Seeing the invisible: Scientific models and visual thinking skills

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Introduction

Science is extremely visual, rooted in *observation* and *communicated* through drawings, photographs, diagrams, graphs, maps, and more (Kierns 1999). The development of visual thinking skills, however, is rarely an explicit learning outcome of undergraduate science. Indeed, articulating explicit learning outcomes for visual thinking is challenging, in part because representations in the disciplines employ *implicit conventions*. Part of a larger project exploring visualizations in undergraduate science education, we present preliminary work that seeks to ***assess the complexity of expert-generated conceptual models of biological systems across six peer-reviewed, high-impact journals***. As part of this work, we present our preliminary coding scheme, which builds on the work of many (e.g., Schönborn and Anderson 2006).

Methods

Using a three-month window (December 2011, January, February, and March 2012), we reviewed selected high-impact journals (Cell, J of Biochemistry, Nature, PNAS, PLoS Bio, and Science) for figures that included **a model of a biological system**. These models included hypothesized structural models, suggested regulatory pathways, and signaling pathways. We attempted to systematically describe each model according to the rubric represented in figure 1. Further, using structure-behavior-function theory as a frame (Hmelo-Silver et al., 2007), we also characterized explicit model behaviors (that is, the relationship between and among structures).

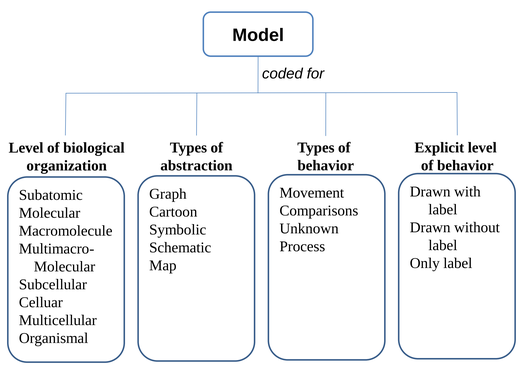
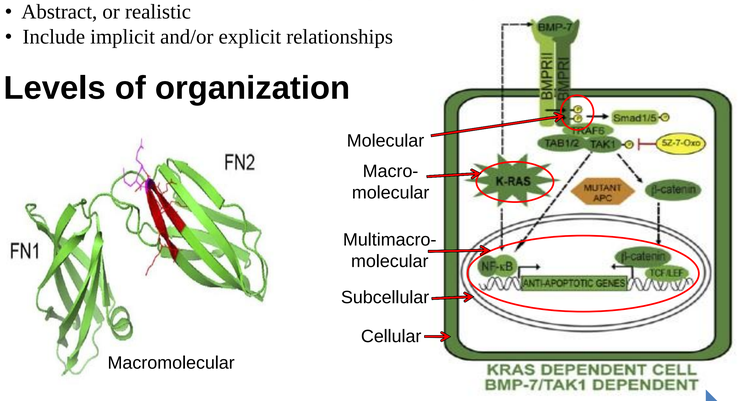


Figure 1. Preliminary model coding rubric

What is a model?

- A conceptual representation of an object, process, or system
- Abstract, or realistic
- Include implicit and/or explicit relationships

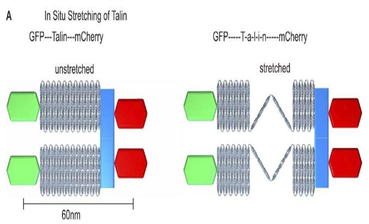
Levels of organization



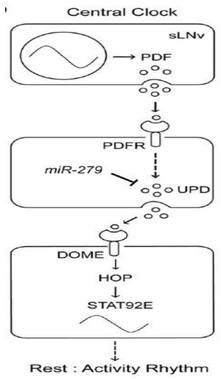
Simple (1 level) → Complex (5)

Type of abstraction

Cartoon

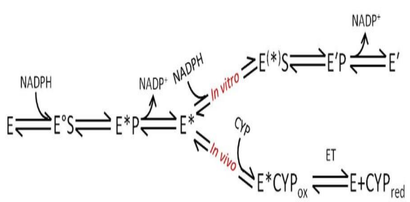


Schematic

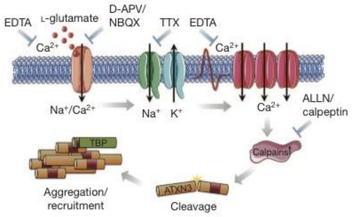


Blended:

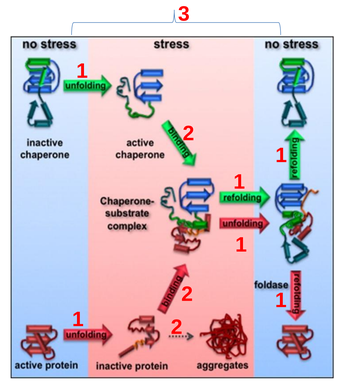
Schematic with symbol



Cartoon with symbol

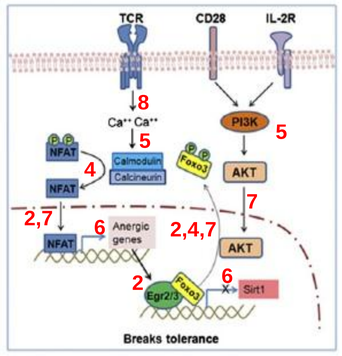


Types of behaviors



Observed behaviors included:

1. Conformational changes
2. Binding
3. Comparison
4. Modification
5. Regulation
6. Gene expression
7. Movement
8. Unknown



Preliminary results

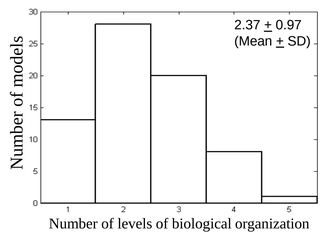


Figure 2. Distribution of biological levels represented in sampled models.

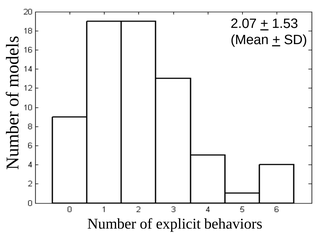


Figure 3. Distribution of explicit behaviors identified in sampled models.

Table 1. Abstractions used in sampled models.

Type of abstraction			
Schematic	Cartoon	Symbolic	Mixed
37	36	31	34

Based on these data, we note published models:

1. Are rendered using a variety of abstractions.
2. Span multiple levels of biological organization.
3. Include multiple types of behaviors.
4. Communicate substantial biological information through *implicit* mechanisms.

Future work

1. In what ways do *textbook models* differ from expert-generated models?
2. Do models used at the micro and molecular level differ substantially from models used at *macro levels*, namely organismal through ecosystem levels?
3. How do we characterize complexity in models that communication through *both explicit and implicit* mechanisms?

Select References

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Schönborn, K. J. and T. R. Anderson. 2006. The importance of visual literacy in the education of biochemists. Biochemistry and Molecular Biology Education 34:94-102.

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