

# BIOMIMETIC DESIGN LAB

UNIVERSITY OF WATERLOO | SCHOOL OF ARCHITECTURE

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Arch 393 | Fall 2022 | 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.*

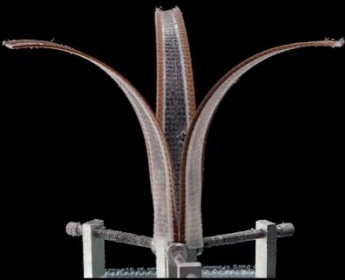
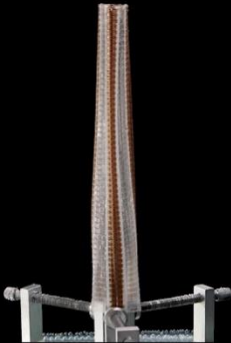
*As of today, the opposite was true in  
the case of technology."*

*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.
- Assess 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

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<sup>1–4</sup>, carnivorous plants to traps insects<sup>5</sup> and super interesting seed dispersal systems<sup>6–9</sup>. 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<sup>10,11</sup>. Shape-change structures using the amazing properties of wood<sup>12,13</sup> are included as they are easier to work with. Wherever in the world you are, you are likely able to find wood<sup>12,14</sup>. These shape-change systems include bilayer systems using veneer composites<sup>15,16</sup>, paper and wood<sup>17</sup>, paper and wax<sup>18,19</sup>, wood on wood<sup>20–24</sup>, wood on metal<sup>25</sup>, and my own 4D printed wood research<sup>26–31</sup>. Furthermore, I am also including initial prototypes that have already addressed architectural applications in facades<sup>32,33</sup>, PV panels<sup>21</sup>, grid shells<sup>34</sup>, or shading systems<sup>35,36</sup>.

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<sup>37–42</sup>, plays a key role in technical education<sup>17,43</sup>, or used as the inspiration of integrative design processes<sup>44–46</sup>. This list might look long but, as you will discover, we have only scratched the surface of what nature has to offer.

## References

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## Biomimetic Design Lab - Fall 2021 - Schedule

	MON 29	TUES 30	WED 31	THU 01 SEPTEMBER	FRI 02	SAT 03	SUN 04
WK01	05 September	06	07 Classes begin	08 AM/PM Lecture 01 P1A Intro	09 Faculty Meeting 1-2:30 pm	10	11
WK02	12 AM/PM Desk Crits All school meeting 12:30 – 1:30 PM	13 Grades available in Quest	14 Reserves removed in classes	15 AM/PM P1A Review P1B Intro	16	17	18
WK03	19 10 AM Interpretive Walk at Rare Site	20 Add period ends	21	22 AM/PM Guest lecture	23	24	25
WK04	26 AM/PM Desk Crits P1B Review P2A Intro	27 Last day to drop a class (Tuition refund deadline 100%)	28	29 AM/PM Desk Crits	30	01 OCTOBER	02
WK05	03 AM/PM Desk Crit	04	05	06 AM/PM P2A Review P2B Intro Guest lecture	07	08 READING WEEK BEGINS	09
WK06	10 Thanksgiving – School Closed	11 READING WEEK School Offices Closed	12 READING WEEK	13 READING WEEK	14 READING WEEK	15 READING WEEK	16 READING WEEK ENDS
WK07	17 AM/PM Desk Crit Faculty Meeting 1-2 pm	18	19	20 AM/PM Desk Crit	21 Convocation	22 Convocation	23
WK08	24 AM/PM P2B Review P3 Intro Guest lecture	25 Tuition refund deadline 50%	26 Faculty Meeting 1-2 pm	27 AM/PM	28	29 OPEN HOUSE	30
WK09	31 AM/PM Desk Crits	01 NOVEMBER	02	03 AM/PM Desk Crits Guest lecture	04	05 Fall open house	06
WK10	07 AM/PM Desk Crits	08	09	10 AM/PM Desk Crits	11	12	13
WK11	14 AM/PM Mid-term Review Group Sessions	15 Faculty Meeting 1-2 pm	16	17 AM/PM Andrew Levitt Tribute Event – Foyer 5:00-6:30 pm	18	19	20
WK12	21 AM/PM Desk Crits	22 Drop with Withdraw Ends	23 Add period begins	24 AM/PM Desk Crits	25	26	27
WK13	28 AM/PM Desk Crits	29	30	01 DECEMBER AM/PM Desk Crits	02	03	04
	05 AM/PM FINAL STUDIO DAY Optional Desk Crits	06 Classes End	07 Scheduled Pause (no class)	08 Scheduled Pause (no class)	09 Exams begin	10	11 393 plotting submission deadline 11PM
	12	13 FINAL REVIEW 3B Studios P3 Due Tuition Due	14	15	16	17	18
	19	20	21	22	23 Exams End Last day of Co-op	24 University Closed	25

## 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. Note that the course also has a participation grade that is assigned to each individual student based on class engagement.

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

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.

## Fair Contingencies for Emergency Remote Teaching

To provide contingency for unforeseen circumstances, the instructor reserves the right to modify course topics and/or assessments and/or weight and/or deadlines with due and fair notice to students. In the event of such challenges, the instructor will work with the Department/Faculty to find reasonable and fair solutions that respect rights and workloads of students, staff, and faculty.

## Course Delivery Platforms & Communication

The course will take place in-person but 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:

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

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. Reviews with international external experts will use this platform

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

## CACB Student Performance Criteria

The BAS/MArch program enables students to achieve the accreditation standards set by the Canadian Architectural Certification Board as described [here](#). This course addresses the CACB criteria and standards that are noted on the Accreditation page of the School of Architecture [website](#).

## 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](mailto: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.