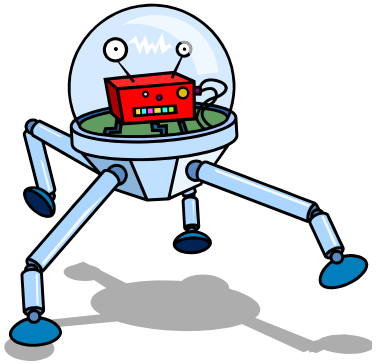
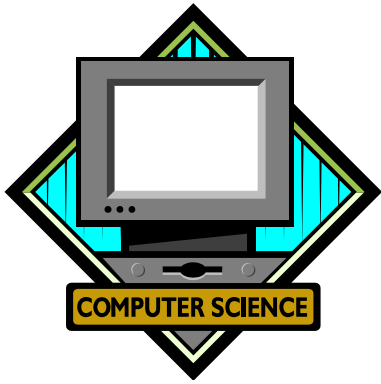
Caltech/LEAD Summer 2012 Computer Science





Lecture 3: July 11, 2012

String Theory

Last time

- Overview of course
- Overview of computer science
- Introduction to Python
  - running programs
  - types, expressions, operators
  - variables and assignment
  - functions (using and defining with `def`)
  - comments

LEAD
Leadership Education And Development

Today

- Strings
  - a fundamental data type
  - an example of an "object"
  - very widely used in practice

But first...

- Donnie needs you to send him an email (to donnie@cs.caltech.edu) with
  - your full name
  - *your* email address (not your parents')
  - what you would like your user name to be (just alphabetic characters and/or numbers; no spaces or symbols)
- He'll use this to set up your csman account (for problem set submissions)
- Please do this today!

Terminology

- In programming, many familiar words are used with unfamiliar meanings
- Example: string
- Doesn't mean this:

Terminology

- In programming, many familiar words are used with unfamiliar meanings
- Example: string
- Instead, it means a *sequence of characters*
- Examples:

```
'this is a string'
"so is this"
```

Applications

- Strings are one of the most-used data types
- Examples:
  - DNA sequences: `"ACCTGGAACT"`
  - Web pages
  - Documents in word processors
  - Computer source code!
  - User interaction (string input/output)
  - etc.
- *Lots* of useful functions predefined for strings

Sequence...

- In Python, strings are just one example of *sequences*
- Other kinds of sequences exist
  - *e.g.* lists, tuples
- Significance:
  - the *same* functions and operators can usually be used with different sequences, and they mean the *same* kind of thing
- In other words:
  - "learn one sequence, learn them all" (almost)

... of characters

- In Python, there is no special data type for characters (letters, digits, etc.)
  - unlike many other computer languages
- A character can only be represented as a string of length 1:
  - `'a'  # the character a (letter)`
  - `'1'  # the character 1 (digit)`
  - `'_'  # the underscore character`
  - `'?'  # question mark (symbol)`

Quotation marks

- Python allows you to use either single or double quotes to represent a string:

```
'I am a string'
"So am I"
```

- You have to be consistent!

```
"This is no good'
'This is also no good"
```

- If you start the string with a single quote, you must end it with a single quote
  - and similarly for double quotes

Quotation marks

- If you leave out the quotation marks, it isn't a string:

```
>>> 'foobar'
'foobar'
>>> foobar
NameError: name 'foobar' is not
  defined
```

- Python interprets `foobar` as a variable name
  - which you haven't defined, so → error

Quotation marks

- One kind of quote can be inside another:

```
"I can have 'single quotes' inside"
'I can have "double quotes" inside'
```

Quotation marks

- However, you can't put the same kind of quote inside itself:

```
s = 'this isn't going to work'
```

- Why not?

```
s = 'this isn't going to work'
```

- Type this into Python and you get:

```
    s = 'this isn't going to work'
                    ^
Syntax error: invalid syntax
```

Syntax errors

- A "syntax error" means that you broke the rules of how the language is written
- In this case:

```
s = 'this isn't going to work'
```

- is interpreted as:

```
s = 'this isn' t going to work'
```

- The `t going to work'` part doesn't make sense to Python
  - so it aborts with an error

Escape sequences

- There is a way to put the same quotation mark inside itself:

```
s  = 'this won\'t be a problem'
s2 = "this won\"t be a problem"
```

- Character sequences beginning with the backslash character (\) are called *escape sequences*
- They change the meaning of the next character in the string
  - Can only be used inside a string!

