Defining Python Functions

- Python functions can be defined, like C, with a fixed number of parameters

```python
def polly(x, a, b, c):
    return a * x ** 2 + b * x + c
```

- functions can be called, like C, with positional arguments

```python
>>> polly(3, 5, -3, 6)
42
```

- or with keyword arguments

```python
>>> polly(a=5, c=6, b=-3, x=3)
42
```

Or with both positional and keyword arguments (keyword must follow positional)

```python
>>> polly(3, c=6, b=-3, a=5)
42
```

- functions can restrict how they are called using special arguments / and *

Default Values for Function Arguments

- default values can be specified for function parameters

```python
def polly(x, a=1, b=2, c=0):
    return a * x ** 2 + b * x + c
```

- allowing functions to be called without specifying all parameters

```python
>>> polly(3)
15
>>> polly(b=1, x=1)
2
```

- convenient consequence - you can add an extra parameter to a function, without changing existing calls, by giving the parameter a default value
Mutable Default Parameter values are Dangerous

- the default value is a single instance
- safe for immutable types: numbers, strings, ...
- unexpected results from mutable types: lists, dicts, ...
  - common bug in Python programs
  - can be used deliberately

```python
def append_one(x = []):
    x.append(1)
    return x
```

```bash
>>> append_one()
[1]
>>> append_one()
[1, 1]
>>> append_one()
[1, 1, 1]
```

Mutable Default values - workaround

```python
def append_one(x = None):
    if x is None:
        x = []
        x.append(1)
    return x
```

```bash
>>> append_one()
[1]
>>> append_one()
[1]
>>> append_one()
[1]
```

Mutable Default values - workaround

```python
def append_one(x = None):
    if x is None:
        x = []
        x.append(1)
    return x
```

```bash
>>> append_one()
[1]
>>> append_one()
[1]
>>> append_one()
[1]
```
Variable Numbers of Function Arguments

- packing/unpacking operators * and ** allow variable number of arguments.
  - Use * to pack positional arguments into tuple
  - Use ** to pack keyword arguments into dict

```python
def f(*args, **kwargs):
    print('positional arguments:', args)
    print('keywords arguments:', kwargs)

>>> f("COMP", 2041, 9044, answer=42, option=False)
positional arguments: ('COMP', 2041, 9044)
keywords arguments: {'answer': 42, 'option': False}
```

Packing Function Arguments

- * and ** can be used in reverse for function calls
  - Use * to unpack iterable (e.g. list or tuple) into positional arguments
  - Use ** to unpack dict into keyword arguments

```python
>>> arguments = ['Hello', 'there', 'Andrew']
>>> keyword_argments = {'end' : '!!!\n', 'sep': ' --- '}
>>> print(arguments, keyword_argments)
['Hello', 'there', 'Andrew'] {'end': '!!!\n', 'sep': ' --- '}
>>> print(*arguments, **keyword_argments)
Hello --- there --- Andrew!!!
```

No main function

- Python has no special “main” function called to started execution (unlike e.g C)
  - importing a file executes any code in it
  - special global variable __name__ set to module name during import
  - if a file is executed rather than imported, __name__ set to special value __main__
  - so can call a function when a file is executed like this

```python
if __name__ == '__main__':
    initial_function()
```
docstrings

- A Python Docstring is a string specified as first statement of function
- use """" triple-quotes

```python
def polly(x, a, b, c):
    """calculate quadratic polynomial"""
    return a * x ** 2 + b * x + c
```

- provides documentation to human readers but also available for automated tools

```python
>>> polly.__doc__
'calculate quadratic polynomial'
```

variable scope

- a variable assigned a value in a function is by default *local* to the function
- a variable not assigned a value in a function is by default *global* to entire program
- keyword `global` can be used to make variable global

```python
def a():
    x = 1
    print('{a}', x, y, z)
def b():
    x = 2
    y = 2
    a()
    print('{b}', x, y, z)
def c():
    x = 3
    y = 3
    global z
    z = 3
    b()
    print('{c}', x, y, z)
```

```python
>>> x = 4
>>> y = 4
>>> z = 4
>>> c()
a 1 4 3
b 2 2 3
c 3 3 3
```
List Comprehensions

- List comprehensions can be used to create lists (iterables) concisely.
- In simple cases, they are more readable than for loops or higher-order functions.
- They can be written as: `expression for value in iterable`

```python
>>> [x**3 for x in range(10)]
[0, 1, 8, 27, 64, 125, 216, 343, 512, 729]
>>> [str(round(math.pi, digits)) for digits in range(1,7)]
```
- They can be written as: `expression for value in iterable if expression2`

```python
>>> [x**3 for x in range(10) if x % 2 == 1]
[1, 27, 125, 343, 729]
```
- list comprehensions can be nested but this may less readable than use of loops

---

Lambda - create a small anonymous function

- The keyword `lambda` provides creation of small anonymous functions
- `lambda` is useful for *higher-order programming* - passing functions to other functions.
- `lambda` allows the creation of a function within an expression.

```python
>>> f = lambda x: x + 42
>>> type(f)
<class 'function'>
>>> f(12)
54
```
- `lambda` function body must be a single expression
  - function body can not contain statements such as `while, return`
  - better to define a named function if body is complex

---

Lambda - variable binding

Beware variables in the lambda expression are bound when the lambda is evaluated, not when it is created.

```python
>>> answer = 42
>>> f = lambda x: x + answer
>>> answer = 15
>>> f(12)
27
```
- Ugly workaround: make the variable the default value of a keyword argument.

```python
>>> answer = 42
>>> f = lambda x, y=answer: x + y
>>> answer = 34
>>> f(12)
47
```
**enumerate - built-in function**

