Marine Gels: Elucidating the DOM-POM Continuum

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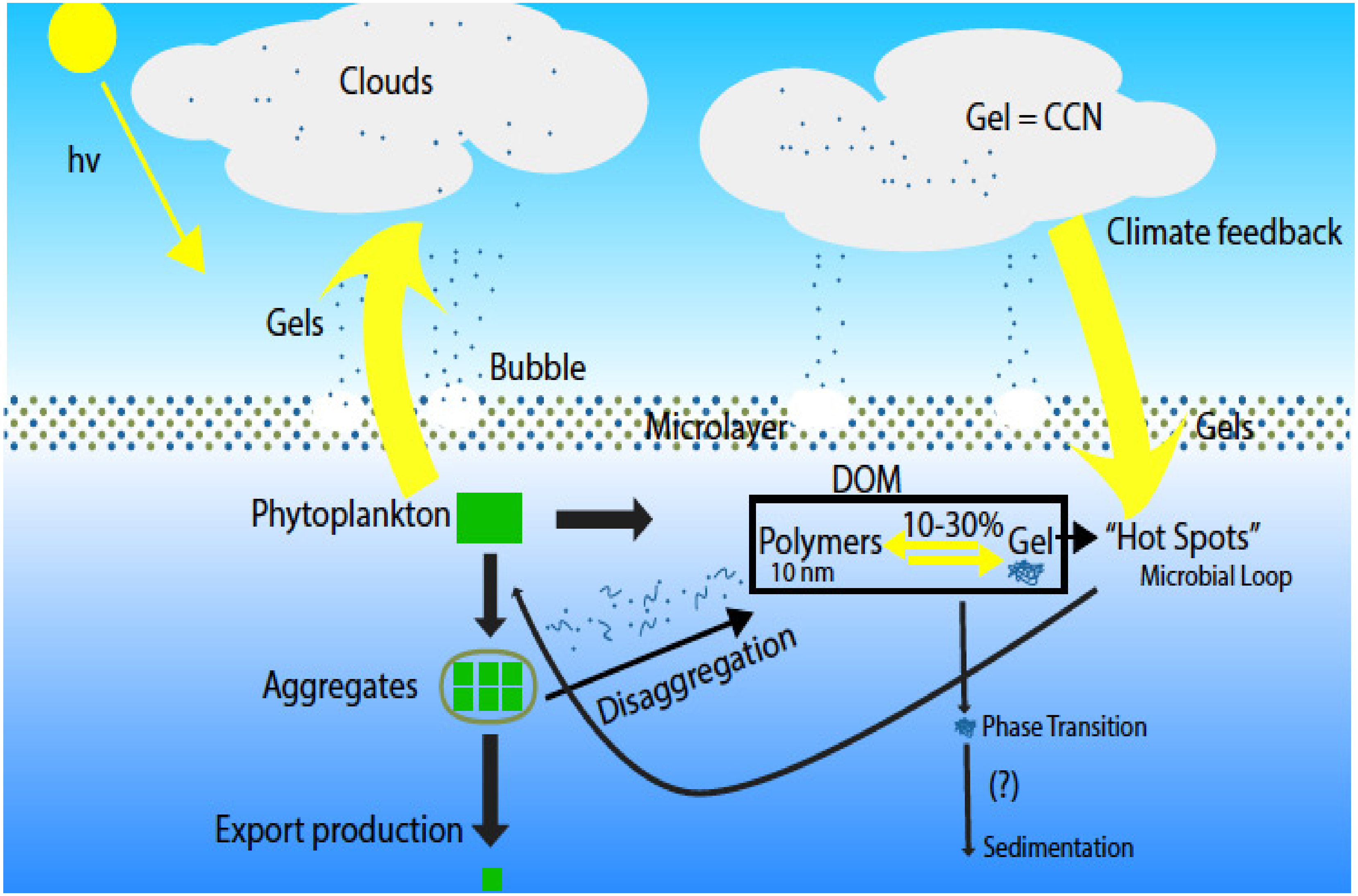
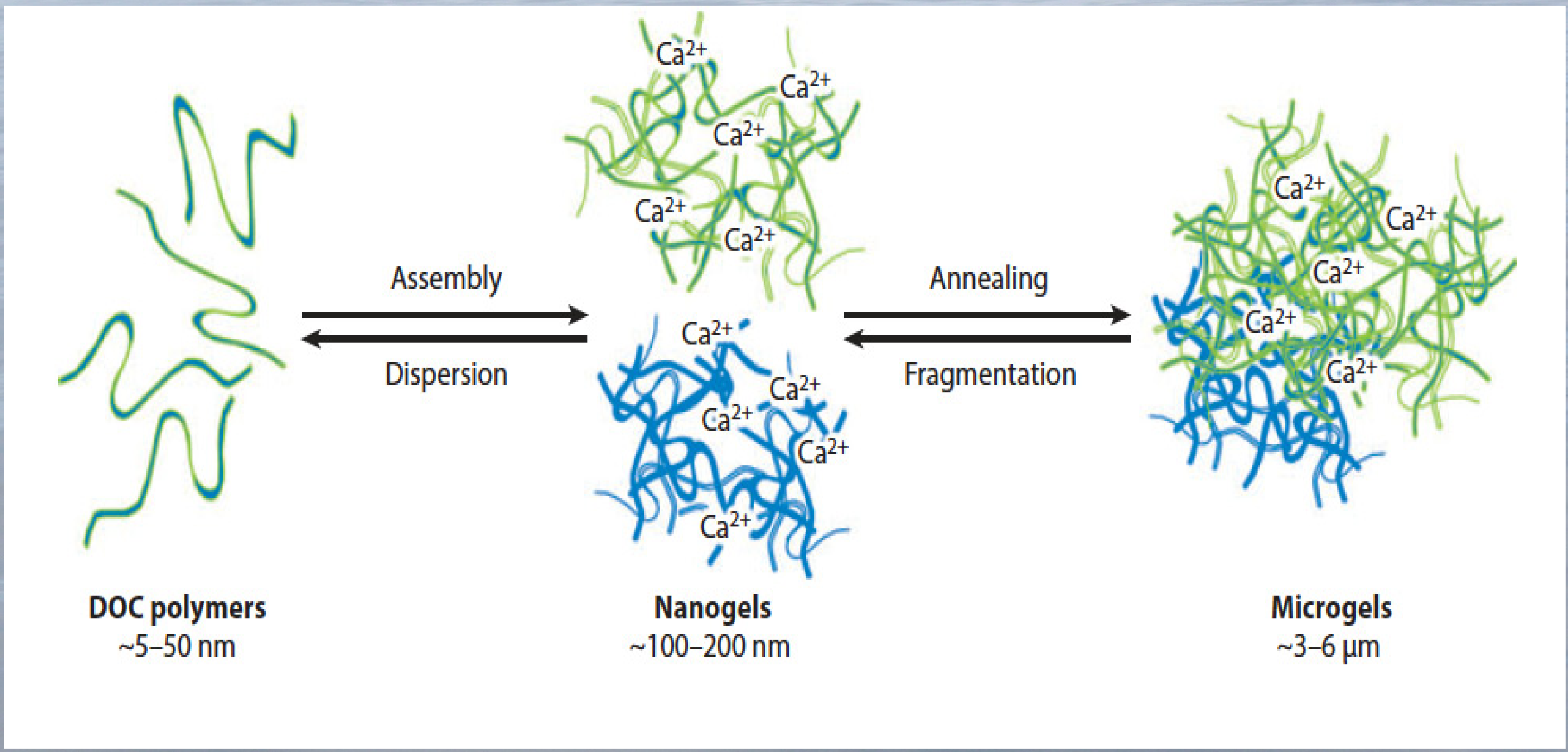
Marine Microgels



Orellana and Leck, 2015

The dissolved-particulate continuum

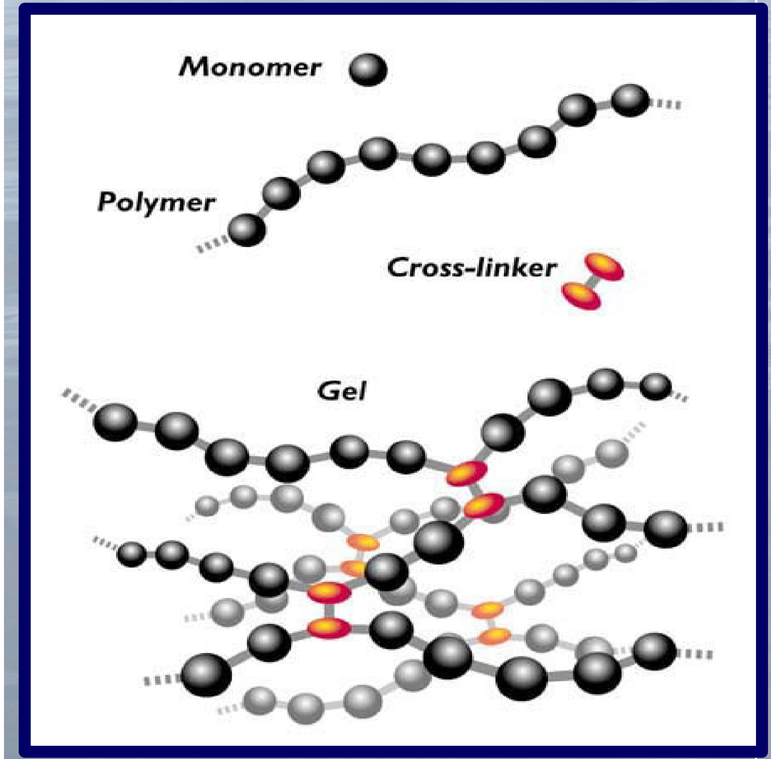
Thermodynamic yield of assembly



Orellana and Verdugo, 2003
Verdugo, 2012

Dissolved Organic Matter

662 Pg C (Hansell et at. 2009)



Operationally defined

filter: 0.7, 0.45, 0.22 (μm)

Complex pool (mostly unknown)

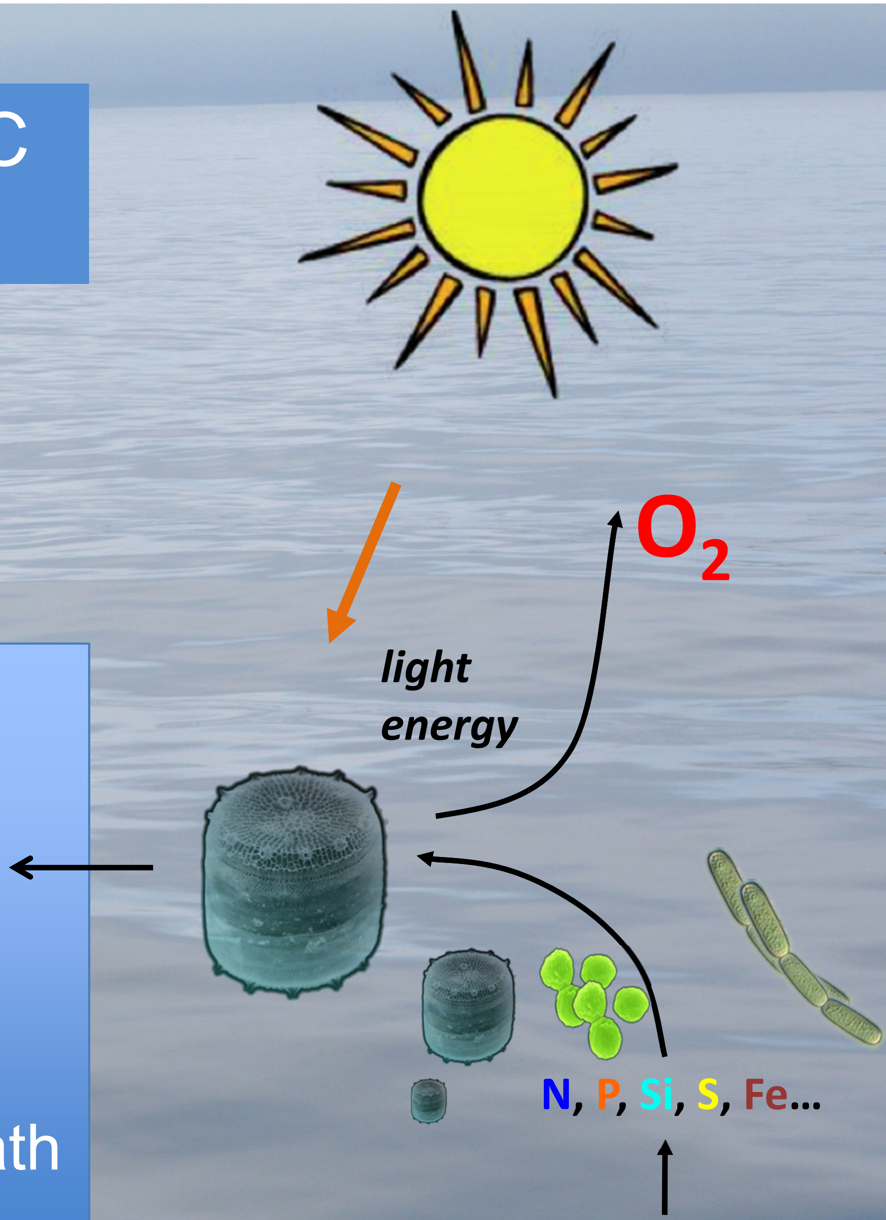
carbohydrates,
proteins
lipids,
nucleic acids
metabolites
lignins
DOC/ DON/CDOM

Sources (?) Sinks (?) Dynamics (?)
Role of polymers (?)

