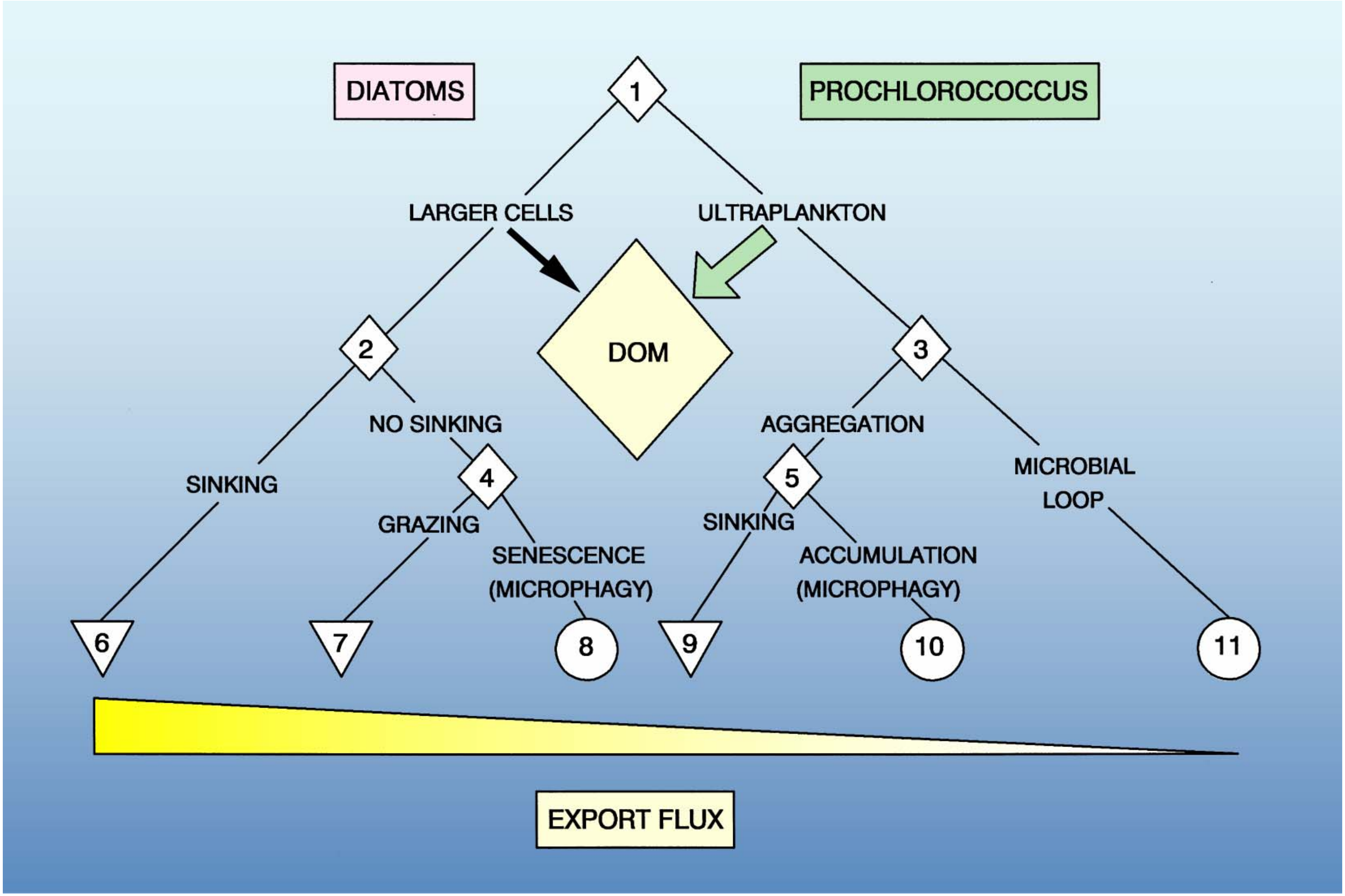
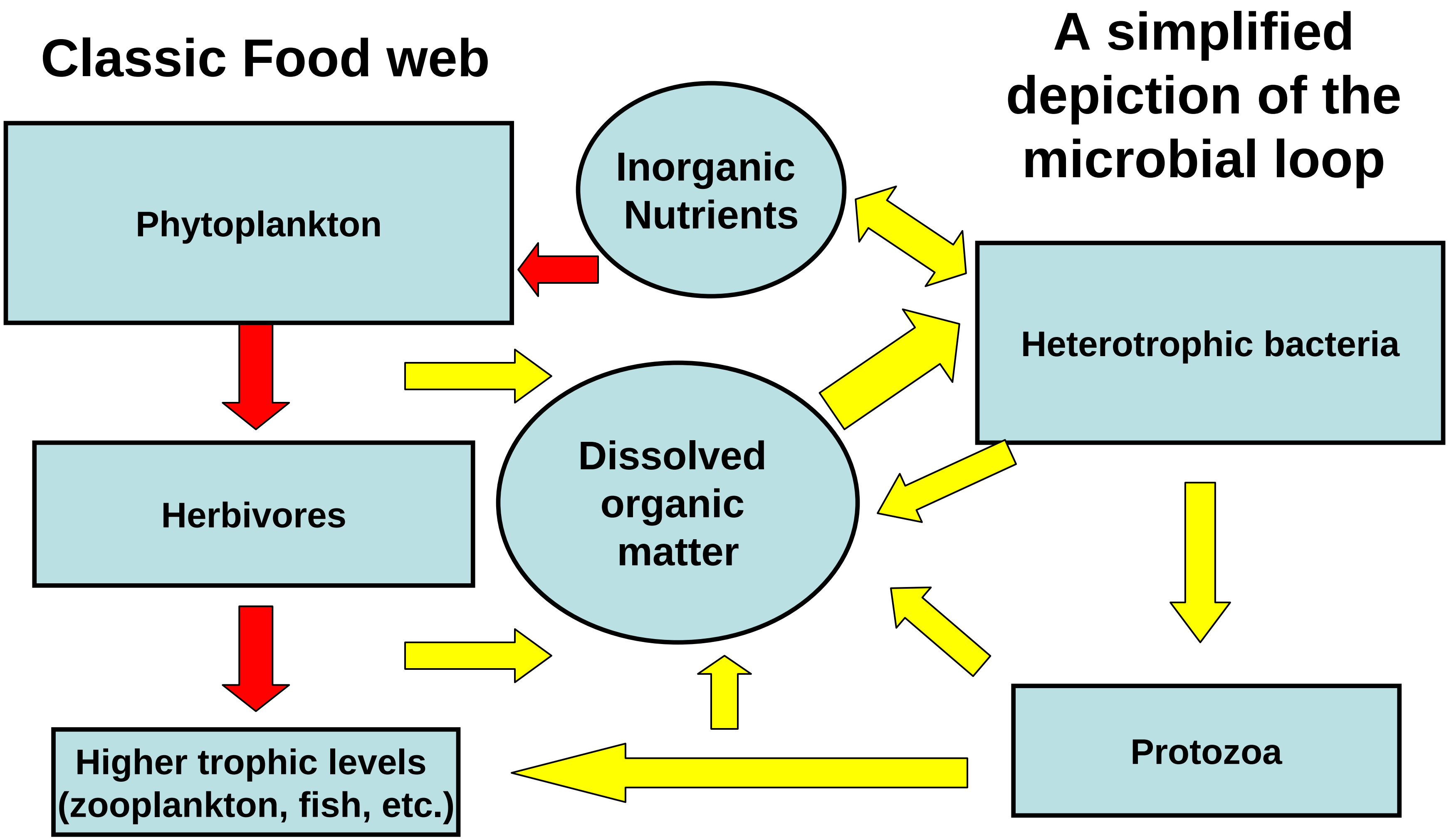
- Where does primary production go?
  - Export
  - Bacteria
  - Grazing
  - Dissolved organic matter


DIATOMS
1
PROCHLOROCOCCUS
LARGER CELLS
ULTRAPLANKTON
DOM
2
3
NO SINKING
AGGREGATION
SINKING
4
5
MICROBIAL LOOP
GRAZING
SINKING
SENESCENCE (MICROPHAGY)
ACCUMULATION (MICROPHAGY)
6
7
8
9
10
11
EXPORT FLUX

