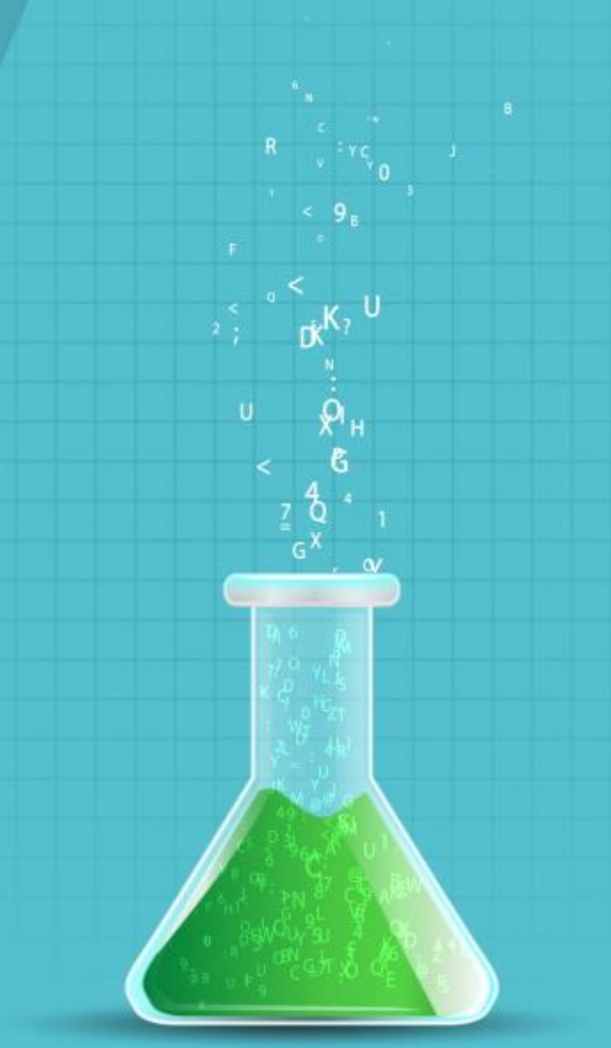
Data Science with Python

Lesson 5—Mathematical Computing with Python (NumPy)

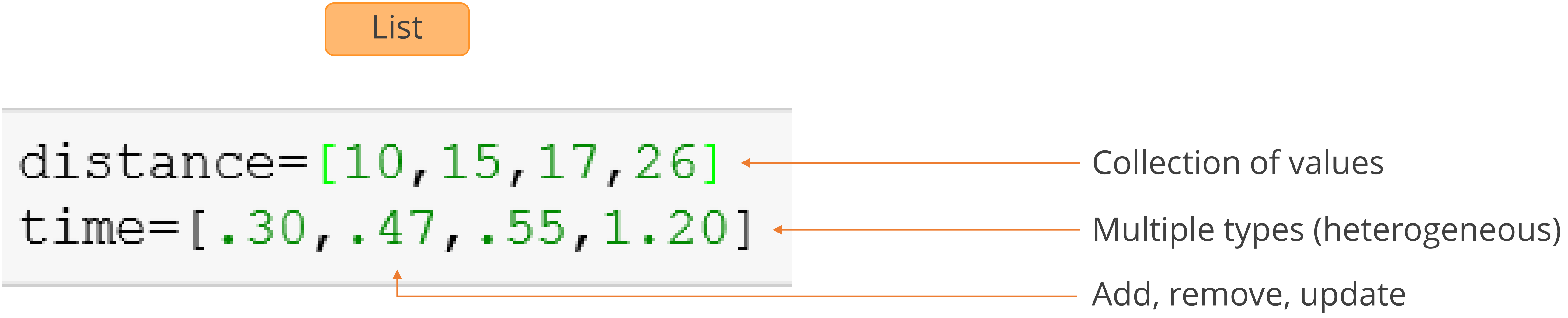
What You’ll Learn

- What NumPy is and why it is important
- Basics of NumPy, including its fundamental objects
- Create and print a NumPy array
- Carry out basic operations in NumPy
- Use shape manipulation and copying methods
- Execute linear algebraic functions
- Build basic programs using NumPy



Quick Recap: Lists

A list is a collection of values. You can individually add, remove, or update these values. A single list can contain multiple data types.



List

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

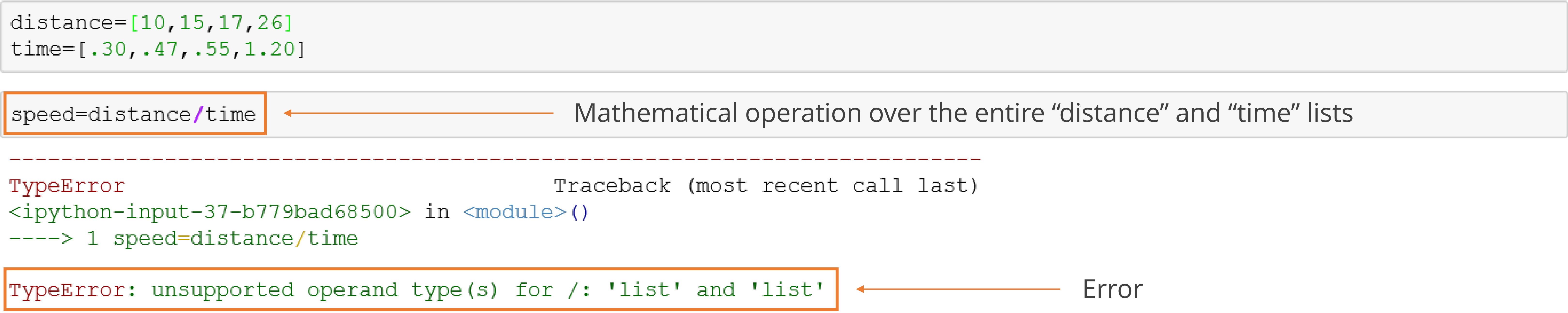
Collection of values

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
```

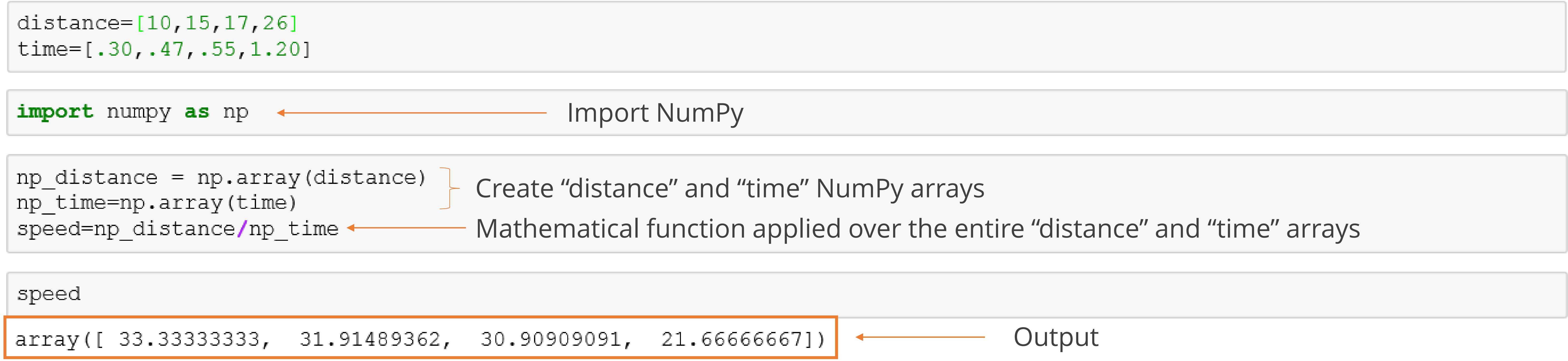
Mathematical operation over the entire “distance” and “time” lists

```
---------------------------------------------------------------------------
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.



```
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
```

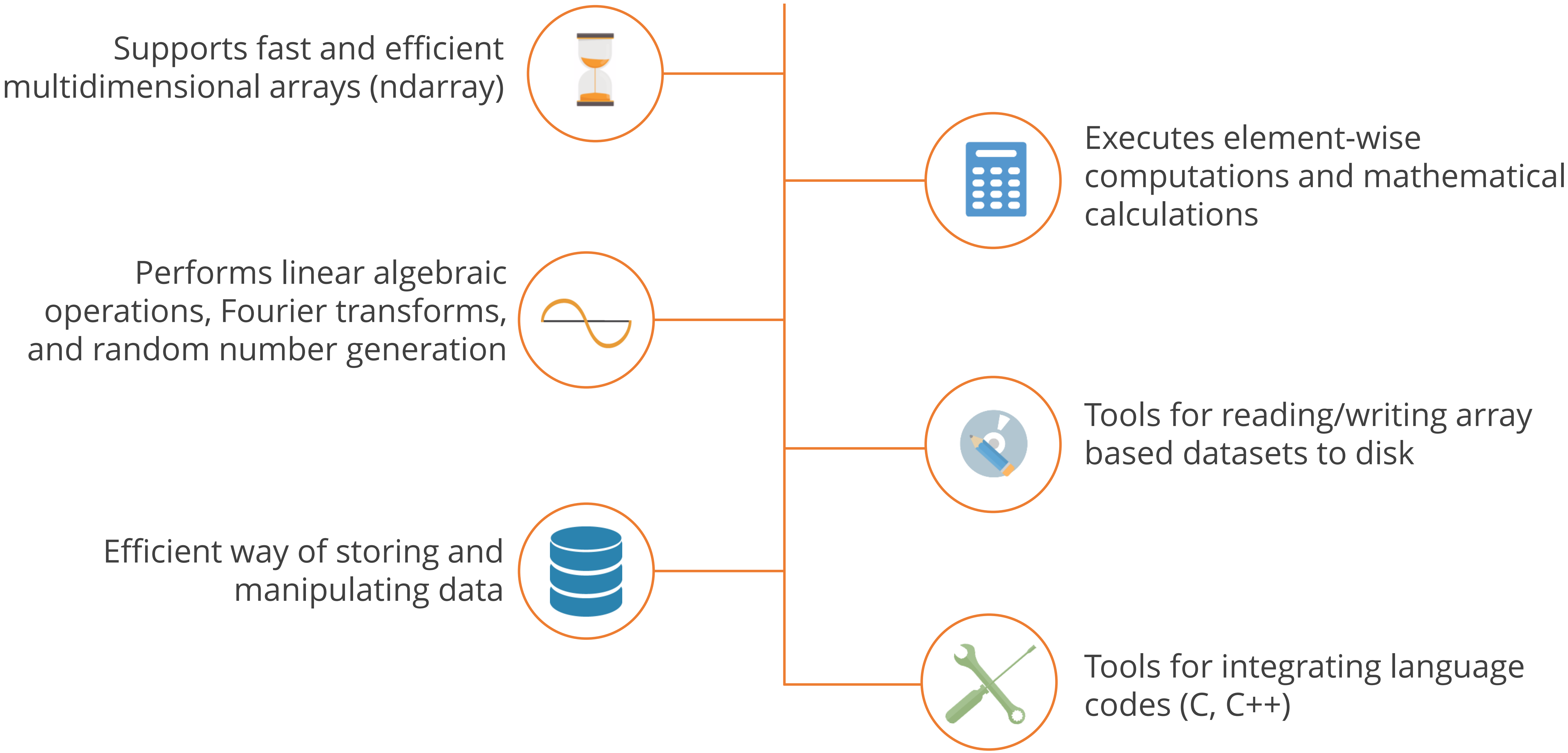
```
array([ 33.33333333,  31.91489362,  30.90909091,  21.66666667])
```

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

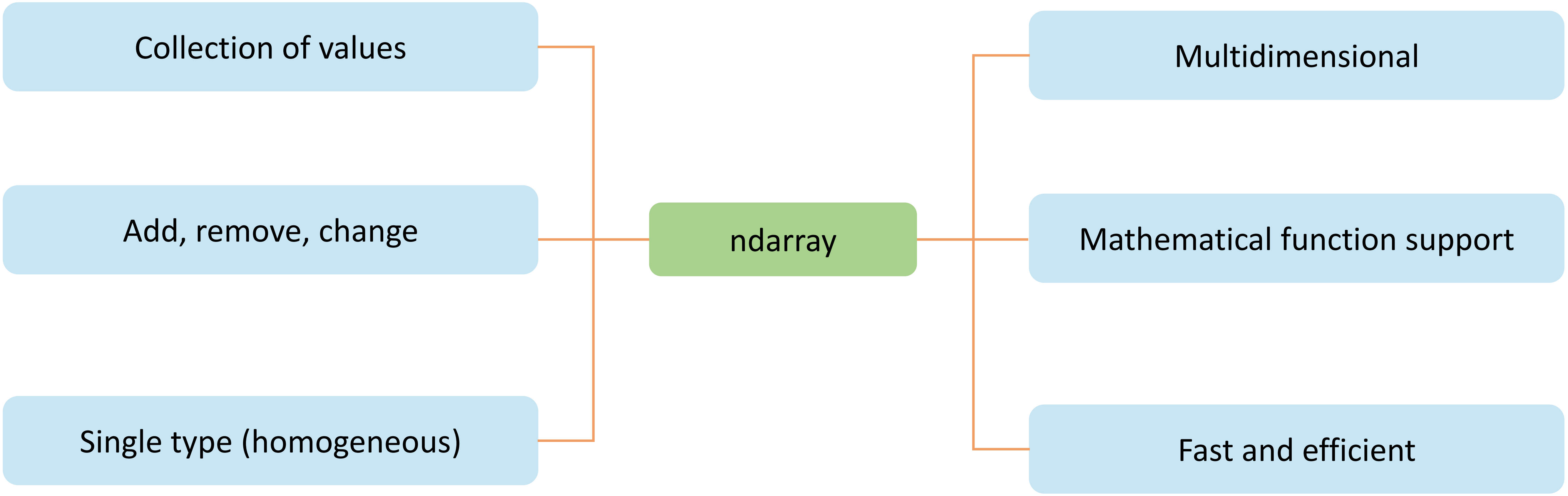
Tools for reading/writing array based datasets to disk

Efficient way of storing and manipulating data

Tools for integrating language codes (C, C++)

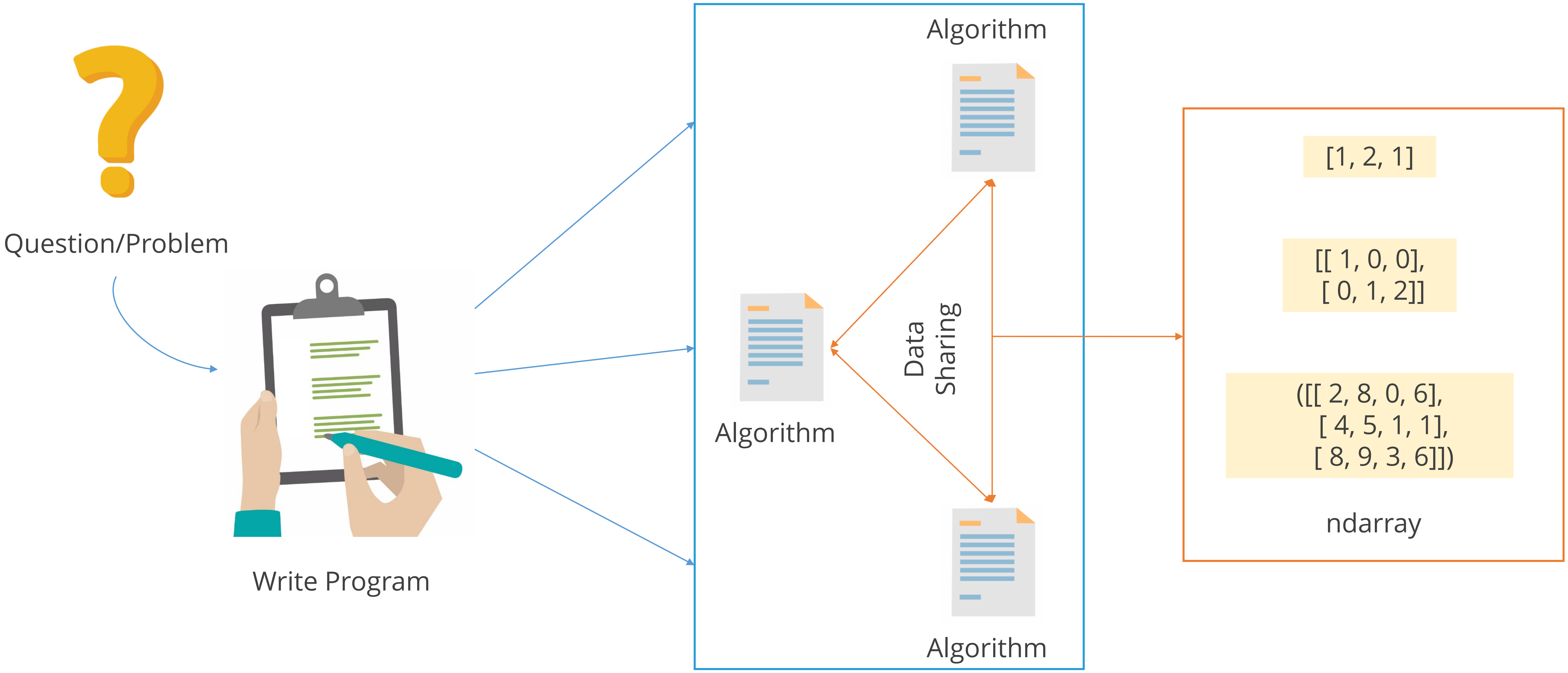
Properties of ndarray

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]]

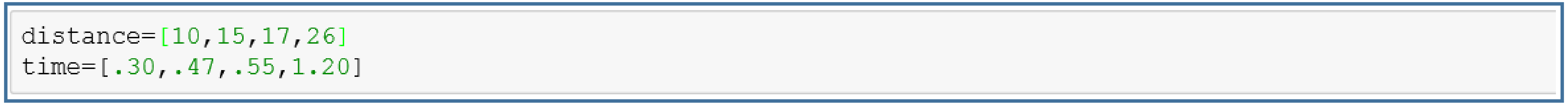
([[2, 8, 0, 6],
[4, 5, 1, 1],
[8, 9, 3, 6]])

ndarray

Knowledge Check—Sequence it Right!

