Dictionaries

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Opening and Reading Text Files

- Python follows the posix conventions:
  - You can open a file
  - You can interact with a file
  - You then close the file
- Easiest done with a **Python context**
  - The context automatically closes the file after use

```
with open(filename) as infile:
    |— statement block  —|
```

Opening and Reading Text Files

- To read from a file, we can use a for loop

```
with open(filename) as infile:
    for line in infile:
        |— do something with each line
```

- Within the for loop, we can use strip( ) in order to break the line apart at white spaces

```
with open(filename) as infile:
    for line in infile:
        for words in line.split( )
```

Dictionaries

- Python has a efficient association data structure — the dictionary
  - Dictionary pairs keys with values
    - Useful for: indices
    - Useful for: translations
    - Useful for: quick lookups
      - E.g.: first letters —> full email address
      - E.g.: human-readable URL —> IP address
      - …

Dictionaries

- Dictionaries are key-value stores
  - Keys — anything, but needs to be immutable
    - Remember: Lists are mutable, strings are immutable
  - Value — anything

Dictionaries

- Dictionaries are created by using curly brackets
  - Can use lists

```
dicc = {1: ‘uno’, 2: ‘dos’, 3: ‘tres’}
```

  - Or can use assignment

```
dicc = {}

dicc[1] = “uno”

dicc[2] = “dos”

dicc[3] = “tres”
```

- Values are assigned / retrieved using the bracket notation

Dictionary

- Dictionary `dicc={}`
- Accessing values:

```
dicc['key']
```

  - With default value

```
dicc.get(key, default_value)
```

  - Or with if - else

```
if key in dicc:
```

- Creating / changing values

```
dicc['key'] = value
```

```
>>> dicc = {1: "uno", 2: "dos", 3: "tres"}
>>> dicc[1]
'uno'
>>> dicc[1] = "one"
>>> dicc[1]
'one'
```

Dictionary

- Deleting from a dictionary

```
dicc = {}
```

  - Use the `del` keyword
    - Raises a key error if the key is not in the dictionary

```
if key in dicc:
    del dicc[key]
```

- Use the pop method, which returns the value

```
value = dicc.pop(key)
value = dicc.pop(key, default)
```

Dictionary

- Checking for existence
  - Use the “in” keyword

```
>>> dicc = {1: "uno", 2: "dos", 3: "tres"}
>>> 1 in dicc
True
>>> 4 not in dicc
True
```

Dictionaries

- A simple program that “learns” Spanish words

```
def test():
    dicc = {}
    while True:
        astr = input("Enter an English word: ")
        if astr == "Stop it":
            return
        elif astr in dicc:
            print(dicc[astr])
        else:
            print("I have not yet learned this word")
            val = input("Please enter the Spanish word: ")
            dicc[astr] = val
```

Dictionaries

- Dictionaries have an internal structure
  - You will learn in Data Structures how to build dictionaries yourselves
  - For the moment, enjoy their power
- You can print dictionaries
  - You will notice that they change structure after inserts and not reflect the order in which you inserted elements
  - This is because they optimize access

Dictionaries

- Deleting all entries in a dictionary
  - use the `clear()` method
- Deleting an entry without fear of creating a key error
  - Use an if statement
  - Use pop with a second argument None
    - `dicc.pop(1, None)`

Dictionaries

- Looping over keys
  - Simplest:
    - `for number in dicc:`
  - iterkeys( ) or iter works the same way
    - `for number in dicc.iterkeys():`
    - `for number in iter(dicc):`

Some Uses of Dictionaries

- Dictionaries can be used to count things.
  - Example: Count the number of letters in a file.
    - We open the file with encoding latin-1 so that there are no encoding errors

```
alphabet = "abcdefghijklmnopqrstuvwxyz"

with open("alice.txt", encoding = "latin-1") as infile:
    dicc = {}
    for letter in alphabet:
        dicc[letter]=0
```