The Microbial Loop

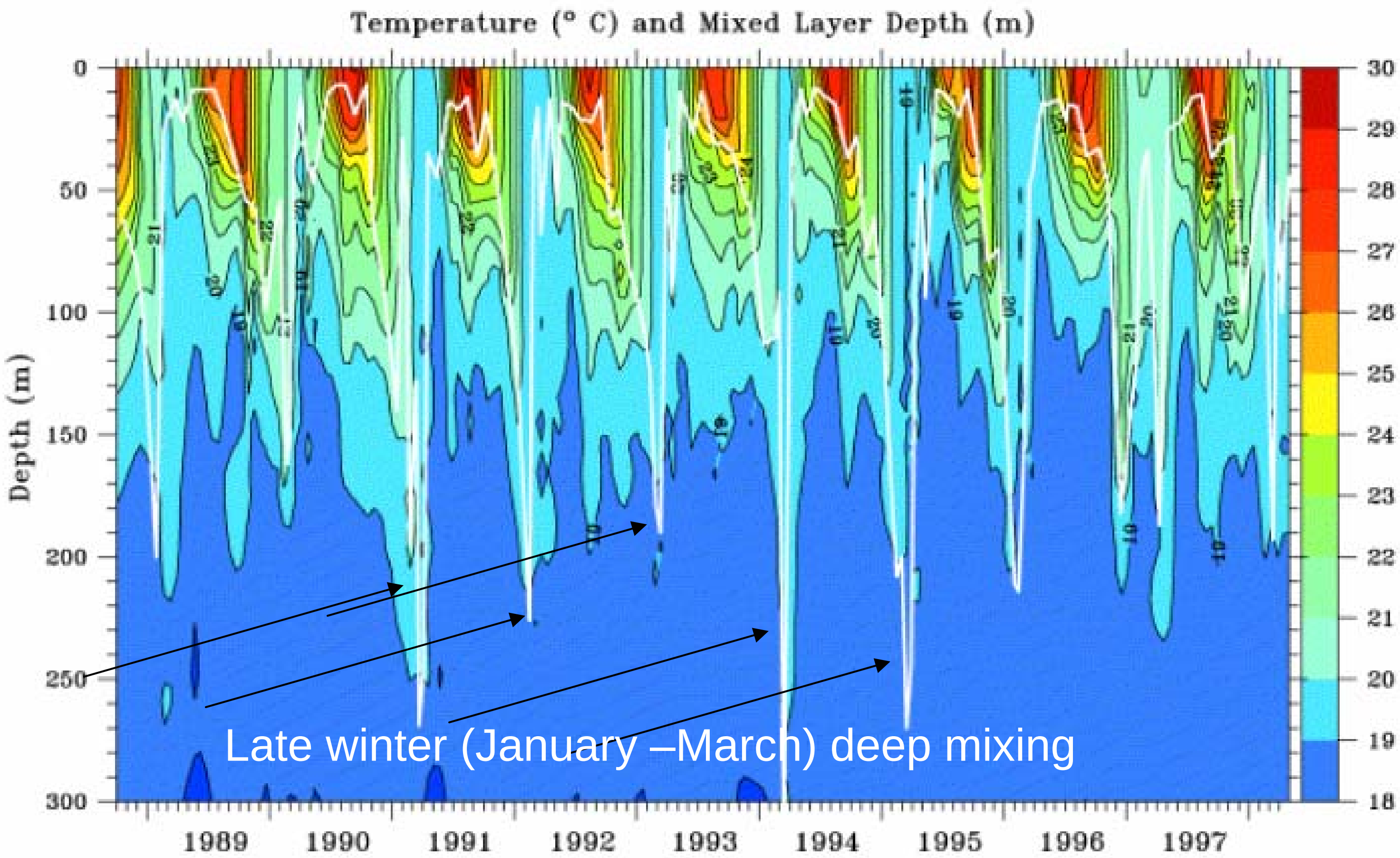


What other components of the biological pump are important?

- The majority of organic material in the ocean is in the dissolved phase (operationally defined as <0.7 μm or 0.2 μm)

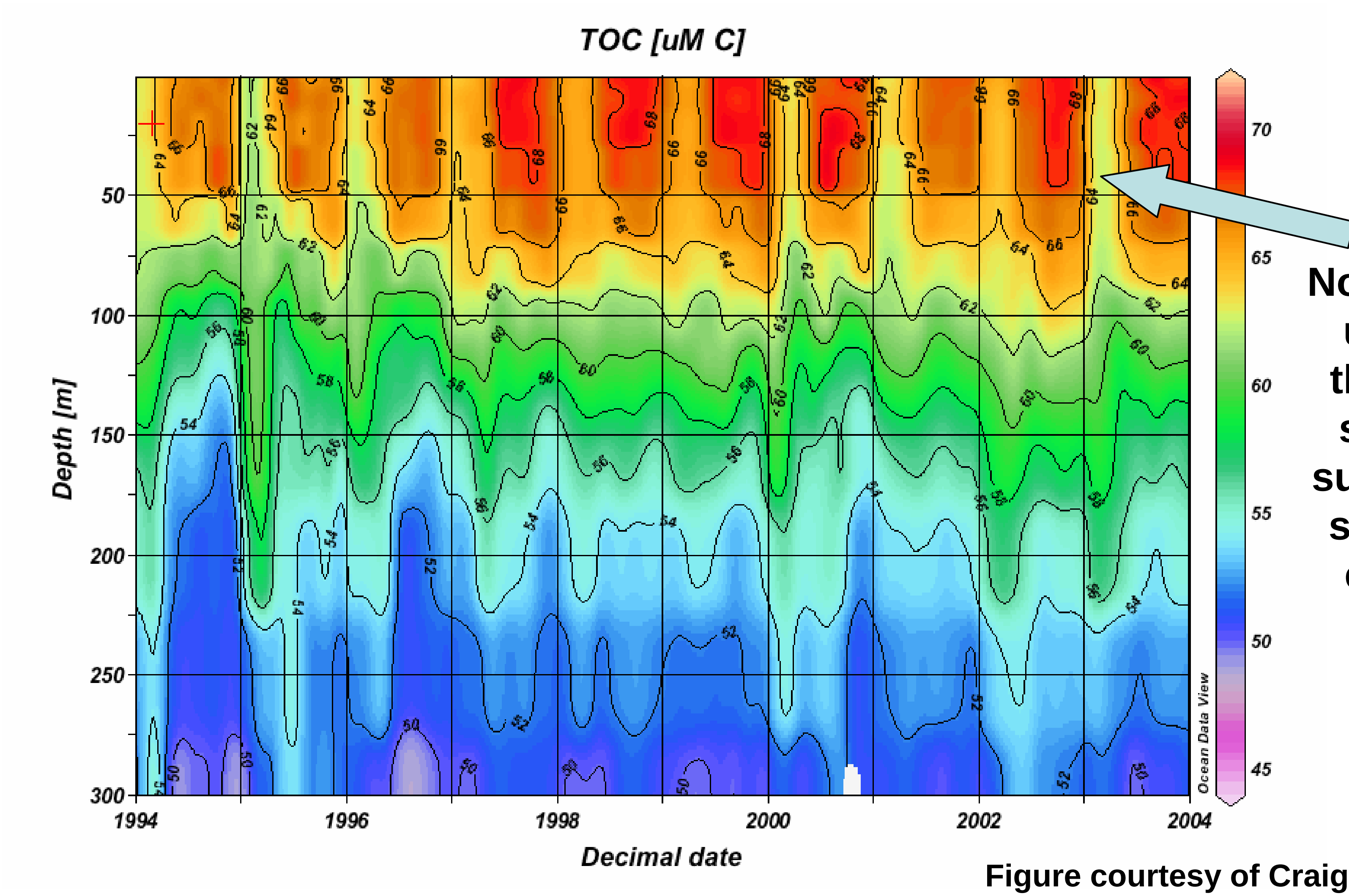
Why dissolved organics matter

- Dissolved organic matter constitutes the largest global reservoir of fixed carbon ~700 x 10^{15} g C.
- Oxidation of even 1% of the seawater DOC pool in a 1 year period would exceed annual anthropogenic CO_2 emissions.
- DOC can also serve as an important component of new production.



Seasonal variations in mixing and temperature in the Sargasso Sea-note winter time deepening of the mixed layer coincides with seasonal cooling.

Upper ocean total organic carbon at BATS Remember DOC = ~98% of the TOC.



Note the build up in DOC through the spring and summer, with subsequent export the following winter.

