

## **Elaboration Phase: Wave Watchers**

***Purpose of the Wave Watchers Activity:*** The purpose of the *Wave Watchers* activity in the Elaboration is to allow students to analyze data collected from three laboratory environments, each with a different color grow light: red, blue, or green. Students identify the wavelengths of light available in each environment, as well as the environment that best promotes plant growth. With this identification, students construct a written argument – supported by empirical evidence – that explains why one environment is more suitable for plant growth than another. These arguments describe the pattern and relationship between available wavelengths of light and resulting plant growth and behavior.

***Learning Objective Addressed in the Elaboration Phase:*** Students identify environmental factors that may positively or negatively affect plant growth.

***Time in Minutes:*** 60

***Evidence Statements Addressed during the Activity:***

- 1. Articulating the explanation of phenomena.** With the data provided in StudentHandoutElaboration1\_Spectra, and StudentHandoutElaboration2\_GrowthData, students use evidence and reasoning to construct a scientific explanation for how wavelengths of light can potentially influence plant growth.
- 2. Evidence.** In StudentHandoutElaboration4\_DataAnalysis, students are tasked to identify and describe the evidence necessary for constructing their scientific explanations. This evidence draws from the data provided in StudentHandoutElaboration1\_Spectra, and StudentHandoutElaboration2\_GrowthData. Students use provided data to describe how plant growth potentially changes in response to changes in the wavelengths available in the environment.
- 3. Reasoning.** As students develop their scientific explanations, they incorporate genetic and environmental influences into their explanation and support their explanations with data provided. Their chain of reasoning includes how plant growth may be influenced by both environmental and genetic factors

## Materials

### **Student Materials:**

StudentHandoutElaboration1\_Spectra  
StudentHandoutElaboration2\_GrowthData  
StudentHandoutElaboration3\_Letter

### **Teacher Materials:**

TeacherHandoutElaboration1\_WaveWatchers  
TeacherHandoutElaboration2\_Rubric

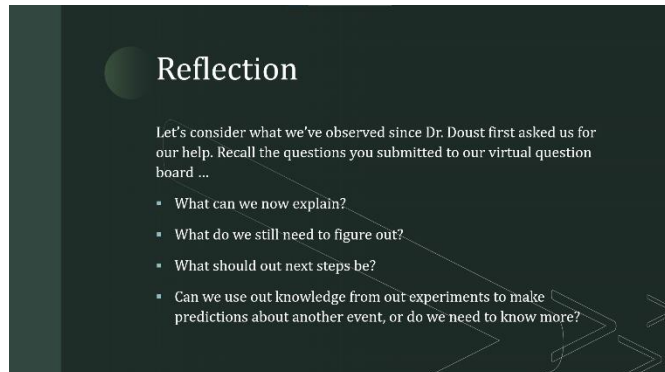
### **Set-up:**

Before class begins, prepare the PowerPoint slides provided in the TeacherHandoutElaboration1\_WaveWatchers (the document you are currently reading). Be sure to reference the questions and discussion points provided for each slide. During this phase of the lesson, the PowerPoint presentation is used to introduce the scenarios discussed in the activity and to share information with students about the visible light spectrum.

### **Procedure – Part 1: Lesson Reflection and Continuation of Narrative**

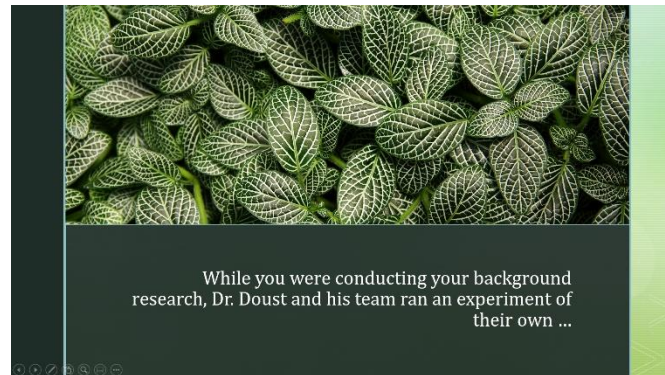
#### Slide #1:

- I begin my class by tasking students to reflect upon what they have observed during the *Rainbow to Grow* lesson thus far.
- I recommend presenting your “Amazon Expedition” Padlet from the Engagement Phase during this discussion.
- Student responses vary, but students typically discuss how some colors of light were more suitable for plant growth in their experiments. However, students typically do not have the prior knowledge to make predictions as to which color best supports plant growth, nor do they usually understand the reasons why. This discussion transitions students into the next portion of the lesson – *Wave Watchers* activity.



