Compsci 101
Images, Tuples

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March 21, 2023

`P` is for …

- **Python**
  - Whatever you want it to be? Language!!!
- **Parameter**
  - When an argument becomes a variable
- **Power Cycle**
  - Not the last resort. But works
- **P2P**
  - From networking to collaboration

Cynthia Rudin

- **Duke CompSci Professor**
  - Univ Buffalo, BS Mathematical Physics, BA Music Theory
  - Princeton, PhD.
- **Works in interpretable machine learning, which is crucial for responsible and trustworthy AI**
- **Winner of Squirrel AI Award for AI for the Benefit of Humanity – 1 million**
  - Detecting crime series
  - Con Edison NYC – underground electrical distribution network

She uses AI's power to help society.

Announcements

- **Assign 4 due Thursday, March 23**
  - Assign 4 Sakai Quiz due tonight!
- **Prelab 8 – do before lab this week**
- **Assign 5 and Apt 5 out on Thursday**

- **Exam 2 coming back soon**
- **APT Quiz 2 starts at end of next week**
  - March 30-April 3

PFTD

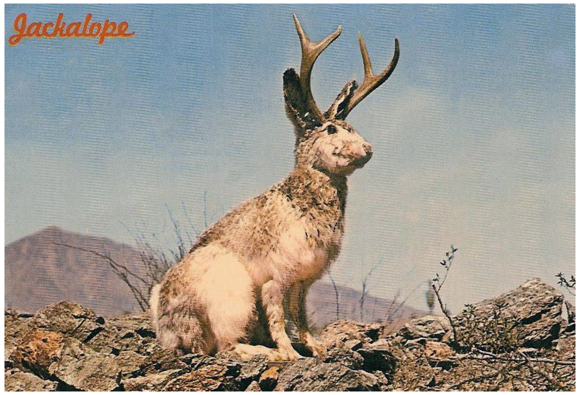
- **Exam 2**
- **Images**
- **Classes and Objects**
- **Tuples sprinkled about**

Images

What is photoshop?

Image Processing

- **Convert image into format for manipulating the image**
  - Visualization, Sharpening, Restoration, Recognition, Measurement, more
  - Resizing, Red-eye Removal, more
  - CrashCourse: Navigating Digital Info
    - http://bit.ly/dukecs101-cc-images



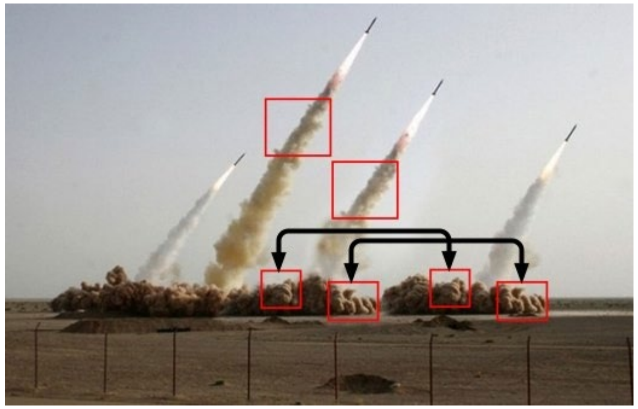


Image Library

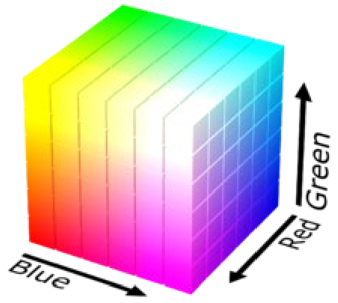
- **PIL: Python Image Library -> Pillow**
  - To install run the command below in a terminal
    - Terminal in PyCharm, not “Python Console”
    - `pip install Pillow`
      - `If that doesn’t work try:`
      - `Python3 –m pip install Pillow`

- **Library has extensive API, far more than we need**
  - Concepts often apply to every image library
  - Realized in Python-specific code/functions

Color Models

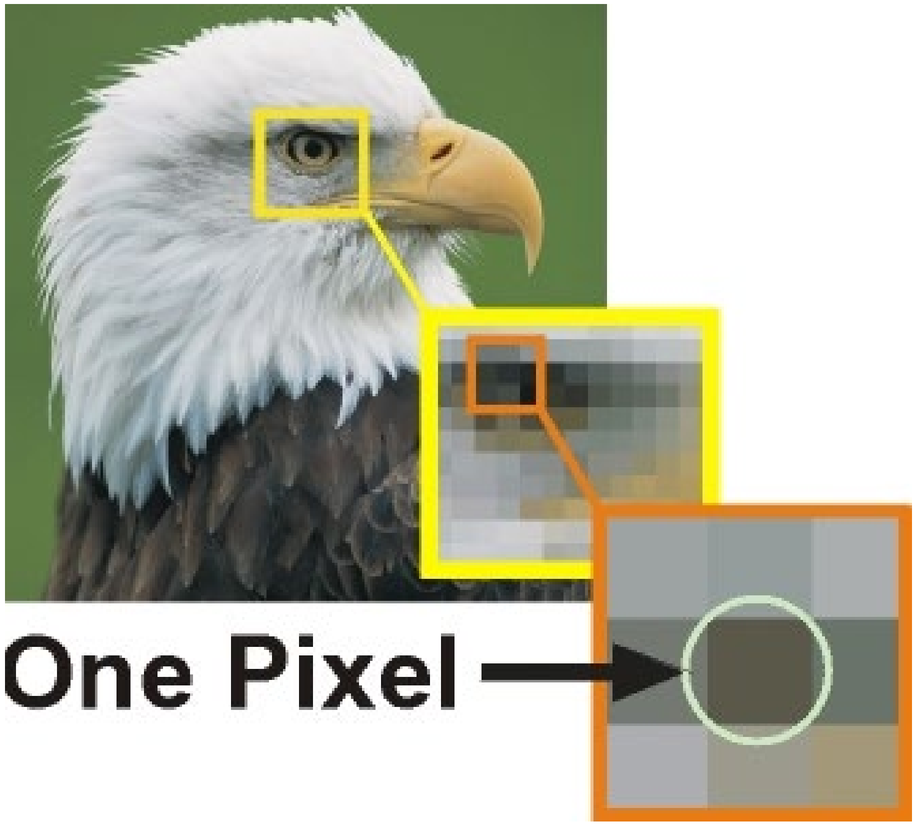
- **Cameras, Displays, Phones, JumboTron: RGB**
  - Additive Color Model: Red, Green, Blue
  - https://en.wikipedia.org/wiki/RGB_color_model

- **Contrast Printers and Print which use CMYK**
  - Subtractive: Cyan, Magenta, Yellow, Key/Black



