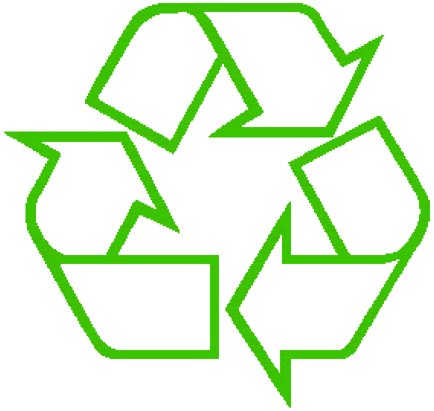

Control flow

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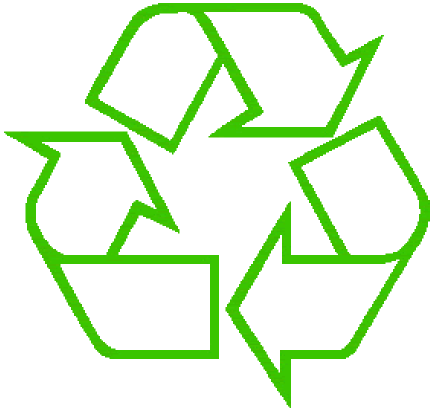


Repeating yourself

Making decisions

Temperature conversion chart

Recall exercise from previous lecture

```
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:

for loop

loop variable or iteration variable

A list

Colon is required

Loop *body* is indented

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

Execute the body 5 times:

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

Indentation is significant

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

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

```
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: 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

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

- 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 body can be multiple statements

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

What is the output?

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

Understand loops through the transformation approach

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
```

Fix this loop

```
# 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

```
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
```

Test your understanding of loops

Puzzle 1:

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

Output:

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

The range function

A typical for loop does not use an explicit list:

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

The list [0,1,2,3,4]

Upper limit (*exclusive*)

`range(5)` = [0,1,2,3,4]

Lower limit (*inclusive*)

`range(1,5)` = [1,2,3,4]

step (distance between elements)

`range(1,10,2)` = [1,3,5,7,9]

Some Loops

```
# 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)
```

Some More Loops

```
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?

Decomposing a list computation

- To compute a value for a list:
  - Compute a partial result for all but the last element
  - Combine the partial result with the last element

Example: sum of a list:

[3, 1, 4, 1, 5, 9, 2, 6, 5]

List z

List y

List c

List b

List a

sum(List a) = sum(List b) + 5
sum(List b) = sum(List c) + 6
…
sum(List y) = sum(List z) + 3
sum(empty list) = 0

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

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:

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

Making decisions

- How do we compute absolute value?

abs(5) = 5

abs(0) = 0

abs(-22) = 22

Absolute value solution

If *the value is negative*, negate it.

Otherwise, use the original value.

```
val = -10

# calculate absolute value of val
if val < 0:
    result = - val
else:
    result = val

print result
```

Another approach
that does the same thing
without using **`result`**:

```
val = -10

if val < 0:
    print - val
else:
    print val
```

In this example, **`result`** will always be assigned a value.

Absolute value solution

As with loops, a sequence of statements could be used in place of a single statement:

```
val = -10

# calculate absolute value of val
if val < 0:
    result = - val
    print "val is negative!"
    print "I had to do extra work!"
else:
    result = val
    print "val is positive"
print result
```

Absolute value solution

What happens here?

```
val = 5

# calculate absolute value of val
if val < 0:
    result = - val
    print "val is negative!"
else:
    for i in range(val):
        print "val is positive!"
    result = val
print result
```

Another if

It is **not required that anything happens**...

```
val = -10

if val < 0:
     print "negative value!"
```

What happens when val = 5?

The if body can be any statements

then clause

```
# height is in km
if height > 100:
  print "space"
else:
  if height > 50:
    print "mesosphere"
  else:
    if height > 20:
      print "stratosphere"
    else:
      print "troposphere"
```

else clause

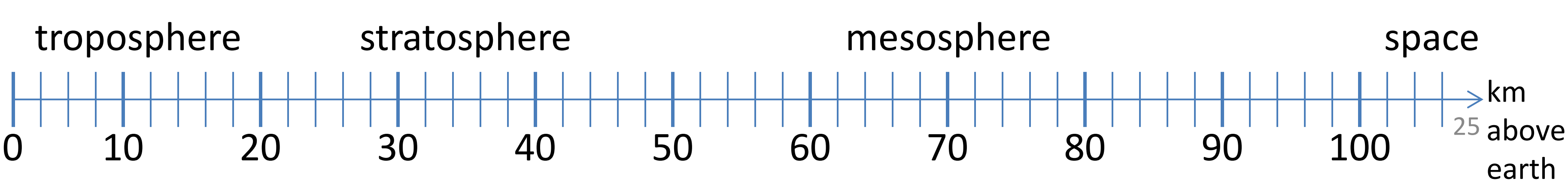
t

e

Execution gets here only if “height > 100” is false

Execution gets here only if “height > 100” is false AND “height > 50” is true

