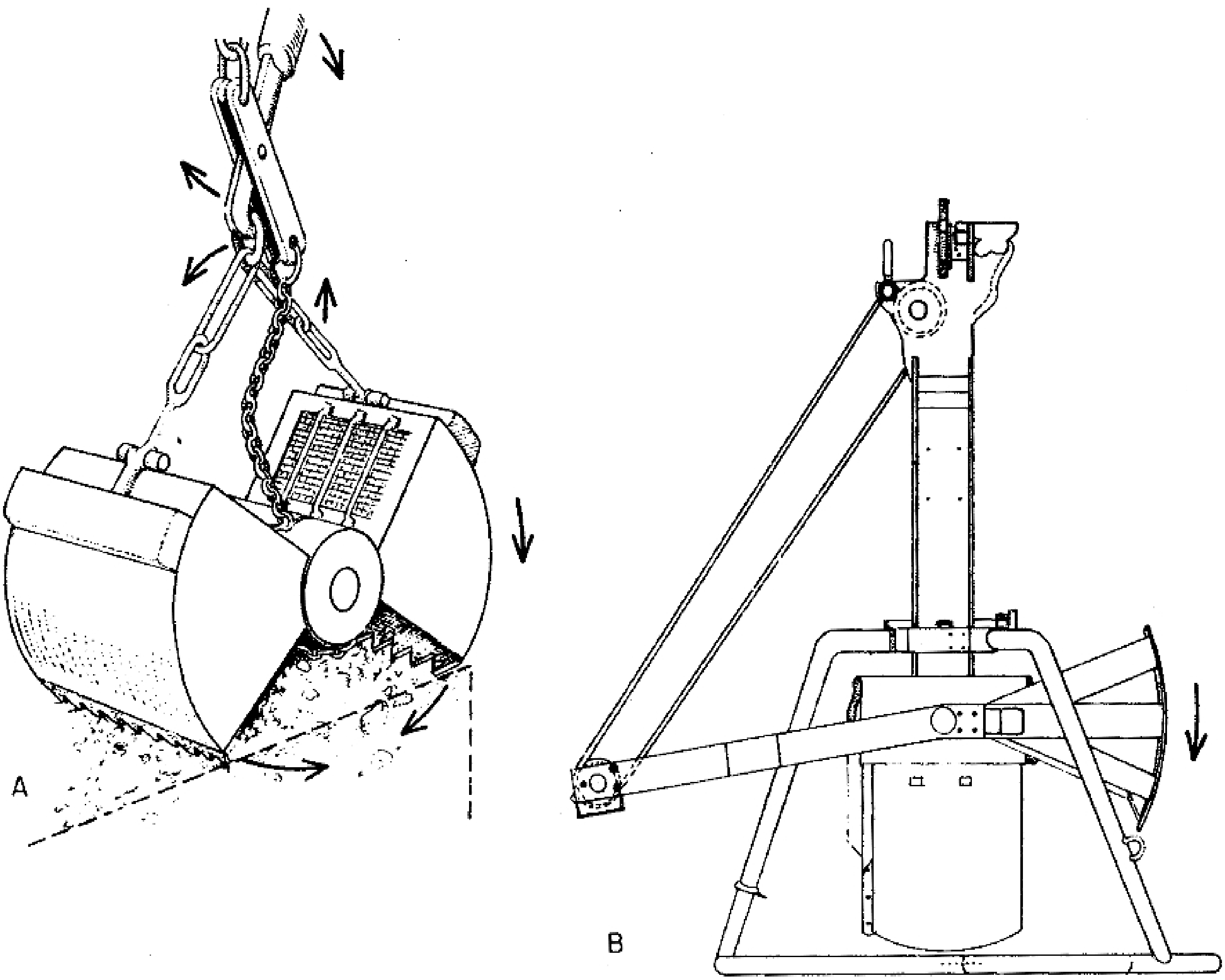
Introduction to the benthos

Sediment properties
Faunal groupings
Bioegeochemistry
Animal-sediment relations
Benthic boundary layer

Benthic sampling devices - scoop 'em up



Some benthic sampling devices. (a) The Peterson grab taking a sample from the seabed. (From McIntyre, 1971, after Hardy, 1959) (b) A box core developed to take samples from the deep-sea bottom. (After Hessler and Jumars, 1974)

Sediment properties

Grain size and sorting

Muds and sands = cohesive and non-cohesive sediments

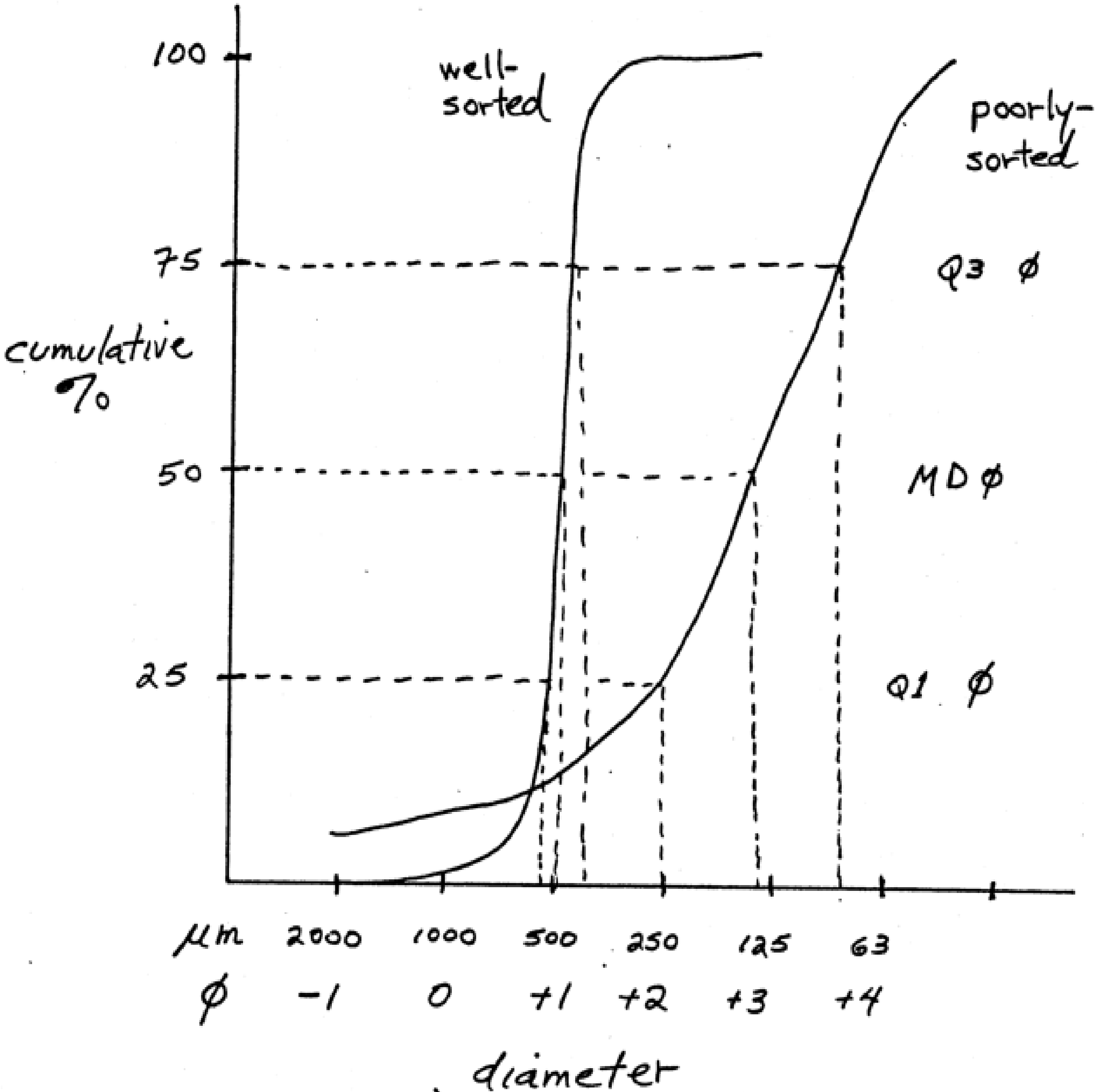
Porosity (water content)

