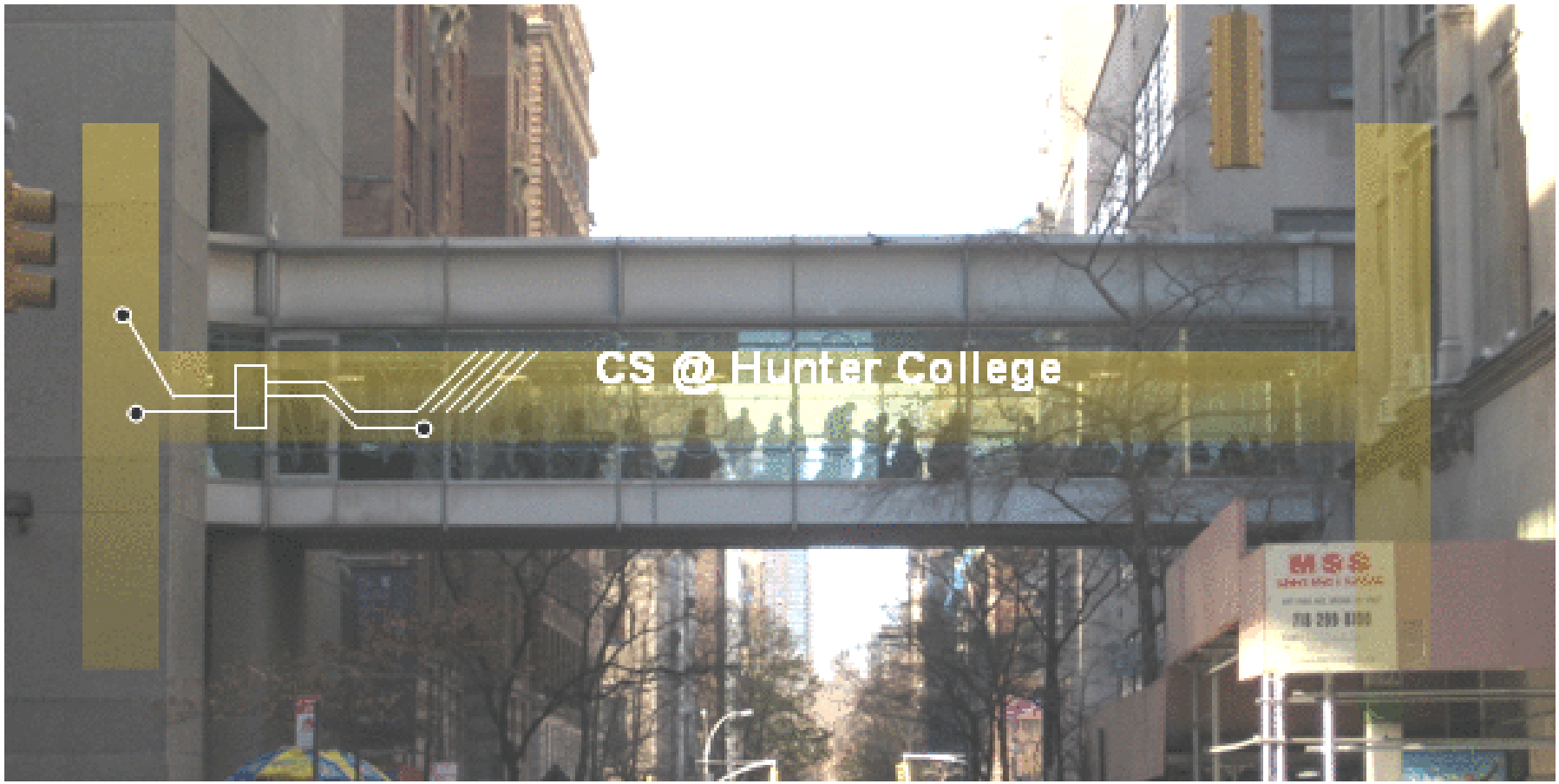
CSci 127: Introduction to Computer Science



hunter.cuny.edu/csci

- This lecture will be recorded

Frequently Asked Questions

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  In this course we have used the input() function.
- **Can we have more time for the Lab quiz?**
  Yes! After a few of you have mentioned feeling too rushed for the lab quiz, I have increased the time to 20 minutes.
  Keep in mind that the final exam will be in the same format and it is also timed. You will have 2 hours for the final exam.

Today's Topics

- Recap: Logical Expressions & Circuits
- Design: Cropping Images
- Accessing Formatted Data

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Recap: Logical Operators

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`False`	`and`	`True`	`False`
`True`	`and`	`False`	`False`
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or

in1		in2	*returns:*
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`False`	`or`	`True`	`True`
`True`	`or`	`False`	`True`
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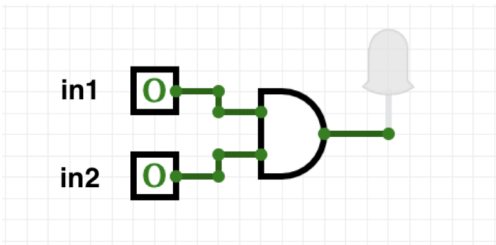
not

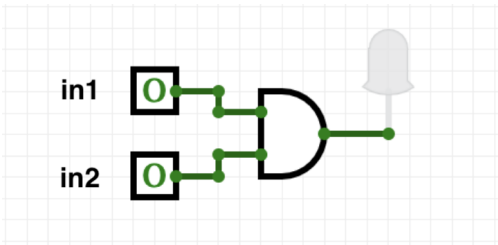
	in1	*returns:*
`not`	`False`	`True`
`not`	`True`	`False`

Logical Operators & Circuits



- Each logical operator (`and`, `or`, & `not`) can be used to join together expressions.

Logical Operators & Circuits



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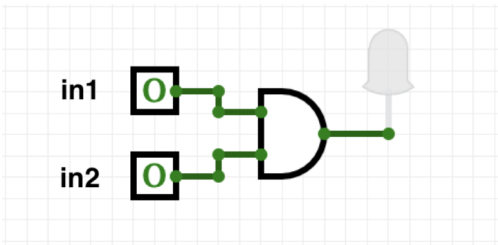
  Example: `in1 and in2`

