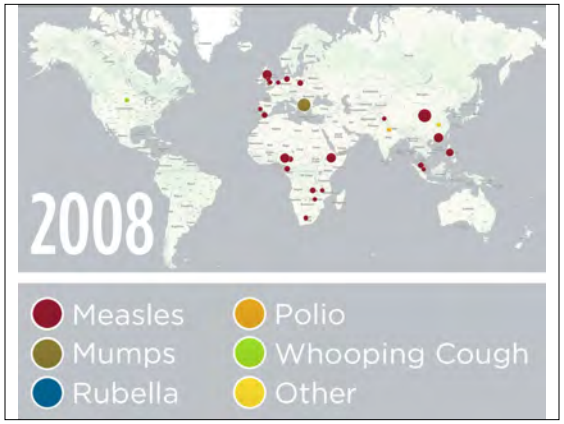
Marjorie Gardner Lecture: Authentic Learning, Student Engagement & Socratic Course Design

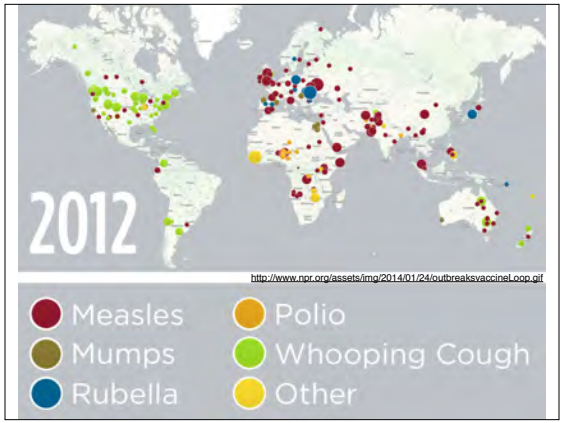
Mike Klymkowsky
Molecular, Cellular, and Developmental Biology
CU Teach & Center for STEM Learning
University of Colorado Boulder

Be Boulder.

education matters

The growing importance of scientific literacy / data-based thinking





http://www.npr.org/assets/img/2014/01/24/outbreaksvaccineLoop.gif

Research article

Teachers teaching misconceptions: a study of factors contributing to high school biology students' acquisition of biological evolution-related misconceptions

Tony B Yates[1]* and Edmund A Marek[2]

* Corresponding author: Tony B Yates tony.yates@okbu.edu ▪ Author Affiliations

1 Oklahoma Baptist University, James E. Hurley College of Science and Mathematics, 500 West University, Shawnee 74804, OK, USA

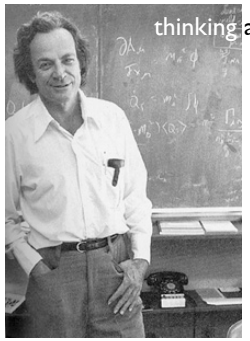
2 Department of Instructional Leadership and Academic Curriculum, University of Oklahoma, 114 Ellsworth Collings Hall, Norman 73019-0260, OK, USA

http://www.evolution-outreach.com/content/7/1/7

Transformative collaborators:

- Kathy Garvin-Doxas: the biology concept inventory (BCI)
- Erin Furtak (SoE / CU Teach): Teaching & Learning Biology (learning video projects)
- Melanie Cooper: CLUE, beSocratic & rewrite of biofundamentals ….

What does teaching/learning science involve?

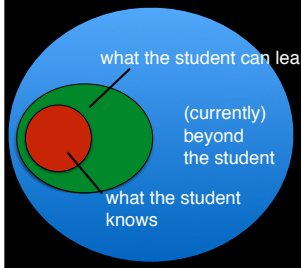


thinking about magnets

http://www.youtube.com/watch?v=MO0r930Sn_8

be explicit: what needs to be already understood

Tuning teaching to students (Vygotsky)



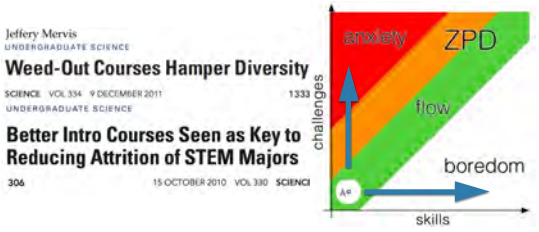
Goals of a coherent curriculum*

avoiding the more complex question of college requirements.

Disciplinary fluency

Analytical skills

Remove unnecessary obstacles



A. Repenning, "Programming Goes to School", CACM, 55, 5, May, 2012.

Be Boulder.

