Lecture 09
Filter, Map, Reduce, and Lambda

Barron has successfully reduced scratching, but the overhead is huge!

based in part on notes from the CS-for-All curriculum developed at Harvey Mudd College

Last Time (lecture 08)

Recursion takeaways

- Any recursive algorithm can be implemented with iteration
- Recursion is a trade-off in efficiency vs. readability
- Avoid multiple recursive calls whenever possible
  - e.g., O(n) vs. O(2^n)

Multiple base cases

- Not always an empty or singular sequence
  - e.g., Palindrome checker: front and back must be equal

Recursion vs. Iteration

- Is the Fibonacci sequence a good function to recurse in practice?
- Searching through directed graphs or file structures are better suited for recursion

Lecture 09 Goals

Lecture 09A:

1. Introduce *high-level* functions: `filter(), map(), & reduce()`
2. Introduce *anonymous* functions: `lambda`

Lecture 09B:

1. Introduction to Object Oriented Programming (OOP)
2. How to find help on objects

`filter()`

- A higher-order function

- Syntax:

  `filter(`*function*, *sequence*`)`

  - applies ***function*** to each element of ***sequence***
    and returns elements for which the function returns ***true***

- filter returns a subset of sequence
  - to *generate* the actual list, we need to apply `list()`

filter() Examples

```
def isDivBy3(x): # is divisible by 3?
    return x % 3 == 0

def isEven(x): # is even?
    return x % 2 == 0

def isCap(s): # is first character capitalized?
    return 'A' <= s[0] <= 'Z’

>>> list(filter(isDivBy3, range(0,31)))
[0, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30]
>>> list(filter(isEven,  filter(isDivBy3, range(0,31))))
[0, 6, 12, 18, 24, 30]
>>> list(filter(isCap, ['he‘,'Martha‘,'tree‘,'George‘,'chop']))
['Martha', 'George']
>>> list(filter(isCap, 'Martha Dandridge-Washington‘))
???
```

filter() Examples

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def isDivBy3(x): # is divisible by 3?
    return x % 3 == 0

def isEven(x): # is even?
    return x % 2 == 0

def isCap(s): # is first character capitalized?
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[0, 6, 12, 18, 24, 30]
>>> list(filter(isCap, ['he‘,'Martha‘,'tree‘,'George‘,'chop']))
['Martha', 'George']
>>> list(filter(isCap, 'Martha Dandridge-Washington'))
['M', 'D', 'W']
```

`map()`

- A higher-order function

- Syntax:

  `map(`*function*, *sequence*`)`

  - applies ***function*** to each element of ***sequence*** and returns the ***results***

- As with `range`:
  - you can think of `map` as producing a list
  - in many cases it can be used like one
  - to *generate* the actual list, we need to use `map()` with `list()`

map() Examples

```
def triple(x):
    return 3*x

def square(x):
    return x*x

def first_char(s):
    return s[0]
```

```
>>> list(map(triple, [0, 1, 2, 3, 4, 5]))
[0, 3, 6, 9, 12, 15]

>>> list(map(square, range(6)))
[0, 1, 4, 9, 16, 25]

>>> list(map(first_char, ['python', 'is', 'fun!']))
???

>>> list(map(triple, 'python'))
???
```

map() Examples

```
def triple(x):
    return 3*x

def square(x):
    return x*x

def first_char(s):
    return s[0]
```

```
>>> list(map(triple, [0, 1, 2, 3, 4, 5]))
[0, 3, 6, 9, 12, 15]

>>> list(map(square, range(6)))
[0, 1, 4, 9, 16, 25]

>>> list(map(first_char, ['python', 'is', 'fun!']))
['p', 'i', 'f']

>>> list(map(triple, 'python'))
['ppp', 'yyy', 'ttt', 'hhh', 'ooo', 'nnn']
```

`reduce()`

- Required: `from functools import reduce`

- Syntax:

```
reduce(f, s)
```

  - reduce continually applies the ***function*** *f(x,y)* to the ***sequence*** *s.* It returns a ***single value***.

For `s = [s1, s2, s3, ... , sn], f(x,y)` is applied to the first two elements.
Note: *`f()`* has 2 input parameters!

The list on which reduce() works looks now like this:

  - [f(s1, s2), s3, ... , sn], In the next step the list is
  - [f(f(s1, s2),s3), ... , sn]

Continue like this until just one element is left and return this element as the result of `reduce()`

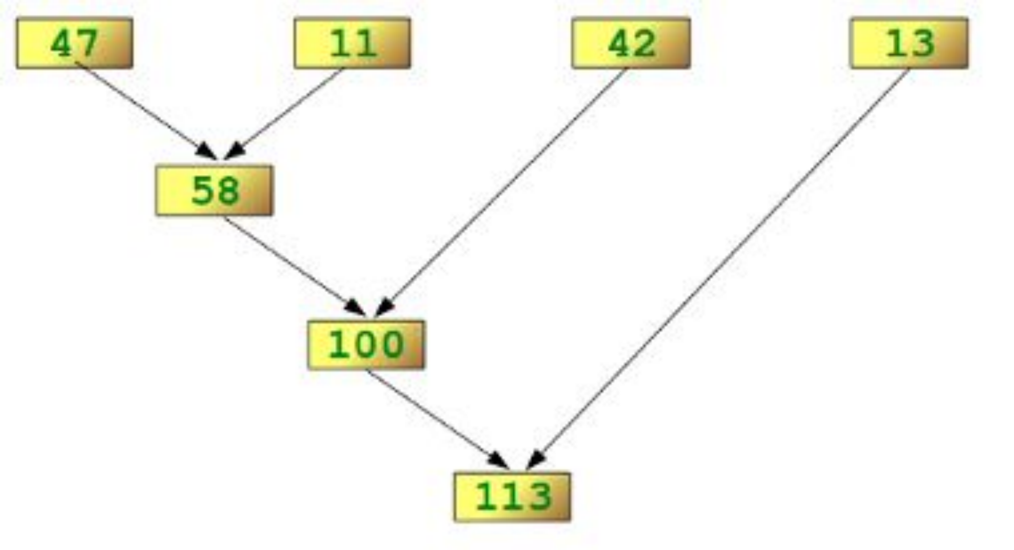
reduce() Examples

```
from functools import reduce


def add(x, y):
    return x+y


>>> reduce(add, [47, 11, 42, 13])
113

    Calculated via add(add(add(47,11), 42), 13)
```



reduce() Examples

```
from functools import reduce


def add(x, y):
    return x+y


def mult(x, y):
    return x*y

>>> reduce(add, range(1,6))
15
>>> reduce(mult, range(1,6))
120
>>> reduce(add, ['Just', 'ice,', ' Now!'])
???
```

reduce() Examples

```
from functools import reduce


def add(x, y):
    return x+y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    return x*y


>>> reduce(add, range(1,6))
15
>>> reduce(mult, range(1,6))
120
>>> reduce(add, ['Just', 'ice,', ' Now!'])
‘Justice, Now!’
```

What will this code output?

```
from functools import reduce


def mult(x, y):
    return x*y

def mystery(n):
    return reduce(mult, range(1,n+1))

print(mystery(4))
```

A. 4

B. 12

C. 24

D. [4 12 24]

E. none of the above

What will this code output?

```
from functools import reduce


def mult(x, y):
    return x*y

def mystery(n):
    return reduce(mult, range(1,n+1))

print(mystery(4))
```

A. 4

B. 12

C. 24

D. [4 12 24]

E. none of the above

What does this code do?

```
from math import log
def isOdd(x):
    return x%2 == 1
def odd_log_sum(n):
    return reduce(add, map(log, filter(isOdd,range(1, n+1))))
print(odd_log_sum(5))
```

Other Useful Built-In Functions

- `sum(list)`: computes & returns the sum of a list of numbers

```
>>> sum([4, 10, 2])
16
```

- Here's how we could define it recursively:

```
def sum(values):
    """ computes the sum of a list of numbers.
        input values: an arbitrary list of 0 or more #s
    """
    if values == []:         # base case
        return 0
    else:
        sum_rest = sum(values[1:])    # recursive case
        return values[0] + sum_rest
```

Other Useful Built-In Functions

- `sum(list)`: computes & returns the sum of a list of numbers

```
>>> sum([4, 10, 2])
16
```

- Here's how we could define it using *reduce*:

```
def add(x,y):
    return x + y

def sum(vals):
    return reduce(add, vals)
```

Lambda Expressions and Anonymous Functions

Lambda Expressions

Python allows one to define functions in a single expression, i.e.,

```
>>> isDivBy3 = (lambda x: x%3==1)
>>> list(filter(isDivBy3, range(0,31)))
[0, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30]
```

Here keyword lambda indicates we’re defining a ***function***, `x` is its ***argument***, and `x%3==1` indicates the ***return value***

Lambda Expressions

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[0, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30]
```

Here keyword lambda indicates we're defining a ***function***, `x` is its ***argument***, and `x%3==1` indicates the ***return value***

