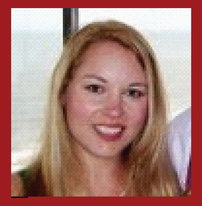
A New Approach toward Teaching Introductory Organismal Biology

Departments of Cell Biology & Molecular Genetics, Curriculum and Instruction, and Physics
University of Maryland, College Park


Todd J. Cooke


Jeffrey Jensen


Janet Coffey


Kristi Hall


Jessica Watkins

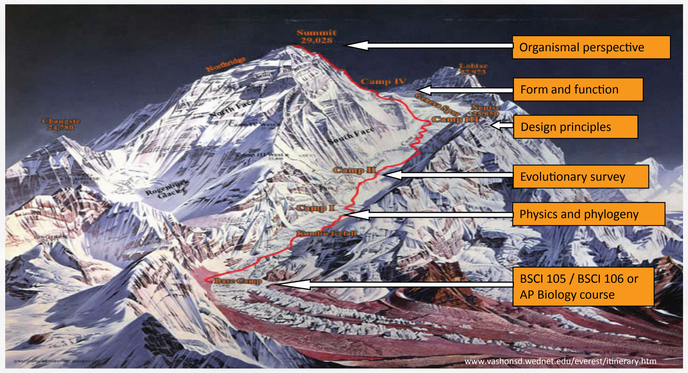

Edward F. Redish

Challenge:

Create an effective principles-based course on the structure, function, and diversity of organisms.

The traditional approach toward introductory organismal biology (OrgBio) is often derided as "the forced march through the phyla," because it involves teaching all the major groups of bacteria, archaea, protists, plants, fungi, and animals, plus separate units on plant and animal function. In our experience, students do not easily identify the fundamental principles governing all organisms from the tsunami of lineage-specific knowledge presented in the traditional course.

Content reform of Org Bio

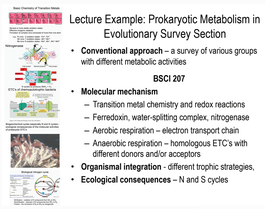


UMD faculty teaching different diversity and physiology classes attempted to identify the overarching principles governing all organisms. The following consensus priniples were used to create the new course -- Principles of Biology III: Organismal Biology.

Principles of Org Bio

1. Universal physical and chemical principles
2. Deep molecular homology
3. Divergent structure-function relationships
4. Convergence
5. Lateral gene transfer
6. Symbiosis
7. Environmental transformation

Lecturing the Principles



Lecture Example: Prokaryotic Metabolism in Evolutionary Survey Section

- **Conventional approach** – a survey of various groups with different metabolic activities

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- **Molecular mechanism**
  - Transition metal chemistry and redox reactions
  - Ferredoxin, water-splitting complex, nitrogenase
  - Aerobic respiration – electron transport chain
  - Anaerobic respiration – homologous ETC's with different donors and/or acceptors
- **Organismal integration** - different trophic strategies,
- **Ecological consequences** – N and S cycles

Lecture example: Nutrient Assimilation in Form and Function Section

- **Conventional approach** – nutrient assimilation in fungal hyphae, plant roots, and vertebrate small intestines are discussed in separate units

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- **Homologous P-type ATPases** for establishing cation electrochemical gradients across plasma membranes
- **Homologous carriers and channels** for transporting molecules into cells
- **Common design features** of nutrient assimilation organs – e.g., elaborated surfaces, high levels of mitochondrial activity
- **Unique structure-function relationships** in fungal hyphae, plant roots, and vertebrate small intestines

When we lectured, we found:

1) *High levels of faculty satisfaction*.

2) *Students "revert to wild-type"*:
short-term memorization and limited deep learning, i.e., the students manifested limited ability to describe, understand, and apply fundamental principles.

3) *"Why are they trying to teach us physics in a biology class?"*
Students had problems with physical and chemical principles, such as thermodynamics, transport processes, oxidation-reduction, scaling, material properties, and biomechanics.

Lectures alone were not effective at conveying fundamental principles!

Expected outcomes of CCLI grant

1) The creation of effective small-group active- engagement exercises (GAEs) for helping the students to learn and apply organismal principles;

2) The initial characterization of how biology students learn physical principles in an introductory biology class

GAEs



Principle	Model	**Major activities** (in addition to small-group brainstorming and class discussion in all exercises)	**Estimated time** (min)
Thermodynamics	Biological energy flow	Flow diagram construction	75
Descent from common ancestors	Phylogenetic trees	Tree thinking	50
Oxidation-reduction	Electron transport chain	Student enactment	50
Endosymbiosis	Pipe cleaner cell models	Guided manipulations	50
Diffusion	Fick's First and Second Laws	Computer simulations	50
Eukaryotic sex	Life cycle	Concept mapping	25
Scaling	Area/volume relationships; power laws	Class demonstrations/ mathematical manipulations	50
Organismal form and function	Model organismal design	Class demonstrations	50
Circulation	Hagen-Poiseuille equation	Discussions	50
Transmembrane transport	Homologous transport proteins	Student enactment	50
Biomechanics	Levers and lever equations	Class demonstrations/ guided experiments	50

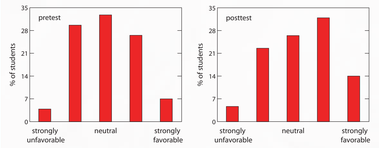
Org Bio transformation

- Replace 1/3 of lecture periods with GAEs
- Small groups of 3-4 in large class of 80
- Focus GAEs on major principles that are not well-conveyed by lectures, as judged from essay answers on previous exams
- Encourage students to use prior biological knowledge to generate quantitative, physical, or conceptual models of these principles
- Create group homework exercises requiring the students to apply these principles toward solving new problems
- Encourage students to discuss the homework problems outside of class, but write up the problems independently of each other.

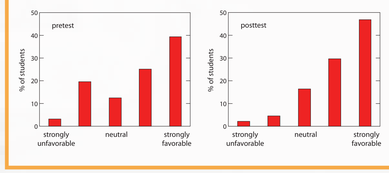
Preliminary assessments

Students completed a pre- and post-survey on their expectations about biology (Maryland Biology Expectations Survey). While we do not see much change in the unreformed courses, the results from the first semester of the reformed course are more encouraging.

Learning biology is a matter of acquiring the factual knowledge presented in class and/or in the textbook.



Biology and physics are:
(A) related to each other by common principles.
(B) separate and independent of each other.



Student evaluations have also shown an increase in student engagement and satisfaction. (average scores on 1-5 scale)

	sp 2008 lecture	sp 2009 clickers	sp 2010 GAEs
The instructor helped create an atmosphere that kept me engaged in the course.	3.91	4.15	4.45
Overall, this instructor was an effective teacher.	4.22	4.36	4.49

[In AP biology] we pretty much followed the way the text book was set up with the different chapters so it would be a chapter just on prokaryotes and then there'd be another chapter just on protists... But [in Org Bio] we've taken a lot of the background and principles and been able to connect them in a way that just flows so much better. *- Jennifer, fa 2010*

expected web dissemination: March 2011

Funding: NSF DUE 09-19816, HHMI

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