Chapter Seven

FILES AND EXCEPTIONS

Chapter Goals

- To read and write text files
- To process collections of data
- To process command line arguments
- To raise and handle exceptions

In this chapter, you will learn how to write programs that manipulate files

Contents

Reading and Writing Text Files

SECTION 7.1

Reading and Writing Text Files

- Text files are very commonly used to store information
  - They are the most ‘portable’ types of data files
- Examples of text files include files that are created with a simple text editor, such as Windows Notepad, and Python source code and HTML files

Opening Files: Reading

- To access a file, you must first *open* it
- Suppose you want to read data from a file named input.txt, located in the same directory as the program
- To open a file for reading, you must provide the name of the file as the first argument to the open function and the string "r" as the second argument:

```
infile = open("input.txt", "r")
```

Opening Files: Reading (2)

- Important things to keep in mind:
  - When opening a file for reading, the file must exist (and otherwise be accessible) or an exception occurs
  - The file object returned by the open function must be saved in a variable
    - All operations for accessing a file are made via the file object

Opening Files: Writing

- To open a file for writing, you provide the name of the file as the first argument to the open function and the string "w" as the second argument:

```
outfile = open("output.txt", "w")
```

- If the output file already exists, it is emptied before the new data is written into it
- If the file does not exist, an empty file is created

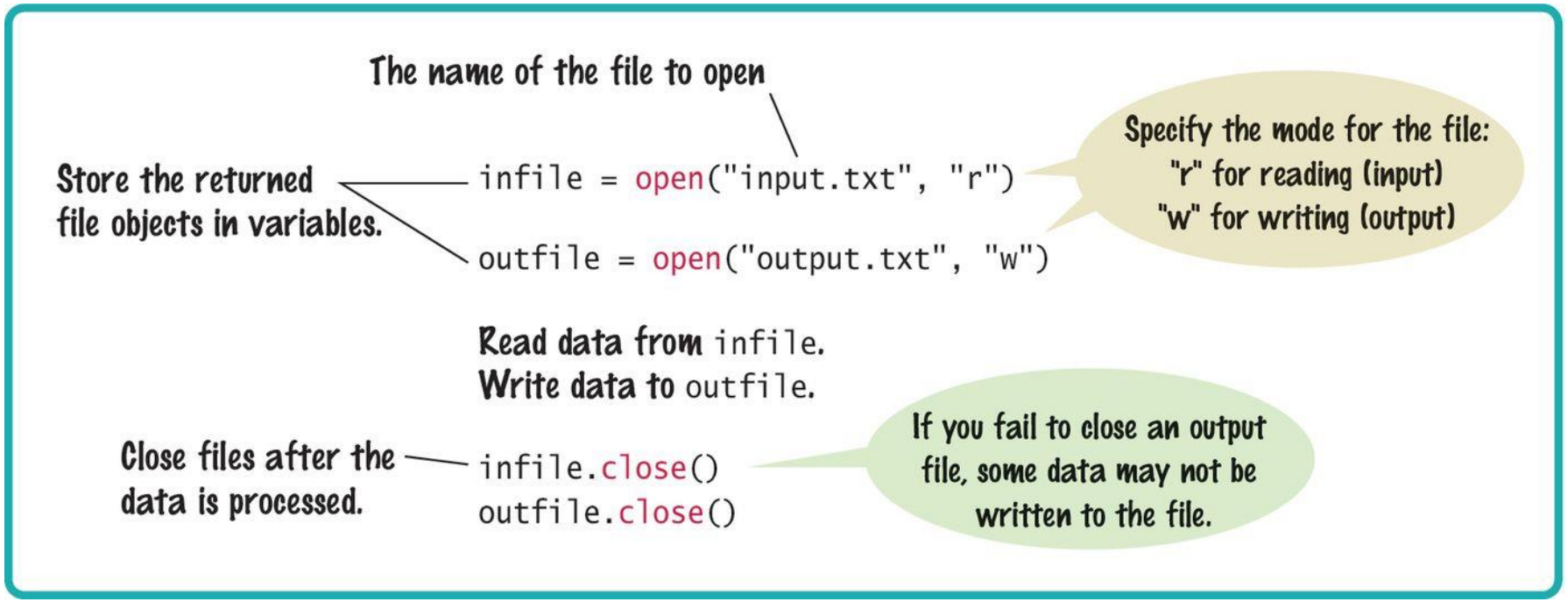
Closing Files: Important

- When you are done processing a file, be sure to *close* the file using the close() method:

```
infile.close()
outfile.close()
```

- If your program exits without closing a file that was opened for writing, some of the output may not be written to the disk file

Syntax: Opening And Closing Files



Reading From a File

- To read a line of text from a file, call the readline() method with the file object that was returned when you opened the file:

```
line = infile.readline()
```

- When a file is opened, an input marker is positioned at the beginning of the file
- The readline() method reads the text, starting at the current position and continuing until the end of the line is encountered
  - The input marker is then moved to the next line

Reading From a File (2)

- For example, suppose input.txt contains the lines

  flying

  circus

- The first call to readline() returns the string "flying\n"
  - Recall that \n denotes the newline character that indicates the end of the line
- If you call readline() a second time, it returns the string "circus\n"

Reading From a File (3)

