[220 / 319] Randomness

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Announcements

- Follow-up courses
  - Direct follow up course: CS 320
  - Computer Sciences: CS 200, 300, 400, 537, 564, 640
- Office Hours
  - Last day of office hours: Friday April 30^{th}.
  - Instructors will be available via Piazza over this weekend to answer questions about final exam.

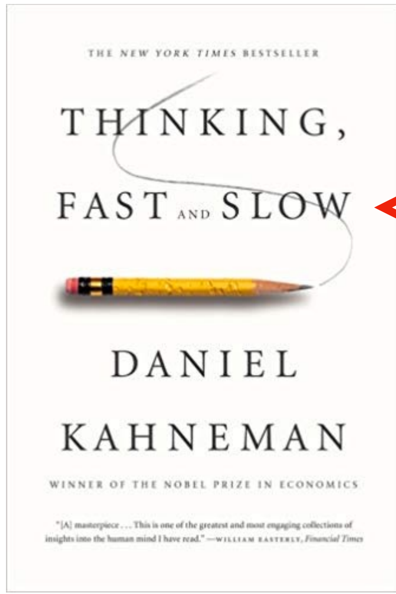
Final exam

- Recommended prep
  - make sure you understand all the worksheet problems
  - review the readings, slides, **lecture demo code**
  - review everything you got wrong on the midterms
  - review the code you wrote for the projects
  - prepare a note sheet (despite open material!)
- Live review session on Friday April 30th
  - LEC 001 / LEC 002 / LEC 003 BBC sessions
  - LEC 004 office hours
  - attend any session

Course evaluations

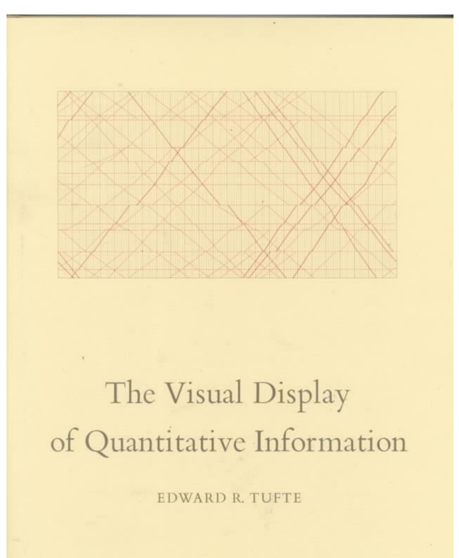
- We value student feedback greatly
- Please bring a smile to your instructors' face by spending a few minutes to fill out evals ☺
  - CS220 SEC 001
  - CS220 SEC 002
  - CS220 SEC 003
  - CS220 SEC 004
  - CS319 SEC 001
  - CS319 SEC 002
  - CS319 SEC 003

Recommended summer reading

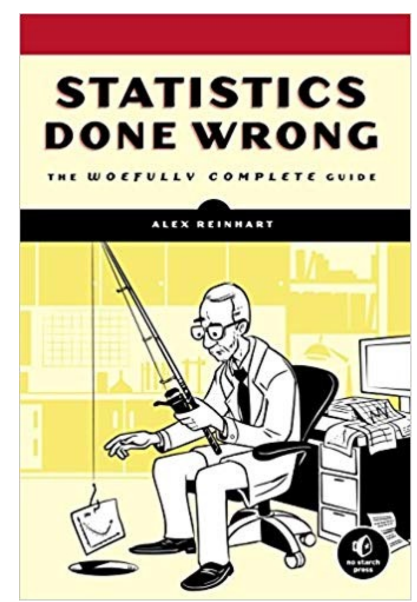


Thinking, Fast and Sl
by Daniel Kahneman

Misconceptions of chance. People expect that a sequence of events generated by a random process will represent the essential characteristics of that process even when the sequence is short. In considering tosses of a coin for heads or tails, for example, people regard the sequence H-T-H-T-T-H to be more likely than the sequence H-H-H-T-T-T, which does not appear random, and also more likely than the sequence H-H-H-H-T-H, which does not represent the fairness of the coin.[7] Thus,

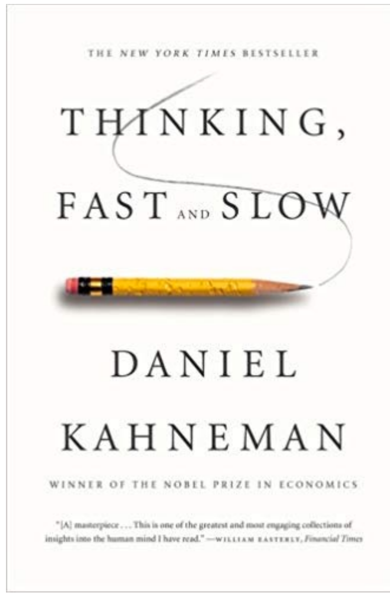


The Visual Display of Quantitative Information
by Edward R. Tufte

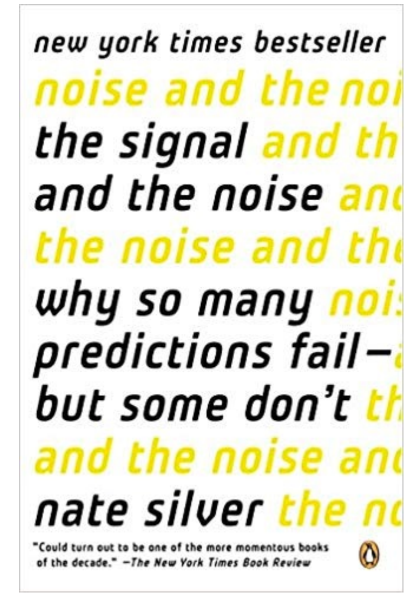


Statistics Done Wrong
by Alex Reinhart

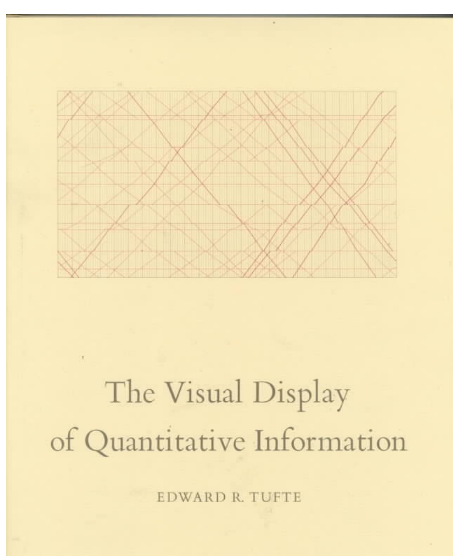
Recommended summer reading



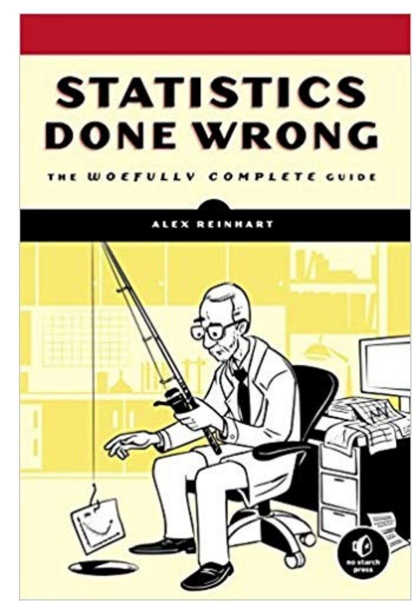
Thinking, Fast and Slow
by Daniel Kahneman



The Signal and the Noise
by Nate Silver



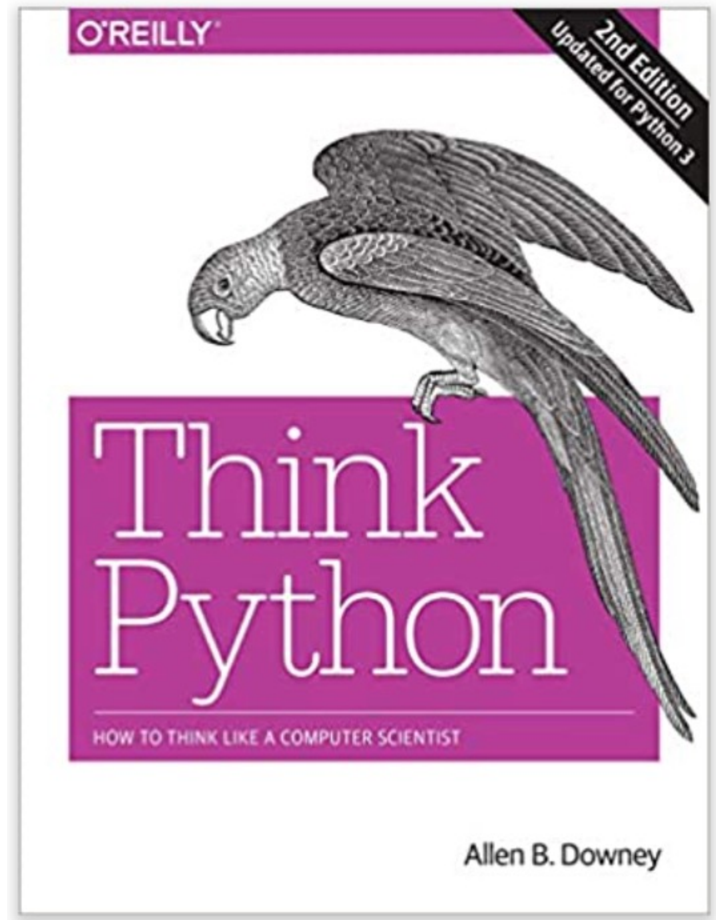
The Visual Display of Quantitative Information
by Edward R. Tufte



Statistics Done Wrong
by Alex Reinhart

Recommended summer reading

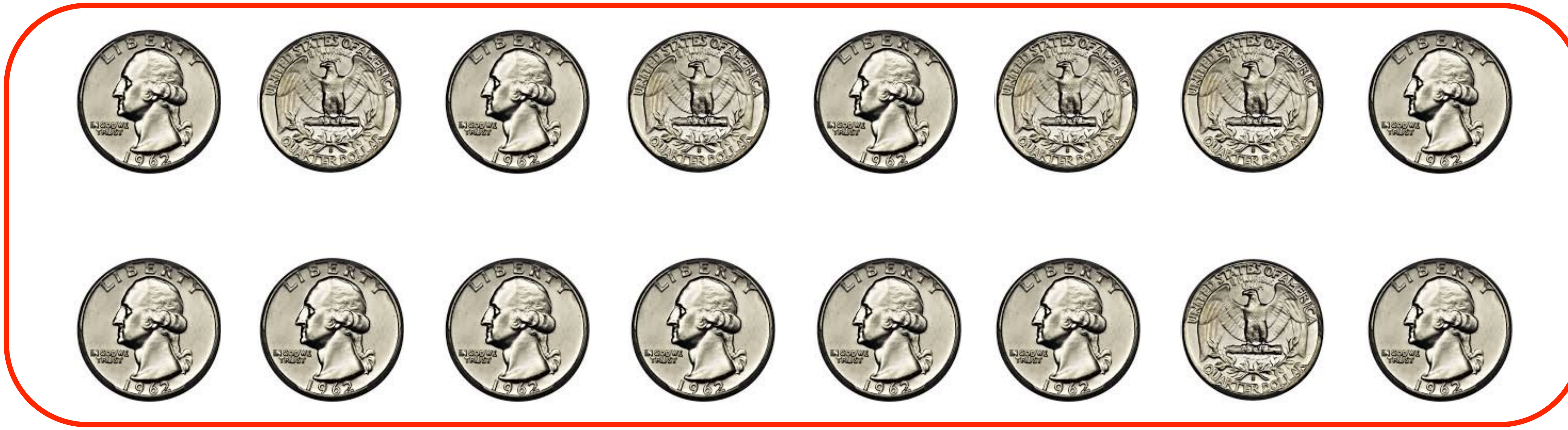
Fluent Python: Clear, Concise, and Effective Programming
by Luciano Ramalho