An image is made up of Pixels

- **A pixel is a square of color**



Images and Pixels

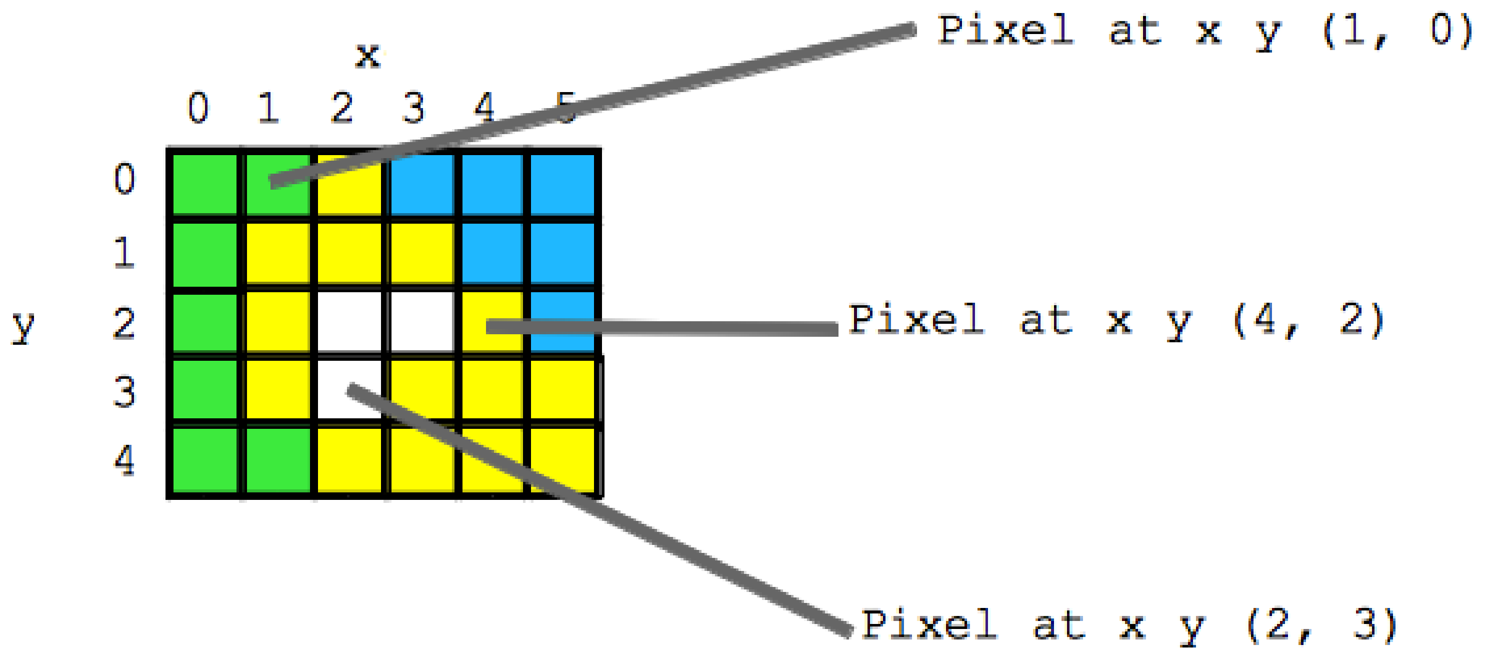
- **Image is a collection of pixels**
  - Organized in rows: # rows is image height
  - Each row has the same length: image width

- **Pixels addressed by (x, y) coordinates**
  - Upper-left (0,0), Lower-right (width-1,height-1)
  - Typically is a single (x, y) entity: tuple

- **Remember: Tuple is immutable, indexed sequence**

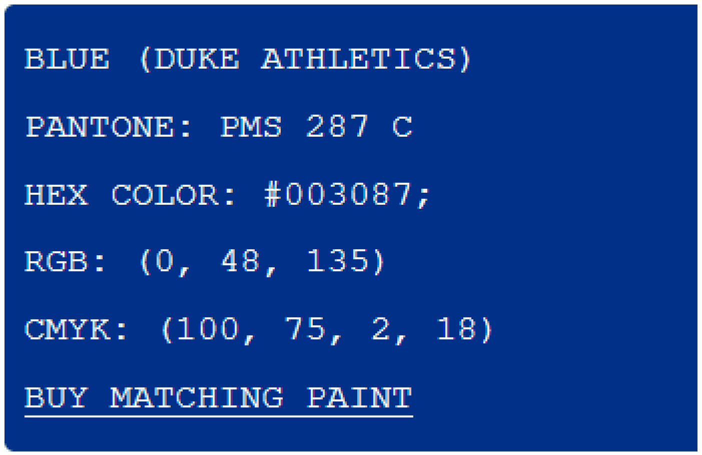
  (a, b, c)

Each pixel has a location in Image



Each pixel has an RGB color

- **Duke has three Duke blues**
- **Duke Athletics RGB: (0, 48, 145)**
- **Two for academics**



BLUE (DUKE ATHLETICS)

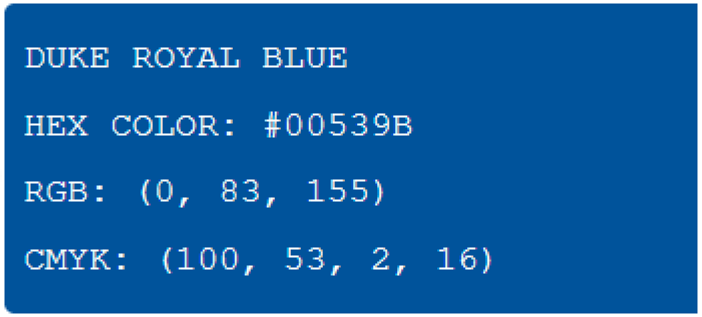
PANTONE: PMS 287 C

HEX COLOR: #003087;

RGB: (0, 48, 135)

CMYK: (100, 75, 2, 18)

BUY MATCHING PAINT

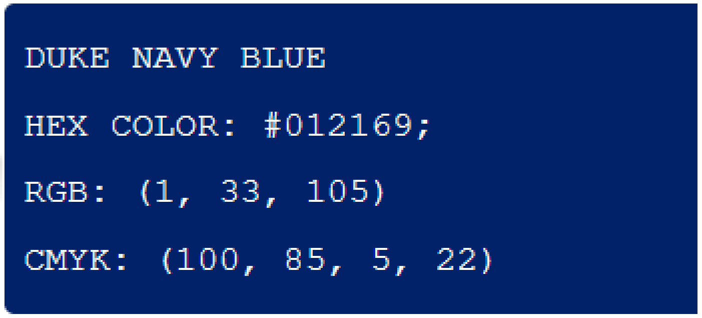


DUKE ROYAL BLUE

HEX COLOR: #00539B

RGB: (0, 83, 155)

CMYK: (100, 53, 2, 16)



DUKE NAVY BLUE

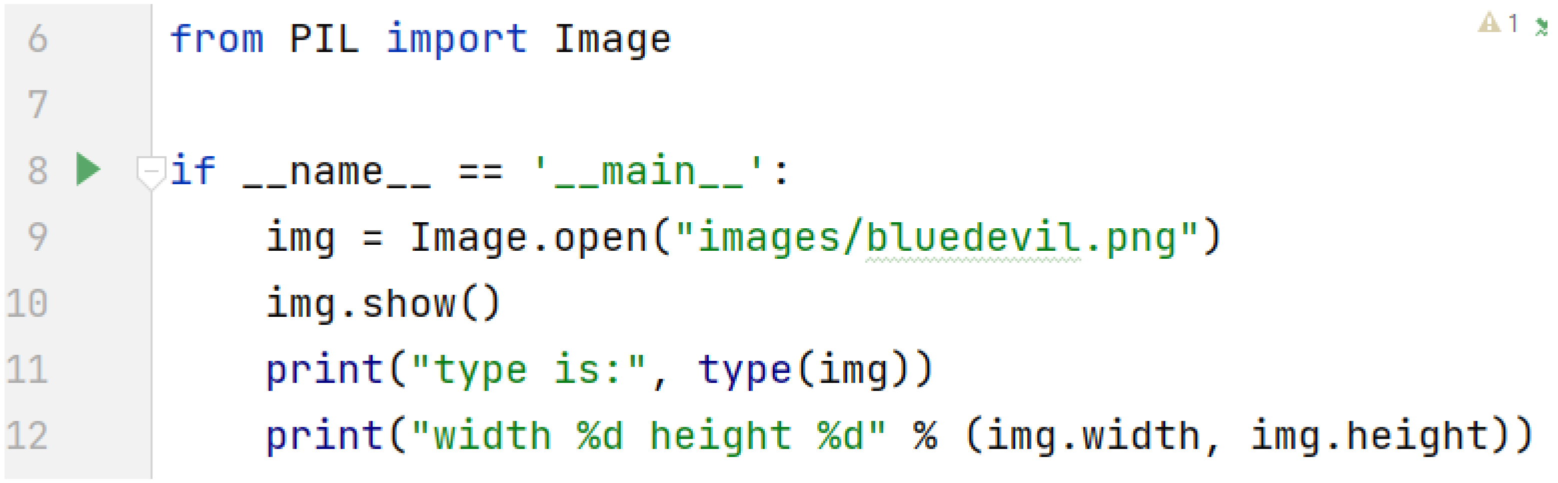
HEX COLOR: #012169;

