

分子机器

molecular machine , nanomachine, nanodevice,
functional nanostucture , etc.

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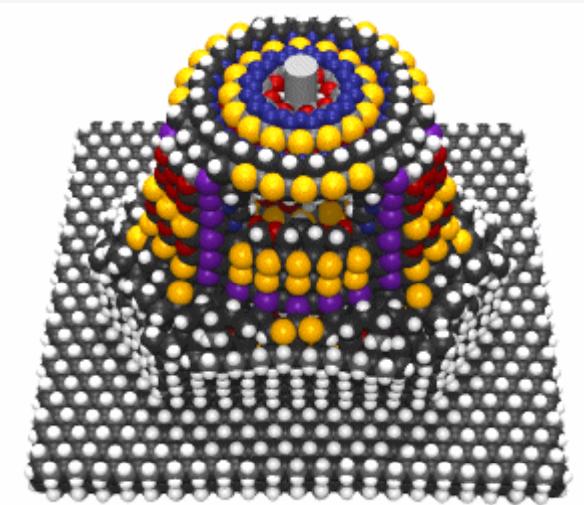
2009/08/23

自然界为我们提供了不竭的创新源泉

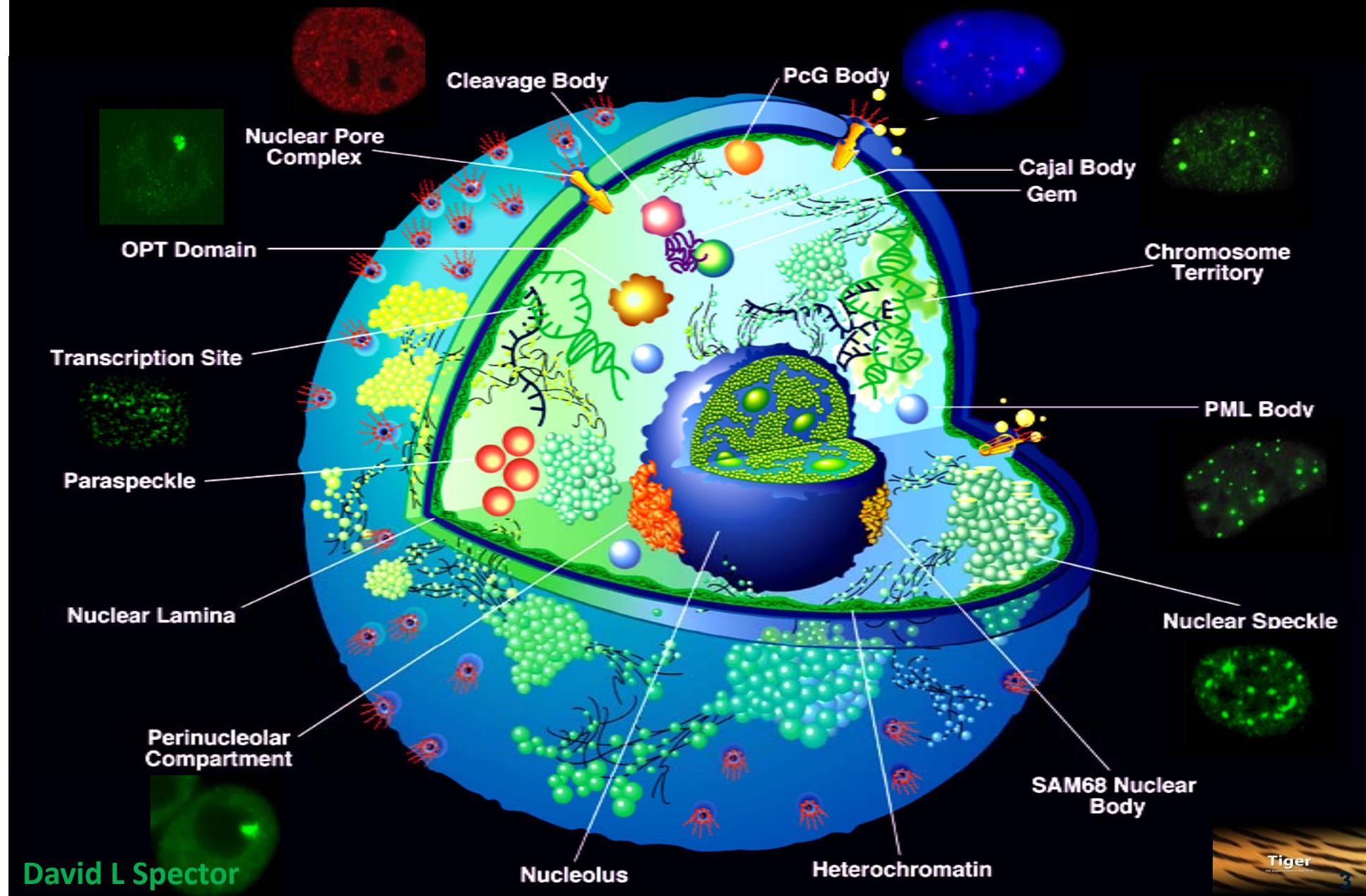
人->机器人



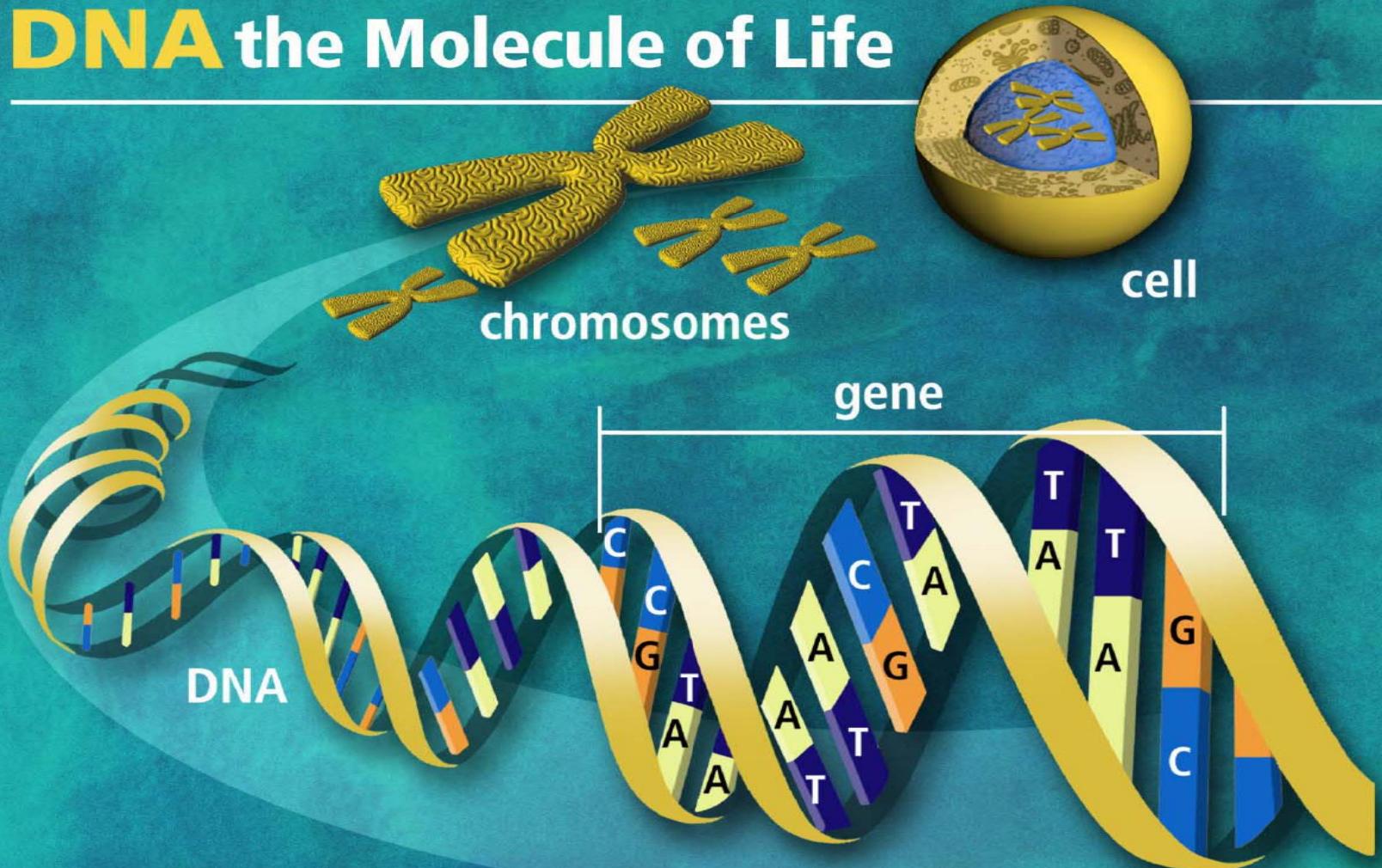
微观生命活动->纳米机器

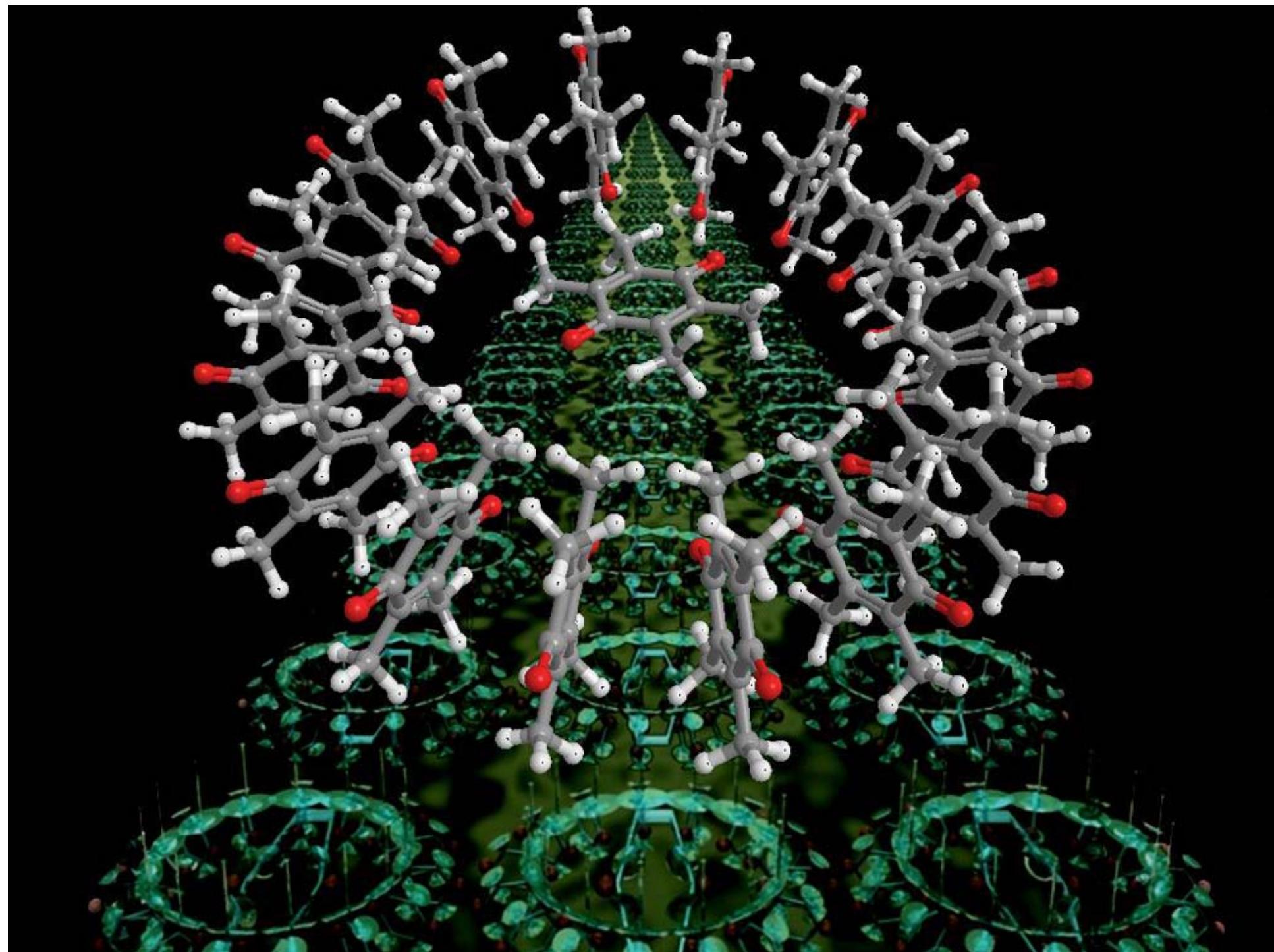


细胞是由无数纳米机器组合的复杂系统



DNA是构建纳米机器的优良材料





分子机器的几种思路

- ◆ 直接借助天然的分子机器（利用细菌等）
 - ◆ 如鞭毛作为运动器件
- ◆ 改造生物
 - ◆ 合成生物学的目标
 - ◆ 国际遗传工程机器竞赛（International Genetics Engineering Machine competition , iGEM）
 - ◆ 分子机器兴趣小组
- ◆ 人工制造纳米机器或仿造生物机器

机器人的构件

- ◆ 感应
- ◆ 判断
- ◆ 输出
- ◆ 运动
- ◆ 反馈
- ◆ 部件-手臂，腿，轮，齿轮，马达

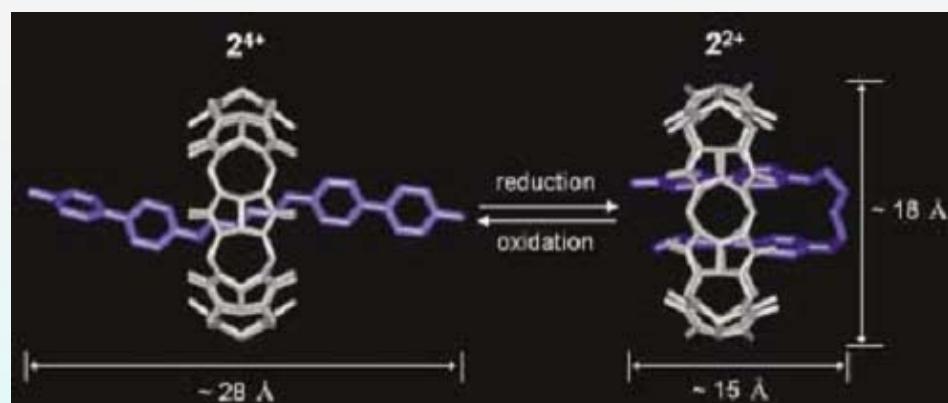
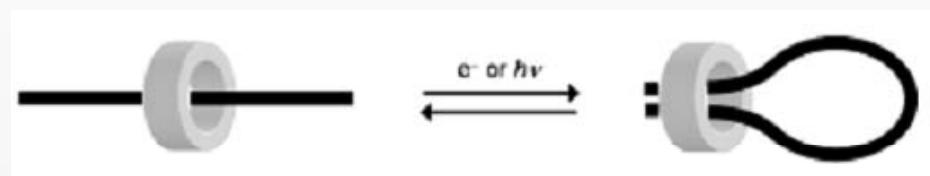
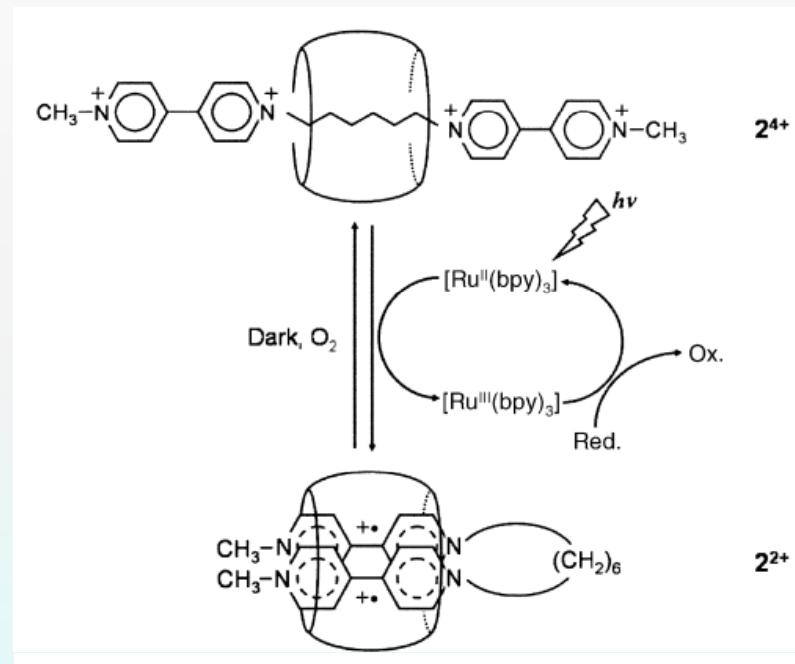
进展综述

- ❖ 基于功能分子、合成分子（非DNA和蛋白质）
- ❖ 基于DNA
- ❖ 基于蛋白质（结构生物学）
 - ❖ 动力蛋白
 - ❖ 功能蛋白复合体（酶、核糖体等）
 - ❖ H⁺泵

基于合成分子的分子机器

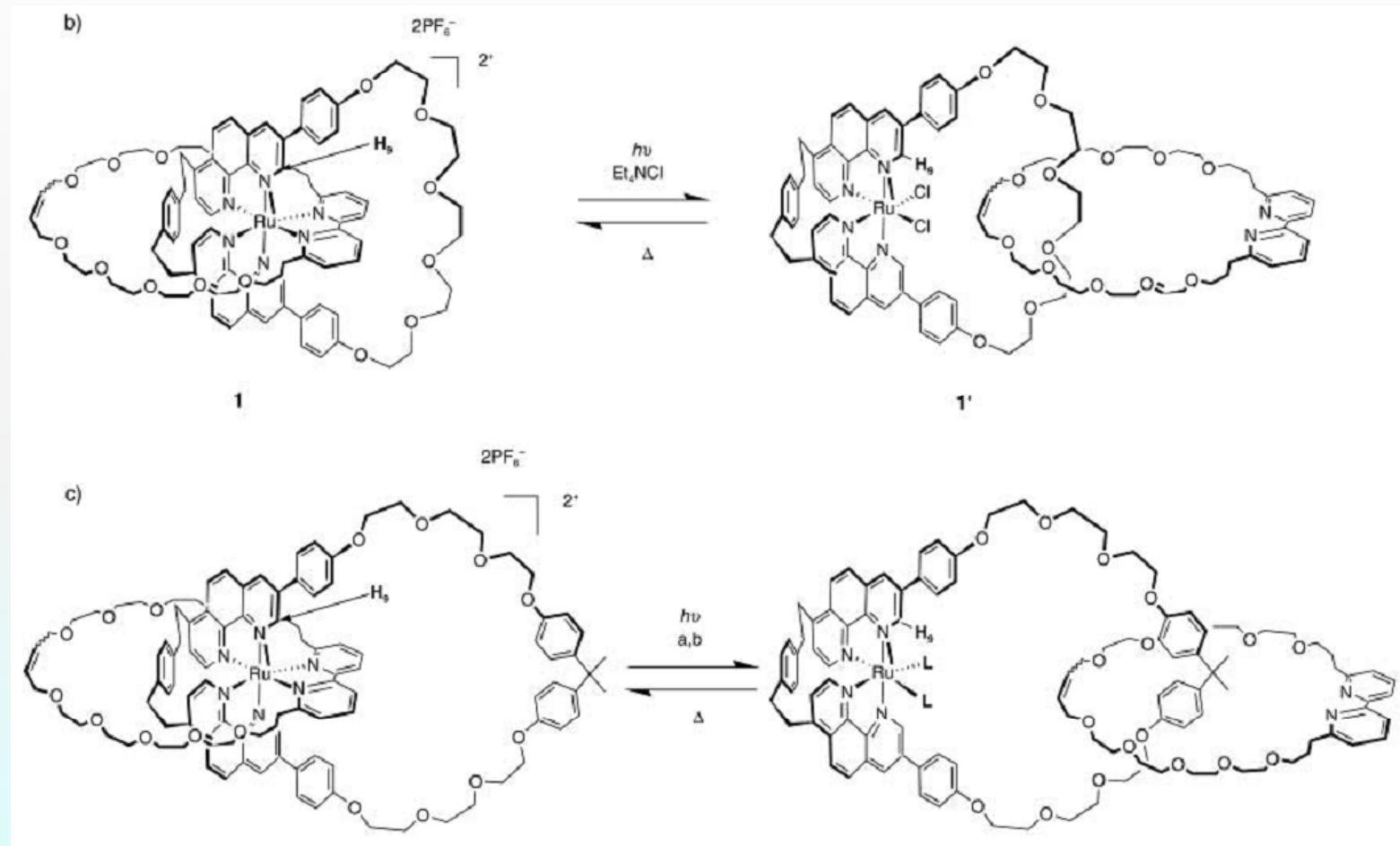


Reversible formation of a molecular loop driven by electrochemical and photochemical stimuli



