Chapter 4
Computing with Strings

Objectives
- To understand the string data type and how strings are represented in the computer.
- To be familiar with various operations that can be performed on strings through built-in functions and the string library.

Objectives (cont.)
- To understand the basic idea of sequences and indexing as they apply to Python strings and lists.
- To be able to apply string formatting to produce attractive, informative program output.
- To understand basic file processing concepts and techniques for reading and writing text files in Python.

Objectives (cont.)
- To understand basic concepts of cryptography.
- To be able to understand and write programs that process textual information.

The String Data Type
- The most common use of personal computers is word processing.
- Text is represented in programs by the string data type.
- A string is a sequence of characters enclosed within quotation marks (") or apostrophes (').

The String Data Type
>>> str1="Hello"
>>> str2='spam'
>>> print str1, str2
Hello spam
>>> type(str1)
<type 'str'>
>>> type(str2)
<type 'str'>
The String Data Type

>>> firstName = input("Please enter your name: ")
Please enter your name: John

Traceback (most recent call last):
File "c:\pyshell\#12\", line 1, in -toplevel-
  firstName = input("Please enter your name: ")
File "<string>\", line 0, in -toplevel-
NameError: name 'John' is not defined

- What happened?

The String Data Type

- The input statement is a delayed expression.
- When you enter a name, it's doing the same
  thing as:
  firstName = John
- The way Python evaluates expressions is to
  look up the value of the variable John and
  store it in firstName.
- Since John didn't have a value, we get a
  NameError.

The String Data Type

- One way to fix this is to enter your
  string input with quotes around it:
  >>> firstName = input("Please enter your name: ")
  Please enter your name: "John"
  >>> print "Hello", firstName
  Hello John
- Even though this works, this is
  cumbersome!

The String Data Type

- There is a better way to handle text – the
  raw_input function.
- raw_input is like input, but it doesn't evaluate
  the expression that the user enters.

  >>> firstName = raw_input("Please enter your name: ")
  Please enter your name: John
  >>> print "Hello", firstName
  Hello John

The String Data Type

- We can access the individual characters
  in a string through indexing.
- The positions in a string are numbered
  from the left, starting with 0.
- The general form is <string>[<expr>],
  where the value of expr determines
  which character is selected from the
  string.
The String Data Type

- **In a string of** \( n \) **characters, the last character is at position** \( n-1 \) **since we start counting with 0.**
- **We can index from the right side using negative indexes.**

```python
>>> greet[-1]
'!
>>> greet[-3]
'
```

The String Data Type

- **Indexing returns a string containing a single character from a larger string.**
- **We can also access a contiguous sequence of characters, called a **substring**, through a process called **slicing**.**

```
>>> greet[0:3]
'Hel'
>>> greet[5:9]
'Bob'
>>> greet[5:]
'Bob'  
>>> greet[:]
'Hello Bob'
```

The String Data Type

- **Slicing:** \(<\text{string}>[<\text{start}>:<\text{end}>]\)
  - start and end should both be ints
  - The slice contains the substring beginning at position start and runs up to **but doesn’t include** the position end.

```
>>> greet[0:3]
'Hel'
>>> greet[5:]
'Bob'
>>> greet[:]
'Hello Bob'
```

The String Data Type

- If either expression is missing, then the start or the end of the string are used.
- Can we put two strings together into a longer string?
- **Concatenation** “glues” two strings together (+)
- **Repetition** builds up a string by multiple concatenations of a string with itself (*)

```
>>> "spam" + "eggs"
'spameggs'
```

```
>>> "spam" + "And" + "Eggs"
'spamAndEggs'
```

```
>>> 3 * "spam"  
'spamspamspam'
>>> *spam" * 5  
'spamspamspamspamspam'
```

```
>>> (3 * "spam") + ("eggs" * 5)  
'spamspamspameggsgeggsgeggs'
```
The String Data Type

```python
>>> len("spam")
4
>>> for ch in "Spaml!:"
    print ch,
S p a m !
```

