Fachhochschule Kiel
University of Applied Sciences

Tools and Programming Languages for Data Science
NumPy

Study Program Data Science

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Python foundations

Data types

Operators

Functions

Control flow and iterators

Programming concepts & paradigms

See also Precourse Programming

Tooling

Installation

Visual Studio Code

Jupyter Notebooks

Packages

Virtual Environments

Git and Github

Python

Data Science Workflow

NumPy pandas matplotlib

Our course agenda

- **Introduction and overview**
- **NumPy**: Basic data handling with Numpy arrays
- **Pandas**
  - Exploratory data analysis
  - Data consolidation
  - Data cleaning
- **Data visualization using Matplotlib and Seaborn**
- **Interacting with APIs**
- **Interacting with SQL databases**
- **Version Control with Git and GitHub**
- **Advanced Python**

Numpy: Numeric Python

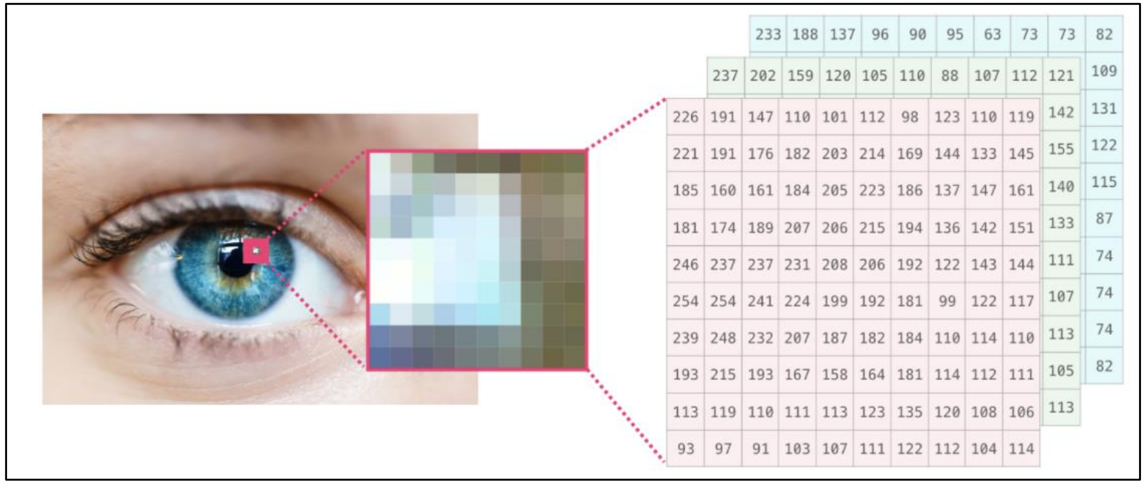
Data science is all about numbers

Original Data

Team	Points
A	25
A	12
B	15
B	14
B	19
B	23
C	25
C	29

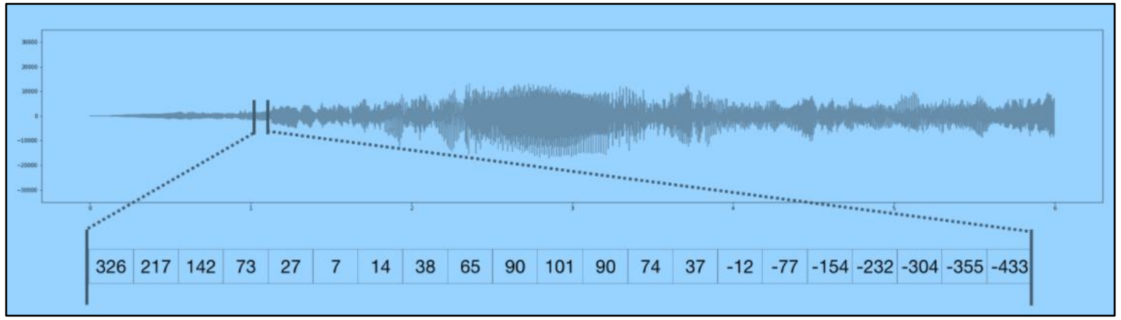
One-Hot Encoded Data

Team_A	Team_B	Team_C	Points
1	0	0	25
1	0	0	12
0	1	0	15
0	1	0	14
0	1	0	19
0	1	0	23
0	0	1	25
0	0	1	29



	text
0	The sky is blue and beautiful
1	Love this blue and beautifl sky
2	The quick brown fox jumps over the lazy dog.
3	A King's breakfast has sausages, ham, bacon, e...
4	I love green eggs, ham, sausages and bacon!
5	The brown fox is quick and the blue dog is lazy!
6	The sky is very blue and the sky is very beaut...
7	The dog is lazy but the brown fox is quick

	bacon	beans	beautifl	beautiful	blue	breakfast
0	0	0	0	1	1	0
1	0	0	1	0	1	0
2	0	0	0	0	0	0
3	1	1	0	0	0	1
4	1	0	0	0	0	0
5	0	0	0	0	1	0
6	0	0	0	1	1	0
7	0	0	0	0	0	0