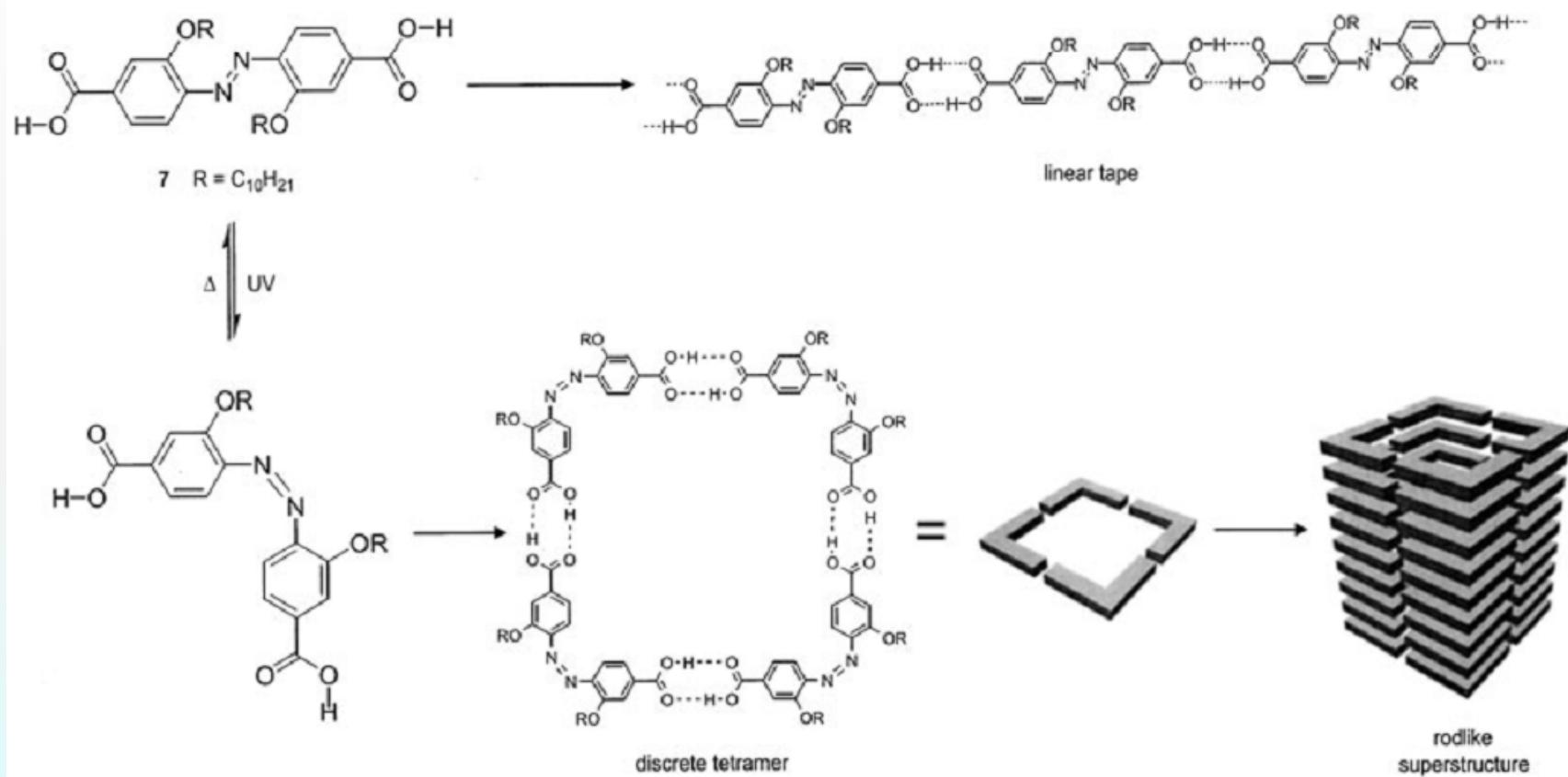
Jeon, W. S. et al *Angew Chem Int Edit* 42, 4097-4100, (2003).

Light-driven machine prototypes based on dissociative excited states



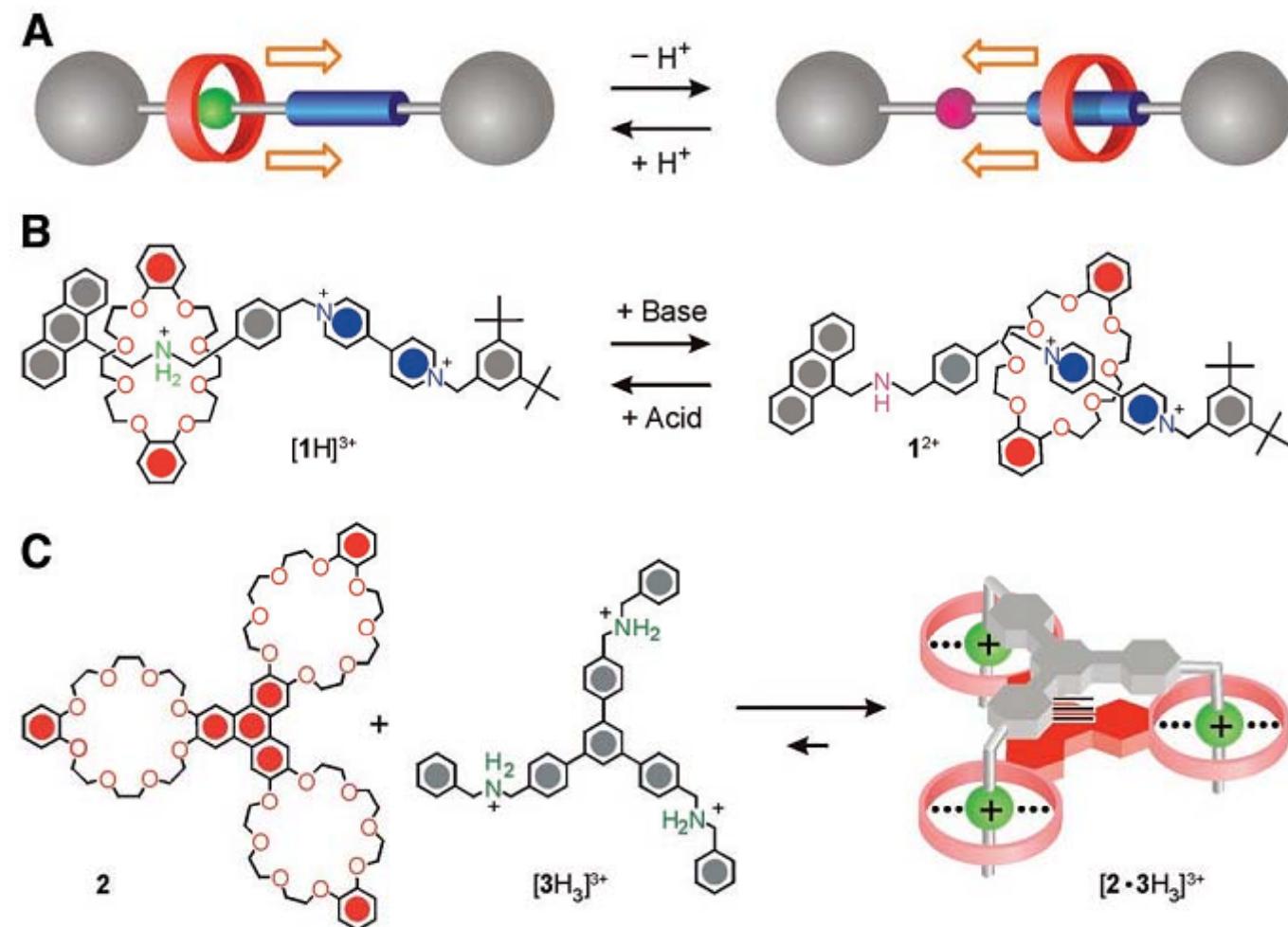
Mobian, P. et al. *Angew Chem Int Edit* 43, 2392-2395, (2004).

Photocontrollable self-assembly



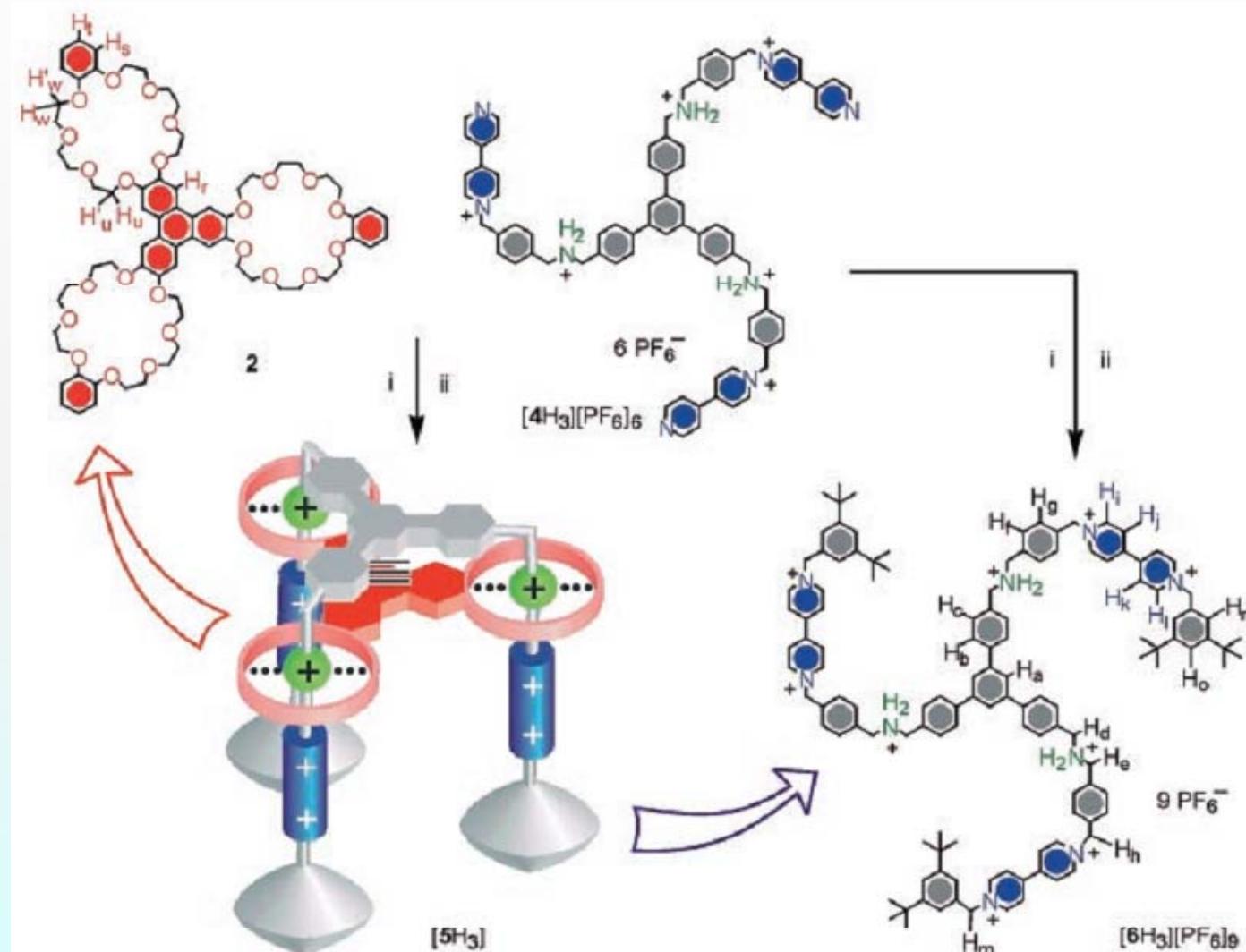
Yagai, S. et al. *Chem-Eur J* 11, 4054-4063, (2005).

**A molecular elevator*



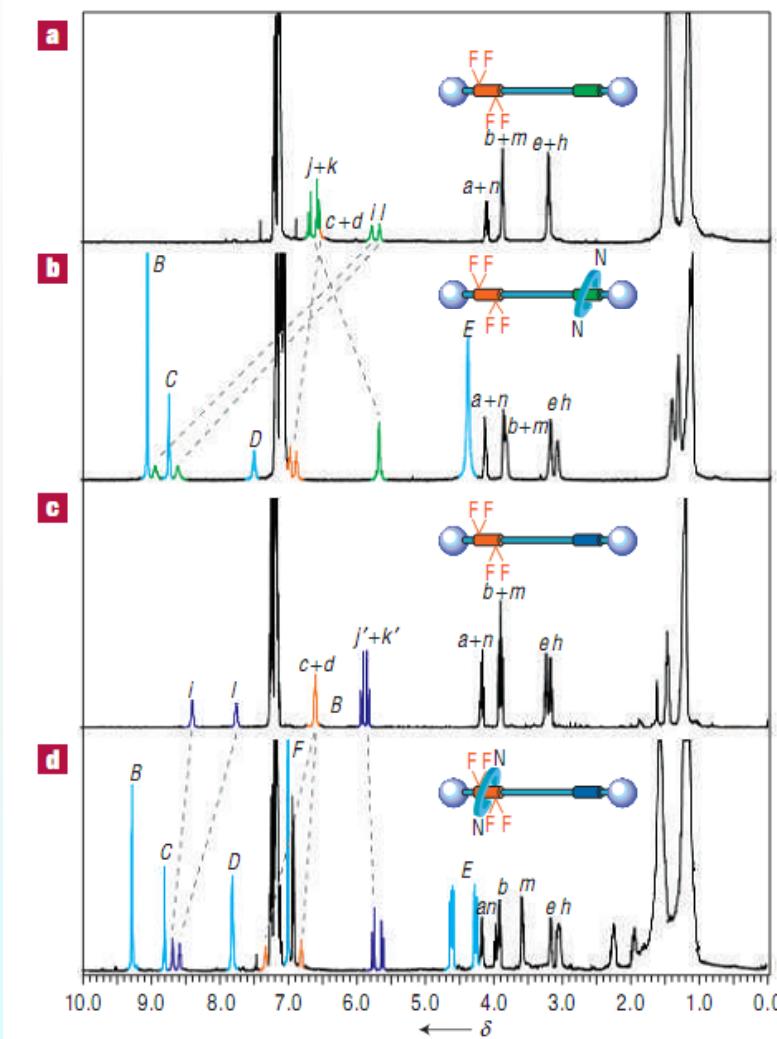
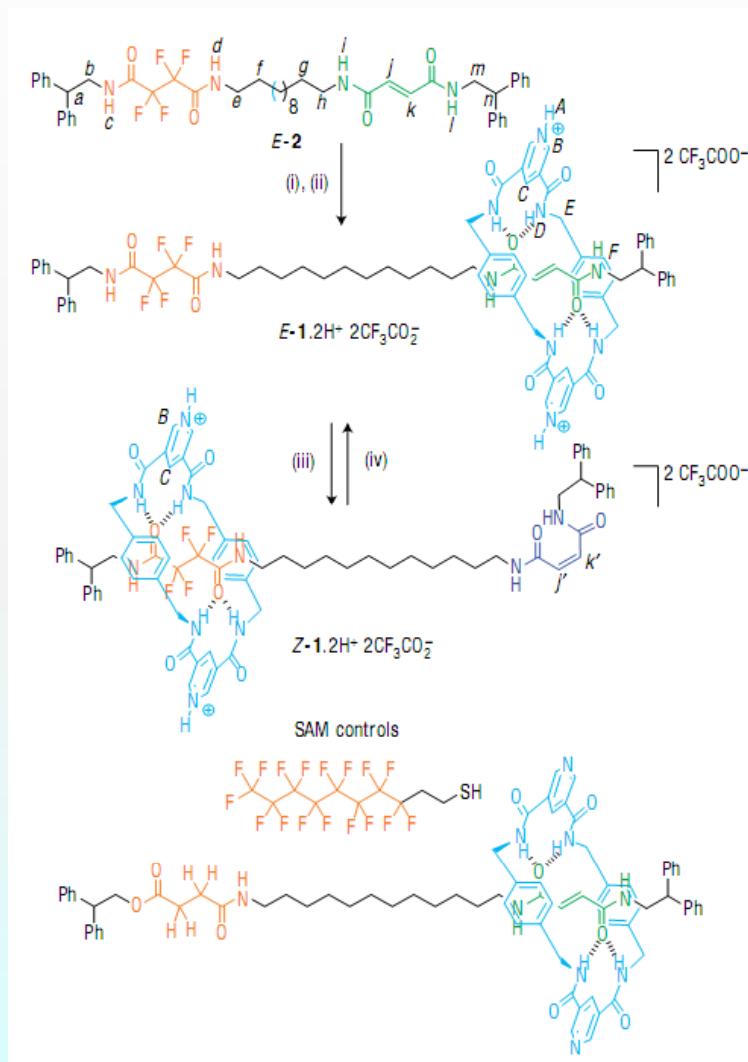
Badjic, J. D. et al. *Science* 303, 1845-1849, (2004).

A molecular elevator

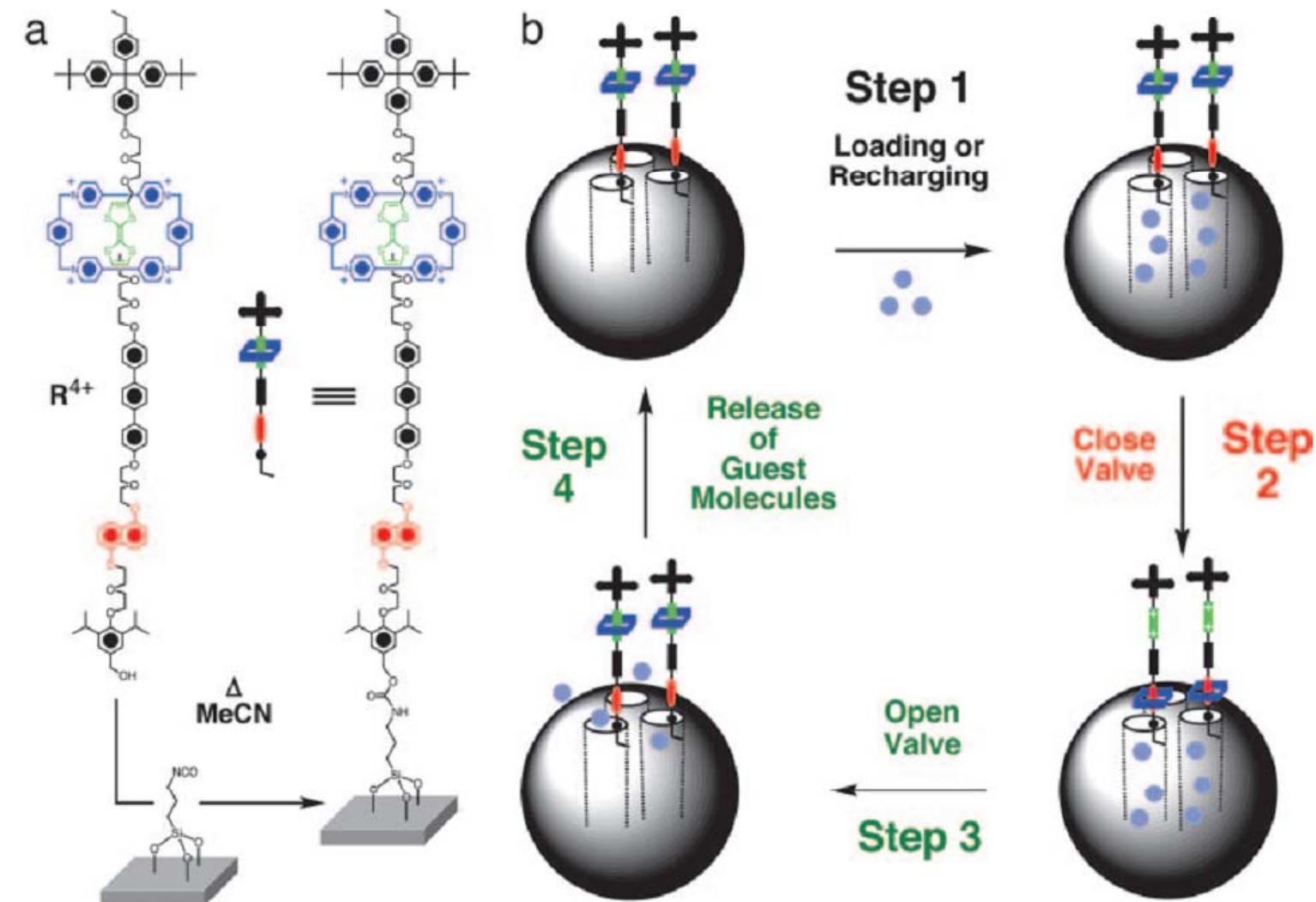


Badjic, J. D. et al. *Science* 303, 1845-1849, (2004).

