# General Education Course Information Sheet

***Please submit this sheet for each proposed course***

*Department & Course Number* **EE BIOL 20**

*Course Title* ***Self-Organization & Emergence in Biology: A Complex Adaptive Systems Approach***

*Indicate if Seminar and/or Writing II course* ____

1 Check the recommended GE foundation area(s) and subgroups(s) for this course

**Foundations of the Arts and Humanities**
- Literary and Cultural Analysis ____
- Philosophic and Linguistic Analysis ____
- Visual and Performance Arts Analysis and Practice ____

**Foundations of Society and Culture**
- Historical Analysis ____
- Social Analysis ____

**Foundations of Scientific Inquiry**
- Physical Science ____
  *With Laboratory or Demonstration Component must be 5 units (or more)* ____
- **Life Science** **x**
  ***With Laboratory or Demonstration Component must be 5 units (or more)*** **x**

2. Briefly describe the rationale for assignment to foundation area(s) and subgroup(s) chosen.

The course views aspects of the origin of life, evolution, cellular processes, organismic biology, ecology, and epidemiology as self-organizing, emergent phenomena -- as complex adaptive systems.

Students attend one two-hour computer-lab each week in which they encounter key simulation-models (no programming required) in these aspects of biological complex adaptive systems.

3. "List faculty member(s) who will serve as instructor (give academic rank):
John Bragin, Lecturer

Do you intend to use graduate student instructors (TAs) in this course? Yes x No ____

If yes, please indicate the number of TAs 1 or more

4. Indicate when do you anticipate teaching this course over the next three years:

| | | | | | | |
|---|---|---|---|---|---|---|
| 2013-2014 | Fall | | Winter | x | Spring | |
| | Enrollment | | Enrollment | 75 | Enrollment | |
| 2014-2015 | Fall | | Winter | x | Spring | |
| | Enrollment | | Enrollment | ? | Enrollment | |
| 2015-2016 | Fall | | Winter | x | Spring | |
| | Enrollment | | Enrollment | ? | Enrollment | |

5. GE Course Units

Is this an ***existing*** course that has been modified for inclusion in the new GE? Yes ____ No x

If yes, provide a brief explanation of what has changed. ____

6. Please present concise arguments for the GE principles applicable to this course.

| | |
|---|---|
| ❑ General Knowledge | First, the course focuses on the complex adaptive systems approach to the subjects of evolution, the origin of life, cellular processes, organismal biology, ecology, and epidemiology. Secondly, students are introduced to the general principles and methods of the new sciences of complexity: a field that is seeking general concepts and methods applicable to a wide range of phenomena across the physio-chemical, biological and human social domains. Thirdly, students gain hands-on experience (in computer labs) with already-existing key simulation models (no programming required) of biological phenomena from the subjects mentioned above. |
| ❑ Integrative Learning | Complex systems science is the interdisciplinary activity *par excellence*. It is both a theoretical and applied discipline that seeks to improve the conditions of human and non-human beings, and to bridge the gaps across the natural sciences (including engineering and the health sciences), the social sciences (including public affairs and management), the arts, and the humanities. This class, of course, centers on biology, but certain topics include human-nonhuman interactions and interactions of organic beings with the physio-chemical environment. |
| ❑ Ethical Implications | Complex systems scientists consider that the use of traditional scientific thinking (linear, equilibrium, normal distributions, etc) is a mistake and has led humans to make terrible errors in the mismanagement and destruction of non-human biology and geobiology of the planet. The new sciences of complexity are *not* perfect or “true” theories or ultimate answers, but (at present) it seems to me (and others) that ethical considerations demand that they be taught and used as the best available concepts and methods. In addition to traditional ideas of ethics as fairness, balance and equity, this is the view of ethics to be taken in this course. |
| ❑ Cultural Diversity | Complex systems science emphasizes the spatial and temporal context of systems under study. Some units of the course deal with the interactions of humans with the non-human biological sphere, such as the areas of conservation, environmental and epidemiological science. Due attention will be paid to the ways in which cultural diversity impacts these interactions. This is also true of the ways in which scientists present and discuss their methods and results. |
| ❑ Critical Thinking | This course emphasizes critical thinking over and over. It particularly demands that students do not take traditional methods (such as normal distributions, linear equations, equilibrium assumptions) as fundamental, but aims to show (at an introductory level) how a different way of thinking is necessary to meet real world phenomena. |
| ❑ Rhetorical Effectiveness | The presentation of scientific findings and the ways in which complexity scientists discuss their methods and results is of particular importance in the area of complex systems science, especially because it is a very new discipline, barely 30 years old, which often challenges the received concepts and methods of biological thinking. |
| ❑ Problem-solving | The problem-solving approaches of complex systems science include the traditional methods students will have encountered in high school and other UCLA science courses, but complex systems science brings a whole new set of concepts and methods to bear that students need to confront and understand. This course will slowly and methodically present these, particularly at the beginning, before applications are presented. |

