ICS 104 - Introduction to Programming in Python and C

Loops

Reading Assignment

- Chapter 4 Sections 1, 2, 3, 5, 6, 7, 8 and 9.

Chapter Learning Outcomes

At the end of this chapter, you will be able to

- implement while and for loops
- become familiar with common loop algorithms
- understand nested loops
- process strings
- generate random numbers

Loops

- In a **loop**, a part of a program is repeated over and over until a specific goal is reached.
- Loops are important for calculations that require repeated steps, and for processing input consisting of many data items.

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The While Loop

- For example, You put $10,000 into a bank account that earns 5 percent interest per year.
- How many years does it take for the account balance to be double the original investment?

Start with a year value of 0, a column for the interest, and a balance of $10,000.

year	interest	balance
0		$10,000

```
Repeat the following steps while the balance is less than $20,000.
    Add 1 to the year value.
    Compute the interest as balance x 0.05 (i.e., 5 percent interest).
    Add the interest to the balance.
Report the final year value as the answer.
```

- Question: How we can implement the "Repeat steps while the balance is less than $20,000?"

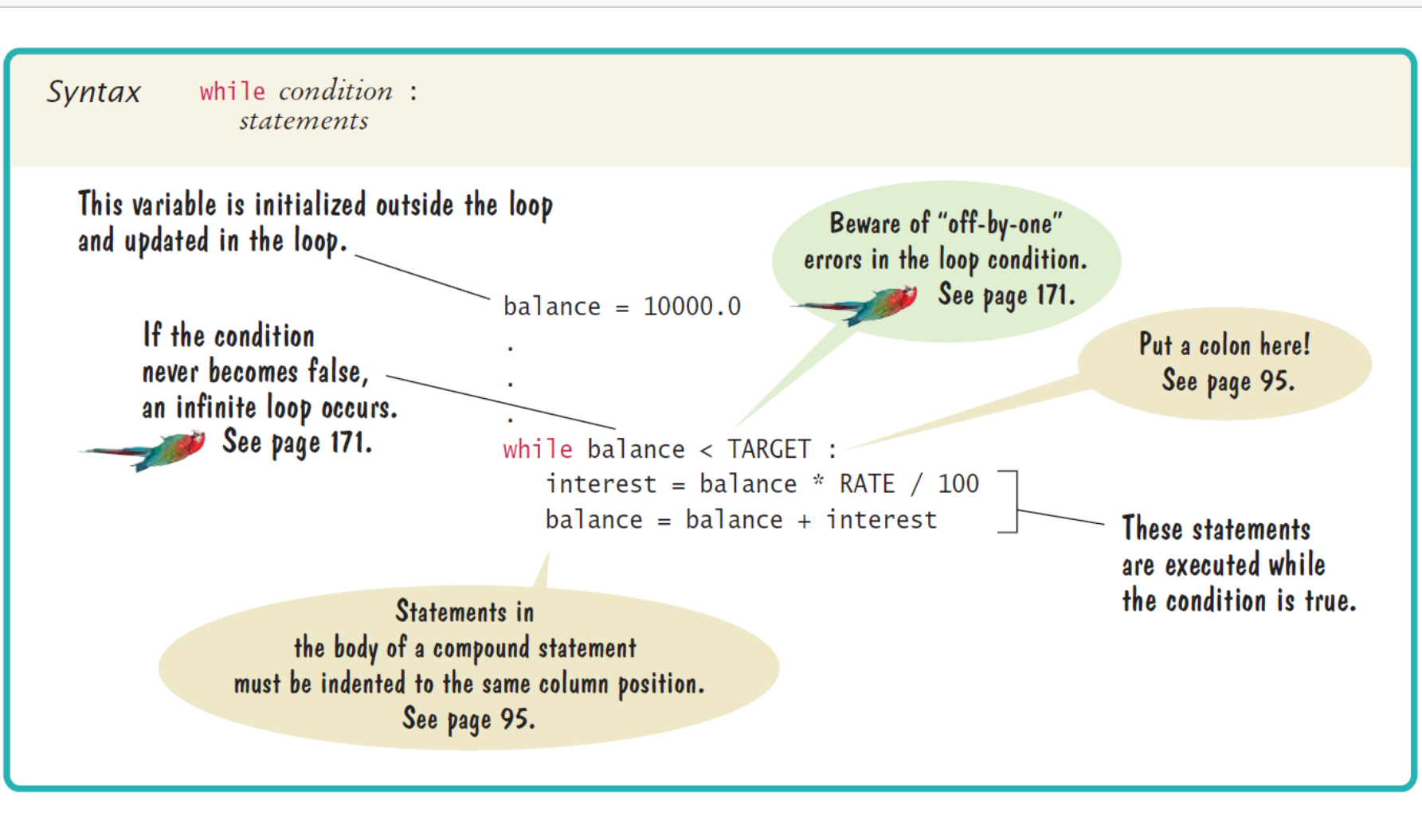
- Answer: Using the while loop statement

The While Loop

`while` *condition* `:`

```
    statements
```

```
In [ ]: while balance < TARGET :
            year = year + 1
            interest = balance * RATE / 100
            balance = balance + interest
```



