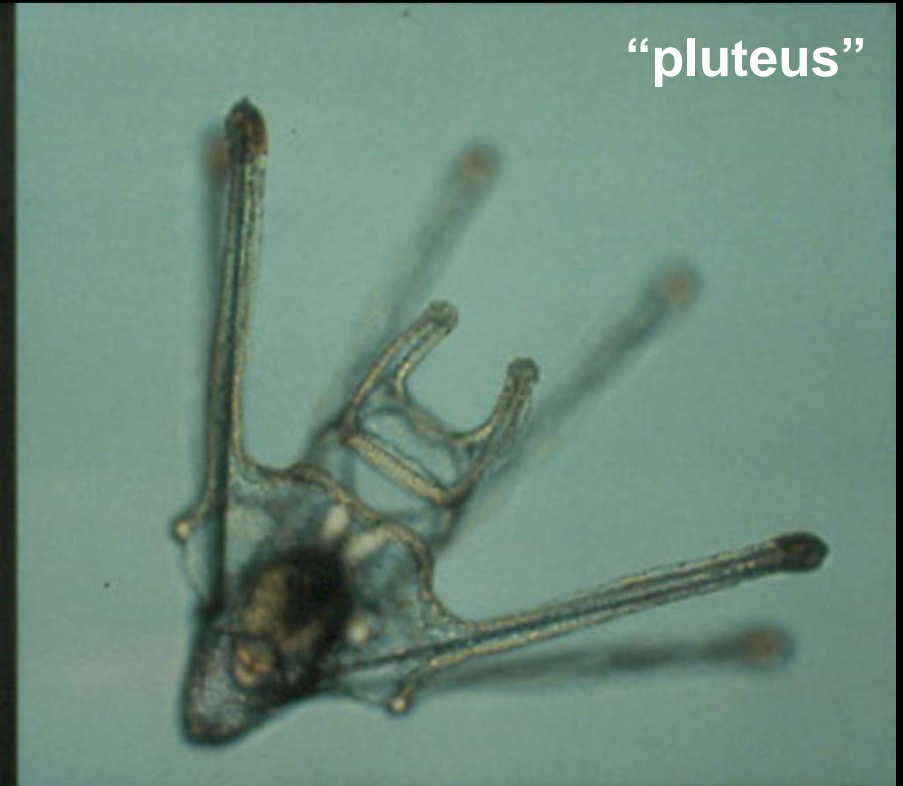


# Sexual reproduction and larval biology



# Animals are life cycles

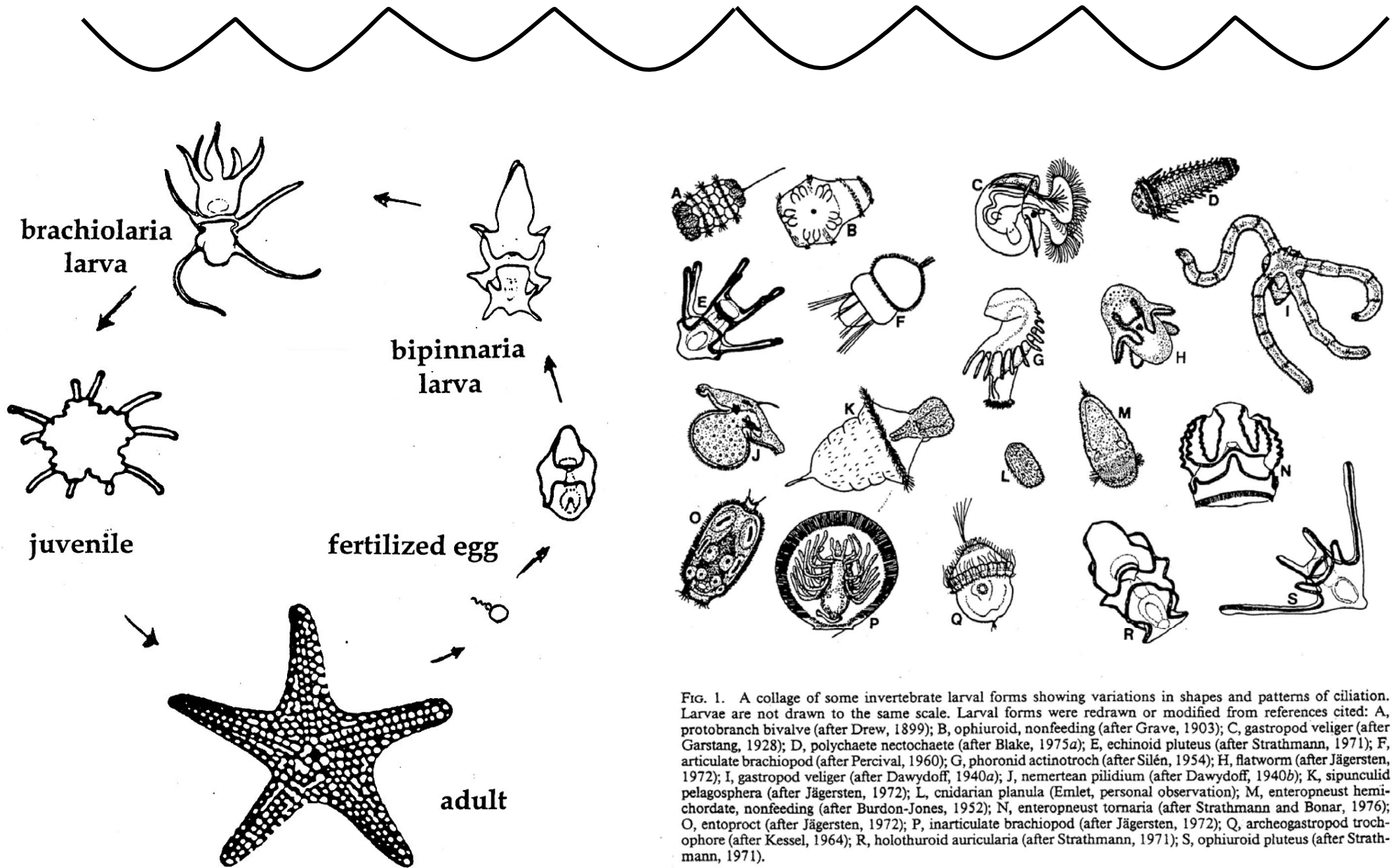


FIG. 1. A collage of some invertebrate larval forms showing variations in shapes and patterns of ciliation. Larvae are not drawn to the same scale. Larval forms were redrawn or modified from references cited: A, protobranch bivalve (after Drew, 1899); B, ophiuroid, nonfeeding (after Grave, 1903); C, gastropod veliger (after Garstang, 1928); D, polychaete nectochaete (after Blake, 1975a); E, echinoid pluteus (after Strathmann, 1971); F, articulate brachiopod (after Percival, 1960); G, phoronid actinotroch (after Silén, 1954); H, flatworm (after Jägersten, 1972); I, gastropod veliger (after Dawydoff, 1940a); J, nemertean pilidium (after Dawydoff, 1940b); K, sipunculid pelagosphera (after Jägersten, 1972); L, cnidarian planula (Emlet, personal observation); M, enteropneust hemichordate, nonfeeding (after Burdon-Jones, 1952); N, enteropneust tornaria (after Strathmann and Bonar, 1976); O, entoproct (after Jägersten, 1972); P, inarticulate brachiopod (after Jägersten, 1972); Q, archeogastropod trochophore (after Kessel, 1964); R, holothuroid auricularia (after Strathmann, 1971); S, ophiuroid pluteus (after Strathmann, 1971).

