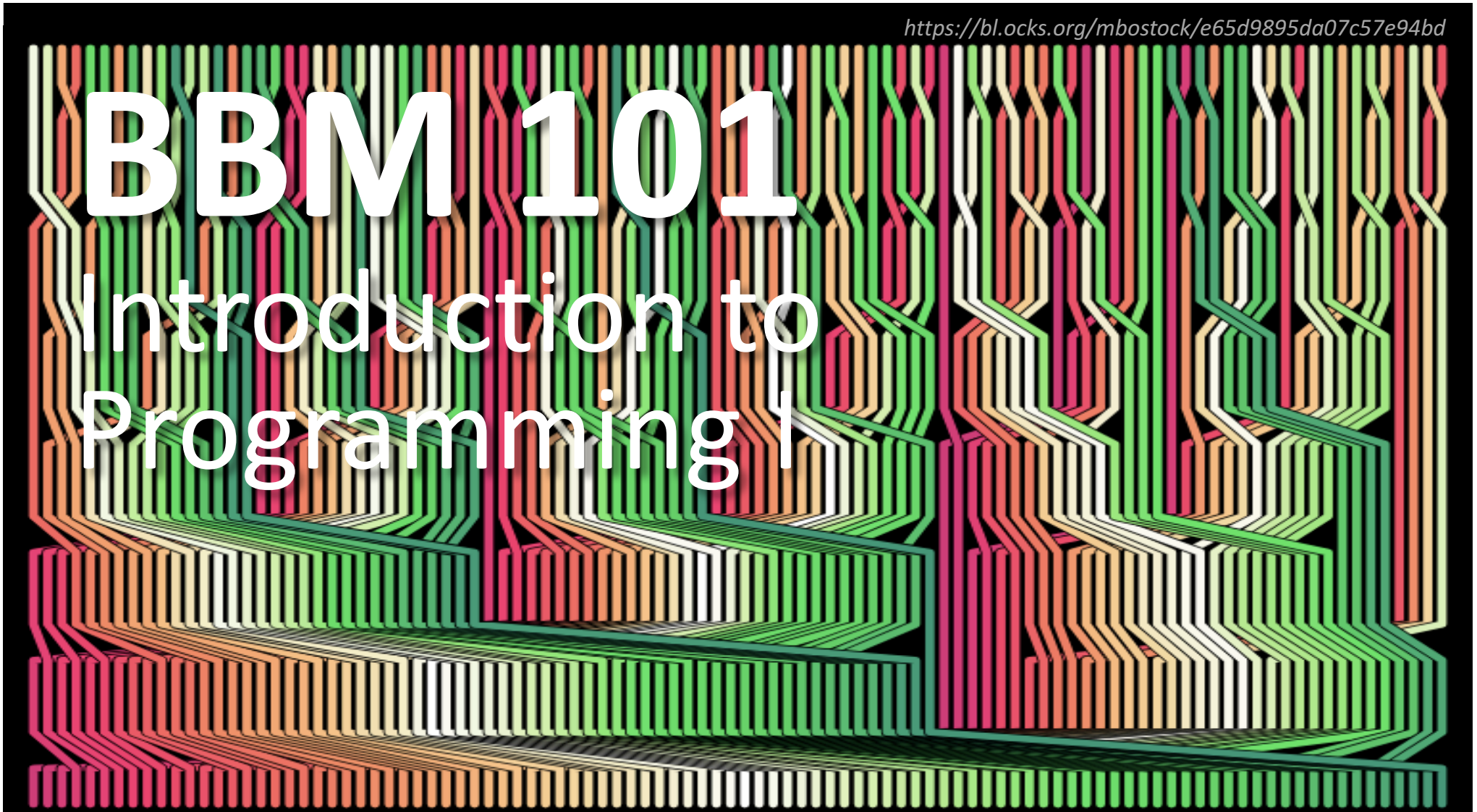

BBM 101

Introduction to Programming I

Lecture #07 – Sorting, List Comprehension, Data Visualization

HACETTEPE UNIVERSITY

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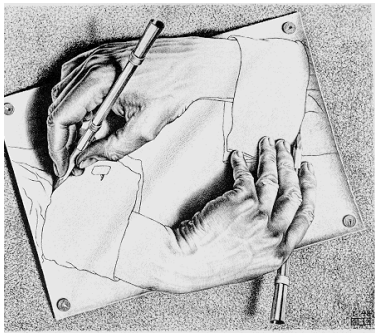
Last time… **Recursion**



Recursion

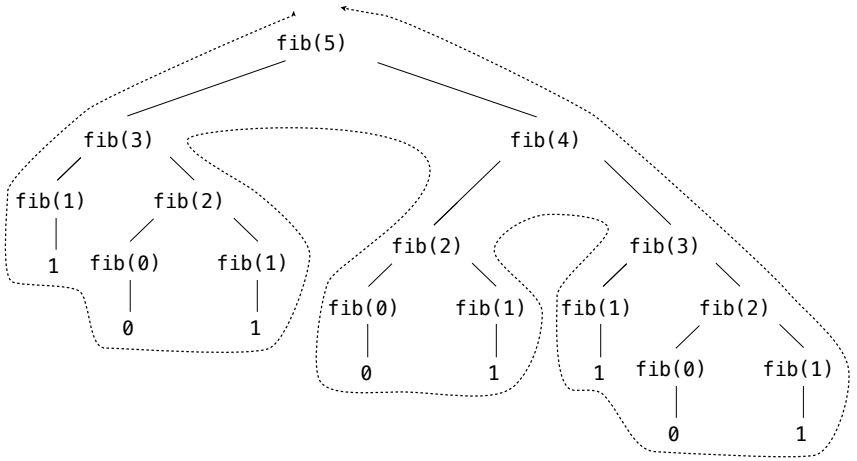
```
def f(n):
    if n == 0:
        return 0
    else:
        return 1 + f(n -
1)
```

Mutual recursion

```
def even(n):
    if n == 0:
        return True
    else:
        return odd(n - 1)

def odd(n):
    if n == 0:
        return False
    else:
        return even(n - 1)
```

Recursion tree

```
def fib(n):
    if n == 0:
        return 1
    elif n == 1:
        return 1
    else:
        return fib(n-2) + fib(n-1)
```



Lecture Overview

- Sorting
- List comprehension
- Data visualization

Disclaimer: Much of the material and slides for this lecture were borrowed from
—R. Anderson, M. Ernst and B. Howe in University of Washington CSE 140
—C. van Loan in Cornell University CS 1110 Introduction to Computing

Lecture Overview

- Sorting
- List comprehension
- Data visualization

Sorting

```
hamlet = "to be or not to be that is the
question whether tis nobler in the mind to
suffer".split()

print("hamlet:", hamlet)

print("sorted(hamlet):", sorted(hamlet))
print("hamlet:", hamlet)

print("hamlet.sort():", hamlet.sort())
print("hamlet:", hamlet)
```

- Lists are mutable – they can be changed
  - including by functions

Sorting

```
hamlet: ['to', 'be', 'or', 'not', 'to', 'be', 'that',
'is', 'the', 'question', 'whether', 'tis', 'nobler',
'in', 'the', 'mind', 'to', 'suffer']

sorted(hamlet): ['be', 'be', 'in', 'is', 'mind',
'nobler', 'not', 'or', 'question', 'suffer', 'that',
'the', 'the', 'tis', 'to', 'to', 'to', 'whether']

hamlet: ['to', 'be', 'or', 'not', 'to', 'be', 'that',
'is', 'the', 'question', 'whether', 'tis', 'nobler',
'in', 'the', 'mind', 'to', 'suffer']

hamlet.sort(): None

hamlet: ['be', 'be', 'in', 'is', 'mind', 'nobler',
'not', 'or', 'question', 'suffer', 'that', 'the',
'the', 'tis', 'to', 'to', 'to', 'whether']
```

Customizing the sort order

Goal: sort a list of names *by last name*

```
names = ["Isaac Newton", "Albert Einstein", "Niels
Bohr", "Marie Curie", "Charles Darwin", "Louis
Pasteur", "Galileo Galilei", "Margaret Mead"]

print("names:", names)
```

This does NOT work:

```
print("sorted(names):", sorted(names))
```

When sorting, how should we compare these names?

```
"Niels Bohr"
"Charles Darwin"
```

```
sorted(names): ['Albert Einstein', 'Charles
Darwin', 'Galileo Galilei', 'Isaac Newton',
'Louis Pasteur', 'Margaret Mead', 'Marie
Curie', 'Niels Bohr']
```

Sort key

A sort key is a different value that you use to sort a list, instead of the actual values in the list

```
def last_name(str):
    return str.split(" ")[1]

print('last_name("Isaac Newton"):',
last_name("Isaac Newton"))
```

Two ways to use a sort key:

1. Create a new list containing the sort key, and then sort it
2. Pass a key function to the sorted function

1. Use a sort key to create a new list

Create a different list that contains the sort key, sort it, then extract the relevant part:

```
names = ["Isaac Newton", "Fred
# keyed_names is a list of [la
keyed_names = []
for name in names:
  keyed_names.append([last_na
```

keyed_names: [['Newton', 'Isaac Newton'], ['Newton', 'Fred Newton'], ['Bohr', 'Niels Bohr']]
sorted(keyed_names): [['Bohr', 'Niels Bohr'], ['Newton', 'Fred Newton'], ['Newton', 'Isaac Newton']]
sorted(keyed_names, reverse = True): [['Newton', 'Isaac Newton'], ['Newton', 'Fred Newton'], ['Bohr', 'Niels Bohr']]

Take a look at the list you created, it can now be sorted:

```
print("keyed_names:", keyed_names)
print("sorted(keyed_names):", sorted(keyed_names))
print("sorted(keyed_names, reverse = True):")
print(sorted(keyed_names, reverse
```

sorted_names: ['Isaac Newton', 'Fred Newton', 'Niels Bohr']

(This works because Python compares two elements that are lists *elementwise*.)

```
sorted_keyed_names = sorted(keyed_names, reverse = True)
sorted_names = []
for keyed_name in sorted_keyed_names:
  sorted_names.append(keyed_name[1])
print("sorted_names:", sorted_names)
```

2) Sort the list new list.

3) Extract the relevant part.

