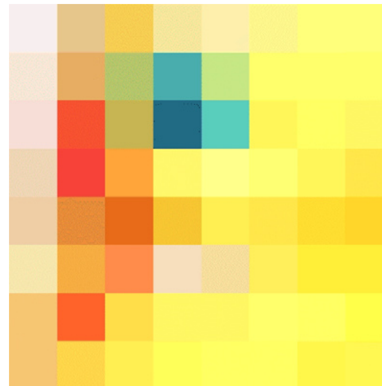
2. Pixels and Colors

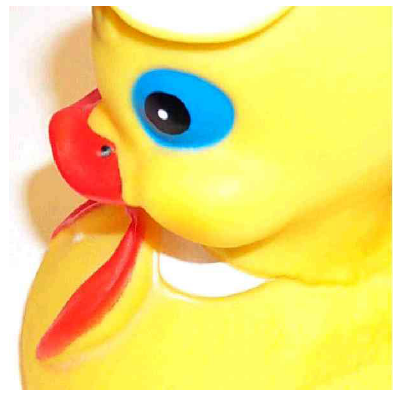
Introduction to Pixels

The term pixel is a truncation of the phrase "picture element" which is exactly what a pixel is. A pixel is the smallest block of color in a digital picture. The term is also used for the smallest block of color on your computer monitor. In fact, to run these activities we recommend that you have the display setting for screen area on your monitor set to at least 1024x768 pixels. What that means is that your monitor has 786,432 blocks of colors arranged in rectangle with 1024 columns and 768 rows.

The resolution of an image refers to the number of pixels used to display an image. A higher resolution image uses more pixels and allows for more detail to be seen in the picture. Scanners and printers will often advertise their resolution in *dots per inch (dpi)*, which is the number of pixels per inch that they are capable of recording or depositing. A document printed at low resolution (fewer dpi) has jagged steps of dots that make up a curve like the letter "O". From a high resolution printer (more dpi), that same letter looks like a smooth circle.



Images of a rubber duck with large pixels and with very small pixels.



Investigation

Pixels and Digital Images

The number of pixels in an image tells you the picture's resolution. More pixels means a higher resolution, allowing you to distinguish more details in the picture.

The ***Pixels*** button of the software ***DigitalImageBasics*** can increase and decrease the resolution of the image, so that you can see how many pixels are necessary to recognize the picture's subject. When you open an image, it will be at the lowest resolution: 2x2=4 pixels. Increase the number of pixels until you can make out what the picture is. Record the resolution needed to recognize the mystery pictures.

Software to use: ***DigitalImageBasics*** with the ***Pixels*** button active.

Use the program ***DigitalImageBasics*** with the ***Pixels*** button activated to fill out the chart on the next page and answer these questions:

Question 2.1. How does the resolution of an image affect what you can see? Why would you need more pixels to identify an image?

Question 2.2. When could you identify an image with large pixels? How does resolution affect interpreting satellite images?

Pixel Count Chart

Mystery Picture #	At what resolution can you recognize the subject of the picture?	What is the subject of this picture?

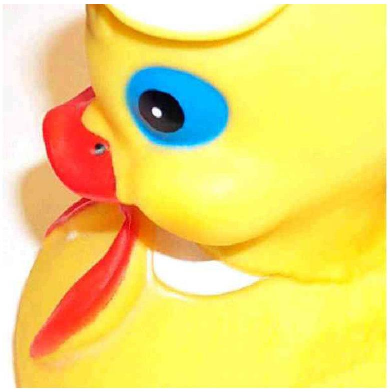
Color Within a Digital Picture

You see color on things around you because light shines into your eye, is received by the cones and rods of your retina, and is converted to electrochemical signals that are then processed through your brain. A digital camera detects color because light shines on sensors in your camera which are sensitive to red, green, and blue. The number of sensors in the camera will define the highest resolution possible for that camera.

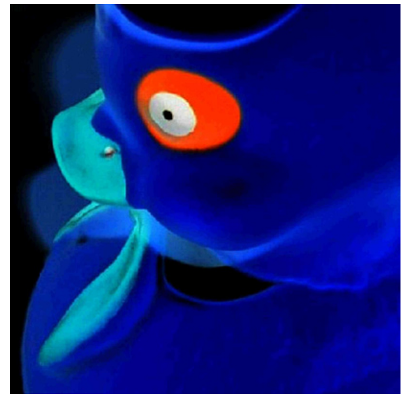
A traditional film-based camera records an image onto a chemically treated plastic. *Digital* cameras record the red, green, and blue intensities for each pixel into a numerical file – the values of color and position of the pixel are defined with numbers. A number of different file types are used to compress the data so the file takes up a minimal amount of computer memory. To display the image on the computer screen, the computer takes the red intensity value for a particular pixel from the file and shines the red component of the pixel at that amount at that place on the computer screen. It does the same thing for the other two primary colors (green and blue) for every pixel in the image.

