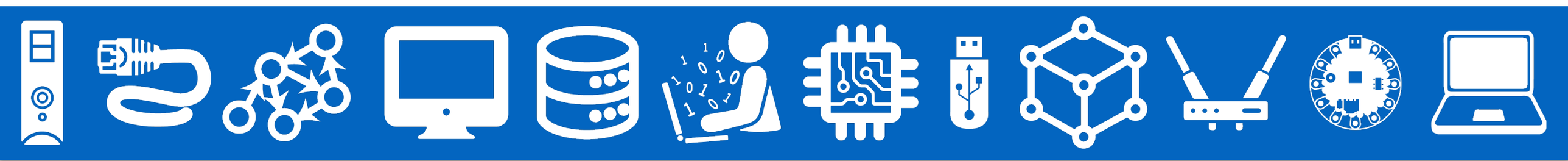
CS134 Lecture: Introduction to Classes & Objects



Announcements & Logistics

- **Lab 7** today/tomorrow
  - Do Pre-Labs **individually** and on **paper**
  - **Put your name on it!**
- **HW 7** due today at 10 pm
- **Final Exam**: Wednesday, December 11 at 9:30am in Wachenheim B11

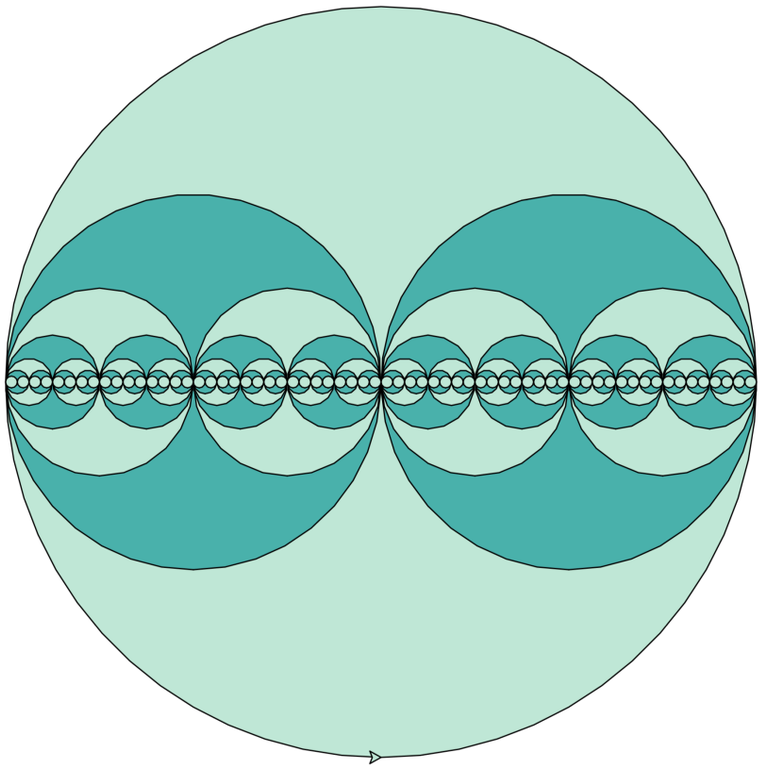
Do You Have Any Questions?

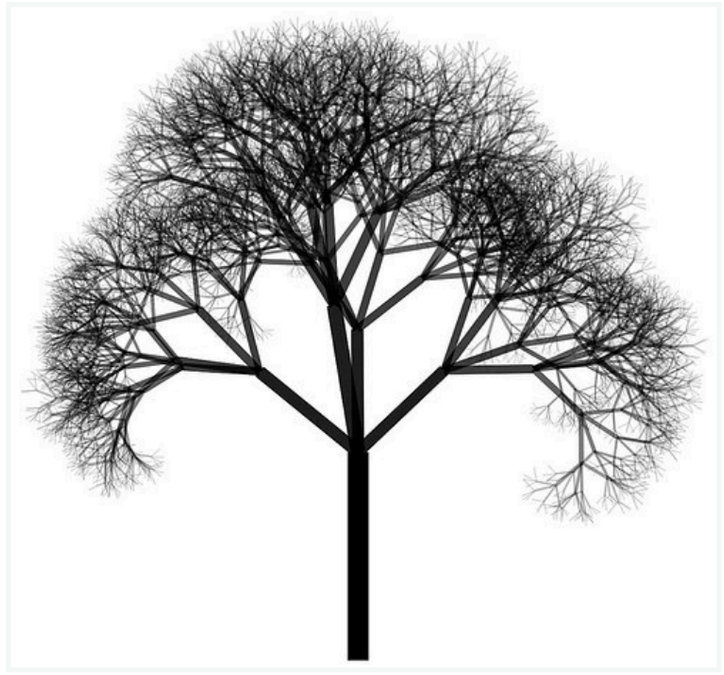
Pair Programming: Best Practices

- Goal is to work together as a team using **one computer**:
  - Driver: controls the keyboard (handles the details, debugging, etc)
  - Navigator: helps guide (big picture person, decides where to go)
- **Both roles are important** and you both should switch roles often!
- **Communication is key**: but be polite, respectful and patient
- Discussing high level strategies and goals early, before writing the code, helps avoid bugs as well as conflict
- Resources:
  - How Pair Programming Really Works by Stuart Wray
  - Longish article on pair programming pros, cons, and strategies

Last Time

- Graphical examples of recursion, important takeaways:
  - how to break down a problem recursively
  - maintaining function invariants across function calls
- Review leftover tree example (similar to shrub question in lab)

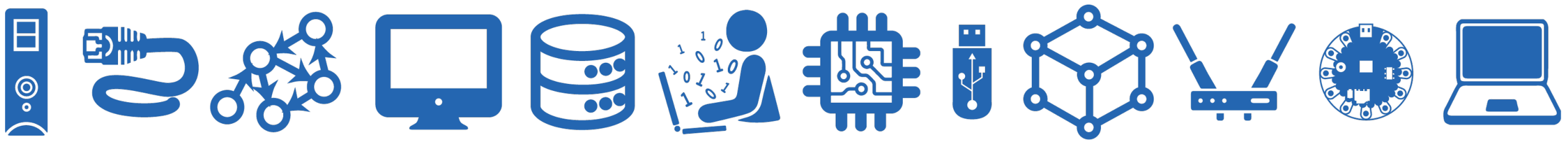




Today

- Start discussing our next topic: **classes** and **objects**
  - Python is an **object oriented programming** (OOP) language
  - Everything in Python is an **object** and has a **type**
- Learn how to define our own **classes** (**types**) and **methods**

Objects in Python



Objects in Python

- We have seen many ways to store data in Python

```
1234 3.14159  "Hello" [1, 5, 7, 11, 13] {1, 2, 3}
{"CA": "California", "MA": "Massachusetts"}
```

- Each of these is an **object**, and every object in Python has:
    - a **type** (int, float, string, list, tuples, dictionaries, sets, etc)
    - an internal **data representation** (primitive or composite)
    - a set of functions/methods for **interacting** with the object
- Vocabulary: A *specific object* is an **instance** of a type
    - `1234` is an instance of an **int**
    - `"Hello"` is an instance of a **string**

type(object)

- The **`type()`** function returns the data type for an object

```
>>> type(1234)
<class 'int'>
>>> type("hello")
<class 'str'>
>>> type([1, 5, 7, 11, 13])
<class 'list'>
>>> type(range(5))
<class 'range'>
```

Objects and Types in Python

- Even functions are a type!
- Guido designed the language according to the principle "first-class everything"

```
>>> def greeting():
...     print("Hello")
...
>>> type(greeting)
<class 'function'>
```

Everything in Python is an object and has a type!

