Advanced Python for Astronomy

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General aspects -1

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  - ... but not only
    - Numerical computations (!!)
    - CGI Applications
    - GUI programming
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The competitors

Several other languages have similar characteristics or cover, at least partially, Python's areas of application.

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- Perl
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- Php
- R
- Matlab ($)
- Octave
- awk
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  - Automatic p-code management
  - python2: `prog.py` → `prog.pyc` → `prog.pyo`
  - python3: ... in directory `__pycache__`

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General aspects -3

Dynamic object creation

```
>>> a=3


>>> a="three"




>>> p=[4,2,3,1]


>>> k=p
```

General aspects -3

Dynamic

Creates an object: “integer number valued 3” and gives it the name **a**

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>>> type(p)
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>>> dir(p)
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>>> p.sort()
>>> k
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>>> del p[2]
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This shows, again, that **k** and **p** are the same object

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General aspects -4

Collections

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>>> atuple = (1, 2, 4, "five", 6.0, -7, "VIII")
>>> alist = [1, "due", 3, "five", 7.96]
>>> adict = {1:"one", 2:2, 3:3.1415926, "five":5}
>>> aset = set(atuple)
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General aspects -4

Collections

tuple: non mutable collection of objects, possibly different in type. Referenced by **index**.

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From the Manual:

Function	Result
`x in s`	*True* if any element of **s** is equal to **x**, else *False*
`x not in s`	*False* if any element of **s** is equal to **x**, else *True*
`s+t`	concatenation of **s** and **t**
`s*n, n*s`	**s** + **s** + **s** + ... **n** times (**n** integer)
`s[i]`	i*th* element of **s** (base 0)
`s[i:j]`	slice of **s** from i*th* to (j-1)*th*
`s[i:j:k]`	slice of **s** from i*th* to (j-1)*th*, with stride k
`len(s)`	length (number of elements) of **s**
`min(s)`	the smallest element in **s**
`max(s)`	the greatest element in **s**
`s.index(x)`	index of the first occurrence of x in **s**
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What's the meaning if **s** is a dictionary?

Comprehension

```
>>> another = [x*x for x in atuple if type(x) is int]
>>> atuple
(1, 2, 4, "cinque", 6.0, -7, "VIII")
>>> another
[1, 4, 16, 49]
```

General aspects -4

Collections

```
>>> atuple = (1, 2, 4, "
>>> alist = [1, "due", 3, "
>>> adict = {1:"one", 2:2, 
>>> aset = set(atuple)
```

tuple: non mutable collection of ob-
je
e

list: mutable collection of objects,
p
b

dictionary: mutable collection of objects, possibly different in type. Ref-
erenced by key

set: mutable collection of unique objects, (*frozenset*: non mutable). Supports usual operations on sets

From the Manual:

Function	Result
`x in s` ⟸	*T* o **x**, else *False*
`x not in s`	*F* to **x**, else *True*
`s+t`	concatenation of **s** and **t**
`s*n, n*s`	**s** + **s** + **s** + ... **n** times (**n** integer)
`s[i]`	i*th* element of **s** (base 0)
`s[i:j]`	slice of **s** from i*th* to (j-1)*th*
`s[i:j:k]`	slice of **s** from i*th* to (j-1)*th*, with stride k
`len(s)`	length (number of elements) of **s**
`min(s)`	the smallest element in **s**
`max(s)`	the greatest element in **s**
`s.index(x)`	index of the first occurrence of x in **s**
`s.count(x)`	number of occurrences of x in **s**

What's the meaning if **s** is a dictionary?

Comprehension

```
>>> another = [x*x for x in atuple if type(x) is int]
>>> atuple
(1, 2, 4, "cinque
>>> another
[1, 4, 16, 49]
```

Flexible syntax to create collections from other collections

General aspects -4

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Flexible syntax to create collections from other collections

Functions and Arguments

file: `funny.py`

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    if toint:
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        cvt = lambda x: x
    if a > b:
        return cvt(a)
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    return cvt(default)
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Functions and Arguments

Function **Definition**

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`lambda`: “in place” function

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How to use functions:

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>>> funny(1.0, 1.0, toint=True, default=6.2831852)
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>>> funny(1.0, toint=True, default=6.283)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: funny() missing 1 required positional argument: ’b’
```

Functions and Arguments

file: `funny.py`

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Only positional arguments

Functions and Arguments

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positional arguments, one optional argument (specified by position), one optional argument (specified by name)

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⇐ Positional arguments are required

Functions and Arguments

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Positional arguments, named arguments (order irrelevant)

Positional arguments are required

In summary:

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- Named arguments are optional and have a default value
- Named arguments may be specified either by position or by name.
- When specified by name, order is irrelevant

Variable arguments -1

Python provides syntax to write functions which can be called with a variable number of arguments, both positional and named.

Let's see the general case:

file: `showarg.py`

```
def showarg(a, b, d=15, *pos, **kw):
    print("Positional required arguments (a,b):", a, b)
    print("Standard named arguments (d):", d)
    print("Positional variable arguments (pos):", pos)
    print("Named variable arguments (kw):", kw)
```

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The **showarg()** function only shows the arguments from the call.

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a, **b** standard positional arguments

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The **showarg()** function only

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****kw**, (*dict*) variable named arguments

Calling `showarg()`:

