

CSci 127: Introduction to Computer Science



Finished the lecture preview?

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Frequently Asked Questions

From lecture slips & email.

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Standard way of representing colors.

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They are Python libraries that includes useful functions, definitions, etc.

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- From lab: what is `numpy` really? And `matplotlib` & `pyplot`?
They are Python libraries that includes useful functions, definitions, etc.
- Could you spend more time on problem solving & algorithms?
Yes! More in upcoming lectures & labs.

Today's Topics



- Recap: Colors
- 2D Arrays & Image Files
- Decisions
- Design Challenge: Airplanes

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- **Recap: Colors**
- 2D Arrays & Image Files
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- Design Challenge: Airplanes

In Pairs or Triples

EmpID:

CSci 127 Mock Final, S19

2. (a) Fill in the boxes with the appropriate hexcode to change the color to match the comments:

```
import turtle
```

```
thomasH = turtle.Turtle()
```

- i. #Change thomasH to be the color black:

```
thomasH.color("# 

|  |  |  |  |  |  |
|--|--|--|--|--|--|
|  |  |  |  |  |  |
|--|--|--|--|--|--|

 ")
```

- ii. #Change thomasH to be the color white:

```
thomasH.color("# 

|  |  |  |  |  |  |
|--|--|--|--|--|--|
|  |  |  |  |  |  |
|--|--|--|--|--|--|

 ")
```

- iii. #Change thomasH to be the brightest color blue:

```
thomasH.color("# 

|  |  |  |  |  |  |
|--|--|--|--|--|--|
|  |  |  |  |  |  |
|--|--|--|--|--|--|

 ")
```

- iv. #Change thomasH to be the color purple:

```
thomasH.color("# 

|  |  |  |  |  |  |
|--|--|--|--|--|--|
|  |  |  |  |  |  |
|--|--|--|--|--|--|

 ")
```

