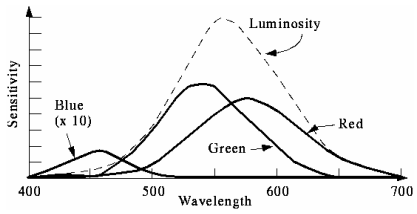
Picture Encoding and Manipulation

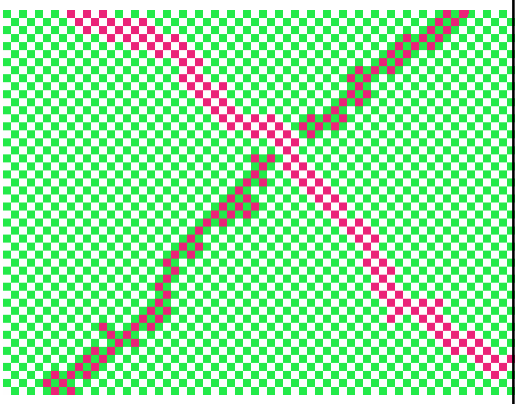
We perceive light different from how it actually is



- Color is continuous
  - Visible light is wavelengths between 370 and 730 nm
    - That's 0.00000037 and 0.00000073 meters
- But we *perceive* light with color sensors that peak around 425 nm (blue), 550 nm (green), and 560 nm (red).
    - Our brain figures out which color is which by figuring out how much of each kind of sensor is responding

Luminance vs. Color

- We perceive borders of things, motion, depth via *luminance*
  - Luminance is *not* the amount of light, but our *perception* of the amount of light.
  - We see blue as "darker" than red, even if same amount of light.
- Much of our luminance perception is based on comparison to backgrounds, not raw values.

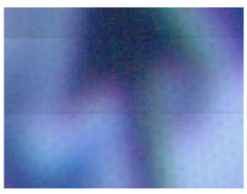


Luminance perception is *color blind*.

Different parts of the brain perceive color and luminance.

Digitizing pictures into dots

- We digitize pictures into many tiny dots
- Enough dots and it looks continuous to the eye
  - Our eye has limited resolution
  - Our background/depth *acuity* is particularly low
- Each picture element is a *pixel*



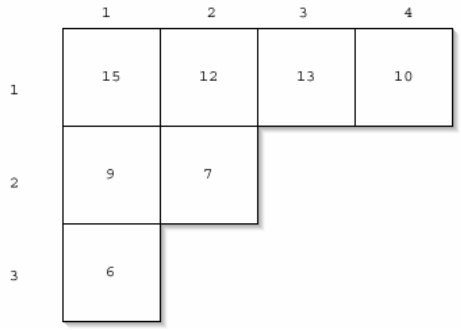
i.e. "picture element"

Pixels in Python

- Pixels are *picture elements*
  - Each pixel in python is an object that "knows" its *color*
    - E.g. given a pixel, a Python function can get the color of it.
  - It also "knows" where it is in the *picture*
    - E.g. given a pixel and a picture, a Python function can find out where the pixel is located in the picture

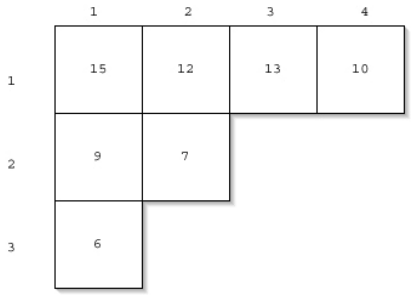
A Picture is a *matrix* of pixels

- It's not a continuous line of elements, that is, a 1-D *array*
- A picture has two dimensions: Width and Height
- We need a 2-dimensional array: a *matrix*



Just the upper left hand corner of a matrix.

