# Why did chlorophyl evolve to be green as opposed to black, which would absorb more energy?

1. Firstly, getting energy from the sun is a great boon to life. Originally it probably came about by accident. A few mutations that allowed certain chemicals to be produced that produced a secondary effect of energy gain. The particular chemicals that combined to form this could have been any color. Nature didn't just decide on a color. Evolution has no goals. It is a series of random fluctuations and sometimes that random new trait just happens to allow a life form to outcompete others and is selectively reinforced. Once you have something that works it works. What works is what stays. Plants work very well even with their green color.

Plants do use other colors of light than just the ones that trigger chlorophyll. Many of these are through secondary processes or secondary dyes. Plants actually use almost 85% of the spectrum in some form or another. They just get most of their energy from Red and Blue.

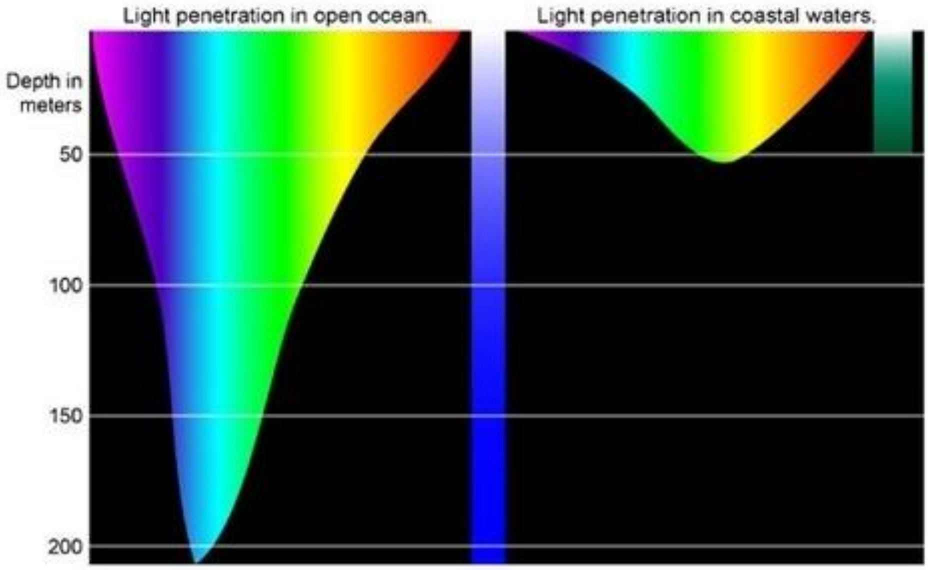
There are several scenarios that have been proposed. Any combination of these factors may be responsible.

**Purple Earth.** It is possible that the very first life form to process light may have been purple colored. This would mean it was reflecting red and blue light and absorbing green. In such a scenario this thing if it was the first to produce energy from light would have out competed against everything else. It would have had a population explosion and possibly covered much of the Earth or at least the oceans.Haloarchaea are an example of a simple life form that uses Retinal andBacteriorhodopsin to produce energy though far less efficiently than photosynthesis. Had this been developed prior to photosynthesis it may have let it spread very far even though it is a less efficient energy production method. A 2% efficiency increase in a market no one has yet tapped is still a huge advantage.

In this scenario becuase the first thing to use light was using green light it left a niche for another form of life to exploit. That niche would have been absorbtion of the Red and Blue spectrums. Which is the same area plants absorb today. They got so good at their niche that they eventually were able to generate much more energy than the first life form did and eventually out competed for the sun. This niche has worked so well that they never developed a full system for the other spectrums.

**Ocean depths.** It is possible that the development of photosynthesis with chlorophyll happened in deep waters farther from land. Blue light is better able to penetrate deeply into water than other colors of light. In the coastal water green is preferred to blue or red but for deeper water distant from land, blue is actually the best energy source. This is due to several factors including particulate and reflectivity off the bottom. This might combine with the first bullet point as the first sun reactive life may have been both coastal and purple.