# Modes of Sexual Reproduction

	Sexes <sup>1</sup>	Broadcast Spawn?	Brood? <sup>2</sup>
Porifera	d, H	Yes <sup>3</sup>	+++
Cnidaria	D, h	Yes <sup>3</sup>	+++
Ctenophora	d, H	Yes	+
Platyhelminthes	d, H	C	+
Nemertea	D, h	Yes	+
Nematoda	D, h	C	++
Annel. Polychaeta	D, h	Yes	++
Sipuncula	D, h	Yes	+
Mollusca	D, H	C <sup>4</sup>	++
Arthro. Crustacea	D, H	C	+++
Hexapoda	D, h	C	+++
Phoronida	d, H	Yes <sup>3</sup>	++
Bryozoa	d, H	Yes <sup>3</sup>	+++
Brachiopoda	D, h	Yes <sup>3</sup>	++
Echinod.	D, h	Yes	++
Hemichordata	D	Yes	-
Urochordata	D, h	Yes	++

<sup>1</sup> Sexes: D = dioecious, H = hermaphrodite, lower case = rare.

<sup>2</sup> Brooding: embryo development encapsulated or on adult body.

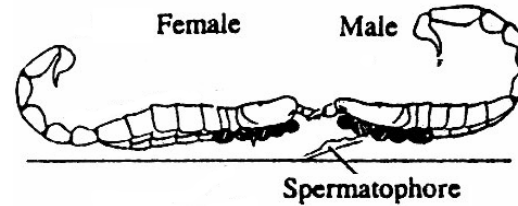
<sup>3</sup> Typically or often only male spawns.

C = copulation (or other direct gamete exchange)

<sup>4</sup> All cephalopods, most gastropods.

## Modes of sexuality

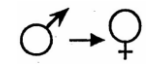
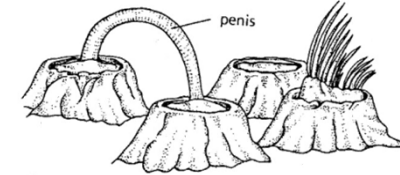
dioecy



hermaphroditism



simultaneous



sequential



## Modes of fertilization

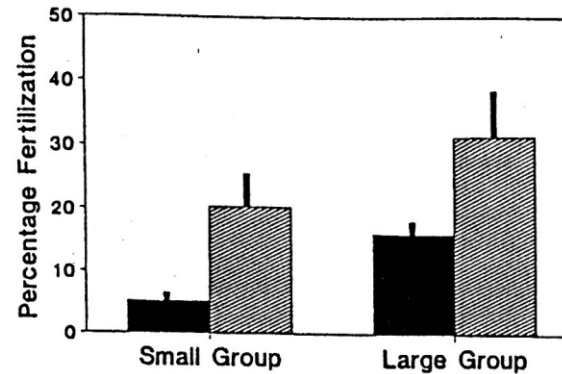
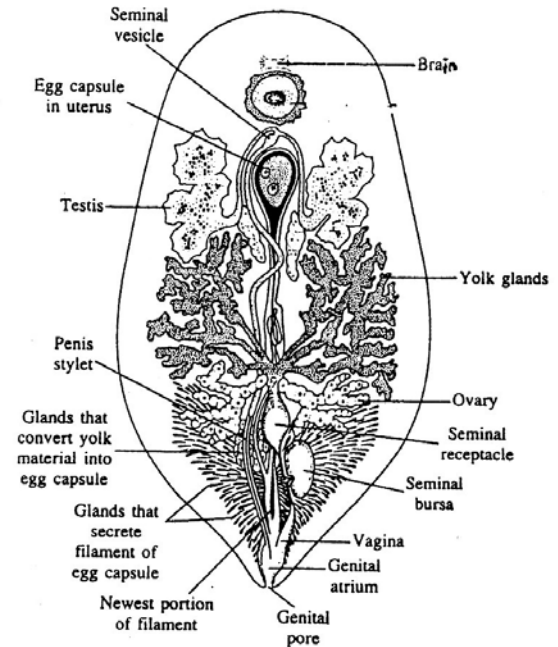


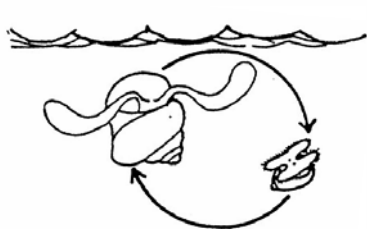
FIG. 4. Percentage of eggs fertilized as a function of spawning-group size and degree of aggregation. Solid bars are dispersed treatments; hatched bars are aggregated treatments.

## Broadcast spawning

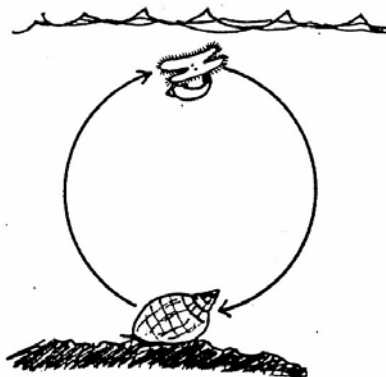
### Insemination



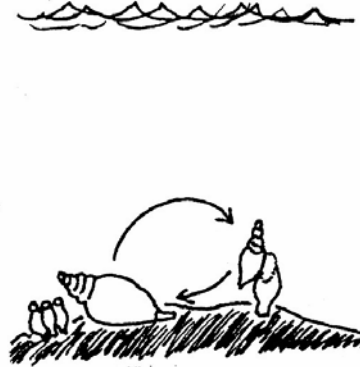
## Modes of habitat use



“holopelagic”



mixed benthic-pelagic



“holobenthic”