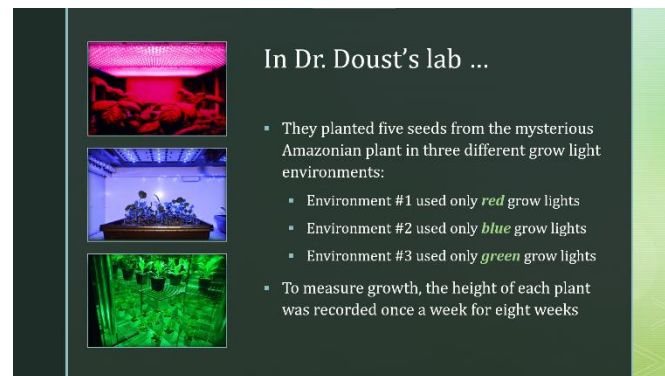
## Slide #2:

- Dr. Doust and his team conducted research as well! Let's see what they observed ...



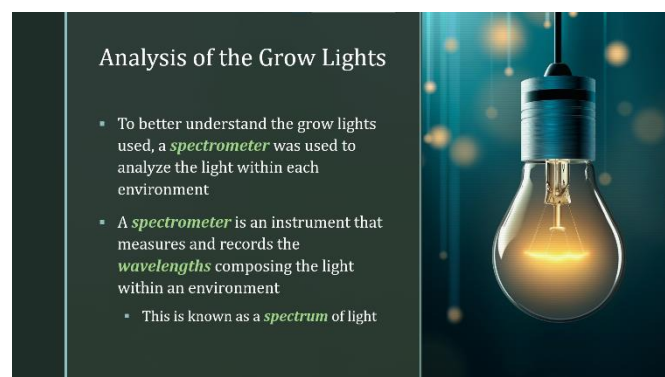
## Slide #3:

- So, let's go over Dr. Doust's experimental design.
  - What is his independent variable?
    - *Answer: grow light color*
  - Dependent variable?
    - *Answer: plant growth*
  - Control(s)?
    - *Answer: soil, moisture, temperature*
  - What kind of data did he describe?
    - *Answer: quantitative*



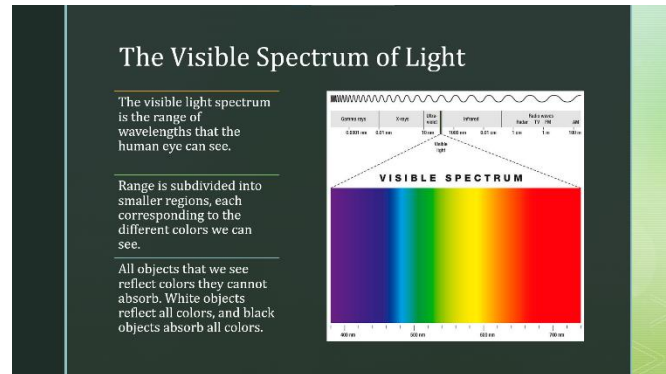
## Slide #4:

- Dr. Doust and his team used a device called a spectrometer to measure the wavelengths that were emitted by each light source.
- But ... what exactly is a wavelength of light? What does that mean?
- And, what does this have to do with different colored grow lights?



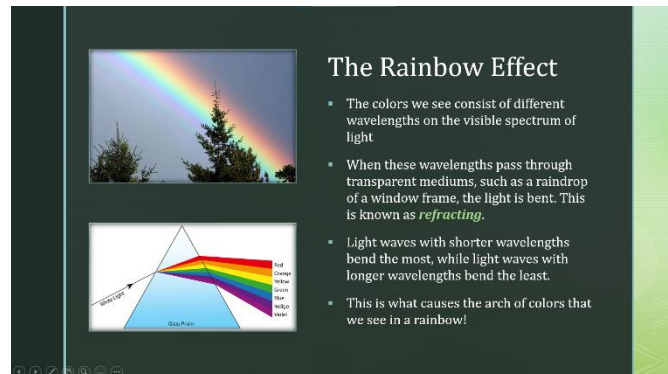
### Slide #5:

- Here we can see that the visible spectrum of light *consists* of different wavelengths, ranging from 380 nanometers to 740 nanometers.
- We also know that wavelengths correspond to different colors ...
  - Based on the image, which color has the longest wavelength?
    - *Answer: red.*
  - Which color has the shortest wavelength?
    - *Answer: violet.*