- v. #Change thomasH to be the color gray:

```
thomasH.color("# 

|  |  |  |  |  |  |
|--|--|--|--|--|--|
|  |  |  |  |  |  |
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- Need to fill in hexcodes (always start with #):

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- Black: 0 0 0 0 0 0

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- Purple: F F 0 0 F F
- Gray: 4 2 4 2 4 2 (any choice where $RR = GG = BB$).

Recap: Colors

Color Name	HEX	Color
<u>Black</u>	<u>#000000</u>	
<u>Navy</u>	<u>#000080</u>	
<u>DarkBlue</u>	<u>#00008B</u>	
<u>MediumBlue</u>	<u>#0000CD</u>	
<u>Blue</u>	<u>#0000FF</u>	






- Can specify by name.

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 - ▶ Amount of Red, Green, and Blue (RGB).

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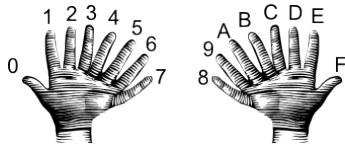
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 - ▶ Hexcodes (base-16 numbers)...

Recap: Hexadecimal








00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F
10	11	12	13	14	15	16	17	18	19	1A	1B	1C	1D	1E	1F
20	21	22	23	24	25	26	27	28	29	2A	2B	2C	2D	2E	2F
30	31	32	33	34	35	36	37	38	39	3A	3B	3C	3D	3E	3F
40	41	42	43	44	45	46	47	48	49	4A	4B	4C	4D	4E	4F
50	51	52	53	54	55	56	57	58	59	5A	5B	5C	5D	5E	5F
60	61	62	63	64	65	66	67	68	69	6A	6B	6C	6D	6E	6F
70	71	72	73	74	75	76	77	78	79	7A	7B	7C	7D	7E	7F
80	81	82	83	84	85	86	87	88	89	8A	8B	8C	8D	8E	8F
90	91	92	93	94	95	96	97	98	99	9A	9B	9C	9D	9E	9F
A0	A1	A2	A3	A4	A5	A6	A7	A8	A9	AA	AB	AC	AD	AE	AF
B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	BA	BB	BC	BD	BE	BF
C0	C1	C2	C3	C4	C5	C6	C7	C8	C9	CA	CB	CC	CD	CE	CF
D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	DA	DB	DC	DD	DE	DF
E0	E1	E2	E3	E4	E5	E6	E7	E8	E9	EA	EB	EC	ED	EE	EF
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Today's Topics



- Recap: Colors
- **2D Arrays & Image Files**
- Decisions
- Design Challenge: Airplanes

Arrays

- An **array** is a sequence of elements, much like a list.

1D array



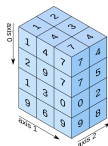
shape: (4,)

2D array



shape: (2, 3)

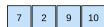
3D array



shape: (4, 3, 2)

Arrays

1D array



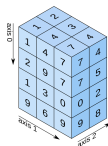
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- A **2D array** is like a grid of elements, think a list of lists.

Arrays

1D array



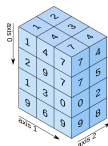
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shape: (4, 3, 2)

- An **array** is a sequence of elements, much like a list.
- A **2D array** is like a grid of elements, think a list of lists.
- Can keep on adding dimensions (3D, etc.)

Arrays

1D array



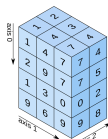
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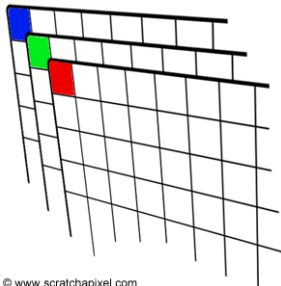
3D array



shape: (4, 3, 2)

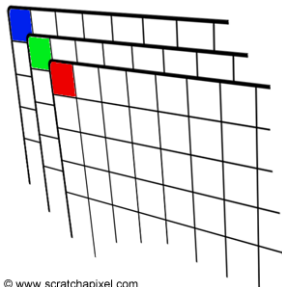
- An **array** is a sequence of elements, much like a list.
- A **2D array** is like a grid of elements, think a list of lists.
- Can keep on adding dimensions (3D, etc.)
- Can access pieces/slices as we do with strings and lists

Images

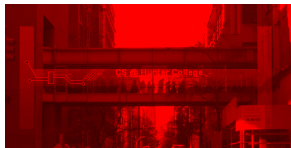


© www.scratchapixel.com

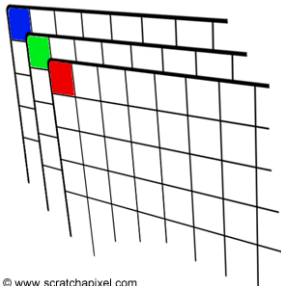
Images



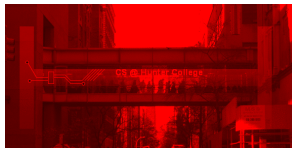
© www.scratchapixel.com



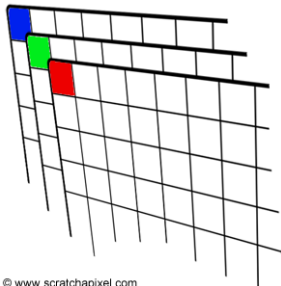
Images



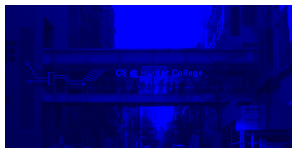
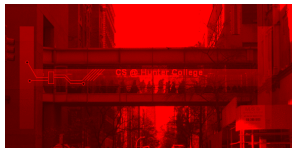
© www.scratchapixel.com



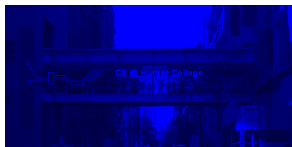
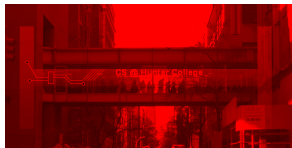
Images



© www.scratchapixel.com

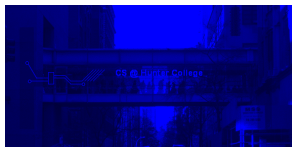
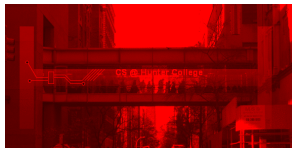


Useful Packages



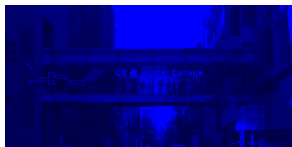
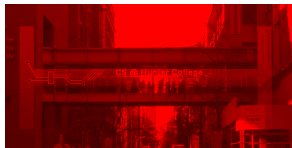
- We will use 2 useful packages for images:

Useful Packages



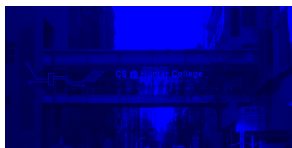
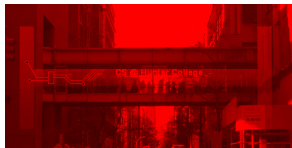
- We will use 2 useful packages for images:
 - ▶ `numpy`: numerical analysis package

Useful Packages



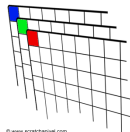
- We will use 2 useful packages for images:
 - ▶ `numpy`: numerical analysis package
 - ▶ `pyplot`: part of `matplotlib` for making graphs and plots

Useful Packages



- We will use 2 useful packages for images:
 - ▶ `numpy`: numerical analysis package
 - ▶ `pyplot`: part of `matplotlib` for making graphs and plots
- See lab notes for installing on your home machine.

Images with pyplot and numpy



#Import the packages for images and arrays:

```
import matplotlib.pyplot as plt
```

```
import numpy as np
```

```
img = plt.imread('csBridge.png')
```

```
plt.imshow(img)
```

```
plt.show()
```

#Read in image from csBridge.png

#Load image into pyplot

#Show the image (waits until close

```
img2 = img.copy()
```

```
img2[:, :, 1] = 0
```

```
img2[:, :, 2] = 0
```

#make a copy of our image

#Set the green channel to 0

#Set the blue channel to 0

```
plt.imshow(img2)
```

```
plt.show()
```

#Load our new image into pyplot

#Show the image (waits until closed to conti

```
plt.imsave('reds.png', img2) #Save the image we created to the file:
```

Images with pyplot and numpy

#Import the packages for images and arrays:

