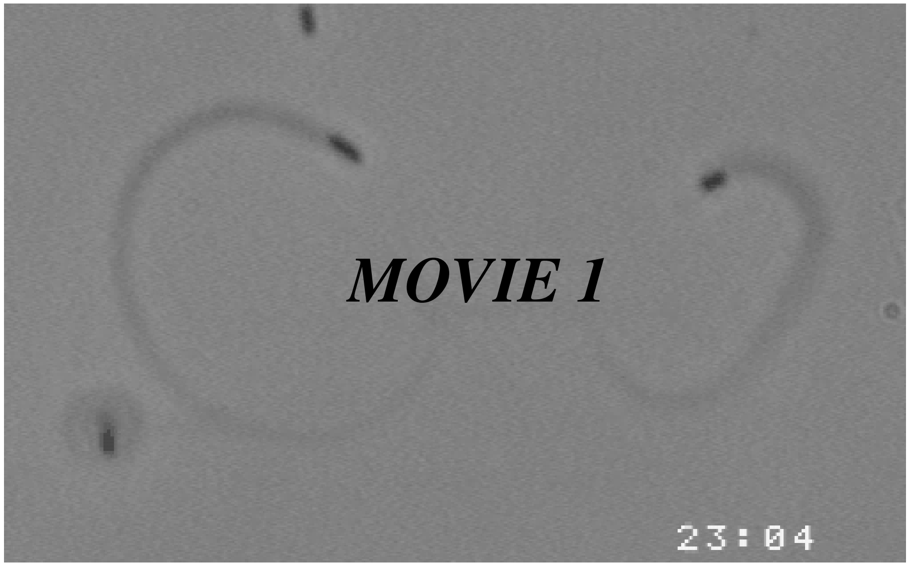
New applications of nanoscale catalysts

Catalytic conversion of chemical to mechanical energy



Example: *Listeria*

Rate ≈ 3 μm/min

Movie courtesy of D. Pantaloni, C. Le Clainche and M.-F. Carlier, CNRS, Gif-sur-Yvette

Bacterium polymerizes a "comet tail" of actin

Provides motility inside infected cell

Requires built-in asymmetry (head different from tail)

Can we design micro- and nano-motors based on this principle?

PENNSTATE

Length scale of chemical motors

Inertial forces vs. surface tension forces

$F = ma = □R^4/□^2$ $F = □R$

Surface tension dominates when $R^3 << □□^2 / □$

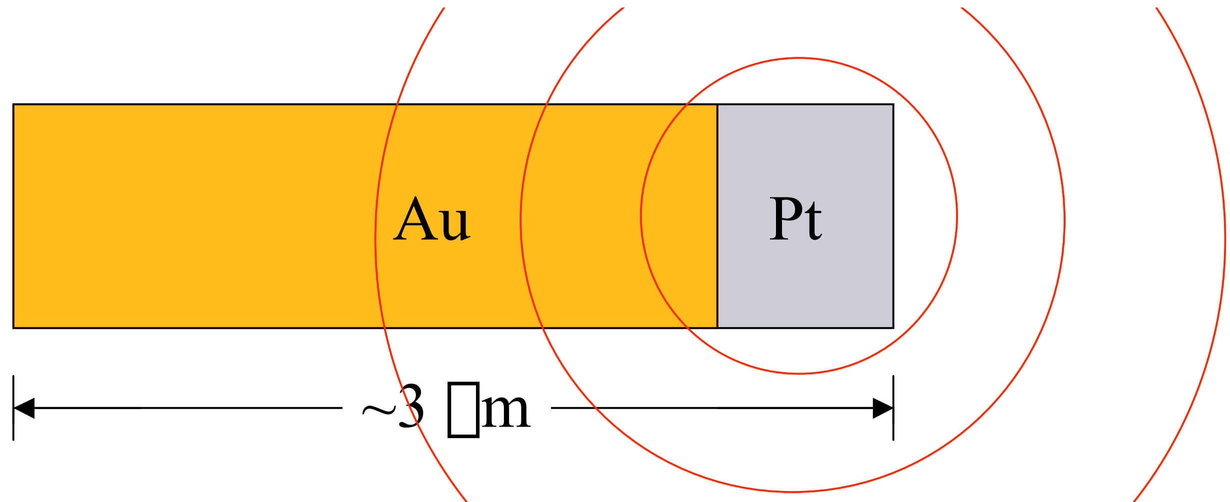
What is the relevant "motor" timescale □?

