Development of Life

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Evolution

• This time with a capital “E”
• Reproduction occurs via DNA
• Any change in the DNA from one generation to the next creates “mutation”
• Causes of mutation:
  • Radiation (all those rock decays; cosmic rays)
  • Chemical contamination
  • “Transcription errors”
• Random mutation produces wide range of changes
DNA Mutation

• Examples
Natural Selection

- Some mutations will be competitively “helpful”, some neutral, some disadvantageous
- Natural selection: those with competitive “edge” more likely to succeed in reproducing; those without are less likely
Natural Selection: Examples

- We have seen this in action on even short timescales:
  - Cockroaches and insecticide
  - TB bacteria and antibiotics
  - Light/dark pepper moths in England:
    - Prior to 1800, mostly light-colored with occasional dark ones (collector items)
    - After Industrial Revolution, trees darkened by soot, dark ones camouflaged, light ones easy to see
    - Light ones disappear (eaten by birds!)
    - Population now dominated by dark moths
Back to Early Life

- Old fossils – like cyanobacteria
- Then … Stromatolites
- Lots and lots of stromatolites!
Stromatolites

- Large agglomerations of single-celled organisms
- First they form “microbial mats” (i.e. “pond scum” layer)
- These layers live, die, get covered by silt
- Next mat forms, etc.
- Produces layered fossils
Modern Stromatolites

• Stromatolites still alive today
• Mostly in places where high acidity or salinity in water removes “predators” (i.e. snails and other grazers)
Atmospheric Bioengineering

- Remember ... atmosphere had no $O_2$ to start
- At about 2.5 GYA, $O_2$ level jumped
- Why?
- LOTS of cyanobacteria and other $CO_2$ breathers!
Development in the Archaic Era

- **Time span from 3.6 GYA to about 0.6 GYA**
- **All single-celled life at this time – LOTS of stromatolites**
- **Responsible for the oxygen-enrichment of the atmosphere** (liberating $O_2$ from $CO_2$)
- **Initially prokaryotes – simpler structure, no nucleus**
- **Eukaryotic fossils date to ~2 GYA**
- **Sterol chemicals begin to show up in rocks about ~2.7 GYA**
- **Sterols only known to come from Eukaryotes now (maybe from Eukaryotes or proto-Eukaryotes then)**
- **Still single-celled, but far more complex …**
Endosymbiotic Theory

- Idea that complex eukaryotes formed from symbiotic relationship between simpler prokaryotic cells
- In other words, big cell “encapsulates” smaller specialized prokaryotes which form mitochondria, chloroplasts, etc.
Endosymbiotic Theory

- Evidence for it:
  - Mitochondria have their own DNA, which is unlike nuclear DNA but similar to prokaryote DNA
  - Chloroplasts actually resemble cyanobacteria
  - "Main cell" offered nucleus which stores most of the mitochondria/plastid DNA in a more "protected" environment
  - Laboratory observations of endosymbiotic relationships developing between some algae and prokaryotes
Single-Celled Evolution

- Move from cyanobacteria (simple) to green algae (complex)
- From prokaryote to eukaryote
- Eukaryotes have 10x to 1,000x more DNA (information for complex structures)
- But still ... only single-celled life found until ~0.6 GYA
- In context:
  - Life has been around for 3.5 GY
  - But single-celled for 2.9 GY of it !!!
  - (for college student scale – as if multi-cell only arrived 3 years ago!)
Early Life: Multi-Cellular

• Around 600 MYA, start seeing a range of multi-cellular organisms
• Seen in sites spread across the world at the same time
• Best examples:
  • The Ediacaran Fauna
• Small fossils (typically a few mm to a few cm)
Cyclomedusa

- Common fossil from this period
- Round symmetry; up to 8-10 inches across (!)
Dickinsonia

- Common fossil from this period
- Round symmetry
Tribrachidium

- Three-fold symmetry, rather than plain round
Spriggina

- Later Ediacaran
- Bilateral symmetry (familiar?)
- Fossils show clear head, mouth
- Centralized structure as well
- First fossil to show “animal” features
**Ediacaran Properties**

- Range of features:
  - Many have round symmetry
  - Others have 3-fold symmetry
  - Later ones show bi-lateral symmetry (like us!)
  - All “soft-bodied” – vaguely reminiscent of jellyfish and anemones
  - For early ones, not sure if they moved around or not – could be “filter feeders”
  - Spriggina sure looks a lot like an “animal”
  - Few, if any, of the Ediacara left recognizable evolutionary “descendants” seen in modern life
Small Shellies

- At transition between Edicaran and the upcoming “Cambrian” era, start seeing fossils with hard shells (~550 MYA)
- Also start seeing more calcium carbonate and phosphates in the rocks
The Cambrian Explosion

- Over a period of just a few million years (unresolved in the geological record – meaning it was geologically “instantaneous”) we suddenly see lots of real “animals”
- Called the “Cambrian Explosion”
Cambrian Examples

- Things that really look like “critters” today (!!)

* Aysheaia - an onychophoran

A modern onychophoran
The Burgess Shale

- Fossil deposit in western Canada provided first examples
- Now many from worldwide

*Thamnauptilon* – a *penatulacean* (sea pen)
The Burgess Shale

Pikaia
- a chordate
The Burgess Shale

*Marella* – an arthropod
Trilobites

- A huge variety of these found in the Cambrian
- Look a lot like Horseshoe Crabs (not actually related though!)
- Have properties including:
  - Armor
  - Legs
  - Mouth
  - Eyes (!!)

Naraoia – a trilobite
Trilobites
Why “Explosion”?

• Note the rapid growth in size from a cell, to a few cells (~3 GY); from a few cells to animals (~0.05 GY); from animals to large animals (~0.01 GY)

• Over only a few million years (versus BILLIONS before) every currently recognized phylum of life on Earth developed in the Cambrian explosion (!)
The Cambrian Explosion

- Initially, at least, land was still totally barren
- No trees, no plants, no critters, no evidence of bacterial life on land either
- The sea, on the other hand, was teeming with life!
Nature Red in Tooth & Claw

- Burgess Shale also provides first conclusive evidence of active predation
What Next?

- So far, so good:
  - We got from bacteria to algae in about 3 billion years (slow progress?)
  - From algae to jellyfish-like Ediacara in about 50 million years (faster)
  - From Ediacara to every known phylum and active predators in a few million years (REALLY fast!)
- How do we go from there to dinosaurs to US?
- Answer: not in a straight line!