






Design of Polymeric Nanostructures for Chemical and Biomedical Applications

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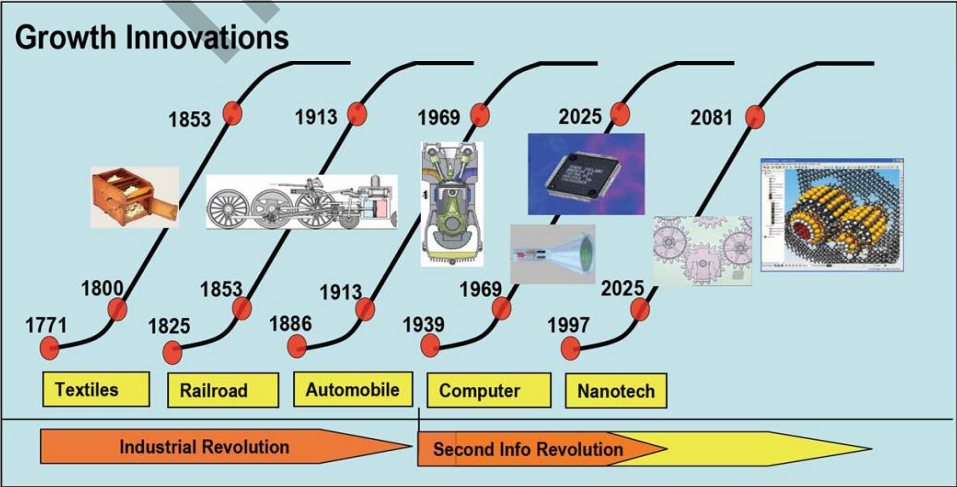


UW Quantum-Nano Centre



Revolutionary Technology Waves

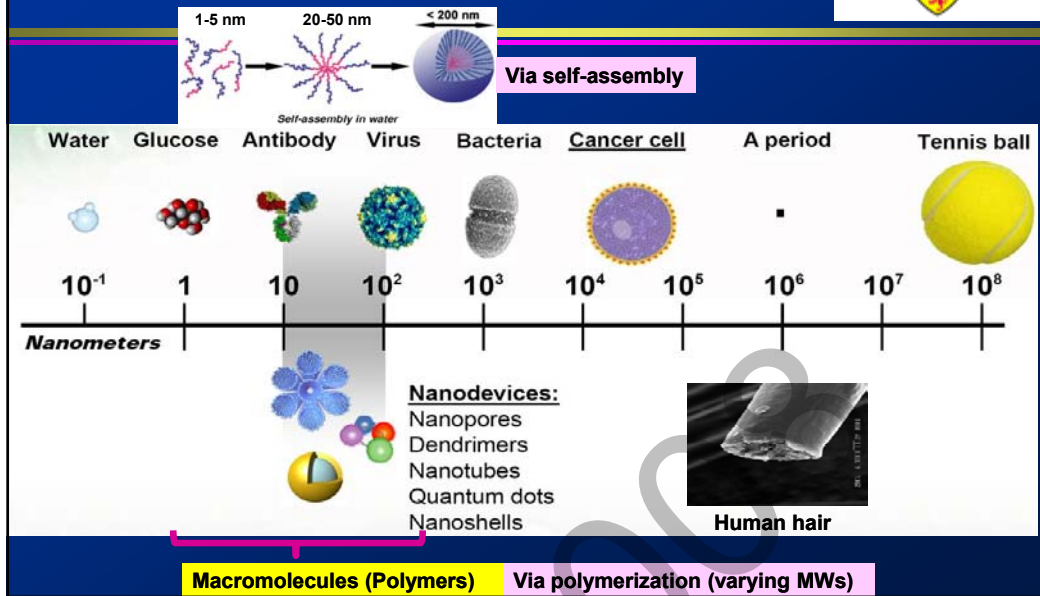
Growth Innovations



The diagram shows a timeline of growth innovations from 1771 to 2081. Key milestones include: 1771 (Textiles), 1800 (Textiles), 1825 (Railroad), 1853 (Railroad), 1886 (Automobile), 1913 (Automobile), 1939 (Computer), 1969 (Computer), 1997 (Computer), 2025 (Computer), 2025 (Nanotech), and 2081 (Nanotech). The Industrial Revolution is marked from 1800 to 1939, and the Second Info Revolution is marked from 1939 to 2081.

Source: Norman Poire, Merrill Lynch

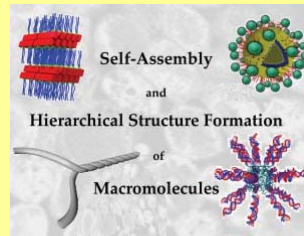
The Size of Things



Visionary in Polymer Science!

“In the meantime, macromolecular chemistry, too, has become a classical discipline, a mature science, with all the advantages and handicaps of maturity. Harvest is plentiful, the results are abundant – but one has to ask: where is the future, where are the adventures?”

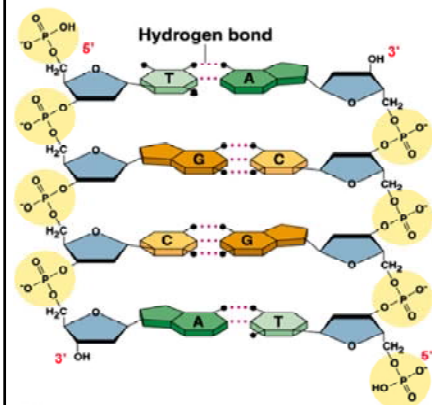
Quote by Helmut Ringsdorf



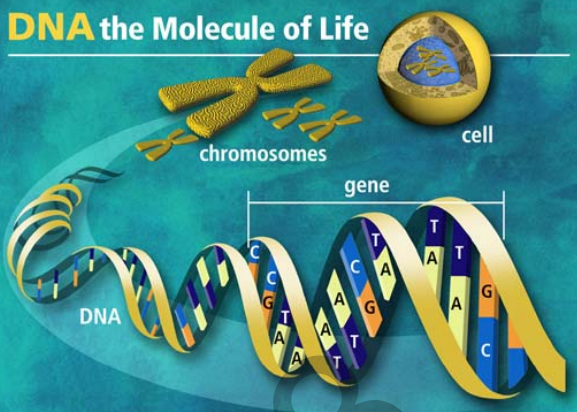
H. Ringsdorf, B. Schlarb, J. Venzmer, *Angew. Chem. Int. Ed. Engl.* 1988, 27, 113.

