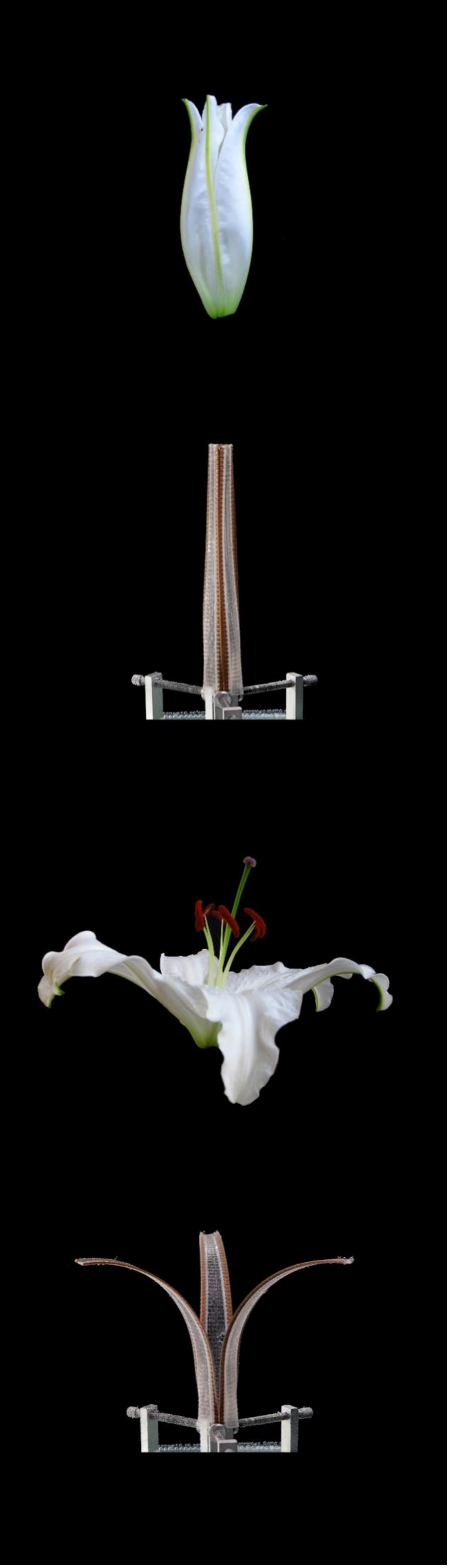

Poppinga, Simon, David Correa, Bernd Bruchmann, Achim Menges, and Thomas Speck. 2020. "Plant Movements as Concept Generators for the Development of Biomimetic Compliant Mechanisms." Integrative and comparative biology. https://doi.org/10.1093/icb/icaa028.

BIOMIMETIC DESIGN LAB

UNIVERSITY OF WATERLOO | SCHOOL OF ARCHITECTURE

David Correa | david.correa@uwaterloo.ca | office 3017

Arch 393 | Fall 2021 | Mondays 9:30 AM – 12:30 PM | 1:30 PM – 5:30 PM
Thursdays 9:30 AM - 12:30 PM | 1:30 PM – 5:30 PM

"In biology material is expensive but shape is cheap.

As of today, the opposite was true in the case of technology."

Julian Vincent 2009

The Biomimetic Design Lab will focus on bio-inspired design strategies that are shaping new technologies and challenging designers to look at the world in new ways. We will look at what lobsters can teach us about structures, how learning from the pine scale is changing homes in New Zealand and how understanding the sand dollar may change the way buildings are made. From the micro-structure of cells, the meso-structures of tissues and bones or the anatomical features of plants, living things have a lot to teach us about high performance and beautiful design.

Studio Summary:

This studio offers students the opportunity to investigate the principles that enable biological organisms to create some of the most technically capable structures using locally available materials. Through an experiment-based approach, students will investigate how nature addresses the relationship between material, shape and structure. In particular, the Lab will focus on organisms, structures and materials that transform and adapt in response to environmental conditions.

Studio Structure

The studio is structured such that extensive material investigations are required.

Students are required to work in teams of 3 – see 'Collaborative Work' section.

