Introduction to Python 2

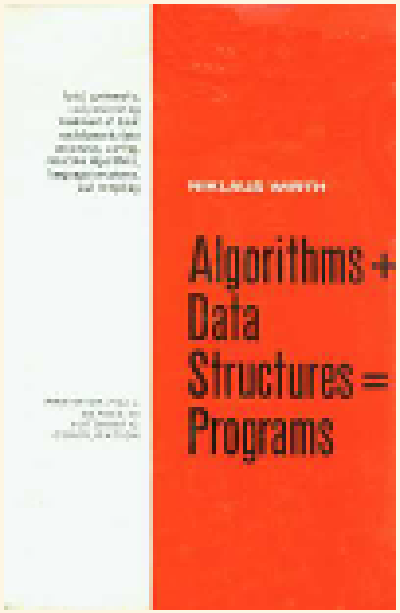
Chang Y. Chung

Office of Population Research

May 2015

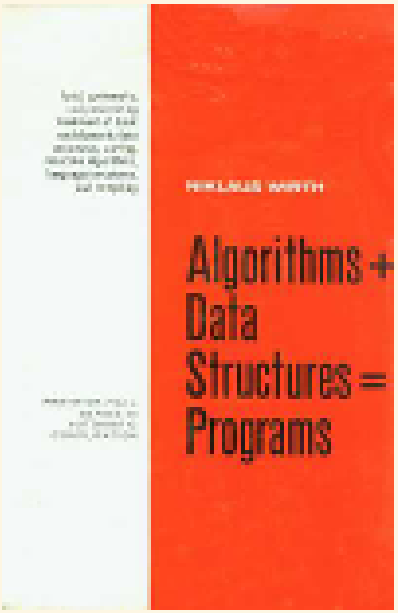
Algorithms + Data Structures = Programs

- Niklaus Wirth (1976)[**?**]



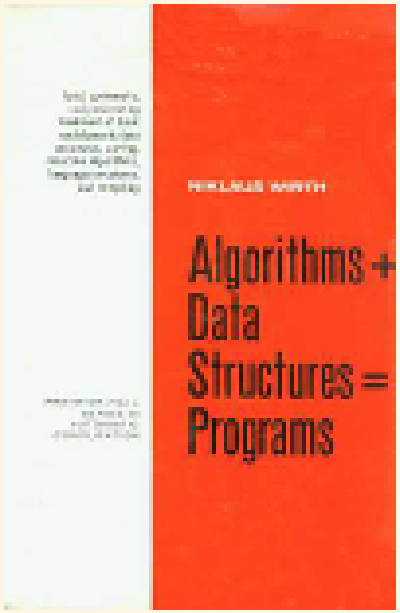
Algorithms + Data Structures = Programs

- Niklaus Wirth (1976)[**?**]
- Python's built-in data structures include:
  - List
  - Dictionary
  - Tuple



Algorithms + Data Structures = Programs

- Niklaus Wirth (1976)[**?**]
- Python's built-in data structures include:
  - List
  - Dictionary
  - Tuple
- We will also briefly talk about:
  - Class
  - Exception Handling



List

- Ordered (indexed) collection of arbitrary objects.
- Mutable – may be changed in place.

List

- Ordered collection of arbitrary objects.

```
1  L = []                       # a new empty list
2  L = list()                   # ditto
3
4  L = [1, 2.5, "abc", [56.7, 78.9]]
5  print len(L)                 # 4
6  print L[1]                   # 2.5 (zero-based)
7  print L[3][0]                # 56.7
8
9  for x in L:
10     print x
11 # 1
12 # 2.5
13 # "abc"
14 # [56.7, 78.9]
15
16 print "abc" in L, L.count("abc"), L.index("abc")
17 # True 1 2
```

List

- Mutable – may be changed in place.

```
1  L = []
2  L.append(5)
3  print L              #[5]
4
5  L[0] = 23
6  print L              #[23]
7
8  M = [87, 999]
9  L.extend(M)          # or L += M
10 print L              #[23, 87, 999]
11
12 del L[2]
13 print L              #[23, 87]
```

