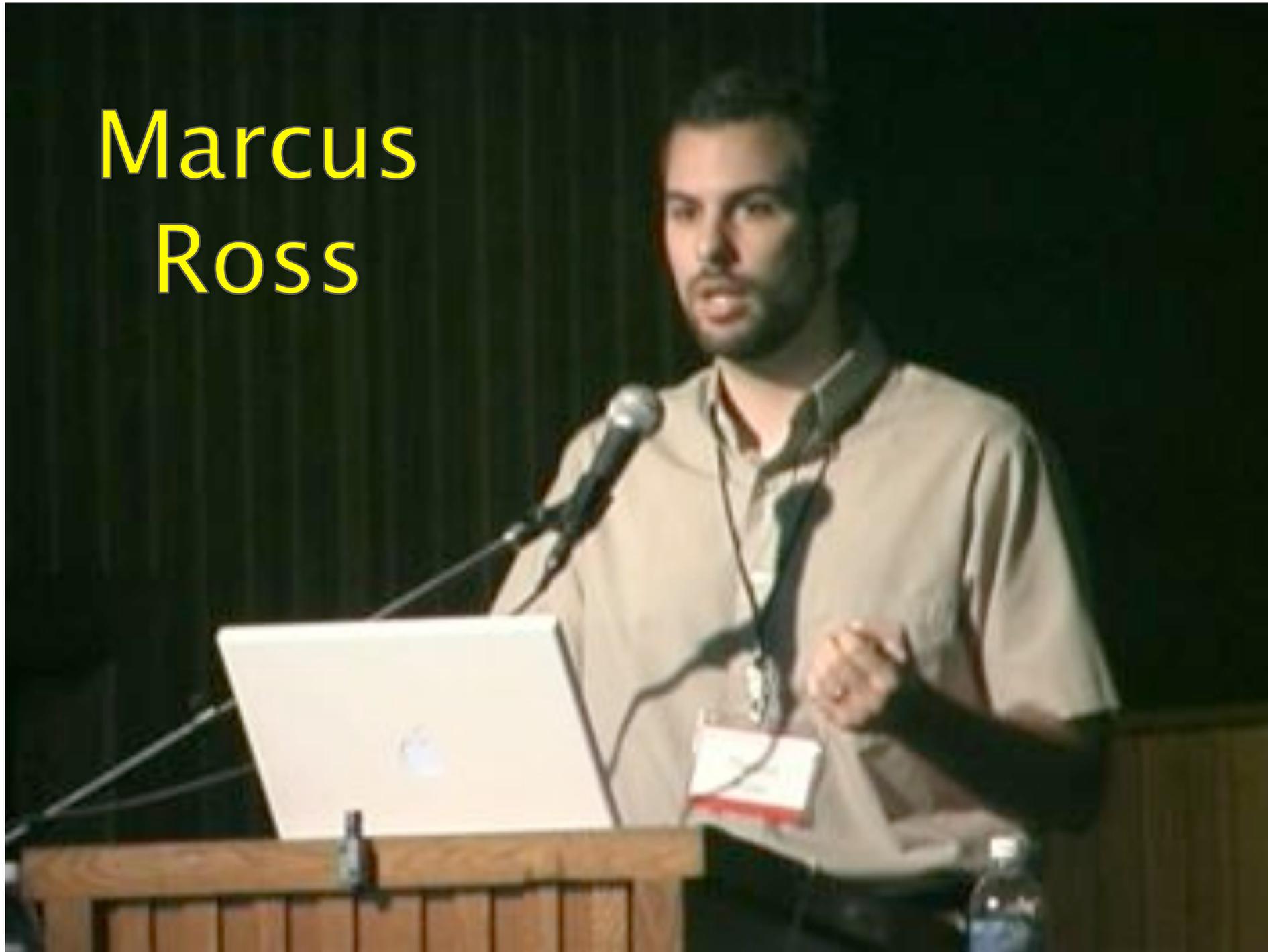
& THE FUTURE OF SCIENCE

APRIL 22-24, 2004 | BIOLA

Biology's Big Bang



Marcus Ross



Extraordinary and Perplexing

- First appearance of most animal body plans
- Sudden appearance, without evidence of ancestry
- Quantum increase of biological information
- Persistent morphological isolation



Persistent Morphological Isolation

Phylum
Ctenophora



Present

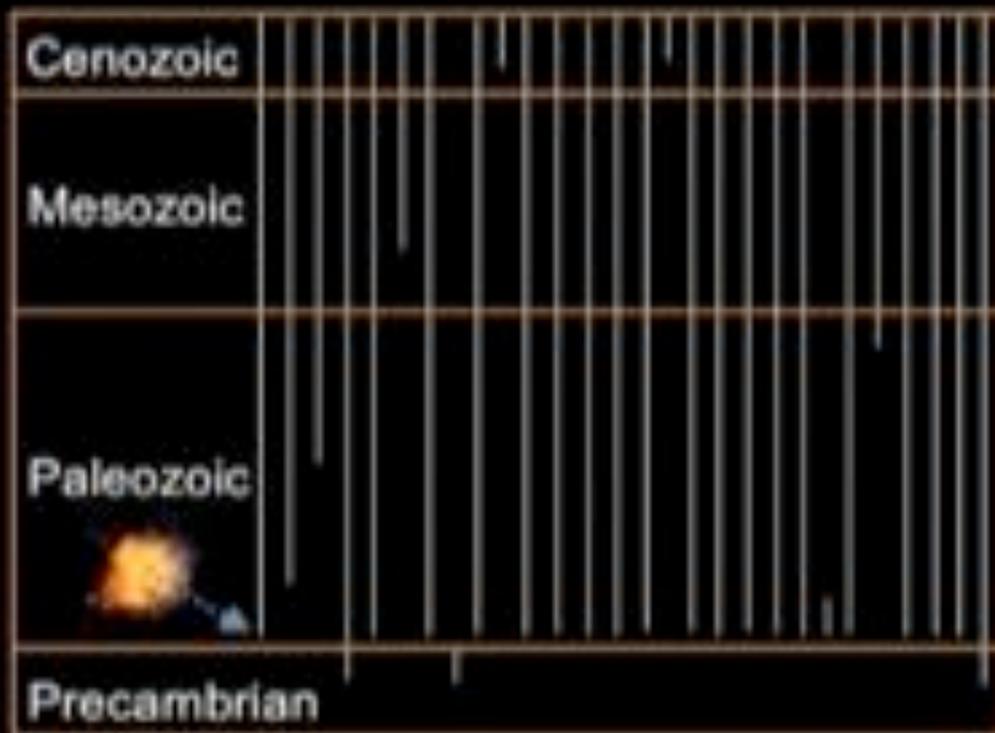
not connected

Cambrian

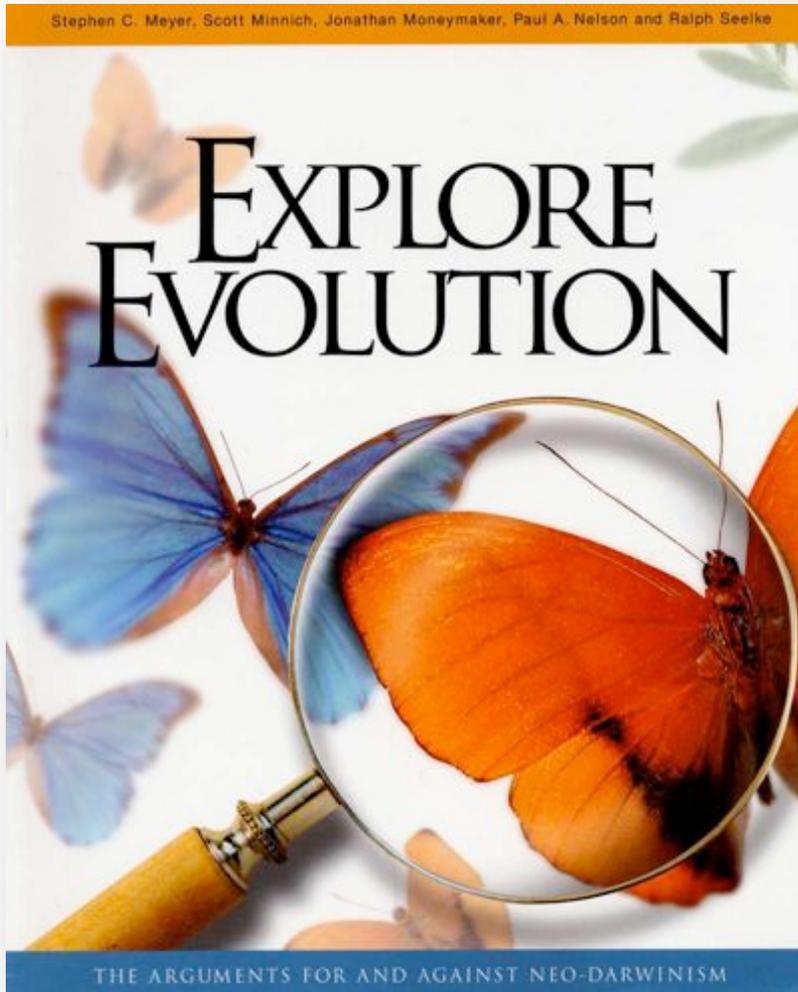
Phylum
Chordata



Origin of the Phyla: Fossils vs. Darwin

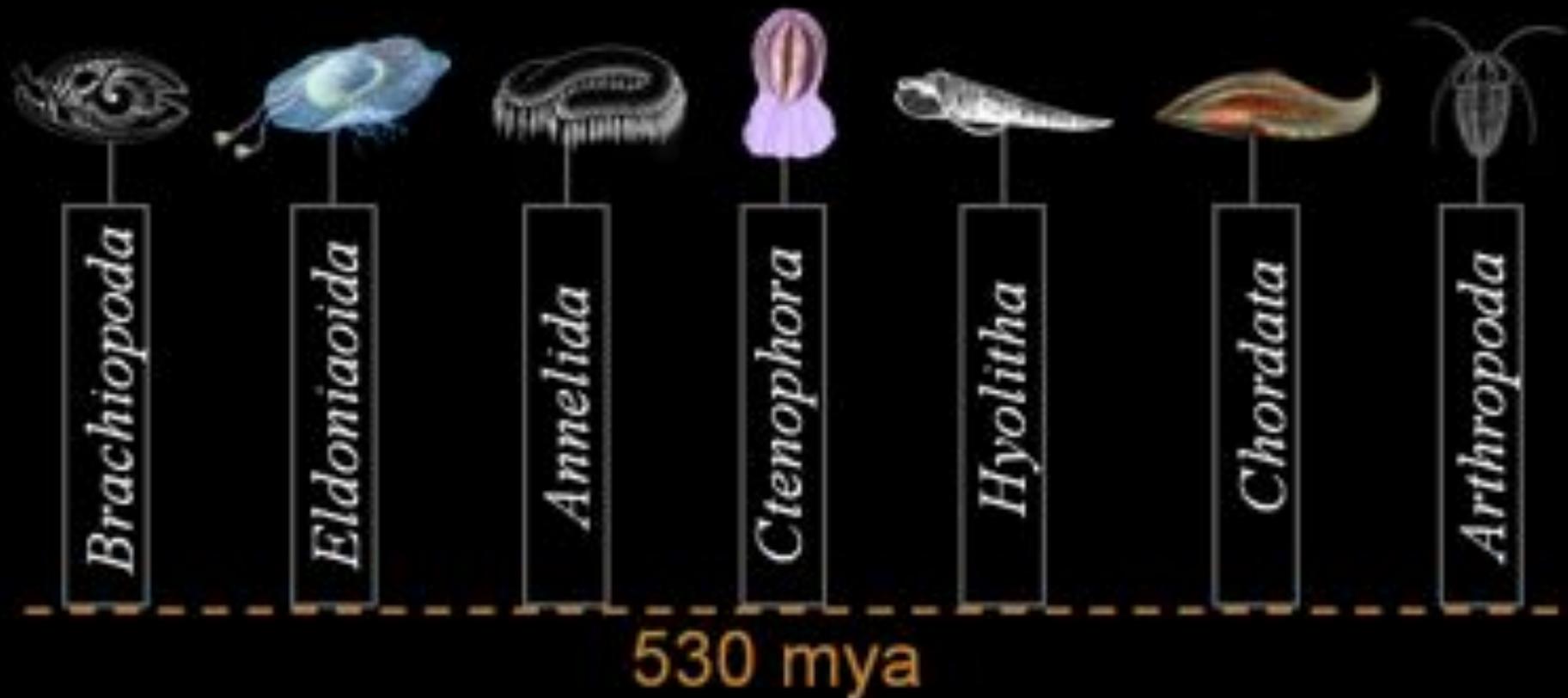


Explore Evolution



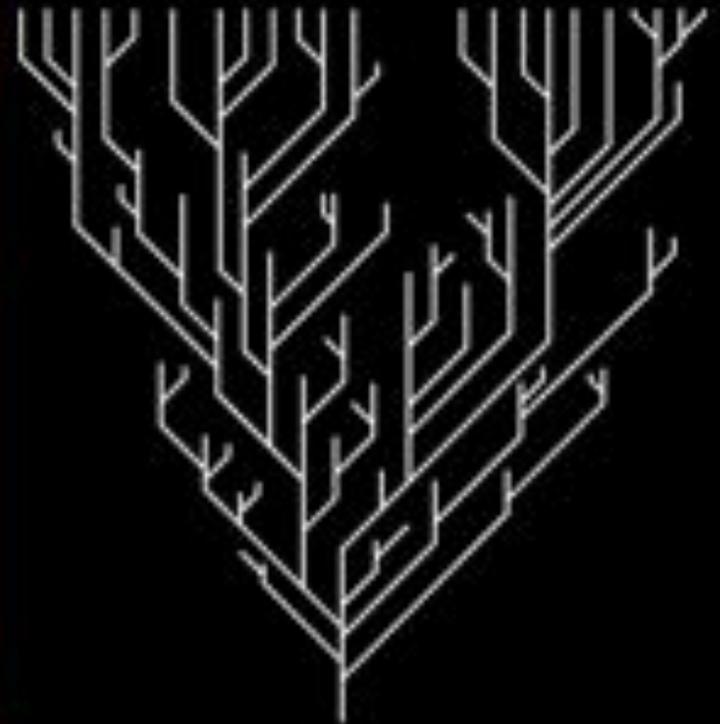
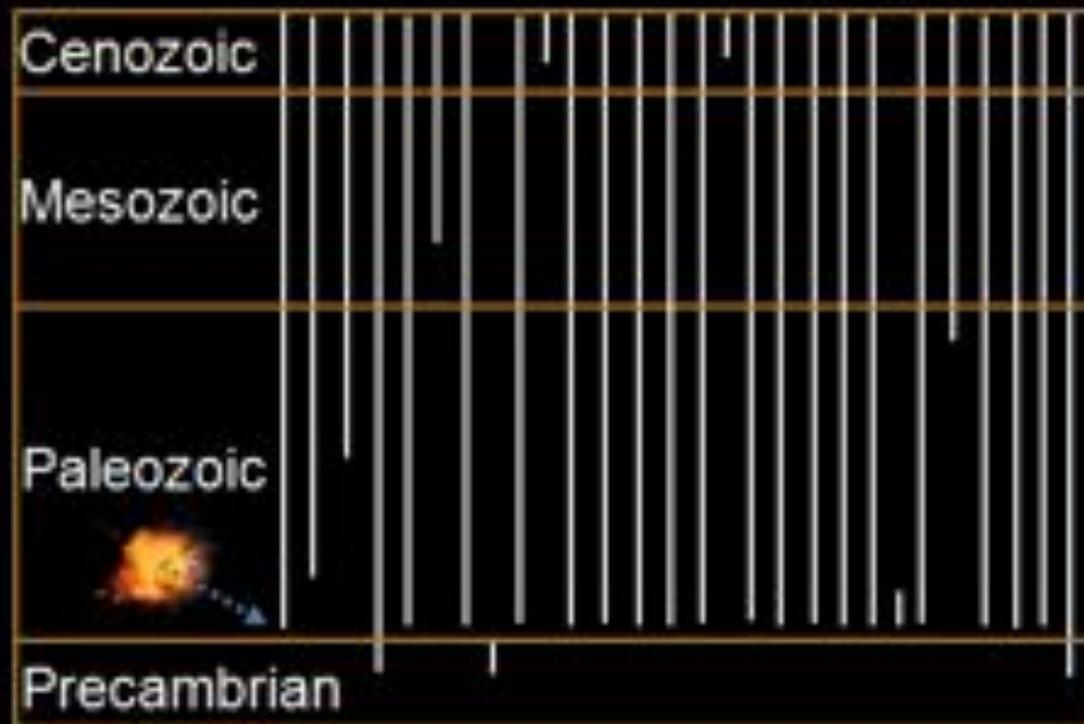
- ▶ **Fossil succession**
- ▶ Homology
- ▶ Embryology
- ▶ Biogeography
- ▶ Natural Selection
- ▶ Mutation
- ▶ ~~Molecular Machines~~

Explosion of Major Animal Groups (Phyla)



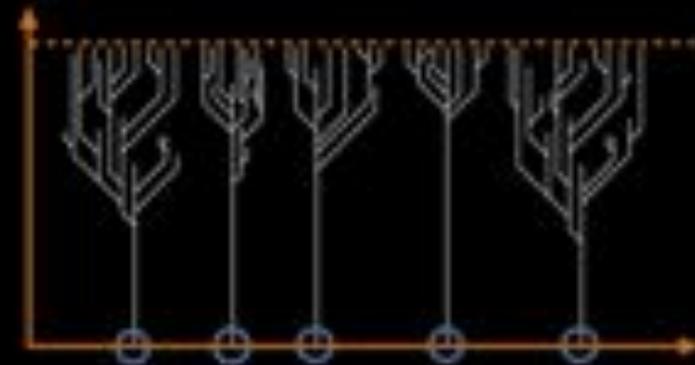
Origin of the Phyla: Fossils vs. Darwin

Over *half* of all animal phyla appear in Cambrian explosion



Two Views of Life

- One branching tree (“*monophyletic*” view)
- *Orchard* of trees (“*polyphyletic*” view)



Examples of Geologically Sudden Appearance

- Mammalian radiation



- "**Big bloom**" of flowering plants



- **Marine Mesozoic** Revolution

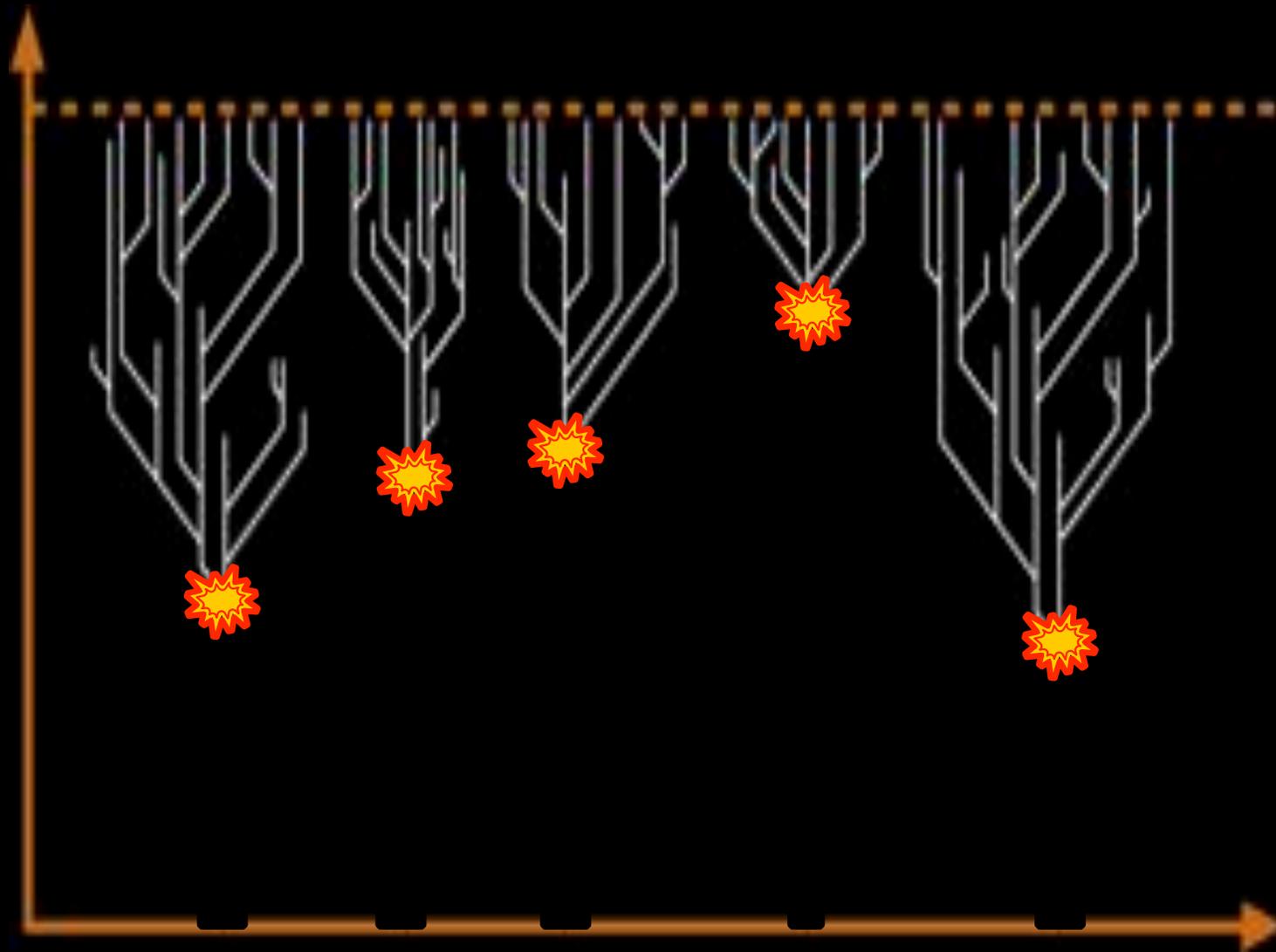


- Cambrian explosion

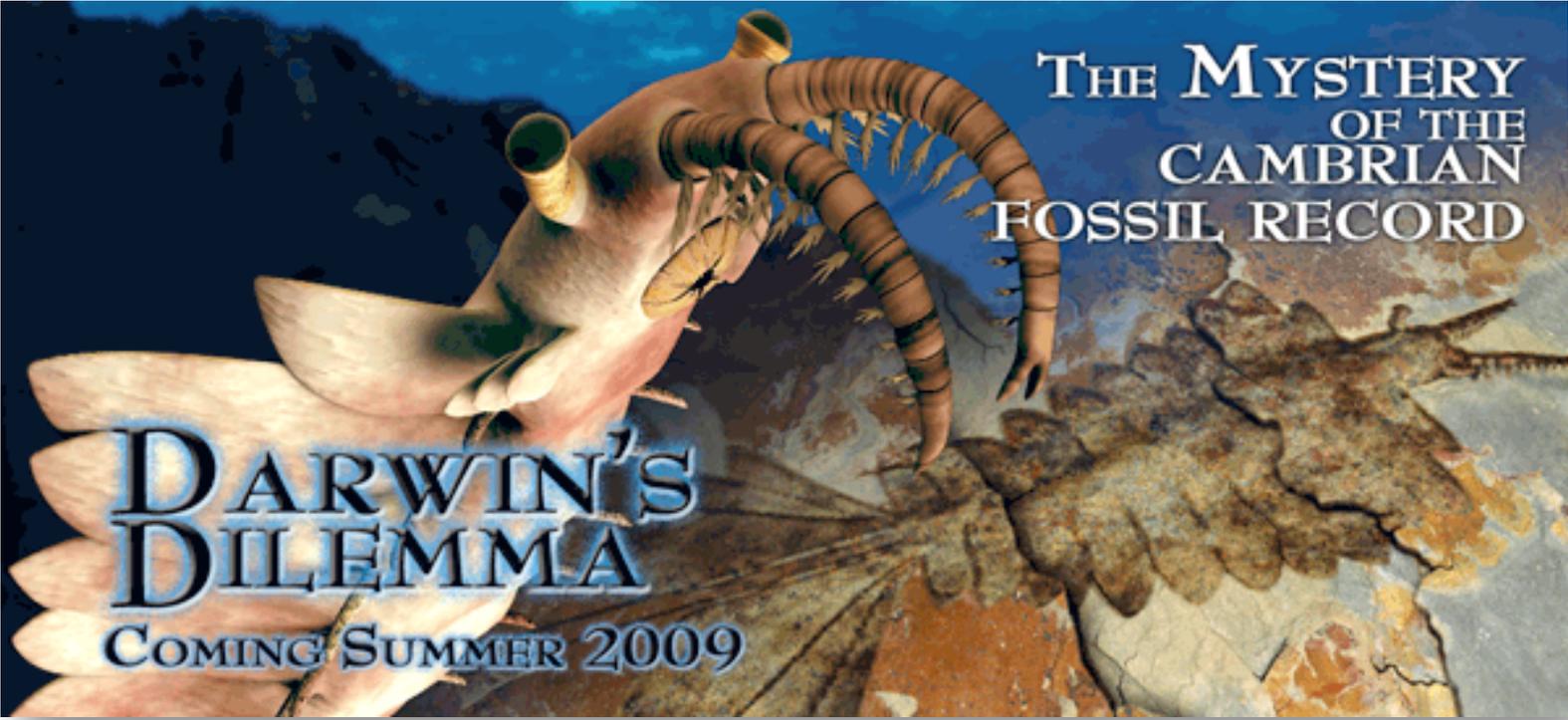




Single “Design Event”