---

The String Data Type

<table>
<thead>
<tr>
<th>Operator</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>+</code></td>
<td>Concatenation</td>
</tr>
<tr>
<td><code>*</code></td>
<td>Repetition</td>
</tr>
<tr>
<td><code>&lt;string&gt;[:]</code></td>
<td>Indexing</td>
</tr>
<tr>
<td><code>&lt;string&gt;[::]</code></td>
<td>Slicing</td>
</tr>
<tr>
<td><code>len(&lt;string&gt;)</code></td>
<td>Length</td>
</tr>
</tbody>
</table>

For `<var> in <string>` iteration through characters

---

Simple String Processing

- Usernames on a computer system
  - First initial, first seven characters of last name
    ```python
    # get user’s first and last names
    first = raw_input(‘Please enter your first name (all lowercase): ’)
    last = raw_input(‘Please enter your last name (all lowercase): ’)
    
    # concatenate first initial with 7 chars of last name
    uname = first[0] + last[:7]
    ```

---

Simple String Processing

- Another use – converting an int that stands for the month into the three letter abbreviation for that month.
- Store all the names in one big string: “JanFebMarAprMayJunJulAugSepOctNovDec”
- Use the month number as an index for slicing this string:
  ```python
  monthAbbrev = months[pos:pos+3]
  ```

---

Simple String Processing

<table>
<thead>
<tr>
<th>Month</th>
<th>Number</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Feb</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Mar</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Apr</td>
<td>4</td>
<td>9</td>
</tr>
</tbody>
</table>

To get the correct position, subtract one from the month number and multiply by three
Simple String Processing

```python
# month.py
# A program to print the abbreviation of a month, given its number

def main():
    # months is used as a lookup table
    n = input("Enter a month number (1-12): ")
    if n in months:
        # compute starting position of month n in months
        pos = int(n) - 1
        # Get the appropriate slice from months
        monthAbbrev = months[pos:pos+1]
        # print the result
        print("The month abbreviation is ", monthAbbrev)
    else:
        print("Invalid month")

main()
```

---

Strings, Lists, and Sequences

- It turns out that strings are really a special kind of sequence, so these operations also apply to sequences!
  ```
  >>> [1, 2, 3, 4]
  [1, 2, 3, 4]
  >>> [1, 2, 3]
  [1, 2, 3]
  >>> grades = ['A', 'B', 'C', 'D', 'F']
  >>> grade[0]
  'A'
  >>> grade[2-4]
  ['C', 'D']
  >>> len(grades)
  5
  ```

- We can use the idea of a list to make our previous month program even simpler!

- We change the lookup table for months to a list:
  ```
  ```

---

Strings, Lists, and Sequences

- Strings are always sequences of characters, but lists can be sequences of arbitrary values.
- Lists can have numbers, strings, or both!

```python
myList = [1, "Spam", 4, "U"]
```
Strings, Lists, and Sequences

- This version of the program is easy to extend to print out the whole month name rather than an abbreviation!

        months = ['January', 'February', 'March', 'April', 'May', 'June',
                  'July', 'August', 'September', 'October', 'November', 'December']

Strings and Secret Codes

- Inside the computer, strings are represented as sequences of 1’s and 0’s, just like numbers.
- A string is stored as a sequence of binary numbers, one number per character.
- It doesn’t matter what value is assigned as long as it’s done consistently.
Strings and Secret Codes

- 0 – 127 are used to represent the characters typically found on American keyboards.
  - 65 – 90 are “A” – “Z”
  - 97 – 122 are “a” – “z”
  - 48 – 57 are “0” – “9”
- The others are punctuation and control codes used to coordinate the sending and receiving of information.

Strings and Secret Codes

- One major problem with ASCII is that it’s American-centric, it doesn’t have many of the symbols necessary for other languages.
- Newer systems use Unicode, an alternate standard that includes support for nearly all written languages.

