

## SCIENCE FICTION, SCIENCE FACT

## Early science fiction got microbots surprisingly right

Robin R. Murphy\*

Since 1931, science fiction has speculated on how microbots might work and how they will change our lives.

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The 1959 lecture of Richard Feynman “There’s Plenty of Room at the Bottom” (1) may have popularized the notion of manipulating matter at progressively smaller scales, but 28 years earlier, the short story “Microhands” by Russian author Boris Stepanovich Zhitkov (2) presciently detailed the real-world open research topics in scale, actuation, sensing, and control that would be needed to accomplish that vision. The hard science story is about what we would now call microbots, microelectromechanical systems (MEMS) operating at the micrometer ( $10^{-6}$  m) scale. Microbots are often conflated with nanorobots, which are protein or molecular structures working at nanometer ( $10^{-9}$  m) dimensions. For example, the 2019 technothriller *Level Five* by William Ledbetter uses “nanobot” to refer to both the barely visible surveillance devices that jump like fleas to hide in hair and the invisible biochemical compounds injected by doctors to regulate (or nefariously manipulate) depression.

Quibbles over “micro” and “nano” aside, the change in scale dramatically alters how real-world microbots function in terms of actuation, sensing, and control (3). Actuation is more demanding because gravitational forces are less important for microbots than for a 100-pound (45-kg) traditional robot. Surface properties and adhesion in micro-scale fluid flow make every movement through a body akin to driving through sticky mud (4). Microbot sensing is directed toward understanding the environment, for example, using a camera to assess the characteristics of growth on an organ, not for autonomously navigating. Control is different as well, with microbots often manipulated by external magnets that are used to nudge them along to the preferred location and orientation (5).

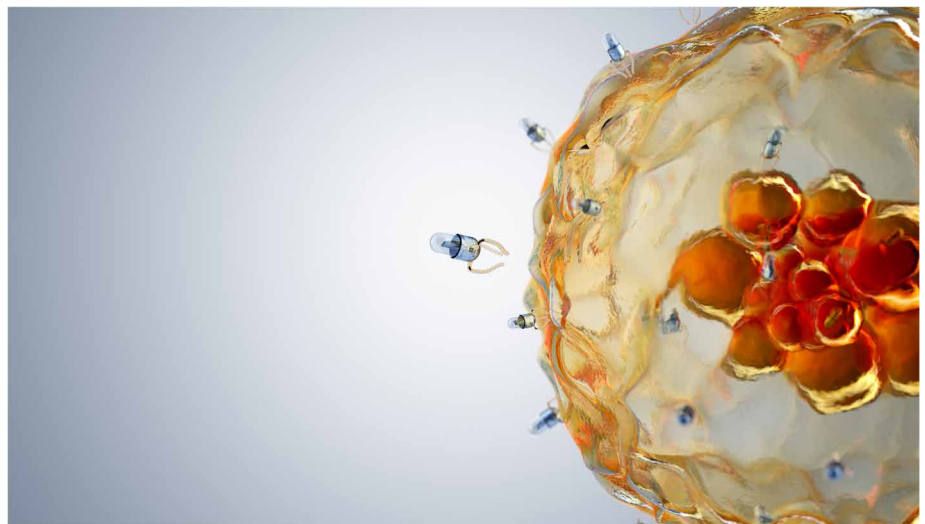
Remarkably for 1931, “Microhands” illustrates the real-world challenges for each

of these functions. In the story, an unnamed inventor creates a pair of recursively smaller and smaller mechanical hands, which he uses for robot surgery on tumors and eyes. The hands are remotely controlled through force feedback gloves connected to the microhands by thin wires in the pre-wireless era. The inventor wears powerful microscope-like eyeglasses to observe what the hands, which are improbably never occluded from view, are doing. Despite his humanitarian urge to stay focused on improving microhands for surgery, the inventor is enchanted with the new vistas now open to him and obsesses with the manufacture of smaller and smaller devices so that he can probe and dissect single-cell organisms. To do so, he must devise new manufacturing techniques to cope with the change in material properties of his MEMS devices and wired connections at an atomic scale. The inventor also has to contend with unanticipated conditions imposed by the change in scale when the membrane of a water droplet becomes an insurmountable physical barrier for the microhand to push through.

“Microhands” falls short only in realistically describing how human operators will

comprehend the device and its interactions with the environment. The force feedback gloves in the story provide a haptic complement to the inventor’s high-magnification optics. The gloves are not a perfect solution, as seen when a ciliate wraps one of its snake-like appendages around the microhands. The ciliate breaks the bots and, via the undamped feedback to the gloves, the inventor’s flesh-and-blood hands as well. Recent science fiction acknowledges the importance of facilitating human comprehension, most notably the 2014 short story by Ian McDonald, “Nanonauts! In Battle with Tiny Death-Subs!” Unlike the inventor in “Microhands,” the human operators, called nanonauts, cannot see the robots’ movements nor make sense of the internal biological structures as they externally control the molecular medical nanobots operating inside the president’s body. To compensate, the nanonauts are provided with a virtual reality visualization of the microbots as Jules Verne-like steampunk submarines flying about a biological landscape rendered as if in a scene from the movie *Fantastic Voyage*.

In the nearly 100 years that science fiction has been imagining microbots, the narratives



all agree on one thing: Microbots offer great value to humanity, especially in medical applications but also in chip and materials manufacturing. However, although speculating on uses is easy, making microbots a reality remains hard even in 2024. Despite the challenges, advances in research have spawned at least four startup companies, and one microbot is beginning phase 1 clinical trials (6). The gap between science fiction and science is closing as roboticists make

admirable progress in addressing the open research questions posed by the fascinating world at a microscale.

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