C-MOULD

Collection of Microorganisms Of Use in Living Design

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Introduction.

C-MOULD is a unique collection of microorganisms with specific use in the arts and design with over 30 different kinds of microorganism. For example, we have bacteria that glow in ethereal shades of blue light, bacteria that make gold and electrically conductive nanowires, and bacteria that produce BioTextiles. We also possess a large collection of naturally pigmented bacteria.

1.0 Naturally pigmented bacteria (Living paints and BioDyes)

When grown on bacteriological agar, most bacteria grow as off-white or cream coloured colonies. Occasionally, however, a bacterial species will produce a brightly coloured colony. Below is the palette of living colours that is available through C-MOULD and such bacteria could be used as paints or textile dyes, for example. Behind their obvious colour, each bacterium also has its own unique "personality" and history (see below), and when used in paintings, each one contributes its own character to the work. In doing so the bacteria become non-human agents. For example, some species are highly motile and able to move, whilst others aren't. Moreover, the production of the coloured pigments isn't for our benefit and is thus adventitious, and these compounds always have other important activities, such as acting as antibiotics or protecting the bacteria from sunlight.

***Serratia marcescens* (red and more)**. This distinctive red pigmented bacterium has been evoked as a natural explanation of the "miraculous" appearance of blood at various times throughout history. For more information on this bacterium and its fascinating history please follow this link: https://exploringtheinvisible.com/2016/01/25/the-aesthetic-bacillus/. The colour of colonies of *S.marscens* is due to its production of the red pigment prodigiosin. Production of this pigment is metabolically expensive for the cells, and when they are grown in the relative comfort of rich laboratory medium, they no longer need to produce prodigiosin. Consequently, in the absence of natural selection for this property, cells of this bacterium lose the ability to produce it and produce white non-pigment producing colonies. Finally, amongst bacteria, this bacterium has the very rare ability to "paint": https://exploringtheinvisible.com/2013/07/16/primitive-culture-an-idea-of-pervading-life-and-will-in-nature/

***Chromobacterium violaceum* (purple)**. Very common in soils from tropical and subtropical regions, this bacterium produces a purple pigment (violacein) which also has powerful antiviral and anticancer activities. Consequently, its colonies are of a striking purple colour.

***Pseudomonas aeruginosa* (pathogenic green)**. This bacterium has a split personality. It is very common in soil and is able to live a blameless life here. However, if it is provided with opportunities (such as failings in the host's anti-infective defence) it will cause disease in most living things, including humans, and accordingly it has been described Nature's pre-eminent universal pathogen. The green pigmentation is due to the production of a compound called Pyocyanin which is readily recovered in large quantities in sputum from patients with cystic fibrosis

who are infected by *P. aeruginosa* and which is important in the ability of this bacterium to cause disease.

***Bacillus atrophaeus* (brown, a surrogate for Anthrax).** A common soil bacterium which is often used as a harmless surrogate for *Bacillus anthracis*, the bacterium which causes anthrax. It has the ability to form tough resting bodies called endospores.

***Vogesella indigofera* (anthropogenic blue).** A rare blue and gold pigmented bacterium that was first isolated from the sediment of a pond that was used for the disposal of highly toxic chemical wastes for 20 years. The blue colour is due to the production of a compound called Indigoidine, a bacterial natural product with antioxidant and antimicrobial activities. The bright blue colour of this compound resembles the industrial dye Indigo, and thus it offers the possibility that Indigoidine might become a new natural blue dye that may find many uses in industry.

***Arthrobacter polychromogenes* (denim blue).** *Arthrobacter* is a genus of bacteria, the members of which, are commonly found in soil. The species *A. polychromogenes* was first isolated when an airborne contaminant landed and grew on agar in a Petri dish and this spiked interest because of the striking appearance of its blue colony. The bacterium produces two blue pigments, the water-soluble compound Indochrome, and the insoluble pigment Indigoidine which might be used as sustainable and natural alternative to the Indigo used to stain denim.

