```
import numpy as np
```

Elementwise Operations

1. Basic Operations

with scalars

```
a = np.array([1, 2, 3, 4]) #create an array
```

```
a + 1
```

```
array([2, 3, 4, 5])
```

← output

```
a ** 2
```

```
array([ 1,  4,  9, 16])
```

←

All arithmetic operates elementwise

```
b = np.ones(4) + 1
```

→ [1., 1., 1., 1.] + 1 → [2., 2., 2., 2.]

```
a - b
```

it will do elementwise subtraction

```
array([-1.,  0.,  1.,  2.])
```

←

```
a * b
```

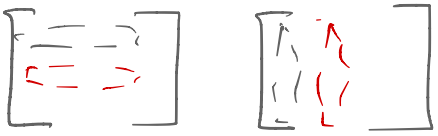
→ elementwise → In 1-D we do "elementwise" operations

```
array([ 2.,  4.,  6.,  8.])
```

←

```
# Matrix multiplication

c = np.diag([1, 2, 3, 4])

print(c * c)
print("******************")
print(c.dot(c))
```

←, ↩ → it is multiplying matrix - matrix multiplication



```
[[ 1  0  0  0]
 [ 0  4  0  0]
 [ 0  0  9  0]
 [ 0  0  0 16]]
******************
[[ 1  0  0  0]
 [ 0  4  0  0]
 [ 0  0  9  0]
 [ 0  0  0 16]]
```

comparisions

```
a = np.array([1, 2, 3, 4])
b = np.array([5, 2, 2, 4])
a == b
```

again "elementwise" comparision.

```
array([False,  True, False,  True], dtype=bool)
```

```
a > b
```

```
array([False, False,  True, False], dtype=bool)
```

```
#array-wise comparisions
a = np.array([1, 2, 3, 4])
b = np.array([5, 2, 2, 4])
c = np.array([1, 2, 3, 4])
```

```
np.array_equal(a, b)
```

comparing whole array

```
False
```

```
np.array_equal(a, c)
```

```
True
```

Logical Operations → "elementwise"

```
a = np.array([1, 1, 0, 0], dtype=bool)
b = np.array([1, 0, 1, 0], dtype=bool)
```

```
np.logical_or(a, b)
```

"elementwise"

```
array([ True,  True,  True, False], dtype=bool)
```

```
np.logical_and(a, b)
```

```
array([ True, False, False, False], dtype=bool)
```

Transcendental functions: → elementwise

```
a = np.arange(5)
```

```
np.sin(a)
```

you can't use just 'sin(a)'. You'll have to use 'np'.

```
array([ 0.        ,  0.84147098,  0.90929743,  0.14112001, -
0.7568025 ])
```

```
np.log(a)
```

```
/Users/satishatcha/.virtualenvs/course/lib/python2.7/site-packages/
ipykernel_launcher.py:1: RuntimeWarning: divide by zero encountered in
log
  """Entry point for launching an IPython kernel.

array([       -inf,  0.        ,  0.69314718,  1.09861229,
1.38629436])
```

```
np.exp(a)   #evaluates e^x for each element in a given input

array([  1.        ,   2.71828183,   7.3890561 ,  20.08553692,
54.59815003])
```

Shape Mismatch

```
a = np.arange(4)
```
→ 1-D array

```
a + np.array([1, 2])
```
→ size should be match in 1-D array.

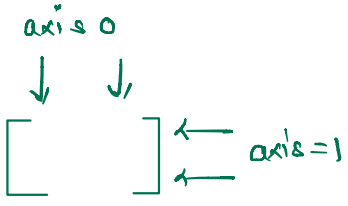
```
---------------------------------------------------------------------------
-----
ValueError                                Traceback (most recent call
last)
<ipython-input-19-f4d5ac434765> in <module>()
      1 a = np.arange(4)
      2
----> 3 a + np.array([1, 2])

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

Basic Reductions

computing sums → the result array has always one less dimensi.