"*One of my goals for Python was to make it so that all objects were "first class." By this, I meant that I wanted all objects that could be named in the language (e.g., integers, strings, functions, classes, modules, methods, and so on) to have equal status. That is, they can be assigned to variables, placed in lists, stored in dictionaries, passed as arguments, and so forth.*" — ***Guido Van Rossum***
(Blog, The History of Python, February 27, 2009)

Stepping Back: Object-Oriented Programming (OOP)

- Python is an **"object-oriented" language**
    - We have been dancing around this reality all semester
    - Today we will embrace it!
- **OOP** (object-oriented programming) is a fundamental programming paradigm
- It has four major principles (vocabulary words!):
    - **Abstraction** - handle complexity by ignoring/hiding messy details
    - **Inheritance** - derive a class from another class that shares a set of attributes and methods
    - **Encapsulation** - bundling data and methods that work together in a class
    - **Polymorphism** - using a single method or operator for different uses
- We'll explore some of these principles in more detail in the coming lectures

What are Objects?

- It's time to *formally* define **objects** in Python
- Objects are:
  - collections of data (variables or **attributes**) and
  - **methods** (functions) that act on the data
- Example of **abstraction**:
  - Abstraction is the art of hiding messy details
  - Methods define behavior but hide implementation and internal representation of data
    - e.g., `.append()` is a method that is applied to a list type: we don't need to know how it works to use it

Example: `[1,2,3,4]` has type `list`

- We've never discussed how Python stores lists *internally*
- Fortunately we typically don't sweat the inner working of lists every time we use them (we've been doing it all semester!)
- How do we manipulate lists? Using the **operators** or **list methods** provided by Python.
  - `list3 = list1 + list2` (concatenation using an operator)
  - `list1.append("dog")` (adding to a list using the append operator, this mutates `list1` rather than creating a new list)
- Recall that we can also use the + operator for strings! This is an example of polymorphism
- **Take away:** Internal representation of objects should be hidden from users. Objects are manipulated through associated **methods**.

Example: `[1,2,3,4]` has type `list`

- We don't really know how Python stores lists internally
- Fortunately we typically don't sweat the inner working of lists every time we use them (we've been doing it all semester!)
- How do we manipulate lists? Using the **operators** or **list methods** provided by Python.
  - `list3 = list1 + list2` (concatenation using an operator)
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- Recall that we can also use the + operator for strings! This is an example of p
- **Take away:** Internal representation of objects should be hidden from users. Objects are manipulated through associated **methods**.

This is the same as `list1+=["dog"]` !!!

What are Methods?

- Methods are *functions* that operate only on the specific object instance that comes before the **dot notation** with which they are called:

```
>>> l = ['mike', 'and']
>>> l.append('ike')
>>> l
['mike', 'and', 'ike']
>>> l.extend(['snap', 'crackle', 'pop'])
>>> l
['mike', 'and', 'ike',
 'snap', 'crackle', 'pop']
>>> l.reverse()
>>> l
['pop', 'crackle', 'snap',
 'ike', 'and', ‘mike']
```

appends a single item to the end of `list l`

Adds a sequence to the end of `list l`

Reverses the order of the list of `list l`

Some methods have arguments, some don't. Just like functions!

What are Methods?

Discover more list & str methods with `pydoc3 list` or `pydoc3 str` !

- Methods are *functions* that operate only on the specific object instance that comes before the **dot notation** with which they are called:

```
>>> s = "    CSCI 134 is great!\n \t"
>>> s.lower()
'    csci 134 is great!\n \t'
>>> s.isalpha()
False
>>> s.strip()
'CSCI 134 is great!'
>>> s.strip()[0].isalpha()
True
>>> "a,b,c,d".split(',')
['a', 'b', 'c', 'd']
```

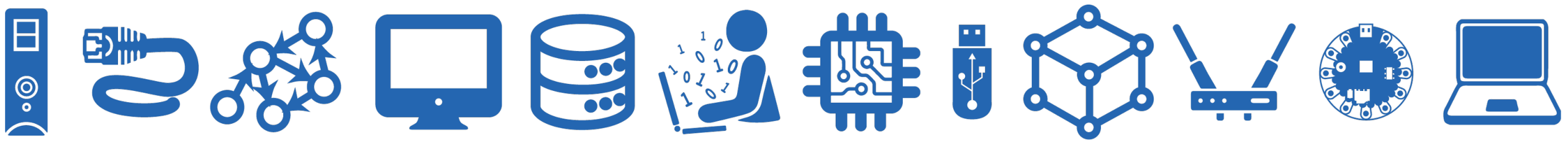
lowercases all characters in the `str`ing `s`

Is the `str`ing `s` made only of letters?

Remove whitespace from left/right sides of the `str`ing `s`

Method calls can be combined, just like function calls!

Defining Our Own Types

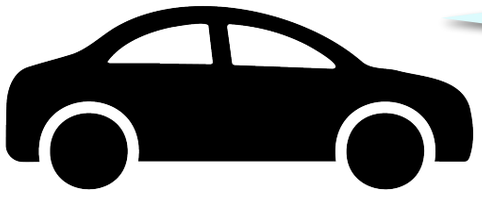


Creating Our Own Types: Classes

- It's time to move beyond just the built in Python objects!
- We can create our own data types by defining our own **classes**
  - Classes are like blueprints for objects in Python
- **Creating** a class involves:
  - Defining the **class name, attributes, methods**
- **Using** the class involves:
  - Creating **new instances** of the class (which create specific objects)
    - ```
      my_list = [1, 2],
      my_other_list = list("abc")
      ```
  - Performing operations on the instances through methods
    - ```
      my_list.append(3)
      ```

