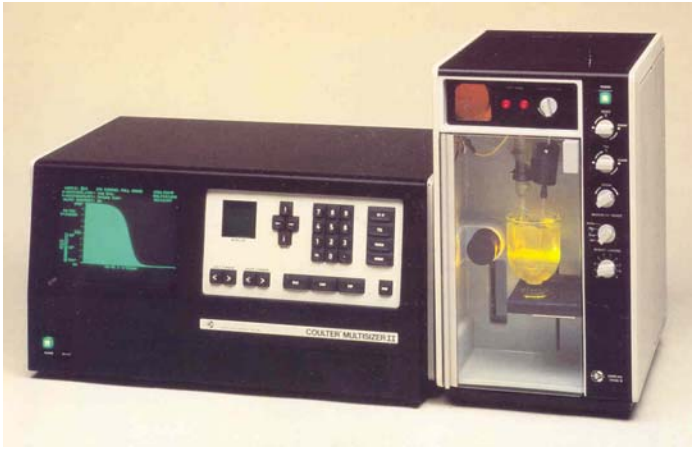
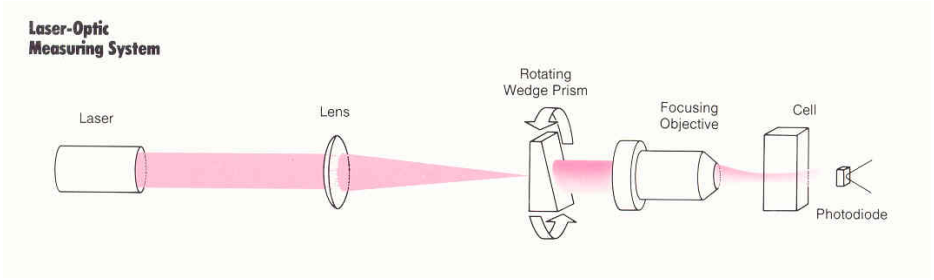




Particle Sizing Systems:

Ex-situ techniques

Different instruments are available– Particle sizes

TABLE 13.7 Different Instruments Used to Measure Particle Size Distributions

Instrument Type	Function	Size Range (μm)
Photon correlation spectroscopy; multiangle laser measurement (Coulter N4 Plus)	Size distribution	0.003–3
Laser diffraction (Coulter LS 100Q)	Size distribution	0.4–950
Laser diffraction (Malvern Mastersizer X)	Size distribution	0.1–2000
Laser time-domain analysis (Galai Cis 2)	Size distribution	0.7–1200
Aperture impedance systems with orifice detection (Coulter Multisizer, Elzone Particle Sizer)	Size distribution, particle concentration	0.4–1200
Acoustic techniques (Matec Applied Sciences)	Size distribution, zeta potential	0.08–10
Capillary hydrodynamic fractionation (Matec CDHF-2000)	Size distribution	0.015–1.1
Dual laser beam/photon correlation spectroscopy (Malvern Zetasizer 4)	Size distribution, zeta potential	0.010–30
Light transmission with orifice (HIAC/Royco Division; Pacific Scientific Co.)	Size distribution, particle concentration	2–400
Settling velocity with *x-ray* detection (SediGraph 5100, Micromeritics)	Size distribution	0.1–300
Image analysis of filtered particles or photographs	Size distribution, particle concentration	>0.2

Laser systems: 0.003 to 2 um

Coulter model N4

Laser systems: 0.3 to 950 um

Coulter model LS

Other Laser-based systems: 0.7 to 1200 um

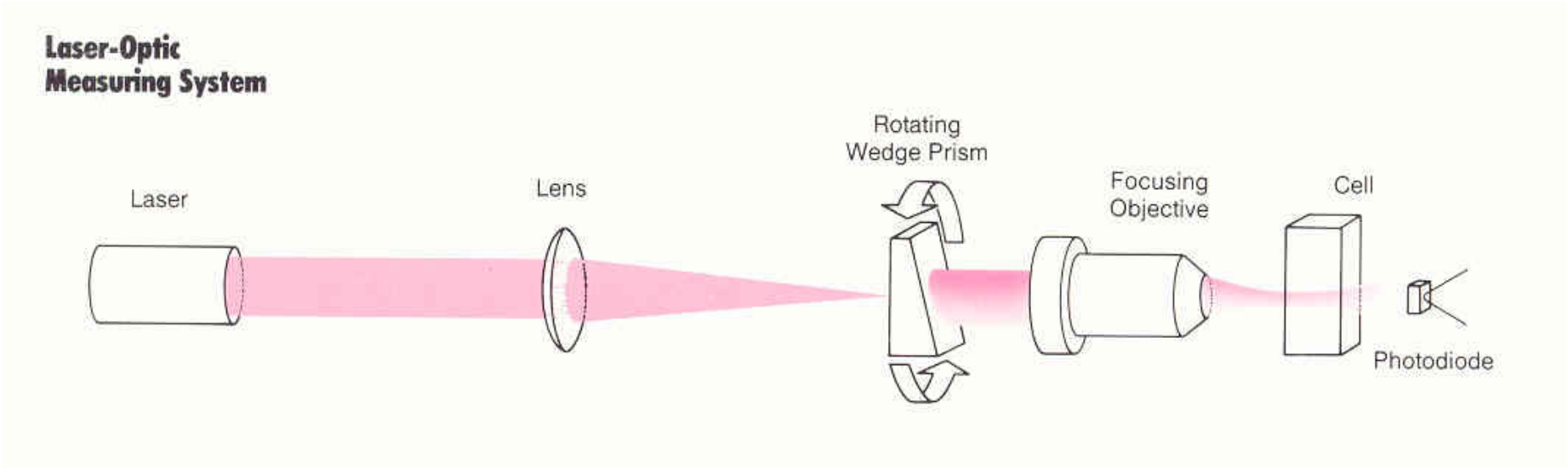
Galai Cis-2 System

Other Laser-based systems: 0.7 to 1200 um

Galai Cis-2 System

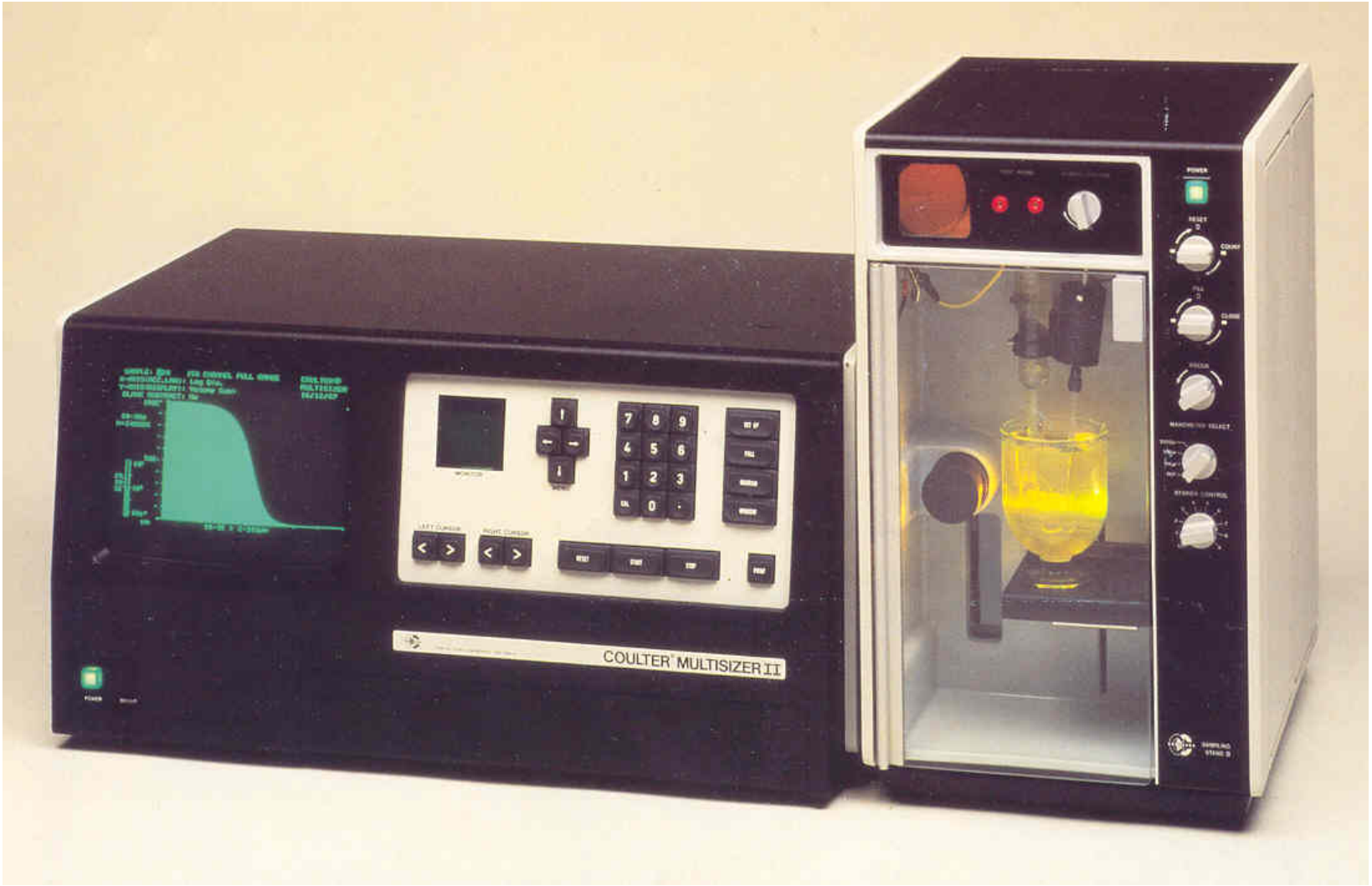
Other Laser-based systems: 0.7 to 1200 um