| | |
|---|---|
| ❑ Library & Information Literacy | I *always* ask my students never to go beyond a word whose meaning they are not absolutely sure they understand. I also ask them to understand the meaning of the word 'meaning', and what a dictionary tells us. I recommend use of the on-line OED, since we can get it via a VPN. I emphasize how many words we use whose meaning we really don't clearly understand.<br>The three-pass approach for study is recommended in this course: First time over the material, read (listen or view) without stopping to worry about understanding individual words/phrases, just get an idea of the overall gist of the piece. Second time, study carefully and do not go by anything that is not fully understood: take notes, underline, look-up words, etc. Third time, go over fairly briskly to take in the whole again as a whole. Sometimes, if the piece is long or complicated, it may be necessary to use a four-pass approach and do the second step twice.<br>I've written a "Guide to Good Studying" which I make available to students on the course website.<br>There will be no assignments requiring student use of the library or on-line research. |

**(A) STUDENT CONTACT PER WEEK (if not applicable write N/A)**

| | | | |
|---|---|---|---|
| 1. | Lecture: | **4** | (hours) |
| 2. | Discussion Section: | **n/a** | (hours) |
| 3. | Labs: | **2** | (hours) |
| 4. | Experiential (service learning, internships, other): | **n/a** | (hours) |
| 5. | Field Trips: | **n/a** | (hours) |

**(A) TOTAL Student Contact Per Week** — **6** **(HOURS)**

**(B) OUT-OF-CLASS HOURS PER WEEK (if not applicable write N/A)**

| | | | |
|---|---|---|---|
| 1. | General Review & Preparation: | **2** | (hours) |
| 2. | Reading | **5** | (hours) |
| 3. | Group Projects: | **n/a** | (hours) |
| 4. | Preparation for Quizzes & Exams: | **2** | (hours) |
| 5. | Information Literacy Exercises: | **n/a** | (hours) |
| 6. | Written Assignments: | **n/a** | (hours) |
| 7. | Research Activity: | **n/a** | (hours) |

**(B) TOTAL Out-of-class time per week** — **9** **(HOURS)**

**GRAND TOTAL (A) + (B) must equal at least 15 hours/week** — **15** **(HOURS)**

Title:

*Self-Organization & Emergence in Biology: A Complex Adaptive Systems Approach*
Short Title: Self-Org in Bio Sys

Course Description:

In this course students discover how the exciting new sciences of complexity (which are thoroughly explained in the course) address cutting-edge research and practical applications in multi-disciplinary approaches to biological systems. Such system-processes range from the machinery of the cell through trans-national epidemics to global climate change. Complex Systems Science seeks to bridge the gaps among the Social Sciences, Natural Sciences, Applied Sciences (including Public Affairs, Engineering, Management & Health Sciences), and the Humanities, in order to better conditions for humans and non-humans alike. In lab sections students explore existing computer simulations (similar to video games), experimenting on "what-if" worlds to determine the outcomes of non-linear, chaotic, complex and far-from-equilibrium processes in cellular, organismal, ecological and evolutionary biology. No previous math, science or computer knowledge is required beyond that necessary to enter UCLA as a Freshman.

Justification:

The complexity approach to biology (particularly the use of agent-based simulation modeling and dynamic network analysis) is rapidly becoming central to research and policy analysis in the life sciences. Although various aspects of complexity biology have been taught in courses at UCLA when the IDP in Human Complex Systems was in existence between Fall 2005 and December 2011, no course in Biological Complex Adaptive Systems has ever existed here. It is time for such a course. And it is time for such a course at the General Education level, because, as Stephen Hawking said, complexity sciences will be the sciences of the 21st century. The concepts, methods and applications of complex systems science will soon become a fundamental approach to the life and social sciences.

