

Switching between magnetotactic and aerotactic sensory-based motion of MC-1 bacterial nanorobots

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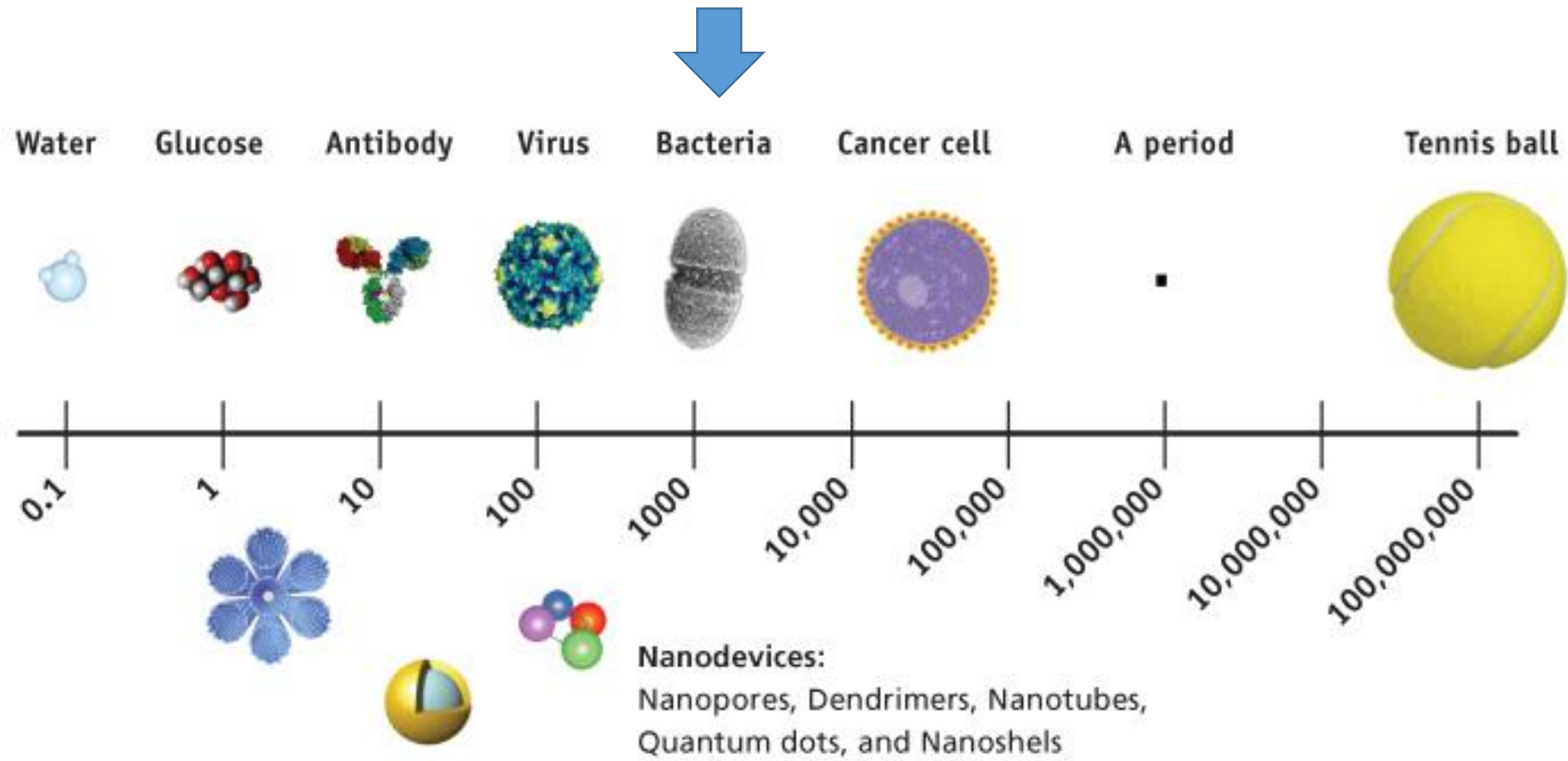
2016

Physiological Pathways to a Tumor

- Narrowest blood vessels (diam. 4 micrometers)
- Interstitial spaces
- The intercellular openings of typically less than 2 μm in diameter between endothelial cells* responsible for much of the vessel leakiness in solid tumors.

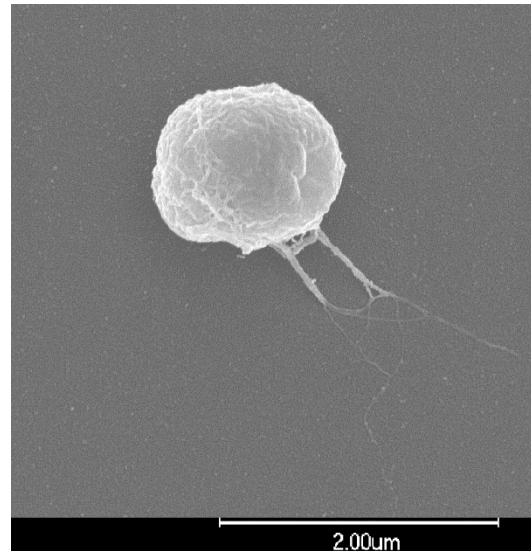
*McDonald D.M. & Baluk P. Significance of blood vessel leakiness in cancer. *Cancer Res.* **62**, 5381-5385 (2002).

