Udacity CS101: Building a Search Engine
Unit 3: Data
Learning to Crawl

Structured Data (Introduction)

The main new topic for Unit 3 is *structured data.* By the end of this unit, you will have finished building a simple web crawler.

The closest thing you have seen to structured data so far is the **string** type introduced in Unit 1, and used in many of the procedures in Unit 2. A string is considered a kind of structured data because you can break it down into its characters and you can operate on sub-sequences of a string. This unit introduces **lists**, a more powerful and general type of structured data. Compared to a string where all of the elements must be characters, in a list the elements can be anything you want such as characters, strings, numbers or even other lists!

The table below summarizes the similarities and differences between strings and lists.

String	**List**
elements are characters	elements may be any Python value
surrounded by singled or double quotes `s = 'yabba!'`	surrounded by square brackets `p = ['y','a','b','b','a','!']`
select elements using <*string*>`[`<*number*>`]` `s[0] → 'y'`	select elements using <*list*>`[`<*number*>`]` `p[0] → 'y'`
select sub-sequence using <*string*>`[`<*number*> `:` <*number*>`]` `s[2:4] → 'bb'`	select sub-sequence using <*list*>`[`<*number*> `:` <*number*>`]` `p[2:4] → ['b','b']`
immutable `s[0] = 'b' → Error` cannot change the value of a string	mutable `p[0] = 'b'` changes the value of the first element of `p`

Q-1: Quiz (Stooges)

Define a variable, **`stooges`**, whose value is a list of the names of the Three Stooges: “Moe”, “Larry”, and “Curly.”

Answer to Q-1

Q-2: Quiz (Days in a Month)

Given the variable:

```
days_in_month = [31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31]
```

define a procedure, **how_many_days**, that takes as input a number representing a month, and outputs the number of days in that month.

```
how_many_days(1) → 31
how_many_days(9) → 30
```

Answer to Q-2

Nested Lists

So far, all of the elements in our lists have been of the same type: strings, numbers, etc. However, there are no restrictions on the types of elements in a list. Elements of a list can be any type you want, you can also mix and match different types of elements in a list.

For example:

```
mixed_up = ['apple', 3, 'oranges', 27,
            [1, 2, ['alpha', 'beta']]]
```

or a more useful example:

```
beatles = [['John', 1940],
           ['Paul', 1942],
           ['George', 1943],
           ['Ringo', 1940]]
```

This list provides information about the names of the Beatles band members, as well as when they were born. Try putting this into your interpreter. When you are typing your code into the interpreter and you want to separate data onto two lines, do so after a comma to make it clear to the interpreter that this is still one list.

```
beatles = [['John', 1940], ['Paul', 1942],
           ['George', 1943], ['Ringo', 1940]]

print beatles
[['John', 1940], ['Paul', 1942], ['George', 1943], ['Ringo', 1940]]

print beatles[3]
['Ringo', 1940]
```

You can also use indexing again on the list that results to obtain an inner element:

```
print beatles[3][0]
Ringo
```

Q-3: Quiz (Countries)

Given the variable **countries** defined as:

```
countries = [['China', 'Beijing', 1350],
             ['India', 'Delhi', 1220],
             ['Romania', 'Bucharest', 21]
             ['United States', 'Washington', 307]]
```

Each list contains the name of a country, its capital, and its approximate population in millions.

Write code to print out the capital of India.

Answer to Q-3

Q-4: Quiz (Relative Size)

What multiple of Romania's population is the population of China? To solve this, you need to divide the population of China by the population of Romania.

Answer to Q-4

Mutation

Mutation means changing the value of an object. Lists support mutation. This is the second main difference between strings and lists.

It might have seemed like we could change the value of strings:

```
s = 'Hello'
s = 'Yello'
```

However, this expression changes the value the variable **s** refers to, but does not change the value of the string **'Hello'**. As another example, consider string concatenation:

```
s = s + 'w'
```

This operation may look like it is changing the value of the string, but that's not what happens. It is not modifying the value of any string, but instead is creating a new string, **'Yellow'**, and assigning the variable **s** to refer to that new string.

Lists can be mutated, thus changing the value of an existing list. Here is a list:

```
p = ['H', 'e', 'l', 'l', 'o']
```

Mutate a list by modifying the value of its elements:

```
p[0] = 'Y'
```

This expression replaces the value in position **0** of **p** with the string **'Y'**. After the assignment, the value of **p** has changed:

```
print p
['Y', 'e', 'l', 'l', 'o']

p[4] = '!'
print p
['Y', 'e', 'l', 'l', '!']
```

Q-5: Quiz (Different Stooges)

Previously, we defined:

```
stooges = ['Moe', 'Larry', 'Curly']
```

In some Stooges films, though, Curly was replaced by Shemp. Write one line of code that changes the value of **stooges** to be:

```
['Moe', 'Larry', 'Shemp']
```

but does not create a new list object.

Answer to Q-5

Aliasing

Now that you know how a mutation modifies an existing list object, you will really be able to see how this is differs from strings when you introduce a new variable.

```
p = ['H', 'e', 'l', 'l', 'o']
p[0] = 'Y'
q = p
```

After this assignment, **p** and **q** refer to the same list: *['Y', 'e', 'l', 'l', 'o']*.

Suppose we use an assignment statement to modify one of the elements of **q**:

```
 q[4] = '!'
```

This also changes the value of **p**:

```
print p
['Y', 'e', 'l', 'l', 'o']
```

After the **q = p** assignment, the names **p** and **q** refer to the same list, so anything we do that mutates that list changes that value both variables refer to.

It is called **aliasing** when there are two names that refer to the same object. Aliasing is very useful, but also can be very confusing since one mutation can impact many variables. If something happens that changes the state of the object, it affects the state of the object for all names that refer to that object.

Strings are Immutable. Note that we cannot mutate strings, since they are *immutable* objects. Try mutating a string in the interpreter:

```
s = 'Hello'
s[0] = 'Y'
'str' object does not support item assignment
```

Mutable and Immutable Objects. The key difference between mutable and immutable objects, is that once an object is mutable, you have to worry about other variables that might refer to the same object. You can change the value of that object and it affects not just variable you think you changed, but other variables that refer to the same object as well.

