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# Electron driven Molecular Motors

# Structure

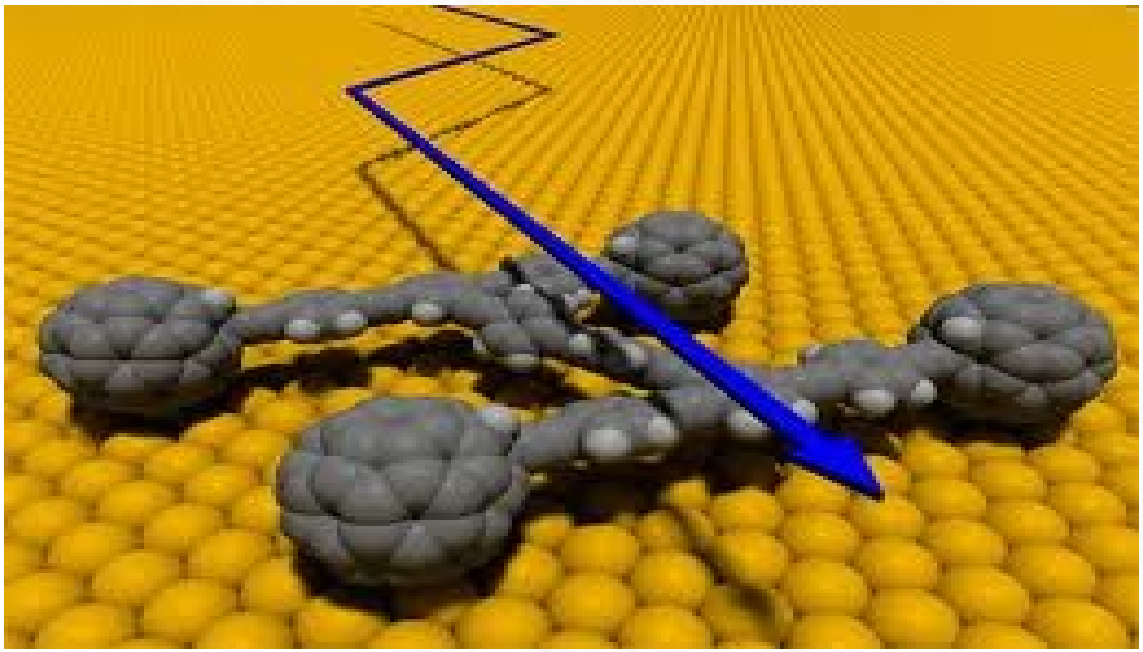
- Introduction
- Types of molecular motors
- Two electron driven motors experiments
- Conclusion

# Introduction

- Invention of wheel
- Many applications arised from that invention
- Components depend on directed motion
- Different ways to drive the wheel