```
>>> from showarg import showarg

>>> showarg(1, 2)
Positional required arguments (a,b): 1 2
Standard named arguments (d): 15
Positional variable arguments (pos): ()
Named variable arguments (kw): {}

>>> showarg(1, 2, 3, 4, 5, 6, opt1=7, opt2=8)
Positional required arguments (a,b): 1 2
Standard named arguments (d): 3
Positional variable arguments (pos): (4, 5, 6)
Named variable arguments (kw): {'opt1': 7, 'opt2': 8}
```

Variable arguments -1

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Call with required arguments only

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Call with required arguments only

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```

Call with variable positional and named arguments

Variable arguments -1

Python provides syntax to write functions which can be called with a variable number of arguments, both positional and named.

Let’s see the general case:

file: `showarg.py`

```
def showarg(a, b, d=15, *pos, **kw):
    print("Positional required
    print("Standard named argu
    print("Positional variable
    print("Named variable argu
```

The **showarg()** function only

a, **b** standard positional argu

****kw**, (*dict*) variable named arguments

Calling `showarg()`:

```
>>> from showarg import showarg

>>> showarg(1, 2)
Positional required arguments (a,b): 1 2
Standard named arguments (d): 15
Positional variable arguments (pos): ()
Named variable arguments (kw): {}

>>> showarg(1, 2, 3, 4, 5, 6, opt1=7, opt2=8)
Positional required arguments (a,b): 1 2
Standard named arguments (d): 3
Positional variable arguments (pos): (4, 5, 6)
Named variable arguments (kw): {'opt1': 7, 'opt2': 8}
```

⇐ Call with required arguments only

⇐ Call with variable positional and named arguments

⇐ Note!

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⇐ Call with required arguments only

⇐ Call with variable positional and named arguments

⇐ Note!

→

Variable arguments -2

Python allows to put arbitrary argument lists in the function call with a syntax analogous to variable argument lists in function definition.

Another way to call `showarg()`:

```
>>> ps=(10,11,12)
>>> ak={"arg1":13, "arg2":14, "arg3":15}

>>> showarg(1, 2, 3, 4, 5, 6, opt1=7, opt2=8, *ps, **ak)
Positional required arguments (a,b): 1 2
Standard named arguments (d): 3
Positional variable arguments (pos): (4, 5, 6, 10, 11, 12)
Named variable arguments (kw): {'opt1': 7, 'opt2': 8, 'arg3': 15,
 'arg2': 14, 'arg1': 13}
```

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Another way to call `showarg()`:

Definition of a *tuple* (**ps**) and a *dictionary* (**ak**)

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Named variable arguments (kw): {’opt1’: 7
 ’arg2’: 14, ’arg1’: 13}
```

Definition of a *tuple* (**ps**) and a *dictionary* (**ak**)

The **pos** *tuple* in the function “receives” positional parameters other than required ones and the content of **ps** *tuple* from the call

Variable arguments -2

Python allows to put arbitrary argument lists in the function call with a syntax analogous to variable argument lists in function definition.

Another way to call `showarg()`:

```
>>> ps=(10,11,12)
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Positional required arguments (a,b): 1 2
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Definition of a *tuple* (**ps**) and a *dictionary* (**ak**)

The **pos** *tuple* in the function “receives” posi-
ti
t
t
f

The **kw** *dictionary* in the function “receives” named variable arguments and the content of **ak** *dictionary* from the call

Variable arguments -2

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→

Modules -1

Module: A block of code contained in a single file

file: `fibo.py`

```
"Module for the computation of Fibonacci series"

MAXFIBO=1000

def fibo(n):
    "Returns the Fibonacci series up to n"
    if n > MAXFIBO: return []
    result = []
    a, b = 0, 1
    while b < n:
        result.append(b)
        a, b = b, a+b
    return result

def fibo_print(n):
    "prints the Fibonacci series up to n"
    ser = fibo(n)
    print("Fibonacci series up to %d:" % n)
    print(ser)

if __name__=='__main__':
    fibo_print(14)
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⇐ The constant **MAXFIBO**

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The constant **MAXFIBO**

The function **fibo()**

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⇐ The constant **MAXFIBO**

⇐ The function **fibo()**

⇐ The function **fibo_print()**

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The constant **MAXFIBO**

The function **fibo()**

The function **fibo_print()**

Some test code

Modules -1

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    fibo_print(14)
```

The constant **MAXFIBO**

The function **fibo()**

The function **fibo_print()**

Some test code

Note: The internal variable `__name__` holds the string `"__main__"` only when the code is directly executed. If, instead, the module is *imported*, as we will see in the next slide, the variable holds the name of the module (`fibo`).
As a consequence when the module is imported, the test code is not executed.

Modules -2

```
>>> import fibo

>>> fibo.fibo(400)
[1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377]

>>> dir(fibo)
['MAXFIBO', '__builtins__', '__cached__', '__doc__', '__file__',
'__loader__', '__name__', '__package__', '__spec__', 'fibo', 'fibo_print']

>>> help(fibo)
Help on module fibo:

NAME
    fibo - Module for the computation of Fibonacci series

FUNCTIONS
    fibo(n)
        Returns the Fibonacci series up to n

    fibo_print(n)
        prints the Fibonacci series up to n

DATA
    MAXFIBO = 1000

FILE
    /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py

>>> fibo.__name__
'fibo'

>>> fibo.__doc__
'Module for the computation of Fibonacci series'

>>> fibo.__file__
'/home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py'

>>> fibo.MAXFIBO
1000

>>> fibo.fibo_print(123)
Fibonacci series up to 123:
[1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]
```

Modules -2

To use a module it must be **imported**

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>>> import fibo

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Modules -2

To use a module it must be **imported**

How to use the module's **fibo()** function

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Fibonacci series up to 123:
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Modules -2

To use a module it must be **imported**

```
>>> import fibo
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How to use the module's **fibo()** function

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The built-in function **dir()** shows module's content.