Figure courtesy of Craig Carlson, UCSB

TOC Profiles at BATS

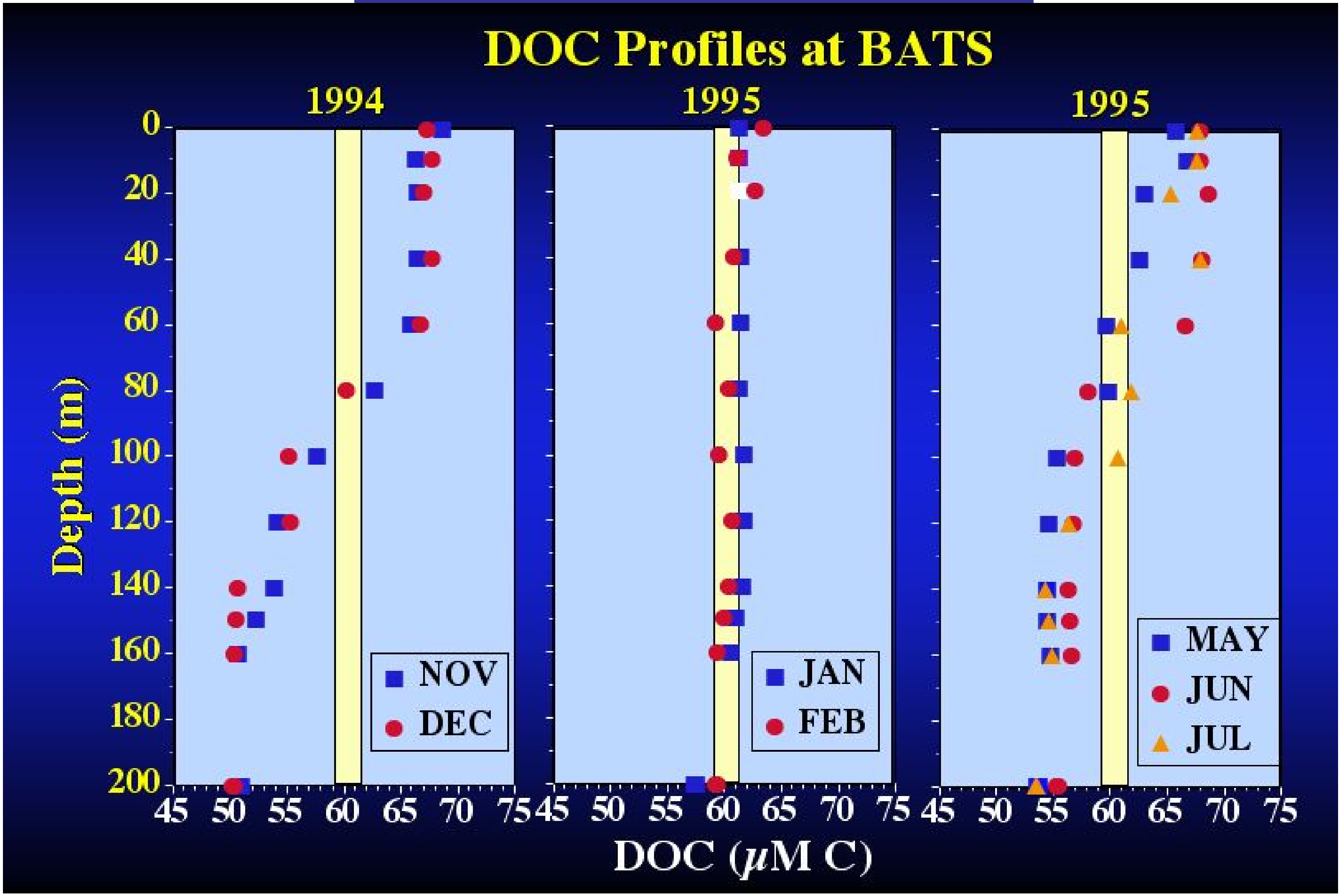


Figure courtesy of Craig Carlson, UCSB

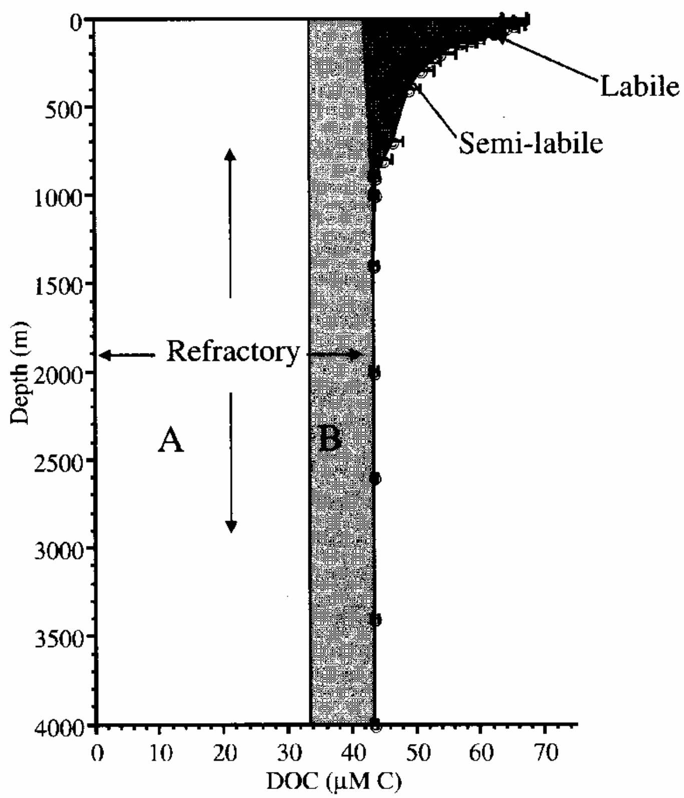


Figure 5 Conceptual cartoon of the various pools of refractory, semilabile, and labile DOC in the open ocean. This figure is based on the mean profile for all DOC data collected at the Bermuda Atlantic Time-series Study (BATS) site in the Northwestern Sargasso Sea. The magnitude and distribution of the various pools of lability will vary depending on the location of the study site and the degree of thermal stratification of the water column (see Hansell, Chapter 15). The refractory pool is divided into two broad pools based on the deep ocean gradient observed by Hansell and Carlson (1998a). They observed the lowest concentration of DOC (34 μM C) in the north Pacific and used this concentration to represent refractory DOC which turns over on time scales of greater than ocean mixing (A, white box). The deep DOC concentrations in excess of the 34 μM C represents the fraction of the biologically refractory pool that turns over on time scales of ocean mixing (i.e., centuries; B, light gray box).

Typical DOC profile : elevated in near surface water, decreasing through the thermocline, stable at depth.

•Labile pools cycle over time scales of hours to days.

•Semi-labile pools persist for weeks to months.

•Refractory material cycles over on time scales ranging from decadal to multi-decadal…perhaps longer…

Contribution of different sources to marine DOM

Sources of DOM
to ocean ecosystems

1. Direct algal excretion
2. Zooplankton (sloppy feeding, excretion)
3. Viral lysis
4. Bacterial release
5. Solubilization of POM

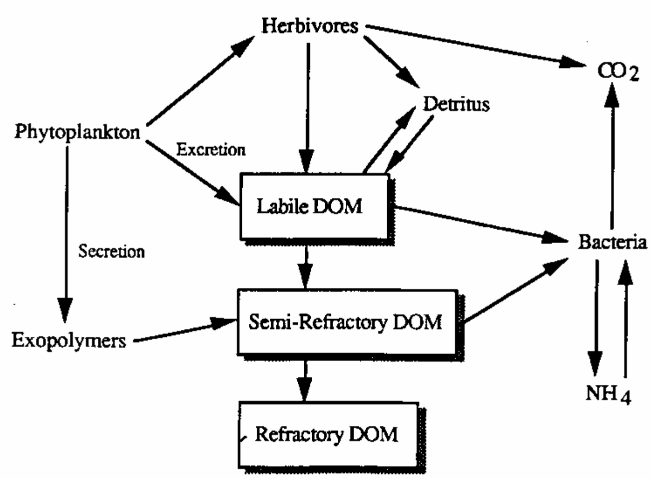
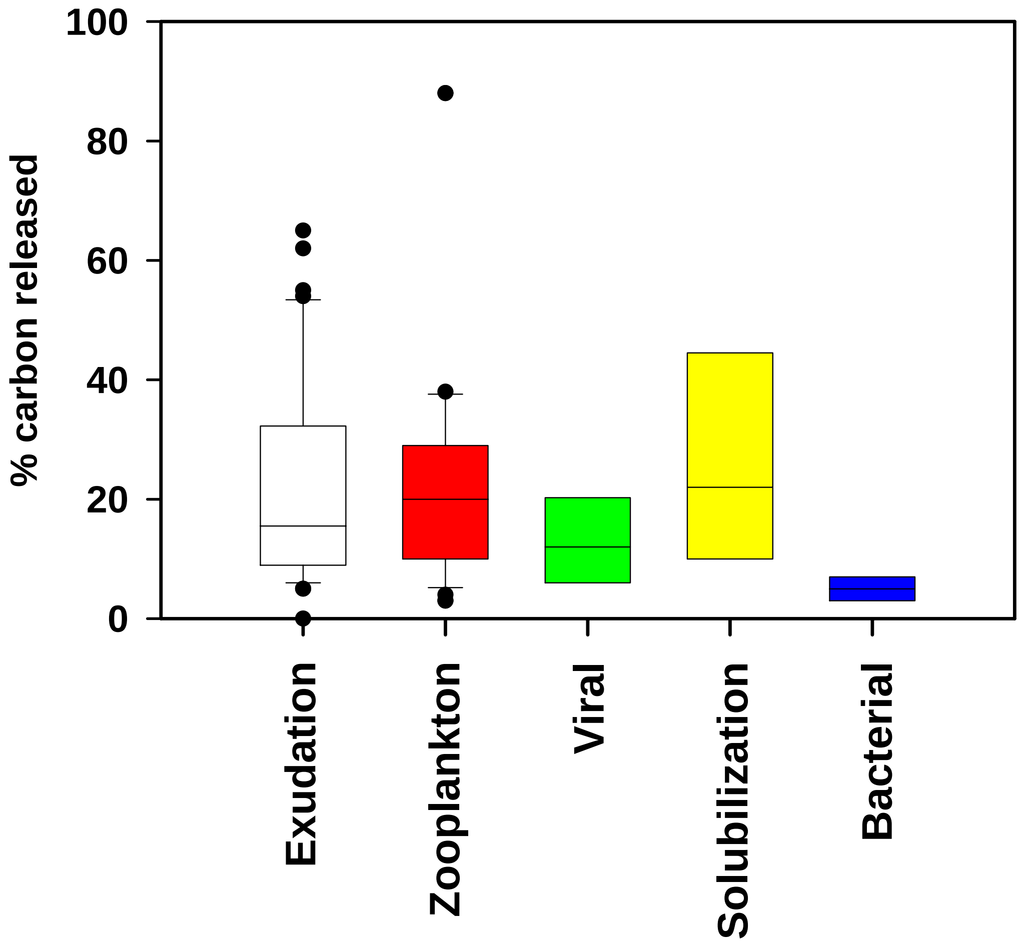
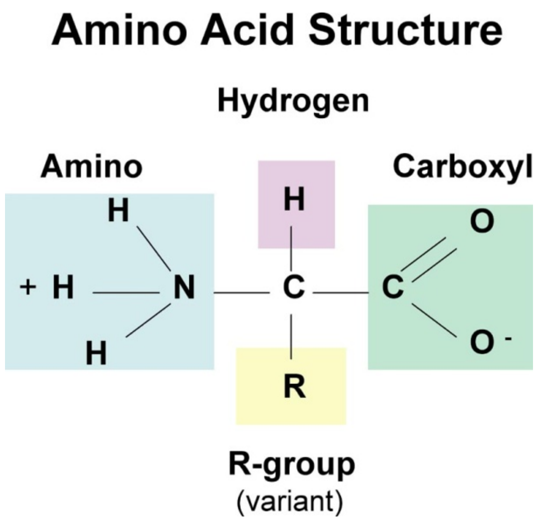


