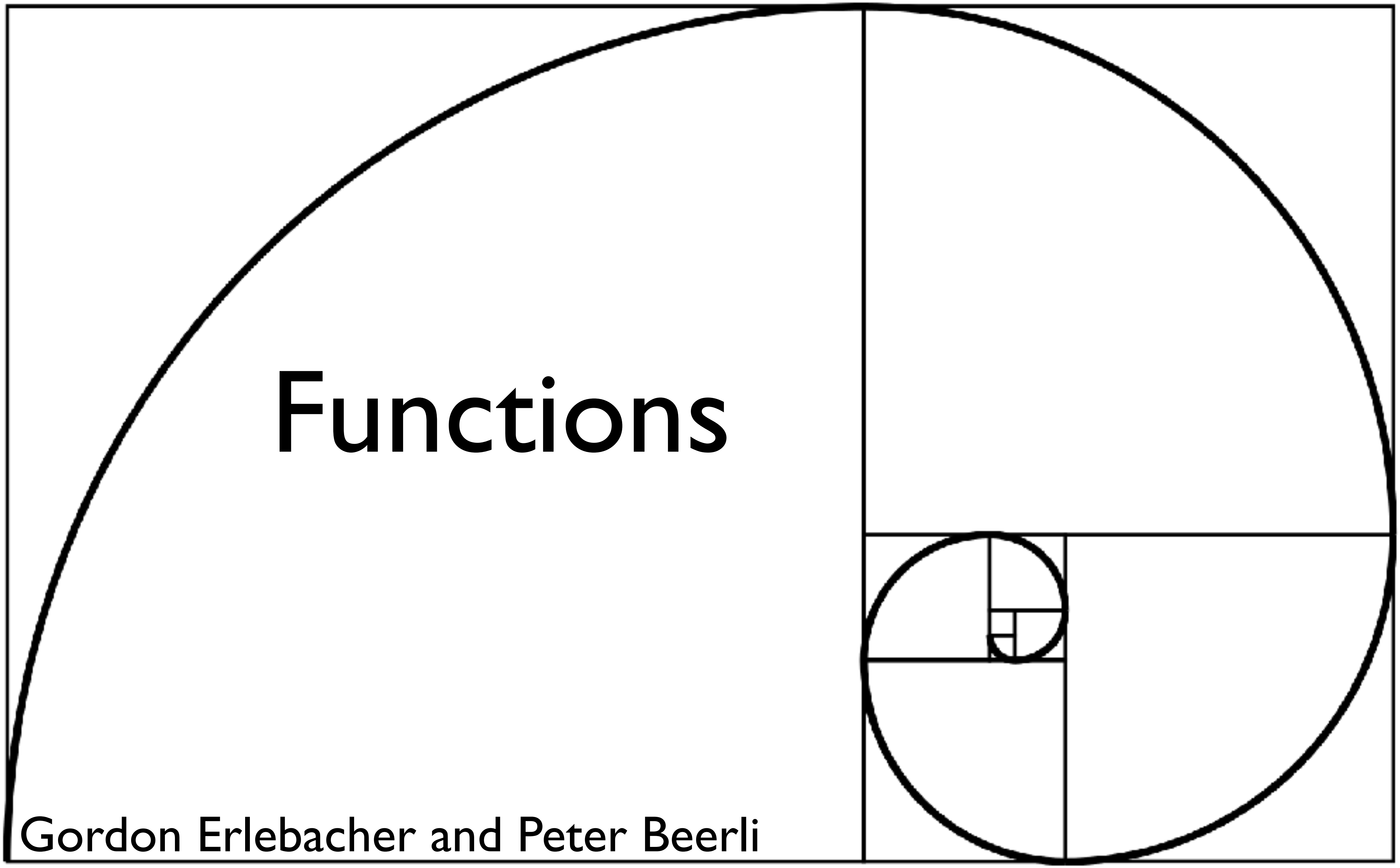

Functions

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Function Tutorials

- Intro to functions
  - http://anh.cs.luc.edu/python/hands-on/3.1/handsonHtml/functions.html
- More on functions
  - http://www.tutorialspoint.com/python/python_functions.htm

What is a Function

- In math: a function is a mapping:
  - input ==> unique output
- In Python:
  - input ==> unique (or no) output
  - However, something must happen
    - change a global variable
    - output to a file, a pipe, to the web

Kinds of Functions

- Simplest regular function

  -
    ```
    def funct(args):
          pass
    ```
- Simplest nontrivial Lambda function

  -
    ```
    a = lambda x: x+2
    a(5)     #  ==> 7
    ```

Python supports the creation of anonymous functions (i.e. functions that are not bound to a name) at runtime, using a construct called **lambda**.

Function Arguments

-
  ```
  def add(x,y):
      return x+y
  ```

-
  ```
  def add(a,b,*lst):
      return a + b + sum(lst)
  add(5,3,7,8,9)    # ==> 32
  ```

Keyword arguments

-
  ```
  def return_args(a,b,c):
      return a,b,c        # also return (a,b,c)
  ```
- add(b=27,a=2,c=10) # ==> (2, 27, 10)
- add(2,c=5,b=3)   # ==> (2 ,3, 5)
- add(2,c=5,a=3)   # error
  - b not defined
- add(b=3,a=2,3) # error
  - keywords must come first

Default Arguments

-
  ```
  def add(x,y=3):
        return x+y
  ```
- add(5)   # returns 8
- add(5,8)   # returns 13
- if less arguments are specified than the number of arguments, the missing arguments take default values
- missing arguments can take default values *if all* given arguments use keywords
- cannot have default arguments and at the same time have arbitrary number of arguments! Why?
- useful for very long argument lists

Variable Number of Arguments

- A function as 2 arguments, but 4 arguments are passed

-
  ```
  def add(x,y,*kw):     # add all arguments
          return x+y+sum(kw)
  ```
- add(3,4,5,6)   # returns 18
- add(3,4,5,6,7) # returns 25
- Cannot use keyword arguments if there are more than 2 arguments since kw is a list of non-keyword arguments, and keywords come after non-keyword arguments

Dictionary argument

-
  ```
  def add(a,b,**kww):
      try:
          print “N:“, kww[‘N’]
      except:
          print “no keyword N”
      return a+b
  ```
- kww returns all excess key-value pairs
- add(3,5,N=35,h=2)
  - returns ==>   N: 35
- add(3,5,NN=35,h=2)
  - returns ==>   ‘no keyword N’
  - type of NN is a string