Principle of operation: Cis 2 system



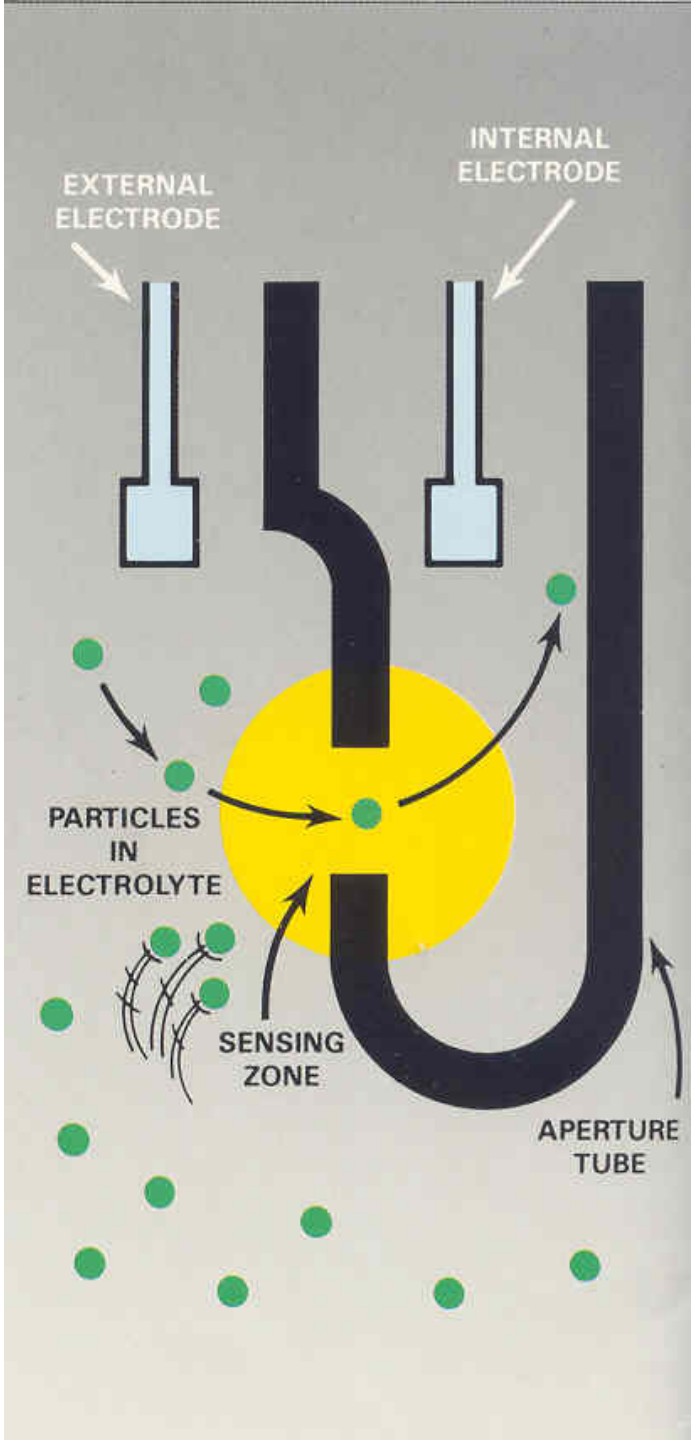
Galai Cis-2 System

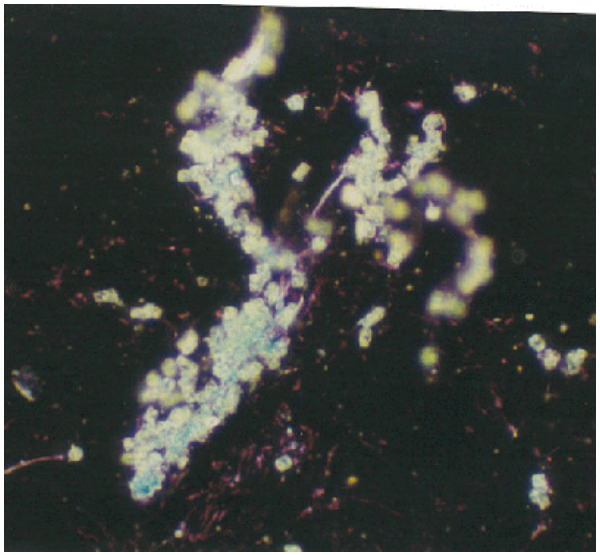
Resistance-type Particle Counter-solid volume (Coulter Counter)

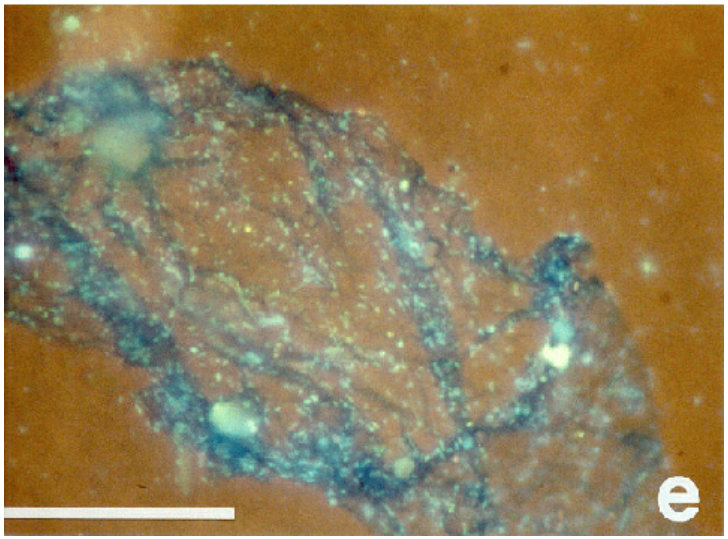


Resistance-type Particle Counter:

Principles of operation







What controls Diatom Coagulation?