This suggests a diameter not exceeding 2 micrometers



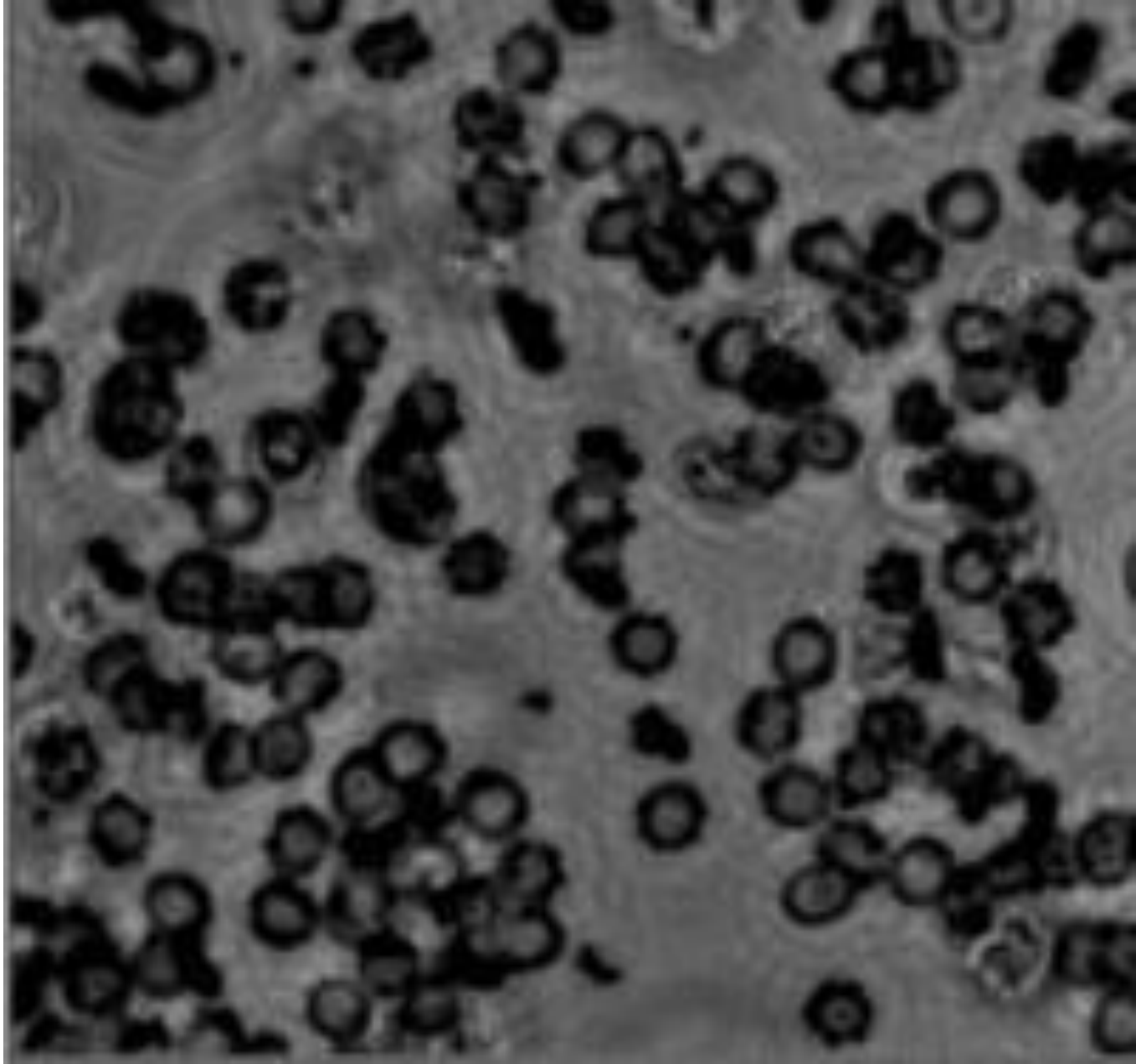
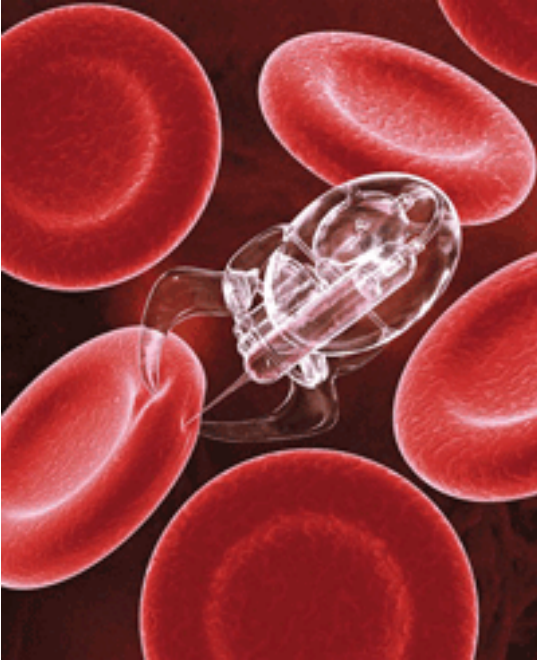
MC-1 Magnetotactic Bacterium

- Since an artificial implementation is far beyond technological feasibility, a potential strategy was to identify a microorganism that has all these specifications and to harness it to act as a “nanorobot” for drug delivery applications

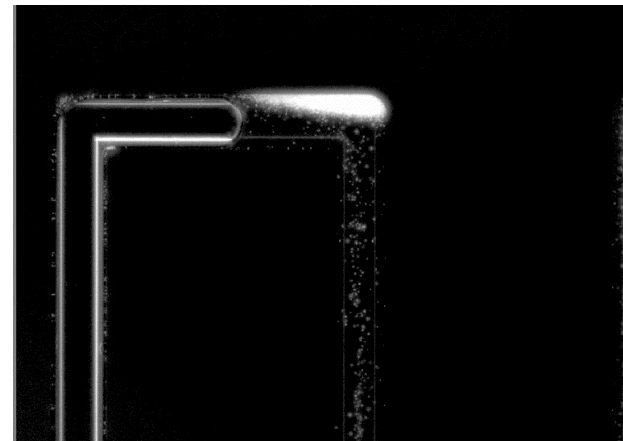
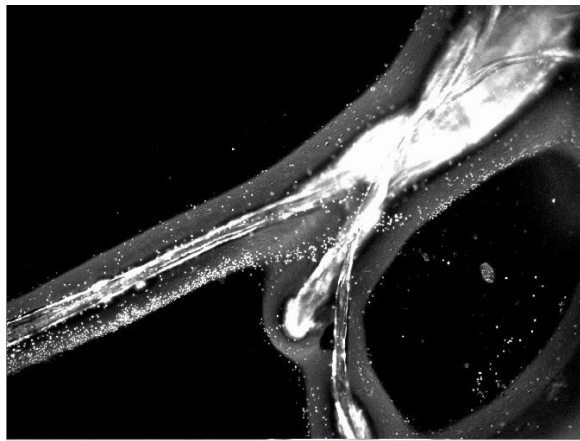
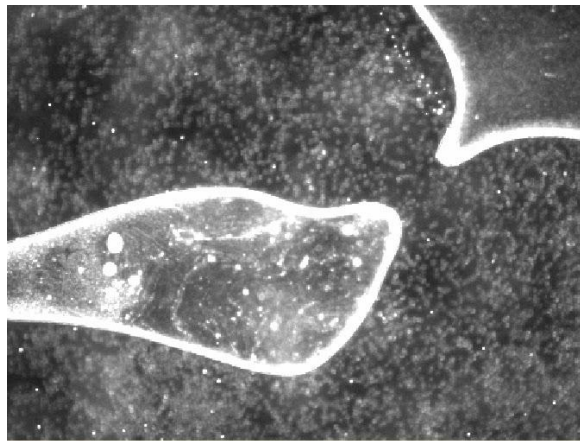
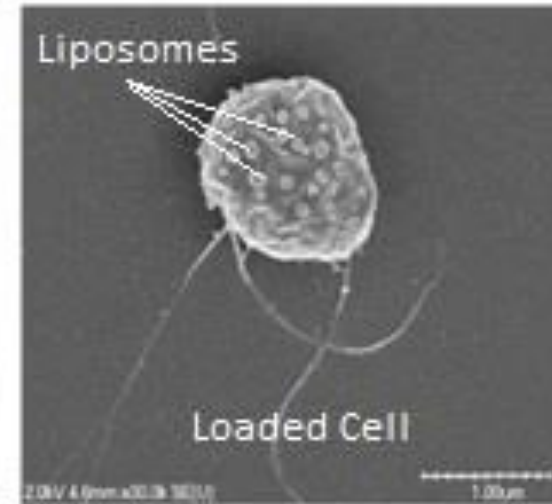
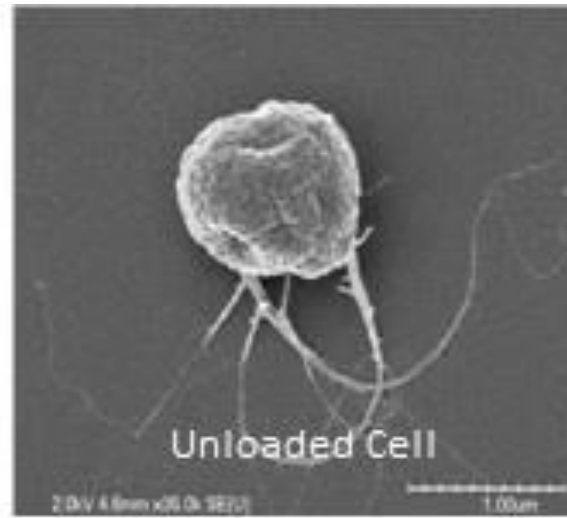
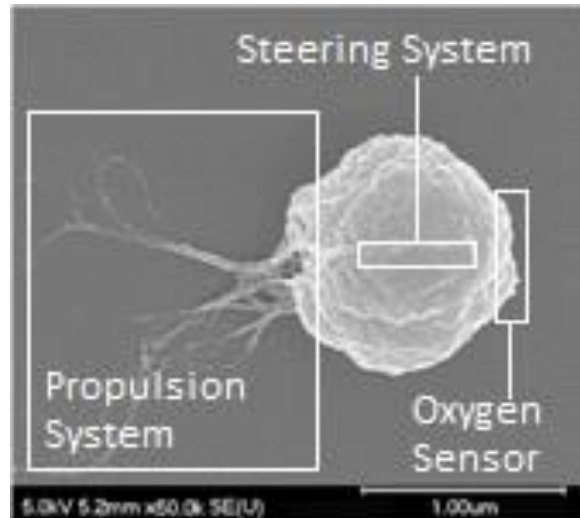


