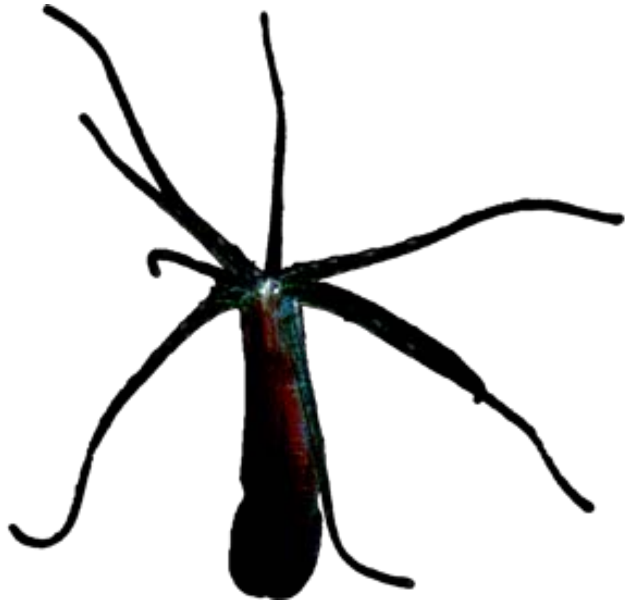
Marine Invertebrates

CAS BI 547



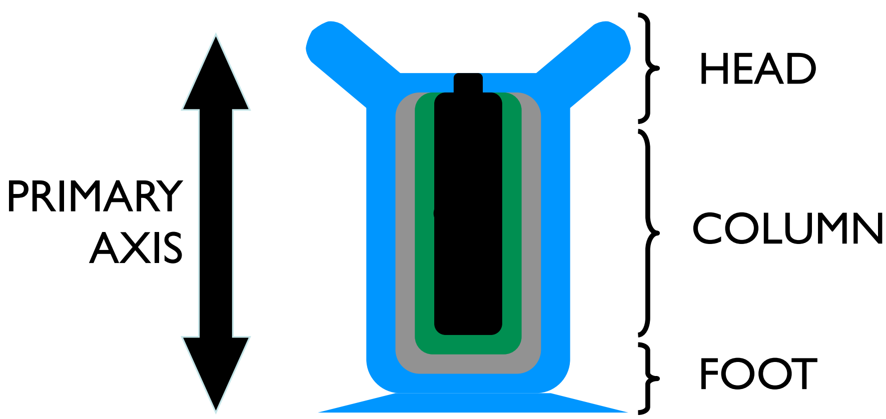
The Starlet Sea Anemone
Nematostella vectensis
by J. R. Finnerty

Merits of *Nematostella* as a model system.

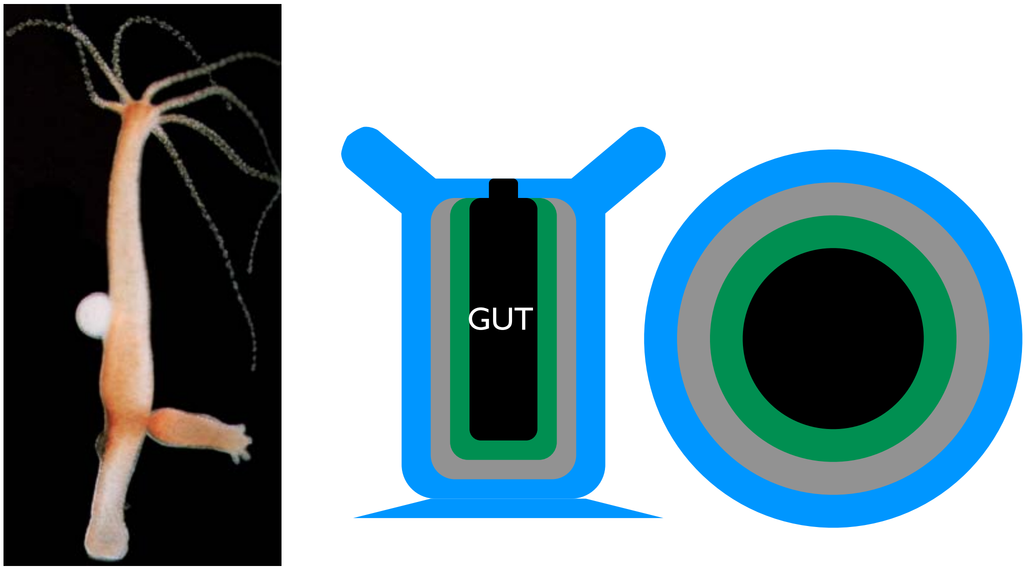
- Morphological simplicity
- Developmental flexibility
- Ease of culture
- Ease of field study
- Phylogenetic position
- Sequenced genome
- Relatively conservative genome evolution.

