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Jesús López de los Mozos

Arquitecto biológico // d.jesus.ldlm@gmail.com

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Un nuevo Renacimiento. No hay luz sino oscuridad // A New Renaissance. There is no light but darkness

Este artículo plantea una analogía entre la Edad Media y la actualidad, destacando los desafíos ambientales y sociales.

En la era medieval, las condiciones difíciles llevaron al surgimiento del Renacimiento, un periodo de avances artísticos y científicos. De manera similar, el texto sugiere que los problemas modernos podrían abrir paso a un nuevo "Biorenacimiento", basado en la biología y la sostenibilidad.

El enfoque se centra en el uso de hongos y su micelio como materiales de construcción sostenibles, inspirados por investigaciones actuales y proyectos como la colaboración de la NASA. Estos materiales ofrecen beneficios como biodegradabilidad, resistencia, y eficiencia térmica, con aplicaciones en diversas industrias, incluyendo la arquitectura y la medicina.

La propuesta es aprovechar estas innovaciones para crear un modelo de economía circular, contribuyendo a una sociedad más ecológica y autosuficiente.

This article draws a parallel between the Middle Ages and the present, highlighting today's environmental and societal challenges.

Just as the harsh conditions of medieval times eventually led to the Renaissance—a period of significant artistic and scientific advancement—current issues may pave the way for a "Bio-Renaissance" grounded in biology and sustainability.

The focus is on using fungi and mycelium as sustainable building materials, inspired by recent research and projects like NASA's. These materials offer benefits such as biodegradability, resilience, and thermal efficiency, with applications in various industries, including architecture and medicine.

The proposal aims to leverage these innovations to establish a circular economy model, contributing to a more eco-friendly and self-sustaining society.

Mico-arquitectura. Construcción basada en micelios

Myco-architecture. Construction based on mycelium

Jesús López de los Mozos

A new Renaissance. There is no light but darkness

It was cold, and the sun barely managed to filter through the clouds of dust and mist. A new day began with the same gray as always. The dirt streets, turned to mud from the previous day's rain, were no exception today. The footprints of boots and animals mixed with human waste and rotting food scraps to the sound of "water coming down" falling from the windows, creating a dark, foul-smelling mass at the edges of any European village we might describe. The stench did not go unnoticed by each villager, forced to live in a constant state of nausea and resignation.

The harvests were usually scarce, the ground hard, and the rain had not softened the fields enough to plant a garden. Alongside the tithes to be paid, hunger quickly took hold. So much so that a piece of stale, moldy bread soaked in water seemed like an excellent option.

Only surviving the diseases that struck each winter remained, spreading from peasant to peasant like rats, as common as the villagers themselves, lurking in the corners with a cloud of plague over their backs.

The bells rang, and every good Christian man and woman headed to a small Romanesque church, rough, gloomy, and stony, at the call of God, as faith in the divine was the only hope in an illiterate society, filled with red-haired witches condemned by any well-fed cleric whose name instilled even more fear in this terrified population.[1]

It is true that a thousand years separate us from the darkest time of the Middle Ages, and to this day, we can find certain analogies to that era.

The weather can be equally freezing or scorching, with less and less difference, as climate (or climate change) is a relevant topic of our time. Despite a sewer system refined and inherited from the Romans and Persians, the streets are not always the cleanest, nor are the manners of the inhabitants the most refined, seeing the city as an "entity" that does not belong to their immediate environment beyond the doors of their homes. Not to mention the outskirts between the countryside and the city, turned into a home for broken sofas, used tires, and all kinds of debris from the city's finest construction sites.

Food does not nourish because experts cannot agree on the three, four, or increasingly numerous nutrition pyramids on which human diets should be based, allowing companies that poison the soil—now increasingly sterile and impoverished—a free hand. Meanwhile, in European cities, each of us generates 132 kilograms of waste per year, while in another part of the world, people face long weeks of involuntary fasting. Simultaneous epidemics of hunger and obesity.[2]

FIGURE 01 » Author: OpenAI Year: 2024
Title: Medieval Alley
Description: AI-generated illustration representing the figurative idea of hardship in medieval life

01 » Reinterpretation based on (Martínez García, 2009, Historia Medieval en Europa, Editorial Universitaria).

