Breaking the Cycle: carbon cycling representations in undergraduate textbooks.

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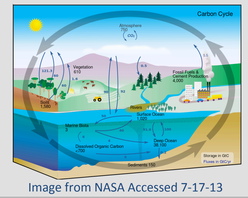


Image from NASA Accessed 7-17-13

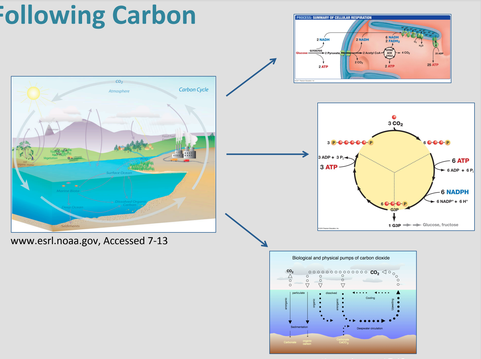
Carbon movement:

The ability to understand and follow carbon through biological systems represents a challenge to undergraduate students. Being able to identify where misunderstandings come from and try to eliminate these challenges to help decrease possible student misconceptions. (Hartley et al, 2011)

Research Questions

- How is carbon typically represented in undergraduate textbooks?
- Does representation differ from introductory biology to upper level ecology texts?
- Does the abstraction type change depending on the system and flux level?

Following Carbon



www.esrl.noaa.gov, Accessed 7-13

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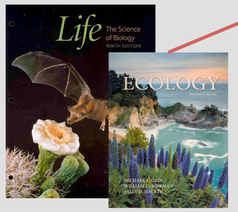
Coding Carbon Visualizations



We selected images that portrayed the movement of carbon, i.e., there was a clear flux, identified either through explicit components of the figure itself or through the figure caption (Table 1).

We then identified the biological system represented (Figure 1).

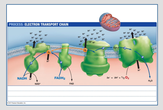
Finally, we identified the type of abstraction used to portray carbon movement (Figure 2). A given figure could have more than one type of abstraction.

To compare introductory to upper division textbooks, we used Yates Chi Squared analysis which is appropriate for limited sample sizes.

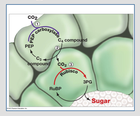
Table 1. Basic fluxes used as criteria for inclusion of visualizations in analysis

Flux*	Definition
Photosynthesis	The process of using sunlight to create energy.
Respiration	Metabolic pathways involved in the oxidation of glucose.
Anthropogenic Combustion	Breakdown of fuel resulting in an exothermic reaction including light and heat.
Consumption	The movement of carbon through one organism eating another.
Decomposition	Processes of composition and respiration

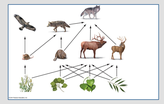
Cellular



Organismal



Community



Ecosystem

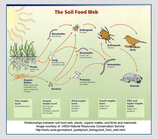
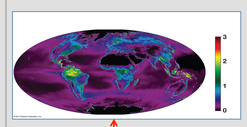
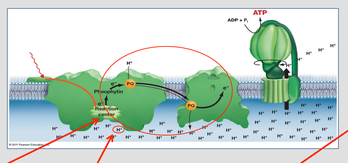


Figure 1. Identifying the focal biological system of a visualization

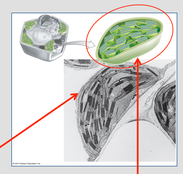


Maps
Visual depictions of relationships between elements of a specific area

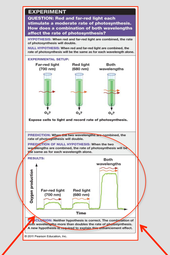


Schematics
Information represented by abstract symbols

Symbolic
Represented by names, labels or abbreviations



Realistic
Representations using real photographs



Cartoons
Computer generated images

Graphs
Relationships between mathematical variables

Tables
Information is relayed in table format

Figure 2. Types of abstraction*

*Double coding of images occurred using these rubrics

Visualizations differ significantly from Introductory Biology to Upper Level Ecology Texts

Biological Flux

- Introductory and upper level books differ significantly (Figure 2), primarily in representing cellular respiration and consumption
- Decomposition and combustion are rarely represented in either text.

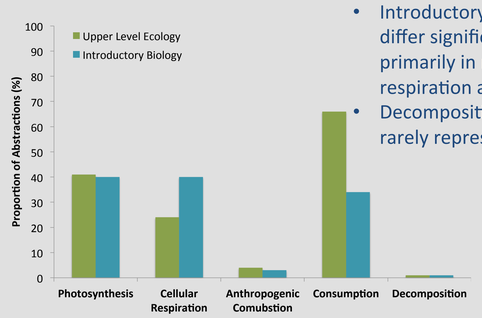


Figure 2. Distribution of abstractions across biological flux. Upper Level Ecology n=96, Introductory Biology n=101, x^2= 12.86, df=4, p=0.01.

