Pointers And Addressing

```
Module Code: ELEE1147

Module Name: Programming for Engineers

Credits: 15

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```

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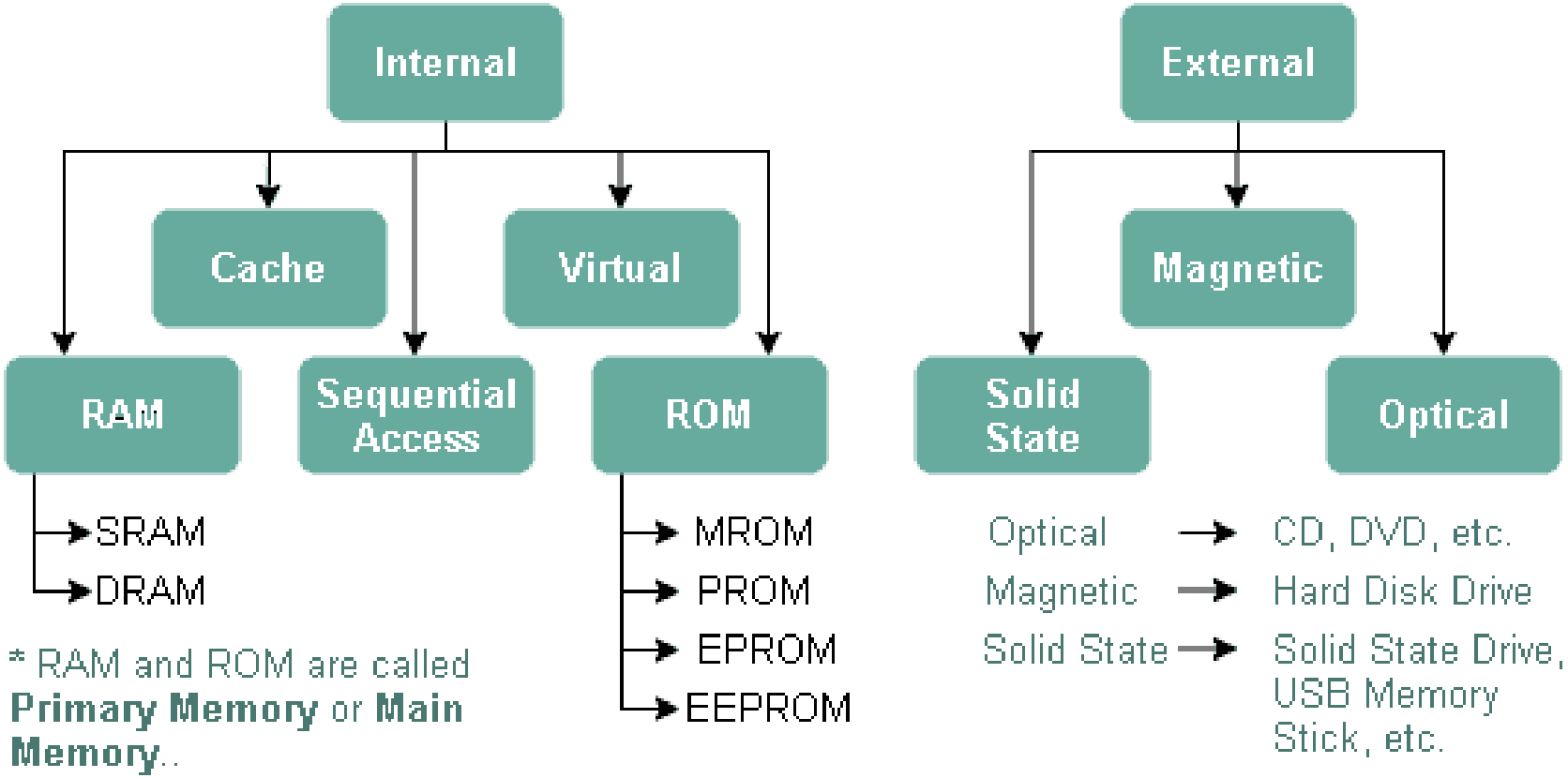
Memory

- Anything that stores information
- ▶ What are the Characteristics?