***Staphylococcus epidermidis* (skin white, a cure for cancer?).** One of the most frequently isolated bacteria to be found on human skin and an important member of the natural human skin microbiota. It is a very close relative of *Staphylococcus aureus* and MRSA. Whilst it isn't as pathogenic as these bacteria, it is a very important opportunistic pathogen, not able to cause illness in otherwise healthy people, but capable of infecting the compromised human host. In fact, it is now the most frequent cause of nosocomial infections (acquired in hospitals), at a rate almost as high as that due *S. aureus*, its more virulent cousin. It also the most frequently isolated bacterium from human skin and is especially common in damp areas like the groin and arm pits. Skin is a surprisingly harsh environment for bacteria, and analysis of the *S. epidermidis* genome shows that this bacterium is well equipped with mechanisms that protect it here, and especially, allow it to tolerate extremes of salt concentration in the form of dried human sweat. It is also highly resistant to many antibiotics including penicillins. Recently, it has been found that *S. epidermidis* produces a compound called 6-N-hydroxyaminopurine (6-HAP) which has been shown to inhibit DNA replication. Notably, the application of 6-HAP-producing strains of *S. epidermidis* to the skin of mice greatly reduces both the number of pre-malignant skin tumours formed when the animals were exposed to ultraviolet light. Moreover, in mice injected regularly with 6-HAP, melanoma tumour growth was slower than in mice not exposed to this compound. It is possible then that this bacterium might possess anti-cancer properties.

***Kocuria rhizophila* (formerly known as *Micrococcus luteus* (sunlight yellow).** This is a very common yellow pigmented human skin inhabitant that has adapted to be able to survive and grow in this unexpectedly harsh environment. In damp regions of the body, such as the armpits, it can give rise to body odour after it breaks down

compounds in sweat. Like human skin is, bacteria are also susceptible to the damaging effects of ultraviolet light (UV), and so exposed to sunlight on a daily basis, *K. rhizophila* synthesises a pigment that absorbs wavelengths of light from 350 to 475 nm. This pigment then absorbs damaging UV light and protects this bacterium from its bactericidal effects. Exposure to these wavelengths of UV, commonly referred to as UVA, has also been correlated with an increased incidence of skin cancer, and so textiles dyed with this bacterium, in addition to being a vivid yellow colour, would possess a BioFunctional sunscreen that would protect the wearer against UVA. Away from the body, *K. rhizophilia* is also an important bacterium in the context of the history of microbiology and medicine, as it played a key role in Alexander Fleming's discovery of lysozyme, to which it shows exquisite sensitivity. In fact, it is readily killed by the lysozyme naturally present in human tears irrespective whether they are generated by happiness or grief. Finally, variants of *K. rhizophila* can precipitate gold by concentrating and crystallizing it on their surface.

***Kocuria rosea* (formerly known as *Micrococcus roseus*) (keratinase pink).** This is another bacterium that is frequently isolated from human skin. Its adaptation to this environment is its ability to breakdown, and thus utilise keratin, the key structural protein making up the outer layer of human skin. The name of the species *rosea*, gives a clue to the colour of its colonies which are bright pink. It also produces a variety of different pigments one of which is canthaxanthin. This is a rust coloured pigment that is approved as a food additive in a number of countries. It is also the active component of tanning pills. When taken at these large doses, many times greater than the amount normally ingested in food, this substance is deposited in various parts of the body, including the skin, where it imparts a golden orange hue, because it accumulates in the panniculus. However, when consumed in these high doses it causes canthaxanthin retinopathy, which can lead to loss of vision, because the pigment accumulates in the macular (the central part of the retina). Finally, by virtue of its colour and keratin digesting activity *K. rosea* may also be involved in a mysterious condition in swans called Pink Feather Syndrome, in which the birds develop a pink coloration on their feathers. Overtime, the pink feathers become degraded, and the swans may die.

***Bacillus subtilis* (model orange).** This bacterium is commonly found in soil and has the ability to form a tough resting bodies called endospores. Also known as the hay bacillus or grass bacillus, it is considered the best studied Gram-positive bacterium and a model organism. It also produces a wide variety of powerful secreted enzymes which are used on an industrial scale by biotechnology companies. In the past its powerful enzymes, that digest proteins, were incorporated into biological washing powders that cleaned "whiter than white". Inhalation of such products, particularly amongst factory workers involved in their preparation, has been shown to cause asthma. Most strains of this bacterial species produce cream coloured colonies. This strain, however, produces colonies that are coloured orange.