The code above is entirely equivalent to

```
def isDivBy3(x): # is divisible by 3
    return x % 3 == 0

>>> list(filter(isDivBy3, range(0,31)))
[0, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30]
```

Anonymous Functions

Python allows one to define functions in a single expression, i.e.,

```
>>> isDivBy3 = (lambda x: x%3==1)
>>> list(filter(isDivBy3, range(0,31)))
[0, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30]
```

Here we have assigned the definition of this function to the variable `isDivBy3`, but we could just as well have used it immediately

```
>>> list(filter(lambda x: x%3==1, range(0,31)))
[0, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30]
```

This last example is an example of the use of an ***anonymous function*** – it never had a name, but it did do its job.

Lambda practice

```
def isEven(x): # is even?
    return x % 2 == 0

def isCap(s): # is first character capitalized?
    return 'A' <= s[0] <= 'Z’

>>> x = list(filter(lambda _____________________, range(0,10)))
[0, 2, 4, 6, 8, 10]

>>> list(filter(lambda _____________________, \
       ['he‘,'Martha‘,'tree‘,'George‘,'chop']))
['Martha', 'George']
```

Lambda practice

```
def isEven(x): # is even?
    return x % 2 == 0

def isCap(s): # is first character capitalized?
    return 'A' <= s[0] <= 'Z’

>>> x = list(filter(lambda x: x % 2 == 0, range(0,10)))
[0, 2, 4, 6, 8, 10)

>>> list(filter(lambda s: 'A' <= s[0] <= 'Z’, \
       ['he‘,'Martha‘,'tree‘,'George‘,'chop']))
['Martha', 'George']
```

Lambda practice

```
>>> list(map(lambda _____________, [0, 1, 2, 3, 4, 5]))
[0, 3, 6, 9, 12, 15]

>>> list(map(lambda _____________, range(6)))
[0, 1, 4, 9, 16, 25]
```

Lambda practice

```
>>> list(map(lambda x: 3*x, [0, 1, 2, 3, 4, 5]))
[0, 3, 6, 9, 12, 15]

>>> list(map(lambda x: x**2, range(6)))
[0, 1, 4, 9, 16, 25]
```

Lambda practice

```
>>> list(map(lambda c: c[1], ['python', 'is', 'fun!']))
???

>>> list(map(lambda c: c*2, 'python'))
???
```

Lambda practice

```
>>> list(map(lambda c: c[1], ['python', 'is', 'fun!']))
[‘y’, ‘s’, ‘u’]

>>> list(map(lambda c: c*2, 'python'))
[‘pp’, ‘yy’, ‘tt’, ‘hh’, ‘oo’, ‘nn’]
```

Lambda practice

```
>>> reduce(lambda ____________, range(1,6))
15
>>> reduce(lambda ____________, range(1,6))
120
>>> reduce(lambda ____________, \
      ['Just', 'ice,’, ‘ Now!’])
‘Justice, Now!’
```

Lambda practice

```
>>> reduce(lambda x,y: x+y, range(1,6))
15
>>> reduce(lambda x,y: x*y, range(1,6))
120
>>> reduce(lambda x,y: x+y, \
      ['Just', 'ice,', ' Now!'])
‘Justice, Now!’
```

When *not* to use anonymous functions

Anonymous functions

1. do not allow testing
2. do not support doc strings
3. can make code really, really confusing

Do not use complex anonymous functions, i.e. ones that are not readily understandable, or easily verifiable by inspection

Concise code is good

Opaque code is bad

See also: https://treyhunner.com/2018/09/stop-writing-lambda-expressions/

When to use anonymous functions

1. There are no existing functions that do what you need

2. The function is trivial: the function doesn’t need a name

3. Having a lambda expression makes your code more understandable than the function names you can think of

Lambda Expression Summary

This function returns the sum of its two arguments

```
(lambda x,y: x+y)
```

Lambda functions can be used wherever function objects are required. They are syntactically restricted to a single expression.