Figure 1 Three major pools of dissolved organic matter (DOM) and the processes contributing to them.

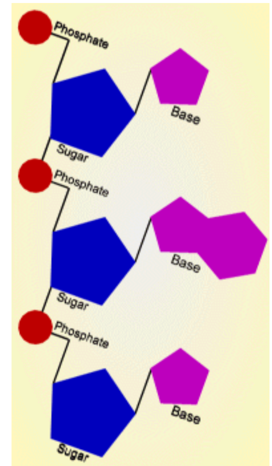


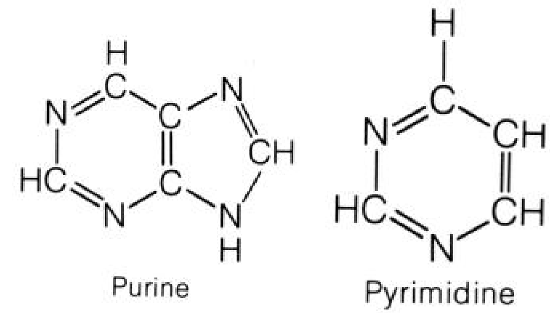
Exudation % ^{14}C primary production, zooplankton % carbon ingested, solubilization % C released from aggregates, bacterial % release from ^{14}C labeled organic substrate. Sources: Nagata (2001), Carlson (2002).



