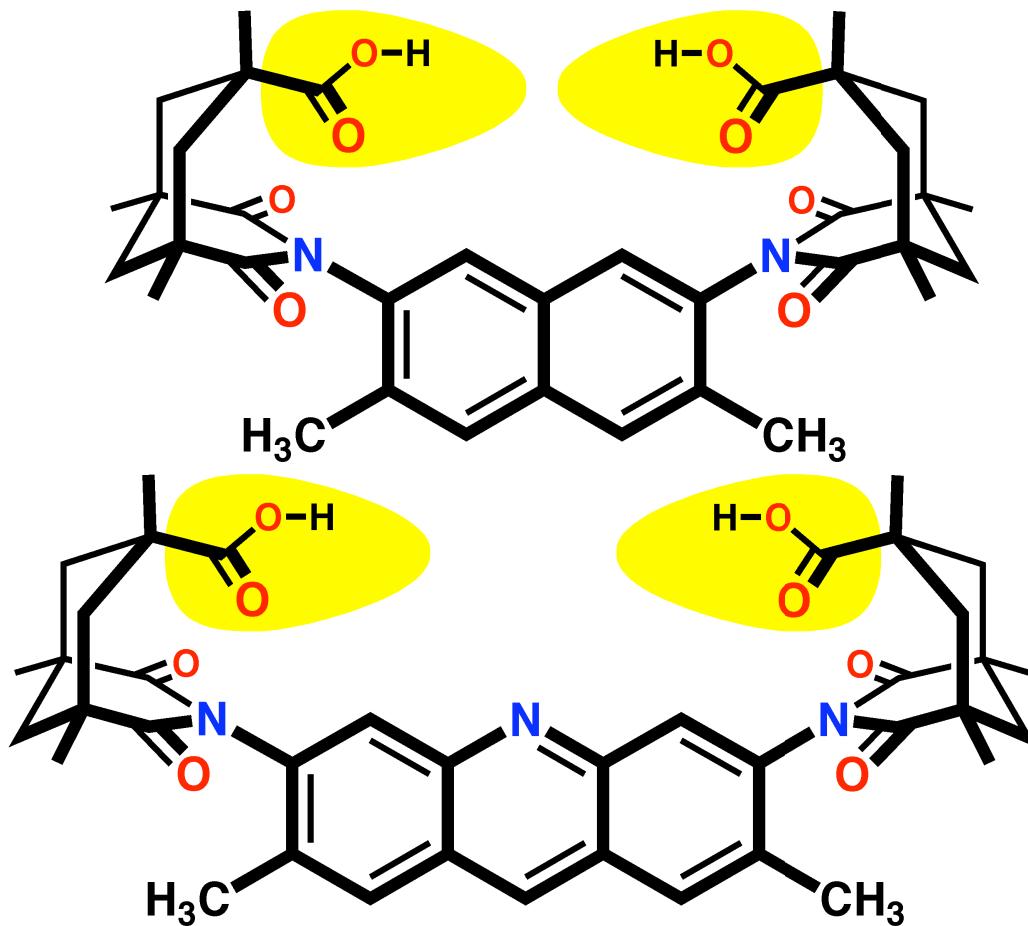




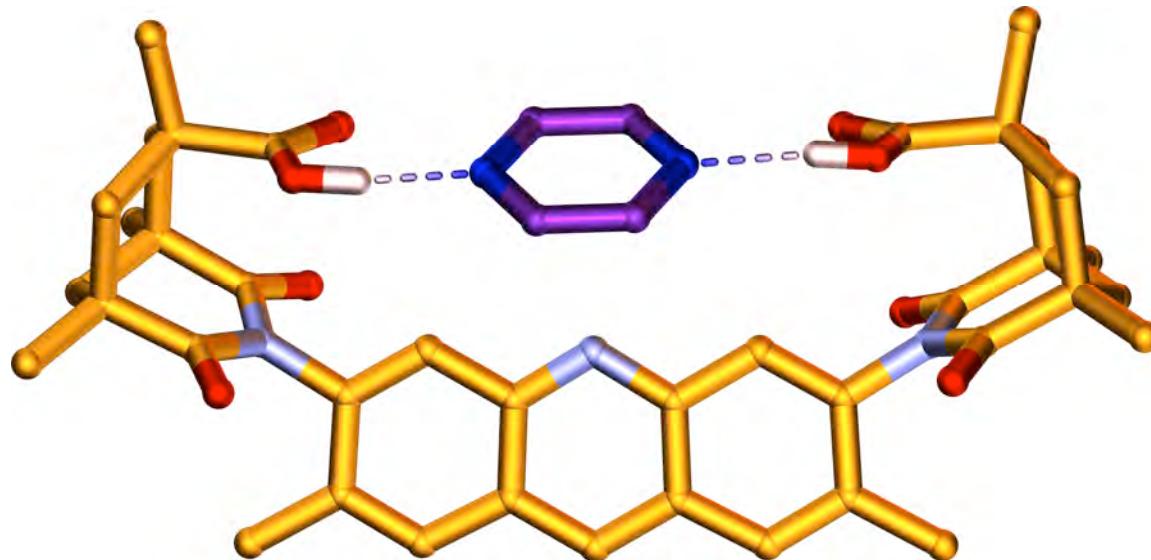
# *The Inner Space of Molecules*

## Molecular Chelating Agents

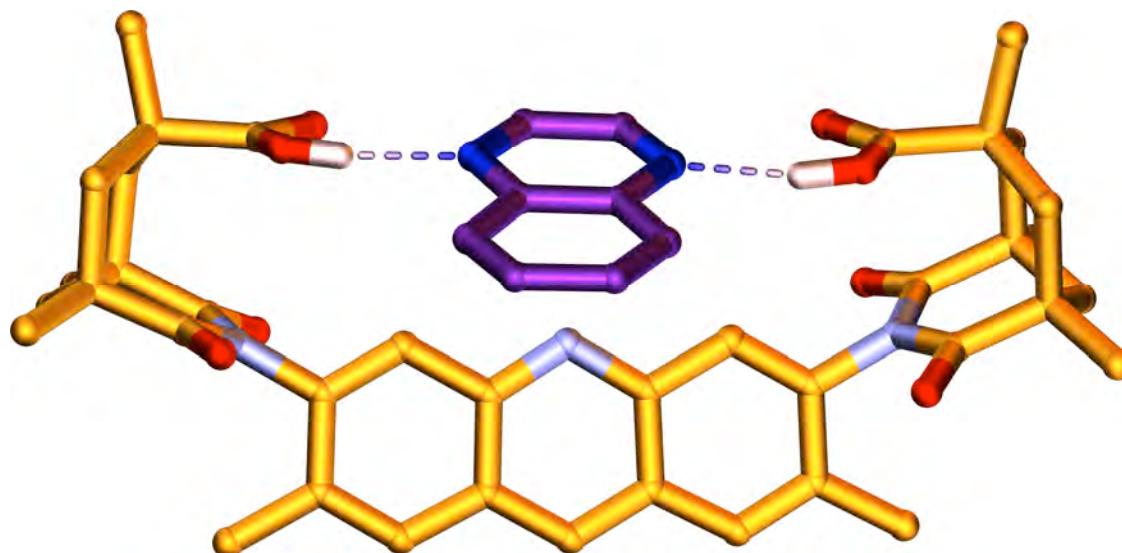


L. Marshall, K. Parris  
D. Nemeth, B. Askew 1985

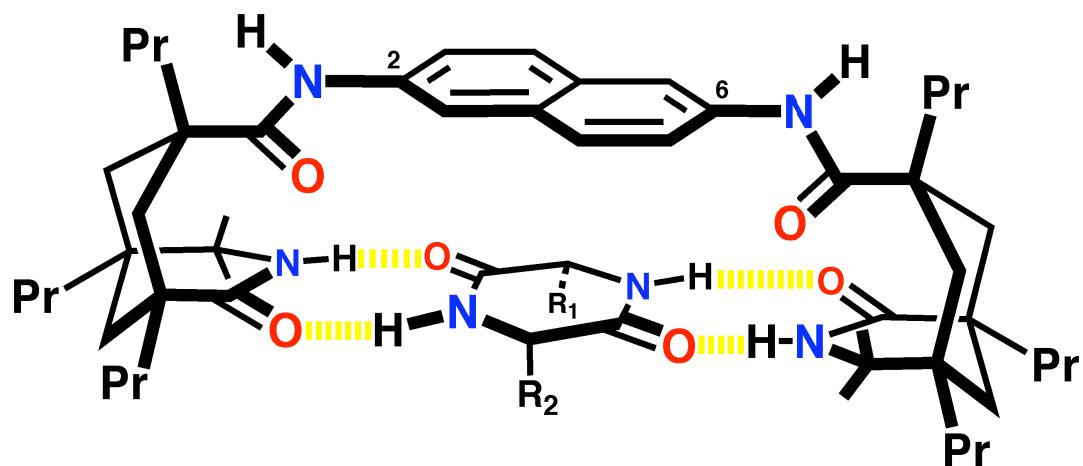
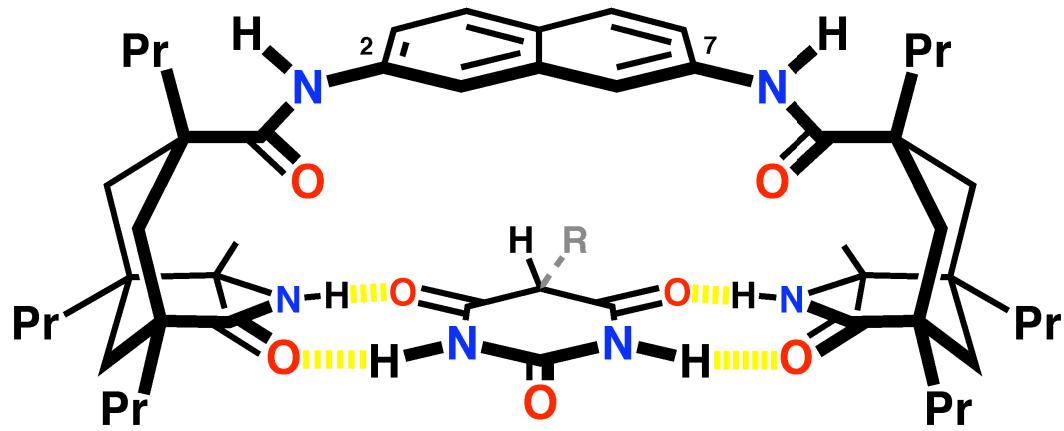
## Pyrazine and Quinoxaline



D. Nemeth  
B. Askew  
1985

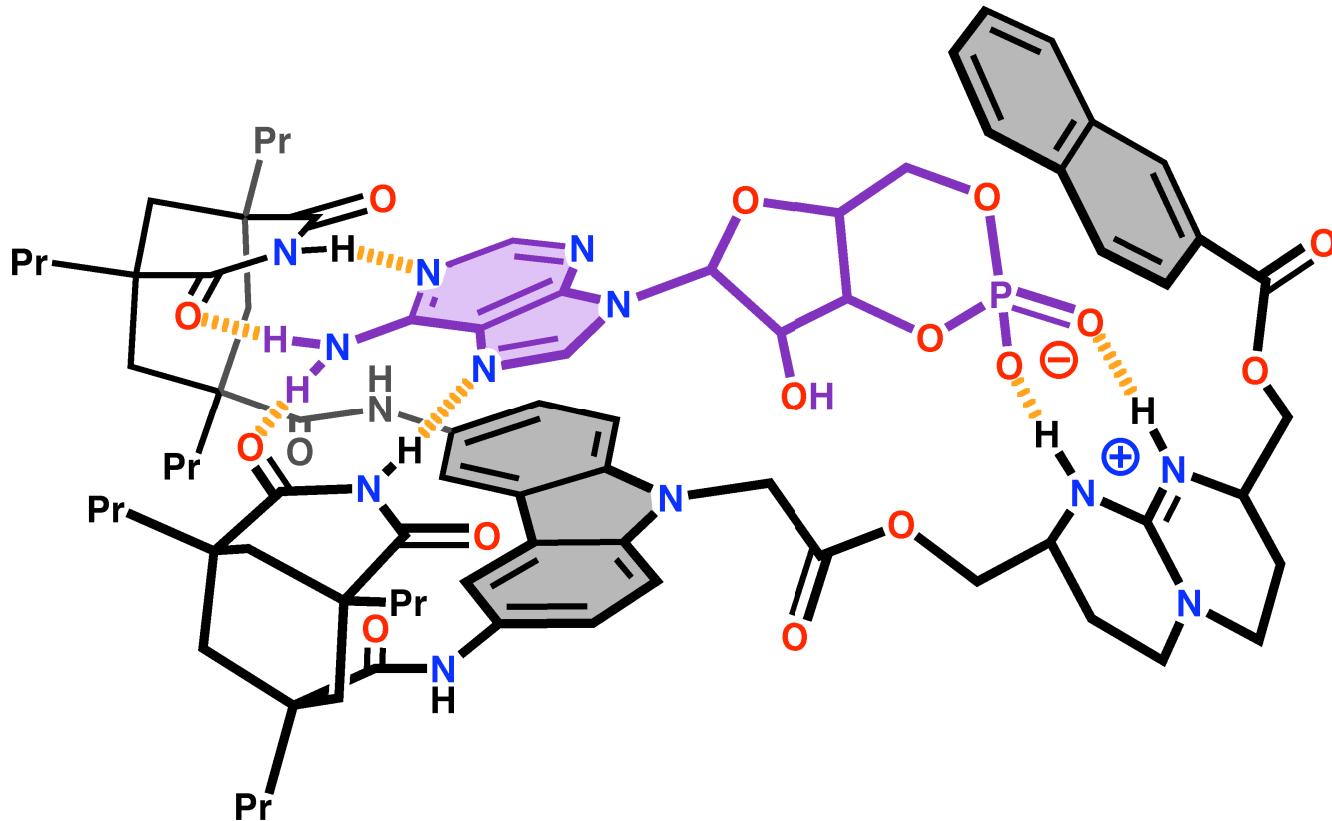


# Barbiturates and Diketopiperazines



K. S. Jeong, 1990

# Receptor for 3',5' Cyclic AMP



**Dr. G. Deslongchamps  
Dr. A. Galan  
Prof. J. de Mendoza, (UAM) 1993**

## **Reversible Encapsulation Phenomena**

***Anticipated:***

***Size and Shape Recognition***

***Reaction Chambers***

***Asymmetric Recognition***

## Reversible Encapsulation Phenomena

***Unanticipated :***

***Single Molecule Solvation***

***Isotope Effects***

***Binary Coding***

***Helical Alkanes***

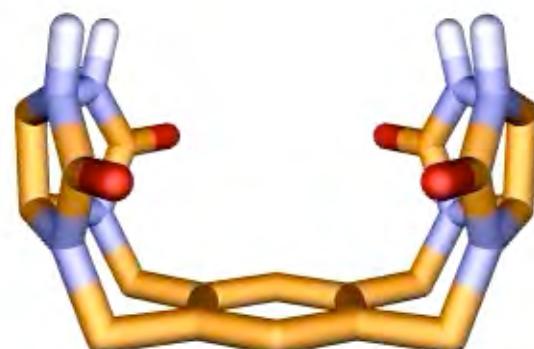
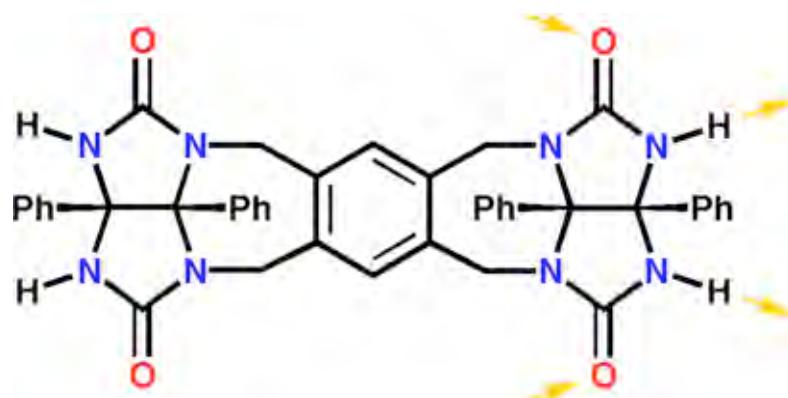
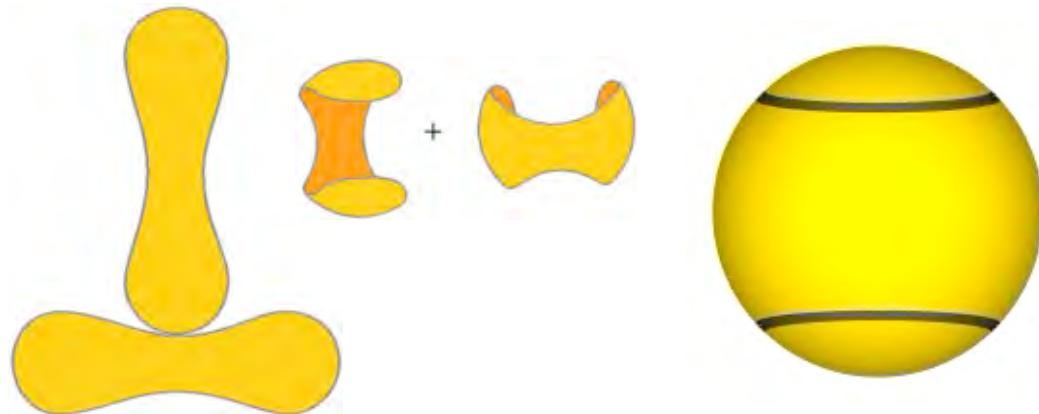
***Chiral Spaces***

***Chemical Amplification***

***Super Capsules***

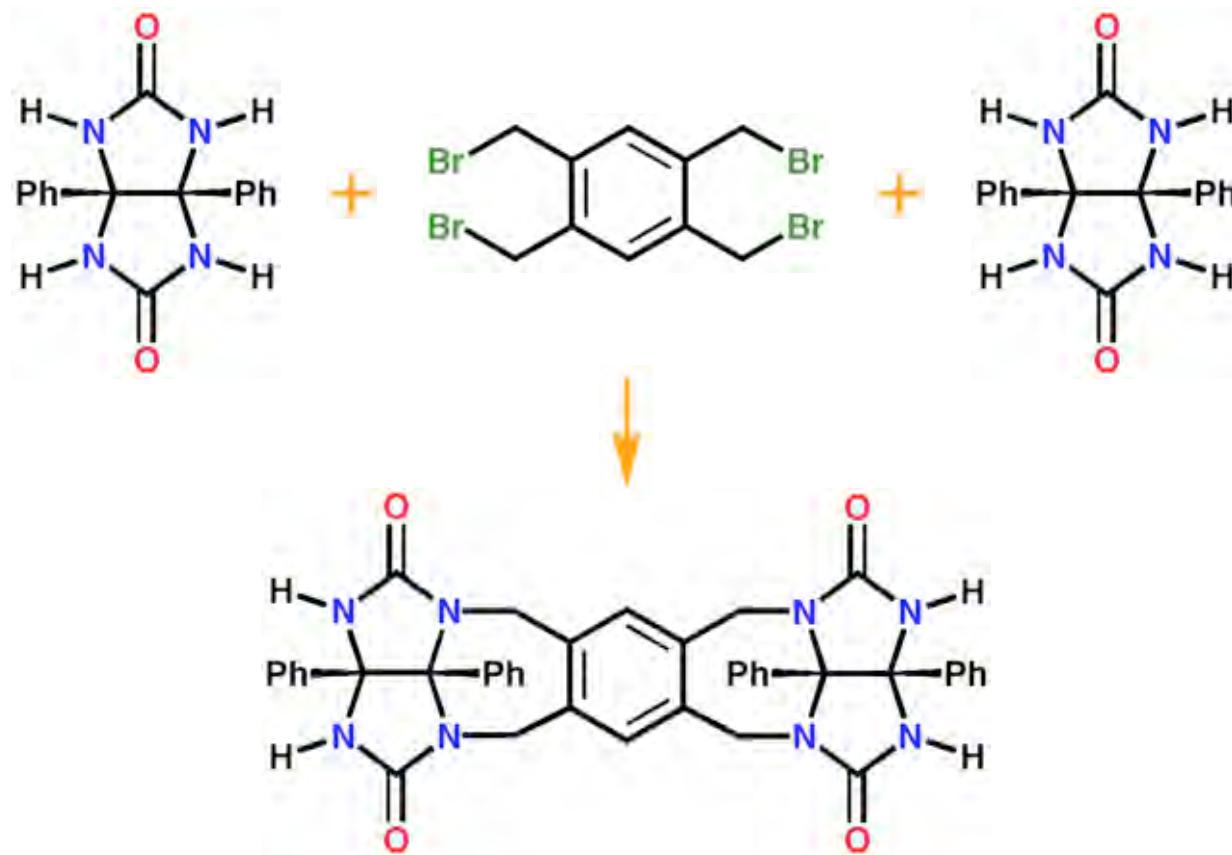
# “Tennis Ball“

## Dimeric Assembly



# “Tennis Ball“

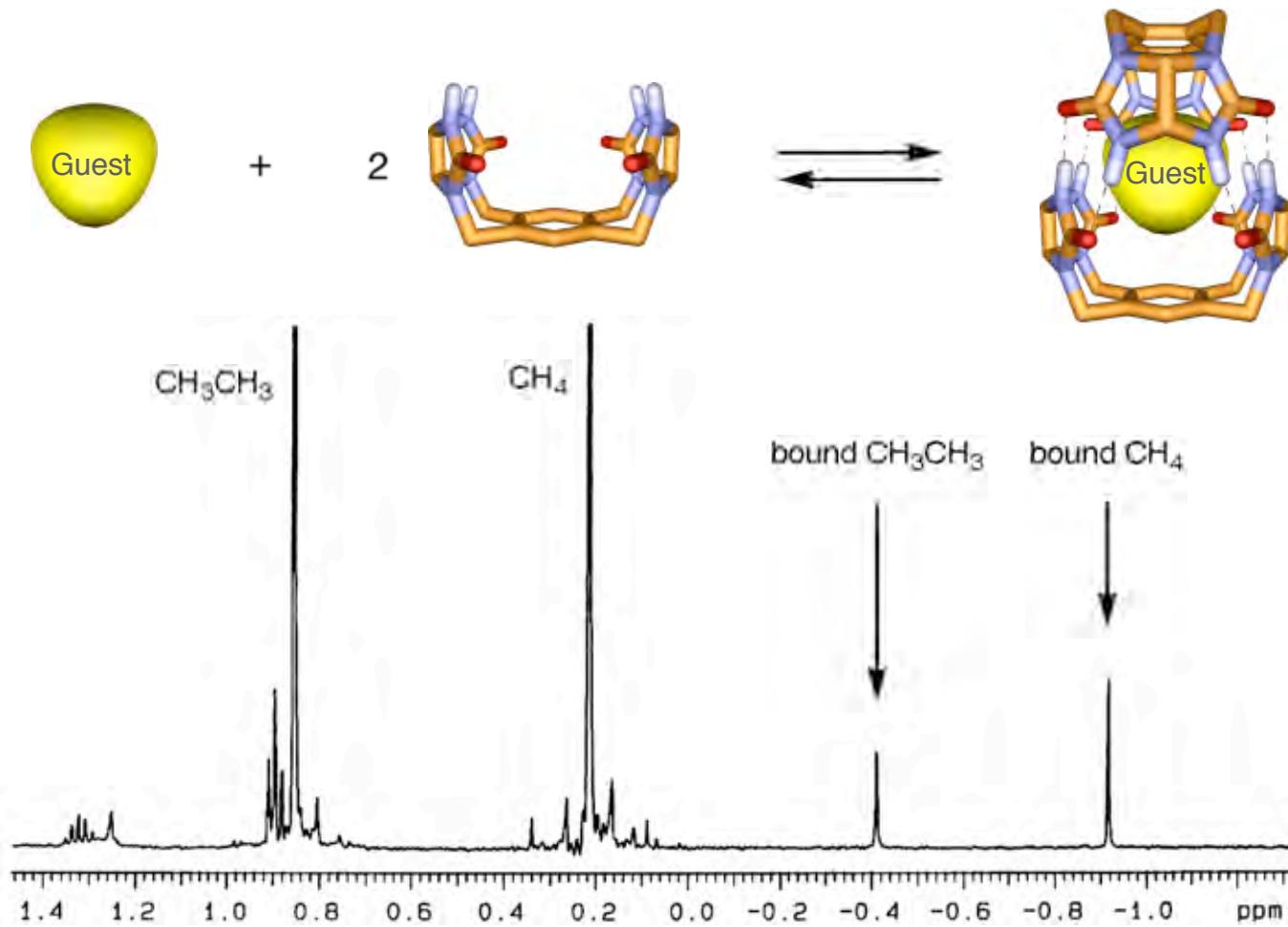
## Synthesis



Dr. Rene Wyler  
Prof. J. de Mendoza (UAM)

# “Tennis Ball“

## NMR Spectrum of Encapsulated Guests



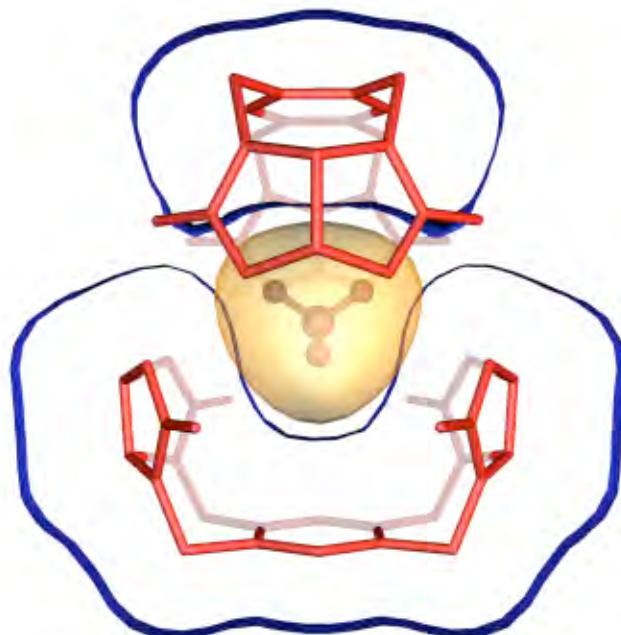
Niel R. Breda

Dr. Rene Wyler, 1994

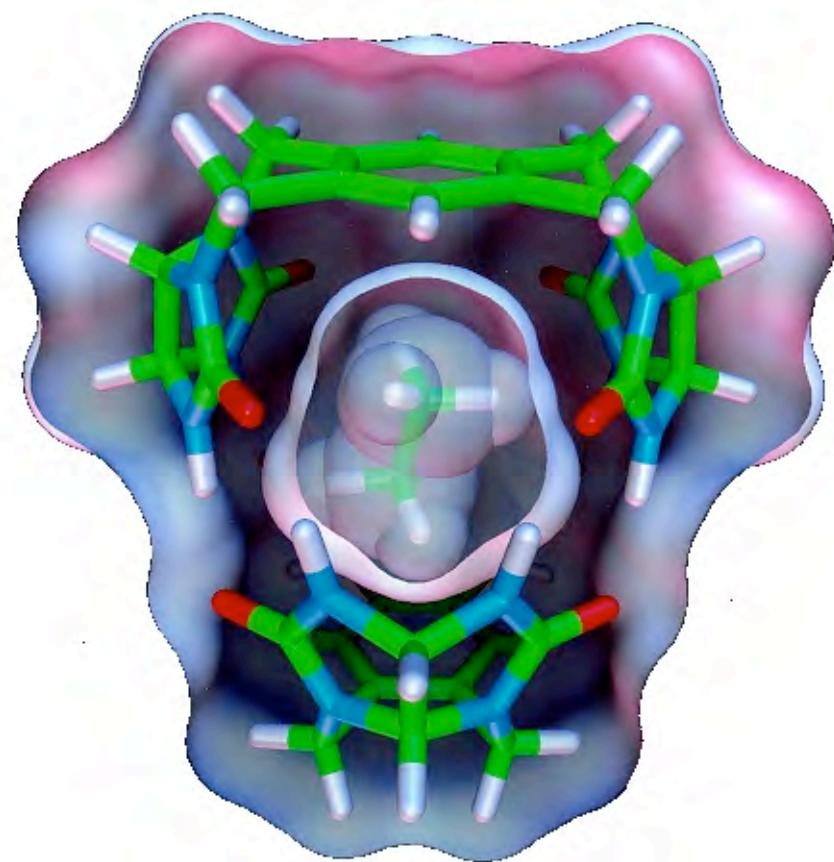
**“Tennis Ball”**       $7 \times 10^{-26} \text{ L}$

**Methane and Ethane Guests**

**Capsule  $\times 10^8$  = tennis ball  $\times 10^8$  = earth**



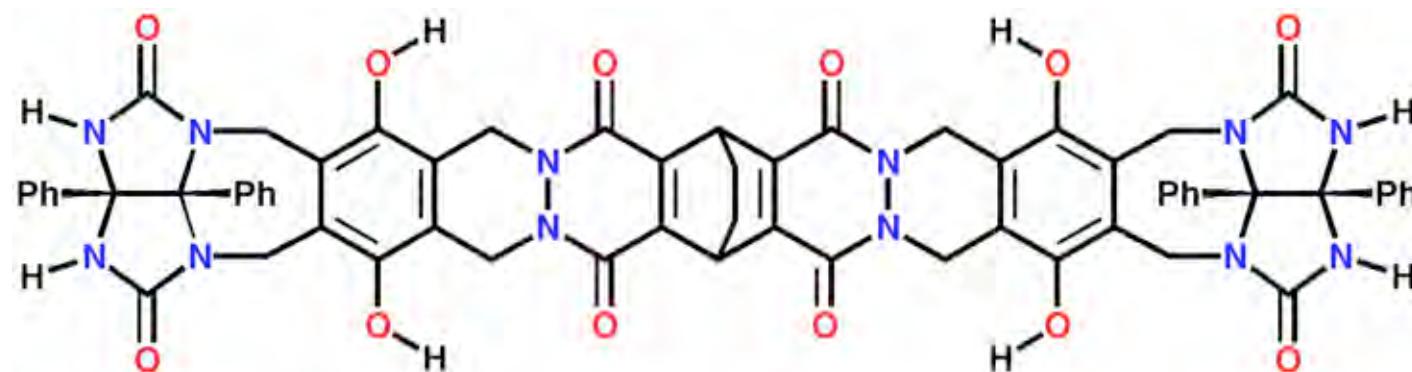
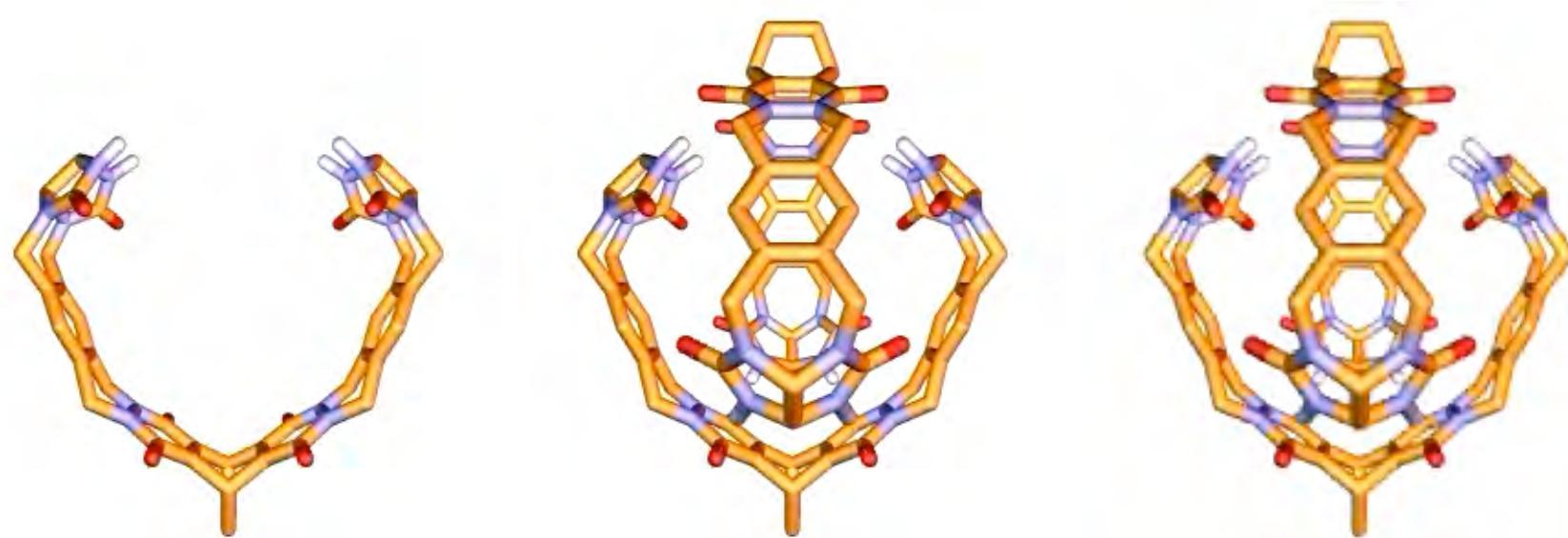
**Dr. Lubo Sebo**



**Prof. Mike Pique (TSRI)**

**“Softball”**

$3 \times 10^{-25} \text{ L}$

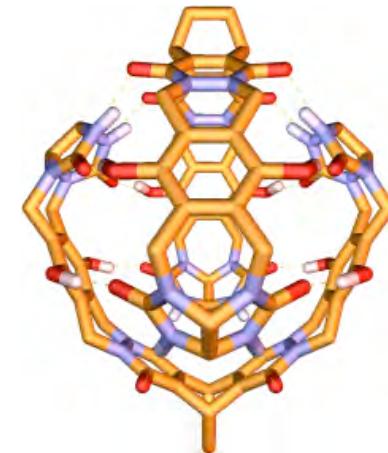
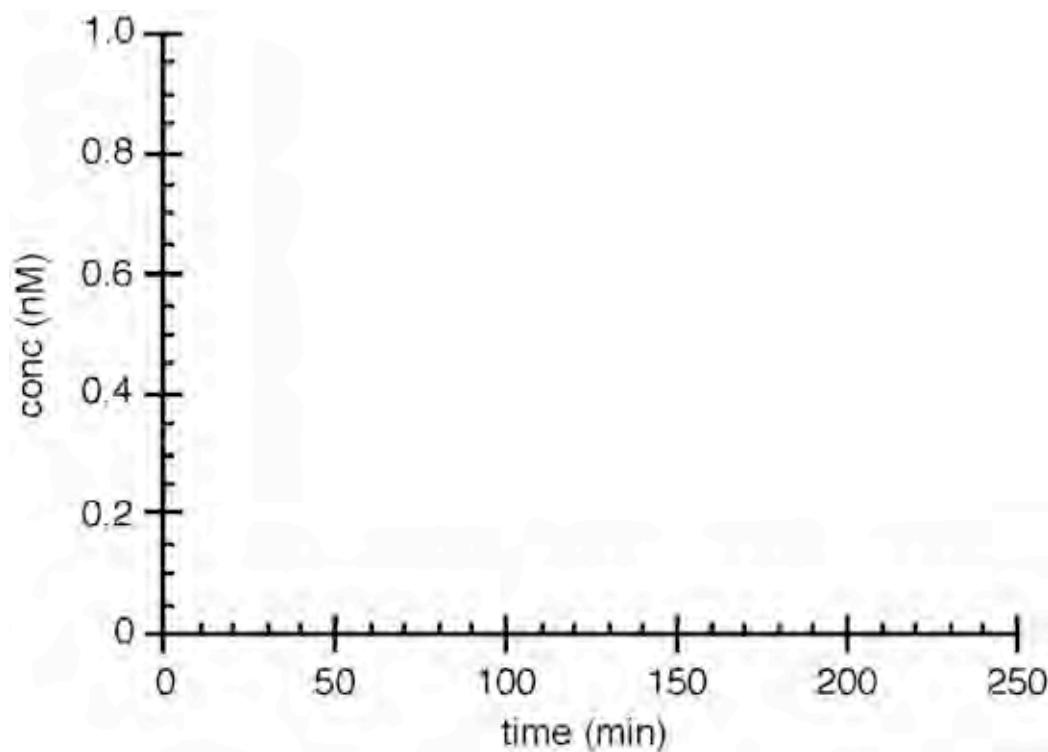
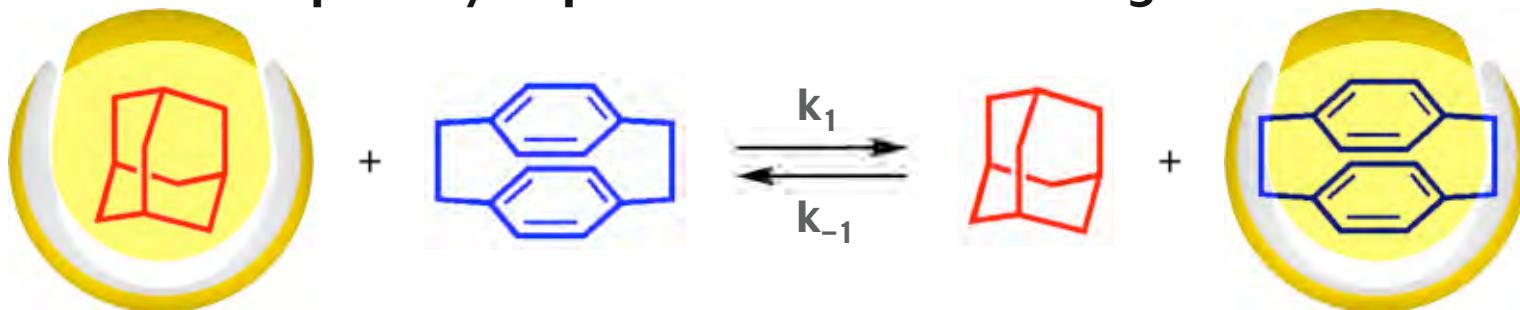


**Dr. Robert Meissner  
Prof. J. de Mendoza (UAM)**

**Jongmin Kang  
Dr. Y. Tokunaga**

# Softball

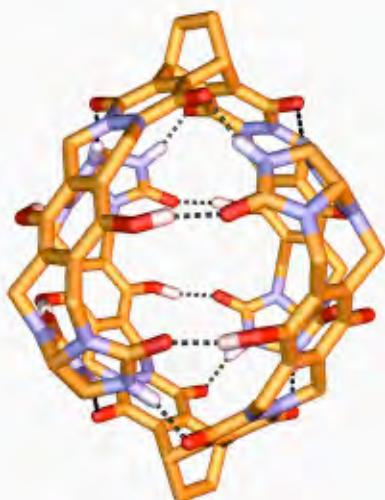
A supramolecular substitution reaction:  
para cyclophane is a much better guest



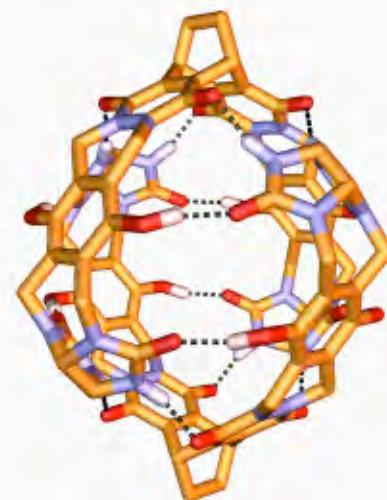
**Dr. Javier Santamaría**  
**Dr. Tomás Martín**  
**Dr. Göran Hilmersson**  
**Dr. Stephen Craig**

# Opening the Softball

Opposite Flaps



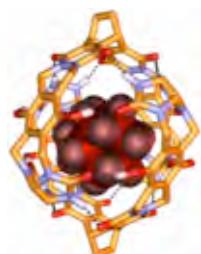
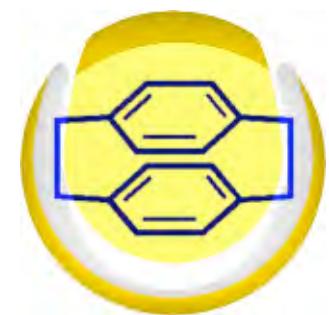
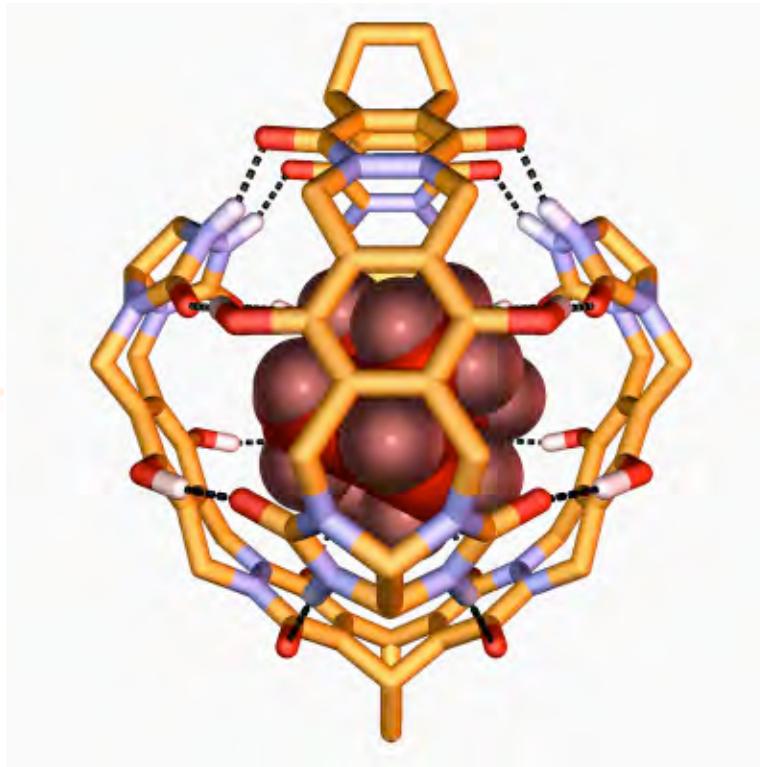
Adjacent Flaps



4 Hydrogen Bonds

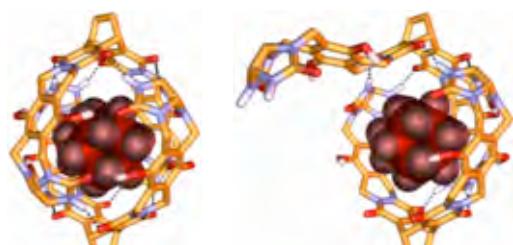
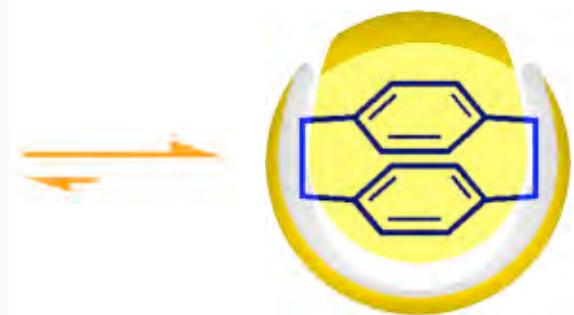
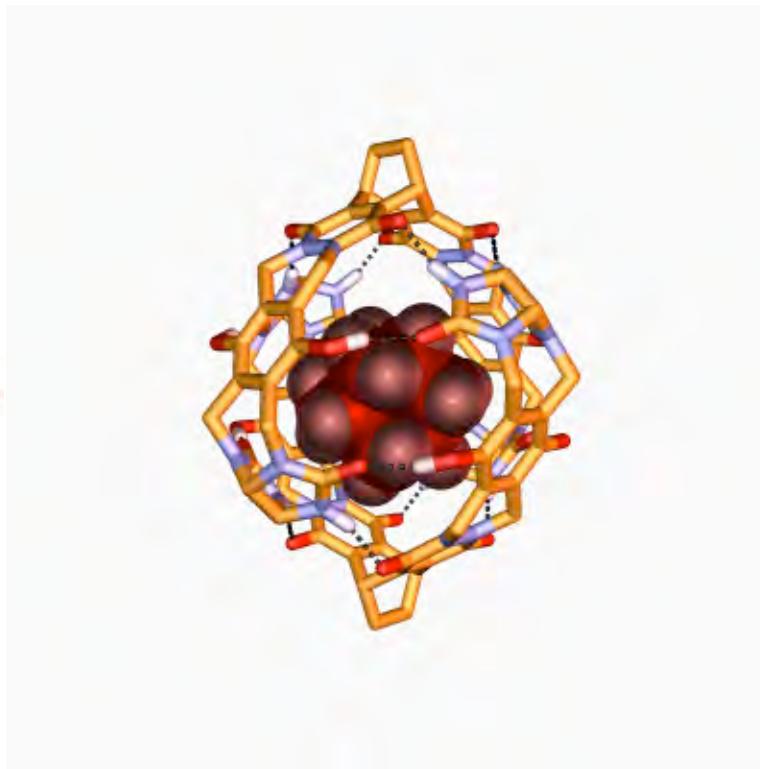
6 Hydrogen Bonds