Surface area

Organic matter

Generally smaller grains have increased surface area and POM

Cumulative Plots + Median diameter



$(\phi = -\log_2 d)$

sorting as quartile deviation:

$$QD = \frac{Q_3\phi - Q_1\phi}{2}$$

Summary of the Udden–Wentworth size classification for sediment grains (after Pettijohn *et al.* 1972). This grade scale is now in almost universal use amongst sedimentologists. Estimation of grain size in the field is aided by small samples of the main classes stuck on perspex.

	US Standard sieve mesh	*Millimeters*		*Phi (ϕ) units*	*Wentworth size class*
	Use wire	4096		-12	
	squares	1024		-10	boulder
GRAVEL		256	256	-8	
		64	64	-6	cobble
		16		-4	pebble
	5	4	4	-2	
	6	3.36		-1.75	
	7	2.83		-1.5	granule
	8	2.38		-1.25	
	10	2.00	2	-1.0	
	12	1.68		-0.75	
	14	1.41		-0.5	very coarse sand
	16	1.19		-0.25	
	18	1.00	1	0.0	
	20	0.84		0.25	
	25	0.71		0.5	coarse sand
	30	0.59		0.75	
	35	0.50	1/2	1.0	
	40	0.42		1.25	
SAND	45	0.35		1.5	medium sand
	50	0.30		1.75	
	60	0.25	1/4	2.0	
	70	0.210		2.25	
	80	0.177		2.5	fine sand
	100	0.149		2.75	
	120	0.125	1/8	3.0	
	140	0.105		3.25	
	170	0.088		3.5	very fine sand
	200	0.074		3.75	
	230	0.0625	1/16	4.0	
	270	0.053		4.25	
	325	0.044		4.5	coarse silt
SILT		0.037		4.75	
		0.031	1/32	5.0	
		0.0156	1/64	6.0	medium silt
	Use	0.0078	1/128	7.0	fine silt
	pipette	0.0039	1/256	8.0	very fine silt
	or	0.0020		9.0	
	hydro-	0.00098		10.0	clay
CLAY	*meter*	0.00049		11.0	
		0.00024		12.0	
		0.00012		13.0	
		0.00006		14.0	

Organisms

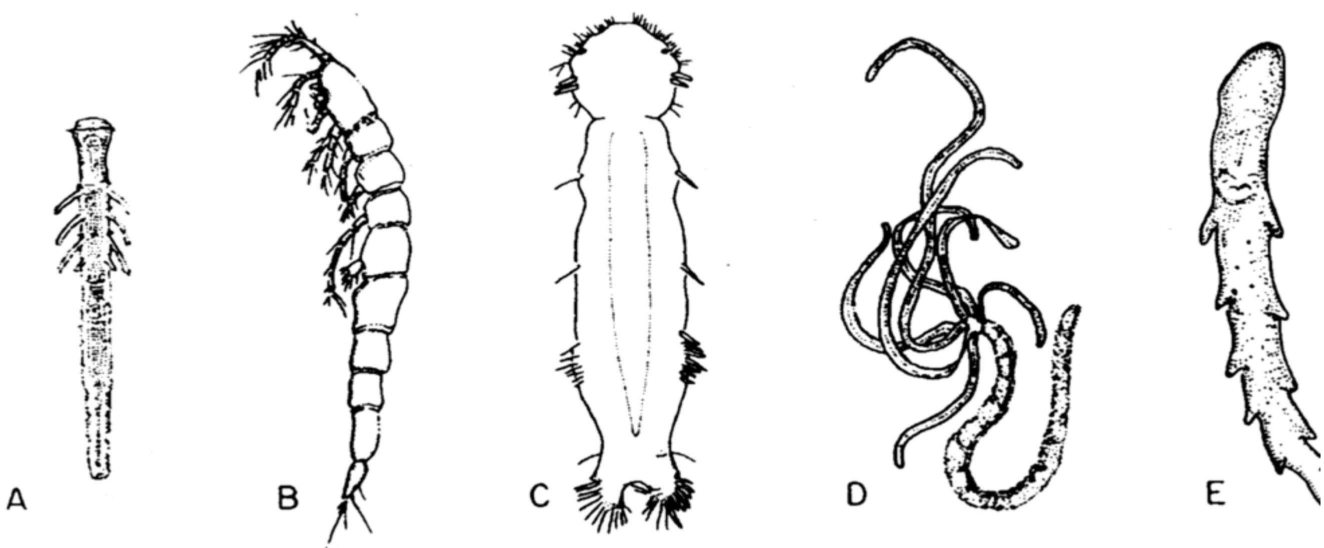
Bacteria (1-10 μm)

