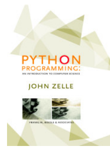
Python Programming: An Introduction To Computer Science



Chapter 8
Loop Structures and Booleans

Objectives

- To understand the concepts of definite and indefinite loops as they are realized in the Python `for` and `while` statements.
- To understand the programming patterns interactive loop and sentinel loop and their implementations using a Python `while` statement.

Objectives

- To understand the programming pattern end-of-file loop and ways of implementing such loops in Python.
- To be able to design and implement solutions to problems involving loop patterns including nested loop structures.

Objectives

- To understand the basic ideas of Boolean algebra and be able to analyze and write Boolean expressions involving Boolean operators.

For Loops: A Quick Review

- The `for` statement allows us to iterate through a sequence of values.
-
```
for <var> in <sequence>:
    <body>
```
- The loop index variable `var` takes on each successive value in the sequence, and the statements in the body of the loop are executed once for each value.

For Loops: A Quick Review

- Suppose we want to write a program that can compute the average of a series of numbers entered by the user.
- To make the program general, it should work with any size set of numbers.
- We don't need to keep track of each number entered, we only need know the running sum and how many numbers have been added.

For Loops: A Quick Review

- We've run into some of these things before!
  - A series of numbers could be handled by some sort of loop. If there are *n* numbers, the loop should execute *n* times.
  - We need a running sum. This will use an accumulator.

For Loops: A Quick Review

- `Input the count of the numbers, n`
- `Initialize sum to 0`
- `Loop n times`
  - `Input a number, x`
  - `Add x to sum`
- `Output average as sum/n`

For Loops: A Quick Review

```
# average1.py
#    A program to average a set of numbers
#    Illustrates counted loop with accumulator

def main():
    n = input("How many numbers do you have? ")
    sum = 0.0
    for i in range(n):
        x = input("Enter a number >> ")
        sum = sum + x
    print "\nThe average of the numbers is", sum / n
```

- Note that sum is initialized to 0.0 so that `sum/n` returns a float!

For Loops: A Quick Review

```
How many numbers do you have? 5
Enter a number >> 32
Enter a number >> 45
Enter a number >> 34
Enter a number >> 76
Enter a number >> 45

The average of the numbers is 46.4
```


Indefinite Loops

- That last program got the job done, but you need to know ahead of time how many numbers you'll be dealing with.
- What we need is a way for the computer to take care of counting how many numbers there are.
- The `for` loop is a definite loop, meaning that the number of iterations is determined when the loop starts.

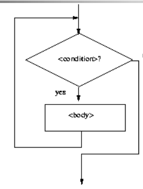
Indefinite Loops

- We can't use a definite loop unless we know the number of iterations ahead of time. We can't know how many iterations we need until all the numbers have been entered.
- We need another tool!
- The *indefinite* or *conditional* loop keeps iterating until certain conditions are met.

Indefinite Loops

- `while <condition>:`
  `    <body>`
- `condition` is a Boolean expression, just like in `if` statements. The body is a sequence of one or more statements.
- Semantically, the body of the loop executes repeatedly as long as the condition remains true. When the condition is false, the loop terminates.

Indefinite Loops



- The condition is tested at the top of the loop. This is known as a *pre-test* loop. If the condition is initially false, the loop body will not execute at all.

Indefinite Loop

- Here's an example of a `while` loop that counts from 0 to 10:

```
i = 0
while i <= 10:
    print i
    i = i + 1
```

- The code has the same output as this `for` loop:

```
for i in range(11):
    print i
```


Indefinite Loop

- The `while` loop requires us to manage the loop variable `i` by initializing it to 0 before the loop and incrementing it at the bottom of the body.
- In the `for` loop this is handled automatically.

Indefinite Loop

- The `while` statement is simple, but yet powerful and dangerous – they are a common source of program errors.
- ```
  i = 0
  while i <= 10:
      print i
  ```
- What happens with this code?