# Guest Exchange in the Softball



16 HB

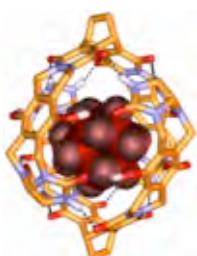
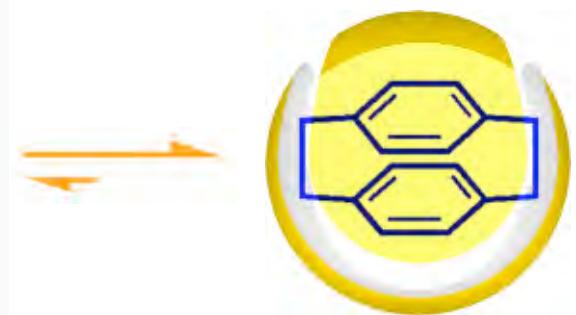
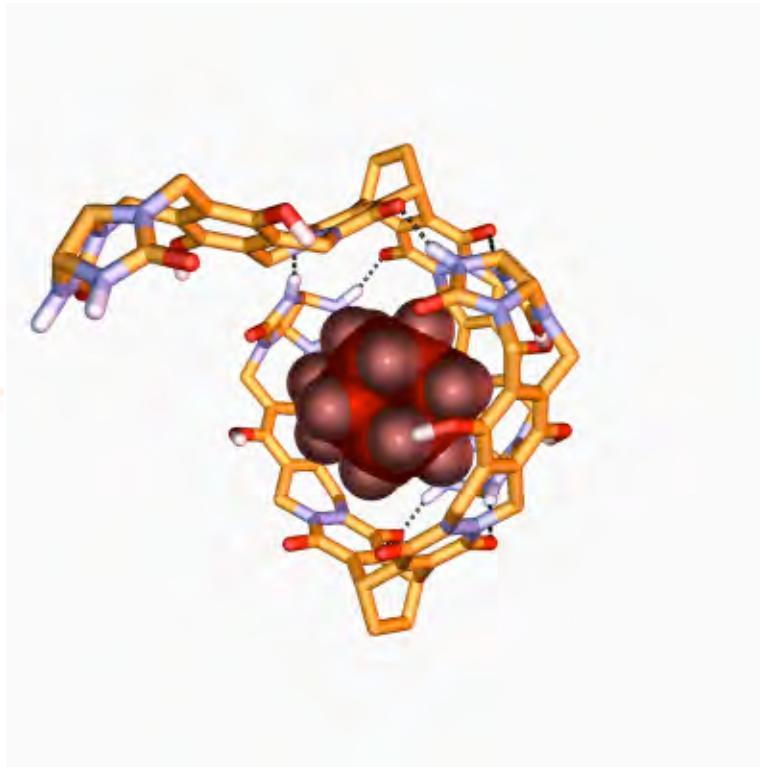
# Guest Exchange in the Softball



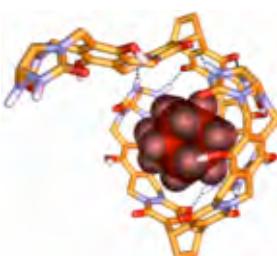
16 HB

10 HB

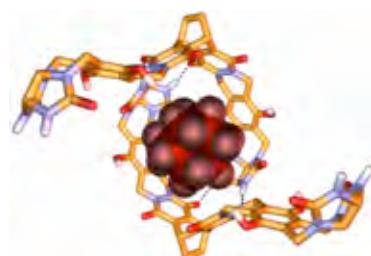
# Guest Exchange in the Softball



16 HB

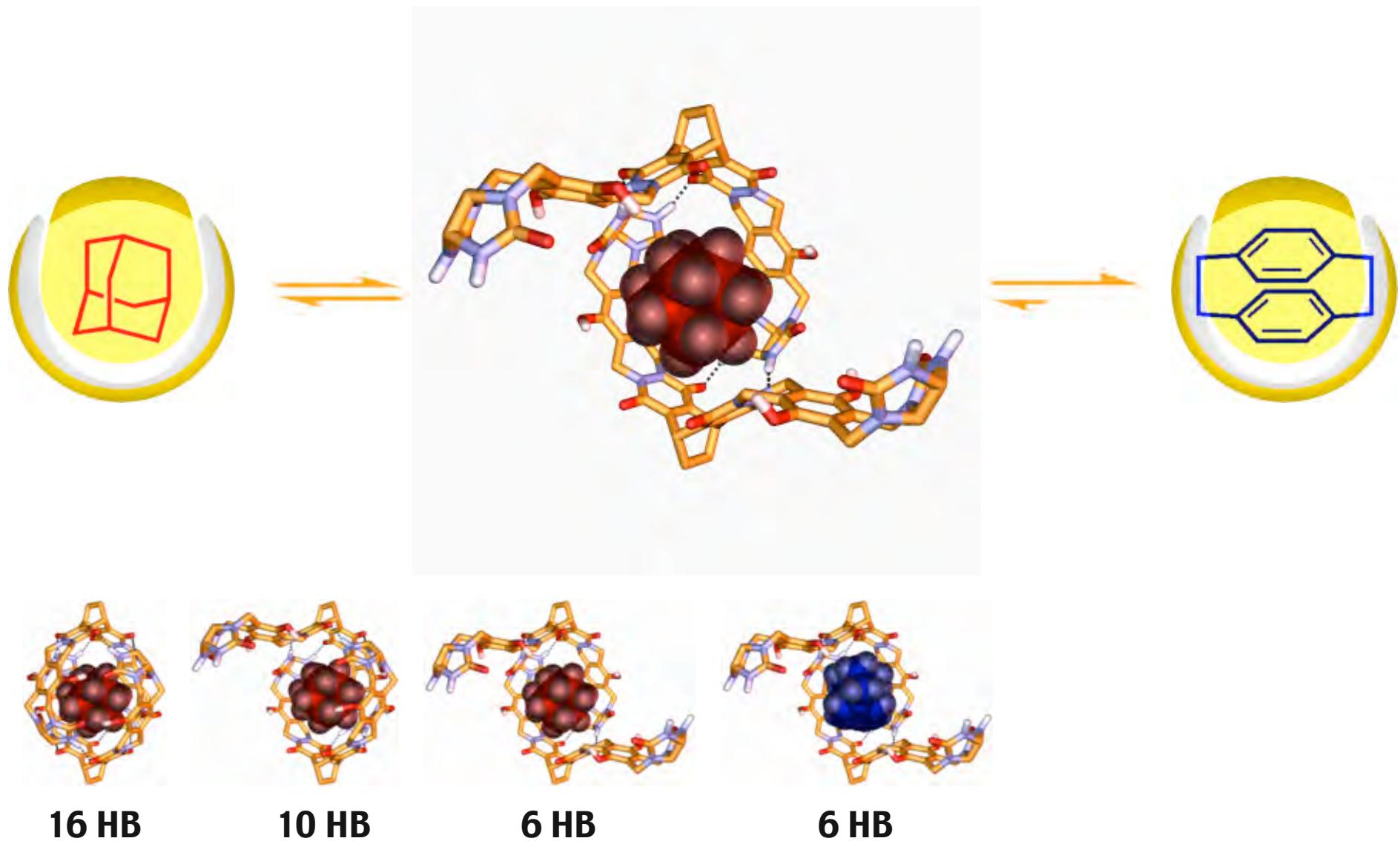


10 HB

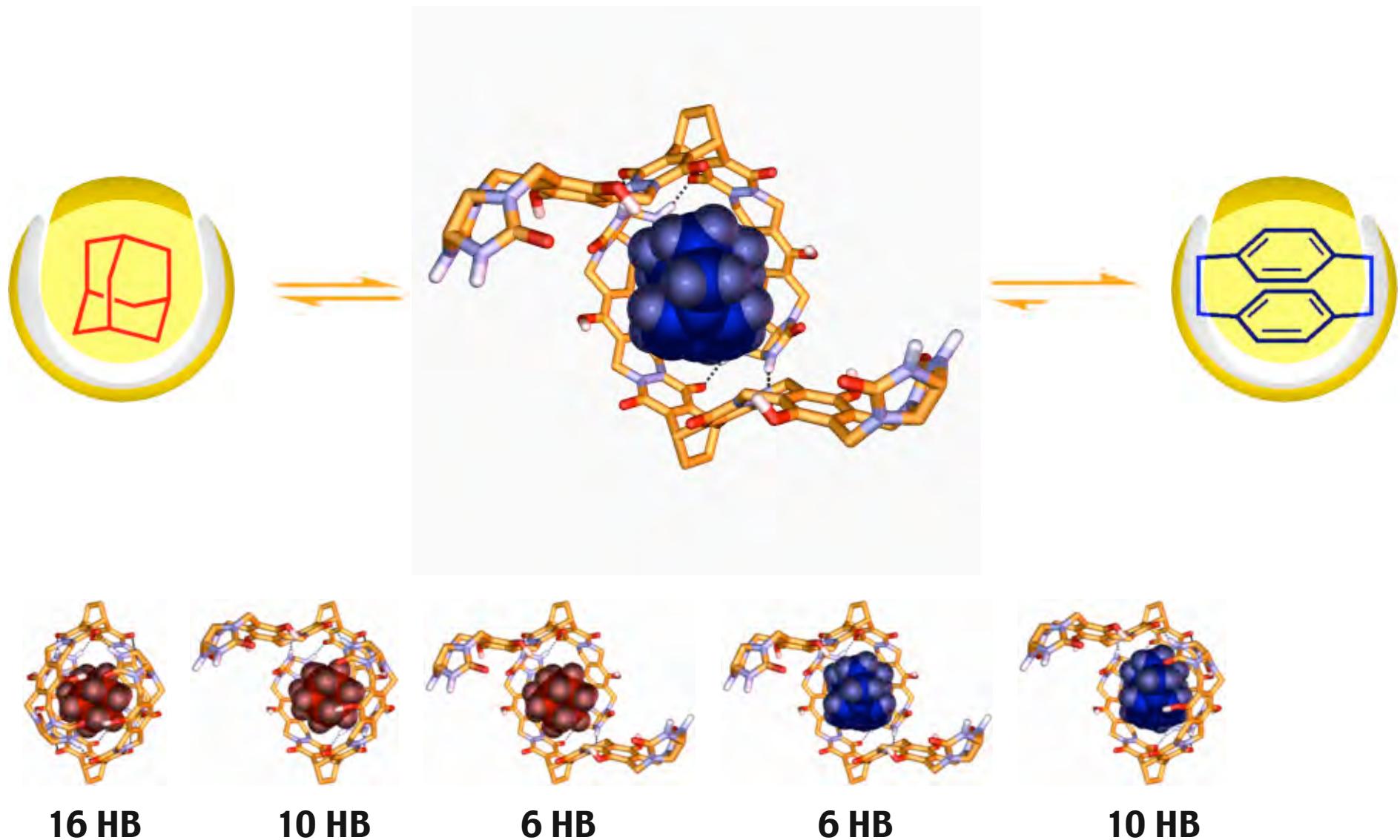


6 HB

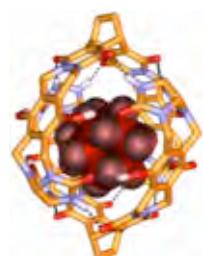
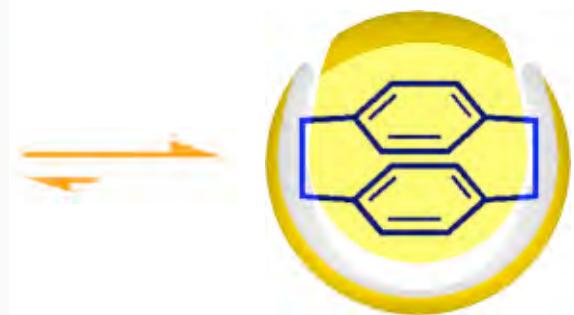
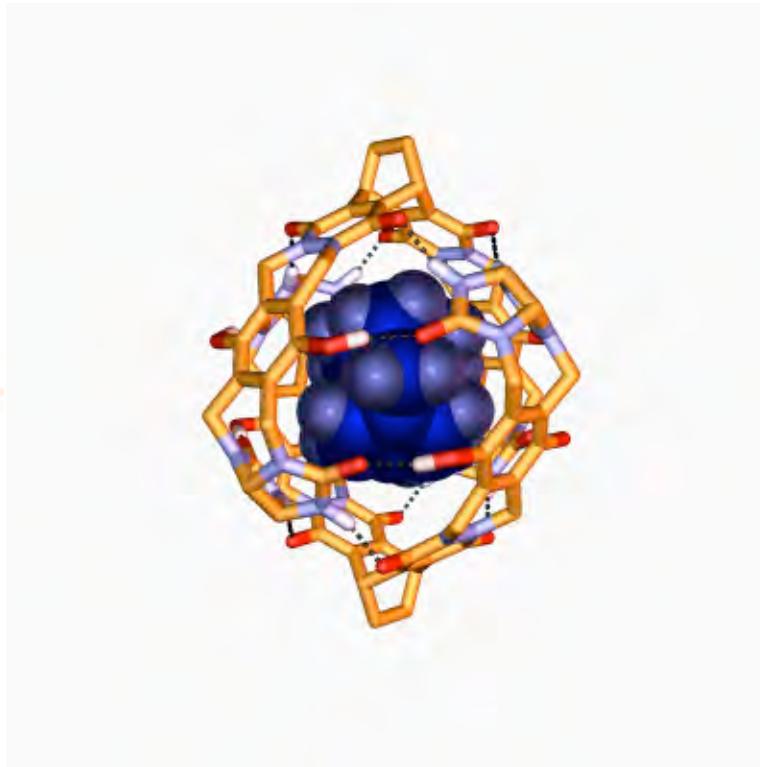
# Guest Exchange in the Softball



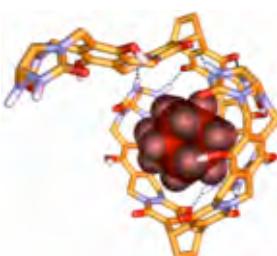
# Guest Exchange in the Softball



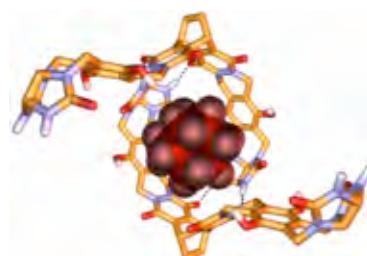
# Guest Exchange in the Softball



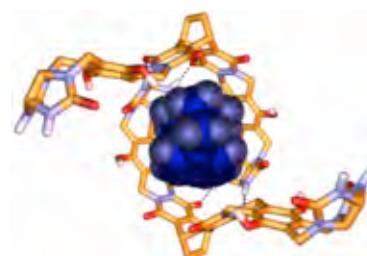
**16 HB**



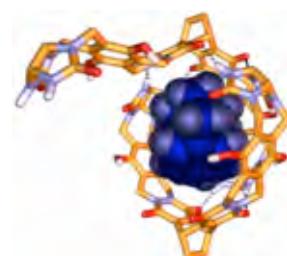
**10 HB**



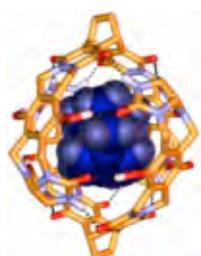
**6 HB**



**6 HB**

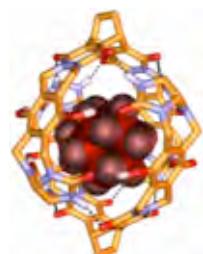
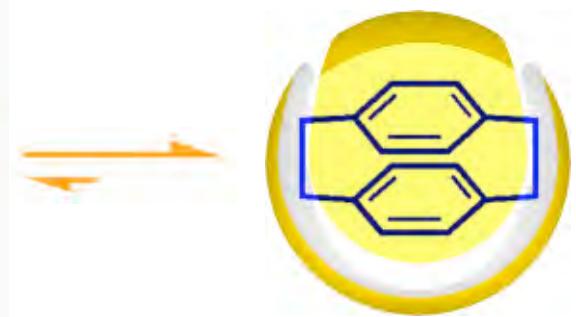
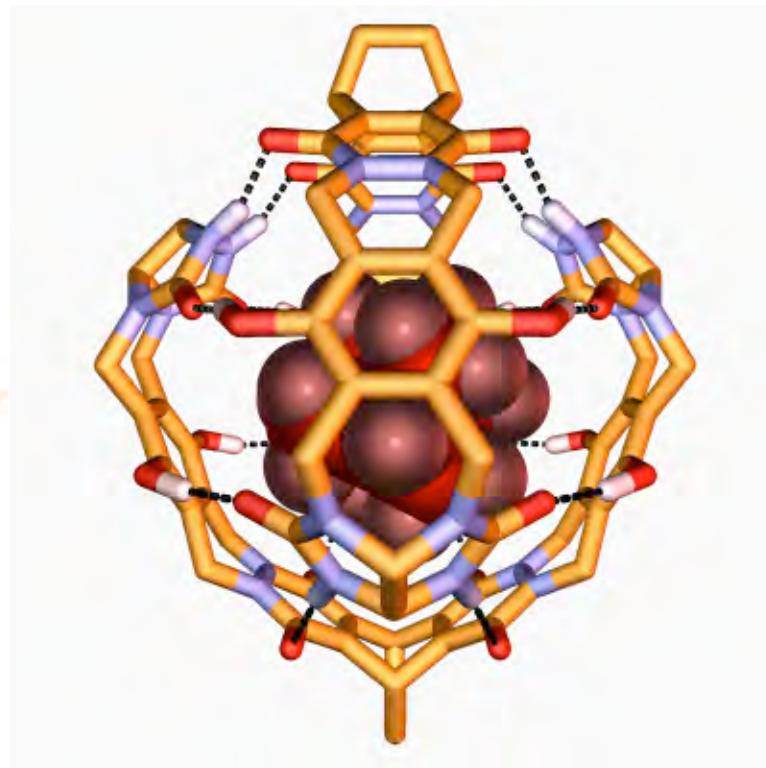


**10 HB**

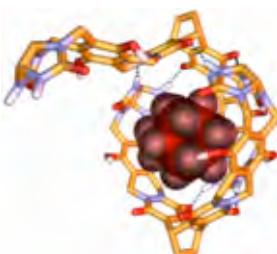


**16 HB**

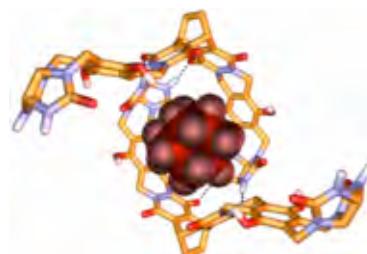
# Guest Exchange in the Softball



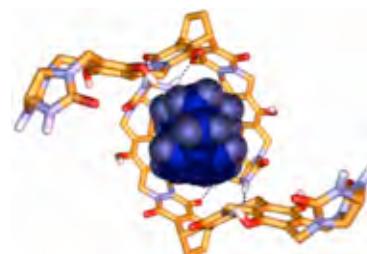
16 HB



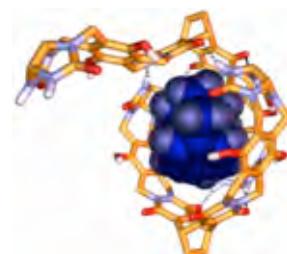
10 HB



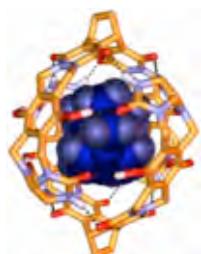
6 HB



6 HB



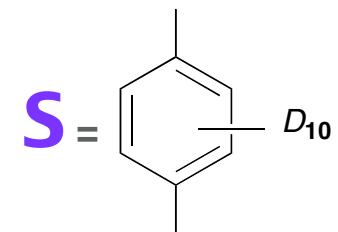
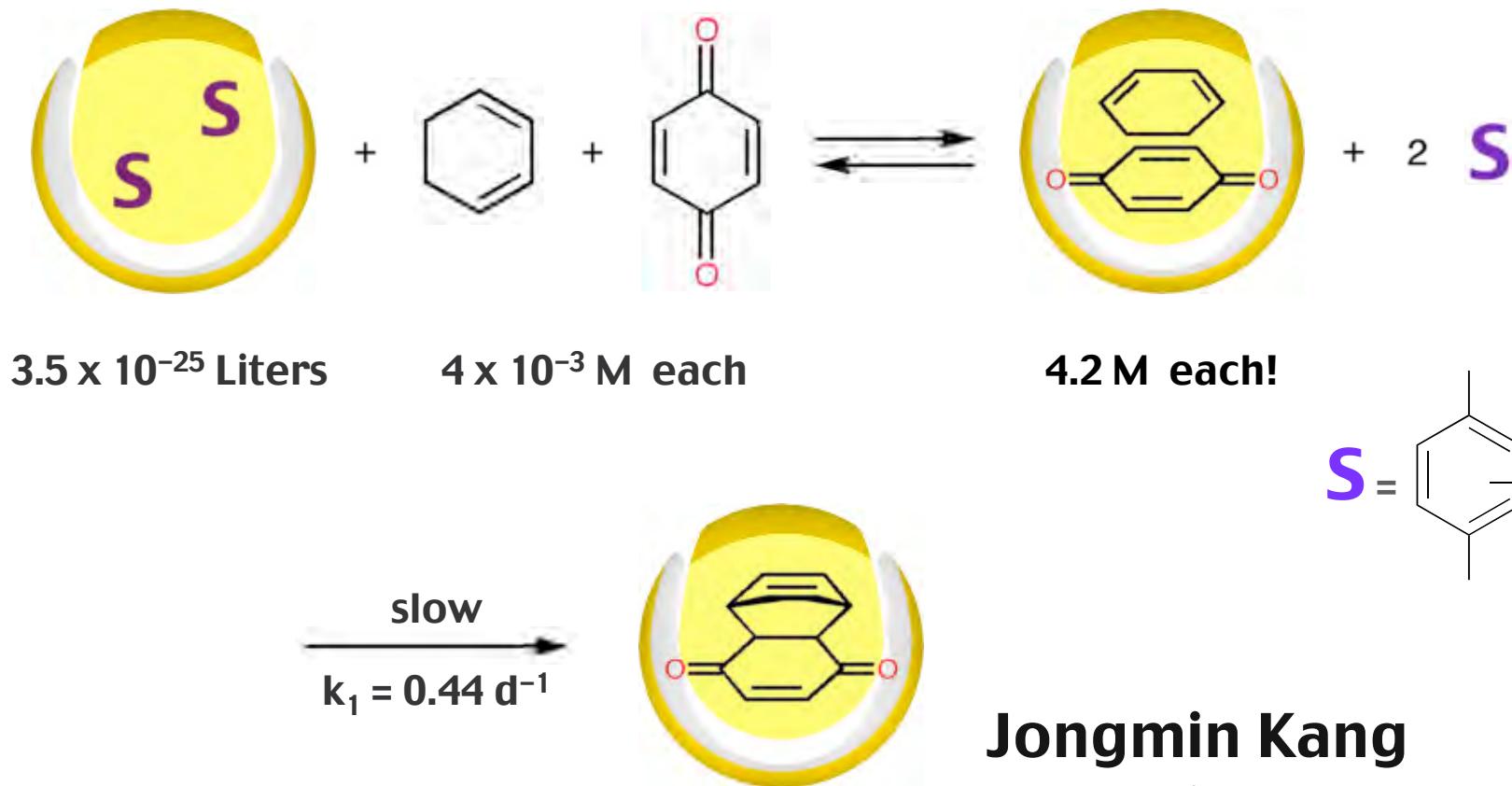
10 HB



16 HB

# Softball

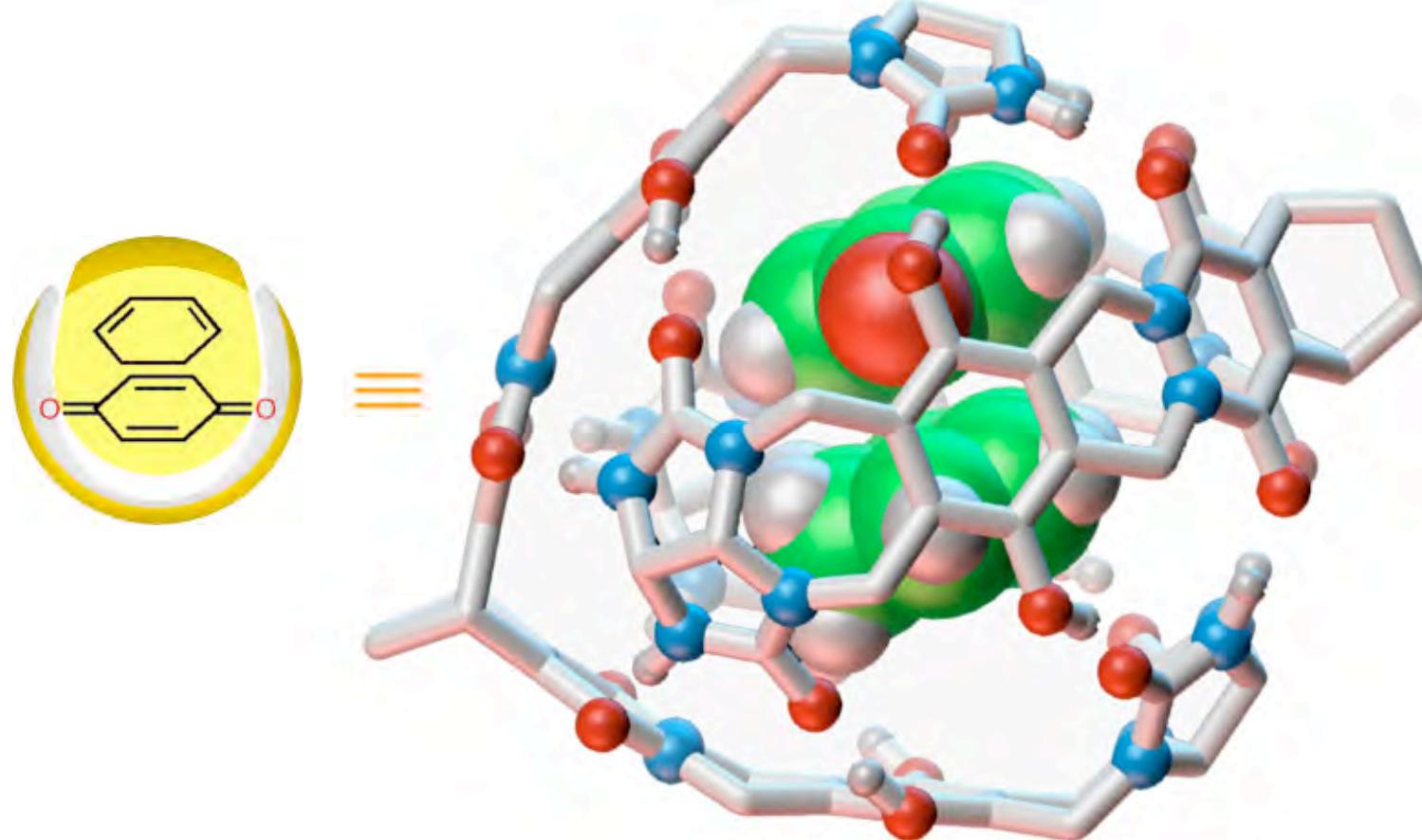
## Accelerated Diels–Alder Reaction



**Jongmin Kang**  
**Dr. Javier Santamaría**  
**Dr. Tomas Martin**  
**Dr. Göran Hilmersson**

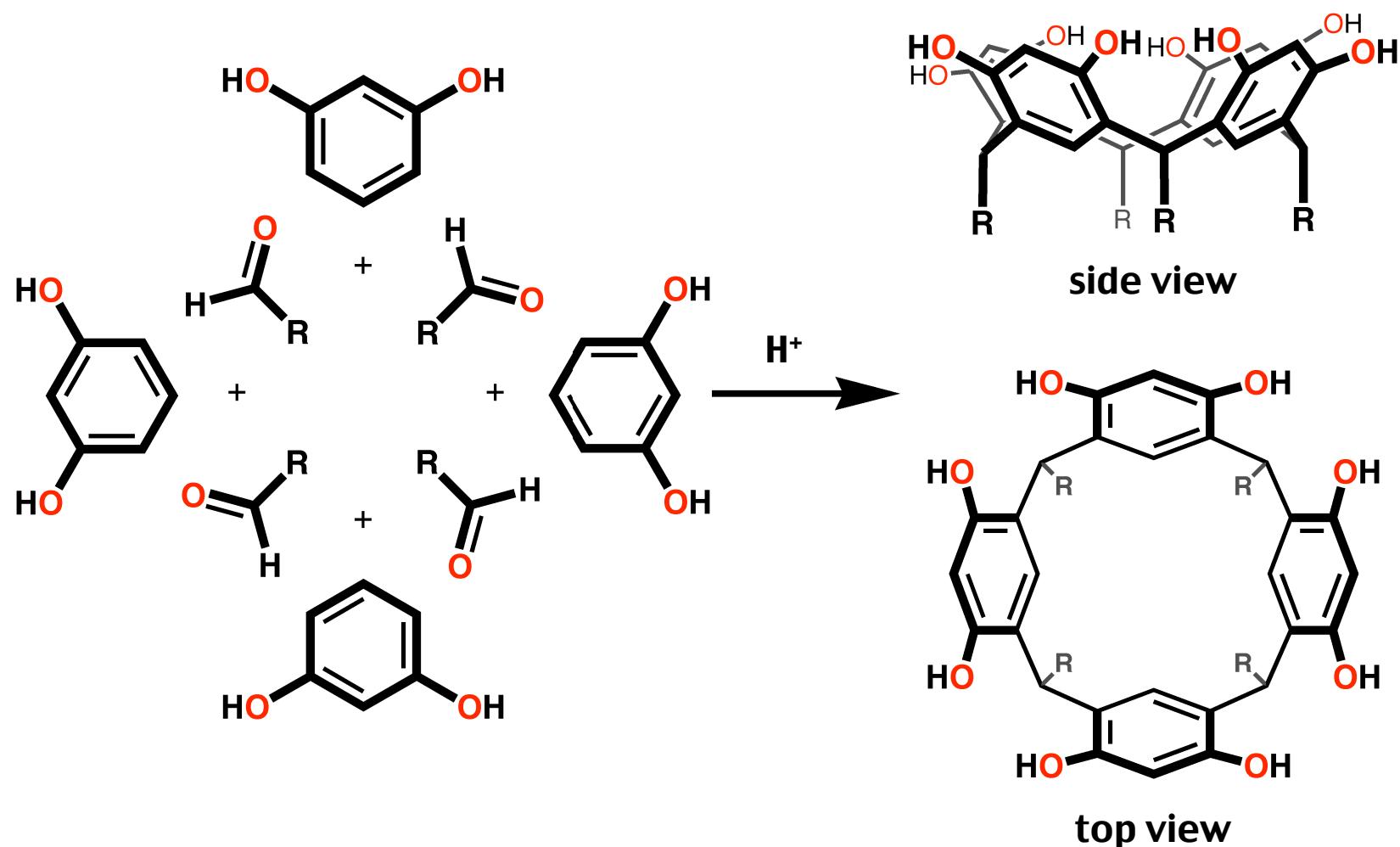
# Softball

## Accelerated Diels-Alder Reaction



Prof. Mike Pique (TSRI)

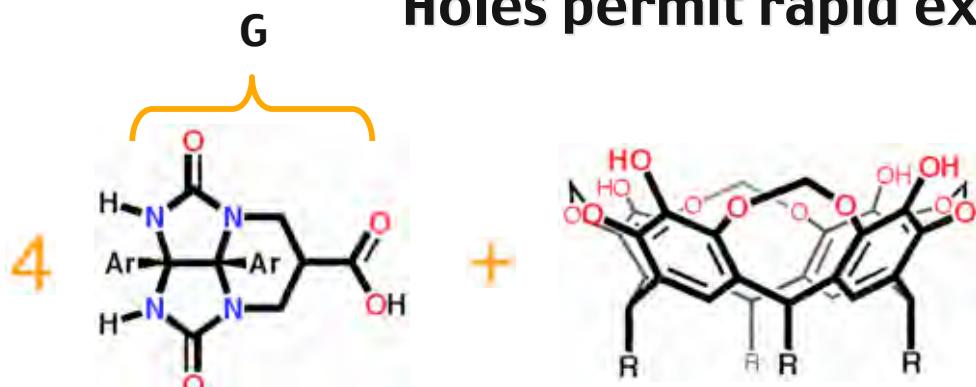
## Resorcin[4]arene Synthesis



Dr. S. Högberg, KTH 1980

# Molecular Sieve $8 \times 10^{-25} \text{ L}$

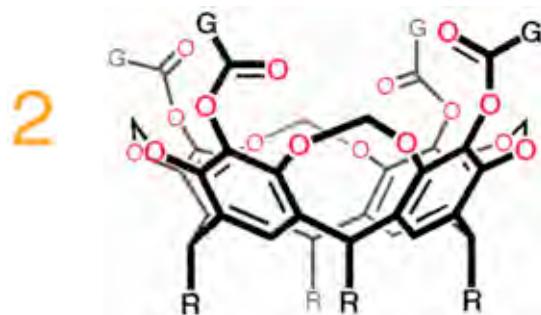
Holes permit rapid exchange of solvents



Ar =  $p\text{-C}_6\text{H}_4-n\text{-C}_7\text{H}_{15}$

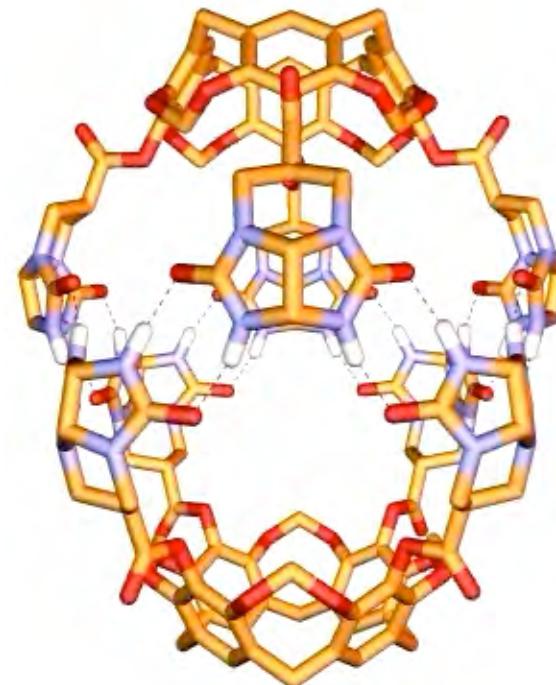
D. J. Cram  
R =  $n\text{-C}_{11}\text{H}_{23}$

PyBOP, NEt<sub>3</sub>  
CH<sub>2</sub>Cl<sub>2</sub>, 48%

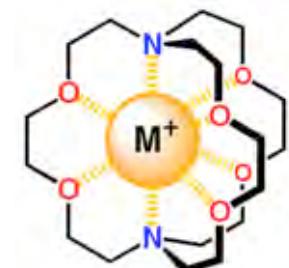
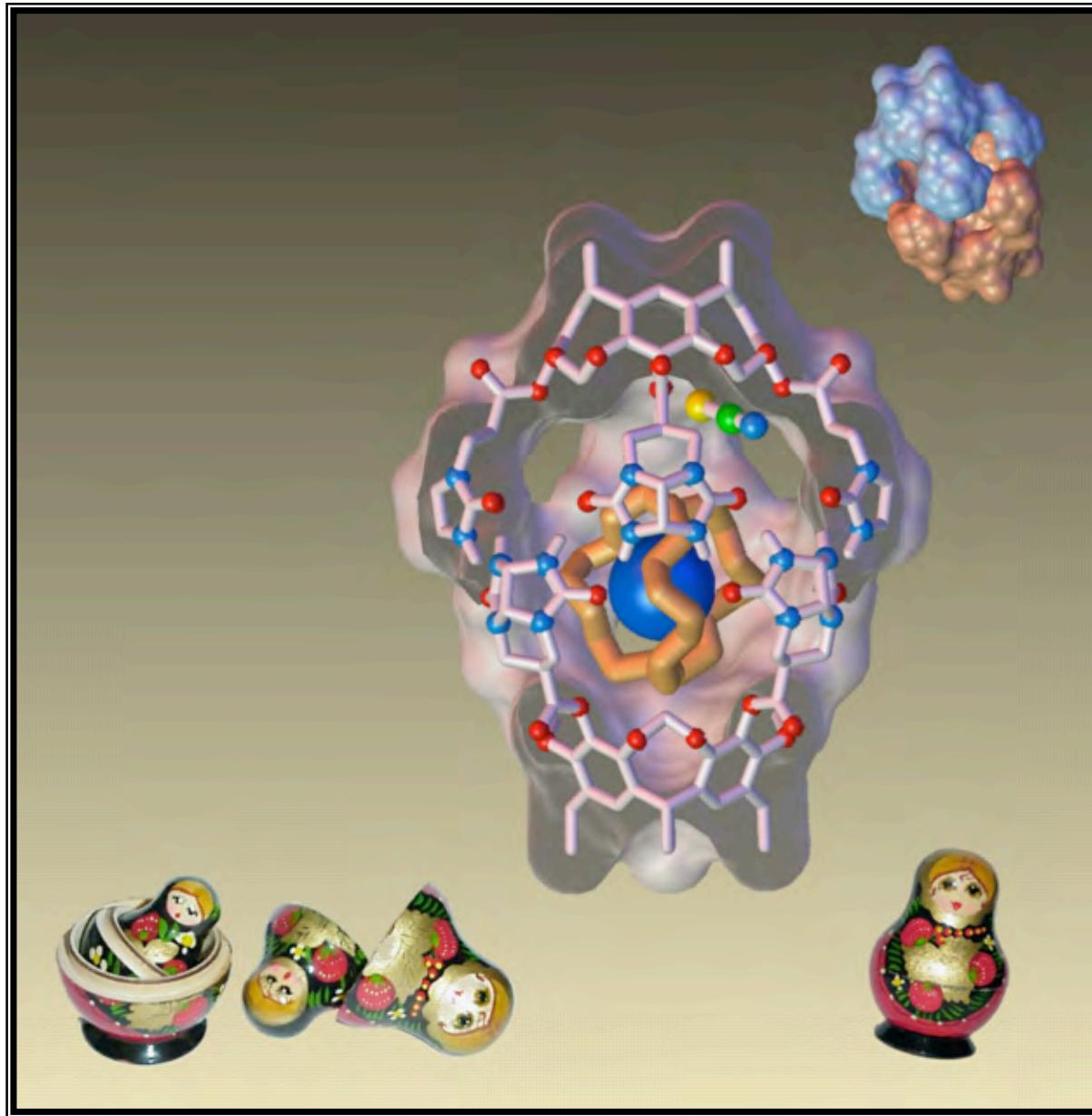


Dr. A. Luetzen  
Dr. A. Renslo

Dr. C. Schalley  
B. O'Leary



# Ions Inside Molecules Inside Molecules

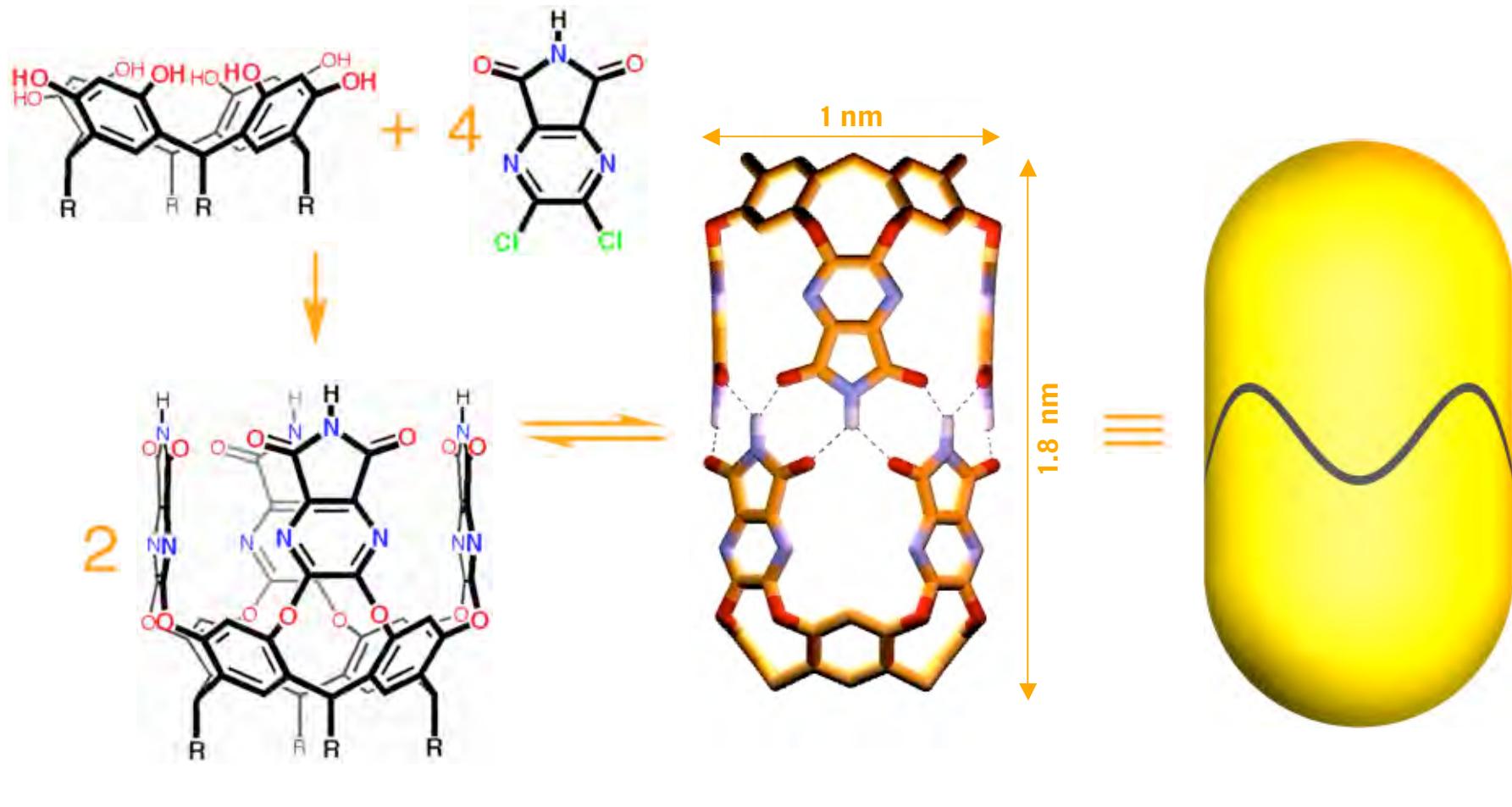


J.-M. Lehn  
 $M = K^+, Sr^{2+}, Ba^{2+}$



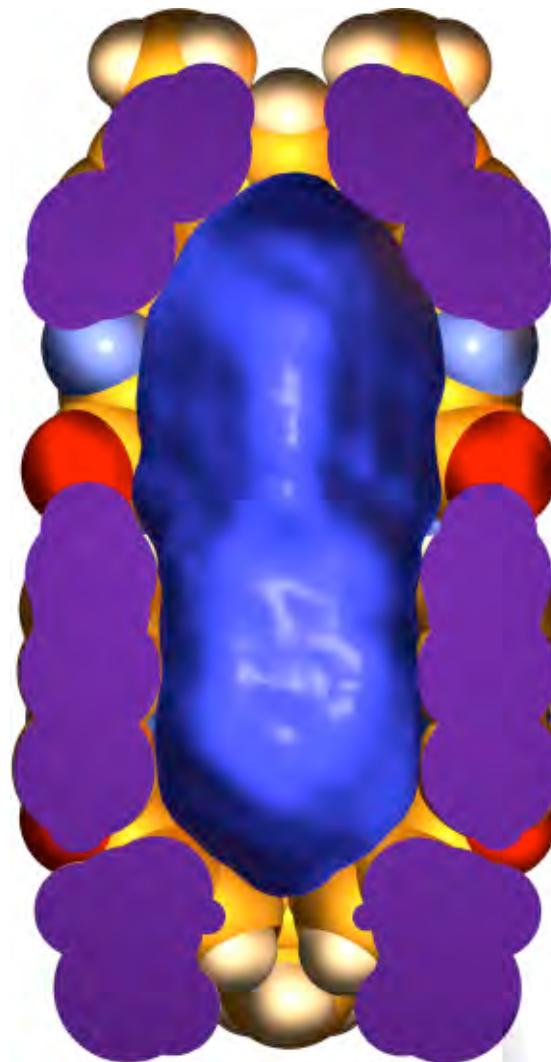
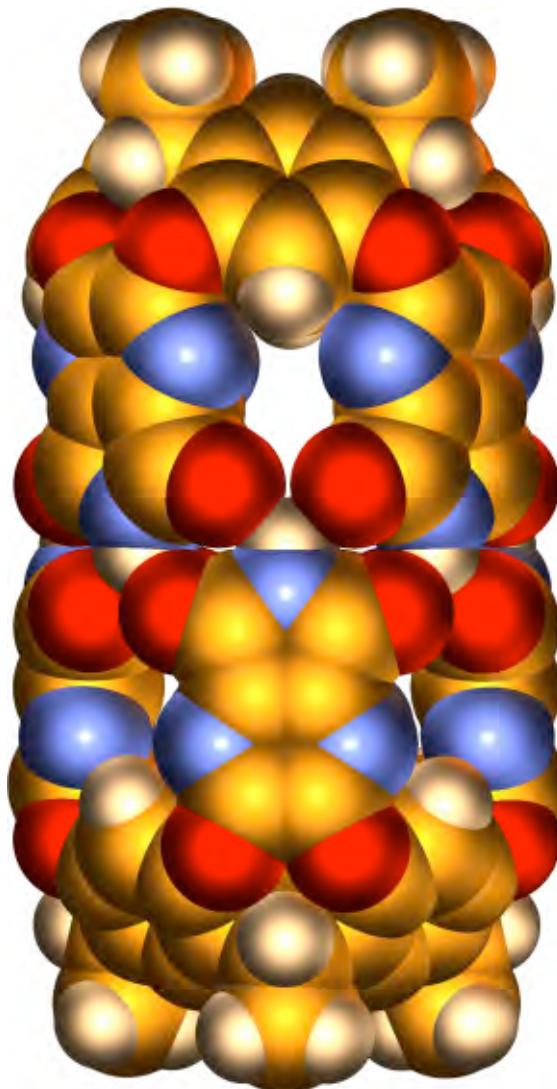
**Dr. A. Luetzen**  
**Dr. A. Renslo**  
**Dr. C. Schalley**  
**B. O'Leary**

