#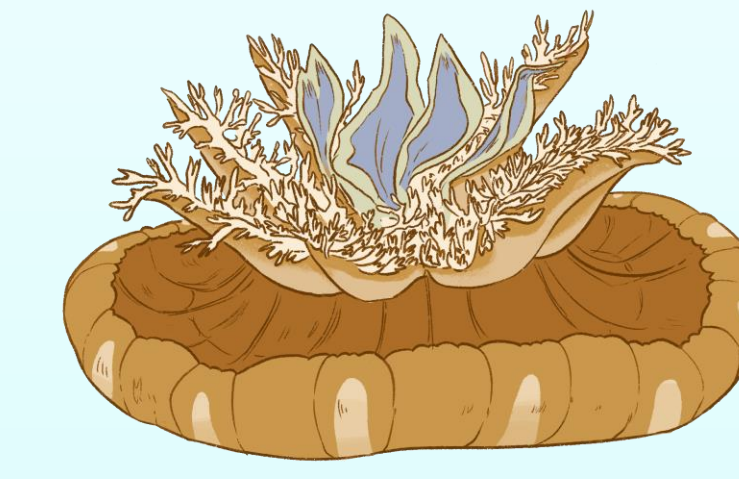 To swim, or not to swim, that is the question: an ancestral state reconstruction based on benthic behaviors across Medusozoa

Kelly E. Walls[1,2], and Allen G. Collins[2,3]

[1]University of Arkansas, Fayetteville, [2]Smithsonian National Museum of Natural History, [3]National Oceanic and Atmospheric Administration NMFS-NSL

REU Site, OCE-1560088

Introduction

Medusozoa is one of the major clades within the phylum Cnidaria. Within Medusozoa, there are four classes: Cubozoa (box jellyfish), Hydrozoa (hydroids, hydromedusae, and siphonophores), Scyphozoa (so called "true jellyfish," such as the moon jelly), and Staurozoa (stalked jellyfish).

The phylogeny of Cnidaria strongly suggests that the ancestral lifeform within the phylum is the polyp and that the swimming medusa (jellyfish) stage has evolved one or more times within Medusozoa [1]. A free-swimming medusa could impact the biology of a lineage in several ways:
- The ability to access new food sources in the water column
- Increased dispersal ability
- Increased species ranges (associated with dispersal)

Medusae are generally viewed as pelagic animals; however, some Medusozoa species prefer the ocean floor [2, 3]. These jellies are said to be benthic/benthopelagic. Not much is known about why they adhere to the bottom of the ocean and the advantages and disadvantages of this behavior have not been studied.

