INTRODUCTION TO PYTHON

http://www.liacs.nl/home/snijssen/CI/

Python

- General-purpose
- Interpreted
- High-level
- Readable code
- Open source (CPython)

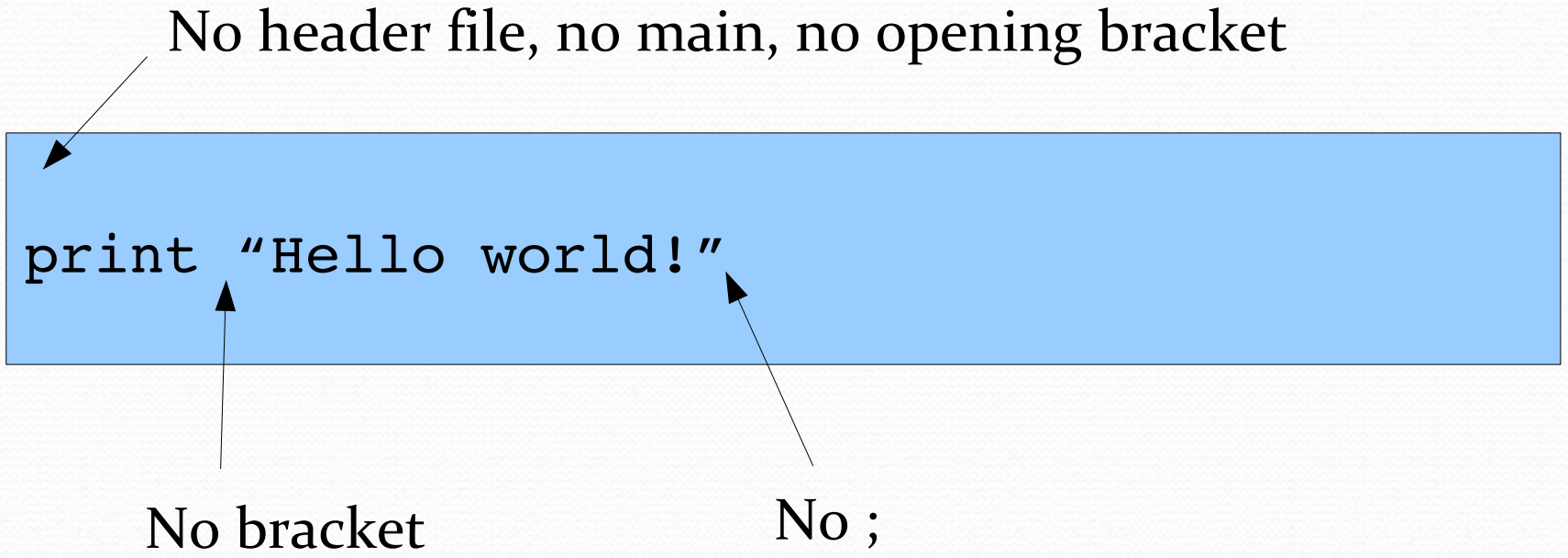
www.python.org

Python History

- Created and maintained by Guido van Rossum at the CWI (Amsterdam, 1980s), at Google (California) and Dropbox (California, now)
- Python 2.x is most common
- Python 3.x (released 2008) is the current standard
  - **not fully compatible with Python 2.x**

We will use what works best for us

Hello World


No header file, no main, no opening bracket
print “Hello world!”
No bracket
No ;

Variables

- Variables have types, but the type depends on what you assign to the variable
- Variables are not declared

