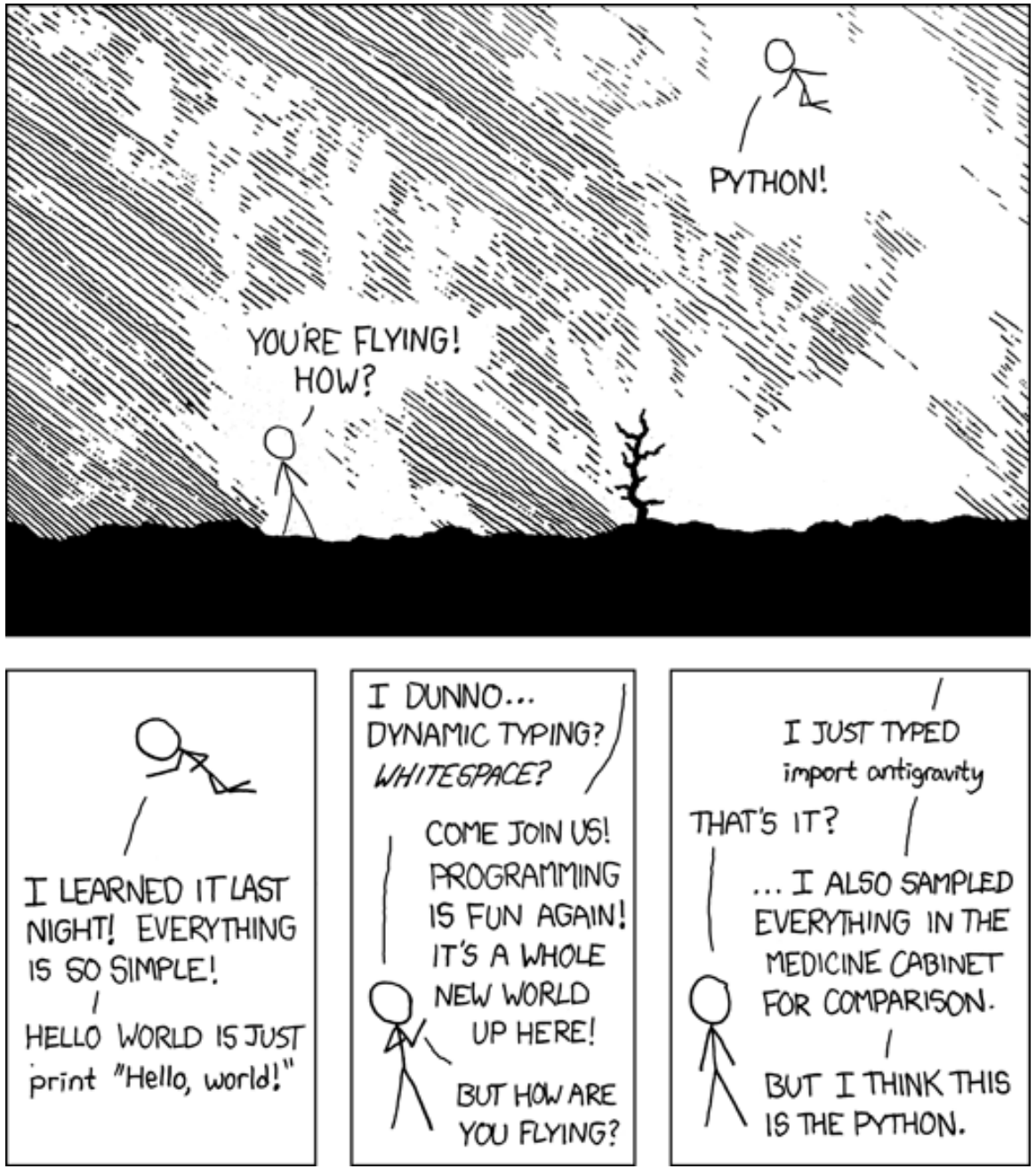


xkcd.com/353

Modules and packages

- import – from – as
- __name__, '__main__'

docs.python.org/3/tutorial/modules.html

Python modules and packages

- A Python module is a *module_name*.py file containing Python code
- A Python package is a collection of modules

Why do you need modules ?

