# 3. Conditional Execution

Topics:

- Boolean values
- Relational operators
- `if` statements
- The Boolean type

## Motivation

Problem:

Assign positive float values to variables `a` and `b` and print the values `a**b` and `b**a`.

Solution:

```
a = input('Enter a pos float: ')
b = input('Enter a pos float: ')
print a**b, b**a
```

## Motivation

Problem:

Assign positive float values to variables `a` and `b` and print the values `a**b` and `b**a`.

Solution:

?

`7**2 < 2**7` `2**3 < 3**2`

## Solution Using If-Else

```
a  = input('Enter a pos float: ')
b  = input('Enter a pos float: ')
aTob = a**b
bToa = b**a
if aTob > bToa:
   print aTob
else:
   print bToa
```

This is what is called "conditional execution."

## If-Else: How Does it Work?

```
aTob = a**b
bToa = b**a
if aTob > bToa:
   print aTob
else:
   print bToa
```

`aTob` → 128

`bToa` → 49

Let's suppose the value of `a` is 2 and the value of `b` is 7.

## Solution Using If-Else

```
aTob = a**b
bToa = b**a
if aTob > bToa:
   print aTob
else:
   print bToa
```

`aTob` → 128

`bToa` → 49

The comparison

`aTob > bToa`

is called a boolean expression. It is either True or False

Is the value of `aTob` larger than the value of `bToa`?

## Solution Using If-Else

```
aTob = a**b
bToa = b**a
if aTob > bToa:
   print aTob
else:
   print bToa
```

aTob ⟶ 128

bToa ⟶ 49

The boolean expression `aTob > bToa` is `True` so execute `print aTob`

Is the value of `aTob` larger than the value of `bToa`? Yes!

## If-Else: How Does it Work?

```
aTob = a**b
bToa = b**a
if aTob > bToa:
   print aTob
else:
   print bToa
```

aTob ⟶ 49

bToa ⟶ 128

Now let's suppose the value of `a` is 7 and the value of `b` is 2.

## If-Else: How Does it Work?

```
aTob = a**b
bToa = b**a
if aTob > bToa:
   print aTob
else:
   print bToa
```

aTob ⟶ 49

bToa ⟶ 128

Is the value of `aTob` larger than the value of `bToa`?

## If-Else: How Does it Work?

```
aTob = a**b
bToa = b**a
if aTob > bToa:
   print aTob
else:
   print bToa
```

aTob ⟶ 49

bToa ⟶ 128

The boolean expression `aTob > bToa` is `False` so execute `print bToa`

Is the value of `aTob` larger than the value of `bToa`? No!

## If-Else: How Does it Work?

```
aTob = a**b
bToa = b**a
if aTob > bToa:
   print aTob
else:
   print bToa
```

Note the punctuation and the indentation.

This is essential syntax.

Forgetting the colons is a major boo boo!

## "Synonym"

```
aTob = a**b
bToa = b**a
if aTob > bToa:
   print aTob
else:
   print bToa
```

```
if a**b > b**a:
   print a**b
else:
   print b**a
```

In a comparison, legal to have general expressions on either side of the "<".

## The `if-else` Construction

```
if Boolean expression :
    Statements to execute if the
      expression if True
else:
    Statements to execute if the
      expression if False
```

This is an example of conditional execution.
The if-else construction is sometimes called "alternative execution"

## The `if-else` Construction

```
if a**b > b**a :
    z = b**a
else:
    z = a**b

print 'The smaller value is:', z
```

The blue box decides whether the green box or the pink box is executed.

After that choice is processed, this print statement is carried out.

## Reminder that Indentation Is Important

```
if x%2==0:
   y = x/2
   print y
else:
   y = (x+1)/2
   print y
```

```
if x%2==0:
   y = x/2
   print y
else:
   y = (x+1)/2
print y
```

If x is even, then the code on the left will print the value of x/2 while the code on the right will print the value of x/2 twice (on separate lines).

## Another Example

Problem:

The last character in a string 5-character string is 'y'. Change the 'y' to 'i' and add 'es'

Solution:

```
s = s[0:4] + 'ies'
```

Want: 'carry' to become 'carries'
Use string slicing and concatenation: 'carr' + 'ies'

## A Modified Problem

If the last character in a 5-character string `s` is 'y', then

1. change the 'y' to 'i'
2. add 'es'
3. assign the result to a variable `plural`.