Relative morphological simplicity

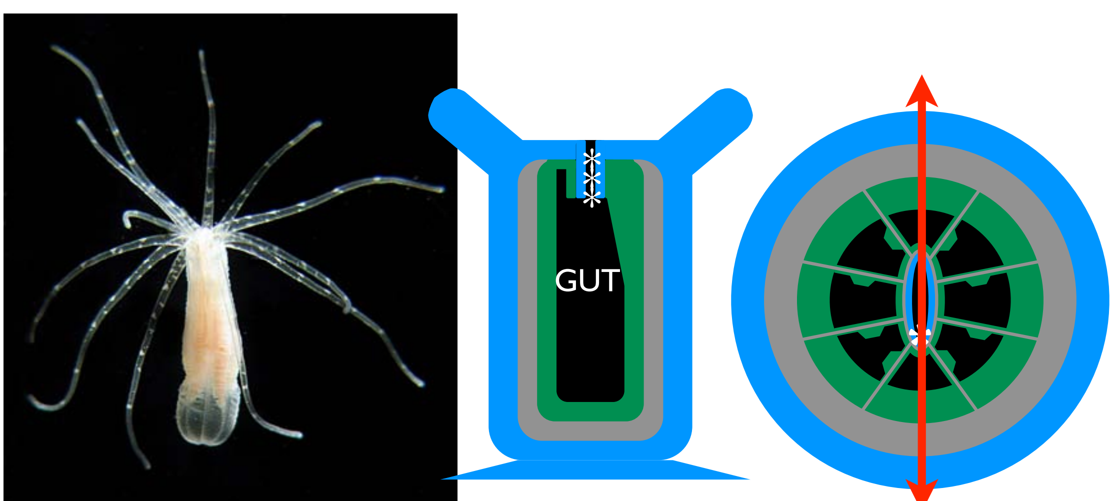
- Diploblastic (2 layers)
- Blind gut (mouth/anus)
- Simple neuromuscular system
  - Nerve net
  - Epitheliomuscle cells
- Unsegmented
- No paired appendages
- But genuinely bilateral!



Hydra — Radial Symmetry

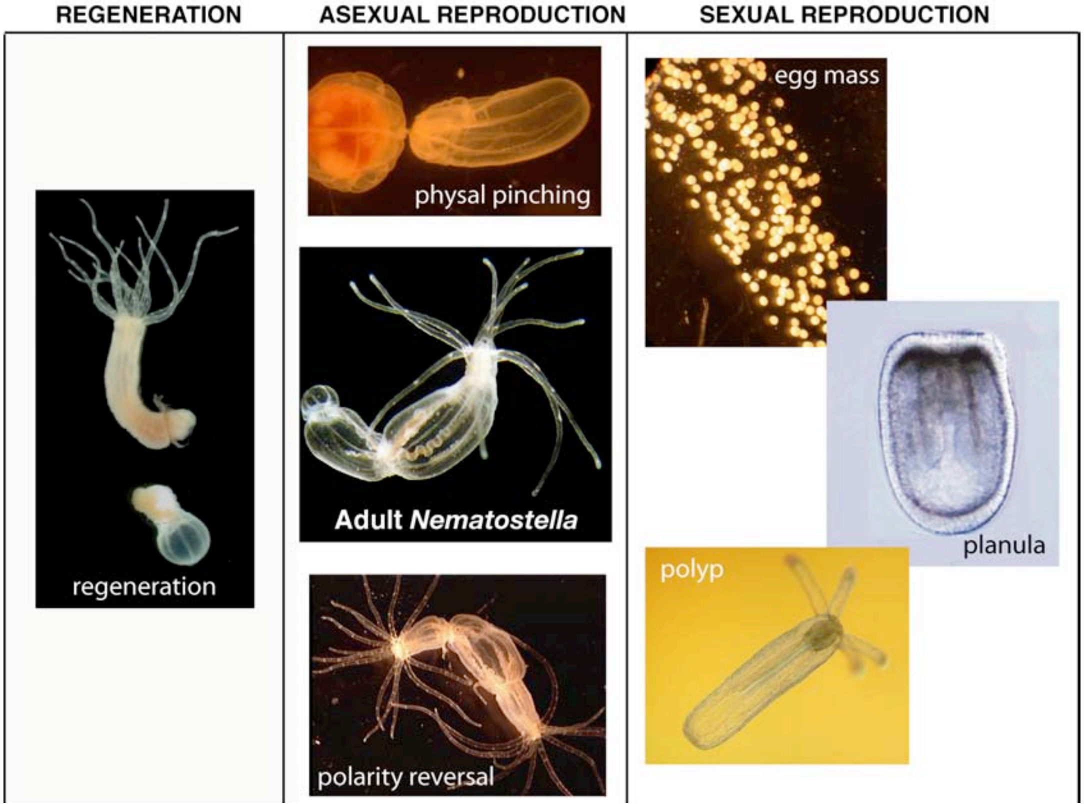


Nematostella — Bilaterally Symmetrical



+ pharynx
+ mesenteries
+ siphonoglyph
+ retractor m.

Developmental Flexibility



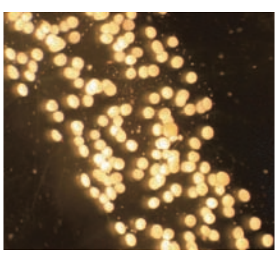
Developmental Flexibility

- Alternate modes of reproduction.
- Presumably tied to different environmental triggers.
- Such flexibility is widespread and perhaps ancestral for animals.
- Hi-lights the fundamental connection between environment and development.
- Unlike the major developmental model systems (e.g., fruit fly, soil nematode, zebrafish), the adult *Nematostella* can arise via four different developmental trajectories.
- All four developmental trajectories occur in the field and are readily observed in the lab.
    - **Embryogenesis** & larval development (following sexual reproduction)
    - **Regeneration** (complete & bidirectional)
    - Asexual fission by "**physal pinching**."
    - Asexual fission by "**polarity reversal**."

Nematostella Embryogenesis

- The sexes are separate.
- On a weekly basis, the female can extrude 100's of eggs (encased in a jelly mass) from her mouth.
- Fertilization is external.
- Cleavage is "highly chaotic."
- Early cell divisions may be asynchronous.
- As a result, the developmental fates of early blastomeres are not stereotyped or predictable.
- A hollow spherical blastula is produced.
- Gastrulation occurs approximately 24 hours after fertilization via the process of invagination.

