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# LEARNING PROGRESSIONS TOWARD ENVIRONMENTAL LITERACY

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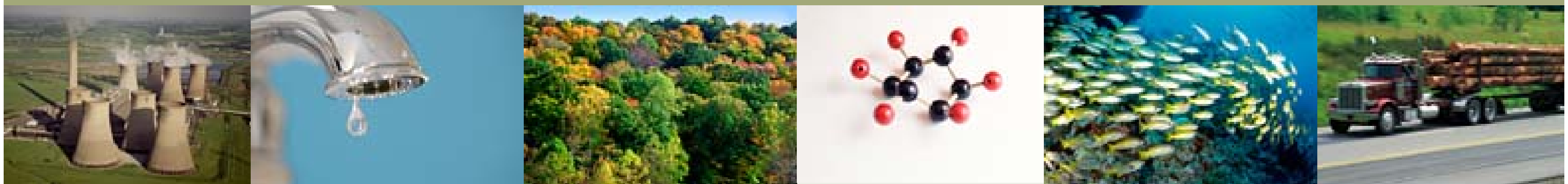

MICHIGAN STATE UNIVERSITY

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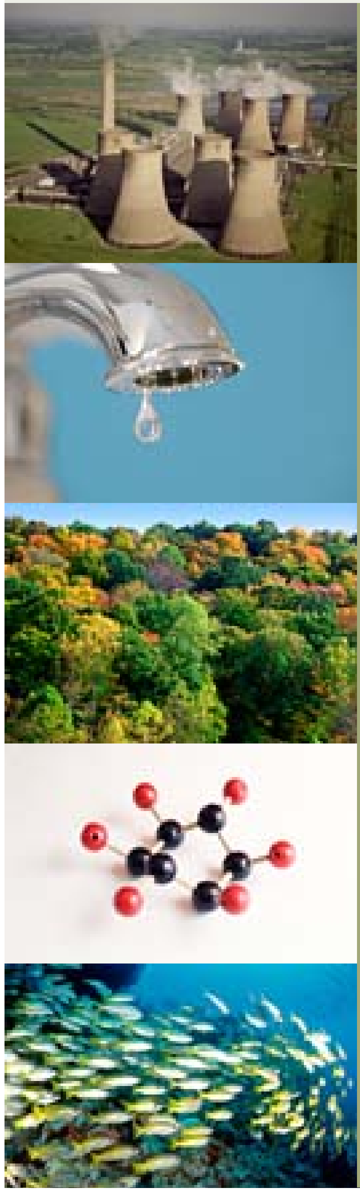
# ENVIRONMENTAL SCIENCE LITERACY RESEARCH GROUP



- Michigan State University
  - Working Groups: Carbon, Water, Biodiversity
- Partners
  - Long Term Ecological Research (LTER) Network
    - Alan Berkowitz, Baltimore Ecosystem Study
    - Ali Whitmer, Santa Barbara Coastal
    - John Moore, Shortgrass Steppe
  - University of California, Berkeley
  - University of Michigan
  - Northwestern University
  - AAAS Project 2061

# PRESENTATION OVERVIEW

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- Environmental Science Literacy in K-12 Ed (Andy)
- Learning Progressions
- Upper Anchor Framework (scientific reasoning)
- Tracing Matter: Examples of student responses and analyses (Lindsey, Chris)
- Levels of the tracing matter progress variable and discussion of data (Hui)
- What’s Next?
- Comments & Questions

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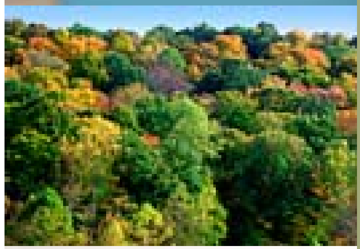
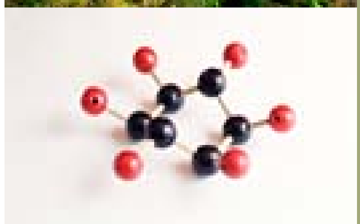
# THE NEED FOR ENVIRONMENTAL SCIENCE LITERACY




- Humans are fundamentally altering natural systems that sustain life on Earth
- Citizens need to understand science to make informed decisions that maintain Earth’s life supporting systems
- Citizens act in multiple roles that affect environmental systems: as learners, consumers, voters, workers, volunteers, and advocates

# RESPONSIBLE CITIZENSHIP and ENVIRONMENTAL SCIENCE LITERACY



Environmental science literacy is the capacity to understand and participate in evidence-based decision-making about the effects of human actions in coupled human and natural environmental systems [LTER: socioecological systems].

(Anderson, et al., 2006)

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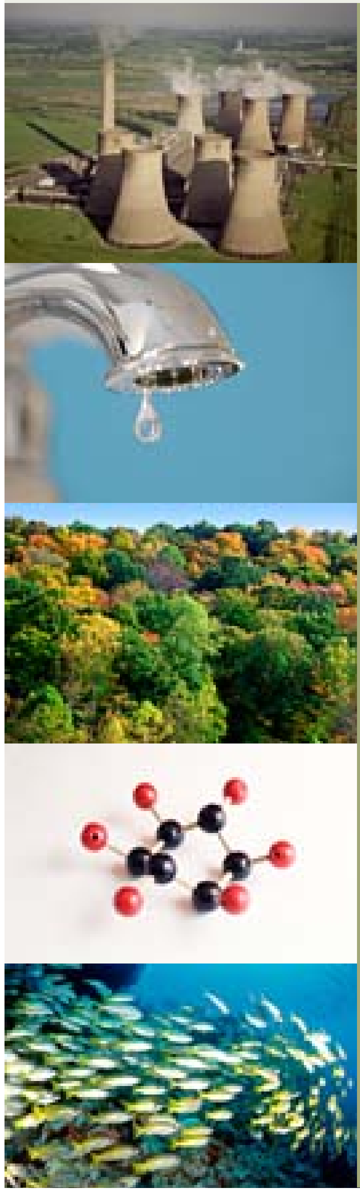
# LEARNING PROGRESSIONS



Learning progressions describe knowledge and practices about topics that are responsive to children’s ways of reasoning, and reflect gradually more sophisticated ways of thinking.