Now for the hard part

Consider disciplinary foundations: core concepts and their empirical bases

Generate **realistic learning goals** & performance expectations

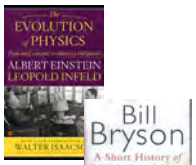
revise as necessary

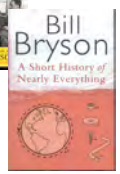
Monitor outcomes

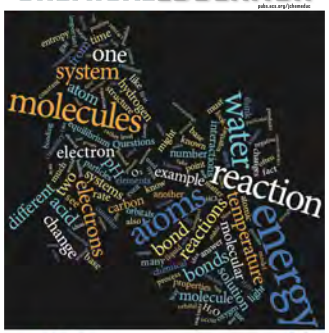
Be Boulder.

CLUE model

Cooper & Klymkowsky, 2013. ***Chemistry, Life, the Universe and Everything*** *(CLUE): A new approach to general chemistry, and a model for curriculum reform.* J. Chem. Ed. Sept.

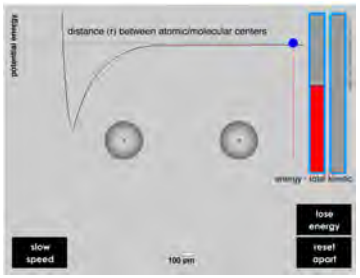






ACS Publications

CLUE's origin



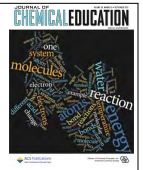
http://besocratic.colorado.edu/CLUE-Chemistry/activities/LondonDispersionForce/1.2-interactions-0.html

Be Boulder.

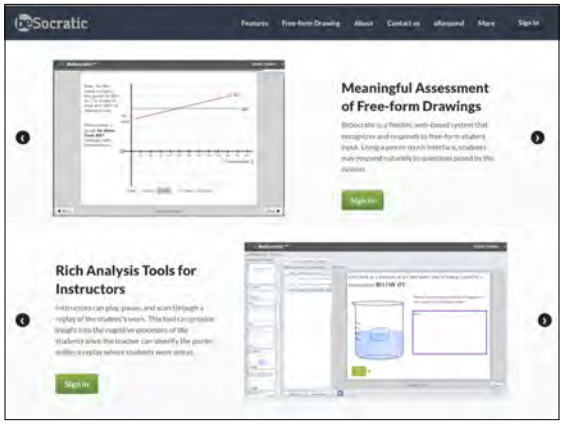
---

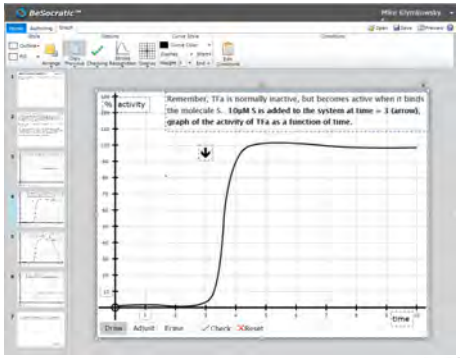
formative assessments, delivered through beSocratic

in class discussion to highlight and resolve difficult ideas

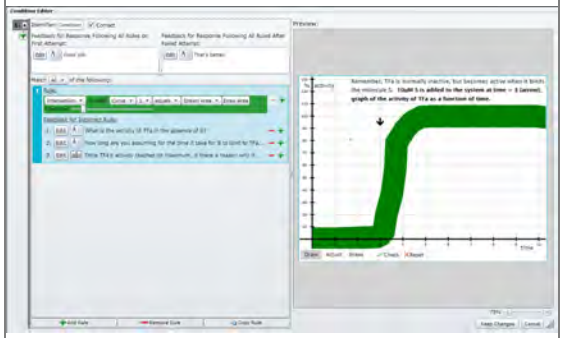


Be Boulder.





Be Boulder.



Be Boulder.

Comparative and longitudinal data

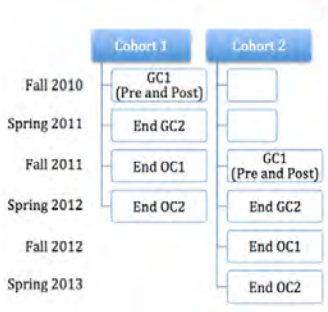
"If we go on testing long enough we will inevitably find something which is 'significant"