Some Uses of Dictionaries

- Create and initialize a dictionary
  - We are only interested in letters

```
alphabet = "abcdefghijklmnopqrstuvwxyz"

with open("alice.txt", encoding = "latin-1") as infile:
    dicc = {}
    for letter in alphabet:
        dicc[letter]=0
```

Some Uses of Dictionaries

- Read the file line by line.
  - Read each letter in the line
    - After changing to lower case, update dictionary

```
alphabet = "abcdefghijklmnopqrstuvwxyz"

with open("alice.txt", encoding = "latin-1") as infile:
    dicc = {}
    for letter in alphabet:
        dicc[letter]=0
    for line in infile:
        for letter in line:
            letter=letter.lower()
            if letter in alphabet:
                dicc[letter]+=1
```

Some Uses of Dictionaries

- Now process the dictionary
  - Calculate the sum of values (i.e. the counts)
  - Pretty-print the results

```
for letter in alphabet:
    cum += dicc[letter]
for letter in alphabet:
    print("{:1s} {:5d} {:5.2f}%”.format(
              letter, dicc[letter], dicc[letter]/cum*100))
```

Some Uses of Dictionaries

- Using lists as dictionary values
  - in order to create an index of words in a file

Some Uses of Dictionaries

- Open file with encoding “latin-1”
  - Read file line by line
    - Break line into words
    - Normalize words by stripping and lowering

```
with open("alice.txt", encoding = "latin-1") as infile:
    index = {}
    word_count = 0
    for line in infile:
        for word in line.split():
            word_count += 1
            word = word.lower().strip(",.;:?![]-'\"")
```

Some Uses of Dictionaries

- Add word to dictionary if long enough

```
with open("alice.txt", encoding = "latin-1") as infile:
    index = {}
    word_count = 0
    for line in infile:
        for word in line.split():
            word_count += 1
            word = word.lower().strip(",.;:?![]-'\"")
            if len(word)>7:
                if word in index:
                    index[word].append(word_count)
                else:
                    index[word] = [word_count]
```

Some Uses of Dictionaries

- Print out results if word is frequent enough

```
for word in index:
    if len(index[word])>2:
        print(word, index[word])
```

A Teaser on Iterators

- Iterators are the hidden engine of many Python features
  - Iterators are almost like lists
    - You always can get the next element
      - Unless you are at the end of a list
  - But they are not lists:
    - All the elements in the list have to be there before the list can be used
      - They need to be stored in memory
      - Which uses up space
      - And can be disastrous if there are just too many

A Teaser on Iterators

- Iterators are only created when there is a need
- Iterators are often hidden from view
- But we will have to use them
  - For our purposes:
    - We can make them explicitly into lists because we are just not working with millions of data items
    - But hopefully, once we get to play with the grown-ups …
- Seriously, we get back to iterators

Multi-Dictionaries

- Problem:
  - Instead of associating one value with a key, we want to associate several values:
    - a “multi-dictionary”
- Solution:
  - The values of the dictionaries should be lists (or sets — coming week)

Multi-Dictionaries

- Example:
  - We want to pass through a file and create an index of important words with their occurrences

```
with open("alice.txt", encoding = "latin-1") as infile:
    dicc = {}
    word_number = 0
    for line in infile:
        for word in line.split():
            word = word.strip(":,.?![]'")
            word = word.lower()
            word_number +=1
            if len(word)>8:
                if word in dicc:
                    dicc[word].append(word_number)
                else:
                    dicc[word]=[word_number]
```

Calculating on Values

- Assume you have a dictionary with numerical values
  - For example: a dictionary with the prices of stocks on September 15, 2018

```
dstocks = {“tata”: 2063.30,
           “hdfc”: 2029.20,
           “hiul”: 1630.15,
            …
          }
```

- You want the average, the maximum, the minimum … price

Solution

- You can access the values of a dictionary through the values method.
  - values( ) returns an iterator of all the values in the dictionary

```
>>> dst = {"apple": 256.34, "fb": 145.23, "ibm": 98.34, "ms": 198.75}
>>> dst.values()
dict_values([256.34, 145.23, 98.34, 198.75])
>>> max(dst.values())
256.34
>>> sum(dst.values())/len(dst.values())
174.665
```

