Python and the Web

Today Python 4LM:

Today :

- Review
- Object-Oriented Python
- Web Requests
- Images in Python
- Web Development in Python
- Python Web Frameworks

Review of Functional Programming

First-Class Functions

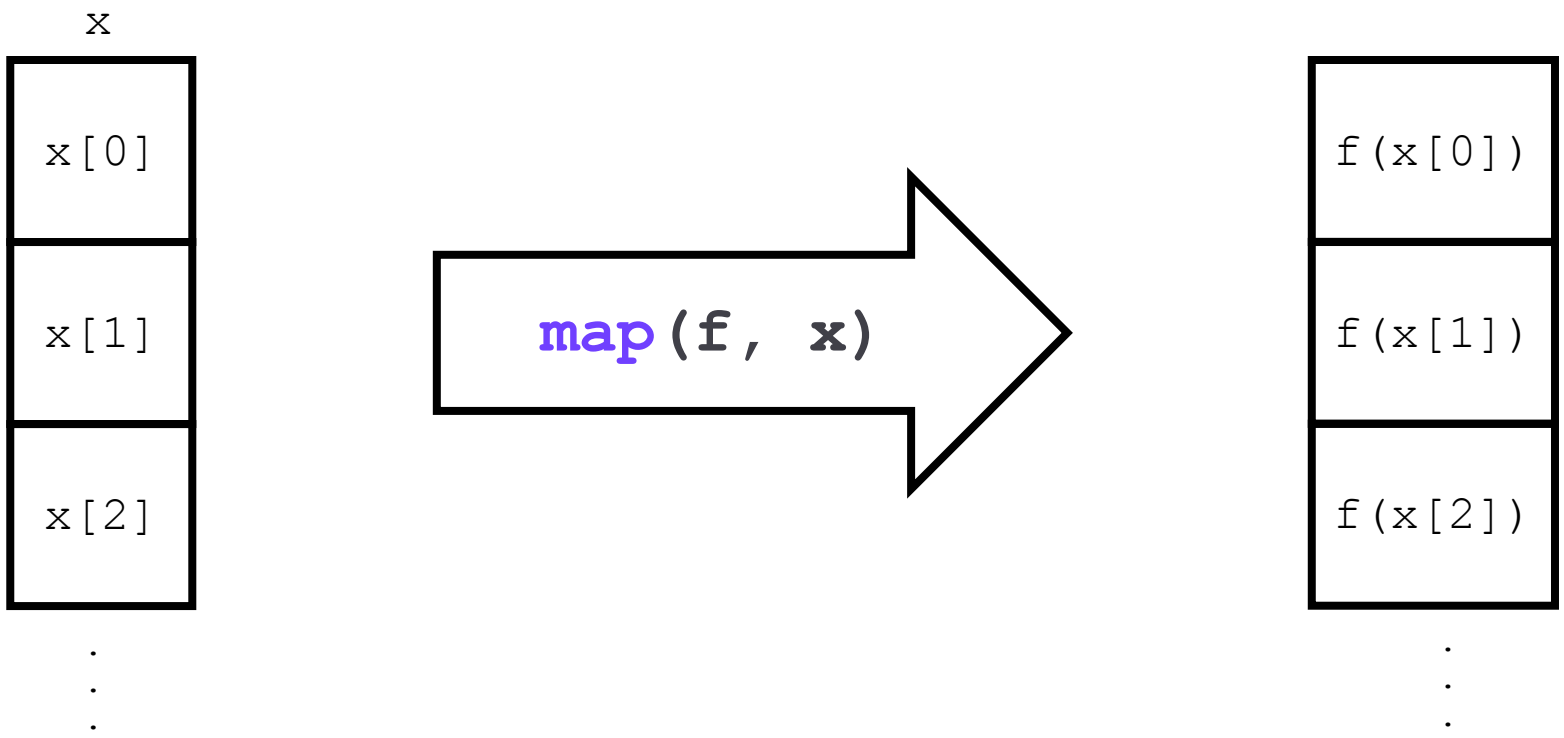
```
def echo(arg):
    return arg

type(echo) # => <class 'function'>
id(echo) # => 4393732128
print(echo) # => <function echo at 0x105e30820>

foo = echo
type(foo) # => <class 'function'>
id(foo) # => 4393732128
print(foo) # => <function echo at 0x105e30820>

isinstance(echo, object) # => True
```

Functions are Objects!

Functions as Parameters and map

Maps a function onto an iterable, returning another iterable.

The iterable is lazily generated, i.e., a generator.



Decorators

```
def cache(fn):
    fn._cache = {}
    def modified_fn(*args):
        if args not in fn._cache:
            fn._cache[args] = fn(*args)

        return fn._cache[args]

    return modified_fn
```

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Defines a new, modified function…

…using the old function in its execution.

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Accepts a function as an argument

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Returns the modified function

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    return fibbi(n-1) + fibbi(n-2) if n >= 2 else 1
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@cache
def fibbi(n):
    return fibbi(n-1) + fibbi(n-2) if n >= 2 else 1

fibbi(100)  # => 573147844013817084101
fibbi(1000) # => 703303677114228158...
```

Object-Oriented Python

Objects, Names, Attributes

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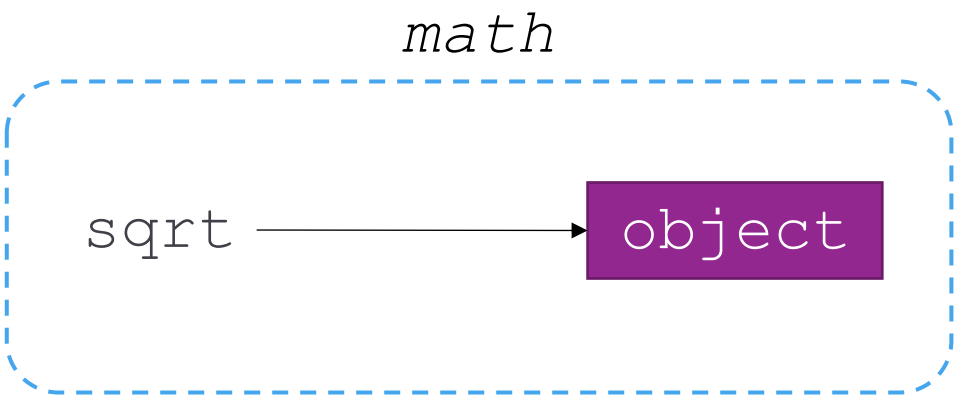
`math.sqrt`



Class Syntax

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class ClassName:
    <statement>
    <statement>
    ...
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    <statement>
    ...
```

The `class` keyword introduces a new class definition…

…but must be executed to have an effect (like `def`).

Class Definitions

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Exiting a class definition creates a *class object.*

- Defining a class `==` creating a class object (like `int`, `str`)
- Defining a class `!=` instantiating a class

Wait, what?

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- Only supports attribute reference.

Class objects *are not* instance objects!

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```
class MyClass:
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class MyClass:
    """A simple example class"""
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Class Definitions

```
class MyClass:
    """A simple example class"""
    num = 41
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class MyClass:
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    def greet(self):
        return "Hello world!"
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Class Definitions

```
class MyClass:
    """A simple example class"""
    num = 41

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MyClass.num   # => 41
MyClass.greet # => <function MyClass.greet>
```

Class Definitions

```
class MyClass:
    """A simple example class"""
    num = 41

    def greet(self):
        return "Hello world!"

MyClass.num   # => 41
MyClass.greet # => <function MyClass.greet>
```

Warning: clients can write to (and overwrite) class attributes!

Class Instantiation

Create an instance object whose attributes/methods/interface is defined by the class.

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No `new`!

Instantiate using parentheses and, optionally, arguments

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x = MyClass(args)
```

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```

"Instantiating" a class constructs an instance object of that class object.

In this case, `x` is an instance object of the `MyClass` class object

We've Seen This Before!

```
float('3.5')     # => 3.5
```

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```
float('3.5')      # => 3.5
str(8)            # => '8'
```

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```
float('3.5')      # => 3.5
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list('unicorn') # => ['u', 'n', 'i', ...]
```

We've Seen This Before!

```
float('3.5')      # => 3.5
str(8)            # => '8'

list('unicorn') # => ['u', 'n', 'i', ...]
set()             # => empty set
```

Custom Construction

Custom Construction

```
class Canadian:
    def __init__(self, first, middle, last, ssn=0):
        self.first_name = first
        self.middle_name = middle
        self.last_name = last
        self.ssn = ssn
```

Custom Construction

```
class Canadian:
    def __init__(self, first, middle, last, ssn=0):
        self.first_name = first
        self.middle_name = middle
        self.last_name = last
        self.ssn = ssn
```

```
michael = Canadian('Michael', 'John', 'Cooper')
```

Custom Construction

```
class Canadian:
    def __init__(self, first, middle, last, ssn=0):
        self.first_name = first
        self.middle_name = middle
        self.last_name = last
        self.ssn = ssn
```

```
michael = Canadian('Michael', 'John', 'Cooper')
michael.first_name  # => 'Michael'
michael.middle_name # => 'John'
michael.last_name   # => 'Cooper'
michael.ssn         # => 0
```

Custom Construction

```
class Canadian:
    def __init__(self, first, middle, last, ssn=0):
        self.first_name = first
        self.middle_name = middle
        self.last_name = last
        self.ssn = ssn
```

```
michael = Canadian('Michael', 'John', 'Cooper')
michael.ssn = 4...
michael.middle_name = 'Jamiroquai'
```

Revisiting Our Earlier Class

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    """A simple example class"""
    num = 41

    def greet(self):
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class MyClass:
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x = MyClass()
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Revisiting Our Earlier Class

```
class MyClass:
    """A simple example class"""
    num = 41

    def greet(self):
        return "Hello world!"
```

```
x = MyClass()
type(x) # => MyClass
```

Revisiting Our Earlier Class

```python
class MyClass:
    """A simple example class"""
    num = 41

    def greet(self):
        return "Hello world!"
```

```python
x = MyClass()
type(x) # => MyClass

x.greet() # => 'Hello world!'
# Weird... doesn't `greet` need an argument?
```

Revisiting Our Earlier Class

```
class MyClass:
    """A simple example class"""
    num = 41

    def greet(self):
        return "Hello world!"
```

```
x = MyClass()
```

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```
class MyClass:
    """A simple example class"""
    num = 41

    def greet(self):
        return "Hello world!"
```

```
x = MyClass()
type(x.greet)        # => method
type(MyClass.greet) # => function
```

Revisiting Our Earlier Class

```
class MyClass:
    """A simple example class"""
    num = 41

    def greet(self):
        return "Hello world!"
```

```
x = MyClass()
type(x.greet)        # => method
type(MyClass.greet) # => function

x.num is MyClass.num      # => True
x.greet is MyClass.greet # => False
```

Methods vs. Functions

A method is a function attached to an object.

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method ~ (object, function)
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Method calls invoke special semantics.

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instance.method(*args, **kwargs)
==
function(instance, *args, **kwargs)
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method ~ (object, function)
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instance.method(*args, **kwargs)
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```
function # => <bound method Class.method>
```

Example:

```
class Unicorn:
    """
    A class to handle unicorn-related awesomeness.
    """
```

```python
class Unicorn:
    """
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    """
    def __init__(self, name, magic_capability=10):
        self.name = name
        self.magic_capability = magic_capability
```

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class Unicorn:
    """
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    """
    def __init__(self, name, magic_capability=10):
        self.name = name
        self.magic_capability = magic_capability

    def cast_spell(self, chant, magic_required=1):
        if self.magic_capability >= magic_required:
```

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    def cast_spell(self, chant, magic_required=1):
        if self.magic_capability >= magic_required:
            print(f"{chant}! The spell was cast.")
            self.magic_capability -= magic_required
```

