Find the Pattern

Efficient Phrases

UNCONSCIOUS OMISSION

COLD WINDOWSILL

INSIDIOUS DOMINION

VOLUMINOUS PILLOWS

VIVID DISILLUSIONS

Data Structures

April 11, 2017

Welcome Back!

Recall

Efficient Phrases

UNCONSCIOUS OMISSION

COLD WINDOWSILL

INSIDIOUS DOMINION

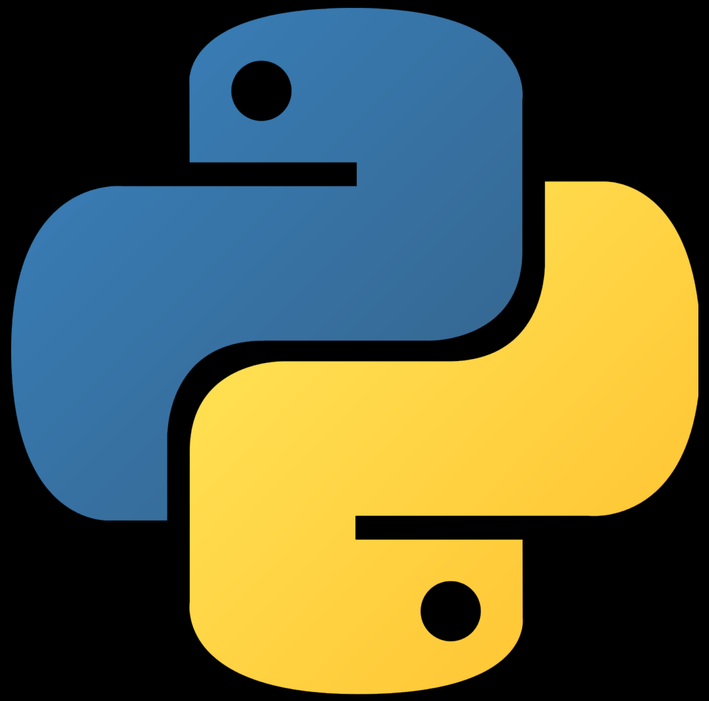
VOLUMINOUS PILLOWS

VIVID DISILLUSIONS

Made only of BCDGIJLMNOPSUVWZ

Time Out for Announcements

Setting up Python

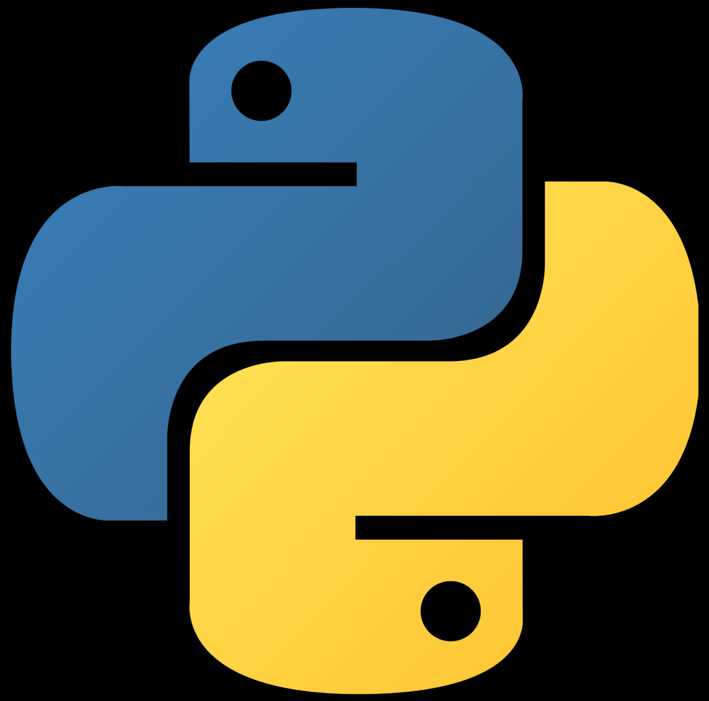


Python 3.4.3

Virtual Environments

Need help? See us after.