RGB: (1, 33, 105)

CMYK: (100, 85, 5, 22)

SimpleDisplay.py

- **Access to PIL and Image module**
  - What type is img?
  - https://pillow.readthedocs.io/en/latest/



```python
from PIL import Image

if __name__ == '__main__':
    img = Image.open("images/bluedevil.png")
    img.show()
    print("type is:", type(img))
    print("width %d height %d" % (img.width, img.height))
```

OUTPUT:

SimpleDisplay.py

- **Access to PIL and Image module**
  - What type is img?
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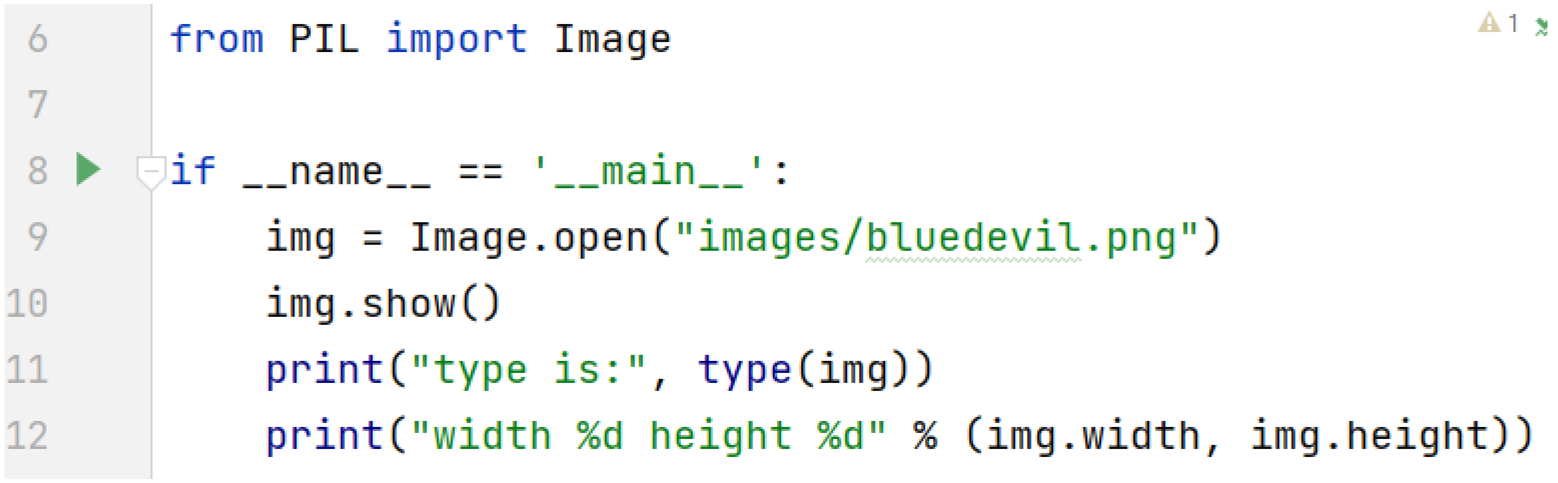

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if __name__ == '__main__':
    img = Image.open("images/bluedevil.png")
    img.show()
    print("type is:", type(img))
    print("width %d height %d" % (img.width, img.height))
```

OUTPUT:

```
type is: <class 'PIL.PngImagePlugin.PngImageFile'>
width 397 height 337
```

String formatting with % operator

- **Use formatted string with % in string to show where to put values**
  - Followed by % and tuple of values
  - %d is for an int
  - %f is for a float
  - %.xf is to specify x digits past the decimal
  - %s is for a string or something that could be shown as a string

String Formatting Examples

```
name = "Xiao"
age = 19
print("%s is %d years old" % (name, age))
alist = [6, 7.8643, 2]
print("%f is a list %s" % (alist[1], alist))
print("fav in %s is %.2f" % (alist, alist[1]))
```

OUTPUT:

String Formatting Examples

```
name = "Xiao"
age = 19
print("%s is %d years old" % (name, age))
alist = [6, 7.8643, 2]
print("%f is a list %s" % (alist[1], alist))
print("fav in %s is %.2f" % (alist, alist[1]))
```

OUTPUT:

```
Xiao is 19 years old
7.864300 is a list [6, 7.8643, 2]
fav in [6, 7.8643, 2] is 7.86
```

WOTO-1 Images
http://bit.ly/101s23-0321-1

What is a class in Python?

- **Class ≈ module ≈ library (for this CS101)**
- **Class – Also blueprint/Factory for creating objects**
  - We've used int, float, str
  - **`<class 'int'>, <class 'list'>`**
  - Everything is a class in Python3

- **Objects are created from a class**
  - x = [5, 6, 7]
  - b = “Moe”
  - c = “Charlotte”

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- **Class – Also blueprint/Factory for creating objects**
  - We've used int, float, str
  - `<class 'int'>, <class 'list'>`
  - Everything is a class in Python3
- **Objects are created from a cla**
  - x = [5, 6, 7]
  - b = “Moe”
  - c = “Charlotte”

x is a list object from the <class ‘list’>

b and c are string objects from the <class ‘str’>

Types

```
print(type(6))
print(type([1,1]))
print(type('blue'))
print(type((6,[7])))

img = Image.open("images/bluedevil.png")
print(type(img))


img = Image.open("images/eastereggs.jpg")
print(type(img))
```

Types

```
print(type(6))              <class 'int’>
print(type([1,1]))          <class 'list'>
print(type('blue’))         <class 'str’>
print(type((6,[7])))        <class 'tuple'>

img = Image.open("images/bluedevil.png")
print(type(img))
<class 'PIL.PngImagePlugin.PngImageFile’>

img = Image.open("images/eastereggs.jpg")
print(type(img))
<class 'PIL.JpegImagePlugin.JpegImageFile'>
```

What is a class in Python?

- **Use . dot notation to access object's innards**
  - **`word = "Hello"`**
    - word is an **object** from the String class
  - **`word.lower()`**
    - **`.lower()`** is a function, but don't call it that!
    - Function that goes with a class is called a **method**
    - **`.lower()`** is a **method** from the String class
  - **`img.width`** is an attribute aka field/property
    - Note there are no ()'s, like a variable

What is a class in Python?

- **Use . dot notation to access object's innards**
  - **`word = "Hello"`**
    - word is an **object** from th
  - **`word.lower()`**
    - **`.lower()`** is a function, but don't call it that!
    - Function that goes with a class is called method
    - **`.lower()`** is a **method** from the String class
  - **`img.width`** is an attribute aka field/property
    - Note there are no ()'s, like

Word is object from String class

Use "dot" to access a String method lower()

Use "dot" to accesss part of object, width

Image Library Basics

- **Library can create/open images in different formats, e.g., .png, .jpg, .gif, …**

- **Images have properties: width, height, type, color-model, and more (variables associated with class)**
  - Functions and fields access these properties, e.g., **`im.width`**, **`im.format`**, and more

- **Pixels are formed as triples (255,255,255), (r,g,b)**
  - In Python these are tuples: immutable sequence

Types