Here is another example:

```
p = ['J', 'a', 'm', 'e', 's']
q = p
p[2] = 'n'
```

Both **p** and **q** now refer to the same list:

```
['J', 'a', 'n', 'e', 's']
```

What happens if you assign **p** a new value, as in:

```
p = [0, 0, 7]
```

In this case, the value of **p** will change, but the value of **q** will remain the same. The assignment changes the value the name **p** refers to, which is different from mutating the object that **p** refers to.

Q-6: Quiz

What is the value of **agent[2]** after running the following code:

```
spy = [0, 0, 7]
agent = spy
spy[2] = agent[2] + 1
```

Answer to Q-6

Q-7: Quiz (Replace Spy)

Define a procedure, **replace_spy**, that takes as its input a list of three numbers and increases the value of the third element of the list to be one more than its previous value. Here is an example of the behavior that you want:

```
spy = [0,0,7]
replace_spy(spy)
print spy
[0, 0, 8]
```

Answer to Q-7

List Operations

There are many built-in operations on lists. Here are a few of the most useful ones here.

Append. The append method adds a new element to the end of a list. The append method mutates the list that it is invoked on, it does not create a new list. The syntax for the append method is:

```
<list>.append(<element>)
```

For example, assume you want to end up with four stooges in your list, instead of just three:

```
stooges = ['Moe', 'Larry', 'Curly']
stooges.append('Shemp')
['Moe', 'Larry', 'Curly', 'Shemp']
```

Concatenation. The **+** operator can be used with lists and is very similar to how it is used to concatenate strings. It produces a new list, it does not mutate either of the input lists.

```
<list> + <list> → <list>
```

For example,

```
[0, 1] + [2, 3] → [0, 1, 2, 3]
```

Length. The **len** operator can be used to find out the length of an object. The **len** operator works for many things other than lists, it works for any object that is a collection of things including strings. The output from **len** is the number of elements in its input.

```
len(<list>) → <number>
```

For example, **len([0,1]) → 2**. Note that **len** only counts the outer elements:

```
len(['a', ['b', ['c', 'd']]]) → 2
```

since the input list contains two elements: **'a'** and **['b', ['c', 'd']]**.

When you invoke **len** on a string, the output is the number of elements in the string.

```
len("Udacity") → 7
```

Q-8: Quiz (Len Quiz)

What is the value of **len(p)** after running the following code:

```
p = [1, 2]
p.append(3)
p = p + [4, 5]
len(p) → ?
```

Answer to Q-8

Q-9: Quiz

What is the value of **len(p)** after running:

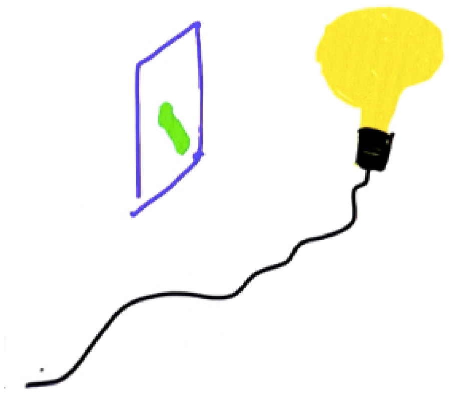
```
p = [1, 2]
q = [3, 4]
p.append(q)
len(p) → ?
```

Answer to Q-9

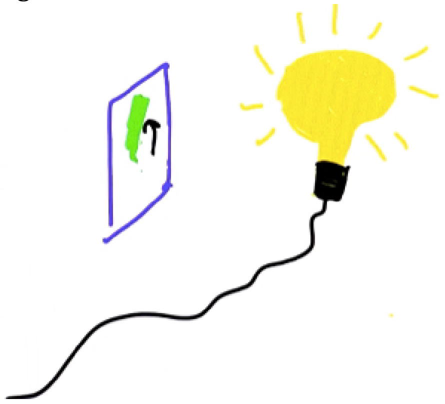
How Computers Store Data

In order to store data you need two things: (1) something that preserves state, and (2) a way to read its state. Our storage mechanism needs to have more than one state, but two states is enough. We can think about this like a light switch, which is connected to a light bulb through some power source. When you turn the light switch on, the light bulb turns on:

Light switch off:



Light switch on:



Flipping the switch changes the state of the light bulb. The light bulb has two different states: it can be on or off. This is what we need to store one **bit** of data. A bit is the fundamental unit of *information*. One bit is enough to decide between two options (for example, on or off for the light bulb). If you had enough light bulbs you could store many bits, which would be enough to be able to store any amount of digital data.

In addition to something that can change state, to read memory you also need something that can sense the state. In terms of a light bulb, that could be an eye or a light sensor, which could see if the light bulb was on or off. This is very similar to the way computers store data, but computers use much less energy and much less space than a light bulb to store one bit.

The fastest memory in your computer works like a switch. Data that is stored directly in the processor, which is called the **register**, is stored like a switch, which makes it very fast to change and read its state. However, a register is like a light bulb in that when you turn the power off, you lose the state. This means that all the data stored in registers is lost when the computer is turned off.

Another way that computers store data is similar to a bucket. We could represent a *one* by a full bucket and represent a *zero* with an empty bucket. To check the state of the bucket, we could weigh the bucket or look at it to figure out whether it is full or empty.

Full bucket = 1:

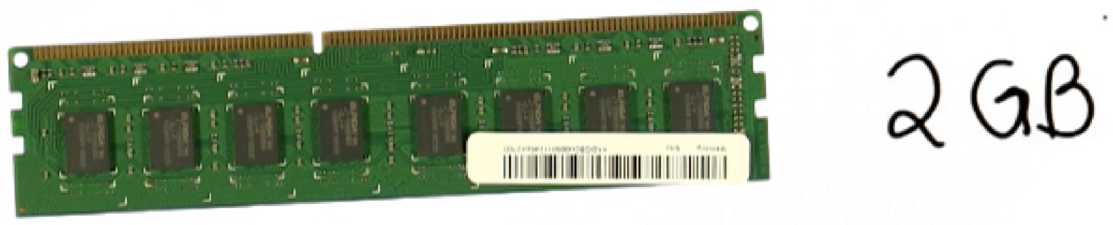
Empty bucket = 0:

The difference between buckets and light bulbs is that buckets leak a little, and water evaporates from the bucket. If you want to store data using a bucket, it will not last forever. Eventually, when all the water evaporates you will be unable to tell the difference between a zero and a one. Computers solve this problem using the **digital abstraction**. There are infinitely many different amount of water that could be in the bucket, but they are all mapped to either a **0** or a **1** value. This means it is okay if some water evaporates, as long as it does not drop below the threshold for representing a **1**.