***Arthrobacter agilis* (artic red).** This bacterium, which produces red pigmented colonies, is frequently isolated from dry rocks and soil. It has also has been found in Antarctic rocks and soils and has the ability to grow at low temperatures. It is through this cold-resistant characteristic that this bacterium may serve as a source for antifreeze proteins, and cold-active functional enzymes and other bioactive molecules in future bioprospecting projects. In addition, A.*agilis* is a plant growth

promoting bacterium and produces a variety of volatile organic compounds that inhibit the growth of a number of important plant pathogenic moulds.

***Rhodococcus rhodochrous* (explosive pink).** This bacterium is frequently isolated from soil, and especially that which is contaminated with industrial pollutants. It is considered to be a significant part of the soil microbial community because of its diverse biodegradation mechanisms. In this context, one strain *R. rhodochrous*, isolated from land contaminated land can degrade and use the nitramide explosive RDX as a sole nitrogen source for growth.

***Dermacoccus nishomiyaensis* (orange).** This orange pigmented bacterium is frequently isolated from mammalian skin.

***Micrococcus varians* (aromatic white).** This bacterium is commonly found in starter culture mixtures utilized in the fermentation of meat products. Among its main characteristics, *M. varians* provides a pleasant colour and flavour to these products.

2.0 Microorganisms producing BioMaterials/BioTextiles.

Microorganisms, such as fungi, bacteria and algae, naturally produce many different types of polymer that may be exploited in the creation of radical new design concepts. Materials from such organisms are not produced mechanically, like traditional textiles, but grown. For example, cellulose, which forms the basis of many traditional textiles like cotton, is usually associated with plants, is also produced by certain species of bacteria and has structural properties that can be exploited in numerous applications.

***Gluconacetobacter xylinus* GXCELL (cellulose).** A number of bacteria including those from the genera, *Escherichia* (*E.coli*), *Salmonella*, *Agrobacterium*, *Pseudomonas*, and *Rhizobium* synthesize cellulose but only the *Gluconacetobacter* produce enough cellulose to justify commercial interest. The most extensively studied species of these is *Gluconacetobacter xylinus*, which plays an important role in the production of Kombucha. This is a fermented, slightly effervescent drink based on sweetened black or green tea which is produced by the action of a symbiotic culture of *G. xylinus* and a yeast. Together these form a thick cellulose rich mat called a Scoby that forms on the interface of the liquid and air. *G. xylinus* extrudes chains of glucose from pores into its growth medium which aggregate into microfibrils, and then bundle to form microbial cellulose ribbons. Of many strains of this bacterium tested at C-MOULD's *G. xylinus* GXCELL produces, by far, the most cellulose. The pure nanocellulose that it produces offers vastly improved tensile properties compared to Kombucha in which the presence of the yeast weakens the overall structure.

***Azotobacter vinelandii* (alginate).** This is free-living bacterium that is widely distributed in in soil and which has a number of interesting features including BioMaterial production and the rare ability to fix nitrogen in the presence of atmospheric oxygen concentration. Bacterial alginates are useful for the production of micro- or nanostructures suitable for medical applications. Moreover, *A. vinelandii* grows on a very simple solution of salts, assimilates nitrogen from the air, and thus could be used to produce sustainable BioMaterials.

***Pseudomonas fluorescens* (levan).** Levan is a polymer made from the sugar fructose Bacterial levans form compact nanospheres offering a broad spectrum of applications. *Pseudomonas fluorescens* produces levan when grown in the presence of sucrose (sugar). In addition, this bacterium is readily found in soil and water, secretes the fluorescent pigment pyoverdin, produces the antibiotic mupirocin, and protects some plant roots from parasitic fungi or nematodes.