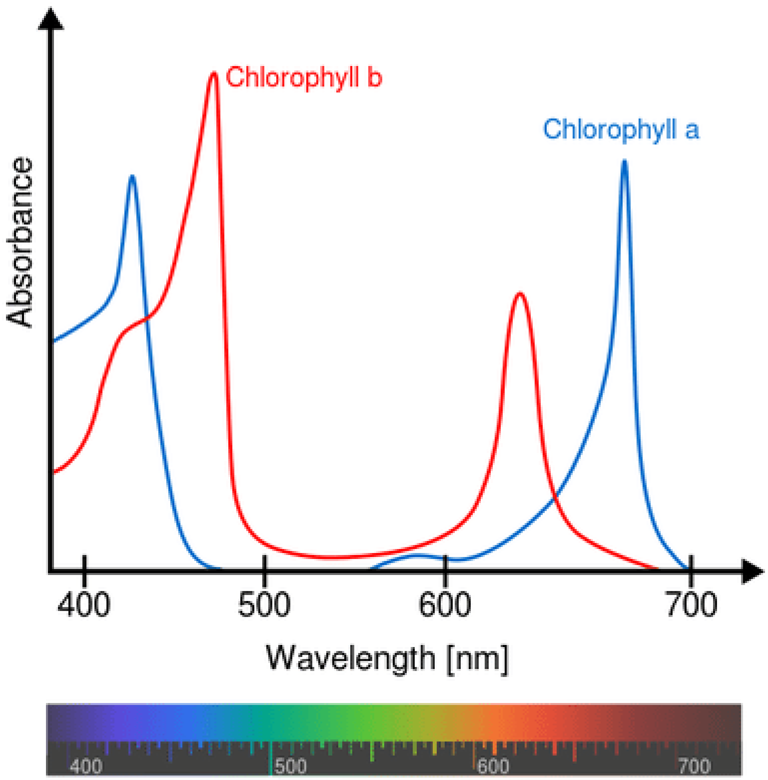
Deeper you go, the bluer things get. ↓ In coastal water, the greener. ↓




**Energy Saturation.** The sun puts out a lot of energy. It is possible that there was no need to try and capture all of the spectrum or that it was actually not beneficial to do so. Often too much sun is more an issue than too little. Too much sun and heat can dry out the plant. It is possible that to gain the benefits of photosynthesis there needed to be a reduction in some energy to balance it out. Much like a black car on a hot summer day a black plant might absorb all of the spectrums but also get far too hot. Blue plus red may just be the sweet spot.

**Too complicated.** Most scientists think photosynthesis was such a complex series of mutations and adaptations that in the history of the Earth it only happened once. All plants thus share one common ancestor. The one process life stumbled on that works just happens to be chlorophyll and its characteristic green color. It was so effective that no new chemical process was needed. Also as stated above plants do use most of the spectrum for some purposes but get the most energy and most efficiency from the red and blue via chlorophyll.

It is very likely it was a combination of several of these factors that lead to plants being green. They take in most of their energy from Red and Blue and reflect the Green away. (They also use some UV light in some plants.)

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2. It is conjectured that Chlorophyll is **not** so good at absorbing sunlight, that is the reason why plants are green. Sunlight's peak wavelength happens to be green (518 nm) {via Wien's displacement law}. So Archaea one of the earliest photo-synthesizers and later Purple sulfur bacteria evolved to absorb light at these wavelengths to be most efficient. So they reject wavelengths at blue and red, thus appear purple.

Now later when the proto-cyano and cyanobacteria came along, they evolved chloroplasts that used the wavelengths left over (mainly blue then red) so as to not compete with the majority. Therefore they absorb blue and red and reflect green, hence are green.