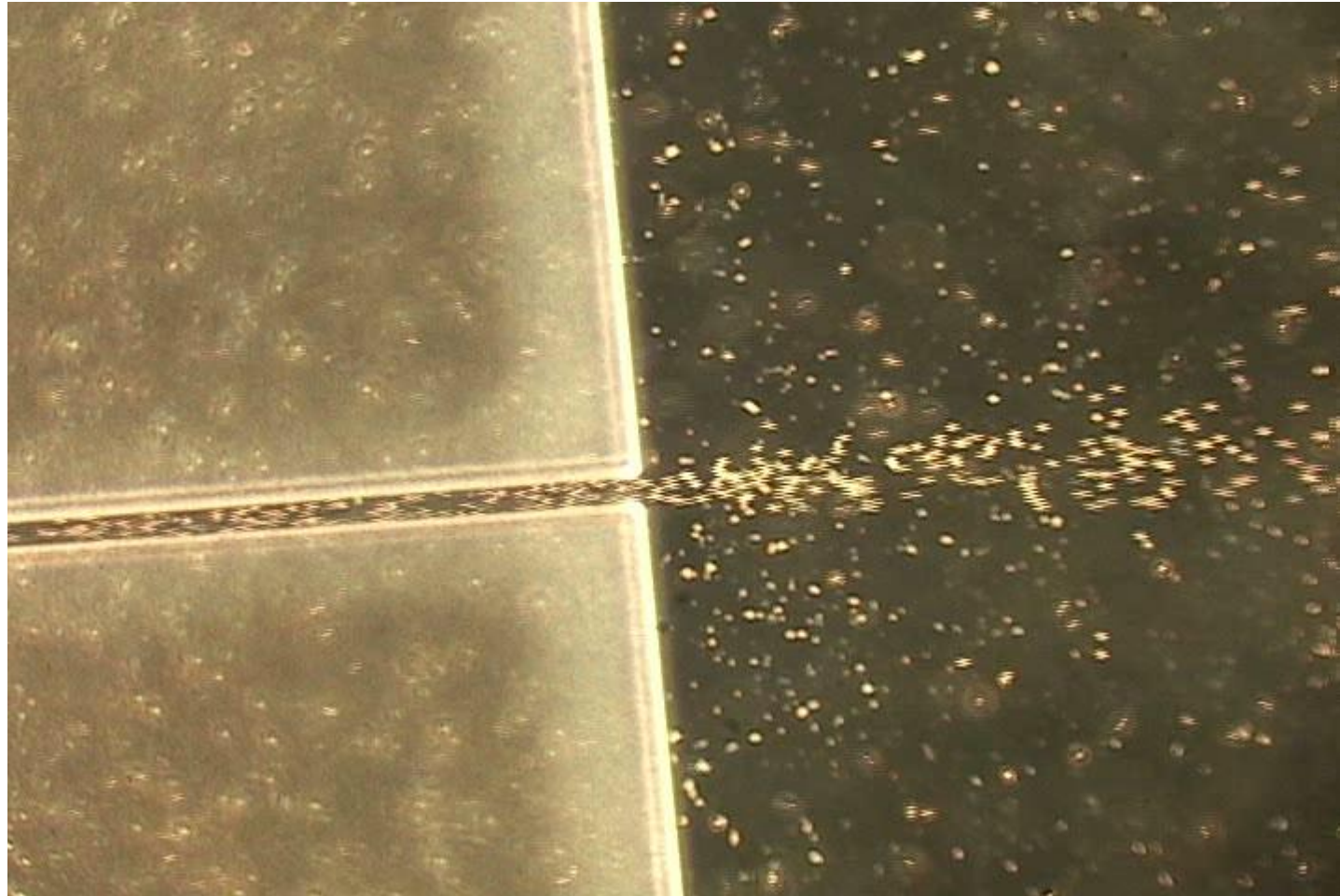
Gram-negative procaryotes

Pettaquamscutt Estuary in Rhode Island, USA



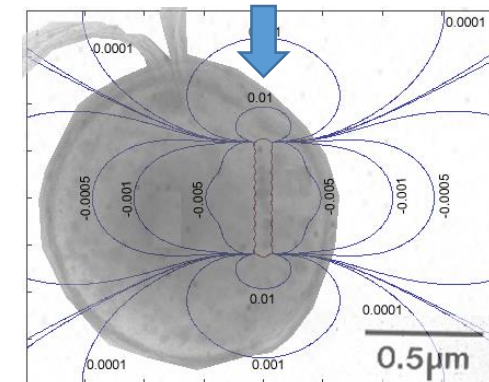
Harnessing What Nature Already Provides

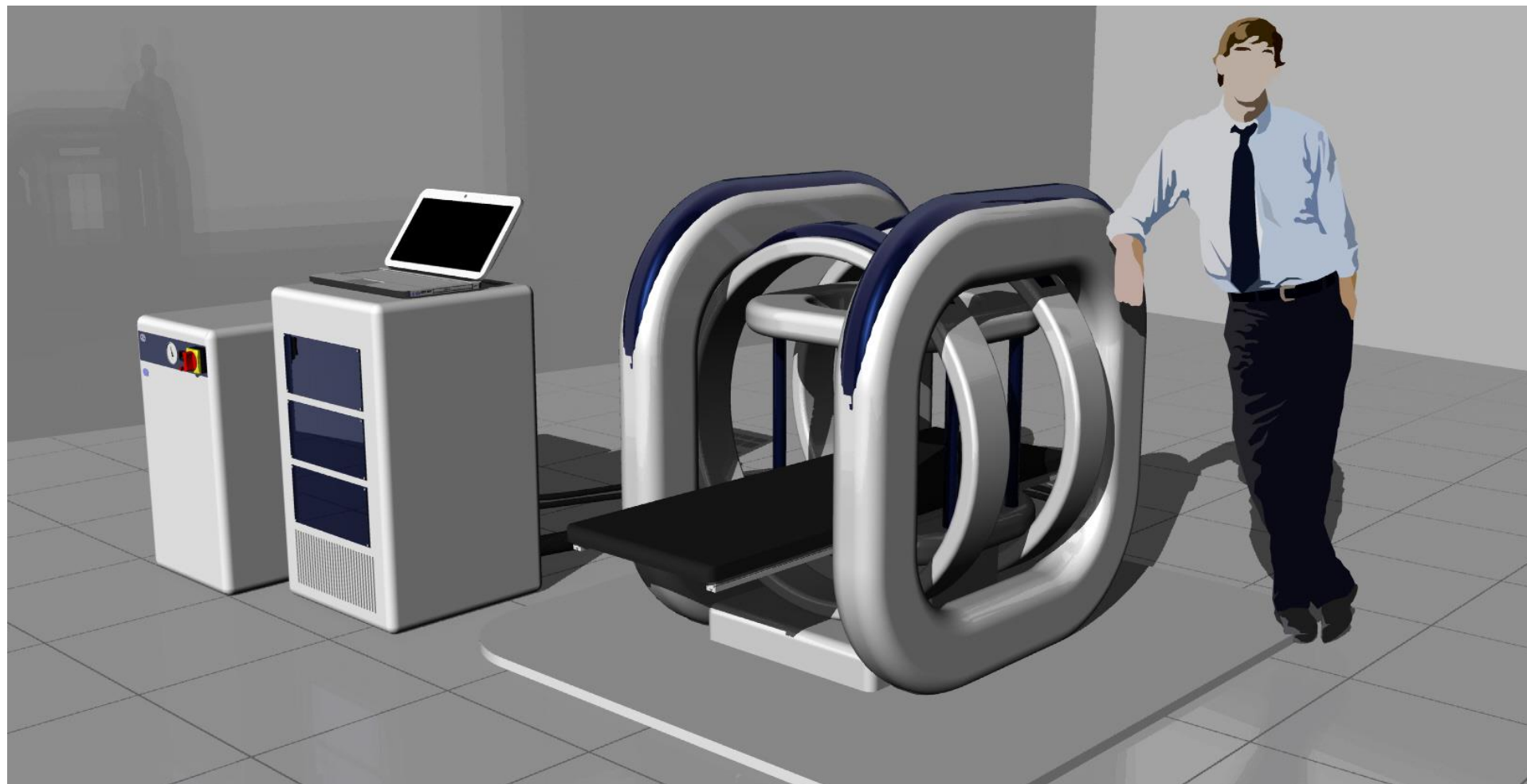




MC-1 Strain Magnetococcus Marinus Natural Migration Behavior

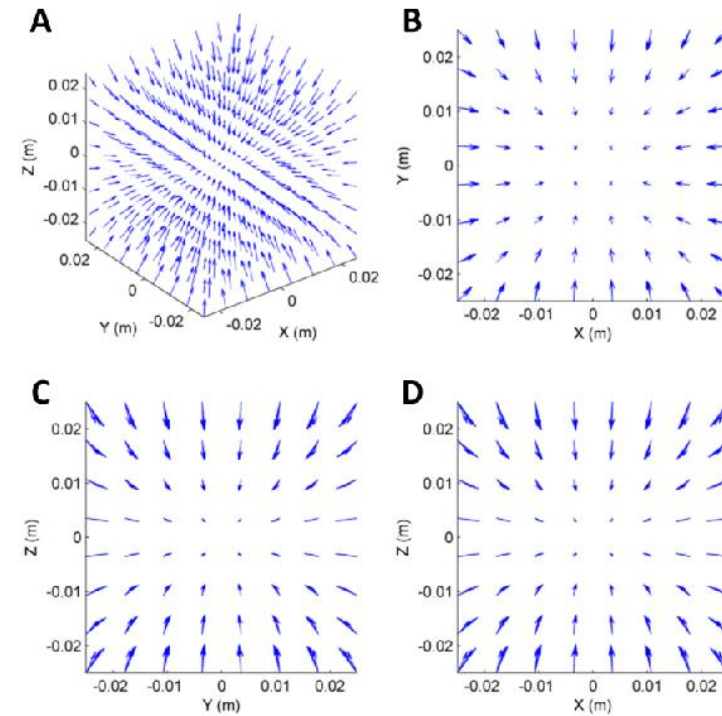
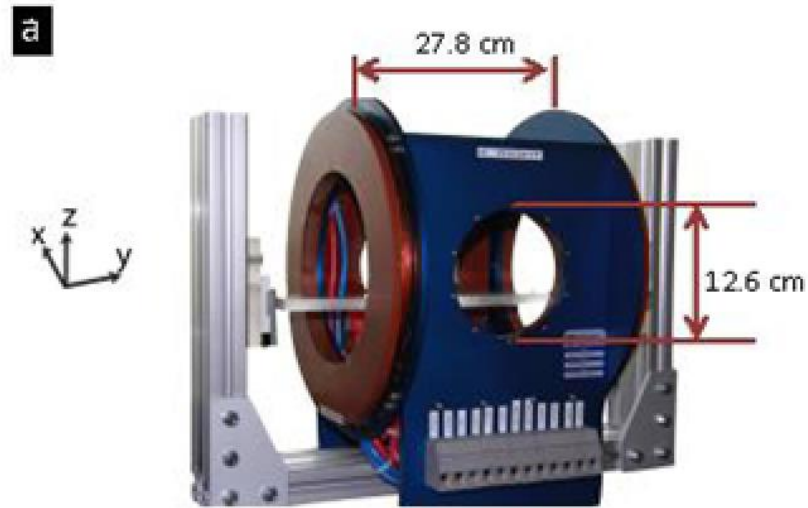
- Contains a chain of magnetic iron-oxide (Fe_3O_4) nano-crystals enclosed in membranes known as magnetosomes acting like a nano-compass needle.