Indefinite Loop

- When Python gets to this loop, `i` is equal to 0, which is less than 10, so the body of the loop is executed, printing 0. Now control returns to the condition, and since `i` is still 0, the loop repeats, etc.
- This is an example of an *infinite loop*.
  ```

Indefinite Loop

- What should you do if you're caught in an infinite loop?
  - First, try pressing control-c
  - If that doesn't work, try control-alt-delete
  - If that doesn't work, push the reset button!

Interactive Loops

- One good use of the indefinite loop is to write *interactive loops*. Interactive loops allow a user to repeat certain portions of a program on demand.
- Remember how we said we needed a way for the computer to keep track of how many numbers had been entered? Let's use another accumulator, called `count`.

Interactive Loops

- At each iteration of the loop, ask the user if there is more data to process. We need to preset it to "yes" to go through the loop the first time.
```
set moredata to "yes"
while moredata is "yes"
    get the next data item
    process the item
    ask user if there is moredata
```


Interactive Loops

- Combining the interactive loop pattern with accumulators for sum and count:
```
initialize sum to 0.0
initialize count to 0
set moredata to "yes"
while moredata is "yes"
   input a number, x
   add x to sum
   add 1 to count
   ask user if there is moredata
output sum/count
```


Interactive Loops

```
# average2.py
#    A program to average a set of numbers
#    Illustrates interactive loop with two accumulators

def main():
    moredata = "yes"
    sum = 0.0
    count = 0
    while moredata[0] == 'y':
        x = input("Enter a number >> ")
        sum = sum + x
        count = count + 1
        moredata = raw_input("Do you have more numbers (yes or no)? ")
    print "\nThe average of the numbers is", sum / count
```

- Using string indexing (moredata[0]) allows us to accept "y", "yes", "yeah" to continue the loop

Interactive Loops

```
Enter a number >> 32
Do you have more numbers (yes or no)? y
Enter a number >> 45
Do you have more numbers (yes or no)? yes
Enter a number >> 34
Do you have more numbers (yes or no)? yup
Enter a number >> 76
Do you have more numbers (yes or no)? y
Enter a number >> 45
Do you have more numbers (yes or no)? nah

The average of the numbers is 46.4
```

Sentinel Loops

- A *sentinel loop* continues to process data until reaching a special value that signals the end.
- This special value is called the *sentinel*.
- The sentinel must be distinguishable from the data since it is not processed as part of the data.

Sentinel Loops

```
get the first data item
while item is not the sentinel
   process the item
   get the next data item
```

- The first item is retrieved before the loop starts. This is sometimes called the *priming read*, since it gets the process started.
- If the first item is the sentinel, the loop terminates and no data is processed.
- Otherwise, the item is processed and the next one is read.

Sentinel Loops

- In our averaging example, assume we are averaging test scores.
- We can assume that there will be no score below 0, so a negative number will be the sentinel.

Sentinel Loops

```
# average3.py
#    A program to average a set of numbers
#    Illustrates sentinel loop using negative input as
   sentinel

def main():
    sum = 0.0
    count = 0
    x = input("Enter a number (negative to quit) >> ")
    while x >= 0:
        sum = sum + x
        count = count + 1
        x = input("Enter a number (negative to quit) >> ")
    print "\nThe average of the numbers is", sum / count
```


Sentinel Loops

```
Enter a number (negative to quit) >> 32
Enter a number (negative to quit) >> 45
Enter a number (negative to quit) >> 34
Enter a number (negative to quit) >> 76
Enter a number (negative to quit) >> 45
Enter a number (negative to quit) >> -1

The average of the numbers is 46.4
```


Sentinel Loops

- This version provides the ease of use of the interactive loop without the hassle of typing 'y' all the time.
- There's still a shortcoming – using this method we can't average a set of positive *and negative* numbers.
- If we do this, our sentinel can no longer be a number.

Sentinel Loops

- We could input all the information as strings.
- Valid input would be converted into numeric form. Use a character-based sentinel.
- We could use the *empty string* (“”)!

Sentinel Loops

```
initialize sum to 0.0
initialize count to 0
input data item as a string, xStr
while xStr is not empty
   convert xStr to a number, x
   add x to sum
   add 1 to count
   input next data item as a string, xStr
Output sum / count
```


Sentinel Loops