The goal of this research was to perform an ancestral state reconstruction in order to infer how many times a benthic/benthopelagic lifestyle has evolved throughout the clade Medusozoa.
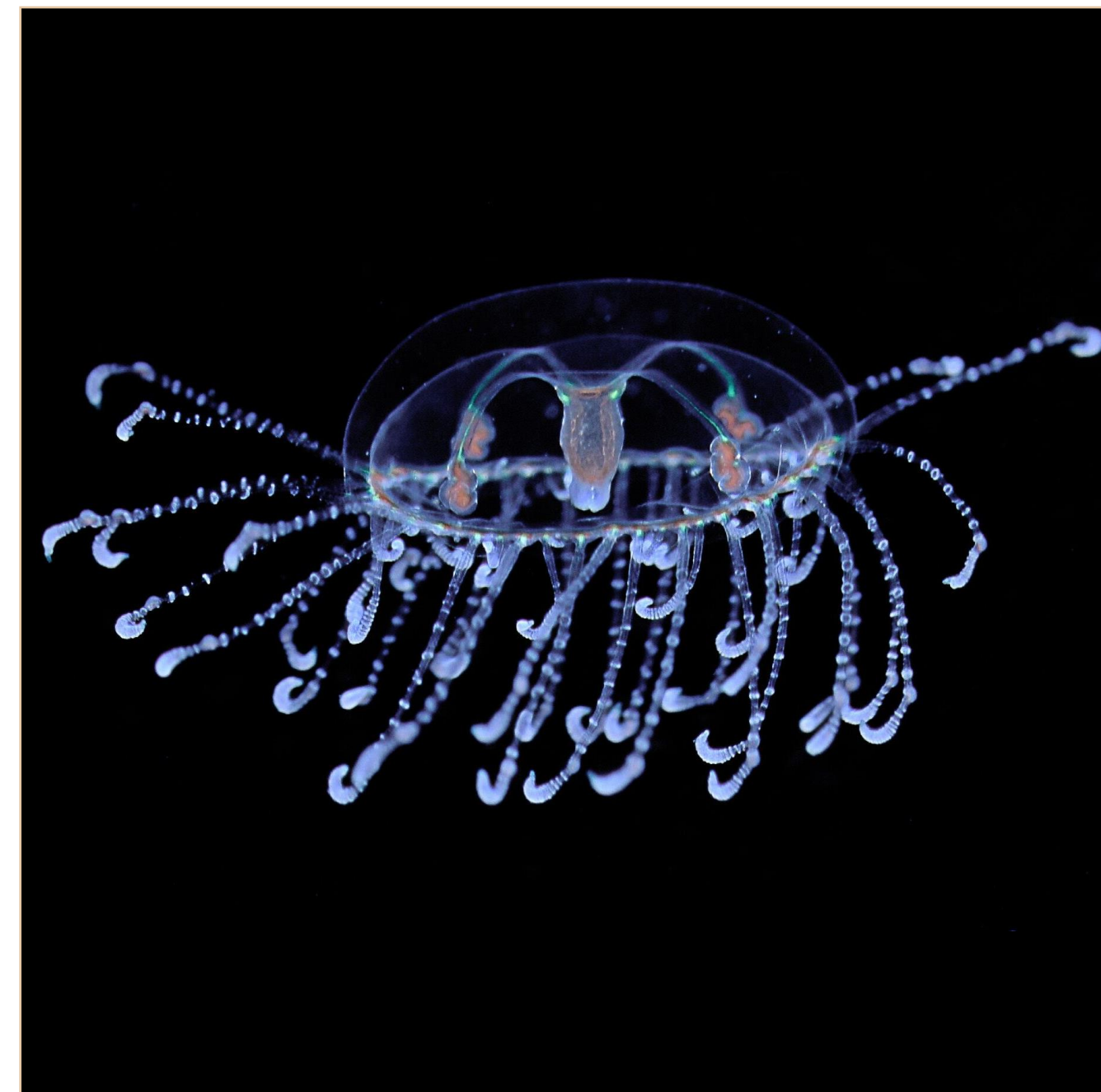

