

# How to Build Sea Urchins & Manufacture Smoking Guns.

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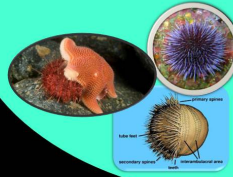
"Although they can develop new technologies for identifying and studying potential smoking guns... historical scientists can never manufacture a smoking gun. If, in fact, every single dinosaur heart was destroyed by the fossilization process, there is nothing anyone can do about it" (Turner 2007, p58)

"When it comes to acquiring knowledge of the past, the only evidence we have to go on consists in observable records, remains, and traces..." (Turner 2007, p158)

## Surrogates (models, simulations, etc...) generate knowledge about the past.

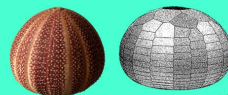
### Crown-group (Post-Palaeozoic) Echinoids (sea urchins, sand dollars, etc...)

The 'test' (spiny outer shell) is constructed from 20 plates arranged into columns.

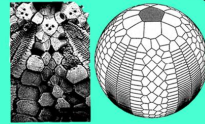


### Zachos (2009):

Constructed a model which 'builds' crown-group echinoids by adding and growing plates. Variables include growth-rate, addition rate and maximum parameter values for ambulacral (underside) and interambulacral (central) plates.



"Paleozoic echinoids appear odd because of their range of morphological disparity... but the same model for growth of individual plates can be applied to both modern and Paleozoic echinoids" (Zachos & Sprinkle, p91).



Left: fossilized stem-group echinoid; right: Zachos & Sprinkle's simulation with 6 insertion points

### Zachos & Sprinkle (2011)

The *Ocular Plate Rule* (OPR): all new interambulacral plates develop connected to the ocular plates, restricting the insertion of new plates to two loci.

By relaxing OPR (increasing the number of insertion points) in Zachos' (2009) model, many stem-group echinoid forms were simulated.

### The results of Zachos & Sprinkle's simulation counts as evidence for H2 over H1.

The law of likelihood:

Observation (O) is evidence for some hypothesis (H<sub>1</sub>) over another (H<sub>2</sub>) when...

$$p(O|H_1) > p(O|H_2)$$

**Problem:** surely the observation of is dependent upon the set up of the simulation (as it is entirely stipulative), not the developmental systems of organisms 250ma dead? The results of their simulation depend upon facts about geometry, software and hardware—not developmental biology!

### Sanctioning (Winsberg 2010)

Scientists *sanction* models through *verification* and *validation*.

*Verified* models are *internally* kosher: (1) produce results meeting the 'physical intuitions' of modellers; (2) follow best practice procedures; (3) approximate the results of established theory.

*Validated* models are *externally* kosher: (1) are able to approximate the results of real-world systems; (2) have similar structures to real-world systems.

$$p(\text{simulation results}|H_2) > p(\text{simulation results}|H_1)$$

is true because *if* H<sub>1</sub> was true, Zachos & Sprinkle's model would not have been sanctioned (i.e., Zachos' 2009 model would not have worked, etc...).

### Stem-group (Palaeozoic) Echinoids



From Smith, Zamora & Alvaro (2013)

- Much higher disparity: 25 to 150+ plates!
- Massive die-off at the end of the Paleozoic (250ma)

What is the difference in development between crown-group and stem-group echinoderms?

H<sub>1</sub>: Stem-group echinoids develop via accretion

H<sub>2</sub>: Stem-group Echinoids (like the crown-group) develop via addition.

### Summary & Conclusions:

- Some philosophers & scientists are pessimistic about uncovering many facts about the past.
- Some of this pessimism is driven by the destruction of traces, and the belief that we cannot 'manufacture' new evidence.
- The development of stem-group echinoderms is mysterious: why were they more disparate than crown-group echinoderms?
- Zachos & Sprinkle (2011) show that qualitatively similar morphologies to stem-group echinoderms are produced by increasing the number of insertion points in Zachos (2009)'s simulation of crown-group echinoderms.
- Their results potentially support (by the law of likelihood) the hypothesis that stem-group disparity is explained by the relaxation of the OPR.
- Zachos & Sprinkle (and other historical scientists) manufacture smoking guns.

### Bibliography

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