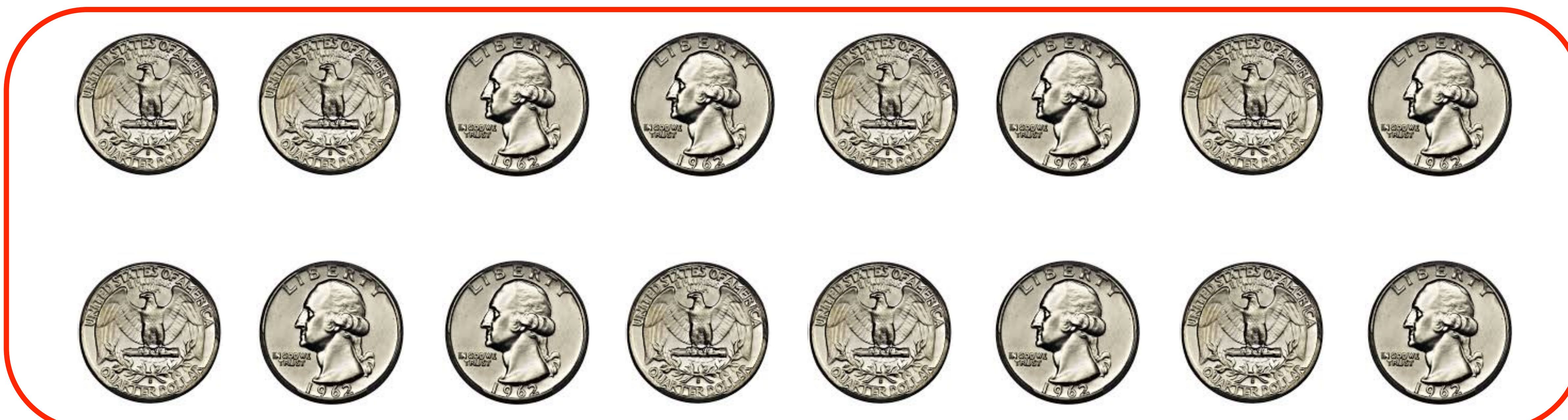
Think Python: How to Think Like a Computer Scientist
by Allen B. Downey

Which series was randomly generated? Which did I pick by hand?

1

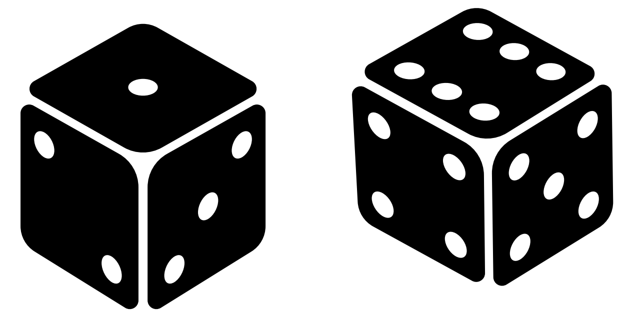


2



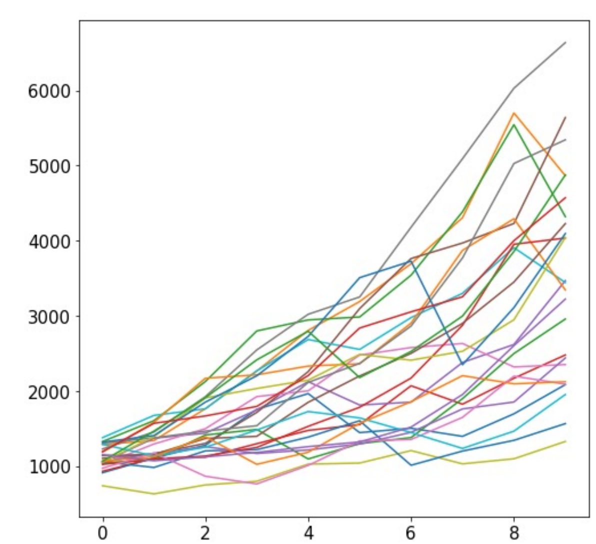
Why Randomize?

Games



Security

Simulation



our focus

Outline

choice()

bugs and seeding

significance

histograms

normal()

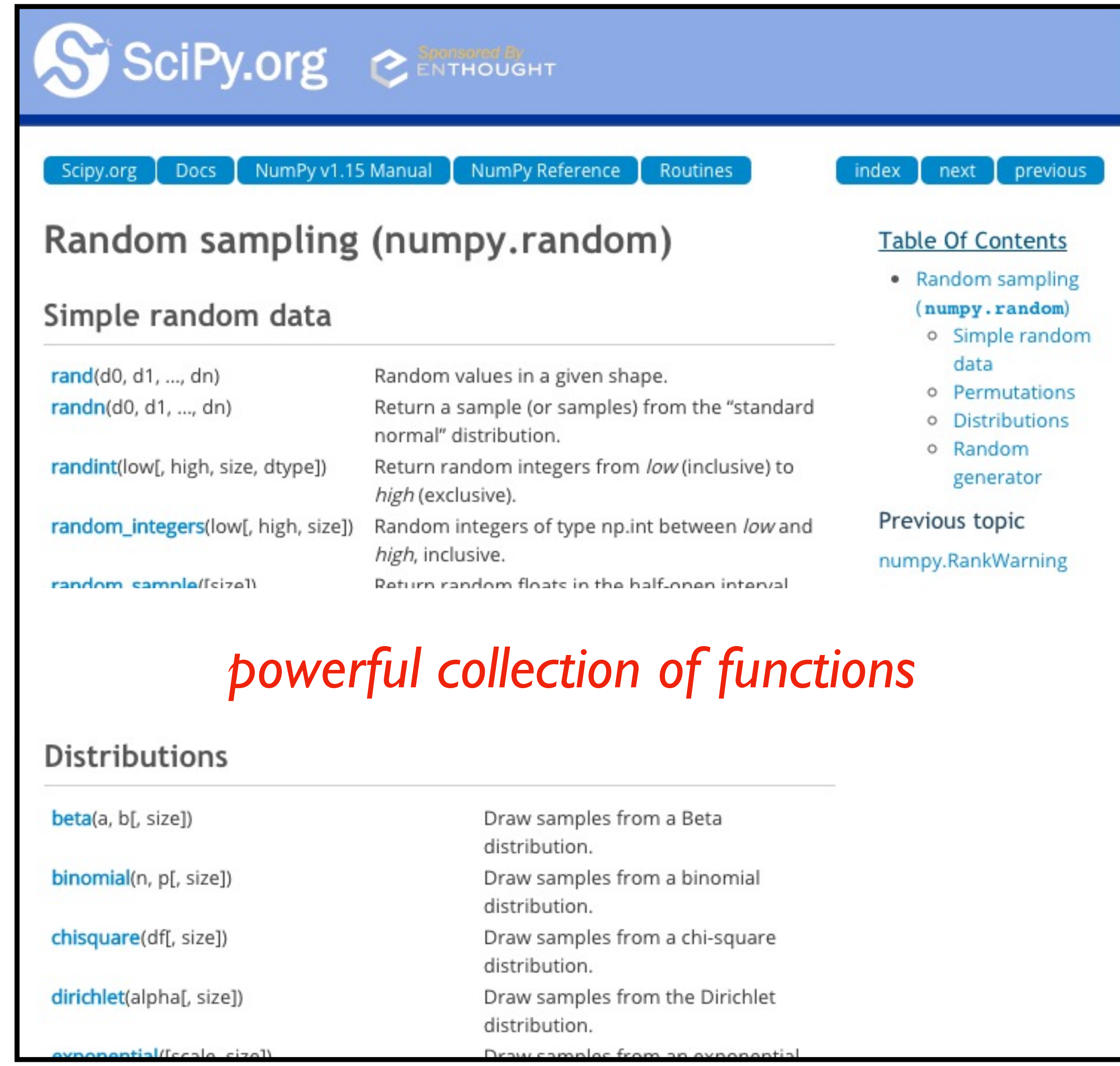
New Functions Today

`numpy.random:`

- powerful collection of functions
- `choice`

`Series.plot.hist:`

- similar to bar plot
- visualize spread of random results



choice

```
from numpy.random import choice

result = choice([<choice1, choice2, …])
```

list of things to randomly choose from

choice

```
from numpy.random import choice

result = choice(["rock", "paper", "scissors"])
```

list of things to randomly choose from

https://www.securifera.com/blog/2015/09/09/mmactf-2015-rock-paper-scissors-rps/

choice

```
from numpy.random import choice

result = choice(["rock", "paper", "scissors"])
print(result)

result = choice(["rock", "paper", "scissors"])
print(result)
```

Output:

```
scissors
rock
```

each time choice is
called, a value is randomly
selected (will vary run to run)

choice

```
from numpy.random import choice

choice(["rock", "paper", "scissors"], size=5)
```

for simulation, we'll often want to compute many random results

choice

```
from numpy.random import choice

choice(["rock", "paper", "scissors"], size=5)
```

```
array(['rock', 'scissors', 'paper', 'rock', 'paper'], dtype='<U8')
```

it's list-like

Random values and Pandas

```
from numpy.random import choice

# random Series
Series(choice(["rock", "paper", "scissors"], size=5))
```

```
0        rock
1        rock
2    scissors
3       paper
4    scissors
dtype: object
```

Random values and Pandas

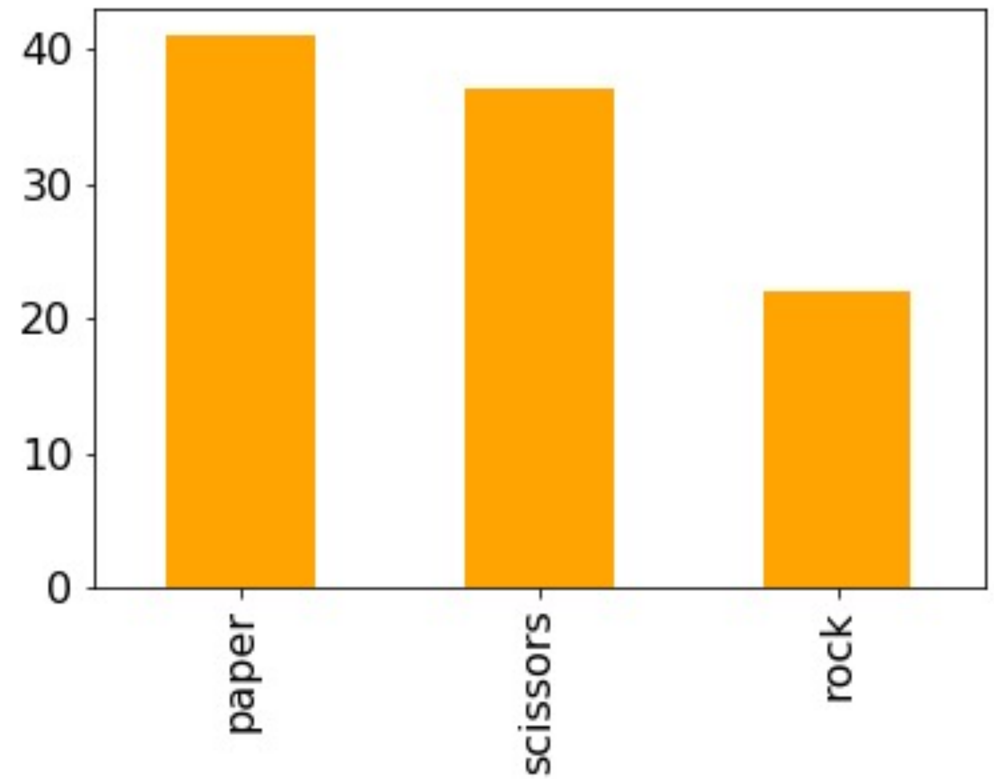
```
from numpy.random import choice

# random Series
DataFrame(choice(["rock", "paper", "scissors"],
                 size=(5,2)))
```

	0	1
0	paper	rock
1	scissors	rock
2	rock	rock
3	scissors	paper
4	rock	scissors

Demo: exploring bias

```
choice(["rock", "paper", "scissors"])
```

Question 1: how can we make sure the randomization isn't biased?