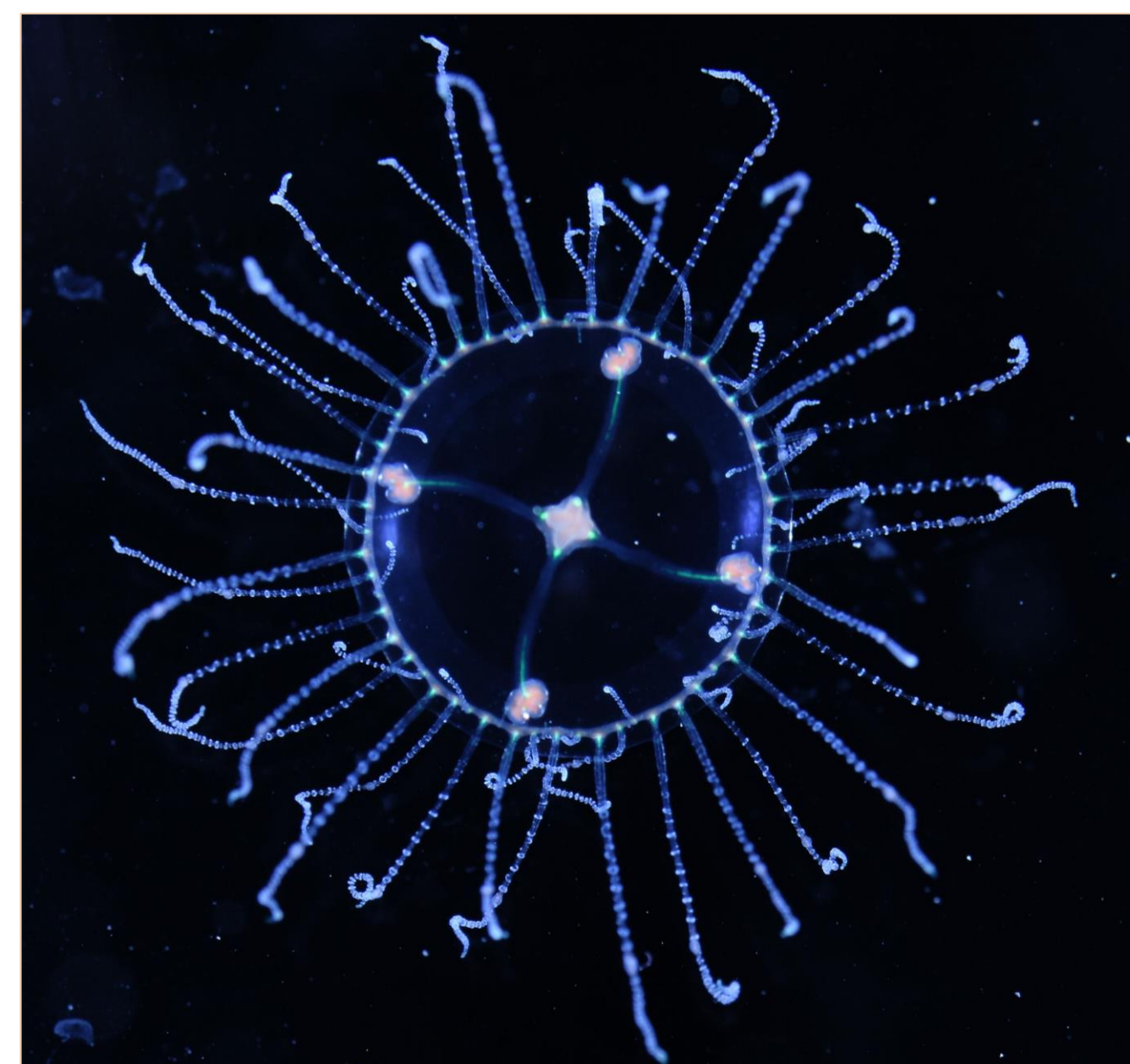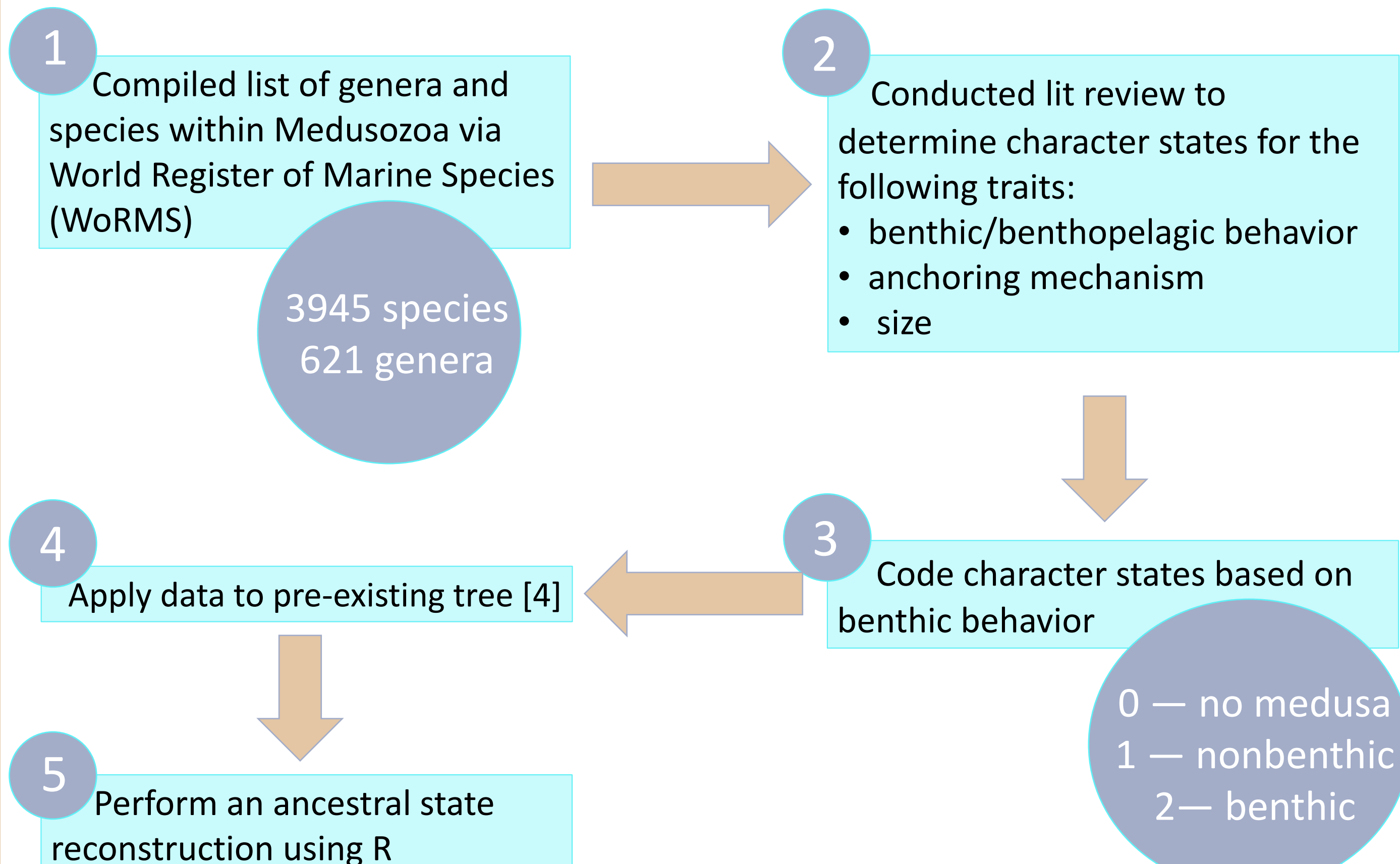**Figure 1.** *Scolionema* medusa in swimming form

