Ghent University
Faculty of Sciences

Python Programming

list comprehensions and modules

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@dawyndt

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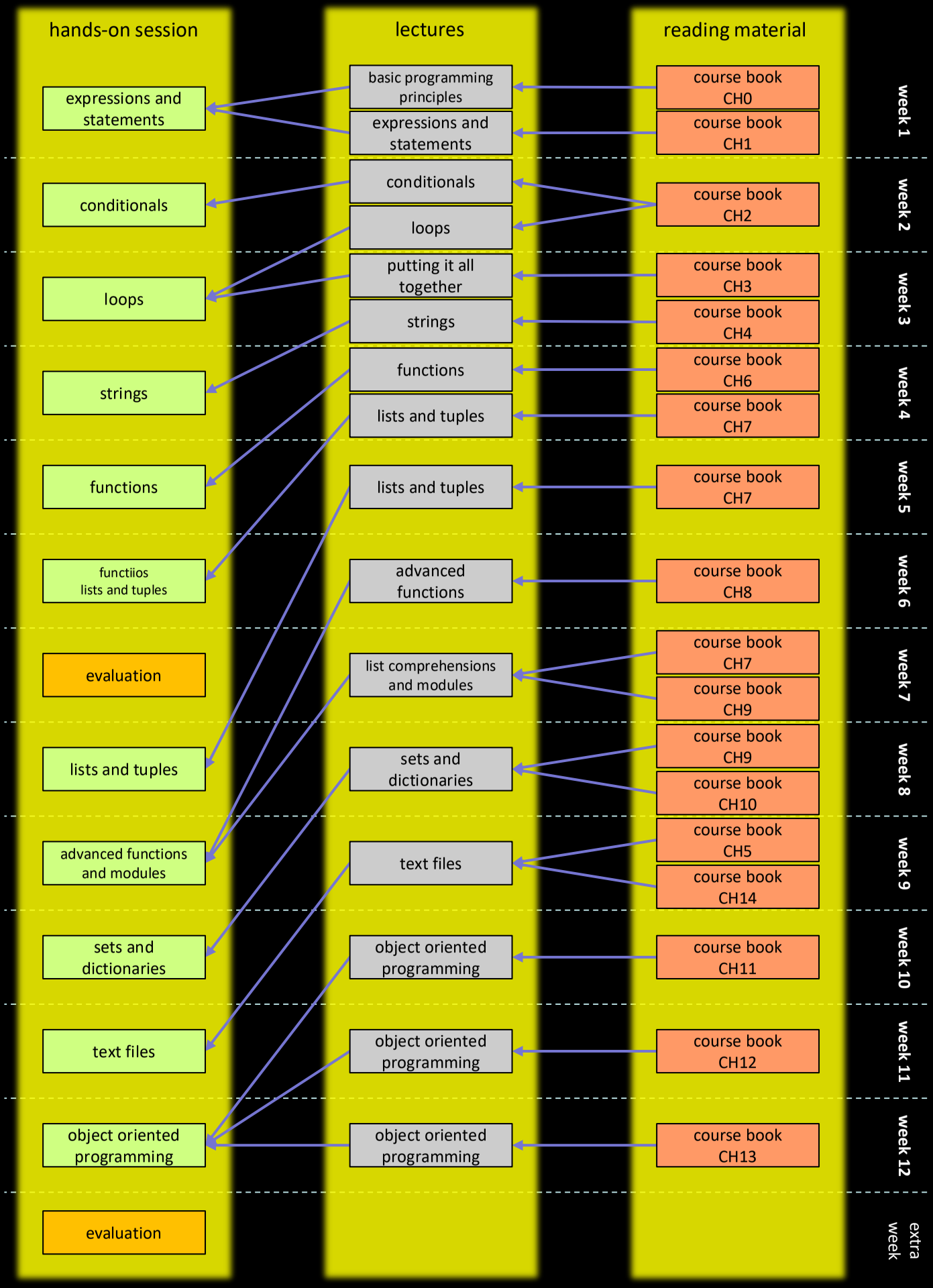
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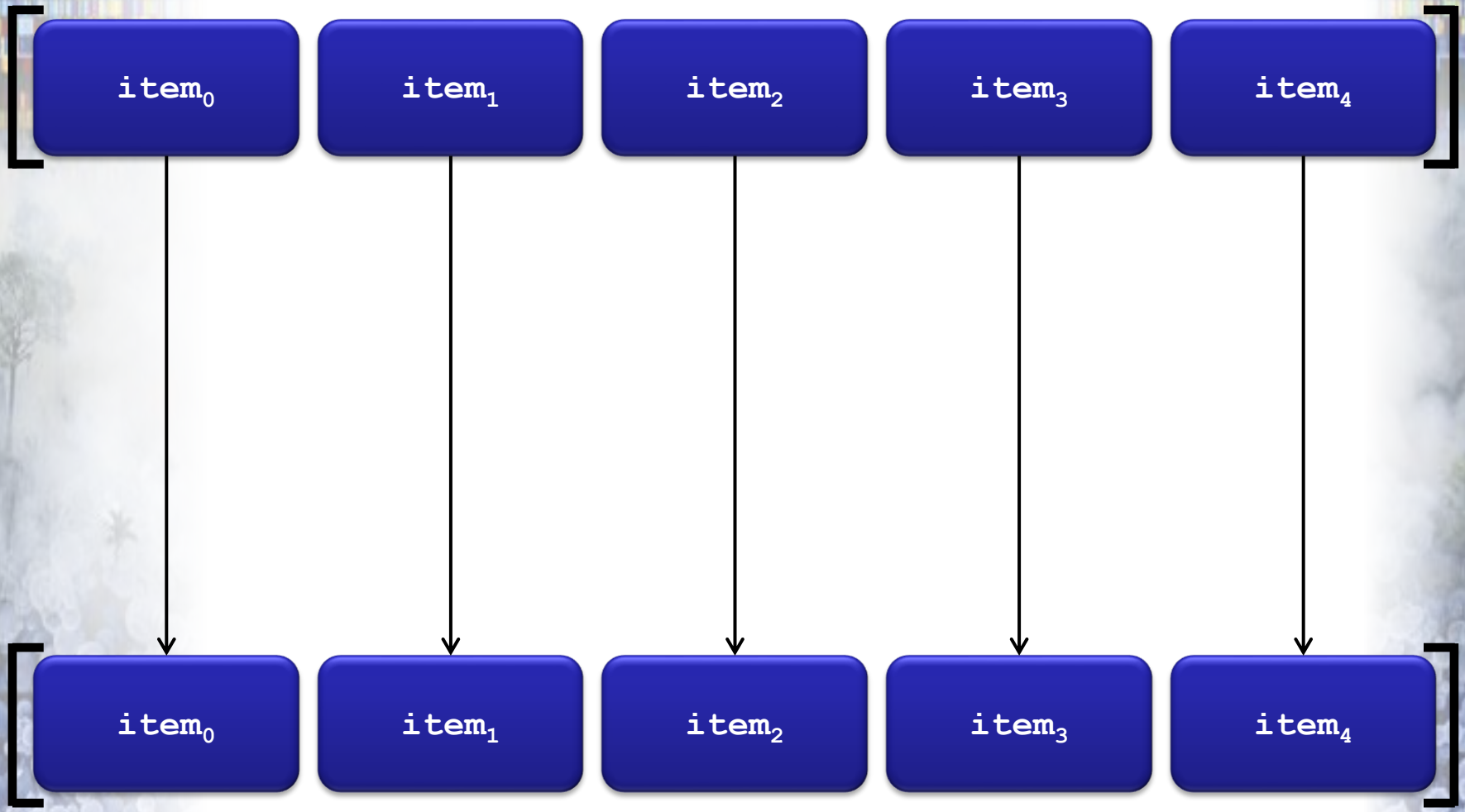
List comprehensions

