Programming Basics and Data Analytics with Python

Mathematical Computing Using NumPy

Learning Objectives

By the end of this lesson, you will be able to:

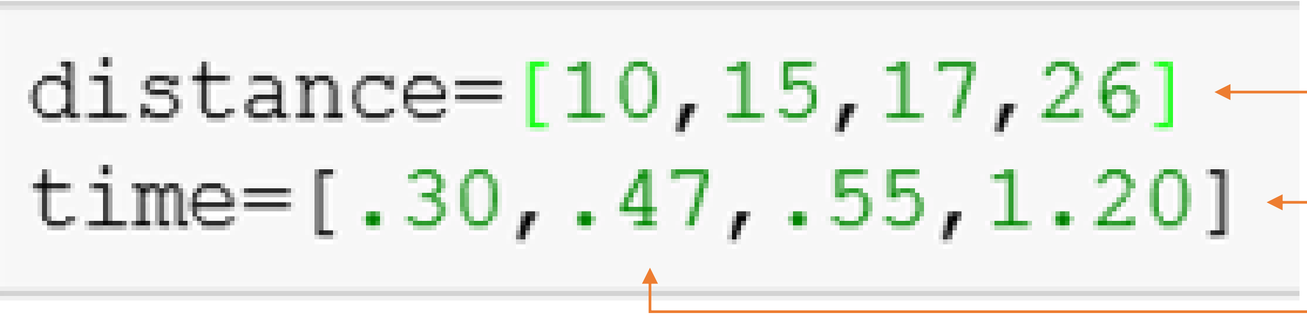
- Explain NumPy and its importance
- Discuss the basics of NumPy, including its fundamental objects
- Demonstrate how to create and print a NumPy array
- Analyze and perform basic operations in NumPy
- Utilize shape manipulation and copying methods
- Demonstrate how to execute linear algebraic functions
- Build basic programs using NumPy

NumPy

Quick Recap: Lists

Below are some of the properties of lists:

List



```
distance=[10,15,17,26]
time=[.30,.47,.55,1.20]
```

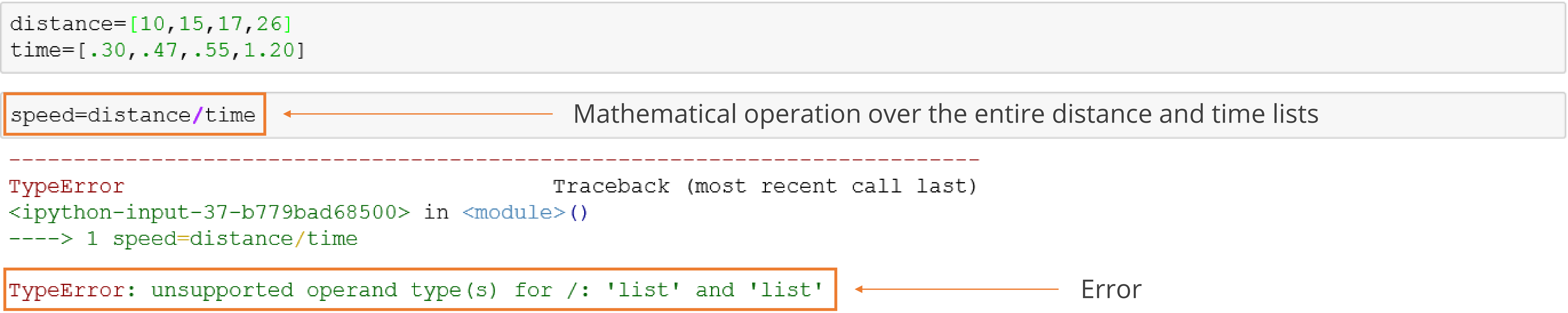
Collection of values

Multiple types (heterogeneous)

Add, remove, update

Limitations of Lists

Though you can change individual values in a list, you cannot apply a mathematical operation over the entire list.



```
distance=[10,15,17,26]
time=[.30,.47,.55,1.20]
```

```
speed=distance/time
```

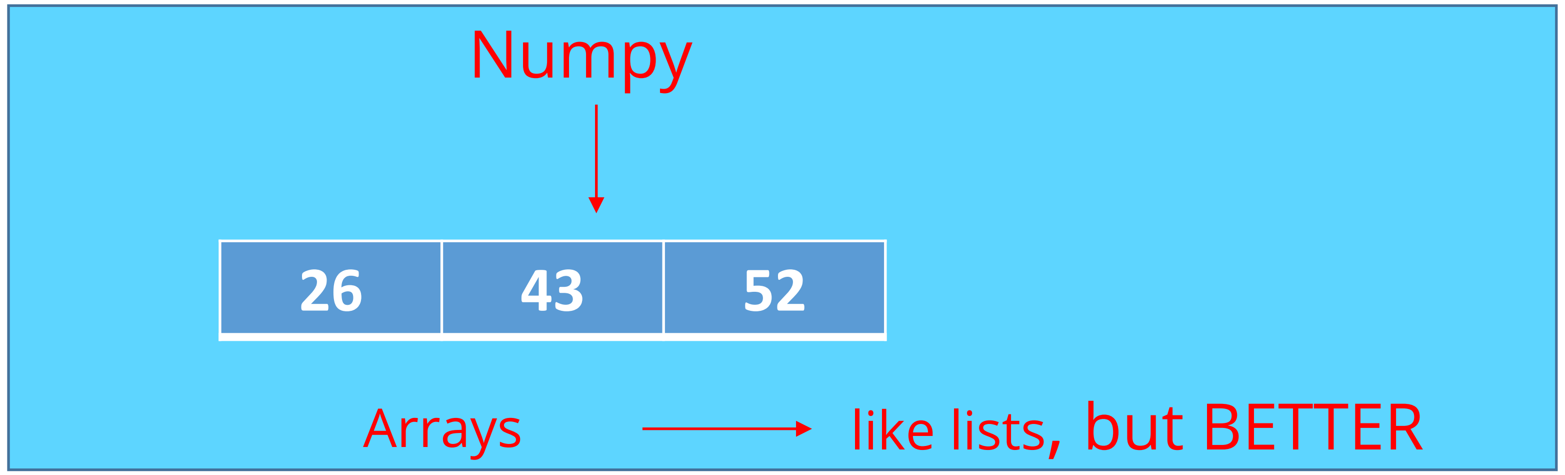
Mathematical operation over the entire distance and time lists

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
<ipython-input-37-b779bad68500> in <module>()
----> 1 speed=distance/time

TypeError: unsupported operand type(s) for /: 'list' and 'list'
```

Error

Why NumPy?

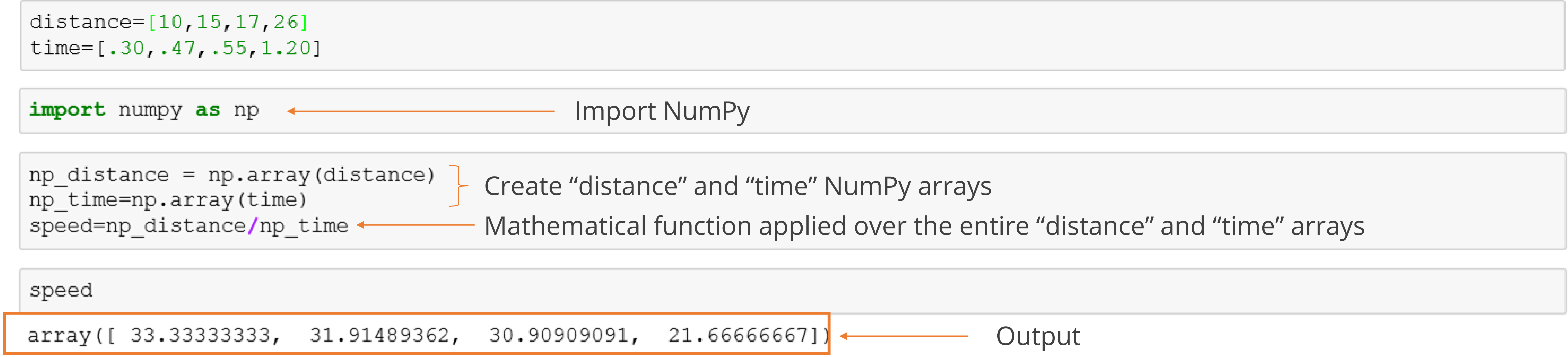
Numerical Python (NumPy) supports multidimensional arrays over which you can easily apply mathematical operations.



Numpy

26	43	52

Arrays → like lists, but BETTER



```
distance=[10,15,17,26]
time=[.30,.47,.55,1.20]
```

```
import numpy as np
```

Import NumPy

```
np_distance = np.array(distance)
np_time=np.array(time)
speed=np_distance/np_time
```

Create “distance” and “time” NumPy arrays

Mathematical function applied over the entire “distance” and “time” arrays

```
speed
```

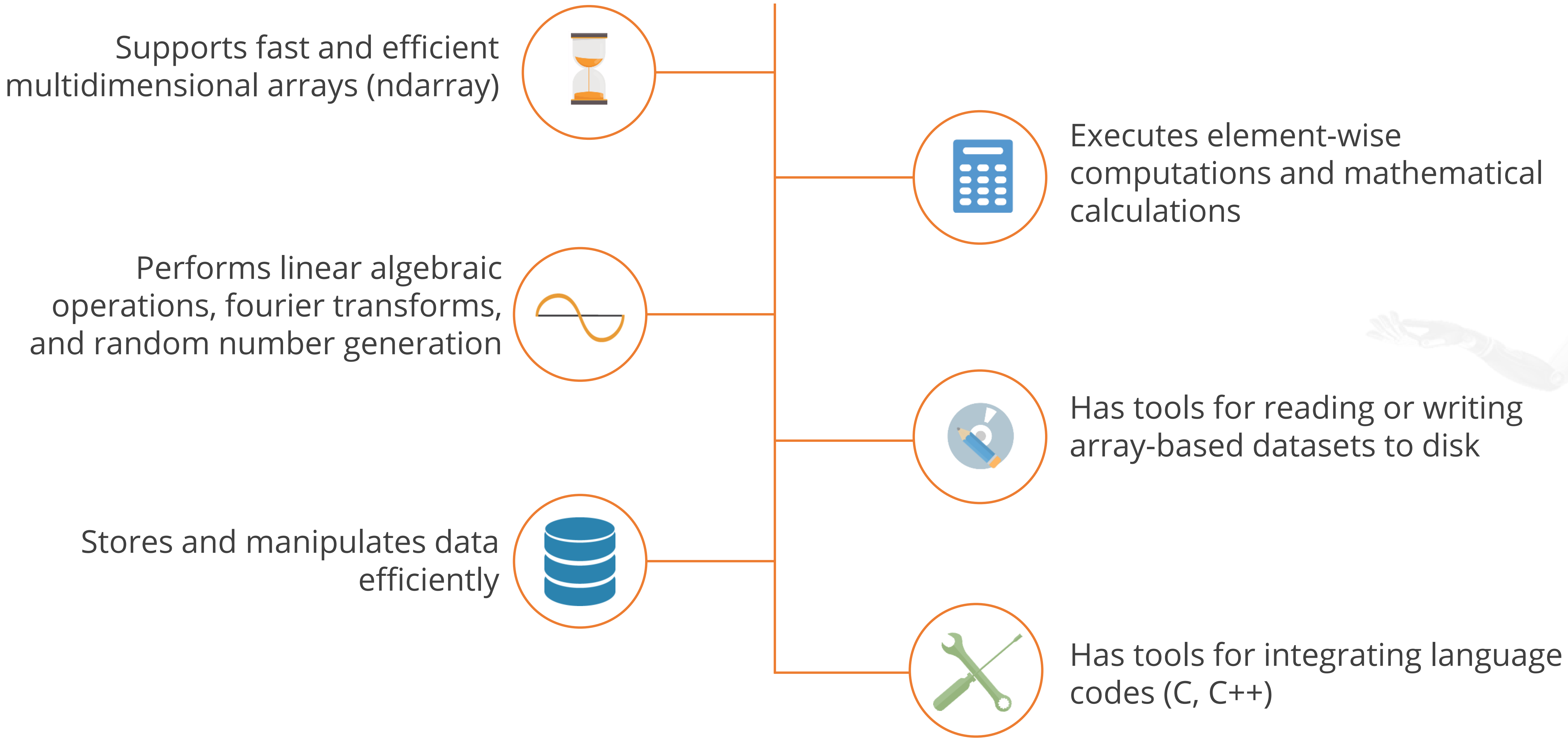
```
array([ 33.33333333,  31.91489362,  30.90909091,  21.66666667])
```

Output

NumPy: Overview

NumPy is the foundational package for mathematical computing in Python.

It has the following properties:



Supports fast and efficient multidimensional arrays (ndarray)

Executes element-wise computations and mathematical calculations

Performs linear algebraic operations, fourier transforms, and random number generation

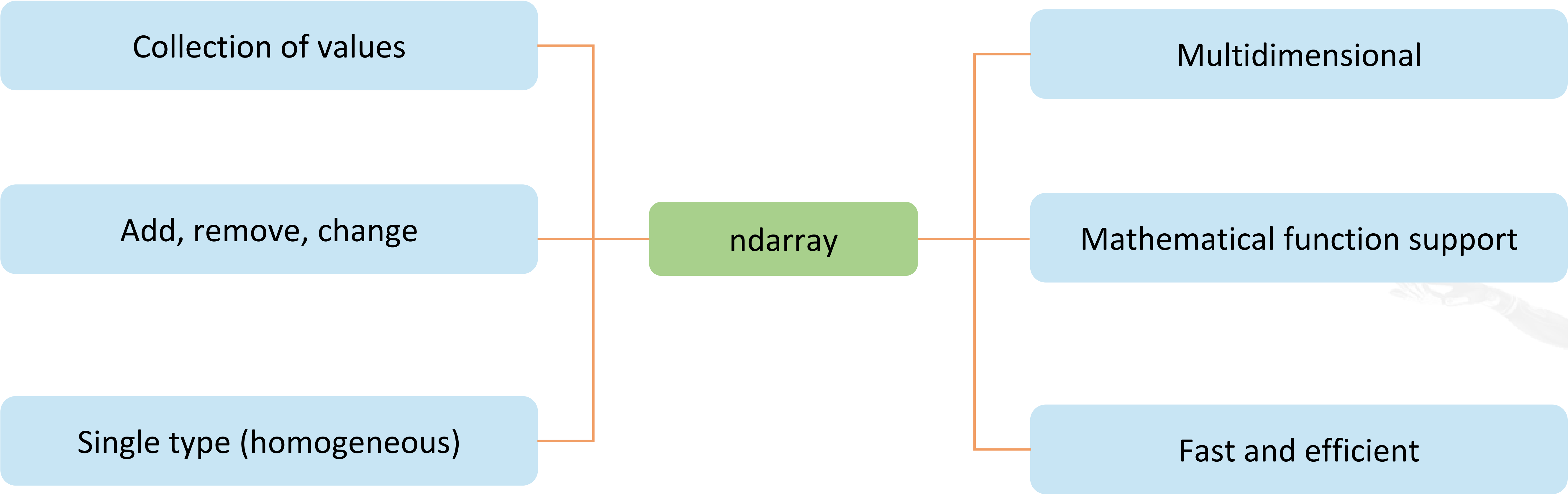
Has tools for reading or writing array-based datasets to disk

Stores and manipulates data efficiently

Has tools for integrating language codes (C, C++)

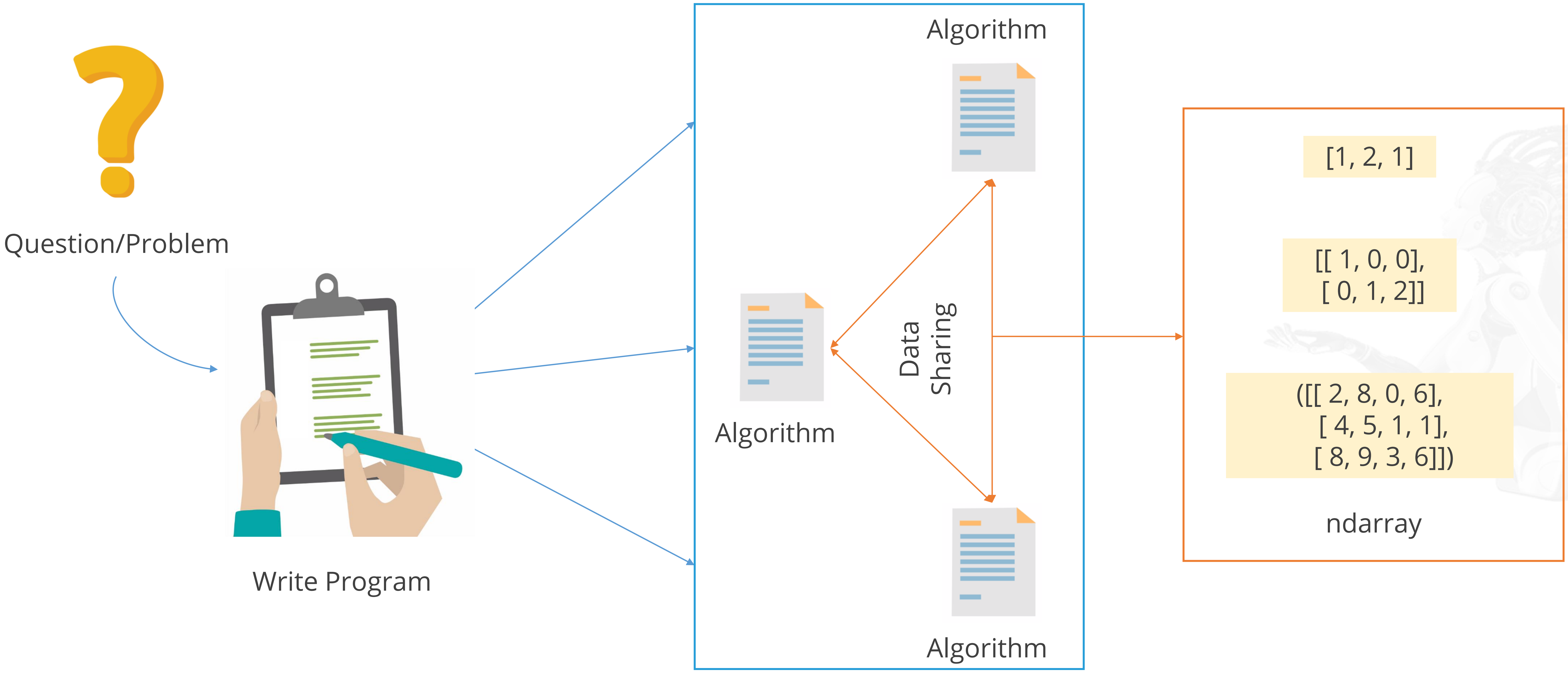
Properties of ndarray

An array in NumPy has the following properties:



Purpose of ndarray

The ndarray in Python is used as the primary container to exchange data between algorithms.



Question/Problem

Write Program

Algorithm

Algorithm

Algorithm

Data Sharing