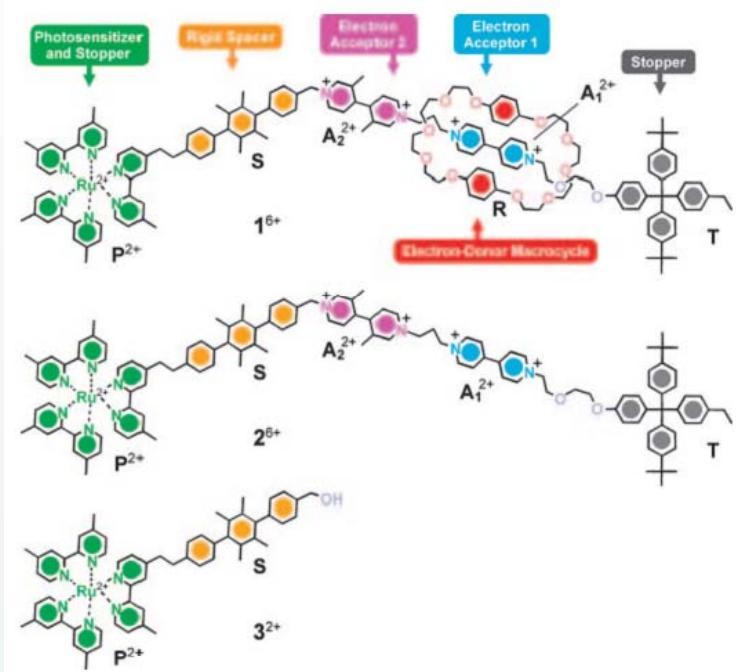
Macroscopic transport by synthetic molecular machines



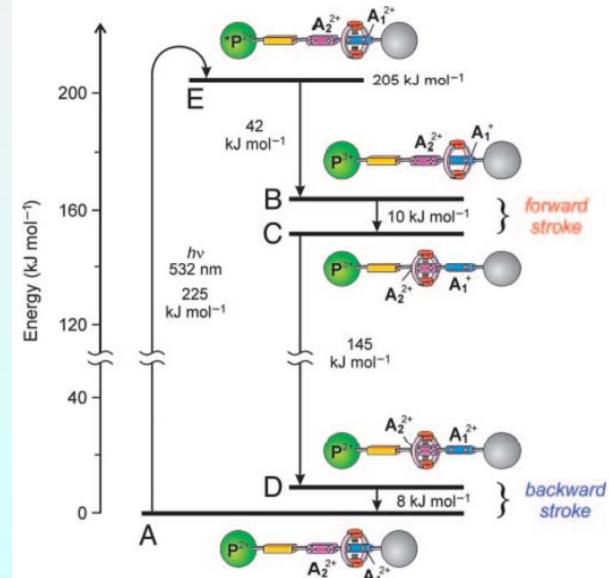
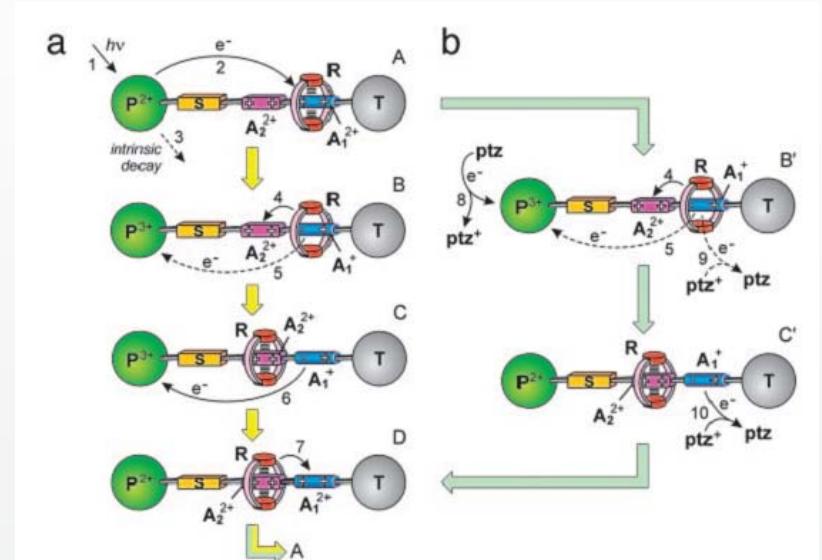
Berna, J. et al *Nat Mater* 4, 704-710, (2005).



Nguyen, T. D. et al. *A reversible molecular valve*. P Natl Acad Sci USA 102, 10029-10034, (2005).

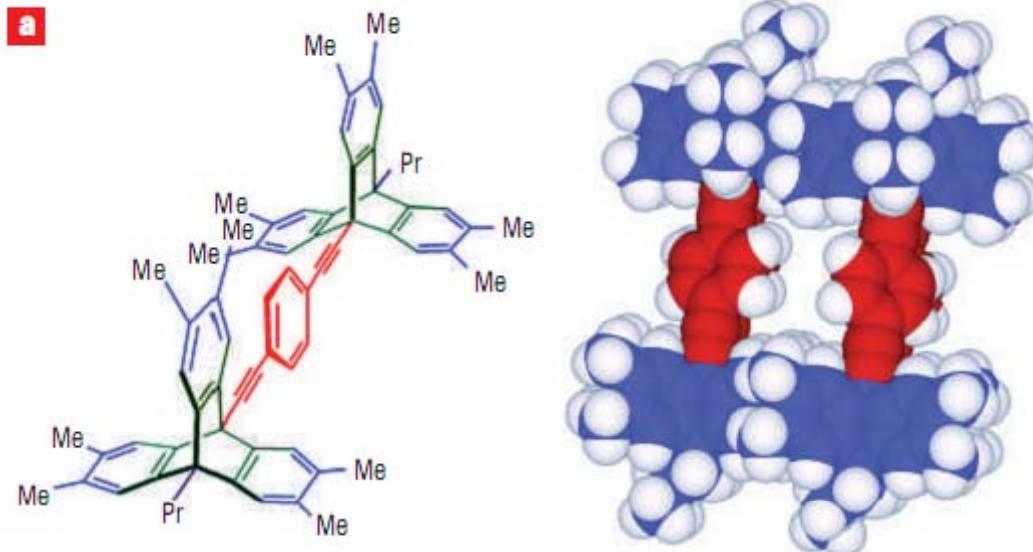


光驱动的纳米马达
Balzani, V. et al. *Autonomous artificial nanomotor powered by sunlight. P Natl Acad Sci USA 103, 1178-1183, (2006)*.

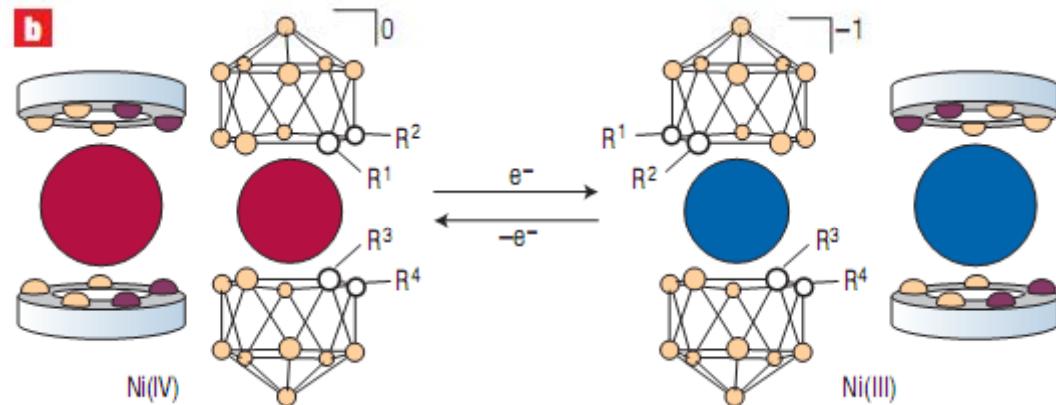


Making molecular machines work

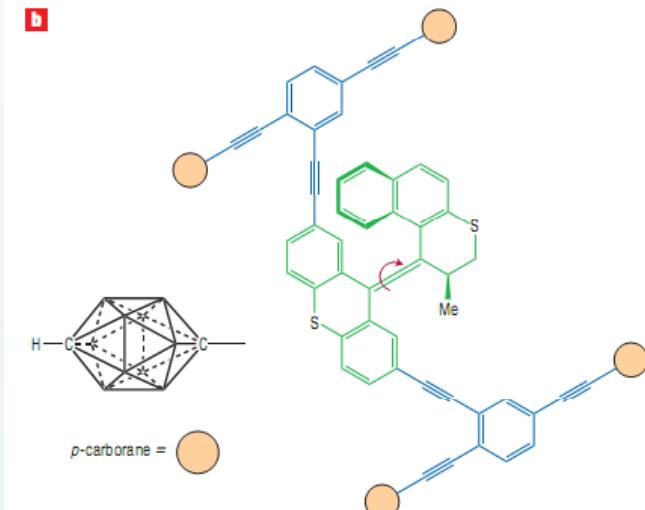
a



b

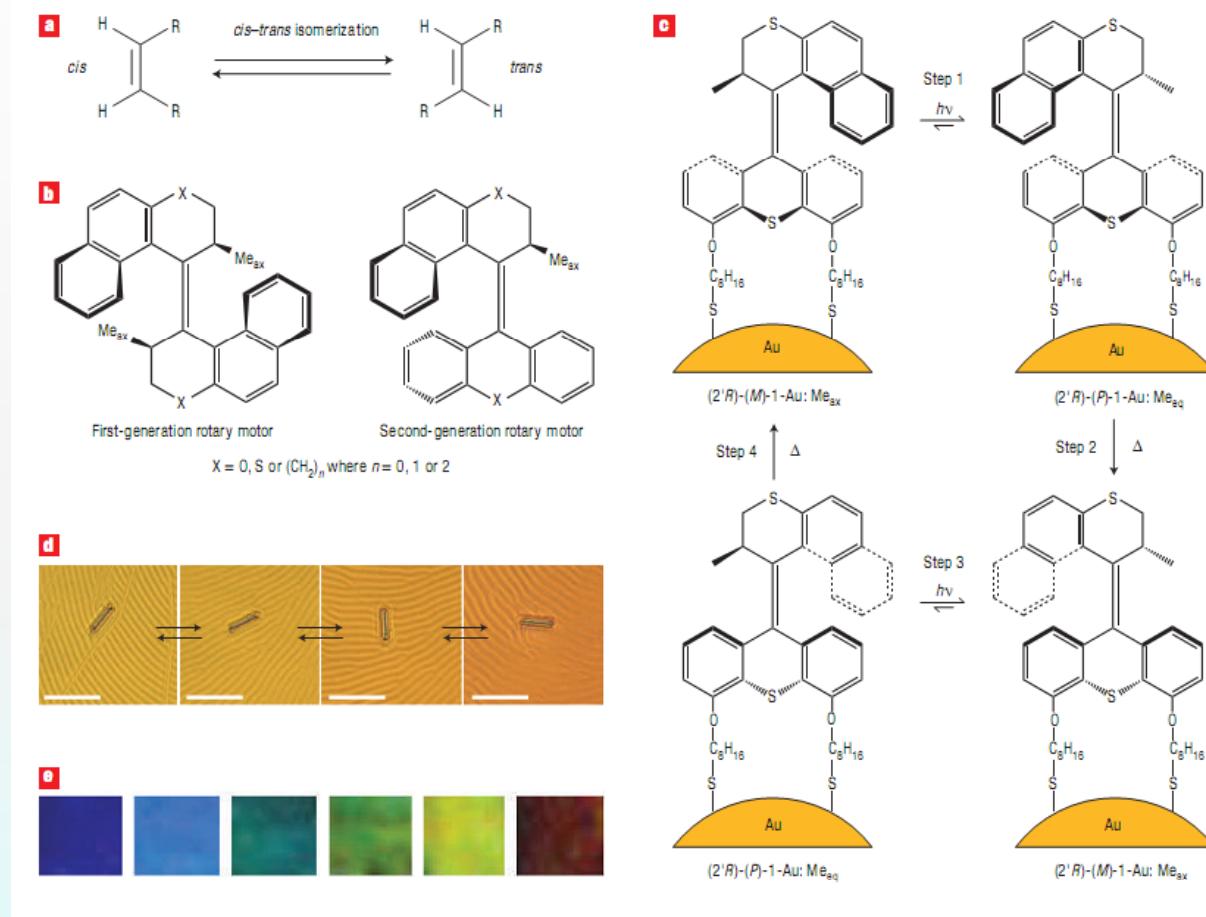


b



综述：Browne, W. R. et al. *Nat Nanotechnol* 1, 25-35, (2006).

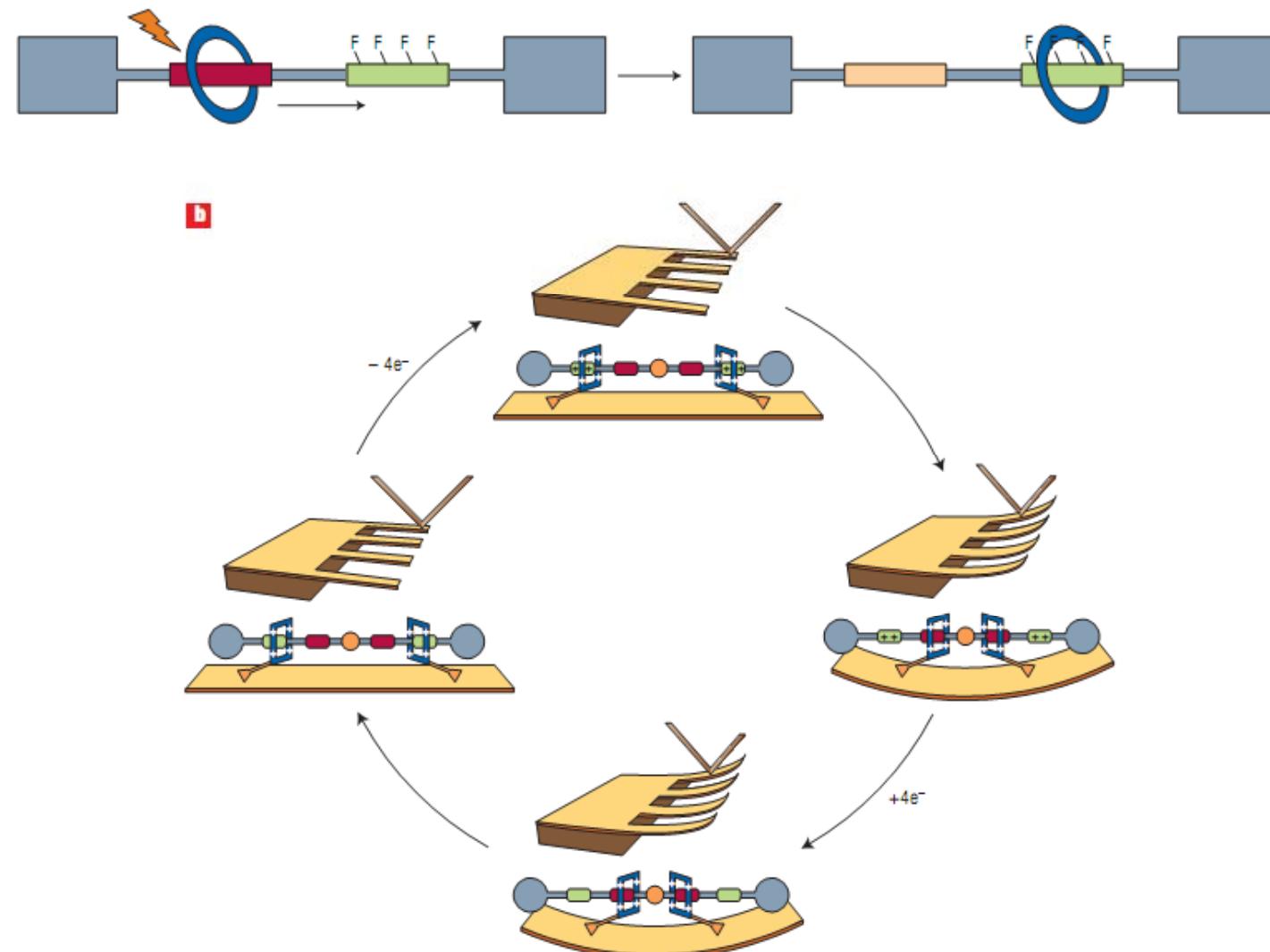
Making molecular machines work



综述: Browne, W. R. et al. *Nat Nanotechnol* 1, 25-35, (2006).

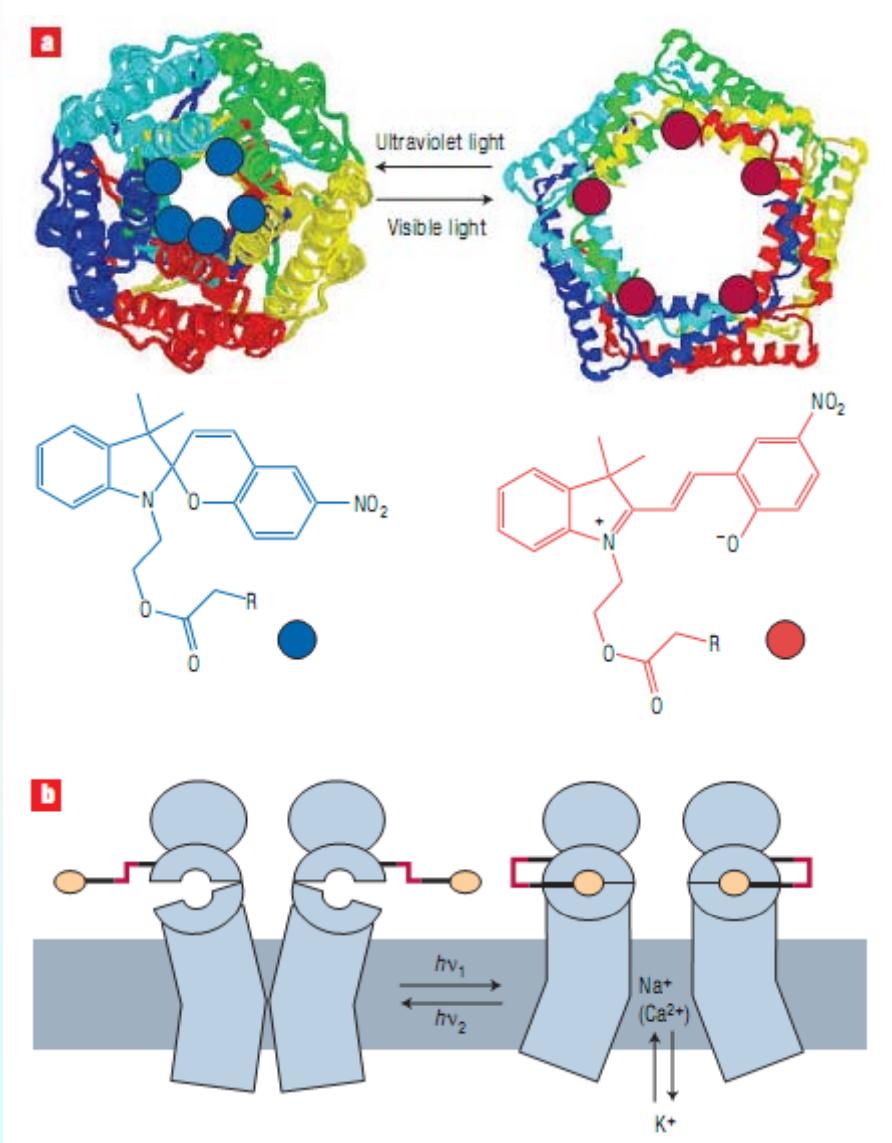
Eelkema, R. et al. *Nanomotor rotates microscale objects*. *Nature* 440, 163-163, (2006). (365nm 光驱动)

Making molecular machines work



综述：Browne, W. R. et al. *Nat Nanotechnol* 1, 25-35, (2006).

