

Polymers and Control of Information

Information Content and Logic Operations in Chemical and Biological Systems

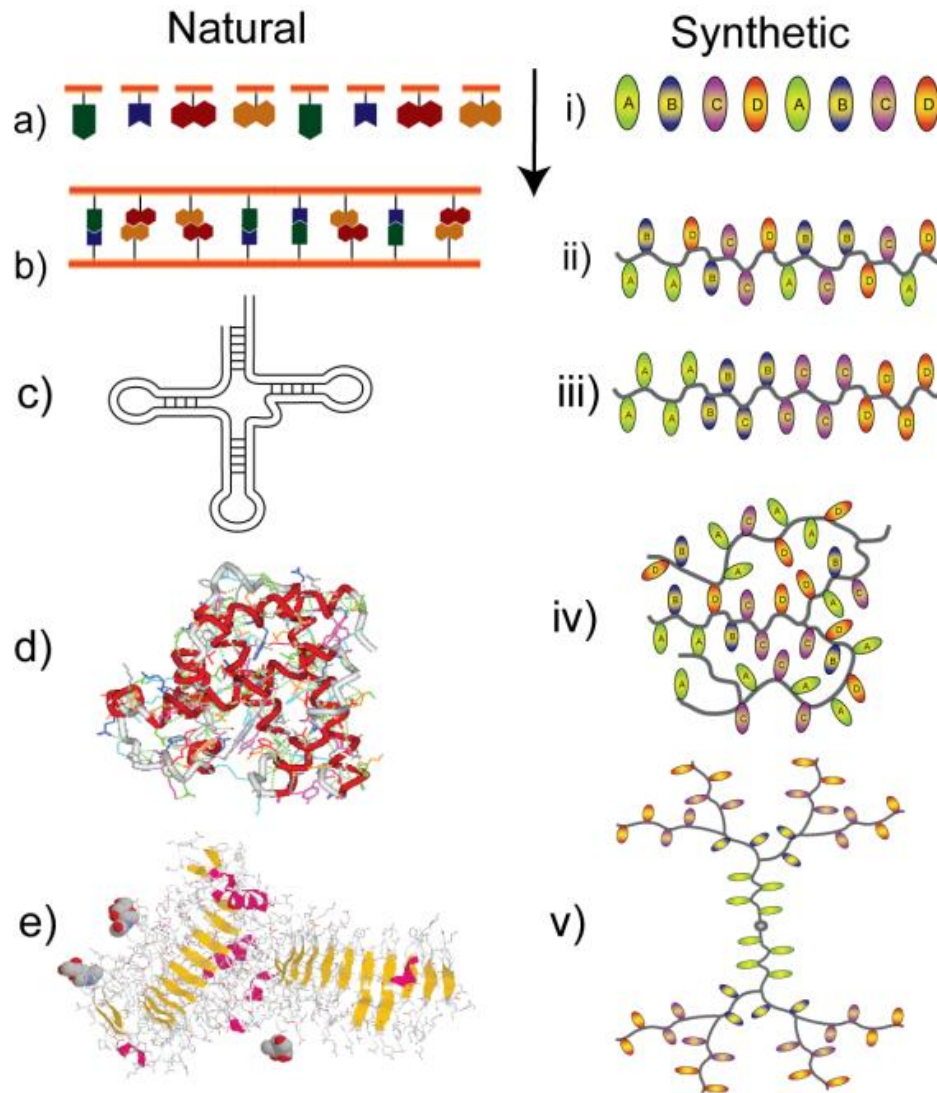
Synthetic Biology Network Meeting,
Sheffield, October 12-13th 2009

Cameron Alexander

*School of Pharmacy, University of Nottingham, University Park,
Nottingham NG7 2RD UK*