- A way to structure code into smaller logical units
- Encapsulation of functionality
- Reuse of code in different programs

- Your can write your own modules and packages or use any of the +400.000 existing packages from pypi.org
- The Python Standard Library consists of the modules listed on docs.python.org/3/library

Defining and importing a module

mymodule.py

```
'''This is a 'print something' module.'''

from random import randint

print('Running my module')

def print_something(n):
    W = ['Eat', 'Sleep', 'Rave', 'Repeat']
    words = (W[randint(0, len(W) - 1)] for _ in range(n))
    print(' '.join(words))

def the_name():
    print('__name__ = "' + __name__ +'"')
```

using_mymodule.py

```
import mymodule

mymodule.the_name()
mymodule.print_something(5)

from mymodule import print_something

print_something(5)
```

Python shell

```
Running my module
__name__ = "mymodule"
Eat Sleep Sleep Sleep Rave
Eat Sleep Rave Repeat Sleep
```

- A module is only run once when imported several times

Some modules mentioned in the course

Module (example functions)	Description
math (pi sqrt ceil log sin)	*basic math*
random (random randint)	*random number generator*
numpy (array shape)	*multi-dimensional data*
pandas	*data tables*
SQLlite	*SQL database*
scipy scipy.optimize (minimize linprog) scipy.spatial (ConvexHull)	*mathematical optimization*
matplotlib matplotlib.pyplot (plot show style) matplotlib.backends.backend_pdf (PdfPages) mpl_toolkits.mplot3d (Axes3D)	*plotting data* *print plots to PDF* *3D plot tools*
doctest (testmod) unittest (assertEqual assertTrue)	*testing using doc strings* *unit testing*
time (time) datetime (date.today)	*current time, coversion of time values*
timeit (timeit)	*time execution of simple code*
heapq	*use a list as a heap*

Module (example functions)	Description
functools (cache lru_cache total_ordering)	*higher order functions and decorators*
itertools (islice permutations)	*Iterator tools*
collections (Counter deque)	*datat structures for collections*
builtins	*module containing the Python builtins*
os (path)	*operating system interface*
sys (argv path)	*system specific functions*
Tkinter PyQt	*graphic user interface*
xml	*xml files (eXtensible Markup Language)*
json	*JSON (JavaScript Object Notation) files*
csv	*comma separated files*
openpyxl	*EXCEL files*
re	*regular expression, string searching*
string (split join lower ascii_letters digits)	*string functions*

Ways of importing modules

import.py

```
# Import a module name in the current namespace
# All definitions in the module are available as <module>.<name>

import math
print(math.sqrt(2))

# Import only one or more specific definitions into current namespace

from math import sqrt, log, ceil
print(ceil(log(sqrt(100), 2)))

# Import specific modules/definitions from a module into current namespace under new names

from math import sqrt as kvadratrod, \
                 log as logaritme  # long import line broken onto multiple lines
import matplotlib.pyplot as plt
print(logaritme(kvadratrod(100)))

# Import all definitions form a module in current namespace
# Deprecated, since unclear what happens to the namespace

from math import *
print(pi)  # where did 'pi' come from?
```

Python shell

```
| 1.4142135623730951
| 4
| 2.302585092994046
| 3.141592653589793
```

`__all__` vs `import *`

- A module can control what is imported by `import *` by defining `__all__`

Python shell

```
> min
| <built-in function min>
> sum
| <built-in function sum>
> import numpy
> numpy.min
| <function amin at 0x0000024768E69F30>  # numpy.min == numpy.amin
> numpy.sum
| <function sum at 0x0000024768E69510>
> from numpy import *
> sum
| <function sum at 0x0000024768E69510>  # numpy.sum
> min
| <built-in function min>  # builtin min
> numpy.__all__
| [..., 'sum', ...]   # 'min' is not in list
```

all.py

```
__all__ = ['f']
def f():
    print('this is f')
def g():
    print('this is g')
```

Python shell

```
> import all
> all.f()
| this is f
> all.g()
| this is g
> from all import *
> f()
| this is f
> g()
| NameError: name 'g' is not defined
```

Performance of different ways of importing

`from math import sqrt`

appears to be faster than

`math.sqrt`

sqrt_performance.py

```
from time import time
import math
start = time()
x = sum(math.sqrt(x) for x in range(10000000))
end = time()
print('math.sqrt', end - start)
from math import sqrt
start = time()
x = sum(sqrt(x) for x in range(10000000))
end = time()
print('from math import sqrt', end - start)
def test(sqrt=math.sqrt):  # abuse of keyword argument
    start = time()
    x = sum(sqrt(x) for x in range(10000000))
    end = time()
    print('bind sqrt to keyword argument', end - start)
test()
```

