Data Structures & Object-Oriented Programming

April 11, 2023

Announcements

- Assignment 0 due Thursday
- Today is the last day to form groups, register for a section in Canvas
- Meet in your ***section room*** this Thursday

  Arpit —

  Chase —

  Will —
- Assignment 1 — which will be in groups! — goes out Thursday

  preview on the next slide...


Dear Data


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Learning Goals

After today, students will be able to:

- Differentiate between the following data structures and describe their properties and methods: lists, tuples, sets, and dictionaries.
- Decide which of the built-in data structures is appropriate for a given task.
- Design and implement custom Python objects (classes) for Python programs to augment Python’s object functionalities.

Agenda

- Built-in data structures
  - Lists, Tuples, Sets, Dictionaries
  - Patterns for working with collections
  - Comprehensions
- Classes
  - High-level overview
  - Magic methods
- Demo: axess.py

Built-in Data Structures

First, a summary

	mutable?	ordered?	iterable?	check inclusion	delimiters
list	✔	✔	over the entries	`O(n)`	`[]`
tuple	✘	✔	over the entries	`O(n)`	`()`
set	✔	✘	over the entries	`O(1)`	`{}`
dictionary	✔	✘	over the keys	`O(1)` for the keys	`{}`

Lists

```
to_remember = ['car keys', 'grading', 'the alamo', 42]
```

Lists are...

- **mutable** — they can be changed after they're created

```
to_remember.remove(42)              # O(n)
to_remember.append('september') # O(1)
```

- **ordered** — there's a 0th element, 1st element, 2nd element, ...

```
to_remember[3] # => 'september'
```

- **heterogeneous** — they can store elements of different types

Lists

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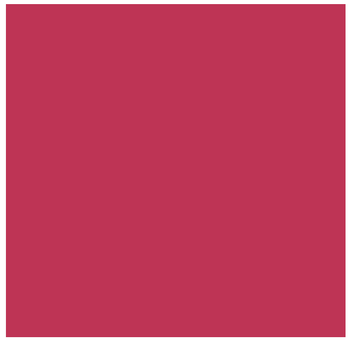
`.remove(elem)`	**Removes the first instance of elem from the list, or raises ValueError.**

Tuples

```
pix = (190, 52, 85)
```



Tuples are...

- **immutable** — can't be changed after creation (consequently, they're hashable)

```
pix[2] = 210 # TypeError: 'tuple' does not support assignment
hash(pix)    # => 8626792735414146673
```

- **ordered** — there's a 0th element, 1st element, 2nd element, ...

```
pix[0] # => 190
```

- **heterogeneous** — they can store elements of different types

Tuples

Tuples are...

- **immutable** — can't be changed after creation (consequently, they're hashable)

Immutability is powerful!

- When you guarantee that you're not going to change the entries, they can be stored in a slightly more efficient way
- Tuples can be hashed if they contain immutable data structures — remember this for later!
- Tuples contain immutable *references*...

```
tup = (1, 2, [3, 4])
tup[2].append(5)
tup # => (1, 2, [3, 4, 5])
```

This is totally valid, but inadvisable!

Putting it together: `filter_pixels`

filter_pixels.py

```
def is_bright(r, g, b):
    avg_val = (r + g + b) / 3
    return avg_val >= 128

def filter_pixels(pixels):
    # apply is_bright to filter the list
    ...

filter_pixels([
  (11, 231, 128), (224, 178, 46), (226, 226, 133), (225, 83, 205),
  (37, 89, 102), (119, 67, 141), (170, 239, 125), (135, 22, 2),
  (83, 105, 96), (16, 19, 96)
])
```

Sets

```
tas = {'chase', 'arpit', 'will', 'chase', 41}
```

Sets are...

- **mutable** — they can be changed after they're created

```
tas.add('arpit') # O(n)
tas.remove(41)   # O(1)
```

- **unordered** — there's no guarantee which element you'll pop

```
tas.pop() # => 'will'
```

- **heterogeneous** — they can store elements of different types
- **unique** — they remove duplicates; every element of a set must be hashable (for now, just think each element must be immutable)

```
tas # => {'chase', 'arpit'}
```

Sets

Sets are... mathematical objects!