- Calling readline() again yields the empty string "" because you have reached the end of the file
- If the file contains a blank line, then readline() returns a string containing only the newline character "\n"

Reading Multiple Lines From a File

- You repeatedly read a line of text and process it until the sentinel value is reached:
- The sentinel value is an empty string, which is returned by the readline() method after the end of file has been reached

```
line = infile.readline()
while line != "" :
    # Process the line.
    line = infile.readline()
```

Converting File Input

- As with the input function, the readline() method can only return strings
- If the file contains numerical data, the strings must be converted to the numerical value using the int() or float() function:

```
value = float(line)
```

- The newline character at the end of the line is ignored when the string is converted to a numerical value

Writing To A File

- For example, we can write the string "Hello, World!" to our output file using the statement:

```
outfile.write("Hello, World!\n")
```

  - Unlike print() when writing text to an output file, *you must explicitly write the newline character to start a new line*

- You can also write formatted strings to a file with the write method:

```
outfile.write("Number of entries: %d\nTotal: %8.2f\n"
  % (count, total))
```

Example: File Reading/Writing

- Suppose you are given a text file that contains a sequence of floating-point values, stored one value per line
- You need to read the values and write them to a new output file, aligned in a column and followed by their total and average value
- If the input file has the contents

  32.0

  54.0

  67.5

  80.25

  115.0

Example: File Reading/Writing (2)

- The output file will contain

  32.00

  54.00

  67.50

  80.25

  115.00

  Total: 348.75

  Average: 69.75

Example One

- Open the file total.py

Common Error

- Backslashes in File Names
  - When using a String literal for a file name with path information, you need to supply each backslash twice:

```
infile = open("c:\\homework\\input.txt", "r")
```

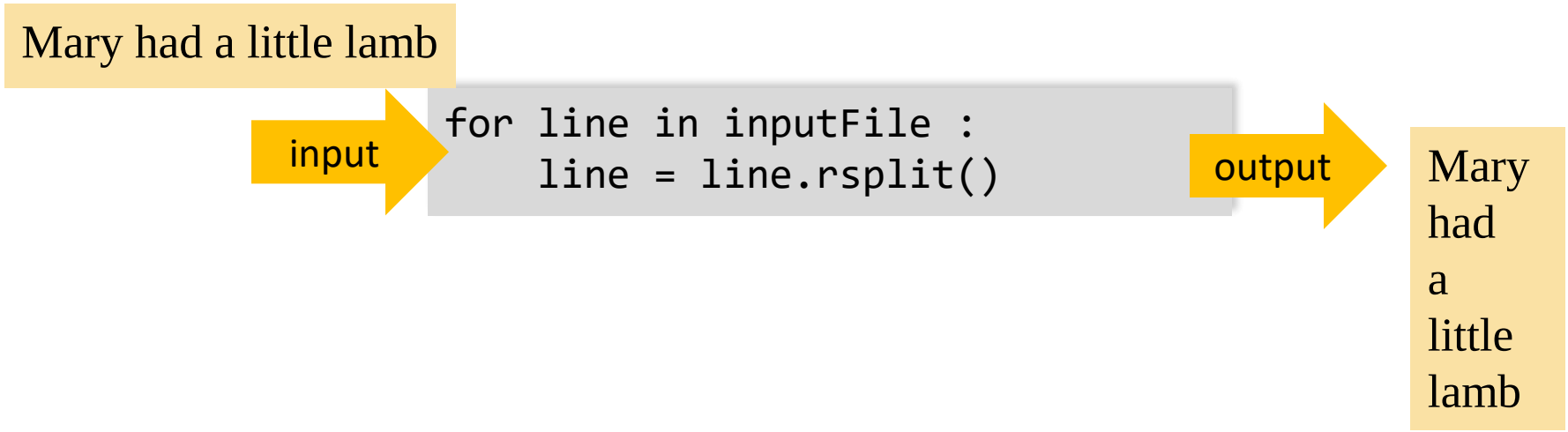
  - A single backslash inside a quoted string is the *escape character*, which means the next character is interpreted differently (for example, '\n' for a newline character)
  - When a user supplies a filename into a program, the user should not type the backslash twice

Text Input and Output

SECTION 7.2

Text Input and Output

- In the following sections, you will learn how to process text with complex contents, and you will learn how to cope with challenges that often occur with real data
- Reading Words Example:



Processing Text Input

- There are times when you want to read input by:
  - Each word
  - Each line
  - A single character

- Python provides methods such: read(), split() and strip() for these tasks

Processing text input is required for almost all types of programs that interact with the user

Text Input and Output

- Python can treat an input file as though it were a container of strings in which each line comprises an individual string
- For example, the following loop reads all lines from a file and prints them:

```
for line in infile :
    print(line)
```

  - At the beginning of each iteration, the loop variable line is assigned the value of a string that contains the next line of text in the file
- There is a critical difference between a file and a container:
  - Once you read the file you must close it before you can iterate over it again

An Example of Reading a File

- We have a file that contains a collection of words; one per line:

spam

and

eggs

Removing The Newline (1)

- Recall that each input line ends with a newline (\n) character
- Generally, the newline character must be removed before the input string is used
- When the first line of the text file is read, the string line contains

Removing The Newline (2)

- To remove the newline character, apply the rstrip() method to the string:

```
line = line.rstrip()
```

- This results in the string:

s	p	a	m

Character Strip Methods

Table 1 Character Stripping Methods

Method	Returns
`s.lstrip()` `s.lstrip(`*chars*`)`	A new version of *s* in which white space (blanks, tabs, and newlines) is removed from the left (the front) of *s*. If provided, characters in the string *chars* are removed instead of white space.
`s.rstrip()` `s.rstrip(`*chars*`)`	Same as `lstrip` except characters are removed from the right (the end) of *s*.
`s.strip()` `s.strip(`*chars*`)`	Similar to `lstrip` and `rstrip`, except characters are removed from the front and end of *s*.

