# (Self – assembly of) patchy colloids / colloidal molecules

Daniela Kraft & Willem Kegel

Van't Hoff laboratory,
Debye Research Institute
Utrecht University, The Netherlands

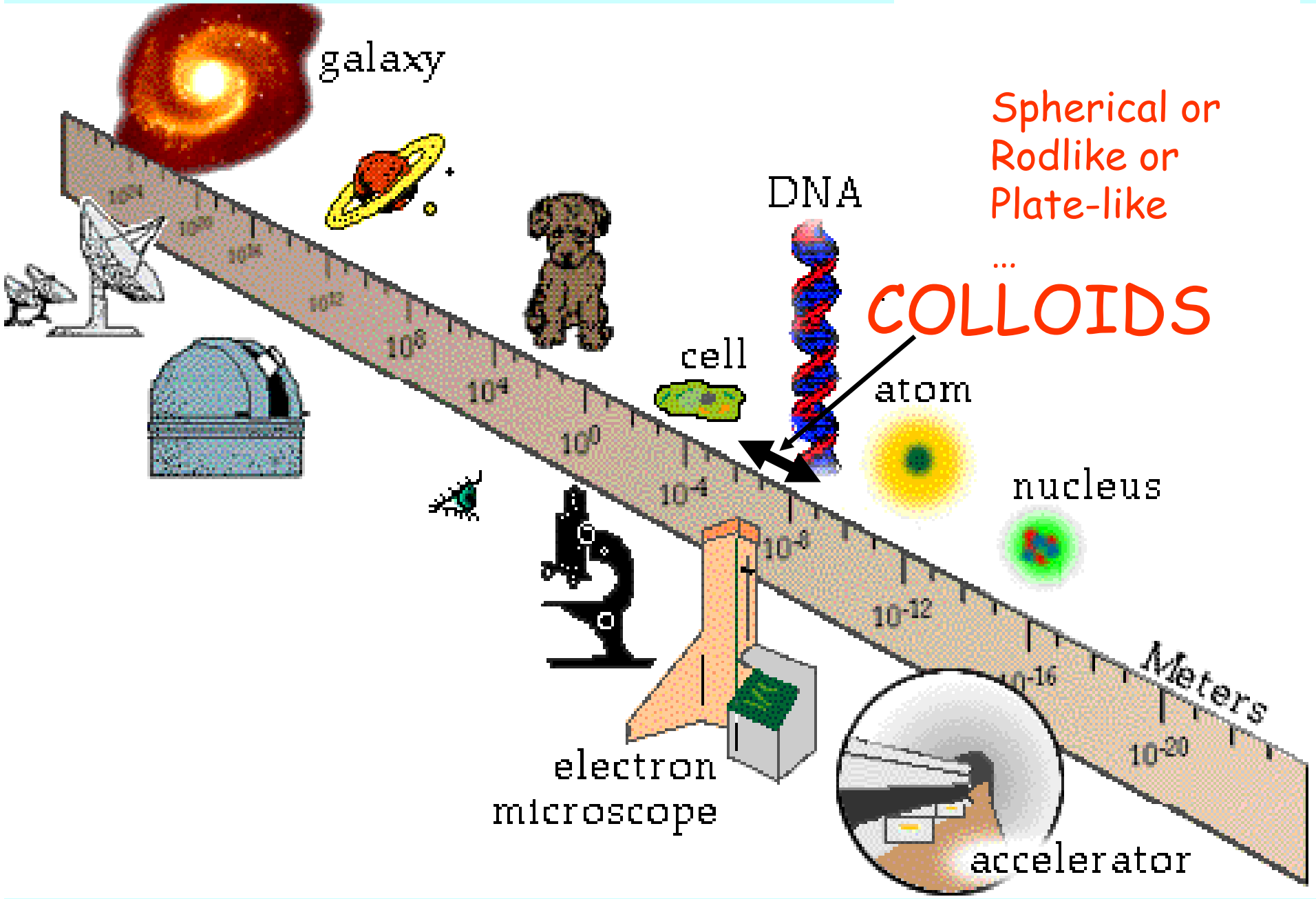
## Wikipedia:

**Self-organization** is a process of attraction and repulsion in which the internal organization of a system, normally an open system, increases in complexity without being guided or managed by an outside source.

## Business Dictionary:

Ability of a system to spontaneously arrange its components or elements in a purposeful (non-random) manner, under appropriate conditions but without the help of an external agency. It is as if the system knows how to 'do its own thing.' Many natural systems such as cells, chemical compounds, galaxies, organisms and planets show this property.

Animal and human communities too display self organization: in every group a member emerges as the leader (who establishes order and rules) and everybody else follows him or her, usually willingly.




Spherical or
Rodlike or
Plate-like
…

COLLOIDS

## Beyond colloids with isotropic interaction

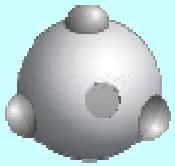
**Patchy colloids / colloidal molecules**

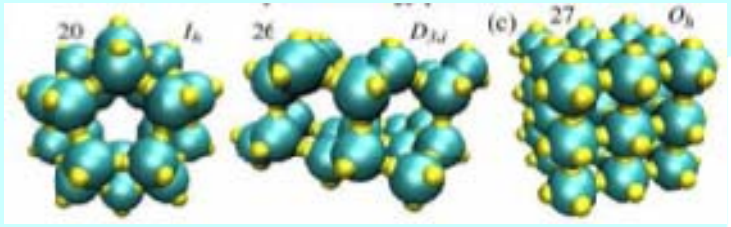
Two parts

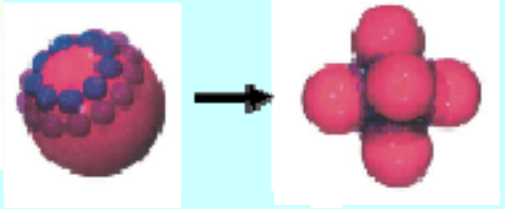
- 1 Formation -> colloidal scale
- 2 Self-organization -> super-colloidal scale

# Motivation: Bottom-up self-assembly of rationally designed building Blocks

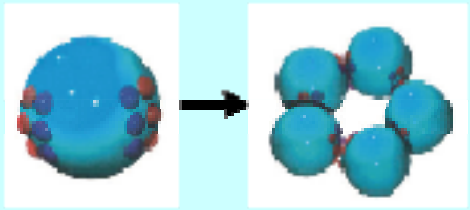
- New Materials & Self-Assembly of nanostructures

