Bioliteracy,Concept Inventories, & beyond...

Mike Klymkowsky
Molecular, Cellular & Developmental Biology + CU Teach / UC Boulder

Bioliteracy,Concept Inventories, & beyond...

or

how I evolved from a simple scientist to someone interested in effective science education.

Mike Klymkowsky
Molecular, Cellular & Developmental Biology + CU Teach / UC Boulder

time line

education
- undergraduate
- graduate
- post-doc

↓

job

↓

↓

↓

↓

↓

today

time line

education

- undergraduate
- graduate
- post-doc

no training in teaching
quantum tunneled through
the educational system

job

today

time line

education

↓

job { assistant professor

↓

↓

↓

↓

↓

today

time line

education

job

assistant
professor

no training in teaching
assigned to teach cell biology!

today

time line

education

job

assistant
professor

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redesigned cell biology lab,
around phototaxis in amoeba

today

time line

education

↓

job { assistant professor → no training in teaching
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↓

redesigned cell biology lab,
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discovered practical
constraints on large
lab courses

↓

↓

↓

↓

today

time line

education

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job { assistant professor → no training in teaching
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redesigned cell biology lab,
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discovered practical
constraints on large
lab courses

↓

concentrated on science

↓

↓

↓

↓

today

time line

education

↓

job

↓

↓ associate professor

↓

↓

↓

today

time line

education

job

associate
professor

Asked to take part in
The Dynamic Cell (CD-ROM)
virtual reality tour of cell

today

time line

education

job

associate
professor

Asked to take part in
The Dynamic Cell (CD-ROM)
virtual reality tour of cell

Developed "Working with the
literature" for Lodish et al (4th ed).

today

time line

education

↓

job

↓

↓

↓

↓

↓

today

professor

time line

education

↓

job

↓

↓

↓

professor → dissatisfaction understanding of independent study students

↓

↓

today

time line

education

job

professor

dissatisfaction understanding of independent study students

Developed and taught Biofundamentals course with associated virtuallaboratory

today

time line

education

job

professor

dissatisfaction understanding of independent study students

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what is fundamental?

today

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education

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professor

dissatisfaction understanding of independent study students

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Developed and taught Biofundamentals course with associated virtuallaboratory

Began work with Kathy Garvin-Doxas on BCI project

today

time line

education

job

professor

dissatisfaction understanding of independent study students

what is fundamental?

Developed and taught Biofundamentals course with associated virtuallaboratory

what do students really know?

Began work with Kathy Garvin-Doxas on BCI project

today

Course design, in general ...

Klymkowsky, 2011. Getting serious about science education. ASBMB Today, Jan

Course design, in general ...

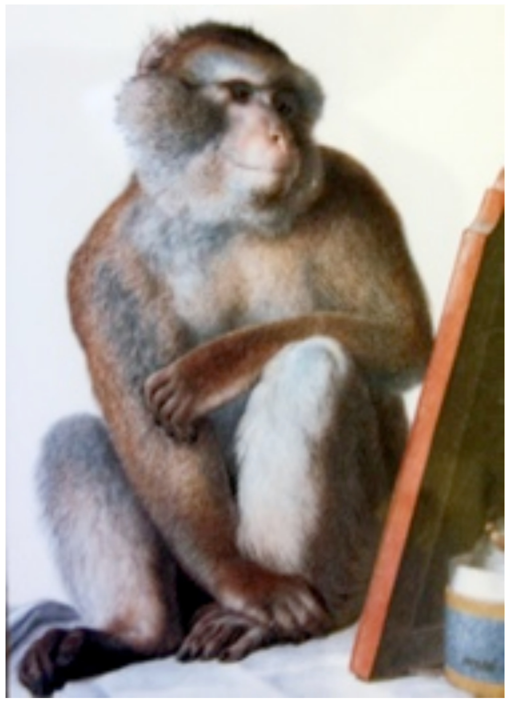
Klymkowsky, 2011. Getting serious about science education. ASBMB Today, Jan

Biofundamentals

no book
(on-line)
tutorials
(in class)
questions
to answer

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

Biofundamentals



Being Biofundamental
Science & its Methods : lab
Life's Origins
Evolution's logic
- Speciation & Extinction
- Adaptation & Selection
- Predators, Prey & Mates
- Non-Adaptive Processes
- Homology & Analogy

Water & Life's Structure : lab
Lipids & Membranes
- Getting through Membranes
- Carriers, Pore and Pumps

A (very) little thermodynamics
- Capturing Energy
- Storing Energy
- Eukaryotic Symbiosis

Chemical basis of heredity
- Nucleic Acid Structure
- DNA replication
- Mutations & Repair

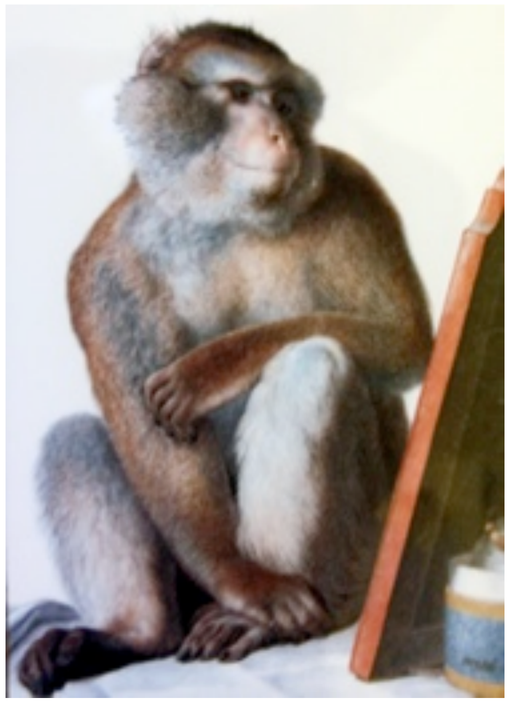
Peptide Bonds & Polypeptides
- Making Polypeptides
- Assemblying Proteins
- Regulating Protein Activities

Regulating gene expression
Regulatory networks
Cell Divison
- Life cycles & Sex ∴
- Stem Cells & Differentiation ∴

Cellular communities
Alternative & Scientific Medicine

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

Biofundamentals

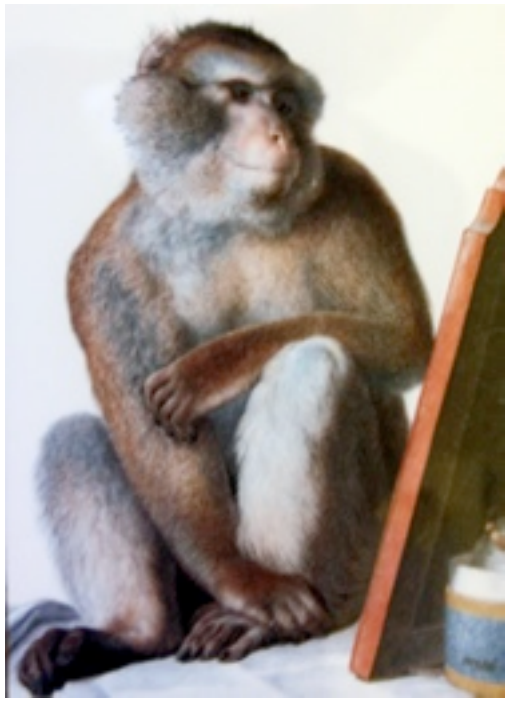


Here's a Question!

- What does it mean to cheat, in terms of sexual selection - is the "cheating" organism actually being consciously deceptive?
- What types of "cheating" behavior do females use with males; or males with females?
- Is Devendra Singh right about "mating budgets"?
- What are the costs involved when a male tries to monopolize one or more females? what are the advantages?
- Does sexual selection have to occur in both sexes?
- What limits runaway selection?

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

Biofundamentals



Research AND Teaching

JOURNAL of COLLEGE SCIENCE TEACHING

Two-Dimensional, Implicit Confidence Tests as a Tool for Recognizing Student Misconceptions

By Michael W. Klymkowsky, Linda B. Taylor, Shana R. Spindler, and R. Kathy Garvin-Doxas

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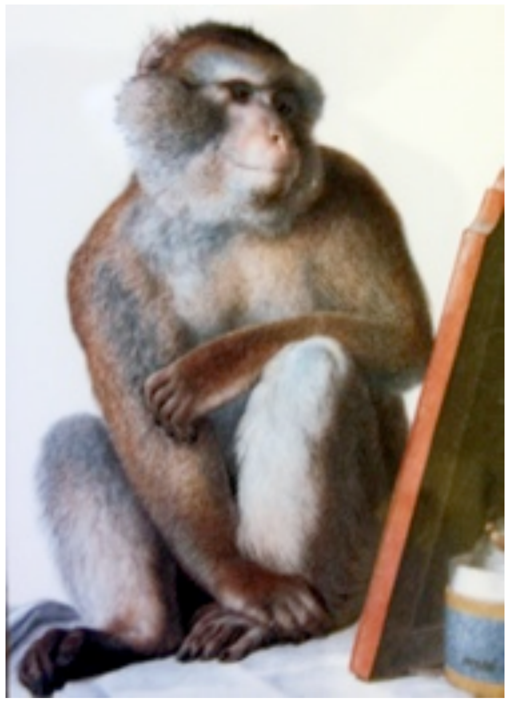

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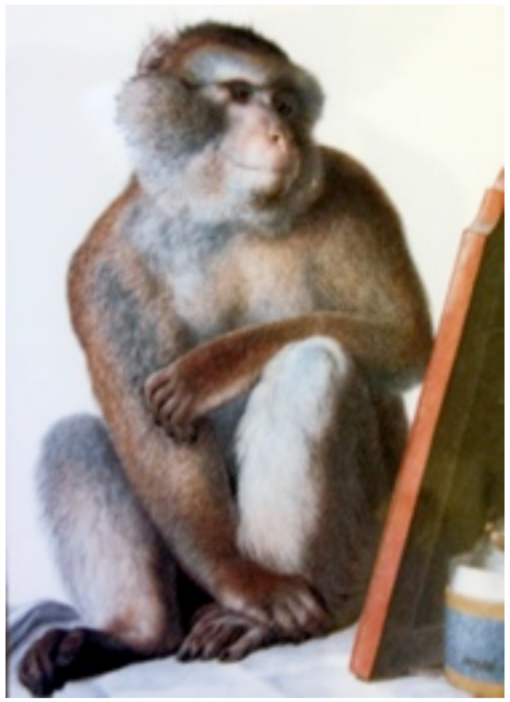

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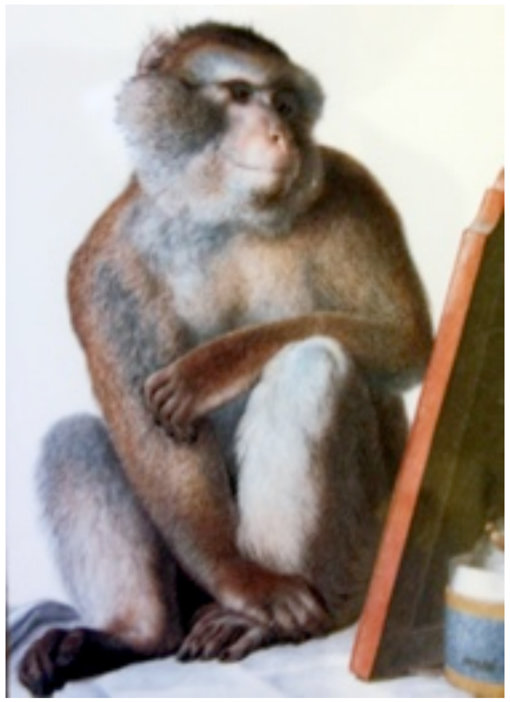

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- possible to be “right” if justification validates choice

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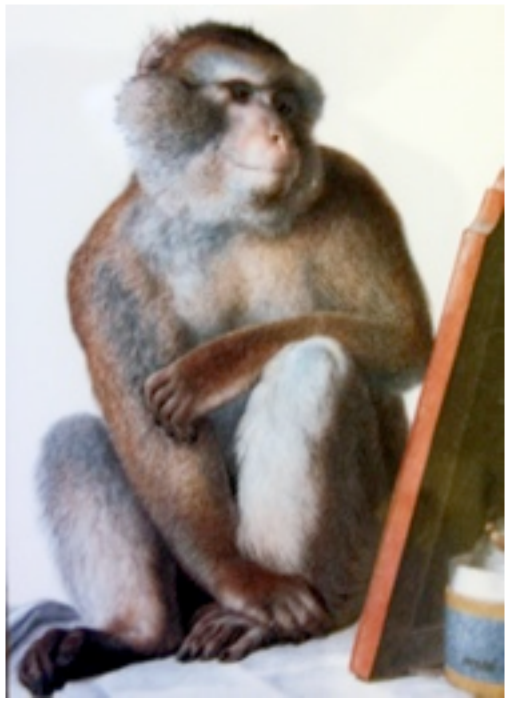

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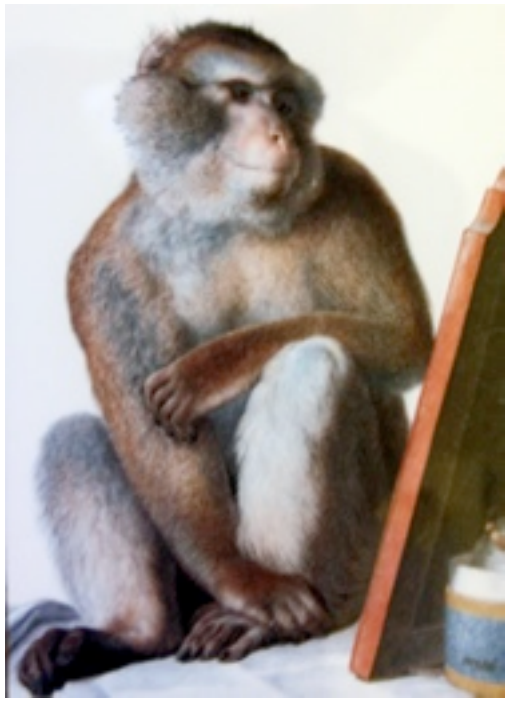

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- penalty for being “confidently” wrong
- small reward for recognizing “not knowing”
- possible to be “right” if justification validates choice
- allows for more ambiguous questions
- emphasizes (to students) importance of thinking / transfer

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

Teaching is like evolution...

Teaching is like evolution...
without selection (that is authentic assessment) things drift.

Ersatz Learning, Inauthentic Testing

John F. McClymer & Lucia Z. Knoles
Assumption College

1992. J. Excell. Coll. Teach. 3:33-50
(available @ http://spot.colorado.edu/~klym)

Ersatz Learning, Inauthentic Testing

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Assumption College

1992. J. Excell. Coll. Teach. 3:33-50
(available @ http://spot.colorado.edu/~klym)

There is "a damaging collusion between students on the one hand and faculty on the other — a collusion in which students agreed to accept bad teaching provided that they were given bad examinations."
– Peter Kennedy

What types of authentic assessment are available?

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- Socratic dialog (formative) / interrogation (summative)

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- Responses to well designed essay questions

Research: Science & Education

A Novel Strategy for Assessing the Effects of Curriculum Reform on Student Competence

John C. Wright
Department of Chemistry, University of Wisconsin, Madison, WI 53706

Susan B. Millar, Steve A. Kosciuk, and Debra L. Penberthy
LEAD Center, University of Wisconsin, Madison, WI 53706

Paul H. Williams
Department of Plant Pathology, University of Wisconsin, Madison, WI 53706

Bruce E. Wampold
Department of Counseling Psychology, University of Wisconsin, Madison, WI 53706

Example, why the "central dogma" important?

DNA

↓ ↑

RNA

↓ ↑

protein

Example, why the "central dogma" important?

DNA

↓ ↑

RNA

↓ ↑

protein

Makes
Lemarckian
evolution
problematic

Example, why the "central dogma" important?

DNA

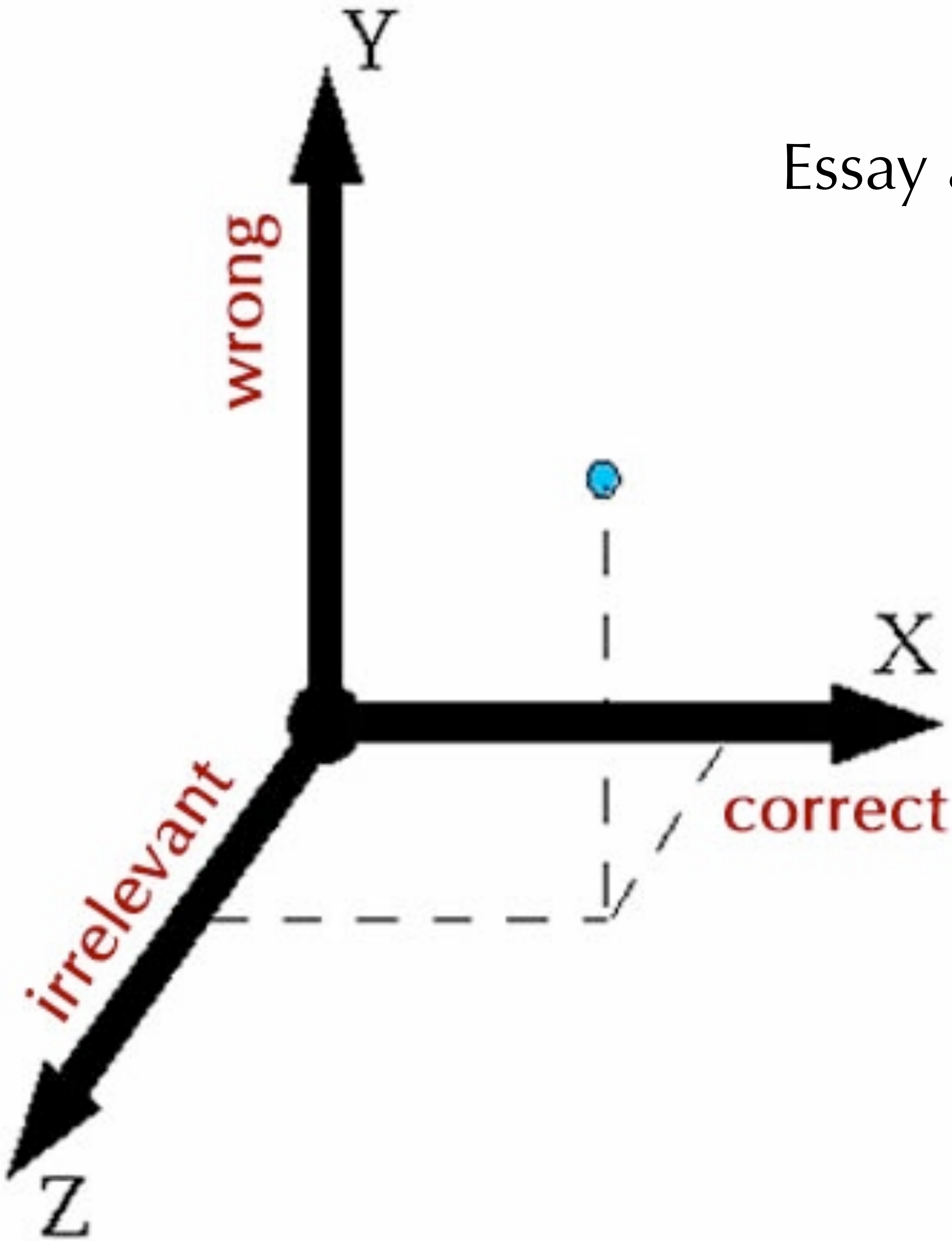
↓ ↑

RNA

↓ ~~↑~~

protein

Makes Lemarckian evolution problematic



Essay answer analysis

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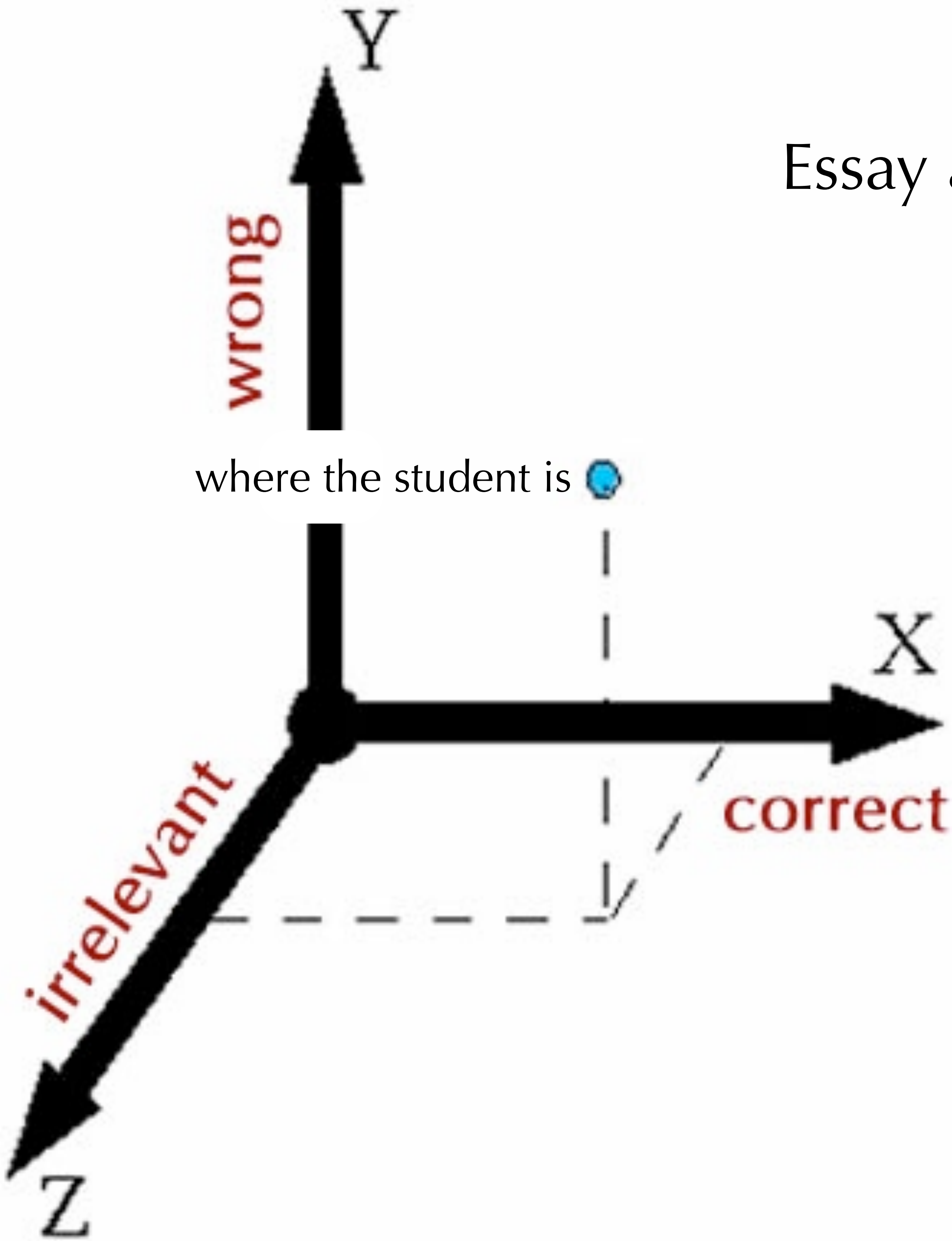