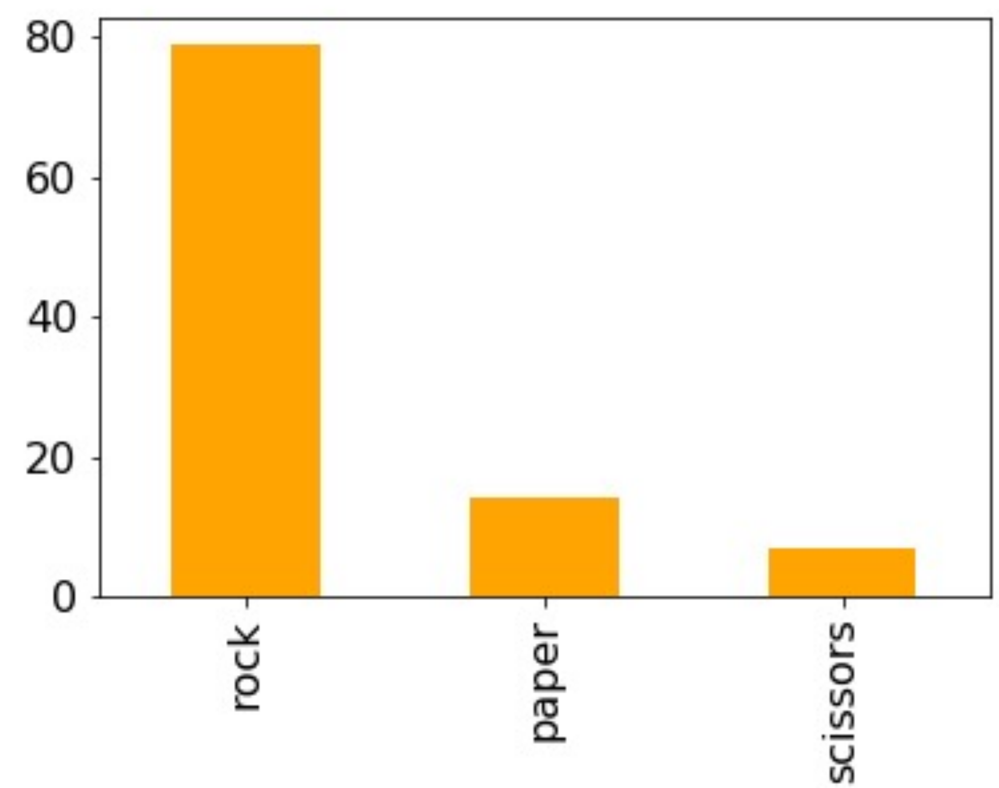


Demo: exploring bias

```
choice(["rock", "paper", "scissors"])
```

Question 1: how can we make sure the randomization isn't biased?

Question 2: how can we make it biased (if we want it to be)?



p=[...]

Random Strings vs. Random Ints

```
from numpy.random import choice, normal

# random string: rock, paper, or scissors
choice(["rock", "paper", "scissors"])

# random int: 0, 1, or 2
choice([0, 1, 2])
```

same

```
# random int (approach 2): 0, 1, or 2
choice(3)
```

random non-negative int
that is **less than 3**

Outline

choice()

bugs and seeding

significance

histograms

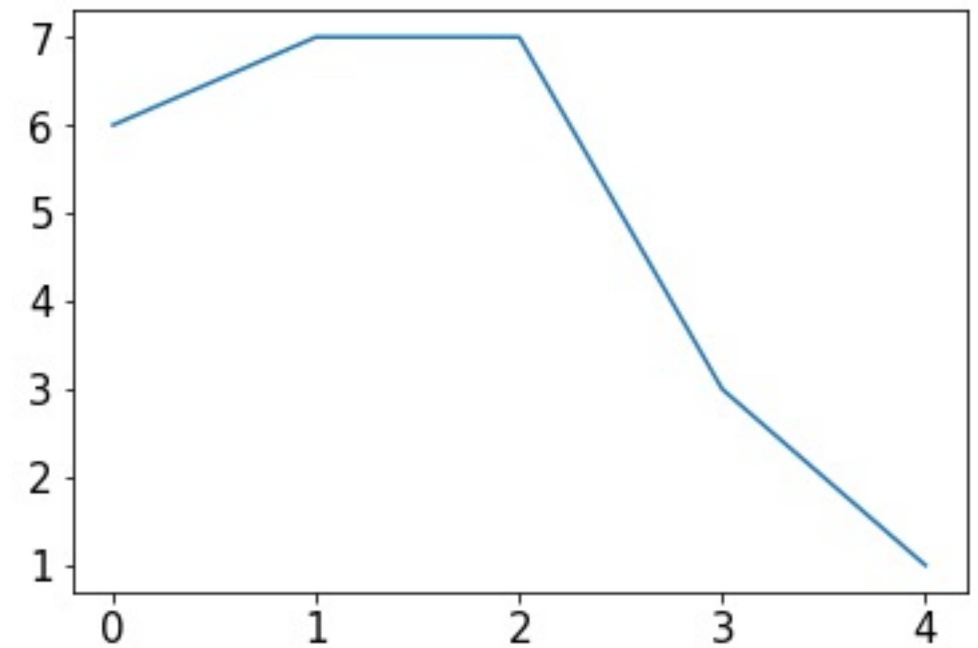
normal()

Example: change over time

```
s = Series(choice(10, size=5))
```

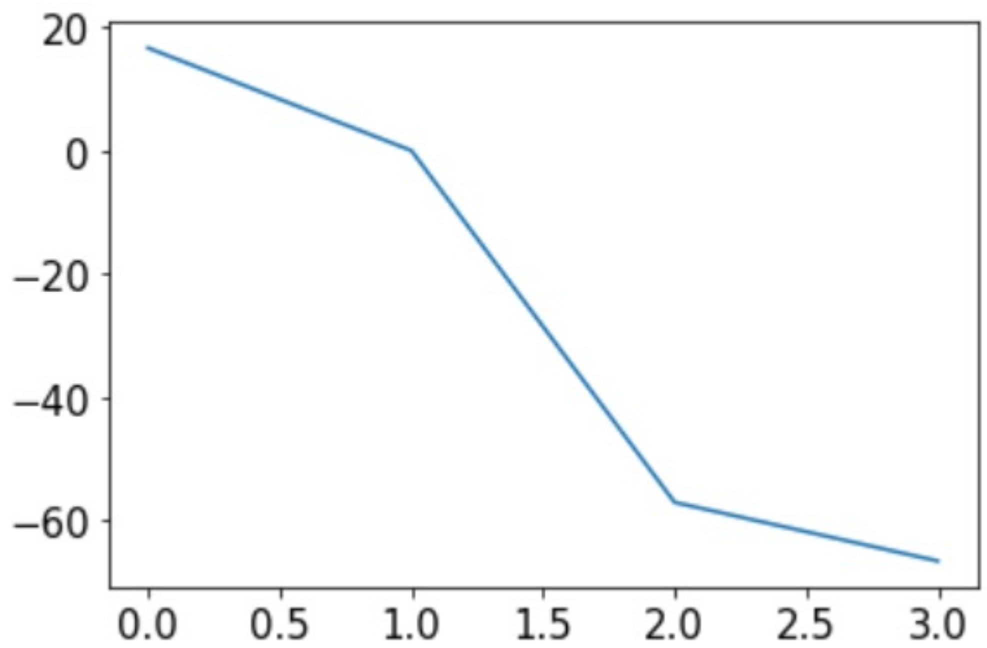
```
0    6
1    7
2    7
3    3
4    1
dtype: int64
```

```
s.plot.line()
```



```
percents = []
for i in range(1, len(s)):
    diff = 100 * (s[i] / s[i-1] - 1)
    percents.append(diff)
Series(percents).plot.line()
```

what are we computing for diff?

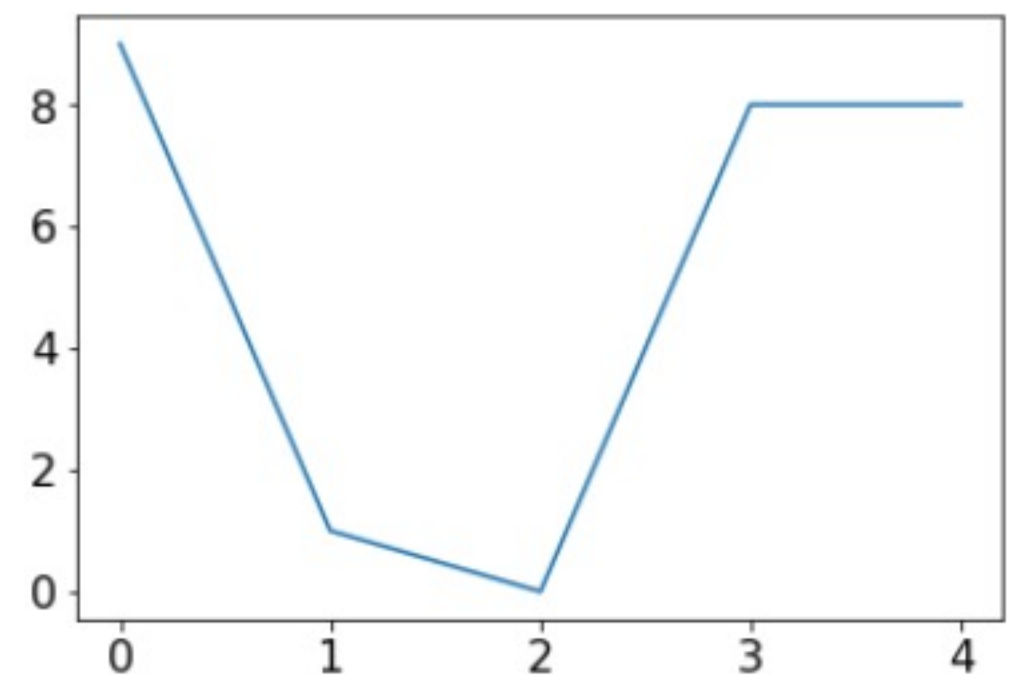


Example: change over time

```
s = Series(choice(10, size=5))
```

```
0     9
1     1
2     0
3     8
4     8
dtype: int64
```

```
s.plot.line()
```




```
percents = []
for i in range(1, len(s)):
    diff = 100 * (s[i] / s[i-1] - 1)
    percents.append(diff)
Series(percents).plot.line()
```

```
/Library/Frameworks/Python.framework/Versions/3.7/lib/
python3.7/site-packages/ipykernel_launcher.py:3: Runti
meWarning: divide by zero encountered in long_scalars
  This is separate from the ipykernel package so we ca
n avoid doing imports until
```

can you identify the bug in the code?