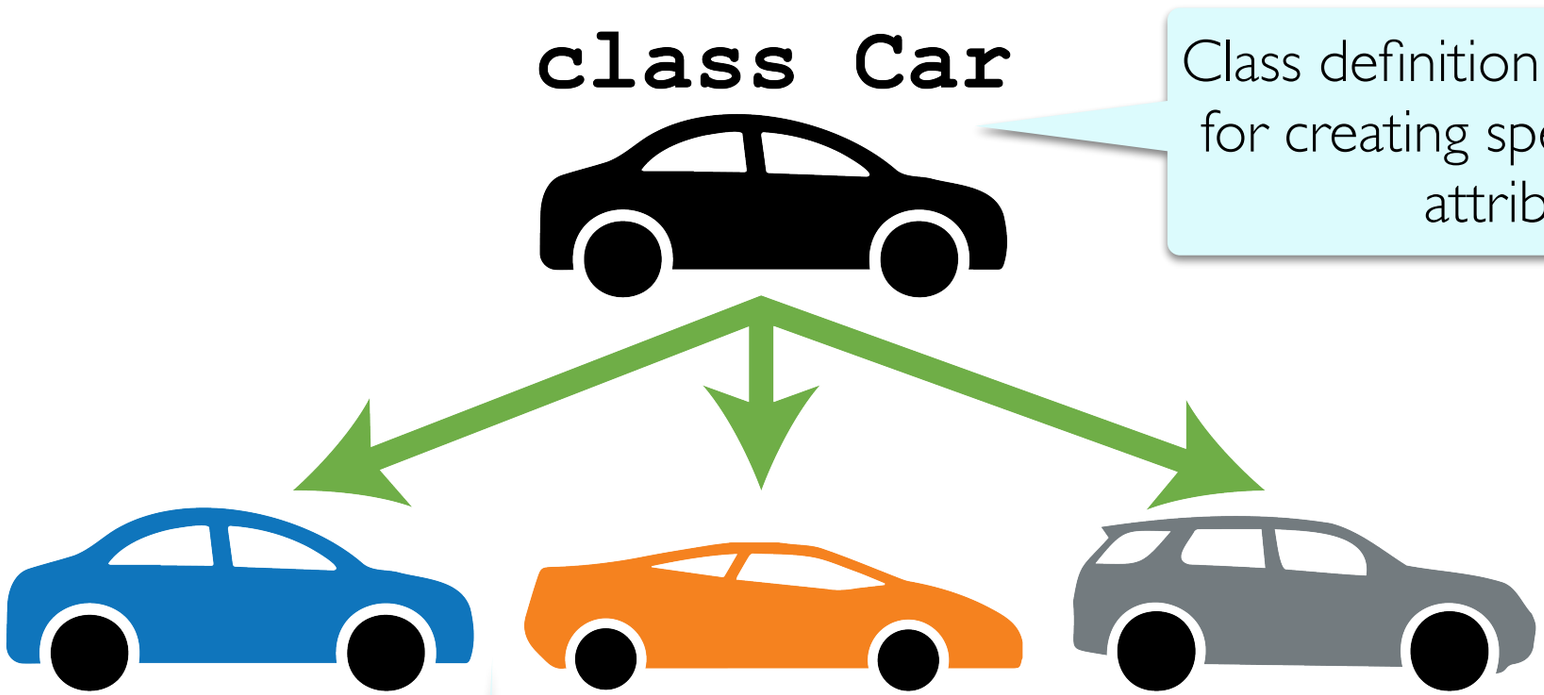
Defining Our Own Type: Car class

`class Car`



Class definition provides a "blueprint" for creating specific cars and specify **attributes** of cars