Otherwise, just add 's' and assign the result to a variable `plural`.

This will require the if-else construction.

## Solution

```
if s[4]=='y':
   plural = s[0:4] + 'ies'
else:
   plural = s + 's'
print s,plural
```

Remember: s[0:4] names the substring comprised of the first 4 characters.

## Discussion of Solution

```
if s[4]=='y':
   plural = s[0:4] + 'ies'
else:
   plural = s + 's'
print s,plural
```

A new comparison is being used.

If you want to check to see if two expressions have the same value, use `==`.

Why? If you say `s[4]='y'` it looks like an assignment.

## Discussion of Solution

```
if s[4]=='y':
   plural = s[0:4] + 'ies'
else:
   plural = s + 's'
print s,plural
```

The print statement is executed after the if-else is processed. E.g.

```
carry  carries
```

## Relational Operators

| | |
|---|---|
| < | Less than |
| > | Greater than |
| <= | Less than or equal to |
| >= | Greater than or equal to |
| == | Equal to |
| != | Not equal to |

## Relational Operators in Action

x ---> 3  y ---> 6

```
  x < y      True
2*x > y      False
  x <= y     True
  x >= y     False
  x == y/2   True
  x != y/2.  False
```

If the expression on the left is a different numerical type then the expression on the right, everything is converted to float.

## Boolean Operations with Strings

Comparing for equality…

```
>>> s = 'abc'
>>> s =='abc'
True
>>> s == 'abc '
False
```

Two strings are equal if they have the same length and agree in each position.

## Boolean Operations with Strings

Comparing for alphabetical order…

```
>>> s = 'Dog'
>>> s >'Horse'
False
>>> s < 'Horse'
True
>>> s < 'dog'
True
```

Alphabetical order. If `s < t` is true then `s` comes before `t` in the "extended dictionary" based on this ordering of characters:
' 0123456789ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz'

## Relational Operators in Action

x ---> 'key'  y ---> 'hockey'

```
      x < y       False
      x > y       True
'hoc'+x <= y      True
      x >= y      True
      x == y[3:]  True
      x != x+'a'  True
```

Comparisons based on alphabetical order.
x<y is false because 'key' does not come before 'hockey' in the dictionary.

## Another Problem

Assume that s1 and s2 are initialized strings.

Write code that prints them in alphabetical order on separate lines.

## Solution

```
if s1<s2:
    print s1
    print s2
else:
    print s2
    print s1
```

s1 ---> 'cat'

s2 ---> 'dog'

s1 < s2

Is this True or False?

## Solution

```
if s1<s2:
    print s1
    print s2
else:
    print s2
    print s1
```

s1 ---> 'cat'

s2 ---> 'dog'

It's true!
Output:

```
cat
dog
```

## Solution

```
if s1<s2:
    print s1
    print s2
else:
    print s2
    print s1
```

s1 ---> 'dog'

s2 ---> 'cat'

s1 < s2

Is this True or False?

## Solution

```
if s1<s2:
    print s1
    print s2
else:
    print s2
    print s1
```

s1 ---> 'dog'

s2 ---> 'cat'

It's false!
Output:

```
cat
dog
```

## Indentation Is Important

```
if s1<s2:
    print s1
    print s2
else:
    print s2
print s1
```

s1 ---> 'cat'

s2 ---> 'dog'

Output:

```
cat
dog
cat
```

## What if You Have More than Two Alternatives?

For example, given a numerical test score between 0 and 100, print out the letter grade equivalent according to these rules:

| | |
|---|---|
| A | 90-100 |
| B | 80-89 |
| C | 70-79 |
| U | <70 |

## The If-Elif-Else Construction

```
x = input('Score: ')
if x>=90:
    grade = 'A'
elif x>=80:
    grade = 'B'
elif x>=70:
    grade = 'C'
else:
    grade = 'U'
print grade
```

Read "elif" as "else if"

## The If-Elif-Else Construction

```
x = input('Score: ')
if x>=90:
    grade = 'A'
elif x>=80:
    grade = 'B'
elif x>=70:
    grade = 'C'
else:
    grade = 'U'
print grade
```

Note the punctuation and the indentation.