Not all bugs are equal!

scary bugs	**"nice" bugs**
non-deterministic system related randomness	deterministic (reproducible)
large data	small data
semantic	syntax

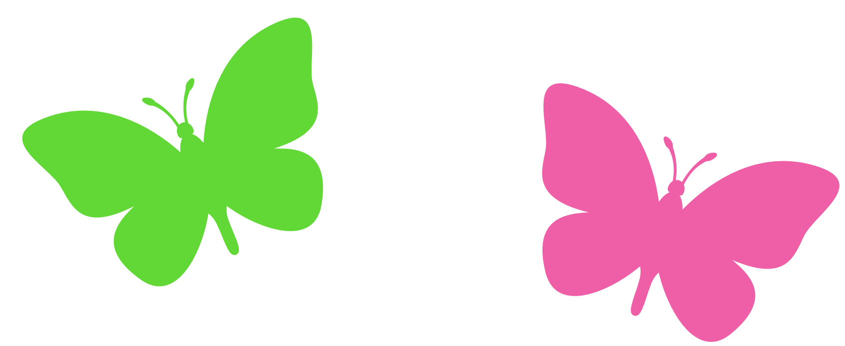
seeding

assert

runtime

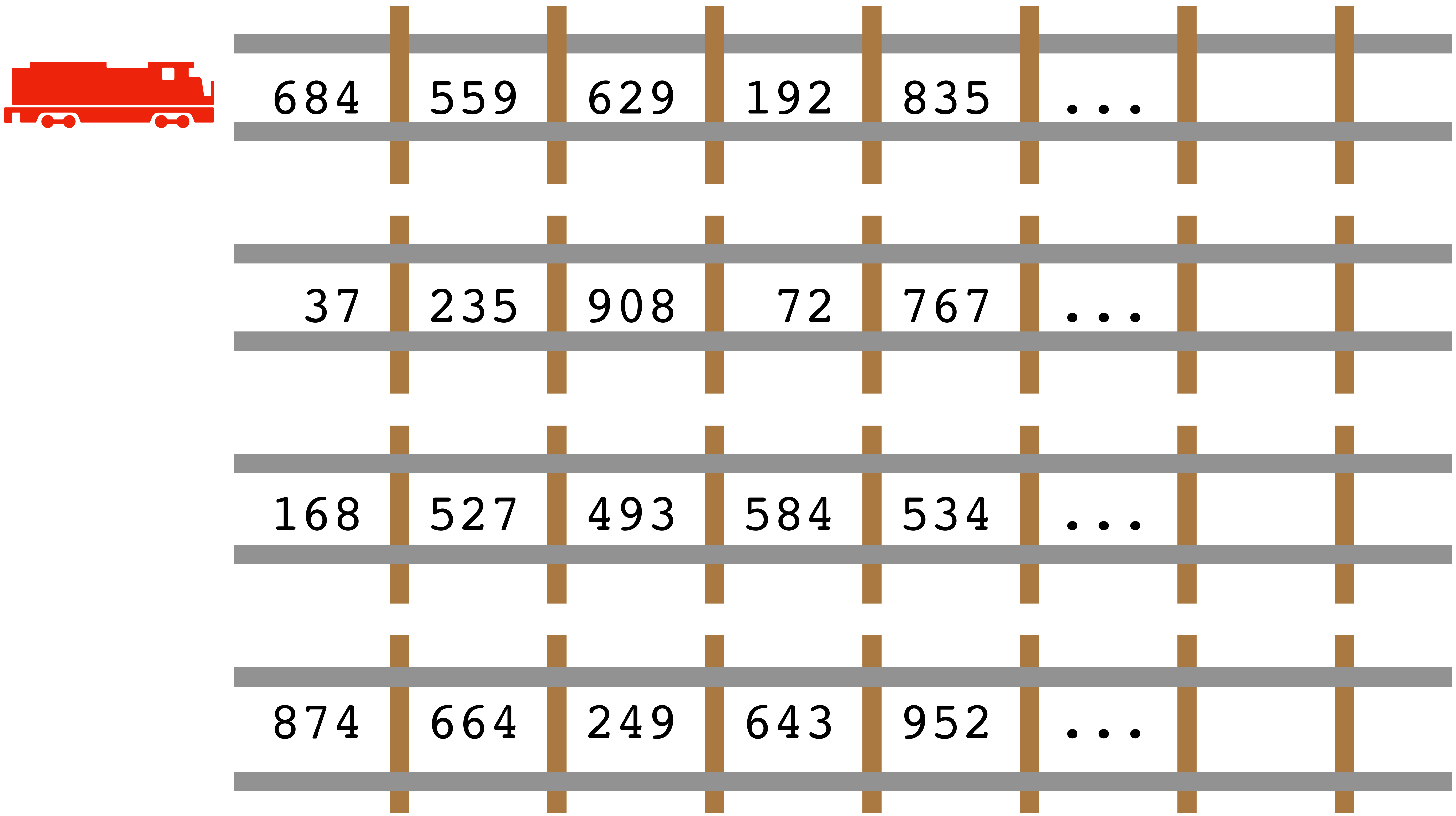
Igor Siwanowicz

https://owlcation.com/stem/5-Badass-Bugs-That-You-Should-Have-Nightmares-About



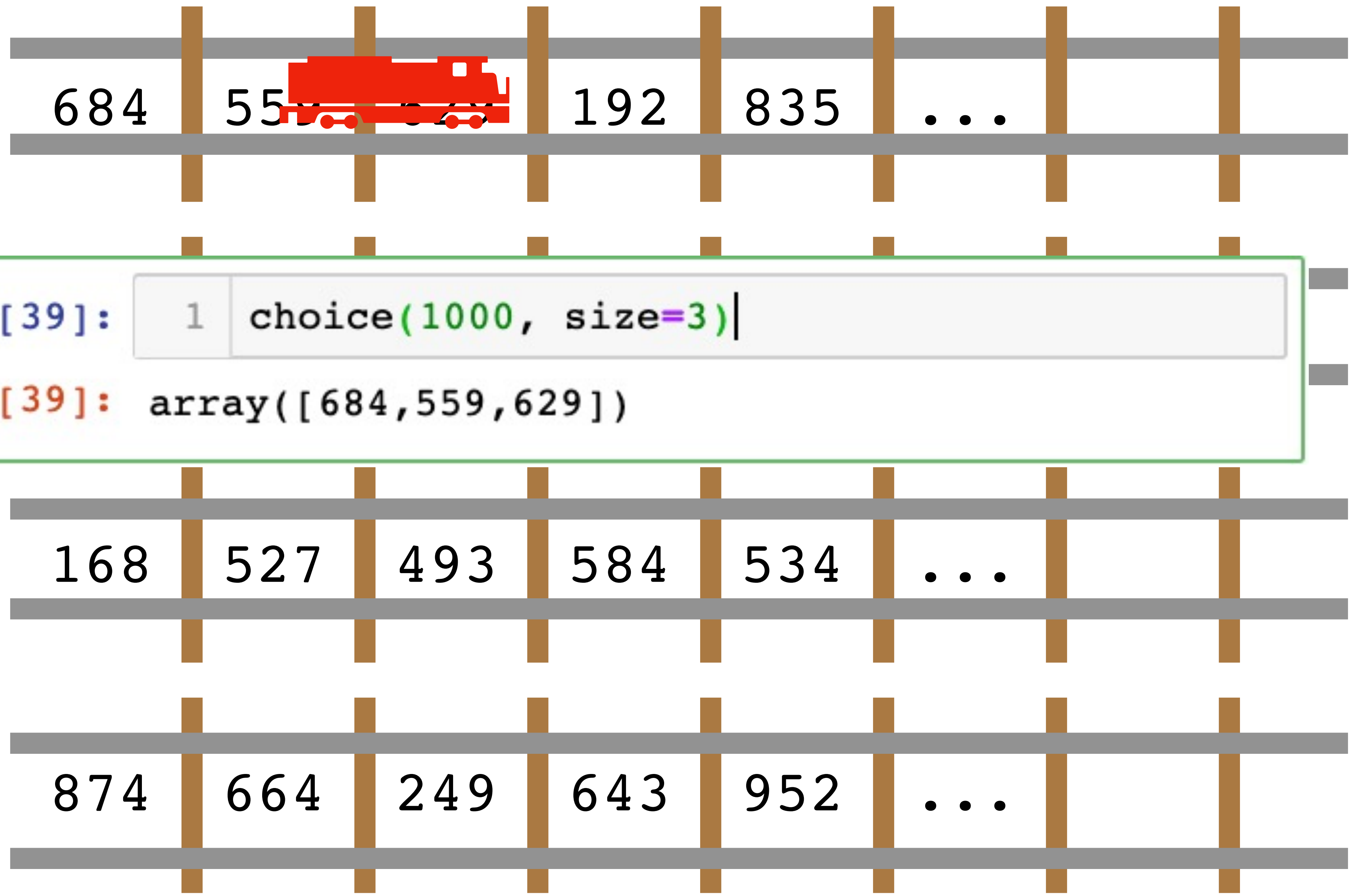
Pseudorandom Generators

"Random" generators are really just *pseudorandom*



Pseudorandom Generators

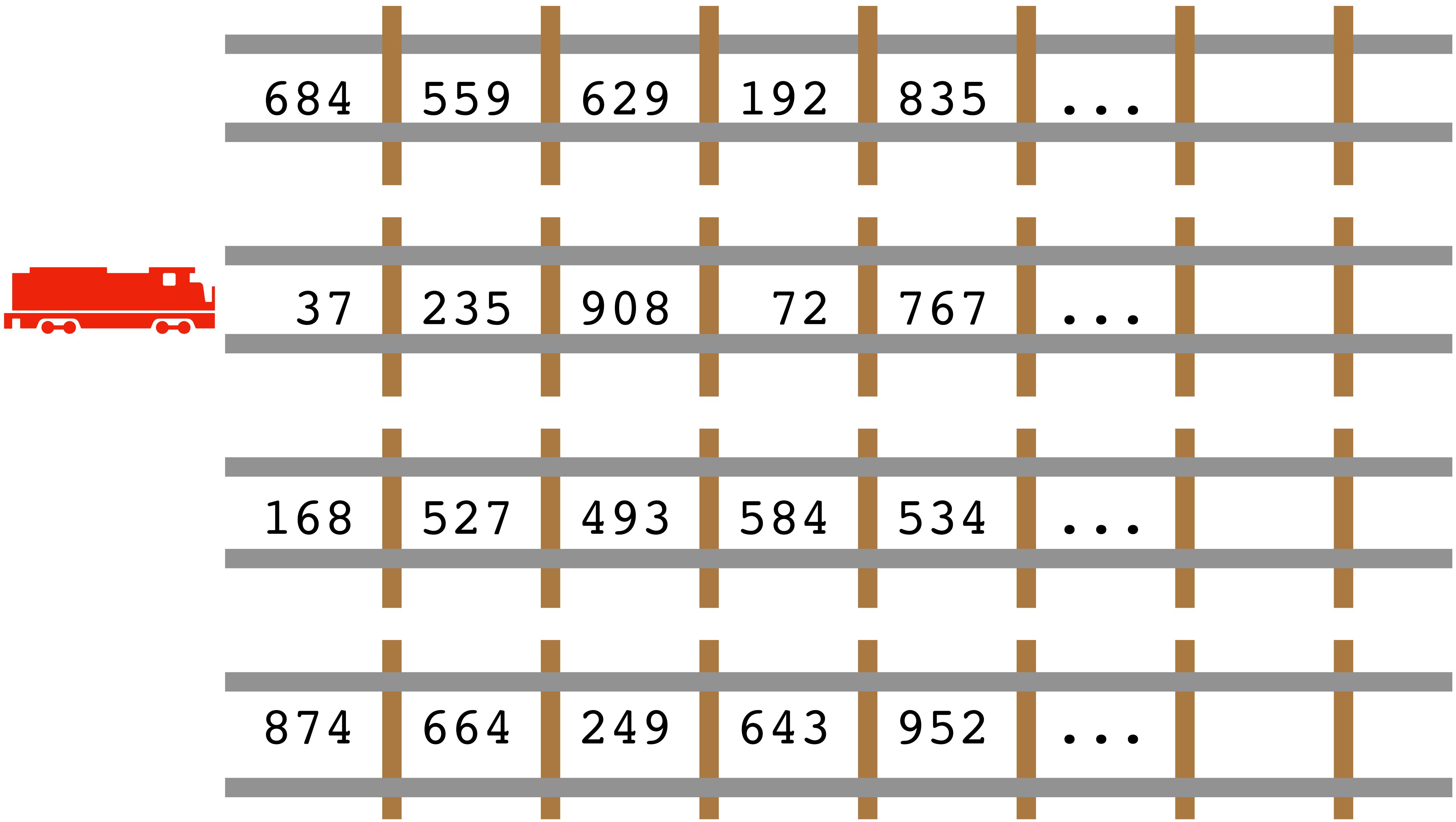
"Random" generators are really just *pseudorandom*




```
In [39]:  choice(1000, size=3)
Out[39]: array([684,559,629])
```