- Downward migration along geomagnetic field lines in conjunction with aerotaxis to efficiently migrate to and maintain position at their preferred low oxygen concentrations.
- Such magnetically-assisted aerotaxis known as magneto-aerotaxis results in the formation of microaerophilic bands of MC-1 cells at O_2 concentrations equivalent to the ones observed in the hypoxic regions of solid tumors.



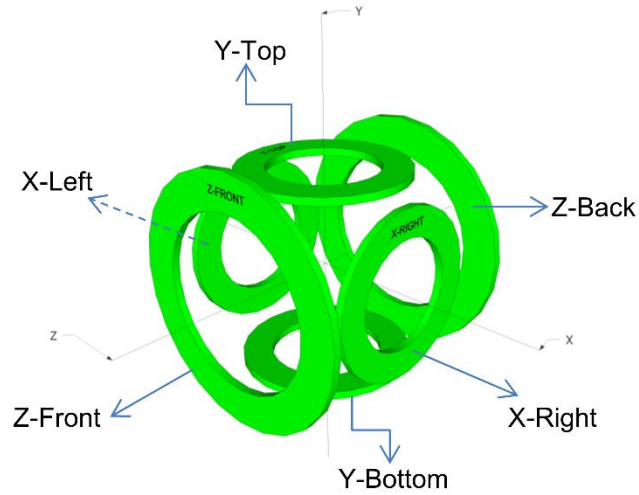
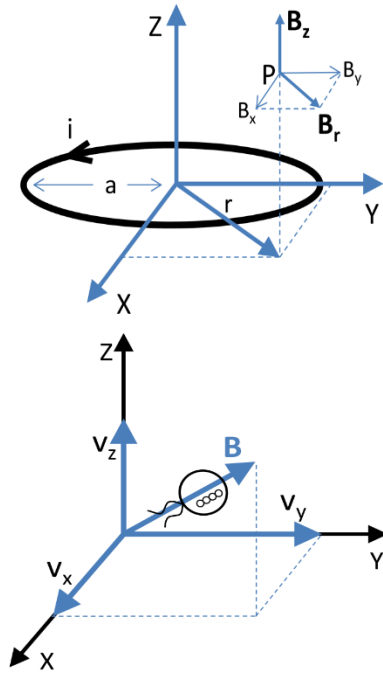