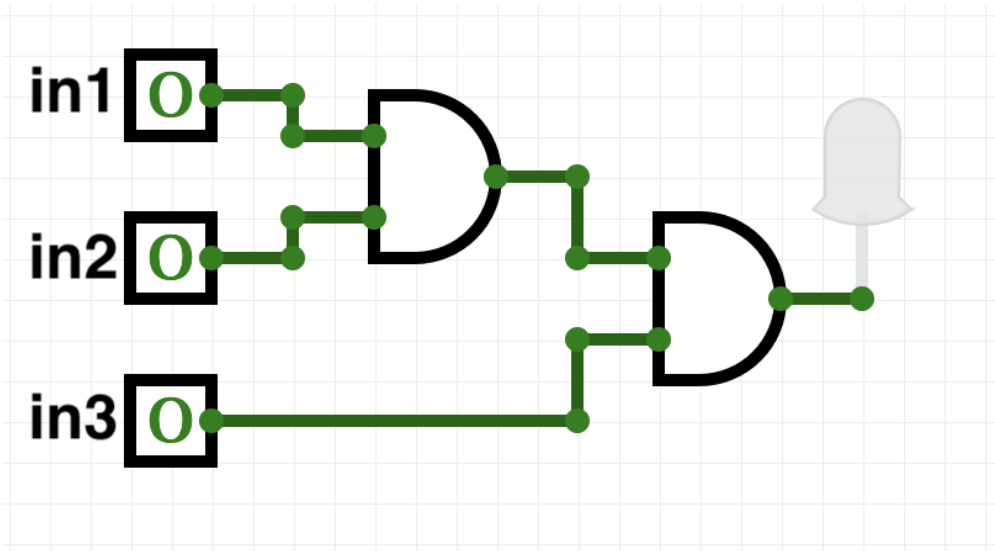
Logical Operators & Circuits



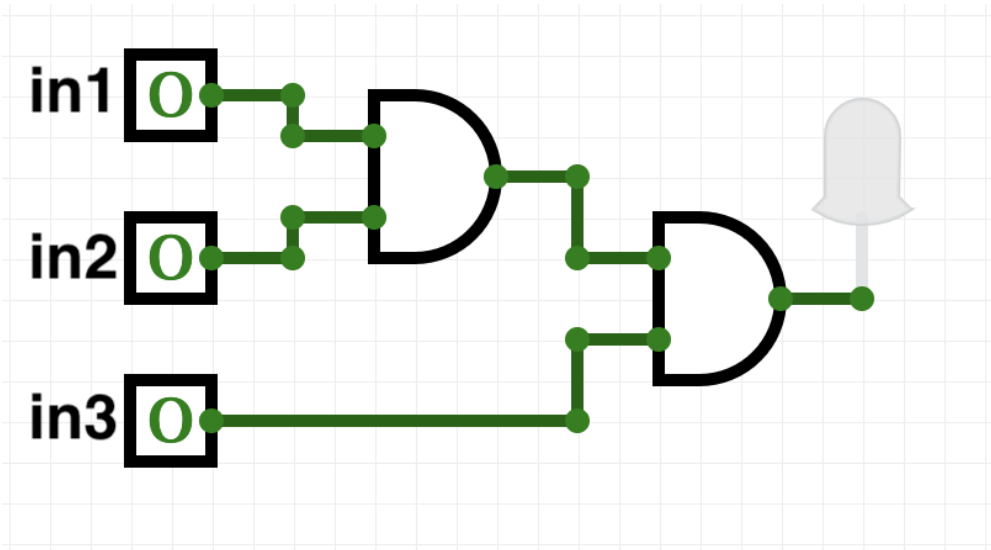
- Each logical operator (`and`, `or`, & `not`) can be used to join together expressions.

  Example: `in1 and in2`
- Each logical operator (`and`, `or`, & `not`) has a corresponding logical circuit that can be used to join together inputs.

Examples: Logical Circuit



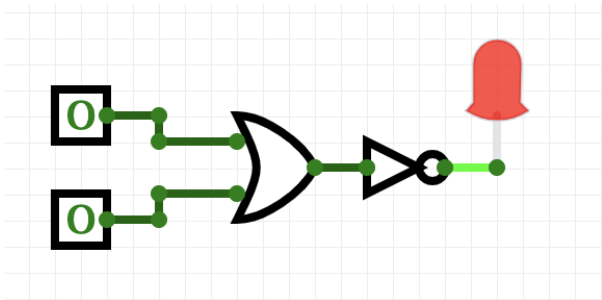
Examples: Logical Circuit

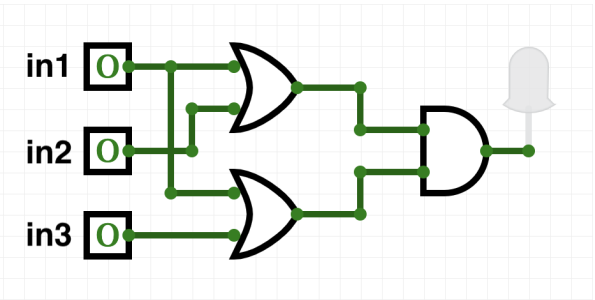


`(in1 and in2) and in3`

More Circuit Examples

Examples from last lecture:





Draw a circuit that corresponds to each logical expression:

- `not( in1 or in2 )`
- `(in1 or in2) and (in1 or in3)`
- `(not(in1 and not in2)) or (in1 and (in2 and in3))`

Challenge:

Predict what the code will do:

- ```
  x = 6
  y = x % 4
  w = y**3
  z = w // 2
  print(x,y,w,z)
  x,y = y,w
  print(x,y,w,z)
  x = y / 2
  print(x,y,w,z)
  ```
- ```
  sports = ["Field Hockey","Swimming","Water Polo"]
  mess = "Qoauxca BrletRce crcx qvBnqa ocUxk"
  result = ""
  for i in range(len(mess)):
      if i % 3 == 0:
          print(mess[i])
          result = result + mess[i]
  print(sports[1], result)
  ```

Python Tutor

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print(x,y,w,z)
x,y = y,w
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(Demo with pythonTutor)

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- **Design: Cropping Images**
- Accessing Formatted Data
- CS Survey: Astrophysics and astropy

Challenge: Design Question

From Final Exam, Fall 2017, V4, #6.

Design an algorithm that reads in an image and displays the lower left corner of the image.

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Input:
Output:
Process: *(Brainstorm for a "To Do" list to accomplish this.)*

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plt.imshow(img2) #Load our new image into pyplot
plt.show() #Show the image (waits until closed to continue)
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Structured Data

	Undergraduate		
College	Full-time	Part-time	Total
Baruch	11,288	3,922	15,210
Brooklyn	10,198	4,208	14,406
City	10,067	3,250	13,317
Hunter	12,223	4,500	16,723
John Jay	9,831	2,843	12,674
Lehman	6,600	4,720	11,320
Medgar Evers	4,760	2,059	6,819
NYCCT	10,912	6,370	17,282
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- Python has several ways to read in such data.
- We will use the popular Python Data Analysis Library (**Pandas**).

Structured Data

pandas

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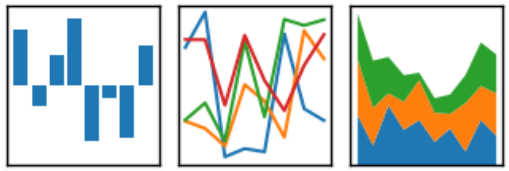

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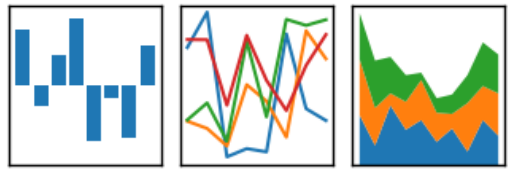

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- Open source and freely available (part of anaconda distribution).

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pandas

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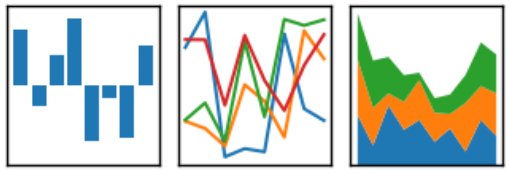

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Structured Data

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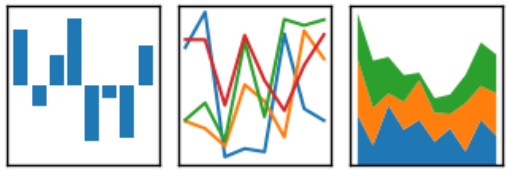

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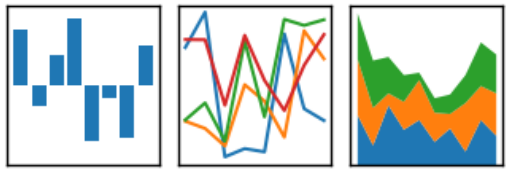

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- To use, add to the top of your program:

```
import pandas as pd
```

CSV Files

	Undergraduate		
College	Full-time	Part-time	Total
Baruch	11,288	3,922	15,210
Brooklyn	10,198	4,208	14,406
City	10,067	3,250	13,317
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- Excel .xls files have much extra formatting.

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nycHistPop.csv

Reading in CSV Files

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- Pandas has its own type, **DataFrame**, that is perfect for holding a sheet of data.
- Often abbreviated: `df`.
- It also has **Series**, that is perfect for holding a row or column of data.