2. Use a sort key as the **`key`** argument

Supply the **`key`** argument to the **`sorted`** function or the **`sort`** function

```
def last_name(str):
    return str.split(" ")[1]
names = ["Isaac Newton", "Fred Newton", "Niels Bohr"]
print("sorted(names, key =
print(sorted(names, key = l

print("sorted(names, key =
print(sorted(names, key = l

print(sorted(names, key = l

def last_name_len(name):
    return len(last_name(name))

print(sorted(names, key = last_name_len))
```

```
sorted(names, key = last_name): ['Niels Bohr',
'Isaac Newton', 'Fred Newton']
sorted(names, key = last_name, reverse = True):
['Isaac Newton', 'Fred Newton', 'Niels Bohr']

['Niels Bohr', 'Fred Newton', 'Isaac Newton']
['Niels Bohr', 'Isaac Newton', 'Fred Newton']
```

`itemgetter` is a function that returns a function..

```
import operator

print(operator.itemgetter(2, 7, 9, 10)("dumbstricken"))
operator.itemgetter(2, 5, 7, 9)("homesickness")
operator.itemgetter(2, 7, 9, 10)("pumpernickel")
operator.itemgetter(2, 3, 6, 7)("seminaked")
operator.itemgetter(1, 2, 4, 5)("smirker")

operator.itemgetter(9, 7, 6, 1)("beatnikism")
operator.itemgetter(14, 13, 5, 1)("Gedankenexperiment")
operator.itemgetter(12, 10, 9, 5)("mountebankism")
```

All: `('m','i','k','e')`

Using `itemgetter`

```
from operator import itemgetter
student_score = ('Robert', 8)
```

`itemgetter(0)(student_score)` ⇒ "Robert"

`itemgetter(1)(student_score)` ⇒ 8

```
student_scores = [('Robert', 8), ('Alice', 9),
('Tina', 7)]
```

- Sort the list by name:

  ```
  sorted(student_scores, key=itemgetter(0) )
  ```

- Sort the list by score

  ```
  sorted(student_scores, key=itemgetter(1) )
  ```

Two Ways to Import `itemgetter`

```
from operator import itemgetter
student_score = ('Robert', 8)
itemgetter(0)(student_score)
```
⇒ “Robert”

```
itemgetter(1)(student_score)
```
⇒ 8

or

```
import operator
student_score = ('Robert', 8)
operator.itemgetter(0)(student_score)
```
⇒ “Robert”

```
operator.itemgetter(1)(student_score)
```
⇒ 8

Sorting based on two criteria

Two approaches:

- Approach #1: Use an **`itemgetter`** with two arguments
- Approach #2: Sort twice (most important sort ***last***)

```
student_scores = [('Robert', 8), ('Alice', 9),
                  ('Tina', 10), ('James', 8)]
```

Goal: sort based on score;
if there is a tie within score, sort by name

Approach #1:

```
sorted(student_scores, key=itemgetter(1,0))
```

Approach #2:

```
sorted_by_name = sorted(student_scores, key=itemgetter(0))
sorted_by_score = sorted(sorted_by_name, key=itemgetter(1))
```

Sort on most important criteria LAST

- Sorted by score (ascending), when there is a tie on score, sort using name

```
from operator import itemgetter
student_scores = [('Robert', 8), ('Alice', 9), ('Tina', 10),
('James', 8)]

sorted_by_name = sorted(student_scores, key=itemgetter(0))
>>> sorted_by_name
[('Alice', 9), ('James', 8), ('Robert', 8), ('Tina', 10)]

sorted_by_score = sorted(sorted_by_name, key=itemgetter(1))
>>> sorted_by_score
[('James', 8), ('Robert', 8), ('Alice', 9), ('Tina', 10)]
```

More sorting based on two criteria

If you want to sort different criteria in different directions, you must use multiple calls to **`sort`** or **`sorted`**

```
student_scores = [('Robert', 8), ('Alice', 9), ('Tina', 10),
('James', 8)]
```

Goal: sort score from highest to lowest; if there is a tie within score, sort by name alphabetically (= lowest to highest)

```
sorted_by_name = sorted(student_scores, key=itemgetter(0) )
sorted_by_hi_score = sorted(sorted_by_name,
      key=itemgetter(1), reverse=True)
```

Sorting: strings vs. numbers

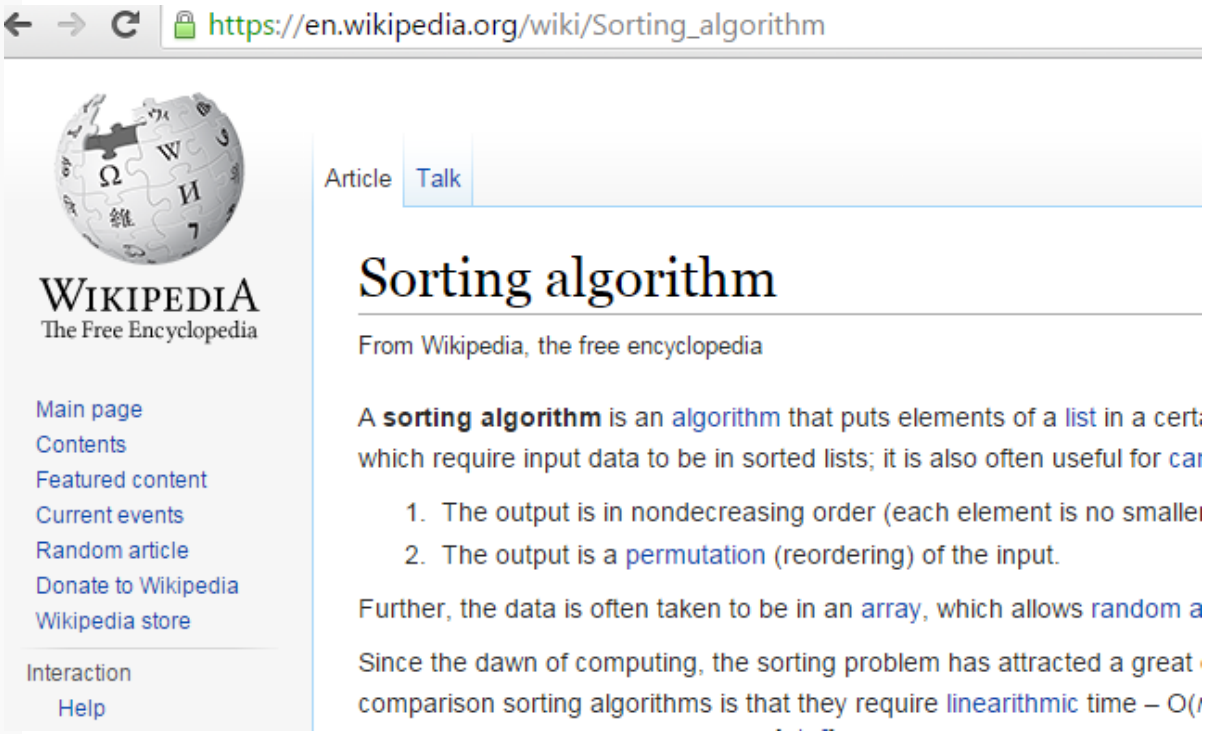
- Sorting the powers of 5:

```
>>> sorted([125, 5, 3125, 625, 25])
[5, 25, 125, 625, 3125]
>>> sorted(["125", "5", "3125", "625", "25"])
['125', '25', '3125', '5', '625']
```