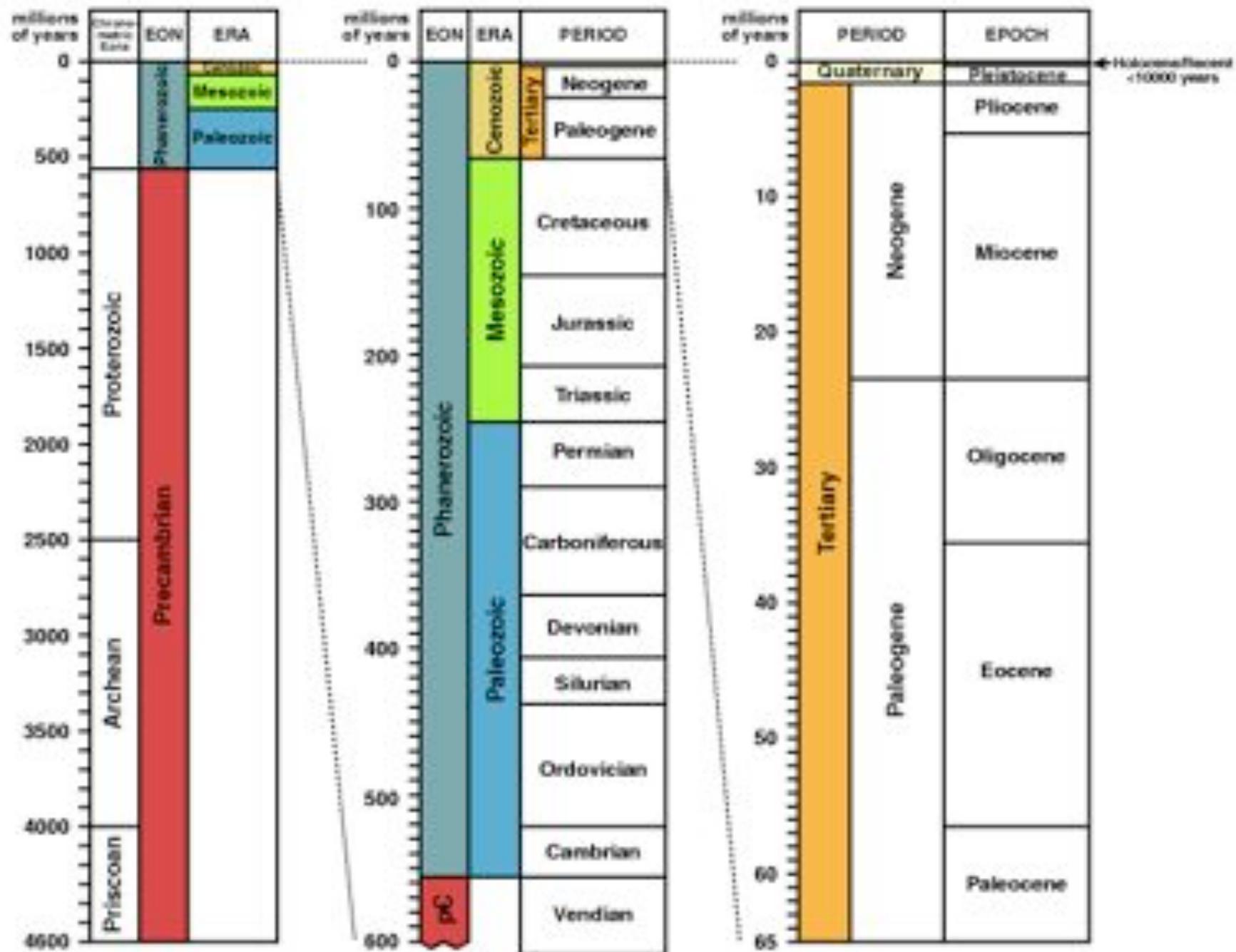


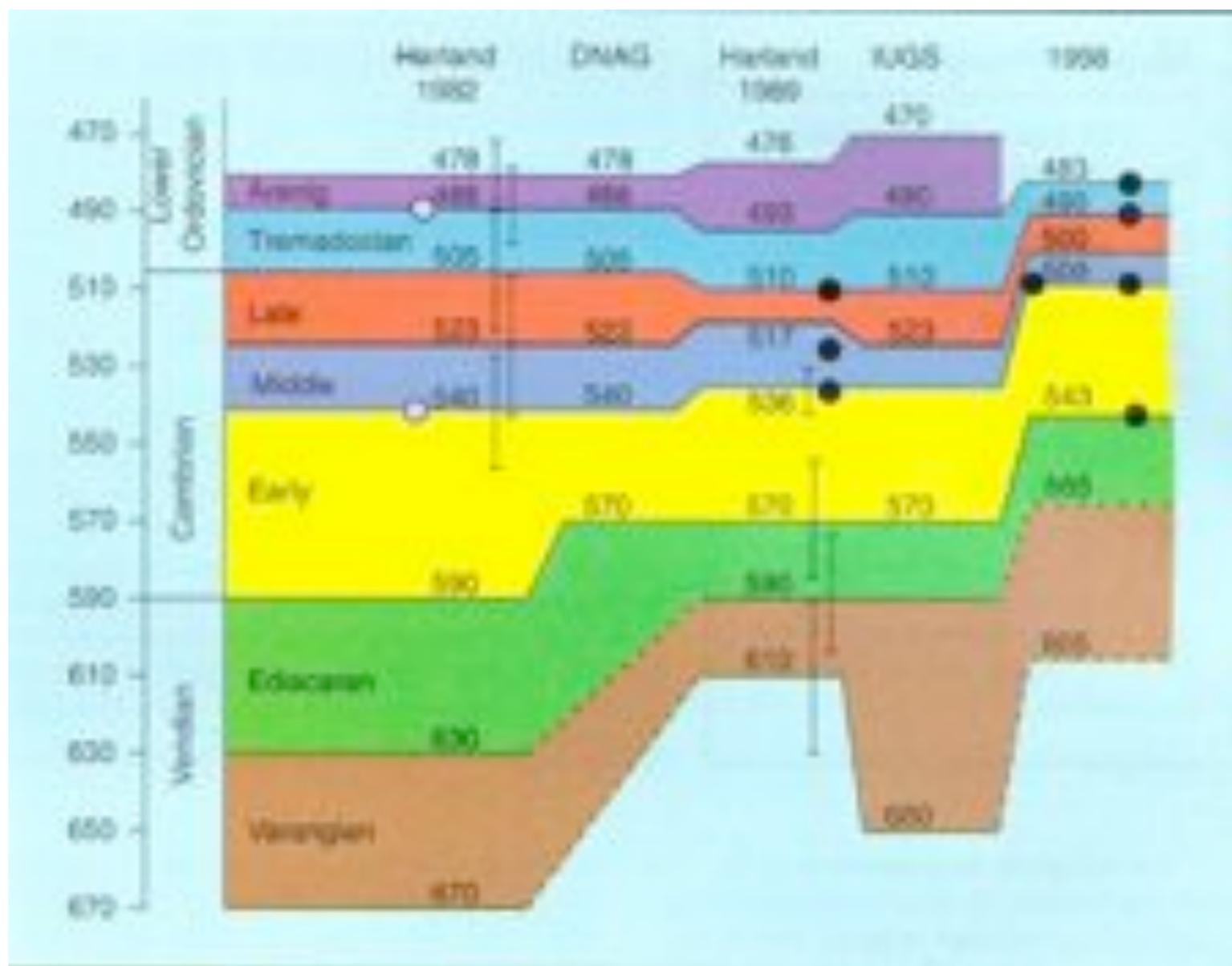
Multiple “Design Events”



THE MYSTERY
OF THE
CAMBRIAN
FOSSIL RECORD

DARWIN'S
DILEMMA
COMING SUMMER 2009

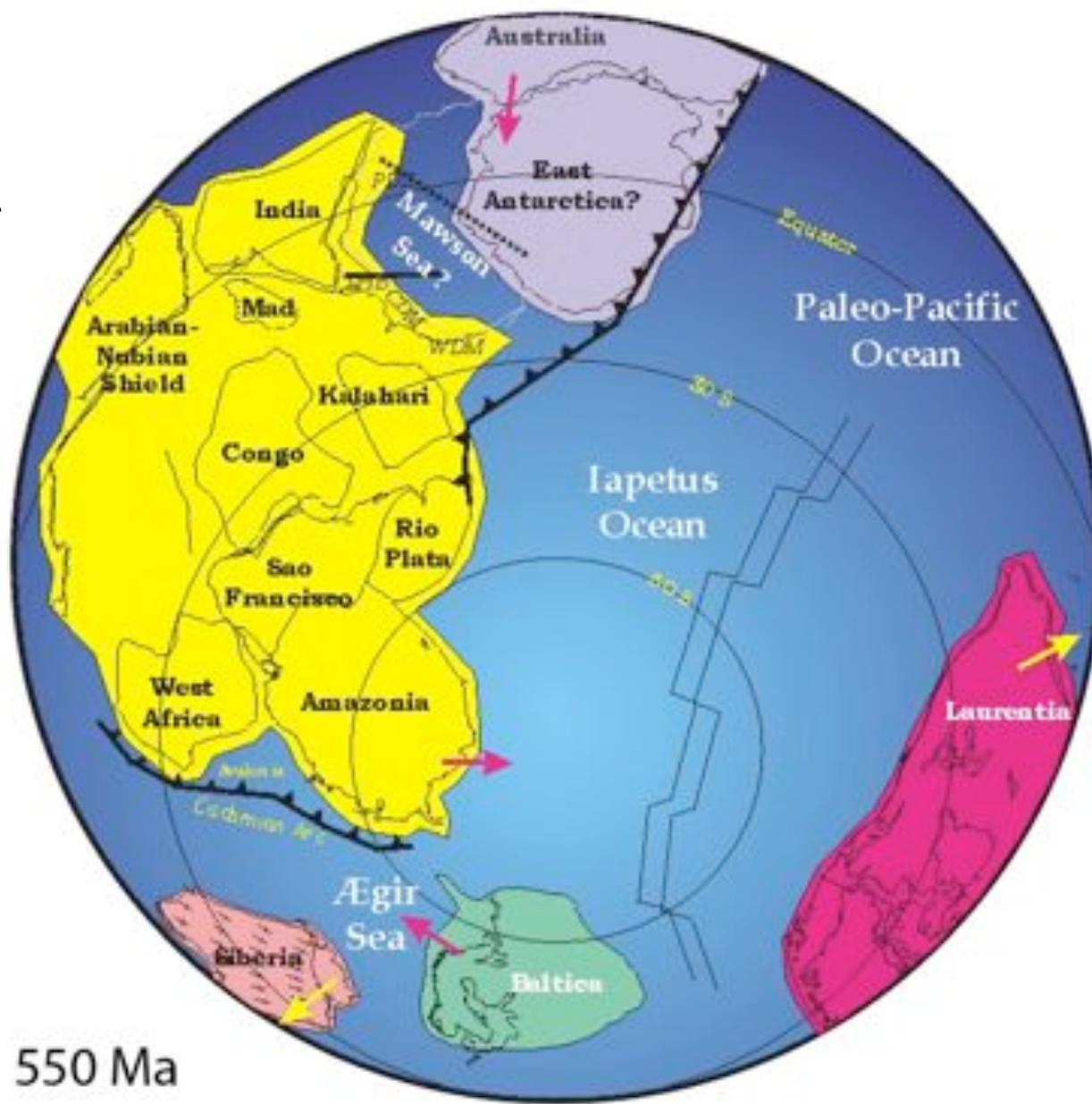




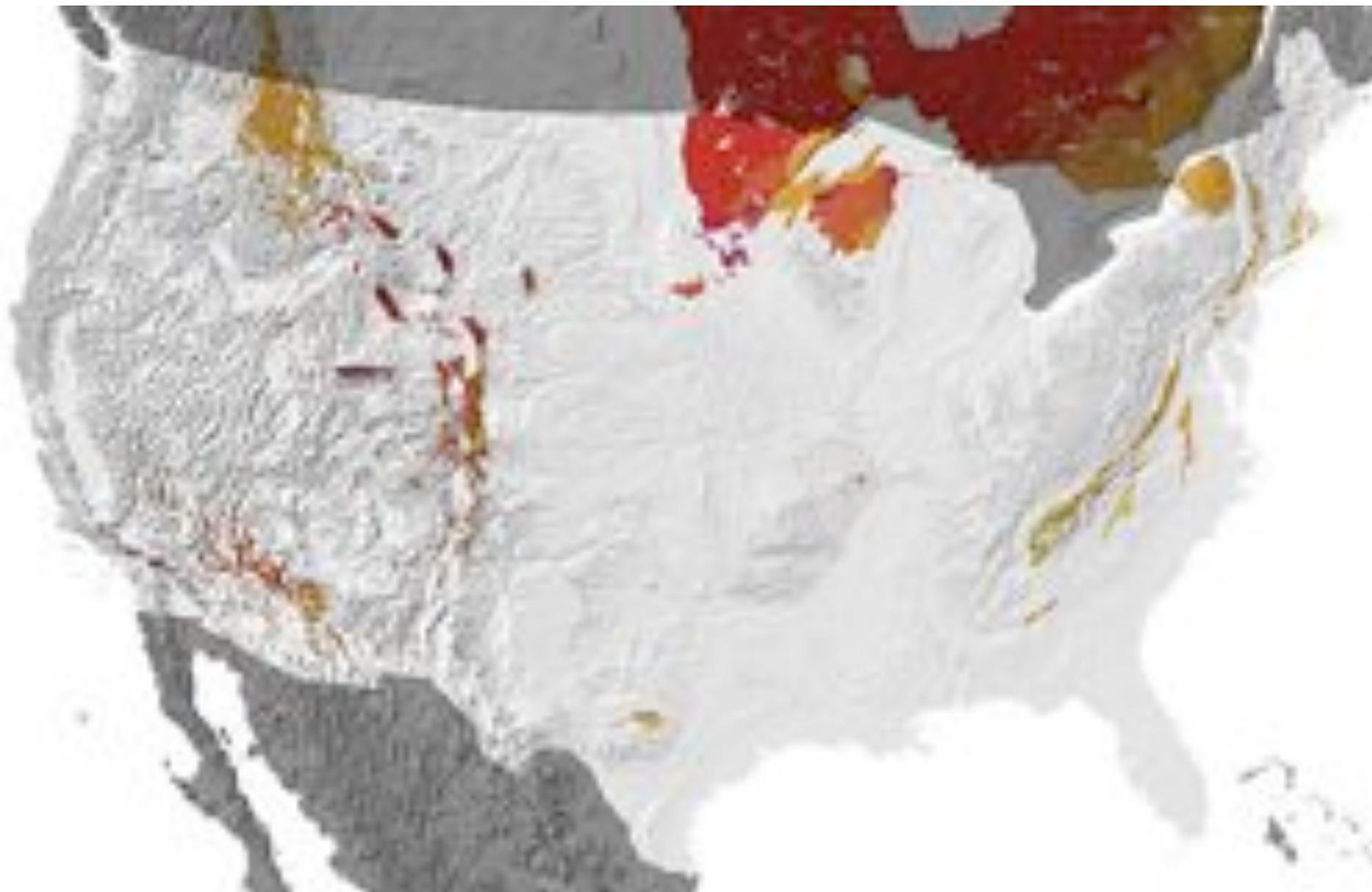
Proterozoic–Cambrian boundary (Newfoundland)



Gondwana

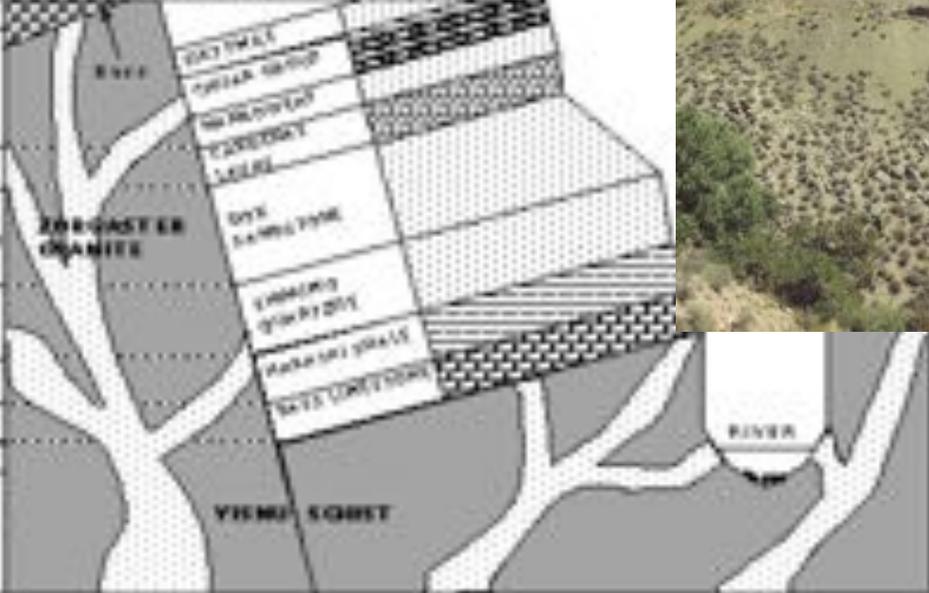
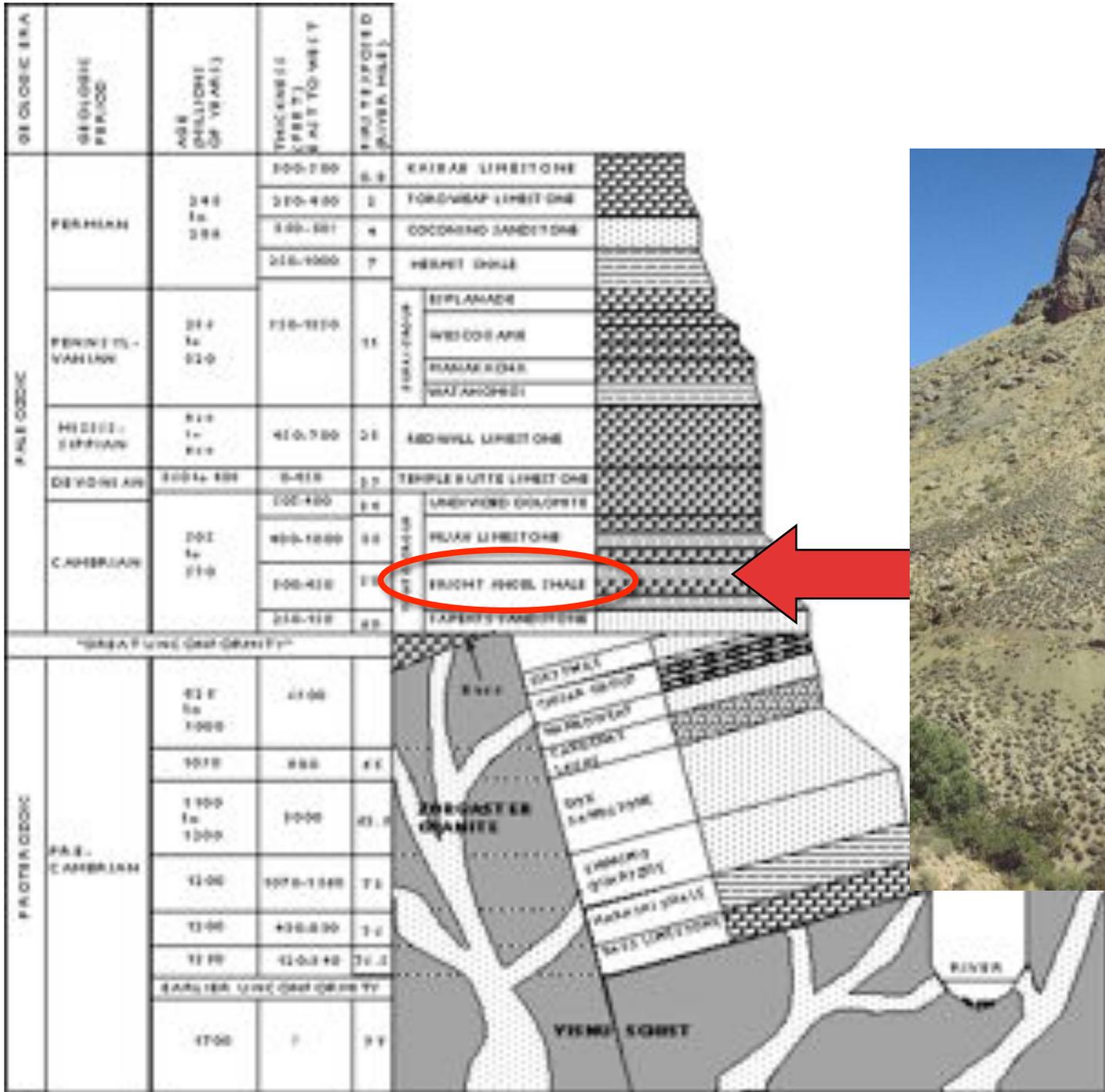


Pre-Cambrian Outcroppings



Cambrian Outcroppings







Becoming A Fossil

Michael Denton



An irreducible gap in **phenotypic** space [i.e. morphology] cannot be taken to imply that there is a similar gap in **genotypic** space [i.e. genetics].

Some Key Ideas

- ▶ Cambrian Explosion – the geologically sudden appearance of many of the Metazoan phyla.
- ▶ Metazoan – multicellular organisms
- ▶ Protostomes and Deuterostomes – two superphyla within the Bilateria differentiated by embryonic cleavage patterns.

Phylum

- ▶ **Morphological** branch of the tree of life
- ▶ Group of organisms sharing a “major body plan”
- ▶ Number of extant phyla differ depending on source, but generally taken to be in the low to mid thirties.
 - Therefore, we should be careful of “essentializing” them.

Phyla: Highest Divisions in Animal Kingdom

Kingdom: Animal



Phylum: basic body plan

Higher
Taxa



Class

Order

Family

Genus

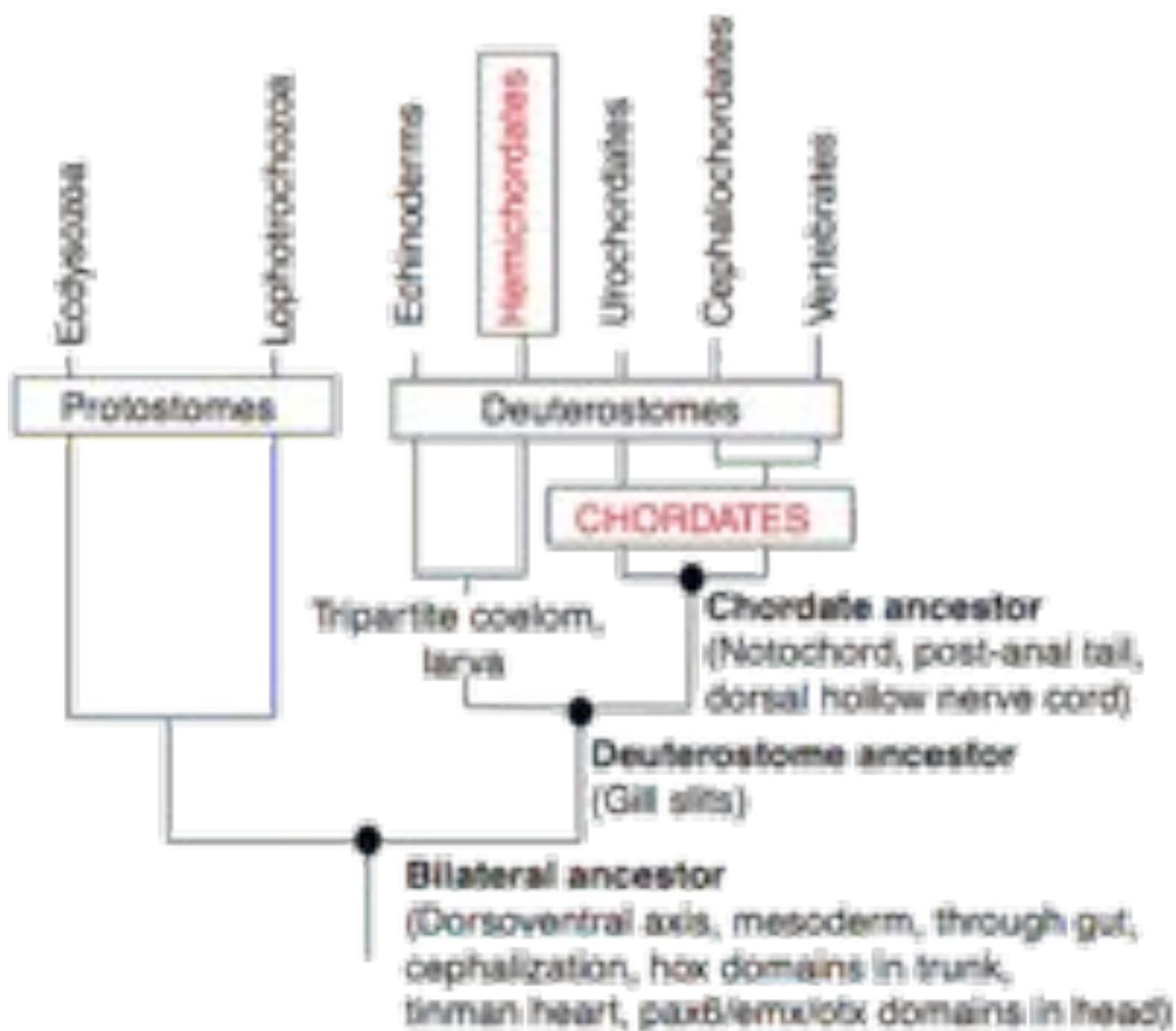
Species

Lower
Taxa

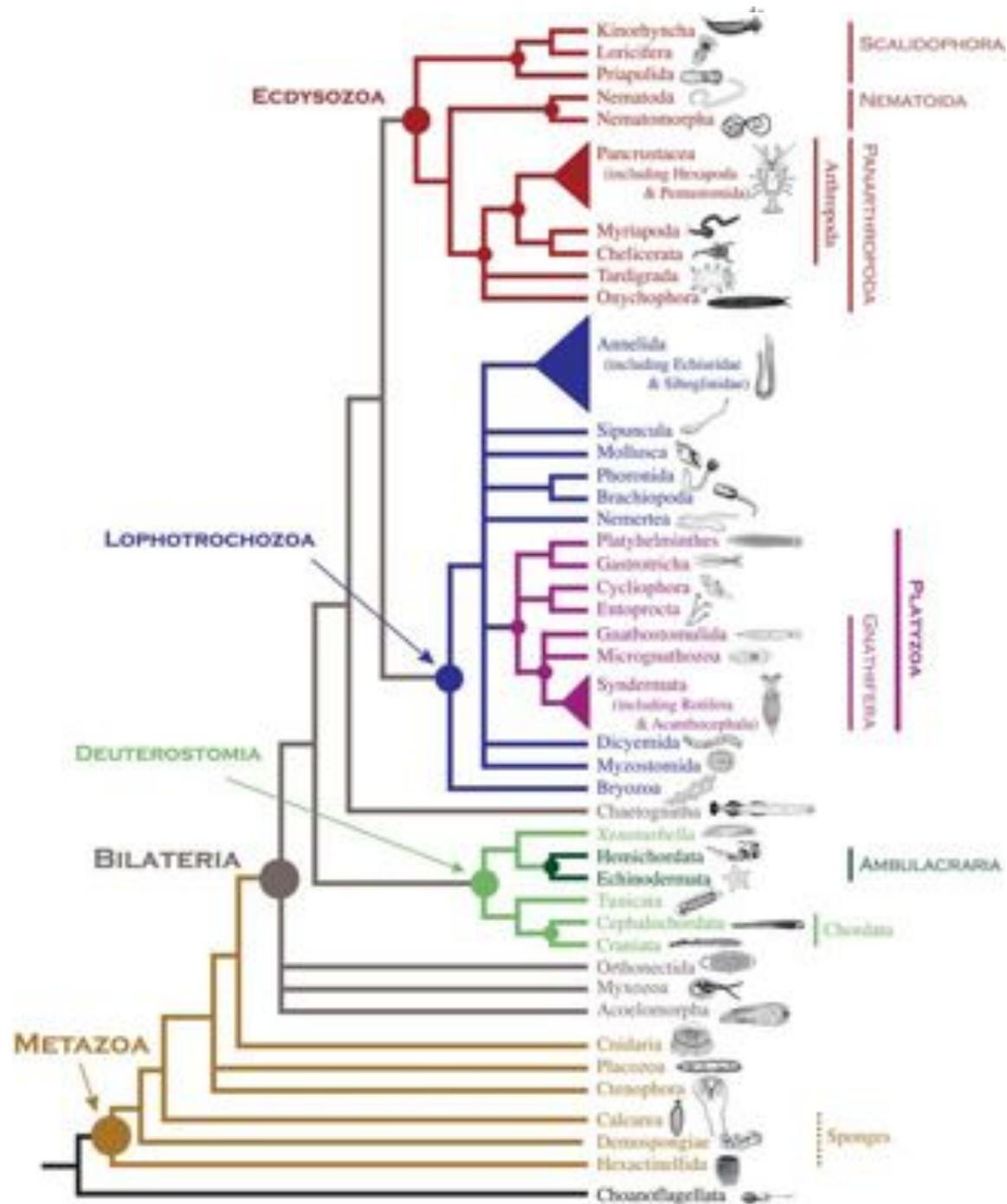
Biological Classification

	Bumble Bee	Polar Bear
Kingdom	Animal	Animal
Phylum	Arthropod	Chordate
Class	Insect	Mammal
Order	Hymenoptera	Carnivora
Family	Apidae	Ursidae
Genus	<i>Bombus</i>	<i>Ursus</i>
Species	<i>terricola</i>	<i>maritimus</i>





Revision based on molecular data.