Nematostella Embryogenesis

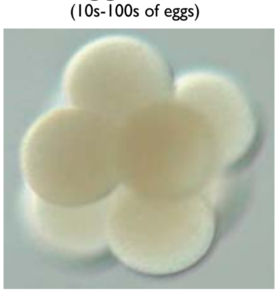


Egg Mass
(10s-100s of eggs)

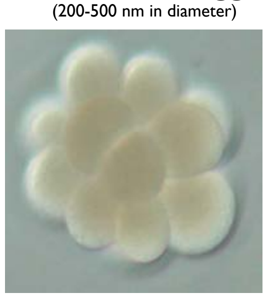
Fertilized Egg
(200-500 nm in diameter)

2-cell stage
(cleavage is holoblastic & equal)

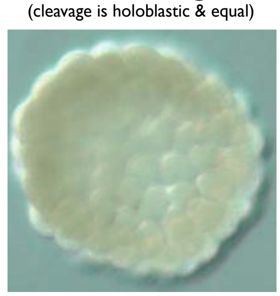
4-cell stage
(3-cell and 5-cell embryos are common)



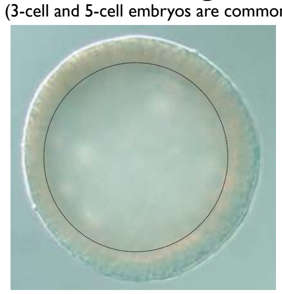
8-cell stage



16-cell stage



Hollow blastula
(~128 cells)



Blastocoel

Nematostella Gastrulation

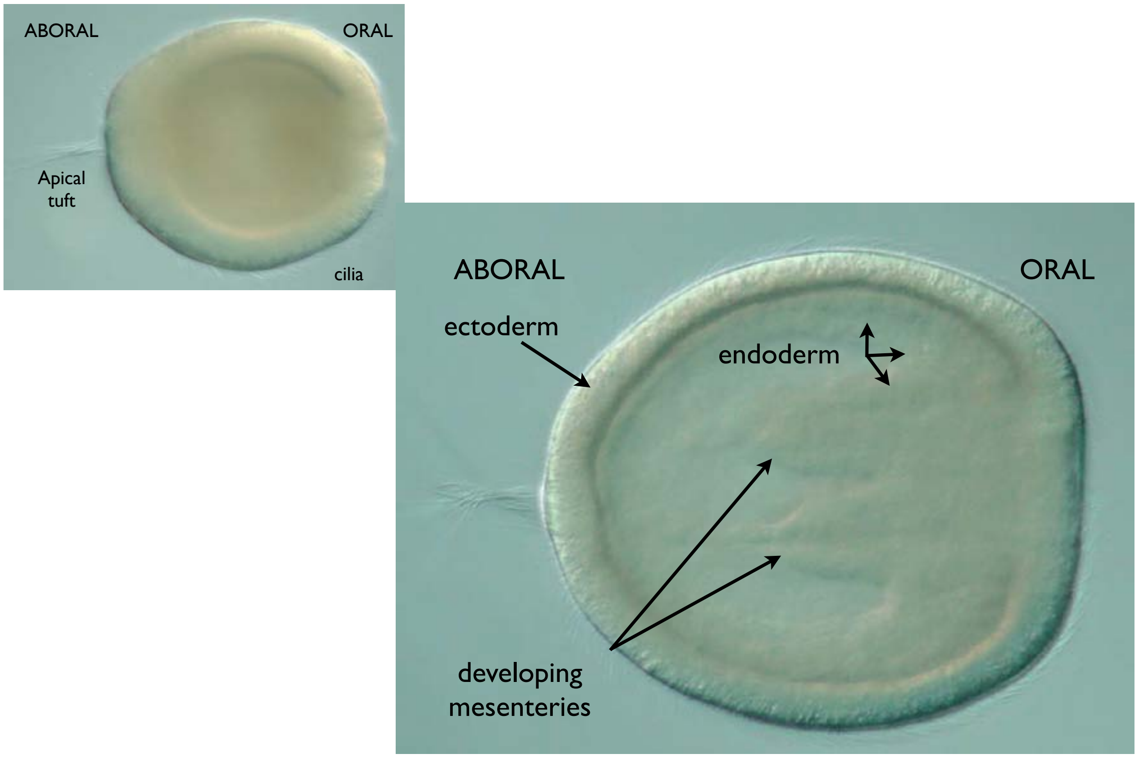
Site of mouth

Onset of gastrulation
(invagination occurs at the blastopore)