Pseudorandom Generators

"Random" generators are really just *pseudorandom*



Pseudorandom Generators

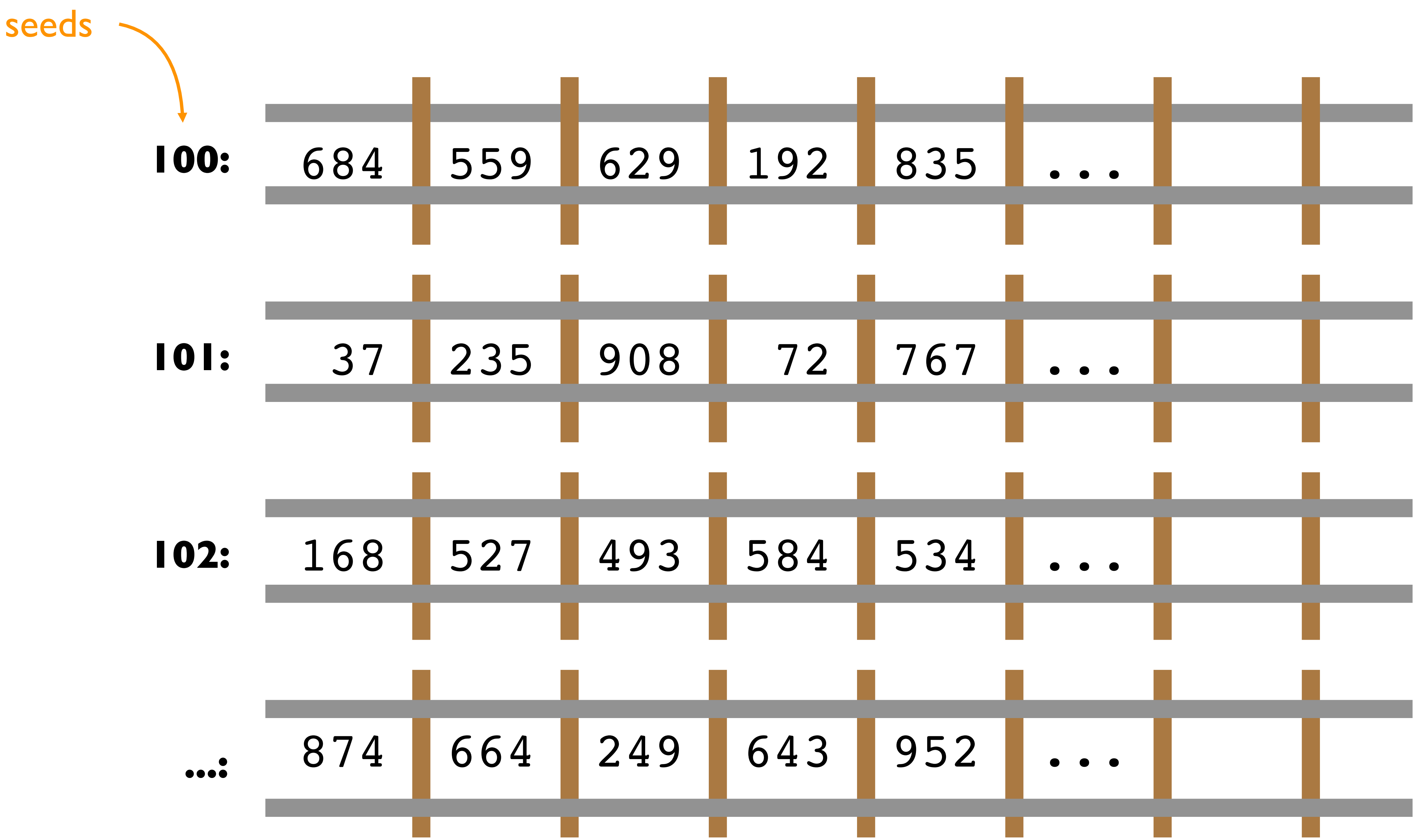
"Random" generators are really just *pseudorandom*

seeds

100:	684	559	629	192	835	...
101:	37	235	908	72	767	...
102:	168	527	493	584	534	...
...:	874	664	249	643	952	...

Pseudorandom Generators

What if I told you that you can **choose** your track?



Seeding

What if I told you that you can **choose** your track?

In [2]:
```
np.random.seed(220)
choice(1000, size = 3)
```
Out[2]:
```
array([883, 732,  15])
```

In [3]:
```
np.random.seed(220)
choice(1000, size = 3)
```
Out[3]:
```
array([883, 732,  15])
```

In [4]:
```
np.random.seed(220)
choice(1000, size = 3)
```
Out[4]:
```
array([883, 732,  15])
```

Seeding

Common approach for simulations:

1. seed using current time
2. print seed
3. use the seed for reproducing bugs, as necessary

In [28]:

```
import time
now = int(time.time())
print("seeding with", now)
np.random.seed(now)
choice(1000, size=3)
```

```
seeding with 1556673136
```

Out[28]:

```
array([352, 734, 362])
```

Outline

choice()

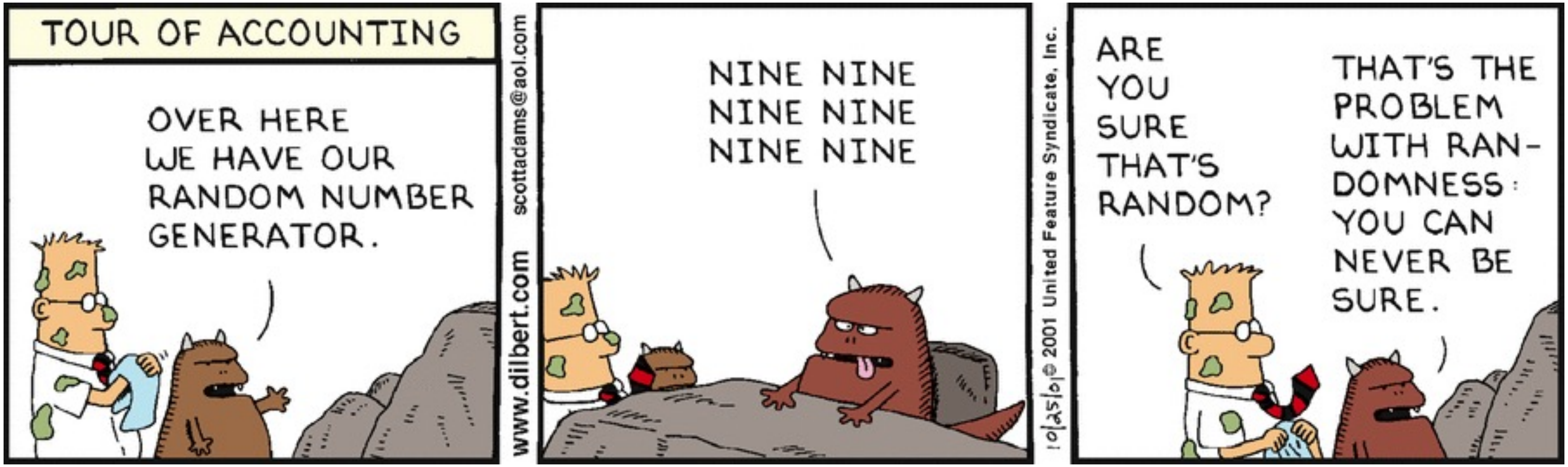
bugs and seeding

significance

histograms

normal()

In a noisy world, what is noteworthy?



https://dilbert.com/strip/2001-10-25

Is this coin biased?

51

49

Call shenanigans?

whoever has the coin cheated
(it's not 50/50 heads/tails)

a statistician might say we're trying to decide if the evidence that the coin isn't fair is **statistically significant**

Is this coin biased?

51 **49**

Call shenanigans? No.

5 **95**

Call shenanigans? Yes.

Note: there is a non-zero probability that a fair coin will do this, but the odds are slim

Is this coin biased?

51 **49**

Call shenanigans? No.

5 **95**

Call shenanigans? Yes.

large skew is good evidence of shenanigans

55 **45**

Call shenanigans? No.

55 million 45 million

Call shenanigans? Yes.

small skew over **large samples** is good evidence

Demo: CoinSim

Call shenanigans?

60 **40**

we got 10 more heads than we expect on average

how common is this?

Strategy: simulate a fair coin

1. "flip" it 100 times using numpy.random.choice
2. count heads
3. repeat above 10K times

```
[50, 61, 51, 44, 39, 43, 51, 49, 49, 38, ...]
```

11 more 12 less

Outline

choice()

bugs and seeding

significance

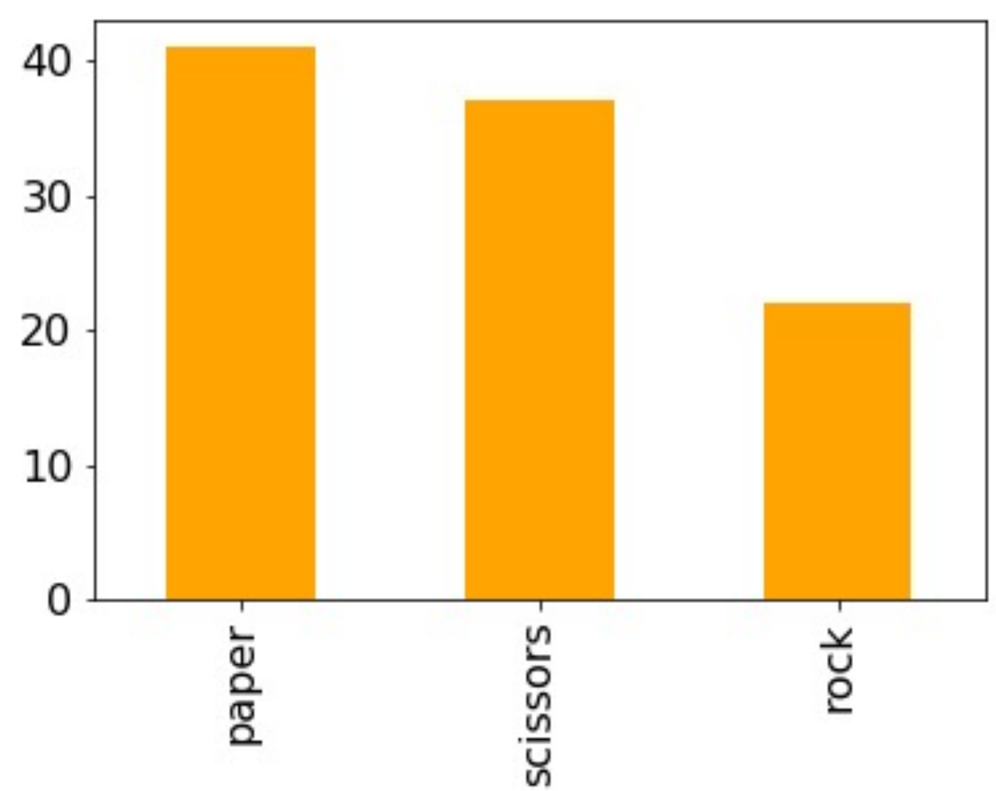
histograms

normal()