http://jalammar.github.io/visual-numpy/

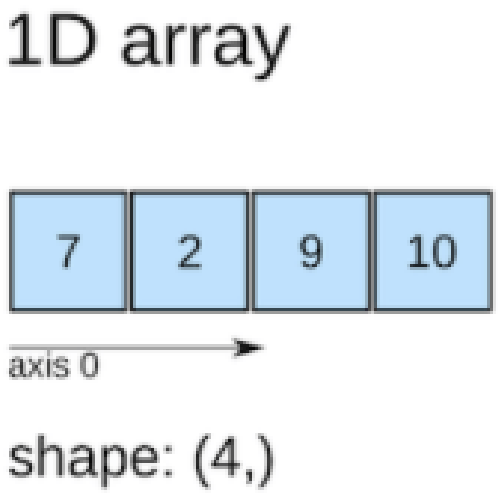
Characteristics of NumPy arrays

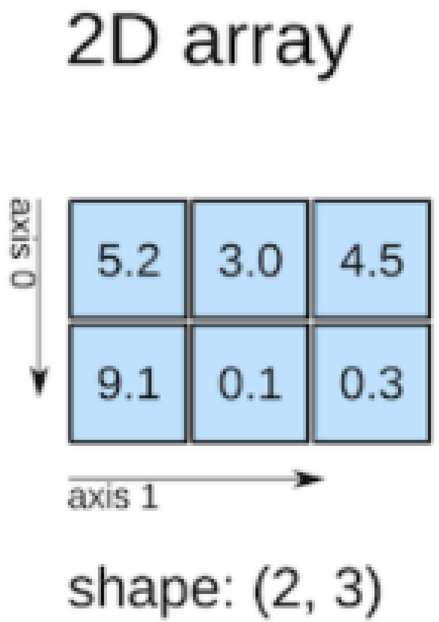
- **Multidimensional:**
  - Vectors (1 dimension), matrices (2), tensors (3 or more)
  - We say „dimensions“ or „axes“
- **Homogeneous data type**
  - All elements must be of the same data type: e.g. only integers
  - Enables efficient storage and fast computations because there is no need for type checking
- **Array attributes**
  - <u>ndim</u>: number of dimensions (e.g. 1, 2, 3, …)
  - <u>shape</u>: length along each dimension (e.g. (50, 5) for data with 50 rows and 5 cols)
  - <u>size</u>: total number of elements (e.g. 250 for data with 50 rows and 5 cols)
  - <u>dtype:</u> data type (e.g. int32, float64, …)

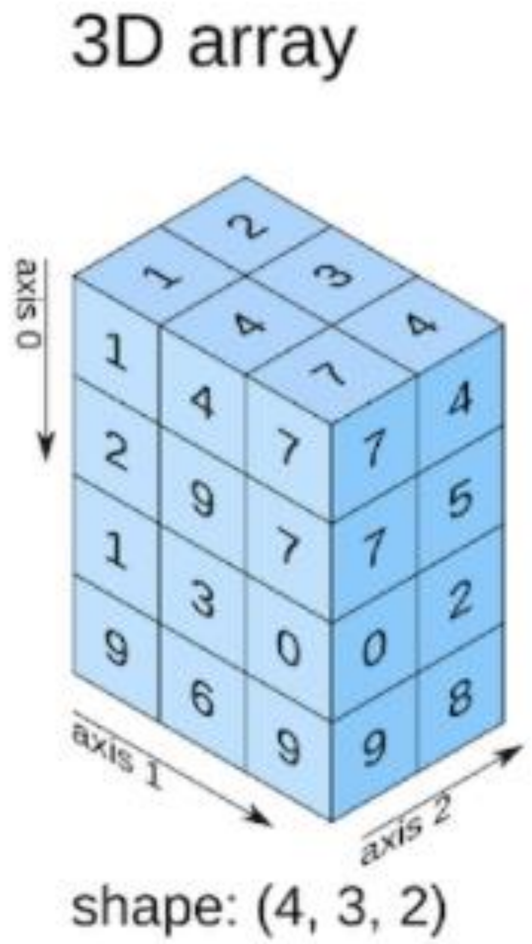
NumPy Key Features

- **Multidimensional arrays**
  - 1, 2, or higher-dimensional data
- **Efficient indexing, slicing and manipulation of array elements**
- **Mathematical/statistical functions** operating on arrays:
  - mean
  - max
  - log
  - …
- **Linear Algebra**
  - dot product
  - solving system of equations
  - …

N-dimensional array








```
np.array([7, 2, 9, 10])
```

```
np.array([(5.2, 3.0, 4.5),
          (9.1, 0.1, 0.3)])
```

Advantages of NumPy

- **Highly performant**
- **Memory efficient**
- Broad range of **operations relevant for data analysis and manipulation**
- **Linked to or interoperable with many other Python packages**
  - Pandas Series and DataFrames are built on numpy
  - Machine learning with scikit-learn expects numpy arrays as input,
  - Arrays can be visualized with matplotlib
  - Pytorch tensors are interoperable with numpy arrays
  - …