```
[1, 2, 1]
```

```
[[ 1, 0, 0],
 [ 0, 1, 2]]
```

```
([[ 2, 8, 0, 6],
  [ 4, 5, 1, 1],
  [ 8, 9, 3, 6]])
```

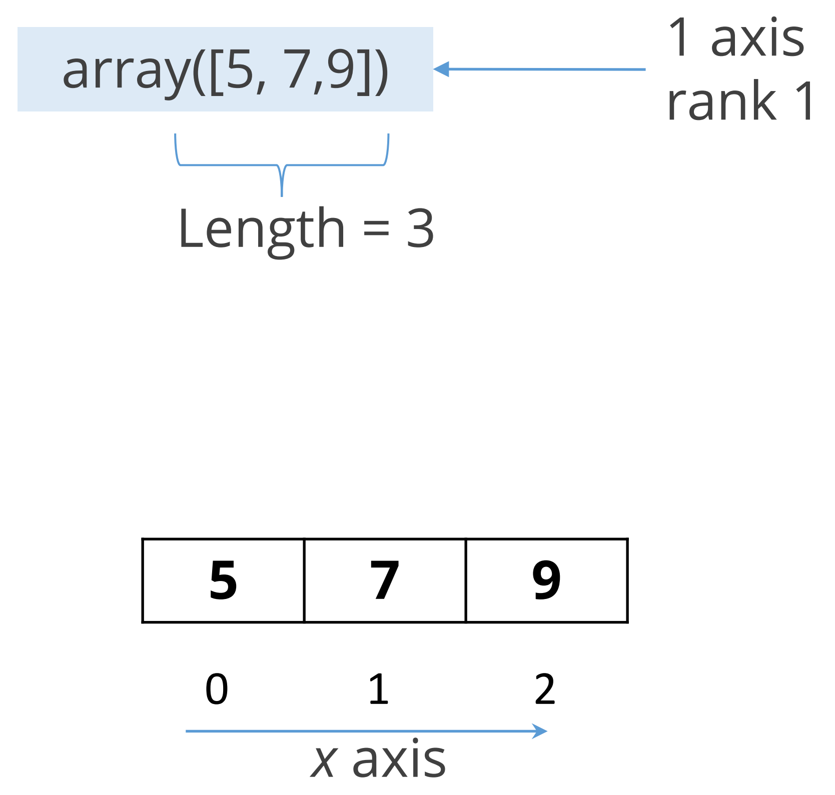
ndarray

Types of Arrays

Arrays can be one-dimensional, two-dimensional, three-dimensional, or multidimensional.

One-Dimensional Array

Printed as rows



```
array([5, 7,9])
```

1 axis
rank 1

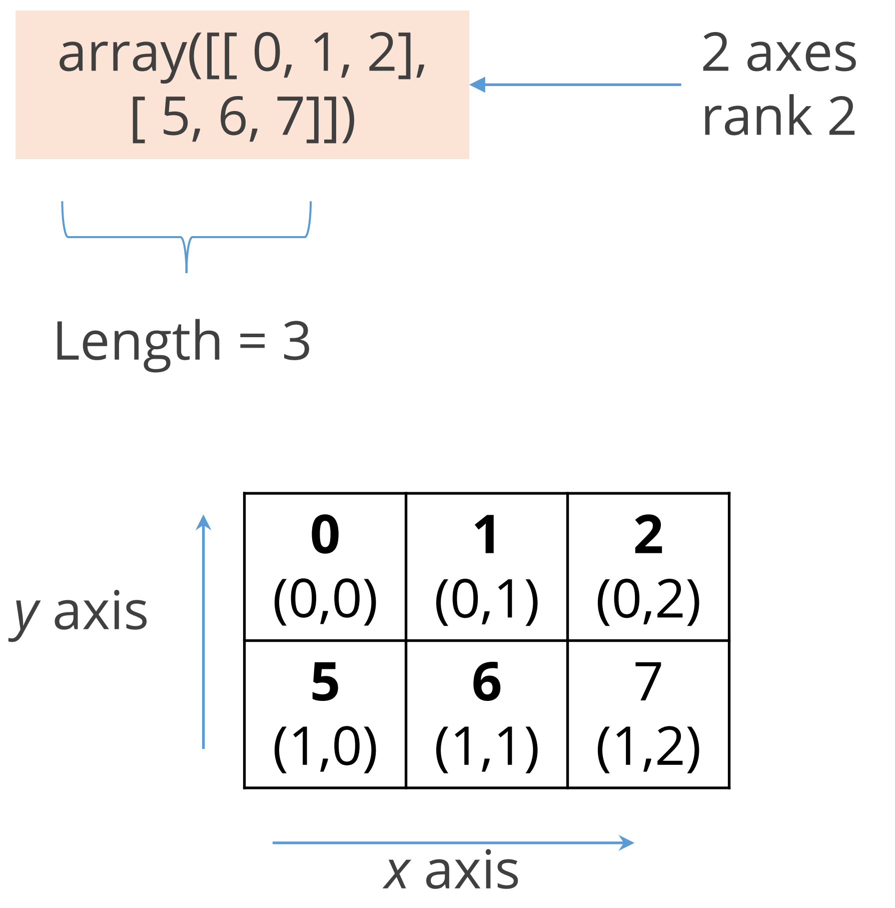
Length = 3

5	7	9
0	1	2

x axis

Two-Dimensional Array

Printed as matrices (2x3)



```
array([[ 0, 1, 2],
       [ 5, 6, 7]])
```

2 axes
rank 2

Length = 3

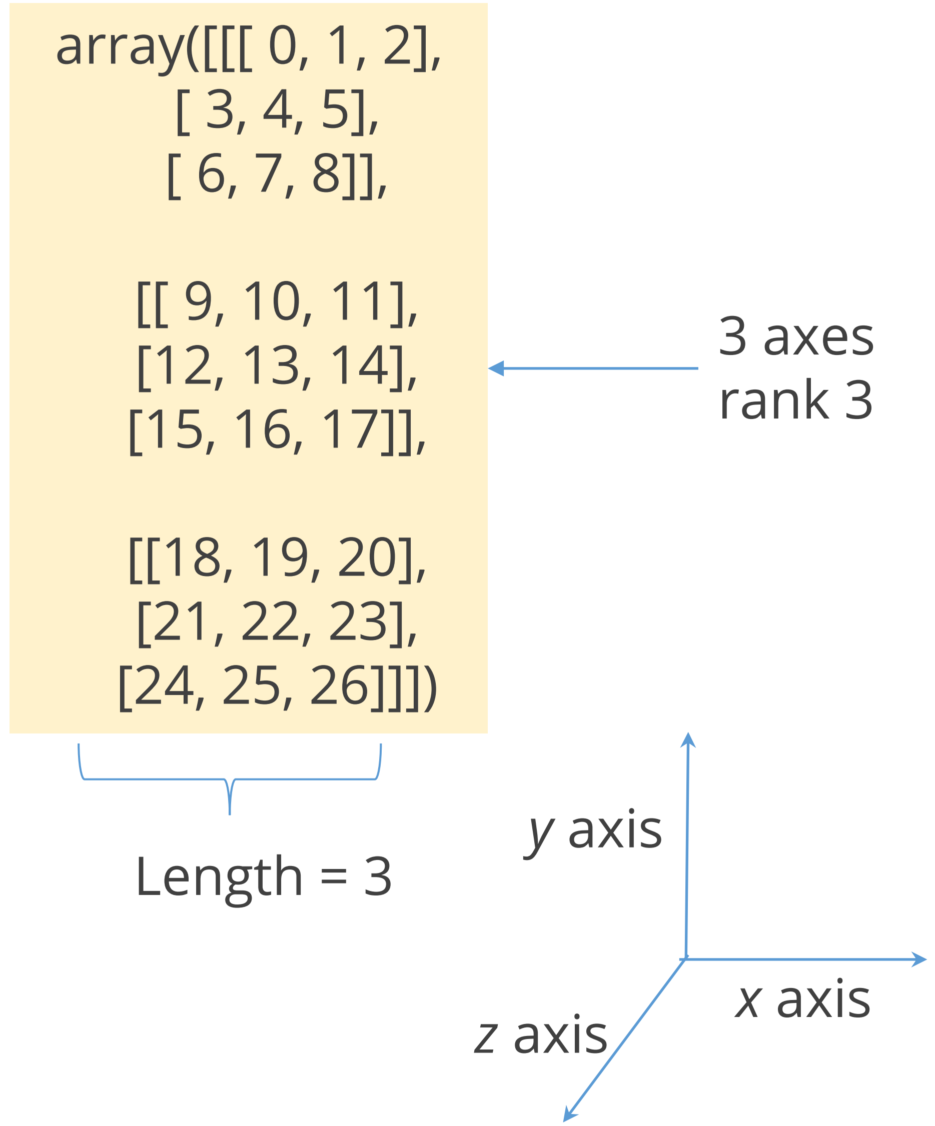
0 (0,0)	**1** (0,1)	**2** (0,2)
5 (1,0)	**6** (1,1)	7 (1,2)

y axis

x axis

Three-Dimensional Array

Printed as list of matrices (3x3x3)



```
array([[[ 0, 1, 2],
        [ 3, 4, 5],
        [ 6, 7, 8]],

       [[ 9, 10, 11],
        [12, 13, 14],
        [15, 16, 17]],

       [[18, 19, 20],
        [21, 22, 23],
        [24, 25, 26]]])
```

3 axes
rank 3

Length = 3

Create and Print NumPy Arrays

Objective: Create the following types of NumPy arrays:

- One-dimensional array
- Array with zeros
- Array with ones
- Two-dimensional array
- Three-dimensional array

Access: To execute the practice, follow these steps:

- Go to the **PRACTICE LABS** tab on your LMS
- Click the **START LAB** button
- Click the **LAUNCH LAB** button to start the lab

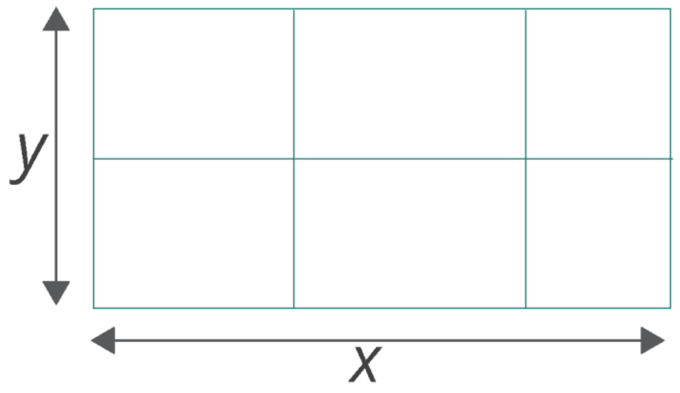
ASSISTED PRACTICE

Class and Attributes of ndarray: .ndim

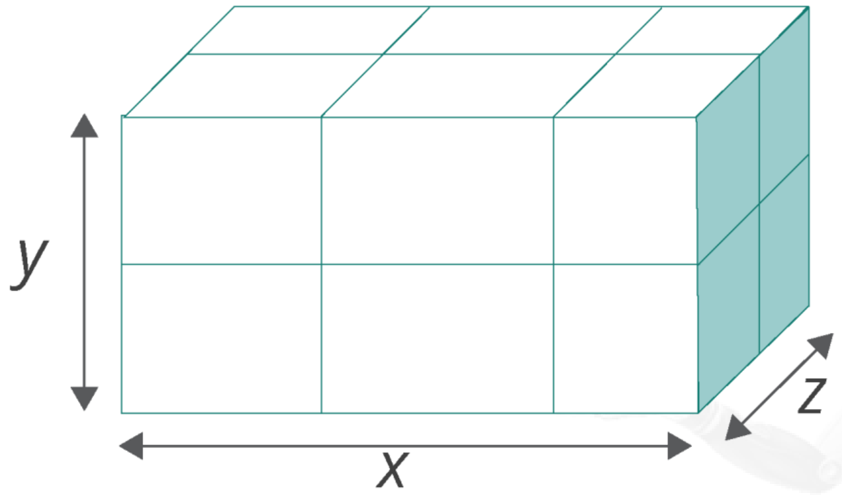
Numpy array class is ndarray, also referred to as numpy.ndarray. The attributes of ndarray are:

- ndarray.ndim
- ndarray.shape
- ndarray.size
- ndarray.dtype

This refers to the number of axes (dimensions) of the array. It is also called the rank of the array.



Two axes or 2D array



Three axes or 3D array

Concept

Example

Class and Attributes of ndarray: .ndim

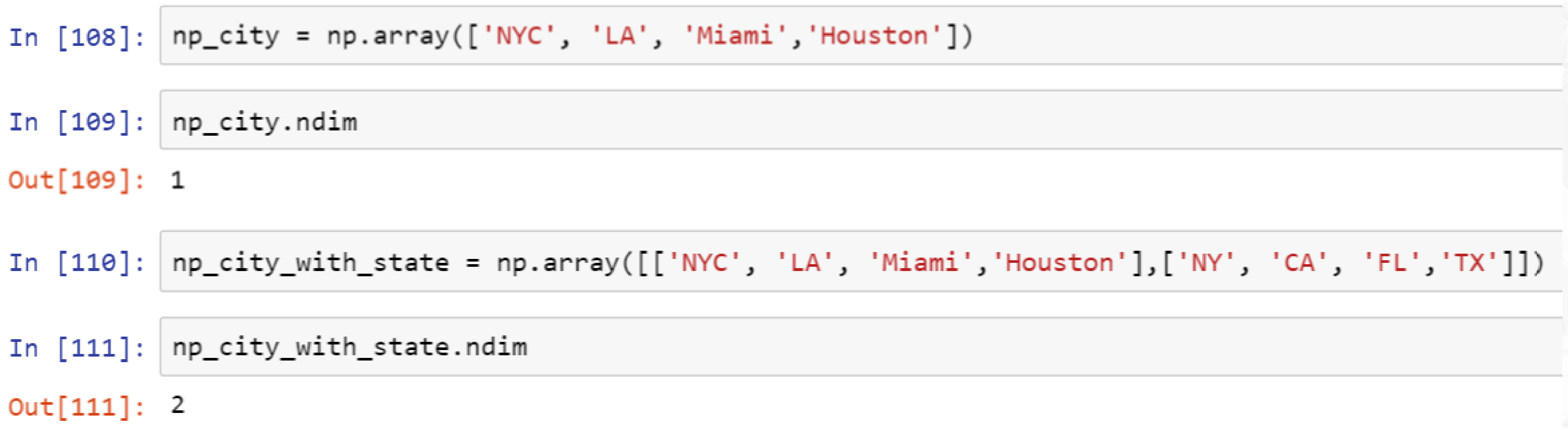
ndarray.ndim

ndarray.shape

ndarray.size

ndarray.dtype

The array np_city is one-dimensional, while the array np_city_with_state is two-dimensional.



```
In [108]: np_city = np.array(['NYC', 'LA', 'Miami','Houston'])

In [109]: np_city.ndim
Out[109]: 1

In [110]: np_city_with_state = np.array([['NYC', 'LA', 'Miami','Houston'],['NY', 'CA', 'FL','TX']])