Frequencies across categories

bars are a good way to view frequencies across categories

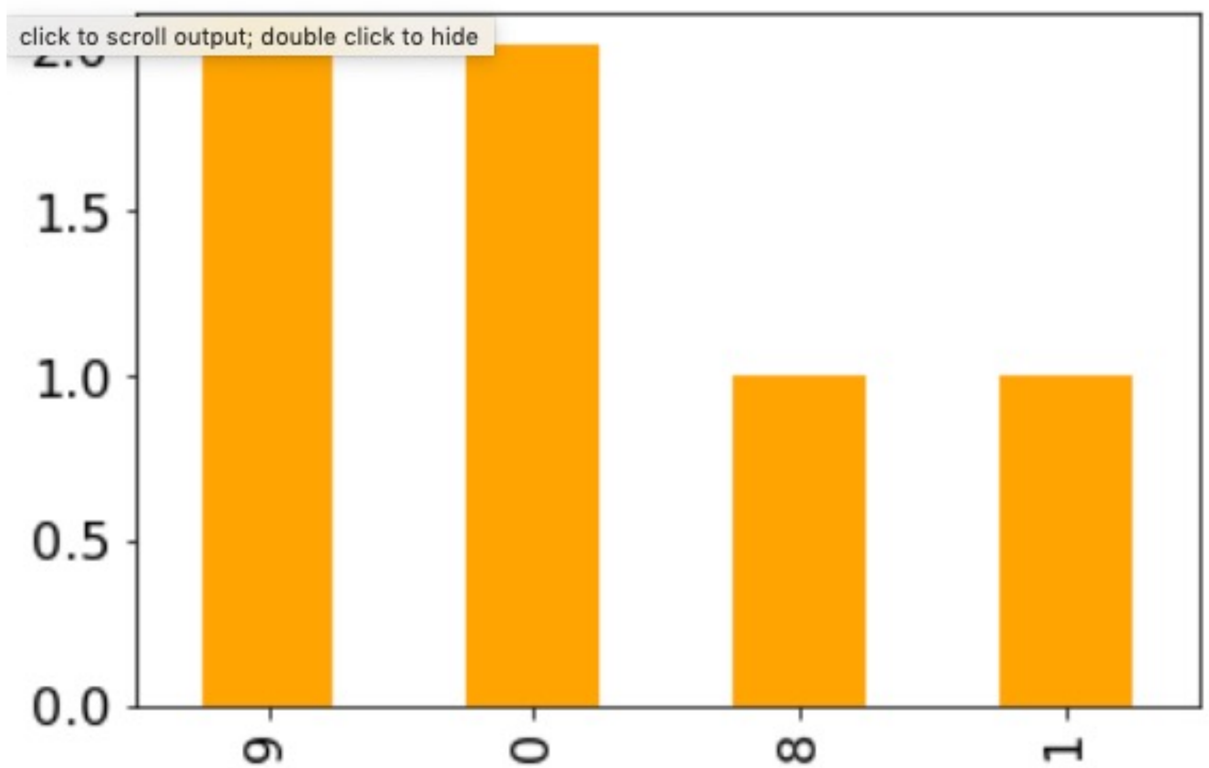
```
s = Series(["rock", "rock", "paper",
            "scissors", "scissors", "scissors"])

s.value_counts().plot.bar(color="orange")
```



Frequencies across numbers

bars are a bad way to view frequencies across numbers

```
s = Series([0, 0, 1, 8, 9, 9])

s.value_counts().plot.bar(color="orange")
```

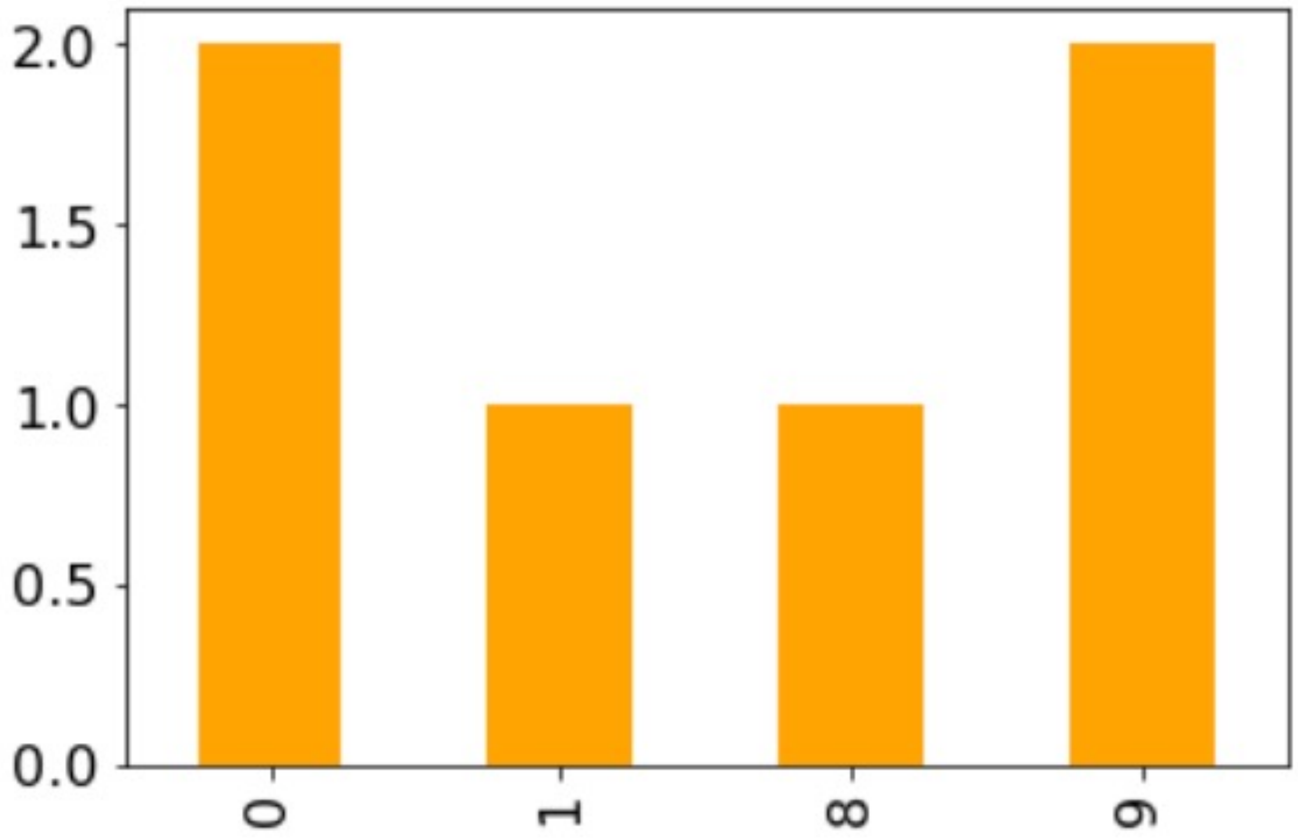


numbers not ordered

Frequencies across numbers

bars are a bad way to view frequencies across numbers

```
s = Series([0, 0, 1, 8, 9, 9])

s.value_counts().sort_index().plot.bar(color="orange")
```



gap between 1 and 8 not obvious

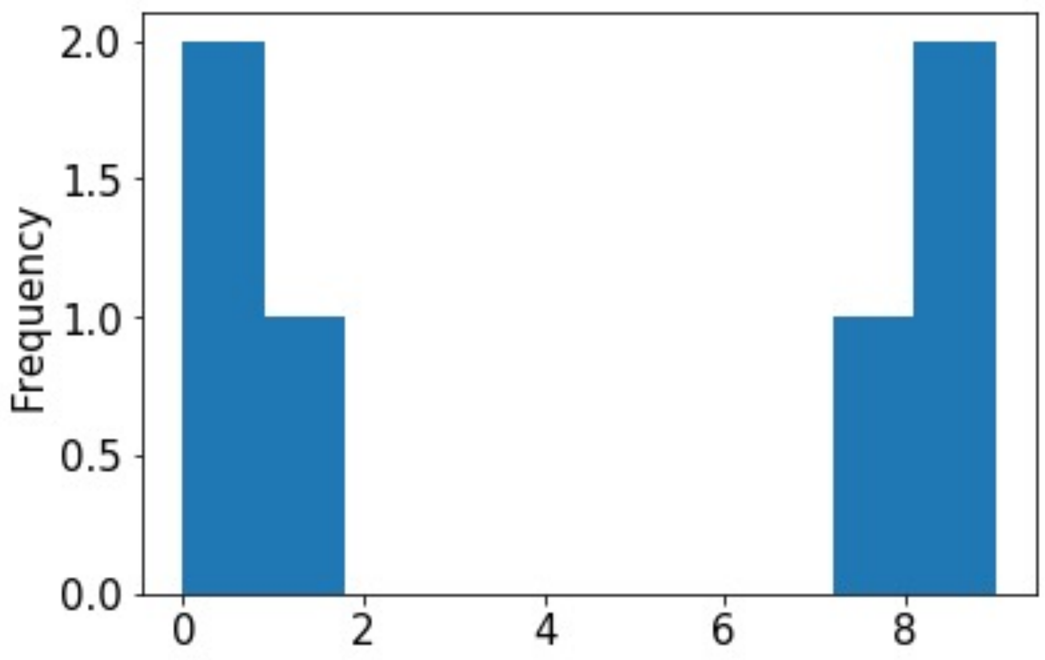
Frequencies across numbers

bars are a bad way to view frequencies across numbers

```
s = Series([0, 0, 1, 8, 9, 9])
```

~~`s.value_counts().sort_index().plot.bar()`~~

```
s.plot.hist()
```



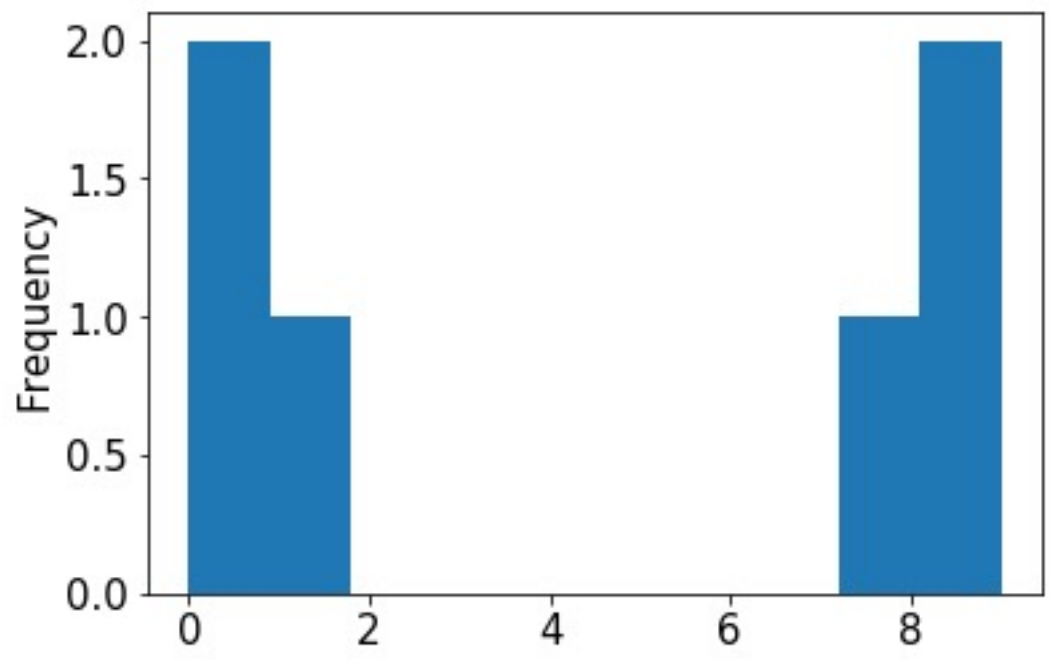
Frequencies across numbers

histograms are a good way to view frequencies across numbers

```
s = Series([0, 0, 1, 8, 9, 9])
```

