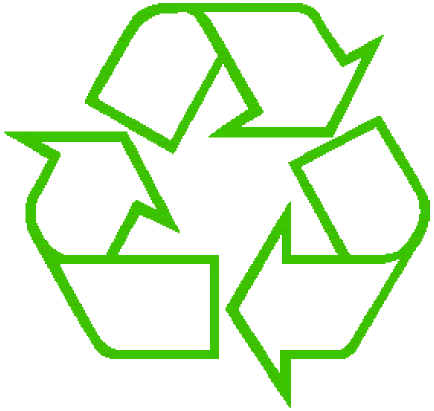

Control flow: Loops

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Temperature conversion chart

Recall exercise from previous lecture

See in python tutor

```
fahr = 30
cent = (fahr - 32) / 9.0 * 5
print(fahr, cent)
fahr = 40
cent = (fahr - 32) / 9.0 * 5
print(fahr, cent)
fahr = 50
cent = (fahr - 32) / 9.0 * 5
print(fahr, cent)
fahr = 60
cent = (fahr - 32) / 9.0 * 5
print(fahr, cent)
fahr = 70
cent = (fahr - 32) / 9.0 * 5
print(fahr, cent)
print("All done")
```

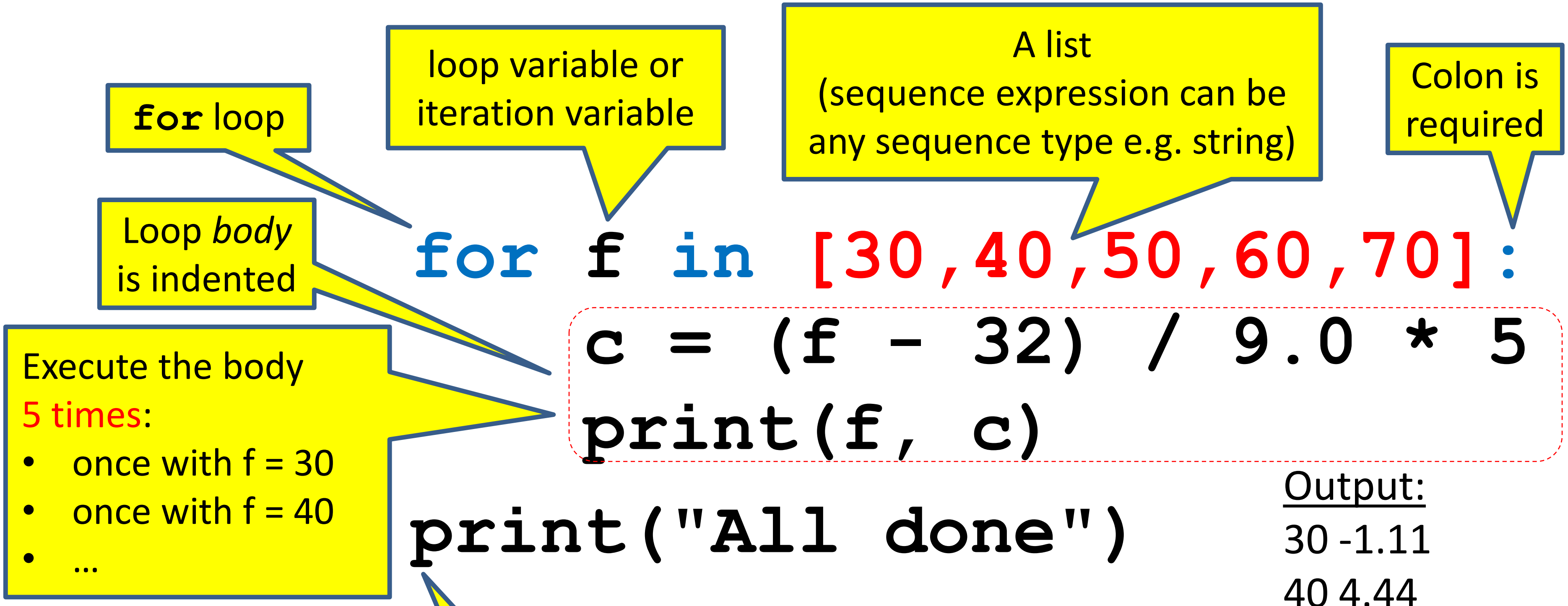
Output:

```
30 -1.11
40 4.44
50 10.0
60 15.56
70 21.11
All done
```