In [111]: np_city_with_state.ndim
Out[111]: 2
```

Concept

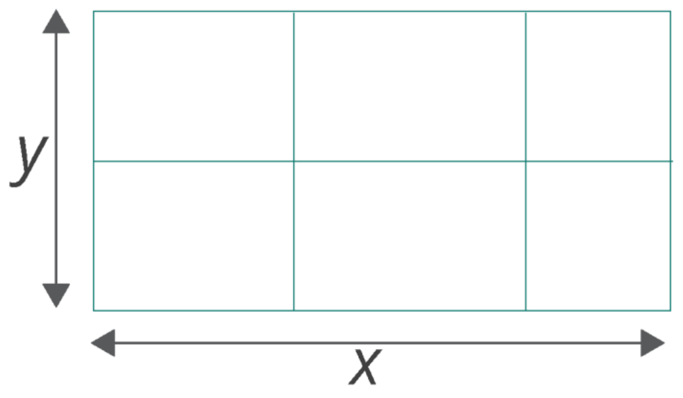
Example

Class and Attributes of ndarray: .shape

Numpy array class is ndarray, also referred to as numpy.ndarray. The attributes of ndarray are:

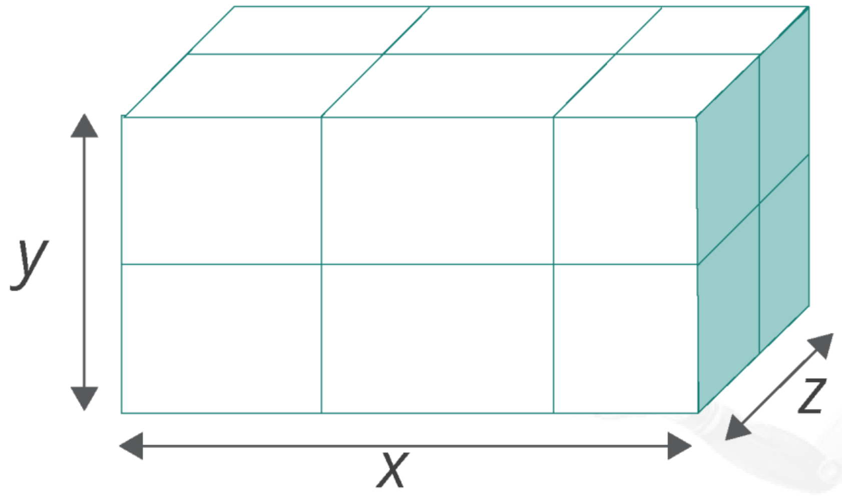
- ndarray.ndim
- ndarray.shape
- ndarray.size
- ndarray.dtype

This consists of a tuple of integers showing the size of the array in each dimension. The length of the shape tuple is the rank or ndim.



2 rows, 3 columns

Shape: (2, 3)



2 rows, 3 columns, 2 ranks

Shape: (2, 3, 2)

Concept

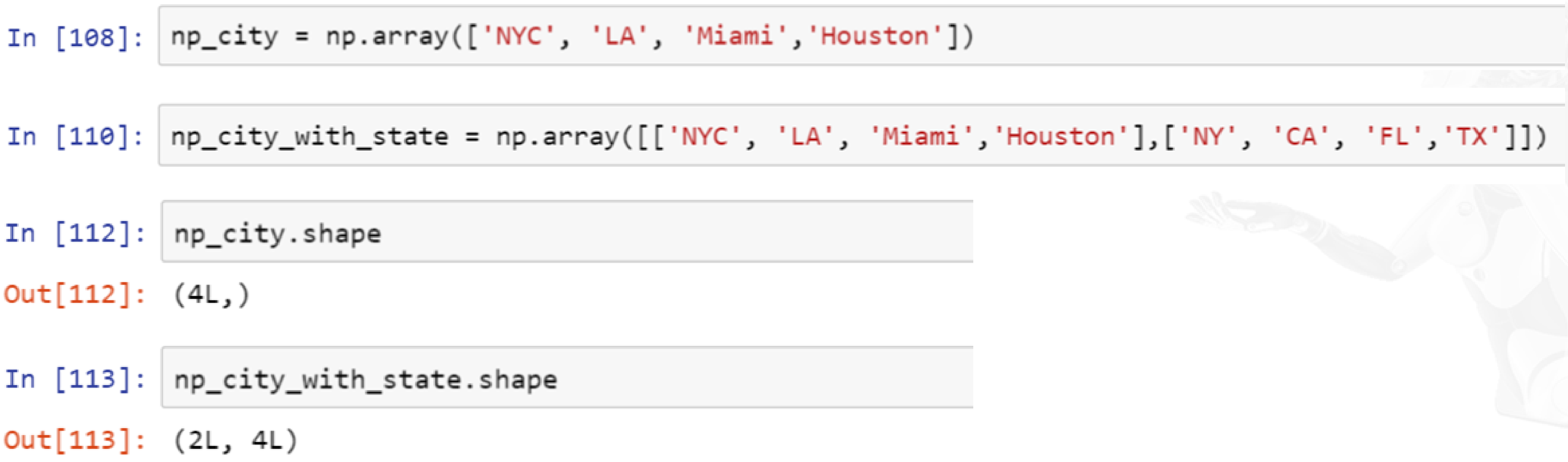
Example

Class and Attributes of ndarray: .shape

Numpy’s array class is “ndarray,” also referred to as “numpy.ndarray.” The attributes of ndarray are:

- ndarray.ndim
- ndarray.shape
- ndarray.size
- ndarray.dtype

The shape tuple of both the arrays indicate their size along each dimension.



```
In [108]: np_city = np.array(['NYC', 'LA', 'Miami','Houston'])

In [110]: np_city_with_state = np.array([['NYC', 'LA', 'Miami','Houston'],['NY', 'CA', 'FL','TX']])

In [112]: np_city.shape
Out[112]: (4L,)

In [113]: np_city_with_state.shape
Out[113]: (2L, 4L)
```

Concept Example

Class and Attributes of ndarray: .size

Numpy’s array class is “ndarray,” also referred to as “numpy.ndarray.” The attributes of ndarray are:

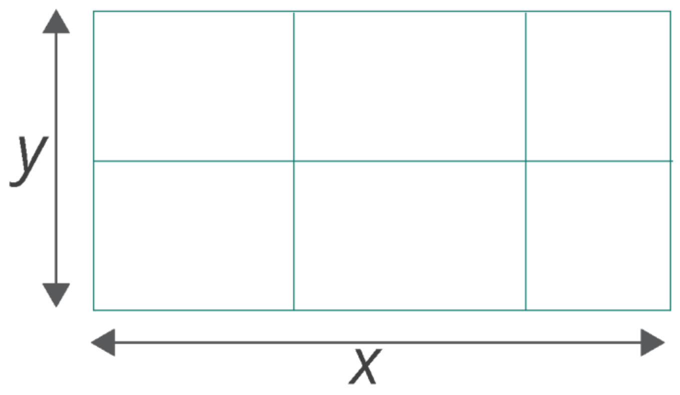
ndarray.ndim

ndarray.shape

ndarray.size

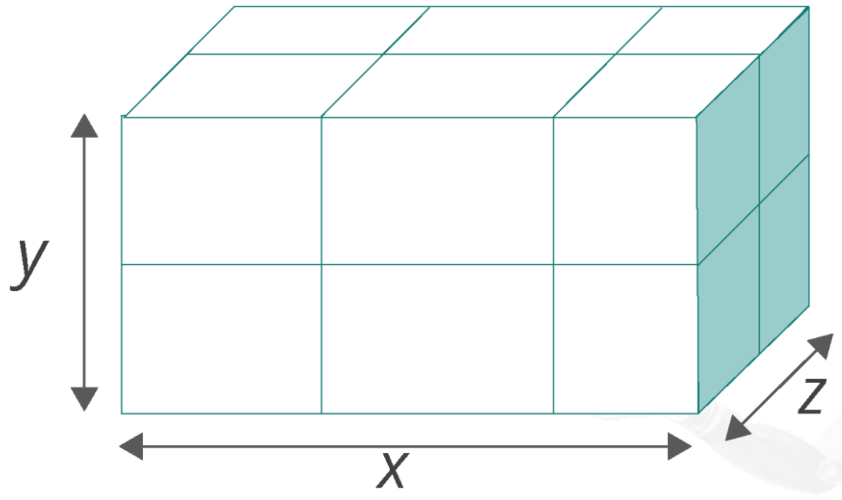
ndarray.dtype

It gives the total number of elements in the array. It is equal to the product of the elements of the shape tuple.



Array contains 6 elements

Array a = (2, 3)
Size = 6



Array contains 12 elements

Array b = (2, 3, 2)
Size = 12

Concept

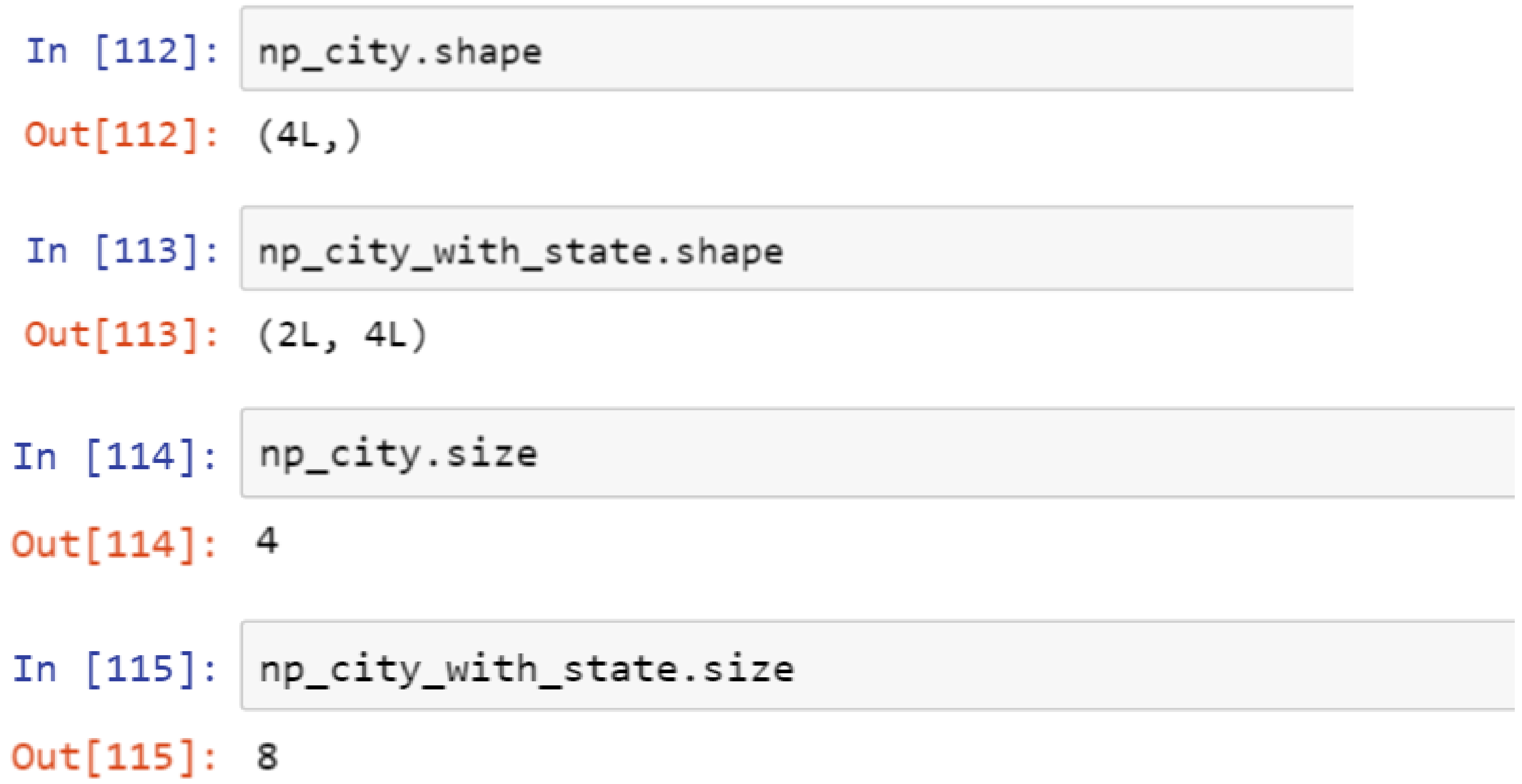
Example

Class and Attributes of ndarray: .size

Numpy’s array class is “ndarray,” also referred to as “numpy.ndarray.” The attributes of ndarray are:

- ndarray.ndim
- ndarray.shape
- ndarray.size
- ndarray.dtype

Look at the examples to see how shape tuples of the arrays are used to calculate their size.



```
In [112]: np_city.shape

Out[112]: (4L,)

In [113]: np_city_with_state.shape

Out[113]: (2L, 4L)

In [114]: np_city.size

Out[114]: 4

In [115]: np_city_with_state.size

Out[115]: 8
```

Concept

Example

Class and Attributes of ndarray: .dtype

Numpy’s array class is “ndarray,” also referred to as “numpy.ndarray.” The attributes of ndarray are:

ndarray.ndim

ndarray.shape

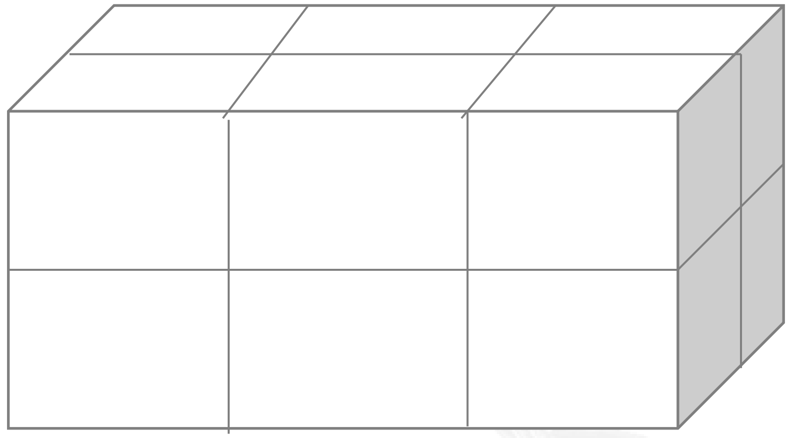
ndarray.size

ndarray.dtype

It’s an object that describes the type of the elements in the array. It can be created or specified using Python.

Array contains integers

Array a = [3, 7, 4]
[2, 1, 0]



Array contains floats

Array b = [1.3, 5.2, 6.7]
[0.2, 8.1, 9.4]

[2.6, 4.2, 3.9]
[7.8, 3.4, 0.8]

Concept

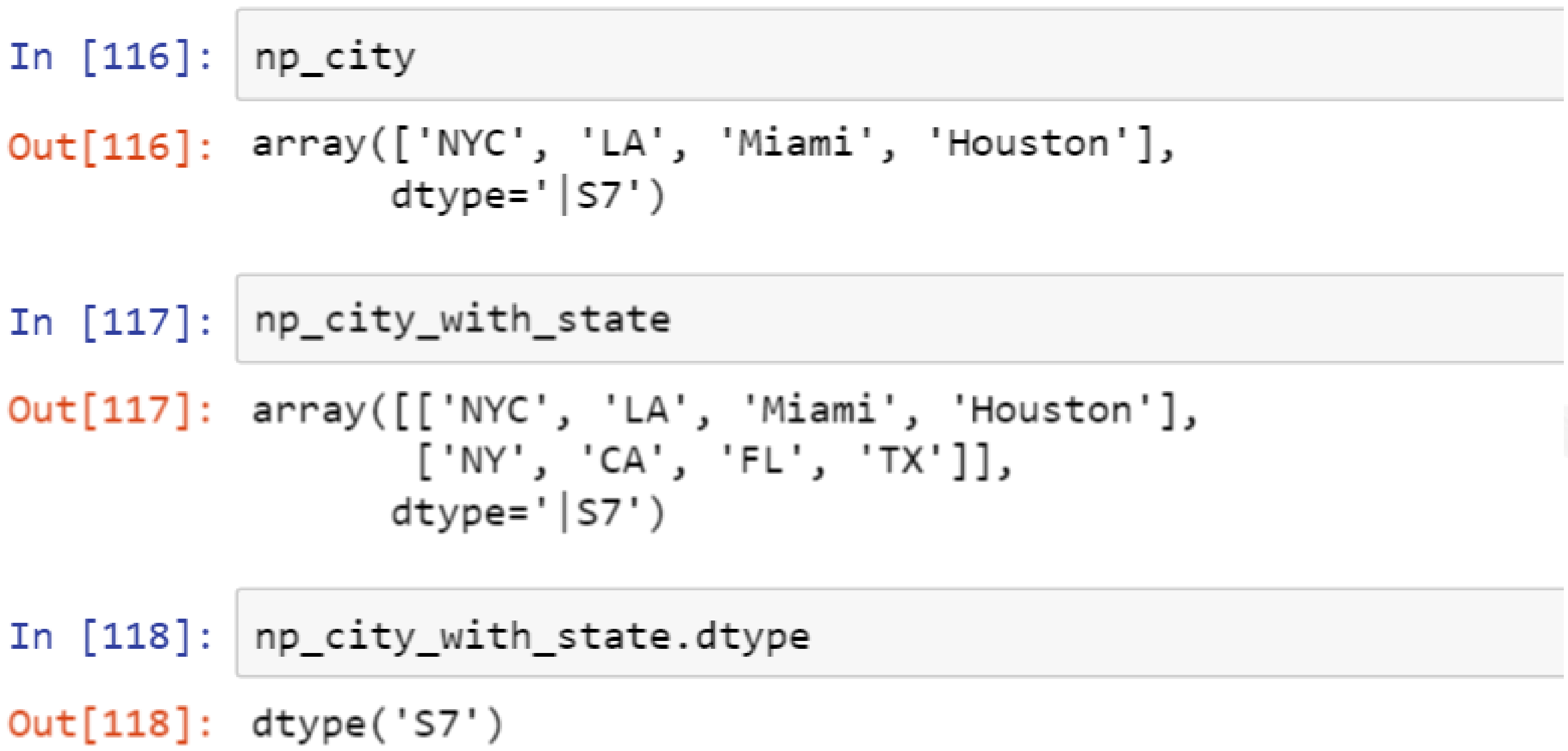
Example

Class and Attributes of ndarray: .dtype

Numpy’s array class is “ndarray,” also referred to as “numpy.ndarray.” The attributes of ndarray are:

- ndarray.ndim
- ndarray.shape
- ndarray.size
- ndarray.dtype

Both the arrays are of string data type (dtype) and the longest string is of length 7, which is Houston.