(Smith & Anderson, 2006)

# LEARNING PROGRESSIONS

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**Upper Anchor**

What high school students should know and be able to do

**Transitions**

**Lower Anchor**

How children think and make sense of the world

# PRACTICES OF ENVIRONMENTAL SCIENCE LITERACY (HANDOUT TABLE 1)

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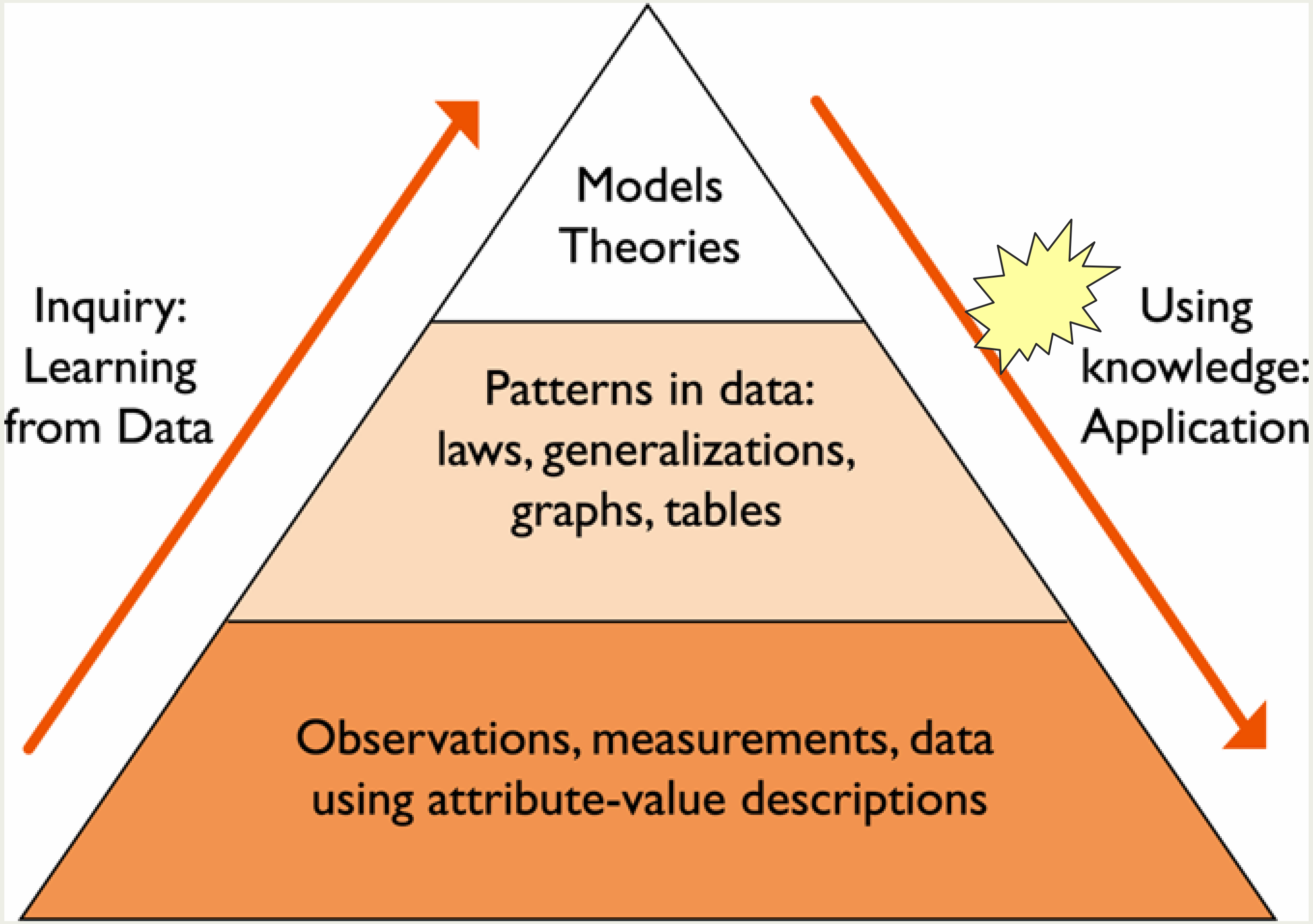
- Engage in **scientific inquiry** to develop and evaluate scientific arguments from evidence
- Use **scientific accounts** of the material world as tools to predict and explain
- Use scientific reasoning in **citizenship practices** of environmental decision-making

# **Upper Anchor:** Producing and Using Accounts



# UPPER ANCHOR ACCOUNTS STRANDS, SYSTEMS, AND PROCESSES

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- **Carbon: Environmental systems create, transform, move, and destroy organic carbon**
  - **Living systems at multiple scales**
  - **Engineered systems at multiple scales**
- **Water: Environmental systems create and move fresh water**
  - Atmospheric water, surface water, ground water, water in living systems, engineered water systems
- **Biodiversity: Environmental systems maintain complex structure and function at multiple scales**
  - Homeostasis: maintaining structure and function
  - Response to environment
  - Change through natural and human selection

# UPPER ANCHOR ACCOUNTS FUNDAMENTAL PRINCIPLES

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- **Structure of Systems**
  - Atomic/molecular scale
  - Macroscopic scale
  - Large scale
- **Constraints on Processes**
  - Tracing matter
  - Tracing energy
  - Tracing information
- **Change over time**
  - Multiple causes and feedback loops
  - Evolution by natural selection

# LOWER ANCHOR ACCOUNTS INFORMAL REASONING

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- **Stories connected by metaphors**
  - What stories do people tell about environmental systems and how do they connect them?
- **Alike and different**
  - How do people name or identify systems, processes, materials, forms of energy, etc.
  - Which ones do they see as alike and different?
- **Egocentrism**
  - How important are human uses and relationships to humans in accounts and ways of describing systems, processes, etc.?