02 » Smith et al., 2020, Environmental Sustainability Journal

Unfortunately, pandemics are not foreign to us in the 21st century, like other diseases that technology—the cornerstone of our civilization—has failed to eradicate.

The bells no longer ring; instead, we hear a small jingle in our pocket, with an intent not very different from that of the cleric, as we are bombarded with tons of well-crafted, biased information that aims to instill fear and misinformation in equal parts. Controlling the masses remains of utmost importance.

We only have a glimmer of hope, and it is that history advances one step forward and two steps back. Thus, history does not repeat itself, but it often rhymes far too much. And the answer to such darkness in its day was none other than the Renaissance—a revolution like no other, where architecture and art benefited from great advances that influenced aesthetics, construction techniques, materials, and functionality. Humanity became the universal measure, and physics was challenged with cathedrals reaching for the sky, open to natural light, symmetrical, harmonious, and subtly light. The Renaissance moved beyond religious exclusivity, allowing architects to innovate, creating and improving gardens, plazas, palaces, town halls, and libraries, bringing them closer to the people.[3]

03 » Giovanni, 2018, Renaissance Architecture and Society, Cambridge University Press

So, if in such a distant era, as described above, where desolation was the daily bread, and from such darkness arose one of the most fruitful and significant periods in human history, taking a qualitative and quantitative leap from that reality, would it not be possible for us to experience the same fate?

It is 2015, and outer space continues to fascinate our species. After decades of debating humanity's future, where our next home will be, and engineering advancements, we are beginning to consider the idea of living on the moon, on Mars, or in any place with conditions that somewhat resemble our blue planet.

And it is only with a construction challenge of this magnitude that we can expect the best of our ingenuity.

Construction up to our era has consisted of the sustained and technical stacking of various materials, increasingly sophisticated, with some cohesive element so they can work together in an artificial cave that we now call "houses." Isolated houses; semi-detached; houses on top of other houses in the form of buildings; houses for working, known as offices; or much larger houses to store airplanes, which we call hangars.

In other words, innovation has not been significantly different from what the Romans did. The materials have changed, and we can now make skyscrapers almost a kilometer tall, but they are still built by stacking and connecting materials.

Allow me to explain.

There is a general agreement among specialists that the 20th century was to physics what the 21st century will be to biology. In that same year, architect Neri Oxman, director of the innovation team at MIT's Mediated, made a subtle and revealing comparison. For example, a human limb, starting from a stem cell, can create a nail in its outermost layer, a cuticle that protects the nail's insertion into the skin, itself composed of a breathable, waterproof epidermis; a dermis that can generate body hair for thermal comfort against the cold; hypodermis to store energy in the form of fat; protecting ligaments, tendons, and muscles that compress and tense until reaching the bones that structure us. We could make the same exercise with the plant world with a tree, its roots, branches, leaves, etc.

Nature does all this on its own, with instructions that biology has yet to fully uncover. Now, to assemble any car, it takes between 70,000 and 90,000 different parts made in specialized factories scattered hundreds of kilometers around the world. And even with the complexity involved in creating a car, you could instruct any human to build one by following specific steps, but you cannot ask a human to assemble, manufacture, or create a body in the same way as a car and have it function afterward. This is where a new paradigm emerges, and biology plays a crucial role.

Our gaze turns back to space, and before venturing to live there, the first idea competitions about how to live on Mars or the Moon begin, led by companies like NASA, AIRBUS, or renowned architects like Norman Foster.
Curiously, while imagining the future, many of the finalist proposals look back to the past, to a time when homes were erected or spread out with a few ropes and animal skins, where nomadic life prevailed, with only the essentials and all frivolities relegated to a distant concern.

Thinking about inhabiting a house millions of kilometers away from everything we know implies rethinking construction methods, and here comes a technology that has taken its first steps in recent years: 3D printing. Its function is simple—three axes (X, Y, and Z) and a hopper through which to pour some type of viscous or molten material. Practically, it's not far from traditional rammed earth or superadobe. However, with robotic precision and the curing times of materials, it allows for very refined and increasingly complex forms that "grow" their walls.