# Cylindrical Capsule

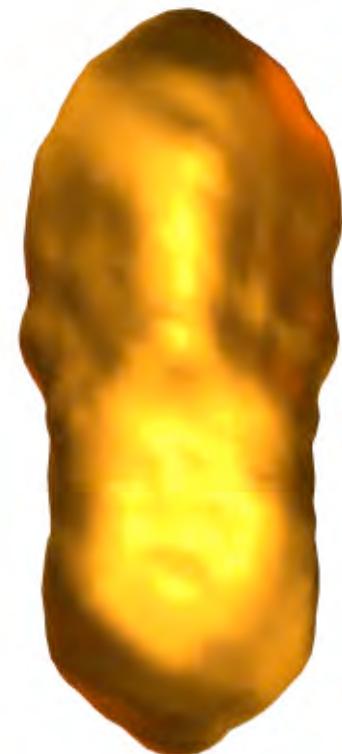


Dr. Thomas Heinz  
Prof. Dmitry Rudkevich

# Cavity of the Cylindrical Capsule



$4.2 \times 10^{-25} \text{ L}$

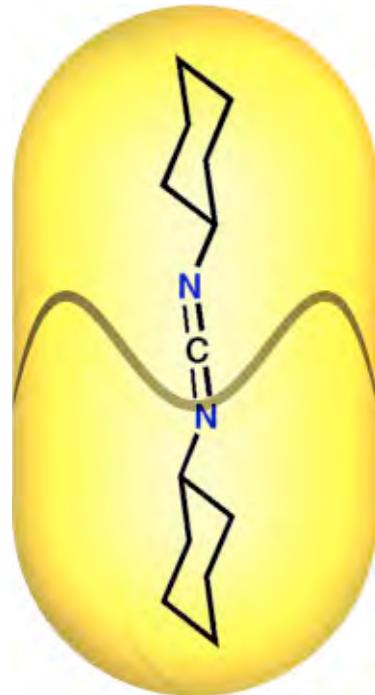


**GRASP**

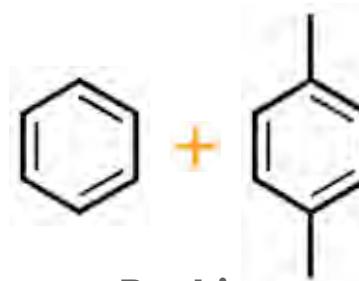


# Cylindrical Capsule

Single guests and combinations fill the space



Packing  
Coefficient  
 $= 0.48$



Packing  
Coefficient  
 $= 0.57$

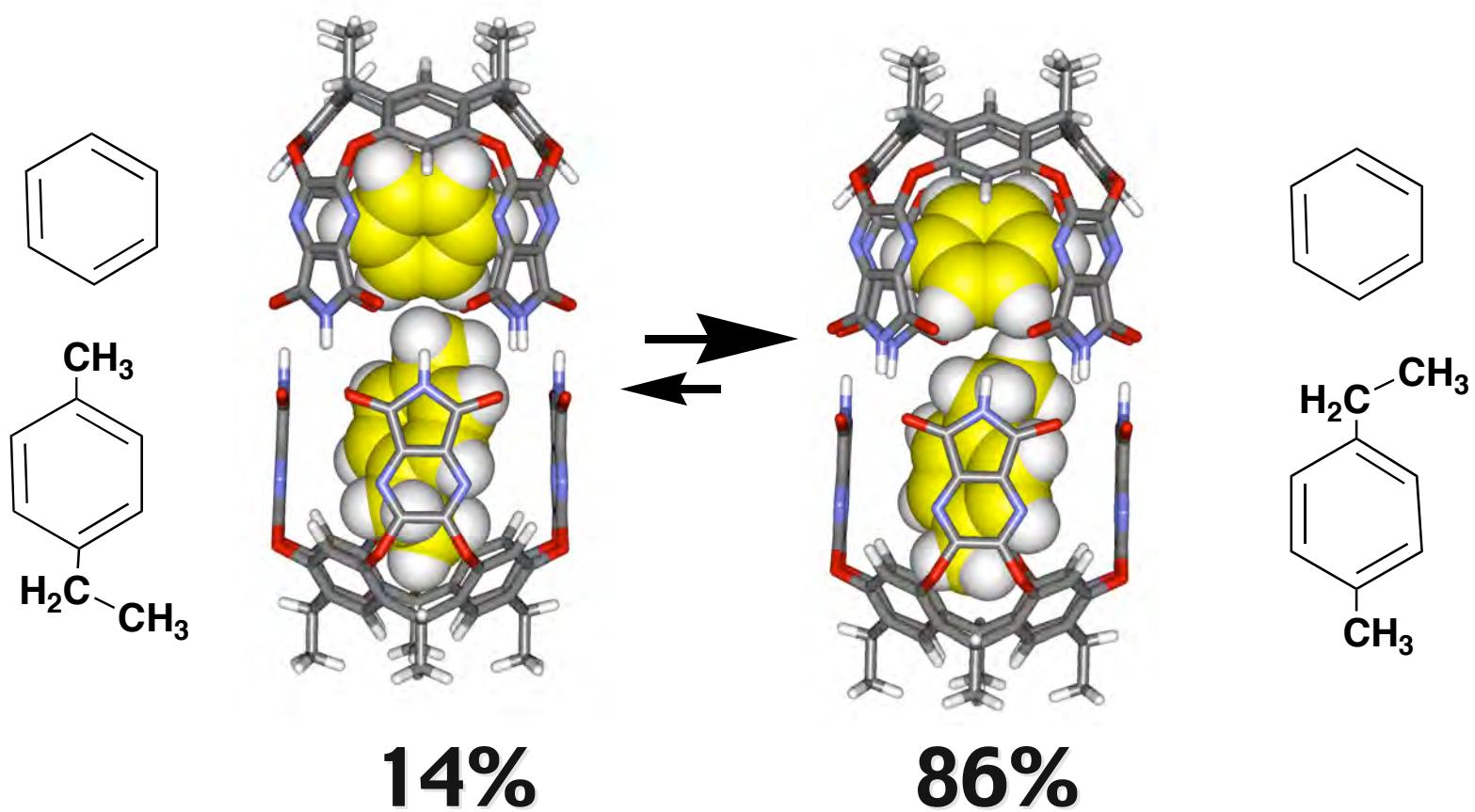


Packing  
Coefficient  
 $= 0.66$

**Prof. Dmitry Rudkevich**

**Dr. Sandro Mecozzi**

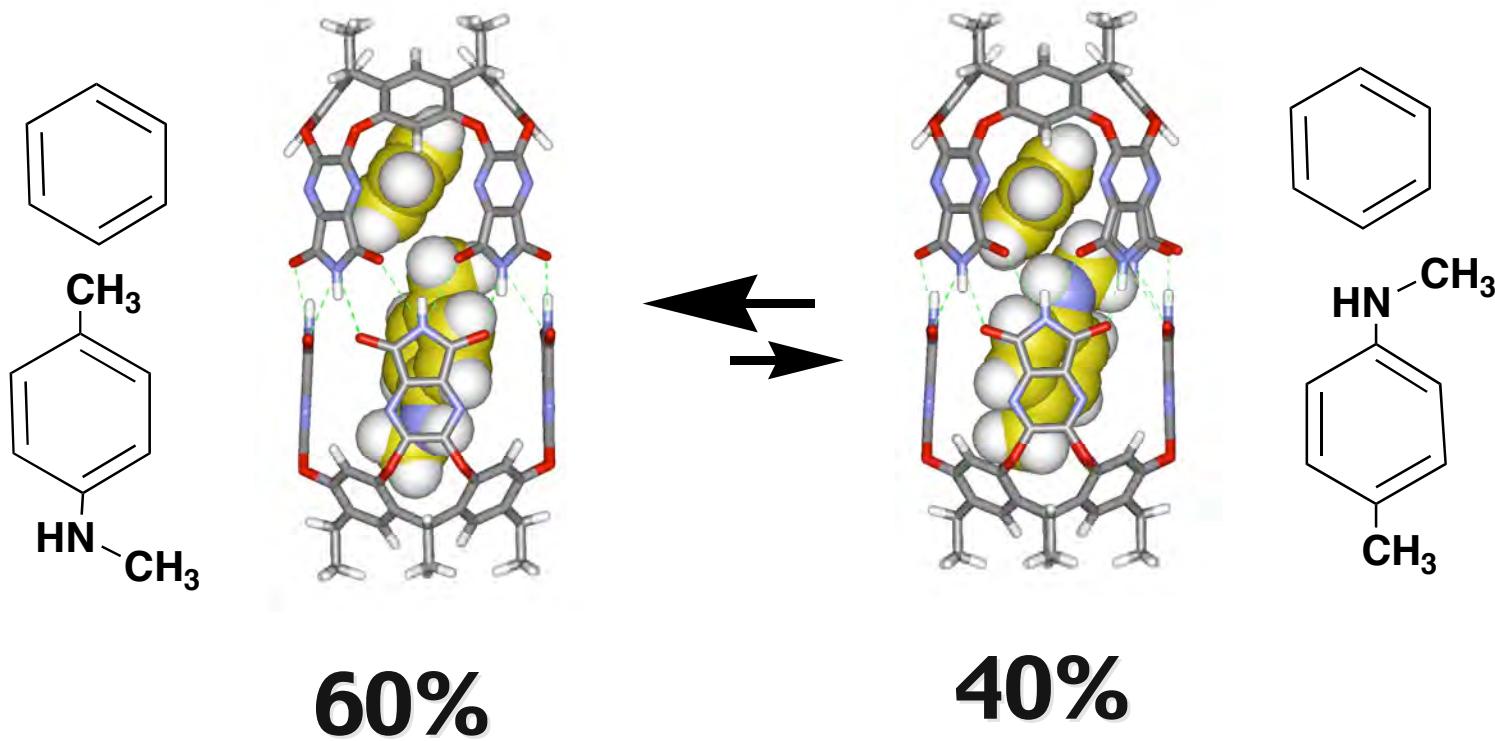
# Single Solute – Solvent Interactions



**Dr. A. Scarso**  
**Dr. A. Shivanyuk**

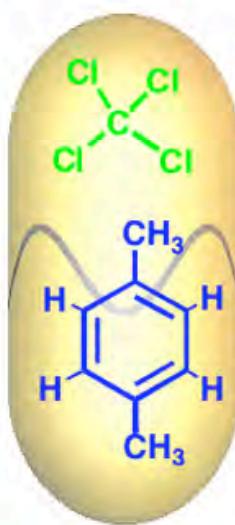
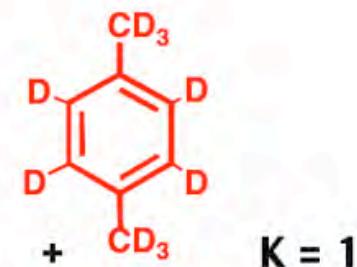
# Single Solute – Solvent Interactions

Revealed by a panel of 15 solvents

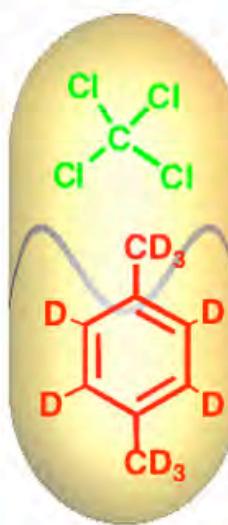
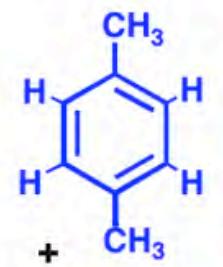


**Dr. A. Scarso**  
**Dr. A. Shivanyuk**

# Equilibrium Isotope Effects

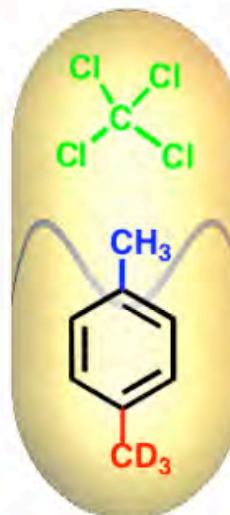


43%



57%

## Social Isomers



57%

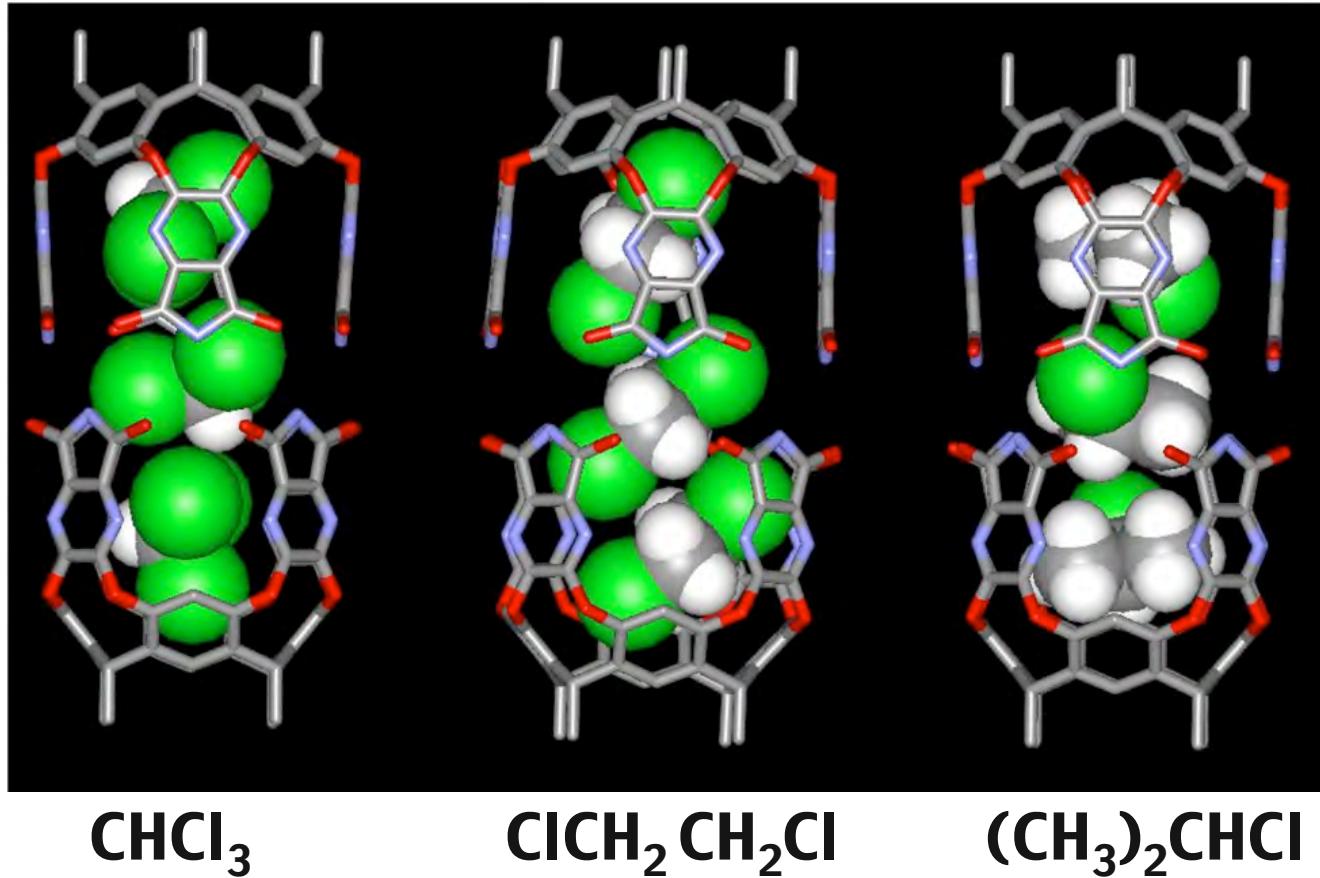


43%

**Dr. A. Scarso  
Dr. D. Rechavi–Robinson  
Theory:  
Prof. K. N. Houk (U.C.L.A.)**

# Cylindrical Capsule

Coencapsulation of three solvent

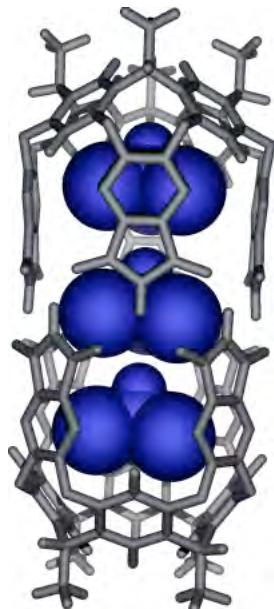


Dr. Alex Shivanyuk

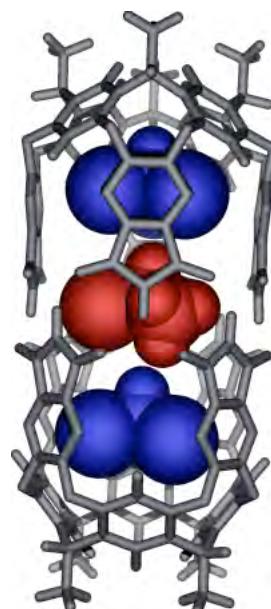
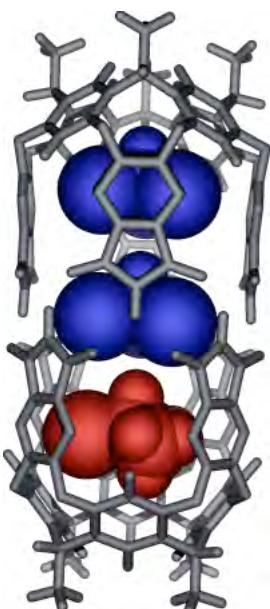
Dr. Masamichi Yamanaka

Prof. P. Ballester

# Isomeric Constellations



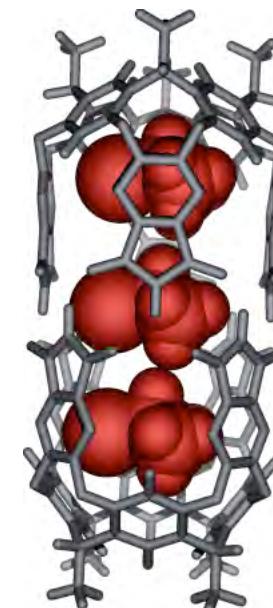
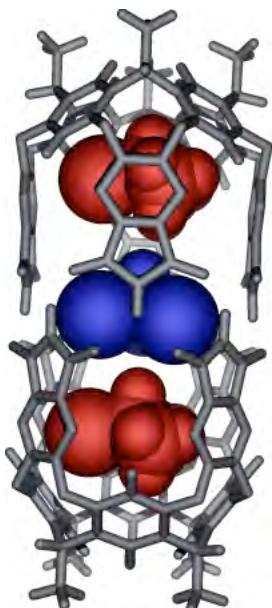
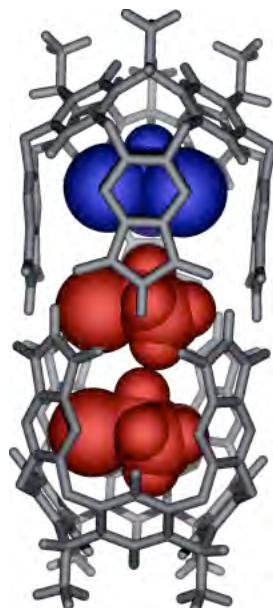
chloroform



A binary coding scheme

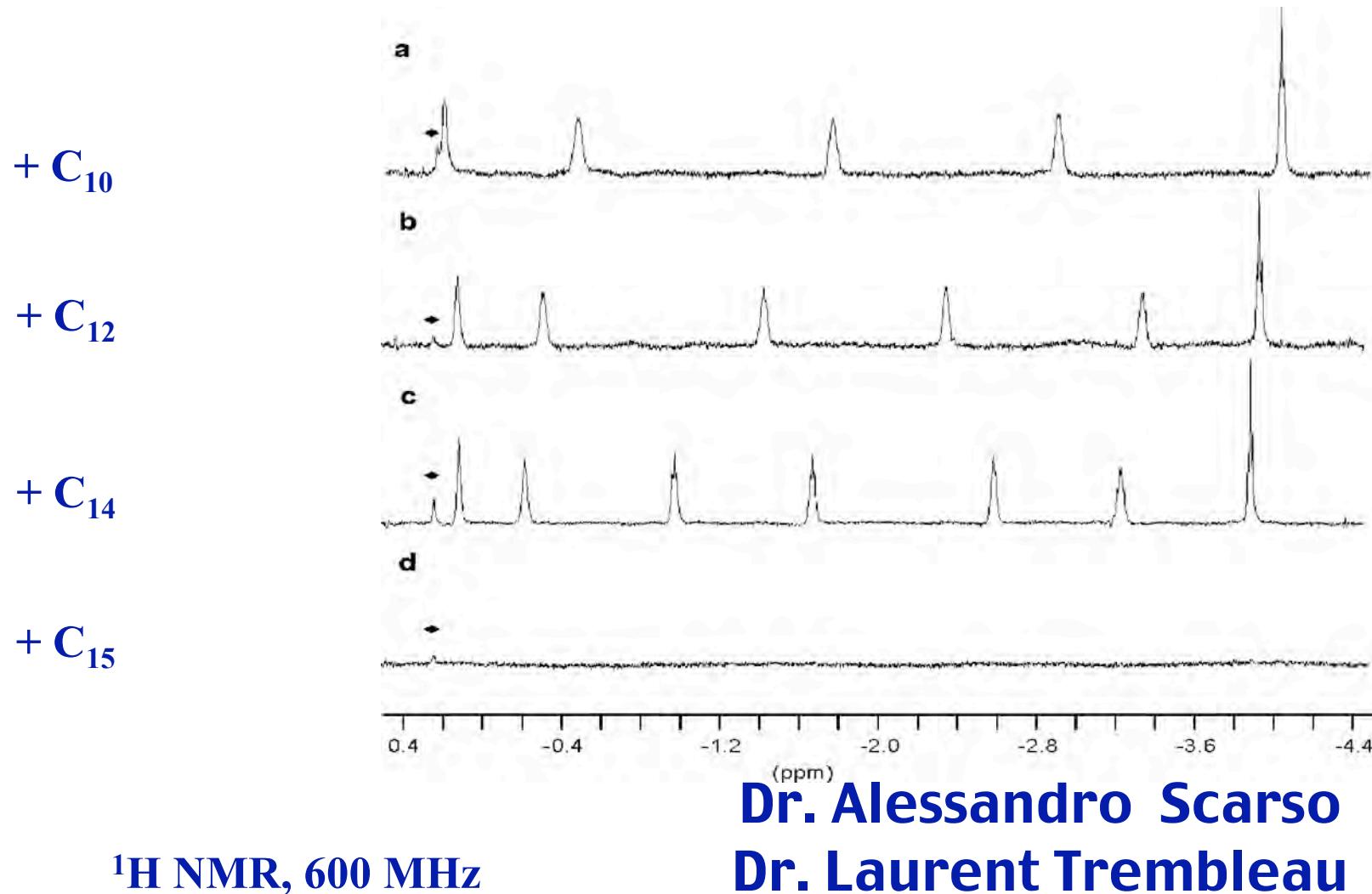
Dr. A. Shivanyuk

Dr. M. Yamanaka



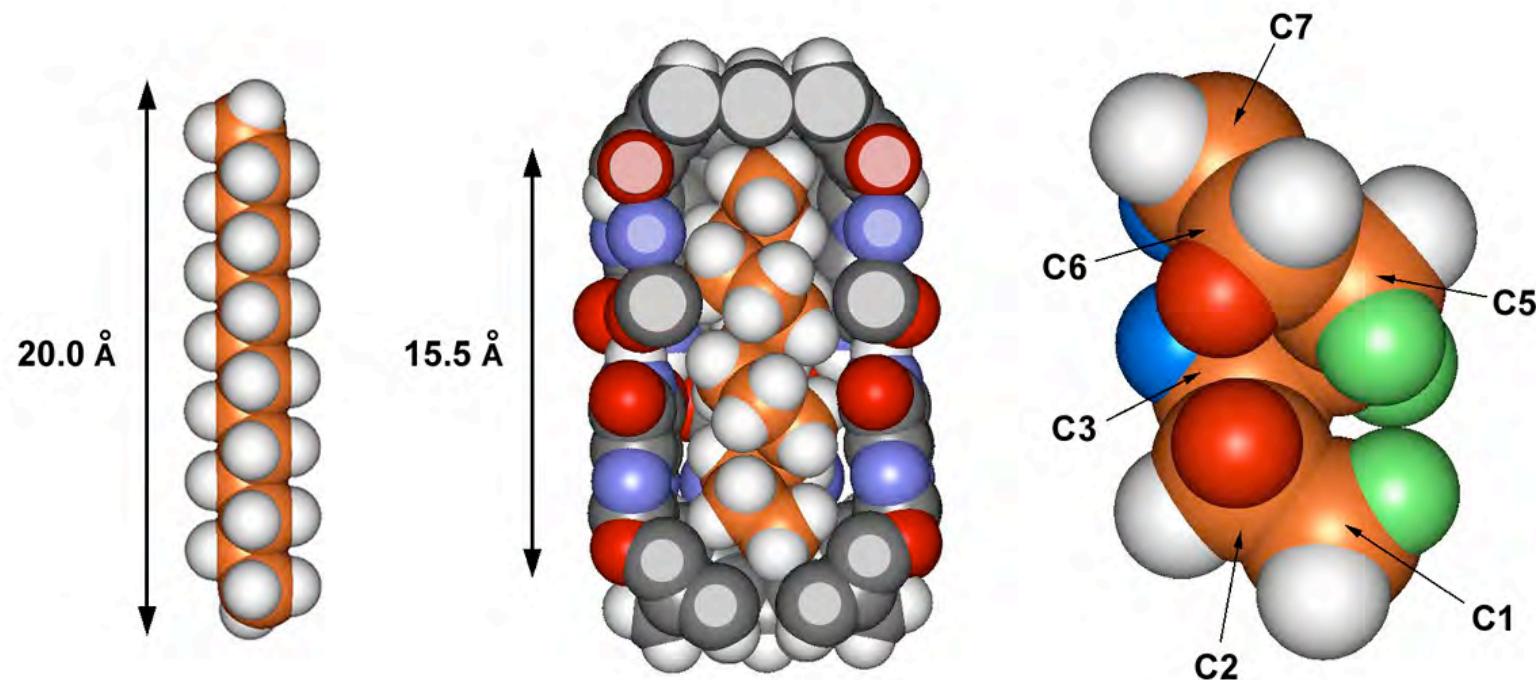
isopropyl  
chloride

# Complexes of the Capsule with Linear Hydrocarbons



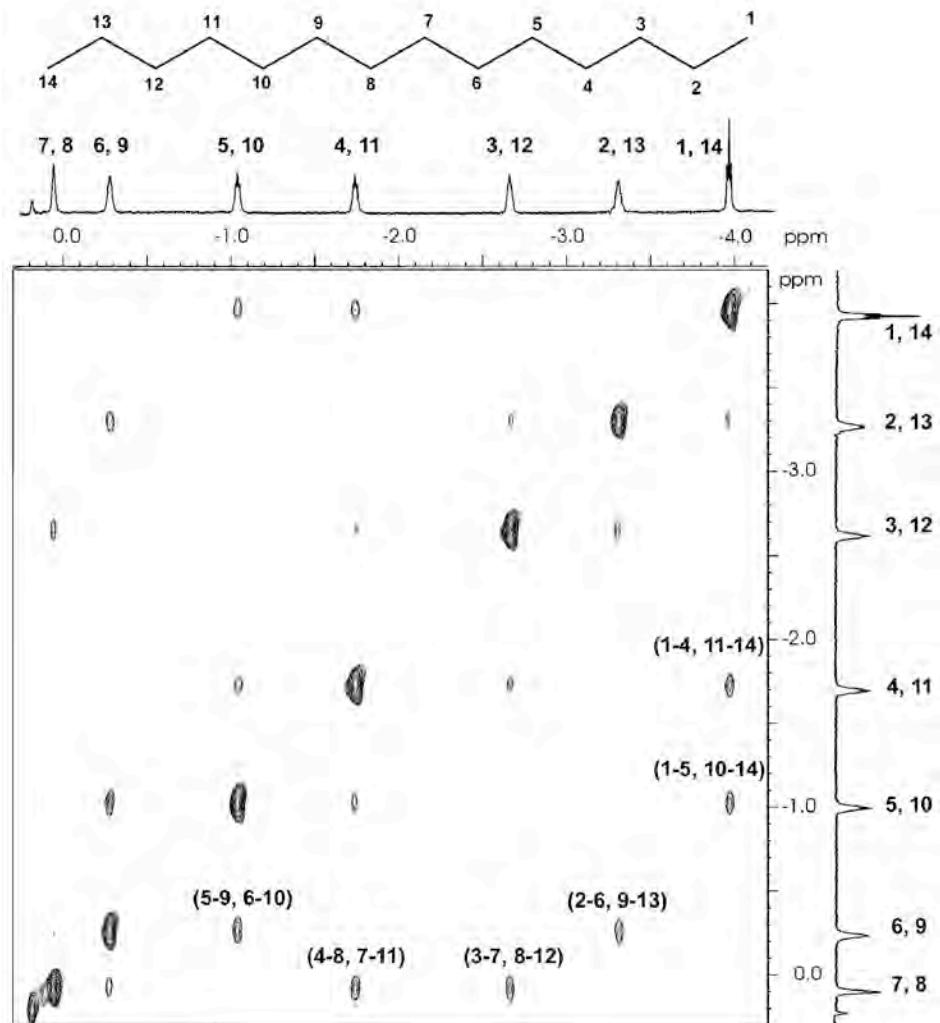
# Straight Chain Hydrocarbons Coil to fit into the Capsule

Gauche conformation:  
0.55 kcal/mol



Dr. Alessandro Scarso  
Dr. Laurent Trembleau

# Capsule-Tetradecane Complex

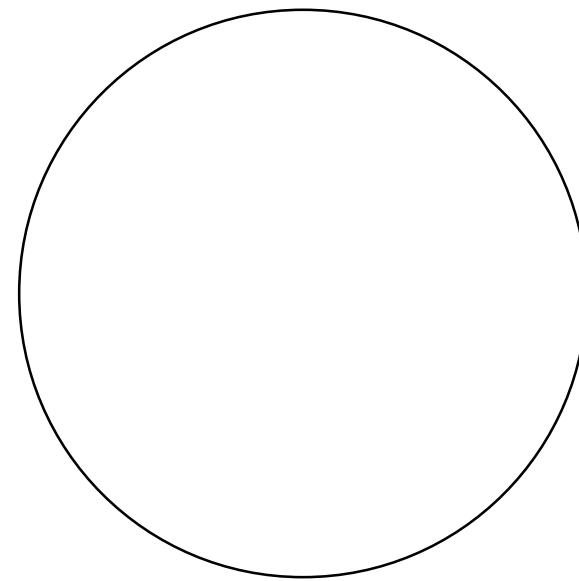
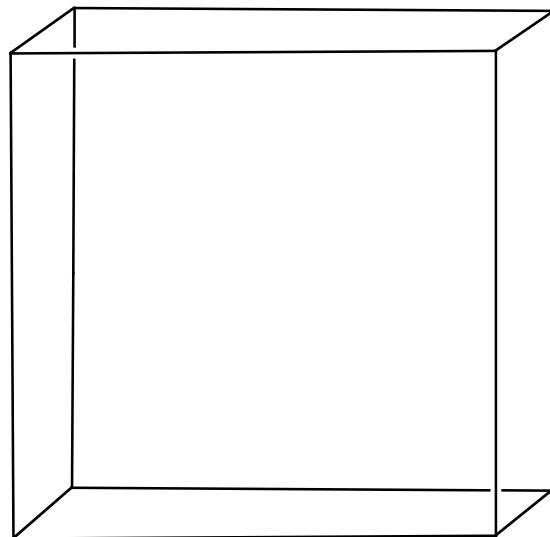


Dr. Alessandro  
Scarso  
Dr. Laurent  
Trembleau

2D-NOESY, 600 MHz, mixing time: 300ms

# *Chiral Spaces*

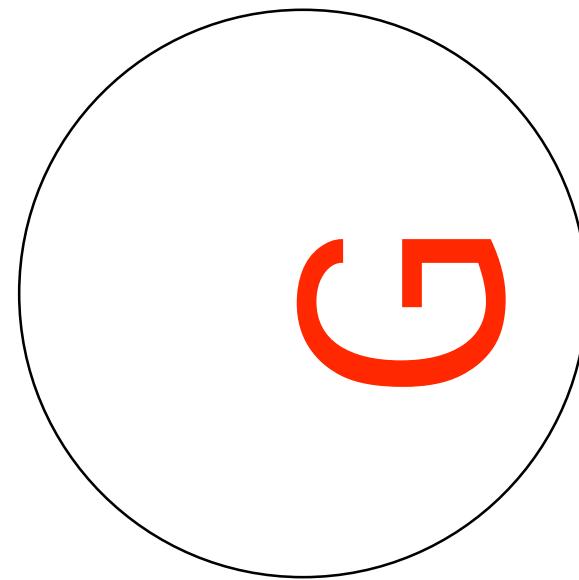
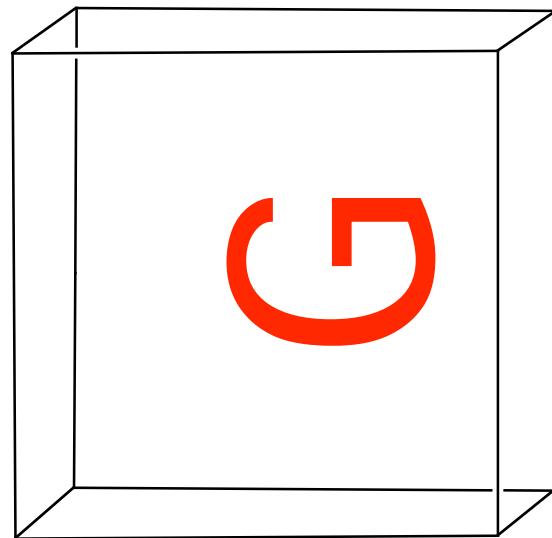
# Achiral Spaces



**Dr. Alessandro Scarso  
Dr. Alexander Shivanyuk**

# Chiral Spaces

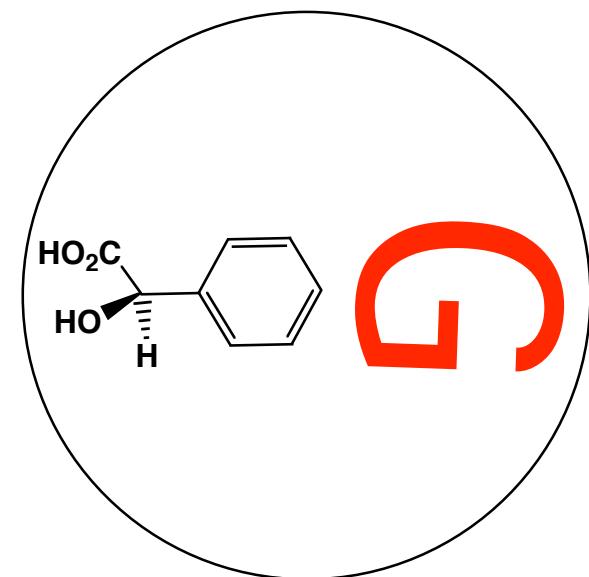
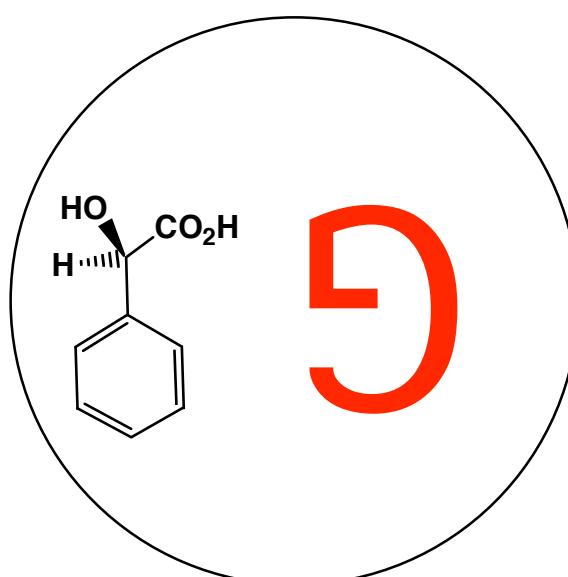
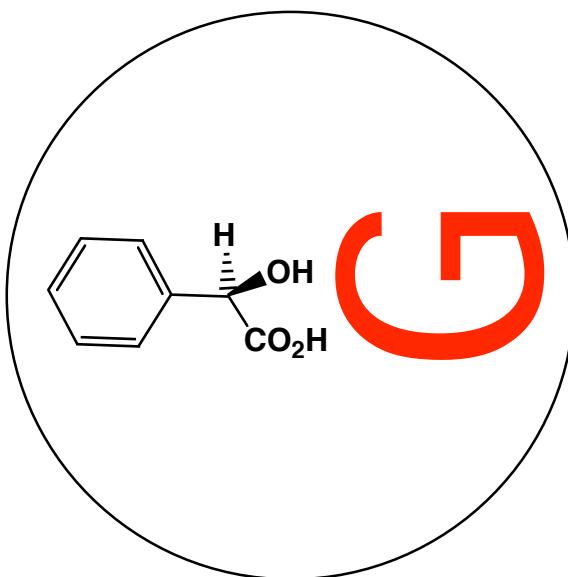
Chiral objects in achiral spaces



**Dr. Alessandro Scarso  
Dr. Alexander Shivanyuk**

# Asymmetric Coencapsulation

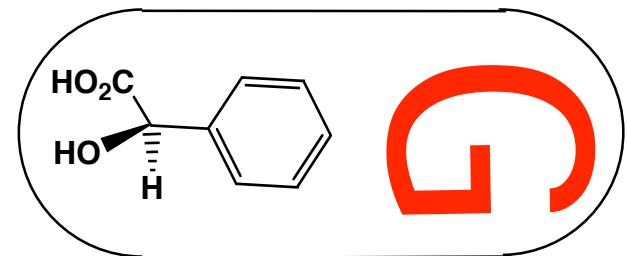
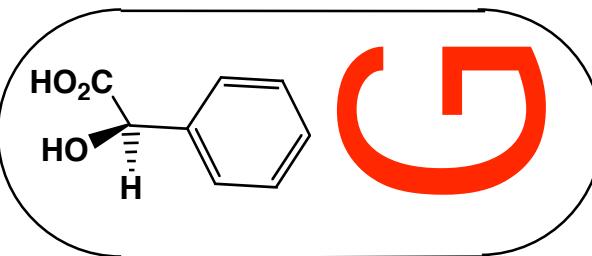
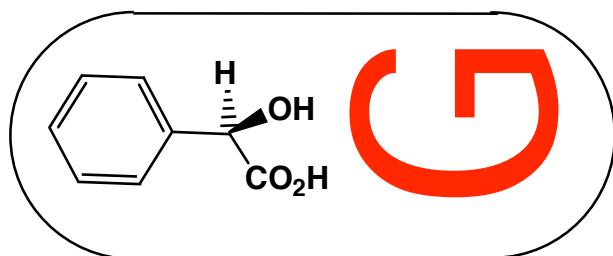
An ensemble of environments



