









#### THE PROTEROZOIC ERA: 2.5 BYA TO 543 MYA

- Most of this era was characterized by prokaryotes and eukaryotic algae.
- First evidence of *multicellular* animal life appeared less than 1 BYA (*But see the next slide*)
- Oldest fossils of multi-cellular animals are 640 million years old.
  - The best-known Precambrian animals are the EDIACARAN FAUNA.
    - Soft-bodied, lacking skeletons.
    - Crept or stood upon the sea floor.
    - · Most don't fit into modern Phyla.



Unclear where they fit in the tree of life



Earliest animal tracks date to **585 million** years ago



















#### PALEOZOIC ERA: CAMBRIAN PERIOD (541 to 500 MYA)

- The "Cambrian Explosion" started about 530 MYA.
- Almost all of the modern phyla and classes of skeletonized marine animals suddenly appear in the fossil record.
- This explosion may have occurred in 30 MY or maybe as little as 5-10 MY (according to the fossil record).
- The most amazing record of this period appears in the BURGESS SHALE, ~505 MYA which is near Banff, BC, Canada.
- Almost all of the fundamentally different animal body plans were present by the end of the Cambrian.
- Cambrian ended with a mass extinction.



How did animals get their skeletons?



Animals with skeletons did not exist before about 550 million years ago. Then, scientists Animals with skeletons did not exist before about 550 million years ago. Then, scientists have proposed, atmospheric oxygen levels rose and the chemistry of the oceans changed in such a way that animals could harmess the minerals required to build hard structural parts. A new analysis of ancient rock layers in Siberia provides support for this idea, showing that the oceans became rich in skeletal building blocks around the same time the first fossils of animals with skeletons start to appear. "This paper goes a lot of the avay toward answering the question of why animals first grew skeletons, and evolved into the animals that we have today," says Ashleigh Hood, a sedimentologist at Yale University who was not involved in the study. The atmosphere today is about 20% oxygen, but that was not always the case. Before about 800 million years ago, it was as low as 0.1% of present day levels. Then, for reasons not fully understood by geologists, oxygen levels started climbing.

http://www.sciencemag.org/news/2016/11/how-did-animals-get-their-skeletons































































### WHAT PRECIPITATED THE CAMBRIAN EXPLOSION?

- Diversification may have been promoted by increasing oxygen levels in the atmosphere.
- Vacant ecological niches may have fostered diversification.
- Key innovations related to multicellularity and the organization of developmental processes may have evolved (e.g., collagen, hierarchies of gene action).
- Nobody knows for sure.
- Or maybe there was no such thing...





# Sufficient oxygen for animal respiration 1,400 million years ago

Shuichang Zhang<sup>a,1</sup>, Xiaomei Wang<sup>a</sup>, Huajian Wang<sup>a</sup>, Christian J. Bjerrum<sup>b.2</sup>, Emma U. Hammarlund M. Mafalda Costa<sup>1,0</sup>, James N. Connelly<sup>1,0</sup>, Baomin Zhang<sup>a</sup>, Jin Su<sup>4</sup>, and Donald E. Canfield<sup>6,1</sup>

# Significance

Nd

How have environmental constraints influenced the timing of animal evolution? It is often argued that oxygen first increased to sufficient levels for animal respiration during the Neoproterozoic Eon, 1,000 million to 542 million years ago, thus explaining the timing of animal evolution. We report geochemical evidence for deep-water oxygenation below an ancient oxygen minimum zone 1,400 million years ago. Oceanographic modeling constrains atmospheric oxygen to a minimum of ~4% of today's values, sufficient oxygen to have fueled early-evolved animal dades. Therefore, we suggest that there was sufficient atmospheric oxygen for animals long before the evolution of animals themselves, and that rising levels of Neoproterozoic oxygen did not contribute to the relatively late appearance of animal life on Earth.



2016 PNAS Early Edit

# First terrestrial plant and fungal life

- Oldest terrestrial plant fossils are 475 myo
- Large forest ecosystems within 100
- million years • Fungi appear ~ 400
  - MyoAssociated with plants



## First terrestrial animal life

- Invertebrate trackways date to 480 mya
  Probably relatives of insects and spiders (Arthropods)
  - Not clear whether they lived on land permanently
- Oldest fossil of fully terrestrial animal dates to 428 mya





• Oldest fossils of tetrapods date to 370 mya



### **BIG PATTERNS IN THE HISTORY OF LIFE**

- If life originated on earth, the main plan may have been set down in a "relatively" short period of time.
- In terms of the appearance of major evolutionary novelties, long periods of stasis appear in the fossil record.
- Explosive periods of diversification appear to follow the "invention' of new genetic mechanisms or ecological changes precipitated by life itself.
- Periods of stasis in the complexity of life appear to be getting shorter – suggesting evolution has "autocatalytic" properties.