# TRAJECTORIES

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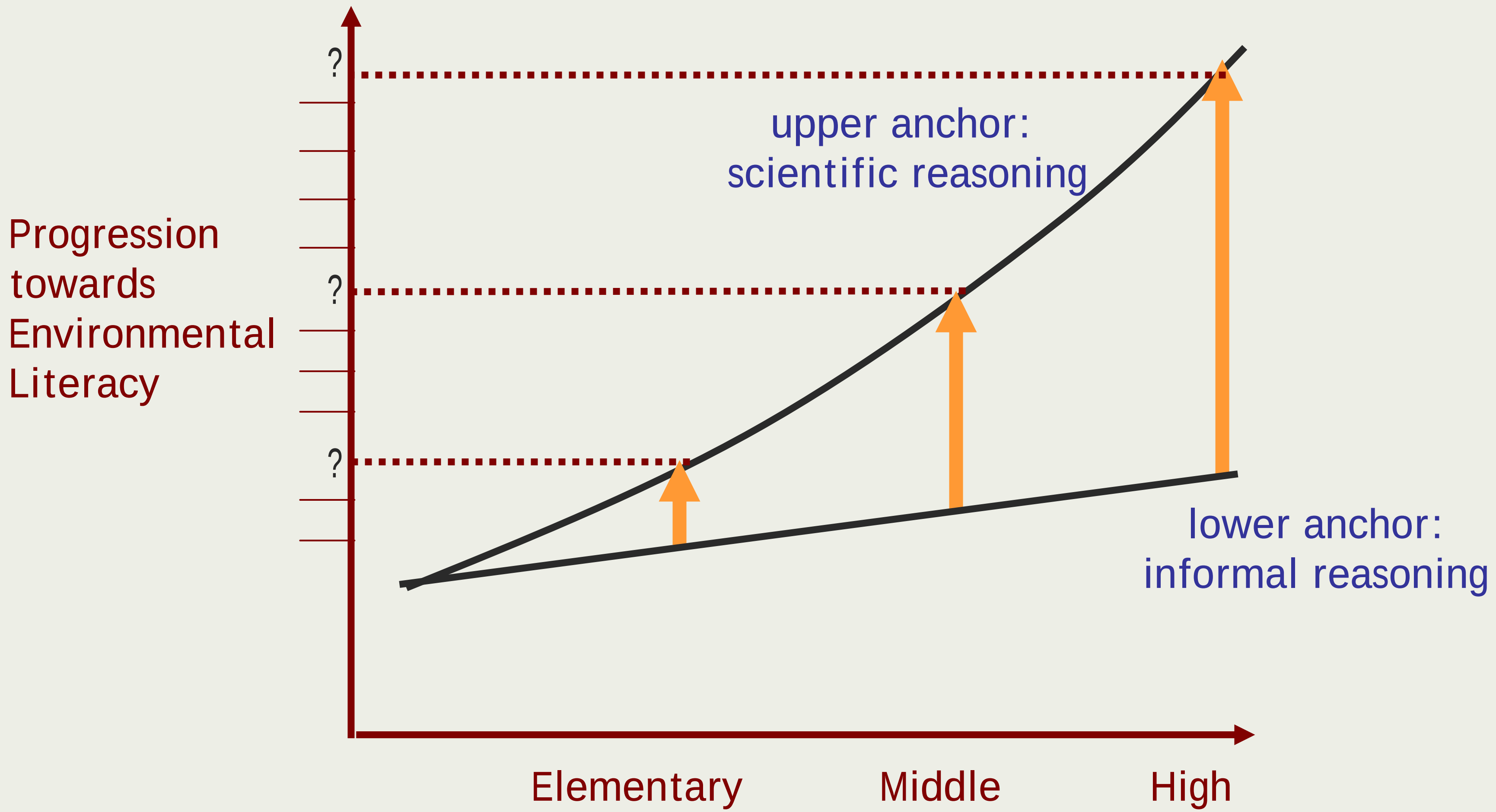

# Carbon Cycling in Coupled Human and Natural Systems (Handout Table 2)

| UPPER ANCHOR- CARBON | | | |
|---|---|---|---|
| **SYSTEMS** | **Coupled Human and Natural Systems** | | |
| **GENERAL PROCESSES** | **Generation (Reduction) of Organic Carbon** | **Modification & Movement of Organic Carbon** | **Oxidation (Destruction) of Organic Carbon** |
| **SPECIFIC PROCESSES** | Photosynthesis, plant growth, primary productivity, reforestation | Synthesis of molecules, digestion, growth, accumulation & sequestration of organic carbon, food chains and webs matter flow, succession | Cellular respiration, weight loss, destruction of organic carbon, decomposition, combustion, energy users, transportation and electrical systems, global warming, urbanization, and industrialization |
| **PROGRESS VARIABLES** | | | |
| **Structure of Systems** | Atomic-Molecular: energy-rich materials (resources & sources), $CO_2$ & $O_2$, chemical bonds<br>Microscopic: single cellular organisms, chloroplasts, organelles, cells<br>Macroscopic: multi-cellular organisms, energy users, energy sources<br>Large: populations & ecosystem, matter pools and reservoirs, energy resources | | |
| **Tracing matter** | Atomic-Molecular: biomolecules, fossil fuels, $CO_2$ & $O_2$<br>Microscopic: cells<br>Macroscopic: growth, weight gain and weight loss<br>Large: ecological matter flow, fossil fuel and transportation systems, atmospheric $CO_2$, air quality | | |
| **Energy Flow** | Microscopic: energy resources and sources<br>Macroscopic: energy transformations and first and second order energy users, energy deliverers<br>Large: ecological energy flow, energy degradation, human energy systems | | |
| **Change over Time** | Large: Succession, reforestation, deforestation, agriculture, global warming, industrialization, urbanization | | |

# Tracing Matter (WTLOSS Worksheet)

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When a person loses weight, what happens to the mass of the fat?

