Midterm Review 2023

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Section 1

Python Types: Containers

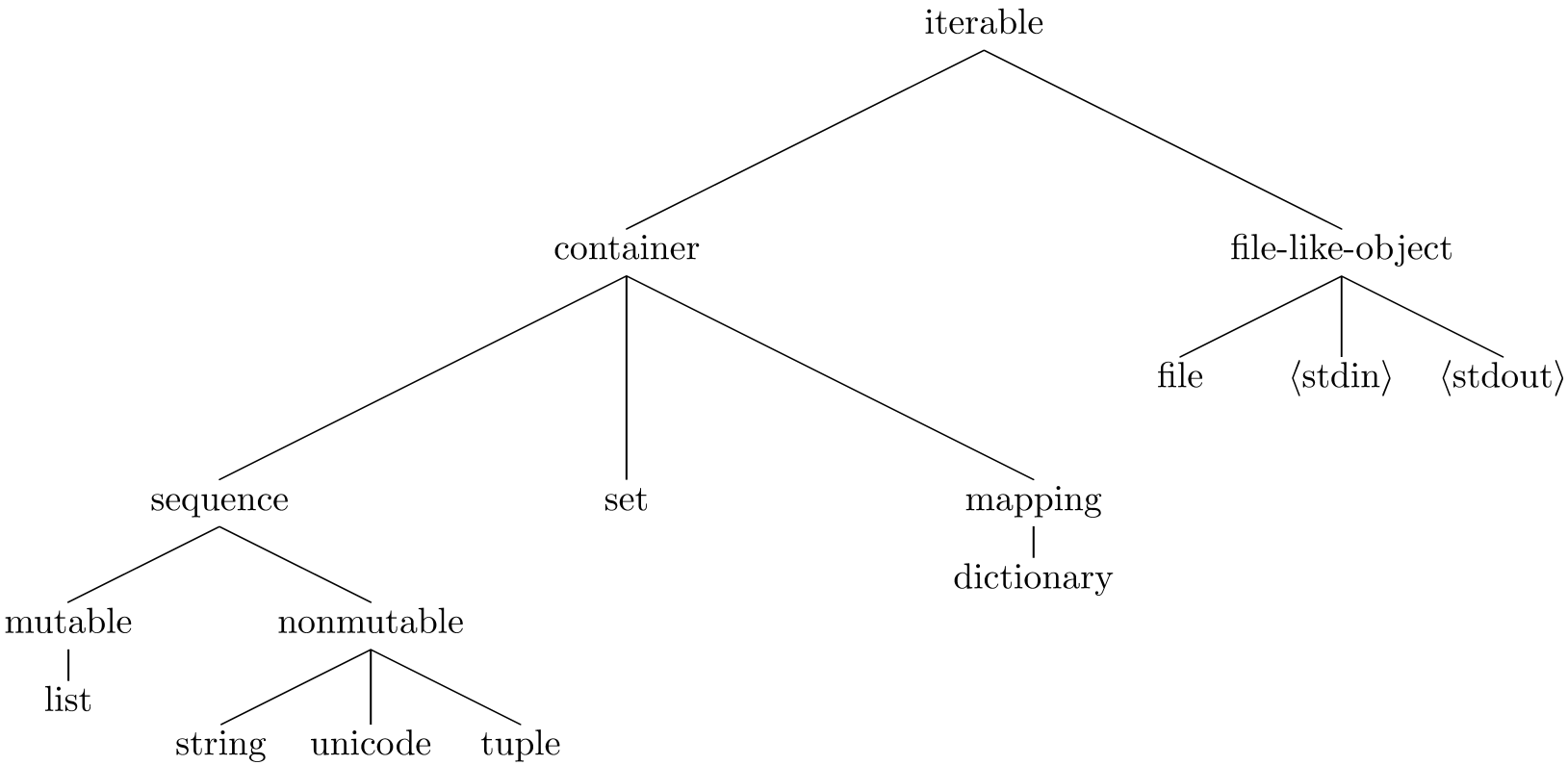
The Big Picture: Where containers fit

1. Simple Types
   - Numbers (three builtin numeric types, `int`, `float`, `complex`)
   - `bool` (`True`, `False`)
   - `NoneType` (`None`)
   - `type` (yes, `type` is a type, and `int`, `float`, `complex`, and `bool` are all instances of that type; `3.2`, `True`, and `None` are not.
2. Iterables includes **Containers** as well as File-like objects, enumerate instances, range instances, and something called generators, which are state-saving functions frozen in mid execution.

Section 2

Containers

Type tree



Python containers fall under **iterables**

String example

Strings are containers. What do they contain?

```
>>> X = 'abcde'
>>> 'c' in X     # X contains element 'c'
True
>>> len(X)       # How many elements does X have?
5
```

Every container supports the **in** test. Every container has a computable number of elements (**len** function).

