GROWN | Bio-fabrication across Ecosystems and Nations

A design studio traveling to Santiago and Patagonia, and collaborating with the Federici Lab at Universidad Católica

Critic: David Benjamin

OVERVIEW

Architects have always worked with the heft and grit of materials. Despite the recent rise of data, digital technologies, and virtual environments, the tangible presence of physical objects is as relevant as ever. But in the past twenty years, there have been dramatic shifts in the environmental context and the material palette available to architects.

One opportunity within this context is to explore new possibilities for grown materials. Rather than keeping the living out of architecture—which has been an assumed goals for most of architectural history—we might start bringing the living into architecture, including growing the building blocks and building systems of our buildings and cities.

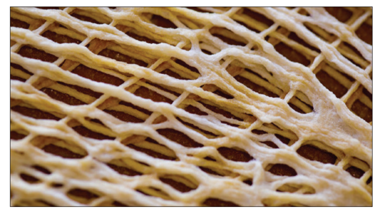
Examples of grown materials include bricks grown from bacteria, fabric grown from microbes, panels grown from mycelium, and of course, all kinds of wood. Some of these grown materials behave like non-grown materials. Others offer new types of performance. All grown materials involve a new relationship to resources, energy, and manufacturing. The framework of grown materials is not about regressing to an old version of nature. It is about inventing a new nature.

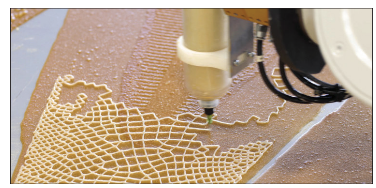
This is the primordial soup of Grown, a design studio exploring the frontier of architecture and bio-materials. In our research, we will become immersed in this new science and its possibilities, dangers, and myths. We will use new software workflows—including parametric modeling, digital simulation, genetic algorithms, and optimization—that allow non-specialists to begin designing with biology. And we will conduct hands-on lab experiments with some of the latest examples of bio-materials.

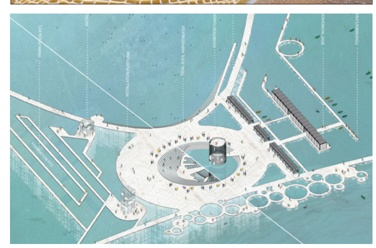
This studio will travel to Santiago to participate in an intensive bio-materials workshop with the Fernan Federici Lab at Univesidad Catolica de Chile. Students will present in-progress work with materials, attend lectures about new developments in biotechnology, and gain hands-on experience with synthetic biology experiments in the lab. The studio will also visit Patagonia as part of a research expedition to identify local ecosystems and learn about local building practices. We will collaborate with Catolica students and faculty and stay in Puerto Williams, the southern-most city in the world, where Catolica has a Biodiversity Research Center and a new fab lab to support interdisciplinary research local organisms "extremophile" organisms.

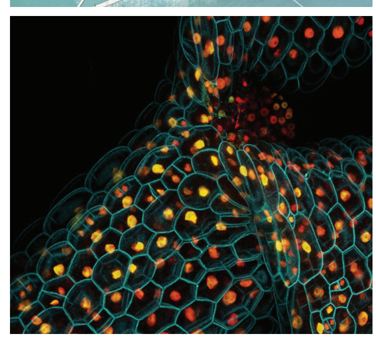
Within this context, we will design new building materials, systems of global production, and definitions of sustainability, as well as the new architecture that these forces generate. We will design at multiple scales simultaneously—from DNA with a radius of about a billionth of a meter, to Earth with a circumference of about 40,000 meters—engaging 16 powers of ten in the same project.