Functions are references

-
  ```
  def add(a,b):
     return a+b
  def sub(a,b):
      return a-b
  ```

-
  ```
  v = add
  v(3,4)     # ==> 7
  v = sub
  v(3,4)     # ==> -1
  ```

-
  ```
  v = [sub, add]
  for i in v:
      print i(5,9)        # returns -4 and 14
  ```

Functions are references

-
  ```
  def calc(fct, a, b):
      return fct(a,b)
  ```

-
  ```
  v = [add, sub]
  for i in v:
      calc(i,5,8)
  ```
- returns   13 and -3

Callbacks

- A reference can be used like any variable
- A variable can be a function argument
  - therefore, a function argument can be a function
- Callback: use functions as arguments

Callbacks

-
  ```
  def calc(fct, a, b):
      return fct(a,b)
  ```

-
  ```
  v = [add, sub]
  for i in v:
      calc(i,5,8)
  ```

- returns   13 and -3

Lambda expressions

- useful to define functions directly in arguments
- elegant, but not necessary
- lambda x,y : body of function
- fct = lambda x,y : x+y
  fct(3,4)   # returns 7
- fct is used like any other function

Flexibility of functions

- Can use functions like any other reference
- Functions can be “transported” from place to place
- Functions can be stored in files
  - use eval or exec to evaluate them
  - EXAMPLE: eval(“15 + 16”)

Basically, `eval` is used to **eval**uate a single dynamically generated Python expression, and `exec` is used to **exec**ute dynamically generated Python code only for its side effects.

`eval` and `exec` have these two differences:

1. `eval` accepts only a **single expression**, `exec` can take a code block that has Python statements: loops, `try: except:`, `class` and function/method `def`initions and so on.

   An expression in Python is whatever you can have on the right-hand side of a variable assignment:

   ```
   a_variable = <anything that you can put here and it still compiles, is an expression>
   ```

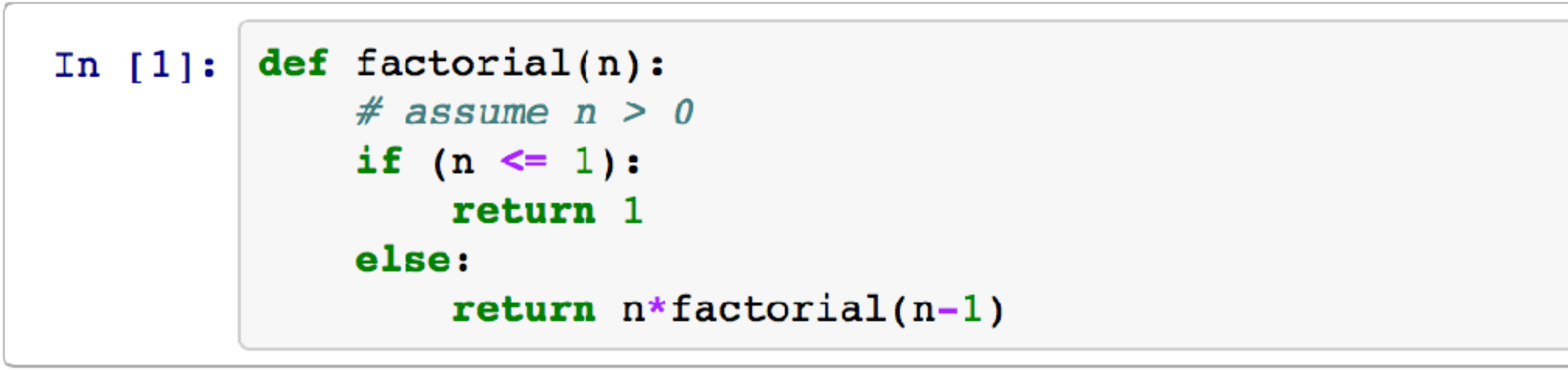
2. `eval` **returns the value** of the given expression, whereas `exec` ignores the return value from its code, and always returns `None` (in Python 2 it is a statement and cannot be used as an expression, so it really does not return anything).

Additionally in Python versions 1-2, `exec` was a statement, because CPython needed to produce a different kind of code object for functions that used `exec` for its side effects inside the function; `exec` is now a function in Python 3.

Thus basically:

```
>>> a = 5
>>> eval('37 + a')   # it is an expression
42
>>> exec('37 + a')   # it is an expression statement
>>> exec('a = 47')   # modify a global variable as a side effect
>>> a
47
>>> eval('a = 47')  # you cannot evaluate a statement
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<string>", line 1
    a = 47
      ^
SyntaxError: invalid syntax
```