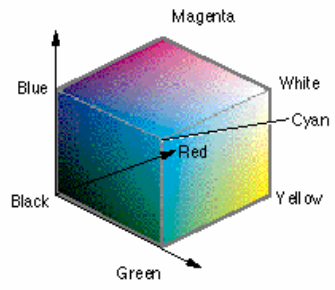
Referencing a matrix

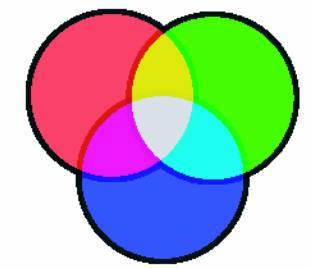


- We talk about positions in a matrix as (x, y), or (horizontal, vertical)
- The origin (1, 1) is in the **upper left** corner of the picture
- Element (2, 1) in the matrix at left is the value 12
- Element (1, 3) is 6

RGB

- In RGB, each color has three component colors:
  - Amount of red
  - Amount of green
  - Amount of blue
- In a CRT each appears as a dot and is blended by our eye.
- In most computer-based models of RGB, a single *byte* (8 bits) is used for each
  - So a complete RGB color is 24 bits, 8 bits of each





How much can we encode in 8 bits?

- Let's walk through it.
  - If we have one bit, we can represent two patterns: 0 and 1.
  - If we have two bits, we can represent four patterns: 00, 01, 10, and 11.
  - If we have three bits, we can represent eight patterns: 000, 001, 010, 011, 100, 101, 110, 111
- The rule: In *n* bits, we can have 2^n patterns
  - In 8 bits, we can have 2^8 patterns, or 256
  - If we make one pattern 0, then the highest value we can represent is 2^8-1, or 255

Encoding RGB

- Each component color (red, green, and blue) is encoded as a single byte
- Colors go from (0, 0, 0) to (255, 255, 255)
  - If all three components are the same, the color is in grayscale
    - (50, 50, 50) at (2, 2)
  - (0, 0, 0) (at position (1, 2) in example) is black
  - (255, 255, 255) is white

Is that enough?

- We're representing color in 24 (3 * 8) bits.
  - That's 16,777,216 (2^{24}) possible colors
  - Our eye can discern millions of colors, so it is pretty close
  - But the real limitation is the physical devices: We don't get 16 million colors out of a monitor
- Some graphics systems support 32 bits per pixel
  - May be more pixels for color
  - More useful is to use the additional 8 bits to represent not color but 256 levels of *translucence*

Media jargon: 4th byte per pixel is the "Alpha channel"

Size of images

	320 x 240 image	**640 x 480 image**	**1024 x 768 monitor**
24 bit color	1,843,200 bits 230,400 bytes	7,372,800 bits 921,600 bytes	18,874,368 bits 2,359,296 bytes
32 bit color	2,457,600 bits 307,200 bytes	9,830,400 bits 1,228,800 bytes	25,165,824 bits 3,145,728 bytes

Reminder: Manipulating Pictures

```
>>> file = pickAFile()
>>> print file
C:\Documents and Settings\Kenrick\My
Documents\Class\CSA109\JES\content\MediaSources\ducks\d
ucks 010.jpg
>>> picture = makePicture(file)
>>> show(picture)
>>> print picture
Picture, filename C:\Documents and Settings\Kenrick\My
Documents\Class\CSA109\JES\content\MediaSources\ducks\d
ucks 010.jpg
height 240 width 320
```

What is a "picture"?

- A picture object in JES is an encoding that represents an image
  - Knows its height and width
    - i.e. it knows how many pixels it contains in both directions
  - Knows its filename
    - A picture isn't a file, it's what you get when you makePicture() a file...but it does "remember" the file it came from.
  - Knows its *window* if it's opened (via *show* and repainted with *repaint*)
    - which we will need to do later….

Manipulating pixels

getPixel(picture, x, y) gets a single pixel.

