GROWN | Bio-materials, Adaptation, and Architecture

A design studio traveling to Santiago, Chile and collaborating with the Fernan 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.

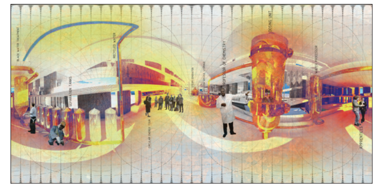
Examples of grown materials include bricks grown from bacteria, fabric grown from microbes, boards grown from mycelium, and of course, all kinds of wood. Some of these grown materials behave like non-grown materials. Others offer new types of performance. All grown materials involve a new relationship 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.

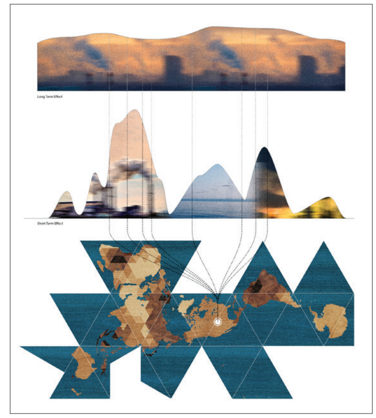
This is the primordial soup of Grown, a design studio exploring the frontier of architecture and bio-materials. In our research, we will become immersed in this new science and its possibilities, dangers, and myths. We will use new software workflows—including parametric modeling, digital simulation, 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.

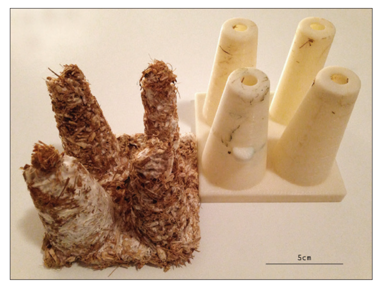
This studio will travel to Santiago, Chile and participate in an intensive bio materials workshop with the Fernan Federici Lab at Univesidad Catolica de Chile. Students will present in-progress work with materials, attend lectures about new developments in biotechnology, and gain hands-on experience with synthetic biology experiments in the lab. The studio may also visit the Atacama Desert as part of a research expedition to identify “extremophile” organisms.

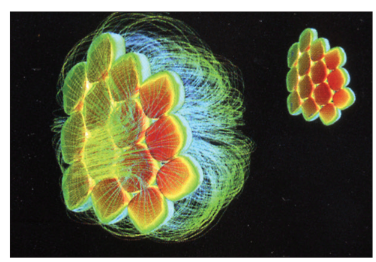
Out of this complex soup, we will design new building materials, systems of global production, and definitions of sustainability, as well as the new architecture that these forces generate. We will design at multiple scales simultaneously—from DNA with a radius of about a billionth of a meter, to Earth 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 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









Images (top to bottom): Factory design and visualization (Benjamin Studio 4, Abraham Murrell and Edward Palka); Global production diagram (Benjamin Studio 4, Ruomeng Wang), Mycelium and 3D printed model (Benjamin Studio 5, Thomas Wegner); Sand-balsted wood (The Living); Digital simulation of acoustics; Tadpole embryo development (Ali Brivanlou Lab).

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.

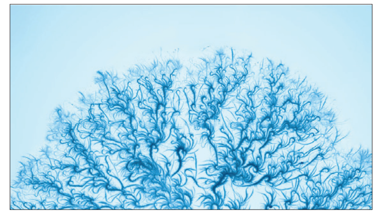
Of course, architects have been drawing on biology for hundreds of years. But this history is largely a conceptual one, drawing on the metaphors, knowledge structures, and imagery of biology, while rarely engaging the actual research protocols of biology or understanding buildings and materials as living 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.

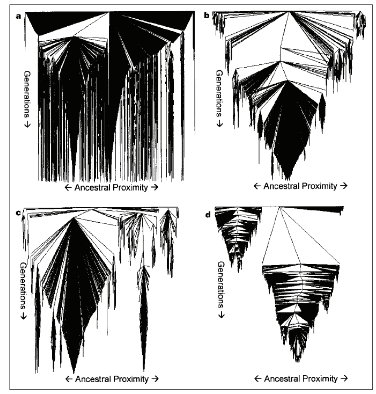
Biology of today is different than biology of a hundred years ago. It is now possible to grow cells on a glass chip isolated from other cells instead of in a living organism. It is now possible to cut and paste DNA and bring to life organisms that never before existed in nature, such as bioengineered 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 inspiring, and they are sometimes terrifying, but this new biology is unequivocally here to stay.