***Penicillium camembertii*.** Fungi play a number of important roles in the production of a variety of famous cheeses. In such, so called mould ripened cheeses, the fungus can generate flavours, most notably in the pungent tang of Stilton and Roquefort. In addition, in other cheeses like Brie and Camembert the fungus is able to provide a white protective skin that surrounds the cheese. For example, in the case of Camembert the mould generates the rind, a highly complex living surface that protects the cheese, and defends it against microorganisms that would otherwise spoil its nutritious and creamy interior. These properties might one day form the basis of living, smart, and functional materials, that would be both self-cleaning or sterilizing. C-MOULD's *P. camembertii* was isolated from the rind of a Camembert cheese. The BioMaterial that it produces has the appearance of suede but is strongly hydrophobic, that is, it strongly repels water, which if applied to the textile forms small beads and simply rolls off. This mould can be simply cultured on the surface of milk (skimmed UHT milk works best as its already sterile) to make a remarkable enzymatically active BioTextile textile is essentially a living fungal biofilm.

Penicillium roquforti. Has the same properties as *P. camembertii* above but this mould was isolated from a Stilton cheese and grows as a blue/green living mat.

***Oscillatoria animalis* (Helion).** A number of groups are investigating the use of bacterially derived materials for BioDesign, and most notably, the production of bacterial cellulose using Kombucha. The production of these materials, however, relies on the provision of some feedstock for the bacteria (which in these cases are heterotrophic), usually in the form of refined sugar, the production of which is energy intensive. Cyanobacteria are auxotrophic and photosynthetic bacteria able to grow with little more than sunlight, air and water, and thus could form the basis of truly sustainable BioMaterials. Moreover, "over 3 billion years of evolutionary history has endowed cyanobacteria with an arsenal of time-tested structural adaptations and physiological mechanisms enabling them to thrive under environmental extremes" Helion, is a unique and living BioTextile made from just sunlight water and air. Its basis is the cyanophyte *Oscillatoria animalis*. Moreover, the microscopic filaments of

this bacteria have a unique and “intelligent” self-weaving activity and demonstrate cooperative behaviour in its innate ability form dense textile-like mats.

3.0 Bacteria generating bioluminescence.

Bioluminescence is the remarkable ability of living organisms to emit light and occurs widely in nature. Bioluminescent bacteria naturally produce light and “glow in the dark”. Whilst there are other types of bioluminescent organisms, most notably fireflies and glow-worms, bacteria are the most widely distributed light-emitting organisms on the Earth. The majority of these exist in seawater with the much smaller remainder living in terrestrial or freshwater environments. Whilst many species of bioluminescent bacteria are capable of living free in the environment, many also live in symbiosis with other marine host organisms such as fish, squid, and nematodes. In the symbiotic relationship, the bacteria are nourished by the host, and at the same time the host utilizes the adopted ability to produce light to communicate, to attract prey, and to escape from predators. In addition, some luminous bacteria are parasitic, with members of the genus *Photorhabdus* infecting insects, such as caterpillars, with nematodes as the intermediate host for the bacteria. In all bioluminescent bacteria the enzyme luciferase catalyses the production of a blue/green light of around 490 nanometres in wavelength.

Photobacterium phosphoreum **HB (bright blue).** The bacterium *Photobacterium phosphoreum* forms a symbiotic relationship with deep sea fishes, where it colonises the light organs of the host, and plays a part, via its bioluminescence, in the attraction of prey and communication. The reliability of the luciferase enzyme system in this bacterium means that it has been used to measure the presence of toxins in aquatic environments such as heavy metals, PCB’s, aromatic hydrocarbons etc., as these poison the light producing biochemistry and result in it producing less or no light at all. C-MOULD’s *P. phosphoreum* HB (Hyper Bright) has been selected as an especially bright bioluminescent bacterium and is amongst the brightest bioluminescent bacteria that we have seen.

Photobacterium leiognathi **2134 (bright blue).** *Photobacterium leiognathi* is a species of bioluminescent bacteria that forms a symbiotic relationship with Ponyfish. The bacteria reside in a luminous organ in the throat of the fish, which is then able to project the bacterial light through the animal’s underside. The bacterium is strongly bioluminescent and is widely used as a demonstration of bioluminescence.