Assignment 0



Q and A for a few Qs

Due tonight @ midnight

Submit via AFS

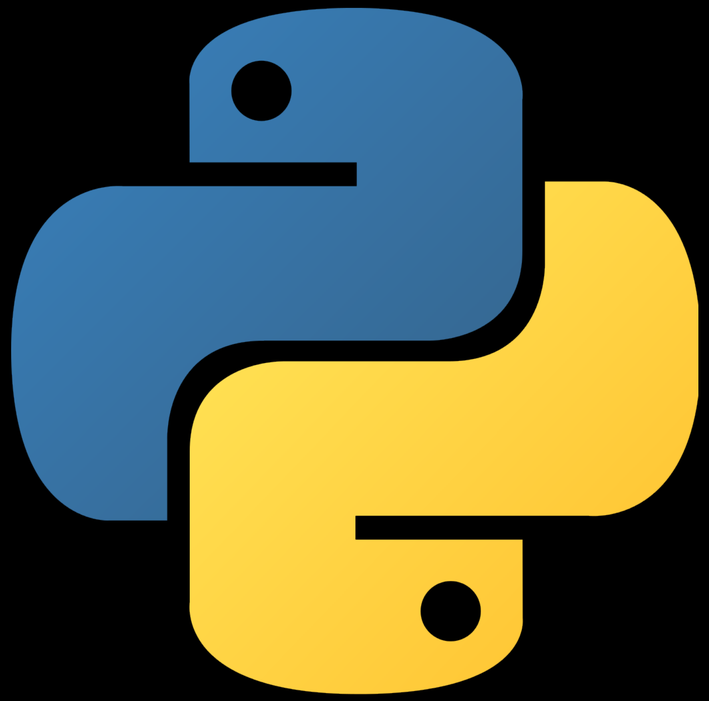
Piazza

CS 41 on Piazza

Course announcements

Enroll and ask questions

Assignment 1



Cryptography Suite!

Caesar, Vigenère, MHKC

Submission on AFS

Thursday's Lab

Practice fundamentals

"Sections" with course staff

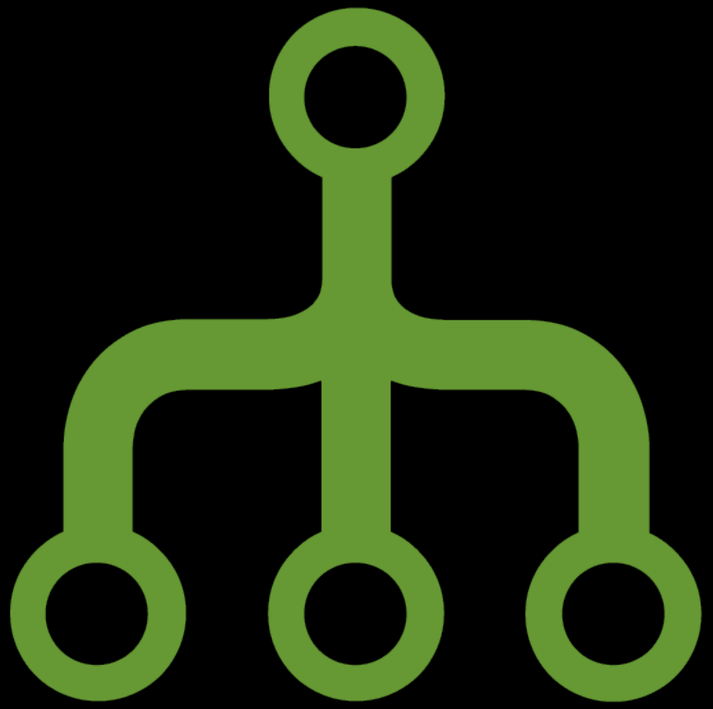
Bring a charged computer!

