

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 — Econ 206

Chase — 380-381T

Will — Encina West 208

- Assignment 1 — which will be in groups! — goes out Thursday
preview on the next slide...

Dear Data

Dear Data

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

<code>.count(elem)</code>	Counts the occurrences of elem in the list.
<code>.index(elem)</code>	Returns the index of the first occurrence of elem in the list.
<code>.append(elem)</code>	Appends the element elem to the end of the list.
<code>.extend(iterable)</code>	Extends the list by appending all elements of iterable to the end.
<code>.insert(idx, elem)</code>	Inserts the element elem at the index idx of the list.
<code>.sort(key=None, reverse=False)</code>	Sorts the list in-place.
<code>elem in lst</code>	Returns True if elem is in the list and False otherwise
<code>del lst[i]</code>	Removes the ith element from the list
<code>.pop(i=-1)</code>	Returns and removes the ith element from the list.
<code>.remove(elem)</code>	Removes the first instance of elem from the list, or raises ValueError.

Tuples

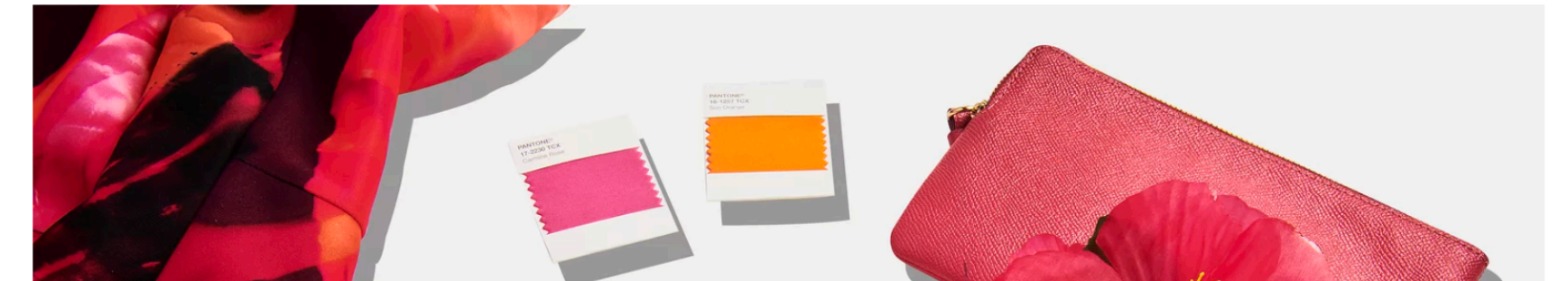
```
pix = (190, 52, 85)
```



How and why Pantone picked 'Viva Magenta' as its 2023 color of the year

December 2, 2022 · 12:50 PM ET

By [Rachel Treisman](#)



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`

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

`filter_pixels.py`

```
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 .
$s \ \leq \ t$	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

Dictionaries

<code>val = d[key]</code>	Access the value in d corresponding to key; place this value into the val variable.
<code>d.copy()</code>	Makes a shallow copy of d.
<code>d.get(key, default)</code>	Returns the value associated with key in d. If key does not exist in d, return default.
<code>d.keys()</code>	Returns a collection of the keys in the dictionary.
<code>d.values()</code>	Returns a collection of the values in the dictionary.
<code>d.items()</code>	Returns a collection of (key, value) tuples in d.
<code>d.clear()</code>	Removes all (key, value) pairs from d.
<code>d.pop(key, default)</code>	Removes key, and its associated value, from d. (Returns the associated value if key is in d, otherwise returns default).

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Patterns for working with collections

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len(collection)
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# create a new data structure from an iterable
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list("abcabc") # => ['a', 'b', 'c', 'a', 'b', 'c']
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set("abcabc")  # => {'a', 'b', 'c'}
```

```
# enumerate a collection
```

```
enumerate(['a', 'b', 41]) # => <(0, 'a'), (1, 'b'), (2, 41)>
```