Dr. Ringsdorf promotes cross-disciplinary discussions and collaborations in the field of **polymer** chemistry, **biology**, **physics** and **medicine**

Self-assembly in Nature: (1) DNA



DNA the Molecule of Life

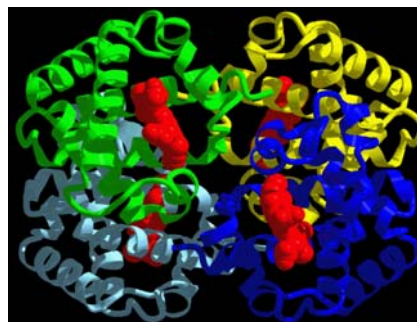
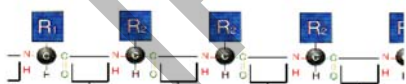


Source: <http://www.paternityexperts.com/img/DNA-of-life.jpg>

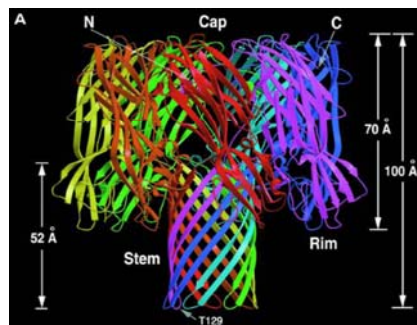
Length of a DNA = 20,000 μm (or 2 m)
Length of a chromosome = 2 μm

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Self-assembly in Nature: (2) Protein



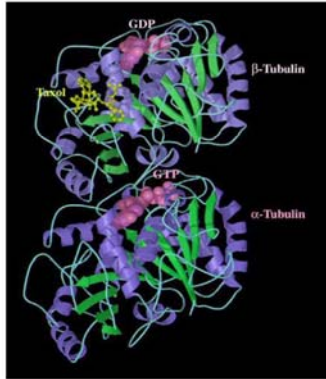
hemoglobin



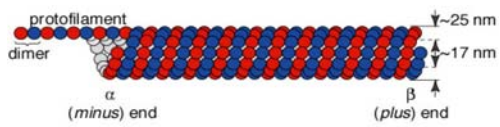
α -hemolysin

http://www.bio.davidson.edu/Courses/Molbio/MolStudents/spring2005/Heiner/hemoglobin_ribbon_4subunits.jpg

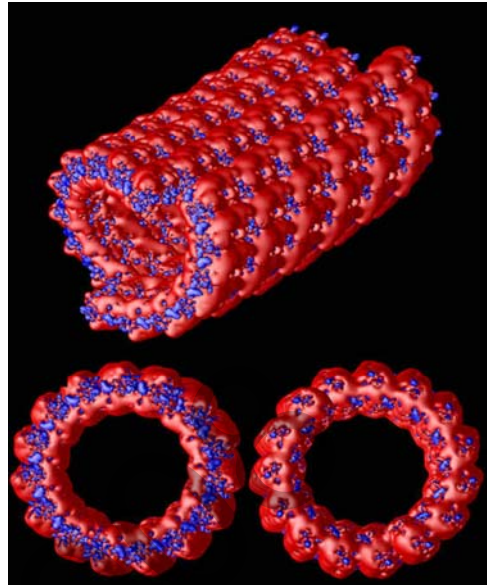
Self-assembly in Nature: (3) Microtubuli



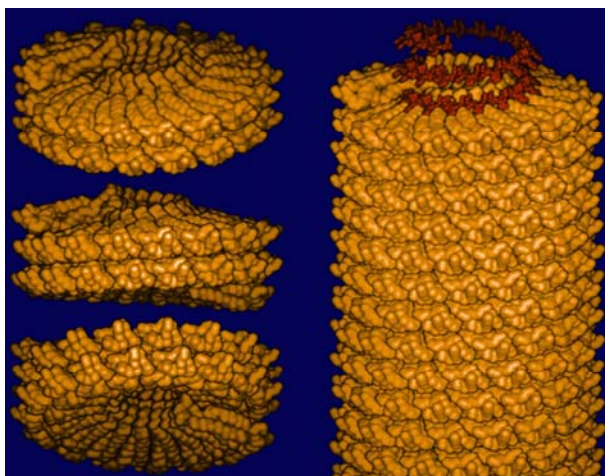
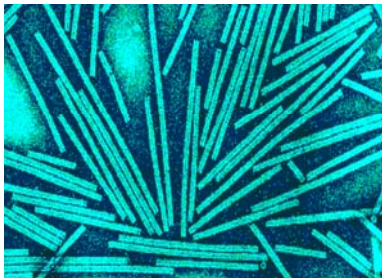
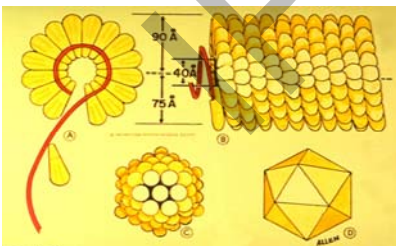
http://cryoem.berkeley.edu/~nieder/em_for_dummies/images/tubulin_ribbon.jpg



<http://www.physics.ucsb.edu/~jenny/r/research1.html>



Self-assembly in Nature: (4) Viral capsids



<http://www.sb.fsu.edu/~caspar/graphics/tmv3.gif>

Self-assembly in Nature: (5) Lipids and Biomembranes

The top left diagram shows a liposome, a spherical vesicle formed by phospholipids. A single phospholipid molecule is shown with a pink head and two tails. The top right diagram illustrates a phospholipid bilayer with labels: 'Polar, hydrophilic "head"', 'Nonpolar, hydrophobic, fatty acid "tails"', and 'Polar, hydrophilic "head"', with 'Aqueous environment' on both sides. The bottom diagram is a detailed cross-section of a cell membrane showing 'PHOSPHOLIPIDS', 'GLYCOLIPID', 'ALPHA-HELIX PROTEIN', 'GLOBULAR PROTEIN', 'HYDROPHOBIC SEGMENT OF ALPHA-HELIX PROTEIN', 'OLIGOSACCHARIDE SIDE CHAIN', and 'CHOLESTEROL'. A copyright notice for 2007 Encyclopedia Britannica, Inc. is present.