List

- More examples.

```
1  def squares(a_list):
2      s = []
3      for el in a_list:
4          s.append(el ** 2)
5      return s
6
7  sq = squares([1,2,3,4])
8  print sq, sum(sq)
9  #[1, 4, 9, 16] 30
```

List

- More examples.

```
def squares(a_list):
    s = []
    for el in a_list:
        s.append(el ** 2)
    return s

sq = squares([1,2,3,4])
print sq, sum(sq)
#[1, 4, 9, 16] 30
```

- Aliasing vs copying

```
L = [1,2,3,4]
M = L           # aliasing
L[0] = 87
print M         #[87, 2, 3, 4]

L = [1,2,3,4]
M = list(L)     # (shallow) copying. M = L[:] also works
L[0] = 87
print M         #[1,2,3,4]
```

Quiz

- Given a list,

```
L = [1, 2, [3, 4], 5, "xyz"]
```

evaluate the following expressions:

```
L[1] == 1
len(L) == 5
L[2] == 3, 4

[3] in L
L.index("xyz") == 4
L[-1] == "xyz"
L[-1][-1] == "z"

any([1, 2, 3]) == True
L[9] == None
len([0,1,2,]) == 3
```

Quiz

- Write a function that, given a list of integers, returns a *new* list of odd numbers only. For instance, given the list, `[0,1,2,3,4]`, this function should return a new list, `[1,3]`. (Hint: Create a new empty list. Loop over the old one appending only odd numbers into the new one. Return the new one.)

Quiz

- Write a function that, given a list of integers, returns a *new* list of odd numbers only. For instance, given the list, `[0,1,2,3,4]`, this function should return a new list, `[1,3]`. (Hint: Create a new empty list. Loop over the old one appending only odd numbers into the new one. Return the new one.)
- An answer.

```
1  def only_odd(a_list):
2      L = []
3      for el in a_list:
4          if el % 2 == 1:
5              L.append(el)
6      return L
7
8  print only_odd([0, 1, 2, 3, 4])
9  #[1, 3]
```

Quiz (cont.)

- (tricky) Write a function similar to the previous one. This time, however, do not return a new list. Just modify the given list so that it has only the odd numbers. (Hint: `del L[0]` removes the first element of the list, `L`)

```
1  def odd_only(a_list):
2      i = 0
3      length = len(a_list)
4      while i < length:
5          if (n % 2) == 0:
6              del a_list[i]
7              i -= 1
8              length -= 1
9          i += 1
10 L = [0, 1, 2, 3, 4]  # check
11 odd_only(L)
12 print L
```

Slice index

- Applies to any sequence types, including `list`, `str`, `tuple`, ...
- Has three (optional) parts separated by a colon (:), `start : end : step`, indicating `start` through but not past `end`, by `step`; Indices point *in-between* the elements.

```
+---+---+---+---+---+---+
| p | y | t | h | o | n |
+---+---+---+---+---+---+
0   1   2   3   4   5   6
-6  -5  -4  -3  -2  -1
```

- Examples:

```
L = ["p", "y", "t", "h", "o", "n"]
print L[:2]          # ["p", "y"] first two
print L[1:3]         # ["y", "t"]
print L[0:5:2]       # ["p", "t", "o"]
print L[-1]          # n the last element
print L[:]           # ["p", "y", "t", "h", "o", "n"] a (shallow) copy
print L[3:]          # ["h", "o", "n"]
print L[-2:]         # ["o", "n"] last two
print L[::-1]        # ["n", "o", "h", "t", "y", "p"] reversed
```

Quiz

- Suppose that you collect friendship network data among six children, each of whom we identify with a number: 0, 1, . . . , 5. The data are represented as a list of lists, where each element list represents the element child's friends.

```
1  L = [[1, 2], [0, 2, 3], [0, 1], [1, 4, 5], [3, 5], [3]]
```

  For instance, the kid 0 friends with the kids 1 and 2, since `L[0] == [1, 2]` Calculate the average number of friends the children have. (Hint: `len()` returns the list size.)

