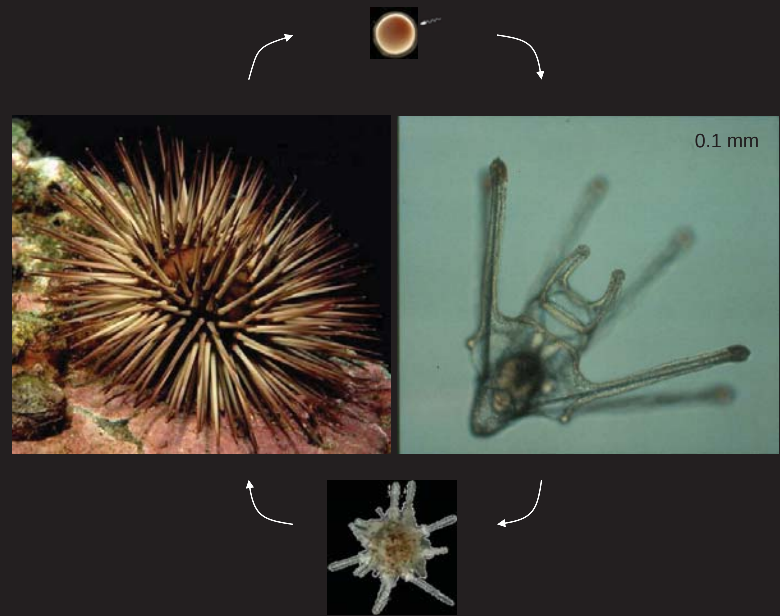
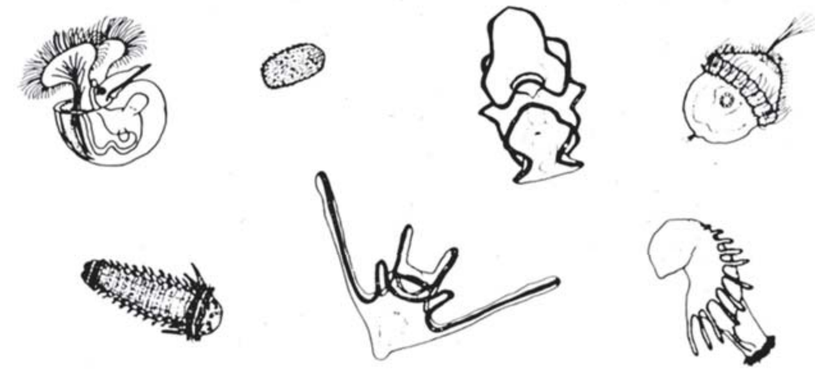
Physical biology: life at small and large scales

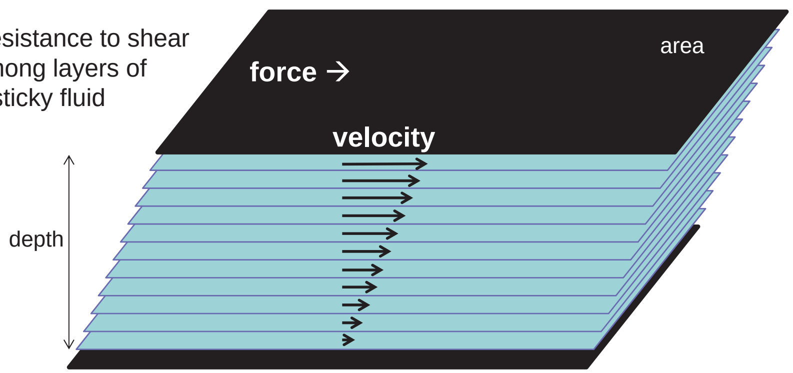


larvae are small and slow



What is viscosity?

