arbon TIME

A Learning Progression-based System for Promoting Understanding of Carbon-transforming Processes *(Carbon: Transformations in Matter and Energy)*

Charles W. (Andy) Anderson

DRK-12 PI Meeting

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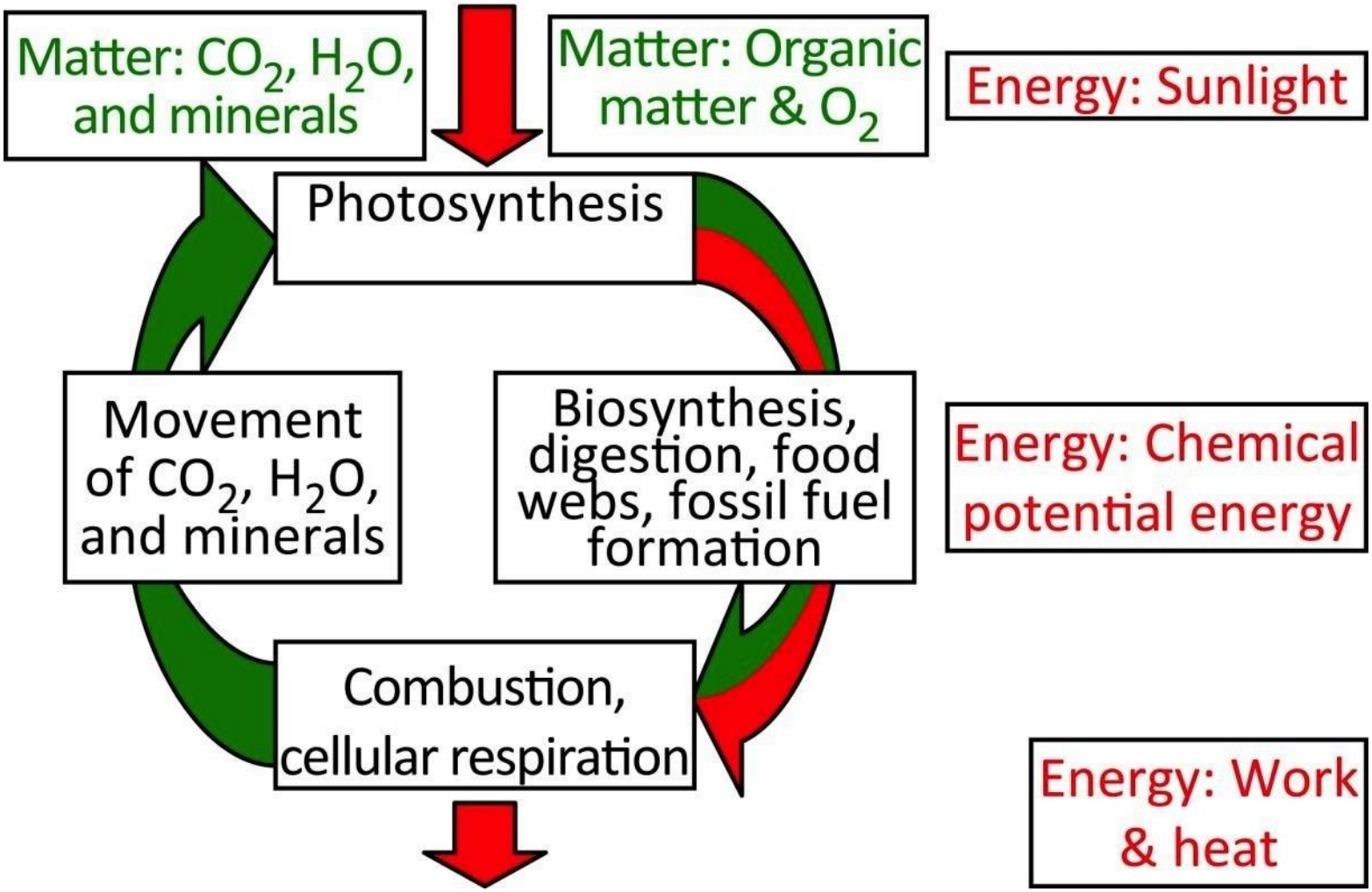
Focus on Carbon-transforming Processes in Socio-Ecological Systems



NGSS Focus for this Work

- Three key *practices*: interpreting and analyzing data, engaging in arguments from evidence, and constructing explanations.
- Two *crosscutting concepts:* systems and system models, and energy and matter: flows cycles, and conservation.
- *Disciplinary core ideas* in the life sciences (LS 1: From molecules to organisms: Structures and processes; LS 2: Ecosystems: Interactions, energy, and dynamics), Earth sciences (ESS 2: Earth's systems; ESS 3: Earth and human activity), and physical sciences (PS 1: Matter and its interactions; PS 3: Energy)

Learning Progressions Include:

- A **learning progression framework**, describing levels of achievement for students learning (Model of cognition)
- **Assessment tools** that reveal students' reasoning: written assessments and clinical interviews (Observation and interpretation)
- **Teaching tools and strategies** that help students make transitions from one level to the next (Empirical validation)

What Progresses?

- **Discourse:** “a socially accepted association among ways of using language, of thinking, and of acting that can be used to identify oneself as a member of a socially meaningful group” (Gee, 1991, p. 3)
- **Practices:** inquiry, accounts, citizenship
- **Knowledge** of processes in human and environmental systems

Learning Progression Levels of Achievement for Carbon Accounts

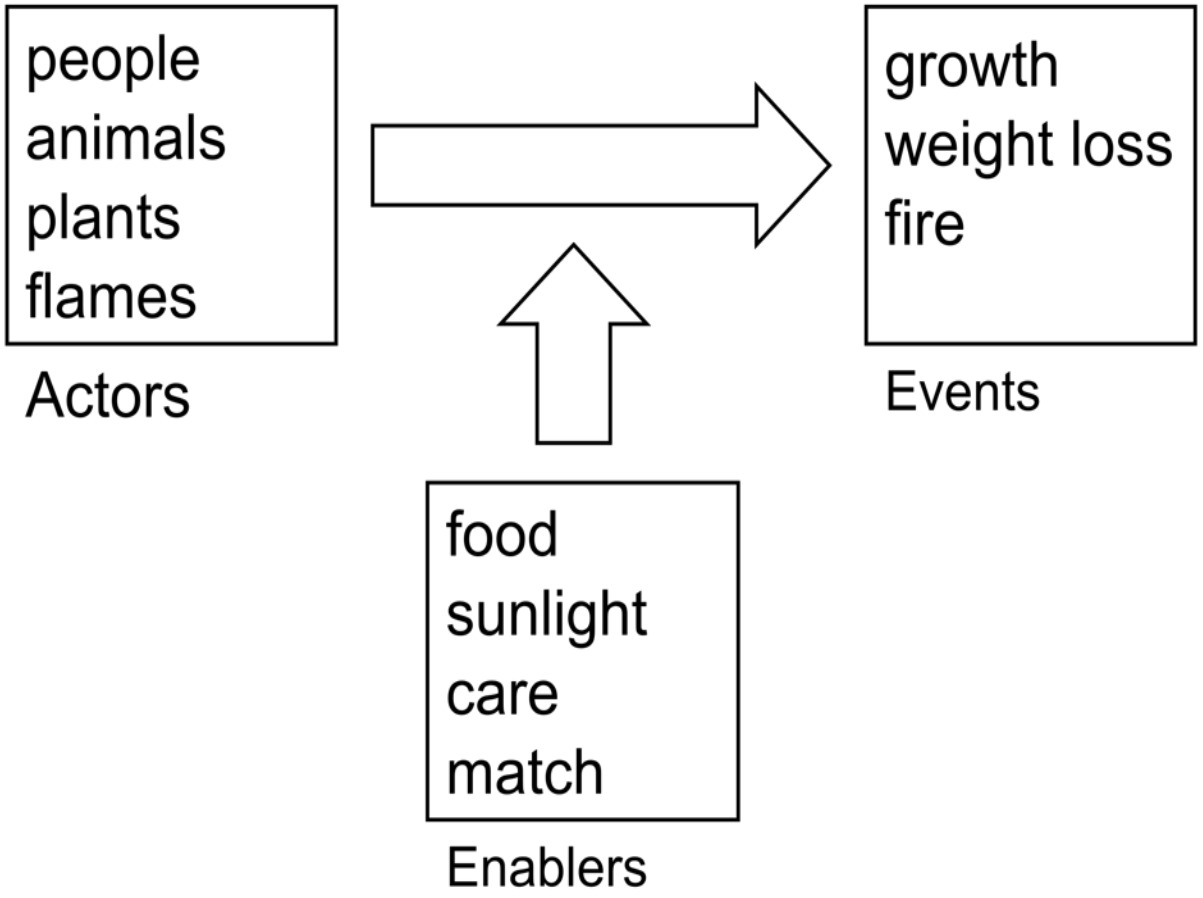
Level 4: Coherent scientific accounts: Students successfully trace matter and energy through carbon-transforming processes at multiple scales in space and time (generally consistent with current national science education standards and with the draft framework for new standards).

Level 3: Incomplete or confused scientific accounts: Students show awareness of important scientific principles and of models at smaller and larger scales, but they have difficulty connecting accounts at different scales and applying principles consistently.

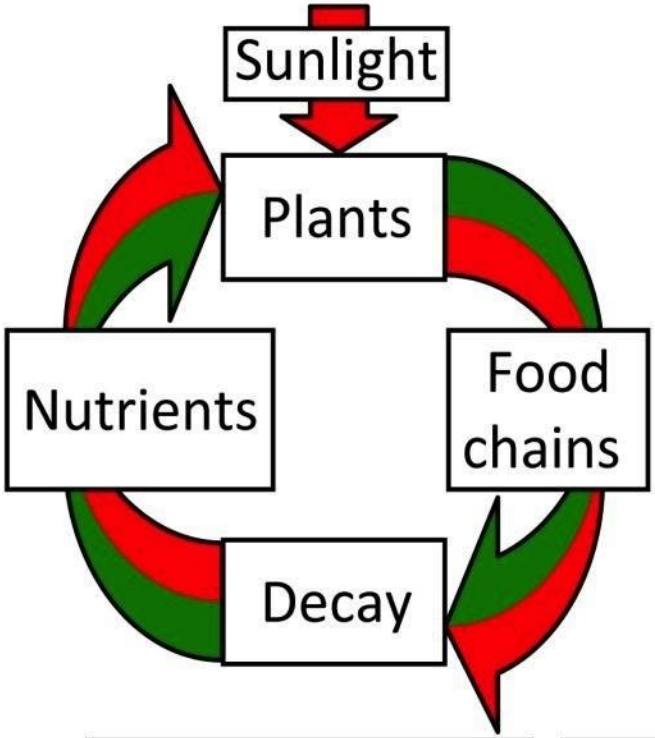
Level 2: Elaborated force-dynamic accounts: Students' accounts continue to focus on actors, enablers, and natural tendencies of inanimate materials, but they add detail and complexity, especially at larger and smaller scales.