List comprehensions



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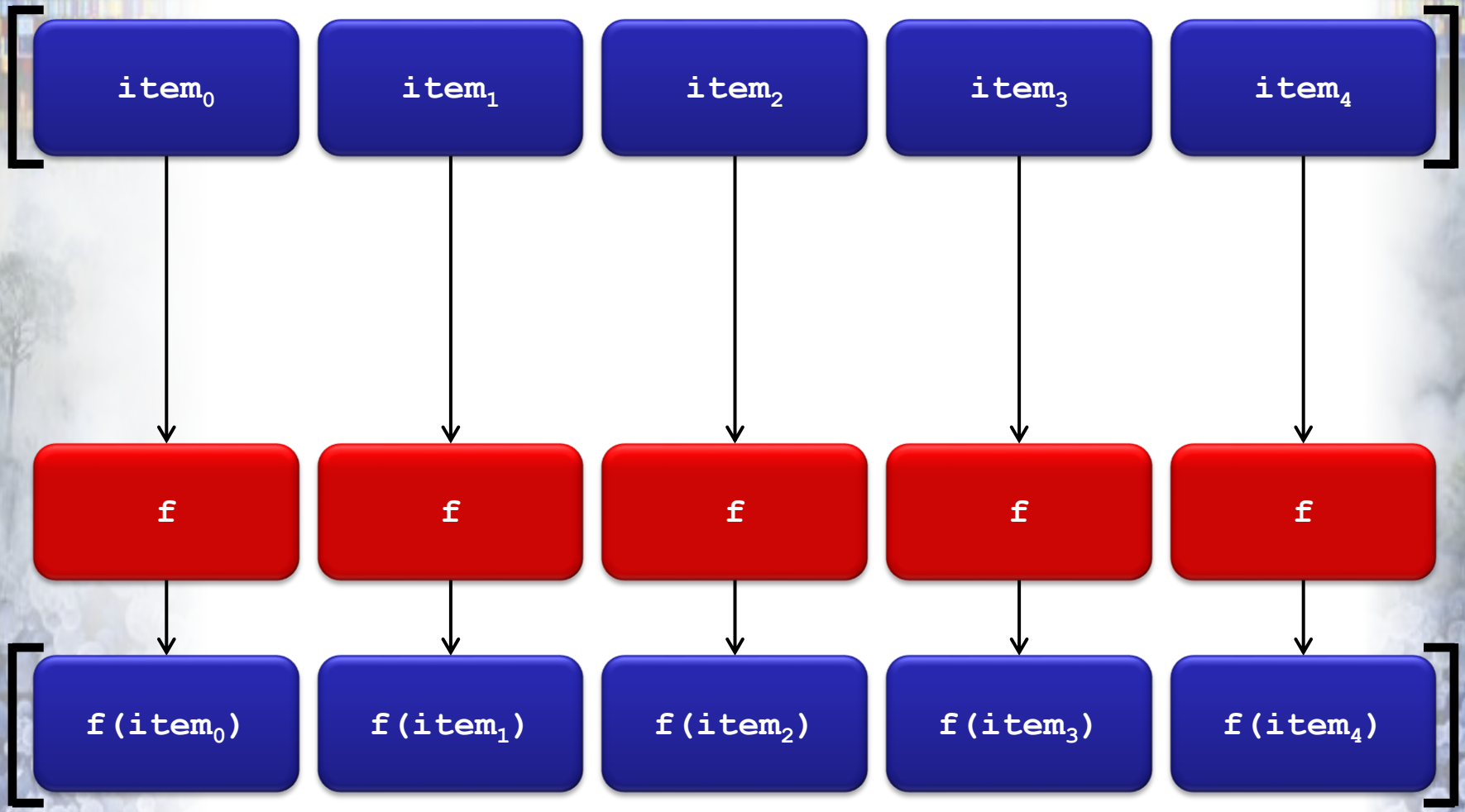
```
newlist = [item for item in oldlist]
```

List comprehensions



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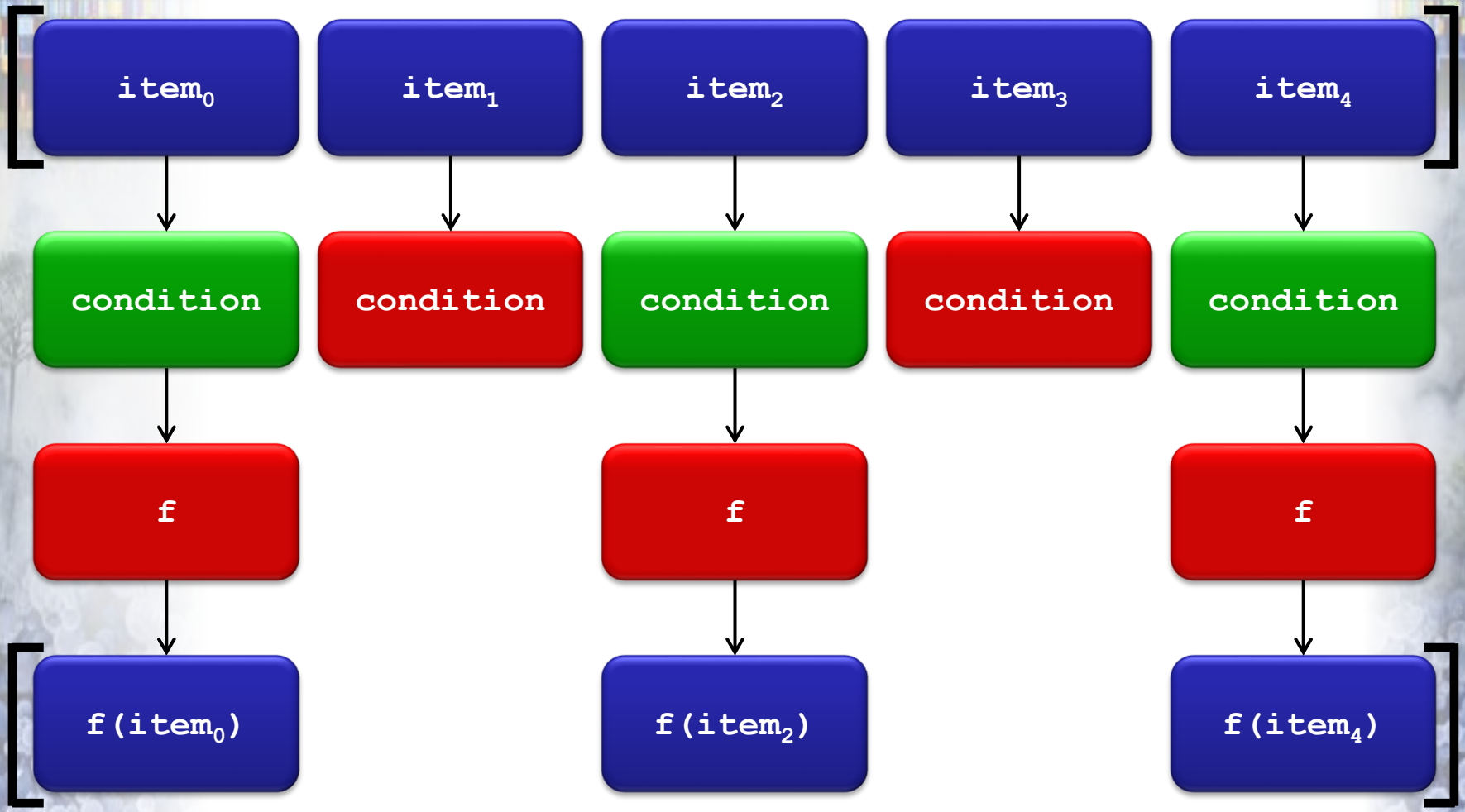
```
newlist = [f(item) for item in oldlist]
```

List comprehensions



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```
newlist = [f(item) for item in oldlist if condition]
```

List comprehensions

- workhorse data type in Python
  - creates new list by applying expression to elements of an initial list
  - heavily used by Python programmers (*pythonic*)
    - lots of examples in code fragments found online
- unusual syntax
  - similar to syntax of **`for`** loop, **`in`** operator and **`if`** statement
  - same three keywords (**`for`**, **`in`** and **`if`**) are also used (sometimes even repeatedly) in list comprehensions

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List comprehensions

- basic format

```
[ expression for variable in iterable ]
```

  - ***expression*** is expression applied to ***variable***
  - for each element of ***iterable*** the list comprehension will
    1. reference element with ***variable***
    2. compute new value as evaluation of ***expression***
       - tuple expressions must be enclosed with round brackets
  - computed values are bundled into a new list that is returned as the result of the list comprehension

```
>>> li = [3, 6, 2, 7]
>>> [2 * elem for elem in li]
[6, 12, 4, 14]
```

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List comprehensions

- basic format

```
[ expression for variable in iterable ]
```

  - ***iterable*** may contain elements of heterogeneous types
    - ***expression*** must be valid for each element of ***iterable***
  - elements of ***iterable*** can also be containers themselves
    - ***variable*** is container of variables with data type and "form" that corresponds to elements of ***iterable***