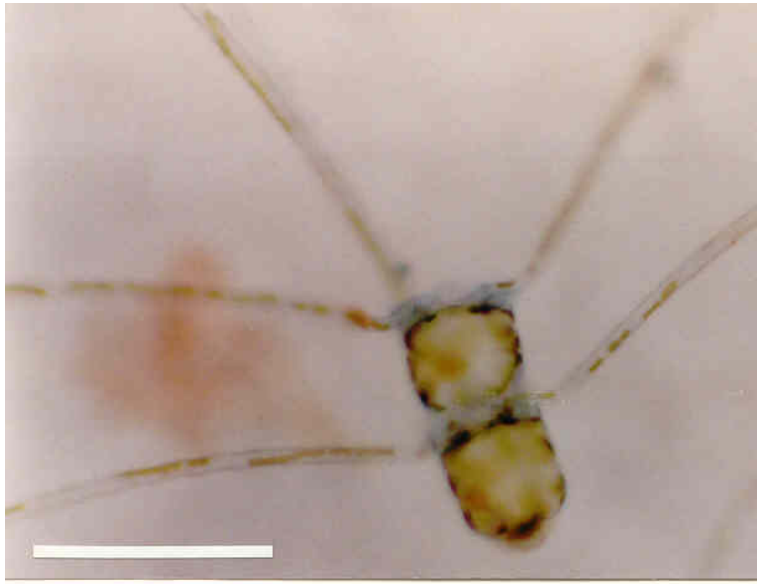
The Discovery of TEP

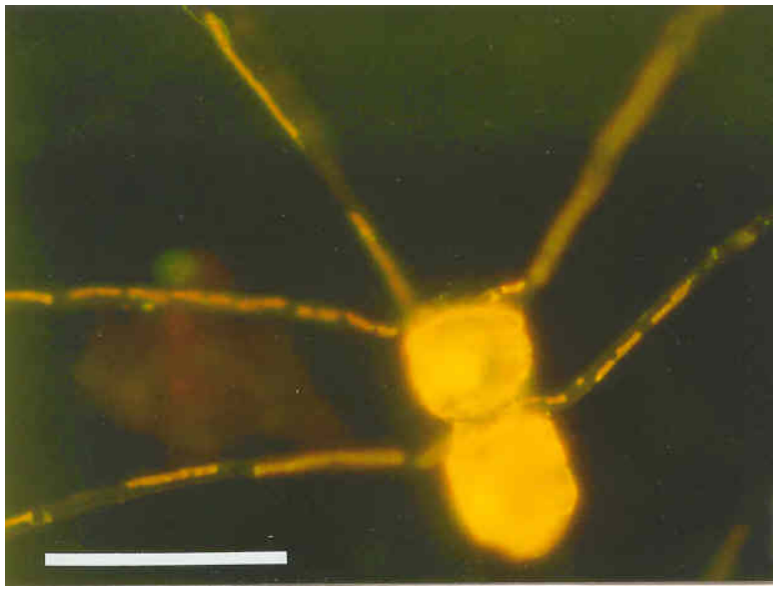
TEP was accidentally discovered during a coagulation test to measure diatom sticking coefficient (α)

• A laboratory culture of *Chaetoceros gracilis* was grown to high concentration

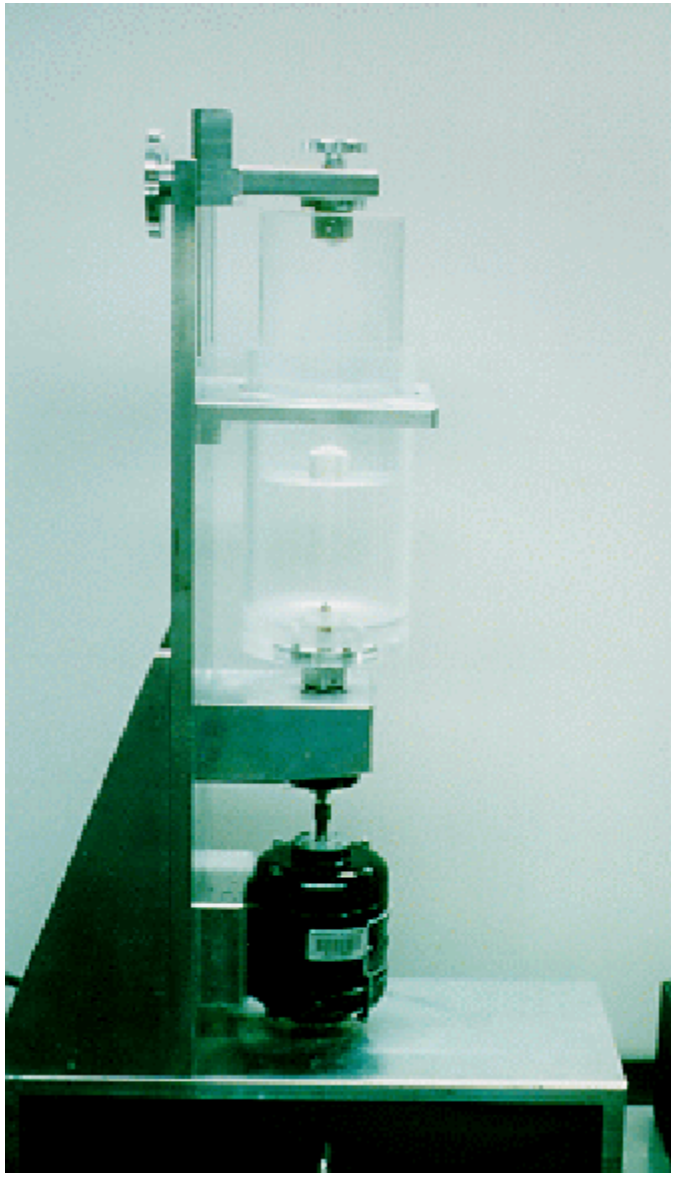
•The culture was placed into a couette device to obtain a uniform and laminar shear environment

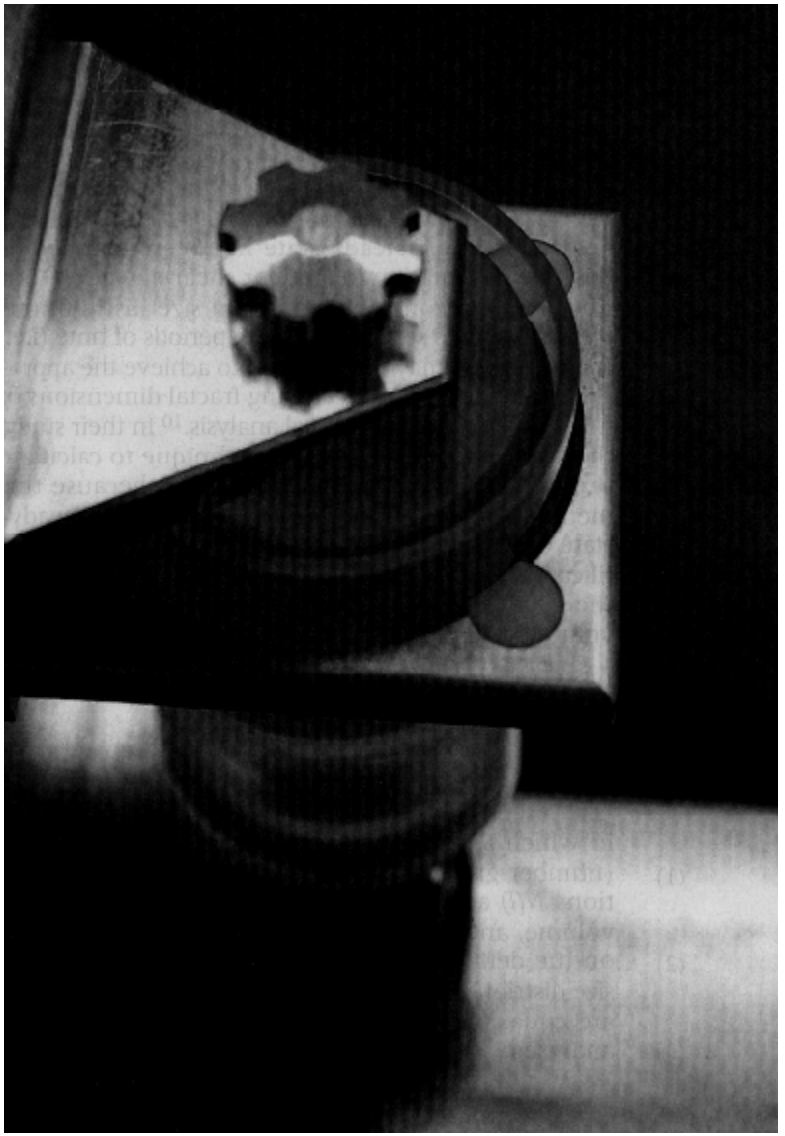
•The sticking coefficient was calculated by measuring the decrease in the number of particles over time (direct microscopic measurements).