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class Unicorn:
    """
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    """
    def __init__(self, name, magic_capability=10):
        self.name = name
        self.magic_capability = magic_capability

    def cast_spell(self, chant, magic_required=1):
        if self.magic_capability >= magic_required:
            print(f"{chant}! The spell was cast.")
            self.magic_capability -= magic_required
        else:
            print(f"{self.name} isn't magical enough.")
```

```
u = Unicorn('Unicornelius', magic_capability=3)

Unicorn.cast_spell # => <function Unicorn.cast_spell>
u.cast_spell # => <bound method Unicorn.cast_spell of ...>

u.cast_spell('Alohomora', magic_required=2)
# (Implicitly calls Unicorn.cast_spell(u, 'Alohamora',
#  magic_required=2))
# Alohomora! The spell was cast.

u.cast_spell('Wingardium Leviosa', magic_required=2)
# Unicornelius isn't magical enough.
```

Web Requests in Python

`requests`: HTTP for Humans

Quickstart

How Websites Work (*very* abridged)

Client

(Chrome, Firefox, Safari, Python)

Server

(google.com, unicornpictures.com, stanford.edu)

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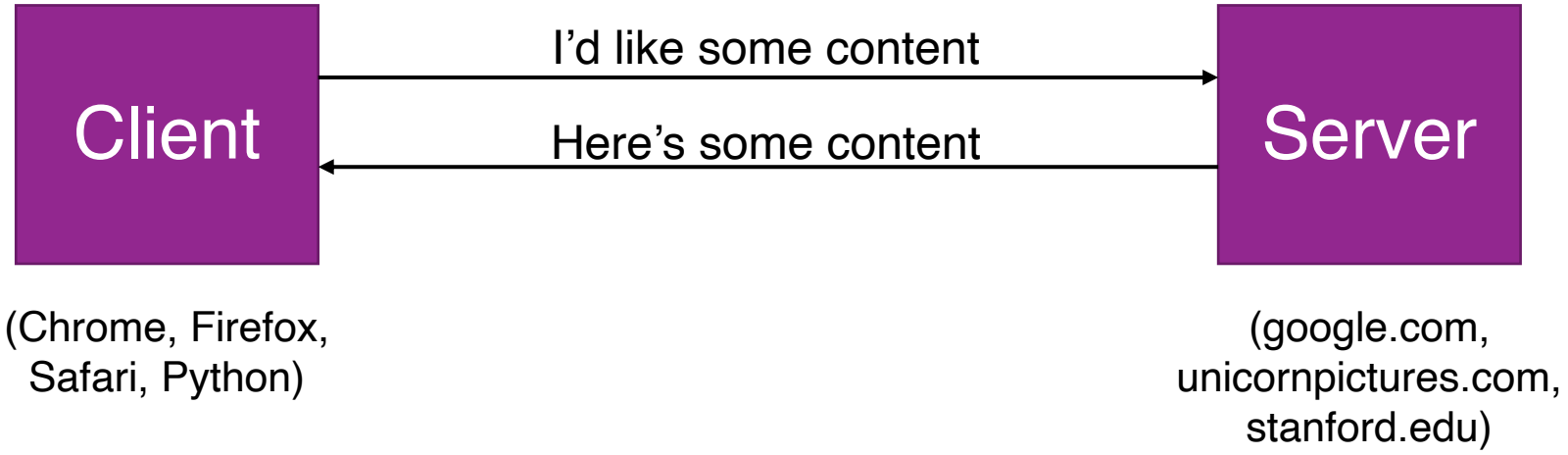

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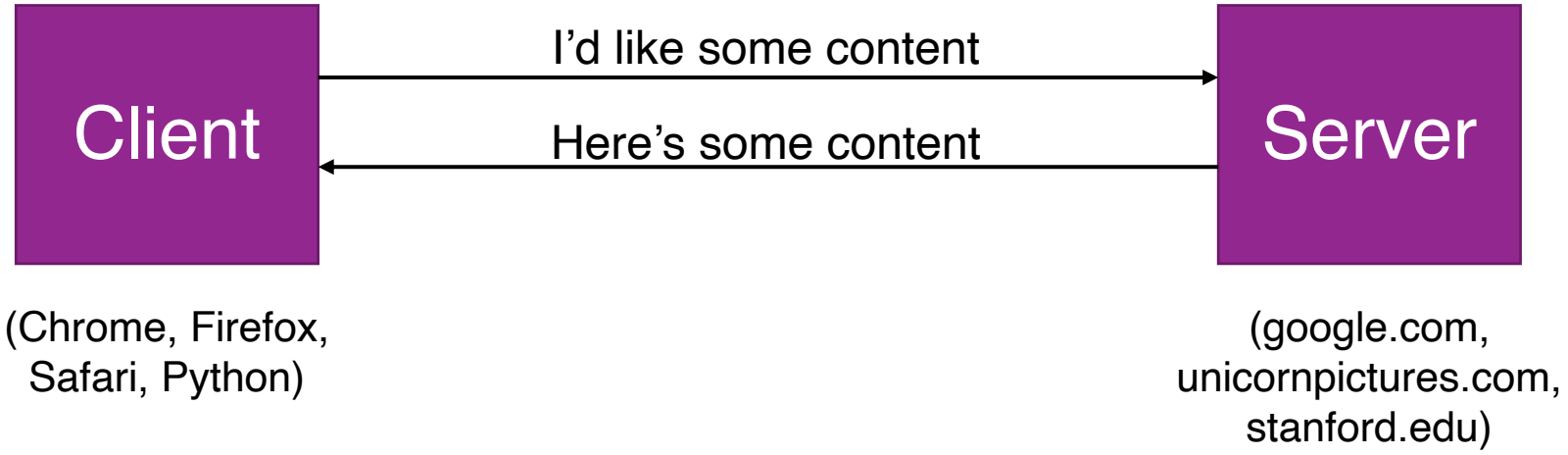

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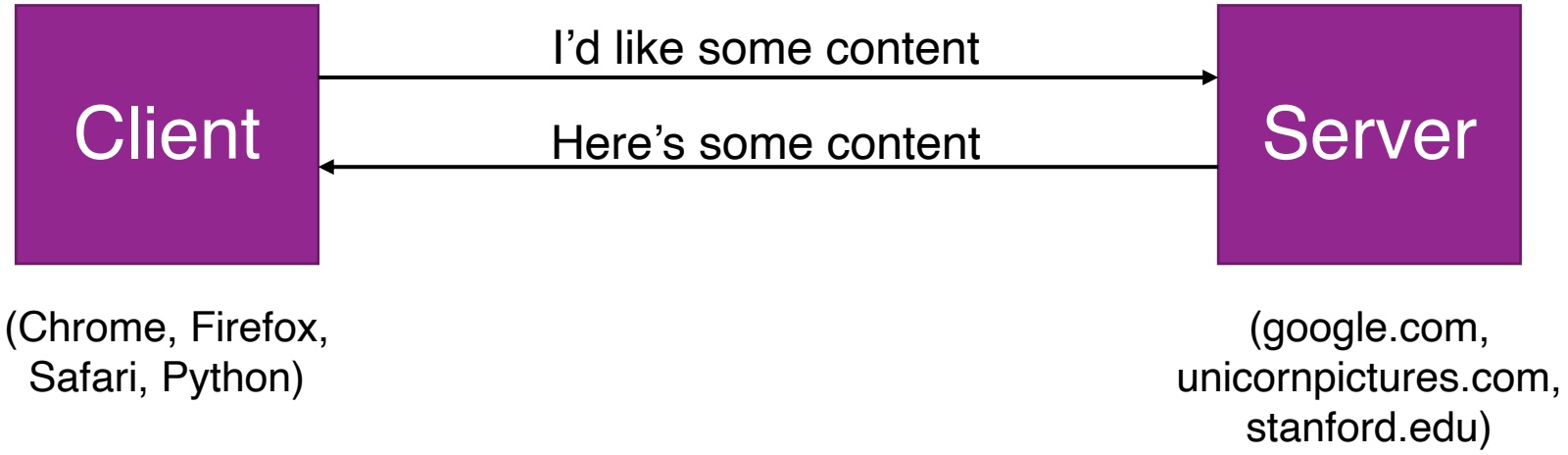

Request Protocols:

I'd like some content →

GET Requests a representation of the specified resource (typically doesn't cause side effects).
https://www.unicornpictures.com/?filter=top&year=2019

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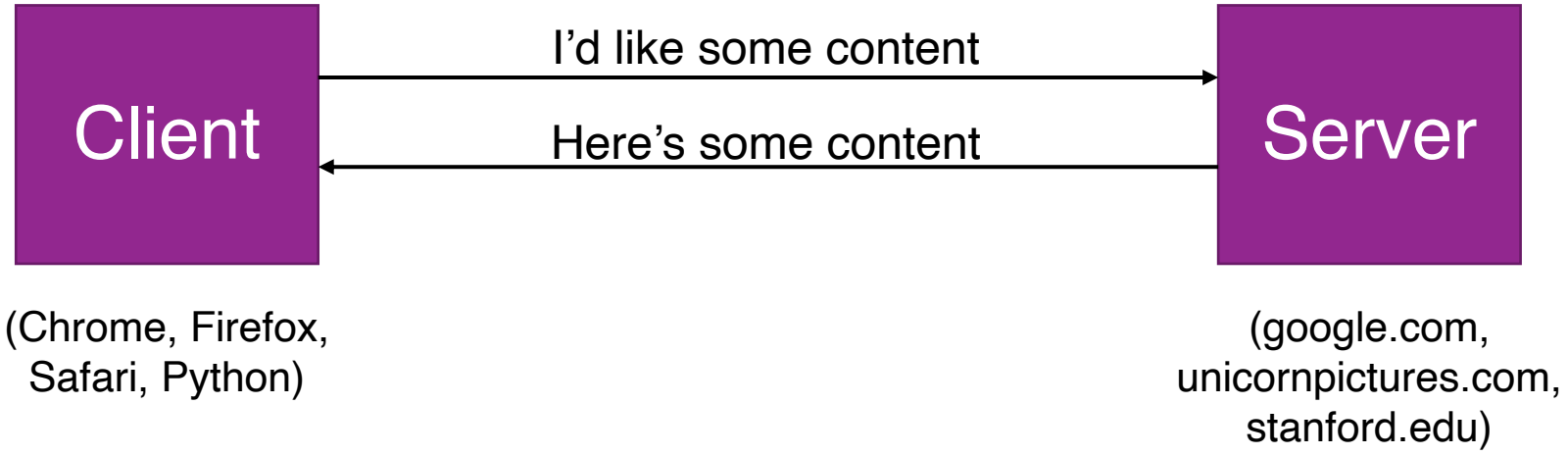

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GET Requests a representation of the specified resource (typically doesn't cause side effects).
https://www.unicornpictures.com/?filter=top&year=2019

POST Submits data to be processed (e.g., from a form) to the resource.
https://www.unicornpictures.com/login
With payload: `{"user": "psarin", "password": "I <3 unic0rns"}`

How Websites Work (*very* abridged)

Response Content Types:

Here's some content

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```
{
    "latitude": 42.434719,
    "longitude": -83.985001,
    "weather": {
        "temperature": 46,
        "pressure": 12,
        "description": "frozen"
    }
}
```

JSON strings must be delimited using double quotes

JSON object keys must be strings

Bools are lowercase

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```

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JSON object keys must be strings

Bools are lowercase

Make sure you know what response type the website will return!

JSON in Python

Any JSON data can be interpreted as a Python object (the inverse is not true, though)!

- Use the `json` package in the standard library.
- Built-in utilities for `requests` and web development packages (coming later).