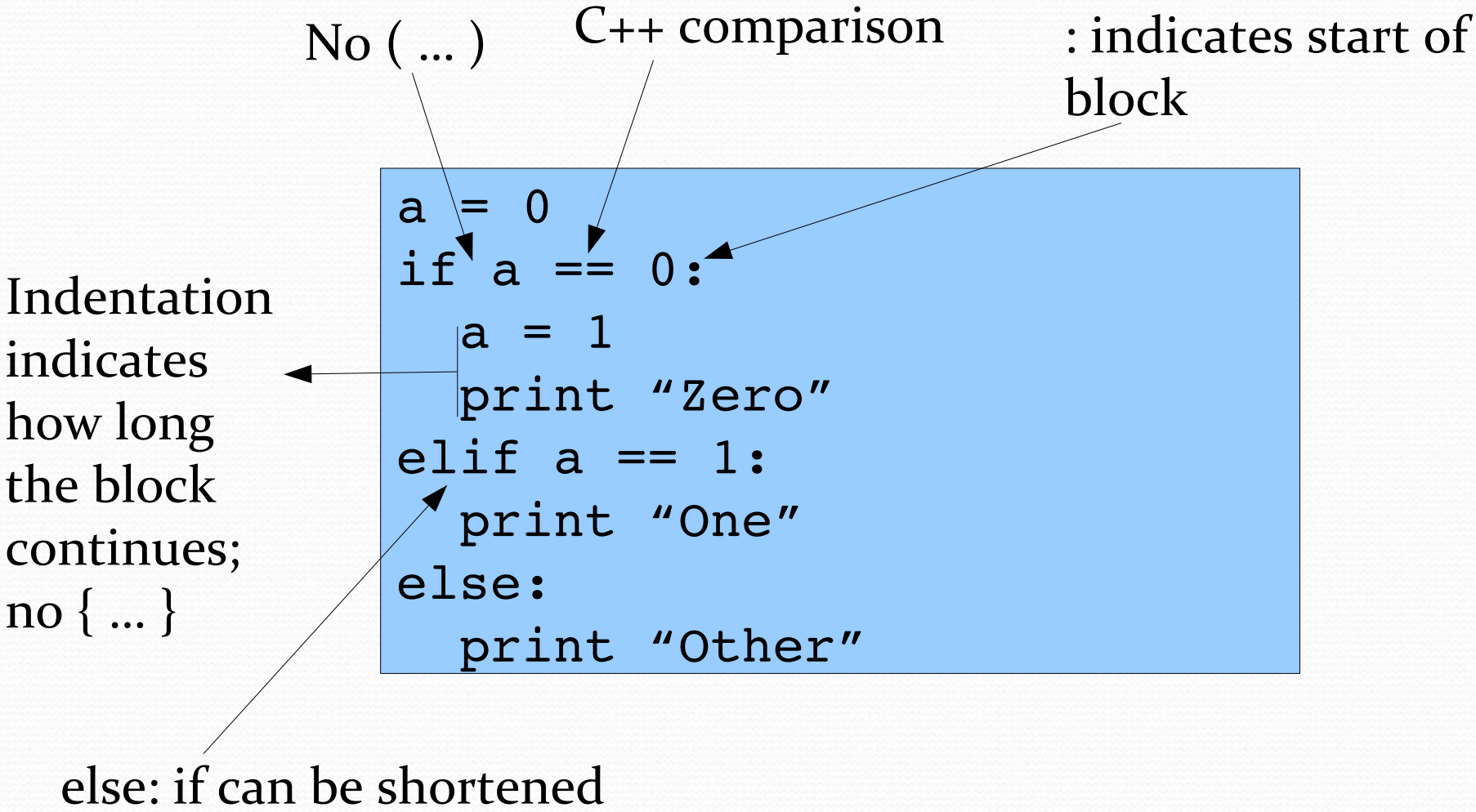
```
a = 0
b = “text”
print a, b
```

adds space as well

```
a, b = 0, “text”
b, a = a, b
print a, b
```

simultaneous assignment allowed

If-statements



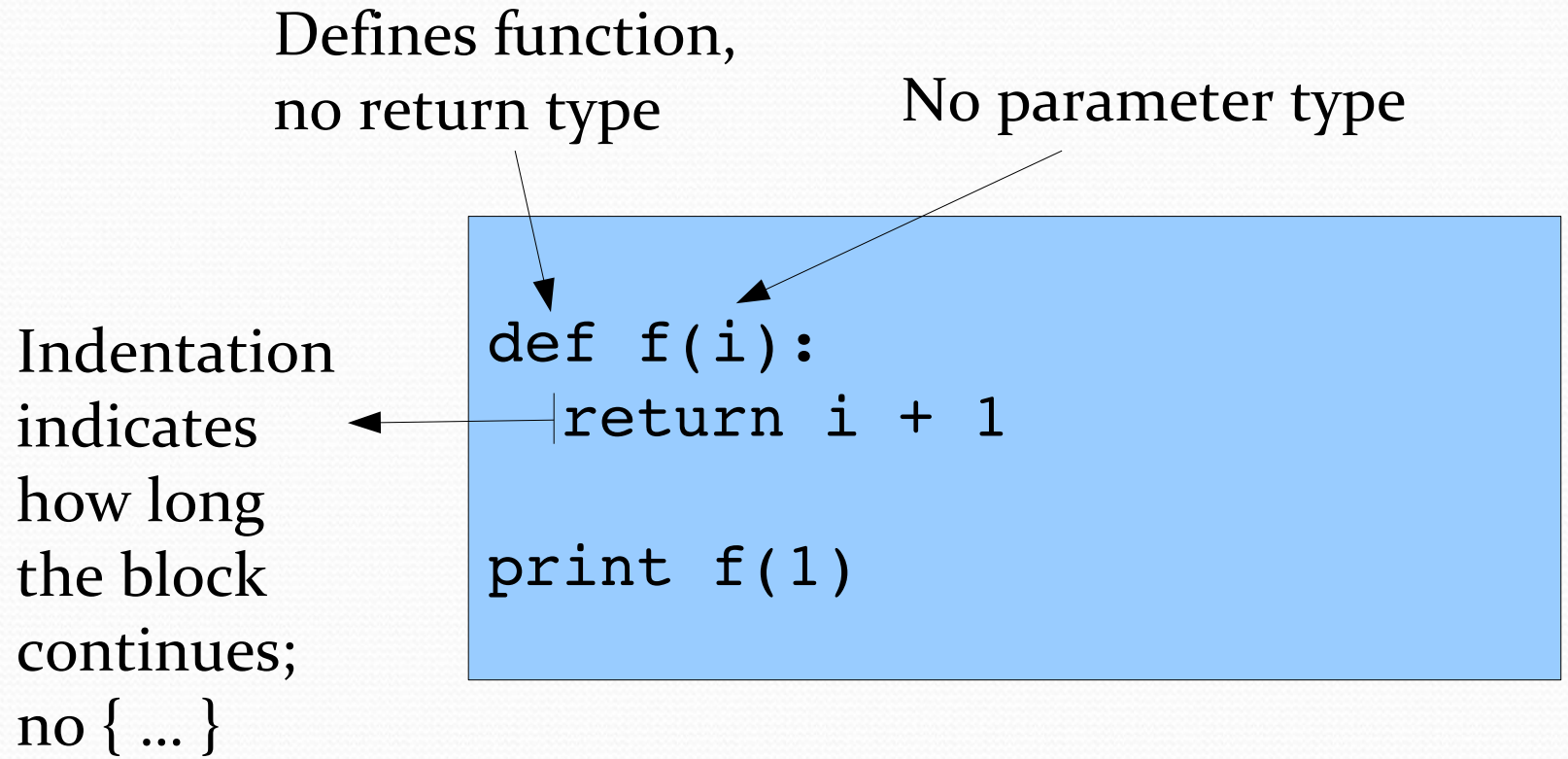
While-statement

```
a = 0
while a < 10:
    print a
    a += 1
```

Indentation indicates how long the block continues; no { ... }

a++ not supported

Functions


Defines function,
no return type
No parameter type
Indentation
indicates
how long
the block
continues;
no { … }
def f(i):
return i + 1
print f(1)

Classes

```
class Dimension:
  width = 10
  height = 10

d = Dimension ()
```

Default value for variable

Create instance by class and () (no new statement)

Reference semantics

```
class Dimension:
  width = 10
  height = 10

def f(dimension):
  dimension.width = 20

d1 = Dimension ()
d2 = d1
f(d1)
print d1.width, d2.width
```

"all variables
are actually pointers"

objects are deleted
(garbage collection)
when there is no
pointer to them.

d2 points to the
same object as d1

prints "20 20"
(like Java)

Class constructors / methods

```
class Dimension:
  width = 10
  height = 10
  def __init__ ( self, w, h ):
    self.width = w
    self.height = h

  def write ( self ):
    print self.width, self.height

d = Dimension ( 3, 3 )
d.write ()
```

