Functions

- functions
- return
- scoping
- arguments
- keyword arguments
- *, **
- global variables

(Simple) functions

- You can define your own functions using:

  `def` ***function-name*** **`(`** var_1, ..., var_k **`):`**
  body code

  var_1, ..., var_k are the *formal parameters*

- If the body code executes

  `return` *expression*

  the result of *expression* will be returned by the function. If expression is omitted or the body code terminates without performing `return`, then `None` is returned

- When *calling* a function ***name*** **`(`** ***value***$_1$**`,...,`** ***value***$_k$ **`)`** body code is executed with var_i=$value_i$

Python shell

```
> def sum3(x, y, z):
      return x + y + z

> sum3(1, 2, 3)
| 6
> sum3(5, 7, 9)
| 21

> def powers(L, power):
      P = [x**power for x in L]
      return P

> powers([2,3,4], 3)
| [8, 27, 64]
```

Questions – `poly(3, "10", '3')`?

```
def poly(z, x, y):
    return z * x + y
```

a) `33`

b) `1010103`

c) `'33'`

d) `'1010103'`

e) TypeError

f) Don’t know

Why functions ?

- Avoid writting the same code multiple times, *re-usability*
- Be able to *name a functionality*
- Clearly state the functionality of a piece of code, *abstraction*: *Input* = arguments, *output* = return value (and/or side effects)
- *Encapsulate* code with clear interface to the dependency to the outside world/code
- Share functionality in modules/libraries/packages with other users, *code sharing*
- Increase *readability* of code, smaller independent blocks of code
- Easier systematically *testing* of code
- ...

Some other Python language features helping structuring programs

- Object orientation
- Modules
- Decorators
- Context managers
- Exceptions
- Doc strings
- doctest

Local variables in functions

- The formal arguments and variables assigned to in the body of a function are created as temporary *local variables*

Global variables		Local variables	
sum3	<function>	x	4
a	3	y	5
y	42	z	6
		a	9
		b	15

state just before `return b`

Python shell

```
> def sum3(x, y, z):
      a = x + y
      b = a + z
      return b

> a = 3
> y = 42
> w = sum3(4, 5, 6)
> w
| 15
> a
| 3
> b
| NameError: name 'b' is not defined
> x
| NameError: name 'x' is not defined
> y
| 42
> sum3
| <function sum3 at 0x0356DA98>
```

Global variables

- Variables in function bodies that are only read, are considered access to *global variables*

```
Python shell
> prefix = "The value is"
> def nice_print(x):
      print(prefix, x)
> nice_print(7)
| The value is 7
> prefix = "Value ="
> nice_print(42)
| Value = 42
```

Global variables		Local variables	
nice_print	<function>	x	42
prefix	"Value ="		

state just before returning from 2nd `nice_print`

Global vs local variables

- If a function contains an assignment to a variable, the variable is local throughout the function – also before the first assignment

Python shell

```
> x = 42
> def f():
      print(x)   # refers to local variable
      x = 7      # x declared local variable
> f()
| UnboundLocalError: local variable 'x' referenced before assignment
```

global

- Global variables that should be updated in the function body must be declared global in the body:

  `global` *variable*, *variable*, ...

- Note: If you only need to read a global variable, it is not required to be declared global (but would be polite to the readers of your code)

Since `counter` assigned in body, `counter` will be considered to be a local variable

Python shell

```
> counter = 1

> def counted_print(x):
      global counter
      print(f'({counter}) {x}')
      counter += 1

> counted_print(7)
| (1) 7
> counted_print(42)
| (2) 42

> def counted_print(x):
      print(f'({counter}) {x}')
      counter += 1

> counted_print(7)
| UnboundLocalError: local variable
  'counter' referenced before
  assignment
```

Question – What value is printed ?

```
x = 1
def f(a):
    global x
    x = x + 1
    return a + x
print(f(2) + f(4))
```

a) 6
b) 7
c) 8
d) 9
e) 10

f) 11
g) 12
h) Don’t know

Arbitrary number of arguments

- If you would like your function to be able to take a variable number of additional arguments in addition to the required, add a **variable* as the last argument
- In a function call *variable* will be assigned a tuple with all the additional arguments

Python shell

```
> def my_print(x, y, *L):
      print("x =", x)
      print("y =", y)
      print("L =", L)

> my_print(2, 3, 4, 5, 6, 7)
| x = 2
| y = 3
| L = (4, 5, 6, 7)
> my_print(42)
| TypeError: my_print() missing 1
  required positional argument: 'y'
```