Characteristics of NumPy arrays

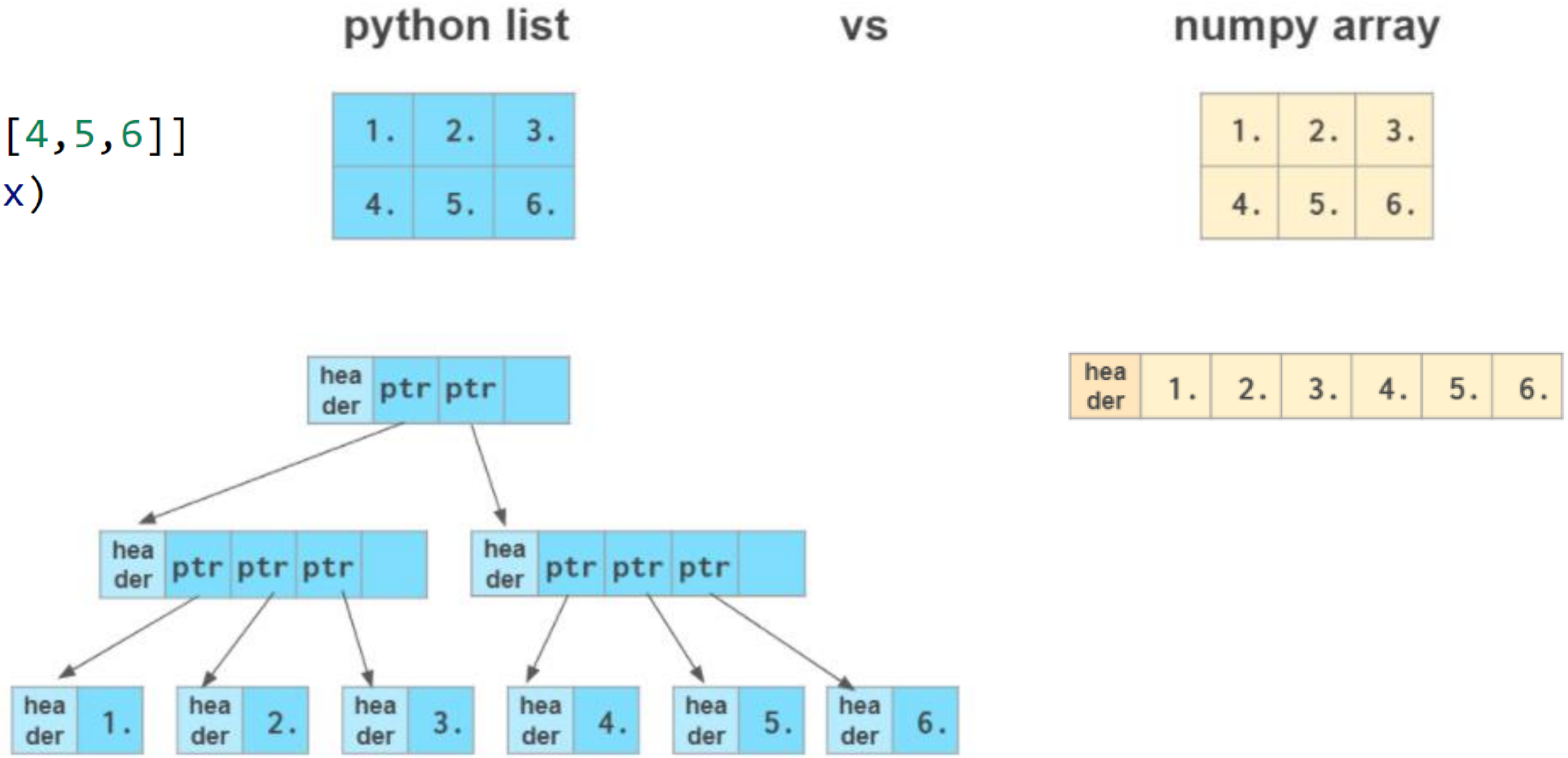
- **„Size-immutable“ / „fixed-size“:**
  - Once the numpy array is created its array size cannot be changed → the number of elements cannot be changed
  - Append, insert, remove leads to creation of a new array
- **“Element-mutable”**
  - Elements within the array can be modified in place → no new array is created
  - Modification of individual elements, slices, or more complex selections (e.g. based on some boolean criterium)

List vs NumPy array

Lists	Numpy Arrays
• Built-in • 1-dimensional • Heterogeneous items • Flexible resizing: adding or deleting elements can often occur in place • Not optimized for Math	• Not built-in • Multi-dimensional • Homogeneous items • Fixed size: adding or deleting items creates a new array • High performance math

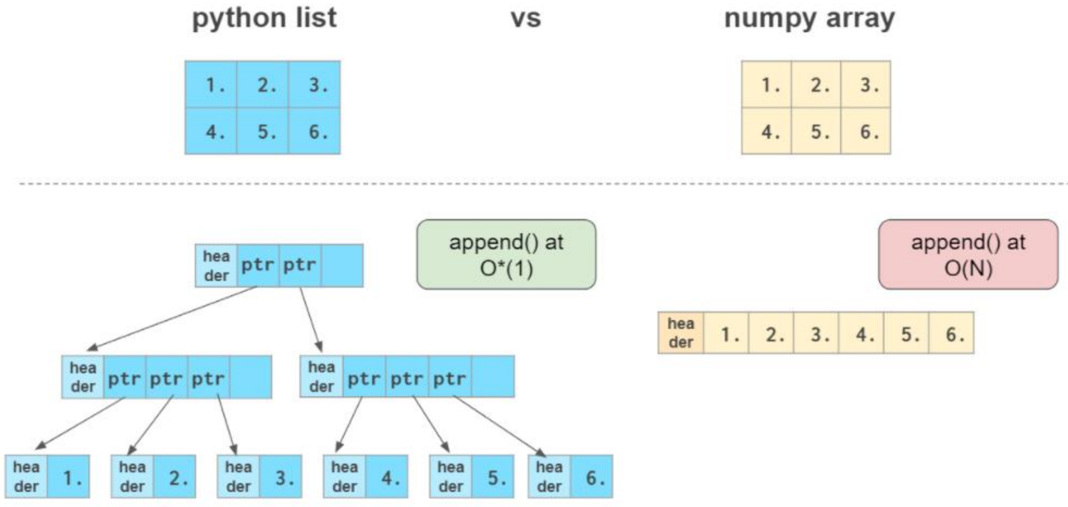
Why are Numpy arrays (usually) faster than lists?

```
x = [[1,2,3],[4,5,6]]
y = np.array(x)
```



Why are Numpy arrays (usually) faster than lists?