"constructor" is always named __init__

a "this" pointer always needs to be added (and is called "self")

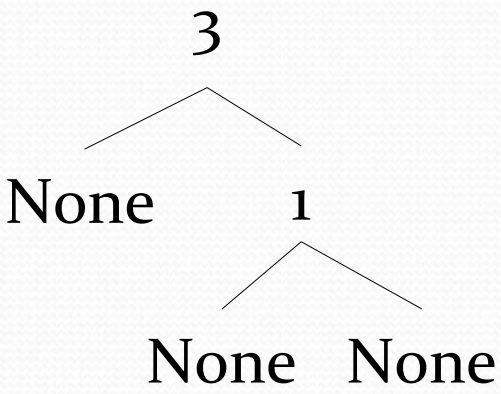
nothing there

Classes: None

```
class Tree:
  def __init__ ( self, v, l, r ):
    self.left = l
    self.right = r
    self.value = v

t = Tree ( 3, None, Tree ( 1, None, None ) )
```

Instead of NULL



Operators

- Mathematical:

  *, +, - , %, &, |, ~ : as in C++

  / : division, always produces float

  // : division, always produces integer

  ** : power-of

- Logical:

  and : instead of &&

  or : instead of ||

  not : instead of !

```
if a > 3 and b > 3:
  print a, b
```

Arithmetic & Boolean Types

- Basic mathematical type names are: **float** (64 bit), **int** (32 bit), **long** (unlimited), **complex** (float real and imaginary)
  - conversions:

```
a = 3
b = float(a)
```

- Boolean: **bool**
  - however: **False** and **True** are written with capitals!

Lists

- Python has a built-in type for lists, and a syntax for constructing lists

```
a = [10, 20, 30]
b = [10, "something", 30 ]
```

Multiple types can be in the same list

- Lists are like arrays, but can do more

```
a = [10, 20, 30]
print a[0]
print a[-1]
```

Prints "10"

Prints "30"

(as also seen in logical and functional programming languages)

Lists

- Slices

```
a = [10, 20, 30]
print a[0:2]
print a[1:]
print a[:2]
```

Prints “[10, 20]”

- Length of a list

```
a = [10, 20, 30]
print len(a)
```

Lists

- Concatenation

```
a = [10, 20, 30]
b = a + [40, 50]
```

- Multiplication

```
a = [10, 20, 30] * 3
```

[10, 20, 30,
10, 20, 30,
10, 20, 30]

- One can test for list membership

```
a = [10, 20, 30]
if 30 in a: print “in”
if 30 not in a: print “out”
```

(Be careful: uses linear search)

Strings

- Strings are also lists

```
a = “text”
print a[0:3], a*3
```

- Conversions to strings need to be done explicitly

```
a = 2
b = “Nummer “ + str(a)
```

- Many convenience functions for strings, eg.

```
print “--”.join([“one”,”two”,”three”])
```

prints “one--two--three”

(More later)

Lists and for-loops

- Important functions that return lists: (Python 2.x)

  range(x) → returns [0,1,2,…,x-1]
  range(x,y) → returns [x,x+1,…,y-1,y]

- For loops are defined for lists (and iterators)

```
for i in range(4):
  print i
```

Prints:
0
1
2
3

Sets

- Possible disadvantages of lists:
  - membership tests: linear search
  - elements can occur multiple times
- If problematic, use `sets`

```
a = { 2, 3, 3 }
print a
```

use { } instead of [ ]

prints "2 3"

```
a.add ( 1 )
print a
```

```
a = set([10,20,30])
print a
```

Tuples

- Tuples are *unmutable* lists
  - unmutable: the list cannot change (i.e., we cannot add or remove a value in the list)

```
a = ( 1, 2 )
print a
```

use `( )` instead of `[ ]`

```
a = 1, 2
print a
```

also creates a tuple

```
a, b = 1, 2
a, b = b, a
print a, b
```

"unpack" a tuple

creates tuple for `(b,a)`, unpacks this in `a,b`

Dictionaries

- Dictionaries are like sets, but associate a *value* to each *key* in a set

```
a = { “anna” : 1, “bill” : 2 }

for i in a:
  print i, a[i]
```