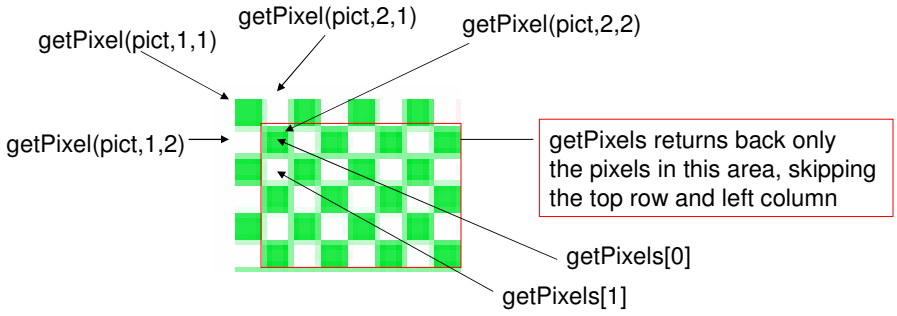
getPixels(picture) gets *all* of them into an array.

```
>>> pixel = getPixel(picture, 1, 1)

>>> print pixel
Pixel, color=color r=168 g=131 b=105

>>> pixels = getPixels(picture)

>>> print pixels[0]
Pixel, color=color r=168 g=131 b=105
```

Square brackets: standard way to refer to an element in an array —which we'll generally *not* use

Close, but not quite

- The preceding slide is not quite true – there is a small bug in the way **getPixels** works



What can we do with a pixel?

- **getRed**, **getGreen**, and **getBlue** are functions that take a pixel as input and return a value between 0 and 255
- **setRed**, **setGreen**, and **setBlue** are functions that take a pixel as input *and* a value between 0 and 255

We can also get, set, and make Colors

- **getColor** takes a pixel as a parameter and returns a Color object from the pixel
- **setColor** takes a pixel as a parameter *and* a Color, then sets the pixel to that color
- **makeColor** takes red, green, and blue values (in that order) each between 0 and 255, and returns a Color object
- **pickAColor** lets you use a color chooser and returns the chosen color
- We also have functions that can **makeLighter** and **makeDarker** an input color

How “close” are two colors?

- Sometimes you need to find the *distance* between two colors, e.g., when deciding if something is a “close enough” match
- How do we measure distance?
  - Pretend it’s Cartesian coordinate system
  - Distance between two points:

$$\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

  - Distance between two colors:

$$\sqrt{(red_1 - red_2)^2 + (green_1 - green_2)^2 + (blue_1 - blue_2)^2}$$

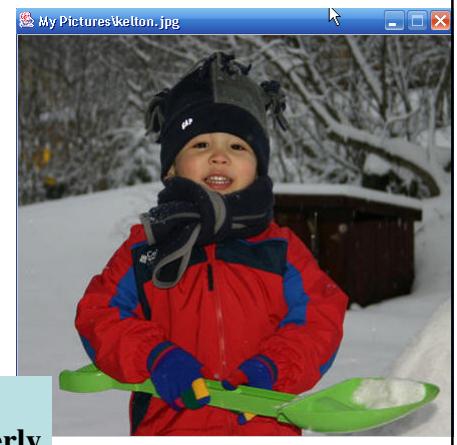
Demonstrating: Manipulating Colors

```
>>> print getRed(pixel)
168
>>> setRed(pixel, 255)
>>> print getRed(pixel)
255
>>> color = getColor(pixel)
>>> print color
color r=255 g=131 b=105
>>> setColor(pixel, color)
>>> newColor = makeColor(0, 100, 0)
>>> print newColor
color r=0 g=100 b=0
>>> setColor(pixel, newColor)
>>> print getColor(pixel)
color r=0 g=100 b=0
```

```
>>> print color
color r=81 g=63 b=51
>>> print newcolor
color r=255 g=51 b=51
>>> print distance(color, newcolor)
174.41330224498358
>>> print color
color r=168 g=131 b=105
>>> print makeDarker(color)
color r=117 g=91 b=73
>>> print color
color r=117 g=91 b=73
>>> newcolor = pickAColor()
>>> print newcolor
color r=255 g=51 b=51
```