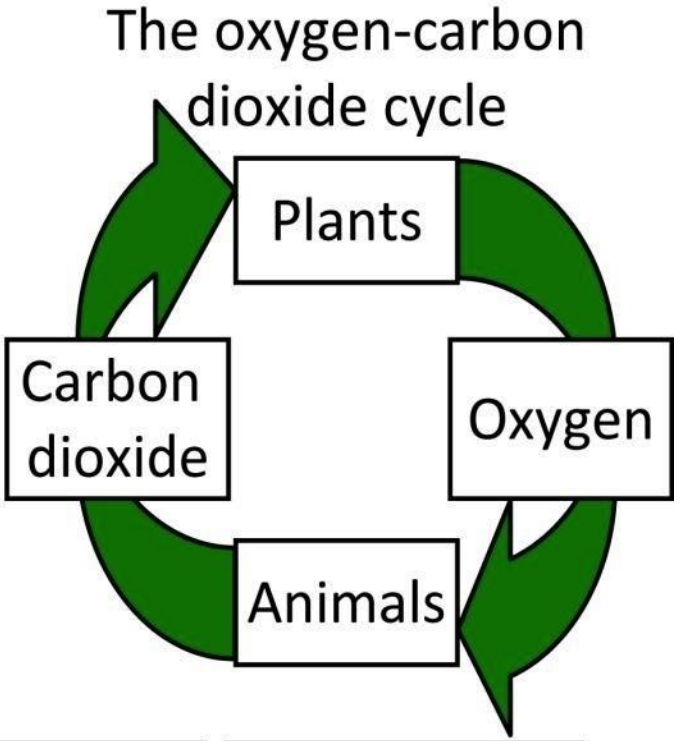
Level 1: Simple force-dynamic accounts: focus on actors, enablers, and natural tendencies of inanimate materials, using relatively short time frames and macroscopic scale phenomena.

Levels 1 and 2: Actors Using Enablers to Accomplish Purposes



Level 3: Nutrient, Energy and O_2-CO_2 Cycles



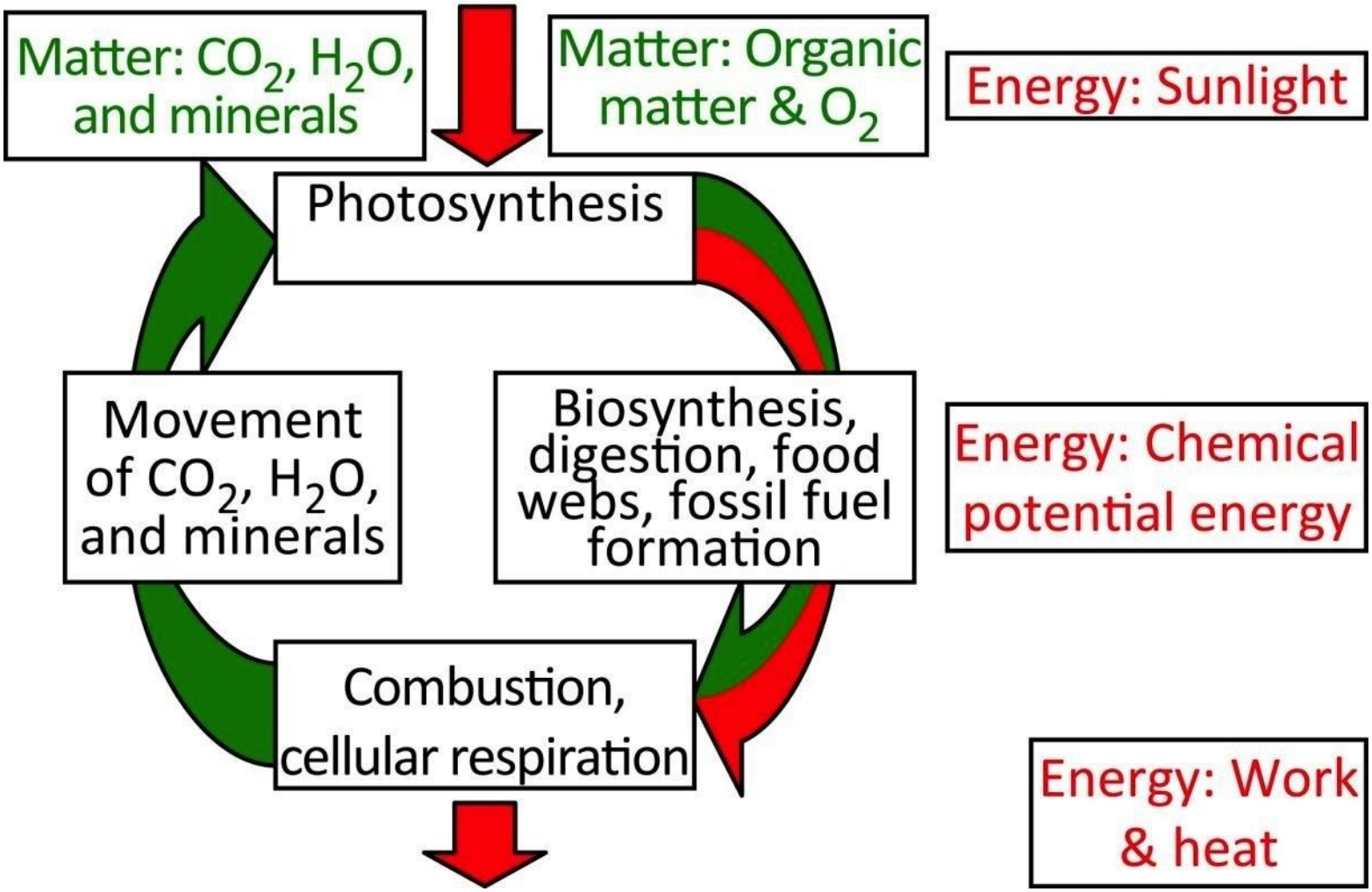


Energy sources for plants: sunlight, nutrients, water

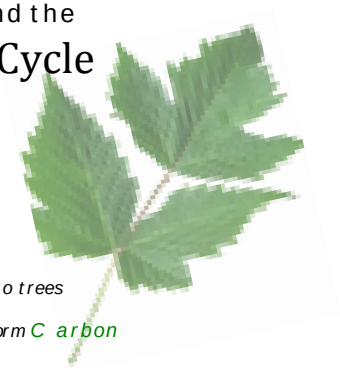
Energy sources for animals: food, water

Decomposers don't need energy

Level 4: Carbon Cycling and Energy Flow



Carbon TIME Curriculum (available on National Geographic Website, 2015)

Systems and Scale - 1 *Systems* and *Scale Teacher's Guide*  *How our systems depend on C arbon and chemical energy: Finding chemical change in life and lifestyles* **The Environmental Literacy Project Carbon: Transformations in Matter and Energy (Carbon TIME) 2011-2012**	Plants and the Carbon Cycle  *How seeds grow to trees and plants transform C arbon* **The Environmental Literacy Project Carbon: Transformations in Matter and Energy (Carbon TIME) 2011-2012**	*Animals* and the *Carbon Cycle*  *How animals use and change C arbon and chemical energy* **The Environmental Literacy Project 2011-2012**
PROCESSES Powers of 10 Combustion	Photosynthesis Biosynthesis Cellular respiration	Digestion Biosynthesis Cellular respiration

KBS LTER
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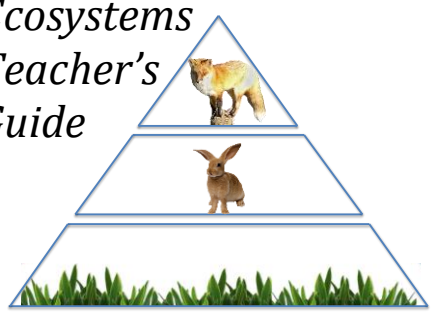
Long-term Ecological Research

Carbon TIME Curriculum, cont.

Decomposers And The Carbon Cycle *Decomposers* and the *Carbon Cycle*  *How decomposition changes* *Carbon and chemical energy* **The Environmental Literacy Project** **2011-2012**	*Ecosystems Teacher's Guide*  *How ecosystems store* *and cycle Carbon* *and chemical energy* **The Environmental Literacy Project** **Carbon: Transformations in Matter and Energy** **(Carbon TIME)** **2011-2012**	Human Energy Systems *Human Energy Systems* *Teacher's Guide*  *How humans use chemical energy* *stored in Carbon bonds* **The Environmental Literacy Project** **Carbon: Transformations in Matter and Energy** **(Carbon TIME)** **2011-2012**
PROCESSES		
Digestion Biosynthesis Cellular respiration	All processes except combustion in ecosystems	Combustion of fossil fuels for energy

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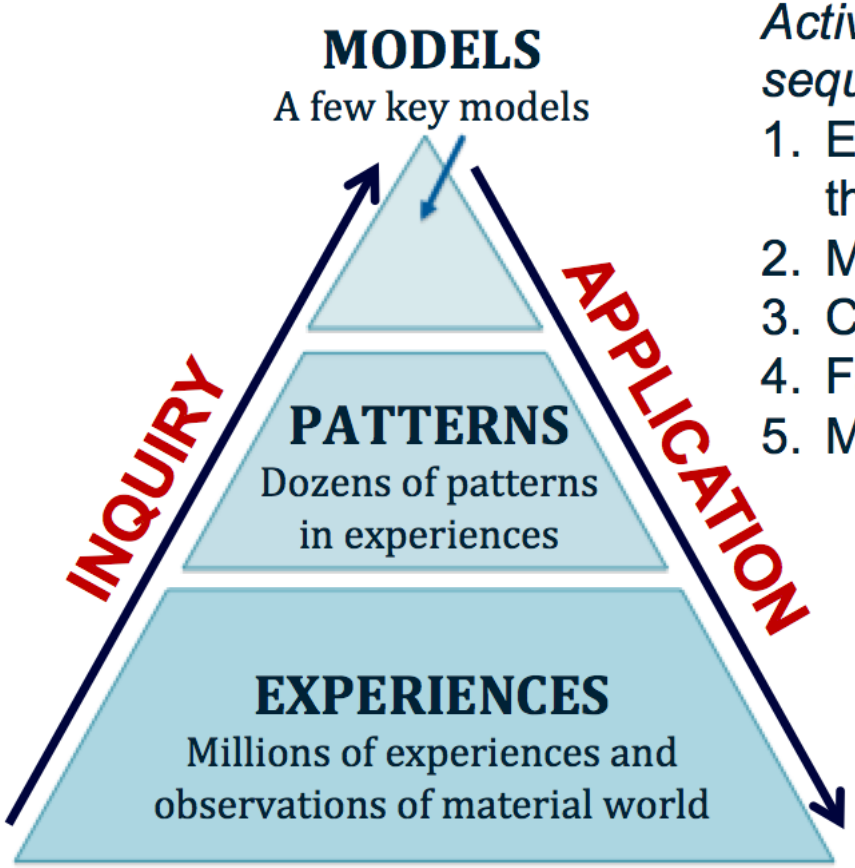
Activity Sequences in a *Carbon TIME* Unit