Primary Production: 48.5 PgC
(20-50%) released as DOM

Processes: DOM

Extracellular release
Viral lysis
Regulated secretion and exocytosis
Apoptosis, programmed cell death
Grazing
Dissolution of large particles

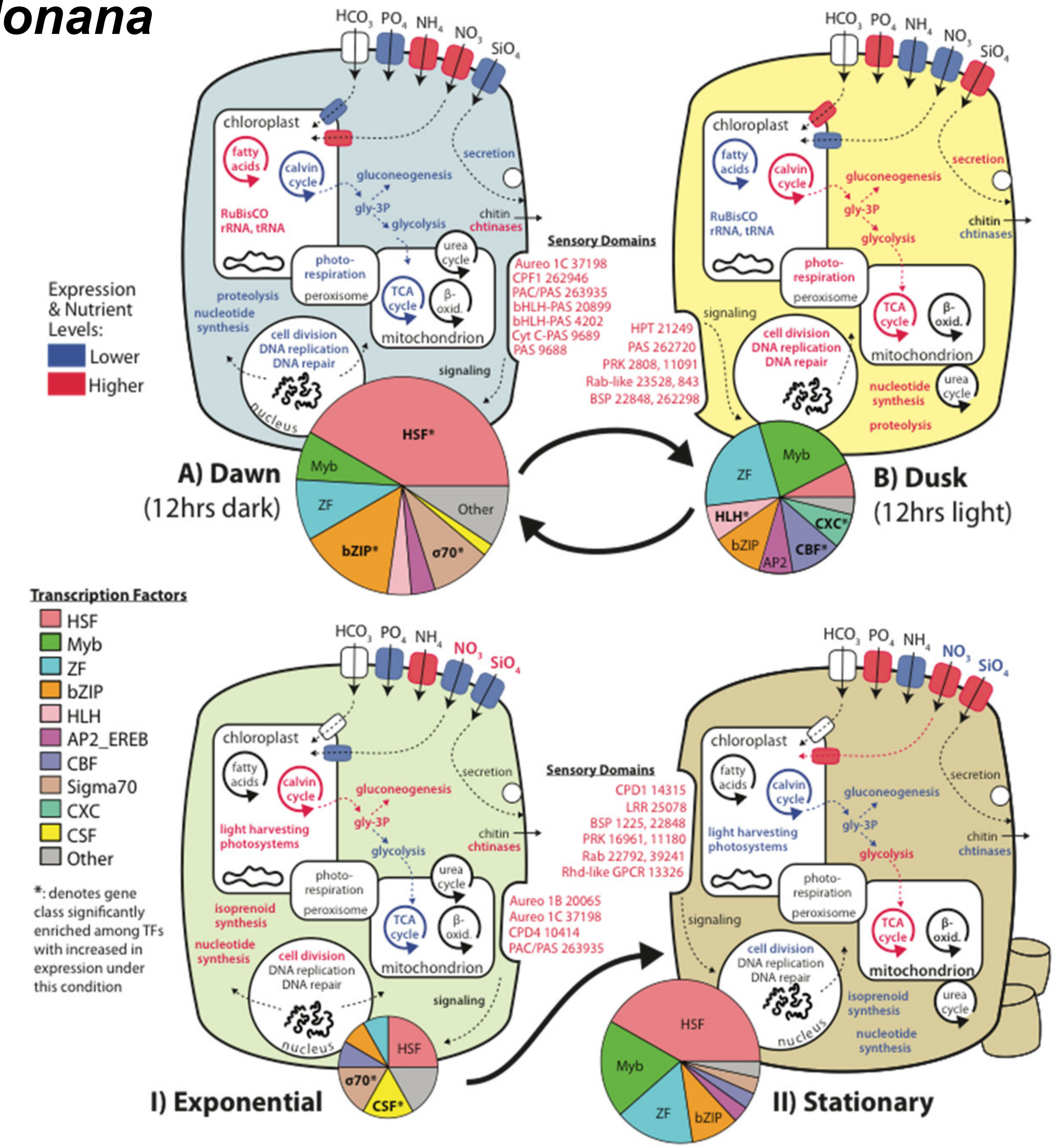


Mechanisms of biopolymer production by phytoplankton and bacteria

Process	Reference
Direct release	(Decho, 1990),
Viral lysis	(Suttle, 2007; Vardi et al., 2012),
Apoptosis and programmed cell death	(Berman-Frank et al., 2004; Bidle & Falkowski, 2004; Orellana et al., 2013), Biddle 2015.
Microbial degradation of POM	(Nagata and Kirchman, 1997),
Grazing	(Strom, 2008; Strom et al., 1997),
Zooplankton sloppy feeding	(Jumars et al., 1989),
Particle dissolution	(Azam and Long, 2001; Carlson, 2002b; Kiørboe and Jackson, 2001; Nagata et al., 2010; Smith et al., 1992),
Vesicle production and regulated exocytosis	(Biller et al., 2014; Chin et al., 2004)

Can we predict polymer production?