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```
len(collection)
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enumerate(['a', 'b', 41]) # => <(0, 'a'), (1, 'b'), (2, 41)>
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```
for i, elem in enumerate(['a', 'b', 41]):
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for i, elem in enumerate(['a', 'b', 41]):
```

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Patterns for working with collections

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```
# sort a collection
```

Patterns for working with collections

```
# sort a collection  
sorted("cbda")
```

```
# => ['a', 'b', 'c', 'd']
```


Patterns for working with collections

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# sort a collection
```

```
sorted("cbda") # => ['a', 'b', 'c', 'd']
```

```
sorted("cbda", reverse=True) # => ['d', 'c', 'b', 'a']
```

Patterns for working with collections

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Patterns for working with collections

```
# sort a collection
sorted("cbda")          # => ['a', 'b', 'c', 'd']
sorted("cbda", reverse=True) # => ['d', 'c', 'b', 'a']

# pairwise combinations
```

Patterns for working with collections

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# sort a collection
sorted("cbda")           # => ['a', 'b', 'c', 'd']
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# pairwise combinations
zip(
```


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# pairwise combinations
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    ['arpit', 'chase', 'will'],
```

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```

```
# pairwise combinations
zip(
    ['arpit', 'chase', 'will'],
    ['B+', 'A', 'A-']
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) # => <('arpit', 'B+'), ('chase', 'A'), <('will', 'A-')>
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for a, b in zip(collection1, collection2):
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# range
```

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# range
range(a, b, c) # => ints from a (inclusive) to b (exclusive)
```

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for a, b in zip(collection1, collection2):
    ...

# range
range(a, b, c) # => ints from a (inclusive) to b (exclusive)
                #      with a step size of c
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
```

Comprehensions

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

`odd_squares.py`

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

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):  
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Go through a collection...

...check some condition...

...apply some operation to the element.

Comprehensions

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

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Comprehensions

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

`odd_squares.py`

```
return [
```

```
    i ** 2
```

...apply some operation to the element.

```
    for i in range(int(num ** (1/2)))
```

Go through a collection...

```
    if (i ** 2) % 2 != 0
```

...check some condition...