Calculating with keys

- Problem:
  - You want to calculate on the keys of a dictionary
- Solution:
  - The keys( ) method returns an iterator of the keys of a dictionary

Finding the most common item in a list

- We use a dictionary as a counter.
  - First way: We can do so by ourselves.
    - Create a dictionary
    - Pass through the list

```
def most_frequent(lista):
    counter = {}
    for x in lista:
        counter[x]=counter.get(x, 0)+1
```

get specifies a default value, it is otherwise equivalent to counter[x]

Finding the most common item in a list

- If we do not want to use get, we can just check whether the list-item is already in the dictionary

```
def most_frequent(lista):
counter = {}
for x in lista:
    if x in counter:
        counter[x]+=1
    else:
        counter[x]=1
```

Finding the most common item in a list

- After counting, we pass through the dictionary to find the maximum element.
  - Notice that we are interested in the key, not the value

```
def most_frequent(lista):
    counter = {}
    for x in lista:
        counter[x]=counter.get(x, 0)+1
    highest_seen = 0
    for x in counter:
        if counter[x]>highest_seen:
            best_key = x
            highest_seen = counter[x]
    return best_key
```

highest_seen contains the highest encountered **value**

Finding the most common item in a list

- After counting, we pass through the dictionary to find the maximum element.
  - Notice that we are interested in the key, not the value

```
def most_frequent(lista):
    counter = {}
    for x in lista:
        counter[x]=counter.get(x, 0)+1
    highest_seen = 0
    for x in counter:
        if counter[x]>highest_seen:
            best_key = x
            highest_seen = counter[x]
    return best_key
```

highest_seen is adjusted whenever we see a higher value in the counter

Finding the most common item in a list

- After counting, we pass through the dictionary to find the maximum element.
  - Notice that we are interested in the key, not the value

```
def most_frequent(lista):
    counter = {}
    for x in lista:
        counter[x]=counter.get(x, 0)+1
    highest_seen = 0
    for x in counter:
        if counter[x]>highest_seen:
            best_key = x
            highest_seen = counter[x]
    return best_key
```

but we also need to remember the key, which we record in best_key

Finding the most common item in a list

- After counting, we pass through the dictionary to find the maximum element.
  - Notice that we are interested in the key, not the value

```
def most_frequent(lista):
    counter = {}
    for x in lista:
        counter[x]=counter.get(x, 0)+1
    highest_seen = 0
    for x in counter:
        if counter[x]>highest_seen:
            best_key = x
            highest_seen = counter[x]
    return best_key
```

because the key with the highest counter value is the result that we return

Finding the most common item in a list

- But we can also use the work of others
  - The `Counter` in the collections module
    - You create a *new object* of type Counter

```
from collections import Counter

def most_frequent(lista):
    ctr = Counter()
```

Defines a new object called ctr ctr is an object of type Counter

Finding the most common item in a list

- Counters are (updated) like dictionaries
  - But they have a default value of 0

```
from collections import Counter


def most_frequent(lista):
    ctr = Counter()
    for item in lista:
        ctr[item] += 1
```

Here we add 1 to the value of `ctr[item]`

No need to initialize!

Finding the most common item in a list

- Counters have a method called `most_common`
  - Argument is the number of most common items
  - Returns a list of pairs

```
from collections import Counter

def most_frequent(lista):
    ctr = Counter()
    for item in lista:
        ctr[item] += 1
    return ctr.most_common(1)[0][0]
```

- **Get a list of one elements.**
- **Get the first (and only) element of the list**
- **Get the first coordinate of that element**

Memoization

- (Some) Computer Scientists love recursion
  - A function calls itself
    - This is super-elegant and the more mathematically inclined pine for this elegance
- But it is not necessarily very fast
  - The more engineeringly inclined think its a waste

Recursion

- When it works
  - Factorials
    - The factorial of *n* is *n* (*n*-1) (*n*-2) (*n*-3) … (4) (3) (2) (1)
    - Define it to be one for negative or zero *n*

Recursion

- This implementation has the function factorial call itself

```
def factorial(number):
    if number<1:
        return 1
    else:
        return number*factorial(number-1)
```

- Here we are calling on the function itself
- Will call factorial(number-1), which will call factorial(number-2), which will call factorial(number -3) … until we call factorial on 1, in which case the recursion stops.

