

STRINGS, BRANCHING, ITERATION

VARIABLES (REVISITED)

■ **name**

- descriptive
- meaningful
- helps you re-read code
- cannot be keywords

■ **value**

- information stored
- can be updated

VARIABLE BINDING WITH =

- compute the **right hand side** → **VALUE**
- store it (aka bind it) in the **left hand side** → **VARIABLE**
- left hand side will be replaced with new value
- = is called assignment

$x = 2$

$x = x * x$

$y = x + 1$

→ Compute value first, then
bind it to variable name; this
will overwrite value of x

BINDING EXAMPLE

- swap variables

– is this ok?

```
x = 1
y = 2
y = x
x = y
```

*This does NOT
do what you
think it does!*

- swap variables

– this is ok!

```
x = 1
y = 2
temp = y
y = x
x = temp
```

TYPES

- variables and expressions
 - `int`
 - `float`
 - `bool`
 - `string` -- NEW
 - ... and others we will see later

STRINGS

- letters, special characters, spaces, digits
- enclose in **quotation marks or single quotes**

```
hi = "hello there"  
greetings = 'hello'
```

- **concatenate** strings

```
name = "eric"  
greet = hi + name  
greeting = hi + " " + name
```

OPERATIONS ON STRINGS

- `'ab' + 'cd'` → **concatenation**
- `3 * 'eric'` → **successive concatenation**
- `len('eric')` → the **length**
- `'eric'[1]` → **indexing**
 - Begins with index 0
 - Attempting to index beyond length - 1 is an error
- `'eric'[1:3]` → **slicing**
 - Extracts sequence starting at first index, and ending before second index
 - If no value before :, start at 0
 - If no value after :, end at length
 - If just :, make a copy of entire sequence

INPUT/OUTPUT: `print`

- used to **output** stuff to console
- keyword is `print`

```
x = 1
print(x)
x_str = str(x)
print("my fav num is", x, ".", "x =", x)
print("my fav num is " + x_str + ". " + "x = " + x_str)
```

INPUT/OUTPUT: `input ("")`

- prints whatever is within the quotes
- user types in something and hits enter
- returns entered sequence
- can bind that value to a variable so can reference

```
text = input("Type anything... ")  
print(5*text)
```

- `input` **returns a string** so must cast if working with numbers

```
num = int(input("Type a number... "))  
print(5*num)
```

IDE's

- painful to just type things into a shell
- better to have a text editor – integrated development environment (IDE)
 - IDLE or Anaconda are examples
- comes with
 - Text editor – use to enter, edit and save your programs
 - Shell – place in which to interact with and run your programs; standard methods to evaluate your programs from the editor or from stored files
 - Integrated debugger (we'll use later)

```
Editor - /Users/ericgrimson/Dropbox (MIT)/Lecture2016New/Lecture2/printExample.py
retirement.py printExample.py getStats.py

1 # -*- coding: utf-8 -*-
2 """
3 Created on Wed Jun  8 11:14:34 2016
4
5 @author: ericgrimson
6 """
7
8
9 x = 1
10 print(x)
11 x_str = str(x)
12 print("my fav num is", x, ".", "x =", x)
13 print("my fav num is " + x_str + "." + "x = " + x_str)
14
```

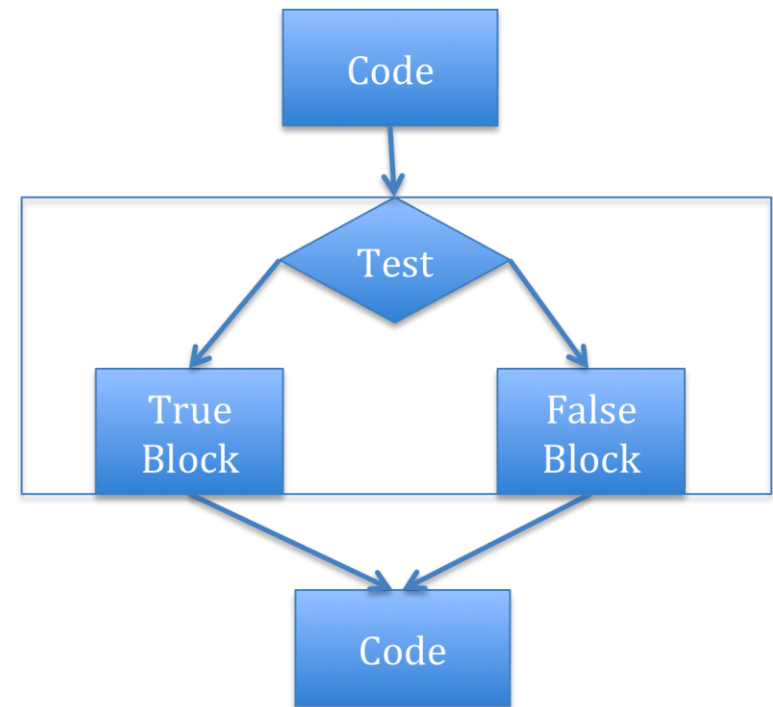
```
IPython console
12: Console 1/A

In [205]: runfile('/Users/ericgrimson/Dropbox
(MIT)/Lecture2016New/Lecture2/printExample.py',
wdir='/Users/ericgrimson/Dropbox (MIT)/Lecture2016New/Lecture2')
1
my fav num is 1 . x = 1
my fav num is 1. x = 1

In [206]:
```

BRANCHING PROGRAMS (REVISITED)

- The simplest branching statement is a **conditional**
 - A test (expression that evaluates to `True` or `False`)
 - A block of code to execute if the test is `True`
 - An optional block of code to execute if the test is `False`



COMPARISON OPERATORS ON `int` and `float`

- `i` and `j` are any variable names

`i > j`

`i >= j`

`i < j`

`i <= j`

`i == j` → **equality** test, True if `i` equals `j`

`i != j` → **inequality** test, True if `i` not equal to `j`

LOGIC OPERATORS ON bools

- a and b are any variable names

`not a` \rightarrow `True` if a is `False`
 `False` if a is `True`

`a and b` \rightarrow `True` if both are `True`

`a or b` \rightarrow `True` if either or both are `True`

CONTROL FLOW - BRANCHING

```
if <condition>:  
    <expression>  
    <expression>  
    ...
```

```
if <condition>:  
    <expression>  
    <expression>  
    ...  
else:  
    <expression>  
    <expression>  
    ...
```

```
if <condition>:  
    <expression>  
    <expression>  
    ...  
elif <condition>:  
    <expression>  
    <expression>  
    ...  
else:  
    <expression>  
    <expression>  
    ...
```

- `<condition>` has a value `True` or `False`
- evaluate expressions in that block if `<condition>` is `True`

USING CONTROL IN LOOPS

- simple branching programs just make choices, but path through code is still linear
- sometimes want to reuse parts of the code
indeterminate number of times

You are in the Lost Forest.



Go left or right?

- You are playing a video game, and are lost in some woods
- If you keep going right, takes you back to this same screen, stuck in a loop

```
if <exit right>:
```

```
  <set background to woods_background>
```

```
  if <exit right>:
```

```
    <set background to woods_background>
```

```
    if <exit right>:
```

```
      <set background to woods_background>
```

```
      and so on and on and on...
```

```
    else:
```

```
      <set background to exit_background>
```

```
  else:
```

```
    <set background to exit_background>
```

```
else:
```

```
  <set background to exit_background>
```

You are in the Lost Forest.



Go left or right?

- You are playing a video game, and are lost in some woods
- If you keep going right, takes you back to this same screen, stuck in a loop

```
while <exit right>:
```

```
    <set background to woods_background>
```

```
<set background to exit_background>
```

CONTROL FLOW:

while LOOPS

```
while <condition>:  
    <expression>  
    <expression>  
    ...
```

- <condition> evaluates to a Boolean
- if <condition> is **True**, do all the steps inside the while code block
- check <condition> again
- repeat until <condition> is **False**

while LOOP EXAMPLE

```
You are in the Lost Forest.  
*****  
*****  
  😊  
*****  
*****  
Go left or right?
```

```
n = input("You are in the Lost Forest. Go left or right? ")  
while n == "right":  
    n = input("You are in the Lost Forest. Go left or right? ")  
print("You got out of the Lost Forest!")
```


CONTROL FLOW:

while and for LOOPS

```
# more complicated with while loop
n = 0
while n < 5:
    print(n)
    n = n+1
```

```
# shortcut with for loop
for n in range(5):
    print(n)
```

*range(5) gives us the integers
0, 1, 2, 3, 4 in turn*

CONTROL FLOW: `for` LOOPS

```
for <variable> in range(<some_num>):  
    <expression>  
    <expression>  
    ...
```

- each time through the loop, `<variable>` takes a value
- first time, `<variable>` starts at the smallest value
- next time, `<variable>` gets the prev value + 1
- etc.

range(start, stop, step)

- default values are `start = 0` and `step = 1` and is optional
- loop until value is `stop - 1`

```
mysum = 0
for i in range(7, 10):
    mysum += i
print(mysum)
```

```
mysum = 0
for i in range(5, 11, 2):
    mysum += i
print(mysum)
```

break STATEMENT

- immediately exits whatever loop it is in
- skips remaining expressions in code block
- exits only innermost loop

```
while <condition_1>:  
    while <condition_2>:  
        <expression_a>  
        break  
        <expression_b>  
    <expression_c>
```

break STATEMENT

```
mysum = 0
for i in range(5, 11, 2):
    mysum += i
    if mysum == 5:
        break
print(mysum)
```

- what happens in this program?

for VS while LOOPS

for loops

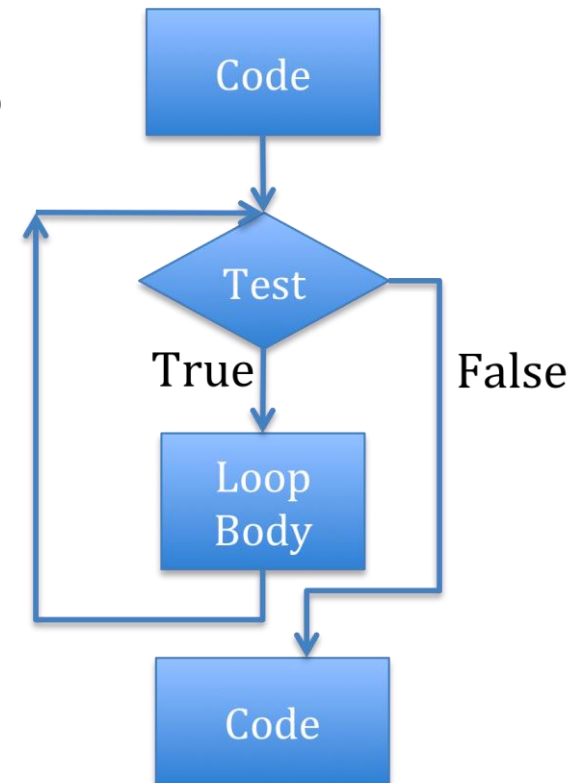
- **know** number of iterations
- can **end early** via `break`
- uses a **counter**
- **can rewrite** a `for` loop using a `while` loop

while loops

- **unbounded** number of iterations
- can **end early** via `break`
- can use a **counter but must initialize** before loop and increment it inside loop
- **may not be able to rewrite** a `while` loop using a `for` loop

ITERATION

- Concept of iteration let's us extend simple branching algorithms to be able to write programs of arbitrary complexity
 - Start with a test
 - If evaluates to `True`, then execute loop body once, and go back to reevaluate the test
 - Repeat until test evaluates to `False`, after which code following iteration statement is executed



AN EXAMPLE

```
x = 3
ans = 0
itersLeft = x
while (itersLeft != 0):
    ans = ans + x
    itersLeft = itersLeft - 1
print(str(x) + '*' + str(x) + ' = ' + str(ans))
```

This code squares the value of x by repetitive addition.

