Functions and Control Structures

David E. Culler

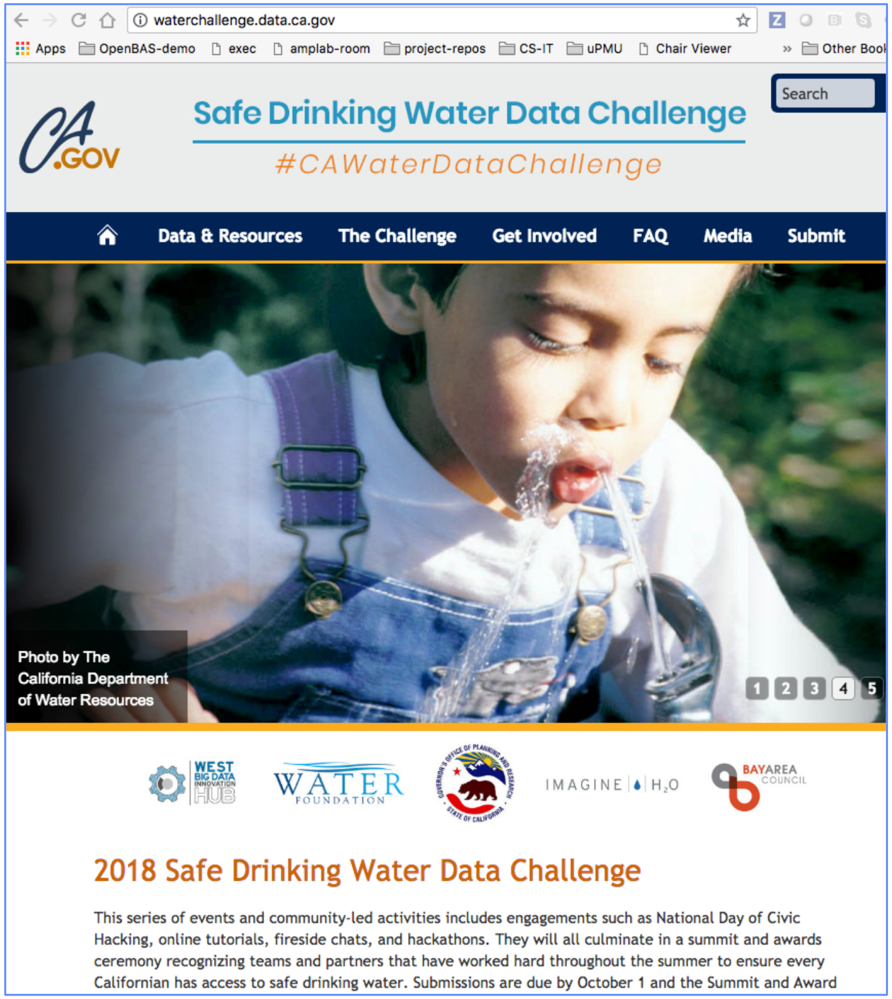
CS8 – Computational Structures in Data Science

http://inst.eecs.berkeley.edu/~cs88

Lecture 3 (there is no lecture 2)

September 10, 2018

Data Science in the News



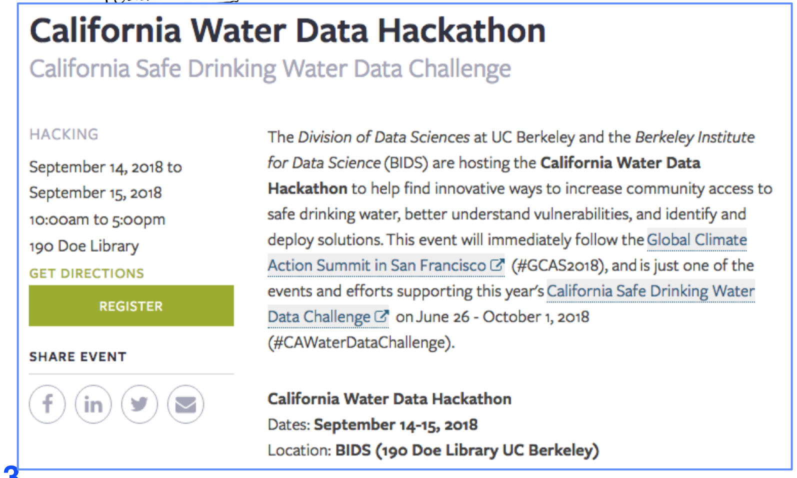
Safe Drinking Water Data Challenge

#CAWaterDataChallenge

2018 Safe Drinking Water Data Challenge

This series of events and community-led activities includes engagements such as National Day of Civic Hacking, online tutorials, fireside chats, and hackathons. They will all culminate in a summit and awards ceremony recognizing teams and partners that have worked hard throughout the summer to ensure every Californian has access to safe drinking water. Submissions are due by October 1 and the Summit and Award

#CAWATERDATACHALLENGE
California SAFE DRINKING WATER data challenge
the Power of open data...
$1500 PRIZE for the MOST INNOVATIVE & IMPACTFUL Solution
what are we GOING to LEAVE to OUR CHILDREN & GRANDCHILDREN if WE DON'T TAKE CARE of OUR DRINKING WATER
what is a DATA Challenge
an OPPORTUNITY for INDIVIDUALS & TEAM-BASED Problem SOLVING
Leverage DATA & TALENT to PROVIDE KNOWLEDGE & INSIGHTS
DIGITAL & MACHINE READABLE DATA MAKES more innovative SOLUTIONS POSSIBLE!
summer 2018
Join now!
BRINGING Talent to BEAR for INNOVATIVE SOLUTIONS for safe DRINKING water...
CA.GOV.OPS
DATA SCIENTIST
CODERS
& Developers
INDUSTRY
PUBLIC
WHO IS NOT HERE that NEEDS to BE?
FUNDERS
TECHNOLOGY SOLUTION PROVIDERS
JUNE 26, 2018
GRAPHICS by steph@10xCOLLECTIVE.COM @STEPHSCRIBES



California Water Data Hackathon

California Safe Drinking Water Data Challenge

HACKING

September 14, 2018 to
September 15, 2018
10:00am to 5:00pm
190 Doe Library

GET DIRECTIONS

REGISTER

SHARE EVENT

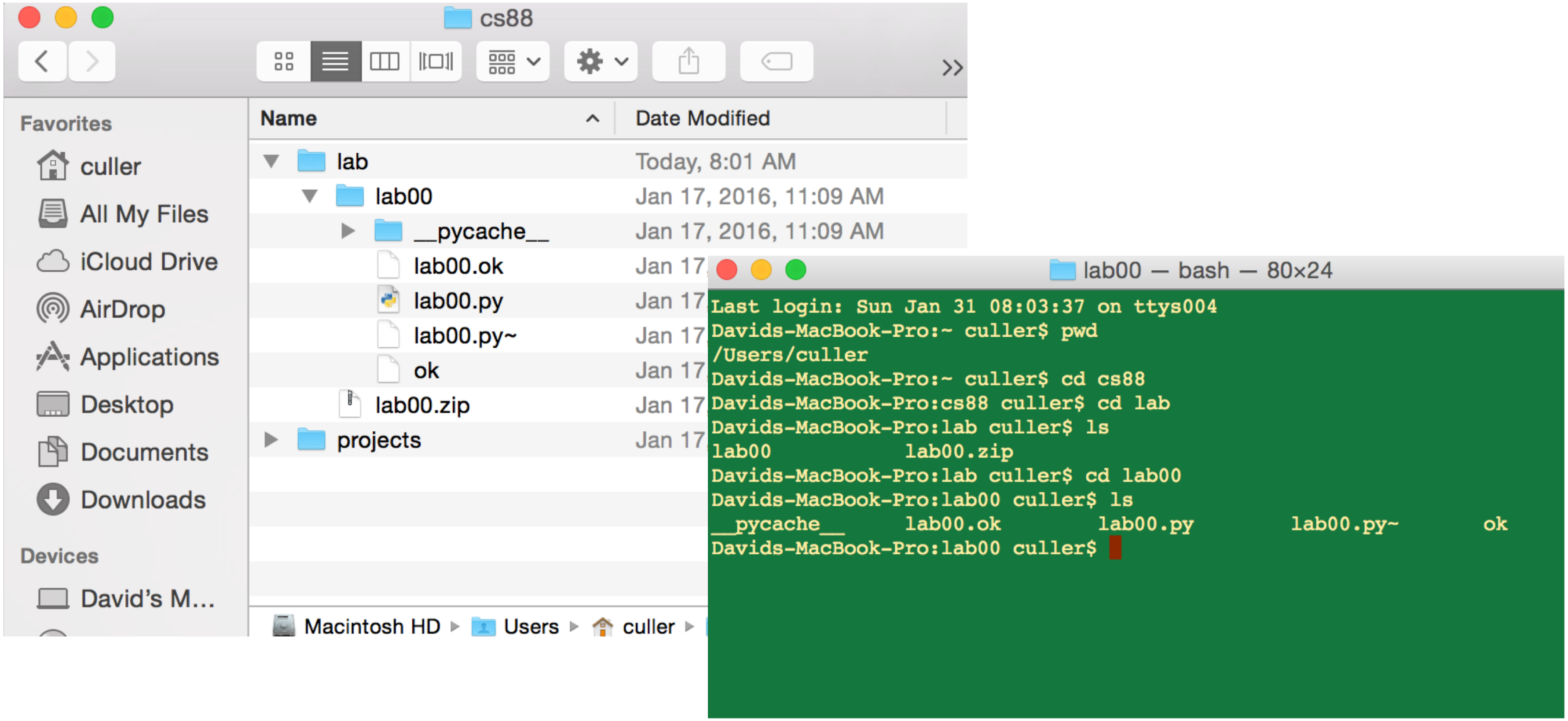
The *Division of Data Sciences* at UC Berkeley and the *Berkeley Institute for Data Science* (BIDS) are hosting the **California Water Data Hackathon** to help find innovative ways to increase community access to safe drinking water, better understand vulnerabilities, and identify and deploy solutions. This event will immediately follow the Global Climate Action Summit in San Francisco (#GCAS2018), and is just one of the events and efforts supporting this year's California Safe Drinking Water Data Challenge on June 26 - October 1, 2018 (#CAWaterDataChallenge).