`s & t`	**Set intersection.**
`s | t`	**Set union.**
`s < t`	Check whether s is a proper subset of t.
`s <= t`	**Check whether s is a subset of t.**
`s ^ t`	Symmetric difference.
`s - t`	**Set difference.**

Mathematical sets and efficient phrases

These are efficient phrases	These aren't efficient phrases
COLD WINDOWSILL	CHILLY WINDOW LEDGE
COOL MILLION	GOOD THOUSAND THOUSAND
VIVID DISILLUSIONS	GRAPHIC DISAPPOINTMENTS
SUSPICIOUS CONCLUSION	MISTRUSTFUL ENDING

What makes an efficient phrase?

Dictionaries

```
passwords = {
    'tara': 'ilovecs41',
    'arpit': None,
    'chase': 'pyth0nrock$'
}
```

Dictionaries are...

- **mutable** — they can be changed after they're created

```
passwords['arpit'] = 'un1c0rn$4lyfe'
del passwords['chase']
```

- **associative** — access values by keys, not position (no 0th, 1st, 2nd, ... element)
- **heterogeneous** — they can store elements of different types
- **unique keys** — each key can only appear once, keys must be hashable

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`d.items()`	Returns a collection of (key, value) tuples in d.
`d.clear()`	**Removes all (key, value) pairs from d.**
`d.pop(key, default)`	Removes key, and its associated value, from d. (Returns the associated value if key is in d, otherwise returns default).

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list("abcabc") # => ['a', 'b', 'c', 'a', 'b', 'c']
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enumerate(['a', 'b', 41]) # => <(0, 'a'), (1, 'b'), (2, 41)>
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# range
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range(a, b, c) # => ints from a (inclusive) to b (exclusive)
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range(a, b, c) # => ints from a (inclusive) to b (exclusive)
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range(3, 10, 2) # => <3, 5, 7, 9>
```

Comprehensions

Write a function that returns a list of all odd square numbers below 100

`odd_squares.py`

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```
for i in range(loop_max):
    if (i ** 2) % 2 != 0:
        output.append(i ** 2)
```

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Go through a collection...

...check some condition...

...apply some operation to the element.

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`odd_squares.py`

```
return [
    i ** 2
    for i in range(int(num ** (1/2)))
    if (i ** 2) % 2 != 0
]
```

...apply some operation to the element.

Go through a collection...

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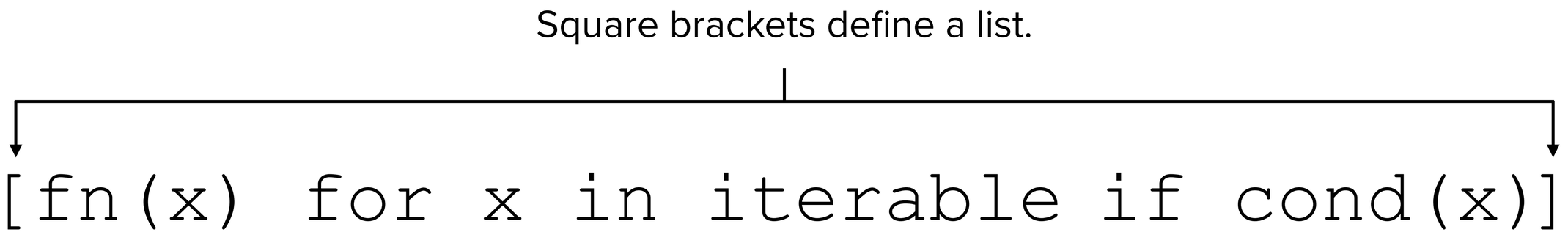
Comprehensions

```
[fn(x) for x in iterable]
```