Temperature conversion chart

A better way to repeat yourself:

See in python tutor



```
for f in [30,40,50,60,70]:
    c = (f - 32) / 9.0 * 5
    print(f, c)
print("All done")
```

for loop

loop variable or iteration variable

A list
(sequence expression can be any sequence type e.g. string)

Colon is required

Loop *body* is indented

Execute the body 5 times:

- once with f = 30
- once with f = 40
- …

Indentation is significant

Note: f and c are not good variable names!

Output:

```
30 -1.11
40 4.44
50 10.0
60 15.56
70 21.11
All done
```

Loop Examples

See in python tutor

```
for num in [2, 4, 6]:
    print(num)
```

Prints the values of sequence

```
for i in [1, 2, 3]:
    print("Hi there!")
```

Does not use values of sequence

sequence is a string

```
for char in "happy":
    print(char)
```

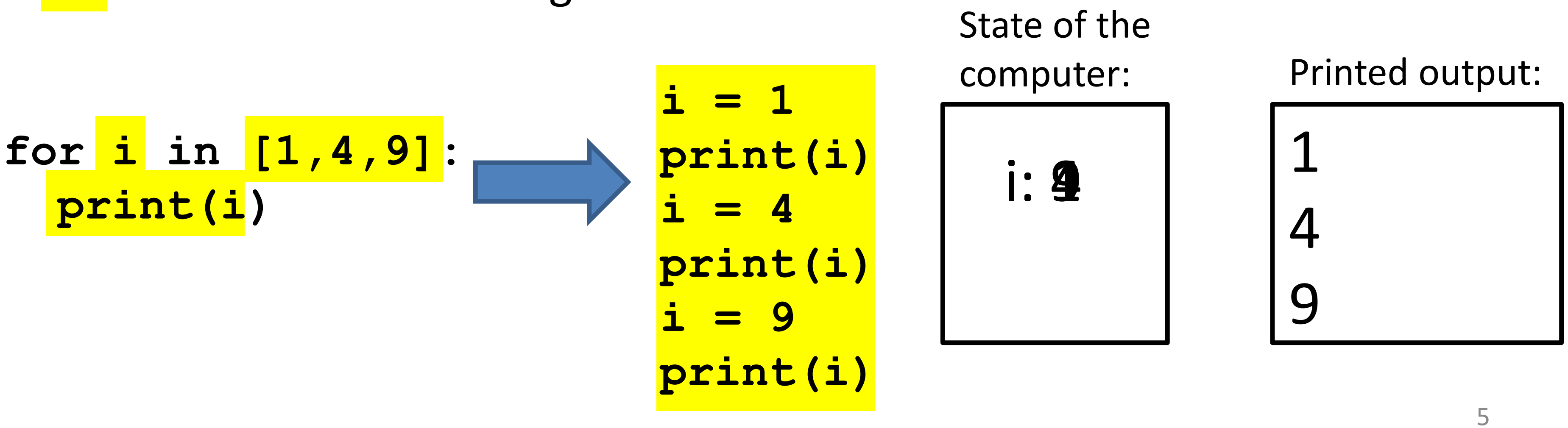
Prints the values of sequence

How a loop is executed: Transformation approach

Idea: convert a **`for`** loop into something we know how to execute

1. Evaluate the sequence expression
2. Write an assignment to the loop variable, for each sequence element
3. Write a copy of the loop after each assignment
4. Execute the resulting statements

See in python tutor



```
for i in [1,4,9]:
  print(i)
```

```
i = 1
print(i)
i = 4
print(i)
i = 9
print(i)
```