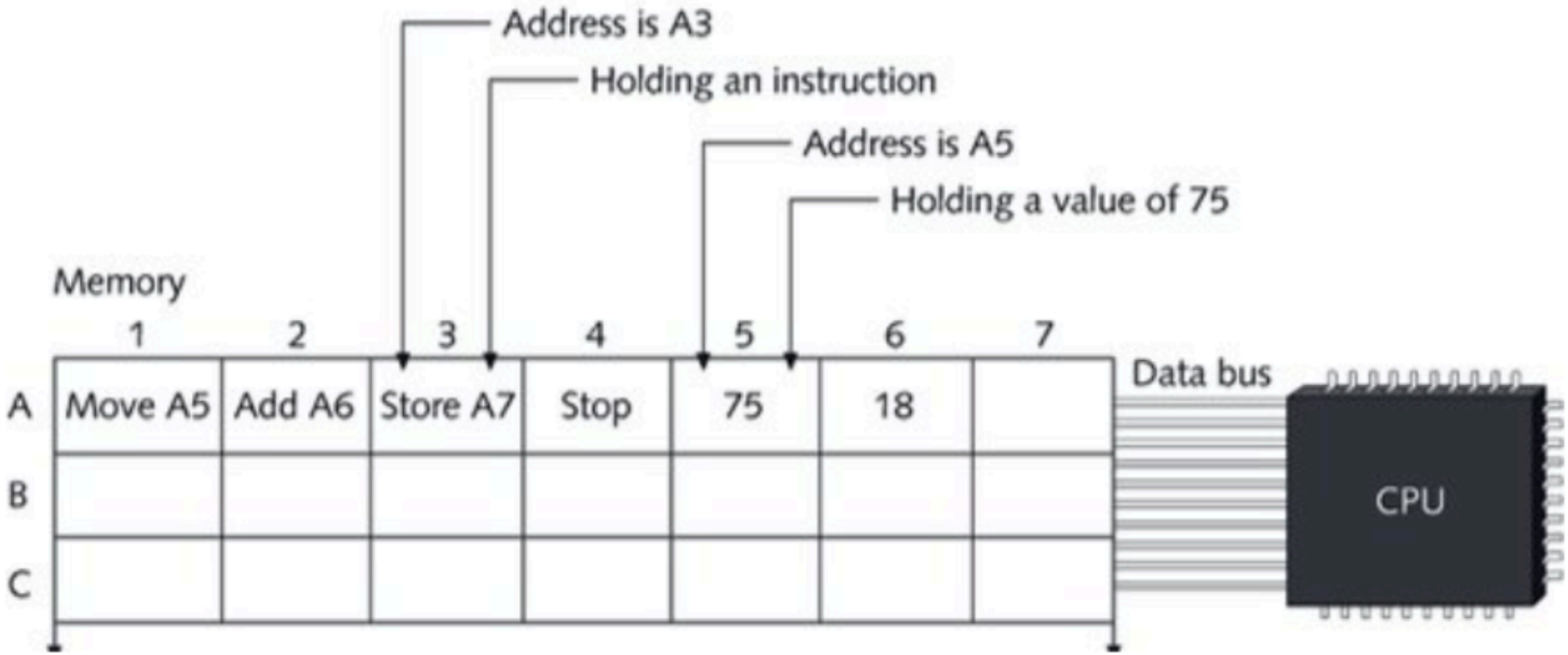
Types of Memory



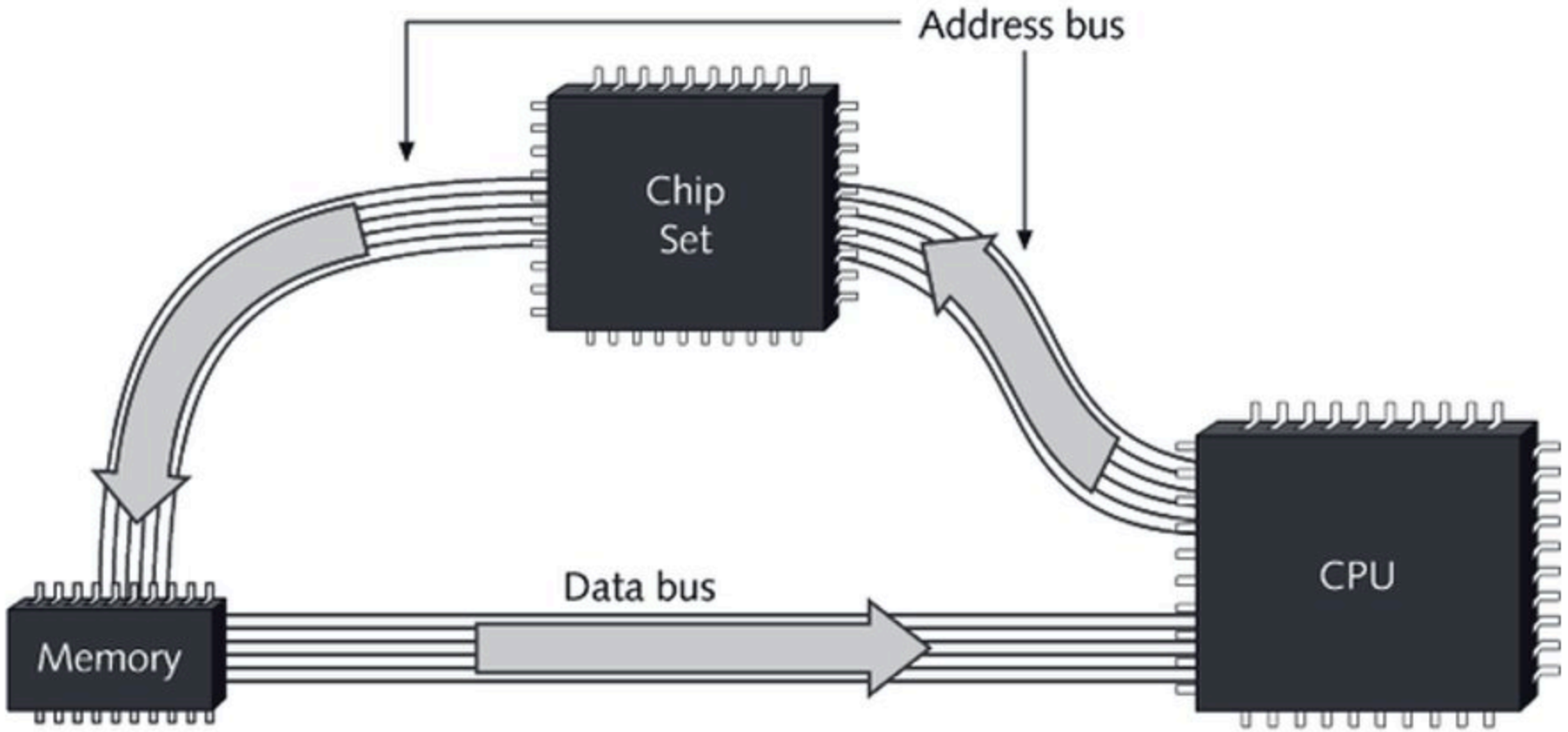
Static RAM, Dynamic RAM

Programmable read-only Memory