Python shell

```
math.sqrt 4.05187726020813
from math import sqrt 3.5011463165283203
bind sqrt to keyword argument 3.261594772338867
```

Listing definitions in a module: dir(*module*)

Python shell

```
> import math
> import matplotlib.pyplot as plt
> dir(math)
| ['__doc__', '__loader__', '__name__', '__package__', '__spec__', 'acos',
  'acosh', 'asin', 'asinh', 'atan', 'atan2', 'atanh', 'ceil', 'copysign',
  'cos', 'cosh', 'degrees', 'e', 'erf', 'erfc', 'exp', 'expm1', 'fabs',
  'factorial', 'floor', 'fmod', 'frexp', 'fsum', 'gamma', 'gcd', 'hypot',
  'inf', 'isclose', 'isfinite', 'isinf', 'isnan', 'ldexp', 'lgamma', 'log',
  'log10', 'log1p', 'log2', 'modf', 'nan', 'pi', 'pow', 'radians', 'sin',
  'sinh', 'sqrt', 'tan', 'tanh', 'tau', 'trunc']
> help(math)
| Help on built-in module math:
| NAME
|     math
| DESCRIPTION
| ...
```

https://docs.python.org/3/library/functions.html#dir

__name__

double.py

```
'''Module double.'''

def f(x):
    '''
    Some doc test code:

    >>> f(21)
    42
    >>> f(7)
    14
    '''

    return 2 * x

print('__name__ =', __name__)

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

Python shell

```
| __name__ = __main__
  ...
  2 passed and 0 failed.
  Test passed.
```

using_double.py

```
import double

print(__name__)
print(double.f(5))
```

Python shell

```
| __name__ = double
  __main__
  10
```

- The variable `__name__` contains the name of the module, or `'__main__'` if the file is run as the main file by the interpreter
- Can e.g. be used to test a module if the module is run independently

module `importlib`

- Implements the `import` statement (Python internal implementation details)
- `importlib.reload(`*module*`)`
  - Reloads a previously imported *module*. Relevant if you have edited the code for the module and want to load the new version in the Python interpreter, without restarting the full program from scratch.

a_constant.py

```
the_constant = 7
```

Python shell

```
> import a_constant  # import module
> a_constant.the_constant
| 7
> from a_constant import the_constant
> the_constant
| 7
# Update 7 to 42 in a_constant.py
> a_constant.the_constant  # new value not reflected
| 7
> import a_constant  # void, module already loaded
> a_constant.the_constant
| 7  # unchanged
> import importlib
> importlib.reload(a_constant)
| <module 'a_constant' from 'C:\\...\\a_constant.py'>
> a_constant.the_constant
| 42
> the_constant
| 7  # imported attributes are not updated by reload
> from a_constant import the_constant  # force update
> the_constant
| 42  # the new value
```

Packages

- A package is a collection of modules (and subpackages) in a folder = package name
- Only folders having an `__init__.py` file are considered packages
- The `__init__.py` can be empty, or contain code that will be loaded when the package is imported, e.g. importing specific modules

mypackage/__init__.py

```
```

mypackage/a.py

```
print('Loading mypackage.a')
def f():
    print('mypackage.a.f')
```

using_mypackage.py

```
import mypackage.a
mypackage.a.f()
```

Python shell

```
Loading mypackage.a
mypackage.a.f
```

A package with a subpackage

mypackage/__init__.py

```
print('loading mypackage')
```

mypackage/a.py

```
print('Loading mypackage.a')
def f():
    print('mypackage.a.f')
```

mypackage/mysubpackage/__init__.py

```
print('loading mypackage.mysubpackage')
import mypackage.mysubpackage.b
```

mypackage/mysubpackage/b.py

```
print('Loading mypackage.mysubpackage.b')
def g():
    print('mypackage.mysubpackage.b.g')
```

using_mysubpackage.py

```
import mypackage.a
mypackage.a.f()
import mypackage.mysubpackage
mypackage.mysubpackage.b.g()
from mypackage.mysubpackage.b import g
g()
```

Python shell