```
import matplotlib.pyplot as plt
```

```
import numpy as np
```



```
img = plt.imread('csBridge.png')
```

```
plt.imshow(img)
```

```
plt.show()
```

#Read in image from csBridge.png

#Load image into pyplot

#Show the image (waits until close



```
img2 = img.copy()
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img2[:, :, 1] = 0
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#make a copy of our image

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plt.imshow(img2)
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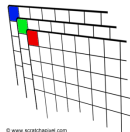
#Load our new image into pyplot

#Show the image (waits until closed to conti

```
plt.imsave('reds.png', img2) #Save the image we created to the file:
```

Creating Images

To create an image from scratch:

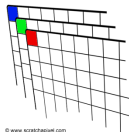


© www.scratchapixel.com

Creating Images

To create an image from scratch:

- 1 Import the libraries.

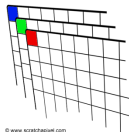


Creating Images

To create an image from scratch:

- 1 Import the libraries.

```
import matplotlib.pyplot as plt  
import numpy as np
```



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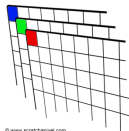
Creating Images

To create an image from scratch:

- 1 Import the libraries.

```
import matplotlib.pyplot as plt  
import numpy as np
```

- 2 Create the image— easy to set all color



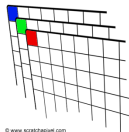
Creating Images

To create an image from scratch:

- 1 Import the libraries.

```
import matplotlib.pyplot as plt  
import numpy as np
```

- 2 Create the image— easy to set all color
 - 1 to 0% (black):



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Creating Images

To create an image from scratch:

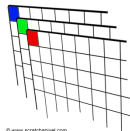
- 1 Import the libraries.

```
import matplotlib.pyplot as plt  
import numpy as np
```

- 2 Create the image— easy to set all color

- 1 to 0% (black):

```
img = np.zeros( (num,num,3) )
```



Creating Images

To create an image from scratch:

- 1 Import the libraries.

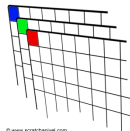
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```

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```
img = np.zeros( (num,num,3) )
```

- 2 to 100% (white):



Creating Images

To create an image from scratch:

- 1 Import the libraries.

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```

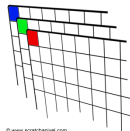
- 2 Create the image– easy to set all color

- 1 to 0% (black):

```
img = np.zeros( (num,num,3) )
```

- 2 to 100% (white):

```
img = np.ones( (num,num,3) )
```



© www.korshapost.com

Creating Images

To create an image from scratch:

- 1 Import the libraries.

```
import matplotlib.pyplot as plt  
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- 2 Create the image– easy to set all color

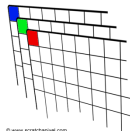
- 1 to 0% (black):

```
img = np.zeros( (num,num,3) )
```

- 2 to 100% (white):

```
img = np.ones( (num,num,3) )
```

- 3 *Do stuff to the pixels to make your image*



Creating Images

To create an image from scratch:

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```
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import numpy as np
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- 2 Create the image– easy to set all color

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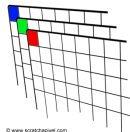
```
img = np.zeros( (num,num,3) )
```

- 2 to 100% (white):

```
img = np.ones( (num,num,3) )
```

- 3 *Do stuff to the pixels to make your image*

- 4 You can display your image:



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Creating Images

To create an image from scratch:

- 1 Import the libraries.

```
import matplotlib.pyplot as plt  
import numpy as np
```

- 2 Create the image– easy to set all color

- 1 to 0% (black):

```
img = np.zeros( (num,num,3) )
```

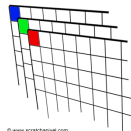
- 2 to 100% (white):

```
img = np.ones( (num,num,3) )
```

- 3 *Do stuff to the pixels to make your image*

- 4 You can display your image:

```
plt.imshow(img)  
plt.show()
```



© www.kerchapiet.com

Creating Images

To create an image from scratch:

- 1 Import the libraries.

```
import matplotlib.pyplot as plt  
import numpy as np
```

- 2 Create the image— easy to set all color

- 1 to 0% (black):

```
img = np.zeros( (num,num,3) )
```

- 2 to 100% (white):

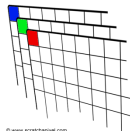
```
img = np.ones( (num,num,3) )
```

- 3 *Do stuff to the pixels to make your image*

- 4 You can display your image:

```
plt.imshow(img)  
plt.show()
```

- 5 And save your image:



Creating Images

To create an image from scratch:

- 1 Import the libraries.

```
import matplotlib.pyplot as plt
import numpy as np
```

- 2 Create the image— easy to set all color

- 1 to 0% (black):

```
img = np.zeros( (num,num,3) )
```

- 2 to 100% (white):

```
img = np.ones( (num,num,3) )
```

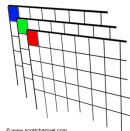
- 3 *Do stuff to the pixels to make your image*