Recursion

- This implementation has the function factorial call itself

```
def factorial(number):
    if number<1:
        return 1
    else:
return number*factorial(number-1)
```

- **The base case:**
  - **We cannot call recursion infinitely often, so we need one.**

Recursion

- The Fibonacci numbers
  - The Fibonacci numbers are defined recursively
  - $f_0 = 0, \qquad f_1 = 1, \qquad f_n = f_{n-1} + f_{n-2}$

```
def fibonacci(number):
    if number <= 0:
        return 0
    if number == 1:
        return 1
    return fibonacci(number-1)+fibonacci(number-2)
```

Recursion

- But this implementation is inane!
  - Takes too long even for small numbers.
    - We can use the time-module in order to obtain the cpu-time
      - We do so once before and after execution of the function
  - This yields approximately the time it takes to execute the function

Recursion

- We just write a function that measures the time

```
def measure(function, number):
    start = time.time()
    function(number)
    print(number, time.time()-start)
```

Recursion

- Now we try it out with factorial and fibonacci
  - Not a problem with factorial

```
27 1.52587890625e-05
28 1.5974044799804688e-05
29 1.52587890625e-05
30 1.5735626220703125e-05
31 1.811981201171875e-05
32 1.71661376953125e-05
33 1.7881393432617188e-05
34 1.7881393432617188e-05
35 1.907348632812 5e-05
36 1.9788742065429688e-05
37 1.8835067749023438e-05
38 2.098083496093 75e-05
39 2.193450927734375e-05
```

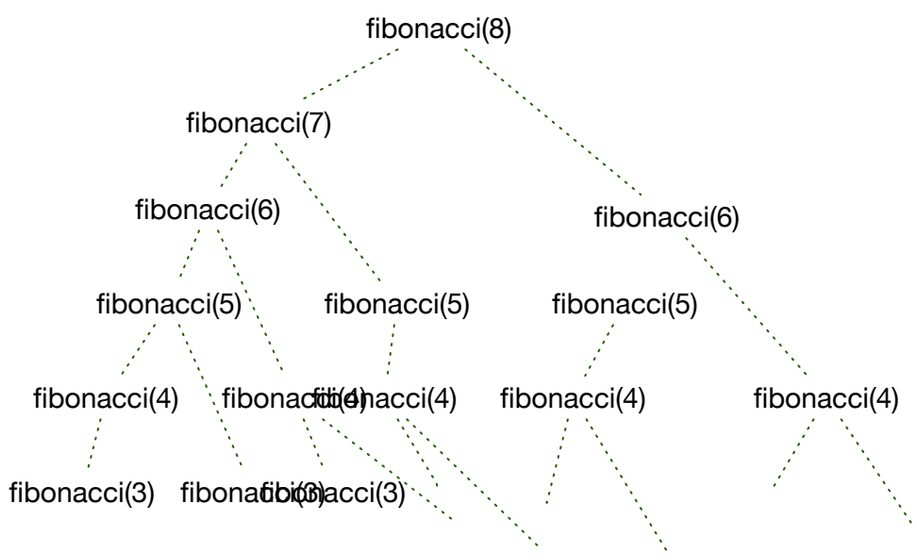
Recursion

- But disastrous for Fibonacci
- It takes 34 seconds in order to calculate fibonacci(39).

```
28 0.17530512809753418
29 0.27112603187561035
30 0.43769311904907227
31 0.7113552093505859
32 1.1374599933624268
33 1.846013069152832
34 2.9945621490478516
35 4.856478929519653
36 7.85633971023 56
37 12.681456804275513
38 20.597038030 62439
39 33.98105502128601
```