Enrollment Update

Back to Python!*

* Follow along with the examples!

Data Structures



Lists

Dictionaries

Tuples

Sets

Advanced Looping

Comprehensions

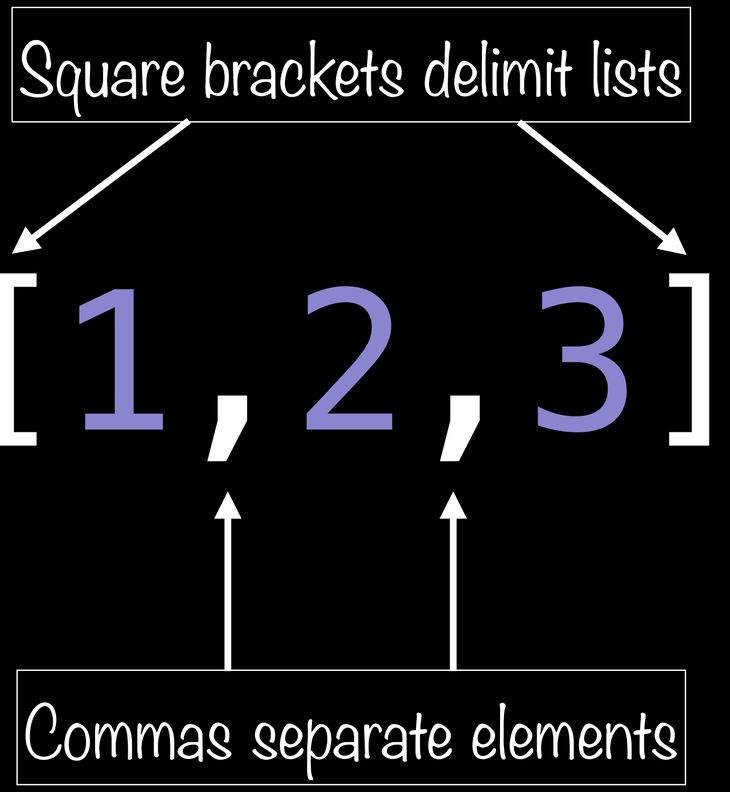
Lists

Finite, ordered, mutable sequence of elements

List

Lists

```
easy_as = [1,2,3]
```



Basic Lists

```
# Create a new list
empty = []
letters = ['a', 'b', 'c', 'd']
numbers = [2, 3, 5]

# Lists can contain elements of different types
mixed = [4, 5, "seconds"]

# Append elements to the end of a list
numbers.append(7)   # numbers == [2, 3, 5, 7]
numbers.append(11)  # numbers == [2, 3, 5, 7, 11]
```

Inspecting List Elements

```
# Access elements at a particular index
numbers[0]  # => 2
numbers[-1]  # => 11

# You can also slice lists - the usual rules apply
letters[:3]  # => ['a', 'b', 'c']
numbers[1:-1]  # => [3, 5, 7]
```

Nested Lists

```
# Lists really can contain anything – even other lists!
x = [letters, numbers]
x  # => [['a', 'b', 'c', 'd'], [2, 3, 5, 7, 11]]
x[0]  # => ['a', 'b', 'c', 'd']
x[0][1]  # => 'b'
x[1][2:]  # => [5, 7, 11]
```

List Method Reference

```
# Extend list by appending elements from the iterable
my_list.extend(iterable)

# Insert object before index
my_list.insert(index, object)

# Remove first occurrence of value, or raise ValueError
my_list.remove(value)

# Remove all items
my_list.clear()
```

More List Methods

```
# Return number of occurrences of value
my_list.count(value)

# Return first index of value, or raise ValueError
my_list.index(value, [start, [stop]])

# Remove, return item at index (def. last) or IndexError
my_list.pop([index])

# Stable sort *in place*
my_list.sort(key=None, reverse=False)

# Reverse *in place*.
my_list.reverse()
```