Dr. Alessandro Scarso  
Dr. Alexander Shivanyuk

# Asymmetric Coencapsulation

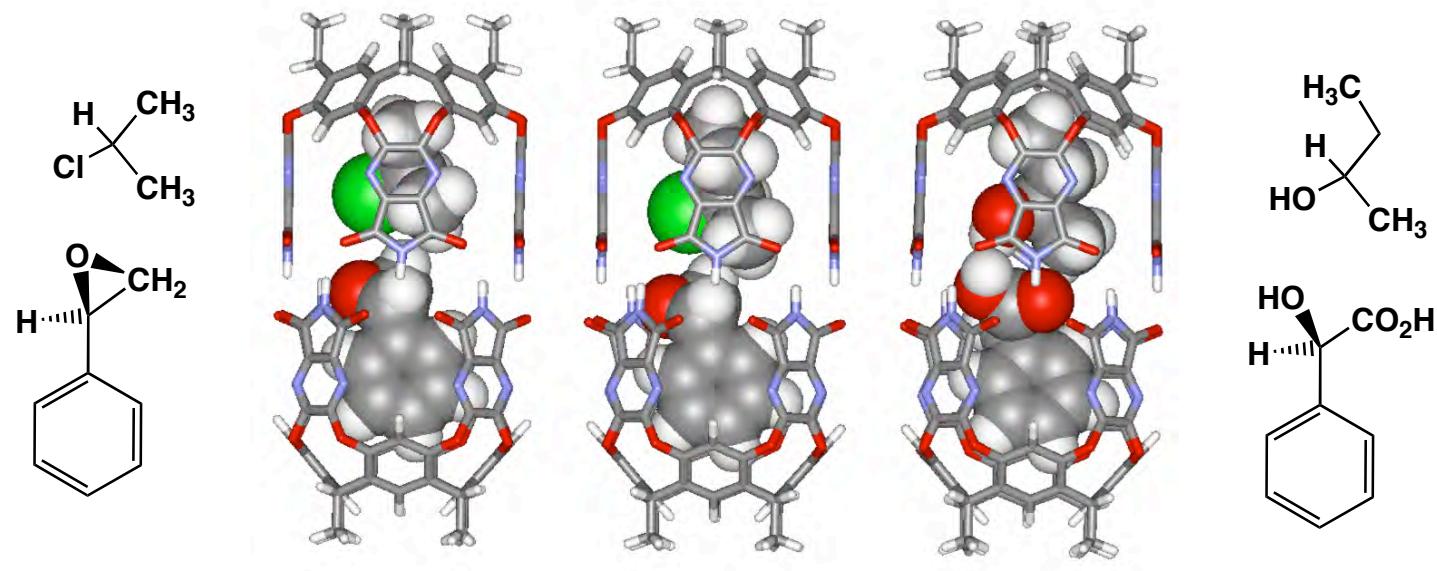
Fixed orientations enhance recognition



Dr. Alessandro Scarso  
Dr. Alexander Shivanyuk

# Asymmetric Coencapsulation

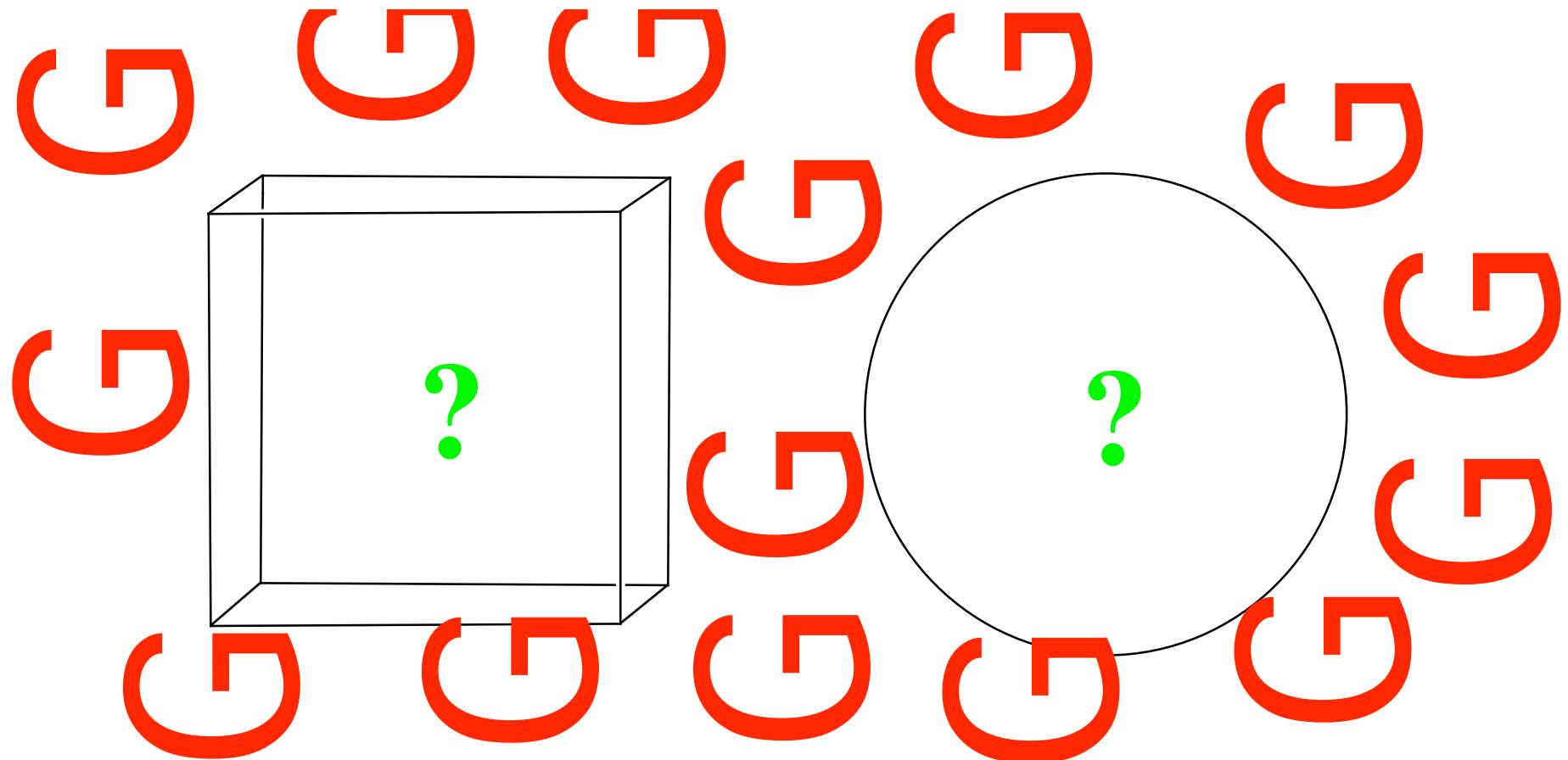
Magnetic and steric effects coexist



Dr. Alessandro Scarso  
Dr. Alexander Shivanyuk

# Asymmetric Exteriors

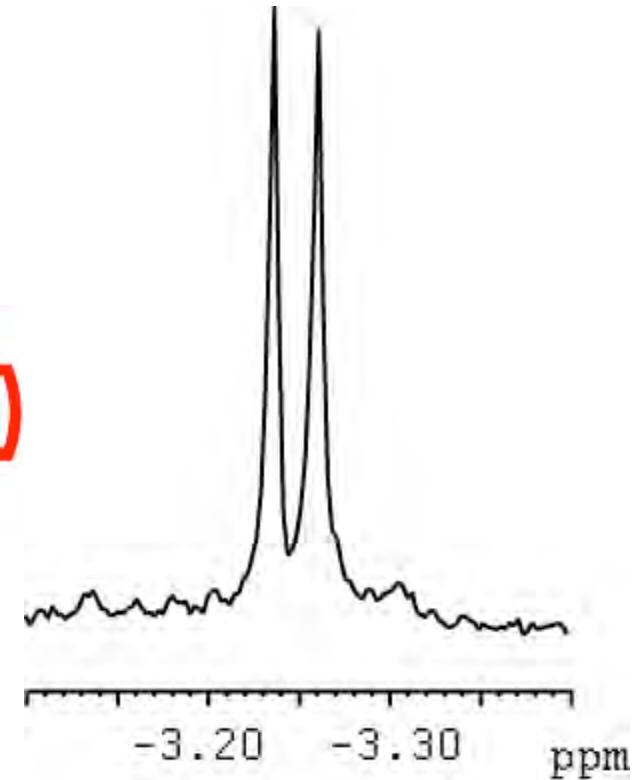
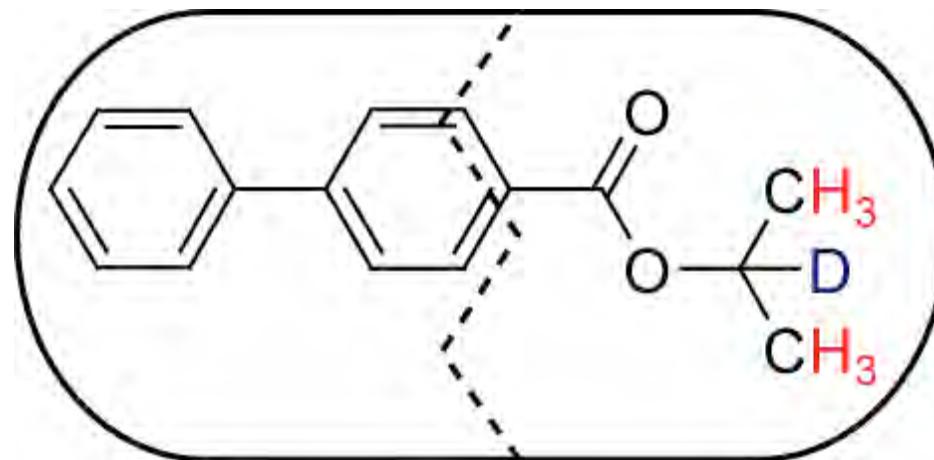
Separation of Steric and Magnetic Effects



Dr. Alessandro Scarso  
Dr. Alexander Shivanyuk

## Asymmetric Exteriors

### Separation of Steric and Magnetic Effects



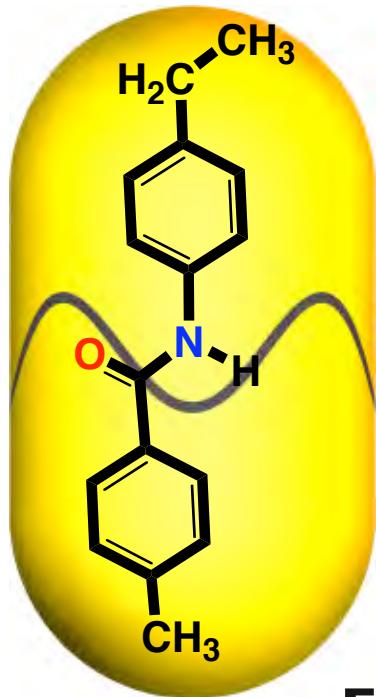
Dr. Toru Amaya

# *Chemical Amplification:*

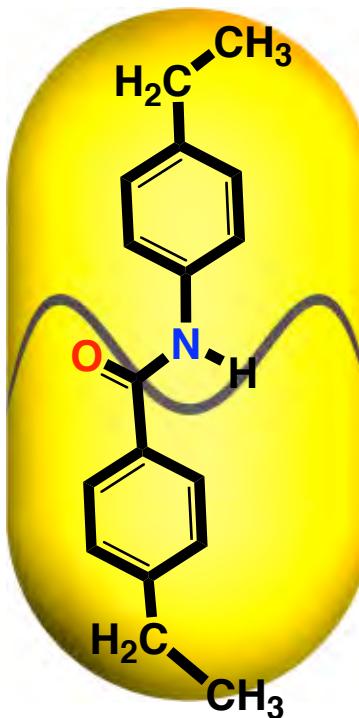
## *A Chain Reaction*

# Length Selection

Rigid guests have no choice



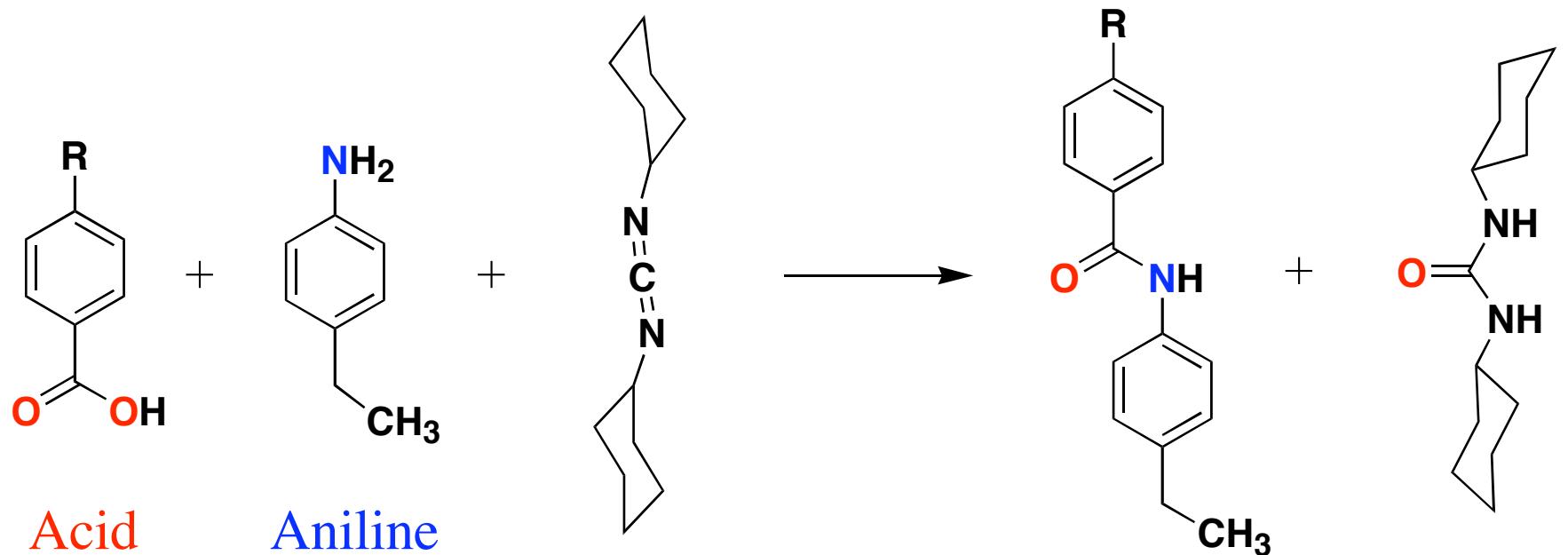
Fits



Doesn't fit

Dr. Steffi Körner  
Dr. Fabio Tucci  
Dr. Thomas Heinz  
Prof. Dmitry Rudkevich

## Long and short anilides formed at the same rate in solution



R = Me, Et

**Dr. J. Chen**

**Dr. S Lin**

**Dr. S. Körner**

**Carbodiimide  
(DCC)**

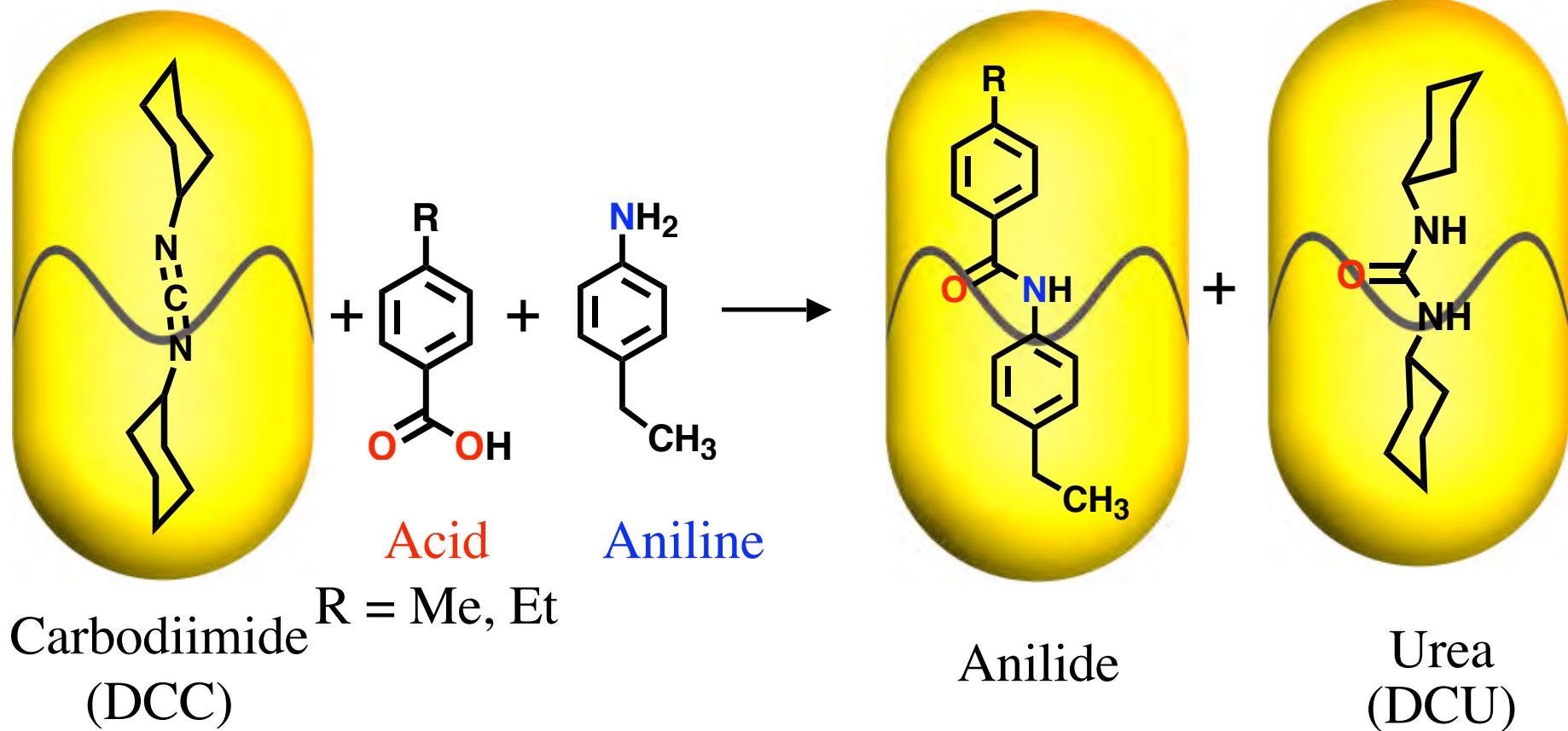
**Anilide**

**Urea  
(DCU)**

**Prof. S. Craig**

**Prof. D. Rudkevich**

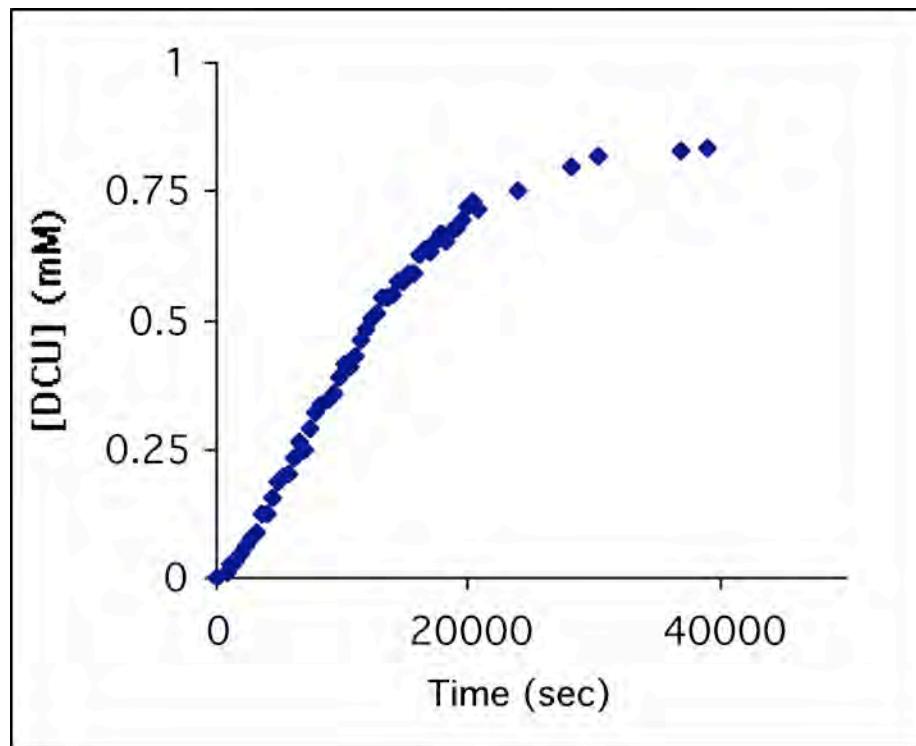
# Chemical Amplification with Encapsulated Reagents



Dr. J. Chen, Dr. S. Lin  
Dr. S. Körner

Prof. S. Craig  
Prof. D. Rudkevich

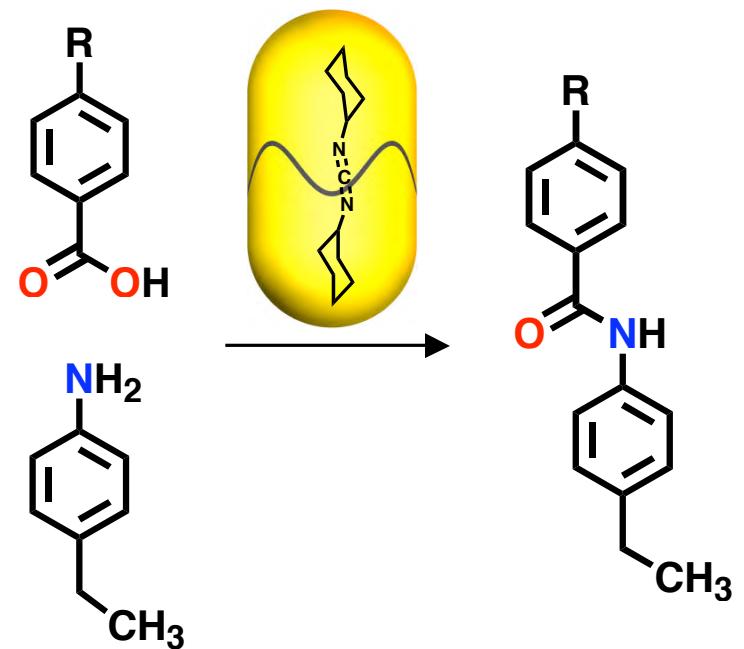
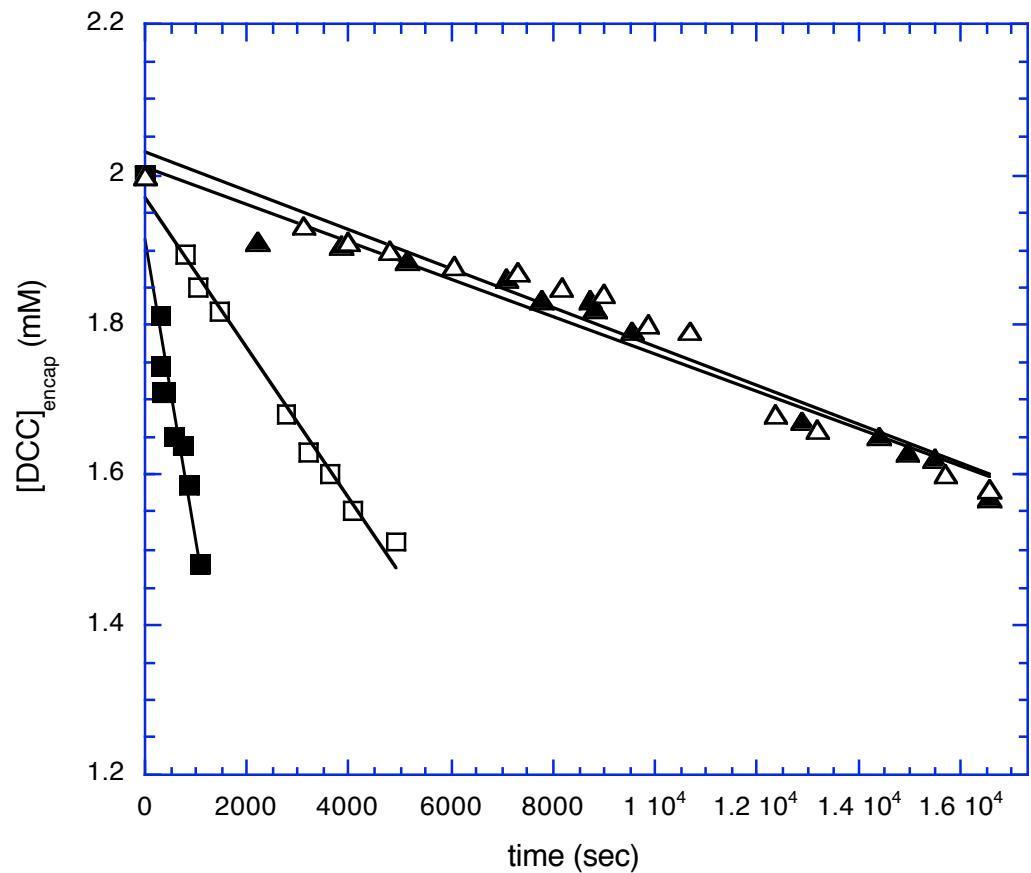
## Sigmoidal product generation of the shorter anilide



Dr. J. Chen, Dr. S. Lin  
Dr. S. Körner

Prof. S. Craig  
Prof. D. Rudkevich

## Product Recognition and Autocatalysis of the shorter, but not longer anilide

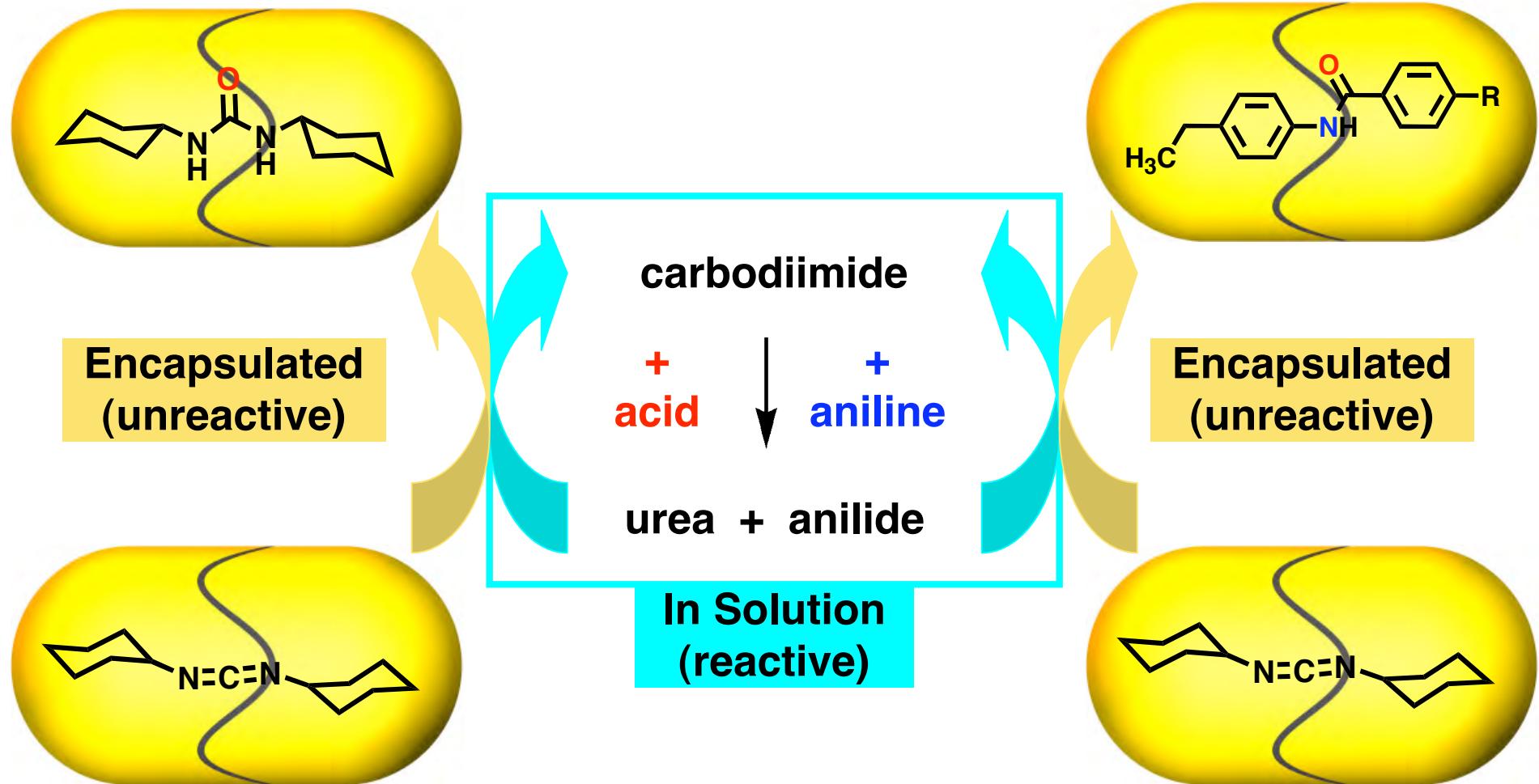


**R = Me, squares**  
**R = Et, triangles**

Dr. J. Chen, Dr. S. Lin  
Dr. S. Körner

Prof. S. Craig  
Prof. D. Rudkevich

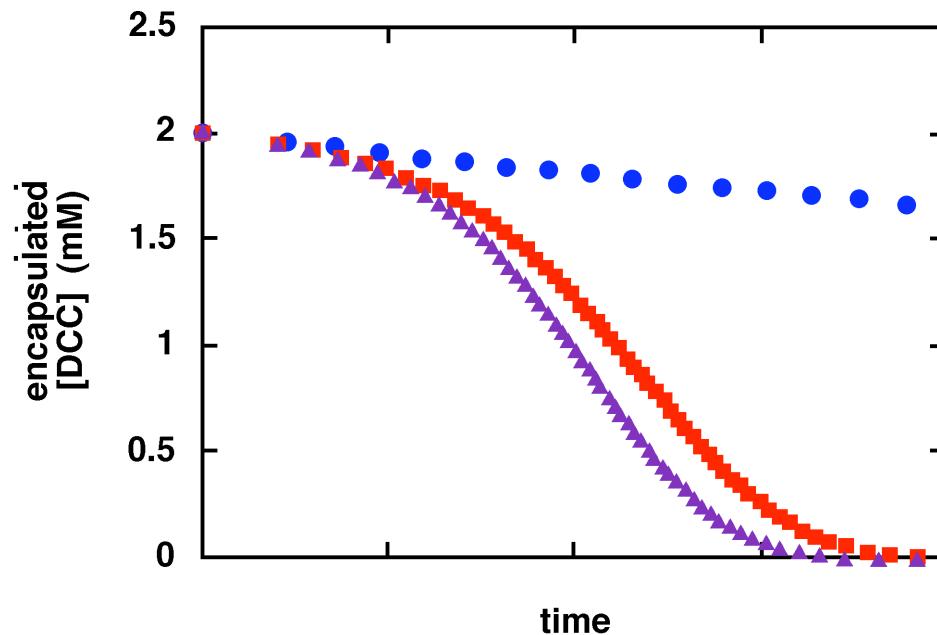
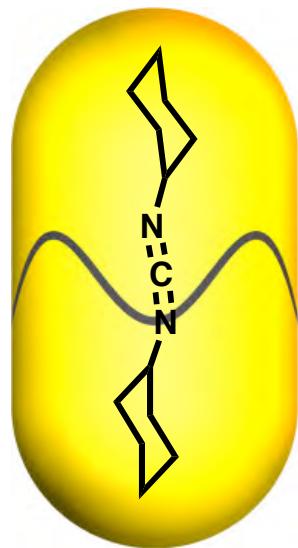
## Amplification mechanism



Dr. J. Chen, Dr. S. Lin  
Dr. S. Körner

Prof. S. Craig  
Prof. D. Rudkevich

## Simulation of the Chain Reaction



● 1 Product  
■ 2 Products  
▲ 3 Products

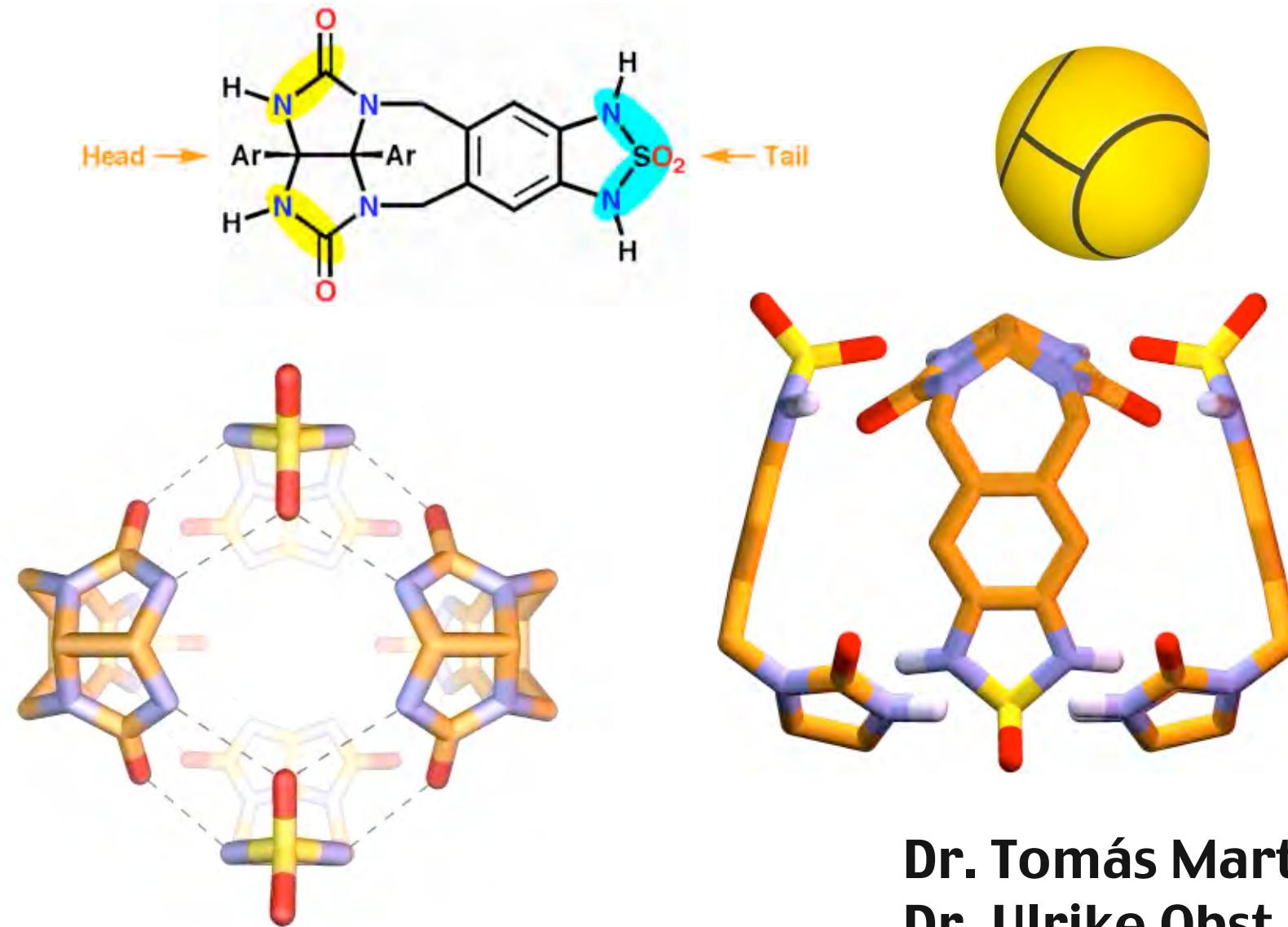
Can Displace DCC



Dr. S. Lin

*Super Capsules*

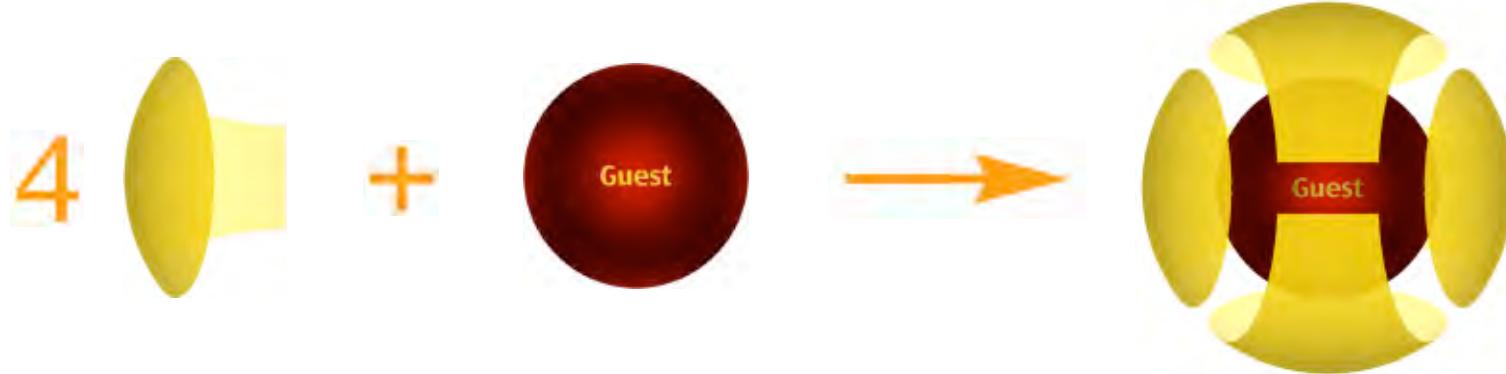
# Tetrameric Capsule $3 \times 10^{-25} \text{ L}$



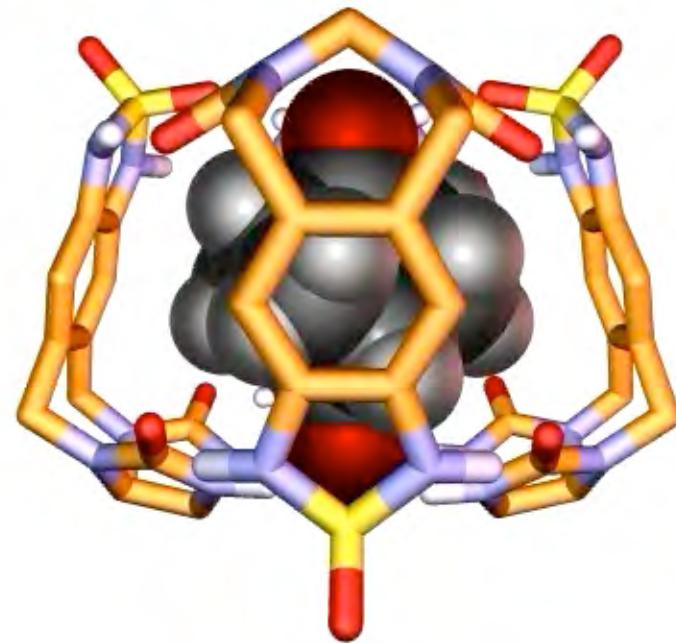
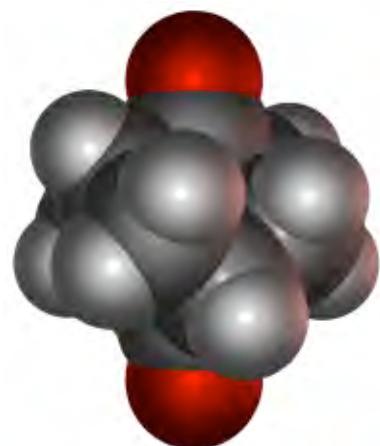
**Dr. Tomás Martín  
Dr. Ulrike Obst**

# Tetrameric Capsule

Assembles when the space is properly filled

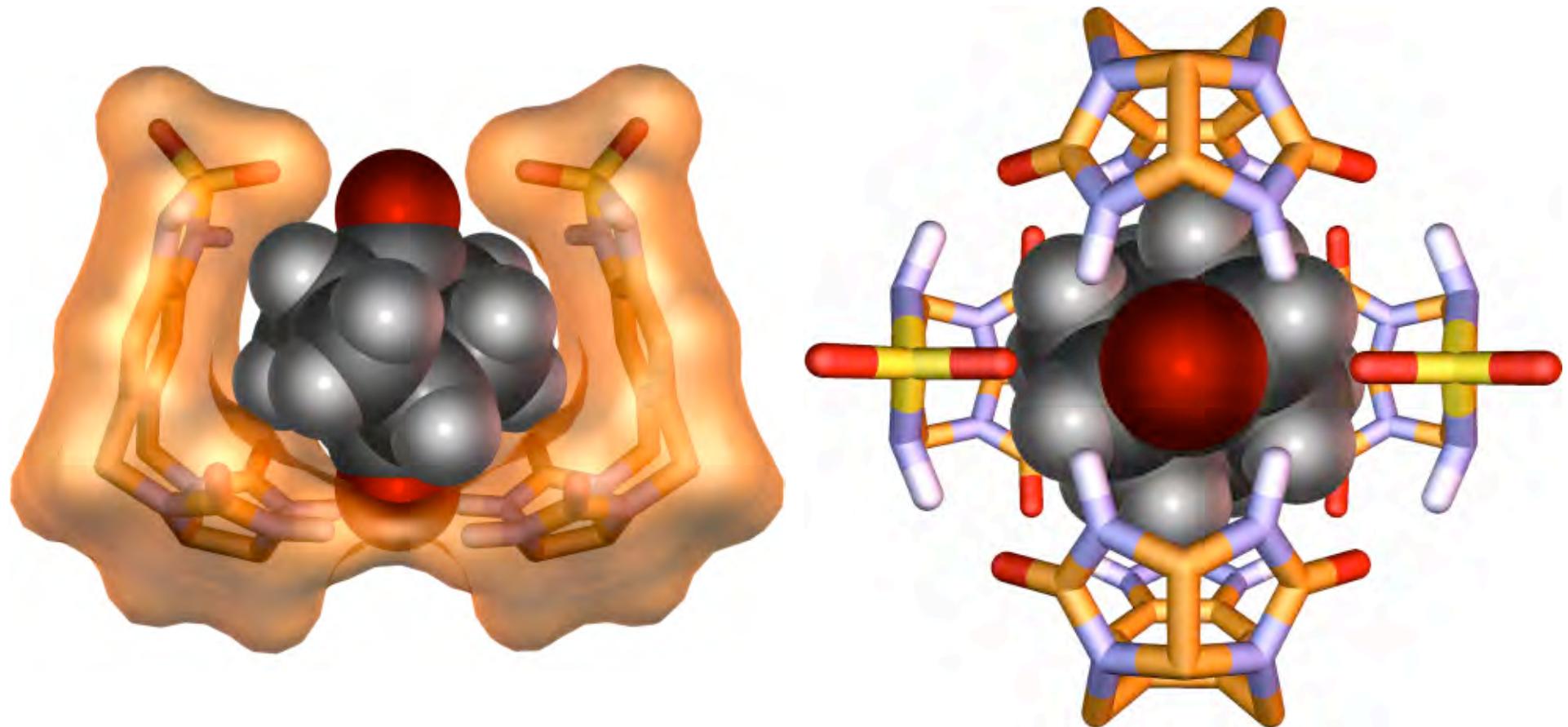


Adamantanedione



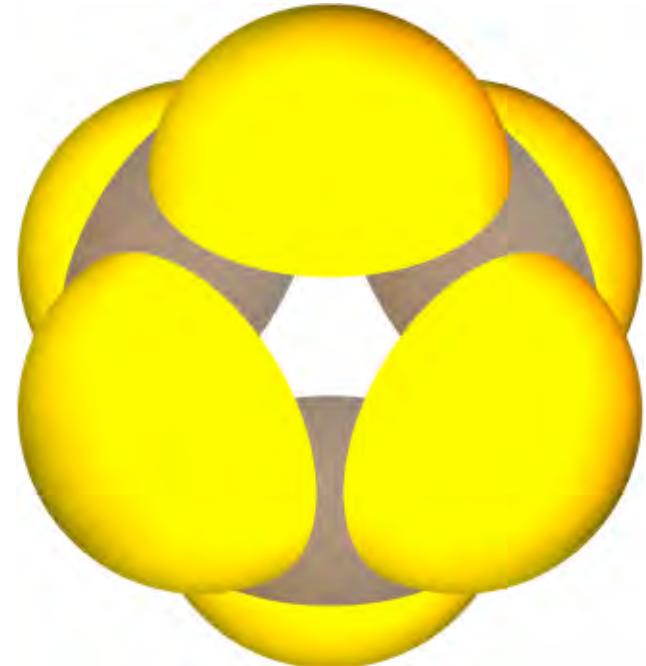
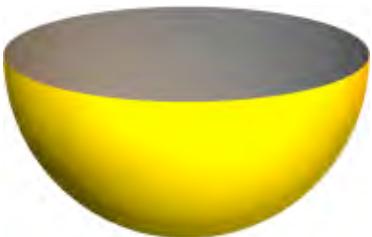
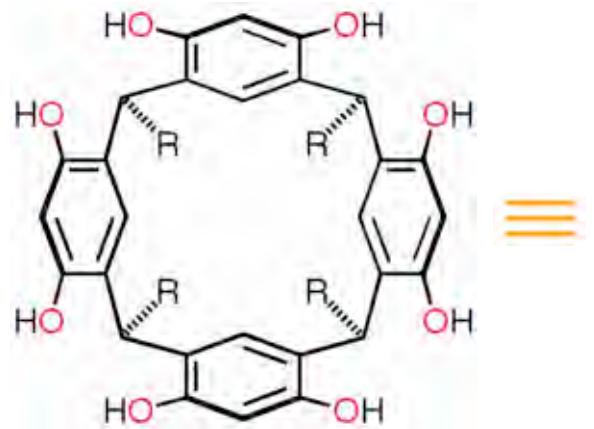
# Tetrameric Capsule X-Ray