```
img = Image.open("images/bluedevil.png")
print(img.format)
```

```
img = Image.open("images/eastereggs.jpg")
print(img.format)
```

Types

```
img = Image.open("images/bluedevil.png")
print(img.format)
```

```
PNG
```

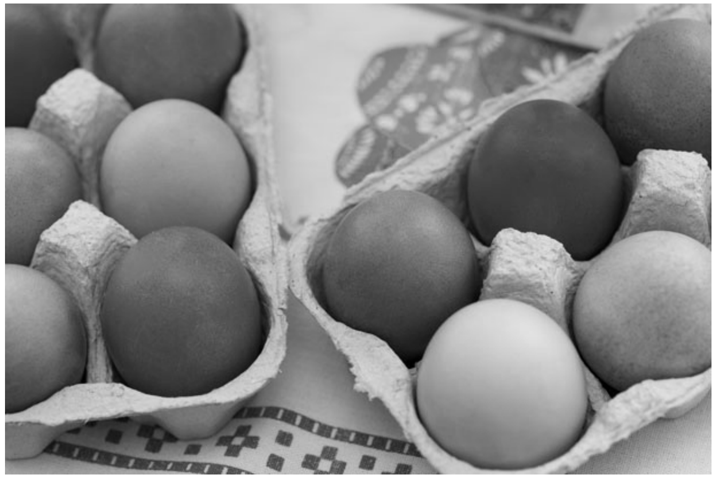
```
img = Image.open("images/eastereggs.jpg")
print(img.format)
```

```
JPEG
```

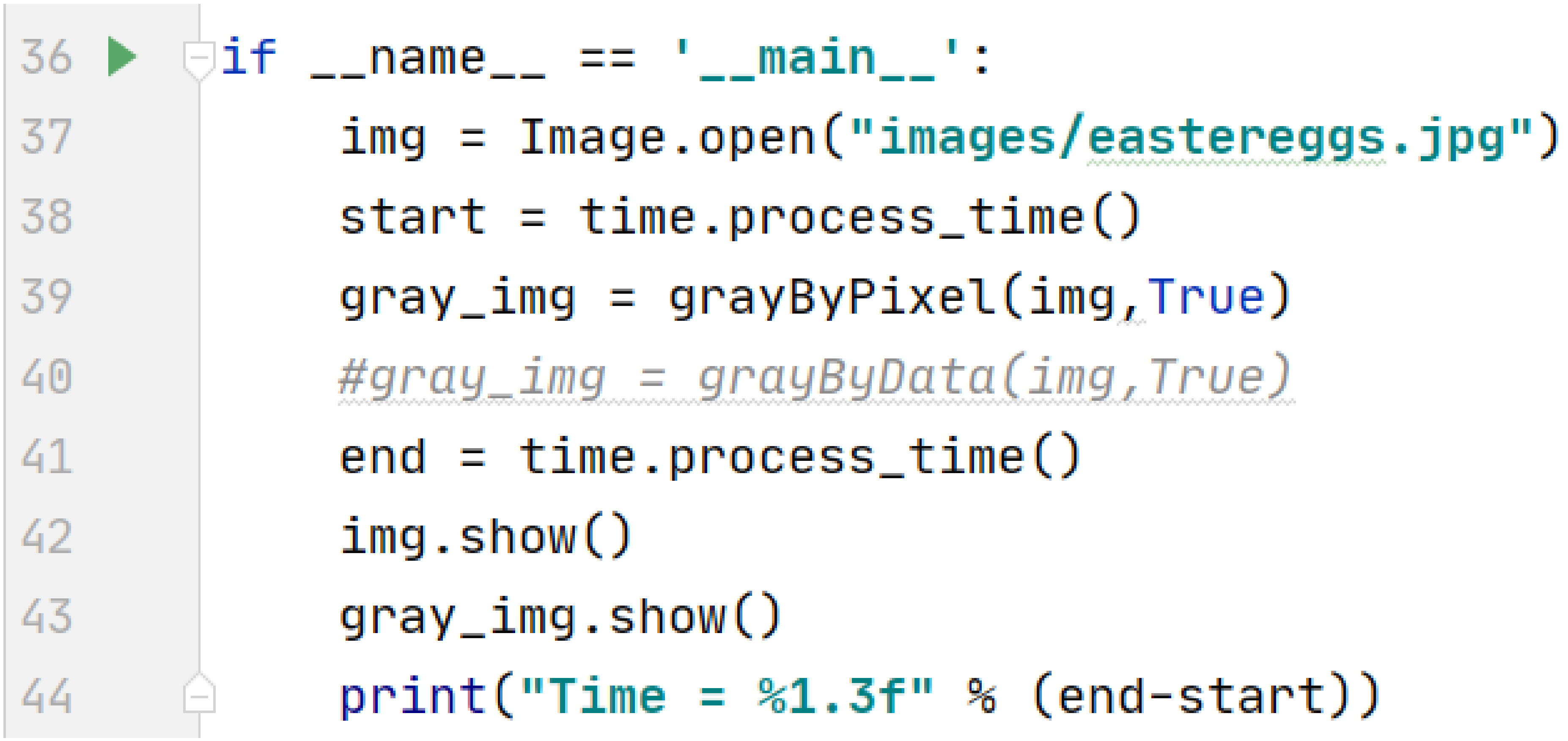
WOTO-2 Classes
http://bit.ly/101s23-0321-2

Demo: Convert Color to Gray

Process each pixel
Convert to gray

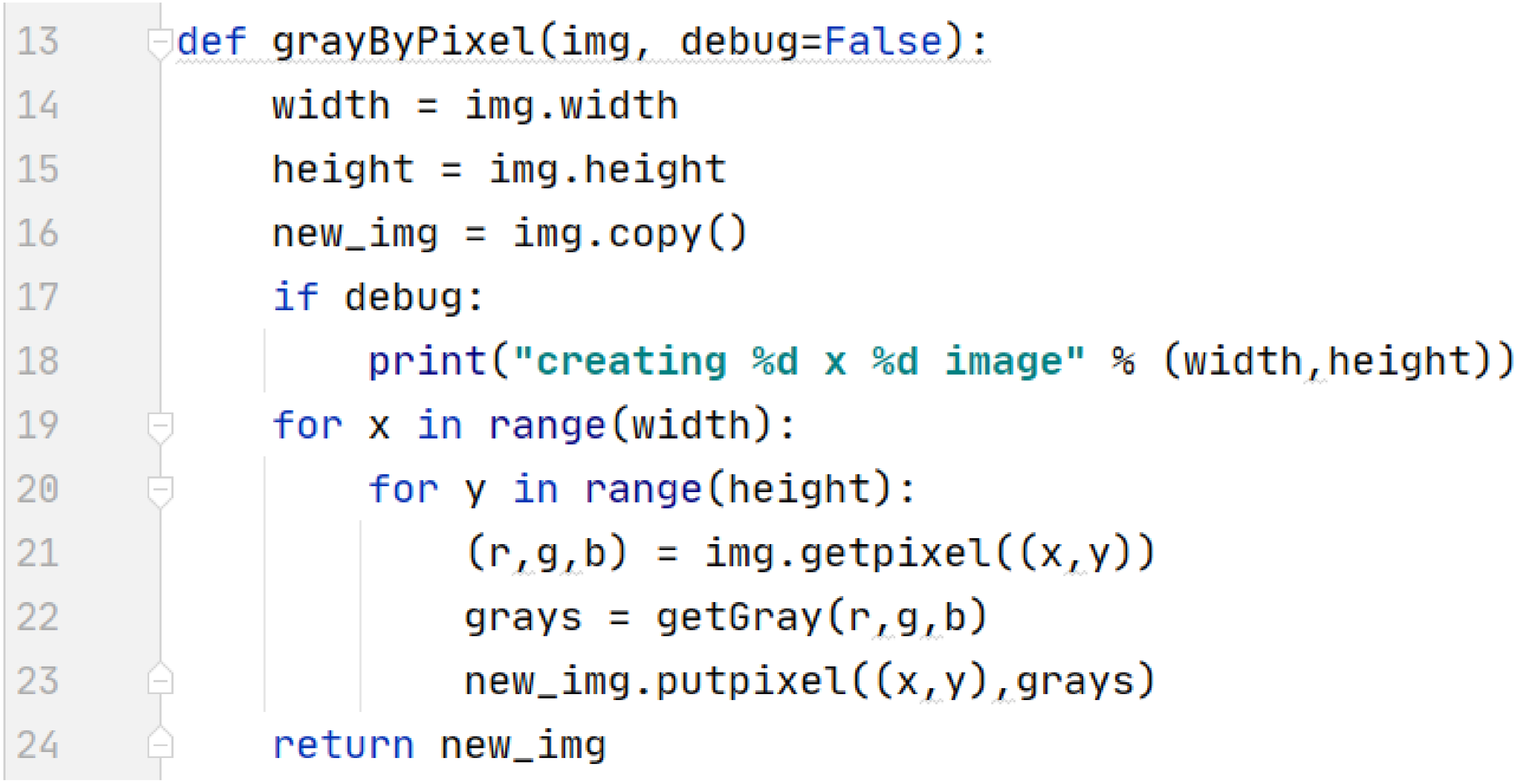


main



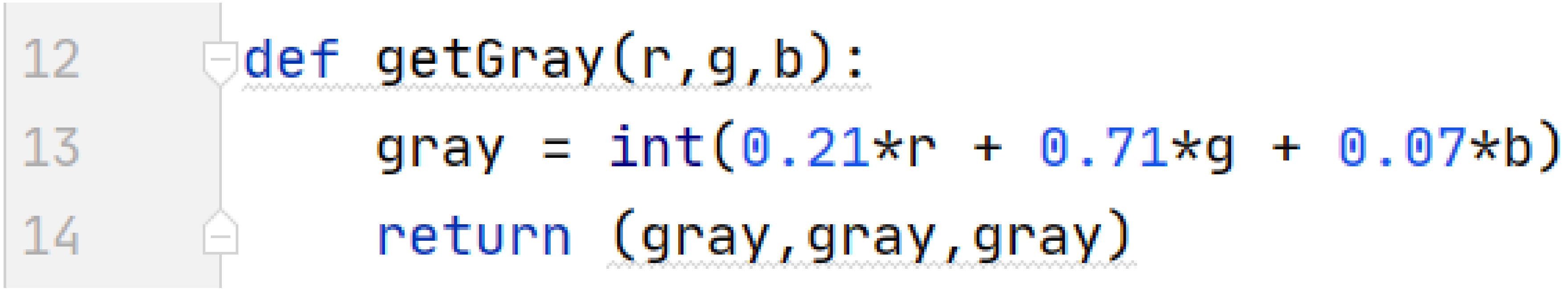
```
if __name__ == '__main__':
    img = Image.open("images/eastereggs.jpg")
    start = time.process_time()
    gray_img = grayByPixel(img,True)
    #gray_img = grayByData(img,True)
    end = time.process_time()
    img.show()
    gray_img.show()
    print("Time = %1.3f" % (end-start))
```

grayByPixel Function