```
>>> li = [3, 'spam', [4, 5]]
>>> [3 * elem for elem in li]
[9, 'spamspamspam', [4, 5, 4, 5, 4, 5]]
>>> li = [('a', 1), ('b', 2), ('c', 7)]
>>> [3 * n for (x, n) in li]
[3, 6, 21]
```

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List comprehensions

- basic format

```
[ expression for variable in iterable ]
```

  - ***expression*** may contain user-defined function
    - ***expression*** must be valid for each element of ***iterable***

```
>>> def subtract(a, b):
...     return a - b
...
>>> li = [(6, 3), (1, 7), (5, 5)]
>>> [subtract(y, x) for (x, y) in li]
[-3, 6, 0]
```

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Additional filtering

- extended format

```
[ expression for variable1 in iterable1
  [ if condition | for variable2 in iterable2 ] … ]
```

  - ***condition*** determines whether or not ***expression*** is applied to individual elements of ***iterable***
    - ***condition*** is tested for each element of ***iterable*** in the preceding ***for*** clause of the list comprehension
    - elements for which ***condition*** is **False** are left out of resulting list before evaluation of **expressie** from the list comprehension

```
>>> li = [3, 6, 2, 7, 1, 9]
>>> [2 * elem for elem in li if elem > 4]
[12, 14, 18]
```

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Additional filtering

```
>>> '1 2 3 4'.split()
['1', '2', '3', '4']
>>> [int(x) for x in '1 2 3 4'.split()]   # conversion
[1, 2, 3, 4]
>>> [x * x for x in range(10)]            # power
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]
>>> [x for x in range(10) if not x % 2]   # odd numbers
[0, 2, 4, 6, 8]
>>> [(b, a) for a, b in [(1, 2), (3, 4)]] # exchange
[(2, 1), (4, 3)]
>>> s = "monty python's flying circus"
>>> [ord(c) for c in s]
[109, 111, 110, 116, 121, 32, 112, 121, 116, 104, … ]
>>> [i for i, c in enumerate(s) if c == ' ']
[5, 14, 21]
>>> [p for p in range(2, 100)
...      if not [x for x in range(2, p) if not p % x]]
[2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, …, 97]
```

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Nesting list comprehensions

- list comprehension takes an iterable as input and returns a list as output
  - list is itself an iterable
  - enables possibility to nest list comprehensions

- example
  - inner comprehension results in list `[4, 3, 5, 2]`
  - outer comprehension results in list `[8, 6, 10, 4]`

```
>>> li = [3, 2, 4, 1]
>>> [2 * elem for elem in [item + 1 for item in li]]
[8, 6, 10, 4]
```

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Nesting list comprehensions

```
>>> vec = [2, 4, 6]
>>> [[x, x**2] for x in vec]
[[2, 4], [4, 16], [6, 36]]
>>> [x, x**2 for x in vec]    # tuple requires round brackets
  File "<stdin>", line 1
    [x, x**2 for x in vec]
               ^
SyntaxError: invalid syntax
>>> [(x, x**2) for x in vec]
[(2, 4), (4, 16), (6, 36)]
>>> vec1 = [2, 4, 6]
>>> vec2 = [4, 3, -9]
>>> [x * y for x in vec1 for y in vec2]
[8, 6, -18, 16, 12, -36, 24, 18, -54]
>>> [x + y for x in vec1 for y in vec2]
[6, 5, -7, 8, 7, -5, 10, 9, -3]
>>> [vec1[i] * vec2[i] for i in range(len(vec1))]
[8, 12, -54]
```

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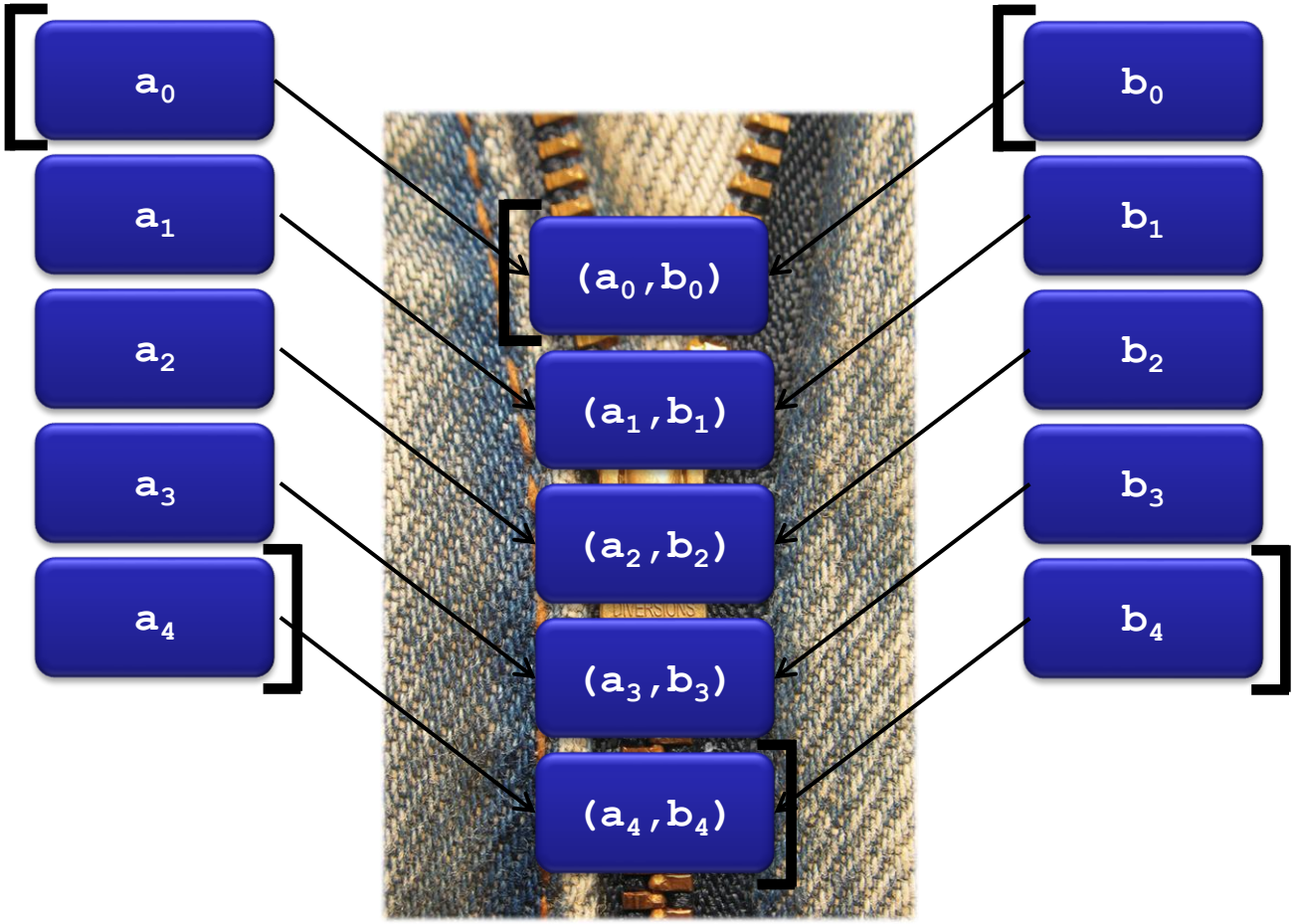
Zip



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Zip

- combines two or more iterable objects by aggregating elements at corresponding positions into tuples that are the elements of a new iterable

```
>>> firstnames = ['John', 'Terry', 'Eric']
>>> lastnames = ['Cleese', 'Gilliam', 'Idle']
>>> names = list(zip(firstnames, lastnames))
>>> names
[('John', 'Cleese'), ('Terry', 'Gilliam'), ('Eric', 'Idle')]
>>> list(zip(*names))      # also works for multiple lists
[('John', 'Terry', 'Eric'), ('Cleese', 'Gilliam', 'Idle')]
                           # * before argument results in
                           # zip(names[0],names[1],names[2])
```

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Modules

Modules

- **module**: file containing Python definitions and statements
  - goal: reuse definitions in other Python code
  - **The Python Standard Library**
    - library of modules that is shipped together with Python
    - "batteries included"
  - Python + standard library + scientific modules
    - Enthought Python Distribution (EDP)
    - Anaconda
  - and many more modules…
    - Python Package Index (aka "The Cheese Shop")

"Don't reinvent the wheel."

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python™

ANACONDA

ENTHOUGHT SCIENTIFIC COMPUTING SOLUTIONS

BATTERIES INCLUDED

Creating modules

- every Python file is automatically also a module
  - brought into scope using the **`import`** statement
  - module are also objects having properties and methods
  - access properties and methods with a dot (*dot operator*)

circle.py