In computers, the buckets are holding electrons instead of water, and we call them **capacitors**. The memory in your computer that works this way is called **DRAM**.

DRAM

Below is a two gigabytes (GB) of DRAM taken out of a computer.



A gigabyte means approximately a billion bytes. One byte is 8 bits.

A gigabyte is actually 2^{30} bytes. This is very close to one billion, but in computing it is usually more convenient to use powers of two.

In Python, the exponentiation operator is denoted with two asterisks:

```
<base> ** <power> → <base><power>
```

For example,

```
print 2 ** 10
1024
```

One kilobyte is 1024 bytes.

```
print 2 ** 20 # one megabyte
1048576

print 2 ** 30 # one gigabyte
1073741824

print 2 ** 40 # one terabyte
109951162776
```

Kilobytes, megabytes, gigabytes, and terabytes are the main units we use to talk about computer memory.

Now, back to the DRAM, which is two gigabytes of memory. Since one gigabyte is 2^{30} bytes, we can compute the total number of bits by multiplying that by 2 (since there are two gigabytes) and 8 (the number of bits in a byte):

$2^{30} * 2 * 8 \sim$ 17 billion light switches
1 byte = 8 bits
1 bit $\sim$ light switch (two states)

Thus, the DRAM shown is like having 17 billion buckets, each one can store one bit.

There are many different types of memory inside your computer, for example, registers, that were mentioned earlier as the fastest memory that is built right into the processor. What distinguishes different types of memory is the time it takes to retrieve a value (this is called **latency**), the cost per bit, and how long it retains its state without power.

For DRAM, the latency is about 12 nanoseconds (recall that there are one billion nanoseconds in a second). The cost of the 2 GB DRAM show is about 10 USD (approximately 7 euros).

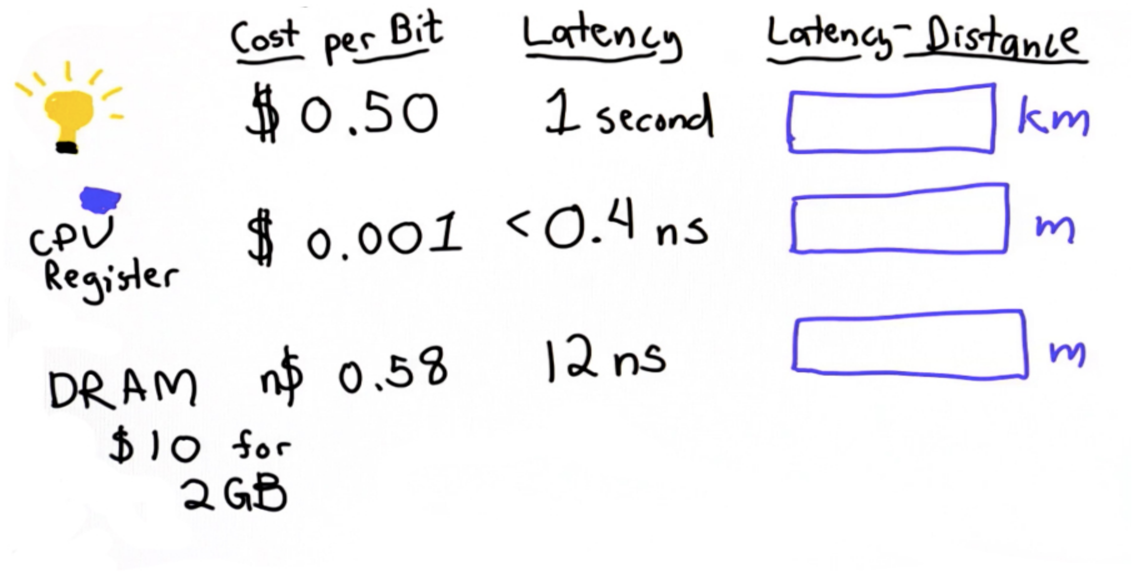
Memory Hierarchy

To get a better understanding of the different types of memory in the computer, let's compare them in terms of **Cost per Bit** and **Latency**. Since times in nanoseconds are hard to relate to, we will convert the latencies into how far light travels in the time it takes to retrieve a stored bit.

Since the costs per bit get pretty low, we introduce a new money unit: one nanodollar (n$) is one billionth of a US dollar, and truly not worth the paper on which it is printed!

Q-10: Quiz

Fill in the **Latency-Distance** for the light bulb, CPU register and DRAM using the information provided. Keep in mind that you will be finding the answers in different units. As a reminder the speed of light is about 300,000 km/sec.