- Use **contiguous memory**
- Each element needs **less memory**
- **No type checking** needed when iterating through object
- **Vectorized operations**: For typical operations on arrays, we can avoid Python loops (slow) → Numpy implicitly delegates execution of loops to underlying C code



But: Slower if the size of the object changes (insert, append, delete)

Element-wise operations

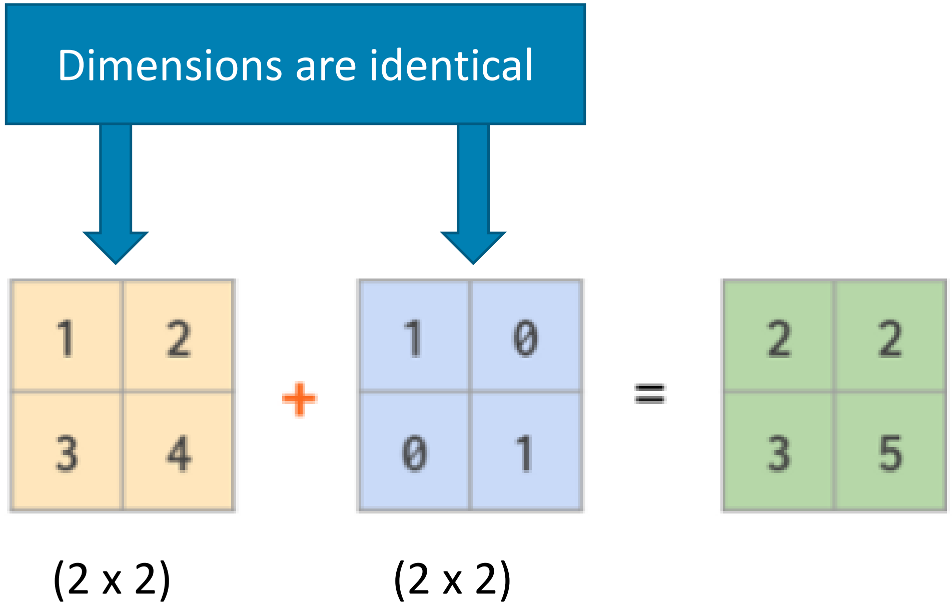
Vectorized operation: no Python loop needed

```python
squared = []
for number in [2, 3]:
    squared.append(number**2)
```

```python
np.array([2, 3])**2
```

$$a^2 \quad = \quad \begin{bmatrix} 2 & 3 \end{bmatrix} \; ** \; 2 \quad = \quad \begin{bmatrix} 4 & 9 \end{bmatrix}$$

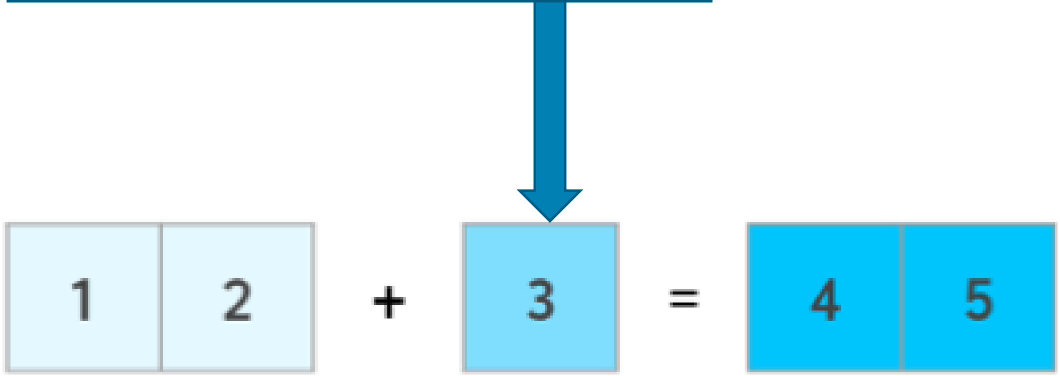
Element-wise operations



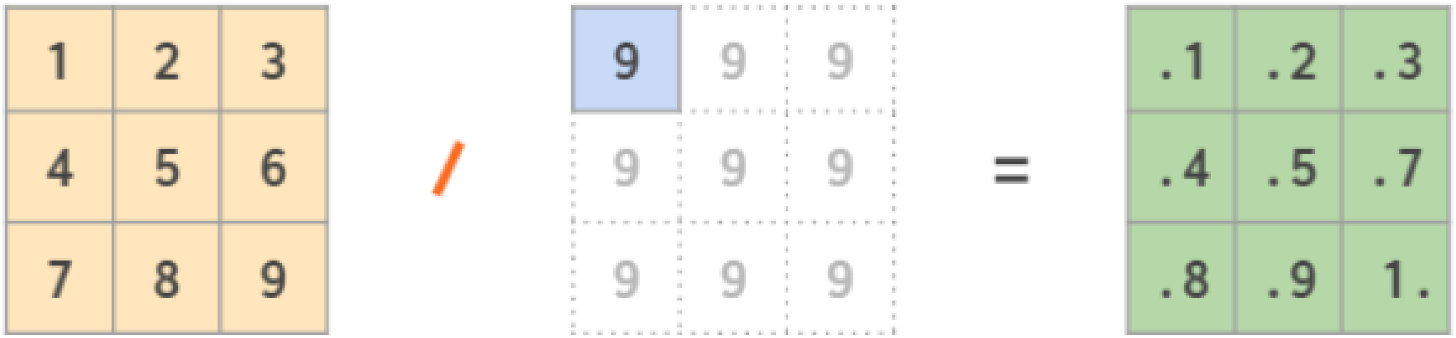

```
x = np.array([[1,2],[3,4]])
y = np.array([[1,0],[0,1]])
x + y
```

