# Programming Principles in Python (CSCI 503)

## Arrays

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# Modules and Packages

- Python allows you to import code from other files, even your own
- A **module** is a collection of definitions
- A **package** is an organized collection of modules
- Modules can be
  - a separate python file
  - a separate C library that is written to be used with Python
  - a built-in module contained in the interpreter
  - a module installed by the user (via conda or pip)
- All types use the same import syntax

[RealPython]

# What is the purpose of having modules or packages?

- Code reuse: makes life easier because others have written solutions to various problems
- Generally forces an organization of code that works together
- Standardizes interfaces; easier maintenance
- Encourages robustness, testing code

- This does take time so don't always create a module or package
  - If you're going to use a method once, it's not worth putting it in a module
  - If you're using the same methods over and over in (especially in different projects), a module or package makes sense

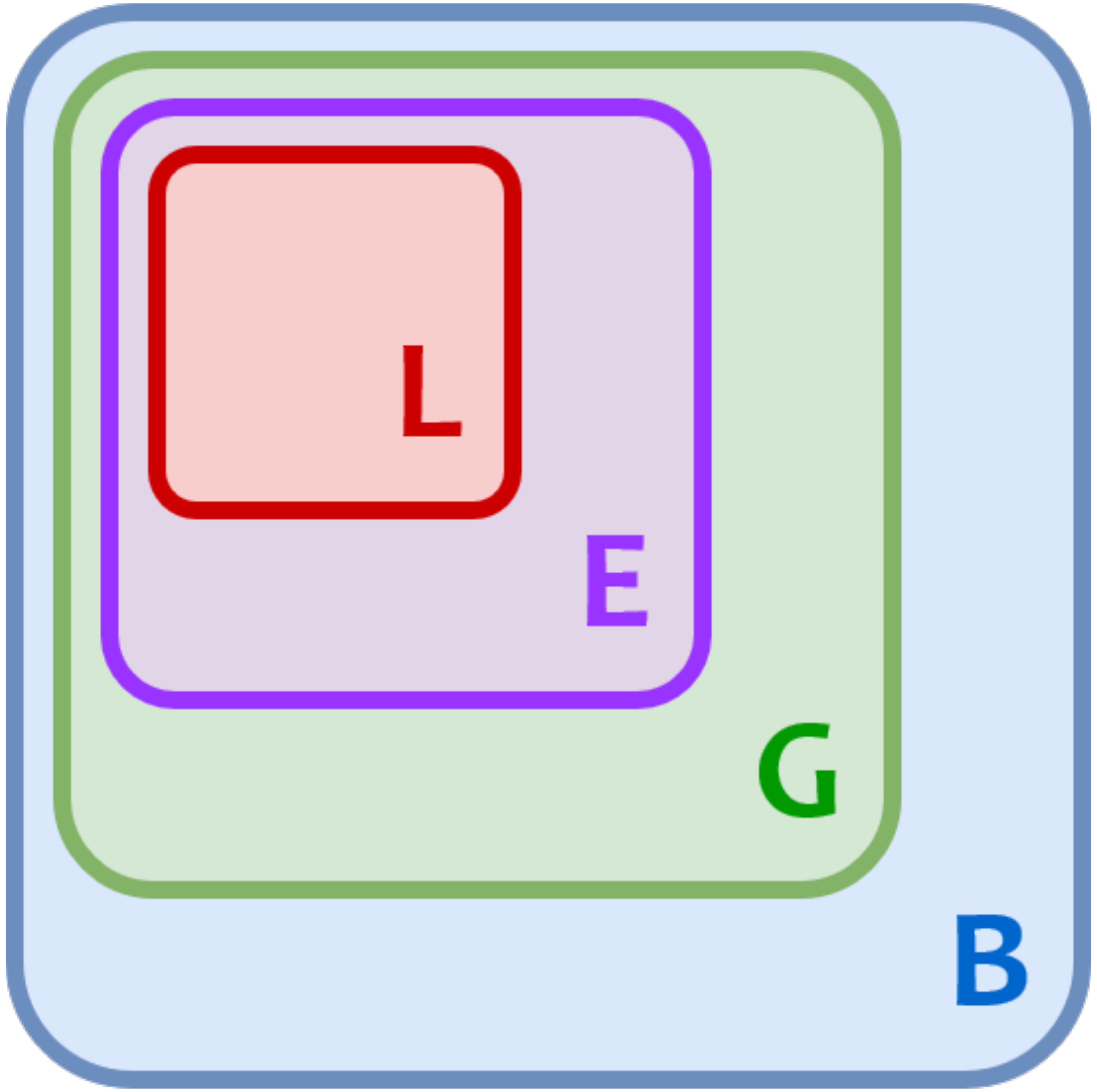
# Importing modules

- `import <module>`
- `import <module> as <another-identifier>`
- `from <module> import <identifer-list>`
- `from <module> import <identifer> as <another-identifier>, …`