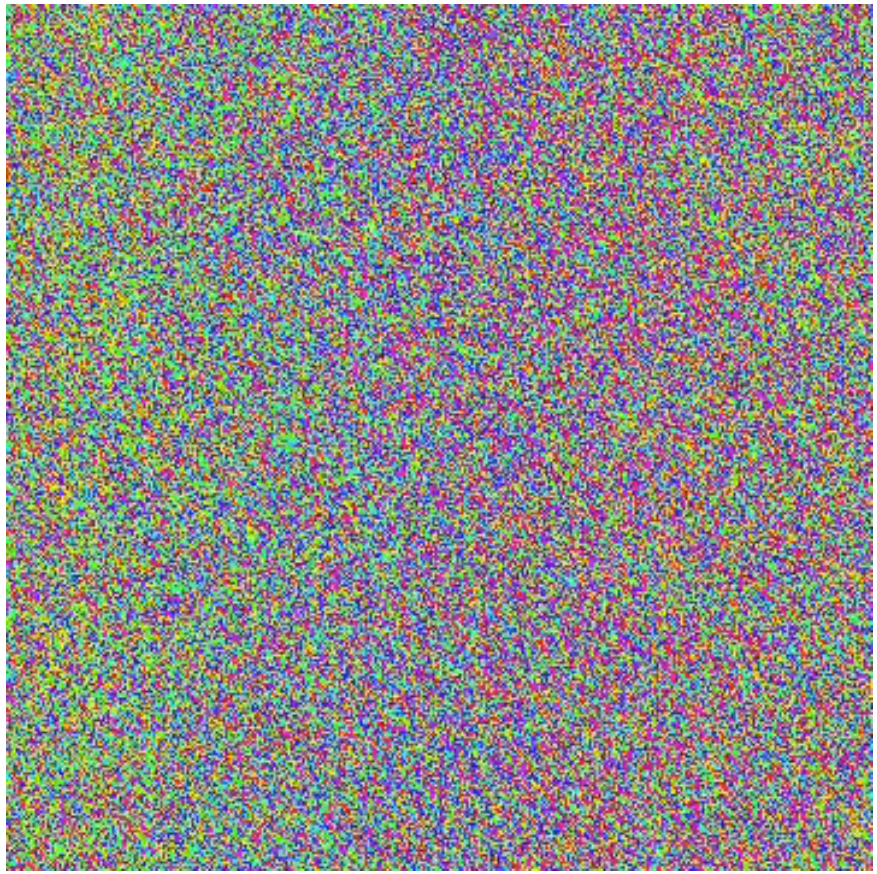
Sorting

from *BBC Documentary: The Secret Rules of Modern Living Algorithms*

Different sorting algorithms



Bubble sort



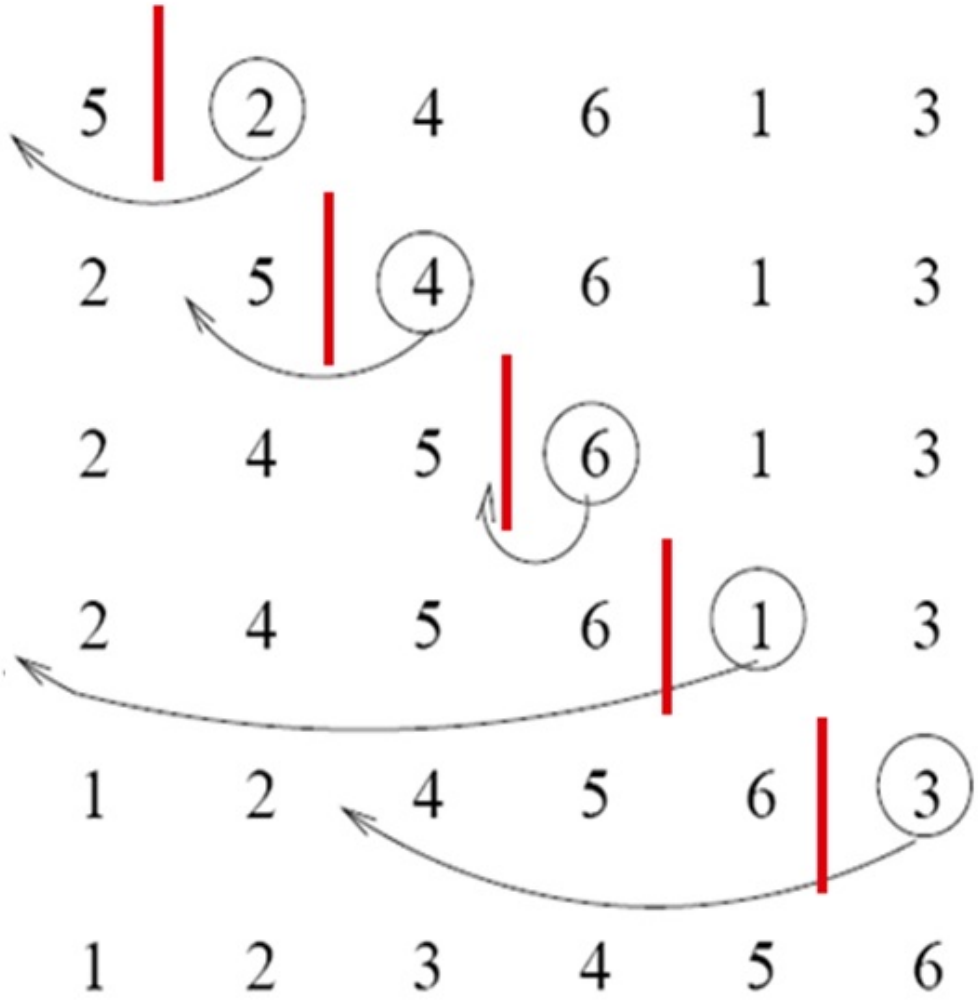
- It repeatedly steps through the list to be sorted,
- compares each pair of adjacent items and swaps them if they are in the wrong order.
- The pass through the list is repeated until no swaps are needed, which indicates that the list is sorted.
- The algorithm, which is a comparison sort, is named for the way smaller elements "bubble" to the top of the list.

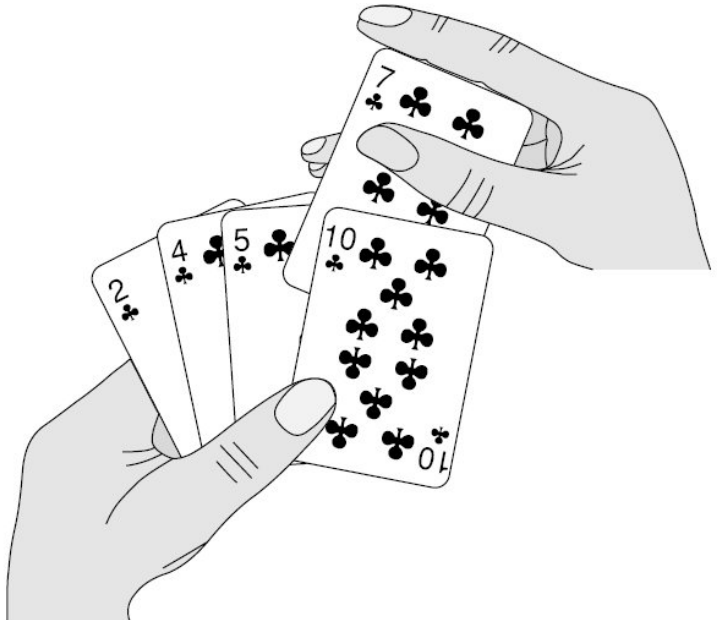
Bubble sort

```
def bubbleSort(alist):
    for passnum in range(len(alist)-1,0,-1):
        for i in range(passnum):
            if alist[i]>alist[i+1]:
                temp = alist[i]
                alist[i] = alist[i+1]
                alist[i+1] = temp

alist = [54,26,93,17,77,31,44,55,20]
bubbleSort(alist)
print(alist)
```

Insertion sort

- Idea:





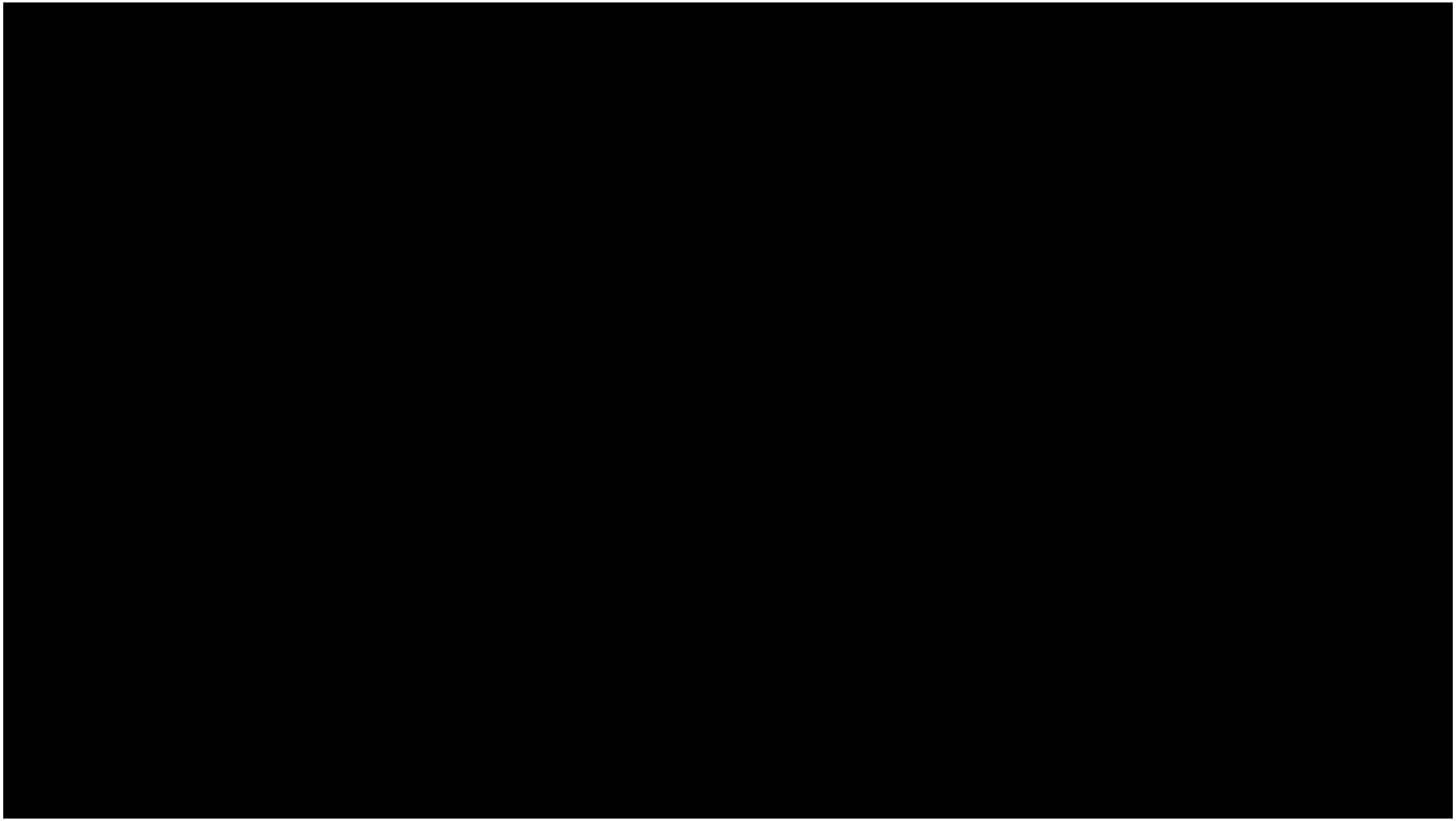
- maintain a sorted sublist in the lower positions of the list.
- Each new item is then "inserted" back into the previous sublist such that the sorted sublist is one item larger.

Done !

Insertion sort

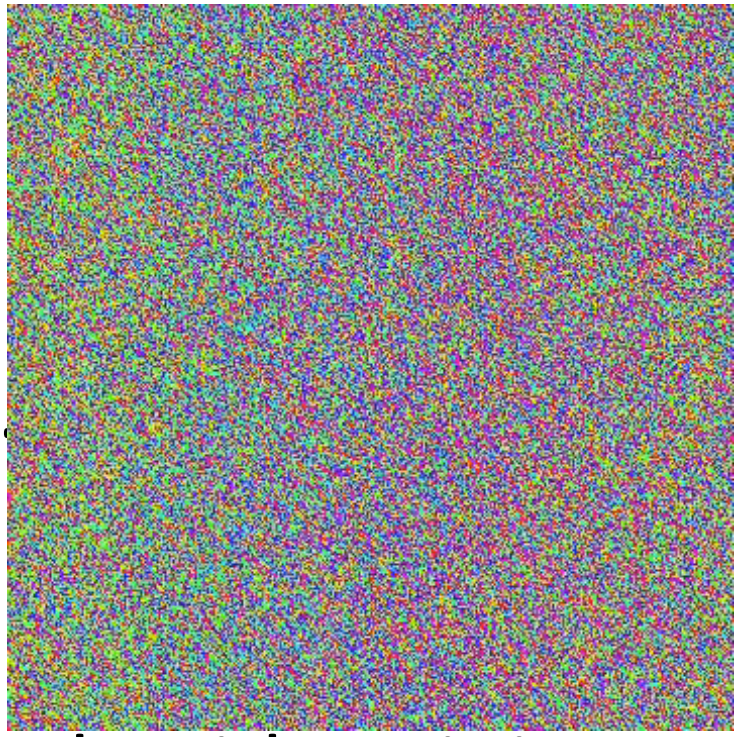
```
def insertionSort(alist):
    for index in range(1,len(alist)):
        currentvalue = alist[index]
        position = index

        while position>0 and alist[position-1]>currentvalue:
              alist[position]=alist[position-1]
              position = position-1

        alist[position]=currentvalue

alist = [54,26,93,17,77,31,44,55,20]
insertionSort(alist)
print(alist)
```

Insertion sort



https://www.youtube.com/watch?v=ROalU379l3U

Mergesort



- Merge sort is a prototypical divide-and-conquer algorithm.
- It was invented in 1945, by John von Neumann.
- Like many divide-and-conquer algorithms it is most easily described recursively.
  1. If the list is of length 0 or 1, it is already sorted.
  2. If the list has more than one element, split the list into two lists, and use mergesort to sort each of them.
  3. Merge the results.