Quiz

- Suppose that you collect friendship network data among six children, each of whom we identify with a number: 0, 1, . . . , 5. The data are represented as a list of lists, where each element list represents the element child's friends.

```
L = [[1, 2], [0, 2, 3], [0, 1], [1, 4, 5], [3, 5], [3]]
```

  For instance, the kid 0 friends with the kids 1 and 2, since `L[0] == [1, 2]` Calculate the average number of friends the children have. (Hint: `len()` returns the list size.)

- An answer:

```
total = 0.0                 # make total a float type
for el in L:
    total += len(el)
avg = total / len(L)
print avg
# 2.1666
```

Quiz (cont.)

- (tricky)Write a function to check if *all* the friendship choices are reciprocated. It should take a list like previous one and return either `True` or `False`. (Hint: You may want to use a utility function below.)

```
1  def mutual(a_list, ego, alter):
2      return alter in a_list[ego] and ego in a_list[alter]
3
4  def all_reciprocated(a_list):
5      for ego in range(len(a_list)):
6          alters = a_list[ego]
7          for alter in alters:
8              if not mutual(a_list, ego, alter):
9                  return False
10     return True
```

List Comprehension

- A concise way to create a list. An example:

```
1  [x for x in range(5) if x % 2 == 1]        #[1, 3]
```

- An equivalent code using the for loop:

```
1  L = []
2  for x in range(5):
3      if x % 2 == 1:
4          L.append(x)                        #[1, 3]
```

- More examples.

```
1  [x - 5 for x in range(6)]                  #[-5, -4, -3, -2, -1, 0]
2  [abs(x) for x in [-2,-1,0,1]]               #[2, 1, 0, 1]
3  [x for x in range(6) if x == x**2]         #[0, 1]
4  [1 for x in [87, 999, "xyz"]]              #[1, 1, 1]
5  [x - y for x in range(2) for y in [7, 8]]  #[-7, -8, -6, -7]
```

Dictionary

- A collection of key-value pairs.
- Indexed by keys.
- Mutable.

Dictionary

- A collection of key-value pairs.
- Indexed by keys.
- Mutable.
- Also known as associative array, map, symbol table, . . .
- Usually implemented as a hash table.

Dictionary

- A collection of key-value pairs, indexed by keys.

```
1  D = {}                                  # an empty dictionary. D=dict() also works
2
3  D["one"] = 1                            # {"one": 1}
4  D["two"] = 2
5  print D                                 # {"one": 1, "two": 2}
6
7  print D.keys()                          # ["two", "one"] arbitrary order!
8  print "three" in D.keys()                # False. "three" in D also works
9
10 D = {"Apple": 116, "Big Mac": 550}
11
12 for key in ["Apple", "Orange", "Big Mac"]:
13     if key in D:
14         value = D[key]
15         print "{0} has {1} calories".format(key, value)
16     else:
17         print "{0} is not found in the dictionary".format(key)
18 # Apple has 116 calories
19 # Orange is not found in the dictionary
20 # Big Mac has 550 calories
```

Dictionary

- More Dictionary examples.

```
D = {"China": 1350, "India":1221, "US":317}
for key in D.keys():
    print "Pop of {0}: {1} mil".format(key, D[key])
# Pop of India: 1221 mil
# Pop of China: 1350 mil
# Pop of US: 317 mil

D = {[1,2]: 23}
# TypeError: unhashable type: 'list'

D = {2: [2, 3], 200: [3, 4], 95: [4, 5]} # OK
print D[2]      # [2, 3]
print D[200]    # [3, 4]
```

A Data Structure

- SAT has three subsections: Critical Reading, Mathematics, and Writing. A result of taking an SAT exam is three scores.

```
1  # data
2  SAT = {"cr":780, "m":790, "w":760}
3  # usage
4  print SAT["m"]          # 790
```

