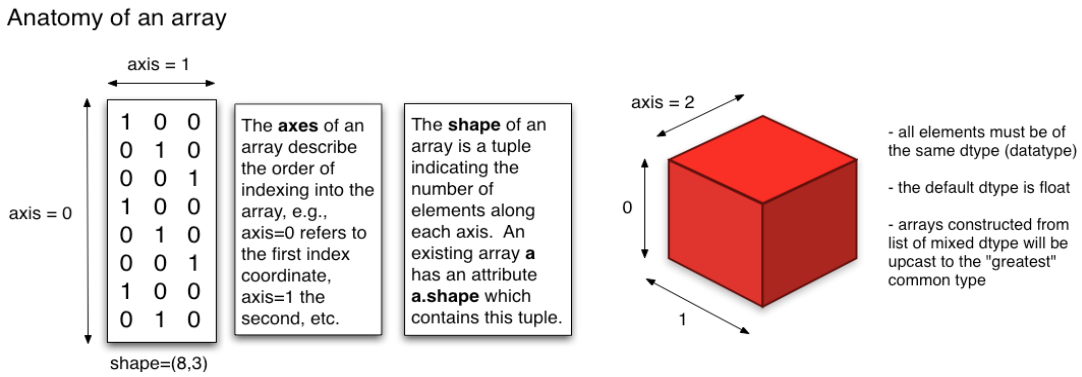
scipy array tip sheet

Arrays are the central datatype introduced in the SciPy package. (The same array objects are accessible within the NumPy package, which is a subset of SciPy. For consistency, we will simplify refer to to SciPy, although some of the online documentation makes reference to NumPy. And technically, array objects are of type `ndarray`, which stands for "n-dimensional array".) The array interface is accessible by importing the scipy module: `import scipy`. Arrays are similar in some respects to Python lists, but are multidimensional, homogeneous in type, and support compact and efficient array-level manipulations. Documentation can be found online at www.scipy.org/Documentation, which also includes links to NumPy Examples (sample usage for many functions) and NumPy for MATLAB Users, if you're so inclined.



Constructing arrays

- `scipy.array(alist)`: construct an n-dimensional array from a Python list (all elements of list must be of same length)

```
a = scipy.array([[1,2,3],[4,5,6]])
b = scipy.array([i*i for i in range(100) if i%2==1])
c = b.tolist()                          # convert array back to Python list
```

- `scipy.zeros(shape, dtype=float)`: construct an n-dimensional array of the specified shape, filled with zeros of the specified dtype; e.g.,

```
a = scipy.zeros(100)                    # a 100-element array of float zeros
b = scipy.zeros((2,8), int)             # a 2x8 array of int zeros
c = scipy.zeros((N,M,L), complex)       # a NxMxL array of complex zeros
```

- `scipy.ones(shape, dtype=float)`: construct an n-dimensional array of the specified shape, filled with ones of the specified dtype; e.g.,

```
a = scipy.ones(10, int)                 # a 10-element array of int ones
b = scipy.pi * scipy.ones((5,5))        # a useful way to fill up an array with a specified value
```

- `scipy.eye(shape, dtype=float)`

```
id = scipy.eye(10,10, int)                          # 10x10 identity matrix (1's on diagonal)
offdiag = scipy.eye(10,10,1)+scipy.eye(10,10,-1)    # off diagonal elements = 1
```

- `scipy.transpose(a)`

```
b = scipy.transpose(a)                  # reverse dimensions of a (even for dim > 2)
b = a.T                                 # equivalent to scipy.transpose(a)
c = scipy.swapaxes(a, axis1, axis2)     # swap specified axes
```

- `scipy.arange` and `scipy.linspace`

```
a = scipy.arange(start, stop, increment)      # like Python range, but with (potentially) real-valued arrays
b = scipy.linspace(start, stop, num_elements) # create array of equally-spaced points based on specifed number of points
```

- Random array constructors in `scipy.random`

```
a = scipy.random.random((100,100))        # 100x100 array of floats uniform on [0.,1.)
b = scipy.random.randint(0,10, (100,))    # 100 random ints uniform on [0, 10), i.e., not including the upper bound 10
c = scipy.random.standard_normal((5,5,5)) # zero-mean, unit-variance Gaussian random numbers in a 5x5x5 array
```

Indexing arrays

- Multidimensional indexing

```
elem = a[i,j,k]       # equiv. to a[i][j][k] but presumably more efficient
```

- "Negative" indexing (wrap around the end of the array)

```
last_elem = a[-1]     # the last element of the array
```