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        prints the Fibonacci series up to n

DATA
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Modules -2

To use a module it must be **imported**

How to use the module's **fibo()** function

The built-in function **dir()** shows module's content.

The built-in function **help()** prints in "document" format the content of some internal variables and other pieces of information derived from the module.

```
>>> import fibo

>>> fibo.fibo(400)
[1, 1, 2, 3, 5, 8,

>>> dir(fibo)
['MAXFIBO', '__built
'__loader__', '__nam

>>> help(fibo)
Help on module fibo:

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DATA
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Fibonacci series up to 123:
[1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]
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Modules -2

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>>> import fibo
```

To use a module it must be **imported**

```
>>> fibo.fibo(400)
[1, 1, 2, 3, 5, 8,
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How to use the module's **fibo()** function

```
>>> dir(fibo)
['MAXFIBO', '__builtins
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```
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Help on module fibo:
```

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```
NAME
    fibo - Module for the computation of Fibonacci series

FUNCTIONS
    fibo(n)
        Returns the Fibonacci series up to n

    fibo_print(n)
        prints the Fibonacci series up to n

DATA
    MAXFIBO = 1000

FILE
    /home/lfini/Personale

>>> fibo.__name__
'fibo'
```

The internal variable **__name__** holds the module's name (because the module has been imported, see also previous slide)

```
>>> fibo.__doc__
'Module for the computation of Fibonacci series'

>>> fibo.__file__
'/home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py'

>>> fibo.MAXFIBO
1000

>>> fibo.fibo_print(123)
Fibonacci series up to 123:
[1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]
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Modules -2

```
>>> import fibo
```

To use a module it must be **imported**

```
>>> fibo.fibo(400)
[1, 1, 2, 3, 5, 8,
```

How to use the module’s **fibo()** function

```
>>> dir(fibo)
['MAXFIBO', '__builtins
'__loader__', '__nam
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The built-in function **dir()** shows module’s content.

```
>>> help(fibo)
Help on module fibo:
```

The built-in function **help()** prints in “document” format the content of some internal variables and other pieces of information derived from the module.

```
NAME
    fibo - Module for the computation of Fibonacci series

FUNCTIONS
    fibo(n)
        Returns the Fibonacci series up to n

    fibo_print(n)
        prints the Fibonacci series up to n

DATA
    MAXFIBO = 1000

FILE
    /home/lfini/Personal

>>> fibo.__name__
'fibo'
```

The internal variable **__name__** holds the module’s name (because the module has been imported, see also previous slide)

```
>>> fibo.__doc__
'Module for the computa
```

The internal variable **__doc__** holds the string which is at the top of source file.

```
>>> fibo.__file__
'/home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py'

>>> fibo.MAXFIBO
1000

>>> fibo.fibo_print(123)
Fibonacci series up to 123:
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Modules -2

```
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To use a module it must be **imported**

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DATA
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```
>>> fibo.__file__
'/home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py
```

The internal variable **__file__** holds the source file path

```
>>> fibo.MAXFIBO
1000

>>> fibo.fibo_print(123)
Fibonacci series up to 123:
[1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]
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Modules -2

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To use a module it must be **imported**

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>>> fibo.fibo(400)
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How to use the module's **fibo()** function

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>>> dir(fibo)
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>>> help(fibo)
Help on module fibo:

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FUNCTIONS
    fibo(n)
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        prints the Fibonacci series up to n

DATA
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FILE
    /home/lfini/Personale
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The built-in function **help()** prints in "document" format the content of some internal variables and other pieces of information derived from the module.

```
>>> fibo.__name__
'fibo'
```

The internal variable __**name**__ holds the module's name (because the module has been imported, see also previous slide)

```
>>> fibo.__doc__
'Module for the computat
```

The internal variable __**doc**__ holds the string which is at the top of source file.

```
>>> fibo.__file__
'/home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py
```

The internal variable __**file**__ holds the source file path

```
>>> fibo.MAXFIBO
1000
```

Getting variable **MAXFIBO**

```
>>> fibo.fibo_print(123)
Fibonacci series up to 123:
[1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]
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How to use the module's **fibo()** function

The built-in function **dir()** shows module's content.

The built-in function **help()** prints in "document" format the content of some internal variables and other pieces of information derived from the module.

The internal variable __**name**__ holds the module's name (because the module has been imported, see also previous slide)

The internal variable __**doc**__ holds the string which is at the top of source file.

The internal variable __**file**__ holds the source file path

Getting variable **MAXFIBO**

How to use the **fibo_print()** function

namespaces and *scope* -1

- A *namespace* is a “container” for names.

namespaces and *scope* -1

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- In a program there is a hierarchy of namespaces.

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file: `prcube.py`

```
note = "The cube of %d is: %d"

cube = 3.1415926

def print_cube(n):
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    print(note % (n, cube))
```

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file: `prcube.py` ⟸

Module `prcube` is a namespace containing names: **note**, **cube**, **print_cube**.

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The function `print_cube()` is another namespace containing names **cube** ed **n**

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Let’s launch the Python interpreter:

```
$ python
Python 3.5.2 (default, Nov 23 2017, 16:37:01)
[GCC 5.4.0 20160609] on linux
Type "help", "copyright", "credits" or "license" for more information.