Microfauna - protozoans (1-100 μm)

Microflora - shallow water only (1-100 μm)

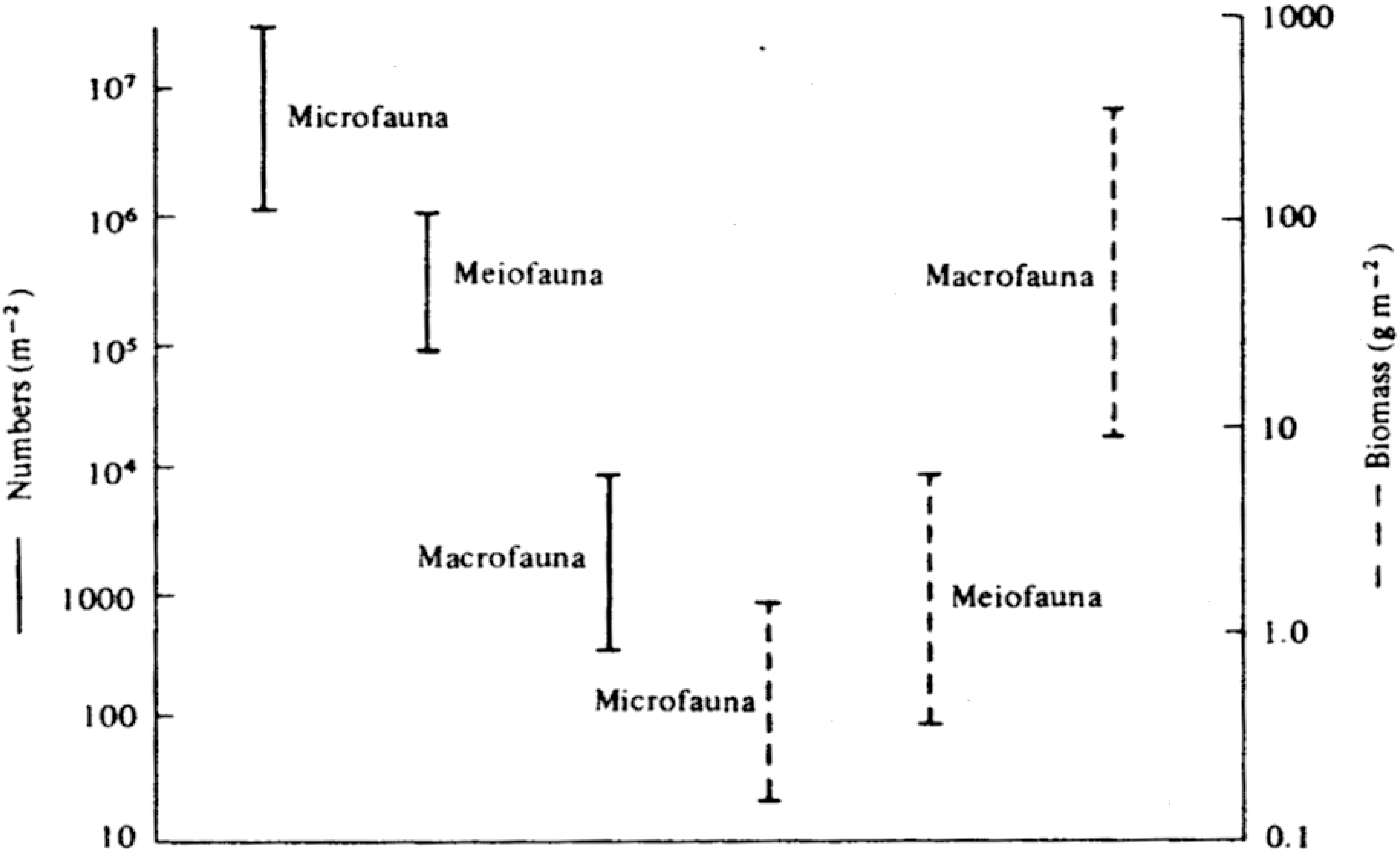
Meiofauna - metazoans (63-500 μm)

Macrofauna - metazoans (>500 μm)