Read "elif" as "else if"

## If-Elif-Else: How it Works

```
x = input('Score: ')
if x>=90:
    grade = 'A'
elif x>=80:
    grade = 'B'
elif x>=70:
    grade = 'C'
else:
    grade = 'U'
print grade
```

x ---> 75

1. Is this true?
2. No.
3. Proceed to the next comparison.

## If-Elif-Else: How it Works

```
x = input('Score: ')
if x>=90:
    grade = 'A'
elif x>=80:
    grade = 'B'
elif x>=70:
    grade = 'C'
else:
    grade = 'U'
print grade
```

x ---> 75

1. Is this true?
2. No.
3. Proceed to the next comparison.

## If-Elif-Else: How it Works

```
x = input('Score: ')
if x>=90:
    grade = 'A'
elif x>=80:
    grade = 'B'
elif x>=70:
    grade = 'C'
else:
    grade = 'U'
print grade
```

x ---> 75

1. Is this true?
2. Yes.
3. Execute the statement(s) it guards and proceed to whatever follows the if-elif-else

The indentation scheme "tells" Python what comes after the if-elif-else

## If-Elif-Else: How it Works

```
x = input('Score: ')
if x>=90:
    grade = 'A'
elif x>=80:
    grade = 'B'
elif x>=70:
    grade = 'C'
else:
    grade = 'U'
print grade
```

x ---> 95

1. Is this true?
2. Yes.
3. Execute the statement(s) it guards and proceed to whatever follows the If-elif-else

## If-Elif-Else: How it Works

```
x = input('Score: ')
if x>=90:
    grade = 'A'
elif x>=80:
    grade = 'B'
elif x>=70:
    grade = 'C'
else:
    grade = 'U'
print grade
```

x ---> 65

1. Is this true?
2. No.
3. Proceed to the next comparison.

## If-Elif-Else: How it Works

```
x = input('Score: ')
if x>=90:
    grade = 'A'
elif x>=80:
    grade = 'B'
elif x>=70:
    grade = 'C'
else:
    grade = 'U'
print grade
```

x ---> 65

1. Is this true?
2. No.
3. Proceed to the next comparison.

## If-Elif-Else: How it Works

```
x = input('Score: ')
if x>=90:
    grade = 'A'
elif x>=80:
    grade = 'B'
elif x>=70:
    grade = 'C'
else:
    grade = 'U'
print grade
```

x ---> 65

1. Is this true?
2. No.
3. Execute "the else"
4. Proceed to what follows the if-elif-else.

## Equivalent Scripts

```
x = input('Score: ')
if x>=90:
    grade = 'A'
elif x>=80:
    grade = 'B'
elif x>=70:
    grade = 'C'
else:
    grade = 'U'
print grade
```

```
x = input('Score: ')
if x>=90:
    print 'A'
elif x>=80:
    print 'B'
elif x>=70:
    print 'C'
else:
    print 'U'
```

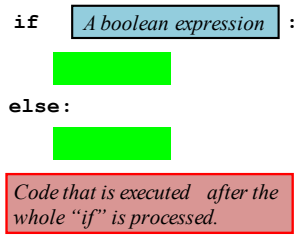
The one on the left is better. The letter grade is an essential feature of the computation and having a variable that houses it is a reminder of that fact.

## Legal Not to Have the "Else"

```
grade = 'B'
nApples = input('#Apples sent to Prof:')
if nApples<10:
   grade = grade + '-'
print grade
```

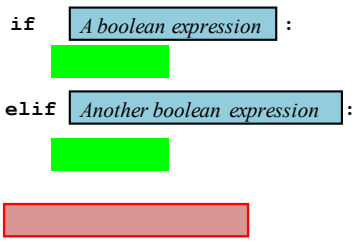
Let's review all the "if" variations…

## Standard `if-else`



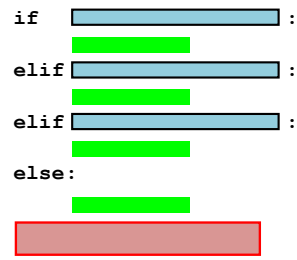

Exactly one of the green boxes is executed

## `if-elif`




If both boolean expressions are false, no green box is executed.
Otherwise, the "first" green box that is "guarded" by a true boolean expression is executed.

## Multiple `if-elif` With Else




The first green box guarded by a true boolean expression is executed.
If they are all false, then the else's green box is executed.

## Multiple `if-elif` With No Else


Note that if all the boolean expressions are False, then no green code is executed.
Otherwise the first green box guarded by a true boolean expression is executed.