Memory Access



Data Flow

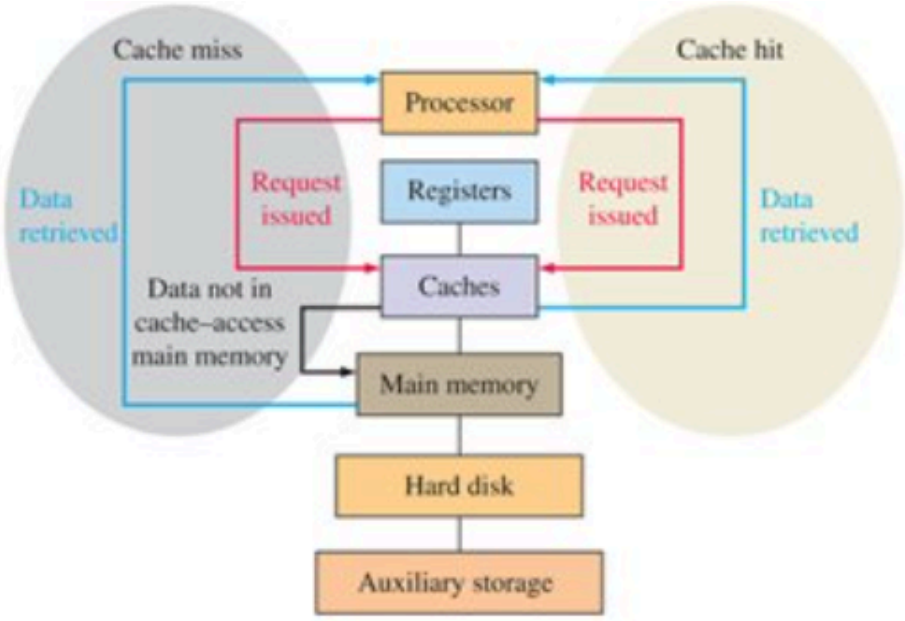


Cache Analogy

Your Brain=CPU

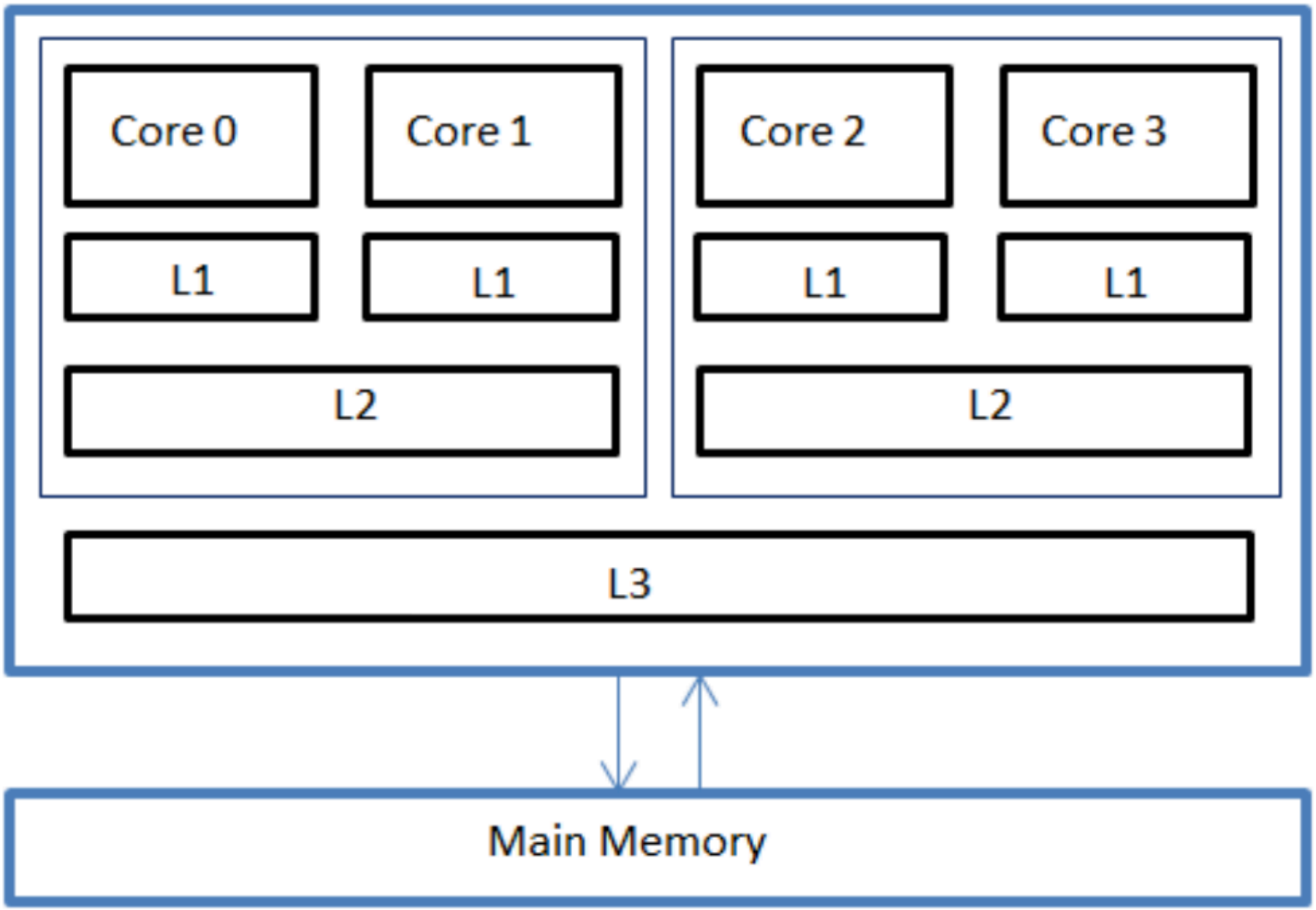
Refrigerator=Cach

Supermarket=RAM



Every time you (CPU) like to eat or drink (Access) something (Data) you first look into refrigerator (Cache), because it saves lot of time (Fast)!