The studio will be structured around three phases, the following is a summary of each.

Please note that a more detailed project brief and evaluation criteria will be provided for each project as they are introduced.

Phase 1: Analytical Observation (2 weeks)

Focusing on plant movements, this phase invites students to explore their local surroundings while seeking to gain a better understanding of the complex organisms that cohabitate with urban and suburban dwellers. Observing local ecosystems and climatic conditions is critical to understanding the complex interdependency that links biological organisms with their local ecosystem.

This phase will involve the collection and time-lapse documentation of locally sourced specimens.

During this phase, students will:

- Explore physical phenomena in nature, through real-world observations of local shape-changing plants, and generate hypothesis about how and why these transformations occur.
- Implement systematic study, observation and experimentation with plant structures.
- Translate qualitative observations into analytical diagrams of functional relations
- Develop methods for investigation of climate and time-dependent phenomena

Phase 2: Detail Analysis and Functional Development (4 weeks)

This phase tests the abstracted principles observed in the first phase through the creation of physical and biomimetic material models. This is a highly creative and rigorous process of iteration where multiple kinematic structures will be made and tested.

- Identify design opportunities and assess technical challenges of both a particular material and a functional biomimetic principle.
- Become experts in slow but progressive design development through an iterative series of evolutionary prototypes
- Build skills in critical analysis through observation and synthesis
- Develop a working prototype of a bio-inspired kinematic model that is climate adaptive

Phase 3: Biomimetic Transfer (6 weeks)

This phase challenges students to apply the biomimetic functional principles to a component-based building façade application. This phase requires students to connect structural, material and environmental functional relationships, borrowed from their biomimetic models to spatial and architectural considerations.

- Synthesize previous biomimetic principles into an architectural façade application
- Mediate between the biomimetic design system and local architectural considerations of site, program and spatial quality.
- Asses the systems feasibility in terms of ecological impact, comfort, aesthetic qualities, as well as capital and operational costs.

Course Goals & Learning Objectives

By the end of the course, students will be able to/have:

1. Define key concepts and ideas that drive biomimetic design
2. Differentiate key structure-function relationships that plant structures use to develop specialized hierarchical materials.
3. A developed "understanding of the broader ecologies that inform the design of buildings and their systems and of the interactions among these ecologies and design decisions." (CACB_B5 Ecological Systems)
4. Introductory understanding of the role that fabrication and manufacturing processes have in defining the properties of material assemblies
5. Demonstrate an understanding of material research, iterative prototyping methodologies, and fabrications, as integral parts of the creative process of design
6. Introductory understanding of the role of design in the development of performance-oriented materials
7. Gained applied knowledge regarding design rules for material selection, design for manufacturability, design for assembly
8. Recognize issues of product safety, risk, and reliability
9. Examine building systems and construction technologies, relative to bio-inspired and ecologically aware techniques of energy conservation, production and consumption.
10. Develop a critical approach to making.
11. Develop an understanding of the nature of and relationship between materials.
12. Build design and detailing skills at a 1:1 scale.
13. Develop a more complex understanding of the overall design process as integrated with other disciplines.

Collaborative Work

Professional practice in architecture, design or engineering takes place through close collaborations between teams of people. Identifying effective ways to communicate, assign responsibilities, identify milestone and achieve objectives are essential skills to succeed in professional practice. For this reason, the studio will require students to work in teams. This collaboration should allow for intensive work and iteration to take place in parallel. Generally, the more iterations are pursued the stronger the work.

Working in groups also means that you will be evaluated as a group – thus, pick your team wisely.

As it will be presented in the course, working online with teams distributed across various continents has been standard practice over the last few decades. However, as difficulties might emerge, faculty will work with students to work through problems and make accommodations in group formations to support the production of high-quality work as needed.

Field Trip

Each individual student will conduct self-administered field-trips to the great outdoors to explore and respectfully collect biological specimens for analysis. This can include your backyard, local parks, forested areas and grocery stores!

Costs

While the term will be conducted online, The Biomimetic Design Lab is a material-oriented investigation. The Lab requires intensive material explorations that have material costs. It is expected that participants can purchase required materials (as locally available) to support these explorations. Please budget $300 / student for the term.