A Data Structure

- SAT has three subsections: Critical Reading, Mathematics, and Writing. A result of taking an SAT exam is three scores.

```
# data
SAT = {"cr":780, "m":790, "w":760}
# usage
print SAT["m"]          # 790
```

- You can take SAT exams more than once.

```
# data
SATs = [{"cr":780, "m":790, "w":760},
        {"cr":800, "m":740, "w":790}]
# usage
print SATs[0]           # {"cr":780, "m":790, "w":760}
print SATs[0]["cr"]     # 780
```

More Complicated Data Structure

- Hypothetical SAT data for two people: Jane and Mary.

```
SAT = {"Jane": {"lastname": "Thompson",
                "test": [{"cr": 700, "m": 690, "w":710}] },
       "Mary": {"lastname": "Smith",
                "test": [{"cr": 780, "m": 790, "w":760},
                         {"cr": 800, "m": 740, "w":790}] }}

print SAT["Jane"]
# {"test": ["cr": 700, "m": 690, "w": 710], "lastname": "Thompson"}

print SAT["Jane"]["lastname"]       # Thompson
print SAT["Jane"]["test"]           # [{"cr": 700, "m": 690, "w":710}]
print SAT["Jane"]["test"][0]        # {"cr": 700, "m": 690, "w": 710}
print SAT["Jane"]["test"][0]["cr"] # 700

mary1 = SAT["Mary"]["test"][1]
print mary1["cr"]                   # 800
```

Quiz

- Make a dictionary of 2012 SAT percentile ranks for the scores from 680 to 700 and for all three subsections. The full table is available at `http://tinyurl.com/k38xve8`. Given this dictionary, say `D`, a lookup, `D[680]["cr"]` should be evaluated to `93`.

Quiz

- Make a dictionary of 2012 SAT percentile ranks for the scores from 680 to 700 and for all three subsections. The full table is available at `http://tinyurl.com/k38xve8`. Given this dictionary, say `D`, a lookup, `D[680]["cr"]` should be evaluated to `93`.
- An answer.

```
D = {700: {"cr": 95, "m": 93, "w": 96},
     690: {"cr": 94, "m": 92, "w": 95},
     680: {"cr": 93, "m": 90, "w": 94}}

print D[680]["cr"]      #93
```

Quiz (cont.)

- (tricky) Write a new dictionary `DD` such that we look up the subsection first and then the score. That is, `DD["cr"][680]` should be evaluated to `93`.
  (Hint: Start with a dictionary below.):

```
DD = {"cr": {700: 95, 690: 94, 680: 93},
      "m": {700: 93, 690: 92, 680: 90},
      "w": {700: 96, 690: 95, 680: 94}}
```

Tuples

- A sequence of values separated by commas.
- Immutable.
- Often automatically *unpacked*.

Tuples

- A sequence of values separated by commas. Immutable.

```
1  T = tuple()                          # empty tuple. T = () works also
2  N = (1)                              # not a tuple
3  T = (1, 2, "abc")                    # a tuple (1, 2, "abc")
4  print T[0]                           # 1
5  T[0] = 9                             # TypeError. immutable
```

- Often automatically unpacked.

```
1  T = (2, 3)
2  a, b = T                             # a is 2, b is 3
3  a, b = b, a                          # a and b swapped.
4
5  D = {"x": 23, "y": 46}
6  D.items()                            # [("y", 46), ("x", 23)]
7  for k, v in D.items():
8      print "%s ==> %d" % (k, v)       # y ==> 46
9                                       # x ==> 23
```

Class

- `class` defines a (user-defined) type, a grouping of some data (properties) and functions that work on the data (methods).
- An object is an *instance* of a type.
- Examples:
  - `int` is a type; `23` is an object.
  - `str` a type; `"abc"` an object.
  - "word document file" a type; "my_diary.docx" is an object
  - We have been using objects.