<http://upload.wikimedia.org/wikipedia/commons/e/ee/CellMembraneDrawing.jpg>

Polymers and Copolymers

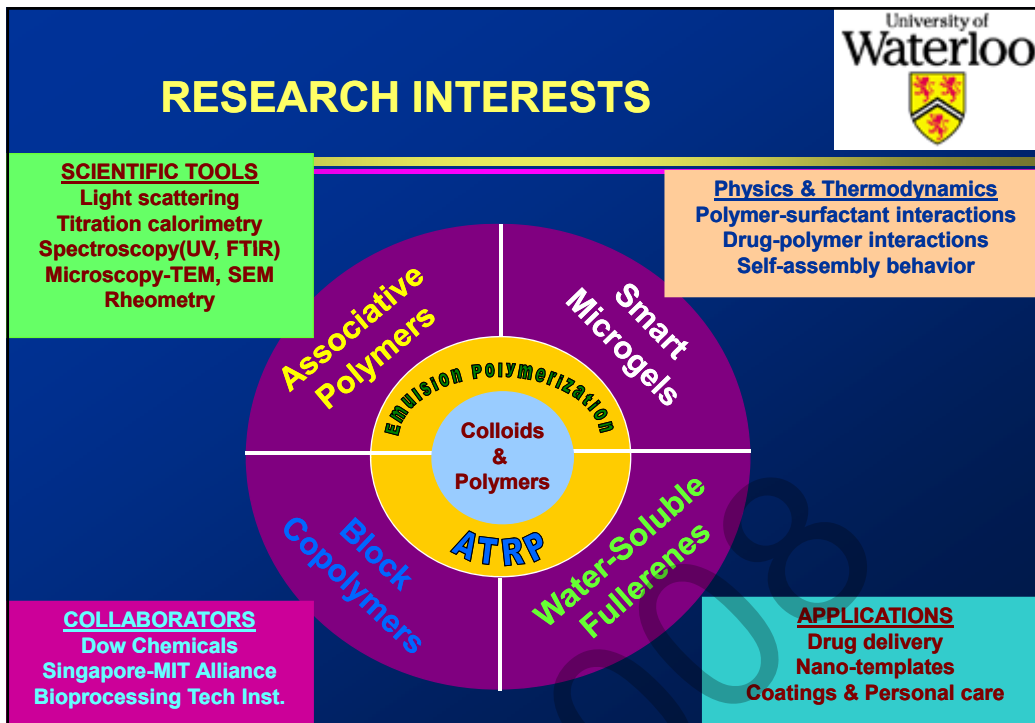
University of Waterloo

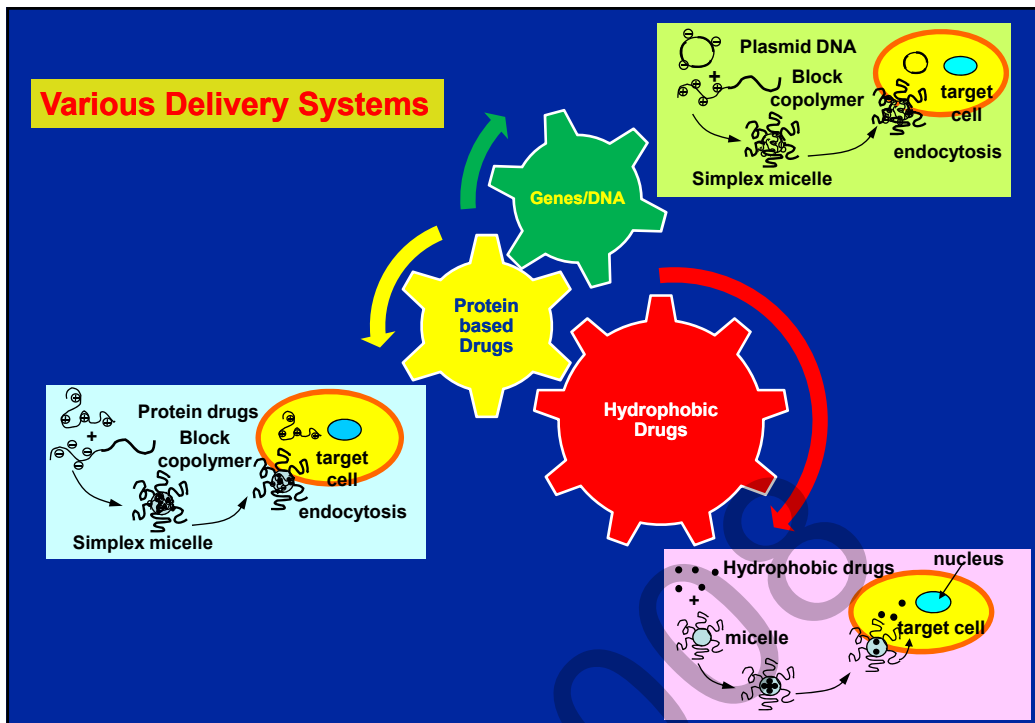
Polymer science, having an old tradition as an interdisciplinary field, can no longer restrict itself to common plastics. Attempts to reach new horizons have already begun.

- Homopolymer
- Alternating copolymer
- Random copolymer
- Di-block copolymer
- Tri-block copolymer
- Copolymers can self-assemble to form nanoscale structures

- Dendrimers
- Others

The left side shows several polymer chains of different colors (green, red, blue) and configurations. The right side shows a spherical dendrimer structure with a central core and branching arms.





POLYMERIC DRUG DELIVERY SYSTEMS

Peptide based block copolymers

Sinaga, A., Hatton, T.A., Tam, K.C., *Macromolecules* (2007), 40, 9064-9073

Sinaga, A., Hatton, T.A., Tam, K.C., *Biomacromolecules* (2007) 8, 2801-2808.

Sinaga, A., Ravi, P., Hatton, T.A., Tam, K.C., *Journal of Polymer Science Part A: Polymer Chemistry* (2007), 45 (13), 2646-2656

Fullerene block copolymers

Wang C., Ravi, P., Tam, K.C., *Langmuir* (2007), 23, 8798-8805.

