

RETURN | Architecture, Biology, and Computation in the Circular Economy

Critic: David Benjamin

OVERVIEW

Cities and buildings have always been **living, breathing organisms**. But the design of architecture typically emphasizes structures that are inert, monotone, and solitary.

The Circular Economy is an emerging framework for a new era of design. This framework is based on an ecosystem with two types of nutrients: **biological nutrients** that are designed to circulate without unhealthy waste products, and **technical nutrients** that are designed to circulate at high quality without material impact. The Circular Economy incorporates the concepts of **resilience**, **anti-fragility**, and **industrial ecology**. It involves **open source** scientific projects and solutions that are healthy in terms of environment, finance, and society.

This framework is not about regressing to an old version of nature. It is about inventing a **new nature**.

In this context, our studio will work on reinventing design ecosystems, global supply chains, financial performance metrics, and **the way we design and manufacture everything**.

Over the course of the semester, we will work on **multiple scales simultaneously**. We will design **rules rather than fixed forms**. We will anticipate and **welcome rapid change, shifting forces, unknowable crises, and uncertainty**.

THE CENTURY OF BIOLOGY

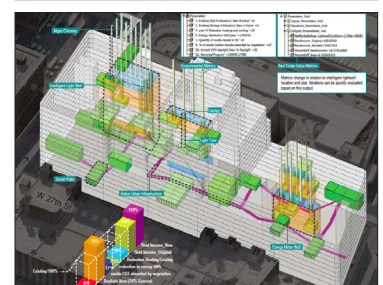
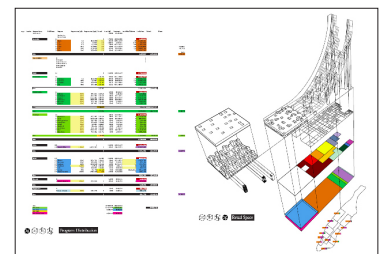
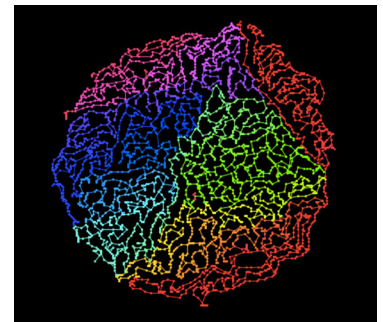
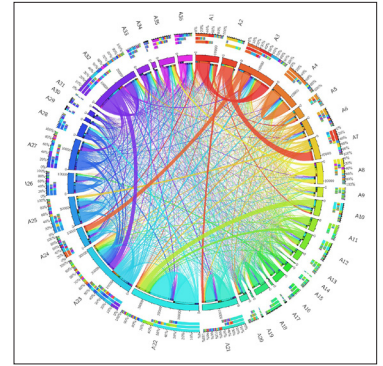
If the Twentieth Century was the Century of Physics, then the Twenty-First Century is the Century of Biology. Biological technologies are advancing exponentially. In the past ten years, it has become possible to image living systems in new ways, to **create computer models of biological cells**, to cut and paste DNA, and to calibrate and combine functions such as **growth, movement, sensing, deposition, regeneration, and self-healing** into novel organisms.

Our studio will interrogate these new biological technologies, combine them with next-generation technologies of computation and engineering, and create new building materials, a **new method of bio-design**, and new architecture that is resilient, revolutionary, and circular.

For our exploration of biological systems, we will work closely with world-leading stem cell biologist Ali Brivanlou and his laboratory at Rockefeller University. Ali will teach a custom workshop for our studio and he will lead students in **hands-on laboratory experiments utilizing some of these latest biological technologies**.

DESIGN AND COMPUTING

Recent advances in **cloud computing, digital simulation, and data science** offer new design tools for the Century of Biology and the Circular Economy. In this



Images (top to bottom): Diagram of Circular Economy in Portugal (via MM & Random Thought); Tadpole embryo development (Ali Brivanlou Lab); Data visualization of bacterial colony growth (Columbia Advanced Data Visualization Project, Danil Nagy); Pre-Circular Economy Global Supply Chain; Exploration of design space through program data (Benjamin Proof Studio, Troy Therrien); Design dashboard metrics (CBIP Studio, Kooho Jung).

studio, we will explore generative geometry, scripting, performance analysis, multi-objective optimization, and biological algorithms.

More specifically, we will push the limits of the specific software packages of Rhino, Grasshopper, Galapagos, and Dynamo. We will also utilize and explore new

custom academic software applications for modeling, simulation, optimization, and data processing.

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.

LIVING FACTORIES

In the Circular Economy, flows of raw materials and energy are composed to create healthy ecosystems.