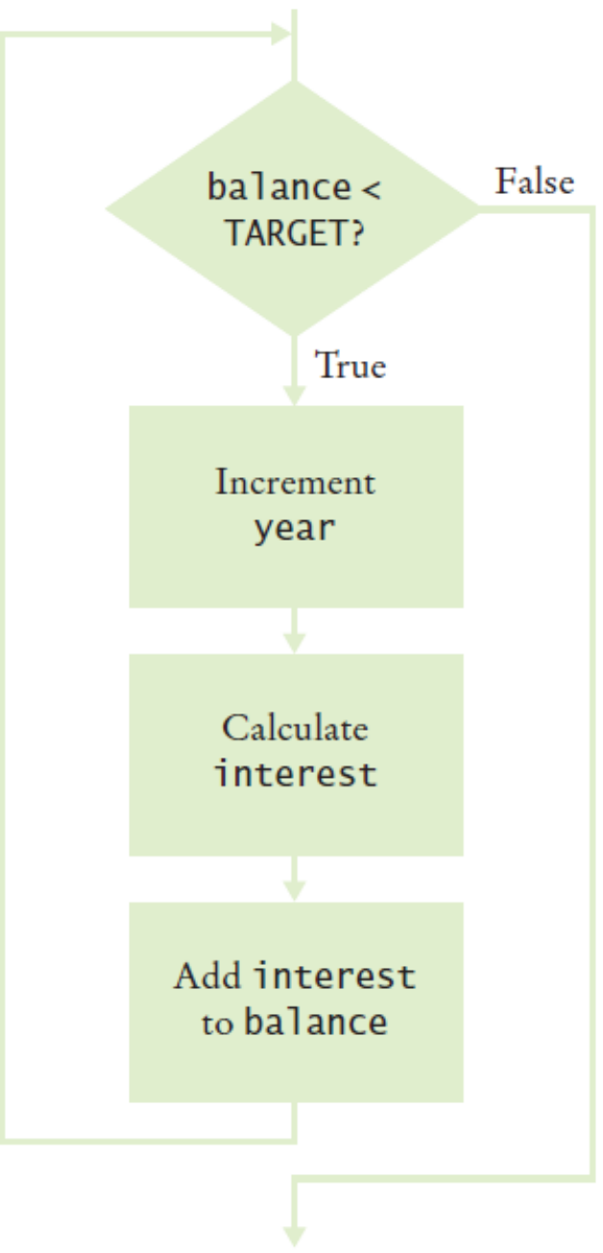
```
Syntax    while condition :
              statements

balance = 10000.0
.
.
.
while balance < TARGET :
   interest = balance * RATE / 100
   balance = balance + interest
```

The While Loop

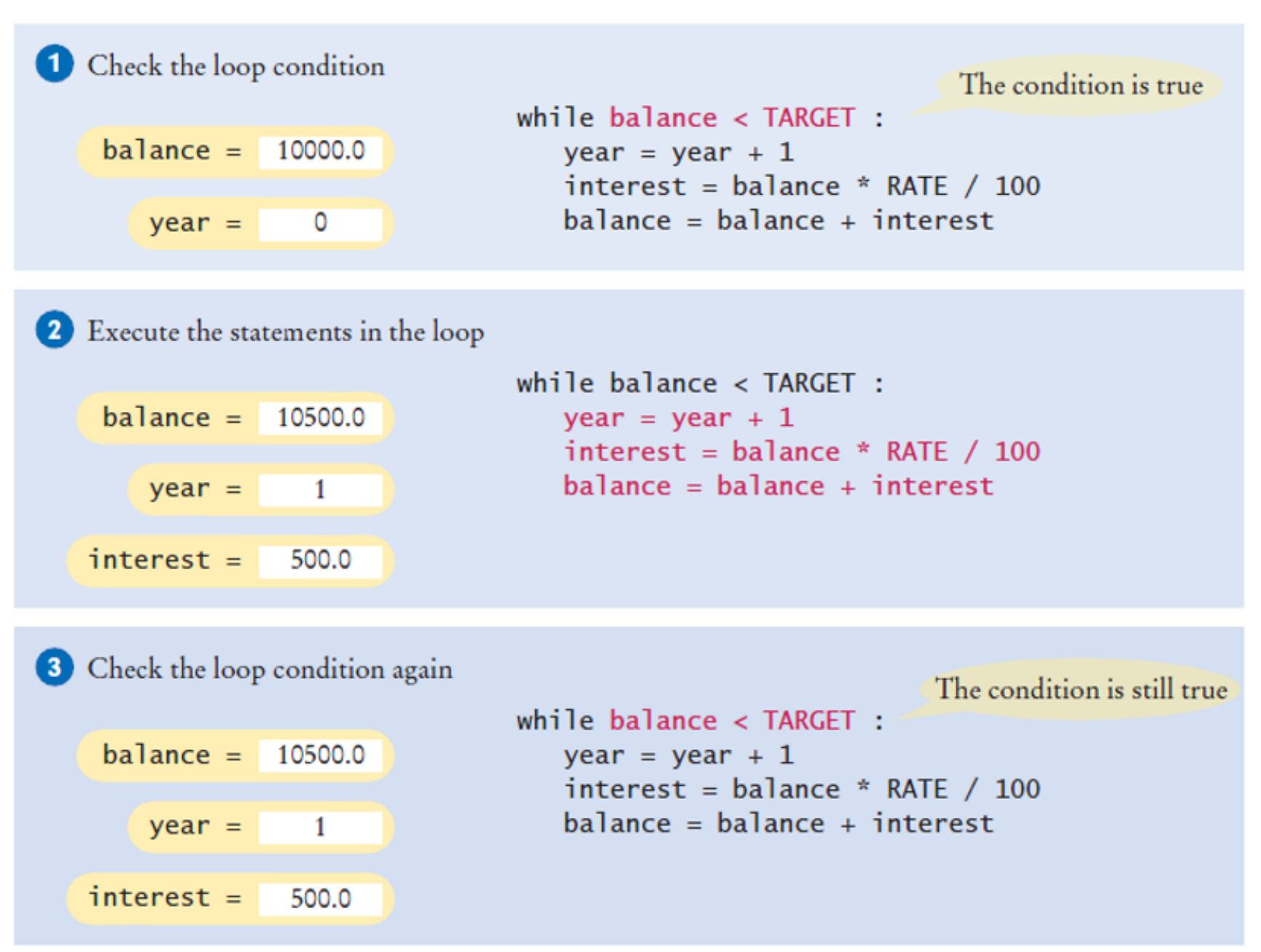
- As long as the condition remains true, the statements inside the **while** statement are executed.
- This statement block is called the **body** of the while statement.