Broadcasting

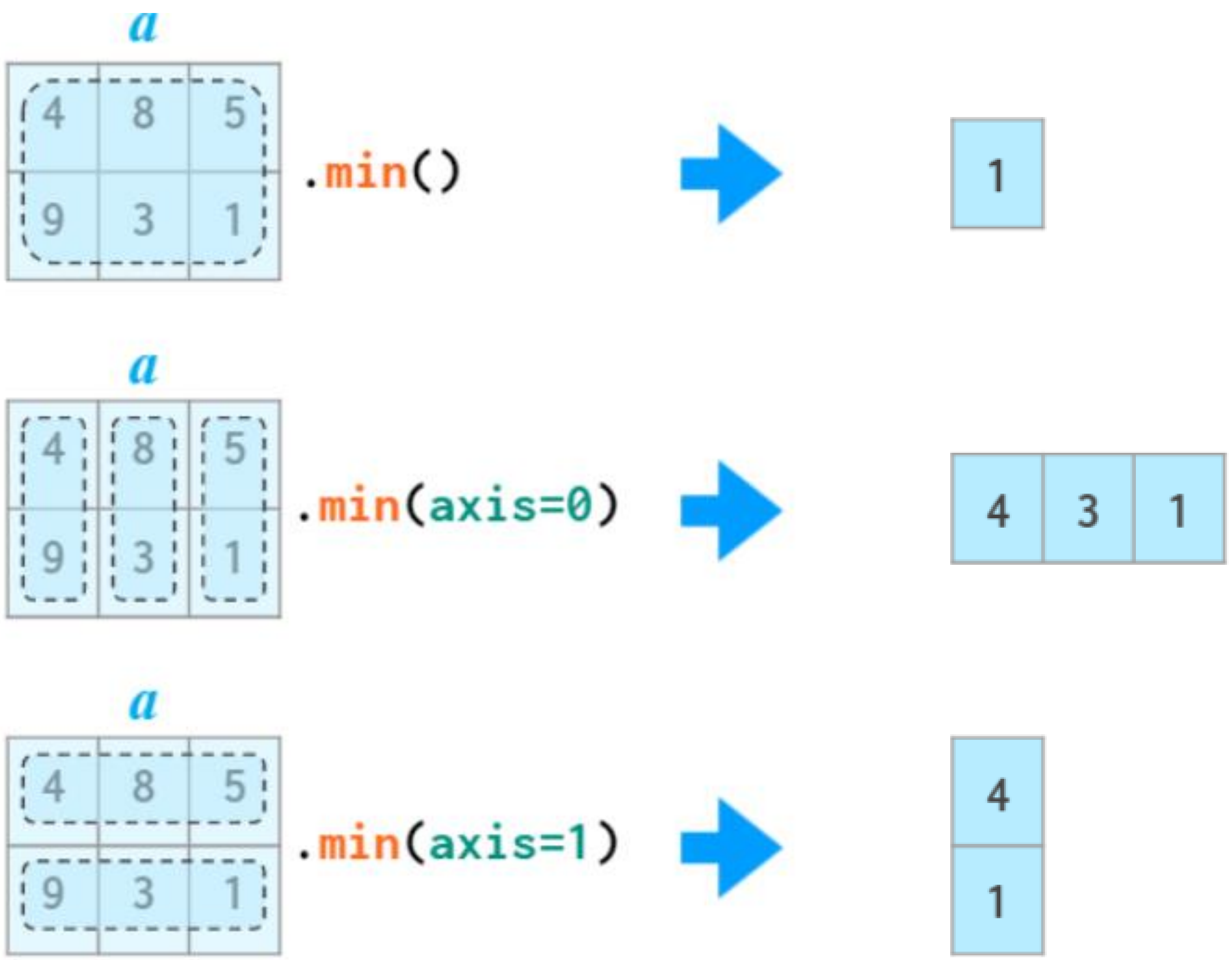
Dimensions of the smaller array are **broadcasted** to fit the dimensions of the larger array




```
np.array([1, 2]) + 3
```