- Movement in nanoscale level

  => Molecular motors
- Goal: directional movement



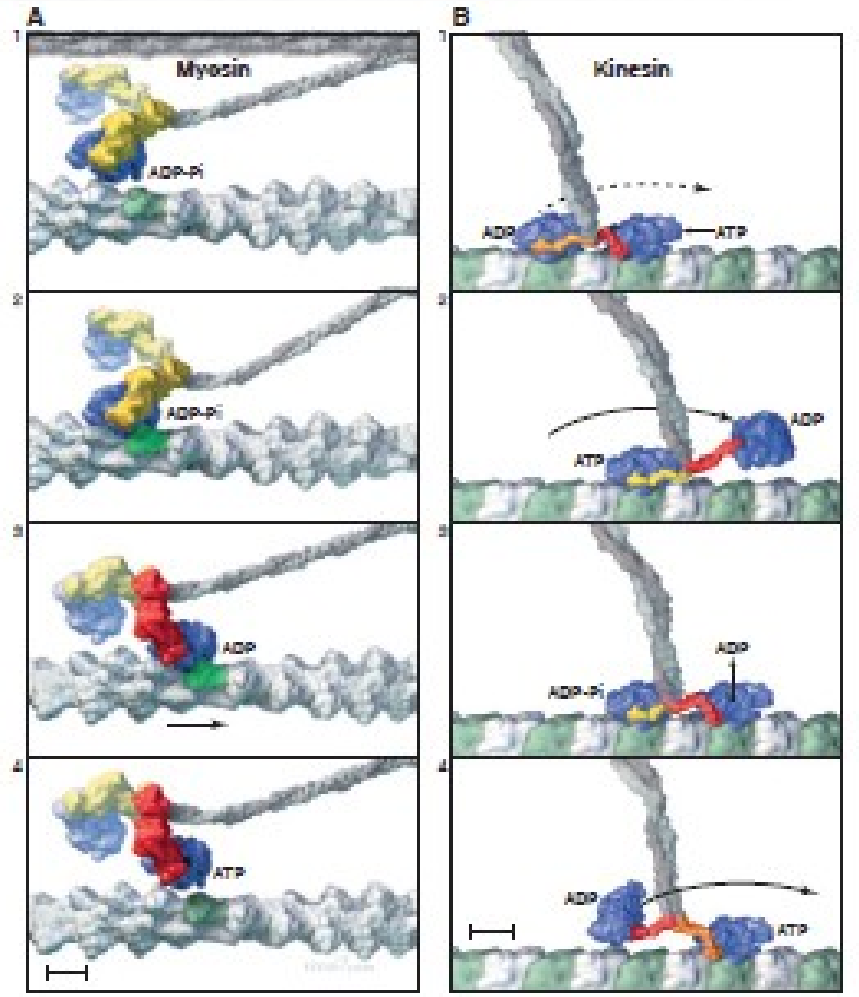
# Types of molecular motors

- Chemically driven motors
- Brownian motors
- Electron driven motors

# Chemically driven motors

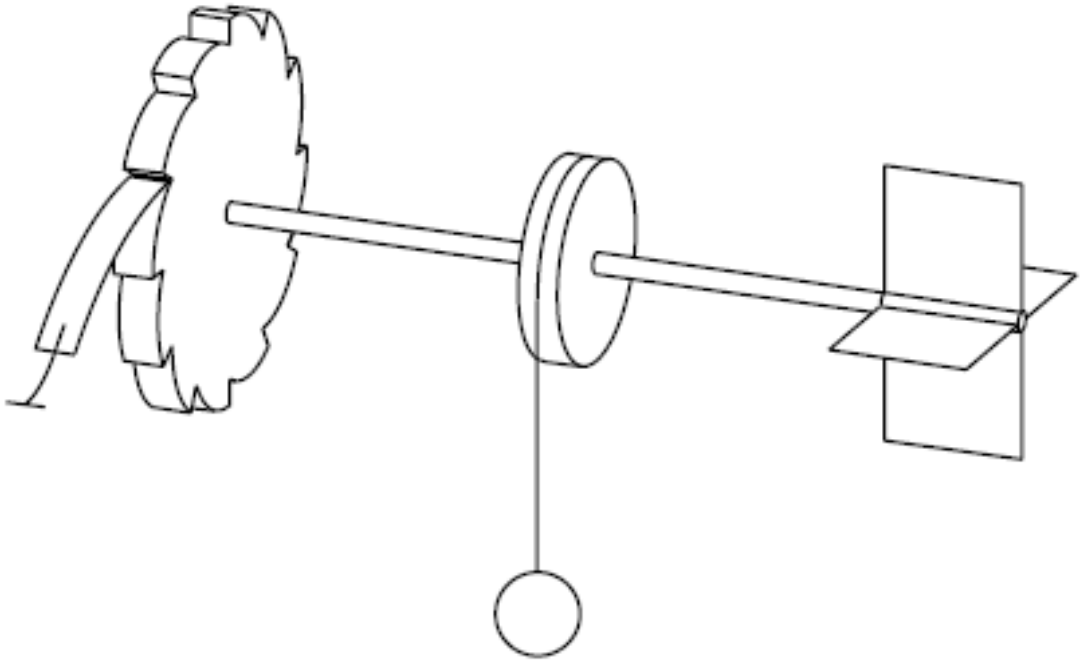
- Muscle myosin and conventional kinesin produce movement (play video)

https://www.youtube.com/watch?v=j8F5GGPACkQ




Vale and Ronald A. Milligan et al. *Science* **288**, 88 (2000)