```
"""Working with circles."""

from math import pi

def perimeter(radius):
    """Perimeter of a circle."""
    return 2 * pi * radius

def area(radius):
    """Area of a circle."""
    return pi * radius ** 2
```

```
>>> radius = 2.87
>>> import circle
>>> type(circle)
<class 'module'>
>>> dir(circle)
['__builtins__', '__cached__', '__doc__',
 '__file__', '__name__', '__package__', 'pi',
 'perimeter', 'area']
>>> circle.perimeter(radius)
18.0327418316
>>> circle.area(radius)
25.8769845284
```

Creating modules

- every Python file is automatically also a module
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from math import pi

def perimeter(radius):
    """Perimeter of a circle."""
    return 2 * pi * radius

def area(radius):
    """Area of a circle."""
    return pi * radius ** 2
```

```
>>> import circle
>>> circle.__name__
'circle'
>>> circle.__doc__
'Working with circles.'
>>> help(circle)
Help on module circle:

NAME
    circle - Working with circles.

FUNCTIONS
    perimeter(radius)
        Perimeter of a circle.
    area(radius)
        Area of a circle.
```

docstring

Creating modules

- every Python file is automatically also a module
  - brought into scope using the **`import`** statement
  - module are also objects having properties and methods
  - access properties and methods with a dot (*dot operator*)

circle.py

```
"""Working with circles."""

from math import pi

def perimeter(radius):
  """Perimeter of a circle."""
  return 2 * pi * radius

def area(radius):
  """Area of a circle."""
  return pi * radius ** 2
```

analysis.py

```
import circle

radius = input('radius: ')

ftest = radius
if '.' in radius:  # float given ?
  ftest = radius.replace('.', '', 1)

if ftest.isdigit():
  radius = float(radius)
  print(circle.perimeter(radius))
  print(circle.area(radius))
```

Module scope

- **namespace**: syntactic container which permits same name to be used in different modules and functions (and classes)
- each module determines its own namespace
  - same name in multiple modules causes no identification problem

module1.py

```
question = 'What is the meaning of life, the Universe, and everything?'
answer = 42
```

module2.py

```
question = 'What is your quest?'
answer = 'To seek the holy grail.'
```

```
>>> import module1
>>> import module2
>>> module1.question
'What is the meaning of life, the Universe, and everything?'
>>> module2.question
'What is your quest?'
```

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answer = 42
```

module2.py

```
question = 'What is your quest?'
answer = 'To seek the holy grail.'
```

```
>>> module1.answer
42
>>> module2.answer
'To seek the holy grail.'
```

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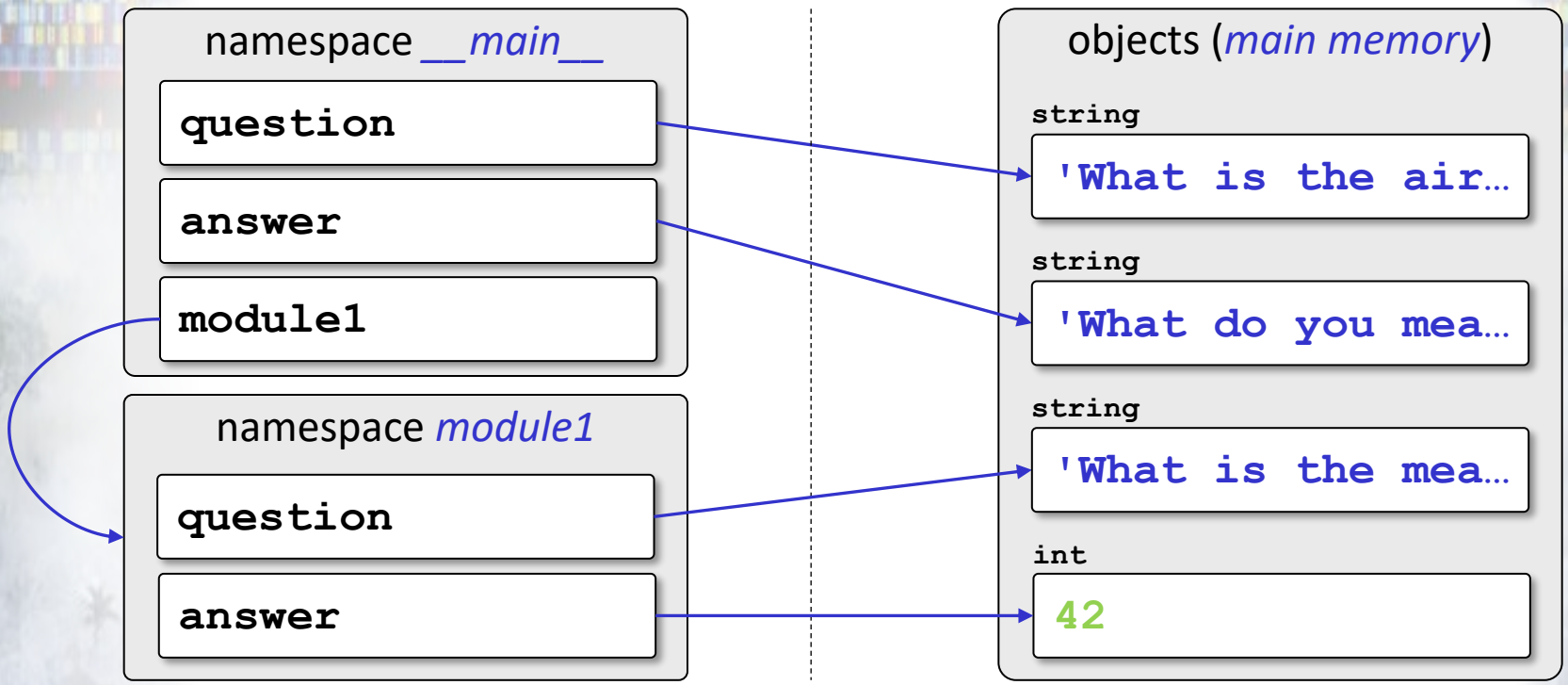
Module scope