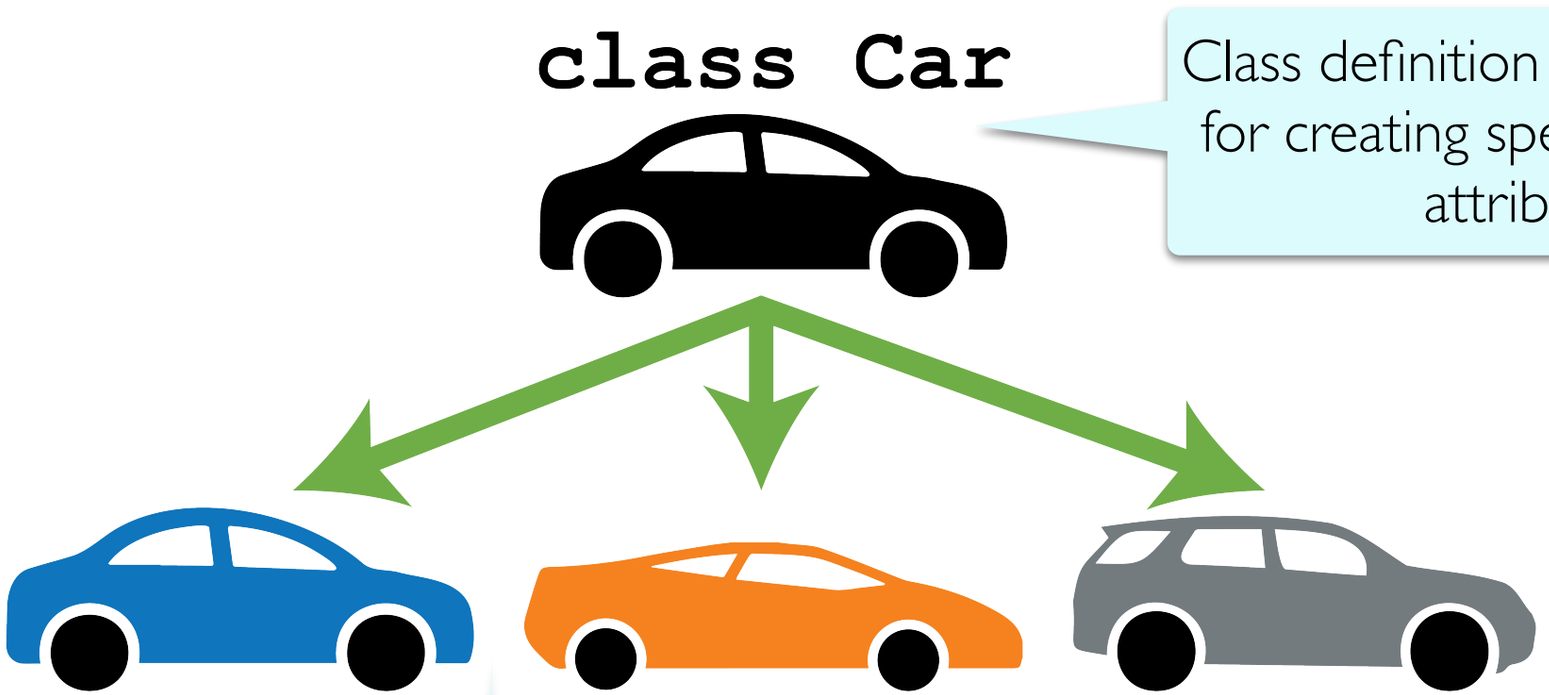
Defining Our Own Type: Car class



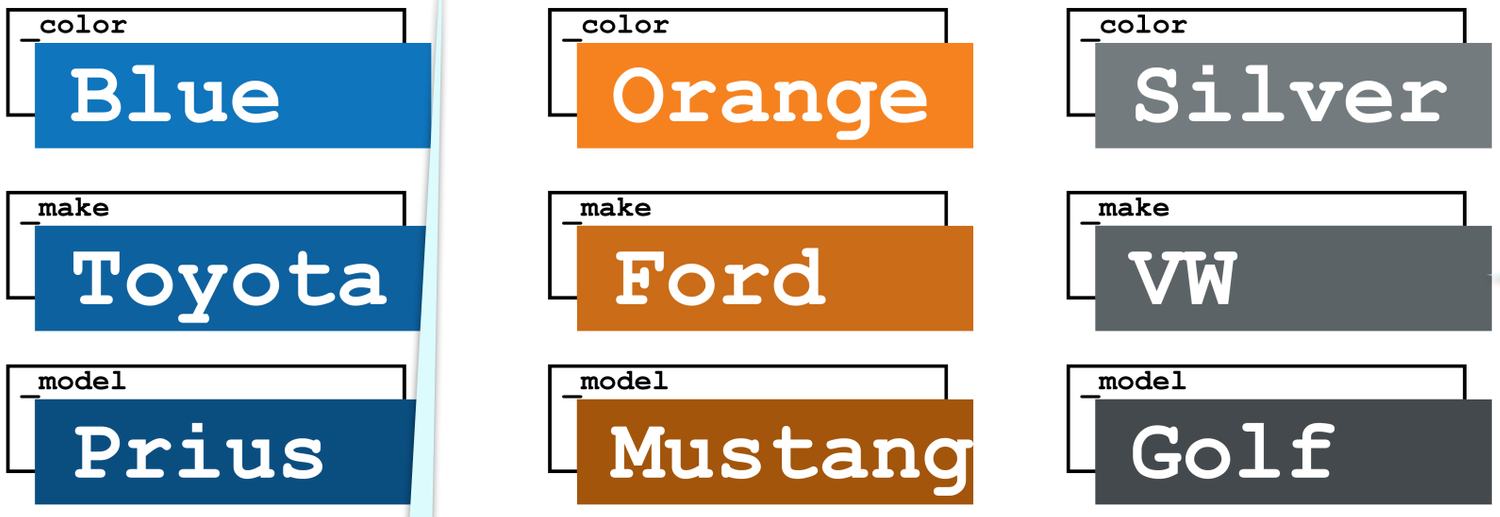
Class definition provides a "blueprint" for creating specific cars and specify attributes of cars

Specific instances of the Car class

Defining Our Own Type: Car class



Class definition provides a "blueprint" for creating specific cars and specify attributes of cars

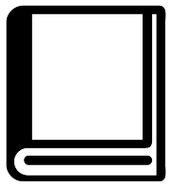


Specific instances of the Car class

Providing values for attributes of the Car class, such as color, make, and model, define key features of individual instances

Defining Our Own Type: Book class

`class Book`



Class definition provides a "blueprint" for creating specific books and specify attributes of books

`_title` **Fellowship of the Ring**	`_title` **Pride and Prejudice**	`_title` **Parable of the Sower**
`_author` **J.R.R. Tolkein**	`_author` **Jane Austen**	`_author` **Octavia Butler**
`_year` **1954**	`_year` **1813**	`_year` **1993**

Specific instances of the Book class

Providing values for attributes of the Book class, such as title, author, and year, define key features of individual instances

Defining Methods of a Class

- Methods are defined as part of the class definition and describe how to interact with the class objects
- Example: Recall the following methods for the list class

```
>>> lst = list()
>>> lst.extend([1,2,3])
>>> lst
[1, 2, 3]
>>> lst.append(4)
>>> lst
[1, 2, 3, 4]
```

dot notation to "call" the method on the object

Defining Methods of a Class

- On the previous slide, we called methods like **`append()`** and **`extend()`** on a particular list **object** **`lst`**.
- We can define methods in our classes in a similar way
- Consider this simple example:

Class name (note the use of CamelCase by convention)

```
class SampleClass:
    """Class to test the use of methods"""
    def greeting(self):
        print("Hello")
```

Defining Methods of a Class

- To create methods that can be called on an instance of a class, they must have a parameter which takes the instance of the class as an argument
- In Python, the **first parameter of a method is always `self`, and is used as a reference to the calling instance**

```
class SampleClass:
    """Class to test the use of methods"""
    def greeting(self):
        print("Hello")
```

All methods include **`self`** as the first parameter.

Our First Method

```
class SampleClass:
    """Class to test the use of methods"""
    def greeting(self):
        print("Hello")
```

- How do we call the greeting method?
  - We create an **instance** of the class and call the method on that instance using dot notation:

```
>>> sample = SampleClass()

>>> sample.greeting()
Hello
```

sample is an instance of SampleClass

Invoke the `greeting()` method on sample

Mysterious `self` Parameter

- Even though method definitions have `self` as the first parameter, **we don't pass this parameter explicitly** when we invoke the methods
- This is because whenever we call a method on an object, the object itself is **implicitly** passed as the first parameter
- Note: In other languages (like Java) this parameter is implicit in method definitions but in Python it is explicit and by convention named **`self`**
- **Take away:**
  - When **defining** methods, always include **self**
  - When **calling** (invoking) methods, the value for self is passed implicitly (meaning, we don't specify it, but it happens automatically)

Mysterious `self` Parameter

- In interactive python:
- *(the id(..) function which returns the identity/address of the object)*

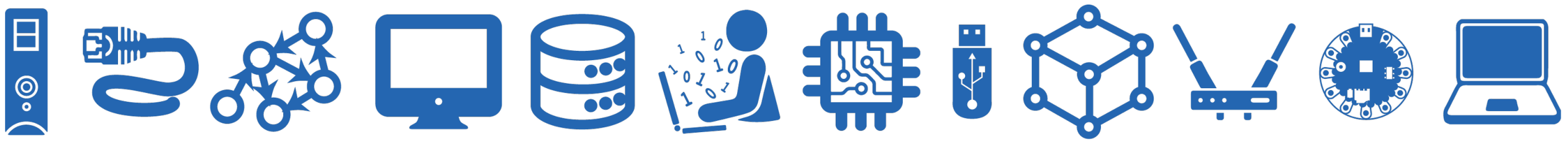
```
>>> class Sample():
...     def __init__(self):
...         print(id(self))

>>> s = Sample()
4404099008

>>> id(s)
4404099008
```

`self` is the instance we are applying the method to!