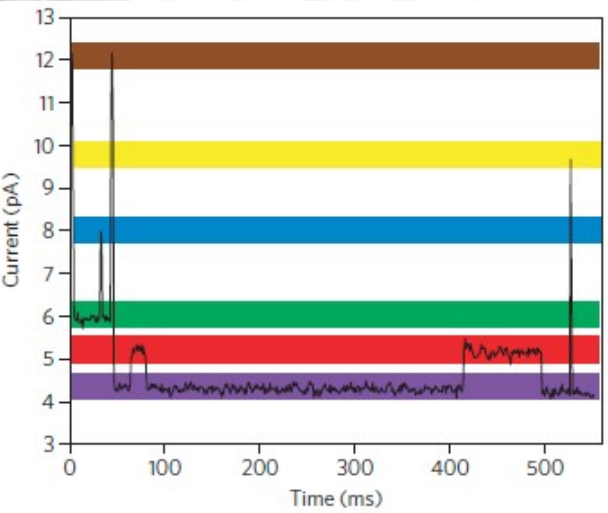
# Brownian motors

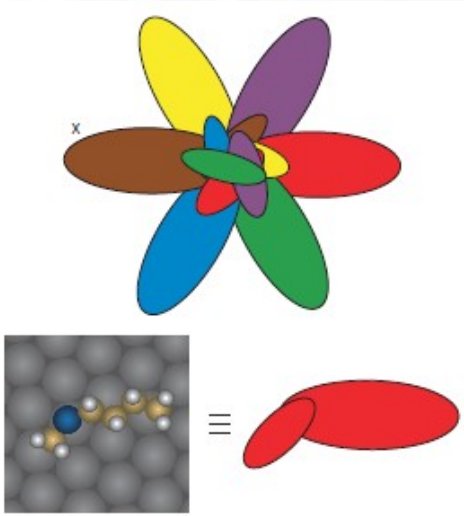


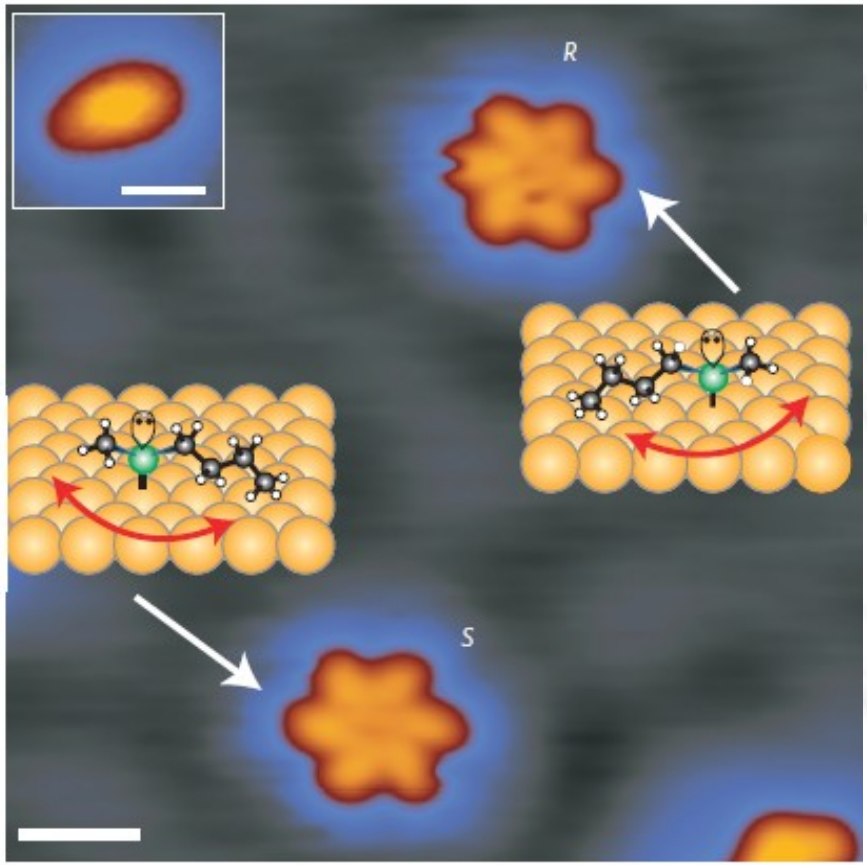
P. Reimann et al.Physics Reports 361 (2002) 57–265

