Why are the Sky Blue and the Grass Green

Dear students, my name is Amal Al-Aboudi. I teach organic chemistry at the University of Jordan. Today, I am going to share with you some knowledge related to the beauty of nature.
We will learn the reasons why we have all of the marvelous colors we see all around us. Let's go, for a few minutes, on an imaginary trip where we can sit on the sea shore and see so many different shades of blue. Let's enjoy the colors of the sun shining behind the clouds.
At sunset, we are fascinated by the amazing colors, with reds being the most dominant. Let's imagine ourselves on a trip in the mountains. The sky is blue over our heads, and the mountains and valleys show us beautiful greens and browns. We may come across a mountain with very unique colors.
Let's imagine ourselves on a trip in the country side during autumn, enjoying the leaves, with their green, yellow and orange colors. Colors are all around us; they give beauty to animals, birds, fish and other marine life, and gem stones…and let's not forget fireworks! Everything around us is beautiful through its colors. Look around you; look at your classmates with their different-colored eyes, hair and skin.
The big question is: Where do these colors come from? What produces them? What makes them different? You may have many more questions in mind. I want you now to discuss these things with your classmates and think of all the questions you have concerning the causes of colors. Try to answer some of these questions. Are you ready? I will be back with you in a few minutes.
Hello again! There are several causes of colors. In fact, they are mostly produced from the way in which matter interacts with light. Before going further, I would like to ask you: What is light? And what is it composed of?
Light is composed of electromagnetic waves which range from many meters in wavelength, such as radio waves, to much shorter wavelengths, such as Gamma beams. The waves that we are interested in today are the visible light waves which can be detected by the human eye, namely "The Visible Spectrum".
"The Visible Spectrum": The human eye can only detect the

electromagnetic waves that have wave lengths between 400 to 700 nanometers.
The nanometer is $1/10^9$ of a meter. If the wave length is about 700 nanometers, then it gives off a red color, while if it has a wave length of about 400 nanometers, then a violet color comes out.
Now, I want you to think of and design an experiment to prove that sunlight contains all the colors of the visible spectrum. I also want you to design an experiment in which you mix all the colors of the visible spectra, and see what happens.
What if we mix all visible spectra colors except green, for instance? I will leave you now to think about these questions and design the experiments, and I will come back in 5 minutes.
Welcome back again! I believe you have come up with an experiment that passes sunlight through a prism. When the light of the sun is exposed to the prism, it is separated and colors of the rainbow will appear. This is called the "VISIBLE SPECTRUM".
Let's go back to the causes of colors. These colors are a result of the interaction of matter with light. How does this happen?
There are many ways in which colors may come out, and there are many causes of colors. First, the matter may absorb part of the visible spectrum and reflect the rest, producing color. Second, the matter may emit part of visible spectrum; that is it may emit a wave length within the visible spectrum range between 400 to 700 nanometers.
Third, the light's path may change as it passes from one medium to another, as seen in this picture. Light could be reflected, scattered, or refracted. This would cause a separation of visible spectrum lengths, giving out color. Now we will use this general knowledge about how light interacts with matter to explain the simple questions we have, such as why is the sky blue? And why does its color change at sunset? Why are the tree's leaves green? And why

do they change colors in autumn?
Let's start with answering the first question; why does the sky appear blue? When the sun’s rays enter the atmosphere, the gas particles present scatter the light. The shorter the wave length, the more it scatters. Thus, the scattering of the red, yellow and orange colors is very slight, so these waves move in straight lines.
Meanwhile the shorter waves, which are represented by the blue and violet colors, scatter in all directions, giving the sky its blue color, as seen in this figure.
When the sun’s rays pass through the atmosphere, the gas particles in the atmosphere scatter the light. The shorter the wave length is, the more it scatters. Thus, scattering of the red, yellow and orange colors is very slight, so these waves move in straight lines. At the same time, the shorter waves, represented by the blue and violet colors, scatter in all directions, giving the sky its blue color.
At sunset, the distance traveled by light becomes longer, and this causes the blue colors to scatter more and more, giving the chance for the red, orange, and yellow colors - which are not affected by the light scattering- to reach us. The beauty of this sunset increases when there are more dust and water particles in the air, increasing the scattering of light and allowing these longer waves to fascinate us with their beautiful colors.
Now I will leave you to consider two questions: 1) why isn’t the sky purple? 2) Imagine you are on the moon, where there is no atmosphere. What do you expect the color of the sky will be? I will leave you for two minutes, and be back later.
Hello, I hope you have come up with an answer to the questions. Now we know the reason why the sky is blue and why it changes color at sunset, namely that the sky colors are produced by light scattering due to the presence of the atmosphere. Let's now consider another cause behind the appearance of colors. Let's look at this beautiful picture together.
Look at this picture, where we can see the green leaves of trees and how