```
x = np.array([1, 2, 3, 4])
np.sum(x)

10

#sum by rows and by columns

x = np.array([[1, 1], [2, 2]])
x

array([[1, 1],
       [2, 2]])

x.sum(axis=0)   #columns first dimension

array([3, 3])
```
→ 1-D (coz 1 square bracket)

```
x.sum(axis=1)  #rows (second dimension)

array([2, 4])
```
→ 1-D



→ for 3-D array, the axis will go from → 0, 1, 2

Other reductions

```
x = np.array([1, 3, 2])
x.min()
```

argmin → 0 , argmax → 2

[1, 3, 2]

```
x.max()
```

→ 3

```
x.argmin()# index of minimum element
```

→ 0

```
x.argmax()# index of maximum element
```

→ 1

```
import numpy as np
a = np.array([[[1,1,1],[2,2,2]],[[3,3,3],[4,4,4]]])
print(a)
print(a.sum(axis = 0))
print(a.sum(axis = 1))
print(a.sum(axis = 2))
```

→ we can use .sum on 3D of n-D array too.

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

 [[3 3 3]
  [4 4 4]]]
[[4 4 4]
 [6 6 6]]
[[3 3 3]
 [7 7 7]]
[[ 3  6]
 [ 9 12]]
```

Logical Operations

```
np.all([True, True, False])
```

→ if all true

False

```
np.any([True, False, False])
```

True

```
#Note: can be used for array comparisions
a = np.zeros((50, 50))
np.any(a != 0)
```

→ [0 - - - 0] 50 × 50

→ False

```
np.all(a == a)
```

→ True

```
a = np.array([1, 2, 3, 2])
b = np.array([2, 2, 3, 2])
c = np.array([6, 4, 4, 5])
((a <= b) & (b <= c)).all()
```

(a <= b) → [T, T, T, T]

& (b <= c) → [T, T, T, T]

[T, T, T, T].all()

[T, T, T, T]

True ←

So here in one-line of code you have compared three arrays.

Statistics

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

x → 1-D, y → 2-D

1.75 ←

```
np.median(x)
```

1.5 ←

```
np.median(y, axis=-1) # last axis (axis → -1)
```

Same as axis = 1

this operation happen with every row.

y = [1 2 3 / 5 6 1] ← axis -1

```
array([ 2.,  5.])

x.std()          # full population standard dev.

0.82915619758884995
```

Example:

Data in populations.txt describes the populations of hares and lynxes (and carrots) in northern Canada during 20 years.

```
#load data into numpy array object
data = np.loadtxt('populations.txt')

data
```

→ we commented this variable name coz we want to use it as a 'variable name' not as a element.

```
array([[  1900.,  30000.,   4000.,  48300.],
       [  1901.,  47200.,   6100.,  48200.],
       [  1902.,  70200.,   9800.,  41500.],
       [  1903.,  77400.,  35200.,  38200.],
       [  1904.,  36300.,  59400.,  40600.],
       [  1905.,  20600.,  41700.,  39800.],
       [  1906.,  18100.,  19000.,  38600.],
       [  1907.,  21400.,  13000.,  42300.],
       [  1908.,  22000.,   8300.,  44500.],
       [  1909.,  25400.,   9100.,  42100.],
       [  1910.,  27100.,   7400.,  46000.],
       [  1911.,  40300.,   8000.,  46800.],
       [  1912.,  57000.,  12300.,  43800.],
       [  1913.,  76600.,  19500.,  40900.],
       [  1914.,  52300.,  45700.,  39400.],
       [  1915.,  19500.,  51100.,  39000.],
       [  1916.,  11200.,  29700.,  36700.],
       [  1917.,   7600.,  15800.,  41800.],
       [  1918.,  14600.,   9700.,  43300.],
       [  1919.,  16200.,  10100.,  41300.],
       [  1920.,  24700.,   8600.,  47300.]])
```

R1 R2 R3 R4

```
year, hares, lynxes, carrots = data.T #columns to variables
print(year)
```

```
[ 1900.  1901.  1902.  1903.  1904.  1905.  1906.  1907.  1908.  1909.
  1910.  1911.  1912.  1913.  1914.  1915.  1916.  1917.  1918.  1919.
  1920.]
```

→ this is array.

```
#The mean population over time
populations = data[:, 1:]
populations
```

take from 1st column to end.