Recursion

- What is the problem?
  - Look at what happens if we calculate fibonacci(9).
  - We calculate fibonacci(8) and fibonacci(7)
  - Since the first one also calculates fibonacci(7), we calculate fibonacci(7) twice.
  - And it gets worse for fibonacci(6), fibonacci(5), …



Memoization

- A simple trick to speed up recursive functions is to remember values that we have already calculated.
- Create a dictionary (possibly global) that stores values already calculated
    - Before any calculation check whether the desired value is in the dictionary
    - If we calculate something, we put the value into the dictionary

Memoization

```
fdic={0: 0, 1:1}

def fibonacci2(number):
    if number in fdic:
        return fdic[number]
    else:
        retval = fibonacci2(number-1)+fibonacci2(number-2)
        fdic[number] = retval
        return retval

for i in range(41):
    measure(fibonacci2, i*50)
```

Memoization

```
fdic={0: 0, 1:1}

def fibonacci2(number):
    if number in fdic:
        return fdic[number]
    else:
        retval = fibonacci2(number-1)+fibonacci2(number-2)
        fdic[number] = retval
        return retval

for i in range(41):
    measure(fibonacci2, i*50)
```

- **Defining the dictionary**

Memoization

```
fdic={0: 0, 1:1}

def fibonacci2(number):
    if number in fdic:
        return fdic[number]
    else:
        retval = fibonacci2(number-1)+fibonacci2(number-2)
        fdic[number] = retval
        return retval

for i in range(41):
    measure(fibonacci2, i*50)
```

- Check whether value is in the dictionary

Memoization

```
fdic={0: 0, 1:1}

def fibonacci2(number):
    if number in fdic:
        return fdic[number]
    else:
        retval = fibonacci2(number-1)+fibonacci2(number-2)
        fdic[number] = retval
        return retval

for i in range(41):
    measure(fibonacci2, i*50)
```

- **Calculation is necessary**

Memoization

```
fdic={0: 0, 1:1}

def fibonacci2(number):
    if number in fdic:
        return fdic[number]
    else:
        retval = fibonacci2(number-1)+fibonacci2(number-2)
        fdic[number] = retval
        return retval

for i in range(41):
    measure(fibonacci2, i*50)
```

- But we store the result in the dictionary in case we use it in the future

Memoization

```
fdic={0: 0, 1:1}

def fibonacci2(number):
    if number in fdic:
        return fdic[number]
    else:
        retval = fibonacci2(number-1)+fibonacci2(number-2)
        fdic[number] = retval
        return retval

for i in range(41):
    measure(fibonacci2, i*50)
```

- And now we measure

Decorators

- Python uses decorators to allow changing functions
- A decorator is implemented by:
  - Creating a function of a function that returns the amended function

Decorators

```
def timeit(function):
    def clocked(*args):
        start_time = time.perf_counter()
        result = function(*args)
        duration = (time.perf_counter() - start_time)
        name = function.__name__
    arg_string = ', '.join(repr(arg) for arg in args)
    print('Function {} with arguments {} ran
           in {} seconds'.format(
        name, arg_string, duration))
    return result
return clocked
```

Decorators

- Decorator takes a function with positional arguments as function
- Decorator defines a new version of the argument function
- And returns it.