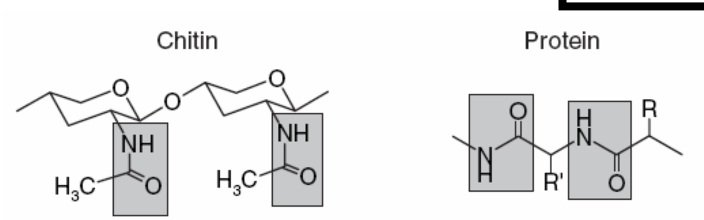
Amino acids

Identified DOM compound classes

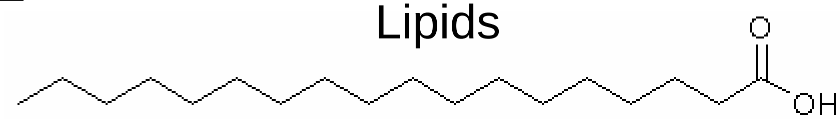


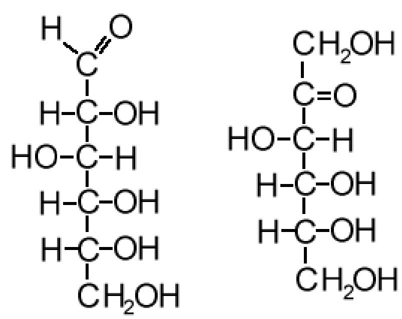


Nucleotides and nucleic acids



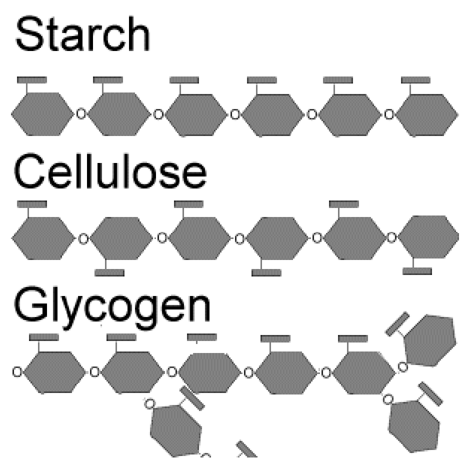
Lipids



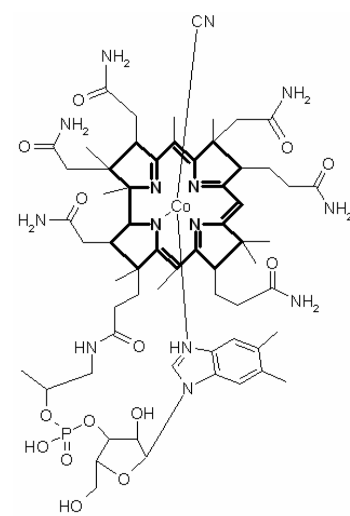


Glucose Fructose

Monosaccharides

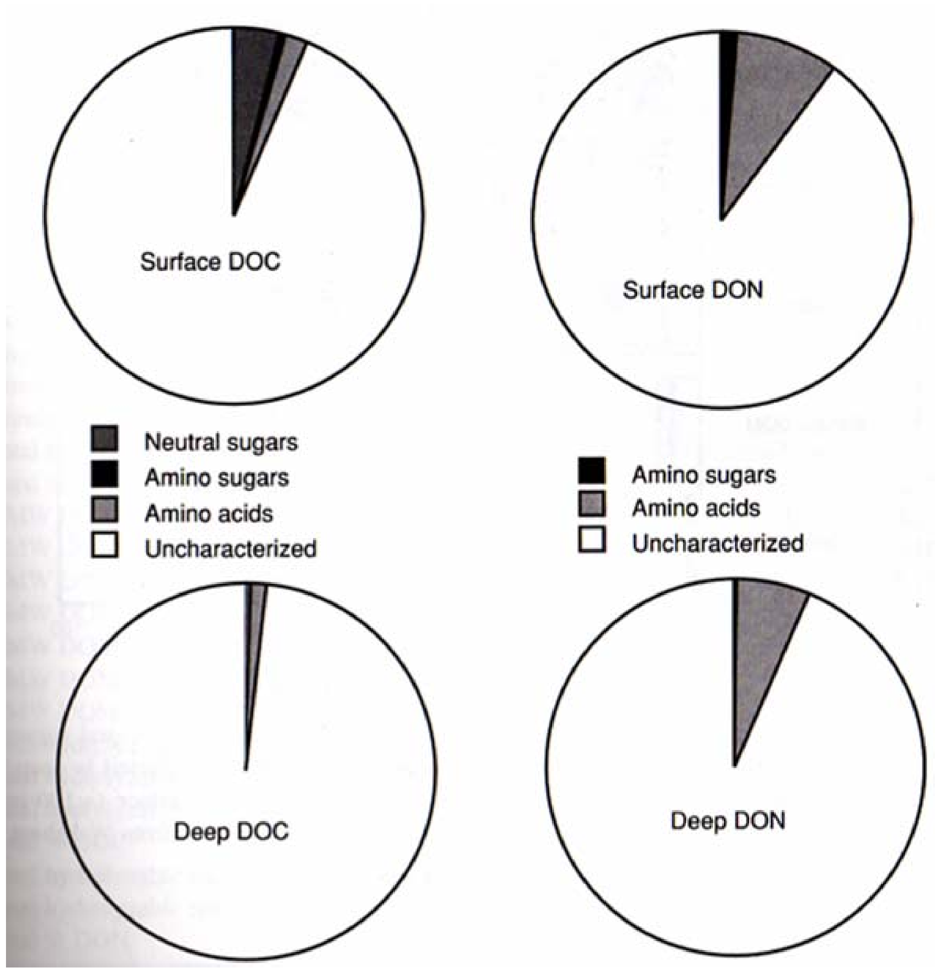


Polysaccharides



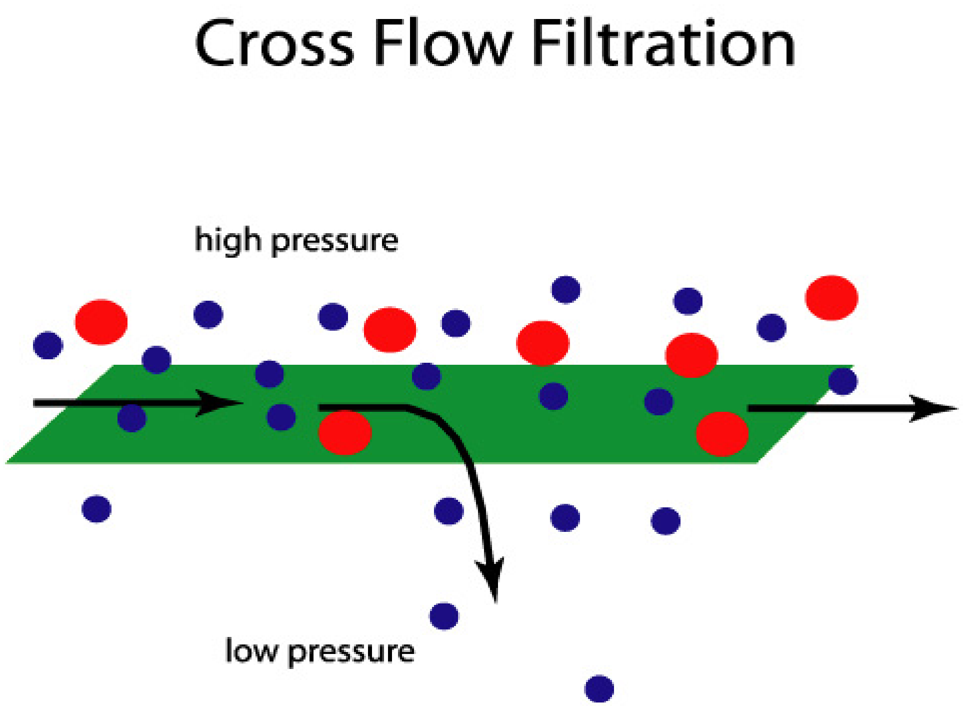
Vitamins

The vast majority of organic matter in the sea remains chemically uncharacterized



Carbohydrates, neutral sugars, amino acids, and amino sugars make up ~20% of the bulk DOC pool in the upper ocean

Isolation of DOM by ultrafiltration



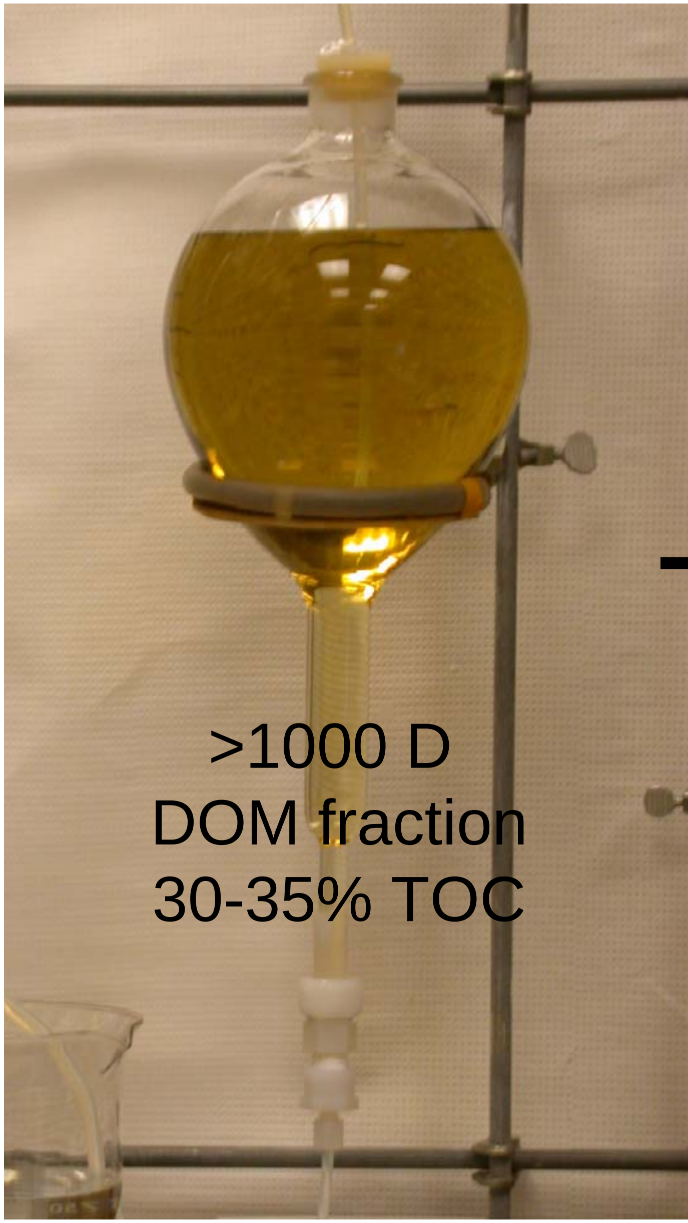
Size selective concentration of DOM

Typically solutes > 1nm are concentrated for subsequent analyses

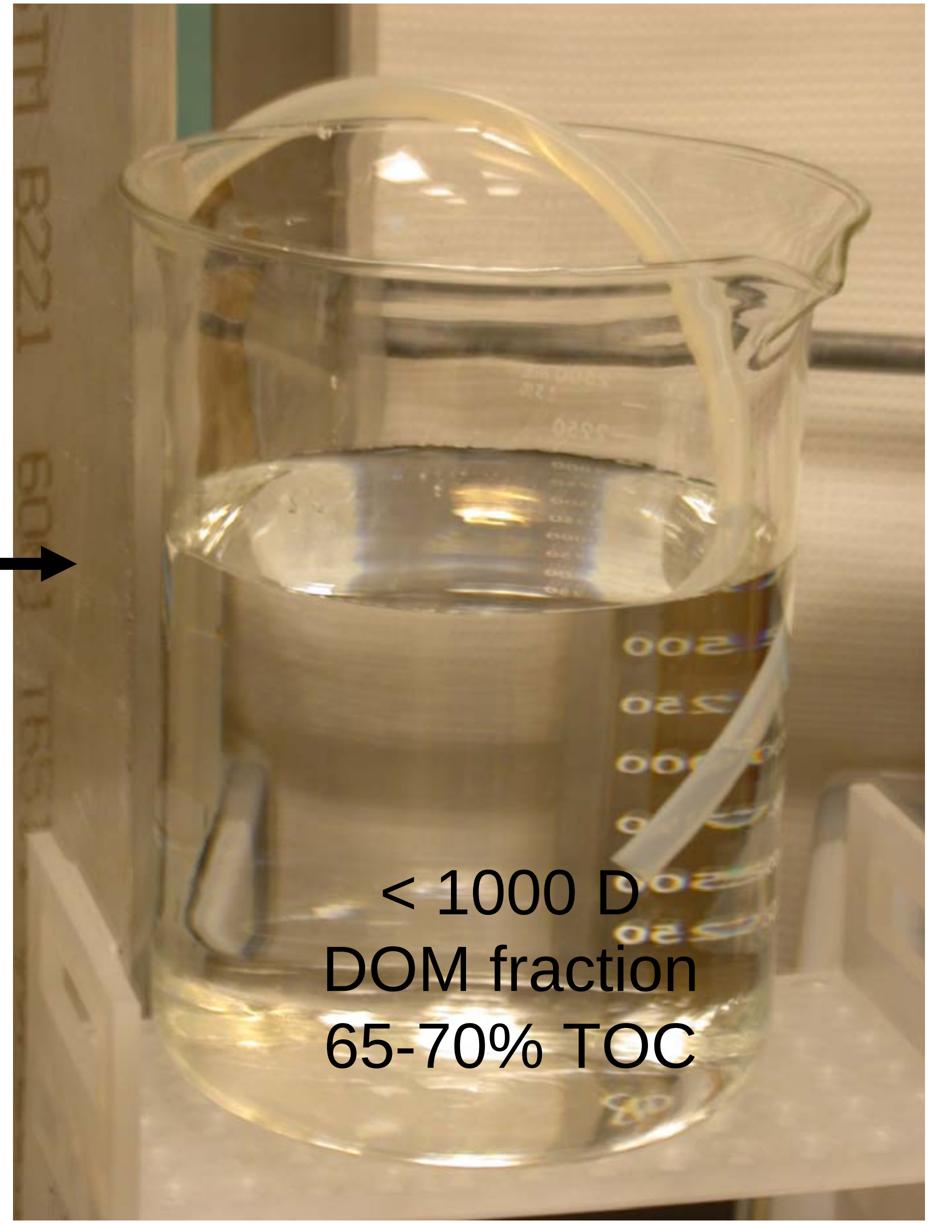
Selects for HMW fraction (about 30-35% TOC)