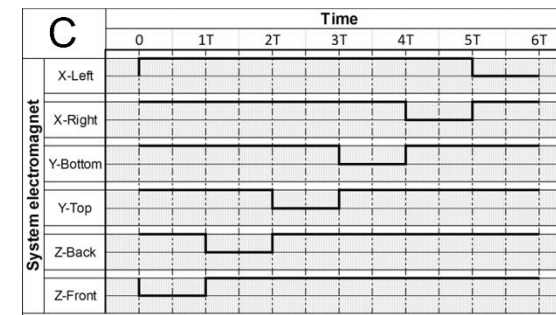
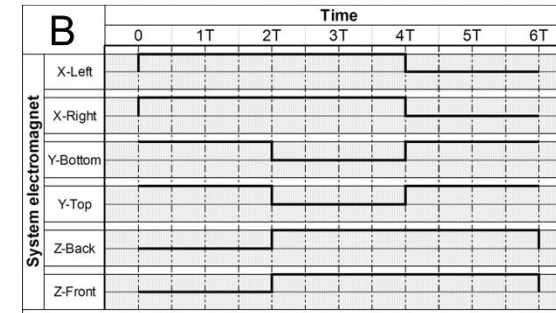
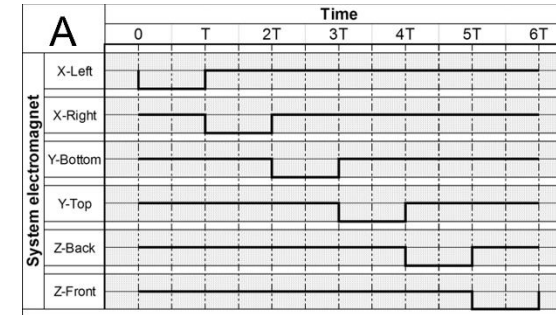
Experimental Magnetotaxis Platform



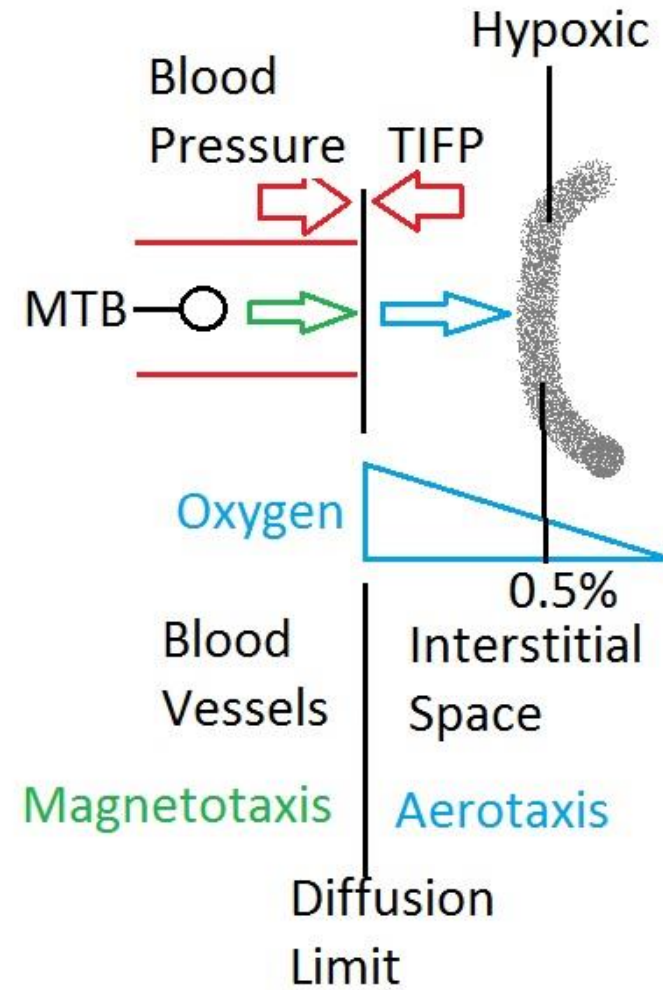
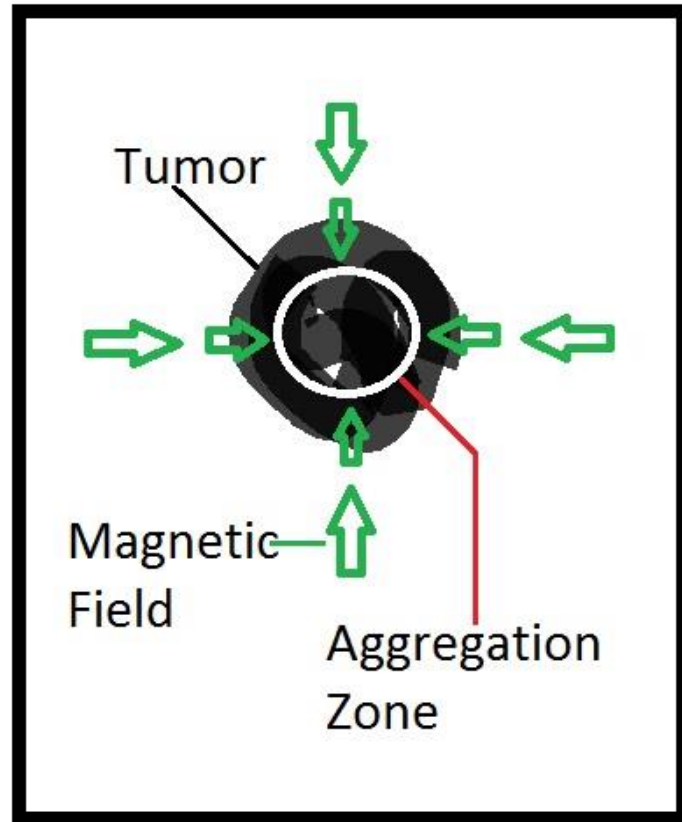
Magnetic Pole