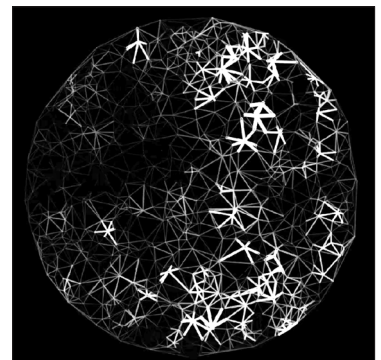
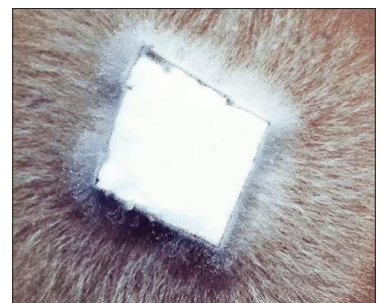
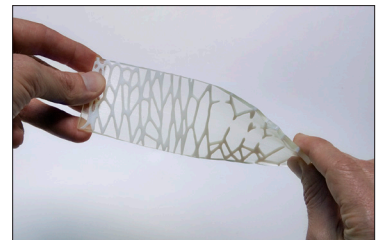
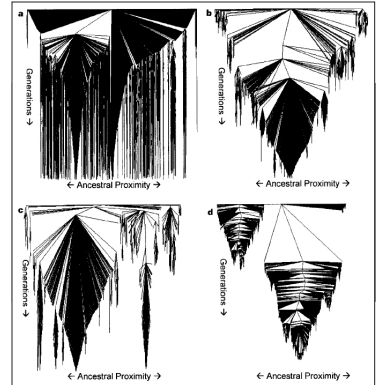
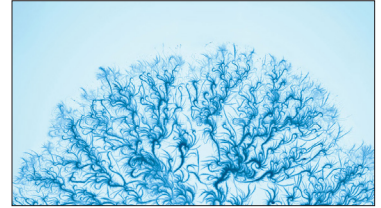
One inspiring example is mycelium-based materials that are grown from waste. This “**low-tech biotech**” approach makes use of agricultural byproducts and living organisms to produce useful objects. The process starts by mixing together chopped-up corn stalks and mycelium and placing them in a mold of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

In a broader sense, this demonstrates how **living organisms can become healthy factories**. 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**.

For our work with material ecosystems, we will visit the research and manufacturing facilities of pioneering mycelium materials start-up, Ecovative Design. We will learn from the latest R&D and collaborate with Ecovative on new possibilities for the future.

INNOVATION LAB AND PILOT FACTORY IN CAMPINAS, BRAZIL

While biotechnology and computation is thriving in typical sites of world-changing 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



Images (top to bottom): Bacteria growth (Eshel Ben-Jacob); Evolutionary computation (Hod Lipson, Computational Synthesis Lab at Cornell); Multi-material 3D print of new composite sheet (Bio Computation, The Living); Mycelium growth (Ecovative Design); Data visualization of animated hair (Columbia Advanced Data Visualization Project, Danil Nagy, Eitan Grinspun, David Benjamin).

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 Ecovative Design in partnership with the government's São Paulo Research Foundation (FAPESP). Like other high-profile corporate buildings from recent history—from Eero Saarinen's IBM Watson Research Center to Norman Foster's proposed Apple Computer Headquarters—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 for the Circular Economy work? How should it integrate the latest clean and precise high technology of DNA 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? In the Circular Economy, what should be returned? And what is the return?

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.

COLLABORATORS

The studio will work with several organizations and companies outside of the School that are personally invested in our method and proposals. Our collaborators will include:

Ali Brivanlou (Lab of Stem Cell Biology, Rockefeller University)

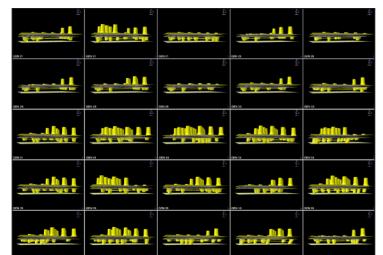
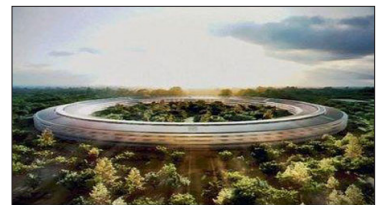
Eben Bayer (Founder and CEO, Ecovative)

Ian Keough (Principal Design Strategist and Inventor of Dynamo, Autodesk)

Hod Lipson (Professor of Aerospace Engineering, Cornell University)

Chas Peppers (Associate, Woods Bagot)

Michael Reed (Designer, Blue Sky Studios, and Professor of CS, Columbia)



Images (top to bottom): Campinas, Brazil; Same; Biotechnology lab using yeast as factories for biofuel (Amyris); Apple Computer Headquarters (Foster and Partners); IBM Watson Research Center (Eero Saarinen); Matrix of design solutions (Benjamin Proof Studio, John Locke).