Cyanobacteria and later plants, have oxygen as the waste product of photosynthesis. Thus slowly Earth became oxygenized. This Great Oxygenation Event wiped out most of the anaerobic organisms including the purple bacteria. So plants are green because chlorophyll is more suited for a blue or a red sun.

3. Because when it comes to evolution, "good enough" is good enough. Evolution is undirected. There's nothing saying "this wavelength of light is most energetic, so it's the one we should use for photosynthesis."

Chlorophyll, the green pigment in oxygenic photosynthetic plants[1] is a porphyrin--a large ring that's bonded together by a group of four nitrogens. This structure allows easy electron transport, which is why it's used for photosynthesis--when a photon strikes the ring, an electron gains energy and can be donated to other molecules which, through a complex electron transport chain, results in the synthesis of sugar. It doesn't matter that the photon that initiates this is the most energetic possible--what matters is that it's the right frequency to interact with chlorophyll and sufficiently energetic to get the process going. There are many kinds of photosynthesis, some of which uses pigments that aren't green. They don't necessarily produce oxygen.

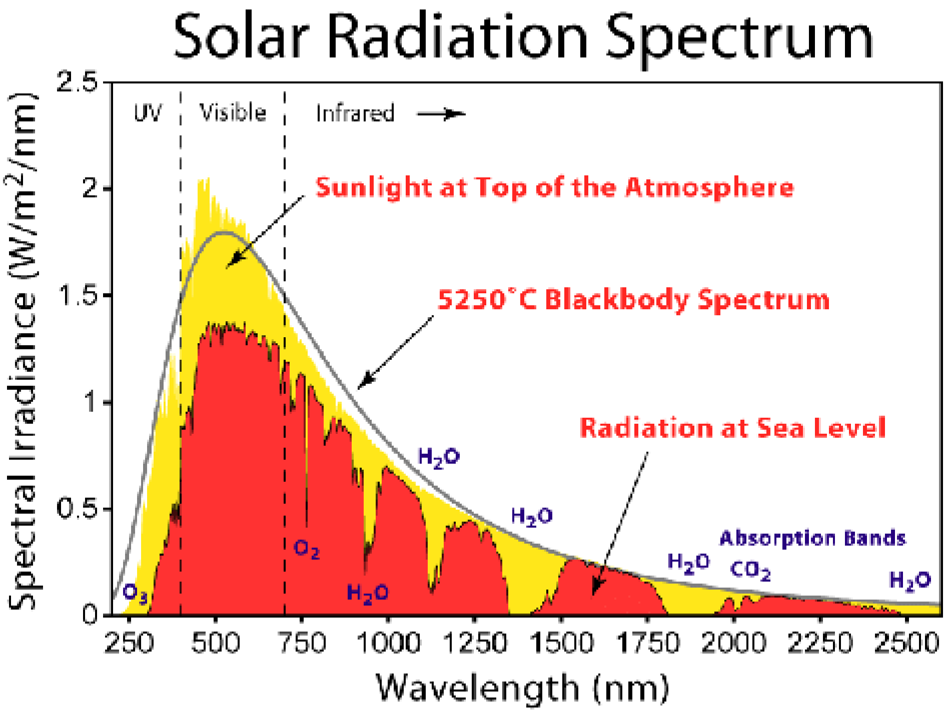
4. There are plant variants with black leaves, and empirically, dark leaves don't provide a clear and consistent advantage. "In full sunlight, green plants branched more abundantly and accumulated shoot biomass quicker than the black plants(.)" - The Functional Significance of Black-Pigmented Leaves: Photosynthesis, Photoprotection and Productivity in Ophiopogon planiscapus 'Nigrescens'

5. As others have pointed out heat dissipation would be a huge issue. Also an issue is that plants are mostly 3-dimensional (despite looking pretty flat), with stacks of chloroplasts all receiving a bit of light and producing energy. In a black plant the light would be absorbed entirely in the surface layer, creating another problem of how to fit all of the energy producing organelles in the greatly reduced volume of a single layer.