Essay answer analysis

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↓ ↑⊗

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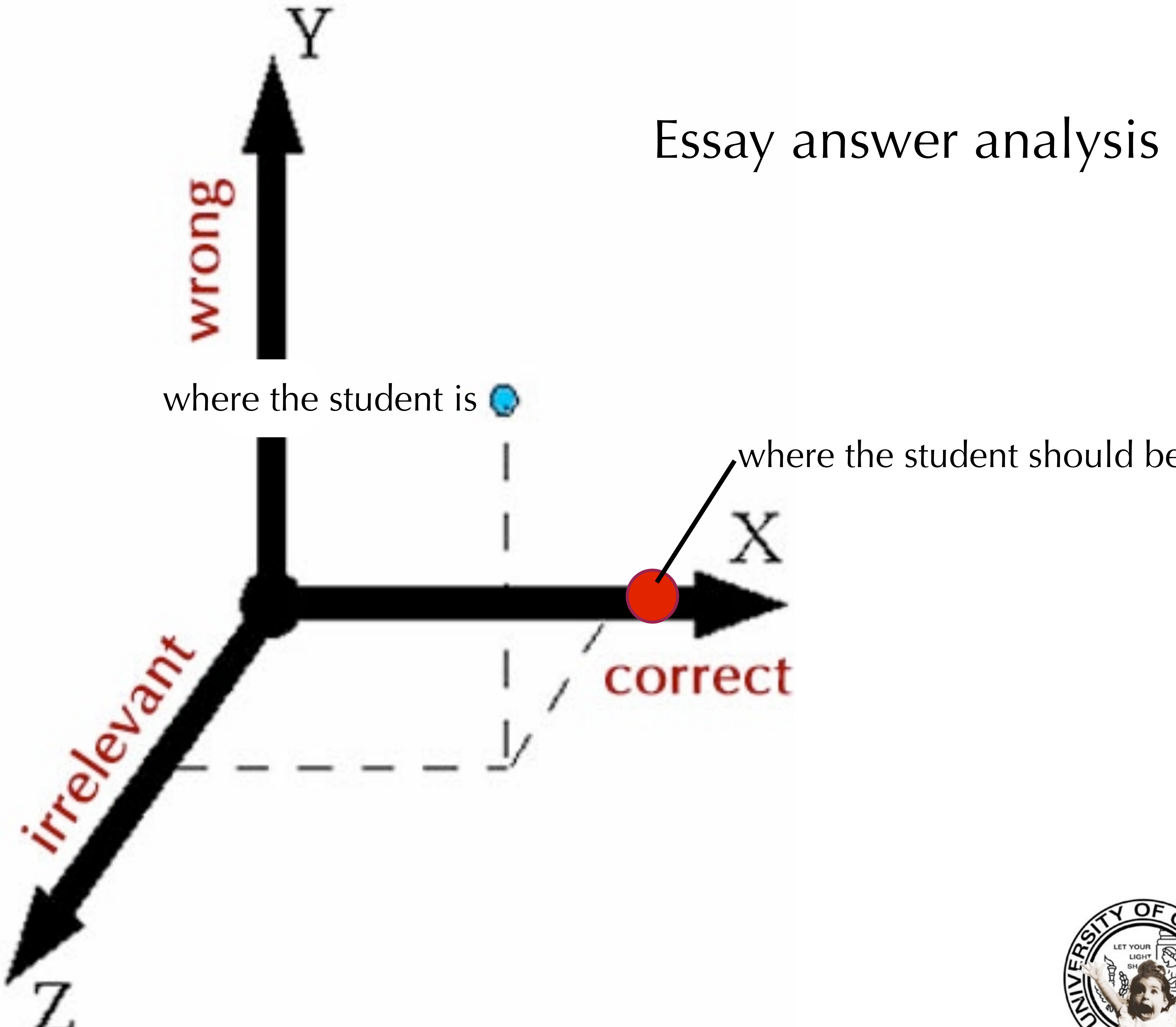
Essay answer analysis



third option: conceptual assessments

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Essay

Bioliteracy and Teaching Efficacy: What Biologists Can Learn from Physicists

Michael W. Klymkowsky,[*,§] Kathy Garvin-Doxas,[†] and Michael Zeilik[‡]

[*]Department of Molecular, Cellular & Developmental Biology and [†]Alliance for Learning, Technology & Society, University of Colorado, Boulder, Boulder, Colorado 80309-0347; and [‡]Institute for Astrophysics, Department of Physics and Astronomy, University of New Mexico, Albuquerque, New Mexico 87131-1156

third option: conceptual assessments

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Huffman, D. and P. Heller (1995). "What does the force concept inventory actually measure?" The Physics Teacher **33**:138-143.

What "concepts" are we talking about?

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One effort: **The Biology Concept Framework**

Khodor et al. 2004. Cell Biol. Ed. **3**:111-121.

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18 major subject headers, 89 secondary headers (and a number of sub-sub headers).

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“11-4. ΔG^o is a thermodynamic property – an inherent characteristic of a reaction regardless of the starting conditions” – a physiochemical concept.

“3-4. Many metabolic pathways are conserved across the evolutionary spectrum (e.g. glycolysis)” which posits an implicit understanding of metabolism, metabolic pathways, evolutionary mechanisms and relationships.

Essays

Thinking about the Conceptual Foundations of the Biological Sciences

CBE Life Sci Educ 9(4): 405-407 2010
DOI: 10.1187/cbe.10-04-0061

M. W. Klymkowsky

Molecular, Cellular and Developmental Biology and CU Teach, University of Colorado Boulder, Boulder CO 80309-0347

Essays

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- **Evolutionary thinking**
  - continuity [cell theory]
  - stochastic processes [drift & mutation]
  - selection → information generation
- **Molecular foundations**
  - thermodynamics: enthalpic & entropic factors
    - self-assembly & systems thinking
    - bond formation & catalysis
  - affinity, specificity, and regulation (allostery)
    - the molecular level effects of mutation

  } physics & chemistry
- **Network behavior**
  - metabolic (non-equilibrium) networks
  - adaptive, homeostatic, & evolving networks
    - e.g., molecular, embryological, neural, immune, ecological

Building the biology concepts instrument - BCi

BCI word cloud

Cornell University Library

arXiv.org > q-bio > arXiv:1012.4501

Quantitative Biology > Other Quantitative Biology

Biological Concepts Instrument (BCI): A diagnostic tool for revealing student thinking

Michael W. Klymkowsky, Sonia M. Underwood, R. Kathleen Garvin-Doxas

(Submitted on 20 Dec 2010)

A key to effective teaching is an awareness and accurate understanding of the thinking and implicit assumptions that students bring to the subject to be learned. In the absence of extensive Socratic interactions with students, one strategy to assess student thinking involves the use of concept inventories (CIs). CIs are typically multiple-choice assessments, constructed based on research into student thinking and language, and designed to reveal the presence of common misconceptions and implicit assumptions pertaining to a particular facet of a subject. Here we describe the open-source Biological Concepts Instrument (BCI), a diagnostic, multiple-choice instrument designed to provide instructors with a preliminary map of a number of basic ideas in molecular level biology. We describe the strategy behind its design, the research upon which it is based, item construction, and its possible uses as a means to reveal and address persistent and often unrecognized conceptual obstacles.

Subjects: **Other Quantitative Biology (q-bio.OT)**
Cite as: **arXiv:1012.4501v1 [q-bio.OT]**

Submission history
From: Mike Klymkowsky [view email]
[v1] Mon, 20 Dec 2010 23:18:58 GMT (428kb)

based on student thinking

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Recognizing Student Misconceptions through Ed's Tools and the Biology Concept Inventory

Article | Metrics | Related Content | Comments: 0

Michael W. Klymkowsky*, Kathy Garvin-Doxas

enables us to recognize difficult ideas

Klymkowsky, 2011.ASBMB Today, Feb

enables us to recognize difficult ideas

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

Klymkowsky, 2011.ASBMB Today, Feb

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feature story

Why is evolution so hard to understand?

Realizing that function and biological meaning can arise from random processes may help people understand and accept evolution

BY MIKE KLYMKOWSKY

Klymkowsky, 2011.ASBMB Today, Feb

yet randomness rarely illustrated

yet randomness rarely illustrated

Q25: Imagine an ADP molecule inside a bacterial cell. Which best describes how it would manage to "find" an ATP synthase so that it could become an ATP molecule?

A. It would follow the hydrogen ion flow.

B. The ATP synthase would grab it.

C. Its electronegativity would attract it to the ATP synthase.

D. It would be actively pumped to the right area.

E. Random movements would bring it to the ATP synthase.

yet randomness rarely illustrated

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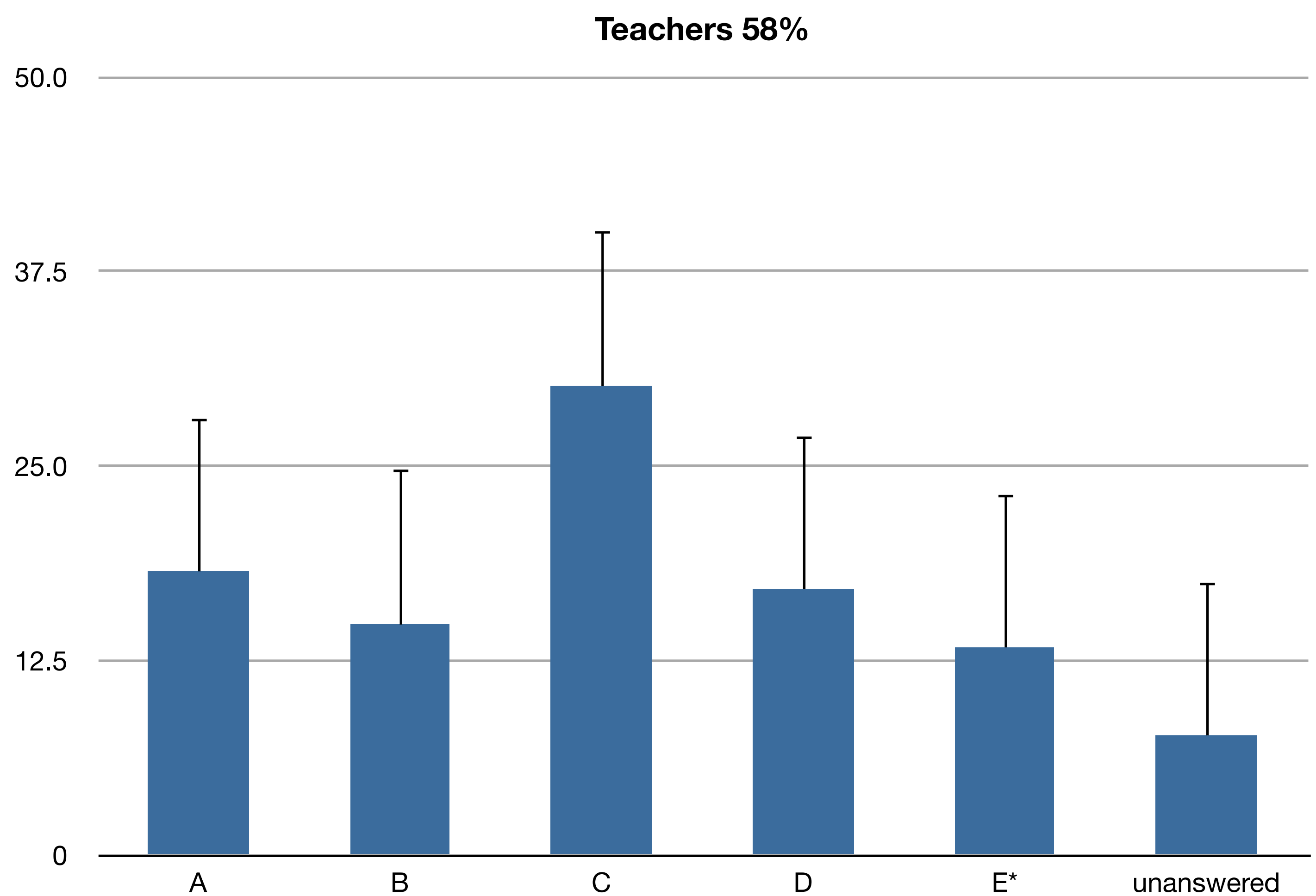

Molecular level confusions

Q13: When we want to know whether a specific molecule will pass through a biological membrane, we need to consider ...

A. the specific types of lipids present in the membrane.

B. the degree to which the molecule is water soluble.

C. whether the molecule is actively repelled by the lipid layer.

D. whether the molecule is harmful to the cell.

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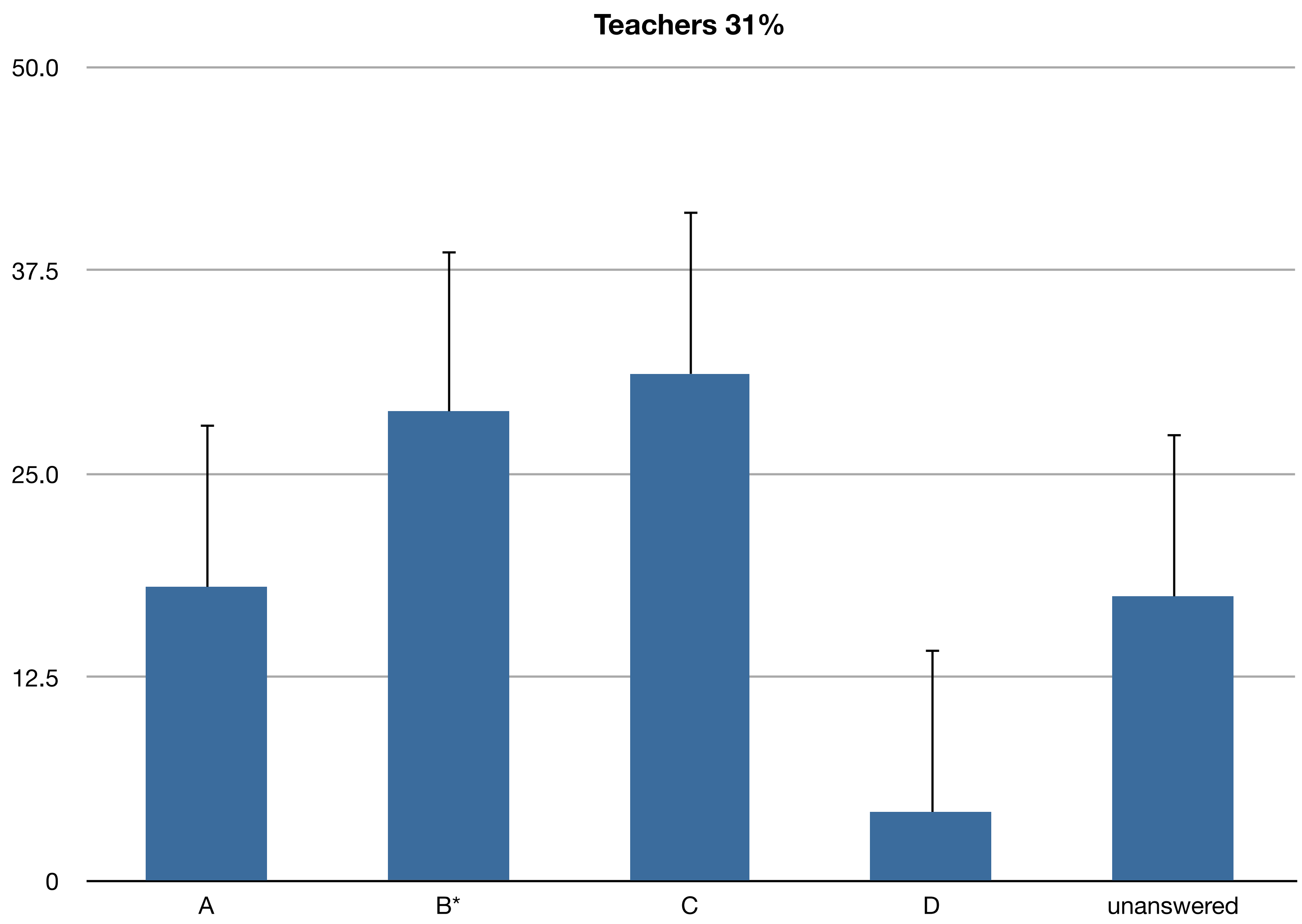
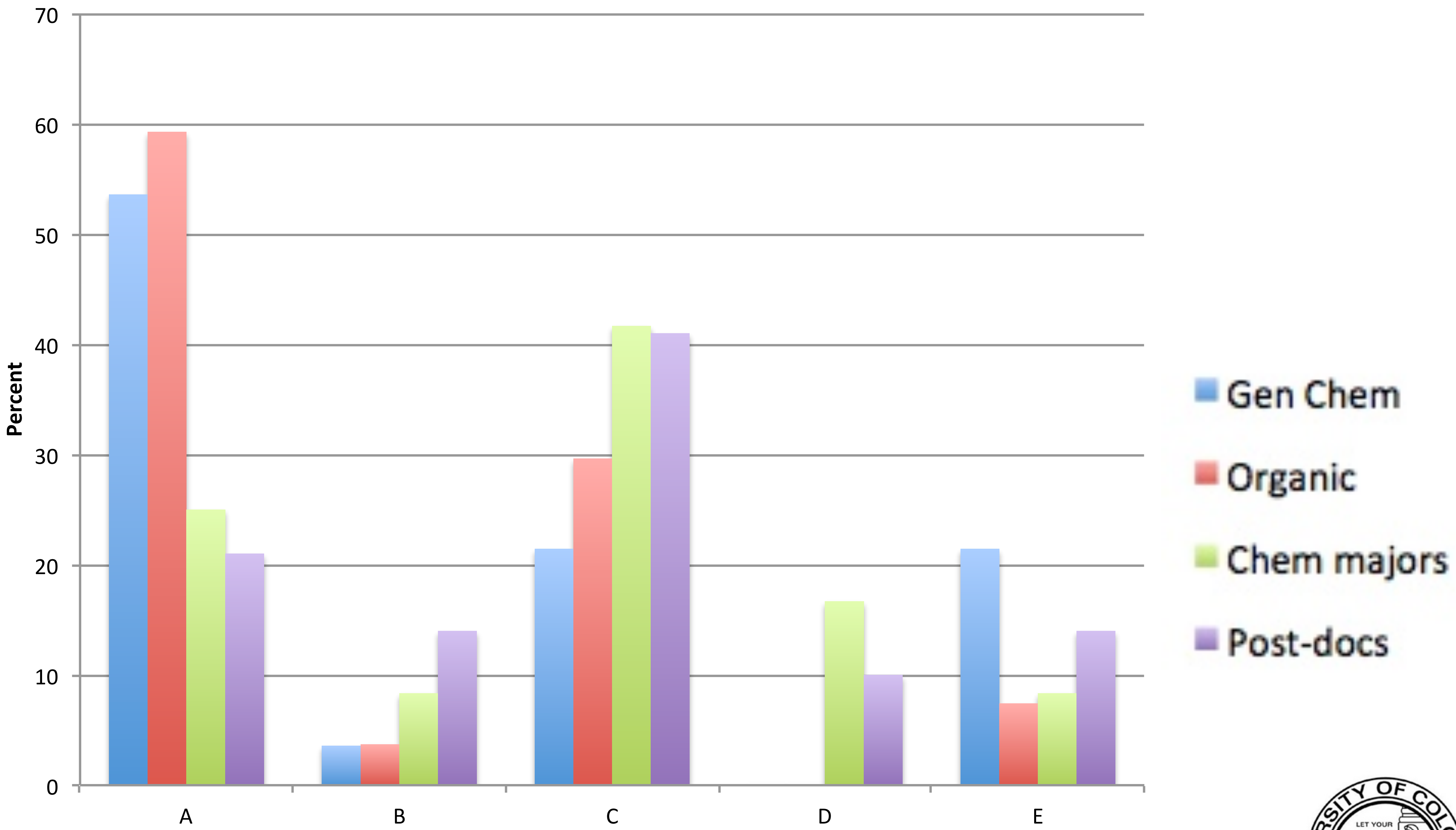


Why don't oil and water mix?