```
]
```

Comprehensions

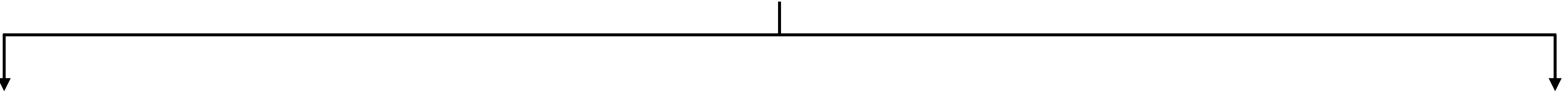
```
[fn(x) for x in iterable]
```

Comprehensions

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

Comprehensions

Square brackets define a list.



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

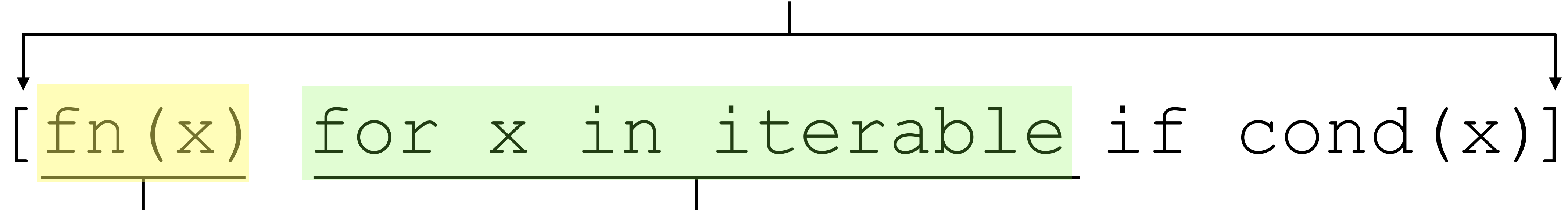
Square brackets define a list.

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[fn(x) for x in iterable if cond(x)]
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Apply this function...

Comprehensions