Ravi, P., Dai, S., Wang, C., Tam, K.C., *Journal of Nanoscience and Nanotechnology* (2007), 7 (4-5), 1176-1196.

Wang, C., Ravi, P., Dai, S., Tam, K.C., *Langmuir* (2006), 22 (17), 7167-7174.

Microgel and nanogel systems

Tan, B.H., Ravi, P., Tan, L.N., Tam, K.C., *Journal of Colloid & Interfacial Science* (2007), 309 (2), 453-463.

2638-2646. Tan, J.P.K., Tam, K.C., *Journal of Controlled Release* (2007), 118, 87-94.

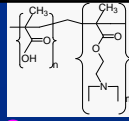
Tan, B.H., Ravi, P., Tam, K.C., *Macromolecular Rapid Communications* (2006), 27, 522-528.

Modified Pluronic block copolymers

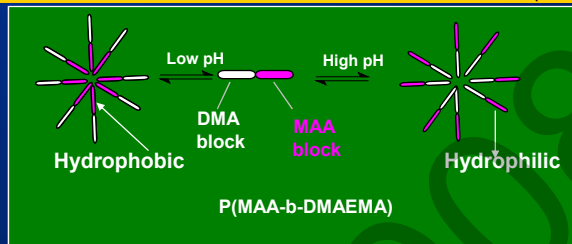
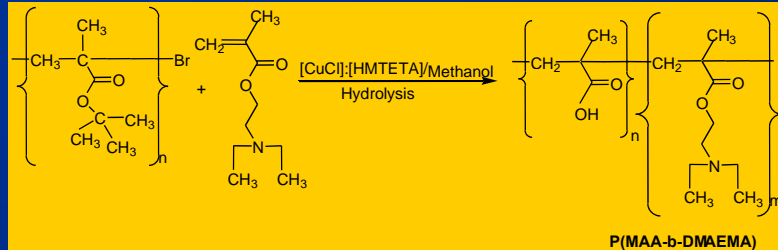
Tian, Y., Bromberg, L., S.N. Lin, Hatton, T.A., Tam, K.C., *Journal of Controlled Release* (2007), 121 (3), 137-145.

Tian, Y., Ravi, P., Bromberg, L., Hatton, T.A., Tam, K.C., *Langmuir* (2007) 23,

Xiong, X.Y., Li, Y., Li, Z., Zhou, C., Tam, K.C., Liu, Z., Xie, G., *Journal of Controlled Release* (2007), 120, 11-17.



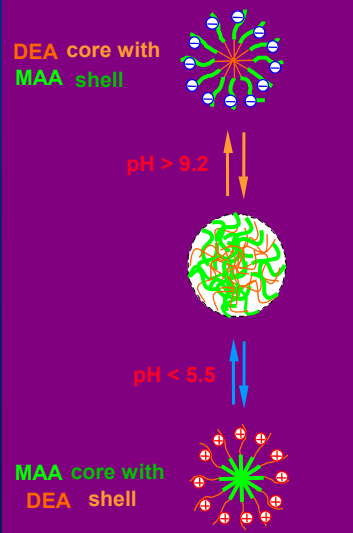
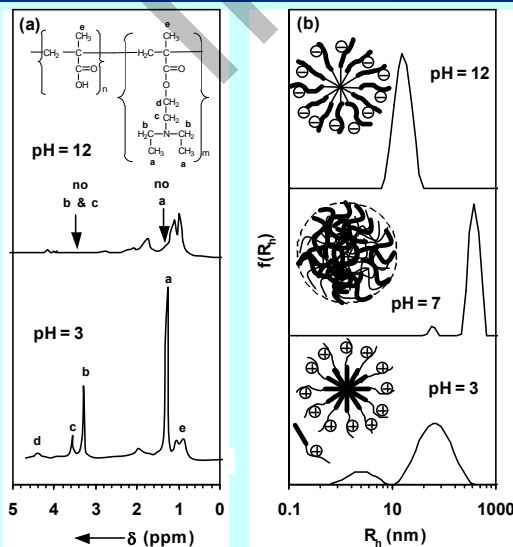
pH responsive reverse micelle



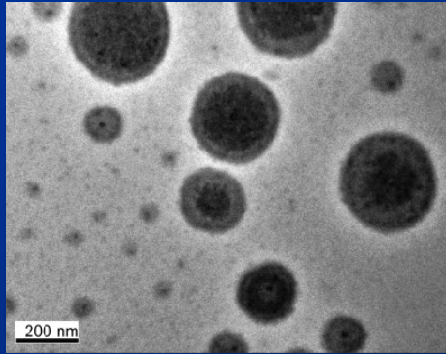
Mao, B.W., Gan, L.H., Gan, Y.Y., Tam, K.C., Tan, O.K., *Polymer* (2005), 46, 10045-10055.

Dai, S., Ravi P., Tam, K.C., Mao B.W., Gan L.H., *Langmuir* (2003), 19, 5175-5177

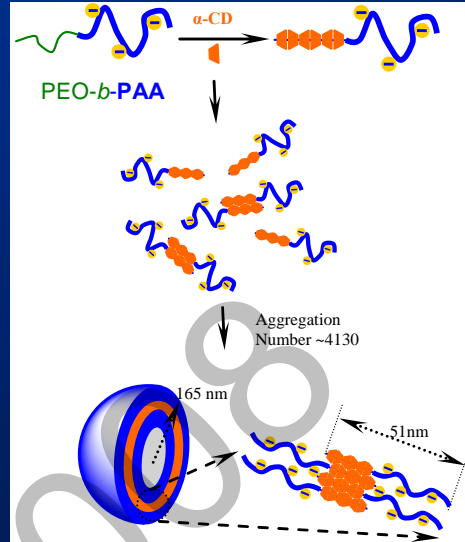
Micellization Behavior of P(DEA-b-MAA)