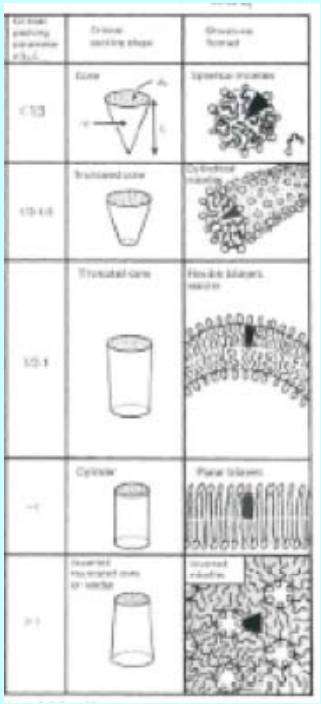




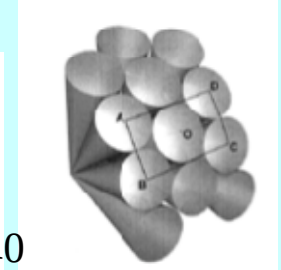



- Model system for :
  - Virus assembly



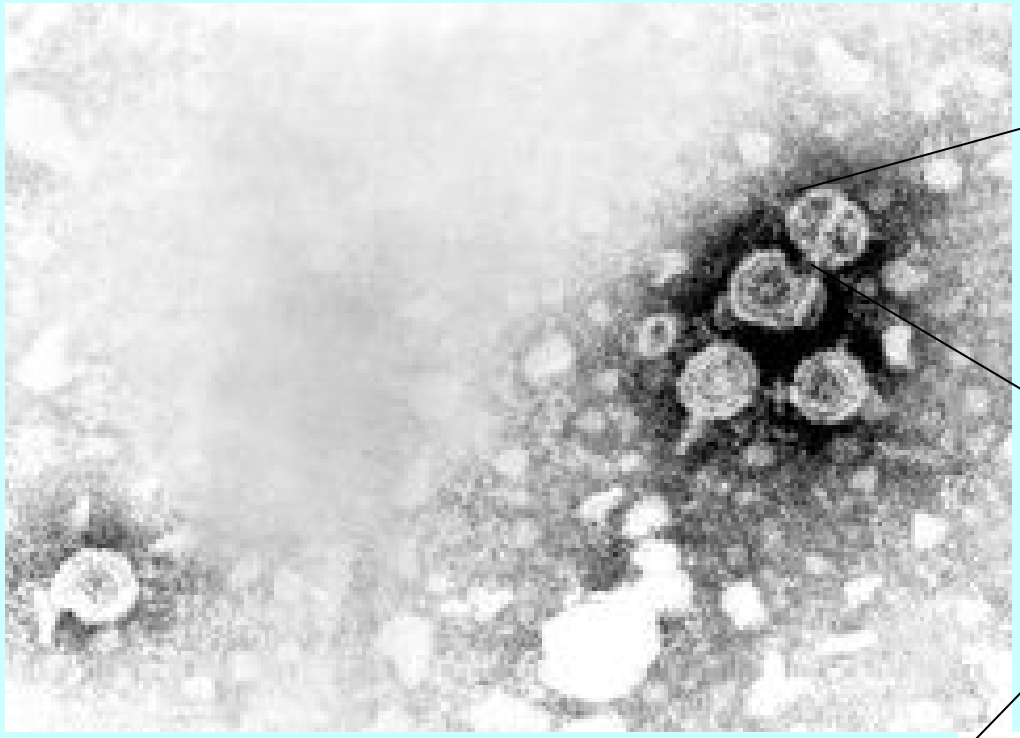


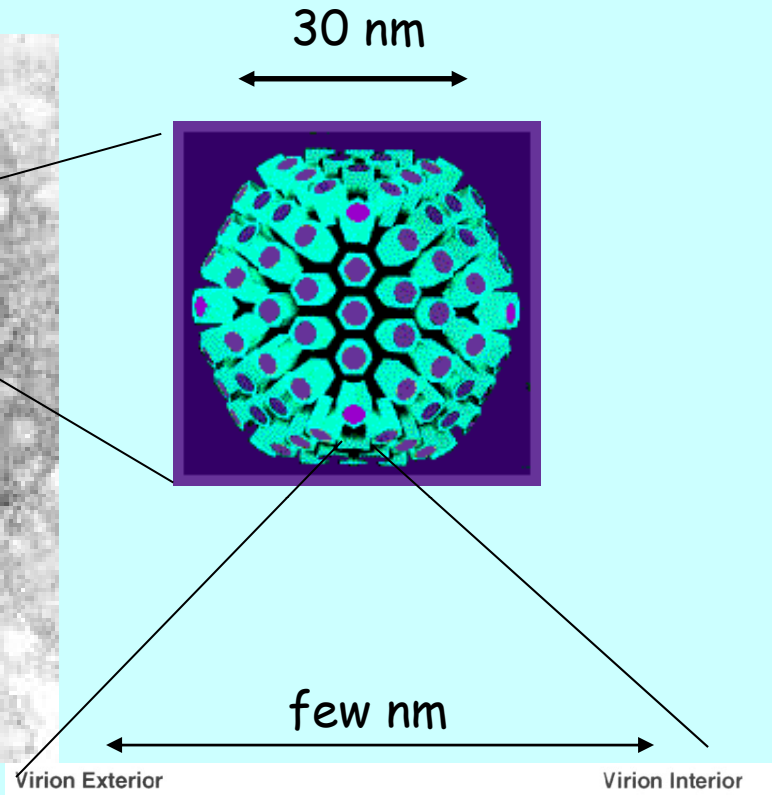
  - Surfactants


$$P = \frac{v_0}{a_0 l_0}$$

# ...virus capsids ~ 'coats' of viruses

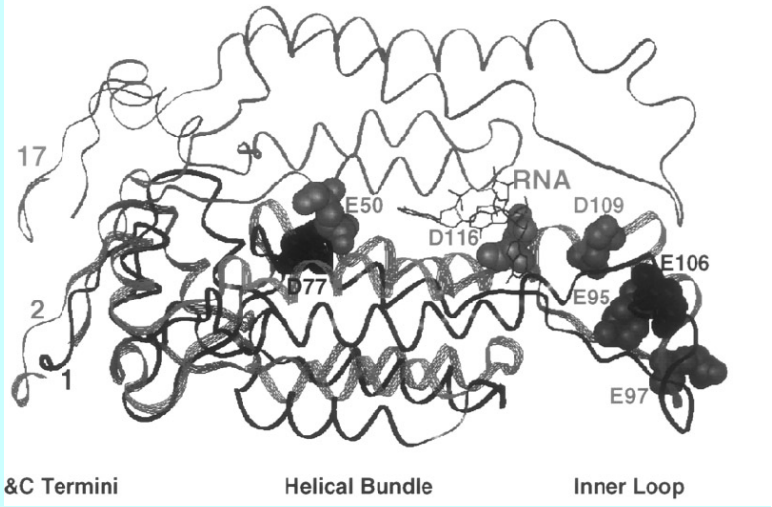




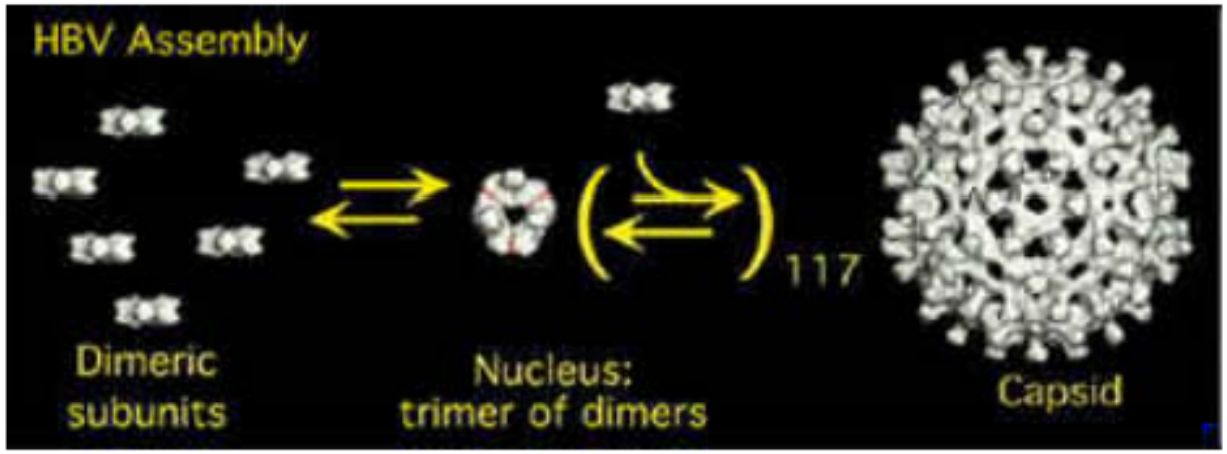

(Un)coating regulated by:
* Hydrophobic interactions between apolar **patches** on protein surface