(a) The mass leaves the person's body as water and carbon dioxide
4 students in 20

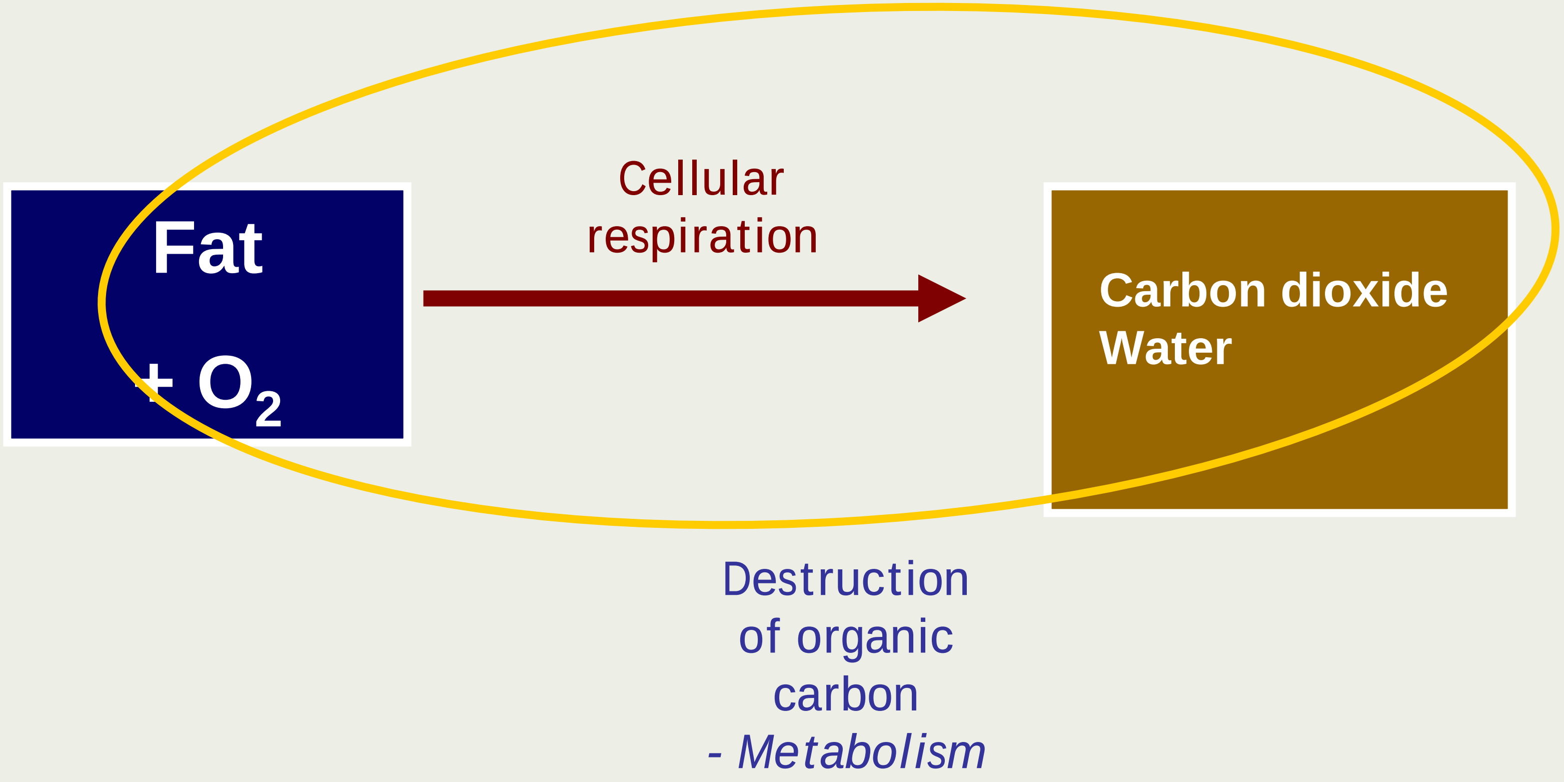
(b) The mass is converted into energy
9 students in 20

(c) The mass is used up providing energy for the person's body function
5 students in 20

(d) The mass leaves the person's body as feces
3 students in 20

Note: 1 student chose both C and D

# Correct Response



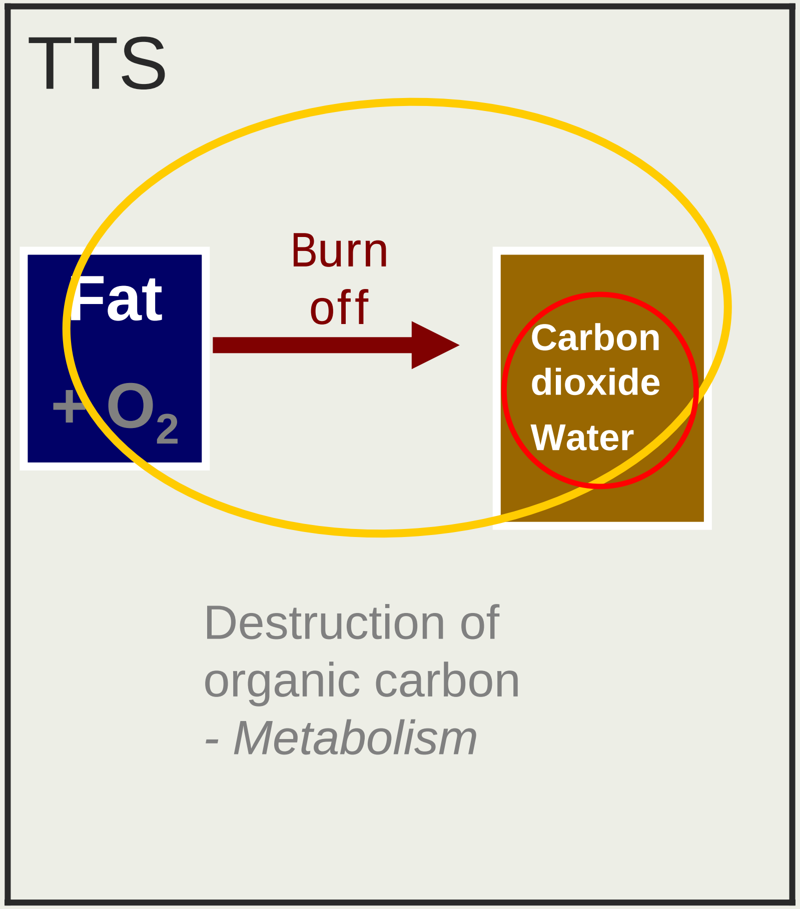
Explain your answer to the previous question. Why do you think this happens to the fat?