~~`s.value_counts().sort_index().plot.bar()`~~

```
s.plot.hist()
```



this kind of plot is called a histogram

Frequencies across numbers

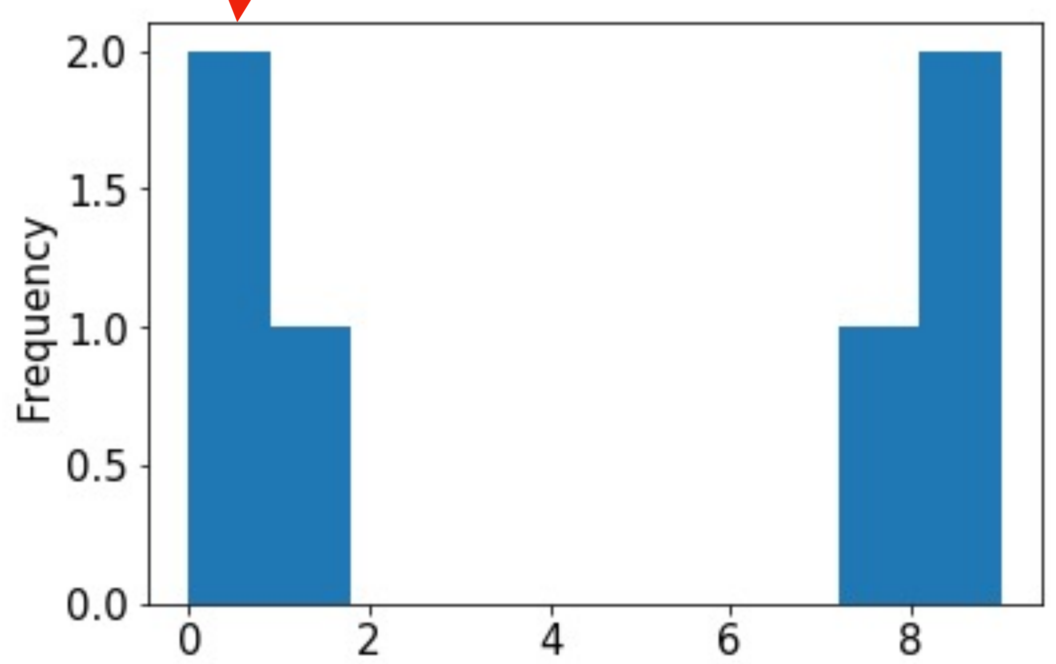
histograms are a good way to view frequencies across numbers

```
s = Series([0.1, 0, 1, 8, 9, 9.2])
```

~~s.value_counts().sort_index().plot.bar()~~

```
s.plot.hist()
```

both 0 and 0.1

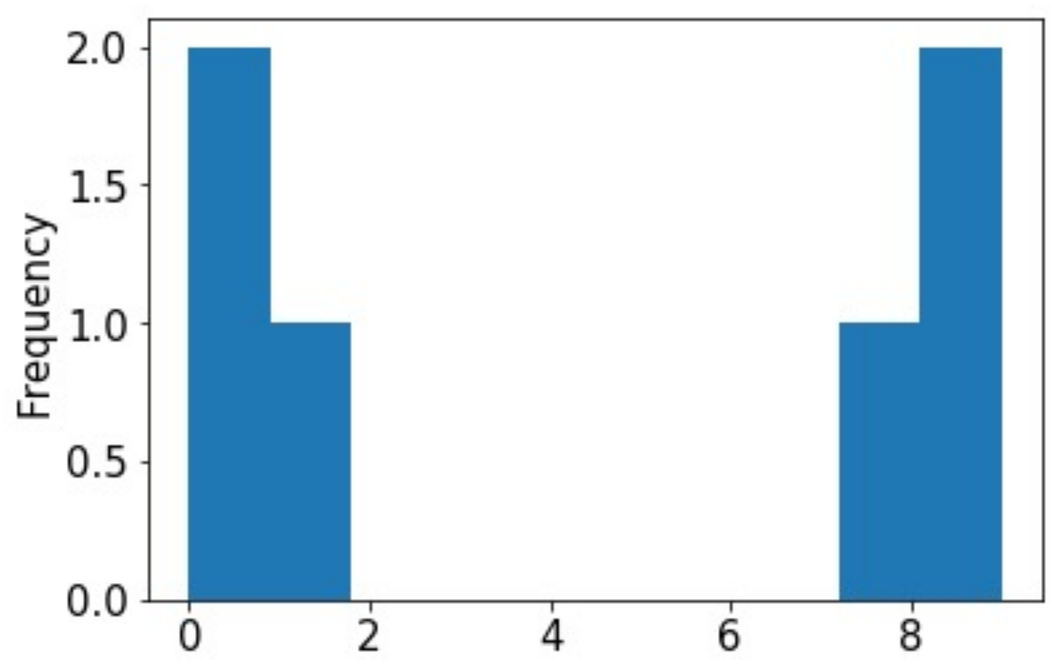


a histogram "bins" nearby numbers to create discrete bars

Frequencies across numbers

histograms are a good way to view frequencies across numbers

```
s = Series([0.1, 0, 1, 8, 9, 9.2])

s.value_counts().sort_index().plot.bar()
s.plot.hist(bins=10)
```



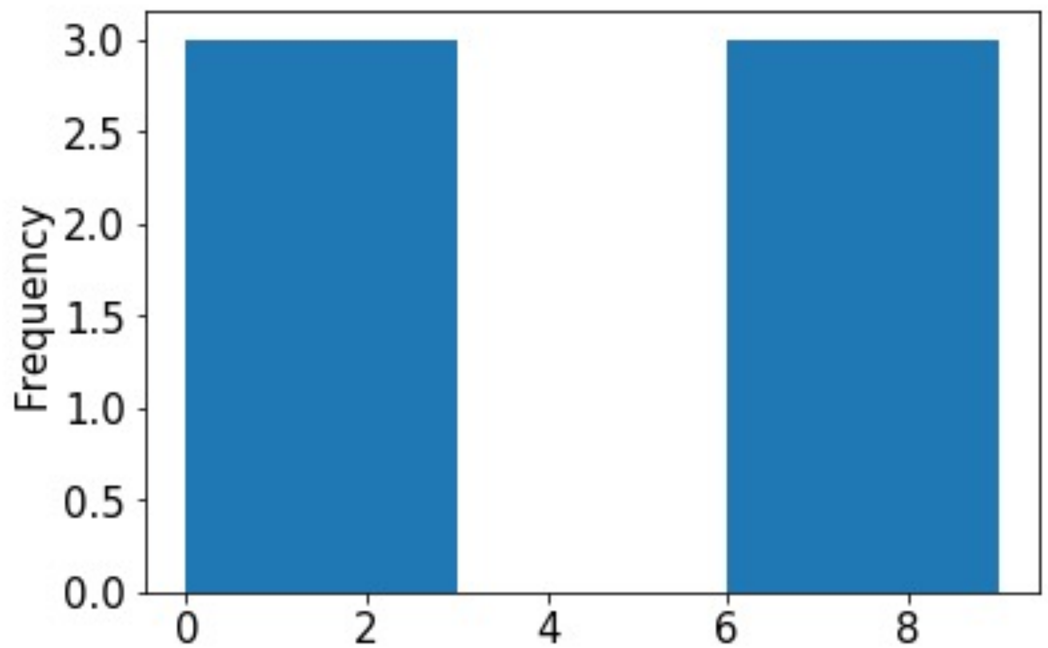
we can control the number of bins

Frequencies across numbers

histograms are a good way to view frequencies across numbers

```
s = Series([0.1, 0, 1, 8, 9, 9.2])
```

```
s.value_counts().sort_index().plot.bar()
s.plot.hist(bins=3)
```

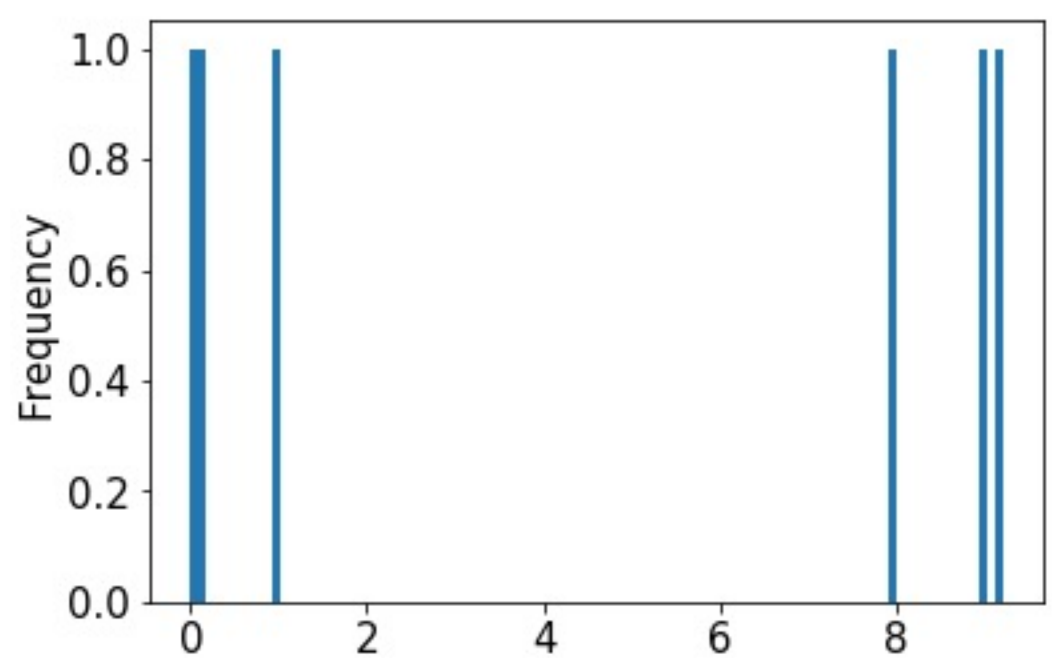


too few bins provides too little detail

Frequencies across numbers

histograms are a good way to view frequencies across numbers

```
s = Series([0.1, 0, 1, 8, 9, 9.2])

s.value_counts().sort_index().plot.bar()
s.plot.hist(bins=100)
```

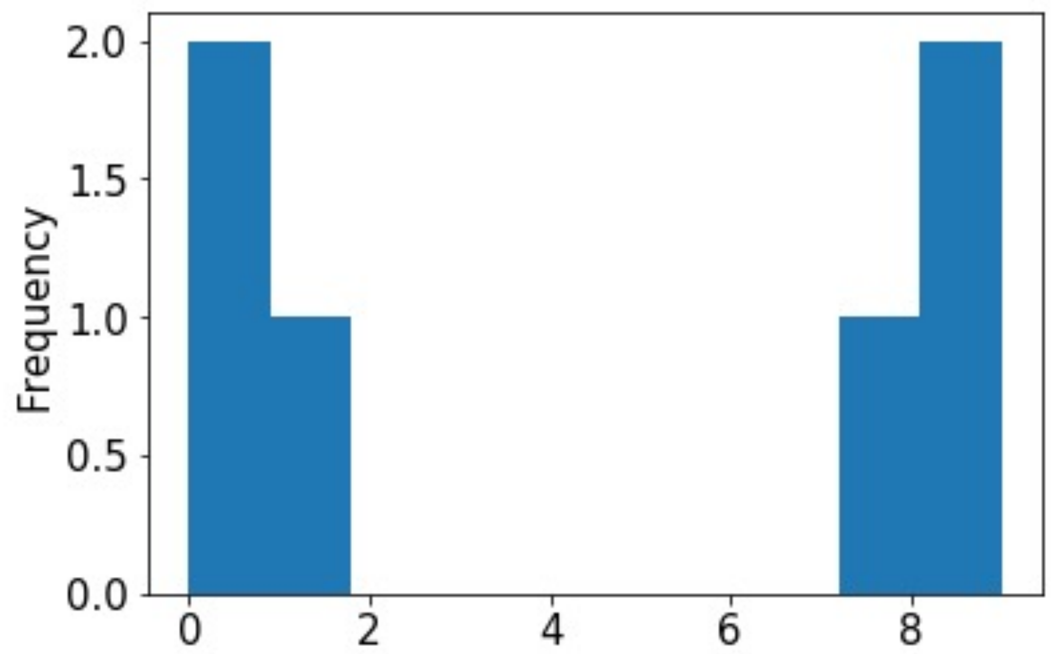


too many bins provides too much detail (equally bad)