A. Like dissolves like
B. Oil and water have different densities which causes them to separate.
C. There are no attractive forces between oil molecules and water molecules, and therefore the hydrogen bonds between water molecules would require too much energy to break.
D. The entropy of the system is higher in the unmixed state, because non-polar molecules cause water molecules to cluster around them.
E. Oil molecules repel water molecules

Why don't oil and water mix?



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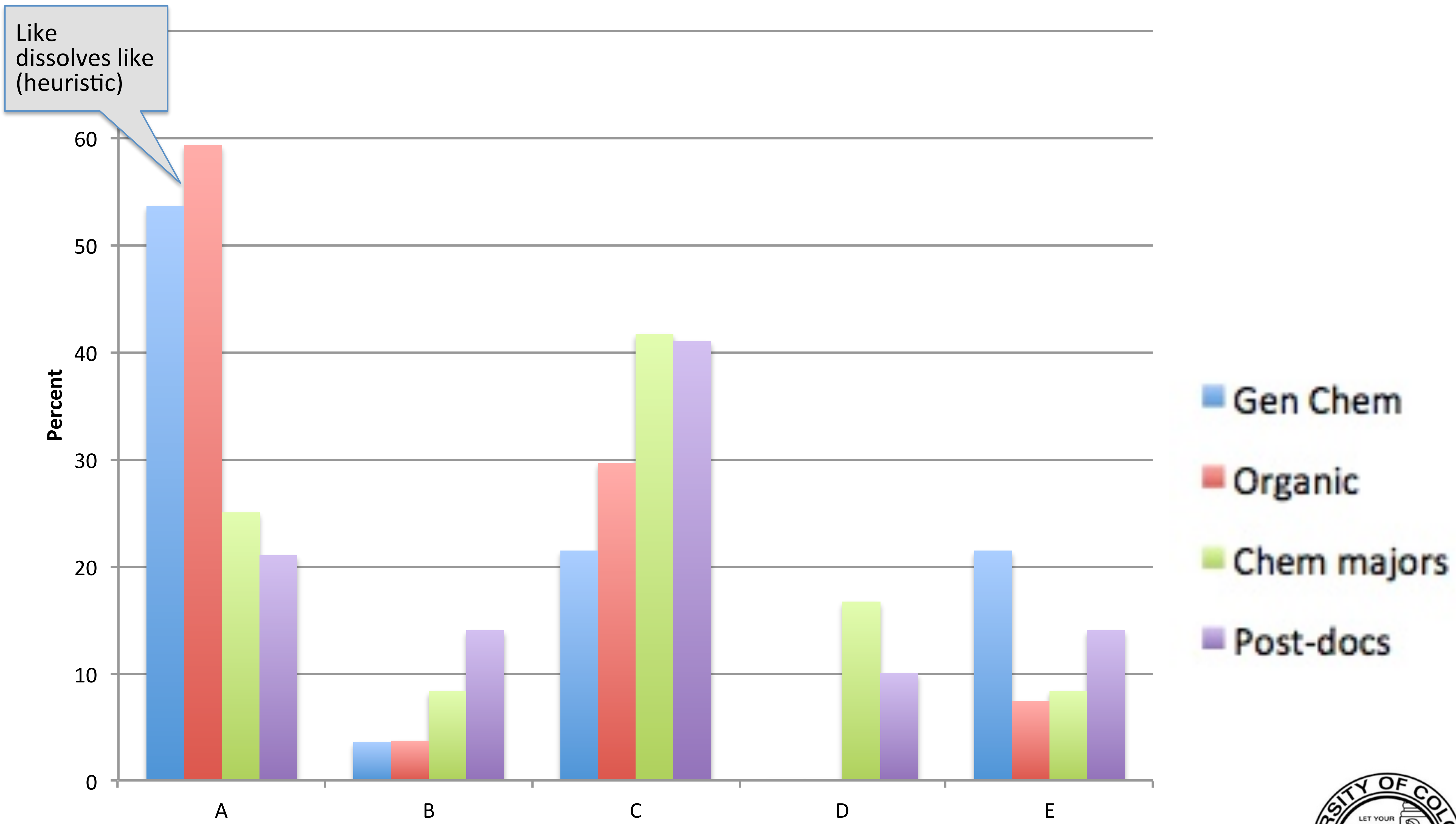

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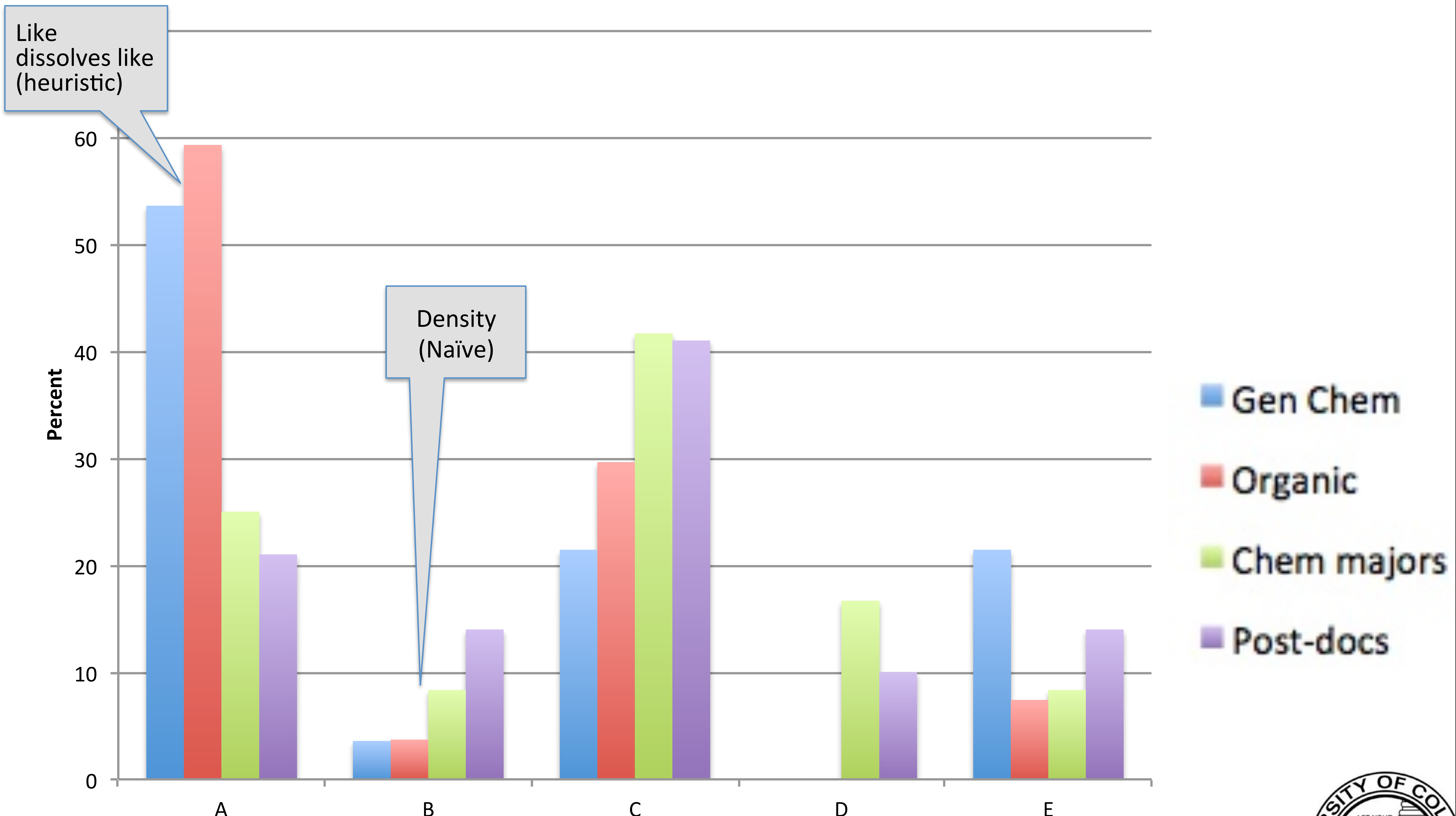

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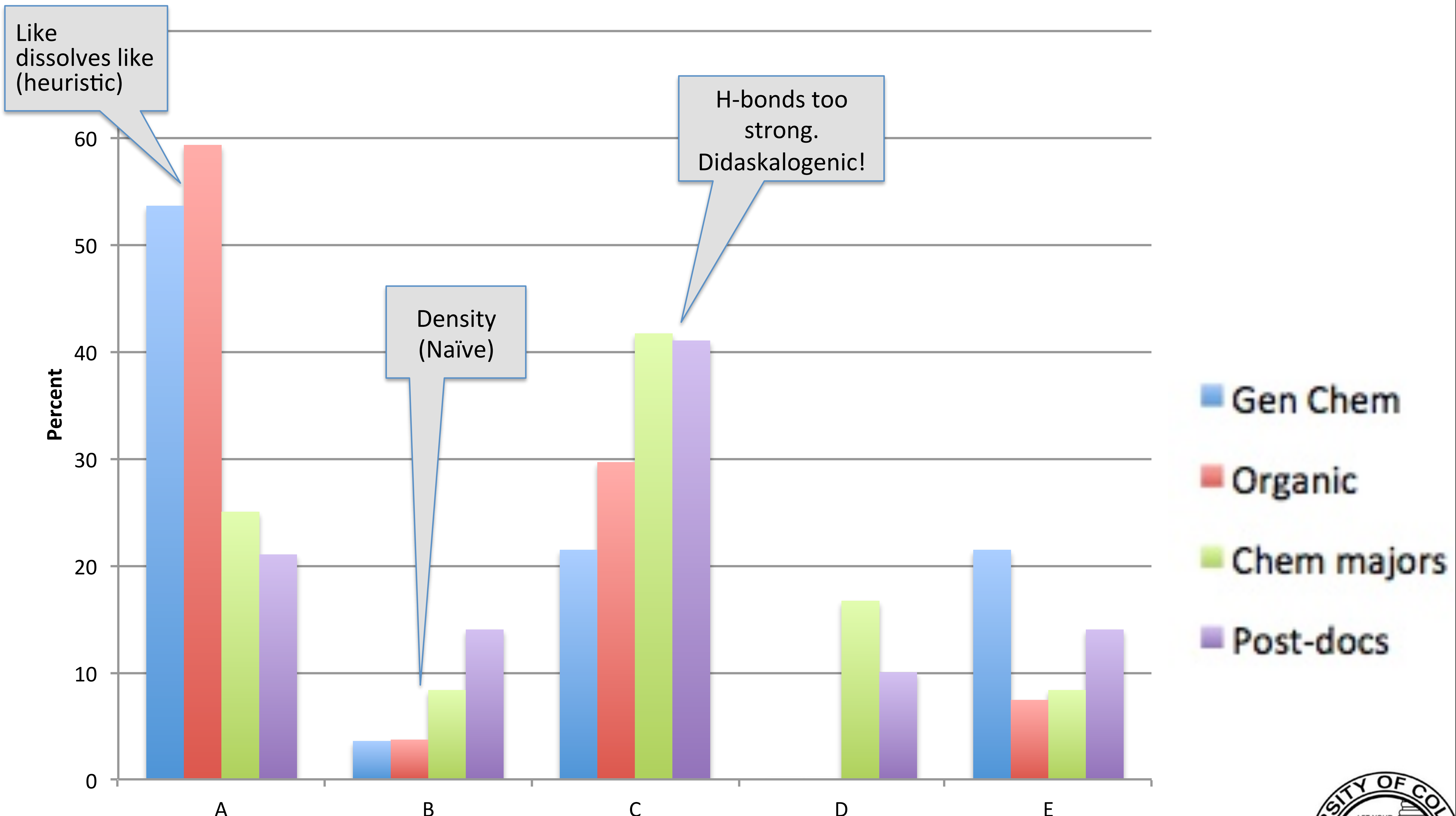

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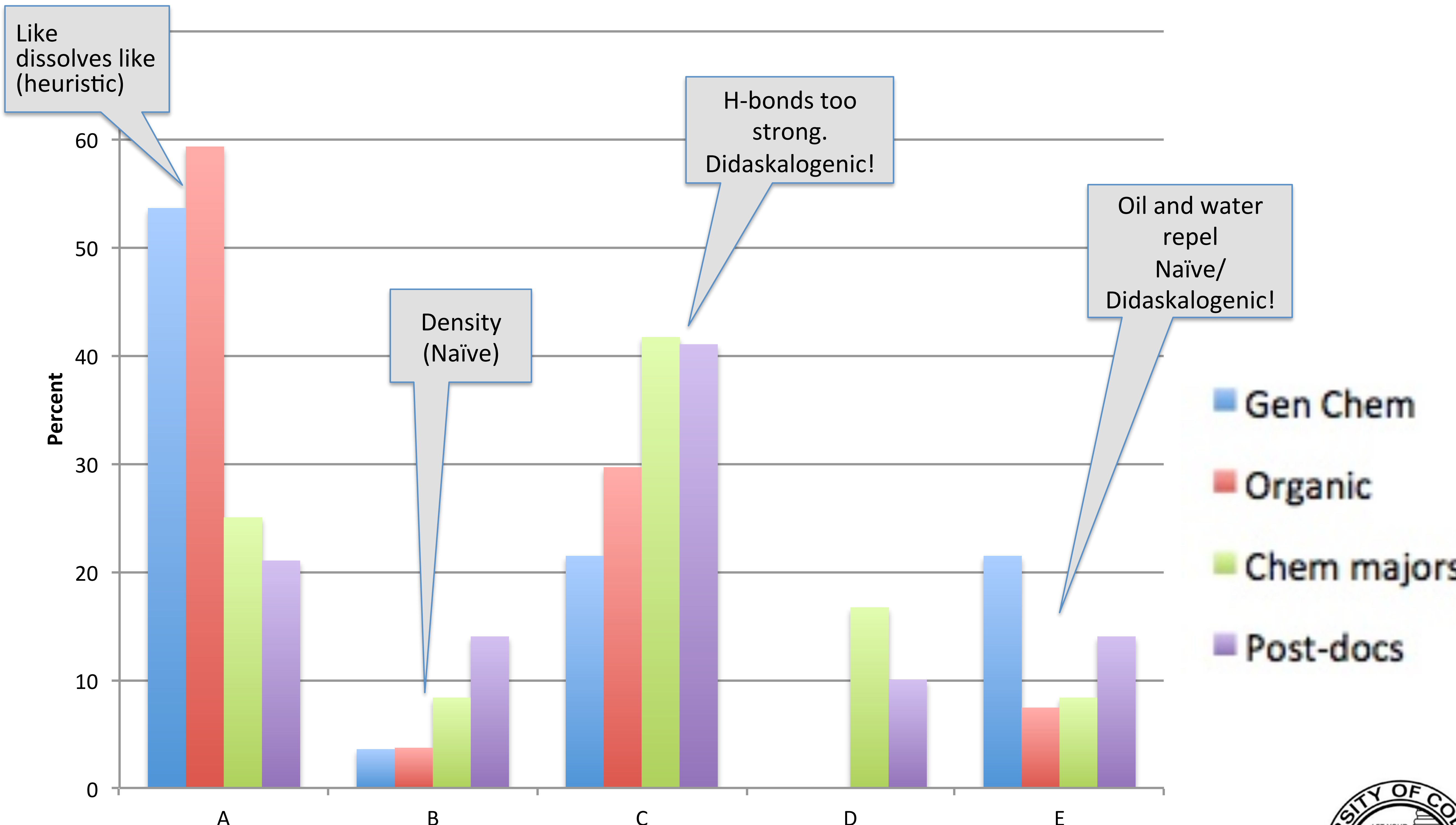

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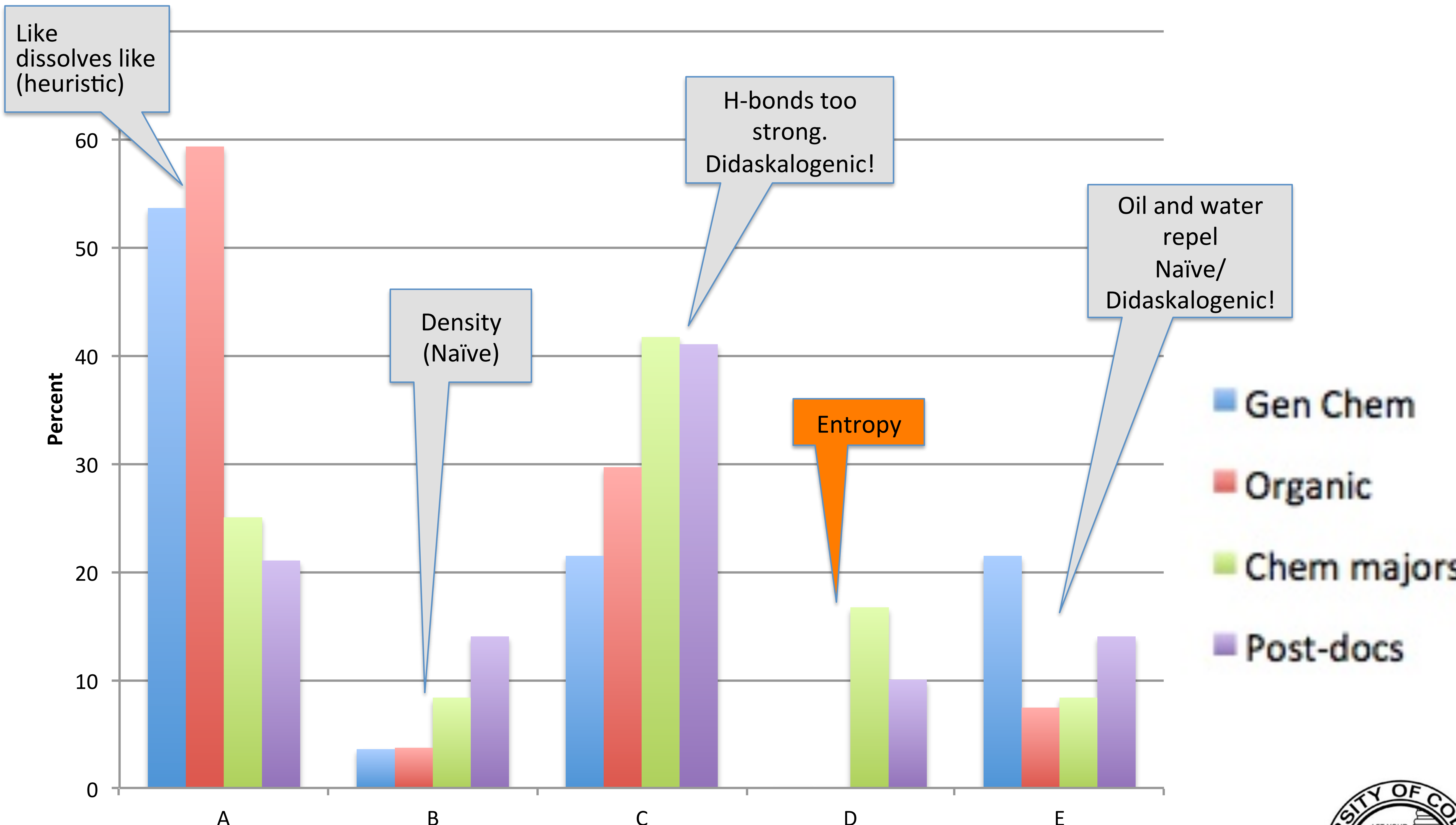

Molecular level confusions

Molecular level confusions

What makes DNA a good place to store information?