## Boolean Operations

| Rainy | Sunny | Rainbow |
|---|---|---|
| True | True | True |
| True | False | False |
| False | True | False |
| False | False | False |

It is possible to combine two boolean values get a new boolean value.

## Boolean Operations

| Sleepy | Tired | Crabby |
|---|---|---|
| True | True | True |
| True | False | True |
| False | True | True |
| False | False | False |

It is possible to combine two boolean values get a new boolean value.

## The and Operation

x ---> 3  y ---> 6  z ---> 9

```
(x < y) and (x < z)     True
(x > y) and (x < z)     False
(x < y) and (x > z)     False
(x > y) and (x > z)     False
```

## The and Operation


| | | |
|---|---|---|
| True | True | True |
| True | False | False |
| False | True | False |
| False | False | False |

Here  and  are Boolean-valued expressions

## Example 1

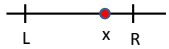
Fact: A length-4 string is a palindrome if the first and last characters are the same and the middle two characters are the same.

```
s = input('length-4 string: ')

if (s[0]==s[3]) and (s[1]==s[2]):
   print 'palindrome'
else:
   print 'not a palindrome'
```

## Example 2

Fact: x is inside the interval [L,R] if it is no smaller than L and no bigger than R.

```
x = input('x: ')
L = input('L: ')
R = input('R: ')

if (L<=x) and (x<=R):
   print 'Inside'
else:
   print 'Outside'
```

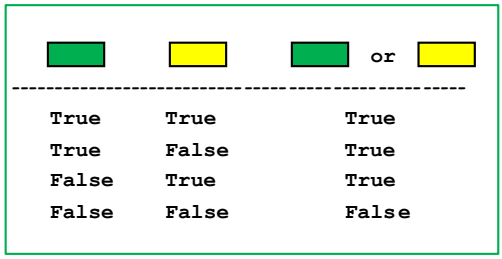



## Equivalent Solutions

```
x = input('x: ')
L = input('L: ')
R = input('R: ')

if (L<=x) and (x<=R):
   print 'Inside'
else:
   print 'Outside'
```

```
x = input('x: ')
L = input('L: ')
R = input('R: ')

if L<=x<=R :
   print 'Inside'
else:
   print 'Outside'
```

## The or Operation



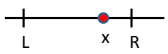
| | | | or | |
|---|---|---|---|---|
| True | | True | | True |
| True | | False | | True |
| False | | True | | True |
| False | | False | | False |

Here ▭ and ▭ are Boolean-valued expressions

## Example 1

Fact: x is inside the interval [L,R] if it is no smaller than L and no bigger than R.

```
x = input('x: ')
L = input('L: ')
R = input('R: ')

if (x<L) or (R<x):
   print 'Outside'
else:
   print 'Inside'
```



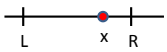

## Equivalent Solutions

Fact: x is inside the interval [L,R] if it is no smaller than L and no bigger than R.

```
if (x<L) or (R<x):
   print 'Outside'
else:
   print 'Inside'
```

```
if (L<=x) and (x<=R):
   print 'Inside'
else:
   print 'Outside'
```

Often you can arrange a conditional execution in several ways.

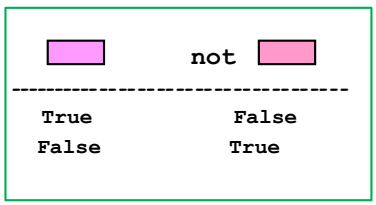



## The not Operation

x ---> 3 y ---> 6

```
not (x < y)    False
not (x > y)    True
```

## The not Operator



| not | |
|---|---|
| True | False |
| False | True |

Here ▭ is a boolean-valued expression

## A Note on Boolean Variables

Boolean expressions either have the value `True` or the value `False`.

When a Boolean expression is evaluated, the result can be stored in a variable, e.g.,

```
outsideInterval =  x<L or R<x
```

We say that `outsideInterval` is a Boolean variable.

## Boolean Variables For Clarity

```
Y = input('Enter a 4-digit integer: ')
CenturyYear = (Y%100 == 0)
if CenturyYear:
    LeapYear = (Y%400 == 0)
else:
    LeapYear = (Y%4 == 0)
```

Thus, 1960, 2000 and 2400 are leap years. 1961 and 1900 are not. This code assigns the value of `True` to `LeapYear` if `Y` encodes a leap year. It assigns the value of `False` to `LeapYear` if `Y` does not encode a leap year.