Semantically, they are just *syntactic sugar* for a normal function definition, i.e., both definitions below are functionally the same

```
add = (lambda x,y: x+y)

def add(x,y): # add two numbers
       return x+y
```

Bringing it all together

Use Filter, Map and/or Reduce to compute with a lambda function

```
def num_vowels(s):
   '''Returns the number of vowels in a string of letters''’
   #Hint: The function string.count(substring) returns the 
total number of times each substring appears in string

def mymax(values):
    ‘’’ returns the largest element in a non-empty list’’’
```

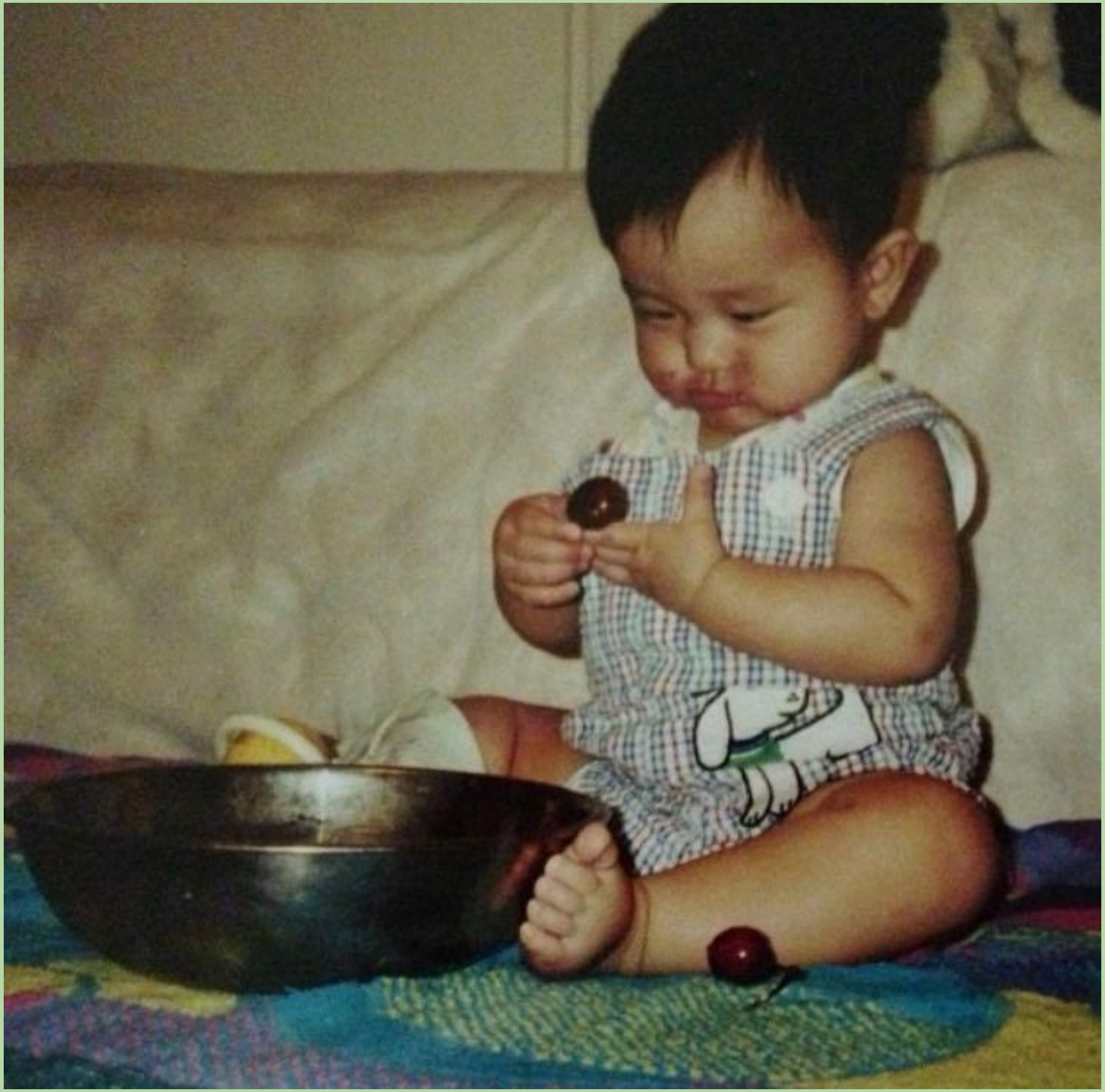
Bringing it all together

Use Filter, Map and/or Reduce to compute with a lambda function

```
def num_vowels(s):
    '''Returns the number of vowels in a string of letters''’
     return reduce(lambda x,y: x+y, map(s.lower().count, 'aeiou'))


def mymax(values):
     ‘’’ returns the largest element in a non-empty list’’’
    return reduce(lambda x,y: x if x > y else y, values)
```