Strings and Secret Codes

- The ord function returns the numeric (ordinal) code of a single character.
- The chr function converts a numeric code to the corresponding character.

```python
>>> ord("A")
65
>>> ord("a")
97
>>> chr(97)
'a'
>>> chr(65)
'A'
```

Strings and Secret Codes

- Using ord and chr we can convert a string into and out of numeric form.
- The encoding algorithm is simple:
  get the message to encode for each character in the message:
  print the letter number of the character
- A for loop iterates over a sequence of objects, so the for loop looks like:
  for ch in <string>

```python
# bgc/main.py
# A program to convert a textual message into a sequence of numbers, utilizing the underlying ASCII encoding.
def main():
    print("This program converts a textual message into a sequence")
    print("of numbers representing the ASCII encoding of the message.
    print
    # Get the message to encode
    message = "happy new year!" (Please enter the message to encode: )
    print
    print "Here are the ASCII codes:"
    # Loop through the message and print out the ASCII values for each character
    print(chr(i)) if i in message
    print(add())  # use comma to print all on one line.
    print
main()
```
Strings and Secret Codes

- The variable `message` is an accumulator variable, initially set to the empty string, the string with no characters (""").
- Each time through the loop, a number from the input is converted to the appropriate character and appended to the end of the accumulator.

Strings and Secret Codes

- How do we get the sequence of numbers to decode?
- Read the input as a single string, then split it apart into substrings, each of which represents one number.

Strings and Secret Codes

- The new algorithm
  
  get the sequence of numbers as a string, inString
  
  message = "" for each of the smaller strings:
  
  change the string of digits into the number it represents
  
  append the ASCII character for that number to message

  print message

- Just like there is a math library, there is a string library with many handy functions.

Strings and Secret Codes

- One of these functions is called `split`. This function will split a string into substrings based on spaces.

  >>> import string
  >>> string.split("Hello string library!")
  ['Hello', 'string', 'library!']

Strings and Secret Codes

- Split can be used on characters other than space, by supplying that character as a second parameter.

  >>> str.split("32,24,25,57", ",")
  ['32', '24', '25', '57']

  >>>

Strings and Secret Codes

- How can we convert a string containing digits into a number?
- Python has a function called `eval` that takes any strings and evaluates it as if it were an expression.

  >>> numStr = "500"
  >>> eval(numStr)
  500

  >>> x = eval(input("Enter a number "))
  Enter a number 3.14
  >>> print x
  3.14
  >>> type (x)
  <type 'float'>
Strings and Secret Codes

- The split function produces a sequence of strings. numString gets each successive substring.
- Each time through the loop, the next substring is converted to the appropriate ASCII character and appended to the end of the message.

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Other String Operations

- There are a number of other string processing functions available in the string library. Try them all!
  - capitalize(s) – Copy of s with only the first character capitalized
  - capwords(s) – Copy of s; first character of each word capitalized
  - center(s, width) – Center s in a field of given width

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Other String Operations

- count(s, sub) – Count the number of occurrences of sub in s
- find(s, sub) – Find the first position where sub occurs in s
- join(list) – Concatenate list of strings into one large string
- ljust(s, width) – Like center, but s is left-justified

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Strings and Secret Codes

- The program converts a textual message into a sequence of numbers representing the ASCII encoding of the message.
- Please enter the message to encode: CS120 is fun!

Here are the ASCII codes:
67 83 49 50 48 32 105 115 32 102 117 110 33

The program converts a sequence of ASCII numbers into the string of text that it represents.
- Please enter the ASCII-encoded message: 67 83 49 50 48 32 105 115 32 102 117 110 33
- The decoded message is: CS120 is fun!

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Other String Operations

- `rstrip(s)` – Copy of `s` with trailing whitespace removed
- `split(s)` – Split `s` into a list of substrings
- `upper(s)` – Copy of `s`; all characters converted to uppercase

```python
>>> s = "Hello, I came here for an argument"
>>> string.capitalize(s)
'Hello, i came here for an argument'
>>> string.capwords(s)
'Hello, I came Here For An Argument'
>>> string.lower(s)
'hello, i came here for an argument'
>>> string.upper(s)
'HELLO, I CAME HERE FOR AN ARGUMENT'
>>> string.replace(s, 'i', 'y')
'hello, you came here for an argument'
>>> string.center(s, 30)
'Hello, I came here for an argument'
```

From Encoding to Encryption

- The process of encoding information for the purpose of keeping it secret or transmitting it privately is called **encryption**.
- **Cryptography** is the study of encryption methods.
- Encryption is used when transmitting credit card and other personal information to a web site.

Strings are represented as a sort of encoding problem, where each character in the string is represented as a number that’s stored in the computer.

The code that is the mapping between character and number is an industry standard, so it’s not “secret”.