JSON	Python
Object	Dictionary
Array	List
String	String
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Null	None

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```
# Load JSON from a file
file_data = json.load(f)
```

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```
# Load JSON from a file
file_data = json.load(f)

# Load JSON from a string
s_data = json.loads('{"Michael": "Favourite Canadian"}')
```

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# Load JSON from a string
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# Convert Python data to JSON, store in a file
json.dump(obj, f)
```

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Object	Dictionary
Array	List
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Raises `TypeError` if object is not JSON serializable

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# Load JSON from a string
s_data = json.loads('{"Michael": "Favourite Canadian"}')

# Convert Python data to JSON, store in a file
json.dump(obj, f)

# Convert Python data to JSON, return as string
json.dumps(obj)
```

JSON	Python
Object	Dictionary
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Raises `TypeError` if object is not JSON serializable

Web Queries in Python

```
# Make a request
```

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```
# Make a request
response = requests.get('https://www.unicornpictures.com/')
```

Web Queries in Python

```
# Make a request
response = requests.get('https://www.unicornpictures.com/')
if response.ok:
```

Web Queries in Python

```
# Make a request
response = requests.get('https://www.unicornpictures.com/')
if response.ok:
    raw_data = repsonse.content
    json_data = response.json() # if the response is in JSON format
```

Web Queries in Python

```
# Make a request
response = requests.get('https://www.unicornpictures.com/')
if response.ok:
    raw_data = repsonse.content
    json_data = response.json() # if the response is in JSON format

# Find the response content type
response = requests.get('https://www.google.com')
response.headers.get('content-type') # => 'text/html; charset=ISO-8859-1'
```

Web Queries in Python

Web Queries in Python

```
# GET with parameters
payload = {'filter': 'top', 'year': 2019}
response = requests.get('https://www.unicornpictures.com/',
                        params=payload)
response.url # => https://www.unicornpictures.com/?filter=top&year=2019
```

Web Queries in Python

```
# GET with parameters
payload = {'filter': 'top', 'year': 2019}
response = requests.get('https://www.unicornpictures.com/',
                        params=payload)
response.url # => https://www.unicornpictures.com/?filter=top&year=2019

# POST with parameters
payload = {'username': 'psarin', 'password': 'I <3 unic0rns'}
response = requests.post('https://www.unicornpictures.com/login',
                         data=payload)
```

Example: /r/cats/

Images

Images and the Web

Image representation on the web is as a sequence of bytes…

```
r = requests.get('https://unicornpictures.com/unicorn.png')
r.content
# => b'\x89PNG\r\n\x1a\n\x00\x00\x00\rIHDR\x00\x00\x03\x08...'
```

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Image representation on the web is as a sequence of bytes…

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```

This isn’t very helpful… we need to process the image.

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```

This isn't very helpful… we need to process the image.

In Python 2, the "Python Imaging Library," or PIL, used to be the primary image manipulation package. Development stopped in ~2010. `Pillow` is a fork of PIL that is still maintained.

```
pip install Pillow
```

```
from PIL import Image
```

Loading an Image

Loading an Image

```
# Open an image by filename
filename = 'unicorn.png'
im = Image.open(filename)
```

Loading an Image

```
# Open an image by filename
filename = 'unicorn.png'
im = Image.open(filename)

# Open a file-like object
with open(filename, 'rb') as f:
    im = Image.open(f)
```

Loading an Image

```
# Open an image by filename
filename = 'unicorn.png'
im = Image.open(filename)

# Open a file-like object
with open(filename, 'rb') as f:
    im = Image.open(f)

# Problem: What if we have an image as bytes?
r = requests.get('https://unicornpictures.com/unicorn.png')
r.content # => b'\x89PNG\r\n\x1a\n\x00\x00\x00\rIHDR\x00\x00\x03\x08...'
```

Loading an Image

```
# Open an image by filename
filename = 'unicorn.png'
im = Image.open(filename)

# Open a file-like object
with open(filename, 'rb') as f:
    im = Image.open(f)

# Problem: What if we have an image as bytes?
r = requests.get('https://unicornpictures.com/unicorn.png')
r.content # => b'\x89PNG\r\n\x1a\n\x00\x00\x00\rIHDR\x00\x00\x03\x08...'

# Solution: *Convert* it to a file-like object
from io import BytesIO
f = BytesIO(r.content) # simulates a file
im = Image.open(f)
```

The “Image” Object

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```
# Display the image in your default image software
im.show()
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# Get metadata about the image
im.format # => 'PNG'
im.size   # => (776, 838)
im.mode   # => 'RGBA'
```

Modify the Image

Modify the Image

```
# Crop to a box with (upper_left, lower_right)
box = (100, 100, 400, 400)
region = im.crop(box)
```

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out = im.rotate(45) # degrees counter-clockwise
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out = im.rotate(45) # degrees counter-clockwise

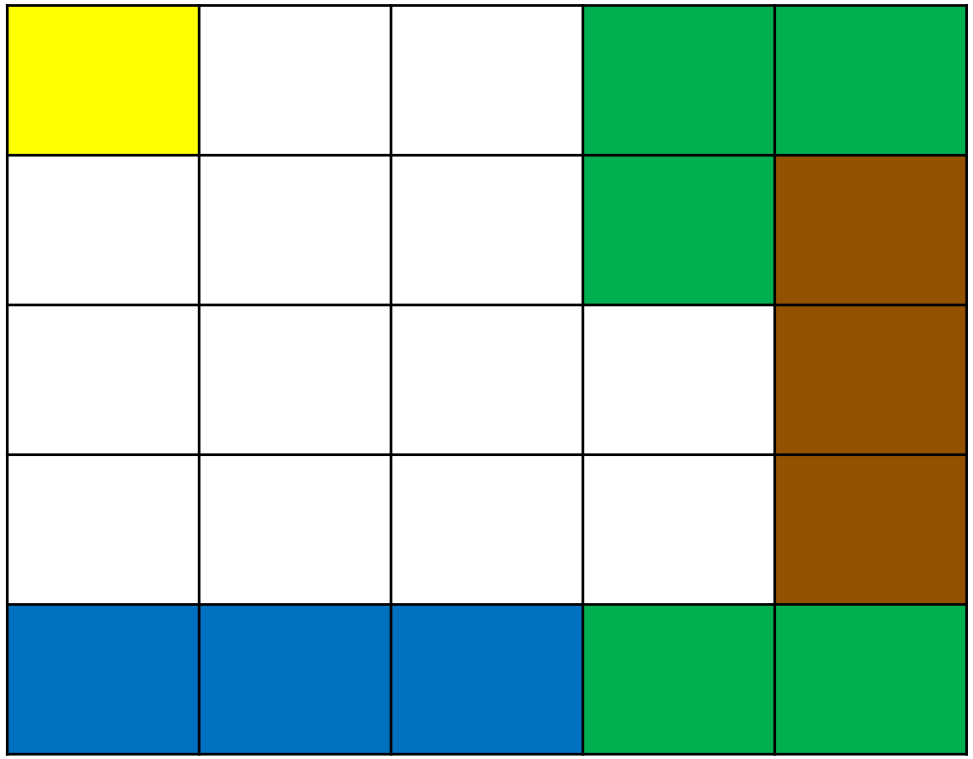
# Point operations
out = im.point(lambda i: min(i, 150))
```

Modify the Image