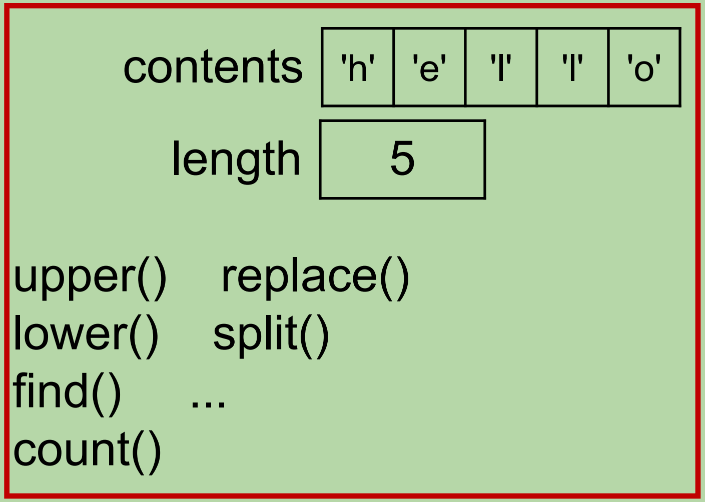
Lecture 09B: Object Oriented Programming



Recall: Strings Are Objects

- In Python, a string is an object.
  - ***attributes:***
    - the characters in the string
    - the length of the string
  - ***methods:*** functions inside the string that we can use to operate on the string

string object for 'hello'

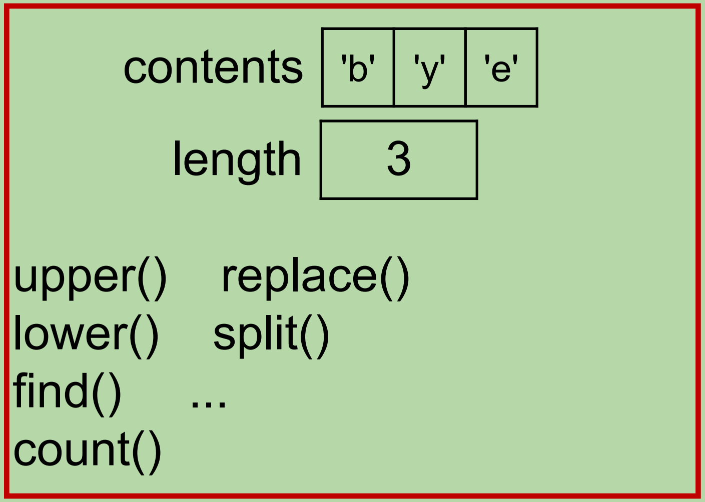


contents 'h' 'e' 'l' 'l' 'o'

length 5

upper() replace()
lower() split()
find() ...
count()

string object for 'bye'



contents 'b' 'y' 'e'

length 3

upper() replace()
lower() split()
find() ...
count()

Recall: String Methods (partial list)

- s.lower(): return a copy of s with all lowercase characters
- s.upper(): return a copy of s with all uppercase characters
- s.find(sub): return the index of the first occurrence of the substring sub in the string s (-1 if not found)
- s.count(sub): return the number of occurrences of the substring sub in the string s (0 if not found)
- s.replace(target, repl): return a new string in which all occurrences of target in s are replaced with repl

Examples of Using String Methods

```
>>> chant = 'We are the Bears!'
>>> chant.upper()


>>> chant.lower()


>>> chant.replace('e', 'o')

>>> chant
```

Examples of Using String Methods

```
>>> chant = 'We are the Bears!'

>>> chant.upper()
'WE ARE THE BEARS!'

>>> chant.lower()
'we are the bears!'

>>> chant.replace('e', 'o')
'Wo aro tho Boars!’


>>> chant
'We are the Bears!'
```

Splitting a String

- The split() method breaks a string into a list of substrings.

```
>>> name = 'Martin Luther King'
>>> name.split()
???
>>> components = name.split()
>>> components[0]
???
```

- By default, it uses *whitespace characters* (spaces, tabs, and newlines) to determine where the splits should occur.