```
>>> question = 'What is the air-speed velocity of an unladen swallow?'
>>> answer = 'What do you mean? An African or European swallow?'
>>> import module1
>>> question
'What is the air-speed velocity of an unladen swallow?'
>>> module1.question
'What is the meaning of life, the Universe, and everything?'
```

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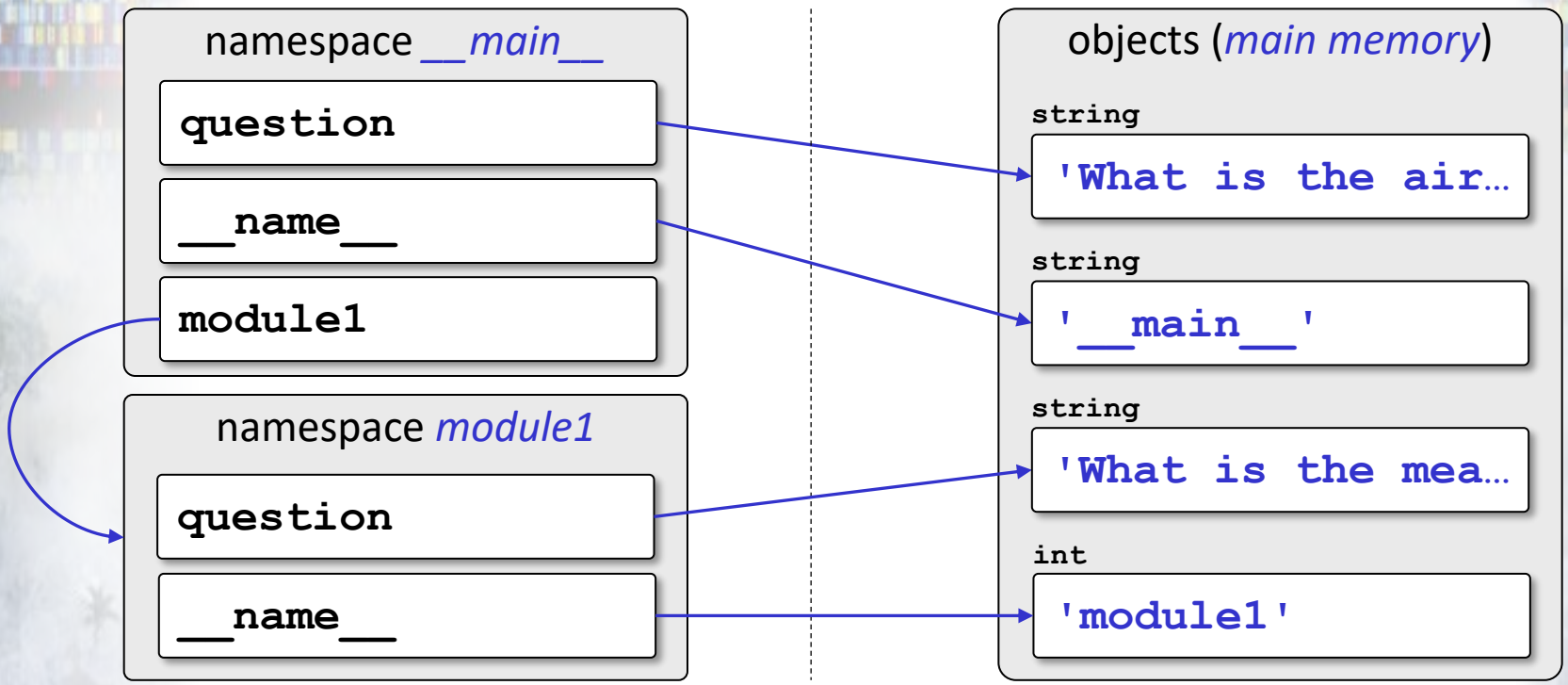
Module scope




```
>>> import module1
>>> __name__
'__main__'
>>> module1.__name__
'module1'
```

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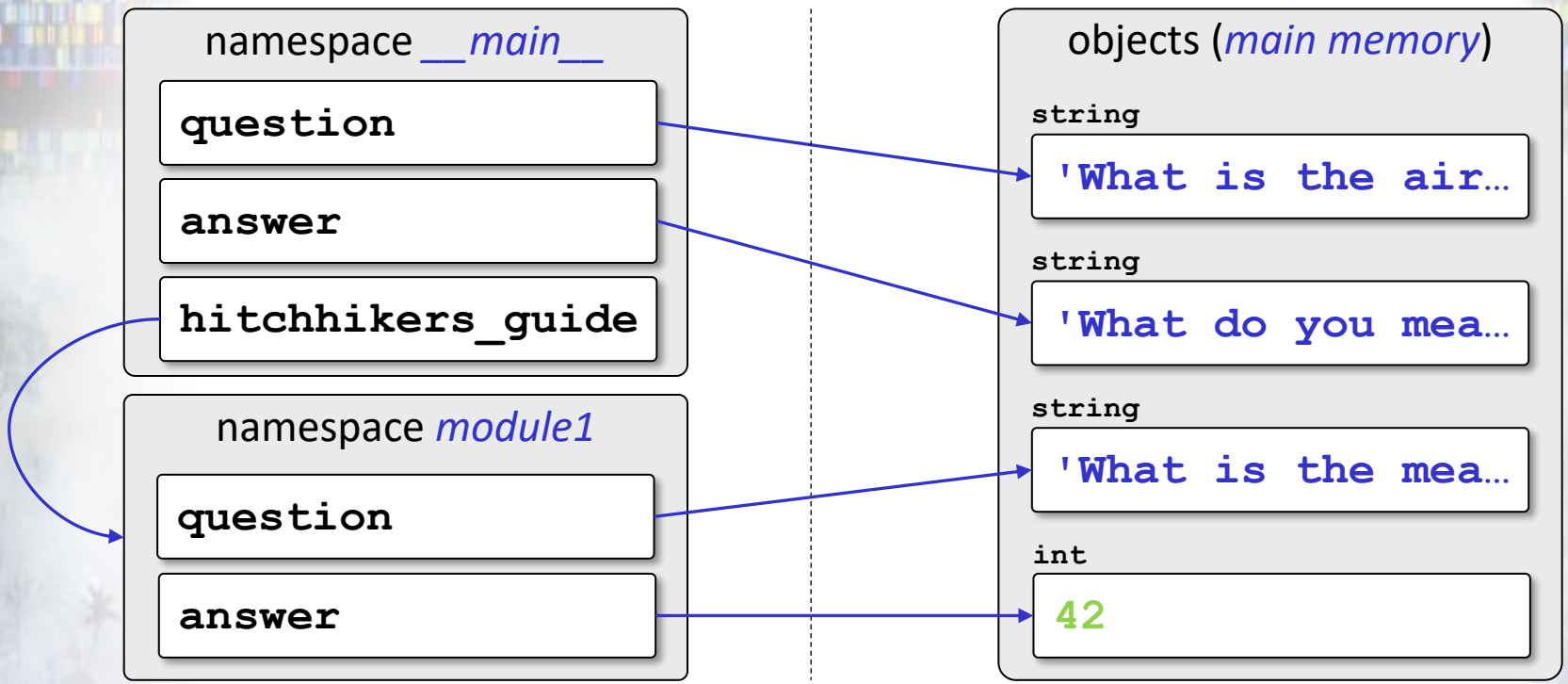
Alternative imports




```
>>> question = 'What is the air-speed velocity of an unladen swallow?'
>>> answer = 'What do you mean? An African or European swallow?'
>>> import module1 as hitchhikers_guide
>>> question
'What is the air-speed velocity of an unladen swallow?'
>>> hitchhikers_guide.question
'What is the meaning of life, the Universe, and everything?'
```

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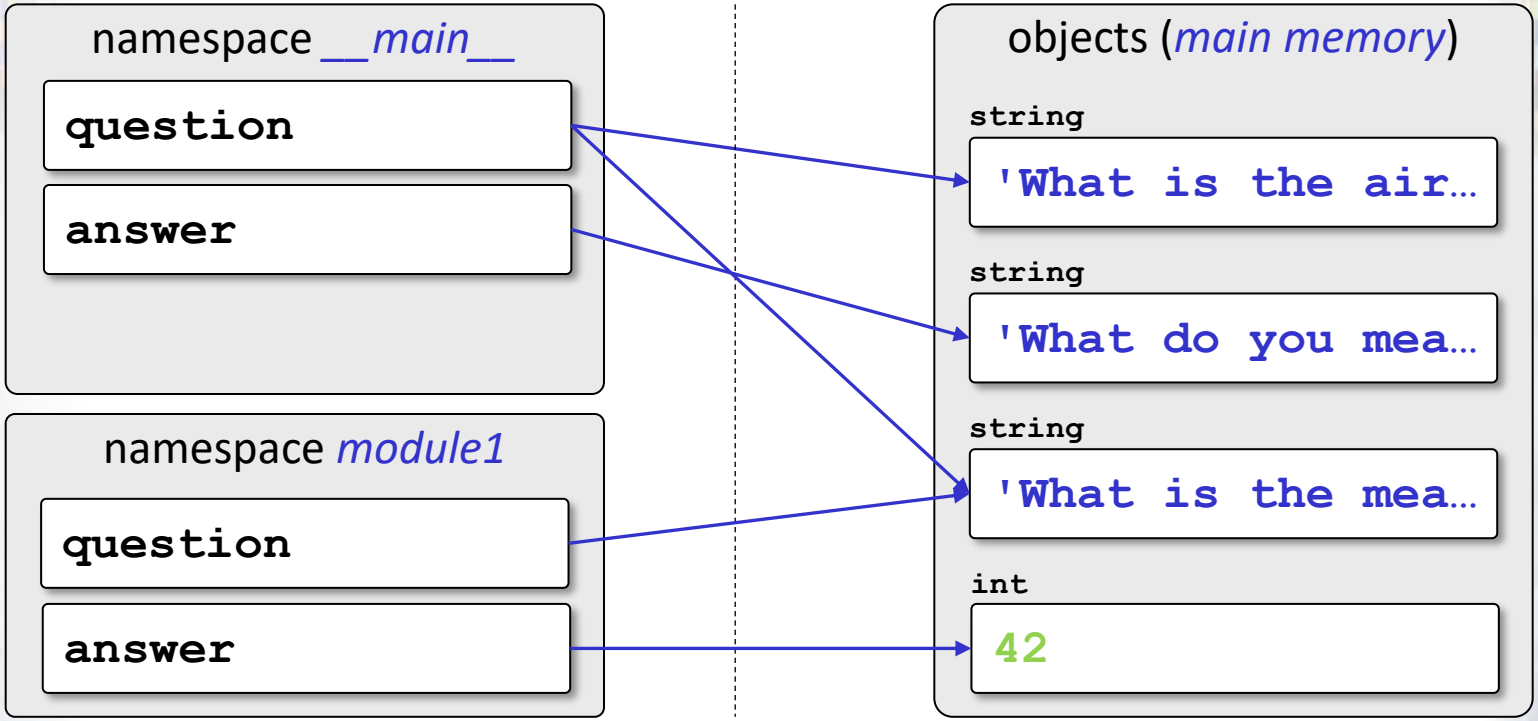
Alternative imports




