

Food and Energy A Multi-Part Investigation

Part I: who eats whom?

Y'know, I thought I saw a fox this morning.

What do foxes eat around here?

Hey, I have an idea:

Get together in small groups and write down everything you can think of that foxes might eat in southern Indiana.

Now, let's collect all of our data: write the names of these animals on the board.

That's a lot.

Hmm...what else might eat these things? Let's write these animals down, too.

This gives us many more animals.

Hmm...what might the animals we thought of as "fox-food" eat?

Etc etc--we can keep expanding this food web using completely realistic information, tying into students' existing knowledge.

- Note that we eventually get to plants as the base of the food web.
- Note also that this is not a food chain--it's too complicated, with too many interactions. This is the way it *really is* in nature. If students develop their own understanding and recognition of this kind of complexity, then they will be better able to recognize the simplifications when we present them.
- Do we dare draw a diagram of this? If so, do we connect the animals' names with arrows or just with lines? If we use arrows, what do the arrows mean? The tradition is to have the arrows point from prey to predator, indicating the flow of energy from prey to predator--but our students don't have the concept of "food as energy" yet! Maybe it's best not to use arrows yet.

So, out there, *all this stuff is going on at once?* Yikes!

But, we can summarize:

Animals eat plants

Or

Animals eat animals that eat plants

Or

Animals eat animals that eat animals that eat plants

What does this tell us?

All of life depends on plants!

- if humans disappeared from the planet tomorrow, nothing would happen
 - if plants disappeared, everything else would die
- apparently, plants are much more important than we are.
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- Note that our students may key on other aspects of light, and may imagine that plants need light to be warm, or that plants sleep when it's dark so they can't grow...

In the end, we'll have to think of another experiment to figure this out. This is parts IV and V, which we could do next, or later.

In the meantime, these two Parts of this group leave us with a couple of questions:

1. What do plants do with light?
2. What do animals do with food?

Part III: What do Animals *Do* With Food?

What does everyone already know about food?

We eat it

Some is pooped out

If we don't get enough we get hungry

" " ...we lose weight

" " ...we get tired

" " ...we could die

If we get too much we get fat

OK, we have some information already. That is, students' previous knowledge is valid information. We should use this information--these observations--to develop understanding.

What does this information tell us?

Food becomes part of our own bodies. It is ...

... needed for young people to grow

... needed for adults to maintain their bodies

... and it *provides energy*

It looks like we actually know a lot already.

But...what's this *energy* bit? I wonder how this works...

Some classrooms have animals and facilities that allow them to do the complete experiment to find out what happens to food. Some do not. Fortunately, the experiment has been performed and published:

In 2000, Knopper and Boily measured lots of stuff for hamsters:

They measured:

Food eaten

Material excreted

Change in body mass

They found:

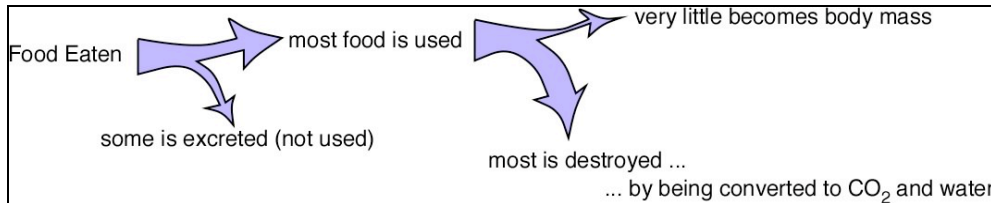
22% of food eaten is excreted

78% of food eaten is actually used

**0.7% of food eaten (and not excreted) appears as increase in body mass
what happens to the remaining 99.3%?**

It seems to disappear.

To understand where it goes, we need to think about the chemistry a little bit. It's not hard. Let's summarize what we just learned from the data, and then just add a tiny bit to it (i.e., the words "converted to CO₂ and water") to indicate the chemistry.



What does this tell us?

Look back at our list of things we know already.

Growing, maintaining adult weight, etc fall under "body mass" part of this diagram.

The other important function of food, *providing energy*, must be related to the food that does *not* become body mass. Therefore, we have to conclude that:

Animals destroy most of their food to extract energy from it

And, it seems that destroying food is a chemical process that converts it to CO₂ and water.

Uhhh...this leaves us with *another* question! how does energy get into food?

The reference:

Knopper and Boily, (2000). The Energy Budget of Captive Siberian Hamsters, *Phodopus sungorus*, Exposed to Photoperiod Changes: Mass Loss Is Caused by a Voluntary Decrease in Food Intake. *Physiol. Biochem. Zool.* 73: 517-522.

4.58 g / day food eaten

excreta = 1.01 g

mass gain = 0.024 g

$1.01 / 4.58 = 0.22$

22% of food eaten → excreted

$0.024 / 4.58 = 0.0052$

0.5% of food eaten → increase in body mass

We can account for 22.5% of food eaten. The rest is gone.

Let's subtract excreta, and compare food *assimilated* vs body mass:

$4.58 - 1.01 = 3.57$ $0.024 / 3.57 = 0.0067 \approx 0.7\% \rightarrow$ body mass

Part IV: Plants and Energy

What we've done so far left us with 2 questions:

How do plants use light?

How does energy get into food?

Consider the following:

In about 1600, Jean Baptista van Helmont did an experiment.

Small willow tree (5 pounds)



Grow for 5 years in 200 pounds of soil

Large willow tree (169 pounds)

Used 2 ounces of soil

≈ 164 pounds came from water and air

(current measurements indicate that willow trees are typically somewhere between 35% and 61% water. Let's use 50% as an estimate to think about van Helmont's data.)

We estimate that van Helmont's willow tree grew 82 pounds of new wood.

What does this tell us?

Apparently, trees (and plants in general) acquire mass from something that is not water, and not soil. It must be air. We can summarize it this way:

Chemical in air + water -----> assembled into plant material, such as wood

We now know that the chemical in air is carbon dioxide, CO₂, so:

Water + CO₂ -----> wood and other plant material

Let's think about one more thing we already know:

Wood burns. Burning wood releases heat, which is energy. The chemistry is this:

Wood + O₂ -----> CO₂ + water + heat (*energy*)

Therefore:

If *destroying* wood (converting it to CO₂ and water) *releases* energy, then:

Building wood from CO₂ and water must *require* energy.

Let's think back about plant food

What did our experiment indicate to us that plants need? Air, minerals, some other small molecules, water, and *light*. The only one of these that we can call "energy" is *light*.

Therefore, *light must be the energy source for building plant material*

Part V: What is Energy?

The concept of "energy" is a serious "learning bottleneck" for most students at most levels, which suggests that it is a tricky subject. It is easy to memorize definitions for the test, but it's hard to understand the concept, *especially* when we refer to "chemical energy" or the "flow of energy in a food chain" or the "energy stored in food."

Perhaps a discussion of energy in general could be helpful. Here is one way:

Uhhh...what's *energy*? How about writing out a list of as many Examples of Energy as we can think of.

We might expect students to come up with:

Electricity, gasoline, coal, wind

Solar energy

Someone running

Heat

Fire

What does this tell us?

all of these are examples of *the same thing*: energy.

- note that this much seems trivially obvious, since we simply wrote down different forms of energy. The hard part--and the learning opportunity--is to figure out the common aspects of these different things. In the end, we'll see that "energy" can pretty much be equated with "movement."

Let's look at each one of these in more detail...

Example of Energy	What it <i>is</i>	What it can do
Electricity	electrons moving in a wire (or in any conductor)	Motor converts it to movement Heater converts it to heat Light bulb converts it to light
Gasoline	a chemical	Burn it -----> heat With engine, this gives movement
Coal	Chemicals from old plants	Burn it -----> heat With turbine, produces electricity
Wind	Moving air molecules	With wind turbine, produces electricity
Someone running	Movement	Move
Heat	Individual molecules moving	Heat other things (heat air, it expands, can drive turbine)
Solar energy	Light	Light absorption converts light to heat Photovoltaic cells convert light absorption to electricity
Fire	Reaction with oxygen	Gives off heat

Do we see any common features that would let us define energy simply?

energy = movement

Molecule movement = heat

Electron movement = electricity

Photon movement = light

Energy can be stored

Water towers, dams--lift stuff up, so it can fall down

coal, wood, other chemicals--things that burn--store energy in their particular types of chemical bonds. FOOD is an example!

The biology of energy and food:

Plants use light energy to assemble small molecules into complex organic molecules.

Animals eat plants, and use some of the plants' molecules to assemble into their own bodies. But they break down most of the food molecules to release the energy stored in those molecules.

Energy enters most food webs as sunlight. Plants capture the energy and use it to build plants. Animals eat the plants, or eat each other. When plants and animals die, bacteria and fungi eat what's left. So, *energy* enters food webs, and "flows" from plants to herbivores to carnivores, and to decomposers. Although the *atoms* follow a kind of cycle (e.g. the carbon cycle, the water cycle, etc) and can be re-used, *energy* flows one way.