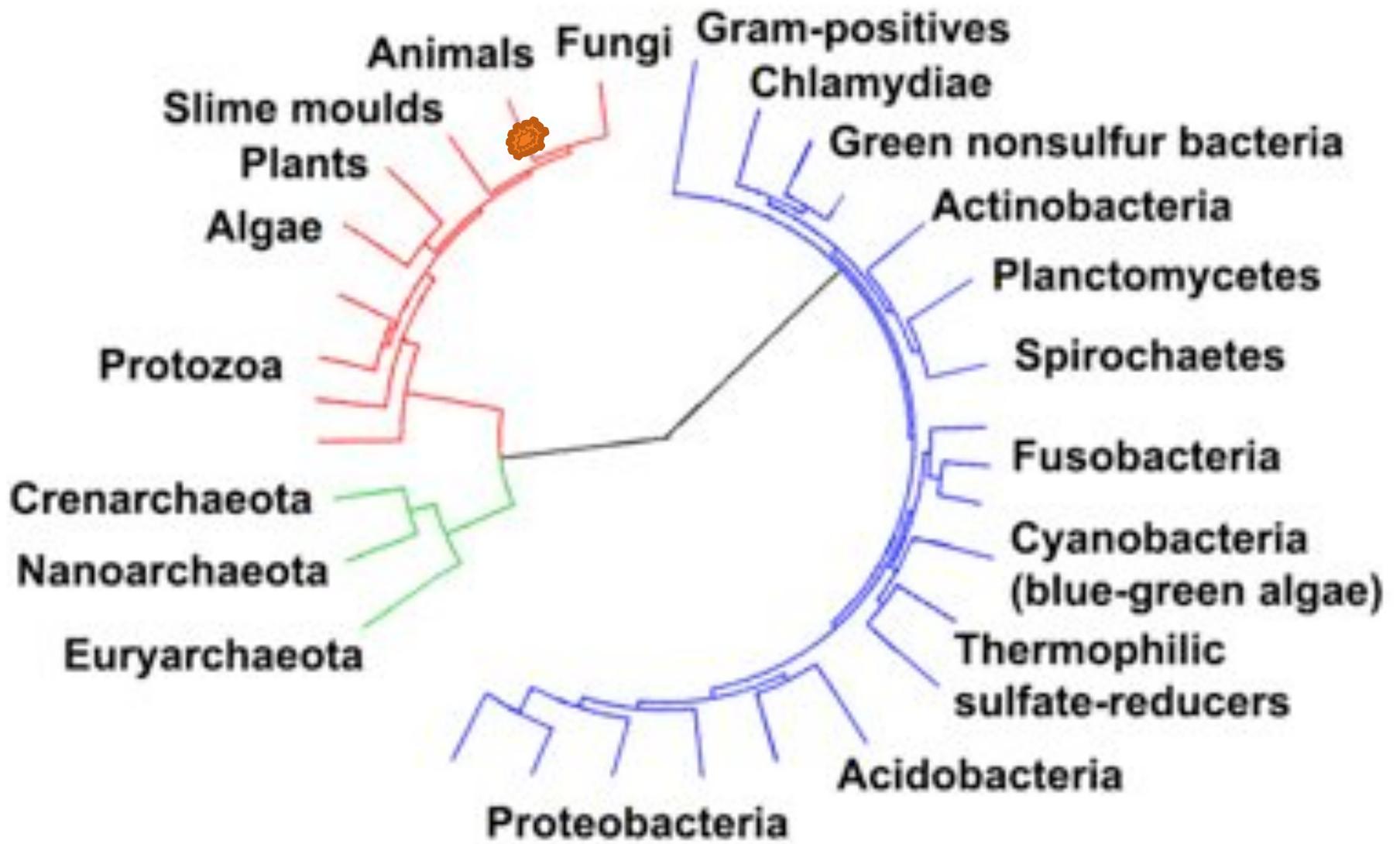
Five Questions

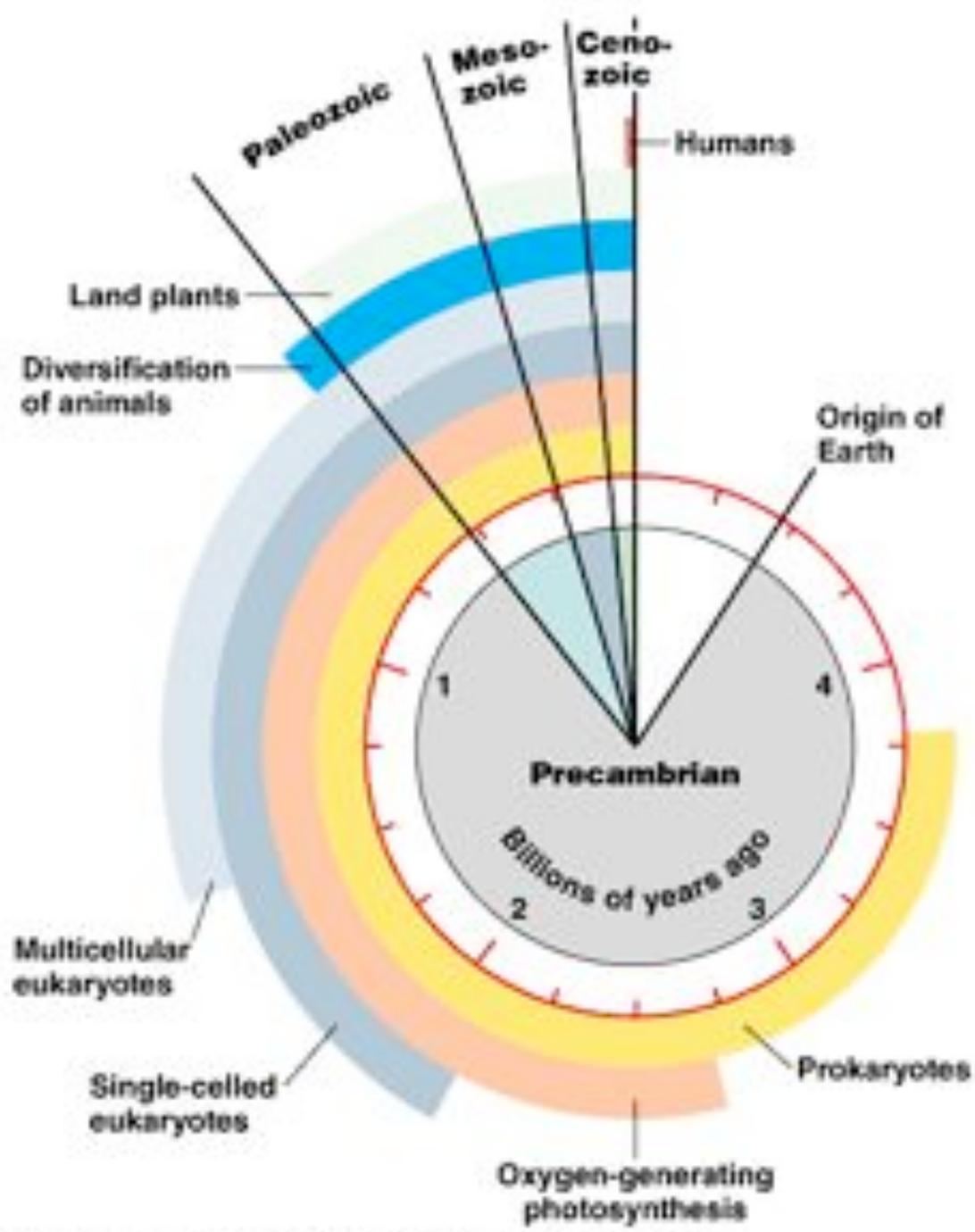
- Was there a Pre-Cambrian fauna?
- What happened in the Cambrian?
- Is the explosion real?
- How did it happen?

FOSSILIZED PHYLA
APPEAR FOR THE
FIRST TIME

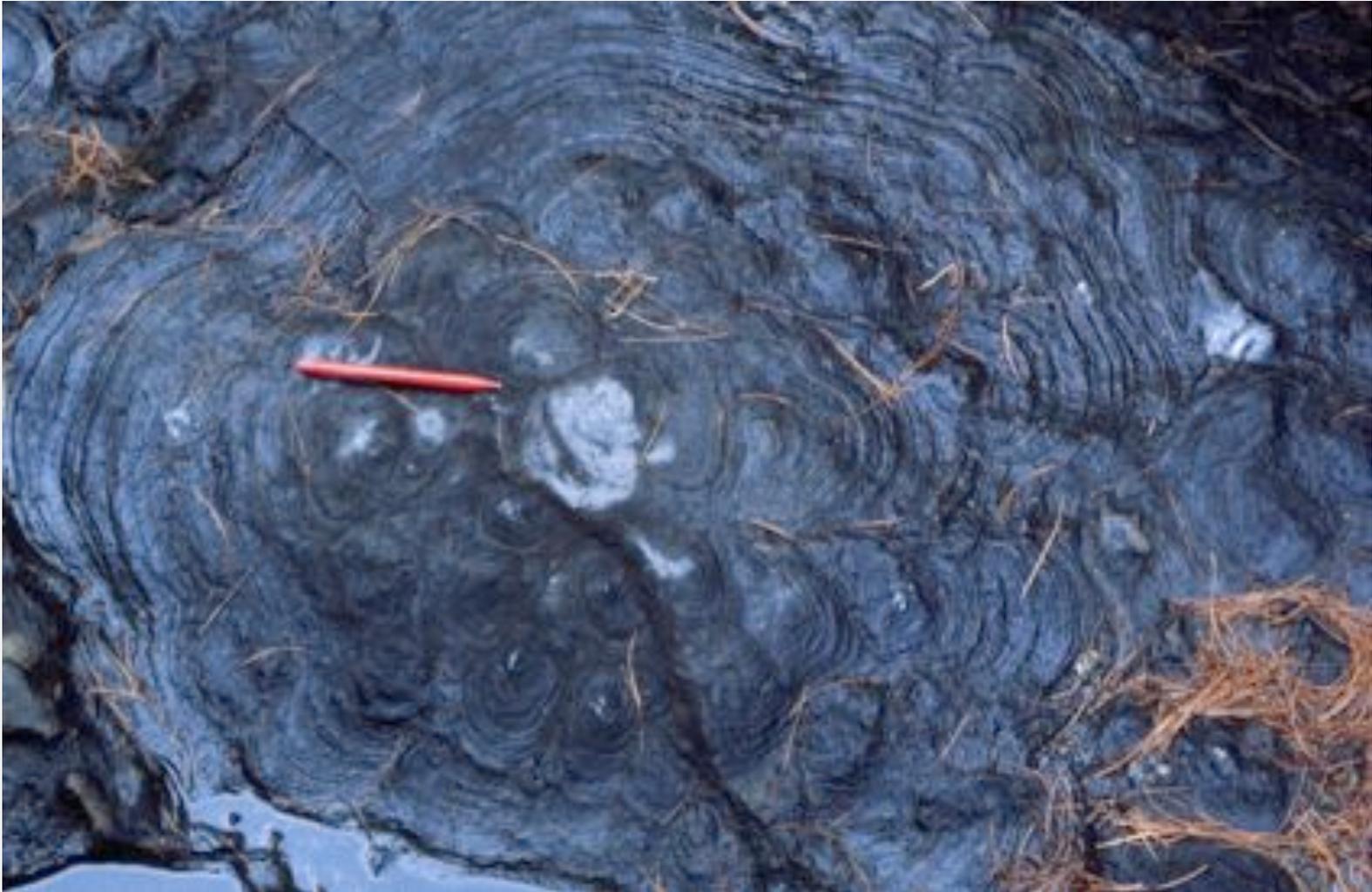


CAMBRIAN AGE



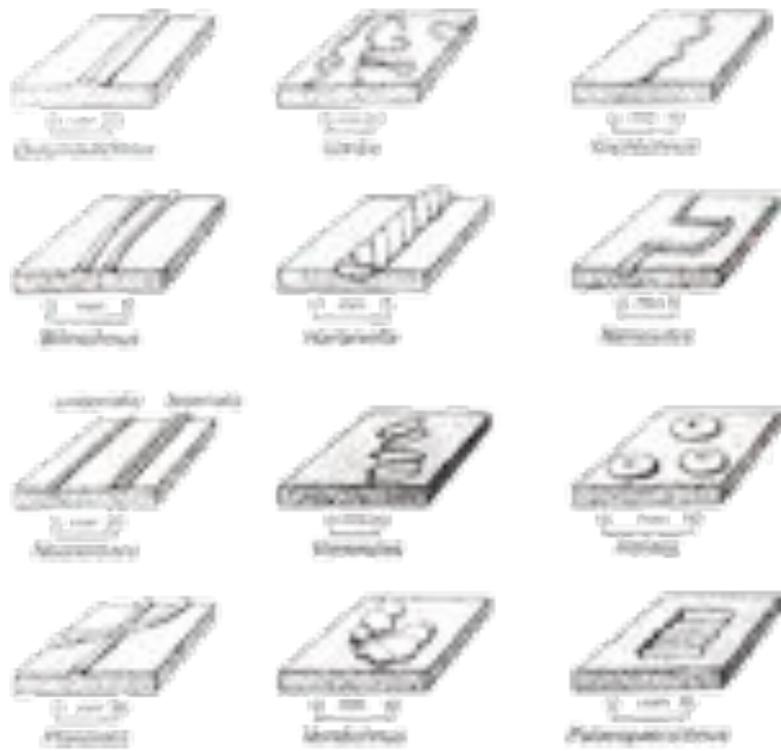


Stromatolites (3,500 my)





Pre-Cambrian Trace Fossils



Early Trace Fossils

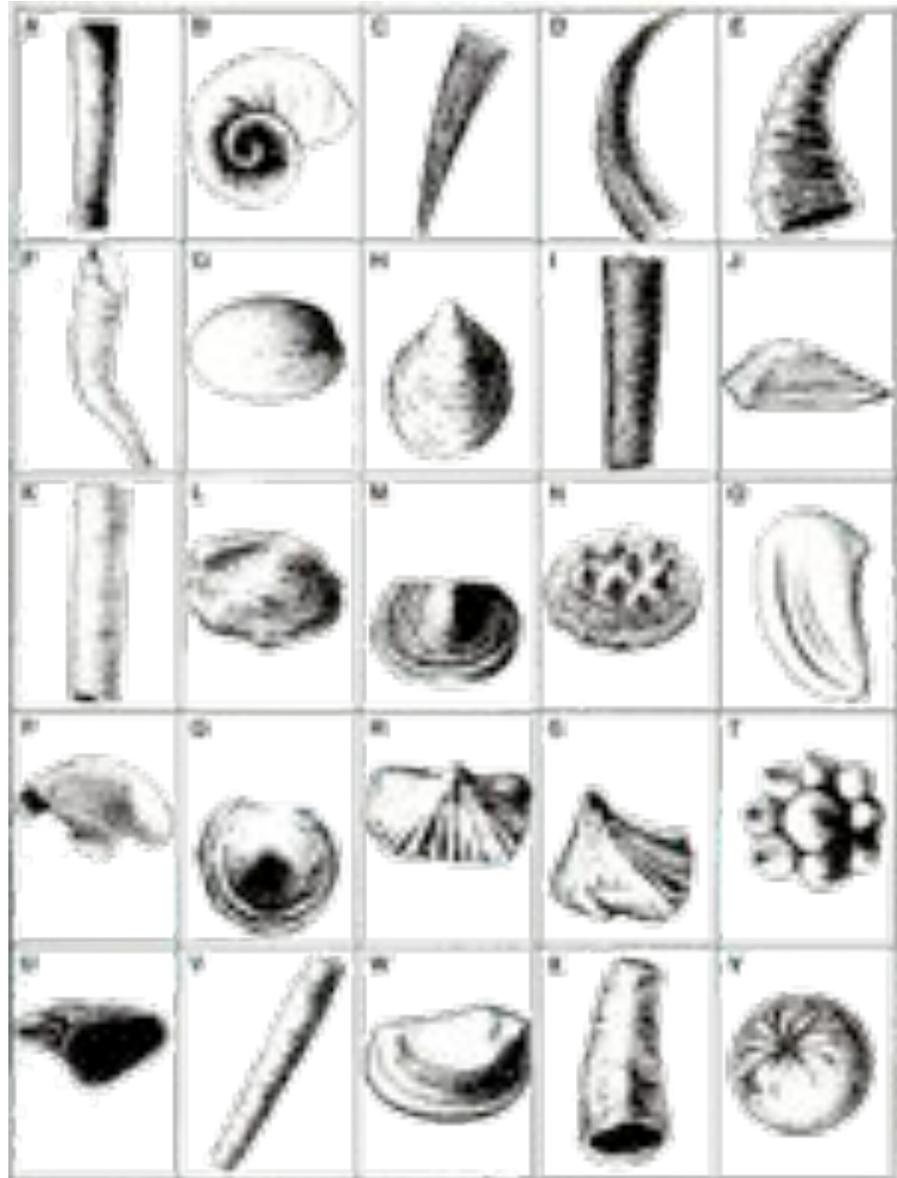


Late Trace Fossils

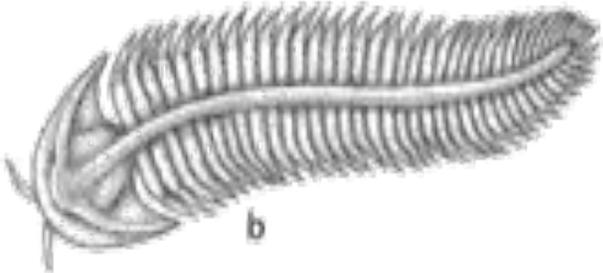
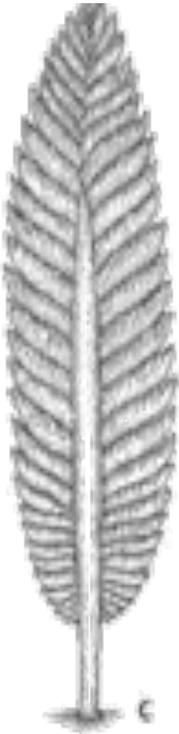




“Small Shelly” Fauna



Ediacarian (Vendian) Fauna (575 my)

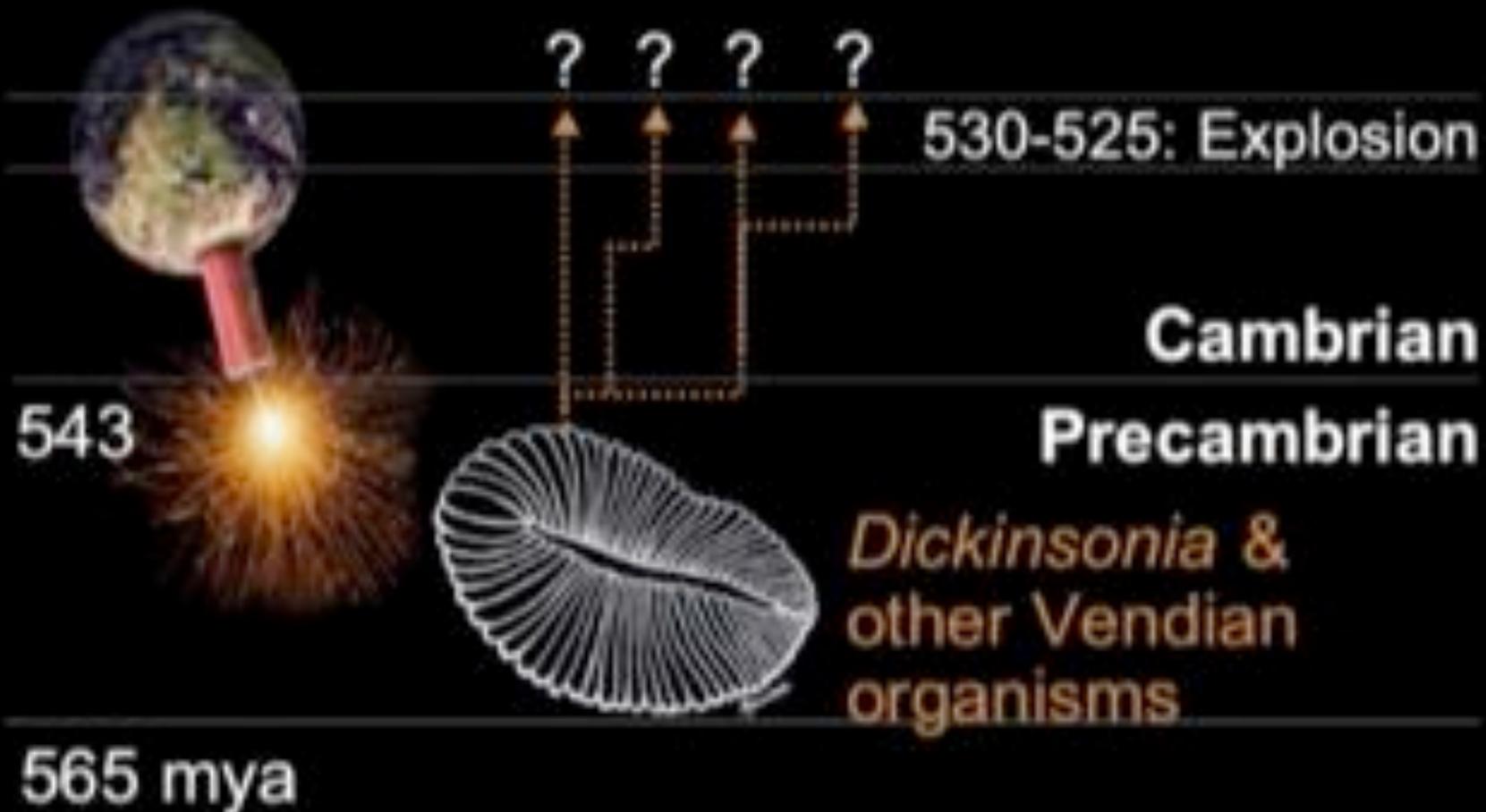




Dickinsonia



Fuse for the Cambrian Explosion?



Vendian Organisms not Transitional

- Not morphologically similar to later Cambrian animals
- Lacked eyes, mouth, and anus
- Probably not animals





Spriggia
Arthropod



Charniodiscus arboreus
Cnidarian

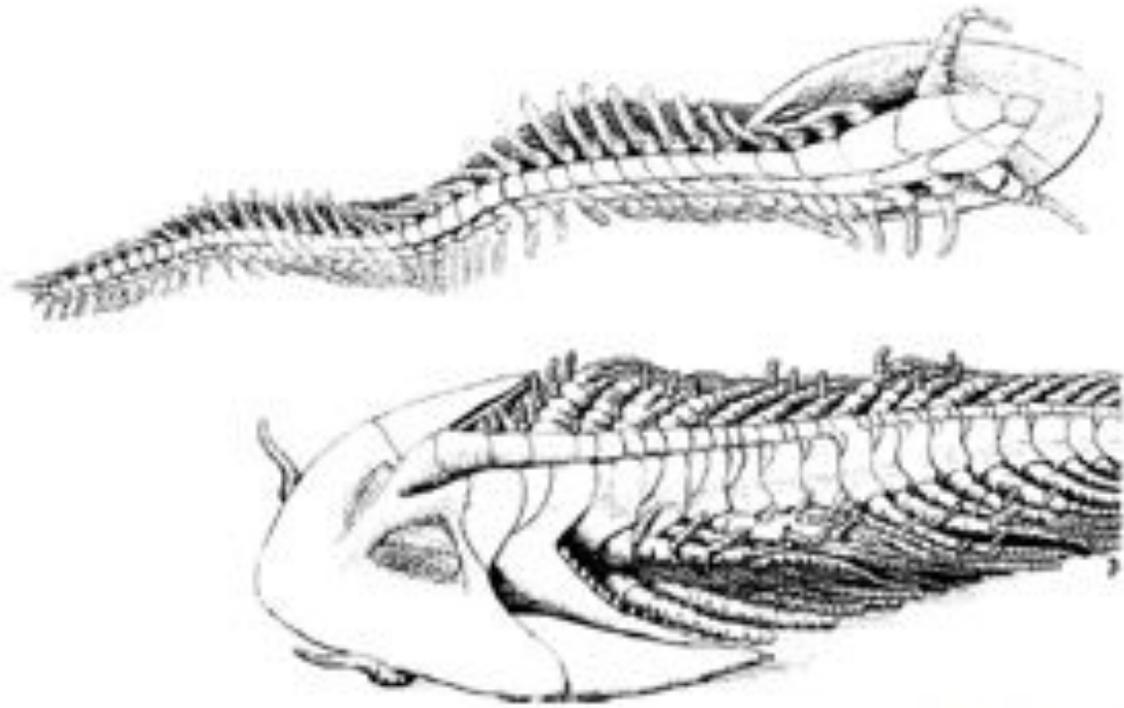
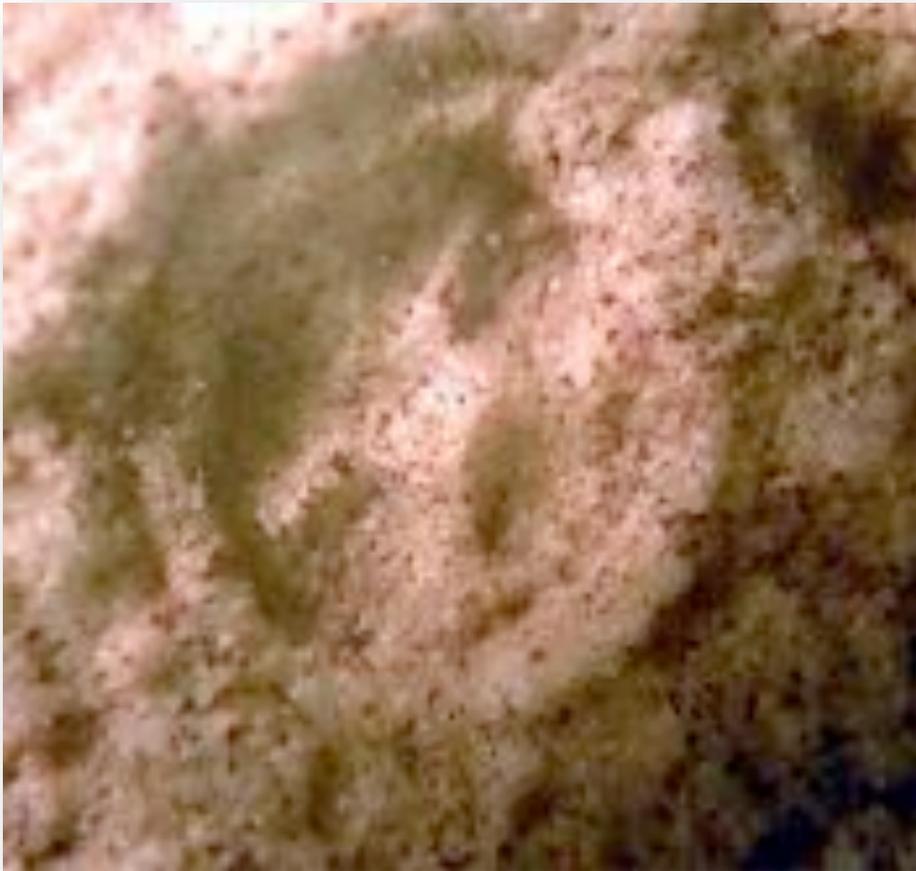


Fig. 12. Sketches of *Spriggina* as envisaged swimming and crawling in life (from Birket-Smith, 1981a).