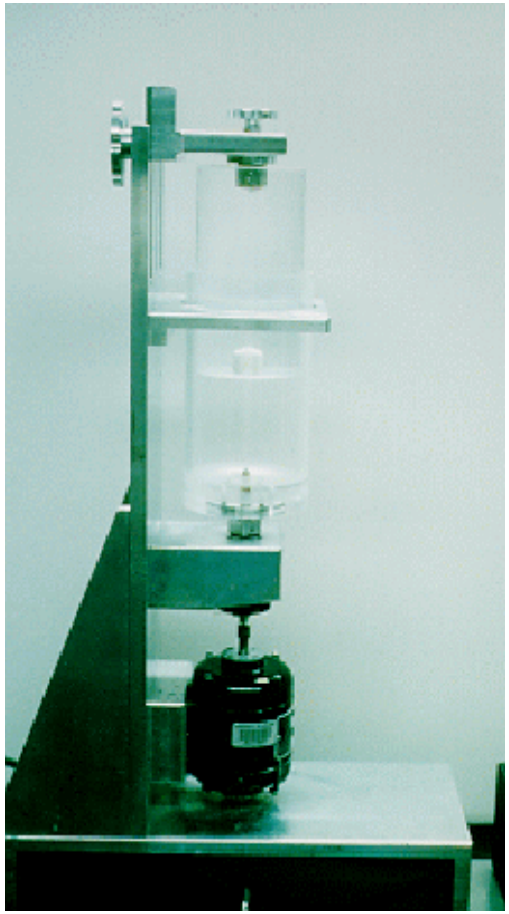
Couette device: laminar shear



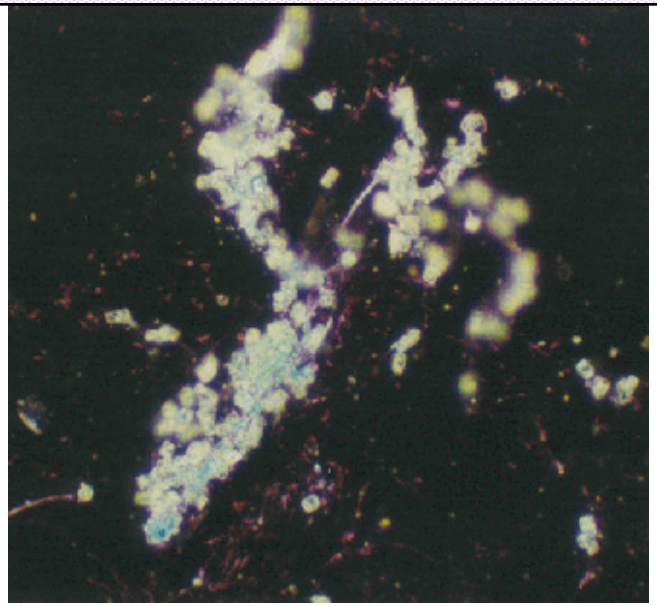


From: Jiang and Logan (1996) J. AWWA

How do Marine Aggregates form so fast from non-spherical particles such as phytoplankton?



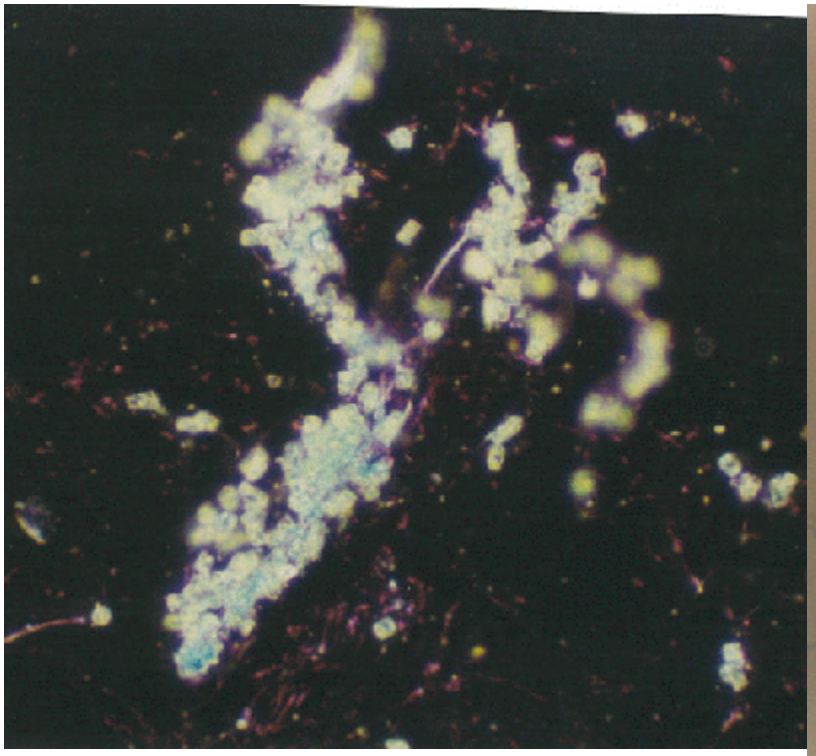
Coagulation tests:
aggregates formed very fast