Some salts collected also

Ultrafiltration high molecular weight DOM (HMWDOM)



membrane filter



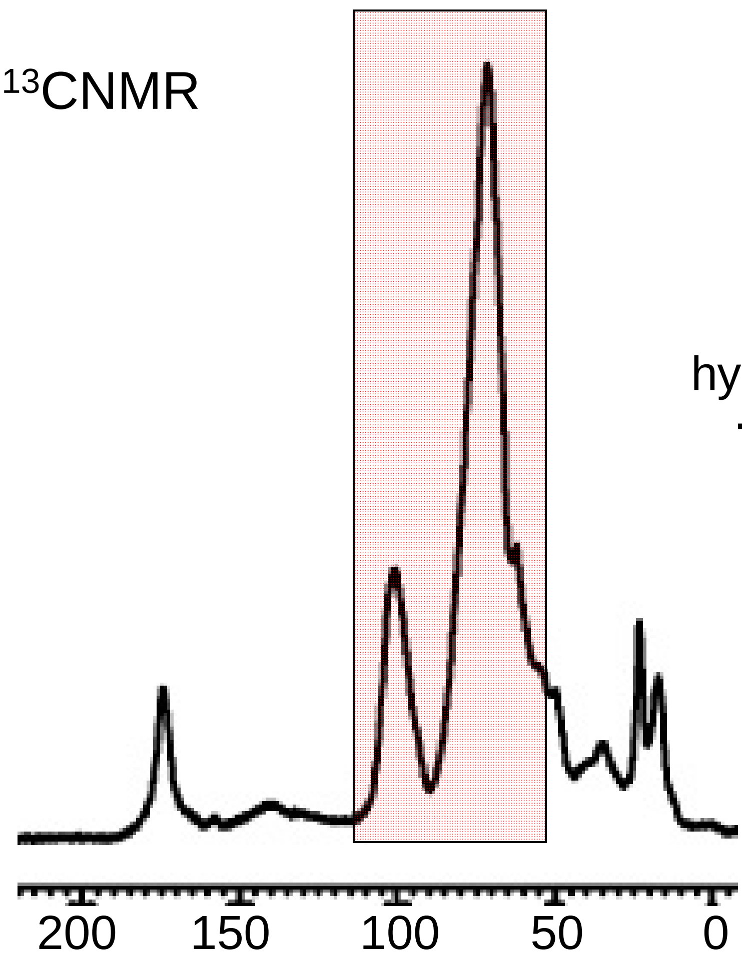
Photos from Dan Repeta

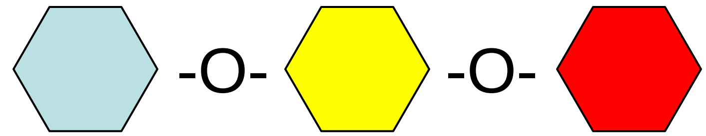

Final product
30-35% of total DOC

Spectral and chemical analyses of HMWDOC

Carbohydrate
50-70% of HMWDOC

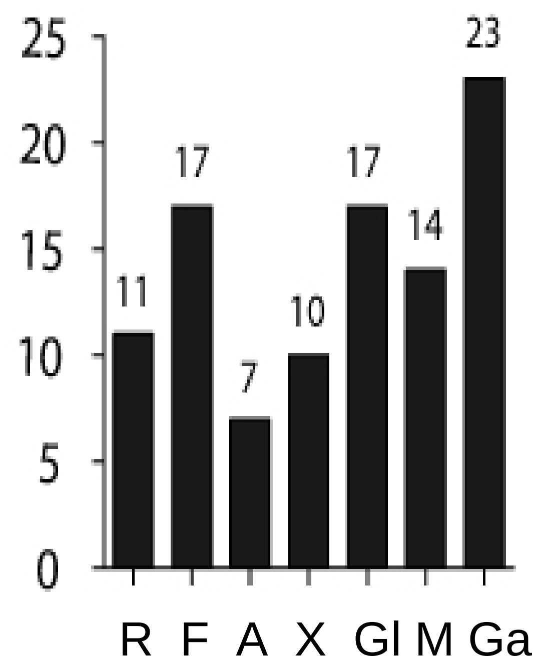
^{13}CNMR



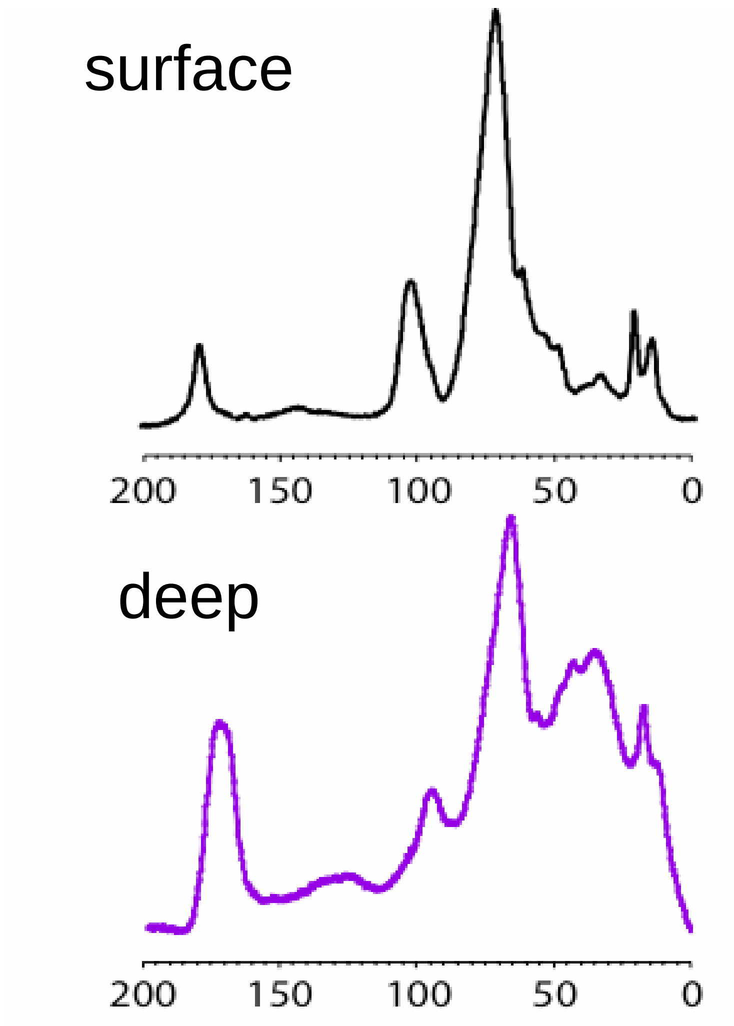


Acid hydrolysis followed by
Monosaccharide analyses
yields 7 major neutral sugars
that represent 5-10% of surface water DOM