- For example, we want to increment the year counter and add interest while the balance is less than the target balance of $20,000:

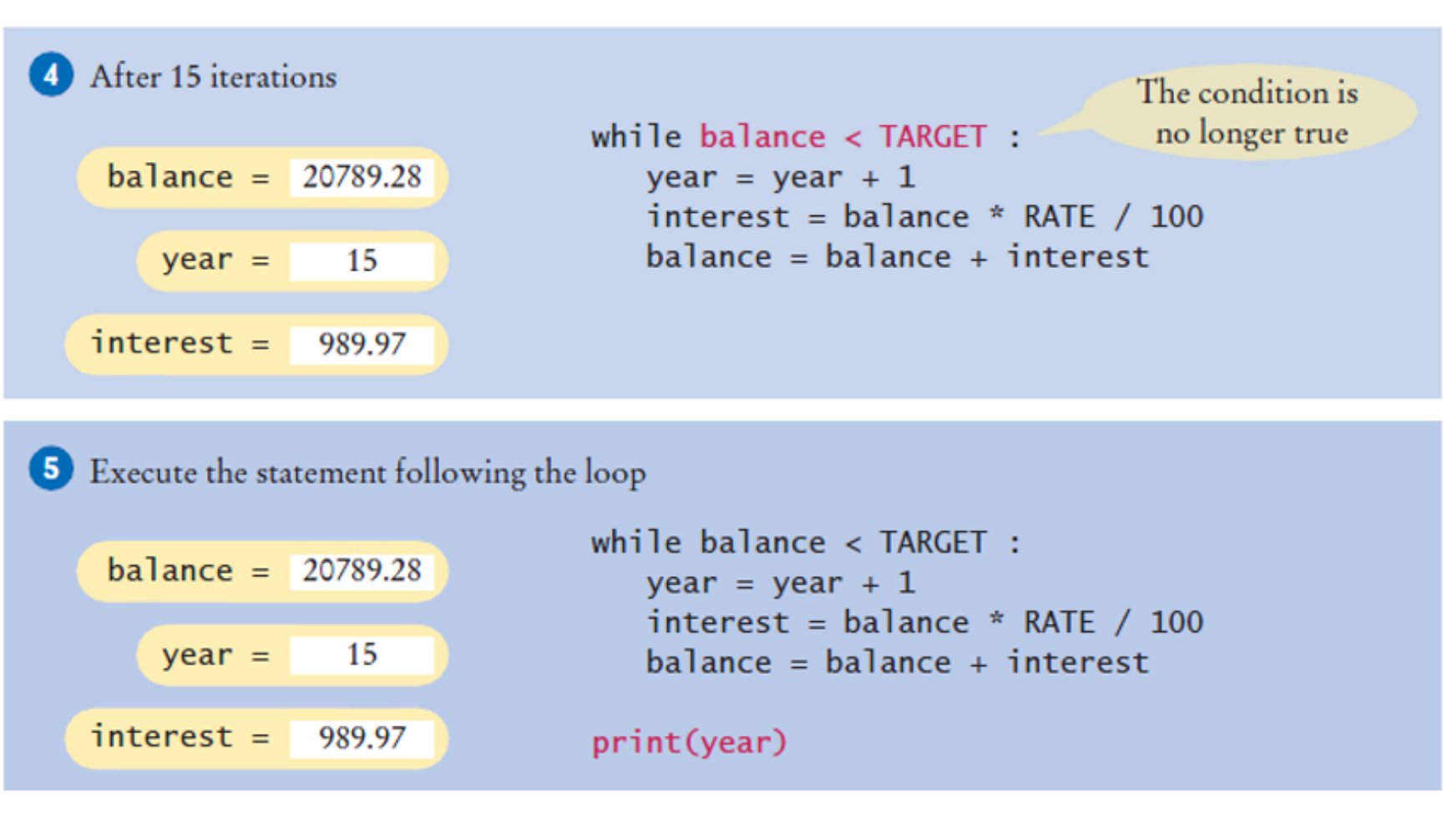


The While Loop

Execution of the Loop



```
while balance < TARGET :
   year = year + 1
   interest = balance * RATE / 100
   balance = balance + interest
```



```
while balance < TARGET :
   year = year + 1
   interest = balance * RATE / 100
   balance = balance + interest

print(year)
```