T. pseudonana

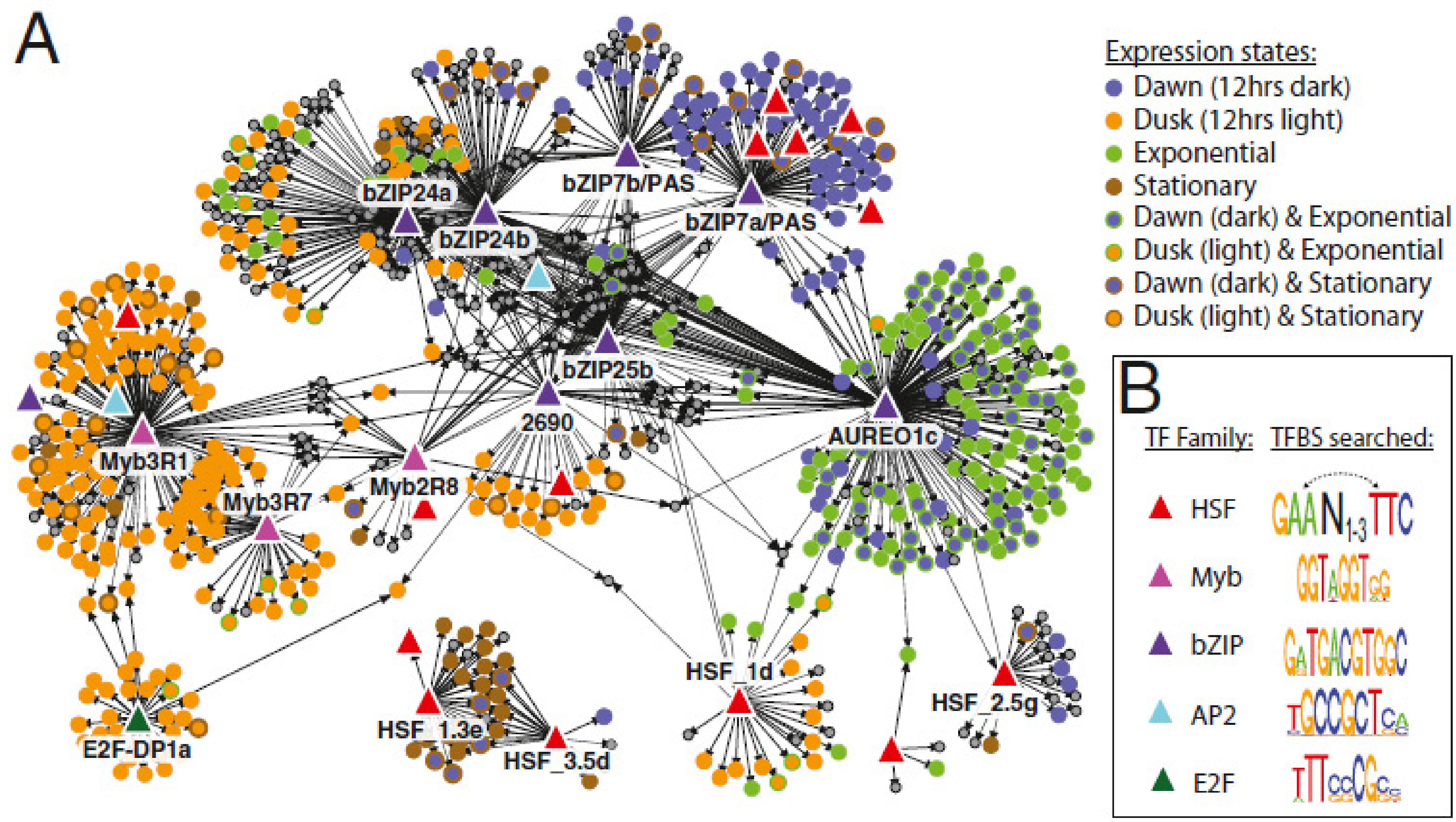


Replete nutrients

Limiting nutrients

Ashworth et al. PNAS 2013

Thalassiosira pseudonana

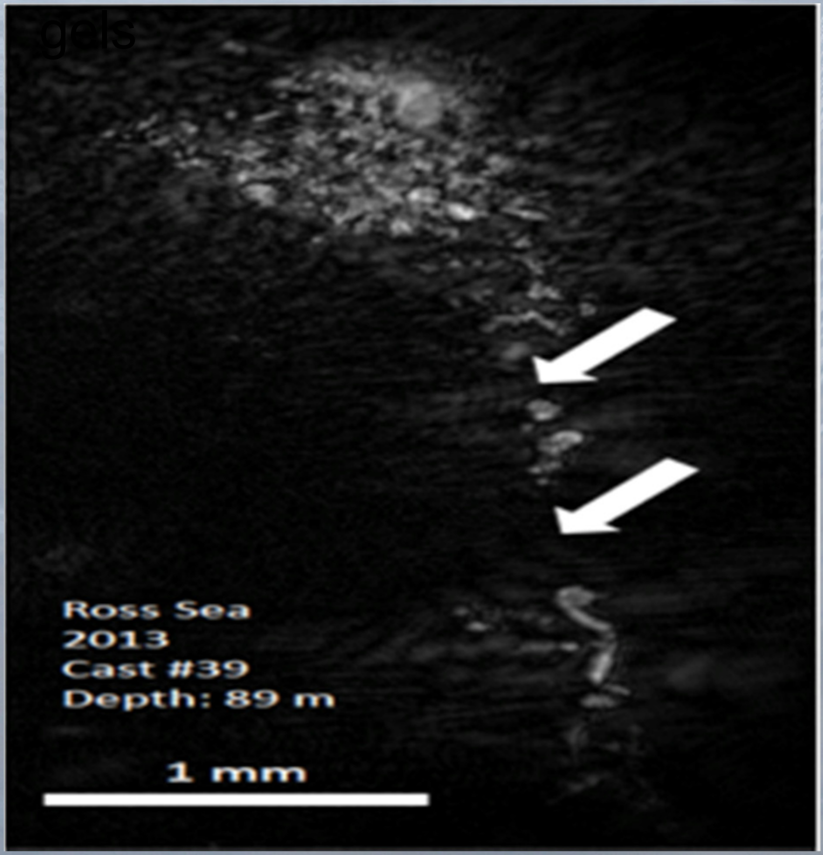


Inferred gene regulatory relationships

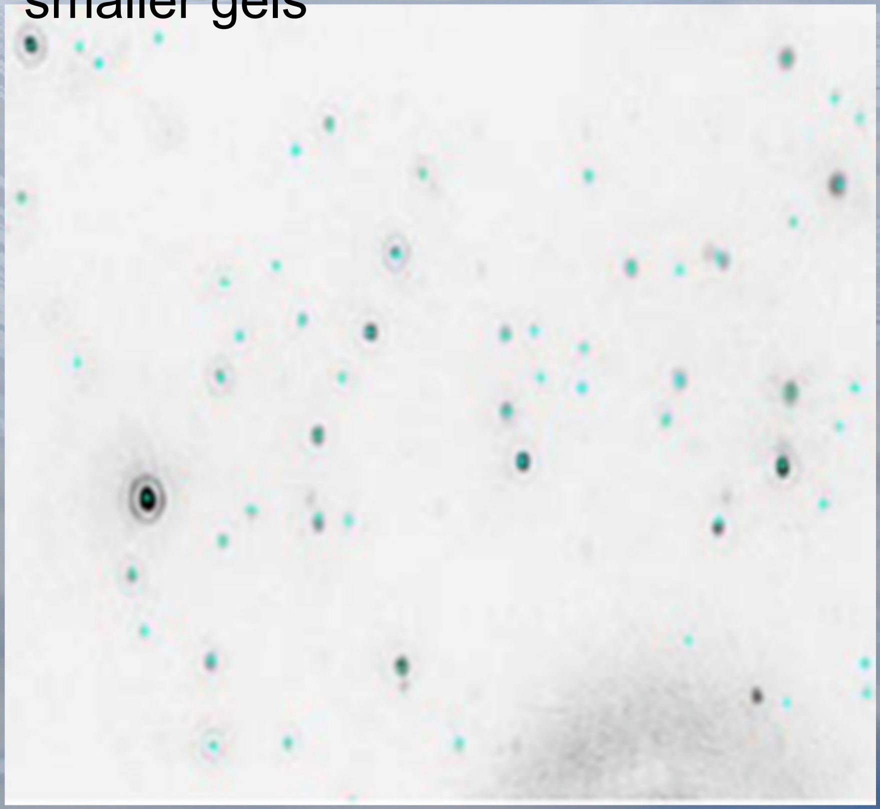
Ashworth et al. PNAS 2013

DOC- POC continuum is influenced by the community structure and metabolic state

Southern Ocean diatom communities produces larger gels

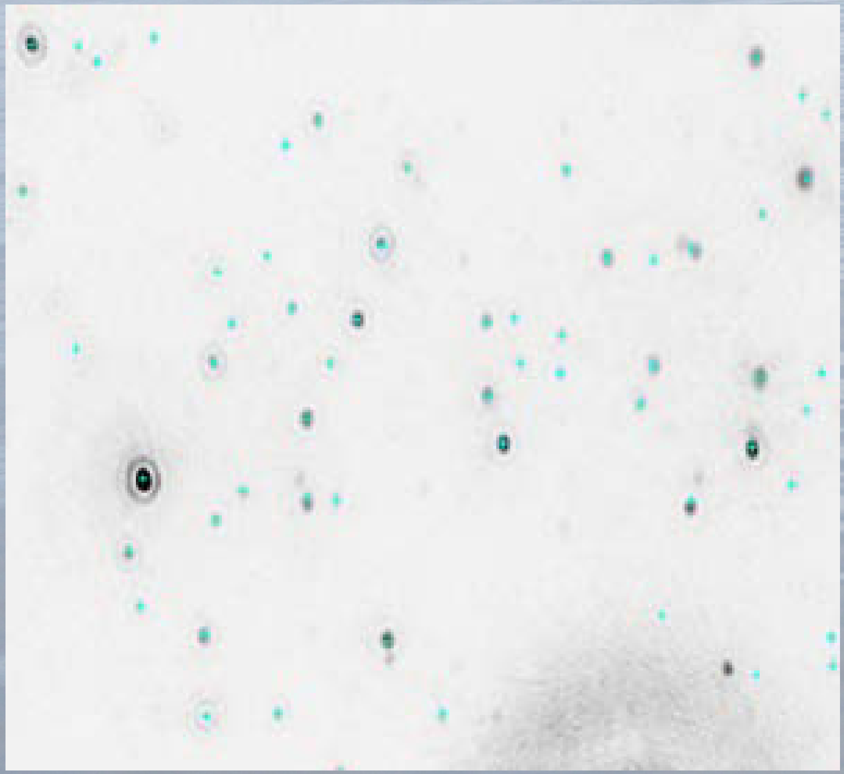


Cyanobacteria and other prokaryote communities produce smaller gels



Orellana et al. unpubl

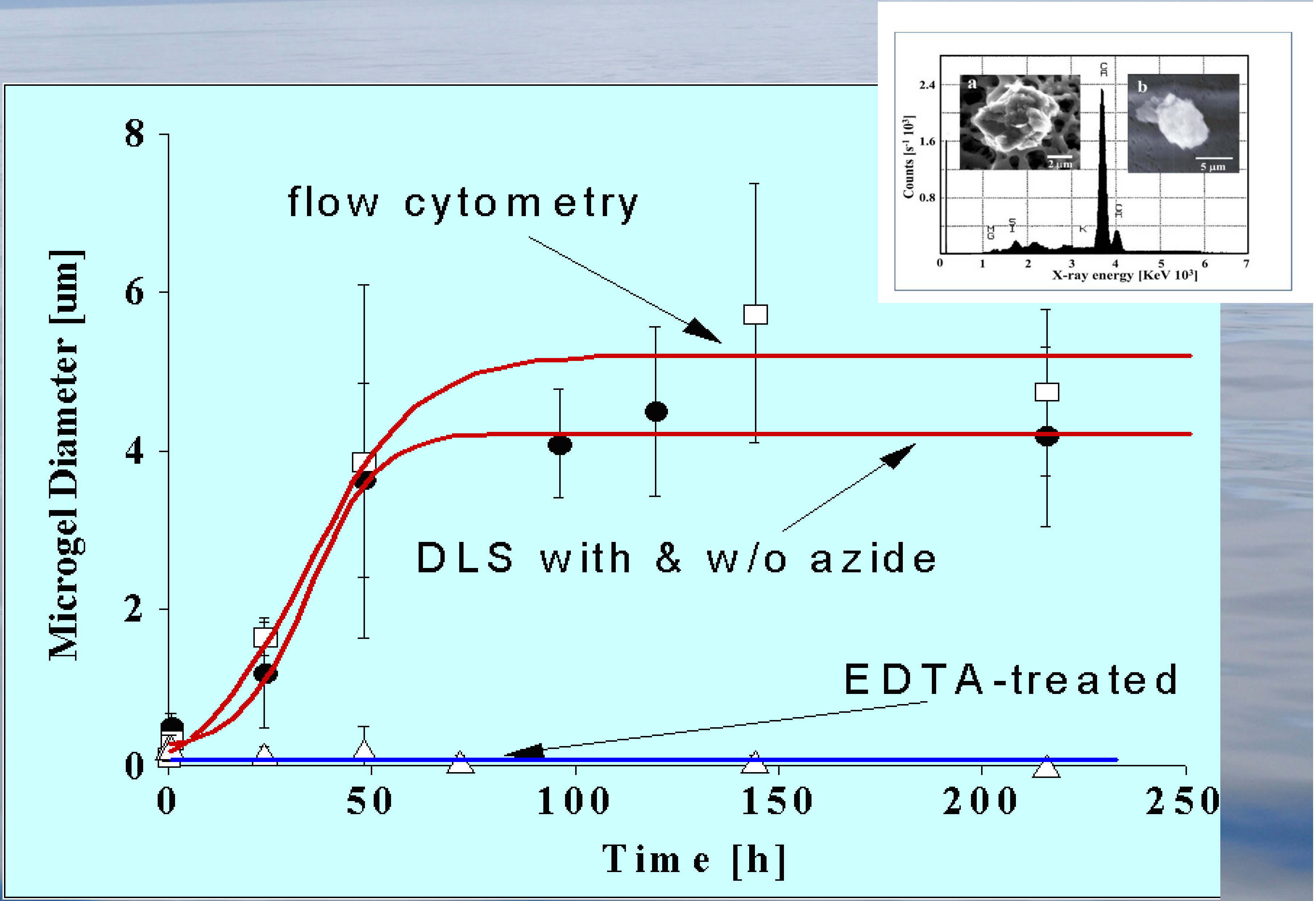
How do gels assemble?



Nanogels
(20nm)

Microgel
(μm)

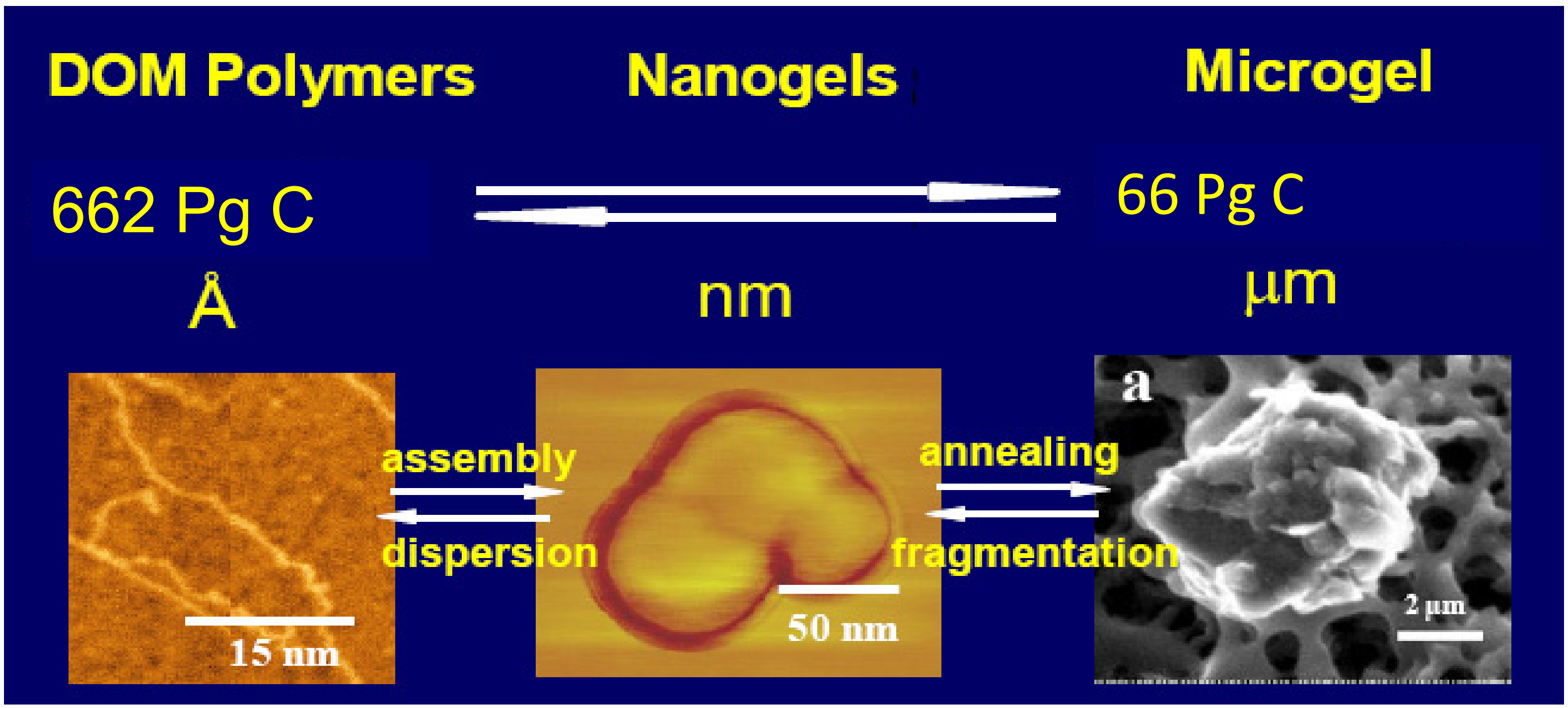
Microgel spontaneous assembly



Chin et al., 1998 Nature

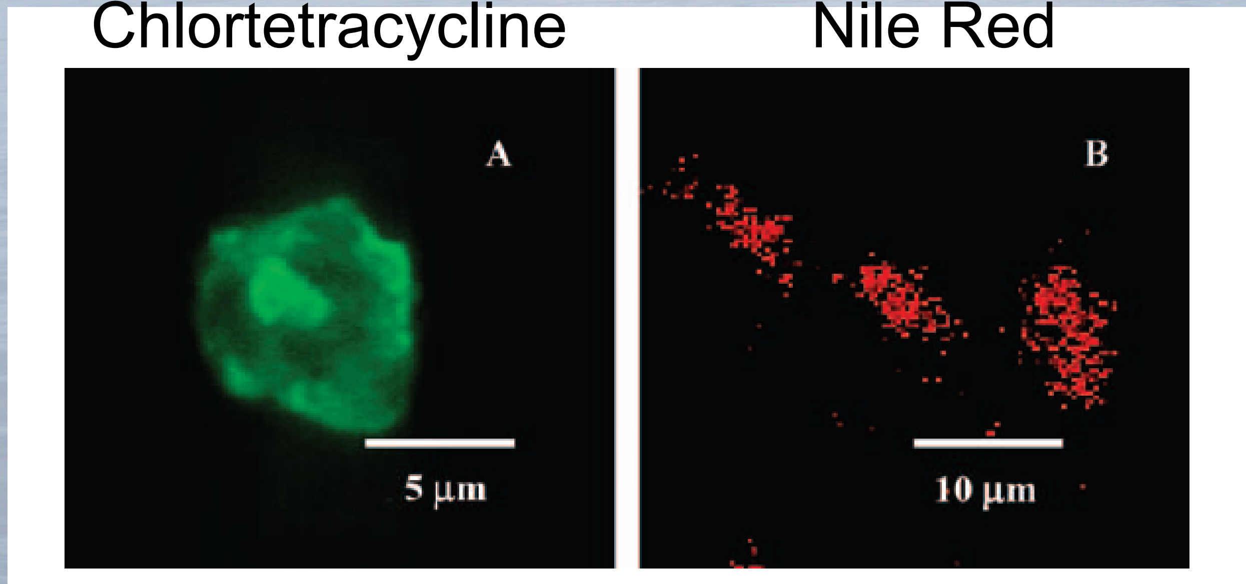
Atomic Force Microscopy

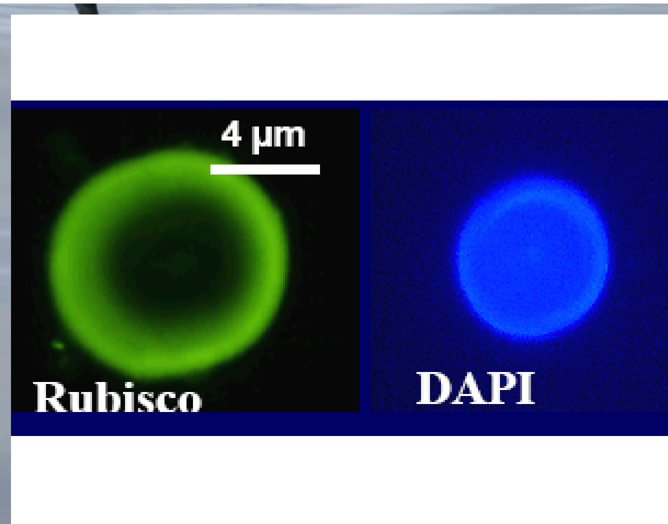
ESEM (environmental scanning electron) microscope)