- `import` imports from the top, `from … import` imports "inner" names
- Need to use the qualified names when using import (`foo.bar.mymethod`)
- as clause **renames** the imported name

# Namespaces

- Namespace is basically a dictionary with names and their values
- Accessing namespaces
  - `__builtins__`, `globals()`, `locals()`
- Examine contents of a namespace: `dir(<namespace>)`
- Python checks for a name in the sequence: local, enclosing, global, builtins
- To access names in outer scopes, use `global` (global) and `nonlocal` (enclosing) declarations




[RealPython]

# Using an imported module

- Import module, and call functions with **fully qualified** name
  - ```
    import math
    math.log10(100)
    math.sqrt(196)
    ```
- Import module into current namespace and use **unqualified** name
  - ```
    from math import log10, sqrt
    log10(100)
    sqrt(196)
    ```

# Reloading a Module?

- If you re-import a module, what happens?
  - ```
    import my_module
    my_module.SECRET_NUMBER # 42
    ```
  - Change the definition of `SECRET_NUMBER` to `14`
  - ```
    import my_module
    my_module.SECRET_NUMBER # Still 42!
    ```
- Modules are **cached** so they are not reloaded on each import call
- Can reload a module via `importlib.reload(<module>)`
- Be careful because **dependencies** will persist! (Order matters)

# Python Packages

- A package is basically a collection of modules in a directory subtree
- Structures a module namespace by allowing dotted names
- Example:

```
- test_pkg/
        __init__.py
        foo.py
        bar.py
        baz/
            fun.py
```

- For packages that are to be executed as scripts, `__main__.py` can also be added

# Finding Packages

- Python Package Index (PyPI) is the standard repository (https://pypi.org) and pip (pip installs packages) is the official python package installer
  - Types of distribution: source (sdist) and wheels (binaries)
  - Each package can specify dependencies
  - Creating a PyPI package requires adding some metadata
- Anaconda is a package index, conda is a package manager
  - conda is language-agnostic (not only Python)
  - solves dependencies
  - conda deals with non-Python dependencies
  - has different channels: default, conda-forge (community-led)

# Installing Packages

- `pip install <package-name>`
- `conda install <package-name>`
- Arguments can be multiple packages
- Be careful! Security exploits using package installation and dependencies (e.g. Alex Birsan)

# Environments

- Both pip and conda support environments
  - venv
  - conda env
- Idea is that you can create different environments for different work
  - environment for cs503
  - environment for research
  - environment for each project

# Assignment 5

- Scripts and Modules
- Write a three modules in a Python package with methods to process Pokémon data
- Write a script to retrieve Pokémon information via command-line arguments
- MaxCP formula fixed by 2021-02-28
- Turn in a zip file with package
- No notebook required, but useful to test your code as you work
    - `%autoreload` or `importlib.reload`

# Arrays

What is the difference between an array and a list (or a tuple)?

# Arrays

- Usually a fixed size—lists are meant to change size
- Are mutable—tuples are not
- Store only one type of data—lists and tuples can store anything
- Are faster to access and manipulate than lists or tuples
- Can be multidimensional:
    - Can have list of lists or tuple of tuples but no guarantee on shape
    - Multidimensional arrays are rectangles, cubes, etc.

# Why NumPy?

- Fast **vectorized** array operations for data munging and cleaning, subsetting and filtering, transformation, and any other kinds of computations
- Common array algorithms like sorting, unique, and set operations
- Efficient descriptive statistics and aggregating/summarizing data
- Data alignment and relational data manipulations for merging and joining together heterogeneous data sets
- Expressing conditional logic as array expressions instead of loops with `if-elif-else` branches
- Group-wise data manipulations (aggregation, transformation, function application).

