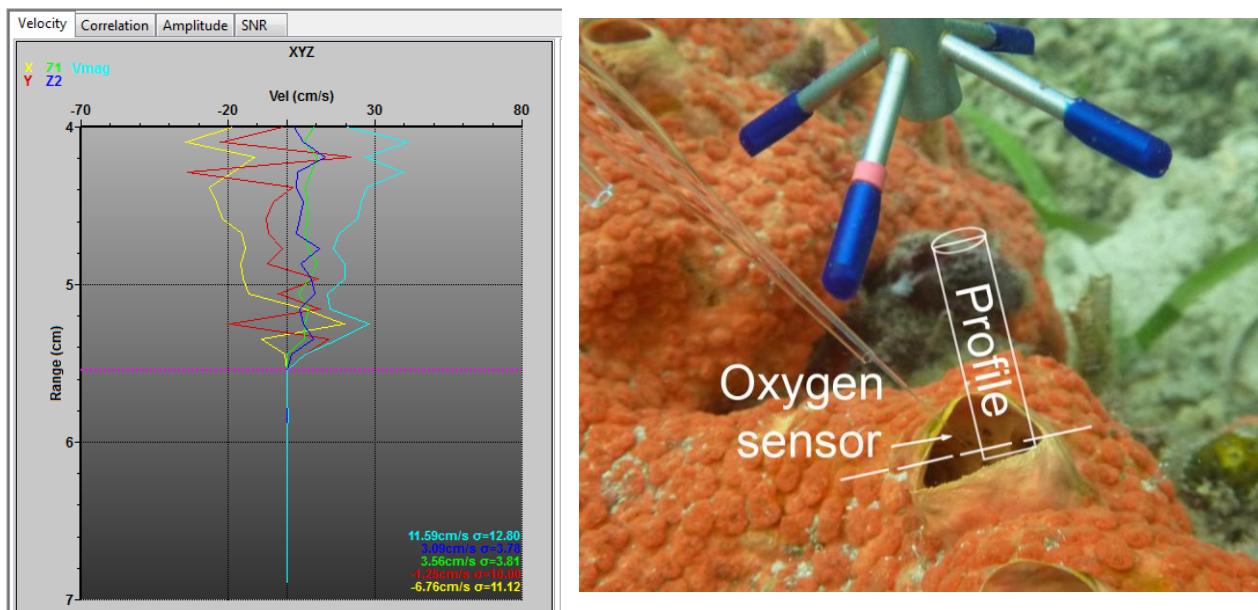


Fig. S1. Feeding filters in four groups of invertebrates used to re-estimate the cost of filtration

(A,B) Scanning electron micrograph (SEM) of the collar of *Spongilla lacustris*, showing the glycocalyx mesh fibrils (arrows) linking adjacent microvilli (Mah et al., 2014) (C) Gill filament of *Mytilus edulis* showing the latero-frontal cirri. (Jones et al., 1992) (D-F) Transmission electron micrographs of the mucus nets in *Chaetopterus variopedatus* (Flood and Fiala-Medioni, 1982) (D), *Ciona intestinalis* (Flood and Fiala-Medioni, 1981) (E), and *Styella plicata* (Flood and Fiala-Medioni, 1981) (F) Scale bars (A, D-F) 1 μ m (B) 300 nm (C) 100 μ m.

Fig. S2. Method of measuring excurrent velocity with the Vectrino Profiler

A) Screen shot (left) of the profiler recording of flow from *Cliona delitrix*. The pink line shows the position of the osculum, just below the osculum lip. The vectors of velocity are: x=yellow, y=red, green and dark blue = two z vectors and pale blue = Vmag (~ scalar). Photo (right) showing the position of the Vectrino Profiler over the osculum of *Cliona delitrix* and the profile. The dashed line shows the position equivalent to the pink line on the figure of the Vectrino record left.



B) Frame grab from a video showing excurrent flow from *Cliona delitrix* (left) and *Callyspongia vaginalis* (right) visualized with fluorescein dye.