```
# average4.py
#    A program to average a set of numbers
#    Illustrates sentinel loop using empty string as sentinel

def main():
    sum = 0.0
    count = 0
    xStr = raw_input("Enter a number (<Enter> to quit) >> ")
    while xStr != "":
        x = eval(xStr)
        sum = sum + x
        count = count + 1
        xStr = raw_input("Enter a number (<Enter> to quit) >> ")
    print "\nThe average of the numbers is", sum / count
```


Sentinel Loops

```
Enter a number (<Enter> to quit) >> 34
Enter a number (<Enter> to quit) >> 23
Enter a number (<Enter> to quit) >> 0
Enter a number (<Enter> to quit) >> -25
Enter a number (<Enter> to quit) >> -34.4
Enter a number (<Enter> to quit) >> 22.7
Enter a number (<Enter> to quit) >>

The average of the numbers is 3.38333333333
```


File Loops

- The biggest disadvantage of our program at this point is that they are interactive.
- What happens if you make a typo on number 43 out of 50?
- A better solution for large data sets is to read the data from a file.

File Loops

```
# average5.py
#     Computes the average of numbers listed in a file.

def main():
    fileName = raw_input("What file are the numbers in? ")
    infile = open(fileName,'r')
    sum = 0.0
    count = 0
    for line in infile.readlines():
        sum = sum + eval(line)
        count = count + 1
    print "\nThe average of the numbers is", sum / count
```

File Loops

- Many languages don't have a mechanism for looping through a file like this. Rather, they use a sentinel!
- We could use `readline` in a loop to get the next line of the file.
- At the end of the file, `readline` returns an empty string, ""

File Loops

```
line = infile.readline()
while line != ""
   #process line
   line = infile.readline()
```

- Does this code correctly handle the case where there's a blank line in the file?
- Yes. An empty line actually ends with the newline character, and `readline` includes the newline. "\n" != ""

File Loops

```
# average6.py
#     Computes the average of numbers listed in a file.

def main():
    fileName = raw_input("What file are the numbers in? ")
    infile = open(fileName,'r')
    sum = 0.0
    count = 0
    line = infile.readline()
    while line != "":
        sum = sum + eval(line)
        count = count + 1
        line = infile.readline()
    print "\nThe average of the numbers is", sum / count
```


Nested Loops

- In the last chapter we saw how we could nest `if` statements. We can also nest loops.
- Suppose we change our specification to allow any number of numbers on a line in the file (separated by commas), rather than one per line.

Nested Loops

- At the top level, we will use a file-processing loop that computes a running sum and count.

```
sum = 0.0
count = 0
line = infile.readline()
while line != "":
    #update sum and count for values in line
    line = infile.readline()
print "\nThe average of the numbers is", sum/count
```


Nested Loops

- In the next level in we need to update the `sum` and `count` in the body of the loop.
- Since each line of the file contains one or more numbers separated by commas, we can split the string into substrings, each of which represents a number.
- Then we need to loop through the substrings, convert each to a number, and add it to `sum`.
- We also need to update `count`.

Nested Loops

```
for xStr in string.split(line, ","):
    sum = sum + eval(xStr)
    count = count + 1
```

- Notice that this `for` statement uses `line`, which is also the loop control variable for the outer loop.

Nested Loops

```
# average7.py
#     Computes the average of numbers listed in a file.
#     Works with multiple numbers on a line.

import string

def main():
    fileName = raw_input("What file are the numbers in? ")
    infile = open(fileName,'r')
    sum = 0.0
    count = 0
    line = infile.readline()
    while line != "":
        for xStr in string.split(line, ","):
            sum = sum + eval(xStr)
            count = count + 1
        line = infile.readline()
    print "\nThe average of the numbers is", sum / count
```


Nested Loops

- The loop that processes the numbers in each line is indented inside of the file processing loop.
- The outer `while` loop iterates once for each line of the file.
- For each iteration of the outer loop, the inner `for` loop iterates as many times as there are numbers on the line.
- When the inner loop finishes, the next line of the file is read, and this process begins again.

Nested Loops

- Designing nested loops –
  - Design the outer loop without worrying about what goes inside
  - Design what goes inside, ignoring the outer loop.
  - Put the pieces together, preserving the nesting.

Computing with Booleans

- `if` and `while` both use Boolean expressions.
- Boolean expressions evaluate to `True` or `False`.
- So far we've used Boolean expressions to compare two values, e.g. (`while x >= 0`)

Boolean Operators

- Sometimes our simple expressions do not seem expressive enough.
- Suppose you need to determine whether two points are in the same position – their *x* coordinates are equal and their *y* coordinates are equal.

Boolean Operators