```
loading mypackage
Loading mypackage.a
mypackage.a.f
loading mypackage.mysubpackage
Loading mypackage.mysubpackage.b
mypackage.mysubpackage.b.g
mypackage.mysubpackage.b.g
```

`__pycache__` folder

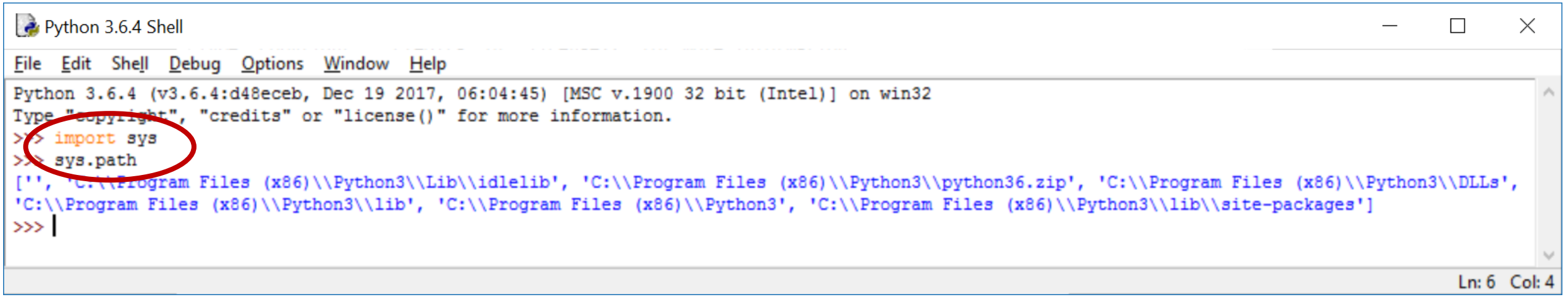
- When Python loads a module the first time it is *compiled* to some intermediate code, and stored as a .pyc file in the `__pycache__` folder.
- If a .pyc file exists for a module, and the .pyc file is newer than the .py file, then `import` loads .pyc – saving time to load the module (but does not make the program itself faster)
- It is safe to delete the `__pycache__` folder – but it will be created again next time a module is loaded

Path to modules