```
# Filter transformations
from PIL import ImageFilter
# Built-in filters:
# - ImageFilter.BLUR
# - ImageFilter.CONTOUR
# - ImageFilter.DETAIL
# - ImageFilter.EDGE_ENHANCE
# - ImageFilter.EMBOSS
# - ImageFilter.FIND_EDGES
# - ImageFilter.SHARPEN
# - ImageFilter.SMOOTH
# - ...and more!
out = im.filter(ImageFilter.BLUR)
```

Modify the Image

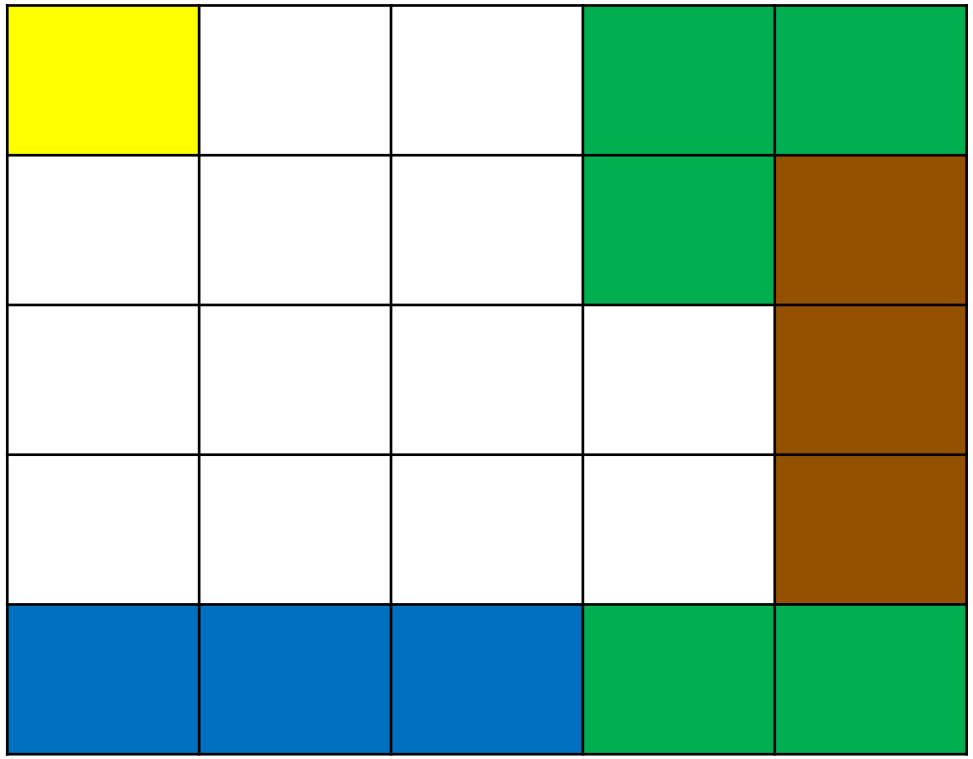
Key insight: an image is an array of *pixels*.



Modify the Image

Key insight: an image is an array of *pixels*.

A pixel is a tuple of *numbers* in `range(256)`.



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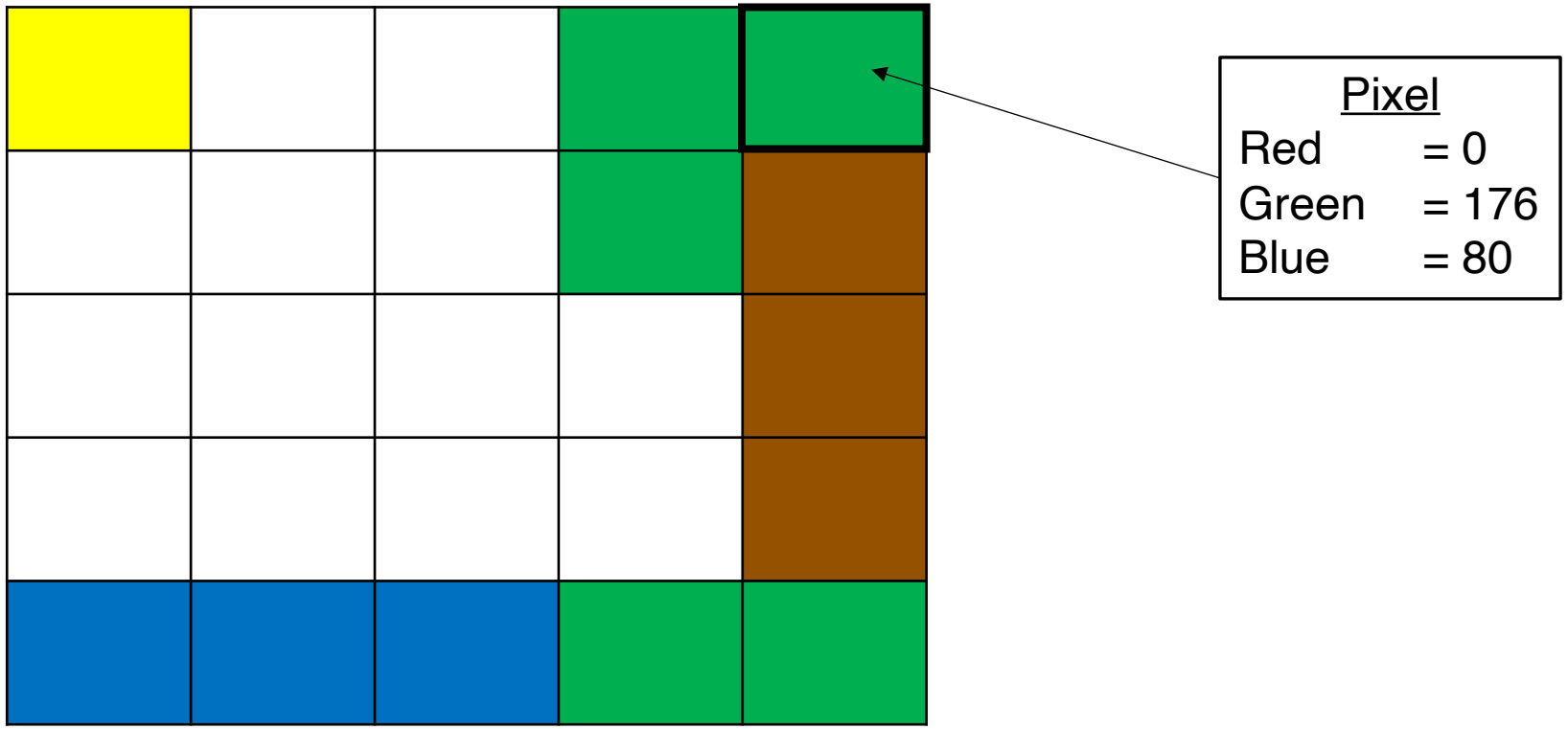