Character Strip Examples

Table 2 Character Stripping Examples

Statement	Result	Comment
`string = "James\n"` `result = string.rstrip()`	J a m e s	The newline character is stripped from the end of the string.
`string = "James \n"` `result = string.rstrip()`	J a m e s	Blank spaces are also stripped from the end of the string.
`string = "James \n"` `result = string.rstrip("\n")`	J a m e s	Only the newline character is stripped.
`name = " Mary "` `result = name.strip()`	M a r y	The blank spaces are stripped from the front and end of the string.
`name = " Mary "` `result = name.lstrip()`	M a r y	The blank spaces are only stripped from the front of the string.

Reading Words

- Sometimes you may need to read the individual words from a text file
- For example, suppose our input file contains two lines of text

  Mary had a little lamb,

  whose fleece was white as snow

Reading Words (2)

- We would like to print to the terminal, one word per line

  Mary

  had

  a

  little

  . . .

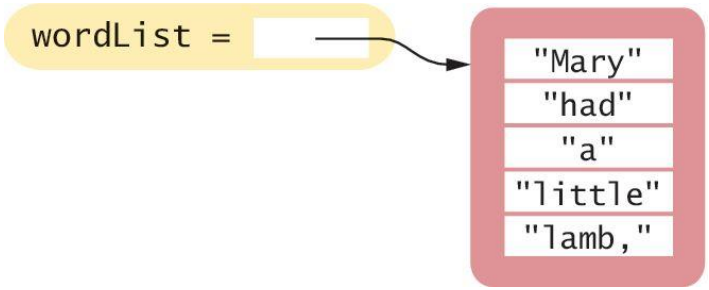
- Because there is no method for reading a word from a file, you must first read a line and then split it into individual words

```
line = line.rstrip()
wordlist = line.split()
```

Reading Words (3)

- The split method returns the list of substrings that results from splitting the string at each blank space
- For example, if line contains the string:

- It will be split into 5 substrings that are stored in a list in the same order in which they occur in the string:



Reading Words (4)

- Notice that the last word in the line contains a comma
- If we only want to print the words contained in the file without punctuation marks, we can strip those from the substrings using the rstrip() method introduced in the previous section:

```
word = word.rstrip(".,?!")
```

Reading Words: Complete Example

```
inputFile = open("lyrics.txt", "r")
for line in inputFile :
    line = line.rstrip()
    wordList = line.split()
    for word in wordList :
        word = word.rstrip(".,?!")
        print(word)

inputFile.close()
```

Example Two

- Open the file lyrics.py

Additional String Splitting Methods

Table 3 String Splitting Methods

Method	Returns

`s.split()`
`s.split(sep)`
`s.split(sep, maxsplit)`
	Returns a list of words from string *s*. If the string *sep* is provided, it is used as the delimiter; otherwise, any white space character is used. If *maxsplit* is provided, then only that number of splits will be made, resulting in at most *maxsplit* + 1 words.

`s.rsplit(sep, maxsplit)`	Same as `split` except the splits are made starting from the end of the string instead of from the front.
`s.splitlines()`	Returns a list containing the individual lines of a string split using the newline character `\n` as the delimiter.

Additional String Splitting Examples

Table 4 String Splitting Examples

Statement	Result	Comment
`string = "a,bc,d"` `string.split(",")`	`"a" "bc" "d"`	The string is split at each comma.
`string = "a b  c"` `string.split()`	`"a" "b" "c"`	The string is split using the blank space as the delimiter. Consecutive blank spaces are treated as one space.
`string = "a b  c"` `string.split(" ")`	`"a" "b" "" "c"`	The string is split using the blank space as the delimiter. With an explicit argument, the consecutive blank spaces are treated as separate delimiters.
`string = "a:bc:d"` `string.split(":", 2)`	`"a" "bc:d"`	The string is split into 2 parts starting from the front. The split is made at the first colon.
`string = "a:bc:d"` `string.rsplit(":", 2)`	`"a:bc" "d"`	The string is split into 2 parts starting from the end. The split is made at the last colon.

Reading Characters

- The read() method takes a single argument that specifies the number of characters to read
- The method returns a string containing the characters
- When supplied with an argument of 1, the read() method returns a string consisting of the next character in the file

```
char = inputFile.read(1)
```

- If the end of the file is reached, it returns an empty string ""

Algorithm: Reading Characters

```
while char != "" :
    Process character
   char = inputFile.read(1)
```

Reading Records

- A text file can contain a collection of **data records** in which each record consists of multiple fields
- For example, a file containing student data may consist of records composed of an identification number, full name, address, and class year
- When working with text files that contain data records, you generally have to read the entire record before you can process it:

```
For each record in the file
    Read the entire record
    Process the record
```

Record Formats: Example

- The organization or format of the records can vary, however, making some formats easier to read than others
- A typical format for such data is to store each field on a separate line of the file with all fields of a single record on consecutive lines:

  China

  1330044605

  India

  1147995898

  United States

  303824646

  . . .