Structure:

*Self-Organization and Emergence in Biology: A Complex Systems Approach* is a five-unit "General Education, Life Science Course in the Foundations of Scientific Inquiry, With a Laboratory". In this course students will learn how the new sciences of complexity address theoretical and applied questions in the origin of life, its evolution, and in biological ecology. The lecture portion will meet four hours per week and the lab section will meet two hours per week. The enrollment for the first edition of the course in Winter 2014 will be set at 75 students, and one TA will be required. Foundation concepts are non-linear, far-from-equilibrium, complex adaptive systems, addressed by such methods as dynamic complex networks and agent-based simulation models, applied to such problems as mass extinctions, speciation events, food webs and animal social networks, flocking and schooling, foraging, predation, pattern formation, and critical transitions in ecological systems. In the laboratory sections students will explore existing computer simulation models through manipulation of input parameters and variables on graphical user interfaces to create “what if” worlds to determine the outcomes of various groups of inputs. This is of both theoretical interest and of applied (policy) interest, given current conservation and environmental efforts in many areas of biology and ecology. Students will also gain very basic programming skills using the free software applications available to them.

Foundations of Scientific Inquiry, Life Sciences, with Laboratory, 5 Units.
2014 Winter: Tu and Th: 10am to 11:50am, Room TBA.

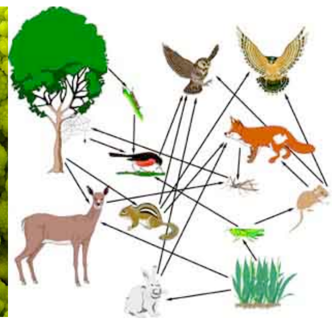
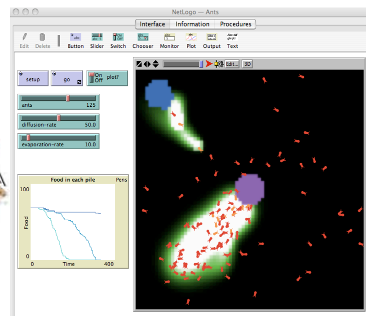
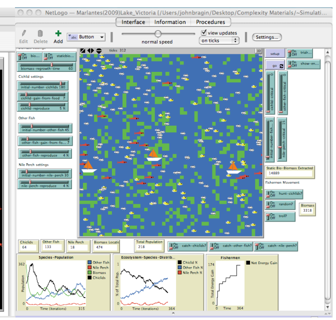
Draft Syllabus: June 16, 2013

**EE BIOL 20**

# *Self-Organization & Emergence in Biology: A Complex Adaptive Systems Approach*

(Short Title: Self-Org in Bio Sys)

**Instructor**: John Bragin, jbragin@ucla.edu
**Course Website URL**: TBA

The new sciences of complexity are applied to problems in the ***origin of life***, its ***evolution***, and ***biological ecology***. ***Complex systems scientists*** explore how ***self-organized*** collective order arises dynamically from the individual, local interactions of numerous interdependent (often heterogeneous) entities, without overall design or central control. Such ***emergent order*** (where the qualities, patterns and processes of each emergent level are different from and not reducible to those of more basic levels) is ubiquitous in biology: from the machinery of the cell to entire ecosystems. Complexity science deals as well with how such systems undergo sudden changes, including catastrophic breakdowns such as mass extinctions, also in the absence of external or central forces. Biological organisms and collectives are by nature ***complex adaptive systems*** where individuals and groups adjust their behavior (through learning and evolution) to the environment (including other individuals and groups). In turn they transform their environment. And then behave under the constraints and opportunities of these global transformations. For these biological systems, complexity scientists extend traditional mathematical and statistical methods with the use of ***agent-based models***. These computer simulations of the behavior of moderate to large numbers of ***networked***, heterogeneous individuals provide generative, evolutionary explanations for the emergent patterns and processes of complex, adaptive and self-organizing biological phenomena.

*Complex systems science* is both a theoretical and applied science: Its practitioners seek to observe, describe, analyze, explain and intervene in the natural and social worlds in order to understand and better the conditions of existence for humans and non-humans alike.

- "In the case of all things which have several parts and in which the totality is not, as it were, a mere heap, but the whole is something besides the parts . . ."
  Aristotle (c. 335-323 BCE): *Metaphysics*, $1045^{a}$ 8-10 (WD Ross, tr)

- "I think the next century will be the century of complexity."
  Stephen Hawking: *San Jose Mercury News*, Jan 23, 2000.