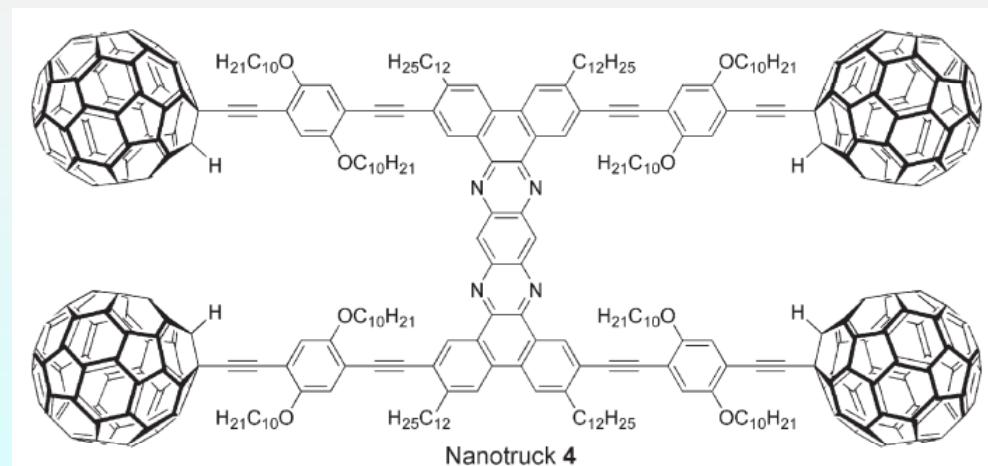
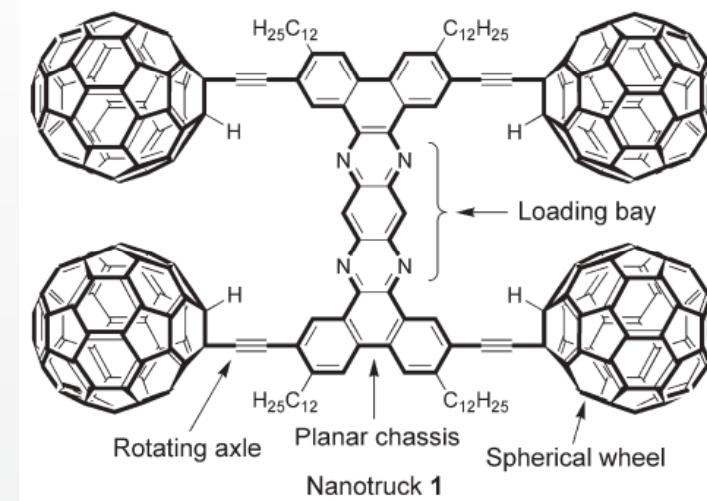
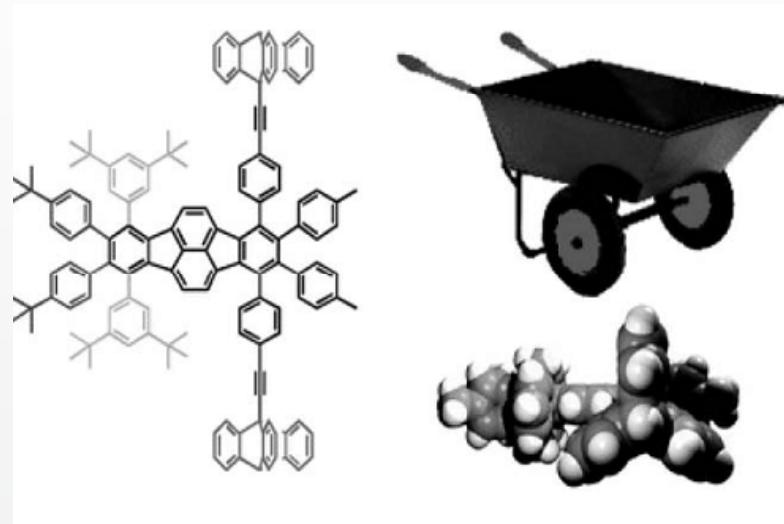
Making molecular machines work



两种阀门开关测策略

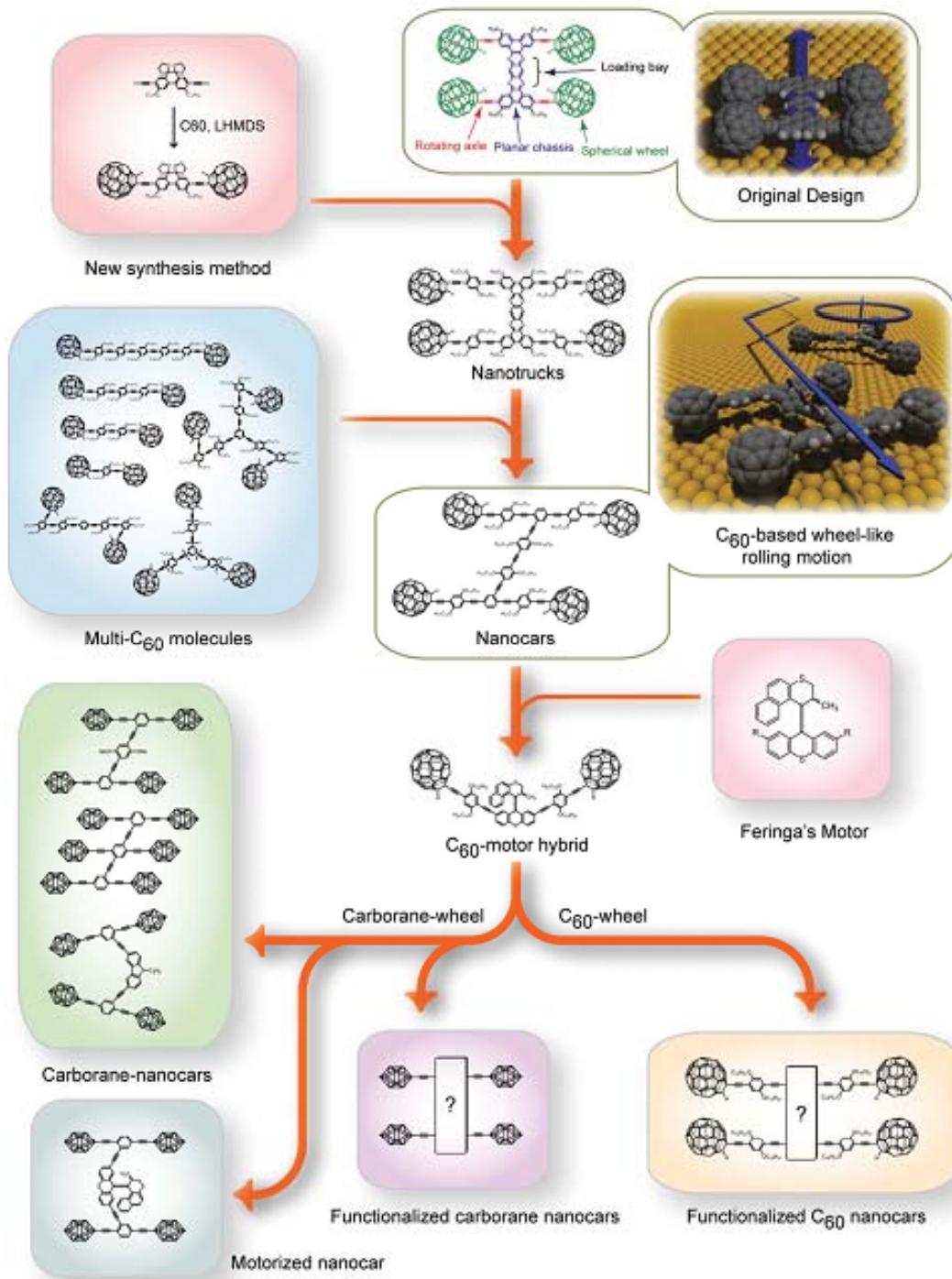
综述：Browne, W. R. et al. *Nat Nanotechnol* 1, 25-35, (2006).

Recent progress on nanovehicles.



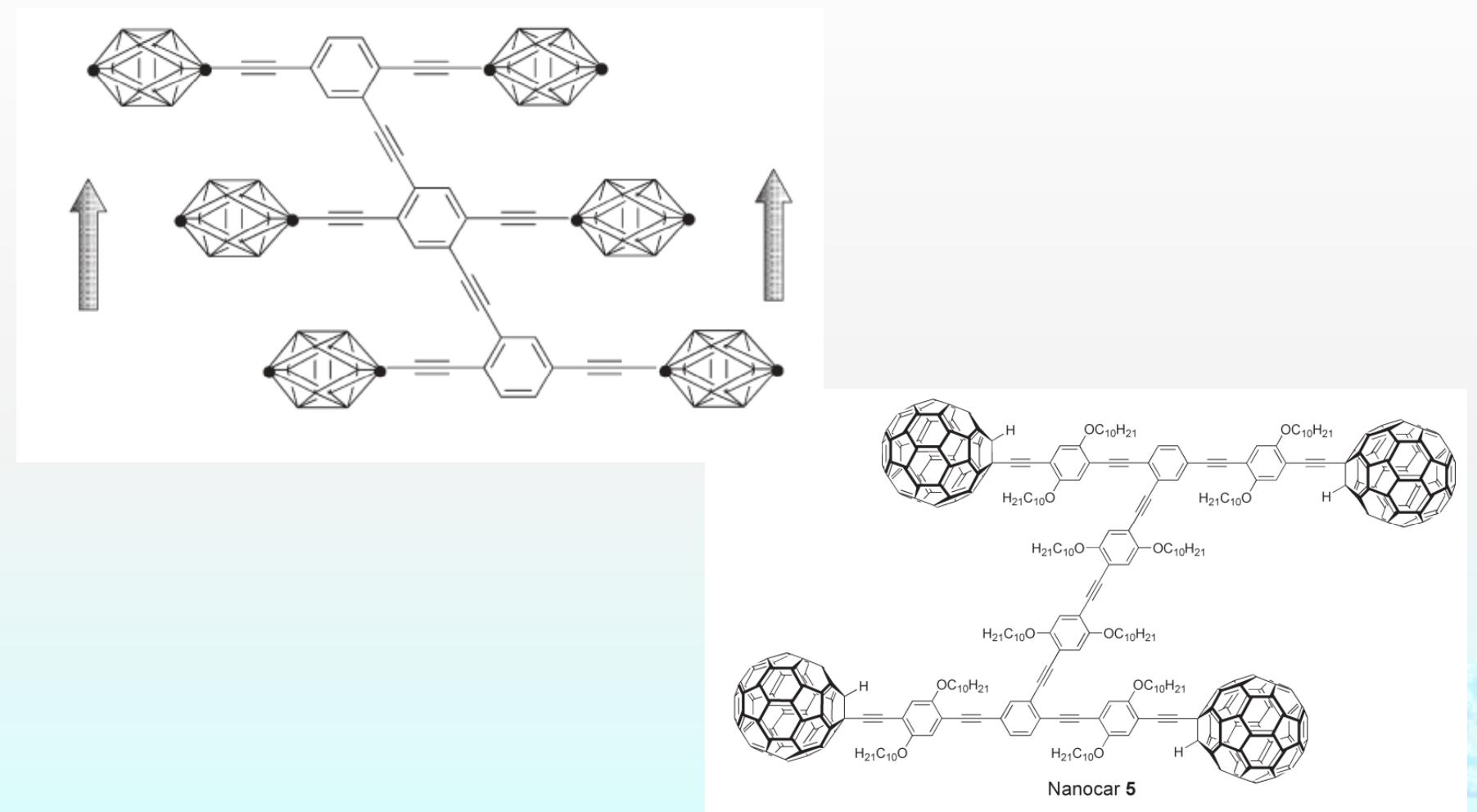
Shirai, Y. et al. *Chem Soc Rev* 35, 1043-1055, (2006).

Recent progress on nanovehicles.



Shirai, Y. et al. *Chem Soc Rev* 35, 1043-1055, (2006).

Recent progress on nanovehicles.

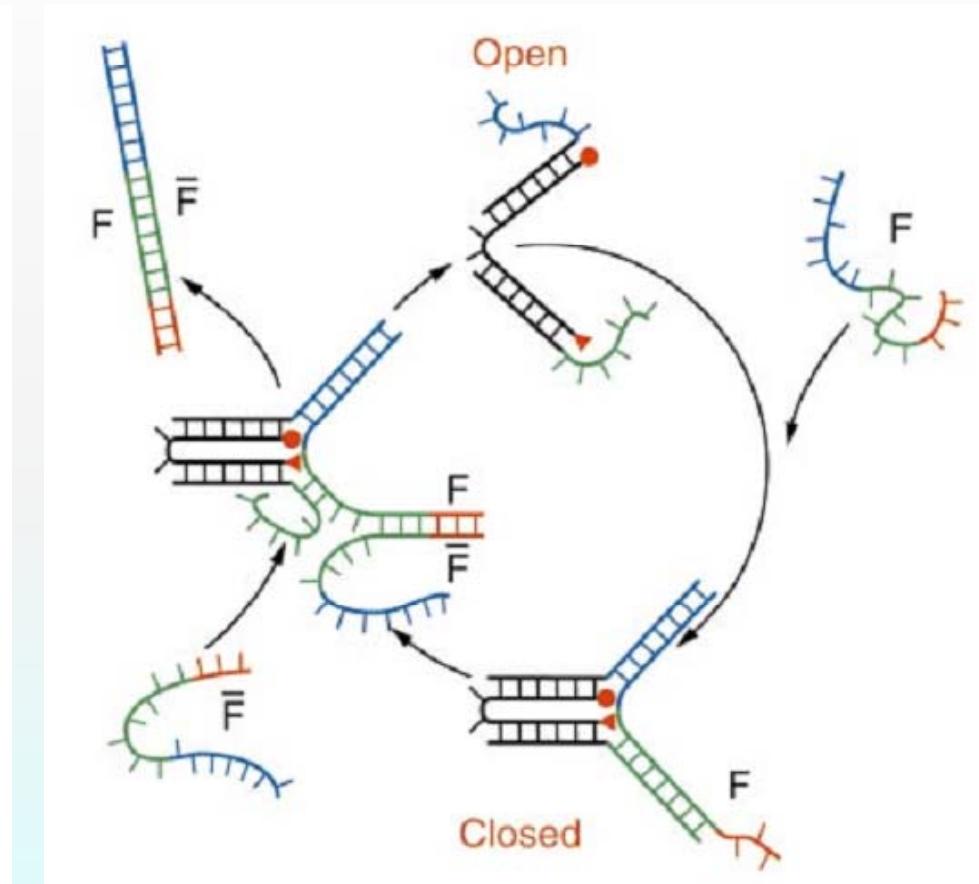
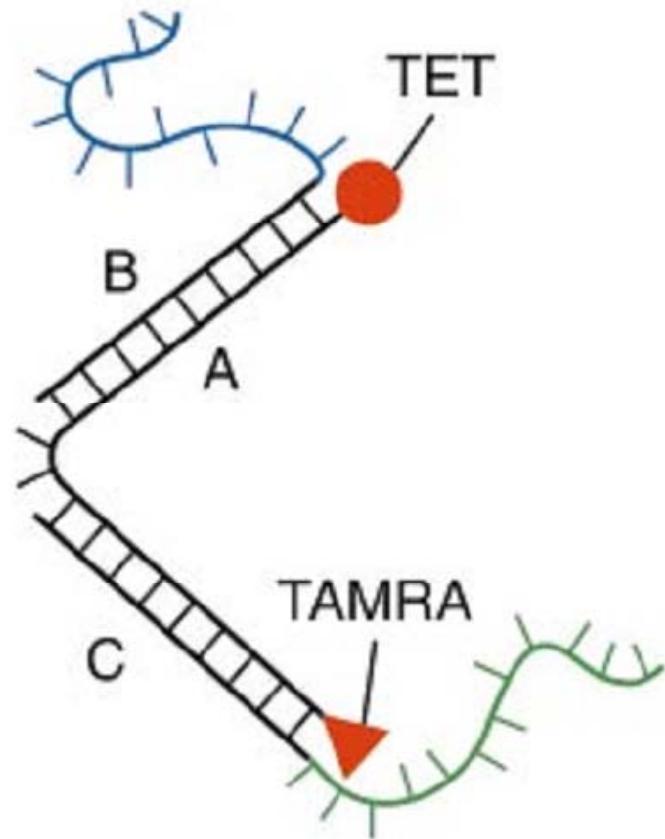


Shirai, Y. et al. *Chem Soc Rev* 35, 1043-1055, (2006).

基于DNA的分子机器

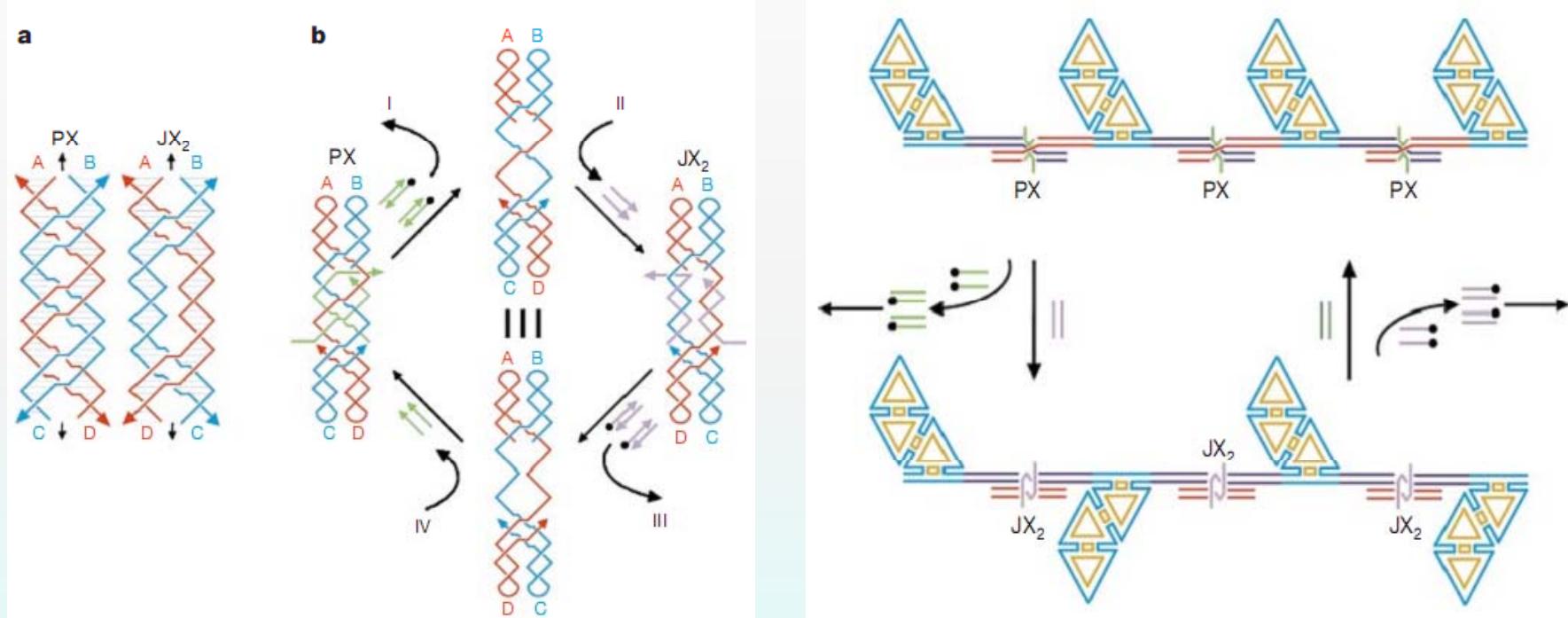


A DNA-fuelled molecular machine made of DNA



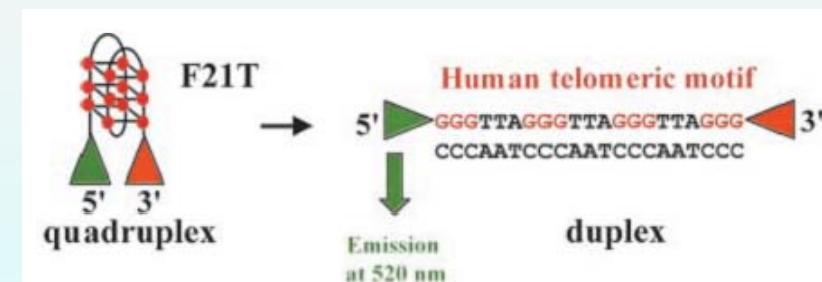
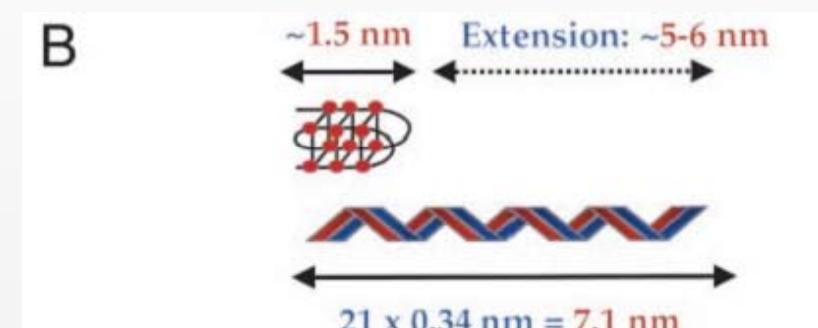
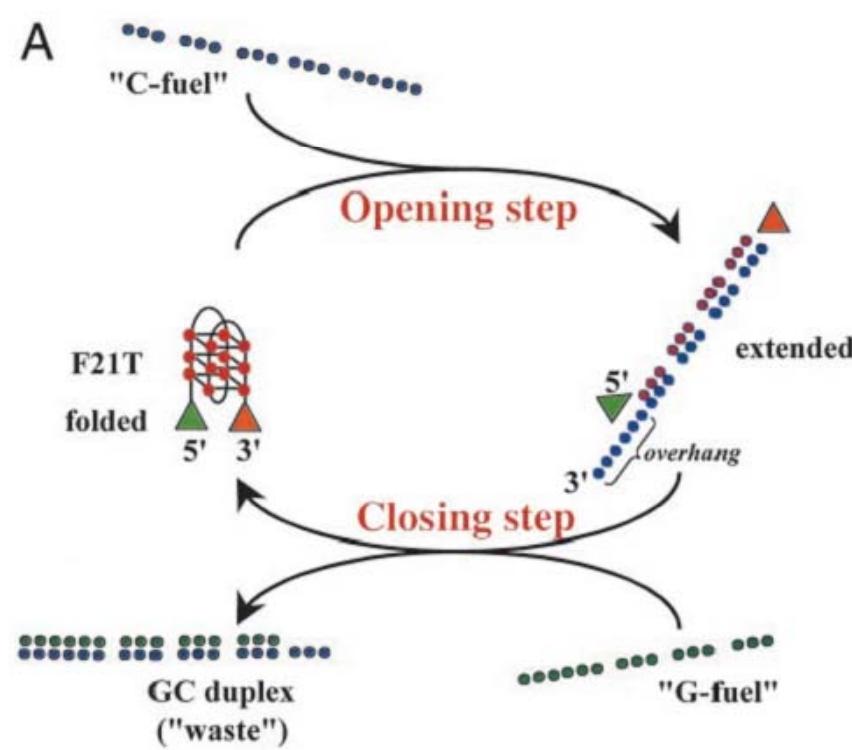
Yurke, B. et al. *A DNA-fuelled molecular machine made of DNA*. *Nature* 406, 605-608, (2000).

A robust DNA mechanical device controlled by hybridization topology.