One of the misconceptions about photosynthesis is that the entire point is to maximize the amount of energy absorbed. The initial problem with taking in sunlight and using it is that sunlight is too much energy. The sun puts out a very large essentially continuous stream of energy, whereas plants need a discrete usable source of energy to carry out lots of micro scale processes (pump ions, move tiny motors along filaments, fold tiny proteins, etc.). The initial problem photosynthesis evolved to solve had nothing to do with efficiency, as energy is completely in excess of what is required. What is the point of more energy if it is completely unusable (as heat, or in units which are not useful for the processes in which the energy is required)? A good example would be if someone received a billion dollar check. Their main problem would not be not having enough money, it would be how to get the money into a form that is useful in their daily life. If they happened to be someone who only shopped at the dollar store then you would have a great example of a cell-sized energy units. From the outside it would look like they were being very thrifty and keeping track of every dollar in their huge fortune, but in reality they are just a person who only needs dollars.

Since then, competitive pressure among photosynthetic organisms has certainly driven gains in efficiency. Also there are organisms that have evolved to live in very low light conditions where eking out nearly all of the energy from the light received is possible. But to answer your question a black plant would absorb more energy, but more energy is not necessarily advantageous.

6. As it was said, evolution is only concerned about "just good enough." But I want to add that in your question details you added the "solar disk center intensity" figure - which isn't really an accurate representation of sunlight on earth. When you include the near 150 million kilometers and atmospheric effects. We get something like this:



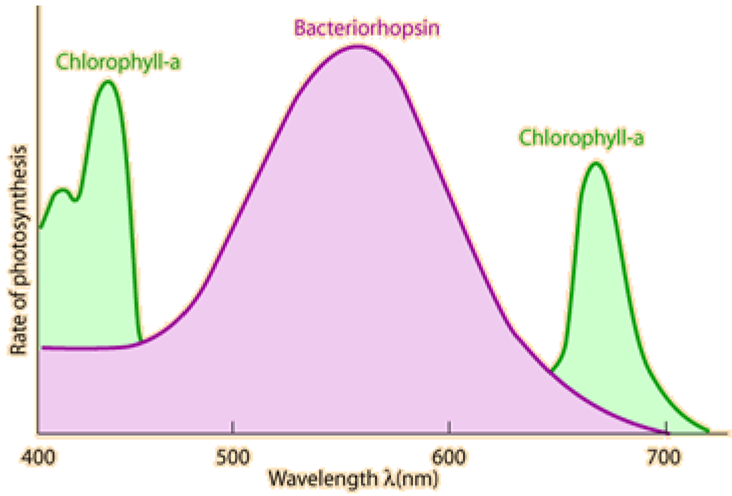

The red represents the radiation at sea level, where plants like to hang out. You see the dips compared to the "sunlight at top of the atmosphere" spectrum due mostly to the absorption bands of atmospheric water. But note that minus purple, the spectrum is nearly constant in the visible range. So really the plant could of equally been orange or yellow or blue with hardly (if any) any loss of efficiency, but as Franklin said, chlorophyll was in supply and chlorophyll is green - thus our pretty green plants.

7. I'm not a plant physiologist or biochemist, but my interpretation of one paper I could find was this:

Plants still absorb green light - 80% of it. Higher land plants are green due to leaf architecture. It's a balance of distribution of light within the leaf profile or canopy, preventing damage from too much light, and balancing that with changing conditions. Chlorophylls a and b happen to be the right balance for that. Earth's ocean used to be filled with purple single cell organism called archea living in the deep sea. These plants absorb green light and let red and blue go through. One theory is that in deep sea, only "minus green" light fall through. Chlorophyll filled leaves are great at absorbing all light wave except those with wavelength corresponding to green. At molecular level, the many layers of chlorophyll spread throughout allows leaf to capture photons most of the green light (up to 80%) eventually. Spread absorption actually allows for less transportation of the processed energy/sugar, and reduce "boiling". Incidentally chlorophyll was just better at converting energy than that found in the purple ones of its ancient arch rival.