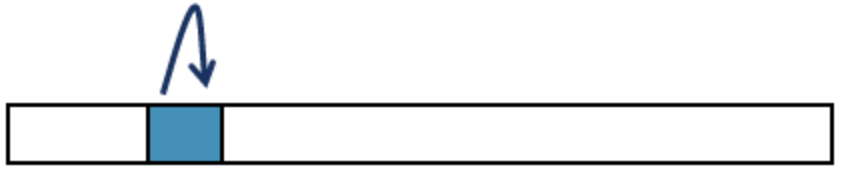
If the item (Data) is not there you have to spend extra time (Slow) to get it (Data) from the supermarket (RAM or main memory)


Core 0
Core 1
Core 2
Core 3
L1
L1
L1
L1
L2
L2
L3
Main Memory

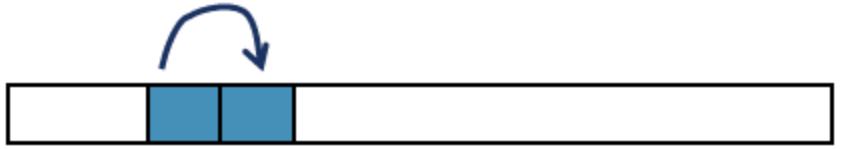
Principle of Locality

Programs tend to use data and instructions with addresses near or equal to those they have used recently

Temporal Locality: Recently referenced items are likely to be referenced again in the near future



Spatial Locality: Items with nearby addresses tend to be referenced close together in time



Locality Example

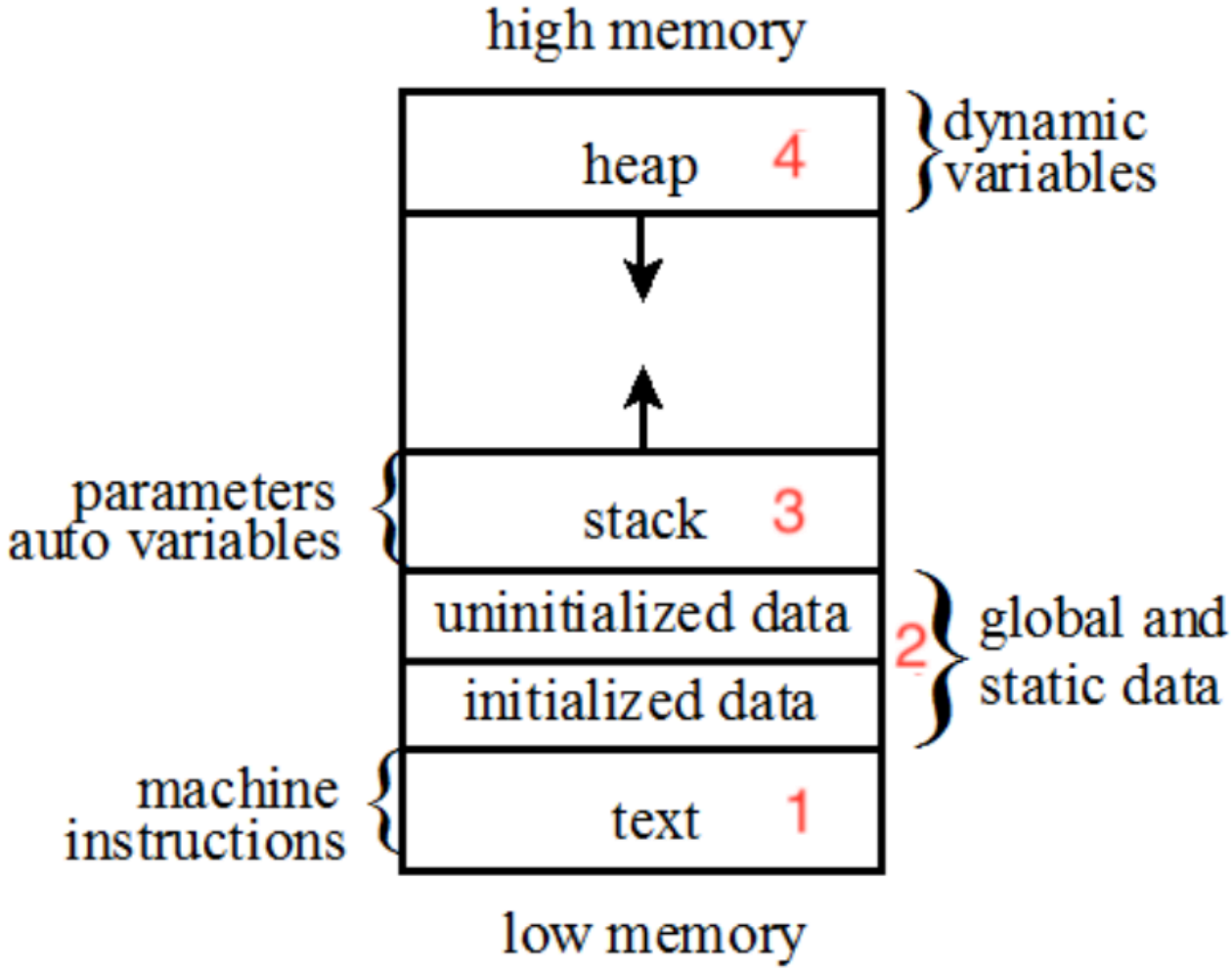
```
int sum = 0;
int a[5];
for ( int i = 0; i < n; i++ )
{
  sum += a[i];
}
```

- Data
  - Access array elements `a[i]` in succession – Spatial Locality
  - Reference `sum` each iteration – Temporal Locality
- Instructions
  - Reference instructions in sequence – Spatial Locality
  - Cycle through loop repeatedly - Temporal Locality

Stack and Heap

General Memory Layout

- **stack**: stores local variables
- **heap**: dynamic memory for programmer to allocate
- **data**: stores global variables, separated into initialized and uninitialized
- **text**: stores the code being executed



Available Address

By convention, we express these addresses in base 16 numbers:

- the smallest possible address is 0x00000000 (where the 0x means base 16),
- and the largest possible address could be 0xFFFFFFFF.