- 4 You can display your image:

```
plt.imshow(img)
plt.show()
```

- 5 And save your image:

```
plt.imsave('myImage.png', img)
```



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More on numpy arrays

```
>>> a[0,3:5]  
array([3,4])
```

```
>>> a[4:,4:]  
array([[44, 45],  
       [54, 55]])
```

```
>>> a[:,2]  
array([2,12,22,32,42,52])
```

```
>>> a[2::2,::2]  
array([[20,22,24],  
       [40,42,44]])
```

0	1	2	3	4	5
10	11	12	13	14	15
20	21	22	23	24	25
30	31	32	33	34	35
40	41	42	43	44	45
50	51	52	53	54	55

numpy tutorial

Slicing & Image Examples

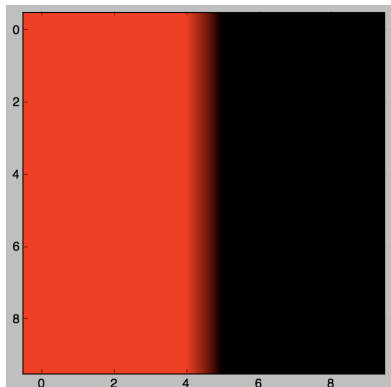
- Basic pattern: *img[rows, columns, channels]* with: *start:stop:step*.

Slicing & Image Examples

- Basic pattern: `img[rows, columns, channels]` with: `start:stop:step`.
- Assuming the libraries are imported, what do the following code fragments produce:
 - ▶ `img = np.zeros((10,10,3))`
`img[0:10,0:5,0:1] = 1`

Slicing & Image Examples

- Basic pattern: `img[rows, columns, channels]` with: `start:stop:step`.
- Assuming the libraries are imported, what do the following code fragments produce:
 - ▶ `img = np.zeros((10,10,3))`
`img[0:10,0:5,0:1] = 1`



Slicing & Image Examples

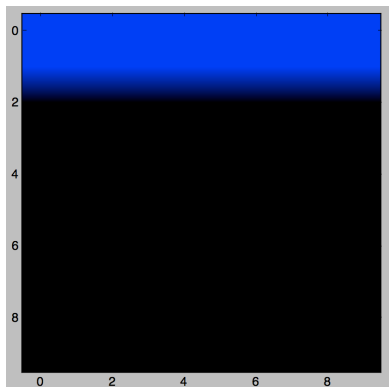
- Basic pattern: `img[rows, columns, channels]` with: `start:stop:step`.
- Assuming the libraries are imported, what do the following code fragments produce:

```
▶ num = 10  
  img = np.zeros( (num,num,3) )  
  img[0:2, :, 2:3] = 1.0
```

Slicing & Image Examples

- Basic pattern: `img[rows, columns, channels]` with: `start:stop:step`.
- Assuming the libraries are imported, what do the following code fragments produce:

```
► num = 10  
img = np.zeros( (num,num,3) )  
img[0:2, :, 2:3] = 1.0
```



Slicing & Image Examples

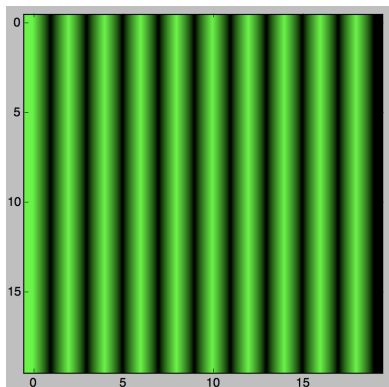
- Basic pattern: `img[rows, columns, channels]` with: `start:stop:step`.
- Assuming the libraries are imported, what do the following code fragments produce:

```
▶ num = int(input('Enter size'))  
  img = np.zeros( (num,num,3) )  
  img[:,::2,1] = 1.0
```

Slicing & Image Examples

- Basic pattern: `img[rows, columns, channels]` with: `start:stop:step`.
- Assuming the libraries are imported, what do the following code fragments produce:

```
▶ num = int(input('Enter size'))  
img = np.zeros( (num,num,3) )  
img[:,::2,1] = 1.0
```



In Pairs or Triples

- Basic pattern: *img[rows, columns, channels]* with: *start:stop:step*.
- Assuming the libraries are imported, what do the following code fragments produce:

```
▶ img = np.ones( (10,10,3) )  
  img[0:10,0:5,0:2] = 0
```

In Pairs or Triples

- Basic pattern: `img[rows, columns, channels]` with: `start:stop:step`.
- Assuming the libraries are imported, what do the following code fragments produce:

- ▶

```
img = np.ones( (10,10,3) )  
img[0:10,0:5,0:2] = 0
```
- ▶

```
num = int(input('Enter size '))  
img = np.ones( (num,num,3) )  
img[:, :, 1:] = 0
```

In Pairs or Triples

- Basic pattern: `img[rows, columns, channels]` with: `start:stop:step`.
- Assuming the libraries are imported, what do the following code fragments produce:

- ▶

```
img = np.ones( (10,10,3) )  
img[0:10,0:5,0:2] = 0
```
- ▶

```
num = int(input('Enter size '))  
img = np.ones( (num,num,3) )  
img[:, :, 1:] = 0
```
- ▶

```
img = np.zeros( (8,8,3) )  
img[:, :, 0] = 1
```