Photorhabdus luminescens **(angel’s glow).** Terrestrial bioluminescent bacteria gave rise to some earliest insights in medical microbiology when bioluminescence first observed in 1825 on two discarded corpses at The Anatomy School in London. When the luminous microorganisms were scraped from the corpses it was found that they could make others glow providing one of the very first practical demonstrations of the role of microorganisms and their transmission. More recently, in the First World War, it was noticed amongst soldiers with serious wound infections that those who survived, frequently had a feature in common, that is wounds that glowed in the dark. Because this mysterious phenomenon was associated with better survival prospects it became known as the “Angel’s Glow”. We know today that this effect was most likely to have been caused by the bacterium *P. luminescens* which is bioluminescent and also produces a variety of antibiotics. Finally, P. *luminescens* is

pathogenic to a wide range of insects and has a complex symbiotic relationship with nematodes.

Photorhabdus asymbiotica **(heat stable blue).** This is another bioluminescent bacterium that kills insects, and causes them to glow in the process, and which is also a human pathogen, causing "glow-in-the dark" wound infections. Like other species of *Photorhabdus*, *P. asymbiotica* forms a symbiotic relationship with insect killing nematodes. However, in contrast to most strains of *P. luminescens,* and all marine bioluminescent bacteria, *P. asymbiotica* can grow at 37 °C (human body temperature) and this is a defining factor in its ability to cause human disease. This characteristic also means that it produces bioluminescence at temperatures well above 30^{o}C unlike marine bioluminescent bacteria.

4.0 Bacteria from soil and also with other notable characteristics.
Bacteria are the most numerous of the soil microorganisms and a teaspoon of productive soil usually contains between 100 million and 1 billion bacterial cells. Soil bacteria mediate many essential soil nutritive cycles and especially the carbon, nitrogen and phosphorous cycles. Bacteria also interact closely with plant roots and can promote plant growth. The bacteria in this section are all originally from soil but have other notable characteristics.

Streptomyces coelicolor **(of woods and Petrichor).** *Streptomyces,* are a beguiling species of bacteria. They are ubiquitous inhabitants of soils, where they play a vital role in the degradation and recycling of decaying natural material. They are also adept at manipulating human senses, as they emit a compound called Geosmin, that is largely responsible for the intoxicating smell of woodlands in autumn and Petrichor, the distinctive and beguiling aroma that accompanies the first heavy rain after a dry spell. They also have a very complex biochemistry and produce the majority of antibiotics used in human and veterinary medicine. *Streptomyces* also generate anti-tumour, anti-parasitic agents, herbicides, and many other active compounds. They are also unique amongst bacteria in that they grow as filaments and have a complex life cycle that generates resting bodies called spores, a process which involves complex regulation of gene expression in space and time. *Streptomyces coelicolor* is by far the best studied member of the genus world-wide and is a model organism. The colour of its colonies report changes in global gene expression and can be easily modulated by changing the bacterium's growth conditions.

Streptomyces griseus **(an ally in the fight against TB).** On the morning of 23rd August 1943 Albert Schatz sat at his workbench and opened is notebook. On page 32, in his meticulous cursive he entered the title of his new experiment "Experiment 11. Antagonistic Actinomycetes". The bacterium that he had isolated was *Streptomyces griseus,* and this was to be a key experiment in the discovery of Streptomycin (which the bacterium produces), the first antibiotic that was to prove effective against tuberculosis. Unfortunately for Schatz, his PhD supervisor Selman Waksman, mounted a vigorous and rather unpleasant campaign which led Waksman, and not Schatz, being awarded Nobel Prize for the discovery in 1952, and also through this, he managed to eliminate the PhD student's role as a co-discoverer from the history books.

***Mycobacterium vaccae* (a bacterial anxiolytic).** Mycobacteria are an important group of bacteria which includes pathogens known to cause serious diseases in humans, including tuberculosis and leprosy. Whilst the diseases caused by this genus of bacteria can be devastating, in contrast one of its members, namely *Mycobacterium vaccae*, is harmless and also ubiquitous in soil. This bacterium was first discovered on the shores of Lake Kyoga in Uganda in the 1990s through a study that linked exposure of people to soil to a better response to administered tuberculosis vaccines. Later it was found that *M. vaccae* had immune-modulating properties that were enhancing the efficacy of the vaccine. In 2004, studies with this bacterium, in lung cancer patients, showed that whilst exposure to *M. vaccae* did not prolong life, it did improve the emotional health of the patients. More recently exposure to this bacterium has been shown in many studies to reduce anxiety, and through this effect, even improve the ability to learn. It is thought that *M. vaccae* can modulate levels of the hormone serotonin, and this in part, may be responsible for its *in vivo* activity. It is possible then that this soil bacterium may have powerful anxiolytic properties that could be used therapeutically.