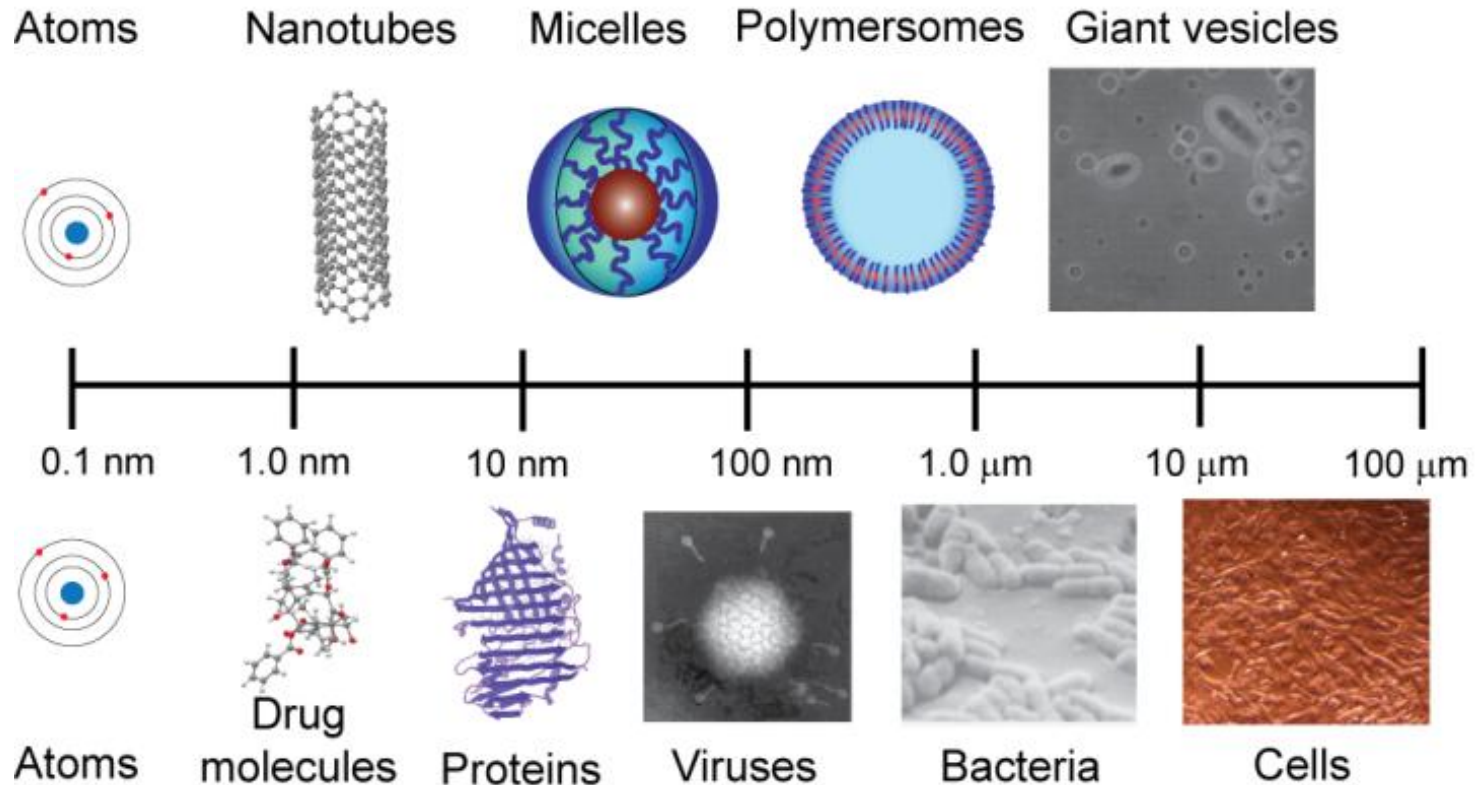
<http://www.nottingham.ac.uk/pharmacy/>

Polymers and Information content



- Structures of natural and synthetic polymers.
- Monomer units (a,i) can be assembled into defined (b) or random (ii) sequences.
- Further complexity via regions of self-complementarity as in t-RNA (c), or in block-co-polymers (iii).
- Cross-linking of polymer chains occurs in both natural polymers via S-S links in proteins (d) or in network polymers (iv).
- Combinations of blocks with complex architectures can be found in glycoproteins (e) and dendrimers (v)

Organisation and self-assembly



- Lengthscales and structures/architectures in synthetic and natural systems of increasing complexity

Polymers in Pharmacy

Intelligent/Responsive Materials for Biomedical Applications

- **What are intelligent materials and why do they matter?**

- ⇒ Examples of **intelligent** materials in nature

- ⇒ 'Smart'/responsive polymers and biomimicry

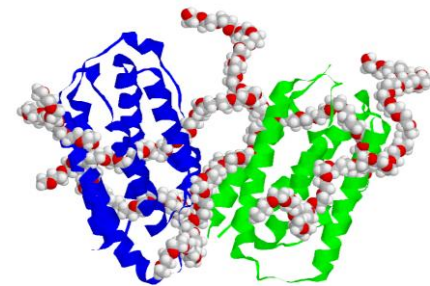
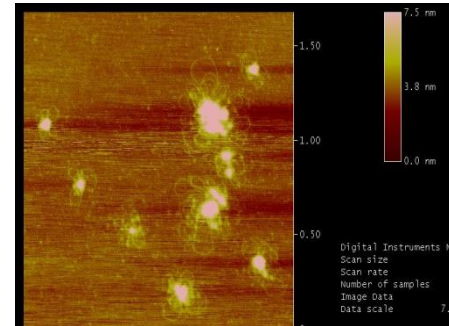
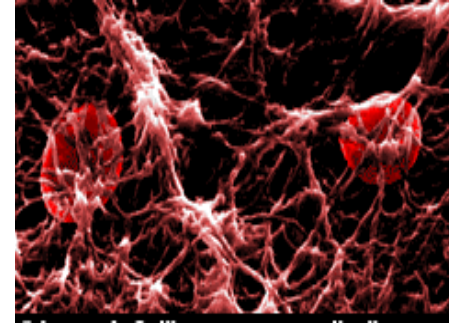
- **Responsive polymers in biomedicine**