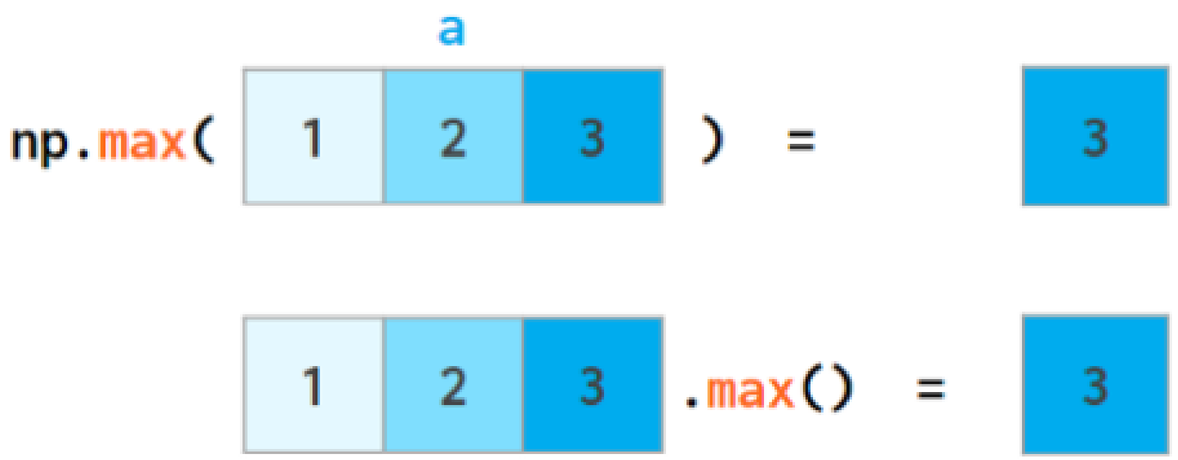
Statistics and the axis Argument



Other statistics / aggregation functions

- min
- max
- mean
- median
- sum
- std
- var
- …

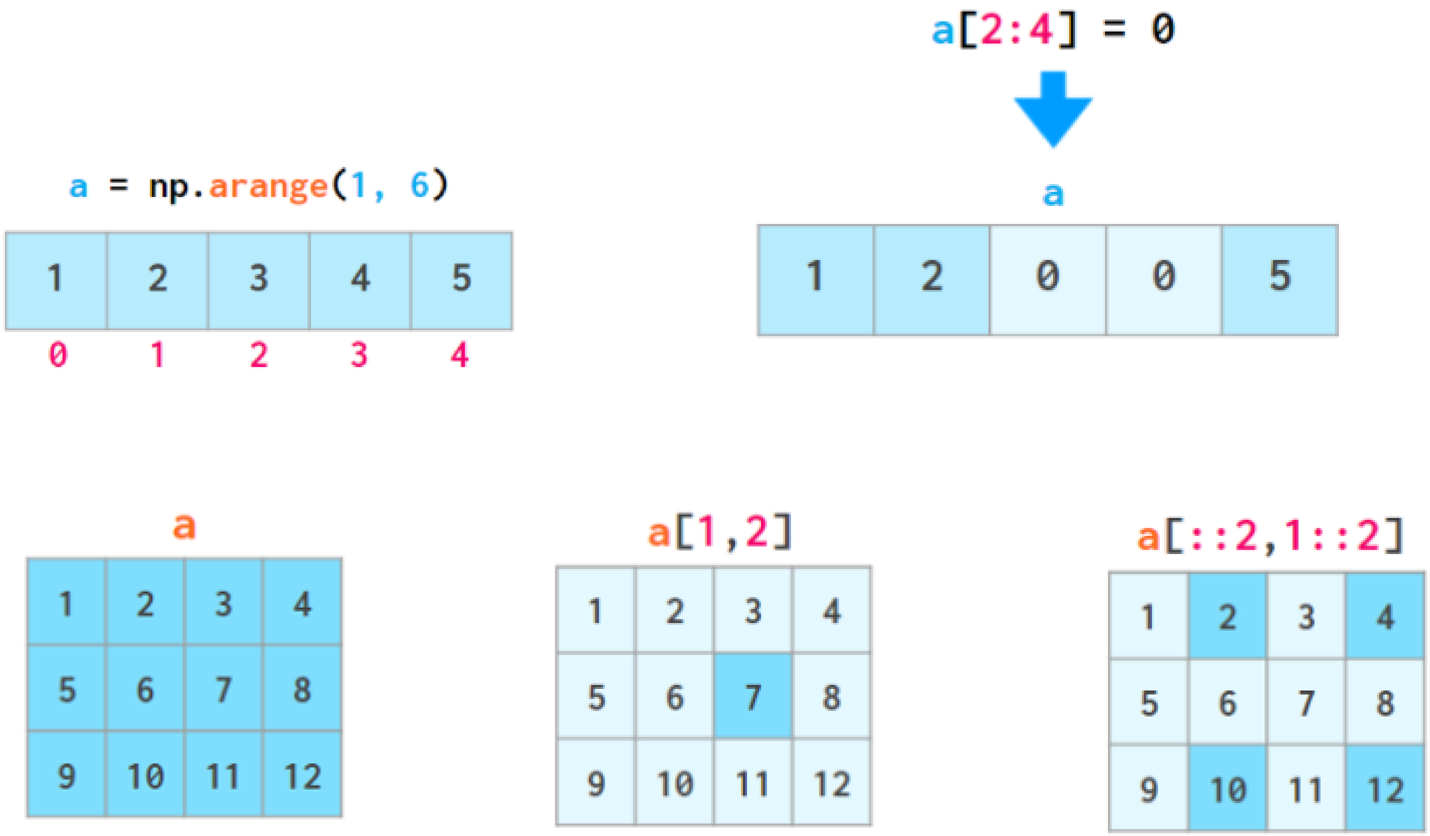
Two alternatives



Top-level function of the numpy module

Method of numpy arrays

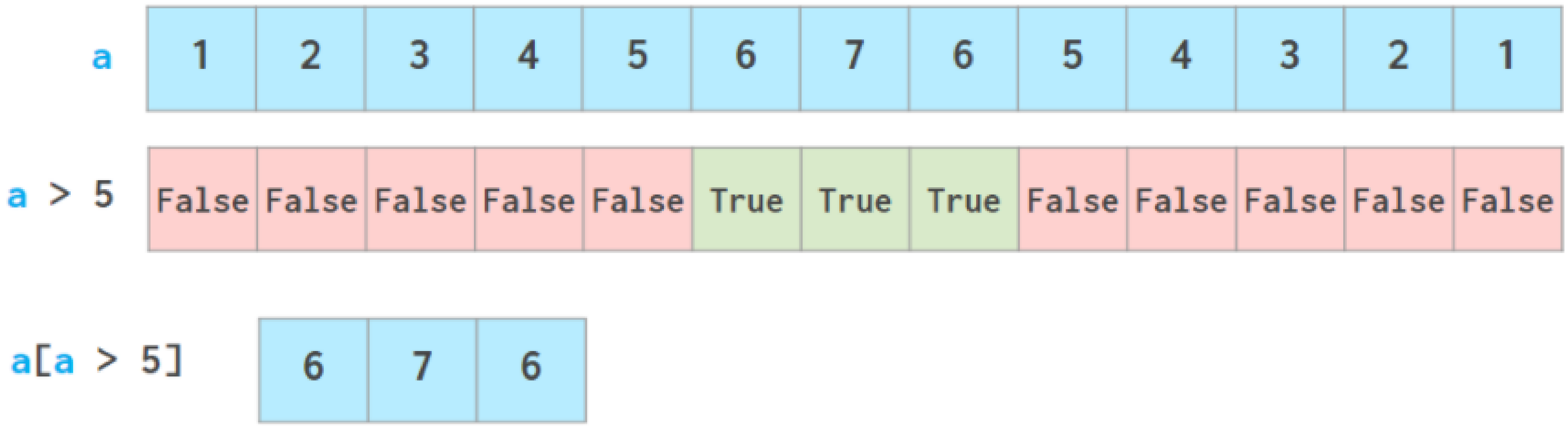
Indexing and Slicing