```
>>> question = 'What is the air-speed velocity of an unladen swallow?'
>>> answer = 'What do you mean? An African or European swallow?'
>>> from module1 import question
>>> question
'What is the meaning of life, the Universe, and everything?'
>>> answer
'What do you mean? An African or European swallow?'
```

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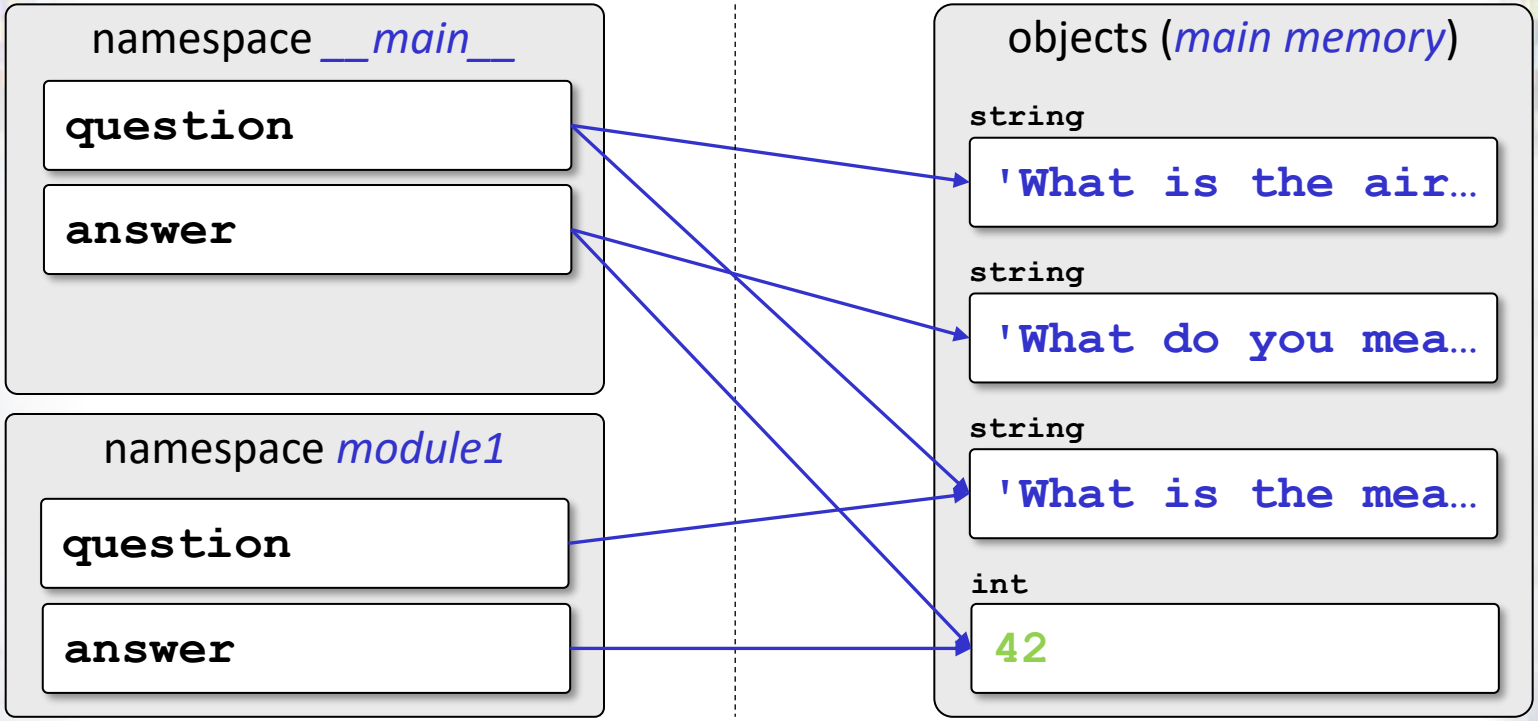
Alternative imports




```
>>> question = 'What is the air-speed velocity of an unladen swallow?'
>>> answer = 'What do you mean? An African or European swallow?'
>>> from module1 import question, answer
>>> question
'What is the meaning of life, the Universe, and everything?'
>>> answer
42
```

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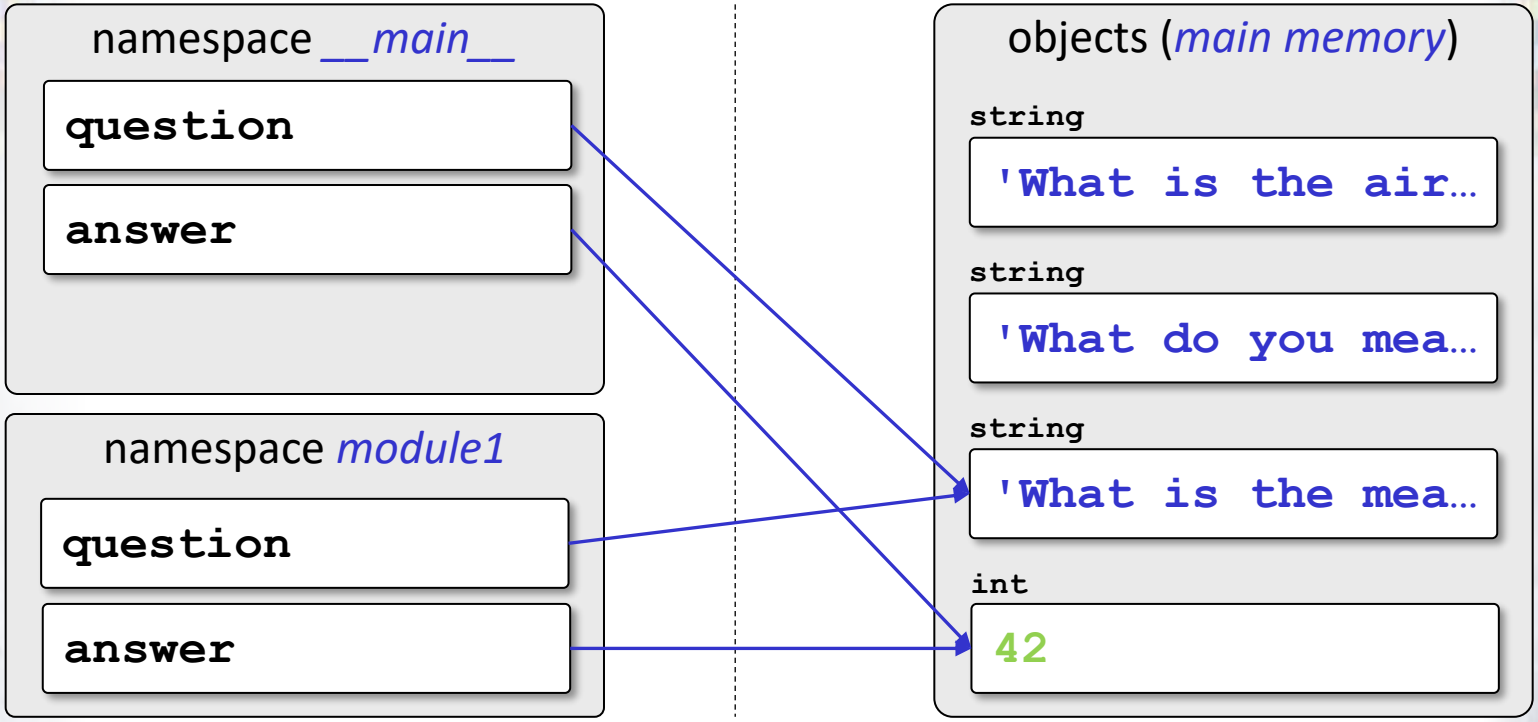
Alternative imports