```python
def grayByPixel(img, debug=False):
    width = img.width
    height = img.height
    new_img = img.copy()
    if debug:
        print("creating %d x %d image" % (width,height))
    for x in range(width):
        for y in range(height):
            (r,g,b) = img.getpixel((x,y))
            grays = getGray(r,g,b)
            new_img.putpixel((x,y),grays)
    return new_img
```

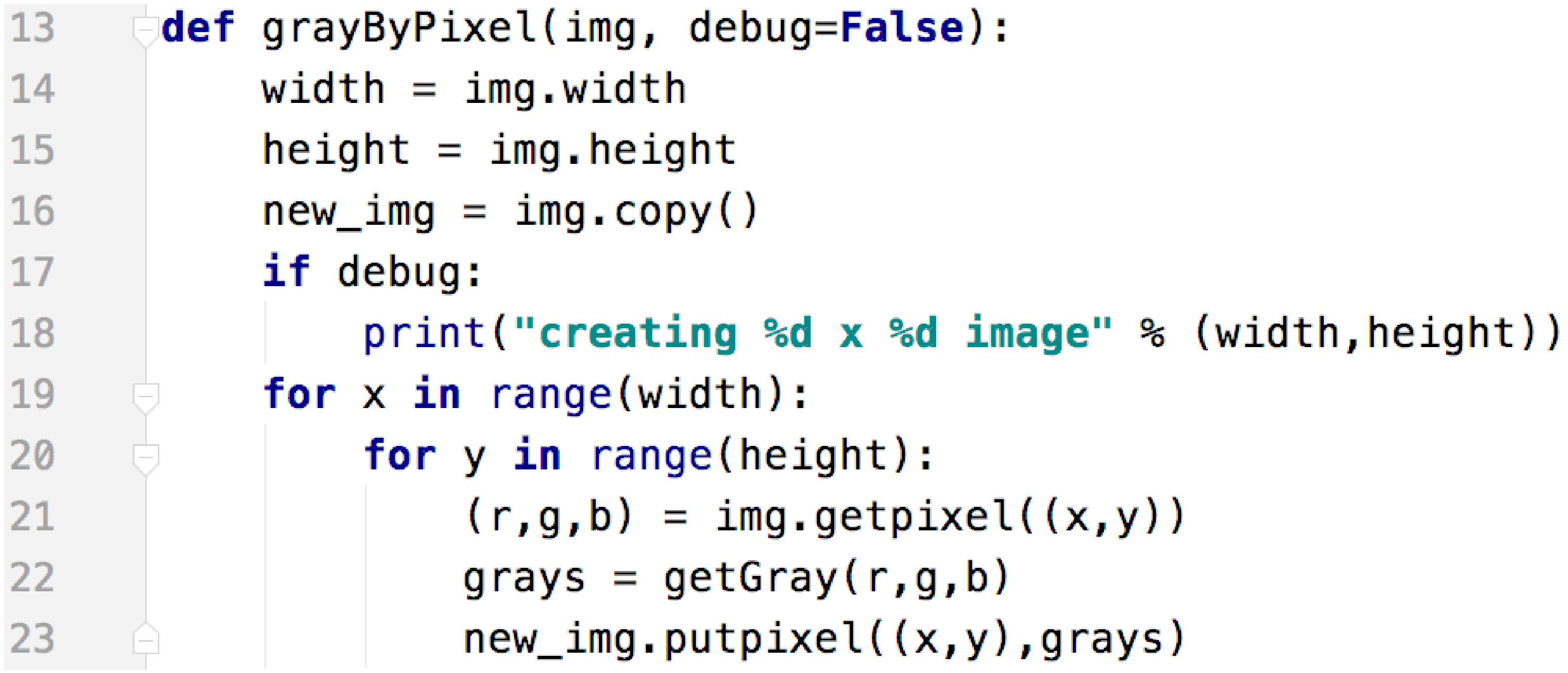
getGray function