We can change pixels directly…

```
>>> pict=makePicture(file)
>>> show(pict)
>>> red = makeColor(255,0,0)
>>> setColor(getPixel(pict, 10, 100),red)
>>> setColor(getPixel(pict, 11, 100),red)
>>> setColor(getPixel(pict, 12, 100),red)
>>> setColor(getPixel(pict, 13, 100),red)
>>> repaint(pict)
```

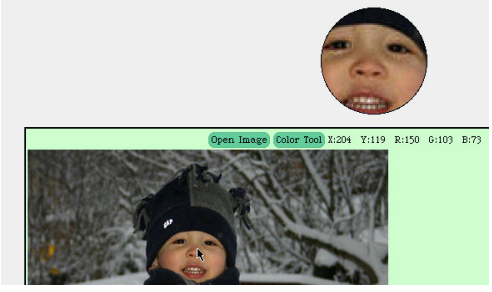


But that's *really* tedious… Manipulating pictures more cleverly is coming up next

How do you find out what RGB values you have? And where?

- Use a paint program – or use the MediaTools!
- Drag mediatools.image onto squeakVM to run

(especially useful when testing and debugging…)



Better Pixel Manipulation - Use a loop!

```
def decreaseRed(picture):
  for p in getPixels(picture):
    value = getRed(p)
    setRed(p, value * 0.5)
```

Used like this:

```
>>> file = r"c:\mediasources\katie.jpg"
>>> picture = makePicture(file)
>>> show(picture)
>>> decreaseRed(picture)
>>> repaint(picture)
```

How loops are written

- **for** is the name of the command
- An *index variable* is used to hold each of the different values of a sequence
- The word **in**
- A function that generates a *sequence*
  - **The index variable will be the name for one value in the sequence, each time through the loop**
- A colon (":")
- And a *block*

What happens when a loop is executed

- The *index variable* is set to an item in the *sequence*
- The block is executed
  - The variable is often used inside the block
- Then execution *loops* to the **for** statement, where the index variable gets set to the next item in the sequence
- Repeat until every value in the sequence was used.

getPixels returns a sequence of pixels

- Each pixel knows its color and place in the original picture
- Change the pixel, you change the picture
- So the loop below assigns the index variable *p* to each pixel in the picture *picture*, one at a time.

```
def decreaseRed(picture):
  for p in getPixels(picture):
    originalRed = getRed(p)
    setRed(p, originalRed * 0.5)
```

Do we need the variable *originalRed*?

- Not really: Remember that we can swap names for data and function calls that are equivalent.

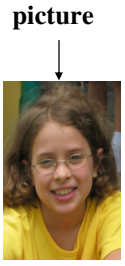
```
def decreaseRed(picture):
  for p in getPixels(picture):
    originalRed = getRed(p)
    setRed(p, originalRed * 0.5)
```

```
def decreaseRed(picture):
  for p in getPixels(picture):
    setRed(p, getRed(p) * 0.5)
```

Let's walk that through slowly…

```
def decreaseRed(picture):
  for p in getPixels(picture):
    originalRed = getRed(p)
    setRed(p, originalRed * 0.5)
```

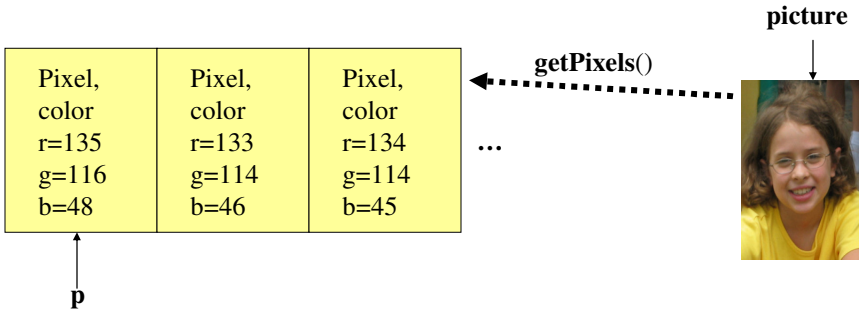
Here we take a picture object in as a parameter to the function and call it **picture**