Seeing Only One Color of Light

When we talk about seeing only one color we are not referring to the condition known as color blindness. People who are colorblind have difficulty distinguishing between certain colors, for example red and green, but they are still capable of perceiving light of both colors. What we are talking about is if you could only see the small range of light wavelengths that is called "red". You would be unable to perceive the spectrum of light including orange, yellow, green, blue, and violet.

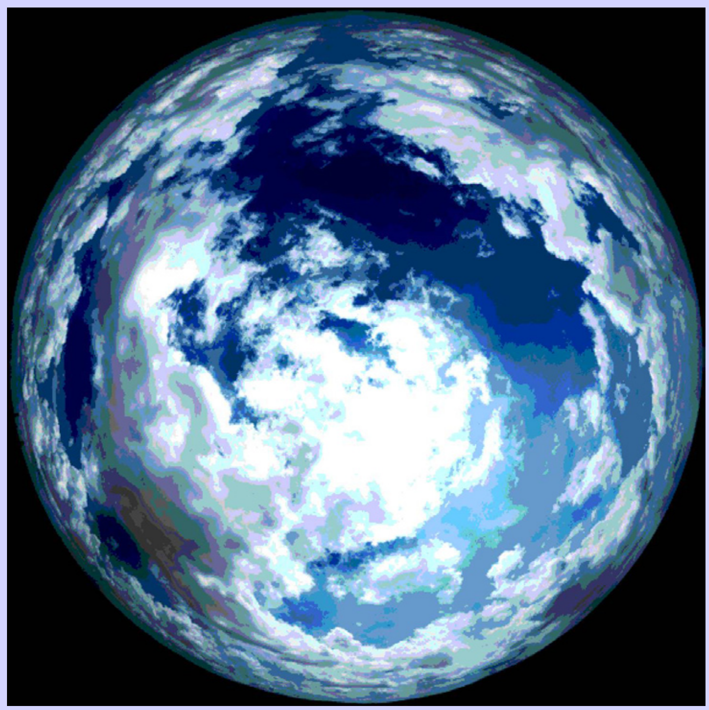


Seeing only two colors of light: *the image at left of a rubber duck has the complete set of red, green, and blue colors, while the one on the right has only red and blue colors.*



In satellite images, each color is data of the image that provides specific information. By turning off all of the light that is not red, we can look solely at the information that red light provides. If we were physically only able to see the range of light that is red, it would appear more like a black and white image than a red and black image. The use of black and white to view such information allows us to make out details and differences in shade and intensity more easily.

Why is the Sky Blue?



The Sun produces white light. White is the combination of all of the colors of the rainbow. When we view sunlight through a prism, we bend the colors so that they are separated. When sunlight shines through our atmosphere, it is bent and scattered by particles. Our atmosphere, because it is largely made up of nitrogen and oxygen, is most efficient at scattering blue wavelengths of light. If you look back at your data from Chapter 1, you will see that if we remove blue from our white light, the color that we are left seeing is yellow. The scattered blue light leaves the sun looking yellow.

But we all know that the sky is not always blue. At sunset and sunrise, the sky includes many more colors from throughout the spectrum. You may have picked up on the use of the word "efficient" above. Other colors of light are scattered by our atmosphere, but not as efficiently as the blue. When the Sun is high in the sky, its light has a shorter distance to travel through the atmosphere and the blue light is scattered. When the sun is low in the sky, the path is much longer and more colors of light are scattered.

While the question "why is the sky blue?" is one of general interest, the reason we are discussing it here is to start thinking about the effect that our atmosphere has on the light that travels through it. If we are going to take an image from space of light that shines from the Sun through the atmosphere and is reflected back up to space, then we must pay attention to what the atmosphere does to that light on its travels.

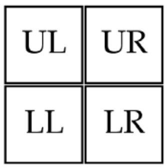
Investigation

Color of a Pixel

Software to use:
DigitalImageBasics with the ***Pixels*** button active.

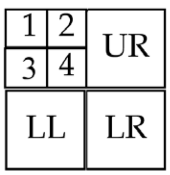
The word *pixel* comes from the phrase "picture element." Each pixel displays the color of a tiny region of the image, and that color is the average color for the entire region. In the following tables you will look at the red, green, and blue intensities of a large pixel and the smaller pixels that define the same region.