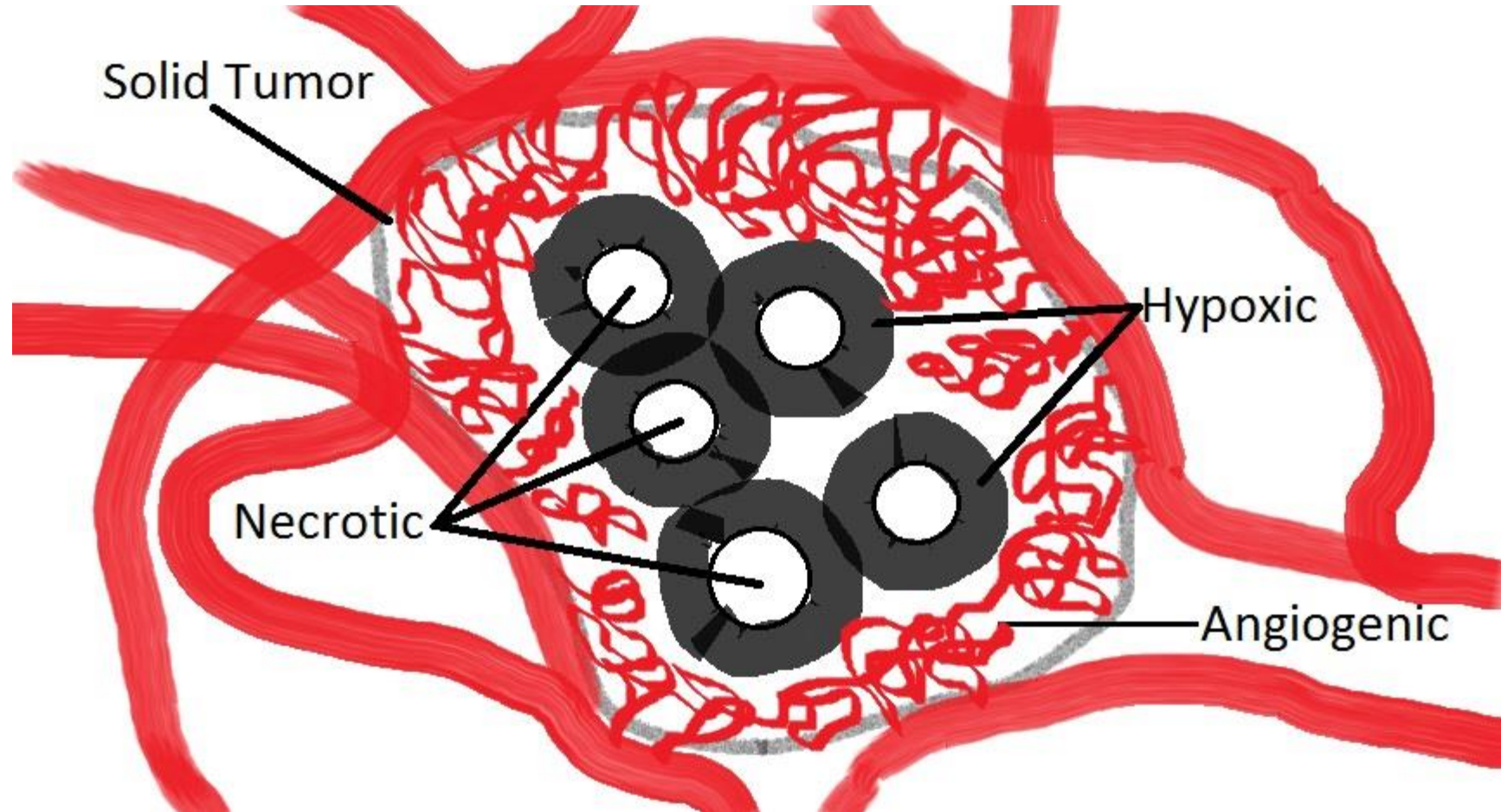


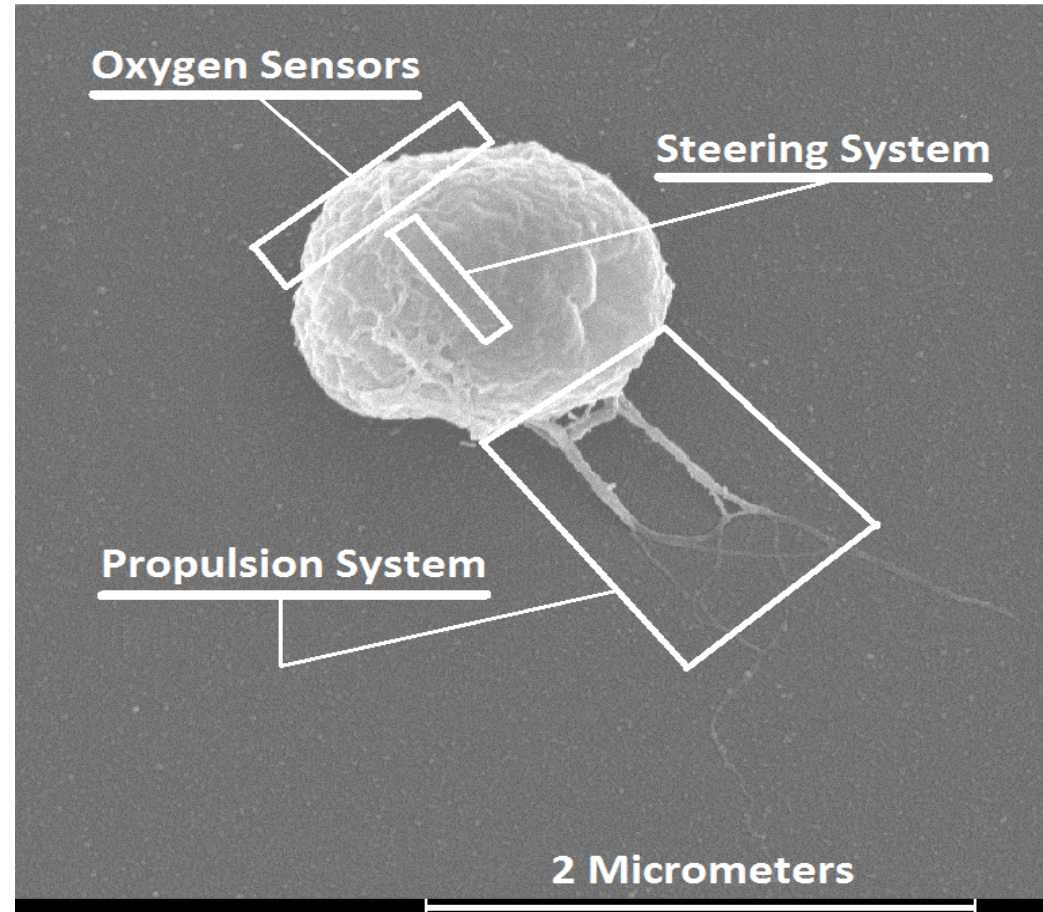
$$B_z = \frac{\mu_0 I}{2\pi a \sqrt{(1+\alpha)^2 + \beta^2}} \left[E(k) \frac{1-\alpha^2-\beta^2}{(1+\alpha)^2 + \beta^2 - 4\alpha} + K(k) \right] \dots$$

