**Supplemental Material 1. Details of the diagnostic questions[1] and their corresponding in-class activities.**

| DQC Question Number & Topic | Biological Processes Assessed | Targeted active-learning activities |
|---|---|---|
| 1 – Seasonal fluctuation of atmospheric $CO_2$ | Photosynthesis<br>Biosynthesis<br>Respiration in plants | Global Climate Change Graphs – Students work in small groups interpreting several IPCC figures, including the Keeling curve, and respond to discussion questions (1-AL and 2-AL,). |
| 2 – Cellular respiration as C source in decomposers | Cellular respiration in decomposers | Cow Graphs – Students work in small groups interpreting two bar graphs showing the amount of carbon in different components of the ecosystem through time with carbon originating from a dead cow. Followed by whole class discussion (Figure 1) (1-AL, 2-AL, 3-MAL).<br><br>Tracing Carbon – Students are given a "you are a carbon atom" scenario and asked to follow the C from the air to a variety of destinations, discussing the processes the atom experiences along the way (1-AL, 2-AL, 3-MAL). |
| 3 - Photosynthesis as C sink | Photosynthesis | Cow Graphs (see above)<br><br>Ecosphere Problem Tasks – Students solve a set of data-rich problems that prompt students to reason both qualitatively and quantitatively about the role of producers, consumers, and decomposers in the cycling of matter and flow of energy in a small enclosed ecosystem (two hour activity, See Maskiewicz, 2006).<br>(1-AL) |
| 4 – Cellular respiration and biosynthesis in decomposers | Cellular respiration in decomposers<br><br>Biosynthesis | Mold Graph – Students work in small groups to interpret a graph showing the change in mass of a piece of fruit and mold and discussion questions (2-AL)<br><br>Ecosphere Problem Tasks (see above) |
| 5 – Photosynthesis and biosynthesis in plants | Photosynthesis<br>Biosynthesis | Carbon from soil – Students work in small groups interpreting a graph showing change in mass of potted plant (dry weight) and soil with discussion questions (2-AL).<br><br>Classic Plant Experiments – Students work in small groups making predictions for and then reasoning about famous classic plant experiments conducted by researchers such as von Helmont, Woodward, and Priestley (Rabinowitch, 1971) (1-AL). |
| 6 – C released by cellular respiration in plants | Cellular respiration in plants | Ecosystem diagram – students draw arrows representing sources and sinks of carbon (2-AL).<br><br>Classic Plant Experiments (see above) |
| 7 – C source for biosynthesis in carnivore | Digestion, biosynthesis, & respiration in animals | Whale-krill-phytoplankton tropic level exercise (e.g, students reason about how much carbon in a whale comes from phytoplankton) (2-AL)<br><br>Coal Box Diagrams – students complete box and arrow diagrams determining, for example, where the carbon in coal originates (1-AL, 2-AL, 3-MAL). |

1 The questions were selected from two DQC sets, Keeling Curve (1) and Grandma Johnson (2-7), both available at http://www.biodqc.org. Hartley *et al.*, (2011), explain that these questions test students' understanding of generative, transformative, and oxidative biological processes across two or more scales of biological organization.