Escape sequences

- Common escape sequences:

`\'` → literal single quote character
  - (even inside a single-quoted string)

`\"` → literal double quote character
  - (even inside a double-quoted string)

`\\` → literal backslash character

`\t` → tab character

`\n` → newline character

Strings are immutable

- A string is a fixed, or *immutable* object
- Once you create a string, you can't change any of the letters inside the string
  - instead, you would have to create a new string

```
here = "Caltexh"   # oops!
here = "Caltech"   # fixed!
```

Concatenating strings

- Two strings can be combined (concatenated) by using the + operator:

```
>>> 'foo' + 'bar'
'foobar'
>>> s1 = 'foo'
>>> s2 = 'bar'
>>> s1 + s2
'foobar'
```

Operator overloading

- Usually, + used with numbers as operands
- Python sometimes uses the same operator to mean different things depending on the type of the operands:
  - + with numbers as operands → addition
  - + with strings as operands → string concatenation
- This is known as "operator overloading"

Empty string

- The empty string is a valid Python object
- Written as `""` or as `''`

```
>>> 'foo' + ''
'foo'
>>> '' + 'foo'
'foo'
```

String + number?

- Can't add strings and numbers:

```
>>> 'foo' + 10
TypeError: cannot concatenate
  'str' and 'int' objects
>>> 10 + 'foo'
TypeError: unsupported operand
  type(s) for +: 'int' and 'str'
```

- Don't assume that Python "knows" how to do something "obvious"

String + number?

- You probably wanted

```
>>> 'foo' + 10
```

- to give

```
'foo10'
```

- There is a way to do this:

```
>>> 'foo' + str(10)
'foo10'
```

- `str` is a built-in function that converts any value into its string representation

String + number?

- How about this?

```
>>> '32' + 10
```

- Python will not convert `10` to `'10'`
  - or `'32'` to `32`
- Python does not "know" that `'32'` represents an integer
  - so doesn't output `'42'`
  - result → error as before

```
>>> '32' + '10'
```

- Result: `'3210'`, not `'42'`

String + number?

- *Rule of thumb*:
  - Nothing gets converted to a string unless you ask it to be converted with `str`
- However, it is OK to add different kinds of numbers

```
>>> 10 + 4.23
14.23
>>> 3.1415926 + 3
6.1415926
```

- Python converts `int` → `float` as needed

String "multiplication"

- In contrast to addition, can "multiply" strings by integers

```
>>> 'foo' * 3
'foofoofoo'
>>> 4 * 'foo'
'foofoofoofoo'
>>> 'foo' * 0
''
```

- Operator `*` is overloaded to work on strings

String "multiplication"

- Can even try weird things:

```
>>> 'foo' * (-3)
''
```

- Were you expecting

```
'oofoofoof'
```

- ?
- *Rule*: When you're not sure, try it in the interpreter!

String "multiplication"

- Don't try multiplying strings by floats!

```
>>> 'foo' * 3.5
TypeError: can't multiply sequence by
  non-int of type 'float'
```

  - Half-characters not yet supported in Python ☺
- Since this doesn't make sense, Python doesn't allow it

Interlude

- Video clip!
- The ancestor of your laptop computer

Multi-line strings

- Normally, strings in Python can only span one line
- Trying to write a string of more than one line gives an error:

```
>>> 'this is a string
SyntaxError: EOL while scanning
  single-quoted string
```

- **EOL** means "End Of Line"
- Even if you intended to end the string on the next line, this won't work

Multi-line strings

- Multi-line strings are written using three quotes (single or double) at either end:

```
'''this is a multi-line
string''' # 3 ' characters
"""this, also, is a multi-
line string""" # 3 " characters
```

- Other than the quoting, exactly the same as a regular string

Multi-line strings

- Multi-line strings often called "triple-quoted strings"
- Single-line strings called "single-quoted strings"
- *NOTE*: "single-quoted" doesn't mean the kind of quoted character used (' or ")
  - it means that there is only one such character to start/end the string

Multi-line strings

- Inside a triple-quoted string, can embed:
  - single or double quote characters
  - in any combination

```
>>> '''This
... is a 'multi-line string"
... with "" embedded '' quotes'''
'This\nis a \'multi-line string"\nwith
  "" embedded \'\' quotes'
```