Unpacking a list of arguments in a function call

- If you have list `L` (or tuple) containing the arguments to a *function call*, you can unpack them in the function call using `*L`

```
L = [x, y, z]
f(*L)
```

is equivalent to calling

```
f(L[0], L[1], L[2])
```

i.e.

```
f(x, y, z)
```

- Note that `f(L)` would pass a single argument to `f`, namely a list
- In a function call several `*` expressions can appear, e.g. `f(*L1, x, *L2, *L3)`

Python shell

```
> import math
> def norm(x, y):
      return math.sqrt(x * x + y * y)
> norm(3, 5)
| 5.830951894845301
> point = (3, 4)
> print(*point, sep=':')
| 3:4
> norm(point)
| TypeError: norm() missing 1 required positional argument: 'y'
> norm(*point)
| 5.0
> def dist(x0, y0, x1, y1):
       return math.sqrt((x1 - x0) ** 2 + (y1 - y0) ** 2)
> p = 3, 7
> q = 7, 4
> dist(p, q)
| TypeError: dist() missing 2 required positional arguments: 'x1' and 'y1'
> dist(*p, *q)
| 5.0
```

Question – How many arguments should `f` take ?

```
a = [1, 2, 3]
b = [4, 5]
c = (6, 7, 8)
d = (9, 10)
f(*a, b, c, *d)
```

a) 4
b) 5
c) 6

d) 7
e) 8
f) 9
g) 10
h) Don’t know

Question – What is `list(zip(*zip(*L)))` ?

```
L = [[1, 2, 3], [4, 5], [6, 7, 8]]
```

a) `[(([1, 2, 3],),), (([4, 5],),), (([6, 7, 8],),)]`

b) `[((1, 4, 6),), ((2, 5, 7),)]`

c) `[(1, 2), (4, 5), (6, 7)]`

d) `[(1, 2, 3), (4, 5), (6, 7, 8)]`

e) `[([1, 2, 3], [4, 5], [6, 7, 8])]`

f) Don't know

Python shell

```
> list(zip((1, 2, 3), (4, 5, 6)))
| [(1, 4), (2, 5), (3, 6)]
```

Keyword arguments

- Previously we have seen the following (strange) function calls

```
print(7, 14, 15, sep=":", end="")
enumerate(my_list, start=1)
```

- *name=* refers to one of the formal arguments, known as a keyword argument
- A *name* can appear at most once in a function call
- In function calls keyword arguments must follow positional arguments
- Improves readability when arguments have non-obvious order

```
complicated_function(
    name="Mickey",
    city="Duckburg",
    state="Calisota",
    occupation="Detective",
    gender="Male"
)
```

Python shell

```
> def sub(x, y):
      return x - y

> sub(9, 4)
| 5
> sub(y=9, x=4)
| -5
```

Keyword arguments, default values

- When calling a function arguments can be ommitted if the corresponding arguments in the function definition have default values *argument=value*
- Arguments with default values must be after those without

Python shell

```
> def my_print(a, b, c=5, d=7):
      print(f'{a=} {b=} {c=} {d=}')

> my_print(2, d=3, b=4)
| a=2, b=4, c=5, d=3
```

Question – What is `f(6, z=2)` ?

```
def f(x, y=3, z=7):
    return x + y + z
```

a) `10`

b) `11`

c) `16`

d) `TypeError: f() missing 1 required positional argument: 'y'`

e) Don’t know

Keyword arguments, mutable default values 

- Be carefull: Default value will be shared among calls (which can be usefull)

The Python Language Reference
8.7 Function definitions

"**Default parameter values are evaluated from left to right when the function definition is executed**. This means that the expression is evaluated once, when the function is defined, and that the same "pre-computed" value is used for each call. This is especially important to understand when a default parameter is a mutable object, such as a list or a dictionary: if the function modifies the object (e.g. by appending an item to a list), the default value is in effect modified. This is generally not what was intended. A way around this is to use None as the default"

Python shell

```
> def list_append(e, L=[]):
      L.append(e)
      return L
> list_append('x', ['y', 'z'])
| ['y', 'z', 'x']
> list_append("a")
| ['a']
> list_append("b")
| ['a', 'b']
> list_append("c")
| ['a', 'b', 'c']
```

