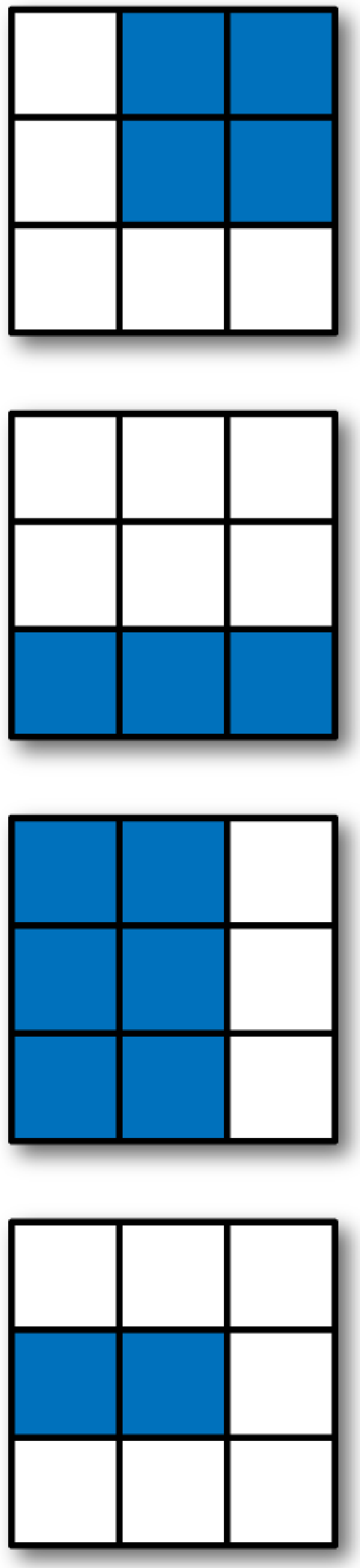
Programming Principles in Python (CSCI 503)

Object-Oriented Programming

Dr. David Koop

2D Array Slicing

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



[W. McKinney, Python for Data Analysis]

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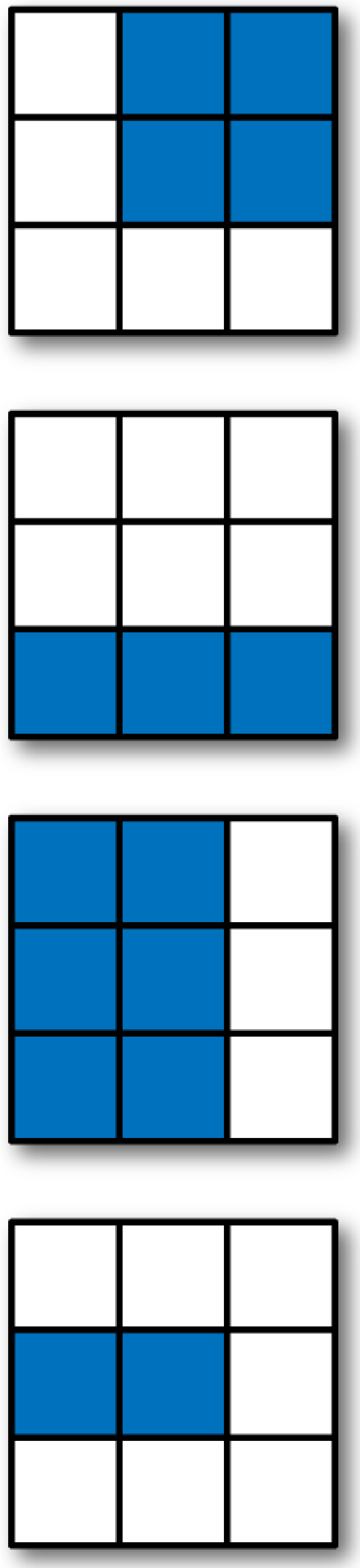