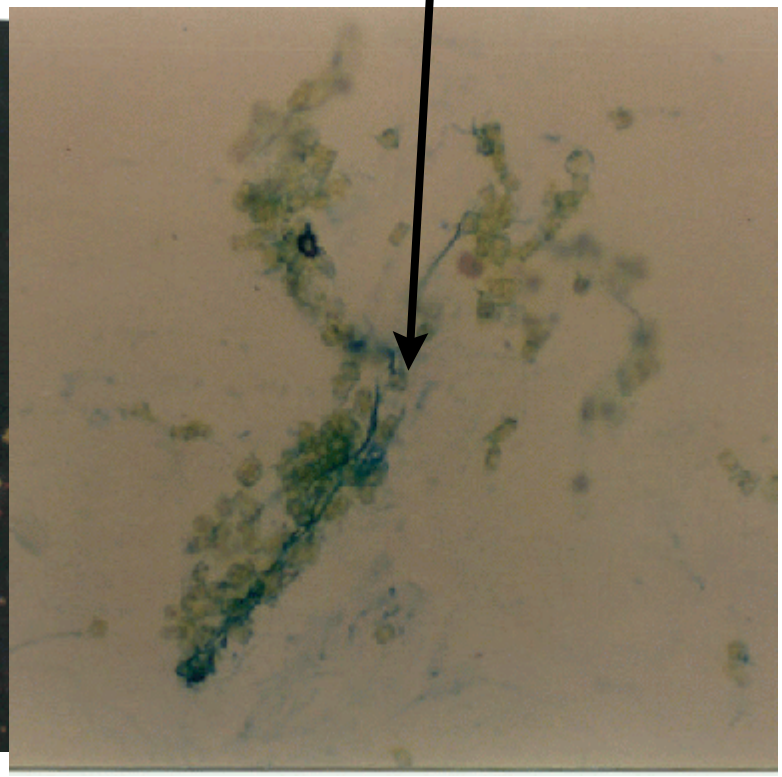


TEP particles drive phytoplankton coagulation

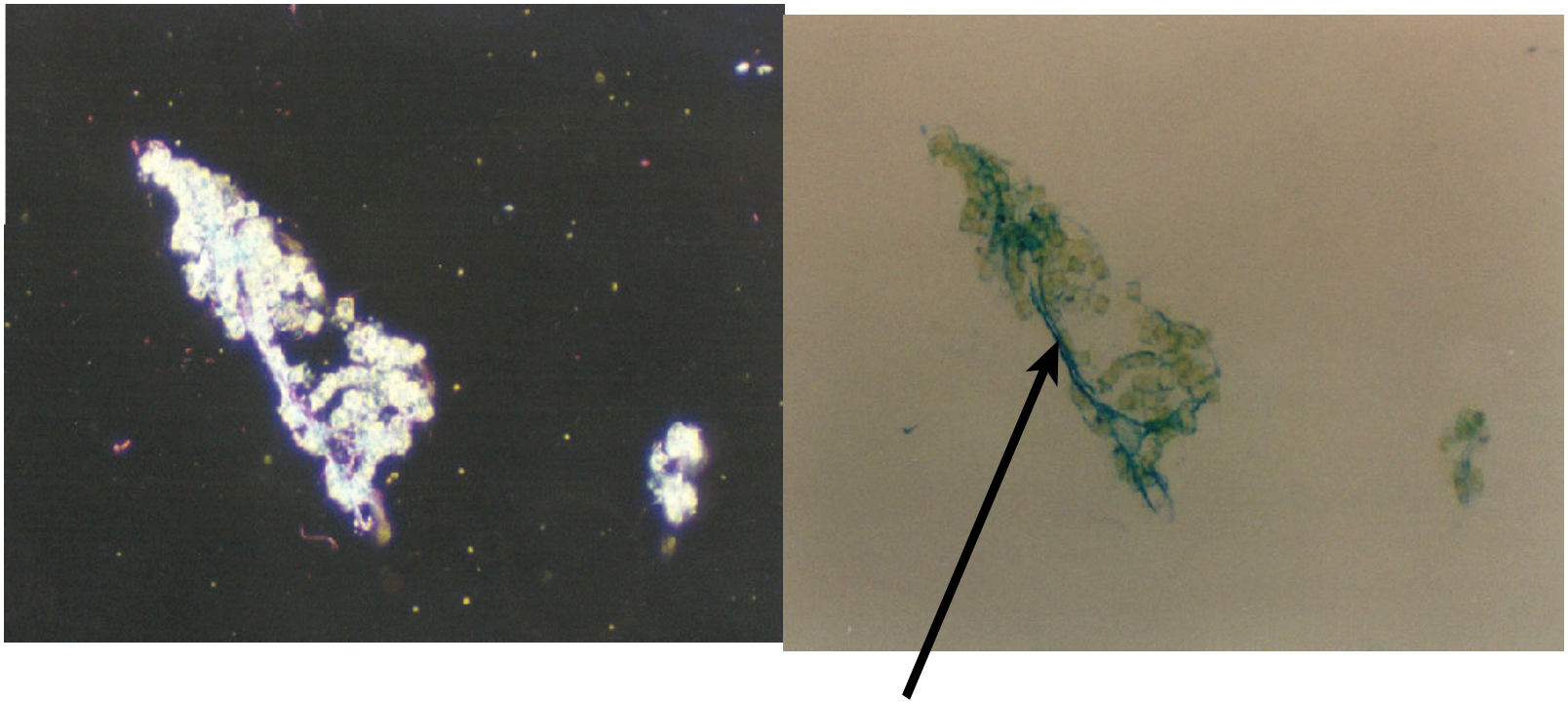
TEP= Transparent Exopolymer particles

TEP can be stained using alcian blue dye (negatively charged polysaccharides)