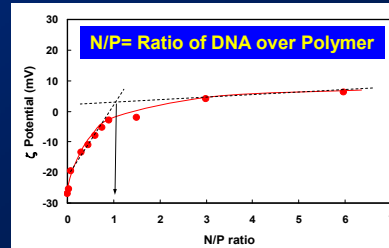
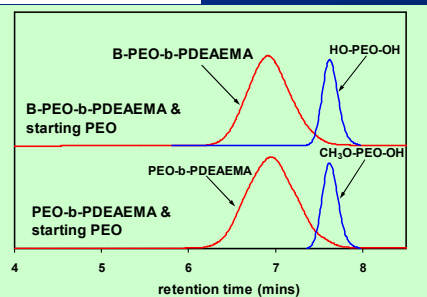
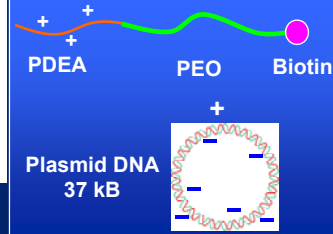
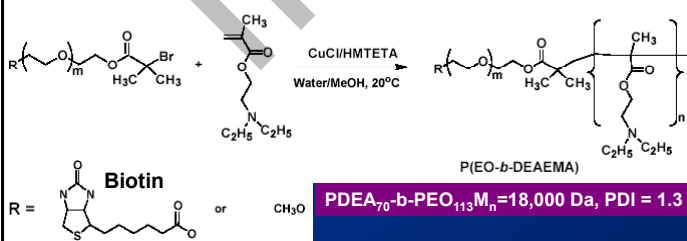
α -Cyclodextrin Induced Assembly of PEO-b-PAA at high pH



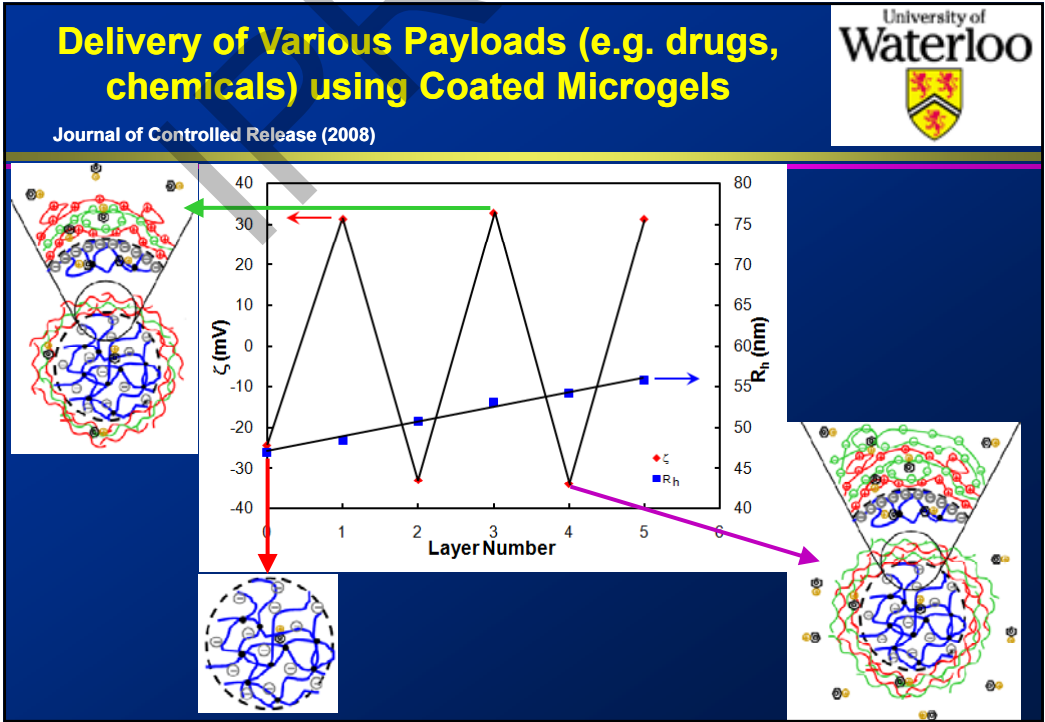
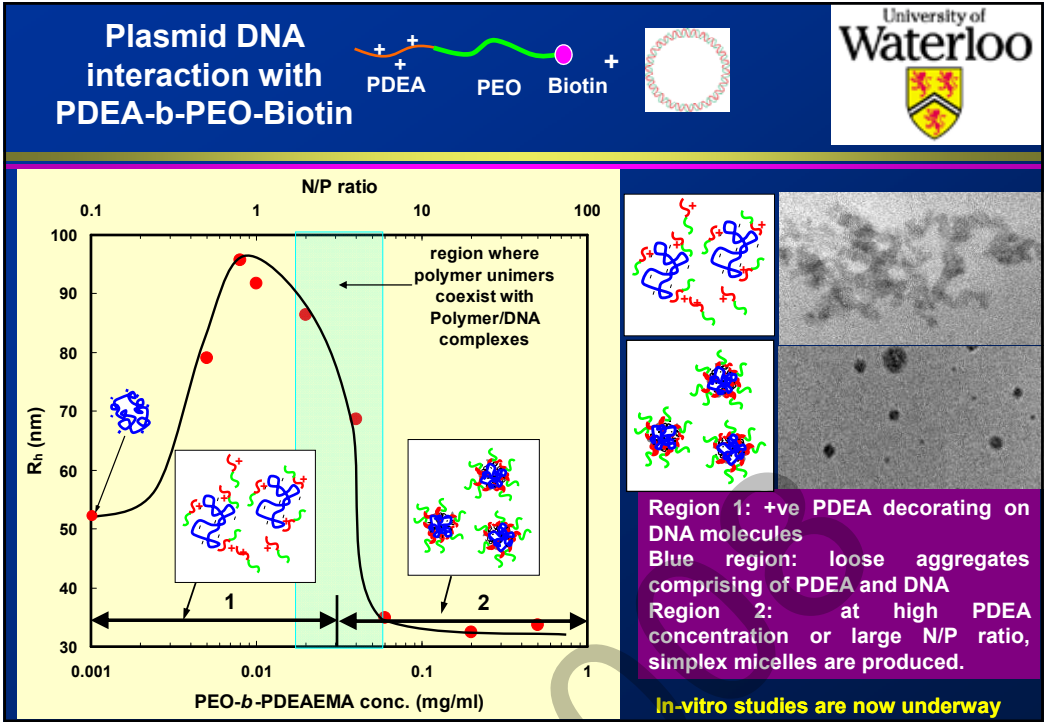
Double-hydrophilic poly(ethylene oxide)-b-poly(acrylic acid) (PEO-*b*-PAA) self-assembled into nanostructures in basic solution upon the addition of α -cyclodextrin (α -CD). Self-assembly was induced by the complexation between α -CD and PEO segments.