Expression	Shape
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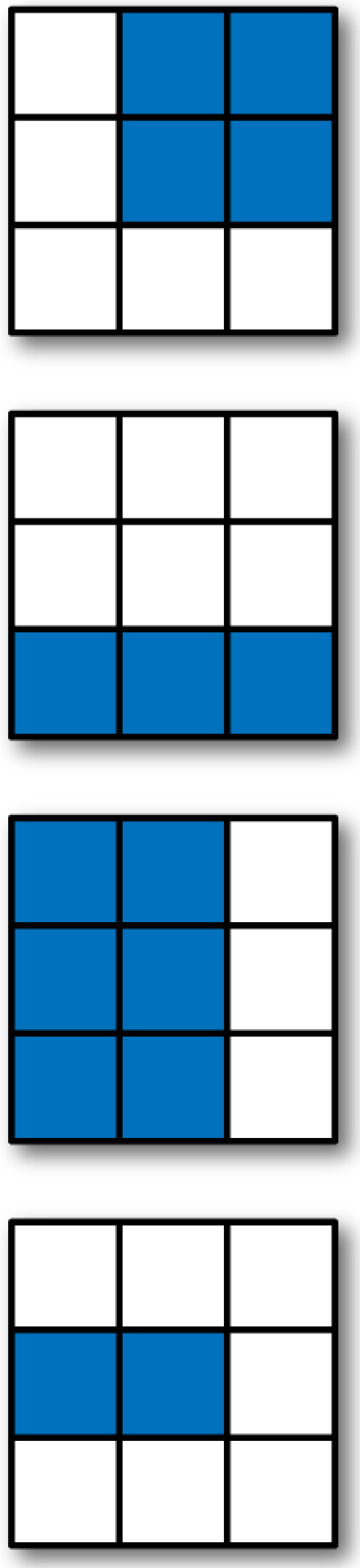

Expression	Shape
`arr[:2, 1:]`	(2, 2)
`arr[2]`	(3,)
`arr[2, :]`	(3,)
`arr[2:, :]`	(1, 3)

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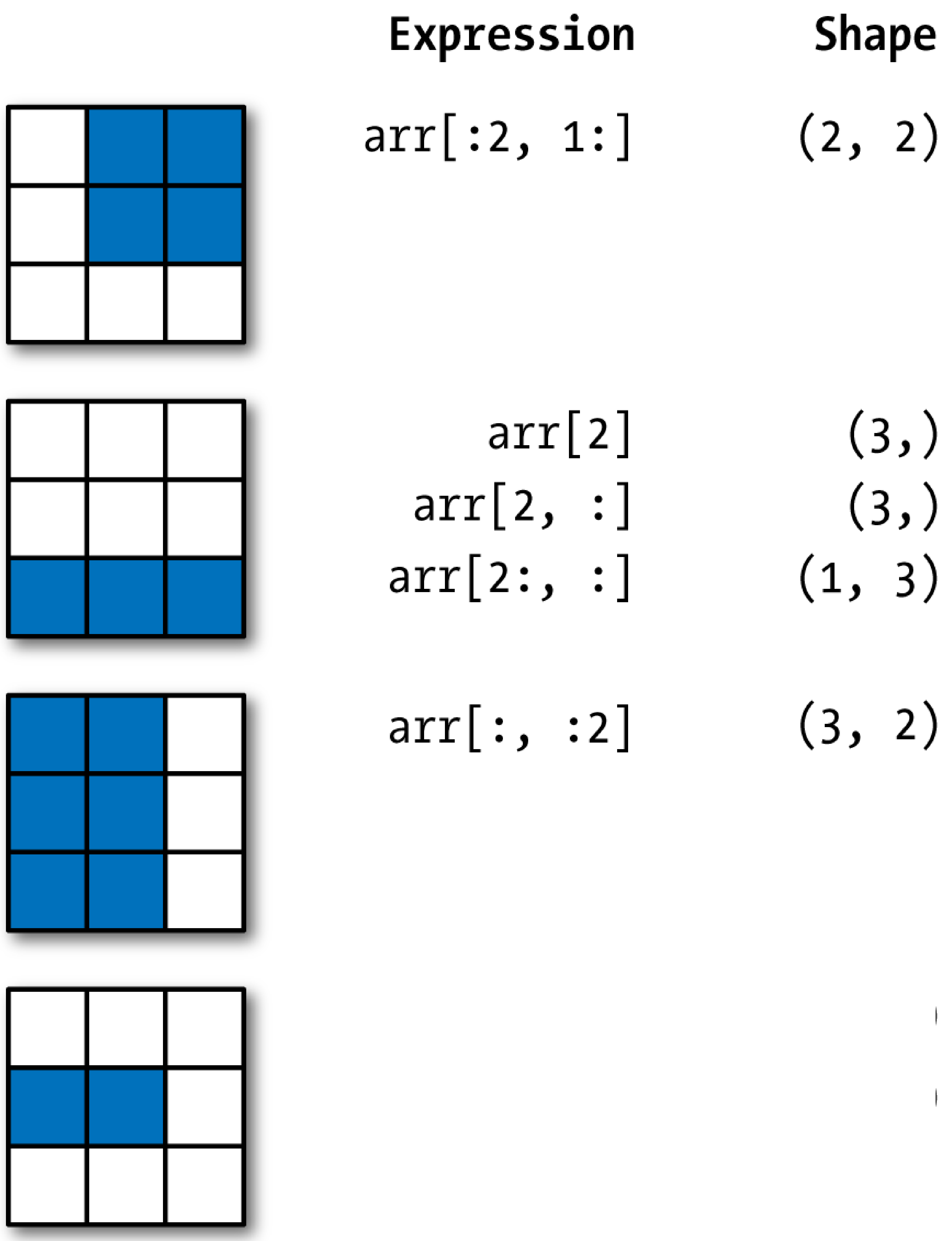

