Compound data types

- Have seen a sampling of different classes of algorithms
  - Exhaustive enumeration
  - Guess and check
  - Bisection
  - Divide and conquer
- All have been applied so far to simple data types
  - Numbers
  - Strings

Compound data types

- Tuples
- Lists
- Dictionaries

Tuples

- Ordered sequence of elements (similar to strings)
- Elements can be more than just characters

```
t1 = (1, ‘two’, 3)
print(t1)

t2 = (t1, ‘four’)
print(t2)
```

Operations on tuples

```
t1 = (1, ‘two’, 3)
t2 = (t1, ‘four’)
```

- Concatenation
- Indexing
- Slicing

```
print(t1+t2)
print((t1+t2)[3])
print((t1+t2)[2:5])
```

- Singletons

```
t3 = (‘five’,)
print(t1+t2+t3)
```

Manipulating tuples

- Can iterate over tuples just as we can iterate over strings

```
def findDivisors(n1, n2):
    """assumes n1 and n2 positive ints
       returns tuple containing
       common divisors of n1 and n2"""
    divisors = () # the empty tuple
    for i in range(1, min(n1, n2) + 1):
        if n1%i == 0 and n2%i == 0:
            divisors = divisors + (i,)
    return divisors
```

Manipulating tuples

- Can iterate over tuples just as we can iterate over strings

```
divs = findDivisors(20, 100)
total = 0
for d in divs:
    total += d
print(total)
```

Lists

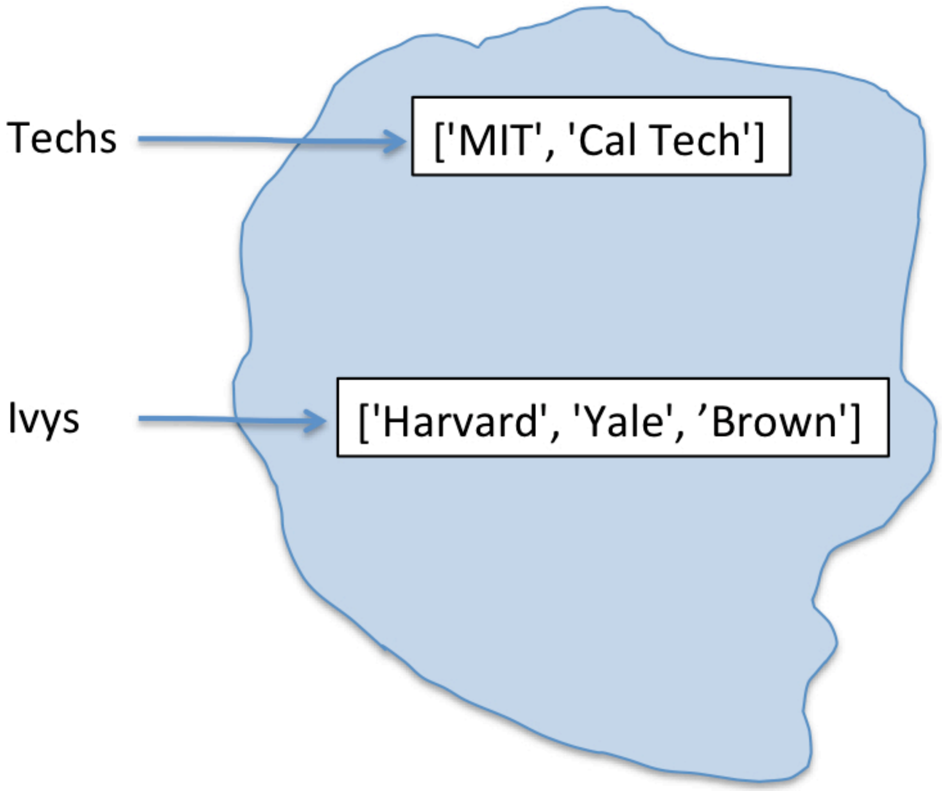
- Look a lot like tuples
  - Ordered sequence of values, each identified by an index
  - Use [1, 2, 3] rather than (1, 2, 3)
  - Singletons are now just [4] rather than (4,)
- **BIG DIFFERENCE**
  - Lists are mutable!!
  - While tuple, int, float, str are immutable
  - So lists can be modified after they are created!

Why should this matter?