- "All stable processes we shall predict. All unstable processes we shall control."
  John von Neumann: original date unknown, quoted in Flake (2000).

**Student Goals**: by the end of this course students will:

- Have a basic understanding of the path from linear & equilibrium thinking to non-linear and far-from-equilibrium thinking in science as it applies to complex phenomena in biological systems;

- Have the tools for a beginning understanding of the conceptual and methodological foundations of these phenomena;

- Understand the differences between aggregate, equation-based modeling approaches and complex network and agent-based simulation modeling approaches; and

- Be conversant at an introductory level with a variety of key simulation models in hypotheses for the origin of life, its evolution, and in theoretical and applied biological ecology; and have some very basic skills in programming network and agent-based simulations in biological ecology.

**Readings / Films / Audio**: All these are posted as password-access-only on the course website. They should be done in the order they appear on the website. Notes on how to study each of these assignments may also appear along with the links to the materials.

**Materials to Purchase**: There are no texts to purchase, all study materials (including simulation models for the lab sections) will be on the course website or can be downloaded from the World Wide Web. However, each student will need a USB Memory stick (aka Flash Drive, or Jump Drive) with at least 250 MB free space for this course that he/she must bring to all lab sections beginning with the first week.

**Participation**: On-time for all 20 lecture sessions and all 10 lab sections. Absence or lateness can be excused by documentation for such things as religious holidays (with two-weeks advance notice), participation on the team of an official UCLA athletic event (also with two weeks advance notice), illness, car trouble, death in the family, legal summons, or because a student is the principal caregiver for someone who is ill.

**Grading**: Letter Grade only. There are 250 total points in the course. Participation at lectures is worth 40 points. Participation at lab sections is worth 40 points. First midterm is worth 40 points. Second midterm is worth 50 points. Final is worth 80 points.

The two midterms will be done as on-line exams. Students will need to sign a pledge concerning the exact guidelines for doing the exams on their own.

**Grade Review Policy:** If a student is dissatisfied with any score received and wishes to appeal, he or she must submit a written request for a review of the score. This request must be submitted no later than one week after the exam or assignment has been graded. The written request must point out some ***egregious*** error or oversight in the scoring process. The burden of proof is upon the student to show precisely where (which part of which question) the grading was clearly wrong about some factual matter.

**Cheating, Plagiarism, Collaborative Work, Multiple Submissions**: Know the rules. Avoid penalties by following the rules. If in double consult:
http://www.registrar.ucla.edu/soc/notices.htm#Anchor_student_37516

Schedule

Unit 00: Course Introduction: Student-Oriented Course Objectives. Why Model and Some Principles of Modeling. Why Simulate and Some Principles of Simulation.

Unit 01: Intro to Dynamical Systems: What is a System and What are the Defining Features of a System. Linear Systems, Non-Linear Systems, and Chaotic Systems.

Unit 02: Introduction to Complexity: General Principles of Self-Organization & Emergence

Unit 03: Non-Equilibrium Thermodynamics, Self-Organized Criticality, and Critical Transitions (Mass Extinctions, Speciation, etc)

Unit 04: Fractals and Scaling Principles

Unit 05: A Complexity Hypothesis for the Origin of Life

Unit 06: Food Webs and Animal Social Networks

Unit 07: Self-Organization: Flocking and Schooling; Synchronization; Ant Foraging and Task Allocation; Pattern Formation

Unit 08: Cellular Automata (including Conway's *Game of Life*)

Unit 09: From Equation-Based Aggregate Modeling to Agent-Based Simulation Modeling

Unit 10: Theories of Complexity in Biological Ecology

Unit 11: Epidemics: From the Playground to the Planet

-- end --

Study Materials List

This is a list of some of the texts, audio and film materials for the lecture portion course. See the Lab Section syllabus for texts used for the lab section.

Camazine, et al (2001): *Self-Organization in Biological Systems* (seven chapters).

Wilkinson (2006): *Fundamental Processes in Ecology: an Earth Systems Approach* (several chapters).

Johnson (2002): *Emergence: The Connected Lives of Ants, Brains, Cities and Software* (several chapters).

Bragin (2012): "An Outline of Complex Systems Science"

Epstein (2008): "Why Model?"

Weaver (1947): "Science and Complexity"

Feynman (1964): "Interacting Hierarchies". Five-minute film portion of a public lecture given at Cornell University.

Nova Science Now (2007): "Emergence". Ten-minute TV Program.