# Brooded development

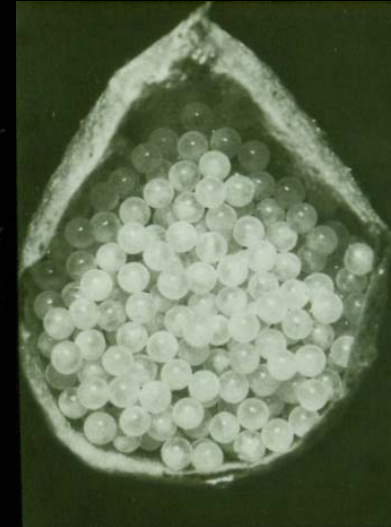


Molluscs

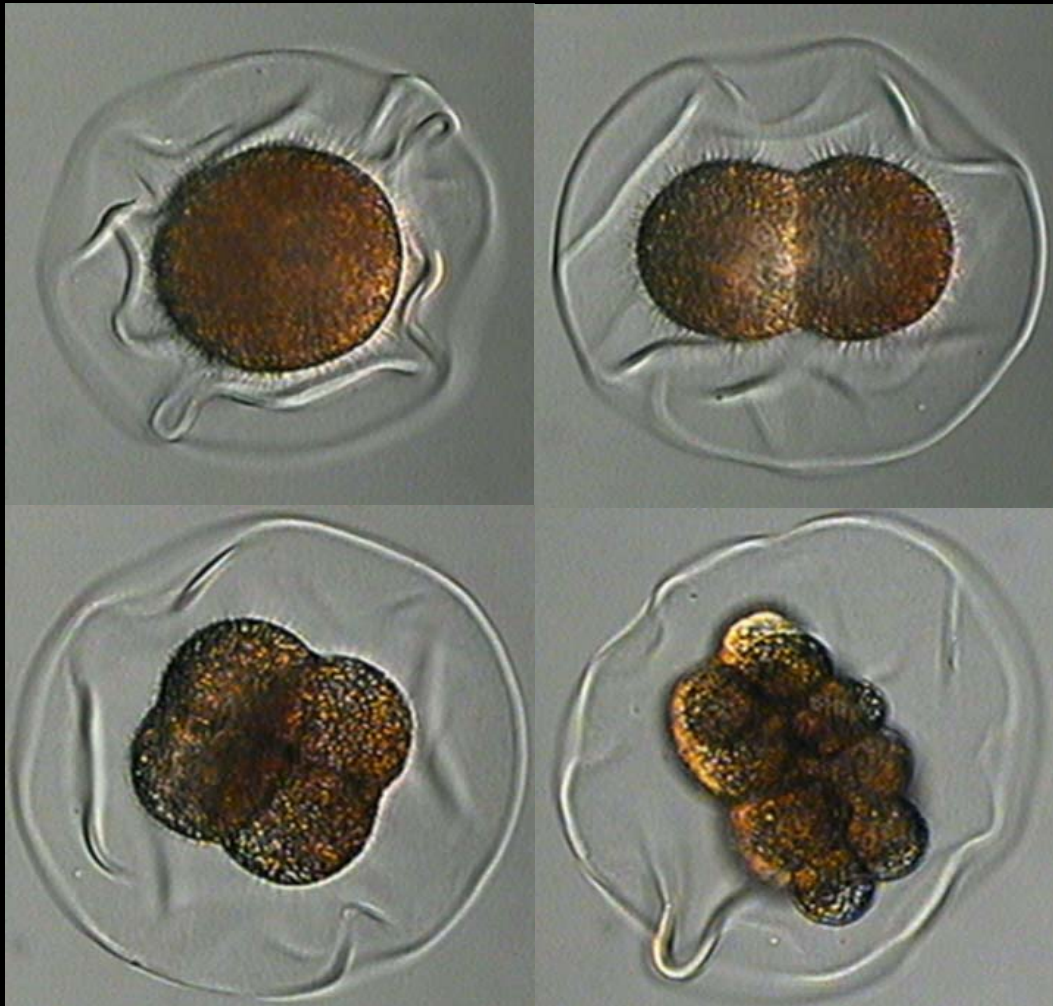
Flatworms



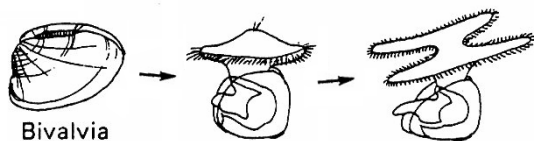
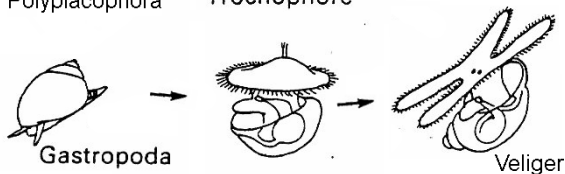
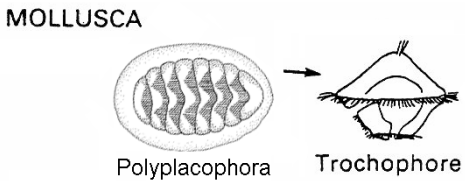
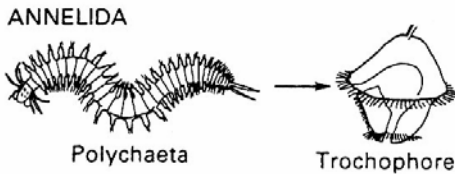
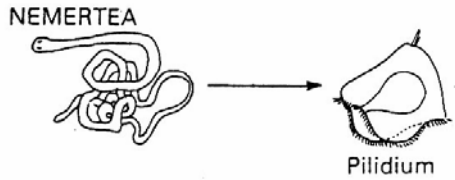
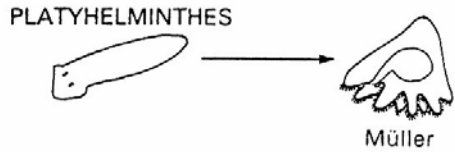
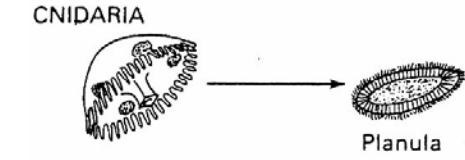
Arthropods



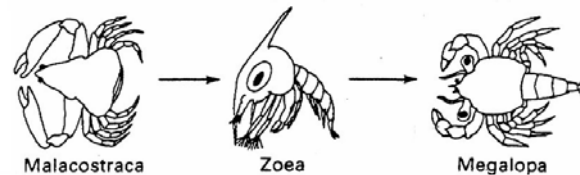
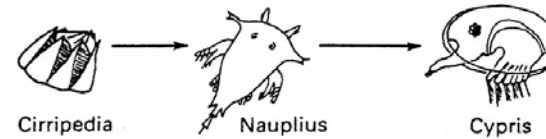
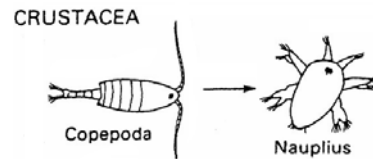
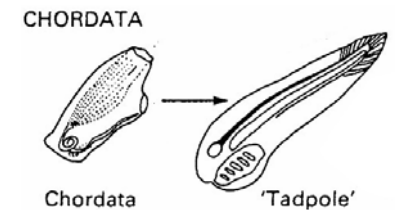
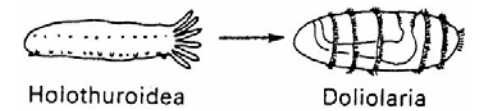
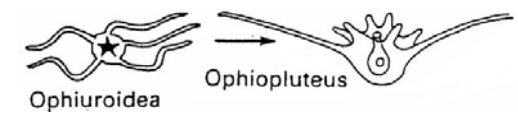
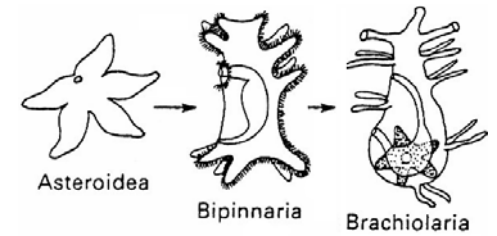
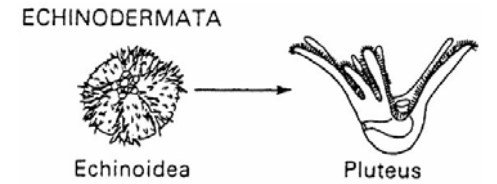
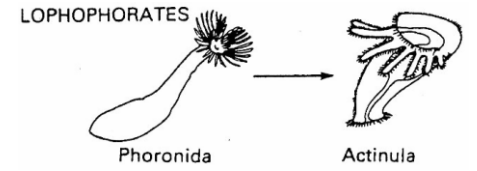
# Early development in...bryozoans