Example: Reading in CSV Files

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```

`nycHistPop.csv`

In Lab 6

Example: Reading in CSV Files

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`nycHistPop.csv`

In Lab 6

Example: Reading in CSV Files

```
import matplotlib.pyplot as plt
import pandas as pd

pop = pd.read_csv('nycHistPop.csv',skiprows=5)
```

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nycHistPop.csv

In Lab 6

Example: Reading in CSV Files

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nycHistPop.csv

In Lab 6

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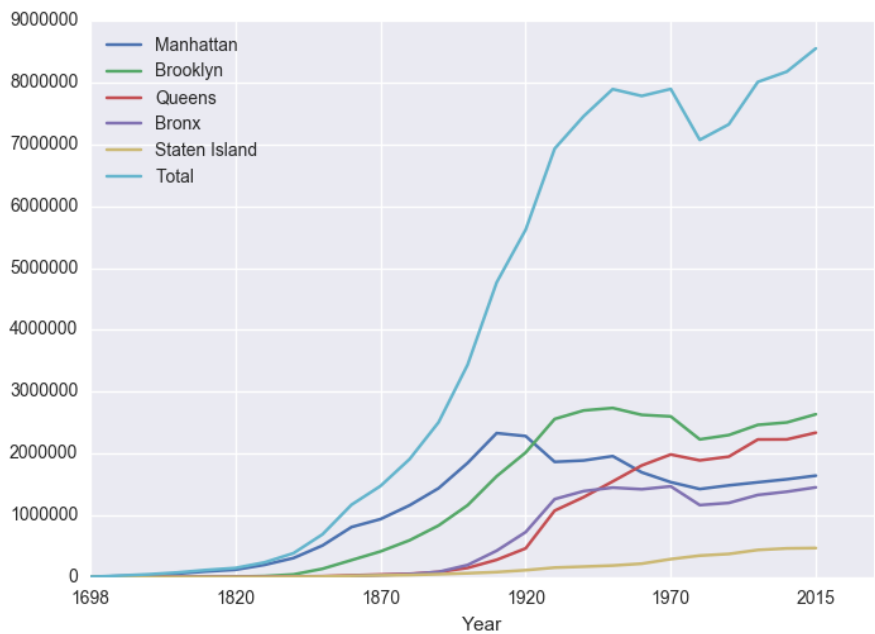
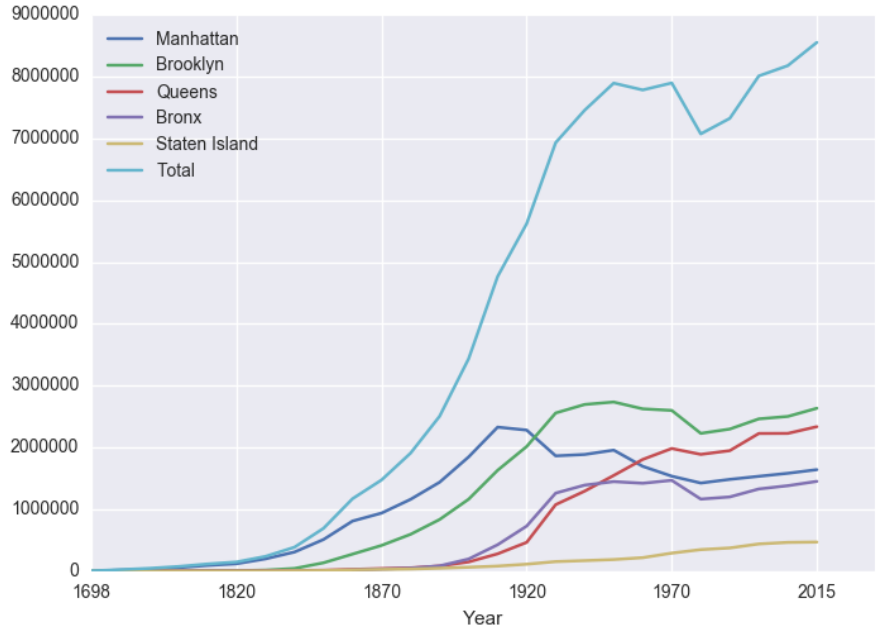
nycHistPop.csv

In Lab 6

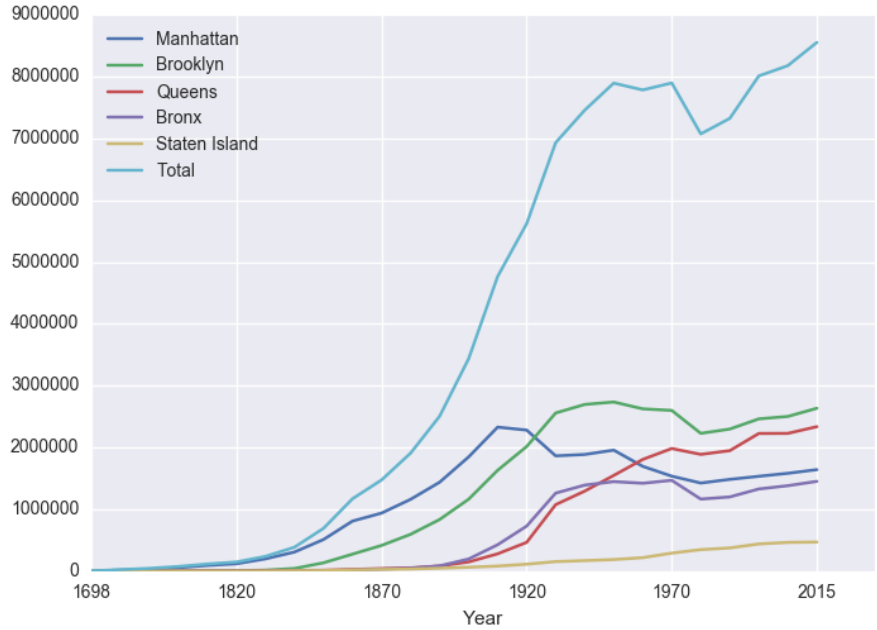


Series in Pandas



- Series can store a column or row of a DataFrame.

Series in Pandas



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- Example: `pop["Manhattan"]` is the Series corresponding to the column of Manhattan data.

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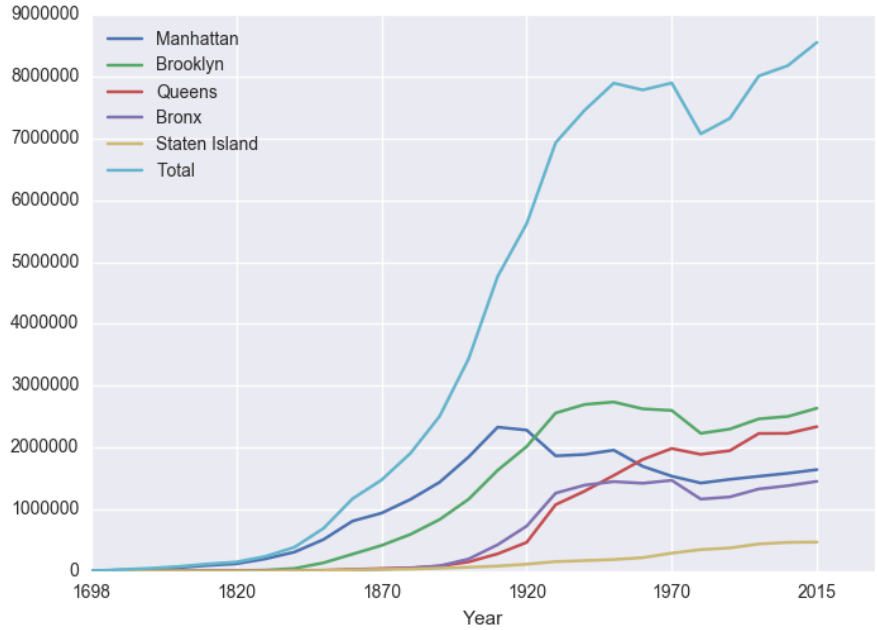