```
>>> question = 'What is the air-speed velocity of an unladen swallow?'
>>> answer = 'What do you mean? An African or European swallow?'
>>> from module1 import *
>>> question
'What is the meaning of life, the Universe, and everything?'
>>> answer
42
```

"Almost always a bad idea."

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Module scope

- **namespace**: syntactic container which permits same name to be used in different modules and functions (and classes)
- functions also have their own namespace

namespace.py

```
def f():
    n = 7
    print(f'n inside f: {n}')

def g():
    n = 42
    print(f'n inside g: {n}')

n = 11
print(f'n before calling f: {n}')
f()
print(f'n after calling f: {n}')
g()
print(f'n after calling g: {n}')
```

```
$ python namespace.py
n before calling f: 11
n inside f: 7
n after calling f: 11
n inside g: 42
n after calling g: 11
$
```

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Import executes statements

- **`import`** is a statement
  - executed when Python encounters it
  - just like any other statement
- statements in module are executed as it is loaded
  - assignment and **`def`** are statements
  - conditionals, loops and anything else can also be used
- names are imported into current namespace

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Import executes statements

```
>>> import three_questions
What is your name?
Sir Galahad of Camelot.
What is your quest?
I seek the Holy Grail.
What is your favorite color?
Blue.  No yell--
Auuuuuuuugh!
>>>
```

three_questions.py

```
answer1 = input('What is your name?\n')
answer2 = input('What is your quest?\n')
answer3 = input('What is your favorite color?\n')
if answer3.lower()[:6] == 'yellow':
    print('Right. Off you go.')
else:
    print('Auuuuuuuugh!')
```

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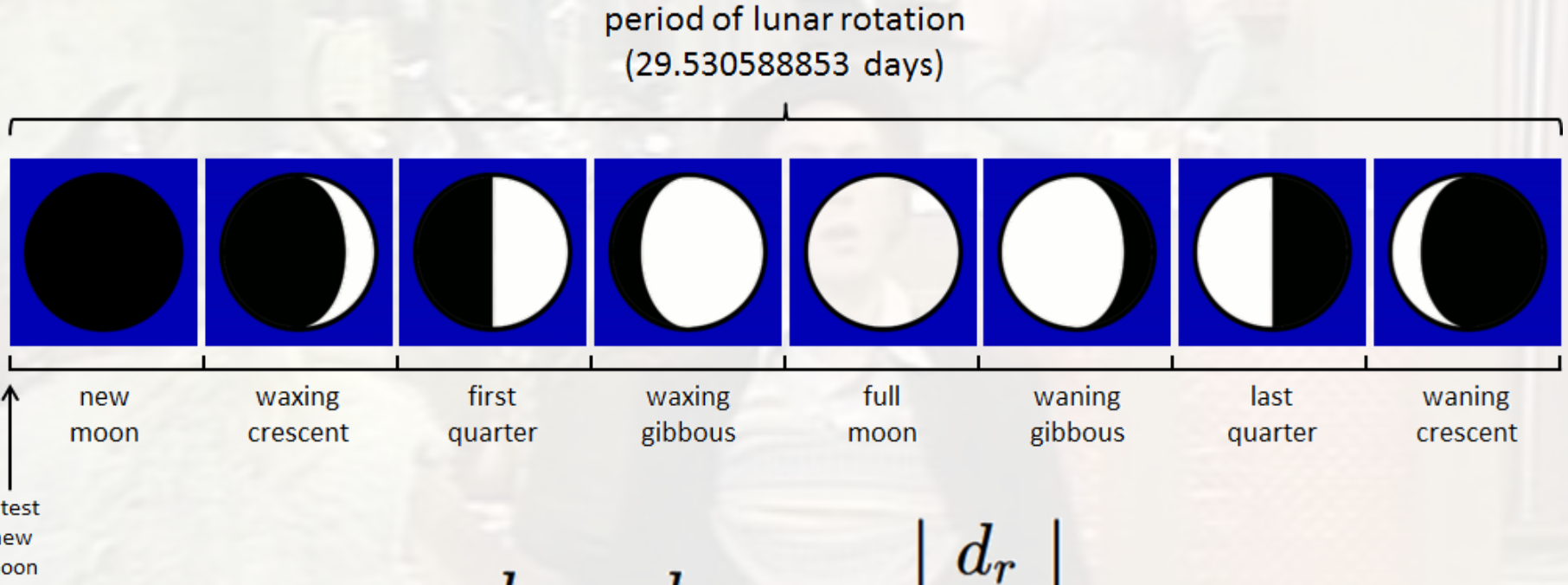
Lunar phases

Lunar phases



$$d_n = d_r - p * \left\lfloor \frac{d_r}{p} \right\rfloor$$

number of days since latest new moon

number of days since reference date (January 6, 2000)

Test-driven development

Test-driven development (TDD) is a software development practice which arrives at a desired feature through a series of small, iterative steps motivated by automated tests (which are *written first*) that express increasing refinements of the desired feature.

Doctests

matrix1.py

```
def makeMatrix(rows, columns):
    """
    Returns a matrix with a given number of rows and
    columns. All matrix elements are initialized to 0.

    >>> makeMatrix(3, 5)
    [[0, 0, 0, 0, 0], [0, 0, 0, 0, 0], [0, 0, 0, 0, 0]]
    """

if __name__ == '__main__':
    import doctest
    doctest.testmod()
```

```
>>> from matrix1 import makeMatrix
>>> makeMatrix(3, 5)
>>> print(makeMatrix(3, 5))
None
>>>
```

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Doctests

```
$ python matrix1.py
**********************************************************************
File "matrix1.py", line 6, in __main__.makeMatrix
Failed example:
    makeMatrix(3, 5)
Expected:
    [[0, 0, 0, 0, 0], [0, 0, 0, 0, 0], [0, 0, 0, 0, 0]]
Got nothing
**********************************************************************
1 items had failures:
   1 of   1 in __main__.makeMatrix
***Test Failed*** 1 failures.
$
```

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Doctests

matrix2.py

```
def makeMatrix(rows, columns):
    """
    Returns a matrix with a given number of rows and
    columns. All matrix elements are initialized to 0.

    >>> makeMatrix(3, 5)
    [[0, 0, 0, 0, 0], [0, 0, 0, 0, 0], [0, 0, 0, 0, 0]]
    """
    return [[0,0,0,0,0], [0,0,0,0,0], [0,0,0,0,0]]

if __name__ == '__main__':
    import doctest
    doctest.testmod()
```

```
$ python matrix2.py
$
```

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Doctests

matrix3.py

```
def makeMatrix(rows, columns):
    """
    Returns a matrix with a given number of rows and
    columns. All matrix elements are initialized to 0.

    >>> makeMatrix(3, 5)
    [[0, 0, 0, 0, 0], [0, 0, 0, 0, 0], [0, 0, 0, 0, 0]]
    >>> makeMatrix(4, 2)
    [[0, 0], [0, 0], [0, 0], [0, 0]]
    """
    return [[0,0,0,0,0], [0,0,0,0,0], [0,0,0,0,0]]

if __name__ == '__main__':
    import doctest
    doctest.testmod()
```

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Doctests

```
$ python matrix3.py
**********************************************************************
File "matrix3.py", line 8, in __main__.makeMatrix
Failed example:
    makeMatrix(4, 2)
Expected:
    [[0, 0], [0, 0], [0, 0], [0, 0]]
Got:
    [[0, 0, 0, 0, 0], [0, 0, 0, 0, 0], [0, 0, 0, 0, 0]]
**********************************************************************
1 items had failures:
   1 of   2 in __main__.makeMatrix
***Test Failed*** 1 failures.
$
```

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Doctests

matrix4.py

```
def makeMatrix(rows, columns):
    """
    Returns a matrix with a given number of rows and
    columns. All matrix elements are initialized to 0.