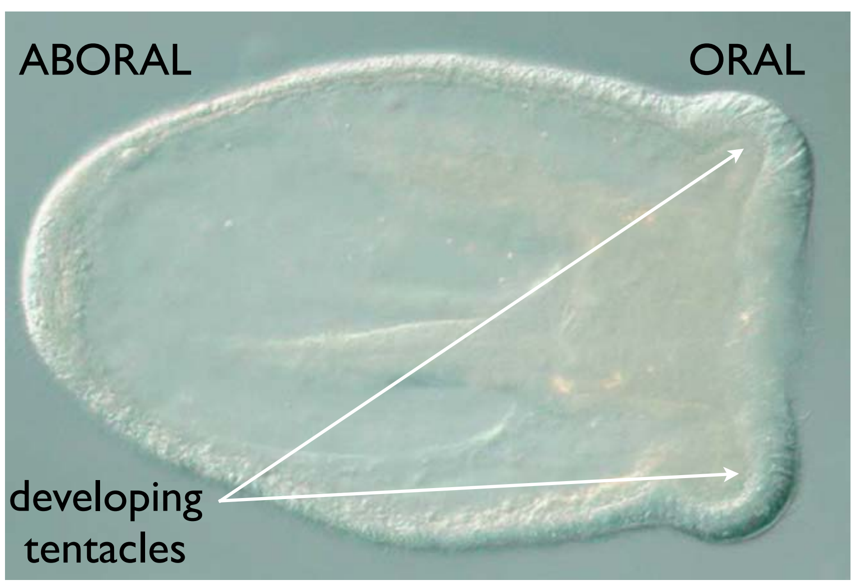
Nematostella Larval Development

- Day 3: gastrula elongates into planula larva.
- Heavily ciliated outer ectoderm.
- Highly motile larva (but stays close to home).
- Prominent "apical tuft" at the aboral end.
- Day 5: tentacle buds form.
- Day 7: larva settles and morphs into a polyp.
- Polyp can spawn ~50 days post fertilization.