Comprehensions

```
[fn(x) for x in iterable if cond(x)]
```

Comprehensions



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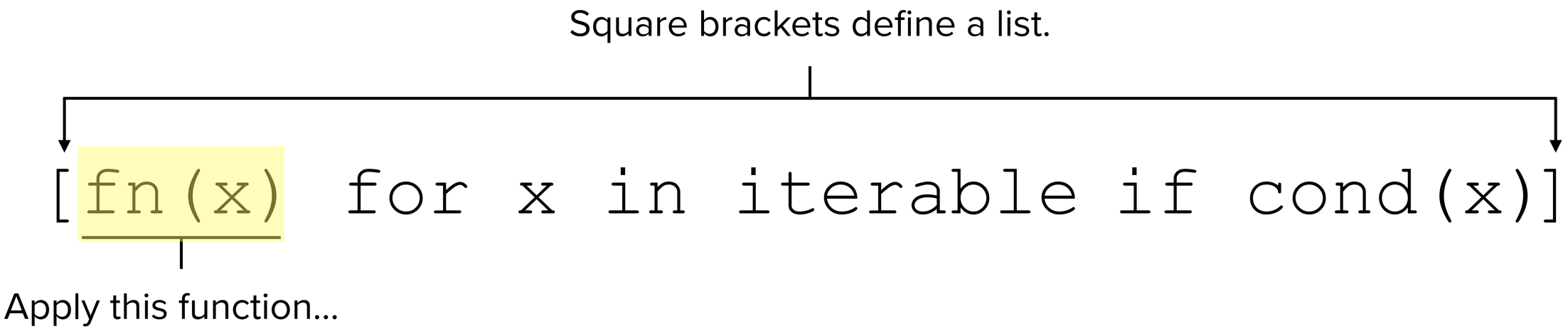

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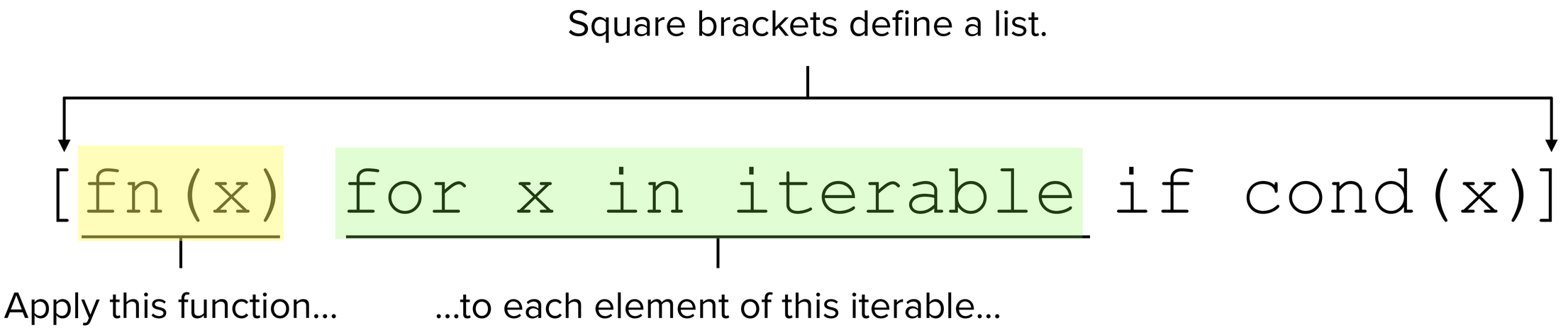