Examples of Built-in Types

- The `str` type has a bunch of methods.

```
"abc".upper()                    # ABC
"abc".find("c")                  # 2
"abc".split("b")                 # ["a", "c"]
```

- `open()` function returns a `file` object (representing an opened file).

```
with open("test.txt", "w") as my_file:
    my_file.write("first line\n")
    my_file.write("second line\n")
    my_file.write("third line")

    print type(my_file)          # <type "file">
    print dir(my_file)           # properties and methods

my_file.write("something")       # error. I/O on closed file
```

Class

- Let’s create a bank account type.

```
class BankAccount:

    def __init__(self, initial_balance=0):
        self.balance = initial_balance

    def deposit(self, amount):
        self.balance += amount

    def withdraw(self, amount):
        self.balance -= amount
```

- Usage examples.

```
my_account = BankAccount(100)
my_account.withdraw(5)
print my_account.balance                    # 95

your_account = BankAccount()
your_account.deposit(100)
your_account.deposit(10)
print your_account.balance                  # 110
```

Quiz

- Implement a Person type(or class) which has three properties (first_name, last_name, and birth_year); and two methods: full_name() and age(). The age() method should take the current year as an argument. You may use the template below.

```
class Person:
    def __init__(self, first, last, year):
        self.first_name = first_name
        self.last_name = last_name
        self.birth_year = birth_year

    def full_name(self):
        return self.first_name + " " + self.last_name

    def age(self, current_year):
        return current_year - self.birth_year

# check
mr_park = Person("Jae-sang", "Park", 1977)
print mr_park.full_name()                    # Jae-sang Park
print mr_park.age(2014)                      # 37
```

Inheritance

- A mechanism for code reuse in object-oriented programming (OOP).
- A subtype is a specialized basetype.

```
1  import webbrowser
2
3  class CoolPerson(Person):
4      def __init__(self, name, birth_year, video):
5          Person.__init__(self, name, None, birth_year)
6          self.video = video
7      def full_name(self):
8          return self.first_name
9      def show_off(self):
10         url = "http://www.youtube.com/watch?v={0}"
11         webbrowser.open(url.format(self.video))
12
13 # check
14 psy = CoolPerson("PSY", 1977, "9bZkp7q19f0")
15 print psy.full_name()                    # PSY
16 print psy.age(2012)                      # 35
17 psy.show_off()                          # show off the style
```

Exception Handling

- An exception is raised when a (run-time) error occurs. By default, the script stops running immediately.

```
L = [0, 1, 2, 3]
print L[5]
# IndexError: list index out of range
```

- `try: ... except: ...` let us catch the exception and handle it.

```
L = [0, 1, 2, 3]
try:
    print L[5]

except IndexError:
    print "no such element"

print "next"
# no such element
# next
```

Throwing Exception

- We can raise (or throw) an exception as well.

```
1  def fetch(a_list, index):
2      if index >= len(a_list):
3          raise IndexError("Uh, oh!")
4      return a_list[index]
5
6  print fetch(L, 5)
7  # IndexError: Uh, oh!
```

- Script can keep going if you catch and handle the exception.

```
1  L = [0, 1, 2, 3]
2  try:
3      print fetch(L, 5)  # this raises an exception
4  except IndexError:
5      print "an exception occurred"
6  print "next"
7  # an exception occurred
8  # next
```

An Example

- urlopen() in urllib2 module raises an exception when the web page is not found.

```
1  import urllib2
2
3  L = ["http://google.com",
4       "http://google.com/somethingfantastic",
5       "http://yahoo.com"]
6
7  # we want to open each page in turn
8  for url in L:
9      try:
10         page = urllib2.urlopen(url)
11         print page.getcode()
12     except urllib2.HTTPError:
13         print "failed to open: {0}".format(url)
14
15 # 200 (a return code of 200 means OK)
16 # failed to open: http://google.com/somethingfantastic
17 # 200
```

Summary

- List – An ordered collection of objects. Mutable.
- Dictionary – A collection of key-value pairs. Mutable.
- Tuple – A sequence of values separated by commas. Immutable.
- Class – Defines a type, a grouping of properties and methods.
- `try`: ... `except`: ... – Catch and handle exceptions.