Yet while we will employ serious tools of biology, engineering, and computer science, we will not limit our studies to technical performance. We will also develop positions about culture and ecology that are difficult to quantify. We will operate in









Images (top to bottom): Factory in Campinas, Brazil (Benjamin Studio 5, Chris Gardner); Same; Aguahoja Artifacts (Neri Oxman); Same; Production center and community center (Benjamin Studio 5, Omar Bacho); Confocal microscope photo of plant cells (Fernan Federici Lab); Mycelium and 3D printed model (Benjamin Studio 5, Thomas Wegner).

both the distant future and the urgent present. We will study the anxieties, fictions, images, and aesthetics of this new science and technology. And over the course of the semester, we will have an informed, critical, and open-ended discussion about biology, materials, and the future of architecture.

BIO DESIGN

There is general consensus that if the Twentieth Century was the century of physics, then the Twenty-first Century is the century of biology. Biology is already the largest field of the sciences, and it now ranks higher than physics in budgets, workforce, and major discoveries.

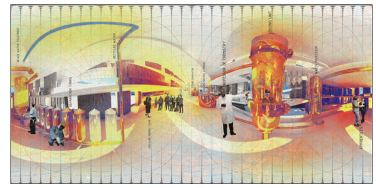
Of course, architects have been drawing on biology for hundreds of years. But this history is largely a conceptual one, drawing on the metaphors, knowledge structures, and imagery of biology, while rarely engaging the actual research protocols of biology or understanding buildings and materials as living biological systems. This conceptual focus may be in part due to the intense difficulty of creating actual living materials and constructing dynamic forms. Yet this context is changing in a fundamental way.

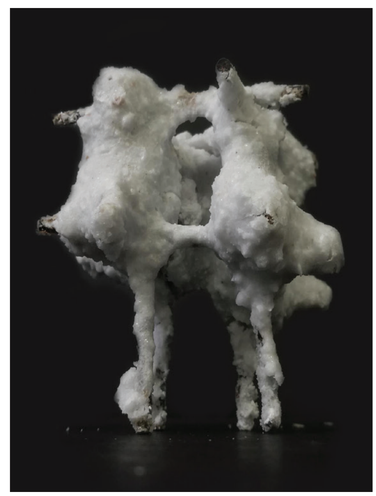
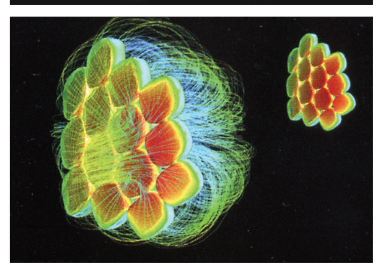
Biology of today is different than biology of a hundred years ago. It is now possible to grow cells on a glass chip isolated from other cells instead of in a living organism. It is now possible to cut and paste DNA and bring to life organisms that never before existed in nature, such as bioengineered yeast that excrete bioplastics. And as of just three years ago, with the demonstration of Crispr-Cas9 and gene drives, it is now possible for humans to re-design or eliminate an entire species very quickly, essentially designing evolution itself. The possibilities are both inspiring and terrifying, but this new biology is unequivocally here to stay.

In addition, it is now possible to apply the latest techniques of computation—such as computer vision and machine learning—to functions such as biological growth. Biology is extremely complex, but when biological functions are encapsulated in computer models, they become a more actionable part of the design ecosystem. Furthermore, the new framework of synthetic biology enables non-specialists—such as architects, artists, material scientists, and computer scientists—to design biological systems even if they are not experts in the complex molecular behavior of the biological parts.

For architects, some aspects of designing with biology may feel like an extension of familiar computation tools. But other aspects are likely to be unfamiliar. Despite recent advances and discoveries, in the near future anyone designing with biology may have to do so with only partial understanding and partial mastery of the forces and systems involved. Design with biology may require design with uncertainty.

