POWERING NANOROBOTS

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We live in a world of technology. We are surrounded by an uncountable number of machines and devices without which we can’t imagine our lives. And what awaits us in the future? Many scientists are trying to answer this question translating into practice the most amazing ideas. Nanorobots are exactly the epitome of their creative and brilliant thinking.

Imagine that we could make cars, aircraft and submarines as small as bacteria or molecules. Microscopic robotic surgeons injected in the body could locate and neutralize the causes of disease. And nanomachines could penetrate the steel beams of bridges or the wings of airplanes fixing invisible cracks before they propagate and cause catastrophic failures. But look under the hood of the nanocar and you will not find an engine. This is the biggest current problem with molecular machines: we know how to build them but we still do not know how to power them.

Nature provides many examples of nanomotors. The cell uses nanoengines to change its shape, push apart its chromosomes as it divides, construct proteins, engulf nutrients, shuttle chemicals around, and so on. All these motors are based on the same principle: they convert chemical energy. Researchers are now making exciting progress toward building artificial nanomotors by applying similar principles. The Harvard team had found that centimeter-scale "boats" with catalytic platinum strips on their stern would spontaneously move on the surface of a tank of water and hydrogen peroxide.

The miniaturized version of the Harvard engine was gold-platinum rod about as long as a bacterial cell (two microns) and half as wide (350 nanometers). Oar rods were mixed into the solution rather than floating on the surface. These tiny catalytic cylinders were essentially immersed in their own fuel. And they did indeed move autonomously at speeds of tens of microns per second bearing an eerie resemblance under the microscope to live swimming bacteria.

One limitation of the first fluid-immersed nanorods was that they moved in random directions and were continuously undergoing random turns because of Brownian motion. In realistic applications, of course, nanomachines will need some mechanism to steer them toward their destination.

The first attempt to solve the steering problem relied on a magnetic field. Nanorods then move in straight lines and can be steered by turning the magnet. This motion is analogous to the behavior of bacteria that align themselves with the earth's weak magnetic field. Scientists Velegol and Sen discovered that catalytic nanorods can follow chemical "bread crumb trails" the way bacteria do. This strategy is called chemotaxis. The particles can also be driven by light or phototaxis. These particles use light to break up molecules and create positive and negative ions. The two types of ions diffuse away at different speeds, setting up an electric field that causes the particles to move.

Nature has found ways to put Brownian motion to work rather than fighting it. Many biological motors are based on the principle of the Brownian ratchet, which uses energy from chemical catalysis not to create motion in a certain direction but to allow Brownian-motion jolts only when they push in the favorable direction, while blocking them when they push in the opposite direction.

Investigators have learned a good deal about how to make nonbiological motors inspired by those of biology, but there is still much to learn about the principles of catalyzed movement on this length scale.

Future work will find as yet unimagined ways to exploit such knowledge in biomedicine, energy conversion, chemical synthesis and other fields.