In Pairs or Triples

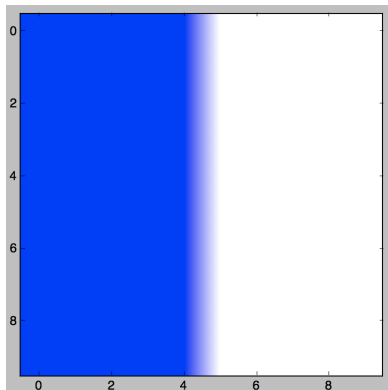
- Basic pattern: *img[rows, columns, channels]* with: *start:stop:step*.
- Assuming the libraries are imported, what do the following code fragments produce:

```
► img = np.ones( (10,10,3) )  
  img[0:10,0:5,0:2] = 0
```


In Pairs or Triples

- Basic pattern: `img[rows, columns, channels]` with: `start:stop:step`.
- Assuming the libraries are imported, what do the following code fragments produce:

```
► img = np.ones( (10,10,3) )  
  img[0:10,0:5,0:2] = 0
```



In Pairs or Triples

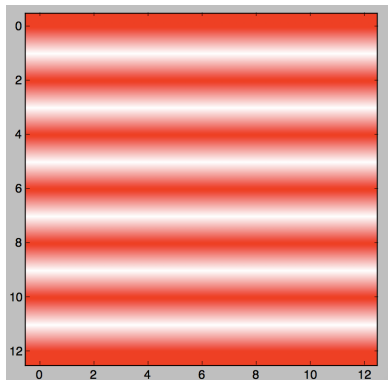
- Basic pattern: *img[rows, columns, channels]* with: *start:stop:step*.
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```
▶ num = int(input('Enter size '))  
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```

In Pairs or Triples

- Basic pattern: *img[rows, columns, channels]* with: *start:stop:step*.
- Assuming the libraries are imported, what do the following code fragments produce:

```
► num = int(input('Enter size '))  
img = np.ones( (num,num,3) )  
img[::2,:,1:] = 0
```



In Pairs or Triples

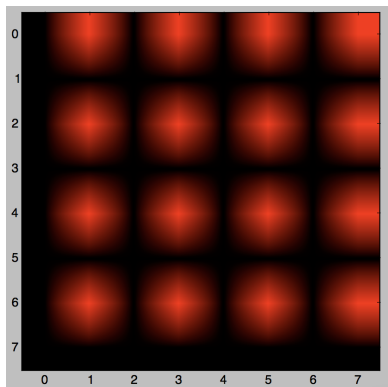
- Basic pattern: *img[rows, columns, channels]* with: *start:stop:step*.
- Assuming the libraries are imported, what do the following code fragments produce:

```
► img = np.zeros( (8,8,3) )  
  img[::2,1::2,0] = 1
```

In Pairs or Triples

- Basic pattern: `img[rows, columns, channels]` with: `start:stop:step`.
- Assuming the libraries are imported, what do the following code fragments produce:

```
► img = np.zeros( (8,8,3) )  
  img[::2,1::2,0] = 1
```



Today's Topics



- Recap: Colors
- 2D Arrays & Images
- Decisions
- Design Challenge: Airplanes

In Pairs or Triples...

	0	1	2	3	4	5	6	7	8	9
0										
1										
2										
3										
4										
5										
6										
7										
8										
9										

- 1 Design a 10 by 10 logo for Hunter College that contains a purple 'H'.

In Pairs or Triples...

	0	1	2	3	4	5	6	7	8	9
0										
1										
2										
3										
4										
5										
6										
7										
8										
9										

- ① Design a 10 by 10 logo for Hunter College that contains a purple 'H'.
- ② Your logo should only contain the colors purple and white.

In Pairs or Triples...

	0	1	2	3	4	5	6	7	8	9
0										
1										
2										
3										
4										
5										
6										
7										
8										
9										

- ① Design a 10 by 10 logo for Hunter College that contains a purple 'H'.
- ② Your logo should only contain the colors purple and white.
- ③ How can you make Python draw the logo?
Write down a "To Do" list of things you need to do.

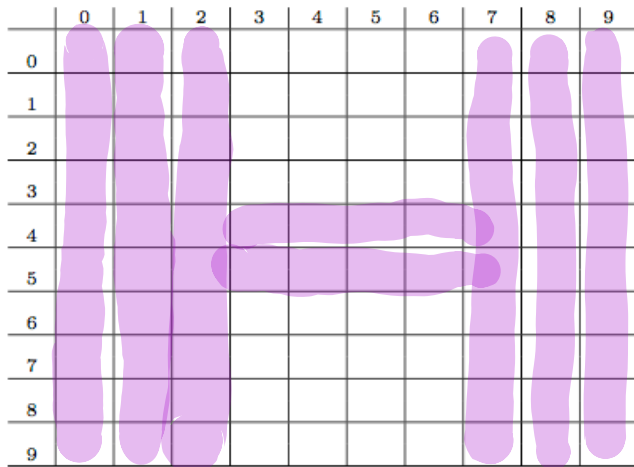
In Pairs or Triples...

