Start at 4:05pm

Please scan the QR code for attendance

P1: Structure

What structure for ?

hold a collection of data items of different types.

```
int array[] = {1, 2, 3};

<type> mixed_arr = {1, 'x'};
```

General Usage

Syntax

```
struct [tag]
{
    member-declarations
} [identifier-list];
```

```
struct mixed
{
  int num;
  char letter;
};

// Usually we declare structure and init like this
// struct tag identifier-list;  do not forget `struct`
struct mixed mixed_arr = {1, 'x'};


// Also, we can declare structures right after the brackets and before the semicolon
struct mixed
{
  int num;
  char letter;
} mixed_arr, mixed_arr2;
// Demo 1_1


// Structure initialisation can be here as well
struct mixed
{
  int num;
  char letter;
} mixed_arr = {1, 'x'};
```

```
// If we only need one structure mix_arr and do not need declare more structures.
// We can ignore the tag
struct
{
  int num;
  char letter;
}mixed_arr;



// rename , simplify
struct mixed
{
  int num;
  char letter;
};


typedef struct mixed MIXED;

MIXED arr = {1, 'x'};
MIXED arr = { .letter = 'x', .num = 1};


// can be written like this as well
typedef struct mixed
{
  int num;
  char letter;
}MIXED;
```

How to access the field in structure ?

```
mixed_arr.number   // 1
mixed_arr.letter   // x
```

Pointer for structure

```
struct mixed mixed_arr = {1, 'x'};
struct mixed* ptr = &mixed_arr;



//Usually we use the arrow
ptr -> number
mixed_arr.number

// The same as follow ?
//
##############################################################
########################
*ptr.number  ?
//
##############################################################
########################

```

Answer:

```
// This will cause some error, why ??
// This operation equlas to *(ptr.number). First, offset. Then dereference


// access the field
(*ptr).number
```

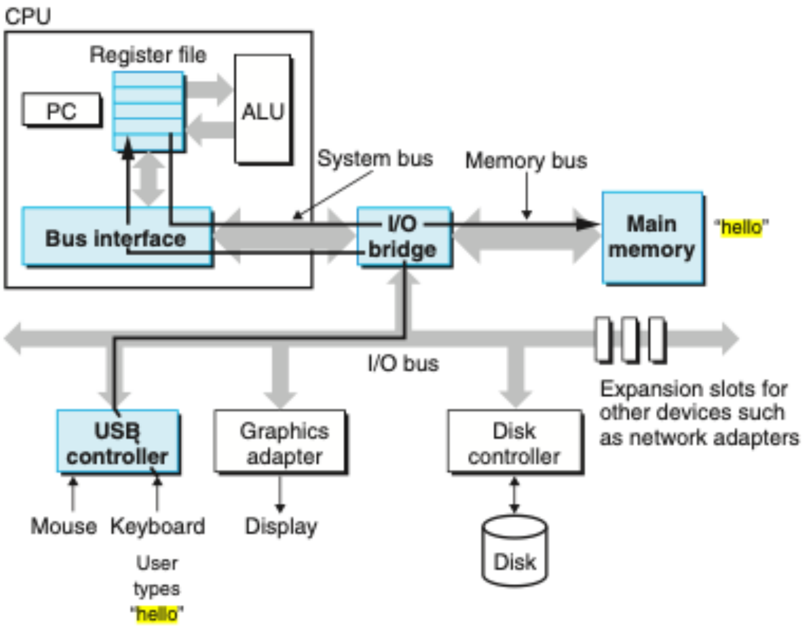
9.12 - 9.13

Memory & Alignment

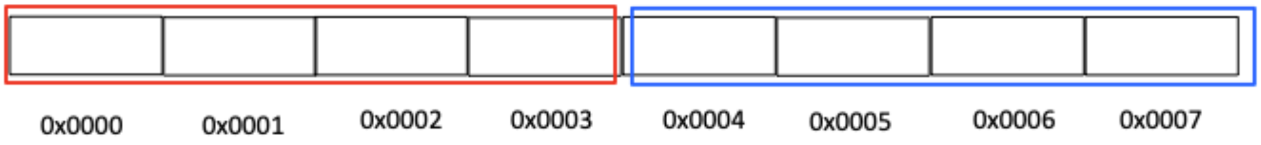
Alignment

How many bytes CPU can read at one time depends on the size of the bus to the main memory.