Resistance to shear among layers of a sticky fluid



$$\text{viscosity} = \frac{force/area}{velocity/depth}$$

http://www.youtube.com/watch?v=PhsmOc7Hb8Q&NR=1 3:08-6:22
http://www.youtube.com/watch?v=zAcwqYezI7A&NR=1 6:53-8:44

Two forces influence motion of an object through a fluid:

- inertia of the object
- viscosity of the fluid

$$\frac{\text{size} * \text{speed}}{\text{viscosity}} = \text{Reynolds number}$$

A RANGE OF REYNOLDS NUMBERS

	$Re = \frac{\text{inertial}}{\text{viscous}}$
Whale swimming at 10 m/s	100,000,000
Fish swimming at 10 m/s	10,000,000
Duck flying at 20 m/s	100,000
Copepod burst swimming at 0.2m/s	100
Larva swimming at 1 mm/s	0.1
Sperm swimming at 0.2 mm/s	0.01
Bacterium swimming at 0.01 mm/s	0.00001

from Vogel (1994)

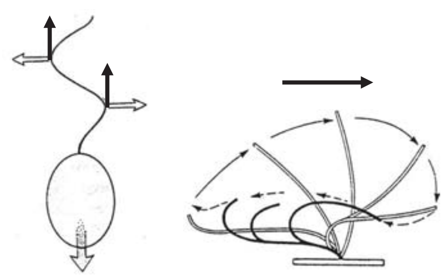
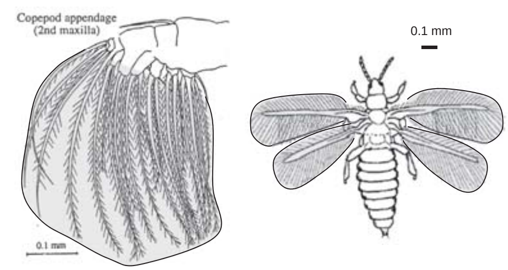


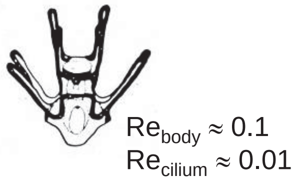
Fig. 10.5 Comparison of the direction of force generated by (a) flagella and (b) cilia.

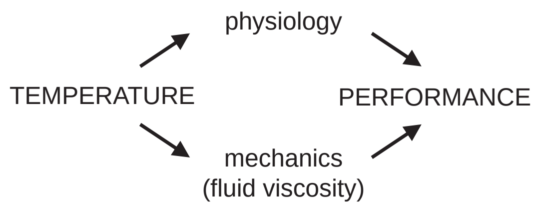


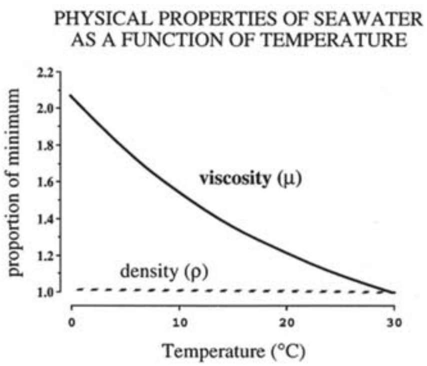
Copepod (2nd maxilla) **Thrips**

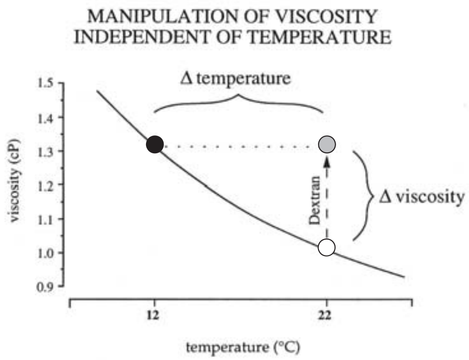
http://www.youtube.com/watch?v=zAcwqYezI7A&NR=1 6:53-8:44