# Presence of metamorphosis and typical larval forms



	Metamorphosis?	Typical larva
Porifera	Yes	amphiblastula
Cnidaria	Yes	planula
Ctenophora	Yes	cydippid
Platyhelminthes	Yes	Müller's, cercariae
Nemertea	Yes	pilidium
Nematoda	No	
Nematomorpha	Yes	gordioid
Acanthocephala	Yes	acanthor
Rotifera	Yes	
Annel. Polychaeta	Yes	<b>trochophore</b>
Sipuncula	Yes	<b>trochophore</b>
Mollusca	Yes	<b>trochophore</b> , veliger
Arthro. Crustacea	Yes	nauplius, zoea
Hexapoda	Yes	caterpillar, grub, maggot
Phoronida	Yes	actinotrocha
Bryozoa	Yes	cyphonautes, coronate
Brachiopoda	Yes	articulate larva
Kamptozoa	Yes	
Echinod. Oph, Ech	Yes	<b>pluteus</b>
Ast, Hol	Yes	bipinnaria, auricularia
Hemichordata	Yes	tornaria
Urochordata	Yes	tadpole
<i>Chaetognatha</i>	No	
<i>Onychophora</i>	No	
<i>Gastrotricha</i>	No	
<i>Kinorhyncha</i>	No	
<i>Loricifera</i>	Yes	<i>Higgins</i>
<i>Tardigrada</i>	No	
<i>Priapulida</i>	Yes	<i>Lorica</i>



# Metamorphosis in three echinoderm classes

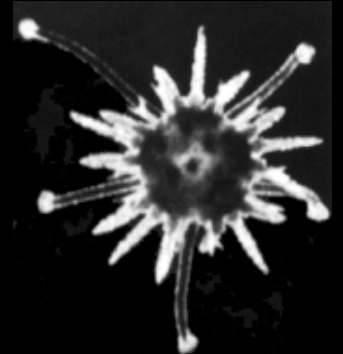
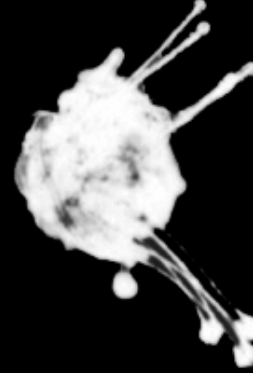
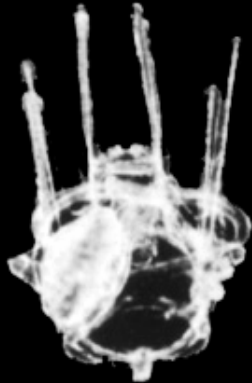
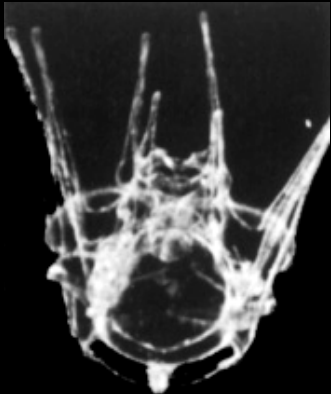
Ophiuroid *pluteus*