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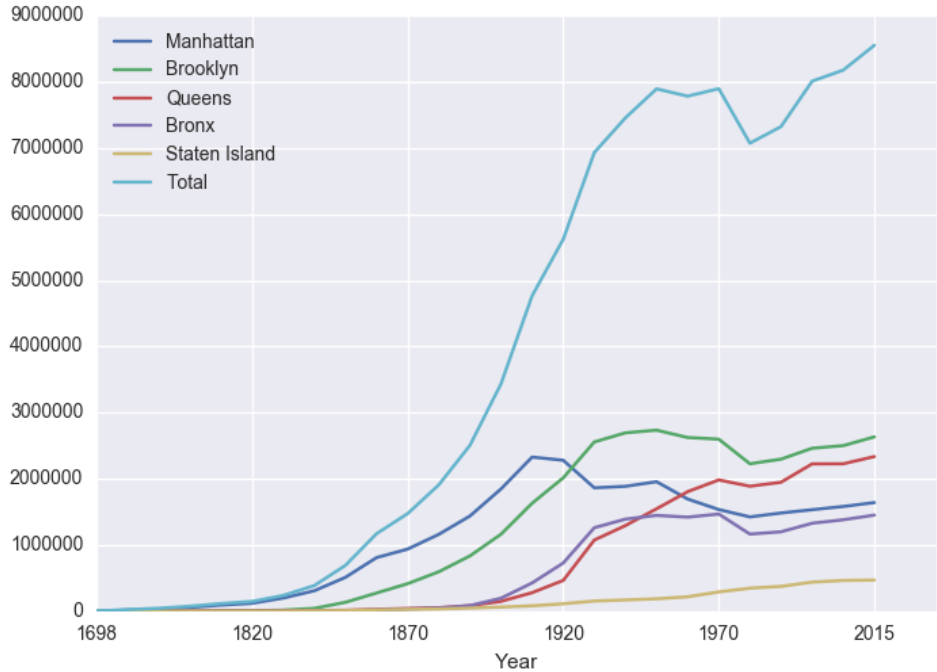
- Example: `pop["Manhattan"]` is the Series corresponding to the column of Manhattan data.
- Example:

```
print("The largest number living in the Bronx is",
pop["Bronx"].max())
```

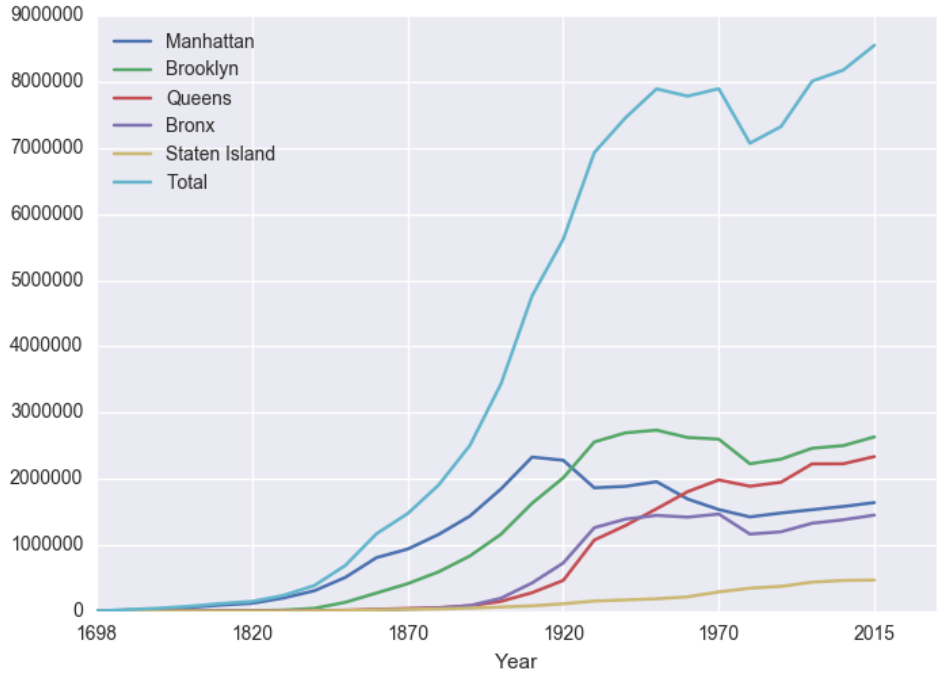
Challenge:



Predict what the following will do:

- `print("Queens:", pop["Queens"].min())`

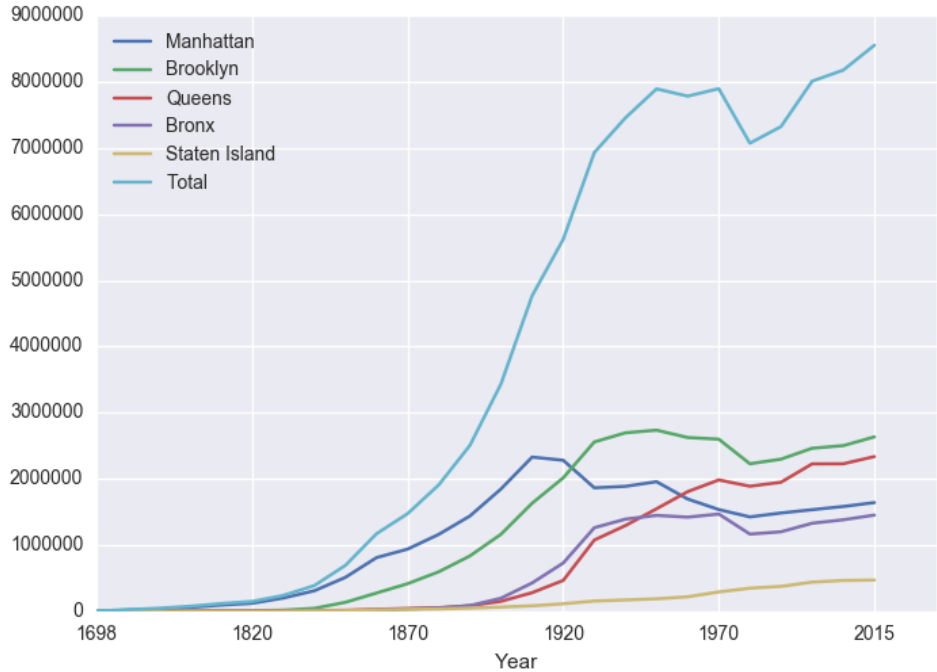
Challenge:



Predict what the following will do:

- `print("Queens:", pop["Queens"].min())`
- `print("S I:", pop["Staten Island"].mean())`

Challenge:



Predict what the following will do:

- `print("Queens:", pop["Queens"].min())`
- `print("S I:", pop["Staten Island"].mean())`
- `print("S I:", pop["Staten Island"].std())`