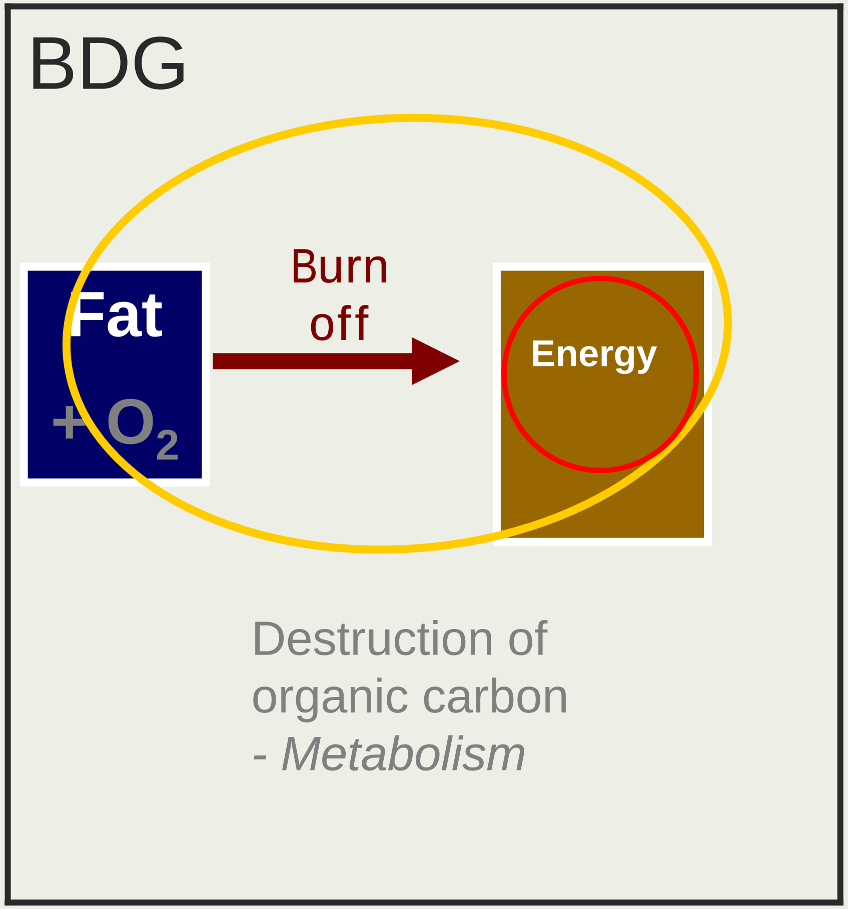
## Student Responses (WTLOSS Worksheet)

TTS: “It leaves as water because all of it burns off and comes out the pours as water and carbon dioxide.” (TTS chose Answer A)

BDG: “The fat is burned of then is used to provide energy.” (BDG chose Answer B)

# Tracing Matter—Students' responses




The gray parts are what the student did not mention in his/her answer

# Tracing Matter (GRANJOHN Worksheet)

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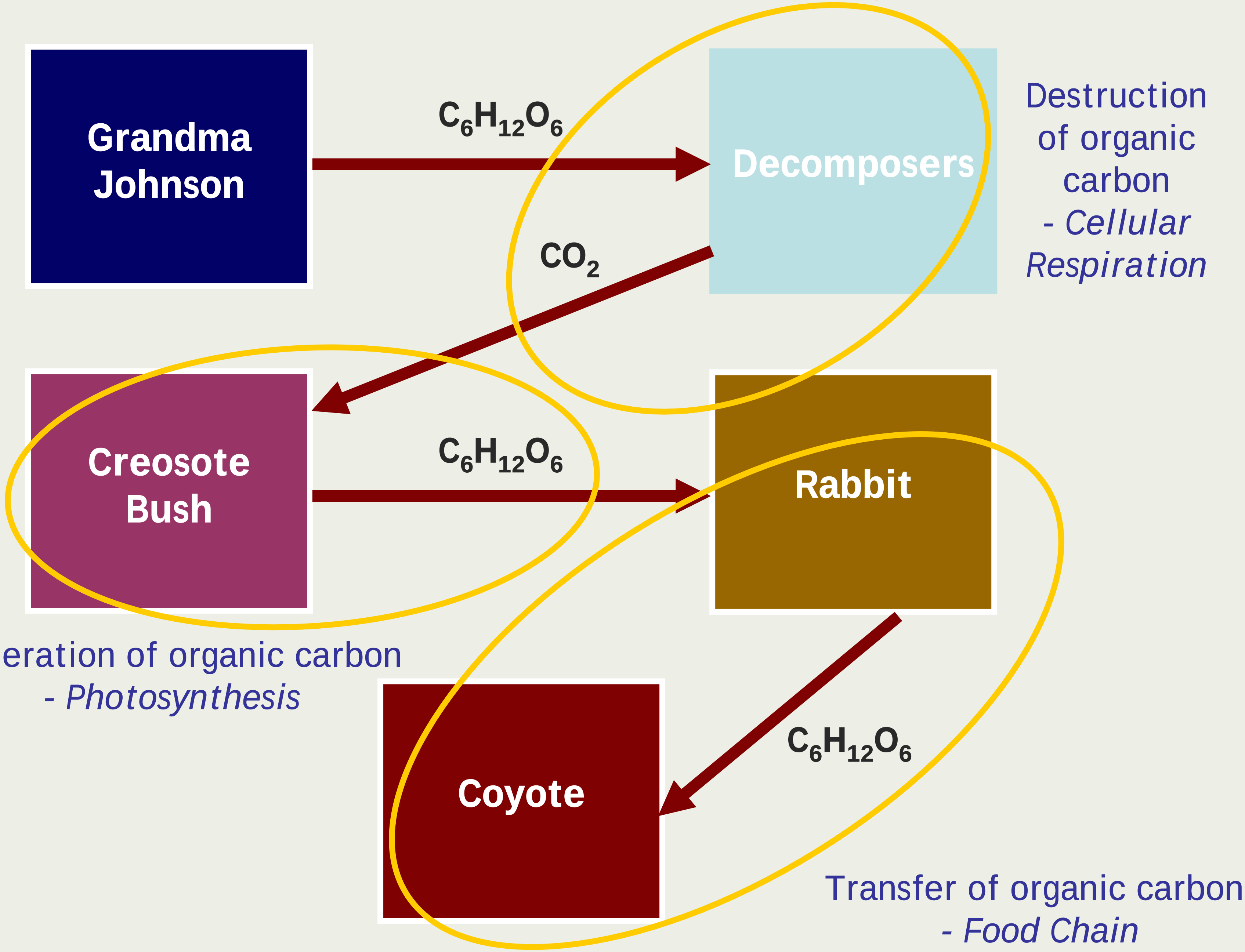
## Grandma Johnson

?