State of the computer:

i: 1 4 9

Printed output:

```
1
4
9
```

How a loop is executed: Direct approach

1. Evaluate the sequence expression
2. While there are sequence elements left:
   a) Assign the loop variable to the next remaining sequence element
   b) Execute the loop body

Current location in list

```
for i in [1,4,9]:
  print(i)
```

State of the computer:

i: 9

Printed output:

```
1
4
9
```

The body can be multiple statements

See in python tutor

Execute whole body, then execute whole body again, etc.

```
for i in [3, 4, 5]:
  print("Start body")
  print(i)
  print(i * i)
```

loop body:
3 statements

Convention: often use i or j as loop variable if values are integers

This is an exception to the rule that
variable names should be descriptive

The body can be multiple statements

Execute whole body, then execute whole body again, etc.

```
for i in [3, 4, 5]:
  print("Start body")
  print(i)
  print(i * i)
```

loop body:
3 statements

```
Output:       NOT:
Start body    Start body
3             Start body
9             Start body
Start body    3
4             4
16            5
Start body    9
5             16
25            25
```

Convention: often use i or j as loop variable if values are integers

This is an exception to the rule that
variable names should be descriptive

Indentation is significant

See in python tutor

- Every statement in the body must have exactly the same indentation
- That’s how Python knows where the body ends

```
for i in [3, 4, 5]:
    print("Start body")
     print(i)
    print(i*i)
```

Error!

- Compare the results of these loops:

```
for f in [30, 40, 50, 60, 70]:
    print(f, (f - 32) / 9.0 * 5)
print("All done")

for f in [30, 40, 50, 60, 70]:
    print(f, (f - 32) / 9.0 * 5)
    print("All done")
```

The range function

A typical for loop does not use an explicit list:

```
for i in range(5):
   … body …
```

Produces a range object

Upper limit (*exclusive*)

`range(5)` → will loop through [0, 1, 2, 3, 4]

Lower limit (*inclusive*)

`range(1,5)` → will loop through [1, 2, 3, 4]

step (distance between elements)

`range(1,10,2)` → will loop through [1, 3, 5, 7, 9]

Some Loops

See in python tutor

```
# Sum of a list of values, what values?
result = 0
for element in range(5):
  result = result + element
print("The sum is: " + str(result))

# Sum of a list of values, what values?
result = 0
for element in range(5, 1, -1):
  result = result + element
print("The sum is:", result)

# Sum of a list of values, what values?
result = 0
for element in range(0, 8, 2):
  result = result + element
print("The sum is:", result)

# Sum of a list of values, what values?
result = 0
size = 5
for element in range(size):
  result = result + element
print("When size = " + str(size) + " result is " + str(result))
```

How to process a list:
One element at a time

- A common pattern when processing a list:

```
result = initial_value
for element in list:
    result = updated result
use result
```

```
# Sum of a list
result = 0
for element in mylist:
  result = result + element
print(result)
```

- ***initial_value*** is a correct result for an empty list
- As each element is processed, **`result`** is a correct result for a prefix of the list
- When all elements have been processed, **`result`** is a correct result for the whole list

See in python tutor

Examples of list processing

```
result = initial_value
for element in list:
  result = updated result
```

- Product of a list:

```
result = 1
for element in mylist:
  result = result * element
```

- Maximum of a list:

```
curr_max = mylist[0]
for element in mylist:
 curr_max = max(curr_max, element)
```

The first element of the list (counting from zero)

- Approximate the value 3 by 1 + 2/3 + 4/9 + 8/27 + 16/81 + … = $(2/3)^0 + (2/3)^1 + (2/3)^2 + (2/3)^3 + \ldots + (2/3)^{10}$

```
result = 0
for element in range(11):
  result = result + (2.0/3.0)**element
```

See in python tutor

Nested Loops

```
for i in [1, 2, 3]:
  print("Before j loop i is", i)
  for j in [50, 100]:
    print("j is", j)
```

What is the output?

More Nested Loops

See in python tutor

How many statements does this loop contain?

```
for i in [0, 1]:
  print("Outer", i)
  for j in [2, 3]:
    print(" Inner", j)
    print("  Sum", i + j)
  print("Outer", i)
```

What is the output?