Arkarua



Echinoderm

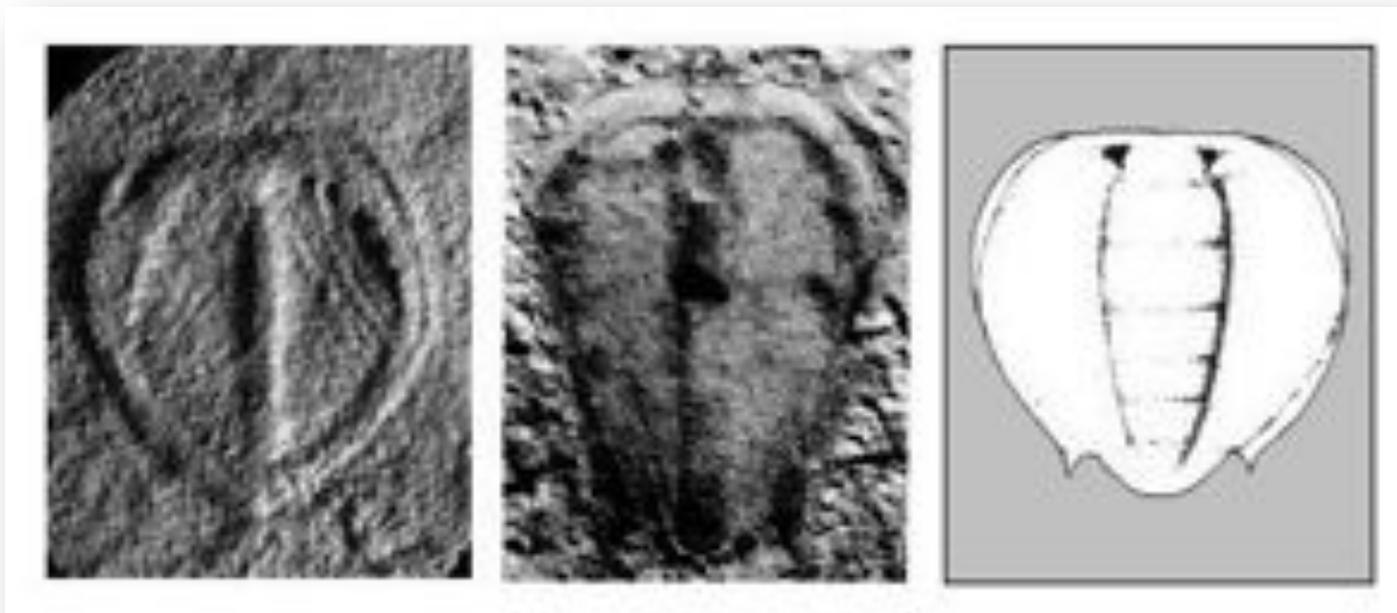
Kimberella



Mollusc

Parvancorina

Precambrian trilobite ancestor
(Arthropod)



A painting of a Cambrian trilobite fossil, showing its segmented body and legs, set against a background of a grid pattern. The trilobite is rendered in shades of blue and purple, with a prominent red segment on its head. The background is a muted, earthy tone with a grid of thin lines.

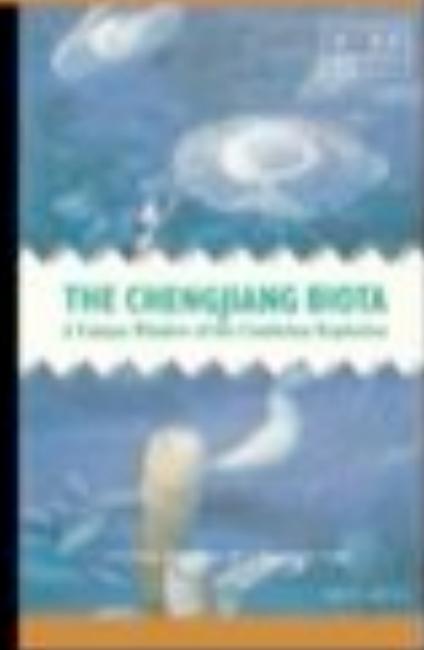
THE CAMBRIAN EXPLOSION:
**WHAT
HAPPENED?**





Location: Chengjiang, China

National Museum of Natural Science (Taiwan, 1996)



DISCOVERY
INSTITUTE

| BIOLOGY'S BIG BANG

THE CAMBRIAN EXPLOSION

Location: Burgess Shale (Canada)

Smithsonian Institution Press (1994)



DISCOVERY INSTITUTE | BIOLOGY'S BIG BANG

THE CAMBRIAN EXPLOSION

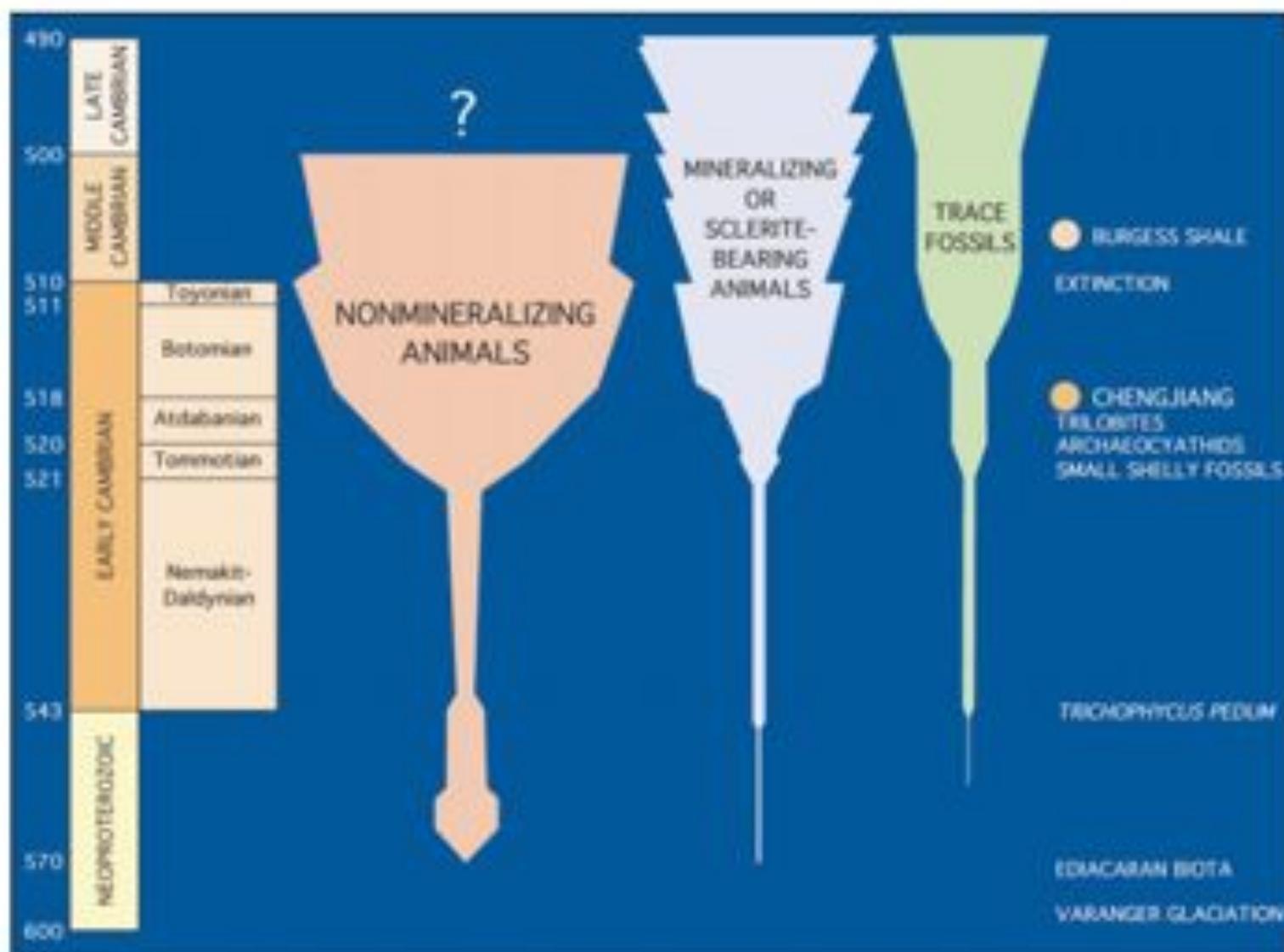
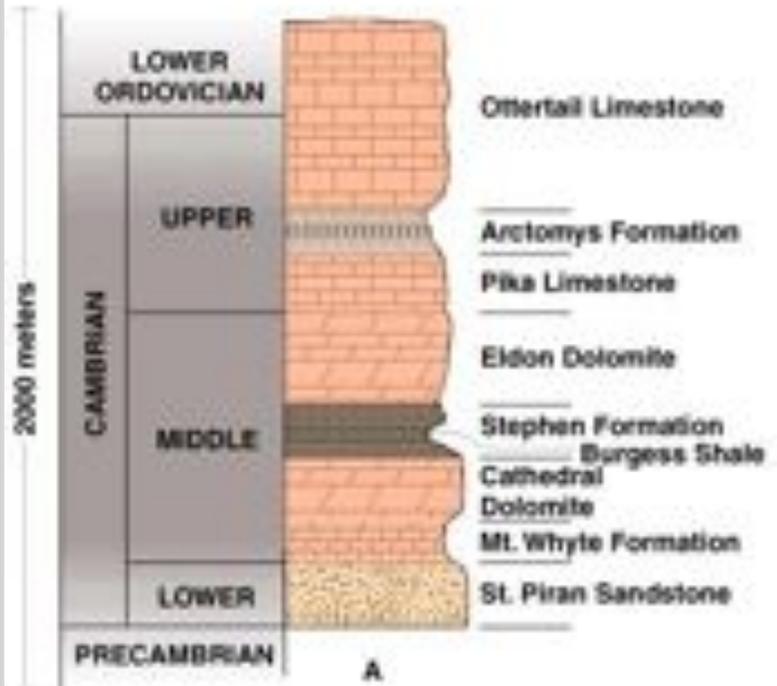


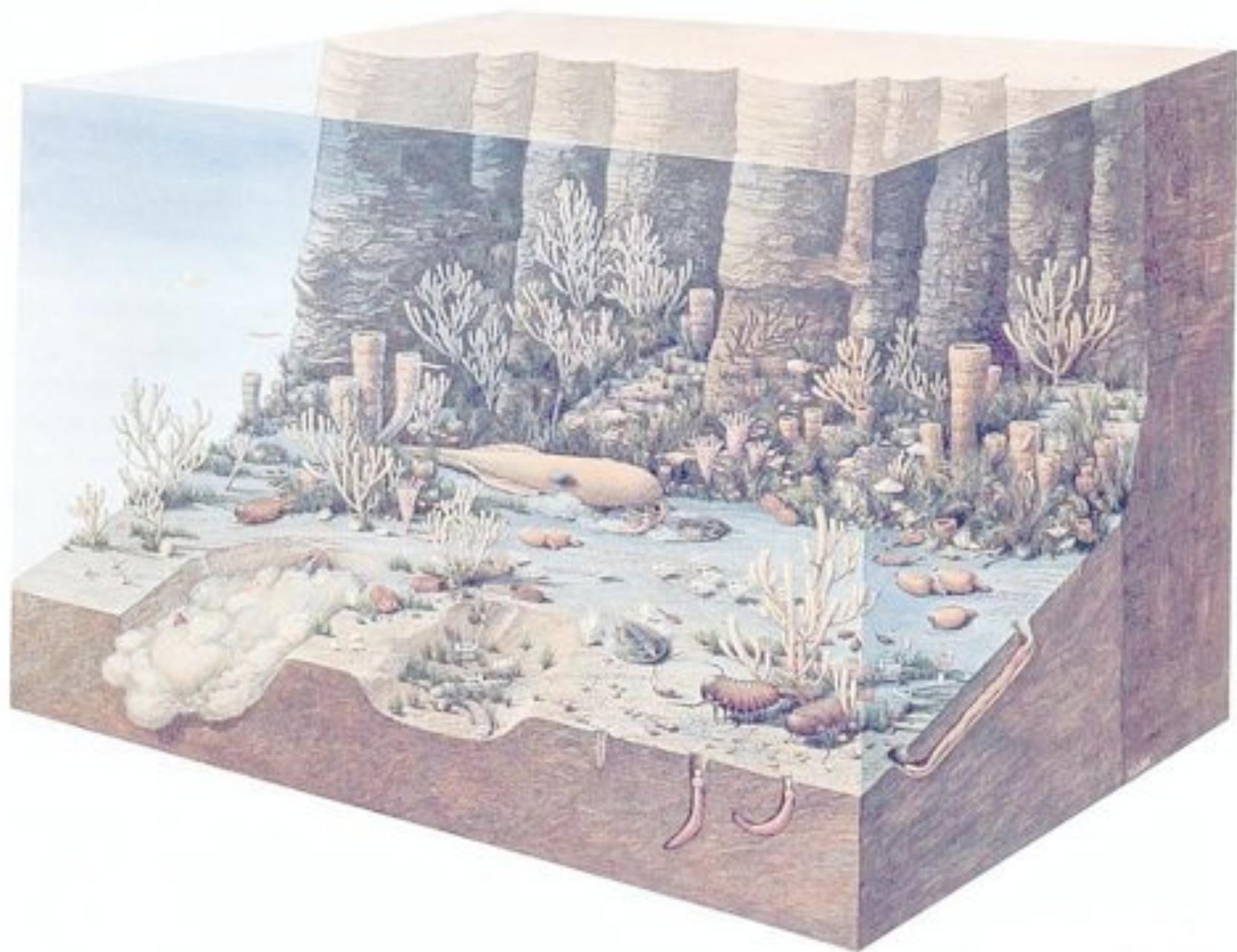
Figure 2. Generalized Late Neoproterozoic–Cambrian stratigraphy and biotic record showing the position of the Chengjiang Biota. Age estimates are extrapolated from Grotzinger et al. (1995), and Landing et al. (1998, 2000).



Burgess Shale ~510 my







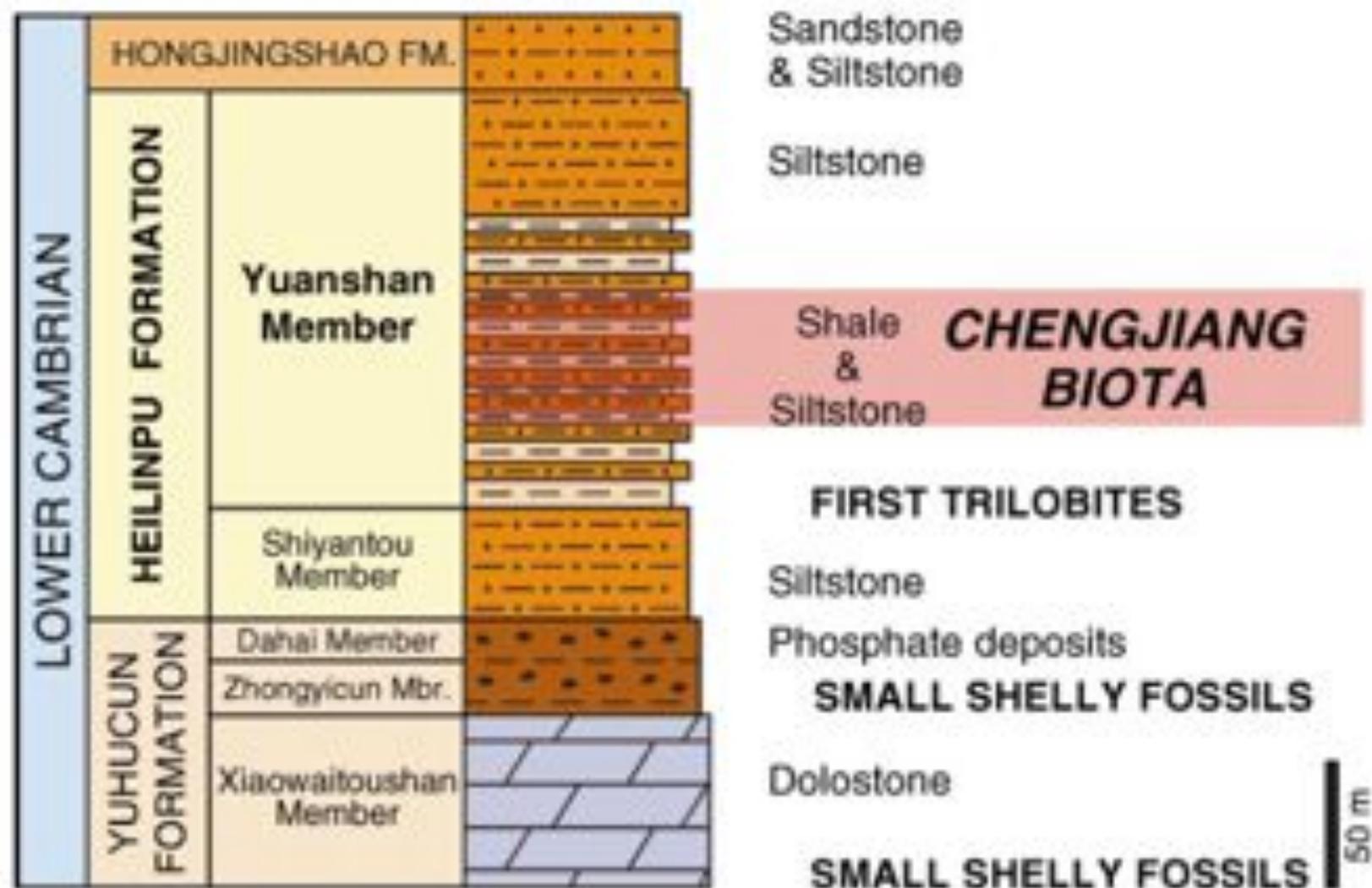


Figure 4. Generalized Lower Cambrian stratigraphy of Yunnan, China, showing the position of beds yielding exceptionally preserved fossils of the Chengjiang Biota, and the relationship of these fossils to some other important fossil occurrences.

Phylum: *Arthropoda* Subphylum: *Crustacea*

Body Plan:

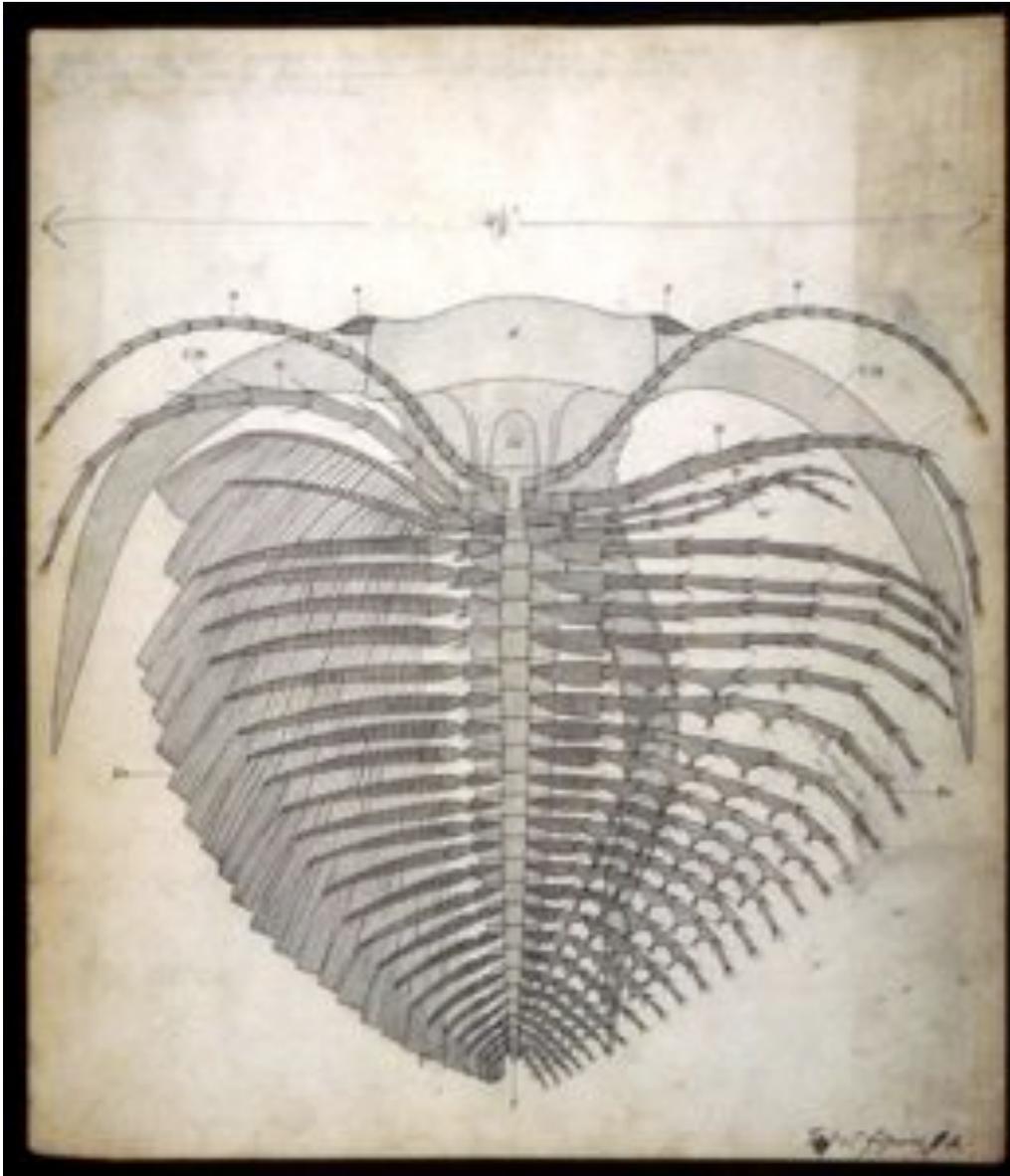
1. Segmented
2. Exoskeleton



Genus: *Waptia*



Marella
(arthropod)



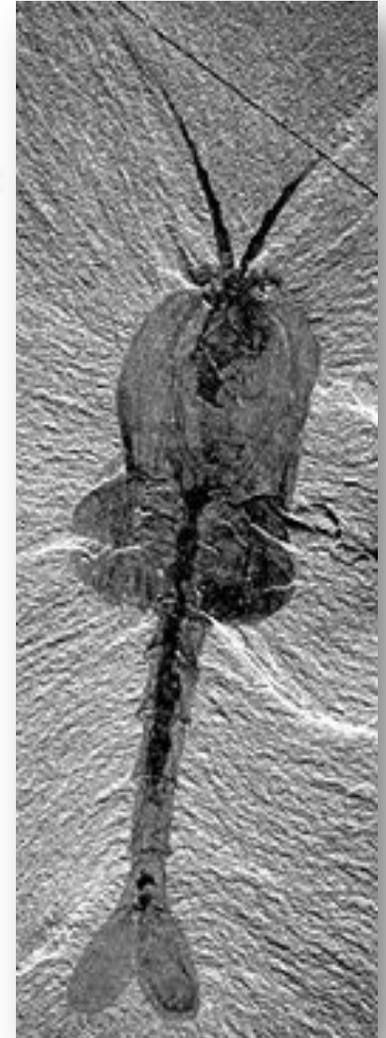
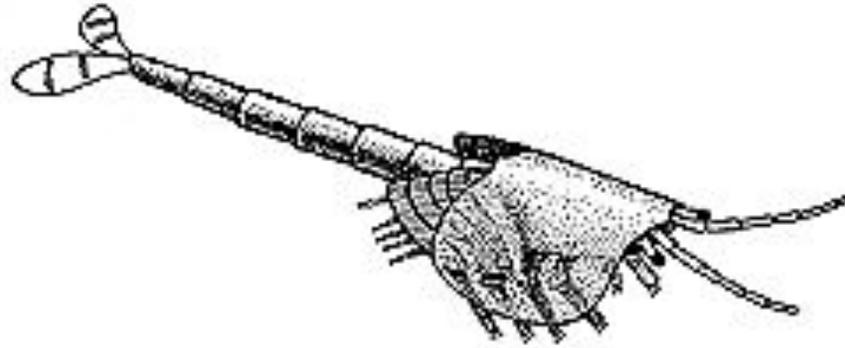
Sidneyia inexpectans



Waptia



Ancestral Crustacea



Subphyla of *Arthropoda*



Crustacea
• shrimp-like



Trilobitomorpha
• three lobes



Anomalocarida
• large predator

Phylum: *Arthropoda* Subphylum: *Anomalocarida*

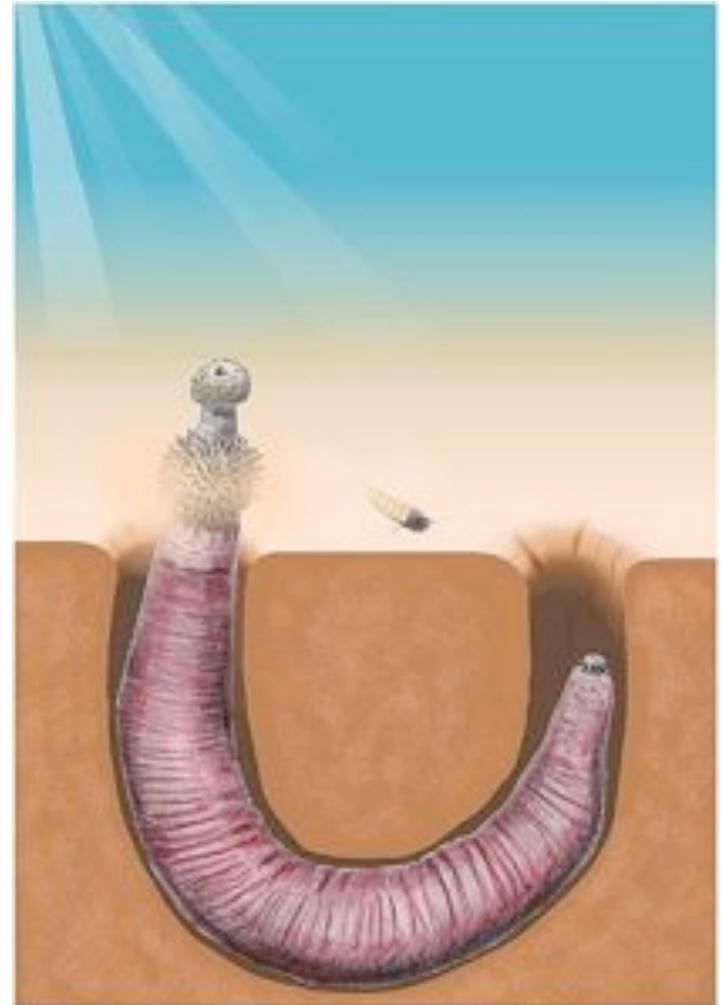
Genus & species: *Anomalocaris saron*

Body Plan:

1. Giant appendages
2. Round mouth





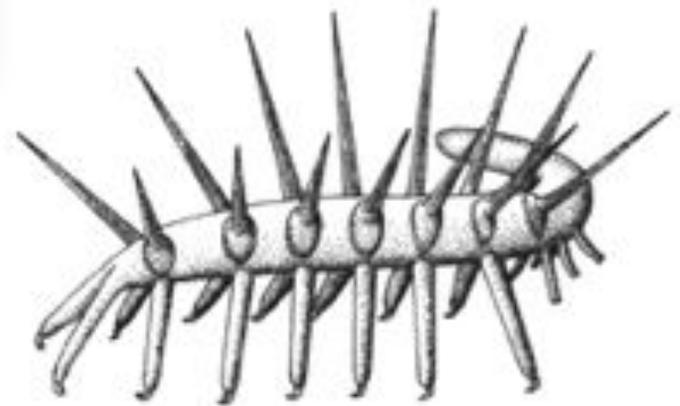


Ottoia
(priapulid)

Opabina (a lobopod)



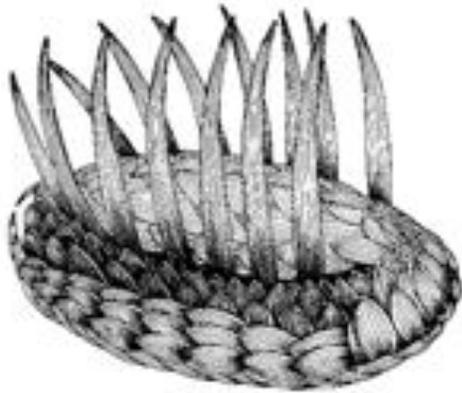
Hallucigenia sparsa



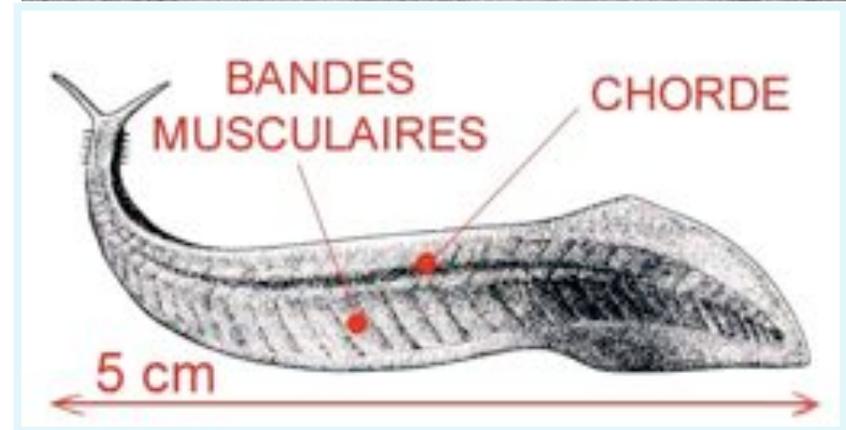
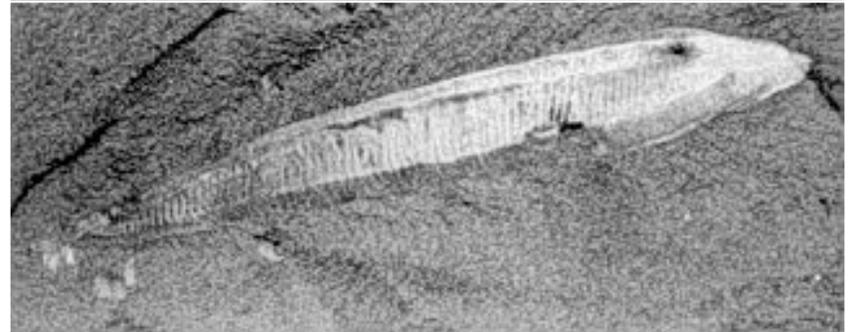
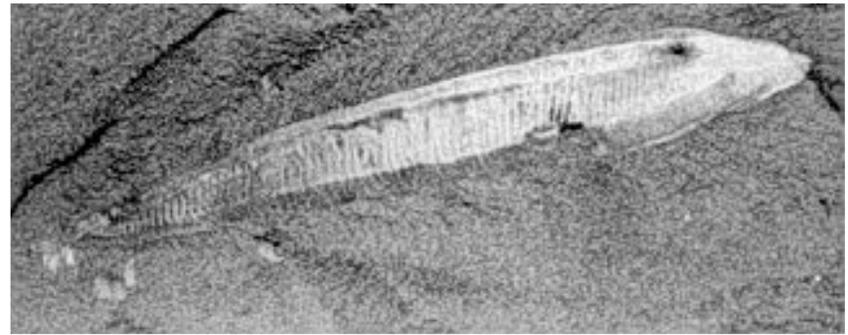
Modern Onychophora



What the %@&^# are these?



