Homework #8 is due Friday, Dec. 2.
Homework #9 is due Friday, Dec. 9.
Midterm #2 is Monday, Dec. 19 from 7–10 p.m.
Warmup Quiz
x = np.zeros((3,3))
for i in range(3):
    for j in range(3):
        x[i,j] = i*j + j

A =
\begin{pmatrix}
0 & 0 & 0 \\
1 & 2 & 3 \\
2 & 4 & 6 \\
\end{pmatrix}

B =
\begin{pmatrix}
0 & 0 & 0 \\
0 & 2 & 4 \\
0 & 4 & 8 \\
\end{pmatrix}

C =
\begin{pmatrix}
0 & 1 & 2 \\
0 & 2 & 4 \\
0 & 3 & 6 \\
\end{pmatrix}
\[ x = \text{np.zeros}( (3,3) ) \]

\[
\begin{align*}
\text{for } i \text{ in range( 3 )}: \\
\text{for } j \text{ in range( 3 )}: \\
\quad x[i,j] = i\times j + j
\end{align*}
\]

\[
\begin{bmatrix}
0 & 0 & 0 \\
1 & 2 & 3 \\
2 & 4 & 6 \\
\end{bmatrix}
\begin{bmatrix}
0 & 0 & 0 \\
0 & 2 & 4 \\
0 & 4 & 8 \\
\end{bmatrix}
\begin{bmatrix}
0 & 1 & 2 \\
0 & 2 & 4 \\
0 & 3 & 6 \\
\end{bmatrix}^\star
\]
Randomness
A philosophical excursus: what is randomness?
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What are some sources of true randomness?
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What are some sources of true randomness?

Consider the following two sequences:

\[ 7 \ 8 \ 5 \ 3 \ 9 \ 8 \ 1 \ 6 \ 3 \ 3 \ 9 \ 7 \ 4 \ 4 \ 8 \ 3 \ 0 \ 9 \ 6 \ 1 \ 5 \ 6 \ 6 \ 0 \ 8 \ 4 \ldots \]

\[ +1, \ -\frac{1}{3}, \ +\frac{1}{5}, \ -\frac{1}{7}, \ -\frac{1}{9}, \ -\frac{1}{11}, \ +\frac{1}{13}, \ -\frac{1}{15}, \ldots \]
A philosophical excursus: what is randomness?

What are some sources of true randomness?

Consider the following two sequences:

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

\[ +1, \frac{1}{3}, \frac{1}{5}, \frac{1}{7}, \frac{1}{9}, \frac{1}{11}, \frac{1}{13}, \frac{1}{15}, \ldots \]

These are derived from the same rule \((\pi/4)\)–but one seems “random” to us.
Pseudorandom numbers come from computer formulae.
Randomness

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- The formula uses a seed (often the system clock time) to start the sequence.
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- It then returns a new number unpredictable to you (but predictable to the formula!) each time you query the function.
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Randomness

- Pseudorandom numbers come from computer formulae.
- The formula uses a seed (often the system clock time) to start the sequence.
- It then returns a new number unpredictable to you (but predictable to the formula!) each time you query the function.
- NumPy uses the Mersenne twister, based on prime number distributions (but you don’t need to know this).
- Dozens of distributions are available—let’s see a few.
randint

- randint returns a random (pseudorandom) integer in a range (which works the same as range).

```python
np.random.randint( 10 )  # random int, [0,10)
np.random.randint( 1,7 )  # random int, [1, 7)
np.random.randint( 0,10, size=(5,5) )  # in array
```
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Randomness

- `hist` (MatPlotLib) creates a histogram.
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```python
x = np.random.randint(0,100,size=(10000,1))
plt.hist(x)
plt.show()
```
hist (MatPlotLib) creates a histogram.

Histograms plot the number of times a value occurs in a data set.

```python
x = np.random.randint(0,100,size=(10000,1))
plt.hist(x)
plt.show()
```
Number guessing (a game for the easily entertained):

```python
import numpy as np
number = np.random.randint(10)+1
guess = input('Guess the number between 1 and 10:
while guess != number:
    guess = input('Nope. Try again:
print('You did it. Hooray.
```
Number guessing (a game for the easily entertained):

```python
import numpy as np
number = np.random.randint(10)+1
guess = input('Guess the number between 1 and 10: ')
while int(guess) != number:
    guess = input('Nope. Try again: ')
print('You did it. Hooray.')
```
**uniform**

- **uniform** returns a random float in the range \([0, 1)\).

```python
np.random.uniform()  # random number, \([0,1)\)
```
uniform

- uniform returns a random float in the range [0, 1).

```python
np.random.uniform()  # random number, [0,1)
np.random.uniform(size=(4,3))  # in array
```
**uniform**

- `uniform` returns a random float in the range [0,1).

```python
np.random.uniform()       # random number, [0,1)
np.random.uniform( size=(4,3) ) # in array
x = np.random.uniform( size=(10000,1) )
plt.hist(x)
plt.show()
```
uniform

- uniform returns a random float in the range [0, 1).

```python
np.random.uniform()  # random number, [0,1)
np.random.uniform( size=(4,3) )  # in array
x = np.random.uniform( size=(10000,1) )
plt.hist(x)
plt.show()
```
uniform

- uniform returns a random float in the range [0, 1).

```python
np.random.uniform()  # random number, [0,1)
np.random.uniform( size=(4,3) )  # in array
x = np.random.uniform( size=(10000,1) )
plt.hist(x, bins=100)
plt.show()
```
uniform

uniform returns a random float in the range [0, 1).