•Screened-Coulomb interactions

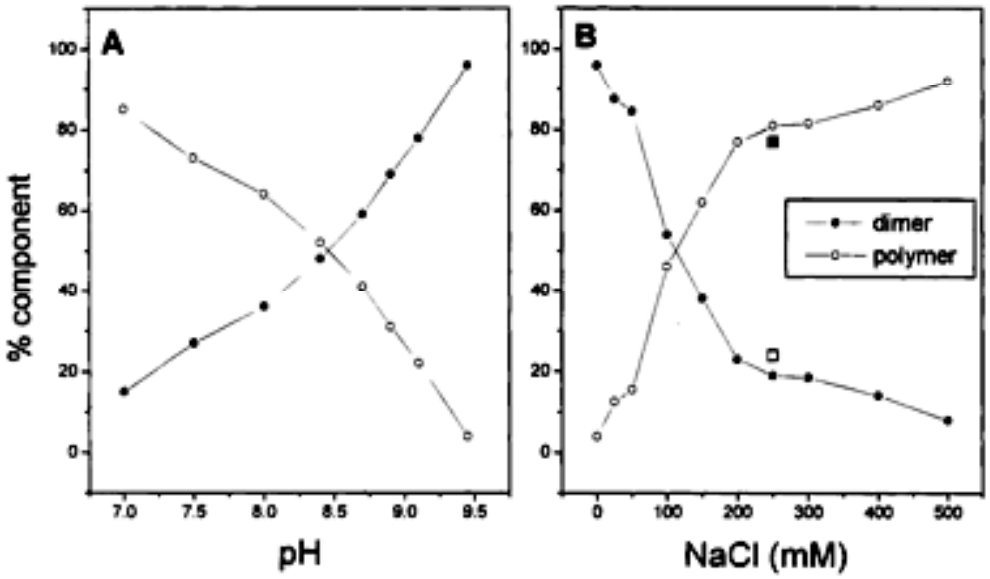
[WKK & P. vd Schoot, BPJ 2004; 2006]



# In vitro self-assembly of hepatitis B virus capsids

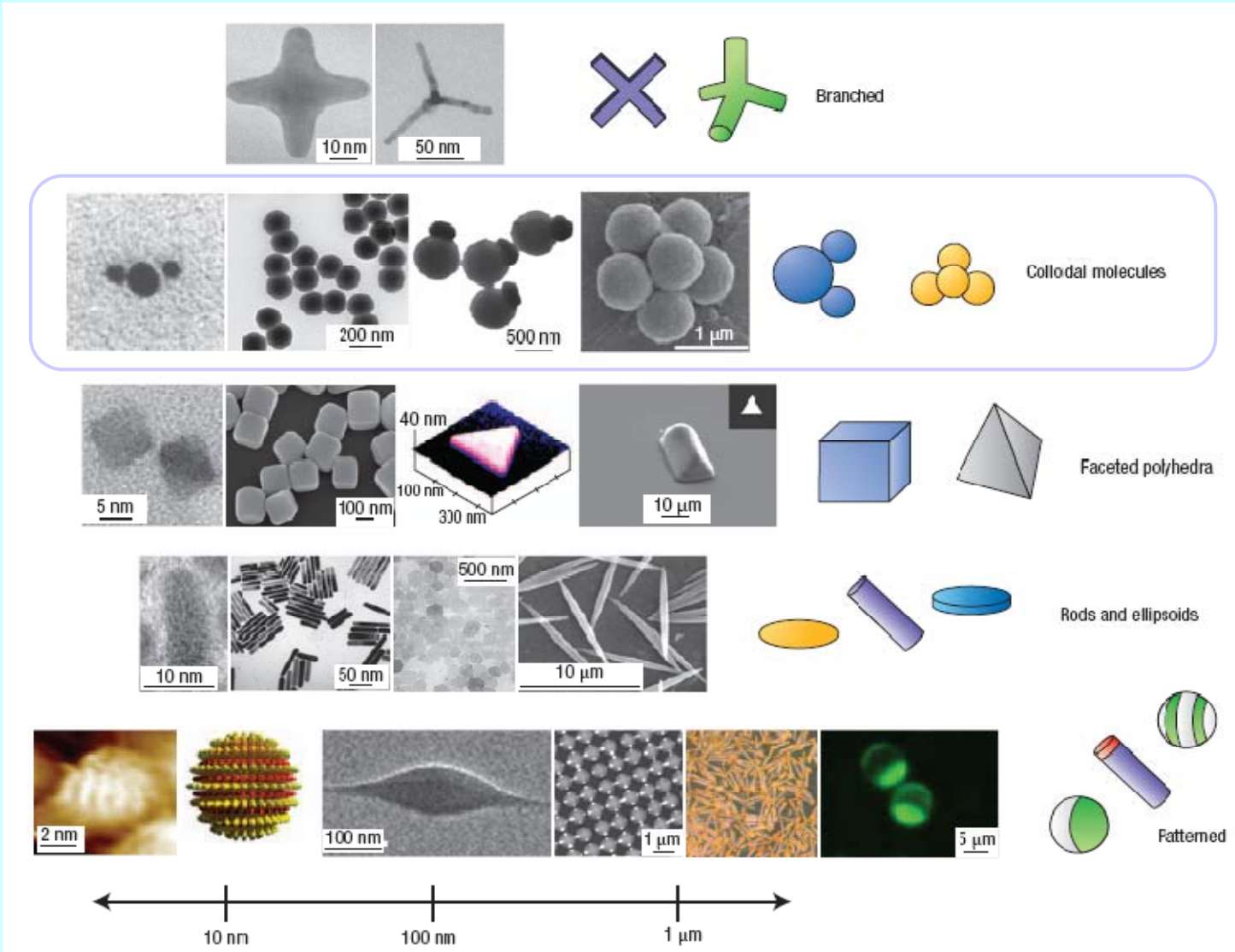



Association
=
**Reversible!**




Wingfield et al. *Biochem* **34** (1995) 4919.

# Anisotropic colloids



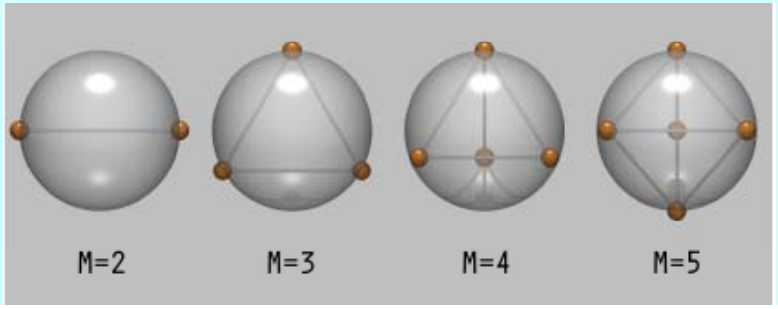

- S. C. Glotzer, M.J. Solomon, Nature Materials, 6, (2007)

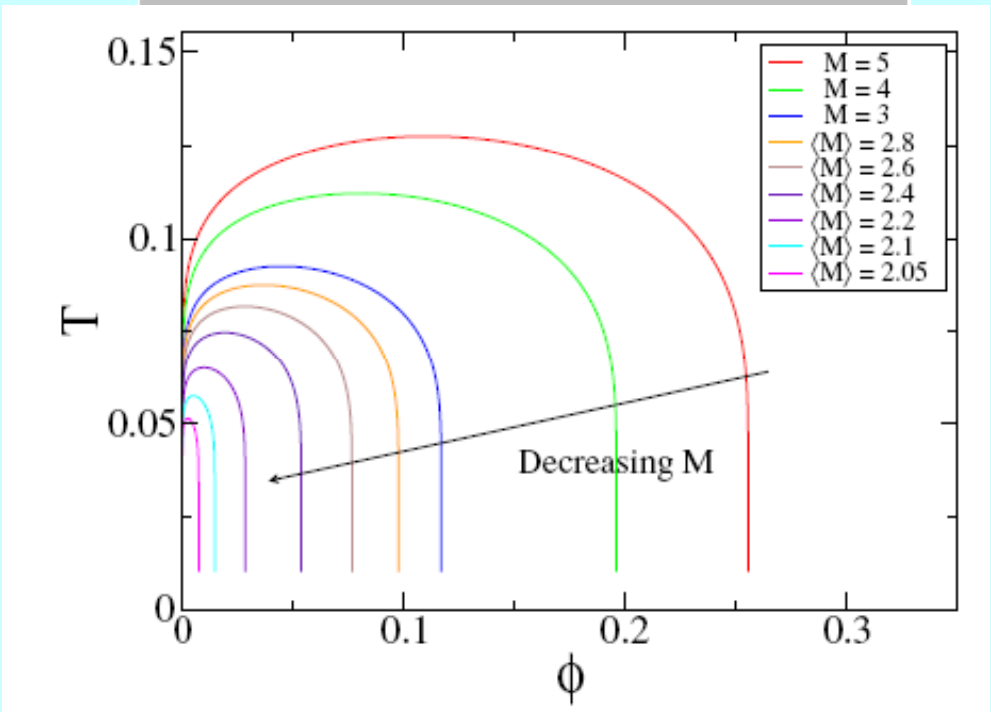
# Many interesting predictions by computer simulation, e.g.,