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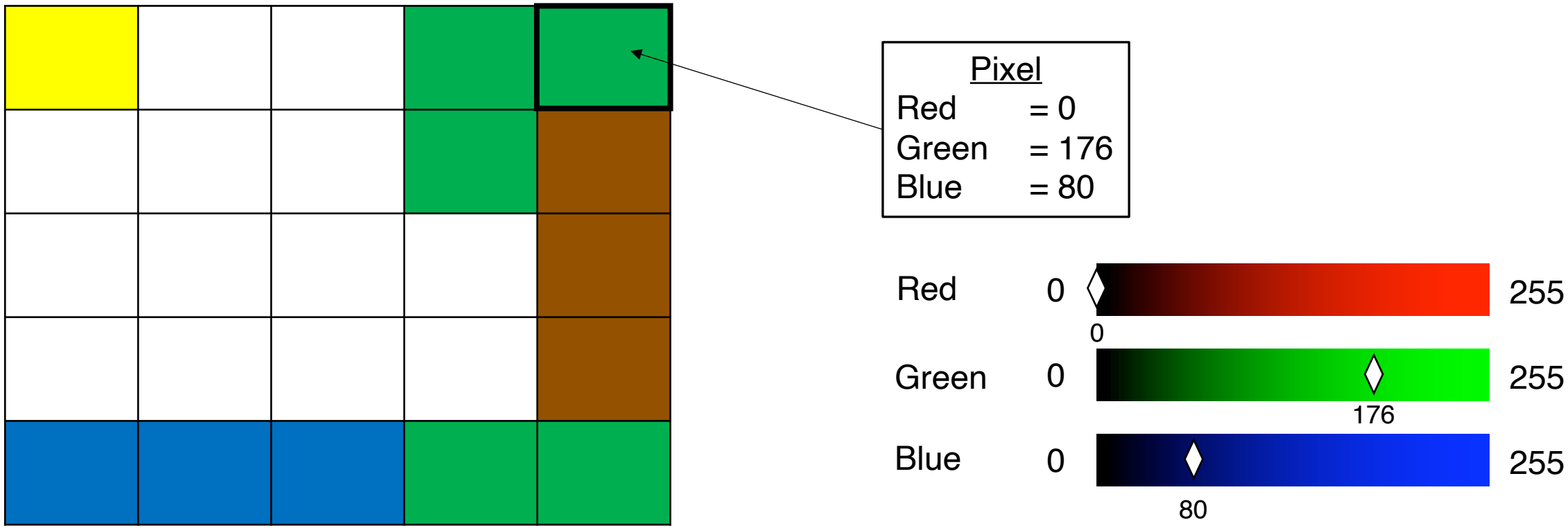

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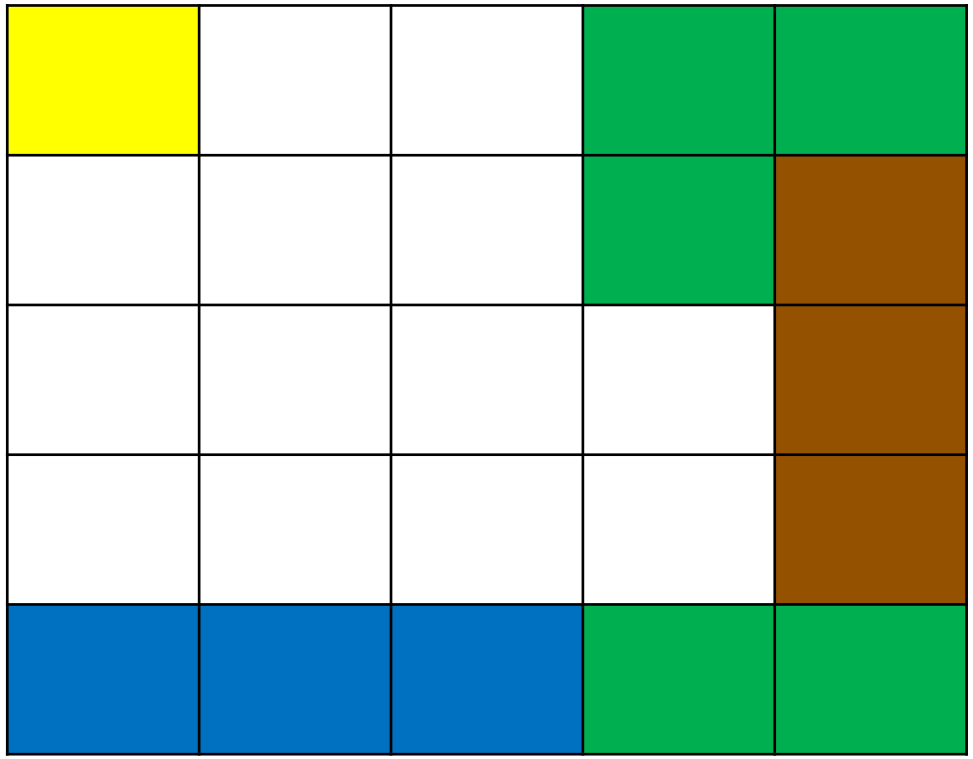

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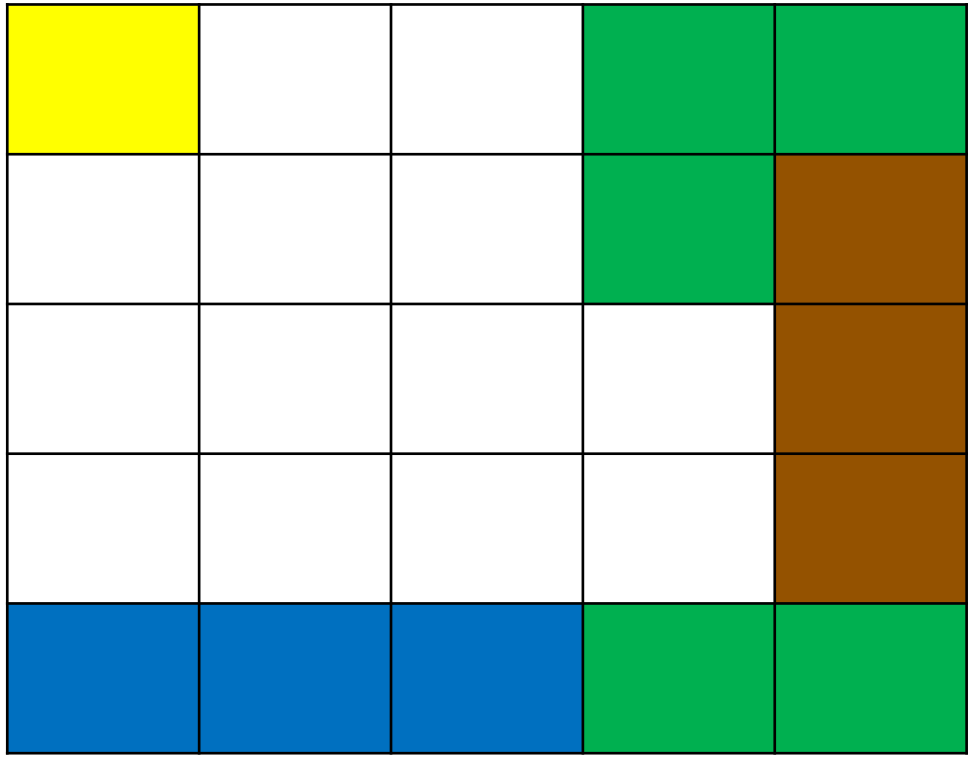

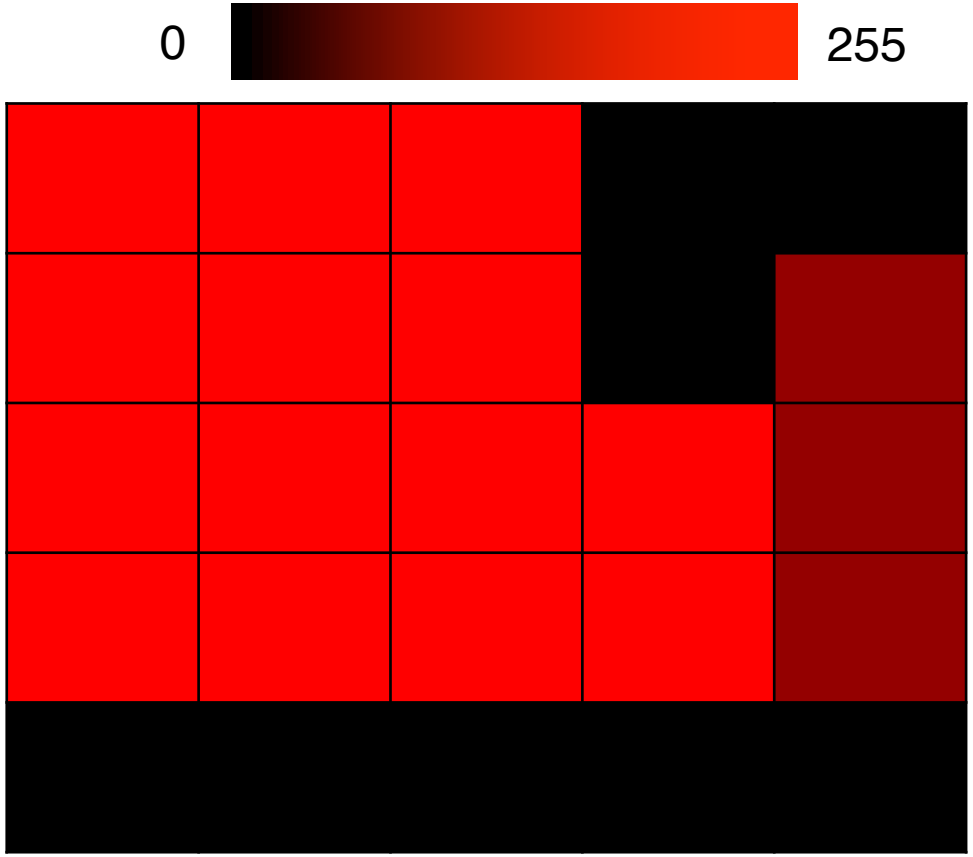

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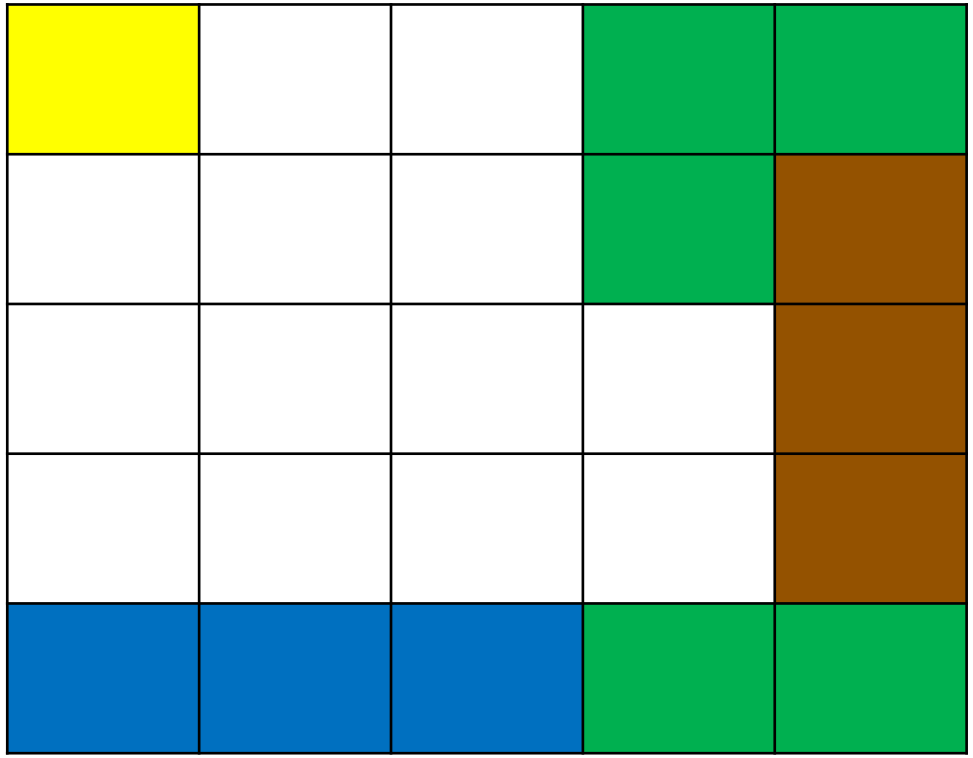

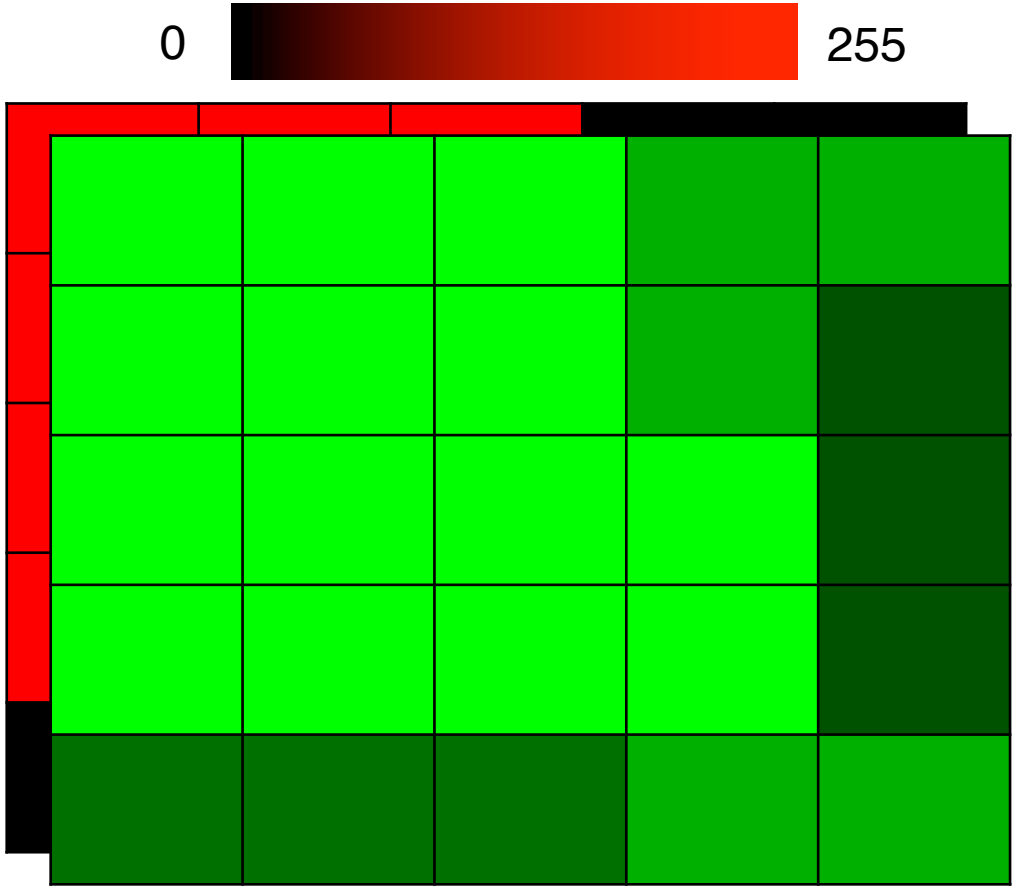

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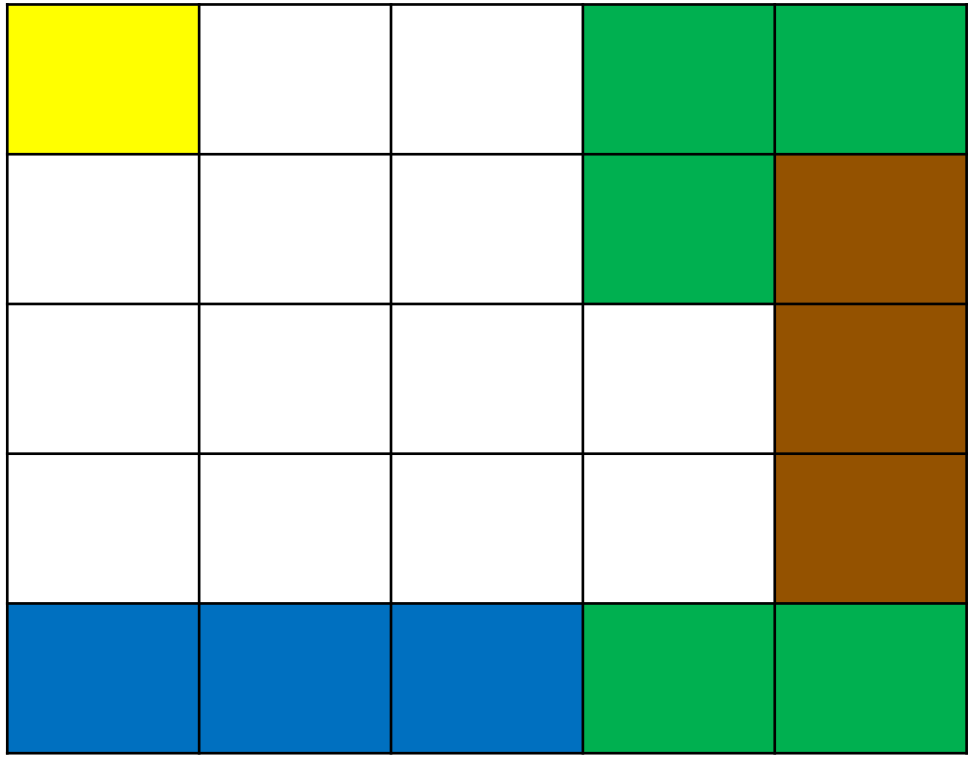

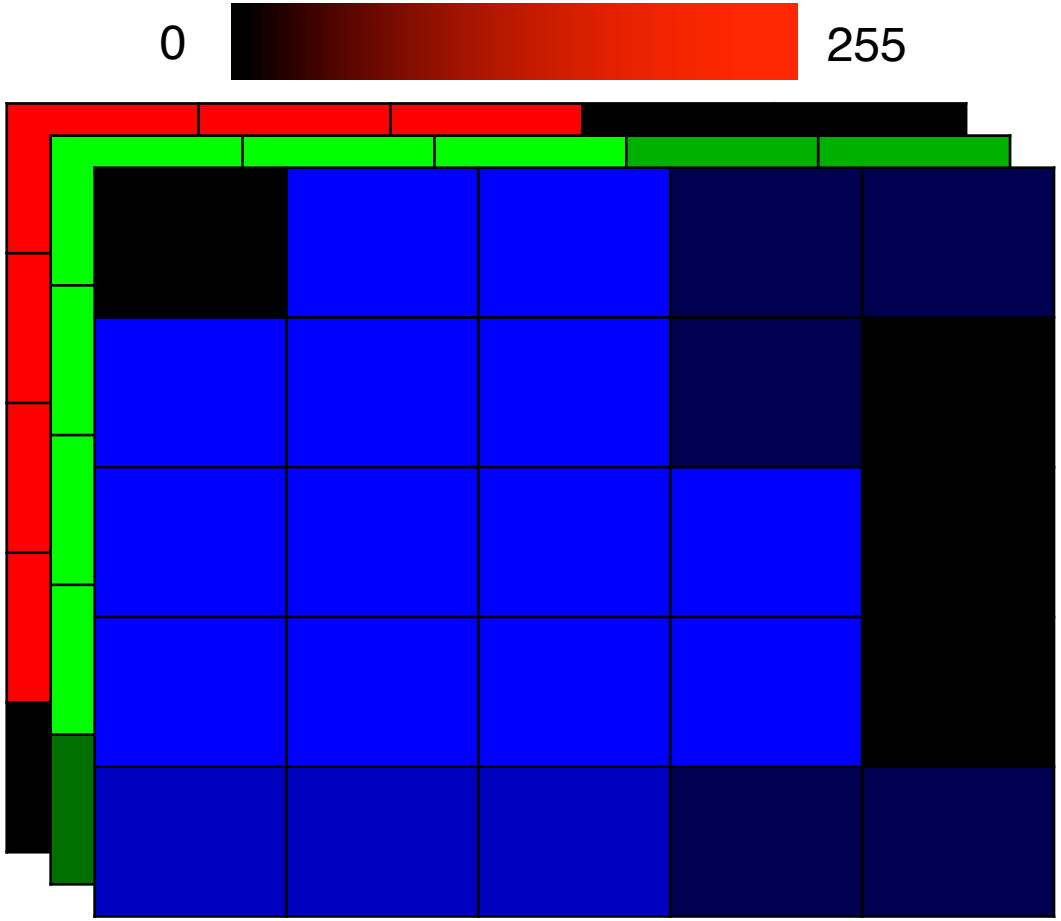

Modify the Image

Modify the Image