More Nested Loops

See in python tutor

How many statements does this loop contain?

```
for i in [0, 1]:
    print("Outer", i)
    for j in [2, 3]:
        print(" Inner", j)
        print("  Sum", i + j)
    print("Outer", i)
```

"nested" loop body: 2 statements

loop body: 3 statements

Output:

```
Outer 0
 Inner 2
  Sum 2
 Inner 3
  Sum 3
Outer 0
Outer 1
 Inner 2
  Sum 3
 Inner 3
  Sum 4
Outer 1
```

What is the output?

Understand loops through the transformation approach

See in python tutor

Key idea:

1. Assign each sequence element to the loop variable
2. Duplicate the body

```
for i in [0, 1]:
  print("Outer", i)
  for j in [2, 3]:
    print(" Inner", j)
```

```
i = 0
print("Outer", i)
for j in [2, 3]:
  print(" Inner", j)
i = 1
print("Outer", i)
for j in [2, 3]:
  print(" Inner", j)
```

```
i = 0
print("Outer", i)
j = 2
print(" Inner", j)
j = 3
print(" Inner", j)
i = 1
print("Outer", i)
for j in [2, 3]:
  print(" Inner", j)
```

See in python tutor

Test your understanding of loops

Output:

Puzzle 1:

```
for i in [0, 1]:
  print(i)
print(i)
```

Puzzle 2:

```
i = 5
for i in []:
  print(i)
```

Puzzle 3:

```
for i in [0, 1]:
  print("Outer", i)
  for i in [2, 3]:
    print(" Inner", i)
  print("Outer", i)
```

inner loop body

outer loop body

See in python tutor

Test your understanding of loops

Output:

Puzzle 1:

```
for i in [0, 1]:
  print(i)
print(i)
```

```
0
1
1
```

Puzzle 2:

```
i = 5
for i in []:
  print(i)
```

(no output)

Puzzle 3:

```
for i in [0, 1]:
  print("Outer", i)
  for i in [2, 3]:
    print(" Inner", i)
  print("Outer", i)
```

Reusing loop variable (don't do this!)

inner loop body

outer loop body

```
Outer 0
  Inner 2
  Inner 3
Outer 3
Outer 1
  Inner 2
  Inner 3
Outer 3
```

Fix this loop

See in python tutor

```
# Goal:  print 1, 2, 3, …, 48, 49, 50
for tens_digit in [0, 1, 2, 3, 4]:
  for ones_digit in [1, 2, 3, 4, 5, 6, 7, 8, 9]:
    print(tens_digit * 10 + ones_digit)
```

What does it actually print?

How can we change it to correct its output?

Moral: Watch out for *edge conditions* (beginning or end of loop)

Some Fixes

See in python tutor

```
for tens_digit in [0, 1, 2, 3, 4]:
  for ones_digit in [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]:
    print(tens_digit * 10 + ones_digit + 1)

for tens_digit in [0, 1, 2, 3, 4]:
  for ones_digit in [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]:
    print(tens_digit * 10 + ones_digit)

for ones_digit in [1, 2, 3, 4, 5, 6, 7, 8, 9]:
    print(ones_digit)
for tens_digit in [1, 2, 3, 4]:
  for ones_digit in [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]:
    print(tens_digit * 10 + ones_digit)
print(50)
```

Some More Loops

See in python tutor

```
for size in [1, 2, 3, 4]:
  print("size is " + str(size))
  for element in range(size):
    print("element is " + str(element))
```

Even More Loops

See in python tutor

```
for size in [1, 2, 3, 4]:
  result = 0
  for element in range(size):
    result = result + element
  print("size=" + str(size) + " result=" + str(result))
print(" We are done!")
```

What happens if we move `result = 0`
to be the first line of the program instead?

Loops over Strings

See in python tutor

```
for letter in "hello":
  print(letter)

my_string = "CSE 160"
for letter in my_string:
  print(letter)

count = 0
for letter in my_string:
  count = count + 1
print(count)
```