8. Because it didn't. That's it, that the only answer. It didn't happen because it didn't happen. Evolution is an undirected process. Except that in this case, **it did.** Chlorophyll absorbs light most strongly in the blue portion of the electromagnetic spectrum, followed by the red portion. Conversely, it is a poor absorber of green and near-green portions of the spectrum, hence the green color of chlorophyll-containing tissues.

9. Given that natural selection has had the entire history of life on earth to try alternatives to photosynthesis by (green) chlorophyll there must be a good reason which we've not yet figured out. There is one genus of bacteria (strictly speaking, Archeae) the Halobacterium that are photoreceptive to a spectrum almost complementary to chlorophyll but which uses a completely different mechanism of energy production.




One can even imagine a composite organism (like a lichen) which combines the two mechanisms to extract more of the total incident energy yet we've not discovered any such creature. Given the heights to which plants work to outcompete each other for light (for example, trees) I'm inclined to agree with William Halmeck that heat management is a strong factor, but we just don't know.

10. We already know why all plants appear green: it's because they're full of the light-absorbing chemical known as chlorophyll. But since they appears green—bouncing back green and yellow light waves—it means it's not 100 percent efficient at absorbing all of the sun's rays. So why aren't all plants black instead? It turns out that scientists aren't quite sure just yet. The leading theory is that modern plant life evolved from bacteria that lived under the sea and only had access to blue and red light streaming through the deep water. So they learned to survive with what they had, and came to rely on the chlorophyl molecule which was adept at turning red and blue light waves into usable energy.

11. Terrific question, and some great answers. I'd like to add that chlorophyll just happens to be the first biological molecule to be successfully studied as exhibiting quantum coherence under ambient conditions. It was previously thought that quantum coherence could only be studied in very cold systems in order to avoid thermal noise. Greg Scholes of the University of Toronto published a breakthrough paper in Nature in 2010:

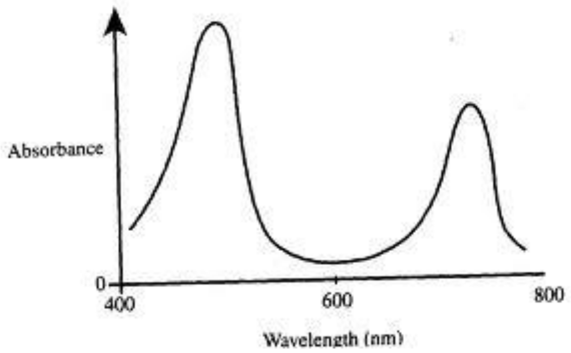
12. Short answer: plant absorbs mostly "blue" and "red" light. They rarely absorb green for its mostly reflected by plant, that makes them green! Long answer : Photosynthesis is the ability of plants to absorb the energy of light, and convert it into energy for the plant. To do this, plants have pigment molecules which absorb the energy of light very well. The pigment responsible for

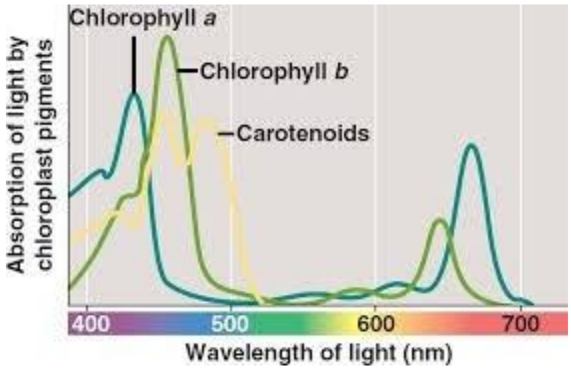
most light-harvesting by plants is chlorophyll, a green pigment. The green color indicates that it is absorbing all the non-green light-- the blues (~425-450 nm), the reds and yellows (600-700 nm). Red and yellow light is longer wavelength, lower energy light, while the blue light is higher energy. In between the two is green light (~500-550 nm). It seems strange that plants would harvest the lower energy red light instead of the higher energy green light, unless you consider that, like all life, plants first evolved in the ocean. Sea water quickly absorbs the high-energy blue and green light, so that only the lower energy, longer wavelength red light can penetrate into the ocean. Since early plants and still most plant-life today, lived in the ocean, optimizing their pigments to absorb the reds and yellows that were present in ocean water was most effective. While the ability to capture the highest energy blue light was retained, the inability to harvest green light appears to be a consequence of the need to be able to absorb the lower energy of red light.