```
if p1.getX() == p2.getX():
    if p1.getY() == p2.getY():
        # points are the same
    else:
        # points are different
else:
    # points are different
```

- It's easy to see that this is an awkward way to evaluate multiple Boolean expressions!
- Let's check out the three Boolean operators `and`, `or`, and `not`.

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Boolean Operators

- The Boolean operators `and` and `or` are used to combine two Boolean expressions and produce a Boolean result.
- `<expr> and <expr>`
- `<expr> or <expr>`

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Boolean Operators

- The `and` of two expressions is true exactly when both of the expressions are true.
- We can represent this in a *truth table*.

P	*Q*	*P and Q*
T	T	T
T	F	F
F	T	F
F	F	F

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Boolean Expressions

- In the truth table, *P* and *Q* represent smaller Boolean expressions.
- Since each expression has two possible values, there are four possible combinations of values.
- The last column gives the value of `P and Q`.

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Boolean Expressions

- The `or` of two expressions is true when either expression is true.

P	*Q*	*P or Q*
T	T	T
T	F	T
F	T	T
F	F	F

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Boolean Expressions

- The only time `or` is false is when both expressions are false.
- Also, note that `or` is true when both expressions are true. This isn't how we normally use "or" in language.

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Boolean Operators

- The `not` operator computes the opposite of a Boolean expression.
- `not` is a *unary* operator, meaning it operates on a single expression.

P	*not P*
T	F
F	T

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Boolean Operators

- We can put these operators together to make arbitrarily complex Boolean expressions.
- The interpretation of the expressions relies on the precedence rules for the operators.

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Boolean Operators

- Consider `a or not b and c`
- How should this be evaluated?
- The order of precedence, from high to low, is `not`, `and`, `or`.
- This statement is equivalent to `(a or ((not b) and c))`
- Since most people don't memorize the the Boolean precedence rules, use parentheses to prevent confusion.

Python Programming, 1/e 57

Boolean Operators

- To test for the co-location of two points, we could use an `and`.
-
```
if p1.getX() == p2.getX() and p2.getY() == p1.getY():
    # points are the same
else:
    # points are different
```
- The entire condition will be true *only* when both of the simpler conditions are true.

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Boolean Operators

- Say you're writing a racquetball simulation. The game is over as soon as either player has scored 15 points.
- How can you represent that in a Boolean expression?
- `scoreA == 15 or scoreB == 15`
- When either of the conditions becomes true, the entire expression is true. If neither condition is true, the expression is false.

Python Programming, 1/e 59

Boolean Operators

- We want to construct a loop that continues as long as the game is **not** over.
- You can do this by taking the negation of the game-over condition as your loop condition!
-
```
while not(scoreA == 15 or scoreB == 15):
    #continue playing
```

Python Programming, 1/e 60

Boolean Operators

- Some racquetball players also use a shutout condition to end the game, where if one player has scored 7 points and the other person hasn't scored yet, the game is over.
- ```
  while not(scoreA == 15 or scoreB == 15 or \
  (scoreA == 7 and scoreB == 0) or (scoreB == 7 and scoreA == 0):
      #continue playing
  ```

Python Programming, 1/e 61

Boolean Operators

- Let's look at volleyball scoring. To win, a volleyball team needs to win by at least two points.
- In volleyball, a team wins at 15 points
- If the score is 15 – 14, play continues, just as it does for 21 – 20.
- `(a >= 15 and a - b >= 2) or (b >= 15 and b - a >= 2)`
- `(a >= 15 or b >= 15) and abs(a - b) >= 2`

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Boolean Algebra

- The ability to formulate, manipulate, and reason with Boolean expressions is an important skill.
- Boolean expressions obey certain algebraic laws called *Boolean logic* or *Boolean algebra.*

Python Programming, 1/e 63

Boolean Algebra

Algebra	Boolean algebra
a * 0 = 0	*a* and false == false
a * 1 = *a*	*a* and true == *a*
a + 0 = *a*	*a* or false == *a*

- `and` has properties similar to multiplication
- `or` has properties similar to addition
- `0` and `1` correspond to false and true, respectively.

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Boolean Algebra

- Anything `or`ed with true is true:
  `a or true == true`
- Both `and` and `or` distribute:
  ```
  a or (b and c) == (a or b) and (a or c)
  a and (b or c) == (a and b) or (a and c)
  ```
- Double negatives cancel out:
  `not(not a) == a`
- DeMorgan's laws:
  ```
  not(a or b) == (not a) and (not b)
  not(a and b) == (not a) or (not b)
  ```

Python Programming, 1/e 65

Boolean Algebra

- We can use these rules to simplify our Boolean expressions.
- ```
  while not(scoreA == 15 or scoreB == 15):
      #continue playing
  ```
- This is saying something like "While it is not the case that player A has 15 or player B has 15, continue playing."
- Applying DeMorgan's law:
  ```
  while (not scoreA == 15) and (not scoreB == 15):
      #continue playing
  ```

Python Programming, 1/e 66

Boolean Algebra

- This becomes:
```
while scoreA != 15 and scoreB != 15
    # continue playing
```
- Isn't this easier to understand? "While player A has not reached 15 and player B has not reached 15, continue playing."

Boolean Algebra

- Sometimes it's easier to figure out when a loop should stop, rather than when the loop should continue.
- In this case, write the loop termination condition and put a `not` in front of it. After a couple applications of DeMorgan's law you are ready to go with a simpler but equivalent expression.

Other Common Structures

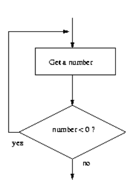
- The `if` and `while` can be used to express every conceivable algorithm.
- For certain problems, an alternative structure can be convenient.

Post-Test Loop

- Say we want to write a program that is supposed to get a nonnegative number from the user.
- If the user types an incorrect input, the program asks for another value.
- This process continues until a valid value has been entered.
- This process is *input validation*.

Post-Test Loop