>>> cube = "The third power"

>>> import prcube

>>> prcube.print_cube(11)
The cube of 11 is: 1331

>>> cube
'The third power'

>>> prcube.cube
3.1415926
```

namespaces and *scope* -1

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Let’s launch the Python interpreter:

The Python interpreter is the level 0 namespace

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$ python
Python 3.5.2 (default, Nov 23 20
[GCC 5.4.0 20160609] on linux
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>>> import prcube

>>> prcube.print_cube(11)
The cube of 11 is: 1331

>>> cube
'The third power'

>>> prcube.cube
3.1415926
```

The Python interpreter is

The name **cube** is created in level 0 namespace

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The **import** statement creates the name **prcube** referring to the full namespace of the `prcube` module.

namespaces and *scope* -1

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The Python interpreter is

The name **cube** is created in level 0 namespace

The **import** statement creates the name **prcube** referring to the full namespace of the `prcube` module.

The **print_cube()** function defines another namespace, containing a variable named **cube**

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The Python interpreter is

The name **cube** is created in level 0 namespace

The **import** statement creates the name **prcube** referring to the full namespace of the `prcube` module.

The **print_cube()** function defines another namespace, containing a variable named **cube**

In the above example the name **cube** shows up three times in three different namespaces, i.e.: referring to three different objects.

namespaces and *scope* -2

- ***Scope***: All the “area” where a name is referred to the same object.
- Scope rules:

namespaces and *scope* -2

- ***Scope***: All the “area” where a name is referred to the same object.
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namespaces and *scope* -2

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namespaces and *scope* -2

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Let’s go back to the previous example:

```
note = "The cube of %d is: %d"

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def print_cube(n):

    cube = n*n*n

    print(note % (n, cube))

....
```

namespaces and *scope* -2

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namespaces and *scope* -2

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Let’s go back to the prev

The name **note** is created here

```
note = "The cube of %d is: %d"

cube = 3.1415926

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....
```

namespaces and *scope* -2

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Let’s go back to the prev

The name **note** is created here

The name **cube**$_1$ is created here

```
note = "The cube of %d is: %d"

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The name **note** is created here

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The name **n** is created here

namespaces and *scope* -2

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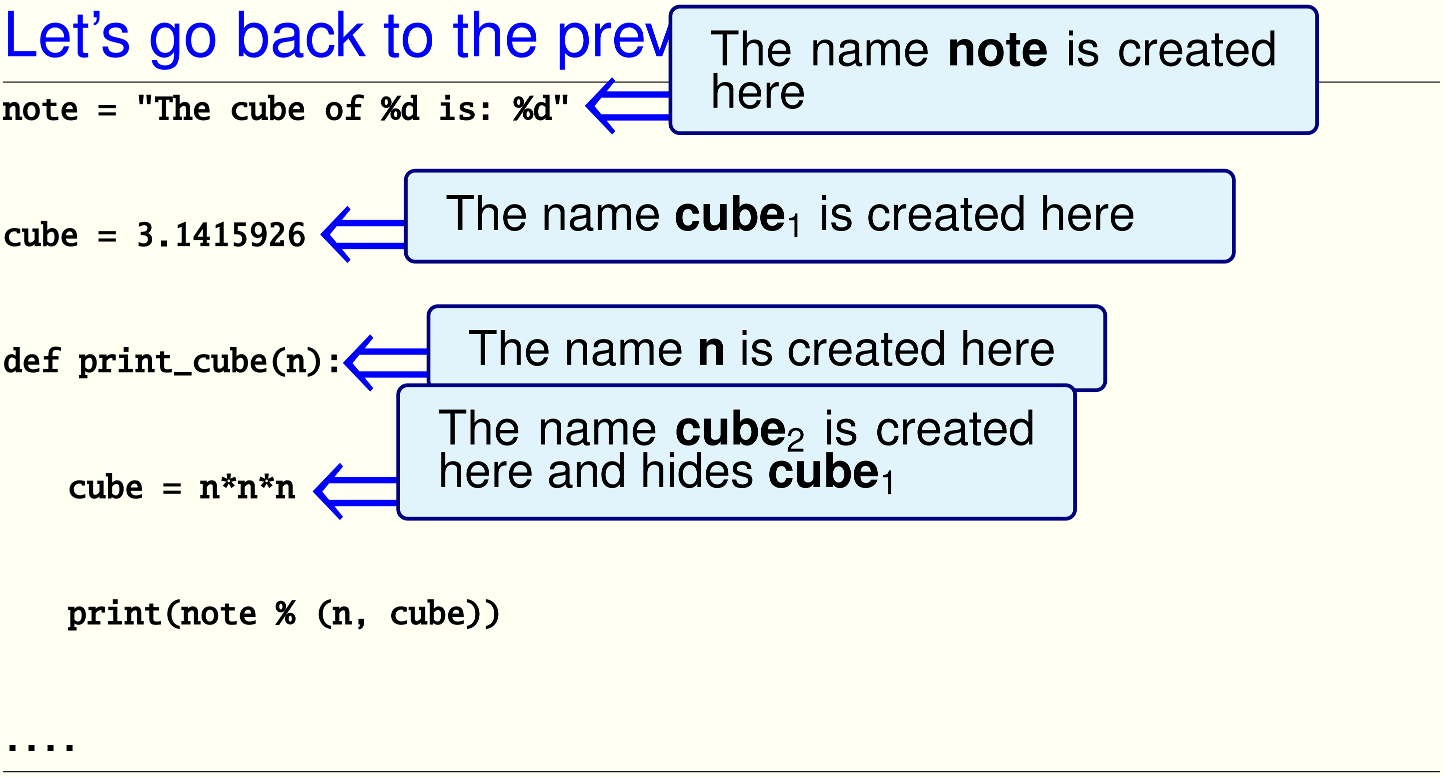

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cube = 3.1415926

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....
```