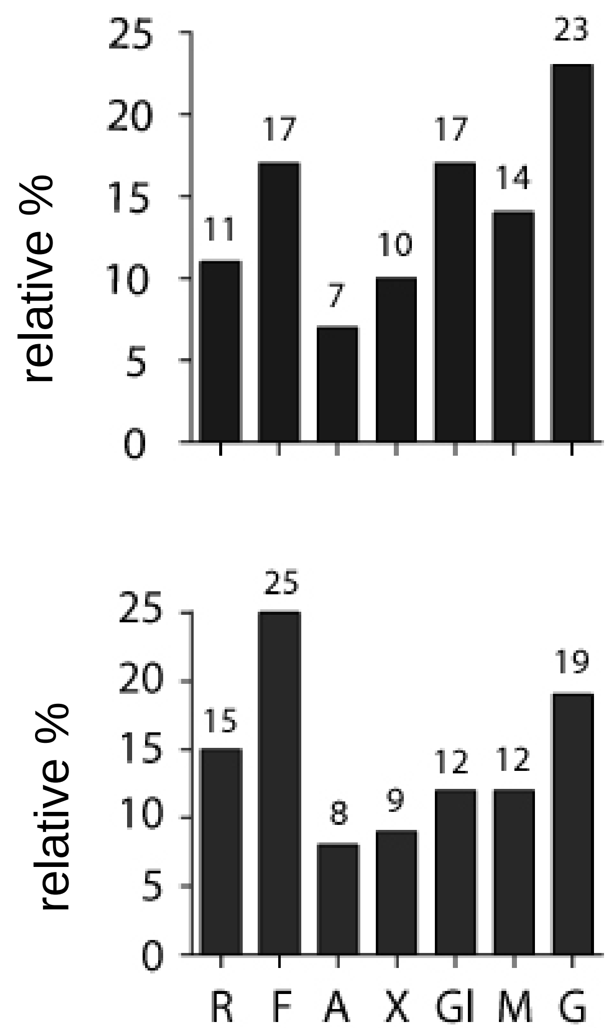
Acid
hydrolysis

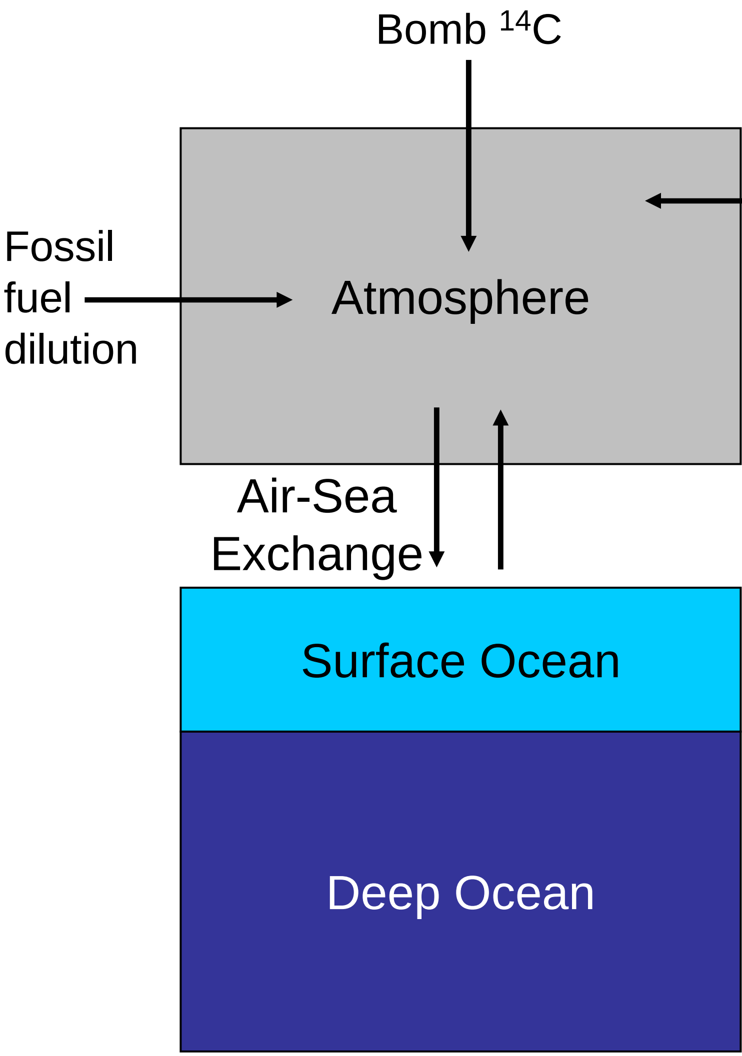


NMR and carbohydrate analyses of deep sea HMWDOC



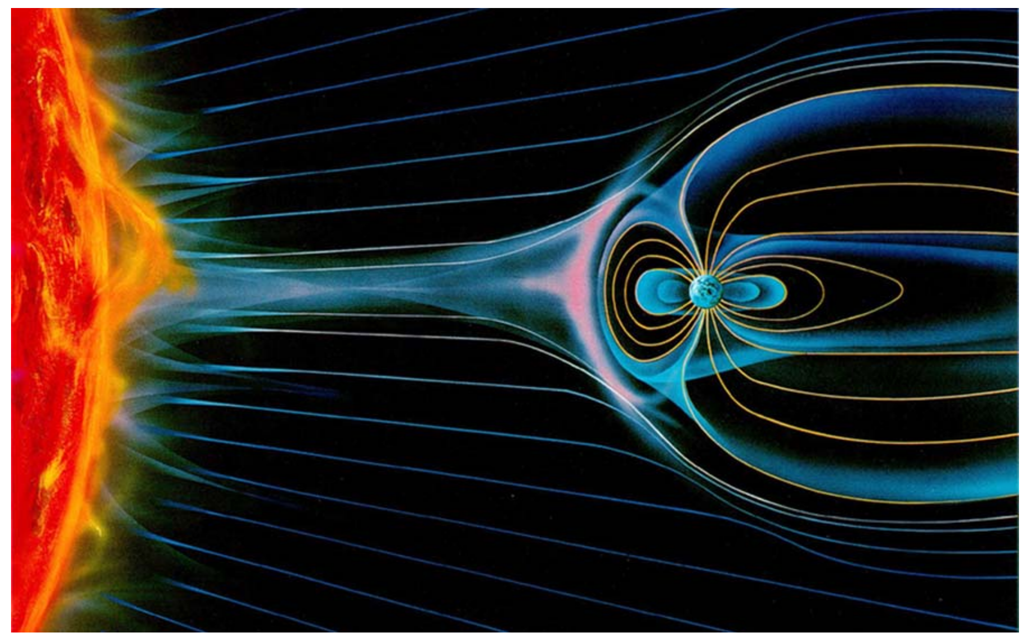
monosaccharide distribution





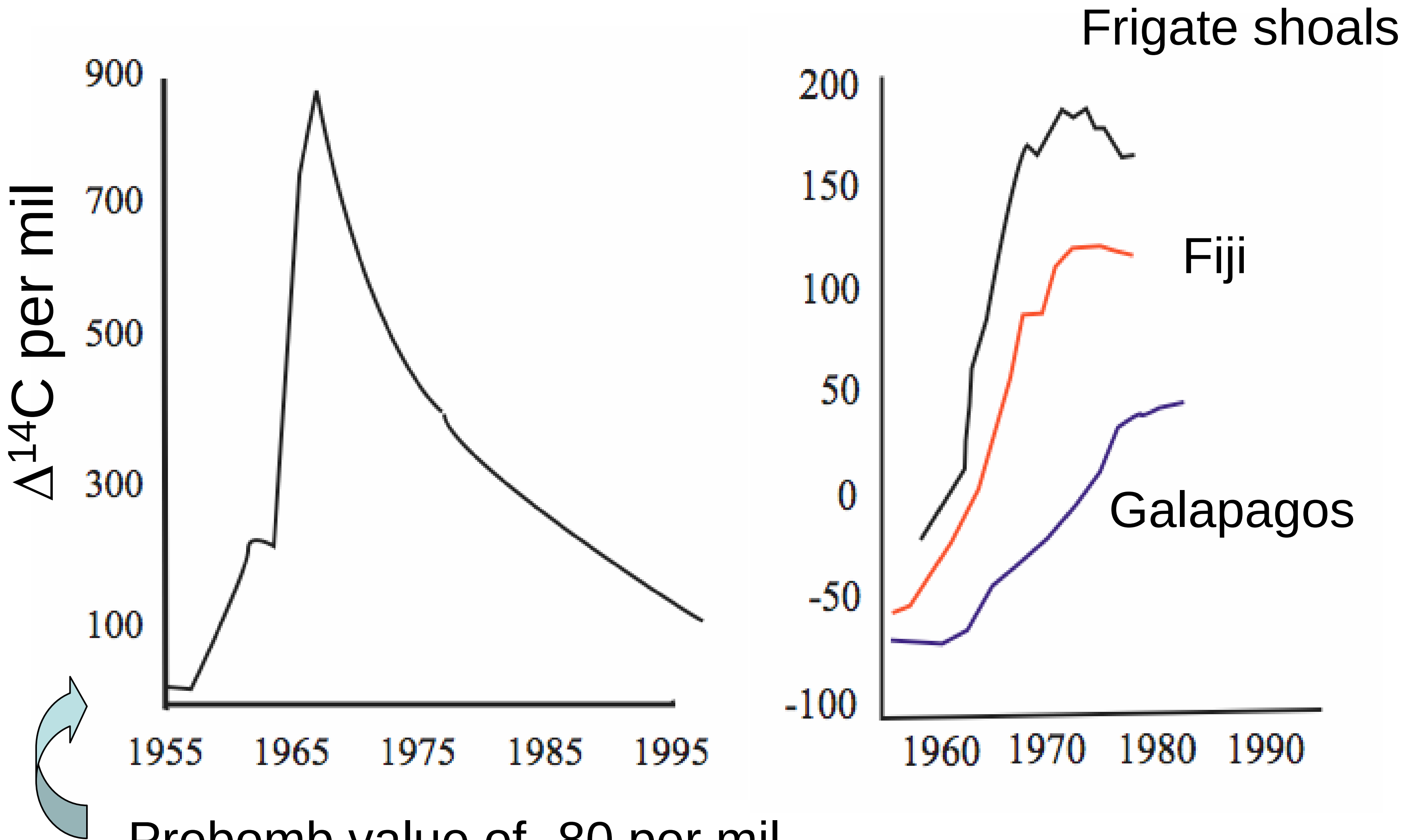
Factors controlling ^{14}C in atmospheric and oceanic reservoirs

Cosmogenic ^{14}C production



^{14}C half-life is 5730 years

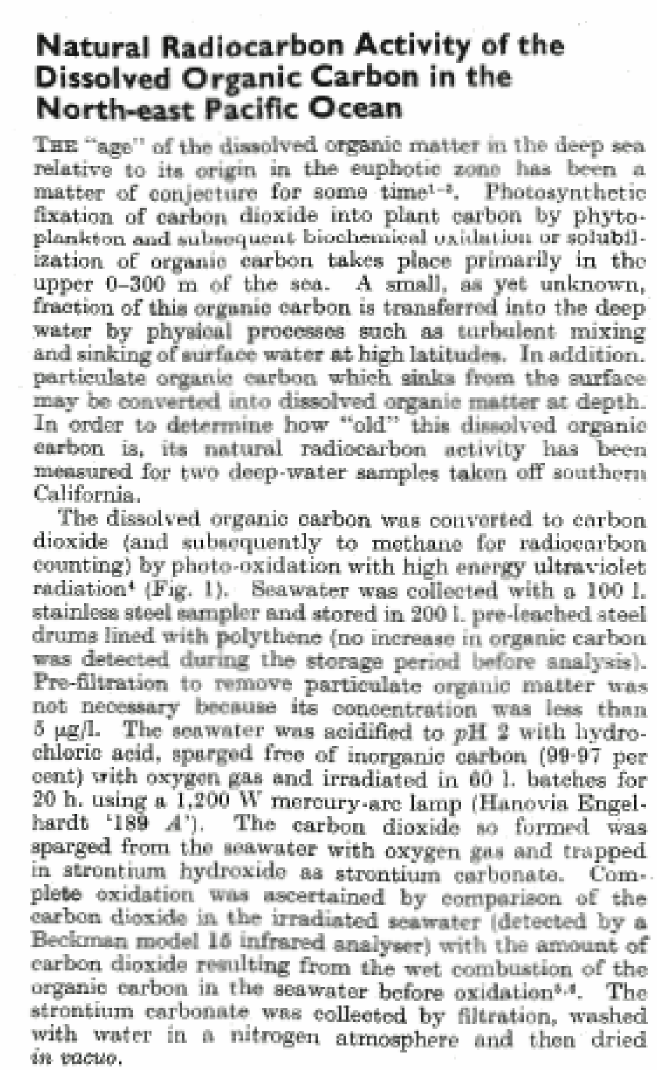
History of radiocarbon in the Atmosphere and ocean