INQUIRY

Activity sequence:

1. Predict
2. Explain
3. Observe
4. Explain



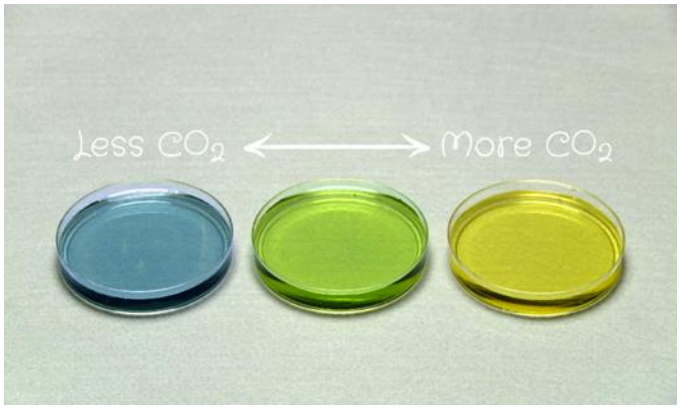
APPLICATION/ CITIZENSHIP

Activity sequence:

1. Establishing the problem
2. Modeling
3. Coaching
4. Fading
5. Maintaining

Inquiry Sequences Include:

Hands-on PEOE sequence



Video investigations. For example:

http://education.nationalgeographic.com/preview/education/media/burning-ethanol/?ar_a=1

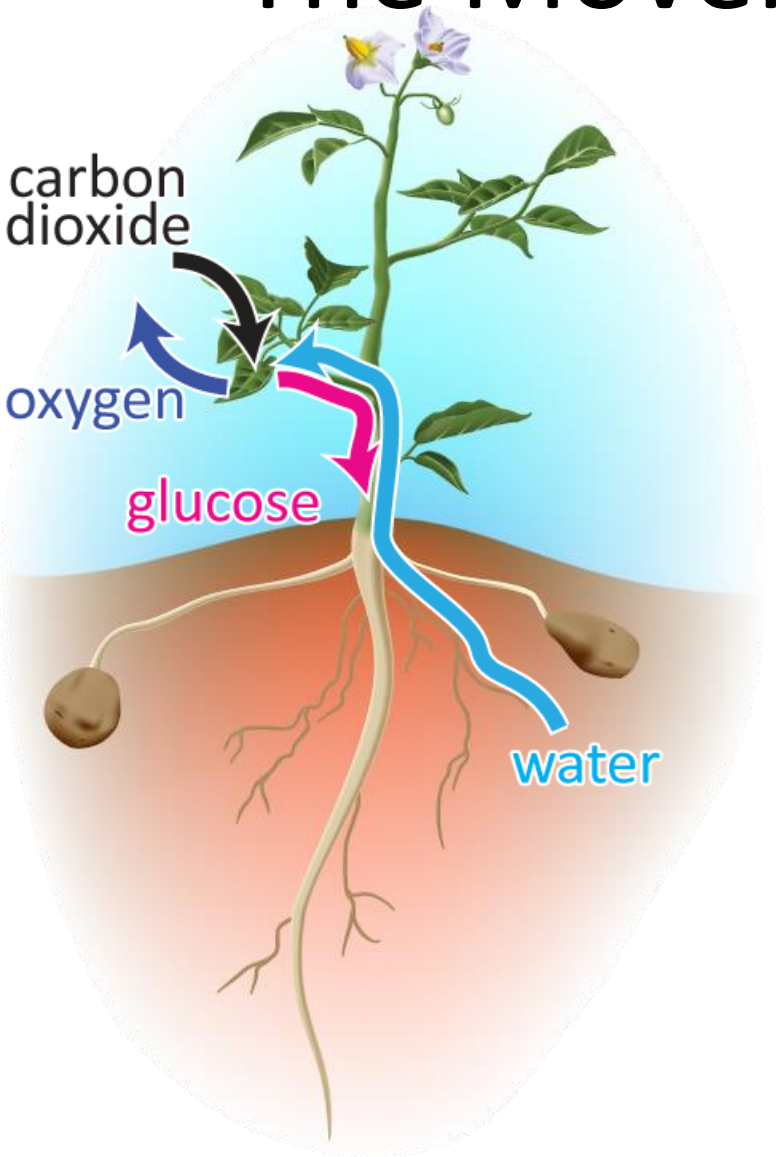
Cognitive Apprenticeship Application Sequences

- Establishing the problem: Unanswered questions from inquiry sequence
- Modeling and coaching: Animations and molecular models, writing a chemical equation
- Coaching and fading: Other problems involving plant growth
- Maintenance: revisiting photosynthesis in other units (especially *Ecosystems* and *Human Energy Systems)*

Plants Lesson 2, Activity 2: Using Molecular Models to Explain Photosynthesis

Answering the Three Questions for plants in the light

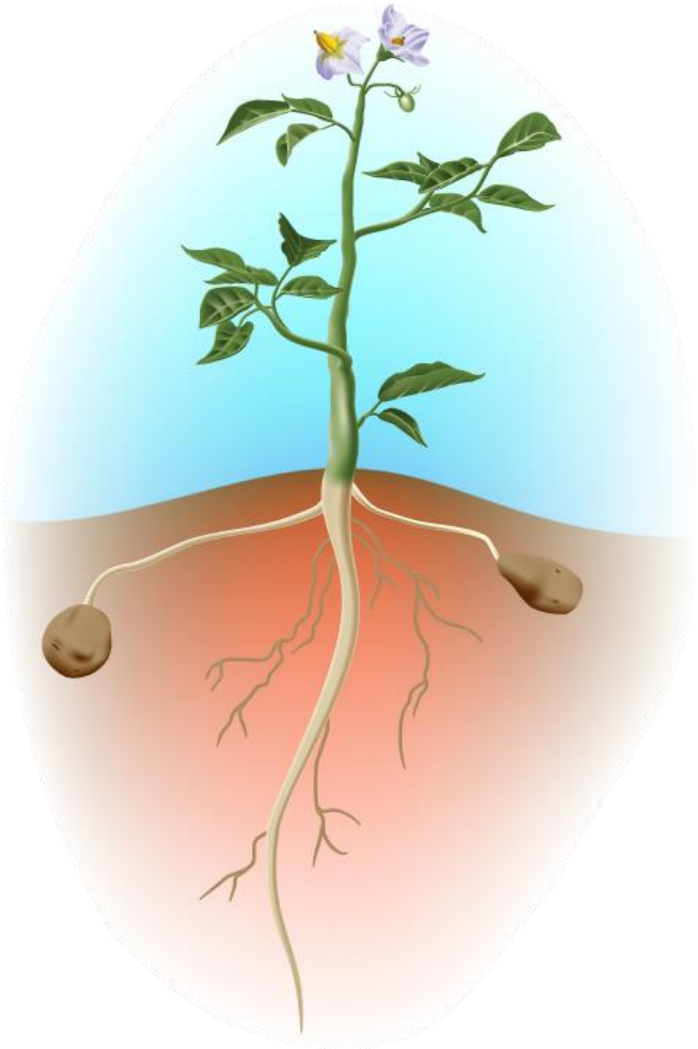
The Movement Question

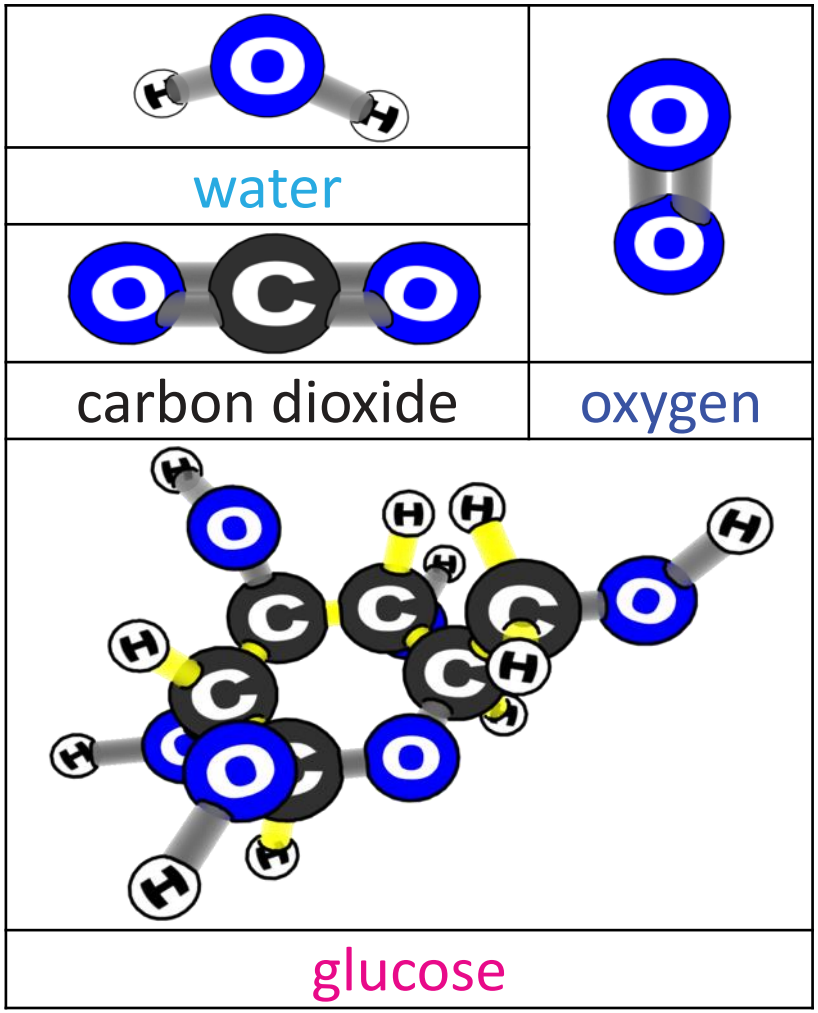


Where are atoms moving **from**?