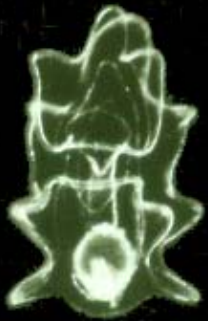
JUVENILE



Echinoid *pluteus*



Asteroid *bipinnaria*

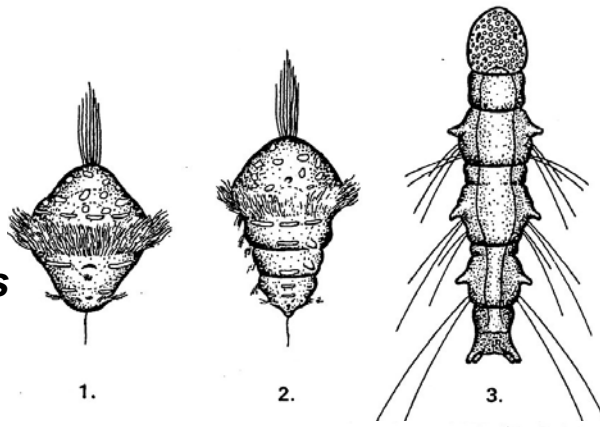


*brachiolaria*

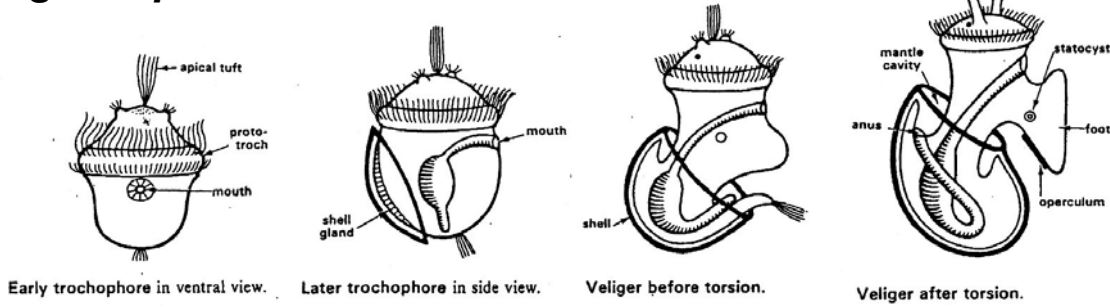


# Some examples of metamorphosis

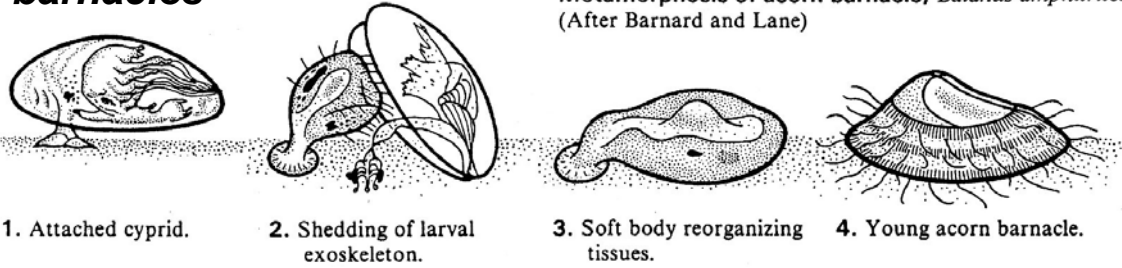
## polychaetes



## gastropods

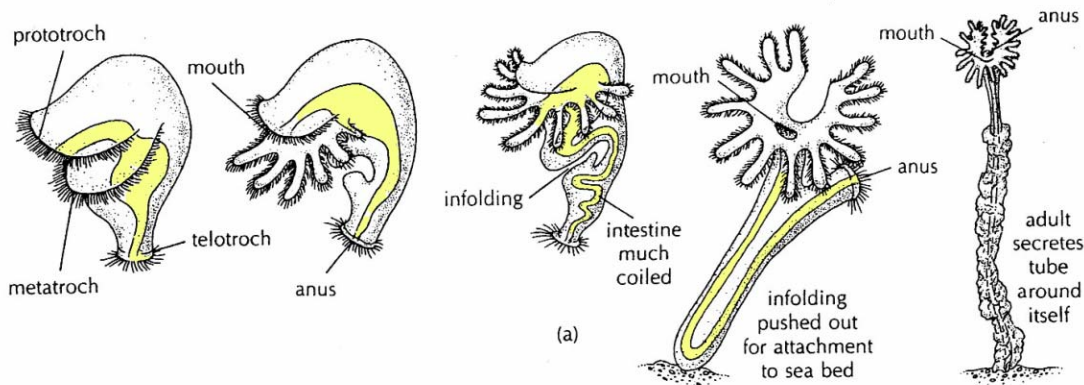


## barnacles

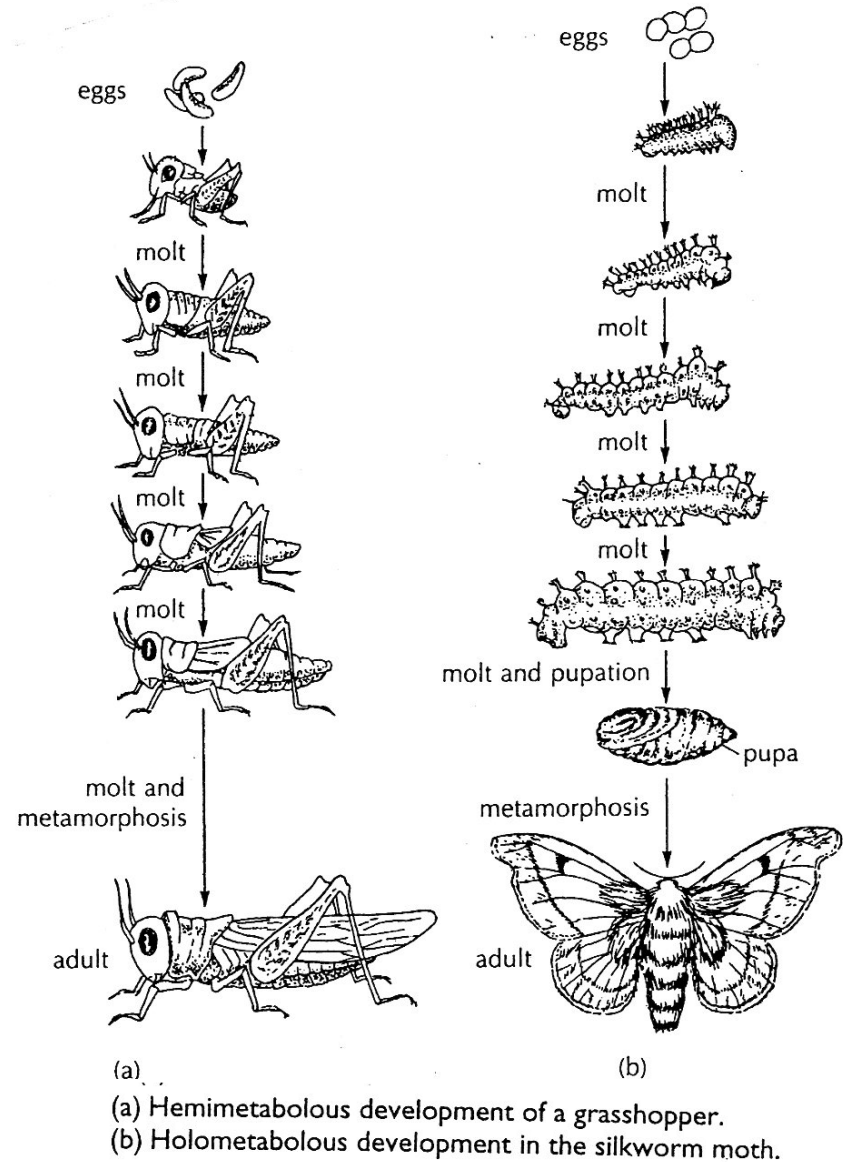


Metamorphosis of acorn barnacle, *Balanus amphitrite*. (After Barnard and Lane)

## phoronids



# Direct and indirect development in terrestrial insects





“actinotroch”



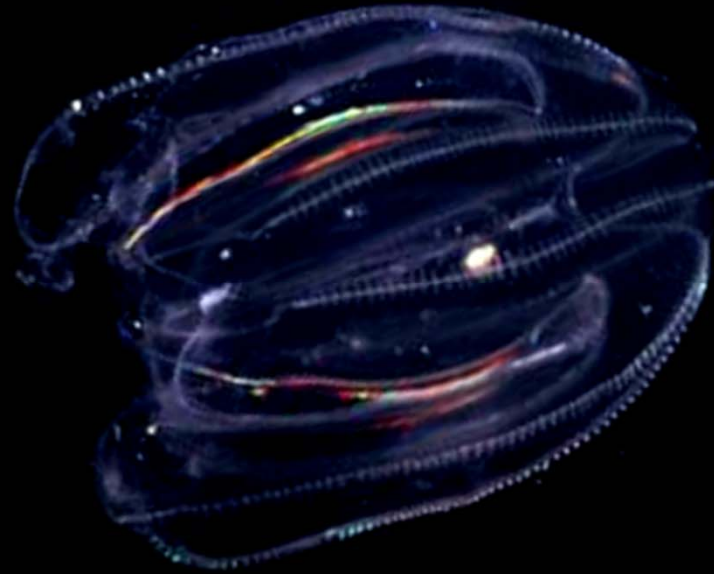
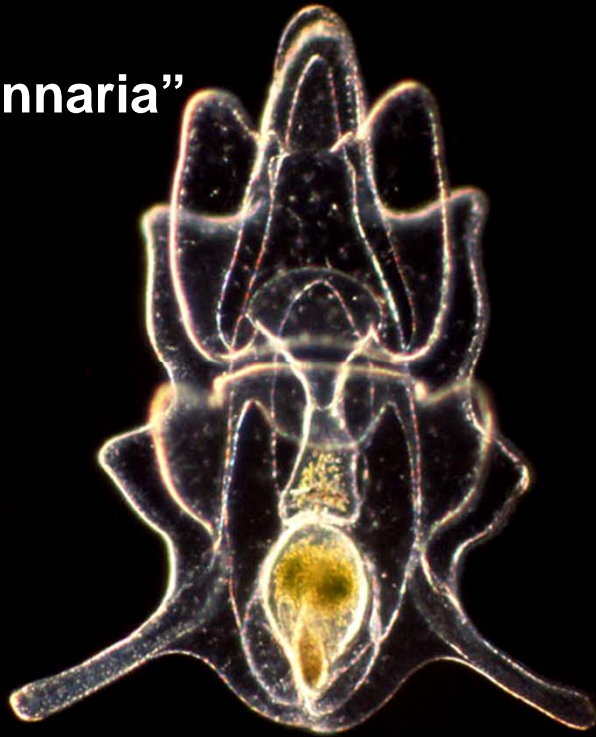
Phoronid

**Who wants to be a larval biologist?**



# Who wants to be a larval biologist?

“bipinnaria”



seastar *Pisaster*

# Who wants to be a larval biologist?

“trochophore”



serpulid polychaete



# Who wants to be a larval biologist?



“veliger”



gastropod



# Who wants to be a larval biologist?

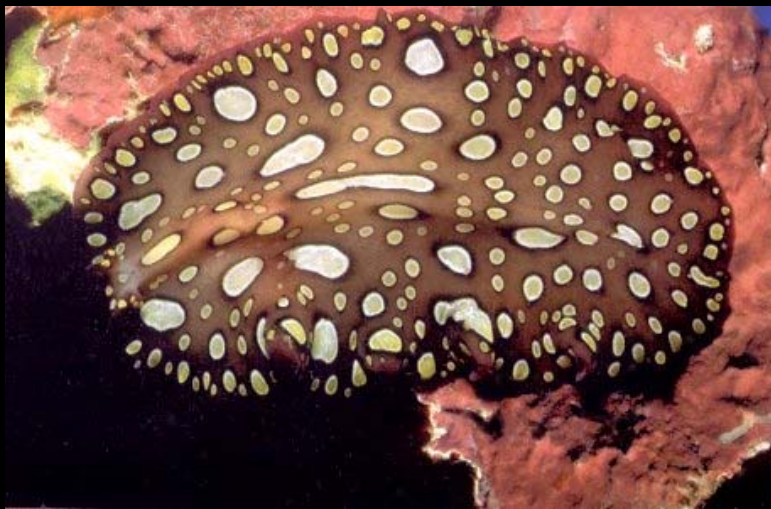
“nauplius”