	0	1	2	3	4	5	6	7	8	9
0										
1										
2										
3										
4										
5										
6										
7										
8										
9										

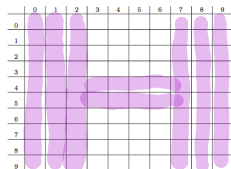
- ① Design a 10 by 10 logo for Hunter College that contains a purple 'H'.
- ② Your logo should only contain the colors purple and white.
- ③ How can you make Python draw the logo?
Write down a "To Do" list of things you need to do.
- ④ If time, refine your steps above into a Python program.

Design a Hunter Logo

One possible solution:

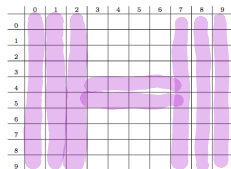


Design a Hunter Logo



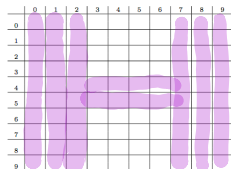
- 1 Create a 10 by 10 array, `logo`, that starts out as all white pixels.

Design a Hunter Logo



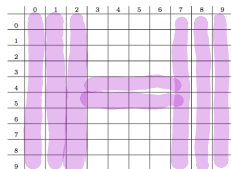
- 1 Create a 10 by 10 array, `logo`, that starts out as all white pixels.
- 2 Set the 3 left columns to be purple.

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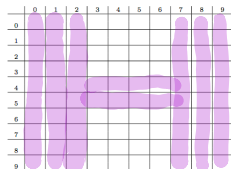
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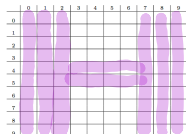
Design a Hunter Logo



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- 2 Set the 3 left columns to be purple.
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- 5 Save `logo` array to a file.

Translating the Design to Code

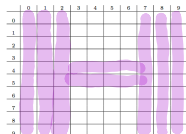
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Translating the Design to Code

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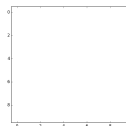
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import matplotlib.pyplot as plt #import libraries for plotting
import numpy as np             #and for arrays (to hold images)
logoImg = np.ones((10,10,3))  #10x10 array with 3 sheets of 1's
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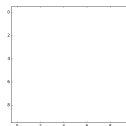


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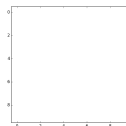
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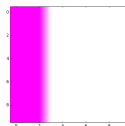
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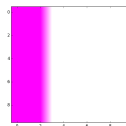
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- 3 Set the 3 right columns to be purple.

```
logoImg[:,7:10,1] = 0 #Turn the green to 0 for last 3 columns
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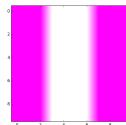
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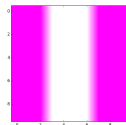
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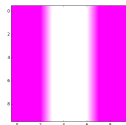
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logoImg[:, -3:, 1] = 0 #Turn the green to 0 for last 3 columns
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- 4 Set the middle 2 rows to be purple.

```
logoImg[4:6, :, 1] = 0 #Turn the green to 0 for middle rows
```



Translating the Design to Code

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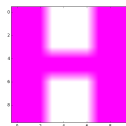
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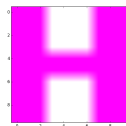
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- 5 Save `logo` array to file.

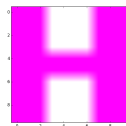
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- 4 Set the middle 2 rows to be purple.

```
logoImg[4:6, :, 1] = 0 #Turn the green to 0 for middle rows
```

- 5 Save logo array to file.

```
plt.imsave("logo.png", logoImg) #Save the image to logo.png
```

Today's Topics



- Recap: Colors
- 2D Arrays & Image Files
- **Decisions**
- Design Challenge: Airplanes

In Pairs or Triples...

Predict what these will do (novel concepts):

```
yearBorn = int(input('Enter year born: '))
if yearBorn < 1946:
    print("Greatest Generation")
elif yearBorn <= 1964:
    print("Baby Boomer")
elif yearBorn <= 1984:
    print("Generation X")
elif yearBorn <= 2004:
    print("Millennial")
else:
    print("TBD")

x = int(input('Enter number: '))
if x % 2 == 0:
    print('Even number')
else:
    print('Odd number')
```

```
import turtle

tess = turtle.Turtle()
myWin = turtle.Screen()      #The graphics window
commands = input("Please enter a command string: ")

for ch in commands:
    #perform action indicated by the character
    if ch == 'F':              #move forward
        tess.forward(50)
    elif ch == 'L':            #turn left
        tess.left(90)
    elif ch == 'R':            #turn right
        tess.right(90)
    elif ch == 'A':            #lift pen
        tess.penup()
    elif ch == 'v':            #lower pen
        tess.pendown()
    elif ch == 'B':            #go backwards
        tess.backward(50)
    elif ch == 'r':            #turn red
        tess.color("red")
    elif ch == 'g':            #turn green
        tess.color("green")
    elif ch == 'b':            #turn blue
        tess.color("blue")
    else:                      #for any other character
        print("Error: do not know the command:", c)
```

Python Tutor

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(Demo with pythonTutor)

IDLE

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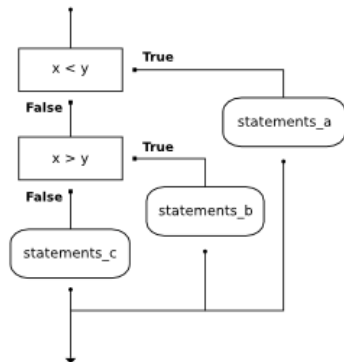
(Demo with IDLE)

Decisions