    >>> makeMatrix(3, 5)
    [[0, 0, 0, 0, 0], [0, 0, 0, 0, 0], [0, 0, 0, 0, 0]]
    >>> makeMatrix(4, 2)
    [[0, 0], [0, 0], [0, 0], [0, 0]]
    """
    return [[0] * columns] * rows

if __name__ == '__main__':
    import doctest
    doctest.testmod()
```

```
$ python matrix4.py
$
```

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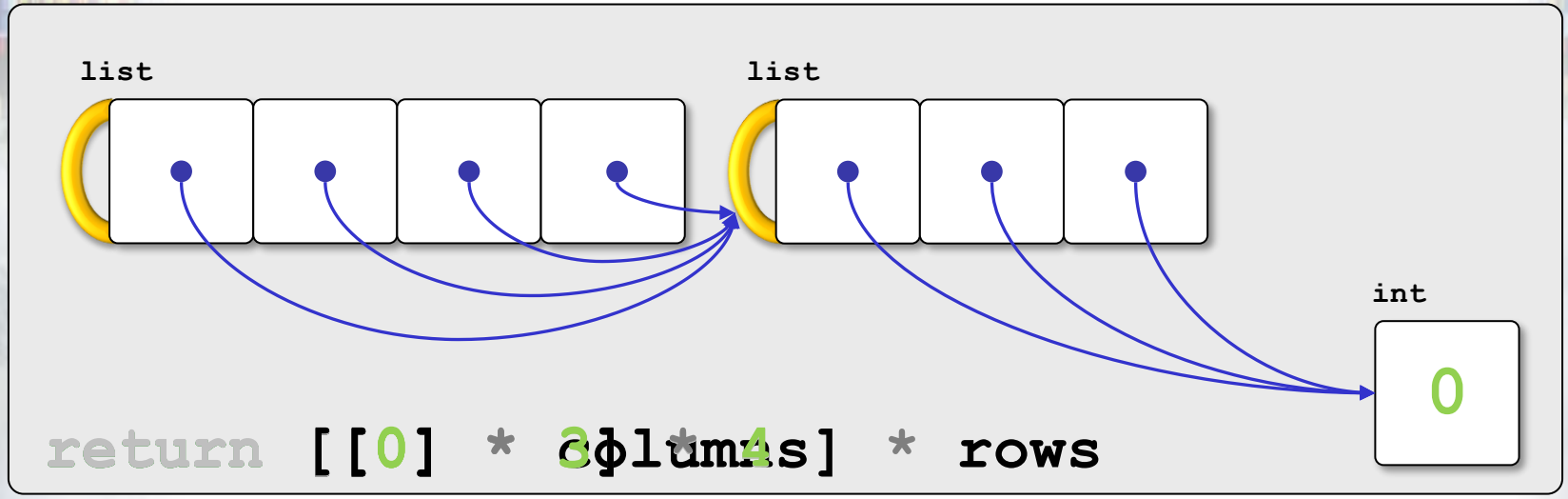
Doctests




```
>>> from matrix4 import *
>>> matrix = makeMatrix(4, 3)
>>> matrix
[[0, 0, 0], [0, 0, 0], [0, 0, 0], [0, 0, 0]]
>>> matrix[1][2] = 7
>>> matrix
[[0, 0, 7], [0, 0, 7], [0, 0, 7], [0, 0, 7]]
```

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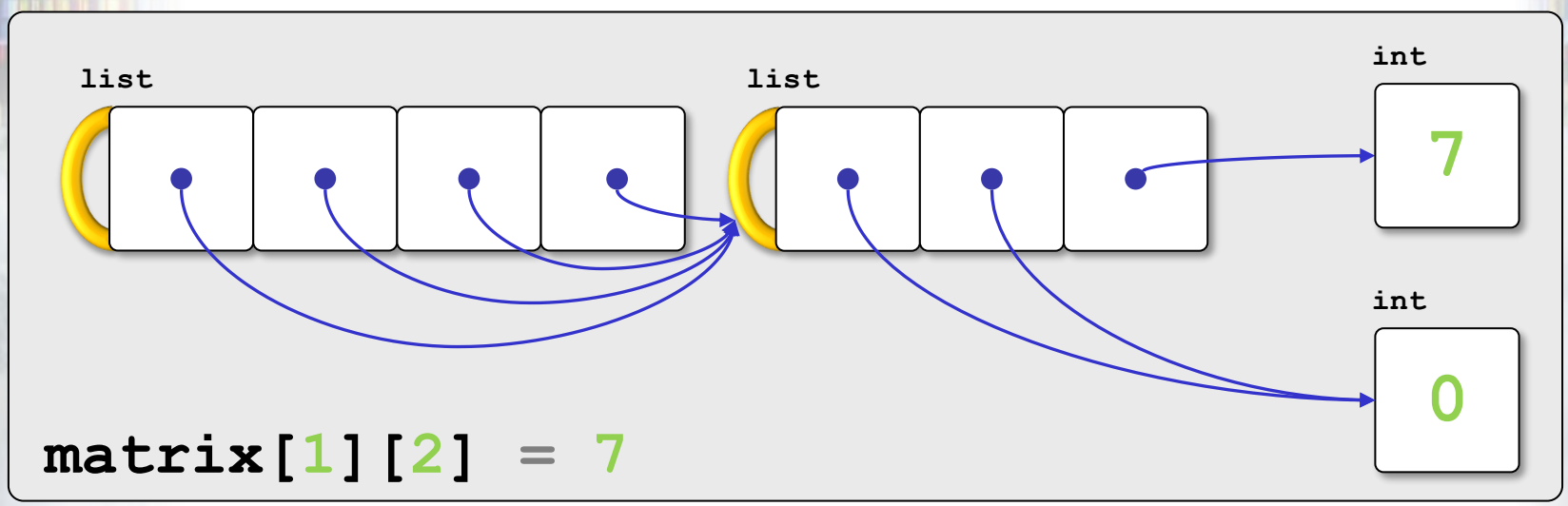
Doctests




```
>>> from matrix4 import *
>>> matrix = makeMatrix(4, 3)
>>> matrix
[[0, 0, 0], [0, 0, 0], [0, 0, 0], [0, 0, 0]]
>>> matrix[1][2] = 7
>>> matrix
[[0, 0, 7], [0, 0, 7], [0, 0, 7], [0, 0, 7]]
```

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Doctests

matrix5.py

```
def makeMatrix(rows, columns):
    """
    Returns a matrix with a given number of rows and
    columns. All matrix elements are initialized to 0.

    >>> makeMatrix(3, 5)
    [[0, 0, 0, 0, 0], [0, 0, 0, 0, 0], [0, 0, 0, 0, 0]]
    >>> makeMatrix(4, 2)
    [[0, 0], [0, 0], [0, 0], [0, 0]]
    >>> matrix = makeMatrix(4, 2)
    >>> matrix[1][1] = 7
    >>> matrix
    [[0, 0], [0, 7], [0, 0], [0, 0]]
    """
    matrix = []
    for row in range(rows):
        matrix += [[0] * coloumns]
    return matrix

if __name__ == '__main__':
    import doctest
    doctest.testmod()
```

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Homework (next lecture)

- course book
  - read chapter 9 (sets and dictionaries)
  - read chapter 10 (more program development)
- read problem description of classroom exercises
  - Simulating polymers
  - Cryptograms
  - Blood types

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Questions or remarks?

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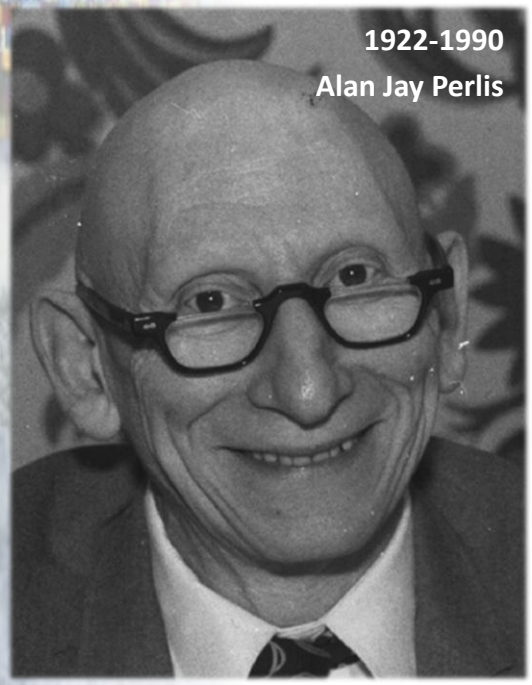
The sky is the limit…



"If a listener nods his head when you're explaining your program, wake him up."

— Alan J. Perlis

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