2x2 pixel resolution



Pixel	***Red Intensity Value***	***Green Intensity Value***	***Blue Intensity Value***
Upper Left (UL)			
Upper Right (UR)			
Lower Left (LL)			
Lower Right (LR)			

4x4 pixel resolution



Pixel	***Red Intensity Value***	***Green Intensity Value***	***Blue Intensity Value***
UL – 1			
UL – 2			
UL – 3			
UL – 4			
Average for each:			

A. Open a mystery picture of your choice in ***DigitalImageBasics*** with the ***Pixels*** button active. With the resolution at the minimum, 2x2=4, show the pixel borders for 2x2. Move the cursor over each pixel and write down the color intensity values (%) shown in the lower, left area of ***DigitalImageBasics*** window.

B. Increase the resolution of the picture to 4x4=16. This time write down the color intensity values for the four pixels that cover the same region as the Upper Left pixel from the 2x2 resolution. In the last row, write the average value of the column.

Question 2.3. Compare the averages from the second chart to the values for the Upper Left pixel from the first chart. How are they alike? What do you expect would be average intensity values for the pixels in this same region if the resolution is 8x8?

Investigation

Switching Colors

Have you ever looked really closely at a television or computer monitor? If you haven't, take a magnifying glass or a small droplet of water and look at your computer monitor. Up close, you will see that your monitor screen is actually a series of red, green, and blue dots shining light at different intensities. When your computer displays an image, it takes the red intensity values from the image file and makes the red dots shine by those amounts. The **ColorPicture** program allows you to change which set of colors in the image file shine as which colors on the computer display—in other words change it so the red intensity values from the image file make the green dots or blue dots on the screen shine instead.

Part 1: Color Circles

Software to use: ***DigitalImageBasics*** with the ***Colors*** button active.

Open the picture <u>*Color Circles 1*</u>. Notice that the initial settings of the program have the same colors for "Color Measured by Camera" and "Displayed Color" (which is the color display on the computer monitor).

Question 2.4. Describe the colors you see in this picture. What color is the circle at the top? On the left? On the right? What other colors do you see in the picture?

Question 2.5. Change the combinations of "Color Measured by Camera" and "Displayed Color." What happens to the circle at the top? Can you make the picture have only one yellow circle?

Part 2: Seeing One Color

Open the picture <u>*Sample: RGB Color Space*</u>. This is a picture where the edges of a cube span all the values of RGB colors. Notice how the colors in this picture are arranged. Imagine what things would look like if your eyes could only see one color.

Question 2.6. What would this picture look like if we were blind to ALL colors except red—that is if we could see ONLY red light? How would the image look different in red than with all colors? Move your mouse over the picture to see the red intensity values of pixels throughout the image.

Question 2.7. Change the view of this picture so that you can only see the red intensity values of the image file. To do this, set all three "Color Measured by Camera" choices to 'Red'. What areas look bright in red light? Which areas look dark? You can also try settng the Blue and Green values to "None".

Question 2.8. Now view the picture with only the blue light. How does the picture look different? What details can you see better in the blue light? What is visible in the red light?

Question 2.9. When all of the computer display colors show the red picture color, why does the image appear black and white? If your eyes were only able to see red, do you think that is what the world would look like?

Part 3: Colors of the Sky

Open the picture *AllSky.jpg*. This is a picture of the sky using a camera with a fish-eye lens, which allows most of the sky to be seen at once. This picture is courtesy of Chuck Wilcox at the Museum of Science, Boston, Massachusetts.

Now that you have learned so much about color and light, get to know the colors in this picture. Move your mouse around the image and notice the color intensity values throughout the picture. Change which picture colors are seen in the computer display colors.

Question 2.10. Which of the three-color components (red, green, or blue) is dominant in the sky? Which color contributes the least intensity to the sky? See the contribution of a color by setting all of the computer display colors to a single picture color.

Question 2.11. If the sky is blue because of tiny atmospheric particles scattering blue light, why is the Sun yellow? Hint: this is a good time to take a look back at the Tri-Color Reference Chart that you created in Part 1.

Question 2.12. If the Sun appears to be yellow, why do clouds appear so white in the image? If you were riding on a satellite thousands of miles above the Earth, what would be the color of the "sky" (or outer space) and what would be the color of sunlight?

Open the picture *sunset.jpg*. This is a picture of the Sun setting over the ocean. Here the sky is yellow and orange while the clouds are dark. Use the **ColorPicture** program to get to know the colors in this picture.

Question 2.13. Why is the color of the sky different at sunset from the middle of the day? What about the clouds and the Sun?

Question 2.14. What color is the dominant color of the water? Where is the blue in this picture?