- ⇒ Biomedical polymers and clinical needs

- ⇒ Responsive polymer complexes and nanoparticles

- **Blurring the boundaries – where synthetic and natural polymers converge**

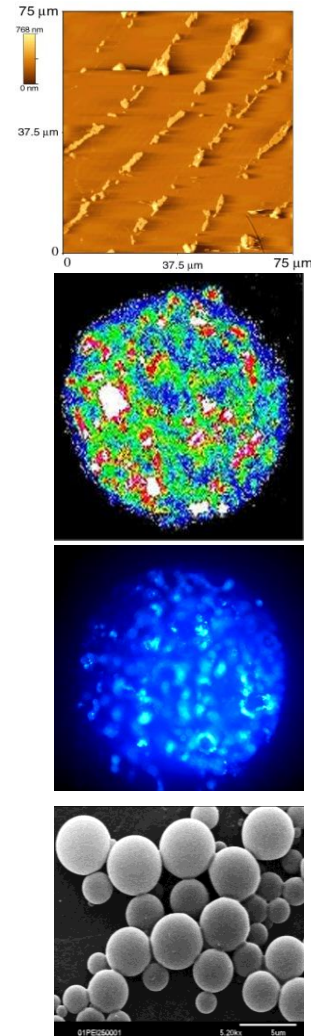
- ⇒ Controlling biological information transfer with 'smart' materials



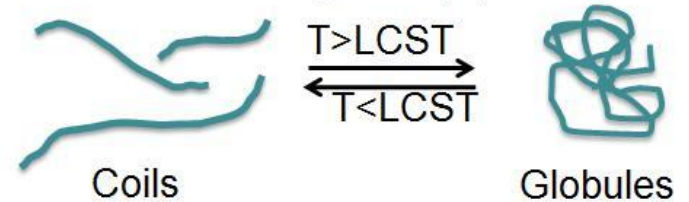
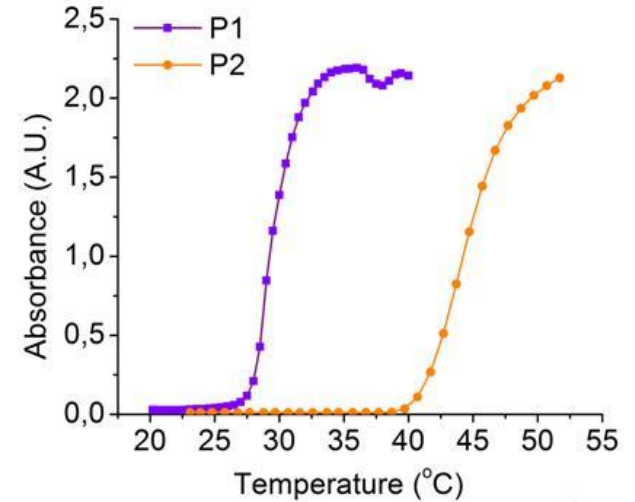
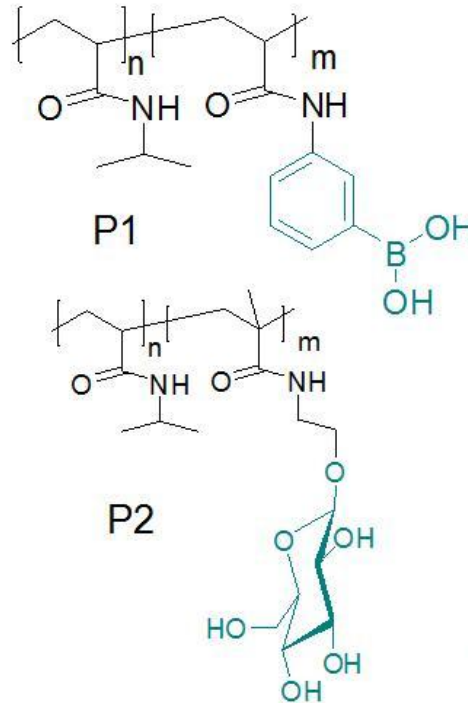
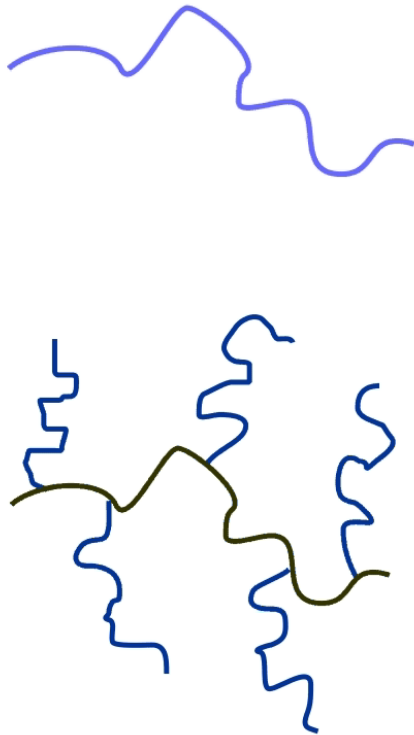
Polymer switches – biomedical context

Why are these useful in biology and medicine?

- New functional materials (macromolecules and polymers) required for:
- **Biosensors**
 - *Recognition elements, signal transduction*
- **Implants / structural biomaterials**
 - Cell capture arrays, anti-fouling surfaces
- **Controlled release materials**
 - *Drug and gene delivery*
 - *Polymer therapeutics*
- **Tissue engineering**
 - Biocompatible/biodegradable scaffolds
- **Ability of stimuli-responsive materials to *change properties in the dynamic biological environment***
- **Restore, replace or enhance** biological function
- Switch leading to logic operations
- Towards a synthetic cell.....