Verdugo and Santschi, 2010

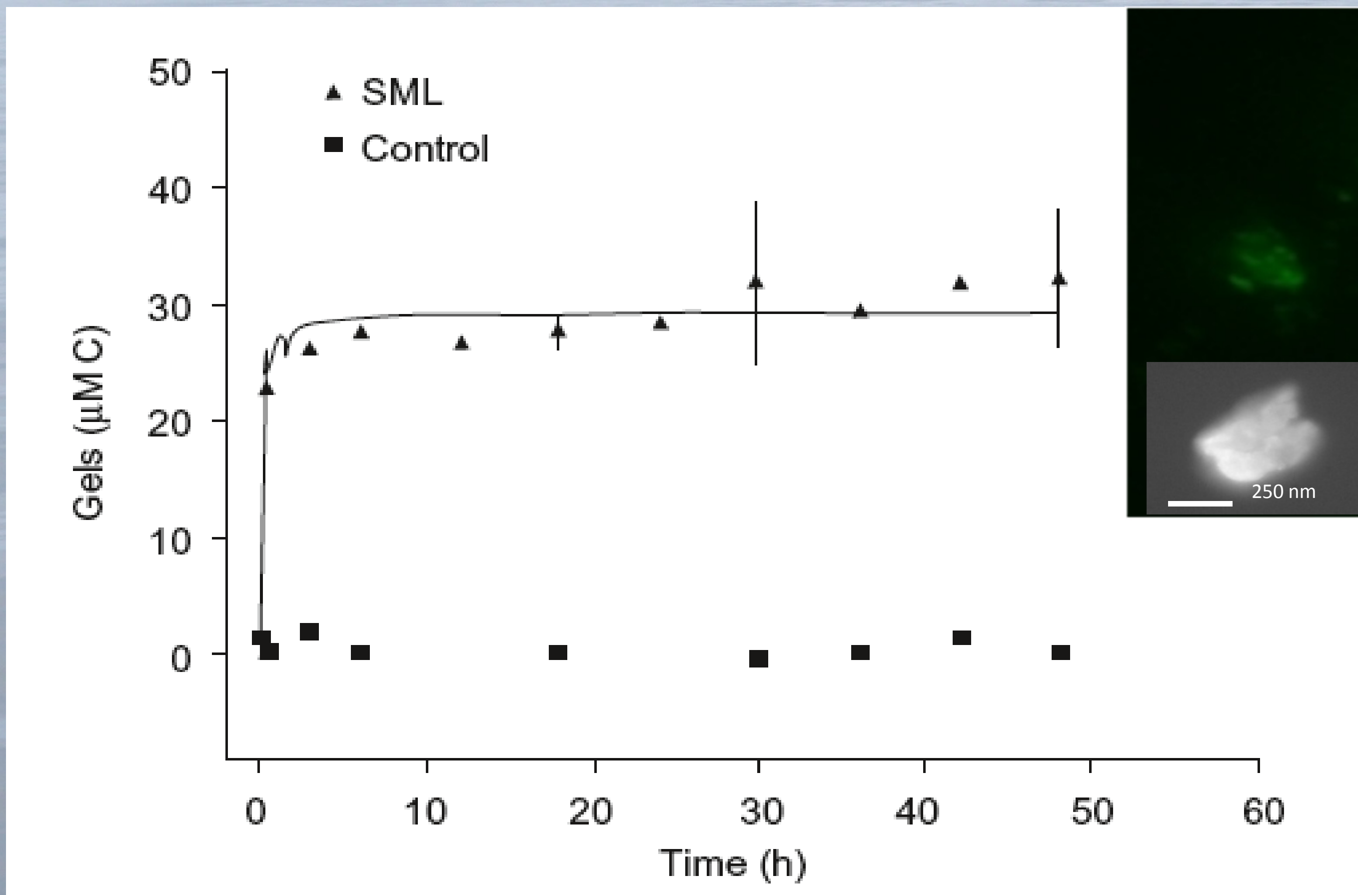
Chemical composition

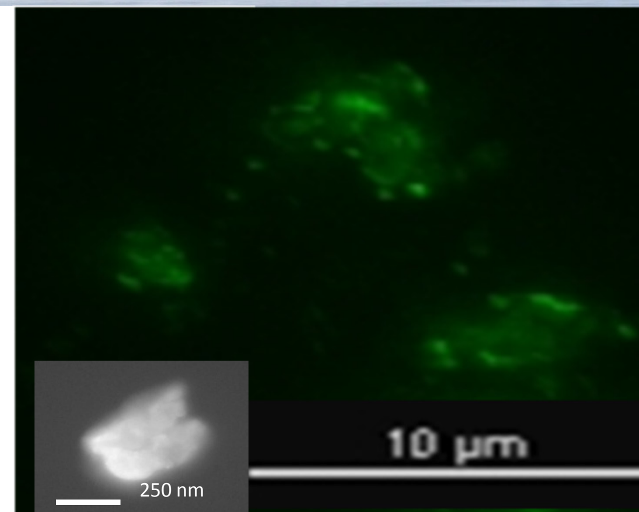




Verdugo & Santschi 2010

Does the polymer composition affect assembly?

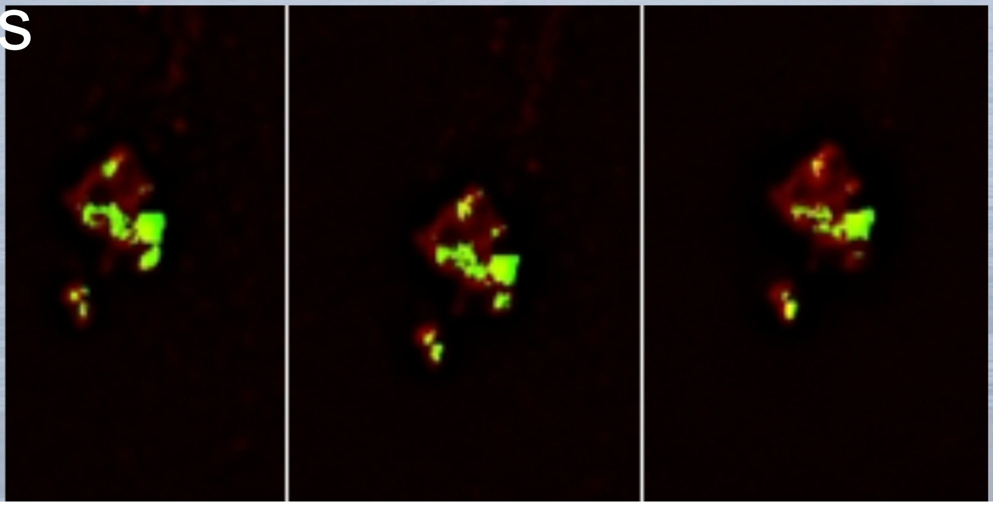


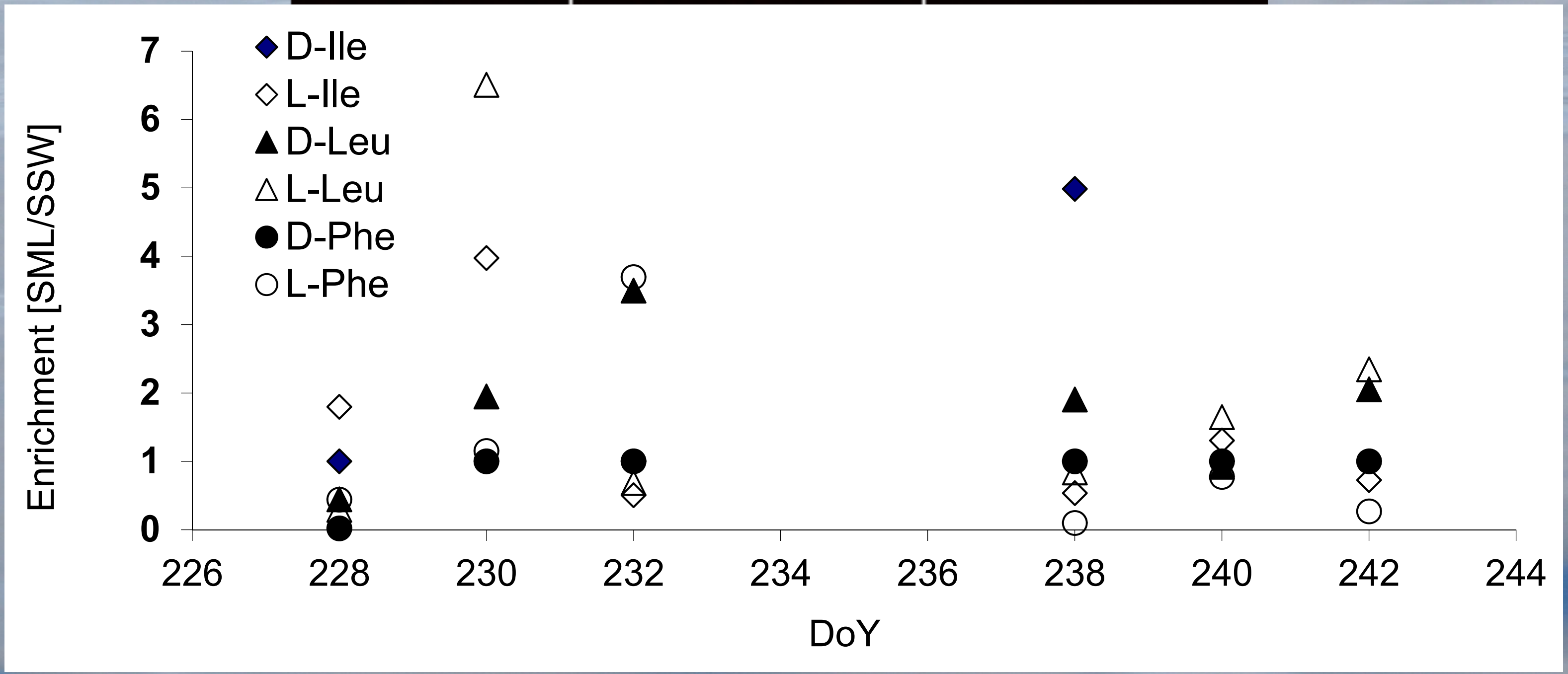


Polymer assembly as a function of time in the high Arctic surface waters (87-88°N, 2-10°W).