Bak (1996): "Complexity and Criticality". (Chapter 1 of his book on self-organized criticality, *How Nature Works*.)

Bragg, ed (2004): "2$^{nd}$ Law". (An eight-minute panel discussion excerpted from a BBC science program, dealing with the second law of thermodynamics in open, living systems.)

West, et al (2004): "Life's Universal Scaling Laws"

Reynolds (1987): "Flocks, Herds, and Schools: A Distributed Behavioral Model".

Yong (2013): "How the Science of Swarms Can Help Us Fight Cancer and Predict the Future". (An article on the work of Iain Couzin.)

Gordon (2002): "The Regulation of Foraging Activity in Red Harvester Ant Colonies".

Chu, et al (2003): "Theories of Complexity". (Based on an analysis of critical transitions in the Lake Victoria ecosystem.)

Ball (2012): “Spreading It Around: Mobility, Disease and Epidemics”.

# Lab Sections for Self-Organization and Emergence in Biological Systems

Two hours per week.

The purpose of the lab section is to introduce students to a variety of computer simulation models of biological phenomena including systems dynamics equation models, complex networks and agent-based simulation models.

In most cases students are not required to do original programming, but explore existing models by means of graphical user interfaces with a wide space of parameters and independent variables that can be tested for their outcomes. This is of both theoretical interest and of applied (policy) interest, given current conservation and environmental efforts in many areas of biology and ecology.

Students will also gain very basic programming skills using the software applications listed below, particularly in weeks 3, 6, 7 and 10.

**Software Applications Used**: *Berkeley Madonna* for Systems Dynamics, *Pajek* for Networks, *Dynamic Causal Iterative Networks*, *Netlogo* for Agent-Based Models.

**Readings** (include): Bragin (2013): “Ordinary Differential Equations”. Nardi (2009): “Iterated Networks”. de Nooy, et al (2011) *Exploratory Social Network Analysis with Pajek* (excerpts). Gilbert (2009): *Agent-Based Modeling* (excerpts). Grimm, et al (2005): *Individual-Based Modeling and Ecology* (excerpts). Railsback, et al (2012): *Agent-Based and Individual-Based Modeling* (excerpts).

<u>Schedule</u>

Week 1: Orientation to software applications used in this course. General exercises in systems concepts, modeling concepts and simulation concepts.

Week 2: Computer-based exercises in linear, non-linear and Chaotic dynamics.

Week 3: Computer-based exercises in self-organized criticality, mass extinctions and speciation.

Week 4: Computer-based exercises in fractals and scaling principles.

Week 5: Computer-based exercises in food web and animal social networks.

Week 6: Computer-based exercises in flocking and schooling, synchronization, ant foraging and task allocation, and pattern formation.

Week 7: Computer-based exercises in cellular automata and Conway's *Game of Life*.

Week 8: Computer-based exercises comparing a systems dynamics predator-prey model with an agent-based predator-prey simulation model

Week 9: Computer-based exercise on biological ecology of Lake Victoria

Week 10: Computer-based exercise on epidemics, including SIR, SIS, HIV and others.

-- end --

## 7. Physical Science Topics and Examples

In addition to the computer science methodology, which is at the core of this course, I think the following content gives good reason to approve this course as an either/or offering in Physical Science/Life Science.

This material occurs both in lectures and in the computer labs.

Non-biological physio-chemical processes are present in all biological and social phenomena and must be taken into account in their scientific exploration and where policy analysis and policy implementation are concerned.

This course is primarily concerned with biological complexity, but it begins at the beginning with a consideration of foundational non-complexity approaches to these physio-chemical processes.

It then addresses complexity in physio-chemical system-processes, especially where such physio-chemical system-processes cooperate with the biological ones.

As the course progresses, these topics (**in bold**) are re-addressed where they are important in considering such things as a complexity hypothesis for the origin of life, aspects of evolution, cellular and organismal processes and biological ecology.

Precedent for this exists. My course Human Complex Systems/Engineering M10A: *Introduction to Complex Systems Science* was approved in 2008 as a GE in Social Analysis or Physical Science (without a Lab) as it is a lecture-only course. During lectures these same key topics and examples are addressed. (The HCS cross-listing no longer exists, since the HCS Program was dismantled in December 2011, but I still teach Engr 10A.)