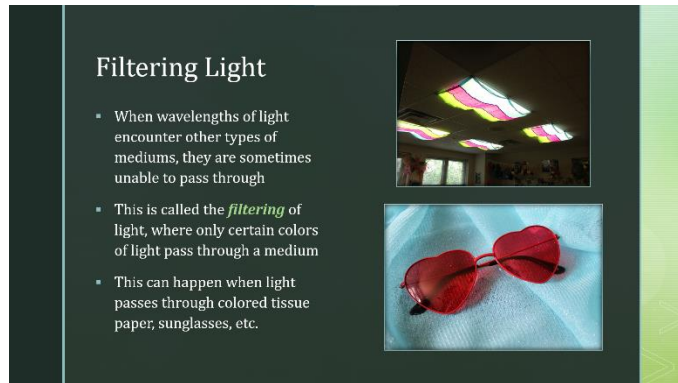
### Slide #6

- On the previous slide, we saw that light is measured by its wavelength ... we see these wavelengths as different colors. Wavelengths of light interact with the objects, mediums, and surfaces we see in the world in different ways.
- A nontransparent object or surface can either absorb or reflect wavelengths of light. We can perceive the color of an object based on the wavelengths of light it reflects.
  - What wavelength(s) of color are reflected from a red apple?
    - *Answer: red.*
  - What wavelength(s) of color are absorbed from a red apple?
    - *Answer: orange, yellow, green, indigo, and violet.*
- This slide shows light waves passing through two transparent objects, the air and a clear prism ... As waves transition from one transparent media to the next, that media causes the light wave to change speed and bend.
  - Which light wave bends the least?
    - *Answer: red.*
  - Which light wave bends the most?
    - *Answer: violet.*
  - Would light change speed and bend if it passed through an apple?
    - *Answer: no, because an apple is not transparent.*



## Slide #7

- Light waves can also be affected by other types of semi-transparent mediums ... here, we can see that some mediums *filter* light. This means that the medium blocks out some wavelengths while allowing others to pass through.
- In these pictures ...
  - What colors of light are filtered through the tissue paper in the top picture?
    - *Answer: yellow, pink, and blue.*
  - What colors of light are filtered through the sunglasses in the bottom picture?
    - *Answer: red.*
- Thinking back to what we did to simulate different wavelengths of light in our experiments ... we used sheets of cellophane. What did these sheets do to the light coming from the sun?
  - *Answer: the cellophane blocked out different colors of light.*
- What is another way to say, “blocking out light”?
  - *Answer: filtering out.*



## Slide #8

- Plants need to conduct photosynthesis as a way to convert light energy into chemical energy needed to grow.
- In our experiments, we used cellophane to filter out certain wavelengths. However, in Dr. Doust's lab, we are using *grow lights* instead of cellophane filters.
  - This way, we can maximize the available wavelengths in each environment, but still observe how different wavelengths impact plant growth.
- The question we must ask ourselves is, “How will different intensities of wavelengths impact plant growth?” ... reminds me of our question from the Amazon Expedition activity: “How can different light colors affect plant growth?”



## **Procedure – Part 2: Wave Watchers – Part 1**

Distribute StudentHandoutElaboration1\_Spectra. In this handout, students collaborate with their group members to analyze three spectral charts. For each grow light environment, students answer the following questions:

1. What are the three most intense wavelength ranges? Include each wavelength's range and intensity.
2. What colors corresponds with each wavelength range?
3. Recall the bright, blue-green, Amazonian plant that Dr. Doust planted in each environment.
  - a. What wavelength(s) would the plant **absorb** in this environment?
  - b. What wavelength(s) would the plant **reflect** in this environment?

**Note:** Here, students are tasked with discussing the intensity of light in in each grow light environment. Light intensity is the rate in which light energy – or photons – spreads on a surface. In other words, light intensity determines how much light energy is striking a given surface or object. It is measured in units of watts per square centimeter. If a light source is more intense, we perceive the light to be brighter; if the intensity is low, we perceive the light to be dimmer. Furthermore, the intensity of light can be determined for individual wavelengths of light. In terms of plants, their green leaves absorb the most wavelengths of light – and the photons within them – from opposite ends of the visible spectrum: red and blue light. Environments with higher **intensities** of blue and red light have a greater amount of photons that a plant may absorb, promoting the plant's ability to conduct photosynthesis and grow.

During this activity, students distinguish between different wavelengths of light – in terms of the intensity of each wavelength – and how each wavelength may interact with the blue-green surface of the Amazonian plant. After analyzing the provided spectral charts, students first identify the wavelengths of light with the highest intensities for each grow light environment. Then, students explain which wavelengths of light would be reflected or absorbed by the Amazonian plant.

I monitor students as they work through the different prompts in the handout. I ask questions such as, “how would you interpret the data in the charts? What do the data imply? What explanation or conclusion can you propose from the evidence?” These leading questions help students to navigate their thoughts as they respond to the writing prompts.