	Speed (km/h)	Body lengths /s
Cheetah	111	25
Human	37.5	5.4
Bacteria (flagellar)	$1.5x10^{-4}$	10

□~ 0.1 s
□= 72 mN/m
□ ~ 1

$R \leq 0.1$ mm

A simple surface tension motor: a cylinder with catalyst at one end



Pt end catalytically decomposes hydrogen peroxide:

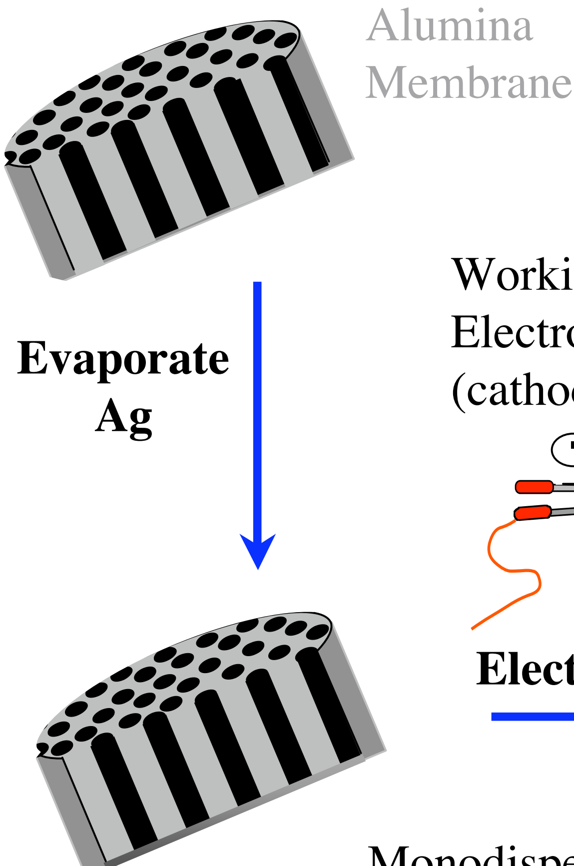
$$H_2O_2 \xrightarrow{Pt} H_2O + O_2$$

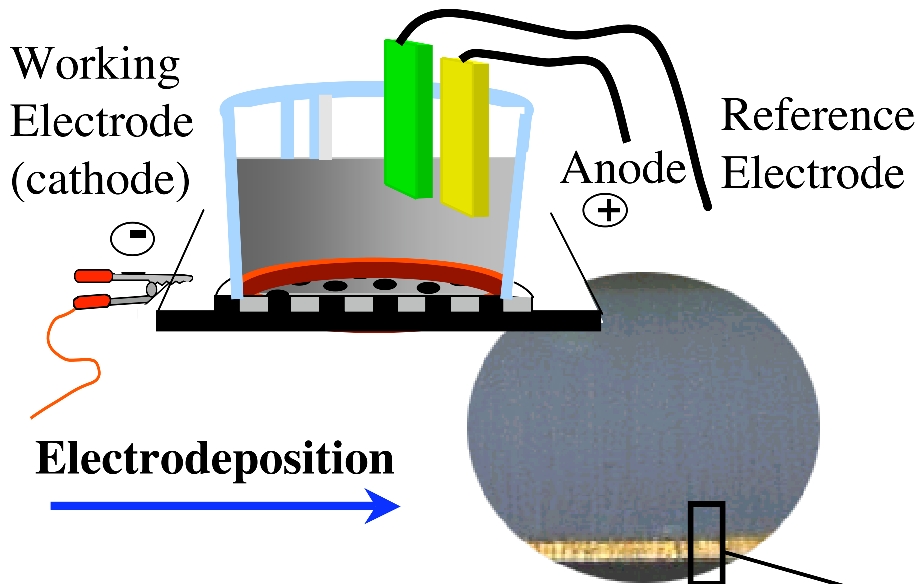
Spontaneous reaction occurs **only** at Pt tip