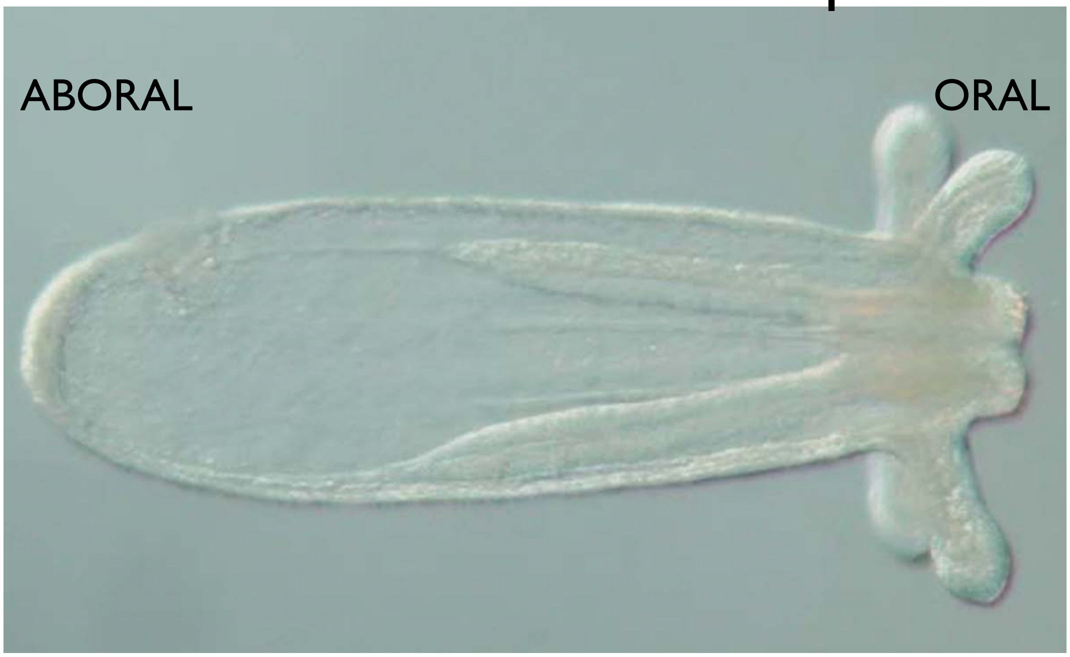
Nematostella Larval Development



Nematostella Larval Development

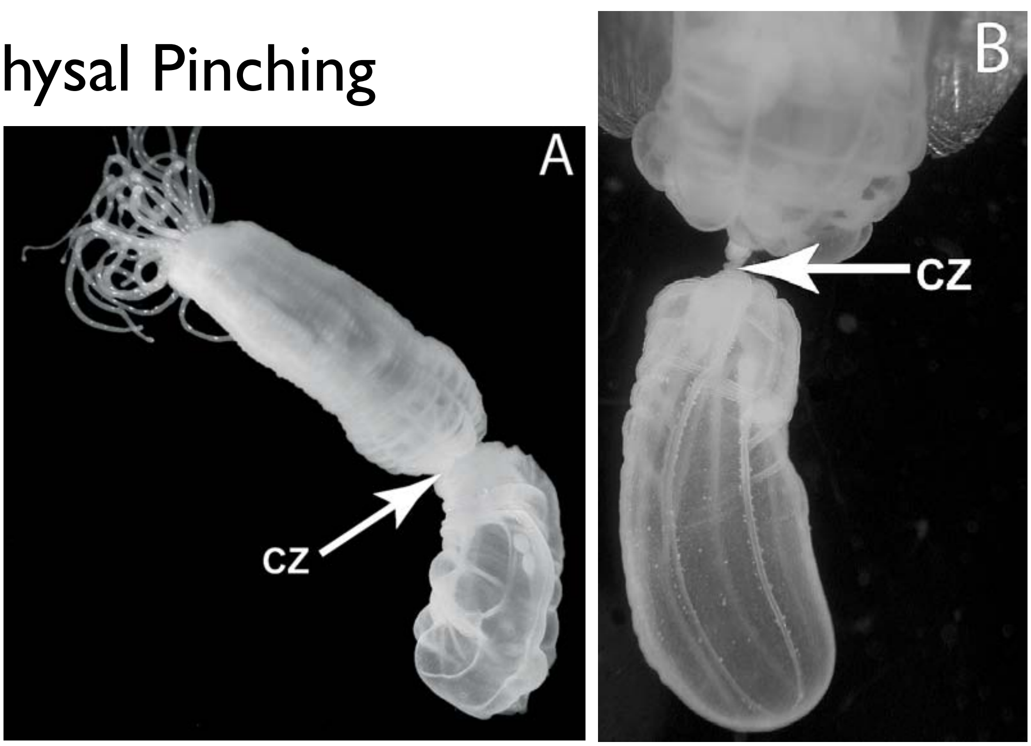


Nematostella Larval Development



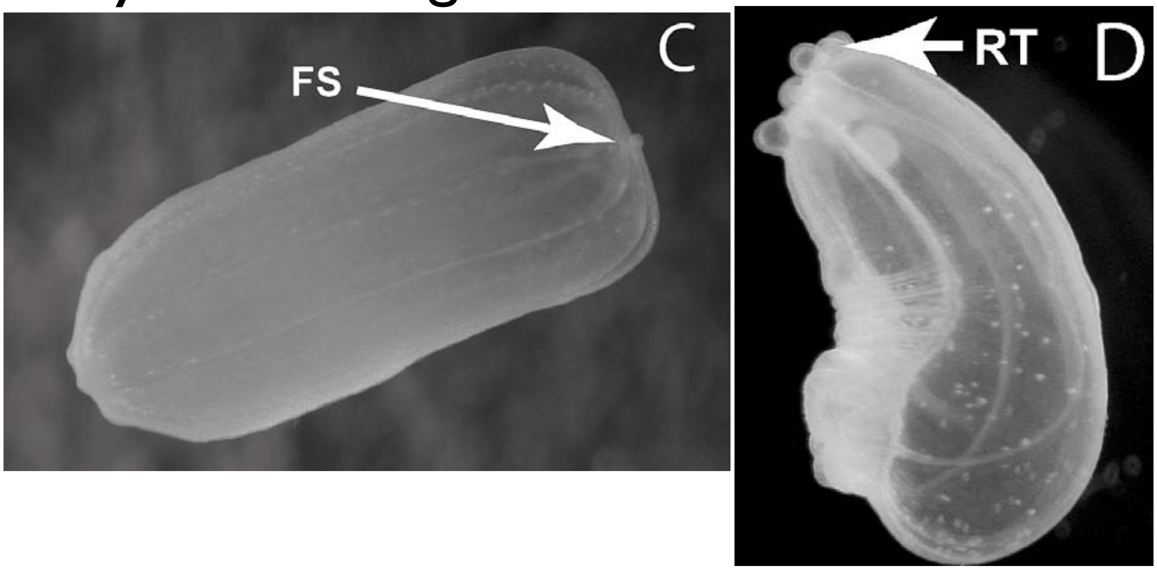
Photos by Patricia Lee

Physal Pinching



Reitzel AR, Burton P, Krone C, Finnerty JR (2007) Comparison of alternate developmental trajectories in the starlet sea anemone *Nematostella vectensis* (Stephenson): embryogenesis, regeneration, and two forms of asexual fission. Invert Biol. **126**: 99-112. [cited by 8]

Physal Pinching



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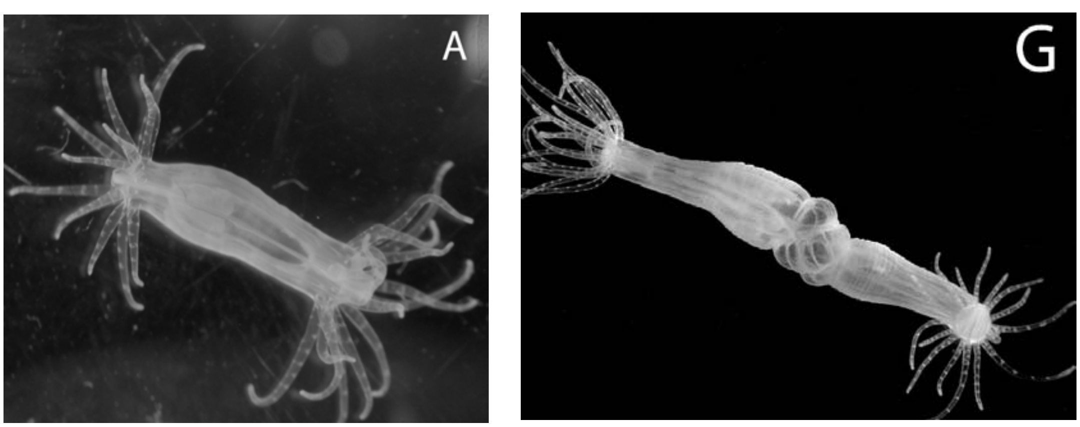
Polarity Reversal



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Reproductive Flexibility

Experimental Advantages of Regeneration

- Establishment of Clonal Lines
  - allows genetic variation to be discriminated from environmental or stochastic variation
- Regeneration as an Eco-Developmental Assay
  - controlled laboratory studies can be used to investigate effects of genotype, environment, and genotype X environment on development

Easy to monitor in the field

- A denizen of semi-permanent salt marsh pools and tidal creeks.
- Accessible from shore.
- Repeated sampling of the same pools makes possible longitudinal studies on natural populations.

Adam Reitzel at Sippewissett Marsh, Cape Cod, MA [Nematostella.org]

- Given the ecological importance of coastal estuaries, *Nematostella* is destined to become an important environmental sentinel species.