Orellana et al. PNAS 2011

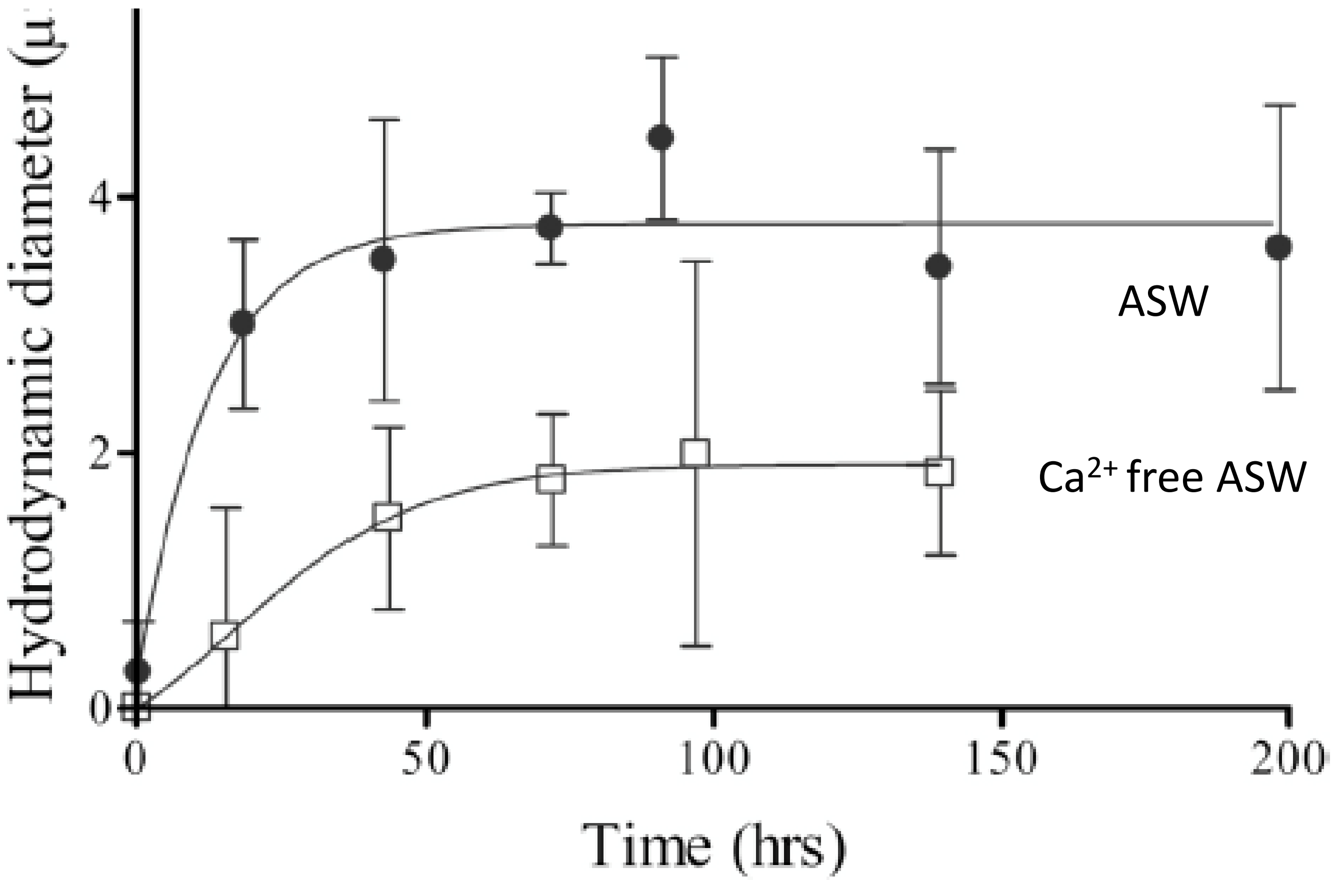
Hydrophobic moieties in polymer gels





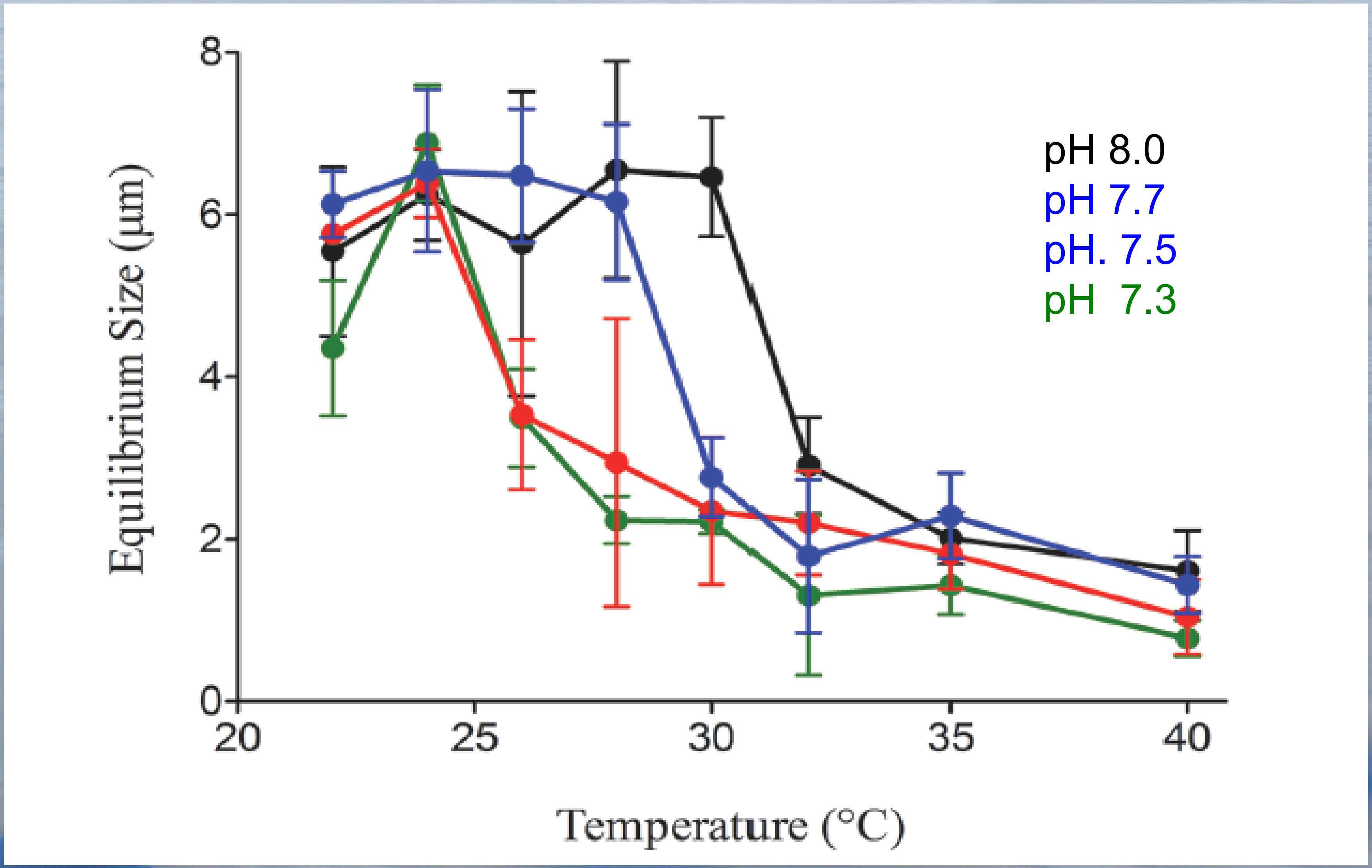
Orellana et al., PNAS, 2011

Spontaneous assembly: hydrophobic moieties in *Emiliania huxleyi*



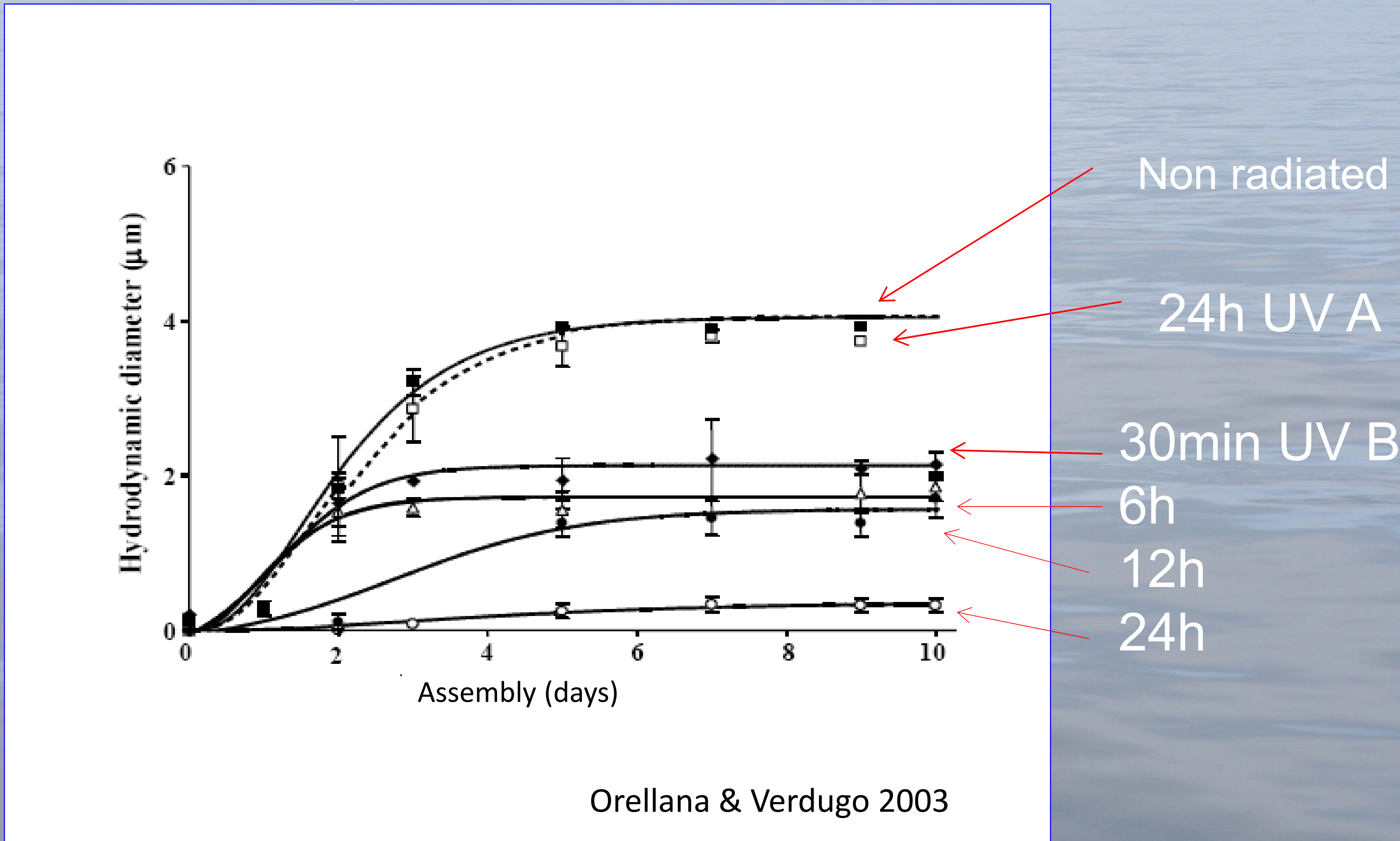
Ding et al.

Dispersion of microgels: synergistic effect of pH and temperature



Chen et al. PLOS one 2015

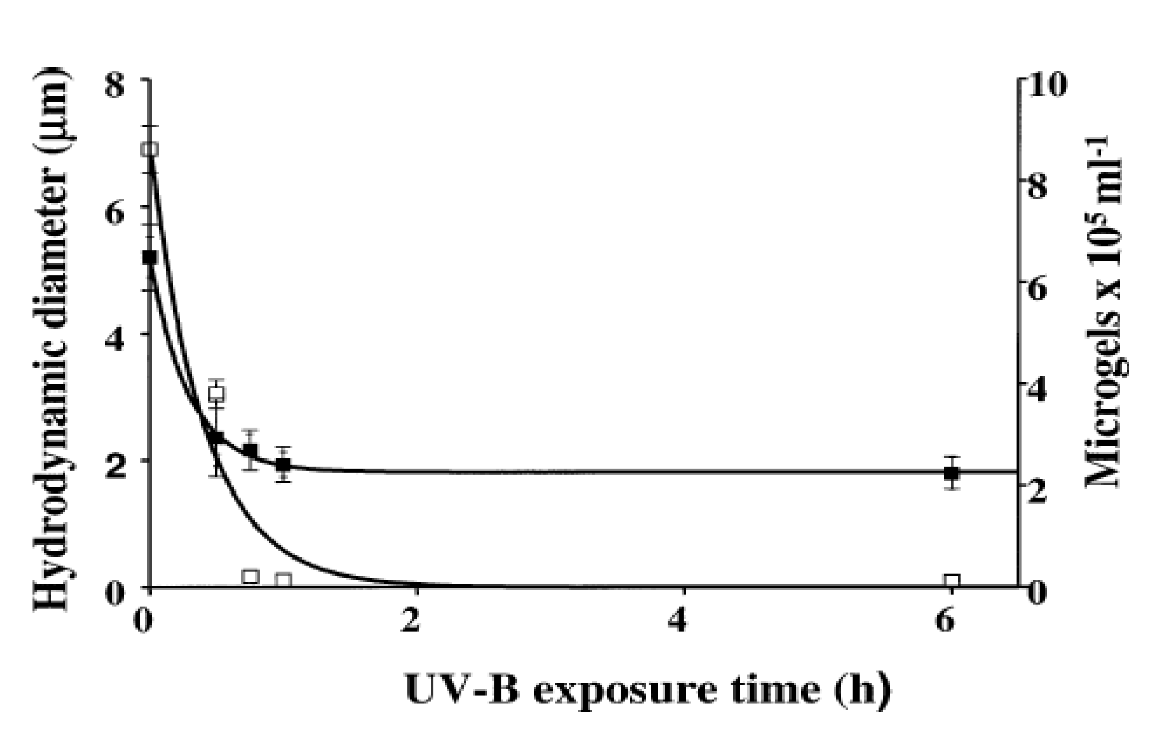
Does polymer size matter?