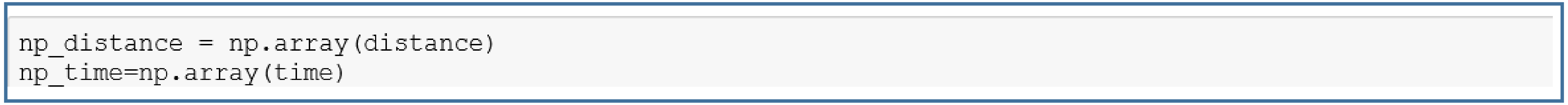
The code here is buggy. You have to correct its sequence to debug it.

1



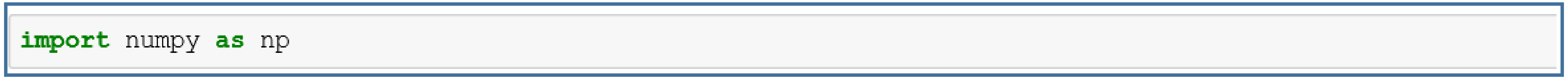
```
distance=[10,15,17,26]
time=[.30,.47,.55,1.20]
```

2



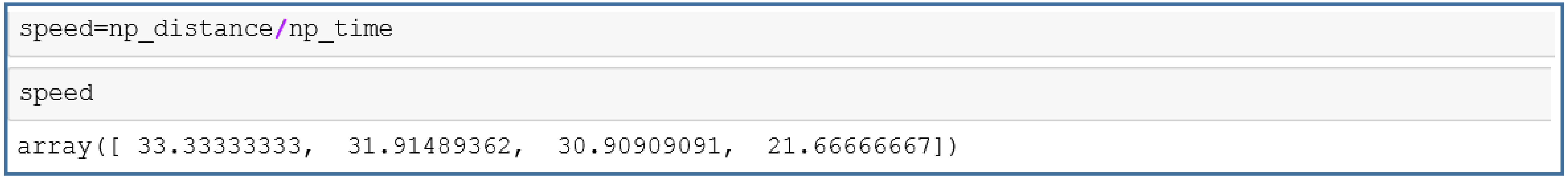
```
np_distance = np.array(distance)
np_time=np.array(time)
```

3



```
import numpy as np
```

4



```
speed=np_distance/np_time
```

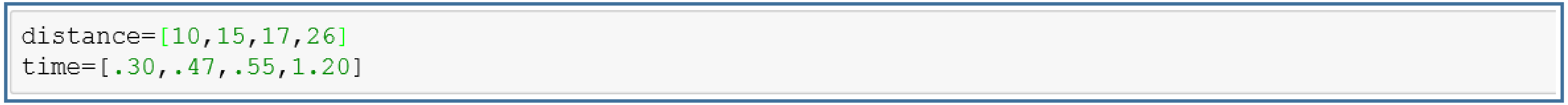
```
speed
```

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

Knowledge Check—Sequence it Right!

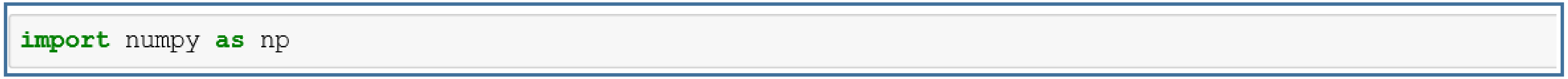
The code here is buggy. You have to correct its sequence to debug it.

1



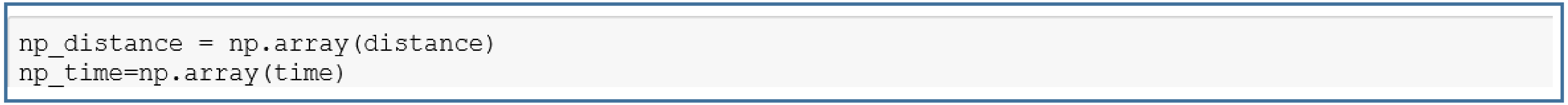
```
distance=[10,15,17,26]
time=[.30,.47,.55,1.20]
```

2



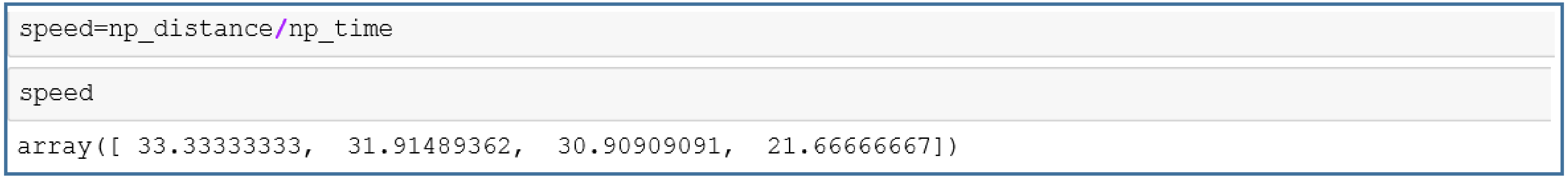
```
import numpy as np
```

3



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

4



```
speed=np_distance/np_time
```

```
speed
```

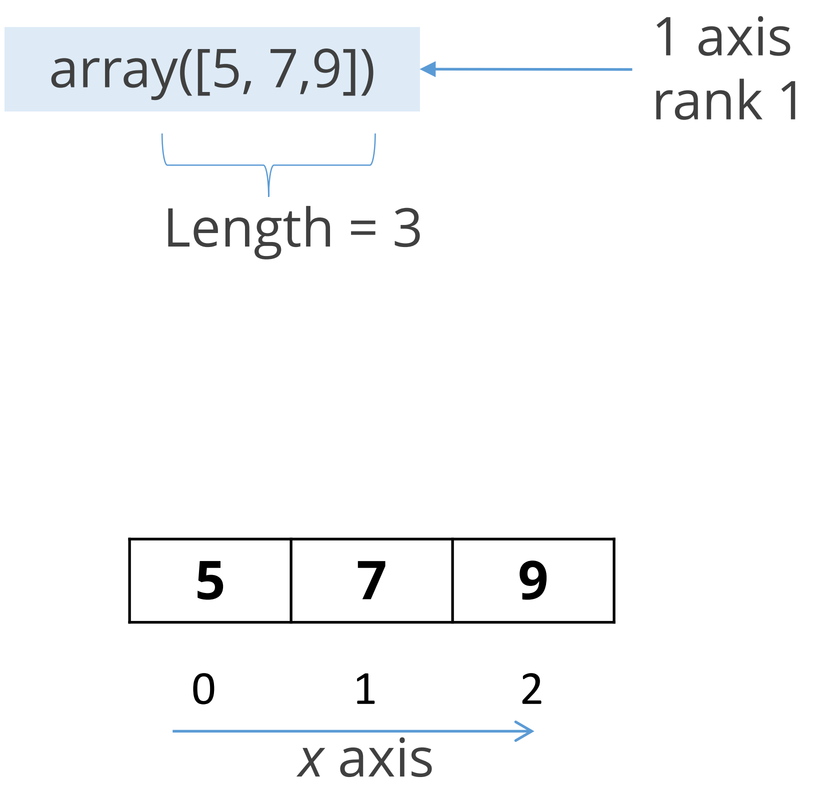
```
array([ 33.33333333,  31.91489362,  30.90909091,  21.66666667])
```

Types of Arrays

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

One-Dimensional Array

Printed as rows



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

1 axis
rank 1

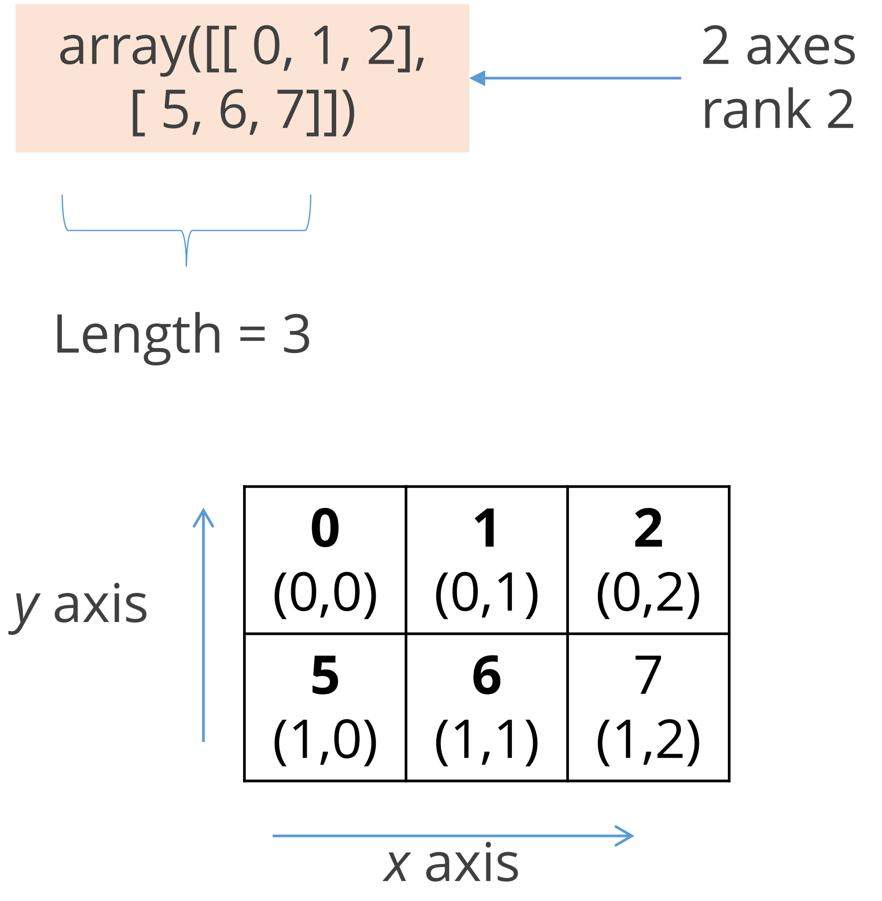
Length = 3

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

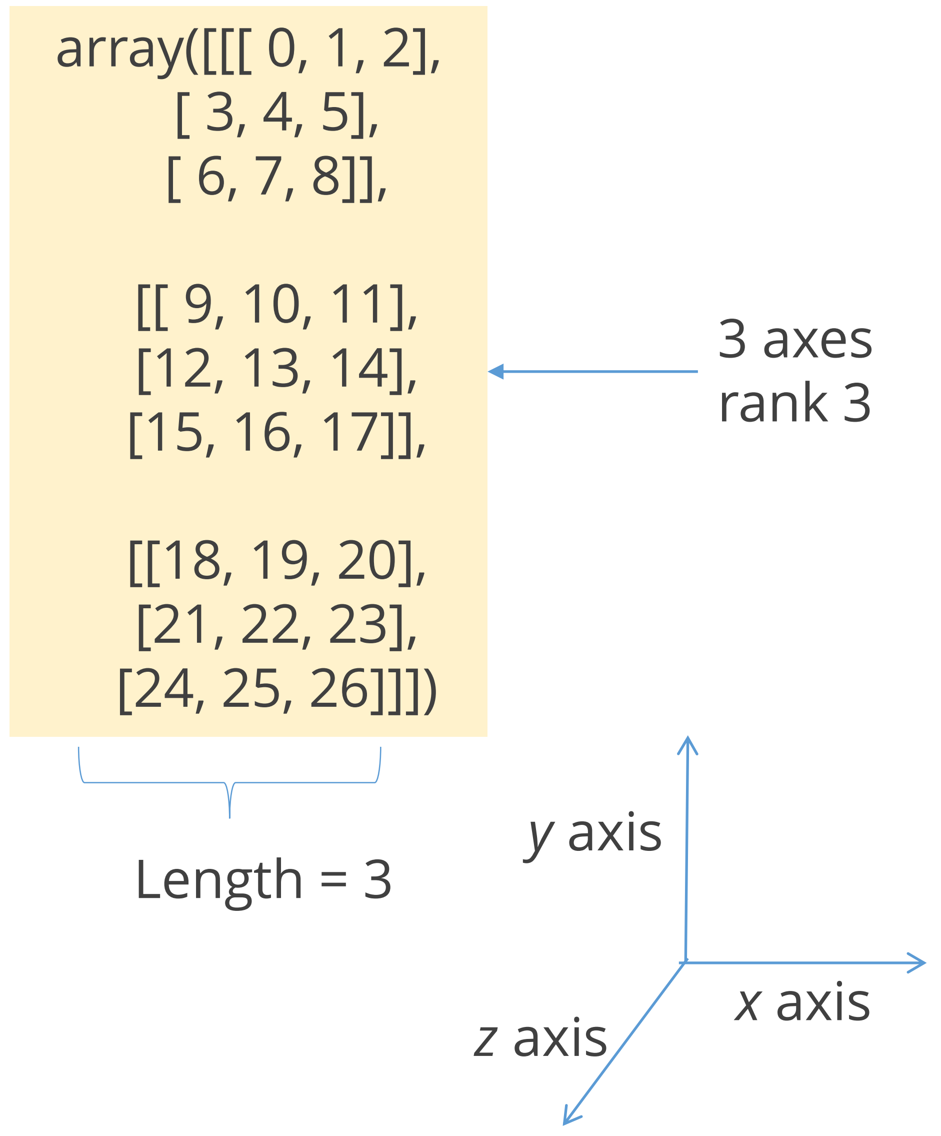
y axis

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

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

Demo 01—Creating and Printing an ndarray

Demonstrate how to create and print an ndarray.

DATA SCIENCE

Knowledge Check

KNOWLEDGE CHECK

How many elements will the following code print?

```
print(np.linspace(4,13,7))
```

a. 4

b. 7

c. 11

d. 13

KNOWLEDGE CHECK

How many elements will the following code print?

```
print(np.linspace(4,13,7))
```

a. 4

b. 7

c. 11

d. 13

The correct answer is **b** .

