HOW TO USE THIS RESOURCE
The image(s) for this resource, Slug Power and Solar Fix, can serve as an anchoring phenomenon to explore the key concepts described below. The pedagogical practice of using phenomena to provide a context for understanding science concepts and topics is an implementation practice supported by the Next Generation Science Standards (NGSS). Phenomena are observable occurrences that students can use to generate science questions for further investigation or design solutions to problems that drive learning. In this way, phenomena connect learning with what is happening in the world while providing students with the opportunity to apply knowledge while they are building it.

The “Implementation Suggestions” and “Teacher Tips” sections provide options for incorporating the images into a curriculum or unit of study, and can be modified to use as a standalone activity or to supplement an existing lesson. The student handout includes reproductions of the images and the “background” section.

KEY CONCEPTS
A. Photosynthesis transforms light energy into stored chemical energy by using sunlight to power the conversion of carbon dioxide plus water into sugars plus released oxygen.
B. Organisms that conduct photosynthesis must be able to capture light energy from their environment.

NGSS PERFORMANCE EXPECTATIONS
HS-LS1-5 Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.

BACKGROUND
The sacoglossan sea slug Elysia crispata can be found sunbathing on Caribbean reefs. The slug feeds on green algae but can survive for more than a month without eating. This is because sea slugs store chloroplasts, organelles in the cells of plants and algae that capture energy from sunlight and convert it to chemical energy by photosynthesis, as they ingest different species of green algae. The chloroplasts are stored in the slug’s digestive epithelium and remain active for up to 3-4 months, providing nutrients from photosynthesis, as well as camouflage by making the slug green in color. “Kleptoplasty,” or “stolen plastids,” is the term for the slugs’ remarkable ability. Some marine protists including foraminifera, dinoflagellates, and ciliates are capable of kleptoplasty, but sea slugs are the only animals to exhibit kleptoplasty. They represent a powerful model system for studying the evolution of photosynthesis in eukaryotes through multiple endosymbiotic events.

Humans depend on photosynthesis because it is responsible for most of Earth’s primary productivity and fossil fuels are obtained mostly from remains of prehistoric plants. A typical plant cell contains about 10 to 100 chloroplasts. Several lines of evidence, including DNA evidence, suggest that chloroplasts evolved from an endosymbiotic event, when a eukaryotic cell incorporated photosynthetic cyanobacteria. Chloroplasts contain their own DNA that descended from the cyanobacterial ancestor.

IMPLEMENTATION SUGGESTIONS
The following suggestions outline several options for incorporating the images into a unit of study as the anchoring phenomenon:
• Engagement, establishing prior knowledge, and providing context:
  - Ask students to describe their observations about the images to one another using the stems, “I notice ... I wonder ...”
- Ask groups of students to generate and refine their own questions about the energy capture. Example focus of student questions might include:
  o Sea slug image
    • The slug’s structure and traits, particularly color, shape, texture, etc.
    • The slug’s habitat, diet, or interactions with its environment.
    • The relationship of the slug photo to the chloroplast image.
  o Chloroplast image
    • The shape or contents of the cells, such as the number of chloroplasts.
    • How the image was prepared, such as whether colors derive from stains.
    • The relationship of this image to the sea slug photo.

- Have students read the captions for each picture, annotating each with the class-derived questions above and/or the following guiding discussion question: “How does each image show how organisms capture energy from their environment during photosynthesis?”
  o Student answers at this stage may be preliminary and may focus on identifying unknown terms or concepts.
  o These will serve as initial ideas that will be refined through further investigation, discussion, and introduction of other models.

- Use and refer to the image throughout the set of lessons or unit of study as the anchor for understanding and explaining about endosymbiosis or energy production. (See resource-pairing suggestions for sequencing options.)

  * Exploration, investigation and assessment:
    - Investigate: Using information from class discussion or other research, students develop evidence-based explanations as to whether the slug is an autotroph or heterotroph and/or its role in an ecosystem.
    - Extension: Explain why kleptoplasty offers the slug a survival advantage.
    - Assessment: Use images as a prompt for students to provide evidence that these slugs “stole” chloroplasts to assess understanding of kleptoplasty as a special case of endosymbiosis. Student answers may include looking for chloroplast DNA, mRNA or proteins in the slugs following ingestion of algae as evidence of chloroplast retention.

**TEACHER TIPS**

- Present students with the image(s) first, before they read the background information.
- Background information may be edited to support student proficiency, course sequence, etc.
- The image(s) may be projected in lieu of handouts.
- Pair or group students to work through one or more of the implementation suggestions.

**Resource-pairing suggestions:**

- Use images prior to investigating evidence for endosymbiotic theory using micrographs/microscopy; video or diagram analysis; etc.
- Use images following an overview of the evolution of mitochondria and chloroplasts.

**AUTHOR**

Sydney Bergman, HHMI
Edited by Paul Beardsley, PhD, and Laura Bonetta, PhD, HHMI