The encoding/decoding programs we wrote use a **substitution cipher**, where each character of the original message, known as the **plaintext**, is replaced by a corresponding symbol in the **cipher alphabet**.

The resulting code is known as the **ciphertext**.
From Encoding to Encryption

- This type of code is relatively easy to break.
- Each letter is always encoded with the same symbol, so using statistical analysis on the frequency of the letters and trial and error, the original message can be determined.

From Encoding to Encryption

- Modern encryption converts messages into numbers.
- Sophisticated mathematical formulas convert these numbers into new numbers – usually this transformation consists of combining the message with another value called the “key”.

From Encoding to Encryption

- To decrypt the message, the receiving end needs an appropriate key so the encoding can be reversed.
- In a private key system the same key is used for encrypting and decrypting messages. Everyone you know would need a copy of this key to communicate with you, but it needs to be kept a secret.

From Encoding to Encryption

- In public key encryption, there are separate keys for encrypting and decrypting the message.
- In public key systems, the encryption key is made publicly available, while the decryption key is kept private.
- Anyone with the public key can send a message, but only the person who holds the private key (decryption key) can decrypt it.

Input/Output as String Manipulation

- Often we will need to do some string operations to prepare our string data for output (‘pretty it up’)
- Let’s say we want to enter a date in the format ‘05/24/2003’ and output “May 24, 2003.” How could we do that?
Input/Output as String Manipulation

- The first two lines are easily implemented:
  ```python
dateStr = raw_input("Enter a date (mm/dd/yyyy): ")
monthStr, dayStr, yearStr = dateStr.split("/",)
```
- The date is input as a string, and then "unpacked" into the three variables by splitting it at the slashes using simultaneous assignment.

Next step: Convert monthStr into a number

- We can use the `eval` function on monthStr to convert "05", for example, into the integer 5. (`eval("05") = 5`)
- Another conversion technique would be to use the `int` function. (`int("05") = 5`)

Input/Output as String Manipulation

- There's one "gotcha" – leading zeros.
  ```python
  >>> int("05")
  5
  >>> eval("05")
  5
  >>> int("023")
  23
  >>> eval("023")
  19
  ```
- What's going on?? Int seems to ignore leading zeroes, but what about eval?

Python allows int literals to be expressed in other number systems than base 10! If an int starts with a 0, Python treats it as a base 8 (octal) number.

- \(023_8 = 2 \times 8 + 3 \times 1 = 19_{10}\)
- OK, that's interesting, but why support other number systems?

Input/Output as String Manipulation

- Computers use base 2 (binary). Octal is a convenient way to represent binary numbers.
- If this makes your brain hurt, just remember to use int rather than eval when converting strings to numbers when there might be leading zeros.

months = ['January', 'February', ..., 'December']
monthStr = months[int(monthStr) - 1]
- Remember that since we start counting at 0, we need to subtract one from the month.
- Now let's concatenate the output string together!
Input/Output as String Manipulation

- Notice how the comma is appended to dayStr with concatenation!
- >>> main()
  Enter a date (mm/dd/yyyy): 01/23/2004
  The converted date is: January 23, 2004

Sometimes we want to convert a number into a string.
- We can use the str function!
  >>> str(500)
  '500'
  >>> value = 3.14
  >>> str(value)
  '3.14'
  >>> print "The value is", str(value) + "."
  The value is 3.14.

If value is a string, we can concatenate a period onto the end of it.
- If value is an int, what happens?
  >>> value = 3.14
  >>> print "The value is", value + "."
  The value is
  Traceback (most recent call last):
  File "<pyshell#10>", line 1, in <toplevel>
  print "The value is", value + "."
  TypeError: unsupported operand type(s) for +: 'float' and 'str'

We now have a complete set of type conversion operations:

<table>
<thead>
<tr>
<th>Function</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>float(expr)</td>
<td>Convert expr to a floating point value</td>
</tr>
<tr>
<td>int(expr)</td>
<td>Convert expr to an integer value</td>
</tr>
<tr>
<td>long(expr)</td>
<td>Convert expr to a long integer value</td>
</tr>
<tr>
<td>str(expr)</td>
<td>Return a string representation of expr</td>
</tr>
<tr>
<td>eval(string)</td>
<td>Evaluate string as an expression</td>
</tr>
</tbody>
</table>