Record Formats: Example

- Reading the data in this format is rather easy
- Because each record consists of two fields, we read two lines from the file for each record

```
line = infile.readline()
while line != "" :
    countryName = line.rstrip()
    line = infile.readline()
    population = int(line)
       Process data record
    line = infile.readline()
```

Record Formats: Example 2

- Another common format stores each data record on a single line
- If the record's fields are separated by a specific delimiter ":" you can extract the fields by splitting the line with the split() method

  China:1330044605

  India:1147995898

  United States:303824646

  . . .

Record Formats: Example 3

- But what if the fields are not separated by a delimiter?

  China 1330044605

  India 1147995898

  United States 303824646

  . . .

- Because some country names have more than one word, we cannot simply use a blank space as the delimiter because multi-word names would be split incorrectly
- Can we use rsplit in this case?

```
inputString = "United States 303824646"
result = inputString.rsplit(" ",1)
print(result)
```

Record Formats: Example 3

- One approach for reading records in this format is to read the line, then search for the first digit in the string returned by readline():

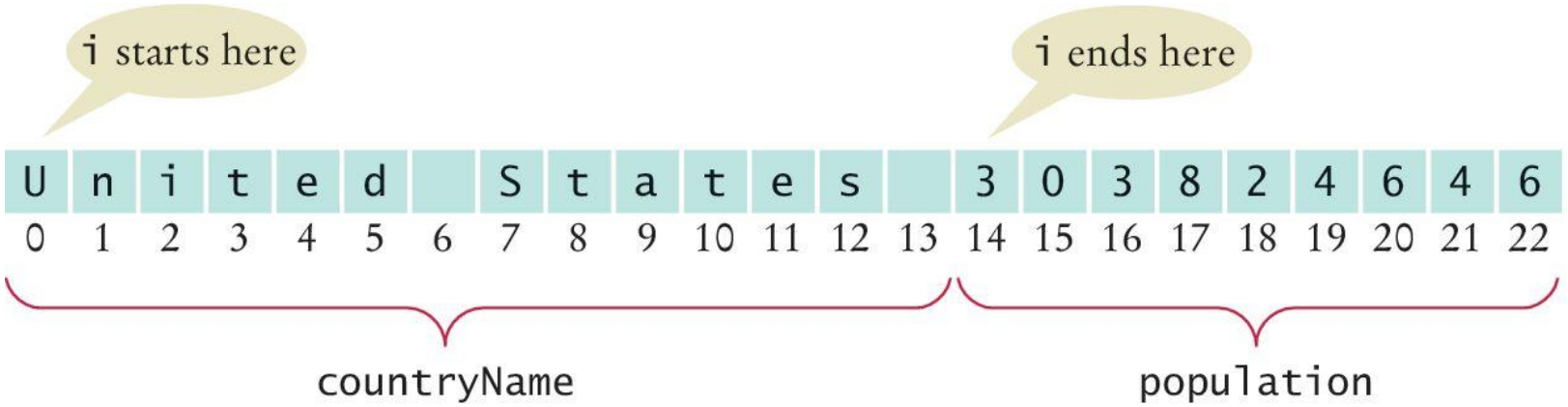
```
i = 0
char = line[0]
while not line[0].isdigit() :
    i = i + 1
```

- You can then extract the country name and population as substrings using the slice operator:

```
countryName = line[0 : i - 1]
population = int(line[i : ])
```

Record Formats: Example 3

- 'Slicing' the string read from file



File Operations

Table 5 File Operations

Operation	Explanation
f = `open(`*filename*`,` *mode*`)`	Opens the file specified by the string *filename*. The *mode* parameter indicates whether the file is opened for reading (`"r"`) or writing (`"w"`). A file object is returned.
f`.close()`	Closes a previously opened file. Once closed, the file cannot be used until it has been reopened.
`string =` *f*`.readline()`	Reads the next line of text from an input file and returns it as a string. An empty string `""` is returned when the end of file is reached.
`string =` *f*`.read(`*num*`)` `string =` *f*`.read()`	Reads the next *num* characters from the input file and returns them as a string. An empty string is returned when all characters have been read from the file. If no argument is supplied, the entire contents of the file is read and returned in a single string.
f`.write(`*string*`)`	Writes the *string* to a file opened for writing.