Summary of Classes and Methods

- **Classes** allow us to define our own data types
- We create **instances** of classes and interact with those instances using methods
- All **methods** belong to a class, and are defined within a class
- A method's purpose is to provide a way to access/manipulate **instances** of the class)
- The first parameter in the method definition is **the reference to the calling instance (self)**
- When **invoking** methods, this reference is provided implicitly

Example: Defining Our Own Class



Defining Our Own Class: Book

- Key features of a class:
    - **Attributes** that describe instance-specific data
    - **Methods** that act on those attributes
- When defining a new class (aka an object blueprint), it's important to identify what **attributes** are required and what actions will be performed using those attributes (**methods**)
- For example, suppose we want to define a new `Book` class
    - Attributes?
    - Methods?

Defining Our Own Class: Book

- Key features of a class:
    - **Attributes** that describe instance-specific data
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- When defining a new class (aka an object blueprint), it's important to identify what **attributes** are required and what actions will be performed using those attributes (**methods**)
- For example, suppose we want to define a new `Book` class
    - Attributes?
        - Title, author, publication year, genre, …
    - Methods?
        - `same_author_as( ), years_since_pub( ), …`

Defining Our Own Class: Book

Name of class (always capitalized by convention)

```
class Book:
    """This class represents a book"""

    # indented body of class
    definition
```

Creating instances of the class:

```
book1 = Book()
book2 = Book()
```

book1 is an instance of class Book

book2 is another (different) instance of class Book

Attributes

- Objects have *state* which is typically held in **instance variables** or (in Pythonic terms) **attributes**.
- Example: For our **Book** class, these include the book's title, author, and publication year
- Every **Book** instance has different attribute *values*!

- In Python, we typically **declare** and **initialize** attributes in a special function known as the **constructor**
- The constructor has a special name — `__init__` — and is typically defined at the top of the class before all other method definitions

Constructing objects with `__init__`

```
class Book:
    """This class represents a book"""

    def __init__(self):
        self.author = ""
        self.title = ""
        self.year = 0
```

author, title, and year are **attributes** of the Book **class**

- Currently the constructor just initializes the attributes to some default values
- Ideally, the constructor should take inputs just like any other function in order to initialize the attributes to the desired values

A Modification To Our Previous Constructor

```
class Book:
    """This class represents a book"""
    # declare Book attributes
    def __init__(self, book_author, book_title, book_year):
        self.author = book_author
        self.title = book_title
        self.year = book_year
```

The arguments are the same as arguments for a function.

Constructing objects with `__init__`

```
class Book:
    """This class represents a book"""


    def __init__(self, book_author, book_title, book_year):

        """ The constructor """
        self.author = book_author

        self.title = book_title

        self.year = book_year
```

```
>>> lotr = Book("J.R.R. Tolkein", "Lord of the Rings", 1954)
>>> lotr.year
1954
>>> print(lotr)
<__main__.Book object at 0x108255f30>
```

- The constructor now takes inputs, but the print function doesn't allow us to comprehend the contents of this object
- To get something more meaningful we need to define a string representation for our object

`__str__` method for Book Class

```
class Book:
      def __init__(self, book_author, book_title, book_year):

     """ The constructor """
            self.author = book_author

            self.title = book_title

            self.year = book_year

     def to_string(self):
```

```
    """ Method that defines string
        representation of book objects
    """
          return "'"+self.title+"', by "+self.author+", pub. "+ str(self.year)
```

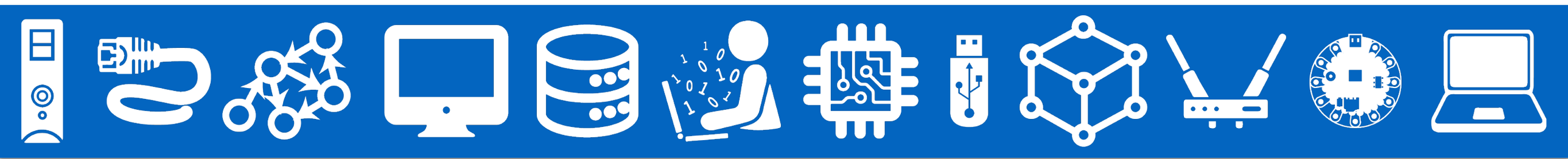
```
>>> lotr = Book("J.R.R. Tolkein", "Lord of the Rings", 1954)
>>> print(lotr.to_string())
'Lord of the Rings', by J.R.R. Tolkien, pub. 1954
```

But wouldn't this be more convenient if we could just print(lotr) or str(lotr)? (foreshadowing!!)

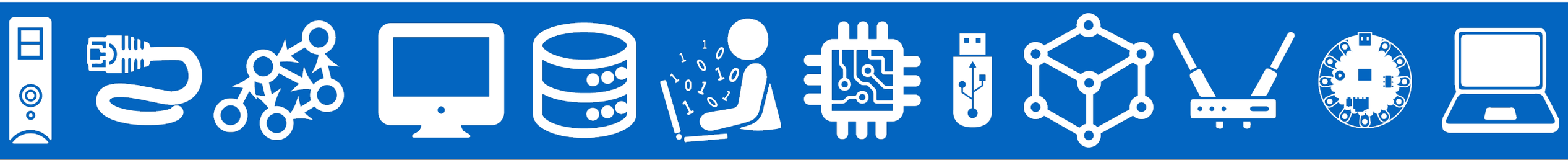
Next up

- So we have attributes and methods
- What actually happens when we create a new instance of a class?
- More on this (and more!) next time

The end!



Lab 7: Recursion



Lab 7 Overview

- **Recursion + Graphical Recursion!**
- Before submitting, make sure you've generated the **correct** image files according to the instructions using
  - `python3 runtests.py final`

Choose one person to be the "driver".
Then trade off who types!