“cyprid”

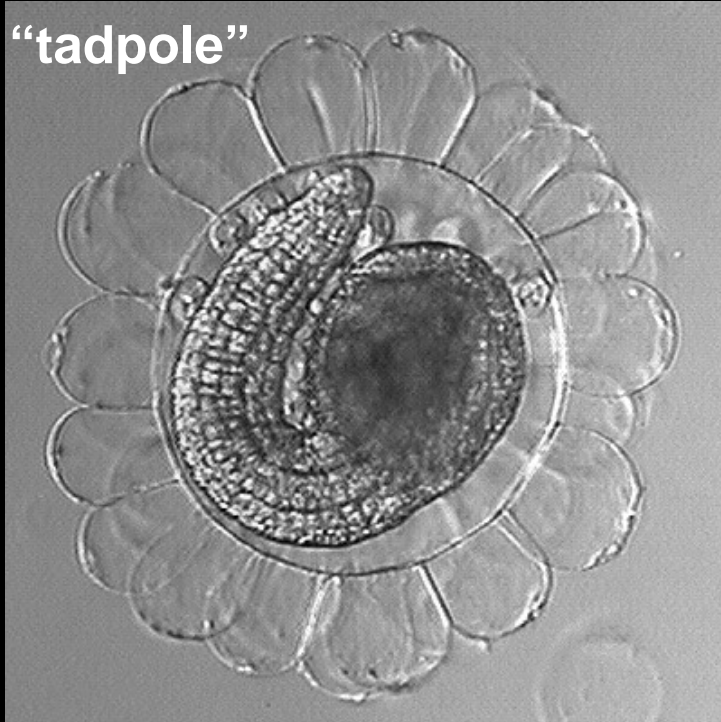


barnacle

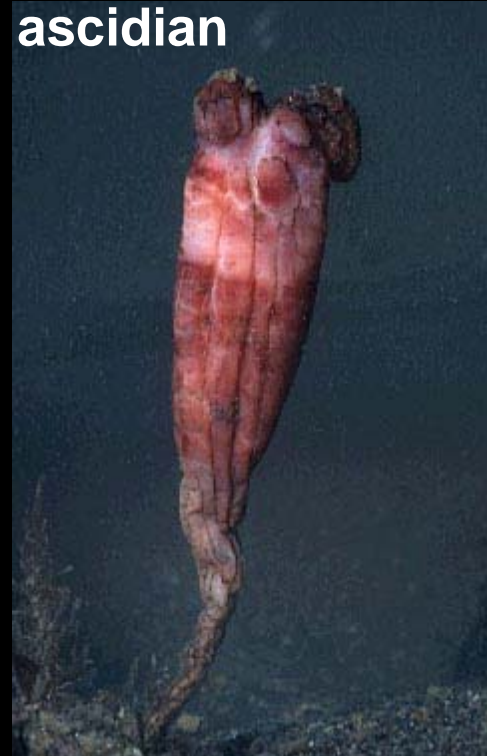


# Who wants to be a larval biologist?

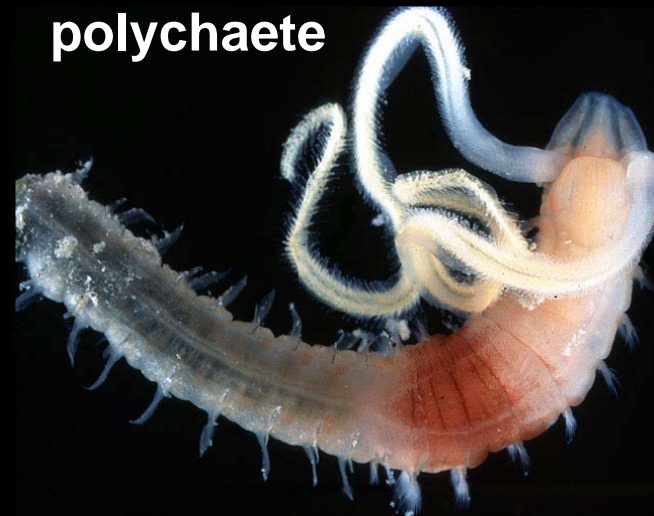
“tadpole”



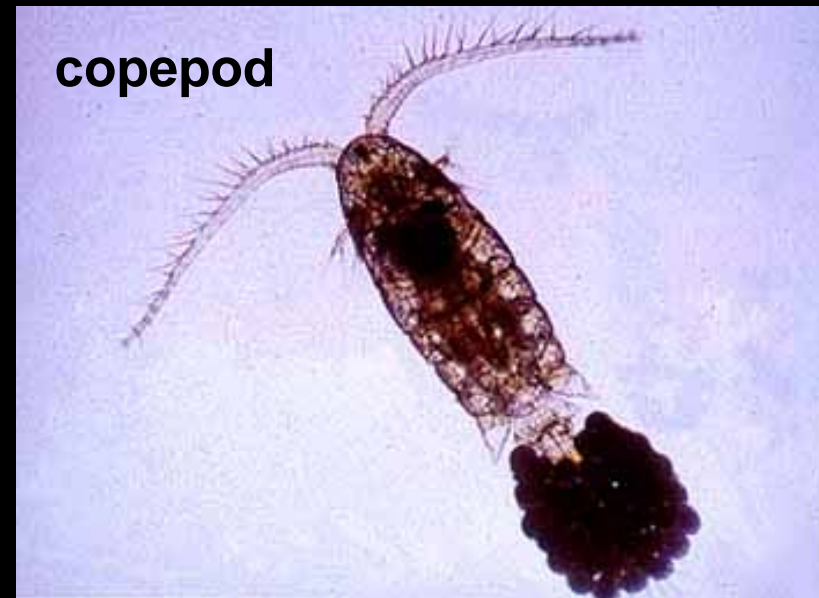
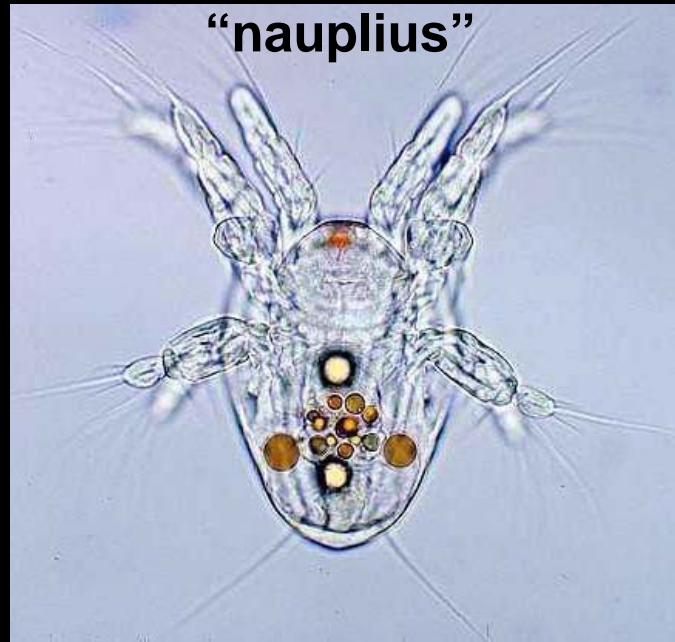
ascidian



# Who wants to be a larval biologist?



# Who wants to be a larval biologist?





# Who wants to be a larval biologist?

“inarticulate  
larva”



brachiopod



# Who wants to be a larval biologist?

“zoea”