[W. McKinney, Python for Data Analysis]

```
import numpy as np
```

# Creating arrays

- `data1 = [6, 7, 8, 0, 1]`
  `arr1 = np.array(data1)`
- `data2 = [[1.5,2,3,4],[5,6,7,8]]`
  `arr2 = np.array(data2)`
- `data3 = np.array([6, "abc", 3.57]) # !!! check !!!`
- Can check the type of an array in `dtype` property
- Types:
  - `arr1.dtype # dtype('int64')`
  - `arr3.dtype # dtype('<U21'), unicode plus # chars`

# Types

- "But I thought Python wasn't stingy about types…"
- numpy aims for speed
- Able to do array arithmetic
- int16, int32, int64, float32, float64, bool, object
- Can specify type explicitly
  - `arr1_float = np.array(data1, dtype='float64')`
- `astype` method allows you to convert between different types of arrays:

```
arr = np.array([1, 2, 3, 4, 5])
arr.dtype
float_arr = arr.astype(np.float64)
```

# numpy data types (dtypes)

| Type | Type code | Description |
|---|---|---|
| int8, uint8 | i1, u1 | Signed and unsigned 8-bit (1 byte) integer types |
| int16, uint16 | i2, u2 | Signed and unsigned 16-bit integer types |
| int32, uint32 | i4, u4 | Signed and unsigned 32-bit integer types |
| int64, uint64 | i8, u8 | Signed and unsigned 64-bit integer types |
| float16 | f2 | Half-precision floating point |
| float32 | f4 or f | Standard single-precision floating point; compatible with C float |
| float64 | f8 or d | Standard double-precision floating point; compatible with C double and Python float object |
| float128 | f16 or g | Extended-precision floating point |
| complex64, complex128, complex256 | c8, c16, c32 | Complex numbers represented by two 32, 64, or 128 floats, respectively |
| bool | ? | Boolean type storing True and False values |
| object | O | Python object type; a value can be any Python object |
| string_ | S | Fixed-length ASCII string type (1 byte per character); for example, to create a string dtype with length 10, use 'S10' |
| unicode_ | U | Fixed-length Unicode type (number of bytes platform specific); same specification semantics as string_ (e.g., 'U10') |

[W. McKinney, Python for Data Analysis]

# Array Shape

- Our normal way of checking the size of a collection is… `len`
- How does this work for arrays?
- ```
  arr1 = np.array([1,2,3,6,9])
  len(arr1) # 5
  ```
- ```
  arr2 = np.array([[1.5,2,3,4],[5,6,7,8]])
  len(arr2) # 2
  ```
- All dimension lengths → shape: `arr2.shape # (2,4)`
- Number of dimensions: `arr2.ndim # 2`
- Can also reshape an array:
  - `arr2.reshape(4,2)`
  - `arr2.reshape(-1,2) # what happens here?`

# Speed Benefits

- Compare random number generation in pure Python versus numpy
- Python:
  - ```
    import random
    %timeit rolls_list = [random.randrange(1,7)
                          for i in range(0, 60_000)]
    ```
- With NumPy:
  - ```
    %timeit rolls_array = np.random.randint(1, 7, 60_000)
    ```
- Significant speedup (80x+)

# Array Programming

- Lists:
  - ```
    c = []
    for i in range(len(a)):
        c.append(a[i] + b[i])
    ```
- How to improve this?
    ```

# Array Programming

- Lists:
  - ```
    c = []
    for i in range(len(a)):
        c.append(a[i] + b[i])
    ```
  - `c = [aa + bb for aa, bb in zip(a,b)]`
- NumPy arrays:
  - `c = a + b`
- More functional-style than imperative
- **Internal iteration** instead of external
    ```

# Operations

- `a = np.array([1,2,3])`
  `b = np.array([6,4,3])`
- (Array, Array) Operations (**Element-wise**)
  - Addition, Subtraction, Multiplication
  - `a + b # array([7, 6, 6])`
- (Scalar, Array) Operations (**Broadcasting**):
  - Addition, Subtraction, Multiplication, Division, Exponentiation
  - `a ** 2 # array([1, 4, 9])`
  - `b + 3 # array([9, 7, 6])`