PRL 97, 168301 (2006) PHYSICAL REVIEW LETTERS week ending 20 OCTOBER 2006

**Phase Diagram of Patchy Colloids: Towards Empty Liquids**

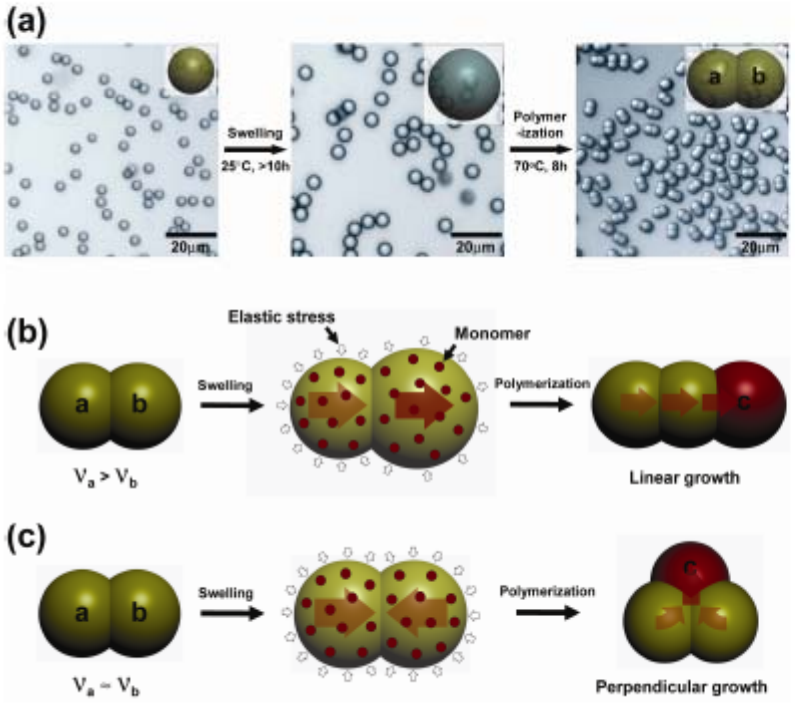
Emanuela Bianchi,[1] Julio Largo,[2] Piero Tartaglia,[1] Emanuela Zaccarelli,[3] and Francesco Sciortino[3]

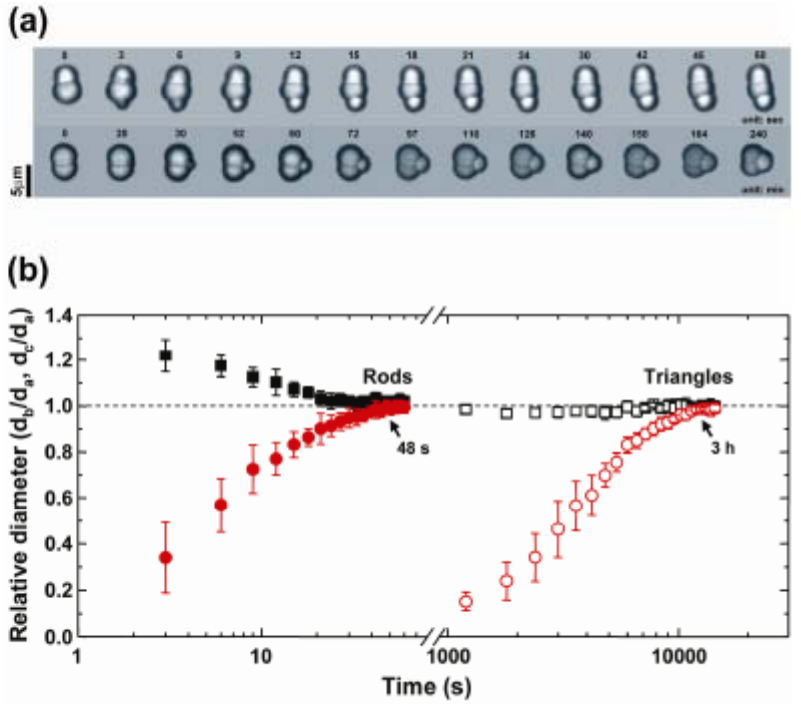


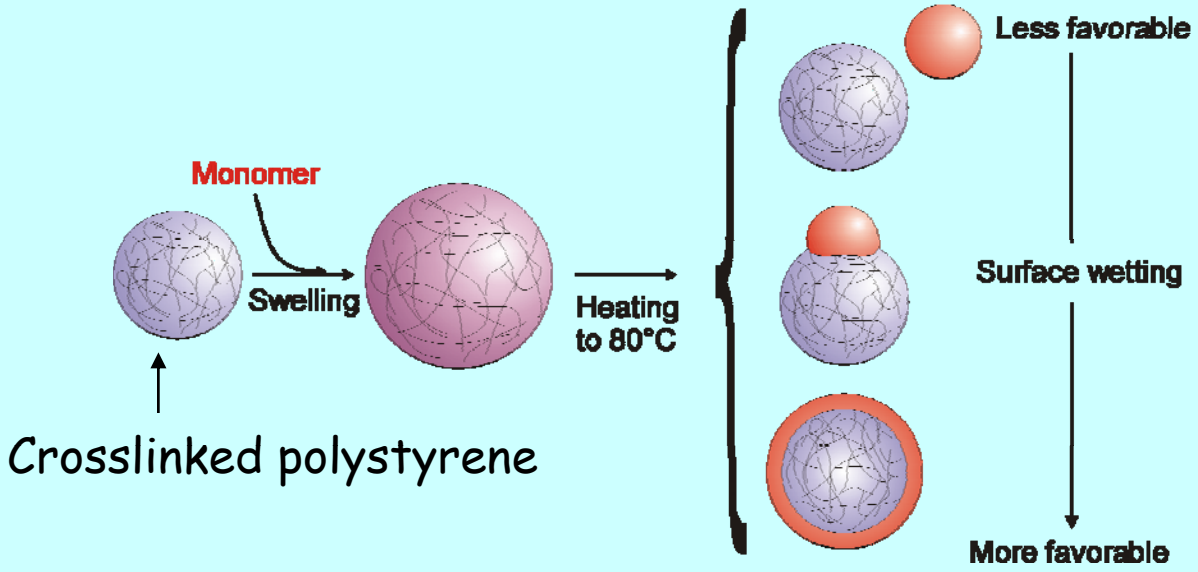
**How to make colloidal molecules (**excl Janus paticles**)?**

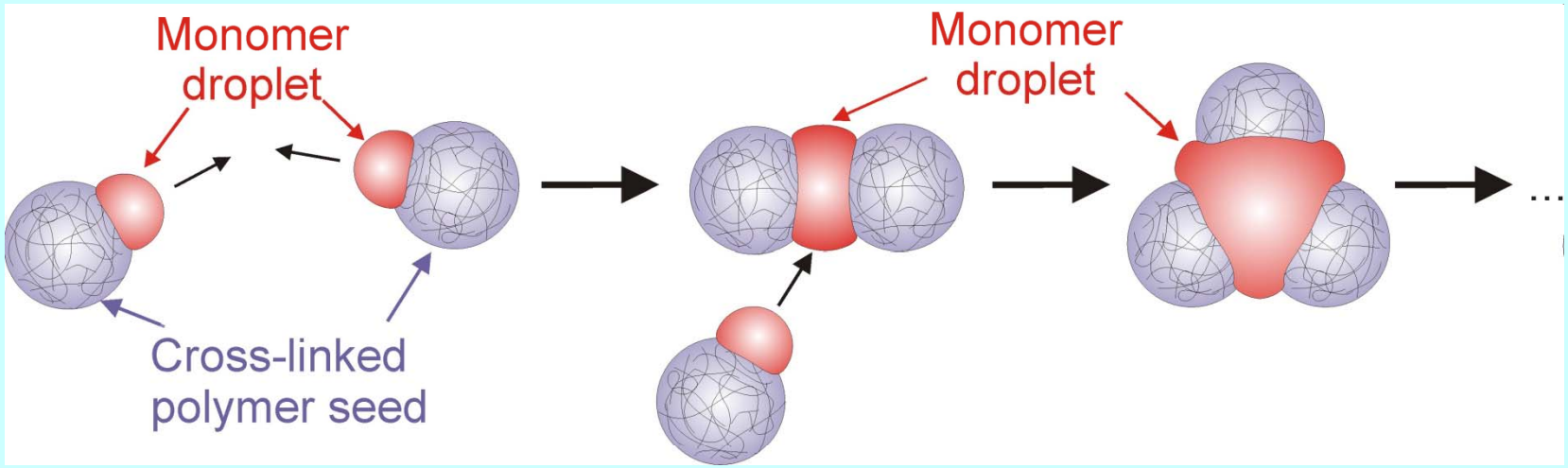
- Manoharan ea, Science 2003 -> emulsion based
- Sheu ea J. Polym. Sci. 1990 -> protrusion formation
- Mock ea, Langmuir 2006 -> contact angle adjustment
- J-W Kim ea, JACS 2006; Adv Mater. 2006