```
# And, more generally...
import numpy as np
a = np.asarray(im)
a.shape # => (838, 776, 4) == (width, height, num_channels)
```

Convert the image to the 3D array of numbers…

Modify the Image

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# And, more generally...
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Convert the image to the 3D array of numbers…

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Convert the image to the 3D array of numbers…

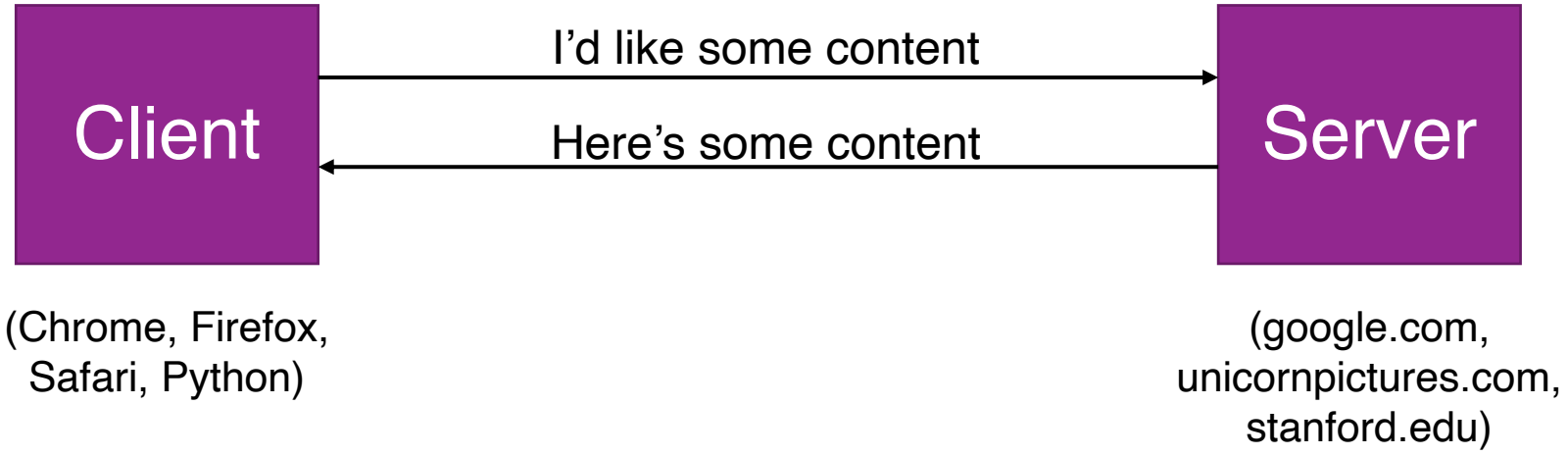
…manipulate that array…

…and convert it back to an image.

We'll learn more about array manipulation with `numpy` next week!

Web Development in Python

How Websites Work (*very* abridged)



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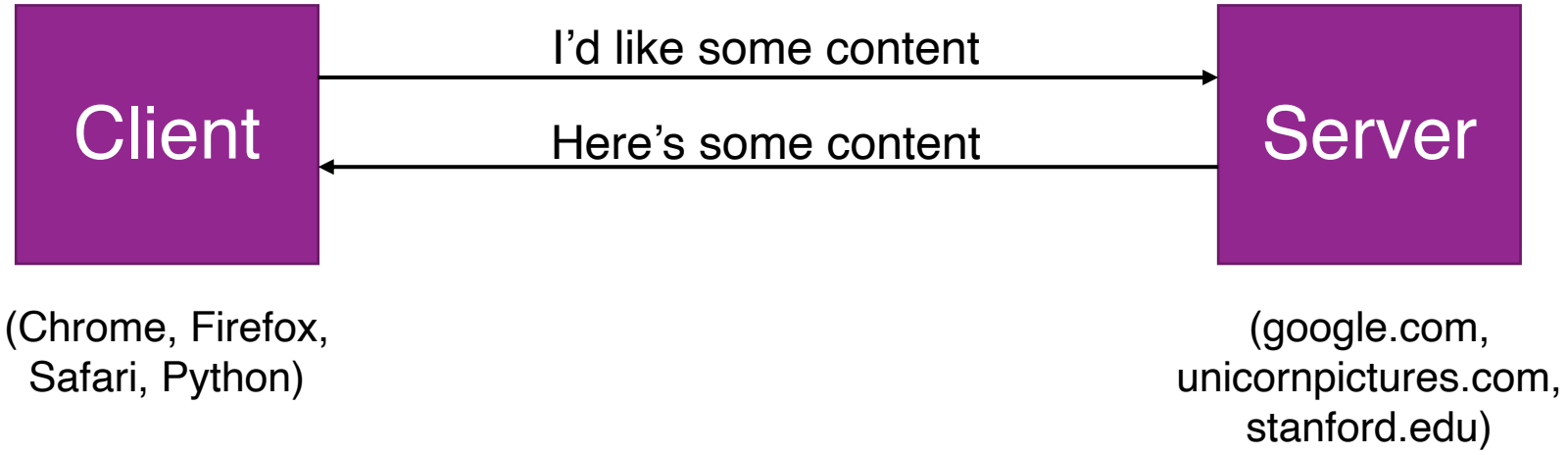

Now: focus on the **server side**.

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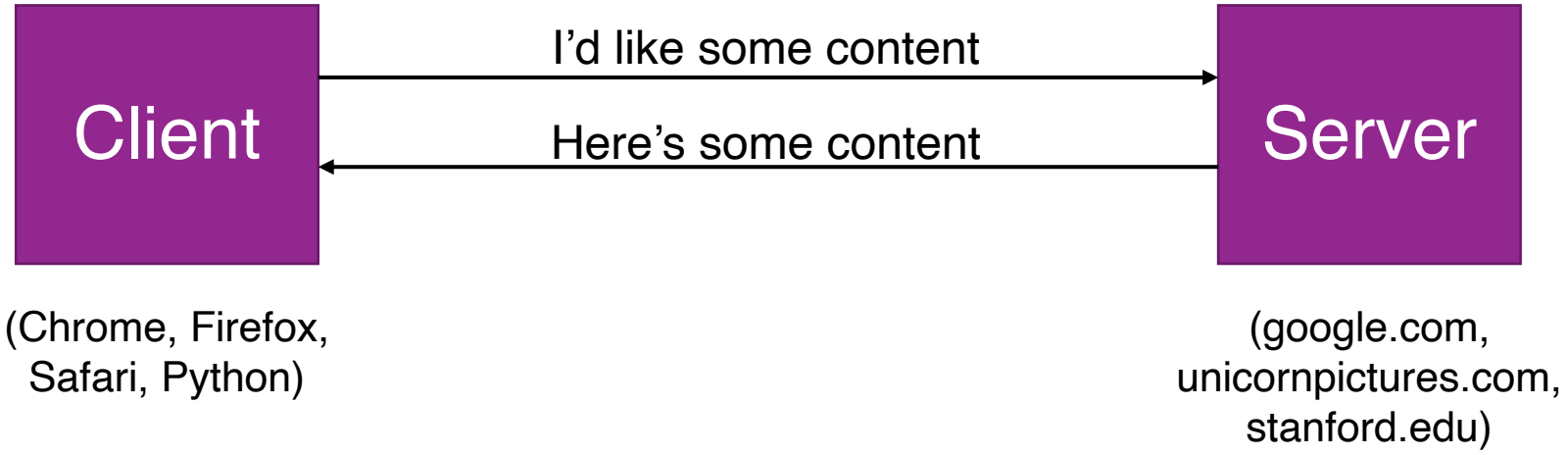

Now: focus on the **server side**.

Client says "I'd like some content…" and the server processes that request to deliver the content.

- E.g., I tell Stanford "I'd like to enroll in CS41; here's my enrollment code." Stanford processes the request to enroll me in CS41 and then responds with a success message.

How does the server process the request?

There are **several** server-side web technologies including those which allow interacting with a database, interacting with other servers, processing user input.

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Today: Python in server-side web development.

- Web routing in Python
- Using templates to render websites
- Processing data

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Today: Python in server-side web development.

- Web routing in Python
- Using templates to render websites
- Processing data

`Flask` is a lightweight library for web development in Python!