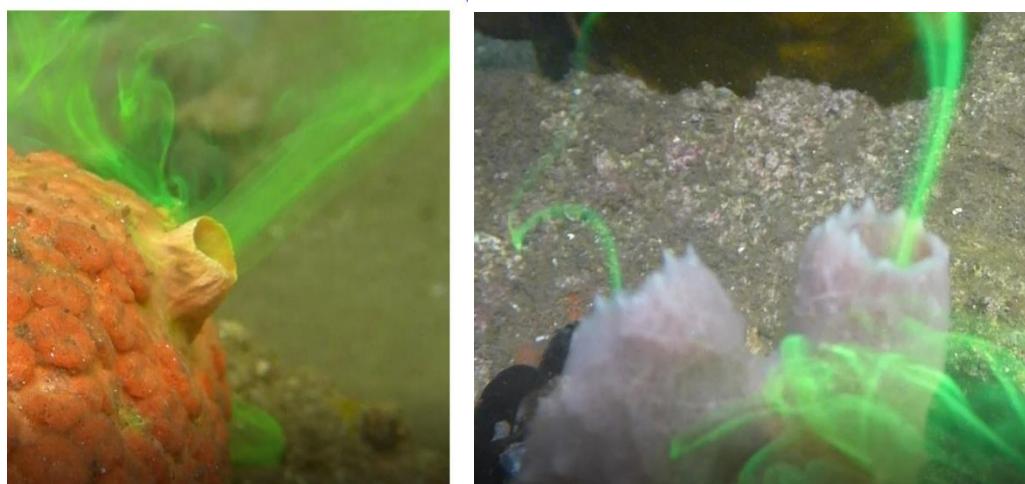


Table S1 - Measuring excurrent velocity

- For the cost of pumping we used mean Z (vertical direction only) velocity, measured just at the top of the osculum
- Scalar velocities measured at that same spot varied greatly depending on the ambient flow and the maximum z velocity of each sponge
- For parabolic flow estimate of the 'average' excurrent velocity would use $0.5 \times$ scalar velocity (shown in column D below). To see the effect on cost that number can be inserted in Cell B16 in each of the Species tabs. Using $0.5 \times$ scalar velocity reduces the volume pumped for *Cliona* and increases it for *Callyspongia* and *Haliclona*
- We considered that for *Cliona*, for example, the z velocity was the major component of scalar velocity, and therefore it would be a gross underestimate of excurrent velocity to estimate parabolic flow and use $0.5 \times$ scalar. In contrast, for *Callyspongia*, the z velocity was lower and the osculum diameter larger, so upon exiting the osculum the ambient flow probably bent the excurrent plume such that scalar velocity grossly overestimated excurrent velocity. (See supplementary videos files of excurrent flow visualized with fluorescein dye.)
- Since we also do not consider the sides of the oscula for all sponges to experience a 'no slip' condition (because water enters the oscula from many canals) there is no other equation to describe the flow across the 'pipe'. Therefore we used the mean Z velocity at Max Z profile to estimate average oscula excurrent velocity

	Effective oscula velocity			Cost of pumping, η (%)	
	mean Z	mean scalar	0.5 *scalar	Using mean scalar velocity	
	at max z profile (cm/s)		(cm/s)	Riisgård and Larsen 1993	Leys et al 2011
<i>Cliona delitrix</i>	11	12.7	6.35	8.71	6.81
<i>Callyspongia vaginalis</i>	5.9	18.9	9.45	5.66	8.6
<i>Tethya californiana</i>	2.2	3.5	1.75	0.64	0.6
<i>Haliclona permollis</i>	3	15.3	7.65	4.84	2.59
<i>Neopetrosia problematica</i>	1.3	4	2	5.37	5.78