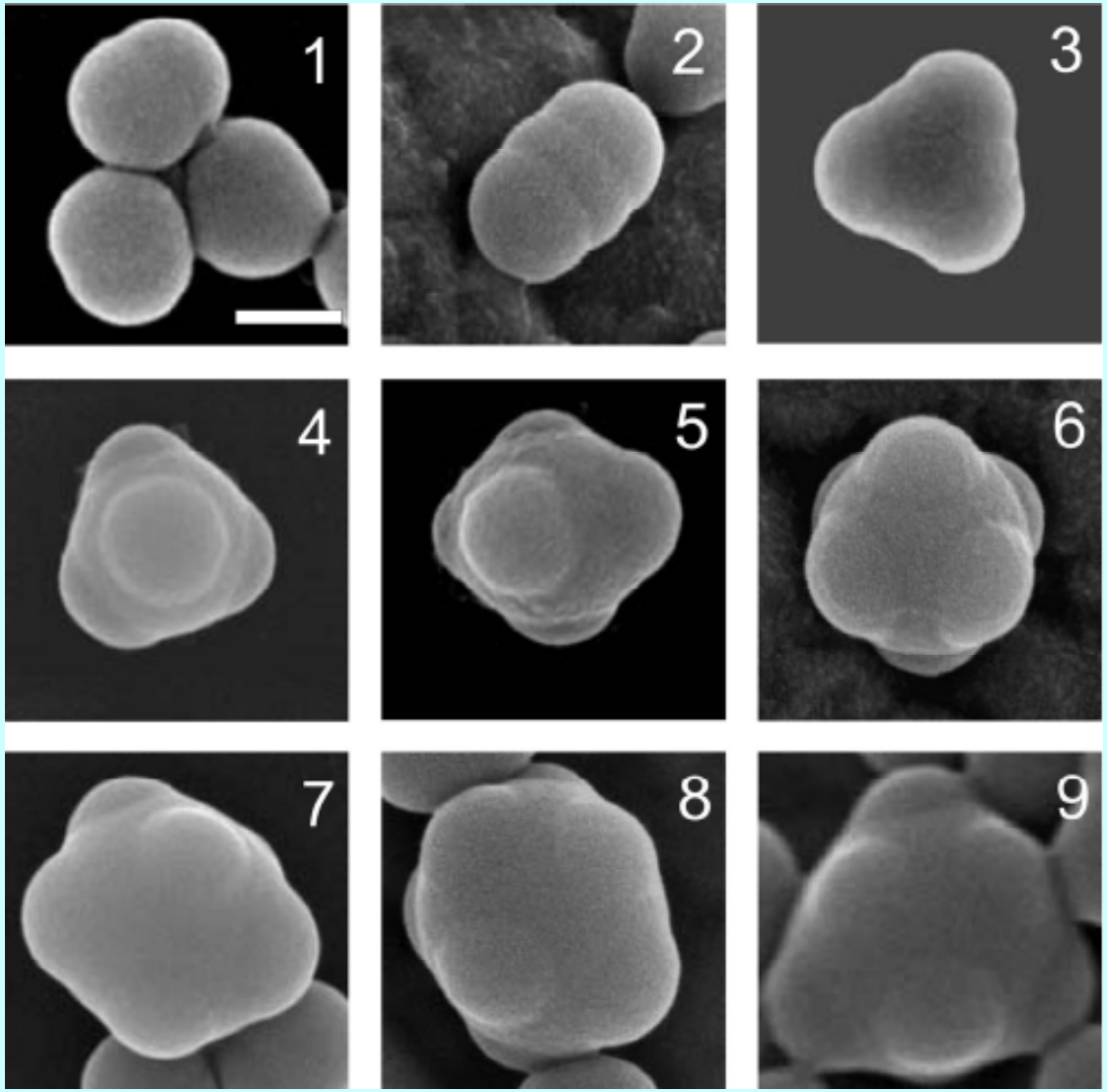
# (spontaneous) formation of colloidal molecules