Mergesort

```
def merge(left, right):
    result = []
    (i,j) = (0, 0)
    while i<len(left) and j<len(right):
       if left[i]<right[j]:
          result.append(left[i])
          i = i + 1
       else:
          result.append(right[j])
          j = j + 1
    while i<len(left):
       result.append(left[i])
       i = i + 1
    while j<len(right):
       result.append(right[j])
       j = j + 1
    return result
```

Mergesort

```
def mergeSort(L):
    if len(L)<2:
        return L[:]
    else:
        middle = len(L)//2
        left = mergeSort(L[:middle])
        right = mergeSort(L[middle:])
        return merge(left, right)

a = mergeSort([2,1,3,4,5,-1,8,6,7])
```

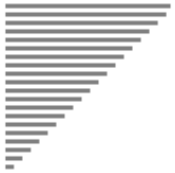
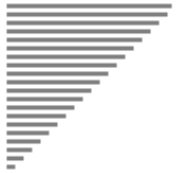
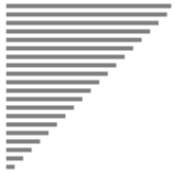
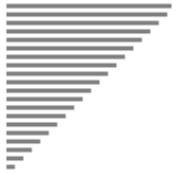
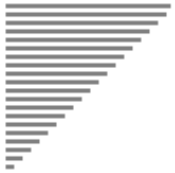
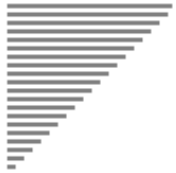
www.sorting-algorithms.com

Sorting Algorithm Animations

Problem Size: 20 · 30 · 40 · 50 Magnification: 1x · 2x · 3x

Algorithm: Insertion · Selection · Bubble · Shell · Merge · Heap · Quick · Quick3

Initial Condition: Random · Nearly Sorted · Reversed · Few Unique

	Insertion	Selection	Bubble	Shell	Merge	Heap	Quick	Quick3
Random								
Nearly Sorted								
Reversed								
Few Unique								

Lecture Overview

- Sorting
- List comprehension
- Data visualization

Three Ways to Define a List

- Explicitly write out the whole thing:

```
squares = [0, 1, 4, 9, 16, 25, 36, 49, 64, 81, 100]
```

- Write a loop to create it:

```
squares = []
for i in range(11):
    squares.append(i*i)
```

- Write a **list comprehension**:

```
squares = [i*i for i in range(11)]
```

- A list comprehension is a concise description of a list
- A list comprehension is shorthand for a loop

Two ways to convert Centigrade to Fahrenheit

```
ctemps = [17.1, 22.3, 18.4, 19.1]
```

With a loop:

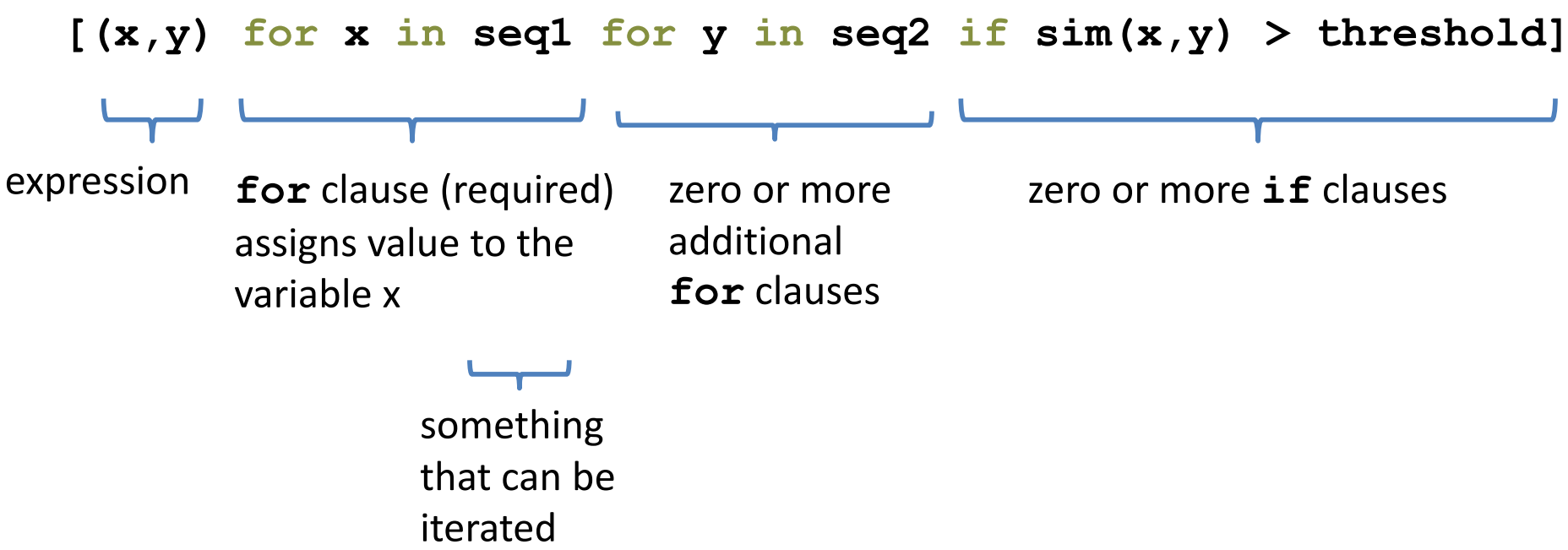
```
ftemps = []
for c in ctemps:
  f = celsius_to_farenheit(c)
  ftemps.append(f)
```

With a list comprehension:

```
ftemps = [celsius_to_farenheit(c) for c in ctemps]
```

The comprehension is usually shorter, more readable, and more efficient.

Syntax of a comprehension



Semantics of a comprehension

```
[(x,y) for x in seq1 for y in seq2 if sim(x,y) > threshold]
```

```
result = []
for x in seq1:
   for y in seq2:
      if sim(x,y) > threshold:
         result.append( (x,y) )
… use result …
```

Types of comprehensions

List

```
[ i*2 for i in range(3) ]
```

Set

```
{ i*2 for i in range(3)}
```

Dictionary

{ *key*: *value* for *item* in *sequence* …}

```
{ i: i*2 for i in range(3)}
```

Cubes of the first 10 natural numbers

Goal:

Produce: [0, 1, 8, 27, 64, 125, 216, 343, 512, 729]

With a loop:

```
cubes = []
for x in range(10):
  cubes.append(x**3)
```

With a list comprehension:

```
cubes = [x**3 for x in range(10)]
```

Powers of 2, 2^0 through 2^{10}

Goal: [1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024]

```
[2**i for i in range(11)]
```

Even elements of a list

Goal: Given an input list **`nums`**, produce a list of the even numbers in **`nums`**

```
nums = [3, 1, 4, 1, 5, 9, 2, 6, 5]
```

$\Rightarrow$ [4, 2, 6]

```
[num for num in nums if num % 2 == 0]
```

Dice Rolls

Goal: A list of all possible dice rolls.

With a loop:

```
rolls = []
for r1 in range(1,7):
  for r2 in range(1,7):
     rolls.append( (r1,r2) )
```

With a list comprehension:

```
rolls = [ (r1,r2) for r1 in range(1,7)
          for r2 in range(1,7)]
```

All above-average 2-die rolls

Goal: Result list should be a list of 2-tuples:
[(2, 6), (3, 5), (3, 6), (4, 4), (4, 5), (4, 6), (5, 3), (5, 4), (5, 5), (5, 6), (6, 2), (6, 3), (6, 4), (6, 5), (6, 6)]

```
[(r1, r2) for r1 in [1,2,3,4,5,6]
          for r2 in [1,2,3,4,5,6]
          if r1 + r2 > 7]
```

OR

```
[(r1, r2) for r1 in range(1, 7)
          for r2 in range(8-r1, 7)]
```

Making a Matrix

Goal: A matrix were each element is the sum of it's row and column numbers.

With a loop:

```
matrix = []
for i in range(5):
    row = []
    for j in range(5):
        row.append(i+j)
    matrix.append(row)
```

```
[[0, 1, 2, 3, 4],
 [1, 2, 3, 4, 5],
 [2, 3, 4, 5, 6],
 [3, 4, 5, 6, 7],
 [4, 5, 6, 7, 8]]
```

With a list comprehension:

```
matrix = [[i+j for j in range(5)] for i in range(5)]
```

Function $4x^2 - 4$

With a loop:

```
num_list = []
for i in range(-10,11):
    num_list.append(4*i**2 - 4)
```

With a list comprehension:

```
num_list = [4*i**2 - 4 for i in range(-10,11)]
```

Normalize a list

With a loop:

```
num_list = [6,4,2,8,9,10,3,2,1,3]
total = float(sum(num_list))
for i in range(len(num_list)):
    num_list[i] =
num_list[i]/float(total)
```

With a list comprehension:

```
num_list = [i/total for i in num_list]
```

Dictionary mapping integers to multiples under 20

With a loop:

```
for n in range(1,11):
    multiples_list = []
    for i in  range(1,21):
        if i%n == 0:
            multiples_list.append(i)
    multiples[n] = multiples_list
```

With a dictionary comprehension:

```
multiples = {n:[i for i in range(1,21) if i%n == 0]
for n in range(1,11) }
```

{1: [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20], 2: [2, 4, 6, 8, 10, 12, 14, 16, 18, 20], 3: [3, 6, 9, 12, 15, 18], 4: [4, 8, 12, 16, 20], 5: [5, 10, 15, 20], 6: [6, 12, 18], 7: [7, 14], 8: [8, 16], 9: [9, 18], 10: [10, 20]}

A word of caution

List comprehensions are great, but they can get confusing. Error on the side of readability.

```
nums = [n for n in range(100) if
        sum([int(j) for j in str(n)]) % 7 == 0]

nums = []
for n in range(100):
   digit_sum = sum([int(j) for j in str(n)])
   if digit_sum % 7 == 0:
      nums.append(n)
```

A word of caution

List comprehensions are great, but they can get confusing. Error on the side of readability.

```
nums = [n for n in range(100) if
sum([int(j) for j in str(n)]) % 7 == 0]
```

```
def sum_digits(n):
    digit_list = [int(i) for i str(n)]
    return sum(digit_list)
nums = [n for n in range(100) if
          sum_digits(n) % 7 == 0]
```

Ternary Assignment

A common pattern in python

```
if x > threshold:
    flag = True
else:
   flag = False
```

Or

```
flag = False
if x > threshold:
   flag = True
```

Ternary Assignment

A common pattern in python

```
if x > threshold:
    flag = True
else:
   flag = False
```

```
flag = True if x > threshold else False
```

Ternary Expression
Three elements

Ternary Assignment

```
flag = True if x > threshold else False
```

Result if true

Condition

Result if false

- Only works for single expressions as results.
- Only works for if and else (no elif)

