# Necessity-the-Mother-of-Invention: Construction biomaterials

(Rachel Armstrong)

Source: Ilaria La Blanca, 2019: https://www.materialincubator.com/building-on-mycelium

**The Necessity: reducing the enormous greenhouse gas emissions of the construction industry**

## The Context

The practice of the built environment, which includes all the buildings, spaces and infrastructures (roads, bridges etc.) around us, is the sector that generates the most carbon emissions of all industries, accounting for 40% of the total global carbon footprint. It consumes huge amounts of energy and resources to produce the materials that shape our environments, and then to operate and maintain them. Two main types of energy are therefore used in the built environment: a) embodied energy, which is concerned with the extraction, processing, and removal of materials; and b) operational energy, which is needed to provide building services (heating, cooling etc) and run all the machines within our homes, industries and businesses.

Image courtesy, Freepik

**The Challenge**

Owing to this harmful impact, governments and industry are seeking new ways of making architecture that are fundamentally sustainable. A new generation of materials are being developed to address the challenge of embodied energy, which are learning from nature by incorporating bioprocesses into their material production. This new generation of biocomposites are grown from agricultural waste like straw, wood chips and hemp, and are cultured with a range of microbes, which renders them biodegradable and very cost effective in their production.

Although they cannot replace structural systems, biocomposites are a contender for all kinds of plastic replacement, being lightweight and compatible with natural systems across their whole product cycle.

Mid Journey, sustainably grown home, courtesy Rolf Hughes.

**The Invention**

As microbes and waste streams are both fundamentally diverse, this emerging field has a broad range of potential applications. To provide a specific focus for discussion, the developments of two specific products will be discussed: microbial cellulose and mycelial biocomposites.

**Mycelium biocomposites**

Mycelium BioComposites (MBCs) are a range of materials that have demonstrated a high potential for sustainable design using a biological approach. In the production of MBCs, fungi are fed with organic waste and serve as a natural polymeric binder through their hyphal networks. Fungal hyphae form a fibrous network made of chitin, proteins, polysaccharides and lipids, which bind particulate matter forming a solid, infiltrated block that comprises the biocomposite.

MBCs are of increasing interest to architecture for their carbon- negative, non-extractive methods of production, and their biodegradability, taking about 12 weeks to degrade in the soil. The current range of MBC share common characteristics e.g., they are relatively lightweight materials, absorb large amounts of water, and have a low compressive strength of approximately 200 kPa. Consequently, the intended range of applications is generally limited to packaging materials, non-wearable materials, composite board, and furniture, with uses limited to interior applications and exhibition settings (e.g., Hi-Fy by The Living MoMA, 2015 and The Growing Pavilion by Grown.bio for Dutch Design Week, 2019).

Owing to their composite nature, the present array of characteristics can be increased and fine tuned by incorporating additives, which will lead to new applications for MBCs with different properties within the practice of the built environment. Currently, a range of small and medium-sized enterprises (SMEs) and research institutions, are actively developing new kinds of MBCs to produce a variety of commercial products, ranging from simple items (e.g., packaging), to biodegradable building materials (e.g., insulation).

**Microbial Cellulose**

Microbes use cellulose to form an extracellular matrix that forms a protective envelope around them. The production of cellulose from microbial ferments was known to the ancient Chinese as a material that was produced as a side product of kombucha, which is a fermented drink that is produced by symbiotic fermentation of sugared tea using a Symbiotic Culture Of *Gluconacetobacter xylinum* (formerly *Acetobacter*) and yeast (SCOBY). Forming a thick pellicle at the air-water interface, this microbial 'leather' has been scientifically documented since 1886. Today kombucha tea is marketed as a popular drink, while the mechanically robust, self-standing pellicle can be dried and used in fashion as an ethical alternative to animal skin, or in next generation sustainable architecture. Microbial cellulose has several advantages over plant cellulose: it is lightweight; is fifteen times stronger than plant cellulose; and is suitable for architectural applications such as facades, furniture or use in green walls. Today it is used by architects, and fashion designers as a sustainable alternative to fossil-fuel derived materials like plastic and synthetic fibres.

Source: Jaroslava Frajová, Prototypes for Humanity: https://www.prototypesforhumanity.com/project/bacterial-cellulose-for-architecture/

**Consequences**

Next generation sustainable buildings must change the performance of our living spaces beyond net zero, which simply means buildings use as much energy as they produce, so that our living spaces have beneficial impacts on the environment. Notably, this new generation of building materials contributes to this goal as biocompatabile (green) alternatives for many hydrocarbon-based products, including Expanded Polystyrene (EPS) used for insulation in the construction industry, which is environmentally toxic and difficult to dispose of responsibly.

Additionally, these materials are low cost, and contribute to the circular economy by using materials that would otherwise be discarded as waste. Although these biomaterials cannot be used in structural systems, and are prone to water damage, their use in indoor environments is proving successful and has catalysed the formation of a range of SMEs like MOGU, BIOHM and Grown. Bio. Further investments in research and development is only going to expand the versatility and scope of this portfolio.

**Significance**

Europe's construction sector is responsible for about half of all extracted materials and energy consumption alongside a third of water consumption and waste generation. Biomaterials such a mycelium biocomposites and microbial cellulose are providing a powerful toolset for a green material revolution to replace fossil-fuel derived hydrocarbon-based materials like plastics, which have huge ecological and societal negative impacts. From drilling for oil to the energy consumed in complex manufacturing processes, and associated toxic waste streams, modern plastics can take thousands of years to decompose, creating significant pollution and disposal problems with their inevitable bioaccumulation into food webs. Using biocomposites in architecture is providing a viable alternative to these fossil fuel-based polymers offering improvements in their environmental performance over their whole lifecycle, including sustainability, lightweight, durability, design flexibility, and health benefits.