# Single-molecule electric motor

- BuSMe on copper surface
- Two terminal setup




Tierney et al.NATURE NANOTECHNOLOGY | VOL 6 | OCTOBER 2011

# Results of the experiment

**Table 1 | Directed rotation of molecular rotors.**

**a,**

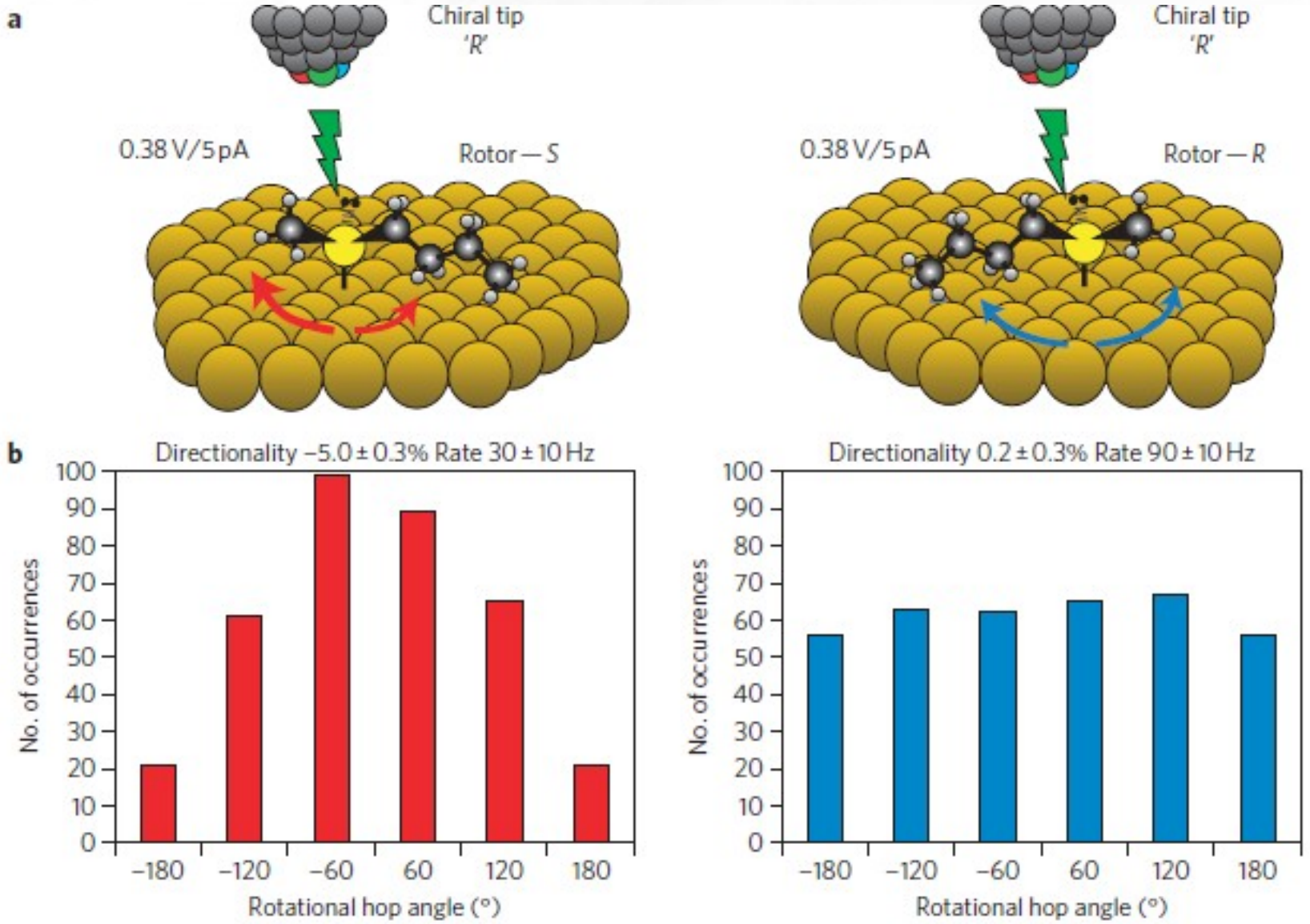
| Molecule | Energy source | Direction (%) | Rate (Hz) | Events counted (no.) |
|---|---|---|---|---|
| (*S*)-BuSMe | Thermal (0.2 V, 5 pA, 8 K) | 0.0±0.3 | 300±140 | 11,890 |
| (*R*)-BuSMe | Thermal (0.2 V, 5 pA, 8 K) | 0.0±0.2 | 330±60 | 10,104 |
| (*S*)-BuSMe | Electrical (0.38 V, 5 pA, 5 K) | −5.0±0.3 | 30±10 | 3,490 |
| (*R*)-BuSMe | Electrical (0.38 V, 5 pA, 5 K) | 0.2±0.3 | 90±10 | 5,070 |