Python shell

```
> def list_append(e, L=None):
      if L == None:
          L = []
      L.append(e)
      return L
> list_append('x', ['y', 'z'])
| ['y', 'z', 'x']
> list_append("a")
| ['a']
> list_append("b")
| ['b']
> list_append("c")
| ['c']
```

Function call, dictionary of keyword arguments

- If you happen to have a *dictionary* containing the keyword arguments you want to pass to function, you can give all dictionary items as arguments using the single argument ***dictionary*

Python shell

```
> print(3, 4, 5, sep=":", end='#\n')
| 3:4:5#
> print_kwarg = {'sep': ':', 'end': '#\n'}
> print(3, 4, 5, **print_kwarg)
| 3:4:5#
```

Function definition, arbitrary keyword arguments

- If you want a function to accept arbitrary keyword arguments, add an argument ***argument* to the function definition
- When the function is called *argument* will be assigned a dictionary containing the excess keyword arguments

Python shell

```
> def my_print(a, b=3, **c):
        print("a =", a)
        print("b =", b)
        print("c =", c)

> my_print(x=27, y=42, a=7)
| a = 7
| b = 3
| c = {'x': 27, 'y': 42}
```

Example

Python shell

```
> L1 = [1, 'a']
> L2 = ['b', 2, 3]
> D1 = {'y':4, 's':10}
> D2 = {'t':11, 'z':5.0}

> def f(a, b, c, d, e, *f, q=0, x=1, y=2, z=3, **kw):
      print(f"{a=}, {b=}, {c=}, {d=}, {e=}, {f=}\n"
            f"{q=}, {x=}, {y=}, {z=}, {kw=}")
> f(7, *L1, 9, *L2, x=7, **D1, w=42, **D2)
| a=7, b=1, c=a, d=9, e=b, f=(2, 3)
| q=0, x=7, y=4, z=5.0, kw={'w': 42, 's': 10, 't': 11}
```

non-keyword arguments must appear before keyword arguments

all arguments must have distinct names

A confusing example

Python shell

```
> def f(*a, **kw):
      print(f'{a=} {kw=}')

> f(a=42)   # no positional arguments
| a=() kw={'a': 42}
```

Forwarding function arguments

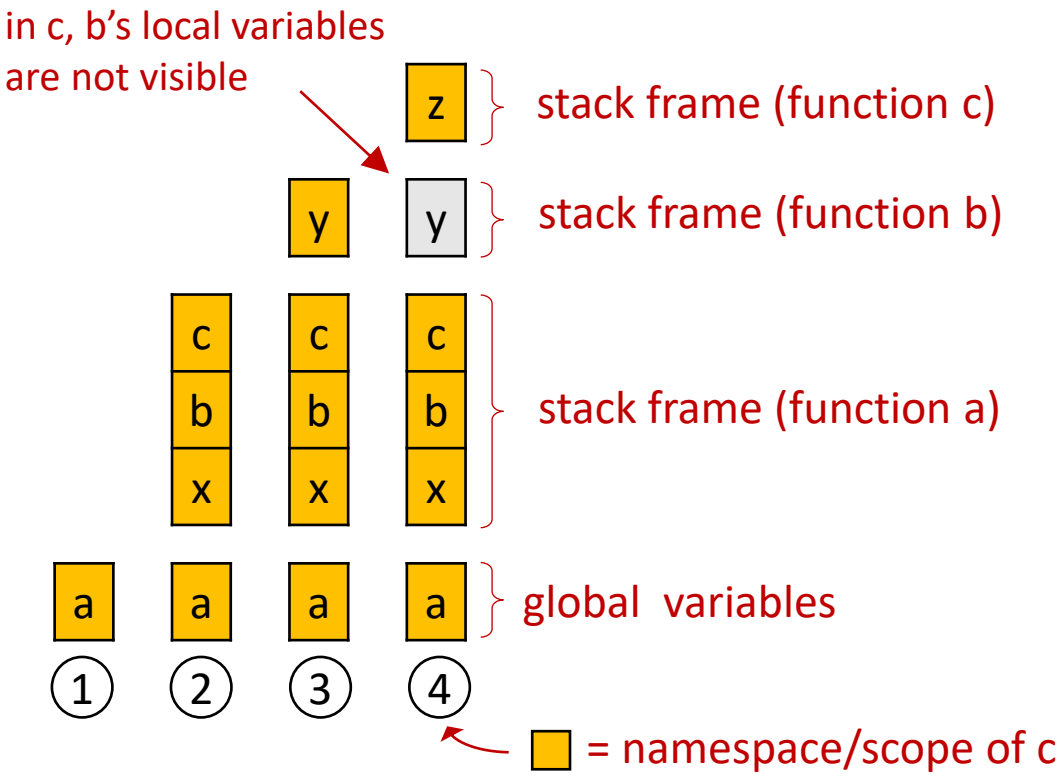
- * and ** can e.g. be used to forward (unknown) arguments to other function calls