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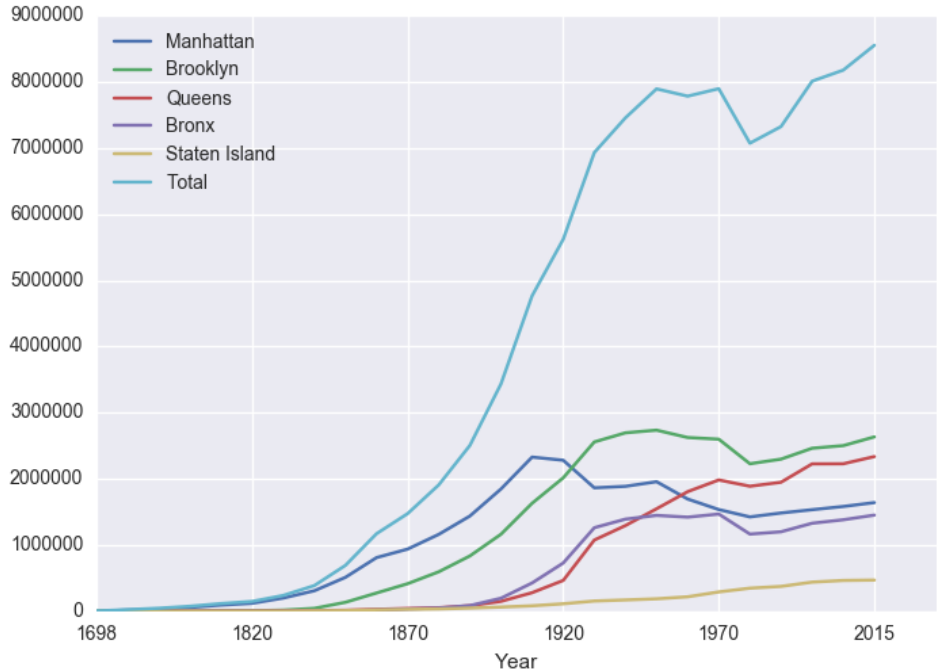
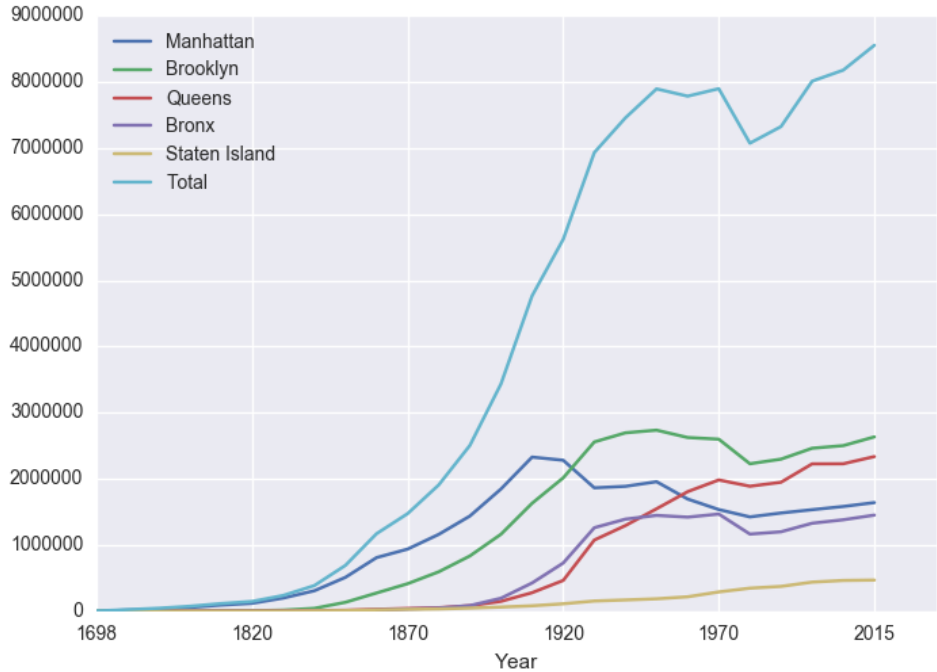


Predict what the following will do:

- `print("Queens:", pop["Queens"].min())`
- `print("S I:", pop["Staten Island"].mean())`
- `print("S I:", pop["Staten Island"].std())`
- `pop.plot.bar(x="Year")`

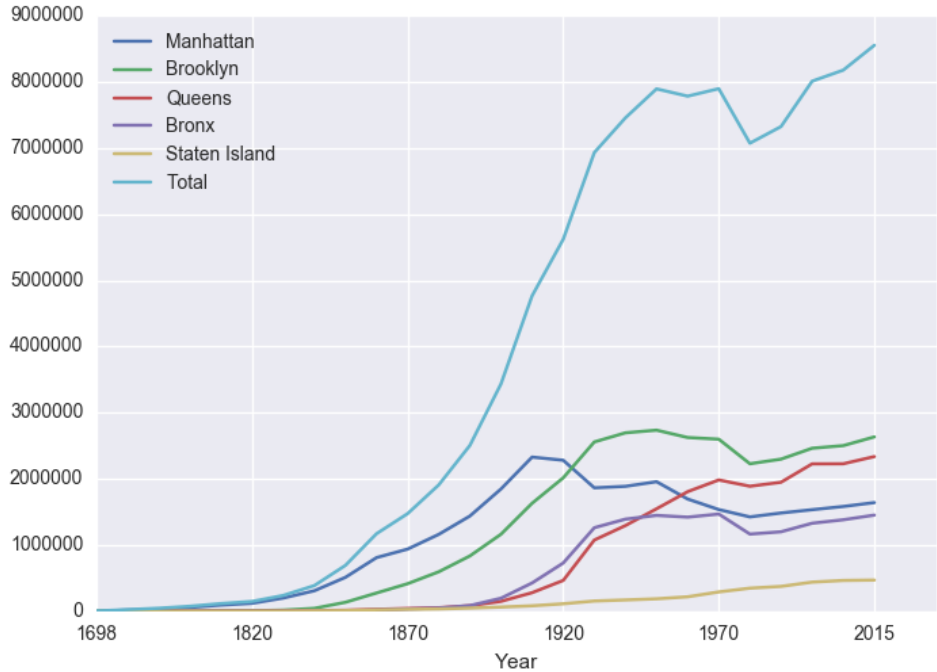
Challenge:



Predict what the following will do:

- `print("Queens:", pop["Queens"].min())`
- `print("S I:", pop["Staten Island"].mean())`
- `print("S I:", pop["Staten Island"].std())`
- `pop.plot.bar(x="Year")`
- `pop.plot.scatter(x="Brooklyn", y= "Total")`

Challenge:



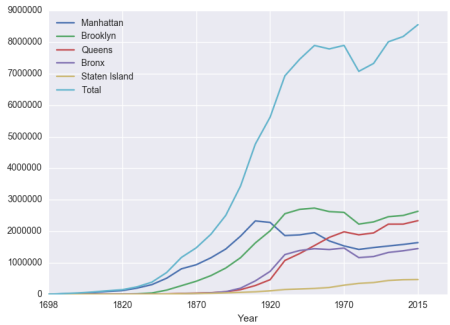
Predict what the following will do:

- `print("Queens:", pop["Queens"].min())`
- `print("S I:", pop["Staten Island"].mean())`
- `print("S I:", pop["Staten Island"].std())`
- `pop.plot.bar(x="Year")`
- `pop.plot.scatter(x="Brooklyn", y= "Total")`
- `pop["Fraction"] = pop["Bronx"]/pop["Total"]`

Solutions

Predict what the following will do:

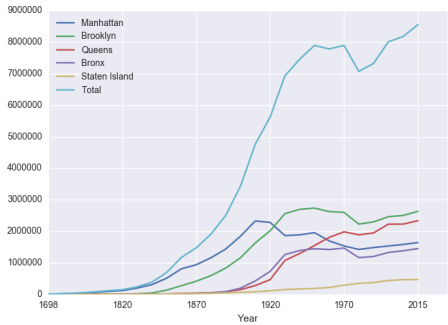
- `print("Queens:", pop["Queens"].min())`



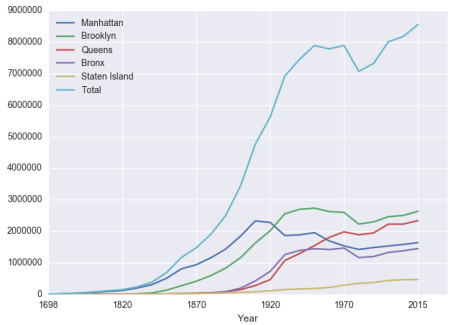
Solutions

Predict what the following will do:

- `print("Queens:", pop["Queens"].min())`
  Minimum value in the column with label "Queens".



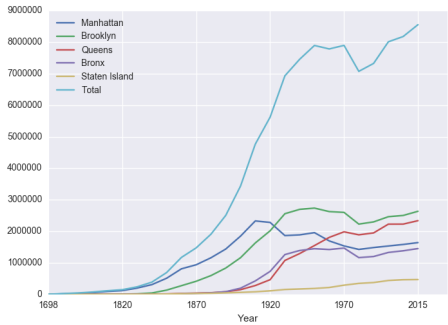
Solutions



Predict what the following will do:

- `print("Queens:", pop["Queens"].min())`
  Minimum value in the column with label "Queens".
- `print("S I:", pop["Staten Island"].mean())`

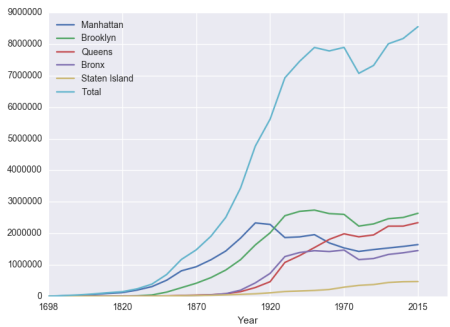
Solutions



Predict what the following will do:

- `print("Queens:", pop["Queens"].min())`
  Minimum value in the column with label "Queens".
- `print("S I:", pop["Staten Island"].mean())`
  Average of values in the column "Staten Island".