Square brackets define a list.

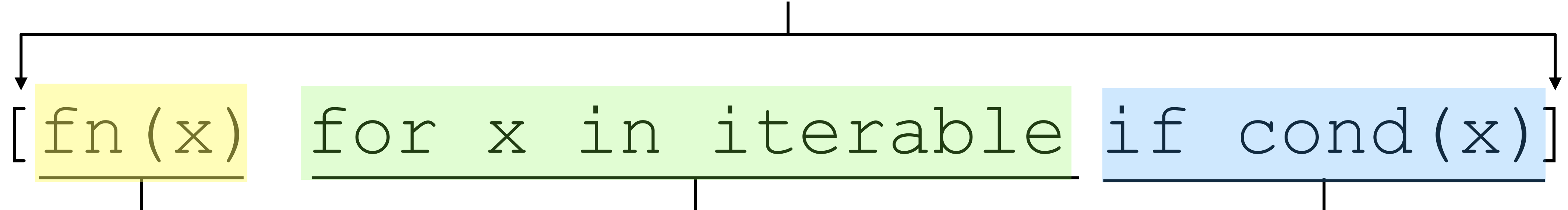


Apply this function...

...to each element of this iterable...

Comprehensions

Square brackets define a list.



Apply this function...

...to each element of this iterable...

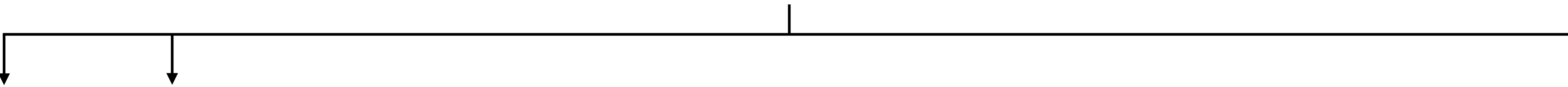
...when this condition holds.

Comprehensions

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

Comprehensions

Curly brackets, colon denote a dictionary!



The diagram consists of a horizontal line with three vertical arrows pointing downwards