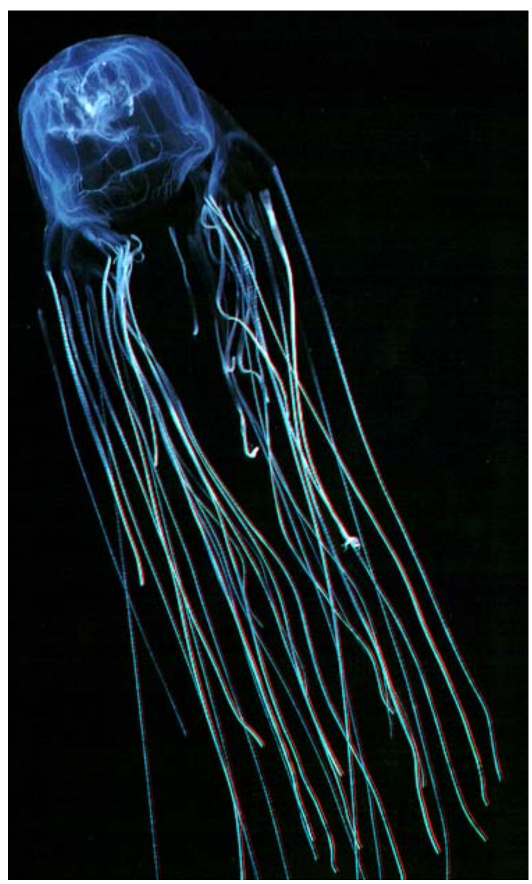
Phylogenetically Informative Position

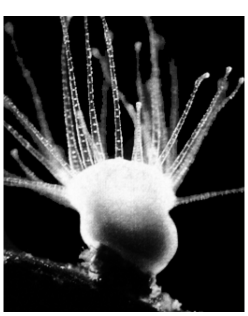
- *Nematostella* is a member of the phylum Cnidaria.
- The Cnidaria is a "basal" metazoan lineage.
- Other members of the Cnidaria include corals, jellyfishes, and hydras.
- Among the basal animal phyla, the Cnidaria appears most closely related to the "Bilateria," the clade that comprises >99% of all extant animals.