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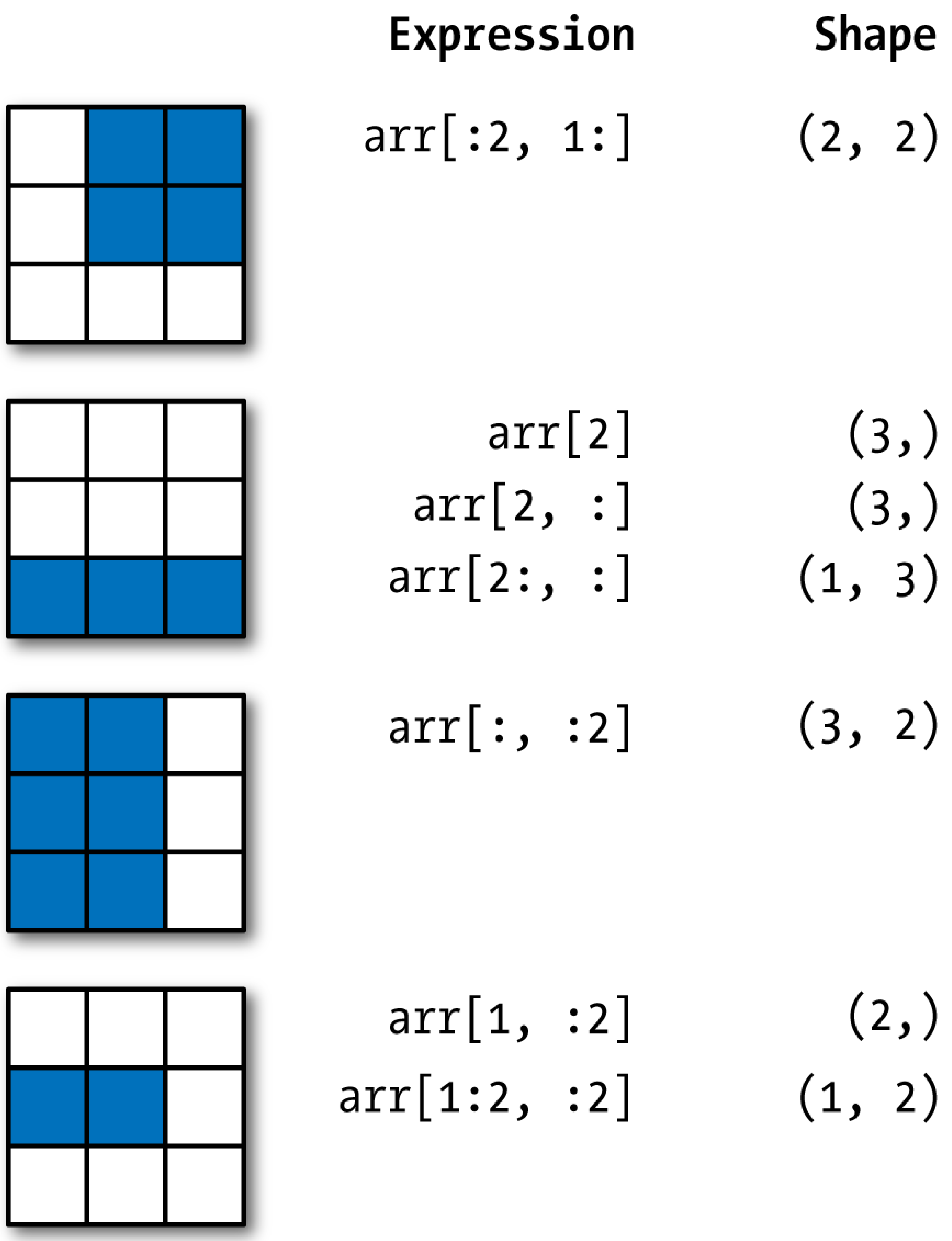