from it. The first arrow points to the opening curly bracket of the first set of curly brackets in the expression below. The second arrow points to the colon in the same expression. The third arrow points to the closing curly bracket of the second set of curly brackets.

$\{ f(k) : g(v) \text{ for } k, v \text{ in iterable if } \text{cond}(k, v) \}$

Comprehensions

Curly brackets, colon denote a dictionary!

A horizontal line with three downward-pointing arrows. The first arrow points to the opening curly bracket of the first part of the comprehension. The second arrow points to the colon. The third arrow points to the closing curly bracket of the entire comprehension.

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

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)
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 - Grades they received in those courses
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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

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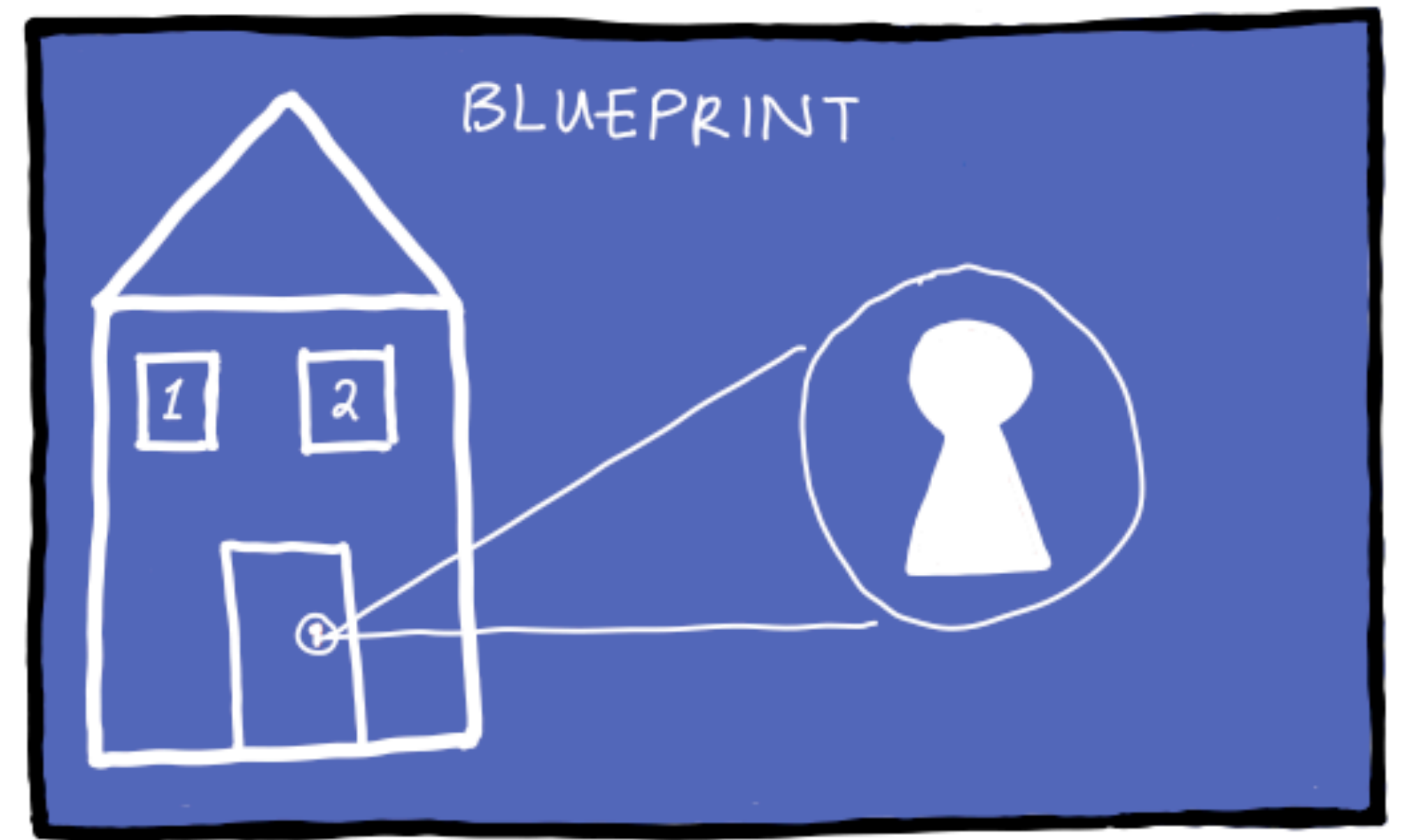