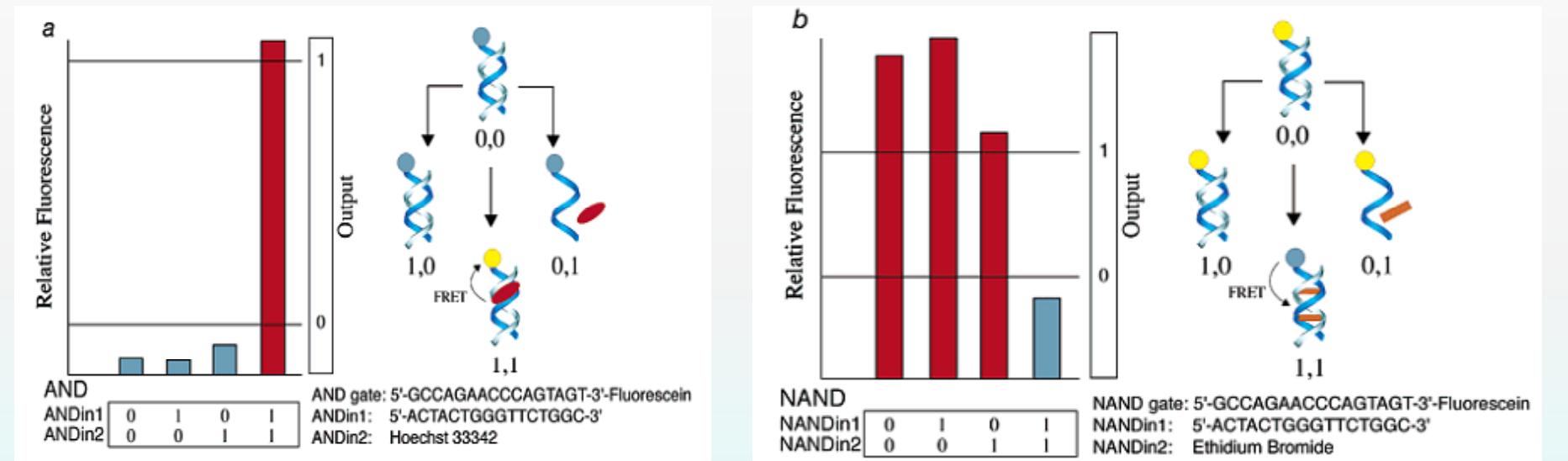
Yan, H. et al. Nature 415, 62-65, (2002).

DNA duplex-quadruplex exchange as the basis for a nanomolecular machine



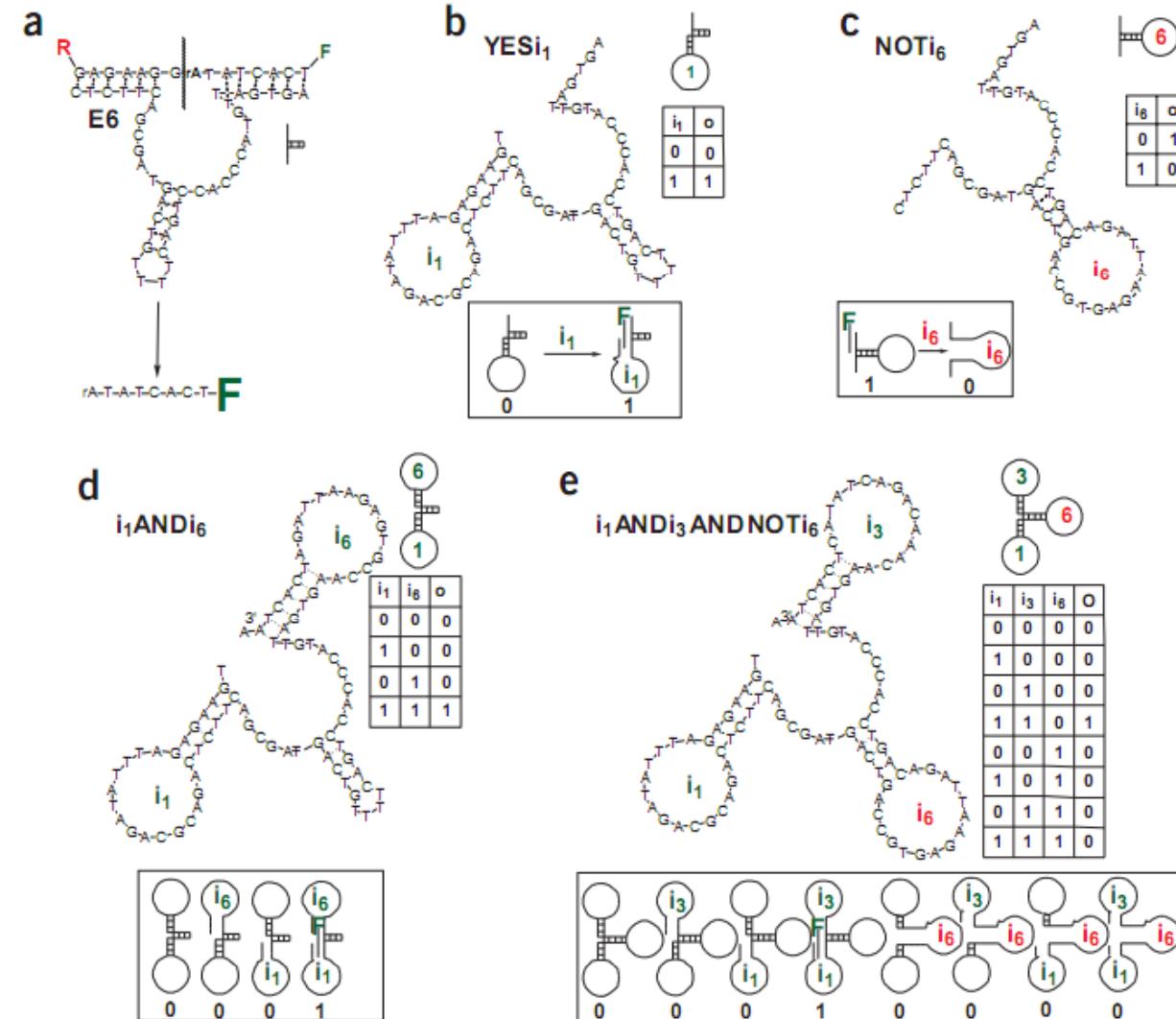
Alberti, P. et al.. *P Natl Acad Sci USA* 100, 1569-1573, (2003).

DNA-based photonic logic gates: AND, NAND, and INHIBIT



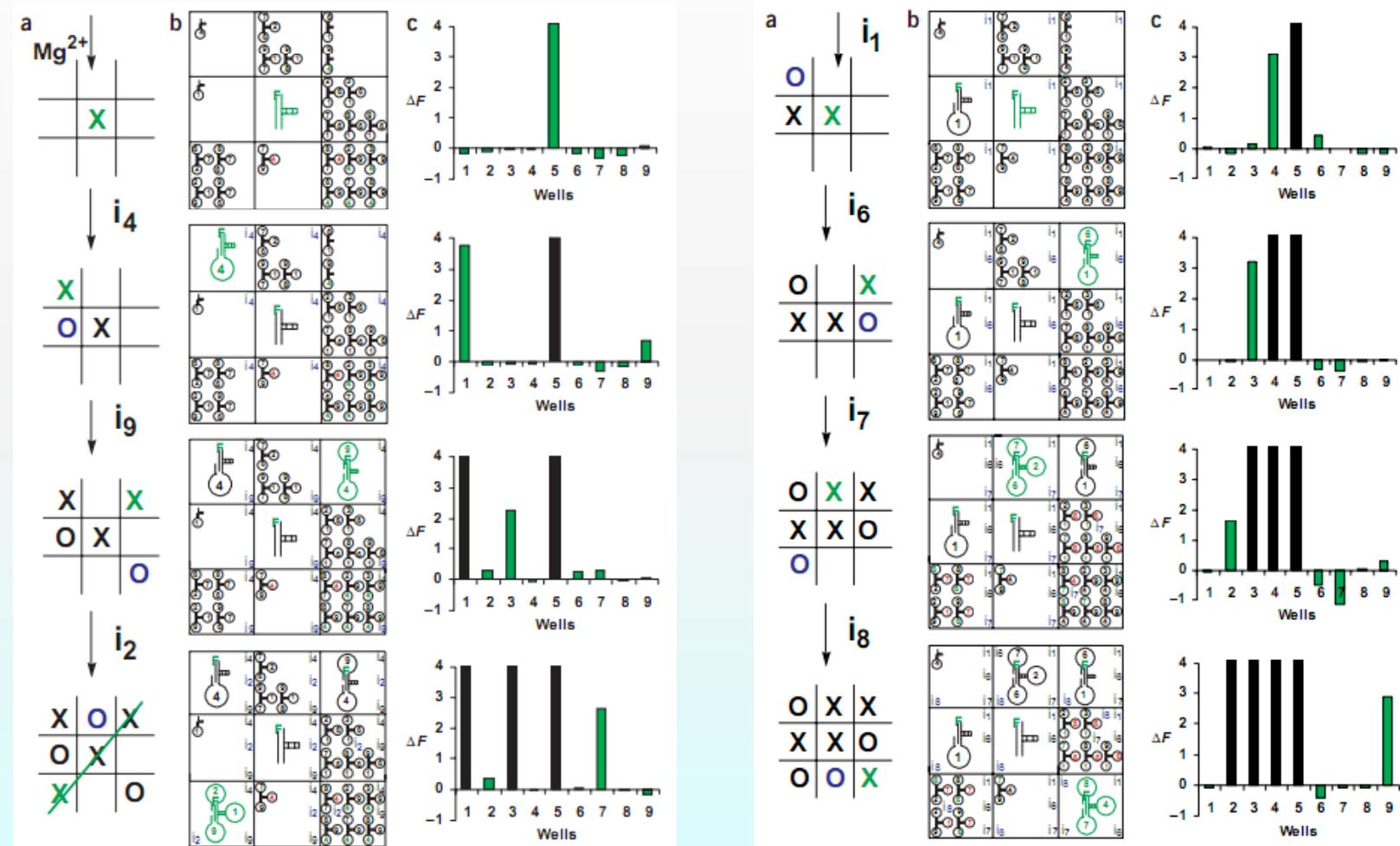
Saghatelian, A. et al. *J Am Chem Soc* 125, 346-347, (2003).

A deoxyribozyme-based molecular automaton (MAYA)



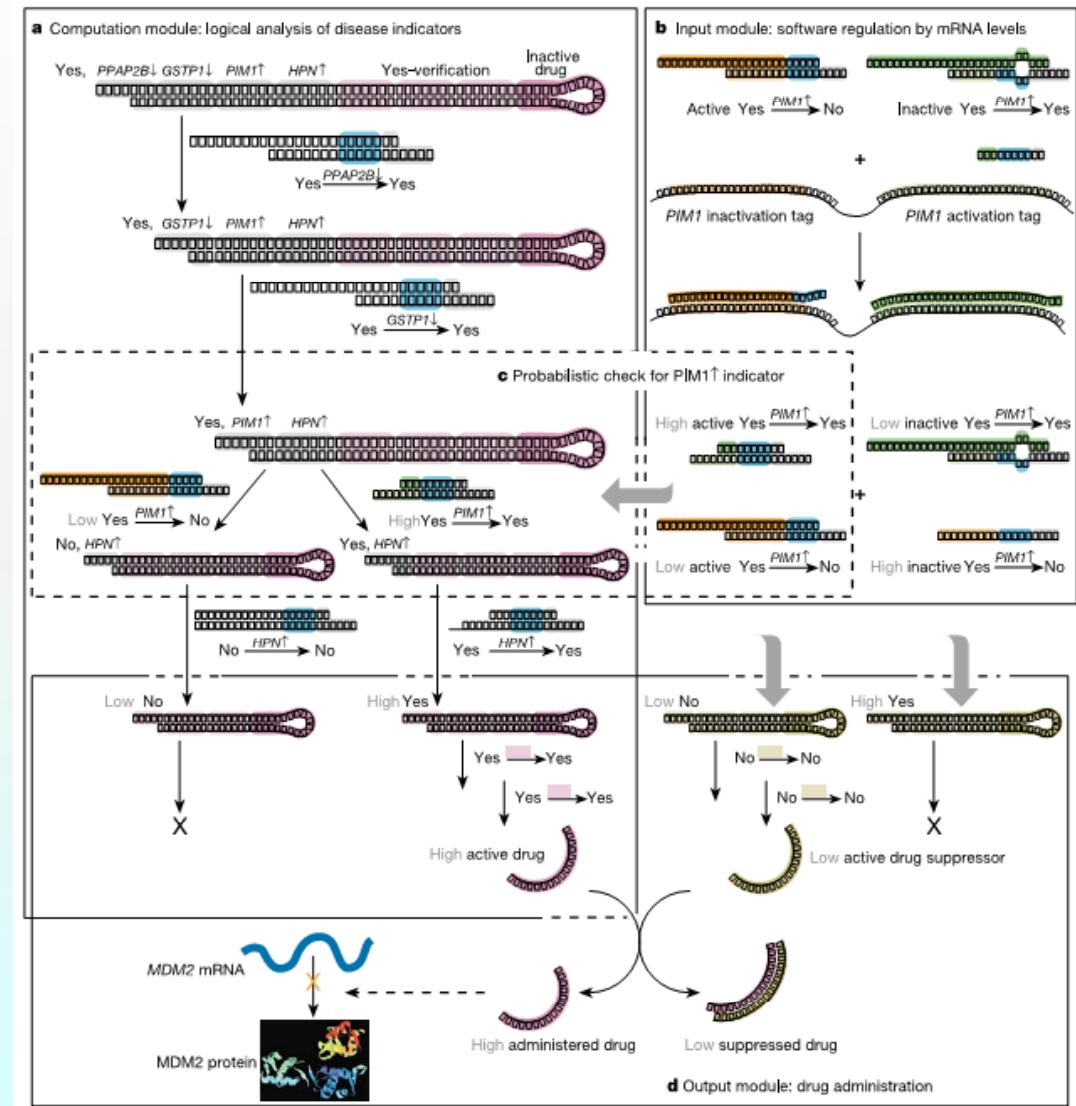
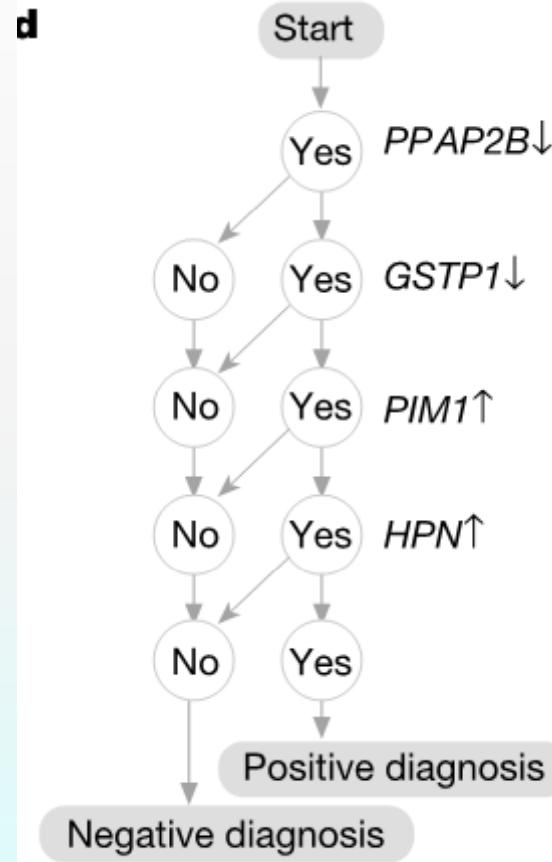
Stojanovic, M. N. et al. *Nat Biotechnol* 21, 1069-1074, (2003).

A deoxyribozyme-based molecular automaton (MAYA)



Stojanovic, M. N. et al. *Nat Biotechnol* 21, 1069-1074, (2003).

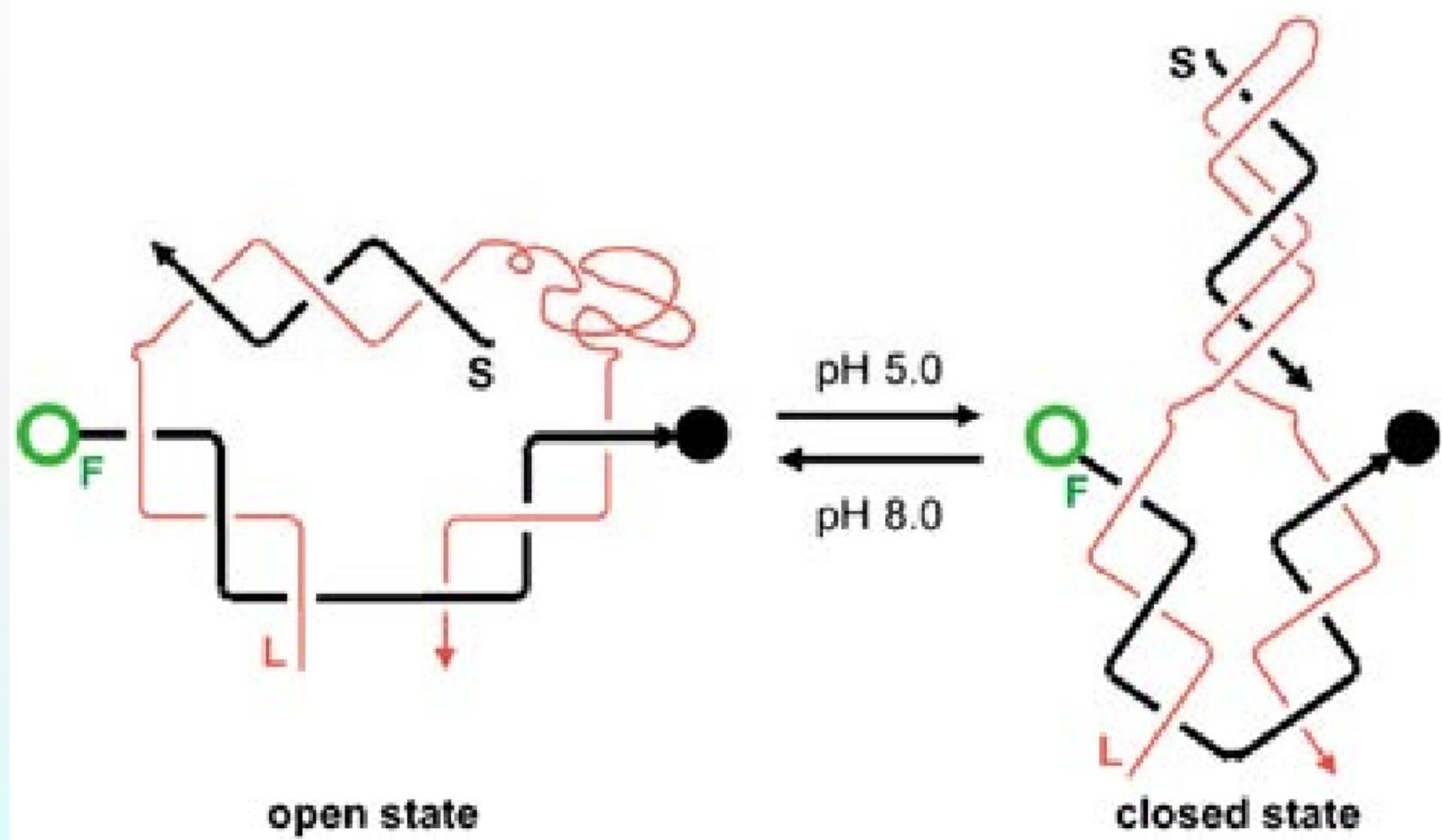
An autonomous molecular computer for logical control of gene expression.



Benenson, Y. et al.
Nature 429, 423-429, (2004).