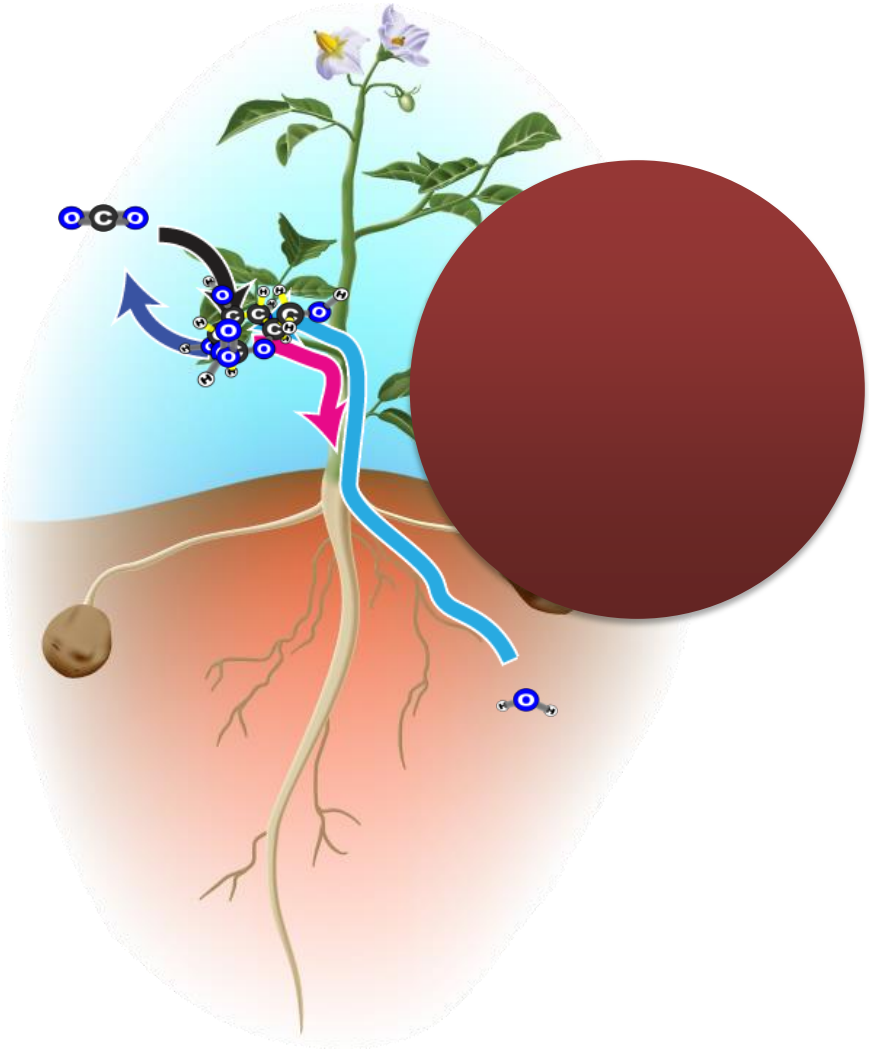
Where are atoms moving **to**?

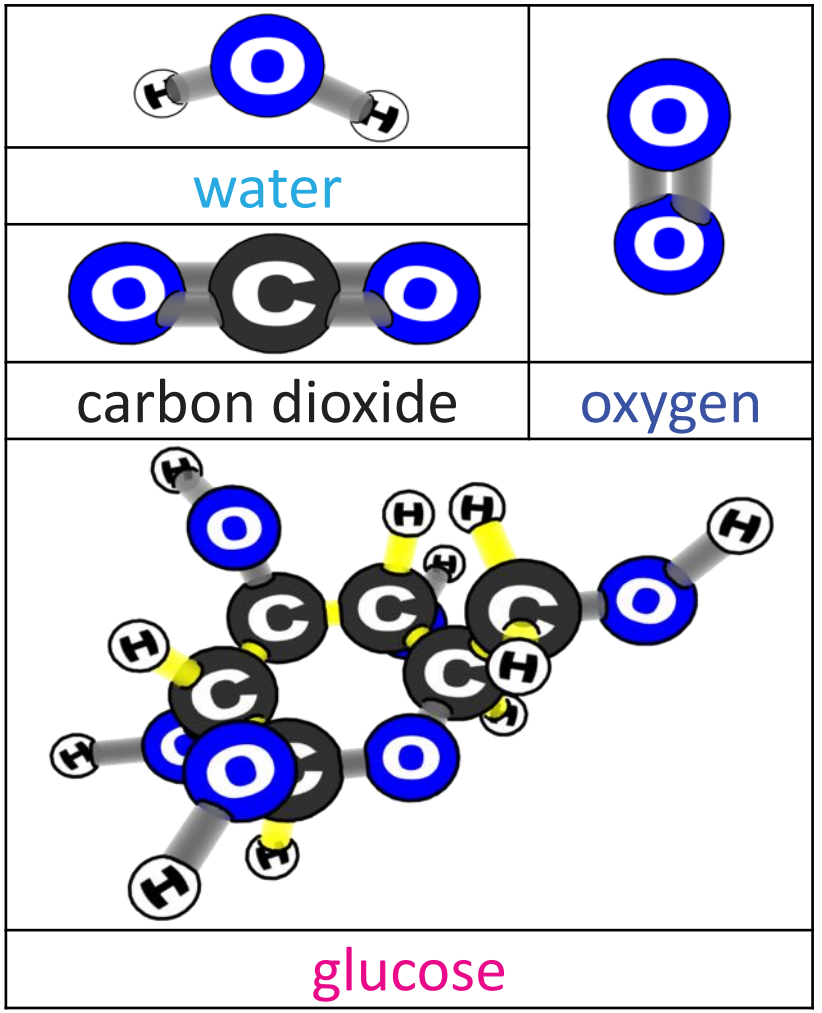
Which atoms and molecules move so that plants can do photosynthesis?



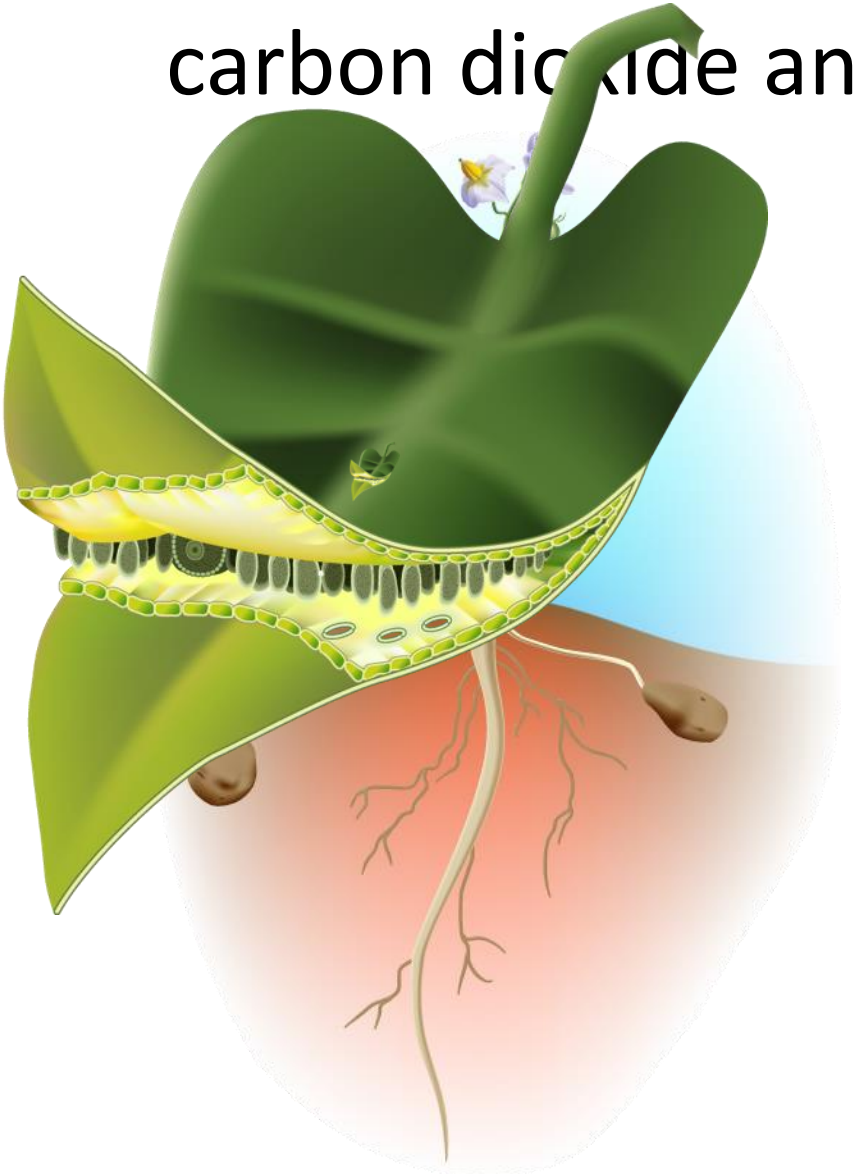


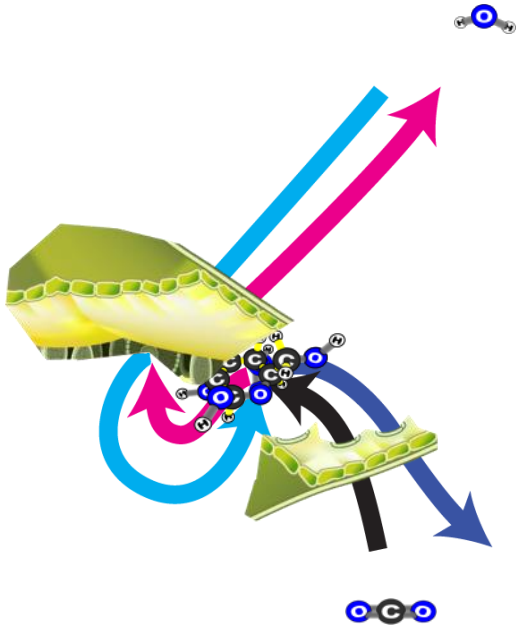
How do glucose water, carbon dioxide and oxygen move for a plant leaf to photosynthesize?