Describe the path of a carbon atom from Grandma Johnson’s remains, to inside the leg muscle of a coyote. **NOTE:** The coyote does not dig up and consume any part of Grandma Johnson’s remains.

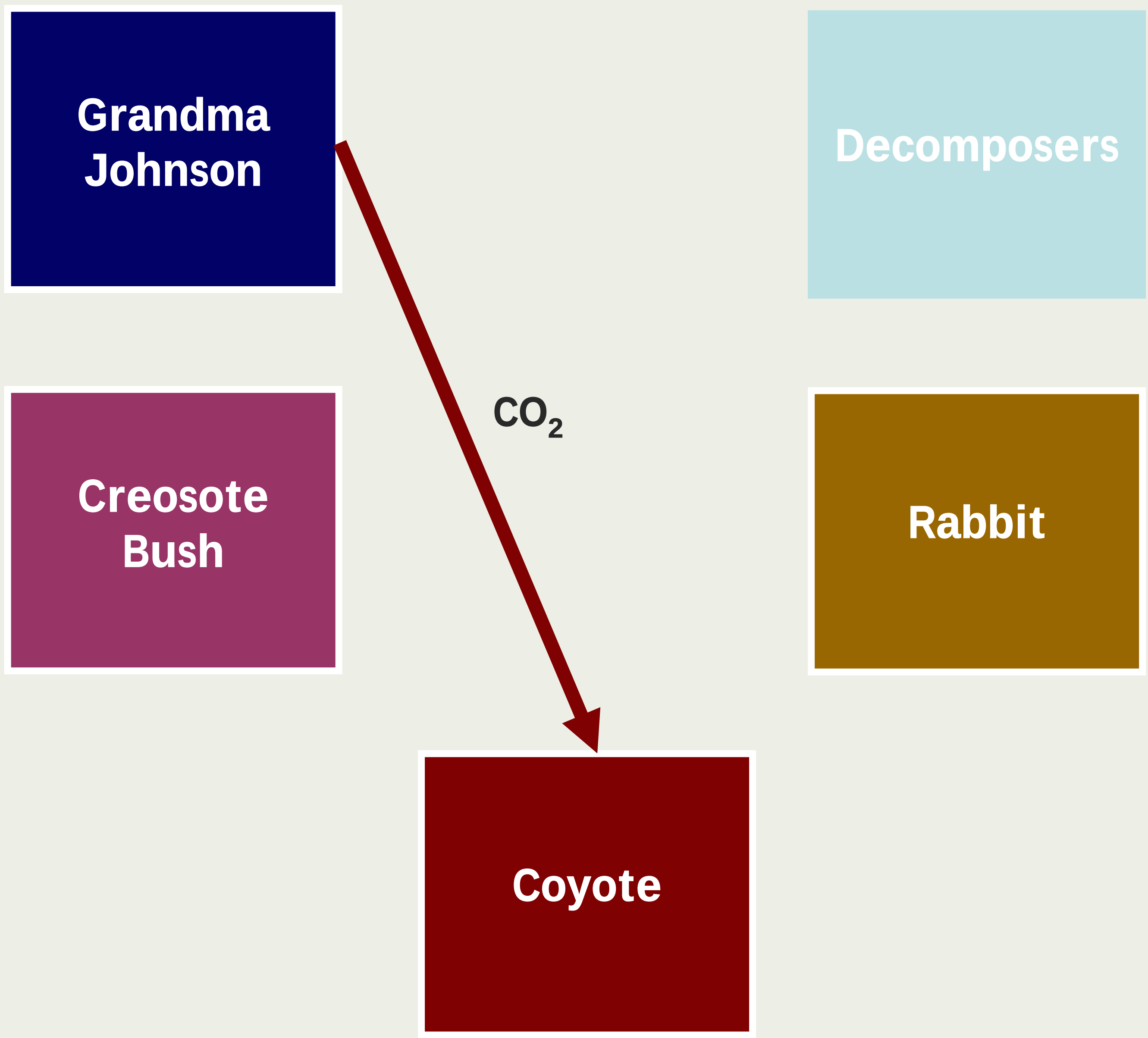
# Inputs and Outputs - Tracing Carbon



# Student Responses (GRANJOHN Worksheet)

CLS: “The carbon atom will leave Grandma Johnson's remains and travel through the soil in to the air. Then the coyote will breath it in as carbon dioxide. The carbon dioxide will travel through the coyote to its leg muscle.”