Adamantanedione Guest

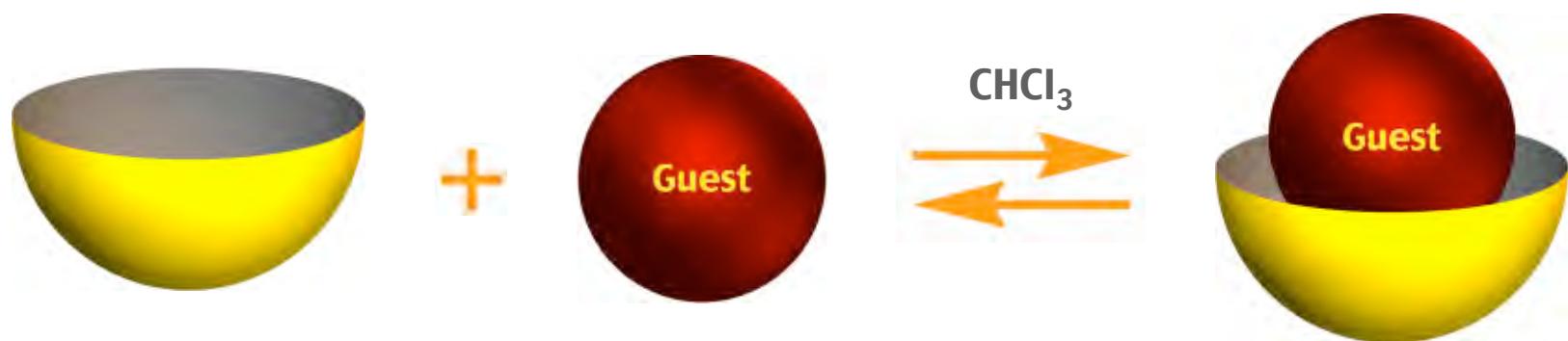


**Dr. Darren Johnson  
Fraser Hof**

## Resorcin[4]arene Octols $1.3 \times 10^{-24} \text{ L}$

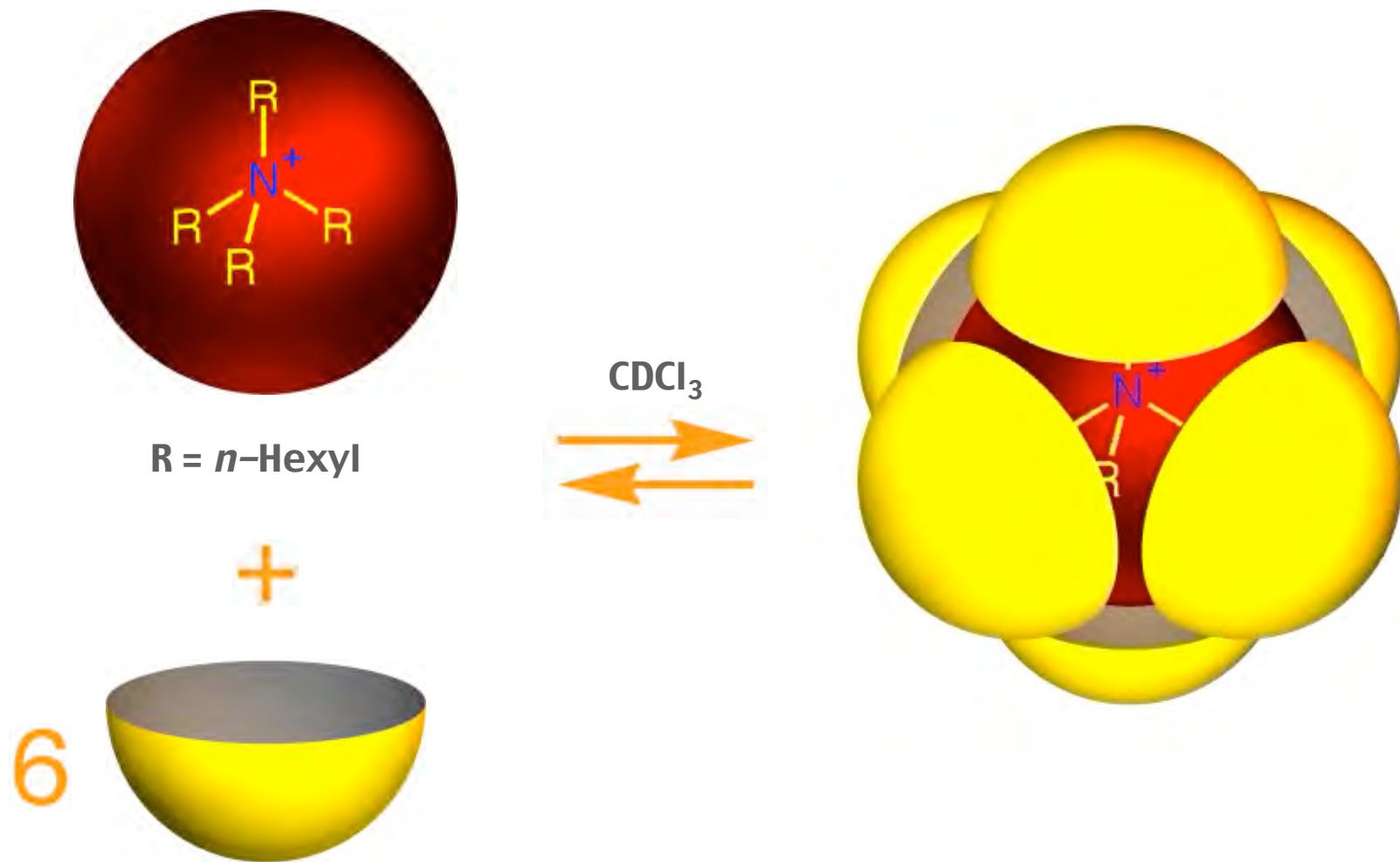


Atwood, MacGillivray 1997



Aoyama, et al 1988, 1989, 1993

## Hexameric Assembly



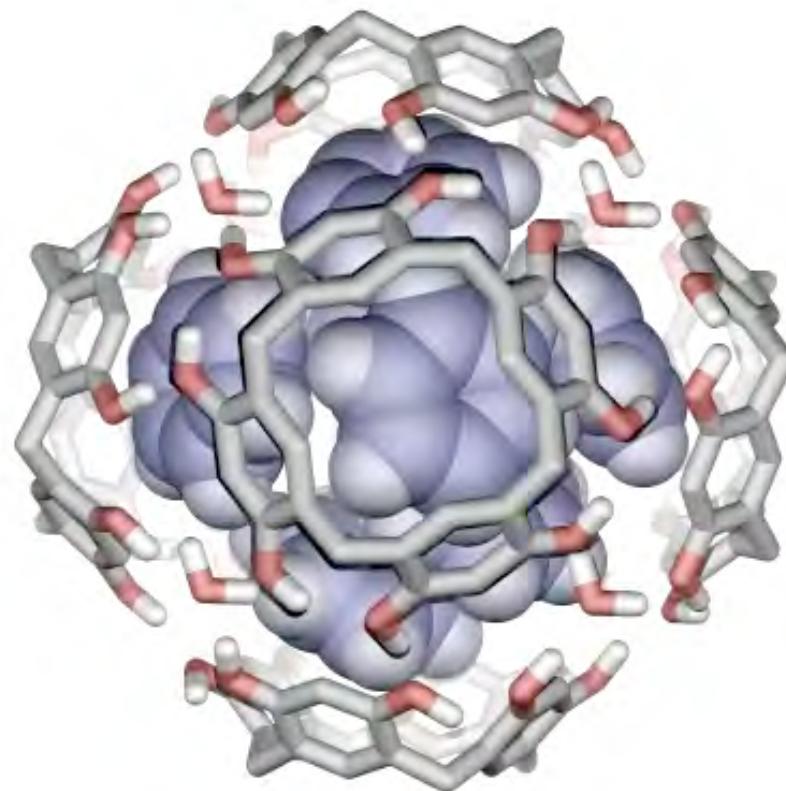
Dr. Alex Shivanyuk

# Resorcin[4]arene Octol Assembly

22 molecules vs. entropy

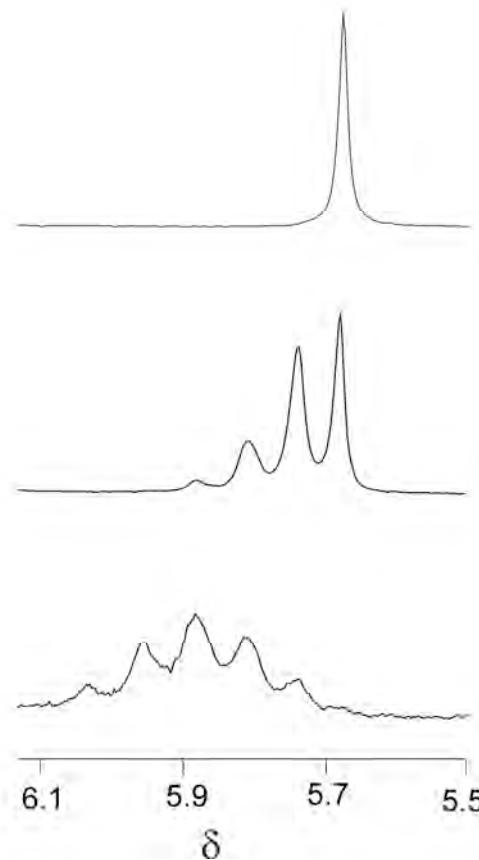
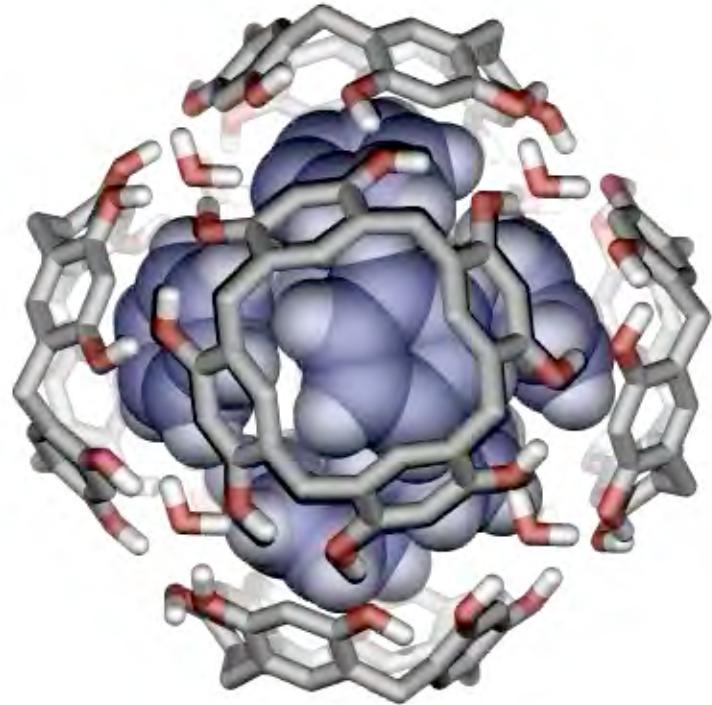


wet  
benzene →



Dr. Alex Shivanyuk  
Liam Palmer

# Hexameric Assembly



**Dr. Alex Shivanyuk**

## Reversible Encapsulation Phenomena

***Unanticipated :***

***Single Molecule Solvation***

***Isotope Effects***

***Binary Coding***

***Helical Alkanes***

***Chiral Spaces***

***Chemical Amplification***

***Super Capsules***

## More Encapsulation Phenomena

*Polymeric Capsules*

*Fluorocarbons*

*Regioselective Reactions*

*Hindered Inversions, Rotations*

*Anion Encapsulation*

**Support**

***Skaggs Institute***

***National Institute  
of General Medical  
Sciences***

**Videos**

*Dr. Lubomir Sebo*

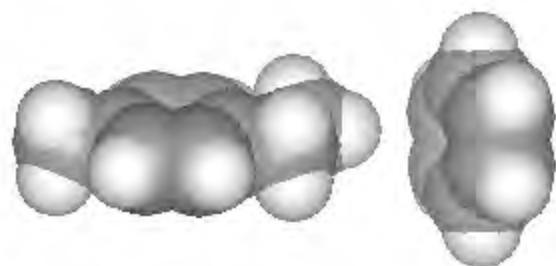
“ ... ‘guest’ and ‘host’ are words that intertwine... Converging, mixing, reciprocating. ... Guests bring ideas from outside”.

Don DeLillo

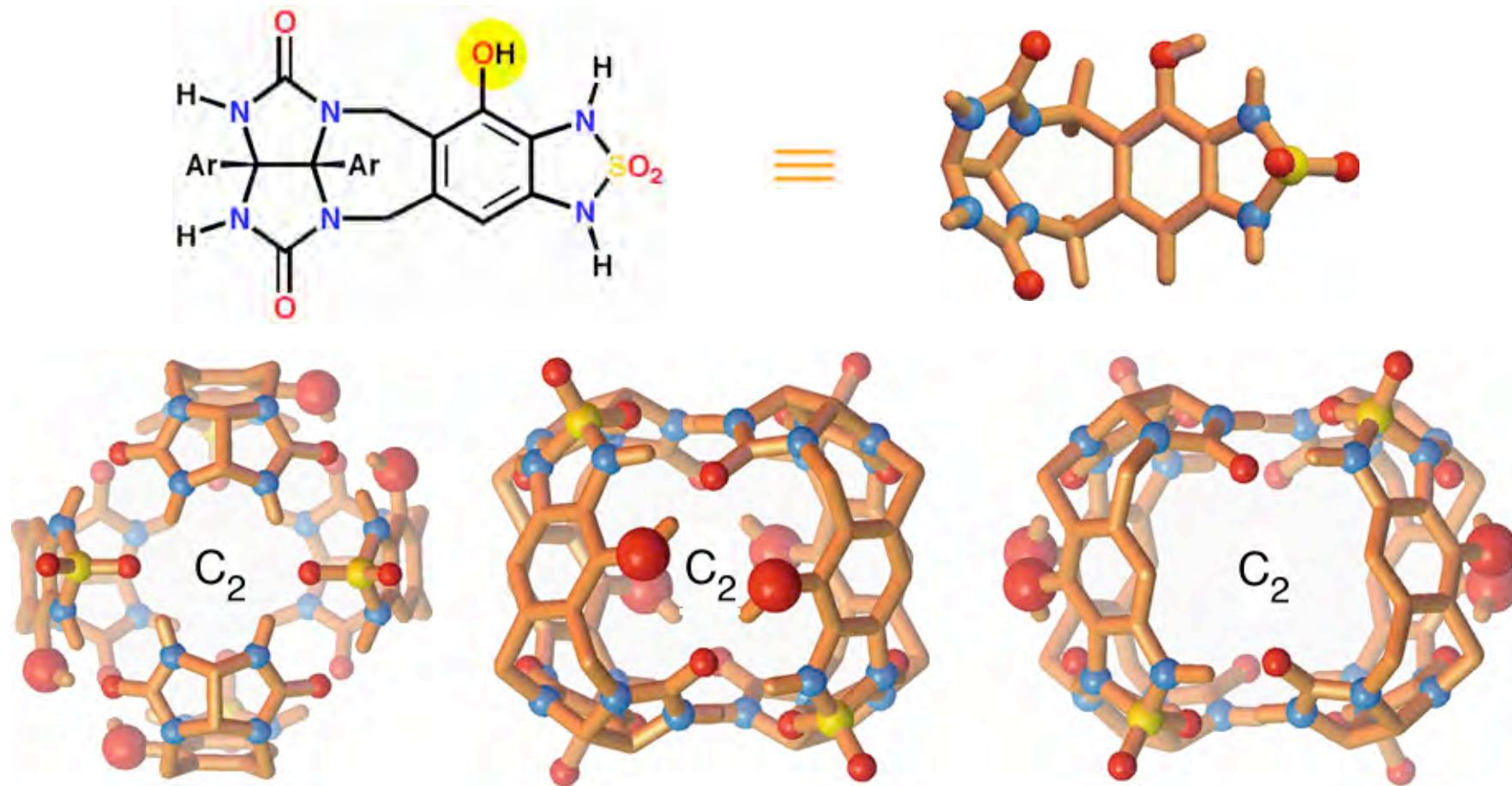
**Mao II**

Viking (Penguin) New York, 1991





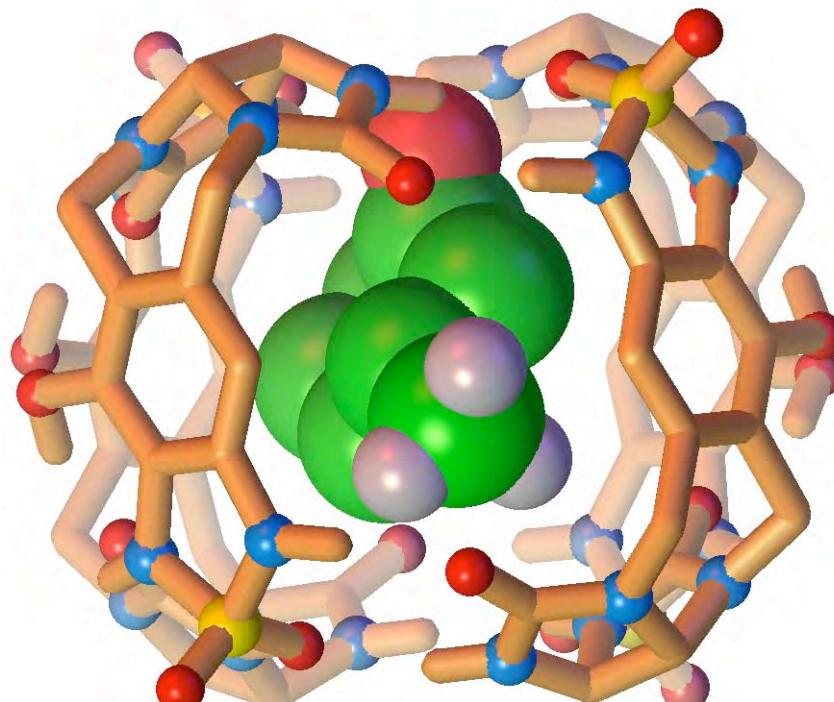
## Chiral Tetrameric Capsule



**Dr. Colin Nuckolls  
Fraser Hof  
Dr. Tomás Martín**

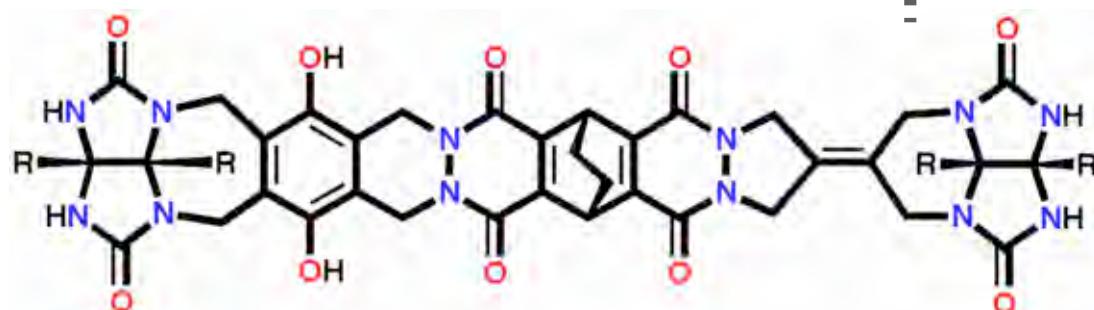
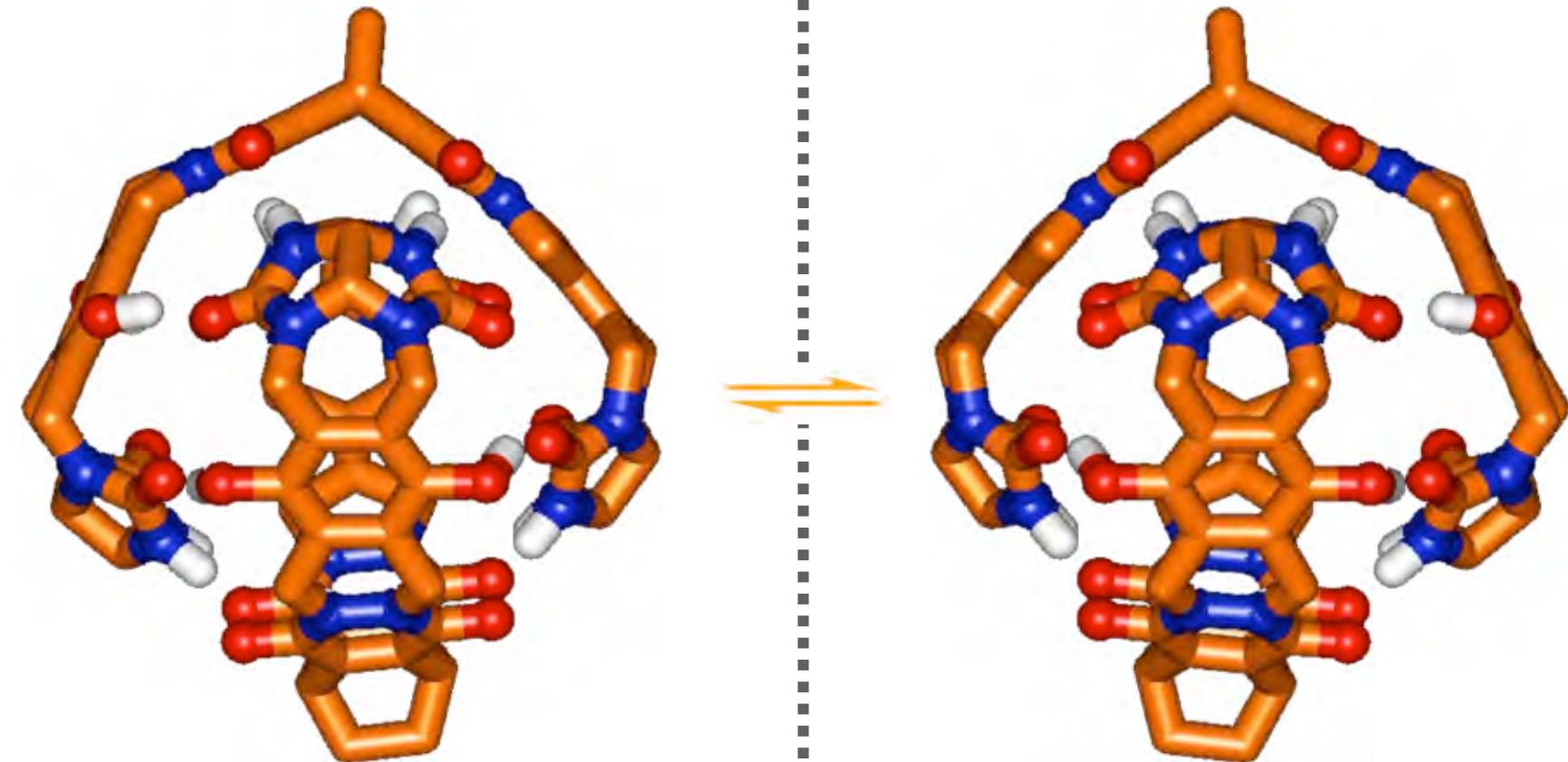
# Chiral Tetrameric Capsule

3-Methylcyclohexane Guest



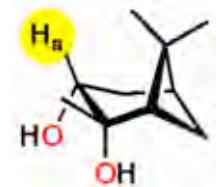
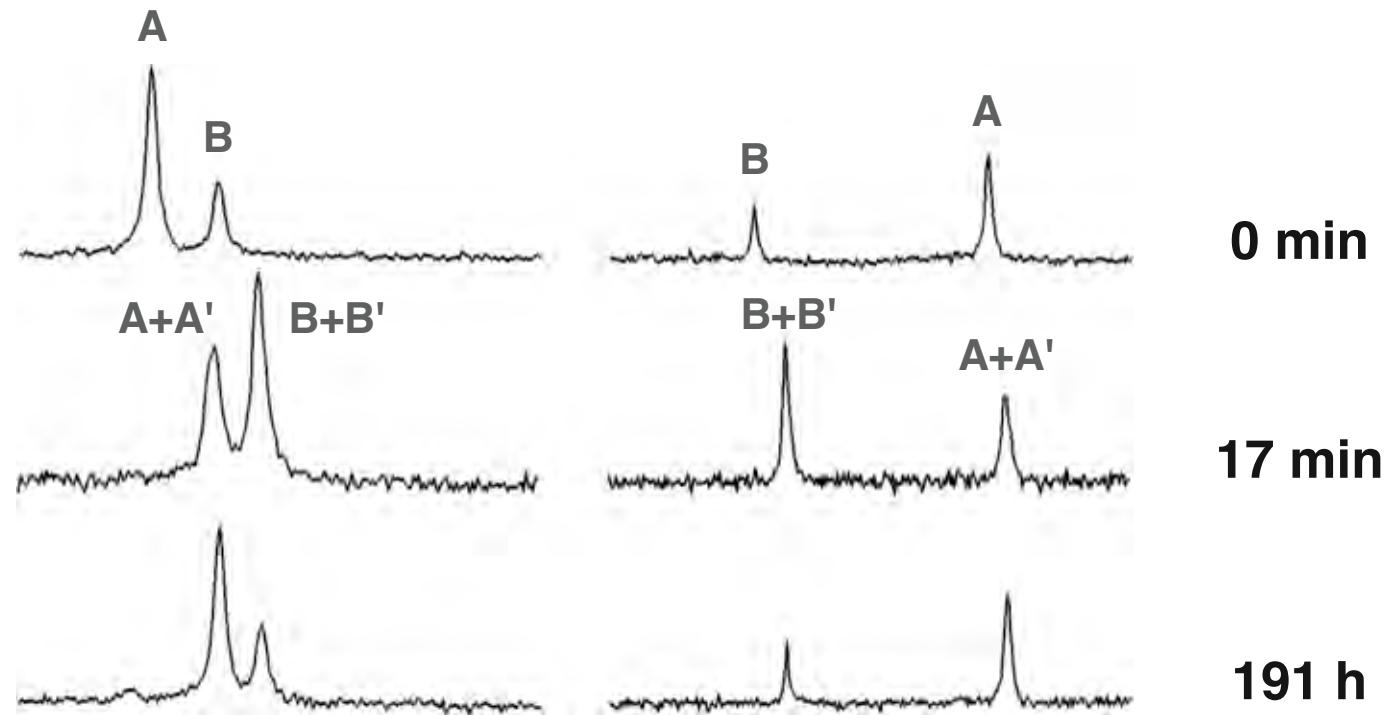
**Dr. Colin Nuckolls  
Fraser Hof  
Dr. Tomás Martín**

# Chiral Softball

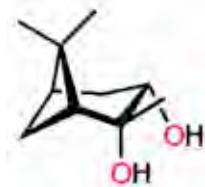


**José M. Rivera**  
**Dr. Stephen L. Craig**  
**Dr. Tomás Martín**

# Chiral Softball



(+)-pinanediol



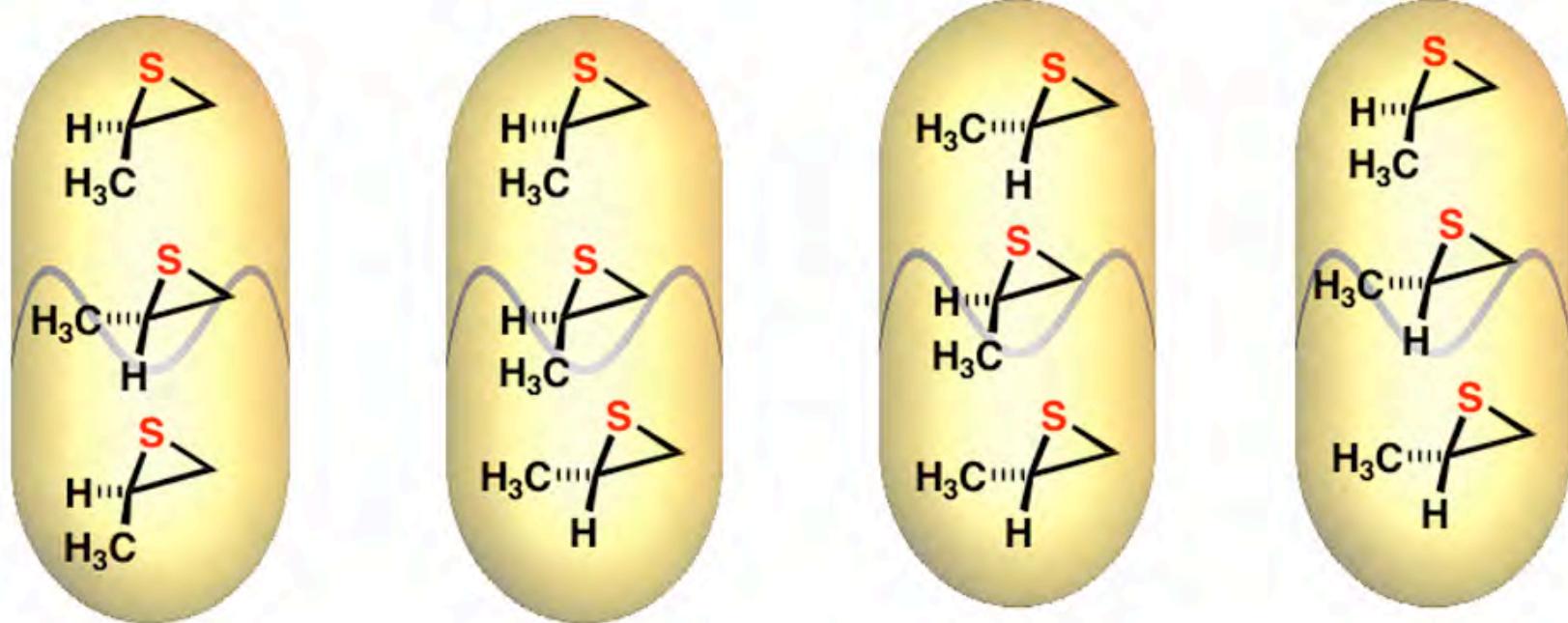
(-)-pinanediol



adamantanol

**José M. Rivera**  
**Dr. Stephen L. Craig**  
**Dr. Tomás Martín**

# Diastereomeric Constellations



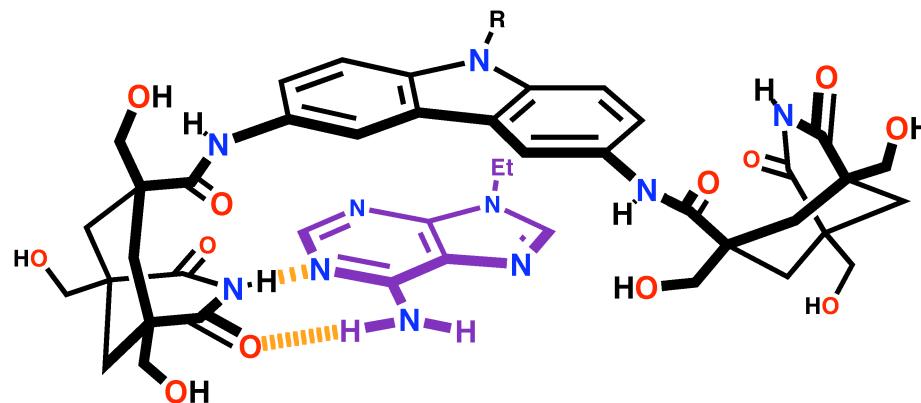
Prof. M. Yamanaka

# Functional Groups Converge to Form an Active Site



# Receptor for Adenine

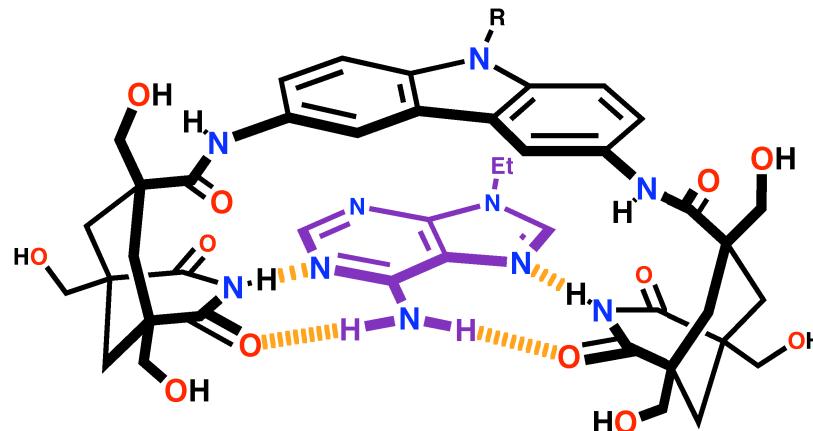
$$K_a = 36 \text{ M}^{-1}$$



$\text{H}_2\text{O}/\text{D}_2\text{O}, 10^\circ\text{C}$   
 $\square = 50 \text{ mM}$

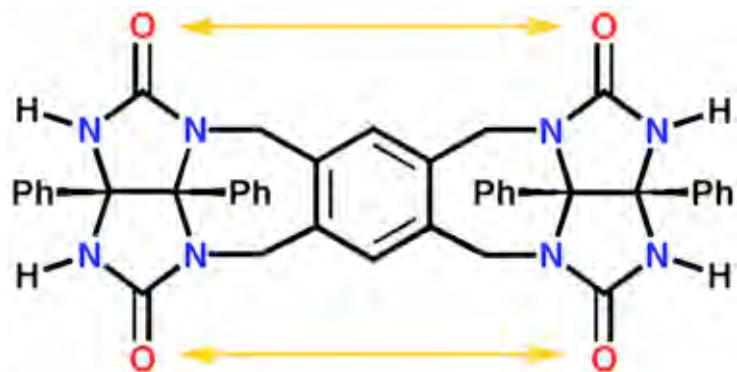
$$\Delta G = 0.3 \text{ kcal mol}^{-1}$$

$$K_a = 62 \text{ M}^{-1}$$

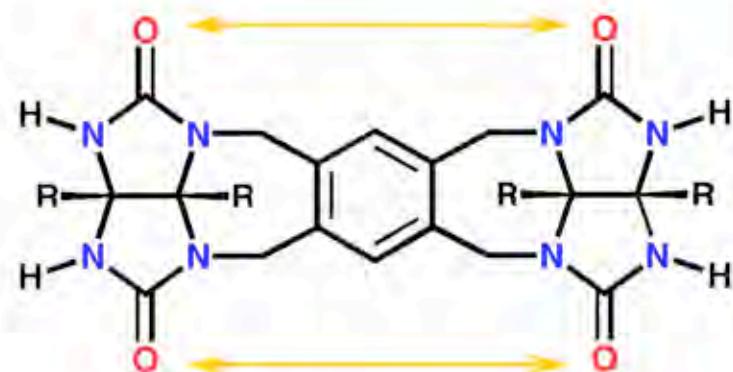


Y. Kato  
M. Conn,  
1990

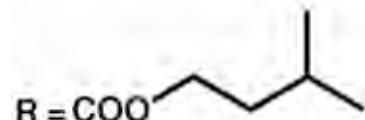
# Extending the Tennis Ball



R = COOEt



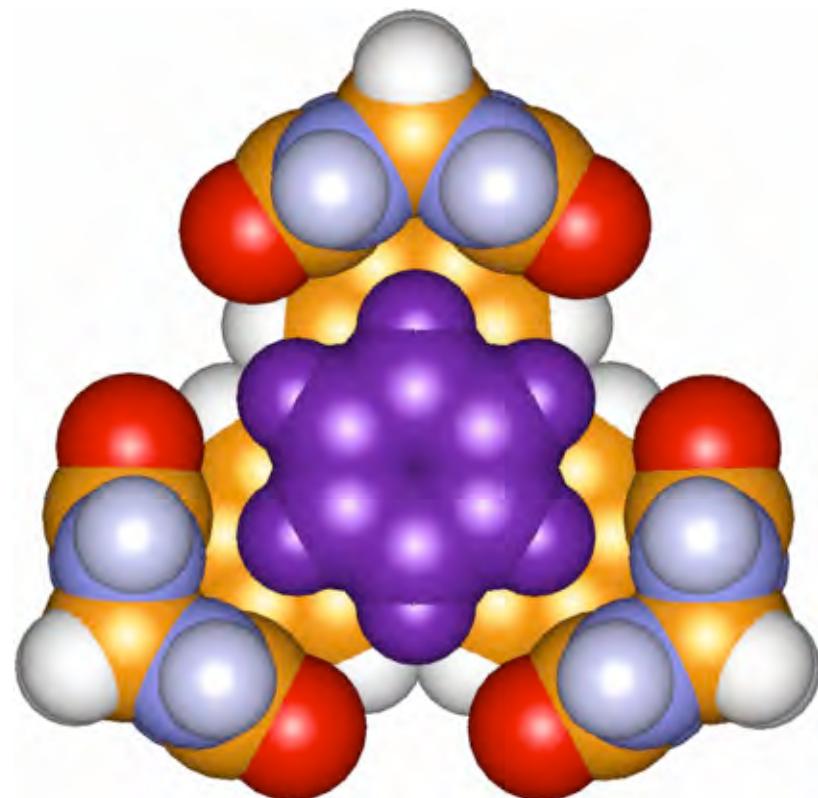
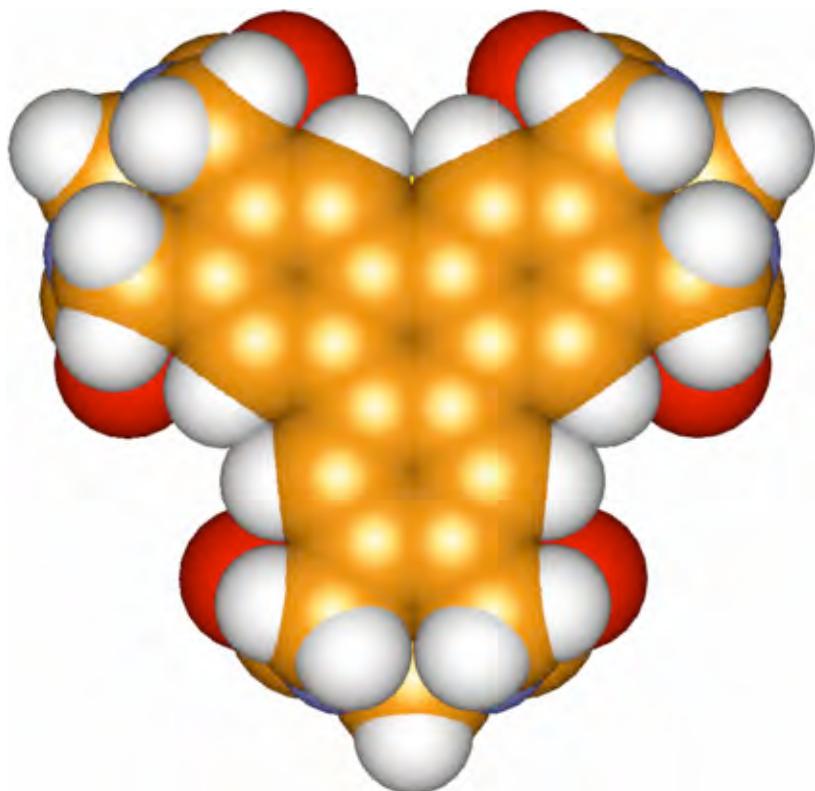
**Robert M. Grotzfeld**  
**Dr. Carlos Valdés**  
**Niel R. Branda**  
**Brendan O'leary**



# *Hindered Inversion and Rotation*

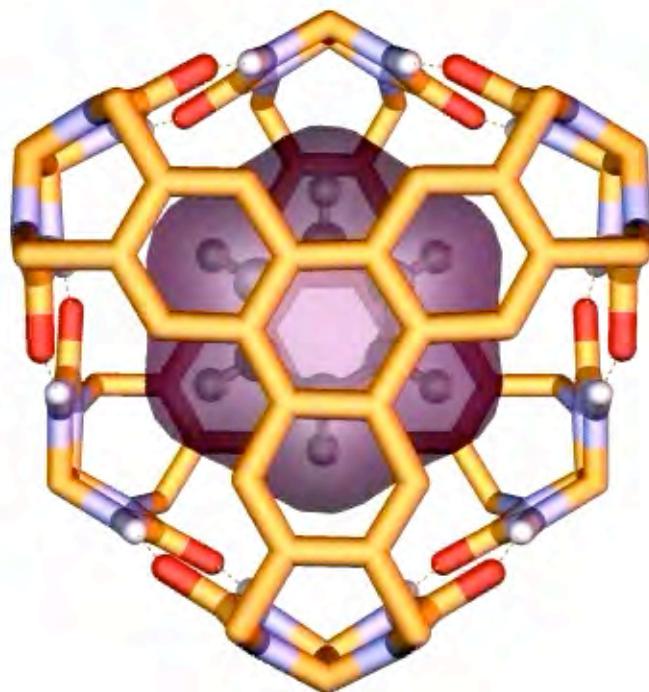
# Jelly Doughnut or Hamburger

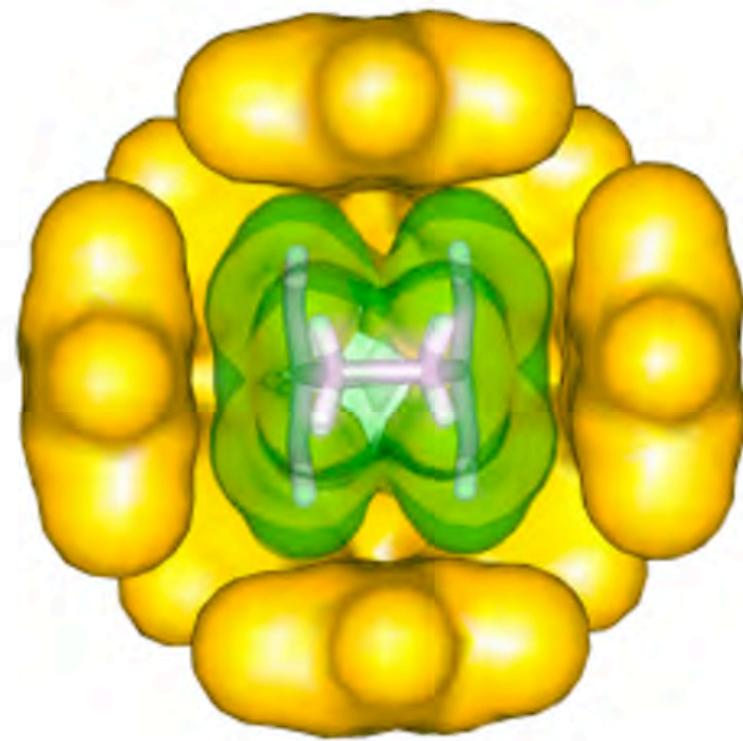
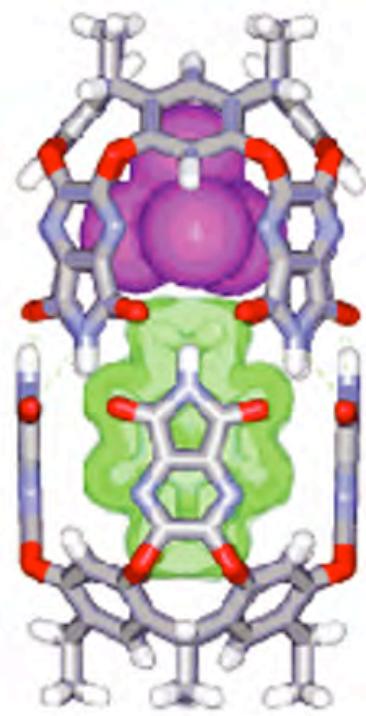
Encapsulated Benzene