The hydrogen bonds that hold it together are very stable and difficult to break.

The bases always bind to their correct partner.

The sequence of bases does not greatly influence the structure of the molecule.

The overall shape of the molecule reflects the information stored in it.

Molecular level confusions

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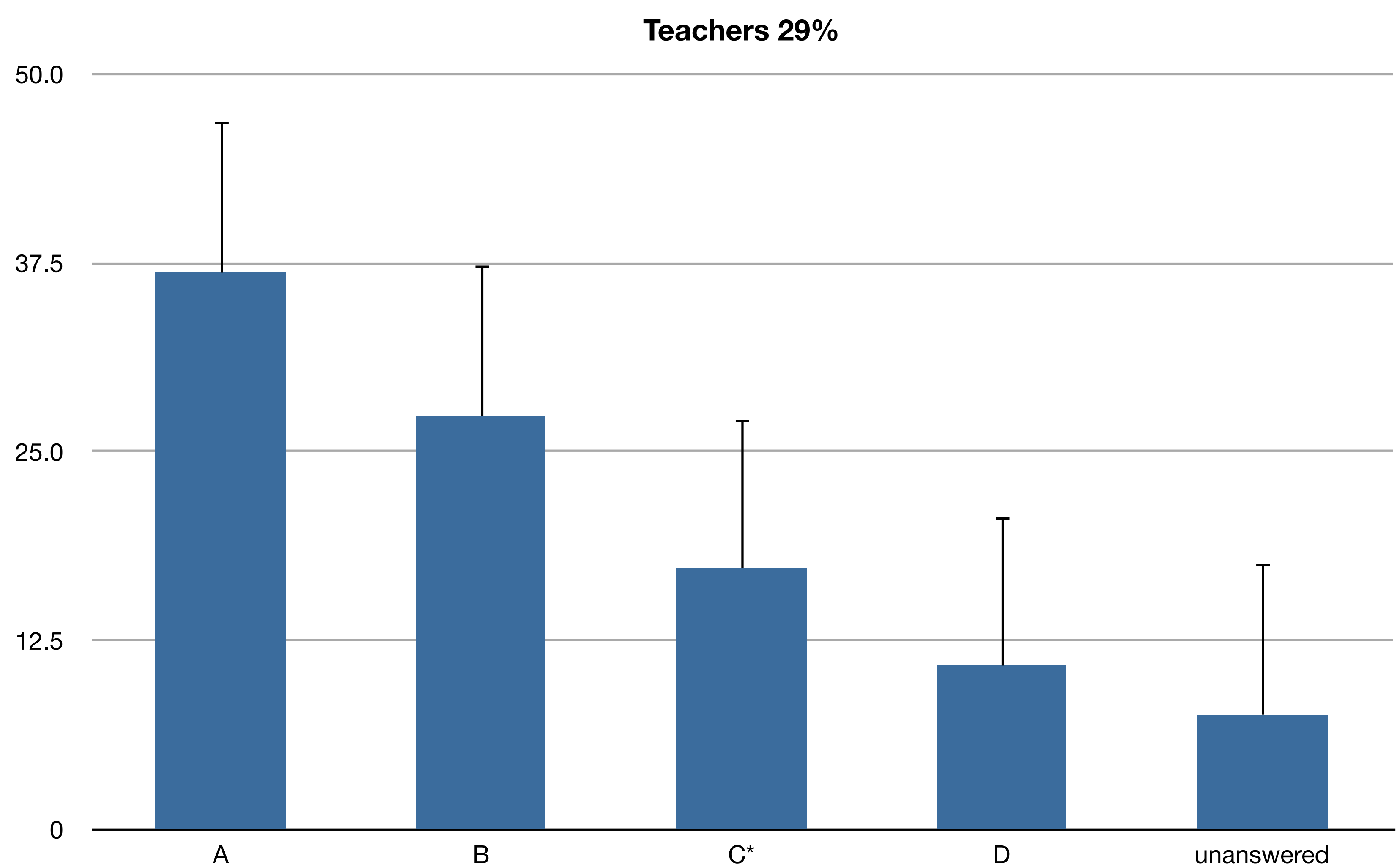

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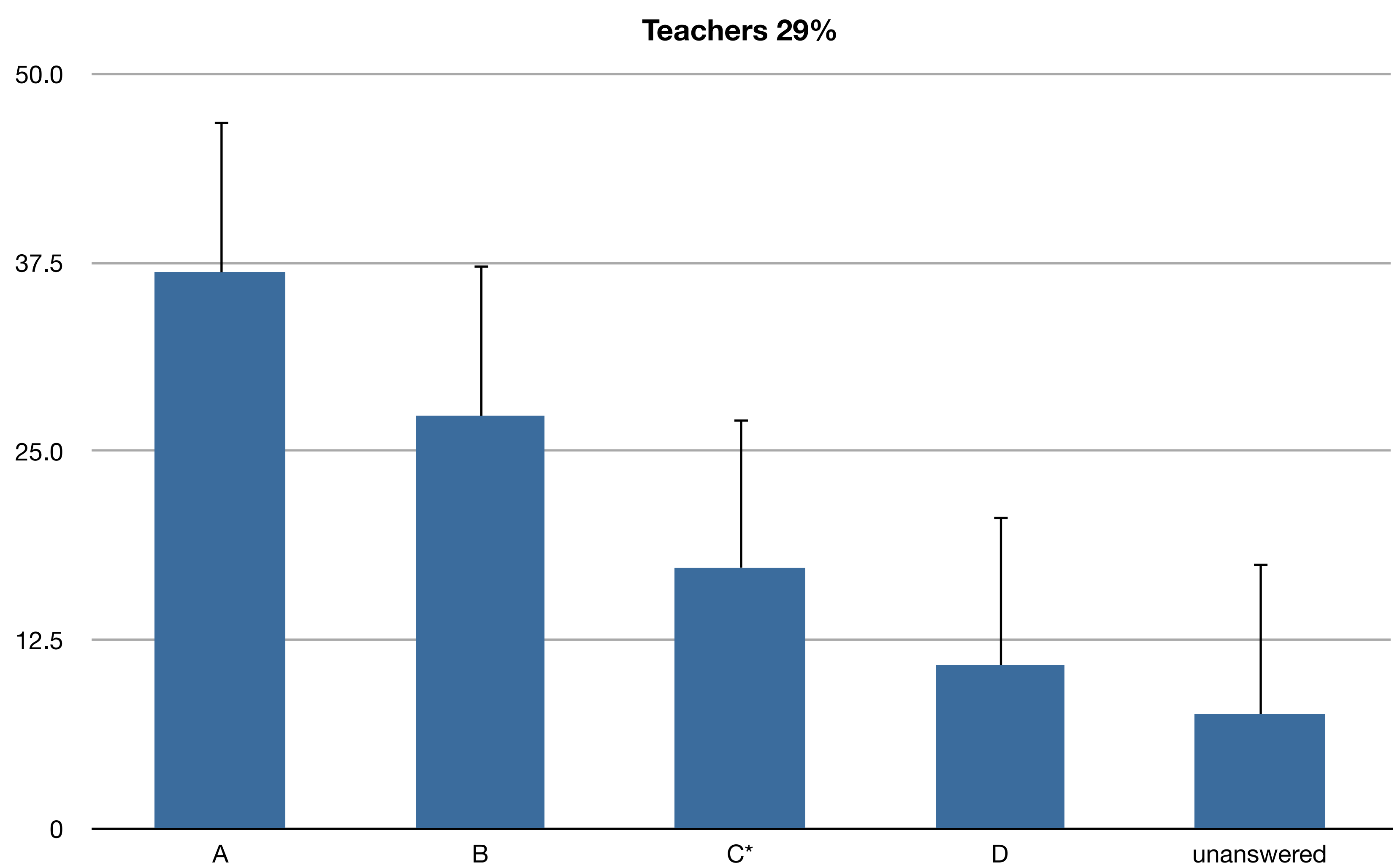

- teachers 29%

In retrospect, the BCi is not a true concept inventory:

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3) many CIs are based on assumption that “professionals” know the right answers! BCi questions are weird, and often confuse “experts”.

Published in: D. Kaplan (Ed.). (2004). *The Sage handbook of quantitative methodology for the social sciences* (pp. 391–408). Thousand Oaks, CA: Sage.

The Null Ritual
What You Always Wanted to Know About Significance Testing but Were Afraid to Ask

Gerd Gigerenzer, Stefan Krauss, and **Oliver Vitouch**[1]

No scientific worker has a fixed level of significance at which from year to year, and in all circumstances, he rejects hypotheses; he rather gives his mind to each particular case in the light of his evidence and his ideas. (Ronald A. Fisher, 1956, p. 42)

It is tempting, if the only tool you have is a hammer, to treat everything as if it were a nail. (A. H. Maslow, 1966, pp. 15–16)

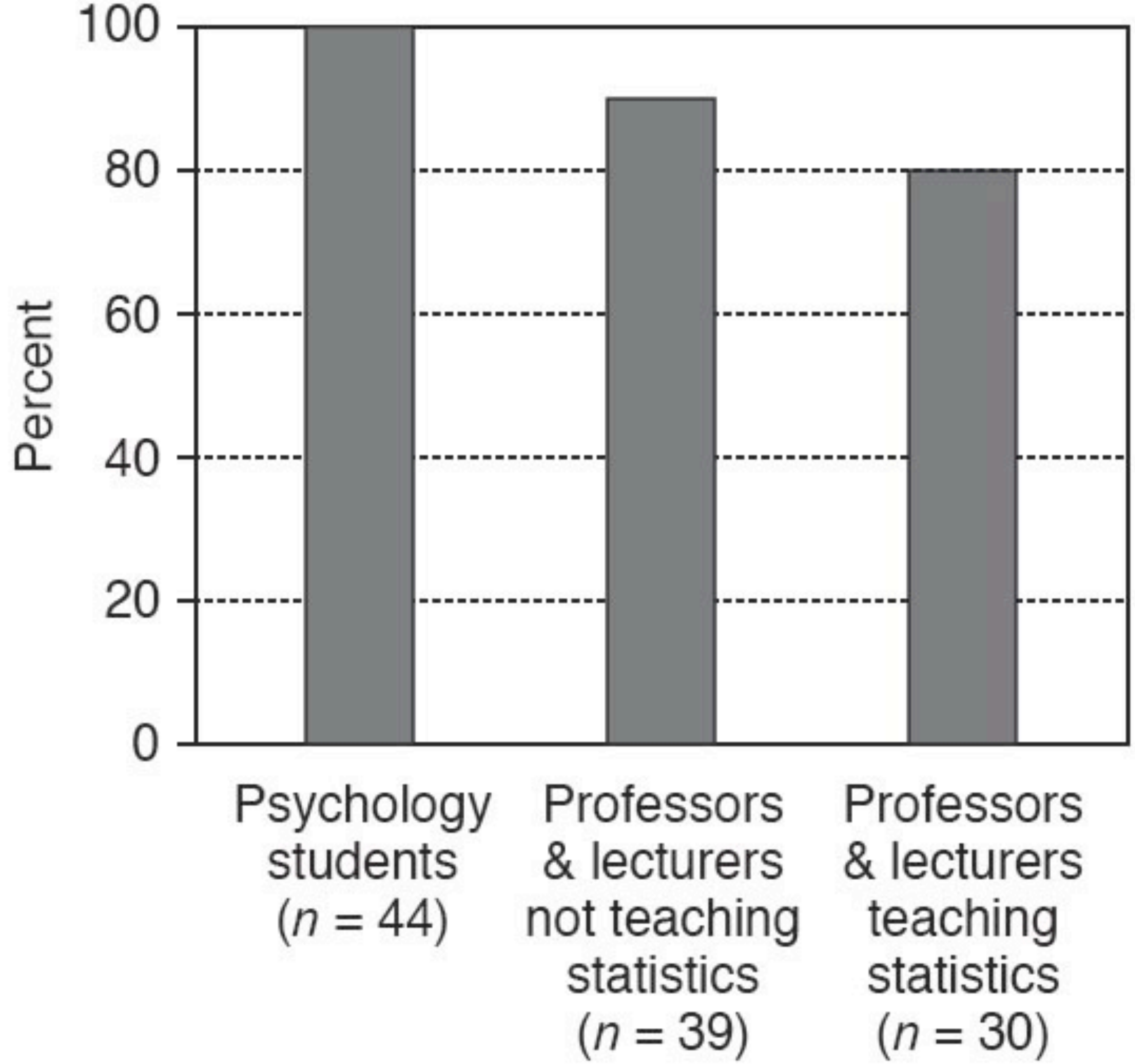

Figure 1. The Amount of Delusions About the Meaning of "p = .01".

Note. The percentage refer to the participants in each group who endorsed one or more of the six false statements (based on Haller & Krauss, 2002).

Gerd Gigerenzer, Stefan Krauss, and Oliver Vitouch

BCi questions as useful diagnostics: particular when students are asked to explain why wrong responses are wrong (and you listen to their answers).

time line

education

↓

job

↓

↓

↓

↓

↓

today

professor → collaboration with Melanie Cooper, Clemson

↑ *what is fundamental?*

Development and Assessment of Chemistry, Life, the Universe & Everything (CLUE)

↓ *what do students know?*

Development of SocraticGraphs / BeSocratic

Caleb Trujillo

Trujillo & Klymkowsky, *Using graph-based assessments within Socratic tutorials to reveal and refine students' analytical thinking about molecular networks. BAMED submitted.*

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Can junior/senior level molecular biology students transfer their understanding to the analysis a simple molecular system?

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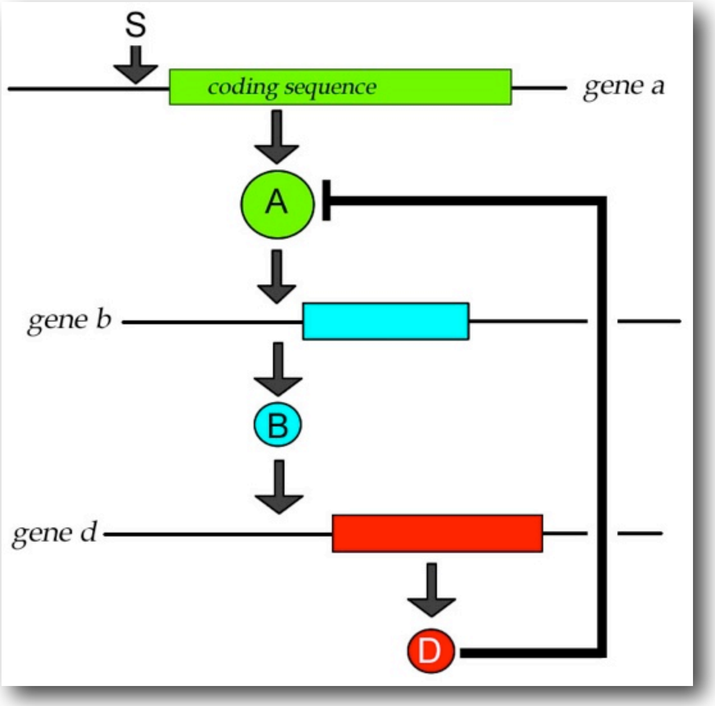

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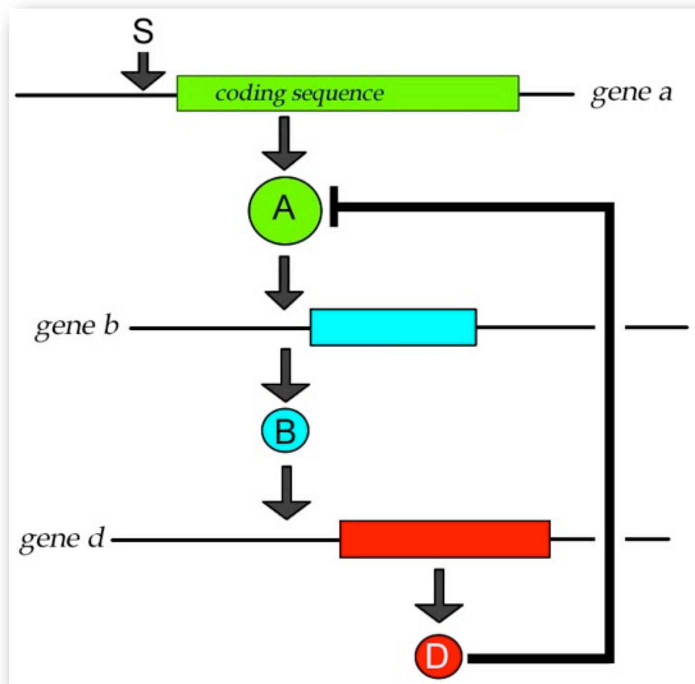

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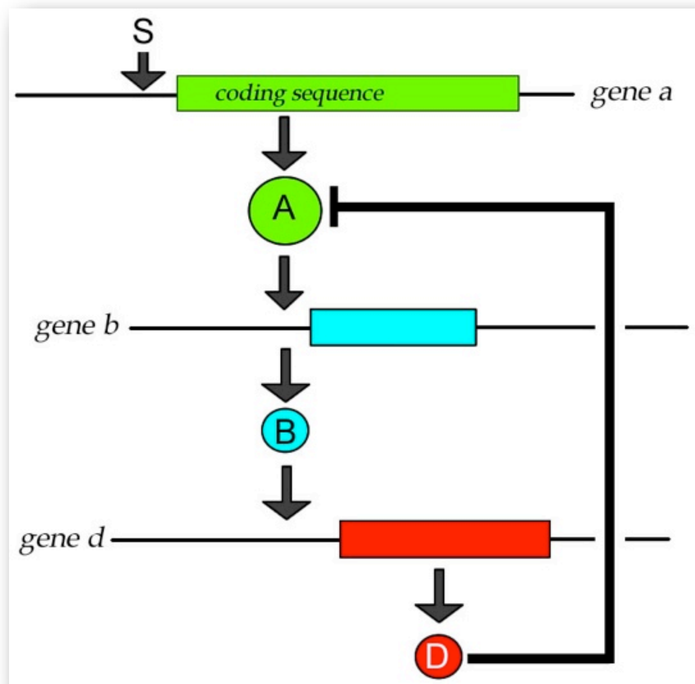