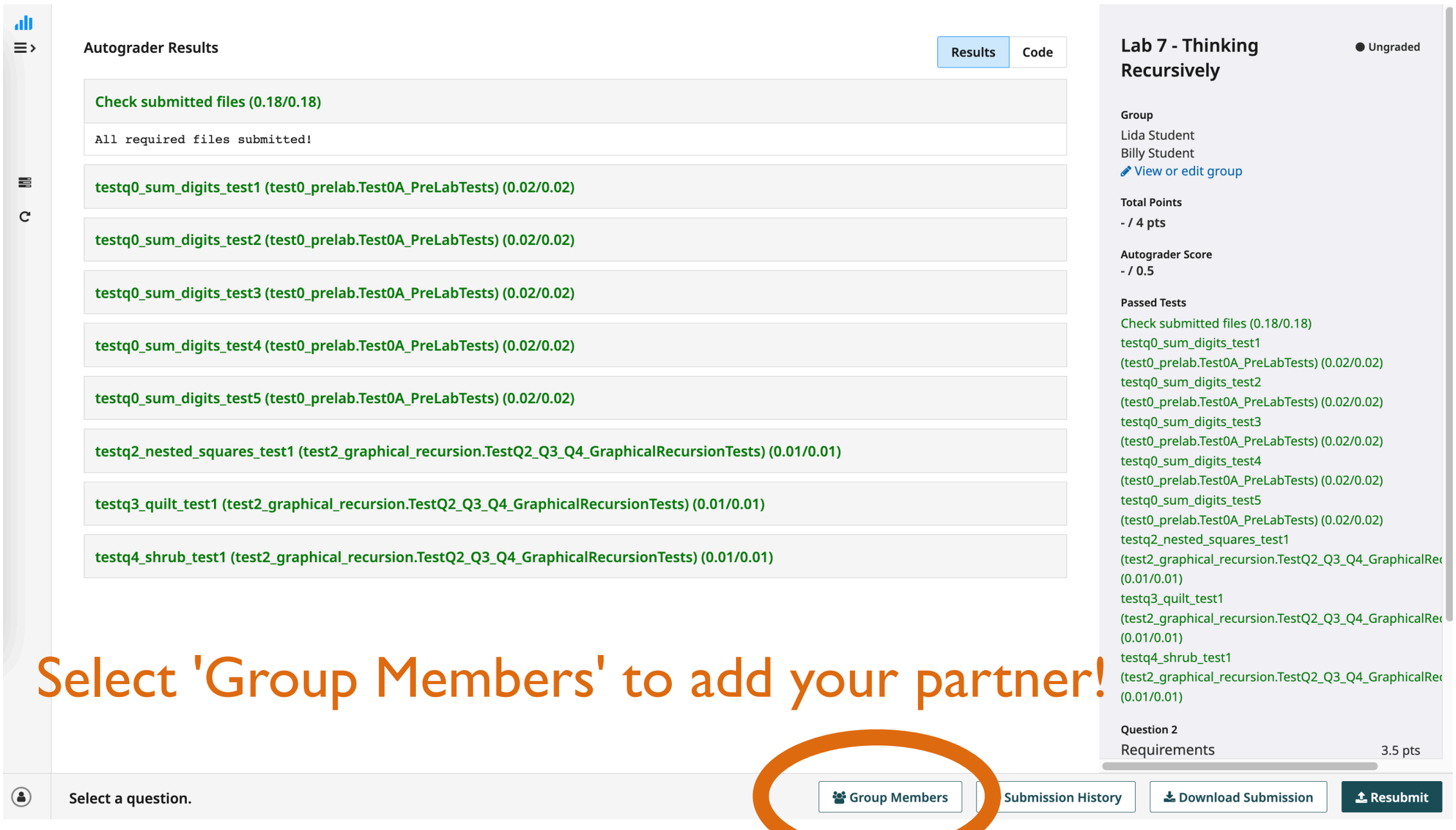
- When working with a partner:
  - Don't both edit the *same* file at the same time
  - BUT you can edit *different* files!
- When done, git add+commit+push
  - Then your partner can either **`git clone`** with those edits
  - Or **`git pull`** if they've already **`git clone`**d the repo

Lab 7 Overview

- Pre-lab exercise: `sum_digits(num)`
  - Similar to `sum_list(num_lst)`, from class, but *with a twist*!
- Bedtime Story
  - Similar to `count_up` and `count_down` from class, but *with a big twist*!
- Recursive Squares
  - Similar to `concentric_circles`, from class, but *with a twist*!
- Square quilt
  - Similar to `nested_circles`, from class, but *with a twist*!
  - Read the handout carefully. Make sure you draw all four quadrants!
- Shrub
  - Similar to `tree`, from class, but *with a twist*!