- You can specify a different separator:

```
>>> date = '11/10/2014'
>>> date.split('/')
???
```

Splitting a String

- The split() method breaks a string into a list of substrings.

```
>>> name = 'Martin Luther King'
>>> name.split()
['Martin', 'Luther', 'King']
>>> components = name.split()
>>> components[0]
'Martin'
```

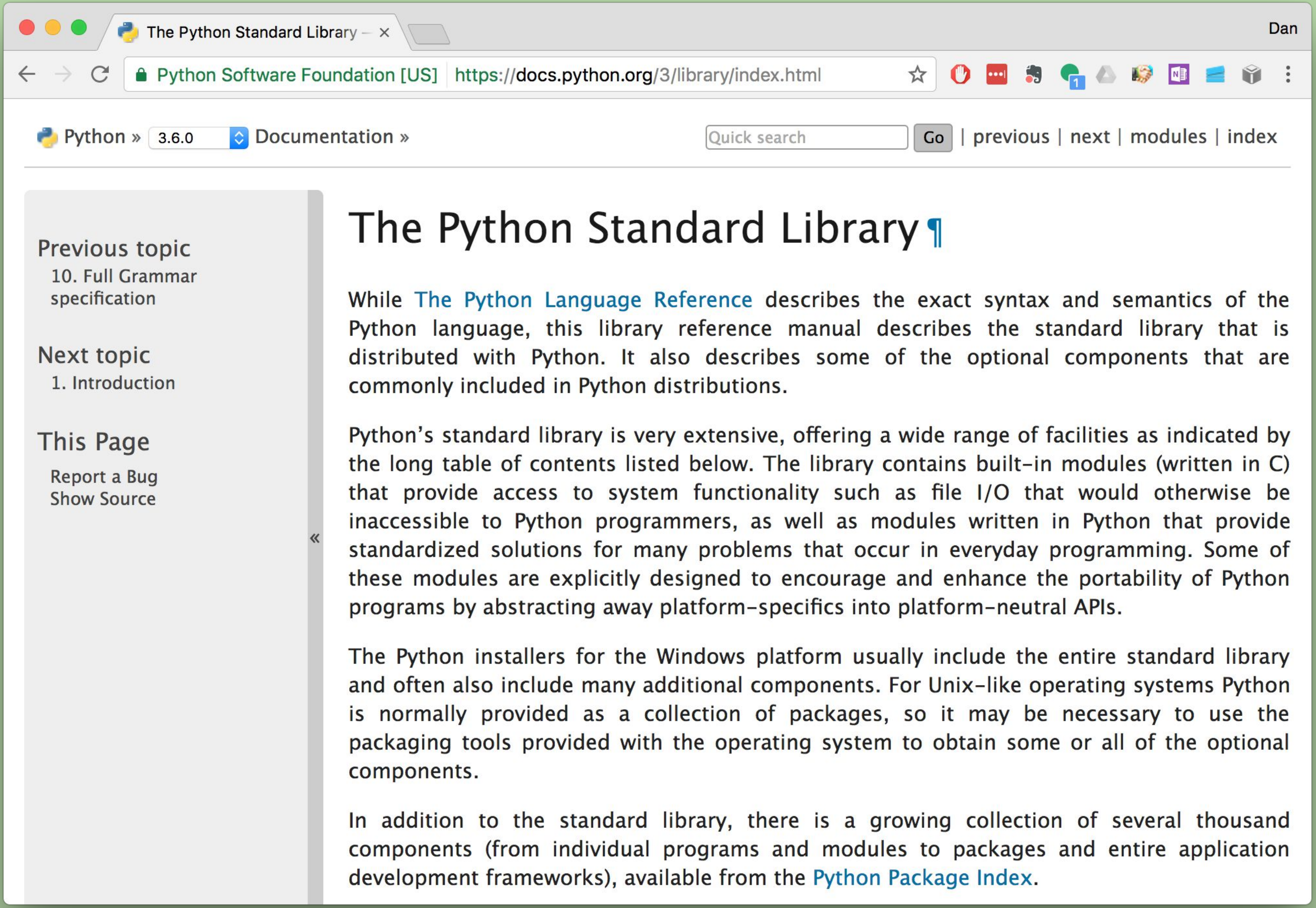
- By default, it uses *whitespace characters* (spaces, tabs, and newlines) to determine where the splits should occur.

- You can specify a different separator:

```
>>> date = '11/10/2014'
>>> date.split('/')
['11', '10', '2014']
```

Discovering What An Object Can Do

- Use the documentation for the **Python Standard Library**:
  docs.python.org/3/library


The Python Standard Library – ×
Dan
Python Software Foundation [US]
https://docs.python.org/3/library/index.html
Python » 3.6.0 Documentation »
Quick search
Go
| previous | next | modules | index
Previous topic
10. Full Grammar specification
Next topic
1. Introduction
This Page
Report a Bug
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«

The Python Standard Library¶

While The Python Language Reference describes the exact syntax and semantics of the Python language, this library reference manual describes the standard library that is distributed with Python. It also describes some of the optional components that are commonly included in Python distributions.