Figure 2. *Scolionema* medusa with tentacles spread in attachment form

Methods

1. Compiled list of genera and species within Medusozoa via World Register of Marine Species (WoRMS)

2. Conducted lit review to determine character states for the following traits:
   - benthic/benthopelagic behavior
   - anchoring mechanism
   - size

3945 species
621 genera

3. Code character states based on benthic behavior

4. Apply data to pre-existing tree [4]

0 — no medusa
1 — nonbenthic
2 — benthic

5. Perform an ancestral state reconstruction using R

Results

Key
- ★ — transition
- Aa — benthic species
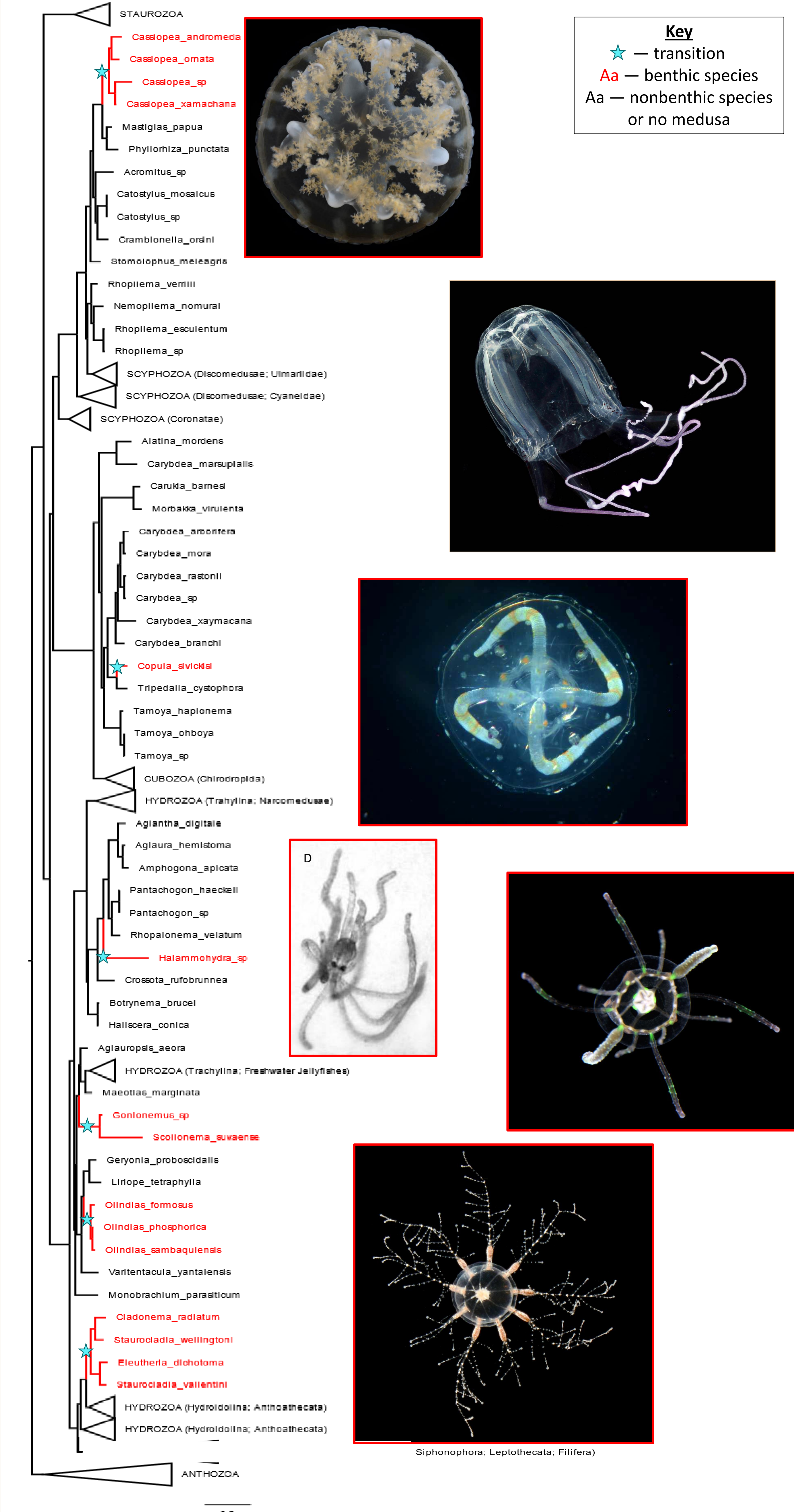- Aa — nonbenthic species or no medusa