The name **note** is created here

The name **cube**$_1$ is created here

The name **n** is created here

The name **cube**$_2$ is created here and hides **cube**$_1$

namespaces and *scope* -2

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    print(note % (n, cube))

....
```

The name **note** is created here

The name **cube**$_1$ is created here

The name **n** is created here

The na
here ar

Here the name **note** is searched up the hierarchy and found one step above. **n** and **cube** are found in the current namespace

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Here the name **cube**$_2$ disappears and **cube** refers again to the object created at the second line of the file

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global namespace -1

A well known, widely used, debugging technique consists in adding print function calls where needed, to show variable values as an help in understanding the sequence of operations.

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global namespace -1

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To avoid the need to remove print functions from the code when finished testing, it is common to place the debugging statements under a conditional statement as in the following example.

file: scope1.py

```
DEBUG = True

def main():
    print("Program starting ...")
    if DEBUG:
        print("Running in debug mode")

if __name__ == "__main__":
    main()
```

file: scope2.py

```
DEBUG = False

def main():
    print("Program starting ...")
    if DEBUG:
        print("Running in debug mode")

if __name__ == "__main__":
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`scope1.py` e `scope2.py` are identical except for the value of variable `DEBUG`.

file: scope2.py

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file: scope2.py

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DEBUG = False ⇐

def main():
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if __name__ == "__main__":
    main()
```

```
$ python scope1.py
Program starting ...
Running in debug mode

$ python scope2.py
Program starting ...
```

global namespace - 2

Usually it is better to be able to select the running mode at program execution without the need to modify the `DEBUG` variable, e.g.: by using an optional parameter on the command line.

global namespace - 2

Usually it is better to be able to select the running mode at program execution without the need to modify the `DEBUG` variable, e.g.: by using an optional parameter on the command line.

file: scope3.py

```
import sys

DEBUG = False

def main():
    if "-d" in sys.argv:
        DEBUG = True

    print("Program starting ...")
    if DEBUG:
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if __name__ == "__main__":
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The **sys.argv** variable holds the command string, split into “words”

global namespace - 2

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Let’s run the program:

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Let’s run the program:

```
$ python scope3.py -d
Program starting ...
Running in debug mode
```

global namespace - 2

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Program starting ...
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⇐ 1. Adding option **-d**

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Let’s run the program:

```
$ python scope3.py -d
Program starting ...
Running in debug mode
```

1. Adding option **-d**

```
$ python scope3.py
Program starting ...
Traceback (most recent call last):
  File "scope3.py", line 14, in <module>
    main()
  File "scope3.py", line 10, in main
    if DEBUG:
UnboundLocalError: local variable 'DEBUG' referenced before assignment
```

global namespace - 2

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Let’s run the program:

```
$ python scope3.py -d
Program starting ...
Running in debug mode
```

1. Adding option **-d**

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$ python scope3.py
Program starting ...
Traceback (most recent call last):
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  File "scope3.py", line 10, in main
    if DEBUG:
UnboundLocalError: local variable ’DEBUG’ referenced before assignment
```

2. Without option **-d**

global namespace - 2

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if __name__ == "__main__":
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```

The **sys.argv** variable holds the command string, split into “words”

Let’s run the program:

```
$ python scope3.py -d
Program starting ...
Running in debug mode
```

1. Adding option **-d**

```
$ python scope3.py
Program starting ...
Traceback (most recent call last):
  File "scope3.py", line 14, in <module>
    main()
  File "scope3.py", line 10, in main
    if DEBUG:
UnboundLocalError: local variable ’DEBUG
```

2. Without option **-d**

Note the error at line 10.

The variable `DEBUG` is not defined!

global namespace - 2

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import sys

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if __name__ == "__main__":
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```

The **sys.argv** variable holds the command string, split into “words”

Let’s run the program:

```
$ python scope3.py -d
Program starting ...
Running in debug mode
```

1. Adding option **-d**

2. Without option **-d**

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$ python scope3.py
Program starting ...
Traceback (most recent call last):
  File "scope3.py", line 14, in <module>
    main()
  File "scope3.py", line 10, in main
    if DEBUG:
UnboundLocalError: local variable ’DEBUG
```

Note the error at line 10.