Decorators

```
def timeit(function):
    def clocked(*args):
        start_time = time.perf_counter()
        result = function(*args)
        duration = (time.perf_counter() - start_time)
        name = function.__name__
    arg_string = ', '.join(repr(arg) for arg in args)
    print('Function {} with arguments {} ran
           in {} seconds'.format(
        name, arg_string, duration))
    return result
return clocked
```

Decorators

- To use a decorator, just put its name on top of the function definition
  - Decorator generator is executed when module is imported (or generator is defined)
  - When decorated function is defined, the modified version is created

Decorators

```
@timeit
def fibonacci(n):
    if n == 0:
        return 0
    if n == 1:
        return 1
    else:
        return fibonacci(n-1)+fibonacci(n-2)
```

Decorators

- If we execute this function, we get to see how often fibonacci is called on arguments already executed

```
>>> fibonacci(10)
Function fibonacci with arguments 1 ran in 5.140000070014139e-07 seconds
Function fibonacci with arguments 0 ran in 1.0870000011209413e-06 seconds
Function fibonacci with arguments 2 ran in 0.1692790839999958 seconds
Function fibonacci with arguments 1 ran in 1.2330000060956081e-06 seconds
Function fibonacci with arguments 3 ran in 0.2676633440000131 seconds
Function fibonacci with arguments 1 ran in 9.8000001003129e-07 seconds
Function fibonacci with arguments 0 ran in 1.0470000120221812e-06 seconds
Function fibonacci with arguments 2 ran in 0.09880945999999824 seconds
Function fibonacci with arguments 4 ran in 0.4692909440000079 seconds
Function fibonacci with arguments 1 ran in 6.51999997103303e-07 seconds
Function fibonacci with arguments 0 ran in 1.0500000087176886e-06 seconds
Function fibonacci with arguments 2 ran in 0.11281222700000626 seconds
Function fibonacci with arguments 1 ran in 1.958000012791672e-06 seconds
Function fibonacci with arguments 3 ran in 0.21685028000000273 seconds
Function fibonacci with arguments 5 ran in 0.7868284680000102 seconds
Function fibonacci with arguments 1 ran in 5.699999742402e-07 seconds
Function fibonacci with arguments 0 ran in 1.0729999928571488e-06 seconds
Function fibonacci with arguments 2 ran in 0.11366798399998856 seconds
Function fibonacci with arguments 1 ran in 1.2930000110600304e-06 seconds
Function fibonacci with arguments 3 ran in 0.2176230820000029 seconds
Function fibonacci with arguments 1 ran in 5.839999914769578e-07 seconds
```

Memoization with lru_cache

- We can define our own memoization decorator
  - But Python has one that uses an LRU cache
    - Memoization is LRU cache with an infinite cache size
  - Import from functools lru_cache

```
@functools.lru_cache
def fib(n):
    if n <= 1:
        return n
    else:
        return fib(n-1)+fib(n-2)
```

Simple Cryptography

- Substitution code:
  - Substitute every letter with a different letter.
  - Easiest do with a dictionary.
    - Read string letter for letter
    - Look up the letter in a dictionary
    - Then replace the letter with the value of the dictionary.

Simple Cryptography

- Example Dictionary:
  - Caesar's code:
    - Move all letters by 5 to the left
    - This is tricky, but we have
      - `ord` ASCII code of a letter
      - `chr` Letter with that code

Simple Cryptography

- Example

```
for letter in string.ascii_letters:
    print(letter, ord(letter), chr(ord(letter)))
```

```
a 97 a
b 98 b
c 99 c
d 100 d
e 101 e
f 102 f
g 103 g
h 104 h
i 105 i
j 106 j
…
U 85 U
V 86 V
W 87 W
X 88 X
Y 89 Y
```

- Small letters between 97-122
- Capital letters between 65 - 90

Simple Cryptography

- Create the dictionary:
  - Distinguish between lower and capital letters
  - Add 5 to the integer equivalent of the code
  - If too big, reduce by 26

Simple Cryptography

- create an empty dictionary

```
def make_dictionary():
    dicc = { }
    for x in string.ascii_letters:
        if 97 <= ord(x) <= 122:  #small letter
            y = ord(x)+5
            if y > 122:
                y = y - 26
        else:  #capital letter
            y = ord(x)+5
            if y > 90:
                y = y - 26
        dicc[x] = chr(y)
return dicc
```