The While Loop

Event-Controlled Loops

```
In [ ]: #  This program computes the time required to double an investment.
        # Create constant variables.
        RATE = 5.0
        INITIAL_BALANCE = 10000.0
        TARGET = 2 * INITIAL_BALANCE

        # Initialize variables used with the loop.
        balance = INITIAL_BALANCE
        year = 0

        # Count the years required for the investment to double.
        while balance < TARGET :
           year = year + 1
           interest = balance * RATE / 100
           balance = balance + interest

        # Print the results.
        print("The investment doubled after", year, "years.")
```

The While Loop

Count-Controlled Loops

- A while loop that is controlled by a counter:

```
In [ ]: counter = 1                  # Initialize the counter

        while counter <= 10 :        # Check the counter
            print(counter)
            counter = counter + 1    # Update the loop variable
```

The While Loop - Student Activity

- What does the following loop print?

```
In [ ]: n =1
        while n < 100:
            n = 2* n
            print(n)
```

The While Loop - Student Activity

- What does the following loop print?

```
In [ ]: i = 0
        total = 0
        while total < 10:
            i = i + 1
            total = total + i
            print(i,total)
```

The while Loop - Student Activity

- What does the following loop print?

```
In [ ]: i = 0
        total = 0
        while total < 0:
            i = i + 1
            total = total - i
            print(i,total)
```

The While Loop

- We want to write loops that read and process a sequence of input values.
- A **sentinel value** denotes the end of a data set, but it is not part of the data.

- We want to write a program that computes the average of a set of salary values.
- We will use any negative value as the sentinel.
  - An employee would surely not work for a negative salary.

```
In [ ]: #  This program prints the average of salary values that are terminated with
        #  a sentinel.

        # Initialize variables to maintain the running total and count.
        total = 0.0
        count = 0

        # Initialize salary to any non-sentinel value.
        salary = 0.0

        # Process data until the sentinel is entered.
        while salary >= 0.0 :
           salary = float(input("Enter a salary or a negative value to finish: "))
           if salary >= 0.0 :
              total = total + salary
              count = count + 1

        # Compute and print the average salary.
        if count > 0 :
           average = total / count
           print("Average salary is", average)
        else :
           print("No data was entered.")
```

Common Loop Algorithms

- Sum and Average Values:

```
In [ ]: total = 0.0
        inputStr = input("Enter value: ")
        while inputStr !="":
            value = float(inputStr)
            total = total + value
            inputStr = input("Enter value: ")
        print("Sum: ",total)
```

Common Loop Algorithms

- Sum and Average Value:

```
In [ ]: total = 0.0
        count = 0
        inputStr = input("Enter value: ")
        while inputStr !="":
            value = float(inputStr)
            total = total + value
            count = count + 1
            inputStr = input("Enter value: ")
        if count > 0:
            average = total/count
        else:
            average = 0.0
        print("Average: ",average)
```

Common Loop Algorithms

- Counting Matches - You want to count how many negative values are included in a sequence of integers.
- Keep a **counter**, a variable that is initialized with 0 and incremented whenever there is a match.

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In a loop that counts matches, a counter is incremented whenever a match is found.

```
In [ ]: negatives = 0
        inputStr = input("Enter value: ")
        while inputStr !="":
            value = int(inputStr)
            if value < 0:
                negatives = negatives + 1
            inputStr = input("Enter value: ")
        print("There were", negatives,"negative values.")
```

The `for` Loop

- Uses of a `for` loop:
  - The `for` loop can be used to iterate over the contents of any container.
  - A container is an object (like a string) that contains or stores a collection of elements.
  - A string is a container that stores a sequence of characters.