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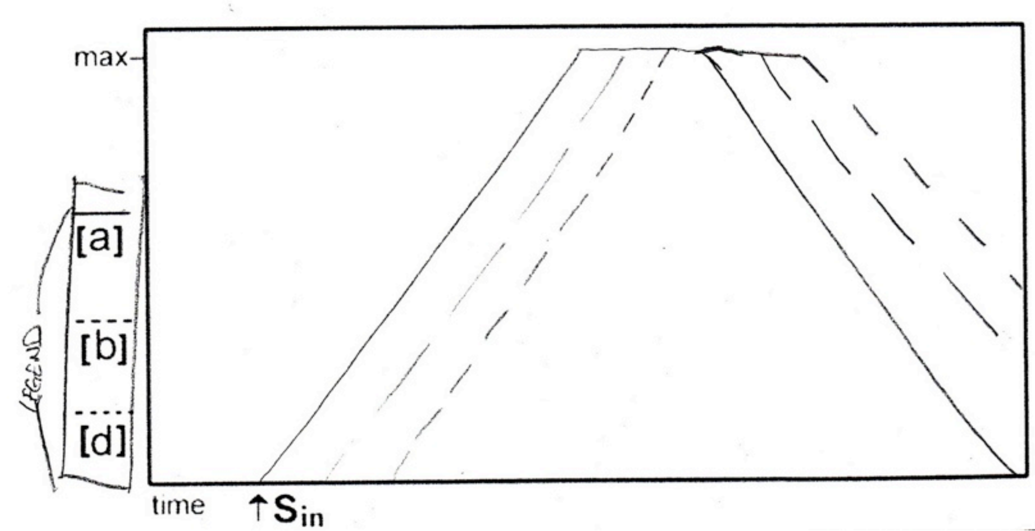

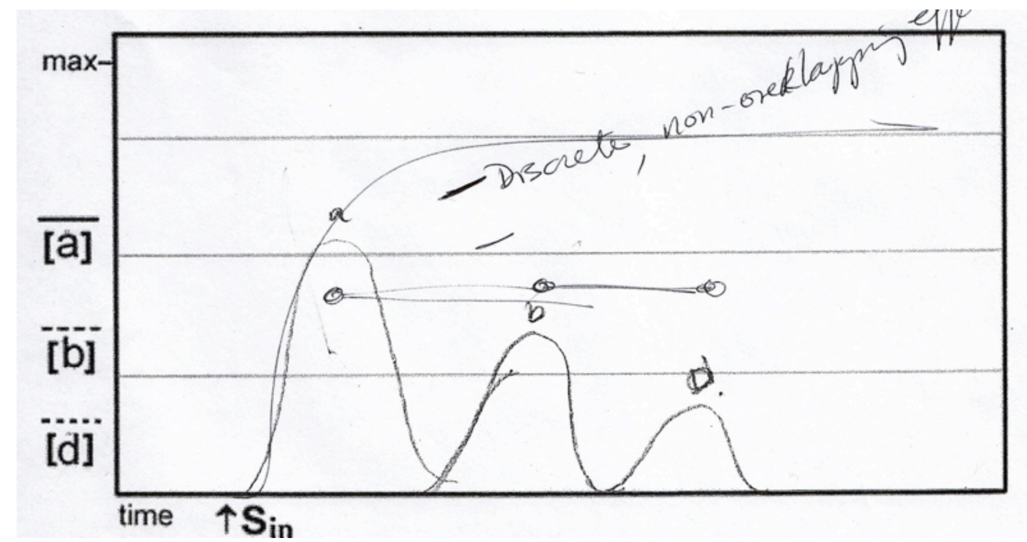

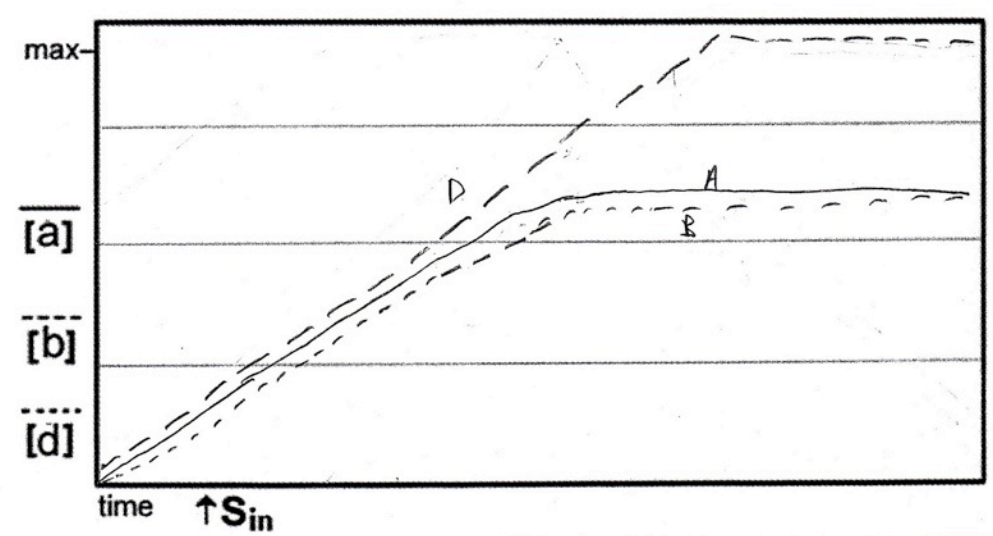

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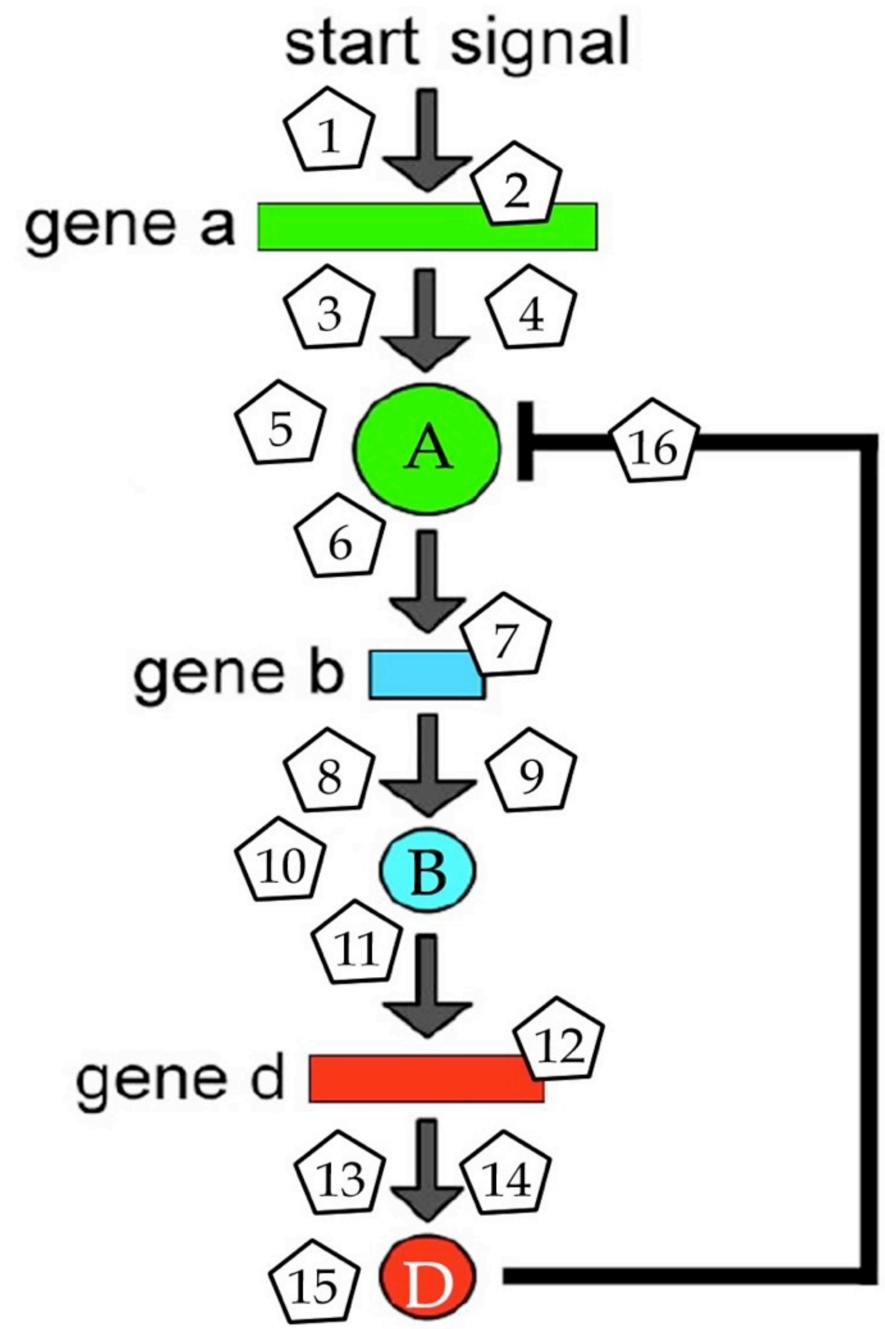
16 assumptions: grouped into four major areas:



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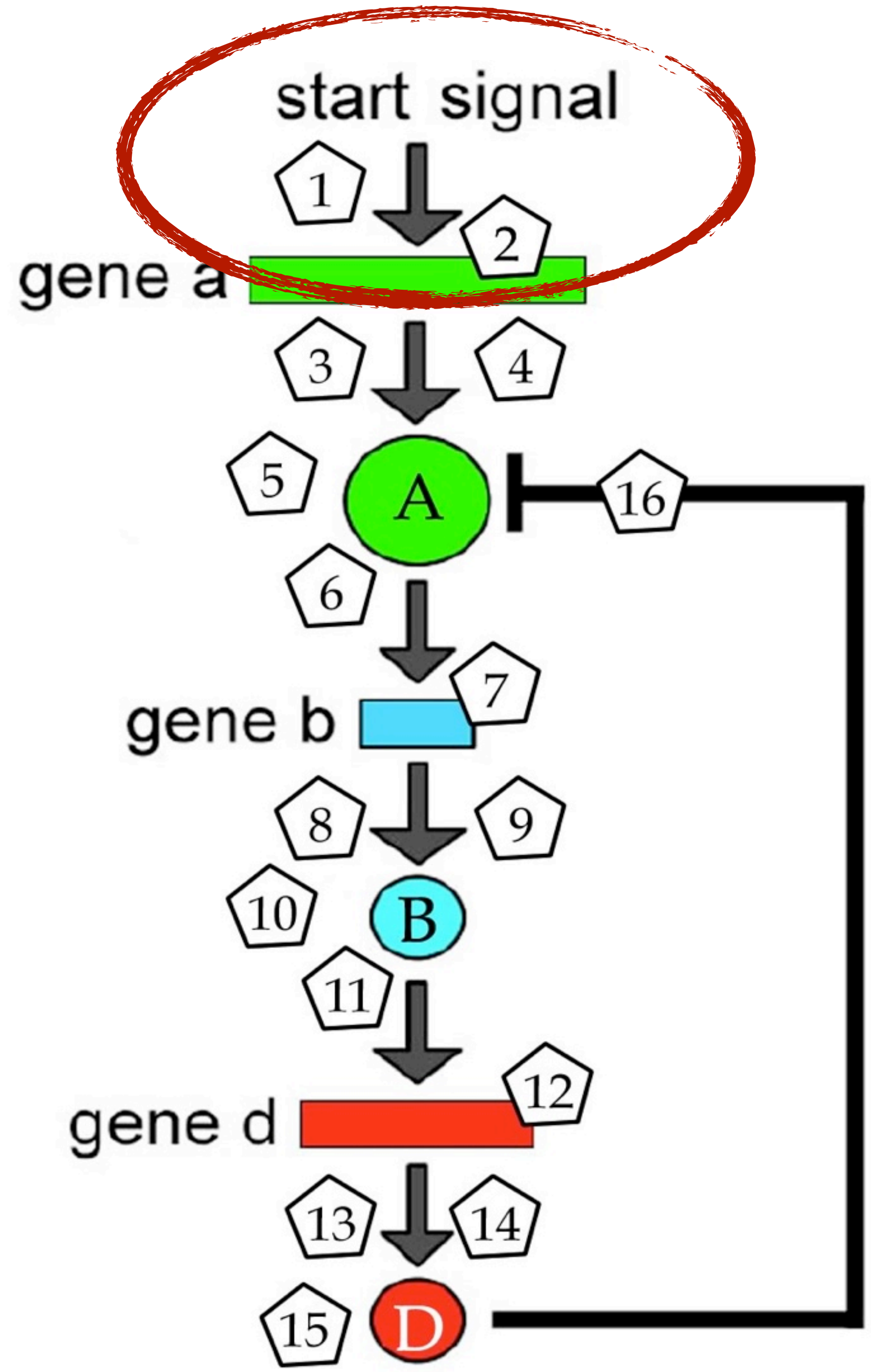

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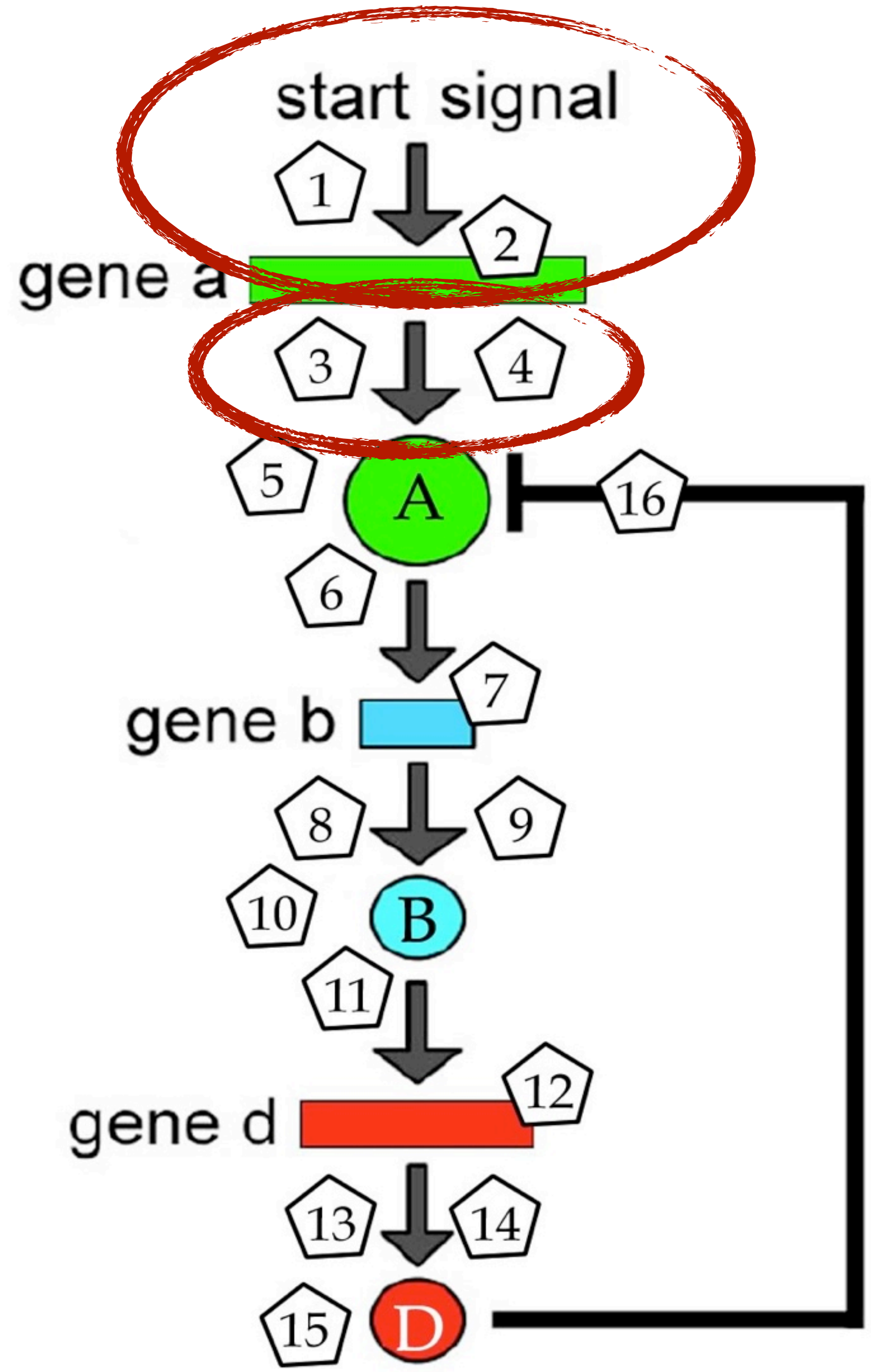

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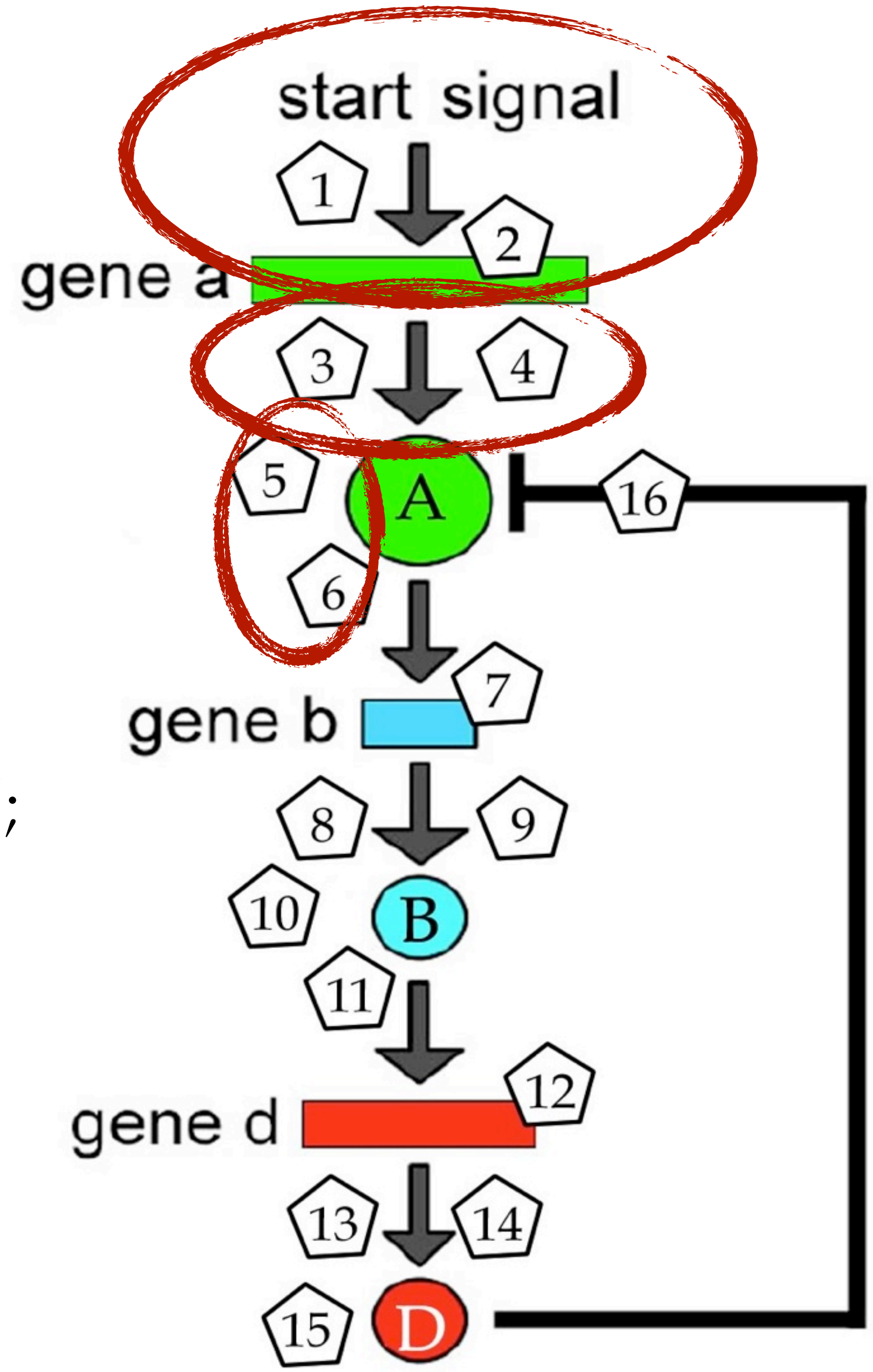