Biological Systems

- The systems represented differ significantly between upper level and introductory texts (Figure 3).
- Upper Level texts focus on Community (58%) and Ecosystem (28%)
- At the introductory level organismal representations are rare (20%)

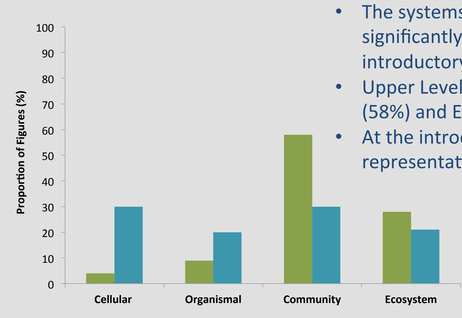


Figure 3. Distribution of abstractions across biological systems. Upper Level Ecology n=96, Introductory Biology n=101, x^2=32.5, df=3, p= <0.001.

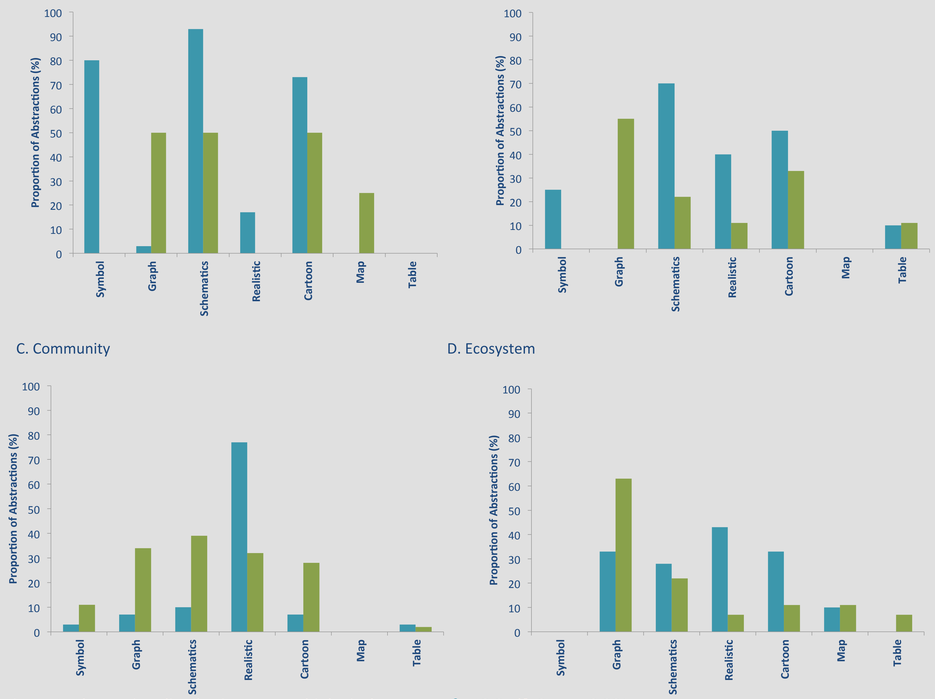


Figure 4. Abstraction distributions across biological systems; x^2= 42.9, df=6, p= < 0.001

Abstraction type

- Introductory biology uses fundamentally different types of abstractions when representing carbon cycling than Upper level ecology (Figure 4)
- For example,
  - At the upper level, organismal carbon cycling was represented primarily through graphs compared to schematics in introductory biology
  - At the upper level, ecosystem-level carbon cycling was represented primarily through graphs compared to realistic images and cartoons in introductory biology
- Overall, the upper level textbook included more graphs than introductory level textbooks
- Conversely, the introductory level textbooks included more realistic pictures and cartoons than the upper level textbook

Conclusions

- Introductory biology differs significantly from Upper level ecology in textbook representations of carbon cycling.
- Further, carbon cycling is represented across biological levels in the Introductory biology texts using markedly different visual representations.
- As a result, students must learn a broad spectrum of visual thinking skills if they are to successfully interpret and reason with the diversity of abstractions when learning how carbon moves through a system.
- This lack of continuity across biological levels and from introductory to upper level course textbooks may contribute to student learning difficulties and misconceptions.
- Future research will include coding additional textbooks to build a robust data set and compare common visualizations to pervasive student misconceptions, as evidenced in existing literature.

References

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Acknowledgments

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