Ternary Assignment

Goal: A list of 'odd' or 'even' if that index is odd or even.

```
the_list = []
for i in range(16):
    if i%2 == 0:
        the_list.append('even')
    else:
        the_list.append('odd')
```

or

```
the_list = []
for i in range(16):
    the_list.append('even' if i%2 == 0 else 'odd')
```

Ternary Assignment

Goal: A list of 'odd' or 'even' if that index is odd or even.

```
the_list = []
for i in range(16):
    if i%2 == 0:
        the_list.append('even')
    else:
        the_list.append('odd')
```

or

```
the_list =
   ['even' if i%2 == 0 else 'odd' for i in range(16)]
```

Lecture Overview

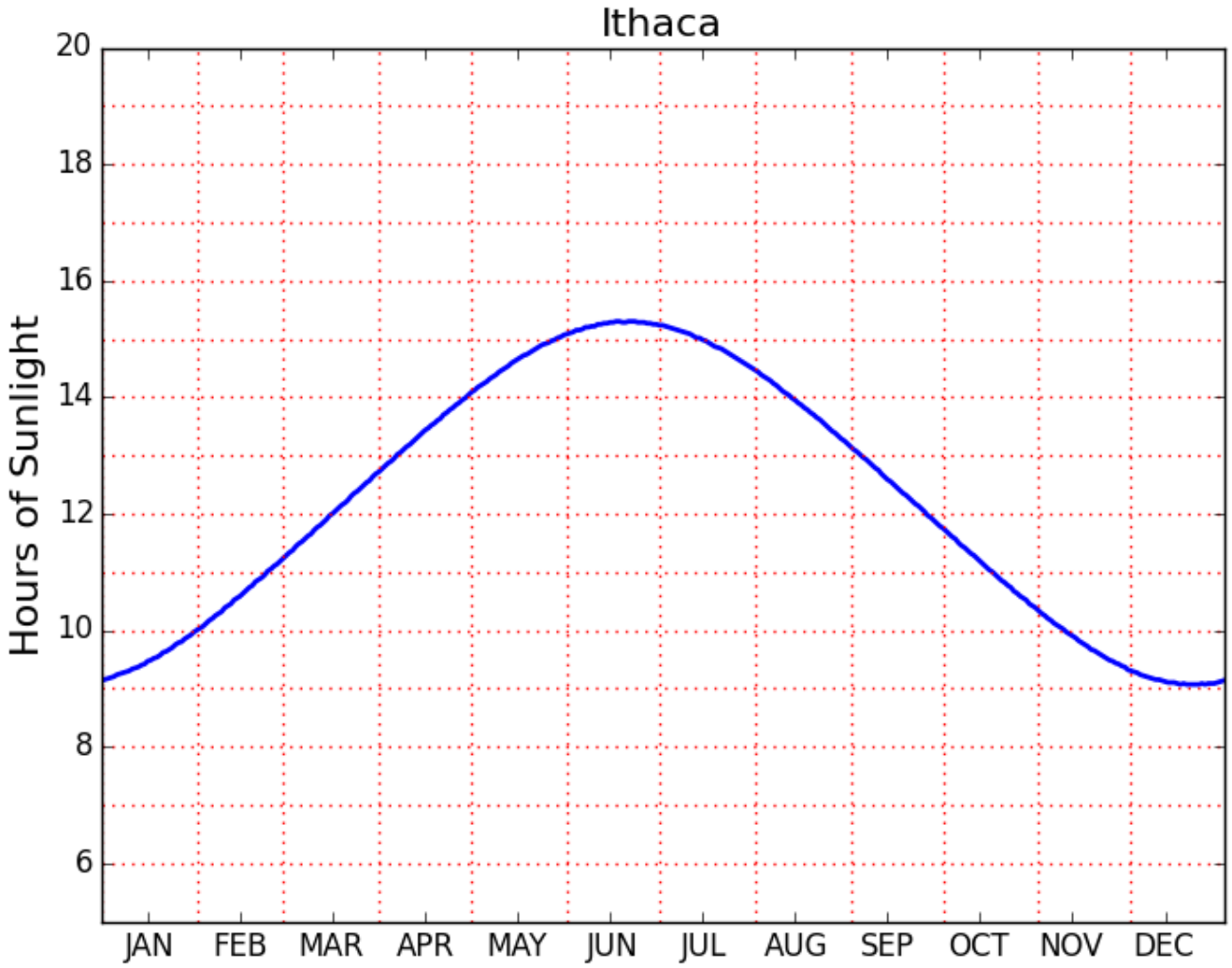
- Sorting
- List comprehension
- Data visualization

A Motivating Problem

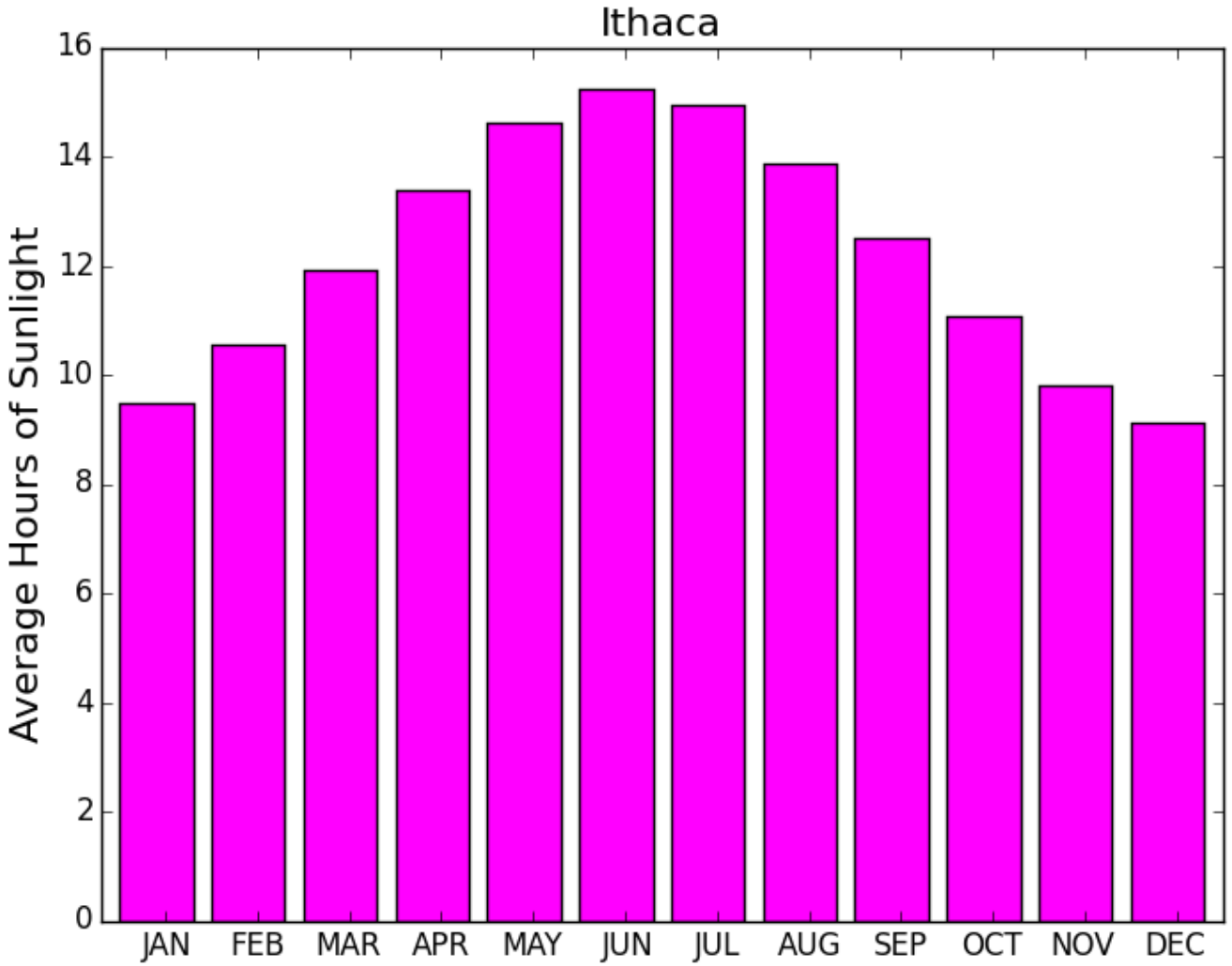
- For various cities around the world, we would like to examine the “Sun Up” time throughout the year.
- How does it vary from day to day?
- What are the monthly averages?

Sun Up Time = Sunset Time – Sunrise Time

How Does Sun-Up Time Vary Day-to-Day?



How Does Sun-Up Time Vary Month-to-Month?



The Task Before Us…

1. Find a website where the data can be found.
2. Get that data into a file on our computer.
3. Understand how the data is laid out in the file.
4. Write python code that gets that data (or some aspect of it) into your Python environment.

Where Do We Get the Data?

- Lots of choices. Google “Sunset Sunrise times”

- We will use the U.S. Naval Observatory data service:

- Visit:

`http://www.usno.navy.mil/`

From the Website...

Astronomical Applications

Data Services

Sun and Moon rise and set times, Moon phases, eclipses, seasons, positions of solar system objects, and other data

Complete Sun and Moon Data for One Day

Sun or Moon Rise/Set Table for One Year

Phases of the Moon

more...

We Downloaded Rise/Set Data For a Number of Cities

Anaheim	Anchorage	Arlington	Athens	Atlanta
Baltimore	Bangkok	Beijing	Berlin	Bogata
Boston	BuenosAires	Cairo	Chicago	Cincinnati
Cleveland	Denver	Detroit	Honolulu	Houston
Ithaca	Johannesburg	KansasCity	Lagos	London
LosAngeles	MexicoCity	Miami	Milwaukee	Minneapolis
Moscow	NewDelhi	NewYork	Oakland	Paris
Philadelphia	Phoenix	Pittsburgh	RiodeJaneiro	Rome
SanFrancisco	Seattle	Seoul	Sydney	Tampa
Teheran	Tokyo	Toronto	Washington	Wellington

One .dat File Per City

RiseSetData

```
Anaheim.dat
Anchorage.dat
Arlington.dat

        :

Toronto.dat
Washington.dat
Wellington.dat
```

We put all these files in a directory called **`RiseSetData`**

.dat and .txt files are common ways to house simple data. Don't worry about the difference.

.txt and .dat Files have Lines

MyFile.dat

```
abcd
123 abc d fdd
xyz
3.14159   2.12345
```

There is an easy way to read the data in such a file line-by-line

Read and Print the Data in `Ithaca.dat`

FileIO.py

```
FileName = 'RiseSetData/Ithaca.dat'
f = file(FileName, 'r')
for s in f:
    print s
f.close()
```

`RiseSetData` and **`FileIO.py`** must be in the same folder.