1. How are early life cycle stages influenced by environmental temperature?
(Podolsky and Emlet 1993)

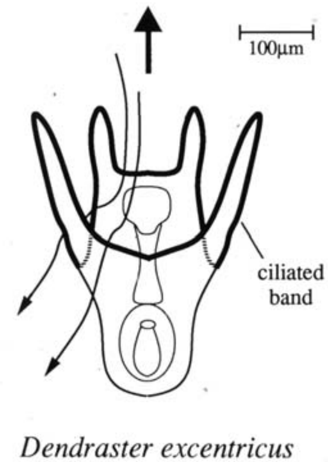


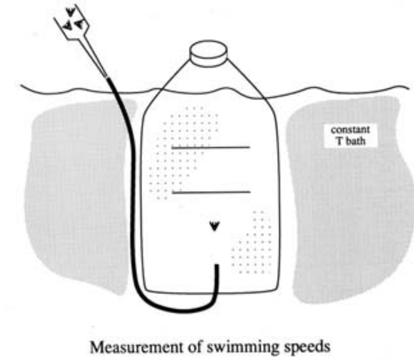


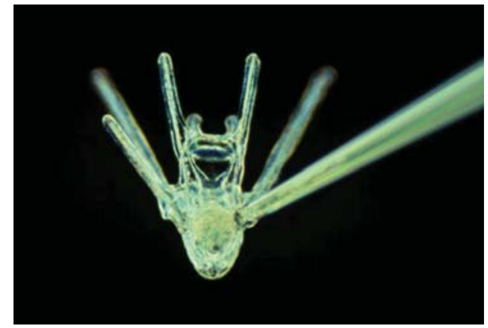




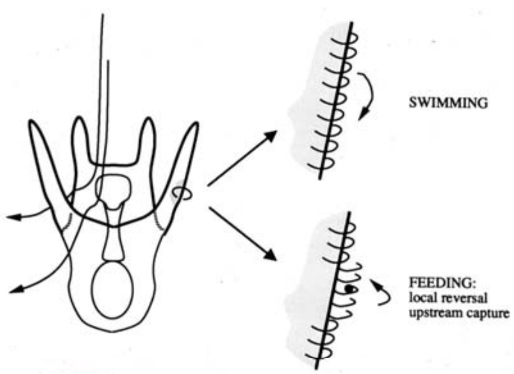
a) Larval swimming & water movement





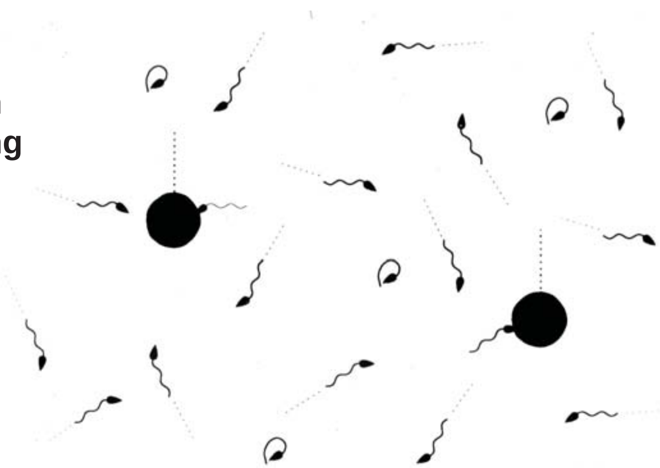