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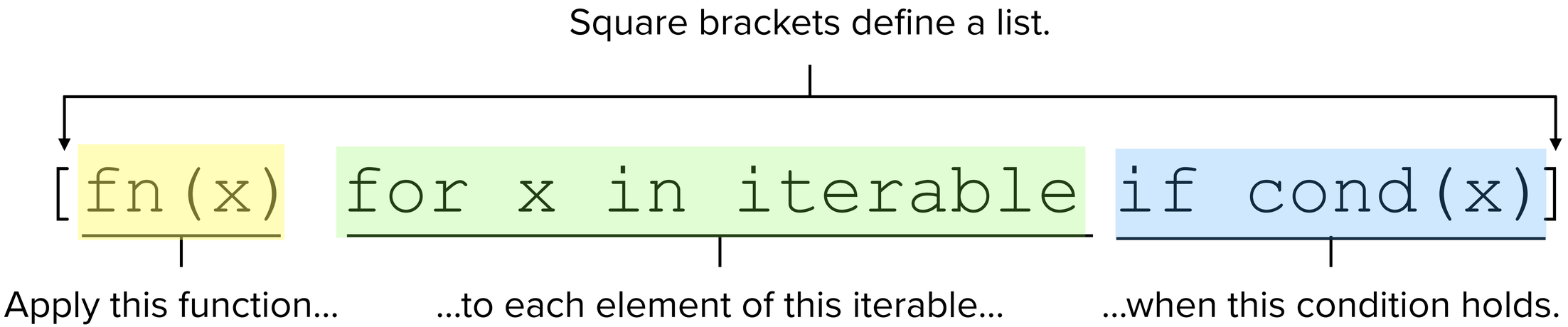
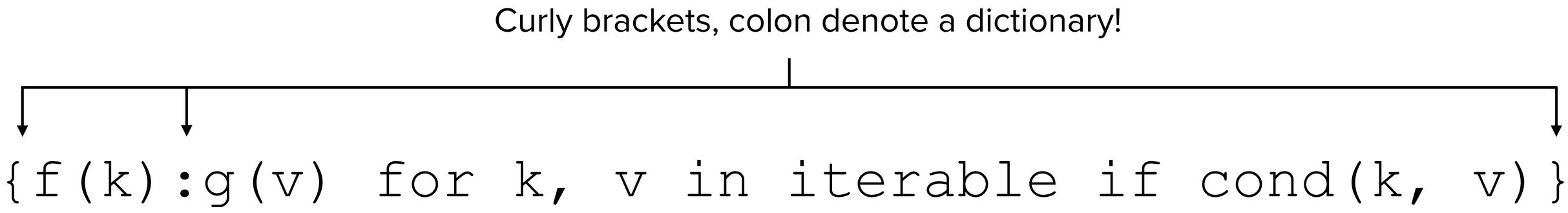


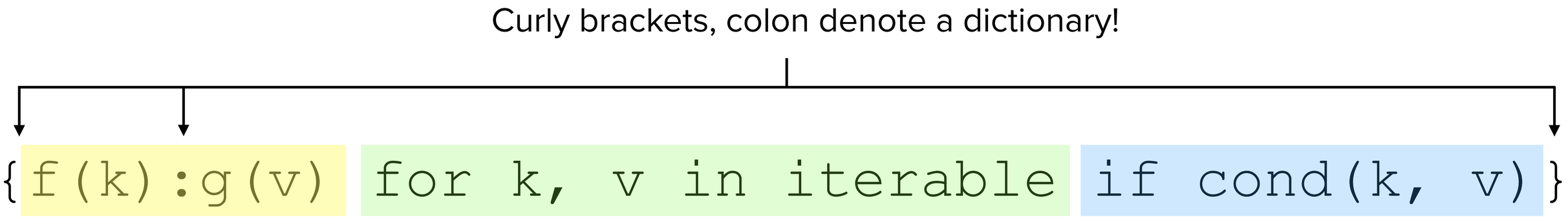
Comprehensions

```
{f(k):g(v) for k, v in iterable if cond(k, v)}
```

Comprehensions



Comprehensions



Let's build a program to help Stanford manage students and courses...

In addition, we'd like a function to enroll a student in a course, which should also check if the student has the necessary prerequisites for the class.

What data structures would you use to solve this problem?

(What would you use to represent a course? A student? How would you implement the enroll function?)

Let's build a program to help Stanford manage students and courses...

Every ***student*** has...

- Name (string)
- SUNet ID (string)
- Collection of courses they've taken in the past
  - Grades they received in those courses
- Collection of courses they're currently taking

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- Name (string)
- SUNet ID (string)
- Collection of courses they've taken in the past
  - Grades they received in those courses
- Collection of courses they're currently taking

Every ***course*** has...

- ID (string) used to identify the course across quarters
- Department (string)
- Course number (string)
- Quarter (string)
- Collection of prerequisites
- Collection of students who are currently enrolled

In addition, we'd like a function to enroll a student in a course, which should also check if the student has the necessary prerequisites for the class.