A Second Example

- Open the file items.py

Command Line Arguments

SECTION 7.3

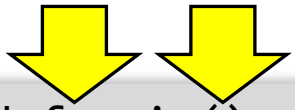
Using Command Line Arguments

- We have multiple ways to execute a program depending on the operating system (and the version of the Operating system) and the python development used
  - We commonly use Wing (our development environment) to run our program
  - We *could* also run the program by typing the name of a program in a terminal window
    - If we use this method we can pass **command line arguments** to the program
    - The command line arguments are passed to the program as strings

Command Line Arguments

- Text based programs can be ‘parameterized’ by using command line arguments
  - Filename and options are often typed after the program name at a command prompt:

```
>python program.py -v input.dat
```



```
def main():
```

  - Python provides access to them as a list, “argv”, of Strings as a parameter to the program, in this case main()

```
argv[0]: "program.py"
argv[1]: "-v"
argv[2]: "input.dat"
```

  - Options (switches) traditionally begin with a dash ‘-’

When to use Command Line Arguments

- For this class we are going to use an interactive user interface
  - The user interface guides the user and is suited to the program we are writing
  - The command line interface has an advantage when you need to automate the execution of a program

Processing Text Files Example

PAGE 360

Steps to Processing Text Files

- Problem Statement:
- Read two country data files, `worldpop.txt` and `worldarea.txt`
- Write a file `world_pop_density.txt` that contains country names and population densities with the country names aligned left and the numbers aligned right

```
Afghanistan          50.56
Akrotiri            127.64
Albania             125.91
Algria               14.18
American Samoa      288.92
. . .
```

Six Steps to Processing Text Files

1. Understand the Processing Task
   i. Process the data “on the go” or store data and then process?
2. Determine which files you need to read and write
3. Choose a mechanism for obtaining the file names
4. Choose between iterating over the file or reading individual lines
   i. If all data is on one line, normally use line input
5. With line-oriented input, extract required data
   i. Examine the line and plan for whitespace, delimiters…
6. Use functions to factor out common tasks

Processing Text Files: Pseudocode

Step 1: Understand the Task

- While there are more lines to be read
  - Read a line from each file
  - Extract the country name
  - population = number following the country name in the line from the first file
  - area = number following the country name in the line from the second file
  - If area != 0
    - density = population / area
  - Print country name and density

Afghanistan	50.56
Akrotiri	127.64
Albania	125.91
Algria	14.18
American Samoa	288.92

Step Two

- Determine the file you need to read and write
  - There are two input files:
    - worldpop.txt
    - worldarea.txt
  - There is one output file:
    - world_pop_density.txt

Step Three

- Choose a mechanism for obtaining the file names
- We have three options:
  - Hardcode the filename as a constant
  - Prompt the user
  - Use a command line argument
- We will use hard-coded files names
  - The file names are constant in this example

Step Four

- Choose between iterating over the file or reading individual lines
- Generally if the data is grouped on lines we iterate over the file
- If the data is spread over several line, we read the individual lines
- In this example we will read individual lines since we are reading from two input files

Step Five

- Extract the data into the individual fields
  - Use spilt or rsplit to extract the data elements

Step Six

- Use functions to factor out common tasks
- Find the repetitive tasks and develop functions to handle them

Example Code

- Open the file population.py

Exception Handling

SECTION 7.4

Exception Handling

- There are two aspects to dealing with run-time program errors:
  1) Detecting Errors
  2) Handling Errors
- The open function can detect an attempt to read from a non-existent file
  - The open function cannot handle the error
  - There are multiple alternatives, the function does not know which is the correct choice
  - The function reports the error to another part of the program to be handled
- Exception handling provides a flexible mechanism for passing control from the point of the error to a **handler** that can deal with the error

Detecting Errors

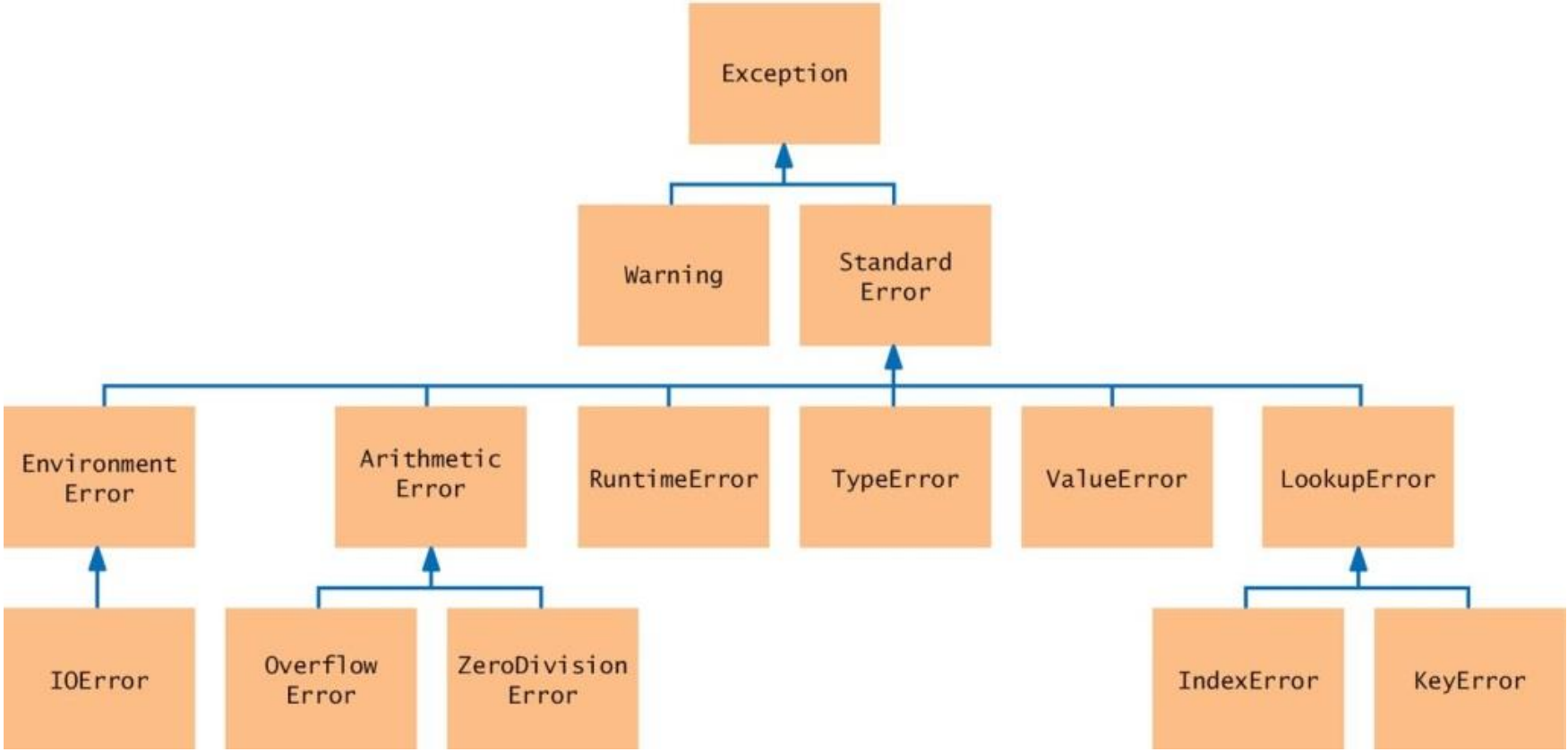
- What do you do if someone tries to withdraw too much money from a bank account?
- You can **raise** an exception
- When you **raise** an exception, execution does not continue with the next statement
  - It transfers to the **exception handler**