Here are some key topics and examples:

<u>**Linearity** in Physical Systems</u>

Galileo's Law of Falling Bodies
Ideal Pendulum (under small displacement)
Galilean Projectile Motion
Newton's Three Laws of Motion

<u>**Chaos** in Physical Systems</u>

Three Body Problem (under Newton's Law of Universal Gravitation)
Lorenz Atmosphere Equations

→

**Equilibrium** in Physical Systems

Computer simulation model, 2nd law of thermodynamics of gas in closed container

**Equilibrium** in Chemical Kinetics

Computer simulation model, two reactants in closed container

**Non-Equilibrium** in Chemical Kinetics

Brusselator
Belousov-Zhabotinsky reaction
Benard cells

**Phase Transitions** in Physical Systems

Ferromagnetic Bar (Curie point)

**Phase Transitions** in Chemical Systems

Boiling water (conduction to convection)

**Complexity** in Physical Systems

Hurricanes
Jupiter's Great Red Spot (a dissipative system-process)

**Random Walk Dynamics** in Physical Systems

Galton Board

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Main Menu | Inventory | Reports | Help | Exit

# New Course Proposal

## Ecology and Evolutionary Biology 20
## Self-Organization & Emergence in Biology: A Complex Adaptive Systems Approach

**Course Number** Ecology and Evolutionary Biology 20

**Title** Self-Organization & Emergence in Biology: A Complex Adaptive Systems Approach

**Short Title** SELF-ORG IN BIO SYS

**Units** Fixed: **5**

**Grading Basis** Letter grade only

**Instructional Format** Lecture - 4 hours per week
Laboratory - 2 hours per week

**TIE Code** LECS - Lecture (Plus Supplementary Activity) [T]

**GE Requirement** Yes

**Requisites** None

**Course Description** In this course students discover how the exciting new sciences of complexity (which are thoroughly explained in the course) address cutting-edge research and practical applications in multi-disciplinary approaches to biological systems. Such system-processes range from the machinery of the cell through trans-national epidemics to global climate change. Complex Systems Science seeks to bridge the gaps among the Social Sciences, Natural Sciences, Applied Sciences (including Public Affairs, Engineering, Management & Health Sciences), and the Humanities, in order to better conditions for humans and non-humans alike. In lab sections students explore existing computer simulations (similar to video games), experimenting on "what-if" worlds to determine the outcomes of non-linear, chaotic, complex and far-from-equilibrium processes in cellular, organismal, ecological and evolutionary biology. No previous math, science or computer knowledge is required beyond that necessary to enter UCLA as a Freshman.

**Justification** The complexity approach to biology (particularly the use of agent-based simulation modeling and dynamic network analysis) is rapidly becoming central to research and policy analysis in the life sciences. Although various aspects of complexity biology have been taught in courses at UCLA when the IDP in Human Complex Systems was in existence between Fall 2005 and December 2011, no course in Biological Complex Adaptive Systems has ever existed here. It is time for such a course. And it is time for such a course at the General Education level, because, as Stephen Hawking said, complexity sciences will be the sciences of the 21st century. The concepts, methods and applications of complex systems science will soon become a fundamental approach to the life and social sciences.

**Syllabus** File *Syllabus_EEB 20.pdf* was previously uploaded. You may view the file by clicking on the file name.

**Supplemental Information**

**Grading Structure** Letter Grade only. There are 250 total points in the course. Participation at lectures is worth 40 points. Participation at lab sections is worth 40 points. First midterm is worth 40 points. Second midterm is worth 50 points. Final is worth 80 points.

**Effective Date** Winter 2014

**Instructor**

| Name | Title |
|---|---|
| John Bragin | Lecturer |

**Quarters Taught** ☐ Fall ☑ Winter ☐ Spring ☐ Summer

**Department** **Ecology and Evolutionary Biology**

**Contact** Name: **JESSICA ANGUS** E-mail: **jangus@lifesci.ucla.edu**

**Routing Help**

## ROUTING STATUS

**Role:** FEC School Coordinator - Castillo,Myrna Dee Figurac (MCASTILLO@COLLEGE.UCLA.EDU) - 3107942018

**Status:** Pending Action

**Role:** Initiator/Submitter - Angus, Jessica Abijay (JANGUS@LIFESCI.UCLA.EDU) - 3108251680

**Status:** Submitted on 8/20/2013 10:41:46 AM

**Comments:** Initiated a New Course Proposal

Back to Course List

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cims@registrar.ucla.edu or (310) 206-7045