Pikia



Phylum: *Chordata* Subphylum: *Vertebrata*

Genus & species: *Mylokunmingia fengjiaoti*

Body Plan:

1. Dorsal nerve cord
2. Backbone



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THE CAMBRIAN EXPLOSION

Phylum: *Chordata* Subphylum: *Vertebrata*

Genus & species: *Haikouichthys ercaicunensis*

Body Plan:

1. Dorsal nerve cord
2. Backbone

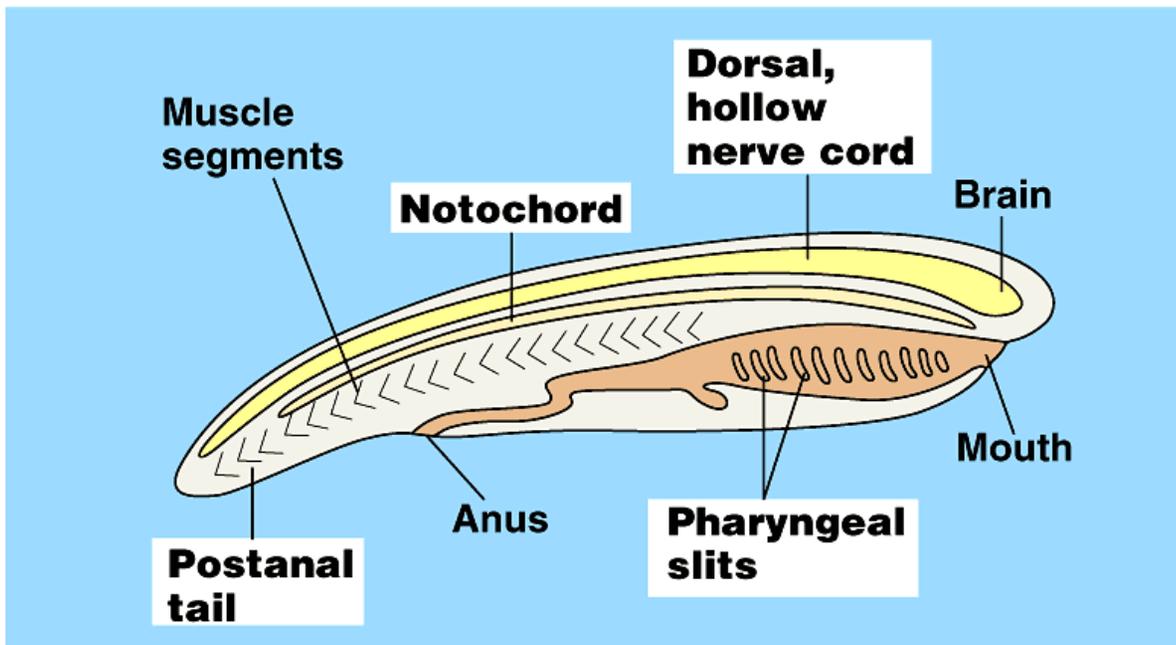
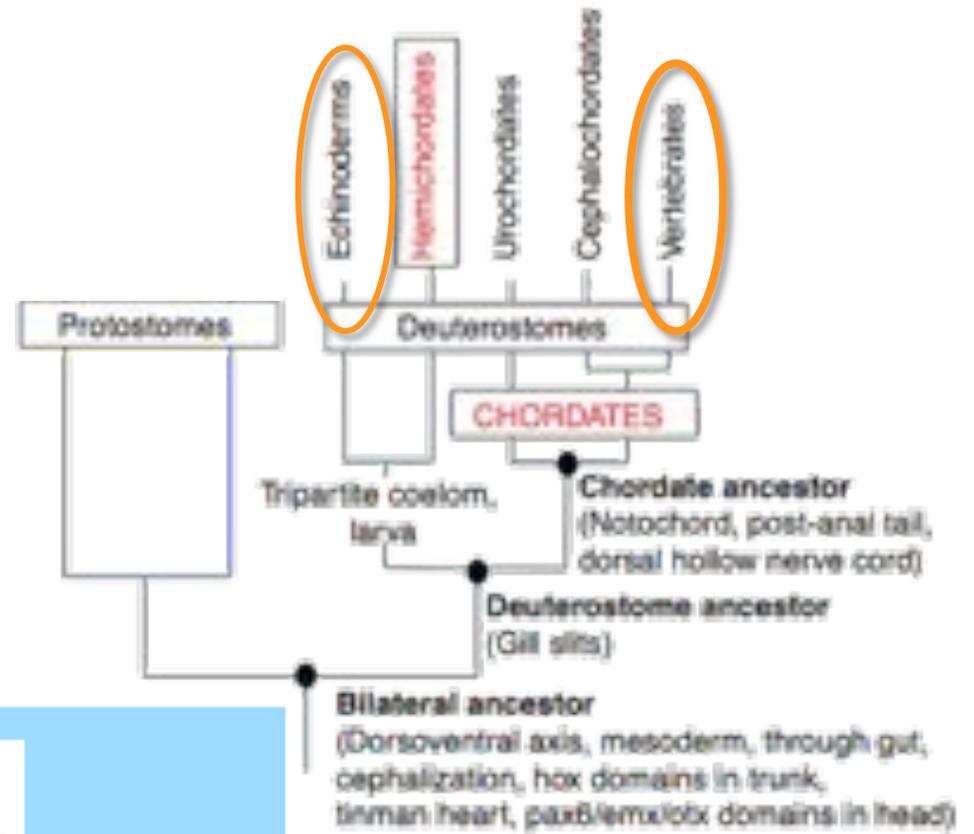


DISCOVERY
INSTITUTE

| BIOLOGY'S BIG BANG

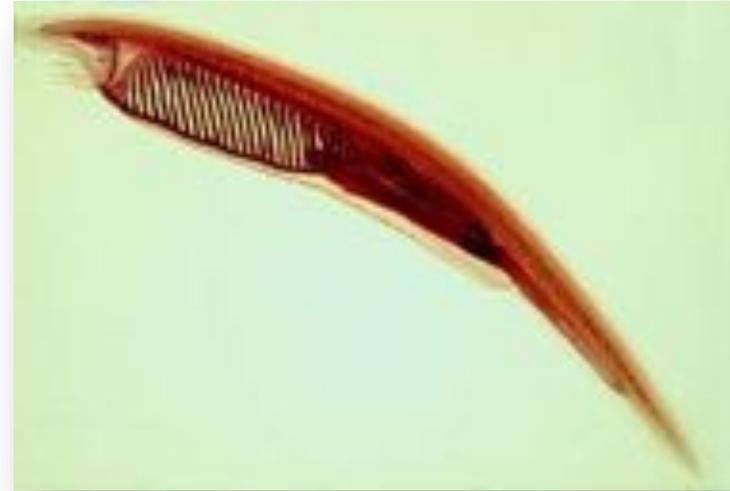
THE CAMBRIAN EXPLOSION

Chordate Evolution





Urochordates (sea squirts)

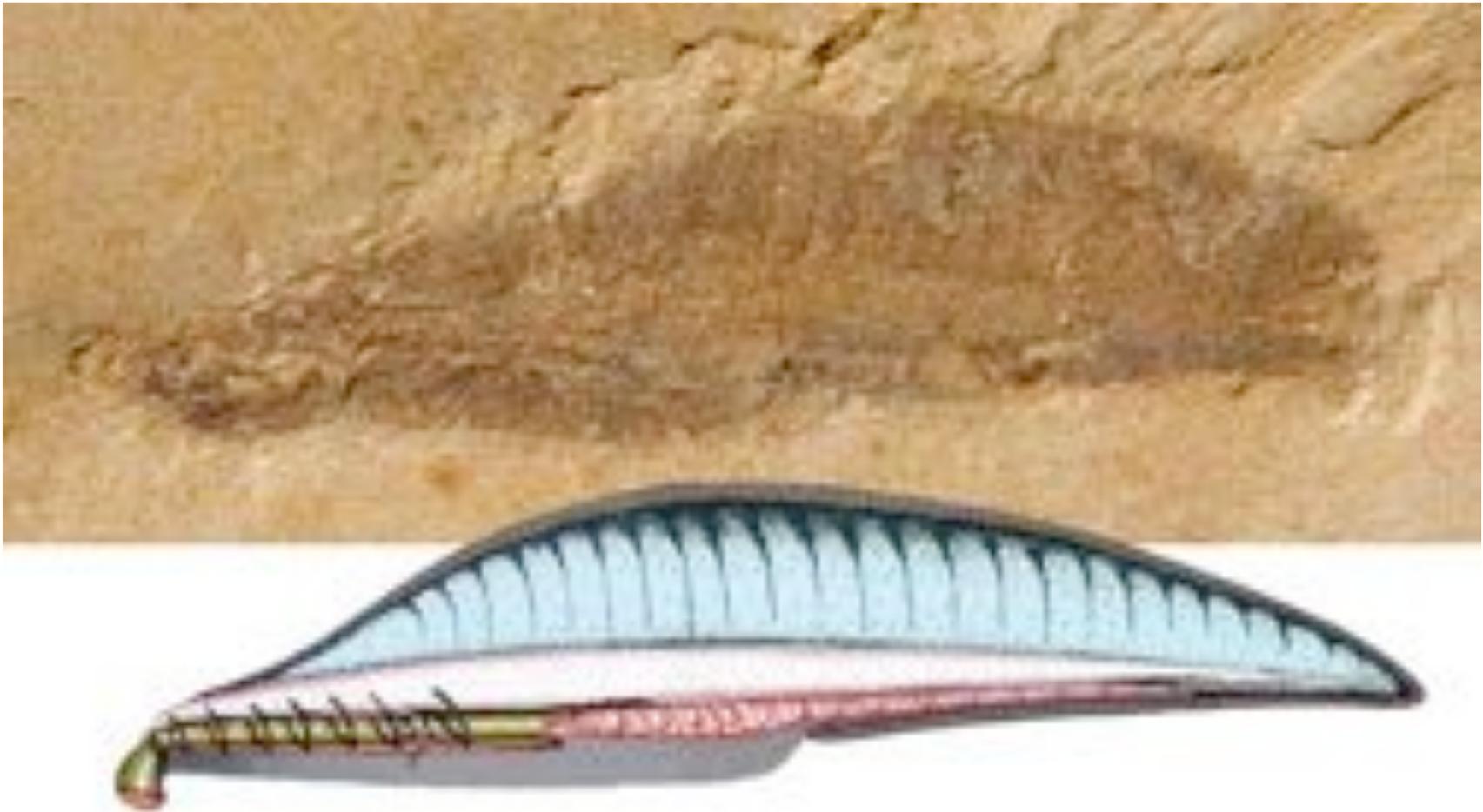


Cephalochordates (amphioxus)



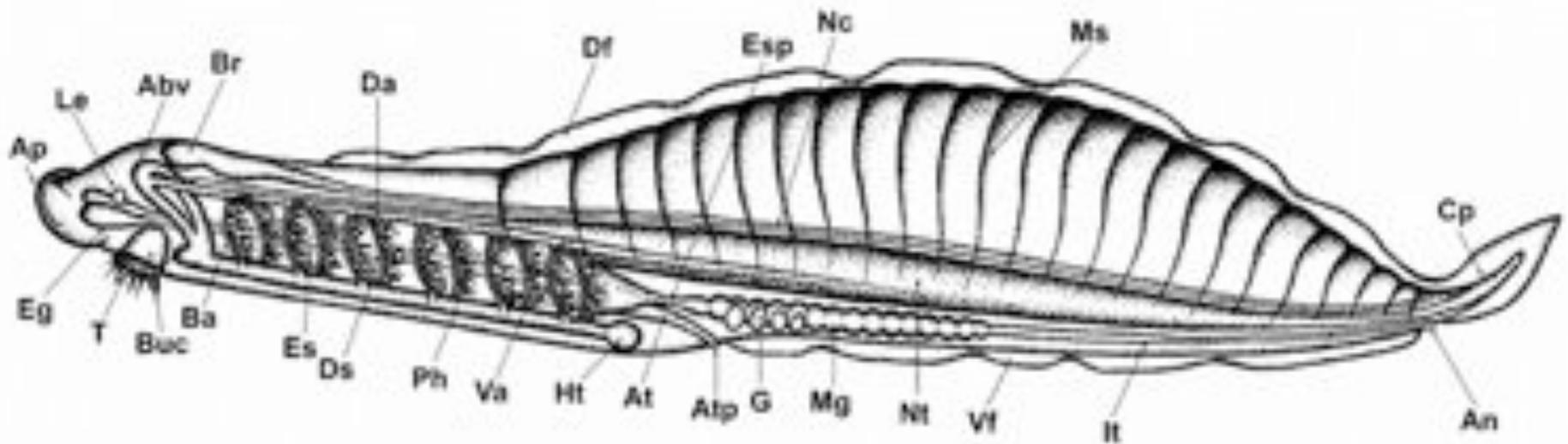
Hemichordates (acorn worms)

Yunnanozoon (hemichordate)

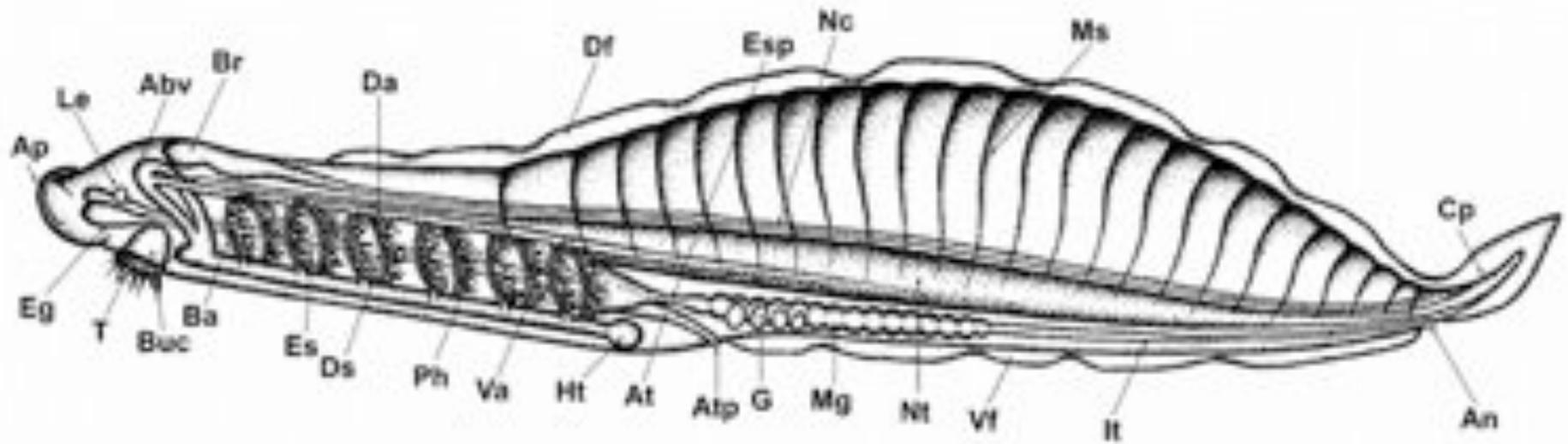


- ▶ **Wells:** “Why don’t textbooks discuss the Cambrian explosion, in which **all major animal groups** appear together in the fossil record **fully formed** instead of branching from a common ancestor – thus contradicting the evolutionary tree of life?”
- ▶ **Reply:** Fish, amphibians, reptiles, birds, and mammals all are post-Cambrian – aren’t these “major groups”?
- ▶ **Wells:** “Fish DID make their first appearance in the Cambrian explosion.”

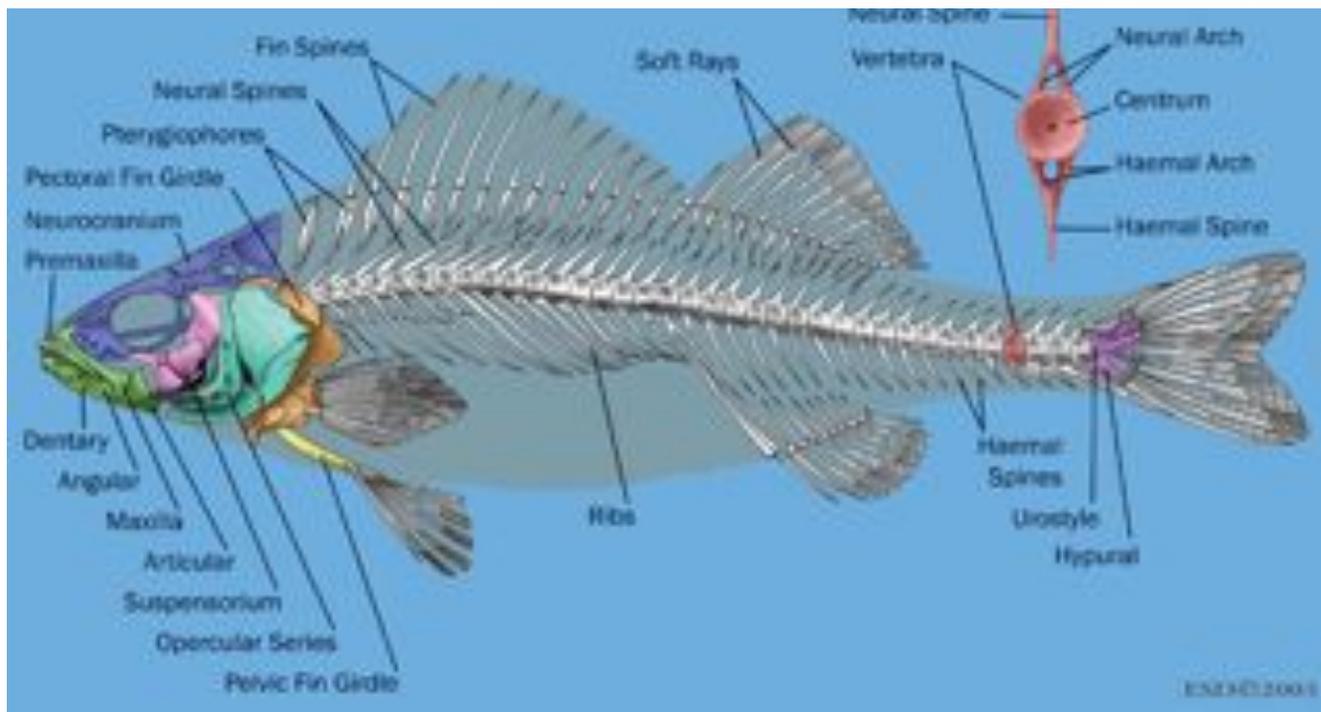
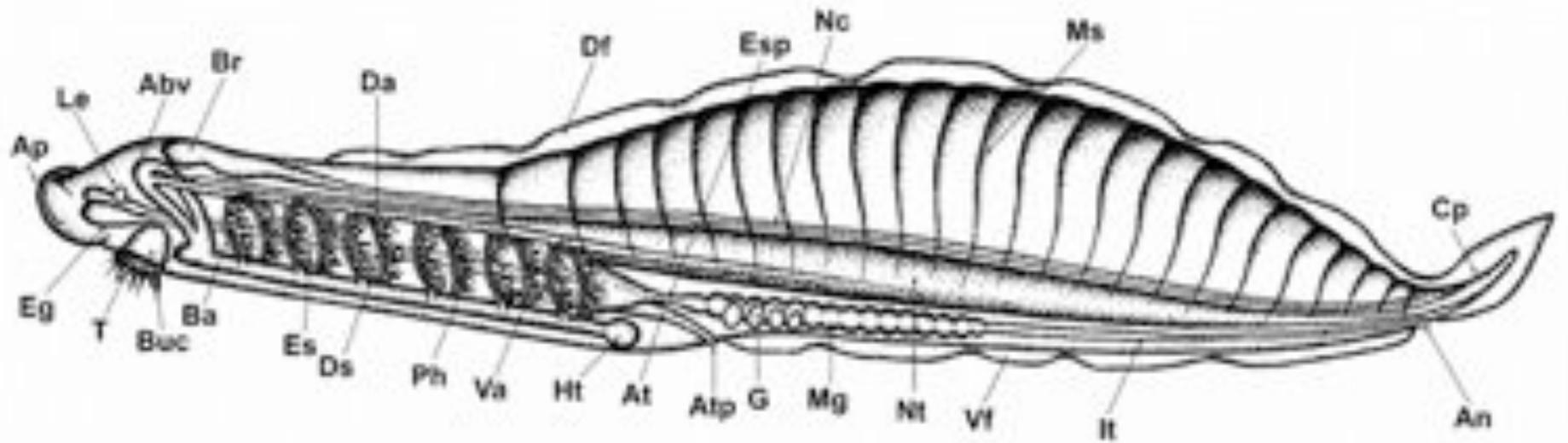
Haikouella lanceolata

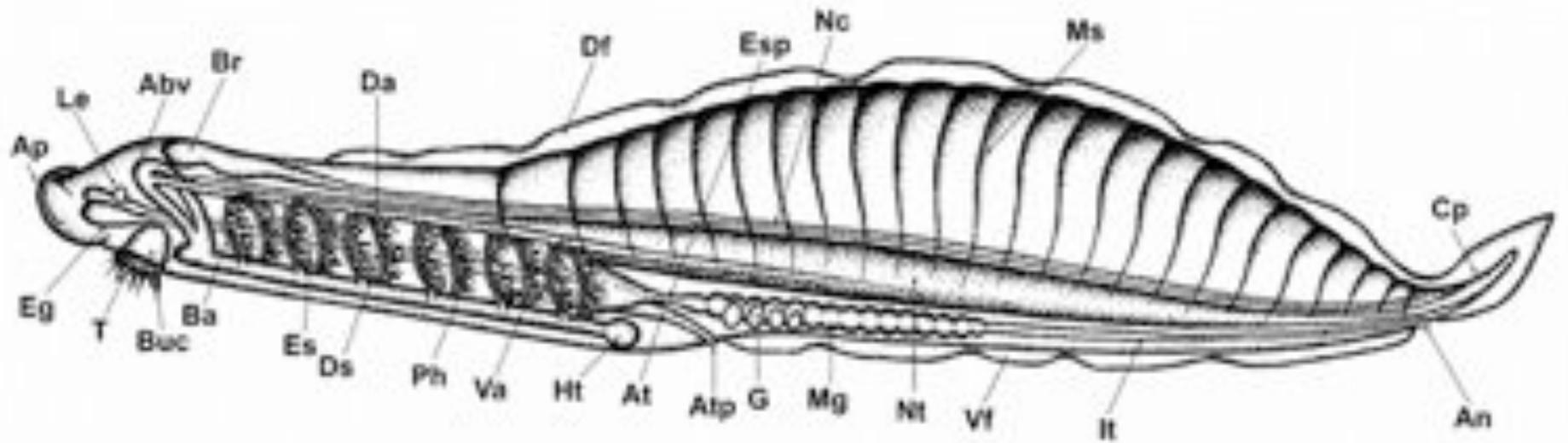


Jun-Yuan Chen, Di-Ying Huang and Chia-Wei Li, "An early Cambrian craniate-like chordate," *Nature* 402 (1999), 518-522.