```
In [116]: np_city

Out[116]: array(['NYC', 'LA', 'Miami', 'Houston'],
                dtype='|S7')

In [117]: np_city_with_state

Out[117]: array([['NYC', 'LA', 'Miami', 'Houston'],
                 ['NY', 'CA', 'FL', 'TX']],
                dtype='|S7')

In [118]: np_city_with_state.dtype

Out[118]: dtype('S7')
```

Concept

Example

Operations

Basic Operations

Using the following operands, you can easily apply various mathematical, logical, and comparison operations on an array.

Mathematical Operations

Addition	+
Subtraction	-
Multiplication	*
Division	/
Exponentiation	**

Logical Operations

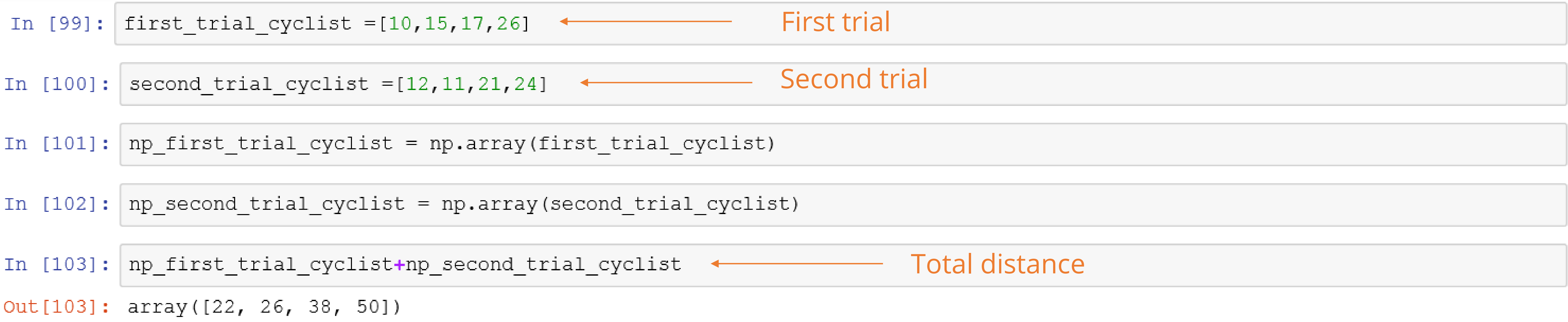
And	&
Or	|
Not	~

Comparison Operations

Greater	>
Greater or equal	>=
Less	<
Less or equal	<=
Equal	==
Not equal	!=

Basic Operations: Example

NumPy uses the indices of the elements in each array to carry out basic operations. In this case, where we are looking at a dataset of four cyclists during two trials, vector addition of the arrays gives the required output.

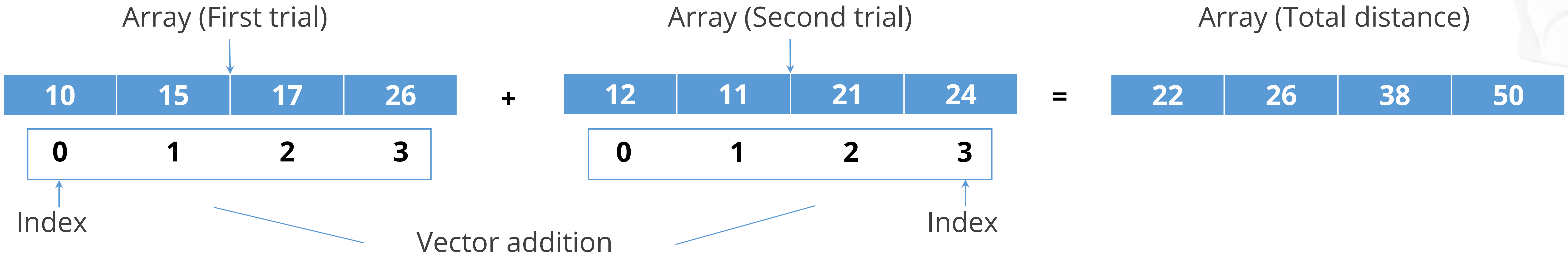


```
In [99]:  first_trial_cyclist =[10,15,17,26]

In [100]: second_trial_cyclist =[12,11,21,24]

In [101]: np_first_trial_cyclist = np.array(first_trial_cyclist)

In [102]: np_second_trial_cyclist = np.array(second_trial_cyclist)

In [103]: np_first_trial_cyclist+np_second_trial_cyclist

Out[103]: array([22, 26, 38, 50])
```

First trial

Second trial

Total distance



Array (First trial)

10 15 17 26

0 1 2 3

Index

+

Array (Second trial)

12 11 21 24

0 1 2 3

Index

=

Array (Total distance)

22 26 38 50

Vector addition

Executing Basic Operations in NumPy Array

Objective: Create a NumPy array and perform the following basic operations:

- Mathematical operations
- Comparison operations
- Logical operations

Access: To execute the practice, follow these steps:

- Go to the **PRACTICE LABS** tab on your LMS
- Click the **START LAB** button
- Click the **LAUNCH LAB** button to start the lab

ASSISTED PRACTICE

Performing Operations Using NumPy Array

Objective: Perform the following operations using NumPy array:

- Count the number of times each value appears in an array of integers

- Create a NumPy array [[0, 1, 2], [3, 4, 5], [6, 7, 8],[9, 10, 11]]) and filter the elements greater than five

- Create a NumPy array having NaN(Not a Number) and print it; also, print the same array omitting all elements which are NaN

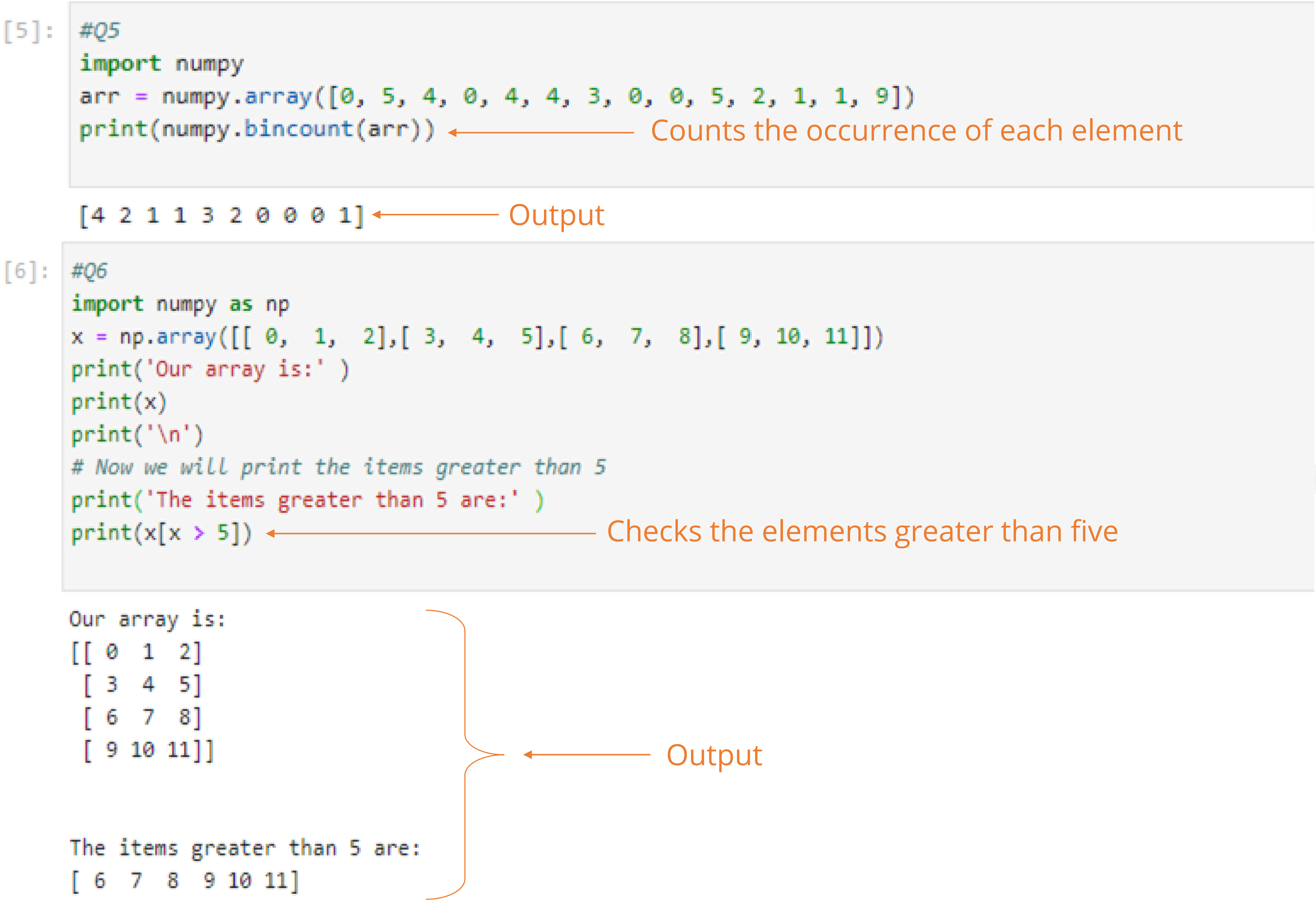
  Example: array([nan, 1., 2., nan, 3., 4., 5.])

- Create a 10x10 array with random values and find the minimum and maximum values

Access: To execute the practice, follow these steps:

- Go to the **PRACTICE LABS** tab on your LMS
- Click the **START LAB** button
- Click the **LAUNCH LAB** button to start the lab

Unassisted Practice: Operations Using NumPy Array



```
[5]: #Q5
     import numpy
     arr = numpy.array([0, 5, 4, 0, 4, 4, 3, 0, 0, 5, 2, 1, 1, 9])
     print(numpy.bincount(arr))
```

Counts the occurrence of each element

```
[4 2 1 1 3 2 0 0 0 1]
```

Output

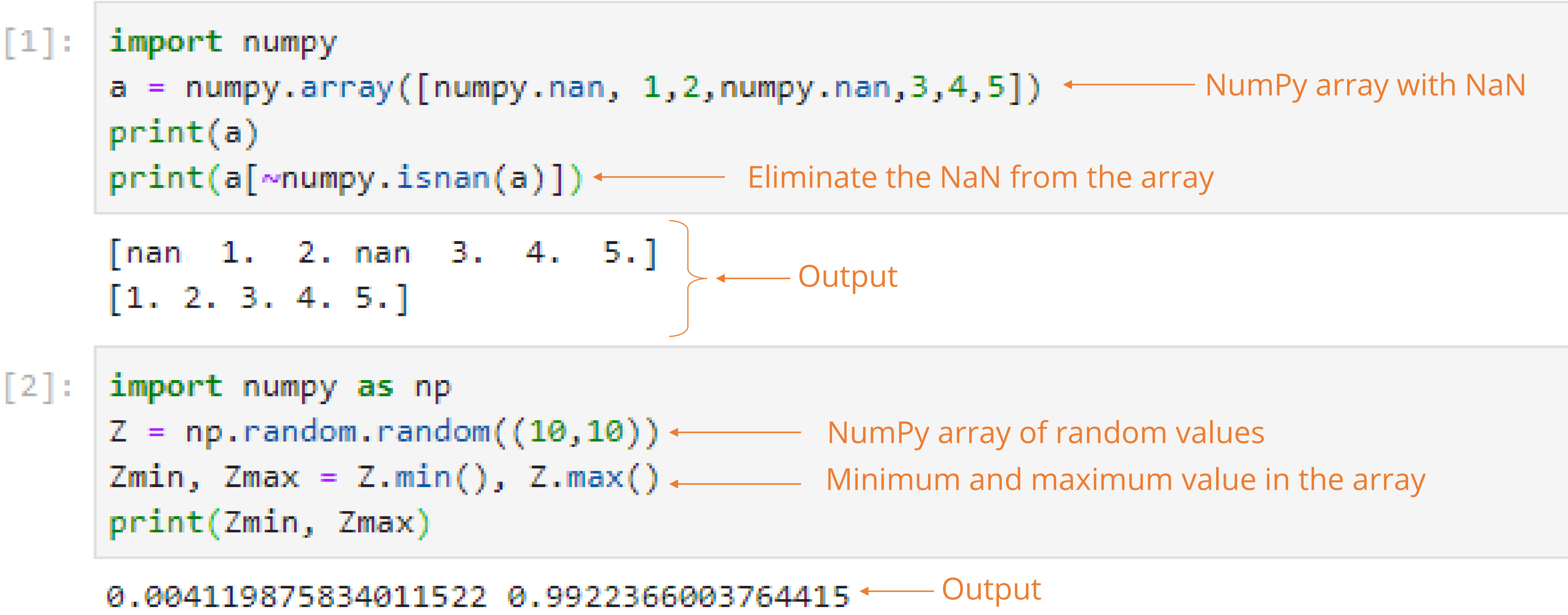
```
[6]: #Q6
     import numpy as np
     x = np.array([[ 0,  1,  2],[ 3,  4,  5],[ 6,  7,  8],[ 9, 10, 11]])
     print('Our array is:' )
     print(x)
     print('\n')
     # Now we will print the items greater than 5
     print('The items greater than 5 are:' )
     print(x[x > 5])
```

Checks the elements greater than five

```
Our array is:
[[ 0  1  2]
 [ 3  4  5]
 [ 6  7  8]
 [ 9 10 11]]


The items greater than 5 are:
[ 6  7  8  9 10 11]
```

Output

Unassisted Practice: Operations Using NumPy Array



[1]:

```
import numpy
a = numpy.array([numpy.nan, 1,2,numpy.nan,3,4,5])
print(a)
print(a[~numpy.isnan(a)])
```

```
[nan  1.  2. nan  3.  4.  5.]
[1. 2. 3. 4. 5.]
```

NumPy array with NaN

Eliminate the NaN from the array

Output

[2]:

```
import numpy as np
Z = np.random.random((10,10))
Zmin, Zmax = Z.min(), Z.max()
print(Zmin, Zmax)
```

```
0.004119875834011522 0.9922366003764415
```

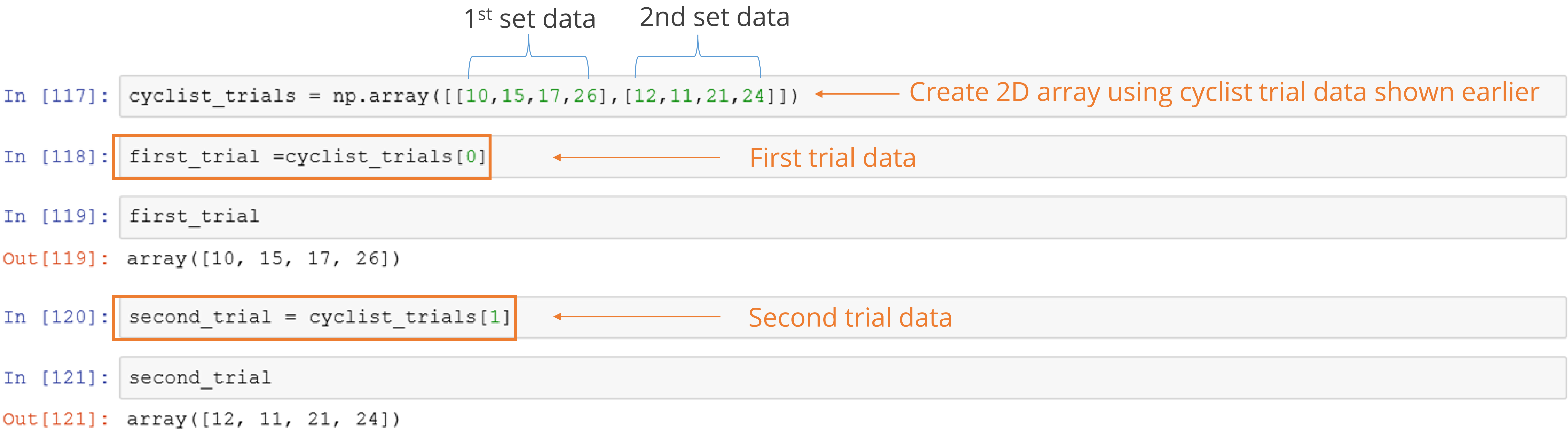
NumPy array of random values

Minimum and maximum value in the array

Output

Accessing Array Elements: Indexing

You can access an entire row of an array by referencing its axis index.



1st set data

2nd set data

```
In [117]: cyclist_trials = np.array([[10,15,17,26],[12,11,21,24]])

In [118]: first_trial =cyclist_trials[0]

In [119]: first_trial

Out[119]: array([10, 15, 17, 26])

In [120]: second_trial = cyclist_trials[1]

In [121]: second_trial

Out[121]: array([12, 11, 21, 24])
```

Create 2D array using cyclist trial data shown earlier

First trial data

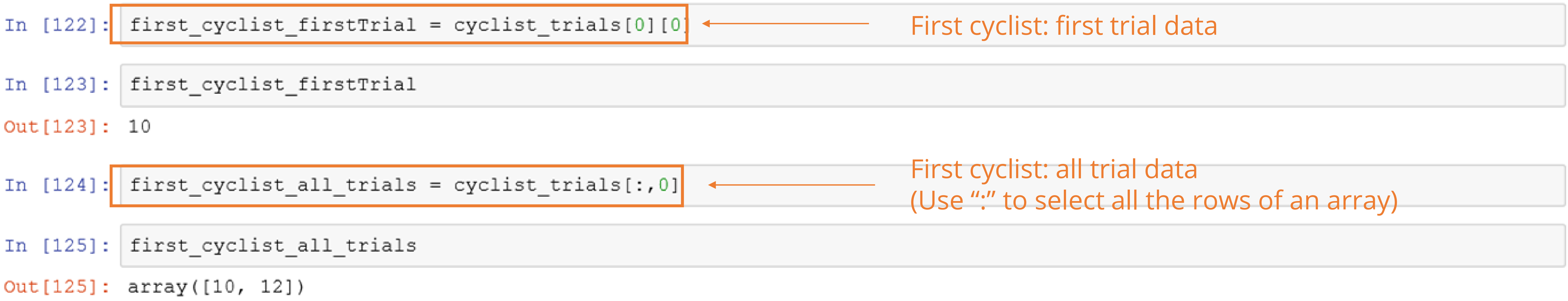
Second trial data

2D array containing cyclists' data

10	15	17	26	First trial (axis 0)
12	11	21	24	Second trial (axis 1)

Accessing Array Elements: Indexing

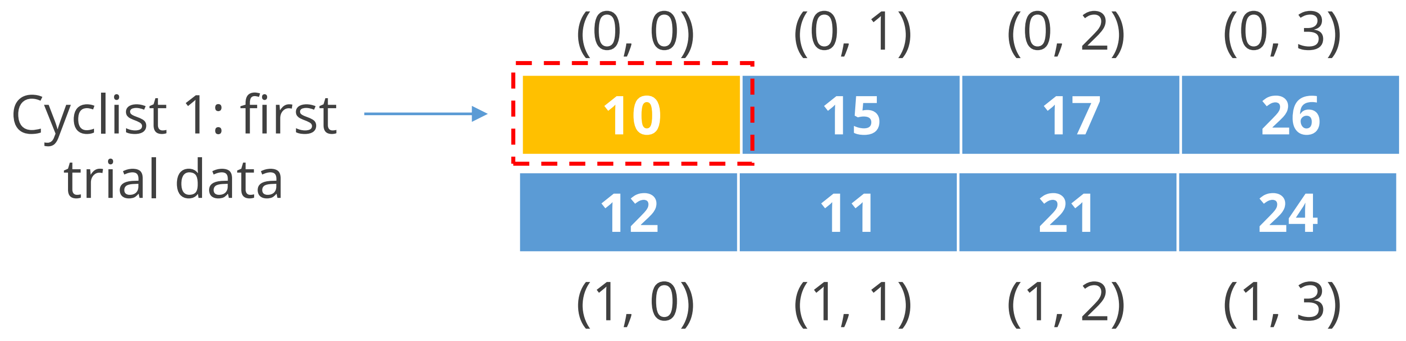
You can refer the indices of the elements in an array to access them. You can also select a particular index of more than one axis at a time.