Martin Bland, J.; Altman, D. G. *British Medical Journal* **1995**, 310, 170

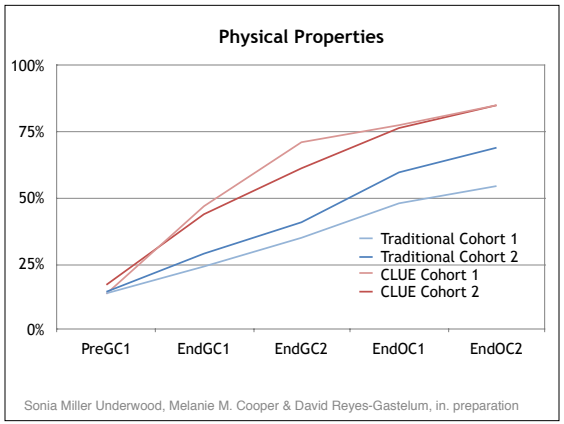
Solution: Discrete-time survival analysis, originated & predominantly found in medical field. Sonia Miller Underwood, M.M. Cooper & D. Reyes-Gastelum, in prep.

Be Boulder.

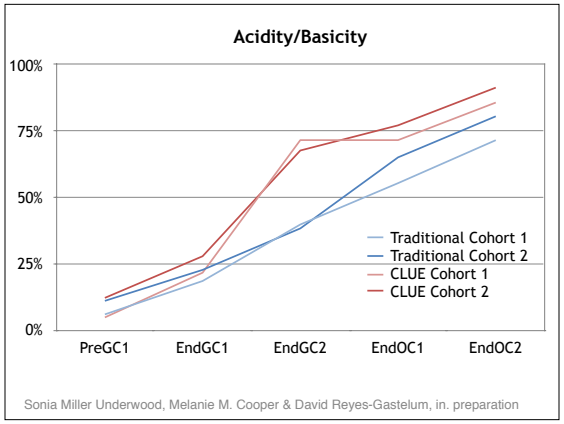
	cohort 1	cohort 2
traditional	N=123	N=111
CLUE	N=88	N=176



Sonia Miller Underwood, Melanie M. Cooper & David Reyes-Gastelum, in. preparation

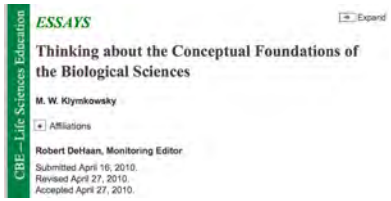


Sonia Miller Underwood, Melanie M. Cooper & David Reyes-Gastelum, in. preparation



Sonia Miller Underwood, Melanie M. Cooper & David Reyes-Gastelum, in. preparation

Coherent curriculum in biology


CBE—Life Sciences Education

ESSAYS

Thinking about the Conceptual Foundations of the Biological Sciences

M. W. Klymkowsky

Affiliations

Robert DeHaan, Monitoring Editor

Submitted April 16, 2010.
Revised April 27, 2010.
Accepted April 27, 2010.

Be Boulder.

* hat tip to Ernst Mayr

Evolutionary thinking: historic continuity (non-essentialist)*, stochastic processes, cost-benefit analyses (selection), social interactions (inclusive fitness)

Homologous subsystems

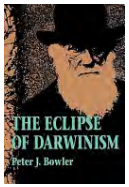
Molecular foundations: thermodynamics (enthalpic & entropic drivers), molecular shapes & interactions, coupled reactions and regulated catalysis, stochastics, and genome dynamics

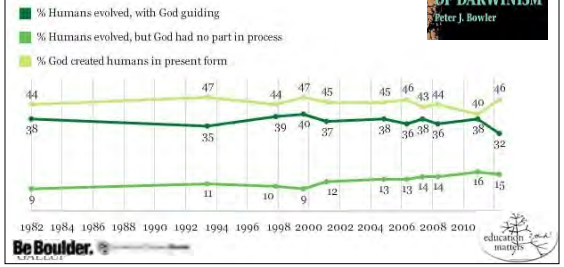
Network behavior: regulatory dynamics of genetic, metabolic, neural, immunological, developmental, and ecological interactions.

Be Boulder.

* hat tip to Ernst Mayr

That random mutations can generate complex traits is not obvious!





Be Boulder.

Article

Understanding Randomness and its Impact on Student Learning: Lessons Learned from Building the Biology Concept Inventory (BCI)

Kathy Garvin-Doxas* and Michael W. Klymkowsky†

*Center for Integrated Plasma Studies and †Molecular, Cellular, and Developmental Biology Department, University of Colorado, Boulder, CO 80309

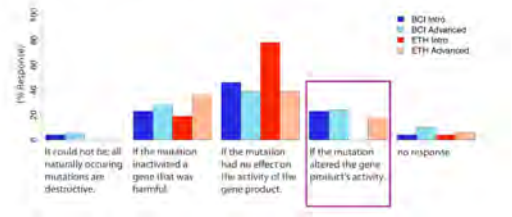
Submitted August 23, 2007; Revised January 14, 2008; Accepted February 7, 2008
Monitoring Editor: Bruce Alberts

CBE—Life Sciences Education
Vol. 7, 227–233, Summer 2008

Because mutations are random, they cannot lead to useful effects; either evolution cannot occur or must require (super-natural) guidance.

