Programming Principles in Python (CSCI 503/490)

Arrays

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Match Statement

- Python 3.10 added a match statement that can be used like a switch statement
- ```
  match val:
      case 1:
          print('1st')
      case 2:
          print('2nd')
      case _:
          print('???')
  ```
- … but this isn't better than if/elif or a dictionary dispatch
- The reason it was introduced is that it can do **more** than a switch statement
  ```

Structural Pattern Matching

- Besides literal cases, match statements can be used to
  - differentiate structure
  - assign values
  - differentiate class instances
- Example:
-
```
match sys.argv:
    case [_, "commit"]:
        print("Committing")
    case [_, 'add', fname]:
        print("Adding file", fname)
```

Patterns

- Sequence Pattern:

```
match sys.argv:
    case [_, "commit"]:
        print("Committing")
    case [_, 'add', *fnames]:
        print("Adding files", fnames)
```

- Or and As Pattern:

```
match command.split():
    case ["go", ("north" | "south" | "east" | "west") as d]:
        current_room = current_room.neighbor(d)
```

Mapping Pattern

- ```
  for action in actions:
      match action:
          case {"text": message, "color": c}:
              ui.set_text_color(c)
              ui.display(message)
          case {"sleep": duration}:
              ui.wait(duration)
          case {"sound": str(url), "format": "mp3"}:
              ui.play(url)
          case {"sound": _, "format": fmt, **rest}:
              warning("Unsupported audio format", fmt, rest)
  ```
- Remember: Any unmatched key-value pairs are **ignored**!
- Can capture other pairs using `**rest`
  ```

Class Pattern

- ```
  @dataclass
  class Click:
      x: float
      y: float
      button: Button # enum(LEFT, MIDDLE, RIGHT)

  for event in events:
      match event:
          case Click(x, y, button=Button.LEFT):
              print("GOT a left click", x, y)
          case Click():
              print("GOT a click")
          case _:
              print("NO click")
  ```
  ```

Assignment 7

- Concurrency, System Integration, and Structural Pattern Matching
- Coming soon…

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 any combination
- 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 aa, bb in zip(a, b):
        c.append(aa + bb)
    ```
- How to improve this?
    ```

Array Programming

- Lists:
  - ```
    c = []
    for aa, bb in zip(a, b):
        c.append(aa + bb)
    ```
  - `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])`