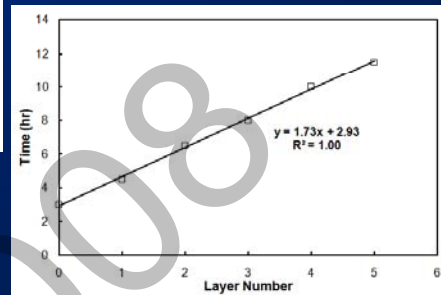
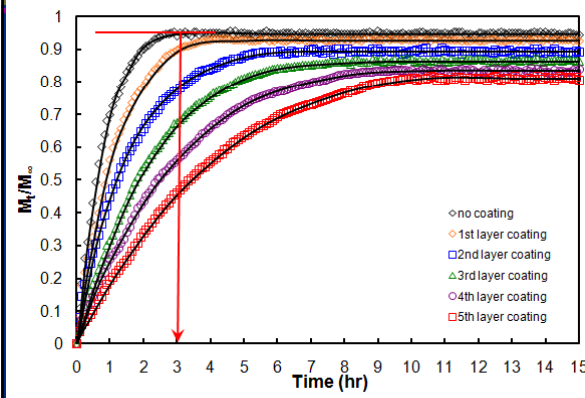
Plasmid DNA interaction with PDEA-b-PEO-Biotin



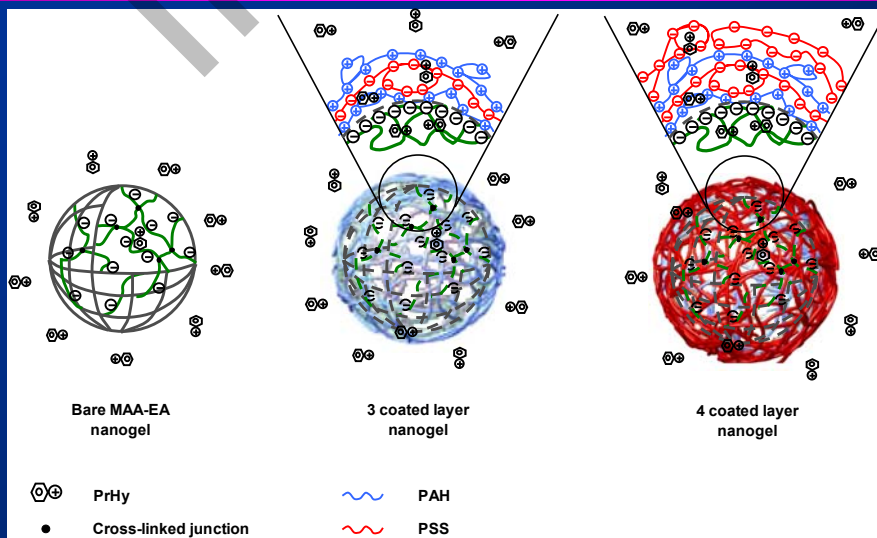
Tan, J.F., Ravi, P., Too, H.P., Hatton, T.A., Tam, K.C., *Biomacromolecules* (2005), 6, 498-506



Release Kinetic from Coated Microgels



Mechanism Controlling Drug Delivery from Coated Microgels



Fullerene System (Bucky Ball)

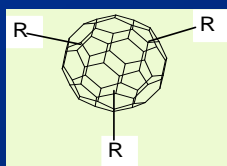
Drawbacks

- ✓ Solubility
- ✓ Processability
- ✓ Applications Hindered

Solutions

- Graft small molecules
- Graft polymers
- Charge transfer complexes

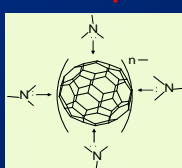
Grafting small groups



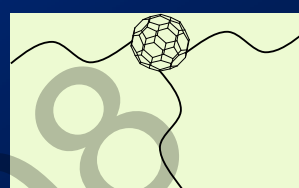
Well-defined grafting



CT Complex



Grafting of Polymers

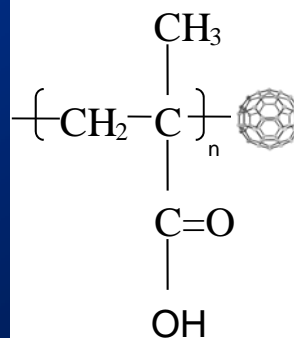


Amphiphilic behaviour

pH-responsive Fullerene System

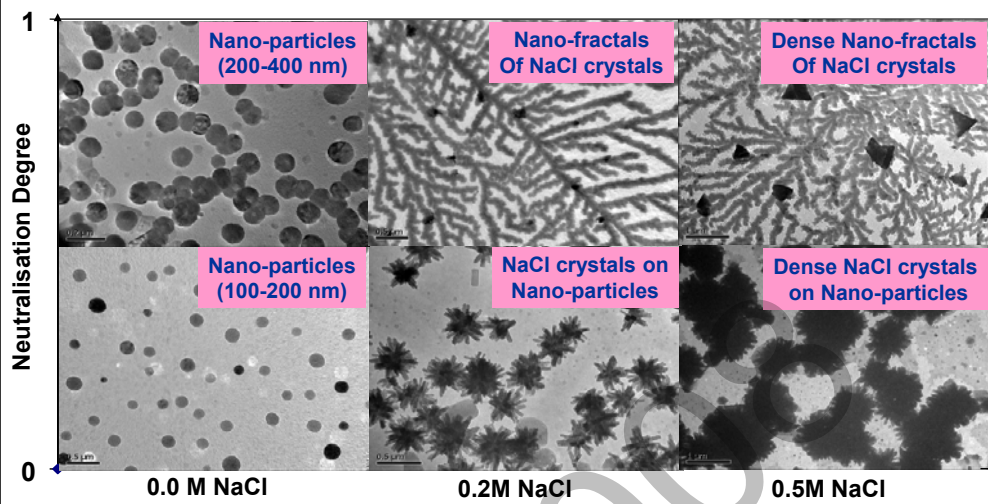
Polymethacrylic acid-b-C60

- PMAA₁₂₅-b-C₆₀
- M_n ~ 10,800 Da
- M_w/M_n = 1.18



Ravi, P., Dai, S., Tan, C.H., Tam, K.C. *Macromolecules* (2005), **38**, 933-939.
 Yu, H., Gan, L. H., Hu, X., Venkatraman, S. S., Tam, K. C., Gan, Y. Y.,
Macromolecules (2005), **38**, 9889-9893
 Teoh, S.K., Ravi, P., Dai, S., Tam, K.C., *Journal of Physical Chemistry B* (2005),
109, 4431-4438.
 Ravi, P., Dai, S., Tam, K.C., *Journal of Physical Chemistry B* (In Press).