Python searches the following folders for a module in the following order:

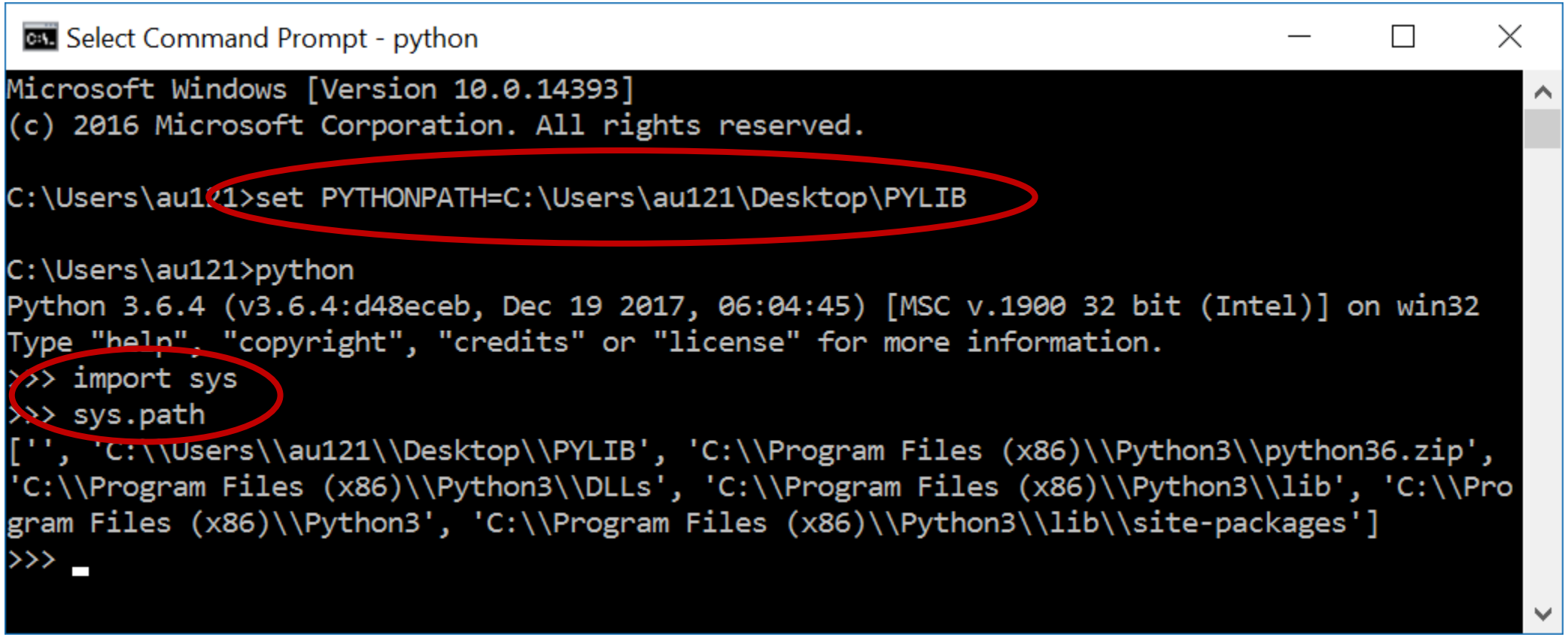
1) The directory containing the input script / current directory
2) *Environment* variable `PYTHONPATH`
3) Installation defaults

The function `path` in the modul `sys` returns a list of the paths



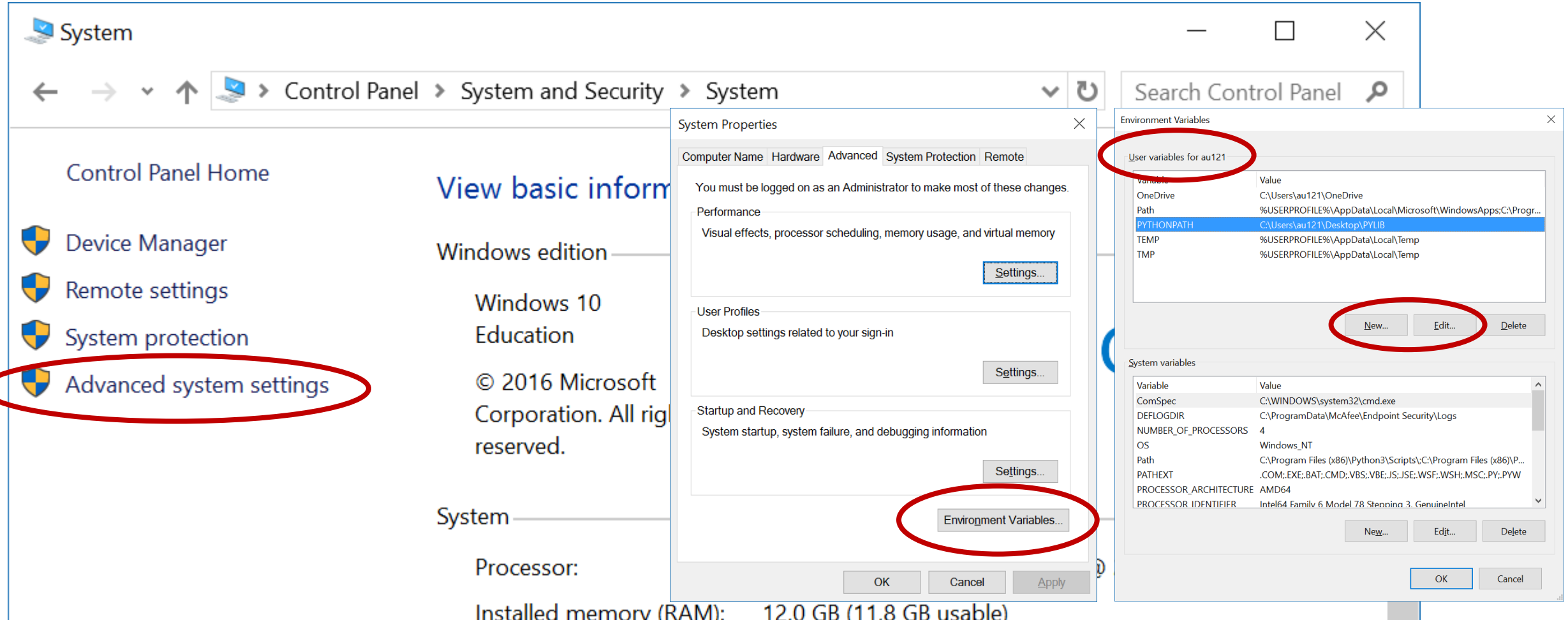
Setting PYTHONPATH from windows shell

- set PYTHONPATH=*paths separated by semicolon*
  (only valid until shell is closed)



Setting PYTHONPATH from control panel

- Control panel > System > Advanced system settings > Environment Variables > User variables > Edit or New PYTHONPATH



Python shell www.python.org/dev/peps/pep-0020/