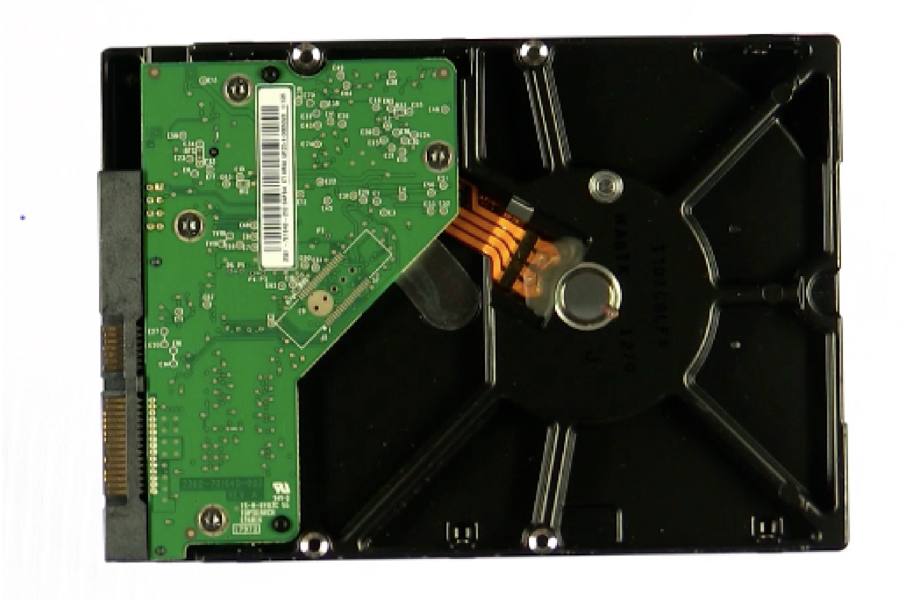


	Cost per Bit	Latency	Latency-Distance
	\$0.50	1 second	☐ km
CPU Register	\$ 0.001	<0.4 ns	☐ m
DRAM \$10 for 2GB	n\$ 0.58	12 ns	☐ m

Answer to Q-10

Hard Drives

Another type of memory in your computer is a **hard drive**. Inside the hard drive there are several disks that spin. The disks store data magnetically, and there is a read-head that can read data from the disks as well as write new data from the disk. Compared to DRAM, this is a very slow way of storing data since it involves spinning a physical disk and moving a read head, but it can store data for far less cost than DRAM. The other advantage of storing data on a hard drive is that it persists. The data is not lost even when the power is turned off.



Where our DRAM was two gigabytes, this hard drive can store one terabyte, which is 500 times as much memory. A terabyte is close to a trillion bytes:

$8 * 2^{40}$ bits ~ 8.8 trillion bits

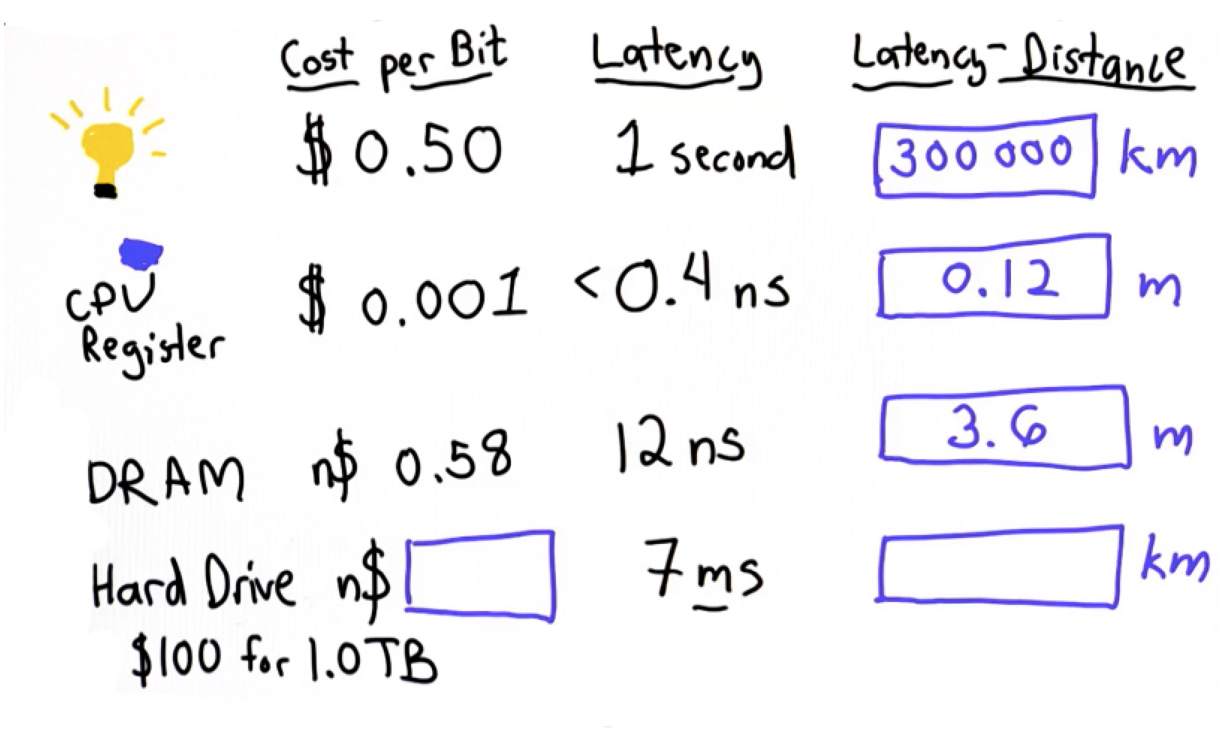
This is enough memory to store about 100 hours of high quality video.

The latency for a hard drive is much higher than it is for DRAM. This is because the hard drive is moving physical things. It operates using disks, so you have to wait for the disk to spin and reach the read-head. Also, if the disk isn't in the right place then you might have to wait for the read-head to move. The average latency for a hard drive is about seven milliseconds (1 millisecond = 1/1000 of a second = 1 million nanoseconds).

The cost of this 1.0 terrabyte hard drive is 100 USD (75 Euros), so the cost per bit is much lower than it is for DRAM memory.

Q-11: Quiz

Add the hard drive data to your unit table. Include how many nanodollars it costs per bit and its latency-distance.



	Cost per Bit	Latency	Latency-Distance
	\$ 0.50	1 second	300 000 km
CPU Register	\$ 0.001	< 0.4 ns	0.12 m
DRAM	n\$ 0.58	12 ns	3.6 m
Hard Drive \$100 for 1.0TB	n\$	7 ms	km

[Answer to Q-11]

Loops on Lists

Since lists are collections of things, it is very useful to be able to go through a list and do something with every element.

In Unit 2, we introduced the **while** loop:

```
while <TestExpression>:
    <Block>
```

If the test expression is True, the **<Block>** is executed. At the end of the block, execution continues by re-evaluating the test expression, and continuing to execute the block as long as the test expression evaluates to true.