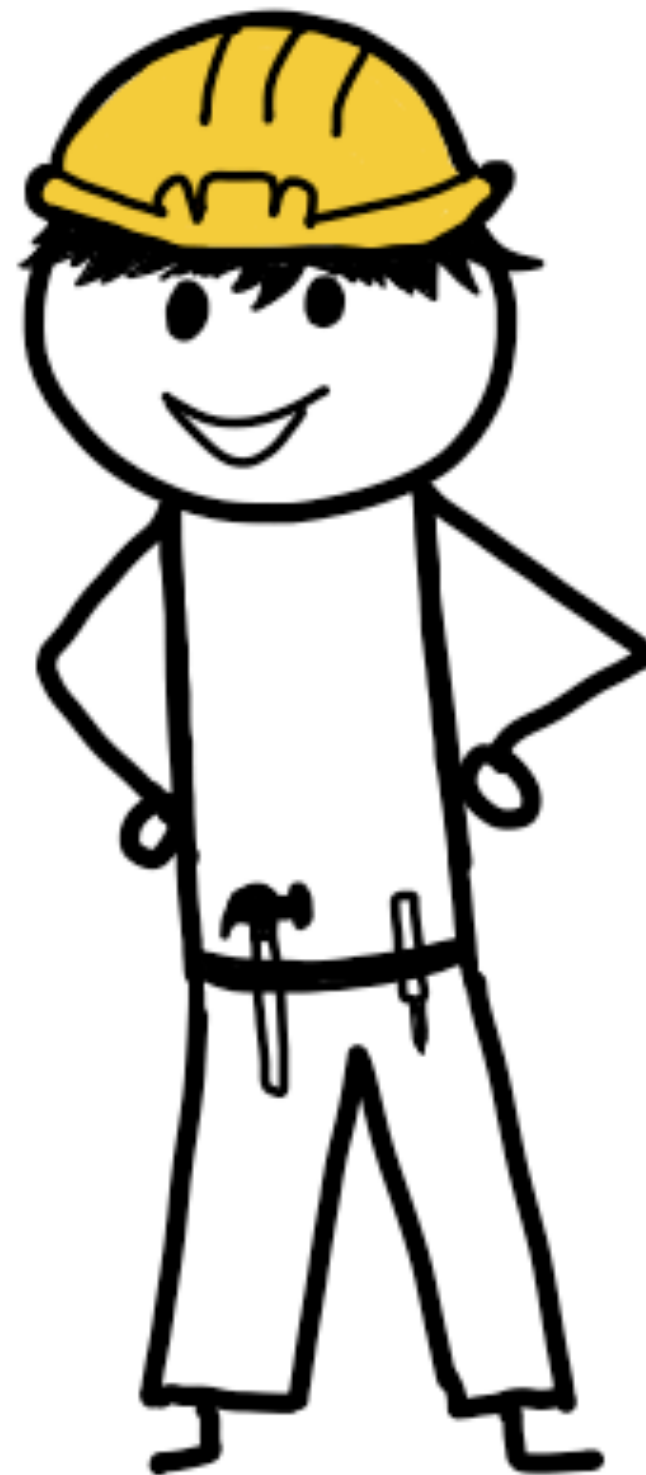
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Classes

High-Level

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

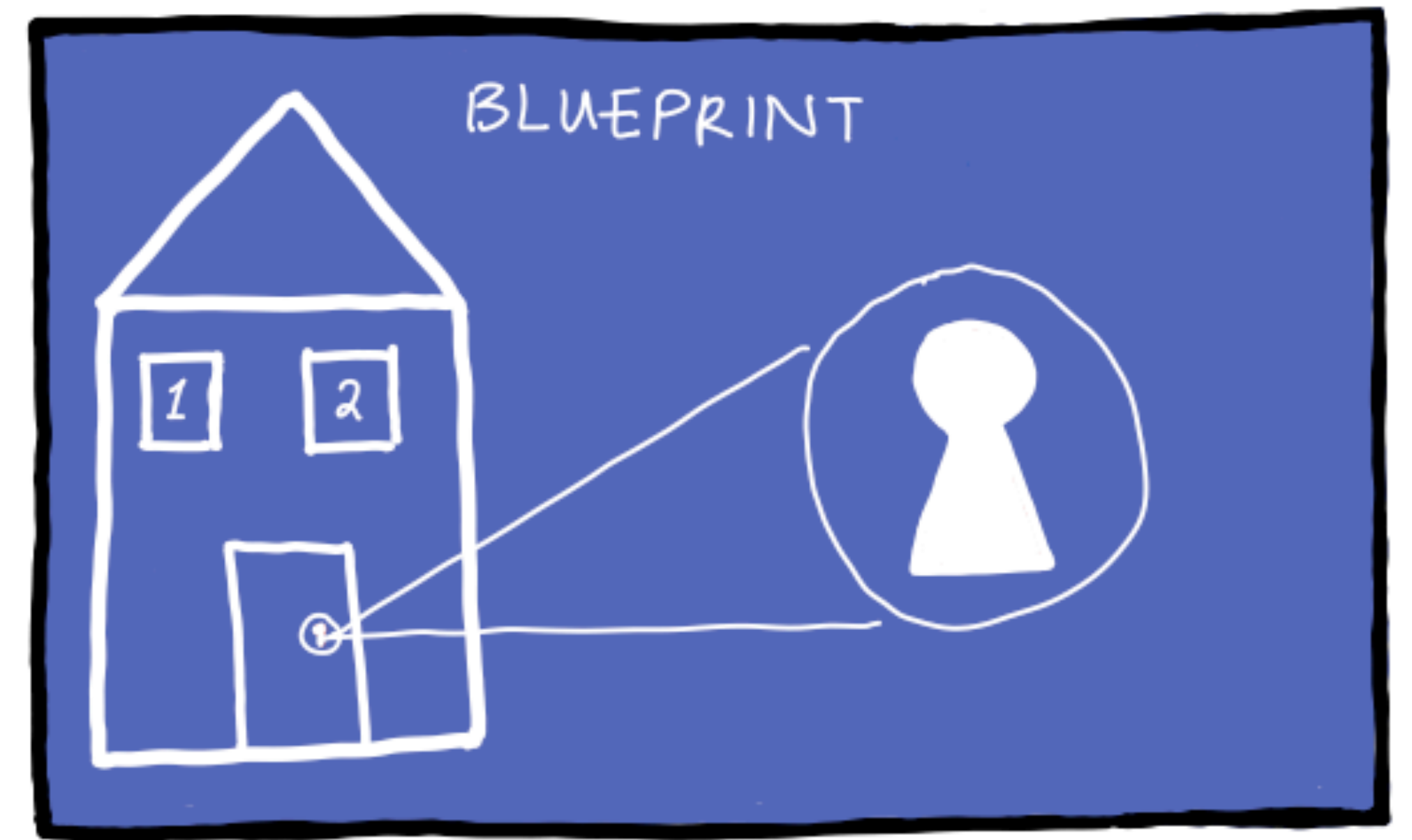
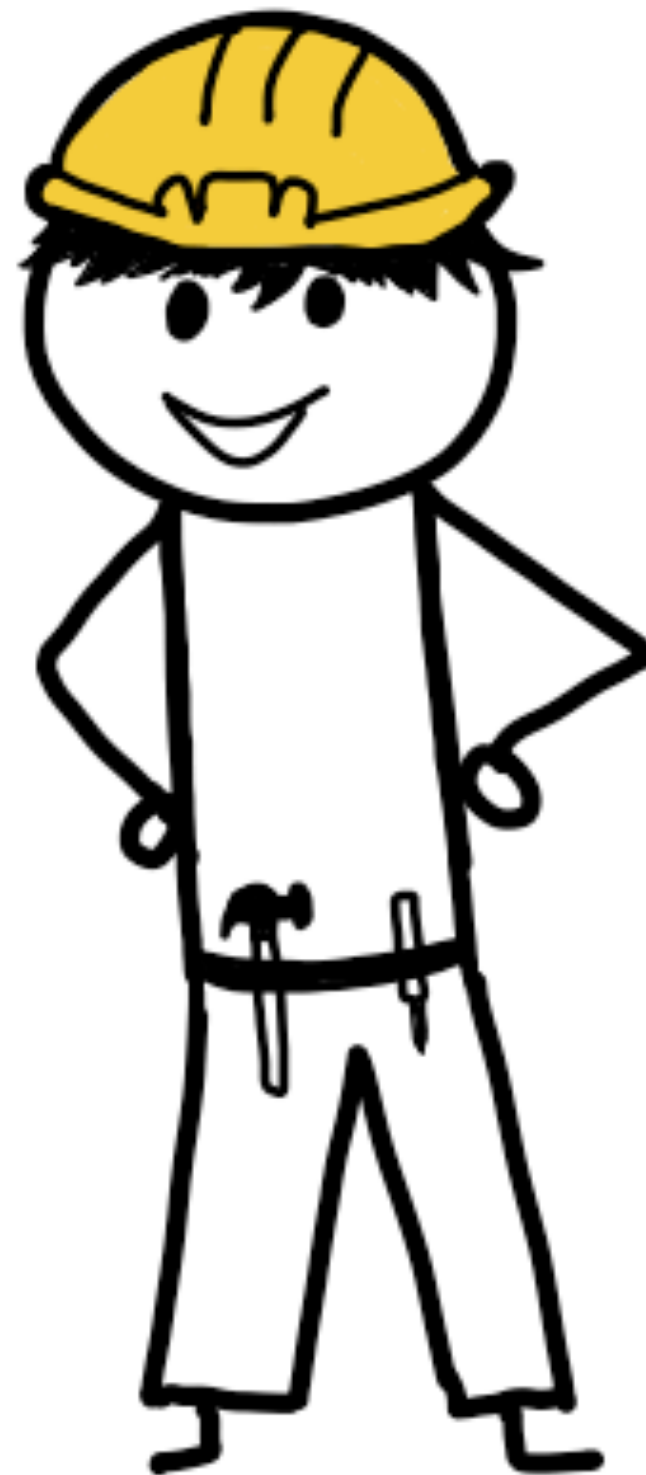
First, I need a blueprint for a house. This is the **class object**.



High-Level

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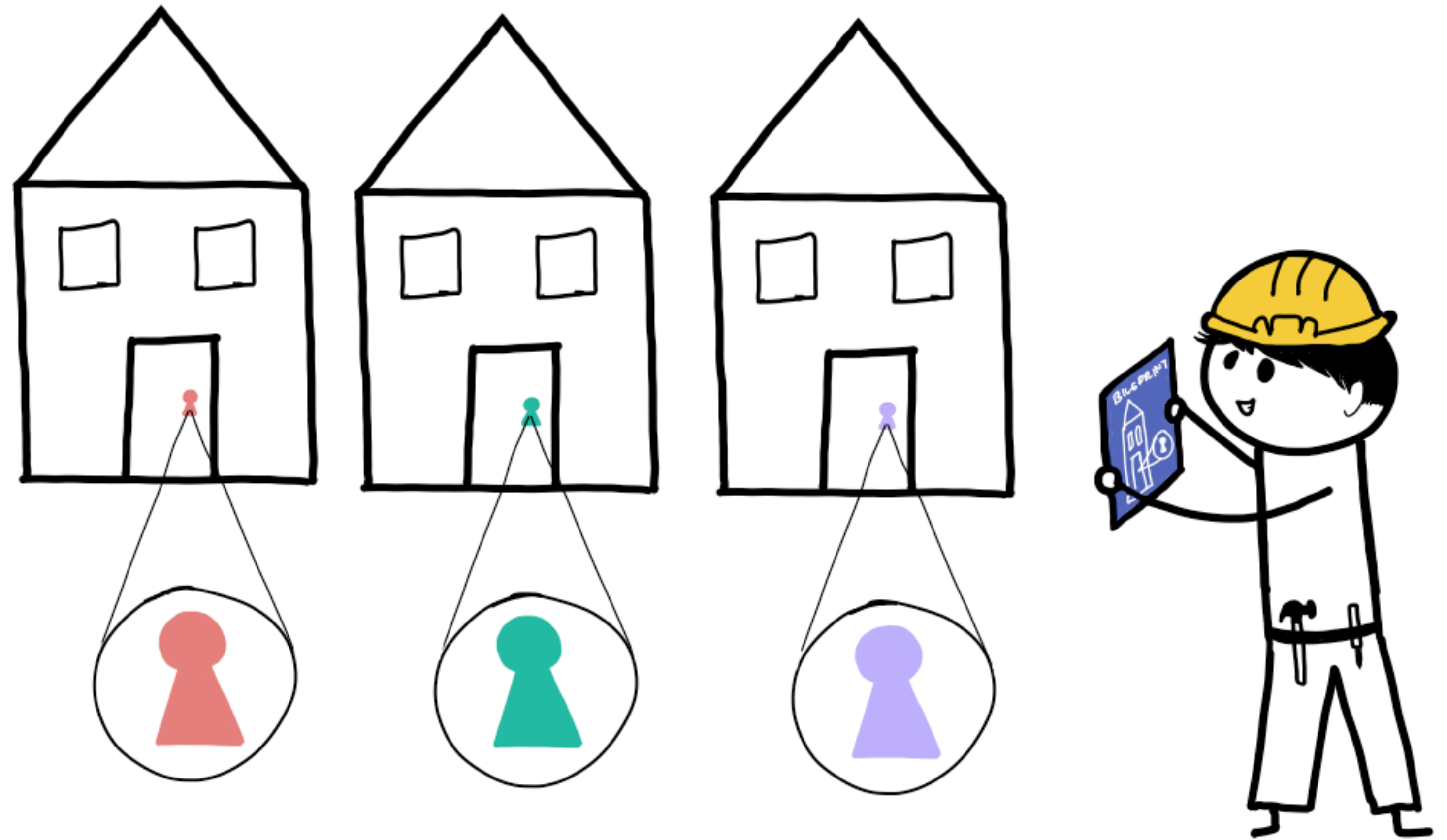


✨ btw y'all, my sister made these! 💜

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
```