Figure 3. Resulting phylogeny with jellyfish photos (A-F); (A) *Cassiopea*, benthic; (B) *Carybdea xaymacana*, nonbenthic; (C) *Copula sivicki*si, benthic; (D) *Halammohydra* sp. (E) *Olindias formosus*, benthic; (F) *Cladonema mayeri*, benthic

Discussion

The phylogeny utilized in this project contained a total of 1102 species, some of which belonged to Anthozoa as opposed to Medusozoa. All Anthozoa members were coded as "0," meaning they lack a medusa stage. In R, ancestral state reconstructions were run using the All Rates Different (ARD) model, Equal Rates (ER) model, and a Symmetric (SYM) model. The ER model was the best fit because it had the greatest AIC.

The ER ancestral state reconstruction was plotted, and the tree revealed the following:
- 15 benthic species representing 9 genera
- 6 transitions states
- No reversals from benthic/benthopelagic behavior to pelagic

The resulting phylogeny (figure 3) suggests that the benthic/benthopelagic behavior has evolved at least 6 times across Medusozoa. However, at least 6 other medusozoan genera, not included in the phylogeny used here, have benthic/benthopelagic medusae.

Future Directions

The next step in this project would be to apply the data collected on the 3,945 species and 621 genera to trees with those species and genera as tips and perform an ancestral state reconstruction. This would give us a better estimate on how many times this character trait evolved.