California Water Data Hackathon
Dates: **September 14-15, 2018**
Location: **BIDS (190 Doe Library UC Berkeley)**

Administrative issues

- Waitlist and Concurrent Enrollment Accepted
- Weekly Schedule
    - Monday Lecture => Read => Friday Lab => Homework (Due Th)
- Lab Assignments complete
- Culler Office Hours after class – here to BIDS 190E
    - Room in the back on the right

WIMP => Program Development



Name	Date Modified
lab	Today, 8:01 AM
lab00	Jan 17, 2016, 11:09 AM
__pycache__	Jan 17, 2016, 11:09 AM
lab00.ok	Jan 17
lab00.py	Jan 17
lab00.py~	Jan 17
ok	Jan 17
lab00.zip	Jan 17
projects	Jan 17

```
Last login: Sun Jan 31 08:03:37 on ttys004
Davids-MacBook-Pro:~ culler$ pwd
/Users/culler
Davids-MacBook-Pro:~ culler$ cd cs88
Davids-MacBook-Pro:cs88 culler$ cd lab
Davids-MacBook-Pro:lab culler$ ls
lab00           lab00.zip
Davids-MacBook-Pro:lab culler$ cd lab00
Davids-MacBook-Pro:lab00 culler$ ls
__pycache__     lab00.ok        lab00.py        lab00.py~       ok
Davids-MacBook-Pro:lab00 culler$ 
```

- **Big Idea: Layers of Abstraction**
  - **The GUI look and feel is built out of files, directories, system code, etc.**

Computational Concepts Toolbox

Computational Concepts Toolbox

- Data type: the “kind” of value and what you can do with it
  - Integers, Floats, Booleans, Strings, [tuples]
- Operators
  - Arithmetic: +, -, *, /, //, %, **
  - Boolean: or, and, not
  - Comparison: <, <=, ==, !=, >=, >
  - Membership: in, is, is not
  - Conditional expression: <t_exp> if <cond> else <f_exp>
- Values
  - literals, variables, results of expression

- Expressions – compute a value
  - Valid use of operators and values
  - Call expression: <fun>(<arg1> , …)

Call Expressions

- Evaluate a function on some arguments
- What would be some useful functions?

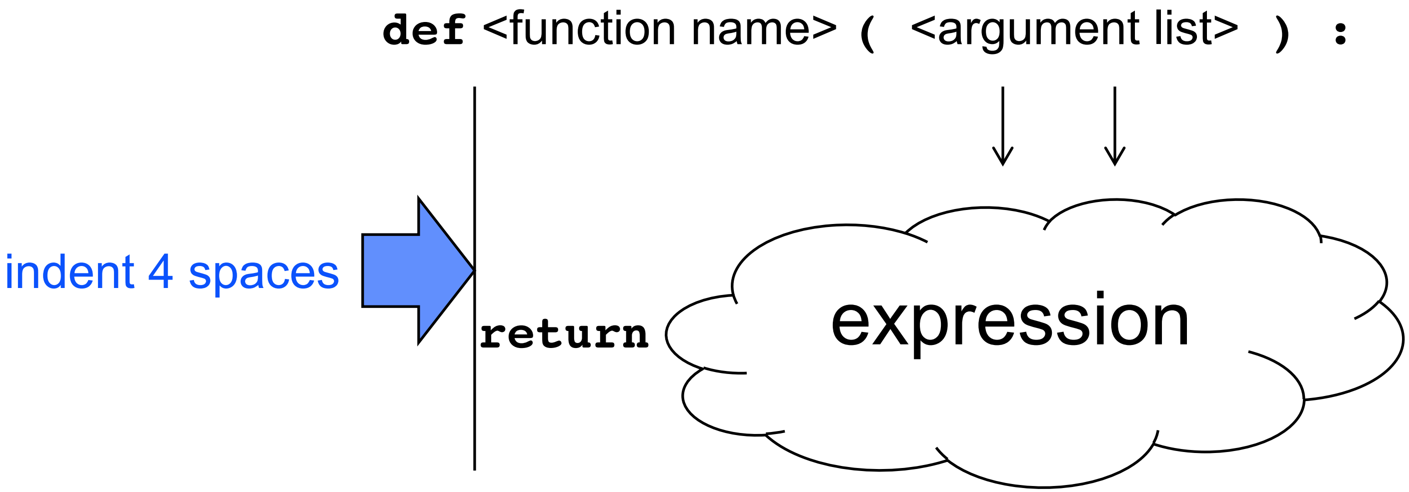
- builtin functions
  - https://docs.python.org/3/library/functions.html
  - min, max, sum
- https://docs.python.org/3/library/
- str
- import math; help(math)

Computational Concepts Toolbox

- Data type
- Operators
- Values
- Expressions

- Statements – take an action
- Assignment Statement
  - <variable> = <expression>
- Sequence of Statements
  - ➢ x = 3
  - ➢ y = 2
  - ➢ print(x+y)