High-Level

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These attributes are shared
among the instances (houses)

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

These attributes are shared among the instances (houses)

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

High-Level

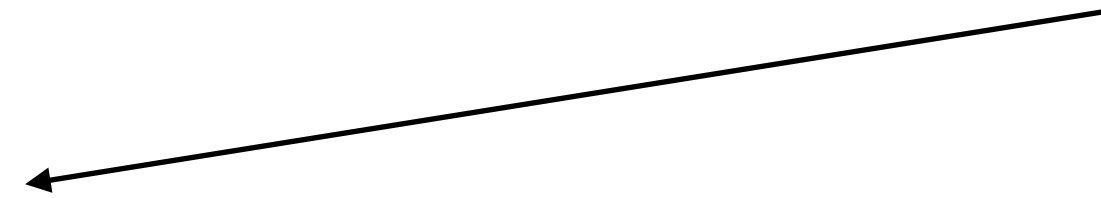
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High-Level

The actual houses

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

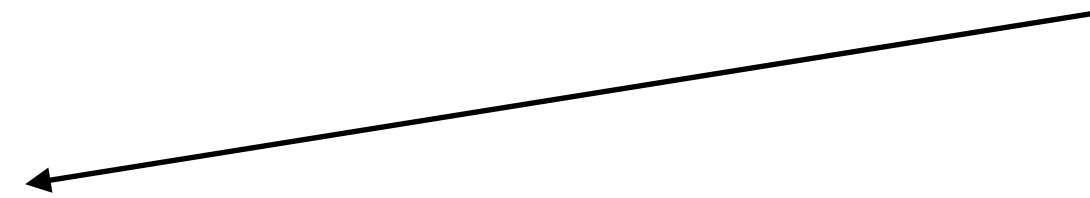


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High-Level

The actual houses

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```
House.utilities['electricity'] # => 'A&E #8675309'  
red.utilities['electricity']   # => 'A&E #8675309'  
green.utilities['electricity'] # => 'A&E #8675309'
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```
red.locked # => True  
blue.locked # => True
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High-Level

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red.utilities['electricity']   # => 'A&E #8675309'  
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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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But wait... what's `self`?

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When the function is run on a class instance, the first parameter to every method is a reference to the object itself. It could be named anything, but `self` is the traditional name.

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

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

But wait... what's `self`?

```
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```

When the function is run on a class instance, the first parameter to every method is a reference to the object itself. It could be named anything, but `self` is the traditional name.

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

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

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
```

Just like a normal function,
__init__ can have
parameters!

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parth = Student('parth sarin', 'noneya') # ValueError
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Just like a normal function,
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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*!