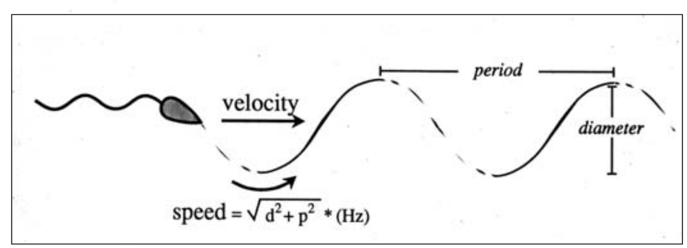
b) Larval feeding

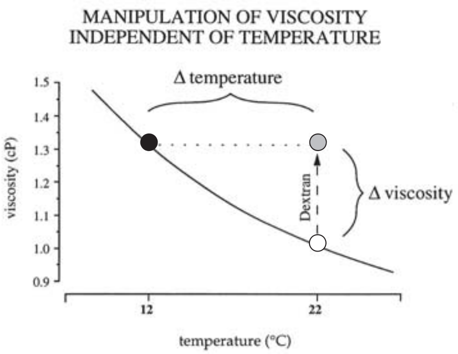


FEEDING EXPERIMENTS
bead sizes (2, 5, 10 μm)
10 min trials

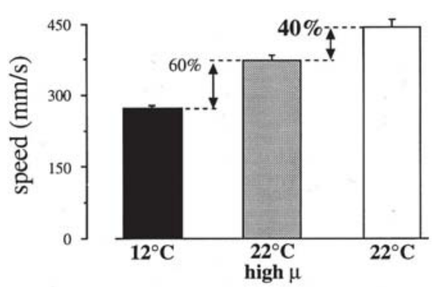
c) Sperm swimming



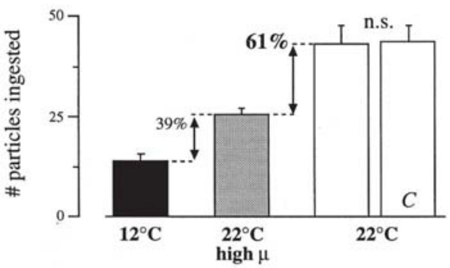




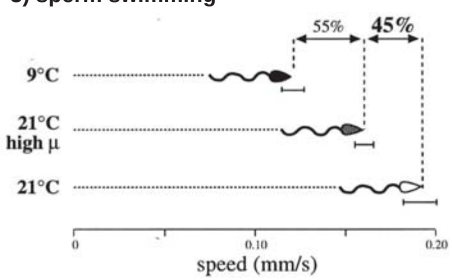
1) larval swimming

