CCN
Handout 1

Introducing Computer Memory and Program Variables

Intro to C Programming

2022-11-28

Learning Goals

1) Students will understand the concept of **program memory** and **memory addressing**
2) Students will understand what **variables** are in the C programming language, as well as how they exist in program memory.

Warm-Up

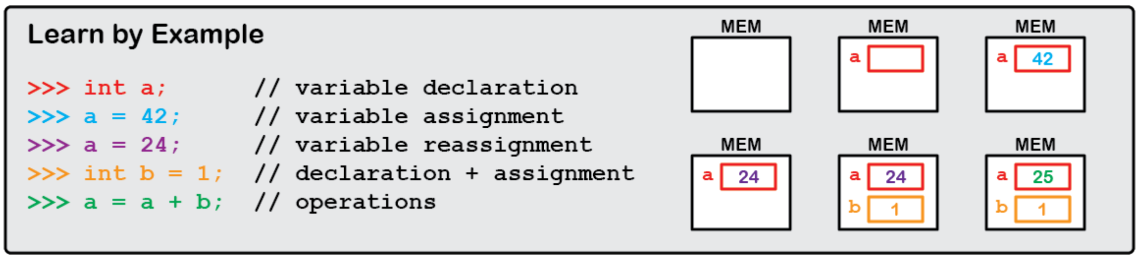
1) Use long multiplication to compute 121×34. First take 30 seconds to try to do this in your head. Then use the space provided for the computation.

2) What do you think this exercise illustrates about people's memory?

1 Variables

Some helpful definitions:

code:	the instructions given to a computer that tell it what to do. a very loose term ("C code", "Python code", "machine code")
variable:	a named container for a value, similar to an algebraic variable



Learn by Example

```
>>> int a;         // variable declaration
>>> a = 42;        // variable assignment
>>> a = 24;        // variable reassignment
>>> int b = 1;     // declaration + assignment
>>> a = a + b;     // operations
```

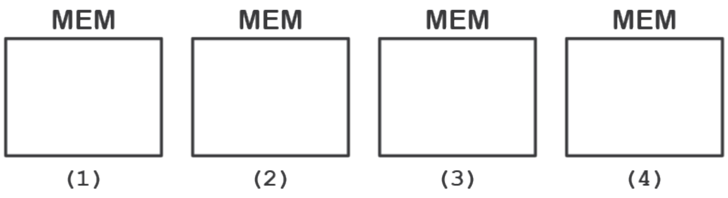
When you declare a variable, the computer sets aside some space in memory that can be used to store variables. How much space is determined by the **variable type**.

Different Data Types

```
>>> int i = 0;       // declare an integer variable i and store 0
>>> char a = 'a';    // declare a character variable a and store 'a'
>>> bool t = true;   // declare a boolean variable t and store true
```

Practice

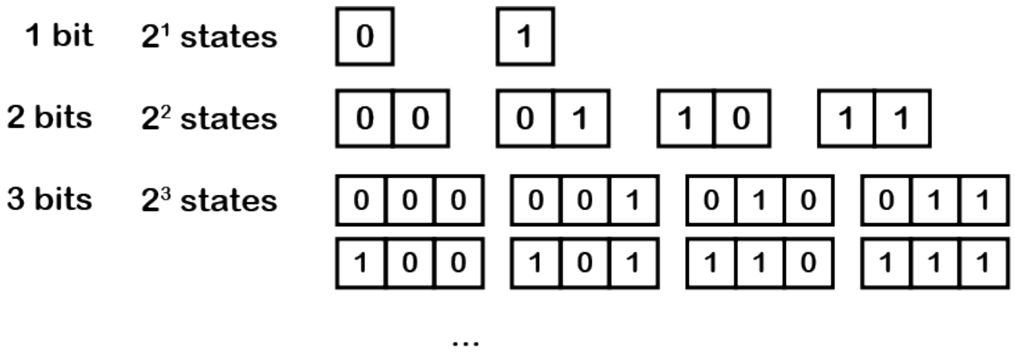
```
>>> int x;           (1)
>>> x = 121;         (2)
>>> int y = 34;      (3)
>>> int z = x * y;   (4)
```



2 Variables in Memory and Memory Organization

To understand how variables actually exist in memory, we need to understand how computer memory is organized.

Computer memory is made up of a whole bunch of units called **bits**. A bit can hold only one of 2 possible values: a *1* or a *0*. When we group bits together, we can store more values by encoding each value as a permutation of *1's* and *0's*. For example, when we have 2 bits, there are 4 possible permutations of *1's* and *0's*, so we can store 4 possible values; when there are 3 bits, there are 8 permutations, and so on and so forth.

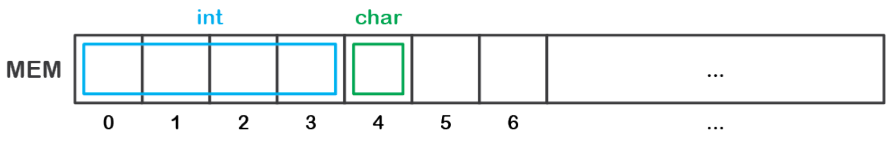


Question: How many possible values can n bits store?

For historical reasons, computer memory is chunked into 8-bit units called **bytes**, so when we organize memory, we organize it by bytes.

You can think of computer memory as a very long chain of contiguous bytes, each of which are numbered with an index. This index is called the **memory address**. Programs can use these addresses to access particular bytes of data in memory.

As already mentioned, when a variable is declared, the computer sets aside some amount of memory to contain it, and the amount is determined by the variable type. Variable types have fixed memory sizes that the computer will allocate, for instance, an `int` type variable is usually 4 bytes, while a `char` variable is 1 byte. If a variable is more than 1 byte, the bytes that the computer allocates must be contiguous.



Practice

How many total bytes of memory are being allocated in following lines of code? (assume `int`'s are 4 bytes and `long`'s are 8 bytes)

```
>>> int a = 0;
>>> int b = 17;
>>> a = a + b;
>>> char c;
>>> long long x;
>>> x = a + b;
>>> short y;
```

Typical Datatype Sizes

`char`	1 byte
`short`	2 bytes
`int`	2 or 4 bytes
`long`	4 or 8 bytes
`long long`	8 bytes