Class ANTHOZOA
sea anemones
corals, & relatives

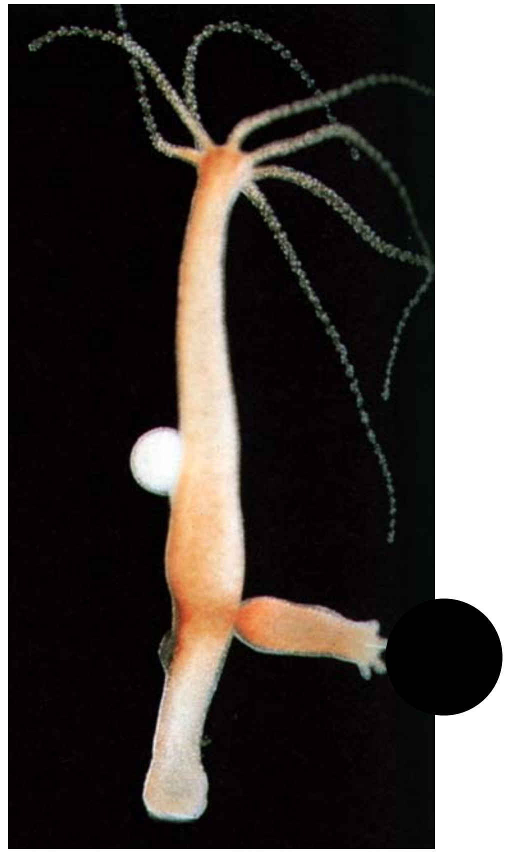
Class SCYPHOZOA
true jellyfishes

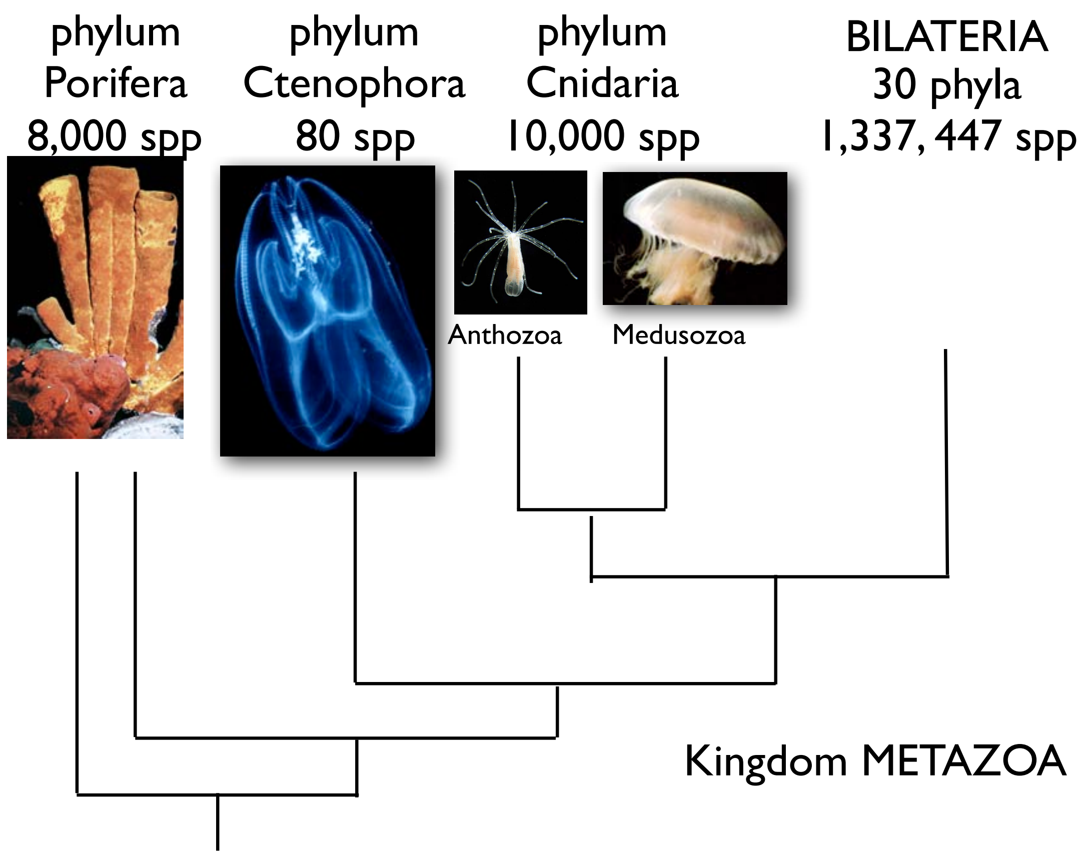
Class CUBOZOA
box jellyfishes





Class HYDROZOA
hydroids, hydromedusae,
& hydras





Sequenced Genome

- Joint Genome Institute (D. Rokhsar, PI)
  - 7.8X whole genome shotgun sequencing
  - 10,804 assembled scaffolds (median ~470 Kb)
  - 356 MB
  - 2N = 30
  - polymorphism rate ~1/125 (~10X humans)
  - ~18,000 "*bona fide*" protein coding genes

"Sea anemone genome reveals the gene repertoire and genomic organization of the eumetazoan ancestor." Putnam NH, Srivastava M, Hellsten H, Dirks B, Chapman J, Salamov A, Terry A, Shapiro H, Lindquist E, Kapitonov VV, Jurka J, Genikhovich G, Grigoviev I, JGI Sequencing Team, Steele RE, Finnerty J, Technau U, Martindale MQ, Rokhsar DS. (In Review at *Science*)

Conservative Genome Evolution

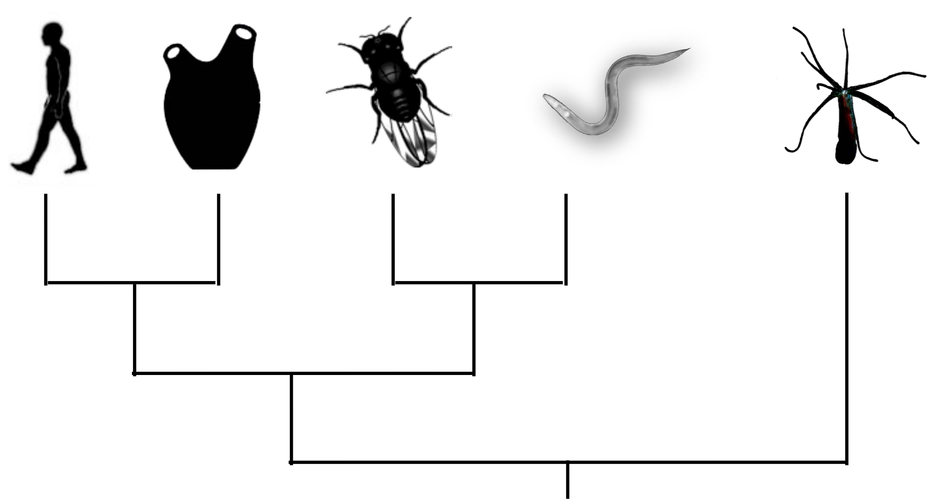
- By many measures, the *Nematostella* genome exhibits greater similarity to the human genome than do the fruit fly or soil nematode genomes.
- The cnidarian-bilaterian ancestor possessed a complex genome.
- *Nematostella's* genome has evolved in a more conservative fashion than the "model" protostomes.
- This only increases *Nematostella's* value for reconstructing early animal genome evolution.

Conservative Genome Evolution

Shared Orthologous Genes

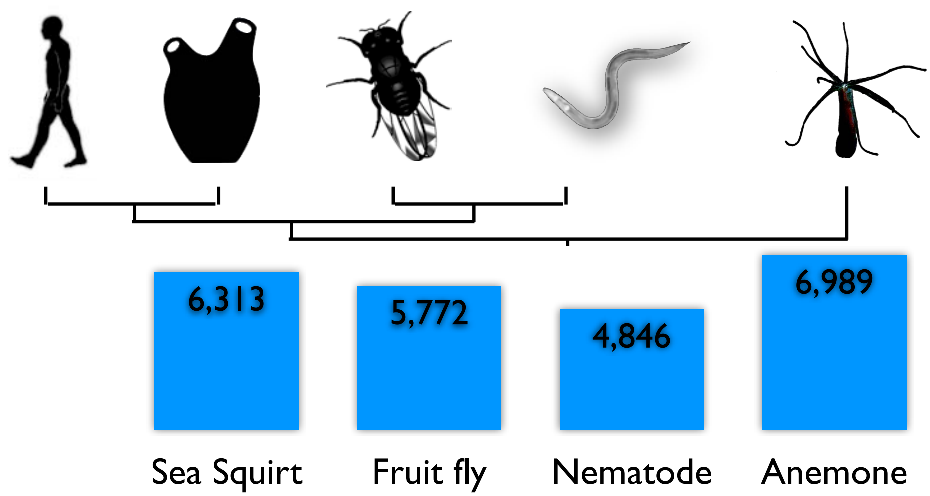
Stella's Surprising "Humanity"

- Pairwise reciprocal BLASTs were used to identifiy putative orthologs of human genes in *Nematostella*, *Drosophila*, *Caenorhabditis*, and *Ciona* (a chordate).