Assembly of marine polymers degraded by UV light exposure

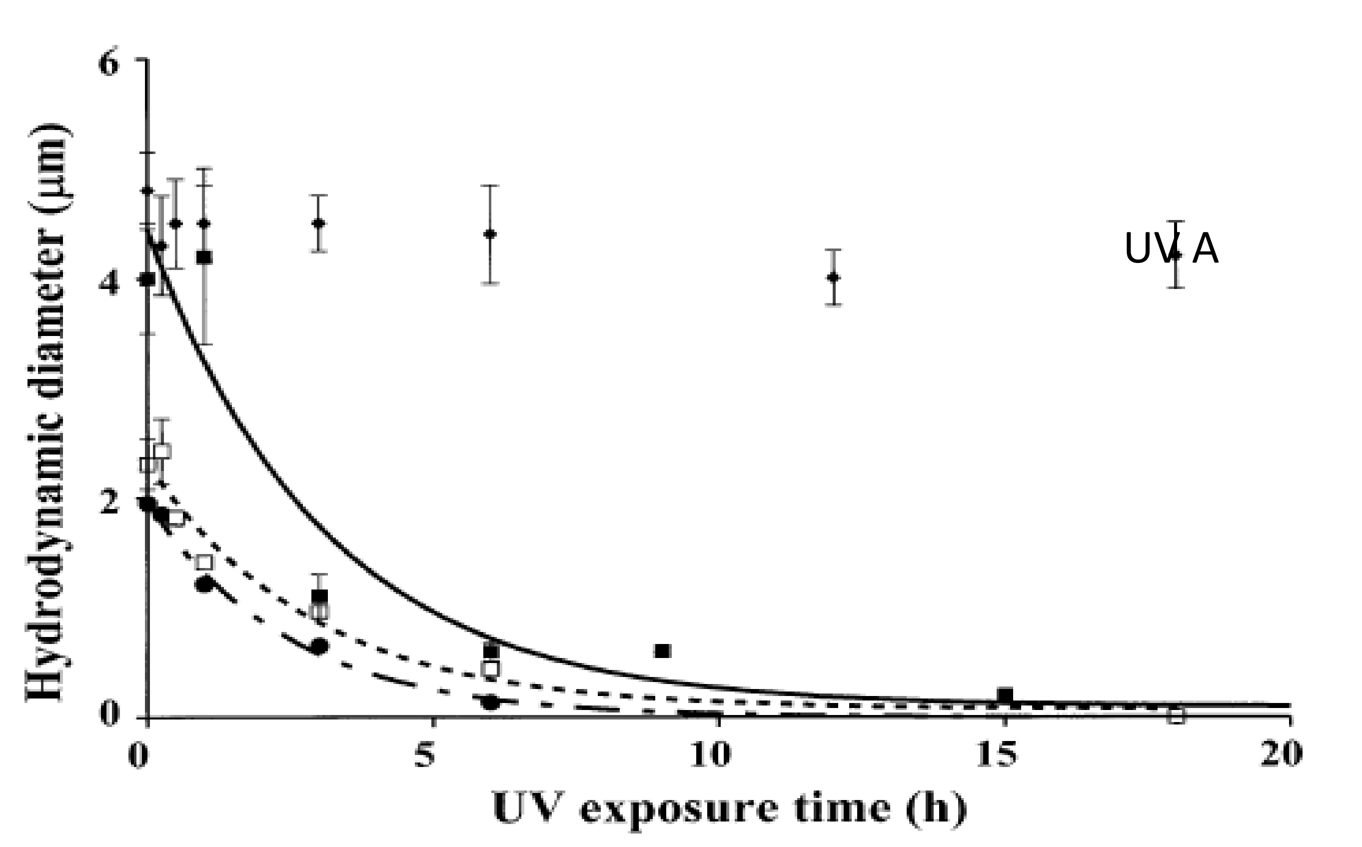
Orellana & Verdugo 2003

Equilibrium polymer size of assembly and concentration of microgels decreases exponentially when irradiated with UV