Use the raise statement to signal an exception

```
if amount > balance :
    raise ValueError("Amount exceeds balance")
```

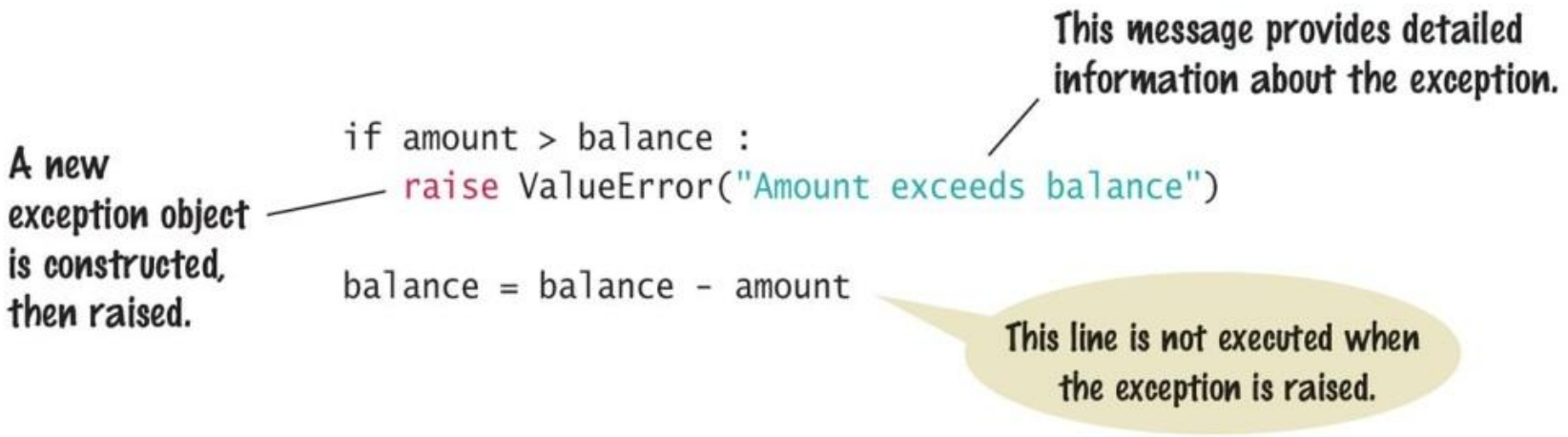
Exception Classes (a subset)

- Look for an appropriate exception



Syntax: Raising an Exception

Syntax `raise` *exceptionObject*



Handling Exceptions

- Every exception should be handled somewhere in the program
- This is a complex problem
  - You need to handle each possible exception and react to it appropriately
- Handling recoverable errors can be done:
  - Simply: exit the program
  - User-friendly: Ask the user to correct the error

Handling Exceptions: Try-Except

- You handle exceptions with the try/except statement
- Place the statement into a location of your program that knows how to handle a particular exception
- The try block contains one or more statements that may cause an exception of the kind that you are willing to handle
- Each except clause contains the handler for an exception type

Syntax: Try-Except

Syntax

```
try :
   statement
   statement
   . . .
except ExceptionType :
   statement
   statement
   . . .
except ExceptionType as varName :
   statement
   statement
   . . .
```

This function can raise an IOError exception.

```
try :
   infile = open("input.txt", "r")

   line = inFile.readline()
   process(line)

except IOError :
   print("Could not open input file.")

except Exception as exceptObj :
   print("Error:", str(exceptObj))
```

When an IOError is raised, execution resumes here.

Additional except clauses can appear here. Place more specific exceptions before more general ones.

This is the exception object that was raised.