Plants also use multiple variants of chlorophyll, as well as accessory pigments such as carotenoids (which give carrots their orange color) to tune themselves to absorbing different wavelengths of light. That makes it impossible to assign a single wavelength of best absorption for all plants. All plants, however, has chlorophyll a, which absorbs most strongly at ~450 nm, or a bright blue color. This wavelength is strong in natural sunlight, and somewhat present in incandescent lights, but is very weak in traditional fluorescent lights. Special plant lights increase the amount of light of this wavelength that they produce. But a 400-500 nm wavelength bulb wouldn't be enough, since many plants take cues for germination, flowering, and growth from the presence of red light as well. Good plant lights produce red light as well, giving plants all the wavelengths of light they need for proper growth.

13. Just grab any biochem text and read up on photosynthesis. The molecular apparatus of photosynthesis is *finely tuned* to use the energy of *two* photons arriving in rapid succession to split *one* water molecule (yielding oxygen as a waste byproduct) and obtain *two protons*. A single photon in the ultraviolet region of the spectrum could provide the required energy. However, the atmosphere attenuates such radiation. So photosynthesis uses two photons in the visible spectrum arriving within a femtosecond timescale. Capturing all incident radiation isn't going to make the process more efficient.

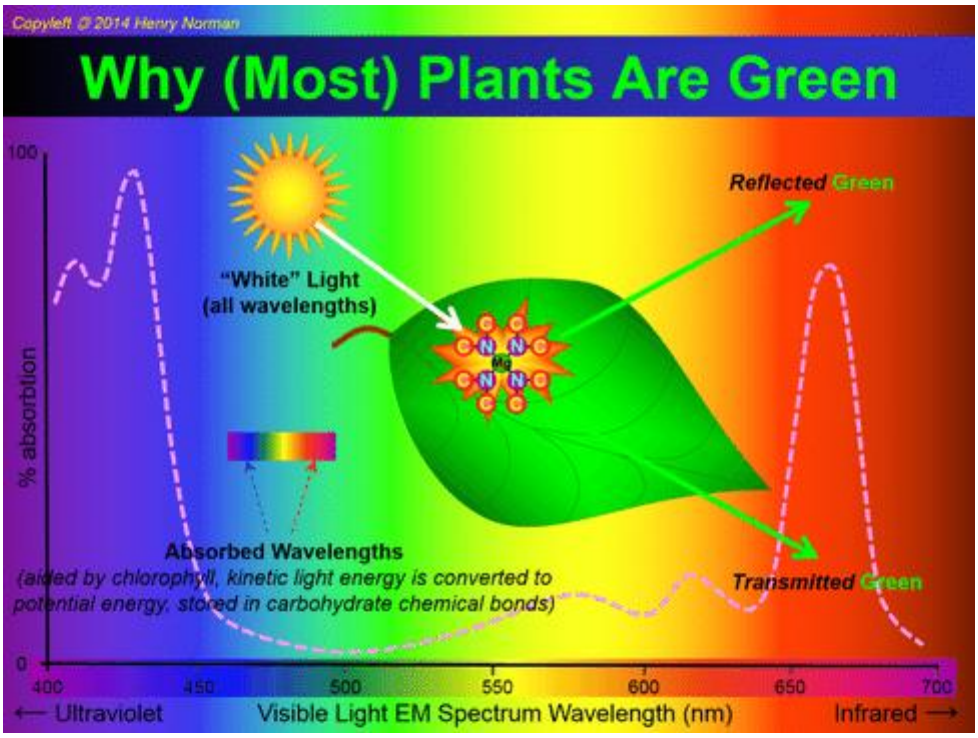
14. Chlorophyll a is the chief pigment associated with photosynthesis.