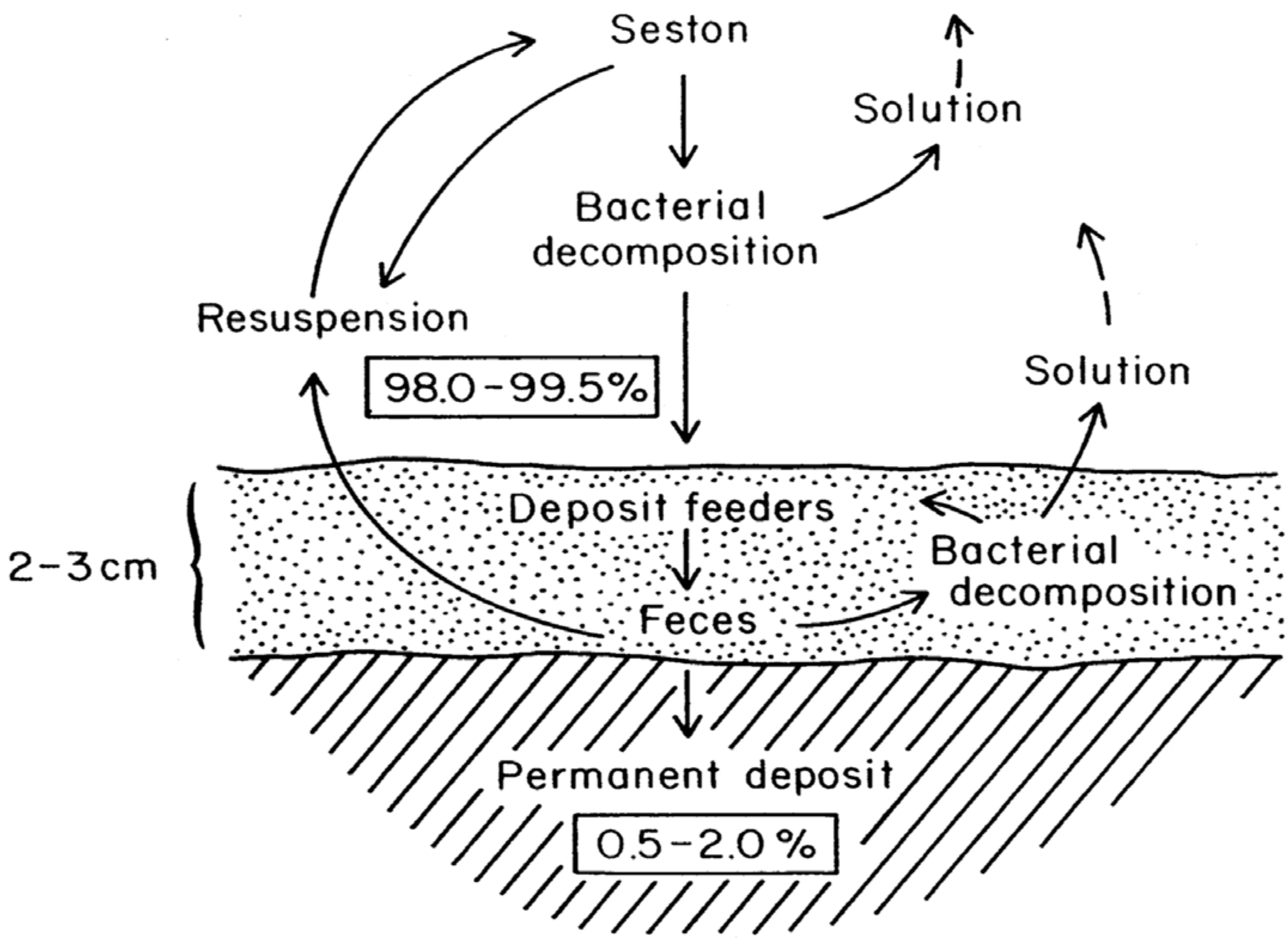


Examples of some meiofaunal organisms, showing convergence to a worm-like body form in different phyla: (a) polychaete, *Psammodrilus;* (b) harpacticoid copepod, *Cylindropsyllis;* (c) gastrotrich, *Dactylopodalia;* (d) hydroid, *Halammohydra;* (e) opisthobranch gastropod, *Pseudovermis*. (After Swedmark, 1964)

Abundance and biomass ranges of macro-, meio- and microtauna from sublittoral sandy sediments. (From Fenchel, 1978.)



Overview of POM pathways in marine sediments



The movement of particulate organic matter in shallow-water environments.
(After Young, 1971)

Macrofauna groups

Infauna

Epifauna

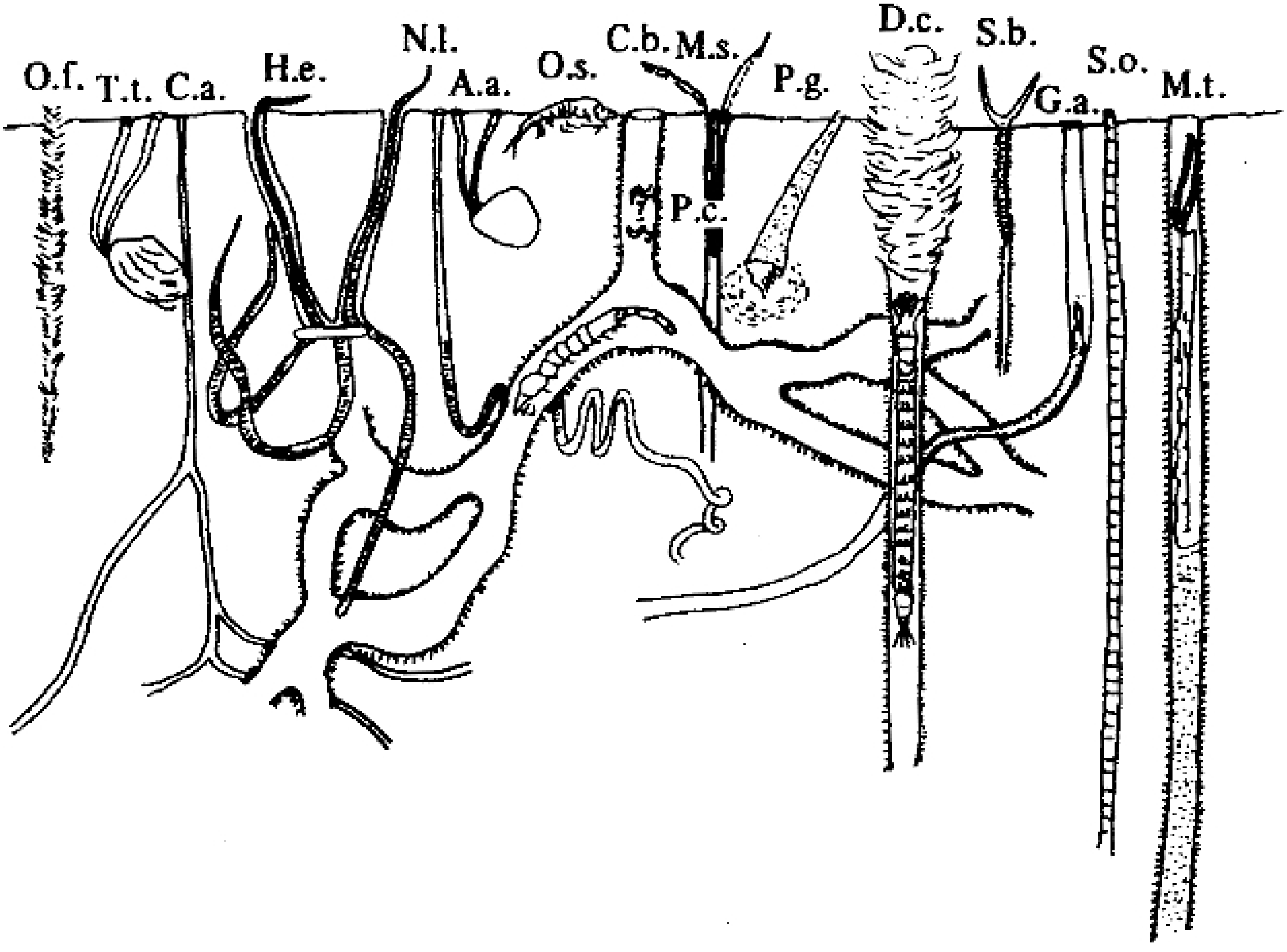
Trophic types (functional groups)