As students develop their explanations for each spectral chart, they identify patterns between wavelengths of light and their reflection or absorption by the Amazonian plant. Students recognize that in environments with more red light, the plant should absorb the red light. Furthermore, in environments with more blue and green light, the plant should reflect the blue and green light. Students arrive at this conclusion because of the Amazonian plant's blueish-green appearance; in connection to what they learned during **Procedure – Part 1**, students resolve that the blue-green plant would reflect the colors that it appears, so it should reflect blue green light and absorb all other wavelengths of light.

With this pattern of reflection and absorption identified, I task students to develop a hypothesis on which environment they think will best promote the growth of the Amazonian plant. This hypothesis is recorded in the sheet StudentHandoutElaboration1\_Spectra. The hypothesis allows students to reflect upon their understanding of the visible spectrum of light, wavelength behavior, and the growth of plants. Furthermore, this exercise promotes students' capability to develop claims, engage in arguments, and provide an explanation based on scientific reasoning and empirical evidence.

### **Procedure – Part 3: Wave Watchers – Part 2**

Once students complete their responses in StudentHandoutElaboration1\_Spectra, provide them with StudentHandoutElaboration2\_GrowthData. Continue with the narrative: “Now that we have analyzed the spectra in each environment and hypothesized which would be best for Dr. Doust’s Amazonian plant ... let’s analyze the growth data he collected in his lab! This will provide us with the information we need to finally answer his question: which of these three grow lab environments will best support the growth of the blue-green Amazonian plant?”

In StudentHandoutElaboration2\_GrowthData, students are tasked to analyze the growth data provided, then develop a graph depicting the data. Using their graphs, students visualize the relationship between the type of grow light and the growth of the plant. Once their graph is complete, students can reflect on the hypothesis they came up with in the previous handout.

**Note:** Middle school students may not have a strong understanding of how to graph data, so I review how to determine the best method for graphing data, as well as the important components of a graph (labeling X and Y axes, graph title, data labels, etc.). To display the provided data, they typically make a line graph. Remind students that line graphs show how numbers change over time. Also, mention that all graphs should be titled, and axes should be labeled with increments and units.

At the end of the StudentHandoutElaboration2\_GrowthData handout, students are tasked to discuss whether their hypothesis was supported or refuted by a scientific rationale. I like to ask questions to facilitate student thinking, such as “what was the basis for your predictions? Were your original assumptions about the data correct? Does the evidence support or refute your claim?”

**Management Tip:** I allow my students to collaborate with their team and share ideas. I monitor students as they work and discuss their ideas to ensure they remain on topic.

#### **Procedure – Part 4: Summative Discussion & Wave Watchers – Part 3**

As a whole class, students discuss the data they analyzed, share their scientific claims, and identify patterns of plant growth in response to different intensities of different wavelengths. Students share an oral argument in support of their explanation for plant growth. Their explanation includes how their plant responded to different wavelengths of light, is supported by the spectral and growth data provided to them, and includes their own scientific reasoning based on their evidence. As students discuss, they begin to draw connections between their claims. They further their recognition and identification of the pattern between light reflection, absorption, and plant growth under different wavelengths of light. Below, I provided some of the questions I use to help students draw connections between their scientific claims to the claims of their peers:

- What evidence do you have to support your claim?
- Do you see any similarities among the scientific claims shared among your peers? Do you see any differences among the scientific claims shared? What do you think these similarities/differences mean? **(Expected Answer: plants grew the tallest in the red grow light environment, and plants grew the shortest in the green grow light environment)**
  - If a plant that receives red light grows more than a plant that does not receive that red light, what could this imply about what this particular plant needs to grow? **(Expected Answer: a plant might need red light to grow; that wavelength color is important for plants)**
  - (After one student connects two claims) Who agrees with their statement? Why/why not?
- Considering all of the claims we shared, what are some of the wavelength colors that the Amazonian plant may need to grow? Are there any wavelengths the plant may not need to grow? **(Expected Answer: plants may need red the most, while they need green the least)**
  - Knowing that objects appear as the wavelength colors they reflect, what does this tell us about the colors of light that the Amazonian plant absorbs? **(Expected Answer: if the plant is seen as blue-green, that means that it reflects blue and green light. This means that it does not absorb green or blue light, but absorbs all other colors of light)**

After this discussion, I distribute StudentHandoutElaboration3\_Letter. In this handout, students are tasked with writing a second letter to Dr. Doust, where they formally answer the question, “which environment is best suited for the growth of the Amazonian plant, and why?” Their letter should provide an argument for their claim, supported by empirical evidence and scientific reasoning.