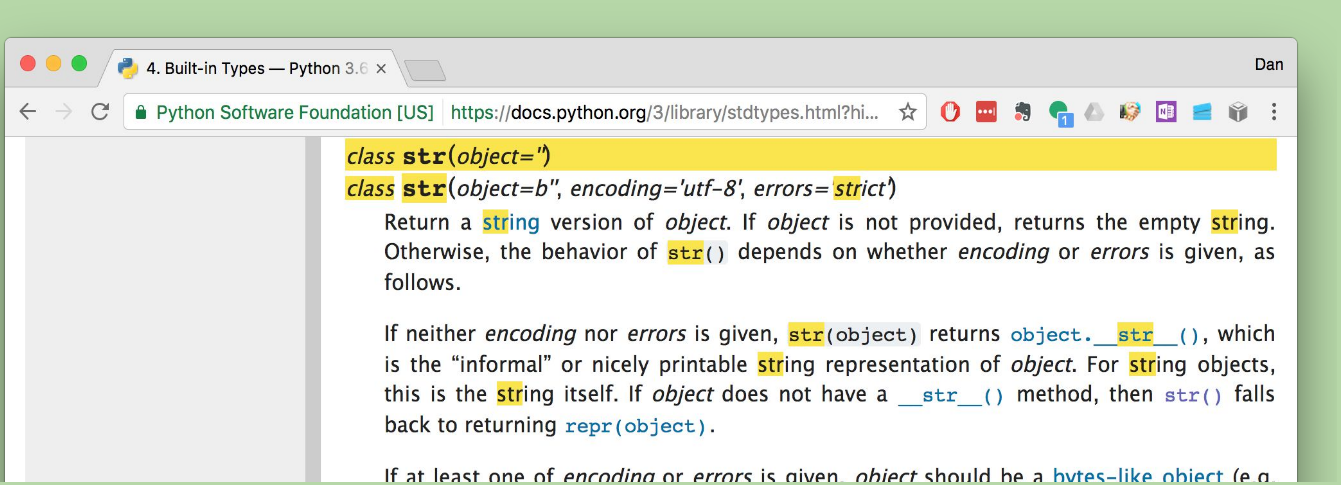
Python’s standard library is very extensive, offering a wide range of facilities as indicated by the long table of contents listed below. The library contains built-in modules (written in C) that provide access to system functionality such as file I/O that would otherwise be inaccessible to Python programmers, as well as modules written in Python that provide standardized solutions for many problems that occur in everyday programming. Some of these modules are explicitly designed to encourage and enhance the portability of Python programs by abstracting away platform-specifics into platform-neutral APIs.

The Python installers for the Windows platform usually include the entire standard library and often also include many additional components. For Unix-like operating systems Python is normally provided as a collection of packages, so it may be necessary to use the packaging tools provided with the operating system to obtain some or all of the optional components.

In addition to the standard library, there is a growing collection of several thousand components (from individual programs and modules to packages and entire application development frameworks), available from the Python Package Index.

Discovering What An Object Can Do (cont.)

- Here's the section on the str type (the type of string objects):


4. Built-in Types — Python 3.6 ×
Dan
Python Software Foundation [US]
https://docs.python.org/3/library/stdtypes.html?hi...

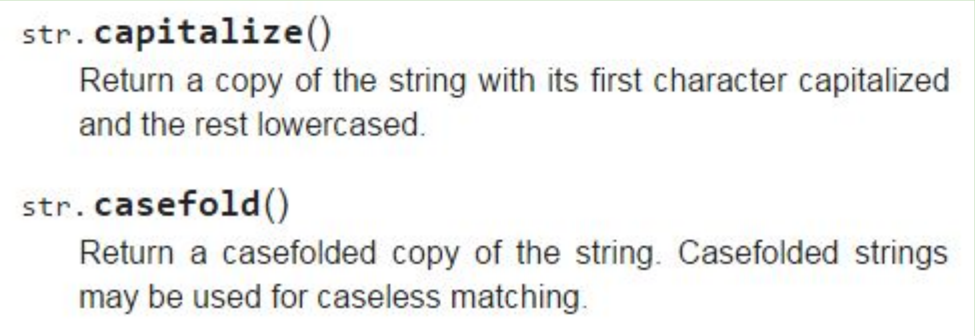
class **str**(*object=''*)
class **str**(*object=b'', encoding='utf-8', errors='strict'*)

Return a string version of *object*. If *object* is not provided, returns the empty string. Otherwise, the behavior of `str()` depends on whether *encoding* or *errors* is given, as follows.