The variable `DEBUG` is not defined!

→

global namespace -3

Let’s go back to scope rules:

- in `scope3.py` we have the assignment:
  `DEBUG = True`

global namespace -3

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file: scope4.py – Working version

```
import sys

DEBUG = False

def main():
    global DEBUG
    if "-d" in sys.argv:
        DEBUG = True

    print("Program starting ...")
    if DEBUG:
        print("Running in debug mode")

if __name__ == "__main__":
    main()
```

global namespace -3

Let's go back to scope rules:

- in `scope3.py` we have the assignment:
  `DEBUG = True`
- the name `DEBUG` is thus located in the *local* namespace of function `main()`
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> The `global DEBUG` statement forces python to create (or search) the name `DEBUG` into the global namespace, i.e.: the topmost in the namespace hierarchy.

Classes and Objects

The **class** is the tool which allows a programmer to define her/his own objects.

file: number.py

```
class Number:
    "An example of class: Number()"
    names=('zero','one','two','three','four',
           'five', 'six','seven','eight','nine')

    def __init__(self, n):
       self.name=Number.names[n]
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Instance attributes

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```

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Standard user defined method: `upper()`

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How to use class Number:

```
>>> from number import Number
>>> a=Number(2)
>>> b=Number(3)
>>> a
<number.Number object at 0x7f9153a695f8>
>>> b
<number.Number object at 0x7f9153a695c0>
>>> print(a, b)
two three
>>> a.value
2
>>> a.upper()
'TWO'
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```

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→

Derived classes

Proceeding further with the previous example:

```
>>> a+b
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: unsupported operand type(s) for +: 'Number' and 'Number'
>>>
```

Derived classes

Proceeding further with the previous example:

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Class `Number` does not provide an implementation for addition

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file: `numberext.py`

```python
from number import Number

class NumberExt(Number):
    "Number with addition"
    def __add__(self, x):
        return NumberExt(self.value+x.value)

    def upper(self):
        return self.name.capitalize()
```

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Let's use the new class:

```
>>> from numberext import NumberExt
>>> a=NumberExt(2)
>>> b=NumberExt(3)
>>> a
<numberext.NumberExt object at 0x7fe17970dc88>
>>> b
<numberext.NumberExt object at 0x7fe17970dc50>
>>> print(a, "+", b, "=", a+b)
two + three = five
>>> a.upper()
'Two'
>>>
```

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Creating two instances of class `NumberExt`

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Creating two instances of class `NumberExt`

The addition operation (**+**) calls implicitly the `__add__()` method. The latter returns an instance of `NumberExt` class with value equal to the sum of the two addends

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Creating two instances of class `NumberExt`

The addition operation (**+**) calls implicitly the `__add__()` method. The latter returns an instance of `NumberExt` class with value equal to the sum of the two addends

N.B.: The class `Number` and its derivatives implement very little of integer arithmetic!

Iterators and Generators -1

Iterators and **generators** are tools to generate sequences of objects in an efficient way.

file: fibo1.py

```
class Fibo:
    "Iterator for the Fibonacci series"
    def __init__(self, maxv):
        self.maxv = maxv

    def __iter__(self):
        self.a = 0
        self.b = 1
        return self

    def __next__(self):
        fib = self.a
        if fib > self.maxv:
            raise StopIteration
        self.a, self.b = self.b, self.a + self.b
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... provided with an `__iter__` method,

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Iterators and **generators** are tools to generate sequences of objects in an efficient way.

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In [3]: fb = list(Fibo(900))

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Context managers are used with the **with** statement

You need not to bother closing the file, because the context manager does it for you: <u>even in case of errors!</u>

Context managers -2

You can build your own context manager by creating a class as in the following example:

Example: a `File` object

```
class File():
    def __init__(self, filename, mode):
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Decorators

Decorators are language constructs which allow to dynamically alter a function, a method or a class without modifying the code of the function or using a subclass.

file: `decorator.py`

```
import time

def my_timer(f):
    def wrapper(*pw, **kw):
        tm0 = time.time()
        ret = f(*pw, **kw)
        tm1 = time.time()
        print("Elapsed time:", tm1-tm0, "s")
    return wrapper
```

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The returned function does “something” with the original one

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A function decorator is a function accepting a function as only argument ...