The `for` Loop

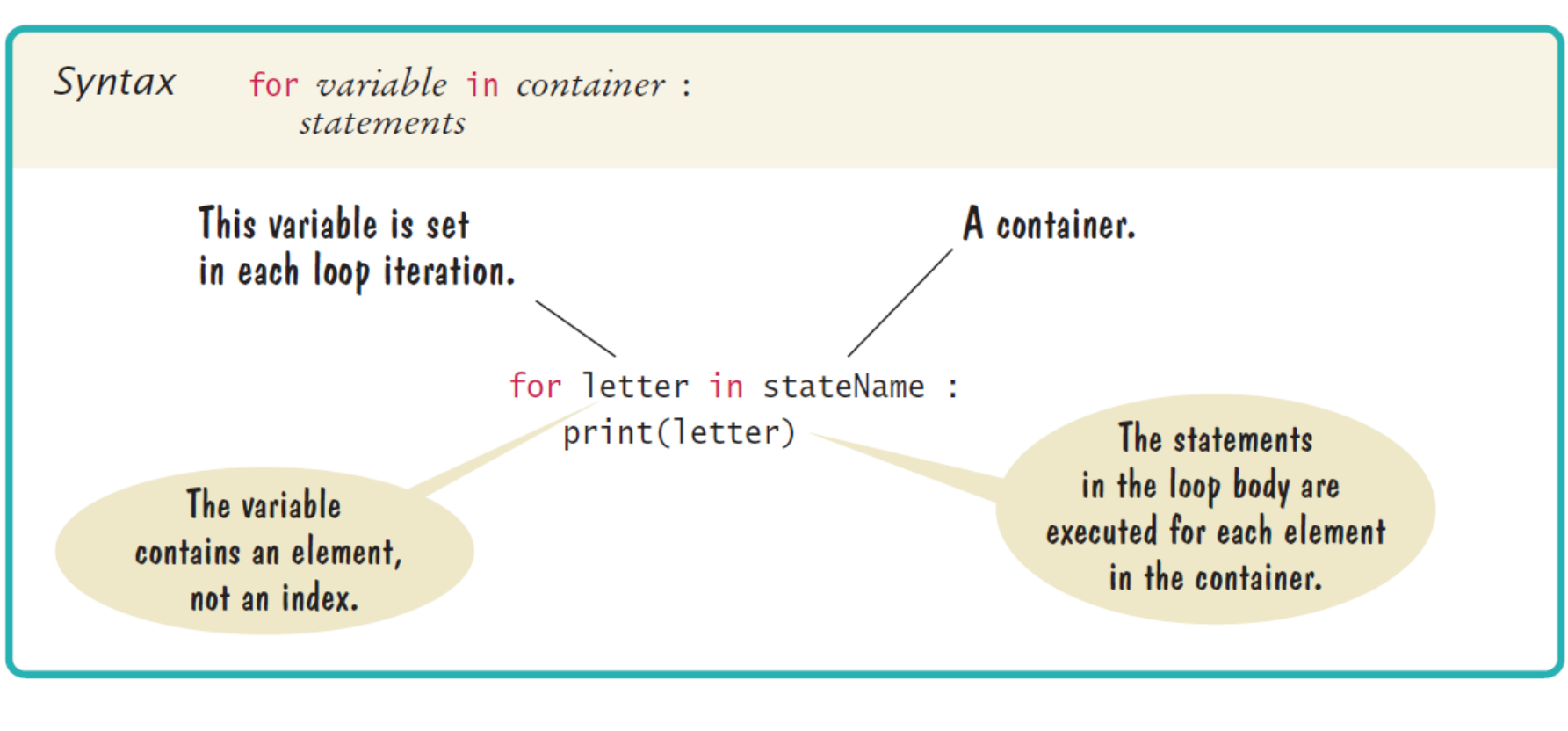
- Suppose we want to print a string, with one character per line.
- We cannot simply print the string using the **print** function.
- Instead, we need to iterate over the characters in the string and print each character individually.

- An important difference between the while loop and the for loop:
  - In the while loop, the index variable i is assigned 0, 1 and so on.
  - In the for loop with a string container `stateName`, the element variable is assigned `stateName[0]`, `stateName[1]`, and so on.

```
In [ ]: stateName = "Virginia"
        for letter in stateName :
            print(letter)
```

- The loop body is executed for each character in the string `stateName`, starting with the first character.
- At the beginning of each loop iteration, the next character is assigned to the variable letter.
- Then the loop body is executed.

for Statement



```
Syntax    for variable in container :
              statements

for letter in stateName :
   print(letter)
```

The `for` Loop

- Can we write this program using a **while** loop?

```
In [ ]: stateName = "Virginia"
        for letter in stateName :
            print(letter)
```

```
In [ ]: i = 0
        stateName = "Virginia"
        while i < len(stateName):
            letter = stateName[i]
            print(letter)
            i = i + 1
```

The for Loop

- The **for** loop can be used with the `range` function to iterate over a range of integer values.
- When we write `range(i,j)`, what are the range values (assuming that $i < j$?)

```
In [ ]: for i in range(1,10):
            print(i)
```