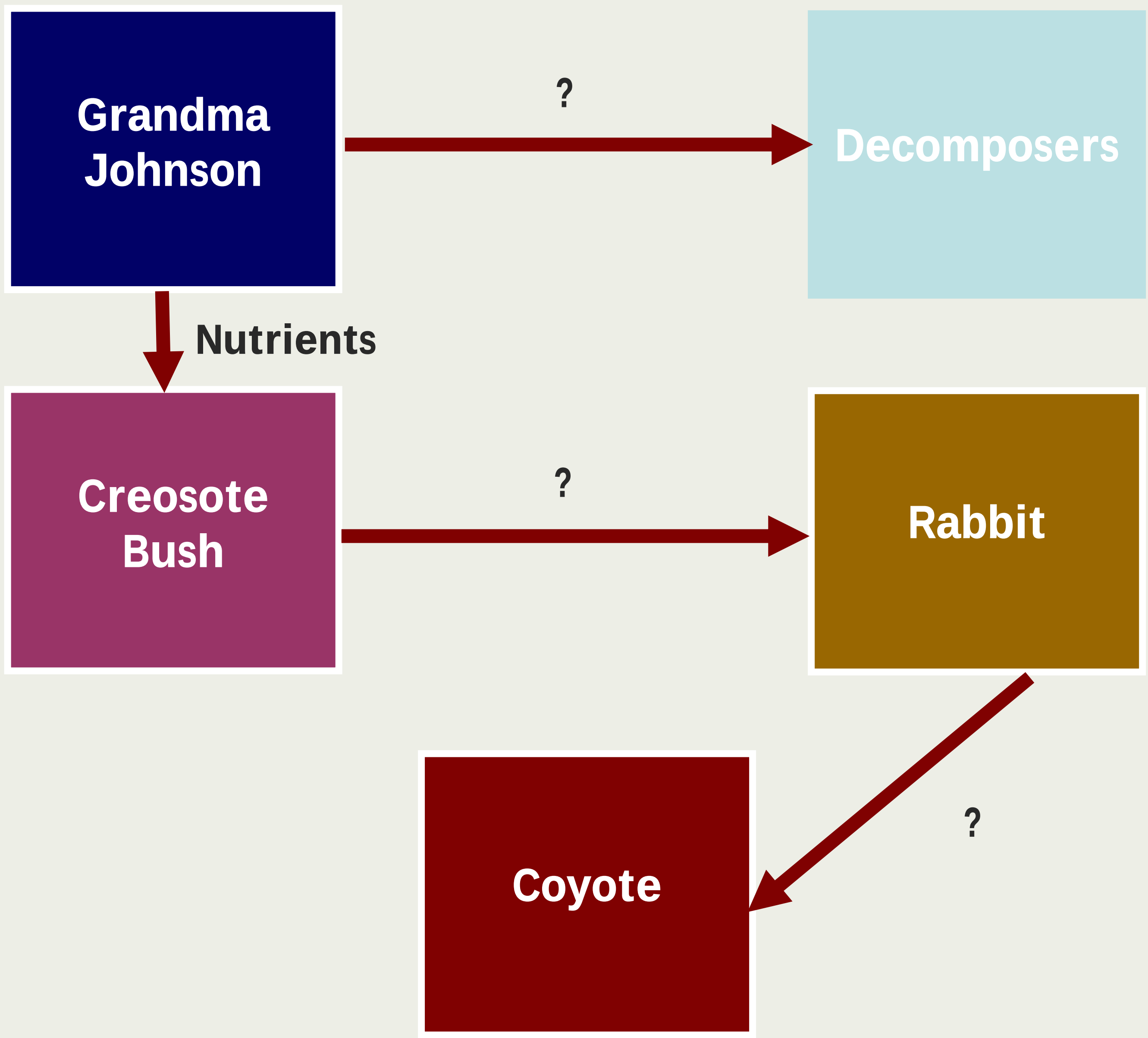
# Tracing Carbon - CLS



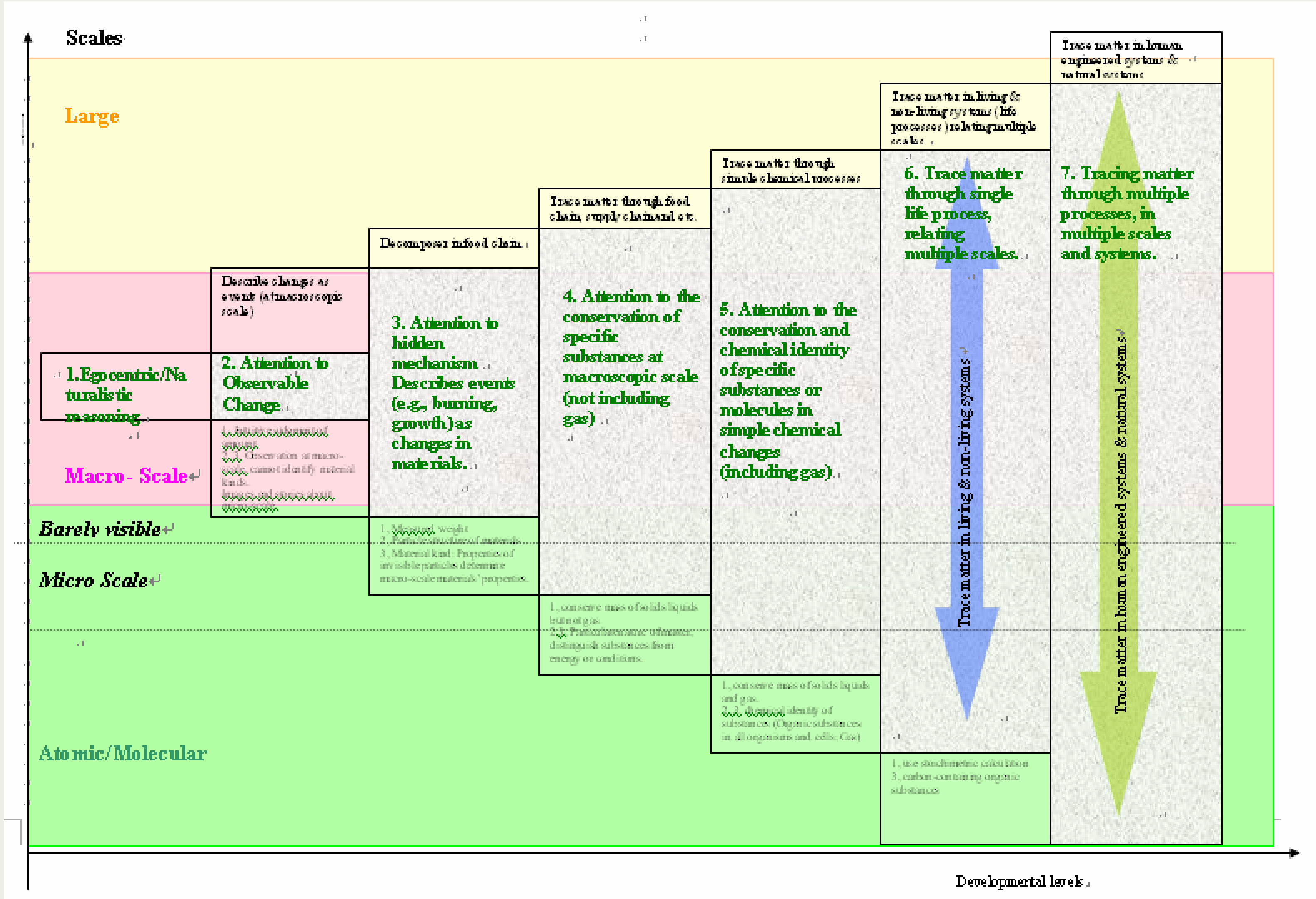
# Student Responses

NLB: “Decomposers break down Grandma Johnson’s remains, leftover nutrients are absorbed into the rests of a creosote bush, a rabbit eats the fruit from the bush, the coyote catches and eats the rabbit.”