## A Summarizing Example

Input a string. If it has even length, then hyphenate in the middle:

baseball  base-ball

If it has odd length, then hyphenate around the middle character:

frisbee  fri-s-bee

## The `len` Function

If ever you need to compute the length of a string then use the built-in function `len`.

```
s = 'abcdef'
n = len(s)
m = n/2
First = s[:m]
Second = s[m:]
```

x ---> 'abcdef'
n ---> 6
m ---> 3
First ---> 'abc'
Second ---> 'def'

## The `len` Function

If ever you need to compute the length of a string then use the built-in function `len`.

```
s = 'abcdefg'
n = len(s)
m = n/2
First = s[:m]
Second = s[m:]
```

x ---> 'abcdefg'
n ---> 7
m ---> 3
First ---> 'abc'
Second ---> 'defg'

## So Let's Solve this Problem

Input a string. If it has even length, then hyphenate in the middle:

baseball  base-ball

If it has odd length, then hyphenate around the middle character:

frisbee  fri-s-bee

## Developing a Solution

Instead of just showing the solution, let's "derive" the solution using a methodology that is called stepwise refinement.

The course is really about problem solving with the computer. So developing problem-solving strategies is VERY IMPORTANT

## "Reformat" the task.

```
Read in the string
Compute its length
if the length is even
    Hyphenate in the middle
else
    Hyphenate around around the middle
    character.
```

Still in English, but it looks a little more like python.

## "Reformat" the task.

```
Read in the string
Compute its length
if the length is even
    Hyphenate in the middle
else
    Hyphenate around around the middle
    character.
```

Turn these into Python

## Refine

```
s = input('Enter a string: ')
n = len(s)
if the length is even
    Hyphenate in the middle
else
    Hyphenate around around the middle
    character.
```

We have turned the first two lines into python.

## Refine Some More

```
s = input('Enter a string: ')
n = len(s)
if the length is even
    Hyphenate in the middle
else
    Hyphenate around around the middle
    character.
```

How do we check if the value in n is even?

## Refine Some More

```
h = input('Enter a string: ')
n = len(s)
if n%2==0:
    # s has even length
    Hyphenate in the middle
else:
    # s has odd length
    Hyphenate around around the middle
    character.
```

We add comments to summarize what we may assume about the value of n.

## Refine Some More

```
h = input('Enter a string: ')
n = len(s)
if n%2==0:
    # s has even length
    Hyphenate in the middle
else:
    # s has odd length
    Hyphenate around around the middle
    character.
```

Figure out the even-length hyphenation

## Even-Length Hyphenation

We look at a small example.
These statements

```
s = 'abcdef'
h = s[0:3] + '-' + s[3:]
```

assign `'abc-def'` to `h`.

In general:

```
m = n/2
h = s[0:m] + '-' + s[m:]
```

## Refine Some More

```
h = input('Enter a string: ')
n = len(s)
if n%2==0:
    # s has even length
    m = n/2
    h = s[0:m] + '-' + s[m:]
else:
    # s has odd length
    Hyphenate around around the middle
    character.
```

## Refine Some More

```
h = input('Enter a string: ')
n = len(s)
if n%2==0:
    # s has even length
     m = n/2
     h = s[0:m] + '-' + s[m:]
else:
    # s has odd length
    Hyphenate around around the middle
    character.
```

Figure out the odd-length hyphenation

## Odd-Length Hyphenation

We look at a small example.
This

```
s = 'abcdefg'
h = s[0:3] + '-' + s[3] + '-' + s[3:]
```

assigns `'abc-d-efg'` to `h`.

In general:

```
m = n/2
h = s[0:m] + '-' + s[m] + '-'+ s[m+1:]
```

## Done!

```
h = input('Enter a string: ')
n = len(s)
if n%2==0:
    # s has even length
    m = n/2
    h = s[0:m] + '-' + s[m:]
else:
    # s has odd length
    m = n/2
    h = s[0:m]+'-'+s[m]+'-'+s[m+1:]
```

## Summary

1. A Boolean expression evaluates to either `True` or `False`
2. A Boolean expression is made up of comparisons that are either `True` or `False`
3. The `and, or, not` operations combine Boolean values.
4. Various `if` constructions can be used to organize conditional execution.