```
pip install flask
```

Installs a command line utility *and* a module.

Our First Web App

hello.py

```
from flask import Flask

app = Flask(__name__)

@app.route('/')
def root():
    return "Welcome! I'm flask!"

@app.route('/<name>')
def greet(name):
    return "Hello, {}! It's great to meet you.".format(name)
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Give Flask an idea of what belongs to our web app…
If the app is in a single module, `__name__` is always the correct parameter.

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The decorator tells Flask to call this function when the base path is accessed.

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`@app.route` accepts variables that will be passed to the function as parameters.

See this link for more routing options!

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The return values are the content served back to the user

Our First Web App

Running `python hello.py` won't work because the `flask` server must be run through its command line interface.

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```
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 * Serving Flask app "hello.py"
 * Running on http://127.0.0.1:5000/
```

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```
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Visit in a web browser to interface with the web app.

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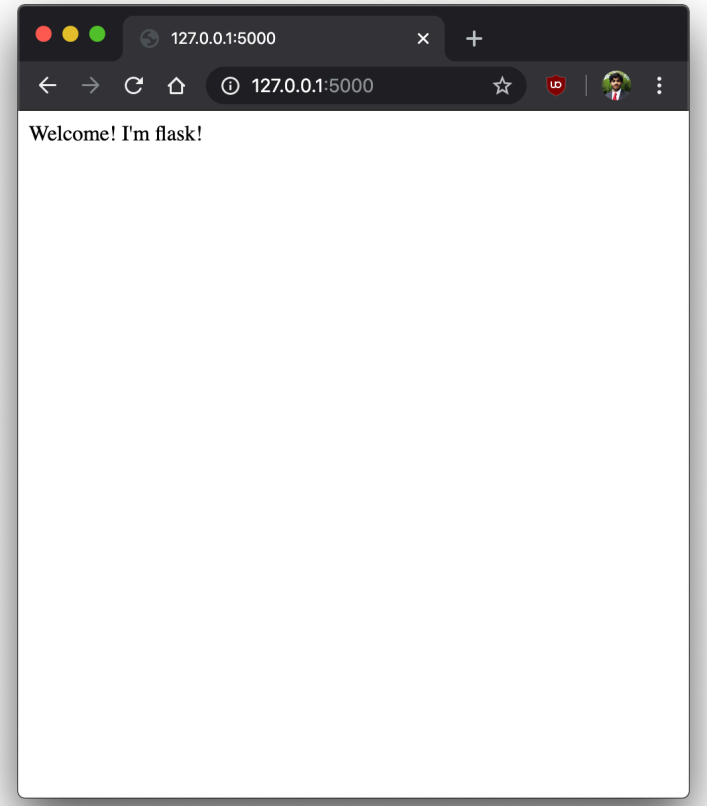

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```
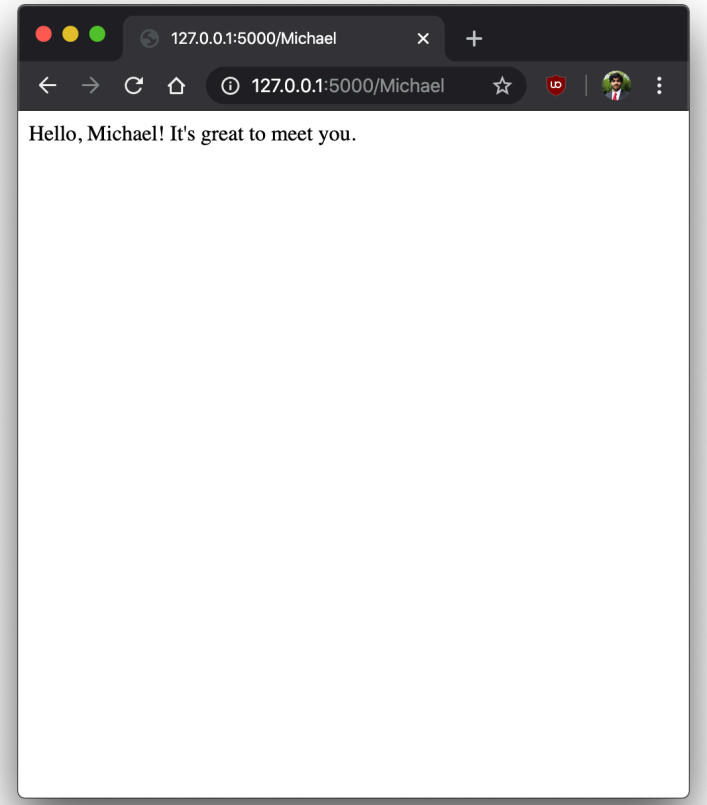

http://127.0.0.1:5000/Michael



More Flask Features

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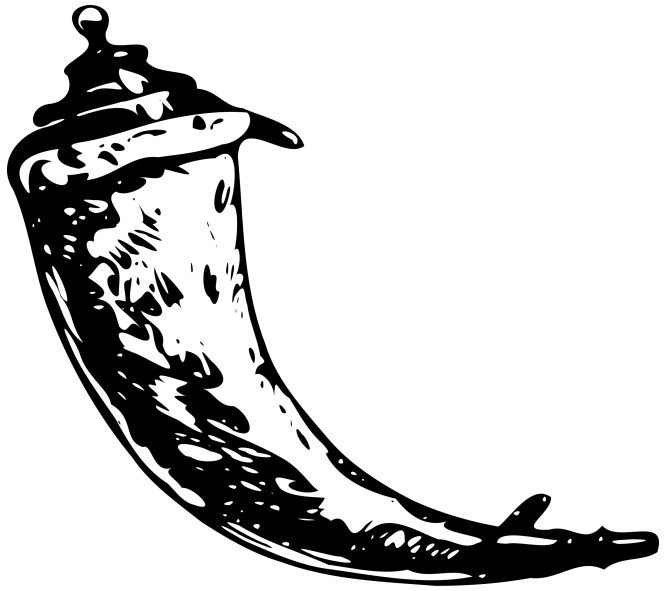
See Quickstart, API Reference, and more! https://flask.palletsprojects.com/

Example: Anagrammer

Python Web Frameworks

Flask



Flask

Lightweight

Beginner-friendly

WSGI by Werkzeug

Templating by Jinja2

Documentation

Flask Mega-Tutorial

Django

"Batteries-included"

Heavily-configurable

Fairly standard

Very fast

Overview

Tutorial

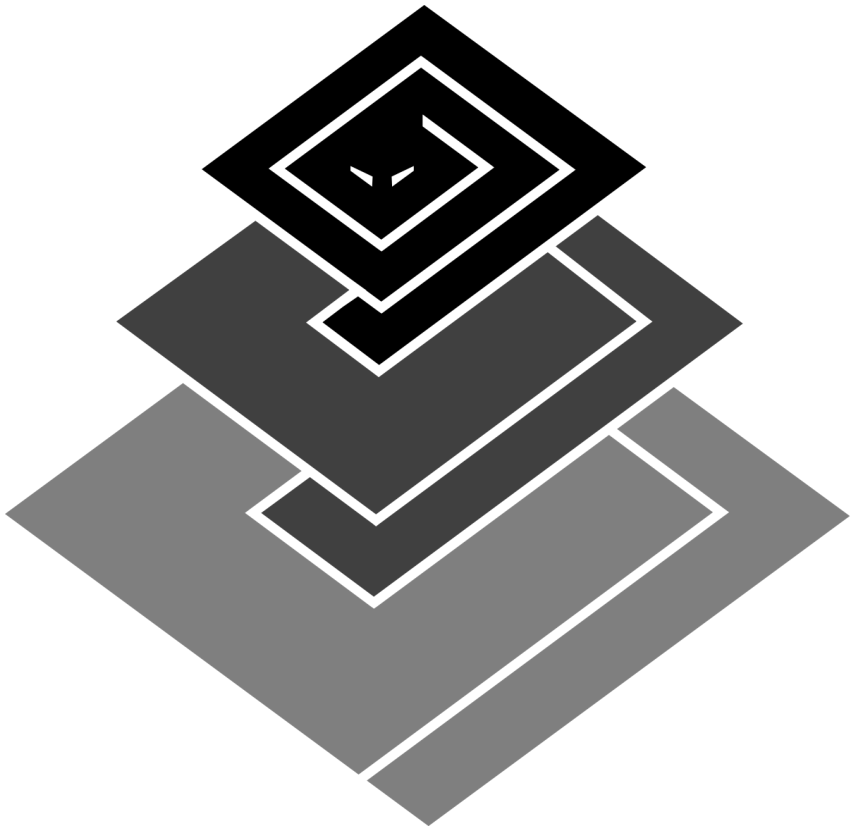
Hello World in Django

```
# polls/views.py
from django.http import HttpResponse
def index(request):
return HttpResponse("Hello, world. You're at the polls index.")

# polls/urls.py
from django.conf.urls import url
from . import views
urlpatterns = [
    url(r'^$', views.index, name='index'),
]

# mysite/urls.py
from django.conf.urls import include, url
from django.contrib import admin

urlpatterns = [
    url(r'^polls/', include('polls.urls')),
    url(r'^admin/', include(admin.site.urls)),
]
```

Run with

```
$ python manage.py runserver
```

Twisted



Asynchronous, event-driven

Networking engine

Fast, but complicated

Documentation

Tutorial

EchoServer in Twisted

```
from twisted.internet import protocol, reactor, endpoints

class Echo(protocol.Protocol):
    def dataReceived(self, data):
        self.transport.write(data)

class EchoFactory(protocol.Factory):
    def buildProtocol(self, addr):
        return Echo()

endpoints.serverFromString(reactor, "tcp:1234").listen(EchoFactory())
reactor.run()
```

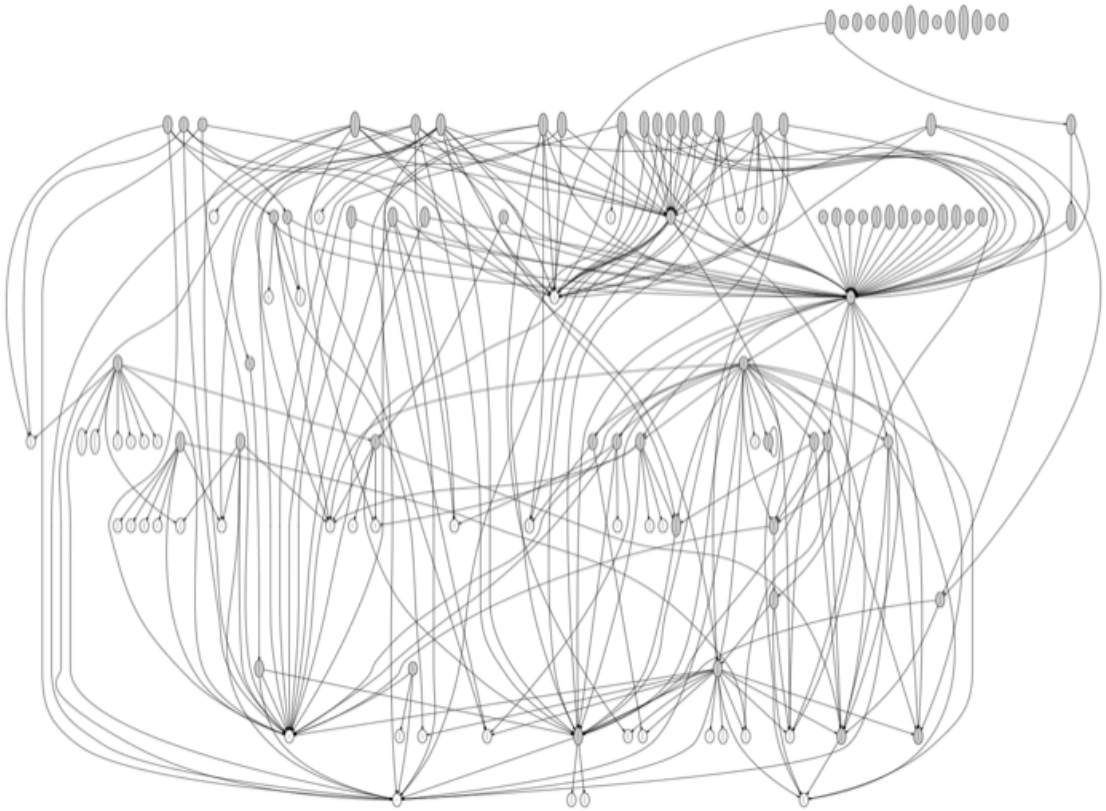
Run with