Defining a Function



`def` <function name> `(` <argument list> `)` `:`

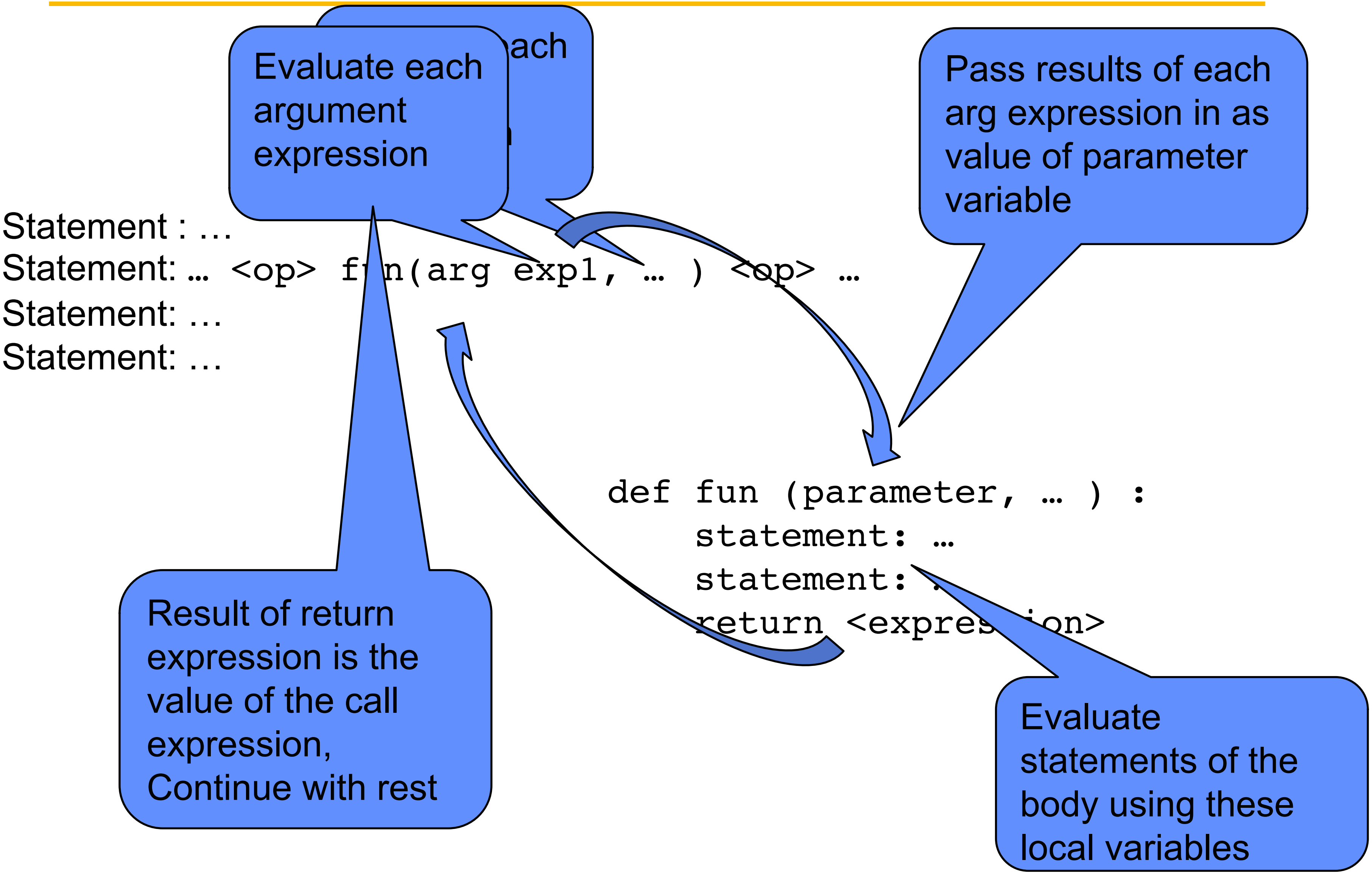
indent 4 spaces

`return`

expression

- **Generalizes an expression or set of statements to apply to lots of instances**
- **A lot like a mathematical function**
  - **maps domain to range, but can do more …**
- **A function should *do one thing well***

Calling and Returning Results



ach

Evaluate each argument expression

Pass results of each arg expression in as value of parameter variable

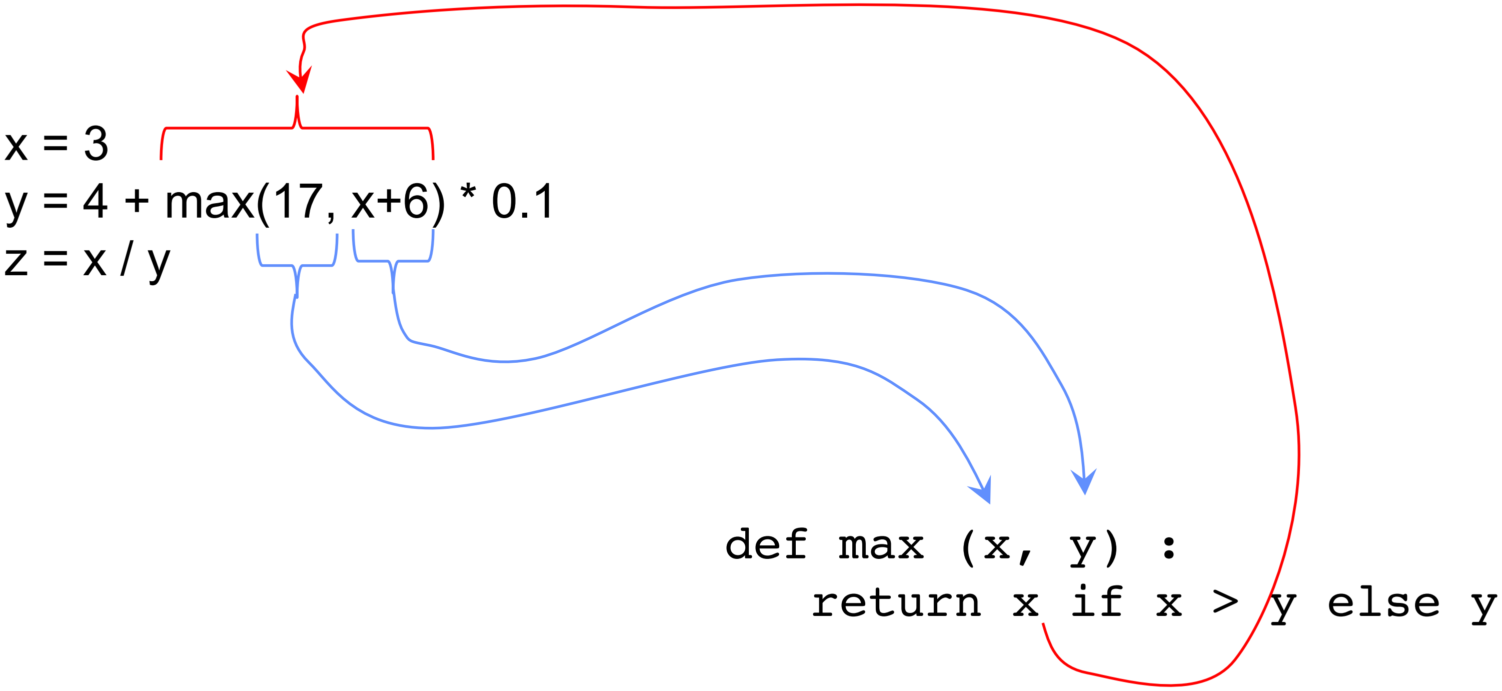
Statement : …
Statement: … `<op> fun(arg exp1, … ) <op> …`
Statement: …
Statement: …

```
def fun (parameter, … ) :
    statement: …
    statement: …
    return <expression>
```

Result of return expression is the value of the call expression, Continue with rest

Evaluate statements of the body using these local variables

Example



```
x = 3
y = 4 + max(17, x+6) * 0.1
z = x / y
```

```
def max (x, y) :
    return x if x > y else y
```

Computational Concepts Toolbox

- Data type
- Operators
- Values
- Expressions
- Sequence of Statements
  - Assignment
  - Function Definition – like assigning to the function name
  - Return

Computational Concepts today

- Good Function Definitions
- Conditional Statement
- Iteration: data-driven (list comprehension)
- Iteration: control-driven (for statement)
  - Structured
- Iteration: while statement
  - More primitive and more general

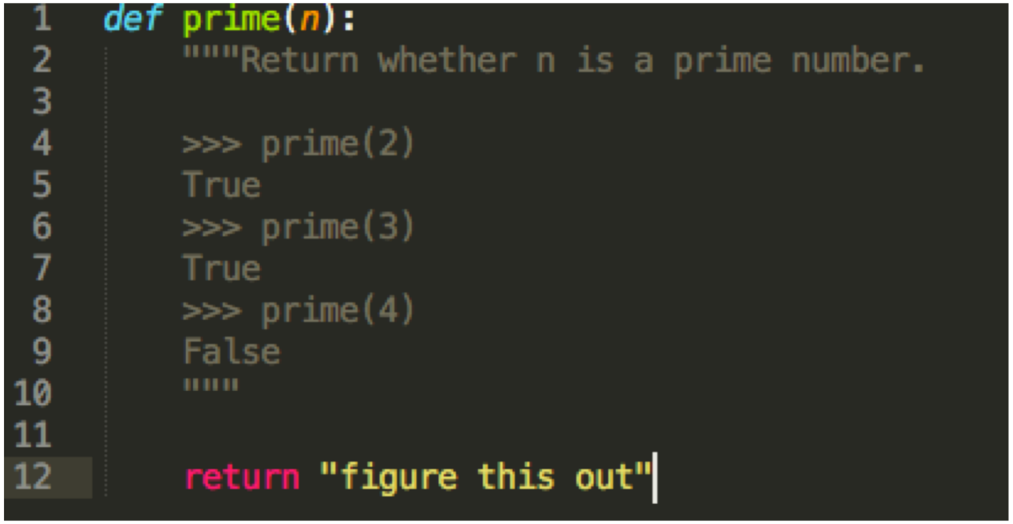
Big Idea: Software Design Patterns

How to write a good function

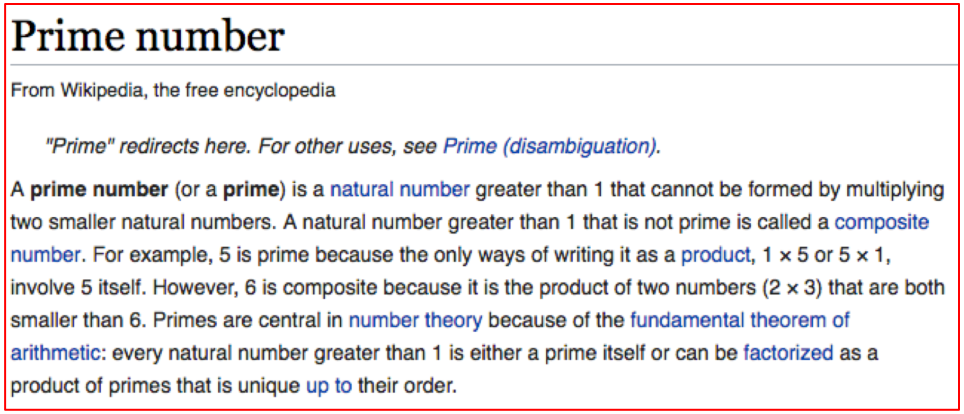
- **Name the function to describe what it does**
  - Function names should be lowercase, with words separated by underscores as necessary to improve readability
- **Choose meaning parameter names**
  - Variable names follow the same convention as function names.
- Write the docstring to explain what it does
  - Not how it does it. What does it return?
- Write doctest to show what it should do.
  - Before you write any code
- Write the code to do it