At the end of class, collect the StudentHandoutElaboration1\_Spectra, StudentHandoutElaboration2\_GrowthData, and StudentHandoutElaboration3\_Letter handouts. I use these forms to check that students were actively participating in constructing their claims, and as a final summative assignment. I then use TeacherHandoutElaboration2\_Rubric to grade their letters.

## Elaboration Phase: Free Response Grading Rubric

The following rubric helps me to grade student responses in their **Wave Watchers – Part 2: Plant Growth** and **Letter to Dr. Doust** handouts during the Elaboration Phase.

### Wave Watchers – Part 2: Plant Growth

| Question         | Below Average Performance<br>(0-1)                                                                                               | Average Performance<br>(2-3)                                                                                                       | Above Average<br>Performance (4)                                                                                   |
|------------------|----------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
| Data<br>Analysis | Analysis is incomplete and/or inaccurate; does not adequately explain how hypothesis was supported or not supported by the data. | Analysis is accurate/partially accurate; completely/partially addresses how hypothesis was supported or not supported by the data. | Analysis is accurate and completely addresses how the data provided supports or does not support their hypothesis. |
| Graph            | Graphs displaying data are incorrect or missing variables (title, key, etc.)                                                     | The graph displays recorded data.                                                                                                  | The graph clearly displays results and trends in data; graph contains all necessary elements.                      |

Total points: \_\_\_\_/8

**Letter to Dr. Doust**

| Question  | Below Average Performance<br>(0-1)                                                                                                       | Average Performance<br>(2-3)                                                                                                                                          | Above Average<br>Performance (4)                                                                                                                                 |
|-----------|------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Claim     | Claim is incomplete and/or scientifically inaccurate; does not adequately address research question.                                     | Claim is scientifically accurate/partially accurate; completely/partially addresses research question.                                                                | Claim is scientifically accurate and completely addresses research question.                                                                                     |
| Evidence  | Data used as evidence does not relate to or support claim at all; evidence for claim is not provided.                                    | The data relates to the claim, but not scientifically appropriate. Data is basic and/or general; could have collected stronger data to address claim.                 | Selects scientifically appropriate data to support claim. Data are thorough; provide enough details and evidence is provided.                                    |
| Reasoning | Reasoning is insufficient or does not connect evidence to claim. Does not show scientific understanding and/or understanding is limited. | Reasoning adequately or loosely connects evidence to claim. Relates to science principles, but weakly supports claim. Reasoning is more general rather than specific. | Reasoning clearly links evidence to claim. Shows how data serves as evidence based on scientific principles. Makes clear connections between claim and evidence. |
| Graph     | Graphs displaying data are incorrect or missing variables (title, key, etc.)                                                             | The graph displays recorded data.                                                                                                                                     | The graph clearly displays results and trends in data; graph contains all necessary elements.                                                                    |

Total points: \_\_\_\_/16

Student name: \_\_\_\_\_ Date: \_\_\_\_\_

## Wave Watchers – Part 1: Electromagnetic Spectra Charts

### Scenario:

While you were conducting your background research, Dr. Doust and his team ran tests of their own. Using a spectrometer, he measured the wavelengths available in each of the environments that he prepared in his lab.

Using *The Visible Light Spectrum* provided below and spectra information found in Charts A, B, and C from each of the three environments, collaborate with your group members to develop an explanation about the wavelengths measured in each chart.

In these explanations, answer each of the following questions:

1. What are the three most intense wavelength ranges? Include each wavelength's range and intensity.
2. What colors corresponds with each wavelength range?
3. Recall the bright, blue-green, Amazonian plant that Dr. Doust planted in each environment.
  - a. What wavelength(s) would the plant **absorb** in this environment?
  - b. What wavelength(s) would the plant **reflect** in this environment?

### *The Visible Light Spectrum:*

Red: 625 to 740 nm (longest wavelength)

Orange: 590 to 625 nm

Yellow: 565 to 590 nm

Green: 520 to 565 nm

Blue: 445 to 520 nm

Indigo: 425 to 445 nm

Violet: 380 to 425 nm (shortest wavelength)