Prebomb value of -80 per mil

DOC cycling via DO^{14}C

Williams, Oeschger, and Kinney; Nature v224 **(1969)**

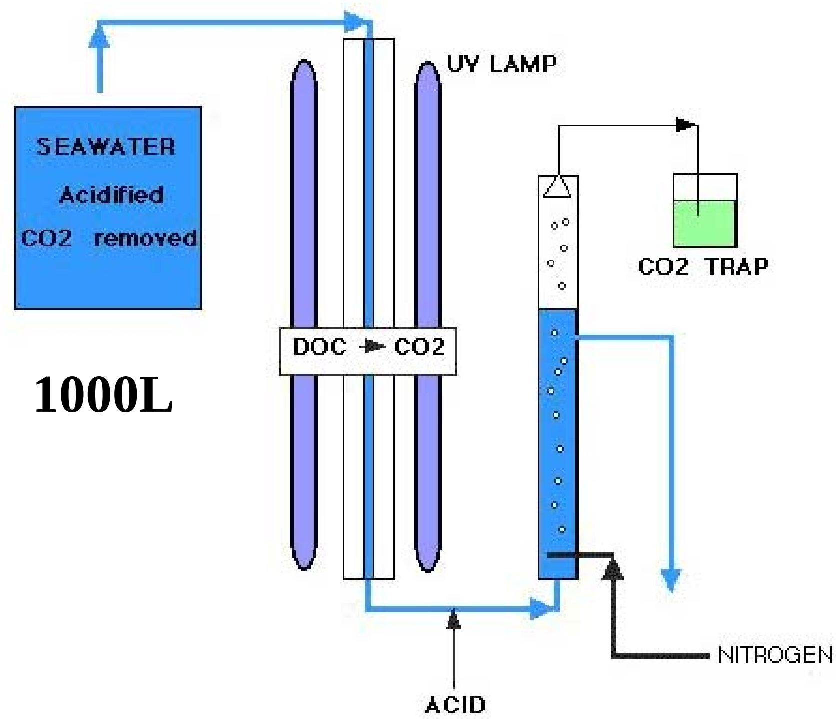


Natural Radiocarbon Activity of the Dissolved Organic Carbon in the North-east Pacific Ocean

THE "age" of the dissolved organic matter in the deep sea relative to its origin in the euphotic zone has been a matter of conjecture for some time[1-3]. Photosynthetic fixation of carbon dioxide into plant carbon by phytoplankton and subsequent biochemical oxidation or solubilization of organic carbon takes place primarily in the upper 0–300 m of the sea. A small, as yet unknown, fraction of this organic carbon is transferred into the deep water by physical processes such as turbulent mixing and sinking of surface water at high latitudes. In addition, particulate organic carbon which sinks from the surface may be converted into dissolved organic matter at depth. In order to determine how "old" this dissolved organic carbon is, its natural radiocarbon activity has been measured for two deep-water samples taken off southern California.

The dissolved organic carbon was converted to carbon dioxide (and subsequently to methane for radiocarbon counting) by photo-oxidation with high energy ultraviolet radiation[4] (Fig. 1). Seawater was collected with a 100 l. stainless steel sampler and stored in 200 l. pre-leached steel drums lined with polythene (no increase in organic carbon was detected during the storage period before analysis). Pre-filtration to remove particulate organic matter was not necessary because its concentration was less than 5 μg/l. The seawater was acidified to *p*H 2 with hydrochloric acid, sparged free of inorganic carbon (99·97 per cent) with oxygen gas and irradiated in 60 l. batches for 20 h. using a 1,200 W mercury-arc lamp (Hanovia Engelhardt '189 *A*'). The carbon dioxide so formed was sparged from the seawater with oxygen gas and trapped in strontium hydroxide as strontium carbonate. Complete oxidation was ascertained by comparison of the carbon dioxide in the irradiated seawater (detected by a Beckman model 15 infrared analyser) with the amount of carbon dioxide resulting from the wet combustion of the organic carbon in the seawater before oxidation[5,6]. The strontium carbonate was collected by filtration, washed with water in a nitrogen atmosphere and then dried *in vacuo*.

UV photooxidation

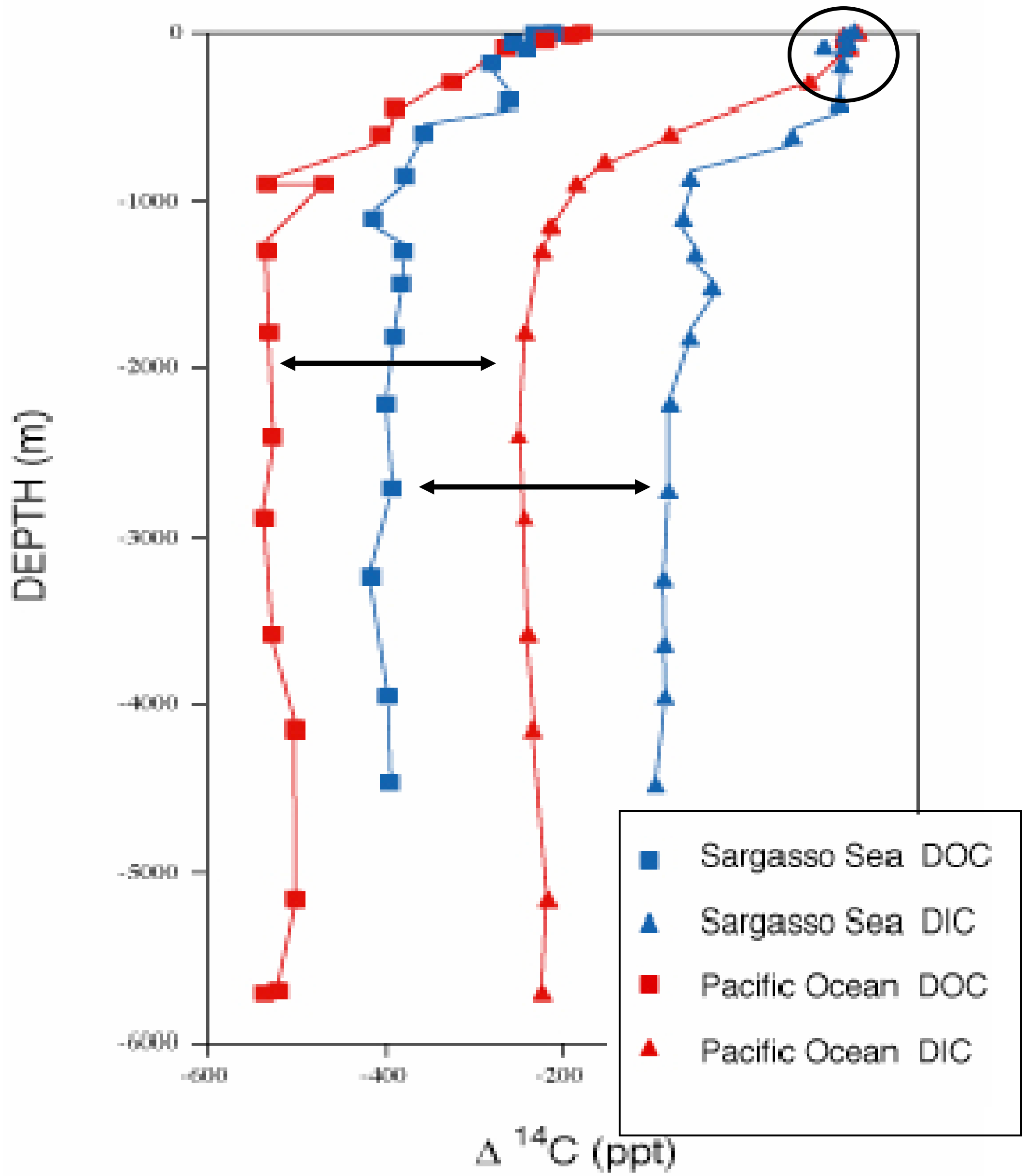


1000L

Depth	Δ14C(‰)	Age
1880m	-351 ‰	-3470±330 ybp
1920m	-341 ‰	-3350±300 ybp

Radiocarbon in the Atlantic and Pacific Oceans

Peter M. Williams and Ellen Druffel; Nature 1987, JGR 1992



DIC ^{14}C in surface waters of the Atlantic and Pacific has the same isotopic value.

DOC is always older than DIC (by 4 kyrs in surface water)

Deep ocean values of DOC are equal to a radiocarbon age of 4000-5000 yrs

Either there is a source of “old” DOC, or DOC persists for several ocean mixing cycles