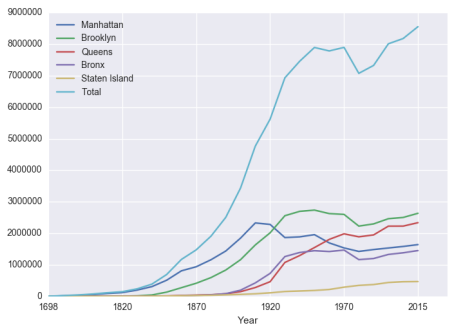
Solutions



Predict what the following will do:

- `print("Queens:", pop["Queens"].min())`
  Minimum value in the column with label "Queens".
- `print("S I:", pop["Staten Island"].mean())`
  Average of values in the column "Staten Island".
- `print("S I :", pop["Staten Island"].std())`

Solutions



Predict what the following will do:

- `print("Queens:", pop["Queens"].min())`
  Minimum value in the column with label "Queens".
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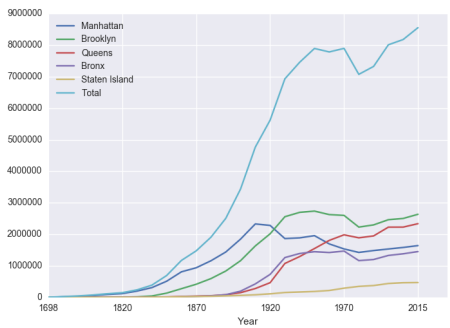
  Average of values in the column "Staten Island".
- `print("S I :", pop["Staten Island"].std())`
  Standard deviation of values in the column "Staten Island".

Solutions



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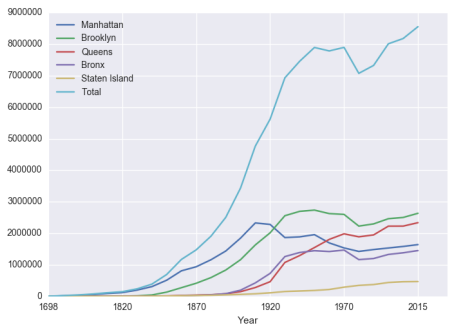
- `print("Queens:", pop["Queens"].min())`
  Minimum value in the column with label "Queens".
- `print("S I:", pop["Staten Island"].mean())`
  Average of values in the column "Staten Island".
- `print("S I :", pop["Staten Island"].std())`
  Standard deviation of values in the column "Staten Island".
- `pop.plot.bar(x="Year")`

Solutions



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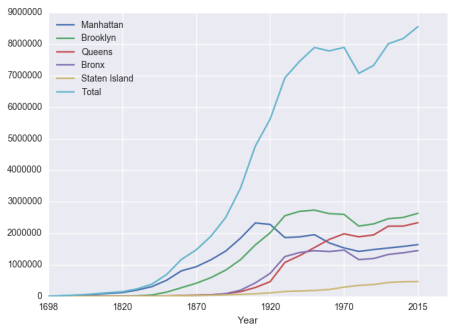
- `print("S I:", pop["Staten Island"].mean())`
  Average of values in the column "Staten Island".
- `print("S I :", pop["Staten Island"].std())`
  Standard deviation of values in the column "Staten Island".
- `pop.plot.bar(x="Year")`
  Bar chart with x-axis "Year".

Solutions



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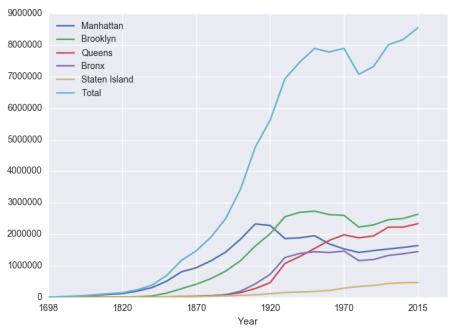
  Average of values in the column "Staten Island".
- `print("S I :", pop["Staten Island"].std())`
  Standard deviation of values in the column "Staten Island".
- `pop.plot.bar(x="Year")`
  Bar chart with x-axis "Year".
- `pop.plot.scatter(x="Brooklyn", y= "Total")`

Solutions



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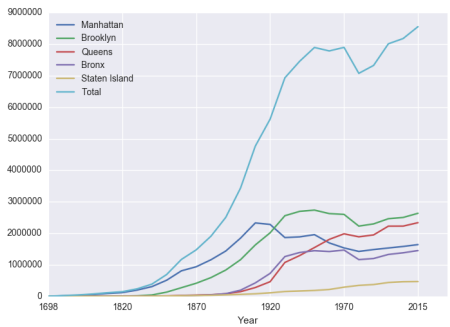
  Average of values in the column "Staten Island".
- `print("S I :", pop["Staten Island"].std())`
  Standard deviation of values in the column "Staten Island".
- `pop.plot.bar(x="Year")`
  Bar chart with x-axis "Year".
- `pop.plot.scatter(x="Brooklyn", y= "Total")`
  Scatter plot of Brooklyn versus Total values.

Solutions



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- `print("Queens:", pop["Queens"].min())`
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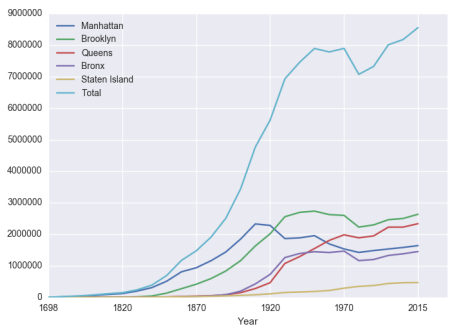
- `print("S I:", pop["Staten Island"].mean())`
  Average of values in the column "Staten Island".
- `print("S I :", pop["Staten Island"].std())`
  Standard deviation of values in the column "Staten Island".
- `pop.plot.bar(x="Year")`
  Bar chart with x-axis "Year".
- `pop.plot.scatter(x="Brooklyn", y= "Total")`
  Scatter plot of Brooklyn versus Total values.
- `pop["Fraction"] = pop["Bronx"]/pop["Total"]`

Solutions



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  Average of values in the column "Staten Island".
- `print("S I :", pop["Staten Island"].std())`
  Standard deviation of values in the column "Staten Island".
- `pop.plot.bar(x="Year")`
  Bar chart with x-axis "Year".
- `pop.plot.scatter(x="Brooklyn", y= "Total")`
  Scatter plot of Brooklyn versus Total values.
- `pop["Fraction"] = pop["Bronx"]/pop["Total"]`
  New column with the fraction of population that lives in the Bronx.

Challenge:

	Undergraduate		
College	Full-time	Part-time	Total
Baruch	11,288	3,922	15,210
Brooklyn	10,198	4,208	14,406
City	10,067	3,250	13,317
Hunter	12,223	4,500	16,723
John Jay	9,831	2,843	12,674
Lehman	6,600	4,720	11,320
Medgar Evers	4,760	2,059	6,819
NYCCT	10,912	6,370	17,282
Queens	11,693	4,633	16,326
Staten Island	9,584	2,948	12,532
York	5,066	3,192	8,258

`cunyF2016.csv`

Write a complete Python program that reads in the file, `cunyF2016.csv`, and produces a scatter plot of full-time versus part-time enrollment.

Challenge:

	Undergraduate		
College	Full-time	Part-time	Total
Baruch	11,288	3,922	15,210
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Write a complete Python program that reads in the file, `cunyF2016.csv`, and produces a scatter plot of full-time versus part-time enrollment.

Solution:

1. *Include pandas & pyplot libraries.*

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Write a complete Python program that reads in the file, `cunyF2016.csv`, and produces a scatter plot of full-time versus part-time enrollment.

Solution:

1. *Include pandas & pyplot libraries.*
2. *Read in the CSV file.*

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Write a complete Python program that reads in the file, `cunyF2016.csv`, and produces a scatter plot of full-time versus part-time enrollment.