Python Style Guide: https://www.python.org/dev/peps/pep-0008/

Example: Prime numbers



```python
def prime(n):
    """Return whether n is a prime number.

    >>> prime(2)
    True
    >>> prime(3)
    True
    >>> prime(4)
    False
    """

    return "figure this out"
```



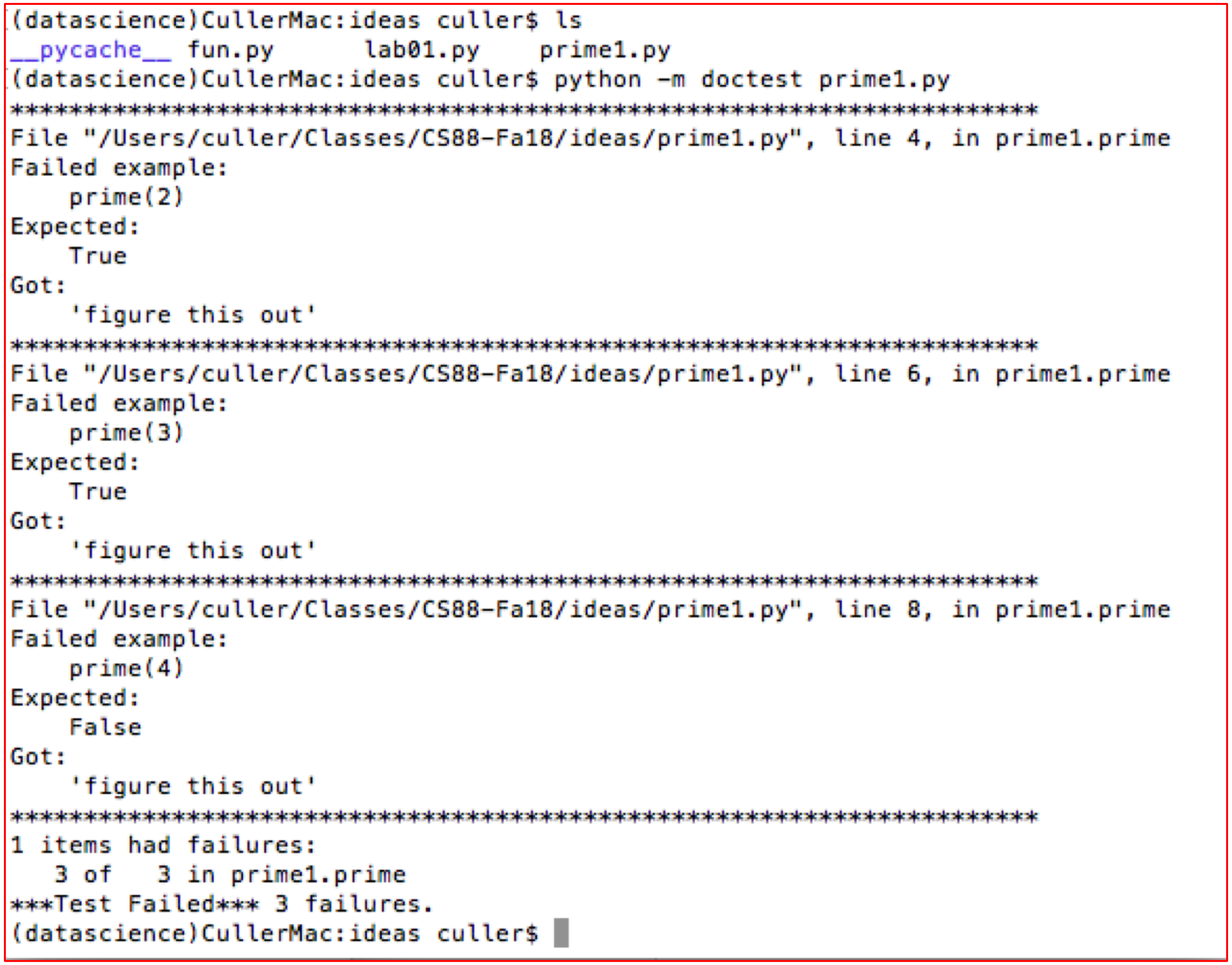
Prime number

From Wikipedia, the free encyclopedia

"Prime" redirects here. For other uses, see Prime (disambiguation).

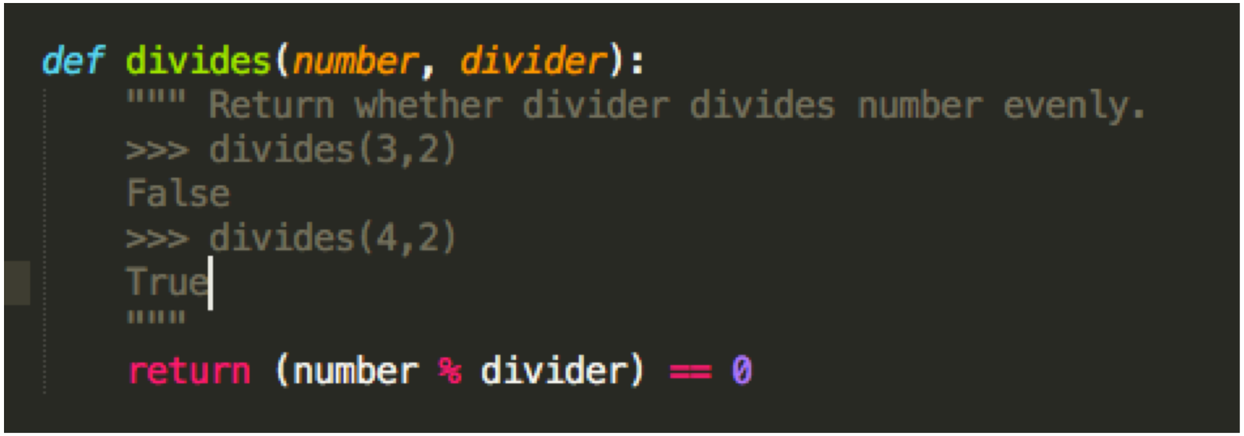
A **prime number** (or a **prime**) is a natural number greater than 1 that cannot be formed by multiplying two smaller natural numbers. A natural number greater than 1 that is not prime is called a composite number. For example, 5 is prime because the only ways of writing it as a product, 1 × 5 or 5 × 1, involve 5 itself. However, 6 is composite because it is the product of two numbers (2 × 3) that are both smaller than 6. Primes are central in number theory because of the fundamental theorem of arithmetic: every natural number greater than 1 is either a prime itself or can be factorized as a product of primes that is unique up to their order.

How’s this work?



```
(datascience)CullerMac:ideas culler$ ls
__pycache__ fun.py      lab01.py    prime1.py
(datascience)CullerMac:ideas culler$ python -m doctest prime1.py
**********************************************************************
File "/Users/culler/Classes/CS88-Fa18/ideas/prime1.py", line 4, in prime1.prime
Failed example:
    prime(2)
Expected:
    True
Got:
    'figure this out'
**********************************************************************
File "/Users/culler/Classes/CS88-Fa18/ideas/prime1.py", line 6, in prime1.prime
Failed example:
    prime(3)
Expected:
    True
Got:
    'figure this out'
**********************************************************************
File "/Users/culler/Classes/CS88-Fa18/ideas/prime1.py", line 8, in prime1.prime
Failed example:
    prime(4)
Expected:
    False
Got:
    'figure this out'
**********************************************************************
1 items had failures:
   3 of   3 in prime1.prime
***Test Failed*** 3 failures.
(datascience)CullerMac:ideas culler$ 
```

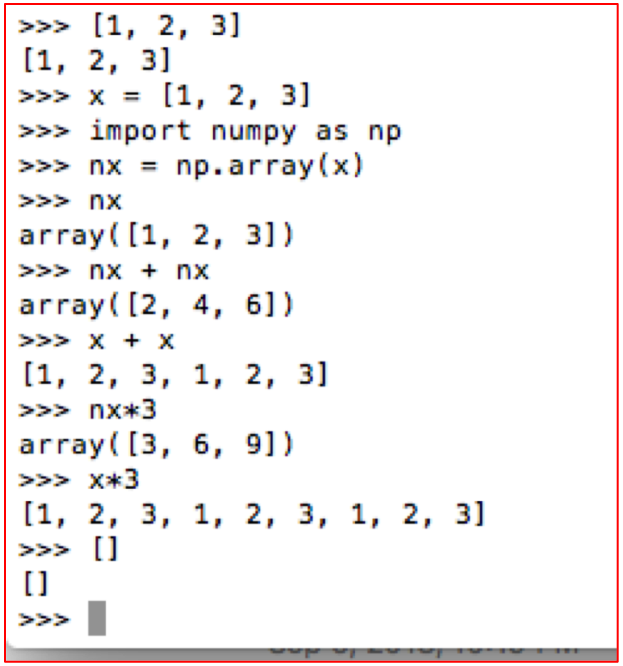
Building some tools



```python
def divides(number, divider):
    """ Return whether divider divides number evenly.
    >>> divides(3,2)
    False
    >>> divides(4,2)
    True
    """
    return (number % divider) == 0
```

A sequence data type

- **A list is an object consisting of an order sequence of values**
- **Its literal is [item0, item1, …]**
- **In data8 you've seen numpy arrays**



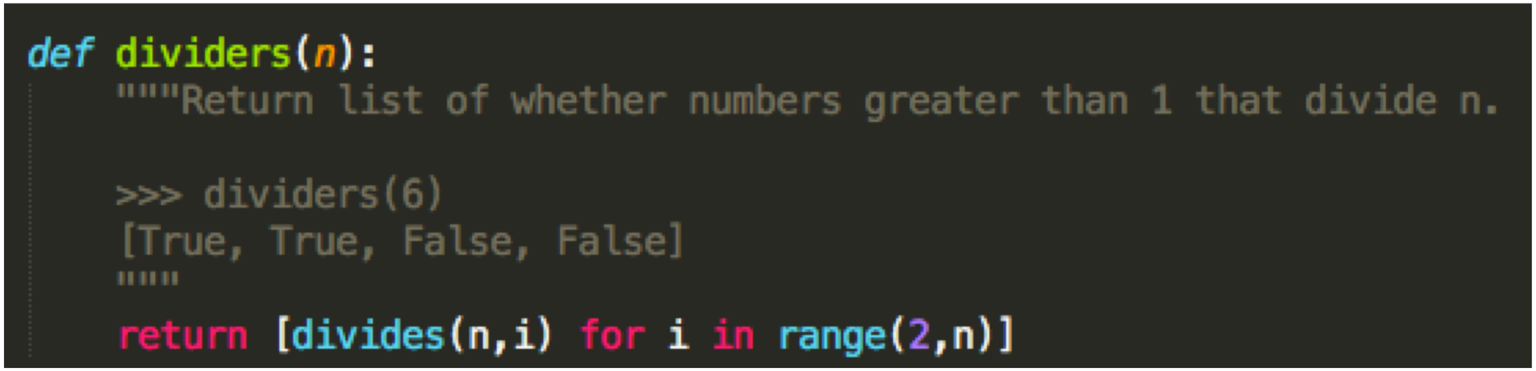
```
>>> [1, 2, 3]
[1, 2, 3]
>>> x = [1, 2, 3]
>>> import numpy as np
>>> nx = np.array(x)
>>> nx
array([1, 2, 3])
>>> nx + nx
array([2, 4, 6])
>>> x + x
[1, 2, 3, 1, 2, 3]
>>> nx*3
array([3, 6, 9])
>>> x*3
[1, 2, 3, 1, 2, 3, 1, 2, 3]
>>> []
[]
>>> 
```

Data-driven iteration

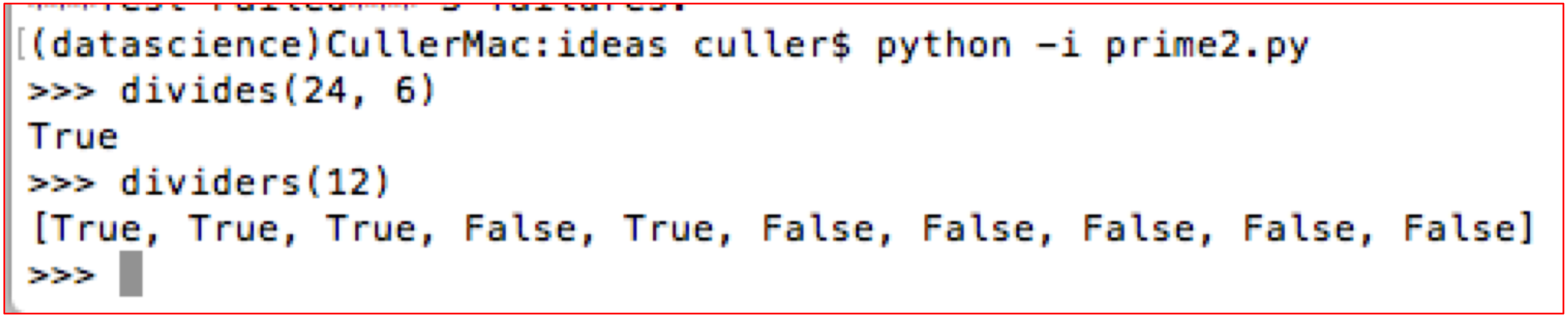
- describe an expression to perform on each item in a sequence
- let the data dictate the control
- Called “list comprehension”

```
[ <expr with loop var> for <loop var> in <sequence expr > ]
```

Building Tools cont.

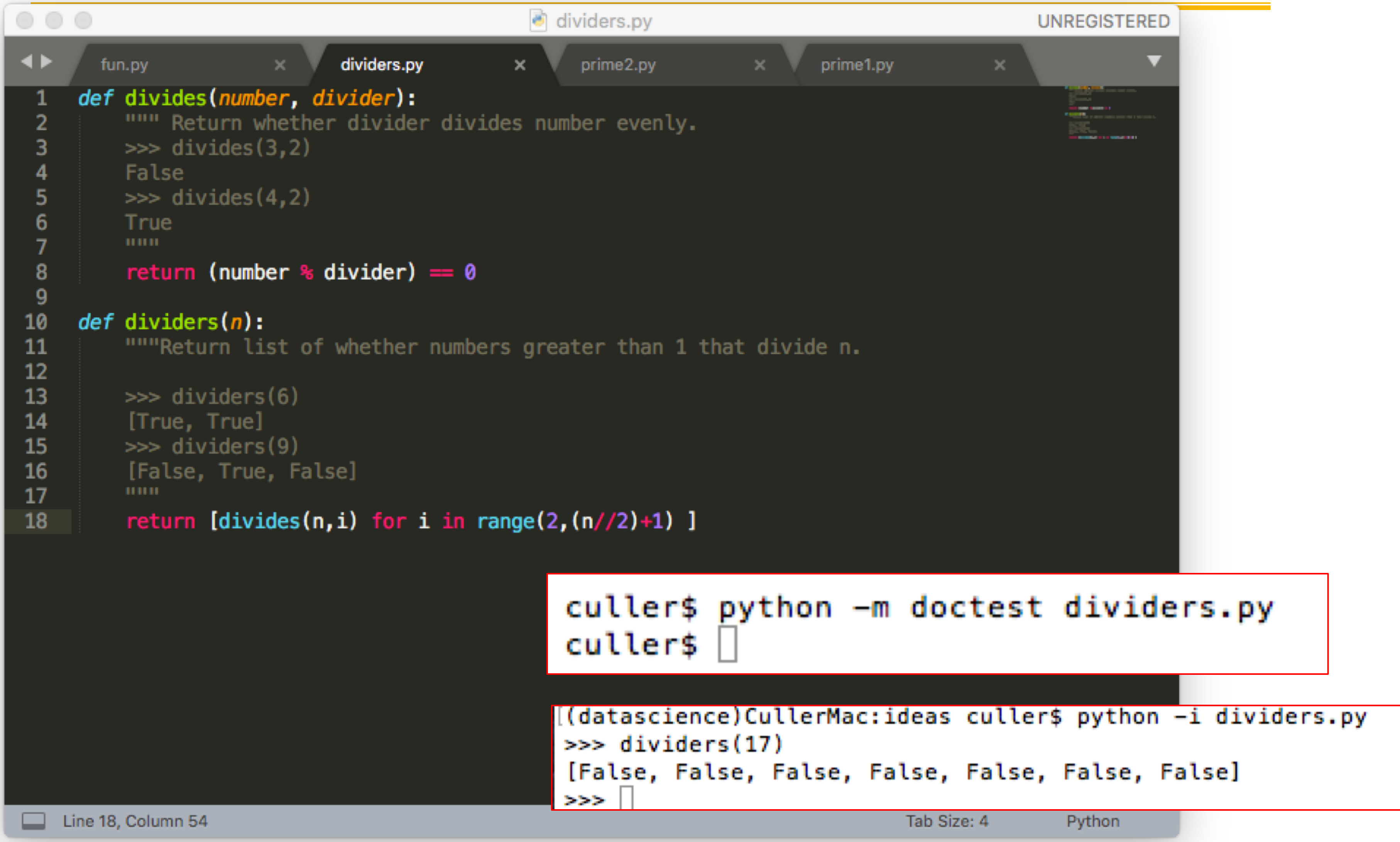


```
def dividers(n):
    """Return list of whether numbers greater than 1 that divide n.

    >>> dividers(6)
    [True, True, False, False]
    """
    return [divides(n,i) for i in range(2,n)]
```



```
***Test Failed*** 3 failures.
(datascience)CullerMac:ideas culler$ python -i prime2.py
>>> divides(24, 6)
True
>>> dividers(12)
[True, True, True, False, True, False, False, False, False, False]
>>> 
```

Building Tools cont.



```python
def divides(number, divider):
    """ Return whether divider divides number evenly.
    >>> divides(3,2)
    False
    >>> divides(4,2)
    True
    """
    return (number % divider) == 0

def dividers(n):
    """Return list of whether numbers greater than 1 that divide n.

    >>> dividers(6)
    [True, True]
    >>> dividers(9)
    [False, True, False]
    """
    return [divides(n,i) for i in range(2,(n//2)+1) ]
```

Line 18, Column 54

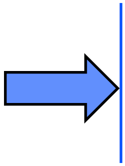
```
culler$ python -m doctest dividers.py
culler$ 
```

```
(datascience)CullerMac:ideas culler$ python -i dividers.py
>>> dividers(17)
[False, False, False, False, False, False, False]
>>> 
```

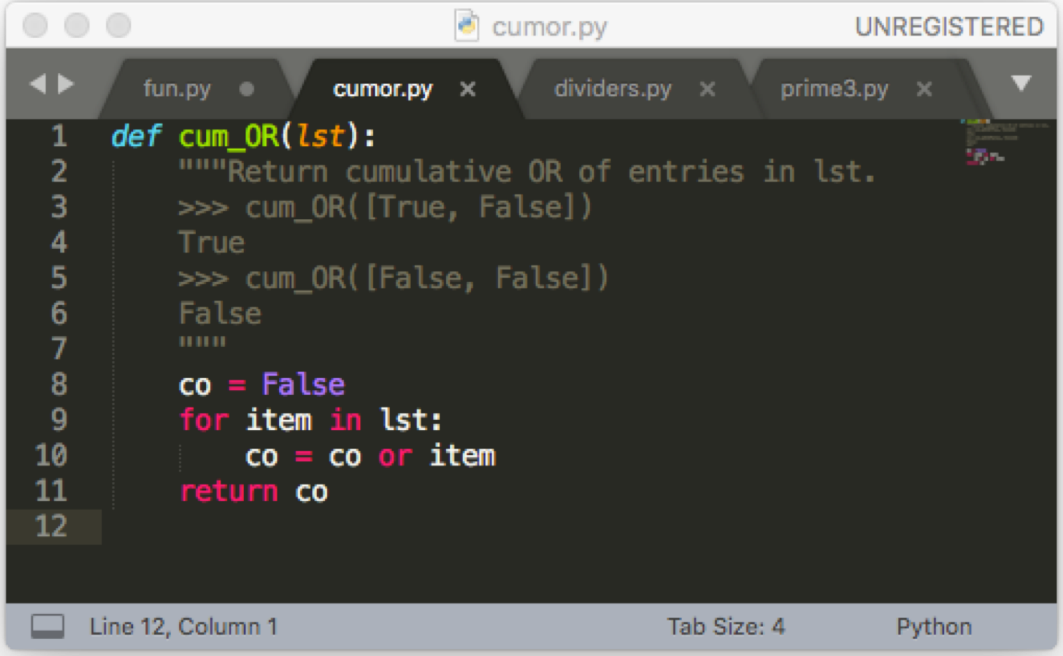
`for` statement – iteration control

- **Repeat a block of statements for a structured sequence of variable bindings**

```
<initialization statements>
for <variables> in <sequence expression>:

    <body statements>

<rest of the program>
```



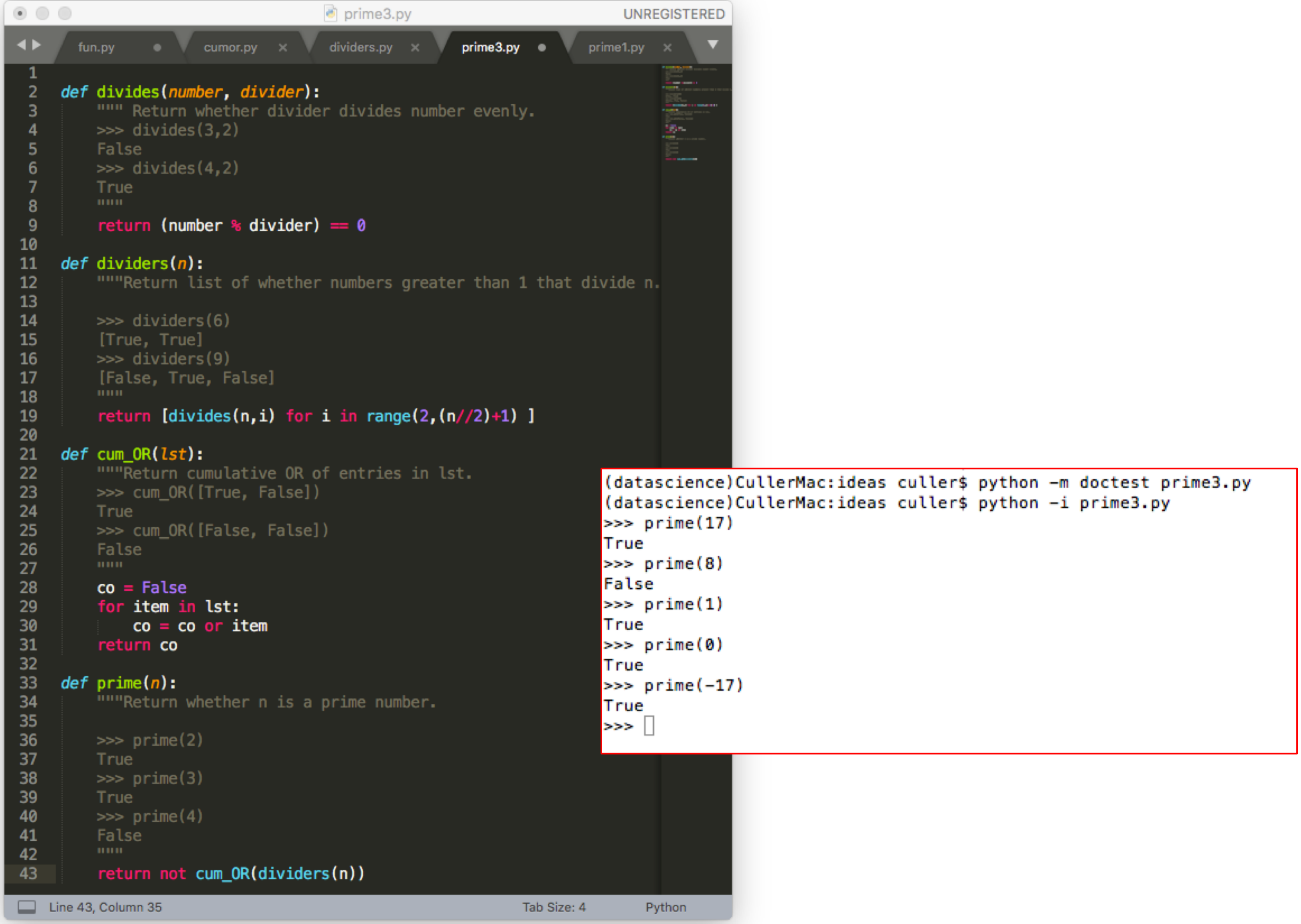
A very basic tool



```python
def cum_OR(lst):
    """Return cumulative OR of entries in lst.
    >>> cum_OR([True, False])
    True
    >>> cum_OR([False, False])
    False
    """
    co = False
    for item in lst:
        co = co or item
    return co
```

- Initialize a variable before loop
- Update it in each iteration
- Final result on exit