`enumerate` returns tuples pairing a count with members of an iterable such as a list.

```python
def my_enumerate(sequence, start=0):
    """return a list equivalent to the iterator returned
    by built-in function enumerate
    """
    n = start
tuples = []
    for element in sequence:
        t = (n, element)
tuples.append(t)
        n += 1
    return tuples
```

`enumerate` is demonstrated in the following example:

```python
>>> languages = ['C', 'Python', 'Shell', 'Rust']
>>> list(enumerate(languages))
[(0, 'C'), (1, 'Python'), (2, 'Shell'), (3, 'Rust')]
>>> list(enumerate(languages, start=42))
[(42, 'C'), (43, 'Python'), (44, 'Shell'), (45, 'Rust')]
```

---

**zip - built-in function**

`zip` returns tuples formed from corresponding members of iterables such as lists.

```python
def my_zip2(sequence1, sequence2):
    """return a list equivalent to the iterator returned by
    built-in function zip called with 2 sequences.
    Note: zip can be given any number of sequences."""
    tuples = []
    for index in range(min(len(sequence1), len(sequence2))):
        t = (sequence1[index], sequence2[index])
tuples.append(t)
    return tuples
```

`zip` is demonstrated in the following example:

```python
>>> editors = ['vi', 'emacs', 'atom', 'VScode', 'nano']
>>> list(zip(editors, languages))
[('vi', 'C'), ('emacs', 'Python'), ('atom', 'Shell'), ('VScode', 'Rust')]
```

---

**list comprehension + zip example**

```python
def dot_product0(a, b):
    """return dot product of 2 lists - using for loop + indexing""
    total = 0
    for i in range(len(a)):
        total += a[i] * b[i]
    return total
```

```python
def dot_product2(a, b):
    """return dot product of 2 lists - using for loop + zip""
    total = 0
    for x, y in zip(a, b):
        total += x * y
    return total
```

---
list comprehension example

```python
def is_odd(number):
    return number % 2 == 2
def odd0(numbers):
    '''extract odd_numbers from list using for loop'''
    odd_numbers = []
    for n in numbers:
        if is_odd(n):
            odd_numbers.append(n)
    return odd_numbers
def odd1(numbers):
    '''extract odd_numbers from list using list comprehension'''
    return [n for n in numbers if is_odd(n)]
```

source code for odd_numbers.py

map - builtin function

map calls a function with argument(s) taken from iterable(s) such as list(s) and returns the functions return values

```python
>>> list(map(str, range(10)))
['0', '1', '2', '3', '4', '5', '6', '7', '8', '9']
>>> list(map(lambda x: x**3, range(10)))
[0, 1, 8, 27, 64, 125, 216, 343, 512, 729]
>>> list(map(lambda x, y: x**y, range(10), range(10)))
[1, 1, 4, 27, 256, 3125, 46656, 823543, 16777216, 387420489]
```

```python
def my_map1(function, sequence):
    '''return a list equivalent to the iterator returned by
    builtin function map called with 1 sequence.
    Note: map can be given more than 1 sequences.'''
    results = []
    for value in sequence:
        result = function(value)
        results.append(result)
    return results
```

source code for builtin.py

list comprehension + zip example

```python
def multiply(x, y):
    '''multiply 2 numbers - operator.mul does this'''
    return x * y
def dot_product4(a, b):
    '''return dot product of 2 lists - map'''
    return sum(map(multiply, a, b))
def dot_product5(a, b):
    '''return dot product of 2 lists - map + lambda'''
    return sum(map(lambda x, y: x * y, a, b))
def dot_product6(a, b):
    '''return dot product of 2 lists - map + operator.mul'''
    return sum(map(operator.mul, a, b))
```

source code for dot_product.py
filter - built-in function

filter returns the elements of an iterable(s) such as list for which the supplied function returns true.

```python
>>> list(filter(lambda x: x % 2 == 0, range(10)))
[0, 2, 4, 6, 8]
```

def my_filter(function, sequence):
    """return a list equivalent to the iterator returned by built-in function filter called with a function.
    Note: filter can be given None instead of a function.""
    filtered = []
    for value in sequence:
        if function(value):
            filtered.append(value)
    return filtered
```

source code for `builtin.py`

filter + lambda example

def is_odd(number):
    return number % 2 == 2

def odd2(numbers):
    """extract odd_numbers from list using filter""
    return filter(is_odd, numbers)

def odd3(numbers):
    """extract odd numbers from list using filter + lambda""
    return filter(lambda n: n % 2 == 2, numbers)
```

source code for `odd_numbers.py`

sorted + lambda example

DAY_LIST = "Sunday Monday Tuesday Wednesday Thursday Friday Saturday".split()
DAY_NUMBER = dict((day, number) for number, day in enumerate(DAY_LIST))

def random_day_of_week():
    return random.choice(DAY_LIST)

def sort_days0(day_list):
    return sorted(day_list, key=lambda day: DAY_NUMBER[day])

def sort_days1(day_list):
    return sorted(day_list, key=DAY_NUMBER.get)
```

source code for `sort_days.py`
The **functools** module provides more functions for higher-order programming, e.g.

```python
>>> # sum first 10 positive integers
>>> functools.reduce(operator.add, range(1, 10))
45
>>> # multiply first 10 positive integers
>>> functools.reduce(operator.mul, range(1, 10))
362880
```

The **itertools** module provides functions for combining and constructing **iterators** allowing efficient handling of arbitrarily long sequences.