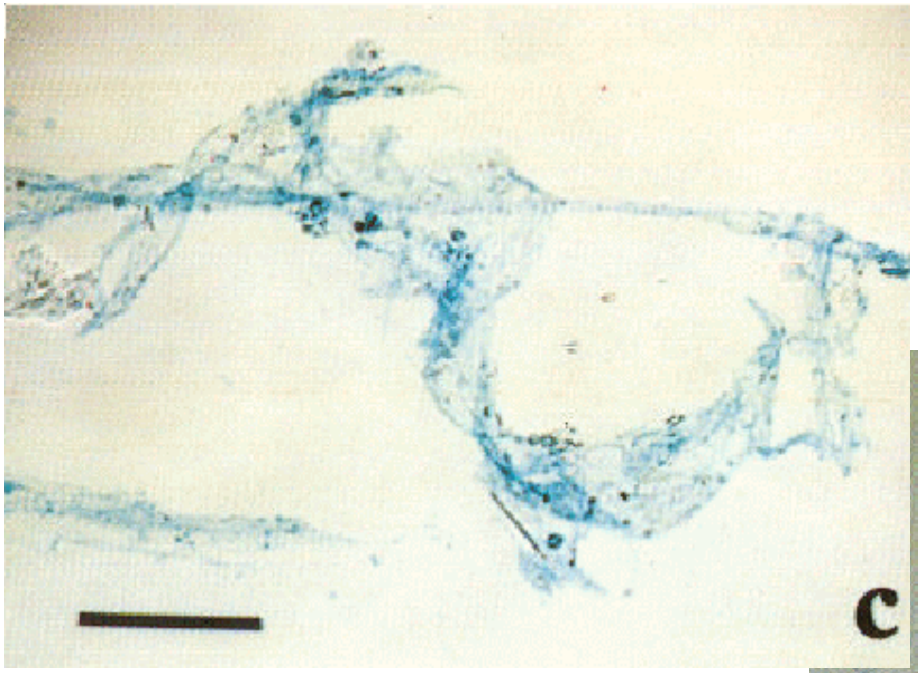


Brightfield image shows
Phytoplankton (*Chatoceros gracilis*)
but not TEP

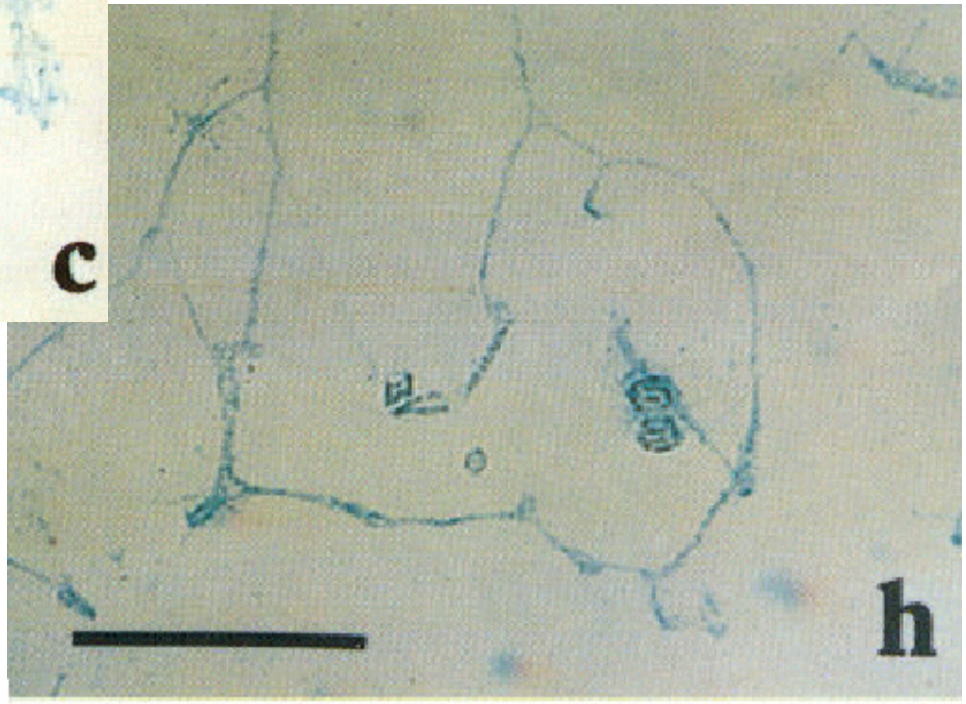


Staining with alcian blue
makes TEP visible

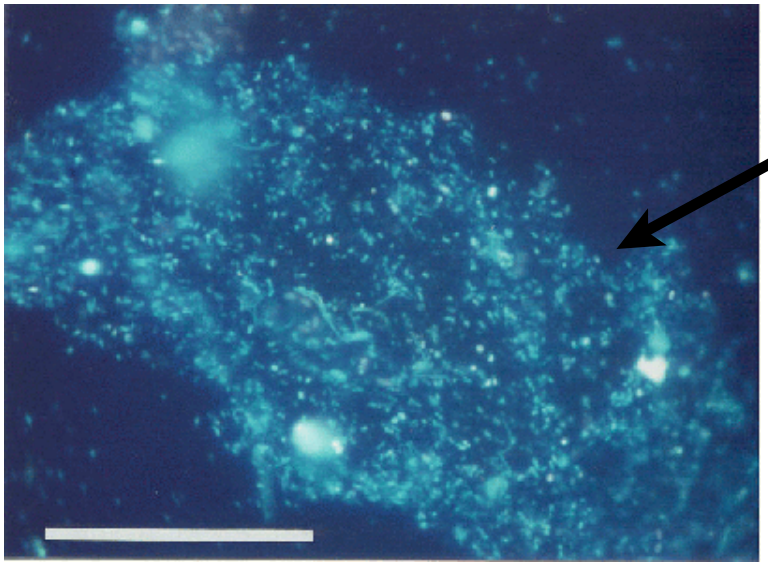
TEP in seawater samples has a fractal morphology (CA Coast)



TEP coagulates, dragging other particles along with it.

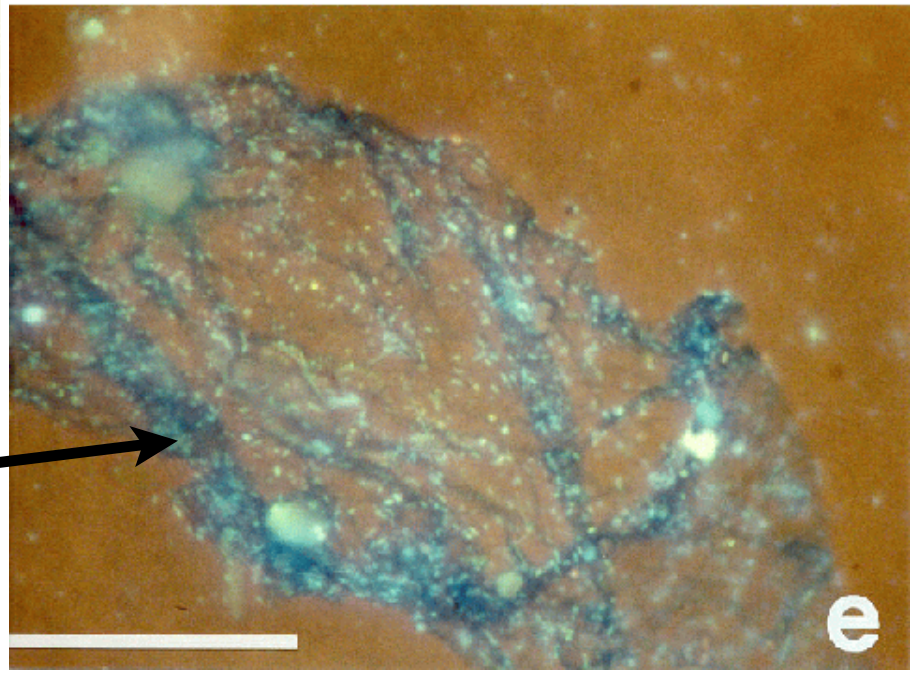


TEP in Lake Constance (Germany)



Lake snow aggregate shows bacteria after staining with DAPI

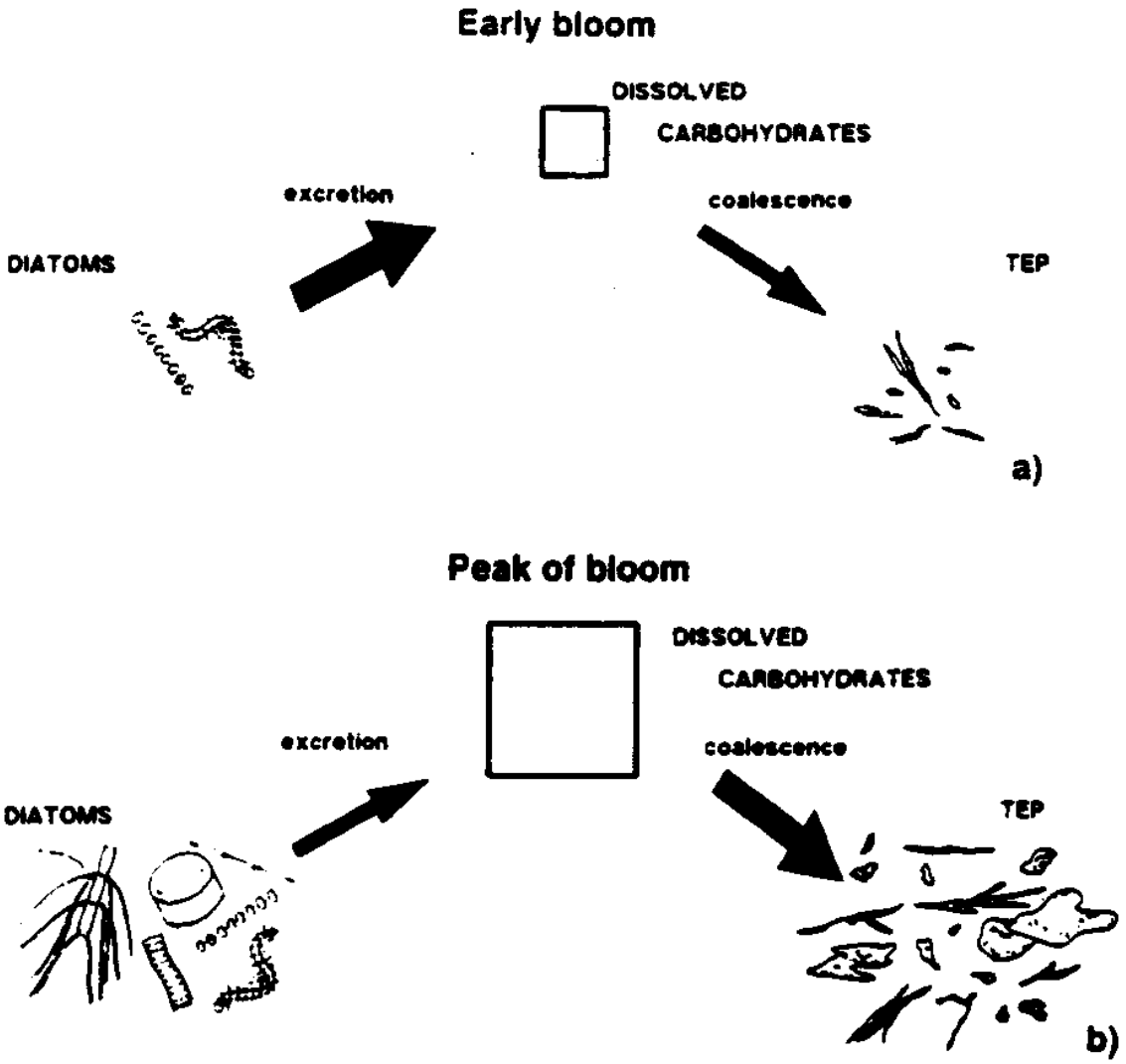
TEP is visible here after staining with alcian blue



How Does A Phytoplankton Bloom Coagulate to Form Marine Snow?