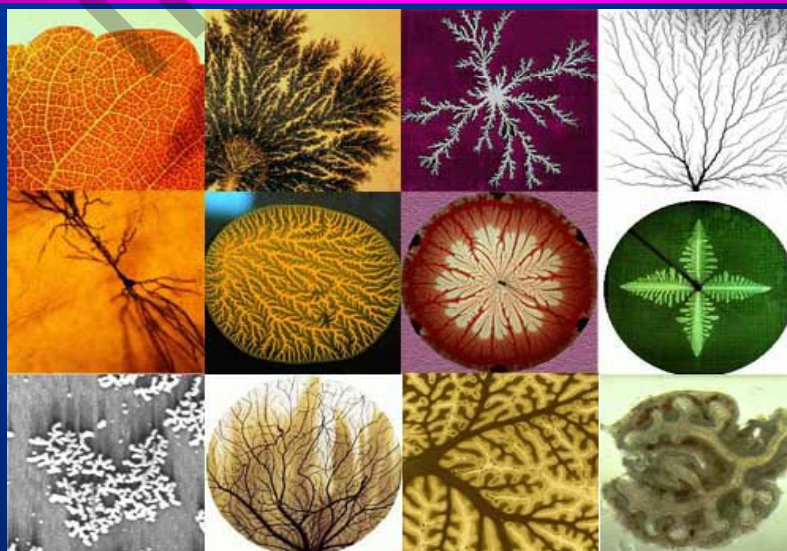
Nano-particles and nano-fractals



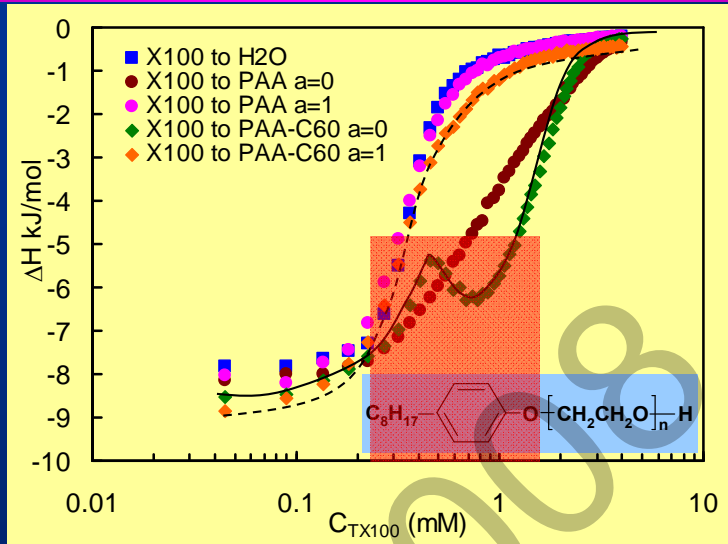
Tan, C.H., Dai, S., Ravi, P., Tam, K.C., Langmuir (2004), 20, 9901-9904