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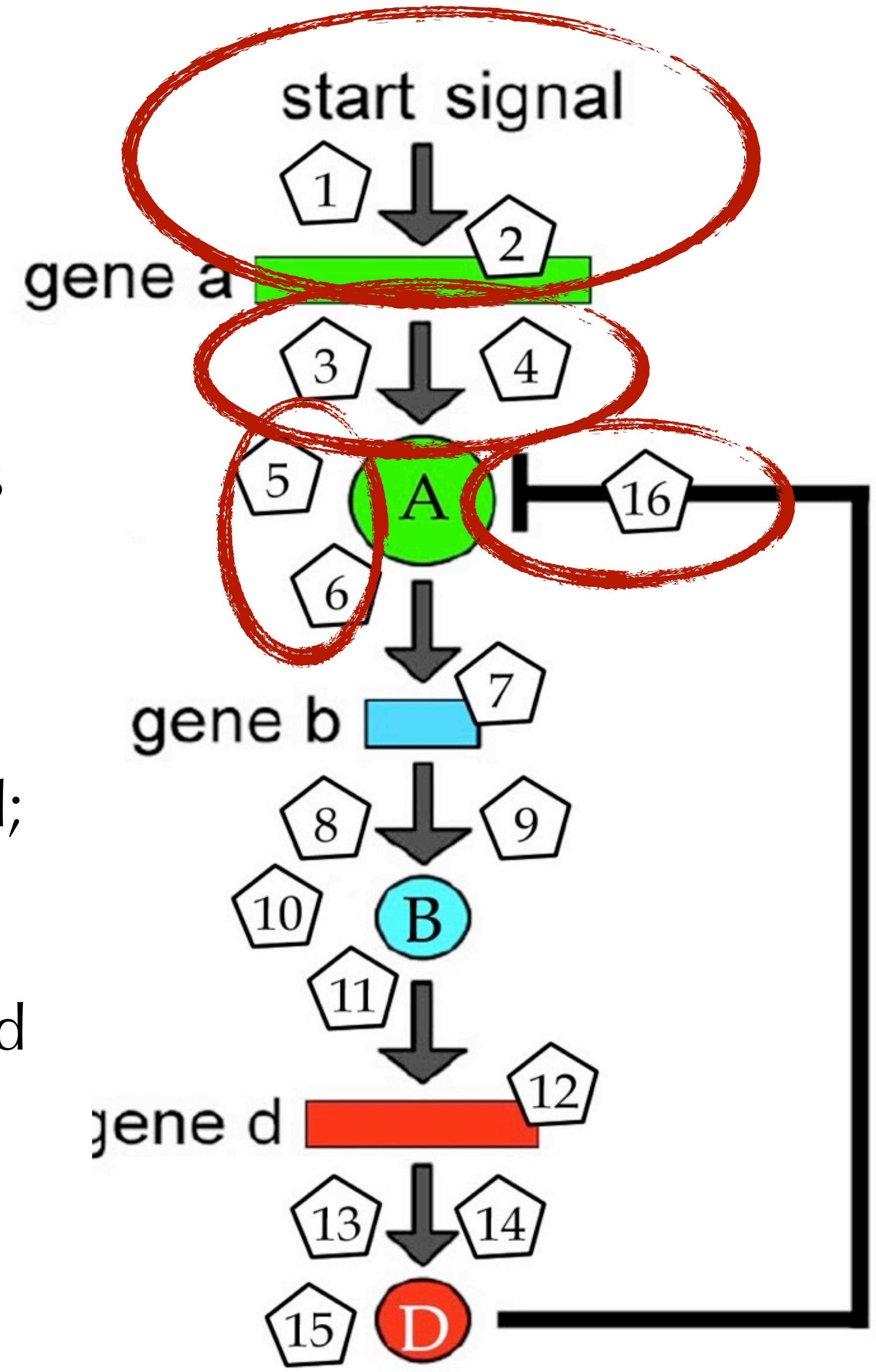

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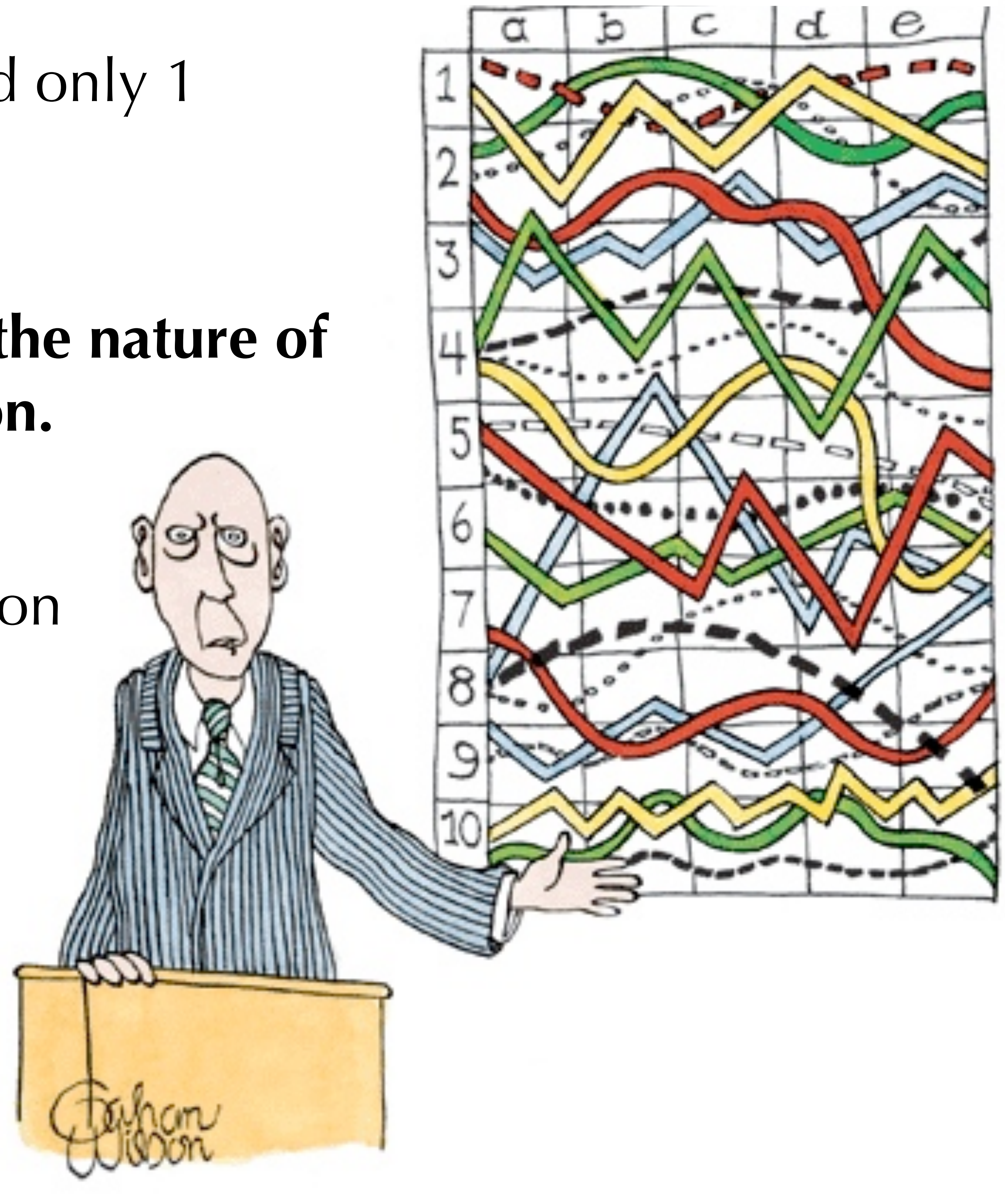

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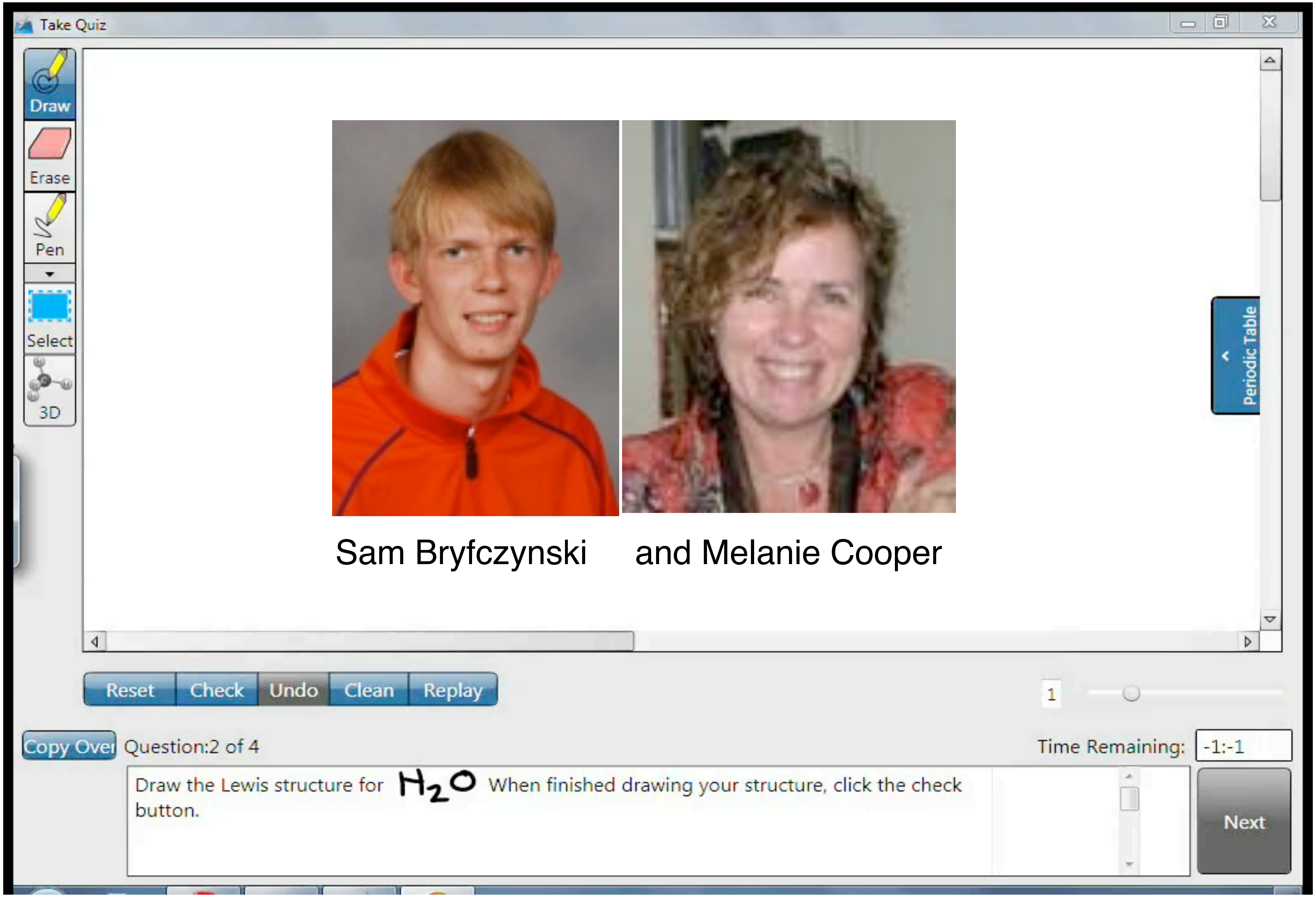
OrganicPad: inspiration for SocraticGraphs



Cooper, et al. *Chem. Educ. Res. Pract.* **2009**, 10, 296-301.
Cooper et al.. 2010 J. Chem Ed.,DOI: 10.1021/ed900004y.

Embodied Cognition – “Gesturing Makes Learning Last”

Cook et al., 2008. *Cognition* **106**, 1047

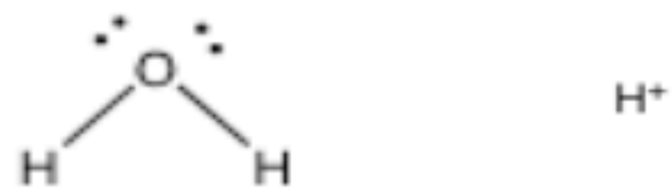
Embodied Cognition – “Gesturing Makes Learning Last”

BeSocratic™

Fullscreen

The arrow always starts on an **electron source** (a nucleophile) and ends on an **electron sink** (an electrophile)

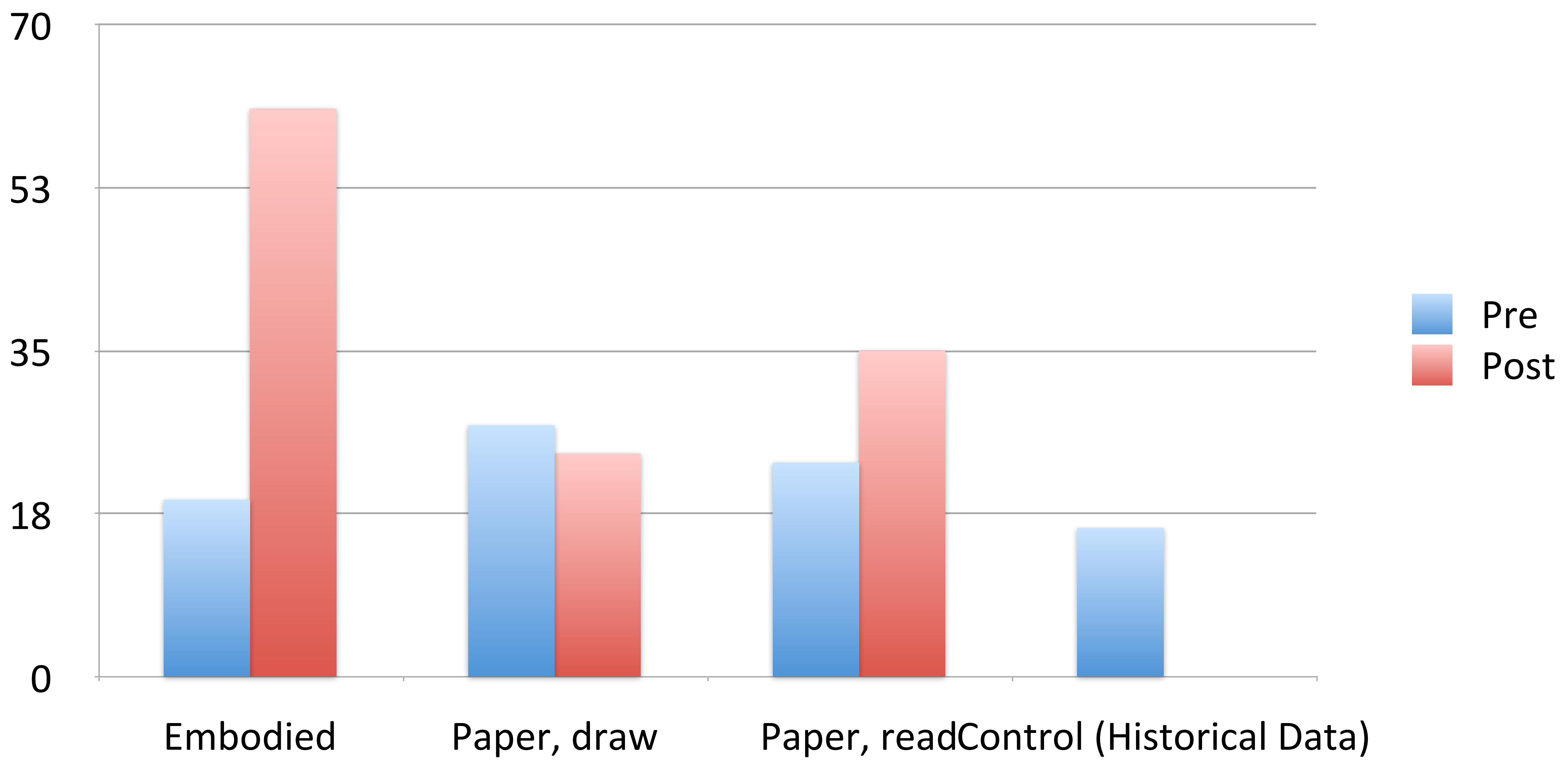
Put your finger on the electron source and trace the path of the electrons from the electron **source** to the electron **sink**



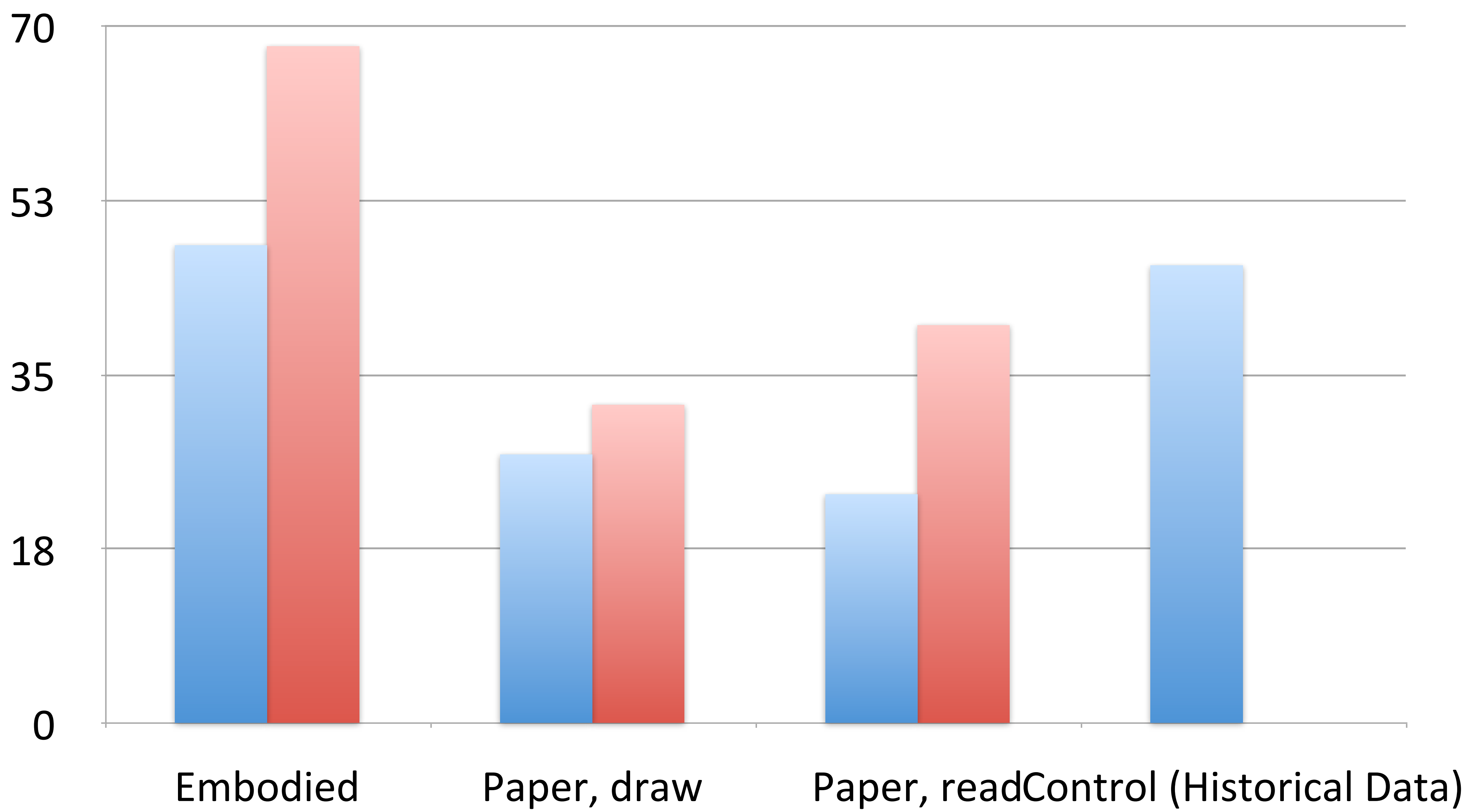
Step 7 of 20

Cook et al., 2008. *Cognition* **106**, 1047

Far Transfer Success Rate (%)



Far Transfer Mechanism Use (%)



BeSocratic/SocraticGraphs

A free-form graphical representation system designed to capture, recognize, **and respond** to student inputs and common mistakes using "prods and perturbations".