- When Python prints the string, it uses `\n` instead of newlines and escapes the internal `'` characters

Typical application

- A web page can be written as a single big multiline string:

```
'''<html>
<head>
  <title>My home page</title>
</head>
<body>
  <p>Welcome to my home page!</p>
</body>
</html>'''
```

Typical application

- Compare to single-line string version:

```
'<html>' + \
'<head>' + \
'  <title>My home page</title>' + \
'</head>' + \
'<body>' + \
'  <p>Welcome to my home page!</p>' + \
'</body>' + \
'</html>'
```

Typical application

- Single-line version is *much* more annoying to write!
- Note: If any expression will not fit on one line, can use `\<return>` to continue it on next line (backslash (`\`) followed immediately by hitting the return key)
- Useful for big expressions, *e.g.*

```
1 + 2 + 3 + \
4 + 5 + 6 + 7 + 8
```

- In previous example, triple quoted string is preferable to using lots of backslash-returns

`print` statement

- To print a string as output from a Python program, use the `print` statement:

```
>>> print "hello!"
hello!
```

- *Note*: not the same as just entering the string `"hello!"`:

```
>>> "hello!"
"hello!"
```

- (This prints the quotes too)

`print` statement

- The important difference:
- In a file of Python code:

```
print "hello!"
```

- will cause `hello!` to be printed, but

```
"hello!"
```

by itself will do nothing

- (Running code in the interactive interpreter is not *exactly* the same as running code in a file.)

`print` statement

- Escape sequences are not shown when using `print`:

```
>>> print "hello!\ngoodbye!"
hello!
goodbye!
```

- Without `print`:

```
>>> "hello!\ngoodbye!"
"hello!\ngoodbye!"
```

- Newline character still there, but printed differently

`print` statement

- `print` automatically adds a newline (`\n`) character after printing:

```
>>> print "hello"
hello
```

- To suppress the newline character, add a comma after the statement:

```
>>> print "hello",
```

- This changes the newline to a space character

`print` statement

- Example use of `,` with print in a file of Python code:

```
print "hello"
print "goodbye"
```

- Gives:

```
hello
goodbye
```

`print` statement

- Example use of `,` with print in a file of Python code:

```
print "hello",
print "goodbye"
```

- Gives:

```
hello goodbye
```

- `,` is rarely needed in practice
- There is also a way to not even print a space after `print` (will see later in course)

`print` statement

- Can print multiple items:

```
>>> i = 10
>>> x = 42.3
>>> print "i =", i, "x =", x
i = 10 x = 42.3
```

- Adjacent items separated by a single space
- Mnemonic: comma in a `print` statement causes a space to be printed

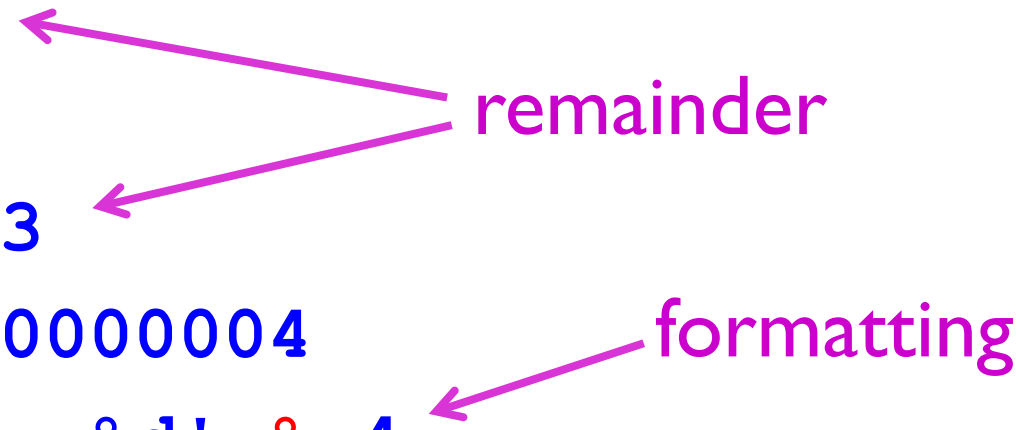
String formatting and %

- Using comma-separated values with `print` is tedious with a lot of values
  - also inflexible → how to specify formatting?
- Better approach: use the `%` formatting operator
- `%` is another overloaded operator
  - With numeric operands, means "remainder after division"
  - With string as left-hand operand, uses string as a *format string* to create a new string

String formatting and %

- Examples of `%` operator in action:

```
>>> 10 % 3
1
>>> 10.4 % 3
1.4000000000000004
>>> '2 + 2 = %d' % 4
'2 + 2 = 4'
```



String formatting and %

- % operator used as a formatting operator takes
  - a *format string* as left operand
  - one or more variables/values as right operand
- Inside the format string:
  - special *format specifiers* indicate what kind of value should be substituted into string at that point
  - returns a *new* string with the substitution
    - format string is not altered!

String formatting and %

- Format specifiers:
  - `%d` means "put an int here"
  - `%f` or `%g` means "put a float here"
  - `%s` means "put a string here"

String formatting and %

- Examples:

```
>>> '2 + 2 = %d' % 4
'2 + 2 = 4'
>>> '4.3 + 5.4 = %f' % 9.7
'4.3 + 5.4 = 9.700000'
>>> '4.3 + 5.4 = %g' % 9.7
'4.3 + 5.4 = 9.7'
>>> 'hello, %s!' % 'Bob'
'hello, Bob!'
```

String formatting and %

- Note: `%s` will always work in any case!
- It will convert the right-hand argument to a string and use that for the substitution

```
>>> '2 + 2 = %s' % 4
'2 + 2 = 4'
>>> '4.3 + 5.4 = %s' % 9.7
'4.3 + 5.4 = 9.7'
```

- But: sometimes want more control over resulting string

String formatting and %

- Format modifiers:
  - a number preceding the format specifier gives the length of the number or string (padded to fit)
    - called the "field width"
  - a number preceding the format specifier and following a decimal point gives the number of decimal points to print (floats only)
    - called the "precision specifier"
  - Can have both of these

String formatting and %

- Examples:

```
>>> '1.234 + 2.345 = %.5f' % 3.579
3.57900
```
← 5 decimal places

```
>>> '1.234 + 2.345 = %.5g' % 3.579
3.579
```
← same number, no trailing 0s

```
>>> '1.234 + 2.345 = %.2f' % 3.579
3.58
```
← round to 2 decimal places

```
>>> '1.234 + 2.345 = %.2g' % 3.579
3.6
```
← round to 2 significant figures

String formatting and %

- Examples:

```
>>> 'My name is %s' % 'Mike'
'My name is Mike'
>>> 'My name is %10s' % 'Mike'
'My name is       Mike'
>>> '1.234 + 2.345 = %10.4f' % 3.579
'1.234 + 2.345 =     3.5790'
>>> '1.234 + 2.345 = %10.4g' % 3.579
'1.234 + 2.345 =      3.579'
```

10 characters

10 characters

10 characters

String formatting

- Can use variables to provide values:

```
>>> i = 10
>>> 'i = %d' % i
'i = 10'
>>> x = 23.4
>>> 'x = %g' % x
'x = 23.4'
>>> s = 'I am a string'
>>> 's = %s' % s
's = I am a string'
```

String formatting

- Can use expressions to provide values:

```
>>> i = 10
>>> 'i = %d' % (i * 20)
'i = 200'
>>> x = 23.4
>>> 'x = %g' % (x / 2)
'x = 11.7'
>>> s = 'I am a string'
>>> 's = %s' % (s + " - NOT!")
's = I am a string - NOT!'
```

String formatting

- Can also format multiple items:

```
>>> i = 10
>>> x = 23.4
>>> s = 'I am a string'
>>> 'i = %d, x = %g, s = %s' % (i, x, s)
'i = 10, x = 23.4, s = I am a string'
```

- The `(i, x, s)` is not special syntax!
- It's an example of a *tuple* (collection object)
  - We'll learn more about tuples in later lectures
- `%` used as a formatting operator knows how to use a tuple to fill in multiple values into one format string

String formatting

- Other format specifiers:
  - `%%` means a literal `%` symbol:

```
>>> 'You need to give %d%% tonight!' % 110
'You need to give 110% tonight!'
```

  - `%i` is another way to say `%d`
    - `i` means "int", `d` means "decimal"
  - Many other uncommon `%` specifiers exist