***Bacillus mycoides* Flügge (The Sensitive Bacillus).** This is a very common bacterial inhabitant of soil which has a unique mechanism of movement. It is a rod-shaped bacterium, that when it divides, the two emergent rods do not separate, and consequently, it forms long filaments of connected rods. The filaments then move and expand as the internal rods divide again and again. It is well known amongst microbiologists for its characteristic spreading colony morphology. Amongst bacteria it is uniquely responsive to structural stress in its growth environment, and its pattern of growth clearly changes in response to this. Consequently, this bacterium would respond to human touch.

***Rhizobium radiobacter* (formerly known as *Agrobacterium tumefaciens*, living carcinogen I)**. This bacterium is biotrophic plant pathogen that can alter the physiology and morphology of its host plant without killing it, resulting in tumour- like structures called galls. Wounded plant tissue is known to attract the bacteria which move towards the plant tissue using chemical signals and which then colonise the plant's intercellular spaces. A cassette of DNA called T- DNA, which originates from the bacterial genome is transferred into the plant's cells and into their nuclei, where it stably integrates into the plant cell genome. The expression of genes within the bacterially derived T-DNA element then leads to the production of bacterial proteins which subvert the plant's cell for the benefit of the bacterium and which reprogram it to promote tumour-formation in host tissues and the production of food sources for the bacteria called opines. The disease is called crown gall disease and it gains its name from the large tumour-like swellings (galls) that typically occur at the crown of the plant, just above soil level.

***Rhizobium rhizogenes* (formerly known as *Agrobacterium rhizogenes,* living carcinogen II).** This is a soil bacterium that causes hairy root disease in dicotyledonous plants, in which induces the formation of proliferative multiple-branched adventitious roots at the site of infection. This are the so-called 'hairy roots'. Like, *Rhizobium radiobacter* above, it mediates its effect on plant growth by transferring a section of its own DNA (R-DNA) into the genome of the infected plant. Hairy root cultures are grown *in vitro* in bioreactors to enable the commercial production of plant metabolic compounds that the original plant is known to secrete.

For example, this is especially important for the production of therapeutic compounds from medicinal plants that are difficult to cultivate in sufficient quantities by other means.

***Monascus purpureus* (hacked statins).** Red yeast rice, is a traditional fermentation which been used to enhance the colour and flavour of foods in China for many centuries. In addition, this ferment has also been used as a traditional medicine to aid digestive and vascular health. Today, red yeast rice is used in Western society as a food supplement and this is recognised for its ability to lower cholesterol. Red yeast rice is the product of the growth of the yeast *Monascus purpureus* on white rice. During its growth, the microorganism produces contain compounds, including monacolin K, the same ingredient that is in the prescription cholesterol-lowering drug lovastatin. Monacolin K, is an inhibitor of endogenous cholesterol synthesis. Due to these cholesterol-lowering effects that have been demonstrated in several well-designed clinical trials, the European Union has accepted a health claim related to monacolin K from red yeast rice and the maintenance of normal blood LDL-cholesterol concentration.

Cupriavidus metallidurans
This bacterium was first isolated in 1976 from the toxic sludge of a metal processing factory located in Belgium. It is remarkable in its ability to thrive in the presence of toxic heavy metals like Cadmium, Zinc and Lead making it an excellent model organism to study the means by which microbes cope with heavy metal stress. This metallophillic bacterium can also flourish in anthropogenic environments containing high concentrations of toxic heavy metal ions, such as mine waste rock piles, efflux streams of metal processing plants, and naturally mineralized zones. Moreover, another remarkable property of *C. metallidurans* is its ability to detoxify gold containing compounds by transforming them into metallic gold. This is a process that the bacterium is believed to also carry out regularly in nature, and here, its precipitation of gold nanoparticles is likely to be a main driver in the genesis and dispersion of gold throughout the natural environment.