Ithaca.dat

- There are 33 lines

```
Ithaca
W07629N4226
1   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
2   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
3   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S


28  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
29  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
30  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
31  R S  R S  R S  R S  R S  R S  R S
```

The provider of the file typically tells you how the data is structured

From the Naval Observatory Website

- The first line names the city and the second line encodes its latitude and longitude, e.g.,

```
Ithaca
W07629N4226
```

and ...

From the Naval Observatory Website

- The rise and set times are then specified day-by-day with the data for each month housed in a pair of columns.
- In particular, columns 2k and 2k+1 have the rise and set times for month k (Jan=1, Feb = 2, Mar = 3, etc.)
- Column 1 specifies day-of-the-month, 1 through 31. Blanks are used for nonexistent dates (e.g., April 31).

The Data for a Particular City is Housed in a 33-line .dat file

```
Ithaca
W07629N4226
 1   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
 2   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
 3   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S


28   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
29   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
30   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
31   R S  R S  R S  R S  R S  R S  R S
```

Line 1 has the name of the city

The Data for a Particular City is Housed in a 33-line .dat file

```
Ithaca
W07629N4226
 1   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
 2   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
 3   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S


28   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
29   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
30   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
31   R S  R S  R S  R S  R S  R S  R S
```

Line 2 encodes its longitude and latitude

Helper Function: `LongLat`

- A latlong string has length 11, e.g. **W08140N4129**

```
def LongLat(s):
    """ Returns a tuple (Long,Lat) of floats that are the
    equivalent (in degrees) of the longitude and latitude
    encoded by s.

    PredC: s an 11-character string of the form 'cdddmmCDDMM'
    where cdddmm specifies longitude in degrees and minutes with
    c =  'W' or 'E' and CDDMM species latitude in degrees and
    minutes with C = 'N' or 'S'
   """
    Long = float(s[1:4])+float(s[4:6])/60
    if s[0]=='E':
       Long = -Long
    Lat = float(s[7:9])+float(s[9:11])/60
    if s[6]=='S':
       Lat = -Lat
    return (Lat,Long)
```

The Data for a Particular City is Housed in a 33-line .dat file

```
Ithaca
W07629N4226
1   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
2   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
3   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S


28  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
29  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
30  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
31  R S  R S  R S  R S  R S  R S  R S
```

The remaining lines house the rise-set data.

Each R and S is a length-4 string: ‘0736’

Helper Function: `ConvertTime`

```
def ConvertTime(s):
    """ Returns a float that is the equivalent (in
    hours) of the time encoded by s.

    '2145' means 9:45 pm.

    PredC: s a 4-character string of the form hhmm
           that specifies time.
    """

    x = float(s[:2])+float(s[2:])/60
    return x
```

- In comes a length-4 string and back comes a float that encodes the time in hours
- ‘0736’ ----> 7 + 36/60 hours ----> 7.6

The Data for a Particular City is Housed in a 33-line .dat file

```
Ithaca
W07629N4226
1   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
2   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
3   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S


28  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
29  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
30  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
31  R S  R S  R S  R S  R S  R S  R S
```

Day -Number followed by 12 rise-set pairs, one pair for each month

The Data for a Particular City is Housed in a 33-line .dat file

```
Ithaca
W07629N4226
1   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
2   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
3   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S


28  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
29  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
30  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
31  R S  R S  R S  R S  R S  R S  R S
```

Day -Number followed by 11 rise-set pairs, one pair for each month except February

The Data for a Particular City is Housed in a 33-line .dat file

```
Ithaca
W07629N4226
 1   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
 2   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
 3   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S


28   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
29   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
30   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
31   R S  R S  R S  R S  R S  R S  R S
```

Day -Number followed by 7 rise-set pairs, one pair for each 31-day month

Recall the Motivating Problem

- For various cities around the world, we would like to examine the “Sun Up” time throughout the year.

- How does it vary from day to day?

- What are the monthly averages?

Daylight

```
def SunUp(CityName):
    FileName = 'RiseSetData/'+CityName+'.dat'
    f = file(FileName, 'r');
    lineNum = 0
    for s in f:
        parts = s.split()
        lineNum+=1
        if lineNum == 1:
            City = parts[0]
        elif lineNum == 2:
            Lat, Long = LatLong(parts[0])
        else:
                Code that builds the RiseTime and SetTime arrays
    f.close()
    return (City, Lat, Long, SetTime - RiseTime)
```

Recall how split works…

```
s = '1 0535 0816 0542 0713'
x = s.split()
print x
['1','0535','0816','0542','0713']
```

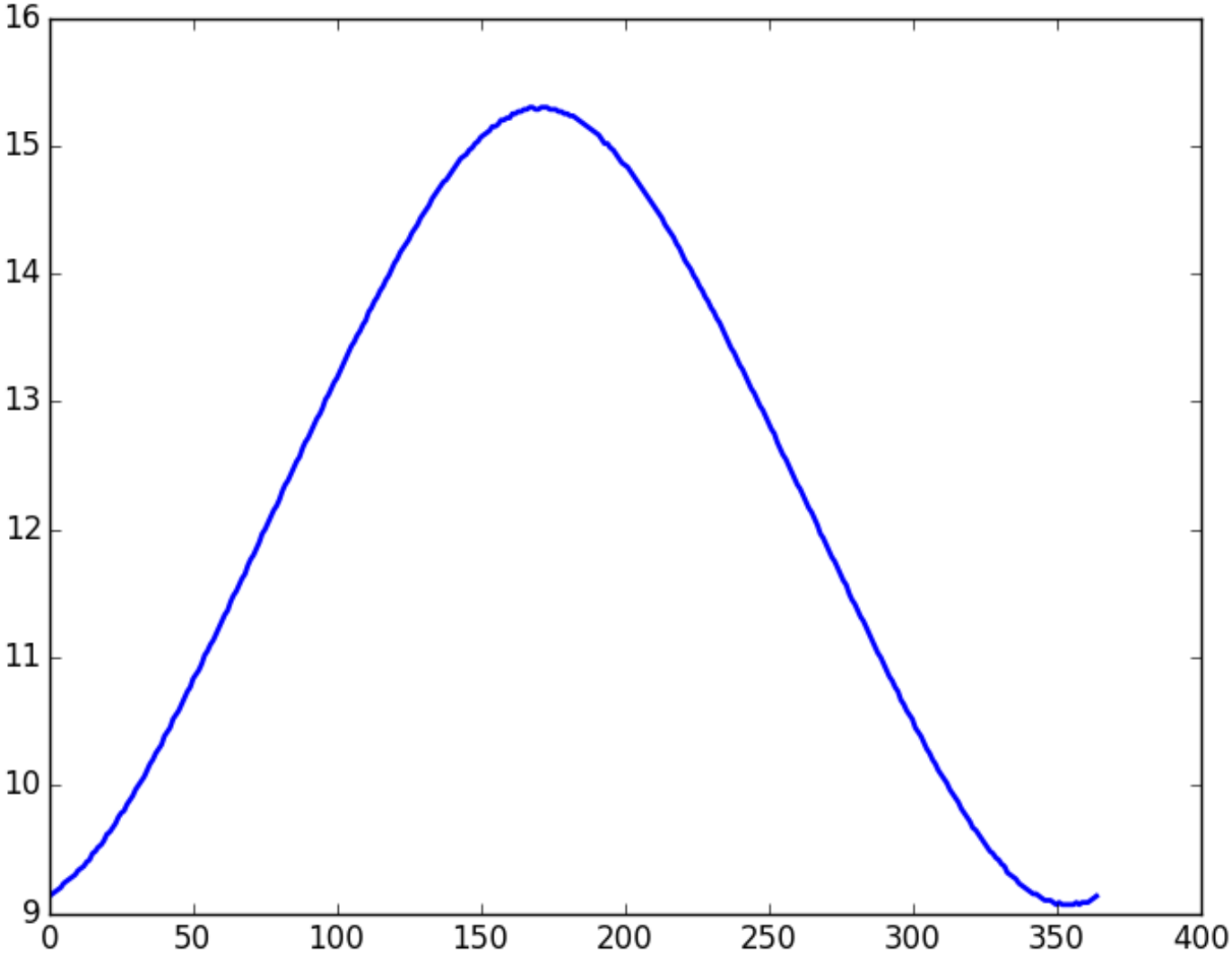
Building `RiseTime` and `SetTime` arrays

```
…
# Remaining lines have rise/set pairs
day = int(parts[0])
# Get all the rise and set times
RiseTimeList = ConvertTime(parts[1:len(parts):2])
SetTimeList  = ConvertTime(parts[2:len(parts):2])
p = len(RiseTimeList)
for k in range(p):
    if day<=28:
        # All months have at least 28 days
        starts  = [0,31,59,90,120,151,181,212,243,273,304,334]
        dayIndex = day + starts[k] - 1
    elif day==29 or day==30:
        # All months except February have a day 29 and a day 30
        starts = [0, 59,90,120,151,181,212,243,273,304,334]
        dayIndex = day + starts[k] - 1
    else:
        # Only January, March, May, July, August, October, and December have
        # a day 31.
        starts = [0,59,120,181,212,273,334]
        dayIndex = day + starts[k] - 1
    RiseTime[dayIndex] = RiseTimeList[k]
    SetTime[dayIndex] = SetTimeList[k]
```

A Simple Plot

```
from pylab import *

# Plot a 1-dim numpy array
City, Lat, Long, D = SunUp('Ithaca')
plot(D)

show()
```

