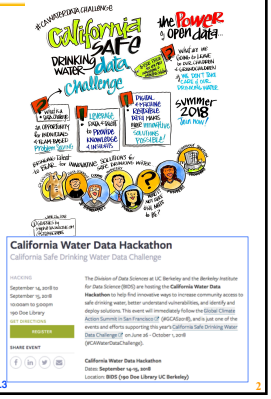
Functions and Control Structures

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

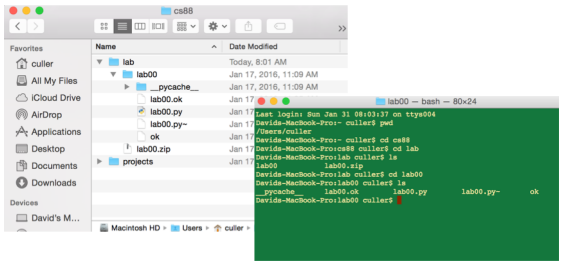
Data Science in the News



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



- 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?

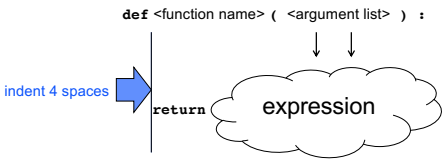
- builtin functions
  - https://docs.python.org/3/library/functions.html
  - min, max, sum
- https://docs.python.org/3/library/
- str
- import math; help(math)

Computational Concepts Toolbox

- Data type
- Operators
- Values
- Expressions

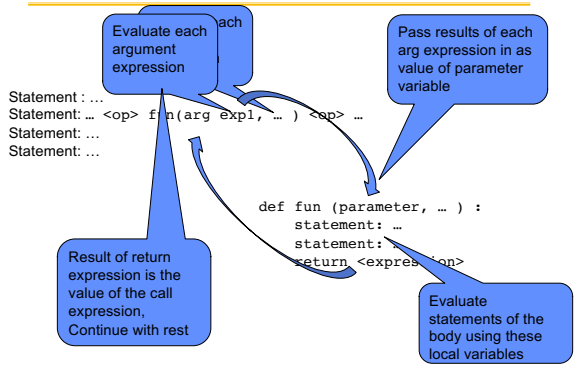
- Statements – take an action
- Assignment Statement
  - <variable> = <expression>
- Sequence of Statements
  - x = 3
  - y = 2
  - print(x+y)

Defining a Function

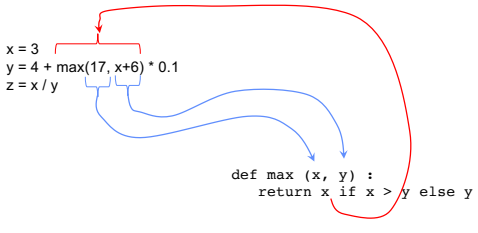


- Generalizes an expression or set of statements to apply to lots of instances
- A lot like a mathematical function
  - maps domain to range, but can do more …
- A function should *do one thing well*

Calling and Returning Results



Example



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

```
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

```
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 > ]
```

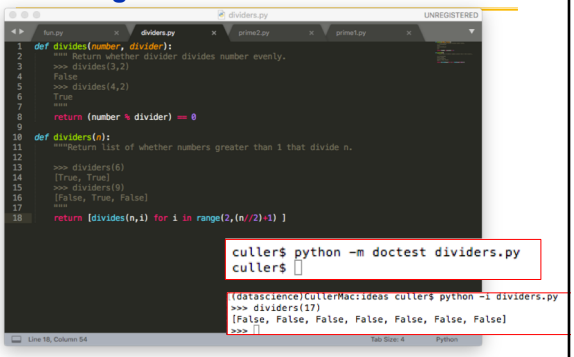

Building Tools cont.

```
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)]
```

```
(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.

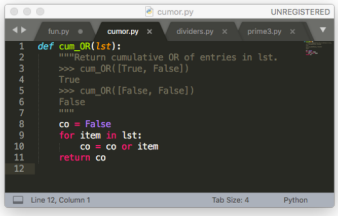


`for` statement – iteration control

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

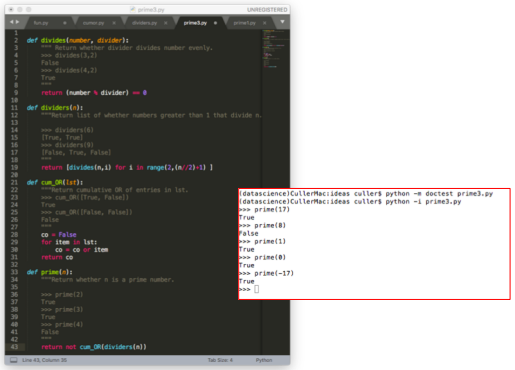
```
<initialization statements>
for <variables> in <sequence expression>:
    <body statements>
<rest of the program>
```


A very basic tool



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

Putting it together



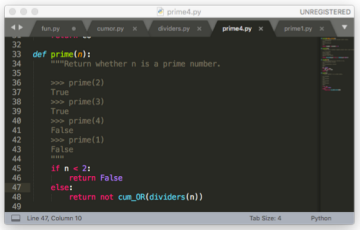
Conditional statement

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

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

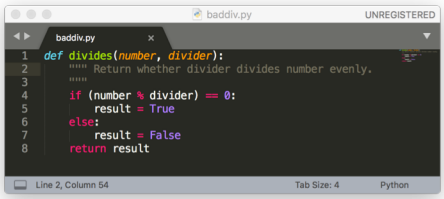
Optional else clause

Getting it right



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

Beware the conditional mess



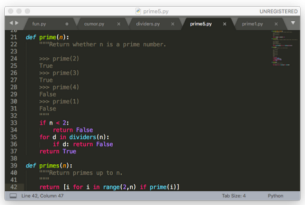
```
def divides(number, divider):
    """ Return whether divider divides number evenly.
    """
    if (number % divider) == 0:
        result = True
    else:
        result = False
    return result
```

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

Combining Concepts

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

Conditional list comprehension



```
[(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

```
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