Similar to lists:

- Same indexing rules
- Applicable to any dimension
- Mutability: elements of an array can be changed in-place → potential side effects between multiple names pointing to the same numpy array

Boolean masking



Linear algebra

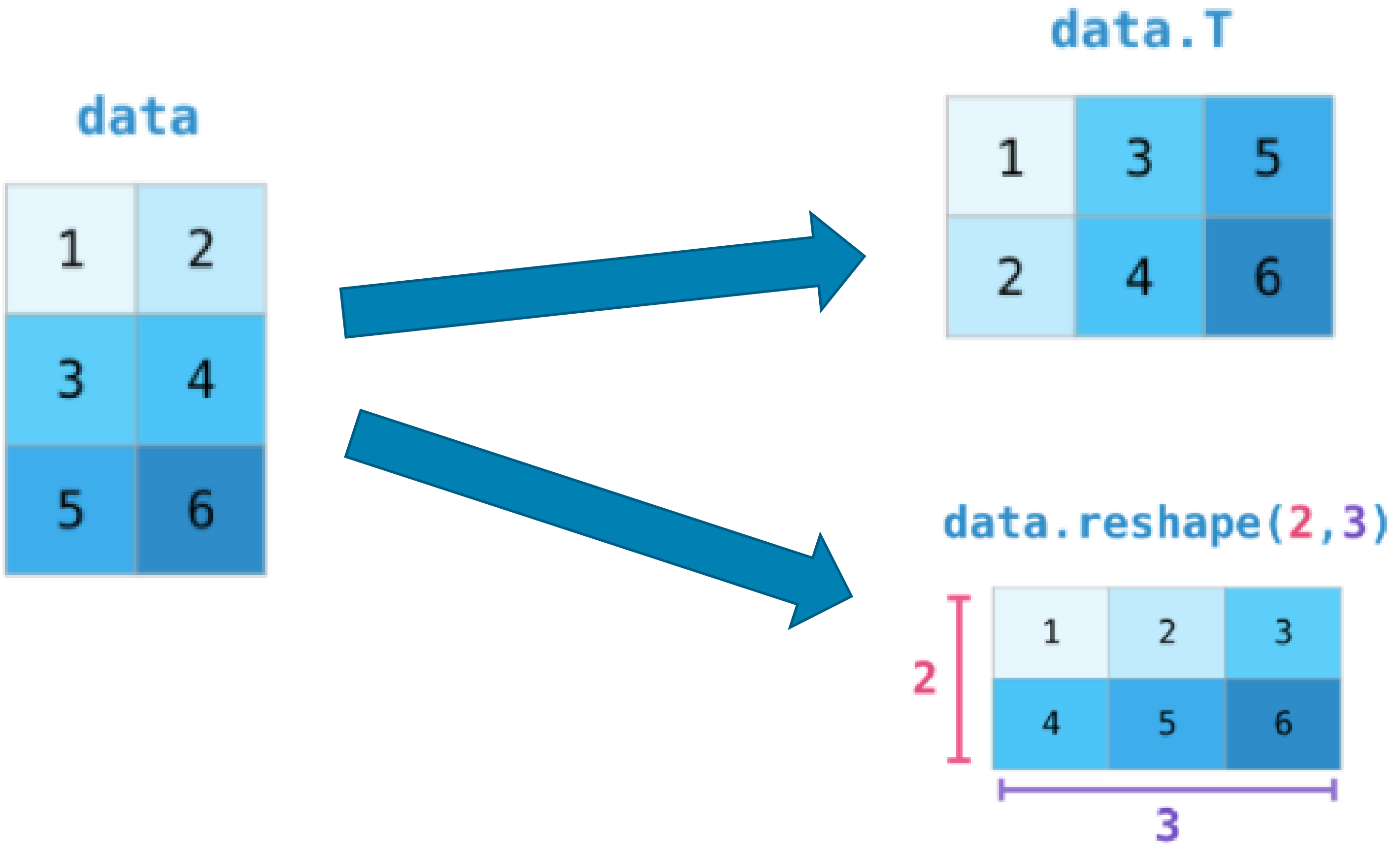
```
x = np.array([[1,2],[5,6],[7,8]])
y = np.array([3,4])

x.dot(y)
x @ y
```

