



**California College of the Arts**

Course of Study

**Applied Biology for Designers and Artists**

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# Applied Biology for Designers and Artists

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### Contents

- I. Course description
  - II. Course objectives
  - III. Course requirements
  - IV. Research project
  - V. Course outline
  - VI. Recommended readings
- 

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### I. COURSE DESCRIPTION

This course introduces students to the basic concepts of biological design. The course teaches basic biological concepts from the molecular to organismal to ecological levels. The information provided will be analyzed in the context of students' interest in creating products and aesthetic expressions. Early on in the course we are going to introduce 10 basic biological design principles that we ask students to reference as we discuss biological processes. Furthermore the course will introduce the students to the current examples of biomimetic design, the various stages of biomimetic design and its importance for the development of sustainable products. Throughout the course we are going to emphasize a systems approach that will enable students to analyze more complex processes in nature and to incorporate systems thinking into their design activities.

### II. COURSE OBJECTIVES

Upon the successful completion of the course the students will have developed the following skills and obtained several basic concepts of biological design:

1. An understanding of the biological design principles and their possible applications.
2. The ability to communicate with a biologist on a basic level.
3. Familiarity with biological terminology.
4. Read and understand a popular but technical treatise on a biological topic.
5. Distinguish among various levels of biological design applications.
6. Understanding of how humans and their activity fit into life's web on our planet.
7. Awareness of the consequences of our society on the health of the planet.

### III. COURSE REQUIREMENTS

- A. Students will be required to read chapters in the assigned textbook or related readings and submit a one page write-up with questions and comments.
- B. There will be mid-term and final exams.
- C. Students will present a 10 - 15 min long summary of the natural history of an organism, the characteristics of a habitat or a scientific articles.  
The students can either pick from a list of suggestions or chose their own related topic.
- D. Students will keep a "Design Journal" with sketches, reflections and ideas of biomimetic design solutions.

### IV. RESEARCH PROJECT

The students will research and present:

- A. A summary of a book chapter or article, or present "The life-history of an organism" or "a habitat".

B. A "Design Journal" to document their reflections and sketches of ideas, in a format of their choice.

## V. COURSE OUTLINE

Lessons are structured into three parts:

- (A) A unit in which we recapitulate the content of the assigned textbook chapter for the week.
- (B) A unit in which we connect the biological knowledge from the text with design solutions that were inspired by nature.
- (C) A unit in which students "take ownership" of the content by presenting a book chapter or a popular science paper.

Alternatively they can present the life history of an organism or a habitat. The topics suggested here are only meant to help. Students are going to be free to choose their own topic after discussing their choice with the instructor.

Week 1: A. Define the interface between biology and design and the potential implication of nature-inspired design.

GOAL: Students recognize the importance of biology for sustainable design solutions.

- 1. Introduction to the course - course objectives
  - a. Introductions of students and instructors
  - b. Introduction of the course, the syllabus and the recommended readings
  - c. Explanation of methods of evaluation
  - d. Choice of student presentations
- 2. Examples of biomimicry
- 3. Introduction of biological design principles
  - B. Video clips from Biomimicry Special followed by discussion.

Week 2: A. Earth as a system & a systems approach to understanding the flow of materials & energy.

GOAL: Students become familiar with a systems view of the world that is defined by material cycles and the flow of energy.

- 1. Earth as a system
- 2. Material cycles
- 3. Energy flows
  - B. Material properties and structures for biomimetic design solutions
- 1. Hierarchical structure of biological material
- 2. Insect cuticles
- 3. Shells and their formation - biomineralization
- 4. Spider silk
- 5. Byssal threads
- C. Presentation of artifacts

ACTIVITY: Students are going to brainstorm about a biological artifact that they found in their environment or that we are going to provide to them.

Week 3: A. The human impact in the context of the web of life.

GOAL: Students see human society and its material flow and energy consumption as part of the web of life.