Table S1 - References

- Fiala-Medioni, A.** (1978). Filter-feeding ethology of benthic invertebrates (Ascidians). IV. Pumping rate, filtration rate, filtration efficiency. *Marine Biology* **48**, 243-249.
- Flood, P. R. and Fiala-Medioni, A.** (1981). Ultrastructure and histochemistry of the food trapping mucous film in benthic filter-feeders (Ascidians). *Acta Zoologica* **62**, 53-65.
- Flood, P. R. and Fiala-Medioni, A.** (1982). Structure of the mucous feeding filter of *Chaetopterus variopedatus*. *Marine Biology* **72**, 27-33.
- Grove, M. W., Finelli, C. M., Wethey, D. S. and Woodin, S. A.** (2000). The effects of symbiotic crabs on the pumping activity and growth rates of *Chaetopterus variopedatus*. *Journal of Experimental Marine Biology and Ecology* **246**, 31-52.
- Jones, H. D., Richards, O. G. and Southern, T. A.** (1992). Gill dimensions, water pumping rate and body size in the mussel *Mytilus edulis* L. *Journal of Experimental Marine Biology and Ecology* **155**, 213-237.
- Jørgensen, C. B., Famme, O., Kristensen, H. S., Larsen, P. S., Møhlenberg, F. and Riisgård, H. U.** (1986). The bivalve pump. *Marine Ecology Progress Series* **34**, 69-77.
- Jørgensen, C. B., Larsen, P. S., Møhlenberg, F. and Riisgård, H. U.** (1988). The mussel pump: properties and modelling. *Marine Ecology Progress Series* **45**, 205-218.
- Mah, J. L., Christensen-Dalsgaard, K. K. and Leys, S. P.** (2014). Choanoflagellate and choanocyte collar-flagellar systems and the assumption of homology. *Evolution & Development* **16**, 25-37.
- Riisgård, H. U.** (1989). Properties and energy cost of the muscular piston pump in the suspension feeding polychate *Chaetopterus variopedatus*. *Marine Ecology Progress Series* **56**, 157-168.
- Riisgård, H. U., Thomassen, S., Jakobsen, H., Weeks, J. M. and Larsen, P. S.** (1993). Suspension feeding in marine sponges *Halichondria panicea* and *Haliclona urceolus*: effects of temperature on filtration rate and energy cost of pumping. *Marine Ecology Progress Series* **96**, 177-188.
- Reiswig, H. M.** (1975a). The aquiferous systems of three marine Demospongiae. *Journal of Morphology* **145**, 493-502.

Table S2 - Estimated cost of pumping (%) for four different groups of filter feeders

The cost of pumping (% of metabolism) is based on the morphometric model summarized by Riisgård and Larsen (1995) and outlined in Equations S2-S2 in Box 1, where d = diameter of the cylindrical fiber, b = space between cylinders, h_1 = width of the mesh; h_2 = length of the mesh; and L = length of inter-filament canals. Cost was estimated using new measurements from the literature for filter dimensions and volume flow rates (blue). In the absence of volume flow rates for *Spongilla lacustris*, estimates for *Haliclona permollis* were used instead. Original estimates for the cost of pumping are in black and the new estimates are shown in red.

Species	Filter dimensions (μm)	Filter Dimension Reference	Volume Flow rate (mL min^{-1})	Volume Flow rate Reference	Estimate of the cost of pumping (%)
Sponges					
<i>Haliclona urceolus</i>	$d=0.14, b=0.25$	Riisgard et al (1993)	6	Riisgard et al (1993)	0.850
	$d=0.14, b=0.25$	Riisgard et al (1993)	6	Riisgard et al (1993)	1.021 *
<i>Haliclona permollis</i>	$d=0.14, b=0.25$	Riisgard et al (1993)	18.84	Reiswig (1975)	3.206
<i>Spongilla lacustris</i>	$h_1=0.048, h_2=0.04, d=0.04$	Mah et al (2014)	6	Riisgard et al (1993)	1.594
	$h_1=0.048, h_2=0.041, d=0.04$	Mah et al (2014)	18.84	Reiswig (1975)	5.004
Bivalves					
<i>Mytilus edulis</i>	$L=200, l=40$	Jorgensen et al 1986a, 1988	60	Jorgensen et al 1986a, 1988	1.562
	$L=200, l=40$	Jorgensen et al 1986a, 1988	67.8	Riisgard et al 2011	1.765
	$L=200, l=16$	Jones et al (1992)	60	Jorgensen et al 1986a, 1988	4.131
	$L=200, l=16$	Jones et al (1992)	67.8	Riisgard et al 2011	4.668
Polychaetes					
<i>Chaetopterus variopedatus</i>	$h_1=2.3, h_2=1.4, d=0.02$	Riisgard (1989)	18	Riisgard (1989)	4.032
	$h_1=2.3, h_2=1.4, d=0.02$	Riisgard (1989)	30	Grove et al (2000)	6.719
	$h_1=0.76 h_2=0.46, d=0.02$	Flood and Fiala-Medioni (1982)	18	Riisgard (1989)	10.903
	$h_1=0.76 h_2=0.46, d=0.02$	Flood and Fiala-Medioni (1982)	30	Grove et al (2000)	18.172
Ascidians					
<i>Styella clava</i>	$h_1=0.35, h_2=1.35, d=0.020$	Riisgard and Larsen (1995)	45.6	Riisgard and Larsen (1995)	0.191
	$h_1=0.35, h_2=1.35, d=0.020$	Riisgard and Larsen (1995)	45.6	Riisgard and Larsen (1995)	0.724 **
Mean of three species	$h_1=0.35, h_2=1.35, d=0.020$	Riisgard and Larsen (1995)	57.5	Fiali-Medioni (1978)	0.913
Mean of six species	$h_1=1.002, h_2=0.366, d = 0.025$	Flood and Fiala Medioni (1981)	45.6	Riisgard and Larsen (1995)	0.815
<i>Styella plicata</i>	$h_1=1.959, h_2=0.5055, d=0.020$	Flood and Fiala Medioni (1981)	83.1	Fiali-Medioni (1978)	0.885
<i>Ciona intestinalis</i>	$h_1=0.640, h_2=0.405, d=0.020$	Flood and Fiala Medioni (1981)	21.5	Fiali-Medioni (1978)	0.376