General Queries on Iterables

```
# Length (len)
len([])  # => 0
len("python")  # => 6
len([4,5,"seconds"])  # => 3


# Membership (in)
0 in []  # => False
'y' in 'python'  # => True
'minutes' in [4, 5, 'seconds']  # => False
```

Dictionaries

Keys can be a variety of types, as long as they are hashable

Mutable map from hashable values to arbitrary objects

Values can be a variety of types too

Dictionary

Create a Dictionary

```
empty = {}
type(empty)       # => dict
empty == dict()   # => True

a = dict(one=1, two=2, three=3)
b = {"one": 1, "two": 2, "three": 3}
a == b  # => True
```

Access and Mutate

```
b = {"one": 1, "two": 2, "three": 3}


# Get
d['one']  # => 1
d['five'] # raises KeyError


# Set
d['two'] = 22  # Modify an existing key
d['four'] = 4  # Add a new key
```

Get with Default

```
d = {"CS":[106, 107, 110], "MATH": [51, 113]}
d["COMPSCI"]  # raises KeyError
```

Use `get()` method to avoid the KeyError

```
d.get("CS")      # => [106, 107, 110]
d.get("PHIL")    # => None (not a KeyError!)


english_classes = d.get("ENGLISH", [])
num_english = len(english_classes)
```

Works even if there were no English classes in our dictionary!

Delete

```
d = {"one": 1, "two": 2, "three": 3}
```

```
del d["one"]
```

Raises `KeyError` if invalid key

```
d.pop("three", default)  # => 3
```

Remove and return `d['three']`
or default value if not in the map

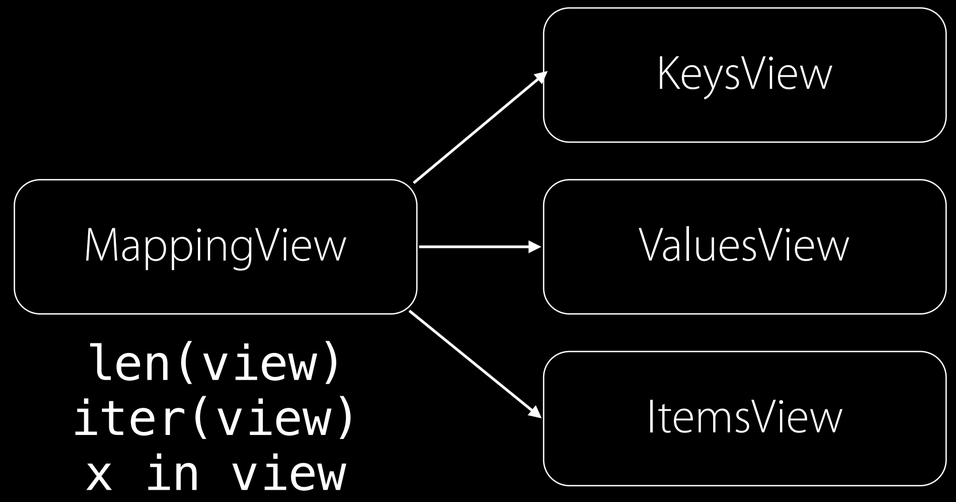
```
d.popitem()  # => ("two", 2)
```

Remove and return an arbitrary
`(key, value)` pair.
Useful for destructive iteration

Dictionaries

```
d = {"one": 1, "two": 2, "three": 3}
d.keys()
d.values()
d.items()
len(d.keys())  # => 3
('one', 1) in d.items()
for value in d.values():
    print(value)
keys_list = list(d.keys())
```

These dictionary views are dynamic, reflecting changes in the underlying dictionary!