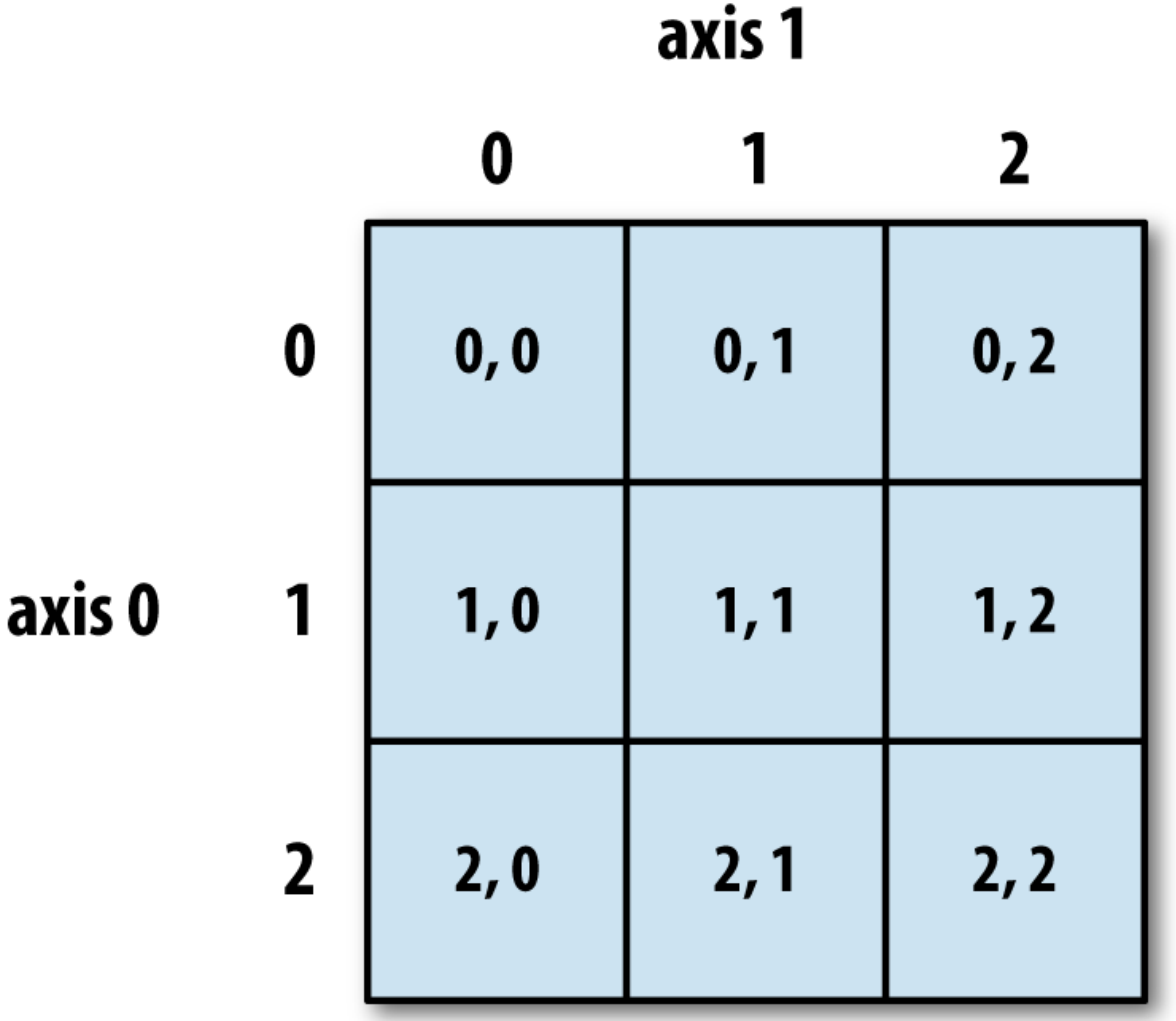
# More on Array Creation

- Zeros: `np.zeros(10)`
- Ones: `np.ones((4,5)) # shape`
- Empty: `np.empty((2,2))`
- _like versions: pass an existing array and matches shape with specified contents
- Range: `np.arange(15) # constructs an array, not iterator!`

# Indexing

- Same as with lists plus shorthand for 2D+
  - `arr1 = np.array([6, 7, 8, 0, 1])`
  - `arr1[1]`
  - `arr1[-1]`
- What about two dimensions?
  - `arr2 = np.array([[1.5,2,3,4],[5,6,7,8]])`
  - `arr[1][1]`
  - `arr[1,1] # shorthand`

# 2D Indexing




[W. McKinney, Python for Data Analysis]