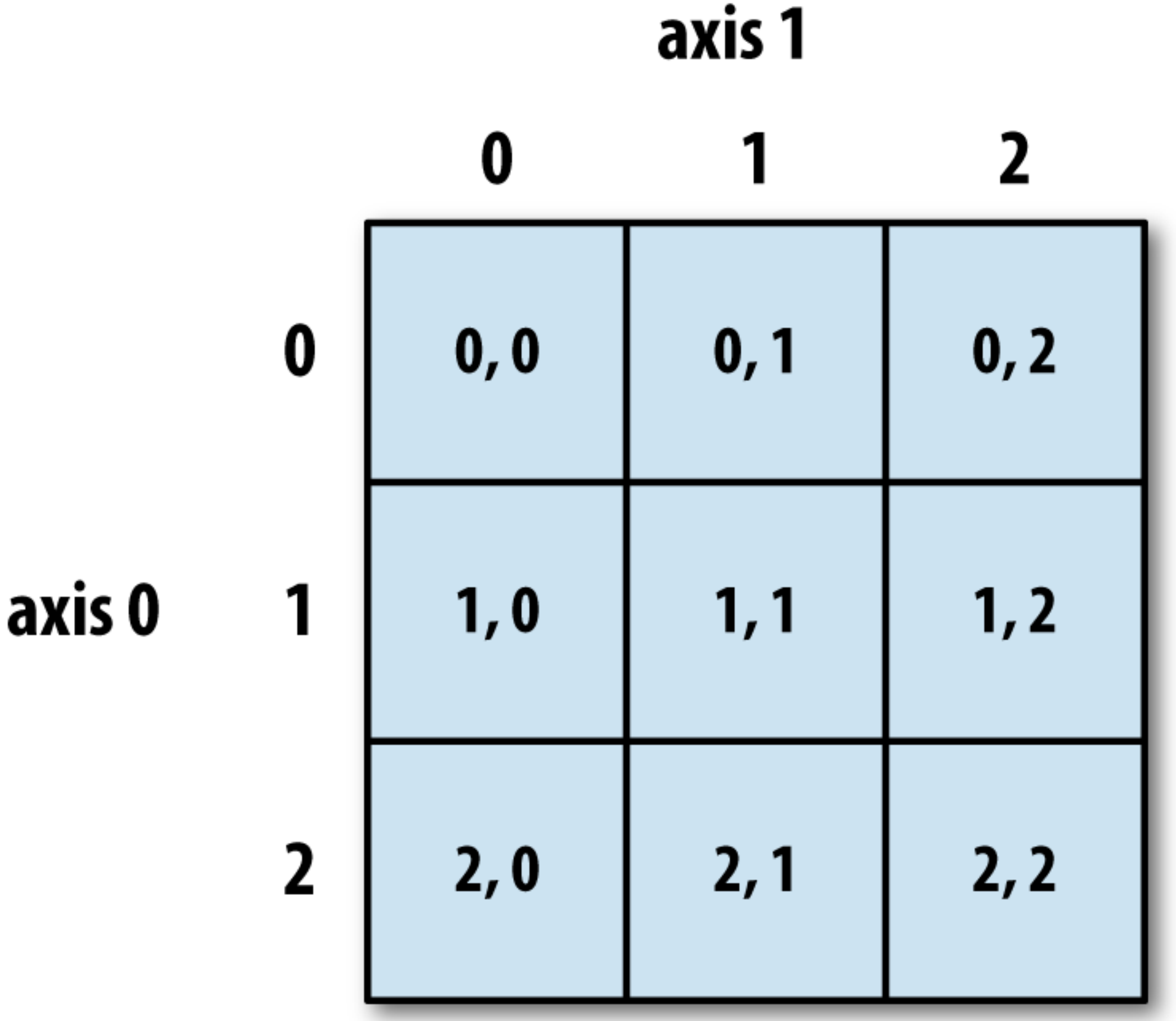
More on Array Creation

- 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

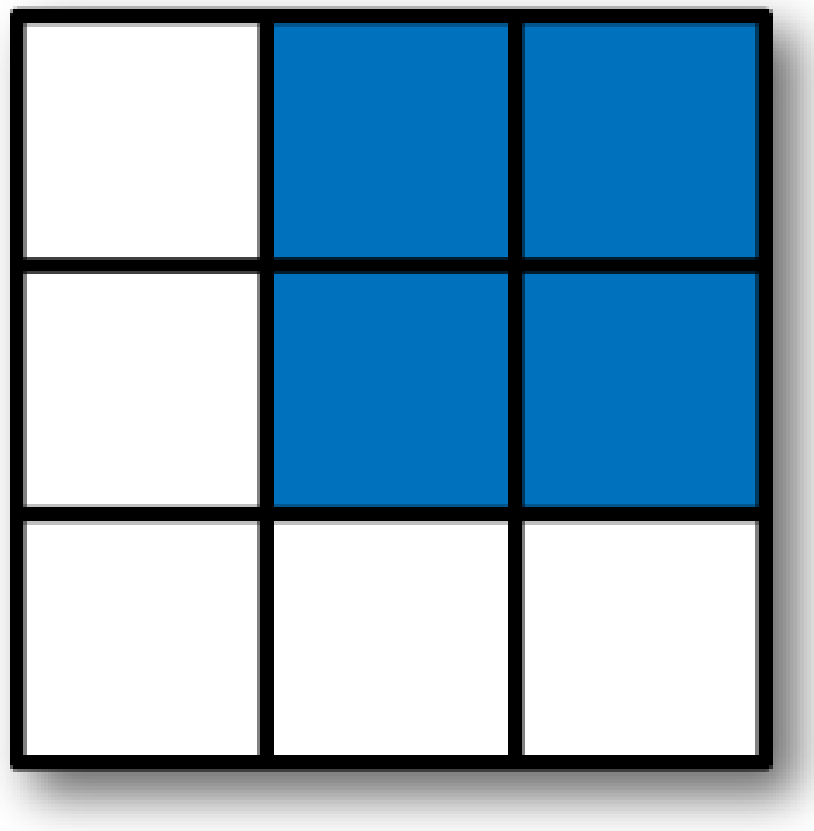
- 1D: Similar to lists
  - `arr1 = np.array([6, 7, 8, 0, 1])`
  - `arr1[2:5] # np.array([8, 0, 1]), sort of`
- Can **mutate** original array:
  - `arr1[2:5] = 3 # supports assignment`
  - `arr1 # the original array changed`
- Slicing returns **views** (copy the array if original array shouldn't change)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