Try-Except: An Example

```
try :
    filename = input("Enter filename: ")
    infile = open(filename, "r")
    line = infile.readline()
    value = int(line)
. . .
except IOError :
    print("Error: file not found.")
except ValueError as exception :
    print("Error:", str(exception))
```

`open()` can raise an IOError exception

`int()` can raise a ValueError exception

Execution transfers here if file cannot be opened

Execution transfers here if the string cannot be converted to an int

If either of these exceptions is raised, the rest of the instructions in the try block are skipped

Example

- If an IOError exception is raised, the **except** clause for the IOError exception is executed
- If a ValueError exception occurs, then second **except** clause is executed
- If any other exception is raised it will not be handled by any of the **except** blocks

Output Messages

- When the body of this handler is executed, it prints the message included with the exception

```
except ValueError as exception :
    print("Error:", str(exception))
```

- For example, if the string passed to the int() function was "35x2", then the message included with the exception will be:

  invalid literal for int() with base 10: '35x2'

Output Messages (2)

- To obtain the message, we must have access to the exception object itself
- You can store the exception object in a variable with the as syntax:

```
except ValueError as exception :
```

- When the handler for ValueError is executed, **exception** is set to the exception object. In our code, we then obtain the message string by calling **str(exception)**

Source of Output Messages

- When you raise an exception, you can provide your own message string. For example, when you call

```
raise ValueError("Amount exceeds balance")
```

- The message of the exception, `"Amount exceeds balance"`, is the string provided as the argument to the constructor

The finally Clause

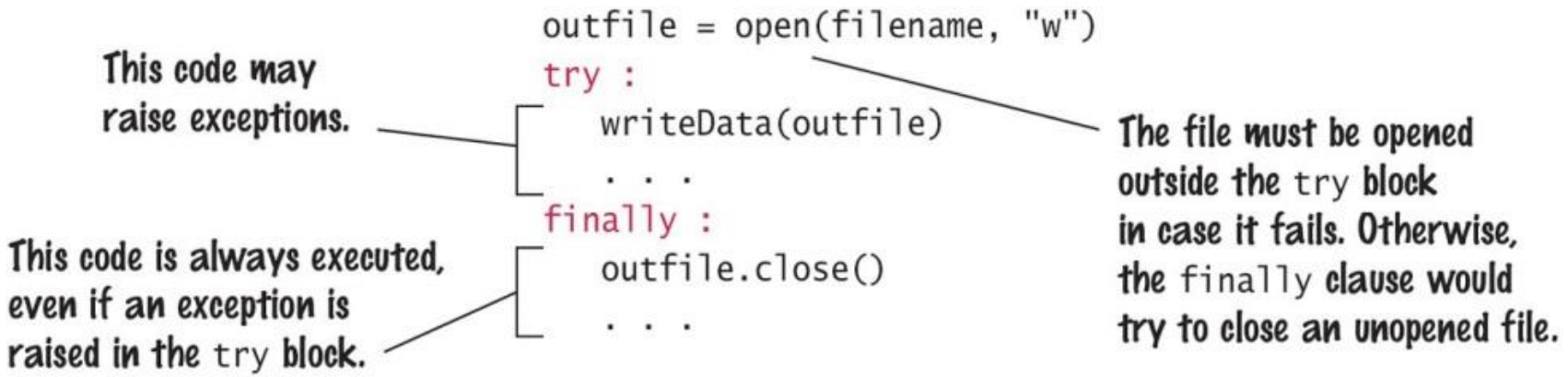
- The finally clause is used when you need to take some action whether or not an exception is raised
- Here is a typical situation
  - It is important to always close an output file whether or not an exception was raised (to ensure that all output is written to the file)
  - Place the call to close() inside a finally clause:

```
outfile = open(filename, "w")
try :
    writeData(outfile)
finally :
    outfile.close()
```

Syntax: The Finally Clause

Syntax

```
try :
   statement
   statement
   . . .
finally :
   statement
   statement
   . . .
```

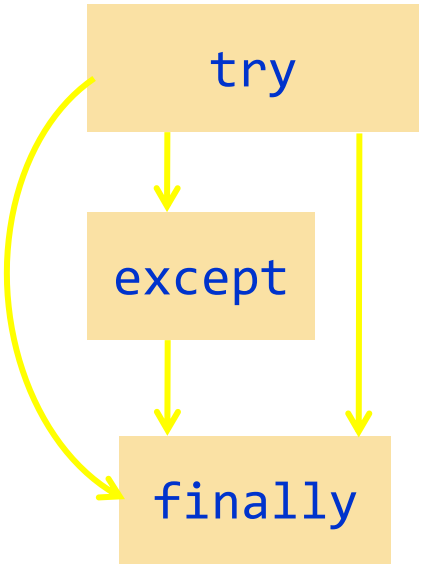


Programming Tip

- Throw exceptions early
  - When a method detects a problem that it cannot solve, it is better to throw an exception rather than try to come up with an imperfect fix
- Catch exceptions late
  - Conversely, a method should only catch an exception if it can really remedy the situation
  - Otherwise, the best remedy is simply to have the exception propagate to its caller, allowing it to be caught by a competent handler