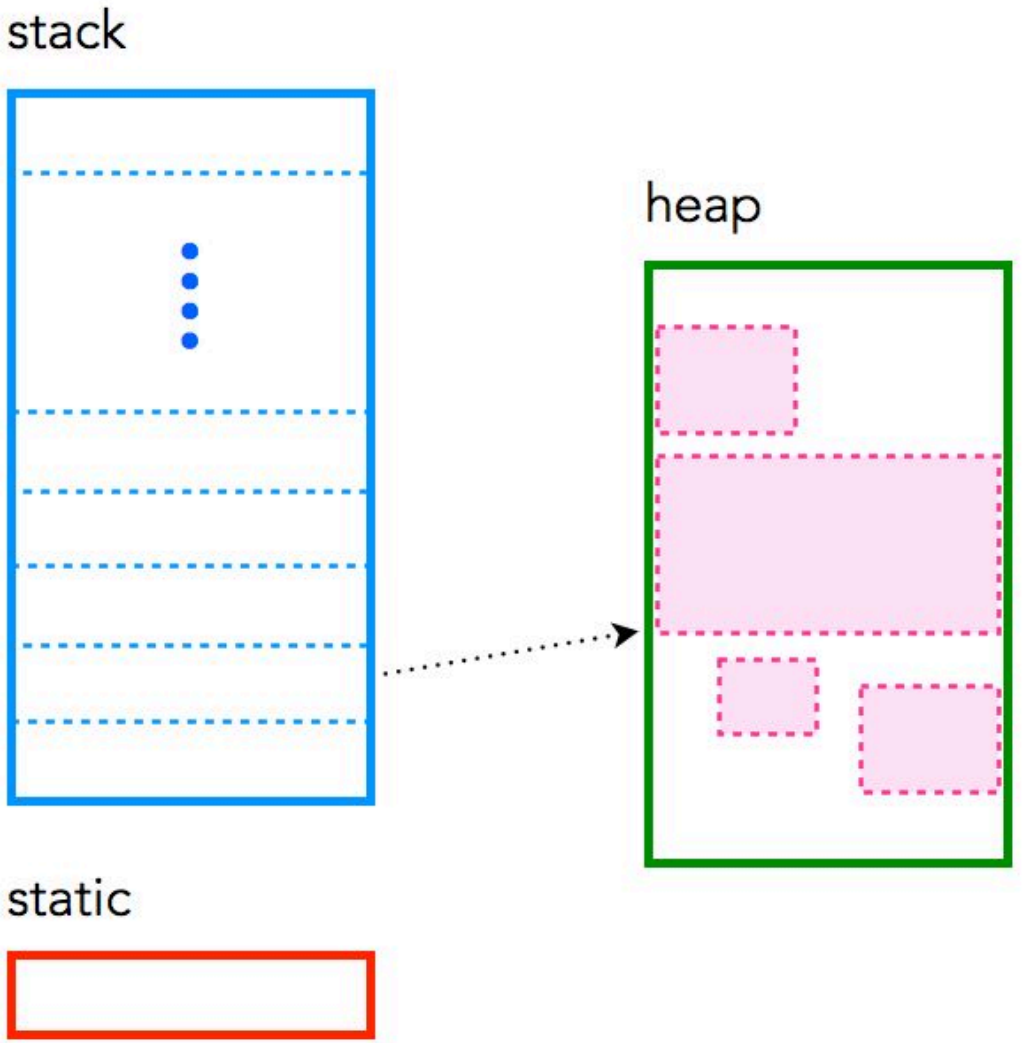
- Which is what in decimal?

Stack, Static and Heap

The great thing about C is that it is so intertwined with memory – and by that I mean that the programmer has quite a good understanding of “what goes where“. C has three different pools of memory.

- **static**: global variable storage, permanent for the entire run of the program.
- **stack**: local variable storage (automatic, continuous memory).
- **heap**: dynamic storage (large pool of memory, not allocated in contiguous order).