```
In [122]: first_cyclist_firstTrial = cyclist_trials[0][0]

In [123]: first_cyclist_firstTrial

Out[123]: 10

In [124]: first_cyclist_all_trials = cyclist_trials[:,0]

In [125]: first_cyclist_all_trials

Out[125]: array([10, 12])
```

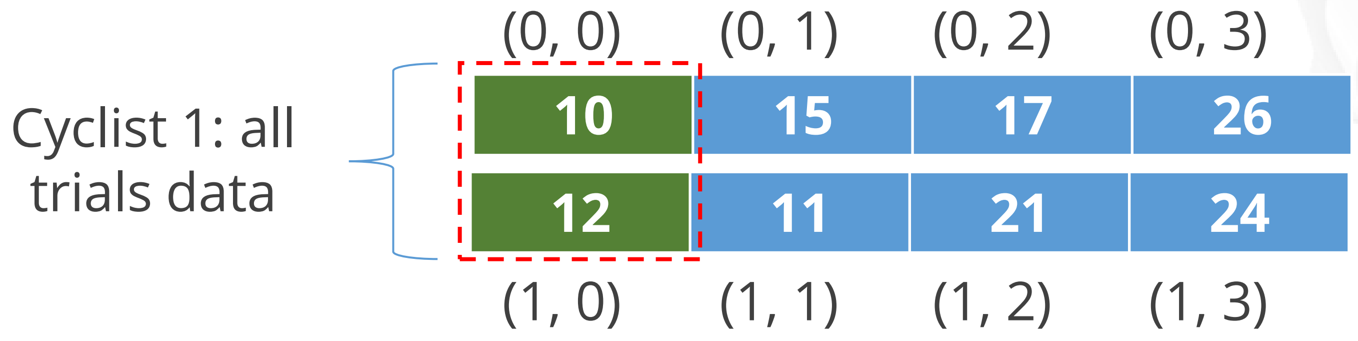
First cyclist: first trial data

First cyclist: all trial data
(Use ":" to select all the rows of an array)



Cyclist 1: first trial data

(0, 0)	(0, 1)	(0, 2)	(0, 3)
10	15	17	26
12	11	21	24
(1, 0)	(1, 1)	(1, 2)	(1, 3)



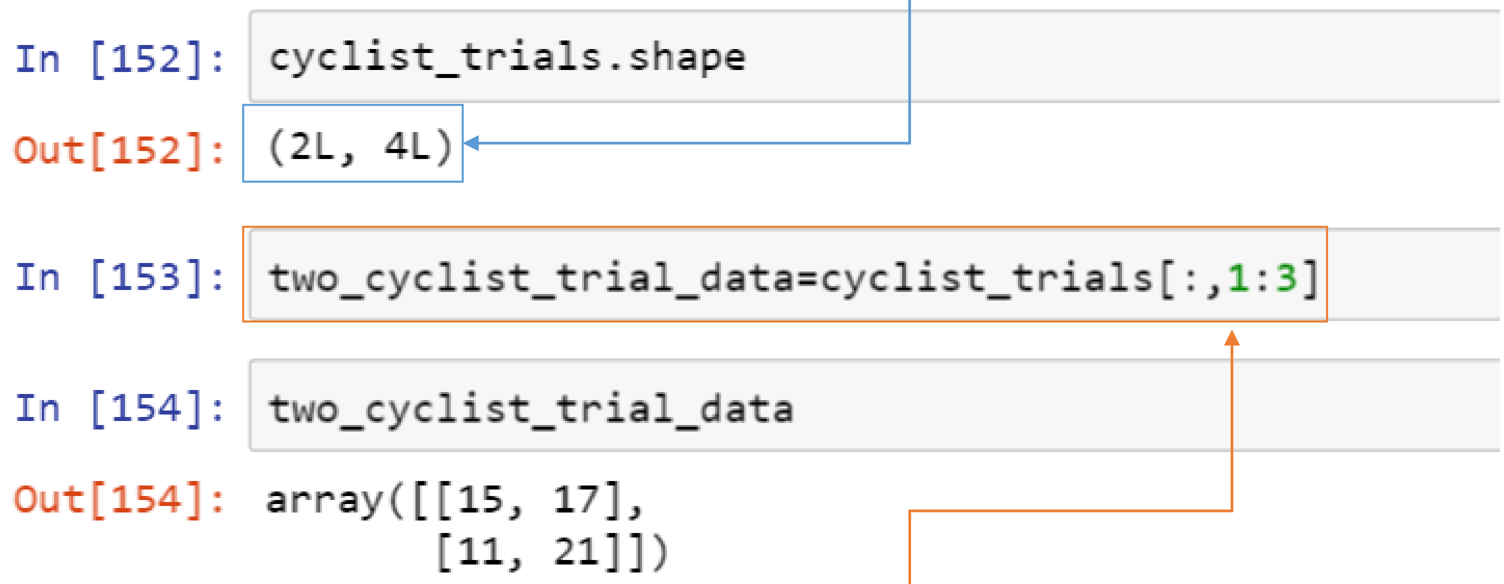
Cyclist 1: all trials data

(0, 0)	(0, 1)	(0, 2)	(0, 3)
10	15	17	26
12	11	21	24
(1, 0)	(1, 1)	(1, 2)	(1, 3)

Accessing Array Elements: Slicing

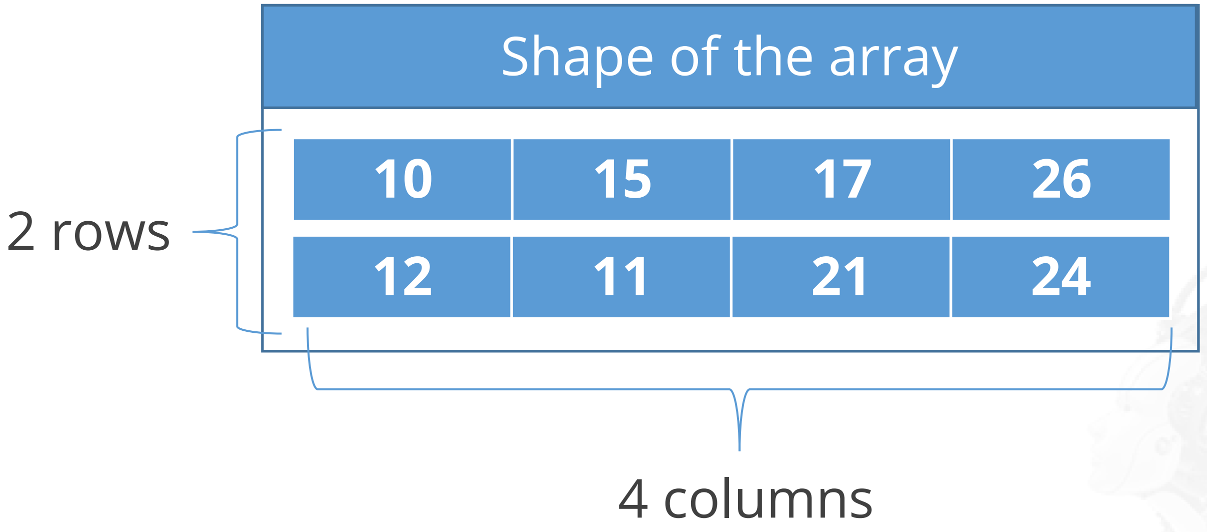
Use the slicing method to access a range of values within an array.

Shape of the array



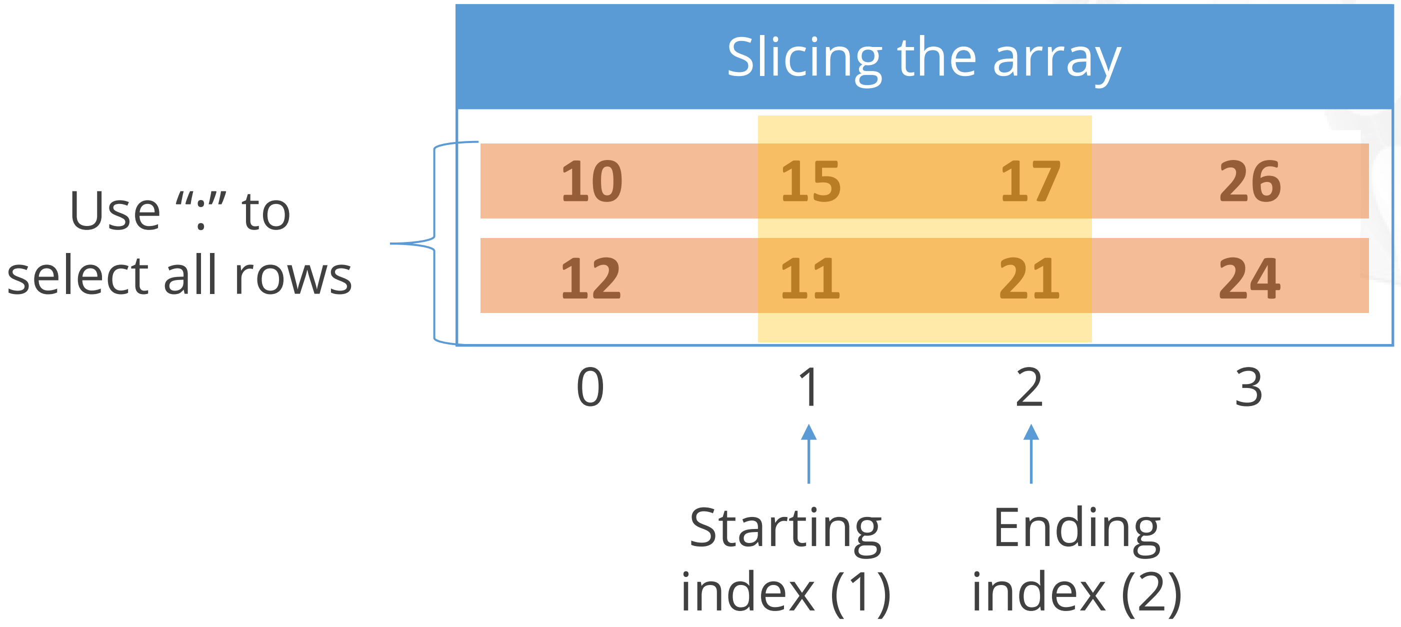
```
In [152]:  cyclist_trials.shape

Out[152]:  (2L, 4L)

In [153]:  two_cyclist_trial_data=cyclist_trials[:,1:3]

In [154]:  two_cyclist_trial_data

Out[154]:  array([[15, 17],
                  [11, 21]])
```

Slicing the array data [: , 1 : 3]
where 1 is inclusive but 3 is not



Shape of the array

10	15	17	26
12	11	21	24

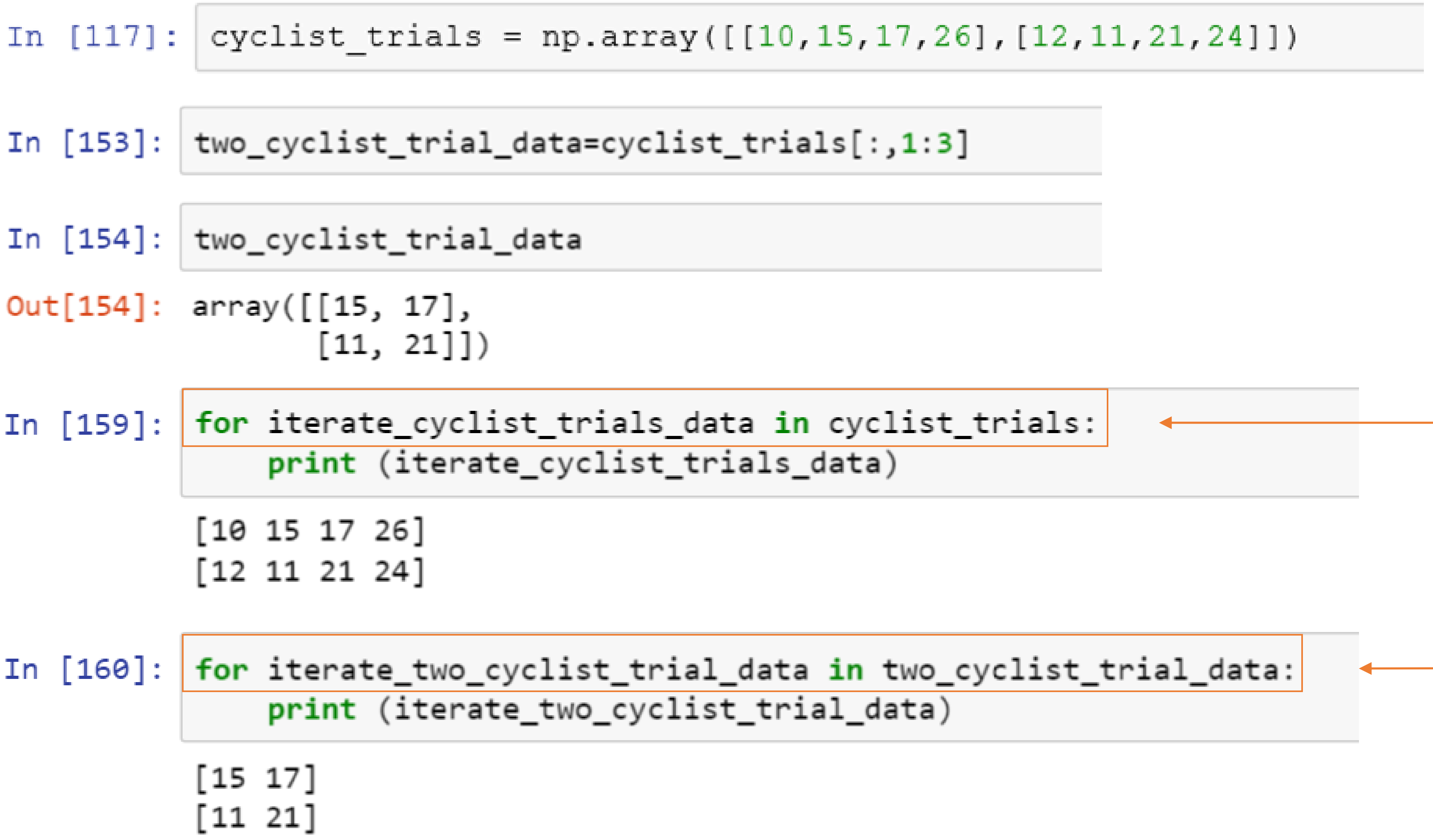


Slicing the array

0	1	2	3
10	15	17	26
12	11	21	24

Accessing Array Elements: Iteration

Use the iteration method to go through each data element present in the dataset.



```
In [117]: cyclist_trials = np.array([[10,15,17,26],[12,11,21,24]])

In [153]: two_cyclist_trial_data=cyclist_trials[:,1:3]

In [154]: two_cyclist_trial_data

Out[154]: array([[15, 17],
                 [11, 21]])

In [159]: for iterate_cyclist_trials_data in cyclist_trials:
              print (iterate_cyclist_trials_data)

          [10 15 17 26]
          [12 11 21 24]

In [160]: for iterate_two_cyclist_trial_data in two_cyclist_trial_data:
              print (iterate_two_cyclist_trial_data)

          [15 17]
          [11 21]
```

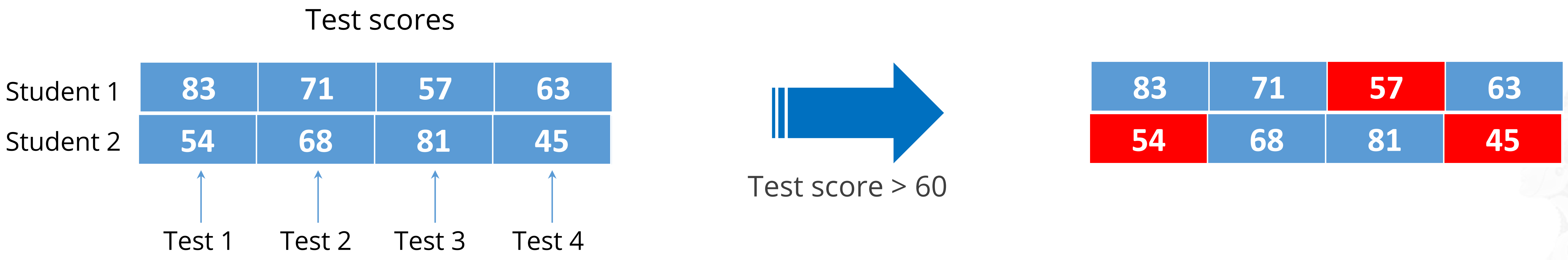
Iterate with “for loop” through the entire dataset

Iterate with “for loop” through the “two cyclist” datasets

Indexing With Boolean Arrays

Boolean arrays are useful when you need to select a dataset according to a set criteria.

Here, the original dataset contains test scores of two students. A Boolean array is used to choose only the scores that are above a given value.

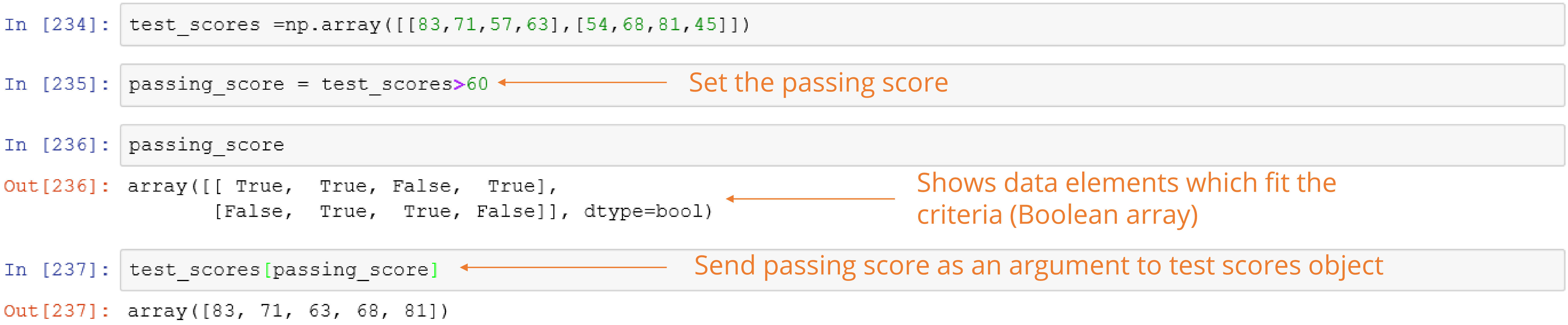


Test scores

	Test 1	Test 2	Test 3	Test 4
Student 1	83	71	57	63
Student 2	54	68	81	45

Test score > 60

83	71	57	63
54	68	81	45