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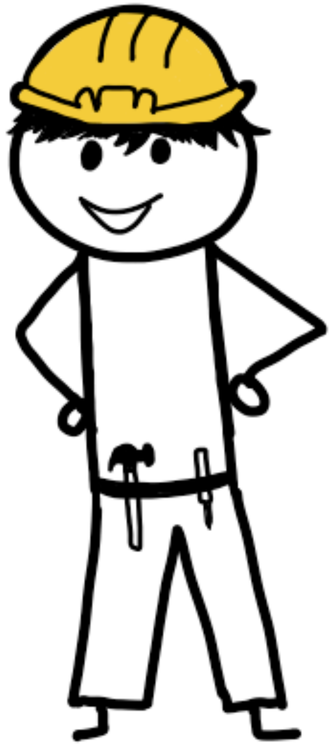
(What would you use to represent a course? A student? How would you implement the enroll function?)

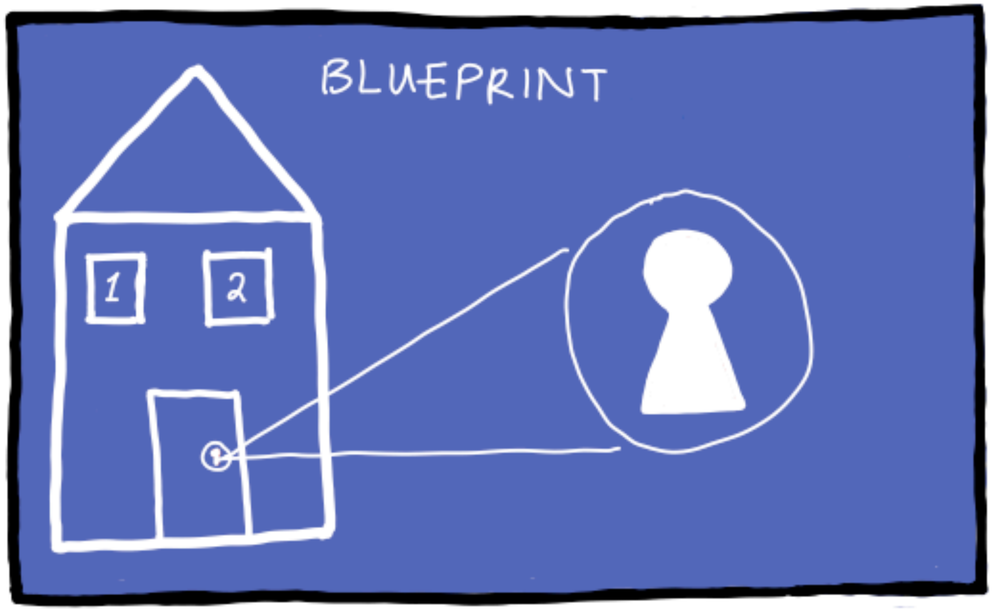
Classes

High-Level

Imagine I'm opening a residential construction company which is going to build several houses...

First, I need a blueprint for a house. This is the **class object**.