Recursive Functions

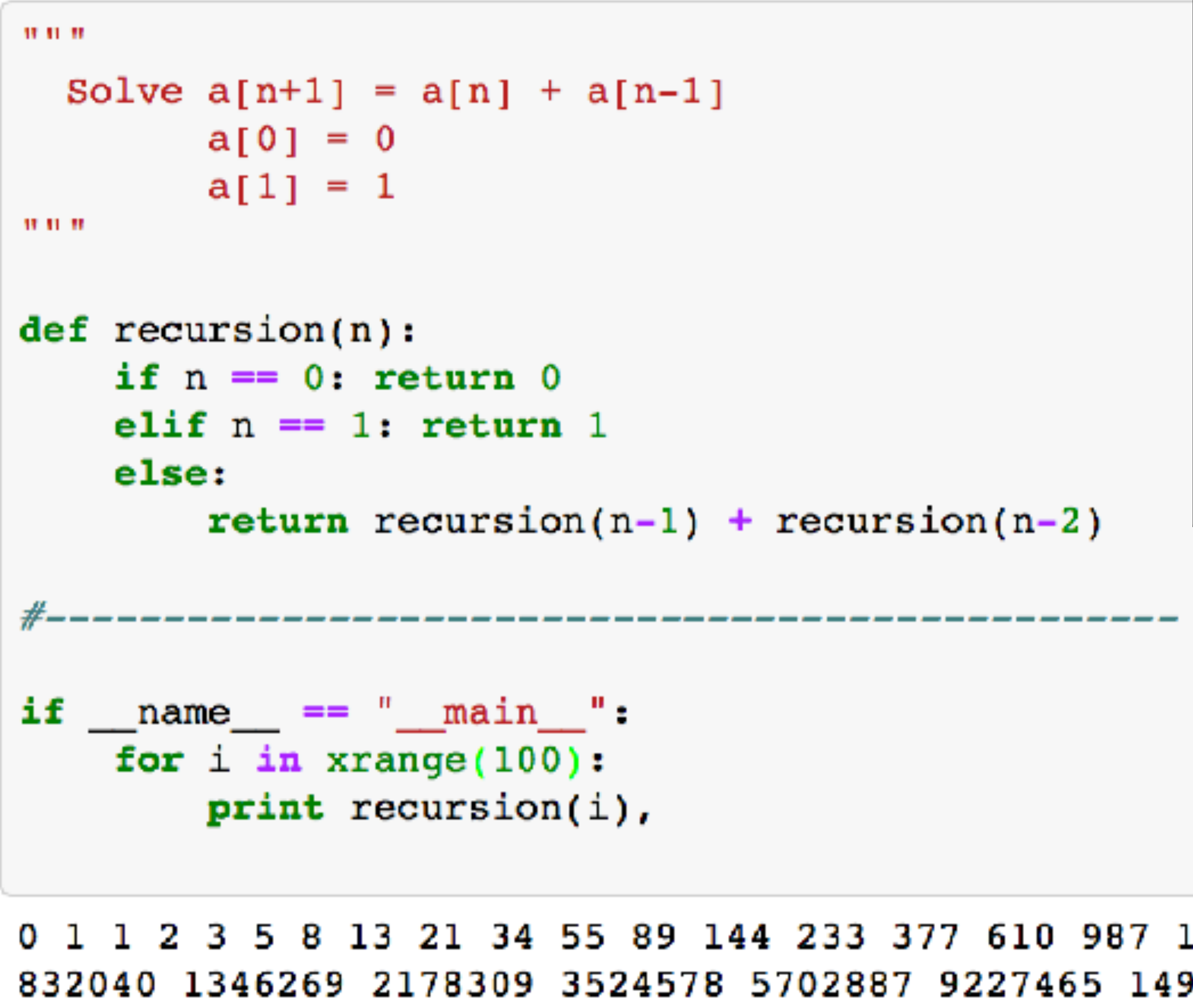


```python
def factorial(n):
    # assume n > 0
    if (n <= 1):
        return 1
    else:
        return n*factorial(n-1)
```

Use of Recursive Functions

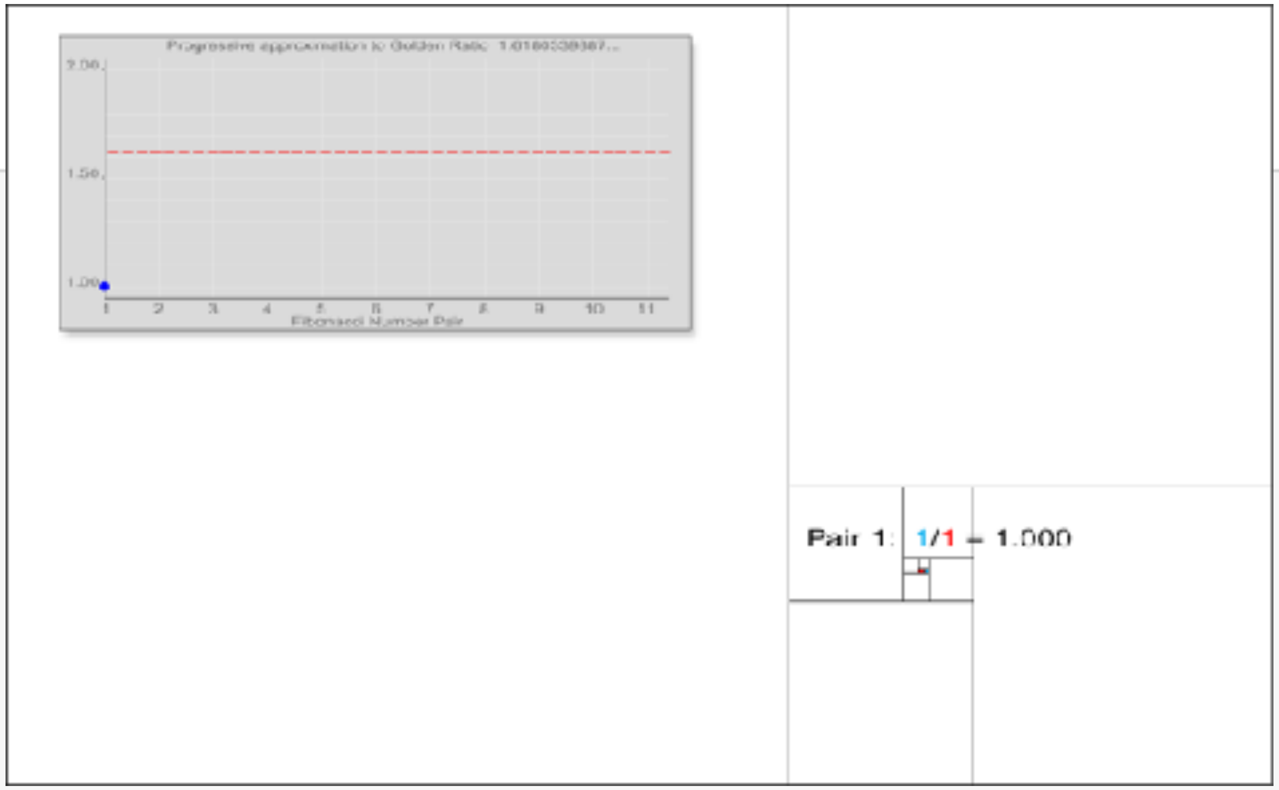
- Any problem where a subset has a similar structure to the whole
    - fractals
    - trees, binary trees, quad-trees, oct-trees
    - solution to recursions
        - a[n+1] = a[n] + a[n-1]
          a[0] = 0,   a[1] = 1
- Harder to program without recursion, although possible
- Use recursion if easier. If too slow, remove recursion at a later stage of development.