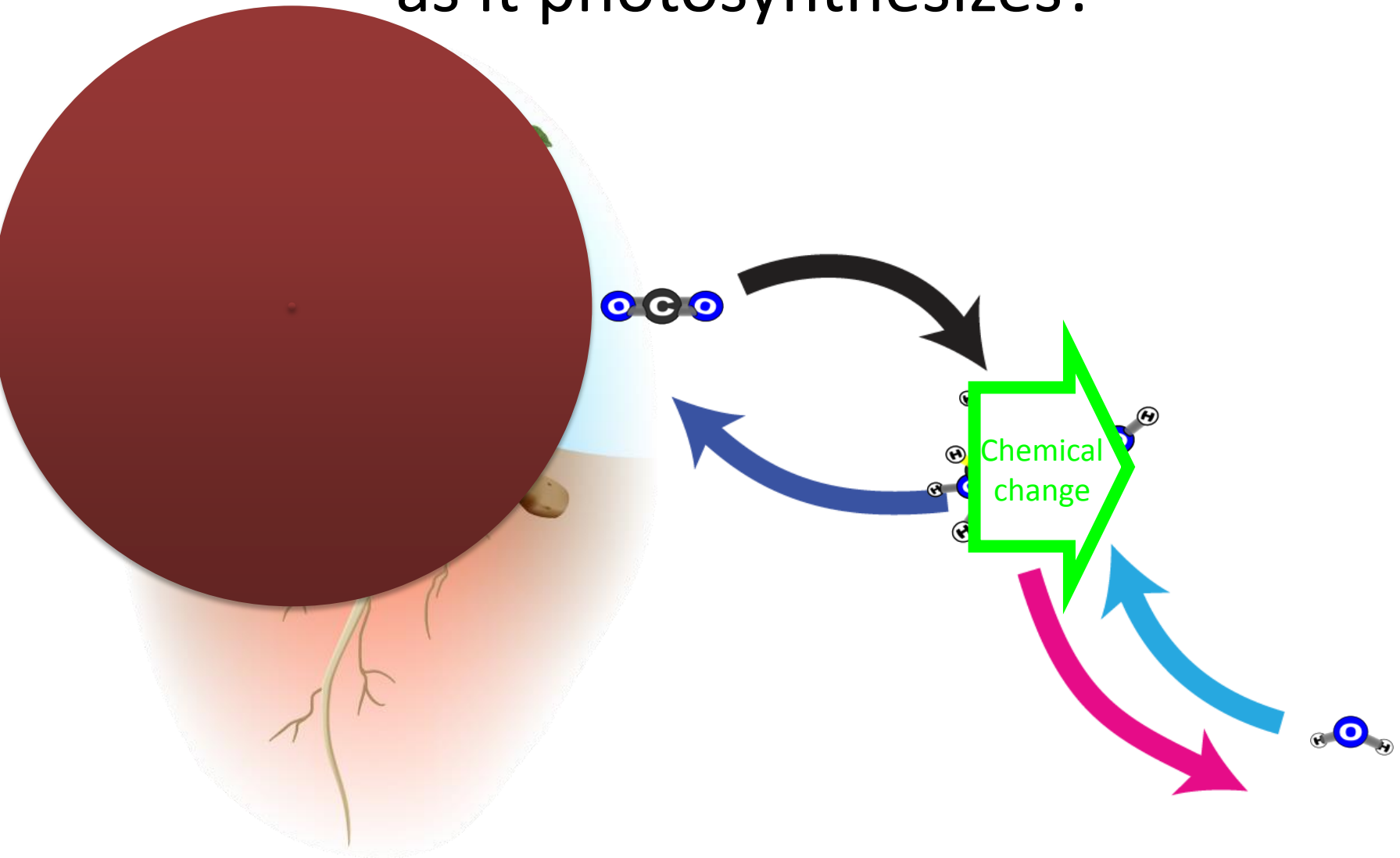


Plants make glucose from carbon dioxide and water in their leaves.





What happens inside the leaf cell as it photosynthesizes?



Comparing photos of reactant and product molecules

Compare the atoms and energy units on the reactant and products sides.

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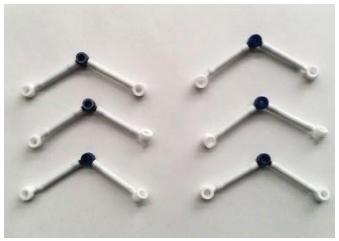
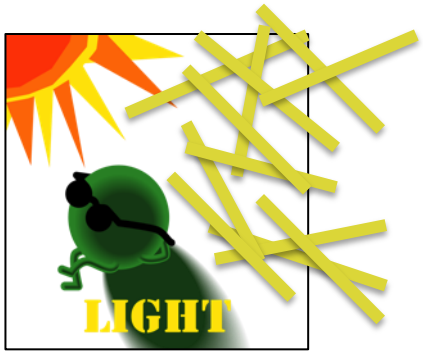
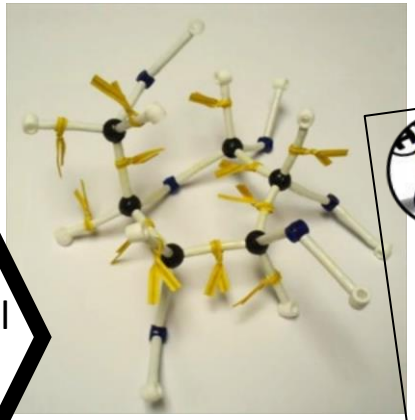
Carbon dioxide