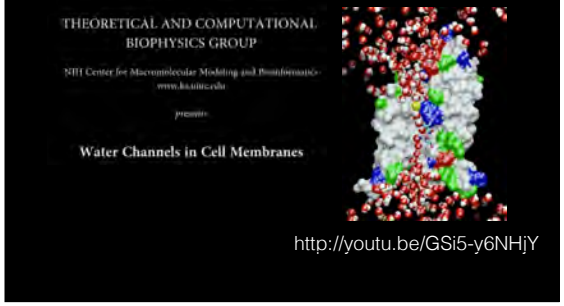
Be Boulder.

How might a mutation be creative?



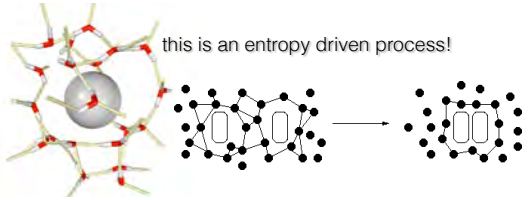
Be Boulder.

Yet randomness is rarely illustrated



http://youtu.be/GSi5-y6NHjY

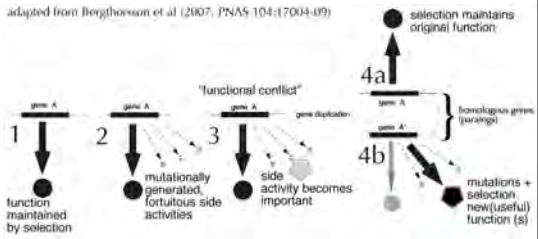
Why do oil and water separate?



this is an entropy driven process!

Be Boulder.

How might a mutation be creative?



Designing a foundations approach to biology

virtual laboratories @ virtuallaboratory.com
with Tom Lundy

http://virtuallaboratory.colorado.edu/BioFun-Support/virtuallabs.htm

virtual laboratories @ virtuallaboratory.com

We will be revising these labs over next year or so, suggestions welcome

- **What is Science lab**: A considering of what makes science different, and how science works in practice.
- **In Water lab**: An introduction to the properties of water, its behavior as a function of temperature, and the diffusion of particles (Brownian motion). *Can be expanded through the use of the vScope to a more mathematical analysis of molecular movements and their role in biological systems.*
- **Introduction to E.coli lab**: An introduction to the basic techniques for handling bacteria in the lab, including dilution and the measure of cellular growth using both light scattering and plating.
- **On Growth lab**: Characterization of bacterial growth as a function of temperature and bacterial survival as a function of time. Provides a context for both Mutation and Adaptation labs.
- **On Mutation lab**: An introduction to bacterial viruses and how they were used by Luria and Delbruck to distinguish between the selection of pre-existing mutations (Darwinian) or the induction specific traits (Lemarkian) processes. *The lab introduces the types of changes that lead to resistance, and could be expanded in this direction, to address questions of viral adaptation to host and vise versa.*
- **On Adaptation lab**: A study of how bacteria adapt to various environment conditions. *future lab expansion into ecological and evolutionary issues associated with niches and speciation.*
- **On Networks lab**: An exploration of emergent behavior from simple gene regulatory networks - in development and not yet available.

These labs rely heavily on Flash, so we apologize, they will not work on an iPad, sorry.

http://virtuallaboratory.colorado.edu/BioFun-Support/virtuallabs.htm

Biofundamentals (MCDB 1111→MCDB1150)

Introduction to Evolutionary & Molecular Biology

syllabus | home | labs

Biofundamentals™ is an attempt to build a more conceptually coherent, rigorous and engaging introductory course in modern biology (testimonial).

We arecurrently transforming Biofundamentals into a book and building enhanced beSocratic activities, which should be ready by Summer 2014. We also hope to have the course available on Albio.cp by that point.

Videos on using the text & constructing arguments.