```
$ python app.py
```

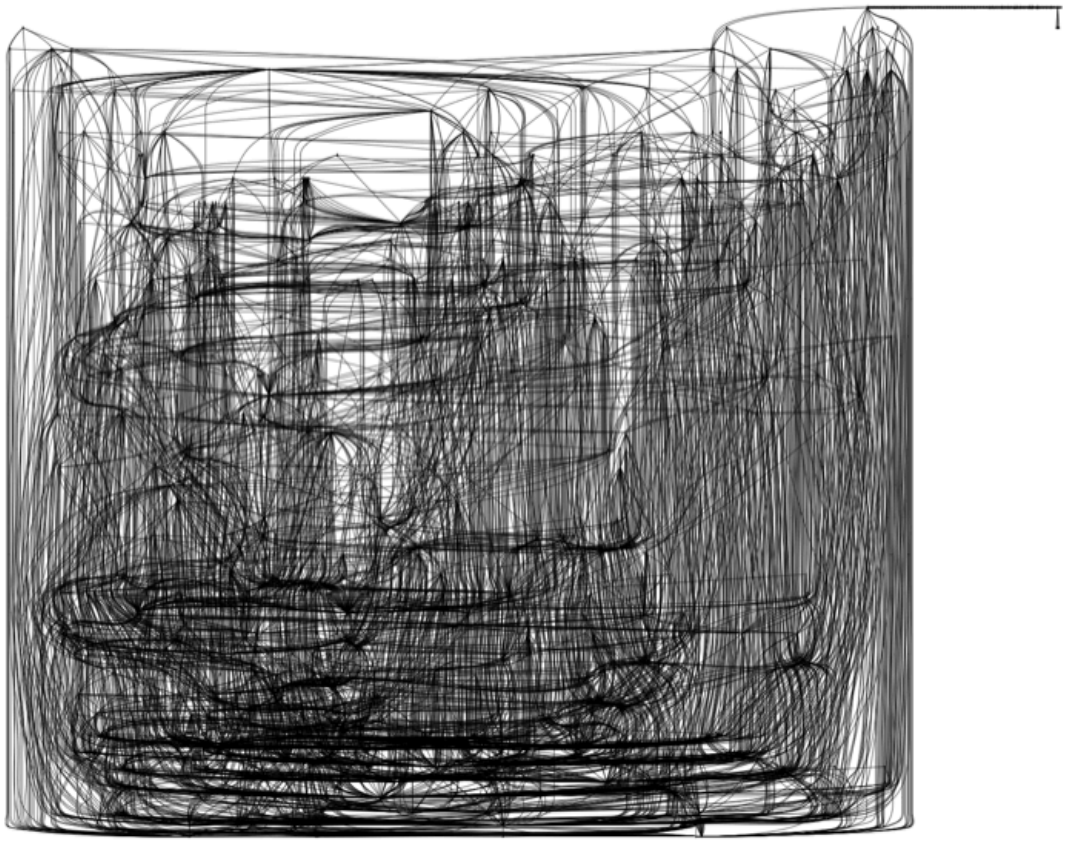
Codebase Complexity

Visualize with `snakefood` and `GraphViz`

Web Frameworks

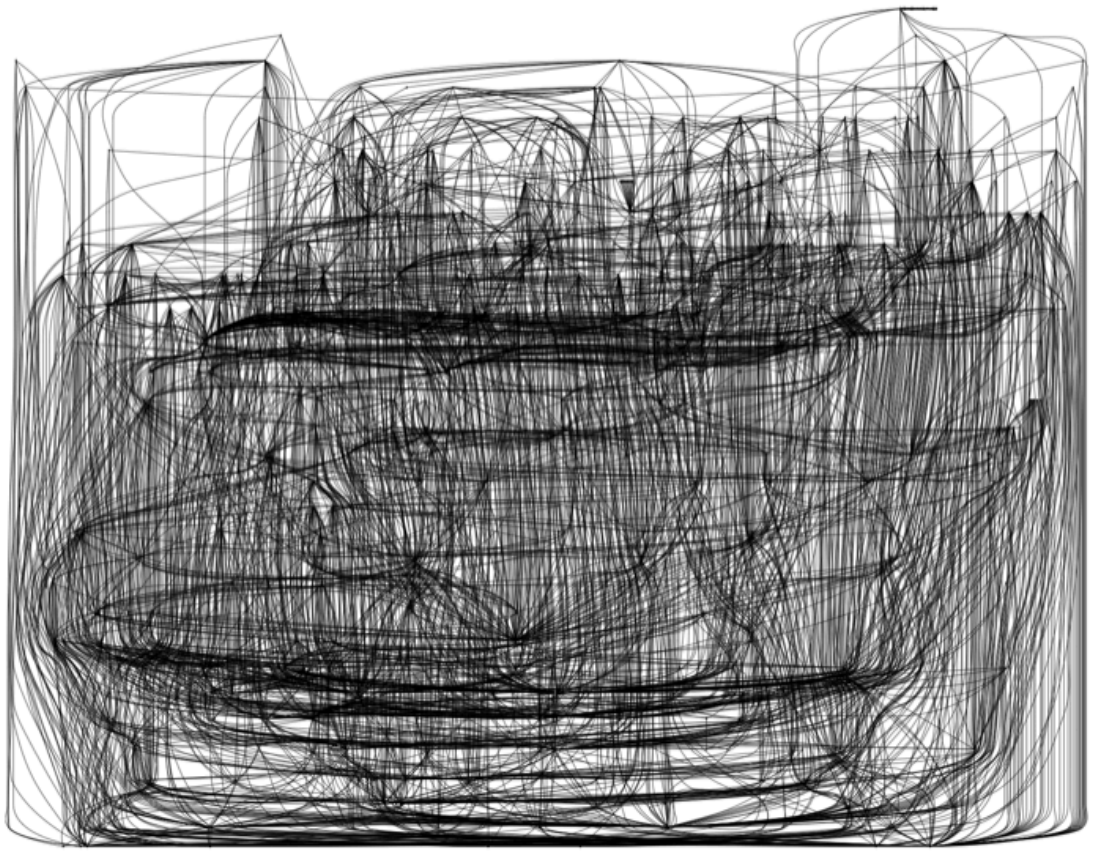


Flask



Django

Wow… Complex



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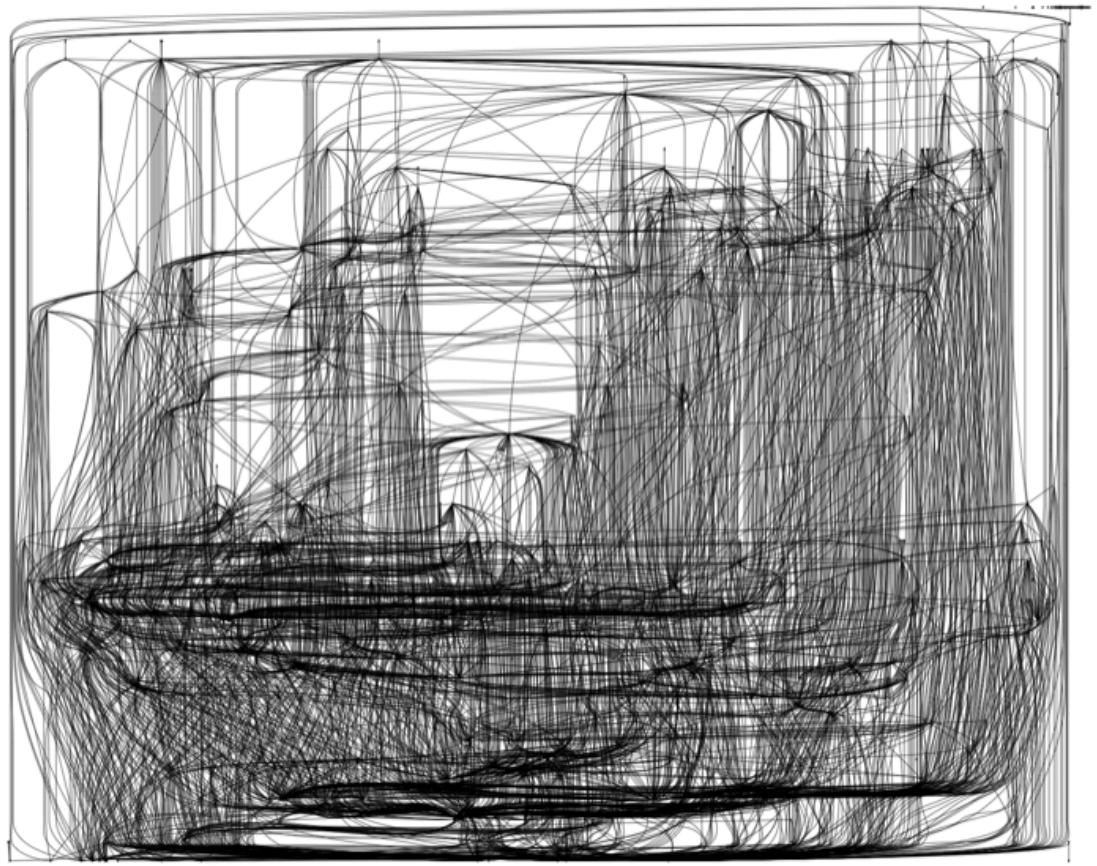
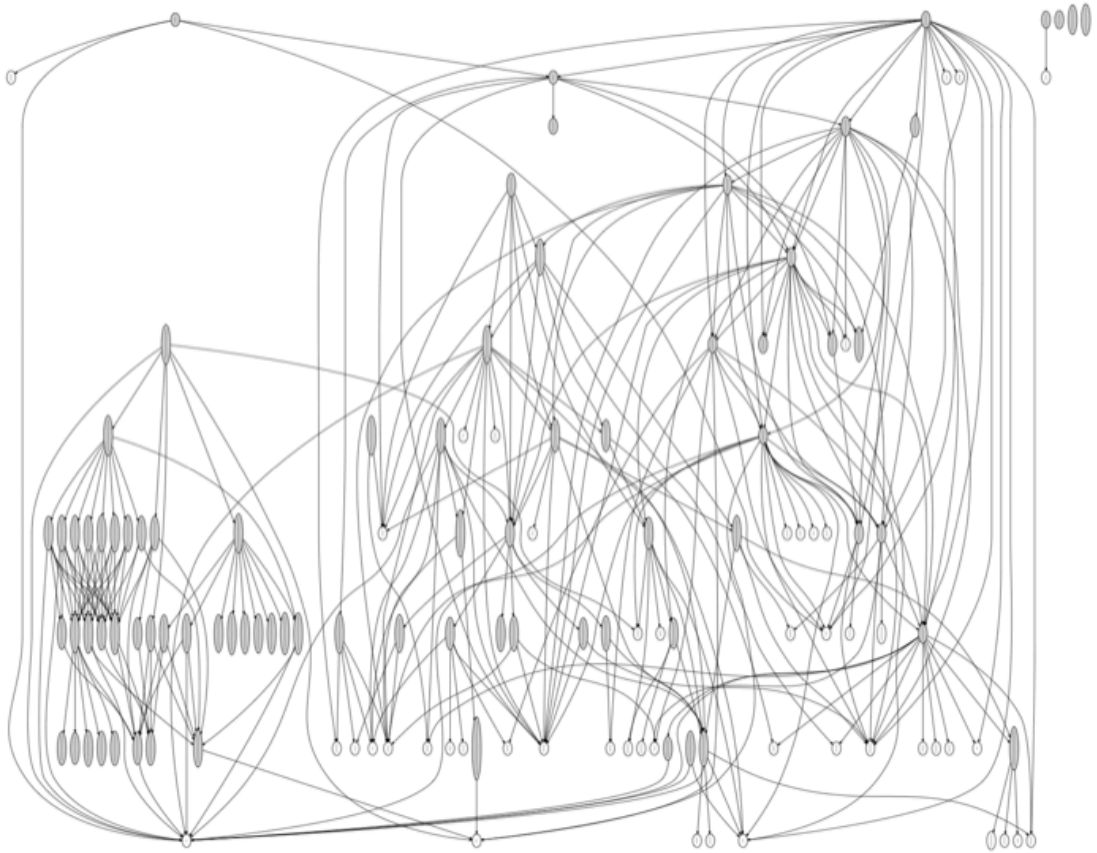
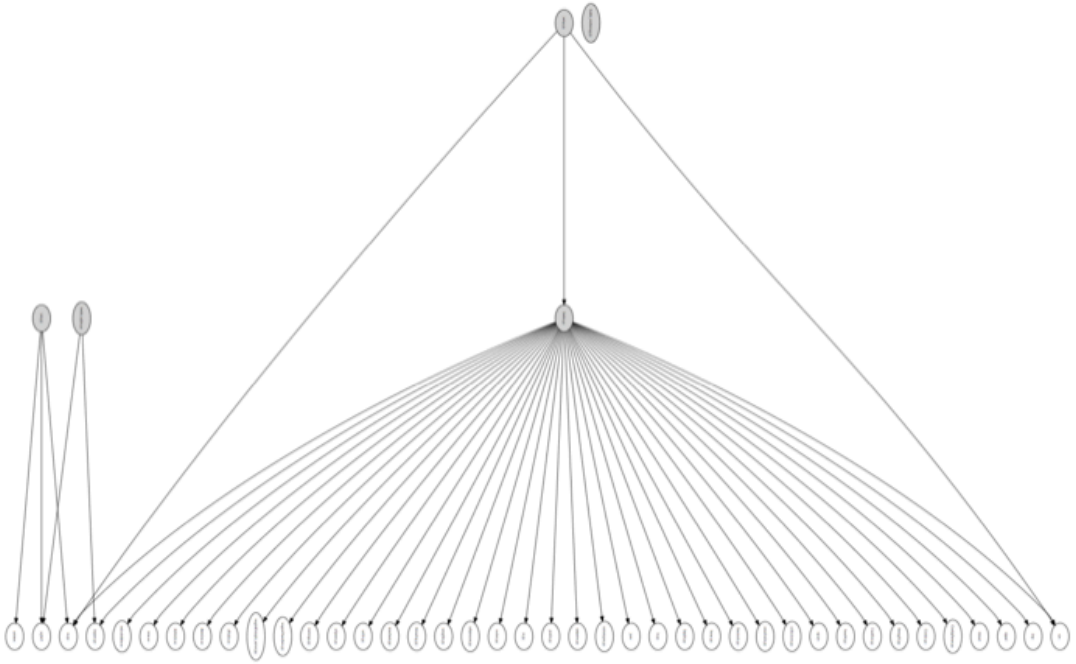


iPython

Ahh… Simple



Requests



Bottle

Next Time…

Build a wallpaper scraper!

or… explore cool packages!

or… help find the unicorn!

The lab is your oyster.