* Cost of pumping re-estimated to use consistent temperatures for kinematic viscosity

** Cost of pumping re-estimated using corrected head loss at the filter

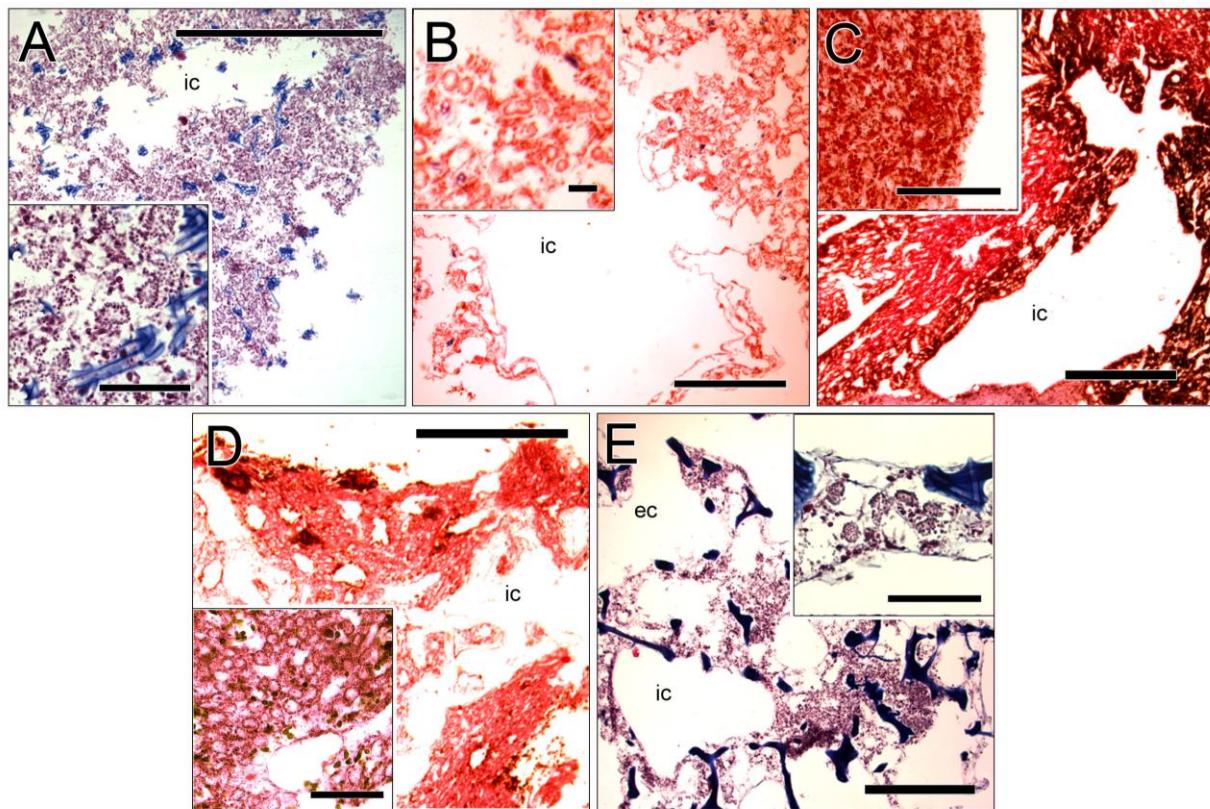


Fig. S3. Histological sections in five species of demosponges| Histological sections in five species of demosponges. Incurrent (ic) and excurrent (ec) canals in (A) *Neopetrosia problematica* (B) *Haliclona mollis* (C) *Tethya californiana* (D) *Cliona delitrix* (E) and *Callyspongia vaginalis*. Insets show choanocyte chambers. Scale bars: 1 mm; insets: 100 μm