```
In [234]: test_scores =np.array([[83,71,57,63],[54,68,81,45]])
```

```
In [235]: passing_score = test_scores>60
```

Set the passing score

```
In [236]: passing_score
Out[236]: array([[ True,  True, False,  True],
                 [False,  True,  True, False]], dtype=bool)
```

Shows data elements which fit the criteria (Boolean array)

```
In [237]: test_scores[passing_score]
```

Send passing score as an argument to test scores object

```
Out[237]: array([83, 71, 63, 68, 81])
```

Copy and Views

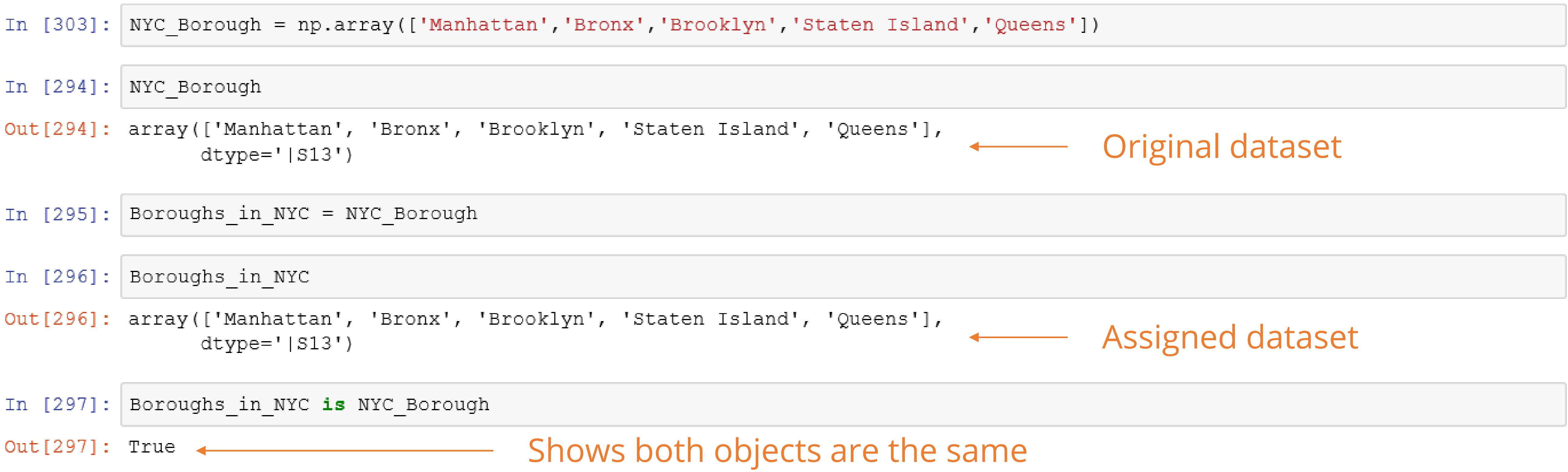
When working with arrays, data is copied into new arrays only in some cases.
Following are the three possible scenarios:

Simple Assignments

View or Shallow Copy

Deep Copy

In this method, a variable is directly assigned the value of another variable. No new copy is made.



```
In [303]: NYC_Borough = np.array(['Manhattan','Bronx','Brooklyn','Staten Island','Queens'])

In [294]: NYC_Borough

Out[294]: array(['Manhattan', 'Bronx', 'Brooklyn', 'Staten Island', 'Queens'],
                dtype='|S13')

In [295]: Boroughs_in_NYC = NYC_Borough

In [296]: Boroughs_in_NYC

Out[296]: array(['Manhattan', 'Bronx', 'Brooklyn', 'Staten Island', 'Queens'],
                dtype='|S13')

In [297]: Boroughs_in_NYC is NYC_Borough

Out[297]: True
```

Original dataset

Assigned dataset

Shows both objects are the same

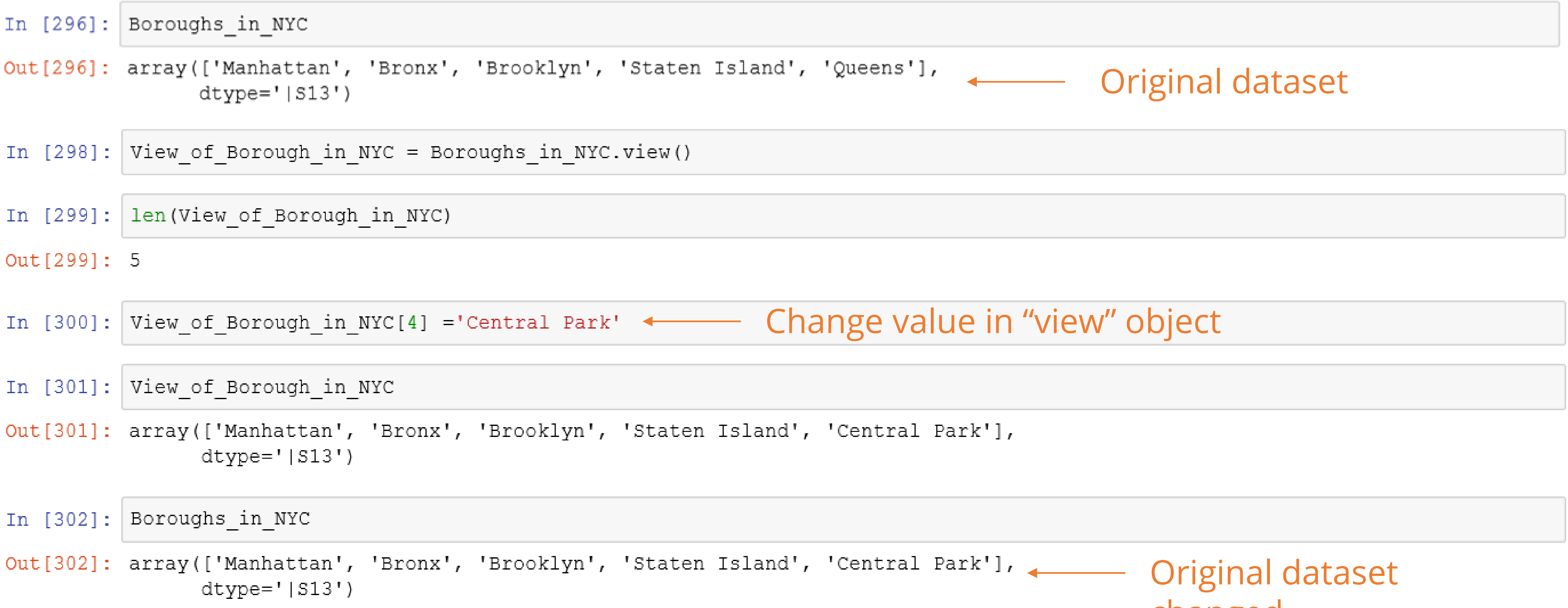
Copy and Views

Simple Assignments

View or Shallow Copy

Deep Copy

A view, also referred to as a shallow copy, creates a new array object.



```
In [296]: Boroughs_in_NYC

Out[296]: array(['Manhattan', 'Bronx', 'Brooklyn', 'Staten Island', 'Queens'],
                dtype='|S13')

In [298]: View_of_Borough_in_NYC = Boroughs_in_NYC.view()

In [299]: len(View_of_Borough_in_NYC)

Out[299]: 5

In [300]: View_of_Borough_in_NYC[4] ='Central Park'

In [301]: View_of_Borough_in_NYC

Out[301]: array(['Manhattan', 'Bronx', 'Brooklyn', 'Staten Island', 'Central Park'],
                dtype='|S13')

In [302]: Boroughs_in_NYC

Out[302]: array(['Manhattan', 'Bronx', 'Brooklyn', 'Staten Island', 'Central Park'],
                dtype='|S13')
```

Original dataset

Change value in “view” object

Original dataset changed

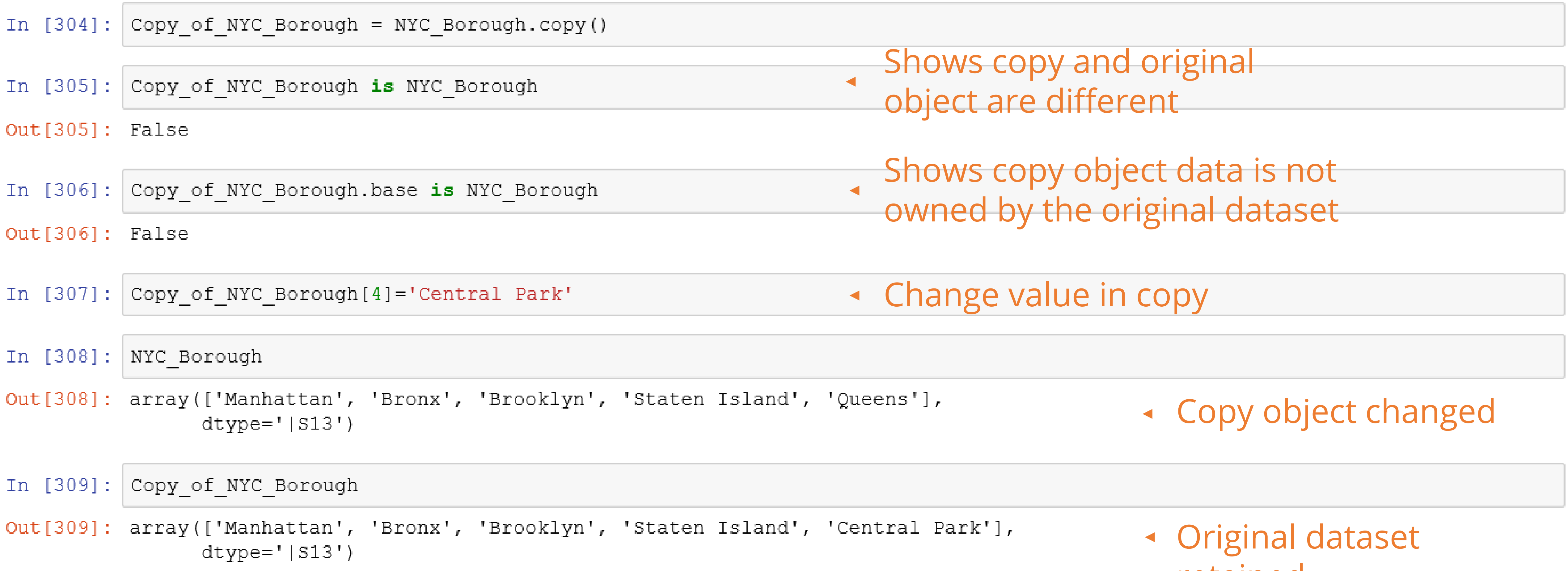
Copy and Views

Simple Assignments

View or Shallow Copy

Deep Copy

Copy is also called deep copy because it entirely copies the original dataset. Any change in the copy will not affect the original dataset.



```
In [304]: Copy_of_NYC_Borough = NYC_Borough.copy()

In [305]: Copy_of_NYC_Borough is NYC_Borough
Out[305]: False

In [306]: Copy_of_NYC_Borough.base is NYC_Borough
Out[306]: False

In [307]: Copy_of_NYC_Borough[4]='Central Park'

In [308]: NYC_Borough
Out[308]: array(['Manhattan', 'Bronx', 'Brooklyn', 'Staten Island', 'Queens'],
                dtype='|S13')

In [309]: Copy_of_NYC_Borough
Out[309]: array(['Manhattan', 'Bronx', 'Brooklyn', 'Staten Island', 'Central Park'],
                dtype='|S13')
```

Shows copy and original object are different

Shows copy object data is not owned by the original dataset

Change value in copy

Copy object changed

Original dataset retained

Demonstrate the Use of Copy and Views

Objective: Demonstrate how the following copies and views are generated from a memory location:

- Simple Assignment

- View or Shallow Copy

- Deep Copy

Access: To execute the practice, follow these steps:

- Go to the **PRACTICE LABS** tab on your LMS
- Click the **START LAB** button
- Click the **LAUNCH LAB** button to start the lab

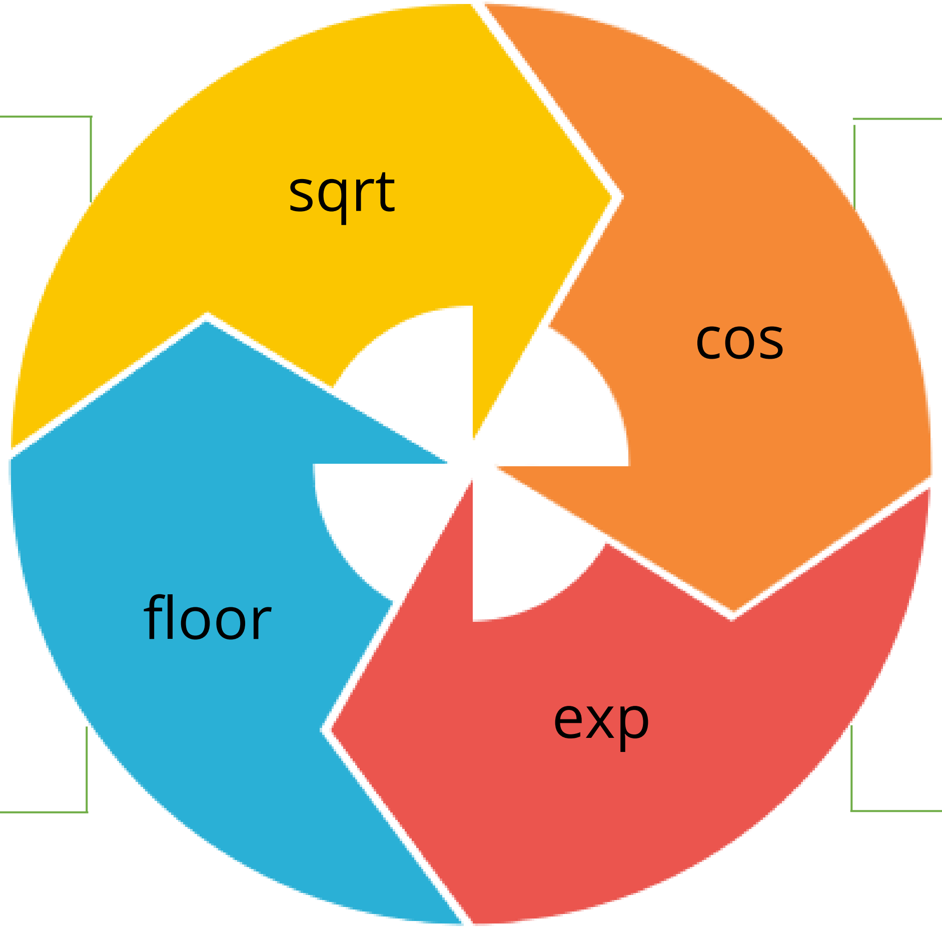
ASSISTED PRACTICE

Universal Functions (ufunc)

NumPy provides useful mathematical functions called universal functions. These functions operate element-wise on an array, producing another array as output. Some of these functions are:

sqrt function provides the square root of every element in the array.

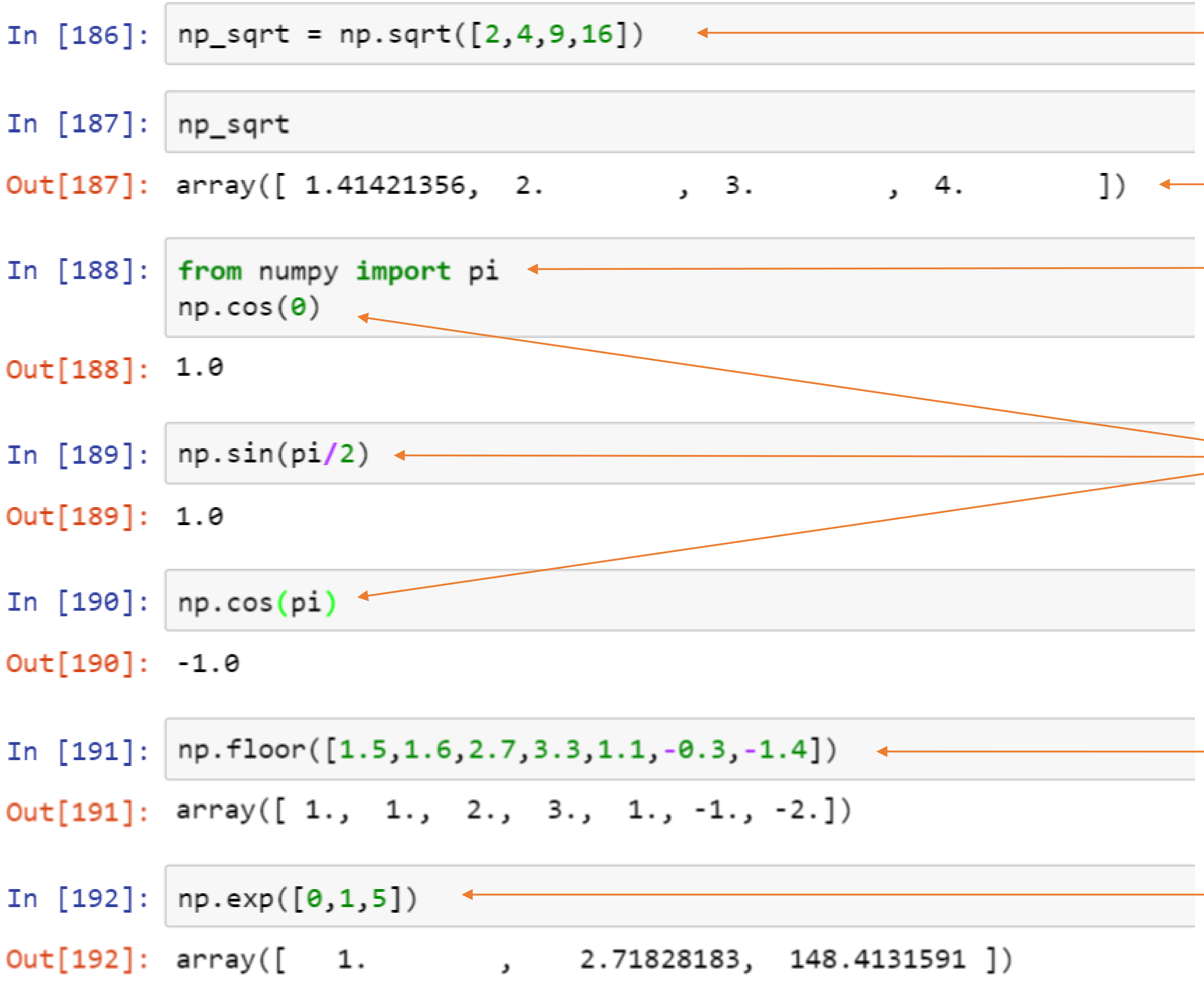
cos function gives cosine values for all elements in the array.



floor function returns the largest integer value of every element in the array.

exp function performs exponentiation on every element in the array.

ufunc: Examples



```
In [186]:  np_sqrt = np.sqrt([2,4,9,16])

In [187]:  np_sqrt

Out[187]:  array([ 1.41421356,  2.        ,  3.        ,  4.        ])

In [188]:  from numpy import pi
           np.cos(0)

Out[188]:  1.0

In [189]:  np.sin(pi/2)

Out[189]:  1.0

In [190]:  np.cos(pi)

Out[190]:  -1.0

In [191]:  np.floor([1.5,1.6,2.7,3.3,1.1,-0.3,-1.4])

Out[191]:  array([ 1.,  1.,  2.,  3.,  1., -1., -2.])