AFM

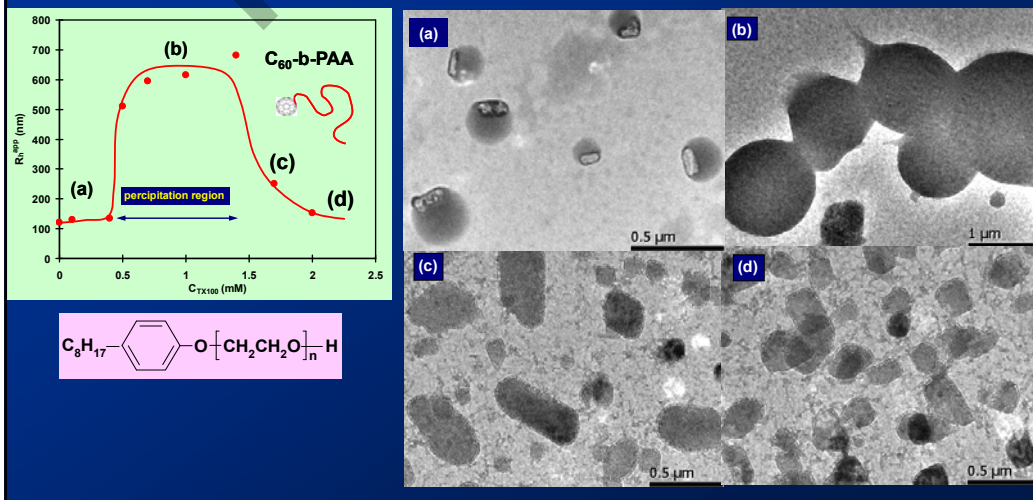
Naturally occurring fractal patterns



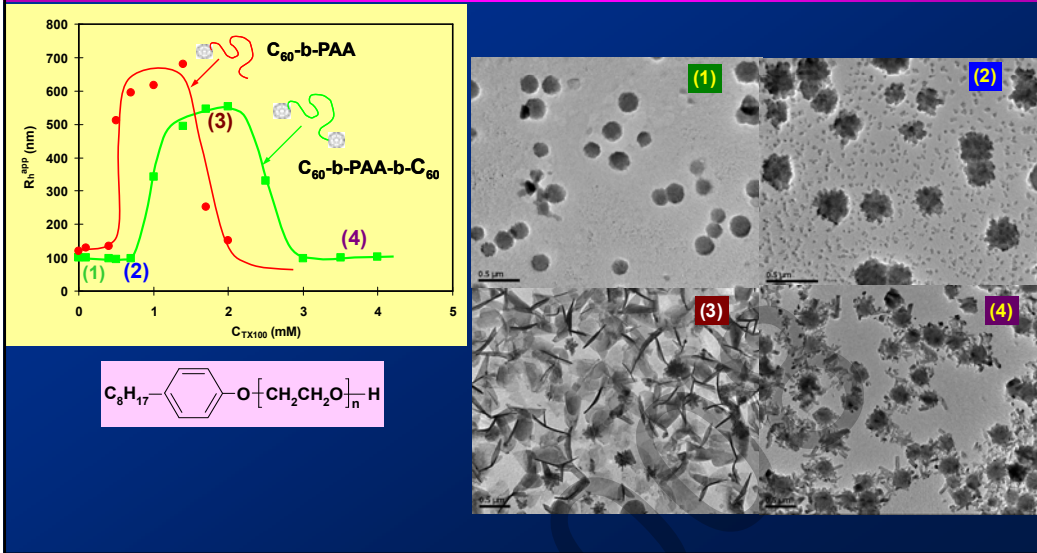
INTERACTION WITH NON-IONIC SURFACTANTS



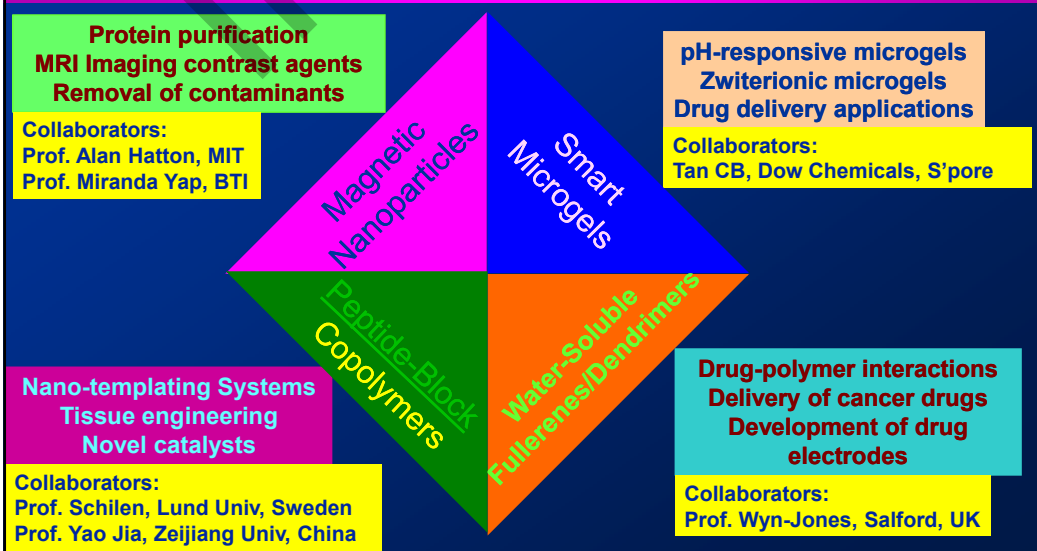
INTERACTION WITH NON-IONIC SURFACTANTS



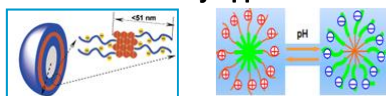
INTERACTION WITH NON-IONIC SURFACTANTS



RECENT RESEARCH ACTIVITIES in NANOTECHNOLOGY

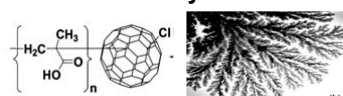


Self-Assembly Systems for Drug and Gene Delivery Applications



Dai, S., Ravi, P., **Tam, K.C.**, *Soft Matter* (2008), 4, 435
 Sinaga, A., Hatton, T.A., **Tam, K.C.**, *Macromolecules* (2007), 40, 9064.
 Tian, Y., Bromberg, L., S.N. Lin, Hatton, T.A., **Tam, K.C.**, *J. Controlled Release* (2007), 121, 137.
 Liu, J.H., Sondjaja, R., **Tam, K.C.**, *Langmuir* (2007), 23, 5106.
 Tan, J.P.K., **Tam, K.C.**, *J. Controlled Release* (2007), 118, 87.
 Tan, J.F., Too, H.P., Hatton, T.A., **Tam, K.C.**, *Langmuir* (2006), 22, 3744.

Water-soluble Stimuli-responsive Fullerene Systems



Ravi, P., Dai, S., Wang, C., **Tam, K.C.**, *J. Nanoscience & Nanotechnology* (2007), 7, 1176.
 Ravi, P., Wang, C., Dai, S., **Tam, K.C.**, *Langmuir* (2006), 22, 7167.
 Ravi, P., Dai, S., **Tam, K.C.**, *J. Physical Chemistry B* (2005), 109, 22791.
 Ravi, P., Dai, S., Tan, C.H., **Tam, K.C.**, *Macromolecules* (2005), 38, 933.

Polymer-Surfactant/Drug Interactions



Wang C., Ravi, P., **Tam, K.C.**, *Langmuir* (2007), 23, 8798.
 Wang, C., Wyn-Jones E., Sidhu, J., **Tam, K.C.**, *Langmuir* (2007), 23, 1635.
 Liao, D.S., Dai, S., **Tam, K.C.**, *J. Physical Chemistry B* (2007), 111, 371.
Tam, K.C., Wyn-Jones, E, *Chemical Society Reviews* (2006), 35, 693.
 Wang C., Ravi, P., **Tam, K.C.**, *Langmuir* (2006), 22, 2927.

Responsive and Smart Microgel/Nanogel Systems



Tan, B.H., **Tam, K.C.**, *Adv. Colloid and Interface Science* (2008),
 Tan, J.P.K., Goh, C.H., **Tam, K.C.**, *European J. Pharmaceutical Science*, (2007), 32, 340.
 Tan, B.H., **Tam, K.C.**, *Polymer* (2007), 48, 6589.
 Tan, B.H., Ravi, P., Tan, L.N., **Tam, K.C.**, *J. Colloid & Interfacial Science* (2007), 309, 453.
 Tan, B.H., Ravi, P., **Tam, K.C.**, *Macromolecular Rapid Communications* (2006), 27, 522.

Former Group Members



Thank you for your attention

I will be happy to answer any questions you may have!
Website: <http://chemeng.uwaterloo.ca/mtam/>



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