Furthermore, an ancestral state reconstruction using multiple character states should be performed. When collecting data, I made note of the anchoring mechanisms of the benthic/benthopelagic jellies and found that the jellies used adhesive organs/sticky pads on either their tentacles or bell. It would be interesting to see how the location of their attachment impacts the ancestral state reconstruction.
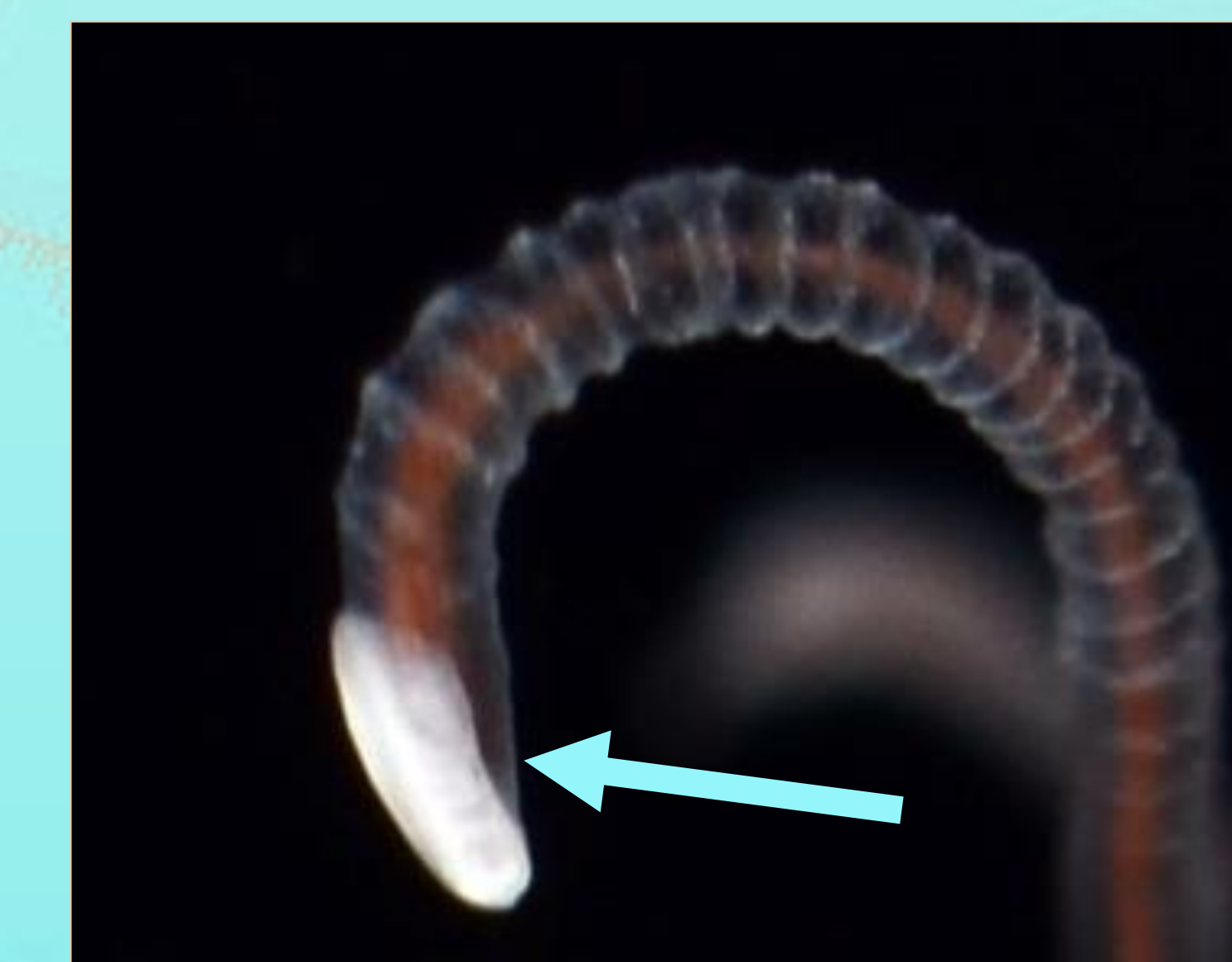

Figure 4. *Vallentinia* tentacle with arrow pointed at adhesive pad

Figure 5. *Copula sivicksi* resting, arrow pointed at adhesive organ on the medusa's bell

Literature

1. Mayer, A. G. (1910). *Medusae of the world: The Hydromedusae* (Vol. 1). Carnegie Institution of Washington.
2. Bouillon, J., Gravili, C., Gili, J. M., & Boero, F. (2006). *An introduction to Hydrozoa.*
3. Hirano, Y. M., Hirano, Y. J., & Yamada, M. (2000). Life in tidepools: distribution and abundance of two crawling hydromedusae, Staurocladia oahuensis and S. bilateralis, on a rocky intertidal shore in Kominato, central Japan. *Scientia marina, 64*(S1), 179-187.
4. Picciani, N., Kerlin, J. R., Sierra, N., Swafford, A. J., Ramirez, M. D., Roberts, N. G., ... & Oakley, T. H. (2018). Prolific origination of eyes in Cnidaria with co-option of non-visual opsins. *Current Biology, 28*(15), 2413-2419.

Acknowledgements