Stella's Surprising "Humanity"

Orthologous gene pairs shared with Human

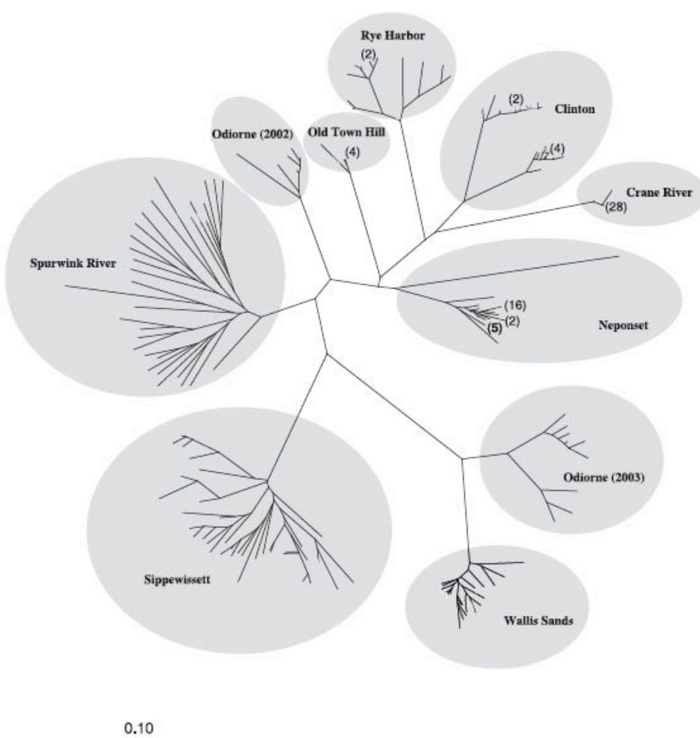


Stella's Surprising "Humanity"

"These results strongly suggest that many genes and gene families previously assumed to be chordate or vertebrate inventions are actually more ancient, and conversely that the fruitfly, soil nematode, and sea squirt lineages have experienced higher levels of divergence and gene loss than *Nematostella*...."

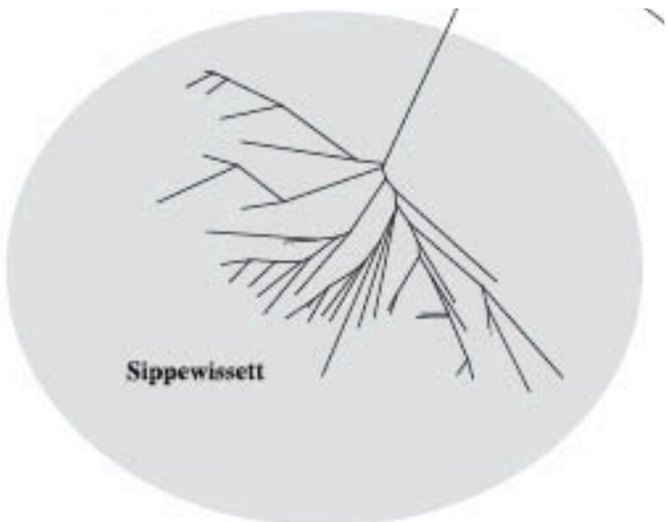
Abundant Genetic Structure & Polymorphism

Regional Population Genetic Structure



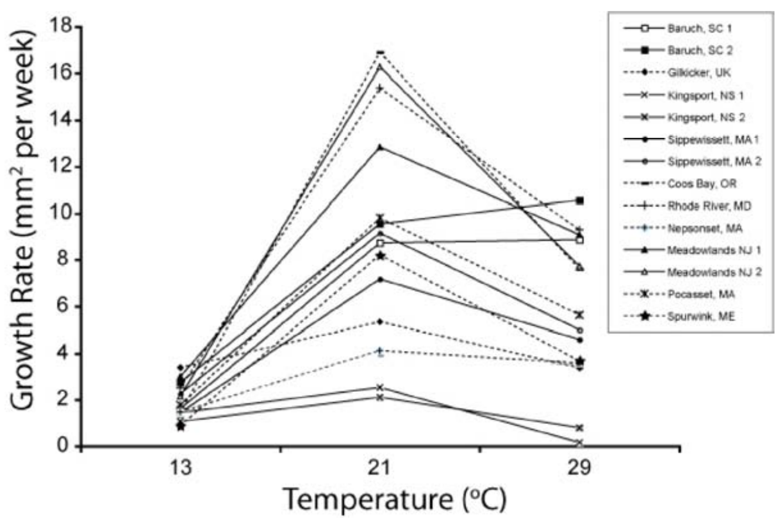
- 154 AFLP loci were used to genetically fingerprint 212 Nematostella.
- Animals from different estuaries appear genetically isolated.

Fine-scale Population Genetic Structure



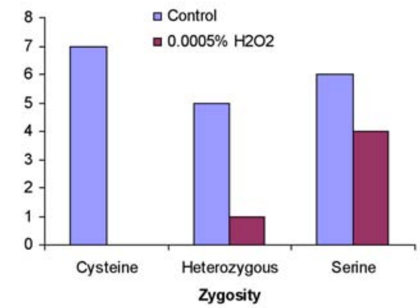
- Within a 500 acre saltmarsh, individuals in different pools segregate into different genetic clusters.
- Animals from different pools appear genetically isolated.

Possibility for Local Adaptation



- Animals from different geographic locales grow better at different temps (e.g., only South Carolina animals grow better at 29 ·C than 21°C).

Possibility for Local Adaptation



- Animals with different genotypes regenerate differently under exposure to peroxide.
- Both variants of the gene occur in Sippewissett.