```
# height is in km
if height > 100:
  print "space"
elif height > 50:
  print "mesosphere"
elif height > 20:
  print "stratosphere"
else:
  print "troposphere"
```



Version 1

```
# height is in km
if height > 100:
  print "space"
else:
  if height > 50:
    print "mesosphere"
  else:
    if height > 20:
      print "stratosphere"
    else:
      print "troposphere"
```

then clause

else clause

t

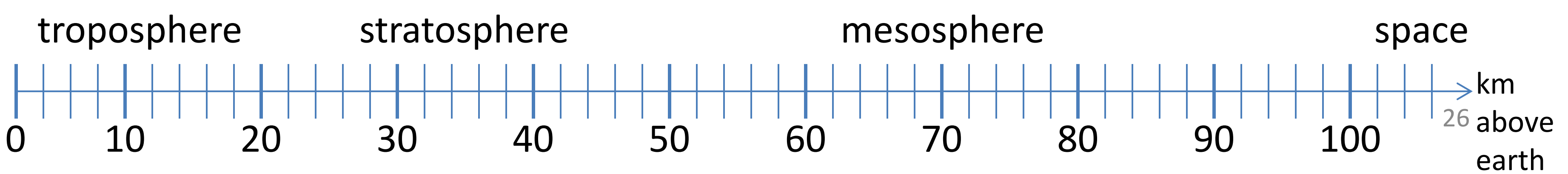
e

t

e

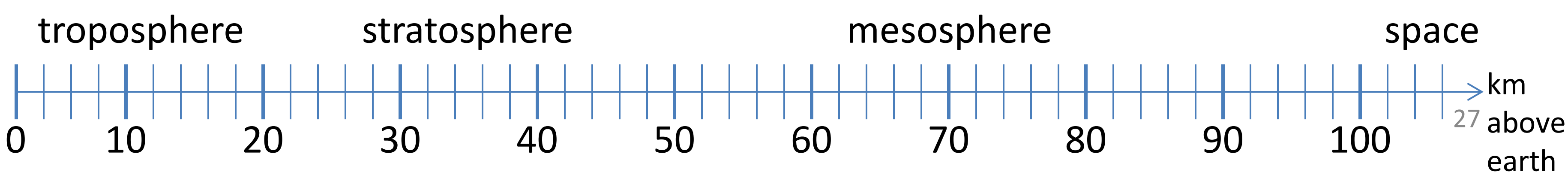
Execution gets here only if “height <= 100” is true

Execution gets here only if “height <= 100” is true AND “height > 50” is true



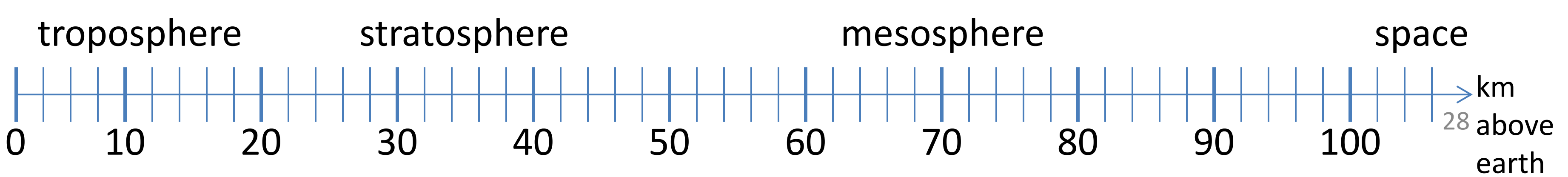
Version 1

```
# height is in km
if height > 100:
  print "space"
else:
  if height > 50:
    print "mesosphere"
  else:
    if height > 20:
      print "stratosphere"
    else:
      print "troposphere"
```



Version 2

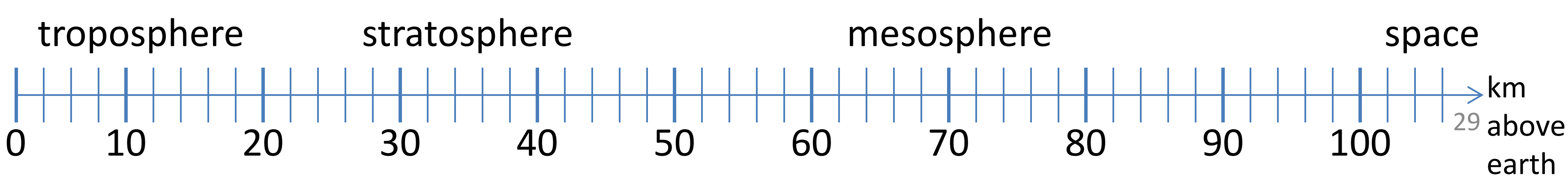
```
if height > 50:
  if height > 100:
    print "space"
  else:
    print "mesosphere"
else:
  if height > 20:
    print "stratosphere"
  else:
    print "troposphere"
```



Version 3