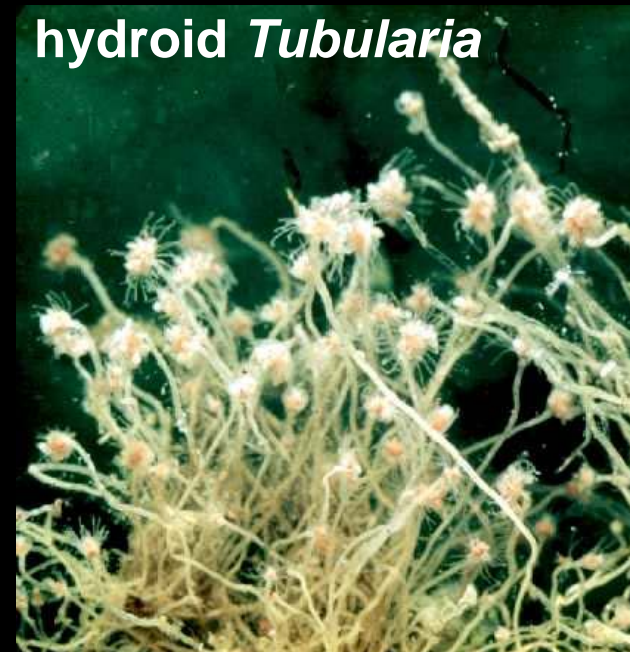
porcelain crab



# Who wants to be a larval biologist?

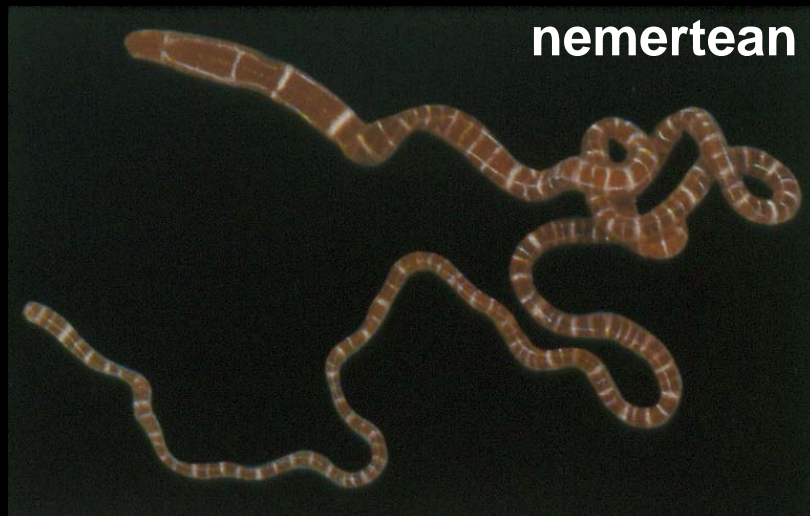


“actinula”



hydroid *Tubularia*

# Who wants to be a larval biologist?



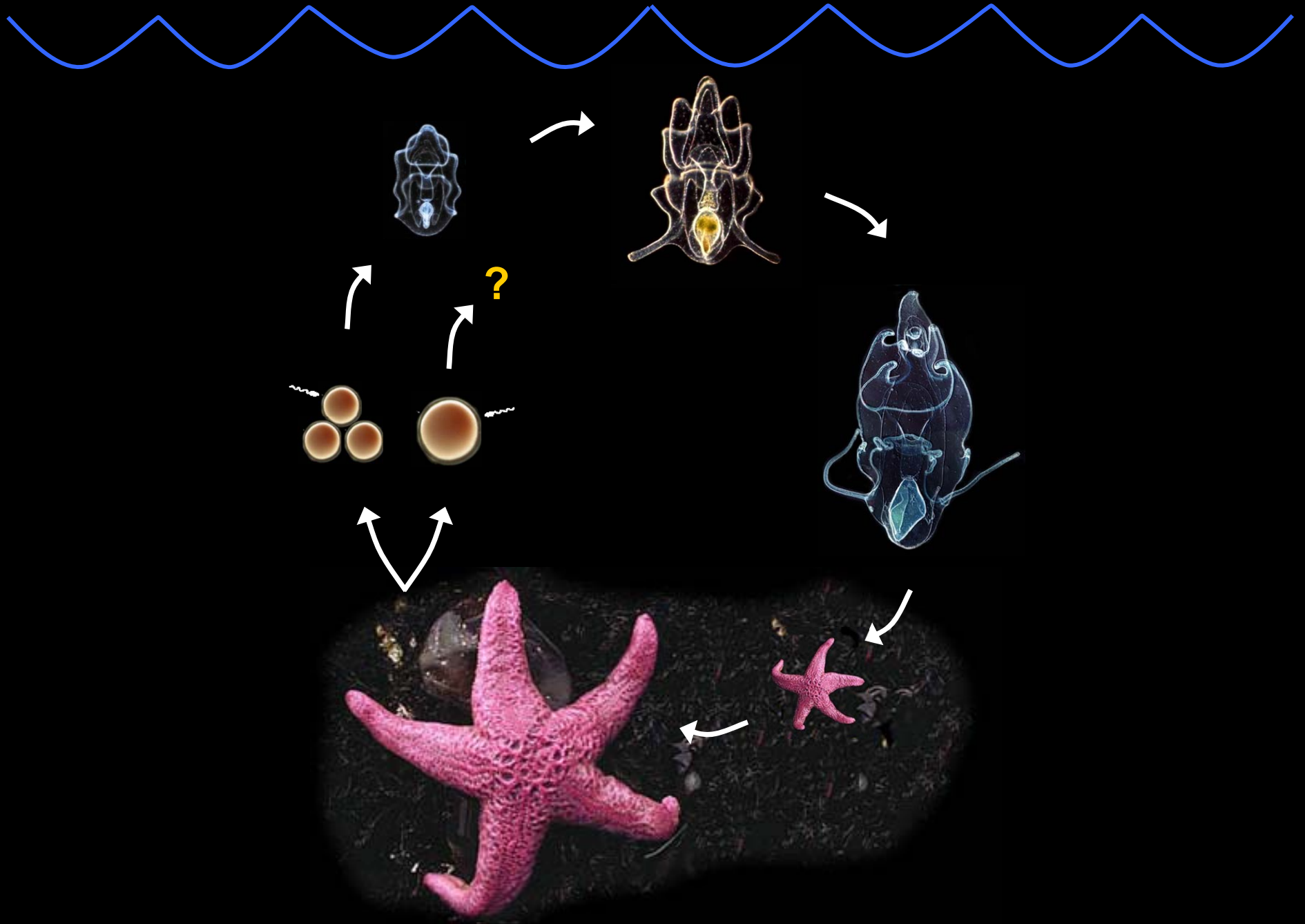
# Who wants to be a larval biologist?