Reference Readings

The following readings are for your reference – a place to look for cool ideas that someone else tested. This includes literature that has studied some of the most captivating plant movement mechanisms used by flowers to bloom [1–4], carnivorous plants to traps insects [5] and super interesting seed dispersal systems [6–9]. While all of the plant movements use water to generate movement, I am only including a few dedicated publications on this topic as it is likely more relevant to understand the specific mechanism as a system[10,11]. Shape-change structures using the amazing properties of wood[12,13] are included as they are easier to work with. Wherever in the world you are, you are likely able to find wood[12,14]. These shape-change systems include bilayer systems using veneer composites[15,16], paper and wood[17], paper and wax[18,19], wood on wood[20–24], wood on metal[25], and my own 4D printed wood research[26–31]. Furthermore, I am also including initial prototypes that have already addressed architectural applications in facades[32,33], PV panels[21], grid shells[34], or shading systems[35,36].

At a much broader conceptual scale, it might be interesting for you to read up on how Nature has also been a source for inspiration in the development of materials[37–42], plays a key role in technical education[17,43], or used as the inspiration of integrative design processes [44–46]. This list might look long but, as you will discover, we have only scratched the surface of what nature has to offer.

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Biomimetic Design Lab- Fall 2021- Schedule

	MON	TUES	WED	THU	FRI	SAT	SUN
	30	31	**01 SEPTEMBER**	02	03	04	05
WK01	06 September	07 Faculty Meeting 1-2:30 pm	08 Mayor's BBQ 1 PM **Classes begin**	09 AM/PM **Lecture 01** P1A Intro All school meeting 12:30 – 1:30 PM	10	11	12
WK02	13 AM/PM Desk Crits	14 Grades available in Quest	15 Faculty Meeting 1-2 pm Reserves removed in classes	16 AM/PM **P1A Review** P1B Intro	17	18	19
WK03	20 AM/PM Desk Crits	21 Add period ends	22	23 AM/PM **P1B Review** P2A Intro	24	25	26
WK04	27 AM/PM Desk Crits	28 Last day to drop a class (Tuition refund deadline 100%)	29 Faculty Meeting 1-2 pm	30 AM/PM Desk Crits	**01 OCTOBER**	02	03
WK05	04 AM/PM Desk Crit	05	06	07 AM/PM **P2A Review** P2B Intro	08	09 READING WEEK BEGINS	10
WK06	11 Thanksgiving – School Closed	12 READING WEEK	13 READING WEEK	14 READING WEEK	15 READING WEEK	16 READING WEEK	17 READING WEEK ENDS
WK07	18 AM/PM Desk Crit	19	20	21 AM/PM Desk Crit	22 Convocation	23 Convocation	24
WK08	25 AM/PM Desk Crit	26 Tuition refund deadline 50%	27 Faculty Meeting 1-2 pm	28 AM/PM **P2B Review** P3 Intro	29	30 OPEN HOUSE	31
WK09	**01 NOVEMBER** AM/PM Desk Crits	02	03	04 AM/PM Desk Crits	05	06	07
WK10	08 AM/PM Desk Crits	09	10 Faculty Meeting 1-2 pm	11 AM/PM Desk Crits	12	13	14
WK11	15 AM/PM Desk Crits	16	17	18 AM/PM **In-Progress Pin-up Group Sessions**	19	20	21
WK12	22 AM/PM Desk Crits	23 Drop with Withdrew Ends	24 Faculty Meeting 1-2 pm Add period begins	25 AM/PM Desk Crits	26	27	28
WK13	29 AM/PM Desk Crits	30	**01 DECEMBER**	02 AM/PM Desk Crits	03	04	05
	06 AM/PM **FINAL STUDIO DAY** Optional Desk Crits	07 **Classes End**	08 Faculty Meeting 1-2 pm	09 Exams begin	10 **FINAL REVIEWS** **3B Studios** **P3 Due**	11	12
	13 FINAL REVIEWS	14 FINAL REVIEWS Tuition Due	15 FINAL REVIEWS	16 FINAL REVIEWS (Arch 442 deadline)	17 M.ARCH THESIS REVIEWS	18	19
	20	21	22 Faculty Meeting 1-2 pm	23 Exams End Last day of Co-op	24 **University Closed**	25	26
	27	28	29	30	31		

