Yamini Jangir slowly descends into the darkness, armed with a head torch, canisters and electrodes. She passes roughly hewn layers of rock, hacked back years ago to make way for the lift shaft. The lift cage eventually judders to a halt, 1.5km below the surface. Siphoning off the water inside, she inserts the electrodes and waits for her prey to ‘bite’. The airless, dark depths of a gold mine in South Dakota might not seem like the best place to look for life. But here, deep under the surface, microorganisms surviving on electricity alone could hold clues as to what kick-started life on Earth, and whether alien life exists on other planets.

THE POWER OF LIFE

Laptops, smartphones and other electronic devices rely on electricity, specifically the flow of electrons. Food is therefore considered an ‘electron donor’ – it’s the power supply. But for these electrons to flow, something needs to be drawing on the supply. Oxygen, an ‘electron acceptor’, scavenges these electrons from other molecules during chemical reactions, therefore generating a flow. The actual process is more nuanced than this but, at its core, this is how all living things are powered.

Bizarre microbes that feed and breathe on electricity alone could be the missing link for how life began on Earth, and may even offer clues as to whether alien life exists on other planets.
These microorganisms, lurking in the deep, dark places of the world, seem to have harnessed the ability to directly consume electrons from their environment – they have a direct line. “All life essentially feeds off electricity,” explains Jangir’s supervisor Prof Moh El-Naggar, from the University of Southern California. “But microbes have managed to take it to the next level.”

**METAL MUNCHERS**

Microbes like the ones that are currently being studied by El-Naggar and his team were first discovered decades ago. Back in the 1980s, researchers found that two different species, *Shewanella* and *Geobacter*, were able to survive without the oxygen that typically generates the flow of electrons. Instead, the bacteria used metal-based minerals, like iron- or manganese-based rocks, as ‘electron acceptors’ to produce an electron flow when oxygen wasn’t present in the environment. Since then, different research groups have discovered more of these microbes, and found that the bacteria weren’t just able to ‘jump’ electrons directly into minerals – they were able pick them up too. In other words they were feeding directly from the minerals by creating a living circuit.

No one knows exactly how many of these electron-eating species there are, but scientific research suggests it is a fairly widespread ability in many kinds of microbes. However, the microbes are most likely to be found in extreme environments that are rich in insoluble substrates. “Deep underground is an obvious place for the electron-eating microbes to live, where the rocks contain elements, such as sulphur and iron, which easily lose or gain electrons,” says Jangir. “But microbes are extremely versatile and use all sorts of methods to survive. Depending on the environment, some use multiple-electron donors and acceptors. For example, the microbe that picks up electrons from electrodes may be perfectly capable of using other more conventional sources of electrons. And the ones that send electrons away to surfaces might be able to use more conventional molecules to breathe, such as nitrates, sulphates and even oxygen.”

**HOW MICROBES FEED ON ELECTRICITY**

Every organism gains its energy by the flow of electrons from an electron donor to an electron acceptor. In humans and other animals these electron donor and acceptor molecules are free to diffuse inside our cells, where they synthesise the ‘energy currency’ of cells, adenosine triphosphate (ATP), in the power stations of the cells.

The same process happens in single-celled organisms (such as archaea and bacteria), but the electron transfer also occurs outside the cell. The microbes that feed on electricity alone transfer electrons to metal oxides, such as iron and manganese minerals in rocks, either by electron-shuttles called ‘flavins’ or along nanowires known as ‘pili’.

1. **Cytochromes** are proteins that are present on the outer membrane of the bacteria. Cytochromes contain ‘heme groups’ that accept and donate electrons, enabling charge to flow along the membrane.

2. Molecules called flavins act as electron shuttles, picking up electrons from the cell and dropping them off at a nearby electron acceptor, such as a mineral substrate. Once the flavins have dropped off the electrons, they travel back to the bacteria to collect some more.

3. Electrons can also travel along nanowires, called ‘pili’, sticking out of the microbe cell body. The pili are also covered in cytochromes, and the electrons use them to ‘hop’ along the nanowire.
**Microbes**

**A Marvellous Microbial Menu**

The strange eating habits of some of the world’s most bizarre bugs

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**Life on the Edge**

These metal-munching microbes are just some of the many tiny, super-powered organisms living in extreme environments on Earth.

**Potty Mouth**

Microbes are often used to break down waste at sewage treatment plants. Bacteria known as azotobacters can survive without oxygen and love nothing better than to break down ammonia and nitrate in human waste, producing a fuel that could, theoretically, be used for space probes.

**Slick Solution**

In April 2010, the Deepwater Horizon oil rig burst into flames, spilling almost five million barrels of oil. Genetically modified Alcanivorax borkumensis microbes were brought in to help with the clean-up operation by breaking down the oil’s molecular structure. When microbes are piled one on top of another in sediment, the nanowires act a bit like straws, so that the microbes at the bottom of the pile can still transfer electrons.

**NuKed!**

In 2014, a team from the University of Manchester discovered that various microbes can degrade the organic material found in nuclear waste. The microbes use the waste as a source of food and energy, and prevent radioactive elements leaching into the environment.

**Smarty Pants**

Stinky underwear can be a problem on any long journey – particularly if you’re aboard the International Space Station. The solution? In the 1990s, Russian scientists tried using various bacteria to degrade soiled underwear and turn the resulting methane into biofuel.

**Plastic Surgery**

Around 300,000 tonnes of plastic swirl around the planet’s oceans at any one time. That’s one giant plastic problem.

**Electron transfer is fundamental to all of life’s energetics. Perhaps it holds the key to discovering life on other planets!**

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**Research Facilaty in South Dakota. They are writing up the results of that research right now. “We don’t yet understand the movement of electrons in biology as well as we understand them in metals or semiconductors,” says El-Naggar. “Yet look at the amazing developments of our digital age that were enabled by an understanding of how electrons move in ‘hard materials.’”**

Microbes that transfer electrons have already been used for tasks like degrading toxic and industrial waste, and recovering metals. Scientists are now looking at how to harness microbial electron transfer to synthesise nanomaterials, and are working on technologies that use microbes to generate electricity.

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**Jean Ormerod is a science journalist and presenter of SciTechVoyage. Her books include 100 Ideas That Changed the World and The World’s Great Wonders.”**