Most important Python type concepts

- Iterables: Can be looped through. All containers are iterables; on the Midterm we focus on containers.
- Containers: Iterables which have length and support the `in` test)
  1. Sequences (as Containers have length, support `in`)
     1. `Tuples, Lists, Strings` (there are other builtin Python sequence types, but not on this midterm).
     2. Sequences contain data in a fixed order.
     3. Data can be indexed by position (integers).
     4. Indexing data by a non-integer is a `TypeError`.
  2. Non-Sequence Containers (Sets and Dictionaries)
     1. Dictionary is a Mapping; key $\mapsto$ value
     2. Set: Unordered, no duplicates

List example

Lists can contain just about any data type

```
>>> L = [24, 3.14, 'w', [1,'a']]
>>> len(L)                          # 4 items
4
>>> 24 in L                         # container supports in test
True
>>> L[2]                            # Indexing by position
'w'
>>> [1,'a'] in L                    # This list contains a list
True
>>> Z = []                          # empty list, length 0
```

General features

1. Every container has an empty version
2. Every container has a delimiter that can be used when listing elements
3. Every type can be used as a function to create new instances

Type	Delimiter	Empty	Function	
list	[...]	[]	list('abc')	['a', 'b', 'c']
tuple	(...)	( )	tuple('abc')	('a', 'b', 'c')
string	"..."	" "	str('abc')	'abc'
dictionary	$\{key : val, \ldots\}$	{ }		
set	{...}	set()	set('abc')	{'c', 'b', 'a'}

Sequences as ordered data

```
>>> L
[24, 3.14, 'w', [1, 'a']]
>>> L[0]     # 1st element, 0-based indices
24
>>> L[1]     # 2nd element
3.14
>>> L[-1]    # last element
[1, 'a']
>>> L[4]     # Raises IndexError
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
IndexError: list index out of range
```

Note: Everuything on this slides works for all sequences, not just lists

Sequence slices

```
>>> L
[24, 3.14, 'w', [1, 'a']]
>>> L[1:3] # sublist of 2nd and 3rd elements
[3.14, 'w']
>>> L[:-1] # sublist excluding last element
[24, 3.14, 'w']
```

S[m:n]: a subsequence containing n-m elements, starting at S[m] and going up through S[n-1]:

Sequence slices II

All sequence indexing works the same

```
>>> T = (23, -1, 'September')
>>> G = 'lawyer'
>>> T[0:2] # Tuple of 1st and 2nd elements
(23, -1)
>>> G[0:2] # T[0:2] # String with 1st and 2nd chars
'la'
>>> T[:-1] # excluding last element
(23, -1)
>>> G[:-1] # excluding last char
'lawye'
```

Dictionaries are mappings I

Represent a systematic mapping **from** one kind of data (keys) **to** another (values).

New York	8,175,133
Los Angeles	3, 792,621
Chicago	2,695,598
Houston	2.099,451

```
{'New York':    8175133,
 'Los Angeles': 3792621,
 'Chicago':     2695598,
 'Houston':     2099451
 }
```

Dictionaries II

```
>>> dd1 = dict([('a',23),('b',-1),('f','September')])
>>> dd1
{'a': 23, 'b': -1, 'f': 'September'}
>>> dd = {'a': 23, 'b': -1, 'f': 'September'}
>>> dd['f']     # element associated with key 'f'
'September'
>>> dd['c']     # Raises KeyError (no IndexError)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
KeyError: 'c'
```

Data is accessed by key, not by a numerical index. Not sequences. In classic python, there is no notion of order in a dictionary.

Sets: No order, no duplicates

```
>>> ss = {23, 'b',  'September'}
>>> ss.add('c')
>>> ss          # can add elements
{'September', 'c', 'b', 23}
>>> ss.add('c')
>>> ss          # no effect, no duplicates
{'September', 'c', 'b', 23}
>>> ss.remove('c')    #  Can remove by key
>>> ss
{'September', 'b', 23}
>>> ss.remove('d')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
KeyError: 'd'
```

Assigning Values/Updating

```
>>> result =  ['January', 'February', 'March', 'April']
>>> result[1] = 'September'  # 2nd element -> 'September'
>>> result
['January', 'September', 'March', 'April']
>>> result[0:2] = ['December']
>>> result                   # First 2 elements changed
['December', 'March', 'April']
```

Expression on the left of = is the same expression that is used for indexing the container. Expression on the right is the new value creating/overwriting data at that index.