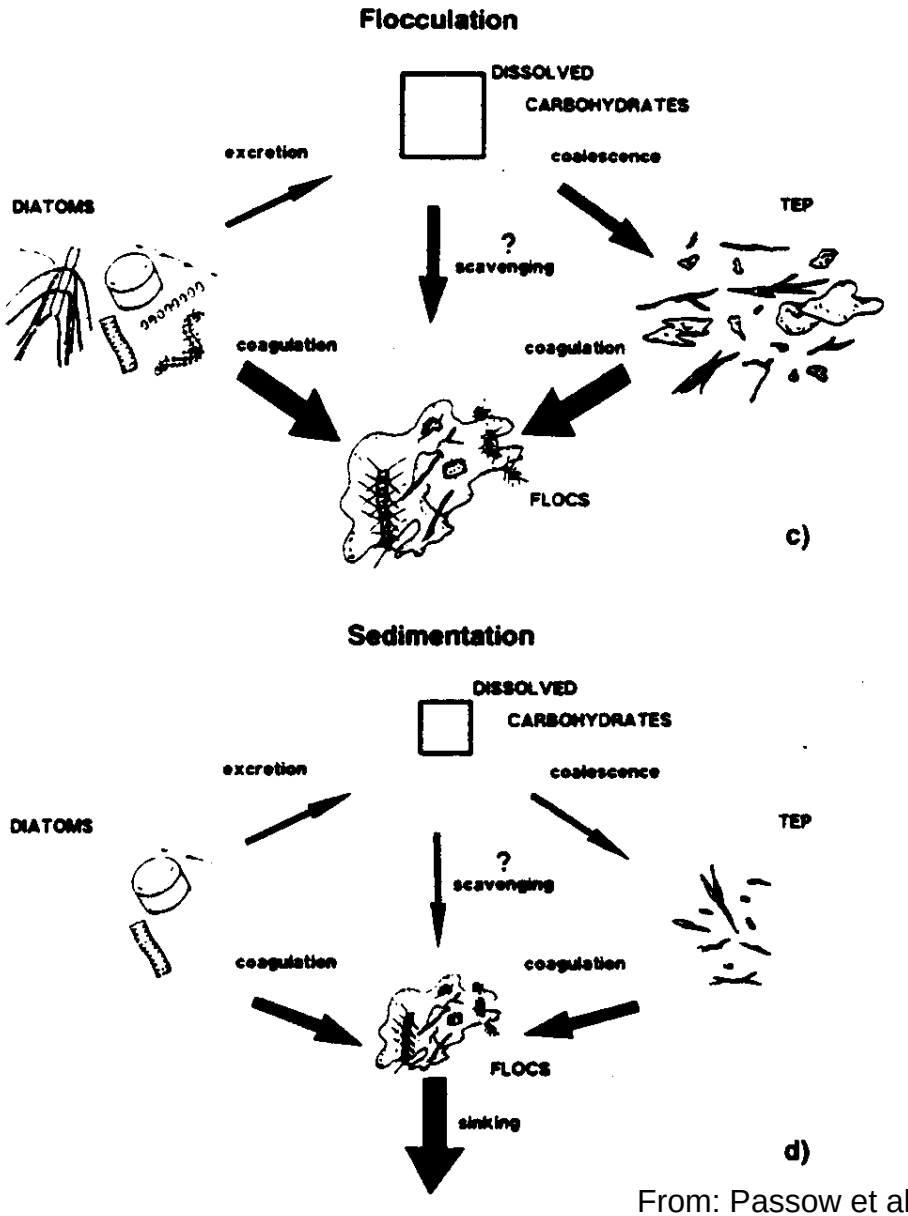
- Phytoplankton bloom necessary for aggregate formation (high concentration of diatoms)
- As diatoms increase in number, they exude high concentrations of polysaccharides
- The polysaccharides coagulate into HMW compounds, and then form fractal fibrils we called TEP
- As the TEP coagulate, diatoms and other material in the water column are captured and form marine snow aggregates.

Cycle of Marine Snow Formation from Diatoms



From: Passow et al. 1994, *Deep Sea Res.* I, 41, 335

Cycle of Marine Snow Formation from Diatoms



From: Passow et al. 1994, *Deep Sea Res.* I, 41, 335

Cycle of *Chatoceros* Growth:

A: Cell density

B: Dissolved carbohydrates

C: TEP

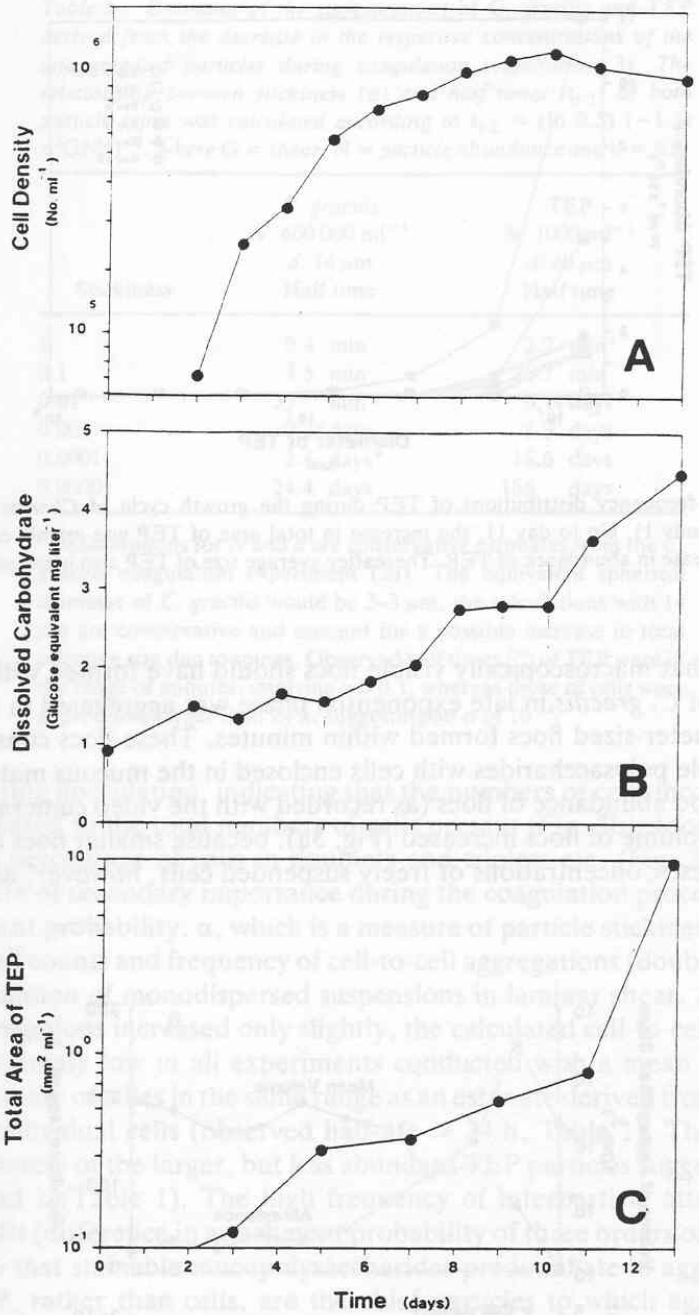


Fig. 1. Growth cycle of *Chaetoceros gracilis* (laboratory study 1): (a) Cell concentration. (b) concentration of dissolved carbohydrates and standard deviation (sometimes too small to be visible), and (c) total amount of TEP as a function of time.