In this case:
- gets the time
- calls the original function
- computes and prints the elapsed time

... and returning a function

Example: decorating a function - File: fibo3.py

```
from decorator import my_timer

@my_timer
def fibo_print(n):
    "Prints n elements of the Fibonacci series"
    result = []
    a, b = 0, 1
    while len(result) < n:
        result.append(b)
        a, b = b, a+b
        print(a, end=" ")
    print()
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The @ operator “decorates” the following function with the given decorator

```
>>> from fibo3 import fibo_print
>>> fibo_print(8)
1 1 2 3 5 8 13 21
Elapsed time: 4.1961669921875e-05 s
>>>
```

Standard Modules and Packages

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The **sys** standard module

Classes, functions and constants directly related with the `Python` interpreter.

Let's explore at the `python` prompt:

- sys.path (See also: PYTHONPATH)
- sys.argv
- sys.exit()

- sys.maxint
- sys.float_info
- sys.maxsize
- sys.platform

- sys.stdin
- sys.stdout
- sys.stderr

The os standard package

Classes, functions and constants directly related with the Operating System.

Let’s explore at the `python` prompt:

- os.sep
- os.linesep
- os.defpath
- os.environ
- os.getenv(”HOME”)
- os.tmpfile()
- os.access(”a.py”,os.R_OK)
- os.curdir
- os.chdir(”newdir”)
- os.listdir(”dirname”)
- os.mkdir(”/dir1/dir2/name”)
- os.makedirs(”/dir1/dir2/name”)
- os.rename(”old”,”new”)
- os.renames(”old”,”new”)
- os.walk(”topdir”)

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- os.mkdir(”/dir1/dir2/name”)
- os.maked
- os.renam
- os.renam
- os.walk(”topdir”)

```
import os

tree=os.walk(".")
for dp,dnames,fnames in tree:
    for fn in fnames:
       print(os.path.join(dp,fn))
```

The `os.path` standard module

Function to manipulate file names and paths in a portable way

Let's explore at the `python` prompt:

- os.path.abspath(path)
- os.path.basename(path)
- os.path.dirname(path)
- os.path.split(path)
- os.path.commonprefix(list)
- os.path.exists(path)
- os.path.getatime(path)
- os.path.getmtime(path)
- os.path.getctime(path)
- os.path.join(path1,path2,..)

Modules: `math`, `cmath`, `random`

Functions on real numbers (`math`) complex numbers (`cmath`) and random numbers generation (`random`)

Let's explore at the `python` prompt:

- help(math), to be noted:
  - fsum
  - expm1
  - log1p
- help(cmath)
- help(random)

Exceptions -1

Errors in python programs are managed by means of exceptions.

file: error.py

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def division(a, b):
    return a/b
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Now let’s force an error:

```
>>> from error import division
>>> division(2.0, 4)
0.5
>>> division(2.0, 0)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "error.py", line 2, in division
    return a/b
ZeroDivisionError: float division by zero
```

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Now let's force an error:

```
>>> from error import division
>>> division(2.0, 4)
0.5
>>> division(2.0, 0)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "error.py", line 2, in division
    return a/b
ZeroDivisionError: float division by zero
```

Exceptions can be catch:

file: error1.py

```
import error

def division(a,b):
    try:
        return error.division(a, b)
    except:
        print("You can't divide by zero!")
```

Exceptions -1

Errors in python programs are managed by means of exceptions.

file: error.py

```
def division(a, b):
    return a/b
```

Now let's force an error:

```
>>> from error import division
>>> division(2.0, 4)
0.5
>>> division(2.0, 0)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
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def division(a,b):
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```

And here it is:

```
>>> from error1 import division
>>> division(2.33, 0)
You can't divide by zero!
>>>
```

Exceptions -1

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def division(a, b):
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Exceptions can be catch:

file: error1.py

```
import error

def division(a,b):
    try:
        return error.div
    except:
        print("You can’t
```

Note that the exception mechanism allows the programmer to manage the error at the proper level.

In the above example the exception is catch in the caller of the function where the error happens.

The principle is: in case of error the exception climbs up the sequence of nested calls until catch. If it is not catch somewhere, the program terminates with proper error message.

And here it is:

```
>>> from error1 import
>>> division(2.33, 0)
You can’t divide by zero!
>>>
```

Exceptions -2

Let’s try something different:

```
>>> division("two", 2)
You can’t divide by zero!
>>>
```

Exceptions -2

Let’s try something di

Our error management is not proper when errors other than zero division happen

```
>>> division("two", 2)
You can’t divide by zero!
>>>
```

Exceptions -2

Let’s try something di

```
>>> division("two", 2)
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Our error management is not proper when errors other than zero division happen

The exception mechanism provides for more detailed management:

file: error2.py

```python
import error

def division(a,b):
    try:
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    except ZeroDivisionError:
        print("You can’t divide by zero!")
```

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file: error2.py

```
import error

def division(a,b):
    try:
        return error.division(a,
    except ZeroDivisionError:
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```

Exceptions have a type. Here we only catch the exception `ZeroDivisionError`.

Exceptions -2

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```

Exceptions have a type. Here we only catch the exception `ZeroDivisionError`.

Now everything works better:

```
>>> from error2 import division
>>> division(2, 0)
You can’t divide by zero!
>>> division("two", 2)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "/home/lfini/Personale/CorsiSeminari/2018-Python/varie/error2.py", line 5
    error.division(a, b)
  File "/home/lfini/Personale/CorsiSeminari/2018-Python/varie/error.py", line 2,
    return a/b
TypeError: unsupported operand type(s) for /: ’str’ and ’int’
```

Exceptions -2

Let's try something di

```
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You can't divide by zero!
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Now everything works better:

```
>>> from error2 import divi
>>> division(2, 0)
You can't divide by zero!
>>> division("two", 2)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "/home/lfini/Personale/CorsiSeminari/2018-Python/varie/error2.py", line 5
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  File "/home/lfini/Personale/CorsiSeminari/2018-Python/varie/error.py", line 2,
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TypeError: unsupported operand type(s) for /: 'str' and 'int'
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⟸ The exception `ZeroDivisionError` is catch and managed by the program.