# Jelly Doughnut or Hamburger

Encapsulated Cyclohexane

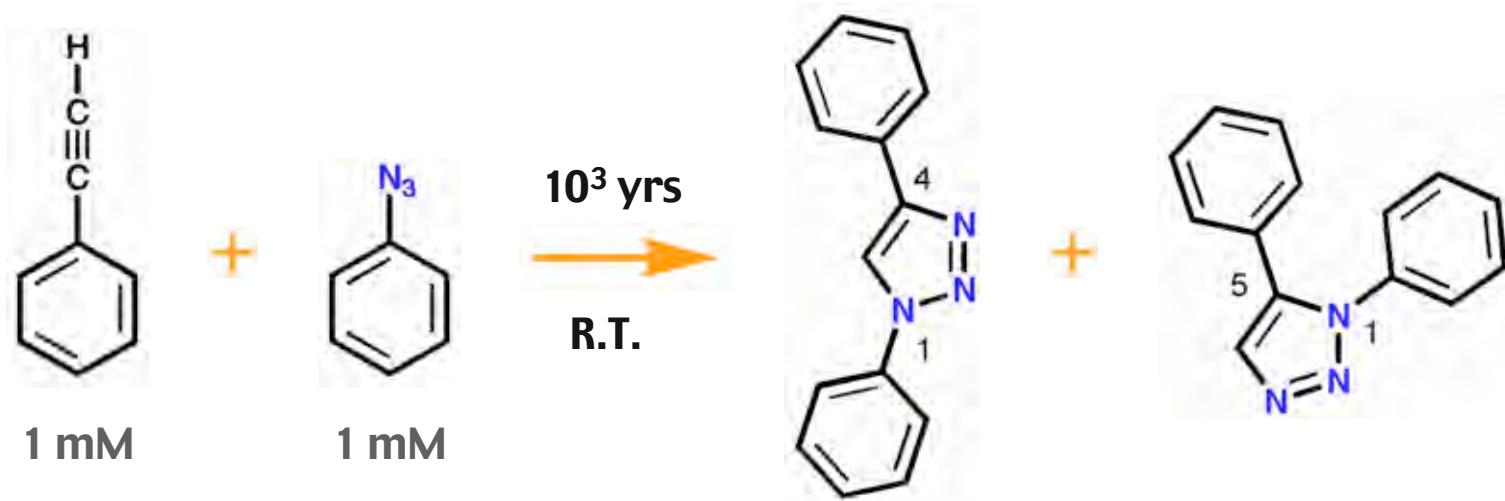




**Dr. A. Scarso  
Dr. H. Onagi**

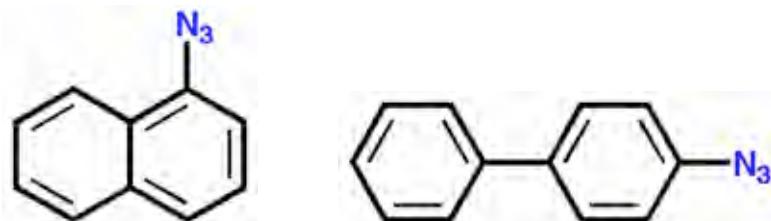
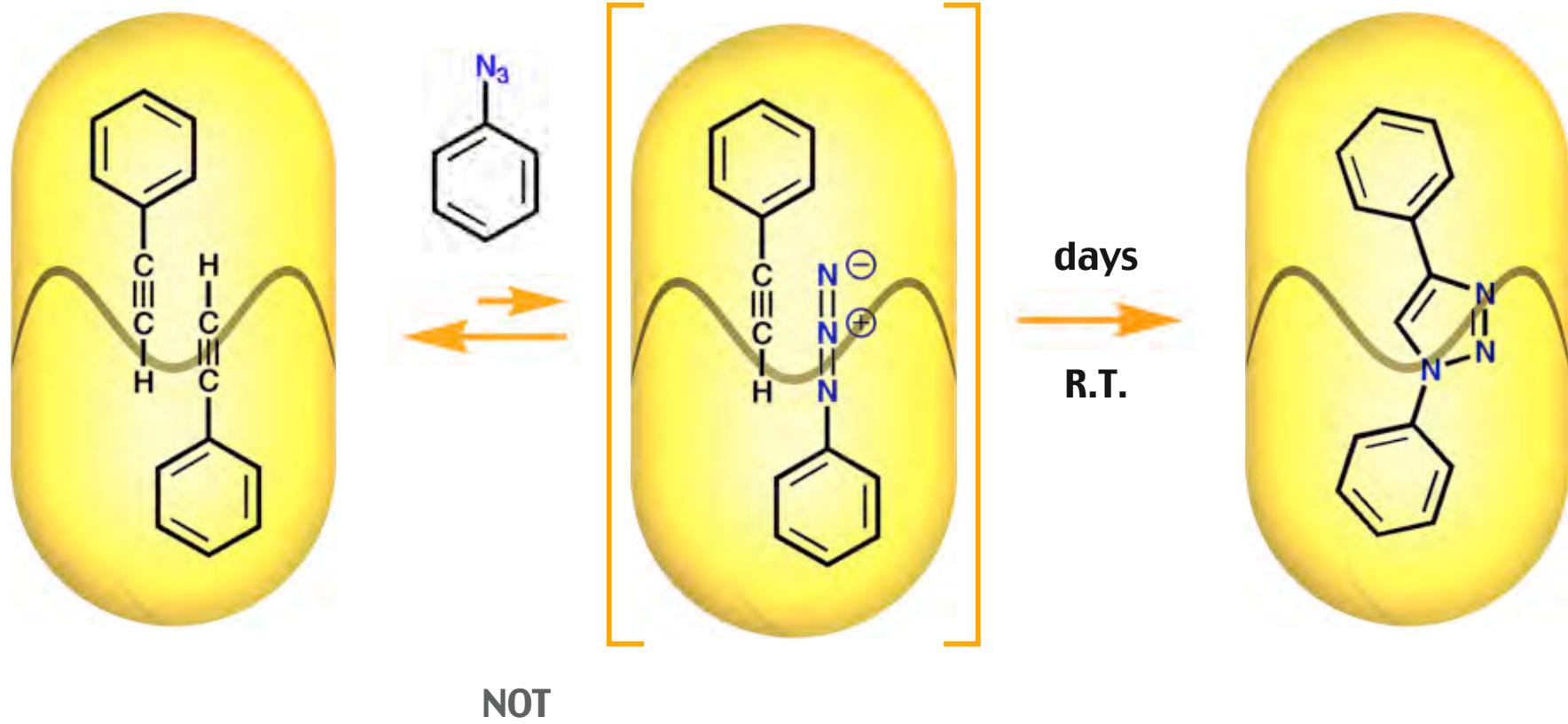
*Regioselectivity*

# Cylindrical Capsule



**Dr. Jian Chen**  
**Dr. Stephen Craig**

# Cylindrical Capsule



**Dr. Jian Chen  
Dr. Stephen Craig**

# *Anion Encapsulation*

# Anion Encapsulation



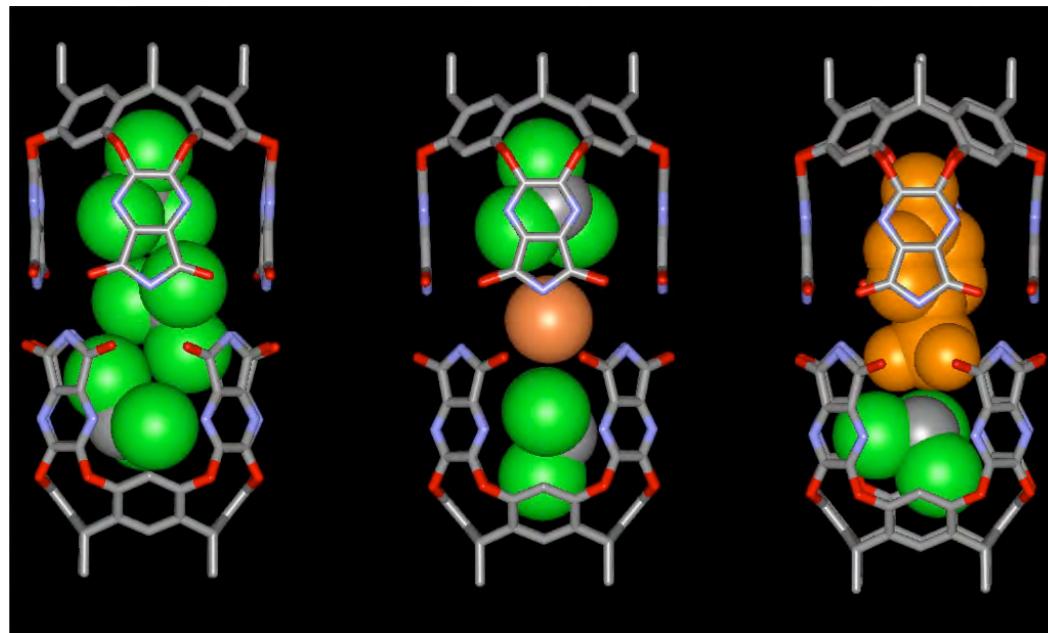
$X^- = \text{Cl}^-$   
 $\text{Br}^-$   
 $\text{BF}_4^-$   
 $\text{PF}_6^-$   
 $\text{IO}_4^-$



Prof. Osamu Hayashida  
Dr. Alex Shivanyuk

# Cylindrical Capsule

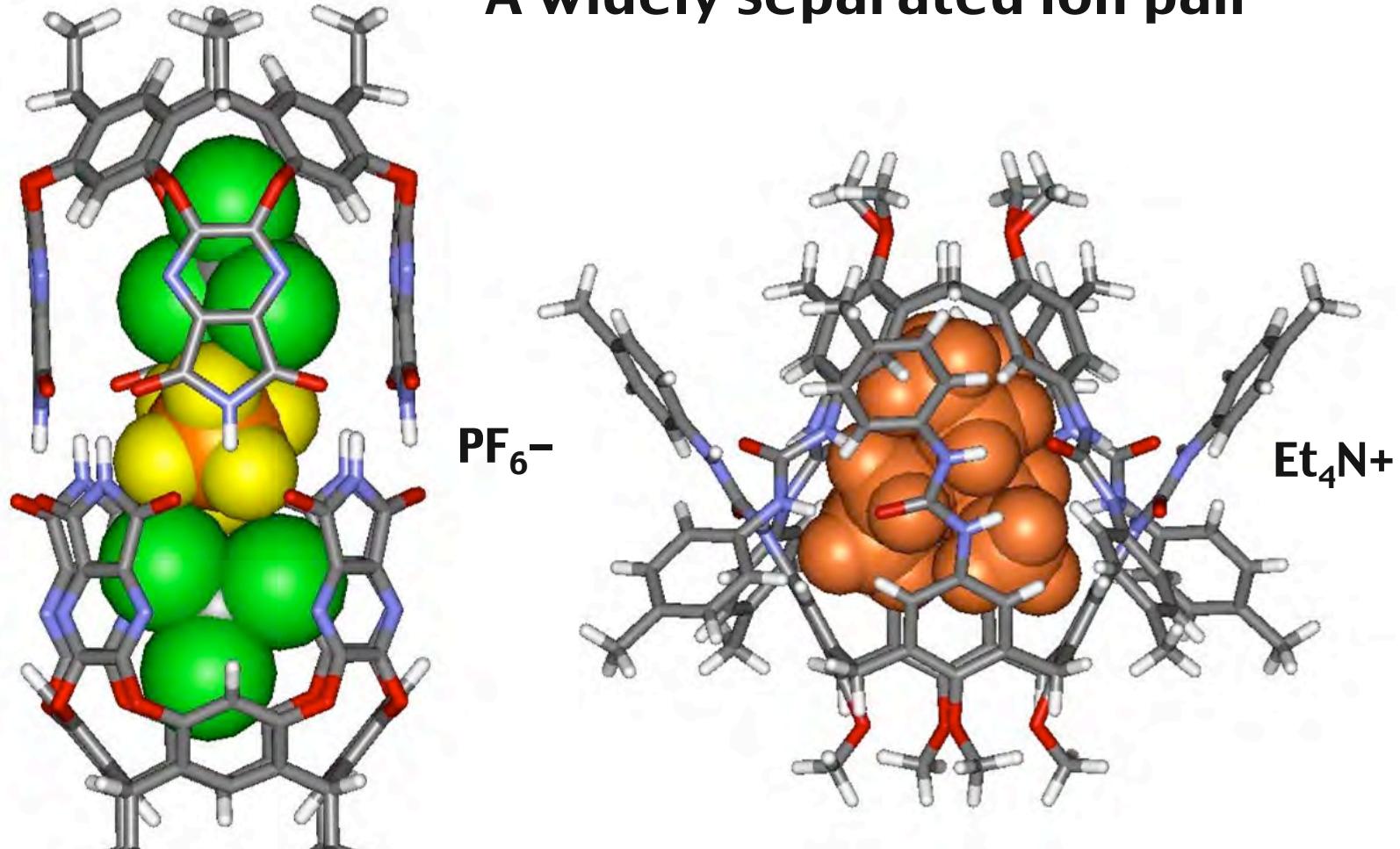
Guests



**Dr. Alex Shivanyuk**

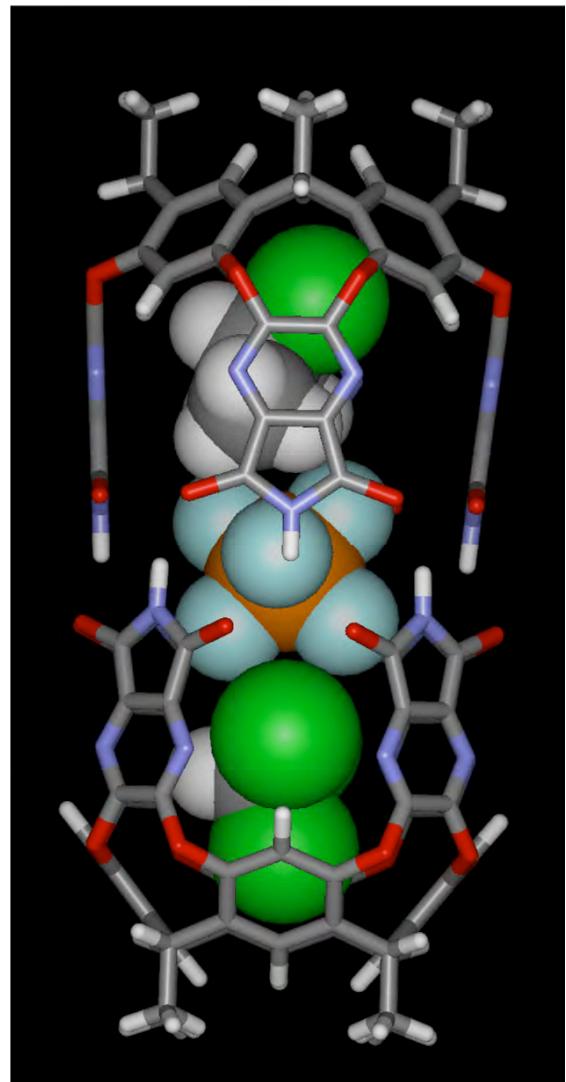
**Prof. O. Hayashida**

## A widely separated ion pair



**Prof. Osamu Hayashida  
Dr. Alex Shivanyuk**

## Anion and two different solvents



**Prof. Osamu Hayashida  
Dr. Alex Shivanyuk**

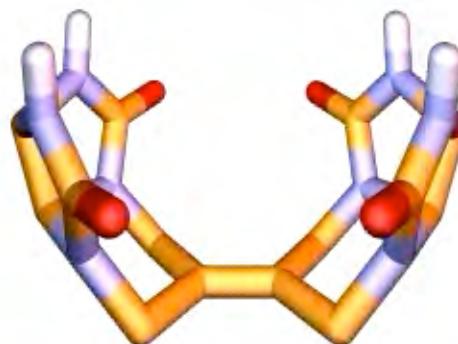
*Filling Space*

# Hacky-Sack

The Smallest Dimeric Capsule



METHANE (PC~0.50) is bound,  
but ETHANE (PC=>.85) is not

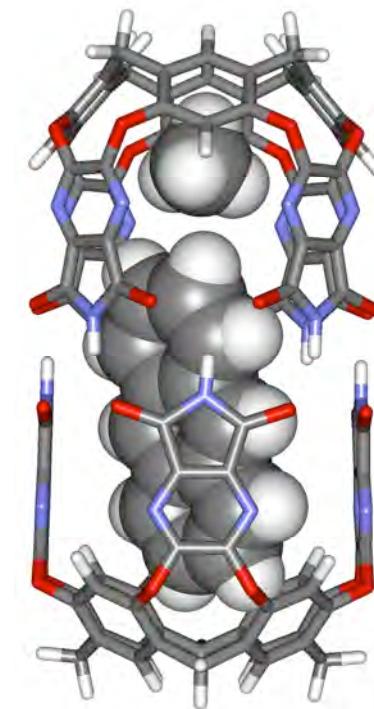
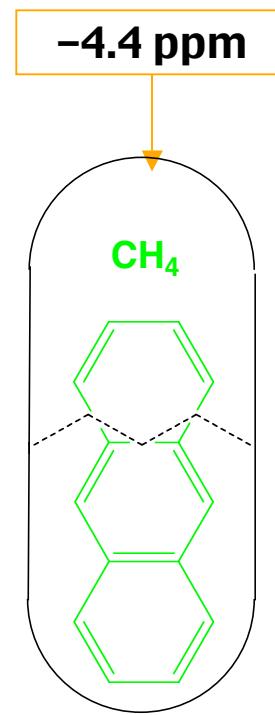
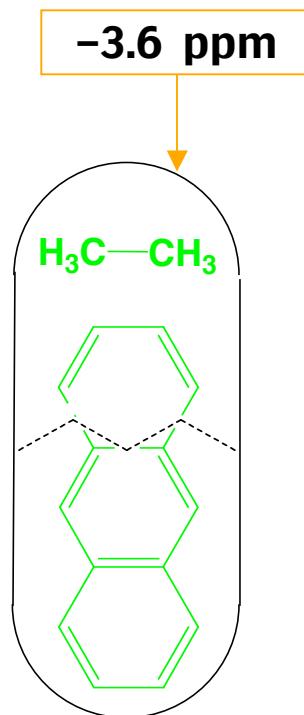


Dr. Leticia Toledo

Dr. Carlos Valdes

# Cylindrical Capsule

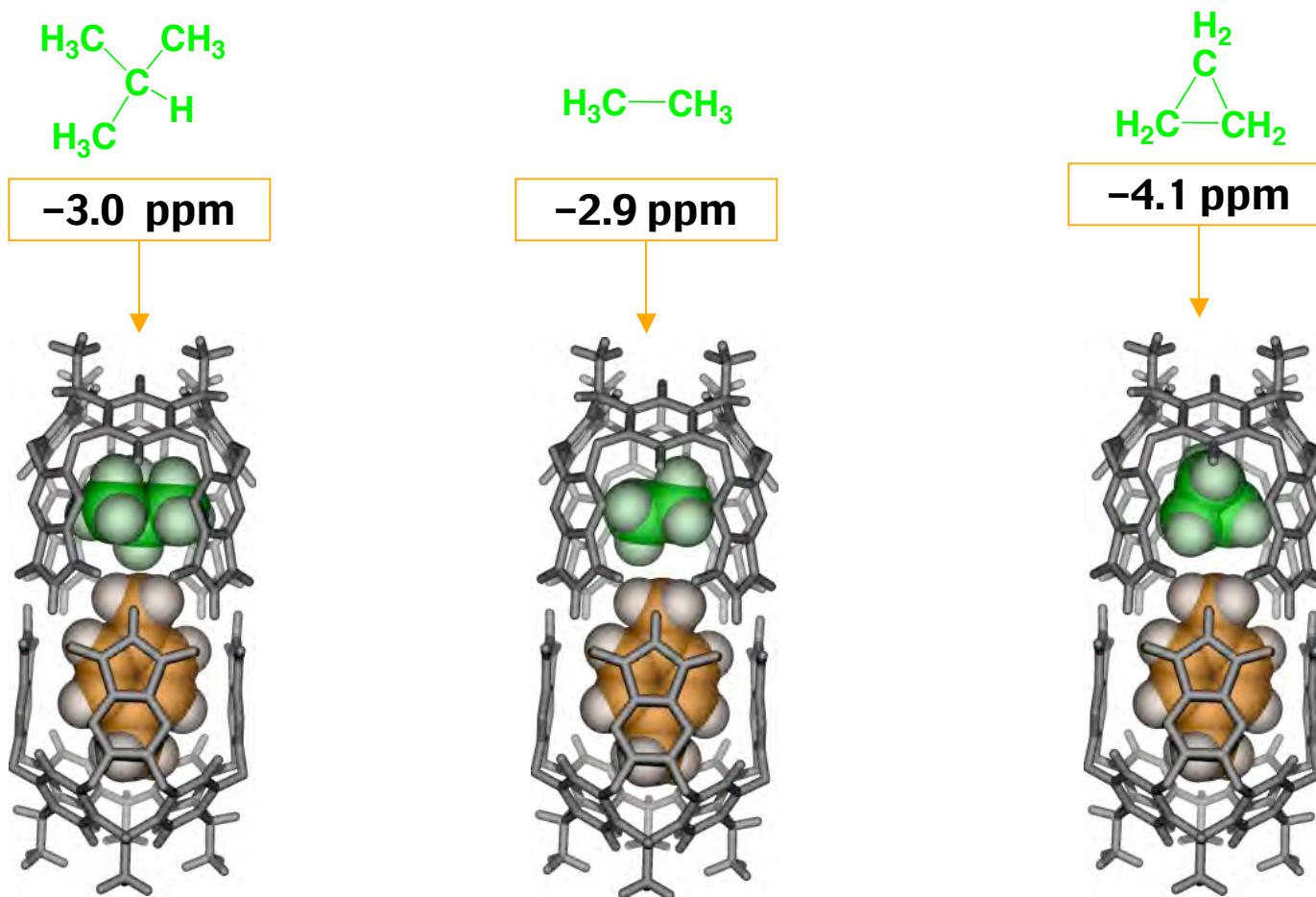
## NMR Shifts of Coencapsulated Gases



**Dr. Alex Shivanyuk**  
**Dr. Alessandro Scarso**

# Cylindrical Capsule

## NMR Shifts of Coencapsulated Gases



**Dr. Alex Shivanyuk**  
**Dr. Alessandro Scarso**

# Liquids

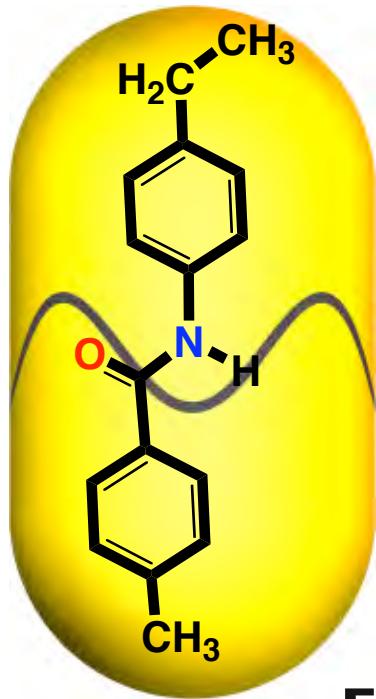
## Packing Coefficient

benzene	0.54
toluene	0.54
<i>n</i> -hexane	0.51
methylene chloride	0.54
chloroform	0.53
diethyl ether	0.51
acetone	0.52
acetonitrile	0.53
methanol	0.54
ethanol	0.55
water	0.63

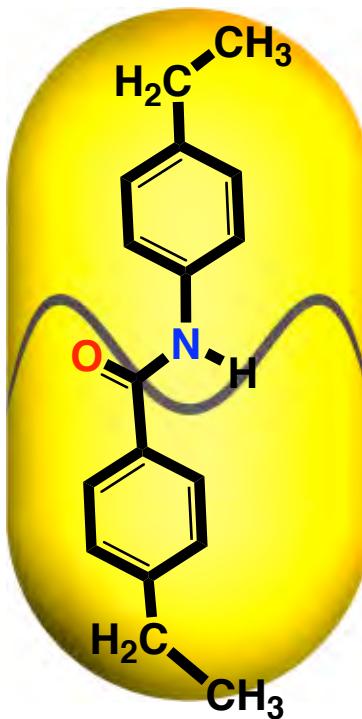
**In a liquid, only slightly more than half of the available space is physically filled by molecules.**

**Dr. Sandro Mecozzi**

## Length Selection



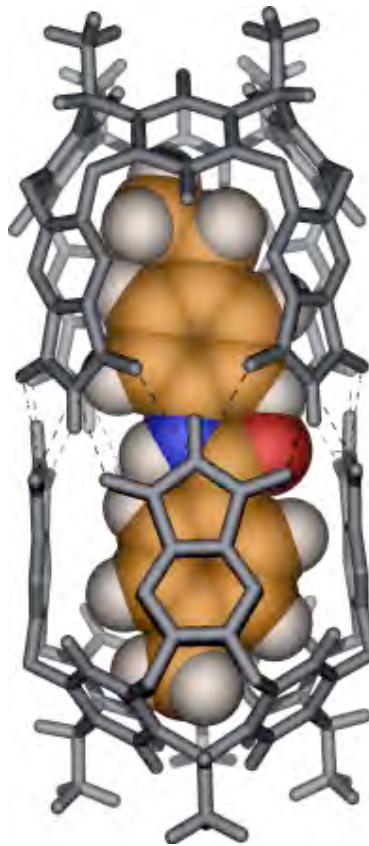
Fits



Doesn't fit

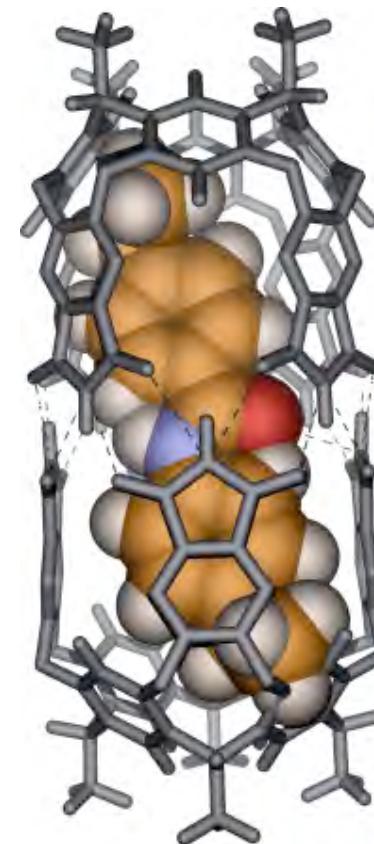
Dr. Steffi Körner  
Dr. Fabio Tucci  
Dr. Thomas Heinz  
Prof. Dmitry Rudkevich

# Length Selection



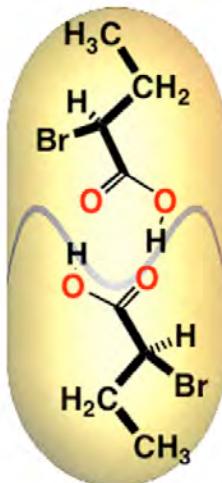
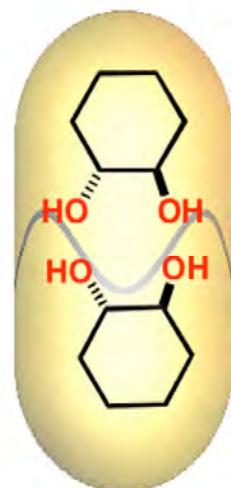
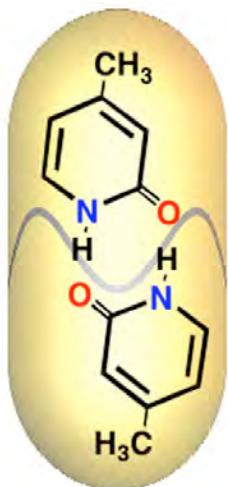
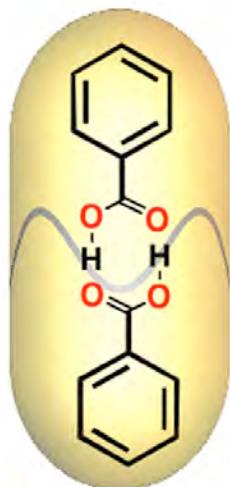
**Fits**

**Dr. Steffi Körner**  
**Dr. Fabio Tucci**  
**Dr. Thomas Heinz**  
**Prof. Dmitry Rudkevich**



**Doesn't fit**

# Complexes Within Complexes



**Prof D. Rudkevich  
Dr. T. Heinz  
Dr. A. Shivanyuk  
Dr. A. Scarso  
Liam Palmer**

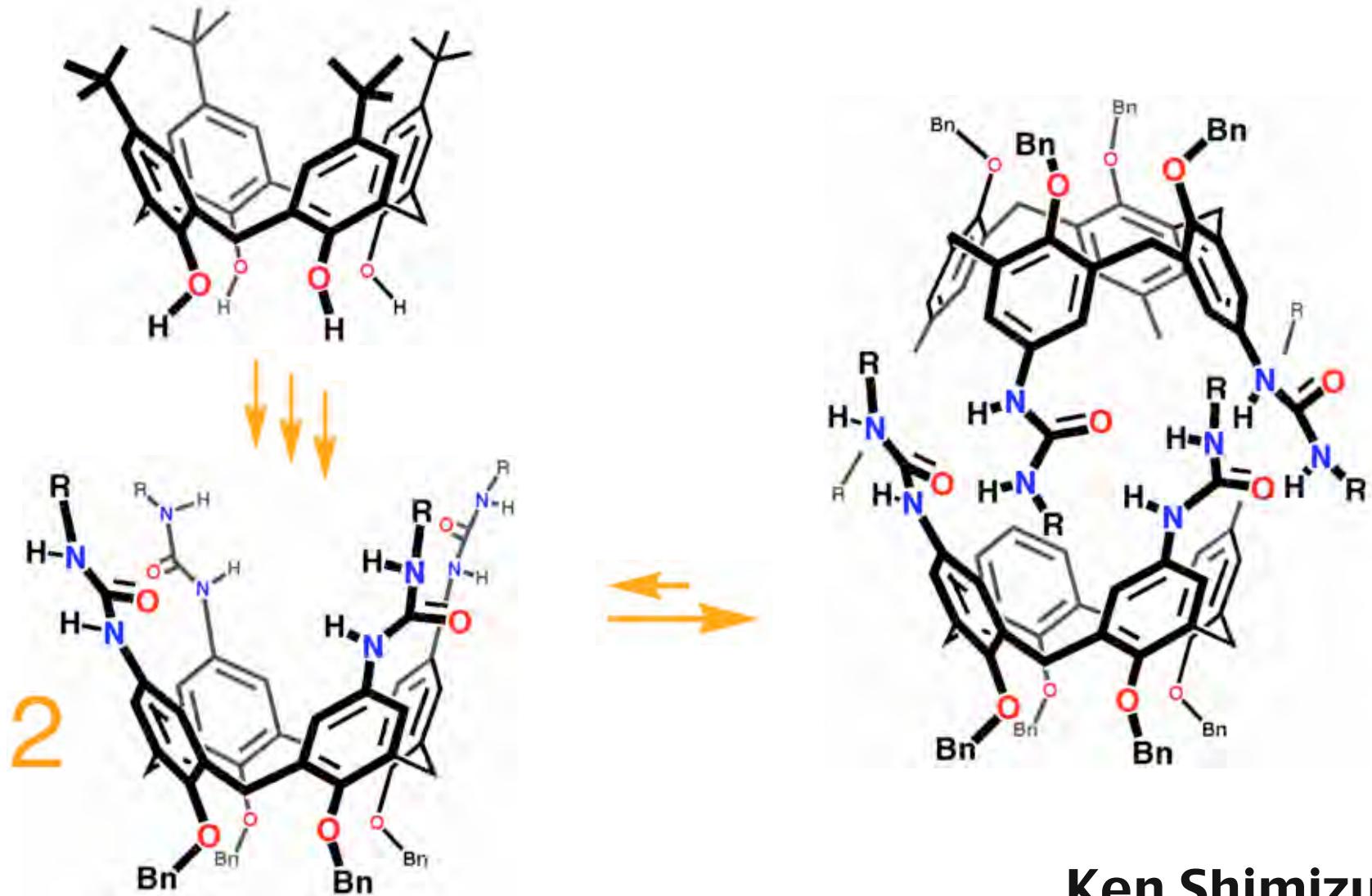
# Choleic Acids

six molecules, and the C<sub>15</sub>–C<sub>29</sub> acids combine with eight molecules of desoxycholic acid.

Rheinboldt regarded the choleic acids as coordination complexes and the numbers just cited as coordination numbers. If such were the case, choleic acids of different coordination numbers should differ in crystalline structure, but Kratky and Giacomello<sup>9</sup> found on X-ray analysis that the choleic acids of the C<sub>4</sub>–C<sub>26</sub> normal fatty acids all show identical interference and intensity patterns and therefore have identical unit cells. The X-ray work, as further interpreted by Cramer,<sup>10</sup> indicates that a choleic acid is an inclusion compound in which molecules of desoxycholic acid fit in the crystal in such a way as to leave a hole, or cylindrical canal, in which the fatty acid or other acholic (non-bile acid) component fits. The second component (guest) is not covalently bonded to the enclosing molecules (host) but, if it is of appropriate size, it is completely fenced in and cannot escape. Thus the Fourier analysis for choleic acids of C<sub>4</sub>–C<sub>26</sub> fatty acids suggests the pattern shown in Fig. 1. The view is along the axis of the chain of the fatty acid (2), which fits into a hole formed by two molecules of bile acid (1, 3). The curvature of pattern (1) or (3) reflects the A/B-*cis* configuration of the molecule (see Chapter 1.3, formula 16). Fig. 2 gives a diagrammatic side view of three choleic acids. The identity period is 7.22 Å, and, if the fatty acid cannot fit into a cylindrical canal section of this length, another section containing another pair of inclosing molecules is utilized. Thus the C<sub>7</sub>-acid (a) is too long for one canal section but is well accommodated by two sections and hence combines with four molecules of desoxycholic acid. The same inclosing system also holds the C<sub>8</sub>-acid (b), but another section of canal is required for the C<sub>9</sub>-acid (c) and the number of bile acid molecules jumps to six.

# *Polymeric Capsules*

# Calixarene Capsule



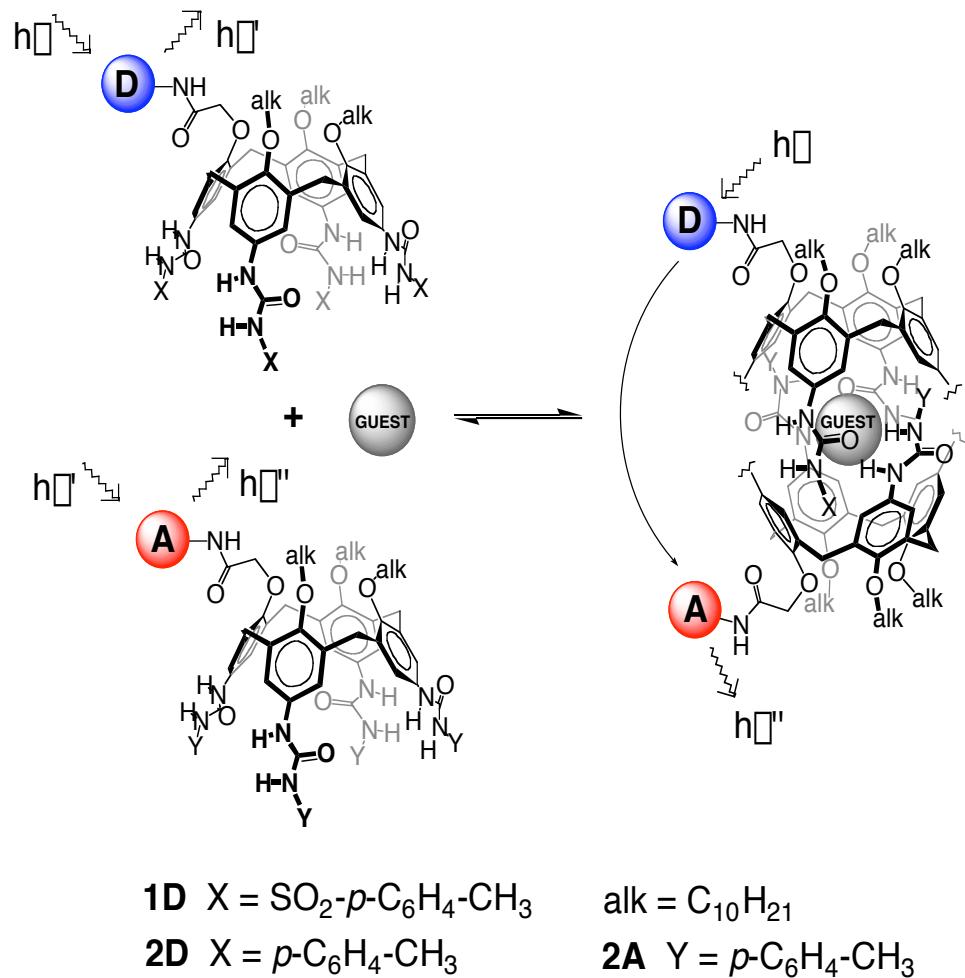
Ken Shimizu

# Fluorescence Resonance Energy Transfer (FRET)

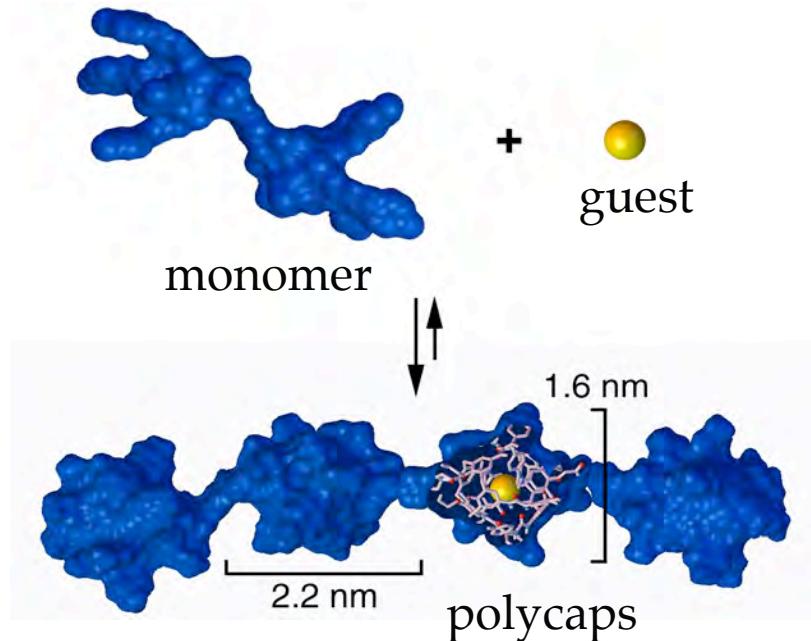
FRET offers:

- Color change signals assembly
- Sensitive at low concentrations (nM); observe free monomer
- Excellent time resolution
- Study *behavior* at dilute concentrations where the assembly process is “slow”

Sulfonyl ureas (**1D**) and aryl ureas (**2A**) form *exclusive* heterodimeric pairs in solution.

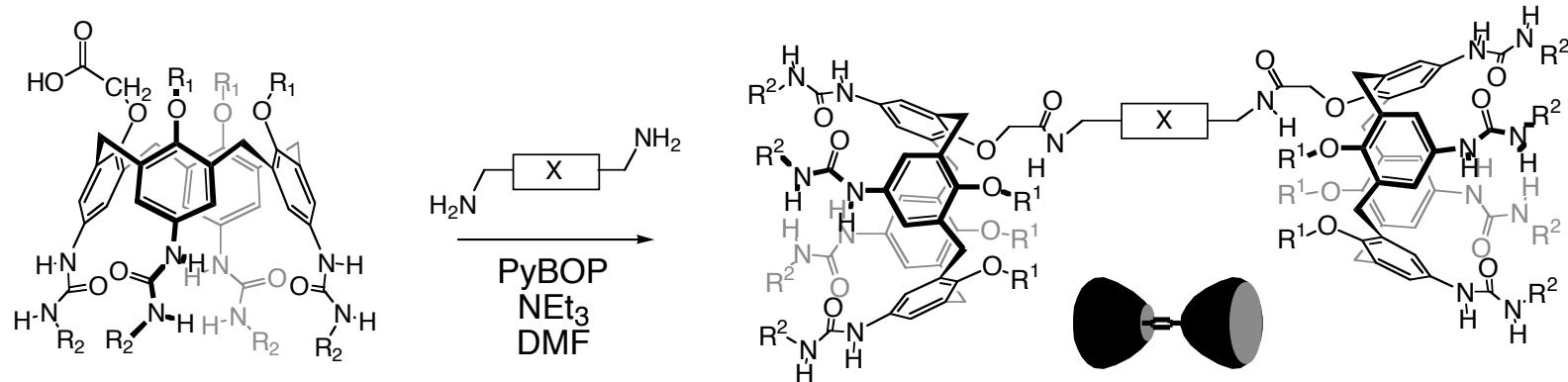


# *Polycaps: Polymeric Capsules*



Why polymers?