```python
np.random.uniform()  # random number, [0,1)
np.random.uniform(size=(4,3)) # in array
x = np.random.uniform(size=(10000,1))
plt.hist(x,bins=100)
plt.show()
```
• `randn` returns a random number selected from the normal distribution with mean 0 and variance 1.

• (Variance is the square of standard deviation.)
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```python
np.random.randn()  # random normal number
```
randn returns a random number selected from the normal distribution with mean 0 and variance 1.

(Variance is the square of standard deviation.)

```python
np.random.randn()  # random normal number
np.random.randn() + 1.0  # mean 1.0
```
randn

- randn returns a random number selected from the normal distribution with mean 0 and variance 1.
- (Variance is the square of standard deviation.)

```python
np.random.randn()  # random normal number
np.random.randn() + 1.0  # mean 1.0
(np.random.randn()) * 4  # variance 4.0
```
\texttt{randn} returns a random number selected from the \texttt{normal} distribution with mean 0 and variance 1.

\begin{verbatim}
x = np.random.randn( 10000 )
plt.hist(x, bins=20)
plt.show()
\end{verbatim}
**randn** returns a random number selected from the normal distribution with mean 0 and variance 1.

```python
x = np.random.randn( 10000 )
plt.hist(x,bins=20)
plt.show()
```
choice randomly samples a one-dimensional array (rather, the first dimension of the array).

```python
x = [ 'red', 'orange', 'yellow', 'green', 'blue'
np.random.choice(x)  # random color
```
choice randomly samples a one-dimensional array but can do so without replacement.
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Replacement means the difference between pulling a card from a deck and putting it back before drawing again (or not).
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Replacement means the difference between pulling a card from a deck and putting it back before drawing again (or not).

```python
x = np.arange(1,53)
c = np.random.choice( x, size=5, replace=False )
```
choice randomly samples a one-dimensional array but can do so without replacement.

Replacement means the difference between pulling a card from a deck and putting it back before drawing again (or not).

```python
x = np.arange(1,53)
c = np.random.choice( x, size=5, replace=False )
```

The foregoing code draws five cards from a deck (no repeat cards allowed).
- **shuffle** randomly reorders an array in place.
- What is its return type?
shuffle randomly reorders an array in place. What is its return type?

```python
x = np.arange(1, 53)
np.random.shuffle(x)
```
shuffle randomly reorders an array in place.

What is its return type?

```python
x = np.arange(1,53)
np.random.shuffle(x)
```

The foregoing code shuffles a deck of cards.
Which of the following will not reproduce the behavior of a six-sided die in c?

A  \( c = np.random.randn(6) + 1 \)

B  \( x = np.arange(1,7) \\
    c = np.random.choice(x) \)

C  \( c = np.random.randint(6) + 1 \)

D  \( d = np.random.uniform(0,6) \\
    c = int(d) + 1 \)
Which of the following will \textbf{not} reproduce the behavior of a six-sided die in \( c \)?

A \( c = \text{np.random.randn}(6) + 1 \)

\* \( c = \text{np.random.randint}(6)+1 \)

B \( x = \text{np.arange}(1,7) \)
   \( c = \text{np.random.choice}(x) \)

C \( c = \text{np.random.randint}(6)+1 \)

D \( d = \text{np.random.uniform}(0,6) \)
   \( c = \text{int}(d) + 1 \)
Our first toy example was pretty lame. What else can we do?
Our first toy example was pretty lame. What else can we do?
Example: Mad Libs
import numpy as np

adjs = []
for line in open('adjectives.txt').readlines():
    adjs.append( line.strip() )

names = []
for line in open('names.txt').readlines():
    names.append( line.strip().split(',
')

verbs = []
for line in open('verbs.txt').readlines():
    verbs.append( line.strip().split(',
')

nouns = []
for line in open('nouns.txt').readlines():
    nouns.append( line.strip() )

# note that names and verbs have a slightly different structure
# than adj and nouns
adj1 = adjs[np.random.randint(len(adjs))]
noun1 = nouns[np.random.randint(len(nouns))]
name = names[np.random.randint(len(names))]
verb = verbs[np.random.randint(len(verbs))]
adj2 = adjs[np.random.randint(len(adjs))]
noun2 = nouns[np.random.randint(len(nouns))]

phrase = adj1.title() + ' ' + noun1 + ' ' + name[0] + ' was so ' + adj2 + ' that ' + name[1] + ' ' + verb[1] + ' a ' + noun2 + '.'
Our first toy example was pretty lame. What else can we do?

- Example: Mad Libs
- Random walk
import numpy as np
import matplotlib.pyplot as plt

x = np.zeros( ( 100,1 ) )
y = np.zeros( ( 100,1 ) )
for i in range(1, len(x)):
    dir = np.random.randint(4)
    if dir == 0:
        x[i] = x[i-1]
        y[i] = y[i-1]+1
    if dir == 1:
        x[i] = x[i-1]+1
        y[i] = y[i-1]
    if dir == 2:
        x[i] = x[i-1]
        y[i] = y[i-1]-1
    if dir == 3:
        x[i] = x[i-1]-1
        y[i] = y[i-1]

plt.plot(x, y)
plt.show()
Our first toy example was pretty lame. What else can we do?

- Example: Mad Libs
- Random walk
- Think of others: games, for instance.
- Also, scientific applications (quantum mechanics).