```python
def getGray(r,g,b):
    gray = int(0.21*r + 0.71*g + 0.07*b)
    return (gray,gray,gray)
```

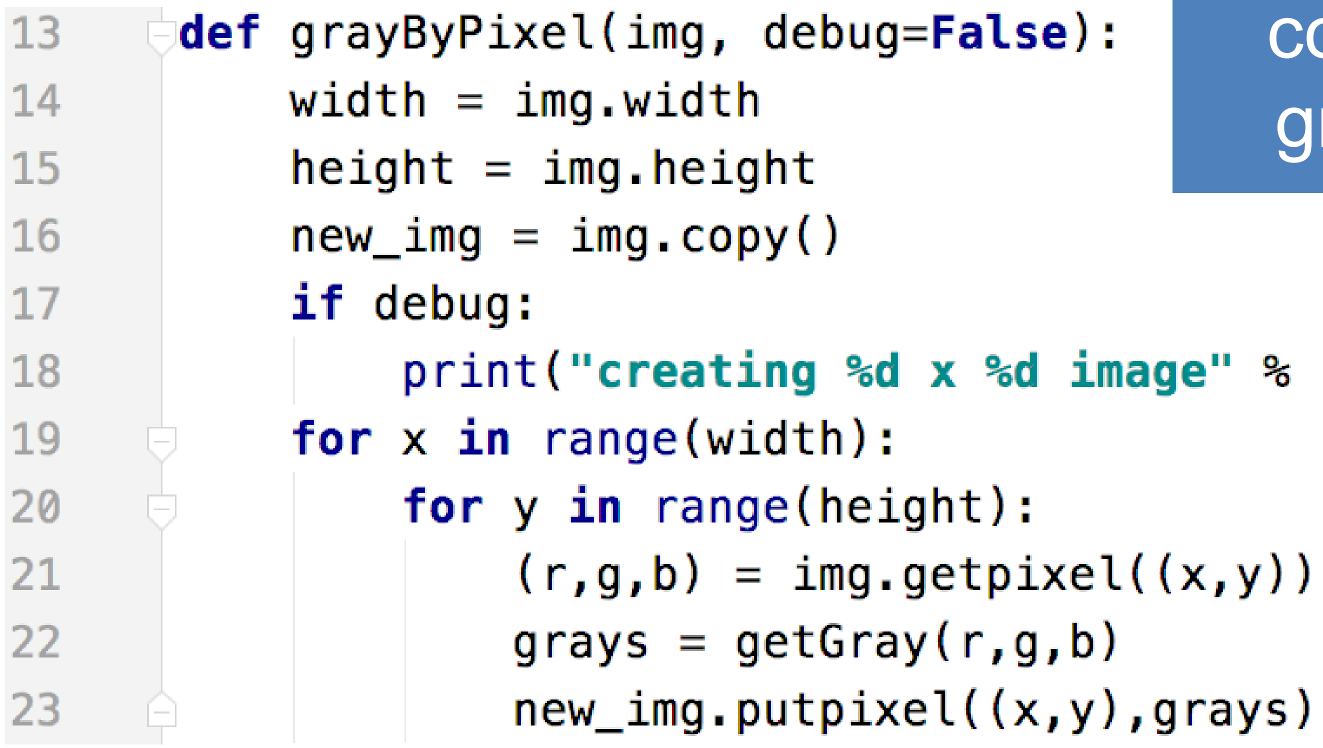
WOTO-3 GrayScale
http://bit.ly/101s23-0321-3

Make Gray: Notice the Tuples!



```python
def grayByPixel(img, debug=False):
    width = img.width
    height = img.height
    new_img = img.copy()
    if debug:
        print("creating %d x %d image" % (width,height))
    for x in range(width):
        for y in range(height):
            (r,g,b) = img.getpixel((x,y))
            grays = getGray(r,g,b)
            new_img.putpixel((x,y),grays)
```

Make Gray: Notice the Tuples!



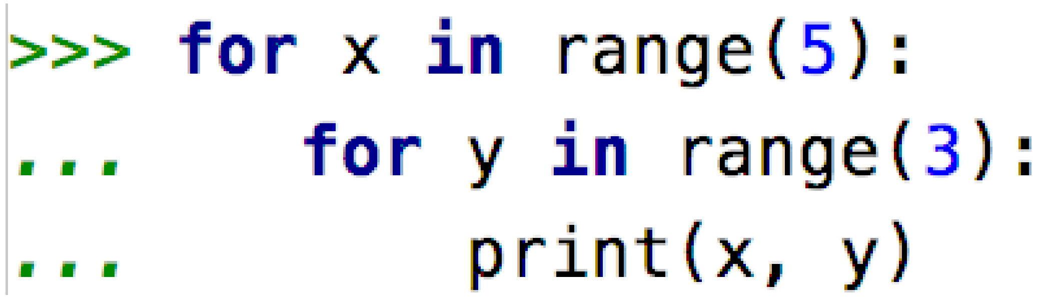
```
def grayByPixel(img, debug=False):
    width = img.width
    height = img.height
    new_img = img.copy()
    if debug:
        print("creating %d x %d image" % (width,height))
    for x in range(width):
        for y in range(height):
            (r,g,b) = img.getpixel((x,y))
            grays = getGray(r,g,b)
            new_img.putpixel((x,y),grays)
```

How does this code make a grey image?

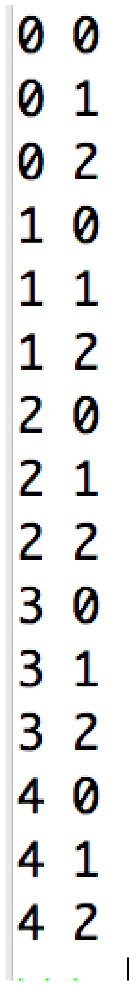
New stuff here, what and where?

Revisiting nested Loops

- **What is printed here? y varies first**
    - Value of x as inner loop iterates?



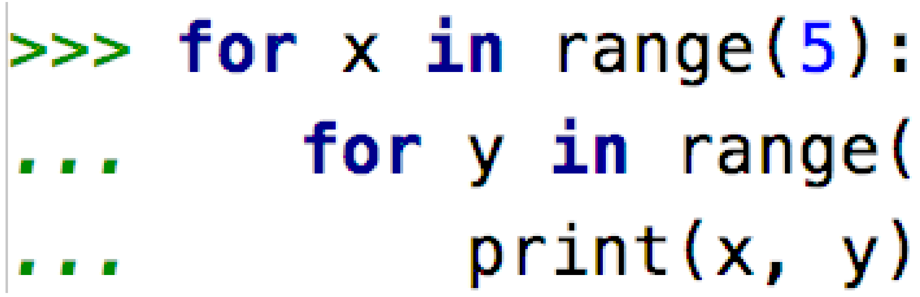
```
>>> for x in range(5):
...     for y in range(3):
...         print(x, y)
```



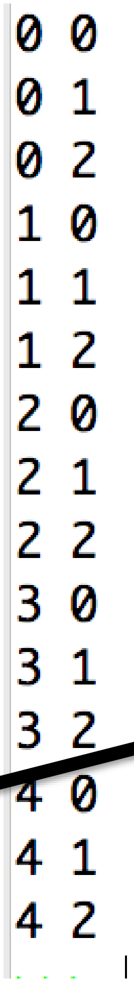
```
0 0
0 1
0 2
1 0
1 1
1 2
2 0
2 1
2 2
3 0
3 1
3 2
4 0
4 1
4 2
...
```

Revisiting nested Loops

- **What is printed here? y varies first**
  - Value of x as inner loop iterates?

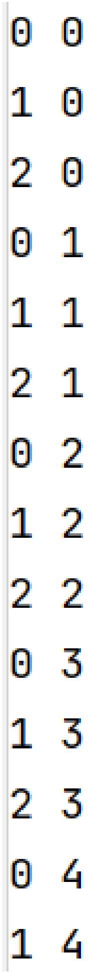