String formatting

- Most often, use `%` along with `print` to print data in a particular format:

```
>>> print 'My name is: %s.' % 'Mike'
My name is: Mike.
>>> print 'pi = %10.6f' % 3.141592653589
pi =   3.141593
>>> print '%d + %d = %d' % (2, 2, 4)
2 + 2 = 4
```

Typical application (again)

- Let's use string formatting to parameterize our web page:

```
print '''
<html>
<head>
  <title>%s's home page</title>
</head>
<body>
  <p>Welcome to %s's home page!</p>
</body>
</html>''' % ('Mike', 'Mike')
```

Typical application (again)

- Results:

```
<html>
<head>
  <title>Mike's Home Page</title>
</head>
<body>
  <p>Welcome to Mike's home page!</p>
</body>
</html>
```

- Much more sophisticated web templating systems exist, but it's basically this idea

User input

- Problem: how to write interactive programs?
  - At some point in the execution of the program, the program has to stop and ask the user for information, get it, then continue
  - Various ways exist to do this
  - Today we'll look at one way: the `raw_input()` function

User input

- `raw_input()` returns a single line read from the keyboard:

[you type this]

```
>>> line = raw_input()
I'm a lumberjack and I'm OK.
>>> line
"I'm a lumberjack and I'm OK."
```

- Question: Why does Python print this with double quotes?
- `raw_input()` also removes the end-of-line (`\n`) character from the line read in
  - which you had to type to finish the line

User input

- **`raw_input`** can take a string argument, which is used as a prompt:

```
>>> SAT = raw_input("Enter your SAT score: ")
Enter your SAT score: 2400
>>> SAT
'2400'
```

[you type this]

- Note that **`SAT`** is still a string!
- **`raw_`** in **`raw_input`** means that the input value is just represented as a string

User input

- To convert to an **`int`**, use the **`int`** conversion function:

```
>>> SATs = raw_input("Enter your SAT score: ")
Enter your SAT score: 2400
>>> SAT = int(SATs)
>>> SAT
2400
```

- Usually, this would be written more simply as:

```
>>> SAT = int(raw_input("Enter your SAT score: "))
```

- Other conversion functions exist: **`float`**, **`str`**, etc.
  - convert from some data item to a particular type
  - an error occurs if conversion can't be done

Strings are objects

- Python is what's known as an "object-oriented" programming language
  - What that means will take many lectures to completely describe
- One aspect is that most nontrivial data types are represented as "objects"
- An "object" is some data + some associated functions that work on that data
- Python strings are an example of a Python object

Object syntax

- Functions that are associated with an object are referred to as methods
  - they're like functions, but the syntax is different (and some other differences which we'll learn later)
- Example method: the `upper` method converts a particular string to upper case

```
>>> 'spam'.upper()
'SPAM'
```

Object syntax

```
'spam'.upper()
```

Object syntax

```
'spam'.upper()
```

the object (being acted upon)

Object syntax

```
'spam'.upper()
```

name of the method

Object syntax

```
'spam'.upper()
```

dot

The dot indicates that this is a method call (like a function call, but on this object)

Object syntax

```
'spam'.upper()
```

argument list

(The argument list is empty in this case.)

Object syntax

- Object syntax is used everywhere in Python, so get used to it!
- Can use on variables too:

```
>>> s = 'spam'
>>> s.upper()
'SPAM'
```

- The name `s` is bound to a string, so this works

String methods

- Lots of string methods, *e.g.*:
- `lower` – converts string to lower case
- `strip` – removes leading/trailing spaces
- `endswith` – check if string ends in another string (`'foobar'.endswith('bar')` → `True`)
- `islower` – check if all characters in string are lower-case (`'foobar'.islower()` → `True`)
- *etc.*
- Consult Python documentation for full list

len

- One function you'd expect to be a method is called `len()`
- It calculates the length of a sequence (which includes strings)

```
>>> len('foobar')
6
```

- If you try this:

```
>>> 'foobar'.len()
```

you get:

```
AttributeError: 'str' object has no
  attribute 'len'
```

`len`

- *Moral:* Python doesn't always do everything in a completely consistent way!
- Sometimes there is a choice: a certain operation can be written as either a function or a method
- Which one Python chooses to use is somewhat arbitrary
  - Sometimes you get both a function *and* a method!
- *Most* of the time, operations on objects are done using methods

Next lecture

- Lists
- Looping (the `for` statement)
- Making decisions (the `if` statement)