: announces value

Prints:

```
bill 2
anna 1
```

→ only keys are retrieved in `for`

→ array-like notation to retrieve value

Dictionaries

- Updating dictionaries

```
a = { “anna” : 1, “bill” : 2 }
a[“christine”] = 3
a.update ( { “donna” : 4, “eric” : 5 } )

a[“eric”] = 6

a.pop ( “donna” )
```

adds christine

Change value of “eric”

Remove “donna”

Reading files

```
f = open ( “test.txt” )
for line in f:
  print line
f.close ()
```

open for reading

retrieve line-per-line as if from a list

Note: `line` includes the end-of-line `\n`; after this `\n`, print by default puts another `\n`

Reading files

```
f = open ( “test.txt” )
f.readline ()
for line in f:
  print line.rstrip ()
f.close ()
```

Read one line

Remove white-space on the right (including \n)

```
line.lstrip ()
```

Remove whitespace on the left

```
line.strip ()
```

Remove whitespace on the left and right

```
line.split ()
```

Splits line in words based on whitespace

Writing files

```
f = open ( “test2.txt”, “w” )
a = [“1\n”,”2\n”,”3\n”]
f.writelines ( a )
f.write ( “something” )
f.close ()
```

open for writing

to write a list, it must consists of strings; add \n for newlines

Modules & Pickle

```
import pickle

a = [ [ 1, 2, 3 ], [ 2, 3, 4 ] ]

f = open ( “dump”, “w” )

pickle.dump ( a, f )
```

use the pickle library

writes any standard Python data structure to disk

```
import pickle

f = open ( “dump” )

print pickle.load ( f )
```

Modules & Pickle

```
from pickle import dump

a = [ [ 1, 2, 3 ], [ 2, 3, 4 ] ]

f = open ( “dump”, “w” )

dump ( a, f )
```

import one function

no need to add library name

```
from pickle import *

f = open ( “dump” )

print load ( f )
```

import all functions

Creating Modules

```
def increase ( x ):
  return x + 1
```

mymodule.py

```
import mymodule

print mymodule.increase ( 2 )
```

Looks in system path and local path for mymodule.py

Command line

```
import sys

print sys.argv
```


Contains a list of all command line arguments

or use the `optparse` module...

Other standard modules

- `math`
- `random`
- `gzip`
- `zipfile`
- `csv`
- `time`
- `optparse`
- `json`
- `xml`
- `...`

Exceptions

```
def search ( l, y ):
  for x in l:
    if x == y:
      raise

try:
  search ( [2, 3, 1, 4], 3 )
except:
  print "found"
```