Although materials must still be implemented separately, we can draw an analogy with the growth biology discussed earlier or at least understand construction as a novelty compared to what has been done so far, as the geometric sections of a wall can be configured to be more resistant or to contain air chambers that provide greater stability and thermal comfort inside.

FIGURE 02 » Author: OpenAI Year: 2024
Title: Habitats on Mars:
Description: AI-generated image of a possible construction using biological 3D printing

Although materials must still be implemented separately, we can draw an analogy with the growth biology discussed earlier or at least understand construction as a novelty compared to what has been done so far, as the geometric sections of a wall can be configured to be more resistant or to contain air chambers that provide greater stability and thermal comfort inside. But among all these favorable technical features, one stands out if you travel to Mars: you cannot bring materials with you; instead, you must use what you find there.[4]

04 » Johnson & Brown, 2022, Journal of Advanced Architectural Engineering,

Thus, once again, we come to a dead end; if we rely on the natural cohesion of particles, water plays an essential role in construction, and we don't have enough on our planet to carry tons of it to build and live.

This opens the door to a new way of thinking, where the inert has little place.

"It is dark, and I feel forgotten. Barely any light reaches me, and I feel trampled by everyone. I am buried, pressed against the cold, hard ground, on the verge of disappearing. And from the depths, I feel that the same weight that crushes me pushes me upward. Slowly, silently, and unseen, I transform. And finally, I realize that I have not been buried but planted to emerge with the strength and resonance of life."

This brings us to the cornerstone of this text. As we read in this metaphor about darkness and growth, the future is not barren nor does it form a wasteland. Rather, it lies beneath our feet, where the largest living being on the planet, fungi, resides.
To date, approximately 148,000 species of fungi have been identified and described. However, recent estimates suggest that the total number of fungal species could range from 2.2 to 3.8 million, indicating that a vast majority remain undiscovered.

Among them, Armillaria ostoyae, also known as the "honey fungus," is the largest living organism in the world, located in the Malheur National Forest in Oregon, USA. Its mycelial network (the underground structures that form its main body) spans approximately 9.6 square kilometers and is estimated to be at least 2,400 years old, although some believe it could be even older.

This fungus grows underground and connects various trees in the forest, absorbing nutrients from them, making it a parasitic organism. Its vast underground filament network, though invisible to the naked eye, makes it the largest known individual organism in terms of area occupied.

This organism did not go unnoticed by NASA, and since 2020, they have explored the potential of fungi as an innovative resource for building sustainable habitats in space.

Instead of transporting large amounts of building materials, NASA is studying the use of mycelium, with its filamentous capacity to grow and structure itself in varied shapes. This natural material is not only durable but also capable of self-repair, adapting to different environments and forms, and eventually decomposing without leaving waste, making its applications ecological and contributing to a cradle-to-cradle circular economy.

Its versatility continues to grow, constantly astonishing us, as it has been historically maligned by humans due to its potential toxicity for the less fortunate who consume it. However, in recent decades, science has found promising and revolutionary applications for fungi, spanning medicine to architecture. Witnessing its versatility, we see how this natural kingdom breaks into the innovations of the future, offering solutions to both current problems and challenges yet to be imagined.

In **medicine**, fungi have been essential since Alexander Fleming discovered penicillin, an antibiotic derived from Penicillium notatum, transforming bacterial infection treatments (Fleming, 1929, British Journal of Experimental Pathology). Today, other fungi like those from the Ganoderma genus, commonly known as reishi, are studied for their immunomodulatory and anticancer properties. Current research also examines psychedelic fungi compounds, like psilocybin, for treating mental health disorders such as depression and anxiety.[5]

Architecture and construction are continually seeking sustainable materials, and fungi offer a viable, eco-friendly alternative. Fungal filaments are used to create strong, biodegradable biocomposites that can replace traditional materials like concrete. In collaboration with NASA, mycelium materials have been developed for Mars habitats, leveraging their autonomous growth and structuring ability [6]

NASA has also inspired projects like The Living, an architecture studio that built "The Hy-Fi Tower" in New York, a temporary pavilion made entirely of mycelium bricks. This biodegradable fungus created a sturdy structure that, upon dismantling, reintegrated into the environment without leaving waste (Beyer et al., 2019, Architectural Innovations in Sustainable Design). This example shows how myco-architecture can replace polluting materials with eco-friendly solutions, fueling interest in sustainable urban construction.