- Arrays as indices

```
i = scipy.array([0,1,2,1])                  # array of indices for the first axis
j = scipy.array([1,2,3,4])                  # array of indices for the second axis
a[i,j]                                      # return array([a[0,1], a[1,2], a[2,3], a[1,4]])
b = scipy.array([True, False, True, False])
```

```
a[b]                                        # return array([a[0], a[2]]) since only b[0] and b[2] are True
```

Slicing arrays (extracting subsections)

- Slice a defined subblock:

```
section = a[10:20, 30:40]         # 10x10 subblock starting at [10,30]
```

- Grab everything up to the beginning/end of the array:

```
asection = a[10:, 30:]            # missing stop index implies until end of array
bsection = b[:10, :30]            # missing start index implies until start of array
```

- Grab an entire column(s)

```
x = a[:, 0]                       # get everything in the 0th column (missing start and stop)
y = a[:, 1]                       # get everything in the 1st column
```

- Slice off the tail end of an array

```
tail = a[-10:]                    # grab the last 10 elements of the array
slab = b[:, -10:]                 # grab a slab of width 10 off the "side" of the array
interior = c[1:-1, 1:-1, 1:-1]    # slice out everything but the outer shell
```

Element-wise functions on arrays

- Arithmetic operations

```
c = a + b      # add a and b element-wise (must be same shape)
d = e * f      # multiply e and f element-wise (NOT matrix multiplication)
g = -h         # negate every element of h
y = (x+1)%2    # swap 0's and 1's in binary array x
z = w > 0.0    # return boolean array indicating which elements are > 0.0
logspace = 10.**scipy.linspace(-6.0, -1.0, 50)   # 50 equally-spaced-in-log points between 1.e-06 and 1.0e-01
```

- Trigonometric operations

```
y = scipy.sin(x)                                  # sin of every element of x
w = scipy.sin([i*i for i in range(100) if i%2==1])  # conversion from list to array as part of function application
z = scipy.exp((0.+1.j) * theta)                   # exp(i * theta) where i = sqrt(-1) = 0.+1.j
```

Summation of arrays

- Simple sums

```
s  = scipy.sum(a)             # sum all elements in a, returning a scalar
s0 = scipy.sum(a, axis=0)     # sum elements along specified axis (=0), returning an array of remaining shape, e.g.,
a  = scipy.ones((10,20,30))
s0 = scipy.sum(a, axis=0)     # s0 has shape (20,30)
```

- Averaging, etc.

```
m = scipy.mean(a, axis)       # compute mean along the specified axis (over entire array if axis=None)
s = scipy.std(a, axis)        # compute standard deviation along the specified axis (over entire array if axis=None)
```

- Cumulative sums

```
s0 = scipy.cumsum(a, axis=0)  # cumulatively sum over 0 axis, returning array with same shape as a
s0 = scipy.cumsum(a)          # cumulatively sum over 0 axis, returning 1D array of length shape[0]*shape[1]*...*shape[dim-1]
```

Various other useful functions and methods (see NumPy Examples at www.scipy.org/Numpy_Example_List_With_Doc)

Many of these work both as separate functions (`scipy.blah(a)`) as well as array methods (`a.blah()`).

- `scipy.any(a)`: return True if any element of a is True
- `scipy.all(a)`: return True if all elements of a are True
- `scipy.alltrue(a, axis)`: perform logical_and along given axis of a
- `scipy.append(a, values, axis)`: append values to a along specified axis
- `scipy.concatenate((a1, a2, ...), axis)`: concatenate tuple of arrays along specified axis
- `scipy.min(a, axis=None)`, `scipy.max(a, axis=None)`: get min/max values of a along specified axis (global min/max if axis=None)
- `scipy.argmin(a, axis=None)`, scipy.argmax(a, axis=None): get indices of min/max of a along specified axis (global min/max if axis=None)
- `scipy.reshape(a, newshape)`: reshape a to newshape (must conserve total number of elements)
- `scipy.matrix(a)`: create matrix from 2D array a (matrices implement matrix multiplication rather than element-wise multiplication)
- `scipy.histogram, scipy.histogram2d, scipy.histogramdd`: 1-dimensional, 2-dimensional, and d-dimensional histograms, respectively
- `scipy.round(a, decimals=0)`: round elements of matrix a to specified number of decimals
- `scipy.sign(a)`: return array of same shape as a, with -1 where $a < 0$, 0 where $a = 0$, and +1 where $a > 0$
- `a.tofile(fid, sep="", format="%s")`: write a to specified file (fid), in either binary or ascii format depending on options
- `scipy.fromfile(file=, dtype=float, count=-1, sep='')`: read array from specified file (binary or ascii)
- `scipy.unique(a)`: return sorted unique elements of array a
- `scipy.where(condition, x, y)`: return array with same shape as condition, where values from x are inserted in positions where condition is True, and values from y where condition is False