Electronic Supplementary Material (ESI) for Lab on a Chip.

Supplementary Information

Magnetic Steering Control of Multi-Cellular Bio-hybrid Microswimmers

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Supplementary Movies:

Number	Title	Description
S1	Motion of a micro-swimmer subjected to a constant magnetic field.	Phase-contrast microscopy of a bacteria-propelled micro-swimmer subjected to no magnetic field for 25 seconds, an increasing magnetic field over 5 seconds, and then a constant magnetic field (B_x = 10 mT) over 2 minutes. The yellow arrow indicates the orientation of the applied field. The video speed is 5x real time.
S2	Flagellar propulsion of a micro-swimmer subjected to a constant magnetic field.	Confocal microscopy of a bacteria-propelled micro-swimmer subjected to a constant magnetic field (B_x = 10 mT) oriented along the horizontal axis, as indicated by the yellow arrow. The bacteria are labeled with Alexa Fluor 594 (Molecular Probes, Eugene, OR). The motion of the flagella, which provide the propulsive force to the bead, can be observed. The video speed is 2x real time.
S3	Micro-swimmer moving in a square path.	Confocal microscopy of a bacteria-propelled micro-swimmer moving in a square path. The magnitude of the magnetic field is kept constant at 10 mT but is rotated 90 degrees every 7 seconds. The yellow arrow indicates the orientation of the applied magnetic field. The bacteria are labeled with Alexa Fluor 594 (Molecular Probes, Eugene, OR). The video speed is 2x real time.
S4	Micro-swimmer spelling "CMU."	Phase-contrast microscopy of a bacteria-propelled micro-swimmer spelling out "CMU" using a pre-programmed magnetic field sequence. The magnitude of the applied field is kept constant (10 mT), but the orientation is varied as indicated by the yellow arrow. The video speed is 5x real time.

Supplementary Figures:

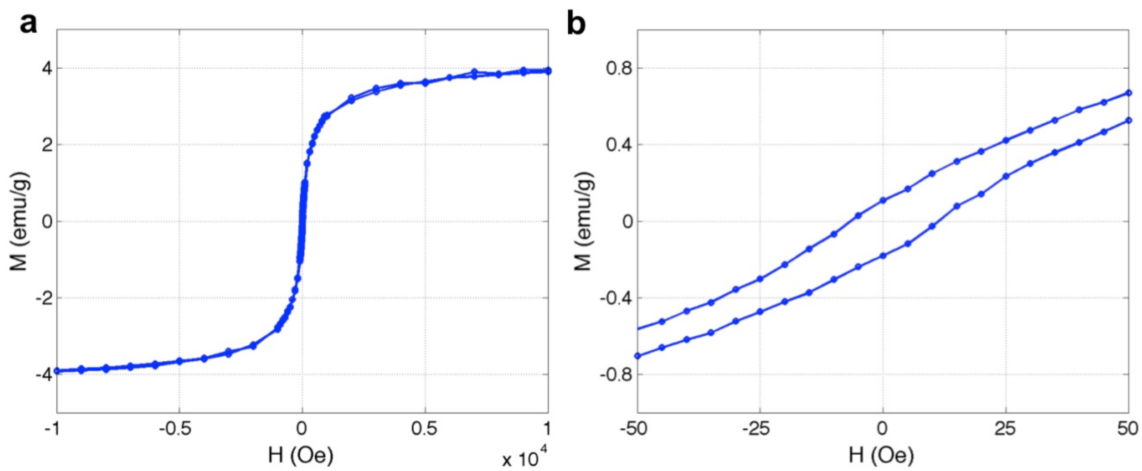

Figure S1. Magnetization curve. (a) The magnetic hysteresis loop of the superparamagnetic beads (6 µm-diameter, streptavidin-coated COMPEL beads, Bangs Laboratories, Inc.) used in this study was measured with a SQUID (superconducting quantum interference device) magnetometer at room temperature (300 K). (b) A zoomed-in portion of the hysteresis loop is shown. The magnetic susceptibility of the beads, χ_b, is calculated to be 0.20 ± 0.05 (95% confidence interval) from the following equation: $\chi_b = \frac{4\pi}{10^3}\rho\frac{\Delta M}{\Delta H}$ [1] where ρ is the bead density (1090 kg/m^3) and $\Delta M/\Delta H$ is the slope of the linear fit to the curve from -25 to 25 Oe.

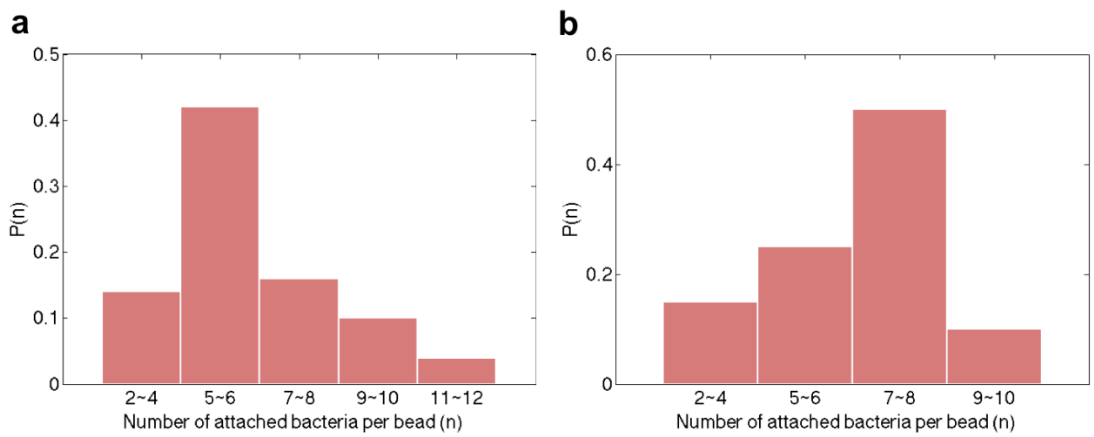

Figure S2. Probability distribution, P(n), of the number of attached bacterial cells. (a) Controllable case (i.e. micoswimmers move along the direction of a 10 mT applied field), where the bacterial attachment number is quantified for a sample size of 43 controllable microswimmers. (b) Uncontrollable case (i.e. microswimmers fail to move along the applied field direction), where the bacterial attachment number is quantified for a sample size of 20 uncontrollable microswimmers.

1. Shevkoplyas, S., Siegel, A., Westervelt, R., Prentiss, M. & Whitesides, G., The force acting on a superparamagnetic bead due to an applied magnetic field. *Lab Chip* **7**, 1294-1302 (2007).