

**HCOL 185 M**  
**Fall 2015**  
*Imitating Nature*

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**Office hours:** Monday 1:30-3:00 PM  
Thursday 8:30-9:45 AM  
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## **COURSE OVERVIEW**

Since times immemorial, humans have been fascinated with the natural world, so much so that we have continuously sought ways to imitate Nature in search of solutions to our daily challenges and to expand the realm of human activities. Many ascribe the original notion that “technology imitates nature” to Aristotle, who defined *mimesis* as the perfection and imitation of nature. Nature’s fascinating designs and elaborate strategies for problem solving are the product of 3.8 billion years of experimentation, the process of organic evolution, *sensu stricto*. While the concept of imitating Nature has been around for millennia, its pursuit as a scientific discipline dates back to the 1950’s when the term *biomimetics* was coined to describe the transfer of ideas from biology to technology. The 1990’s witnessed the birth of *biomimicry*, a new science that studies Nature’s models and then imitates or takes inspiration from these designs and processes to solve human problems. But the goal of *biomimicry* is not simply to rob Nature of its secrets for human’s technological prowess. *Biomimicry* also aims to instill among its practitioners a sense of awe and respect for Nature; that Nature’s best ideas are only there for the taking if we protect and preserve our natural surroundings. Truly innovative bio-inspired solutions should transform human lives while also creating a more sustainable world. In this course, students will become familiar with the discovery, scientific, and technological processes that turn a Nature-inspired idea into an invention, whether it is an intellectual concept, a process, a material, or a device.

## **LEARNING GOALS**

Upon completion of the course, you will be able to:

1. Be conversant in *biomimetics* and *biomimicry*, including their foundational and conceptual bases.
2. Learn how to search the scientific and engineering literature and how to critically analyze and interpret journal articles on biomimetics.
3. Provide examples of bio-inspired human inventions that improve standard of living and influence human health and society well-being.
4. Examine a biological system and understand how ideas and concepts derived from nature are turned into practical applications.
5. Learn to effectively organize an interdisciplinary group effort that involves the development of an idea, integration of information, creative thinking, and delegation of responsibilities towards a common goal.
6. Become an effective problem solver through critical thinking and team work.
7. Competently communicate, orally and in writing, the development and practical application of a novel biomimetic.
8. Learn to critically evaluate and provide constructive criticism to the work of others.

## **COURSE REQUIREMENTS**

*Access to an electronic device (laptop, ipad or smart phone) is recommended. Their usage in class will be solely for the purpose of researching a class-related topic. This policy will be strictly enforced.*

**Attendance.** Attendance and class participation is mandatory. Fifty percent of your grade will be based on attendance and participation. Only documented excuses for absence will be accepted. It is the responsibility of the student to inform Professor Vigoreaux by email prior to the start of the class if he/she will be absent. Acceptable excuses are sickness, participation in intercollegiate athletics or research-related activities, observation of religious holiday, and family emergency. Professor Vigoreaux reserves the right to request verifiable documentation of your absence. The third unexcused absence will result in a 5% deduction of your total grade. Each additional unexcused absence will incur a 5% deduction of the total grade.

Students who are participating in intercollegiate athletics or research-related activities are expected to provide a two week notice of the absence. You are responsible for making up the missed coursework and are expected to adhere to the established due dates for assignments.

**Class Format.** This course is not structured as a traditional lecture. While there will be a handful of presentations by the instructor, most meeting times will be dedicated to group activities centered on a group project. Preparation and participation are important for a successful learning experience. You are expected to show up on time and well prepared to contribute to your group discussion and to offer feedback to other groups. Students are expected to treat fellow students with respect and provide courteous attention to the comments made by all participants.

**Readings.** There is no assigned textbook. The instructor and the students will assign a few mandatory journal readings. You are expected to create your own reading list, on your topic of choice, of at least ten sources that you have studied and that will also serve as references for your final report. A list of readings is provided at the end of this document to introduce you to the concepts of nature observation and bio-inspired innovations. It is by no means a comprehensive or a mandatory reading list.