Now, get the pixels

```
def decreaseRed(picture):
  for p in getPixels(picture):
    originalRed = getRed(p)
    setRed(p, originalRed * 0.5)
```

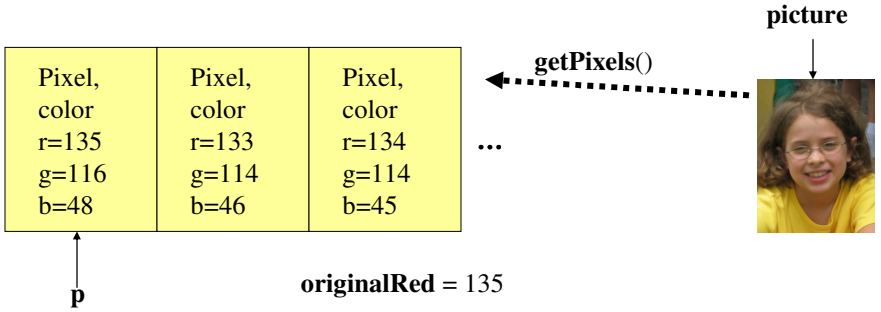
We get all the pixels from the **picture**, then make **p** be the name of each one *one at a time*



Get the red value from pixel

```
def decreaseRed(picture):
  for p in getPixels(picture):
    originalRed = getRed(p)
    setRed(p, originalRed * 0.5)
```

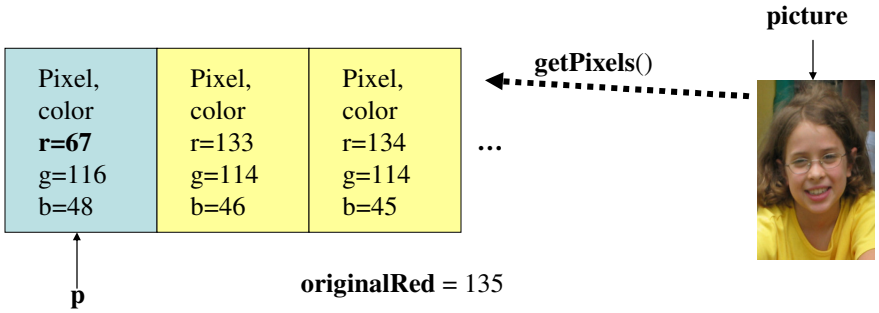
We get the red value of pixel **p** and name it **originalRed**



Now change the pixel

```
def decreaseRed(picture):
  for p in getPixels(picture):
    originalRed = getRed(p)
    setRed(p, originalRed * 0.5)
```

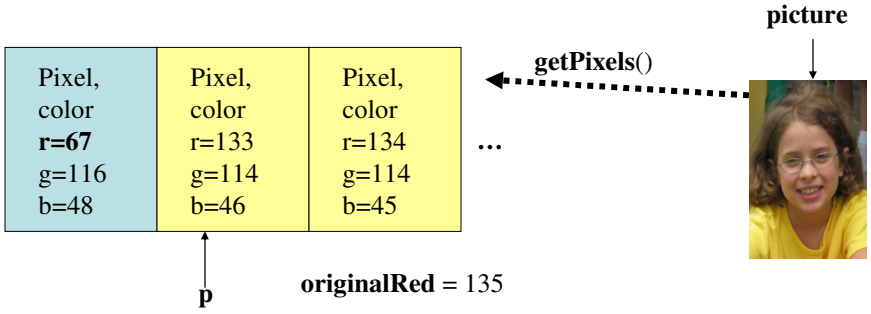
Set the red value of pixel **p** to 0.5 (50%) of **originalRed**



Then move on to the next pixel

```
def decreaseRed(picture):
  for p in getPixels(picture):
    originalRed = getRed(p)
    setRed(p, originalRed * 0.5)
```