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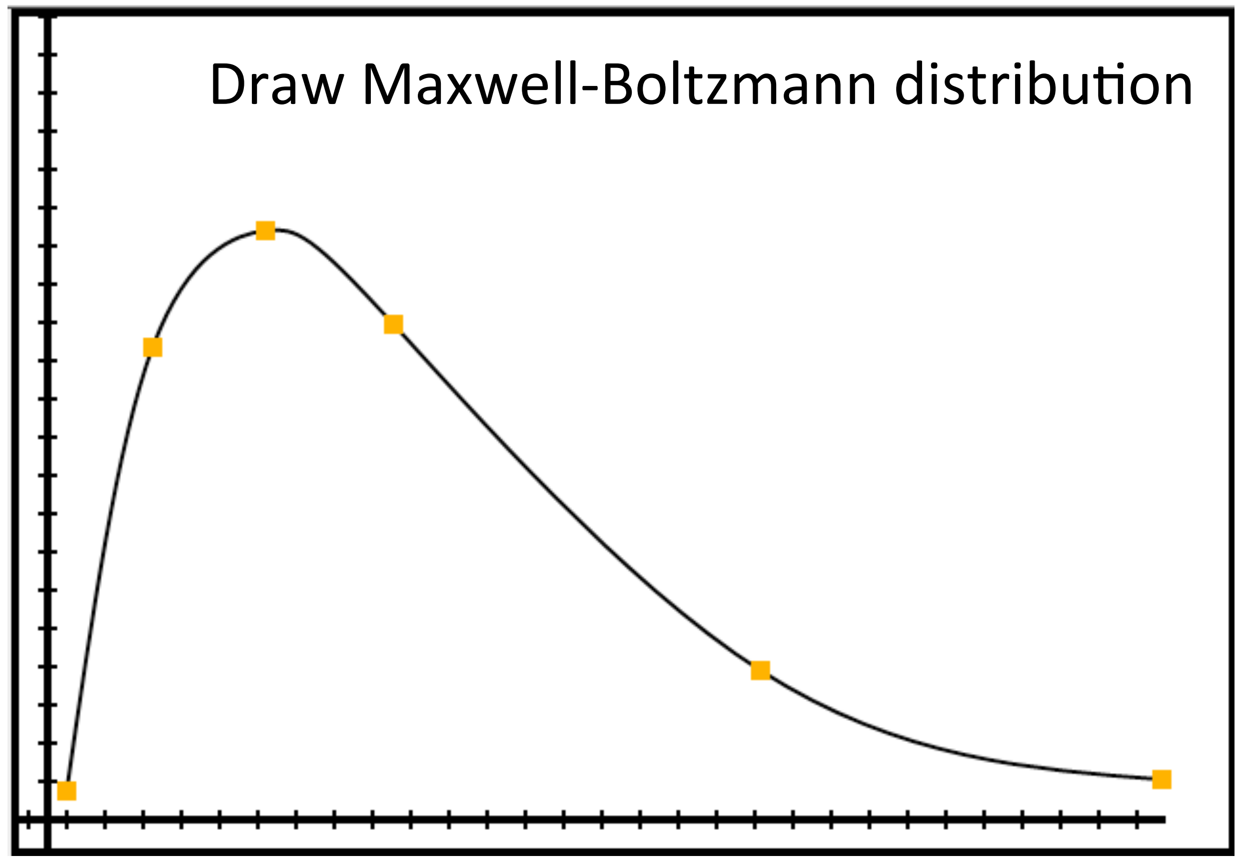

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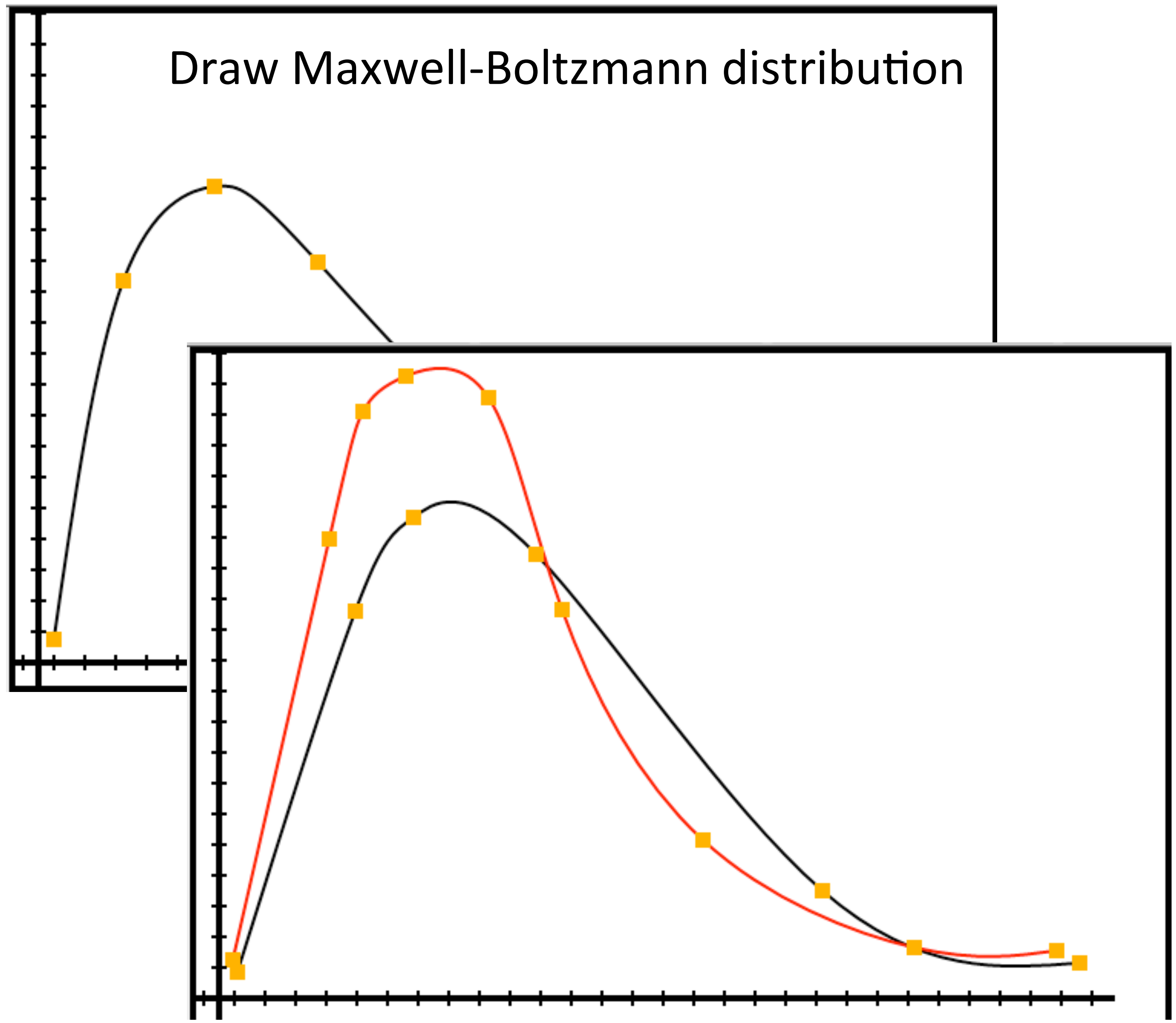

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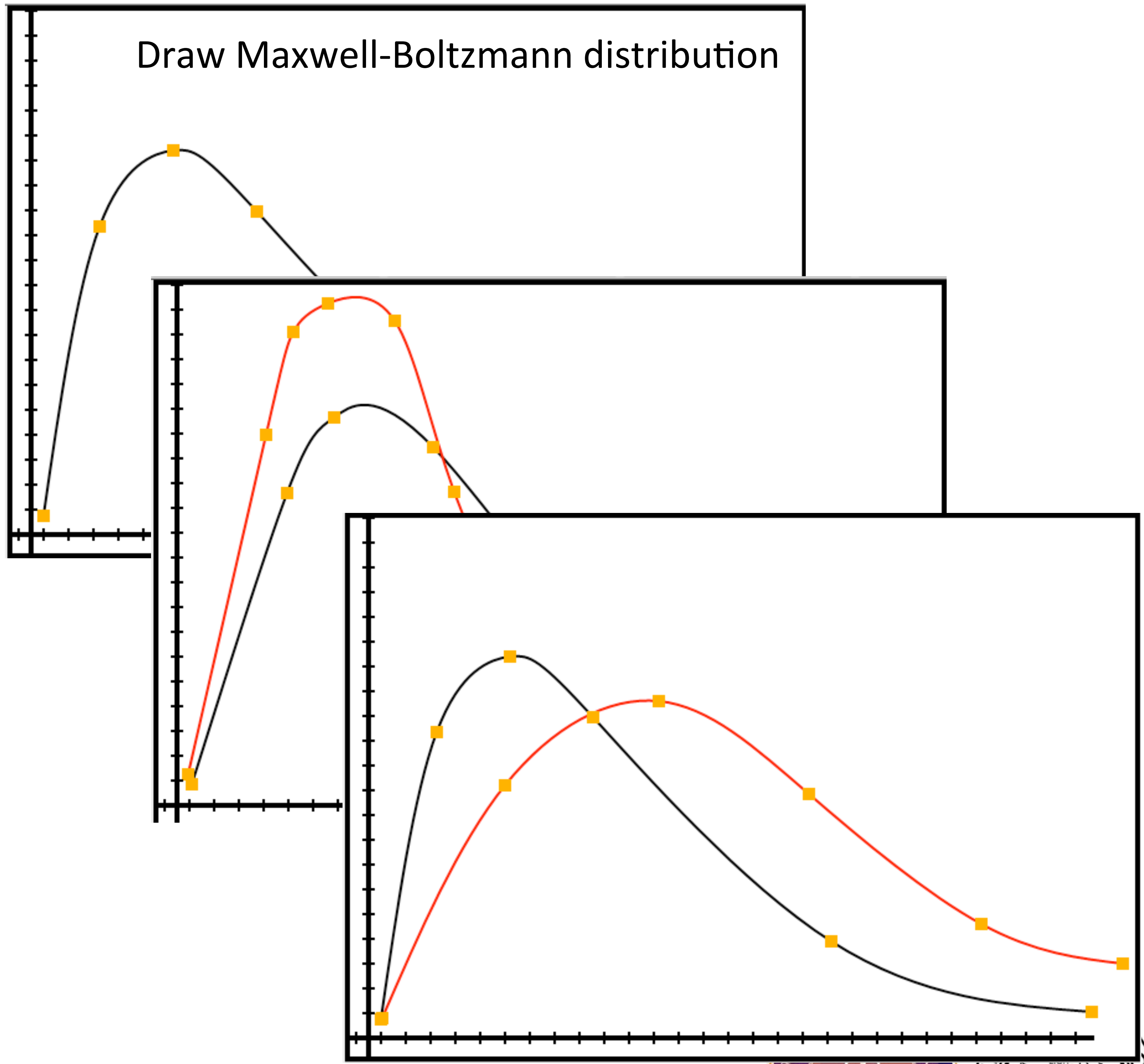
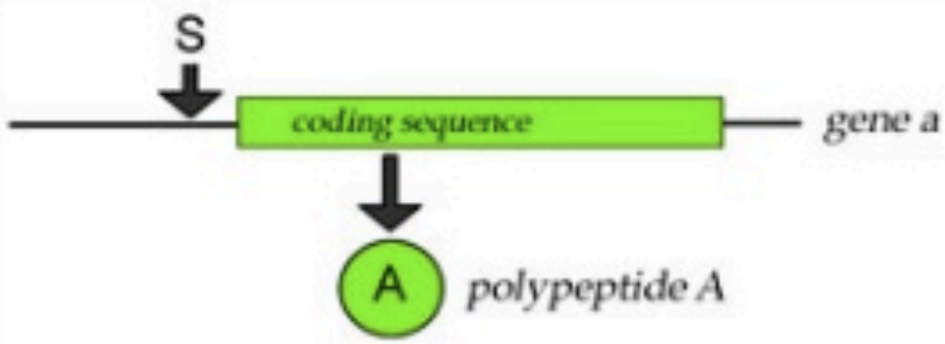
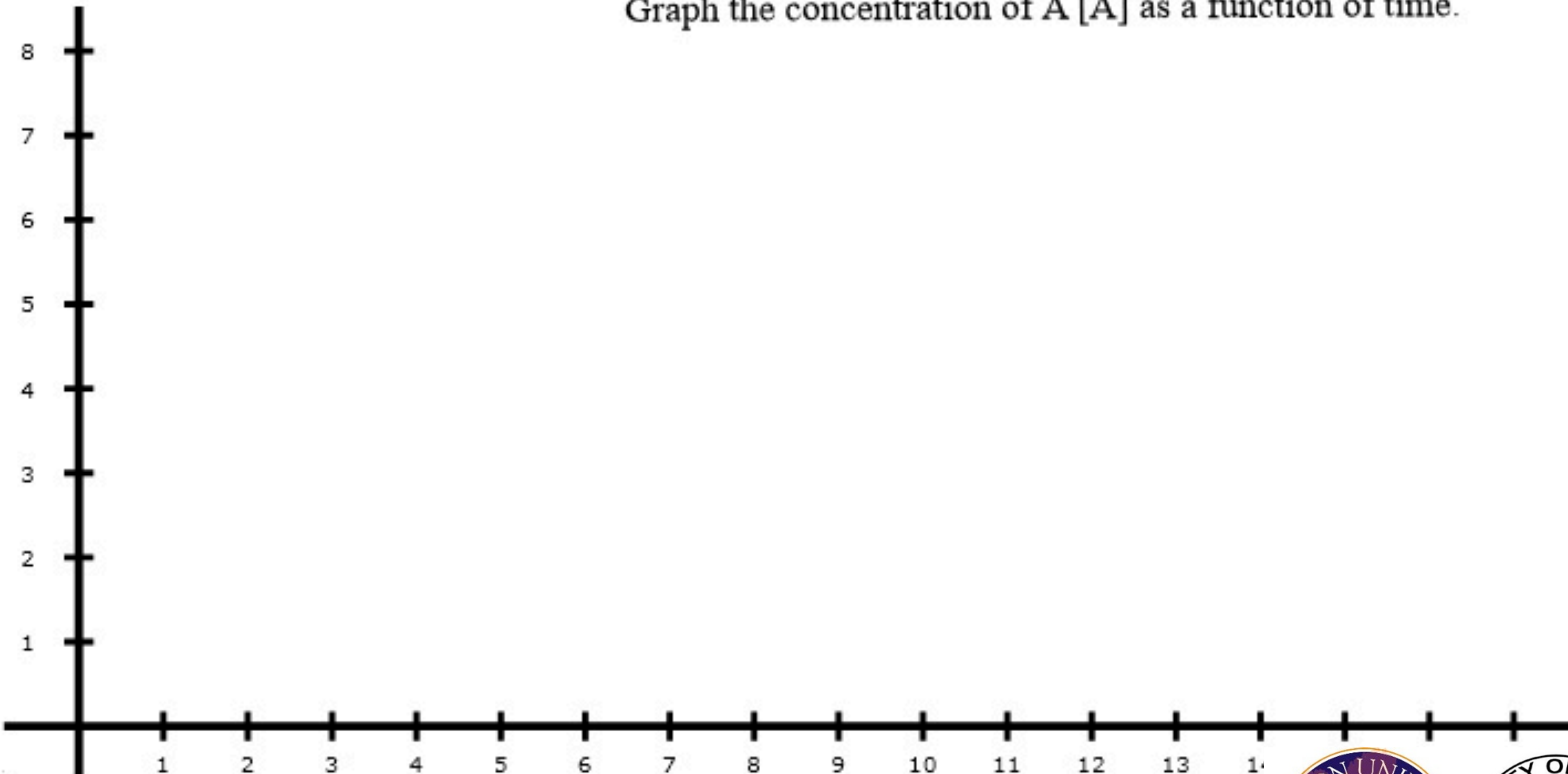




Let us try and predict how our simple system behaves.

At time 0, the concentration of A polypeptide is 0.
S is added at time = 2 and remains in the system thereafter.
Expression of the gene is dependent upon the presence of S.
The concentration of [A] reaches its maximum at time t = 12.

Graph the concentration of A [A] as a function of time.



Draw Adjust Erase Reset Unknown Check

SocraticGraphs™

time line

education

job

today

professor

with Melanie Cooper, Clemson

Development and Assessment of Chemistry, Life, the Universe & Everything (CLUE)

Development of SocraticGraphs / BeSocratic

Chemistry has an image problem

Chemistry has an image problem

"Chemistry is the subject that at least 6 out of every 6.0225 Americans insist they "flunked in high school."

Angier, N. (2007). ***The canon: A whirligig tour of the beautiful basics of science. New York: Houghton Mifflin.***

If you listen to chemists, it is biologists′ fault that students believe that **breaking bonds** releases energy, but

Based on ed's tools question analyses by Cooper et al.

If you listen to chemists, it is biologists' fault that students believe that **breaking bonds** releases energy, but

yet...

Level	% with misconceptions
Gen Chem (77)	50
Organic (172)	65
Inorganic (13)	54
Analytical (35)	51
P Chem (16)	56
Graduate students (21)	68
Post Docs (25)	68

Based on ed's tools question analyses by Cooper et al.

Evidence that current textbook design and approaches to teaching actually are counterproductive

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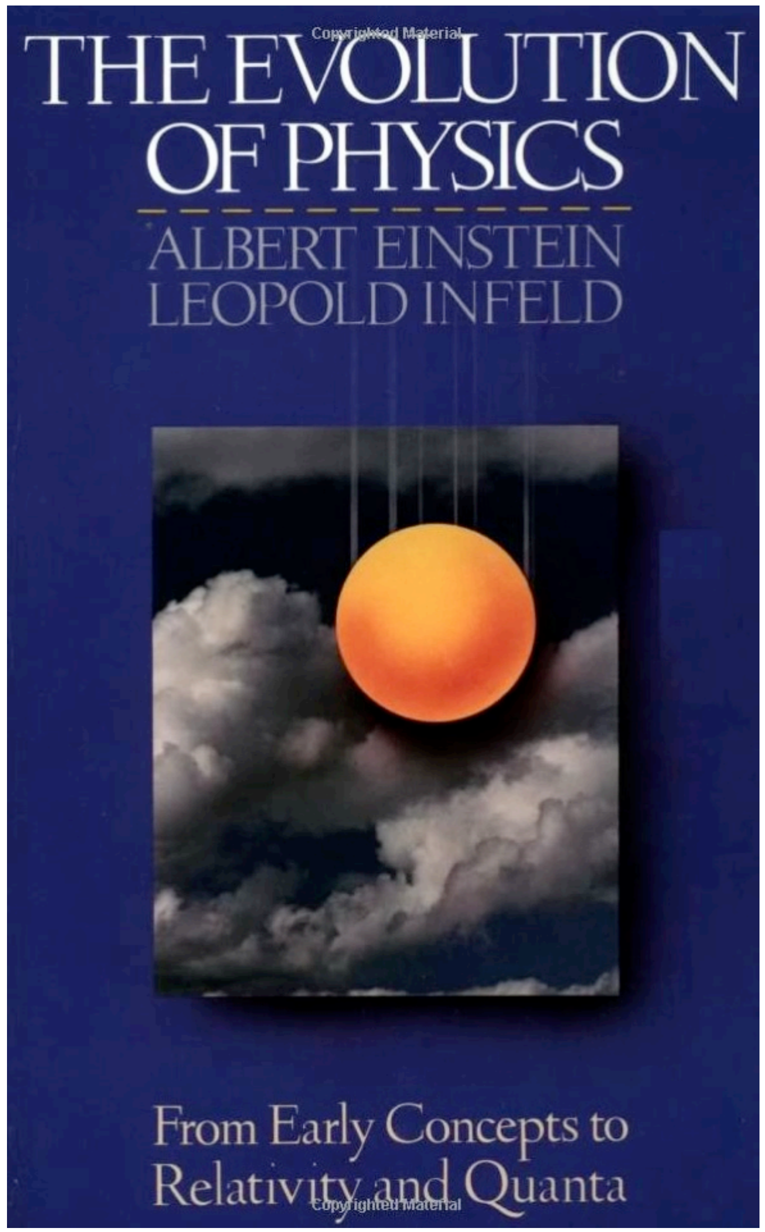