Q-12: Quiz

Define a procedure called **print_all_elements** that takes as input a list **p** and prints out every element of that list. Here is a start:

```
def print_all_elements(p):
    i = 0
    while __________:
        print p[i]
        i = i + 1
```

Answer to Q-12

For Loops

In Python there is a more convenient way to loop through the elements of a list: the **for** loop. The syntax looks like this:

```
for <name> in <list>:
    <block>
```

The loop goes through each element of the list in turn, assigning that element to the ***<name>*** and evaluating the ***<block>***. Using the **for** loop, we can use less code than we needed using the **while** loop to define the procedure **print_all_elements**:

```
def print_all_elements(p):
    for e in p:
        print e
```

Let's walk-through what happens when you apply this **for** loop to a list:

```
mylist = [1, 2, 3]
print_all_elements(mylist)
```

When you pass in **mylist** to **print_all_elements** the variable **p** will refer to the list that contains the three elements, **1**, **2** and **3**. When the loop is executed, the variable **e** is assigned to the first element in the list, and the body of the loop will print the first element. So, for the first iteration the value of **e** will be **1**. The block is executed, printing out **1**. Since there are more elements in the list, execution continues, assigning **2** to the **e**. Again, the block is executed, but this time it prints out **2**. Execution continues for the third iteration, which prints out **3**. There are no more elements in the list, so the **for** loop is complete and execution continues with the next statement (in this case, there is no following statement, so execution finishes).

Q-13: Quiz (Sum List)

Define a procedure, **`sum_list`**, that takes as its input a list of numbers, and produces as its output the sum of all the elements in the input list.

For example,

```
sum_list([1, 7, 4]) → 12
```

Answer to Q-13

Q-14: Quiz (Measure Udacity)

Define a procedure, **`measure_udacity`**, that takes as its input a list of strings, and outputs a number that is a count of the number of elements in the input list that start with an uppercase letter **`'U'`**.

For example,

```
measure_udacity(['Dave', 'Sebastian', 'Katy'])
0

measure_udacity(['Umika', 'Umberto'])
2
```

Answer to Q-14

Q-15: Quiz (Find Element)

Define a procedure, **`find_element`**, that takes as its input a list and a value of any type, and outputs the index of the first element in the input list that matches the value. If there is no matching element, output **`-1`**.

Examples:

```
find_element([1, 2, 3], 3) → 2
find_element(['alpha', 'beta'], 'gamma') → -1
```

Answer to Q-15

Index

There are many other ways to define **`find_element`**. A built-in list operation that we have not yet introduced that makes it easier to write **`find_element`** is the **`index`** method:

```
<list>.index(<value>) → <position> or error
```

The **`index`** method is invoked on a list by passing in a value, and the output is the first position where that value sits in the list. If the list that does not contain any occurrences of the value you pass in, **index** produces an error (this is different from the **find** method for strings which we used in Unit 1, that returns a **-1** when the target string is not found).

Examples:

```
p = [0, 1, 2]
print p.index(2)
2

p = [0, 1, 2, 2, 2]
print p.index(2)
2
```

Even though there are many **2**s in the list, the output is the first position where **2** occurs.

```
p = [0, 1, 2]
print p.index(3)
ValueError: list.index(x): x not in list
```

Since the requested behavior of **find_element** is to output **-1** when the input element is not found, we cannot use **index** directly to implement **find_element** since **index** produces an error when the element is not found. Instead, we can use another list operation, **in**, to first test if the element is anywhere in the list. We have already seen **in** used in the for loop, however outside of a **for** loop header it means something different:

```
<value> in <list> → <Boolean>
```

The output is **True** if the list contains an element matching value, and **False** if it does not.

Examples:

```
p = [0, 1, 2]
print 3 in p
False
print 1 in p
True
```

Similarly, you can use **not in**, which has the opposite meaning of **in**:

```
<value> not in <list>
```

If the value is not in the list the result of ***<value>* not in *<list>*** is **True**, and if the ***<value>*** is in the ***<list>*** than the result is **False**.

These two expressions are equivalent:

```
<value> not in <list> ≡ not <value> in <list>
```

Q-16: Quiz

Define **find_element**, this time using index.

Answer to Q-16

Q-17: Quiz (Union)

Define a procedure, **union**, that takes as inputs two lists. It should modify the first input list to be the set union of the two lists.

Examples:

```
a = [1, 2, 3]
b = [2, 4, 6]
union(a, b)
print a
[1, 2, 3, 4, 6]
print b
[2, 4, 6]
```

Answer to Q-17

Pop

The **pop** operation mutates a list by removing its last element. It returns the value of the element that was removed.

```
    <list>.pop() → element
```

Example:

```
    a = [1, 2, 3]
    b = a # both a and b refer to the same list
    x = a.pop() # value of x is 3, and a and b now refer to the list [1, 2]
```

Q-18: Quiz (Pop Quiz)

Assume **p** refers to a list with at least two elements. Which of these code fragments does not change the final value **p**.

1.
```
p.append(3)
p.pop()
```

2.
```
x = p.pop()
y = p.pop()
p.append(x)
p.append(y)
```

3.
```
x = p.pop()
p.append(x)
```

4.
```
x = p.pop()
y = p.pop()
p.append(y)
p.append(x)
```

Answer to Q-18

Collecting Links

Now we are ready to finish our web crawler!

Let's recap how the web crawler should work to find all the links that can be found from a seed page. We need to start by finding all the links on the seed page, but instead of just printing them like we did in Unit 2, we need to store them in a list so we can use them to keep going. We will go through all the links in that list to continue our crawl, and keep going as long as there are more pages to crawl.

The first step to define a procedure **`get_all_links`** that takes as input a string that represents the text on a web page and produces as output a list containing all the URLs that are targets of link tags on that page.

Get All Links

Let's recap the code we had from Unit 2:

```
def print_all_links(page):
    while True:
        url, endpos = get_next_target(page)
        if url:
            print url
            page = page[endpos:]
        else:
            break
```

We defined a procedure, **`get_next_target`**, that would take a page, search for the first link on that page, return that as the value of **`url`** and also return the position at the end of the quote is so we know where to continue.

Then, we defined the procedure, **`print_all_links`**, that keeps going as long as there are more links on the page. It will repeatedly find the next target, print it out, and advance the page past the end position.