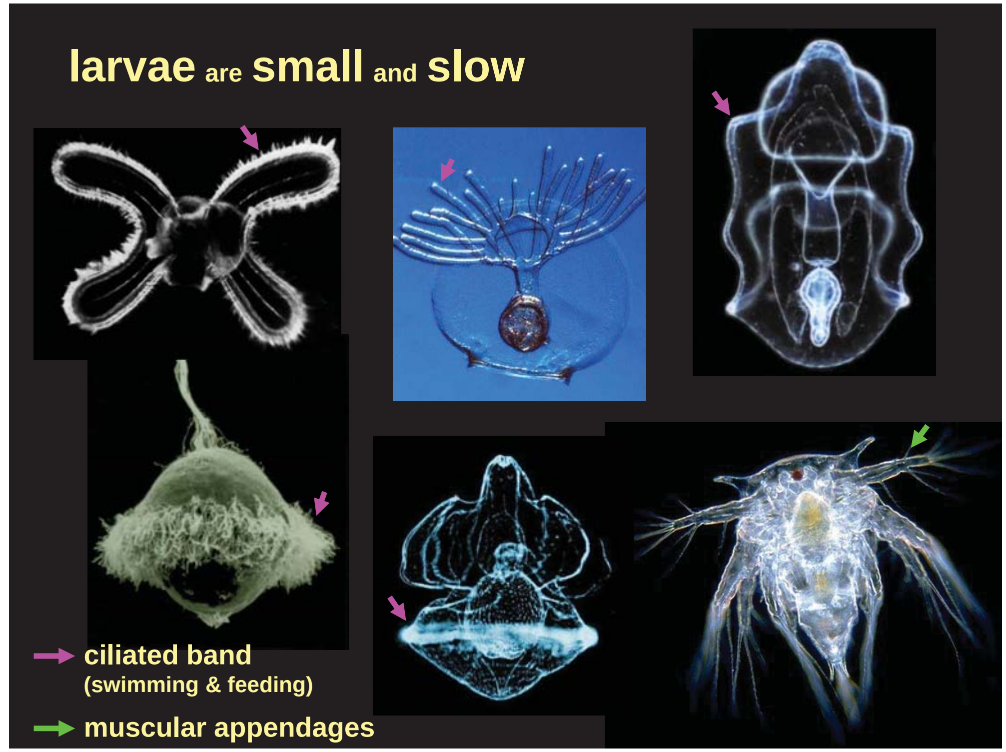


2) larval feeding



3) sperm swimming





most organisms are small and slow

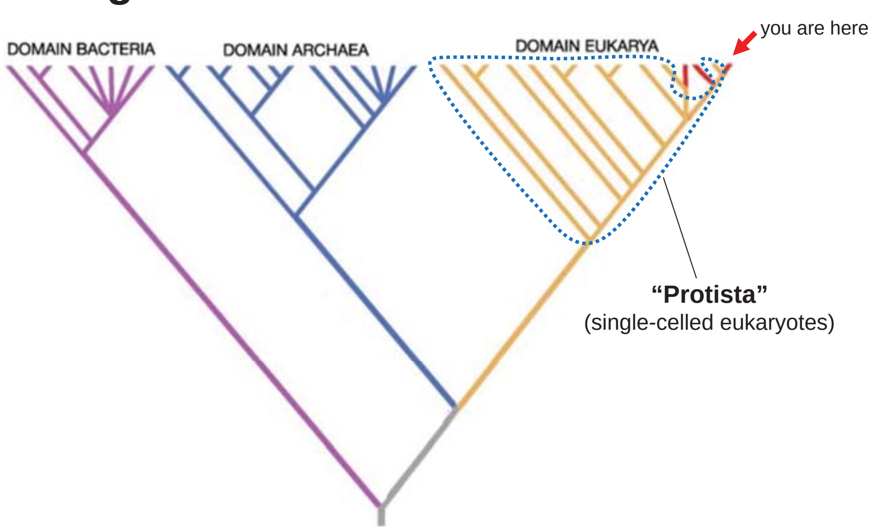
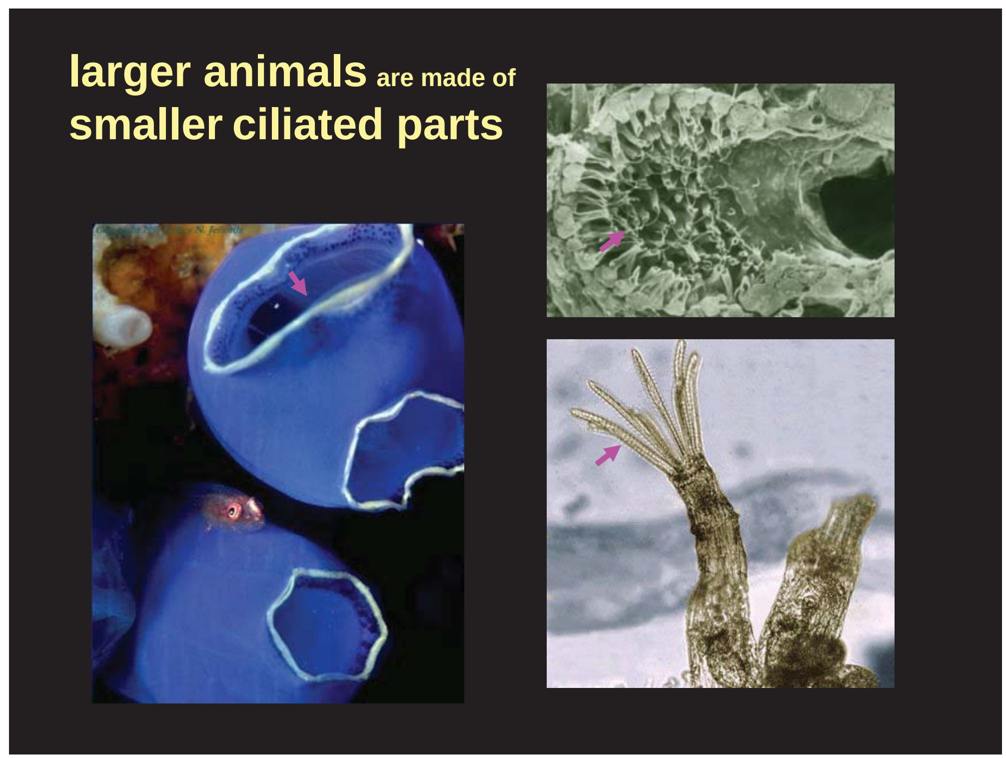


Figure 11.5 An estimate of the phylogeny of all living organisms This tree is based on the analysis of nucleotide sequences of small subunit rRNAs. From Woese (1996).