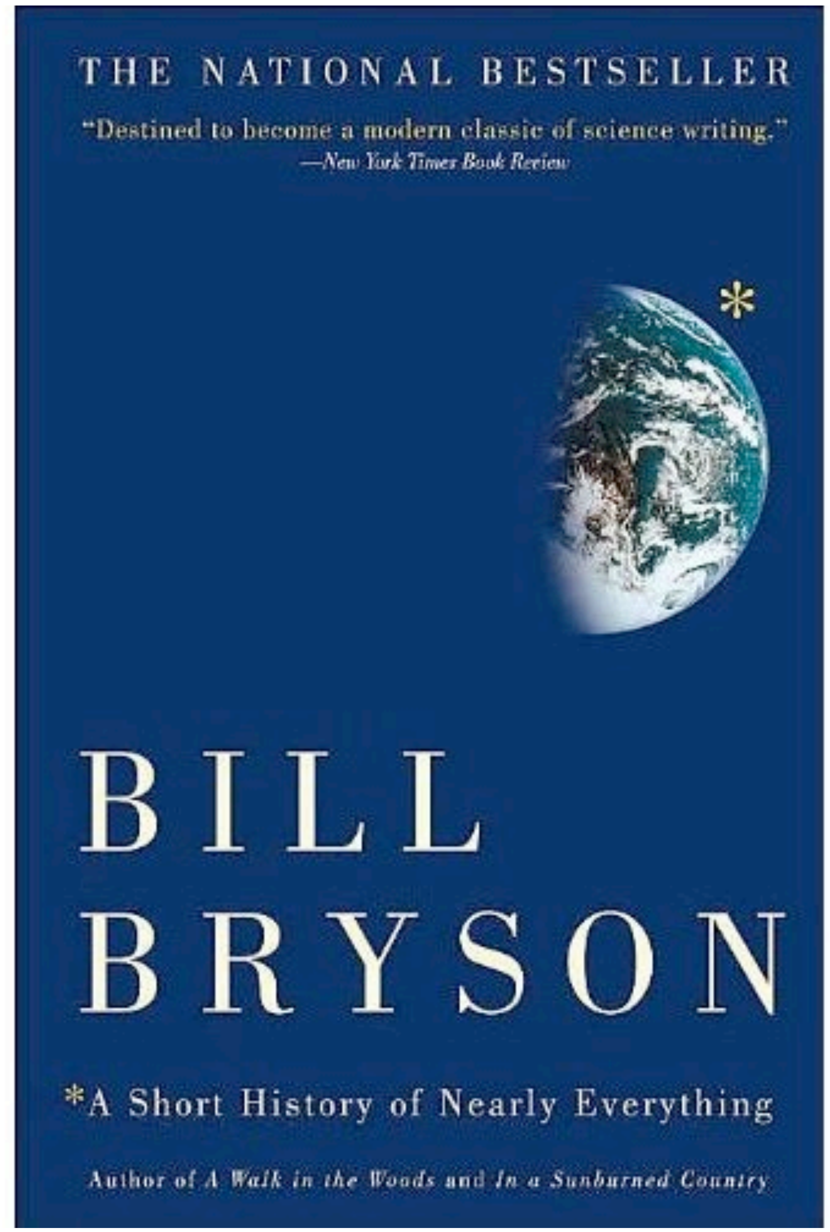

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chemistry life the universe and everything

Melanie Cooper Clemson University
&
Mike Klymkowsky UC Boulder

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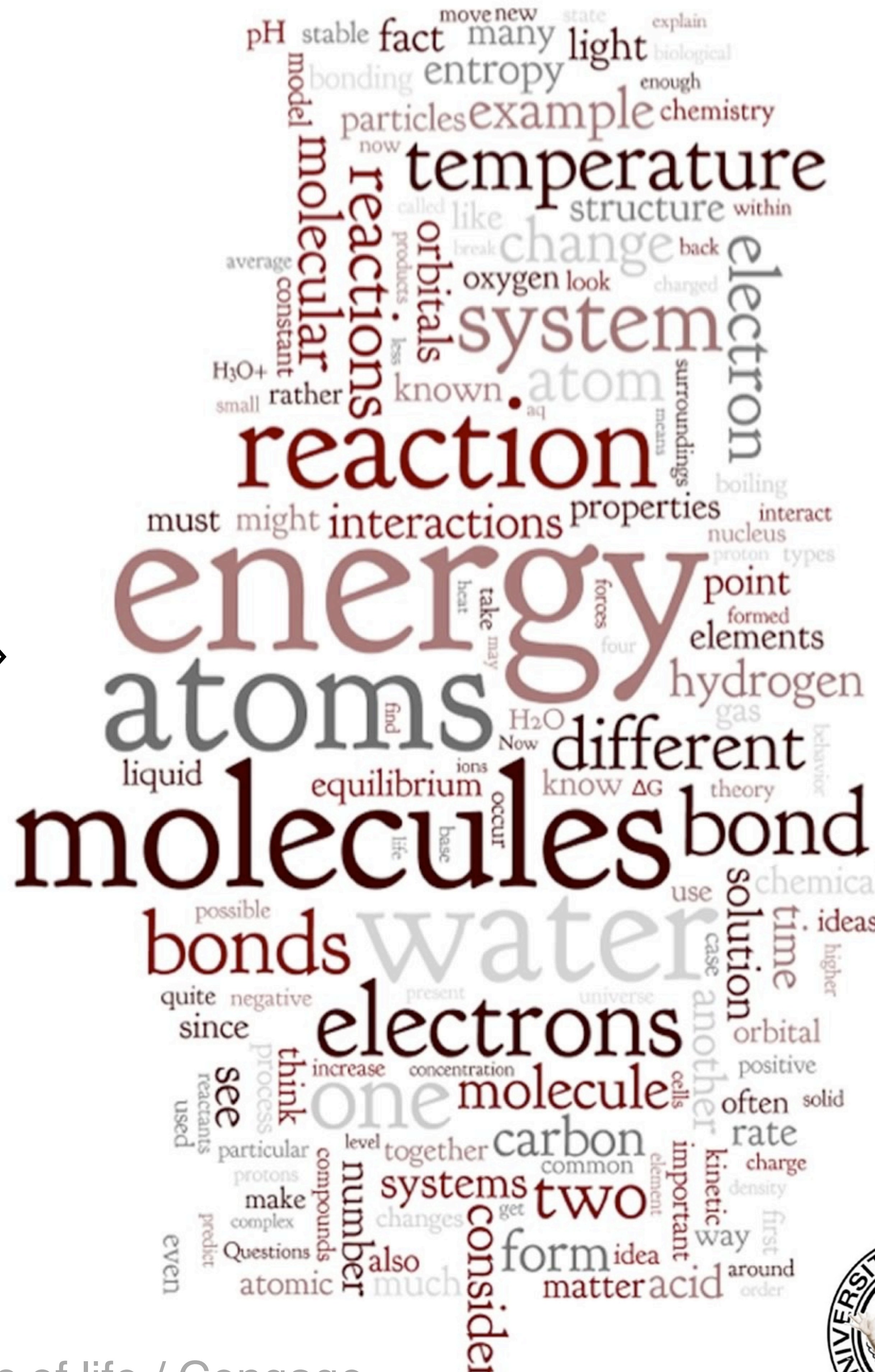

For both CLUE & Biofundamentals

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- Is there an optimum order of topics?

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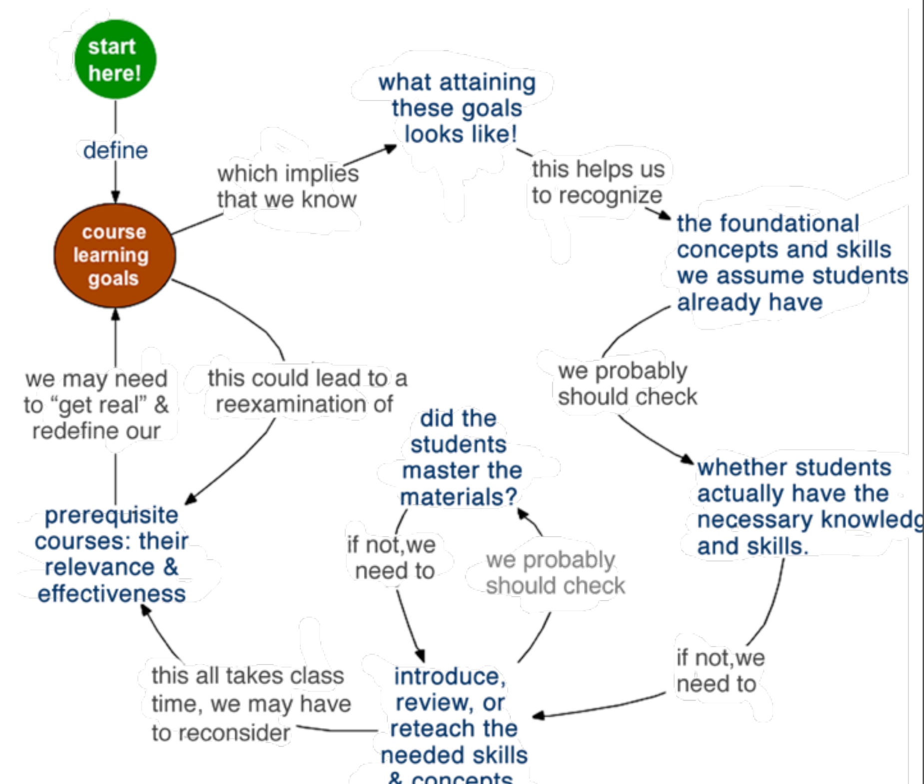

Learning Approach

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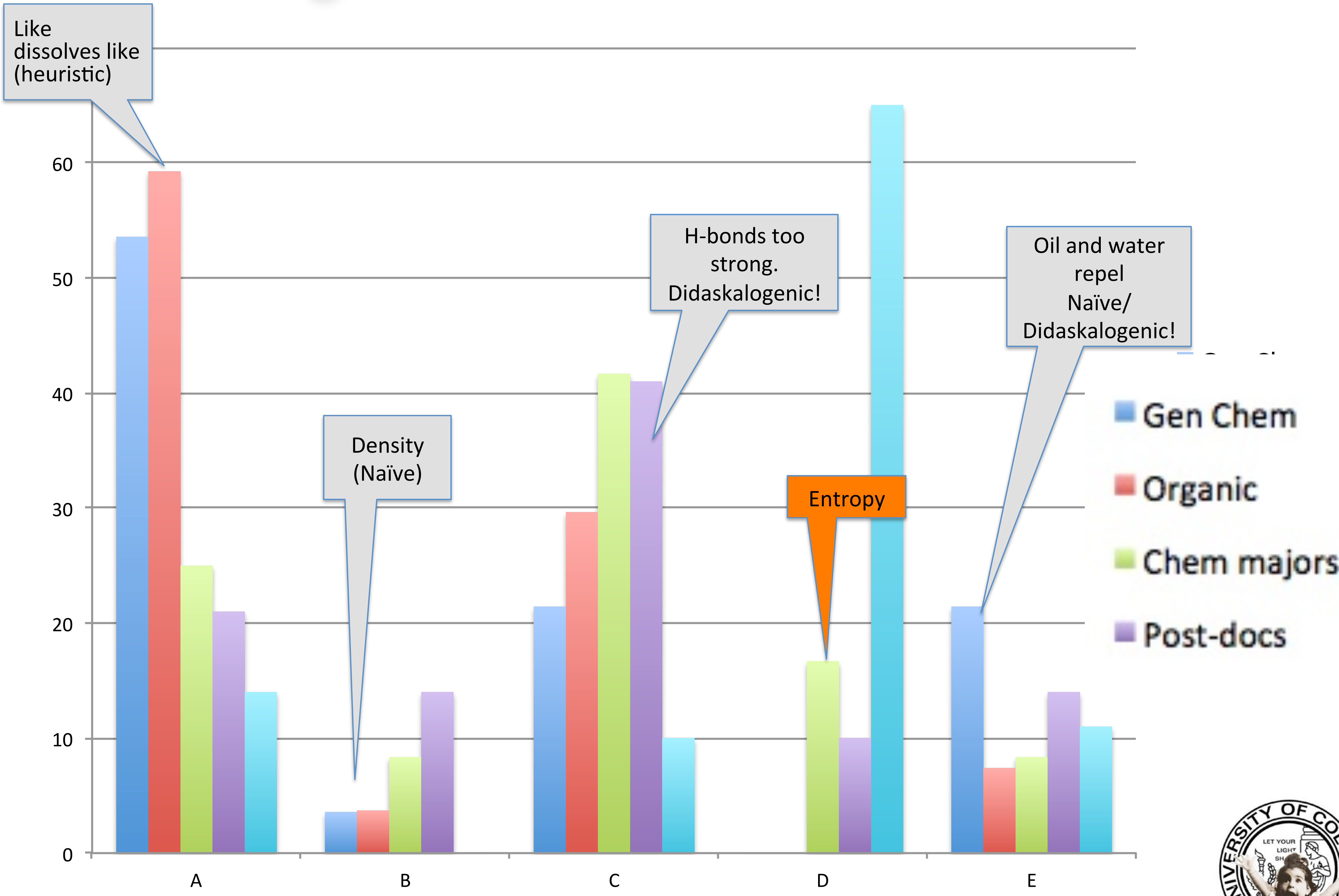
    - Karpicke & Roediger *et al. 2008*. The critical importance of retrieval for learning. *Science* ***319,*** *966-8*.

Data coming in: oil and water mix?



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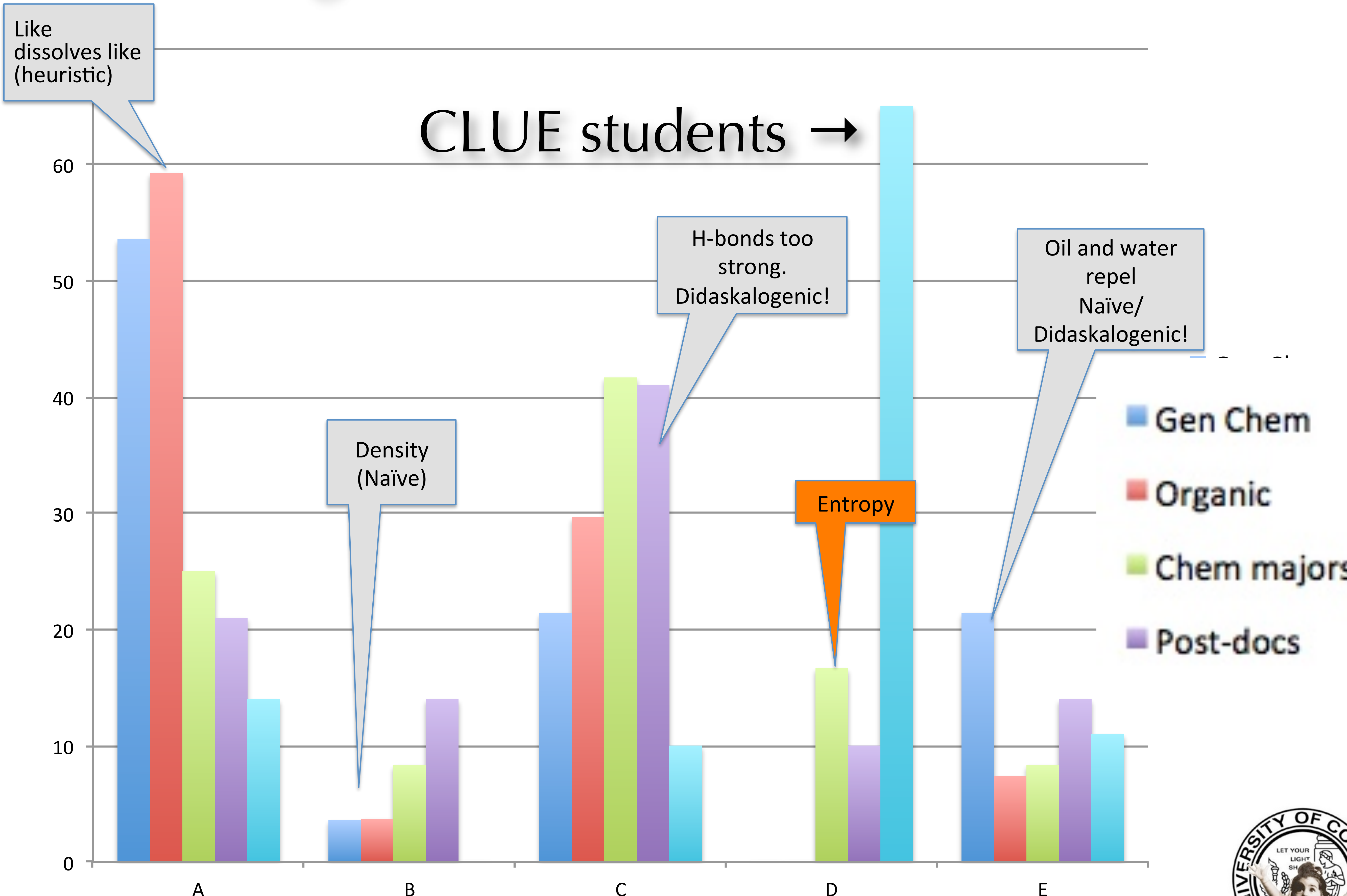
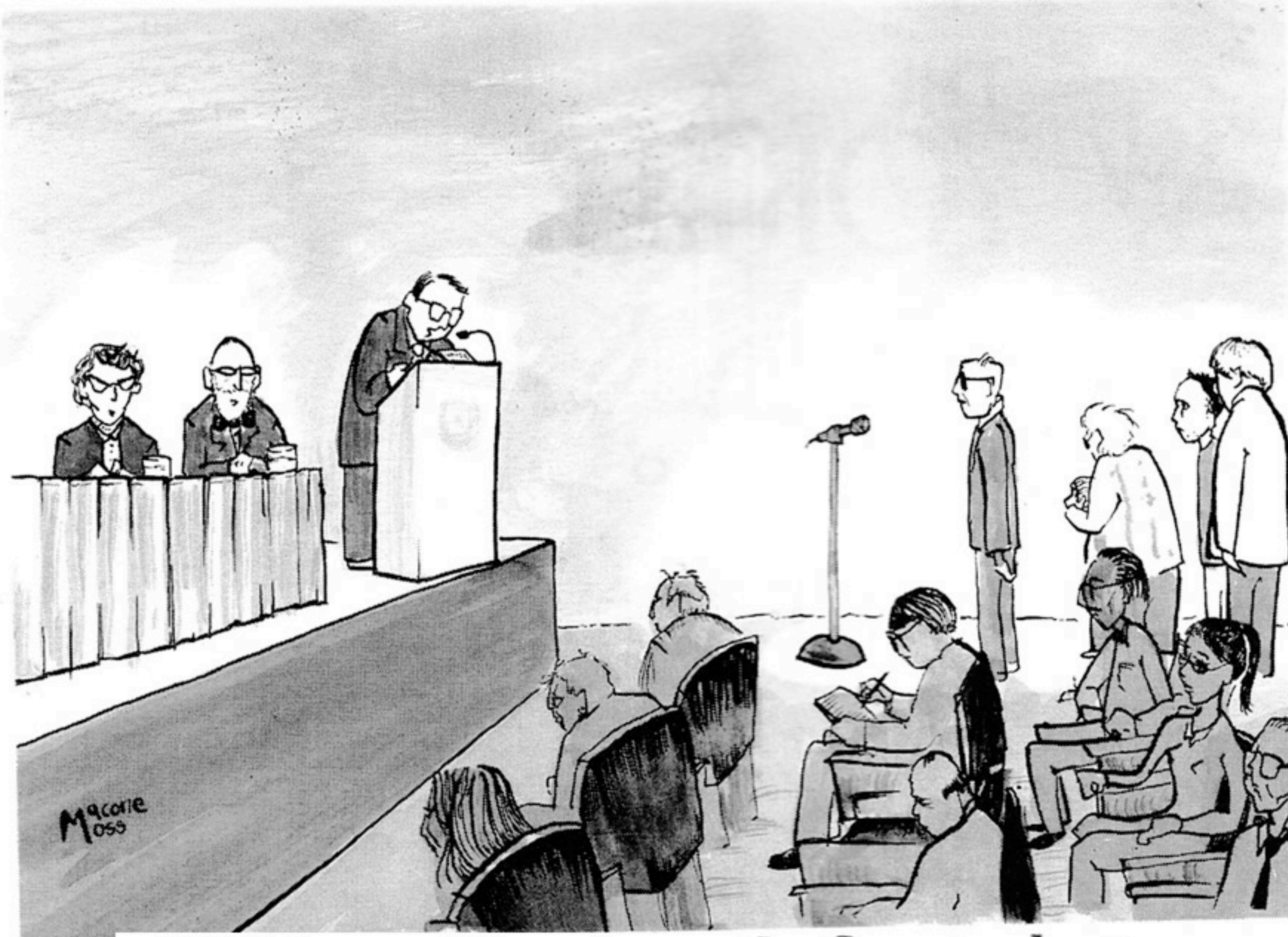


More information:

Google: Biofundamentals, Bioliteracy,
BeSocratic.clemson or colorado.edu



“We’d now like to open the floor to shorter speeches disguised as questions.”