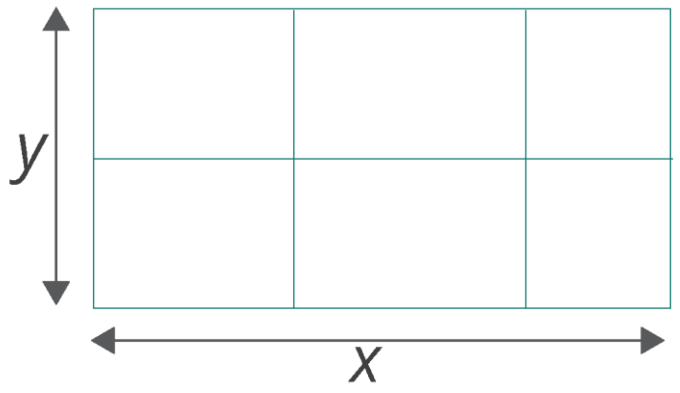
Explanation: In the "linspace" function, "4" is the starting element and "13" is the end element. The last number "7" specifies that a total of seven equally spaced elements should be created between "4" and "13," both numbers inclusive. In this case, the "linspace" function creates the following array: [4. 5.5 7. 8.5 10. 11.5 13.]

Class and Attributes of ndarray—.ndim

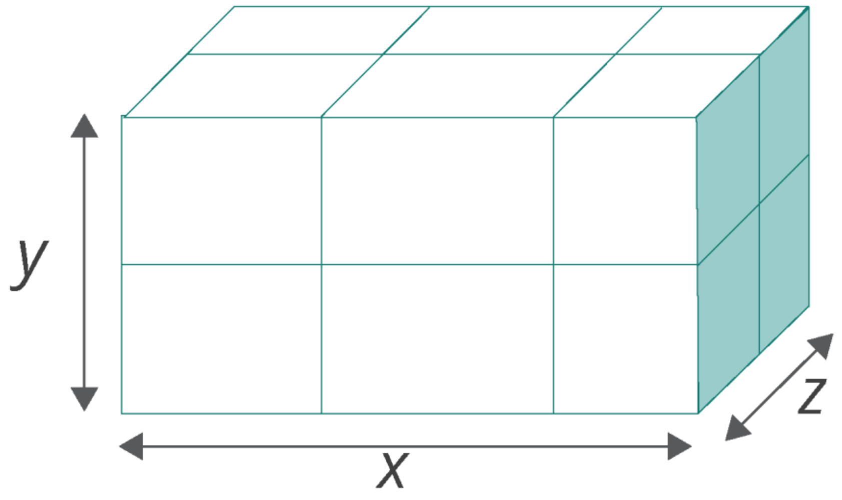
Numpy’s array class is “ndarray,” also referred to as “numpy.ndarray.” The attributes of ndarray are:

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

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

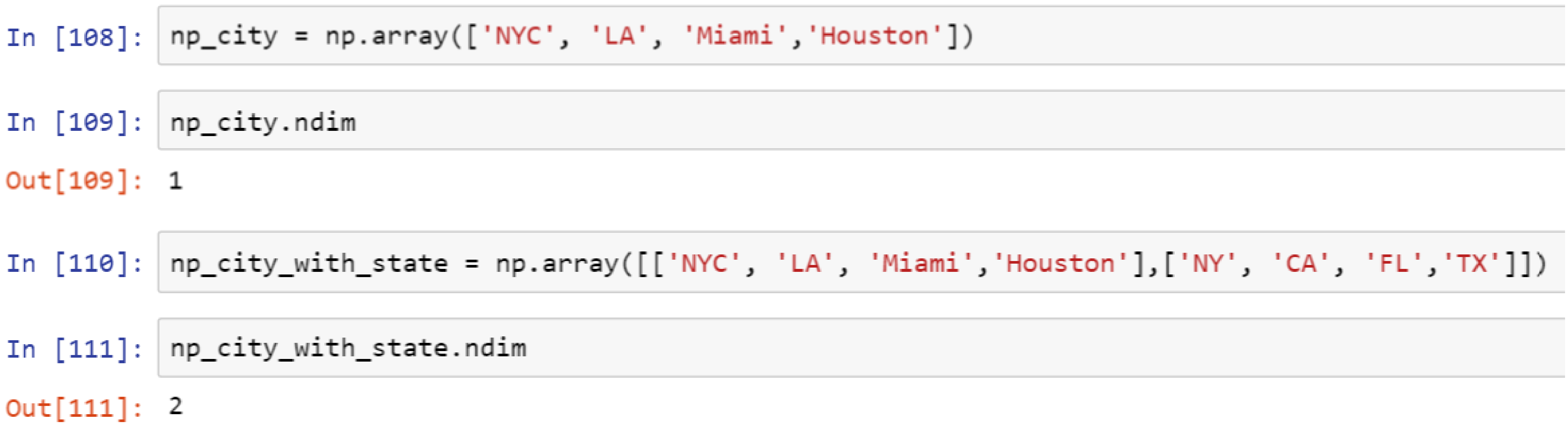
Concept Example

Class and Attributes of ndarray—.ndim

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

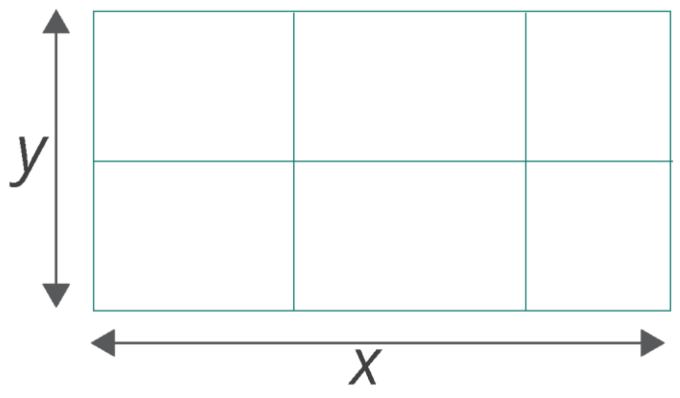
ndarray.ndim

ndarray.shape

ndarray.size

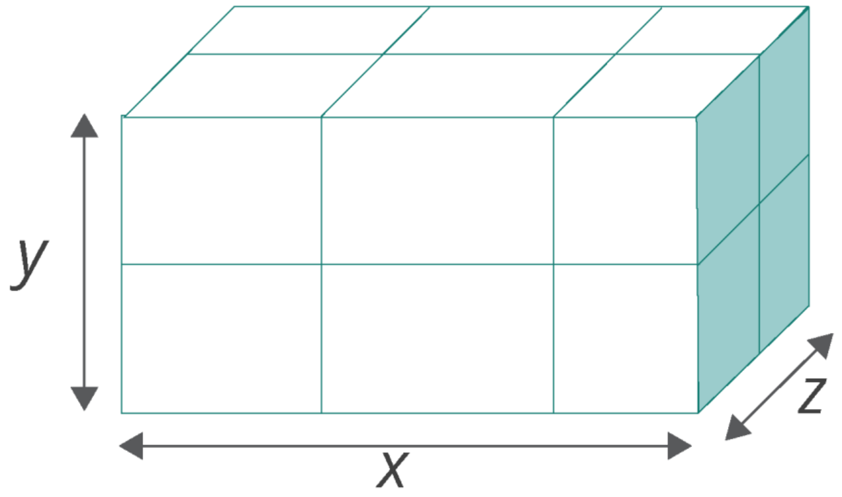
ndarray.dtype

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:

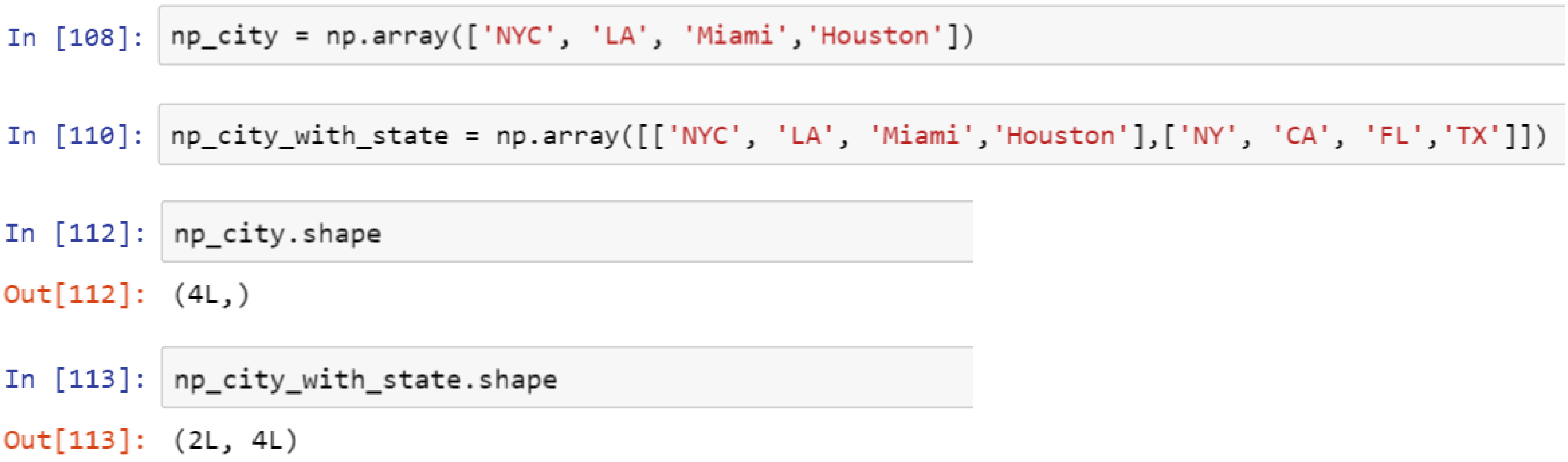
ndarray.ndim

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:

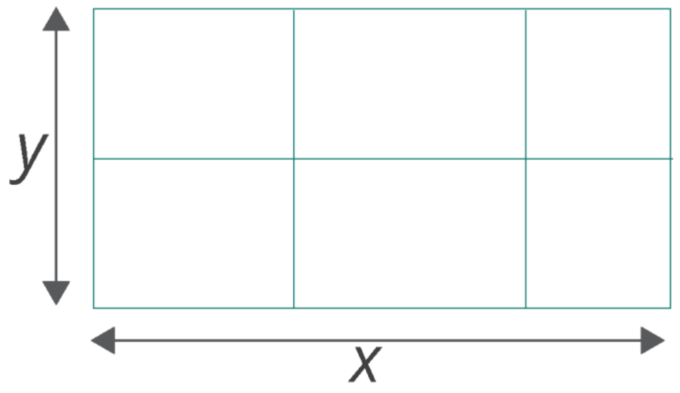
ndarray.ndim

ndarray.shape

ndarray.size

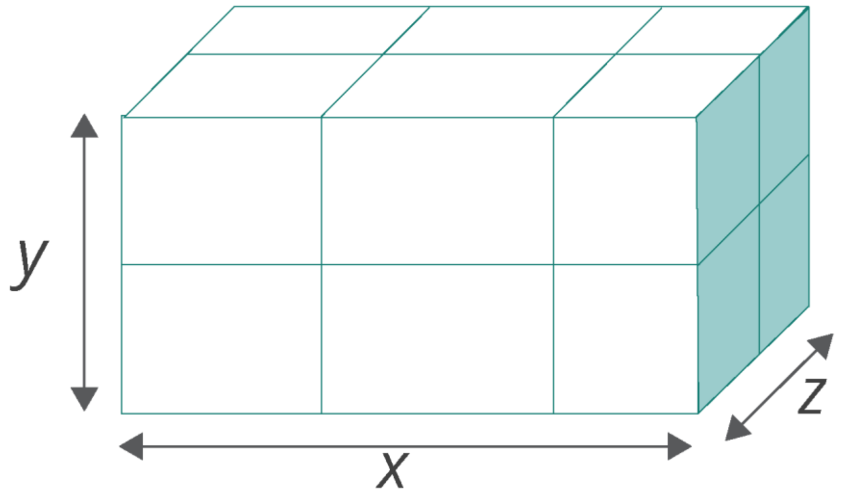
ndarray.dtype

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:

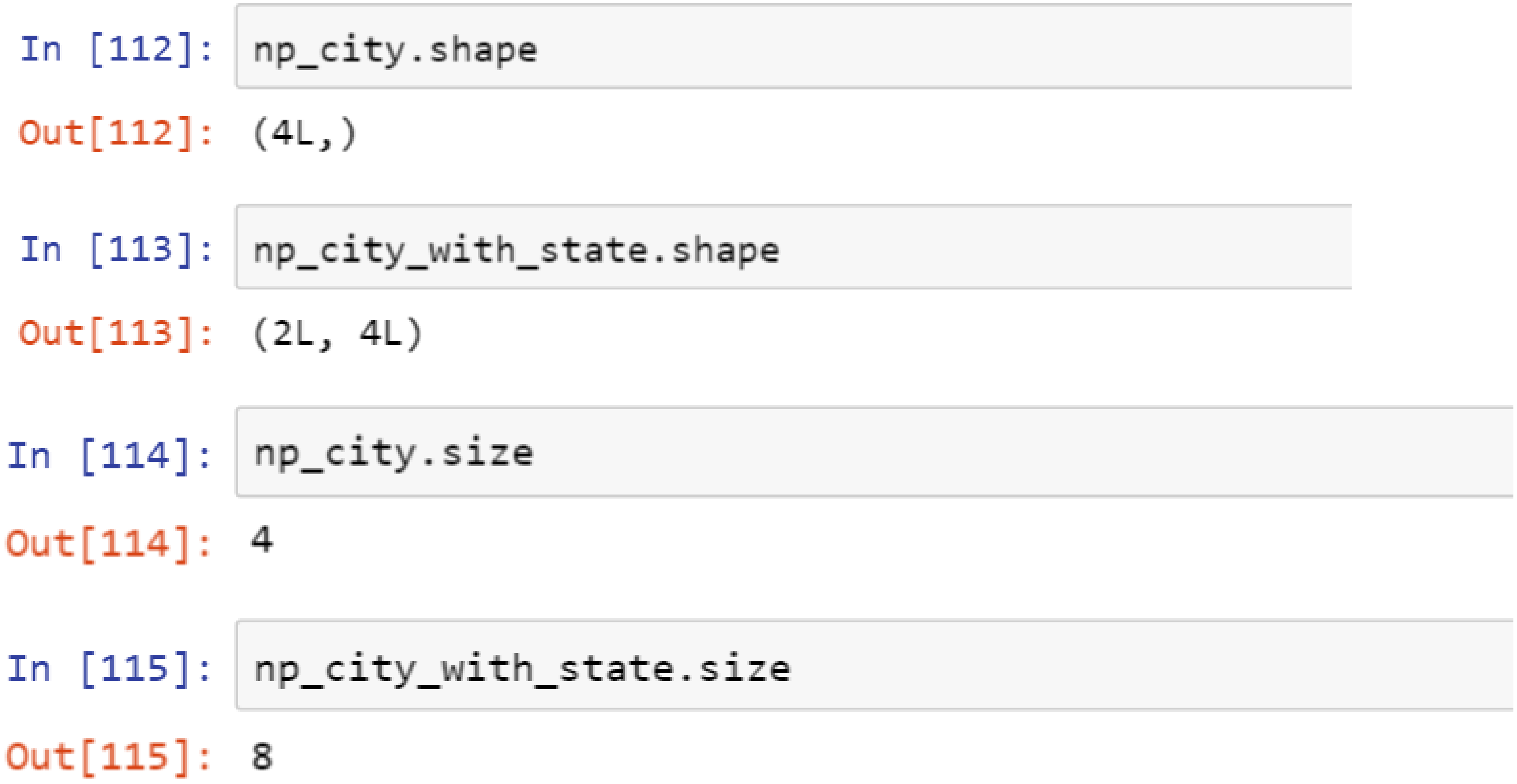
ndarray.ndim

ndarray.shape

ndarray.size

ndarray.dtype

Look at the examples to see how the 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