```
> import this
| The Zen of Python, by Tim Peters
|
| Beautiful is better than ugly.
| Explicit is better than implicit.
| Simple is better than complex.
| Complex is better than complicated.
| Flat is better than nested.
| Sparse is better than dense.
| Readability counts.
| Special cases aren't special enough to break the rules.
| Although practicality beats purity.
| Errors should never pass silently.
| Unless explicitly silenced.
| In the face of ambiguity, refuse the temptation to guess.
| There should be one-- and preferably only one --obvious way to do it.
| Although that way may not be obvious at first unless you're Dutch.
| Now is better than never.
| Although never is often better than *right* now.
| If the implementation is hard to explain, it's a bad idea.
| If the implementation is easy to explain, it may be a good idea.
| Namespaces are one honking great idea -- let's do more of those!
```

module **heapq** (Priority Queue)

- Implements a binary **heap** (Williams 1964).
- Stores a set of elements in a standard list, where arbitrary elements can be inserted efficiently and the *smallest element* can be extracted efficiently

heapq.heappush
heapq.heappop

docs.python.org/3/library/heapq.html

J. W. J. Williams. *Algorithm 232: Heapsort*. Communications of the ACM (1964)

heap.py

```
import heapq
from random import random

H = []  # a heap is just a list

for _ in range(10):
    heapq.heappush(H, random())

while True:
    x = heapq.heappop(H)
    print(x)
    heapq.heappush(H, x + random())
```

Python shell

```
0.20569933892764458
0.27057819339616174
0.31115615362876237
0.4841062272152259
0.5054280956005357
0.509387117524076
0.598647195480462
0.7035150735555027
0.7073929685826221
0.7091224012815325
0.714213496127318
0.727868481291271
0.8051275413759873
0.8279523767282903
0.8626022363202895
0.9376631236263869
```

Valid heap

- A *valid heap* satisfies for all i:

  $L[i] \leq L[2 \cdot i + 1]$ and $L[i] \leq L[2 \cdot i + 2]$

- **`heapify(L)`** rearranges the elements in a list to make the list a valid heap

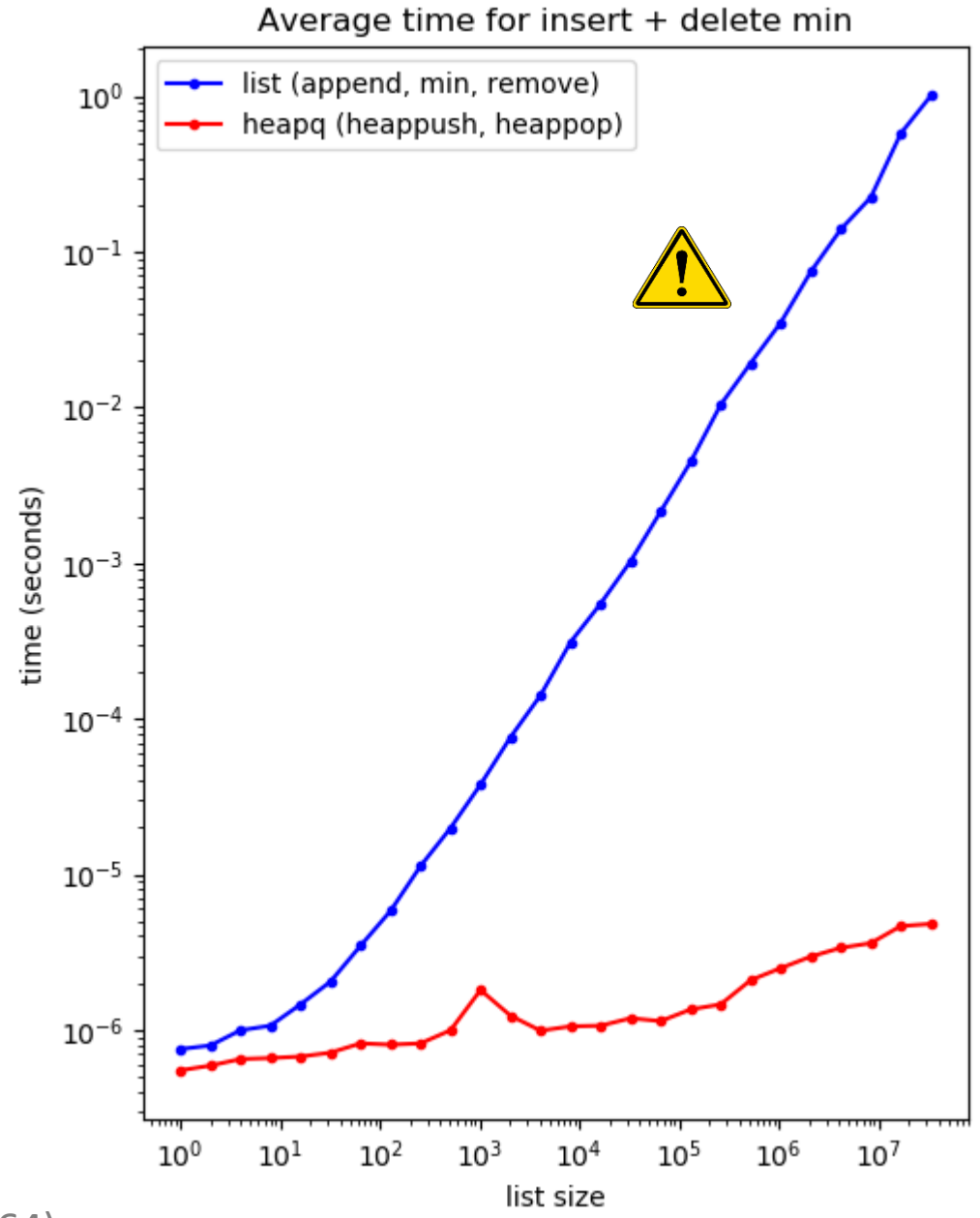
Python shell