Orellana & Verdugo, L&O 2003

Exponential decrease of microgels with UVB exposure

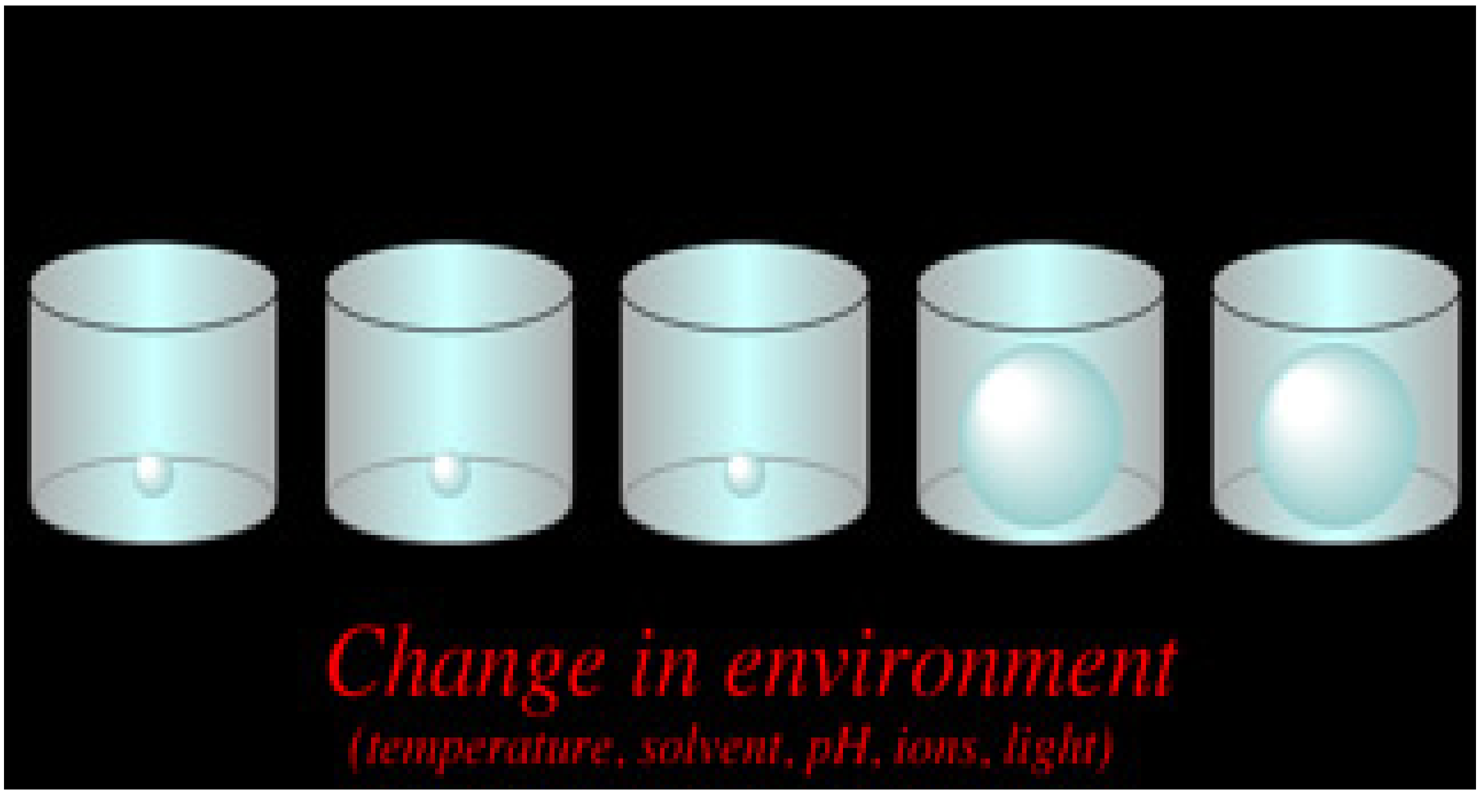


Orellana and Verdugo, L&O 2003

Volume phase transition

Electric field

light



pollutant
s

Heat

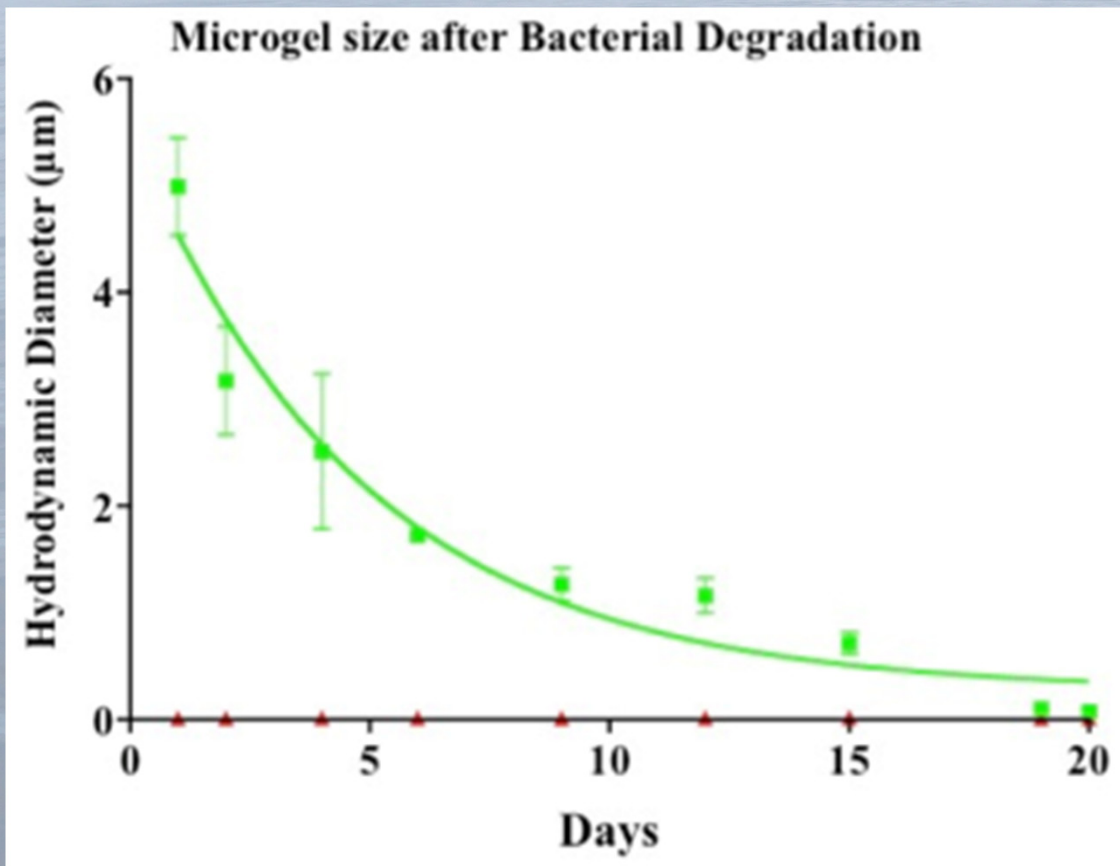
Ions and pH

+ -

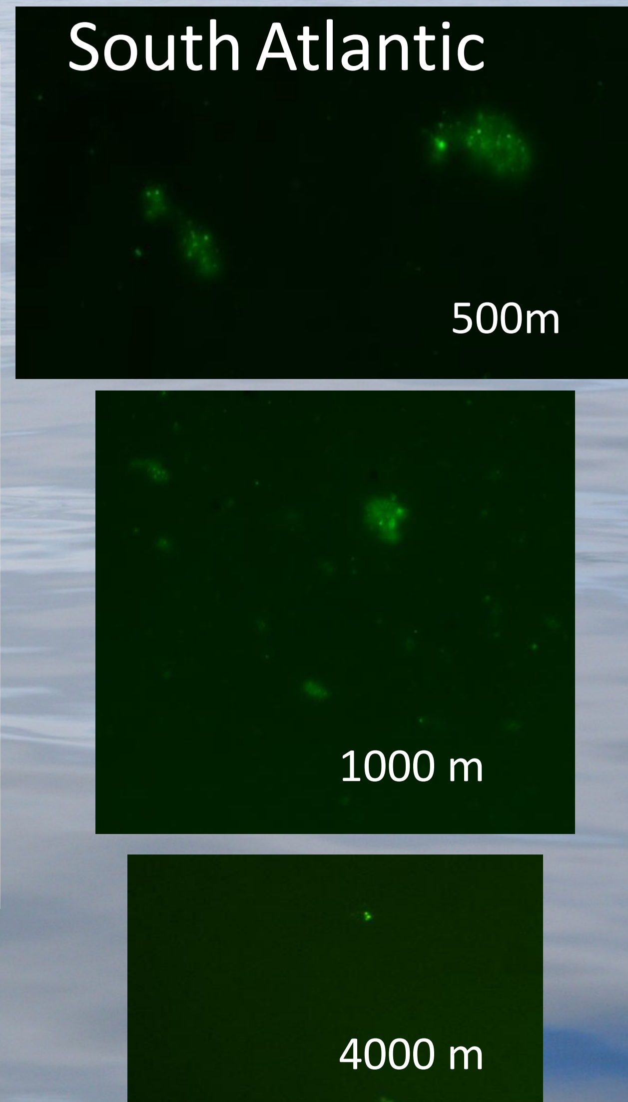
Biochemicals

T. Tanaka, 1993

Bacterial degradation

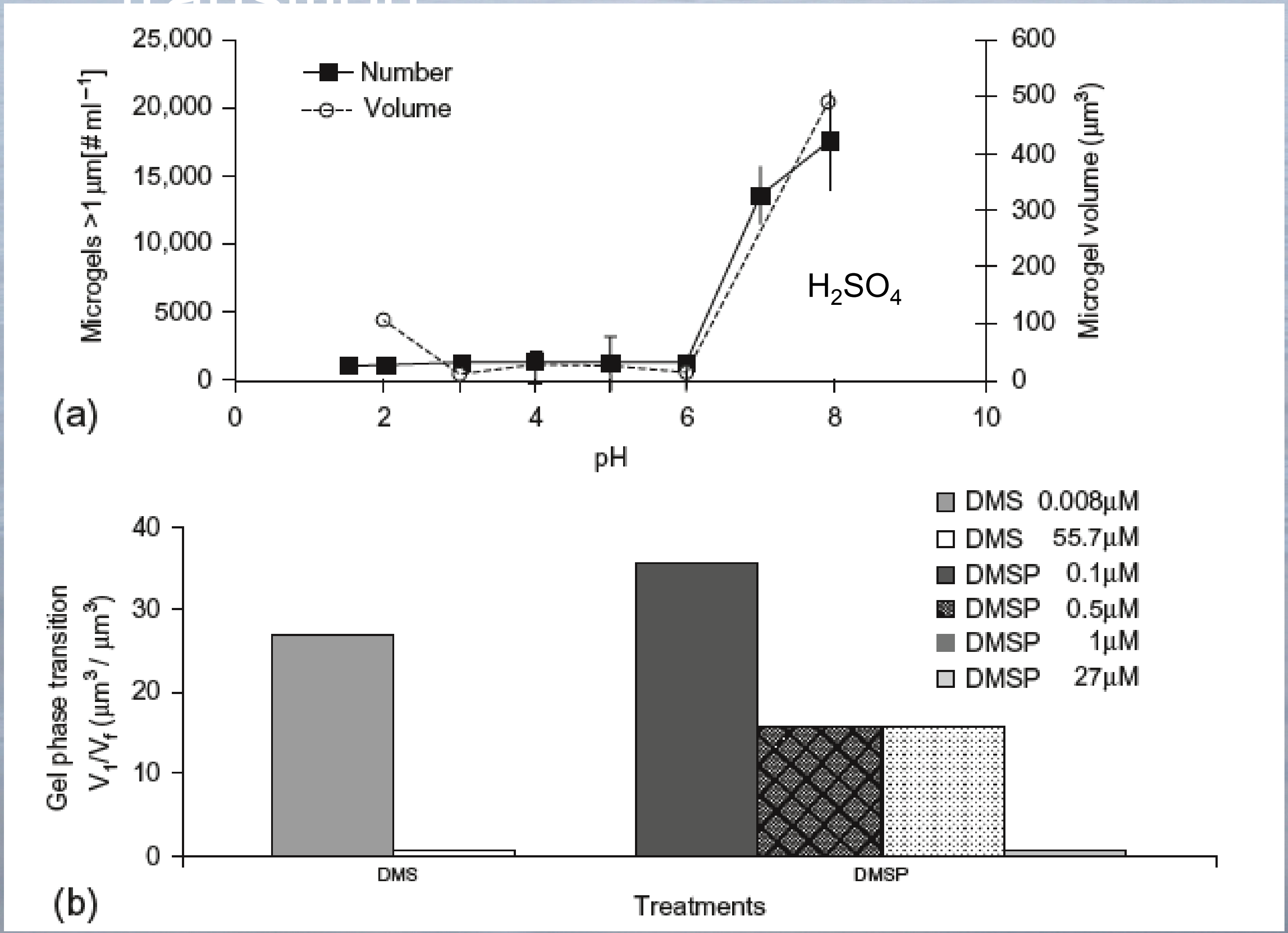


Assembly of microgels after microbial degradation (Orellana et al. unpub.)

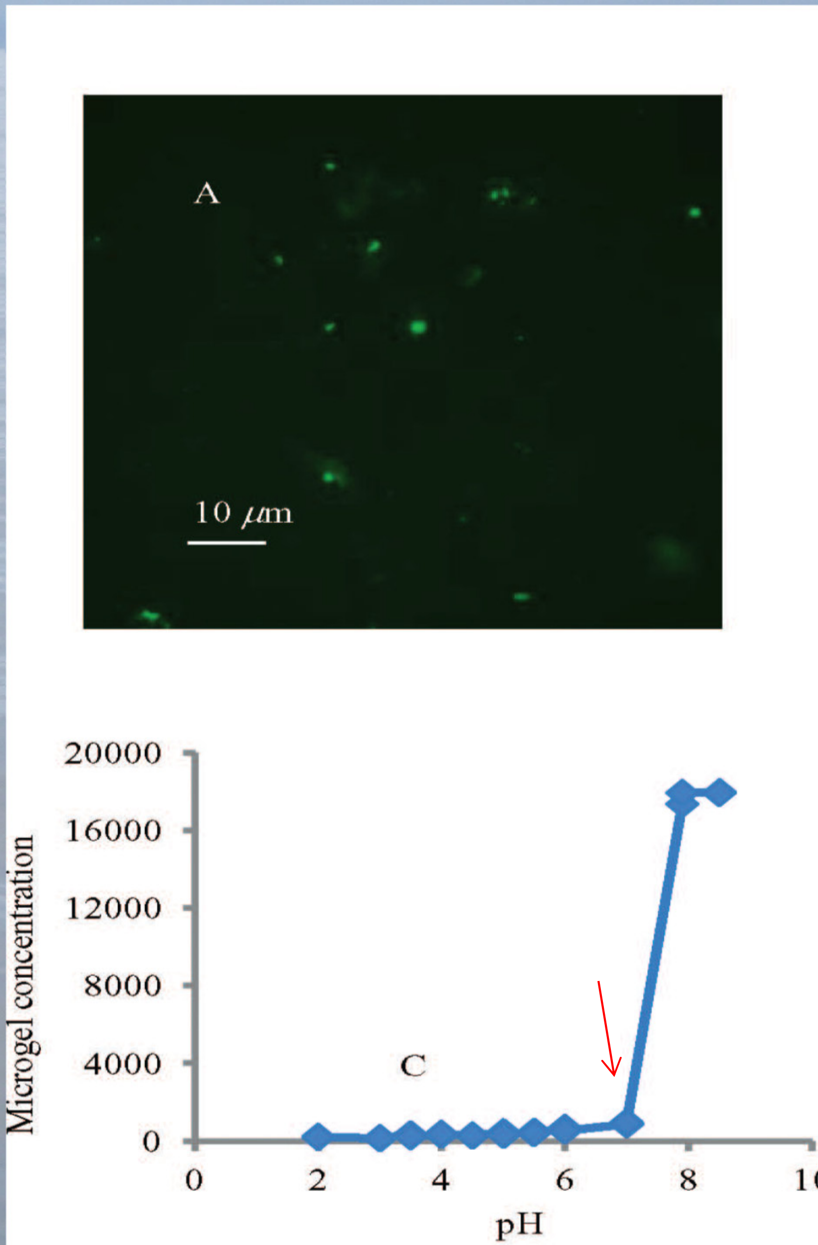


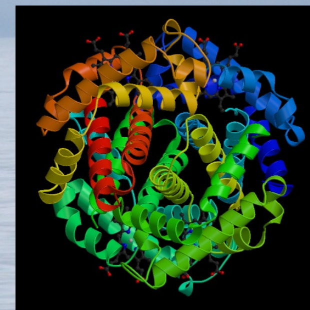
Ditt et al., submitted

Microgel volume phase transition



Orellana et al. 2011

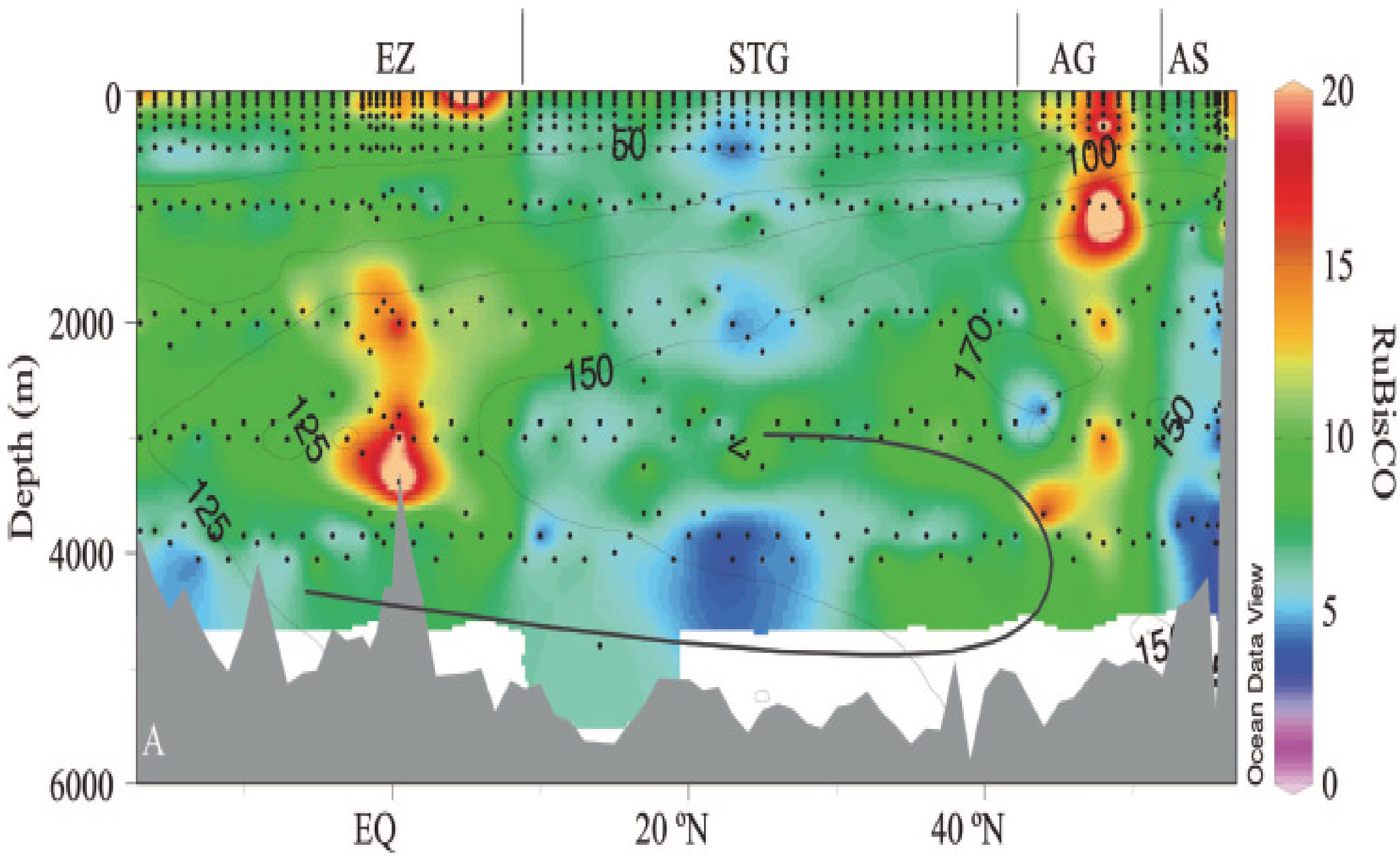




RuBisCO Microgels
Deep Pacific Ocean
(3000m)