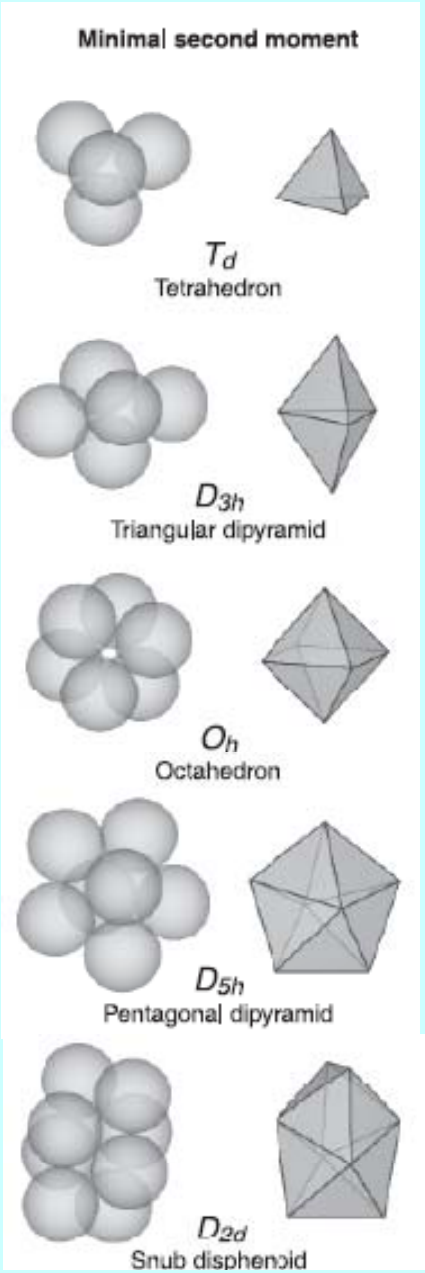




DJ Kraft, ea JACS 2009; *editors choice* Science 2009

# Can control number of patches



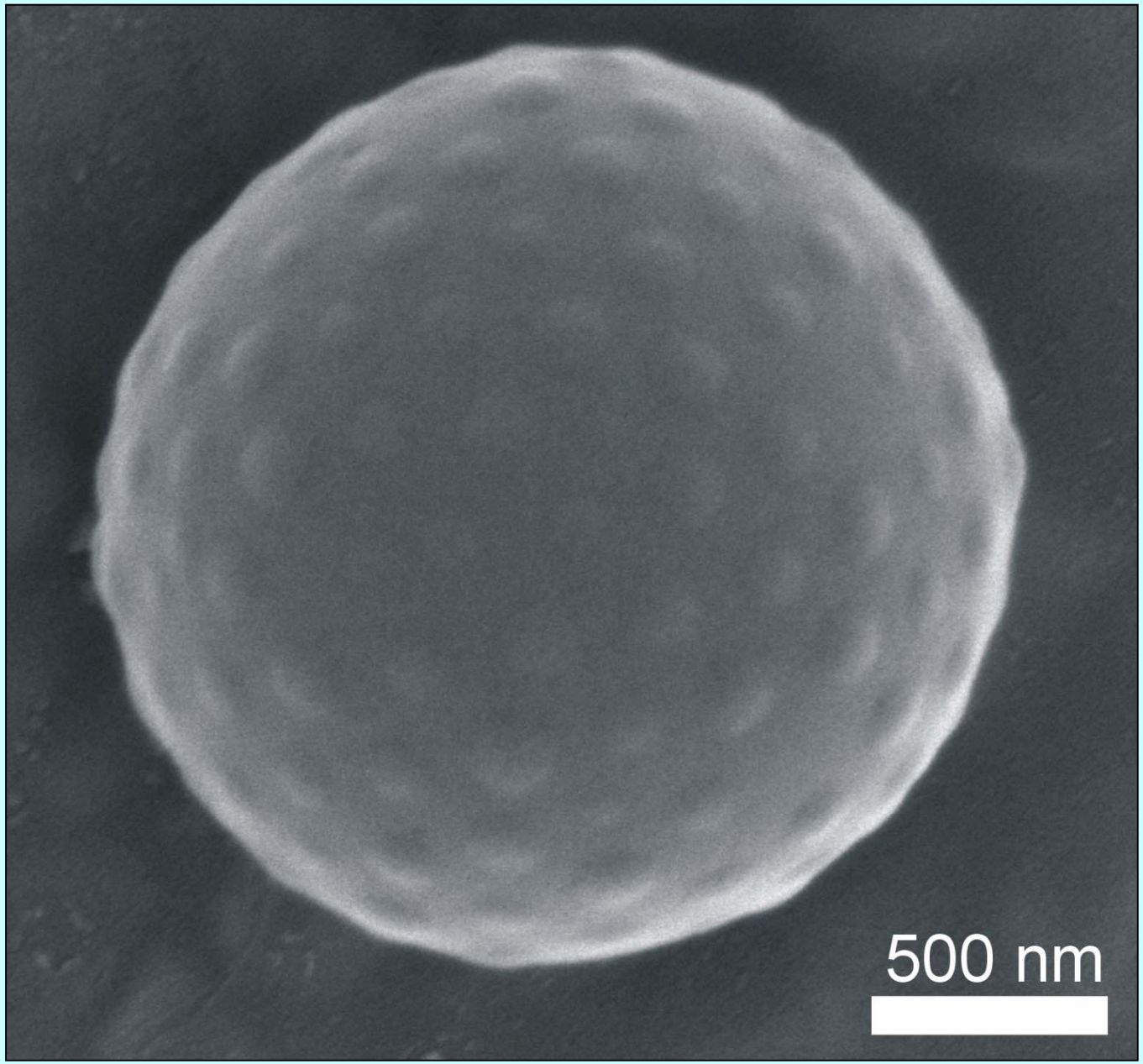

DJ Kraft ea JACS 2009




As in Manoharan ea Science 2003

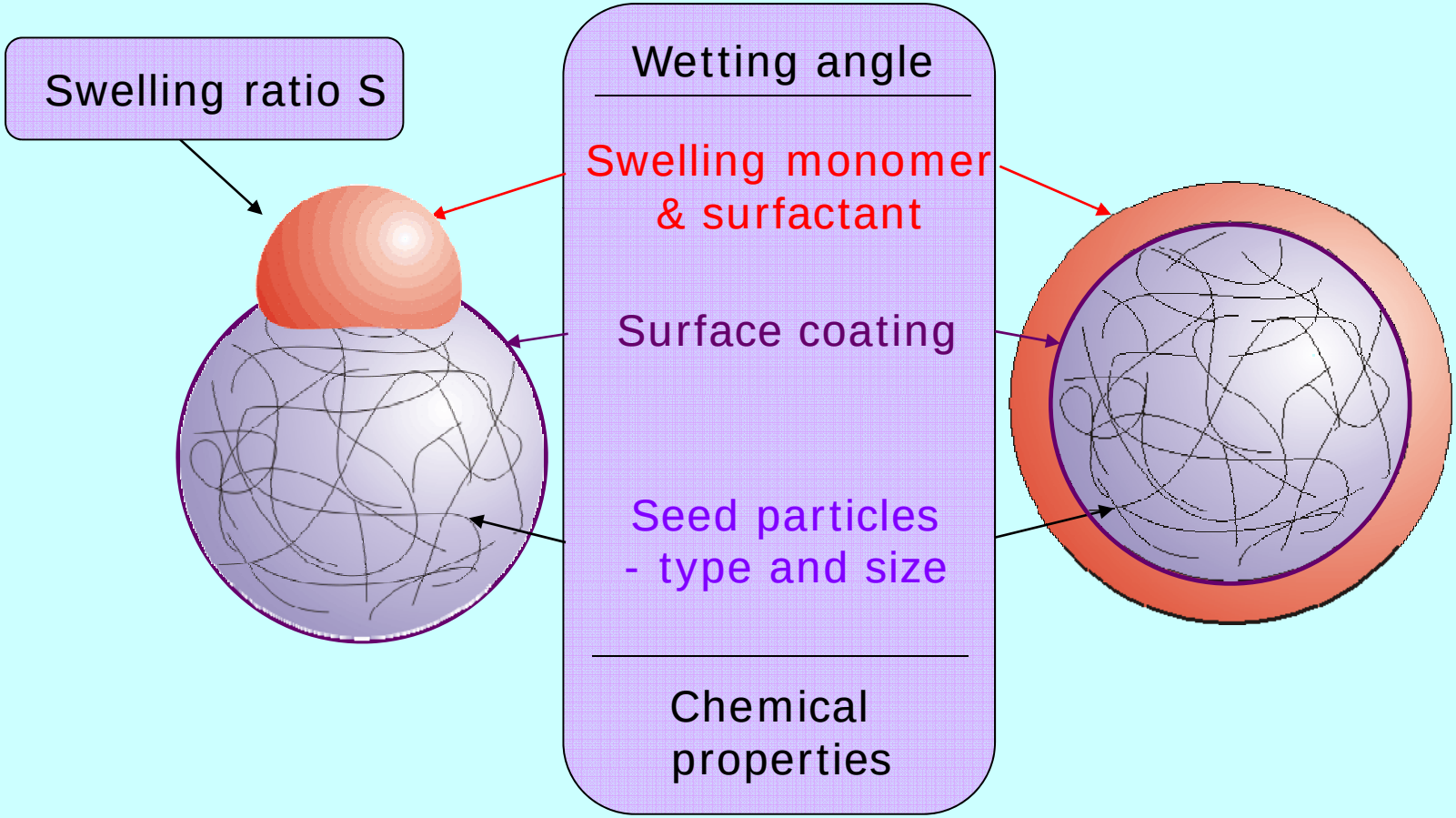
$A_{covered} \sim N$

$A_{free} \sim N^{2/3}$