***Shewanella* oneidensis MR-1 (electrically conductive nanowires).** A member of the *Shewanella* genus was originally identified in 1931 as one of a number of species of bacteria growing on putrid butter. Then, in 1988, a research group became curious about the unexplained levels of reduced manganese present in New York's largest freshwater lake, Lake Oneida. This was because, in nature, manganese usually exists in its oxidized form and so the scientists hypothesized that some biological mechanism was reducing the manganese. Eventually, the group discovered the bacterium *Shewanella oneidensis* MR-1, which respires by transferring electrons to reduced manganese, to be responsible for this process. In addition, this bacterium has also been shown to synthesize pilus-like, electrically conducive appendages known as bacterial nanowires which appear to packaged together multiple filaments to form a type of conductive cable. The bacterium can use these structures to transport electrons, allowing them to perhaps build intricate biological circuits, to communicate electronically or share electrical energy. Nanowires may also allow electron transfer between the living and the non-living and between cells and inorganic systems. In addition, in the future, *S. oneidensis* may form the basis of semiconducting biomaterials for making bioelectronic devices.

***Vibrio natriegens* (a new genomic powerhouse?).** Originally isolated from a salt marsh, *Vibrio natriegens* is a free living bacterium with the fastest generation time of any organism known (< 10 minutes). The recombinant DNA technologies that have revolutionised biomedical research are mostly reliant on *E. coli*, which has a lengthy growth rate (around 30 minutes) that consumes experimental time. Because of this, *Vibrio natriegens* is likely to become a new genomic powerhouse that will rapidly drive synthetic biology, and through this, will usher in a new era of advanced biotechnology.

***Chromobacterium violaceum* CV026 (deep purple, a colourful reporter of bacteria-to-bacteria communication)**. The wild-type or parental strain of this bacterium is common in soils from tropical and subtropical regions. It is notable because it produces the purple pigment (violacein) and so its colonies are of a striking purple colour. The expression of this pigment (and thus the colour) is dependent on bacteria-to-bacteria communication so that when a small number of bacteria are present no pigment is produced but when many bacterial cells are present it produces the pigment. When the wild-type strain grows as colonies, individual bacteria within the colony are continually sending and receiving signals, and consequently, pigment is produced, and the colonies will be purple. CV026 is a mutant strain of *C. violaceum*. Whilst this strain retains it quorum sensing detection mechanism, it has been genetically modified to be effectively "mute" and thus cannot generate its own quorum sensing signals. In being so, this strain serves as a unique monitor for the detection of bacteria-to-bacteria communication. When grown alone on agar, because it cannot produce quorum sensing signals by itself, it forms white and non-pigmented colonies. However, if grown in proximity to an unrelated bacterial colony that produces its own quorum sensing signal, CV026 can receive this chemical communication signal, and then respond to it, by producing a purple pigment. Consequently, when it detects compatible quorum sensing signal from other bacteria, its growth becomes purple in colour.

***Pectobacterium carotovorum* (formerly known as *Erwinia carotovora,* the carrot eater and C6-HSL emitter).** This bacterial species is an important and ubiquitous plant pathogen with a diverse host range, including many agriculturally and scientifically important plant species (e.g. carrot, potato, tomato, cucurbits, onion, green peppers, etc.). Furthermore, it is an economically important bacterium in the context of postharvest losses, as it is a common cause of decay and spoilage in stored vegetables (including carrots from which it derives its species name as *carotovorum* or carrot eater) and fruit where it causes a characteristic bacterial soft rot. This bacterium produces an arsenal of enzymes (e.g. pectinases, cellulases, etc.) which degrade plant cell walls and tissue and which facilitates infection. Its inclusion in C-MOULD is due to its production of C6-HSL, a quorum sensing signal that can be detected by *C. violaceum* CV026 (above). When used in tandem, this combination of bacteria can be used to discover quorum sensing inhibitory molecules, that because bacteria-to-bacteria communication is key to their ability to cause disease, may serve as novel types of antibiotics.