```
> from random import randint
> L = [randint(1, 20) for _ in range(10)]
> L  # just random numbers
| [18, 1, 15, 17, 4, 14, 11, 3, 4, 9]
> import heapq
> heapq.heapify(L)  # make L a valid heap
> L
| [1, 3, 11, 4, 4, 14, 15, 17, 18, 9]
> print(heapq.heappop(L))
| 1
> L
| [3, 4, 11, 4, 9, 14, 15, 17, 18]
> heapq.heappush(L, 7)
> L
| [3, 4, 11, 4, 7, 14, 15, 17, 18, 9]
```

J. W. J. Williams. *Algorithm 232: Heapsort*. Communications of the ACM (1964)

Why `heapq` ?

- `min` and `remove` on a list take *linear time* (runs through the whole list)
- heapq supports `heappush` and `heappop` in *logarithmic time*
- For lists of length 30.000.000 the performance gain is a factor 200.000



J. W. J. Williams. *Algorithm 232: Heapsort*. Communications of the ACM (1964)

heap_performance.py (generating plot on previous slide)

```
import heapq
from random import random
import matplotlib.pyplot as plt
from time import time
import gc  # garbage collection

size = []
time_heap = []
time_list = []

for i in range(26):
    n = 2 ** i
    size.append(n)

    L = [random() for _ in range(n)]
    R = max(1, 2 ** 23 // n)
    gc.collect()
    start = time()
    for _ in range(R):
        L.append(random())
        x = min(L)
        L.remove(x)
    end = time()
    time_list.append((end - start) / R)
```

(B)

```
    L = None  # avoid MemoryError
    L = [random() for _ in range(n)]
    heapq.heapify(L)  # make L a legal heap
    gc.collect()
    start = time()
    for _ in range(100000):
        heapq.heappush(L, random())
        x = heapq.heappop(L)
    end = time()
    time_heap.append((end - start) / 100000)

plt.title('Average time for insert + delete min')
plt.xlabel('list size')
plt.ylabel('time (seconds)')
plt.plot(size, time_list, 'b.-',
         label='list (append, min, remove)')
plt.plot(size, time_heap, 'r.-',
         label='heapq (heappush, heappop)')
plt.xscale('log')
plt.yscale('log')
plt.legend()
plt.show()
```

(A)

(B)

(A) Avoid out of memory error for largest experiment, by allowing old `L` to be garbage collected

(B) Reduce noise in experiments by forcing Python garbage collection before measurement