In [192]:  np.exp([0,1,5])

Out[192]:  array([   1.        ,    2.71828183,  148.4131591 ])
```

Numbers for which square root will be calculated

Square root values

Import pi*

Trigonometric functions

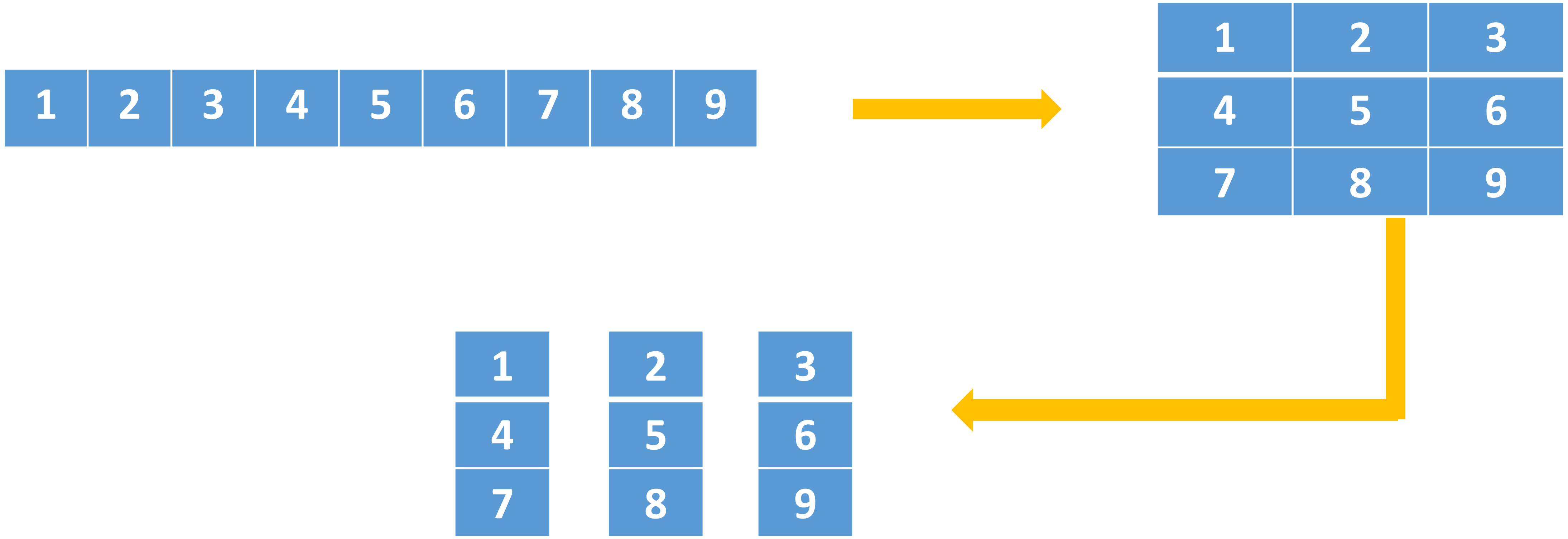
Return the floor of the input element-wise

Exponential functions for complex mathematical calculations

Shape Manipulation

You can use certain functions to manipulate the shape of an array.

The shape of an array can be changed according to the requirement using the NumPy library functions.



1	2	3	4	5	6	7	8	9

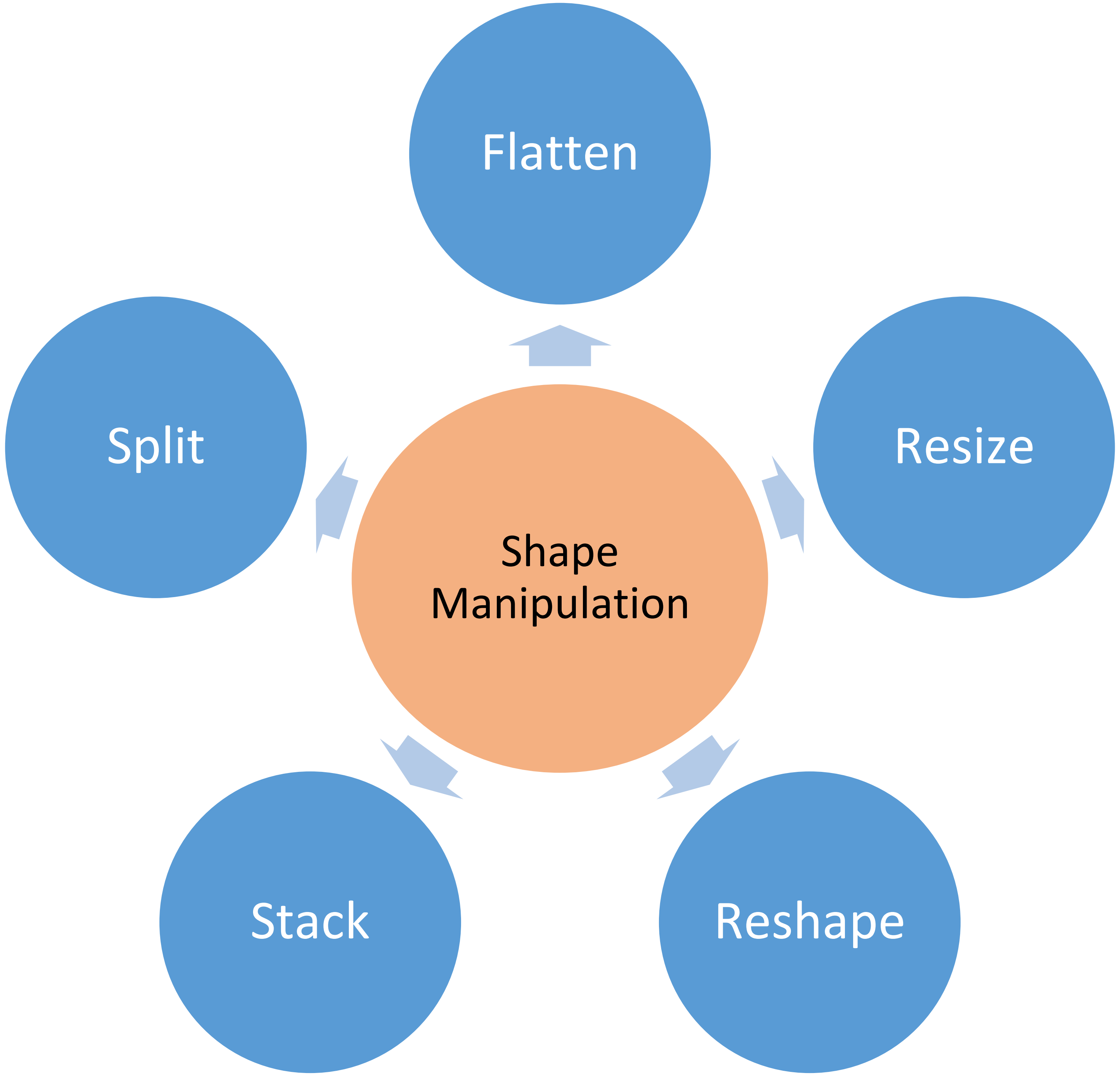
1	2	3
4	5	6
7	8	9

1	2	3
4	5	6
7	8	9

Array shape manipulation methods → Data Wrangling

Shape Manipulation

Some common methods for manipulating shapes are:



Manipulate the Shape of an Array

Objective: Use common manipulation functions like ravel, reshape, resize, hsplit, and hstack to manipulate the shape of a NumPy array.

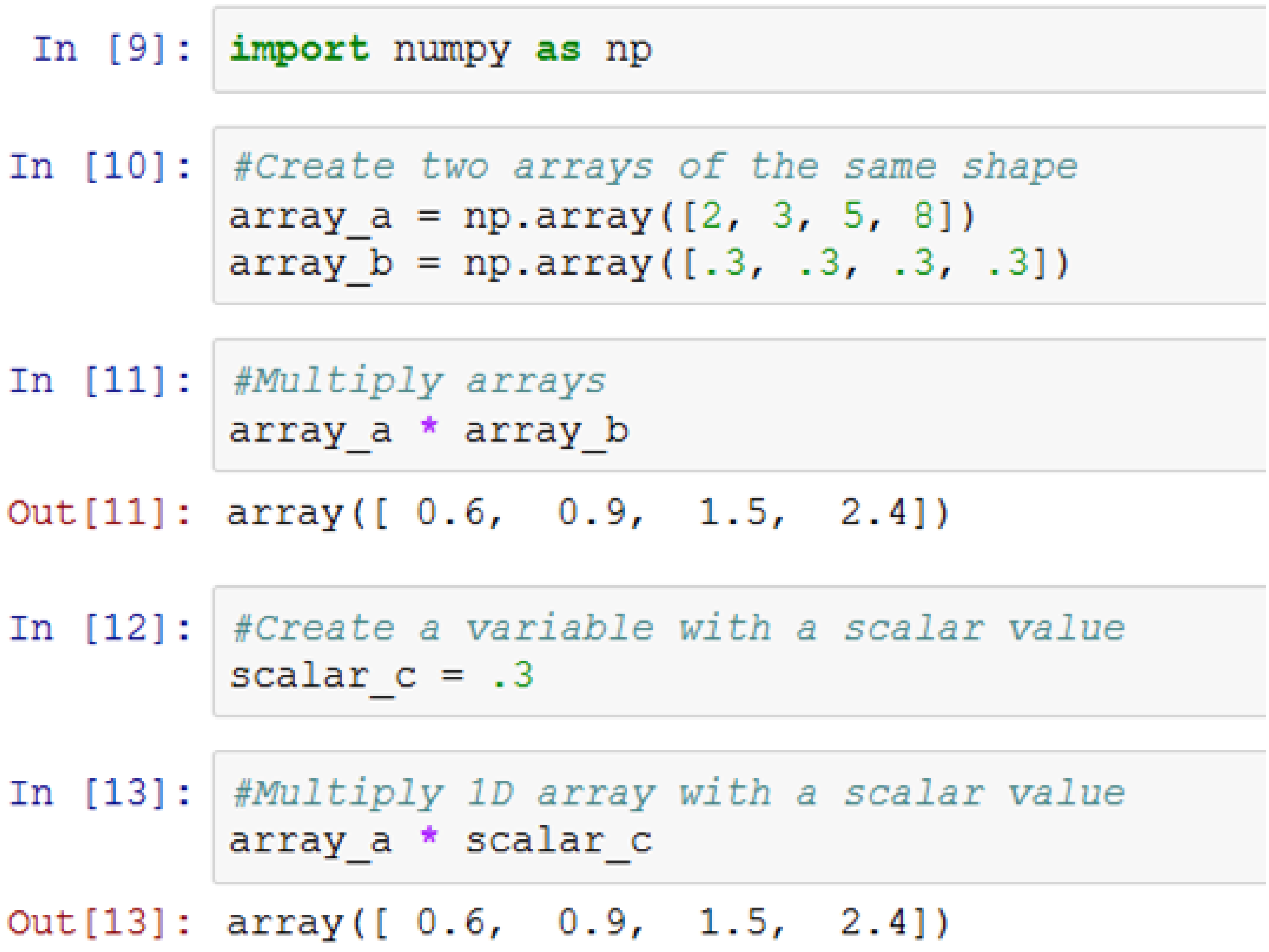
Access: To execute the practice, follow these steps:

- Go to the **PRACTICE LABS** tab on your LMS
- Click the **START LAB** button
- Click the **LAUNCH LAB** button to start the lab

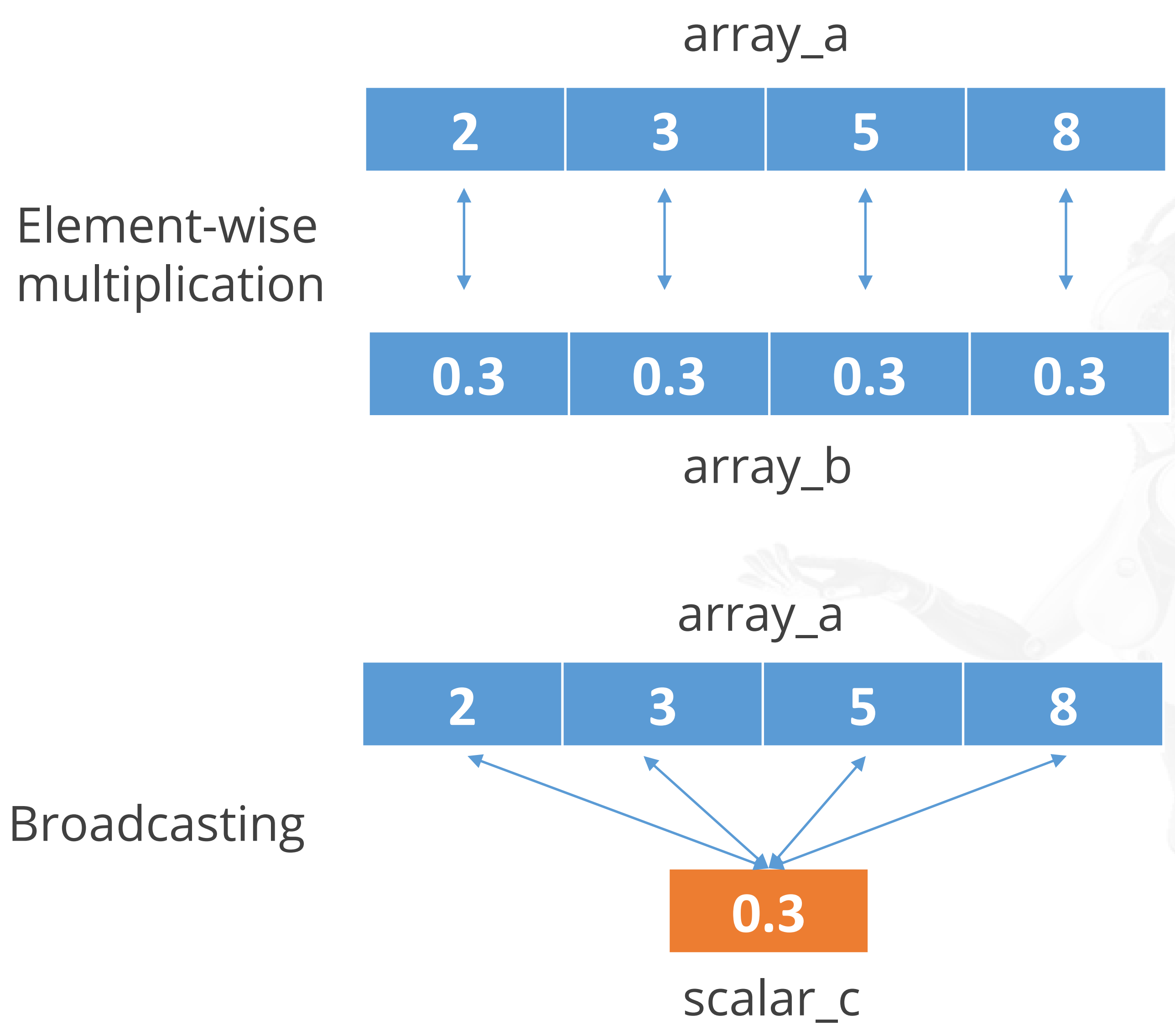
ASSISTED PRACTICE

Broadcasting

NumPy uses broadcasting to carry out arithmetic operations between arrays of different shapes. In this method, NumPy automatically broadcasts the smaller array over the larger array.



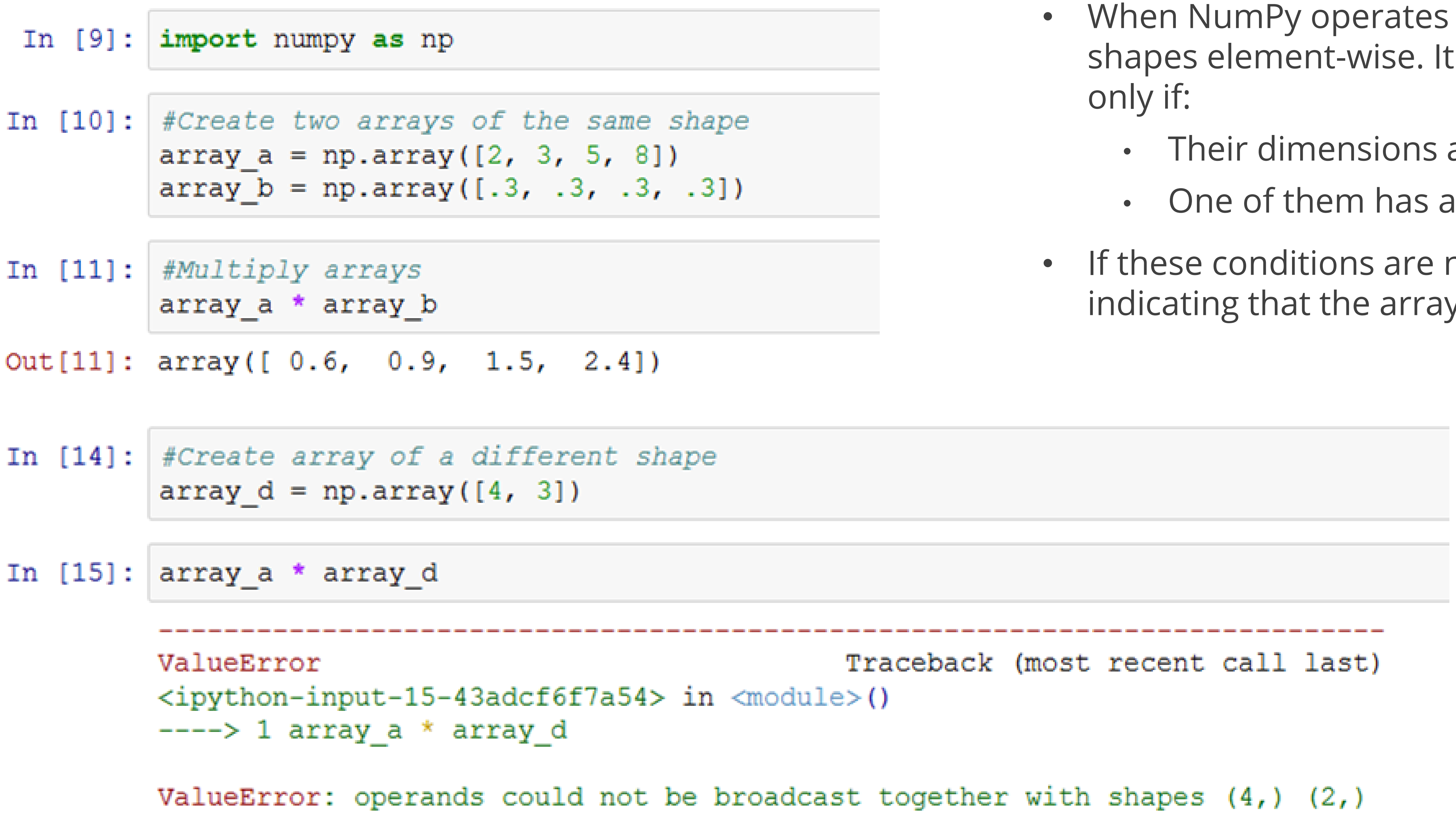
```
In [9]:  import numpy as np