From: Passow et al. 1994, *Deep Sea Res.* I, 41, 335

Potential for Snow Formation can be Estimated from Particle Half Life

Assuming TEP are a monodisperse population of particles, the coagulation rate is:

$$\frac{dC}{dt} \approx -\alpha\, k_t\, C$$

Where:

k_t= the collision constant for turbulent shear

C_0= TEP particle concentration

V_p= volume of TEP based on TEP size

G= shear rate in fluid

$$k_t = 2.48 C_0 v_p G$$

Combining, solving and simplifying, the TEP half life is calculated as:

$$t_{1/2} = \frac{\ln 2}{1.3 \alpha G C_0 l^3}$$

See: Logan et al. 1995, *Deep Sea Res.* II, 42, 203

Half lives of TEP particles in Lake Constance, Germany

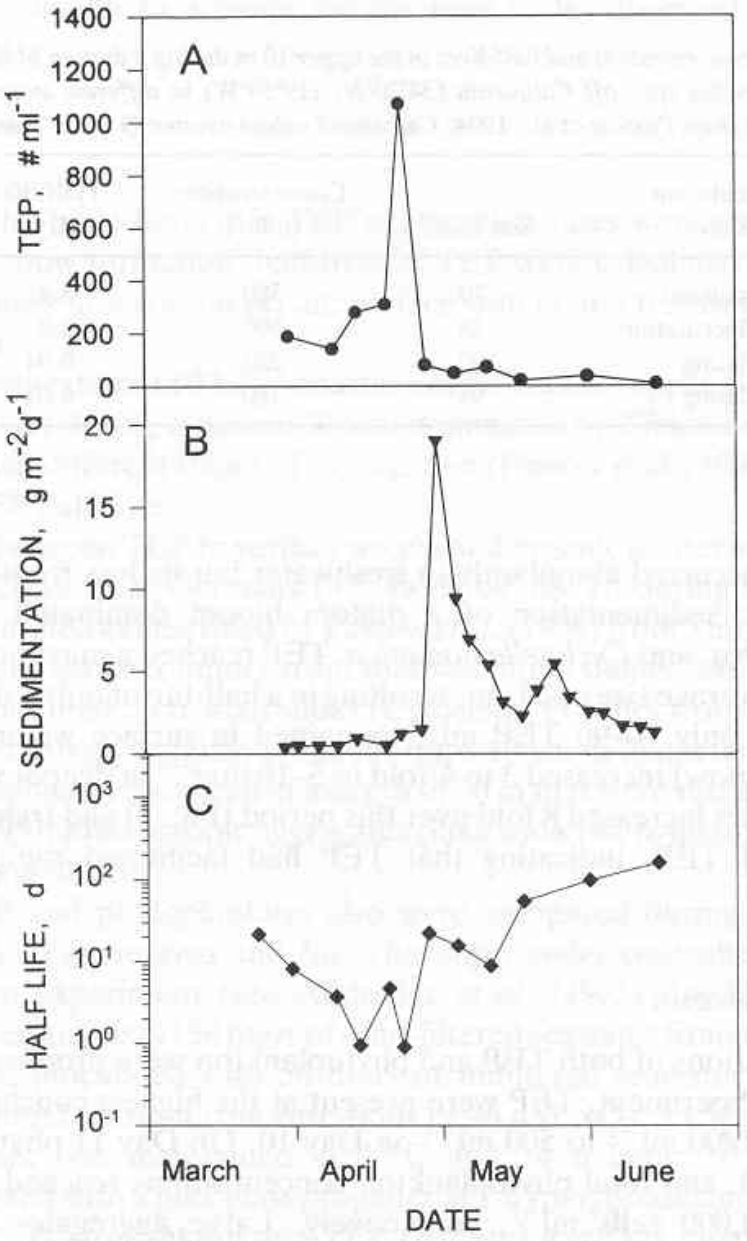


Fig. 1. (A) The concentration of TEP; (B) sedimentation rates of particulate mass; and (C) th
half lives of TEP particles in surface waters of Lake Constance during the spring of 1993. The peal
in sedimentation follows the peak and disappearance of TEP from surface waters. Short half-live
(<1 day) support high TEP coagulation rates. (Calculations assume $G = 1\ s^{-1}$ and $\alpha = 1$.)

From: Logan et al. 1995, *Deep Sea Res.* II, 42, 203

Half lives of TEP in a mesocosm during a simulated phytoplankton bloom

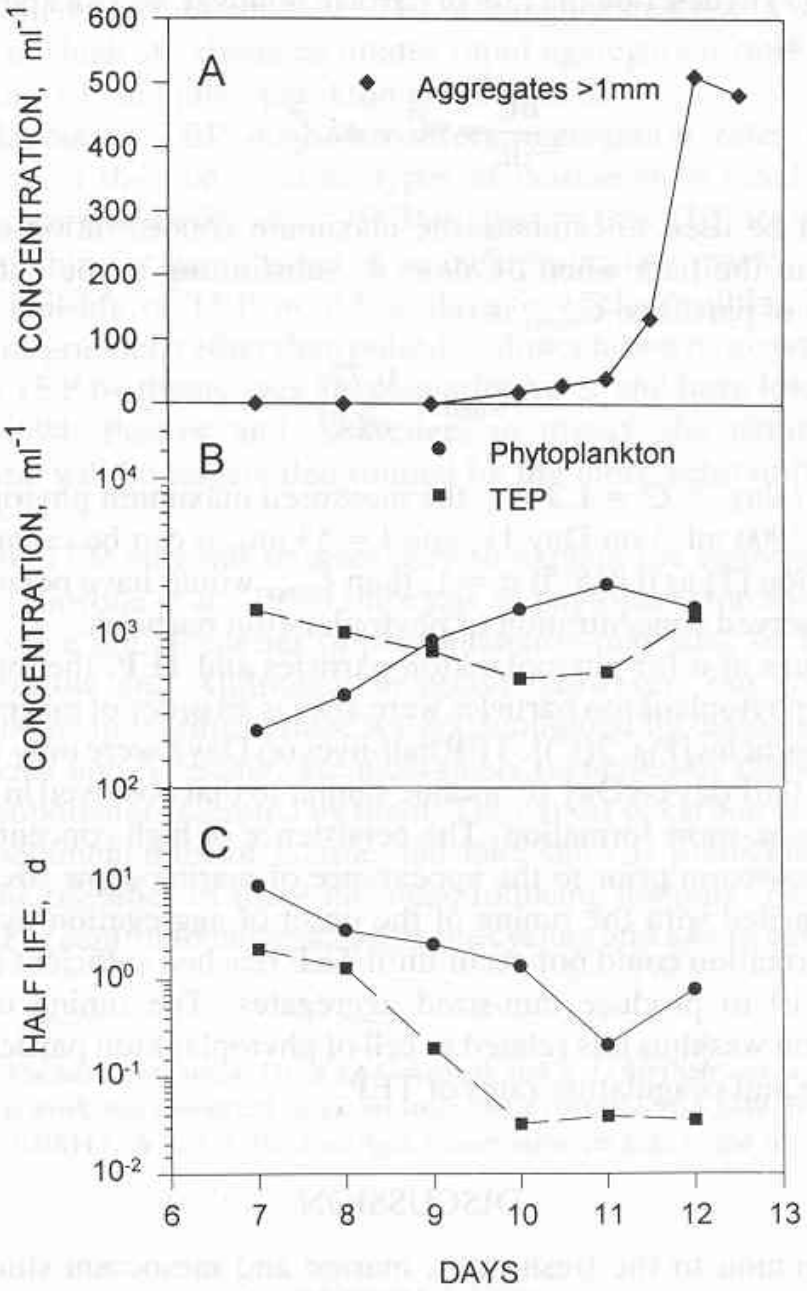


Fig. 2. (A) Size distributions, (B) concentrations, and (C) half-lives of TEP and phytoplankton particles in the mesocosm.

From: Logan et al. 1995, *Deep Sea Res.* II, 42, 203

CONCLUSIONS

- Cell-cell collision frequencies are low.
- Phytoplankton blooms result in high concentrations of particulate polysaccharides
- The coagulation of these particulate materials produces TEP
- TEP forms diatom aggregates because the TEP capture diatoms (like big, sticky, nets)