- 1. Life's web and the dynamic of ecosystems.
- 2. Feedback loops.
- 3. Material and energy flow in ecosystems
- 4. Top-down and bottom-up regulation
- 5. Creating diversity: Intermediate disturbance hypothesis
- 6. The human impact on ecosystems
  - a. Habitat fragmentation
  - b. Habitat destruction
  - c. Pollution
  - d. Excessive harvesting
  - e. Invasive species
  - f. Climate change
  - g. Decline of biodiversity

## B. Materials and their life-cycle

1. Bio-Plastik
2. Cellulose
3. Woods and grasses
4. Glues

## C. Material and energy flow - case studies.

Student presentations (topic - resources):

1. Natural systems agriculture - chapter 2 in "Biomimicry" by Janine Benyus plus video
2. "Interface, Inc." - a case study of a sustainable company in a book chapter by Ray Anderson
3. "A watershed" - a case study of the service of nature to access clean drinking water in a book chapter by Gretchen Daily And Katherine Allison

Week 4: A. The "unity in diversity" theme of biological design.

GOAL: Students see the general patterns of how life is designed.

1. The building blocks of life.
2. The transmission of information
3. Conditions conducive to life
4. The flow of energy
5. Competition and cooperation

## B. Form and function

1. Adhesion
2. Shock absorption
3. Stability of spheres
4. Abrasion devices
5. Fluid- and aero-dynamics
6. Surfaces - the Lotus-effect
7. Packaging

## C. Student presentations and discussions:

1. "Extremophiles" - selected chapters out of "Life on the Edge" by Michael Gross
2. "Living Machines" - selected chapters out of "From Eco-Cities to Living Machines" by Nancy Jack Todd and John Todd

Week 5: A. Biological units of energy, how they are produced and energy efficiency.

GOAL: Students understand the basic concept of energy production and consumption in organisms.

1. Chemical bonds as energy
2. Photosynthesis
3. Respiration
4. The flow of energy in ecosystems

## B. Solar technology

1. Butterfly wings and thermoregulation
2. Biogene photovoltaic processes
3. Hydration via thermal condensation

## C. Student presentations and discussions:

1. "Endothermic fish" - thermoregulation in tuna and other large pelagic fish provides a good example of energy conservation (selected material from "Animal Physiology" textbooks)
2. "Plant metabolism" - to conserve water and produce building material plants have developed strategies that provide an example for energy efficiency (chapter from "Biology" by Neil Campbell and Jane Reece)
3. "Energy production under oxygen limitations" - organisms have adapted to low oxygen conditions and provide a good example of efficient energy production under extreme conditions (chapter from "Animal Physiology" by Richard Hill et al.)
4. "Photosynthesis" chapter in "Biomimicry" and in "Biology"

Week 6: A. The coding and decoding of biological information.

GOAL: Students understand the basic concept of biological information and its role in life.

1. DNA and the coding of information
2. The concept of the gene

3. The decoding machinery - the making of proteins.
4. An excursion into the concepts of science: the different kinds of reductionism
  - B. Sensors and information networks
    1. Eyes of flies and spiders
    2. Thermal sensor in Melanophila beetles
  3. Neural networks and their regulation
    - C. Student presentations and discussions:
      1. "The meanings of genes" - selected chapter from "The century of the gene" by Evelyn Fox Keller.
      2. "The meanings of memes" - selected chapter from "The meme machine" by Susan Blackmore
      3. "Insect and crabs eyes" - selected chapter from "Animal Physiology" by Richard Hill et al.

Week 7: Field trip to the Californian Academy of Science

GOAL: Meeting with a naturalist. Have someone tell us about the new green design of the California Academy of Science.

Week 8: A. Biological feedback loops

GOAL: Students understand the basic concept of feedback loops and regulatory processes in biological systems.

1. Regulation of transcription
2. Regulation of protein function
3. Ecological food webs and their feedback loops
4. Regulation of ecosystems

DESIGN APPLICATION: Analogy between human communities and businesses and ecosystems.