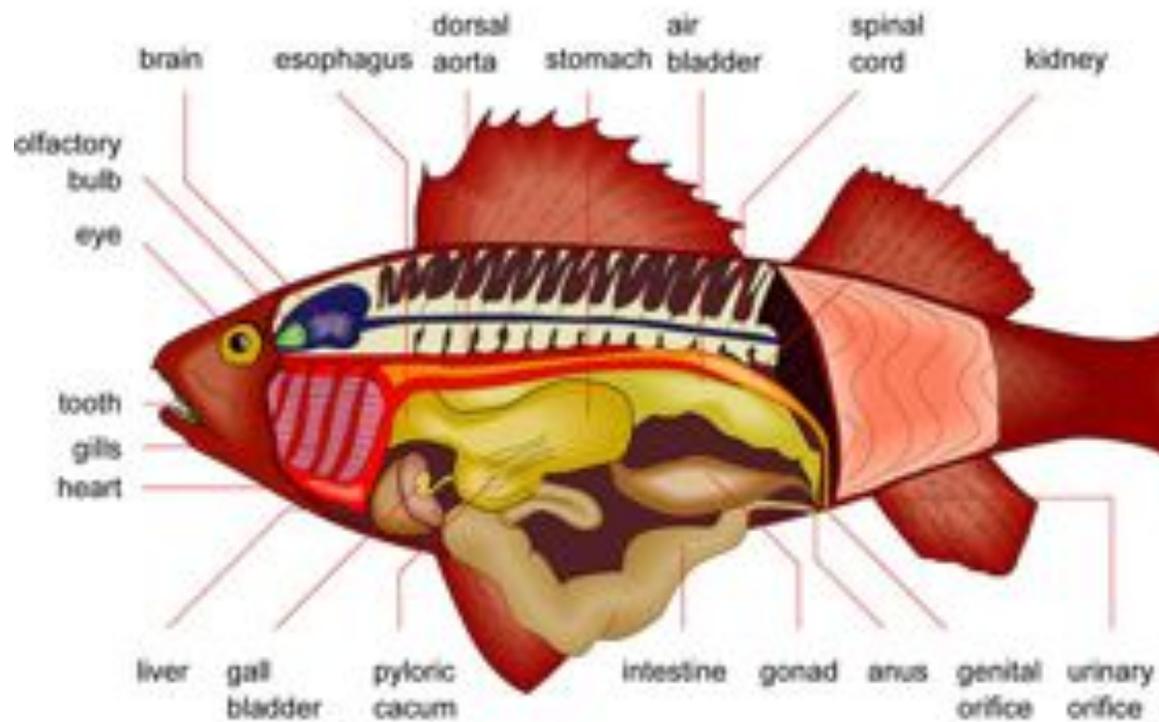


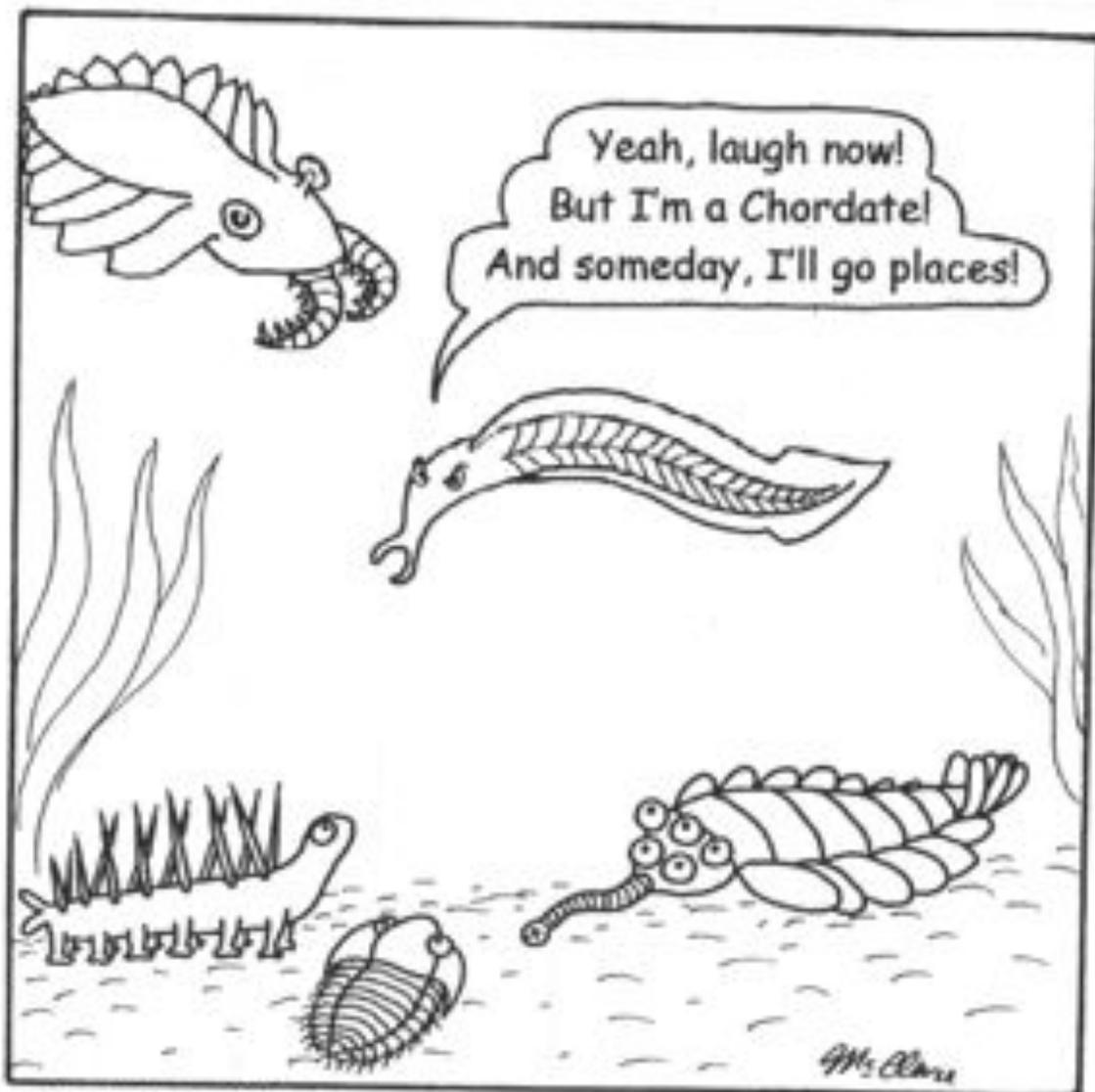
“Here we describe a recently discovered **craniate-like chordate**, *Haikouella lanceolata*, from 305 fossil specimens in Haikou near Kunming. This 530 million-year-old **fish-like** animal resembles the contemporaneous *Yunnanozoon* from the Chengjiang fauna (about 35 km southeast of Haikou) in several anatomic features. ... These findings indicate that *Haikouella* probably represents a very early **craniate-like chordate** that lived near the beginning of the Cambrian period during the main burst of the Cambrian explosion. These findings will add to the debate on the evolutionary transition from invertebrate to vertebrate”





INTERNAL ANATOMY OF A BONY FISH





THE COUNCIL OF INDIAN EDUCATION

M. S. CLARK

MATT WELLS

Life in the Lower Cambrian Period

Haikouichthys



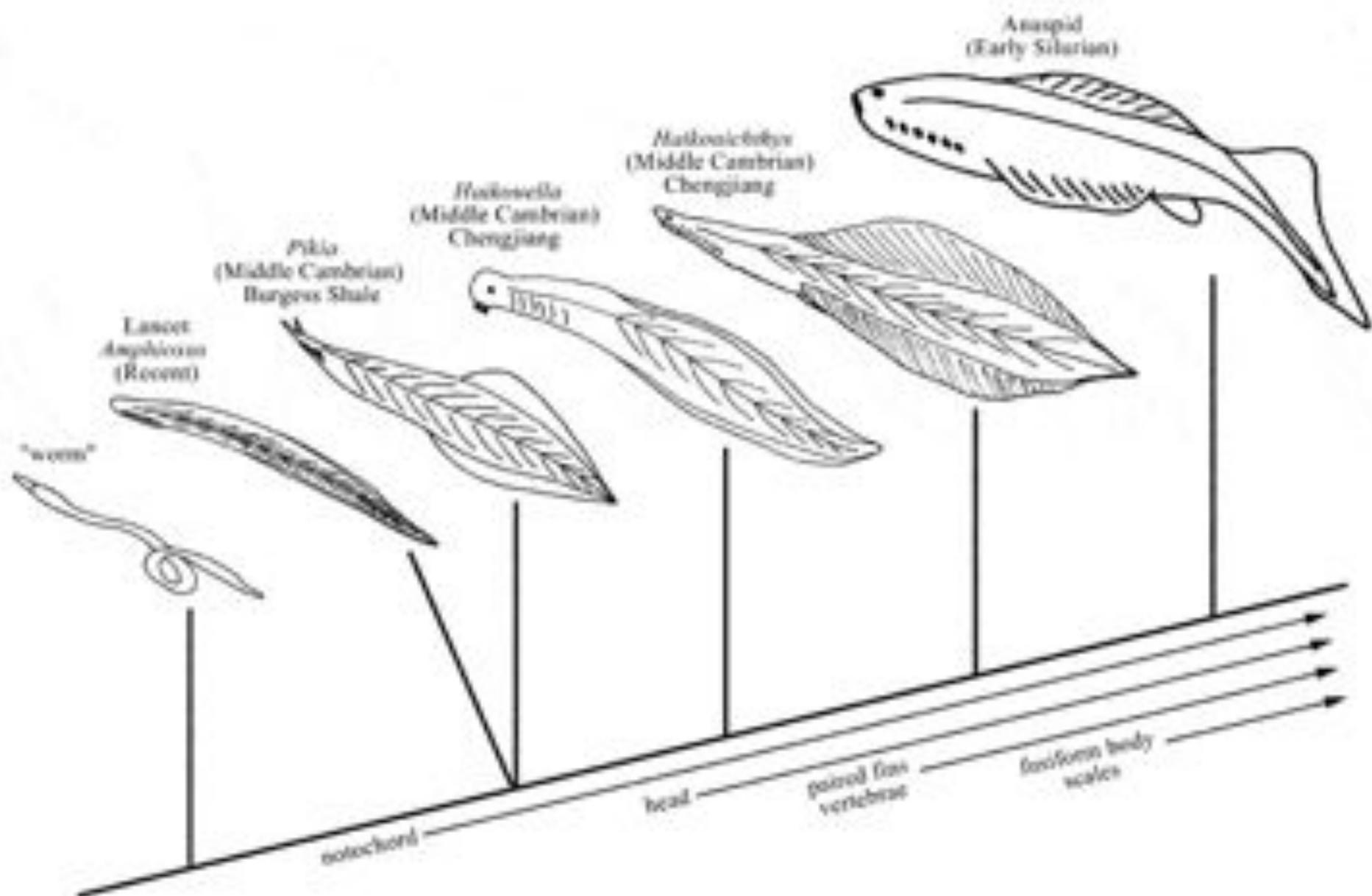
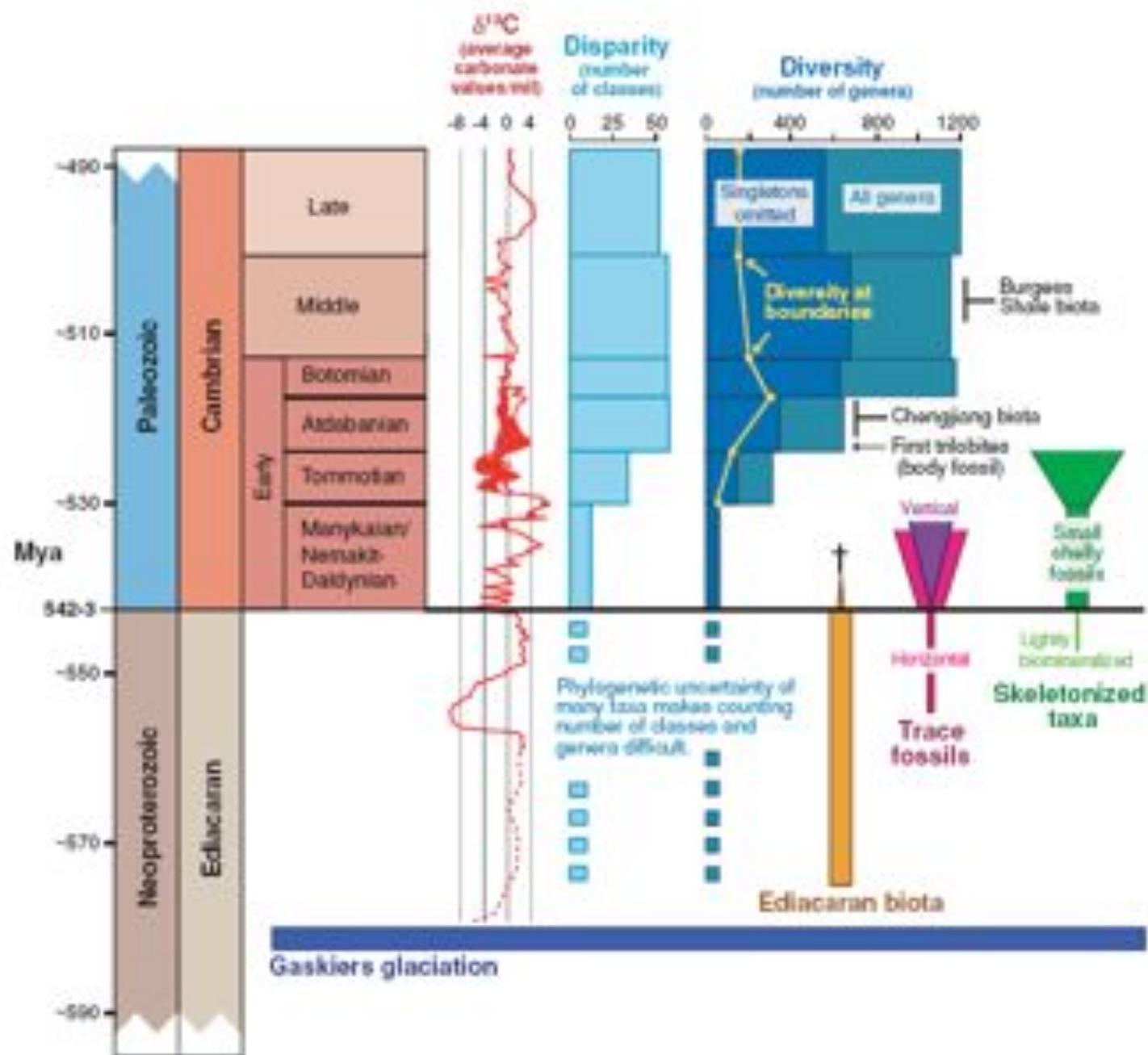


Figure 3. Stepwise evolution of vertebrate features as shown by the extant and fossil record.

An Ediacarian Chordate





Top-Down: "Disparity before Diversity"

Kingdom: Animal

Phylum

Class

Order

Top



Down

Family

Diversity
minor differences

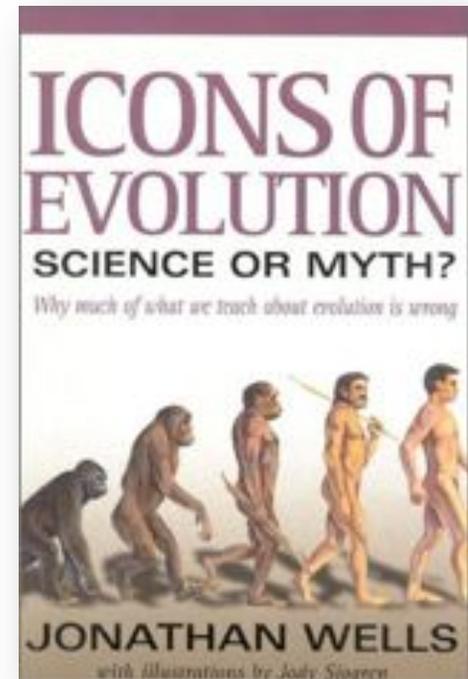
Genus

Species

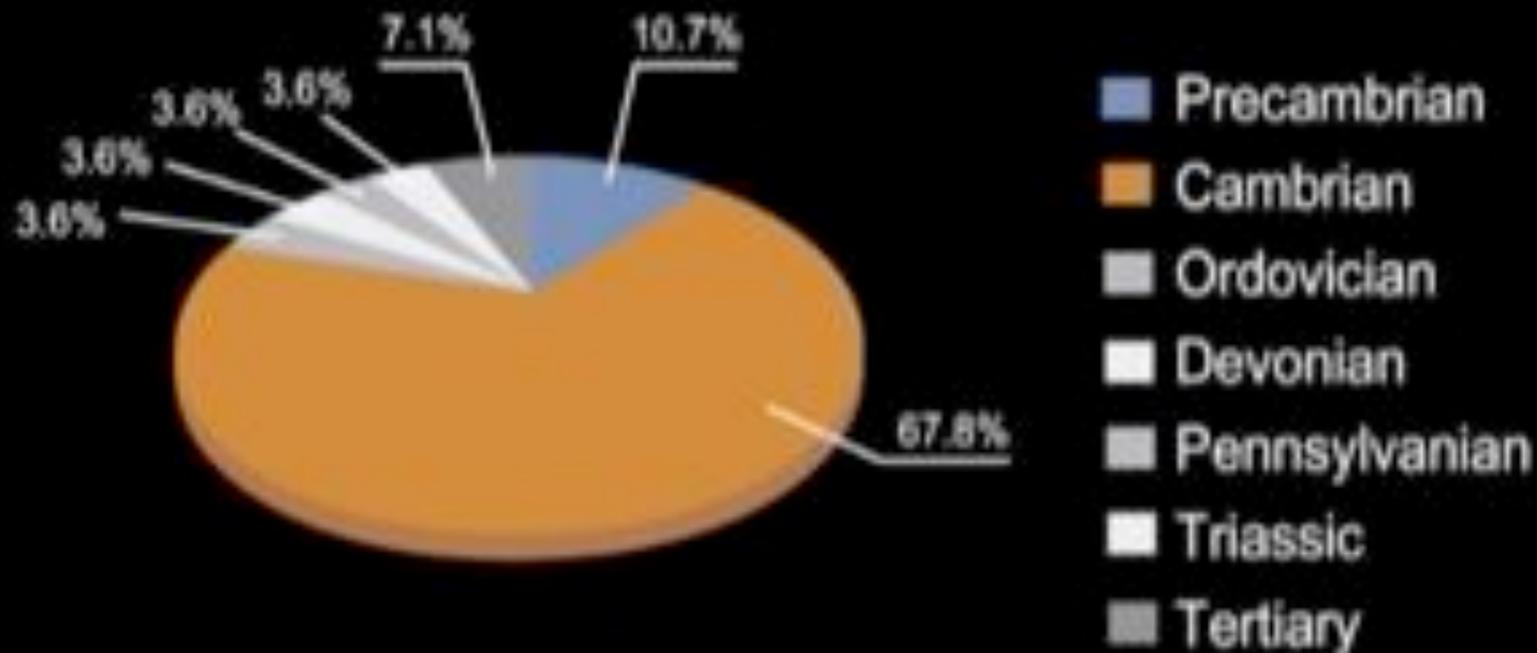


Jonathan Wells' claim

- ▶ “The Cambrian explosion gave rise to **most of the animal phyla alive today**, as well as some that are now extinct.” (p. 39).
- ▶ Chart gives **18** “major living animal phyla”
 - “One phylum (the sponges) and possibly two others appeared just before the Cambria; two worm phyla appeared much later, in the Carboniferous ... and one [phylum] in the Ordovician.”
 - Therefore, claim is that **12 of 18 (66%)** phyla appeared in the Cambrian



Animal Phyla First Appearances: Based on Fossil Data Alone



Phyla without a fossil record (12 of 34)

- Placozoa
- Mesozoa
- Platyhelminthes
- Gnathostomulida
- Gastrotricha
- Acantochephalata
- Loricifera
- Kinorhyncha
- Pogonophora
- Sipuncula
- Phoronida
- Urochordata

Mainstream viewpoint (Extant)

Pre Cambrian (5+4)

- ▶ Echinodermata
- ▶ Cnidaria
- ▶ Porifera
- ▶ Mollusca
- ▶ Arthropoda

- ▶ Chordata (?)
- ▶ Annelida (?)
- ▶ Platyhelminthes (?)
- ▶ Echiura (?)

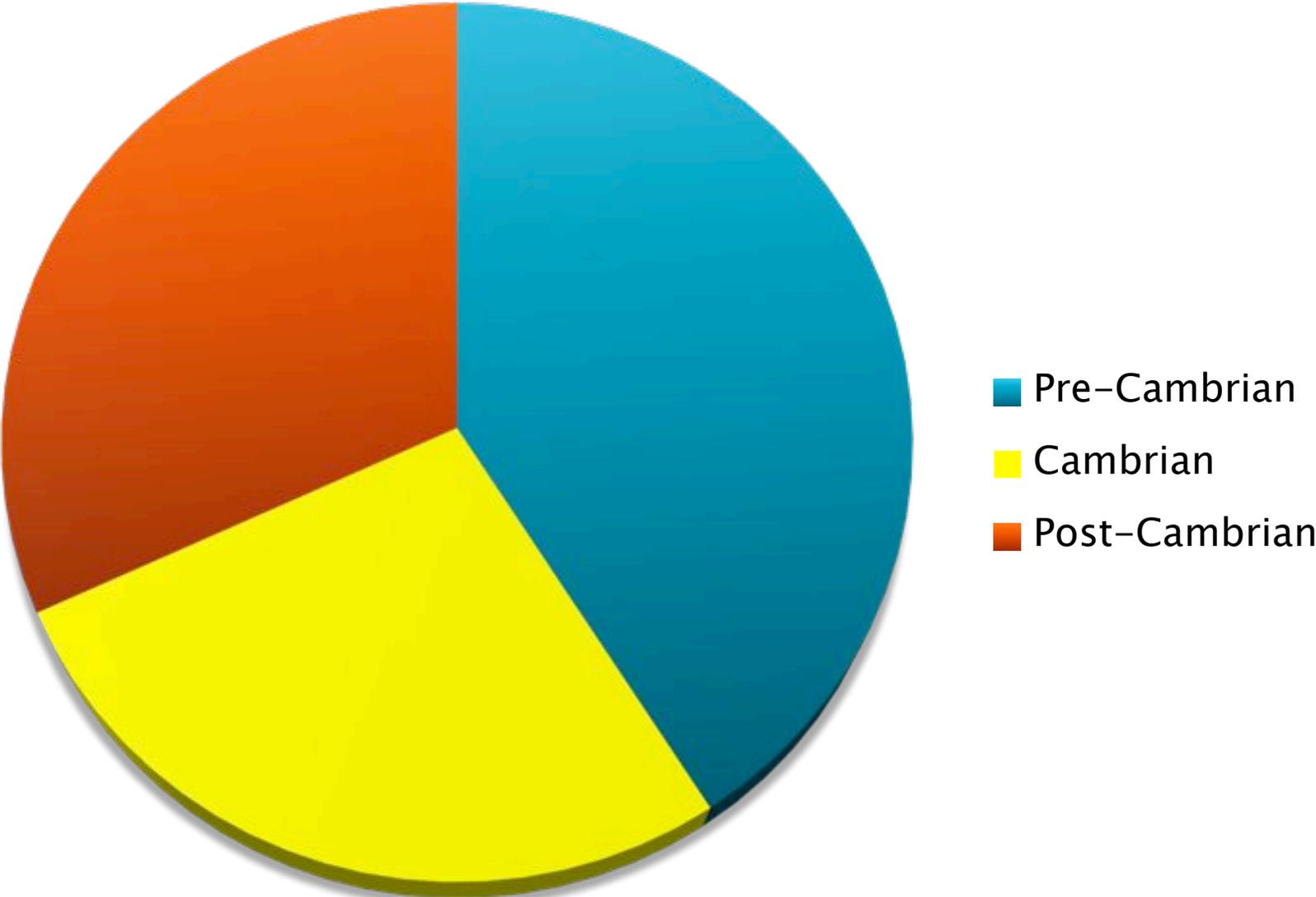
Cambrian (6)

- ▶ Brachiopoda
- ▶ Onychophora
- ▶ Tardigrada
- ▶ Priapulida
- ▶ Chaetognatha
- ▶ Hemichordata

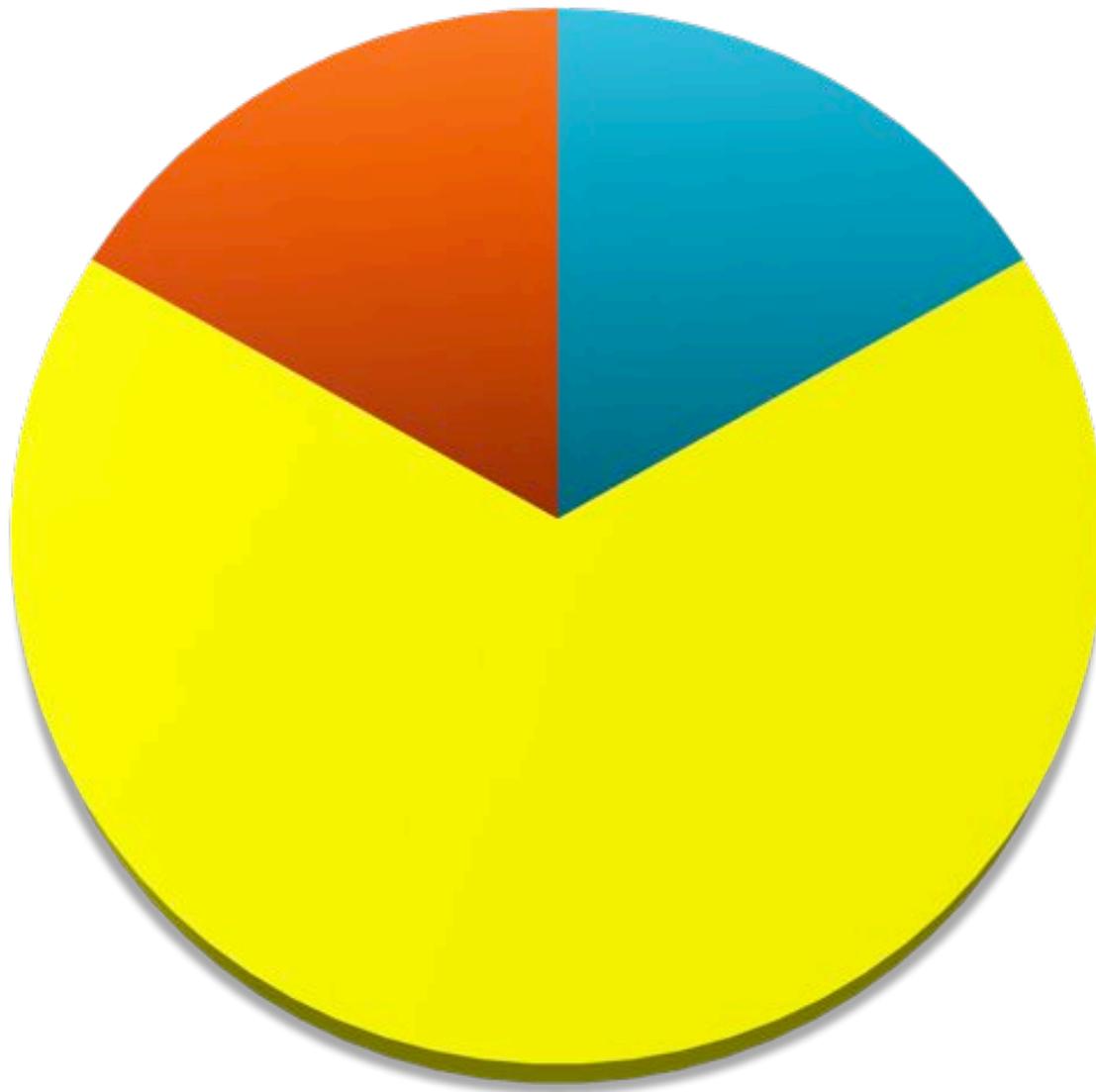
Post-Cambrian (7)