take all the rows

0 1 2

```
array([[ 30000.,   4000.,  48300.],
       [ 47200.,   6100.,  48200.],
       [ 70200.,   9800.,  41500.],
```

```
       [ 77400.,  35200.,  38200.],
       [ 36300.,  59400.,  40600.],
       [ 20600.,  41700.,  39800.],
       [ 18100.,  19000.,  38600.],
       [ 21400.,  13000.,  42300.],
       [ 22000.,   8300.,  44500.],
       [ 25400.,   9100.,  42100.],
       [ 27100.,   7400.,  46000.],
       [ 40300.,   8000.,  46800.],
       [ 57000.,  12300.,  43800.],
       [ 76600.,  19500.,  40900.],
       [ 52300.,  45700.,  39400.],
       [ 19500.,  51100.,  39000.],
       [ 11200.,  29700.,  36700.],
       [  7600.,  15800.,  41800.],
       [ 14600.,   9700.,  43300.],
       [ 16200.,  10100.,  41300.],
       [ 24700.,   8600.,  47300.]])
```

```
#sample standard deviations
populations.std(axis=0)
```

```
array([ 20897.90645809,  16254.59153691,   3322.50622558])
```

```
#which species has the highest population each year?

np.argmax(populations, axis=1)
```

```
array([2, 2, 0, 0, 1, 1, 2, 2, 2, 2, 2, 2, 0, 0, 0, 1, 2, 2, 2, 2, 2])
```

Broadcasting

Basic operations on numpy arrays (addition, etc.) are elementwise

This works on arrays of the same size. Nevertheless, It's also possible to do operations on arrays of different sizes if NumPy can transform these arrays so that they all have the same size: this conversion is called broadcasting.

The image below gives an example of broadcasting:

title

tile func

copy '3' times row

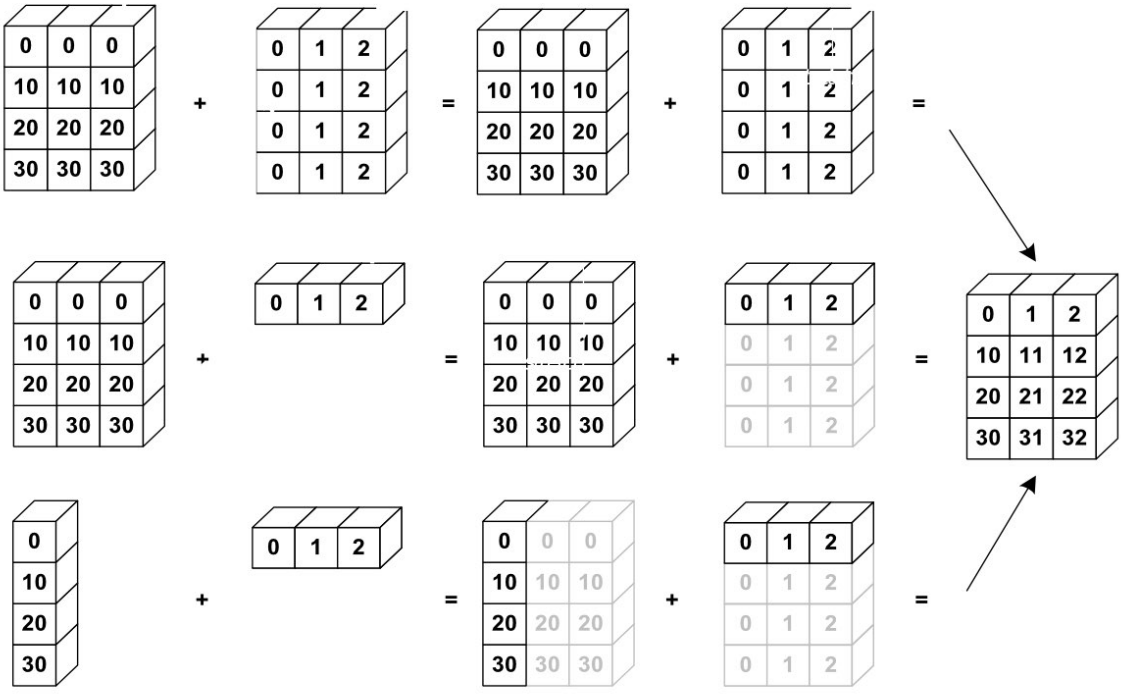
copy '1' time column

```
a = np.tile(np.arange(0, 40, 10), (3,1))
print(a)

print("**************")
a=a.T
print(a)
```