**Writing.** There are four writing assignments related to the major class project, a White Paper describing a novel bio-inspired invention. All assignments are group assignments that include a description of each member's contribution. The class schedule indicates the due date for each writing component. In addition, each group is responsible for writing a 200-500 summary of a research paper discussion. Assignments turned in one day after the due date will be automatically deducted 5% points and an additional 5% points for each late day thereafter, up to five days. Assignments that are more than five days overdue will not be accepted. In addition, each group will keep a detailed log of their discussions.

**Evaluations.** This is a peer-reviewed class. All students will participate in the evaluation of other students through anonymous questionnaires. The evaluation and feedback you provide to other students will in turn be part of your evaluation. While all of the "assignments" will be group projects, you will be graded by your individual effort and not all members of the one group may receive the same grade. The instructor will evaluate your group and class participation.

**Communication.** All communication with the instructor will take place through @uvm.edu email. When sending an email to the instructor, please include reference to this course on the subject line. My name is

Jim Vigoreaux and I prefer not to be greeted by 'Hey' or 'Howdy' but by Jim Vigoreaux, Professor, Dr. Vigoreaux, or Professor Vigoreaux.

**Academic Integrity.** All students must abide by the Code of Academic Integrity (<http://www.uvm.edu/policies/student/acadintegrity.pdf>). Any violation of this policy will result in immediate disciplinary action.

**Support Services.** There are a variety of services available (ACCESS, Learning Co-op, Writing Center) to help with any number of difficulties. For more information see:

- Academic Support Programs <http://www.uvm.edu/aspprogs>
- Writing Center <http://www.uvm.edu/wid/writingcenter/>
- Library <http://library.uvm.edu/specialists/>

### GRADING

Each of the following components will contribute to your overall grade of 300 points. Note that 50% of your grade will be based on in-class activities (participation, evaluations, presentations) while the other 50% will be based on the writing project.

<u>Class activities</u>	
Participation & Feedback forms	15%
Group contributions	10%
Presentations	15%
Evaluations	5%
Discussion log	5%
<u>White Paper</u>	
Ideas/Topic/Outline	5%
Draft 1	10%
News Release	15%
Final	20%

The final grade will be determined as follows:

98% and up	A+	78% to 80.9%	B-	61% to 65.9%	D
91% to 97.9%	A	76% to 77.9%	C+	56% to 60.9%	D-
88% to 90.9%	A-	71% to 75.9%	C	55.9% or less	F
86% to 87.9%	B+	68% to 70.9%	C-		
81% to 85.9%	B	66% to 67.9%	D+		

**Participation grade.** Professor Vigoreaux will keep track of attendance, tardiness, meeting assigned deadlines, group obligations, overall effort, and interest in class activities.

Participation Rubric	
<b>A</b>	Attends 90% of the classes or better, never late, meets all deadlines, participates in most class discussions, group leader, organized presentations, provides constructive feedback
<b>B</b>	Attends 85% of the classes or better, rarely late, meets most deadlines, participates in class discussions more often than not, active group participant, contributes to presentations, provides constructive feedback regularly
<b>C</b>	Attends less than 85% of classes, sometimes late, meets most deadlines, periodically participates in class discussions, average group participant, some contribution to presentations, provides constructive feedback irregularly
<b>D</b>	Attends less than 80% of classes, often late, meets less than half of deadlines, minimal participation in class discussions, minimal group participation, minimal contribution to presentations, rarely provides constructive feedback
<b>F</b>	Attends less than 75% of classes, often late, misses most deadlines, minimal to no participation in class discussions, minimal to no group participation, minimal to contribution to presentations, provides no constructive feedback