Water



Chemical change



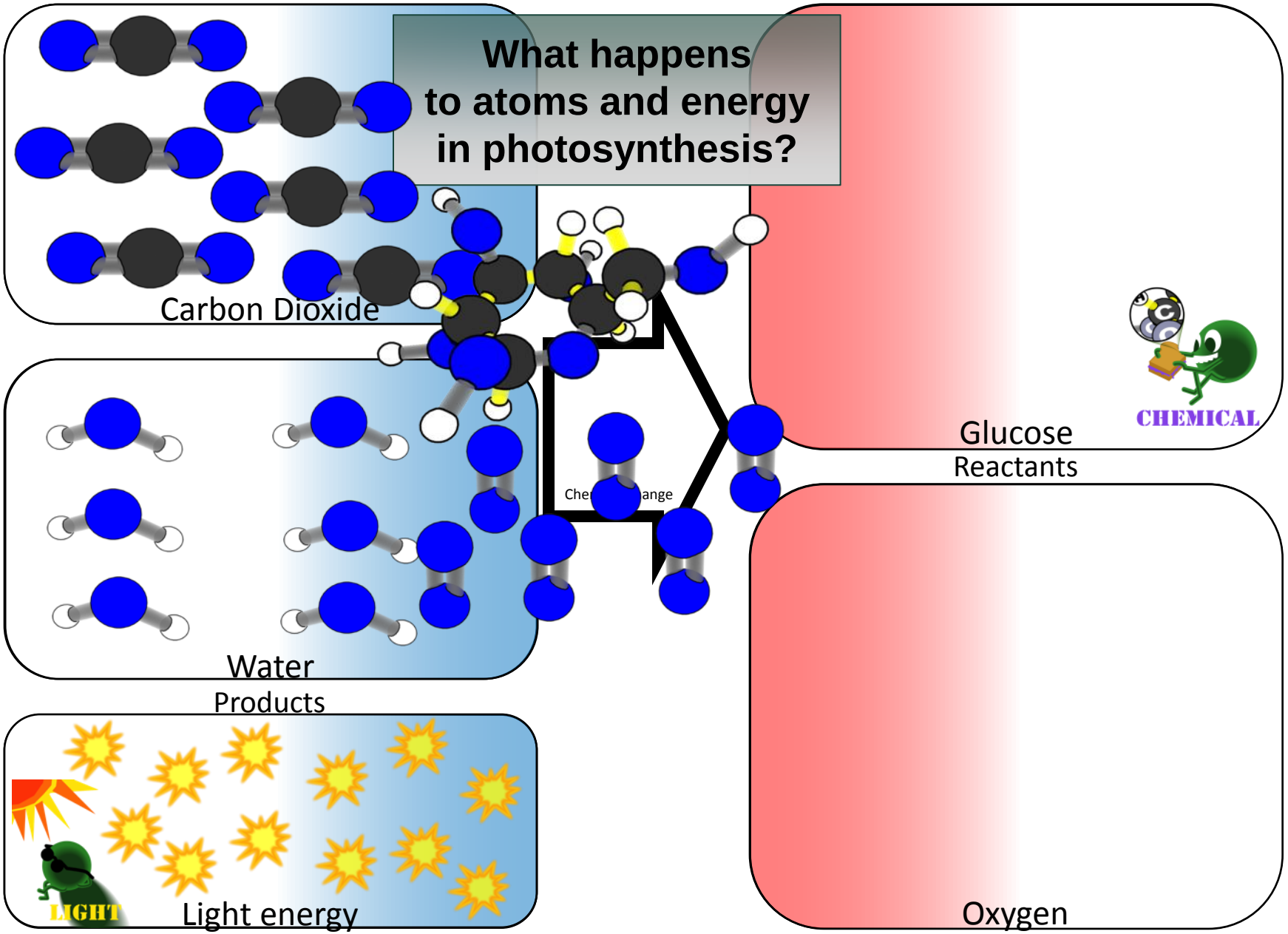
Glucose

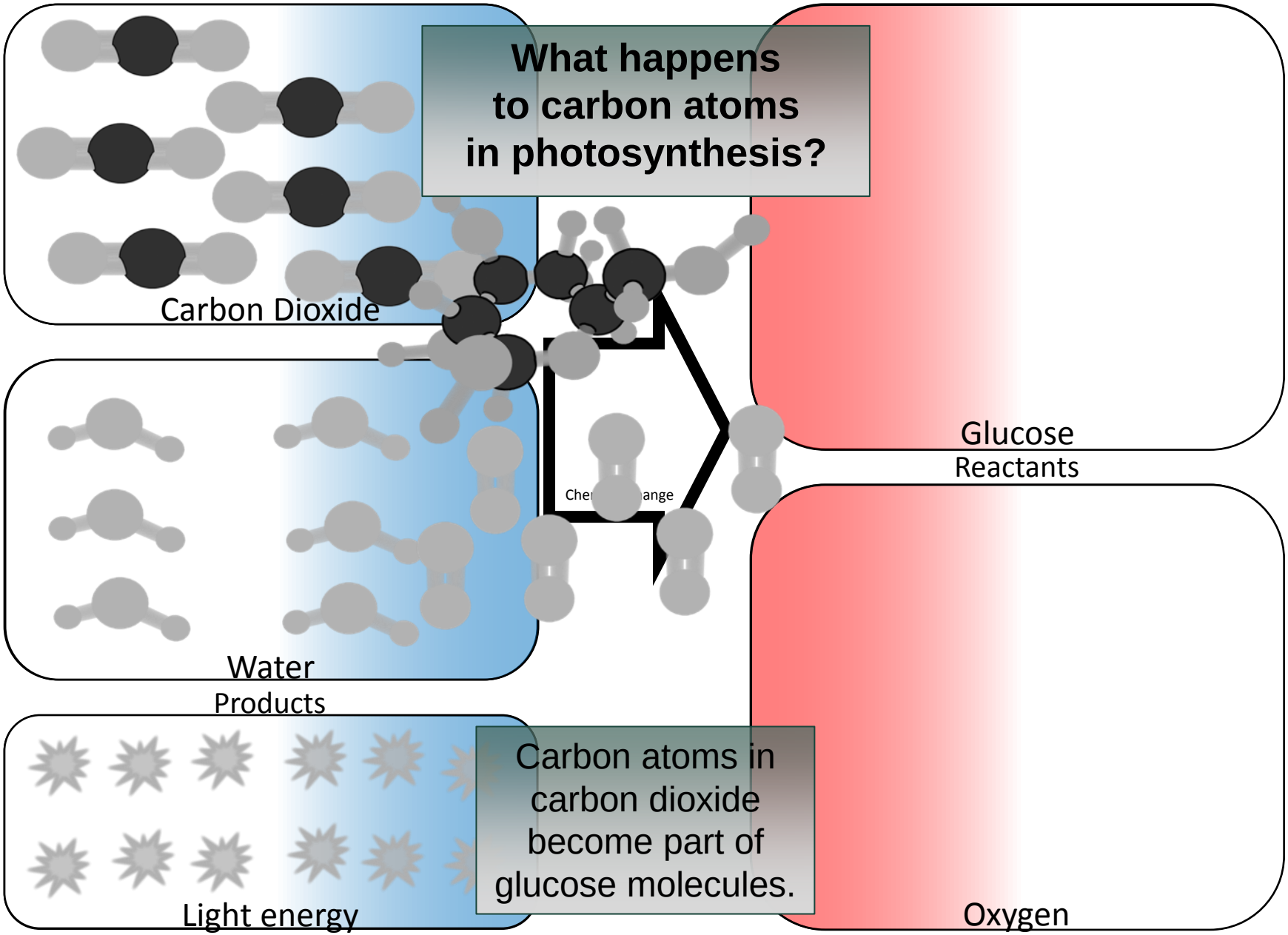
Oxygen

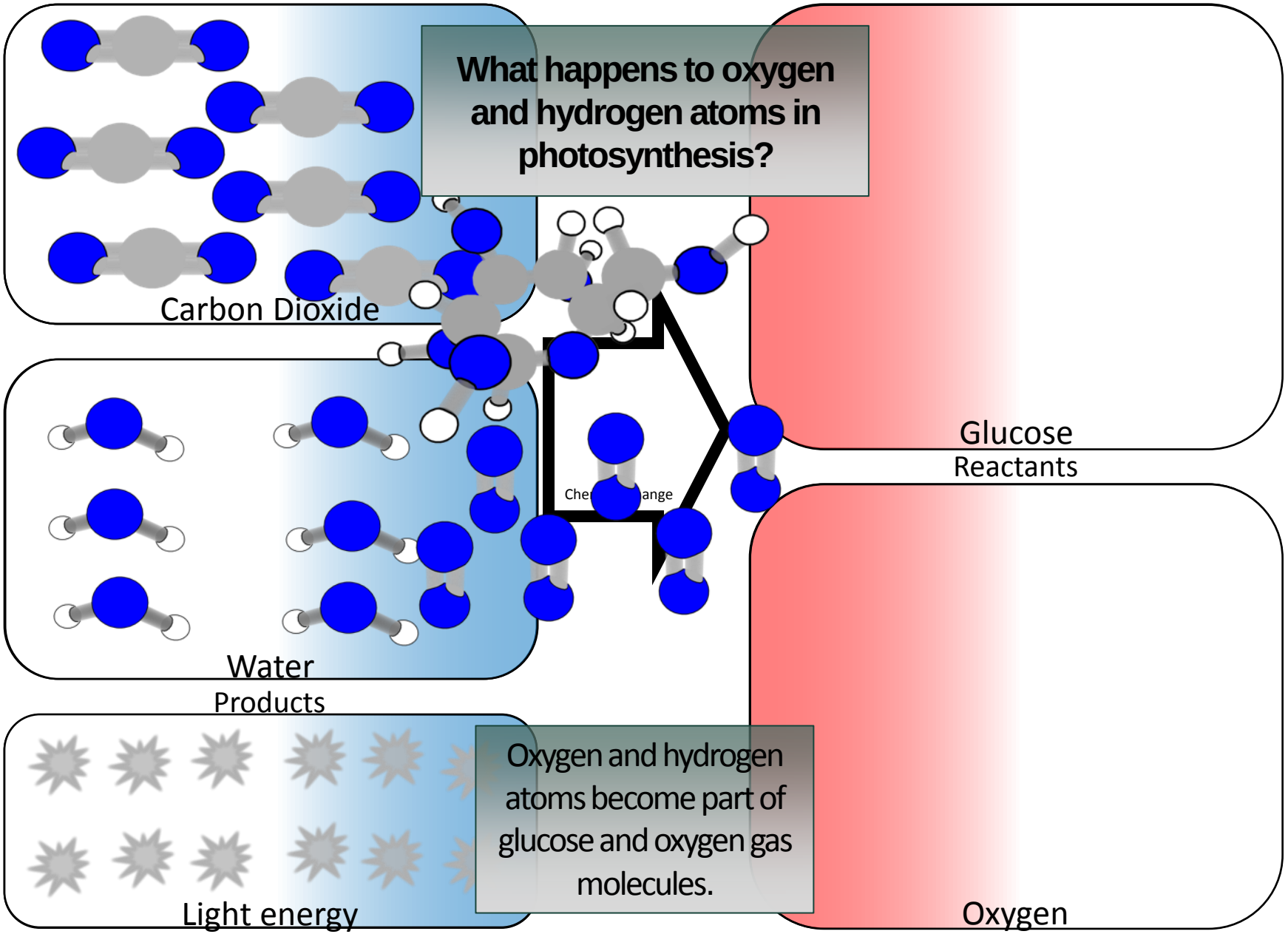
Reactants

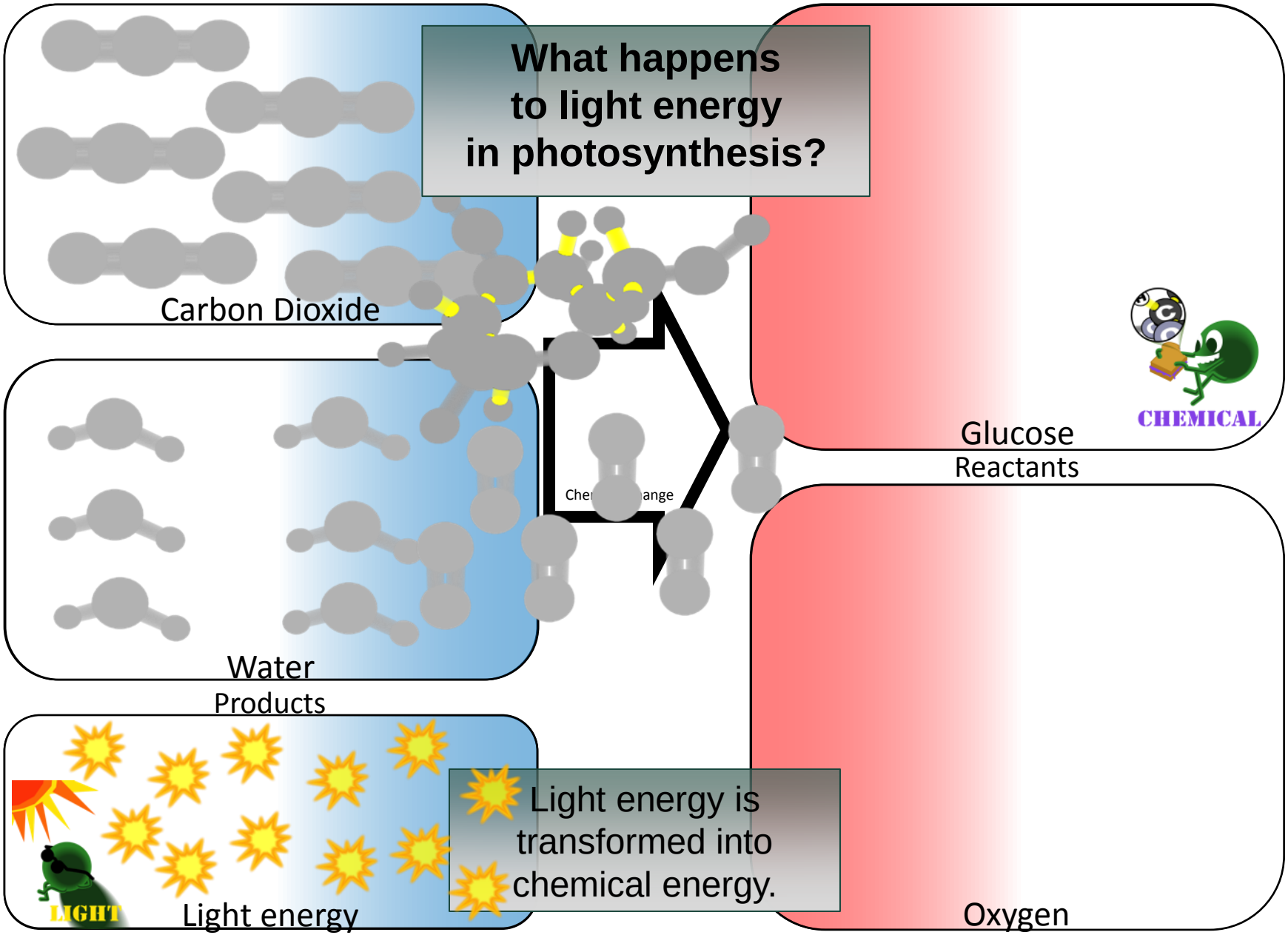
Products

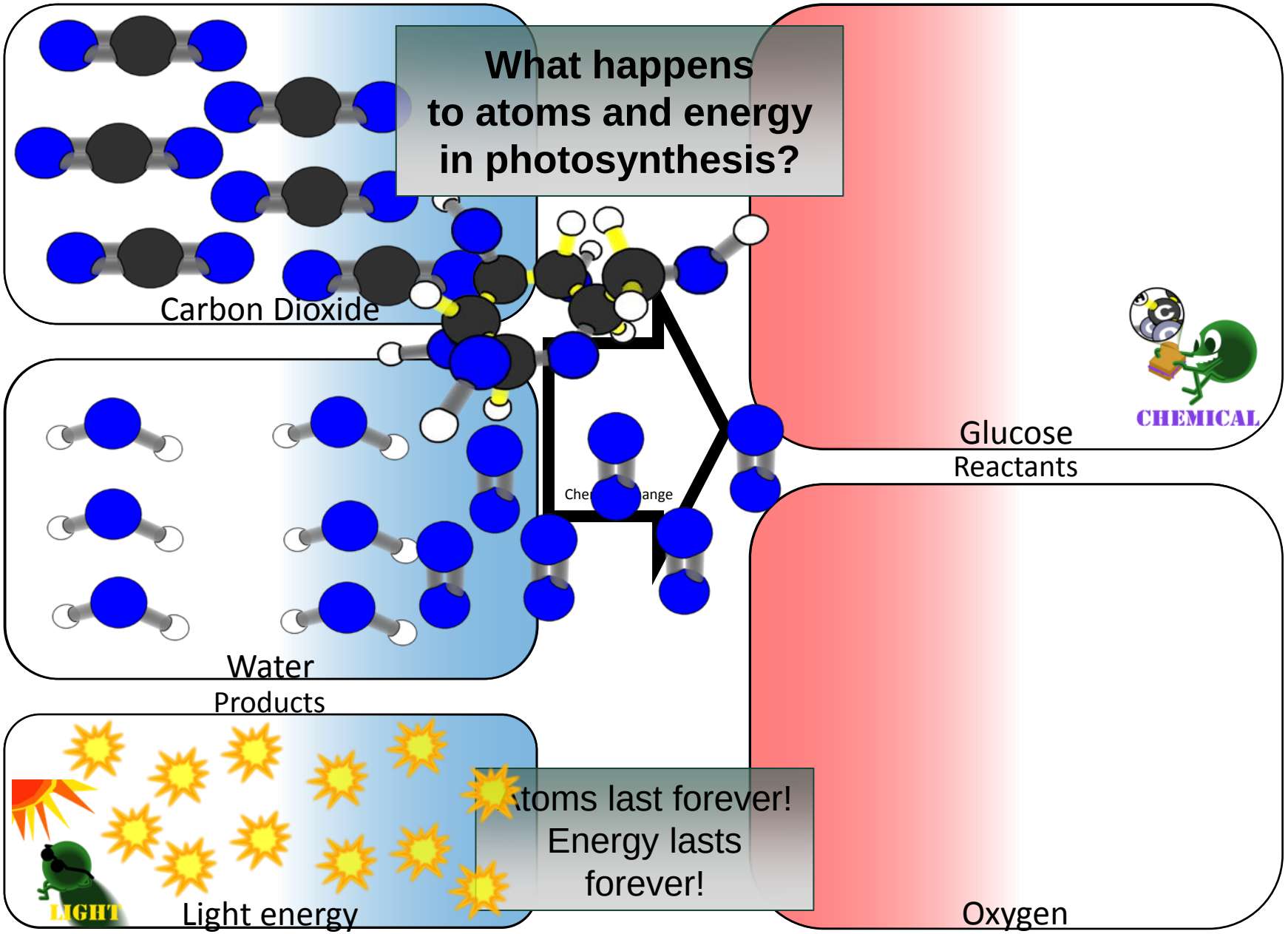
Remember: **Atoms last forever** (so you can rearrange atoms into new molecules, but can't add or subtract atoms). **Energy lasts forever** (so you can change forms of energy, but energy units can't appear or go away).