↳ way of making 2-D matrix

```
[[ 0 10 20 30]
 [ 0 10 20 30]
```

2-D array don't follow element wise



```
 [ 0 10 20 30]]
*************
[[ 0  0  0]
 [10 10 10]
 [20 20 20]
 [30 30 30]]
```

```
b = np.array([0, 1, 2])
b
```

→ [0, 1, 2]

```
array([0, 1, 2])
```

```
a + b
```

```
array([[ 0,  1,  2],
       [10, 11, 12],
       [20, 21, 22],
       [30, 31, 32]])
```

```
a = np.arange(0, 40, 10)
a.shape
```

→ [0, 10, 20, 30]

→ (4,) → 1-D array

```
a = a[:, np.newaxis]  # adds a new axis -> 2D array
a.shape
```

→ Converting 1-D array to 2-D array.

```
(4, 1)
```

```
a
```

→

```
array([[ 0],
       [10],
       [20],
       [30]])
```

```
a + b
```

(3rd Case) b = [0, 1, 2]

→

```
array([[ 0,  1,  2],
       [10, 11, 12],
       [20, 21, 22],
       [30, 31, 32]])
```

Array Shape Manipulation

Flattening

```
a = np.array([[1, 2, 3], [4, 5, 6]])
a.ravel() #Return a contiguous flattened array. A 1-D array,
```

→ 2D to 1D

```
    containing the elements of the input, is returned. A copy is made only
    if needed.
```

→
```
array([1, 2, 3, 4, 5, 6])
```

```
a.T #Transpose
```

→
```
array([[1, 4],
       [2, 5],
       [3, 6]])
```

```
a.T.ravel()
```

```
array([1, 4, 2, 5, 3, 6])
```

Reshaping

The inverse operation to flattening:

```
print(a.shape)
print(a)
```

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

```
b = a.ravel()
print(b)
```

→
```
[1 2 3 4 5 6]
```

```
b = b.reshape((2, 3))
b
```

! - - - - -> to Convert 1D to 2D

→
```
array([[1, 2, 3],
       [4, 5, 6]])
```

```
b[0, 0] = 100
a
```

→ print(a)

↪
```
array([[100,   2,   3],
       [  4,   5,   6]])
```

[reshape sometime does "copy" instead of "view". They are sharing same location.]

Note and Beware: reshape may also return a copy!:

```
a = np.zeros((3, 2))
b = a.T.reshape(3*2)
b[0] = 50
a
```

→ here, "reshape" is "copying" not "viewing".

```
array([[ 0.,  0.],
       [ 0.,  0.],
       [ 0.,  0.]])
```

Adding a Dimension

Indexing with the np.newaxis object allows us to add an axis to an array

newaxis is used to increase the dimension of the existing array by one more dimension, when used once. Thus,

1D array will become 2D array

2D array will become 3D array

3D array will become 4D array and so on

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

```
array([1, 2, 3])
```

```
z[:, np.newaxis]
```

```
array([[1],
       [2],
       [3]])
```