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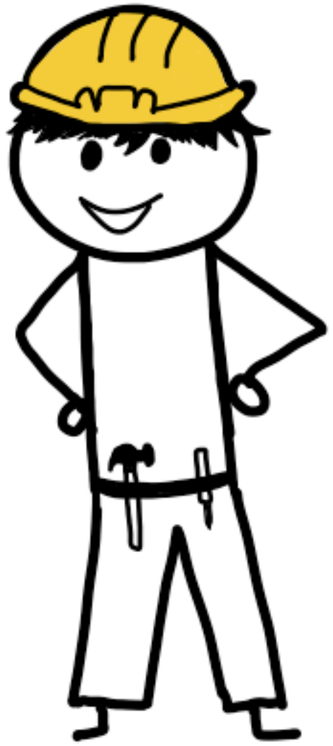
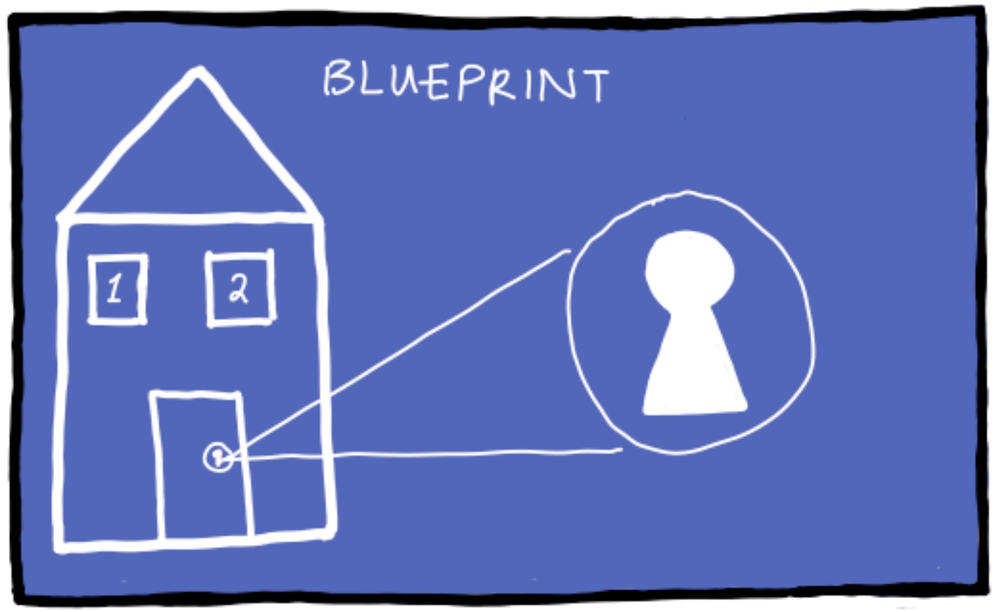