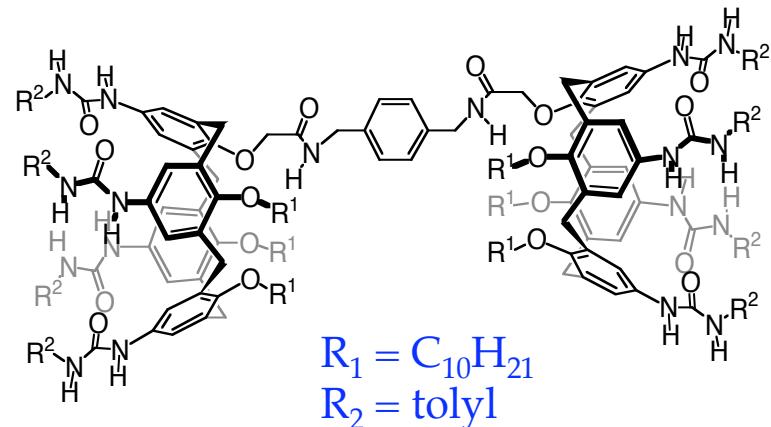
- Control of chemical and stereochemical preferences
- Strong association ( $K_A$   $10^6$ – $10^8$  M $^{-1}$ )
- Rapid dissociation/equilibrium
- Functional: Responsive to external signals (guest, solvent, temperature)
- Modular construction leads to structural variety



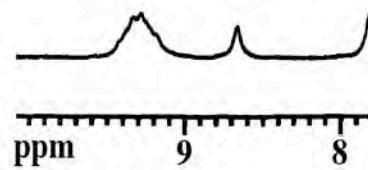
# *<sup>1</sup>H NMR: Still a Valuable Tool*

## Measurements include:

- Dilution/VT studies
- Chain termination experiments
- Guest encapsulation studies

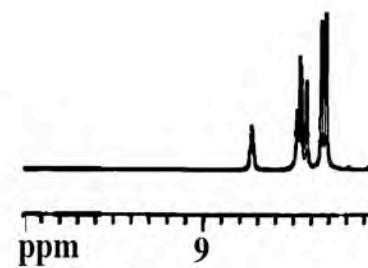


$\text{CDCl}_3$

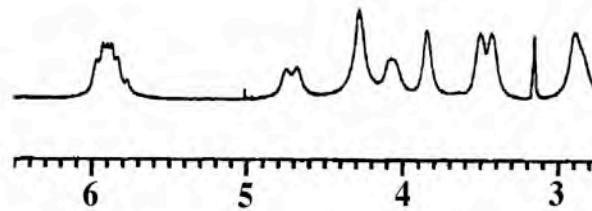


ppm

$\text{DMF}-d_7$



ppm

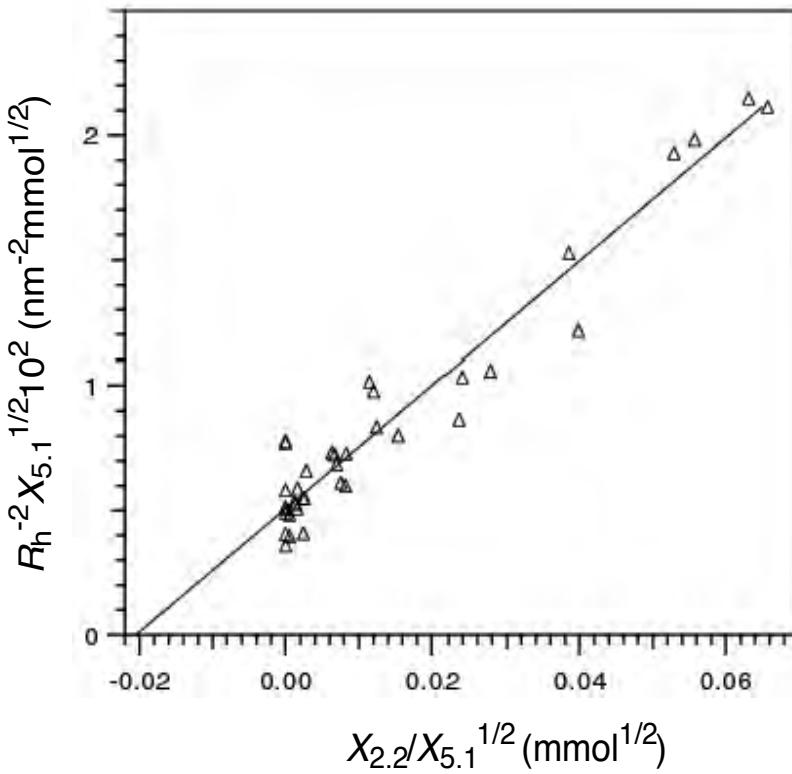
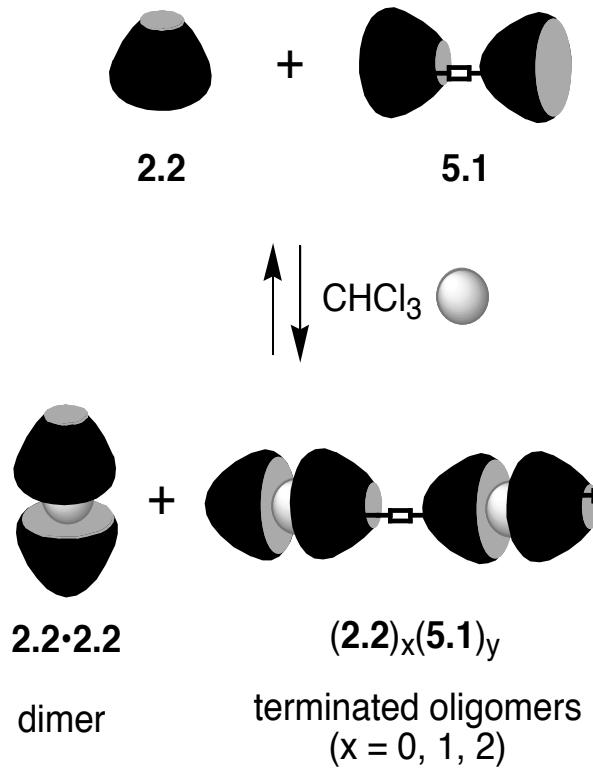


ppm



ppm

## Quasielastic Light Scattering (Benedek, MIT)

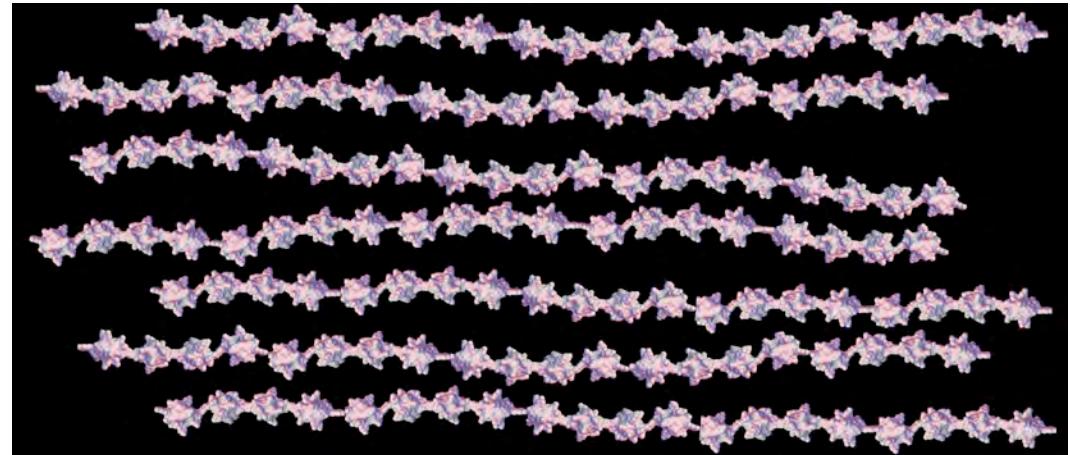
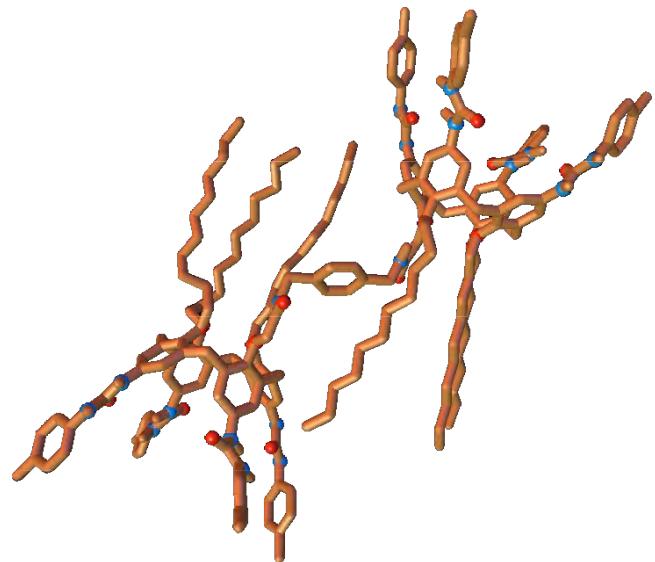


- $K_A = 2.3 \times 10^6 \text{ M}^{-1}$  in chloroform
- Between 0.25–2.5 mM, DP = 10–60 (MW = 31,000–186,000)

- Persistence length  $\sim 4$  monomers (ca. 9 nm)
- $c^* \sim 2.7 \text{ mM}$

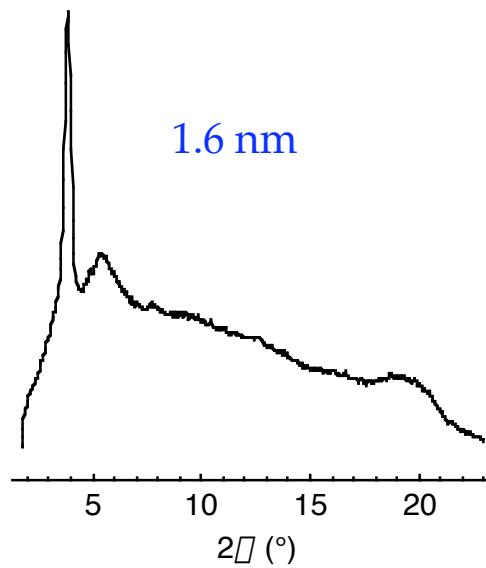
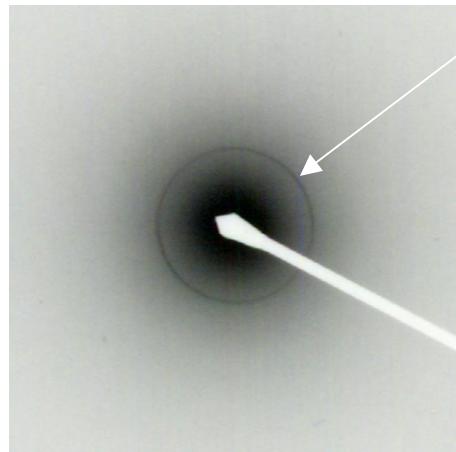
Polycaps are good models through which to study "living" polymerizations

# Liquid-Crystalline Polycaps

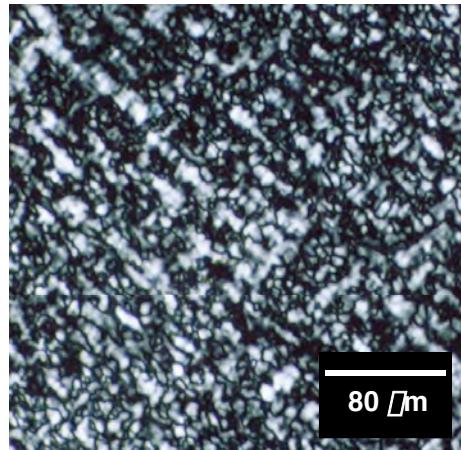


~ 2.2 nm

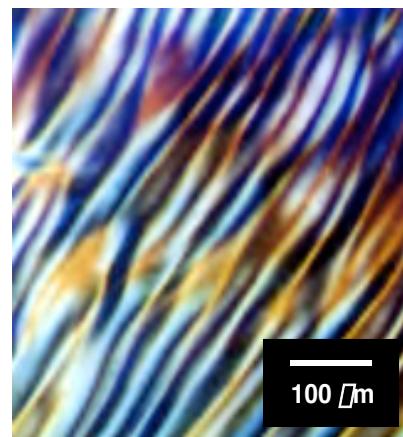
electron  
diffraction



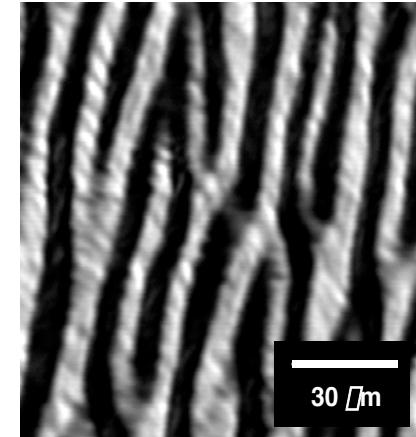
# *LC Phases and Well-Ordered Fibers*



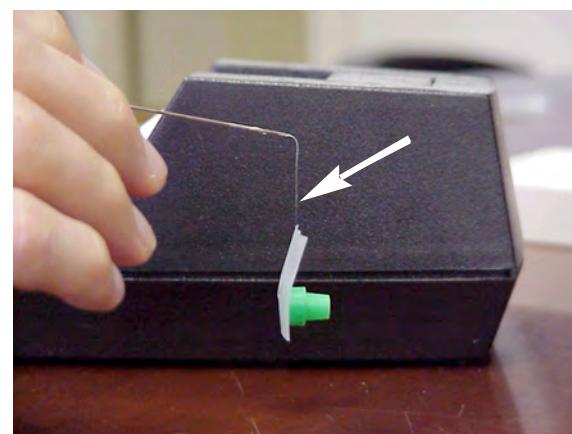
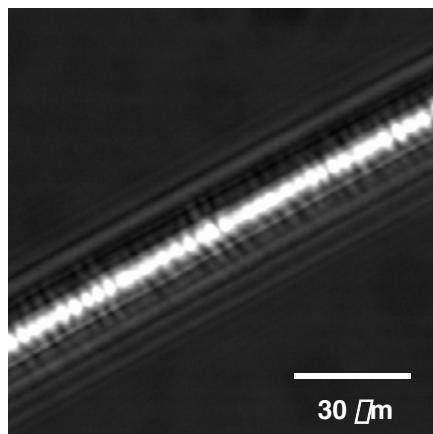
nematic phase ( $\text{CHCl}_3$ )



organization upon shear

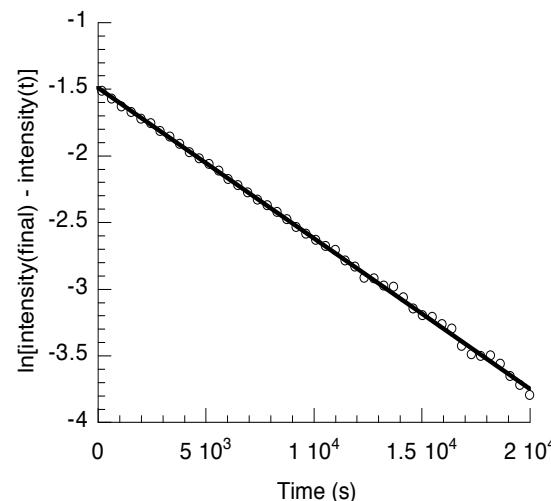
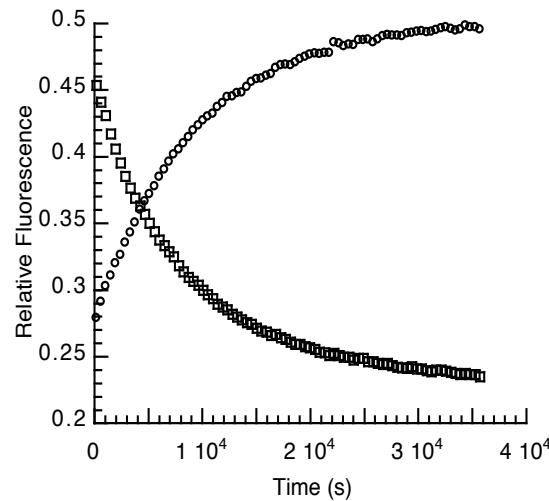


uniformly  
aligned fibers



high  
tensile strength

# Rate and Equilibrium Constants

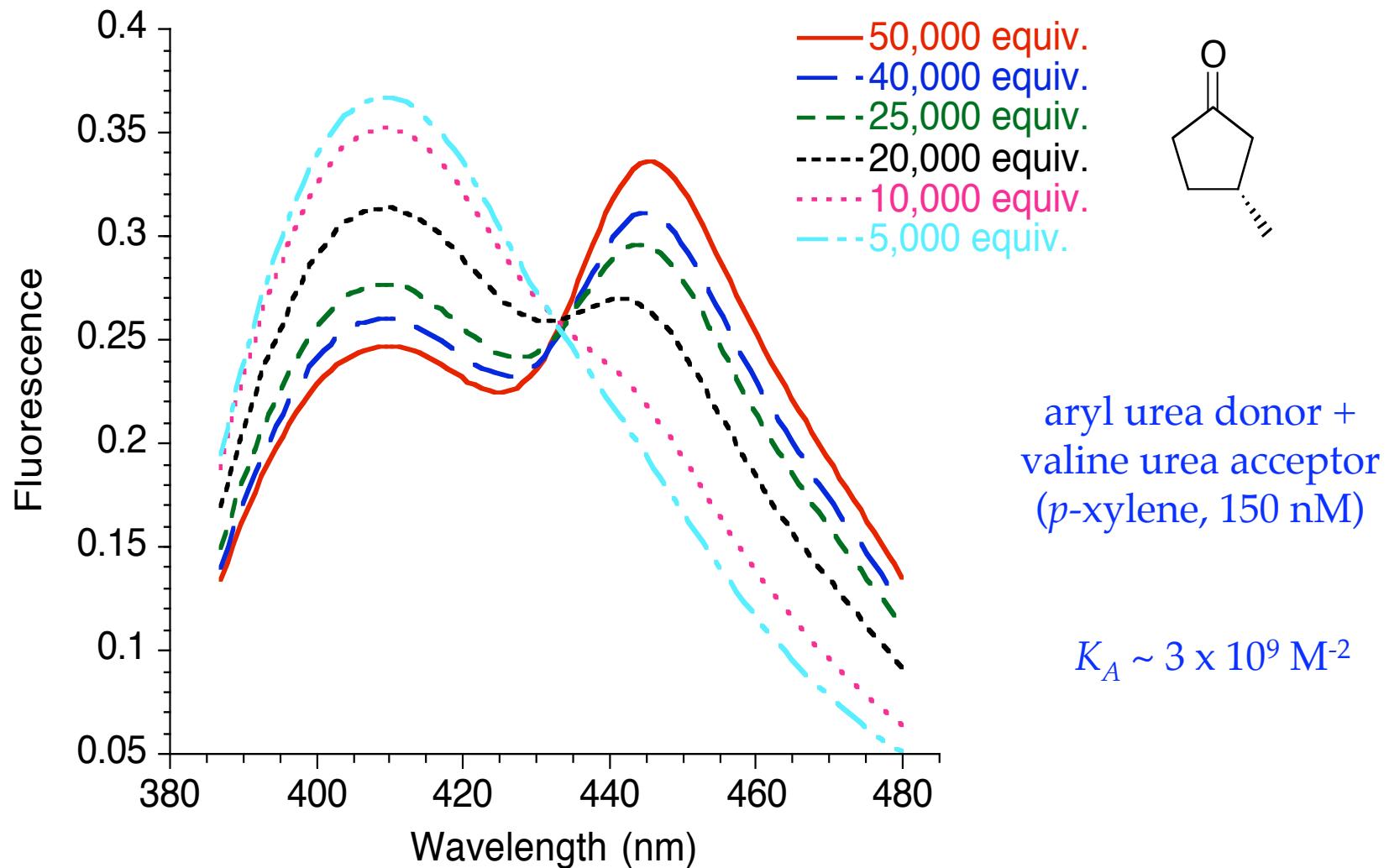


	Solvent	$k_{\text{ass}} (\text{M}^{-1} \text{s}^{-1})^{\text{a}}$	$k_{\text{diss}} (\text{s}^{-1})^{\text{a}}$	$K_A (\text{M}^{-1})^{\text{a}}$
1•1	$\text{CHCl}_3$	— <sup>b</sup>	— <sup>b</sup>	— <sup>b</sup>
1•2	$\text{CHCl}_3$	$2.7 \square 10^3$	$2.3 \square 10^{-5}$	$1.2 \square 10^8$
2•2	$\text{CHCl}_3$	$1.5 \square 10^4$	$6.4 \square 10^{-3}$	$2.4 \square 10^6$
1•1	$\text{C}_6\text{H}_6$	$< 50$	$5.4 \square 10^{-5}$	$< 10^6$
1•2	$\text{C}_6\text{H}_6$	$3 \square 10^3$	$5 \square 10^{-6}$	$6 \square 10^8$
2•2	$\text{C}_6\text{H}_6$	$1.3 \square 10^4$	$2.8 \square 10^{-4}$	$4.6 \square 10^7$

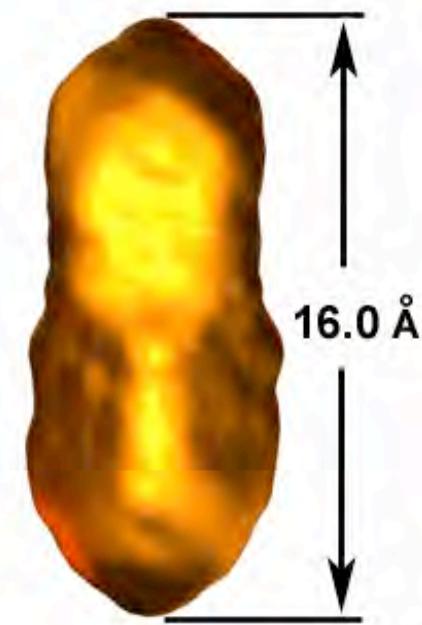
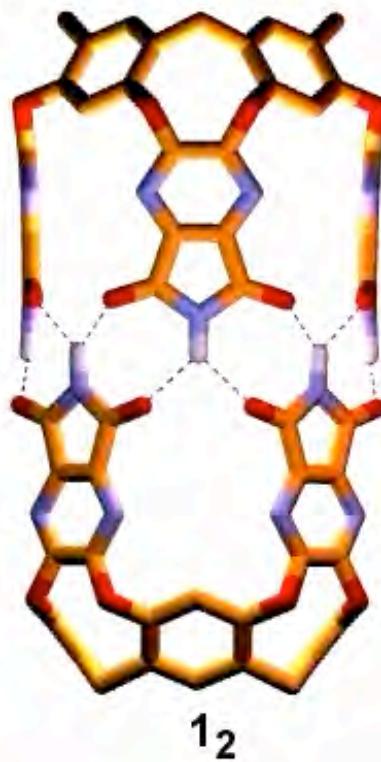
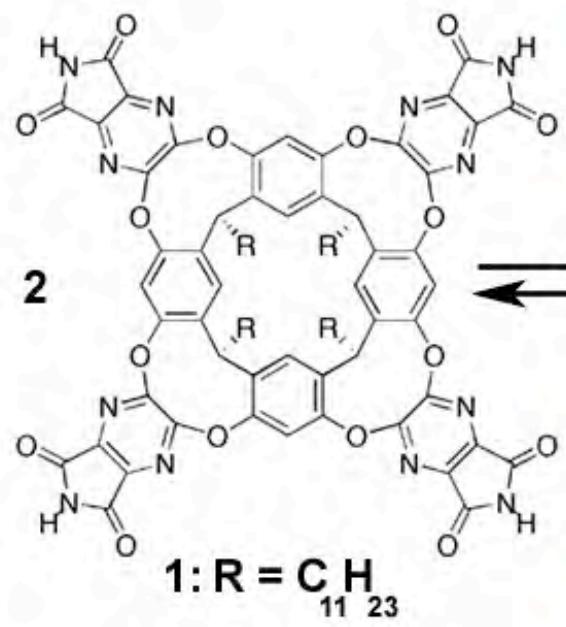
<sup>a</sup>Uncertainties in  $k_{\text{diss}}$  are  $\pm 15\%$ , and in  $k_{\text{ass}}$  and  $K_A$  are  $\pm 40\%$ .

<sup>b</sup>Compound 1 does not appear to form a well-defined dimer in  $\text{CHCl}_3$  by NMR, and its behavior in this work is consistent with a species that is effectively monomeric at these concentrations.

# Analyte Detection



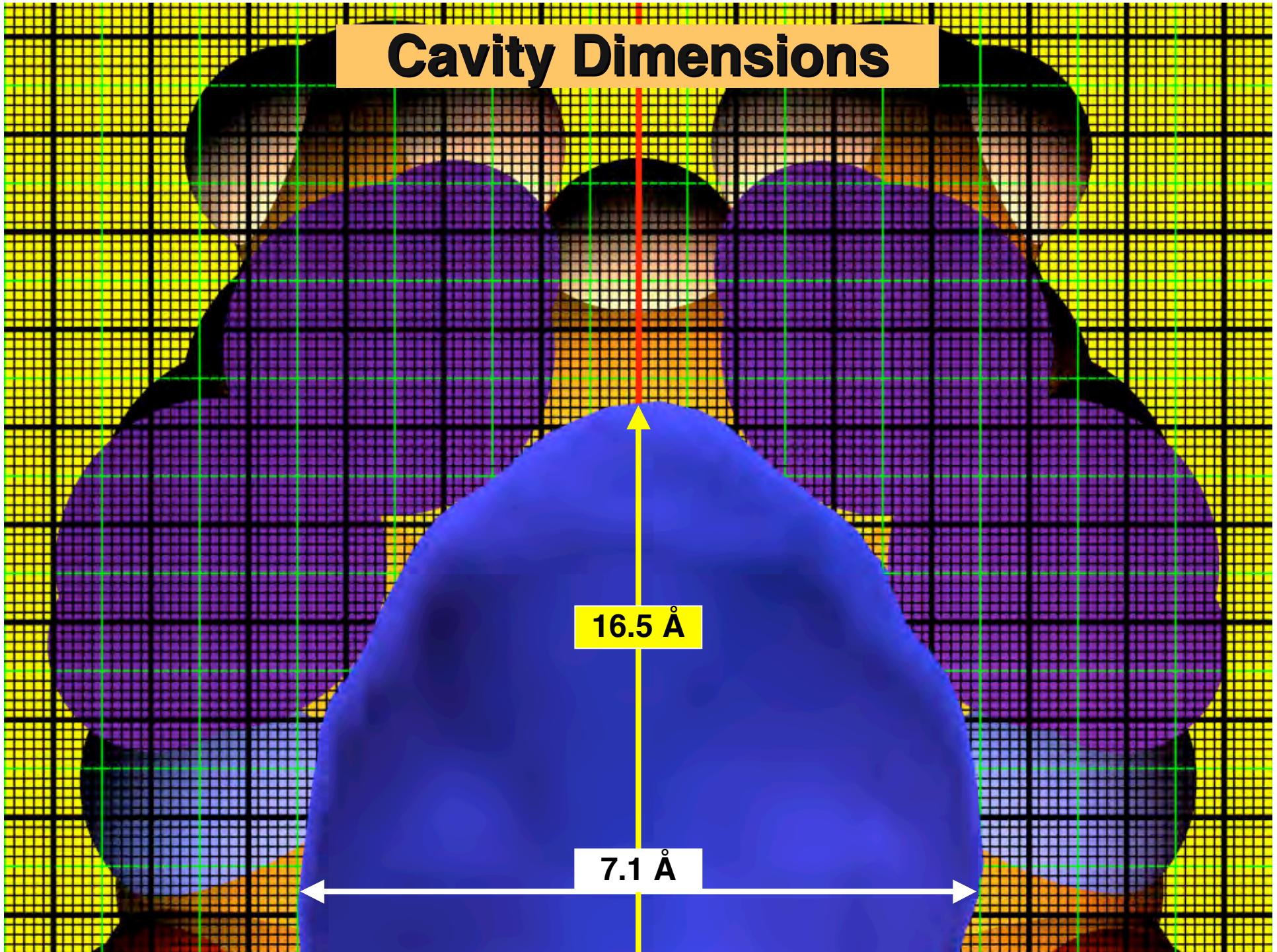
*Coiling*

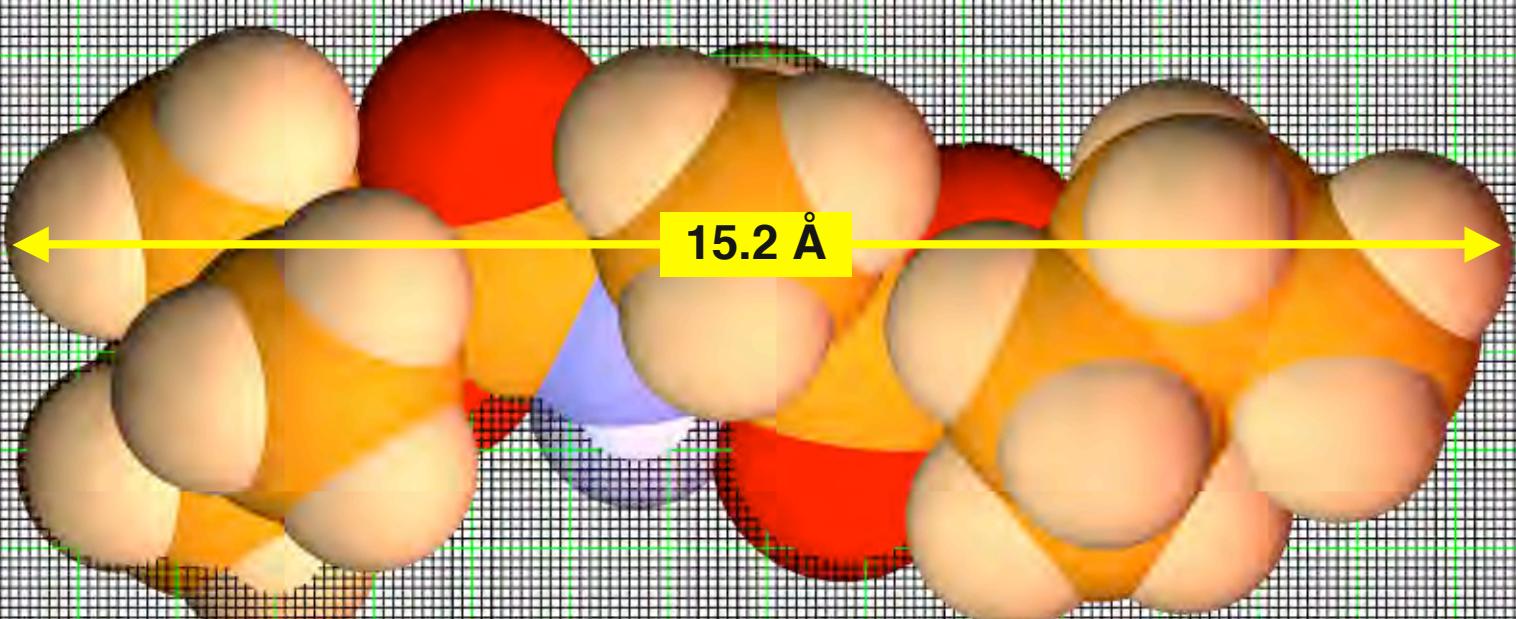


# Cavity Dimensions

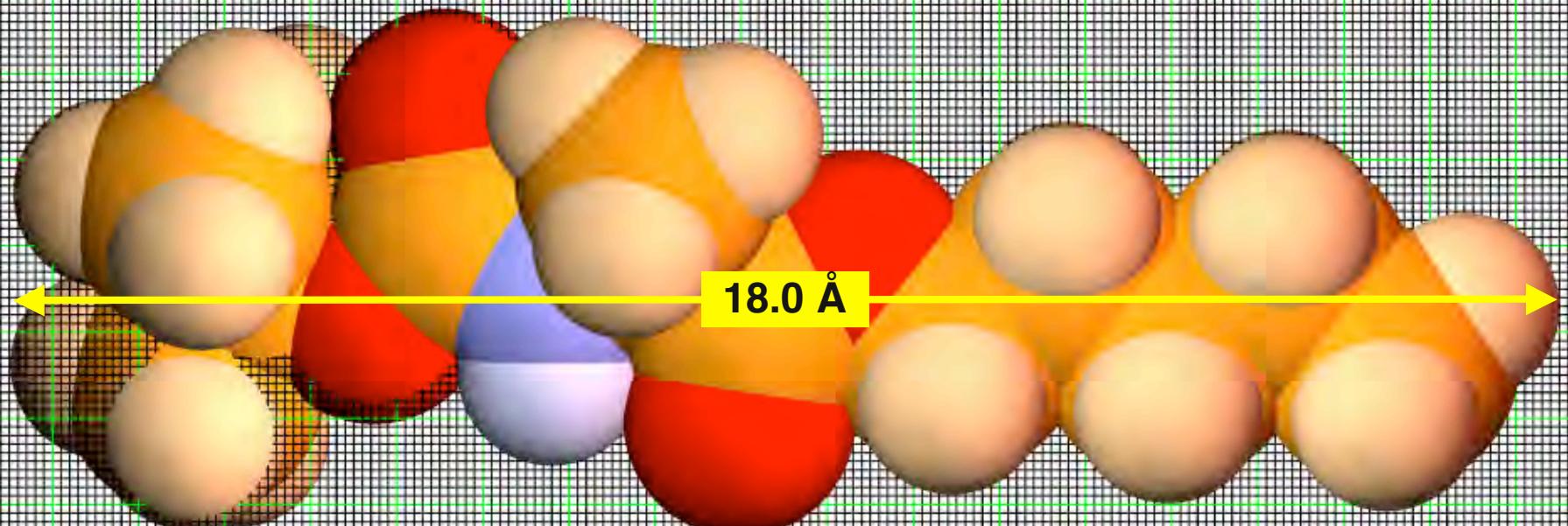
16.5 Å

7.1 Å

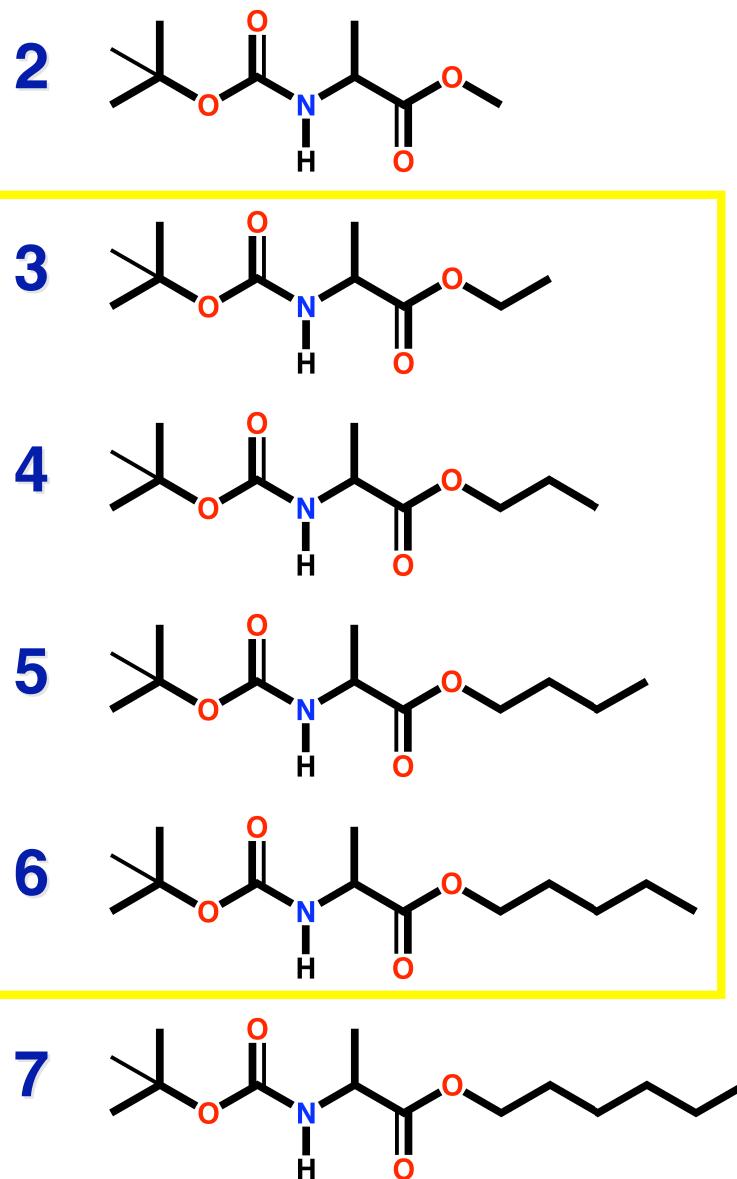




## Folded and Unfolded Guests



# Guest Volume and Packing Coeficient



181 Å<sup>3</sup>      43%

199 Å<sup>3</sup>      47%

215 Å<sup>3</sup>      51%

231 Å<sup>3</sup>      55%

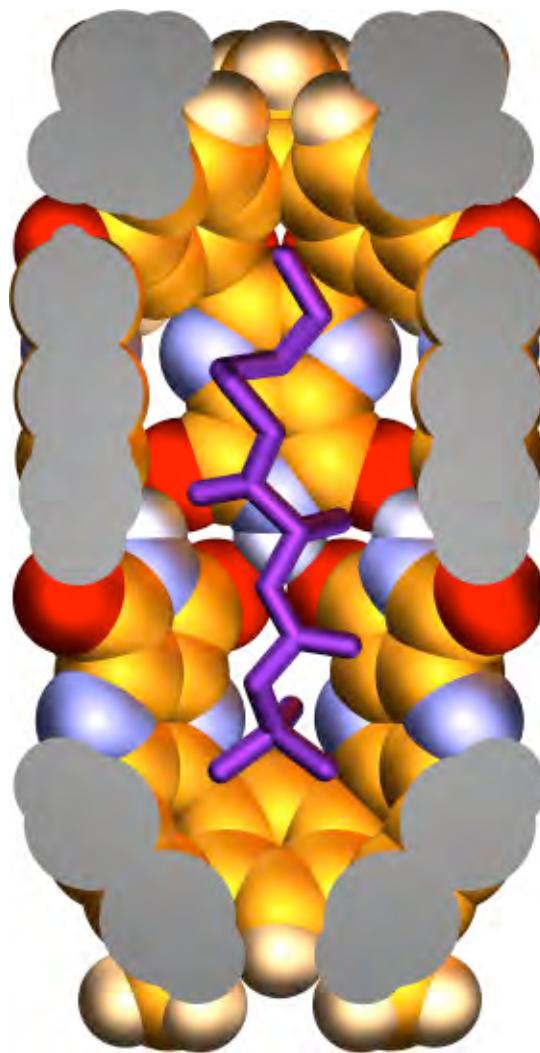
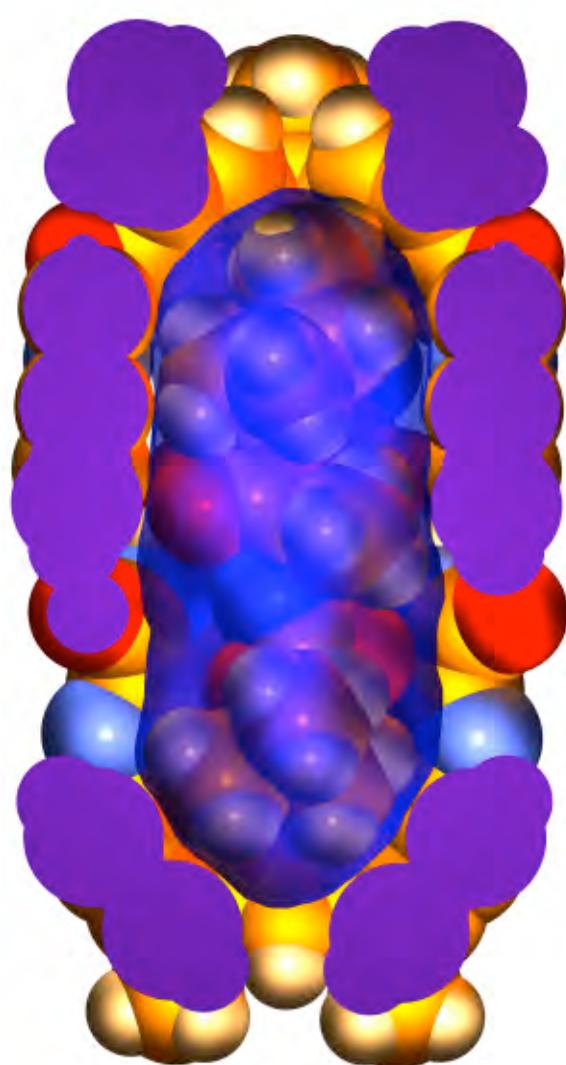
246 Å<sup>3</sup>      58%