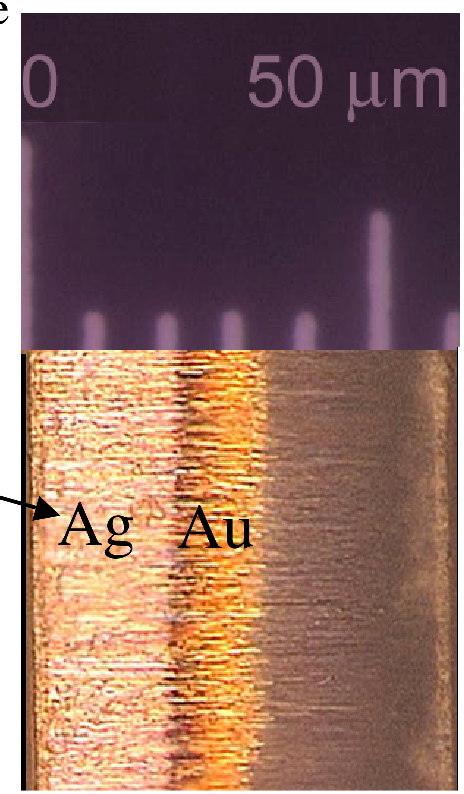
Experiments: Wally Paxton
Ayusman Sen
Tom Mallouk

Theory: Paul Lammert
Vin Crespi
Tom Mallouk

Electrochemical replication of porous membranes







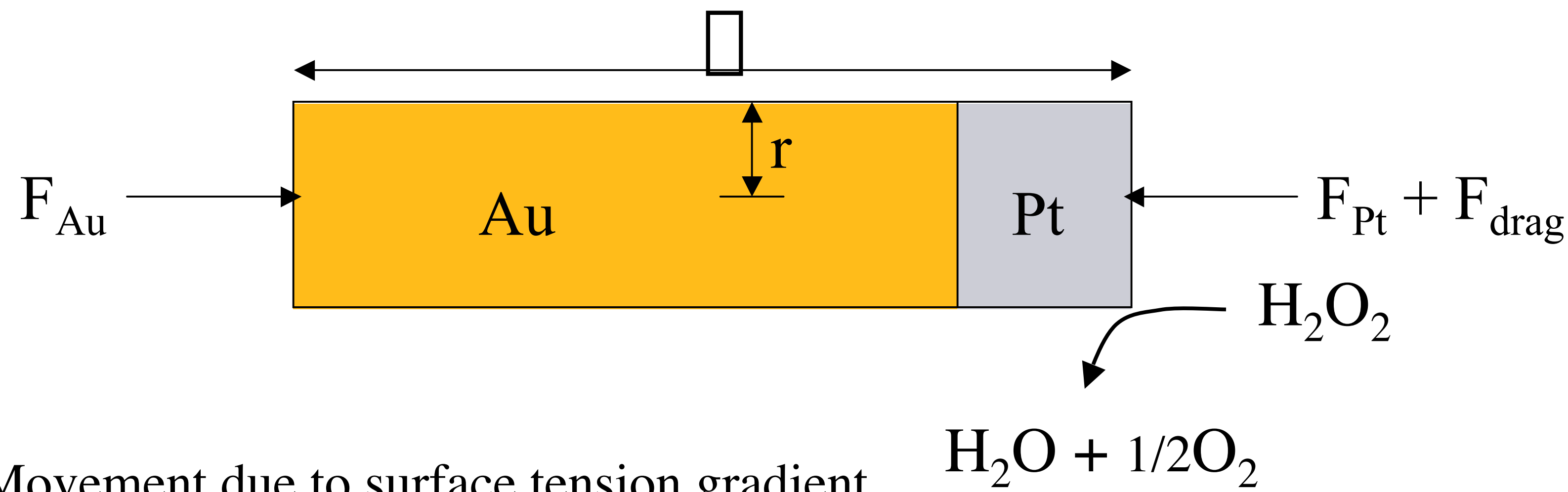
Monodisperse nanowires

60 nm -10 µm long, 20 - 350 nm diameter

Front-back asymmetry easily achieved by sequential electroplating

Reactive motion: Au-Pt wires in 2.5% H_2O_2

Surface tension mechanism



- Movement due to surface tension gradient
- At constant v_t, $F_{Au} + F_{Pt} + F_{drag} = 0$
- $2\pi r(□_{Au} - □_{Pt})\cdot$rxn rate $\approx 6\pi\mu v_t r$ ➡ $v_t \sim □□ \sim r^2/□$
- Similar method demostrated for turning micro-gears (Dr. Jeff Catchmark - PSU)

<u>Better catalysts</u> (higher rate) needed for scaling to sub-micron regime

<u>Assembly</u> of nanoparticles is also important for making catalytic micro-machines

Systems based on other fuels (e.g., glucose) needed for other media (e.g., in vivo)