Fibonacci sequence

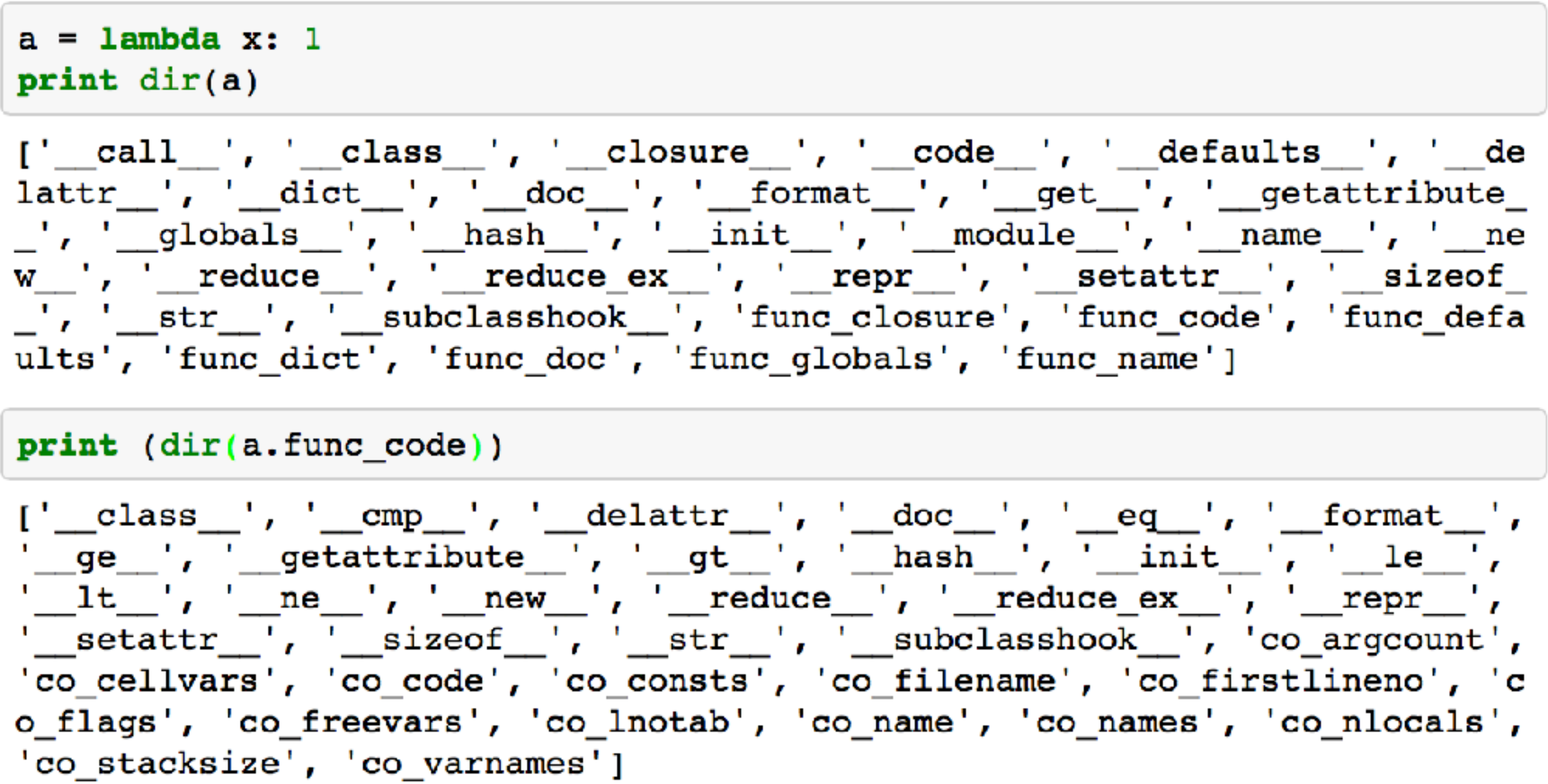


```
"""
  Solve a[n+1] = a[n] + a[n-1]
        a[0] = 0
        a[1] = 1
"""

def recursion(n):
    if n == 0: return 0
    elif n == 1: return 1
    else:
        return recursion(n-1) + recursion(n-2)

#-------------------------------------------------

if __name__ == "__main__":
    for i in xrange(100):
        print recursion(i),
```

```
0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597 2584 4181 6765 10946 17711 28657 46368 7502
832040 1346269 2178309 3524578 5702887 9227465 14930352 24157817 39088169 63245986
```



Function methods



```
a = lambda x: 1
print dir(a)
```

```
['__call__', '__class__', '__closure__', '__code__', '__defaults__', '__de
lattr__', '__dict__', '__doc__', '__format__', '__get__', '__getattribute_
_', '__globals__', '__hash__', '__init__', '__module__', '__name__', '__ne
w__', '__reduce__', '__reduce_ex__', '__repr__', '__setattr__', '__sizeof_
_', '__str__', '__subclasshook__', 'func_closure', 'func_code', 'func_defa
ults', 'func_dict', 'func_doc', 'func_globals', 'func_name']
```

```
print (dir(a.func_code))
```

```
['__class__', '__cmp__', '__delattr__', '__doc__', '__eq__', '__format__',
'__ge__', '__getattribute__', '__gt__', '__hash__', '__init__', '__le__',
'__lt__', '__ne__', '__new__', '__reduce__', '__reduce_ex__', '__repr__',
'__setattr__', '__sizeof__', '__str__', '__subclasshook__', 'co_argcount',
'co_cellvars', 'co_code', 'co_consts', 'co_filename', 'co_firstlineno', 'c
o_flags', 'co_freevars', 'co_lnotab', 'co_name', 'co_names', 'co_nlocals',
'co_stacksize', 'co_varnames']
```

Context

- All variables inside a function are local
- Global variables can be accessed but not changed except via the *global* declaration
  (the web: "If you want to simply access a global variable you just use its name. However to **change** its value you need to use the global keyword.")
- A global variable can be defined from within a function!

```
def example():
    global v
    v = 5

print v          # returns 5. Exception without global
```

```
total = 9
globvar = 11

def add(a, b):
    total = 3      # does not affect global variable
    return a+b+total+globvar

def add_glob(a, b):
    global total
    total = 3      # changes the global variable total
    return a+b+total

print add(3,5)        # returns 22 (3+5+3+11)
print total         # returns 9
print add_glob(3,5)  # returns 17
print total         # returns 3
```