Deposit feeders

Suspension feeders

Infauna

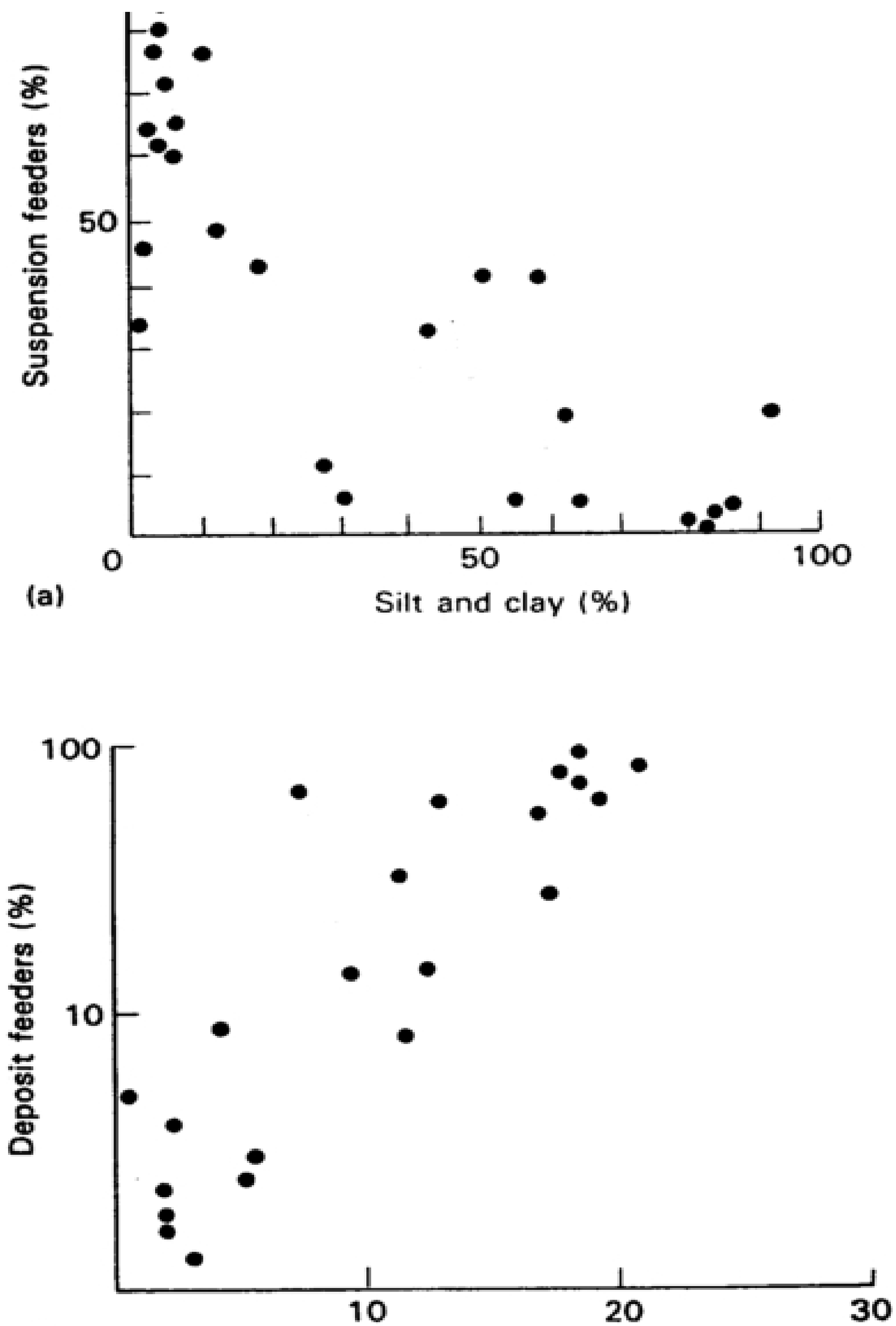
Location of most important benthic animals, burrow and tubes in a shallow-shelf environment in Georgia, USA. A.a., *Abra aequalis*; C.a., *Capitomastus* cf. *aciculatus*; C.b., *Calianassa biformis*; D.c., *Diopatra cuprea*; G.a., *Glycera americana*; H.e., *Hemipholis elongata*; M.s., *Magelona* sp.; M.t., *Mesochaetopterus taylori*; N.l., *Notomastus latericeus*; O.f., *Owenia fusiformis*; O.s., *Oxyurosthylis smithi*; P.c., *Pinnixa chaetopterana*; P.g., *Pectinaria gouldi*; S.b., *Spiophanes bombyx*; S.o., *Spiochaetopterus oculatus*; T.t., *Tellina* cf. *texana*. (After Dörjes & Howard, 1975.)



Bacteria and microfauna/flora exist in complex sediment communities as in sulfidic sediments (sulfuretum)

The microflora and fauna in the surface of the *Beggiatoa* patches. (*Oscillatoria, Beggiatoa, Thiovolum*, diatoms, euglenoids, nematode, *Tracheloraphis* sp., *Frontonia marina, Diophrys scutum. Trochiloides recta*).

Suspension feeders and deposit feeders utilize different substrates due to food availability and turbidity



Proportions of (a) suspension- and (b) deposit-feeding macrofauna in benthic populations from marine sediments with varying amounts of fine particles. From Menzies *et al.* (1973).