Dimension Shuffling

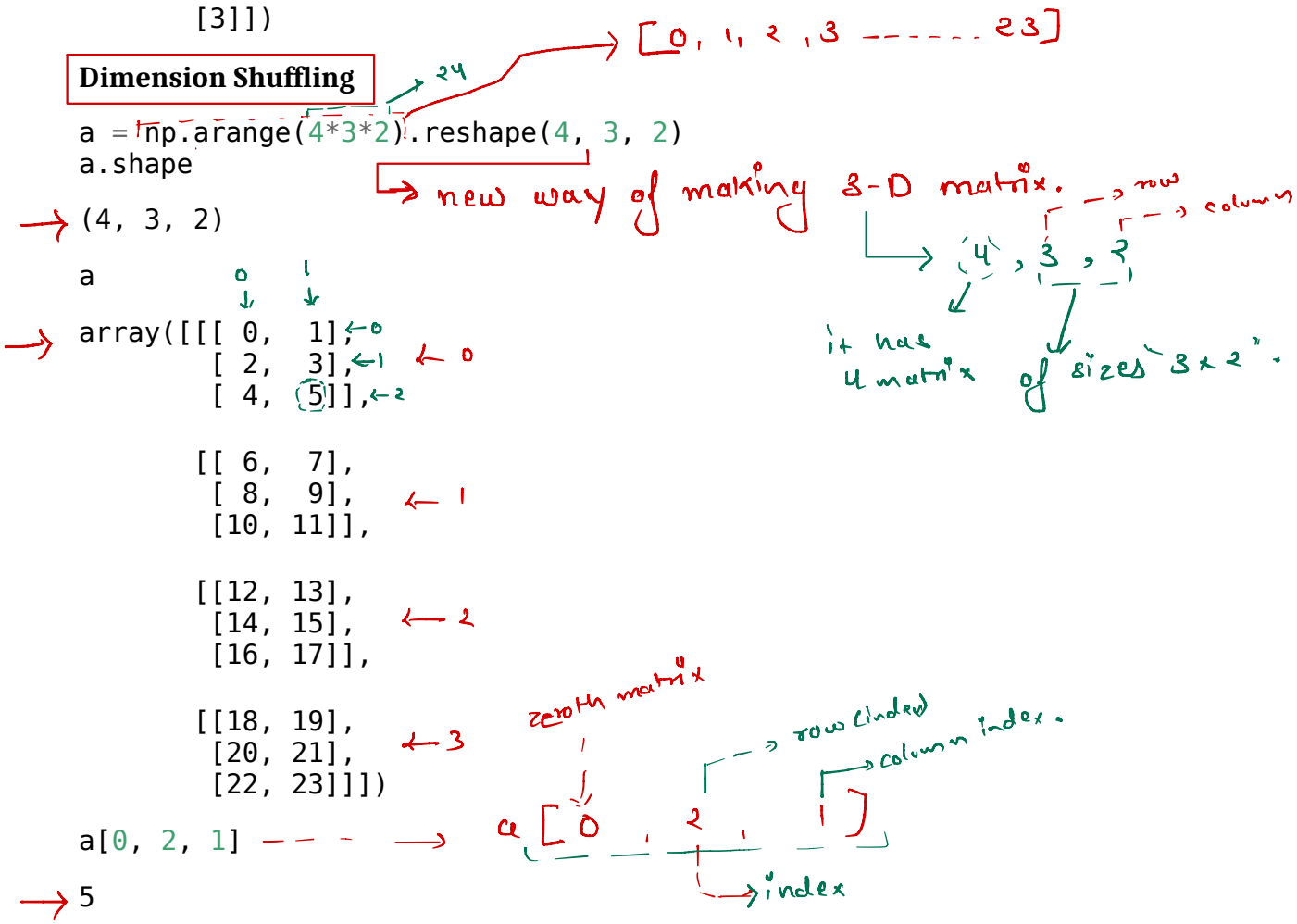
```
a = np.arange(4*3*2).reshape(4, 3, 2)
a.shape
```

```
(4, 3, 2)
```

```
a
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]]])
```

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

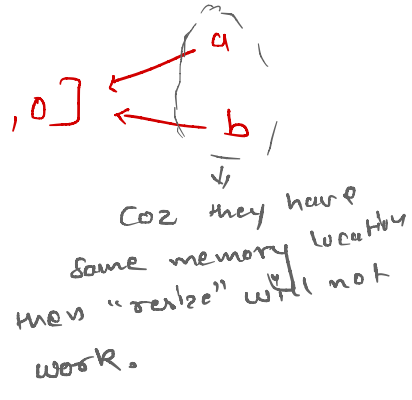
```
5
```



Resizing

```
a = np.arange(4)
a.resize((8,))
a
```

```
array([0, 1, 2, 3, 0, 0, 0, 0])
```



However, it must not be referred to somewhere else:

```
b = a
a.resize((4,))
```

```
---------------------------------------------------------------------------
ValueError                                Traceback (most recent call last)
<ipython-input-68-702766c88583> in <module>()
      1 b = a
----> 2 a.resize((4,))

ValueError: cannot resize an array that references or is referenced
by another array in this way.  Use the resize function
```

Sorting Data

```
#Sorting along an axis:
a = np.array([[5, 4, 6], [2, 3, 2]])
b = np.sort(a, axis=1)
b
```

```
array([[4, 5, 6],
       [2, 2, 3]])
```

```
#in-place sort
a.sort(axis=1)
a
```

```
array([[4, 5, 6],
       [2, 2, 3]])
```

```
#sorting with fancy indexing
a = np.array([4, 3, 1, 2])
j = np.argsort(a)
j
```

```
array([2, 3, 1, 0])
```

```
a[j]
```

```
array([1, 2, 3, 4])
```