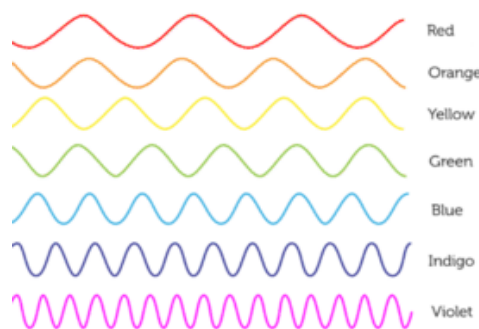
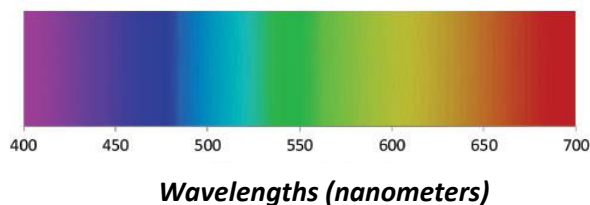
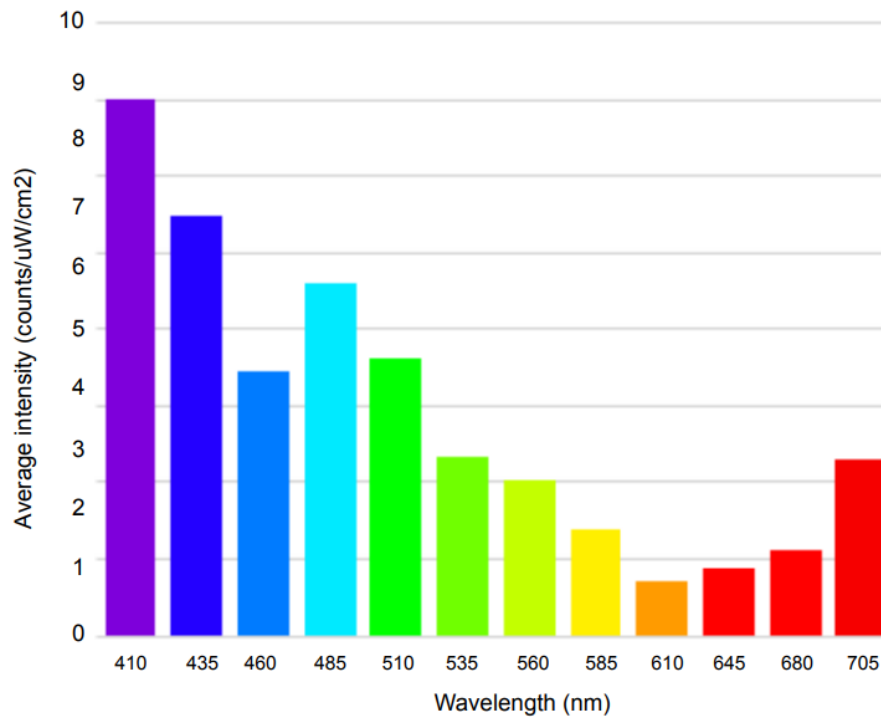


**Chart A:**  
**Average Calibrated Spectral Intensity Under Blue Glow Light**



***Explain the wavelengths of light measured in Chart A:***

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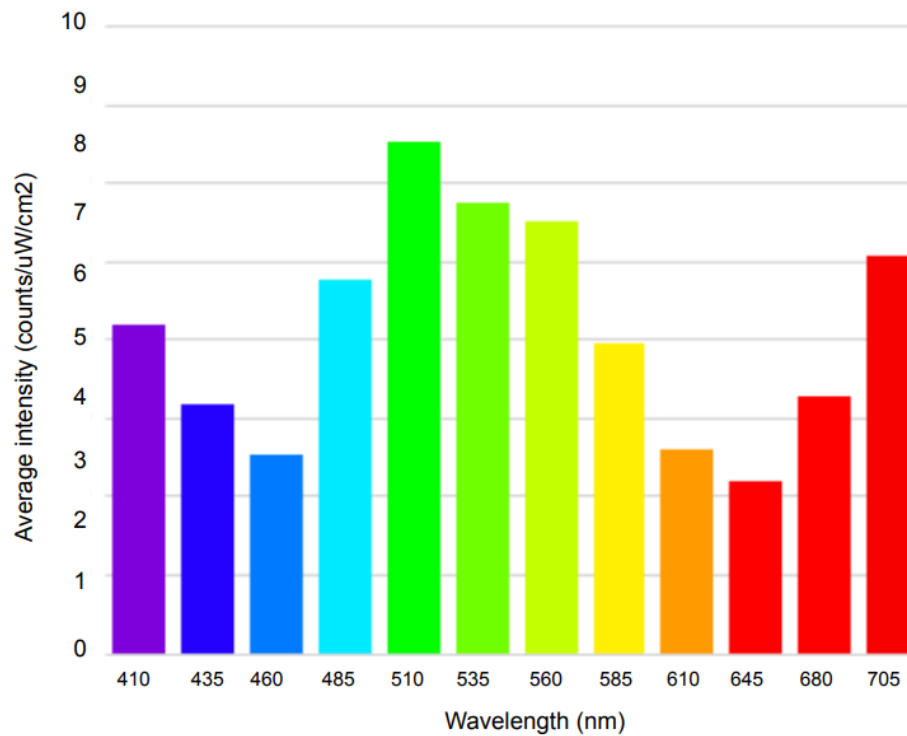
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**Chart B:**  
**Average Calibrated Spectral Intensity Under Green Glow Light**