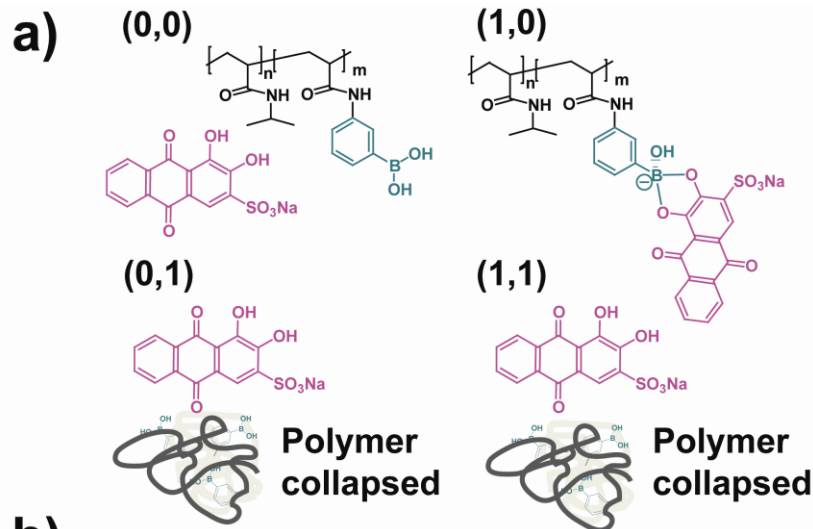


Polymer logic operators

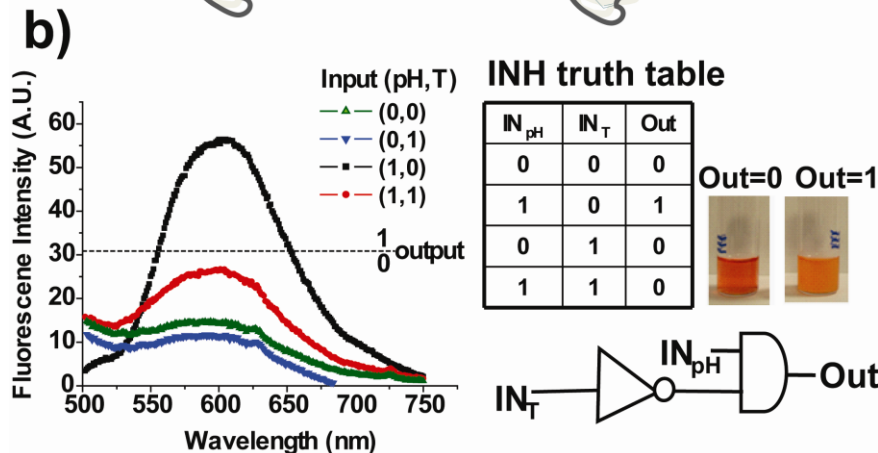


- Combination of phase transitions and binding events to describe logic gates

Polymer INH Gate

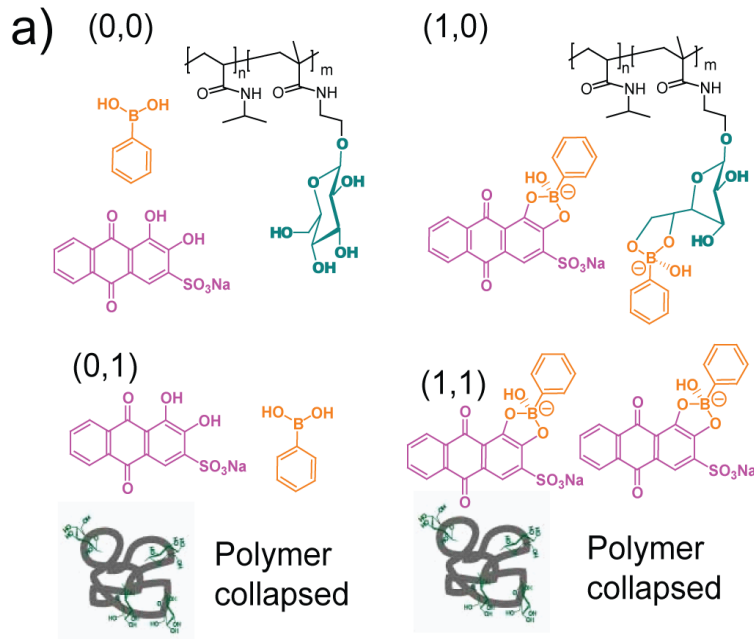


- P1- Alizarin Red interactions at all four possible input combinations are shown in a).
- Fluorescence output is recorded as output in b) and construction of the INHIBIT truth table

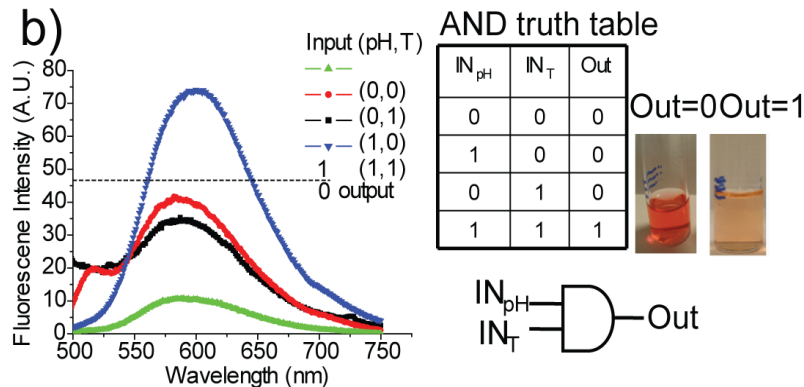


- Pasparakis, G.; et al. *Soft Matter* **2009**, 5, 3839 – 3841.