Exceptions -2

Let’s try something di

```
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You can’t divide by zero!
>>>
```

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```

The exception `ZeroDivisionError` is catch and managed by the program.

Any other exception is not managed, and causes program termination.

Exceptions -2

Let's try something di

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>>> division("two", 2)
You can't divide by zero!
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```

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Debug and test

Python is provided with a debugger (**pdb**) which allows to control program execution:

- defining breakpoints
- executing a program step by step
- looking into variables
- executing functions at the prompt

Let's see an example:

```
 pdb fibo.py
> /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py(1)<module>()
-> "Module for the computation of Fibonacci series"
(Pdb) b 9
Breakpoint 1 at /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py:9
(Pdb) c
> /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py(9)fibo()
-> a, b = 0, 1
(Pdb) n
> /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py(10)fibo()
-> while b < n:
(Pdb) n
> /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py(11)fibo()
-> result.append(b)
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(Pdb) n
> /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py(12)fibo()
-> a, b = b, a+b
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```

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Start the debugger on program `fibo.py`. The debugger stops immediately at the first line of the program

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Start the debugger on program `fibo.py`. The debugger stops immediately at the first line of the program

Set a breakpoint at line number 9

Continue (actually: start) the execution

```
 pdb fibo.py
> /home/lfini/Perso                                                 dule>()
-> "Module for 
(Pdb) b 9
Breakpoint 1 at                                              on/varie/fibo.py:9
(Pdb) c
> /home/lfini/                                                 py(9)fibo()
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```

Debug and test

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Let’s see an e

Start the debugger on program `fibo.py`. The debugger stops immediately at the first line of the program

Set a breakpoint at line number 9

Con

The debugger stops at the breakpoint (just before executing line 9)

```
 pdb fibo.py
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Breakpoint 1 at                                        ython/varie/fibo.py:9
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Execute a number of steps

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-> while b < n:
(Pdb) n
> /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py(11)fibo()
-> result.append(b)
(Pdb) n
> /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py(12)fibo()
-> a, b = b, a+b
(Pdb) p result
[1, 1]
```

Debug and test

Python is provided with a debugger (**pdb**) which allows to control program execution:

- defining breakpoints
- executing a program step by step
- looking into variables
- executing functions at the prompt

Let's see an e

Start the debugger on program `fibo.py`. The debugger stops immediately at the first line of the program

Set a breakpoint at line number 9

Con

The debugger stops at the breakpoint (just before executing line 9)

Execute a number of steps

```
 pdb fibo.py
> /home/lfini/Perso                                               dule>()
-> "Module for
(Pdb) b 9
Breakpoint 1 at                                                  Python/varie/fibo.py:9
(Pdb) c
> /home/lfini/                                                   bo()
-> a, b = 0, 1
(Pdb) n
> /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py(10)fibo()
-> while b <
(Pdb) n
> /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py(11)fibo()
-> result.append(b)
(Pdb) n
> /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py(12)fibo()
-> a, b = b, a+b
(Pdb) n
> /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py(10)fibo()
-> while b < n:
(Pdb) n
> /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py(11)fibo()
-> result.append(b)
(Pdb) n
> /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py(12)fibo()
-> a, b = b, a+b
(Pdb) p result
[1, 1]
```

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Let’s see an e

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> /home/lfini/Person                                        dule>()
-> "Module for
(Pdb) b 9
Breakpoint 1 at                                      Python/varie/fibo.py:9
(Pdb) c
> /home/lfini/                                                  bo()
-> a, b = 0, 1
(Pdb) n
> /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py(10)fibo()
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(Pdb) n
> /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py(11)fibo()
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(Pdb) n
> /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py(12)fibo()
-> a, b = b, a+b
(Pdb) p result
[1, 1]
```

Start the debugger on program `fibo.py`. The debugger stops immediately at the first line of the program

Set a breakpoint at line number 9

Con

The debugger stops at the breakpoint (just before executing line 9)

Execute a number of steps

Debug and test

Python is provided with a debugger (**pdb**) which allows to control program execution:

- defining breakpoints
- executing a program step by step
- looking into variables
- executing functions at the prompt

Let's see an e

Start the debugger on program `fibo.py`. The debugger stops immediately at the first line of the program

```
 pdb fibo.py
> /home/lfini/Persor                                          dule>()
-> "Module for
```

Set a breakpoint at line number 9

```
(Pdb) b 9
Breakpoint 1 at                                           Python/varie/fibo.py:9
(Pdb) c
```

Con

The debugger stops at the breakpoint (just before executing line 9)

```
> /home/lfini/                                                bo()
-> a, b = 0, 1
(Pdb) n
> /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py(10)fibo()
-> while b <
```

Execute a number of steps

```
(Pdb) n
> /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py(11)fibo()
-> result.append(b)
(Pdb) n
> /home/lfini/Personale/CorsiSeminari/2018-Python/varie/fibo.py(12)fibo()
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-> a, b = b, a+b
(Pdb) p result
[1, 1]
```

Now see what's in variable `result`