```
if x < y:  
    print("x is less than y")  
elif x > y:  
    print("x is greater than y")  
else:  
    print("x and y must be equal")
```

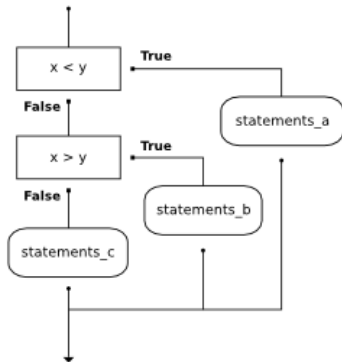
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Decisions

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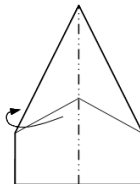
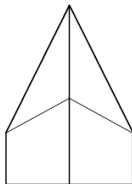
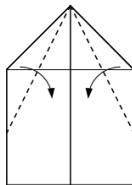
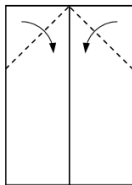
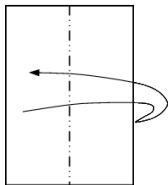
(This was just a first glance, will do much more on decisions over the next several weeks.)

Today's Topics



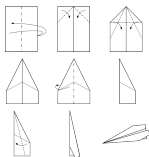
- Recap: Colors
- 2D Arrays & Image Files
- Decisions
- **Design Challenge: Airplanes**

Design Challenge: Planes



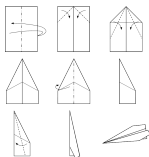
Design Challenge: Planes

- A classic write-an-algorithm challenge for introductory programming.



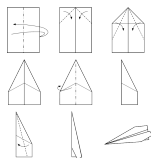
Design Challenge: Planes

- A classic write-an-algorithm challenge for introductory programming.
- With a slight twist:



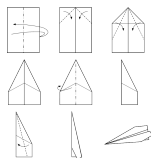
Design Challenge: Planes

- A classic write-an-algorithm challenge for introductory programming.
- With a slight twist: refining designs



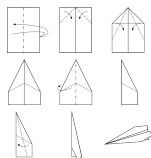
Design Challenge: Planes

- A classic write-an-algorithm challenge for introductory programming.
- With a slight twist: refining designs
 - ▶ As a team, write down your design.



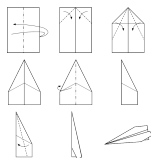
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- With a slight twist: refining designs
 - ▶ As a team, write down your design.
 - ▶ Exchange with another team.



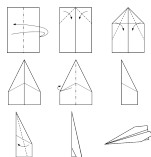
Design Challenge: Planes

- A classic write-an-algorithm challenge for introductory programming.
- With a slight twist: refining designs
 - ▶ As a team, write down your design.
 - ▶ Exchange with another team.
 - ▶ They build an airplane to your design (test plane) **without consulting you**.



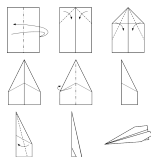
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- With a slight twist: refining designs
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 - ▶ You exchange test planes, and **revise your algorithm**.



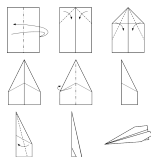
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 - ▶ The build team makes 3 copies of your paper airplane,



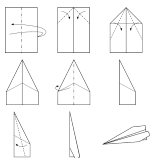
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 - ▶ As a team, write down your design.
 - ▶ Exchange with another team.
 - ▶ They build an airplane to your design (test plane) **without consulting you**.
 - ▶ You exchange test planes, and **revise your algorithm**.
 - ▶ The build team makes 3 copies of your paper airplane, and flies it from the balcony (must be behind first row of seats).



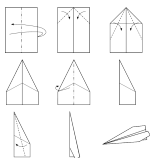
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 - ▶ Will be judged on closeness to the stage.



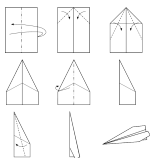
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 - ▶ Winning design/build team gets chocolate.



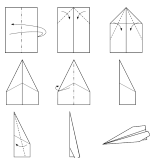
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 - ▶ Will be judged on closeness to the stage.
 - ▶ Winning design/build team gets chocolate.
- Remember to pick up all your airplanes!



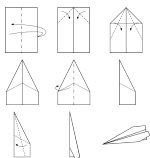
Design Challenge: Initial Design (2 Minutes)

- A classic write-an-algorithm challenge for introductory programming.
- With a slight twist: refining designs
 - ▶ **As a team, write down your design.**
 - ▶ Exchange with another team.
 - ▶ They build an airplane to your design (test plane) without consulting you.
 - ▶ You exchange test planes, and revise your algorithm.