Figure 2 Operation of the molecular computer. The complete sequences for all molecules (orange) displaces the 5' → 3' strand of the transition molecule Yes^{PIM1}No and dest

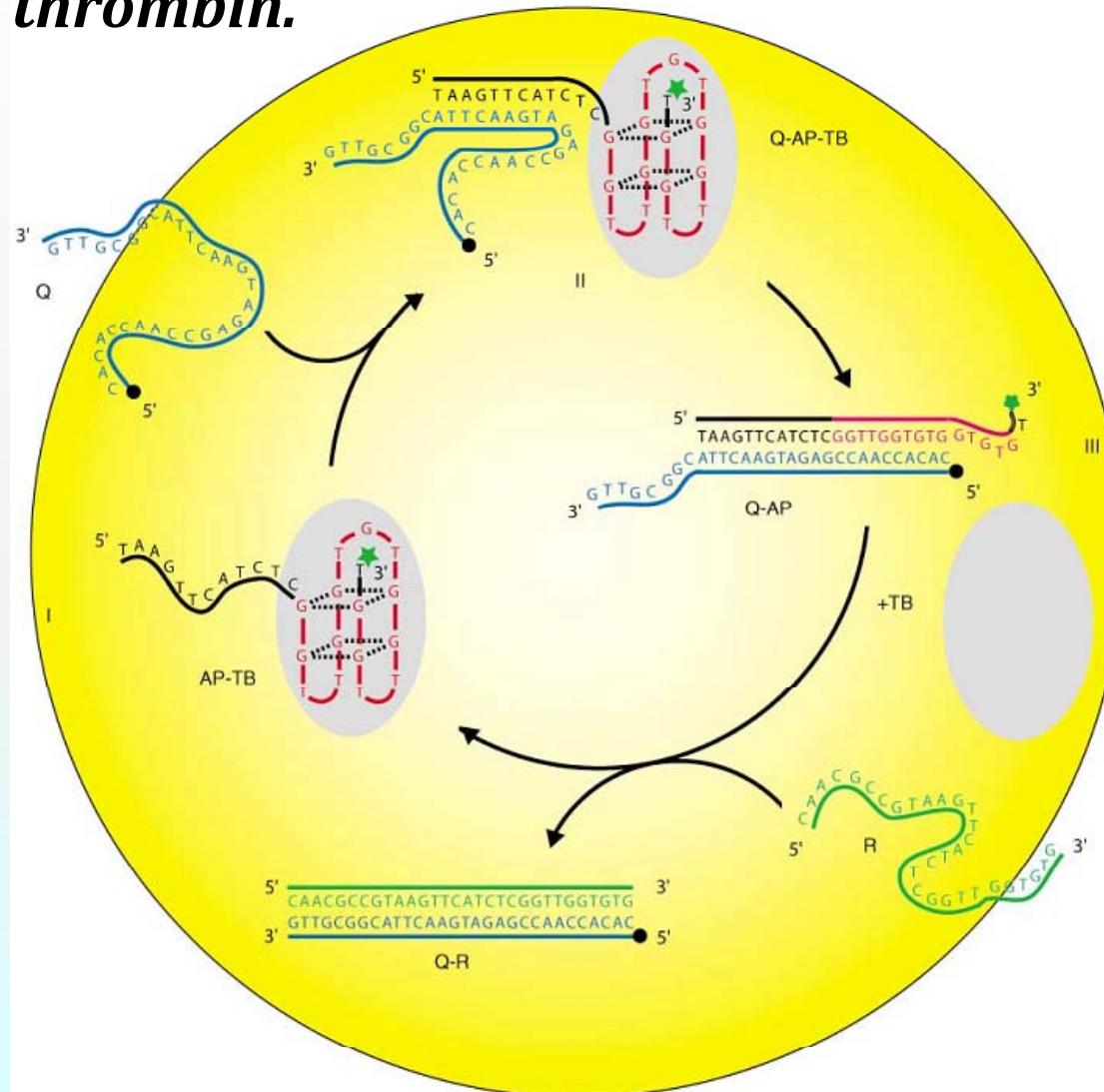
A DNA nanomachine based on a duplex-triplex transition



可以用于调控通道的开关

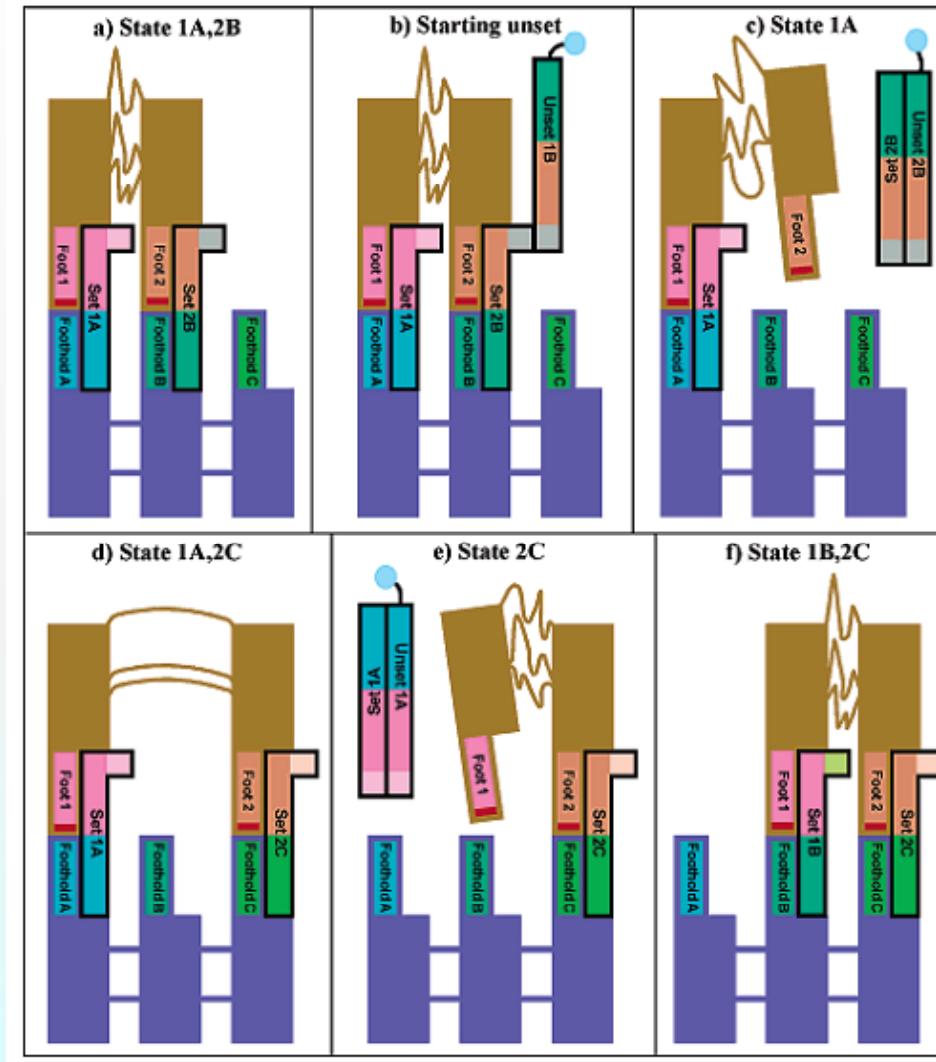
Chen, Y. et al. *Angew Chem Int Edit* 43, 5335-5338, (2004).

A DNA-based machine that can cyclically bind and release thrombin.



Dittmer, W. U. et al. *Angew Chem Int Edit* 43, 3550-3553, (2004).

A precisely controlled DNA biped walking device

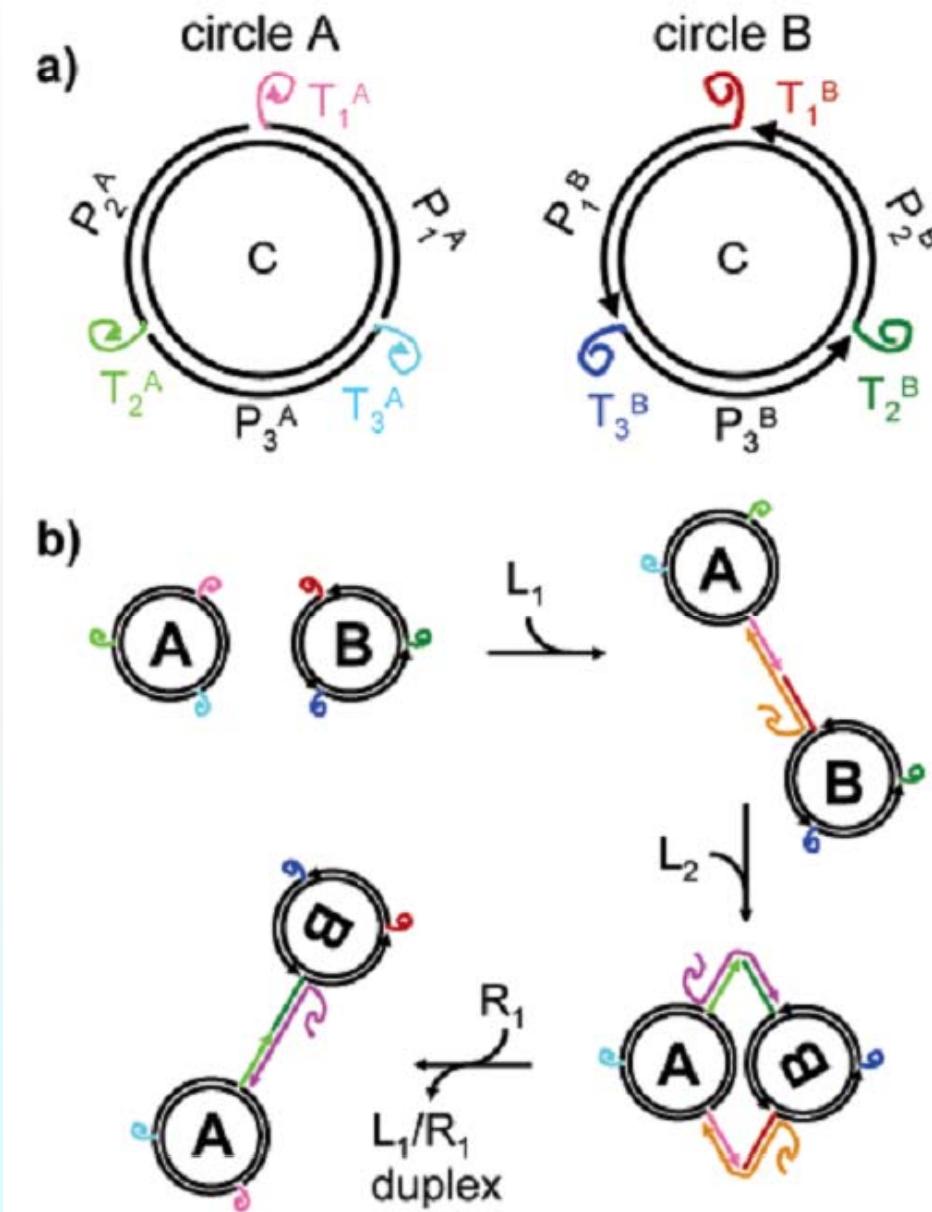


双足运动，开始出现运动的DNA器件

Sherman, W. B. et al. *Nano Lett* 4, 1203-1207, (2004).

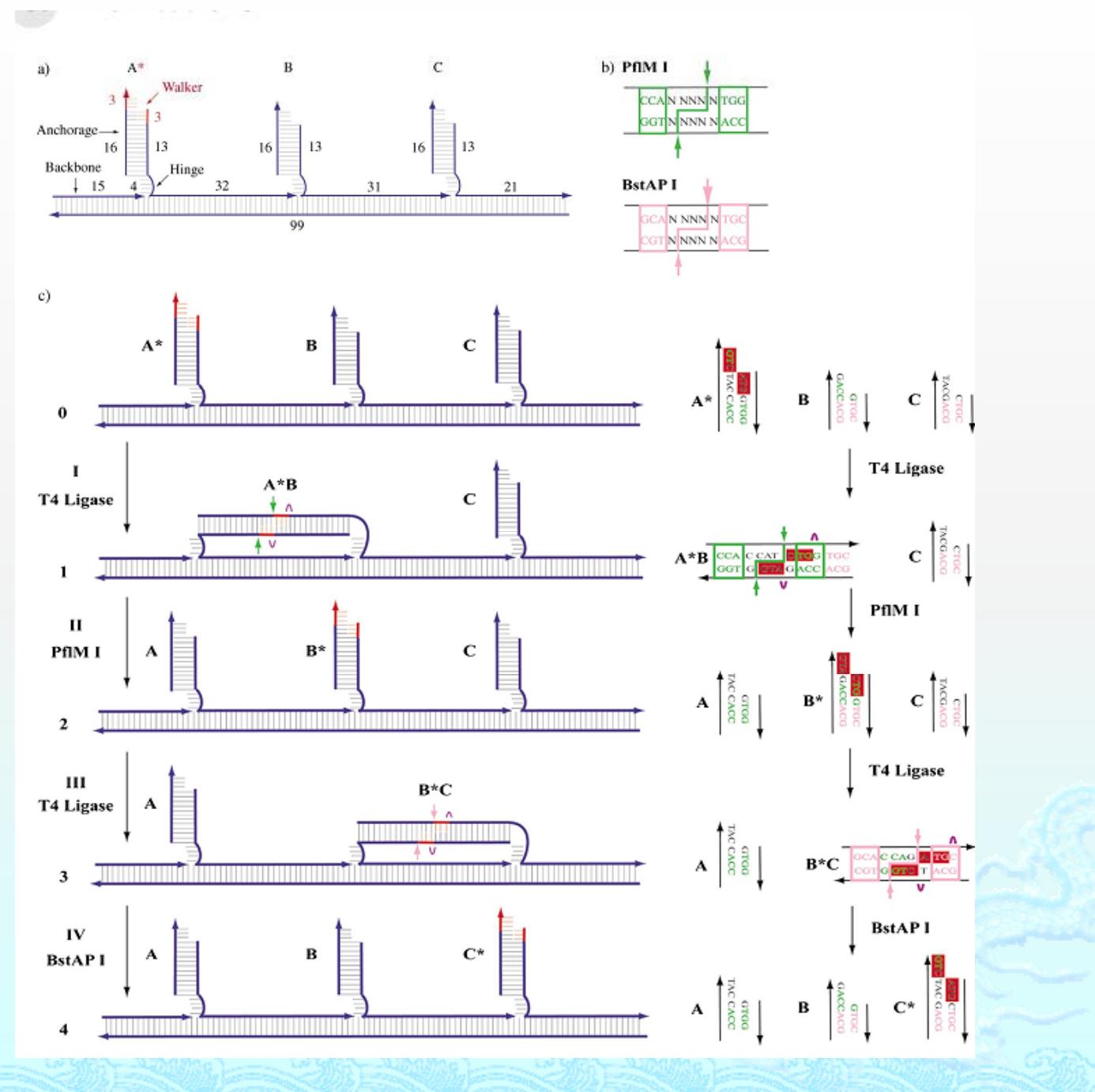
Molecular gears

联动的分子齿轮



Tian, Y. et al. *J Am Chem Soc*
126, 11410-11411, (2004).

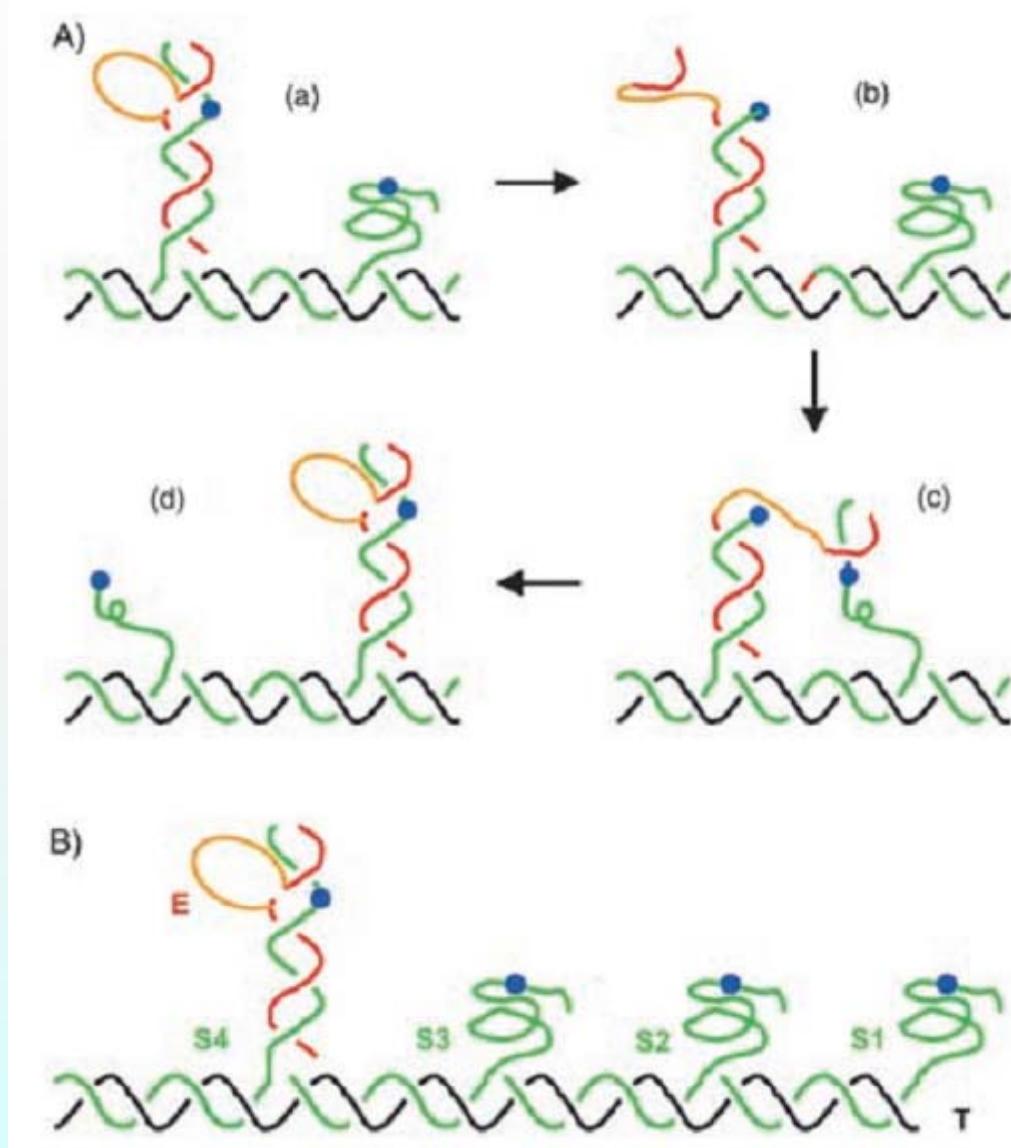
A unidirectional DNA walker that moves autonomously along a track.



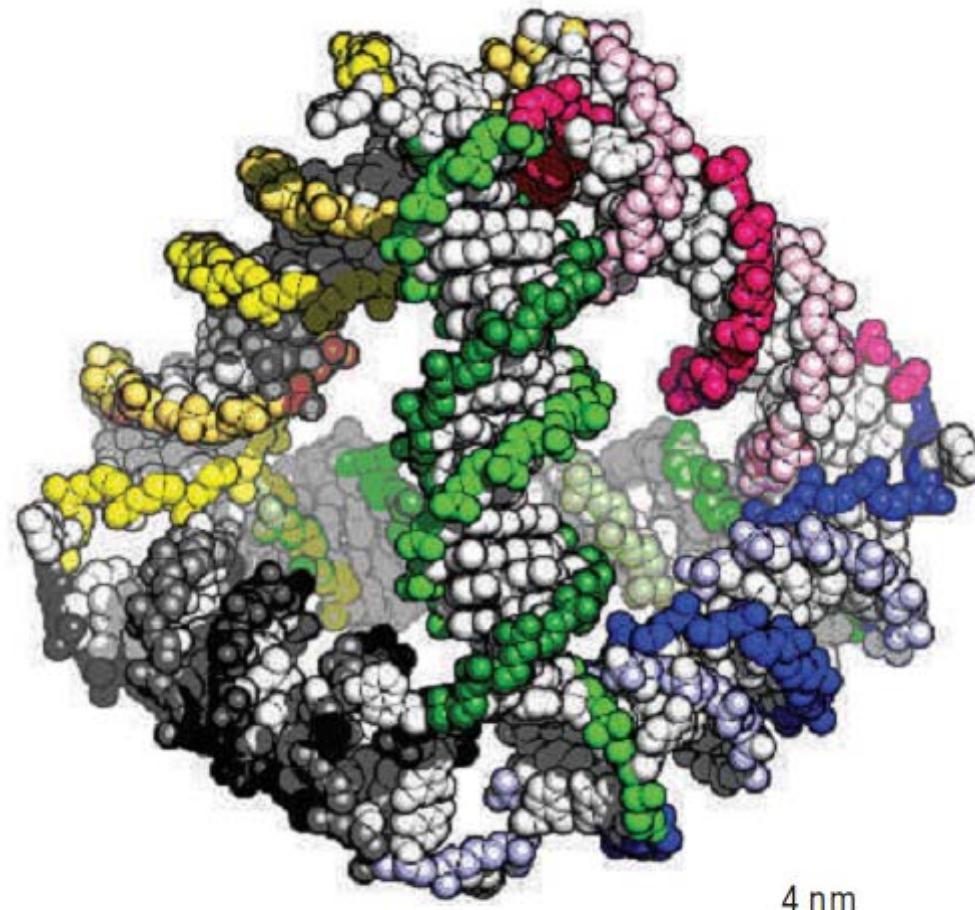
Yin, P. et al. *Angew Chem Int Edit* 43, 4906-4911, (2004).

**Molecular devices - A
DNAzyme that walks
processively and
autonomously along
a one-dimensional
track.**

Tian, Y. et al. *Angew Chem Int Edit* 44, 4355-4358, (2005).