Python shell

```
> def my_print(*positional_arguments, sep=":", **keyword_arguments):
      print(*positional_arguments, sep=sep, **keyword_arguments)
> my_print(7, 42)
| 7:42
> my_print("x", "y", end="<")
| x:y<
> my_print("x", "y", sep="_")
| x_y
```

Local function definitions and namespaces

- Function definitions can contain (nested) local function definitions, only accessable inside the function
- *static/lexical scoping*, i.e. can see from the code which variables are in scope



Python shell

```
> def a(x):
      def b(y):
          print(f'b: {y=} {x=}')
          c(y + 1)
      def c(z):
          print(f'c: {z=} {x=}')
      print(f'a: {x=}')
      b(x + 1)
> a(42)
| a: x=42
| b: y=43 x=42
| c: z=44 x=42
```

3 4 2 1

Example – nested function definitions

Python shell

```
> def a(x):
      def b(y):
          print(f'Enter b ({y=}, {x=})')
          c(y + 1)
          print('leaving b')
      def c(x):  # x hides argument of function a
          def d(z):
              print(f'Enter d ({z=}, {x=})')
              print('leaving d')
          print(f'Enter c ({x=})')
          d(x + 1)
          print('leaving c')
      print(f'Enter a ({x=})')
      b(x + 1)
      print('leaving a')
```

```
> a(5)
| Enter a (x=5)
| Enter b (y=6, x=5)
| Enter c (x=7)
| Enter d (z=8, x=7)
| leaving d
| leaving c
| leaving b
| leaving a
```

Functions must be defined before you can call them…

Python shell

```
> f()
| NameError: name 'f' is not defined
> def f():
      print('Hi')
> f()
| Hi
> def f():
      g()  # g not yet defined locally
      def g():
          print('Howdy')
> f()
| UnboundLocalError: cannot access local variable 'g' where it is not associated with a value
> def f():
      def g():
          print('Howdy')
      g()
> f()
| Howdy
```

Example – nested functions and default values

Python shell

```
> def init_none(var_name):
>     print('initializing', var_name)
>     return None  # redundant line
> def f(a=init_none('a')):
>     def g(b=init_none('b')):
>         print('b =', b)
>     print("a =", a)
>     g(a + 1)
| initializing a
> f(10)
| initializing b
| a = 10
| b = 11
```

nonlocal

- The keyword `nonlocal` makes local identifiers refer to previously bound variables in the nearest *enclosing scope excluding globals*

- `nonlocal` *variable*, *variable*, ...

Python shell

```
> x = 0

> def f():
      y = 1
      def f_helper(z):
          global x
          nonlocal y
          print(f'({x}:{y}) {z}')
          y += 1
          x += 3
      f_helper(7)
      f_helper(42)

> f()
| (0:1) 7
| (3:2) 42
> f()
| (6:1) 7
| (9:2) 42
```

docs.python.org/3/reference/simple_stmts.html#the-nonlocal-statement

Positional and keyword only arguments

- A function definition can contain / and * as arguments
- Arguments before / must be provided as positional arguments in a call
- Arguments after * cannot be positional arguments

Python shell

```
> def f(a, /, b, *, c):
      print(a, b, c)

> f(a=1, b=2, c=3)
| TypeError: f() got some positional-only arguments passed as keyword arguments: 'a'
> f(1, b=2, c=3)
| 1 2 3
> f(1, 2, c=3)
| 1 2 3
> f(1, 2, 3)
| TypeError: f() takes 2 positional arguments but 3 were given
```

A note on Python and functions

- Similarities between Python and other languages:
  - functions are widely supported (sometimes called methods and procedures)
  - scoping rules is present in many languages (but details differ)
- Python specific (but nice):
  - how to handle global, local and nonlocal variables
  - keyword arguments
  - *, **