What we want to do to change this is instead of printing out the URL each time we find one, we want to collect the URLs so we may use them to keep crawling and find new pages. To do this, we will create a list of all of the links we find. We change the **`print_all_links`** procedure into **`get_all_links`** so that we can use the output, which will be a list of links, which will correspond to the links we were originally printing out.

Links

As an example of how this should work, there is a test page at http://www.udacity.com/cs101x/index.html. It contains three link tags that point to pages about crawling, walking, and flying (you can check them out for yourself by clicking on links on the test page in your web browser).

Here is how **get_all_links** should behave:

```
    links = get_all_links(get_page('http://www.udacity.com/cs101x/
index.html')
    print links
    ['http://www.udacity.com/cs101x/crawling.html',
     'http://www.udacity.com/cs101x/walking.html',
     'http://www.udacity.com/cs101x/flying.html']
```

Because the result is a list, we can use it to continue crawling pages. Think on your own how to define **get_all_links**, but if you get stuck, use the following quizzes to step through the changes we need to make.

Q-19: Quiz - Starting get_all_links

What should the initial value of **links** be? Remember, our goal for **get_all_links** is to return a list of all the links found on a page. We will use the **links** variable to refer to a list that contains all the links we have found.

```
def get_all_links(page):
    links = __________
    while True:
        url, endpos = get_next_target(page)
        if url:
            print url
            page = page[endpos:]
        else:
            break
```

Answer to Q-19

Q-20: Quiz - Updating Links

What do we replace **`print url`** with to update the value of **`links`**?

```
def get_all_links(page):
    links = []
    while True:
        url, endpos = get_next_target(page)
        if url:
            ~~print url~~_
            page = page[endpos:]
        else:
            break
```

Answer to Q-20

Q-21: Quiz - Finishing Links

For this last quiz on **`get_all_links`**, let's figure out how to get the output:

```
def get_all_links(page):
    links = []
    while True:
        url, endpos = get_next_target(page)
        if url:
            links.append(url)
            page = page[endpos:]
        else:
            break
    ___________________   (fill in here)
```

Answer to Q-21

Finishing the Web Crawler

At this point we are ready to finish the web crawler. The web crawler is meant to be able to find links on a seed page, make them into a list and then follow those links to new pages where there may be more links, which you want your web crawler to follow.

In order to do this the web crawler needs to keep track of all the pages. Use the variable **`tocrawl`** as a list of pages left to crawl. Use the variable **`crawled`** to store the list of pages crawled.

Crawling Process - First Attempt

Here is a description of the crawling process. We call this **pseudocode** since it is more precise than English and structured sort of like Python code, but is not actual Python code. As we develop more complex algorithms, it is useful to describe them in pseudocode before attempting to write the Python code to implement them. (In this case, it is also done to give you an opportunity to write the Python code yourself!)

```
start with tocrawl = [seed]
crawled = []
while there are more pages tocrawl:
    pick a page from tocrawl
    add that page to crawled
    add all the link targets on this page to tocrawl
return crawled
```

Q-22: Quiz

What would happen if we follow this process on the test site, starting with the seed page **`http://www.udacity.com/cs101x/index.html`** ?

a. It will return a list of *all* the urls reachable from the seed page.
b. It will return a list of *some* of the urls reachable from the seed page.
c. It will never return.

Answer to Q-22

The next several quizzes implement our web crawling procedure, **`crawl_web`**, that takes as input a seed page url, and outputs a list of all the urls that can be reached by following links starting from the seed page.

Q-23: Quiz

To start the **`crawl_web`** procedure, provide the initial values of **`tocrawl`** and **`crawl`**:

```
def crawl_web(seed):
    tocrawl = ______ ← initialize this variable
    crawl = ________ ← initialize this variable
```

Answer to Q-23

Q-24: Quiz - Crawl the Web Loop

The next step is to write a loop to do the crawling, where we keep going as long as there are pages to crawl. To do this, we will use a **`while`** loop, with **`tocrawl`** as our test condition. We could use **`len(tocraw) == 0`** to test if the list is empty. There is an easier way to write this using just **`tocrawl`**. An empty list (a list with no elements) is interpreted as false, and every non-empty list is interpreted as true.

Inside the loop, we need to choose a page to crawl. For this quiz, your goal is to figure out a good way to do this. There are many ways to do this, but using things we have learned in this unit you can do it using one line of code that both initializes **`page`** to the next page we want to crawl and removes that page from the **`tocrawl`** list.

```
def crawl_web(seed):
    tocrawl = [seed]
    crawled = []
    while tocrawl:
        page = ____________
```

Answer to Q-24

Q-25: Quiz - Crawl If

The next step is to manage the problem of cycles in the links. We do not want to crawl pages that we've already crawled, so what we need is someway of testing whether the page was crawled.

To make a decision like this, we use **if**. We need a test condition for **if** that will only do the stuff we do to crawl a page if it has not been crawled before.

```
def crawl_web(seed):
    tocrawl = [seed]
    crawled = []
    while tocrawl:
        page = tocrawl.pop()
        if ___________________
```

Answer to Q-25

Q-26: Quiz - Finishing Crawl Web

Now we're ready to finish writing our crawler. Write two lines of code to update the value of **tocrawl** to reflect all of the new links found on **page** and update the value of **crawled** to keep track of the pages that have been crawled.

```
def crawl_web(seed):
    tocrawl = [seed]
    crawled = []
    while tocrawl:
        page = tocrawl.pop()
        if page not in crawled:
            ______________________
            ______________________
    return crawled
```

Answer to Q-26

Conclusion

Anna Patterson has been working on search engines for more than a decade. She led the development of the world's largest web index for the **http://recall.archive.org/** project. For more of her insights on building search engines, see her article, *Why Writing Your Own Search Engine Is Hard* (ACM Queue, April 2004). She is currently a Director of Research at Google, working on Android.

Answers

A-1: Answer

```
stooges = ['Moe', 'Larry', 'Curly']
```

A-2: Answer

```
def how_many_days(month):
    return days_in_month[month - 1]
```

Note that we need to subtract `1` from `month` since lists are indexed starting from `0`.