Programming Tip

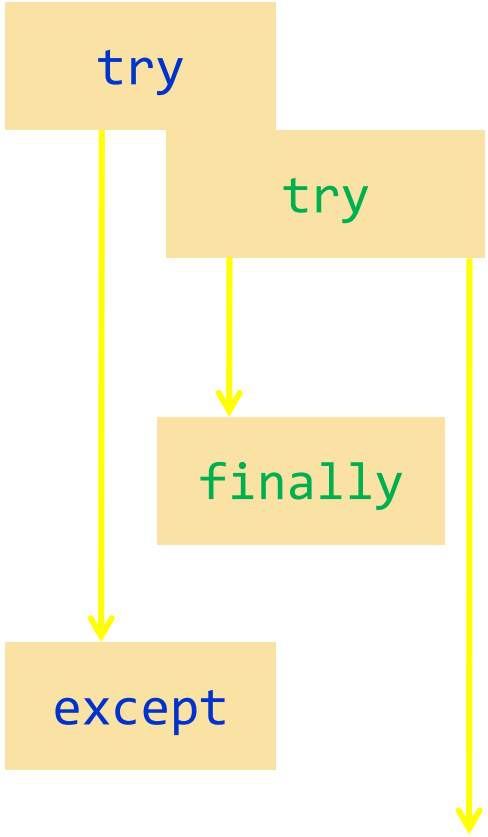
- Do not use except and finally in the same try block
  - The finally clause is executed whenever the try block is exited in any of three ways:
    1. After completing the last statement of the try block
    2. After completing the last statement of a except clause, if this try block caught an exception
    3. When an exception was raised in the try block and not handled



Programming Tip

- It is better to use two (nested) `try` clauses to control the flow

```
try :
    outfile = open(filename, "w")
  try :
    # Write output to outfile
  finally :
    out.close()  # Close resources
except IOError :
  # Handle exception
```



The `With` Statement

- Because a try/finally statement for opening and closing files is so common, Python has a special shortcut:

```
with open(filename, "w") as outfile :
    Write output to outfile
```

- This with statement opens the file with the given name, sets outfile to the file object, and closes the file object when the end of the statement has been reached or an exception is raised

Handling Input Errors

SECTION 7.6

Handling Input Errors

- File Reading Application Example
  - Goal: Read a file of data values
    - First line is the count of values
    - Remaining lines have values
  - Risks:
    - The file may not exist
      - The open() function will raise an exception when the file does not exist
    - The file might have data in the wrong format
      - When there are fewer data items than expected, or when the file doesn't start with the count of values, the program will raise a ValueError exception
      - Finally, when there are more inputs than expected, a RuntimeError exception should be raised

```
3
1.45
-2.1
0.05
```

Handling Input Errors: main()

- Outline for method with all exception handling

```
done = False
while not done :
try:
    # Prompt user for file name
    data = readFile(filename)  # May raise exceptions
    # Process data
    done = true;
  except IOError:
      print("File not found.")
  except ValueError :
      print("File contents invalid.")
  except RuntimeError as error:
      print("Error:", str(error))
```

Handling Input Errors: readFile()

- Creates the file object and calls the readData() function
- No exception handling (no except clauses)
- finally clause closes file in all cases (exception or not)

```
def readFile(filename) :
    inFile = open(filename, "r") # May throw exceptions
    try
      return readData(inFile)
    finally
      in.close()
```

Handling Input Errors: `readData()`

- No exception handling (no try or except clauses)
- raise creates an ValueError exception and exits
- RuntimeError exception can occur

```
def readData(inFile) :
    line = inFile.readline()
    numberOfValues = int(line) # May raise a ValueError exception.
    data = []
    for i in range(numberOfValues) :
        line = inFile.readline()
        value = int(line) # May raise a ValueError exception.
        data.append(value)
    # Make sure there are no more values in the file.
    line = inFile.readline()
    # Extra data in file
    if line != "" :
        raise RuntimeError("End of file expected.")
    return data
```

Once Scenario

1. main calls readFile
2. readFile calls readData
3. readData calls int
4. There is no integer in the input, and int raises a ValueError exception
5. readData has no except clause; it terminates immediately
6. readFile has no except clause; it terminates immediately after executing the finally clause and closing the file
7. The IOError except clause is skipped
8. The ValueError except clause is executed

Example Code

- Open the file analyzedata.py

Summary: File Input/Output

- When opening a file, you supply the name of the file stored on disk and the mode in which the file is to be opened
- Close all files when you are done processing them
- Use the readline() method to obtain lines of text from a file
- Write to a file using the write() method or the print() function

Summary: Processing Text Files

- You can iterate over a file object to read the lines of text in the file
- Use the rstrip() method to remove the newline character from a line of text
- Use the split() method to split a string into individual words
- Read one or more characters with the read() method

Command Line Arguments

- Programs that start from the command line receive the command line arguments in the argv list defined in the sys module

Summary: Exceptions (1)

- To signal an exceptional condition, use the raise statement to raise an exception object
- When you raise an exception, processing continues in an exception handler
- Place the statements that can cause an exception inside a try block, and the handler inside an except clause
- Once a try block is entered, the statements in a finally clause are guaranteed to be executed, whether or not an exception is raised

Summary: Exceptions (2)

- Raise an exception as soon as a problem is detected
  - Handle it only when the problem can be handled
- When designing a program, ask yourself what kinds of exceptions can occur
- For each exception, you need to decide which part of your program can competently handle it