STEPPING THROUGH CODE

```
x = 3
```

```
ans = 0
```

```
itersLeft = x
```

```
while (itersLeft != 0):
```

```
    ans = ans + x
```

```
    itersLeft = itersLeft - 1
```

```
print(str(x) + '*' + str(x) + ' = ' + str(ans))
```

x	ans	itersLeft
3	0	3
	3	2
	6	1
	9	0

The diagram illustrates the state of variables x, ans, and itersLeft during the execution of the while loop. Red circles highlight the values, and red arrows show the flow of updates. The first row shows the initial state: x=3, ans=0, itersLeft=3. The subsequent rows show the state after each iteration: ans is updated to 3, 6, and 9, and itersLeft is updated to 2, 1, and 0. The value of x remains constant at 3 throughout the loop.

Some properties of iteration loops:

- need to set an iteration variable outside the loop
- need to test variable to determine when done
- need to change variable within the loop, in addition to other work

ITERATIVE CODE

- Branching structures (conditionals) let us jump to different pieces of code based on a test
 - Programs are **constant time**
- Looping structures (e.g., while) let us repeat pieces of code until a condition is satisfied
 - Programs now take time that depends on values of variables, as well as length of program

CLASSES OF ALGORITHMS

- Iterative algorithms allow us to do more complex things than simple arithmetic
- We can repeat a sequence of steps multiple times based on some decision; leads to new classes of algorithms
- One useful example are “guess and check” methods

GUESS AND CHECK

- Remember our “declarative” definition of square root of x
- If we could guess possible values for square root (call it g), then can use definition to check if $g * g = x$
- We just need a good way to generate guesses

FINDING CUBE ROOT OF INTEGER

- One way to use this idea of generating guesses in order to find a cube root of x is to first try 0^{**3} , then 1^{**3} , then 2^{**3} , and so on
- Can stop when reach k such that $k^{**3} > x$
- Only a finite number of cases to try

SOME CODE

```
x = int(input('Enter an integer: '))
ans = 0
while ans**3 < x:
    ans = ans + 1
if ans**3 != x:
    print(str(x) + ' is not a perfect cube')
else:
    print('Cube root of ' + str(x) + ' is ' + str(ans))
```


EXTENDING SCOPE

- Only works for positive integers
- Easy to fix by keeping track of sign, looking for solution to positive case

SOME CODE

```
x = int(input('Enter an integer: '))
ans = 0
while ans**3 < abs(x):
    ans = ans + 1
if ans**3 != abs(x):
    print(str(x) + ' is not a perfect cube')
else:
    if x < 0:
        ans = - ans
    print('Cube root of ' + str(x) + ' is ' + str(ans))
```

LOOP CHARACTERISTICS

- Need a loop variable
 - Initialized outside loop
 - Changes within loop
 - Test for termination depends on variable
- Useful to think about a **decrementing function**
 - Maps set of program variables into an integer
 - When loop is entered, value is non-negative
 - When value is ≤ 0 , loop terminates, and
 - Value is decreased every time through loop
- Here we can use `abs(x) - ans**3`

WHAT IF MISS A CONDITION?

- Suppose we don't initialize the variable?
 - Likely get a `NameError`; or worse use an expected value to initiate the computation
- Suppose we don't change the variable inside the loop?
 - Will end up in an infinite loop, never reaching the terminating condition

GUESS-AND-CHECK

- you are able to **guess a value** for solution
- you are able to **check if the solution is correct**
- keep guessing until find solution or guessed all values
- the process is **exhaustive enumeration**

CLEANER GUESS-AND-CHECK

– cube root

```
cube = 8
```

```
for guess in range(cube+1):
```

```
    if guess**3 == cube:
```

```
        print("Cube root of ", cube, " is ", guess)
```

CLEANER GUESS-AND-CHECK – cube root

```
cube = 8

for guess in range(abs(cube)+1):
    if guess**3 >= abs(cube):
        break
if guess**3 != abs(cube):
    print(cube, 'is not a perfect cube')
else:
    if cube < 0:
        guess = -guess
    print('Cube root of ' + str(cube) + ' is ' + str(guess))
```

EXHAUSTIVE ENUMERATION

- Guess and check methods can work on problems with a finite number of possibilities
- Exhaustive enumeration is a good way to generate guesses in an organized manner