Frequencies across numbers

histograms are a good way to view frequencies across numbers

```
s = Series([0.1, 0, 1, 8, 9, 9.2])

s.value_counts().sort_index().plot.bar()
s.plot.hist(bins=10)
```



pandas chooses the default bin boundaries

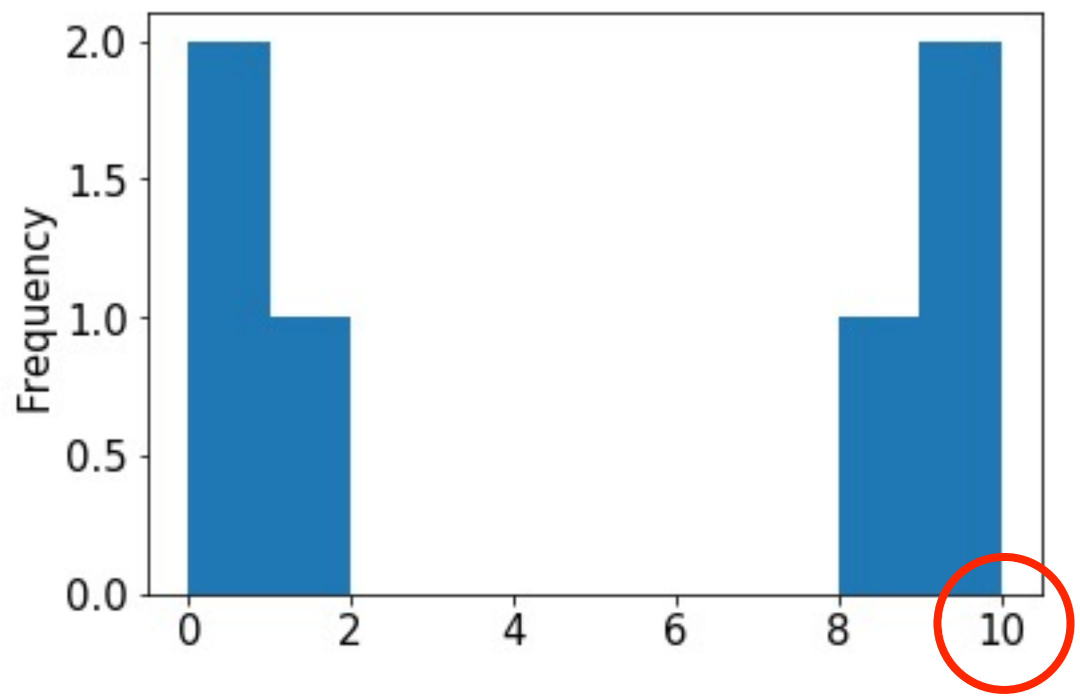
Frequencies across numbers

histograms are a good way to view frequencies across numbers

```
s = Series([0.1, 0, 1, 8, 9, 9.2])
```

~~s.value_counts().sort_index().plot.bar()~~

```
s.plot.hist(bins=[0,1,2,3,4,5,6,7,8,9,10])
```

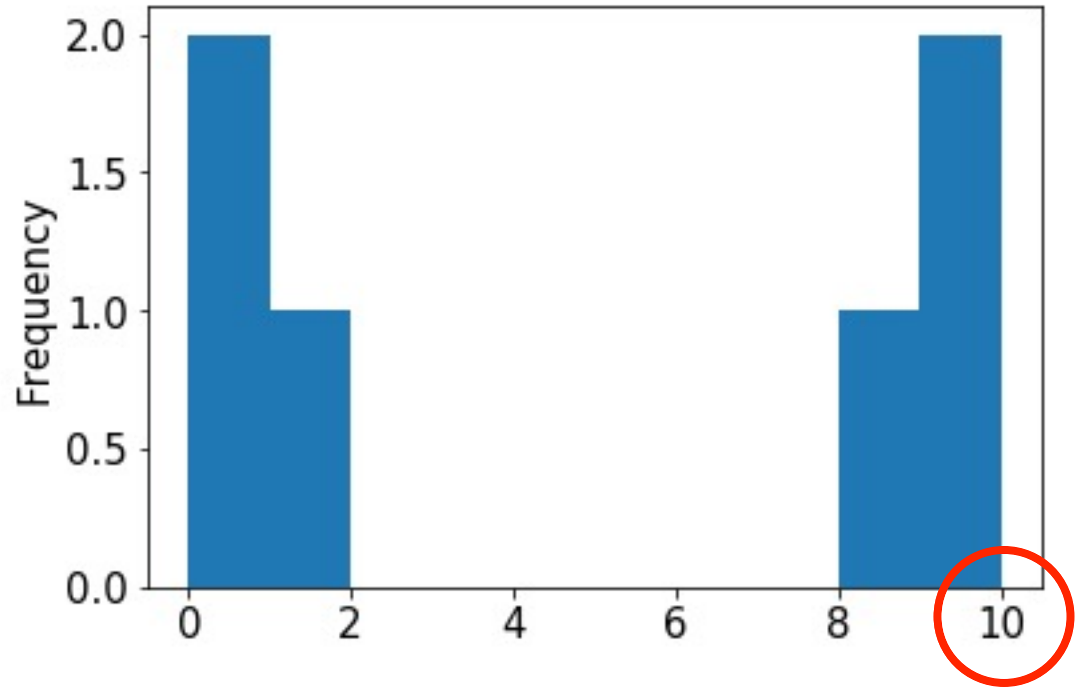


we can override the defaults

Frequencies across numbers

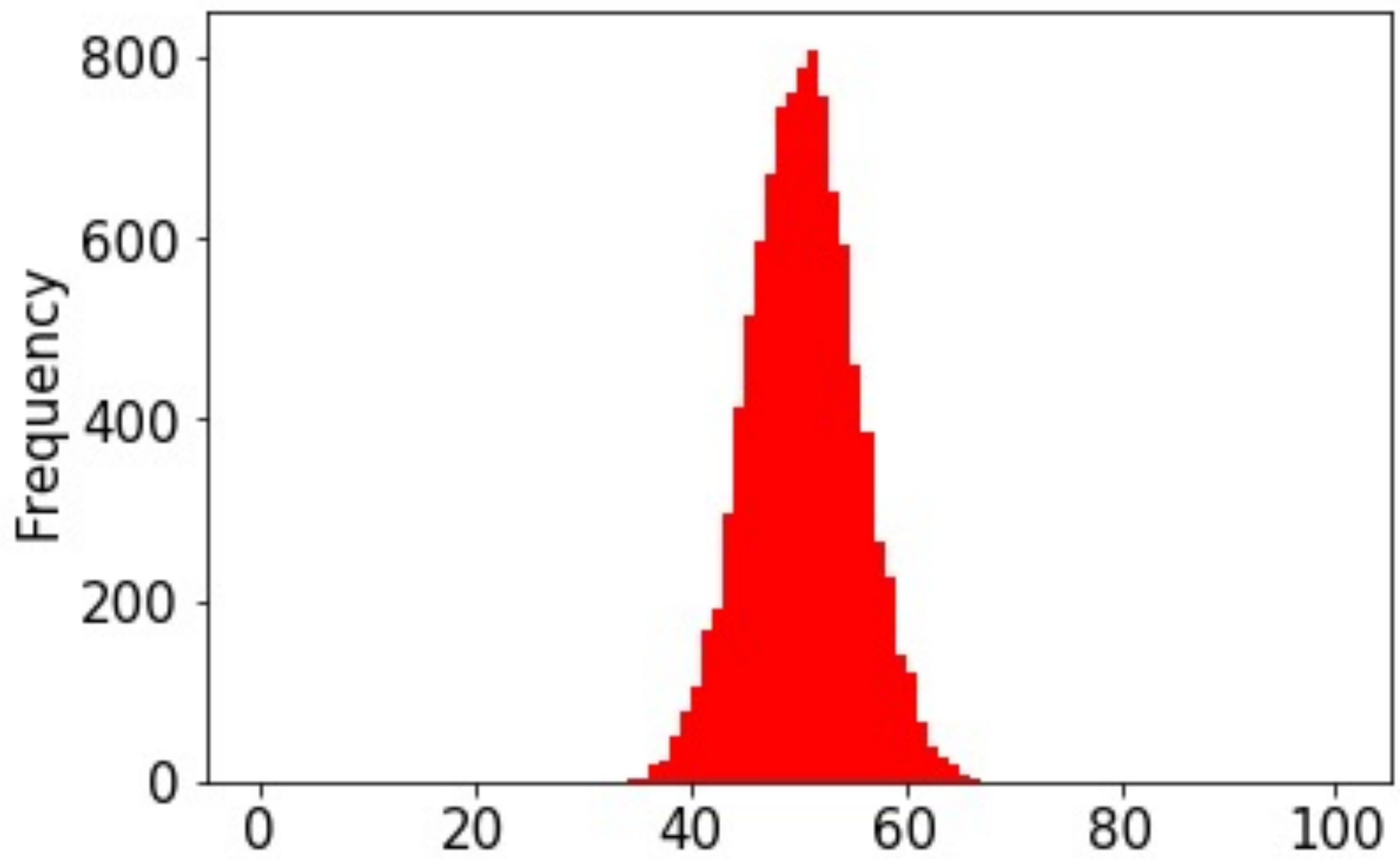
histograms are a good way to view frequencies across numbers

```
s = Series([0.1, 0, 1, 8, 9, 9.2])

s.value_counts().sort_index().plot.bar()
s.plot.hist(bins=range(11))
```



this is easily done with range

Demo: Visualize CoinSim Results



number of heads (out of 100)

numpy can directly generate random numbers fitting a normal distribution

this shape resembles what we often call a normal distribution or a "bell curve"

in general, if we take large samples enough times, the sample averages will look like this (we won't discuss exceptions here)

Outline

choice()

bugs and seeding

significance

histograms

normal()

normal

```
from numpy.random import choice, normal
import numpy as np

for i in range(10):
    print(normal())
```

Output:

```
-0.18638553993371157
0.028884529167692474
1.247456111372642
-0.5388224399358179
-0.4514332213638852
-1.4001861112018241
0.2811937151186804
0.260886189855659
-0.19246288728955144
0.2979572961710292
```

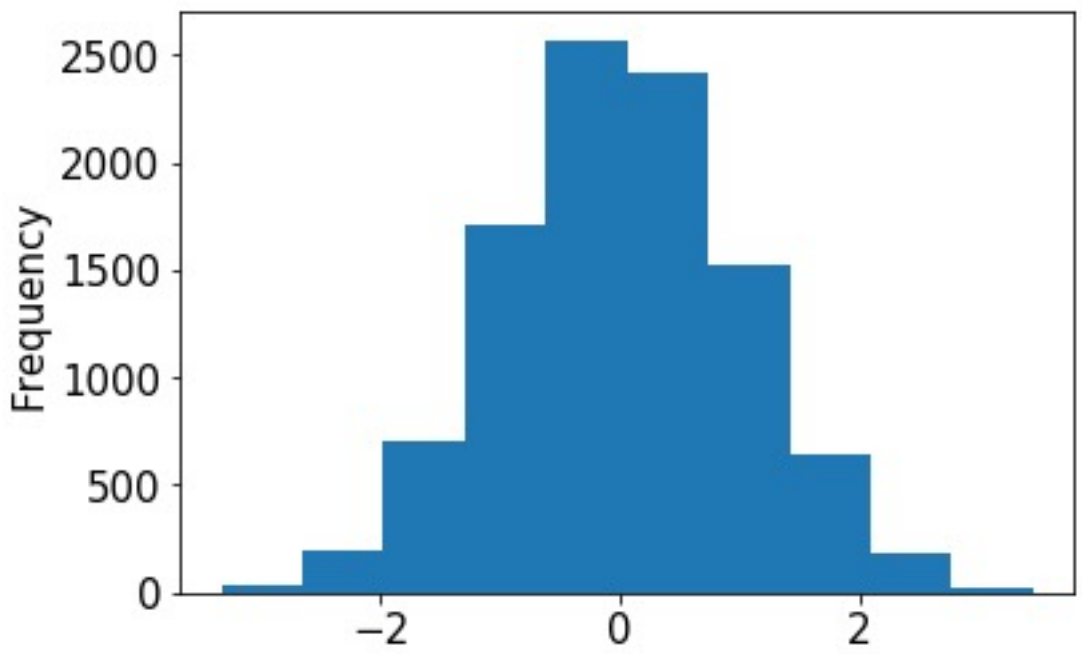
average is 0 (over many calls)

numbers closer to 0 more likely

-x just as likely as x

normal

```
from numpy.random import choice, normal
import numpy as np

s = Series(normal(size=10000))

s.plot.hist()
```



normal

```
from numpy.random import choice, normal
import numpy as np

s = Series(normal(size=10000))

s.plot.hist(bins=100)
```