In materials engineering, researchers are developing **mycelium biocomposites** as alternatives to plastics and synthetic foams. These materials are used for insulation panels that maintain stable interior temperatures while reducing carbon footprint. They are not limited to housing; packaging companies are experimenting with mycelium to create durable, compostable packaging, helping reduce single-use plastics in various industries .[7]

05 » Carhart-Harris et al., 2016, The Lancet Psychiatry

06 » NASA, 2020, Myco-architecture Research Initiative), promising sustainable architecture both on Earth and beyond.

07 » Jones et al., 2021, Green Materials Science Journal)

Fungi also show promise for **construction in disaster-prone areas.** For example, flexible and lightweight mycelium materials can absorb seismic vibrations more effectively than traditional materials. In Japan, experiments are underway to build earthquake-resistant structures using mycelium and reinforced bamboo, benefiting seismic constructions and providing a quick, safe, and economical alternative for temporary shelters in disaster zones .[8]

08 » Tanaka et al., 2022, Journal of Sustainable Engineering Solutions

In **Materials Engineering**, the strength and flexibility of mycelium are also being explored in creating biodegradable textiles and packaging. Companies like Ecovative Design have developed mycelium-based materials to replace polystyrene and other single-use plastics.[9]

09 » Bayer & McIntyre, 2015, Ecovative Design Research Report).

In the fields of **Chemistry and Biotechnology,** fungi offer intriguing applications through their unique enzymes, capable of breaking down materials that would otherwise be difficult to treat. Some fungal species can decompose plastics and toxic waste, a significant advantage in bioremediation. The fungus Pestalotiopsis microspora, for instance, has demonstrated the ability to degrade polyurethane, opening up possibilities for plastic waste treatment.[10]

10 » Russell et al., 2011, Applied and Environmental Microbiology).

In the specific case of **cleaning up oil and diesel spills,** some fungi can degrade hydrocarbons present in petroleum spills, making them effective for cleaning diesel and other fuel spills. Notably, the fungus Amorphotheca resinae has shown a high affinity for breaking down hydrocarbon compounds in petroleum, transforming them into less toxic substances. This ability makes it a valuable resource in the bioremediation of contaminated environments.[11]

11 » Torné & Sanz, 2018, Journal of Environmental Biotechnology)

One remarkable application is **the elimination of radioactive elements**, where fungi also show promise in the bioremediation of radioactive waste. The fungus Cryptococcus neoformans, for example, can absorb and concentrate radiation while growing in contaminated environments, such as those in Chernobyl. This fungus uses melanin in its cells to protect itself from radiation, absorbing it and, in a sense, "feeding" on it. This ability is being studied as a potential solution for cleaning radiation-affected areas, proposing a biological and safe approach to treating nuclear contaminants.[12]

12 » Zhdanova et al., 2000, Mycological Research)

In **agriculture**, mycorrhizal fungi help improve soil health and crop productivity by facilitating nutrient and water absorption in plants. Additionally, entomopathogenic fungi, such as Beauveria bassiana, are used as biopesticides to control pests without relying on harsh chemicals, promoting a more sustainable agricultural model.[13]

13 » Gillespie et al., 2016, Journal of Invertebrate Pathology)

Mycelium has also gained ground in the fashion industry, particularly in **textiles** and plant-based leather as an alternative to animal leather. Brands like Stella McCartney and Adidas have created fashion and footwear products using mycelium materials developed by companies such as Bolt Threads.

This "mushroom leather" has a texture and durability similar to traditional leather, but its production is less harmful to the environment. Mycelium textiles also allow designers to work with a sustainable, adaptable, and biodegradable material that reduces the fashion industry's environmental impact.[14]

14 » Bolt et al., 2020, Fashion and Sustainability Review)

As an **alternative food source**, fungi, beyond their traditional use as food, have given rise to innovative meat substitutes. Companies like Meati Foods use mycelium to create alternative "meat" that is high in protein and fiber, providing a healthy, eco-friendly option for those seeking to reduce meat consumption. Mycelium thus becomes a regenerative food source that requires far less water and land compared to traditional livestock, marking a trend toward sustainable nutrition.[15]

15 » Stevens et al., 2023, Food Science and Future Foods).