***Explain the wavelengths of light measured in Chart B:***

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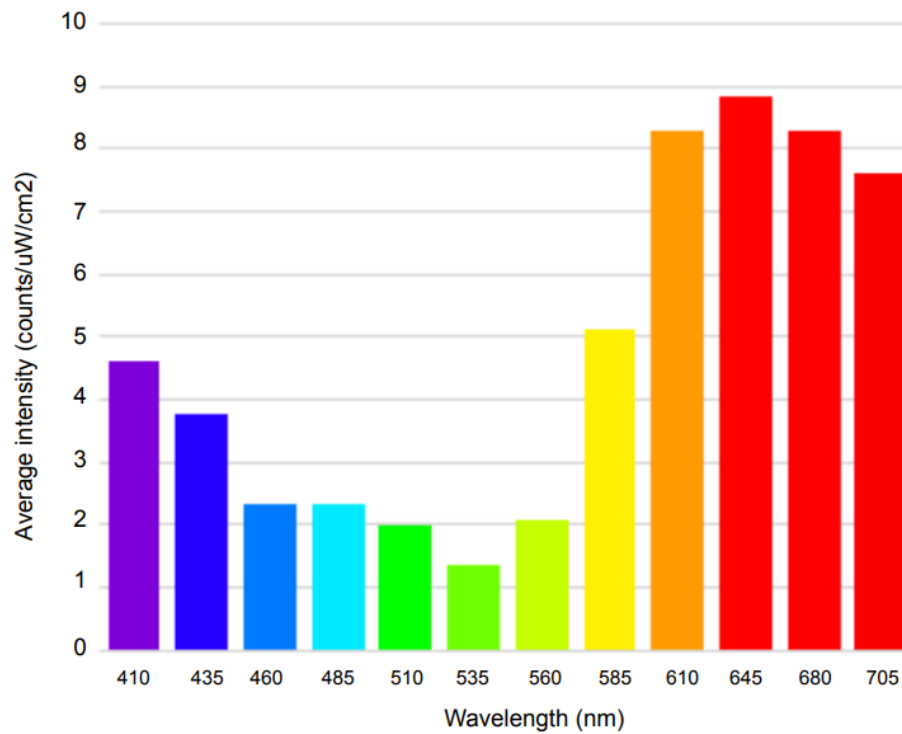
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**Chart C:**  
**Average Calibrated Spectral Intensity Under Red Glow Light**



***Explain the wavelengths of light measured in Chart C:***

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**Data Analysis:** Based on the three spectra charts, the blueish green color of the Amazonian plant, your understanding of the electromagnetic spectrum, and wavelengths, which of the following environments would **BEST** support the growth of the mysterious Amazonian plant? Support your answer with scientific evidence.

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Student name: \_\_\_\_\_ Date: \_\_\_\_\_