Bacteria in marine sediments

Grain-attached and free-living

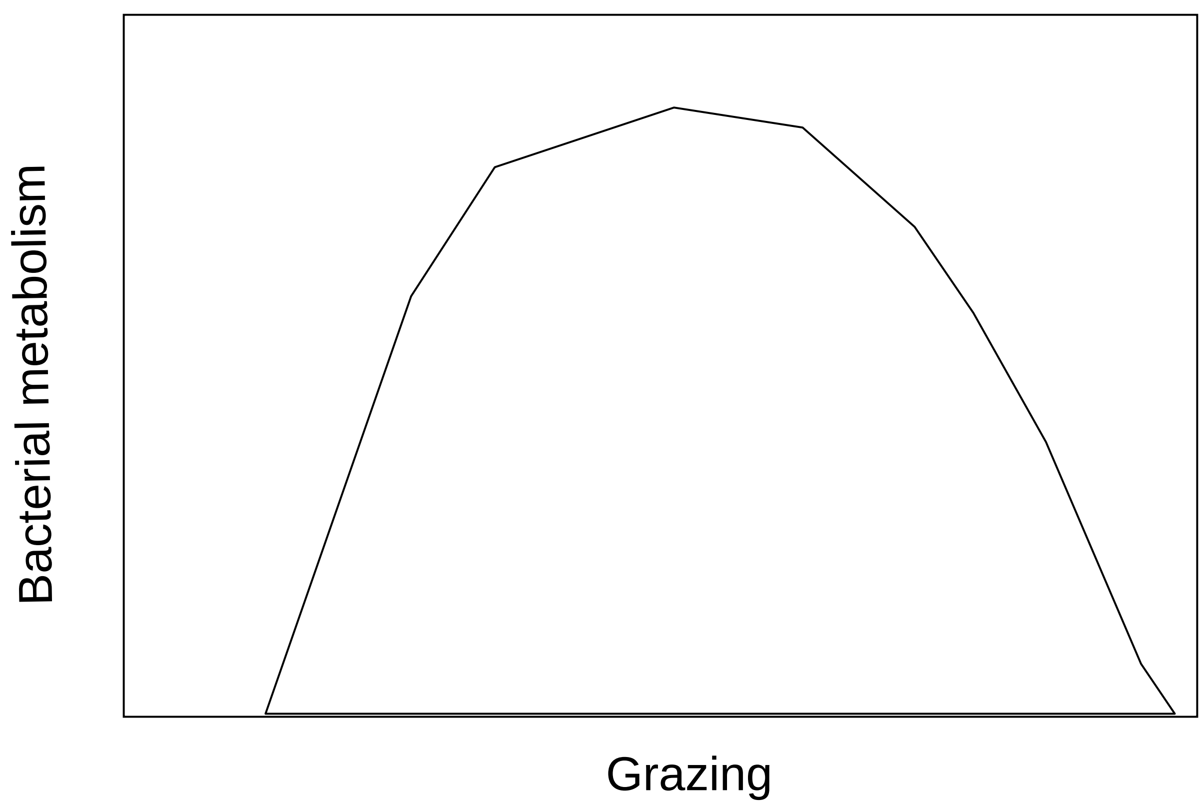
Consistent biomass (10^9/g sediment)

Many inactive

Density related to grain size, surface area, POM

Physiological types (sulfate reducers, nitrifiers, etc.)

Gardening - grazers stimulate bacterial activity by keeping them in log phase (e.g. macrofauna burrow)



Yamamoto & Lopez 1985. J. Exp. Mar. Biol. Ecol. 90: 209

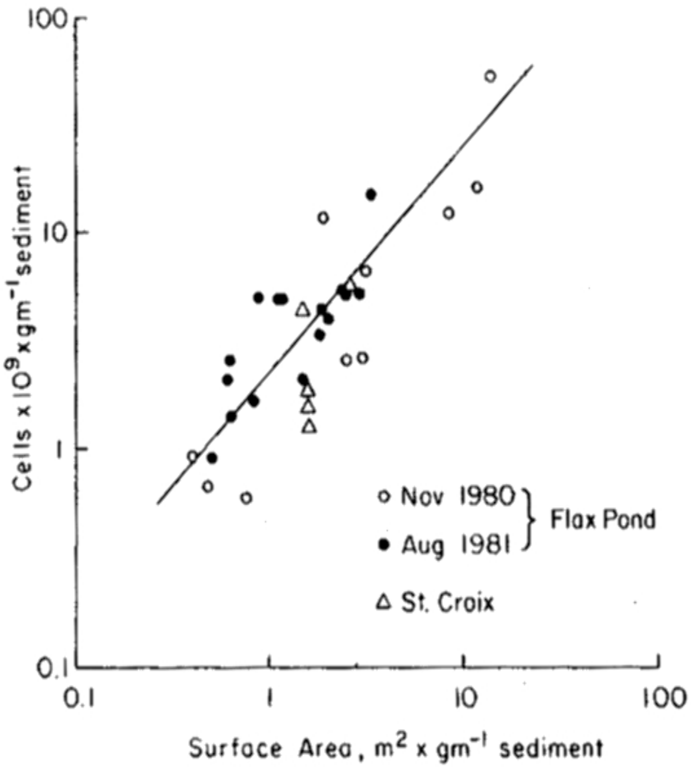


Fig. 1. Relationship between sediment surface area and bacterial abundance for intertidal samples collected from Flax Pond salt marsh: the equation for the fitted line is