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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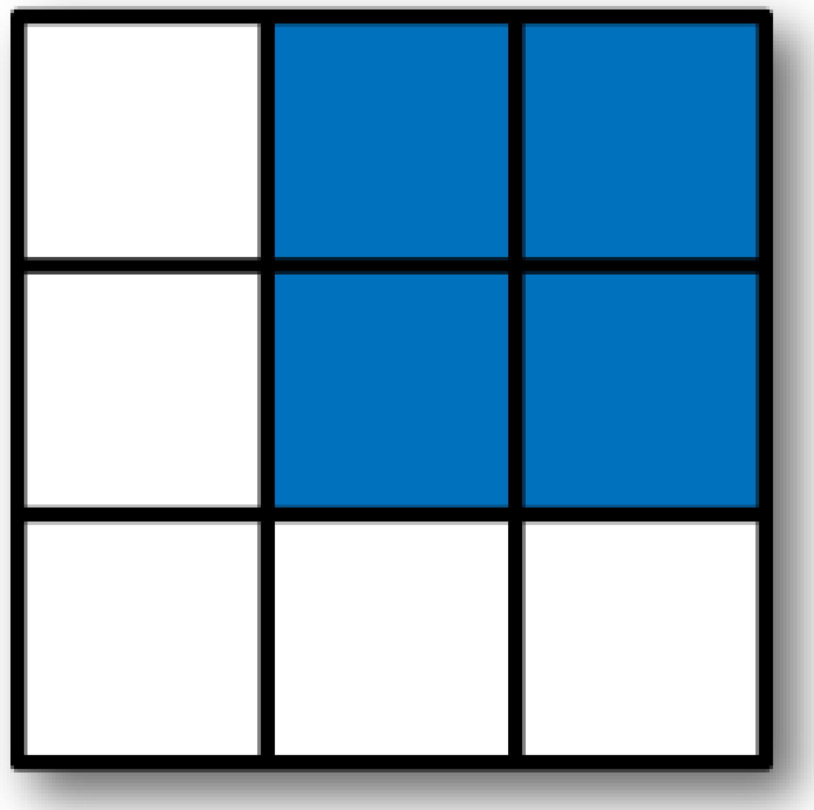
2D Array Slicing

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



`arr[:2,1:]`

[W. McKinney, Python for Data Analysis]

More Reshaping

- reshape:
  - `arr2.reshape(4,2) # returns new view`
- resize:
  - `arr2.resize(4,2) # no return, modifies arr2 in place`
- flatten:
  - `arr2.flatten() # array([1.5,2.,3.,4.,5.,6.,7.,8.])`
- ravel:
  - `arr2.ravel() # array([1.5,2.,3.,4.,5.,6.,7.,8.])`
- flatten and ravel look the same, but ravel is a **view**

Array Transformations

- Transpose
  - `arr2.T # flip rows and columns`
- Stacking: take iterable of arrays and stack them horizontally/vertically
  - `arrh1 = np.arange(3)`
  - `arrh2 = np.arange(3,6)`
  - `np.vstack([arrh1, arrh2])`
  - `np.hstack([arr1.T, arr2.T]) # ???`