And in this sense, design with biology may feel like the opposite of design with computation and Building Information Modeling (BIM). Design with BIM involves complete control of all of the features, relationships, datasets, and tolerances of a project. It overcomes complexity with human logic and precision. Every feature of the model is authored by architects, engineers, or contractors. But design with biology may involve designing on top of existing machines that were authored




Images (top to bottom): Factory design and visualization (Benjamin Studio 4, Abraham Murrell and Edward Palka); Bio-fabrication process for CNC-sandblasted wood (Embodied Computation Lab, The Living); Botanical Fur (Carole Collet); Calcite precipitation model (Benjamin Studio 5, Omar Bacho); Digital simulation of acoustics; Tadpole embryo development (Ali Brivanlou Lab).

by natural forces, rather than designing machines from scratch. It may require managing a few known forces that will inevitably interact with many unknown forces.

This biological outlook offers an important counterpoint to the framework of efficiency that has long been implied in computational thought. The abstraction of data, economies, ecologies, and life itself—which is always latent within an algorithmic outlook on the world—lends itself to a strain of managerialism and runs the risk of neutralizing difference (as in the case of artificial intelligence's "white guy problem") or promoting single-minded bottom-line results (such as maximizing profit at the expense of more egalitarian and qualitative goals).

By contrast, the biological outlook of a "good solution" that has evolved in part due to random variations, asks us to leave any pretense of universalizing optimization to the side. This outlook aims for variation, diversity, and robustness of the population rather than perfection of the individual. Biology demands that we see things more multiply. It suggests that there are many versions of the good enough.

COMPUTATIONAL DESIGN

Our studio will interrogate this biological outlook, and develop a corresponding, updated version of computation and engineering. Recent advances in cloud computing, digital simulation, and data science offer new design tools for design with biology. In this studio, we will explore generative design, scripting, digital simulation, and biological algorithms.

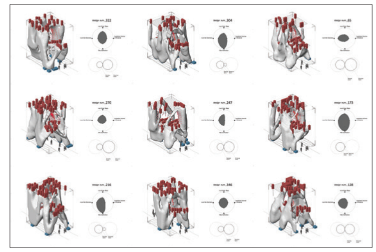
This hybrid of algorithms and the physical world allows for new design possibilities and a new outlook on nature. In this studio, we will use software to investigate data, to explore a very wide potential design space, to minimize our preconceptions, to avoid relying on old rules of thumb, and to derive unexpected high-performing results. For our purposes, computation will not be about achieving cold-blooded efficiency—but rather it will be about enhancing our creativity.

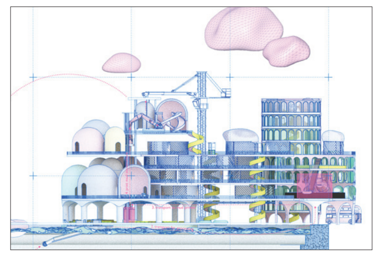
Yet while this studio will explore new frontiers of design and computing, no prior experience is necessary.

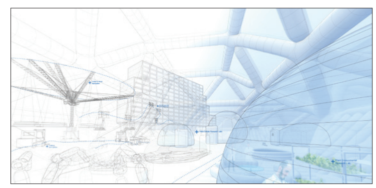
GROWING BUILDING MATERIALS

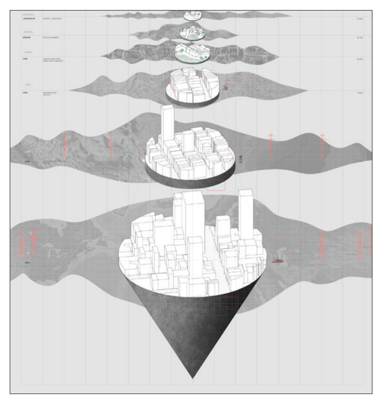
We will apply these digital and physical processes to the design of new materials, building systems, and architecture. Building materials no longer need to be static and inert. They no longer need to be produced by methods of heat, beat, and treat. Architects can begin to collaborate with natural systems rather than resist them. They can engage reciprocal flows of resources and energy rather than simply consuming resources and breaking the flow of energy.