String Formatting

- String formatting is an easy way to get beautiful output!
  Change Counter
  Please enter the count of each coin type:
  Quarters: 5
  Dimes: 0
  Nickels: 0
  Pennies: 0
  The total value of your change is 1.5
- Shouldn’t that be more like $1.50??
String Formatting

- We can format our output by modifying the print statement as follows:
  
  ```python
  print "The total value of your change is $%.2f \pm \% (total)
  
  Now we get something like:
  
  The total value of your change is $1.50
  
  With numbers, % means the remainder operation. With strings it is a string formatting operator.
  ```

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String Formatting

```python
print "The total value of your change is $%.2f \pm \% (total)

- The template contains a single specifier: %.2f
- The value of total will be inserted into the template in place of the specifier.
- The specifier tells us this is a floating point number (f) with two decimal places (.2)
```

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String Formatting

- The formatting specifier has the form: %<width>.<precision><type-char>
- Type-char can be decimal, float, string (decimal is base-10 ints)
- <width> and <precision> are optional.
- <width> tells us how many spaces to use to display the value. 0 means to use as much space as necessary.

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String Formatting

- If you don’t give it enough space using <width>, Python will expand the space until the result fits.
- <precision> is used with floating point numbers to indicate the number of places to display after the decimal.
- %.2f means to use as much space as necessary and two decimal places to display a floating point number.

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String Formatting

```python
>>> "Hello Yes %s, you may have already won $%.2f \% \("Mr.", "Smith", 10000) hello Mr. Smith, you may have already won $10000"

>>> This int, %d, was placed in a field of width 7 % (7)
This int, 7, was placed in a field of width 7

>>> This int, %d, was placed in a field of width 10 % (10)
This int, 10, was placed in a field of width 10

>>> This int, %d, was placed in a field of width 10 % (7)
This int, 7, was placed in a field of width 10

>>> This float, %.2f, has width 10 and precision 5 % (3.145926)
This float, 3.14159, has width 10 and precision 5

>>> This float, %.6f, has width 6 and precision 5 % (3.145926)
This float, 3.14159, has width 6 and precision 5

>>> 'Compare %.2f and %.2f ' (3.14, 3.14)
'Compare 3.140000 and 3.1400000000000000000000
```
String Formatting

- If the width is wider than needed, the value is right-justified by default. You can left-justify using a negative width (%-10.5f)
- If you display enough digits of a floating point number, you will usually get a “surprise”. The computer can’t represent 3.14 exactly as a floating point number. The closest value is actually slightly larger!

Better Change Counter

- With what we know now about floating point numbers, we might be uneasy about using them in a money situation.
- One way around this problem is to keep trace of money in cents using an int or long int, and convert it into dollars and cents when output.

```
def main():
    print("Change Counter")
    print("Please enter the count of each coin type.")
    quarters = input("Quarters: ")
    dimes = input("Dimes: ")
    nickels = input("Nickels: ")
    pennies = input("Pennies: ")
    total = quarters * 25 + dimes * 10 + nickels * 5 + pennies
    print("The total value of your change is $\%d.%02d")")
    % (total/100, total%100)
main()
```
Multi-Line Strings

- A file is a sequence of data that is stored in secondary memory (disk drive).
- Files can contain any data type, but the easiest to work with are text.
- A file usually contains more than one line of text. Lines of text are separated with a special character, the newline character.

You can think of newline as the character produced when you press the <Enter> key.
- In Python, this character is represented as ‘\n’, just as tab is represented as ‘\t’.

Multi-Line Strings

- Hello
  World

Goodbye 32
- When stored in a file:
  Hello\nWorld\n\nGoodbye 32\n
You can print multiple lines of output with a single print statement using this same technique of embedding the newline character.
- These special characters only affect things when printed. They don’t do anything during evaluation.

File Processing

- The process of opening a file involves associating a file on disk with a variable.
- We can manipulate the file by manipulating this variable.
  - Read from the file
  - Write to the file

When done with the file, it needs to be closed. Closing the file causes any outstanding operations and other bookkeeping for the file to be completed.
- In some cases, not properly closing a file could result in data loss.
File Processing

- Reading a file into a word processor
  - File opened
  - Contents read into RAM
  - File closed
  - Changes to the file are made to the copy stored in memory, not on the disk.