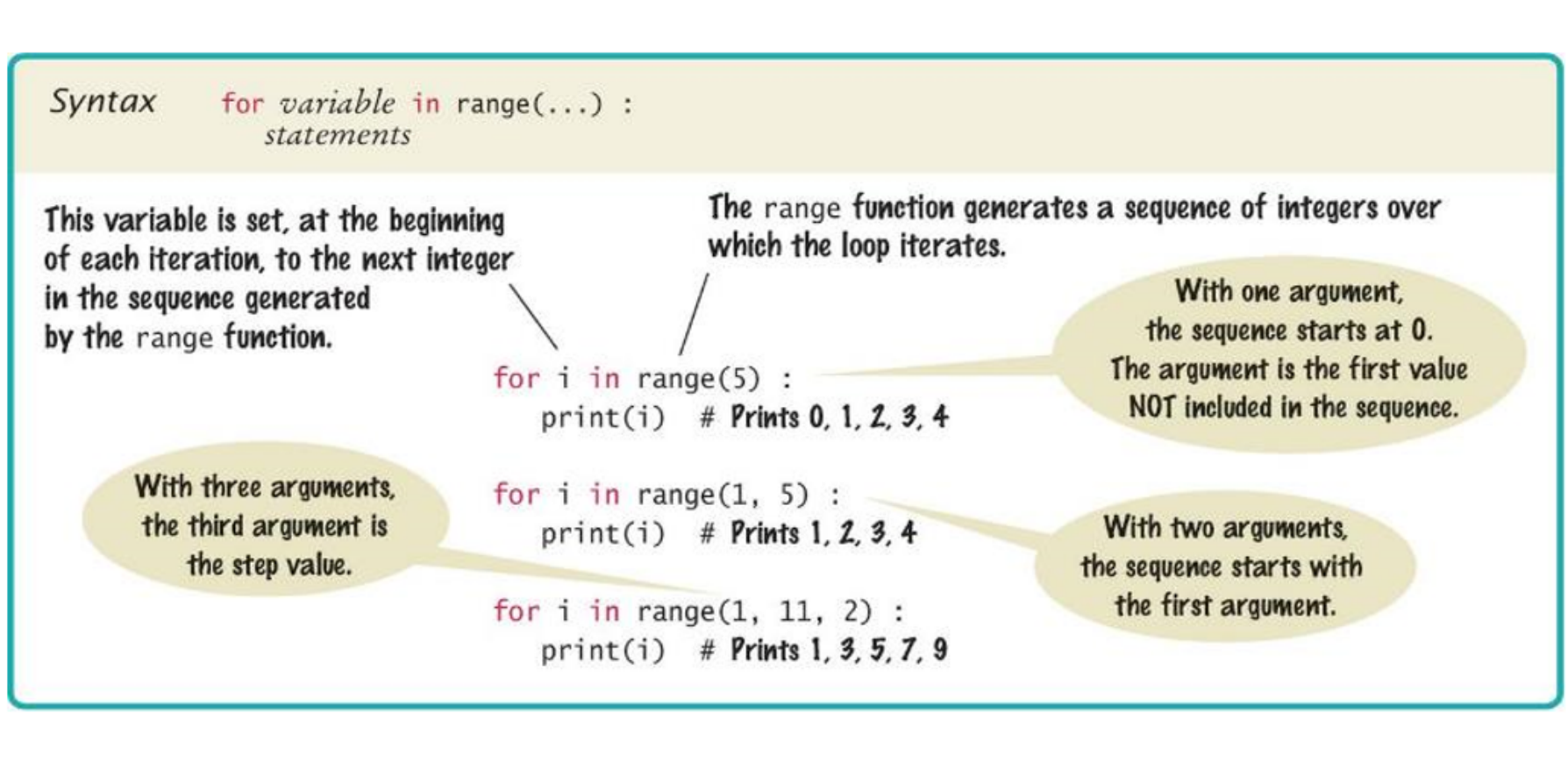
Student Activity

- Write an equivalent while loop for the previous example:

```
In [ ]: i = 1
        while i < 10:
            print(i)
            i = i + 1
```

The range Function

- You can use a for loop as a count-controlled loop to iterate over a range of integer values.
- We use the `range` function for generating a sequence of integers that are less than the argument that can be used with the for loop.



```
Syntax    for variable in range(...) :
              statements

for i in range(5) :
   print(i)   # Prints 0, 1, 2, 3, 4

for i in range(1, 5) :
   print(i)   # Prints 1, 2, 3, 4

for i in range(1, 11, 2) :
   print(i)   # Prints 1, 3, 5, 7, 9
```

The for Loop - Student Activity

- Use the **for** loop to print only the odd values between 1 and 10 using the **range** function.

```
In [ ]: for i in range(1,10,2):
            print(i)
```

Nested Loop

- When the body of a loop contains another loop, the loops are nested.
- A typical use of nested loops is printing a table with rows and colums.

- For example, we will print the powers of x as in the following table.

x^1	x^2	x^3	x^4
1	1	1	1
2	4	8	16
3	9	27	81
…	…	…	…
10	100	1000	10000

Nested Loop

- The pseudocode for printing the table is as follows:

```
Print table header.
For x from 1 to 10
    Print table row.
    Print new line.
```