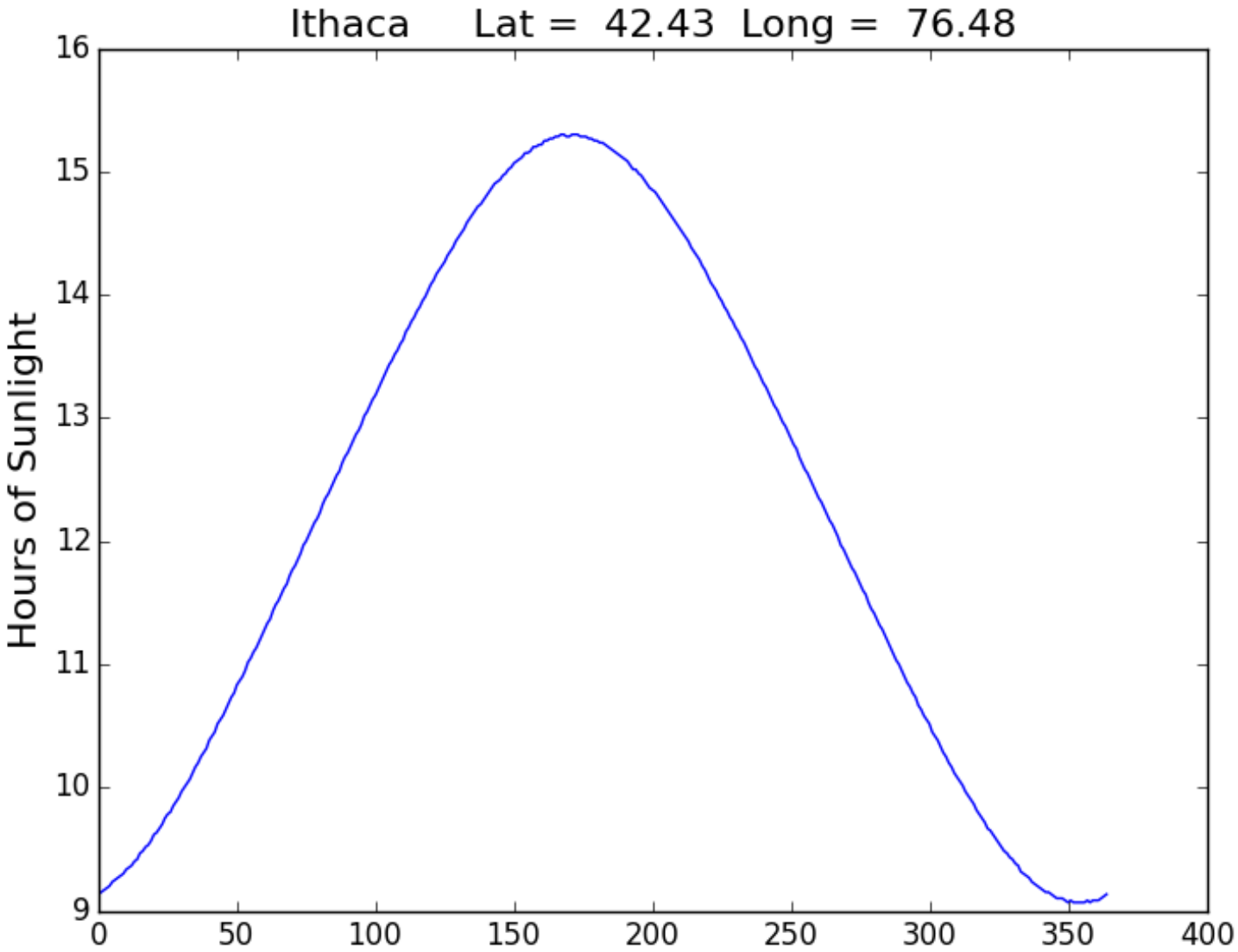
This is how you display the values in a numpy array like D.



How about a title and a labeling of the y-axis?

A Simple Plot

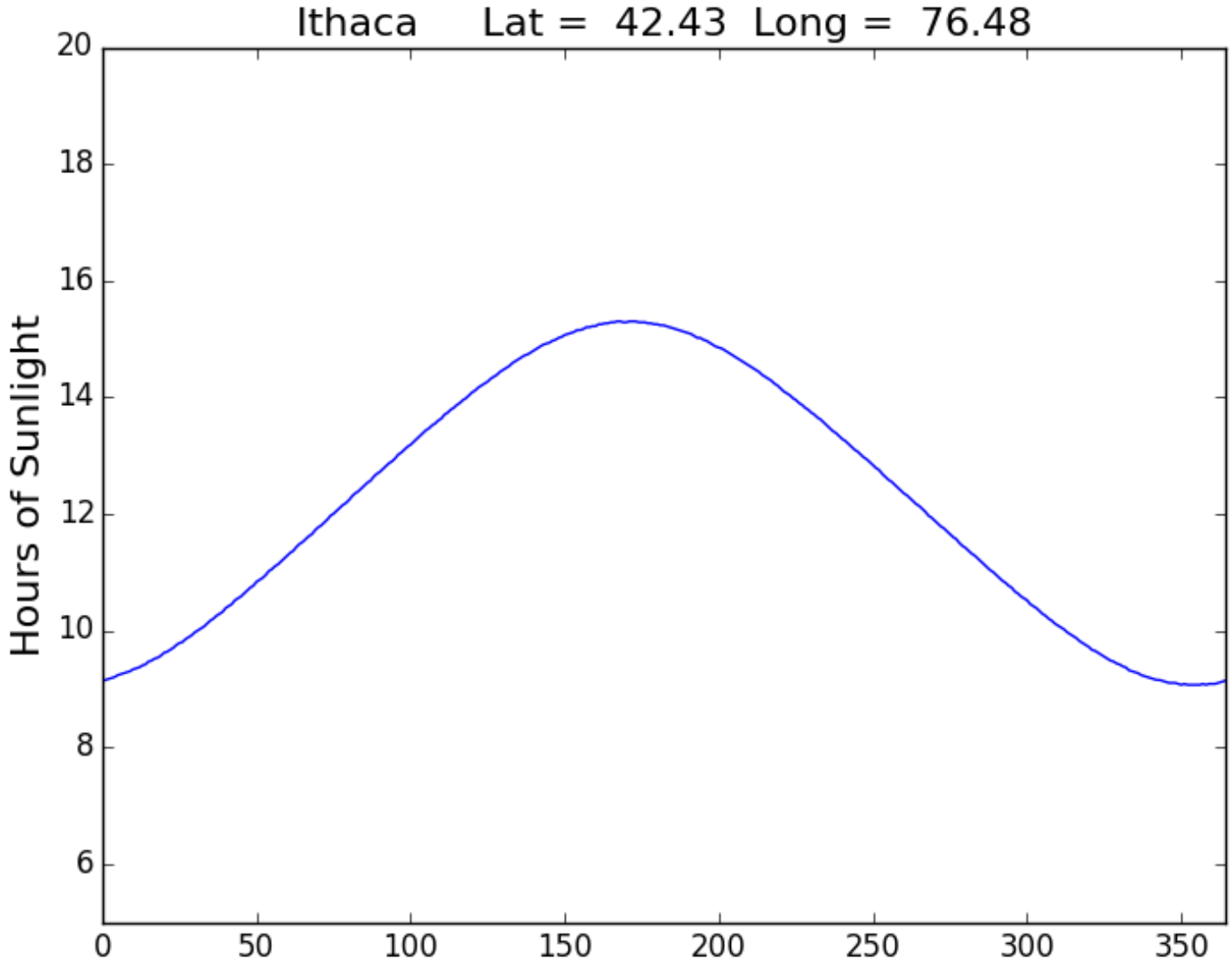
```
# Plot a 1-dim numpy array
City, Lat, Long, D = SunUp('Ithaca')
plot(D)

# The title
titlestr = '%s Lat = %6.2f Long = %6.2f' % (City,Lat,Long)
title(titlestr,fontsize=16)
# Label the y-axis
ylabel('Hours of Sunlight',fontsize=16)

show()
```



Modify the x range and the y range

A Simple Plot

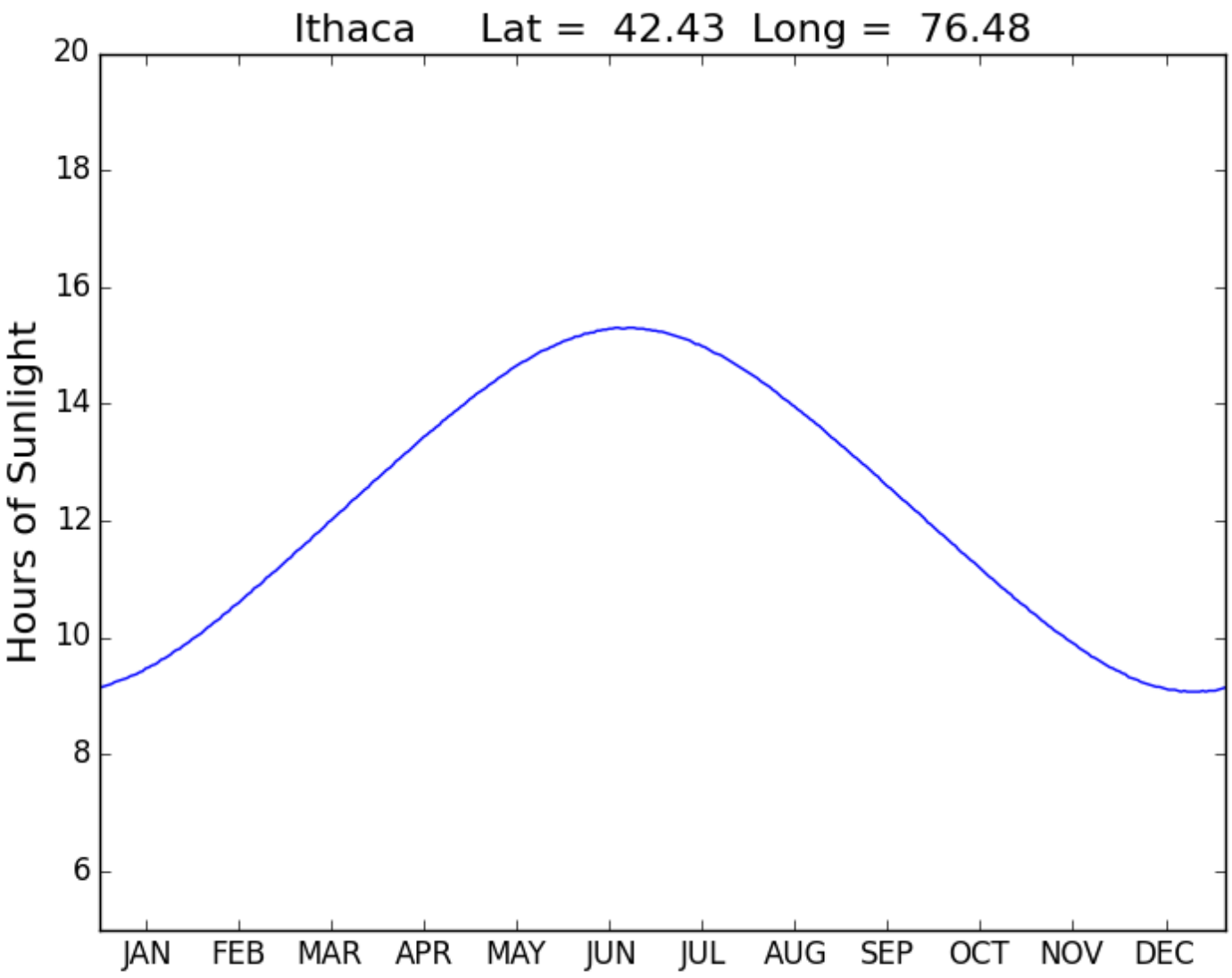
```
# Plot a 1-dim numpy array
City, Lat, Long, D = SunUp('Ithaca')
plot(D)

# The title
titlestr = '%s Lat = %6.2f Long = %6.2f' % (City,Lat,Long)
title(titlestr,fontsize=16)
# Label the y-axis
ylabel('Hours of Sunlight',fontsize=16)

# set the range of x and the range of y
xlim(0,364)
ylim(5,20)

show()
```