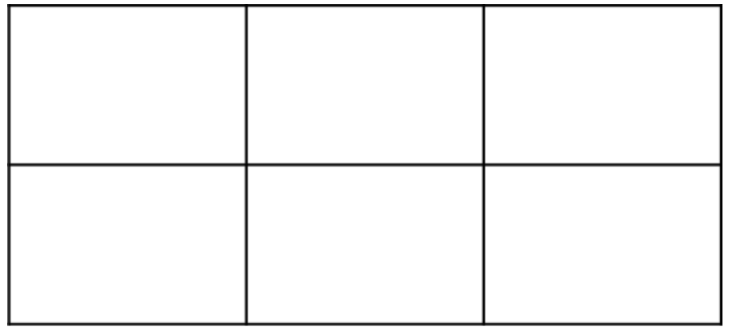
Example

Class and Attributes of ndarray—.dtype

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

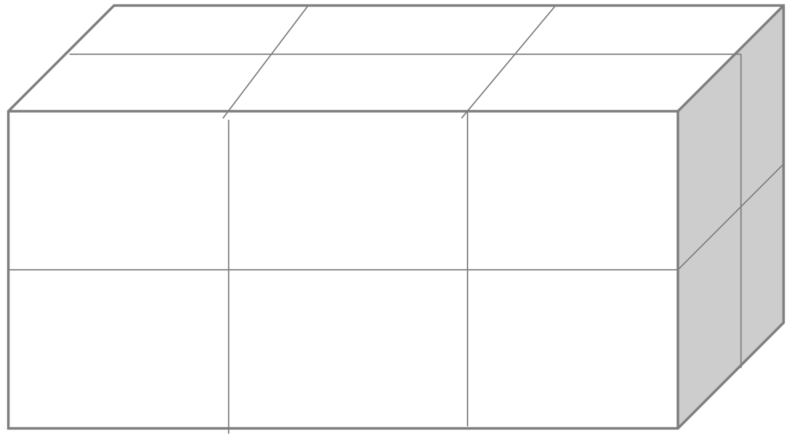
- ndarray.ndim
- ndarray.shape
- ndarray.size
- ndarray.dtype

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

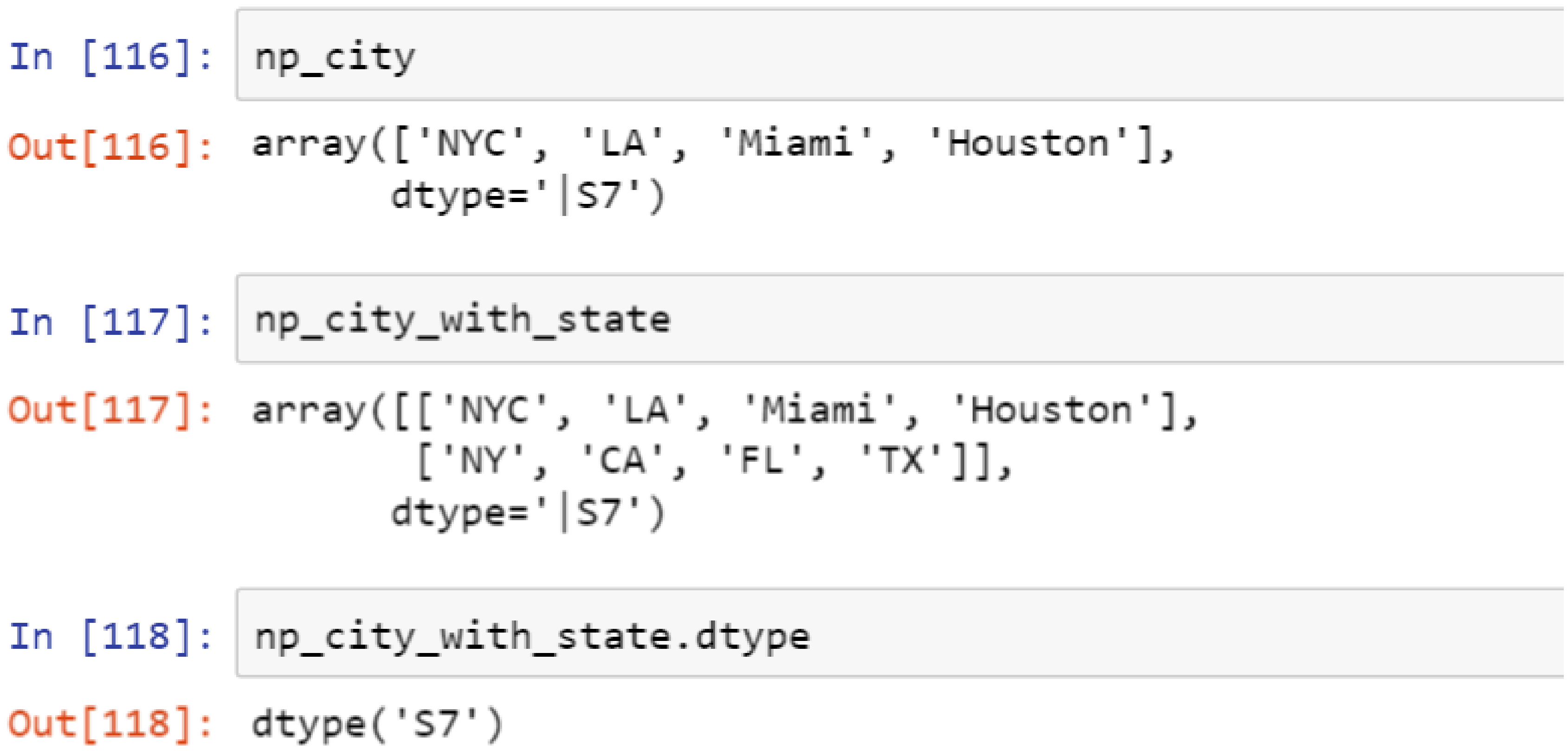
Example

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

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

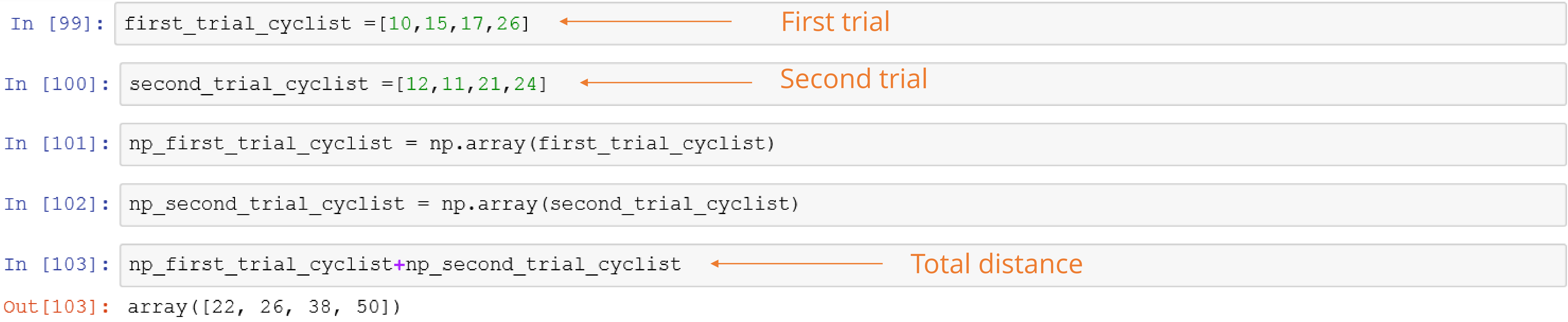
Greater	>
Greater or equal	>=
Less	<
Less or equal	<=
Equal	==
Not equal	!=

Demo 03—Executing Basic Operations

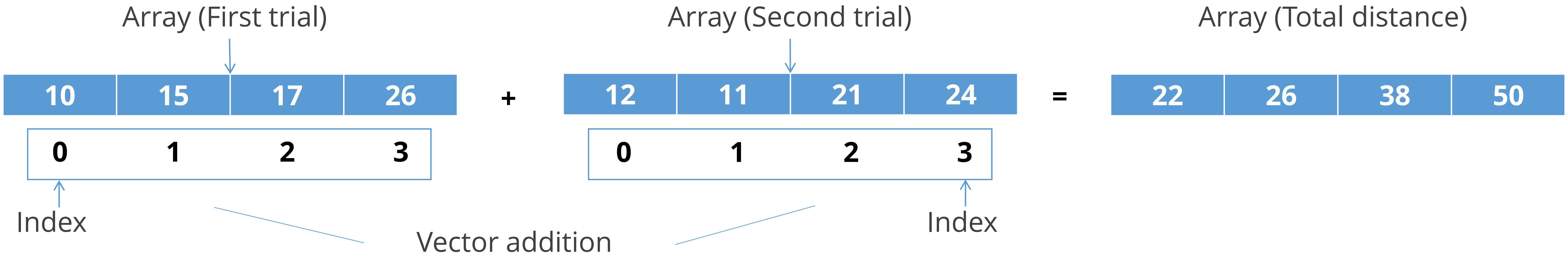
Demonstrate how to apply some basic operations on an array.

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])
```

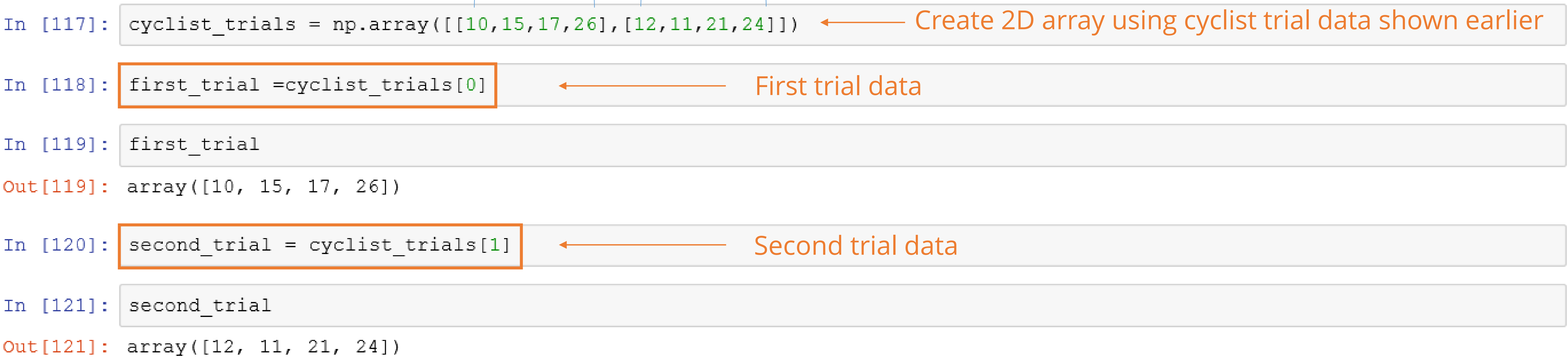


Accessing Array Elements: Indexing

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

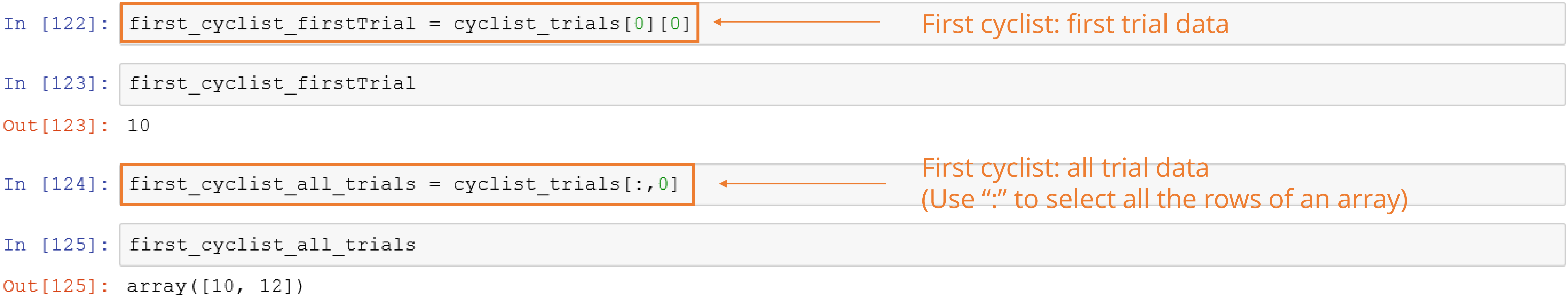
Second trial data

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 (contd.)

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.

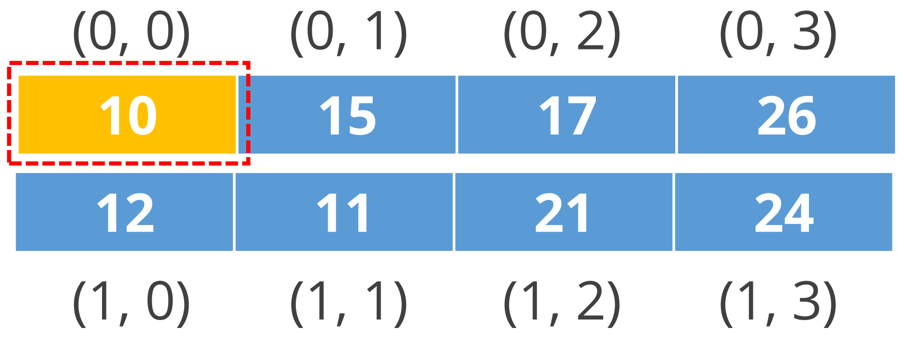


```
In [122]: first_cyclist_firstTrial = cyclist_trials[0][0]

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

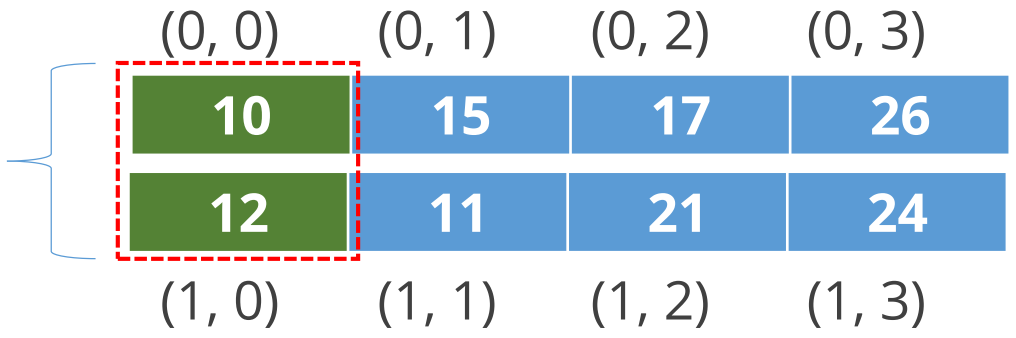
First cyclist: all trial data
(Use ":" to select all the rows of an array)

