The Los Alamos bug

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Containment This relies on the fact that oil and water do not mix. The components of each individual Bug are contained by a droplet of fatty acids, suspended in a watery solution enclosed by a test tube. Each fatty acid molecule has a negatively charged head which is attracted to water and which faces out into the watery environment, and a water-hating oily tail facing inward.

Heredity

Instead of DNA the Bug has short stretches of peptide nucleic acid, or PNA. Like DNA, PNA is made of two intertwining strands containing the genetic "letters" A, T, C and G. And like DNA, the sequences of letters on these stands complement each other. A pairs up with T and C pairs with G.

The strands have a peptide backbone which does not carry an electrical charge, so will dissolve in fat. This means that the molecules of PNA prefer to face the inside of the fatty acid droplet, like crumbs embedded in the surface of a piece of chewing gum.

This gives the molecule unusual mobility. In its usual double-stranded form, with its two peptide backbones facing outwards, a PNA molecule is completely fat-soluble, so it will sink into the oily centre of the Bug's droplet. But above some critical temperature, the two strands of the PNA double helix separate spontaneously. When this happens, the bases, which bear a slight charge, are exposed and attracted to the Bug's watery environment.

So these single-stranded PNA molecules should then migrate to the edge of the droplet where the backbone can remain in the oil while the bases interact with the water outside.

This mobility provides the handle needed to control replication. The plan is to supply the Bug with short bits of single-stranded PNA precursors, just half the length of its tiny genome. If a single-stranded PNA gene on the Bug's surface encounters two of these "nutrient" PNAs with the right base sequences, it will pair with them to form a double-stranded PNA molecule. This should then sink down into the droplet, where conditions favour the joining-up of the two "nutrient" fragments into a whole strand.

Eventually, the double-stranded molecule will dissociate once again and its two strands drift back to the surface where each can pick up new partners - a rudimentary form of replication.

Metabolism

The third essential part of the Bug's life - metabolism - has also been pared to its barest minimum. The researchers plan to "feed" the Bug with fatty acid precursors. These will have photosensitive molecules attached their charged "head" ends. These photosensitive caps mask the charged head, making the molecules completely fat soluble. This means they will tend to collect within the Bug's droplets.

When light strikes the photosensitive cap, it breaks off, exposing the negatively charged fatty acid head, which migrates back to the surface of the droplet. Eventually, so many new fatty acids will be produced that they will not all fit on the surface and the droplet will split in two to create a larger surface area.

The Bug will also be supplied with inactive PNA precursors bound to a photosensitive molecule. Once

again, when light strikes this photosensitiser, it breaks off to release the active PNA fragment.

Effective metabolism also requires one more step to prevent the photosensitive molecule, once broken off, from re-sticking to the fatty acid or PNA and so deactivating it once again. The PNA genetic material prevents this by acting as a rudimentary wire, conducting electrons to neutralise the photosensitiser. In this way, the Bug's "genome" plays an active role in the metabolic process.

Evolution

If all goes according to plan, these three components - container, genome, metabolism - should fit together to provide all the essentials for Darwinian evolution. As the Bugs grow and reproduce, corralled in a test tube, natural selection should favour PNA base sequences that pair up and split off fastest, and also conduct electrons most efficiently to the photosensitisers.

Synthetic slaves

Artificial organisms could be custom-built for particular tasks:

- break down toxic compounds
- produce useful chemicals such as hydrogen fuel
- act as "living pharmaceuticals", delivering drugs in the body in an adaptive way
- be tiny diagnosticians, roaming our bodies, collecting information and checking for problems
- become part of machines that can repair themselves as living beings do

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