File Processing

- Saving a word processing file
  - The original file on the disk is reopened in a mode that will allow writing (this actually erases the old contents)
  - File writing operations copy the version of the document in memory to the disk
  - The file is closed

File Processing

- Working with text files in Python
  - Associate a file with a variable using the open function
    `<filevar> = open(<name>, <mode>)`
  - Name is a string with the actual file name on the disk. The mode is either ‘r’ or ‘w’ depending on whether we are reading or writing the file.
  - Infile = open(“numbers.dat”, “r”)

File Processing

- `<filevar>.read()` – returns the entire remaining contents of the file as a single (possibly large, multi-line) string
- `<filevar>.readline()` – returns the next line of the file. This is all text up to and including the next newline character
- `<filevar>.readlines()` – returns a list of the remaining lines in the file. Each list item is a single line including the newline characters.

File Processing

- `printfile.py`
  - `printfile(filename)`: consists of:
    - `# filename = raw_input(“Enter filename: “)`
    - `# data = open(filename)`
    - `# data = data.read()`
    - `print data`
  - `main()`: consists of:
    - `# First, prompt the user for a file name`
    - `# Open the file for reading through the variable infile`
    - `# The file is read as one string and stored in the variable data`

- `readline` can be used to read the next line from a file, including the trailing newline character
  - `# infile = open(someFile, ‘r’)`
  - `# for i in range(5):
  #   line = infile.readline()`
  - `# print line[:-1]`
  - This reads the first 5 lines of a file
  - Slicing is used to strip out the newline characters at the ends of the lines
File Processing

- Another way to loop through the contents of a file is to read it in with readlines and then loop through the resulting list.
- `infile = open(someFile, 'r')`
  for line in infile.readlines():
    # Line processing here
  infile.close()

File Processing

- Python treats the file itself as a sequence of lines!
- `infile = open(someFile, 'r')`
  for line in infile:
    # process the line here
  infile.close()

File Processing

- Opening a file for writing prepares the file to receive data
- If you open an existing file for writing, you wipe out the file’s contents. If the named file does not exist, a new one is created.
- `Outfile = open("mydata.out", 'w')`
- `<filevar>.write(<string>)`

File Processing

- `outfile = open("example.out", 'w')`
  `count = 1`
  `outfile.write("This is the first line\n")`
  `count = count + 1`
  `outfile.write("This is line number %d\n" % (count))`
  `outfile.close()`
- If you want to output something that is not a string you need to convert. Using the string formatting operators are an easy way to do this.
  - This is the first line
  - This is line number 2

Example Program: Batch Usernames

- `Batch` mode processing is where program input and output are done through files (the program is not designed to be interactive)
- Let’s create usernames for a computer system where the first and last names come from an input file.

Example Program: Batch Usernames

- `# userfile.py`
- `# Program to create a file of usernames in batch mode.`
- `import string`
- `def main():`
  `print "This program creates a file of usernames from a"`
  `print "file of names."
  `ifilename = raw_input("What file are the names in? ")`
  `outfilename = raw_input("What file should the usernames go in? ")`
  `if open the files`
  `ifile = open(ifilename, 'r')`
  `outfile = open(outfilename, 'w')`
Example Program: Batch Usernames

```python
# process each line of the input file
for line in infile:
    # get the first and last names from line
    first, last = string.split(line)
    # create a username
    uname = string.lower(first[0] + last[-1])
    # write it to the output file
    outfile.write(uname + '
')
# close both files
infol.close()
outfile.close()
print "Usernames have been written to", outfile
```

Things to note:
- It's not unusual for programs to have multiple files open for reading and writing at the same time.
- The lower function is used to convert the names into all lower case, in the event the names are mixed upper and lower case.
- We need to concatenate '\n' to our output to the file, otherwise the user names would be all run together on one line.

Coming Attraction: Objects

- Have you noticed the dot notation with the file variable? `infol.read()`
- This is different than other functions that act on a variable, like `abs(x)`, not `x.abs()`.
- In Python, files are objects, meaning that the data and operations are combined. The operations, called methods, are invoked using this dot notation.
- Strings and lists are also objects. More on this later!