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

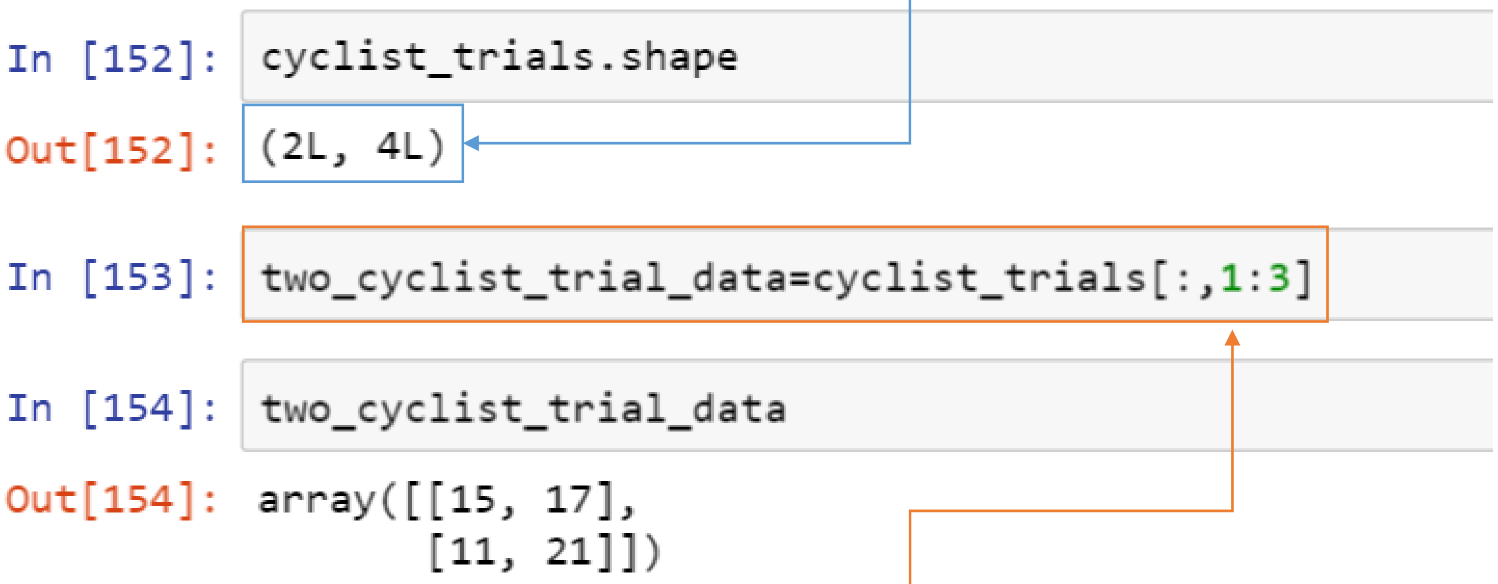


(0, 0)	(0, 1)	(0, 2)	(0, 3)
10	15	17	26
12	11	21	24
(1, 0)	(1, 1)	(1, 2)	(1, 3)

Accessing Array Elements: Slicing

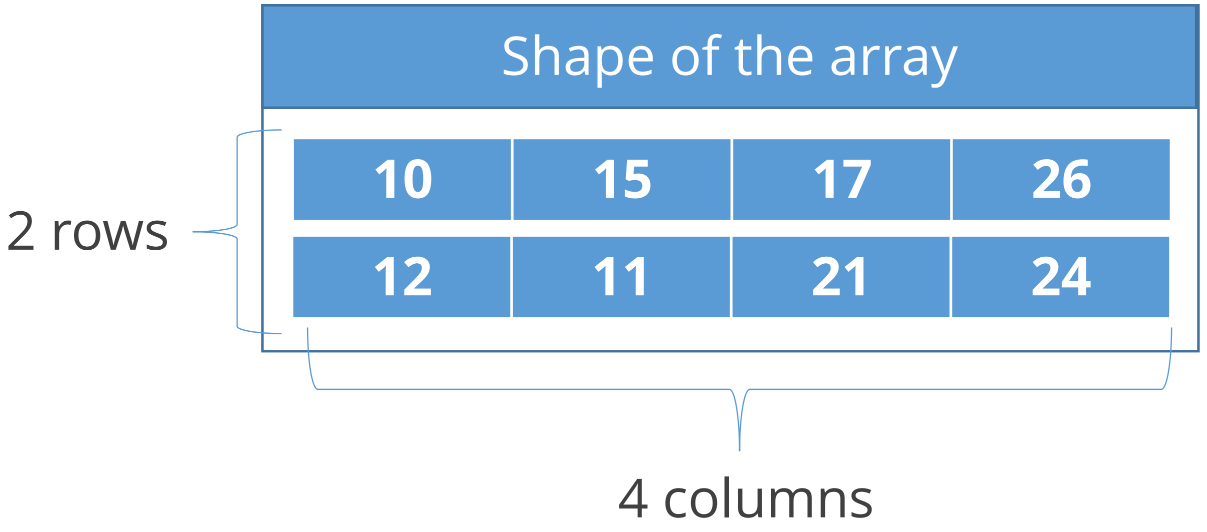
Use the slicing method to access a range of values within an array.

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

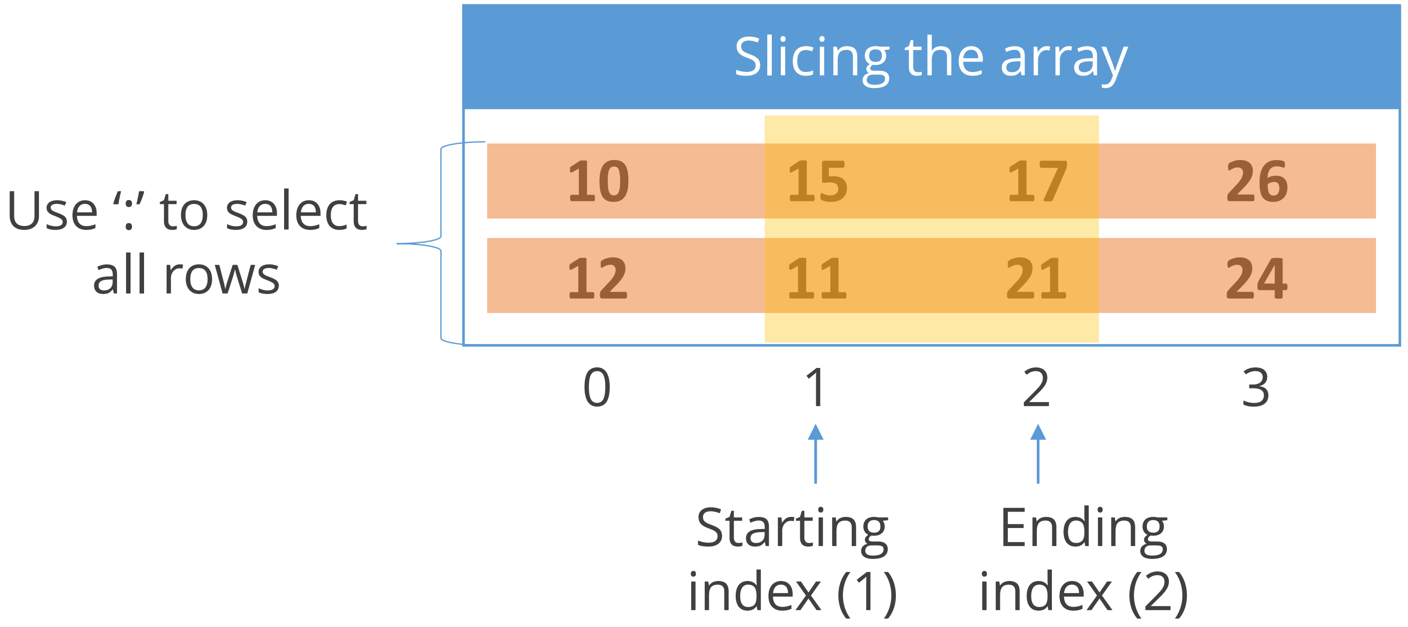


Shape of the array

10	15	17	26
12	11	21	24

2 rows

4 columns



Slicing the array

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

Use ':' to select all rows

Starting index (1)

Ending index (2)

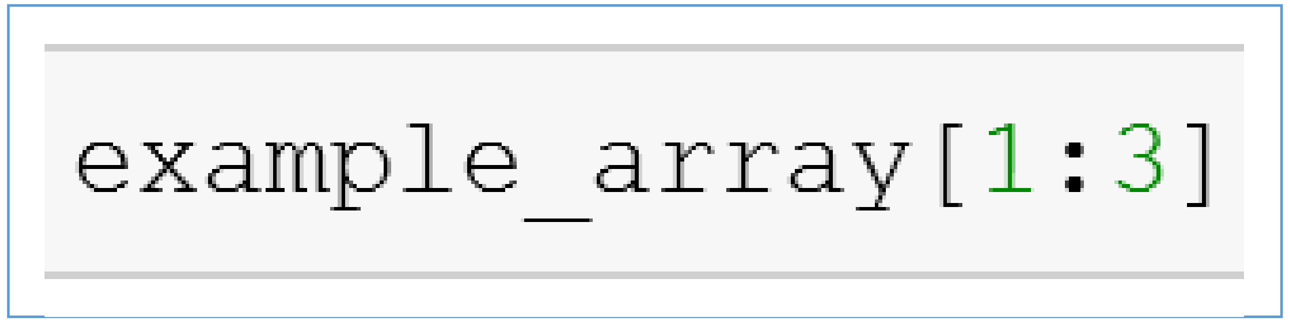
Activity—Slice It!

Select any two elements from the array to see how the statement required to slice the range changes.

Rules of the Game

- Choose the first element of the range. Then, choose the element that ends the range.
- See how the values in the statement change according to your choices.
- Refresh to try again.

5	8	10	21

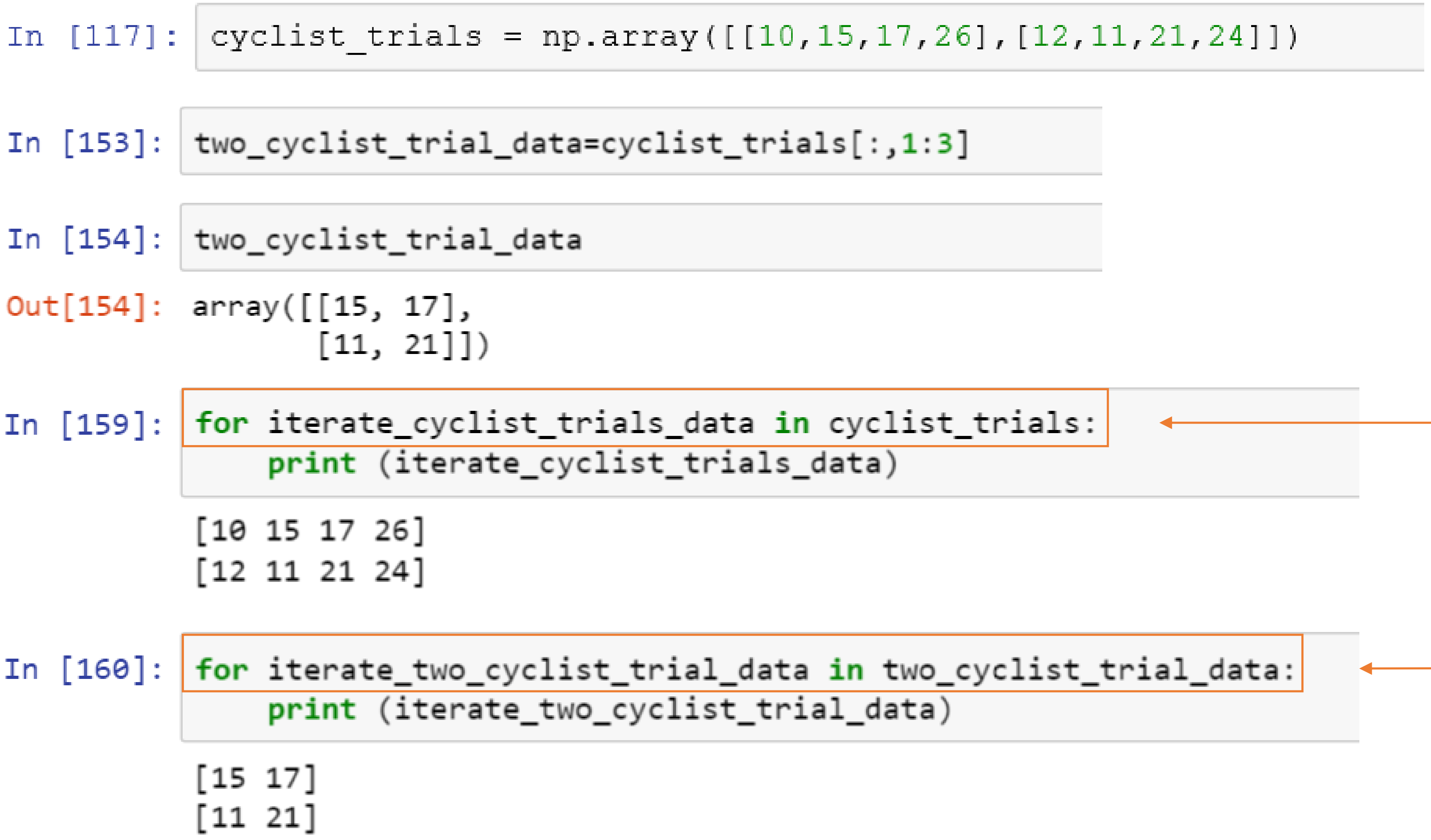


```
example_array[1:3]
```

Select any two elements from the array.