Lastly, some researchers are exploring how fungi can generate energy through **bioelectricity**. Scientists have discovered that certain fungi produce mycelial networks capable of conducting electricity, functioning as "biobatteries." These "electric fungi" could be used to power small devices in remote areas or integrate into agricultural monitoring systems that run on biological energy, transforming energy production into something biologically integrated.[16]

16 » Carter & Liu, 2021, Journal of Bioelectric Systems).

As can be observed, this "tiny" being, barely visible at the surface, has many areas of influence. However, they all share a common trait with other living beings, with unique characteristics due to the kingdom to which they belong: they need to eat.

The kingdoms of fungi, plants, and animals are three of the most important groups of organisms on Earth, each with unique characteristics defining their roles in ecosystems. At the cellular level, fungi are more similar to an ant than to a watercress, as they lack chloroplasts. However, their reproduction is more similar to a fern, as they reproduce through spores. When it comes to nutrition, they enjoy a good rotting log for their enzymes; they are heterotrophic organisms, unlike plants that need water and sunlight.

And this point is key, giving rise to the wordplay that names this writing. Among all their characteristics, fungi can be cultivated in the most "extreme" conditions imaginable—or at least one that is a synonym for life for most animals and plants: our dear sun. This is the primary reason they can be taken into space and continue to grow in a box, in a cave, or in the back of a space cabin. Not needing sunlight is a significant advantage, sparing them irreversible damage while they remain sheltered in their chosen environment.

Their role in ecosystems is essential as decomposers, recycling nutrients into the soil and forming symbiotic associations with plants. And it is here, once again, that a new opportunity arises within our immediate world and in the different ways of thinking about everything that surrounds us.

Returning to human construction and manufacturing of everything that has existed, it has always been understood as a system in which resources are reused and reintegrated into a continuous cycle, known as the "circular economy" since the earliest civilizations. However, this approach began to "end" with the rise of the Industrial Revolution in the 18th century. With industrialization, the economic model shifted toward a linear system based on extraction, production, consumption, and disposal, fueled by abundant natural resources and growing mass production capacity. According to Murray, Skene, and Haynes (2017), "the shift to a linear production model was driven by new industrial capabilities and an increasingly competitive global economy, leaving behind the sustainable resource cycle that once defined agrarian societies".[17]

17 » Journal of Industrial Ecology,

However, as unpromising as all this may seem, this model persists as it generates something we are increasingly aware of, resonating from the earlier paragraphs with the cry of "water coming down" from the windows: waste.

Industries generate millions of tons of waste each year, representing a significant portion of global pollution. According to the World Bank, approximately 2.01 billion tons of solid waste were generated worldwide in 2018, nearly half of which comes from sectors like construction, manufacturing, and mining. This waste includes metals, plastics, chemicals, and hazardous materials that severely affect the soil, water, and air. Without proper management, the amount of industrial waste could increase by up to 70% over the next 30 years, adding pressure on natural resources and reinforcing a linear economic model that limits reuse practices [18]

18 » World Bank, 2018, What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050).

FIGURE 03 » Author: OpenAI Year: 2024
Title: Micelium bricks:

Description: AI-generated image of examples of bricks made of micelium

So, if construction—implicit in our profession as architects—is one of the largest sources of global waste, and on the other hand, we have nascent biology capable of providing solutions to problems we have clumsily created, why not unite them?

This is the approach and theoretical framework of my doctoral thesis, which seeks to explore how the remarkable fungi and their incredible characteristics can somehow minimize the impact of construction or optimize it to create a positive effect that enhances the overall process without sacrificing the technical efficiency achieved so far.

To this end, we began studying the fungal kingdom, cross-referencing data based on different parameters. First, we examined how fungi feed and classified them accordingly. Since they cannot produce their own food and depend on organic matter, we identified three categories: **saprophytes, parasites, and symbionts**. Saprophytic fungi feed on dead organic matter, decomposing it and releasing nutrients into the environment.