- ```
  repeat
      get a number from the user
  until number is >= 0
  ```



Post-Test Loop

- When the condition test comes after the body of the loop it's called a *post-test loop*.
- A post-test loop always executes the body of the code at least once.
- Python doesn't have a built-in statement to do this, but we can do it with a slightly modified `while` loop.
  ```

Post-Test Loop

- We seed the loop condition so we're guaranteed to execute the loop once.

```
number = -1
while number < 0:
    number = input("Enter a positive number: ")
```

- By setting `number` to –1, we force the loop body to execute at least once.

Post-Test Loop

- Some programmers prefer to simulate a post-test loop by using the Python `break` statement.
- Executing `break` causes Python to immediately exit the enclosing loop.
- `break` is sometimes used to exit what looks like an infinite loop.

Post-Test Loop

- The same algorithm implemented with a `break`:

```
while True:
    number = input("Enter a positive number: ")
    if x >= 0: break # Exit loop if number is valid
```

- A while loop continues as long as the expression evaluates to true. Since `True` *always* evaluates to true, it looks like an infinite loop!

Post-Test Loop

- When the value of *x* is nonnegative, the `break` statement executes, which terminates the loop.
- If the body of an `if` is only one line long, you can place it right after the `:`!
- Wouldn't it be nice if the program gave a warning when the input was invalid?

Post-Test Loop

- In the `while` loop version, this is awkward:

```
number = -1
while number < 0:
    number = input("Enter a positive number: ")
    if number < 0:
        print "The number you entered was not positive"
```

- We're doing the validity check in two places!

Post-Test Loop

- Adding the warning to the `break` version only adds an `else` statement:

```
while True:
    number = input("Enter a positive number: ")
    if x >= 0:
        break # Exit loop if number is valid
    else:
        print "The number you entered was not positive."
```

Loop and a Half

- Stylistically, some programmers prefer the following approach:

```
while True:
    number = input("Enter a positive number: ")
    if x >= 0: break # Loop exit
    print "The number you entered was not positive"
```

- Here the loop exit is in the middle of the loop body. This is what we mean by a *loop and a half*.