What happens to atoms and energy in photosynthesis?
Carbon Dioxide
Water
Products
Light energy
LIGHT
Glucose
Reactants
CHEMICAL
Oxygen


What happens to carbon atoms in photosynthesis?
Carbon Dioxide
Water
Products
Light energy
Glucose
Reactants
Oxygen
Carbon atoms in carbon dioxide become part of glucose molecules.


What happens to oxygen and hydrogen atoms in photosynthesis?
Carbon Dioxide
Water
Products
Glucose
Reactants
Light energy
Oxygen
Oxygen and hydrogen atoms become part of glucose and oxygen gas molecules.


What happens to light energy in photosynthesis?
Carbon Dioxide
Water
Products
Glucose
Reactants
Oxygen
CHEMICAL
LIGHT
Light energy
Light energy is transformed into chemical energy.


What happens to atoms and energy in photosynthesis?
Carbon Dioxide
Water
Products
Glucose
Reactants
CHEMICAL
Oxygen
Light energy
LIGHT
toms last forever!
Energy lasts forever!

Writing a Chemical Equation

- Writing in symbols: Chemists use an arrow to show how reactants change into products:
  [reactant molecule formulas] → [product molecule formulas]
- Saying in words: Chemists read the arrow as "yield" or "yields":
  [reactant molecule names] yield(s) [product molecule names]
- Equations must be **balanced:** Atoms last forever, so reactant and product molecules must have the same number of each kind of atom.

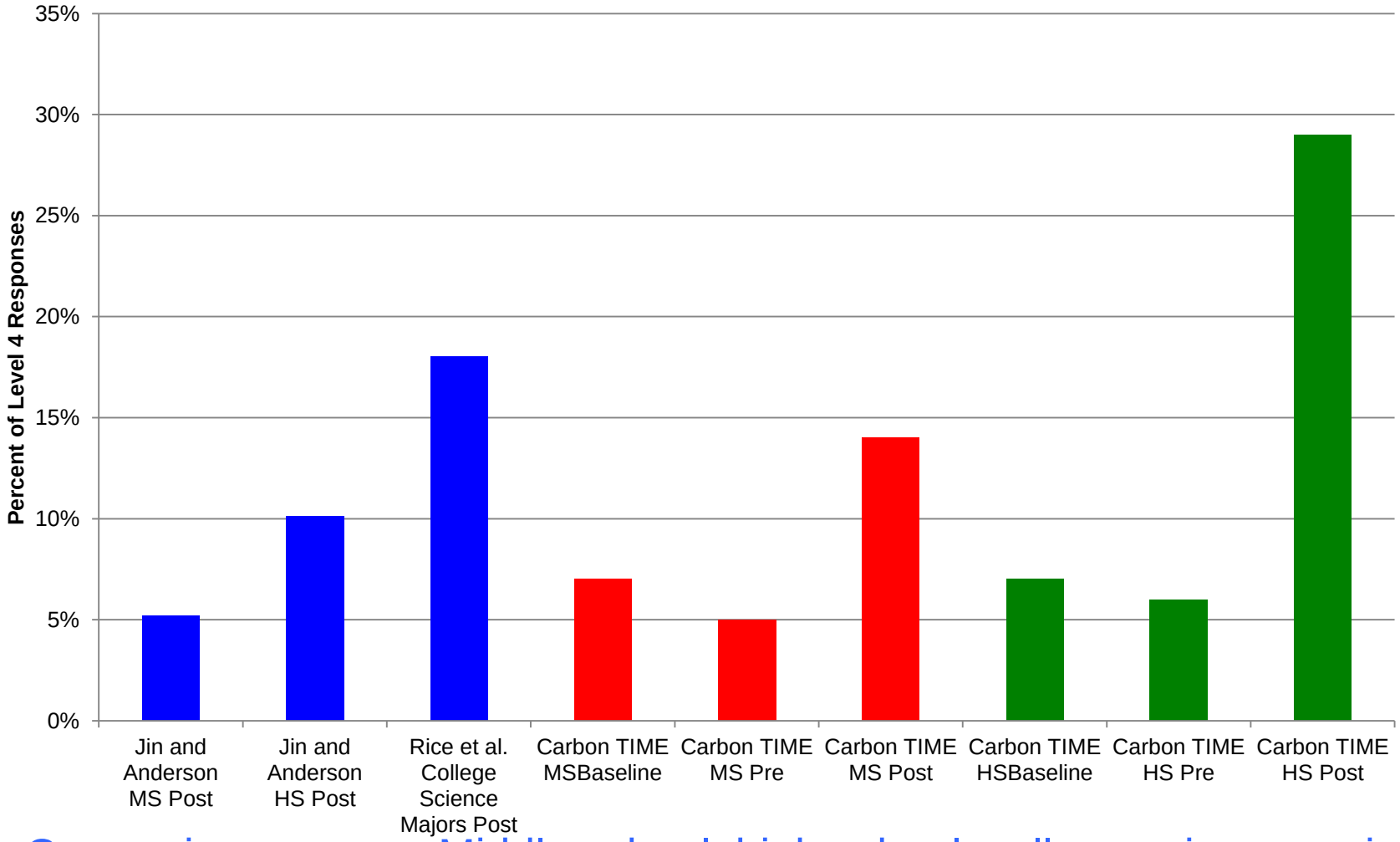
- Try it: can you write a balanced chemical equation to show the chemical change for **photosynthesis**?

Chemical Equation for **Photosynthesis**

$6H_2O + 6CO_2 \rightarrow C_6H_{12}O_6 + 6O_2$

(in words: water and carbon dioxide yield glucose and oxygen)