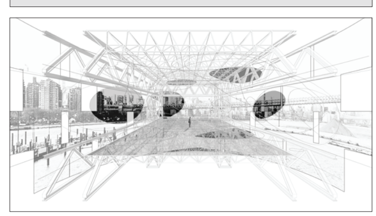
One inspiring example is mycelium-based materials that are grown from waste. This "low-tech biotech" approach makes use of agricultural byproducts and living organisms to produce useful objects. The process starts by mixing together chopped-up corn stalks and mycelium and placing them in a mold of any shape. In five days the mixture grows into a solid object. The physical object is similar to











Images (top to bottom): Factory in Campinas, Brazil (Benjamin Studio 5, Chris Gardner); Generative design for community-built grown structure (Benjamin Studio 5, Lorenzo Villaggi); Production facility (Benjamin Studio 4, Yanling Deng); Inflatable government response center (Benjamin Studio 4, Quentin Yiu); Recycling center (Benjamin Studio 4, Michael Hoehn); Software for custom CNC-sandblasting of wood (Embodied Computation Lab, The Living).

Styrofoam, but it involves almost no waste, no energy required for manufacturing, and no carbon emissions. In addition, the object is completely biodegradable. Styrofoam and other petroleum-based plastics take hundreds or thousands of years to decompose. Mycelium material returns to earth in 60 days. Petroleum-based plastics are linear. Mycelium material is circular.

Other examples include bacteria that fuse sand into bricks with no heat required, microbes living in a vat that eat sugar and generate sheets of fabric-like material, and engineered bamboo that is both stronger and more flexible than natural bamboo.

In a broader sense, this approach demonstrates how living organisms can become healthy factories to grow material. Energy consumption can be reduced. Manufacturing waste can be nearly eliminated. Equipment from Industrial Revolution-era manufacturing can be retired. And new objects, buildings, and cities can be imagined.

REDEFINING GLOBAL PRODUCTION

Once building materials can be grown rather than mined, the way buildings are designed and constructed will change, and current production flows and global supply chains will be tansformed.

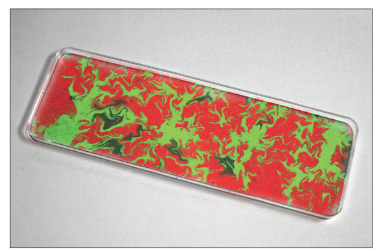
In addition to working with new building materials and new building systems, this studio will explore new cycles of global production. It will investigate the possibility of local production of building materials, similar to the movement for local production of food. It will explore how a nation might pursue material independence, in a manner similar to the pursuit of energy independence. It will explore the social and political implications of a massive transition in the way building materials are created and distributed. It will speculate about what this might mean for buildings, for cities, for developing countries, and for the trend of globalization.

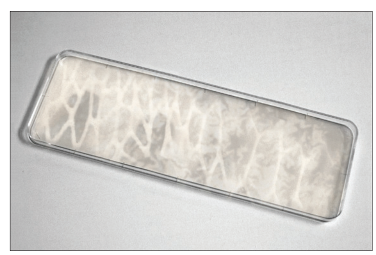
TRAVEL TO SANTIAGO AND PATAGONIA, CHILE

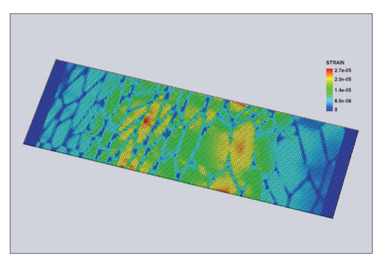
This studio will involve an intensive bio materials workshop with the Fernan Federici Lab at Univesidad Catolica de Chile. The studio will travel to Chile in early November, and students will present in-progress work with materials, attend lectures about new developments in biotechnology, and gain hands-on experience with synthetic biology experiments in the lab. The studio will then visit Patagonia as part of a research expedition to to identify local ecosystems and organisms, and to learn about local building practices and ways of enganing the grown world. We will collaborate with Catolica students and faculty and visit Puerto Williams, the southern-most city in the world, where Catolica has a Biodiversity Research Center and a new fab lab to support interdisciplinary research.