Official Business

ARCH 393 is scheduled as follows:

Mondays 9:30 AM – 12:30 PM | 1:30 PM – 5:30 PM

Thursdays 9:30 AM - 12:30 PM | 1:30 PM – 5:30 PM

Course Time Zone

All dates and times communicated in the document are expressed in Eastern Time (Local time in Waterloo Ontario, Canada). Eastern Standard Time (EST, UTC−05:00) applies November to March and Eastern Daylight Time (EDT, UTC−05:00) applies from March to November.

Grades

Students must complete all projects and assignments and obtain a passing average of at least 60% in order to receive credit for this course.

- Individual Class Participation – 10%

- Course Project – Phase 1: 15%
- Course Project – Phase 2: 25%
- Course Project – Phase 3: 50% [Final Project]

Note on Passing Grades

The standard minimum passing grade in each ARCH course is 50% with the following exceptions: the minimum passing grade is 60% for all studio courses (ARCH 192, ARCH 193, ARCH 292, ARCH 293, ARCH 392, **ARCH 393**, ARCH 492, and ARCH 493). Grades below the specified passing grade result in a course failure.

Evaluation

Each assignment throughout the term will be assessed on the following basis:

- Ambition, clarity and appropriateness of the ideas addressed within the work.
- Invention, innovation and vision embodied within the work.
- Criticality/integration of bio-inspired principles and biomimetic models in design proposals.
- Architectural/spatial quality and technical resolution of the proposition.
- The effectiveness and completeness of project documentation and the work's capacity to communicate a project's intentions in the author's absence.
- Integrity in the development of the project from initial to final phase.
- Precision and craft of physical artifacts created.

In addition to this list, a more specific set of measures will be identified in individual project handouts. Grades will be made available to students through LEARN. Faculty will do their best to publish grades in a timely manner.

Participation

The Studio is a structured space for experiential investigation and speculative dialogue. Each student and student group are expected to provide constructive feedback with regard to their own work and the work of others.

Participation includes active engagement in lectures, desk-crits and reviews.

The work in the Studio also requires a commitment to the development of multiple iterative physical prototypes.

Late Work

Assignments that are handed in late will receive an initial penalty of 20% on the first calendar day late and a 5% penalty per calendar day thereafter. After 5 calendar days, the assignment will receive a 0%.

Only in the case of a justified medical or personal reason will these penalties be waived, and only if these have been officially submitted to the Undergraduate Student Services Co-Ordinator and accepted by the Undergraduate Office.

Students seeking accommodations due to COVID-19, are to follow Covid-19-related accommodations as outlined by the university here: (https://uwaterloo.ca/coronavirus/academic-information/undergraduate-student-information#accommodations)

COVID-19 Special Statement

Given the continuously evolving situation around COVID-19, students are to refer to the University of Waterloo's developing information resource page (https://uwaterloo.ca/coronavirus/) for up-to-date information on academic updates, health services, important dates, co-op, accommodation rules and other university level responses to COVID-19.

Technological Platforms

Since there will be no access to the computer lab at the school, students are expected to have Rhino on their computers. While associative modelling workflows for geometric modelling are encouraged, they are not required.

Image capturing (camera) and video editing software, such as Adobe Premier, will be needed to appropriately document specimens in the field and under controlled conditions.

Remote Course Delivery Platforms & Communication

During remote learning, we will be using additional platforms to deliver, organize and share course content, learning and work. Here is a breakdown of tools we will use in this course:

MS TEAMS – Virtual Hub for the course. Used for organizing course documents, activities and discussions. Students will be added to the course team in the first week of class.

LEARN – Official communication, work submission, and grade recording and release.

MIRO – group desk-crits, graphic feedback, discussion with classmates' work.

Student Notice of Recording

The course's official Notice of Recording document is found on the course's LEARN site. This document outlines shared responsibilities for instructors and students around issues of privacy and security. Each student is responsible for reviewing this document.