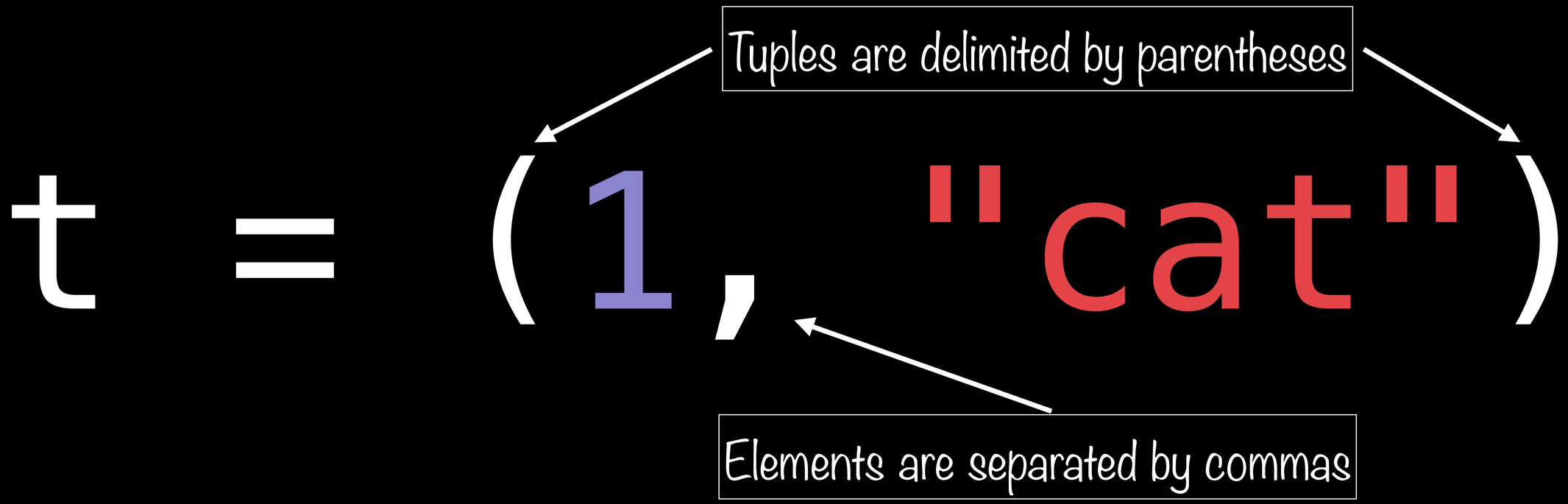
Common Dict Operations

```
len(d)
key in d  # equiv. to `key in d.keys()`
value in d.values()
d.copy()
d.clear()
for key in d:  # equiv. to `for key in d.keys():`
    print(key)
```

Tuples

Immutable Sequences

Tuple


Tuples are delimited by parentheses
t = (1, "cat")
Elements are separated by commas

Primary Motivations

Store collections of heterogeneous data

- Think `struct`- or `SQL`-like objects

"Freeze" sequence to ensure hashability

- Tuples can be dictionary keys, but lists cannot

Enforce immutability for fixed-size collections

Tuples

```
fish = (1, 2, "red", "blue")
fish[0]          # => 1
fish[0] = 7      # Raises a TypeError

len(fish)        # => 4
fish[:2]         # => (1, 2)
"red" in fish    # => True
```

You can't change any elements in a tuple!

Although the usual sequence methods still work

Argument Packing and Unpacking

```
t = 12345, 54321, 'hello!'
print(t) # (12345, 54321, 'hello!')
type(t)  # => tuple


x, y, z = t
x  # => 12345
y  # => 54321
z  # => 'hello!'
```

Comma-separated Rvalues are converted to a tuple

Comma-separated Lvalues are unpacked automatically

Swapping Values

Have
```
x = 5
y = 6
```

Want
```
x = 6
y = 5
```

```
temp = x
x = y
y = temp

print(x, y)
# => 6 5
```

Temporary Variable

```
x = x ^ y
y = x ^ y
x = x ^ y

print(x, y)
# => 6 5
```

XOR Magic

```
x, y = y, x


print(x, y)
# => 6 5
```

Tuple Packing

Have
```
x = 5
y = 6
```

Want
```
x = 6
y = 5
```

First, `y, x` is packed into the tuple `(6, 5)`

```
x, y = y, x
```

Then, `(6, 5)` is unpacked into the variables `x` and `y` respectively

Fibonacci Sequence

```
def fib(n):
    """Prints the first n Fibonacci numbers."""
    a, b = 0, 1
    for i in range(n):
        print(i, a)
        a, b = b, a + b
```