As we can see,chlorophyll a absorbs red and blue wavelengths to a higher extent. Green light isn't rejected but rate of photosynthesis is more with red and blue wavelengths of light.

15. Neo-Darwinism Does Not Satisfactorily Explain All of Evolution — that (most) plants are green because green is ***reflected*** (least absorbed wavelengths) — here's a graph illustrating why:




16. The chlorophyll that is the main molecule in photosynthesis is green. And is inside a mainly transparent leaf. Black leaves would block light from reaching the chlorophyll, reducing the efficiency of photosynthesis which is already very low.

17. The color of plant leaves is due to the pigments present in it. Chlorophylls are green in color and have mechanism to absorb 400 and 700 nm wavelength from white visible light. Violet colored leaves containing anthocyanin pigments are also present. These absorb light energy of other wavelengths but pass it on to chlorophyll for the ultimate photosynthetic reaction. Some dark violet leaves are near to black but altogether black photosynthetic leaves have not evolved and donot exist exist per se as per my knowledge.

18. I think that within the chlorophyl molecule there is always a magnesium ion or atom, and I think that this gives the leaf its green colour. A black leaf would inhibit the light from working within this molecule. Gratuitous black coloration would probably block the light in my view. But I am admittedly working on hearsay in this answer.

19. Plants reflect green because chlorophil is green--nothing more. Evolution works by random chance--there is no over-riding algorithm that seeks out the most efficient solution.

20. The spectrum of white light has seven colours. in these the leaves i.e the food producers of the autotrophs absorb and are very sensitive to red and violet part of the spectrum while reflecting the green part . Due to this reflecting act of the leaves they appear green. hope the answer was helpful.

21. One advantage in using only a portion of the spectrum is heat management. Proteins are more likely to unravel at higher temperatures.

22. I realize they're an exception, but black plants exist. Here's Black Mondo Grass (Osphiopogon planiscapus 'Nigrescens')

23. There is a hypothesis (though not enough evidence to prove or disprove either way) that the first photosynthetic organisms on earth absorbed green wavelengths of light, and that chlorophyll-

using organisms were an underdog that had to scavenge what wavelengths were left - the red and blue wavelengths. But due to some quirk these chlorophyll-using organisms managed to dominate, leaving us with only chlorophyll-using organisms today and us wondering why they don't use the green wavelengths. I think it's a neat explanation, but very difficult to varify or invalidate given that it's extremely unlikely for a specimen to have survived intact enough for us to determine these things today. The "good enough" hypothesis is also compelling.

24. I've also heard it said that the green spectrum is a bit to strong for the present chlorophyll, making it harmfull to the molecular structure.

Why is chlorophyll green when the light emitted from the Sun is most intense at the green range of the spectrum?

How did a panda's black and white coloring evolve?

Is it possible for a material to absorb all energy that impacts it and disperse that energy as light?

Do black holes absorb energy?

Why do black objects absorb more heat energy than white or colored objects?

How does chlorophyll absorb light and how does it convert it to energy?

How does the green pigment in plants absorb light energy?

How do darker colours absorb more light energy?

Which Chlorophyll reflects green light?

Why are the tyres of the car black? Why can't it be any other?

Biology: How did chlorophyll f evolve?

What are the reasons chlorophyll is green?

Why does chlorophyll make plants appear green?

How does the black color absorbing much heat energy than white?

Do green organisms necessarily have chlorophyll?