Polymer AND Gate



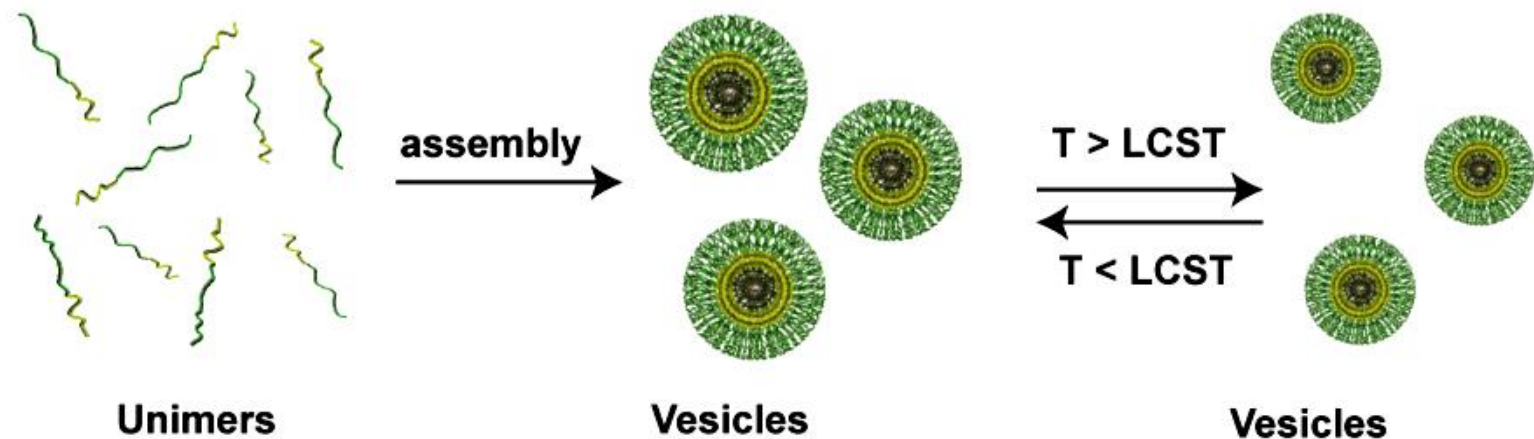
- P2-AR-PBA interactions at all four possible input combinations are shown in a)
- Fluorescence emission is recorded as output in b) with construction of the AND truth table.



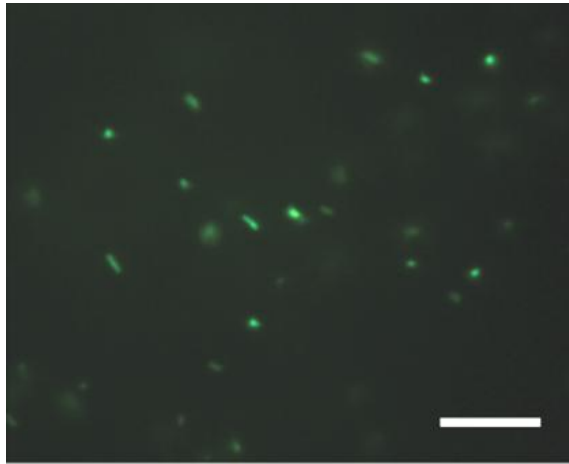
- Pasparakis, G.; et al. *Soft Matter* **2009**, 5, 3839 – 3841.

Towards a synthetic cell.....

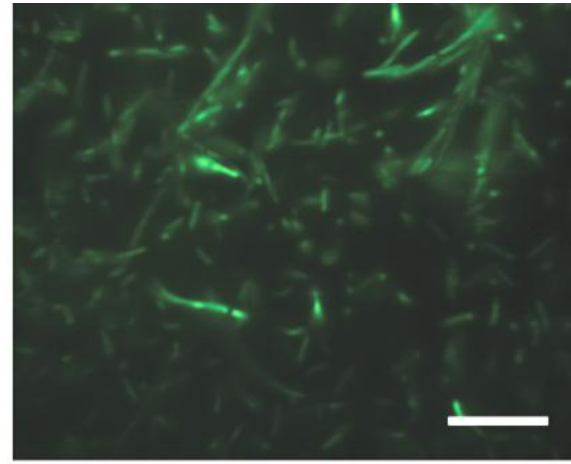
- Biocompatible vesicles as long-circulating carriers
- Polymer self-assembly into higher-order structures
- Cell-mimics with hydrophobic 'cell-wall' and glycosylated surfaces
- Potential for cross-talk with biological cells