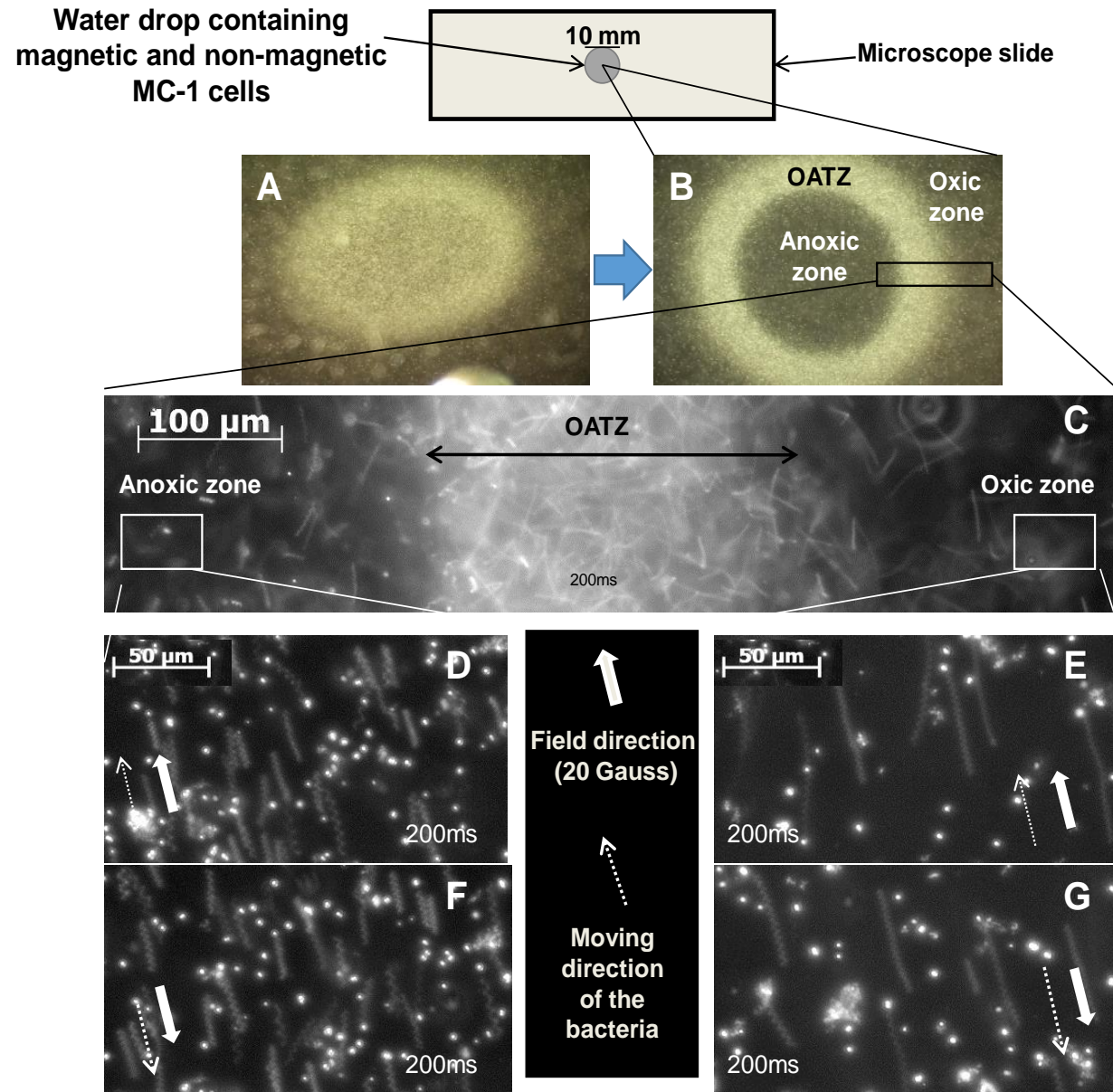


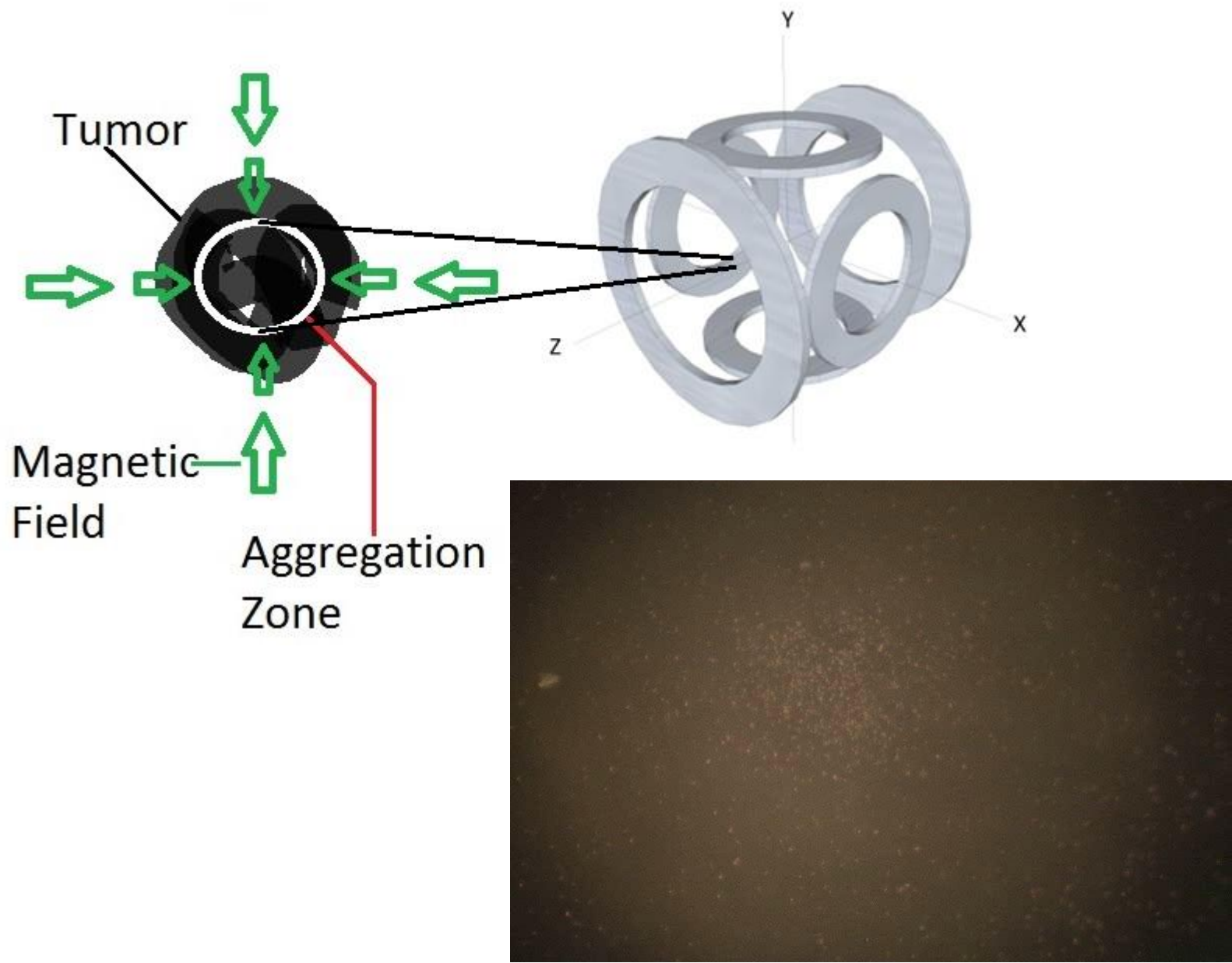
Basic Principle









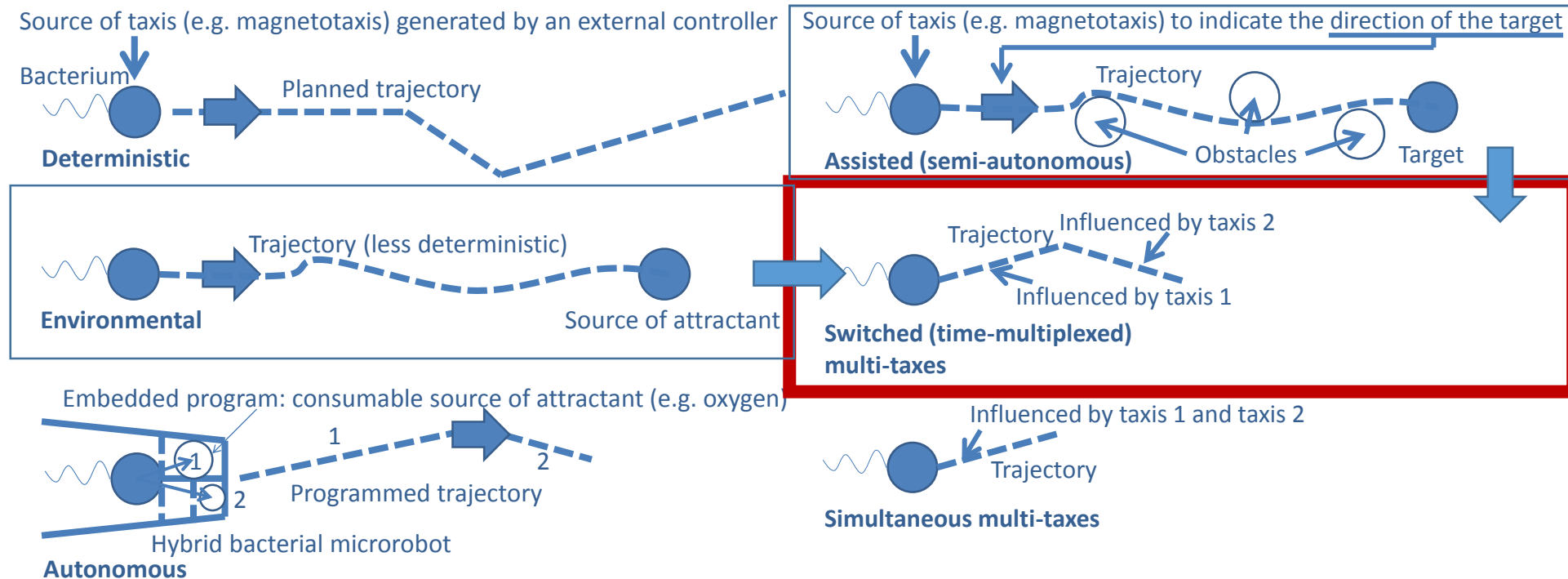


Oxygen Sensors – Microaerophilic Behavior

(Objective: Autonomous Targeting of Tumor Hypoxic Zones)

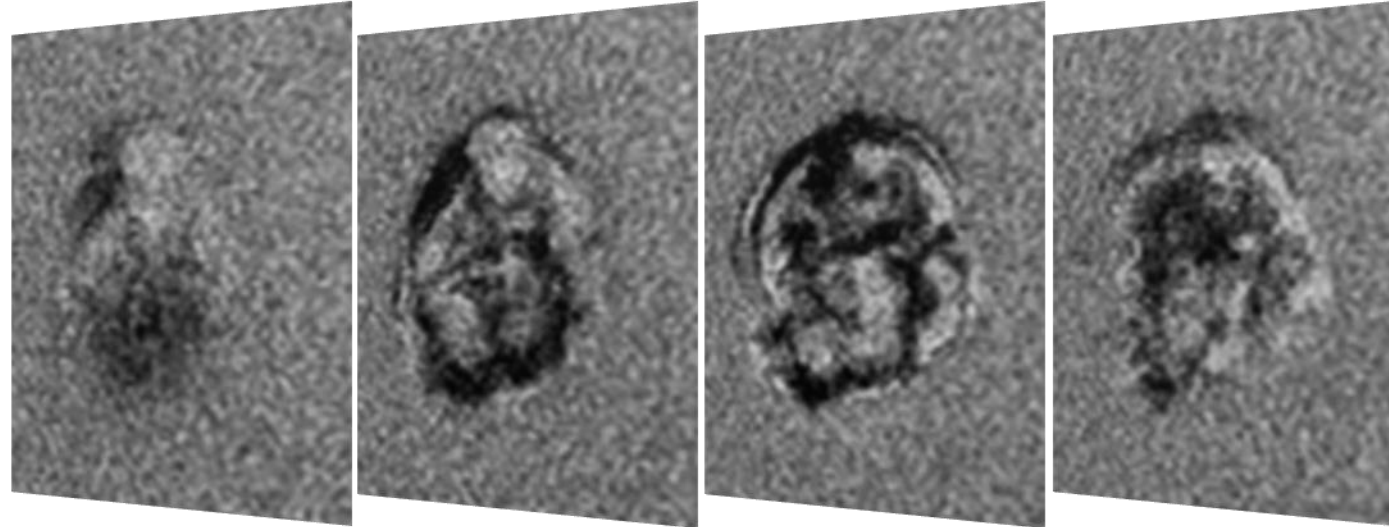


Switched Taxis-based Directional Control

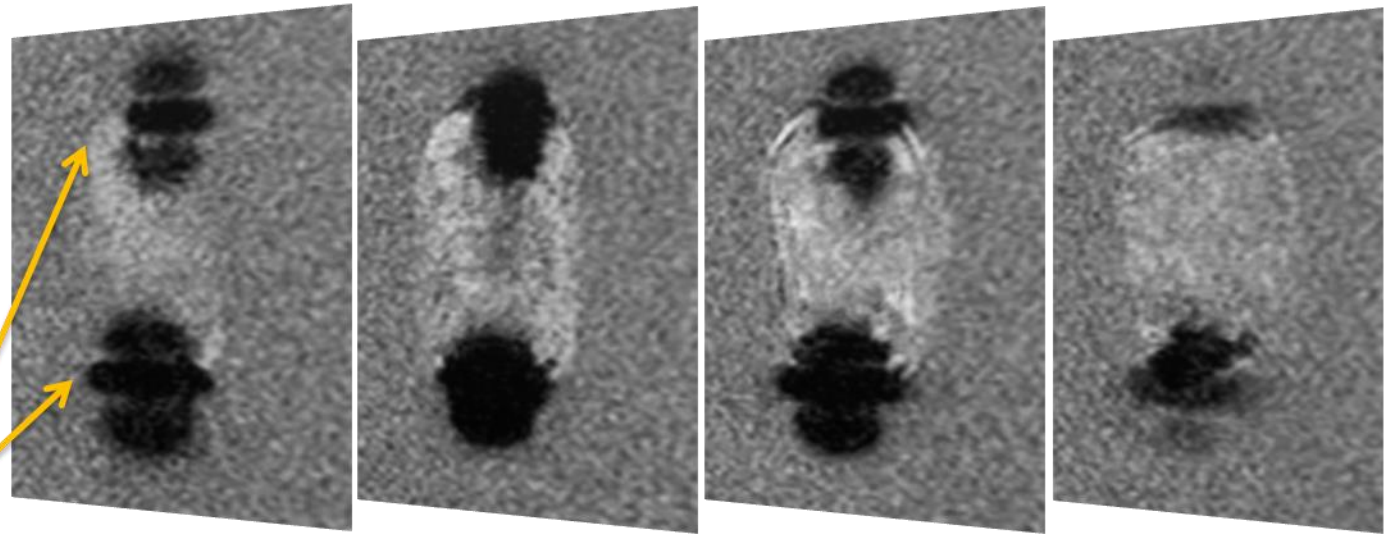


Reference: S. Martel, "Bacterial Microsystems and Microrobots," *Biomed. Microdevices*, 2013

**MTB-Particle
complex**



Particle alone



**Injection
sites**

Acknowledgements

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- In alphabetical order (current immediate collaborators in medical applications only):
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- N. Beauchemin – Biochemist, McGill University
- G. Beaudoin – Medical Physics and MRI sequencing, University of Montréal
- F. Cheriet – Medical imaging, Polytechnique Montréal
- L. Gaboury – Pathologist, University of Montréal
- H. Girouard – Pharmaceutical, University of Montréal
- S. Kadoury – Medical image registration, Polytechnique Montréal
- M. Lafleur – Chemist, University of Montréal
- M. Mohammadi – Biologist, bacterial culture, Polytechnique Montréal
- D. Radzioch – Immunologist, McGill University
- G. Soulez – Interventional Radiologist, University of Montréal
- M. Tabrizian – Biomaterials and Bio-interfaces, McGill University
- T. Vuong – Radio-oncologist, McGill University
- Etc...

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