2. How have hydrodynamic forces selected for variation in the morphology of intertidal sea urchins?

(Denny and Gaylord 1996)

Colobocentrotus
wave-swept intertidal areas

Echinometra
protected intertidal areas

Denny and Gaylord (1996)

Q: What forces do sea urchins experience?

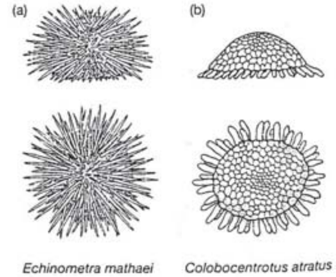


Figure 8.11 Two species of intertidal sea urchin Redrawn from Denny and Gaylord (1996).

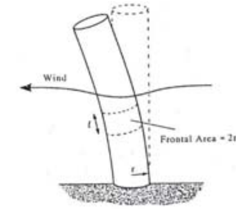


Fig. 4.23 An upright cylinder in flow experiences a drag.

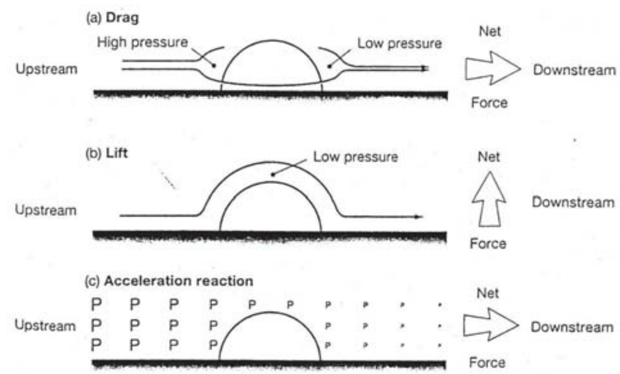
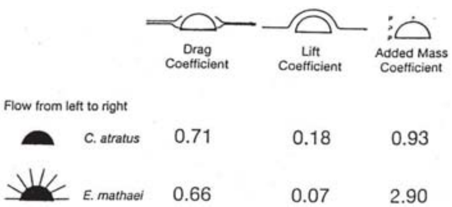


Figure 8.12 Three forces experienced by an urchin clinging to a rock in the intertidal zone (a) Drag. The fine arrows represent the flow of water around the urchin. The large arrow indicates the direction of the net force due to drag. (b) Lift. The fine arrow represents the flow of water over the top of the urchin. The large arrow indicates the direction of the net force due to lift. (c) The acceleration reaction. The P's represent the pressure in water that is accelerating over the urchin from upstream to downstream. Bigger P's indicate higher pressure. The large arrow indicates the direction of the net force due to the acceleration reaction. See text for details.

Figure 8.13 Estimates of the forces experienced by sea urchins of different shapes The drag and lift coefficients reported here characterize the drag and lift experienced by urchins at a water velocity typical of the intertidal (Reynolds number = 10^5; see Denny and Gaylord 1996). The added mass coefficients characterize the acceleration reaction experienced by urchins. Based on the data and equations in Denny and Gaylord (1996).

Denny and Gaylord (1996)

Q: What is the probability of dislodgment?



Flow from left to right	Drag Coefficient	Lift Coefficient	Added Mass Coefficient
C. atratus	0.71	0.18	0.93
E. mathaei	0.66	0.07	2.90

Fig. 4.24 When the size of an object is increased isometrically, the ratio of frontal to attachment area is constant. As a result, the ratio of drag to strength is constant. In contrast, volume increases faster than attachment area, and the ratio of accelerational force to strength increases.