Variable Types

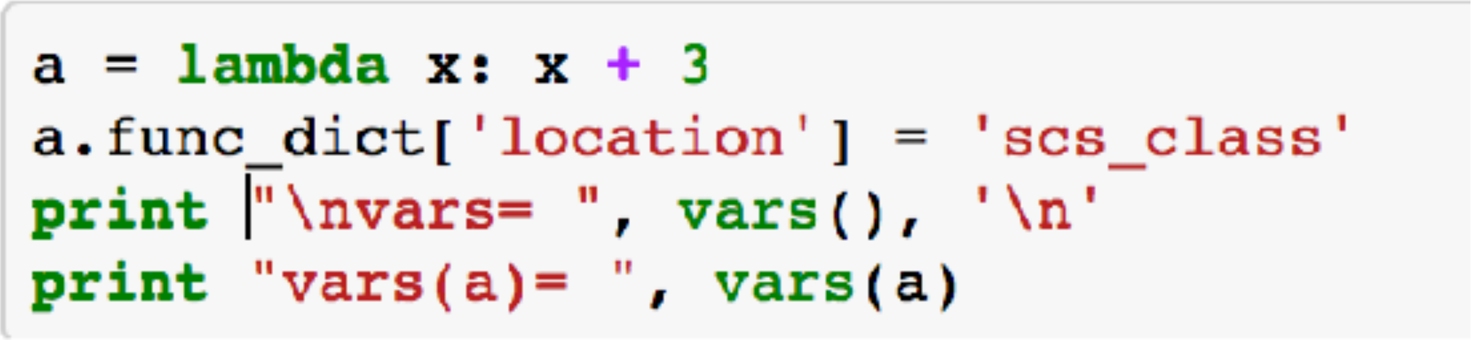
- locals() : local variables
- globals() : global variables
- vars(obj) : object dictionary
- vars() : same as locals()

```
total, newvar = 9, 11

def add(a, b):
    total = 3
    print "locals= ", locals()
    print "globals= ", globals()
    return a+b+total+newvar

def add_glob(a, b):
    global total
    total = 3  # changes the global total
    print "locals= ", locals()
    print "globals= ", globals()
    return a+b+total

add(3,4)
print "------------------------"
add_glob(3,4)
```

Output

```
locals=  {'a': 3, 'total': 3, 'b': 4}
globals=  {'add_glob': <function
add_glob at 0x379830>, '__builtins__':
<module '__builtin__' (built-in)>,
'__file__': 'context.py', '__package__':
None, 'add': <function add at
0x379870>, '__name__': '__main__',
'total': 9, 'newvar': 11, '__doc__': None}
------------------------
locals=  {'a': 3, 'b': 4}
globals=  {'add_glob': <function
add_glob at 0x379830>, '__builtins__':
<module '__builtin__' (built-in)>,
'__file__': 'context.py', '__package__':
None, 'add': <function add at
0x379870>, '__name__': '__main__',
'total': 3, 'newvar': 11, '__doc__': None}
```

vars()



```
a = lambda x: x + 3
a.func_dict['location'] = 'scs_class'
print "\nvars= ", vars(), '\n'
print "vars(a)= ", vars(a)
```

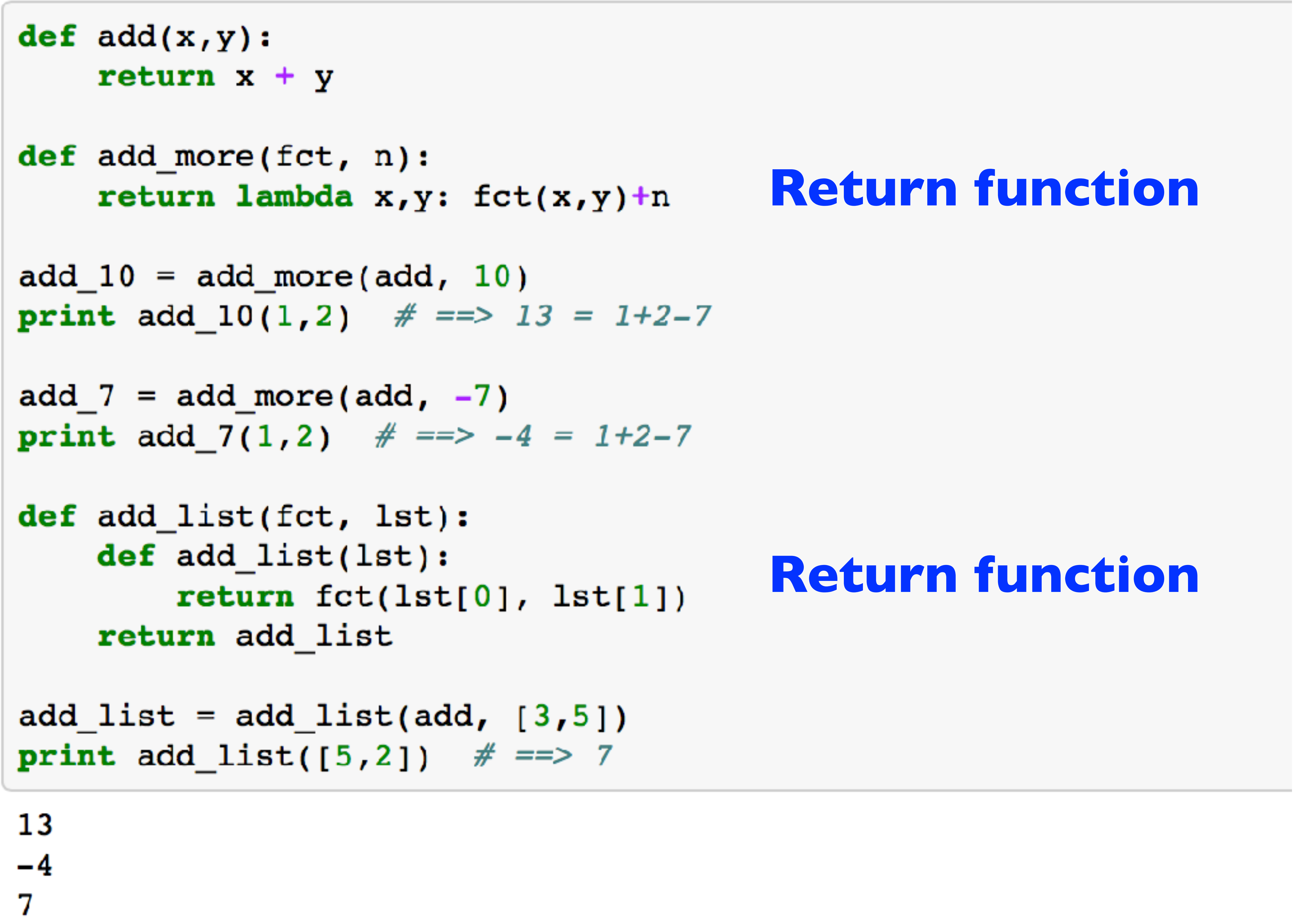
Output

python vars_demo.py

```
vars=  {'a': <function <lambda> at 0x1004d5848>, '__builtins__': <module
'__builtin__' (built-in)>, '__file__': 'temp.py', '__package__': None, '__name__':
'__main__', '__doc__': None}

vars(a)=  {'location': 'scs_class'}
```