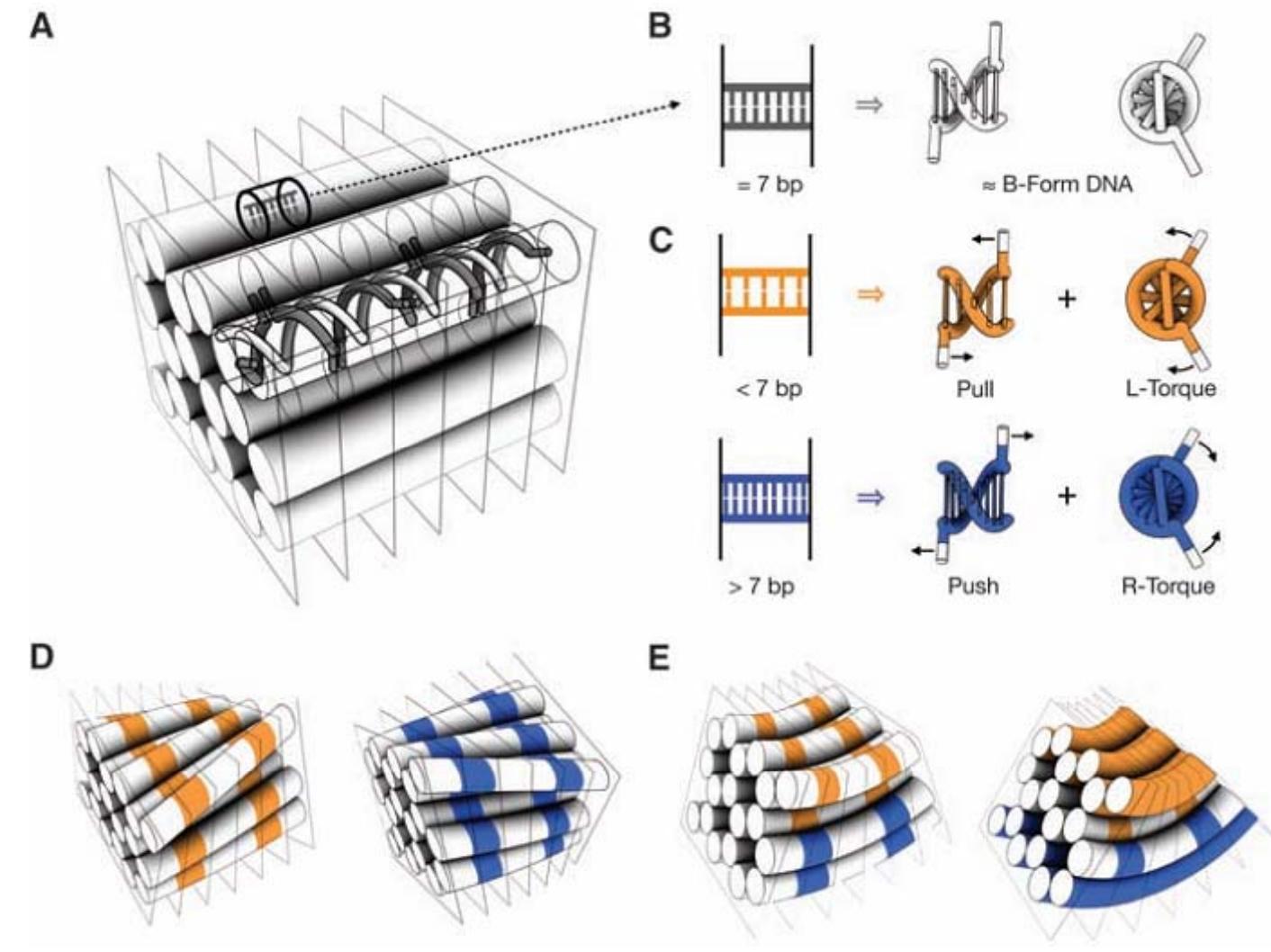


DNA nanomachines.



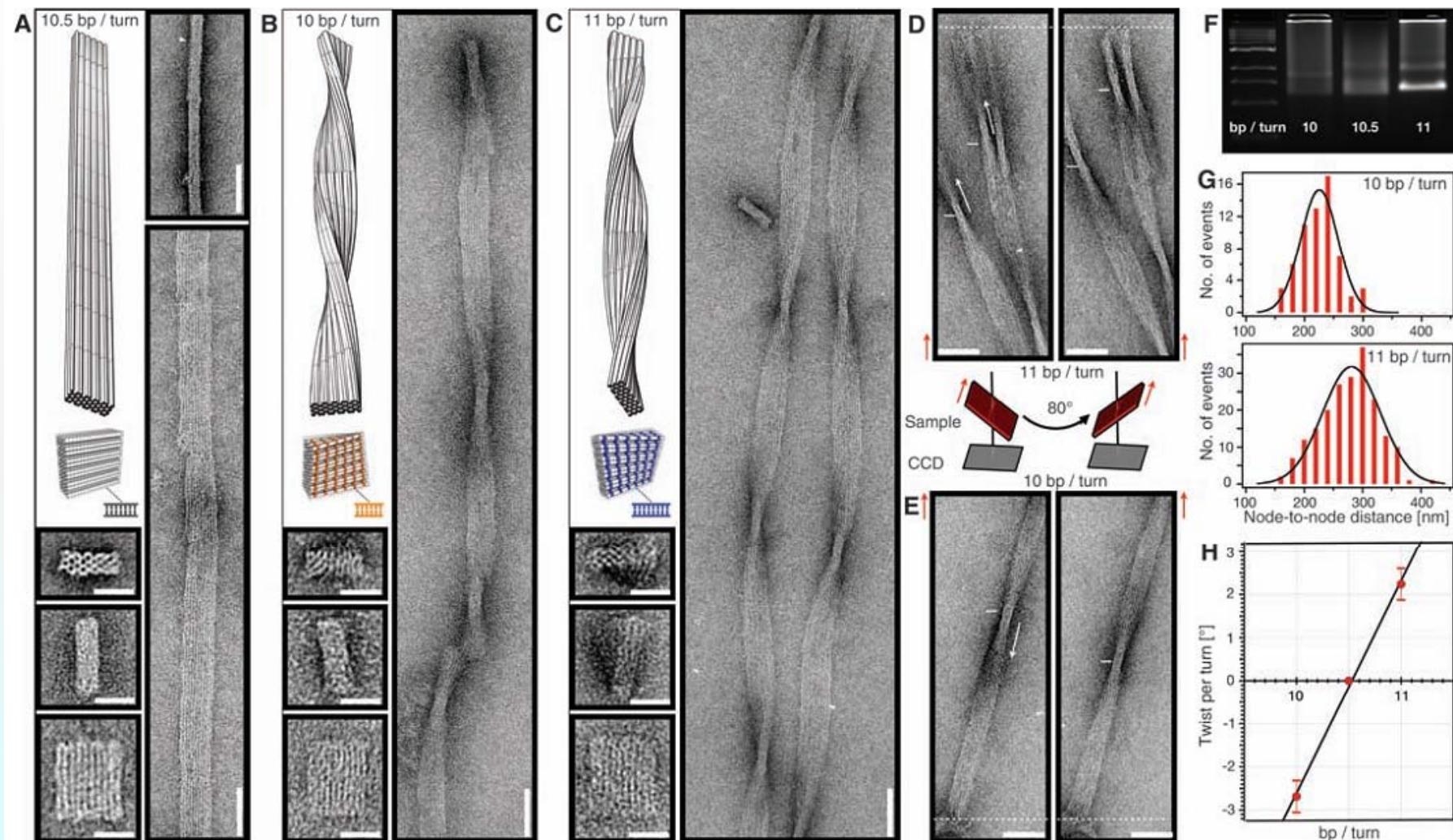
综述: Bath, J. et al *Nat Nanotechnol* 2, 275-284, (2007).

Folding DNA into Twisted and Curved Nanoscale Shapes



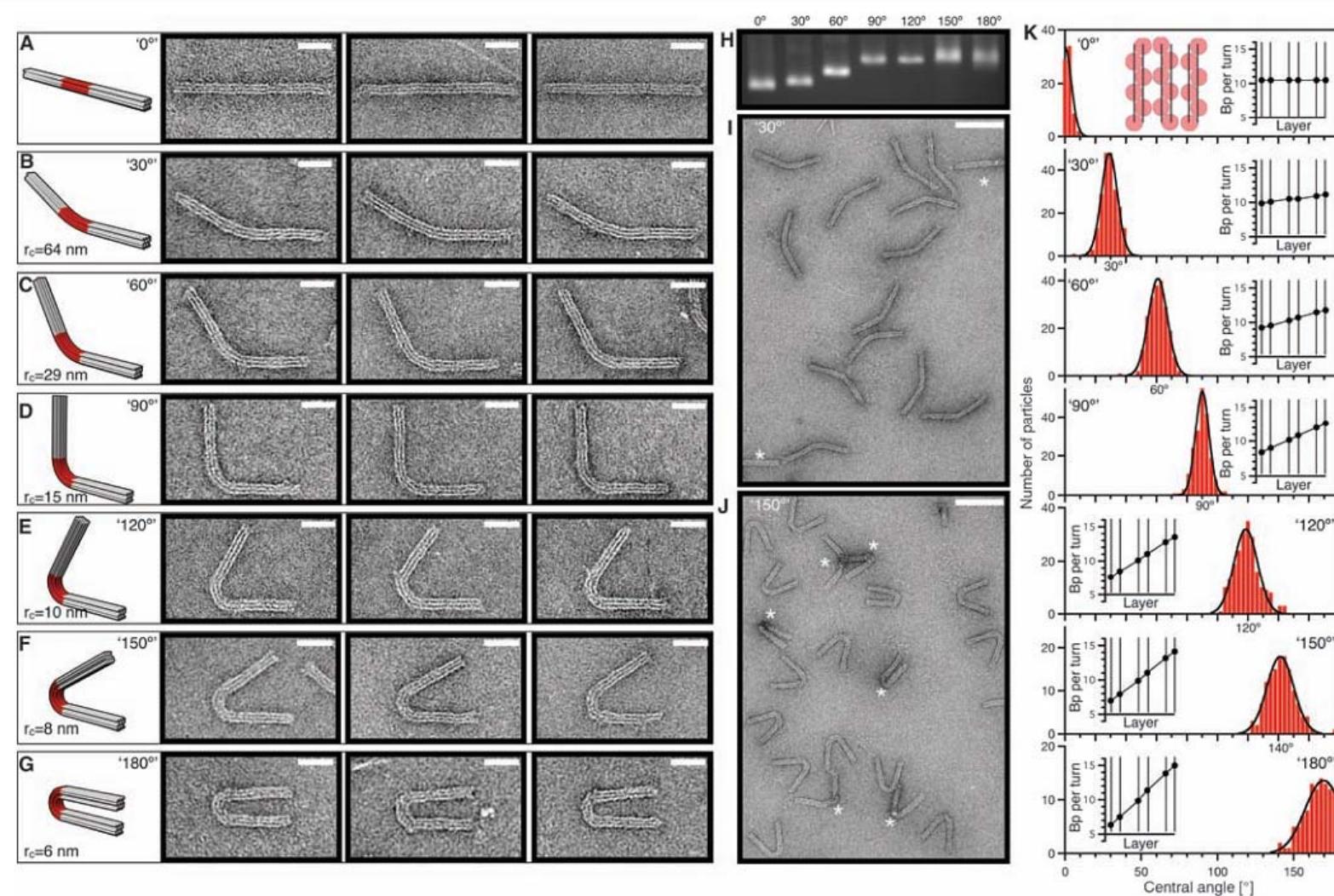
Dietz, H. et al. *Science* 325, 725-730, (2009).

Folding DNA into Twisted and Curved Nanoscale Shapes



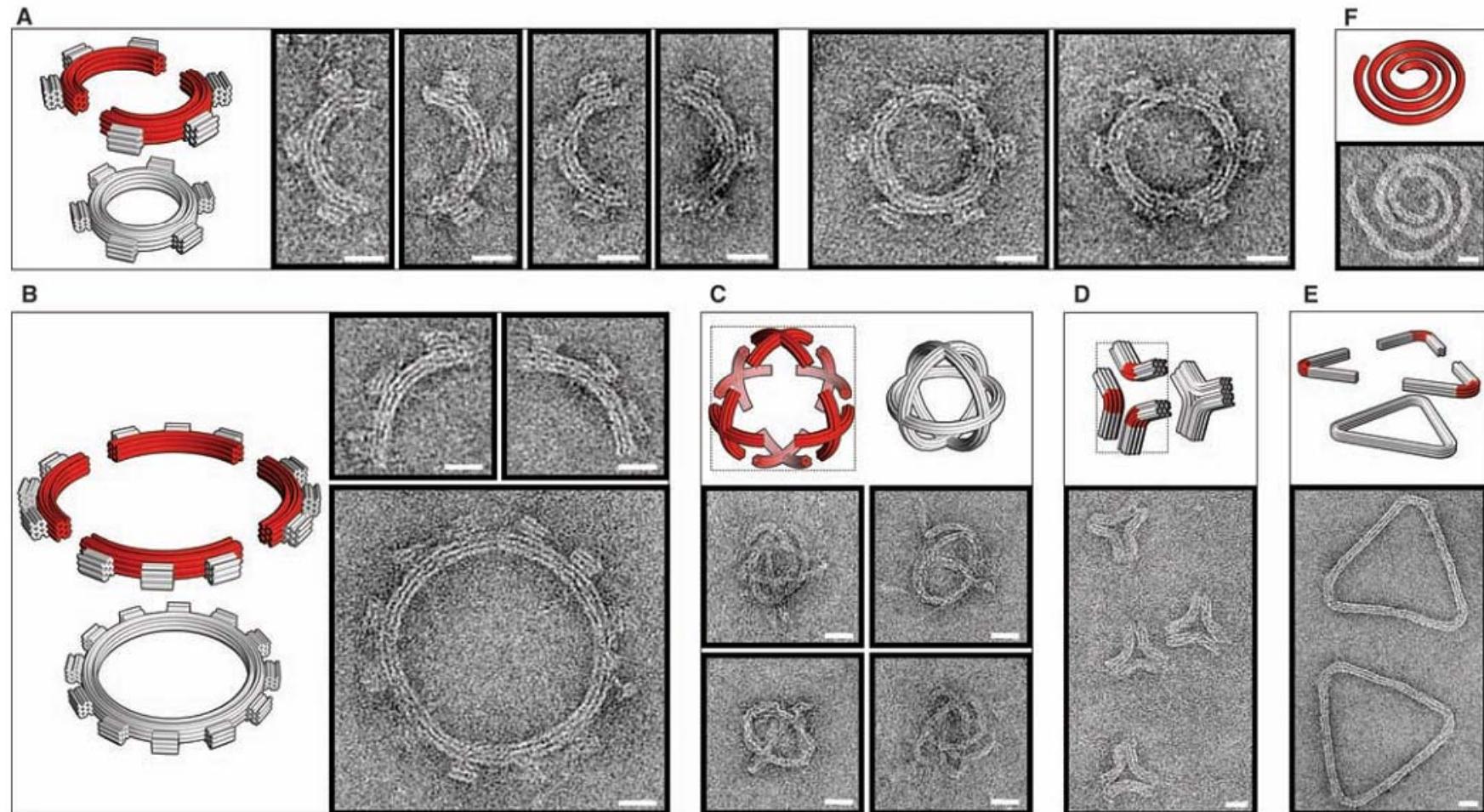
Dietz, H. et al. *Science* 325, 725-730, (2009).

Folding DNA into Twisted and Curved Nanoscale Shapes



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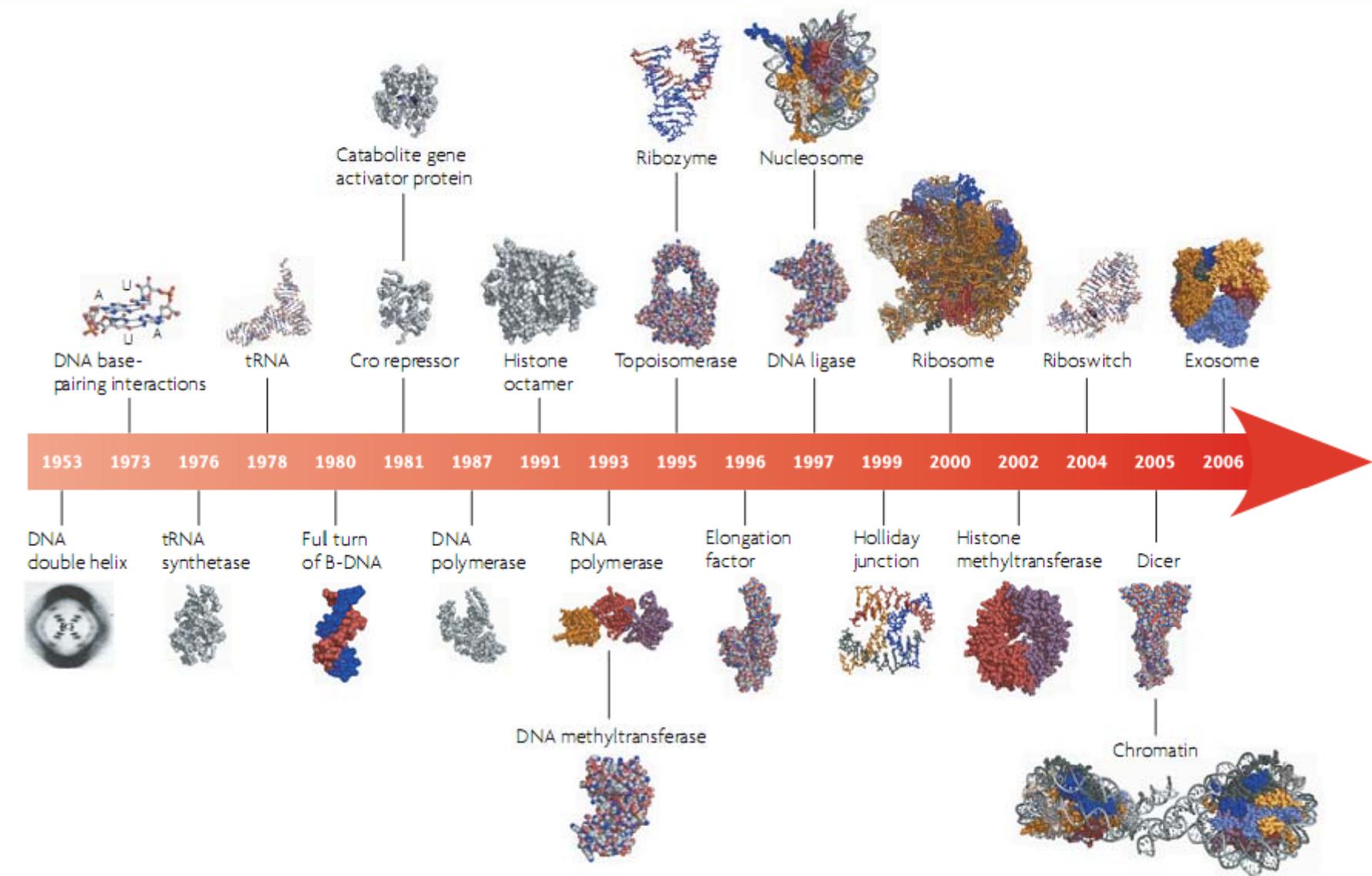
Folding DNA into Twisted and Curved Nanoscale Shapes



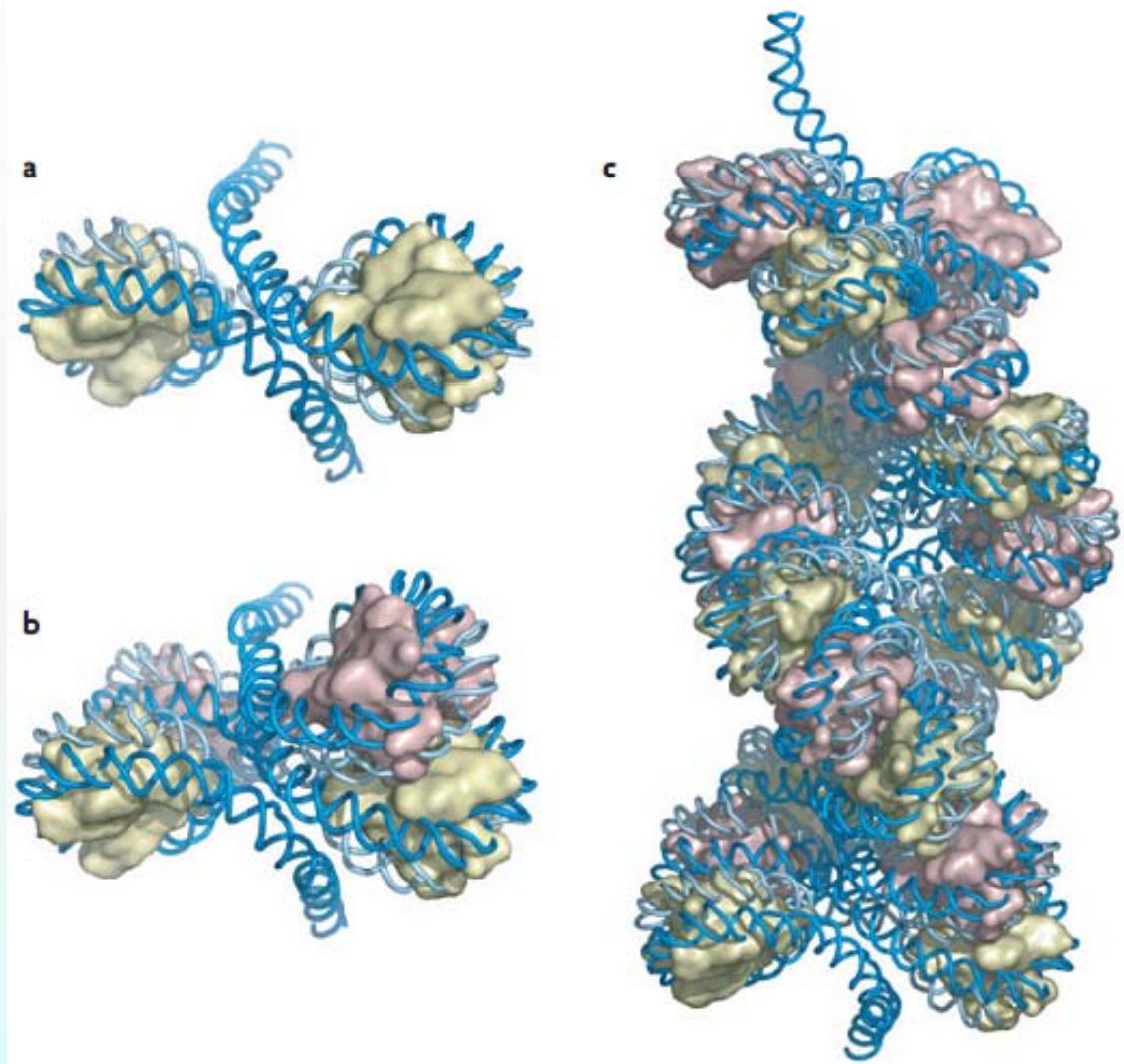
Dietz, H. et al. *Science* 325, 725-730, (2009).