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Boolean Indexing

- `names == 'Bob'` gives back booleans that represent the element-wise comparison with the array `names`
- Boolean arrays can be used to index into another array:
  - `data[names == 'Bob']`
- Can even mix and match with integer slicing
- Can do boolean operations (`&`, `|`) between arrays (just like addition, subtraction)
  - `data[(names == 'Bob') | (names == 'Will')]`
- Note: `or` and `and` do not work with arrays
- We can set values too! `data[data < 0] = 0`

Object-Oriented Programming Concepts

- Abstraction: simplify, hide implementation details, don't repeat yourself
- Encapsulation: represent an entity fully, keep attributes and methods together
- Inheritance: reuse (don't reinvent the wheel), specialization
- Polymorphism: methods are handled by a single interface with different implementations (overriding)

Vehicle Example

- Suppose we are implementing a city simulation, and want to model vehicles driving on the road
- How do we represent a vehicle?
  - Information (attributes): make, model, year, color, num_doors, engine_type, mileage, acceleration, top_speed, braking_speed
  - Methods (actions): compute_estimated_value(), drive(num_seconds, acceleration), turn_left(), turn_right(), change_lane(dir), brake(), check_collision(other_vehicle)

Class vs. Instance

- A **class** is a blueprint for creating instances
  - e.g. Vehicle
- An **instance** is an single object created from a class
  - e.g. 2000 Red Toyota Camry
  - Each object has its own attributes
  - Instance methods produce results unique to each particular instance

Classes and Instances in Python

- Class Definition:
  - ```
    class Vehicle:
        def __init__(self, make, model, year, color):
            self.make = make
            self.model = model
            self.year = year
            self.color = color

        def age(self):
            return 2021 - self.year
    ```
- Instances:
  - `car1 = Vehicle('Toyota', 'Camry', 2000, 'red')`
  - `car2 = Vehicle('Dodge', 'Caravan', 2015, 'gray')`
    ```

Components

- Constructor: `__init__`
- Instance Attributes: `self.make`, `self.model`, `self.year`
- Instance Methods: `def age`, `def set_age`
- Using classes and instances:
  - `car1 = Vehicle('Toyota', 'Camry', 2000, 'red')`
  - `car1.set_age(20)`
- Visibility: no declaration, convention with underscore: `_color_hex`
- String Representation: define `__str__`, call `str()`

Properties

- Properties allow transformations and checks but are accessed like attributes
- getter and setter have same name, but different decorators
- Decorators (`@<decorator-name>`) do some magic
-
```
@property
def age(self):
    return 2021 - self.year
```
-
```
@age.setter
def age(self, age):
    self.year = 2021 - age
```
- Using property:
  - `car1.age = 20`

Class Attributes

- We can add class attributes inside the class indentation:
- Access by prefixing with **class name** or `self`