262 Å<sup>3</sup>      62%

Dr. Lubo  
Sebo

Prof.  
Osamu  
Hayashida

# Longest Encapsulated Ester

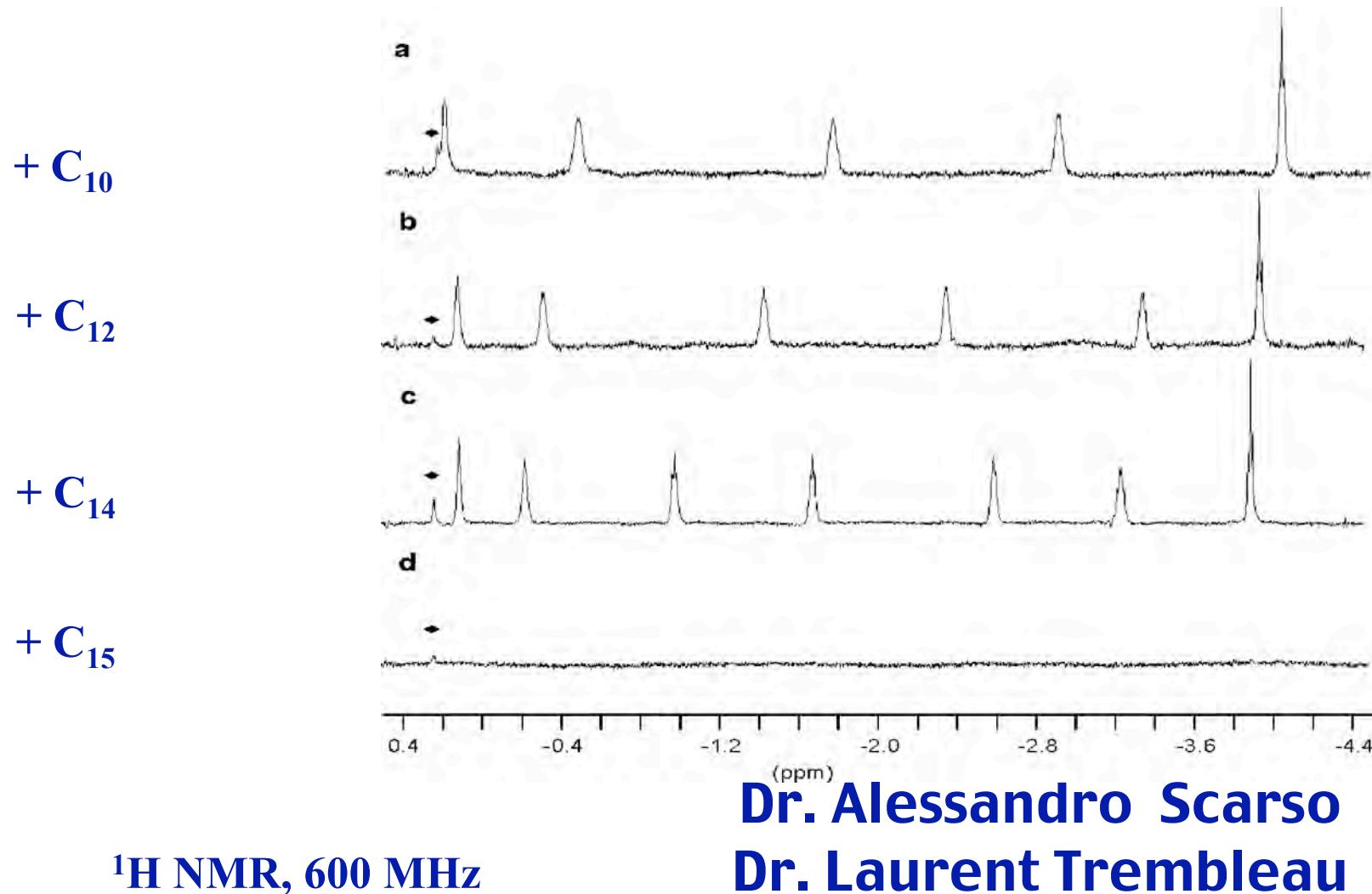


6

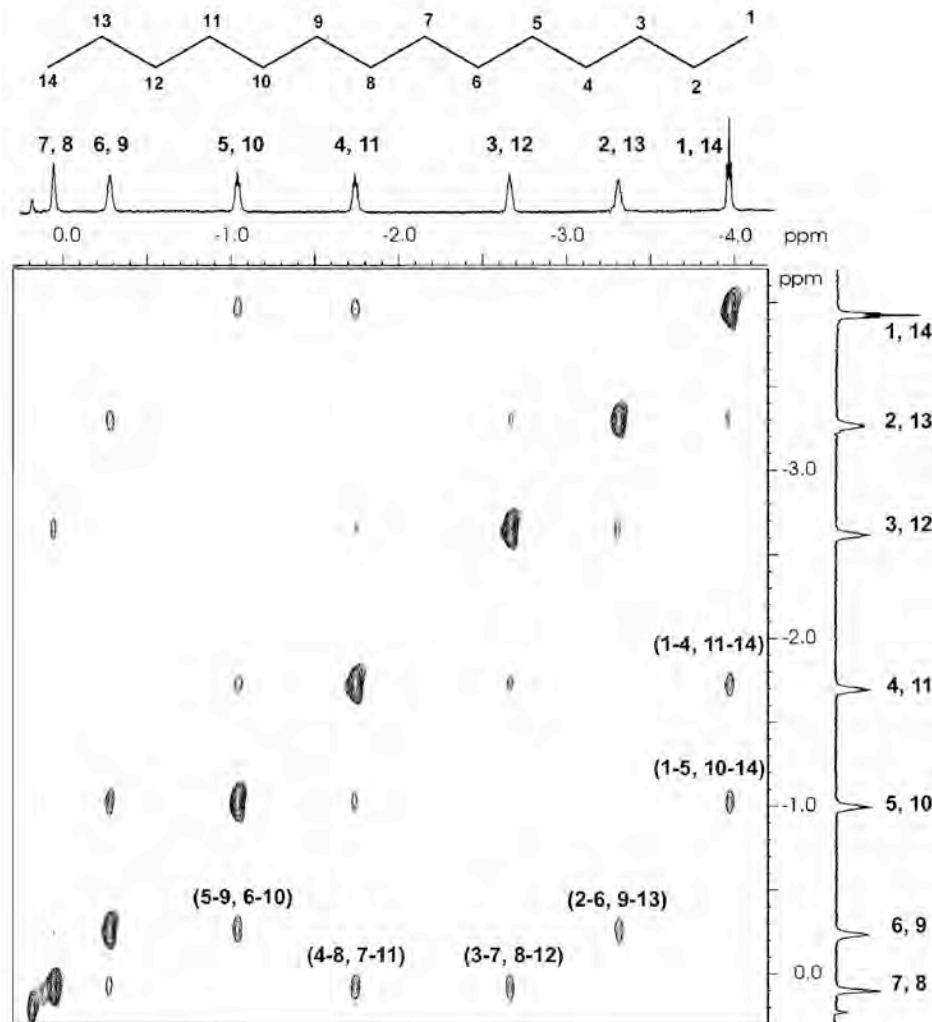
424 Å<sup>3</sup>

*GRASP*

# Complexes of the Capsule with Linear Hydrocarbons



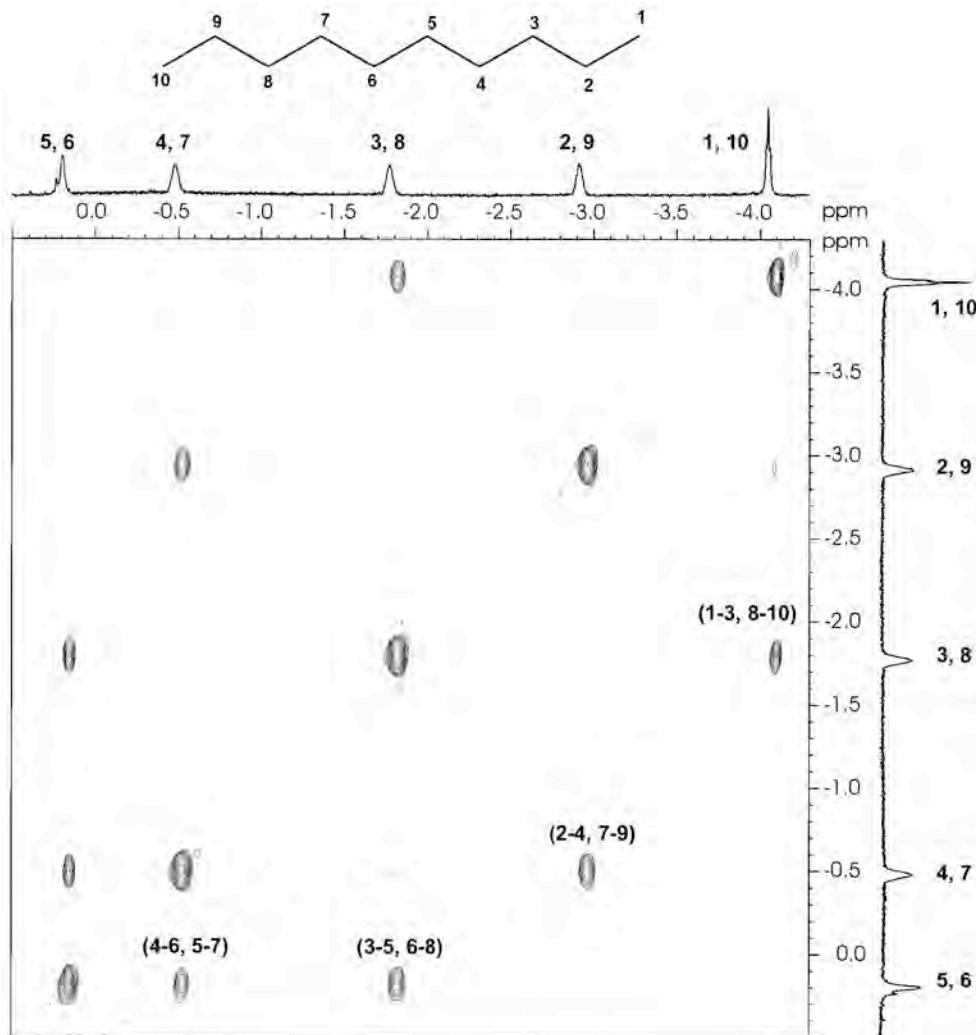
# Capsule-Tetradecane Complex



**Dr. Alessandro  
Scarso**  
**Dr. Laurent  
Trembleau**

**2D-NOESY, 600 MHz, mixing time: 300ms**

# Capsule-Decane Complex

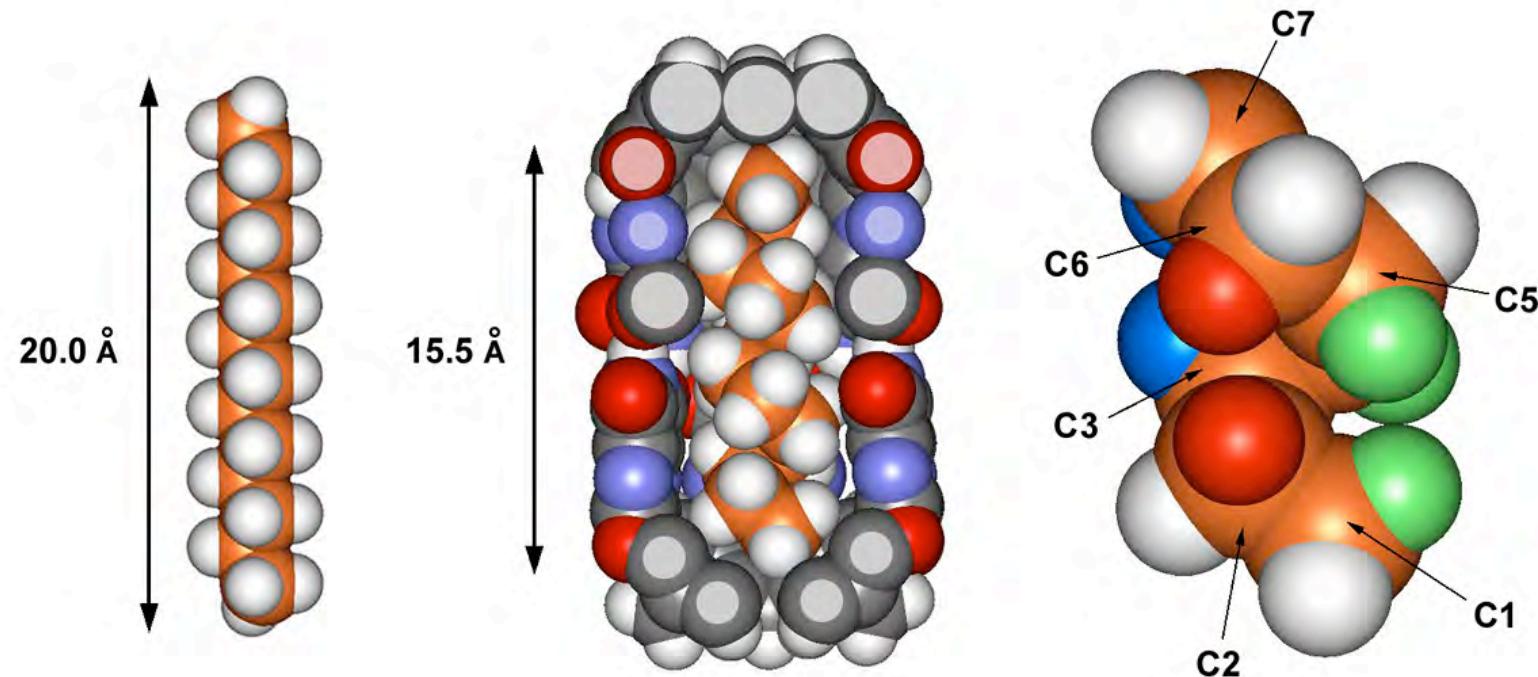


**Dr. Alessandro  
Scarso**  
**Dr. Laurent  
Trembleau**

**2D-NOESY, 600 MHz, mixing time: 300ms**

# Straight Chain Hydrocarbons Coil to fit into the Capsule

Gauche: 0.55 kcal/mol

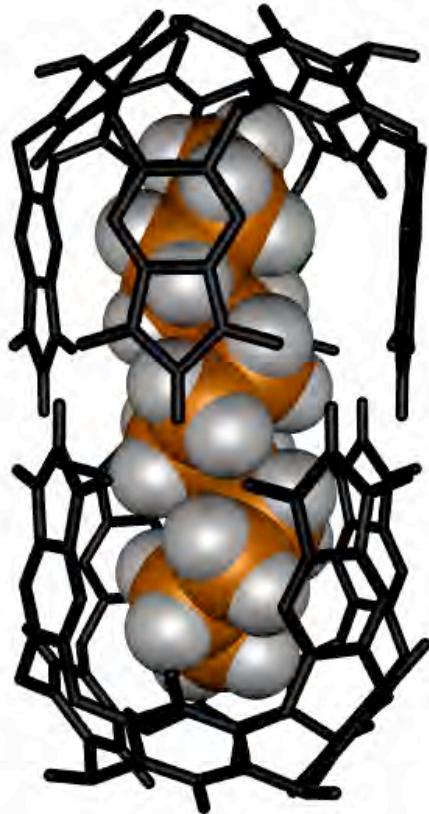


Dr. Alessandro Scarso  
Dr. Laurent Trembleau

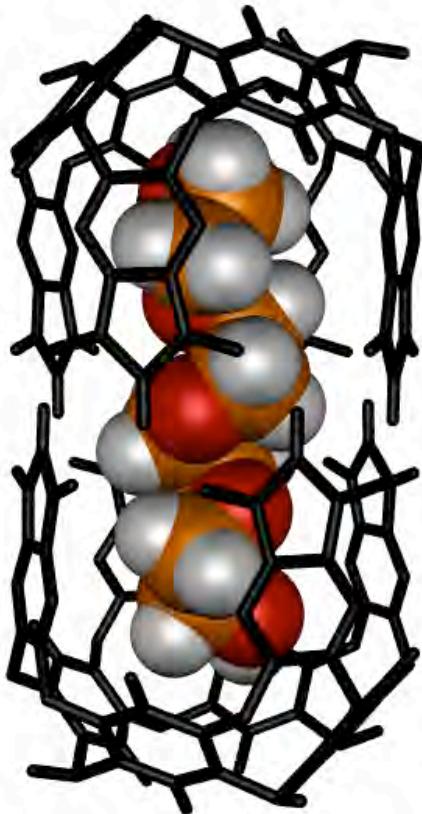
# Characteristics of the Hydrocarbons

Alkane	Length (Å)	Surface Area (Å <sup>2</sup> )	Volume (Å <sup>3</sup> )	PC (%)
C <sub>10</sub> H <sub>22</sub> extended	15.0	196	167	39
C <sub>12</sub> H <sub>26</sub> extended	17.5	230	200	47
C <sub>12</sub> H <sub>26</sub> coiled	13.6	207	206	48
C <sub>14</sub> H <sub>30</sub> extended	20.0	264	235	-
C <sub>14</sub> H <sub>30</sub> coiled	15.5	235	240	56
C <sub>14</sub> H <sub>28</sub> coiled	16.0	239	239	56
C <sub>15</sub> H <sub>32</sub> coiled	16.3	251	258	-

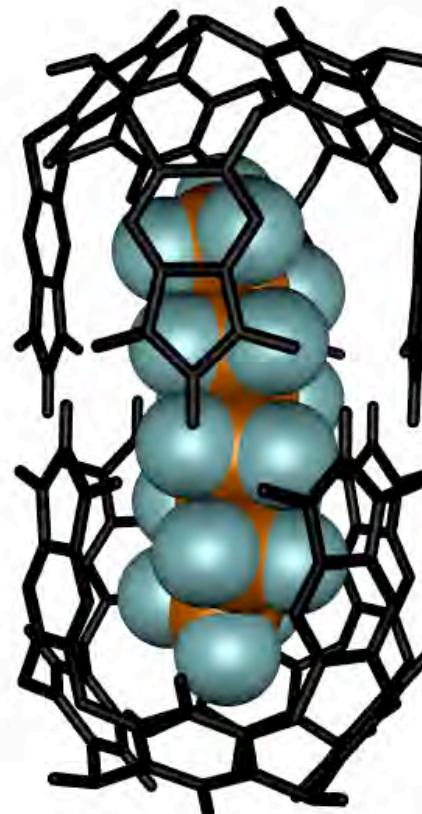
Calculated using Grasp after energy minimization of the structures



*n*-tridecane



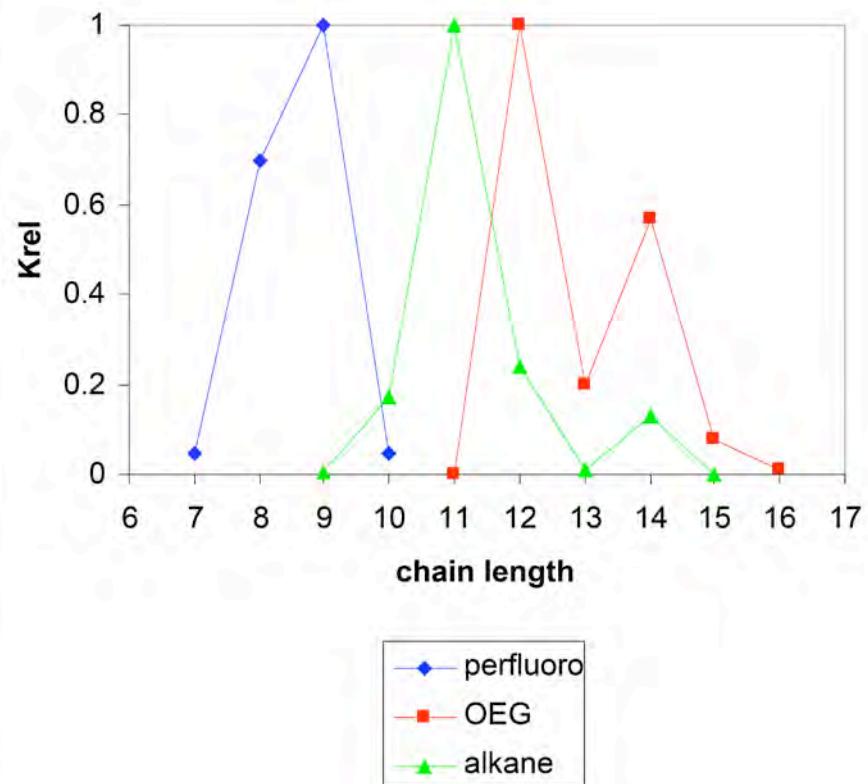
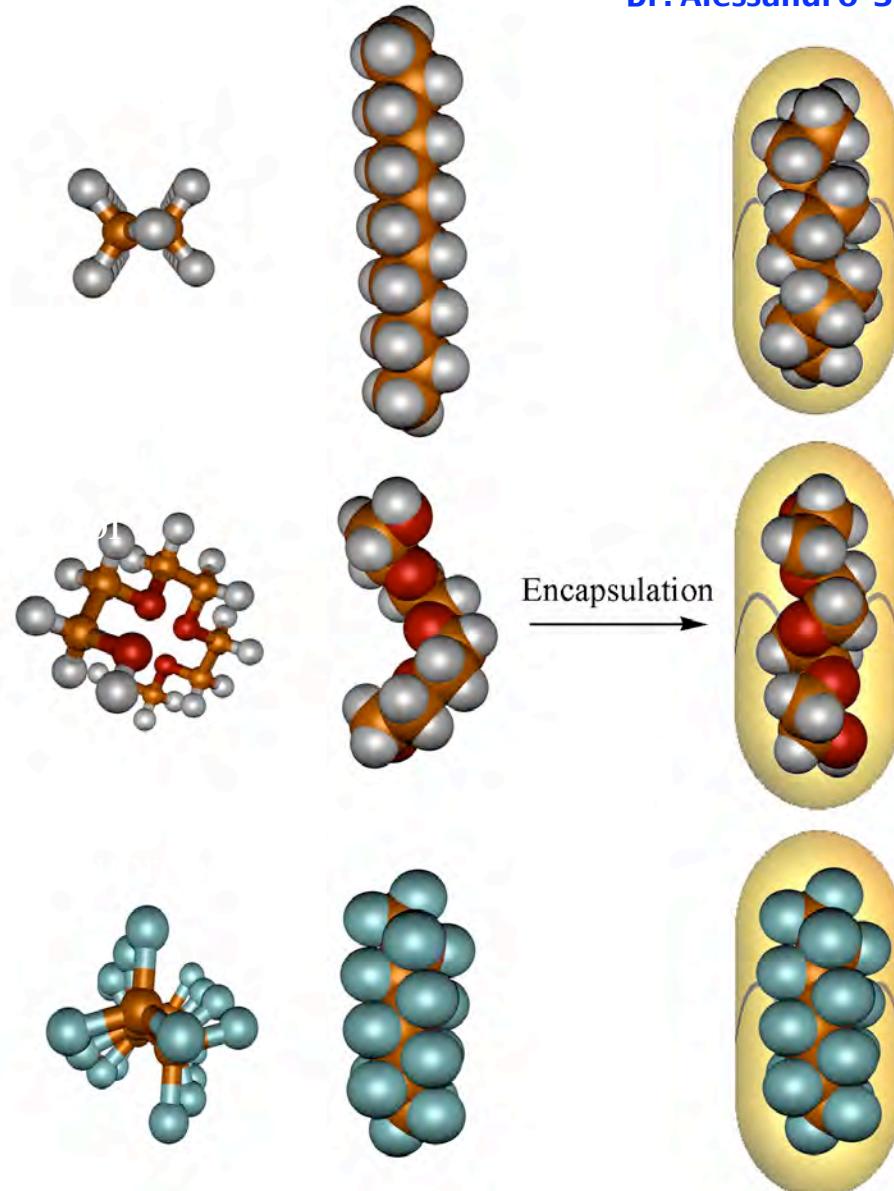
tetraethylene glycol



perfluoro-*n*-octane

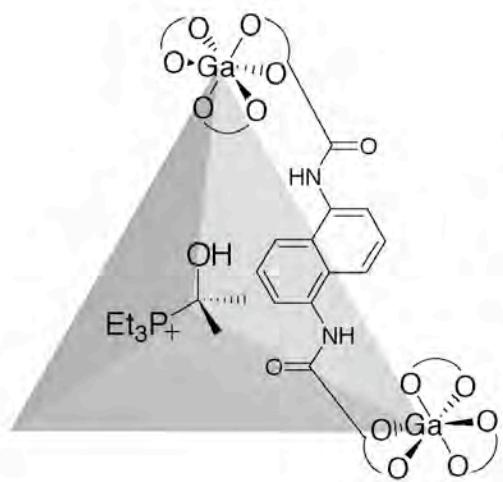
Dr. Alessandro Scarso, Byron Purse Dr. Laurent Trembleau

Dr. Alessandro Scarso, Byron Purse Dr. Laurent Trembleau

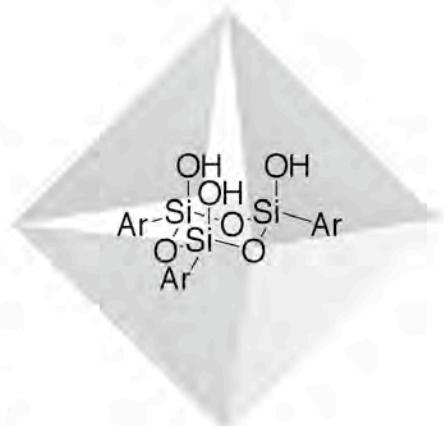


# *Reactive Intermediates*

# Stabilization of Reactive Species

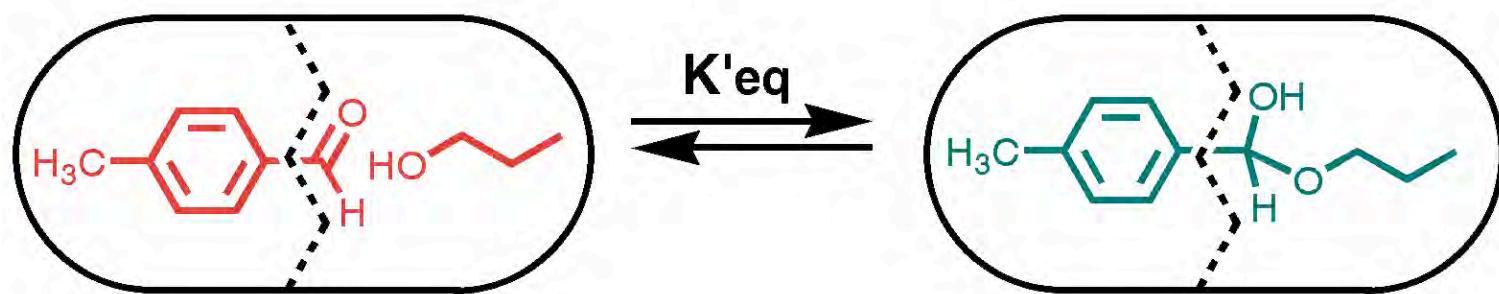


**Raymond, 2000**



**Fujita, 2000**

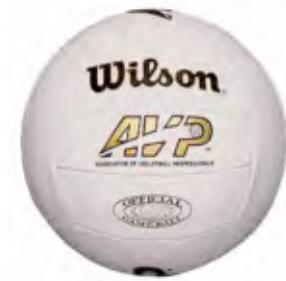
# Heimacetal Stabilization



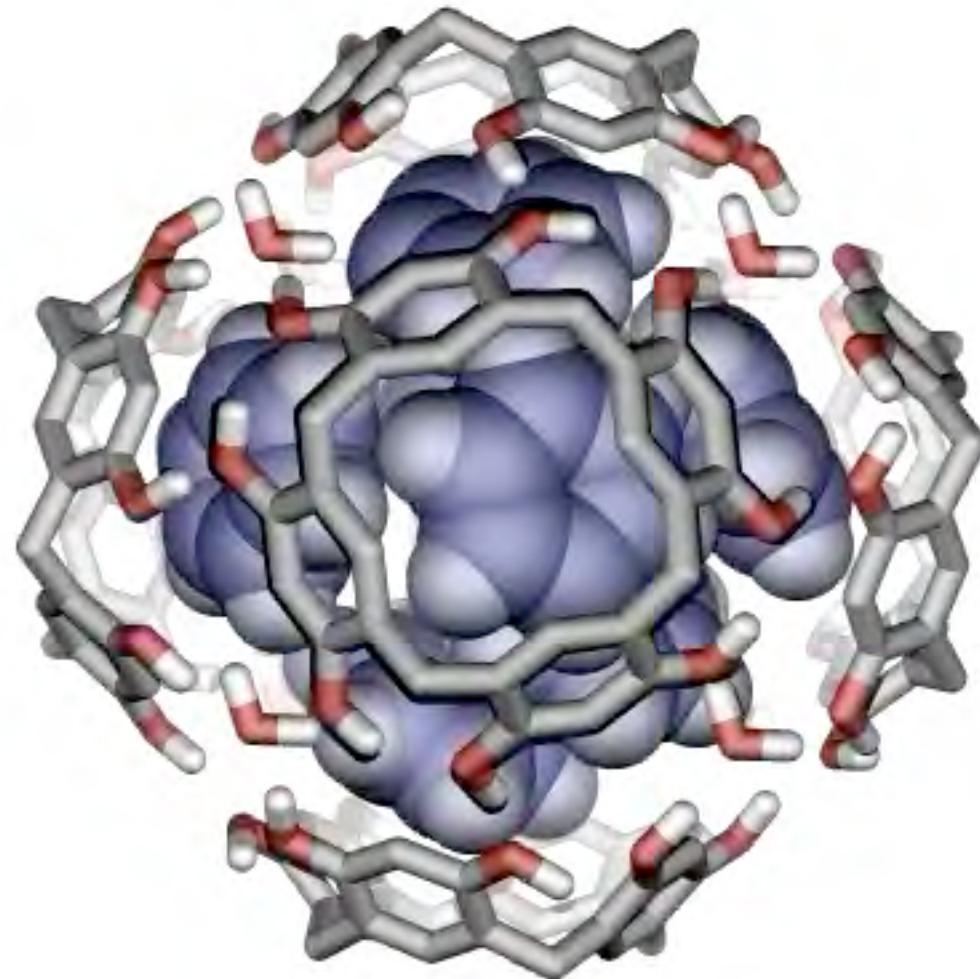
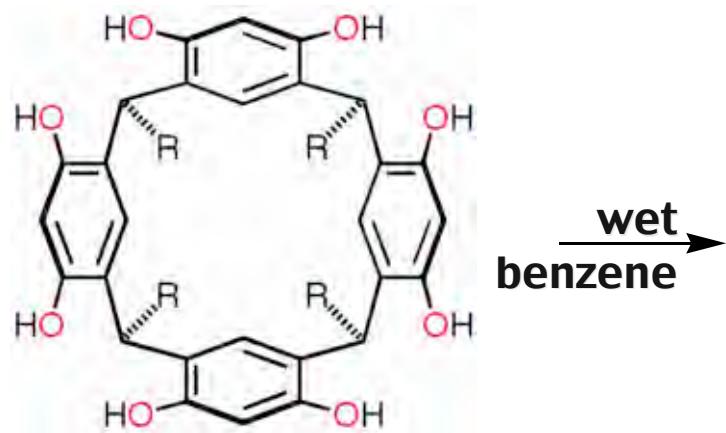
Dr. Masamichi Yamanaka

*Hexamer*

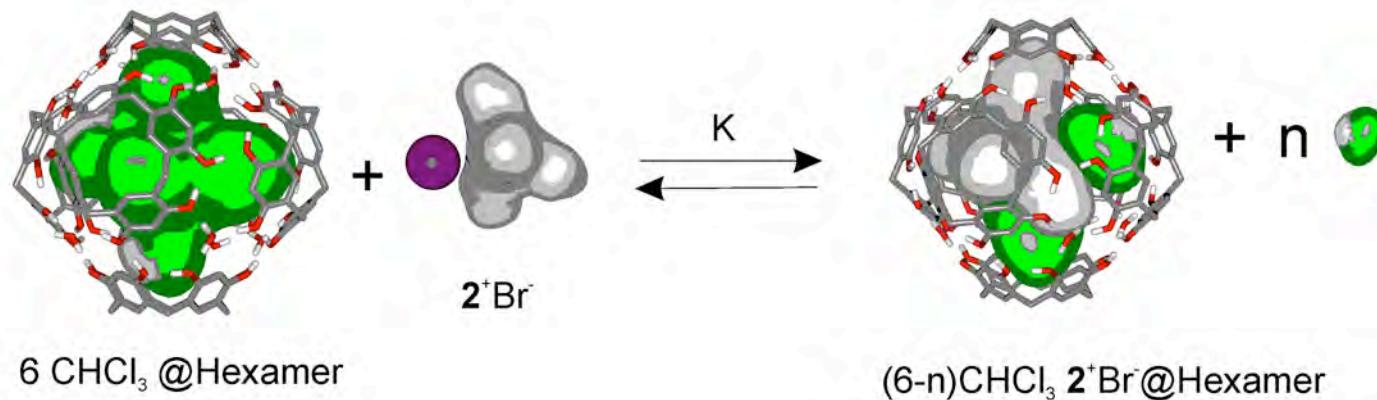
# Volleyball Seams



# Resorcin[4]arene Octol Assembly



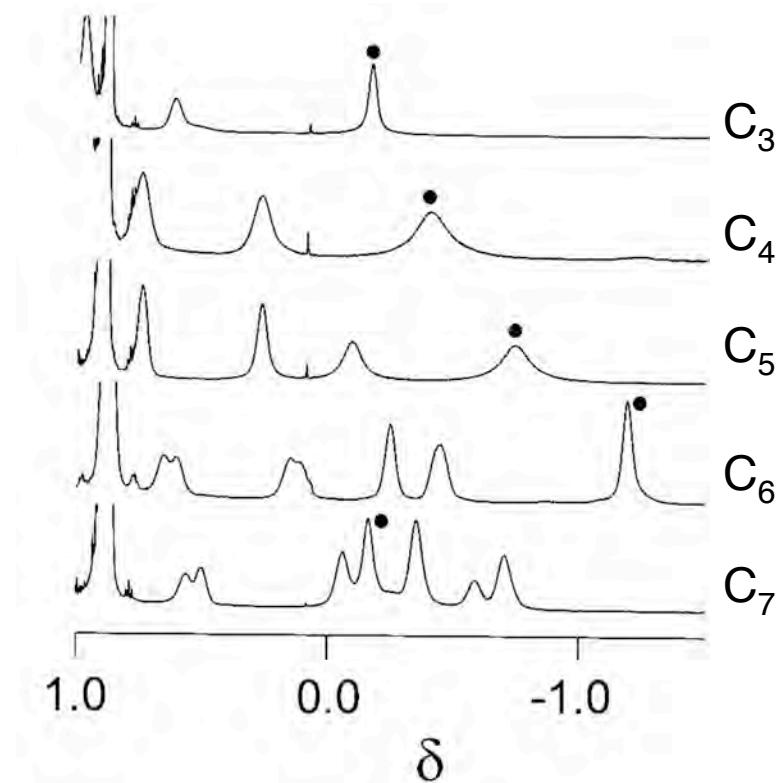
**Dr. Alex Shivanyuk  
Liam Palmer**



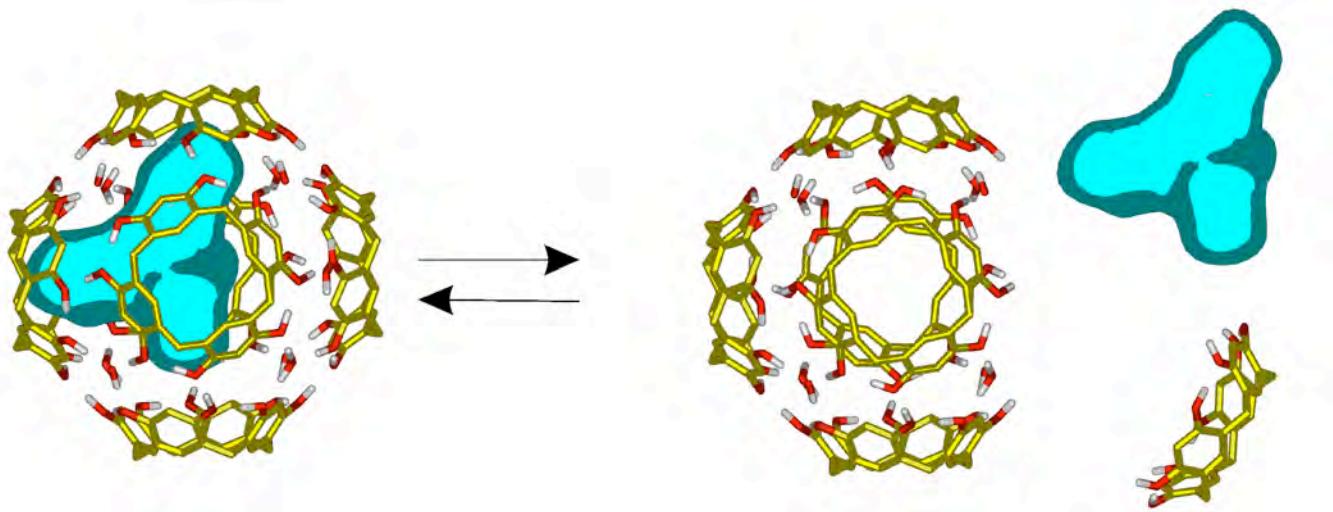
Guest	K
$\text{C}_{3-5}$	$>10^4 \text{ M}^{-1}$
$\text{C}_6$	$1,200 \text{ M}^{-1}$
$\text{C}_7$	$450 \text{ M}^{-1}$
$\text{C}_8$	$150 \text{ M}^{-1}$

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## $\text{R}_4\text{N}^+$ in Hexamer



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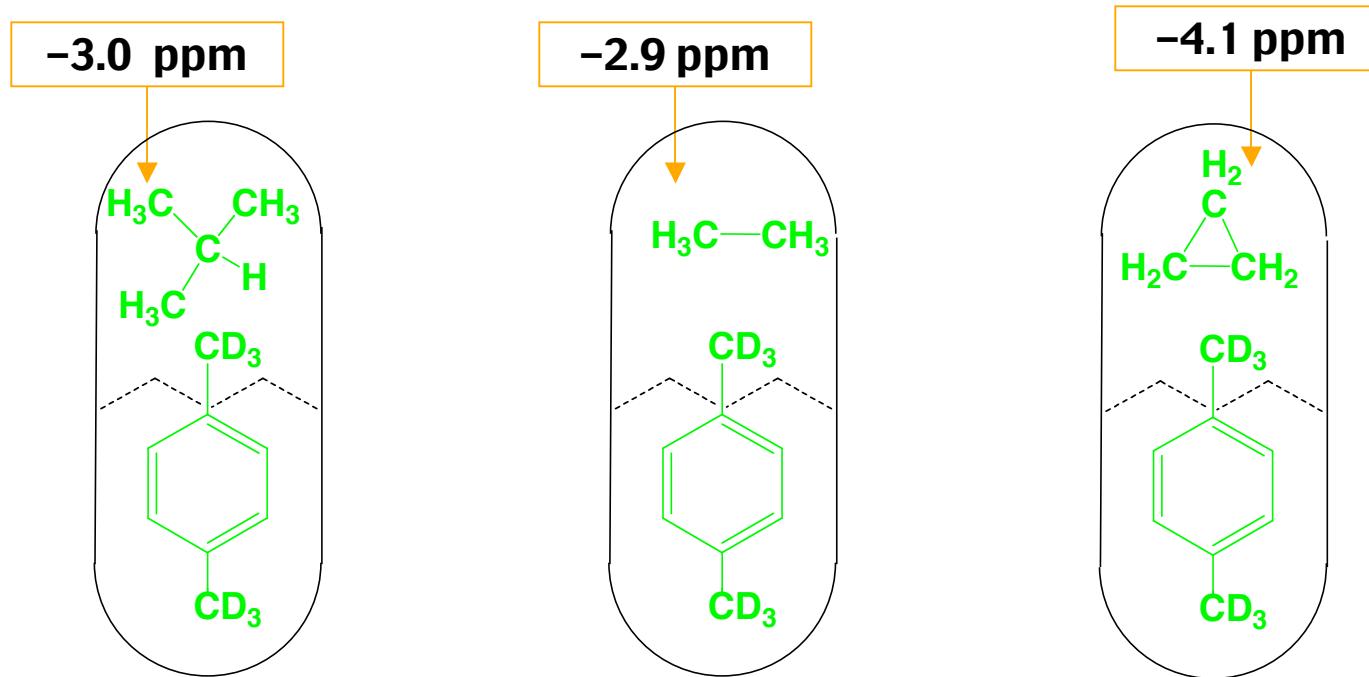
Guest	$\Delta G^*$ kcal/mol
C <sub>3</sub>	13.1
C <sub>4</sub>	14.8
C <sub>5</sub>	16.7
C <sub>7</sub>	17.1

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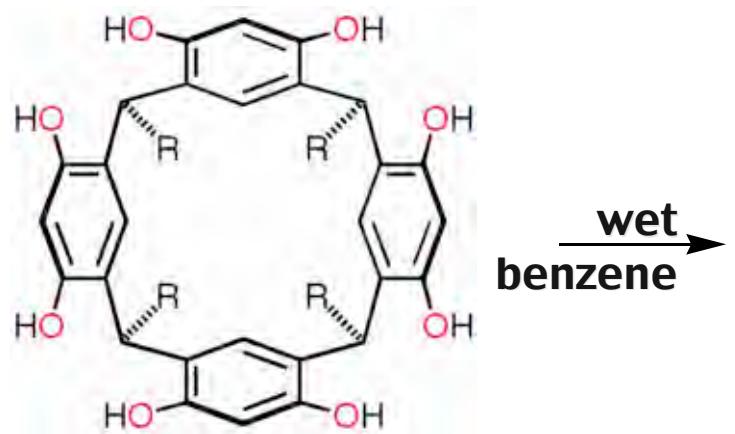
# Cylindrical Capsule

## NMR Shifts of Coencapsulated Gases

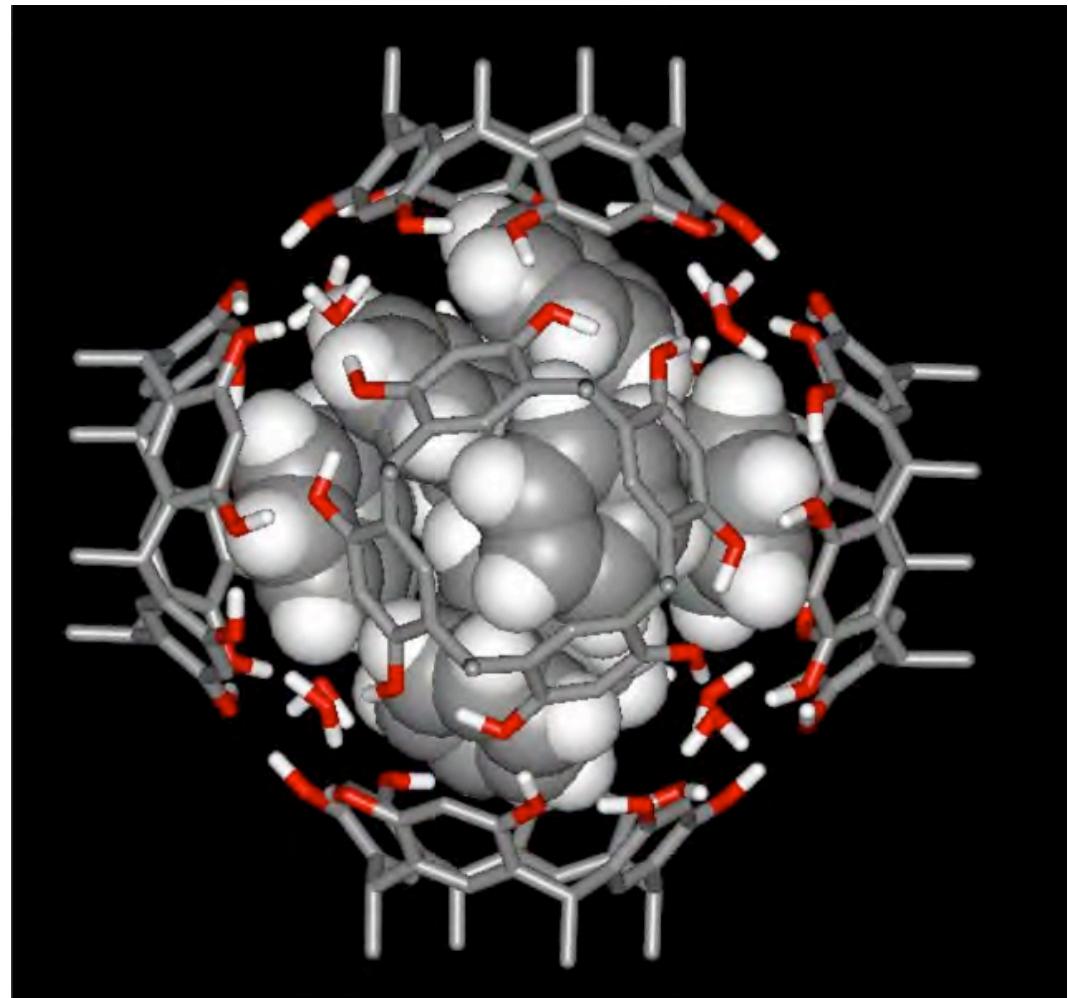


**Dr. Alex Shivanyuk**  
**Dr. Alessandro Scarso**

## Resorcin[4]arene Octol Assembly



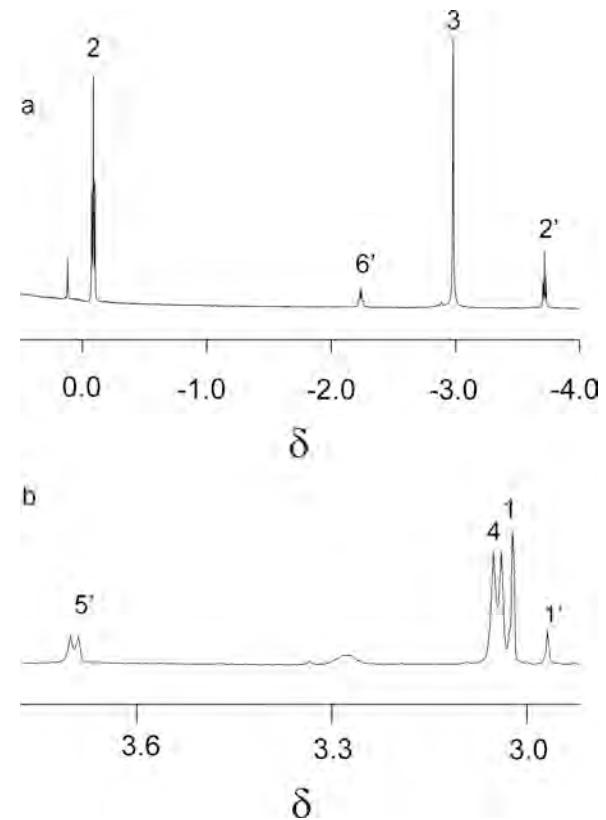
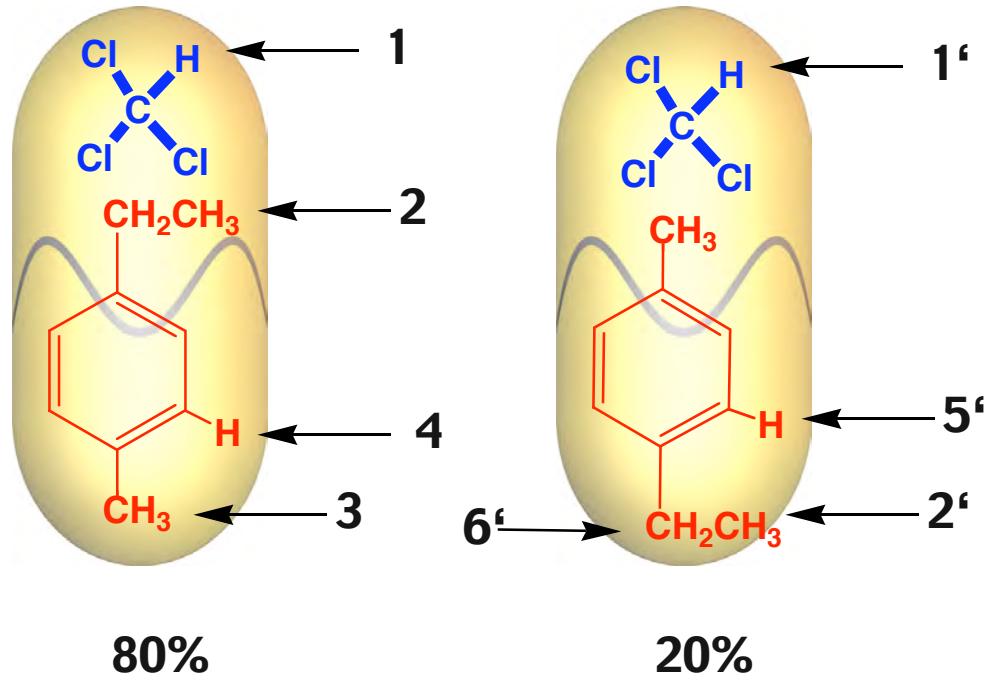
wet  
benzene



Dr. Alex Shivanyuk

# Cylindrical Capsule

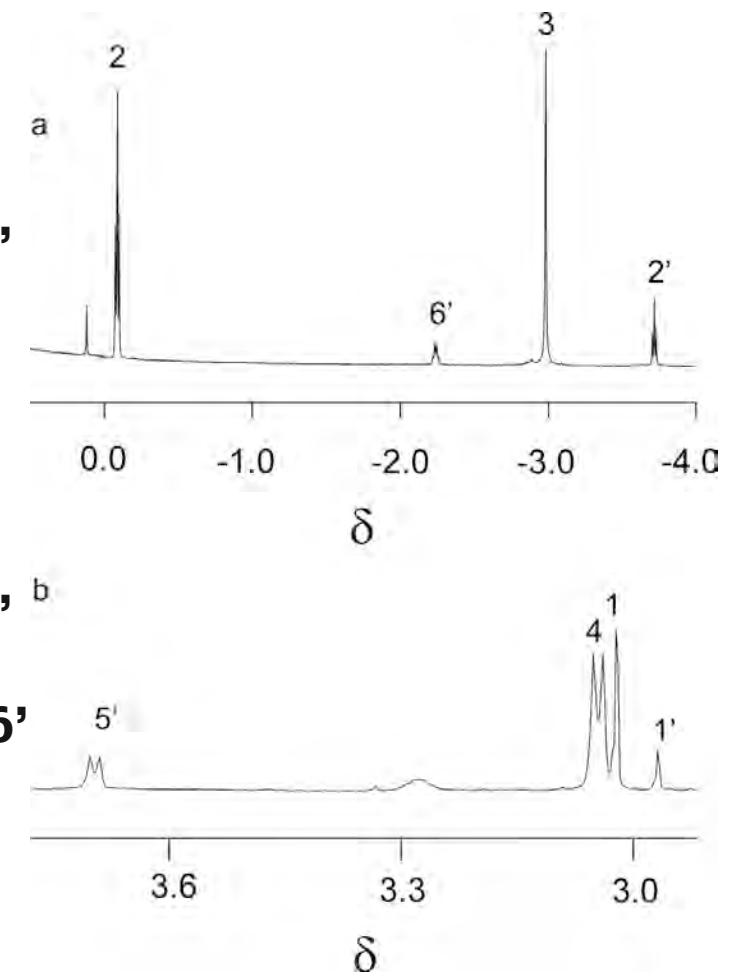
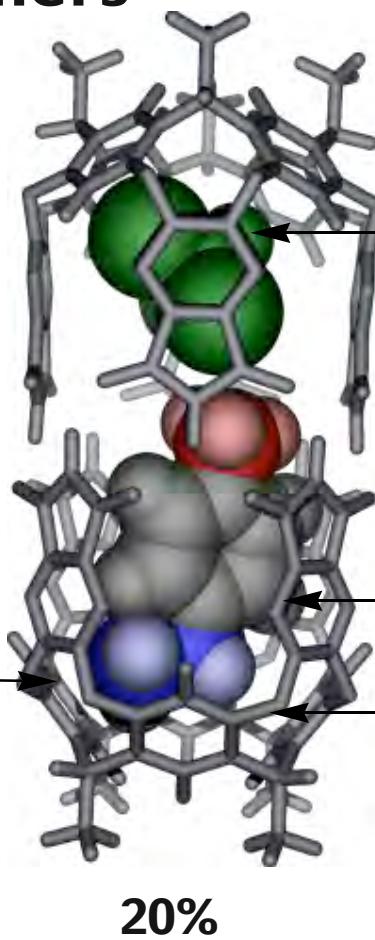
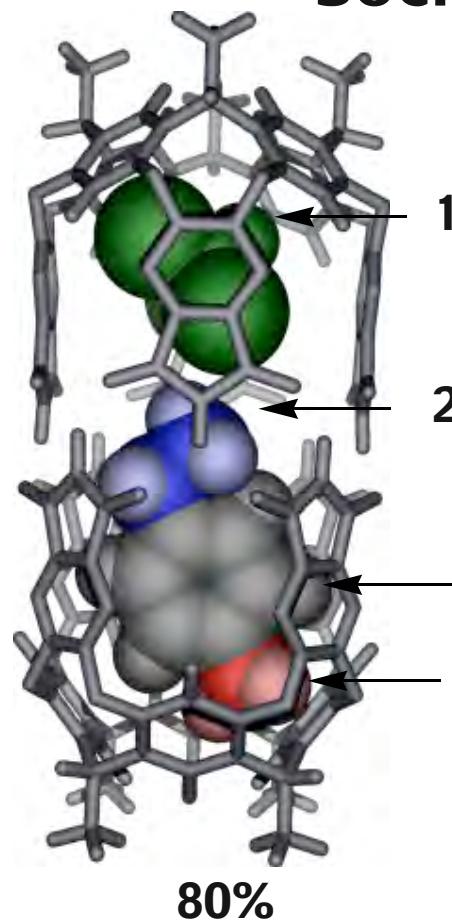
## Social isomers



Dr. Alex Shivanyuk

# Cylindrical Capsule

## Social isomers



Dr. Alessandro Scarso

Dr. Alex Shivanyuk

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# *Polymeric Capsules*

*Molecular Assembly  
and Encapsulation*