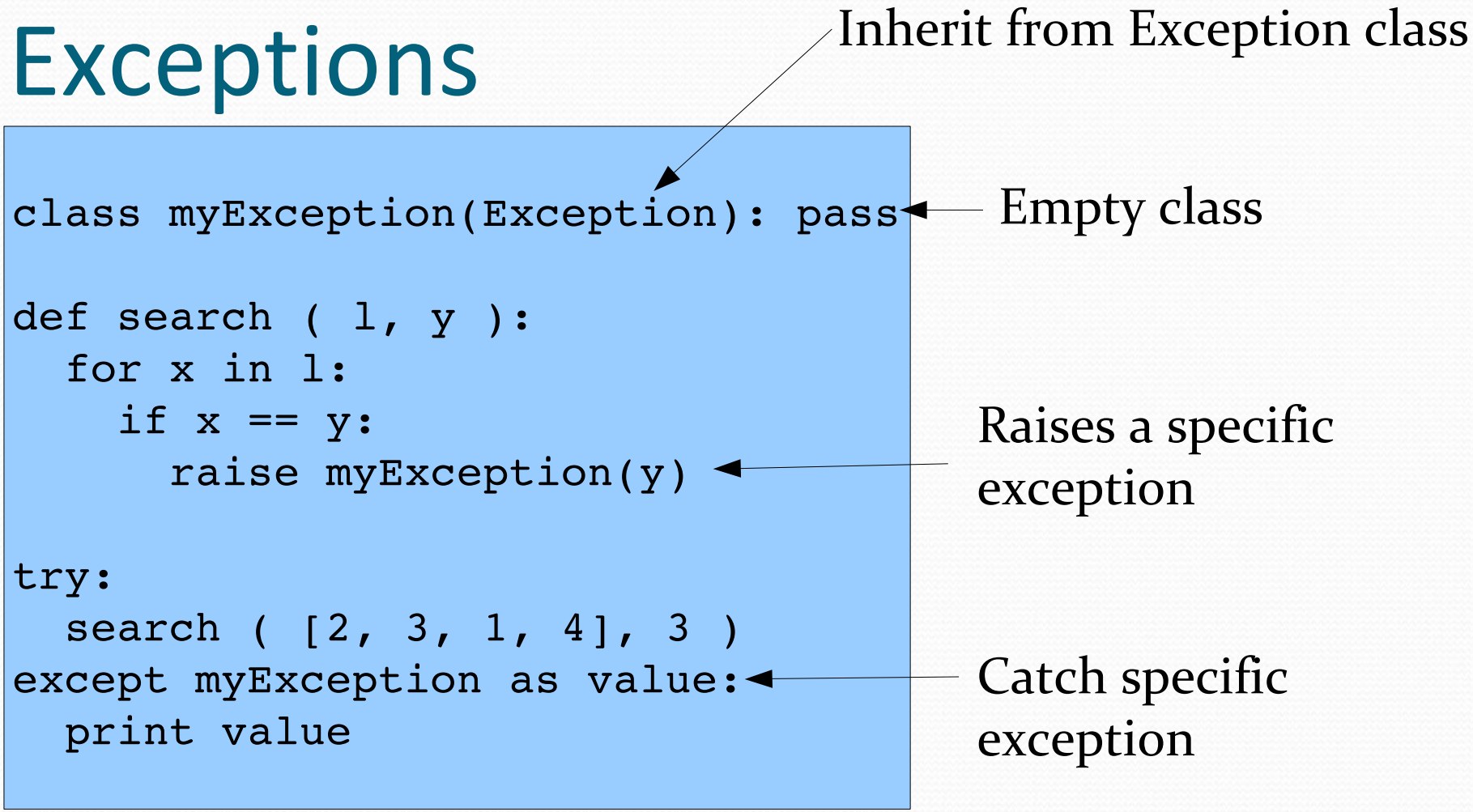
Raises an exception

Catch exceptions

Only executed if exception raised

(note: `if 3 in [2,3,1,4]: print "found"` would have been shorter)

Exceptions


Inherit from Exception class
class myException(Exception): pass
Empty class
def search (l, y):
for x in l:
if x == y:
raise myException(y)
Raises a specific exception
try:
search ([2, 3, 1, 4], 3)
except myException as value:
print value
Catch specific exception

Functions as Objects

- Python functions can be stored in variables

```
def f(i):
  return i + 1

a = f

print a(1)
```

Function Closures

```
def add(i):
  def sum(j):
    return i + j
  return sum

addone = add(1)

print addone(2)
```

value of `i` at the moment `g` is returned is stored together with `g` in `a`

Return function with one argument

Generators: yield

- if a function contains a `yield` statement, it can't have a `return` statement – when called, the function always immediately returns a generator object for itself
- each time the `next ()` operator is called, the function continues to be executed where it left off

```
def generator ( i ):
  print i
  yield
  print i+1


a = generator ( 1 )
a.next ()
a.next ()
```

Generators: yield

- a `yield` statement can also "return" a value

```
def till ( n ):
  i = 0
  while i < n:
    yield i
    i += 1

a = till ( 10 )
print a.next ()
print a.next ()
```

Generators: yield

- a `yield` statement can also "return" a value

```
def till ( n ):
  i = 0
  while i < n:
    yield i
    i += 1

a = till ( 10 )
print a.next ()
print a.next ()
```

Generators & for loops

- `for` loops also apply to generators

```
def till ( n ):
  i = 0
  while i < n:
    yield i
    i += 1

for i in till ( 10 ):
  print i
```

- in Python 2.x, `xrange(i)` is a generator (`range(i)` returns a list)
- in Python 3.x `range(i)` is a generator (`list(range(i))` creates a list by executing the generator)

List comprehension

```
a = [ i for i in xrange(10) if i != 2 ]
print a
```

source of elements

condition(s) on elements

$$\{i \in \{0, 1, \cdots\} \mid i \neq 2\}$$

Close to mathematical notation!