Putting it together



```python

def divides(number, divider):
    """ Return whether divider divides number evenly.
    >>> divides(3,2)
    False
    >>> divides(4,2)
    True
    """
    return (number % divider) == 0

def dividers(n):
    """Return list of whether numbers greater than 1 that divide n.

    >>> dividers(6)
    [True, True]
    >>> dividers(9)
    [False, True, False]
    """
    return [divides(n,i) for i in range(2,(n//2)+1) ]

def cum_OR(lst):
    """Return cumulative OR of entries in lst.
    >>> cum_OR([True, False])
    True
    >>> cum_OR([False, False])
    False
    """
    co = False
    for item in lst:
        co = co or item
    return co

def prime(n):
    """Return whether n is a prime number.

    >>> prime(2)
    True
    >>> prime(3)
    True
    >>> prime(4)
    False
    """
    return not cum_OR(dividers(n))
```

```
(datascience)CullerMac:ideas culler$ python -m doctest prime3.py
(datascience)CullerMac:ideas culler$ python -i prime3.py
>>> prime(17)
True
>>> prime(8)
False
>>> prime(1)
True
>>> prime(0)
True
>>> prime(-17)
True
>>> 
```

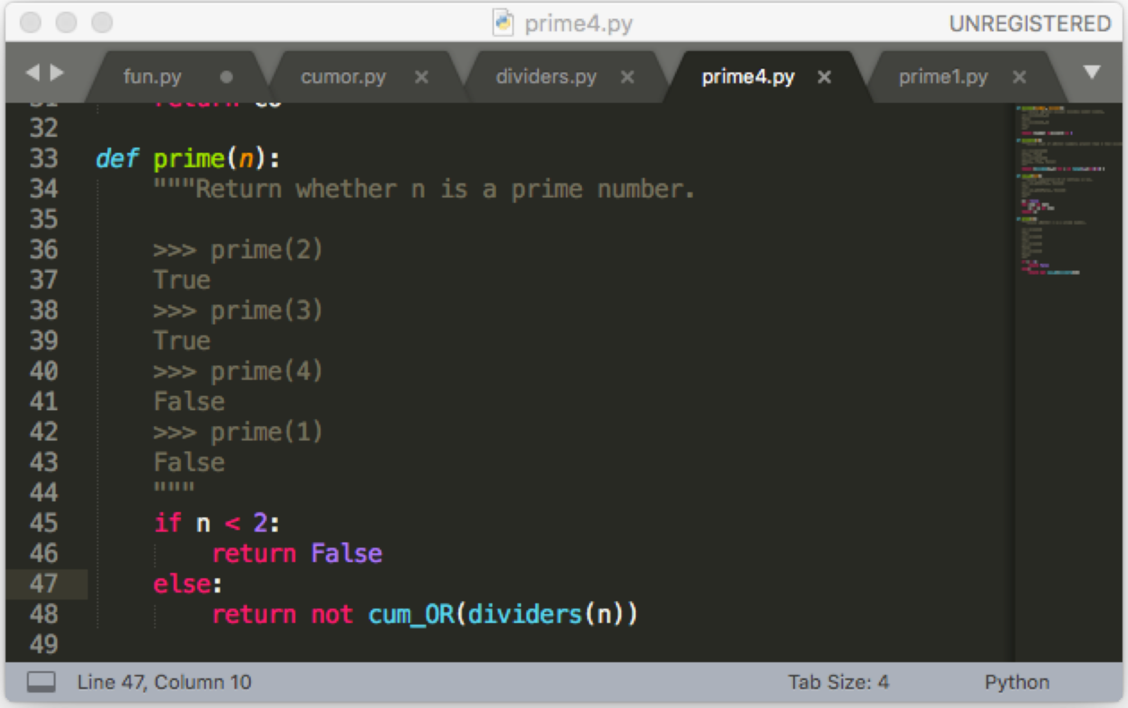
Conditional statement

- **Do some statements, conditional on a *predicate* expression**

```
if <predicate>:
    <true statements>
else:
    <false statements>
```

Optional else clause

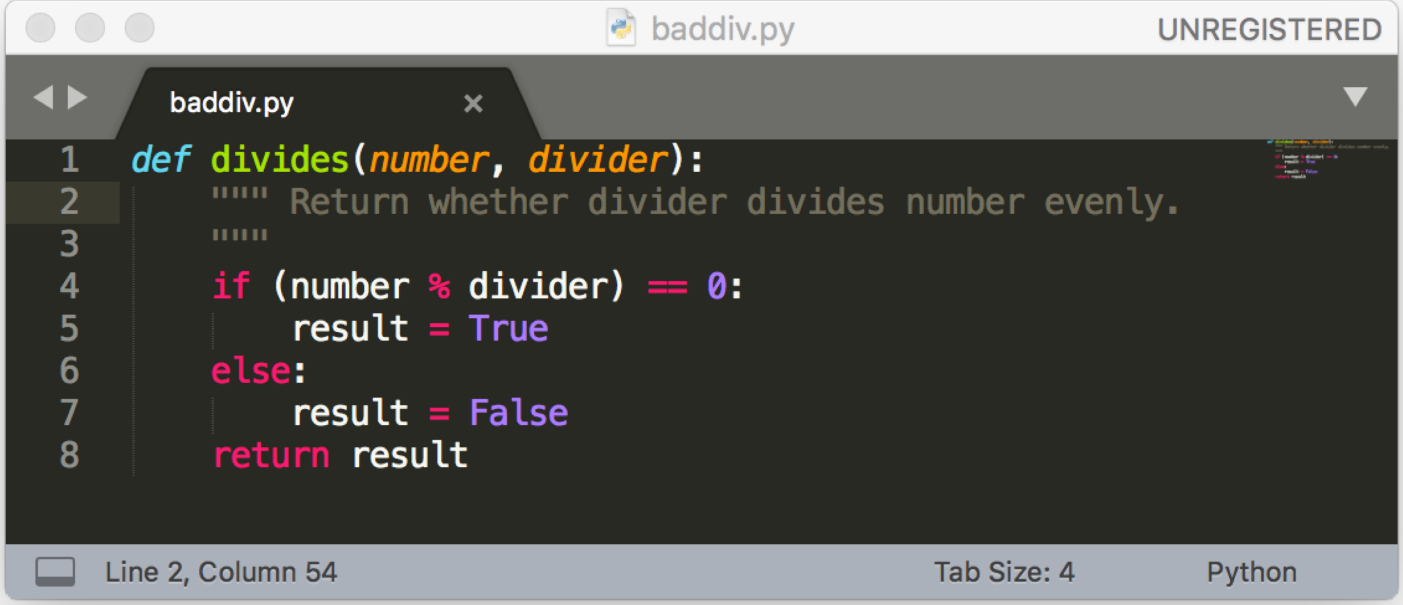
Getting it right



```python
def prime(n):
    """Return whether n is a prime number.

    >>> prime(2)
    True
    >>> prime(3)
    True
    >>> prime(4)
    False
    >>> prime(1)
    False
    """
    if n < 2:
        return False
    else:
        return not cum_OR(dividers(n))
```

- **Conditional used to handle the special case**
  - **Guards whether the logic applies**

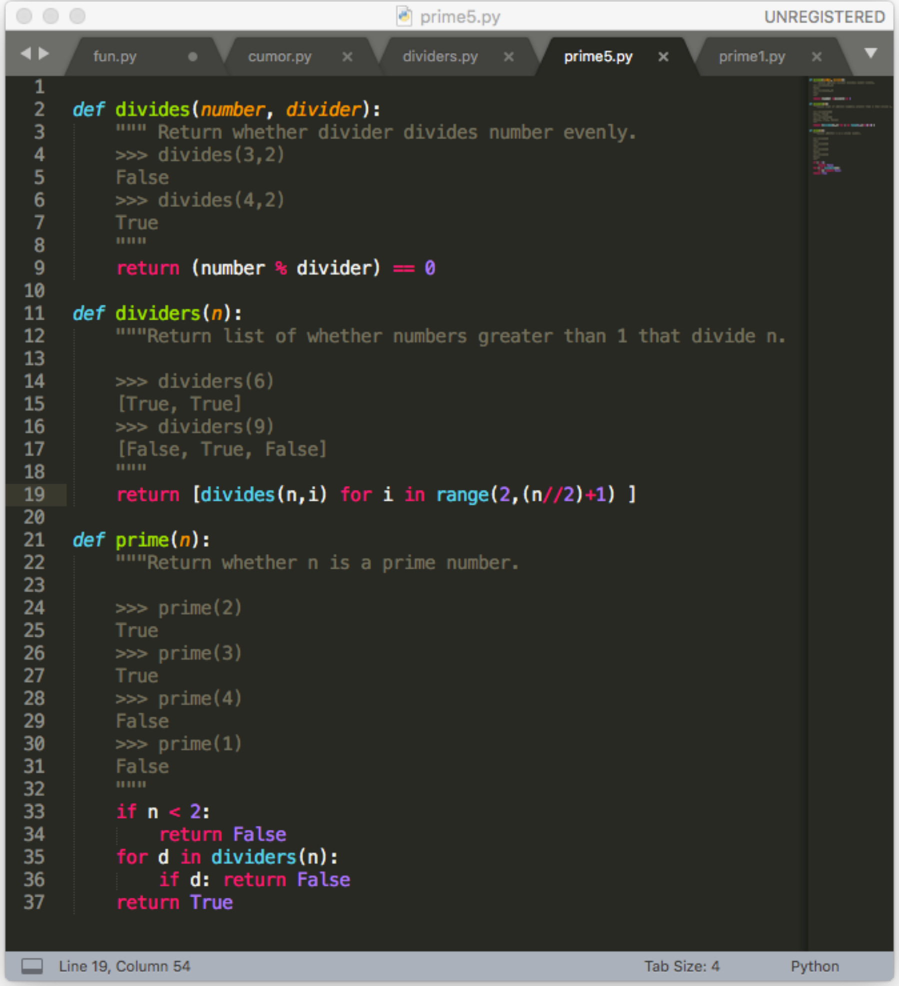
Beware the conditional mess



```python
def divides(number, divider):
    """ Return whether divider divides number evenly.
    """
    if (number % divider) == 0:
        result = True
    else:
        result = False
    return result
```

- **What's wrong with this function?**

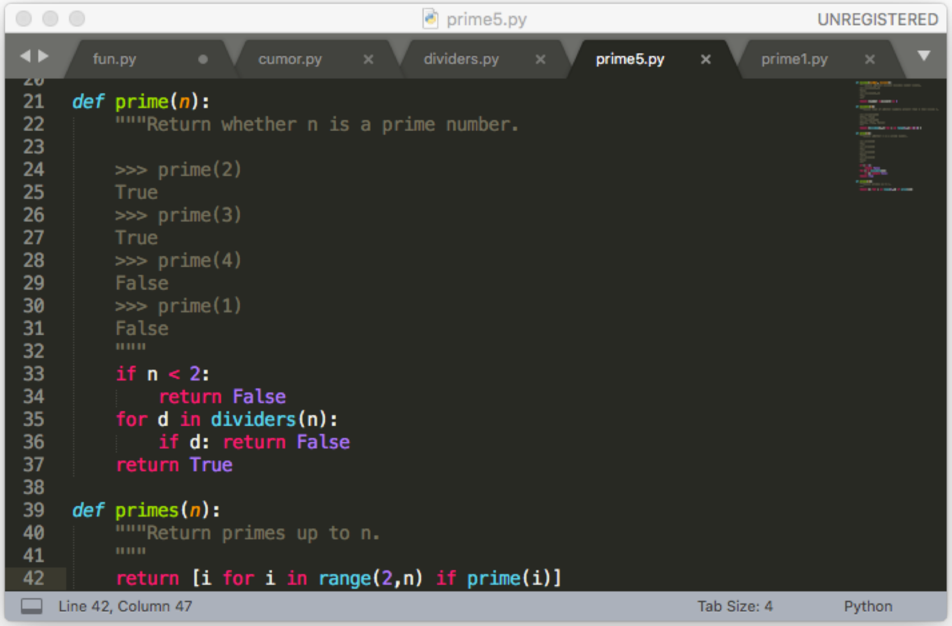
Combining Concepts



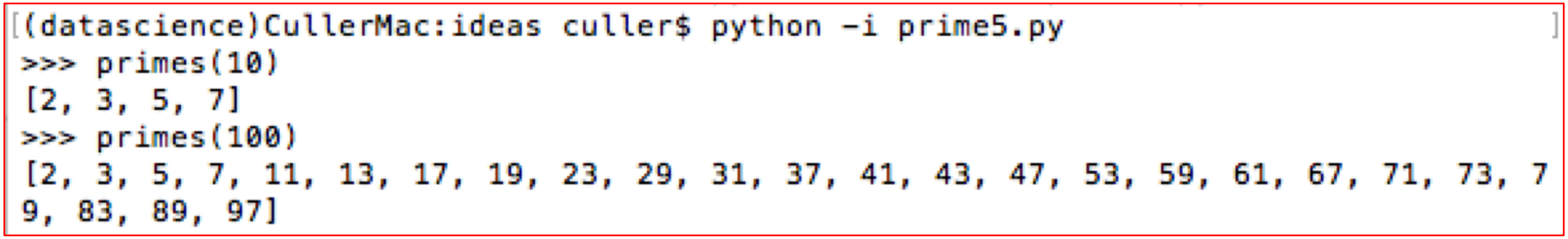
```python

def divides(number, divider):
    """ Return whether divider divides number evenly.
    >>> divides(3,2)
    False
    >>> divides(4,2)
    True
    """
    return (number % divider) == 0

def dividers(n):
    """Return list of whether numbers greater than 1 that divide n.

    >>> dividers(6)
    [True, True]
    >>> dividers(9)
    [False, True, False]
    """
    return [divides(n,i) for i in range(2,(n//2)+1) ]

def prime(n):
    """Return whether n is a prime number.

    >>> prime(2)
    True
    >>> prime(3)
    True
    >>> prime(4)
    False
    >>> prime(1)
    False
    """
    if n < 2:
        return False
    for d in dividers(n):
        if d: return False
    return True
```

- **Return does not have to be at the end**
  - **Nesting within conditionals can simplify expression**

Conditional list comprehension



```python
def prime(n):
    """Return whether n is a prime number.

    >>> prime(2)
    True
    >>> prime(3)
    True
    >>> prime(4)
    False
    >>> prime(1)
    False
    """
    if n < 2:
        return False
    for d in dividers(n):
        if d: return False
    return True

def primes(n):
    """Return primes up to n.
    """
    return [i for i in range(2,n) if prime(i)]
```



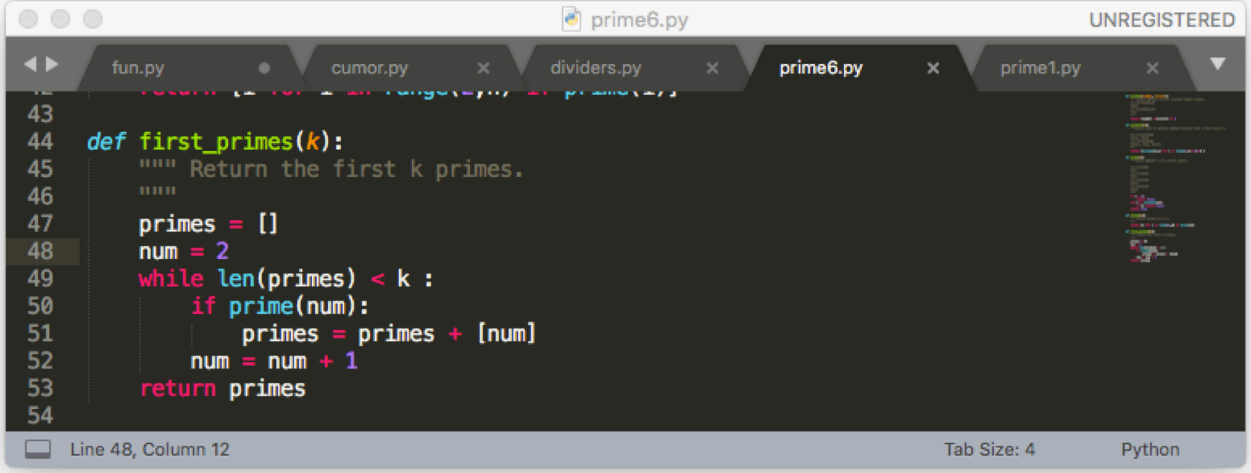
```
[(datascience)CullerMac:ideas culler$ python -i prime5.py                ]
>>> primes(10)
[2, 3, 5, 7]
>>> primes(100)
[2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41, 43, 47, 53, 59, 61, 67, 71, 73, 7
9, 83, 89, 97]
```

while statement – iteration control

- **Repeat a block of statements until a predicate expression is satisfied**

```
<initialization statements>
while <predicate expression>:
   <body statements>

<rest of the program>
```

Putting even more together



```python
    return [i for i in range(2,n) if prime(i)]

def first_primes(k):
    """ Return the first k primes.
    """
    primes = []
    num = 2
    while len(primes) < k :
        if prime(num):
            primes = primes + [num]
        num = num + 1
    return primes

```

- Iteration not simple linear sequence
- Accumulation of values distinct from control

Computational Concepts Toolbox

- Data type
- Operators
- Values => scalars, functions & sequences
- Expressions
  - Iteration: data-driven (list comprehension)
- Sequence of Statements
  - Assignment
  - Function Definition – with doctest
  - Return
  - Conditionals
- Iteration: control-driven (for statement)
  - Structured
- Iteration: while statement
  - More primitive and more general