- Some data objects we want to treat as fixed
  - Can create new versions of them
  - Can bind variable names to them
  - But don't want to change them
  - Generally valuable when these data objects will be referenced frequently but elements don't change
- Some data objects may want to support modifications to elements, either for efficiency or because elements are prone to change
- Mutable structures are more prone to bugs in use, but provide great flexibility

Visualizing lists

```
Techs = ['MIT',
  'Cal Tech']
Ivys = ['Harvard',
  'Yale', 'Brown']


>>>Ivys[1]
'Yale'
```



Structures of lists

- Consider

```
Univs = [Techs, Ivys]
Univs1 = [['MIT', 'Cal Tech'],
          ['Harvard', 'Yale', 'Brown']]
```

- Are these the same thing?
  – They print the same thing
  – But let's try adding something to one of these

Mutability of lists

- Let’s evaluate

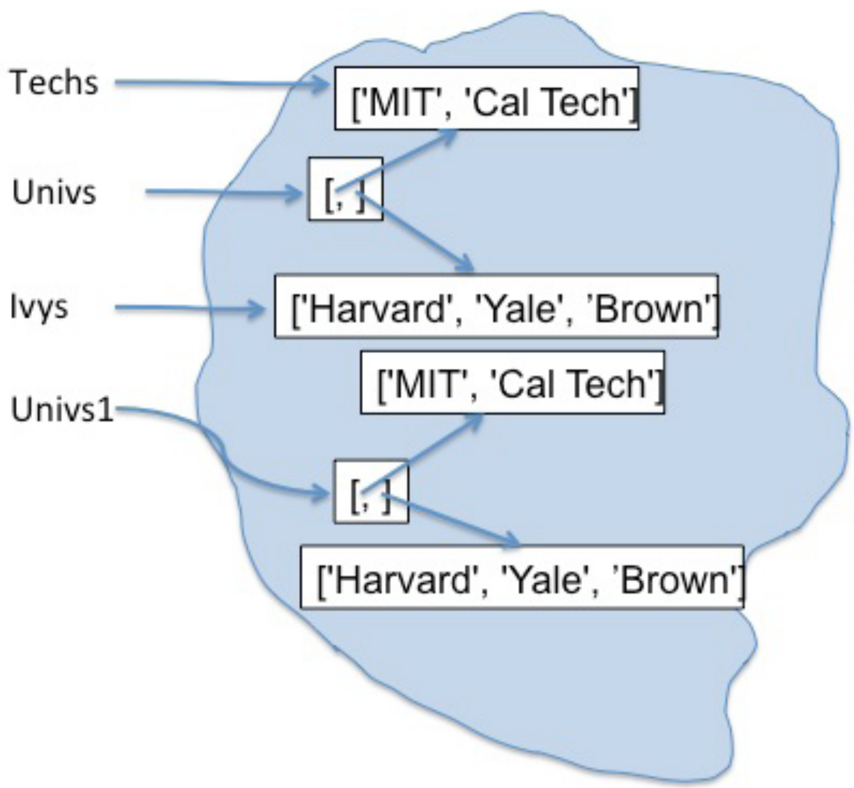
```
Techs.append('RPI')
```

- Append is a method (hence the .) that has a **side effect**
  - It doesn’t create a new list, it mutates the existing one to add a new element to the end
- So if we print Univs and Univs1 we get different things