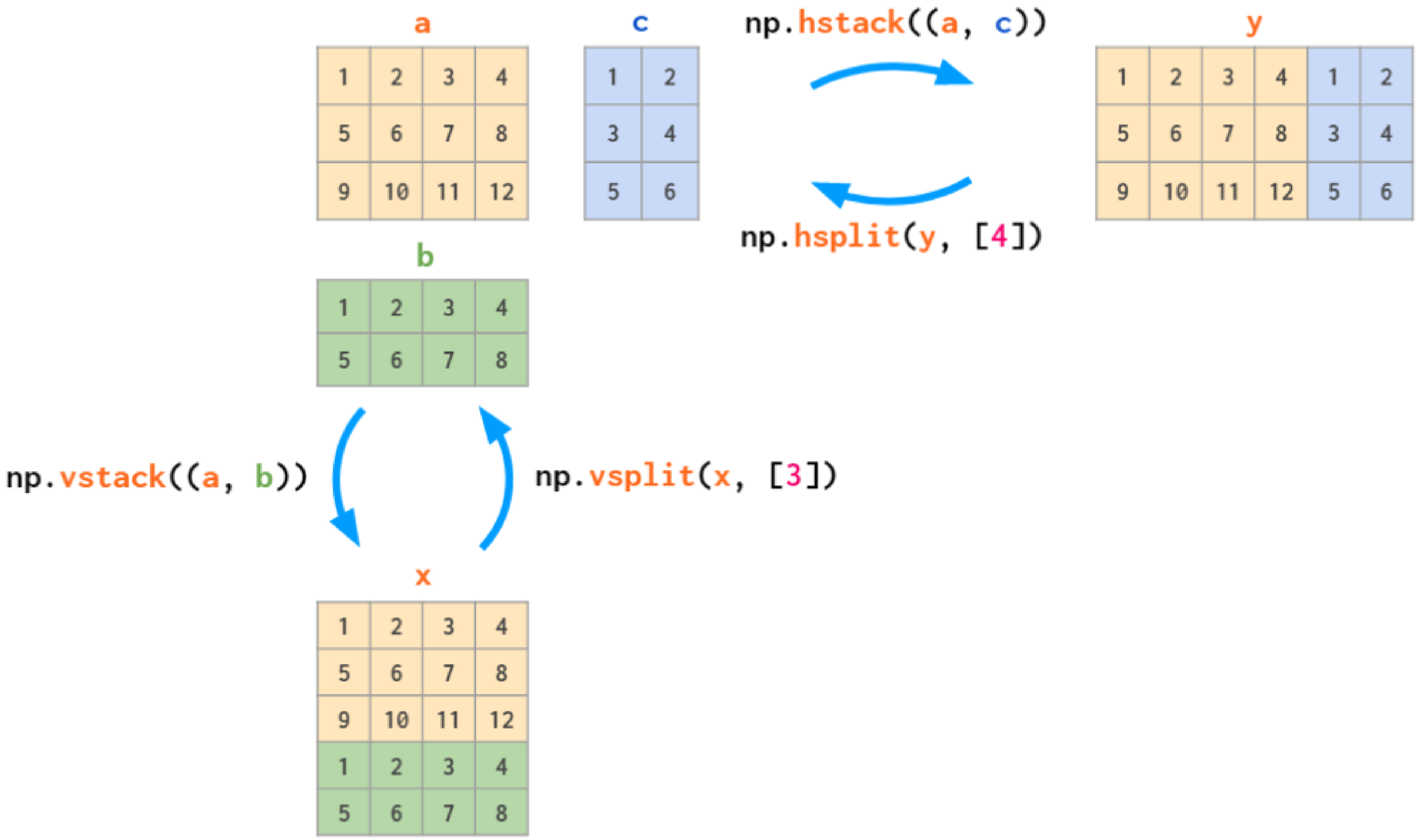
$$\begin{bmatrix}1&2\\5&6\\7&8\end{bmatrix}\cdot\begin{bmatrix}3\\4\end{bmatrix} \longrightarrow \begin{array}{c}\begin{bmatrix}3&4\end{bmatrix}\\ \begin{bmatrix}1&2\\5&6\\7&8\end{bmatrix}\end{array} = \begin{bmatrix}1\cdot3+2\cdot4\\5\cdot3+6\cdot4\\7\cdot3+8\cdot4\end{bmatrix} = \begin{bmatrix}11\\39\\53\end{bmatrix}$$

(3 x 2) (2 x 1) (3 x 1)

Transpose and reshape



Stacking and splitting



References

Visual guides to Numpy:

- https://betterprogramming.pub/numpy-illustrated-the-visual-guide-to-numpy-3b1d4976de1d
- http://jalammar.github.io/visual-numpy/