## TENTATIVE SCHEDULE

Date	Class Activity	Due
Sept 1	*Introductions and Overview	
Sept 3	*Imitating Nature 1.0	^Lepora <i>et al.</i> "State of the art in biomimetics"
Sept 8	Working groups: planning 1 – ideas	
Sept 10	*How to think like Leonardo da Vinci	^Heinrich "Nature is the foundation of wonder"
Sept 15	*How to write a White Paper	
Sept 17	Visit to Bailey-Howe	#Preliminary ideas for Group Project
Sept 22	Working groups: planning 2	#Discussion log (DL1)
Sept 24	Working groups: informal group presentations	#Feedback form 1
Sept 29	*Research paper: class discussion	^Guerrete <i>et al</i> (2013) and ^"How to read and understand a scientific paper"
Oct 1	Working groups	#Project outline and three or more references; identify experts
Oct 6	Class presentation: Groups 1, 2, 3	#In class evaluation A: Groups 4, 5, 6
Oct 8	Class presentation: Groups 4, 5, 6	#In class evaluation A: Groups 1, 2, 3
Oct 13	Working groups	#DL2; Consult the experts
Oct 15	Working groups	#DL3; Provide research paper to class
Oct 20	Working groups	#White paper draft 1
Oct 22	^Research paper: class discussion (Group 4)	##Group 1 research paper write up
Oct 27	^Research paper: class discussion (Group 5)	##Group 2 research paper write up
Oct 29	^Research paper: class discussion (Group 6)	##Group 3 research paper write up
Nov 3	^Research paper: class discussion (Group 1)	##Group 4 research paper write up
Nov 5	^Research paper: class discussion (Group 2)	##Group 5 research paper write up
Nov 10	^Research paper: class discussion (Group 3)	##Group 6 research paper write up
Nov 12	*News release overview Working groups	DL4#
Nov 17	Group-to-Group vetting (1&4; 2&5; 3&6)	#Feedback form 2
Nov 19	Working groups	500-1000 word news release due
Nov 24	Thanksgiving Recess	
Nov 26	Thanksgiving Recess	
Dec 1	Working groups	HCOL course evaluation – first 15 min
Dec 3	Class presentations: Groups 1, 2, 3	#In class evaluation B: Groups 3, 4, 5
Dec 8	Class presentations: Groups 4, 5, 6	#In class evaluation B: Groups 1, 2, 3
<b>Dec 15</b>		<b>Final White Paper due by 10:00AM</b>
	*Presentations by Dr. Vigoreaux	#due by the end of the day (midnight) ##due by the end of the day (midnight) of the next class period
		^ read before class

## SOURCES OF INSPIRATION

### Websites

1. *Bioinspiration and Biomimetics* (journal): <http://iopscience.iop.org/1748-3190/>
2. *Biomaterials* (journal): <http://www.journals.elsevier.com/biomaterials/>
3. *California Institute of Technology's Center for Bioinspired Engineering*:  
<http://bioinspired.caltech.edu/>
4. *National Academy of Inventors*:  
[www.academyofinventors.org](http://www.academyofinventors.org)
5. *Bioinspiration and Robotics*:  
[http://www.intechopen.com/books/bioinspiration\\_and\\_robotics\\_walking\\_and\\_climbing\\_robots](http://www.intechopen.com/books/bioinspiration_and_robotics_walking_and_climbing_robots)
6. *Biomimicry 3.8*:  
<http://biomimicry.net/>
7. *Wyss Institute for Biologically Inspired Engineering*: <http://wyss.harvard.edu>
8. *TED Talks*: <http://www.ted.com/topics/biomimicry>
9. *Best inventions using Biomimicry*:  
<http://www.treehugger.com/clean-technology/14-best-inventions-using-biomimicry-2011.html>
10. *Biomimetic Millisystems Lab*: <http://robotics.eecs.berkeley.edu/~ronf/Biomimetics.html>
11. *The Critical Thinking Community*: [www.criticalthinking.org](http://www.criticalthinking.org)