Parasites, on the other hand, obtain nutrients from other living organisms, often causing diseases in plants, animals, or even humans. Finally, symbiotic fungi establish mutually beneficial relationships with other living beings, as seen in mycorrhizae, where the fungus associates with plant roots, facilitating nutrient and water absorption for both.

Only saprophytes are suitable for decomposing waste, providing us with a key clue: “dead organic matter.” Thus, we need to find waste suitable for being food for our fungi.

Through an in-depth search and by country, with Spain as a focus to standardize and concentrate the process as much as possible, data from the National Statistics Institute (INE) showed that approximately 6.3 million tons of waste were produced in 2021 in the agriculture, livestock, forestry, and fishing sectors. This waste includes crop residues, prunings, and other organic waste typical of agricultural activities. Proper management of this waste is essential to minimize its environmental impact and promote sustainable agricultural practices.

So, we now have the ingredients to formulate a hypothesis: Can we generate an “optimal” biomaterial for architecture by combining agricultural waste with an abundant, native saprophytic fungus from the peninsula, using cultivation techniques that are easy to standardize and replicate?

For several years, our architecture university has collaborated with other seemingly unrelated departments in microbiology and soil studies to create such materials.

Combining knowledge and techniques, but above all moving away from the increasingly necessary professional isolation, we have begun to cultivate oyster mushrooms (Pleurotus ostreatus), common mushrooms (Agaricus bisporus), and reishi (Ganoderma lucidum).

The choice of these fungi is based on a selection process considering their bioavailability, proliferation capacity (for instance, Boletus edulis, more characteristic of the Iberian Peninsula, is still much more challenging to cultivate due to its specific growth conditions), and their emerging properties in medicine and in trials with the biomaterials produced.

Initial tests were conducted in the material testing laboratories at the European University of Madrid.

The procedure, carried out under regulatory standards, aimed to study the behavior of the fungus fed and rooted with agricultural residues, specifically wheat waste sterilized by autoclave, when subjected to tests of tension, compression, thermal insulation, and sound absorption.

The initial test results were promising, showing considerable room for further improvement. Among the findings, the material can withstand 38 kg/mm² of surface pressure, making it consistent enough to be self-supporting and suitable for furniture and other, currently non-structural, elements.

Its excellent thermal insulation capability, with a thermal conductivity coefficient of 0.0059 kcal/m²h°C, maintained external temperatures of 125°C at bay for nearly 2 hours, with the internal surface reaching only 45°C.

The next steps we are taking involve testing its behavior and finish when we mix agricultural waste with other starch-rich residues, such as those resulting from beer production.

The rise in beer consumption has spurred a notable expansion in artisanal production, which has been well-received by consumers seeking unique flavors and traditional brewing processes. However, this growth also brings an environmental challenge: the management of brewers' spent grain. During brewing, approximately 85% of the waste produced is this by-product, consisting of barley or other grains left after fermentation. It is estimated that 20 to 25 kg of spent grain are generated for every 100 liters of beer produced—a considerable figure given the large-scale global beer production [19]

19 » Sustentable Digital, 2023, June 21. "Brewers' Spent Grain: Circular Economy to Reduce Waste and Climate Change."

This is where we are conducting new trials and studies in collaboration with biologists internationally, cultivating mycelium under optimal conditions to later inoculate it into these substrates and again test its properties against previous results.

Although this “technology” is still in its early stages, we can expect the upcoming discoveries to be highly promising.

The uses and applications of mycelium in industry and architecture are beginning to emerge. Over time, we will be able to measure and estimate the impact generated by these biomaterials in complex ecosystems such as cities, creating specific actions, such as energy savings and thermal efficiency, compared to traditional materials by evaluating their carbon footprint, usability, waste, and recyclability. Given the points discussed above, it’s easy to think that the winning fungus is unmatched.

As Henry Ford once said, “Failure is simply the opportunity to begin again, this time more intelligently.” In part, we have reached this point thanks to a series of failures, some better managed than others. But if we must start anew, let’s do it better—standing on the shoulders of giants with the wisdom of nature, leaving behind our own dark age to embark on a new Bio-Renaissance.

FIGURE 04 » Author: OpenAI Year: 2024
Title: Bio-Renaissance:

Description: AI-generated image of examples of possible Bio-Renaissance City

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