What happens if you pass in a number that is not a valid month? For example:

```
print how_many_days(13)
Traceback (most recent call last):
    File "/code/knowvm/input/test.py", line 8, in <module>
        print how_many_days(13)
    File "/code/knowvm/input/test.py", line 6, in how_many_days
        return days_in_month[month - 1]
IndexError: list index out of range
```

This procedure returned an error because there are only 12 elements in the list, so it is an error to request an element at position 12.

A-3: Answer

```
print countries[1][1]
Delhi
```

A-4: Answer

```
print countries[0][2] / countries[2][2]
64
```

Remember that the interpreter is performing integer division, truncating the result to the whole number. To get a more precise answer, make one of the values a floating point number:

```
countries = [['China', 'Beijing', 1350],
             ['India', 'Delhi', 1220],
             ['Romania', 'Bucharest', 21.] # add a decimal point
```

```
                 ['United States', 'Washington', 307]]
  print countries[0][2]/ countries[2][2]
    64.2857142857
```

(Of course, the actual populations are approximations, so 64 if probably a better answer.)

A-5: Answer

```
    stooges[2] = 'Shemp'
```

A-6: Answer

```
    8
```

A-7: Answer

```
    def replace_spy(p): # this takes one parameter as its input, called p
        p[2] = p[2] + 1
```

A-8: Answer

```
    p = [1, 2]
    p.append(3)
    p = p + [4, 5]
    len(p)
    5
```

Let's run through this code line by line so that you know exactly what is going on.

The first line assigns **p** to a list.

The next statement invokes **append** on **p**, passing in the value 3, adding it to the end of the list.

Then, the **+** operator creates a new list combining the two operands, **p** and another list, which becomes the new list object assigned to **p**. The length of the new list object is five.

A-9: Answer

```
    p = [1, 2]
    q = [3, 4]
    p.append(q)
    len(p)
    3
```

The first statement creates the list with the elements, 1 and 2, and assigns that list to the variable **p** .

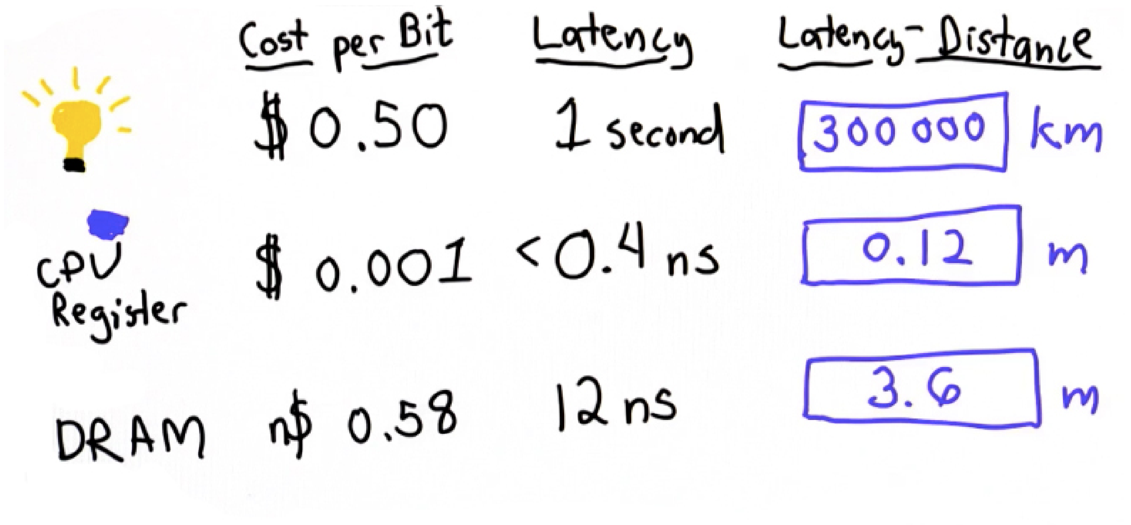
The second statement creates a list with the elements, 3 and 4, and assigns that list to the variable **q**.

The append statement adds just one new element to **p**, the list object **q**.

Try this in your interpreter to see how it looks when you **`print p`**.

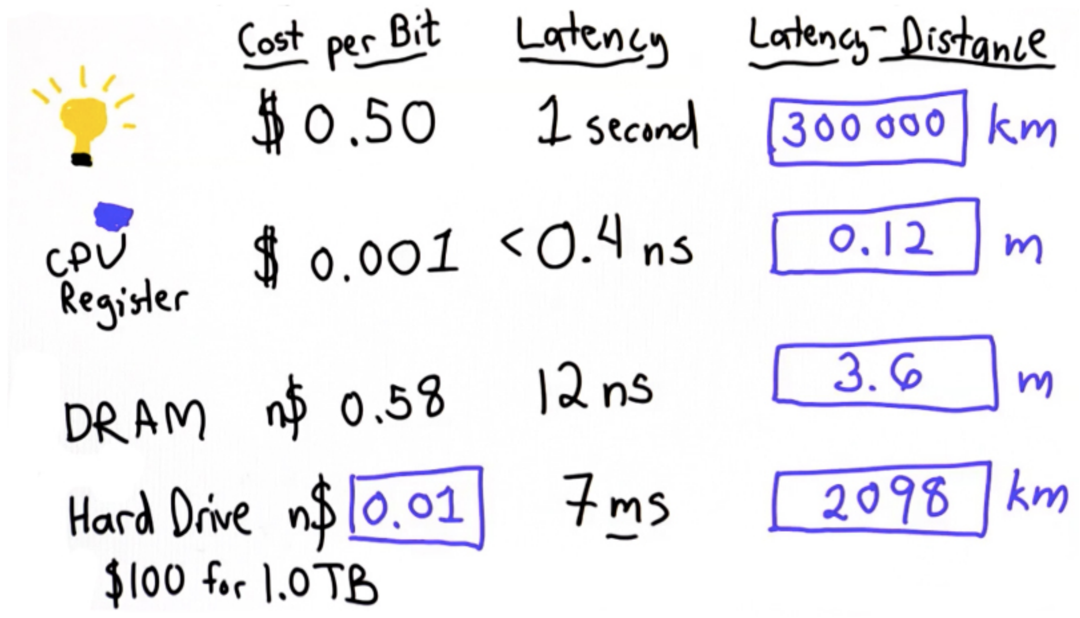
```
p = [1, 2]
q = [3, 4]
p.append(q)
len(p)
3
print p
[1, 2, [3, 4]]
```