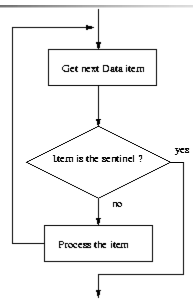
Loop and a Half

- The loop and a half is an elegant way to avoid the priming read in a sentinel loop.


```
while True:
    get next data item
    if the item is the sentinel: break
    process the item
```

- This method is faithful to the idea of the sentinel loop, the sentinel value is not processed!

Loop and a Half



Loop and a Half

- To use or not use `break`. That is the question!
- The use of break is mostly a matter of style and taste.
- Avoid using break often within loops, because the logic of a loop is hard to follow when there are multiple exits.

Boolean Expressions as Decisions

- Boolean expressions can be used as control structures themselves.
- Suppose you're writing a program that keeps going as long as the user enters a response that starts with 'y' (like our interactive loop).
- One way you could do it:

```
while response[0] == "y" or response[0] == "Y":
```


Boolean Expressions as Decisions

- Be careful! You can't take shortcuts:

```
while response[0] == "y" or "Y":
```

- Why doesn't this work?
- Python has a `bool` type that internally uses 1 and 0 to represent `True` and `False`, respectively.
- The Python condition operators, like `==`, always evaluate to a value of type `bool`.

Boolean Expressions as Decisions

- However, Python will let you evaluate any built-in data type as a Boolean. For numbers (int, float, and long ints), zero is considered `False`, anything else is considered `True`.

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Boolean Expressions as Decisions

```
>>> bool(0)
False
>>> bool(1)
True
>>> bool(32)
True
>>> bool("Hello")
True
>>> bool("")
False
>>> bool([1,2,3])
True
>>> bool([])
False
```

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Boolean Expressions as Decisions

- An empty sequence is interpreted as `False` while any non-empty sequence is taken to mean `True`.
- The Boolean operators have operational definitions that make them useful for other purposes.

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Boolean Expressions as Decisions

Operator	Operational definition
x `and` *y*	If *x* is false, return *x*. Otherwise, return *y*.
x `or` *y*	If *x* is true, return *x*. Otherwise, return *y*.
`not` *x*	If *x* is false, return `True`. Otherwise, return `False`.

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Boolean Expressions as Decisions

- Consider *x* `and` *y*. In order for this to be true, both *x* and *y* must be true.
- As soon as one of them is found to be false, we know the expression as a whole is false and we don't need to finish evaluating the expression.
- So, if *x* is false, Python should return a false result, namely *x*.

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Boolean Expressions as Decisions

- If *x* is true, then whether the expression as a whole is true or false depends on *y*.
- By returning *y*, if *y* is true, then true is returned. If *y* is false, then false is returned.

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Boolean Expressions as Decisions

- These definitions show that Python's Booleans are *short-circuit* operators, meaning that a true or false is returned as soon as the result is known.
- In an `and` where the first expression is false and in an `or`, where the first expression is true, Python will not evaluate the second expression.

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Boolean Expressions as Decisions

- `response[0] == "y" or "Y"`
- The Boolean operator is combining two operations.
- Here's an equivalent expression:
  `(response[0] == "y") or ("Y")`
- By the operational description of `or`, this expression returns either `True`, if response[0] equals "y", or "Y", both of which are interpreted by Python as true.

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Boolean Expressions as Decisions

- Sometimes we write programs that prompt for information but offer a default value obtained by simply pressing `<Enter>`
- Since the string used by `ans` can be treated as a Boolean, the code can be further simplified.

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Boolean Expressions as Decisions

```
ans = raw_input("What flavor fo you want [vanilla]:
")
if ans:
    flavor = ans
else:
    flavor = "vanilla"
```

- If the user just hits `<Enter>`, `ans` will be an empty string, which Python interprets as false.

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Boolean Expressions as Decisions

- We can code this even more succinctly!
```
ans = raw_input("What flavor fo you want [vanilla]: ")
flavor = ans or "vanilla"
```
- Remember, any non-empty answer is interpreted as `True`.
- This exercise could be boiled down into one line!
```
flavor = raw_input("What flavor do you want
[vanilla]:" ) or "vanilla"
```

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Boolean Expressions as Decisions

- Again, if you understand this method, feel free to utilize it. Just make sure that if your code is tricky, that it's well documented!

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