Assigning Values Dictionary

```
>>> dd
{'a': 23, 'b': -1, 'f': 'September'}
>>> dd['a'] = 25
>>> dd                    # New value for old key
{'a': 25, 'b': -1, 'f': 'September'}
>>> dd['e'] = 22
>>> dd                    # New key, new value
{'a': 25, 'b': -1, 'f': 'September', 'e': 22}
```

Expression on the left of = is the same expression that is used for indexing a dictionary. Expression on the right is the new value creating/overwriting data at that index.

Mutability

```
>>> G = 'back'
>>> G[0] = 's'     # Strings are immutable
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'str' object does not support item assignment
```

Trying to assign to/update a mutable type is a TypeError

Mutability Summary

Mutable	Immutable
list	tuple
dict	??
set	frozenset
??	str

Trying to assign to/update a mutable type is a `TypeError`

Non-Updates

```
>>> G
'back'
>>> G + 's'
'backs'
>>> G  # This didnt change G, so OK
'back'
```

The + operator concatenates sequences together, makes copies of the two sequences, no updating (works with all sequences)

Updating methods

```
>>> L
[24, 3.14, 'w', [1, 'a']]
>>> L.append('s')
>>> L  # This changes L
[24, 3.14, 'w', [1, 'a'], 's']
```

Not on midterm (`.append(...)`, `.extend(...)`, `.add(...)`)

Summary of basic container properties

Type	Sequence?	Mutable?	Contents
list	yes	yes	unrestricted
tuple	yes	no	unrestricted
set	no	yes	immutable
frozenset	no	**no**	immutable
string	yes	no	i in string $\Rightarrow$ i is a string
dict	no	yes	key must be immutable

Section 3

Loops, Functions, Conditionals

Loops

```
>>> L2 = ['zaza', 'baba', 'dcdc', 'mlml']
>>> res1 = [ ]
>>> for x in L2:
...     if x not in ['baba','cbcb']:
...         res1.append(x)
...
>>> res1
['zaza', 'dcdc', 'mlml']
>>> res2 = [x for x in L2 if x not in ['baba','cbcb']]
>>> res2
['zaza', 'dcdc', 'mlml']
```

Functions

```
>>> [x for x in L2 if x not in ['baba','cbcb']]
['zaza', 'dcdc', 'mlml']
>>> def filter_from(Seq1, Seq2):
...     return [x for x in Seq1 if x not in Seq2]
...
>>> beatles = ['john','paul','george', 'ringo']
>>> wings = ['paul','linda','denny']
>>> res3 = filter_from(beatles, wings)
>>> res3
['john', 'george', 'ringo']
```

Function calls

Define a function `filter_from_upper` that upper cases all the elements of sequence that do not belong to a second given sequence. It should call `filter_from`.

```
>>> def filter_from_upper(Seq1, Seq2):
...     return [x.upper() for x in filter_from(Seq1, Seq2)]
...
>>> beatles = ['john','paul','george', 'ringo']
>>> wings = ['paul','linda','denny']
>>> res4 = filter_from_upper(beatles, wings)
>>> res4
['JOHN', 'GEORGE', 'RINGO']
```

Loops and function concepts

- Loops
  1. `for`-loops
  2. `list`-comprehensions
- Functions
  1. Function Definition Syntax

def FunctionName ($Param_1$, $Param_2$, ...):

$Line_1$
$Line_2$
return PythonExpression
...
$Line_n$

  2. Calling a function from inside another function

Conditionals

X is an integer

```
>>> X = 5
>>> if X > 6:
...     result = 'Greater than 6'
... elif X > 5:
...     result = 'X = 6!'
... else:
...     result = 'Less than 6'
...
>>> result
'Less than 6'
```

Section 4

Numpy

1- and 2-D arrays

```
>>> import numpy as np
>>> a1d =  np.arange(12)
>>> a1d
array([ 0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11])
>>> a2d = np.arange(12).reshape((3,4))
>>> a2d
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11]])
```

Indexing 1- and 2-D arrays

```
>>> a1d
array([ 0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11])
>>> a1d[3]   # 1D array, 1 index suffices
3
>>> a2d
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11]])
>>> a2d[2,1]  # 2D array: [row,col] index
9
```

Slicing 1- and 2-D arrays

```
>>> a1d
array([ 0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11])
>>> a1d[2:4]
array([2, 3])
>>> a2d
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11]])
>>> a2d[1:3,:]
array([[ 4,  5,  6,  7],
       [ 8,  9, 10, 11]])
>>> a2d[:,1:3]
array([[ 1,  2],
       [ 5,  6],
       [ 9, 10]])
```

Broadcasting

```
>>> a2d
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11]])
>>> 2* a2d    #On midterm
array([[ 0,  2,  4,  6],
       [ 8, 10, 12, 14],
       [16, 18, 20, 22]])
>>> a2d * np.array([1,2,3,4])  # Weight each col differently
array([[ 0,  2,  6, 12],
       [ 4, 10, 18, 28],
       [ 8, 18, 30, 44]])
```