If neither *encoding* nor *errors* is given, `str(object)` returns `object.__str__()`, which is the "informal" or nicely printable string representation of *object*. For string objects, this is the string itself. If *object* does not have a `__str__()` method, then `str()` falls back to returning `repr(object)`.

If at least one of *encoding* or *errors* is given, *object* should be a bytes-like object (e.g.

- Scrolling down shows us the available methods:



str.**capitalize**()

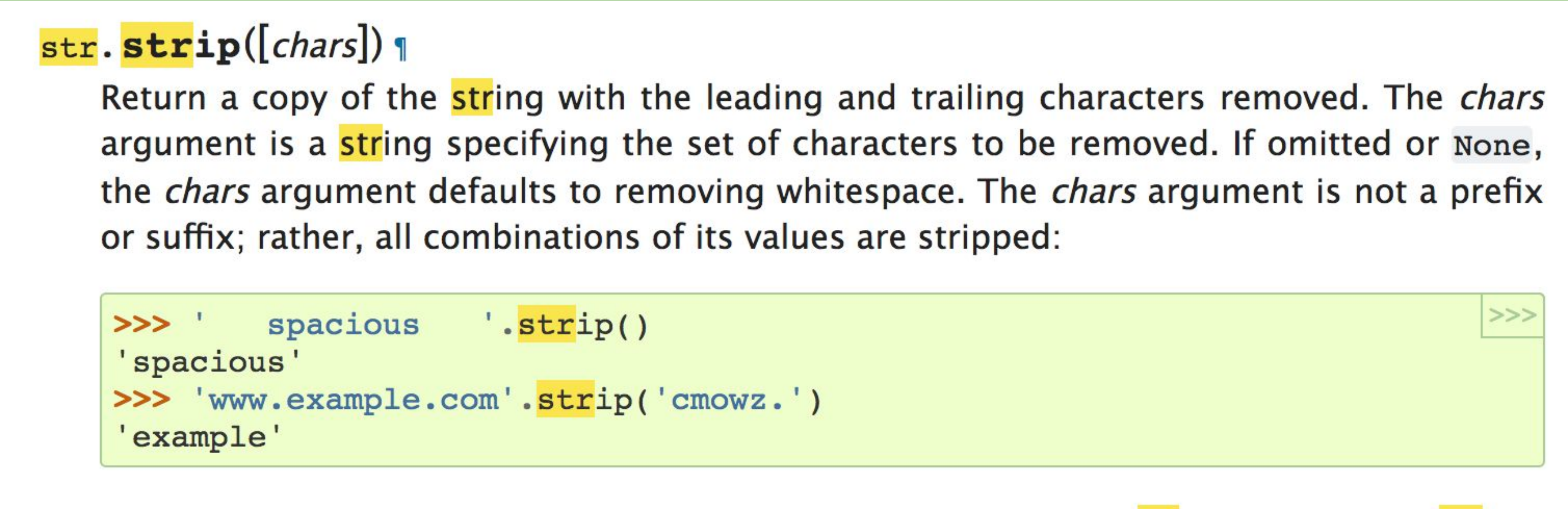
Return a copy of the string with its first character capitalized and the rest lowercased.

str.**casefold**()

Return a casefolded copy of the string. Casefolded strings may be used for caseless matching.

Discovering What An Object Can Do (cont.)

- Scrolling down, we can find info. about a method called strip():



str.strip([*chars*]) ¶

Return a copy of the string with the leading and trailing characters removed. The *chars* argument is a string specifying the set of characters to be removed. If omitted or `None`, the *chars* argument defaults to removing whitespace. The *chars* argument is not a prefix or suffix; rather, all combinations of its values are stripped:

```
>>> '   spacious   '.strip()
'spacious'
>>> 'www.example.com'.strip('cmowz.')
'example'
```

What is the output of this program?

```
s = '    programming   '
s = s.strip()
s.upper()
s = s.split('r')
print(s)
```

A. ['   p', 'og', 'amming   ']

B. ['p', 'og', 'amming']

C. ['   P', 'OG', 'AMMING   ']

D. ['P', 'OG', 'AMMING']

E. none of the above

What is the output of this program?

```
s = '    programming    '
s = s.strip()       # s = 'programming'
s.upper()           # 'PROGRAMMING' (no change to s!)
s = s.split('r')   # s = ['p', 'og', 'amming']
print(s)
```

A. ['   p', 'og', 'amming   ']

B. **['p', 'og', 'amming']**

C. ['   P', 'OG', 'AMMING   ']

D. ['P', 'OG', 'AMMING']

E. none of the above