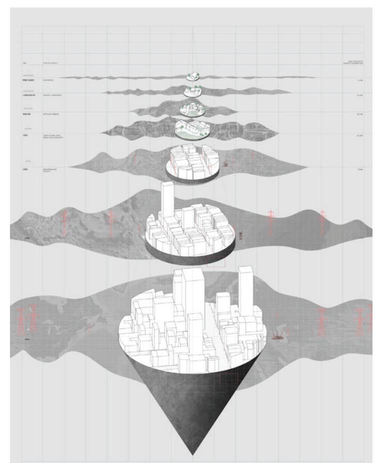
In addition, it is now possible to apply the latest techniques of computation—such as computer vision and machine learning—to functions such as biological growth. Biology is extremely complex, but when biological functions are encapsulated in computer models, they become a more actionable part of the 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.

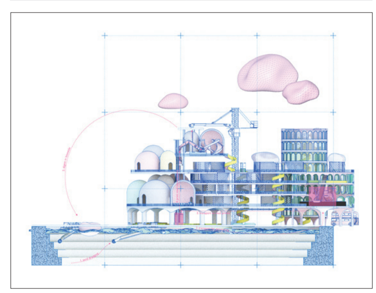
For architects, some aspects of designing with biology may feel like an extension of familiar computation tools. But other aspects are likely to be unfamiliar. Despite recent advances and discoveries, in the near future anyone designing with biology may have to do so with only partial understanding and 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): Community center and local grown materials (Benjamin Studio 5, Lorenzo Villaggi); Bacteria growth (Eshel Ben-Jacob); Evolutionary computation (Hod Lipson, Computational Synthesis Lab at Cornell); Global production at multiple scales (Benjamin Studio 4, Rae Zhuang); Material production and education (Benjamin Studio 4, Yanling Deng).

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.

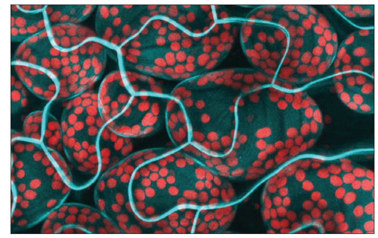
This hybrid of algorithms and the physical world allows for new design possibilities and a new outlook on nature. In this studio, we will use software to investigate data, to explore a very wide potential design space, to minimize our preconceptions, to avoid relying on old rules of thumb, and to derive 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.

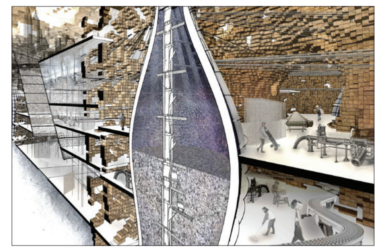
Yet while this studio will explore new frontiers of design and computing, no prior experience is necessary.

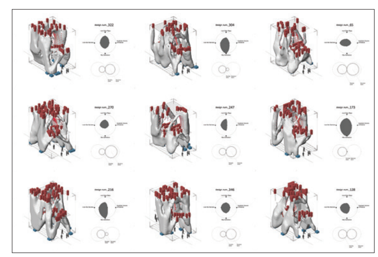
GROWING BUILDING MATERIALS

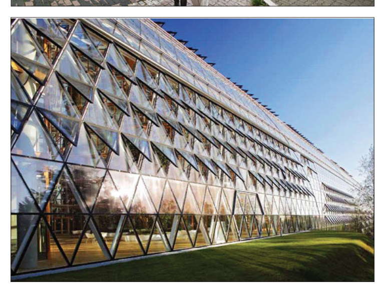
We will apply these digital and physical processes to the design of new materials, building systems, and architecture. Building materials no longer need to be static and inert. They no longer need to be produced by methods of heat, beat, and treat. Architects can begin to collaborate with natural systems 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): Campinas, Brazil; Same; Confocal image of cell structure (Fernan Federici Lab); Production from waste (Benjamin Studio 4, Troy Lacombe); Generative design of grown structure (Benjamin Studio 5, Lorenzo Villaggi); Facotry in Campinas (Benjamin Studio 5, Casey Worrell); Apple Computer Headquarters (Foster and Partners); IBM Watson Research Center (Eero Saarinen).

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.

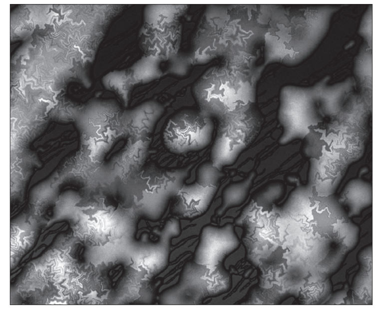
In addition to working with new building materials and new building systems, this studio will explore new cycles of global production. It will investigate the possibility of local production of building materials, similar to the movement for local production of food. It will explore how a nation might 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.