Stack, Static and Heap



Static

Static memory persists throughout the entire life of the program, and is usually used to store things like global variables, or variables created with the static clause. For example:

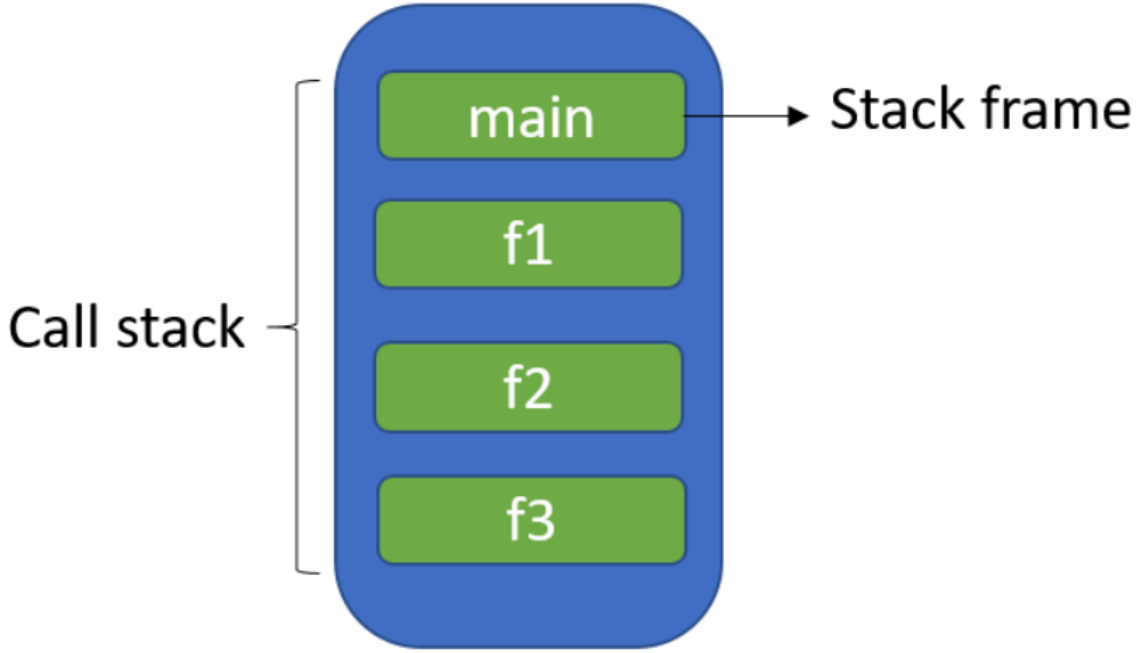
```
int somenumber = 5;
```

On many systems this variable uses 4 bytes of memory. This memory can come from one of two places. If a variable is declared outside of a function, it is considered global, meaning it is accessible anywhere in the program. Global variables are static,

```
static int somenumber = 5;
```

Stack

- The stack is managed by the CPU, there is no ability to modify it
- Variables are allocated and freed automatically
- The stack it not limitless – most have an upper bound
- The stack grows and shrinks as variables are created and destroyed
- Stack variables only exist whilst the function that created them exists



Stack

- It's a `LIFO`, "Last-In,-First-Out", structure. Every time a function declares a new variable it is "pushed" onto the stack.
- The stack is managed by the CPU, there is `no ability` to modify it
- Variables are allocated and freed `automatically`
- The stack it not limitless – most have an `upper bound`
- The stack `grows and shrinks` as variables are created and destroyed
- Stack variables only exist `whilst` the `function` that created them `exists`

Stack Overflow

A stack overflow `occurs if the call stack pointer exceeds the stack bound`. The call stack may consist of a limited amount of address space, often determined at the start of the program.

Heap

The heap is the diametrically `opposite of the stack`.

- The heap is `managed` by the `programmer`, the ability to modify it is somewhat boundless
- The heap is large, and is usually `limited` by the `physical memory` available in an embedded environment and in a PC it is stored within paging files on main memory (SSD)
- This is memory that is not automatically managed – you have to explicitly allocate (using functions such as `malloc()`, `calloc()`, `realloc()`), and deallocate (`free()`) the memory.