### Research Articles

1. Lepora NF *et al* (2013) *The state of the art in biomimetics*. **Bioinspir. Biomim.** 8: doi:10.1088/1748-3182/8/1/013001
2. Vincent JFV *et al* (2006) *Biomimetics: its practice and theory*. **J. R. Soc. Interface** 3: 471.
3. Flammang BE and Porter ME (2011) *Bioinspiration: Applying mechanical design to experimental biology*. **Integrative Comp Biol** 51: 128.
4. Ma KY *et al* (2013) *Controlled flight of a biologically inspired, insect-scale robot*. **Science** 340: 603.
5. Garnier S *et al* (2013) *Do ants need to estimate the geometrical properties of trail bifurcations to find an effective route? A swarm robotics test bed*. **PLOS Computational Biology** 9: e1002903.
6. Holbrook CT *et al* (2010) *Social insects inspire human design*. **Biol. Lett.** 6:431.
7. Lv S *et al* (2010) *Designed biomaterials to mimic the mechanical properties of muscle*. **Nature** 465: 69.
8. Liu K *et al* (2013) *Powerful, multifunctional torsional micromuscles activated by phase transition*. **Adv. Mater.** DOI: 10.1002/adma.201304064.
9. Nawroth JC *et al* (2012) *A tissue-engineered jellyfish with biomimetic propulsion*. **Nature** 30: 792.
10. Lapidot S *et al* (2012) *Clues for biomimetics from natural composite materials*. **Nanomedicine** 7:1409.
11. Szyndler MW *et al* (2013) *Entrapment of bed bugs by leaf trichomes inspires microfabrication of biomimetic surfaces*. **J.R.Soc. Interface** 10: 20130174.
12. Lentink D and Biewener AA (2010) *Nature-inspired flight – beyond the lead*. **Bioinspir. Biomim** 5: doi:10.1088/1748-3182/5/4/040201 [this is an editorial reviewing the content of the entire issue dedicated to the topic of nature-inspired flight].
13. **Nature** 519 (26 March 2015). Outlook section on Biomaterials.  
[http://www.nature.com/nature/journal/v519/n7544\\_suppl/full/519S1a.html](http://www.nature.com/nature/journal/v519/n7544_suppl/full/519S1a.html)

### Books

#### General Reference

1. Benyus, J. *Biomimicry*. William Morrow and Company, 1997; 308pp.
2. Lakhata A and Martin-Palma RJ. *Engineered Biomimicry*. Elsevier, 2013; 496 pp.
3. Kumar, C. *Biomimetic and Bioinspired Nanomaterials*. Wiley-VCH Verlag GmbH & Co, 2010; 564 pp.
4. Mazzoleni, I. *Architecture Follows Nature: Biomimetic principles for innovative design*. CRC Press, Taylor & Francis Group, LLC, 2013; 242 pp.
5. Harman, J. *The Shark's Paintbrush: Biomimicry and how nature is inspiring innovation*.
6. *Functional Properties of Bio-Inspired Surfaces*. Favret EA and Fuentes NO, editors. World Scientific Publishing Company. 2009. 416pp.
7. *Handbook of Biomimetics and Bioinspiration: Biologically-driven engineering of materials, processes, devices, and systems*. Jabbari E, Kim DH, Lee LP, Ghaemmaghami A, Khademhosseini A, Editors. World Scientific Series in Nanoscience and Nanotechnology: Volume 9. 2014. 1380 pp.
8. Capra, F. *The Science of Leonardo*. Doubleday, 2007. 329 pp.

#### Observing nature with fervor

9. Heinrich, B. *The trees in my forest*. HarperCollins Publishers, 1997. 237pp. (Many other Heinrich books are also excellent sources: *Bumblebee economics*, *Winter World*, *Ravens in Winter*).
10. Worster, D. *A passion for nature: The life of John Muir*. Oxford University press, 2008. 544 pp.
11. Thoreau, HD. *Walden, or Life in the woods*. Ticknor and Fields, 1854.
12. Darwin, C. *On the origin of species*. 1859.
13. Wilson, Edward O. *The diversity of life*. W.W. Norton and Company, 1992.