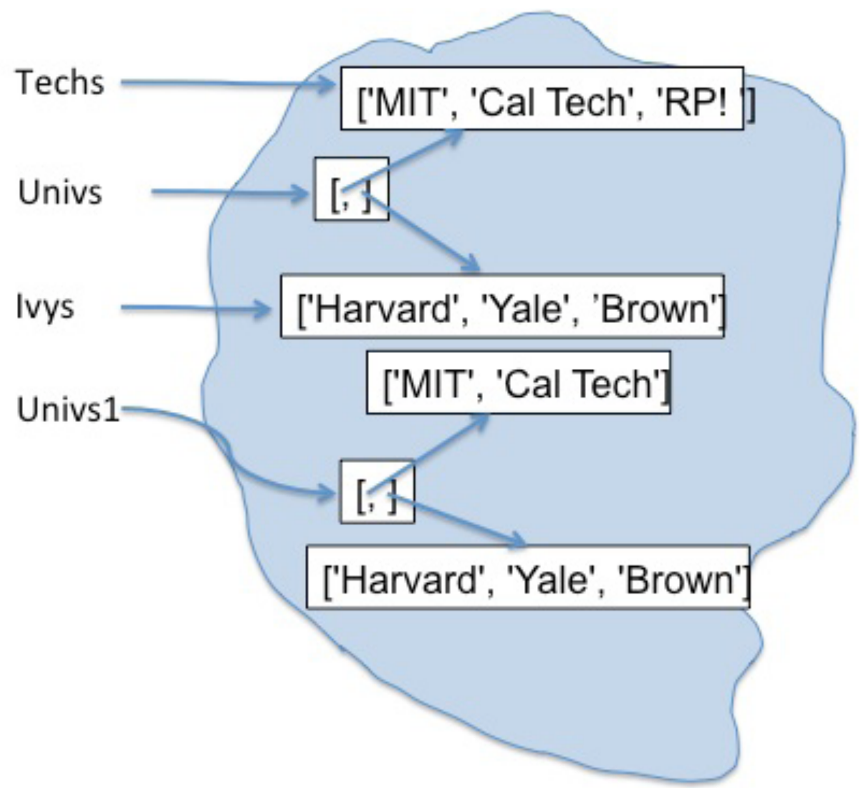
```
print(Univs)
Univs = [['MIT', 'Cal Tech',
  'RPI'], ['Harvard', 'Yale',
  'Brown']]

Print(Univs1)
Univs1 = [['MIT', 'Cal Tech'],
  ['Harvard', 'Yale', 'Brown']]
```

Why?

- Bindings before append



- Bindings after append



Observations

- Elements of `Univs` are not copies of the lists to which `Techs` and `Ivys` are bound, but are the lists themselves!
- This effect is called **aliasing**:
  - There are two distinct paths to a data object
    - One through the variable `Techs`
    - A second through the first element of list object to which `Univs` is bound
  - Can mutate object through either path, but effect will be visible through both
  - Convenient but **treacherous**

We can directly change elements

```
>>> Techs
['MIT', 'Cal Tech', 'RPI']

>>> Techs[2] = 'WPI'
```

Cannot do this with tuples!

```
>>> Techs
['MIT', 'Cal Tech', 'WPI']
```

Operations on lists

- Iteration

```
for e in Univs:
    print('Univs contains ')
    print(e)
    print('   which contains')
    for u in e:
        print('          ' + u)
```

Append versus flatten

`Techs.append(Ivys)`

Side Effect

Then `Techs` returns

```
['MIT', 'Cal Tech', 'RPI',
  ['Harvard', 'Yale', 'Brown']]
```

`flat = Techs + Ivys`

Creates a new list

Then `flat` returns

```
['MIT', 'Cal Tech',
  'RPI','Harvard', 'Yale', 'Brown']
```

In more detail

```
>>>Techs
['MIT', 'Cal Tech',
  'RPI’]

>>>Techs.append(Ivys)

>>>Techs
['MIT', 'Cal Tech',
  'RPI', ['Harvard',
  'Yale', 'Brown']]
```

```
>>>Techs
['MIT', 'Cal Tech',
  'RPI’]

>>>flat = Techs + Ivys

>>>flat
['MIT', 'Cal Tech',
  'RPI’, 'Harvard',
  'Yale', 'Brown’]

>>>Techs
['MIT', 'Cal Tech',
  'RPI’]
```

Cloning

- Avoid mutating a list over which one is iterating
- Example:

```
def removeDups(L1, L2):
    for e1 in L1:
        if e1 in L2:
          L1.remove(e1)
```

```
L1 = [1,2,3,4]
L2 = [1,2,5,6]
removeDups(L1, L2)
```

Then

```
print(L1)
```

returns

```
[2, 3, 4]
```

Why?

```
def removeDups(L1, L2):
    for e1 in L1:
        if e1 in L2:
          L1.remove(e1)
```

- Inside for loop, Python keeps track of where it is in list using internal counter
- When we mutate a list, we change its length but Python doesn't update counter

Better is to clone

```
def removeDupsBetter(L1, L2):
    L1Start = L1[:]
    for e1 in L1Start:
        if e1 in L2:
            L1.remove(e1)
```

```
L1 = [1,2,3,4]
L2 = [1,2,5,6]
removeDupsBetter(L1,
  L2)
```

Then

`print(L1)`

returns

`[3, 4]`

Note that using `L1Start = L1` is not sufficient

Functions as Objects

- Functions are **first class objects:**
  - They have types
  - They can be elements of data structures like lists
  - They can appear in expressions
    - As part of an assignment statement
    - As an argument to a function!!
- Particular useful to use functions as arguments when coupled with lists
  - Aka **higher order programming**