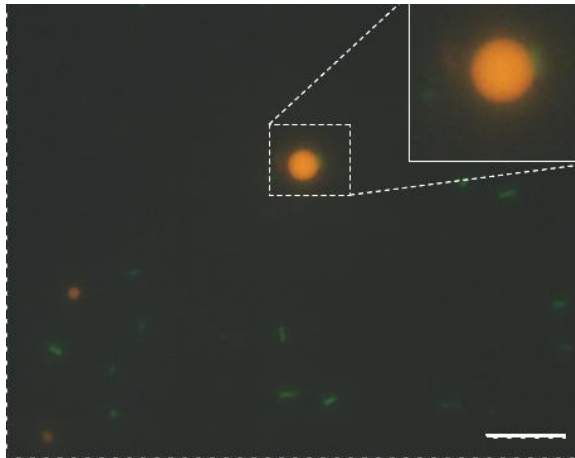
Specificity of interaction



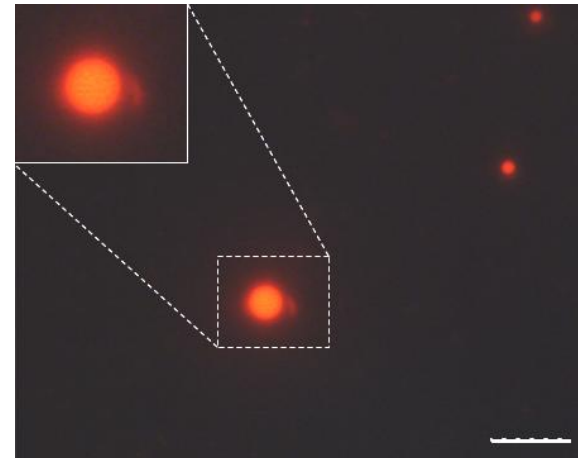
a)



b)

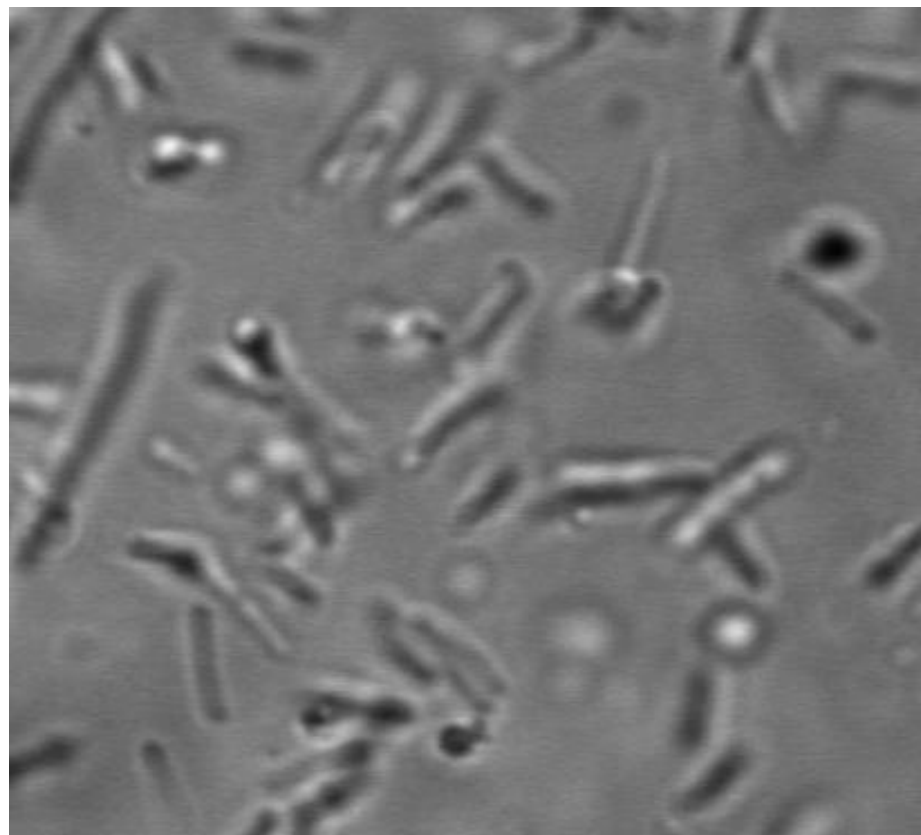
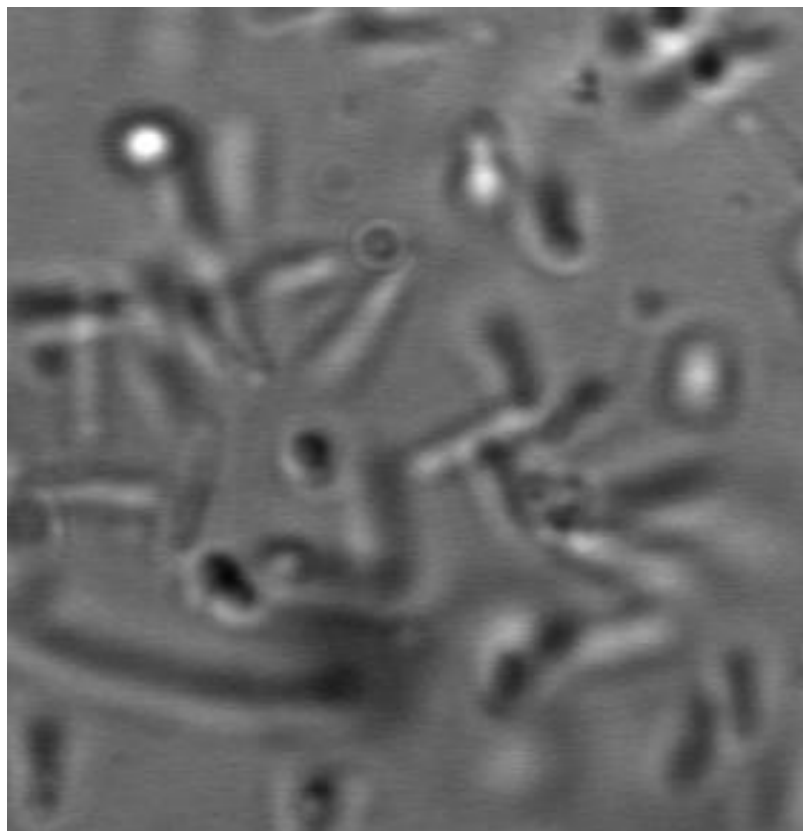