Simple Cryptography

- walk through all letters

```
def make_dictionary():
    dicc = { }
    for x in string.ascii_letters:
        if 97 <= ord(x) <= 122:  #small letter
            y = ord(x)+5
            if y > 122:
                y = y - 26
        else:  #capital letter
            y = ord(x)+5
            if y > 90:
                y = y - 26
        dicc[x] = chr(y)
return dicc
```

Simple Cryptography

- use ord to find out whether this is a small letter

```
def make_dictionary():
    dicc = { }
    for x in string.ascii_letters:
        if 97 <= ord(x) <= 122:  #small letter
            y = ord(x)+5
            if y > 122:
                y = y - 26
        else:  #capital letter
            y = ord(x)+5
            if y > 90:
                y = y - 26
        dicc[x] = chr(y)
    return dicc
```

Simple Cryptography

- add 5 to the ord

```
def make_dictionary():
    dicc = { }
    for x in string.ascii_letters:
        if 97 <= ord(x) <= 122:  #small letter
            y = ord(x)+5
            if y > 122:
                y = y - 26
        else:  #capital letter
            y = ord(x)+5
            if y > 90:
                y = y - 26
        dicc[x] = chr(y)
    return dicc
```

Simple Cryptography

- and deal with overshoot

```
def make_dictionary():
    dicc = { }
    for x in string.ascii_letters:
        if 97 <= ord(x) <= 122:  #small letter
            y = ord(x)+5
            if y > 122:
                y = y - 26
        else:  #capital letter
            y = ord(x)+5
            if y > 90:
                y = y - 26
        dicc[x] = chr(y)
return dicc
```

Simple Cryptography

- Same for capital letters

```
def make_dictionary():
    dicc = { }
    for x in string.ascii_letters:
        if 97 <= ord(x) <= 122:  #small letter
            y = ord(x)+5
            if y > 122:
                y = y - 26
        else:  #capital letter
            y = ord(x)+5
            if y > 90:
                y = y - 26
        dicc[x] = chr(y)
return dicc
```

Simple Cryptography

- Result (You really need to test these guys)
-

```
>>> dicc = make_dictionary()
>>> dicc
{'a': 'f', 'b': 'g', 'c': 'h', 'd': 'i', 'e': 'j', 'f': 'k',
'g': 'l', 'h': 'm', 'i': 'n', 'j': 'o', 'k': 'p', 'l': 'q',
'm': 'r', 'n': 's', 'o': 't', 'p': 'u', 'q': 'v', 'r': 'w',
's': 'x', 't': 'y', 'u': 'z', 'v': 'a', 'w': 'b', 'x': 'c',
'y': 'd', 'z': 'e', 'A': 'F', 'B': 'G', 'C': 'H', 'D': 'I',
'E': 'J', 'F': 'K', 'G': 'L', 'H': 'M', 'I': 'N', 'J': 'O',
'K': 'P', 'L': 'Q', 'M': 'R', 'N': 'S', 'O': 'T', 'P': 'U',
'Q': 'V', 'R': 'W', 'S': 'X', 'T': 'Y', 'U': 'Z', 'V': 'A',
'W': 'B', 'X': 'C', 'Y': 'D', 'Z': 'E'}
```

Simple Cryptography

- Encoding is simple:

```
def encoding(a_string, dictionary):
result = [ ]
for letter in a_string:
    if letter in dictionary:
        result.append(dictionary[letter])
    else:
        result.append(letter)
return ''.join(result)
```

Simple Cryptography

- Example:

```
>>> encoding('Britishers on the left. Nena Sahib: Move back the
elephants by 100 yards and prepare artillery firing', dicc)
'Gwnynxmjwx ts ymj qjky. Sjsf Xfmng: Rtaj gfhp ymj jqjumfsyx gd 100
dfwix fsi uwjufwj fwynqqjwd knwnsl'
```