Returning a function

- Very straightforward
- Function is a reference variable
- Given a function, one can find out how many arguments it has and other properties



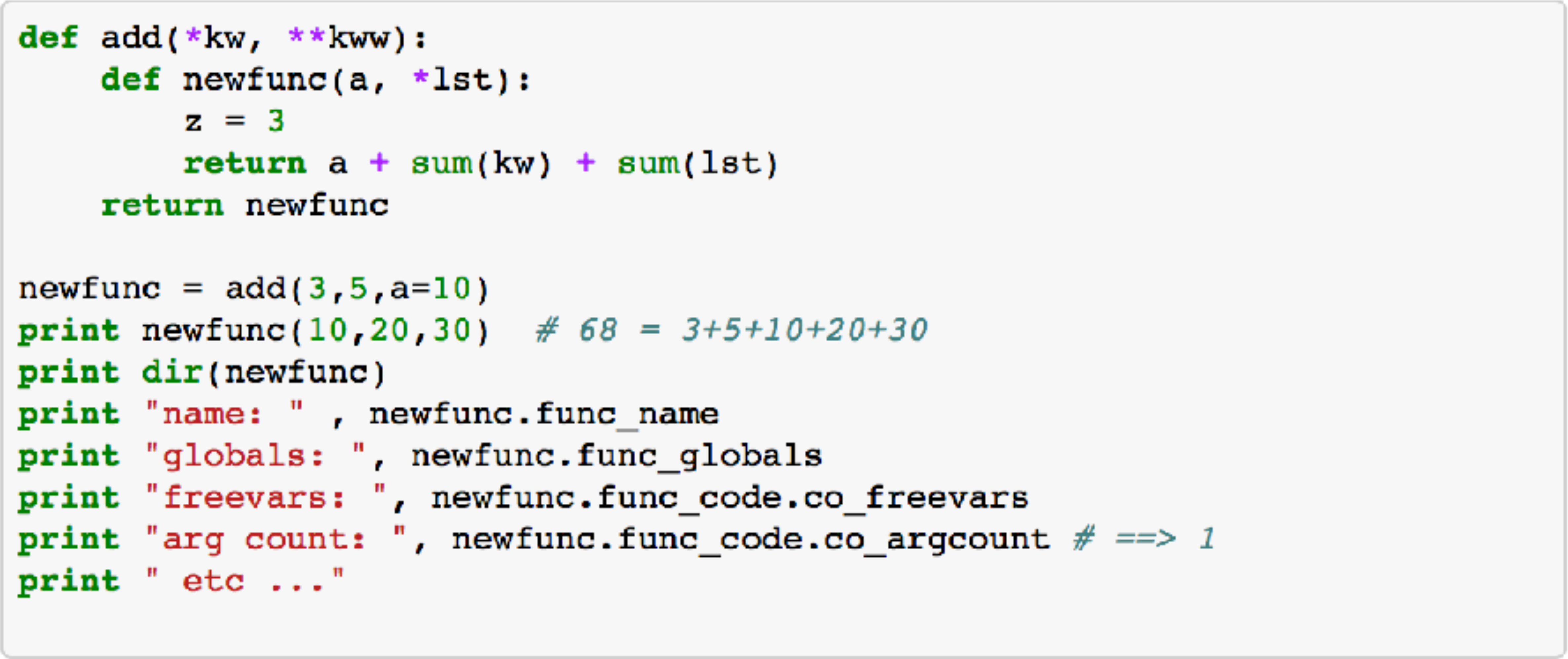
```python
def add(x,y):
    return x + y

def add_more(fct, n):
    return lambda x,y: fct(x,y)+n

add_10 = add_more(add, 10)
print add_10(1,2)  # ==> 13 = 1+2-7

add_7 = add_more(add, -7)
print add_7(1,2)  # ==> -4 = 1+2-7

def add_list(fct, lst):
    def add_list(lst):
        return fct(lst[0], lst[1])
    return add_list

add_list = add_list(add, [3,5])
print add_list([5,2])  # ==> 7
```

```
13
-4
7
```