```
- class Vehicle:
        CURRENT_YEAR = 2021
        …
        @age.setter
        def age(self, age):
            if age < 0 or age > Vehicle.CURRENT_YEAR - 1885:
                print("Invalid age, will not set")
            else:
                self.year = self.CURRENT_YEAR - age
```

- Constants should be CAPITALIZED
- This is not a great constant! (`EARLIEST_YEAR = 1885` would be!)

Inheritance

- Is-a relationship: Car is a Vehicle, Truck is a Vehicle
- Make sure it isn't composition (has-a) relationship: Vehicle has wheels, Vehicle has a steering wheel
- Subclass is specialization of base class (superclass)
  - Car is a subclass of Vehicle, Truck is a subclass of Vehicle
- Can have an entire hierarchy of classes (e.g. Chevy Bolt is subclass of Car which is a subclass of Vehicle)
- Single inheritance: only one base class
- Multiple inheritance: allows more than base class
  - Many languages don't support, Python does

Subclass

- Just put superclass(-es) in parentheses after the class declaration
-
```
class Car(Vehicle):
    def __init__(self, make, model, year, color, num_doors):
        super().__init__(make, model, year, color)
        self.num_doors = num_doors

    def open_door(self):
        …
```
- `super()` is a special method that locates the base class
  - Constructor should call superclass constructor
  - Extra arguments should be initialized and extra instance methods

Overriding Methods

- ```
  class Rectangle:
      def __init__(self, height,
                   width):
          self.h = height
          self.w = weight

      def set_height(self, height):
          self.h = height
      def area(self):
          return self.h * self.w
  ```
- ```
  class Square(Rectangle):
      def __init__(self, side):
          super().__init__(side, side)

      def set_height(self, height):
          self.h = height
          self.w = height
  ```

- `s = Square(4)`
- `s.set_height(8)`
  - Which method is called?
  - Polymorphism
  - Resolves according to inheritance hierarchy
- `s.area() # 64`
  - If no method defined, goes up the inheritance hierarchy until found

Checking InstanceOf/Inheritance

- How can we see if an object is an instance of a particular class or whether a particular class is a subclass of another?
- Both check is-a relationship (but differently
- `issubclass(cls1, cls2)`: checks if `cls1` is-a (subclass) of `cls2`
- `isinstance(obj, cls)`: checks if `obj` is-a (instance) of `cls`
- Note that `isinstance` is `True` if `obj` is an instance of a class that is a subclass of `cls`
  - ```
    car = Car('Toyota','Camry', 2000, 'red', 4)
    isinstance(car, Vehicle) # True
    ```
    ```

Interfaces

- In some languages, can define an abstract base class
  - The structure is defined but **without implementation**
  - Alternatively, some methods are defined abstract, others are implemented
- Interfaces are important for types
  - Method can specify a particular type that can be abstract
  - This doesn't matter as much in Python
- Python has ABC (Abstract Base Class)
  - Solution to be able to check for mappings, sequences via `isinstance`, etc.
  - `abc.Mapping`, `abc.Sequence`, `abc.MutableSequence`

Duck Typing

- "If it looks like a duck and quacks like a duck, it must be a duck."
- Python "does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used"
- ```
  class Rectangle:
      def area(self):
          …
  ```
- ```
  class Circle:
      def area(self):
          …
  ```
- It doesn't matter that they don't have a common base class as long as they respond to the methods/attributes we expect: `shape.area()`

[Python Glossary]

Multiple Inheritance

- Can have a class inherit from two different superclasses
- HybridCar inherits from Car and Hybrid
- Python allows this!
  - `class HybridCar(Car, Hybrid): …`
- Problem: how is `super()` is defined?
  - Diamond Problem
  - Python use the **method resolution order** (MRO) to determine order of calls

Mixins

- Sometimes, we just want to add a particular method to a bunch of different classes
- For example: `print_as_dict()`
- A mixin class allows us to specify one or more methods and add it as the second
- Caution: Python searches from left to right so a base class should be at the right with mixing

Operator Overloading

- Dunder methods
- Examples:
  - `__add__(self, right)`
  - `__iadd__(self, right)`