```
if height > 100:
  print "space"
elif height > 50:
  print "mesosphere"
elif height > 20:
  print "stratosphere"
else:
  print "troposphere"
```

ONE of the print statements is guaranteed to execute: whichever condition it encounters **first** that is true

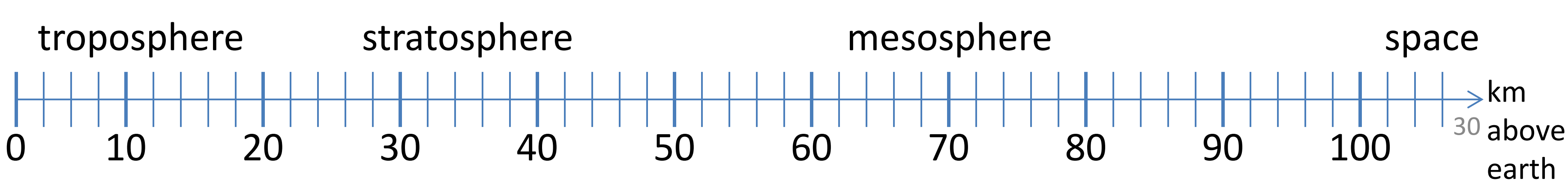


Order Matters

```
# version 3
if height > 100:
  print "space"
elif height > 50:
  print "mesosphere"
elif height > 20:
  print "stratosphere"
else:
  print "troposphere"
```

```
# broken version 3
if height > 20:
  print "stratosphere"
elif height > 50:
  print "mesosphere"
elif height > 100:
  print "space"
else:
  print "troposphere"
```

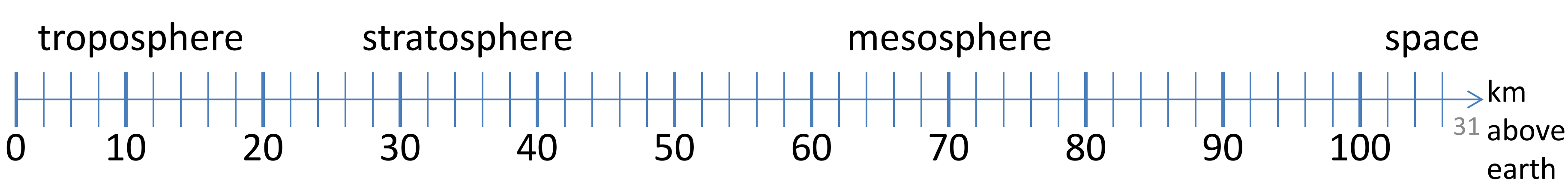
Try height = 72 on both versions, what happens?



Version 3

```
# incomplete version 3
if height > 100:
  print "space"
elif height > 50:
  print "mesosphere"
elif height > 20:
  print "stratosphere"
```

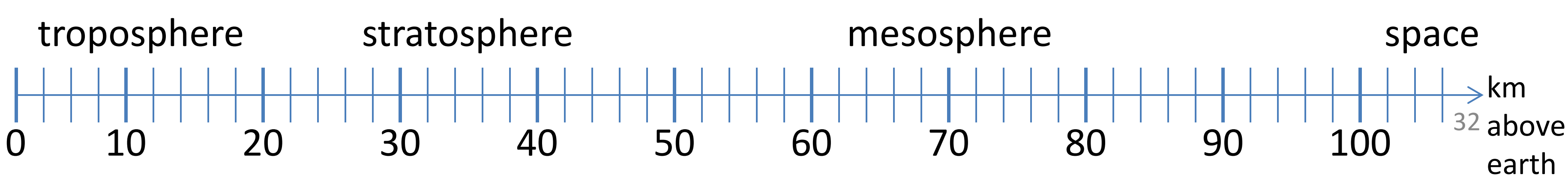
In this case it is possible that nothing is printed at all, when?



What Happens here?

```
# height is in km
if height > 100:
  print "space"
if height > 50:
  print "mesosphere"
if height > 20:
  print "stratosphere"
else:
  print "troposphere"
```

Try height = 72



The then clause *or* the else clause is executed

```
speed = 54
limit = 55
if speed <= limit:
    print "Good job!"
else:
    print "You owe $", speed/fine
```

What if we change speed to 64?