Return function

Return function

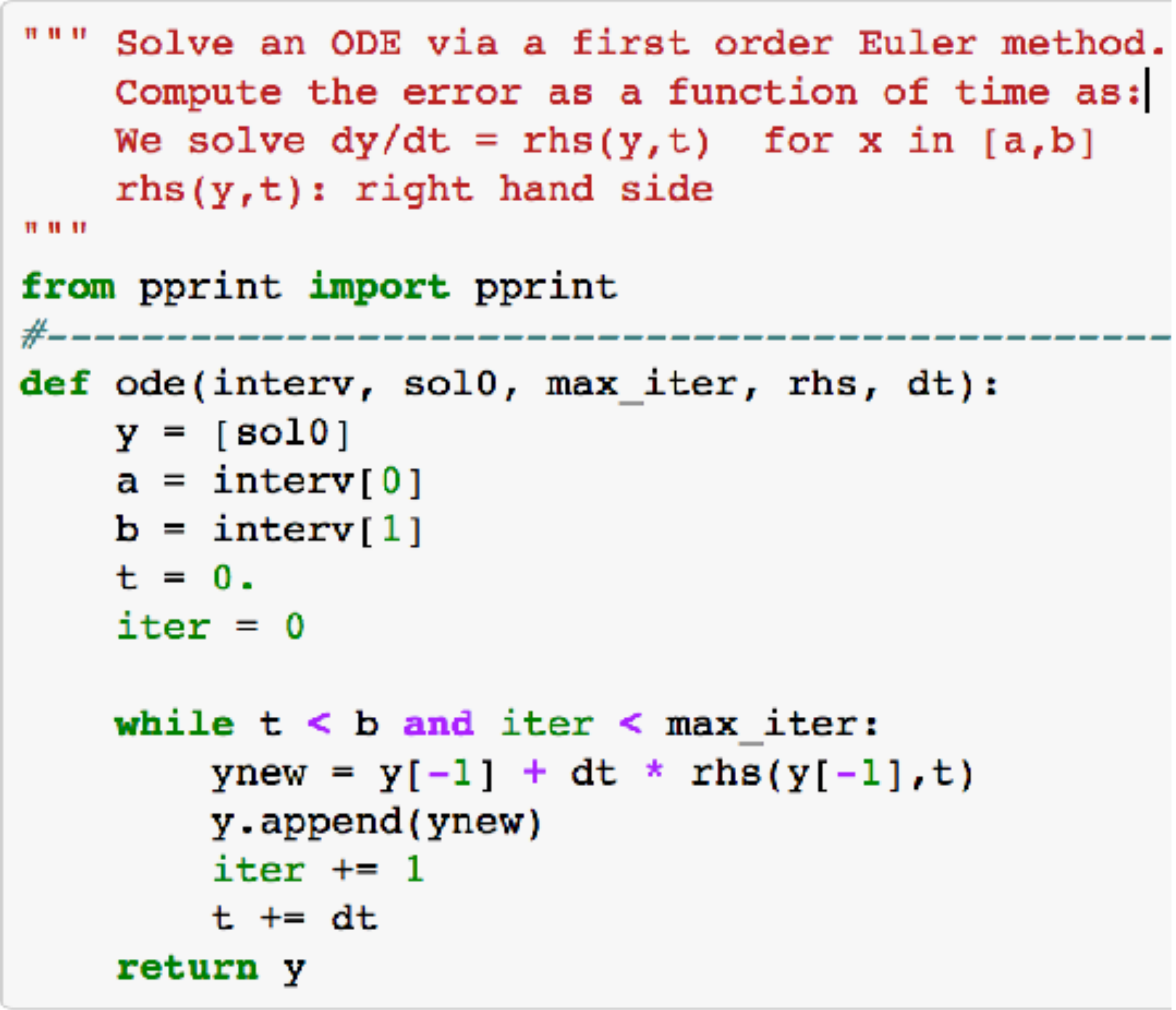
Function Properties



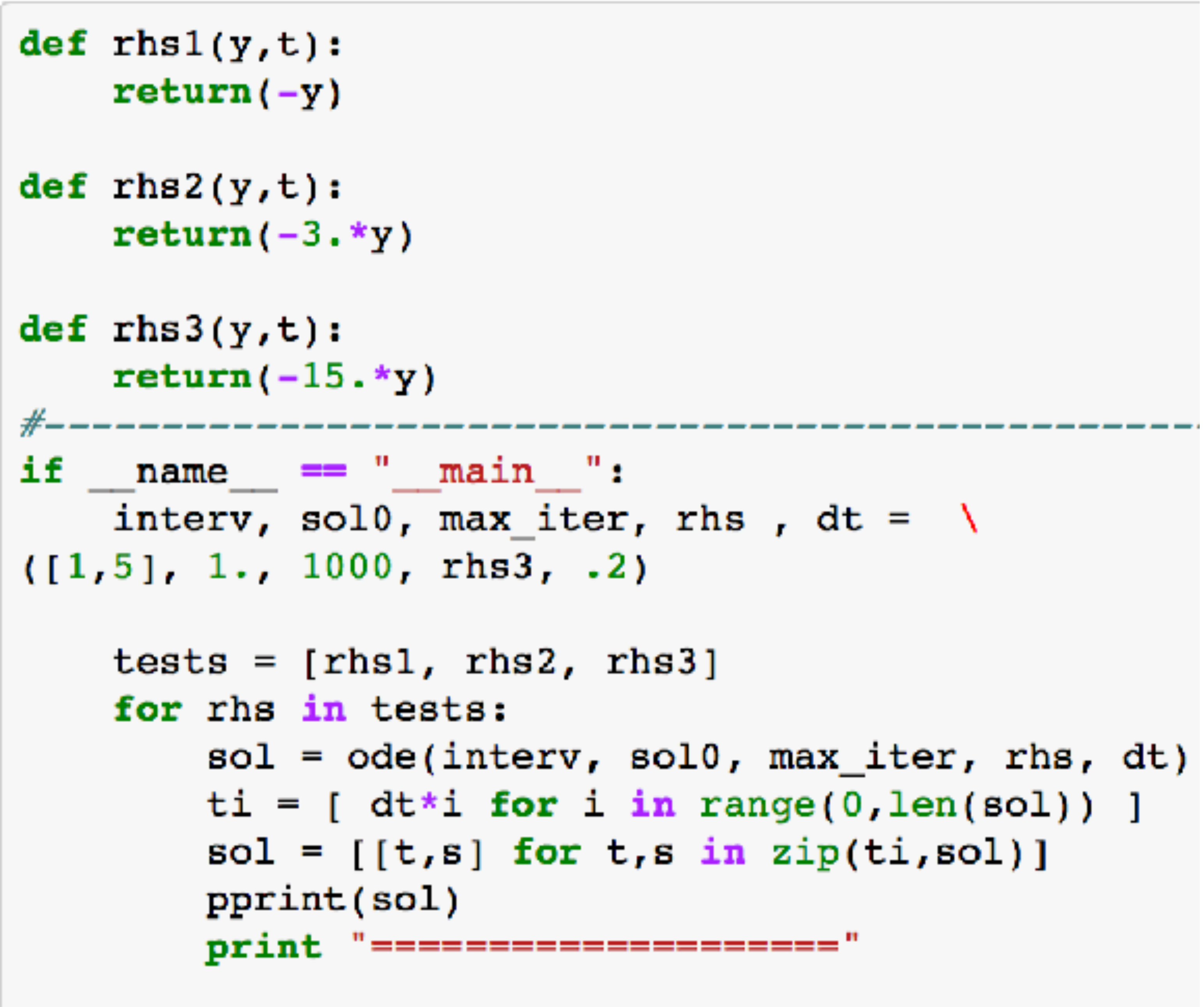
```
def add(*kw, **kww):
    def newfunc(a, *lst):
        z = 3
        return a + sum(kw) + sum(lst)
    return newfunc

newfunc = add(3,5,a=10)
print newfunc(10,20,30)  # 68 = 3+5+10+20+30
print dir(newfunc)
print "name: " , newfunc.func_name
print "globals: ", newfunc.func_globals
print "freevars: ", newfunc.func_code.co_freevars
print "arg count: ", newfunc.func_code.co_argcount # ==> 1
print " etc ..."
```

```
68
['__call__', '__class__', '__closure__', '__code__', '__defaults__', '__delattr__',
'__dict__', '__doc__', '__format__', '__get__', '__getattribute__', '__globals__',
'__hash__', '__init__', '__module__', '__name__', '__new__', '__reduce__',
'__reduce_ex__', '__repr__', '__setattr__', '__sizeof__', '__str__', '__subclasshook__',
'func_closure', 'func_code', 'func_defaults', 'func_dict', 'func_doc', 'func_globals',
'func_name']
name:  newfunc
globals:  {'__builtins__': <module '__builtin__' (built-in)>, '__file__': 'temp.py',
'__package__': None, 'add': <function add at 0x1006d5848>, '__name__': '__main__',
'__doc__': None, 'newfunc': <function newfunc at 0x1006d55f0>}
freevars:  ('kw',)
arg count:  1
 etc ...
```