```
>>> for x in range(5):
...     for y in range(3):
...         print(x, y)
```



```
0 0
0 1
0 2
1 0
1 1
1 2
2 0
2 1
2 2
3 0
3 1
3 2
4 0
4 1
4 2
```

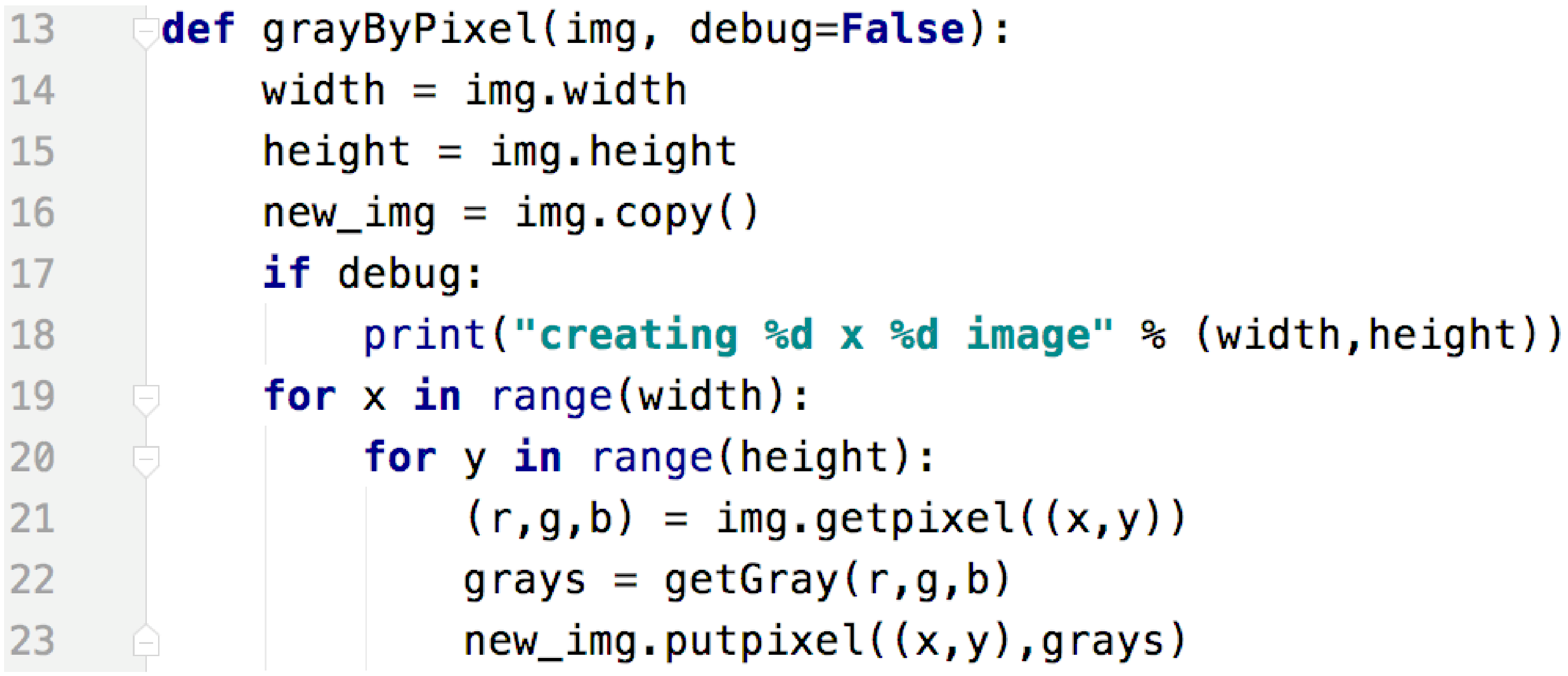
print(y, x)



```
0 0
1 0
2 0
0 1
1 1
2 1
0 2
1 2
2 2
0 3
1 3
2 3
0 4
1 4
```

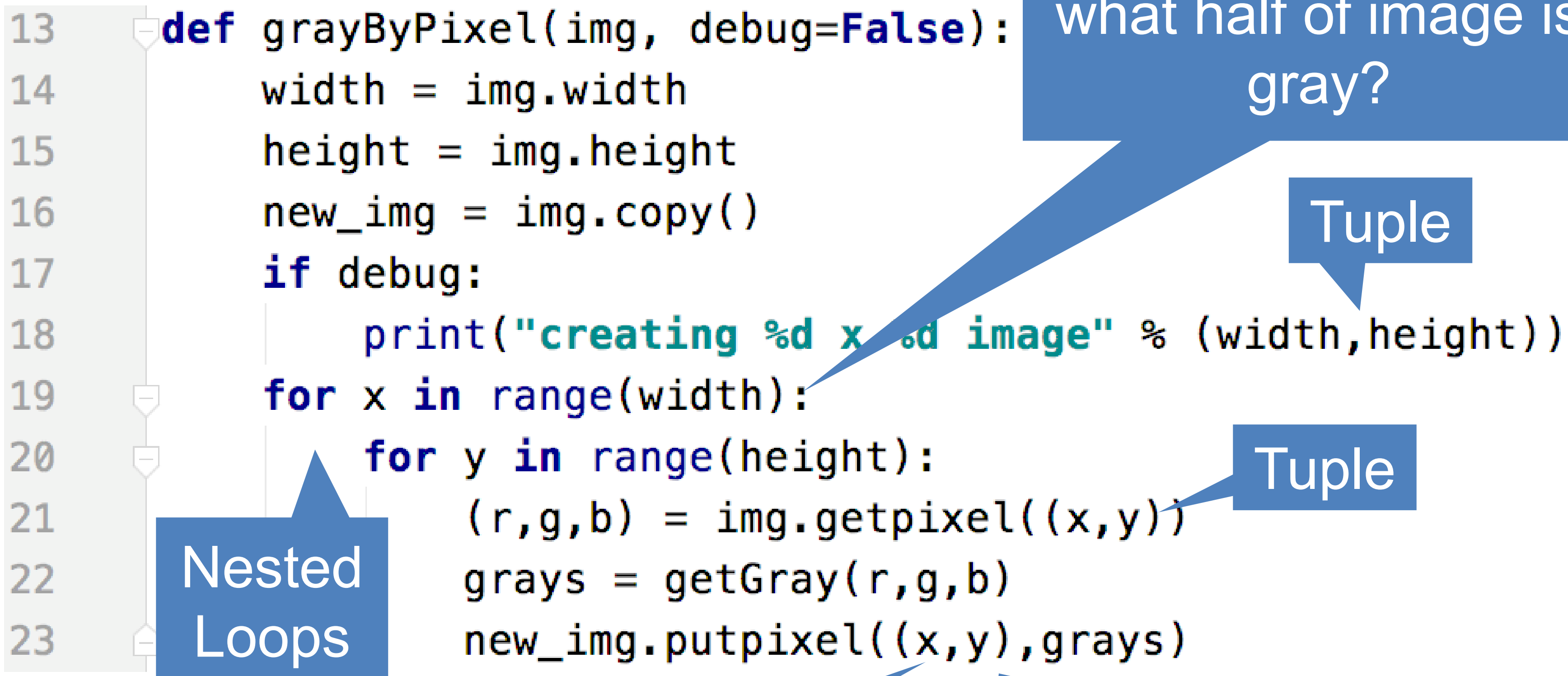
Why is the first column have the number repeated like that?
What if the print became:
`print(y, x)`?

Make Gray cont.