“tornaria”



hemichordate

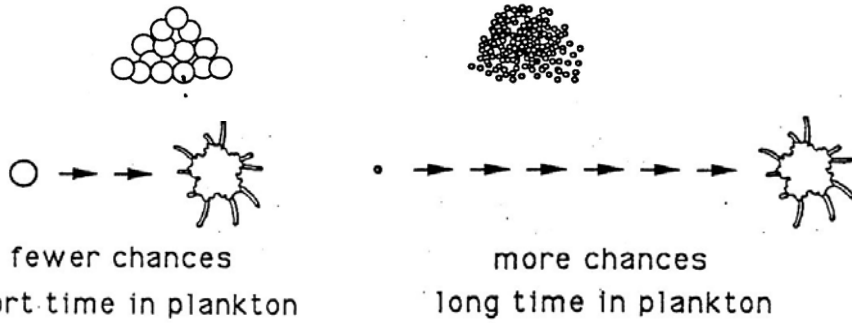
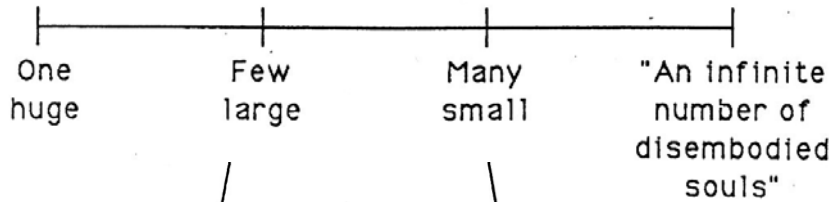
# Animals are life cycles



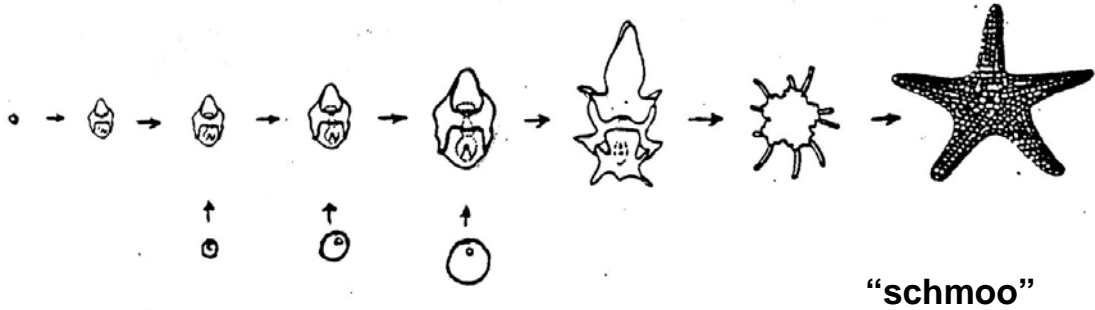
# Life-history evolution of marine invertebrates

## the "time-fecundity model"

**tradeoff:**  
egg size vs.  
egg number

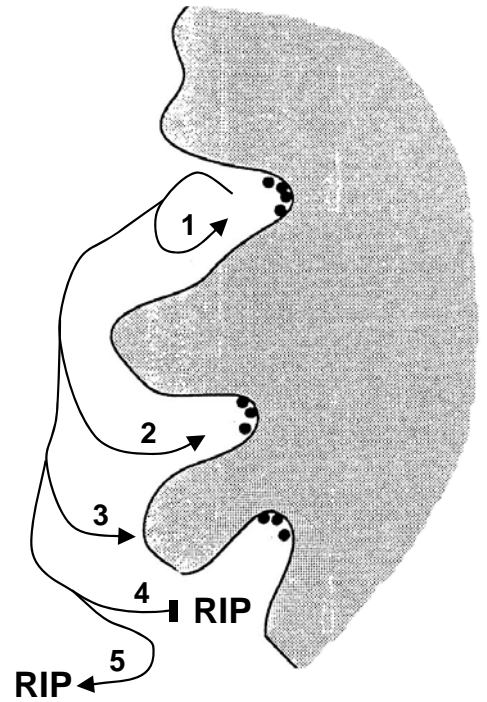


**life-history strategies**

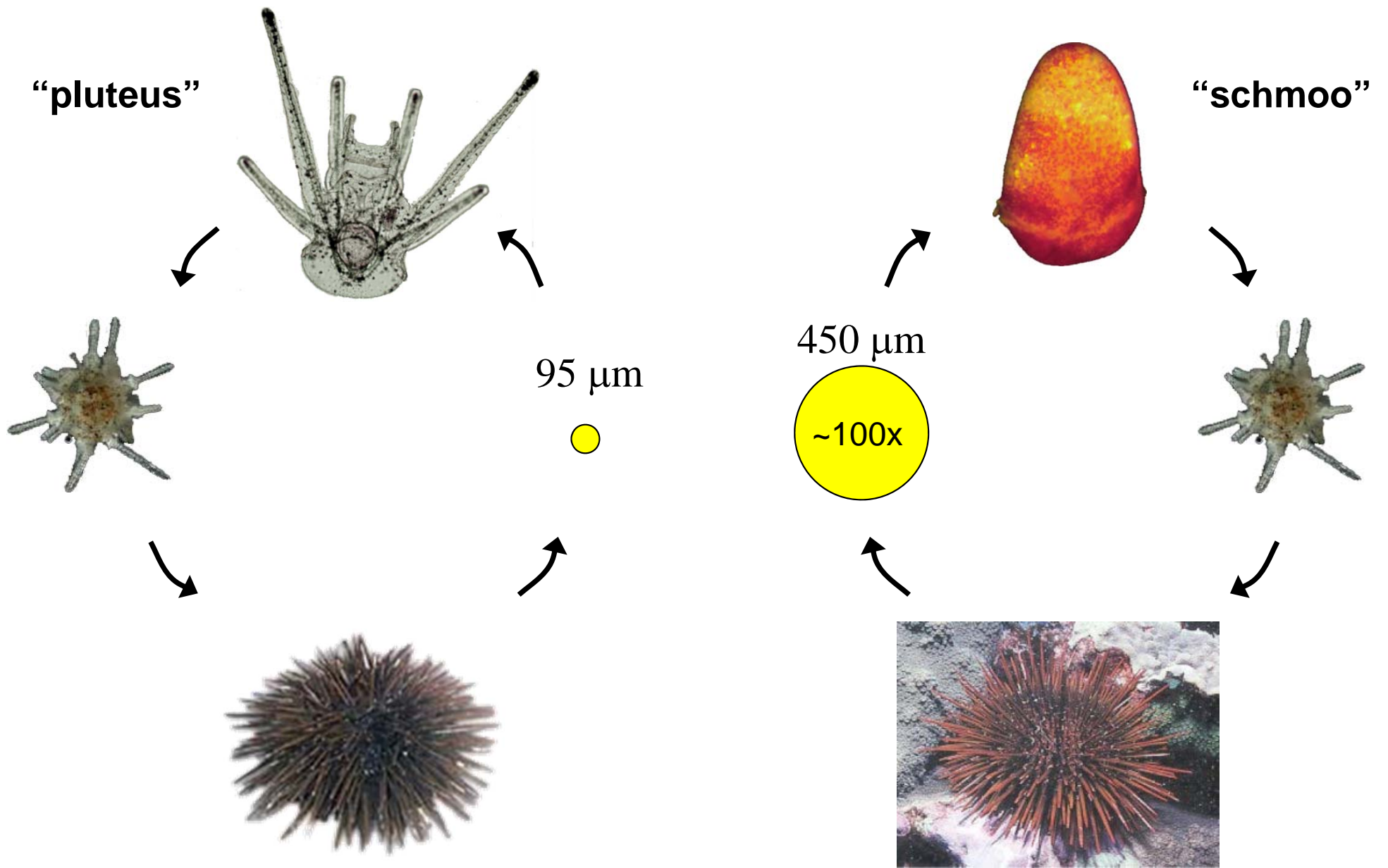


**consequences of investment in different egg sizes**

**Risks of time in the plankton**



- Consequences for egg size evolution of:**
- Food supply?
  - Predation risk?
  - Offshore currents?



*Heliocidaris tuberculata*

*H. erythrogramma*