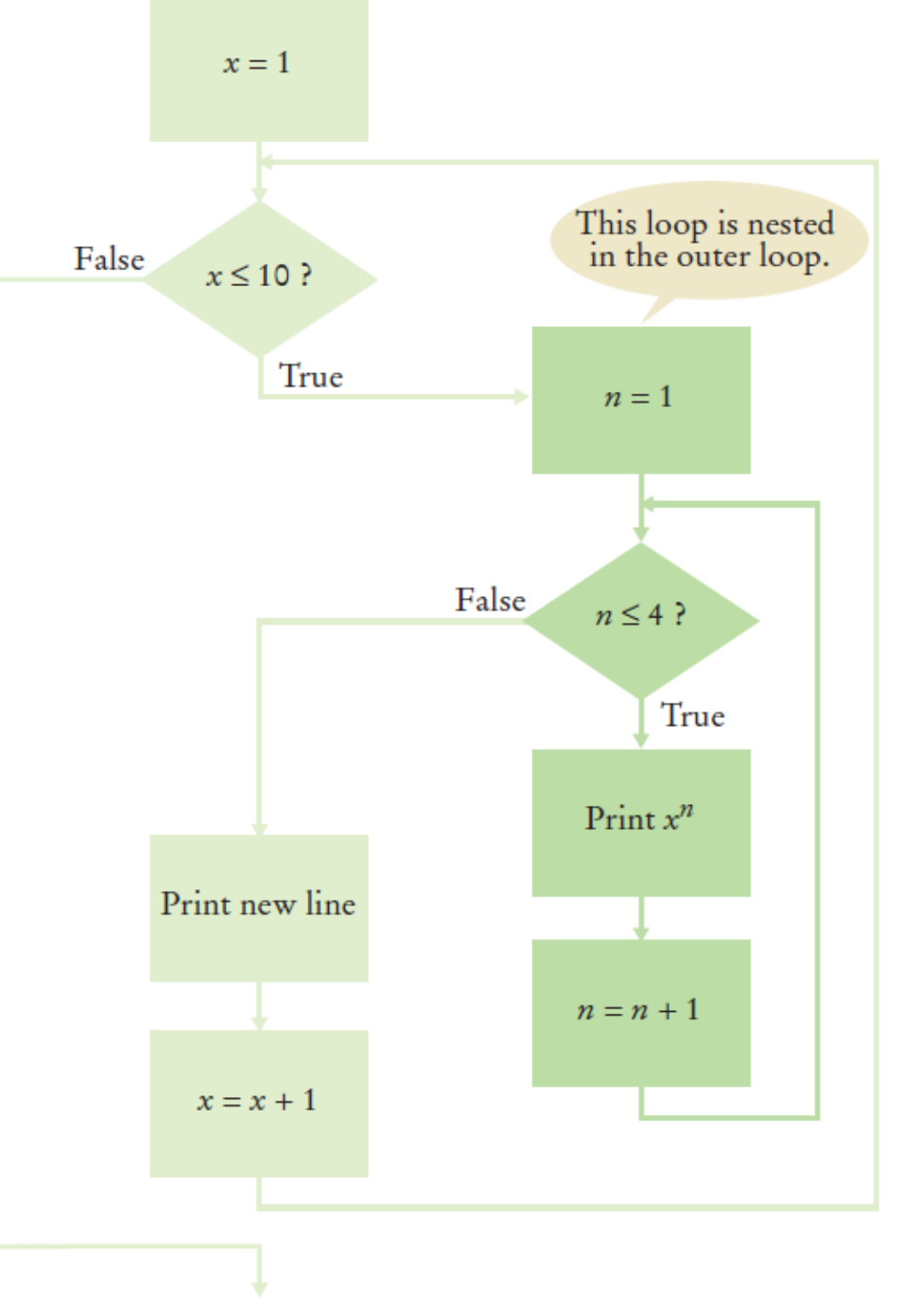
- How do you print a table row?

- You need to print a value for each component.
- This requires a second loop.

```
For n from 1 to 4
    Print x$^n$.
```

- This loop must be placed inside the preceding loop. We say that the inner loop is **nested** inside the outer loop.

Nested Loop



Side Note Regarding the `print` Function

- The `print` function displays an end of line by default.
- If we want to change this behavior, we can set the `end` parameter to another string.
  - The default value of the `end` parameter is \n.
- Consider the following example

```
In [ ]: course = "ICS 104"
        University = "KFUPM"
        print(course, end = "@")
        print(University)
```

Nested Loop

```
In [ ]: #  This program prints a table of powers of x.
        # Initialize constant variables for the max ranges.
        NMAX = 4
        XMAX = 10

        # Print table header.
        for n in range(1, NMAX + 1) :
            print("%10d" % n, end="")

        print()
        for n in range(1, NMAX + 1) :
            print("%10s" % "x ", end="")

        print("\n", "    ", "-" * 35)

        # Print table body.
        for x in range(1, XMAX + 1) :
           # Print the x row in the table.
            for n in range(1, NMAX + 1) :
                print("%10.0f" % x ** n, end="")
            print()
```

Processing Strings

- A common use of loops is to process or evaluate strings.
- For example, you may need to count the number of occurrences of one or more characters in a string or verify that the contents of a string meet certain criteria.

Counting Matches

- For example, suppose you need to count the number of uppercase letters contained in a string.

```
In [ ]: string = "This is a Test Message"
        uppercase = 0
        for char in string:
            if char.isupper():
                uppercase = uppercase + 1
        print("The number of uppercase letters are:",uppercase)
```

Finding All Matches

- For example, suppose you are asked to print the position of each uppercase letter in a sentence.

```
In [ ]: sentence = input("Enter a sentence: ")
        for i in range(len(sentence)):
            if sentence[i].isupper():
                print(i)
```

Finding the First or Last Match

- When you count the value that fulfills a condition, you need to look at all values.
- However, if your task is to find a match, then you can stop as soon as the condition is fulfilled.

```
In [ ]: string = "A1"
        found = False
        position = 0
        while not found and position < len(string):
            if string[position].isdigit():
                found = True
            else:
                position = position + 1
        if found:
            print("First digit occurs at position",position)
        else:
            print("The string does not contain a digit.")
```

Processing Strings - Student Activity

- What if we need to find the position of the last digit in the string?

```
In [ ]: string = "A1B2"
        found = False
        position = len(string) -1
        while not found and position >=0:
            if string[position].isdigit():
                found = True
            else:
                position = position -1
        if found:
            print("Last digit occurs at position",position)
        else:
            print("The string does not contain a digit.")
```