B. Locomotion and energy efficiency

1. Walking and swimming robots
2. Reduction of drag
3. Shark skin
4. Flight

C. Student presentations and discussions

1. "Your organism" - a students selection of an organism and its natural history
2. "Your habitat" - a students selection of a habitat and its natural history
3. "Ecological architecture"

Week 9: A. The cellular machinery

GOAL: Students understand the basic concept of cellular processes.

1. Proteins and their catalytic function
2. The control of protein function
3. "Unity AND diversity" work together to adapt organisms to their environment

B. Proteins' role in biomimetic design solutions

1. Keratin

C. Student presentations and discussions:

1. "Your organism" - a students selection of an organism and its natural history
2. "Your habitat" - a students selection of a habitat and its natural history

Week 10: A. The scale and organization of biological systems.

GOAL: Students understand that the interaction between parts can create properties that are complex and represent more than the sum of its parts.

1. Emergent properties
2. Cooperation from cells to organisms
3. Chemical gradients as information for cooperation
4. Symbiotic relationships

C. Sketching of biological structure

Student presentation and discussions:

1. "Charles Darwin and Alfred Wallace" - chapter from "Darwin" by Jonathan Hodge and Gregory Radick
2. "The story of Barbara McClintock" - chapters from "A feeling for the organism" by Evelyn Fox Keller
3. "Learning to see nature as a naturalist" - selected chapter from "Naturalist" by Edward O. Wilson

Week 11: A & B. A naturalist perspective on biodiversity.  
Form to function - material properties and mechanical design in nature.  
An introduction in "keying out" plants and animals -

C. Student presentations and discussions:

4. "Your organism" - a student's selection of an organism and its natural history
5. "Your habitat" - a student's selection of a habitat and its natural history

Week 12: A. The evolutionary process I

GOAL: Understand the basic concept of natural selection and how it contributed to the evolution of life.

1. A brief history of life
2. The sources of variation
3. Natural selection
  - B. PBS series on "Evolution" - discussion.
  - C. Student presentations:
1. "Human evolutionary history" - selected chapter from "Becoming human" by Ian Tattersall.

Week 13: The evolutionary process II

GOAL: Students deepen their understanding of the evolutionary process and its importance for assessing the role of humans in life.

1. Co-evolution
2. Nature versus nurture
3. Human evolution
4. The basic concepts of evolutionary epistemology
  - B. The incorporation of the evolutionary process into the design process.
  - C. Student presentations:

Open slots - up for suggestions.

Week 14: A. Final

B. What is biomimicry? A critique of the class and the promise of biological design.

## VI. TEXT AND RECOMMENDED READINGS

Hoagland, Mahlon and Bert Dodson (1998): *The Way Life Works*. Three Rivers Press, New York. A fun introduction into biology - seven informative and illustrated chapters.

Sussman, Art (2000): *Dr. Art's Guide to Planet Earth*. Chelsea Green, San Francisco. - A short introduction into Earth as a system - easy read.

Benyus, Janine M. (1997): *Biomimicry: Innovation Inspired by Nature*. Perennial, New York.

Recommended additional readings (selected chapters):

Campbell, Neil A. and Jane B. Reece (2002): *Biology*. Benjamin Cummings, San Francisco, 6th edition.

Gross, Michael (1996): *Life on the Edge. Amazing Creatures Thriving in Extreme Environments*. Plenum Trade, New York.

Hill, Richard W., Gordon A. Wyse and Margaret Anderson (2004). *Animal Physiology*. Sinauer Associates, Sunderland.

Keller, Evelyn F. (1983): *A Feeling for the Organism: The Life and Work of Barbara McClintock*. Freeman, New York.

Keller, Evelyn F. (2000): *The Century of the Gene*. Harvard University Press, Cambridge.

Waage, Sissel (2003): *Ants, Galileo, and Gandhi. Designing the Future of Business through Nature, Genius, and Compassion*. Greenleaf, Sheffield, United Kingdom.

Recommended periodicals:

Science News  
New Scientist  
Natural History

Recommended websites:

[www.planetguide.net](http://www.planetguide.net)