A New Example

```
for index, color in enumerate(['red','green','blue']):
    print(index, color)


# =>
# 0 red
# 1 green
# 2 blue
```

This also means you should almost never use
`for i in range(len(sequence)):`

Quirks

```
empty = ()
singleton = ("value",)
plain_string = "value"  # Note plain_string != singleton
len(empty)      # => 0
len(singleton)  # => 1

v = ([1, 2, 3], ['a', 'b', 'c'])
v[0].append(4)
v  # => ([1, 2, 3, 4], ['a', 'b', 'c'])
```

Tuples contain (immutable) references to underlying objects!

Sets

Unordered collection of distinct hashable elements

Set

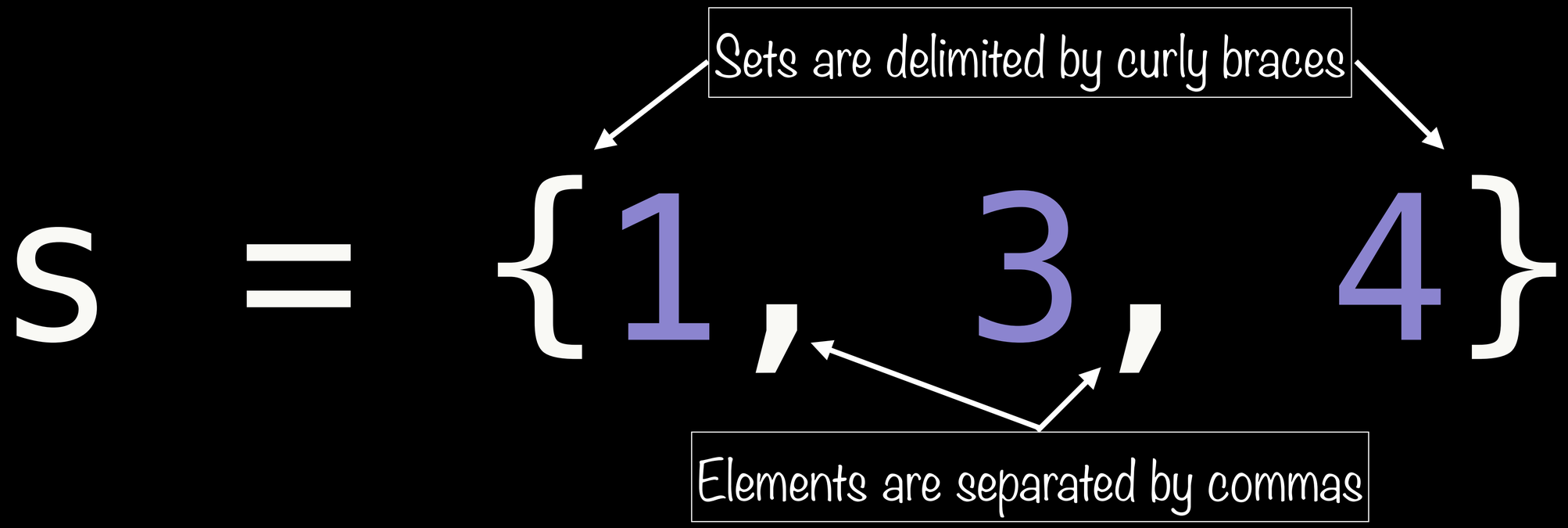
Primary Motivations

Fast membership testing

- O(1) vs. O(n)

Eliminate duplicate entries

Easy set operations (intersection, union, etc.)



Unordered collection of distinct hashable elements

Why not {}?