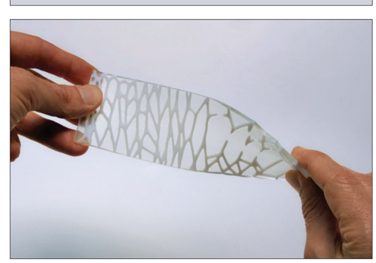
COLLABORATION WITH GROWN MATERIALS MANUFACTURERS

In addition to this workshop, the studio will visit or meet online with several grown material experts, including Ecovative (a company that uses mycelium and









Images (top to bottom): Factory in Campinas, Brazil (Benjamin Studio 5, Chris Gardner); Bacterial cellulose (BioCouture); Bacteria-grown brick (BioMason); Bacterial patterning (Fernan Federici Lab and The Living); Same; Simulation of multi-material sheet (The Living); 3D pinted model of multi-material composite sheet (The Living).

agricultural waste to grow packaging material and boards), BioMason (a company that uses bacteria and sand to grows bricks), Modern Meadow (a company that uses synthetic cells to grow leather without animals), and Material Connexion (a materials library that hosts an extensive catalog of grown and hybrid materials). While these applications may seem like science fiction, some of the giant companies known for providing the materials of the Twentieth Century are betting on their success. 3M is investing in mycelium as a materials platform as flexible as plastics. And the former chief of staff for the chief science officer at DuPont recently became chief technology officer at Modern Meadow.

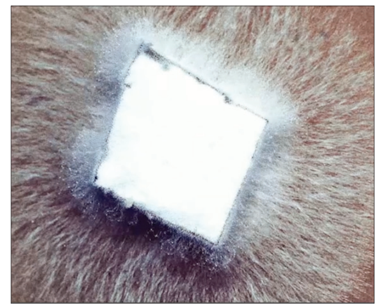
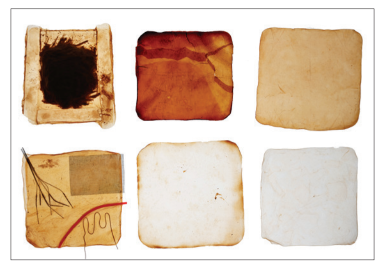
INTERNATIONAL CENTER FOR FAIR AND EQUITABLE BIODIVERSITY

In 2014, the Nagoya Protocol (an extension of the Convention on Biological Diversity) was established by the international community with the goal of ensuring fair and equitable benefits from the utilization of genetic resources. It has now been ratified by 106 United Nations states and the European Union. And among other things, this means that there are strict limitations on transporting organisms—including living bio-materials—across national borders. This prototcol adds a wrinkle to the inevitable march of globalization. It suggests that new ecosystems of local materials may arise. It challenges the Silicon Valley views of openness, innovation, and human-invented biotechnologies.

Our studio will investigate the implications of the Nagoya Protocol and design an International Center for Fair and Equitable Biodiversity in Patagonia. This mixed-use building will respond to a wide range of natural and artificial forces. It will incorporate research labs, offices, residences, community servies, and production facilities. More broadly, the project will bring together local building practices and technology, politics and bio-materials, nations and ecosystems, biotechnology and the Global South.

Over the course of the semester, we will apply all of our best biology, computing, and imagination to the design of innovative and viable building proposals.




Images (top to bottom): Mycelium Grow-It-Yourself material (Ecovative and Benjamin Studio 5); Mycelium brick (The Living); Mycelium grown (Ecovative); Bacterial cellulose (Benjamin Studio 5, Chris Gardner); Glacier in Patagonia; Mycelium with natural reinforcement (Benjamin Studio 5, Lorenzo Villaggi); Seeds grown inside mycelium material (Benjamin Studio 5, Peter Hunt).