Accessing Array Elements: Iteration

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



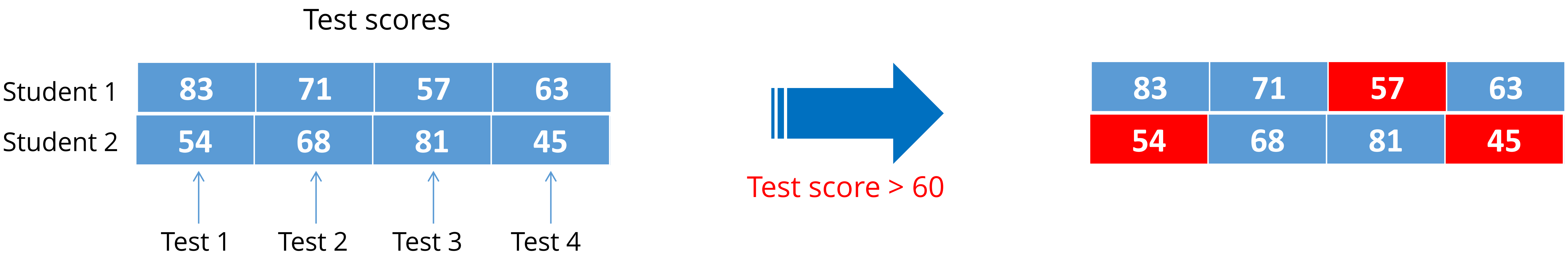
```
In [117]: cyclist_trials = np.array([[10,15,17,26],[12,11,21,24]])

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 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 set criteria. Here, the original dataset contains test scores of two students. You can use a Boolean array to choose only the scores that are above a given value.

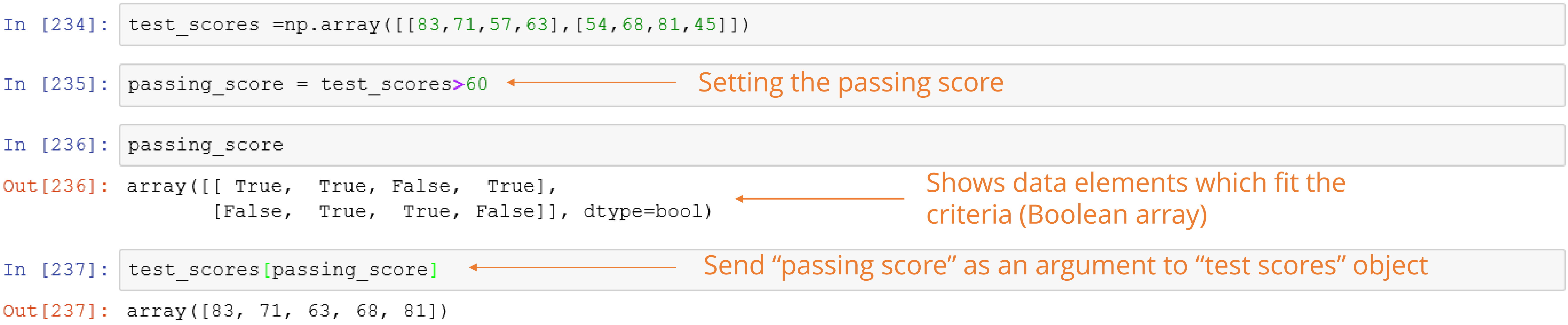


Test scores

	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

In [236]: passing_score

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

In [237]: test_scores[passing_score]

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

Setting the passing score

Shows data elements which fit the criteria (Boolean array)

Send “passing score” as an argument to “test scores” object

Copy and Views

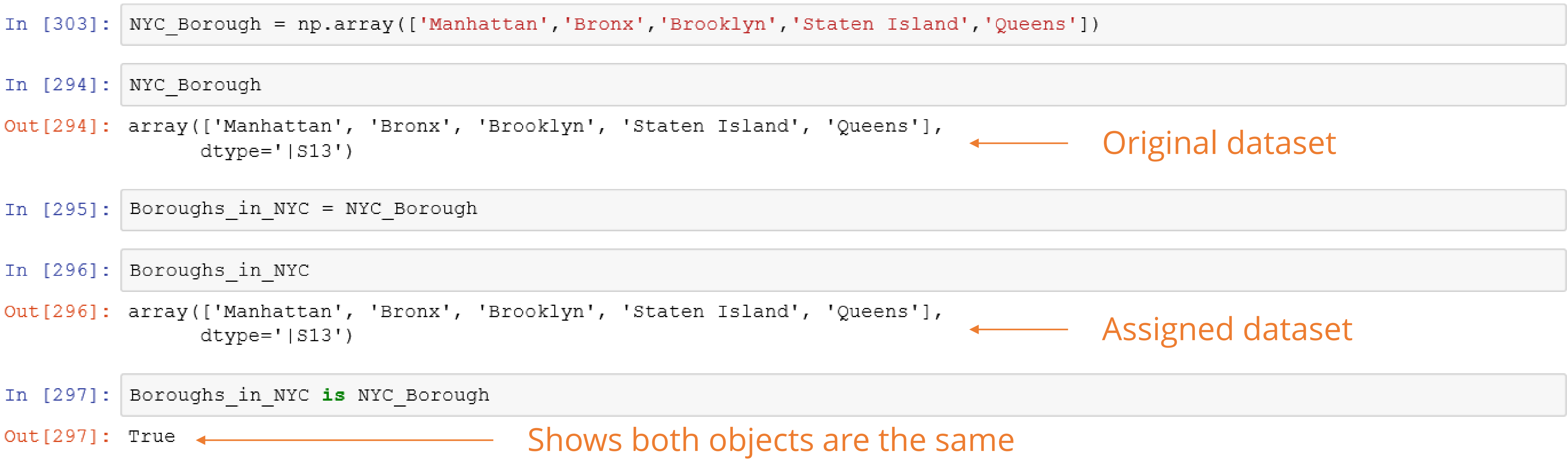
When working with arrays, data is copied into new arrays only in some cases. Following are the three possible scenarios:

Simple Assignments

View/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

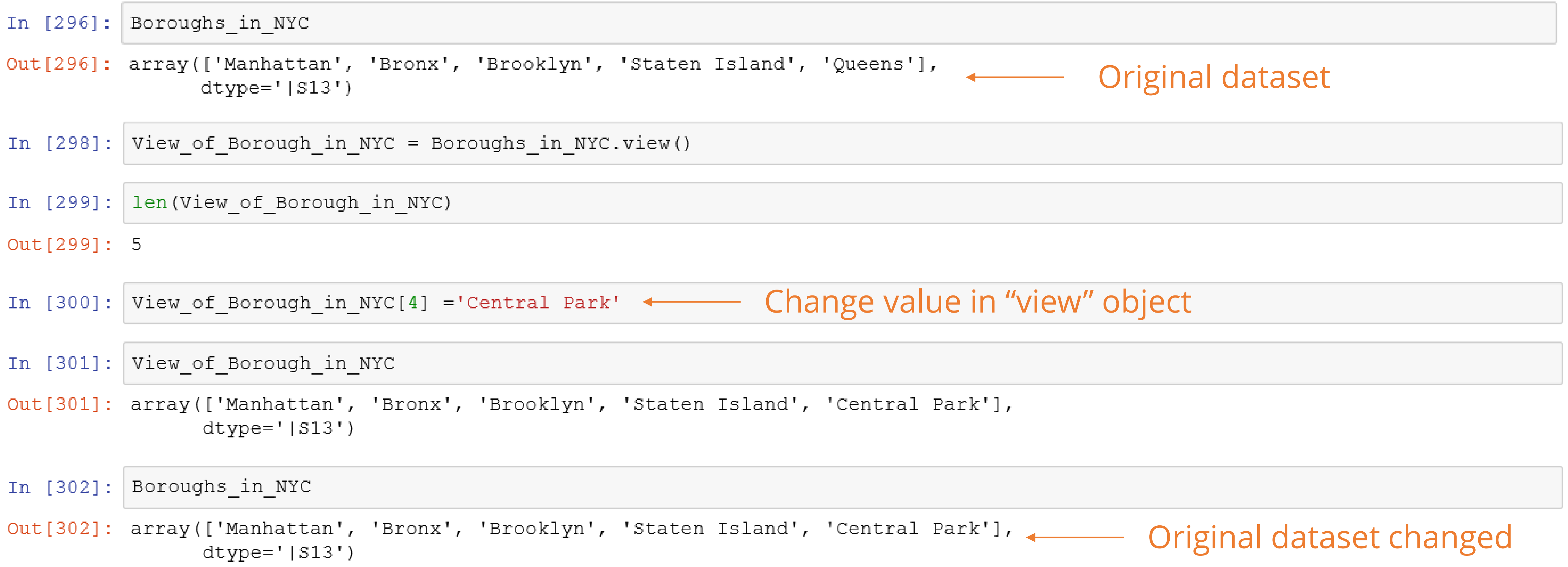
When working with arrays, data is copied into new arrays only in some cases. There are three possible scenarios:

Simple Assignments

View/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

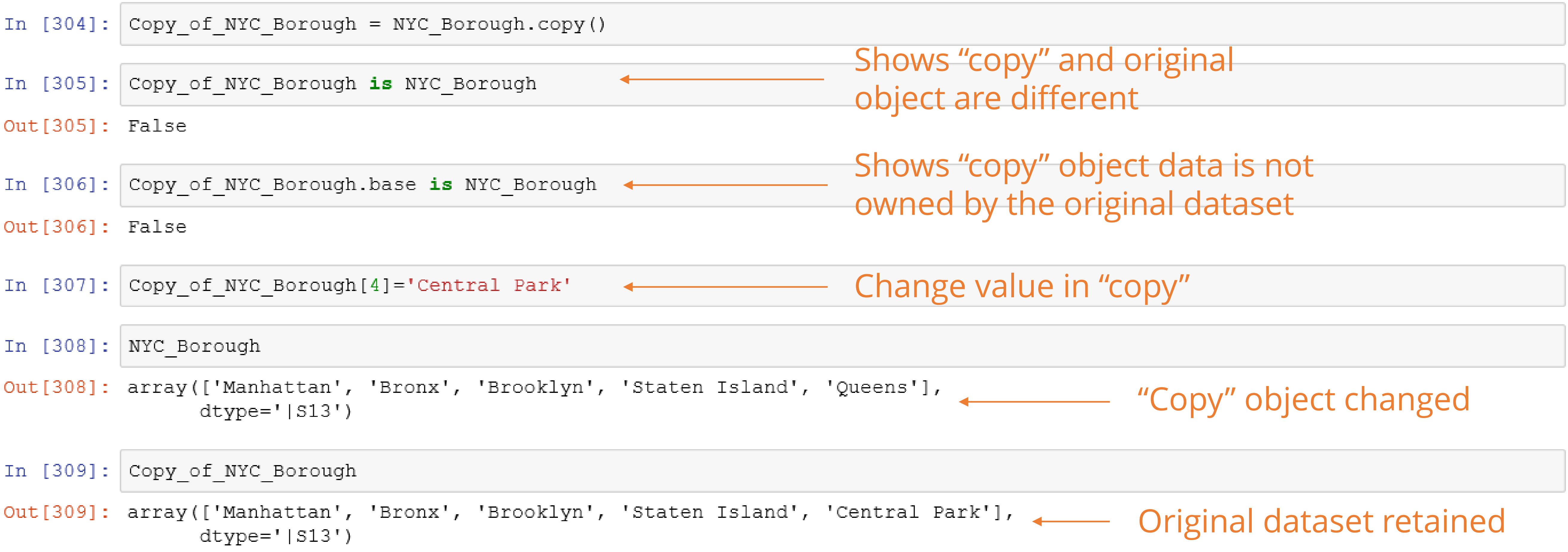
When working with arrays, data is copied into new arrays only in some cases. There are three possible scenarios:

Simple Assignments

View/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

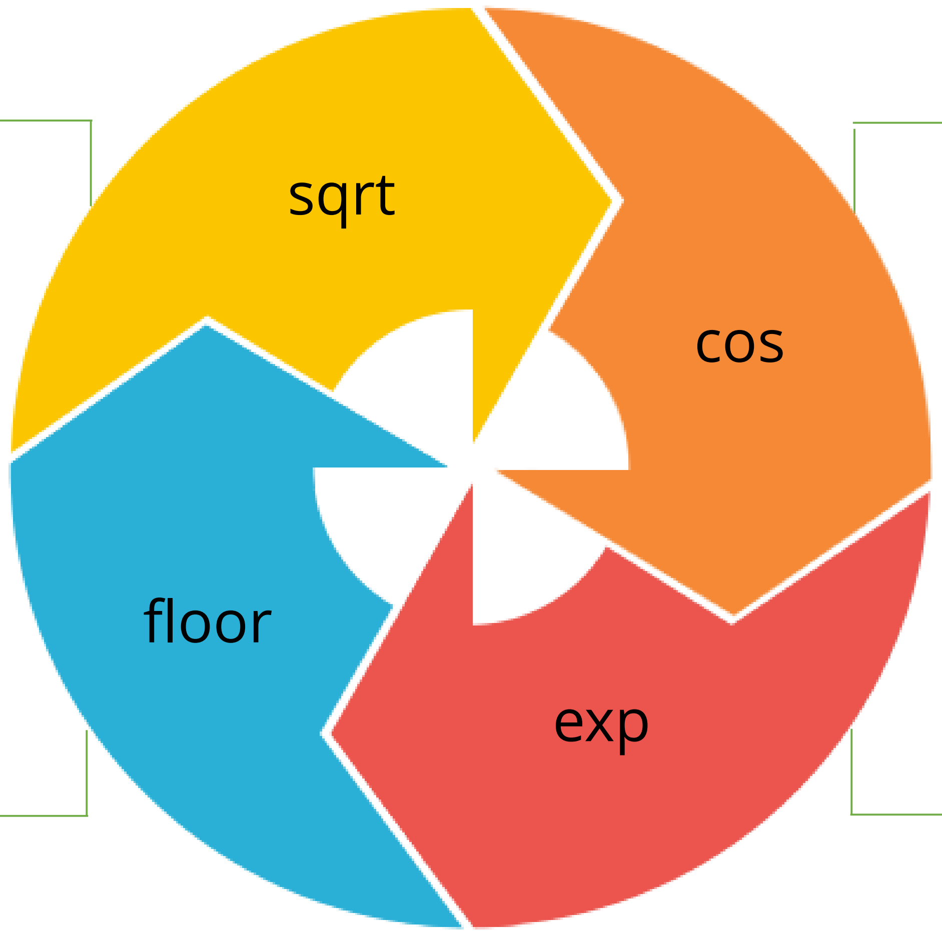
Original dataset retained

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 listed here:

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

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

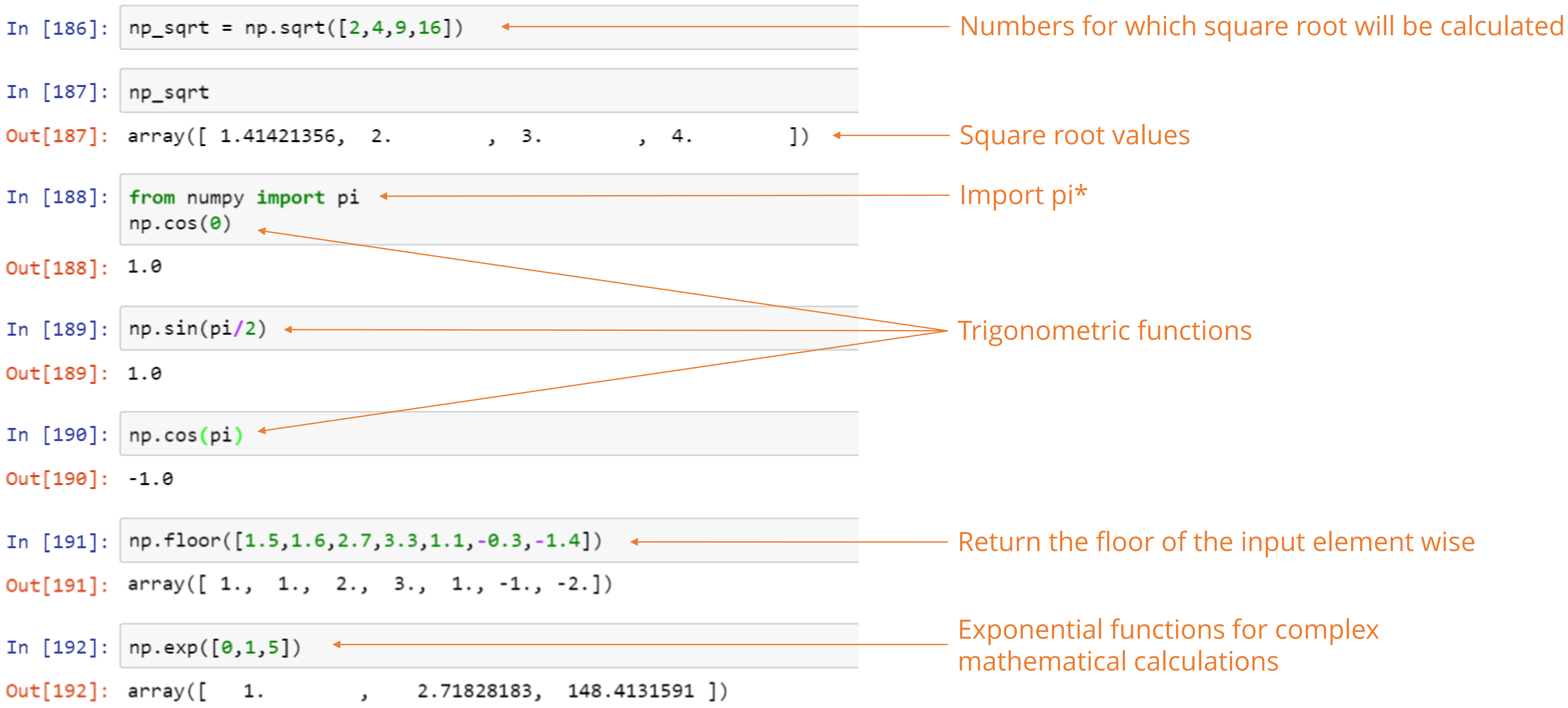


cos function gives cosine values for all elements in the array.

exp function performs exponentiation on each element.

ufunc—Examples

Let's look at some common 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*

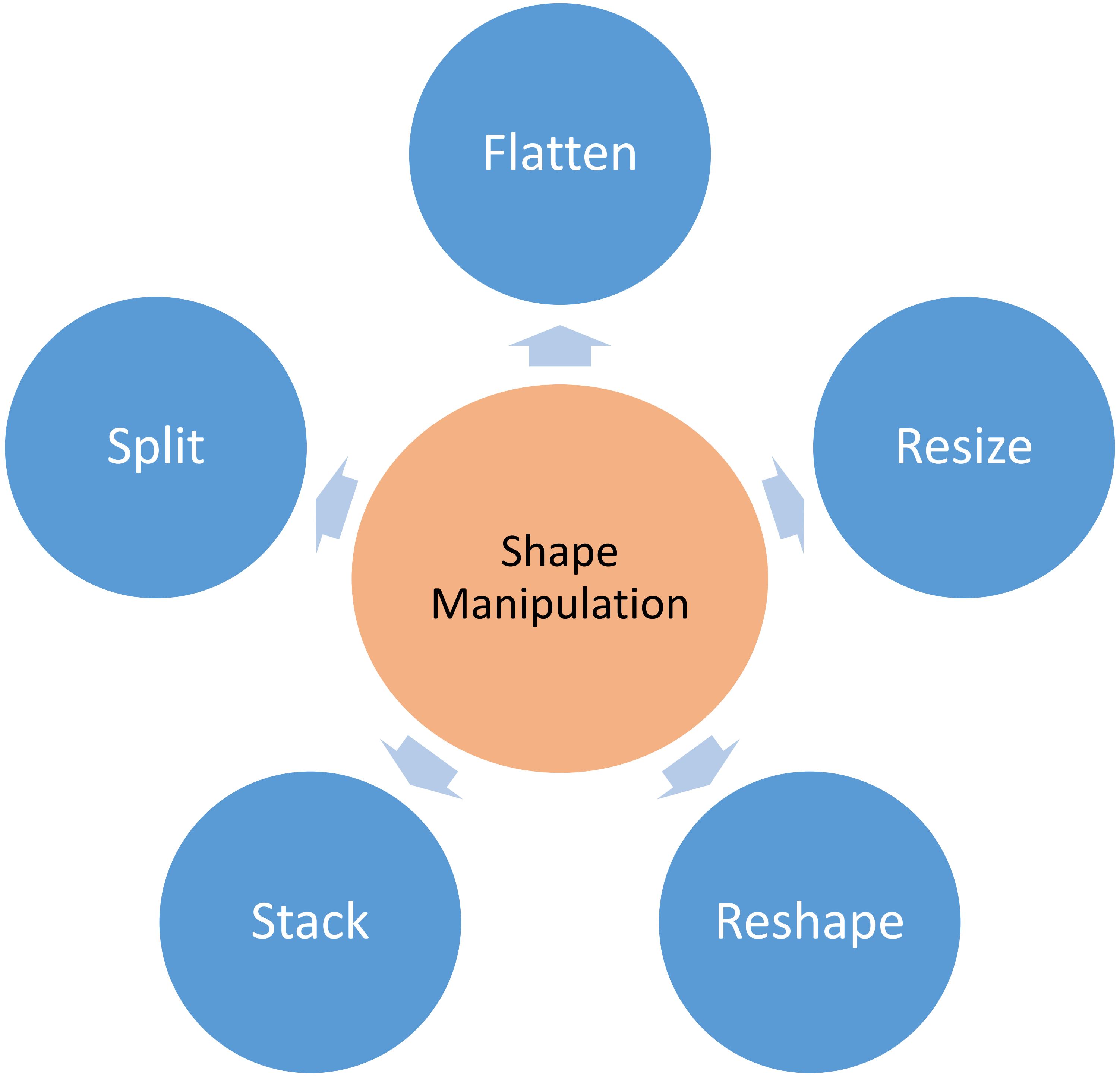
Trigonometric functions

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 to do the following:



Shape Manipulation

Flatten

Resize

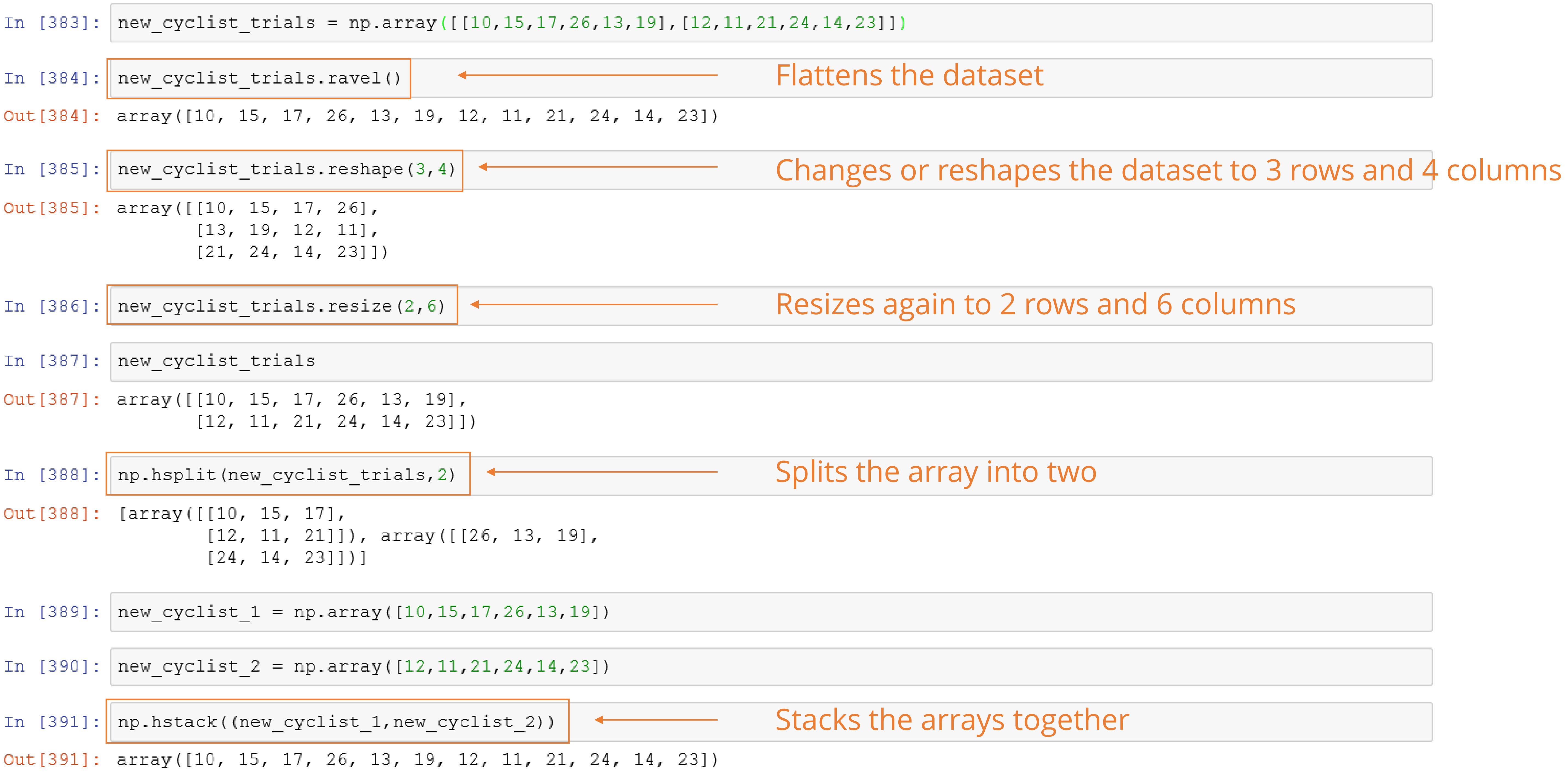
Reshape

Stack

Split

Shape Manipulation—Example

You can use certain functions to manipulate the shape of an array to do the following:



```
In [383]: new_cyclist_trials = np.array([[10,15,17,26,13,19],[12,11,21,24,14,23]])

In [384]: new_cyclist_trials.ravel()
```

Flattens the dataset

```
Out[384]: array([10, 15, 17, 26, 13, 19, 12, 11, 21, 24, 14, 23])

In [385]: new_cyclist_trials.reshape(3,4)
```

Changes or reshapes the dataset to 3 rows and 4 columns

```
Out[385]: array([[10, 15, 17, 26],
                 [13, 19, 12, 11],
                 [21, 24, 14, 23]])

In [386]: new_cyclist_trials.resize(2,6)
```

Resizes again to 2 rows and 6 columns

```
In [387]: new_cyclist_trials

Out[387]: array([[10, 15, 17, 26, 13, 19],
                 [12, 11, 21, 24, 14, 23]])

In [388]: np.hsplit(new_cyclist_trials,2)
```

Splits the array into two

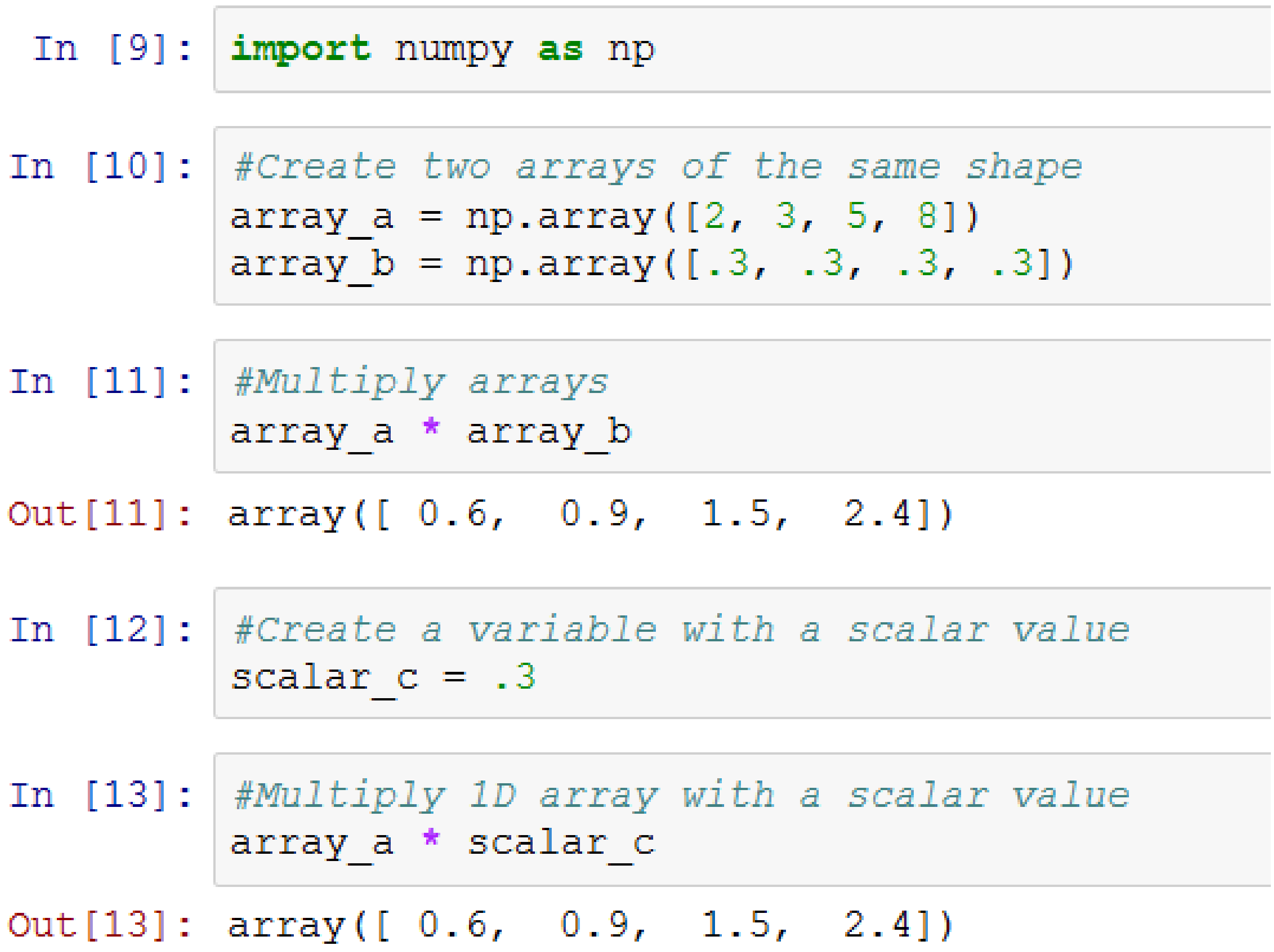
```
Out[388]: [array([[10, 15, 17],
                  [12, 11, 21]]), array([[26, 13, 19],
                  [24, 14, 23]])]

In [389]: new_cyclist_1 = np.array([10,15,17,26,13,19])

In [390]: new_cyclist_2 = np.array([12,11,21,24,14,23])

In [391]: np.hstack((new_cyclist_1,new_cyclist_2))
```

Stacks the arrays together

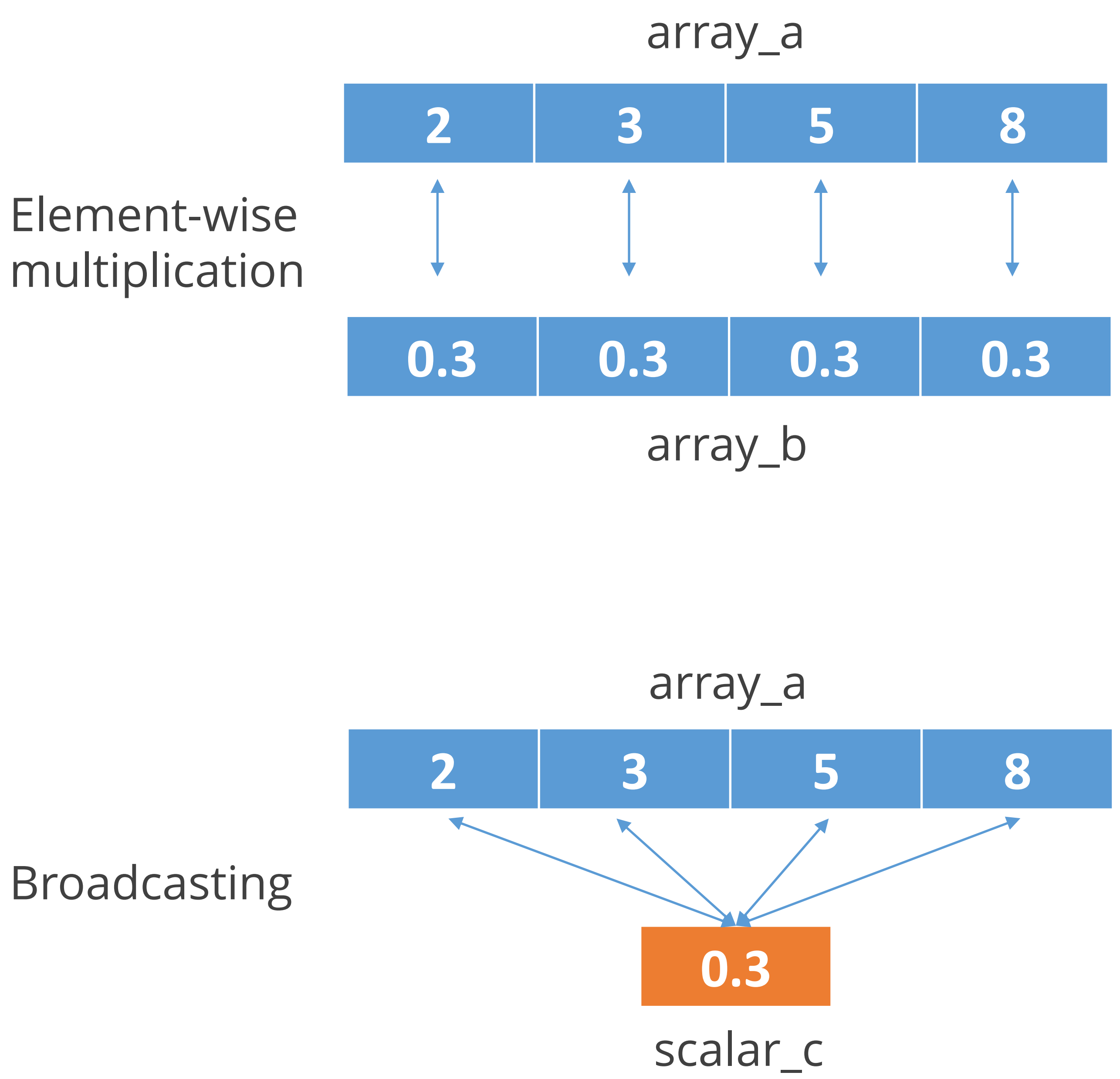
```
Out[391]: array([10, 15, 17, 26, 13, 19, 12, 11, 21, 24, 14, 23])
```

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.

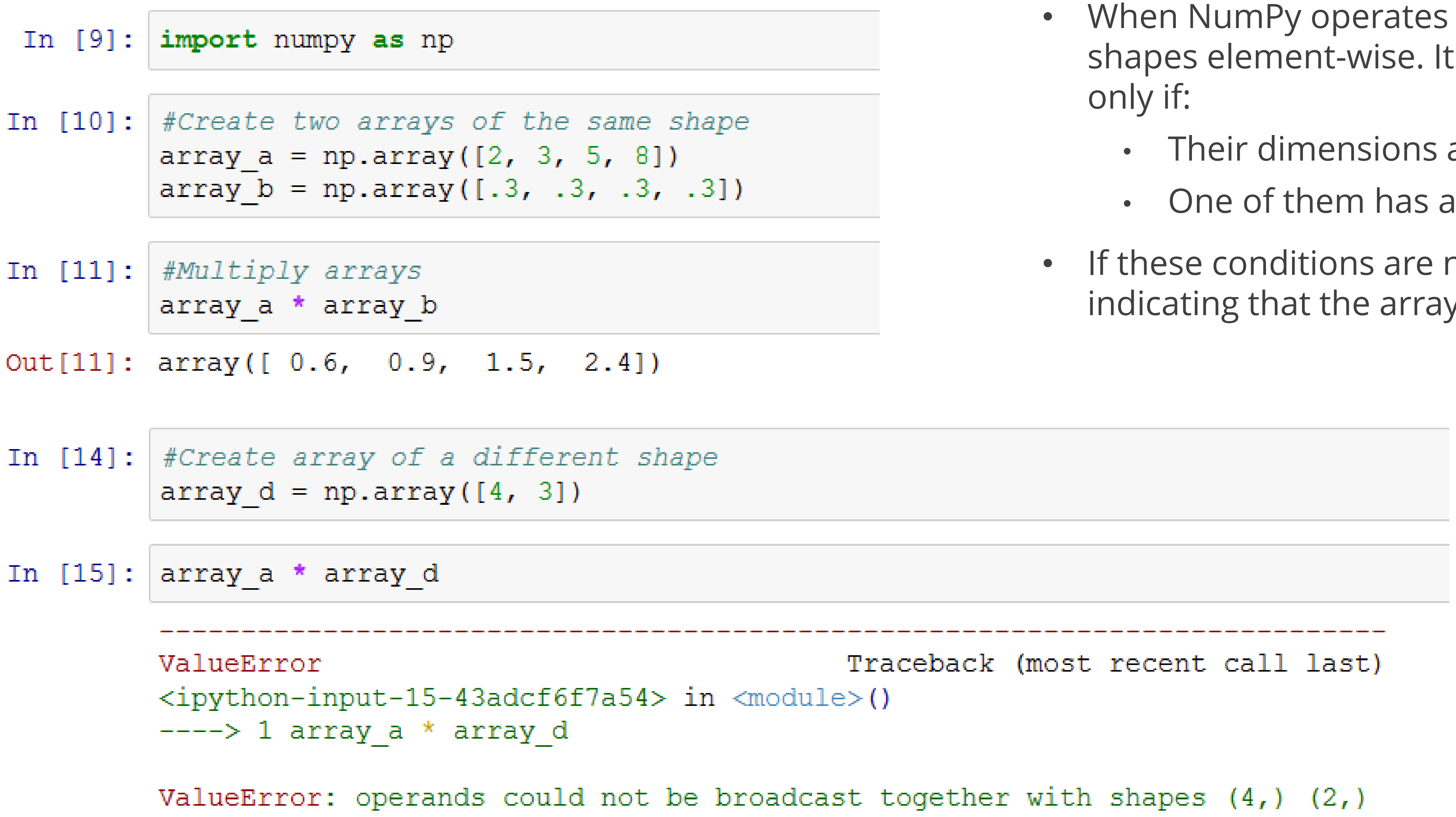