A-10: Answer



	Cost per Bit	Latency	Latency-Distance
	\$ 0.50	1 second	300 000 km
CPU Register	\$ 0.001	<0.4 ns	0.12 m
DRAM	n\$ 0.58	12 ns	3.6 m

A-11: Answer



	Cost per Bit	Latency	Latency-Distance
	$0.50	1 second	300 000 km
CPU Register	$ 0.001	<0.4 ns	0.12 m
DRAM	n$ 0.58	12 ns	3.6 m
Hard Drive $100 for 1.0TB	n$ 0.01	7 ms	2098 km

A-12: Answer

When the procedure starts **p** refers to some list that was passed in, and since we want the procedure to work on any list there is no need to assume anything about the list. Since **i** has the value zero, it means that the value of **p** index **i** is the first element of the list **p**. In the loop body, this value is printed, **print p[i]**, and then move on to the next element by increasing **i** by one, **i = i + 1**. This will continue for each element of the list.

Now, what you need for the test condition of the **while** loop is to figure out when to stop. Recall that the len operator tells you the length of a list. The highest index in the list is the value of **len(p)**. So, we want the test condition of the loop to make sure that **i** has not exceeded that last index. Here is one way to write that condition:

```
i < = len(p)-1
```

which is equivalent to a simplier expression:

```
i < len(p)
```

We can write the final code as:

```
def print_all_elements(p):
    i = 0
    while i < len(p):
        print p[i]
        i = i + 1
```

A-13: Answer

```
    def sum_list(p):
        result = 0
        for e in p:
            result = result + e
        return result

    print sum_list([1, 4, 7])
    12
```

A-14: Answer

```
    def measure_udacity(U):
        count = 0
        for e in U:
            if e[0] == 'U':
                count = count + 1
        return count
```

A-15: Answer

There are a many ways to answer this question. One way is to use a while loop:

```
    def find_element(p,t):
        i = 0
        while i < len(p):
            if p[i] == t:
                return i
```

The risky thing about using while loops instead of for loops is that it is really easy to forget that you need to increase the index variable. If the loop is left at **`return i`** it would run forever because the value of **`i`** would never change. Make sure you remember increase the value of **`i`**, and include the return statement for when the while loop is finished, so that the code reads:

```
    def find_element(p,t):
        i = 0
        while i < len(p):
            if p[i] == t:
                return i
            i = i + 1
        return -1
```

Another way to answer this question is to use a for loop. It may seem more intuitive to use a while loop rather than a for loop because the value you want to return from **`find_element`** is the index itself. When you use a for loop you do not keep track of the index, you just go through each element in order. Here is how you would write a for loop:

```
    def find_element(p, t):
        i = 0
        for e in p:
            if e == t:
                return i
            i = i + 1
        return -1
```

A-16: Answer

Here is one way:

```
    def find_element(p,t):
        if t in p:
            return p.index(t)
        else:
            return -1
```

Here is another way:

```
    def find_element(p,t):
        if t not in p:
            return -1
        return p.index(t)
```

A-17: Answer

```
    def union(p, q):
        for e in q:
            if e not in p:
                p.append(e)
```

A-18: Answer

All of the code fragments except for 2, do not change the value of **`p`**.

A-19: Answer

We want links to start out as an empty list:

```
    links = []
```

A-20: Answer

We want to append the **`url`** to **`links`**. This will add that value to the list that links refers to, keeping track of all the URLs that we found on that page.

```
    def get_all_links(page):
        links = []
          while True:
            url, endpos = get_next_target(page)
            if url:
                links.append(url)
                page = page[endpos:]
            else:
                break
```

A-21: Answer

We need a return statement:

```
        return links
```

A-22: Answer

The answer is c. This is because the stopping test for the while loop will keep going as long as there are pages in **`tocrawl`**. So in order to finish, you need to know that the value of **`tocrawl`** eventually becomes empty. If you look at the test site and follow the 'walk' link, you get to a page that has a link to 'crawling,' which goes back to the index and follow the 'walk' link again -- over and over. The crawler will never finish because it will always find a link to crawl.

To avoid this, you need to make sure you don't crawl pages that have already been crawled. You can do this by adding a test that checks to see if a certain page has already been crawled.

A-23: Answer

```
    def crawl_web(seed):
        tocrawl = [seed]
        crawl = []
```

A-24: Answer

The best way to answer this is to use **pop. pop** is the only thing we've seen that actually removes elements from a list and also has the property of returning that element. If we use **tocrawl.pop()**, that will get us the last element in the **tocrawl** list, remove that element from the list **tocrawl**, and assign that to the variable **page**.

```
def crawl_web(seed):
    tocrawl = [seed]
    crawled = []
    while tocrawl:
        page = tocrawl.pop()
```

Because we are getting the last element first, we are implementing what is called a **depth-first search**. That means as we crawl web pages, we will look at first link on each page in the chain of pages until we get to the end. Only then, will we start to look at the second link on the first page and each subsequent page. If our goal was to get a good corpus of the web quickly, doing a depth-first search is probably not the best way to do that. If we complete our search, no matter what order we follow, we'll find the same set of pages. If we aren't able to complete the search, and with a real web crawler there are far too many pages to wait until we crawl them all to return a result, then the order with which we view the pages matters a lot.

A-25: Answer

We should only crawl the page if we have not crawled it already. The **crawled** variable keeps track of the pages we have crawled already. So, we want to test if the page is not in crawled. If it page is not in **crawled**, then we crawl. If it is, then we keep going. We are going to do nothing else in this iteration in the while loop and go on to check the next page.

```
        if page not in crawled:
            ...
```

A-26: Answer

First, we need to add all the links we find on a page to **page**, which we can do using the **union** procedure from an earlier quiz this unit. Using **append**, we can keep track of the pages we have already crawled.

```
def crawl_web(seed):
    tocrawl = [seed]
    crawled = []
```

```
while tocrawl:
    page = tocrawl.pop()
    if page not in crawled:
        union (tocrawl, get_all_links(get_page(page)))
        crawled.append(page)
return crawled
```