Processing Strings - Student Activity

- It is important to validate user input before it is used in computations.
- But data validation is not limited to verifying that user input is a specific value or falls within a valid range.
- It is also common to require user input to be entered in a specific format.
- For example, consider the task of verifying whether a string contains a correctly formatted telephone number.
  - In USA, telephone numbers consist of three parts, area code, exchange, and line number **(###)###-####**.
- Hint: We will need a loop that can exit early if an invalid character or an out of place symbol is encountered while processing the string:

In [ ]:

```
string = "(323)570-1234"
valid = len(string) == 13
position = 0
while valid and position < len(string):
    if position == 0:
        valid = string[position] == "("
    elif position == 4:
        valid = string[position] == ")"
    elif position == 8:
        valid = string[position] == "-"
    else:
        valid = string[position].isdigit()
    position = position + 1
if valid:
    print("The string contains a valid phone number.")
else:
    print("The string does not contain a valid phone number")
```

Processing Strings: Slices

- Sometimes, we are interested in looking at a part of a string.
- For example, assume that we would like to extract the area code from the telephone number.
  - For `phoneNumber = "(323)570-1234"`, we would like to extract `323`.

- This can be done through a `for` loop or a `while` loop.

- However, the code will have too many statements. Can you implement it?

In [ ]:

```
## Finding the area code without using the slice operator
```

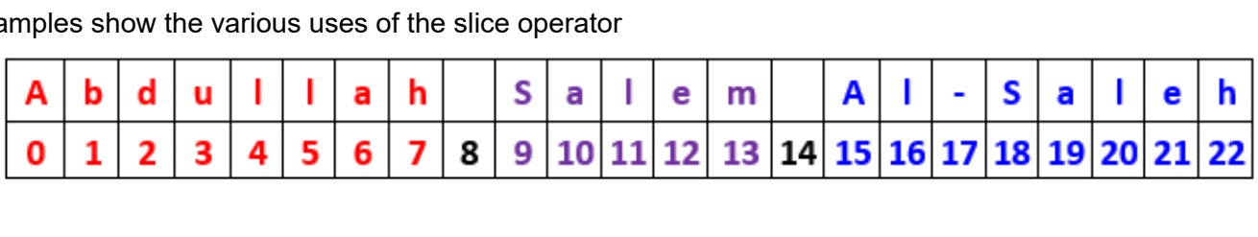
- This can be achieved using the `slice` operator, **[:]**. For example,

In [ ]:

```
## Finding the area code using the slice operator
phoneNumber = "(323)570-1234"
areaCode = phoneNumber[1:4]
print("The area code is "+ areaCode)
```

Examples

- The following examples show the various uses of the slice operator



A	b	d	u	l	l	a	h		S	a	l	e	m		A	l	-	S	a	l	e	h
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22

In [ ]:

```
Name = "Abdullah Salem Al-Saleh"
```

In [ ]:

```
print(Name[0:8])
```

In [ ]:

```
print(Name[:8])
```

In [ ]:

```
print(Name[9:])
```

In [ ]:

```
print(Name[7:22:3])
```

Application: Random Numbers and Simulations

- A simulation program uses the computer to simulate an activity in the real world.
- Simulations are commonly used for predicting climate change, analyzing traffic, picking stocks, and many other applications in science and business.
- In many simulations, one or more loops are used to modify the state of a system and observe the change.

Generating Random Numbers

- Many events in the real world are difficult to predict with absolute precision, yet we can sometimes know the average behavior quite well.
- For example, a store may know from experience that a customer arrives every five minutes.
  - Of course, that is an average—customers don't arrive in five minute intervals.
  - To accurately model customer traffic, you want to take that random fluctuation into account.
  - Now, how can you run such a simulation in the computer?

The `random` function

- The Python library has a random number generator that produces numbers that appear to be completely random.
- Calling random() yields a random floating-point number that is ≥ 0 and < 1.
- Call random() again, and you get a different number.
- The random function is defined in the random module.

In [ ]:

```
from random import random
for i in range(10):
    value = random()
    print(value)
```

The `randint` function

- For example, to simulate the throw of a die, you need random integers between 1 and 6.
- Hint: Python provides a separate function for generating a random integer within a given range:
  - `randint(a,b)` # generates an integer from $\{a, a+1, a+2, \ldots, b-1, b\}$ "randomly"

In [ ]:

```
#  This program simulates tosses of a pair of dice.
from random import randint

for i in range(10) :
    # Generate two random numbers between 1 and 6, inclusive.
    d1 = randint(1, 6)
    d2 = randint(1, 6)

    # Print the two values.
    print(d1, d2)
```

Summary

- while loops
- for loops
- while loops are very commonly used (general purpose)
- Uses of the for loop:
  - The for loop can be used to iterate over the contents of any container.
  - A for loop can also be used as a count-controlled loop that iterates over a range of integer values.

Summary

- Each loop requires the following steps:
  - Initialization (setup variables to start looping)
  - Condition (test if we should execute loop body)
  - Update (change something each time through)
- A loop executes instructions repeatedly while a condition is True.
- Avoid infinite loops.
- Loops are commonly used to process strings
- Loops are also used to generate pseudo-random numbers for simulation purposes.