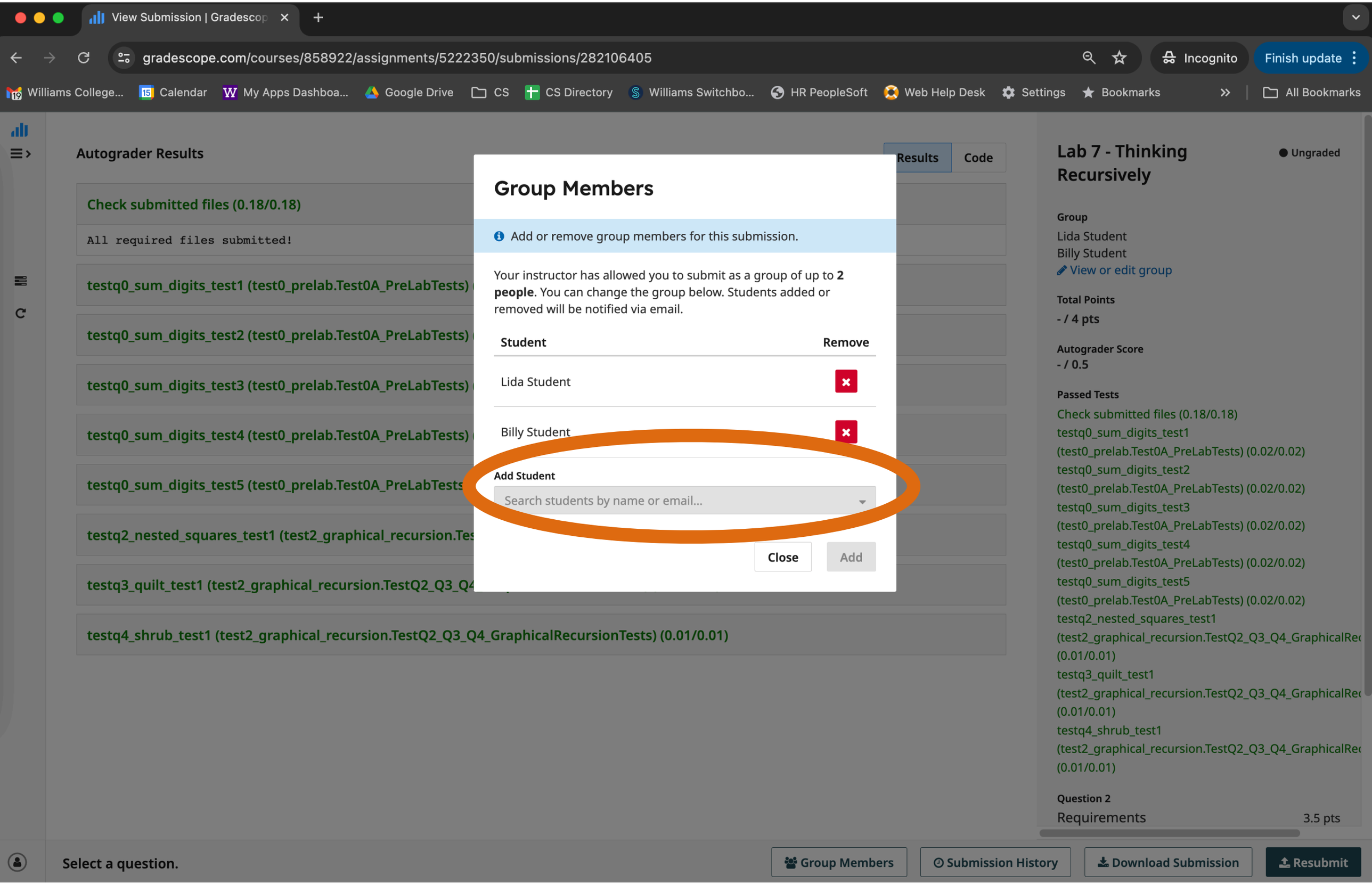
Gradescope with a Partner

- Only submit **one lab for your group!**

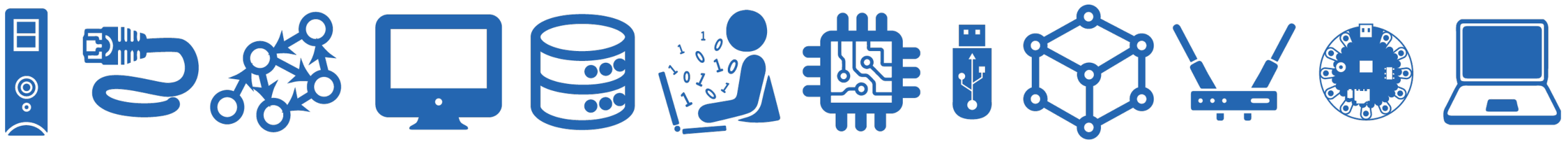


Select 'Group Members' to add your partner!