```python
def grayByPixel(img, debug=False):
    width = img.width
    height = img.height
    new_img = img.copy()
    if debug:
        print("creating %d x %d image" % (width,height))
    for x in range(width):
        for y in range(height):
            (r,g,b) = img.getpixel((x,y))
            grays = getGray(r,g,b)
            new_img.putpixel((x,y),grays)
```

Make Gray cont.



```
def grayByPixel(img, debug=False):
    width = img.width
    height = img.height
    new_img = img.copy()
    if debug:
        print("creating %d x %d image" % (width,height))
    for x in range(width):
        for y in range(height):
            (r,g,b) = img.getpixel((x,y))
            grays = getGray(r,g,b)
            new_img.putpixel((x,y),grays)
```

If stop code halfway, what half of image is gray?

Tuple

Tuple

Nested Loops

Tuple

How many parameters does putpixel have?

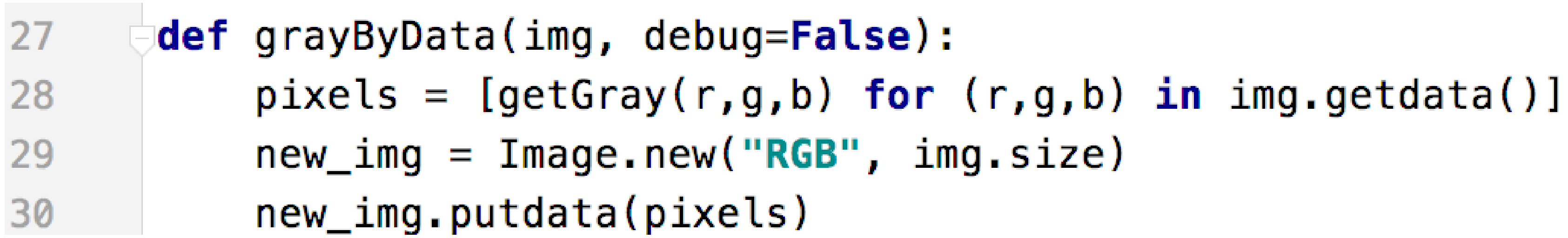
Accessing Individual Pixels is Inefficient

- **Accessing each one one-at-a-time is inefficient**
  - Python can do better "under the hood"

- **PIL provides a function `img.getdata()`**
  - Returns list-like object for accessing all pixels
  - Similar to how file is a sequence of characters
  - Symmetry: `img.putdata(sequence)`

Processing all Pixels at Once

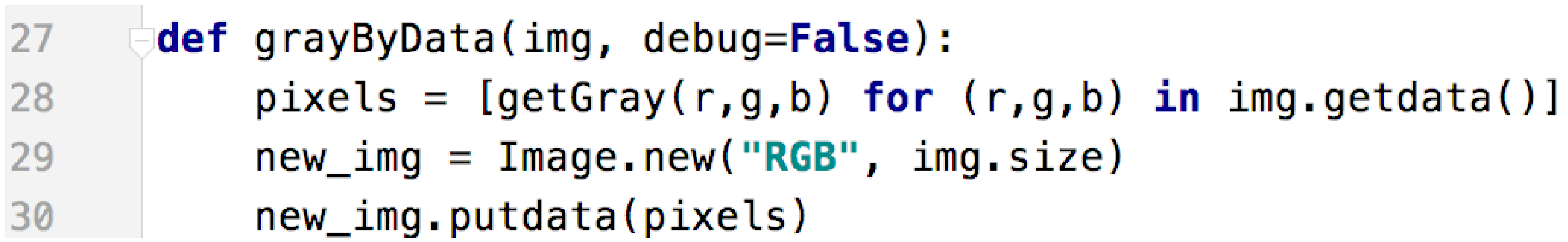
- **Treat `img.getdata()` as list, it's not quite a list**
  - Iterable: object use in “`for` … `in` …” loop



```python
def grayByData(img, debug=False):
    pixels = [getGray(r,g,b) for (r,g,b) in img.getdata()]
    new_img = Image.new("RGB", img.size)
    new_img.putdata(pixels)
```

Processing all Pixels at Once

- **Treat `img.getdata()` as list, it's not quite a list**
    - Iterable: object use in "`for` … `in` …" loop



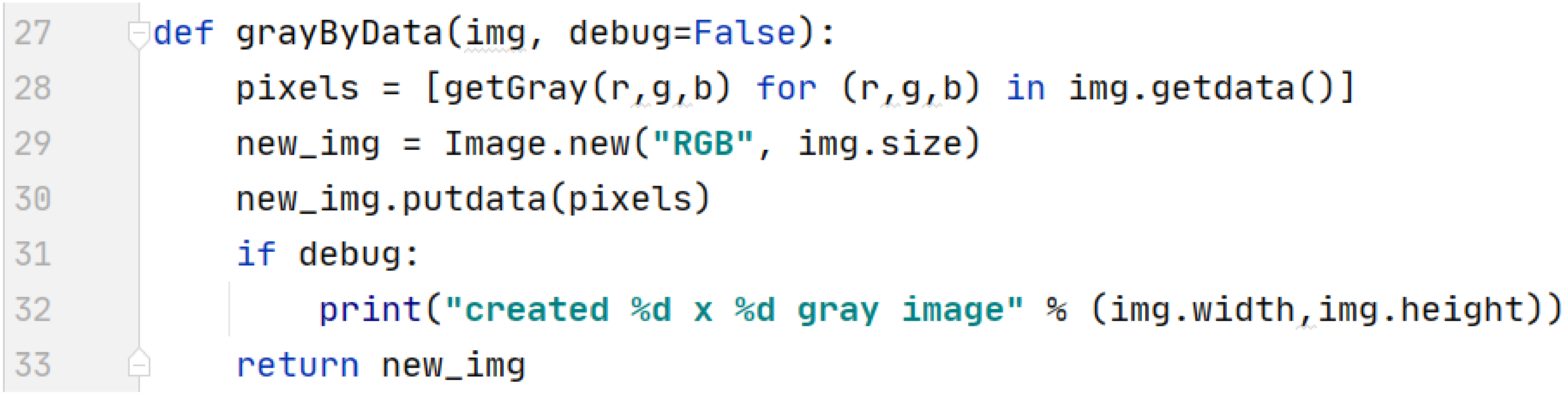
```
def grayByData(img, debug=False):
    pixels = [getGray(r,g,b) for (r,g,b) in img.getdata()]
    new_img = Image.new("RGB", img.size)
    new_img.putdata(pixels)
```

Think: An image is 2D and putdata(seq) takes a 1D sequence. How did we get an image?

Hint: What type are the elements in the list comprehension?

Hint: What do we know about the length of that sequence and the sequence putdata(…) needs?

GrayByData



```
def grayByData(img, debug=False):
    pixels = [getGray(r,g,b) for (r,g,b) in img.getdata()]
    new_img = Image.new("RGB", img.size)
    new_img.putdata(pixels)
    if debug:
        print("created %d x %d gray image" % (img.width,img.height))
    return new_img
```

Summary of Image functions

- **Many, many more**
  - http://bit.ly/pillow-image

Image function/method	Purpose
`im.show()`	Display image on screen
`im.save("foo.jpg")`	Save image with filename
`im.copy()`	Return copy of im
`im.getdata()`	Return iterable pixel sequence
`im.load()`	Return Pixel collection indexed by tuple (x,y)

WOTO-4 More on Images

http://bit.ly/101s23-0321-4