- The heap **requires pointers** to access it

```c
#include <stdio.h>
#include <stdlib.h>

int main(void)
{
    int y = 4; char *str;

    printf("stack memory: %d\n", y);

    str = malloc(100*sizeof(char));
    str[0] = 'm';
    for(int i =0; i< 100; i++)
    {
        printf("heap memory: %c\n", str[i]);
    }
    free(str);
    printf("heap memory: %c\n", str[0]);
    return 0;
}
```

Memory Allocation

a character, 1 byte of memory which is:

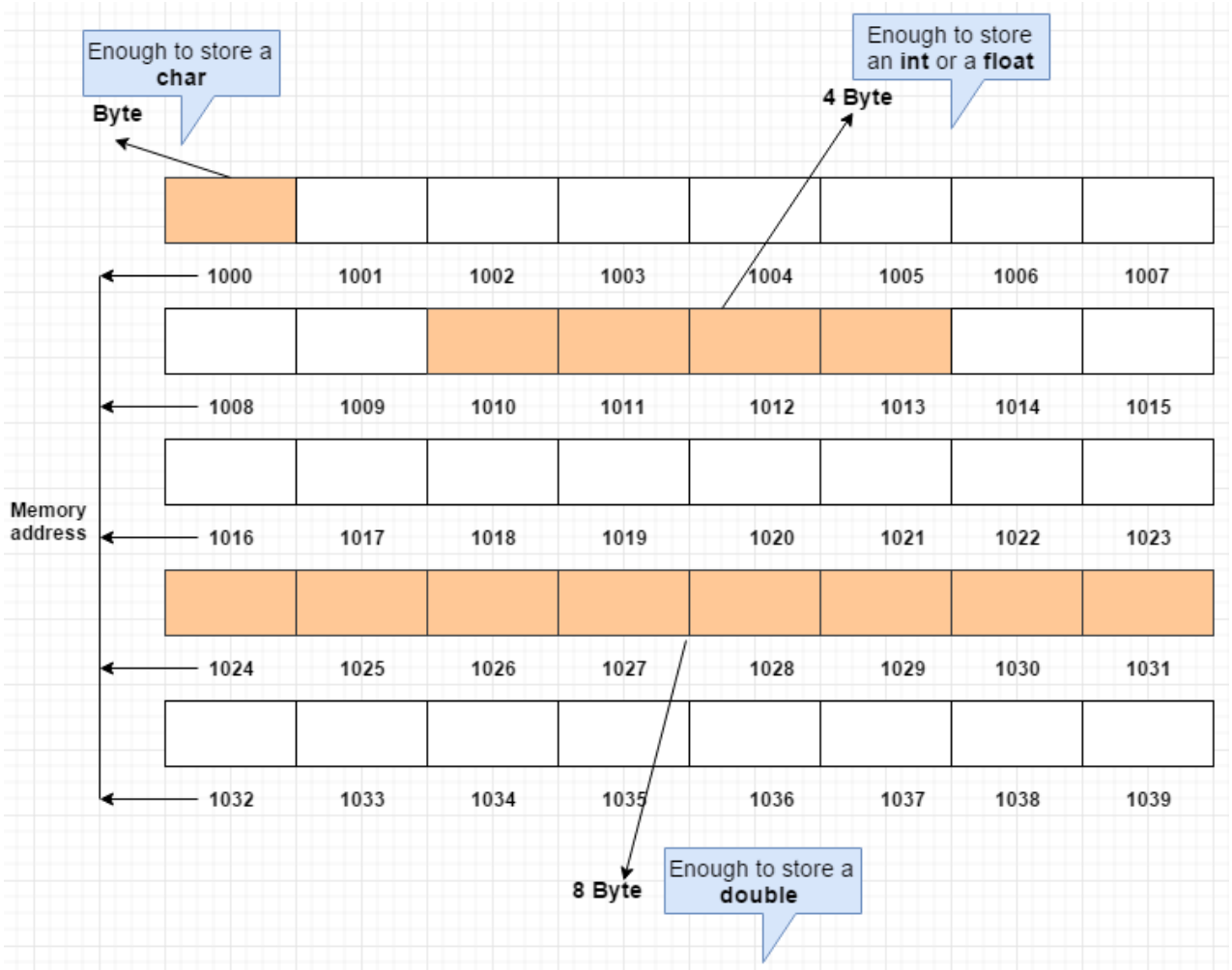
$$8\ bit = 1 * 8$$

an integer or a float, 4 byte of memory which is:

$$32\ bit = 4 * 8$$

a double value, 8 byte of memory which is :

$$64\ bit = 8 * 8$$



Memory Allocation: Pointers and Addresssing

- In C/C++/C# you can access a variables address using the `&` and `*` symbol.
- With ‘address of’ `&` we can reference the variable’s address when used with itself.

- A ‘pointer’ `*` is a variable that stores the address of another variable.
- Be warned, playing with unprotected memory is dangerous and can cause systems to crash and even become unrecoverable.

Memory Allocation: C

```c
int main ()
{ // The variable has its own address (unknown to us now)
  int n = 11;
  // this variable stores the address of the other variable
  int *ptrToN = n;
  printf("n's address: %d and %d ptrToN value \n", &n, ptrToN);
  printf("n's value: %d and ptrToN points to value %d \n", n, *ptrToN);
  return 0;
}
```

▶

Output to terminal:

Memory Allocation Array: C

```c
int main ()
{
  int n = 11, i;
  char ptr[11] = "hello world";

  for (i = 0; i < n; i++)
  {
    printf ("\t%p      ||   ptr[%d]    =    %c\n", &ptr[i],i,ptr[i]);
  }

  printf("\t%p      ||   ptr[]     =  %c \n", &ptr,*ptr);

  return 0;
}
```