**b,**

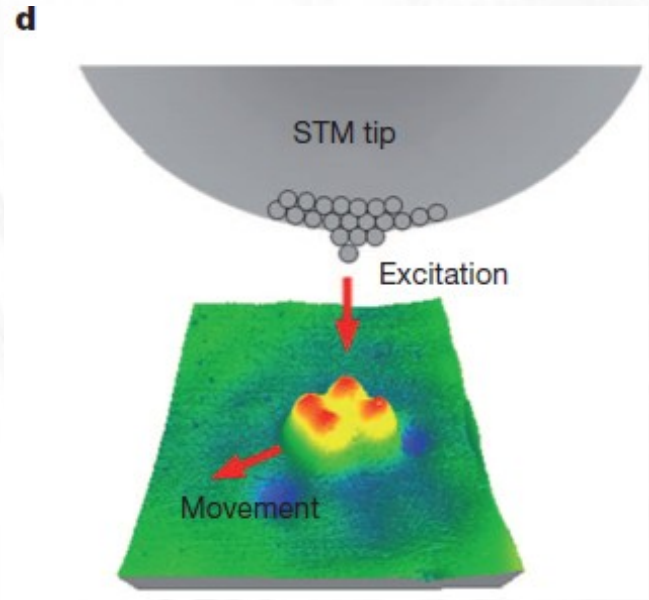
**Electrically driven rotation (0.38 V, 5 pA, 5 K)**

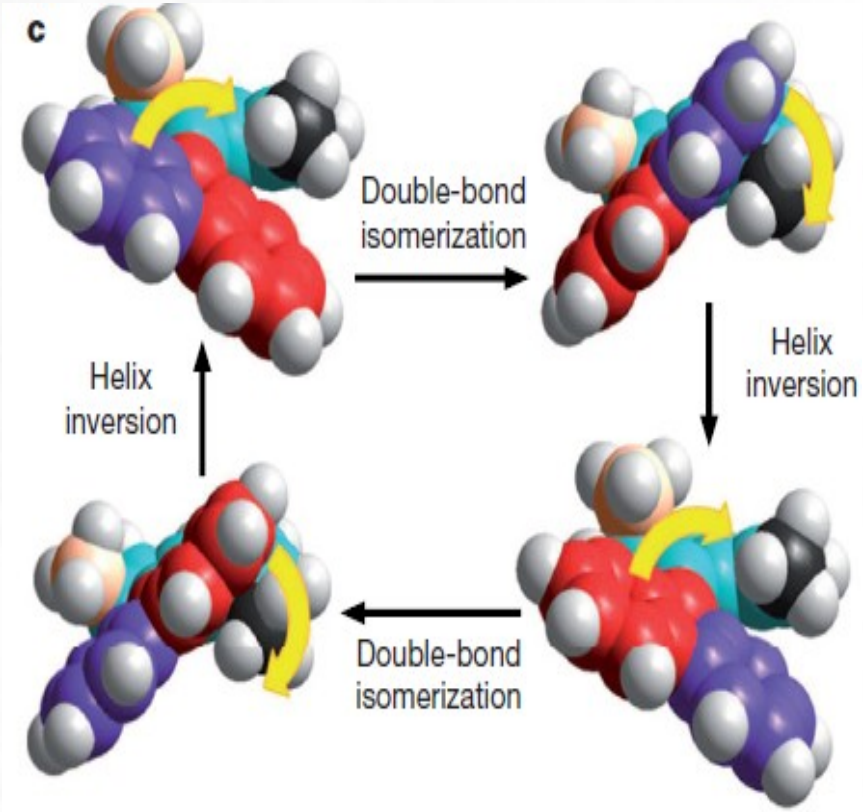
| | Direction (%) | | Rate (Hz) | | Events counted (no.) | |
|---|---|---|---|---|---|---|
| | *R* | *S* | *R* | *S* | *R* | *S* |
| Tip 1 | 0.2±0.3 | −5.0±0.3 | 90±10 | 30±10 | 5,070 | 3,490 |
| Tip 2 | 0.8±0.2 | −2.9±0.4 | 40±10 | 30±10 | 5,192 | 4,575 |
| Tip 3 | −0.3±0.1 | −0.3±0.1 | 13±8 | 14±9 | 4,002 | 4,333 |
| Tip 4 | 1.1±0.2 | −0.3±0.1 | 80±20 | 120±30 | 3,027 | 5,059 |