> - The **width** of the **databus** determines the **amount of data** transfered per **memory operation**



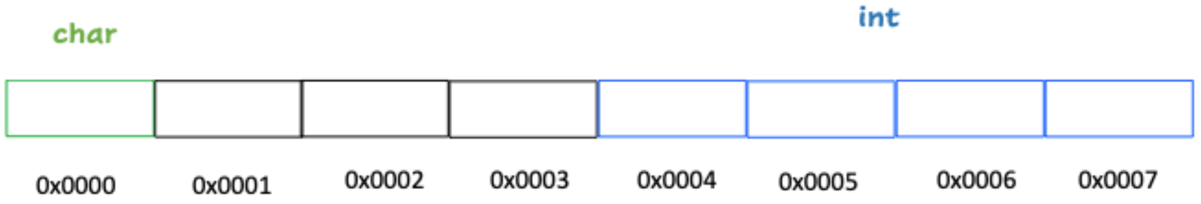
Assuming the CPU can only read 4 bytes at one time



```
struct st {
  char letter;
  int number;
};
```

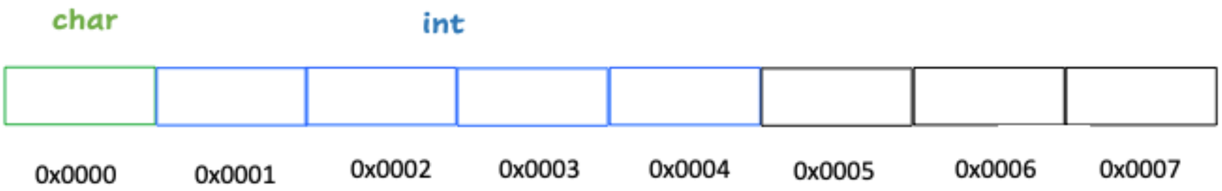
1. With Alignment

   Access `int`



2. Without Alignment

   CPU need read twice for the INTEGER. And need extra operations to concatenate the info of int



Order matters

```
struct st {
  // align by 4
  char letter; // |  1 byte letter|  1 byte c | two bytes for
padding |
  char c;
  int number;        // | 4 bytes|
};
```

```
struct st {
  char letter;     | 1byte for letter | 3 bytes for padding|
  int number;      | 4 bytes|
  char c;          | 1 byte| 3 padding|
};
```

- Which one has smaller size ?

> Padding content has no guarantee to be 0

> Alignment means a variable V has to be put at address divisible by sizeof(V).

Rules for struct

> http://www.catb.org/esr/structure-packing/ (The Lost Art of Structure Packing)
>
> specific principles

In general, a struct instance will have the alignment of its widest scalar member.

> aggregate types: structure, array

See previous two example

- Another example

```
// in 64-bit OS pointer:  8 bytes
struct foo5 {
    char c;

    struct foo5_inner {
        char *p;
        short x;
        char pad2[6];
    } inner;
};
```

9.16

For 3 minutes

9.20

Answer

```
struct foo5 {
    char c;           /* 1 byte + (7) padding */

    struct foo5_inner {
        char *p;      /* 8 bytes */    // align by the largest scalar member 8
        short x;      /* 2 bytes */
        char pad2[6]; /* 6 bytes */
    } inner;
};

/*
  The char *p member in the inner struct forces the outer struct to be pointer-aligned as well as the inner.
*/
```

9.21

P2: Union

The difference between a structure and a union is: each member of the structure occupies different memory and has no influence on each other; while all members of the union occupy the same memory, modifying one member will affect all other members.