```
In [9]:  import numpy as np

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])
```



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])
```

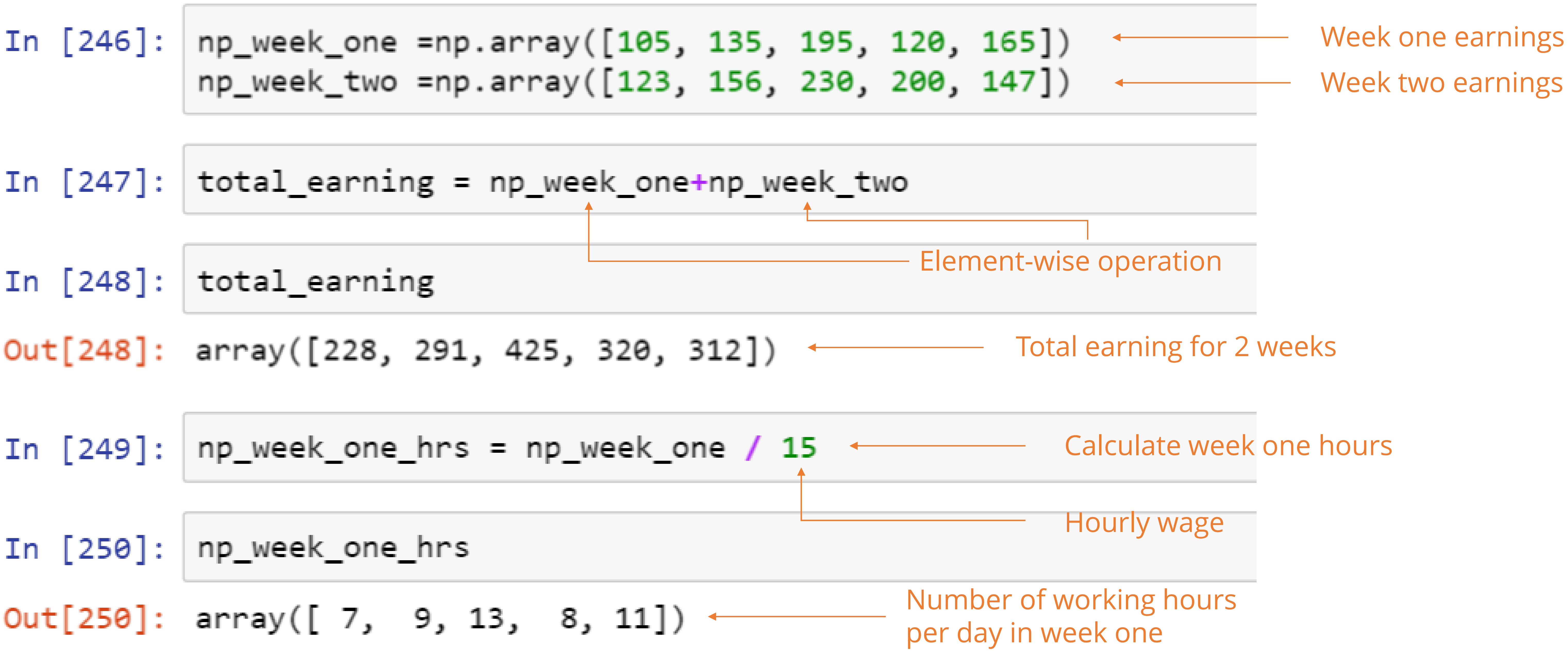
```
In [14]: #Create array of a different shape
         array_d = np.array([4, 3])
```

```
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

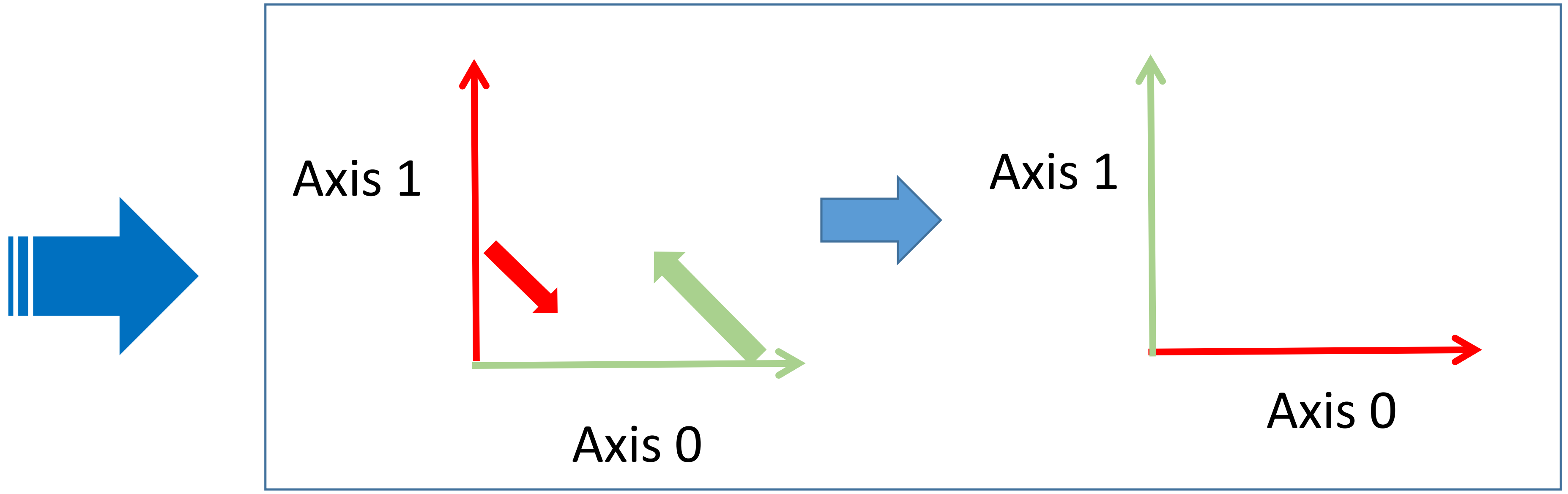
Number of working hours per day in week one

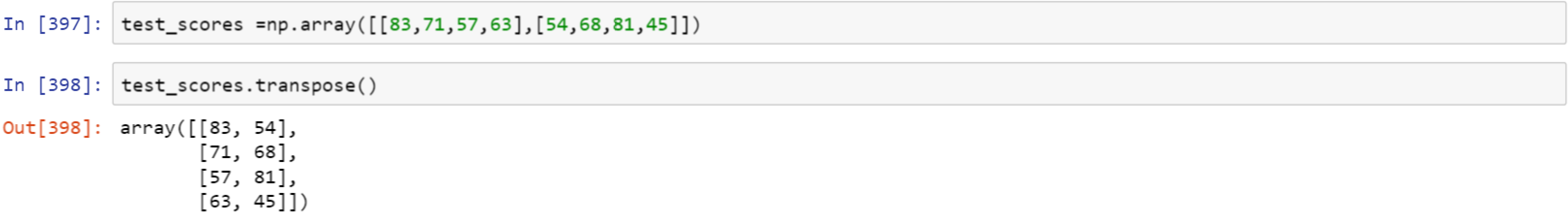
Linear Algebra—Transpose

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



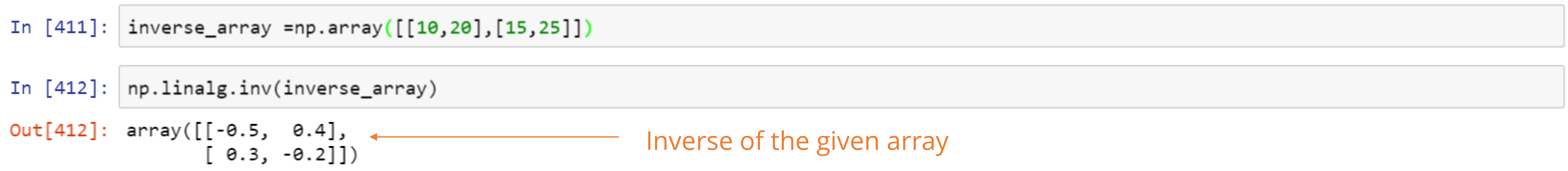


```
In [397]: test_scores =np.array([[83,71,57,63],[54,68,81,45]])

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()

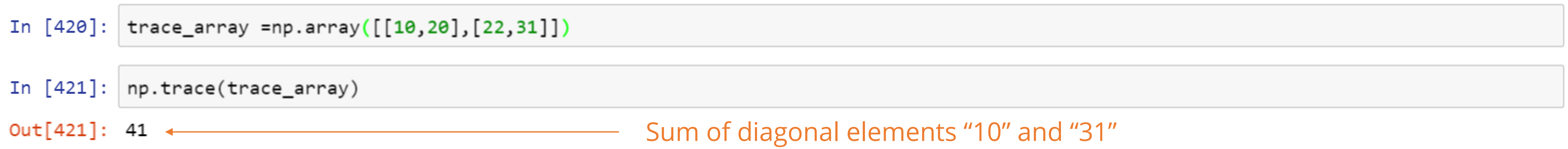


```
In [411]: inverse_array =np.array([[10,20],[15,25]])

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”

Assignment

Assignment 01

Problem

Instructions

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, and
- Print the highest GDP value, lowest GDP value, mean GDP value, standardized GDP value, and the sum of all the GDPs.

Assignment 01

Problem Instructions

Instructions to perform the assignment:

- Download the GDP dataset from the “Resource” tab. You can copy the data provided to help you with your assignment.

Common instructions:

- If you are new to Python, download the “Anaconda Installation Instructions” document from the “Resources” tab to view the steps for installing Anaconda and the Jupyter notebook.
- Download the “Assignment 02” notebook and upload it on the Jupyter notebook to access it.
- Follow the cues provided to complete the assignment.

Assignment

Assignment 02

Problem

Instructions

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

- Find and print the name of the country that won maximum 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, and
- Print each country name with the total number of medals won.

Assignment 02

Problem | Instructions

Instructions to perform the assignment:

- Download the “Olympic 2012 Medal Tally” dataset. Use the data provided to create relevant and required variables.

Common instructions:

- If you are new to Python, download the “Anaconda Installation Instructions” document from the “Resources” tab to view the steps for installing Anaconda and the Jupyter notebook.
- Download the “Assignment 01” notebook and upload it on the Jupyter notebook to access it.
- Follow the cues provided to complete the assignment.

? Quiz

QUIZ

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]

QUIZ

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** .

Explanation: 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.

QUIZ

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

QUIZ

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.

Explanation: 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.

QUIZ 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

QUIZ

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**.

Explanation: 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.

QUIZ

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 zeroes

QUIZ

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 zeroes

The correct answer is **b**.

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

QUIZ

5

Which statement will slice the highlighted data?

11	14	21	32	53	64

a. [3 : 5]

b. [3 : 6]

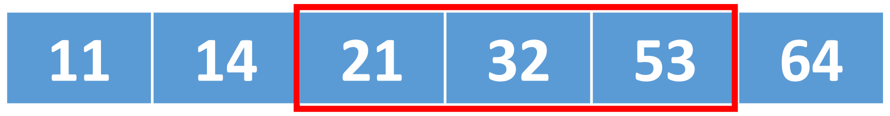
c. [2 : 5]

d. [2 : 4]

QUIZ

5

Which statement will slice the highlighted data?



11	14	21	32	53	64

a. [3 : 5]

b. [3 : 6]

c. [2 : 5]

d. [2 : 4]

The correct answer is c .

Explanation: Let’s assume that the index of the first element is *m* and the second element is *n*. Then, you need to use the statement “[*n* : *m* + 1]” to slice the required dataset. In this case, the index of the element “21” is “2” and that of “53” is “4.” So, the correct statement to use would be [2 : 5].

Key Takeaways

- NumPy is a very powerful Python library for mathematical and scientific computing.
- You can create and print NumPy arrays using different methods.
- Arrays can be one-dimensional, two-dimensional, three-dimensional, or multi-dimensional.
- NumPy uses basic operations, data access techniques, and copy and view techniques for data wrangling.
- NumPy can also manipulate data using various array shape manipulation techniques.
- NumPy can perform linear algebra functions to fix problematic datasets and execute mathematical operations.

This concludes “Mathematical Computing with Python (NumPy).”

The next lesson is “Scientific Computing with Python (SciPy).”