- Bryozoa
- Ctenophora
- Nematoda
- Nemertini
- Entoprocta
- Rotifera
- Nematomorpha

Extant Phyla with a Fossil Record



Well's version



■ Pre-Cambrian

■ Cambrian

■ Post-Cambrian

Extinct Phyla (23)

Pre Cambrian (5)

- Dickinsoniids
- Sprigginids
- Trilobozoans
- Proarticulates
- Petalonamaeids

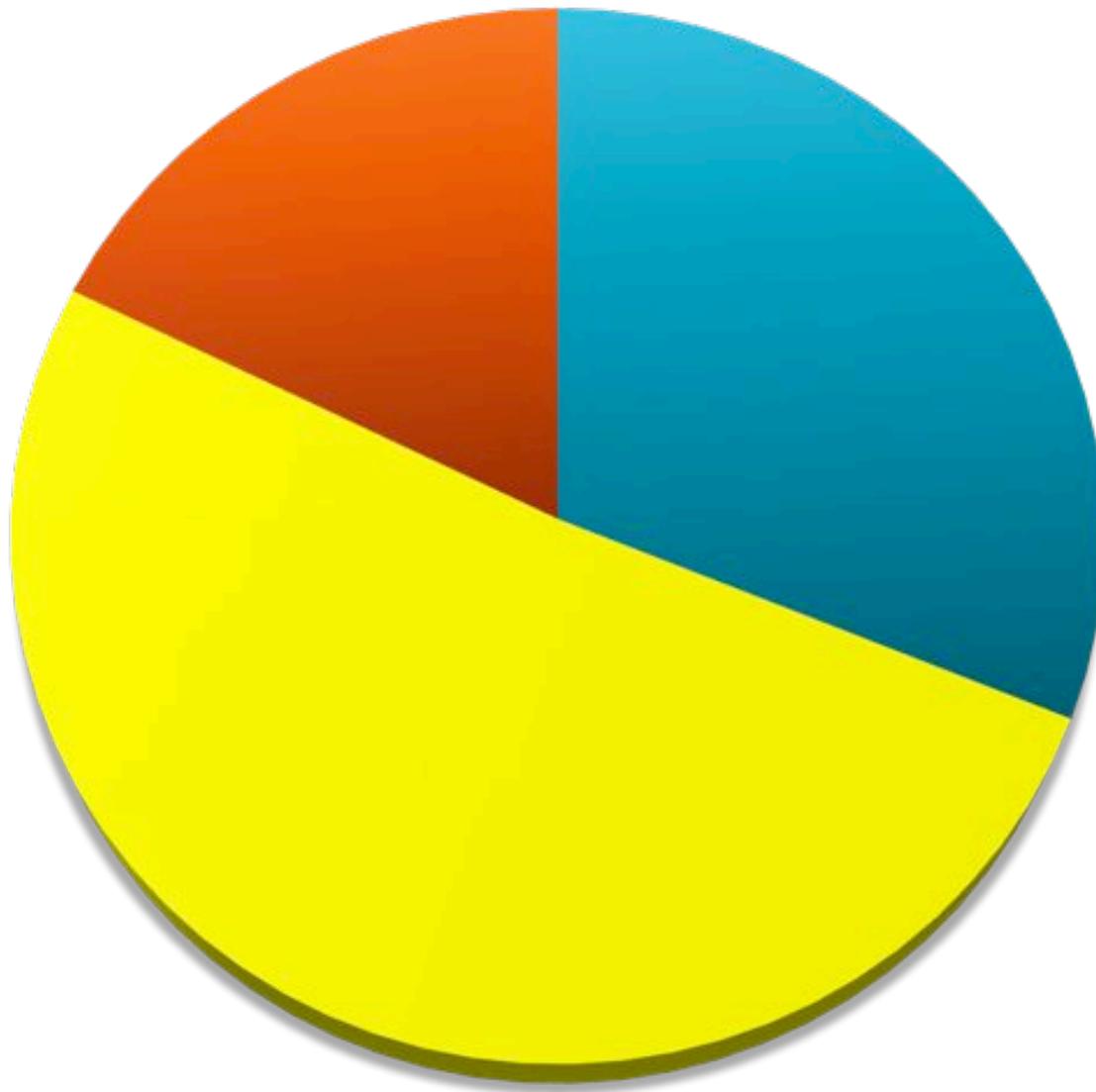
Cambrian (17)

- Dinomischids
- Eldoniids
- Rotadiscids
- Paropsonemids
- Cambroclaves
- Conodonts
- Protoconodonts
- Microdictyonilids
- Anomalocariids
- Amiskwiids
- Banffids
- Palaeoscolecidians
- Chancelloriids
- Sachitids
- Siphonocuchitids
- Halkieriids
- Hyloliths

Post-Cambrian (1)

- Tullimonstrids

All Phyla with a Fossil Record



■ Pre-Cambrian

■ Cambrian

■ Post-Cambrian

Questions

- ▶ Was there a Pre–Cambrian fauna?
- ▶ What happened in the Cambrian?
- ▶ **Is the explosion real?**
- ▶ How did it happen?

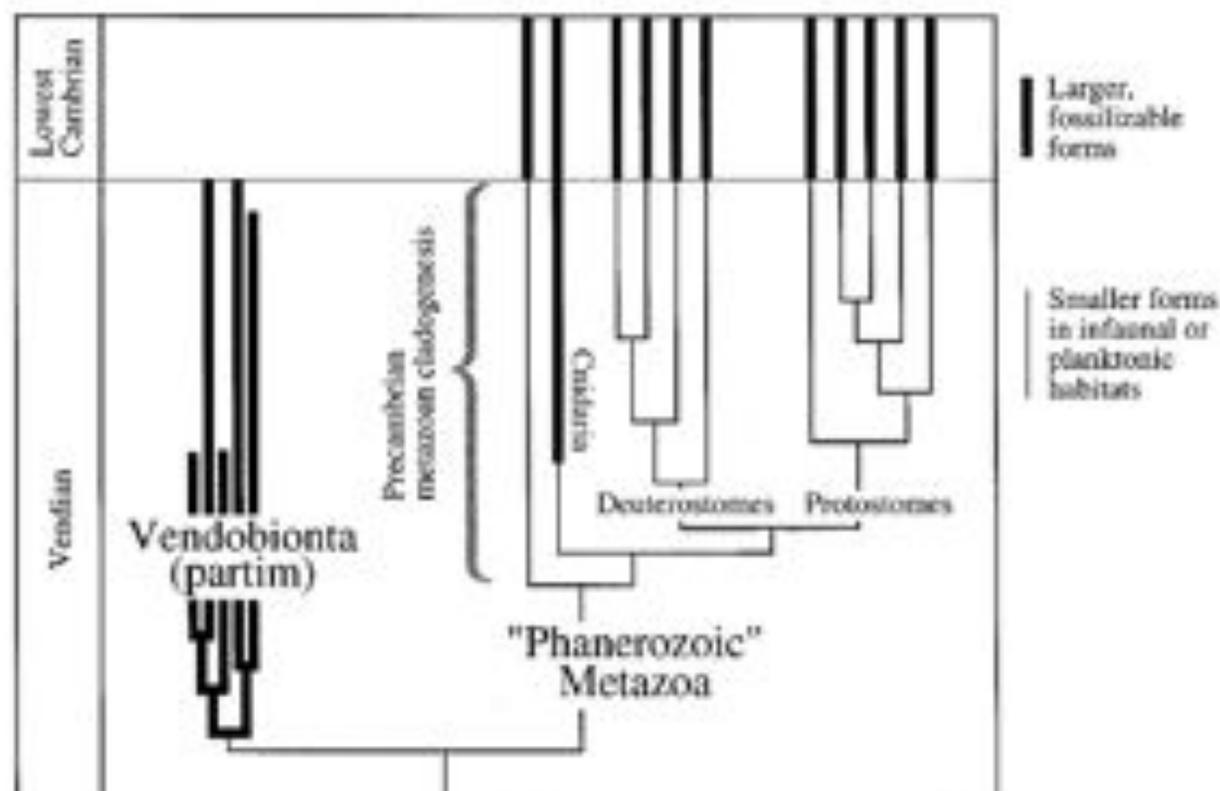
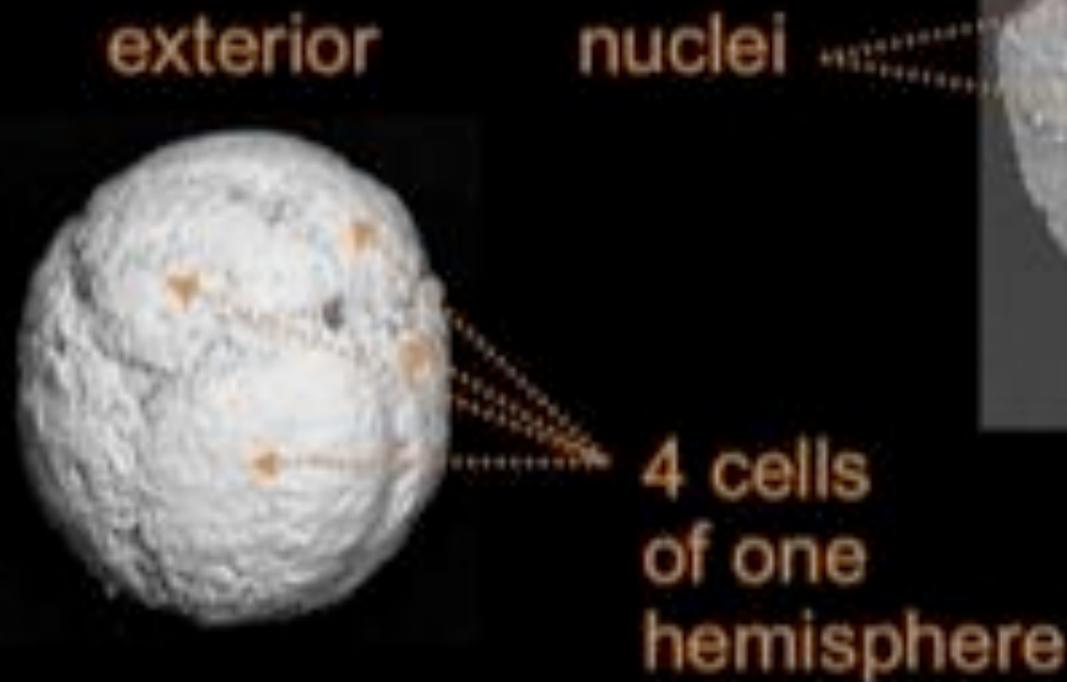


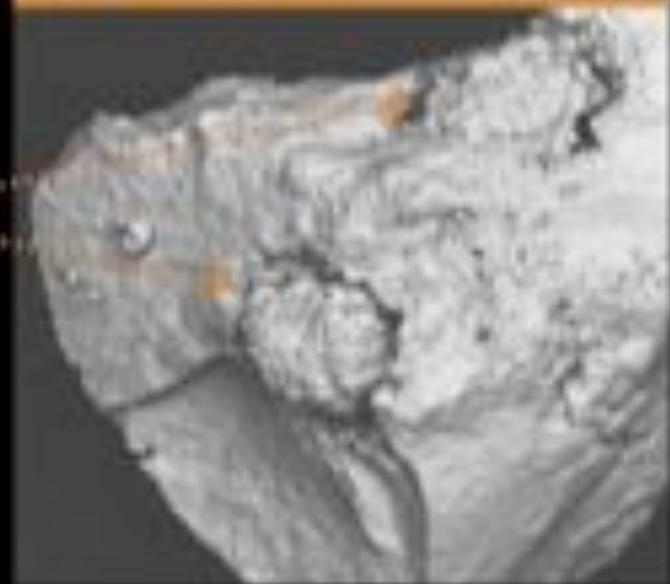
Figure 5. Possible model for clado-genesis during the Vendian and basal Cambrian, adopting the scenario described in this paper. Lineages comprising large animals in habitats readily capable of fossilization are represented by thickened lines, while smaller forms which may have lived in meiofaunal or planktonic niches are shown in thinner lines.

Soft Sponge Embryos in Precambrian

Early cell division



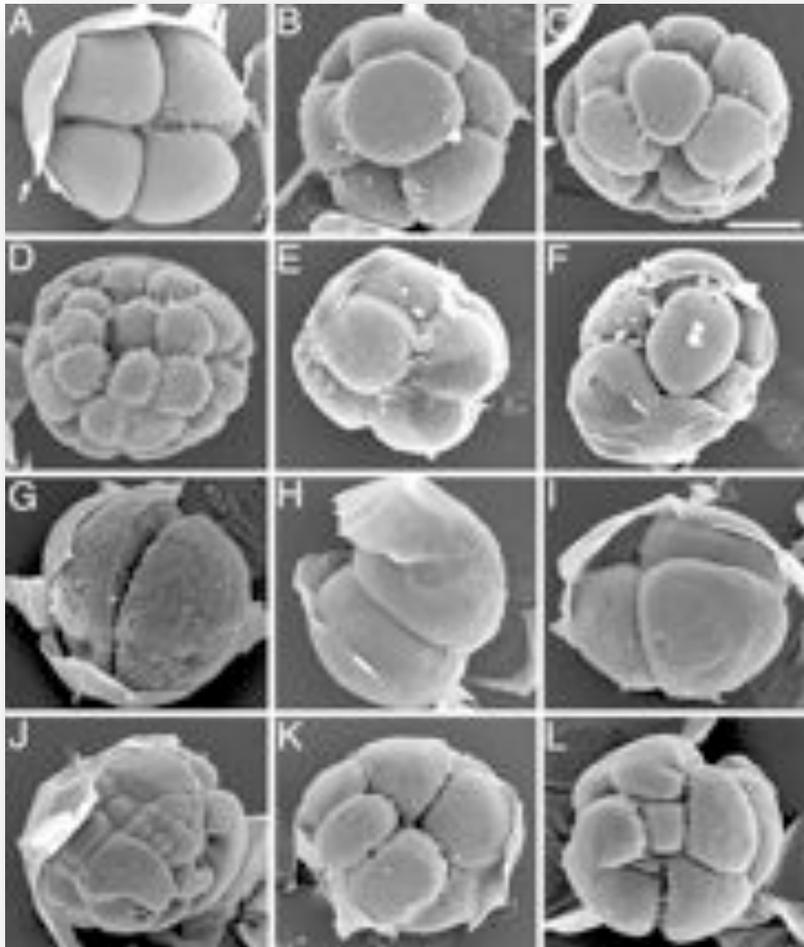
"Opened" Embryo



Stephen Meyer

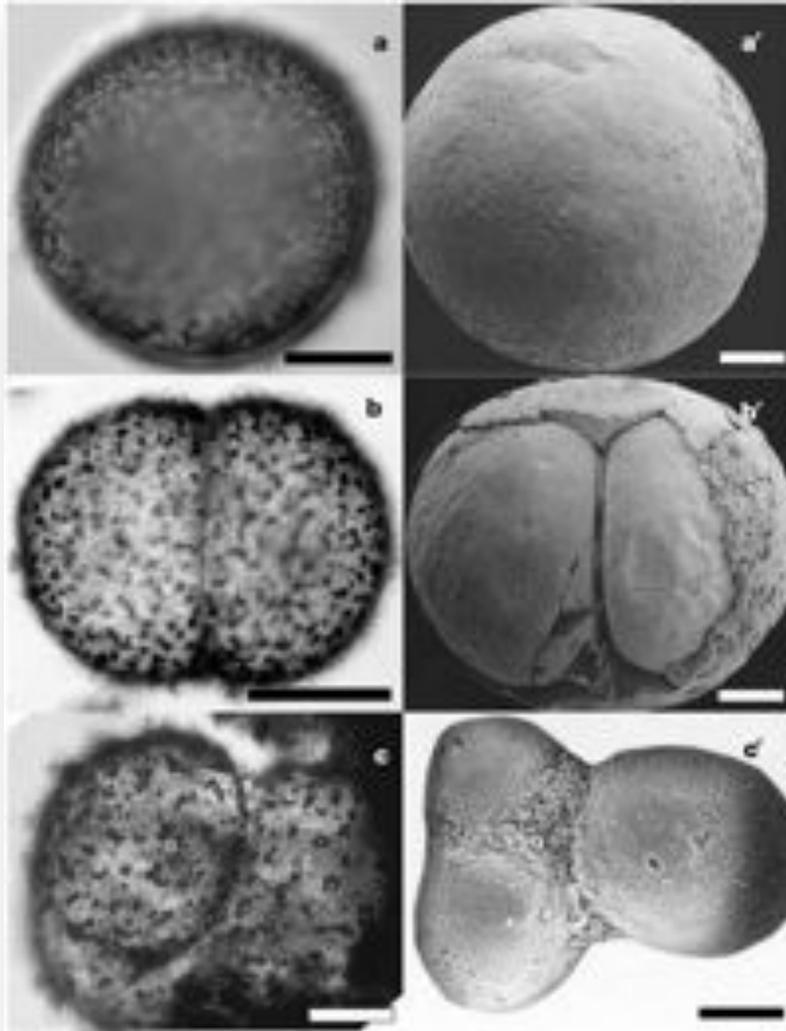
- ▶ Talking of **pre-Cambrian** cnidarian (sponge) embryos:
 - “If you can preserve an embryo, you can preserve an animal. If those animals were there, we should have found them. And they’re not there.”
- ▶ Ignores:
 - Special conditions required for preservation
 - We haven’t found pre-Cambrian adult sponges
 - Pre-Cambrian specimens create a problem for the “explosion”!

Experimental taphonomy shows the feasibility of fossil embryos



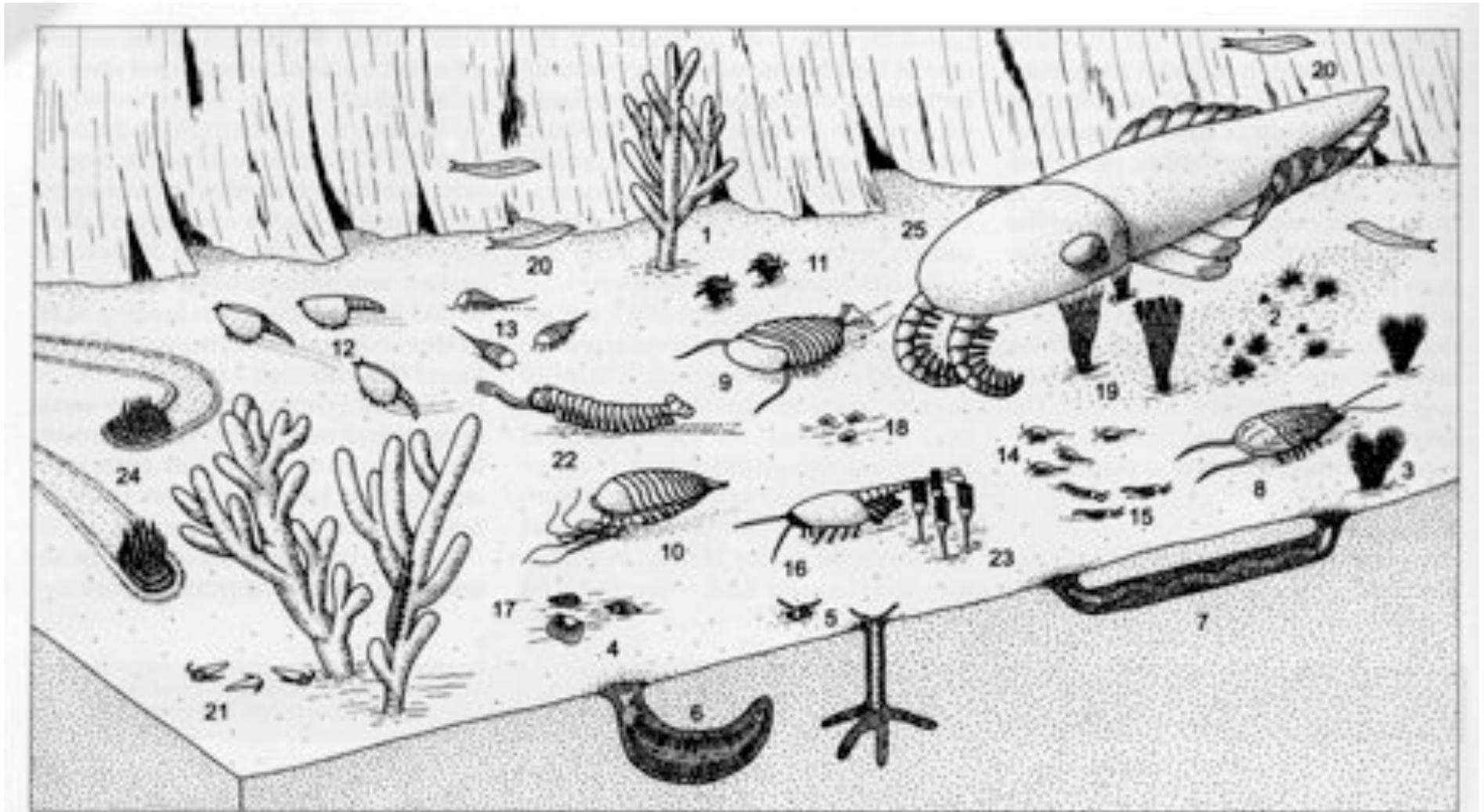
“Under conditions that prevent autolysis, embryos within the fertilization envelope can be preserved with good morphology for sufficiently long periods for mineralization to occur. The reported fossil record exhibits size bias, but we show that embryo size is unlikely to be a major factor in preservation. Under some conditions of death, fossilized remains will not accurately reflect the cell structure of the living organism. **Although embryos within the fertilization envelope have high preservation potential, primary larvae have negligible preservation potential.** Thus the paleo-embryological record may have strong biases on developmental stages preserved.”

But are these actually embryos?



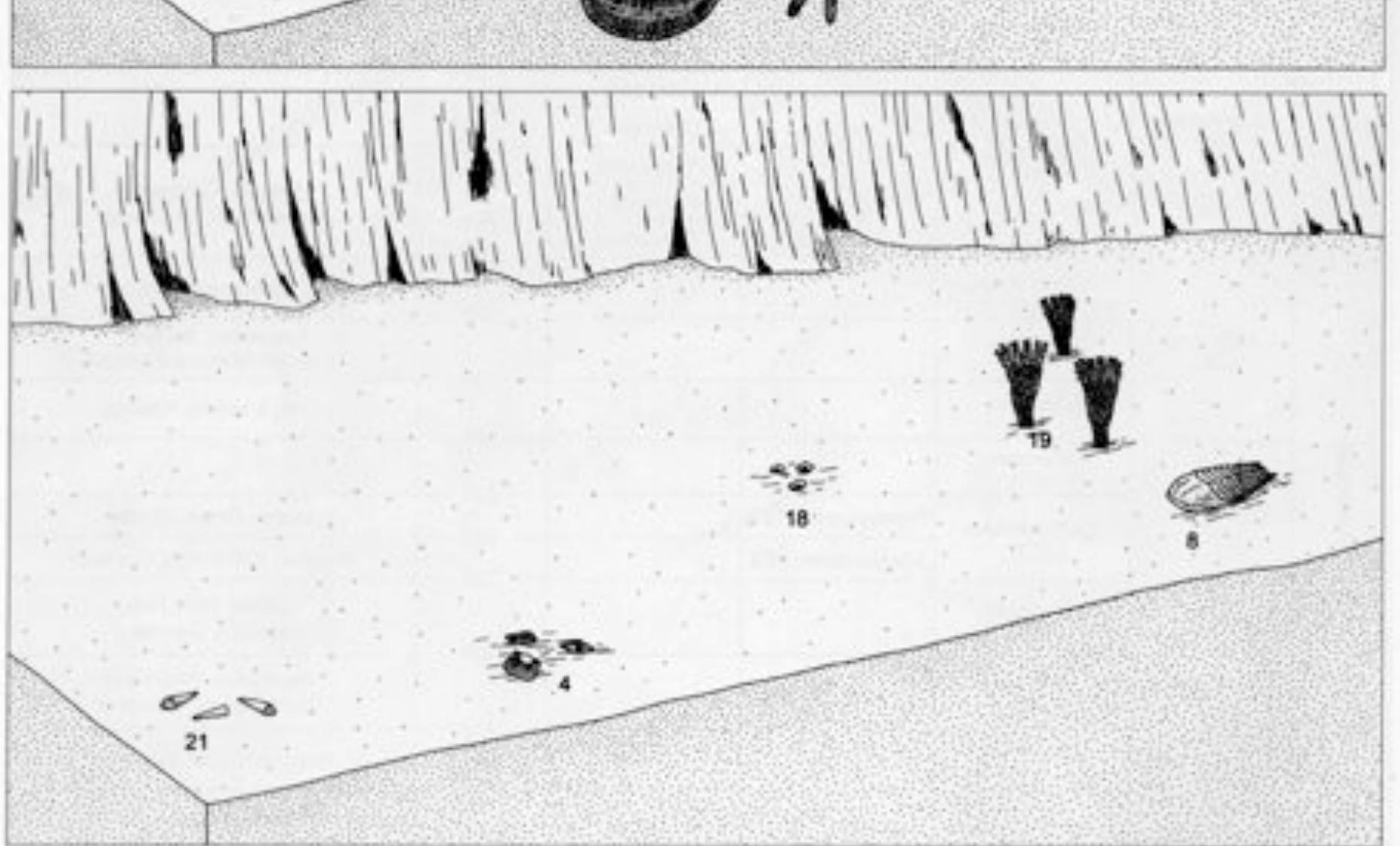
Perhaps fossilized
sulfur-oxidizing
bacteria of the genus
Thiomargarita

Bailey JV, Joye SB, Kalanetra KM, Flood
BE, Corsetti FA (2007) Evidence of giant
sulphur bacteria in Neoproterozoic
phosphorites. *Nature*



The importance of *Lagerstätten*





Conclusion from Fossil Record

- ▶ Metazoans certainly originated *significantly* earlier than 570my. A date of **700my** would not conflict with the evidence currently to hand.
- ▶ We thus see an approximately **170 million year** period for the evolution of the Cambrian fauna.