# Slicing

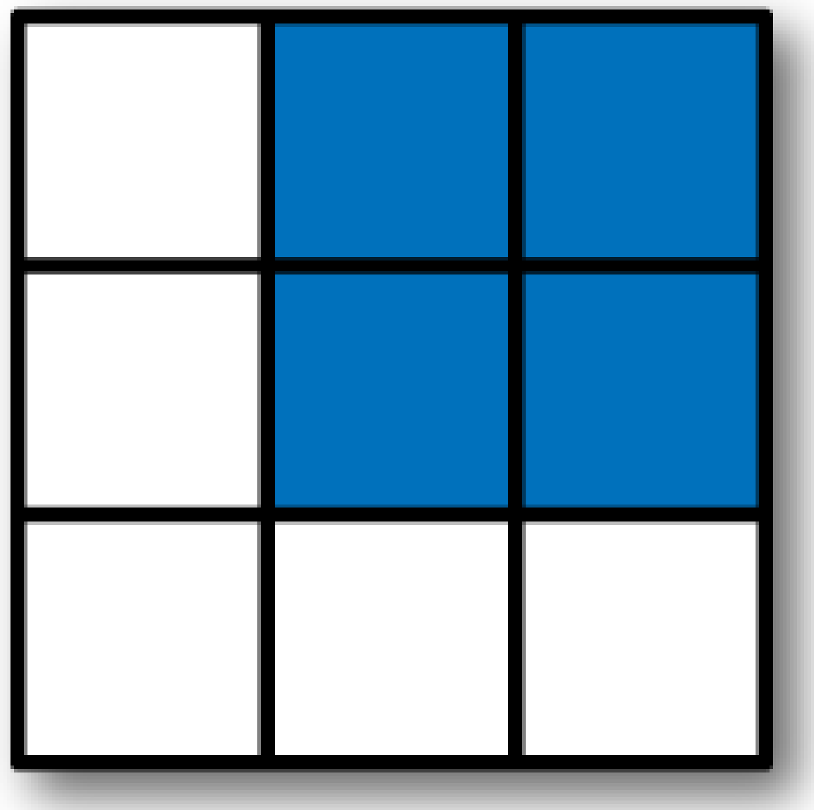
- 1D: Similar to lists
  - `arr1 = np.array([6, 7, 8, 0, 1])`
  - `arr1[2:5] # np.array([8,0,1]), sort of`
- Can **mutate** original array:
  - `arr1[2:5] = 3 # supports assignment`
- Slicing returns **views** (copy the array if original array shouldn't change)
  - arr1 #
  - `arr1.copy()` or `arr1[2:5].copy()` will copy

# Slicing

- 2D+: comma separated indices as shorthand:
  - `arr2 = np.array([[1.5,2,3,4],[5,6,7,8]])`
  - `a[1:3,1:3]`
  - `a[1:3,:] # works like in single-dimensional lists`
- Can combine index and slice in different dimensions
  - `a[1,:] # gives a row`
  - `a[:,1] # gives a column`

# 2D Array Slicing

How to obtain the blue slice from array `arr`?



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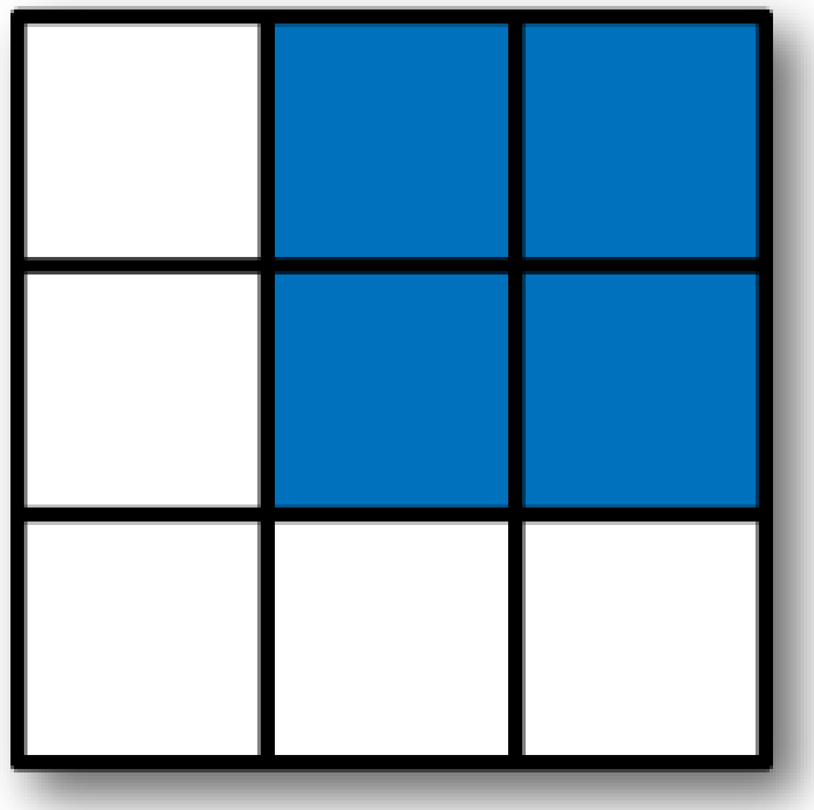

`arr[:2,1:]`

[W. McKinney, Python for Data Analysis]