$$y = 2.279x - 0.65, \; r = 0.847, \; n = 26, \; P < 0.001.$$

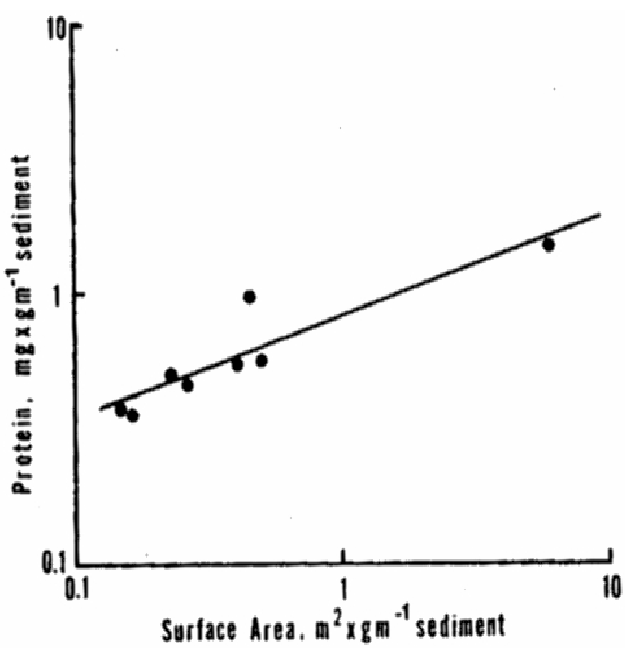


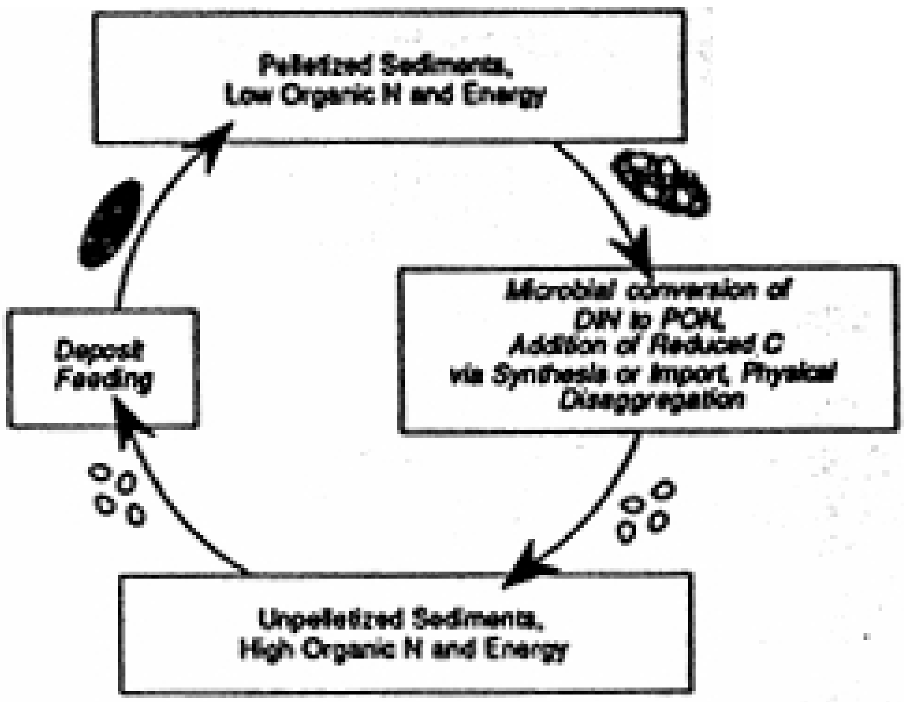
Fig. 2. Microcosm experiment results of surface specific protein loading on model sediment, expressed as initial protein concentration vs. specific surface area.

Detrital food chains

Labile and refractory particulate organic matter (POM)
- phytoplankton vs macrophytes
- C/N as a rough quality indicator

Bacterial converison of POM enhances N

Importance of fecal pellets as a detrital substrate



The deposit-feeding cycle as revealed by the closed-system experiments of Newell (1965). Deposit feeders pelletize sediments into a form unlikely to be ingested (large particles of high specific gravity relative to organic-rich aggregates), at least by the individual that does the pelletizing. Benthic bacteria and plants take dissolved inorganic nitrogen (DIN) as NH_4^+ and NO_3^- dissolved in seawater and convert it to particulate organic nitrogen (PON) in the form of their own cellular contents. Energy-rich chemical bonds fuel the cycle and originate locally from photosynthesis or other ("autotrophic") processes that convert inorganic to organic carbon or are imported as dissolved organic matter from overlying water or as organic particles sedimenting out of the water column. As this resource renewal occurs, the bindings of the pellet degrade and the pellets disaggregate physically (although the force for this disaggregation may come either from fluid stresses or from mechanical activities of small organisms on the seabed. The underlying idea is that the resource for deposit feeding is renewable.