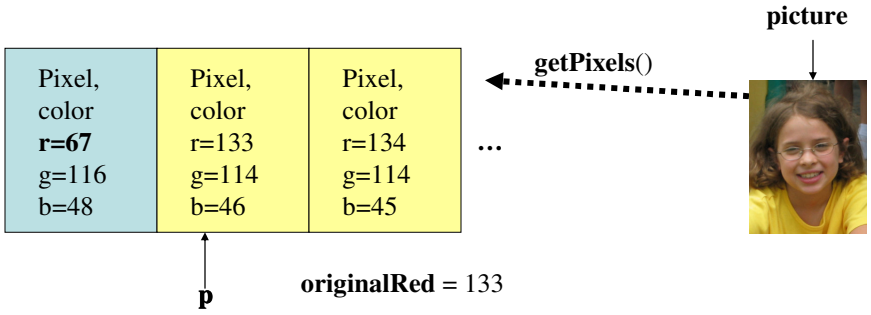
Move on to the next pixel and name *it* **p**



Get its red value

```
def decreaseRed(picture):
  for p in getPixels(picture):
    originalRed = getRed(p)
    setRed(p, originalRed * 0.5)
```

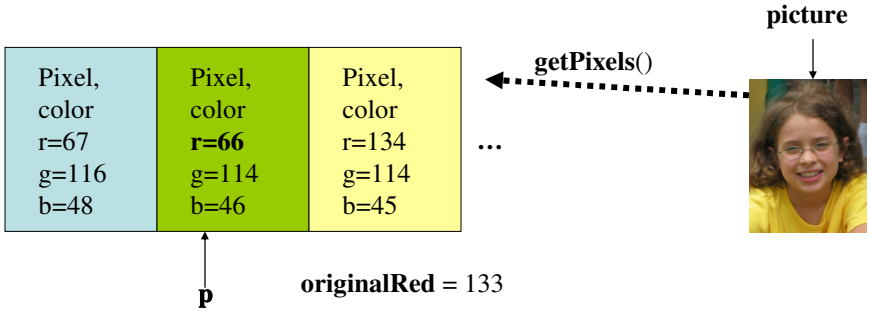
Set **originalRed** to the red value at the new **p**, then change the red at that new pixel.



And change *this* red value

```
def decreaseRed(picture):
  for p in getPixels(picture):
    originalRed = getRed(p)
    setRed(p, originalRed * 0.5)
```

Change the red value at pixel **p** to 50% of value



And eventually, we do all pixels

- We go from this… to this!

"Tracing/Stepping/Walking through" the program

- What we just did is called "stepping" or "walking through" the program
  - You consider each step of the program, in the order that the computer would execute it
  - You consider what *exactly* would happen
  - You write down what values each variable (name) has at each point.
- It's one of the most important *debugging* skills you can have.
  - And *everyone* has to do a *lot* of debugging, especially at first.

Did that really work? How can we be sure?

- Sure, the picture *looks* different, but did we actually decrease the amount of red? By as much as we thought?
- Let's check it!

```
>>> file = pickAFile()
>>> print file
C:\Documents and Settings\Kenrick Mock\My
Documents\mediasources\barbara.jpg
>>> pict = makePicture(file)
>>> pixel = getPixel(pict, 2, 2)
>>> print pixel
Pixel, color=color r=168 g=131 b=105
>>> decreaseRed(pict)
>>> newPixel = getPixel(pict, 2, 2)
>>> print newPixel
Pixel, color=color r=84 g=131 b=105
>>> print 168 * 0.5
84.0
```

Didn't use 1,1 because of getPixels bug

Want to save the new picture?

- **writePictureTo**(picture, ”filename.jpg”)
- Writes the picture out as a JPEG
- ***Be sure to end your filename as “.jpg”!***
- If you don’t specify a full path, will be saved in the same directory as JES.

Checking it in the MediaTools