Example

```
def applyToEach(L, f):
    """assumes L is a list, f a function
       mutates L by replacing each element,
       e, of L by f(e)"""
    for i in range(len(L)):
        L[i] = f(L[i])
```

Example

```
def applyToEach(L, f):
    for i in
  range(len(L)):
        L[i] = f(L[

applyToEach(L, abs)
print(L)

applyToEach(L, int)
print(L)

applyToEach(L, fact)
print(L)

applyToEach(L, fib)
print(L)
```

```
L = [1, -2, 3.4]
```

Example

```
def applyToEach(L, f):
    for i in range(len(L)):
        L[i] = f(L[i])

applyToEach(L, abs)
print(L)

applyToEach(L, int)
print(L)

applyToEach(L, fact)
print(L)

applyToEach(L, fib)
print(L)
```

```
L = [1, -2, 3.4]
```

```
[1, 2,
 3.3999999999999999]
```

Example

```
def applyToEach(L, f):
    for i in range(len(L)):
        L[i] = f(L[i])

applyToEach(L, abs)
print(L)

applyToEach(L, int)
print(L)

applyToEach(L, fact)
print(L)

applyToEach(L, fib)
print(L)
```

```
L = [1, -2, 3.4]
```

```
[1, 2, 3.3999999999999]
```

```
[1, 2, 3]
```

Example

```
def applyToEach(L, f):
    for i in range(len(L)):
        L[i] = f(L[i])

applyToEach(L, abs)
print(L)

applyToEach(L, int)
print(L)

applyToEach(L, fact)
print(L)

applyToEach(L, fib)
print(L)
```

```
L = [1, -2, 3.4]

[1, 2, 3.3999999999999]

[1, 2, 3]

[1, 2, 6]
```

Example

```
def applyToEach(L, f):
    for i in range(len(L)):
        L[i] = f(L[i])

applyToEach(L, abs)
print(L)

applyToEach(L, int)
print(L)

applyToEach(L, fact)
print(L)

applyToEach(L, fib)
print(L)
```

```
L = [1, -2, 3.4]

[1, 2, 3.3999999999999]

[1, 2, 3]

[1, 2, 6]

[1, 2, 13]
```

Lists of functions

```
def applyFuns(L, x):
    for f in L:
        print(f(x))

applyFuns([abs, int, fact, fib], 4)
4
4
24
5
```

Generalizations of higher order functions

- Python provides a general purpose HOP, `map`
- Simple form – a unary function and a collection of suitable arguments
  - `map(abs, [1, -2, 3, -4])`
  - `[1, 2, 3, 4]`
- General form – an n-ary function and n collections of arguments
  - L1 = [1, 28, 36]
  - L2 = [2, 57, 9]
  - map(min, L1, L2)
  - [1, 28, 9]

Dictionaries

- `Dict` is generalization of lists, but now indices don't have to be integers – can be values of any immutable type
- Refer to indices as **keys**, since arbitrary in form
- A `dict` is then a collection of `<key, value>` pairs
- Syntax
  - `monthNumbers = { 'Jan':1, 'Feb':2, 'Mar':3, 1:'Jan', 2:'Feb', 3:'Mar'}`

```
monthNumbers = { 'Jan':1, 'Feb':2,
                 'Mar':3, 1:'Jan',
                 2:'Feb', 3:'Mar'}
```

We access by using a key

```
monthNumbers =
   {'Jan':1, 'Feb':2,
    'Mar':3, 1:'Jan',
    2:'Feb', 3:'Mar'}
```

`monthNumbers['Jan']`

returns

`1`

`monthNumbers[1]`

returns

`'Jan'`

Entries in a dict are unordered, and can only be accessed by a key, not an index

Operations on dicts

- Insertion

```
monthNumbers['Apr'] = 4
```

- Iteration

```
collect = []

for e in monthNumbers:
  collect.append(e)
```

`collect` is now

```
[1, 2, 'Mar', 'Feb', 'Apr', 'Jan', 3]
```

Compare to

```
monthNumbers.keys()
```

Keys can be complex

```
myDict = {(1,2): 'twelve',
          (1,3): 'thirteen'}
```

```
myDict[(1,2)]
```

returns

```
'twelve'
```

Note that keys must be immutable, so have to use a tuple, not a list

We will return to dicts and their methods later