they change during autumn to yellow or red. I wonder- why do leaves have a green color, and why does it change to red or yellow?
You may know that the green color of tree leaves is due to the presence of a compound called "CHLOROPHYLL". It is a compound produced by plants to change the sun's rays into energy in a process called "photosynthesis". But why is chlorophyll green? Let's look at its chemical composition. The green color in the leaves is due to the presence of a compound produced by plants called "chlorophyll", which helps the plants turn the sun's light into energy in a process called "photosynthesis".
But, why is chlorophyll green? Let's look at its chemical composition. It contains many double bonds that are located close to each other. This allows it to absorb part of the visible spectrum; then the chlorophyll absorbs all the colors of the spectrum and reflects the green to give the leaves their green color, due to the presence of the chlorophyll.
But what happens in autumn? Where does the chlorophyll color go in this season?
During autumn, the temperature drops, the days become shorter, and the time to which the plants are exposed to sunlight decreases, lessening the production of chlorophyll. It starts to decompose, so the green color disappears. This gives the chance for the other pigments present in the tree leaves to show up, such as beta-carotene and anthocyanins.
Look at the chemical composition of carotene, notice the presence of many double bonds located close to each other. Also, in the chemical composition of anthocyanins, there are many double bonds that are located close to each other. As I mentioned before, this chemical structure gives the chance for the chemicals to absorb part of the visible spectrum and reflect the rest, which gives them their distinct color.
There are a large number of chemical compounds that belong to the carotene family. Their presence gives off yellow, orange, and brown colors. Let's

look at this picture. The presence of carotene in carrots gives them their orange color; it is claimed that the name “carotene” is derived from this vegetable. The presence of carotene in corn gives it a yellow color.
The difference here is a result of the different chemical structure of the compounds in the carotenoid family. Anthocyanins give red and purple colors. Let's look at the color of apples; the red color of apples is due to the presence of anthocyanins, and the purple color of grapes is due to the presence of anthocyanins, too. We can conclude now that the colors found in plants are due to the presence of chemical compounds that have a chemical structure with many double bonds close to each other. This chemical structure allows these chemicals to absorb some colors of the visible spectrum and reflect the rest, giving them their distinct color.
We can see these colors or compounds by conducting certain experiments, such as "CHROMATOGRAPHY". I will leave you now to carry out this experiment with your teacher and be back with you in 5 minutes. Enjoy!
Hello! I hope you have enjoyed the experiment of separating the colors of plants. Do you know, my students, what the relation between the pink color of flamingoes, salmon and carrots is? Look at the orange color in flamingoes, and in salmon. This color is due to the presence of carotene compounds that are found in carrots, as well.
I have answered a few questions, and left some more for you to consider yourselves. Before I leave, I would like to say that knowledge starts with asking a question, a simple one, such as "why is the sky blue?" Or "why are leaves green?" From such questions and searching for answers, the journey of knowledge starts, and we start learning. Knowledge is a journey that never ends. Thank you so much.
Dear teacher, good day! Thank you so much for choosing this module for your students. I hope you will find it interesting and beneficial.
You may think, at first glance, that the topic of colors is very easy for 9th or 10^{th} grade students. However, when it comes to an accurate scientific