Simple Cryptography

- To decode:
  - Can use the same method, but need to revert the dictionary

```
{'f': 'a', 'g': 'b', 'h': 'c', 'i': 'd', 'j': 'e',
'k': 'f', 'l': 'g', 'm': 'h', 'n': 'i', 'o': 'j',
'p': 'k', 'q': 'l', 'r': 'm', 's': 'n', 't': 'o',
'u': 'p', 'v': 'q', 'w': 'r', 'x': 's', 'y': 't',
'z': 'u', 'a': 'v', 'b': 'w', 'c': 'x', 'd': 'y',
'e': 'z', 'F': 'A', 'G': 'B', 'H': 'C', 'I': 'D',
'J': 'E', 'K': 'F', 'L': 'G', 'M': 'H', 'N': 'I',
'O': 'J', 'P': 'K', 'Q': 'L', 'R': 'M', 'S': 'N',
'T': 'O', 'U': 'P', 'V': 'Q', 'W': 'R', 'X': 'S',
'Y': 'T', 'Z': 'U', 'A': 'V', 'B': 'W', 'C': 'X',
'D': 'Y', 'E': 'Z'}
```

Simple Cryptography

- To revert the dictionary:
  - Create a new dictionary
  - Walk through the dictionary
  - Add to the new dictionary:
    - The value of the old dictionary as key
    - The key of the old dictionary as value

Simple Cryptography

```
def revert_dictionary(dictionary):
    dicc = {}
    for key in dictionary:
        dicc[dictionary[key]] = key
return dicc
```

Simple Cryptography

- Example:

```
>>> encoding('Gwnynxmjwx ts ymj qjky. Sjsf Xfmng: Rtaj gfhp ymj
jqjumfsyx gd 100 dfwix fsi uwjufwj fwynqqjwd knwnsl',dic2)
'Britishers on the left. Nena Sahib: Move back the elephants by 100
yards and prepare artillery firing'
```

Simple Cryptography

- How to beat this encryption
  - Count frequencies
    - Total frequencies of letters
    - If you can, frequencies of beginning letters
    - Frequencies of bigrams (two consecutive letters) …

Simple Cryptography

- Here is how we count letters in a dictionary

```
def total_frequ(a_string):
    dicc = { }
    for letter in string.ascii_letters:
        dicc[letter] = 0
for letter in a_string:
    letter = letter.lower()
    if letter in dicc:
        dicc[letter]=dicc[letter]+1
return dicc
```

Simple Cryptography

- When we apply it:

```
>>> total_frequ('Gwnynxmjwx ts ymj qjky. Sjsf Xfmng:
Rtaj gfhp ymj jqjumfsyx gd 100 dfwix fsi uwjufwj
fwynqqjwd knwnsl')
{'a': 1, 'b': 0, 'c': 0, 'd': 3, 'e': 0, 'f': 8, 'g': 4,
'h': 1, 'i': 2, 'j': 11, 'k': 2, 'l': 1, 'm': 5, 'n': 6,
'o': 0, 'p': 1, 'q': 4, 'r': 1, 's': 6, 't': 2, 'u': 3,
'v': 0, 'w': 8, 'x': 5, 'y': 6, 'z': 0, 'A': 0, 'B': 0,
'C': 0, 'D': 0, 'E': 0, 'F': 0, 'G': 0, 'H': 0, 'I': 0,
'J': 0, 'K': 0, 'L': 0, 'M': 0, 'N': 0, 'O': 0, 'P': 0,
'Q': 0, 'R': 0, 'S': 0, 'T': 0, 'U': 0, 'V': 0, 'W': 0,
'X': 0, 'Y': 0, 'Z': 0}
```

- Most frequent letter in English is ‘e’:
- Possible substitutions: ‘e’ -> ‘f’, ‘e’ -> ‘j’, ‘w’ -> ‘e’

Simple Cryptography

- Works better with longer text, but in this one we would already guess ‘e’.
- Now look at bigrams, beginning letters, etc.
- You can find frequency distributions of letters in different languages or you can download files (e.g. Project Gutenberg) and count yourself

Simple Cryptography

Simple Cryptography