List comprehension

```
1. a = [ i for i in xrange(10) if i != 2 ]
2. print a
```

```
1. vector<int> a;
2. for ( int i = 0; i < 10; i++ )
3.  if ( i != 2 )
4.    a.push_back ( i );

5. for ( int i = 0; i < 10; i++ )
6.   cout << a[i] << " ";
7. cout << endl;
```

List comprehension

```
def quicksort(list):
  if list:
    return \
      quicksort ( [ x for x in list[1:] if x < list[0] ] ) \
      + [list[0]] + \
      quicksort ( [ x for x in list[1:] if x > list[0] ] )
  else:
    return []

print quicksort([5,1,3,2,4])
```

Map

- Still long:

```
def f(i): return i+1
a = range(10)
b = [ f(i) for i in a ]
```

- Shorter:

```
def f(i): return i+1
a = range(10)
b = map(f,a)
```


apply `f` on each element in the list

Map

```
a = [ [ 1, 2, 3 ], [ 2, 3, 4 ] ]

f = open ( “output”, “w” )

for x in a:
  f.write ( “ “.join ( map ( str, x ) ) + “\n” )
```

Reduce

- Still long:

```
def f(i,j): return i+j
a = range(10)
b = 0
for i in a: b = f(i,b)
```

- Shorter:

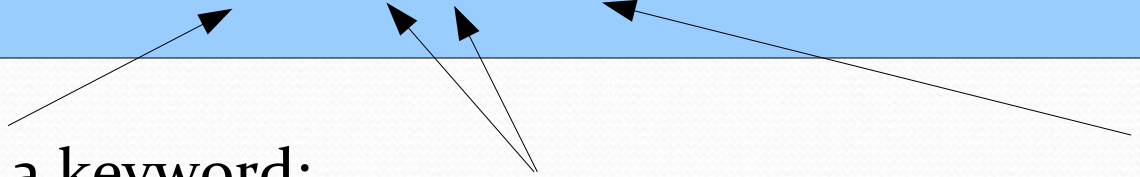
```
def f(i,j): return i+j
a = range(10)
b = reduce(f,a)
```

Note: Google's map/reduce framework based on combining on a large scale map & reduce to perform calculations

Lambda functions

- Inline definition of functions without name

```
a = range(10)
b = reduce(lambda i,j: i+j,a)
```



lambda is a keyword; function without name

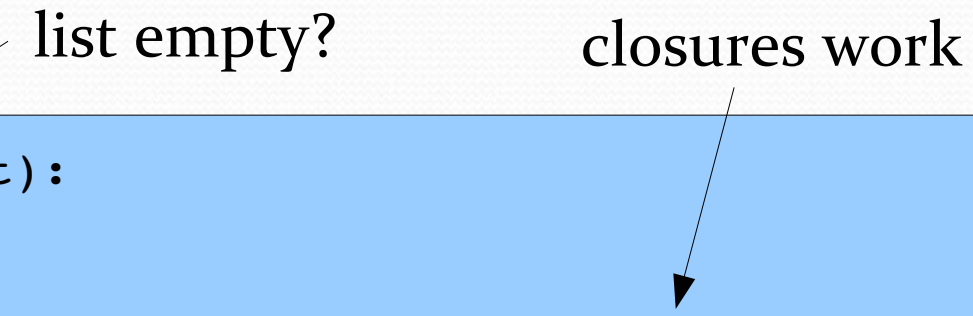
parameters of the function

return of the function

Only useful for functions that can be written with one expression

Filter

- Create sublist of a list based on boolean test




```
def quicksort(list):
  if list:
    return \
      quicksort ( filter(lambda x:x < list[0], list[1:] ) ) \
      + [list[0]] + \
      quicksort ( filter(lambda x:x > list[0], list[1:] ) )
  else:
    return []

print quicksort([5,1,3,2,4])
```

Math-like notation

- Sum

```
print sum([i**2 for in xrange(10)])
```

$$\sum_{i=0}^{9} i^2$$

- Max

```
print max([i**2 for in xrange(10)])
```

- And?

```
def land(l): return reduce(lambda x,y: x and y, l)
print land([True]*5)
```