Gradescope with a Partner



Pair Programming

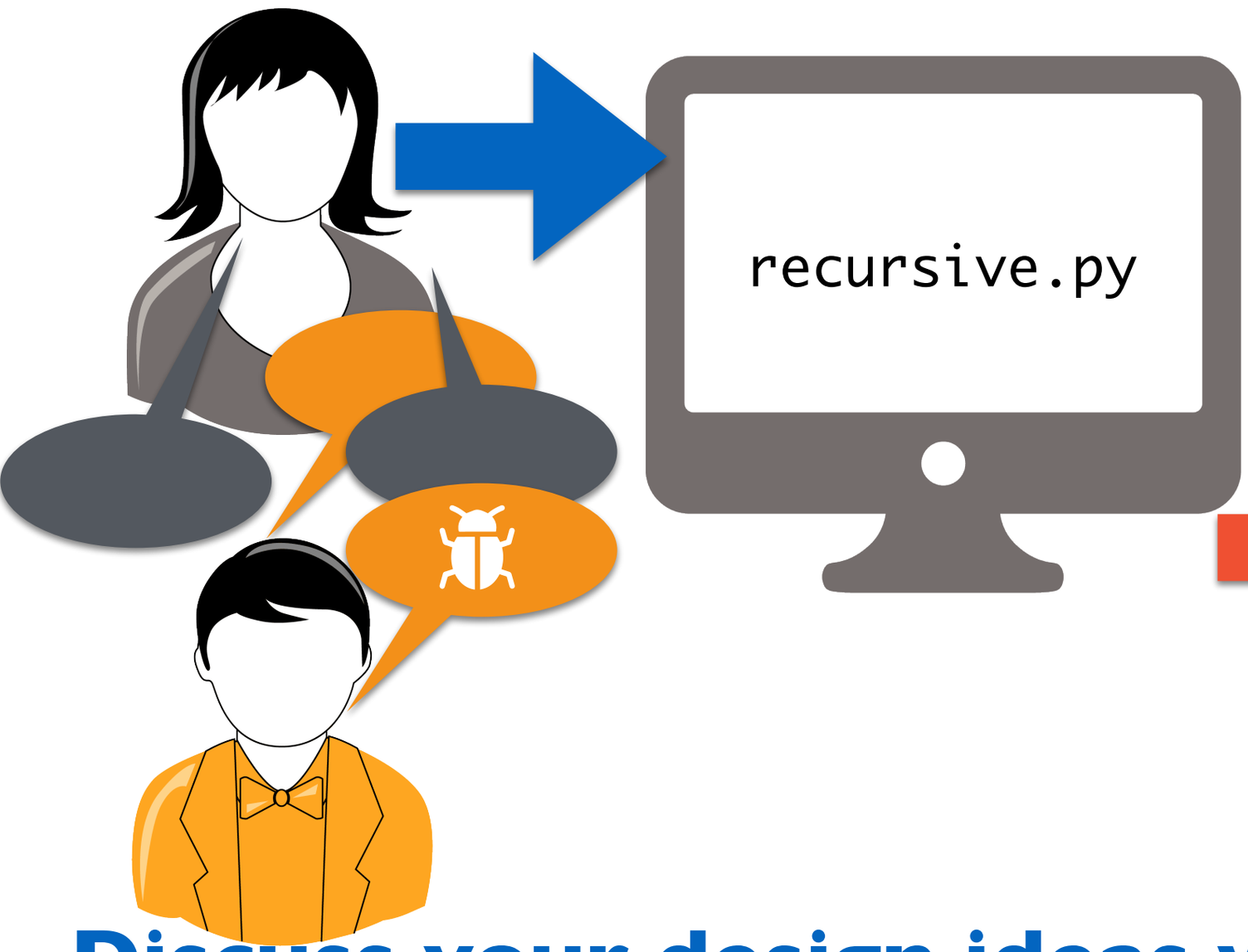


Working with a Partner

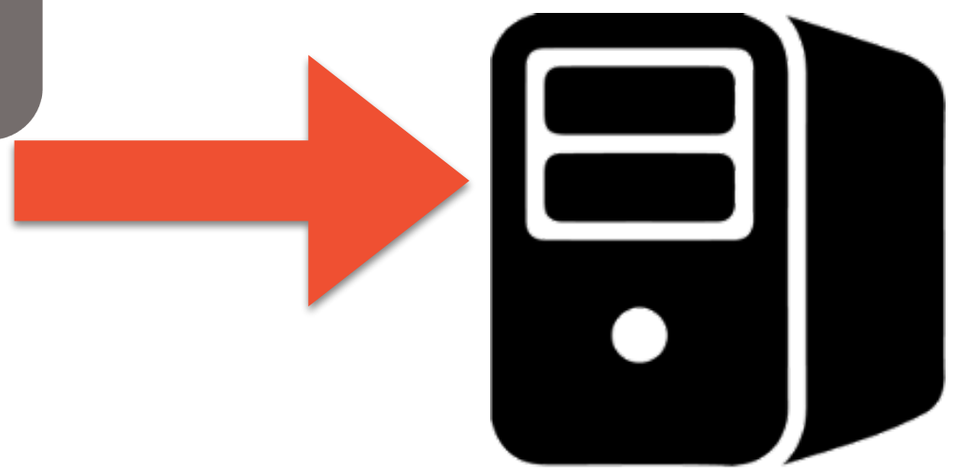
- "Pair Programming" (or programming with a partner) is an *Agile* software development technique from Extreme Programming
  - It's used in the real world!
  - Produces better solutions than produced individually!
  - Spreads knowledge!
  - It's good to be able to talk through complex ideas with someone else before diving into implementation details
  - Benefit from *both* partners' knowledge of problem-solving & debugging

`git` with a Partner

Pair Programming: One person "drives",
take turns who uses keyboard/mouse



Repository or "repo"



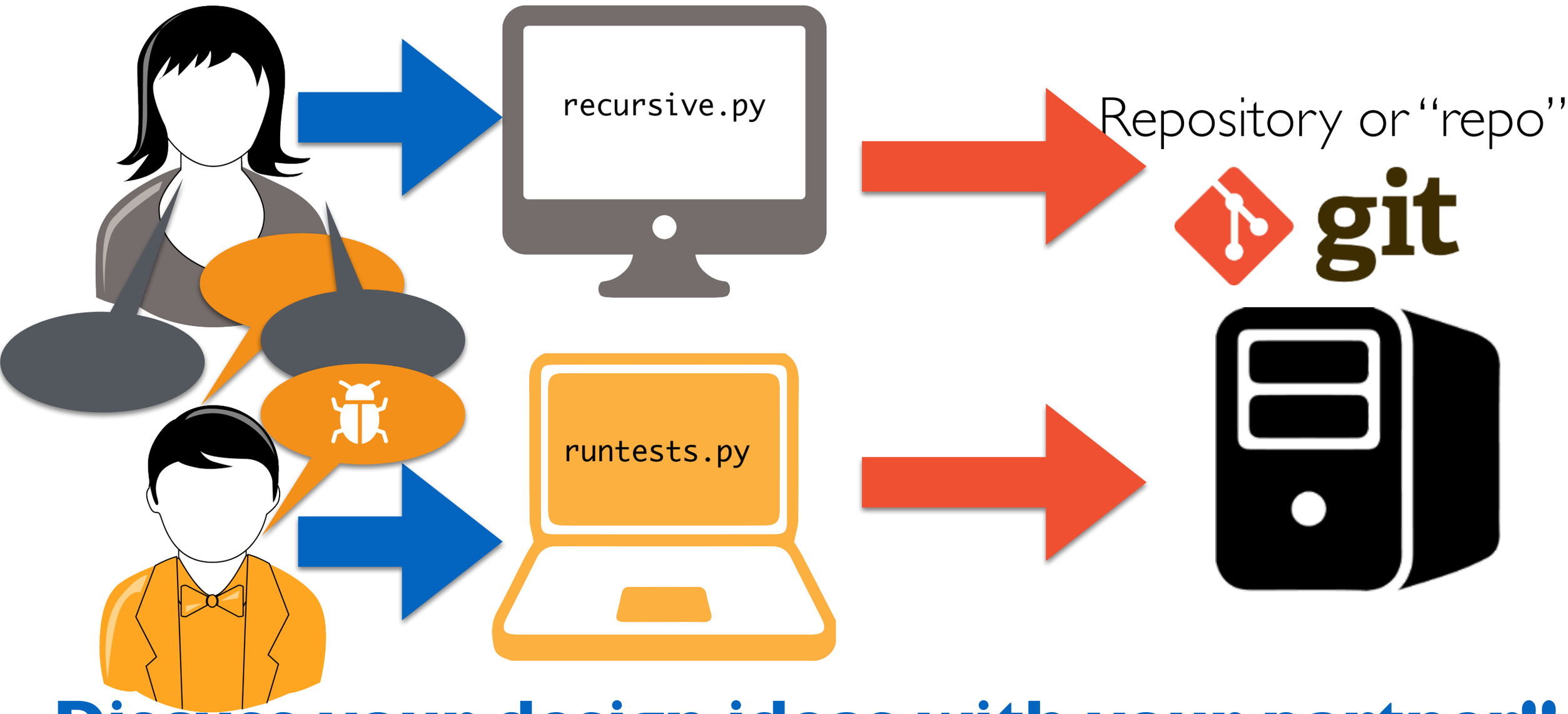
Discuss your design ideas with your partner!!

Identify bugs & bug fixes together!

`git` with a Partner

Jigsaw Programming:

Two partners, two different Python files!



Discuss your design ideas with your partner!!

Identify bugs & bug fixes together!

`git` with a Partner

Jigsaw Programming:

Two partners, two different Python files!

If an editor opens up saying files were merged: that's okay, just save & exit ("Ctrl+x" and then "y")

Discuss your design ideas with your partner!!

Identify bugs & bug fixes together!

`git` with a Partner

DO: Talk to your partner *a lot*!

DO NOT WORK ON THE SAME FILE AT THE SAME TIME!

There will be frustration!

And suffering!

And Lida will probably have to save you!

VS Code Live Share can handle this:
https://learn.microsoft.com/en-us/visualstudio/liveshare/

(if you can set it up on your own!)

Git Reminders

- If machine doesn't have the repo, **`git clone`** the repo
  - Grab URL from https://evolene.cs.williams.edu/ (or Lida's email)
  - `git clone <URL HERE>`
- **`git add/commit/push`** frequently, as you get work done

- To grab your partner's edits, **`git pull`**
  - (if you've already **`git clone`**d the repo)
  - If you have not **`git clone`**d the repo, then **`git clone`**

Git Workflow Reminder

- Starting a work session:
    - Always **pull most recent version** before making any edits (**clone** if using a new machine)
- Middle of a work session:
    - **Commit changes** to all files first (git commit -am "message") commits changes to all files already on evolene
    - After commit, **pull again** to get your partner's edits
    - If an editor opens up saying files were merged: that's okay, just save & exit ("Ctrl+x" and then "y")
    - Then **push your edits** to evolene (can check evolene to make sure it worked)
- Do the above steps (commit, pull, push) frequently
- Can check status anytime by typing `git status`
- Let us know if you face any issues!

Do You Have Any Questions?