Tricky broadcasting not on midterm

Elementwise arithmetic

```
>>> x = np.arange(8).reshape((2,4))
>>> x
array([[0, 1, 2, 3],
       [4, 5, 6, 7]])
>>> y = np.arange(0,16,2).reshape((2,4))
>>> y
array([[ 0,  2,  4,  6],
       [ 8, 10, 12, 14]])
>>> x + y    # On midterm
array([[ 0,  3,  6,  9],
       [12, 15, 18, 21]])
```

Boolean arrays

```
>>> a1d
array([ 0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11])
>>> a1d > 5          # Broadcasting happens
array([False, False, False, False, False, False,  True,  True,
        True,  True,  True])
>>> a1d[a1d > 5]    # Using the Boolean array to index a1d
array([ 6,  7,  8,  9, 10, 11])
>>> a2d[a2d > 7]
array([ 8,  9, 10, 11])
```

Using the Boolean array for indexing is called **masking**

Masking 2D arrays to select rows

```
>>> a2d
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11]])
>>> a2d[:,2] > 5    # Applying a Boolean test to col2 of a2d
array([False,  True,  True])
>>> a2d[a2d[:,2] > 5,:] # Rows with col2 val > 5
array([[ 4,  5,  6,  7],
       [ 8,  9, 10, 11]])
```

Placing a Boolean constraint on a col of a 2D array creates a Boolean array of the right length to select rows

Boolean connectives I

```
>>> a2d
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11]])
>>> a2d[a2d[:,1] < 9]    # Rows with col1 val < 9
array([[0, 1, 2, 3],
       [4, 5, 6, 7]])
>>> a2d[a2d[:,2] > 5,:]  # Rows with col2 val > 5
array([[ 4,  5,  6,  7],
       [ 8,  9, 10, 11]])
>>> a2d[(a2d[:,1] < 9) & (a2d[:,2] > 5)] # Combining masks
array([[4, 5, 6, 7]])
```

Boolean connectives II

Given

bc1 = a2d[:,2] > 5
bc2 = a2d[:,1] < 9

We can create the following Boolean combinations:

bc1 & bc2	bc1 and bc2
bc1 | bc2	bc1 or bc2
∼ bc1	not bc1
∼ bc1 & bc2	bc2 and not bc1
∼ (bc1 | bc2)	neither bc1 nor bc2

Data with numpy arrays

```
>>> from sklearn.datasets import load_iris
>>> data = load_iris()
>>> features = data['data']
>>> target = data['target']
```

Note that it's not necessary to import numpy to use the arrays defined in the dataset.

Iris data: 1- and 2D array

```
>>> target[:5]     #  Gives species 0 or 1 or 2 of each iris
array([0, 0, 0, 0, 0])
>>> features[:5,:]    #  Gives 4 measurements for each iris
array([[5.1, 3.5, 1.4, 0.2],
       [4.9, 3. , 1.4, 0.2],
       [4.7, 3.2, 1.3, 0.2],
       [4.6, 3.1, 1.5, 0.2],
       [5. , 3.6, 1.4, 0.2]])
```

Data features

```
>>> data.feature_names[:2]     #  Names of first two cols
['sepal length (cm)', 'sepal width (cm)']
>>> data.feature_names[2:]     #  Names of last two cols
['petal length (cm)', 'petal width (cm)']
>>> data.target_names          #  Names for species vals 0,1,2
array(['setosa', 'versicolor', 'virginica'], dtype='<U10')
>>> (features[:,2] > 1.5)[:5]
array([False, False, False, False, False])
>>> features[(features[:,2] > 1.5)][:5]
array([[5.4, 3.9, 1.7, 0.4],
       [4.8, 3.4, 1.6, 0.2],
       [5.7, 3.8, 1.7, 0.3],
       [5.4, 3.4, 1.7, 0.2],
       [5.1, 3.3, 1.7, 0.5]])
```

Section 5

Odds and Ends

Functions/Methods

1. for x in range(5):
   x = 0, 1, 2, 3, 4
2. String methods: .title(), .lower(), .upper(), .split(), .join()
3. Dictionary methods: .keys(), .values(), .items()
4. Operators:
   - + (numbers, sequences), in (containers on the RHS)
   - Boolean operators: ==, <, >,

Gotchas: String Operators, String looping

```
>>> 'aa' < 'ab'
True
>>> 'ab' < 'aa'
False
>>> 'ab' < 'ab'
False
>>> 'aa' + 'b' + 'dd'
'aabdd'
>>> ['a' + x.title() for x in 'bcde']
['aB', 'aC', 'aD', 'aE']
>>> ['a' + x.title() for x in ['bc','de','fg']]
['aBc', 'aDe', 'aFg']
```