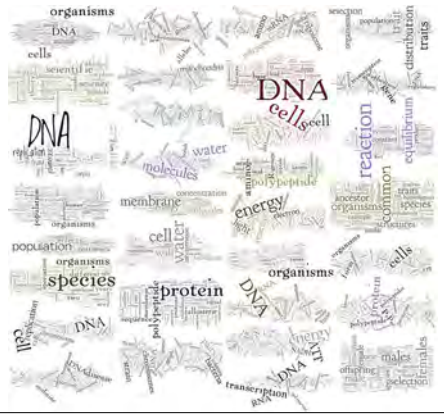
Each reading includes questions to answer and ponder, as well as a beSocratic activities designed to help you consolidate your learning. Class time is spent considering the most difficult ideas.

Our goal is not to sort students but improve teaching by placing difficult ideas in a coherent context.

Biofundamentals™ is part of a larger curricular redesign effort that includes CSM, Calculus, Systems, and Modeling, CLUE: Chemistry, life, the universe & everything, and perhaps a more relevant physics course based on the evolution of physics.

MERLOT Be Boulder.

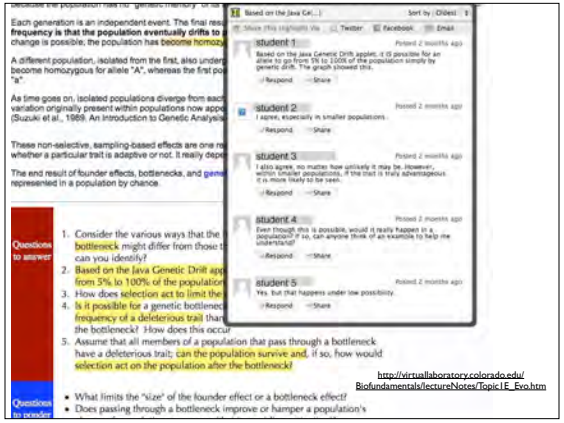
http://virtuallaboratory.colorado.edu/Biofundamentals/



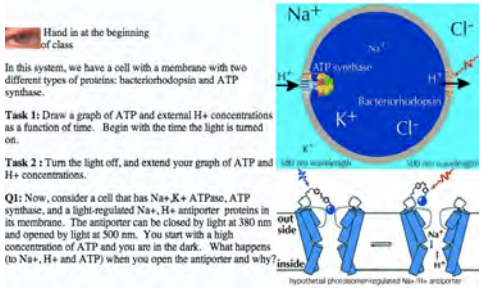
Biofundamentals (MCDB 1111→MCDB1150)

interactive text (nota bene: nb.mit.edu) &
formative assessments: beSocratic activities

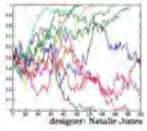
Be Boulder.



Allow students to construct (and defend) their understanding

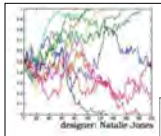


Predict (graph) the effect on a ionophore on ATP production.

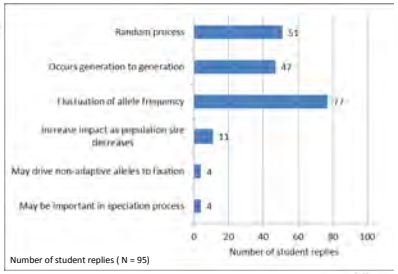


Explain what genetic drift is and how it influences evolution.

Be Boulder.



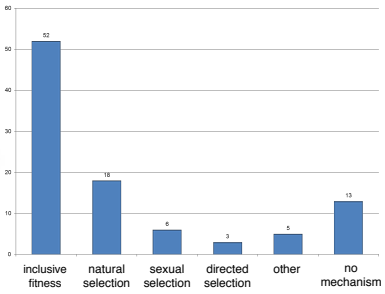
Explain what genetic drift is and how it influences evolution.



Number of student replies (N = 95)

Be Boulder.

How is it possible for evolutionary mechanisms (mutation, drift, selection) to produce highly social species in which individuals display self-sacrifice, empathy, and compassion for non-relatives?



Argumentation

Explain why it is rare that two species occupy exactly the same ecological niche.

a. most populations cannot evolve to fit most niches
b. organisms avoid conflict
c. one "design" is generally better than the other
d. each was uniquely created.

Explain why a wrong choice is wrong.

Students (~30% of the time) restate their original answer.

Strategy:

emphasize to students that they need to **make a specific claim, identify** the concepts, ideas, and data used, and them connect them with a **logical argument**.

Revising Biofundamentals for Fall 2014

- Give students more practice in analysis, explanation, and critique (the application of knowledge)
- Confidence to build from core observations and concepts
- As with CLUE, redesign includes an outsider's perspective

Support from NSF for BCI, CLUE, beSocratic, Physics/Thermo/Biology projects

Questions, concerns, violent disagreements?

Be Boulder.