**a,** The rate and direction of rotation of the (*R*)- and (*S*)-surface-bound enantiomers of BuSMe were measured for electrical excitation and, as a control, for thermal excitation. Thermal control experiments showed no preferred rotational direction, whereas electrical excitation led to directional rotation of the *S* form of BuSMe. **b,** The rate and direction of rotation of the *R* and *S* forms were also measured for electrical excitation by one of four STM tips. For tips 1, 2 and 4, there were significant differences in the behaviour of the *R* and *S* forms of the molecules. Positive (negative) % indicates anticlockwise (clockwise) rotation. The error bars reflect one standard deviation from the mean.


a
Chiral tip
'R'
0.38 V/5 pA
Rotor — S
Chiral tip
'R'
0.38 V/5 pA
Rotor — R
b
Directionality −5.0 ± 0.3% Rate 30 ± 10 Hz
No. of occurrences
Rotational hop angle (°)
Directionality 0.2 ± 0.3% Rate 90 ± 10 Hz
No. of occurrences
Rotational hop angle (°)

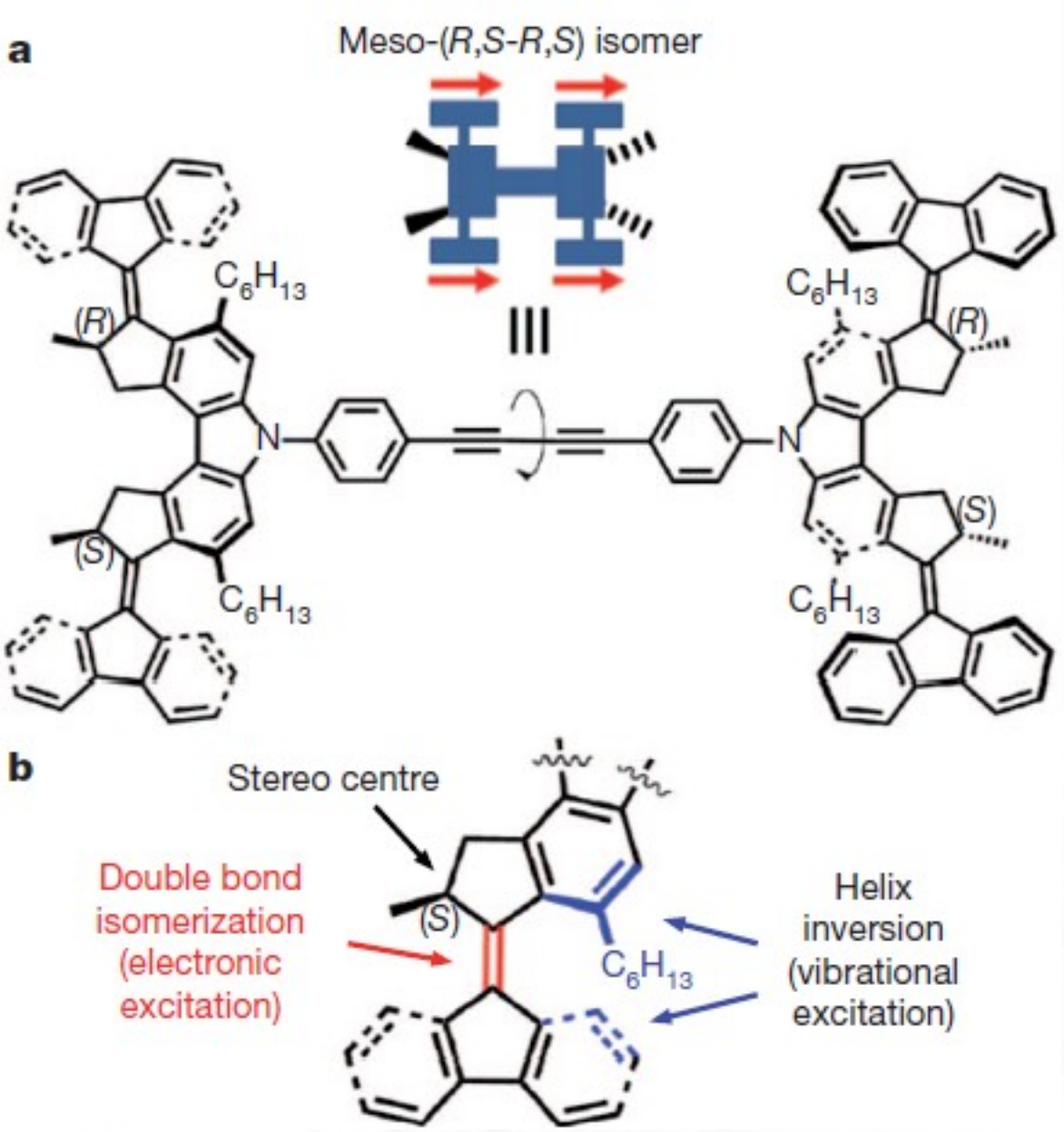
# Four wheeled molecular motor



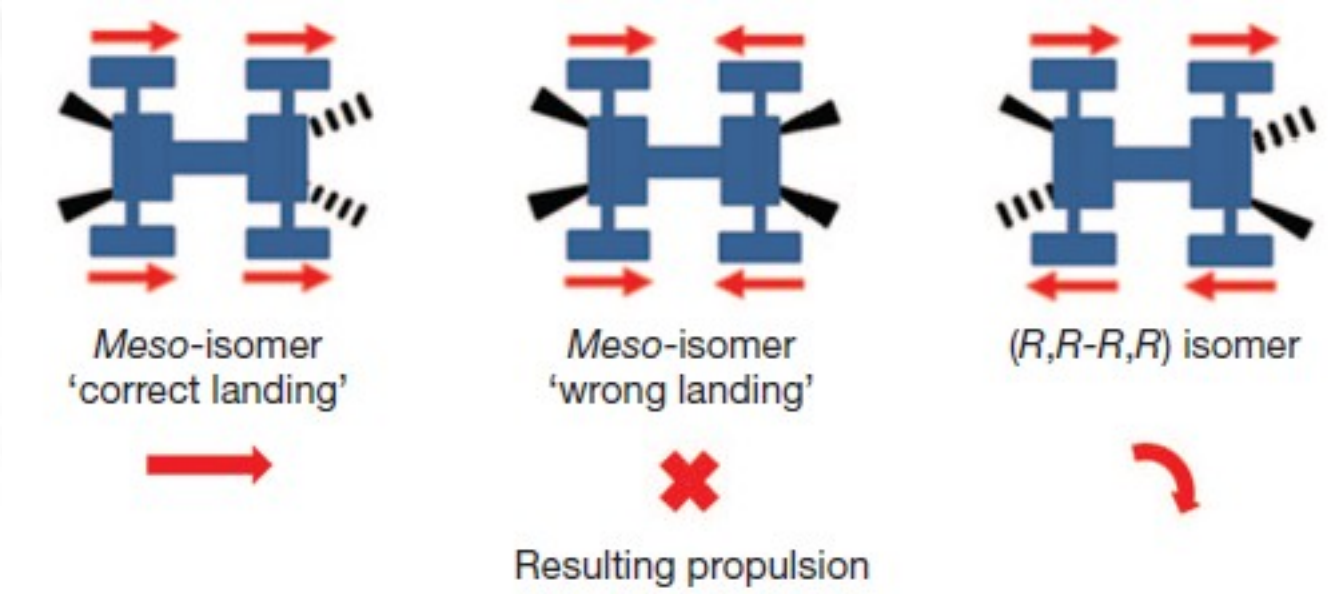



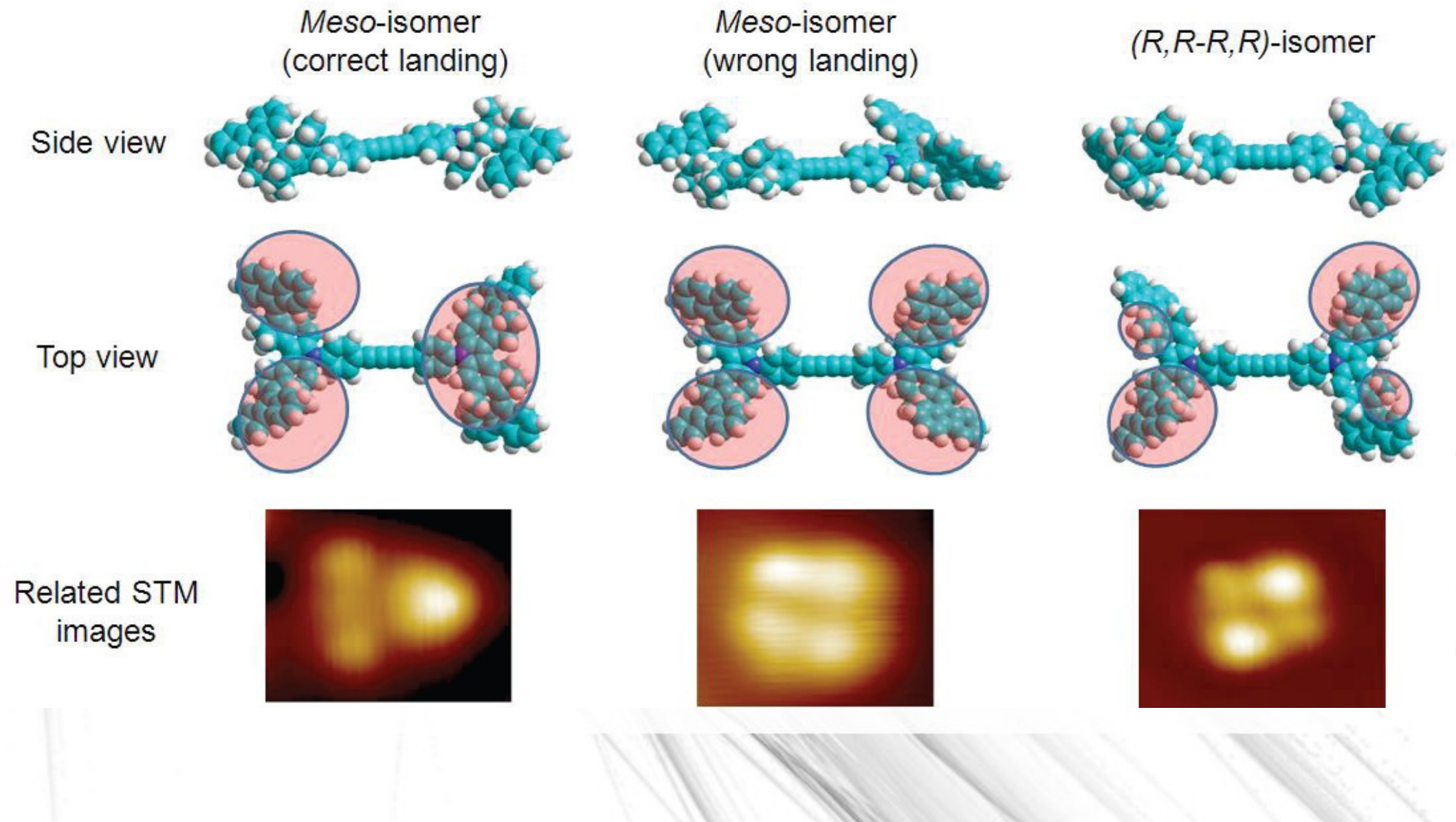

http://www.youtube.com/watch?v=I5JgJsjq3Q4

Kudernac et al.N AT U R E | V O L 4 7 9 | 1 0 N O V E M B E R 2 0 1 1


a
Meso-(R,S-R,S) isomer
C6H13
(R)
(S)
N
b
Stereo centre
Double bond isomerization (electronic excitation)
Helix inversion (vibrational excitation)

# Landing of isomer




*Meso*-isomer
(correct landing)
*Meso*-isomer
(wrong landing)
*(R,R-R,R)*-isomer
Side view
Top view
Related STM
images

# Conclusion

- This work showed that we are able to achieve a directed motion
- Driving this motor leads to rotational dynamics which depend on the chirality of the contact electrode(tip) and the motorcomplex
- All molecular motors require contact electrodes; structure and chirality importent!

# Remarks

- Results => directional movement possible
- But only 5%!
- Have to increase for applications
- Kudernac: single molelular rotors are not directional; how to achieve directional movement?

- Thank you for your attention

Questions?