基于天然分子的分子机器





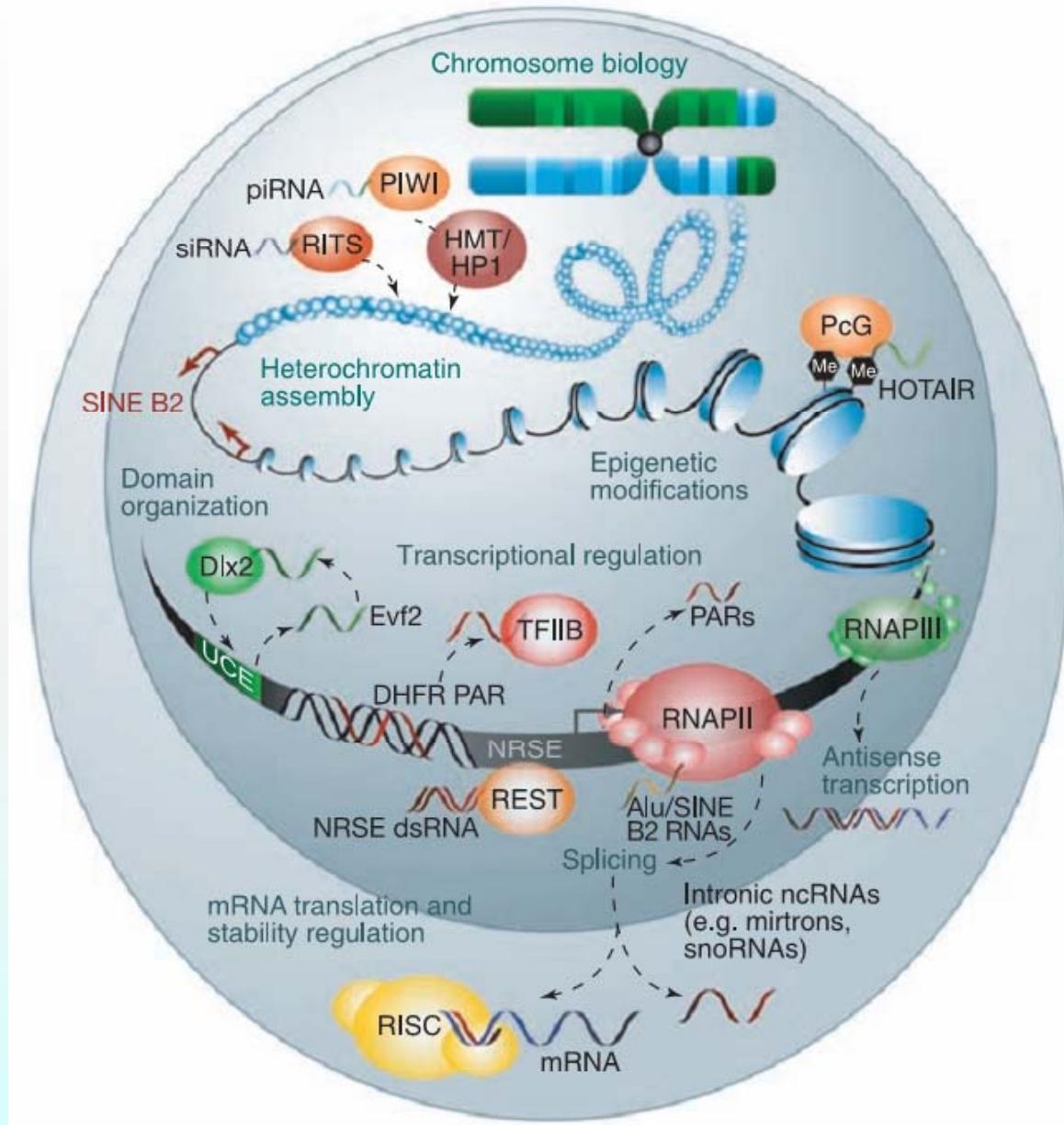
Laskowski, R. A. et al. *Understanding the molecular machinery of genetics through 3D structures*. *Nature Reviews Genetics* 9, 141-151, (2008).



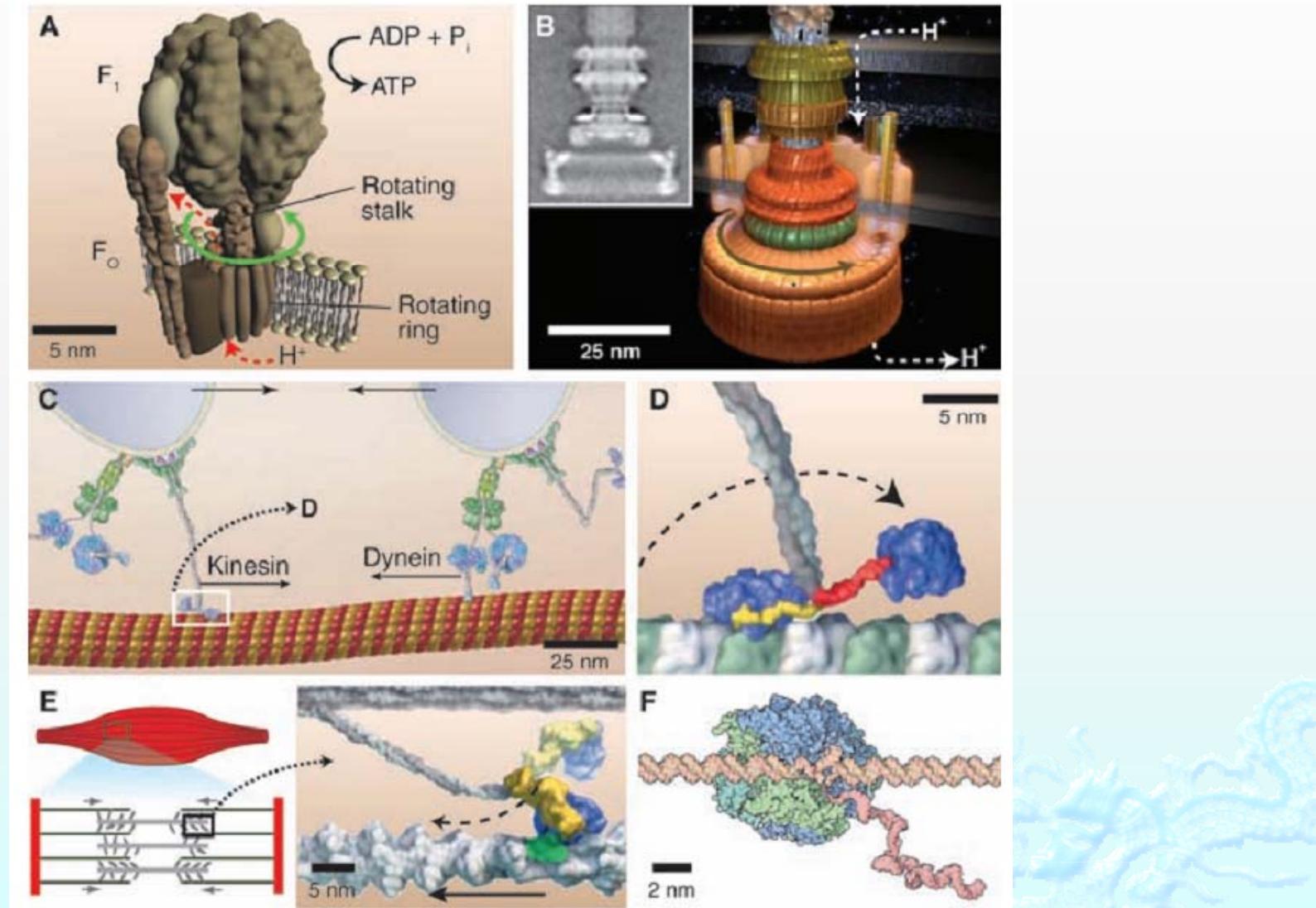
Laskowski, R. A. et al. *Understanding the molecular machinery of genetics through 3D structures*. *Nature Reviews Genetics* 9, 141-151, (2008).

The eukaryotic genome as an RNA machine.

Amaral, P. P. et al.
Science 319, 1787-1789, (2008).

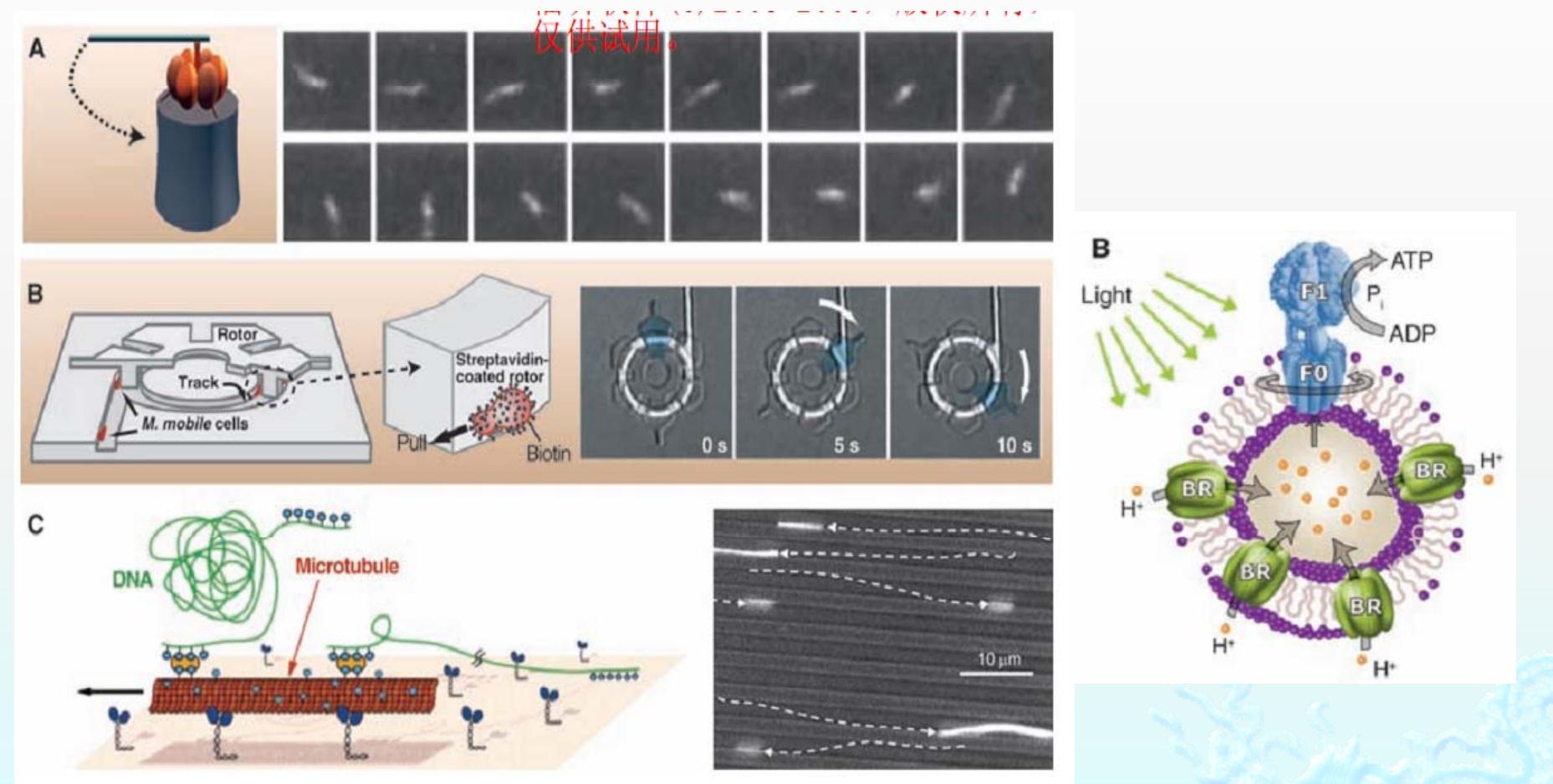


Motor proteins at work for nanotechnology



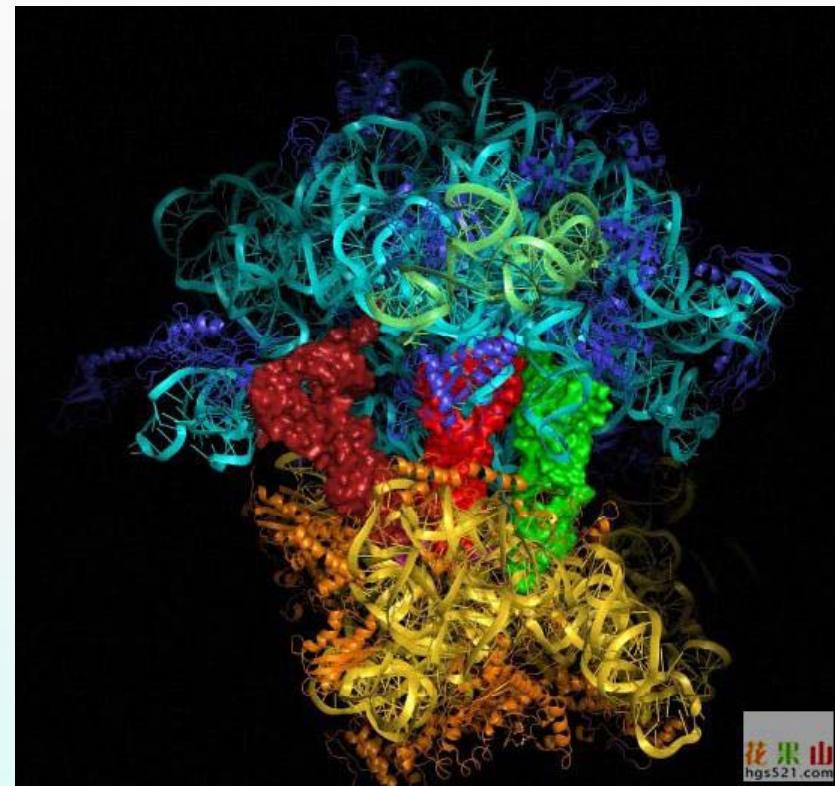
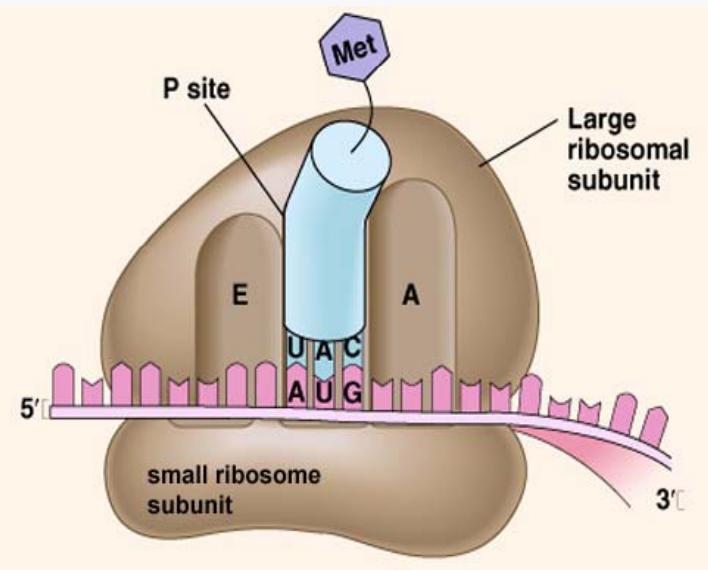
van den Heuvel, M. G. L. et al. *Science* 317, 333-336, (2007).

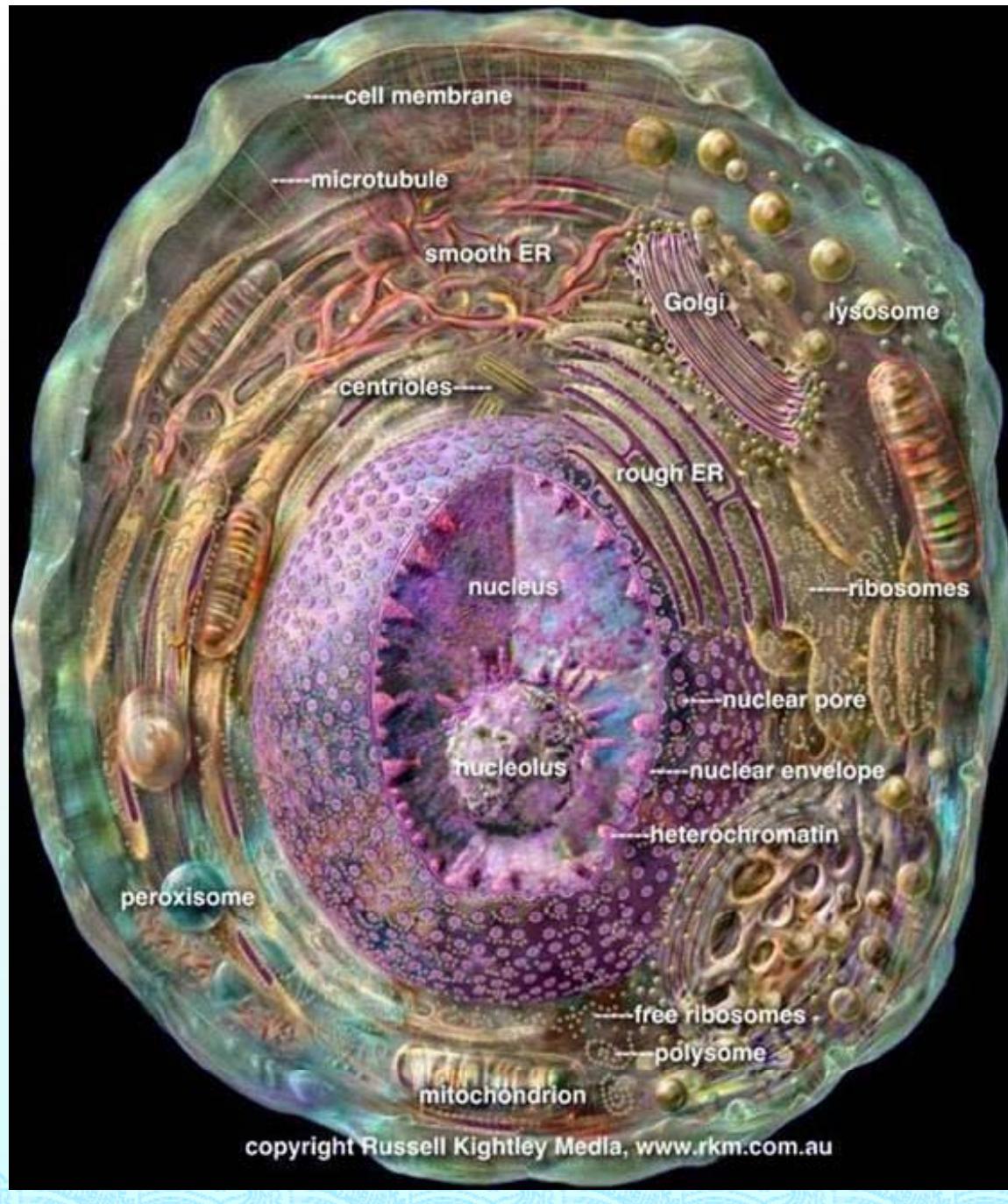
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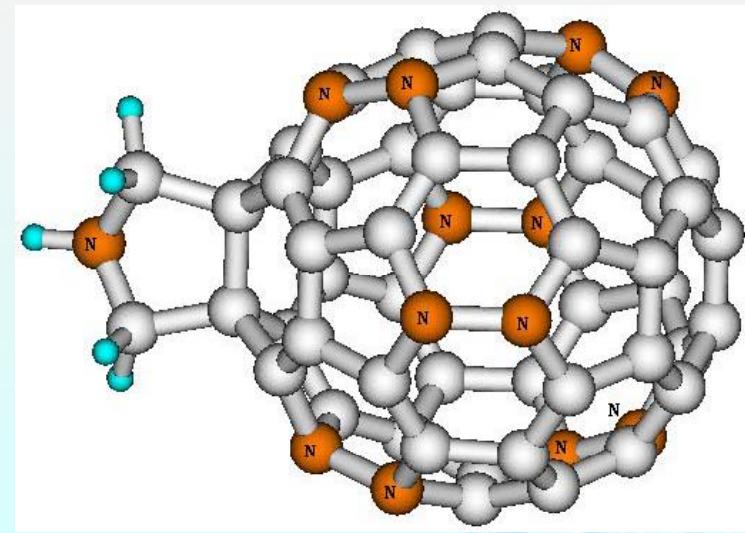
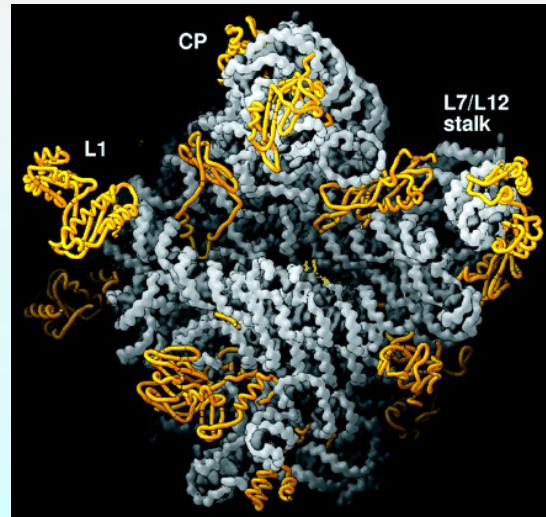
生物体内的合成机器—核糖体





可以开展的工作

- ◆ 探索搭建新的零部件
- ◆ 利用已有的零部件组建器件
- ◆ 借助生命科学中的功能蛋白质





Thank You!