## Wave Watchers – Part 2: Plant Growth

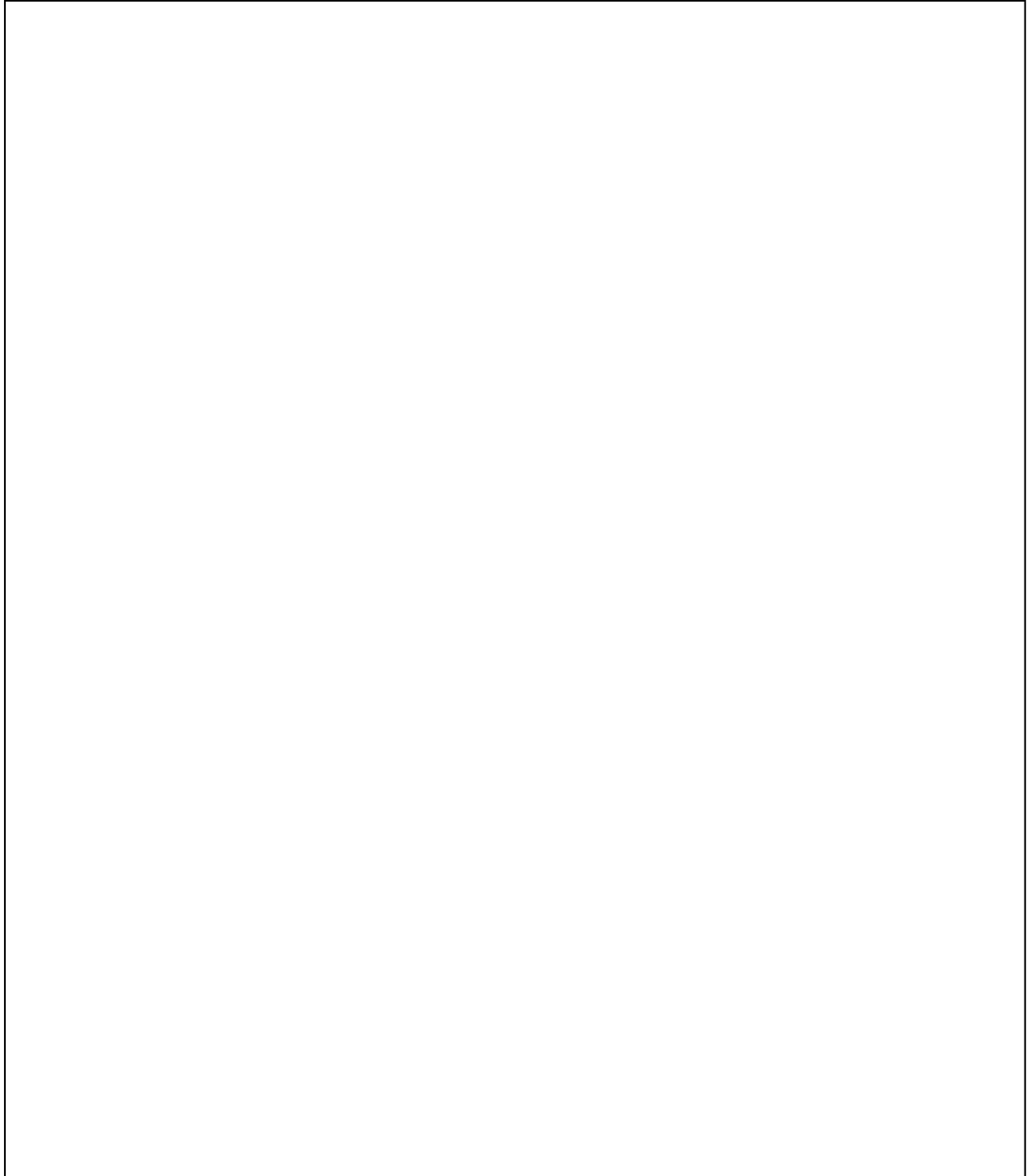
### Scenario:

Now that you have analyzed the range of wavelengths available in each environment, Dr. Doust thinks we can finally answer his question! Under which light conditions did the mysterious plant grow best? He and his lab team placed the seeds from the bright blue-green plant in the following environments: a grow light lab with either blue lights, green lights, or red lights. Dr. Doust recorded the mysterious plants' growth in each environment for eight weeks. The average height of five plants at each weekly interval was recorded (see data table below).

| Time<br>(weeks) | Blue Light Height<br>(cm) | Green Light Height<br>(cm) | Red Light Height<br>(cm) |
|-----------------|---------------------------|----------------------------|--------------------------|
| 1               | 0                         | 0                          | 1                        |
| 2               | 1                         | 2                          | 4                        |
| 3               | 2                         | 3                          | 6                        |
| 4               | 2.5                       | 4                          | 9                        |
| 5               | 3                         | 5                          | 11                       |
| 6               | 4                         | 6                          | 13                       |
| 7               | 4.5                       | 6.5                        | 16                       |
| 8               | 5                         | 7                          | 18                       |

**Graph Dr. Doust's growth data in the space below:**

Using the data provided in the table, draw a graph to display Dr. Doust's data. Include properly marked increments, axes titles, and graph titles. If necessary, include a key for any symbols or colors you use to symbolize different sets of data.

A large, empty rectangular box with a thin black border, intended for drawing a graph. The box is oriented vertically and occupies the lower half of the page.

**Data Analysis:** Was your hypothesis from Part 1 supported by the data? Explain why or why not.

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Student name: \_\_\_\_\_ Date: \_\_\_\_\_

### **Wave Watchers – Part 3: Letter to Dr. Doust**

In the space below, compose a letter addressed to Dr. Doust to formally answer his question: Which light environment is best for the growth of the mysterious Amazonian plant, and why? State your scientific claim, the data you selected to use as evidence, and an argument to explain why your claim is correct based on your selected data. Discuss your reasoning for how your selected evidence supports your scientific claim.

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