In [10]: #Create two arrays of the same shape
         array_a = np.array([2, 3, 5, 8])
         array_b = np.array([.3, .3, .3, .3])

In [11]: #Multiply arrays
         array_a * array_b

Out[11]: array([ 0.6,  0.9,  1.5,  2.4])

In [12]: #Create a variable with a scalar value
         scalar_c = .3

In [13]: #Multiply 1D array with a scalar value
         array_a * scalar_c

Out[13]: array([ 0.6,  0.9,  1.5,  2.4])
```



If the shape doesn't match with array_a, NumPy doesn't have to create copies of scalar values. Instead, broadcast scalar value over the entire array to find the product.

Broadcasting: Constraints

Though broadcasting can help carry out mathematical operations between different-shaped arrays, they are subject to certain constraints as listed below:

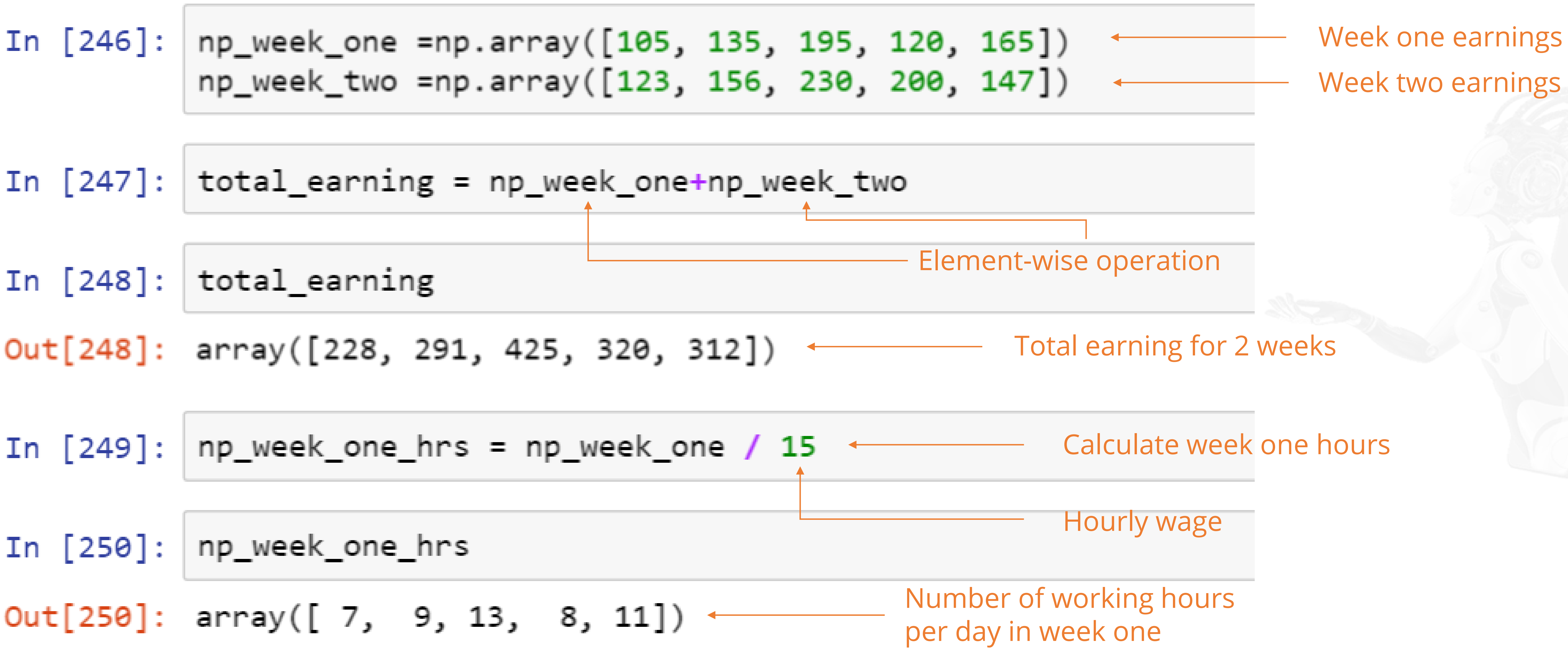


```
 In [9]: import numpy as np

In [10]: #Create two arrays of the same shape
         array_a = np.array([2, 3, 5, 8])
         array_b = np.array([.3, .3, .3, .3])

In [11]: #Multiply arrays
         array_a * array_b

Out[11]: array([ 0.6,  0.9,  1.5,  2.4])

In [14]: #Create array of a different shape
         array_d = np.array([4, 3])

In [15]: array_a * array_d

         ---------------------------------------------------------------------------
         ValueError                                Traceback (most recent call last)
         <ipython-input-15-43adcf6f7a54> in <module>()
         ----> 1 array_a * array_d

         ValueError: operands could not be broadcast together with shapes (4,) (2,)
```

- When NumPy operates on two arrays, it compares their shapes element-wise. It finds these shapes compatible only if:
  - Their dimensions are the same or
  - One of them has a dimension of size 1
- If these conditions are not met, a ValueError is thrown, indicating that the arrays have incompatible shapes.

Broadcasting: Example

Let’s look at an example to see how broadcasting works to calculate the number of working hours of a worker per day in a certain week.



```
In [246]: np_week_one =np.array([105, 135, 195, 120, 165])
          np_week_two =np.array([123, 156, 230, 200, 147])

In [247]: total_earning = np_week_one+np_week_two

In [248]: total_earning

Out[248]: array([228, 291, 425, 320, 312])

In [249]: np_week_one_hrs = np_week_one / 15

In [250]: np_week_one_hrs

Out[250]: array([ 7,  9, 13,  8, 11])
```

Week one earnings

Week two earnings

Element-wise operation

Total earning for 2 weeks

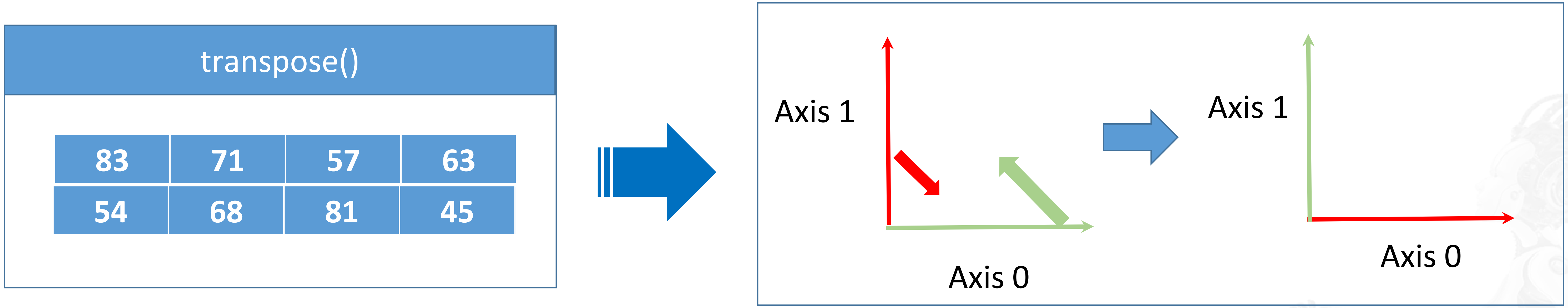
Calculate week one hours

Hourly wage

Number of working hours per day in week one

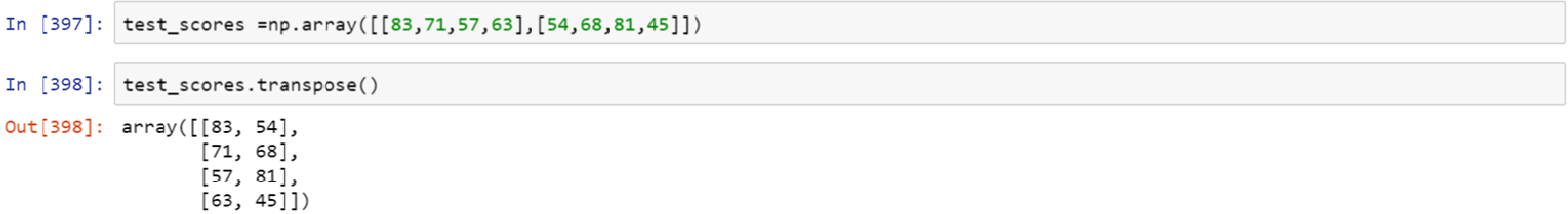
Linear Algebra: Transpose

NumPy can carry out linear algebraic functions as well. The transpose() function can help you interchange rows as columns, and vice-versa.



transpose()

83	71	57	63
54	68	81	45

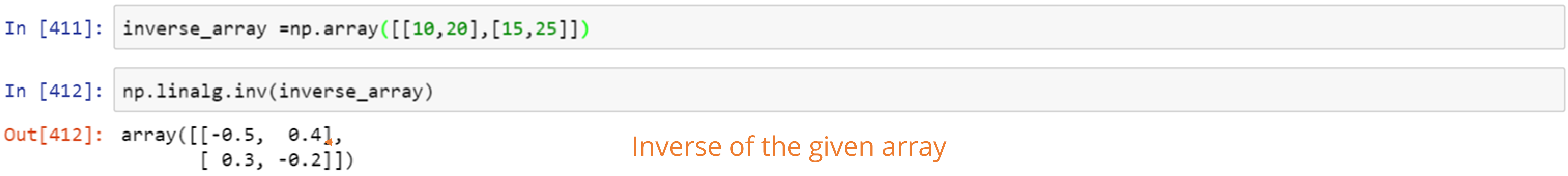


```
In [397]:  test_scores =np.array([[83,71,57,63],[54,68,81,45]])

In [398]:  test_scores.transpose()

Out[398]:  array([[83, 54],
                  [71, 68],
                  [57, 81],
                  [63, 45]])
```

Linear Algebra: Inverse and Trace Functions

Using NumPy, you can also find the inverse of an array and add its diagonal data elements.

np.linalg.inv()

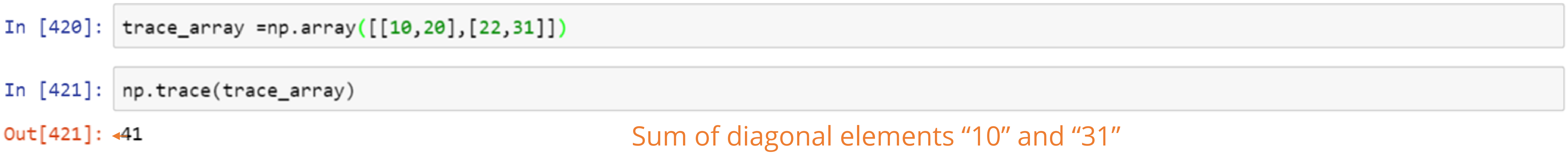


```
In [411]: inverse_array =np.array([[10,20],[15,25]])

In [412]: np.linalg.inv(inverse_array)

Out[412]: array([[-0.5,  0.4],
                 [ 0.3, -0.2]])
```

Inverse of the given array

* Can be applied **only** on a square matrix

np.trace()



```
In [420]: trace_array =np.array([[10,20],[22,31]])

In [421]: np.trace(trace_array)

Out[421]: 41
```

Sum of diagonal elements “10” and “31”

Key Takeaways

You are now able to:

- Explain NumPy and its importance
- Discuss the basics of NumPy, including its fundamental objects
- Demonstrate how to create and print a NumPy array
- Analyze and perform basic operations in NumPy
- Utilize shape manipulation and copying methods
- Demonstrate how to execute linear algebraic functions
- Build basic programs using NumPy

Knowledge Check

Knowledge Check

1

Which of the following arrays is valid?

a. [1, 0.3, 8, 6.4]

b. [“Lucy”, 16, “Susan”, 23, “Carrie”, 37]

c. [True, False, “False”, True]

d. [3.14j, 7.3j, 5.1j, 2j]

Knowledge Check

1

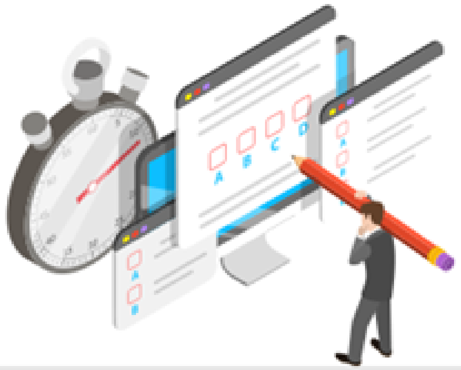
Which of the following arrays is valid?

a. [1, 0.3, 8, 6.4]

b. [“Lucy”, 16, “Susan”, 23, “Carrie”, 37]

c. [True, False, “False”, True]

d. [3.14j, 7.3j, 5.1j, 2j]



The correct answer is **d**

A NumPy ndarray can hold only a single data type, which makes it homogenous. NumPy supports integers, floats, Booleans, and even complex numbers. Of all the options provided, only the array containing complex numbers is homogenous. All the other options contain more than one data type.

Knowledge Check

2

Which function is most useful to convert a multidimensional array into a one-dimensional array?

a. ravel()

b. reshape()

c. resize() and reshape()

d. All of the above

Knowledge Check

2

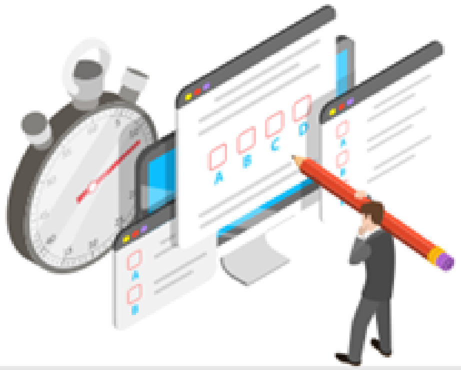
Which function is most useful to convert a multidimensional array into a one-dimensional array?

a. ravel()

b. reshape()

c. resize() and reshape()

d. All of the above



The correct answer is **a**

The function ravel() is used to convert a multidimensional array into a one-dimensional array. Though reshape() also functions in a similar way, it creates a new array instead of transforming the input array.

Knowledge Check

3

The np.trace() method gives the sum of _____.

a. the entire array

b. the diagonal elements from left to right

c. the diagonal elements from right to left

d. consecutive rows of an array

Knowledge Check

3

The np.trace() method gives the sum of _____.

a. the entire array

b. the diagonal elements from left to right

c. the diagonal elements from right to left

d. consecutive rows of an array

The correct answer is **b**

The trace() function is used to find the sum of the diagonal elements in an array. It is carried out in an incremental order of the indices. Therefore, it can only add diagonal values from left to right and not vice-versa.

Knowledge Check

4

The function np.transpose() when applied on a one-dimensional array gives _____.

a. a reverse array

b. an unchanged original array

c. an inverse array

d. all elements with zeros

Knowledge Check

4

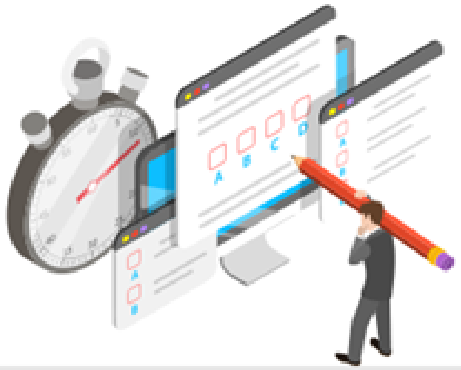
The function np.transpose() when applied on a one-dimensional array gives _____.

a. a reverse array

b. an unchanged original array

c. an inverse array

d. all elements with zeros



The correct answer is **b**

Transposing a one-dimensional array does not change it in any way. It returns an unchanged view of the original array.

Country GDP

Evaluate the dataset containing the GDPs of different countries to:

- Find and print the name of the country with the highest GDP
- Find and print the name of the country with the lowest GDP
- Print out text and input values iteratively
- Print out the entire list of the countries with their GDPs
- Print the highest GDP value, lowest GDP value, mean GDP value, standardized GDP value, and the sum of all the GDPs

Olympic 2012 Medal Tally

Evaluate the dataset of the Summer Olympics, London 2012, to:

- Find and print the name of the country that won maximum number of gold medals
- Find and print the countries who won more than 20 gold medals
- Print the medal tally
- Print each country name with the corresponding number of gold medals
- Print each country name with the total number of medals won

LESSON-END PROJECT

Thank You