explanation of the causes of different colors, we will learn some interesting things. This module aims to show the importance of learning science, and its role in helping us have a deeper and better understanding of our surroundings.
It also aims at motivating students to search and think about their surroundings by asking questions, and not to take things for granted. That is why I have chosen a few simple questions: why is the sky blue? Why does it change color at the sunset? And why are leaves green? Why do they change color to yellow or red in autumn?
During the first break, dear teacher, please let your students ask any questions they may have about the causes of color, and write these questions down on the board, to come back to them by the end of the lesson. Then ask the students: who knows the answer of any of the listed questions? Allow them all to participate.
This will take about 3 to 5 minutes. During the second break, ask the students: who can design an experiment to prove that light contains the visible spectrum? Discuss all of the students' ideas. Then allow two or three students to carry out the experiment of passing light through the prism.
In case you do not have a prism, you can show the following filmed experiment. To do the experiment of separating light through the prism, you will need the following tools: a glass prism, a light source, and a white sheet of paper to collect the light.
Switch on the light source, position the prism so that light passes through it, and try to collect the light coming out of it. Notice the colors of the rainbow appear: from red, yellow to violet; also note the color density is different. And the light intensity is different from one color to another. After the experiment of light separation through a prism is done, ask the students: what might happen if we mix the colors of light together?
You can use Newton's wheel for this experiment. When the wheel is turned, we note the disappearance of all colors. If you do not have a ready Newton's wheel, you can make one easily. Then ask your students: what will happen if we omit one of the colors of the wheel and turn it? Surely they will not

disappear, and the resulting color will be a mix of the remaining ones.
In the third part, we answered the main question: why is the sky blue? And the answer is: because of the scattering of light. We learned that the shorter the wave length is, the more the scattering will be. We have another question: why isn't the sky purple? There are two reasons for this:
The first reason is that the intensity of the purple color in sunlight is weak. The second reason is that the human eye is more sensitive to the color blue than it is to purple, and as it is said "Beauty is in the eye of the beholder", we say that the blue is in the eye of the beholder, as well.
The other question that was asked is: what is the color of the sky on the moon? Remind the students that there is no atmosphere surrounding the moon. Discuss their answers. I expect you will hear answers that the sky is black on the moon. You may ask them to look for the sky color on other planets of our galaxy.
Dear teacher, one of the most interesting experiments is using a diluted solution of milk to prove the scattering of light. To perform this experiment, you need a transparent glass full of a diluted solution of milk. You can make this by adding a few drops of milk to a glass full of water.
Use your light source and a sheet of paper to collect the light. To conduct the experiment, turn on the light source and direct it towards the glass of diluted milk. The diluted milk mixture will scatter the light. Note the light blue color of the milk in the glass. Then, put the sheet of paper behind the glass. Notice the red and yellow colors that appear on paper. This proves that red and yellow colors are less affected by the light scattering, while the blue color is still found in the glass.
This is exactly why we perceive the colors of the sky and sunset as we do. That is the reason for the experiment. We have now reached the fourth part of this didactic module. At the end of this part, you can carry out the "CHROMATOGRAPHY" experiment, showing the separation of plants

colors. You can divide the students into groups of 3 to 5 students each.
You need, my dear teacher, to prepare plant extract one day before the experiment, as mentioned in the attached experiment manual. You can use different plants. I will demonstrate to you, my dear teacher, how to separate the colors of plants through the "CHROMATOGRAPHY" experiment.
Let’s do it now. You will need the following tools: a silica plate or filter paper, capillary tubes or a dropper, a glass with a cover, acetone, and pieces of plant treated with acetone. Add some acetone to pieces of plant one day before carrying out the experiment, and keep it covered to prevent the acetone’s evaporation.
Here are the steps of the experiment. Using the capillary tube, take a drop of the plant extract and apply it at about 1 cm from the base of the filter paper. Add the drop gradually, so that the circle does not widen. Repeat this process several times, and wait until you are sure that the acetone has evaporated.
Repeat that until the extract is gone. After each application, make sure the circle you got is not too big. Put the treated filter paper in the glass after adding enough acetone. Note that the amount of acetone should be small, so that it doesn’t reach the extract.
The acetone diffusion begins. As you can see, the acetone diffuses to the top of the filter paper and helps with separating the colors of the plant extract. If we leave it for a while, we will see the colors of the plants start to appear on the filter paper.
As mentioned above, a silica plate can be used for the same purpose, and you will observe the same result. You will notice that the colors begin to separate. You may observe that there is more than one pigment in the plant leaves; you may notice the chlorophyll, and another yellow compound resulting from carotene, as well as another green pigment similar to

chlorophyll.
As you complete this didactic module, please go back to the questions posed at the beginning, and ask the students to always search for the answers to such questions. Thank you again, I hope your objectives have been accomplished through this module and you use another didactic module in the future. Many thanks!