 - ▶ The build team makes 3 copies of your paper airplane, and flies it from the balcony (must be behind first row of seats).
 - ▶ Will be judged on closeness to the stage.
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- Remember to pick up all your airplanes!



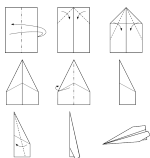
Design Challenge: Test Build (2 Minutes)

- A classic write-an-algorithm challenge for introductory programming.
- With a slight twist: refining designs
 - ▶ As a team, write down your design.
 - ▶ **Exchange with another team.**
 - ▶ **They build an airplane to your design (test plane) without consulting you.**
 - ▶ You exchange test planes, and revise your algorithm.
 - ▶ The build team makes 3 copies of your paper airplane, and flies it from the balcony (must be behind first row of seats).
 - ▶ Will be judged on closeness to the stage.
 - ▶ Winning design/build team gets chocolate.
- Remember to pick up all your airplanes!



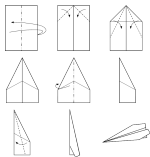
Design Challenge: Revise Design (3 Minutes)

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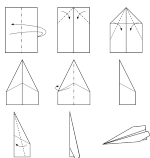
Design Challenge: Build Final Planes (2 Minutes)

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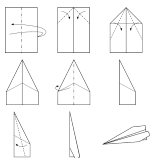
Design Challenge: Test Planes (3 Minutes)

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Design Challenge: Retrieve Planes (2 Minutes)

- A classic write-an-algorithm challenge for introductory programming.
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 - ▶ You exchange test planes, and revise your algorithm.
 - ▶ The build team makes 3 copies of your paper airplane, and flies it from the balcony (must be behind first row of seats).
 - ▶ Will be judged on closeness to the stage.
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- **Remember to pick up all your airplanes!**



Recap



- On lecture slip, write down a topic you wish we had spent more time (and why).

Recap



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- In Python, we introduced:

Recap



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Recap

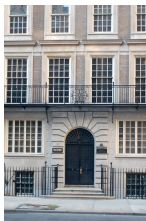


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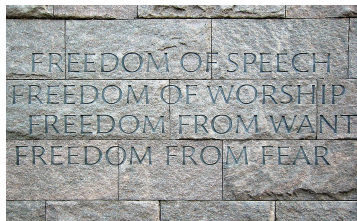
Practice Quiz & Final Questions



(NYTimes)



(Hunter College)



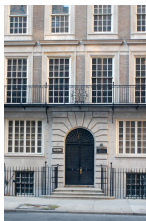
(FDR 4 FP)

- Since you must pass the final exam to pass the course, we end every lecture with final exam review.

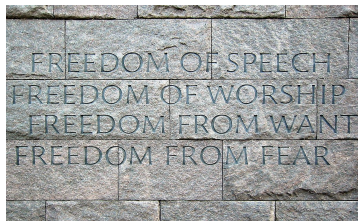
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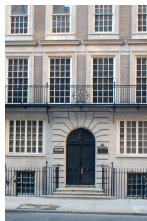
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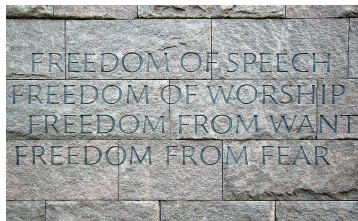
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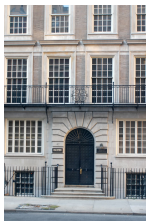
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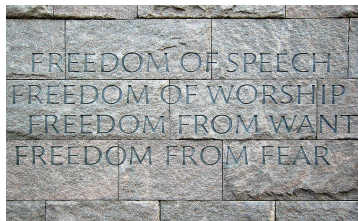
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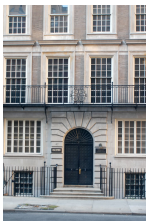
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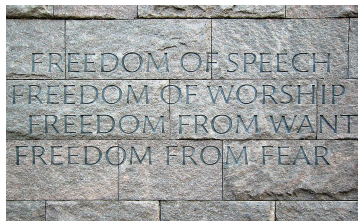
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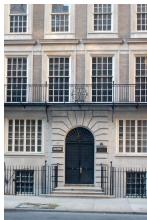
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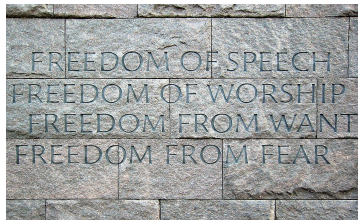
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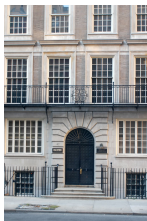
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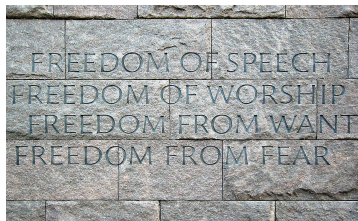
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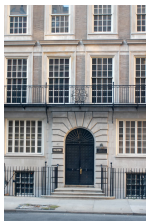
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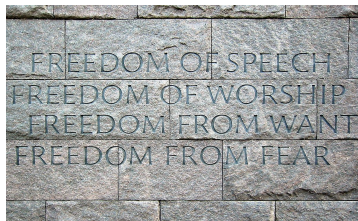
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- We're starting with Fall 2017, Version 3.

Writing Boards



- Return writing boards as you leave...