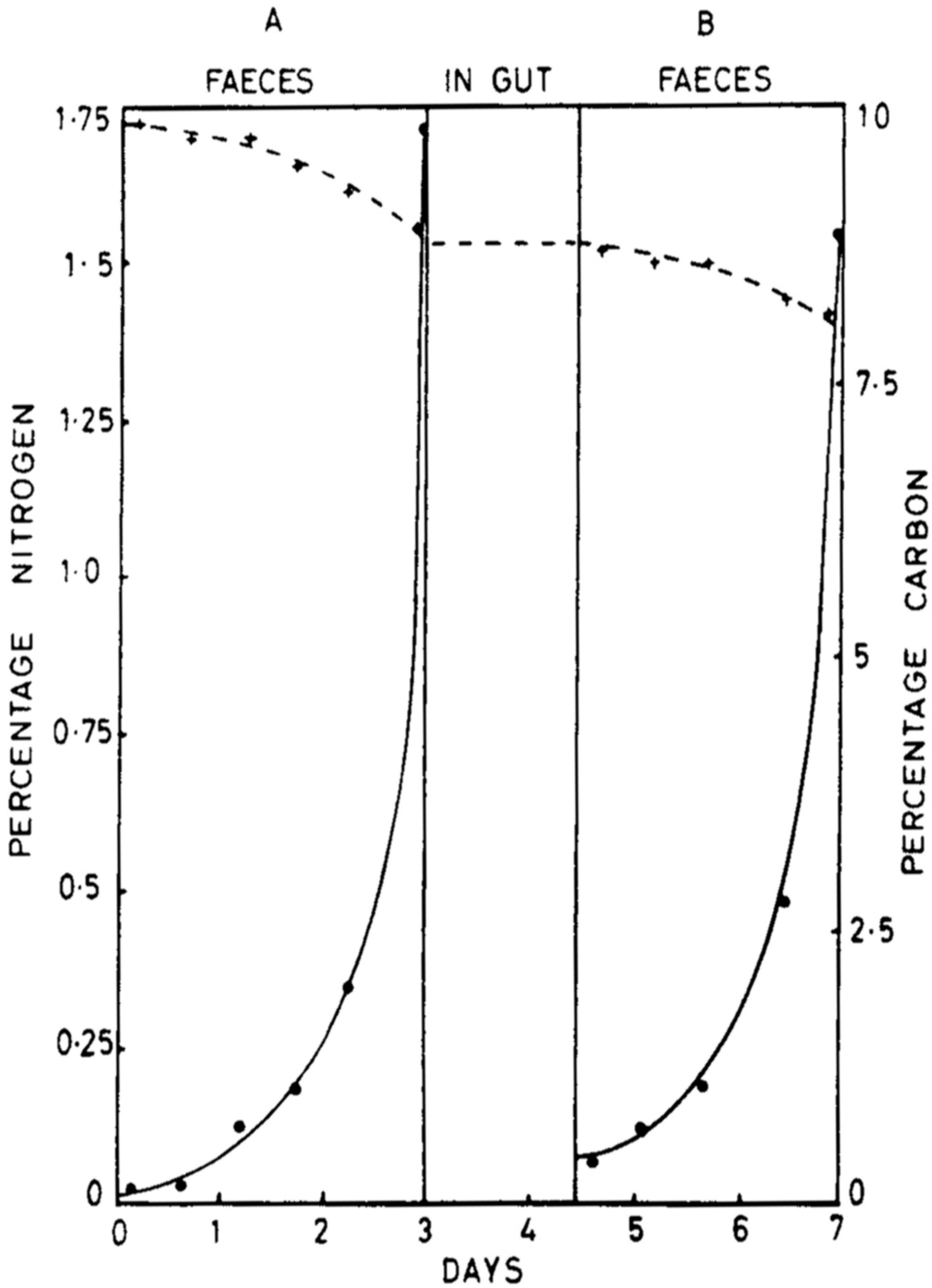
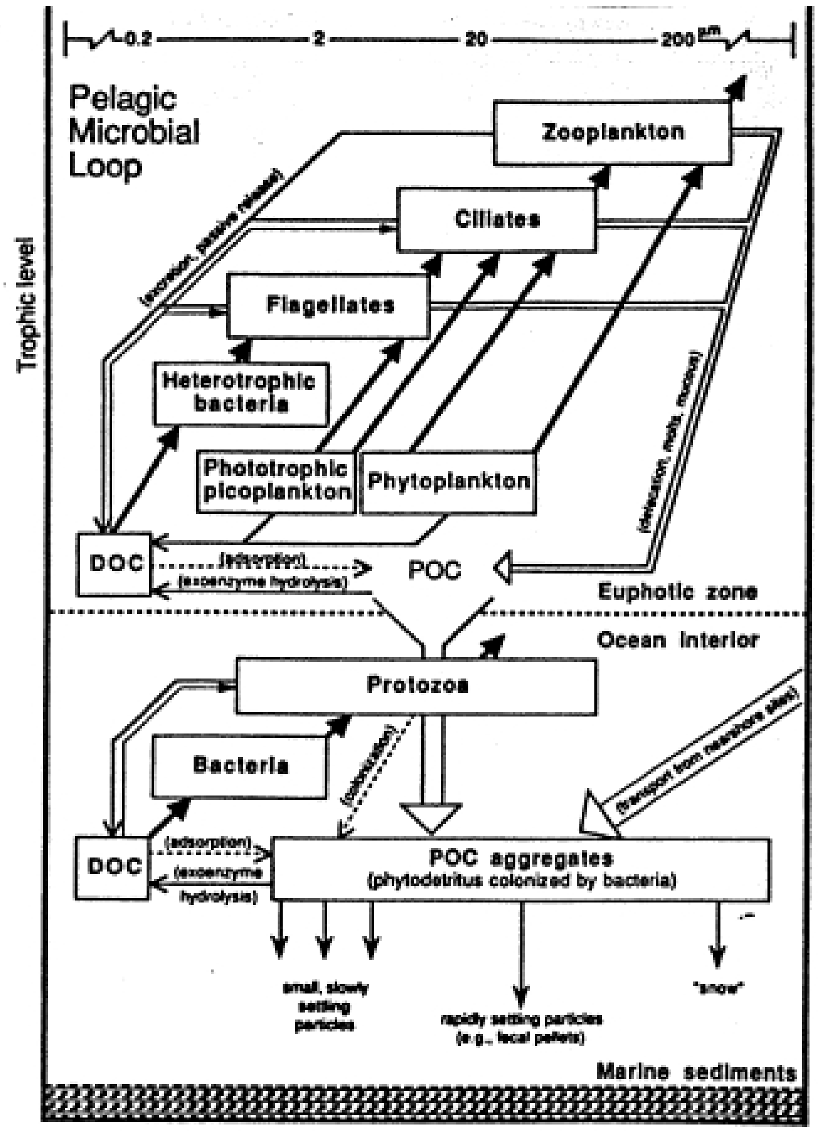
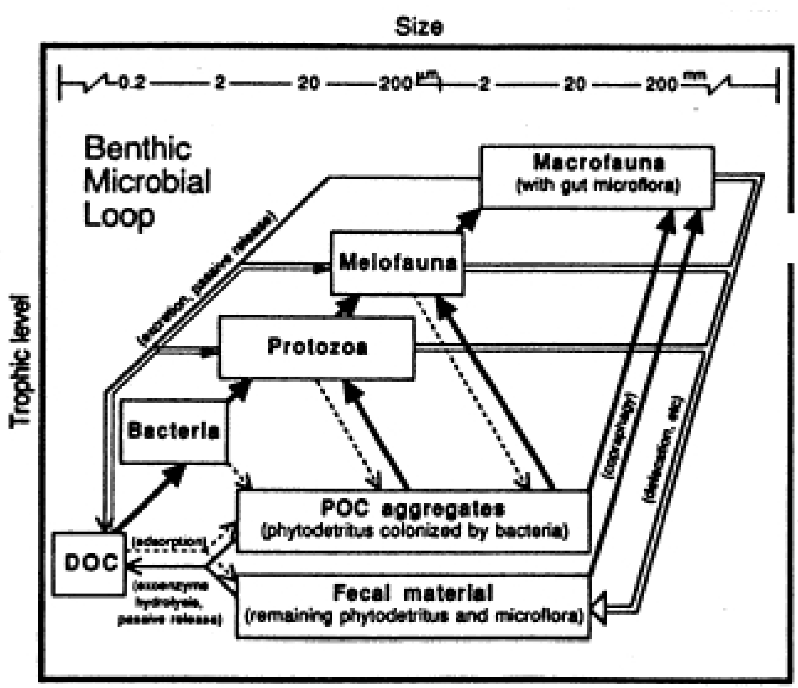


Fig. 3.—Percentage organic carbon and nitrogen in faeces cultured at 18° C in sea water under a neon light, (A) before and (B) after feeding to *Hydrobia ulvae*. Each point represents the mean of two estimations.

Microbial loops



Sources and general description of particulate organic carbon (POC) that reaches the benthic environment. Excess POC produced but not recycled within the pelagic microbial loop of the euphotic zone [upper panel, taken from Azam et al. (1983)], as well as POC (including terrestrial phytodetritus) transported laterally from nearshore environments, forms aggregates that sink into the ocean interior, where they may be altered further, depending on sinking rate, by passage through additional (nonphotosynthetic) microbial loops (an example is shown in the lower panel) before reaching the seafloor. Solid triangular arrowheads indicate energy flow to higher trophic levels; open arrowheads, loss of nonliving POC; line arrowheads, flow of dissolved organic carbon (DOC).



Benthic microbial loop in marine sediments, based on the supply of POC aggregates escaping pelagic loops (Fig. 3), adapted from the detrital food chain model of Fenchel and Jørgensen (1977) and the pelagic microbial loop described by Azam et al. (1983). Solid triangular arrowheads indicate energy flow to higher trophic levels; open arrowheads, loss of POC; line arrowheads, flow of dissolved organic carbon (DOC); dotted arrows, colonization. Since virtually all POC in surface marine sediments passes through animal guts before final burial, the distinction between POC aggregates and fecal material is conceptually ambiguous; both are given equal status in providing base support for the microbial loop [according to Pace et al. (1984)]. For the same reason, the importance of gut microflora in sediment diagenesis cannot be overemphasized.