All live lectures, seminars and presentations including questions and answers will be recorded and made available through official course platforms (LEARN and/or MS Teams).

Students wishing not to be captured in the recordings have the option of participating through the direct chat or question and answer functions in the meeting platforms used.

Course events, if any, that will not be recorded are indicated in the course schedule.

Individual desk critiques/meetings and small group meetings will not be recorded.

Mental Health Support

All of us need a support system. We encourage you to seek out mental health supports when they are needed. Please reach out to:

Campus Wellness
[https://uwaterloo.ca/campus-wellness/]

Counselling Services
[https://uwaterloo.ca/campus-wellness/counselling-services]

We understand that these circumstances can be troubling, and you may need to speak with someone for emotional support. Good2Talk [https://good2talk.ca/] is a post-secondary student helpline based in Ontario, Canada that is available to all students.

Equity, Diversity and Inclusion Commitment

The School of Architecture is committed to foster and support equity, diversity and inclusion. If you experience discrimination, micro-aggression, or other forms of racism, sexism, discrimination against 2SLGBTQ+, or disability, there are several pathways available for addressing this:

A) If you feel comfortable bringing this up directly with the faculty, staff or student who has said or done something offensive, we invite you, or a friend, to speak directly with this person. People make mistakes and dealing them directly in the present may be the most effective means of addressing the issue.

B) you can reach out to either the Undergraduate office, Graduate office, or Director (Anne Bordeleau). If you contact any of these people in confidence, they are bound to preserve your anonymity and follow up on your report.

C) You can choose to report centrally to the Equity Office. The Equity Office can be reached by emailing equity@uwaterloo.ca. More information on the functions and services of the equity office can be found here: https://uwaterloo.ca/human-rights-equity-inclusion/about/equity-office.

D) Racial Advocacy for Inclusion, Solidarity and Equity (RAISE) is a student-led Waterloo Undergraduate Student Association (WUSA) service launching in the Winter 2019 term. RAISE serves to address racism and xenophobia on the University of Waterloo campus with initiatives reflective of RAISE's three pillars of Education and Advocacy, Peer-to-Peer Support, and Community Building. The initiatives include but are not limited to: formal means to report and confront racism, accessible and considerate peer-support, and organization of social events to cultivate both an uplifting and united community. You can report an incident using their online form.

Academic integrity, grievance, discipline, appeals and note for students with disabilities:

Academic integrity: In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. [Check the Office of Academic Integrity for more information.]

Grievance: A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4. When in doubt, please be certain to contact the department's administrative assistant who will provide further assistance.

Discipline: A student is expected to know what constitutes academic integrity to avoid committing an academic offence, and to take responsibility for his/her actions. [Check the Office of Academic Integrity for more information.] A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course instructor, academic advisor, or the undergraduate associate dean. For information on categories of offences and types of penalties, students should refer to Policy 71, Student Discipline. For typical penalties, check Guidelines for the Assessment of Penalties.

Appeals: A decision made or penalty imposed under Policy 70, Student Petitions and Grievances (other than a petition) or Policy 71, Student Discipline may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to Policy 72, Student Appeals.

Note for students with disabilities: AccessAbility Services, located in Needles Hall, Room 1401, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with AccessAbility Services at the beginning of each academic term.

Turnitin.com: Text matching software (Turnitin®) may be used to screen assignments in this course. Turnitin® is used to verify that all materials and sources in assignments are documented. Students' submissions are stored on a U.S. server, therefore students must be given an alternative (e.g., scaffolded assignment or annotated bibliography), if they are concerned about their privacy and/or security. Students will be given due notice, in the first week of the term and/or at the time assignment details are provided, about arrangements and alternatives for the use of Turnitin in this course.

It is the responsibility of the student to notify the instructor if they, in the first week of term or at the time assignment details are provided, wish to submit the alternate assignment.

Land Acknowledgement

We acknowledge that the School of Architecture is located on the traditional territory of the Neutral, Anishinaabeg and Haudenosaunee peoples. The University is situated on the Haldimand Tract, the land promised to the Six Nations that includes 10 kilometres on each side of the Grand River.