Solution:

1. *Include pandas & pyplot libraries.*
2. *Read in the CSV file.*
3. *Set up a scatter plot.*

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`cunyF2016.csv`

Write a complete Python program that reads in the file, `cunyF2016.csv`, and produces a scatter plot of full-time versus part-time enrollment.

Solution:

1. *Include pandas & pyplot libraries.*
2. *Read in the CSV file.*
3. *Set up a scatter plot.*
4. *Display plot.*

Challenge:

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Solution:

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`cunyF2016.csv`

Solution:

1. *Include pandas & pyplot libraries.*

```
import matplotlib.pyplot as plt
import pandas as pd
```

Challenge:

Write a complete Python program that reads in the file, `cunyF2016.csv`, and produces a scatter plot of full-time versus part-time enrollment.

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`cunyF2016.csv`

Solution:

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   ```
   import matplotlib.pyplot as plt
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`cunyF2016.csv`

Write a complete Python program that reads in the file, `cunyF2016.csv`, and produces a scatter plot of full-time versus part-time enrollment.

Solution:

1. *Include pandas & pyplot libraries.*
```
import matplotlib.pyplot as plt
import pandas as pd
```
2. *Read in the CSV file.*
```
pop=pd.read_csv('cunyF2016.csv',skiprows=1)
```

Challenge:

Write a complete Python program that reads in the file, `cunyF2016.csv`, and produces a scatter plot of full-time versus part-time enrollment.

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`cunyF2016.csv`

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   ```
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   ```
3. *Set up a scatter plot.*

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Solution:

1. *Include pandas & pyplot libraries.*
```
import matplotlib.pyplot as plt
import pandas as pd
```
2. *Read in the CSV file.*
```
pop=pd.read_csv('cunyF2016.csv',skiprows=1)
```
3. *Set up a scatter plot.*
```
pop.plot.scatter(x="Full-time",y="Part-time")
```

Challenge:

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Brooklyn	10,198	4,208	14,406
City	10,067	3,250	13,317
Hunter	12,223	4,500	16,723
John Jay	9,831	2,843	12,674
Lehman	6,600	4,720	11,320
Medgar Evers	4,760	2,059	6,819
NYCCT	10,912	6,370	17,282
Queens	11,693	4,633	16,326
Staten Island	9,584	2,948	12,532
York	5,066	3,192	8,258

`cunyF2016.csv`

Write a complete Python program that reads in the file, `cunyF2016.csv`, and produces a scatter plot of full-time versus part-time enrollment.

Solution:

1. *Include pandas & pyplot libraries.*
```
import matplotlib.pyplot as plt
import pandas as pd
```
2. *Read in the CSV file.*
```
pop=pd.read_csv('cunyF2016.csv',skiprows=1)
```
3. *Set up a scatter plot.*
```
pop.plot.scatter(x="Full-time",y="Part-time")
```
4. *Display plot.*

Challenge:

Write a complete Python program that reads in the file, `cunyF2016.csv`, and produces a scatter plot of full-time versus part-time enrollment.

	Undergraduate		
College	Full-time	Part-time	Total
Baruch	11,288	3,922	15,210
Brooklyn	10,198	4,208	14,406
City	10,067	3,250	13,317
Hunter	12,223	4,500	16,723
John Jay	9,831	2,843	12,674
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`cunyF2016.csv`

Solution:

1. *Include pandas & pyplot libraries.*
```
import matplotlib.pyplot as plt
import pandas as pd
```
2. *Read in the CSV file.*
```
pop=pd.read_csv('cunyF2016.csv',skiprows=1)
```
3. *Set up a scatter plot.*
```
pop.plot.scatter(x="Full-time",y="Part-time")
```
4. *Display plot.*
```
plt.show()
```

Lecture Quiz

- Log-in to Gradescope
- Find LECTURE 6 Quiz
- Take the quiz
- **You have 3 minutes**

groupby()

Sometimes you have **recurring values in a column** and you want to examine the data for a particular value.

Rain in Australia				
Date	Location	MinTemp	MaxTemp	Rainfall
12/1/08	Albury	13.4	22.9	0.6
5/22/15	BadgerysCree	11	15.6	1.6
3/17/11	BadgerysCree	18.1	25.8	16.6
7/27/10	Cobar	5.3	17.2	0
9/5/10	Moree	12.1	19.8	23.4
1/23/12	CoffsHarbour	20	24.4	28
7/15/11	Moree	2.8	19	0
1/28/10	Newcastle	22.2	28	0
12/2/15	Moree	20.1	32	4.8
	...			

`AustraliaRain.csv`

groupby()

Sometimes you have **recurring values in a column** and you want to examine the data for a particular value.

For example, to **find the average rainfall at each location***:*

Rain in Australia				
Date	**Location**	**MinTemp**	**MaxTemp**	**Rainfall**
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	...			

`AustraliaRain.csv`

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```
import pandas as pd
```

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7/15/11	Moree	2.8	19	0
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`AustraliaRain.csv`

groupby()

Sometimes you have **recurring values in a column** and you want to examine the data for a particular value.

For example, to **find the average rainfall at each location**:

1. *Import libraries.*
   `import pandas as pd`
2. *Read in the CSV file.*
   `rain = pd.read_csv('AustraliaRain.csv',skiprows=1)`
3. *Group the data by location.*
   `groupAvg = rain.`**`groupby('Location')`**

Rain in Australia				
Date	Location	MinTemp	MaxTemp	Rainfall
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`AustraliaRain.csv`

groupby()

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`AustraliaRain.csv`

For example, to **find the average rainfall at each location**:

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   ```
   import pandas as pd
   ```
2. *Read in the CSV file.*
   ```
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3. *Group the data by location.*
   ```
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4. *Print the average rainfall at each location.*
   ```
   print(groupAvg['Rainfall'].mean())
   ```

groupby()

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1/28/10	Newcastle	22.2	28	0
12/2/15	Moree	20.1	32	4.8
	...			

AustraliaRain.csv

```
Adelaide            1.572185
Albany              2.255073
Albury              1.925710
AliceSprings        0.869355
BadgerysCreek       2.207925
Ballarat            1.688830
Bendigo             1.621452
Brisbane            3.160536
Cairns              5.765317
Canberra            1.735038
Cobar               1.129262
CoffsHarbour        5.054592
Dartmoor            2.148554
```

Sometimes you have **recurring values in a column** and you want to examine the data for a particular value.

For example, to **find the average rainfall at each location**:

1. *Import libraries.*
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   ```
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   ```
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   ```
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   ```
   print(groupAvg['Rainfall'].mean())
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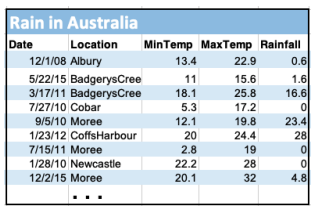
groupby()

Sometimes you have **recurring values in a column** and you want to examine the data for a particular value.

For example, to **find the average rainfall at one location, e.g. Albury***:*



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`AustraliaRain.csv`

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`AustraliaRain.csv`

1. *Import libraries.*
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2. *Read in the CSV file.*
   ```
   rain =
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3. **Group the data by location get data for group Albury.**
   ```
   AlburyAvg =
   rain.groupby(['Location']).get_group('Albury')
   ```

groupby()

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   ```
4. *Print the average rainfall in Albury.*
   ```
   print(AlburyAvg['Rainfall'].mean())
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groupby()

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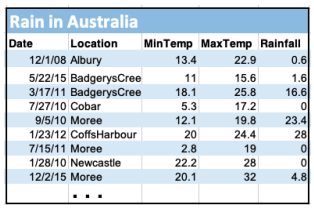
For example, to **find the average rainfall at one location, e.g. Albury***:*



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	...			