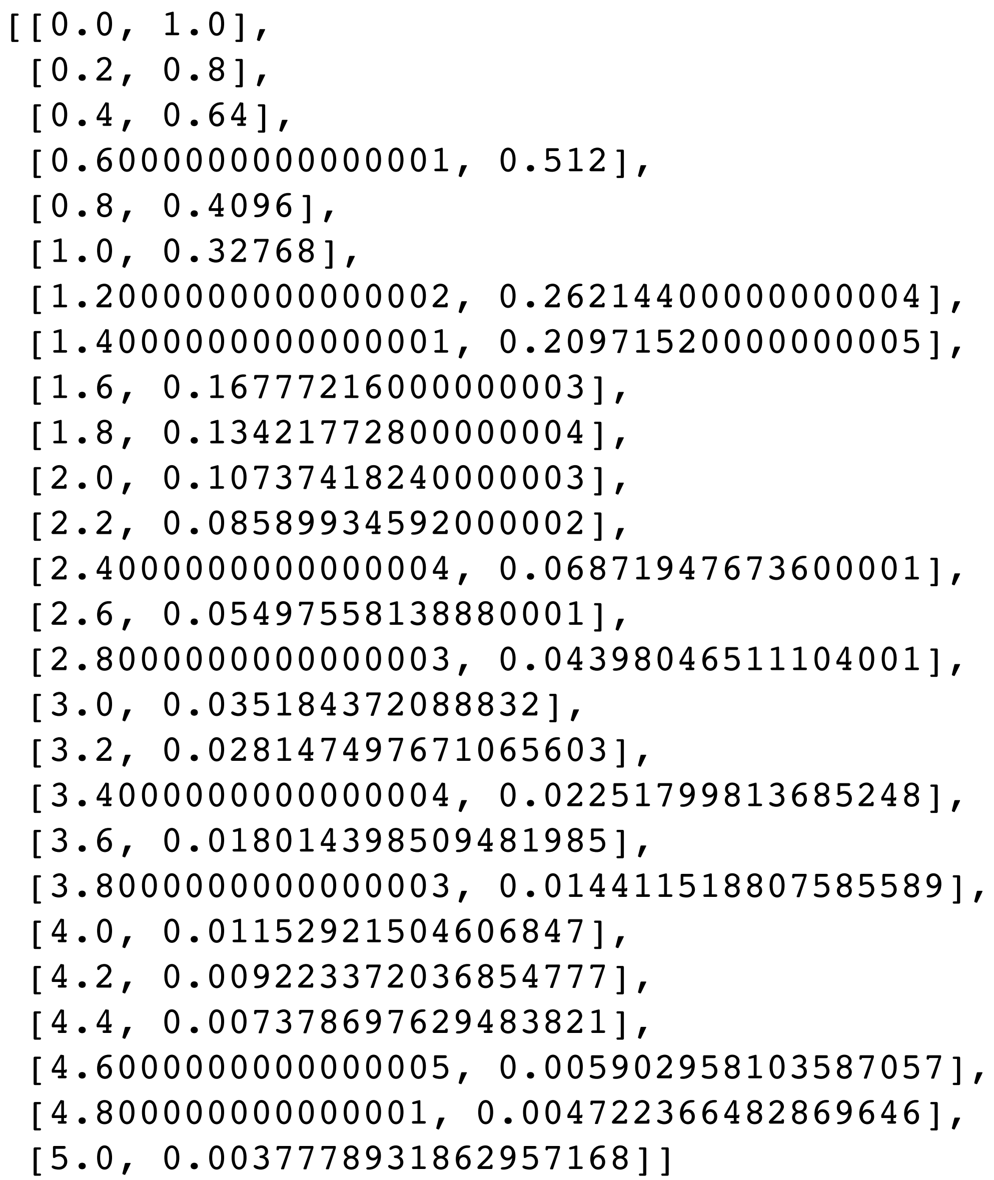
Example of callback function: First order Differential Equation



```
""" Solve an ODE via a first order Euler method.
    Compute the error as a function of time as:
    We solve dy/dt = rhs(y,t)  for x in [a,b]
    rhs(y,t): right hand side
"""
from pprint import pprint
#-----------------------------------------------
def ode(interv, sol0, max_iter, rhs, dt):
    y = [sol0]
    a = interv[0]
    b = interv[1]
    t = 0.
    iter = 0

    while t < b and iter < max_iter:
        ynew = y[-1] + dt * rhs(y[-1],t)
        y.append(ynew)
        iter += 1
        t += dt
    return y
```



```
def rhs1(y,t):
    return(-y)

def rhs2(y,t):
    return(-3.*y)

def rhs3(y,t):
    return(-15.*y)
#-----------------------------------------------------
if __name__ == "__main__":
    interv, sol0, max_iter, rhs , dt =  \
([1,5], 1., 1000, rhs3, .2)

    tests = [rhs1, rhs2, rhs3]
    for rhs in tests:
        sol = ode(interv, sol0, max_iter, rhs, dt)
        ti = [ dt*i for i in range(0,len(sol)) ]
        sol = [[t,s] for t,s in zip(ti,sol)]
        pprint(sol)
        print "===================="
```



```
[[0.0, 1.0],
 [0.2, 0.8],
 [0.4, 0.64],
 [0.6000000000000001, 0.512],
 [0.8, 0.4096],
 [1.0, 0.32768],
 [1.2000000000000002, 0.26214400000000004],
 [1.4000000000000001, 0.20971520000000005],
 [1.6, 0.16777216000000003],
 [1.8, 0.13421772800000004],
 [2.0, 0.10737418240000003],
 [2.2, 0.08589934592000002],
 [2.4000000000000004, 0.06871947673600001],
 [2.6, 0.05497558138880001],
 [2.8000000000000003, 0.04398046511104001],
 [3.0, 0.035184372088832],
 [3.2, 0.028147497671065603],
 [3.4000000000000004, 0.02251799813685248],
 [3.6, 0.018014398509481985],
 [3.8000000000000003, 0.014411518807585589],
 [4.0, 0.01152921504606847],
 [4.2, 0.009223372036854777],
 [4.4, 0.007378697629483821],
 [4.6000000000000005, 0.005902958103587057],
 [4.800000000000001, 0.004722366482869646],
 [5.0, 0.0037778931862957168]]
```