Percentages of Level 4 Responses

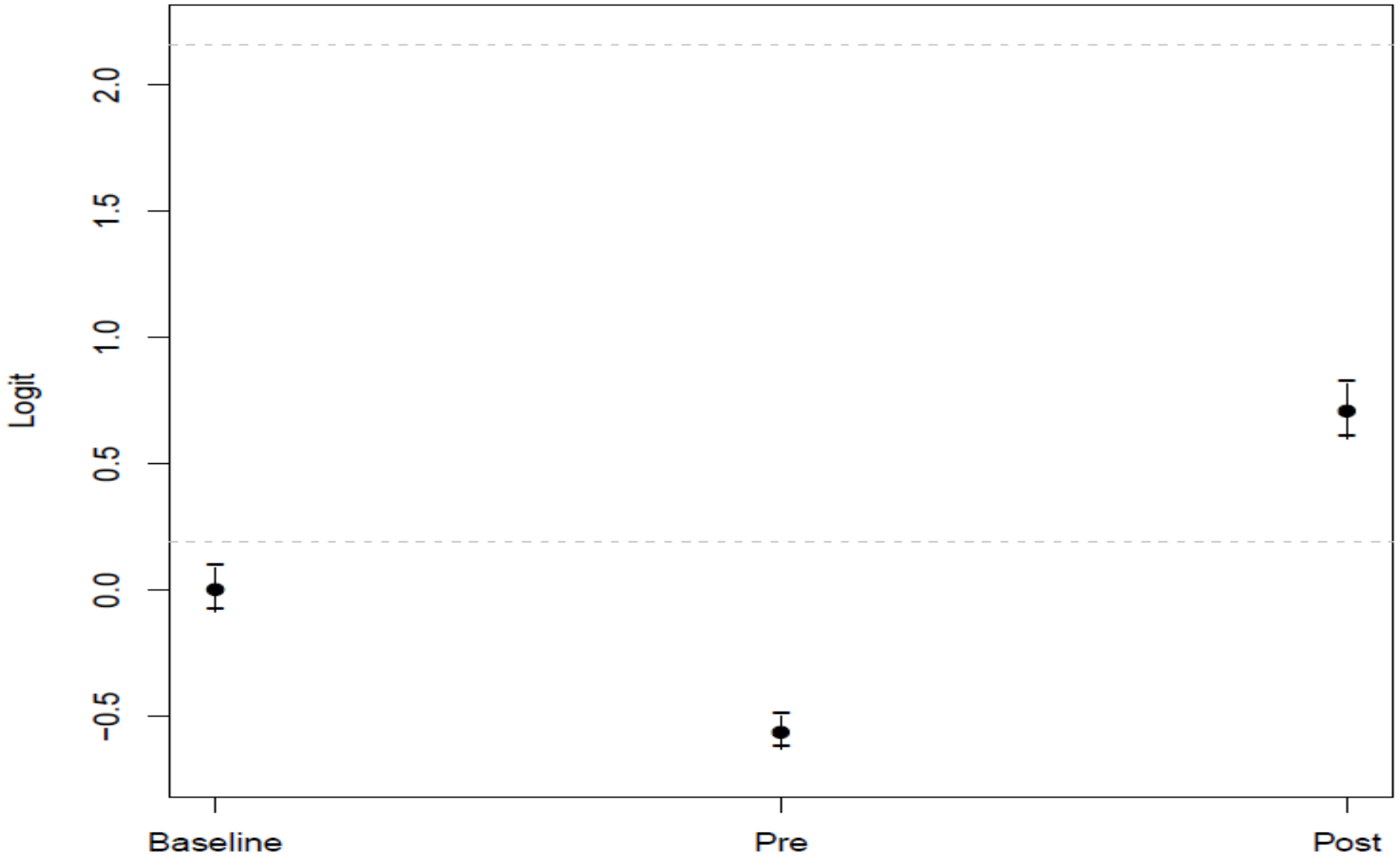


Blue: Comparison groups: Middle school, high school, college science majors

Red: Carbon TIME middle school: baseline, pre, post

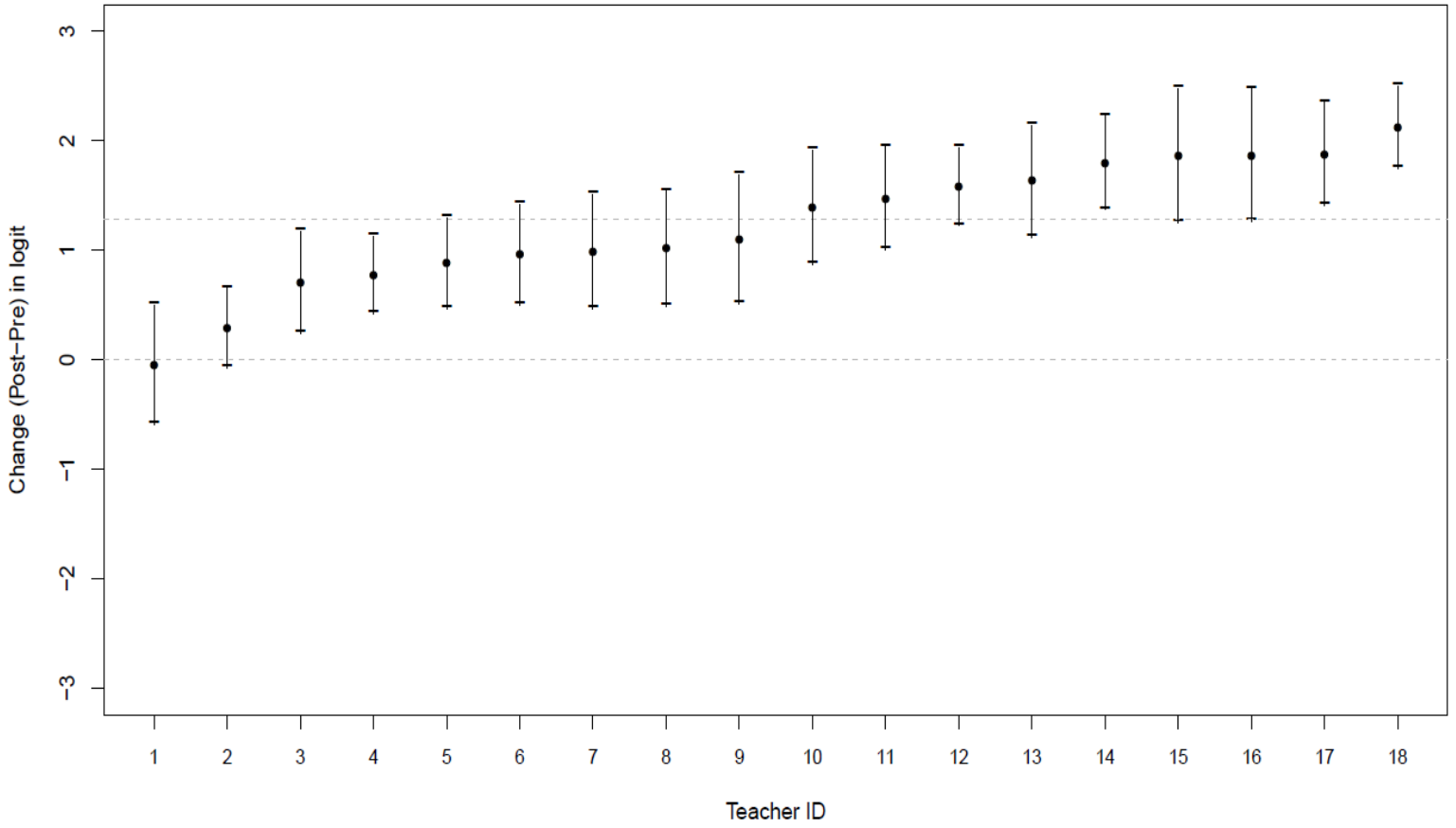
Green: Carbon TIME high school: baseline, pre, post

IRT-based Analyses of Cohorts 1 and 2



Baseline, pre, and post achievement for Cohort 1 and Cohort 2 students. Error bars represent 95% confidence intervals. Dashed lines are mean thresholds for learning progression Levels 3 and 4.

Comparing Student Learning for Different Teachers



Student learning for Cohort 2 teachers. Error bars represent 95% confidence intervals. Dashed lines represent (a) no learning and (b) average learning gain for all teachers.

Hypotheses about Important Differences among Teachers

- Purpose: Conveying a consistent sense of purpose across lessons and units
- Principles: Consistent focus on tracing matter and energy and connecting scales
- Talk moves (cf., Michaels and O'Connor): Using a repertoire of strategies to elicit students' ideas and discuss them critically
- Curiosity: Actively exploring scientific data and models and students' ideas

Interview conducted by a more successful teacher

TEACHER 30: How does the tree use sunlight to grow?

STUDENT: Sunlight helps it in photosynthesis and photosynthesis is how the leaves make their food which helps them to continue to grow so the sunlight helps the tree.

TEACHER 30: Just a second ago I thought I heard you said that the soil provides nutrients which is like its food and now you're saying that the tree … the sunlight comes from … so could you clarify that, I'm a little … could you clarify that for me?

STUDENT: The sunlight mainly helps with the growth of the leaves but the nutrients in the soil help with the growth of the trunk and the leaves so mainly but it takes time for the tree to get to the point where it's growing leaves so while it doesn't have leaves any more it's still using the nutrients from the soil.

Interview conducted by a less successful teacher

STUDENT: The sunlight gives … I think it helps with the tree's life cycle.

TEACHER 6: The sunlight helps with the tree's life cycle? Okay. Is water giving it any energy?

STUDENT: It helps it grow more.

TEACHER 6: Okay. Do you know how it helps it grow or how do you think it helps it grow?

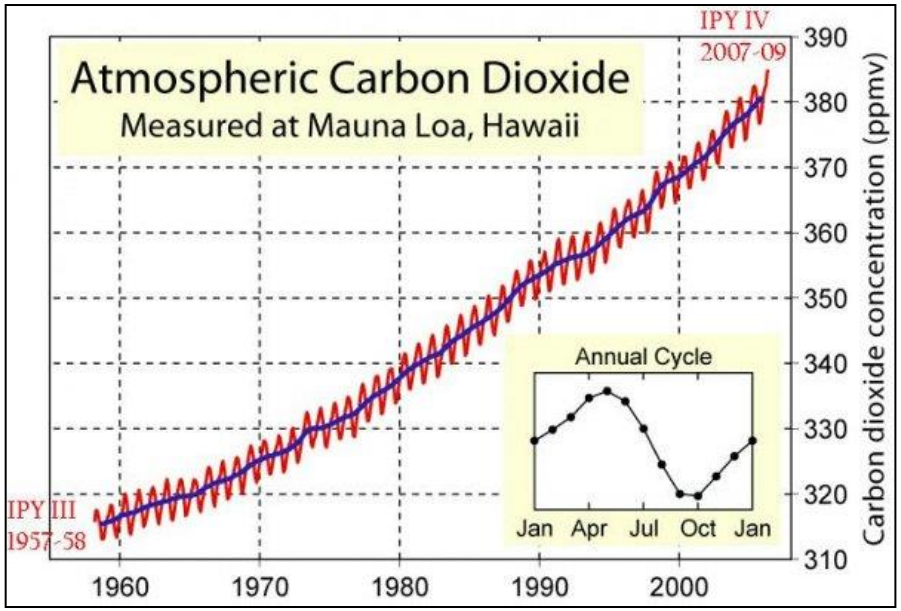
STUDENT: It's kind of like the tree's food.

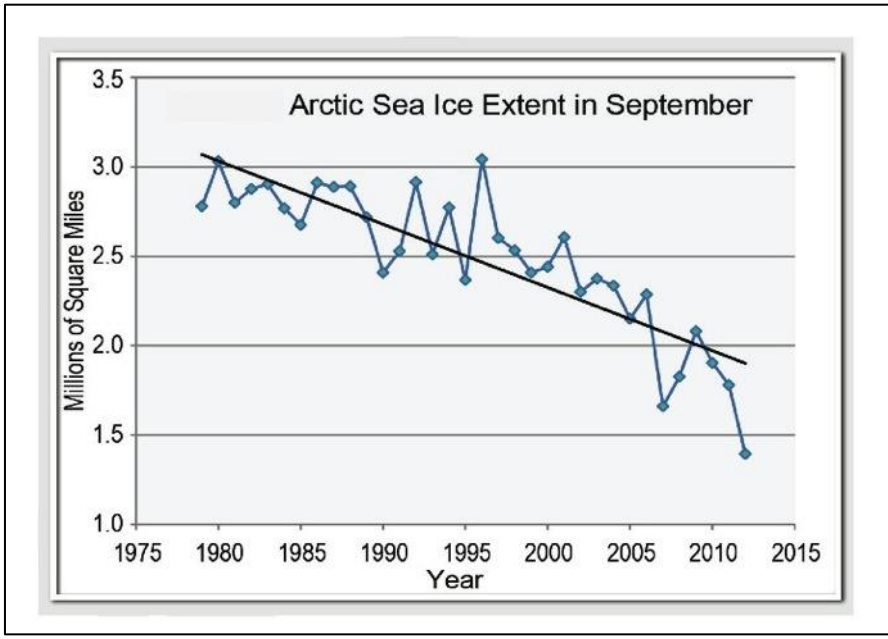
TEACHER 6: Okay. How about the nutrients?

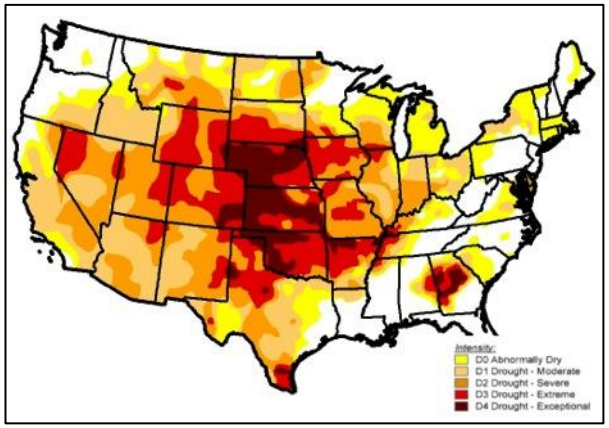
STUDENT: The nutrients is also its food.

TEACHER 6: Also its food? All right. Okay these are the right cards. All right, so we have six cards here…(moving on to next task)

To do: Investigating students' reasoning about large-scale data, climate change, and sustainability







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