# Tracing Carbon - NLB



# Tracing Matter Progress Variable (Handout Figure 1)



# Tracing Matter Progress Variable (Handout Table 3)

| Level | Hierarchy of Systems | Material Kind & Properties of Matter |
|---|---|---|
| 7 | Describes movements of matter through multiple processes at multiple scales | Correctly characterizes reactants and products of processes in terms of how they affect organic carbon compounds |
| 6 | Traces elements or atoms through single life process, relating multiple scales | Correctly identifies reactants and products of single life process |
| 5 | Describes movements of matters in simple chemical changes at atomic-molecular scale. (not just events) | Correctly identifies reactants and products in simple chemical changes. |
| 4 | Describe matter movement at macroscopic scale. (not just events). | Correctly identifies some reactants and products of simple chemical changes. Identifies solids, liquids, but not gases involved in chemical or physical changes. |
| 3 | Attention to hidden mechanism. Describes events as changes in materials. | Attention to hidden mechanism, but cannot identify any material kinds. |
| 2 | Describes changes as events (at macroscopic scale) | Identifies changes by using common sense of natural phenomena, but not as changes in materials |
| 1 | Egocentric/Naturalistic Reasoning: Respondents use human analogy to explain the changes in materials | Egocentric/Naturalistic Reasoning: Respondents use human analogy to explain the changes in materials |

# Discussion of Student Responses

- Look at Excel workbook to discuss how we are mapping individual responses onto levels of the Tracing Matter progress variable

# General Trends from Elementary to High School

- **From stories to model-based accounts**
  - Shift from *why* to *how*--purposes to mechanisms
  - BUT lack knowledge of critical parts of systems
- **From macroscopic to hierarchy of systems**
  - Increased awareness of atomic-molecular and large-scale systems
  - BUT little success in connecting accounts at different levels
- **Increasing awareness of constraints on processes**
  - Increasing awareness of conservation laws
  - BUT rarely successful in constraint-based reasoning
- **Increasing awareness of “invisible” parts of systems**
  - Increasing detail and complexity
  - BUT *gases, decomposers, connections between human and natural systems* remain “invisible”

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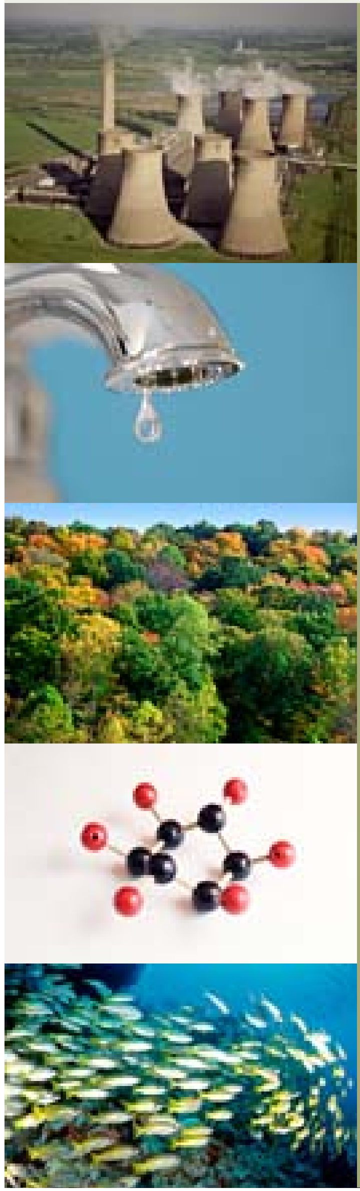
# WHAT'S NEXT?



- Increase emphasis on inquiry and citizenship in addition to accounts
- Refine assessments
- Conduct teaching experiments to refine understanding of how students engage with and learn about environmental science
- Use research to…
  - Inform development of curriculum materials
  - Inform development of new standards for formal K-12 science education

# WHAT QUESTIONS OR PROBLEMS MIGHT DRIVE TRANSITIONS?

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- Extending experience and reducing it to order
  - New experiences
  - Questions about quality of data
  - Moving the boundary between visible and invisible parts of systems
- Questions about needs of organisms and why
- Questions about mechanisms: How does this happen?

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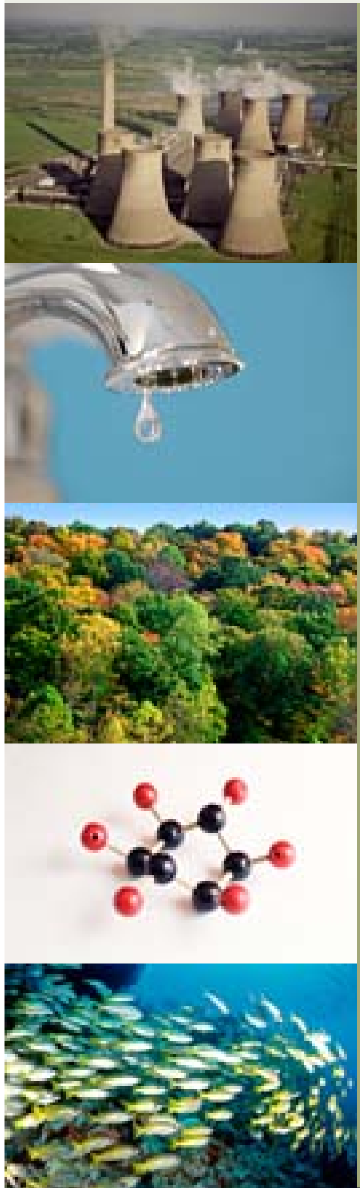
# QUESTIONS & COMMENTS
# MORE INFORMATION



QUESTIONS? COMMENTS? QUERIES?

## MORE INFORMATION

Paper, tests and other materials
are available on our website at…

**http://edr1.educ.msu.edu/EnvironmentalLit/index.htm**