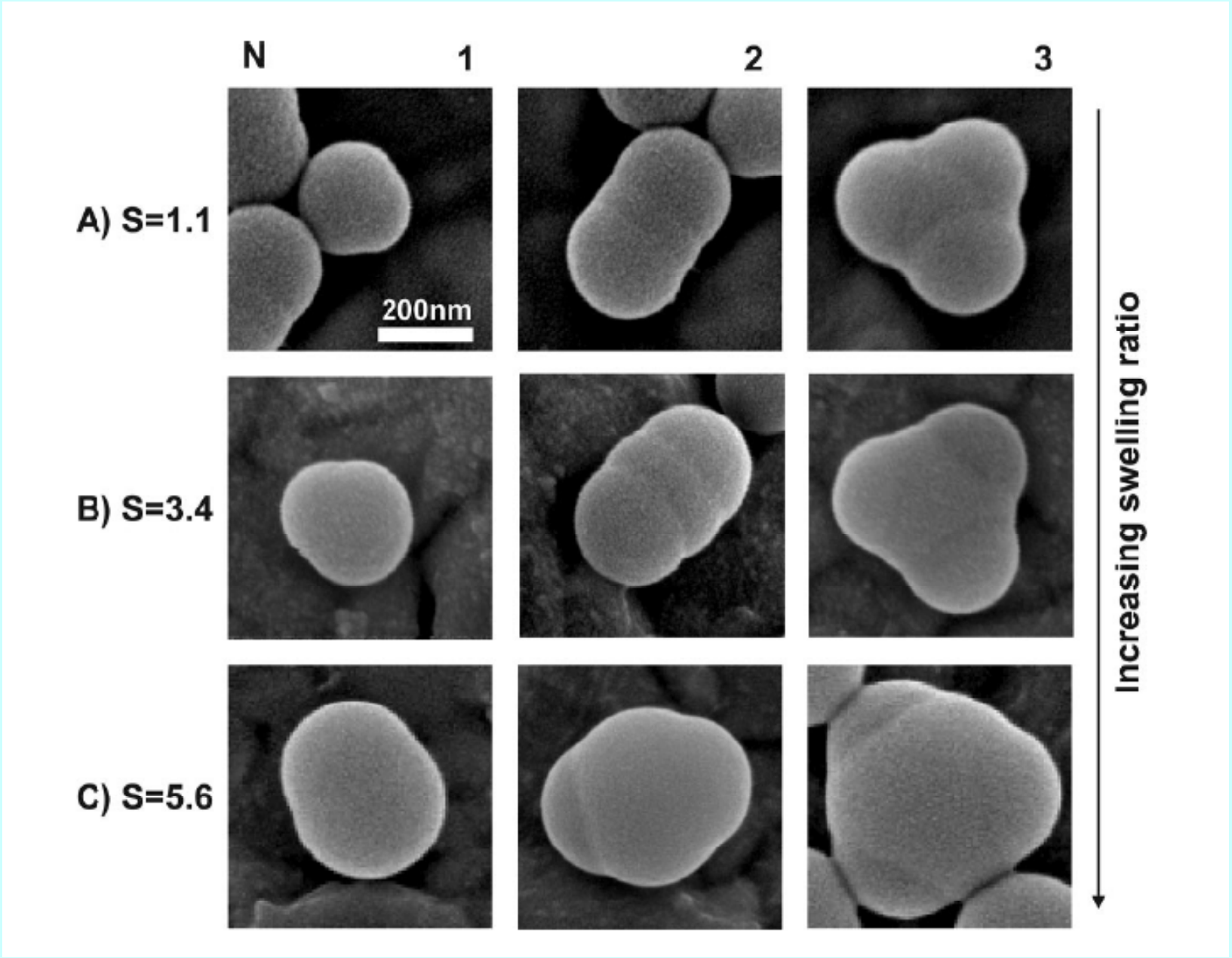



..limiting situation (N large)

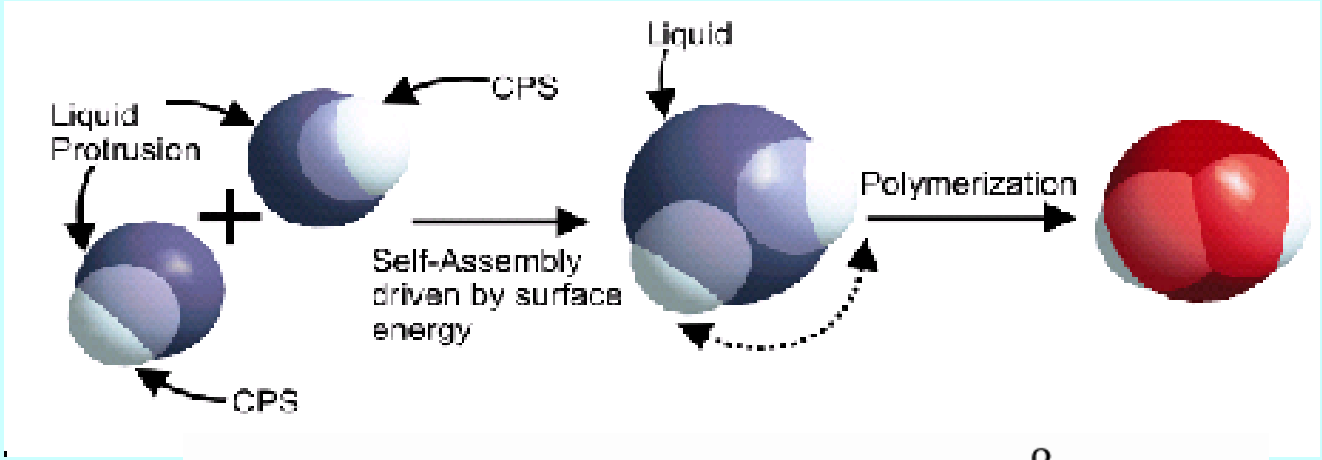
# Parameters to change shape and properties



# Can control relative patch size

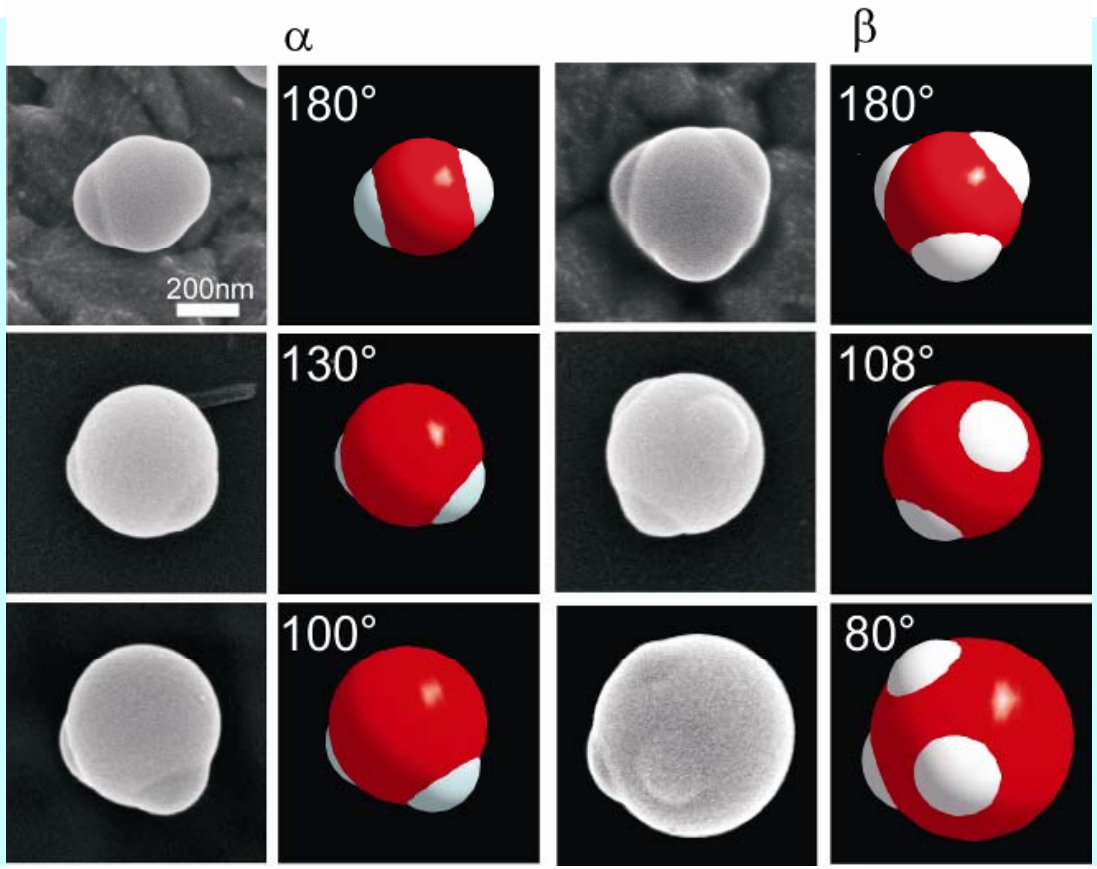


# Can control patch angle [DJ Kraft ea Soft Matt 2009]

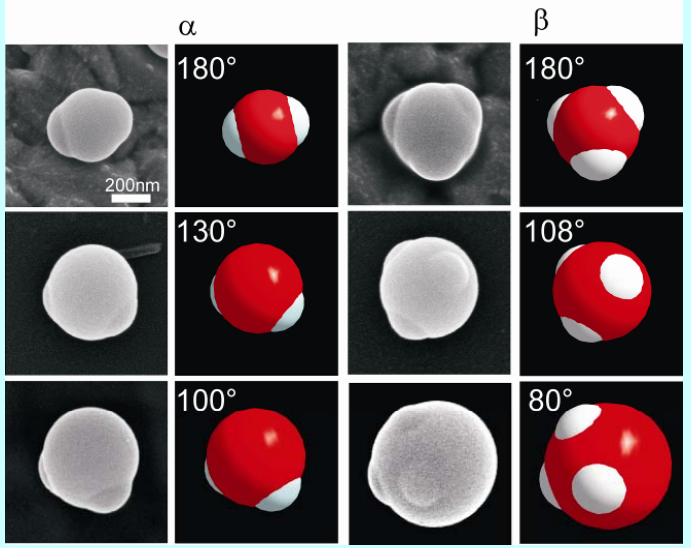



Plausible mechanism:

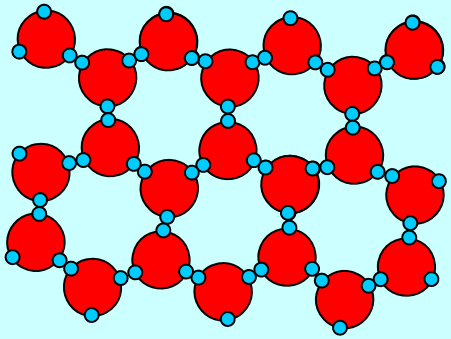
Depletion forces generated during polymerization

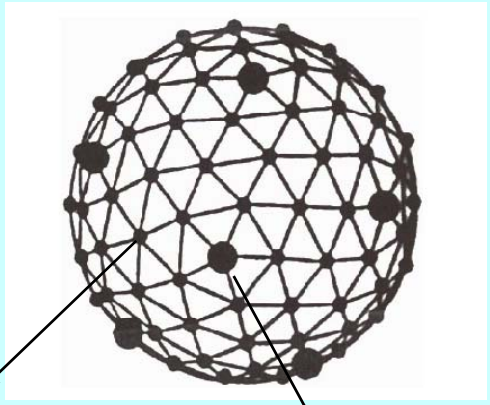


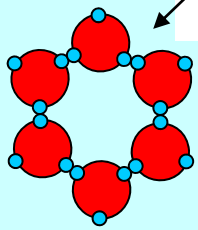
(Towards) **colloids with a valence**…

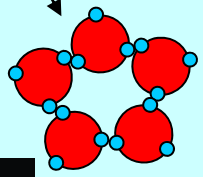



If we can make the patches sticky we may, e.g., ….

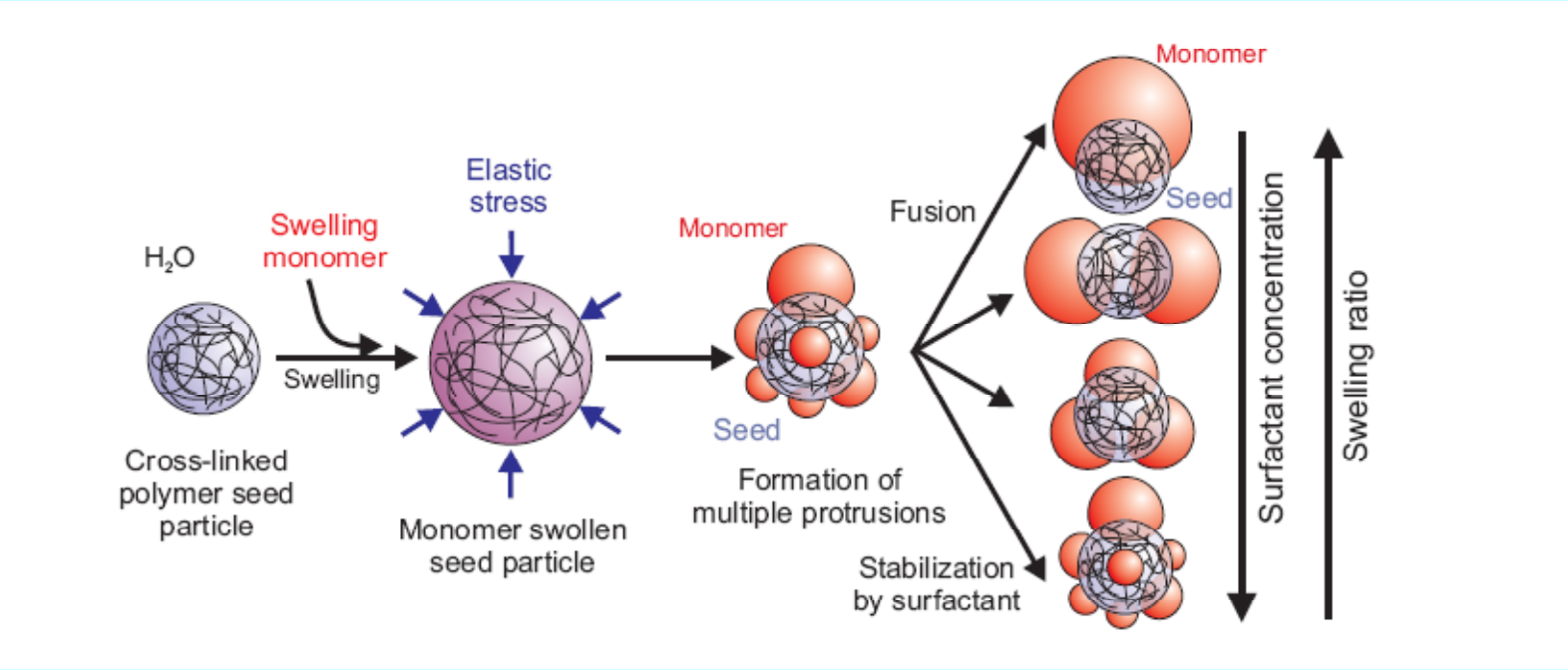


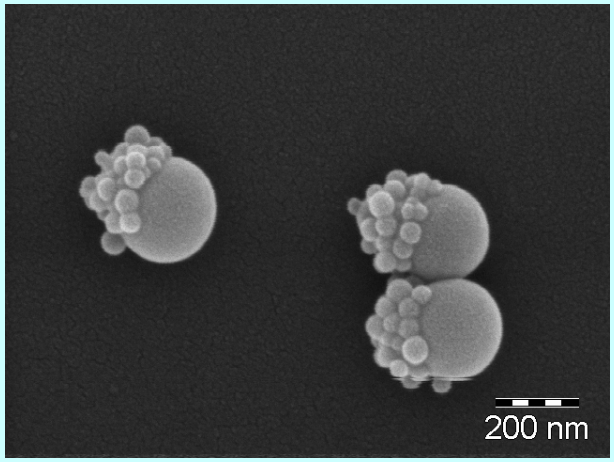


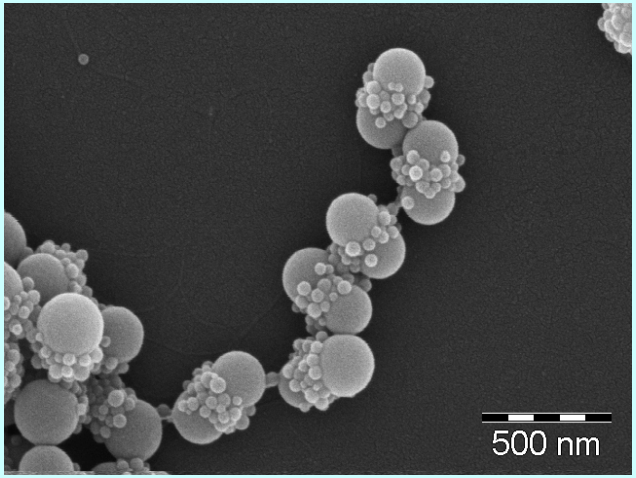




# There is more (to come)




PS + pNIPAM: Squid-like particles (Kraft ea TBS)

# Thank You!

And:

Ran Ni, Marjolein Dijkstra, Jan Groenewold
(UU)

Kisun Yoon, David Weitz (Harvard)

Dana Breed, Mark Elsesser, David Pine
(NYU)