Common Set Operations

```
empty_set = set()
set_from_list = set([1, 2, 1, 4, 3]) # => {1, 3, 4, 2}

basket = {"apple", "orange", "apple", "pear", "banana"}
len(basket)                  # => 4
"orange" in basket           # => True
"crabgrass" in basket  # => False

for fruit in basket:
    print(fruit, end='/')
# => pear/banana/apple/orange/
```

O(1) membership testing

Common Set Operations

```
a = set("mississippi")  # {'i', 'm', 'p', 's'}

a.add('r')
a.remove('m')  # raises KeyError if 'm' is not present
a.discard('x')  # same as remove, except no error

a.pop()  # => 's' (or 'i' or 'p')
a.clear()
len(a)  # => 0
```

Common Set Operations

```
a = set("abracadabra")  # {'a', 'r', 'b', 'c', 'd'}
b = set("alacazam")     # {'a', 'm', 'c', 'l', 'z'}

# Set difference
a - b  # => {'r', 'd', 'b'}

# Union
a | b  # => {'a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'}

# Intersection
a & b  # => {'a', 'c'}

# Symmetric Difference
a ^ b  # => {'r', 'd', 'b', 'm', 'z', 'l'}
```

Rewriting `is_efficient`

```
EFFICIENT_LETTERS = "BCDGIJLMNOPSUVWZ"


def is_efficient(word):
    for letter in word:
        if letter not in EFFICIENT_LETTERS:
            return False
    return True
```

Rewriting `is_efficient`

```
EFFICIENT_LETTERS = set("BCDGIJLMNOPSUVWZ")


def is_efficient(word):
    return set(word) <= EFFICIENT_LETTERS
```

Is the set of letters in this word a subset of the efficient letters?

Looping Techniques

Items in Dictionary

```
knights = {'gallahad': 'the pure', 'robin': 'the brave'}
for k, v in knights.items():
    print(k, v)

# =>
# gallahad the pure
# robin the brave
```

zip

```
questions = ['name', 'quest', 'favorite color']
answers = ['Lancelot', 'To seek the holy grail', 'Blue']
for q, a in zip(questions, answers):
    print('What is your {0}? {1}.'.format(q, a))

# =>
# What is your name? Lancelot.
# What is your quest? To seek the holy grail.
# What is your favorite color? Blue.
```

The `zip()` function generates pairs of entries from its arguments.

Reverse Iteration

```
for i in reversed(range(1, 10, 2)):
    print(i, end=', ')

# =>
# 9, 7, 5, 3, 1,
```

To loop over a sequence in reverse,
first specify the sequence in a forward direction
and then call the `reversed()` function.

Sorted Iteration

```
basket = ['pear', 'banana', 'orange', 'pear', 'apple']
for fruit in sorted(basket):
    print(fruit)
# =>
# apple
# banana
# orange
# pear
# pear
```

To loop over a sequence in sorted order,
use the `sorted()` function which returns
a new sorted list while leaving the source unaltered.

Comprehensions

Concise syntax for creating data structures

Comprehensions

Example

```
squares = []
for x in range(100):
    squares.append(x**2)

print(squares[:5] + squares[-5:])
# [0, 1, 4, 9, 16, 9025, 9216, 9409, 9604, 9801]
```

[

]

Square brackets indicate that we're building a list

Loop over the specified iterable

```
[f(xs) for xs in iter]
```

Apply some operation to the loop variable(s) to generate new list elements

```
[f(xs) for xs in iter if pred(xs)]
```

Only keep elements that satisfy a predicate condition

Examples of List Comprehensions

```
[word.lower() for word in sentence]
[word for word in sentence if len(word) > 8]


[(x, x ** 2, x ** 3) for x in range(10)]
[(i,j) for i in range(5) for j in range(i)]
```

Be careful - "simple is better than complex"