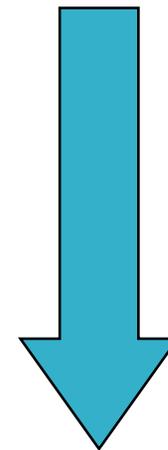
Summary of Fossil Evidence

▶ Pre-Cambrian Fauna (soft-bodied)

- 3,500 my – Stomatolites (Australia) – bacterial remains
- 1,100 my – Trace fossils (India)
- 600 my – Early bilaterans
- 575 my – Edicarian Fauna – Unknown affinities (?)
- 570 my – Possible Metazoan embryos (China)
- 555 my – *Kimberella* (early mollusk)
- 545 my – “Small shelly” metazoan fauna

▶ Cambrian Fauna (soft and hard-bodied)

- 540 my – *Treptichnus* worm marks beginning
- 535 my – Sirivs Passet Fauna (Greenland)
- 535 my – Increasing mineralized skeletons
- 530 to 520 – Start of “Explosion”
- 520 my – Chenjiang Fauna (China)
- 510 my – Burgess Shale Fauna (Canada)



“Exponentially”
increasing
diversity

See Valentine *et al.* Development 126:851 (1999)

Other estimates

- ▶ Bromham *et al.*(1998)
 - 1,500 mybp (Meyer gives this as 680 my)

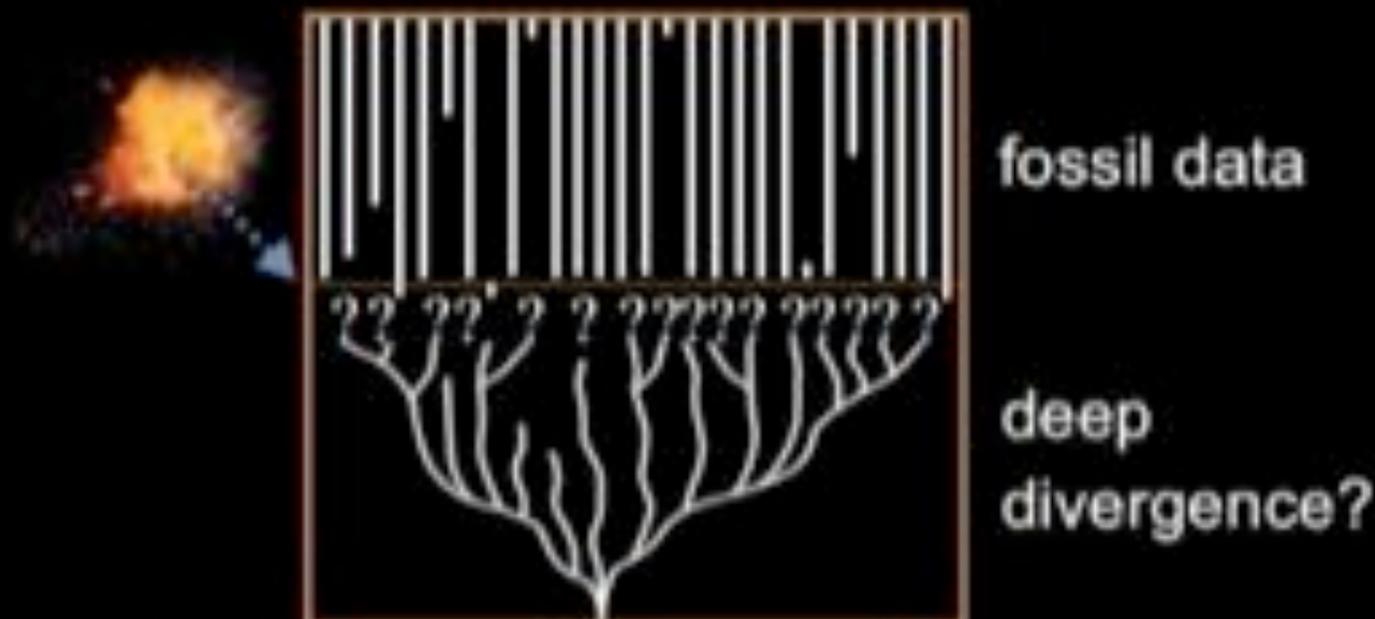
- ▶ Ayala, Rzhetsky & Ayala (1998)
 - 670 mybp for Protostome / Deuterostome split
 - Still 130my before the start of the Cambrian

“Molecular Clocks Do Not Support the Cambrian Explosion”

“The fossil record has long supported the view that most animal phyla originated during a brief period approximately 520 MYA known as the Cambrian explosion. However, molecular data analyzed over the past 3 decades have found deeper divergences among animals (~800 to 1,200 MYA), with and without the assumption of a global molecular clock. Recently, two studies have instead reported time estimates apparently consistent with the fossil record. Here, we demonstrate that methodological problems in these studies cast doubt on the accuracy and interpretations of the results obtained. In the study by Peterson et al., young time estimates were obtained because fossil calibrations were used as maximum limits rather than as minimum limits, and not because invertebrate calibrations were used. In the study by Aris-Brosou and Yang, young time estimates were obtained because of problems with rate models and other methods specific to the study, and not because Bayesian methods were used. This also led to many anomalous findings in their study, including a primate-rodent divergence at 320 MYA. With these results aside, molecular clocks continue to support a long period of animal evolution before the Cambrian explosion of fossils.”

Three Deep Divergence Difficulties

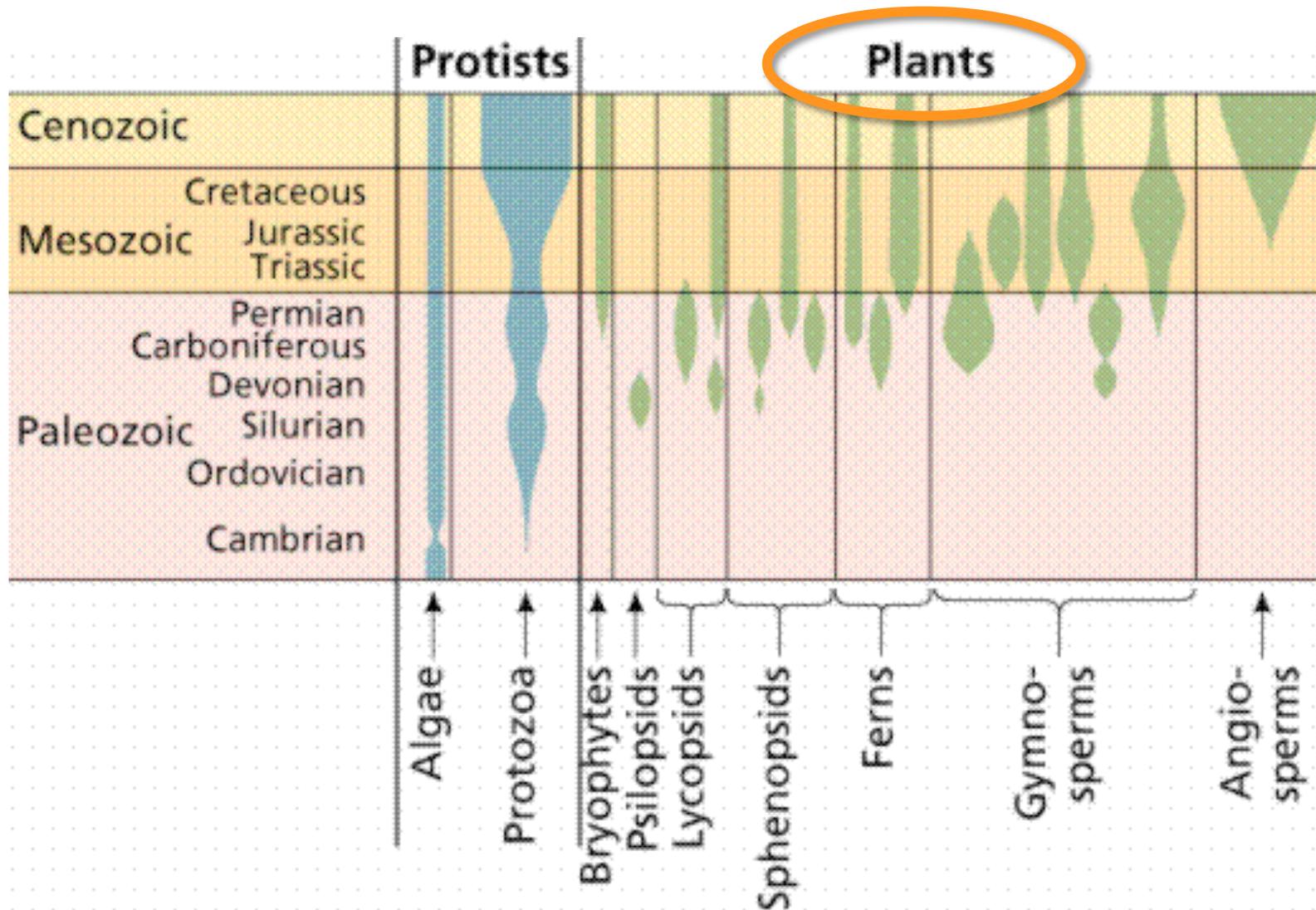
1. No fossil evidence
2. Conflicting predictions of timing
3. Assumes universal common ancestry



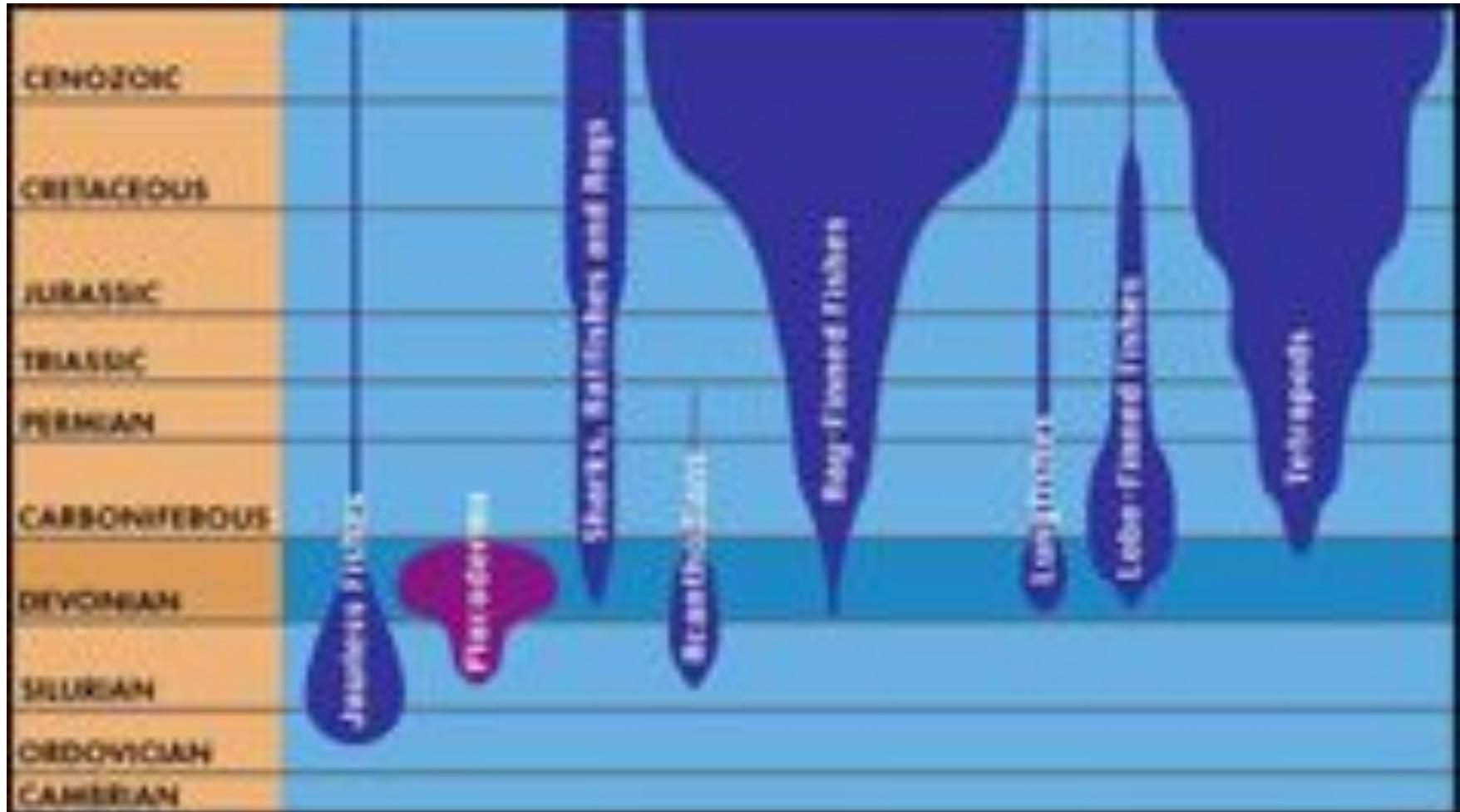
Worth Remembering

- ▶ **Major branches** on the Tree of Life (e.g. fungi, bacteria and other groups) actually *pre-date* the Cambrian.
- ▶ **All** plants post-date the Cambrian, and flowering plants, by far the dominant form of land life today, only appeared about 140 mya
- ▶ **None** of the animal groups that people think of as major taxonomic groups, such as mammals, reptiles, birds, or insects, appeared in the Cambrian.

After The Cambrian

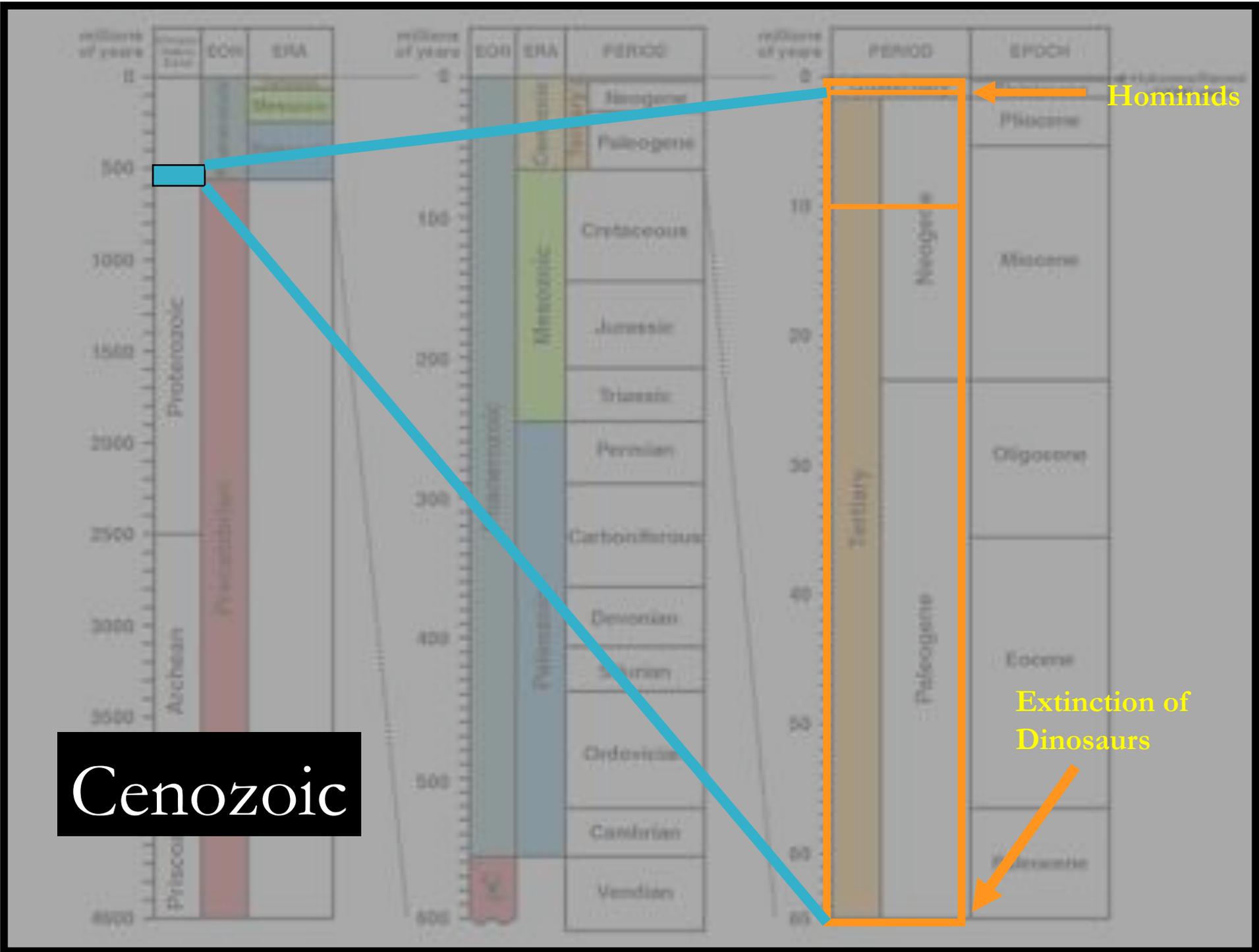


Chordate Diversification



After the Cambrian

- ▶ **Paleozoic** (510 – 245my)
 - Origin of plants, insects, bony fish, amphibians, reptiles, mammal-like reptiles,
 - Permian (marine) extinction
- ▶ **Mesozoic** (245 – 65 my)
 - Radiation of dinosaurs, early mammals & birds
 - Appearance of flowering plants
 - Cretaceous extinction
- ▶ **Cenozoic** (65 my – present)
 - Major radiation of mammals, birds & insects
 - Origin of primates and humans

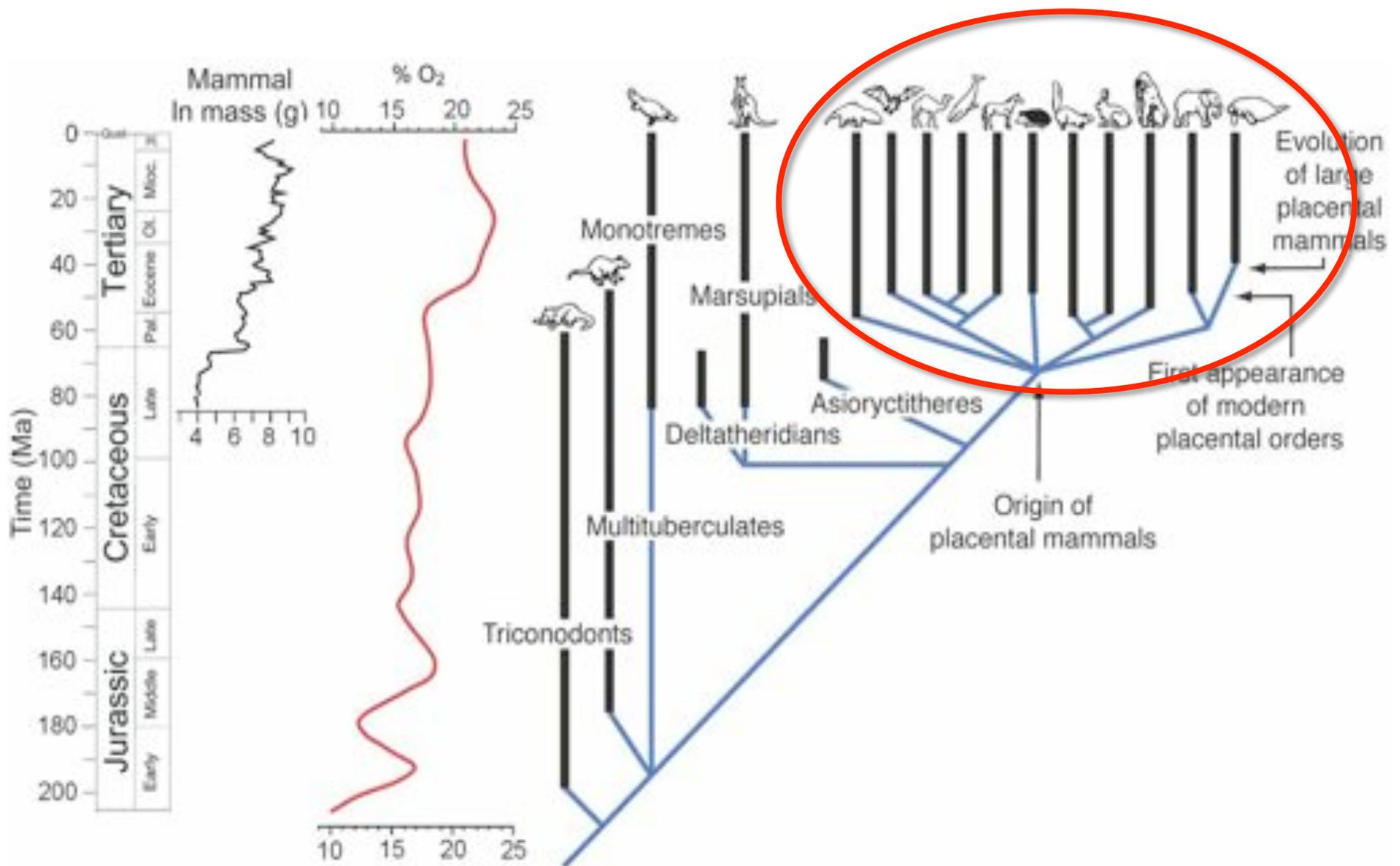


Cenozoic

Hominids

Extinction of Dinosaurs

Mammalian Diversification



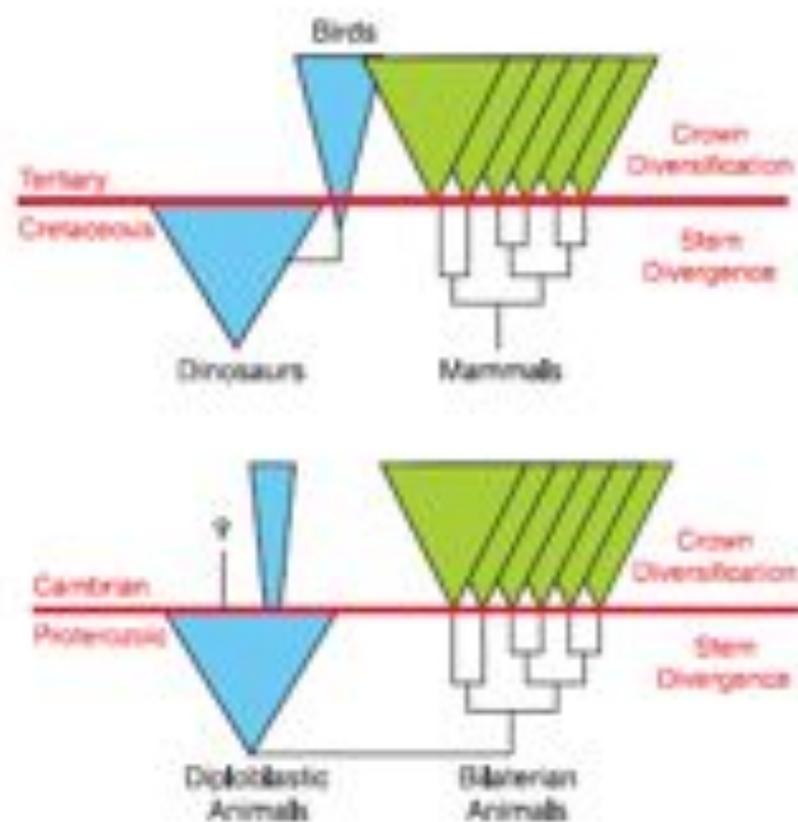


Fig. 5. Comparison of evolutionary dynamics across the Proterozoic-Cambrian and Cretaceous-Tertiary boundaries. The history of terrestrial vertebrates, in which mammals radiated only after dinosaurs suffered mass extinction, may provide a framework for understanding the successive radiations of Ediacarian-grade and crown-group bilaterian animals.

Five Questions

- Was there a Pre-Cambrian fauna?
 - Yes – including multicellular ancestors of Cambrian forms.
- What happened in the Cambrian?
 - A geologically rapid morphological diversification
- Is the explosion real?
 - Yes, but it was phenotypic rather than genotypic.
- How did it happen?

Design Theory and the Cambrian Explosion

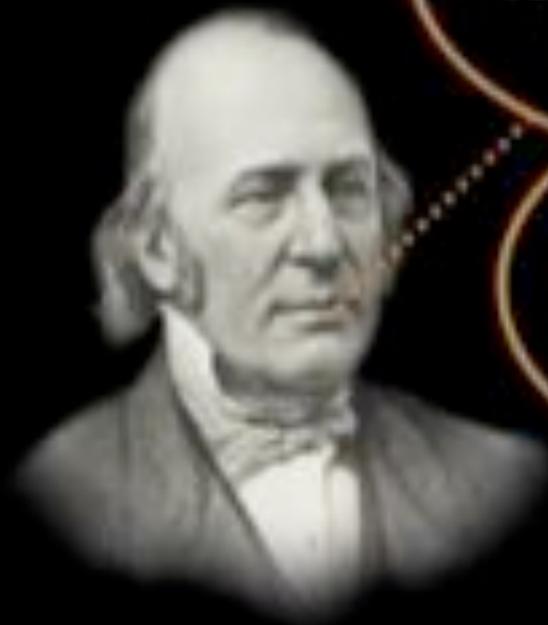
- Quantum increase of biological information
- Persistent morphological isolation
- Top-down pattern of appearance
- Sudden appearance without ancestry



A MIND CAN
LEAP TO NEW
DESIGNS

Agassiz vs. Darwin on Cambrian Explosion

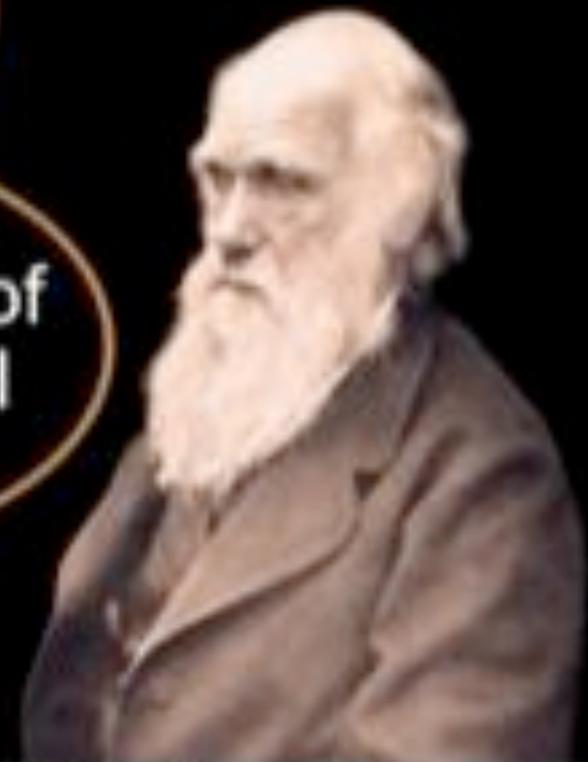
Agassiz



These fossils
tell of "acts of
the mind"

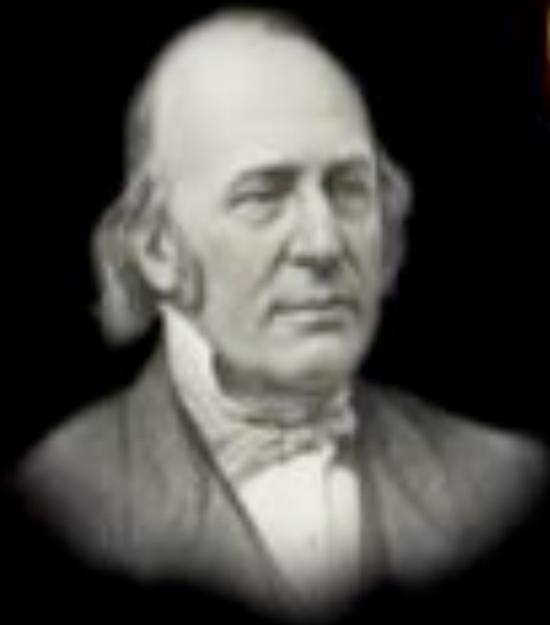
"intervention of
an intellectual
power"

Darwin



Agassiz vs. Darwin on Cambrian Explosion

Agassiz



Darwin



The fossil
evidence is
misleading

There *must* be a
naturalistic
explanation



DISCOVERY
INSTITUTE

BIOLOGY'S BIG BANG

THE CAMBRIAN EXPLOSION

Inference to the Best Naturalistic Explanation?

NEO-DARWINISM



PUNCTUATED EQUILIBRIUM

Cambrian Explosion

■ ■ ■ ■ ■ no intelligent causes allowed ■ ■ ■ ■ ■

INTELLIGENT DESIGN



How did this all happen?



How did this all happen?



- ▶ **Environmental changes**
- ▶ Opening of new niches
- ▶ Development of predator/prey systems
- ▶ Development of visual systems
- ▶ Ecological **feedback**
- ▶ Activation of genetic pathways (see next week)