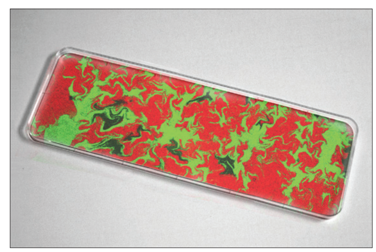
TRAVEL TO SANTIAGO, CHILE

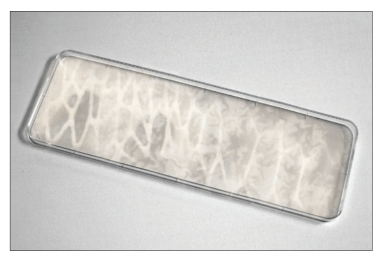
This studio will involve an intensive bio materials workshop with the Fernan Federici Lab at Univesidad Catolica de Chile. The studio will travel to Chile during the week of October 15, and students will present in-progress work with materials, attend lectures about new developments in biotechnology, and gain hands-on experience with synthetic biology experiments in the lab. The studio may also visit the Atacama Desert as part of a research expedition to identify "extremophile" organisms (such as bacteria that live in very hot and dry climates, or microorganisms that use arsenic rather than phosphorous as a scaffold for their DNA, suggesting new possibilities for grown materials and a new conception of life on earth).

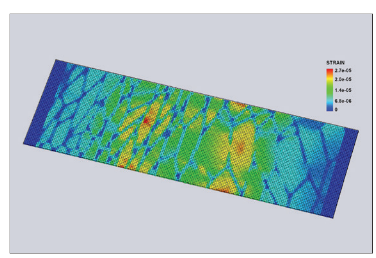
COLLABORATION WITH GROWN MATERIALS MANUFACTURERS

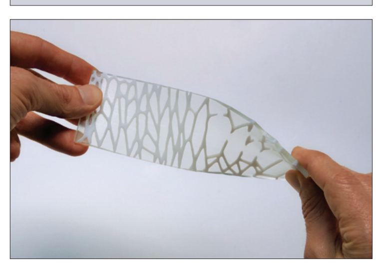
In addition to this workshop, the studio will visit or meet online with several grown material experts, including Ecovative (a company that uses mycelium and agricultural waste to grow packaging material and boards), BioMason (a company











Images (top to bottom): Cellular patterning (Fernan Federici Lab); 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).

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.

GOVERNMENT INNOVATION LAB AND PILOT FACTORY IN CAMPINAS, BRAZIL

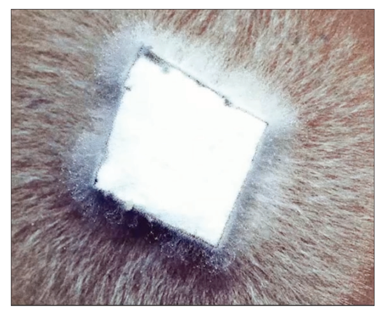
While biotechnology and computation is thriving in typical sites of innovation such as Silicon Valley, it is also growing roots in less expected locations such as interior Brazil. Due to Brazil's advanced ethanol infrastructure, its recent investment in biotechnology, and its abundant land resources, the country is poised to lead the world in clean biofuel, as well as related new manufacturing processes such as growing building materials.

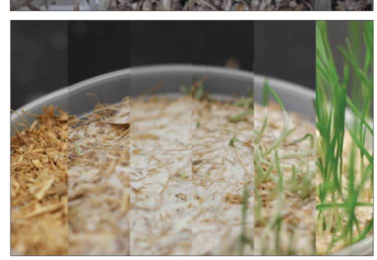
Campinas, Brazil is home of the perfect biological machine for converting light and carbon dioxide into the energy source for this revolution: sugarcane. We will follow the new frontier of biology to Campinas, where several biotechnology start-ups have already established outposts. We will apply our explorations to the design of a pilot factory and technology showcase building for the Brazilian government's São Paulo Research Foundation (FAPESP). Our building will serve functional goals for new work and production processes, and it will be an icon for new technologies and their corresponding corporate and political interests.

How should this building integrate the latest clean and precise high technology of biology with the ancient and dirty low technology of agriculture? How should it balance physical and cultural production? How should it showcase the latest innovations in biological manufacturing? What should be its public image?

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): Physical model incorporating grown materials (Benjamin Studio 4, Tonia Chi); Mycelium Grow-It-Yourself material (Ecovative and Benjamin Studio 5); Mycelium brick (The Living); Mycelium grown (Ecovative); Wood; Mycelium with natural reinforcement (Benjamin Studio 5, Lorenzo Villaggi); Seeds grown inside mycelium material (Benjamin Studio 5, Peter Hunt).