Orellana and Hansell 20

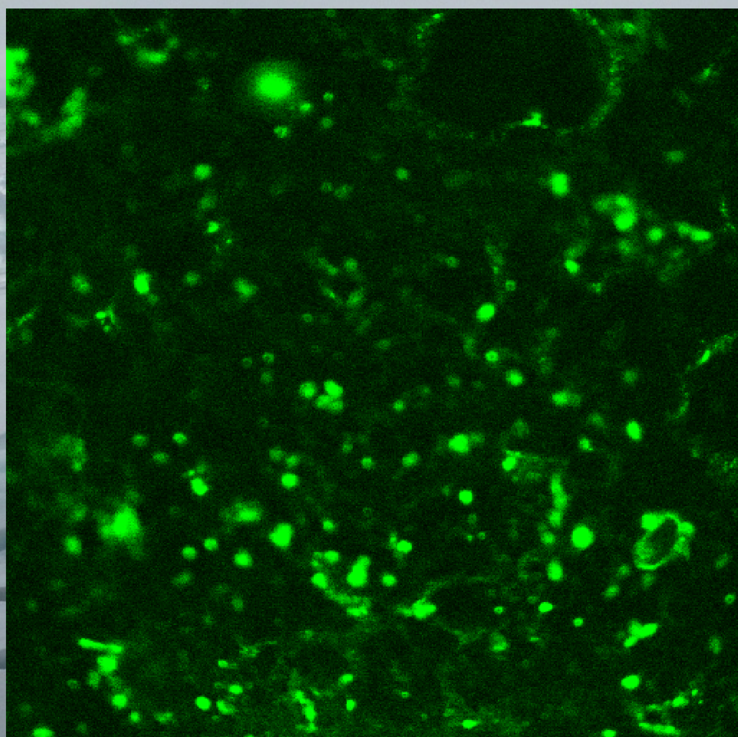
RuBisCO in the deep Pacific Ocean



Orellana & Hansell 2012

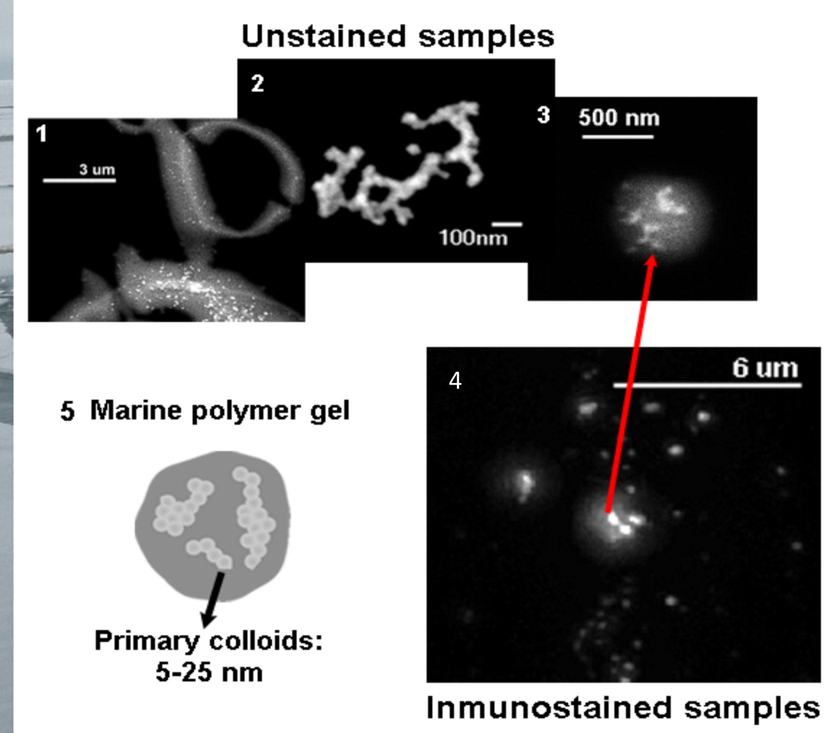
Microgels in clouds, fog and aerosol particles.

Immunostained cloud microgels



Confocal microscope

Field Emission Scanning microscope



Fractal structure

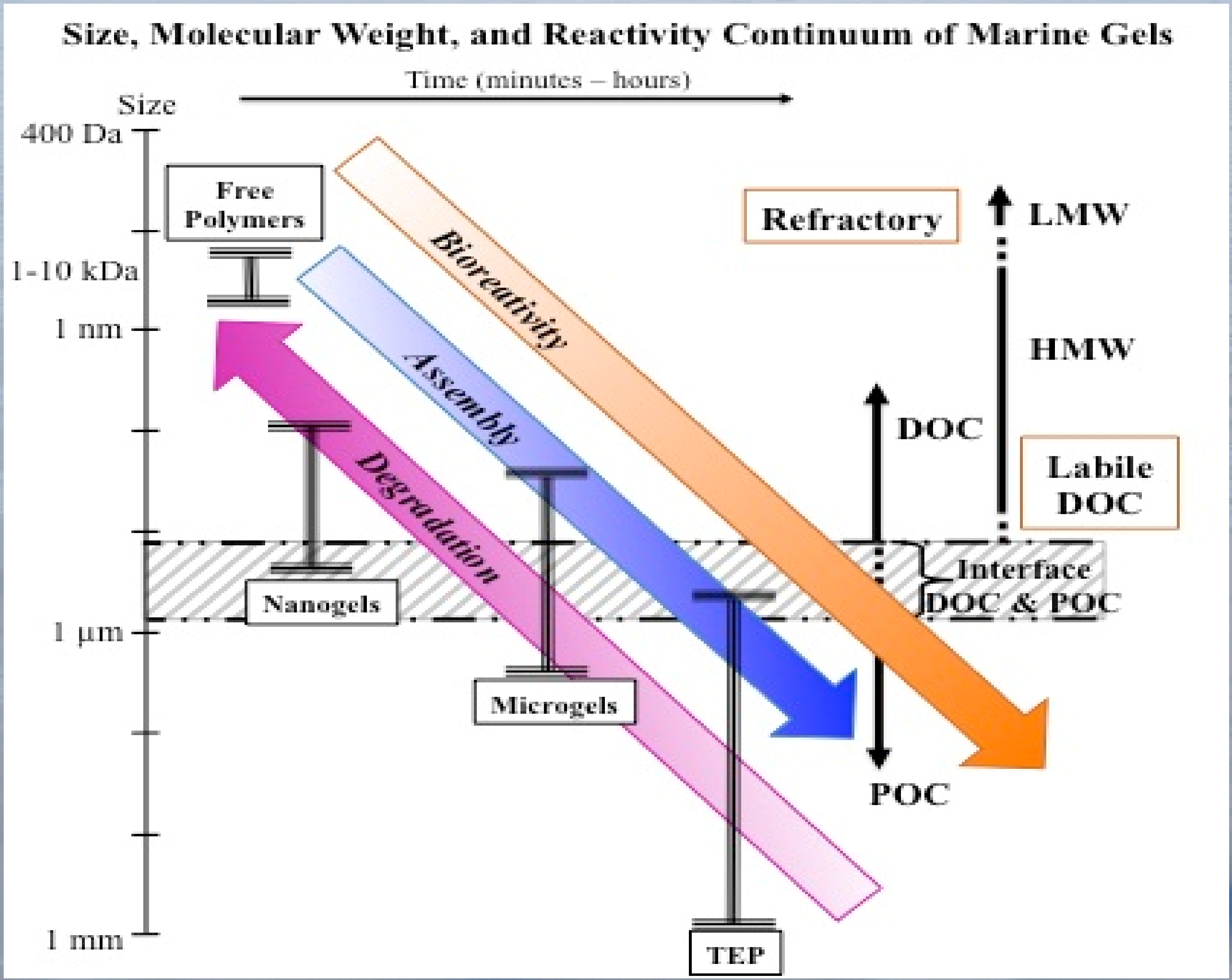
Tangled nanometer
Sized gels

Orellana et al. 2011

Properties of gels versus solid colloids: Characteristic Features and Reactions

	Gels	Other
Structural units bend, fold, reptate and intertwine	Yes	No
Internal dialectric properties different from the bulk	Yes	No
Non-Newtonian Rheology & porous structure	Yes	?
Defined internal topology of their polymer network	Yes	?
Defined mechanisms of assembly and stability	Yes	No
Defined kinetics of assembly/dispersion and swelling	Yes	No
Characteristic polymer gel phase transitions	Yes	No
Defined ion (Donnan) and hydrophobic partition properties	Yes	No

DOM-POM continuum

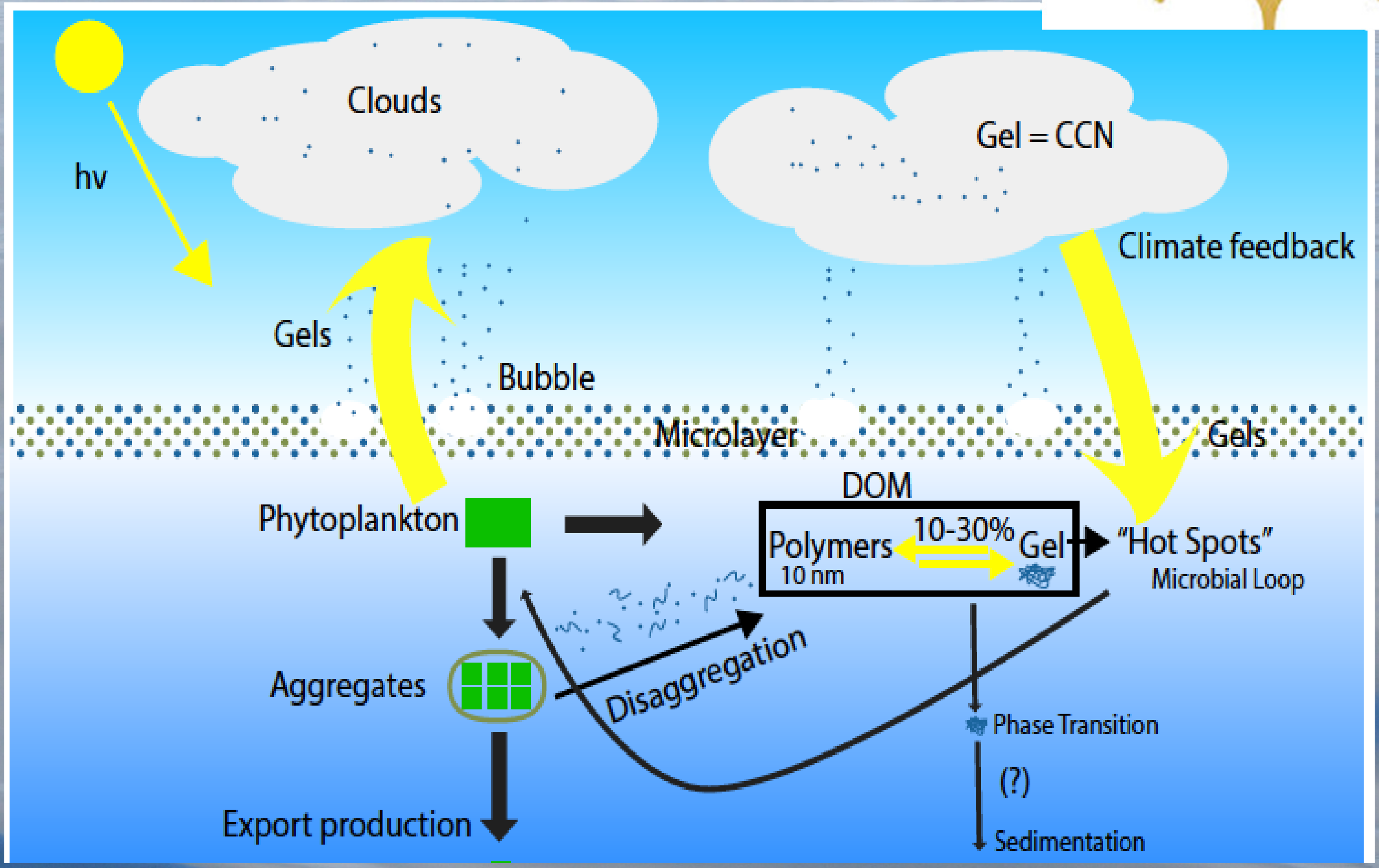


Adapted from Verdugo et al.

Elucidating the DOM-POM Continuum

- Soft matter physics allows understanding structure and dynamics of DOC biopolymer
- Assembly: explains formation of particles in seawater
- Emergent properties (phase transition) explain chemical landscape

Thank you!



Clouds
hv
Gel = CCN
Climate feedback
Gels
Bubble
Microlayer
Gels
DOM
Phytoplankton
Polymers
10 nm
10-30%
Gel
"Hot Spots"
Microbial Loop
Aggregates
Disaggregation
Phase Transition
(?)
Export production
Sedimentation