Your Turn

```
[0, 1, 2, 3] -> [1, 3, 5, 7]
[3, 5, 9, 8] -> [True, False, True, False]
range(10) -> [0, 1, 4, 9, …, 81]

["apple", "orange", "pear"] -> ["A", "O", "P"]
["apple", "orange", "pear"] -> ["apple", "pear"]
["apple", "orange", "pear"] ->
                [("apple", 5), ("orange", 6), ("pear", 4)]
```

Other Comprehensions

```
# Dictionary Comprehensions
{key_func(vars):val_func(vars) for vars in iterable}
{v:k for k, v in d.items()}

# Set Comprehensions
{func(vars) for vars in iterable}
{word for word in hamlet if is_palindrome(word.lower())}
```

Comprehensions as Higher-Level Transformations

Usually, data structures focus on individual elements.

Comprehensions represent abstract transformations.

Don't say how to build something, just what you want.

Soon: Functional Programming - push this to the extreme!

Your Turn

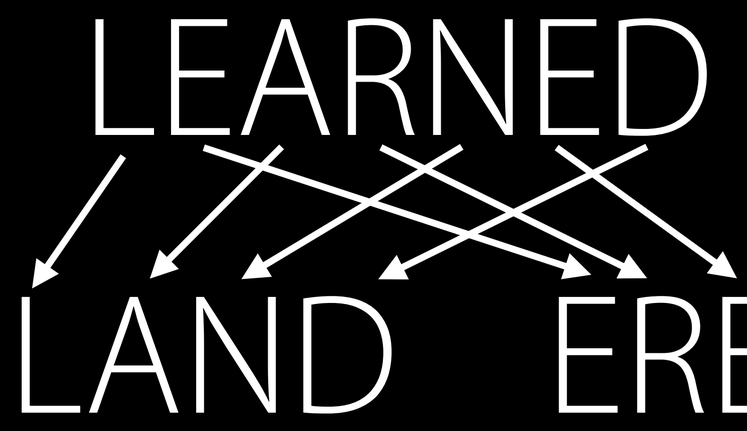
Triad Phrases

LEARNED THEOREMS

POOREST AGRARIANS

WOODED ORIOLE

Triad Phrase



Alternate letters spell out two words

Surpassing Phrases

SUPERB SUBWAY

PORKY HOGS

TURNIP FIELDS

Surpassing Phrase

SUPERB

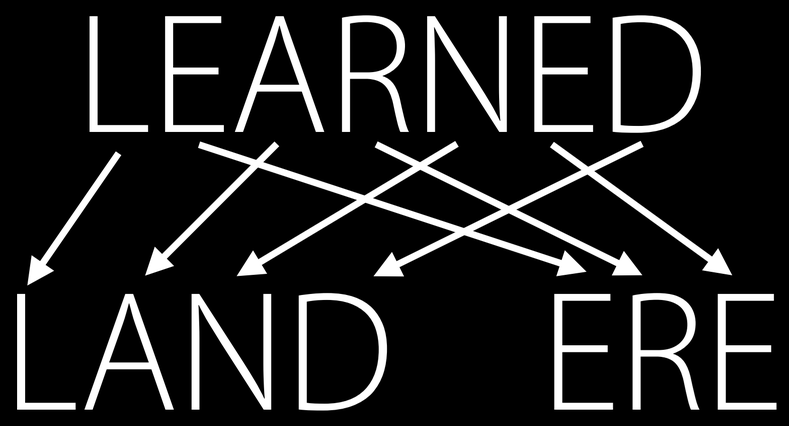
SU / UP / PE / ER / RB

2 / 5 / 11 / 13 / 16

```
ord('a') # => 97
chr(97) # => 'a'
```

Gaps between adjacent letters increase

Triad Phrases



Surpassing Phrases

SUPERB

SU / UP / PE / ER / RB

2 / 5 / 11 / 13 / 16

```
ord('a') # => 97
chr(97) # => 'a'
```

/usr/share/dict/words or

http://stanfordpython.com/res/misc/words

Next Time

Next Time

Get Your Hands Dirty!

Explore Data Structures

Investigate Odd Behavior