Label the x-axis with month names

A Simple Plot

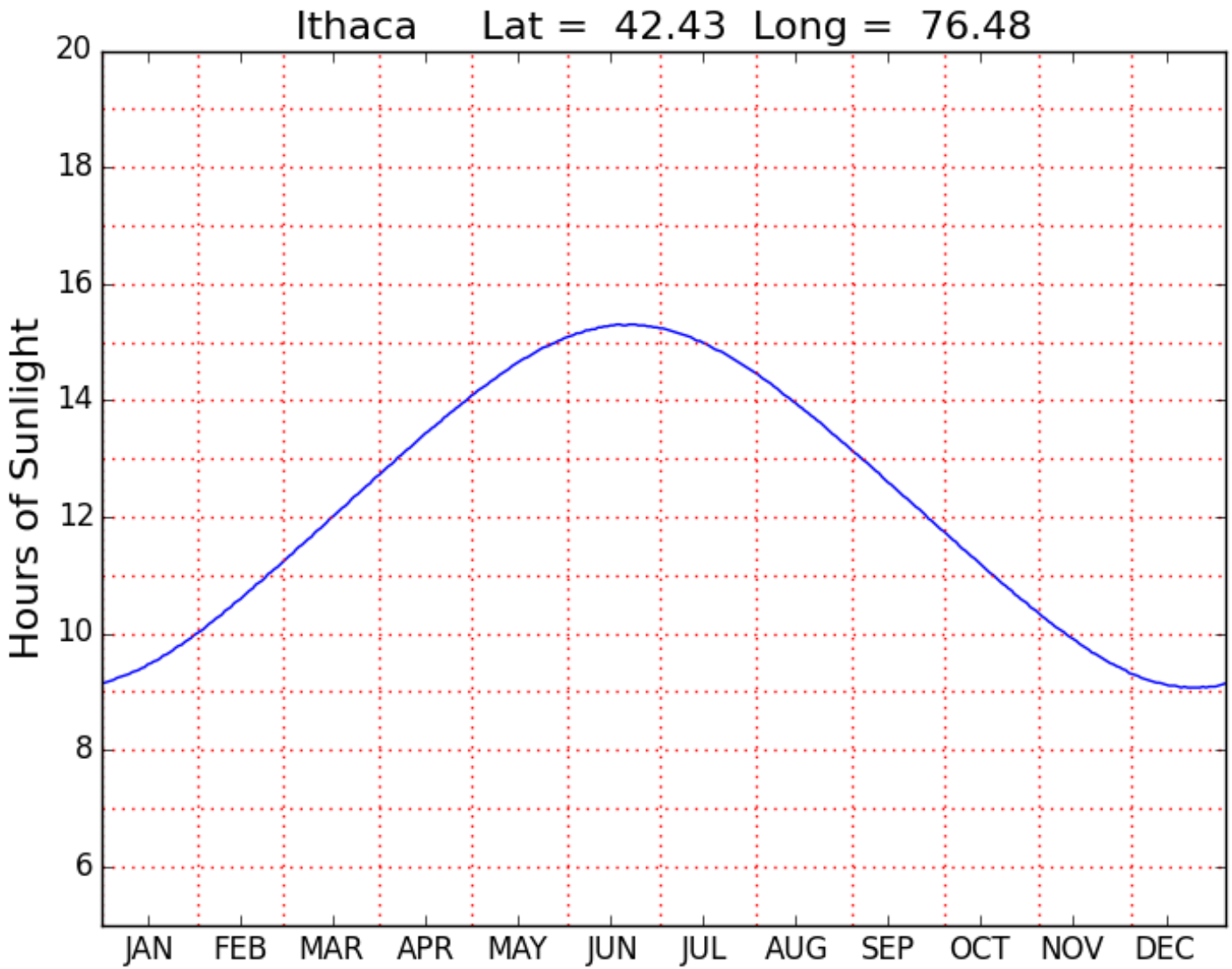
```
# Plot a 1-dim numpy array
City, Lat, Long, D = SunUp('Ithaca')
plot(D)

# The title
titlestr = '%s Lat = %6.2f Long = %6.2f' % (City,Lat,Long)
title(titlestr,fontsize=16)
# Label the y-axis
ylabel('Hours of Sunlight',fontsize=16)

# set the range of x and the range of y
xlim(0,364)
ylim(5,20)

# Position ticks along the x-axis and label them
c = ['JAN','FEB','MAR','APR','MAY','JUN','JUL','AUG','SEP','OCT','NOV','DEC']
t = [15,45,75,105,135,165,195,225,255,285,315,345]
xticks( t,c)

show()
```


Ithaca Lat = 42.43 Long = 76.48
Hours of Sunlight
20
18
16
14
12
10
8
6
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Add a Grid

A Simple Plot

```
# Plot a 1-dim numpy array
City, Lat, Long, D = SunUp('Ithaca')
plot(D)

# The title
titlestr = '%s Lat = %6.2f Long = %6.2f' % (City,Lat,Long)
title(titlestr,fontsize=16)
# Label the y-axis
ylabel('Hours of Sunlight',fontsize=16)

# set the range of x and the range of y
xlim(0,364)
ylim(5,20)

# Position ticks along the x-axis and label them
c = ['JAN','FEB','MAR','APR','MAY','JUN','JUL','AUG','SEP','OCT','NOV','DEC']
t = [15,45,75,105,135,165,195,225,255,285,315,345]
xticks( t,c)

# Draw a grid
for k in range(6,20):
    # Draw horizontal line from (0,k) to (65,k)
    plot(array([0,365]),array([k,k]),color='red',linestyle=':')
for k in [0, 31, 59, 90, 120, 151, 181, 212, 243, 273, 304, 334]:
    # Draw vertical line from  (k,5)) to (k,20))
    plot(array([k,k]),array([5,20]),color='red',linestyle=':')

show()
```

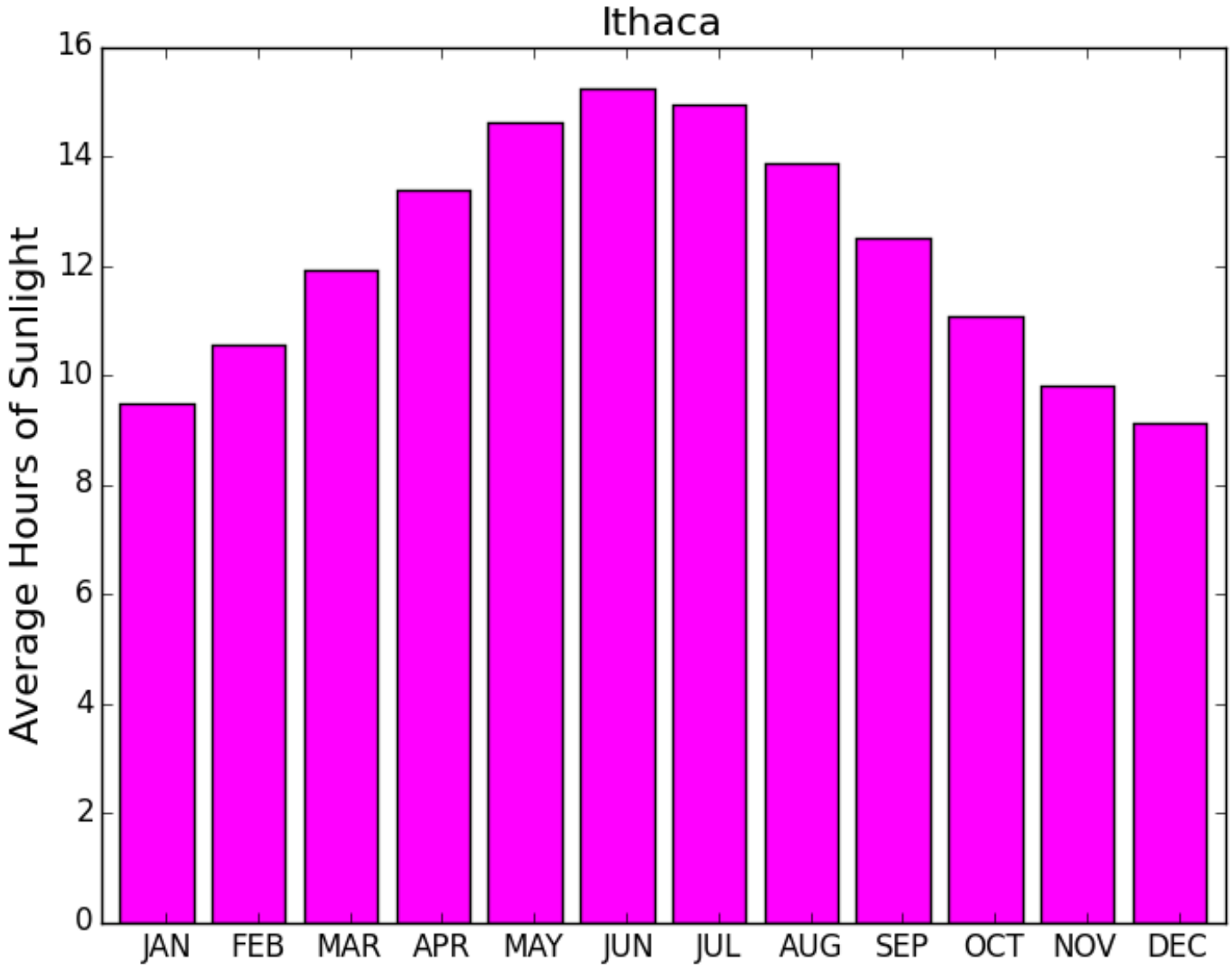

Ithaca Lat = 42.43 Long = 76.48
Hours of Sunlight
20
18
16
14
12
10
8
6
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Monthly Averages

```
def MonthAverages(CityName):
    x = zeros((12,1))
   City, Lat, Long, D = SunUp(CityName)
   start = [0, 31, 59, 90, 120, 151, 181, 212, 243, 273, 304, 334]
   finish = [30, 58, 89, 119, 150, 180, 211, 242, 272, 303, 333,364]
   for k in range(12):
       z = D[start[k]:finish[k]]
       x[k] = sum(z)/len(z)
   return x
```

A Bar Plot

```
M = MonthAverages('Ithaca')


bar(range(12),M,facecolor='magenta')
xlim(-.2,12)
ylabel('Average Hours of Sunlight')
title(A.City,fontsize=16)
show()
```


Ithaca
Average Hours of Sunlight
0
2
4
6
8
10
12
14
16
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC