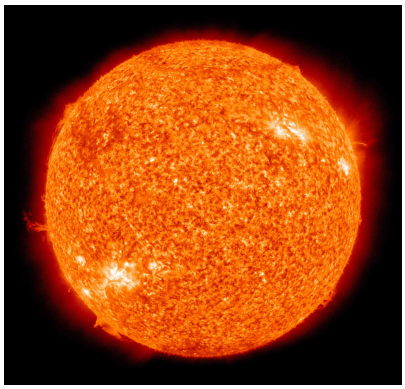
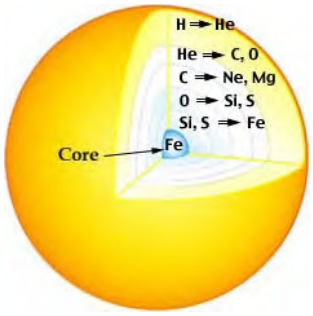
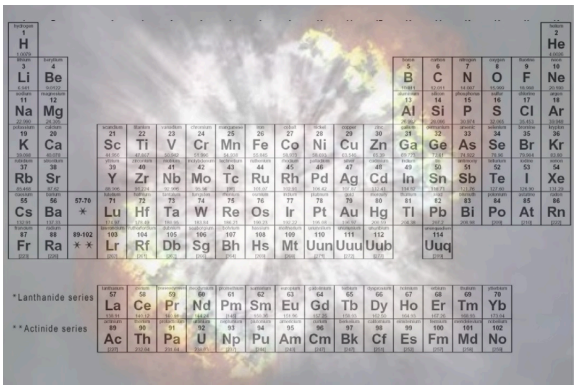
Starlight to Honey

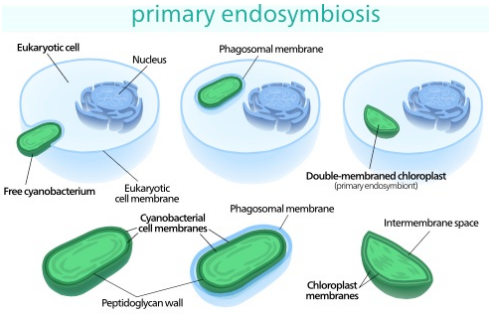
All of the atoms in a honeybee, all of the elements except hydrogen, have their origin in the explosion of ancient stars, which burned and then vanished in supernovae and whose residual matter formed the planets and our sun. Bees, like us and everything else on earth, are *stardust*.







Honey is starlight. At the sun's core, gravity creates temperatures of 10,000,000 degrees [*temperature is particle speed*], and when hydrogen atoms smash together at such velocities in this nuclear fusion furnace, they fuse into helium. As that happens, <u>a bit of *matter is converted to energy*</u> **:** ***light*** (*H + H ➔ He +* ***hv***). Each newborn photon takes over *100,000 years to make its way to the sun's outer layer* (*so dense is the matter in a star*, so many collisions along the way). During its long journey, each high energy gamma-ray photon that was produced by hydrogen fusion is scattered and converted into millions of photons of <u>*visible* *light*</u>. Finally launching from the surface, moving at the only speed it ever can, light arrives *8 minutes later* at the planet we call home [*light = photon/particle = ray/wave*]. Only a tiny fraction of photons ever impacts a leaf of green, but when it does, a machine far exceeding any Rube Goldberg contraption is set into motion **...** on the way to honey production.



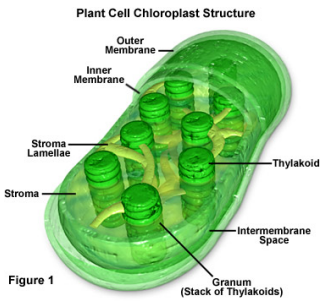
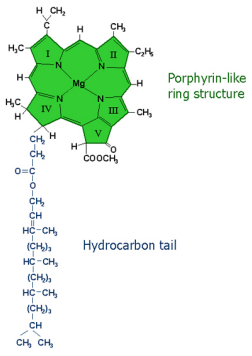


Figure 1



Passing through the waxy leaf cuticle, some photons enter membrane-bound structures in the plant cell that look strangely similar to bacteria - because chloroplasts in fact *are remnant structures of photosynthesizing prokaryotes* that took up residence in nucleated cells some 1,200,000,000 years ago, an act of biological union (endosymbiosis) that forever changed the course of our planet's history, as photosynthesis became a property of eukaryotic cells - first green algae, then higher plants, ultimately including angiosperms - flowering plants.

Within the chloroplast, stacked membranes organize an elaborate system of coordinated chemical structures, including chlorophyll, that forms the critical intermediate able to *catch photons pitched from the sun*, ultimately converting their energy into ATP, the singular molecule that fuels the engines of life. Thus, energy released during formation of *nuclear bonds* in the core of the sun is stored again in formation of *chemical bonds* at the base of the biosphere.

It's a light-induced twitch in the chlorophyll ring structure that mediates this grand event, and only light at just the right wavelengths (430nm , 660nm) does the trick. ATP thus generated is put to good use, powering activity of the *most abundant protein on earth* - *RuBisCo* (*ribulose-1,5-biphosphate carboxylase oxygenase*), which uses atmospheric carbon and oxygen (from CO_2) and hydrogen (from H_2O) to make simple carbohydrates **-** *from scratch* ! [The oxygen from H_20 is released as a byproduct.] Other enzymes move the process along, forming glucose and fructose - and some sucrose. Nectaries of flowers secrete these sweet compounds, attracting pollinators, including honeybees.

Now the bees begin their work, foragers of each colony flying hundreds of thousands of miles each season, gathering tiny volumes of nectar from tens of millions of flowers to fill the cells of their honeycomb, adding the enzyme invertase along the way, which splits most of the sucrose into its components, glucose and fructose. Unloading the harvest into their wax cells, the bees concentrate this modified nectar into honey (80% sugars, 20% H_2O) by careful assessment of its water content, fanning the honeycomb surface to speed evaporation. When honey in each hexagonal cell reaches just the right concentration, it is sealed with a cap of newly made wax. Pure starlight.

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