`AustraliaRain.csv`

```
1.9257104647275156
```

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   ```
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   ```
2. *Read in the CSV file.*
   ```
   rain =
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   ```
   print(AlburyAvg['Rainfall'].mean())
   ```

Design Challenge

Stars						
Temperature (K)	Luminosity(L/Lo)	Radius(R/Ro)	Absolute magnitude(Mv)	Star type	Star color	Spectral Class
3068	0.0024	0.17	16.12	Brown Dwarf	Red	M
25000	0.056	0.0084	10.58	White Dwarf	Blue White	B
2650	0.00069	0.11	17.45	Brown Dwarf	Red	M
11790	0.00015	0.011	12.59	White Dwarf	Yellowish White	F
15276	1136	7.2	-1.97	Main Sequence	Blue-white	B
5800	0.81	0.9	5.05	Main Sequence	yellow-white	F
16500	0.013	0.014	11.89	White Dwarf	Blue White	B
3192	0.00362	0.1967	13.53	Red Dwarf	Red	M
6380	1.35	0.98	2.93	Main Sequence	yellow-white	F
3834	272000	1183	-9.2	Hypergiant	Red	M

- Design an algorithm that:
  - Prints the luminosity of the brightest star.
  - Prints the temperature of the coldest star.
  - Prints the average radius of a Hypergiant.

Design Challenge - Solution

Stars						
Temperature (K)	Luminosity(L/Lo)	Radius(R/Ro)	Absolute magnitude(Mv)	Star type	Star color	Spectral Class
3068	0.0024	0.17	16.12	Brown Dwarf	Red	M
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- **Libraries:** pandas

Design Challenge - Solution

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- **Libraries:** pandas
- **Process:**
  - Print **max** of **'Luminosity'** column

Design Challenge - Solution

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6380	1.35	0.98	2.93	Main Sequence	yellow-white	F
3834	272000	1183	-9.2	Hypergiant	Red	M

- **Libraries:** pandas
- **Process:**
  - Print **max** of **'Luminosity'** column
  - Print **min** of **'Temperature'** column

Design Challenge - Solution

Stars						
Temperature (K)	Luminosity(L/Lo)	Radius(R/Ro)	Absolute magnitude(Mv)	Star type	Star color	Spectral Class
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- **Libraries:** pandas
- **Process:**
  - Print **max** of **'Luminosity'** column
  - Print **min** of **'Temperature'** column
  - **groupby 'Star Type'** and take **averages**, then print **max of 'Radius'** column

Design Challenge - Solution

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- **Libraries:** pandas
- **Process:**
  - Print **max** of **'Luminosity'** column
  - Print **min** of **'Temperature'** column
  - **groupby 'Star Type'** and take **averages**, then print **max of 'Radius'** column
  - OR **groupby 'Star Type'** and **get group 'Hypergiant'** to print **average 'Radius'**

Design Challenge - Code

- **Libraries:** pandas

```
import pandas as pd
stars = pd.read_csv('Stars.csv')
```

Design Challenge - Code

- **Libraries:** pandas

```
import pandas as pd
stars = pd.read_csv('Stars.csv')
```

- **Process:**
  - Print **max** of **'Luminosity'** column

```
print(stars['Luminosity(L/Lo)'].max())
```

Design Challenge - Code

- **Libraries:** pandas

```
import pandas as pd
stars = pd.read_csv('Stars.csv')
```

- **Process:**
  - Print **max** of **'Luminosity'** column

```
print(stars['Luminosity(L/Lo)'].max())
```

  - Prints **min** of **'Temperature'** column and store it in temp variable

```
print( stars['Temperature (K)'].min())
```

Design Challenge - Code

- **Libraries:** pandas

```
import pandas as pd
stars = pd.read_csv('Stars.csv')
```

- **Process:**
  - Print **max** of **'Luminosity'** column

```
print(stars['Luminosity(L/Lo)'].max())
```

  - Prints **min** of **'Temperature'** column and store it in temp variable

```
print( stars['Temperature (K)'].min())
```

  - **groupby 'Star Type'** and take **averages**, then print **max of 'Radius'** column

```
print(stars.groupby(['Star type'])\
.mean()['Radius(R/Ro)'].max())
```

Design Challenge - Code

- **Libraries:** pandas

```
import pandas as pd
stars = pd.read_csv('Stars.csv')
```

- **Process:**
  - Print **max** of **'Luminosity'** column

```
print(stars['Luminosity(L/Lo)'].max())
```

  - Prints **min** of **'Temperature'** column and store it in temp variable

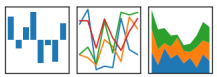
```
print( stars['Temperature (K)'].min())
```

  - OR **groupby 'Star Type'** and **get group 'Hypergiant'** to print **average 'Radius'**

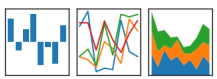
```
print(stars.groupby(['Star type'])\
.get_group('Hypergiant').mean()['Radius(R/Ro)'])
```

Recap

- Recap: Logical Expressions & Circuits

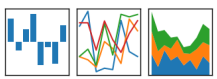
pandas $y_{it} = \beta' x_{it} + \mu_i + \epsilon_{it}$ 

Recap

pandas $y_{it} = \beta' x_{it} + \mu_i + \epsilon_{it}$ 

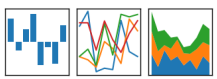
- Recap: Logical Expressions & Circuits
- Accessing Formatted Data:
  - Pandas library has elegant solutions for accessing & analyzing structured data.

Recap

pandas 

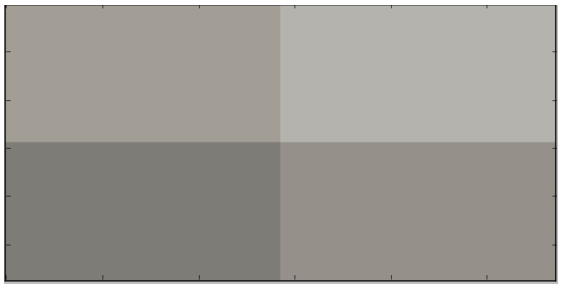
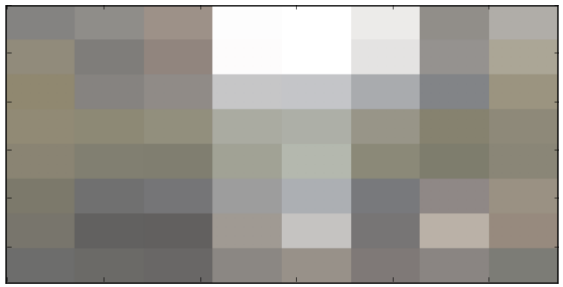
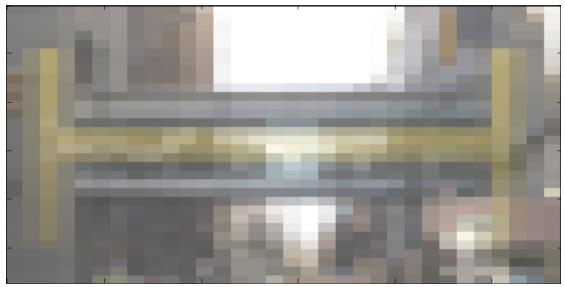
- Recap: Logical Expressions & Circuits
- Accessing Formatted Data:
  - Pandas library has elegant solutions for accessing & analyzing structured data.
  - Can manipulate individual columns or rows ('Series').

Recap

pandas 

- Recap: Logical Expressions & Circuits
- Accessing Formatted Data:
  - Pandas library has elegant solutions for accessing & analyzing structured data.
  - Can manipulate individual columns or rows ('Series').
  - Has useful functions for the entire sheet ('DataFrame') such as plotting.

Practice Quiz & Final Questions

- Since you must pass the final exam to pass the course, we end every lecture with final exam review.
- Pull out something to write on (not to be turned in).
- Lightning rounds:
  - write as much you can for 60 seconds;
  - followed by answer; and
  - repeat.
- Past exams are on the webpage (under Final Exam Information).
- We're starting with Spring 2018, Version 1.

See you next week!

Before next lecture, don't forget to:

- Work on this week's Online Lab

See you next week!

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- Optional - attend live Lab Review on Wednesday 1-2:30pm

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- Submit this week's 5 programming assignments (programs 26-30)

See you next week!

Before next lecture, don't forget to:

- Work on this week's Online Lab
- Optional - attend live Lab Review on Wednesday 1-2:30pm
- Take the Lab Quiz on Gradescope by 6pm on Wednesday
- Submit this week's 5 programming assignments (programs 26-30)
- At any point, visit our Drop-In Tutoring if you need help!!!