c)

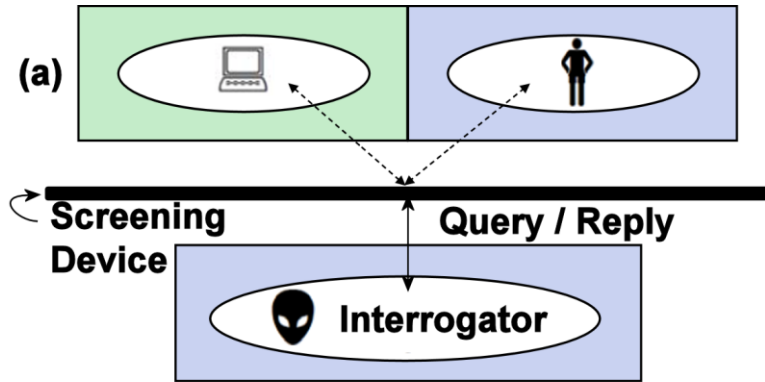


d)

Dynamics of interaction

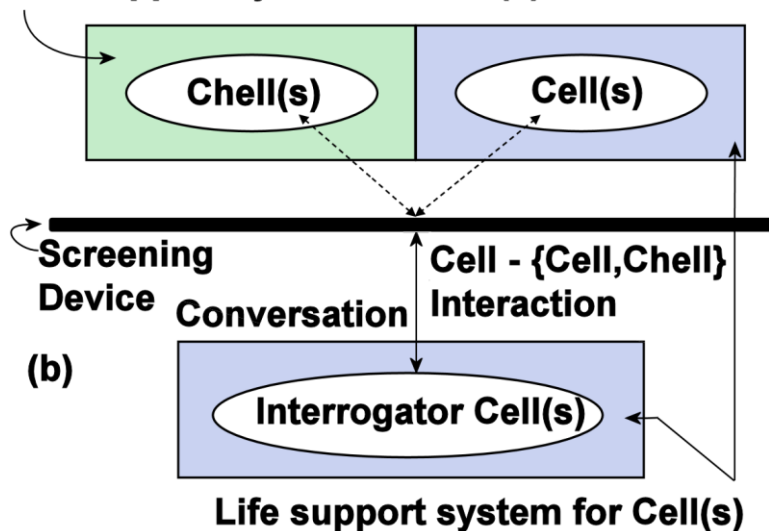


A Turing test for CHELLs



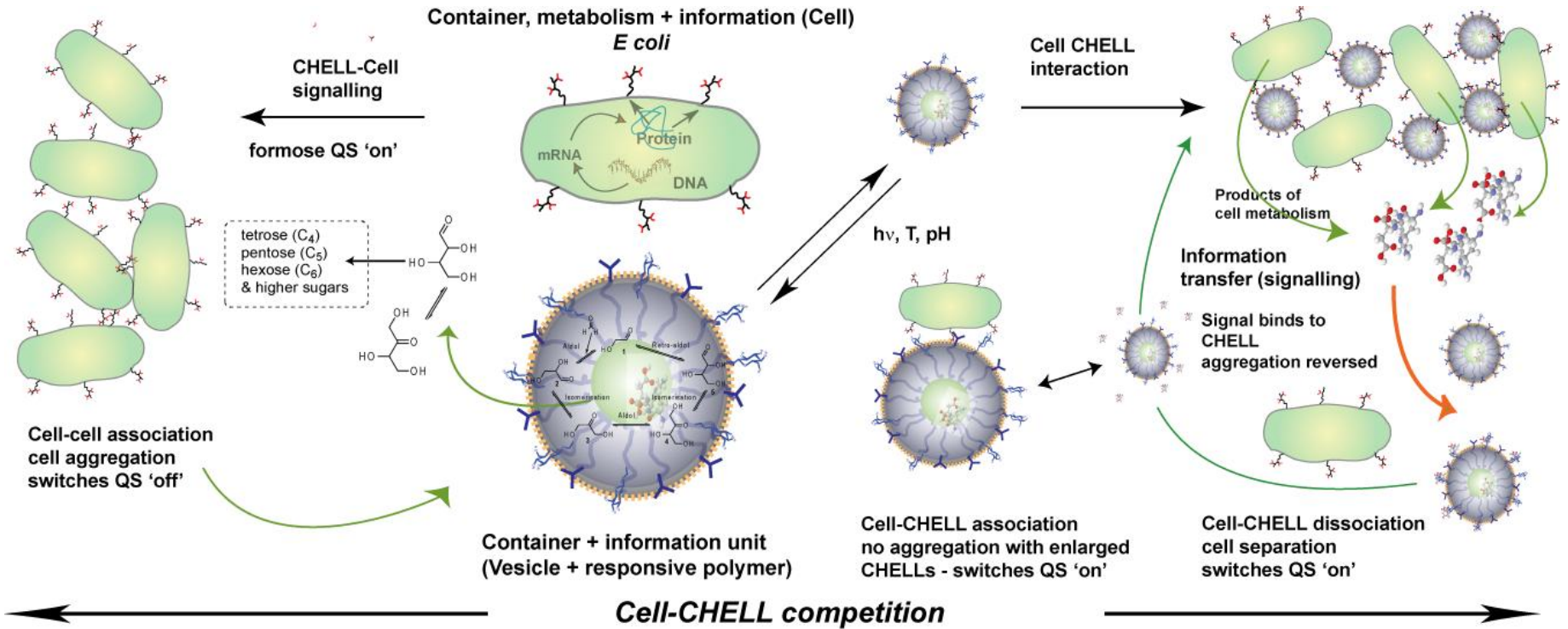
(a) Representation of the classic Turing test with an intelligent interrogator (i.e. person, interacting with two compartments, each containing either a computer or a person, the location of which is unknown to the interrogator).

Life support system for Chell(s)



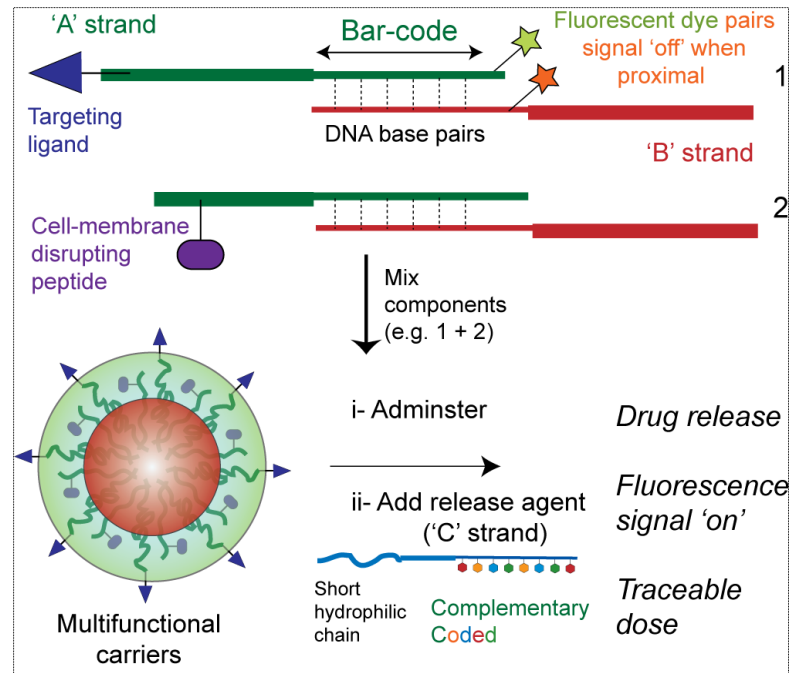
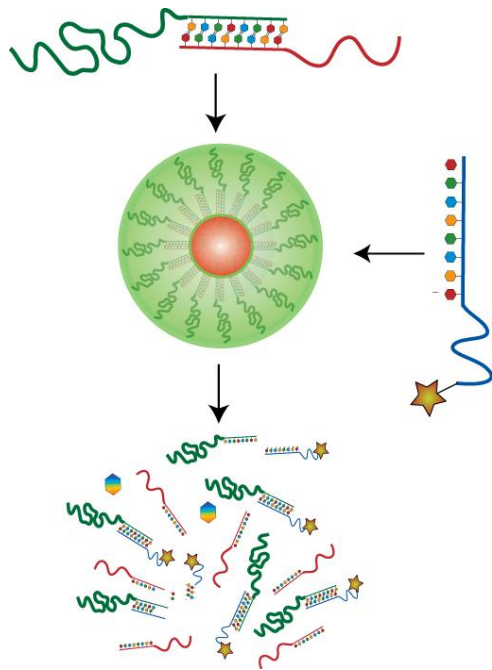
(b) Extension of this interrogator or interaction between cells and Chemical cELLS ('Chell's) containing signal-intercepting polymers

Enacting the Turing Test....



Future Directions

- Synthetic Biology needs 'intelligent' materials
- New polymer chemistries offer unprecedented control over carrier vehicle structure and properties
 - Easier formulation
 - Reduced complexity in regulatory issues
- Truly 'smart' *in situ* diagnostics and therapeutics will soon be made in the lab – ***what else can we do with these materials?***



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