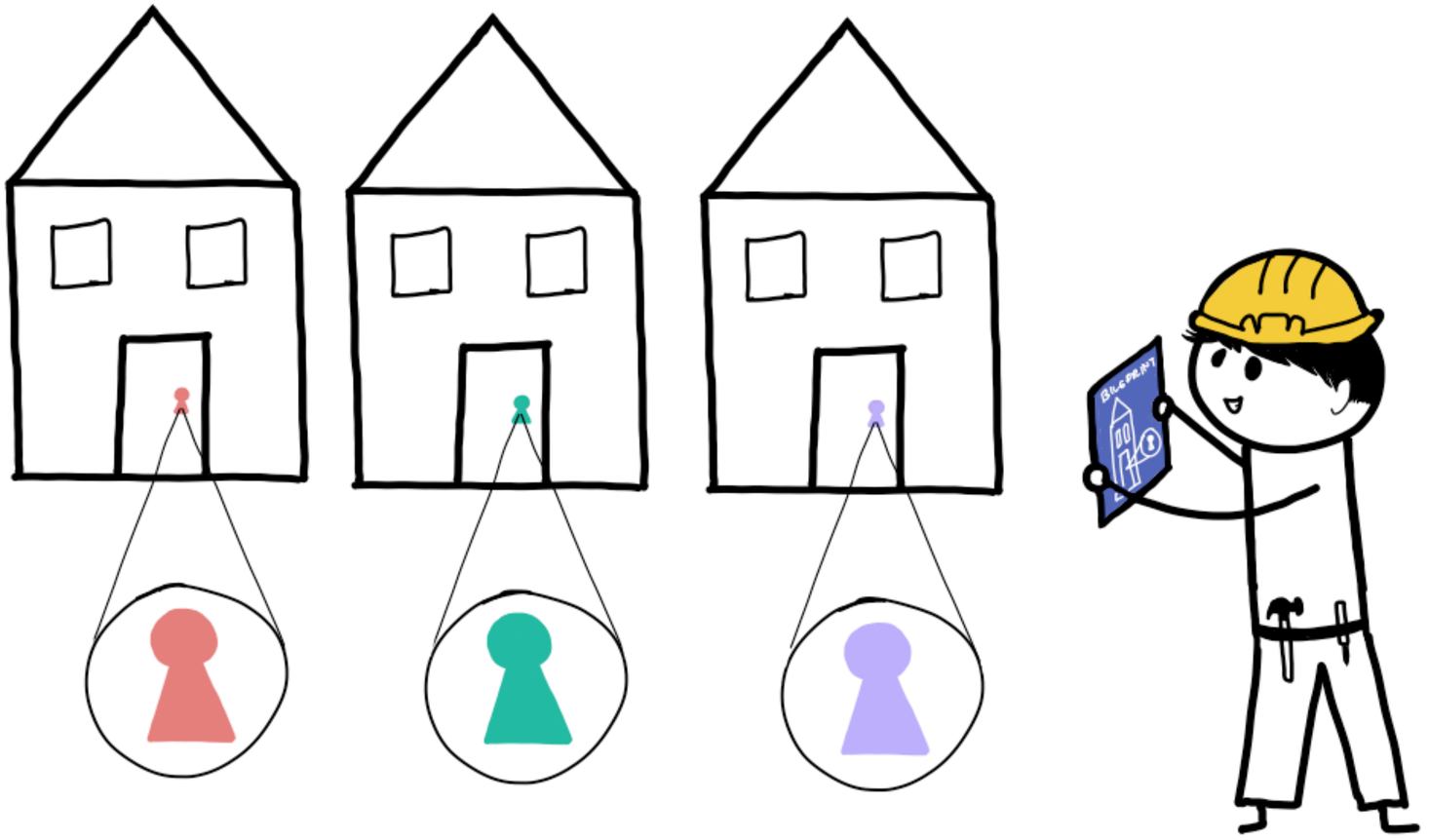


✨ btw y'all, my sister made these! 💜

High-Level

Then, I can use that blueprint to build several houses. Some properties of the houses will be the same and others will be different.

Each house is **an instance (object)** of the class.



High-Level

The blueprint for a house

```
class House:
    utilities = {
        'electricity': 'A&E #8675309',
        'water': 'Palo Alto Mutual #6054756961'
    }

    def __init__(self):
        self.locked = True
```

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This is run every time an instance is declared and sets up instance-specific properties (it's the "constructor")

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High-Level

The actual houses


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red = House()
blue = House()
green = House()
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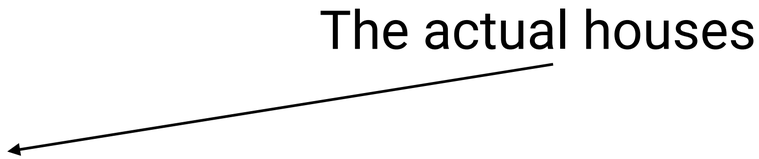


```
red = House()
blue = House()
green = House()

House.utilities['electricity'] # => 'A&E #8675309'
red.utilities['electricity']   # => 'A&E #8675309'
green.utilities['electricity'] # => 'A&E #8675309'
```

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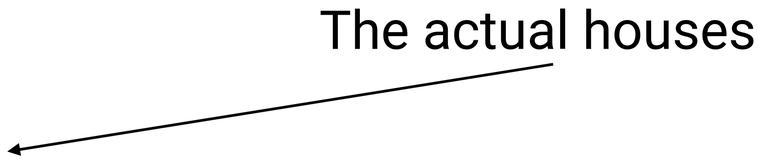


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red.locked  # => True
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red.locked  # => True
blue.locked # => True

red.locked = False
blue.locked # => True
```

Note: In Python, all attributes are public

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House.__init__  # => <function __init__(self)>

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red.__init__  # => <bound method House.__init__>
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```

This applies to other methods as well, not just `__init__`.

```
instance.method(some args) ~ function(instance, some args)
```

Custom Instantiation

```
class Student:
    def __init__(self, name, sunet):
        self.name = name.title()

        # validate the SUNet
        if not set(sunet) <= set('0123456789'):
            raise ValueError(f"Invalid SUNet: {sunet}.")
        self.sunet = sunet
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Just like a normal function, `__init__` can have parameters!

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Just like a normal function, `__init__` can have parameters!

```
parth = Student('parth sarin', 'noneya') # ValueError

tara = Student('tara jones', '5625165')
tara.name # => 'Tara Jones'
```

Magic Methods

Python Uses Magic Methods!

```
str(x)   # => x.__str__()

x == y   # => x.__eq__(y)
x < y    # => x.__lt__(y)
x + y    # => x.__add__(y)

next(x)  # => x.__next__()
len(x)   # => x.__len__()
hash(x)  # => x.__hash__()

el in x # => x.__contains__(el)
```

Full list here!

Let's build Axess!