So the memory occupied by the union should be enough to store the largest member of the union. (+ padding as well)

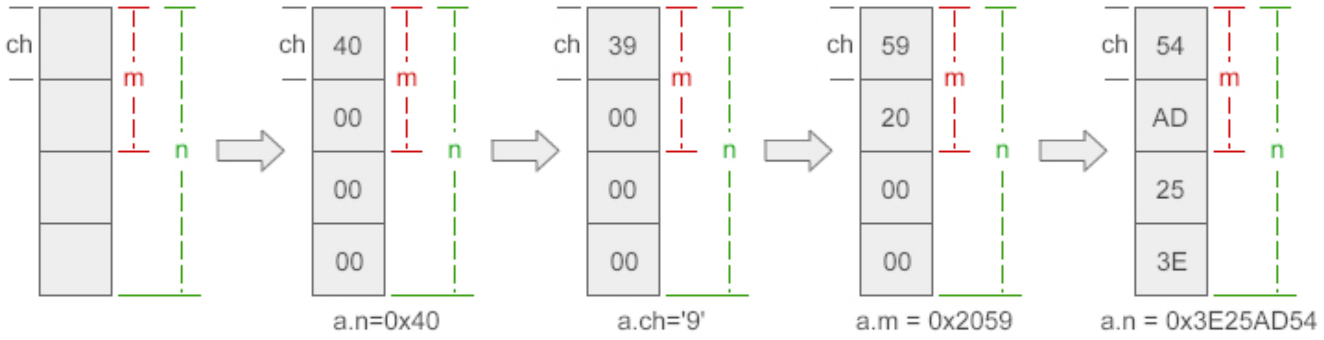
```c
#include <stdio.h>

union data{
    int n; // 4
    char ch;  // 1
    short m; // 2
};

int main(){
    union data a;
    printf("%zu, %zu\n", sizeof(a), sizeof(union data) );
    a.n = 0x40;
    printf("%X, %c, %hX\n", a.n, a.ch, a.m);
    a.ch = '9';
    printf("%X, %c, %hX\n", a.n, a.ch, a.m);
    a.m = 0x2059;
    printf("%X, %c, %hX\n", a.n, a.ch, a.m);
    a.n = 0x3E25AD54;
    printf("%X, %c, %hX\n", a.n, a.ch, a.m);
    return 0;
}

/*
  "%X": Unsigned hexadecimal integer (uppercase)
  "%hX" h is length "short"
  0x40 = 64 decimal => check ASCII @
  '9' ASCII  39

*/
```



```
4, 4
40, @, 40
39, 9, 39
2059, Y, 2059
3E25AD54, T, AD54
```

> Tutorial/Week4/Q1, Q2, Q3

Q3 10min Give structure.

```
struct customer{
  char name[100];
  char object[100];
  int age;
}
```

Back at 4: 57

9: 55   + 5 code

5 minutes break

10:05

P3: Bitfield

1 byte = 8 bits

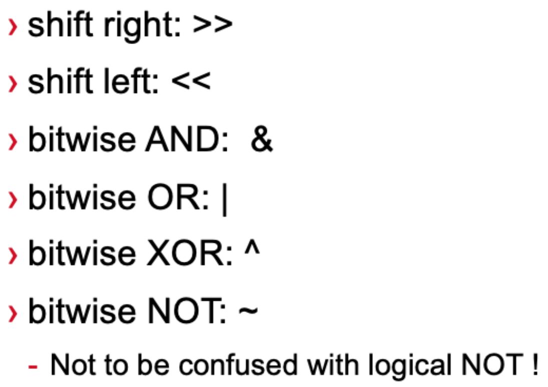
Specify a size, in bits, for elements of a structure

```
struct bs{
    unsigned m;
    unsigned n: 4; // maximum 1111 = 15
    unsigned char ch: 6; // max 111111 = 63
};

// unsigned int  == unsigned
// Sometimes it will overflow

// The C language standard stipulates that the width of a bit field cannot exceed the length of the data type to which it is attached
```

Some basic operations



- shift right: >>
- shift left: <<
- bitwise AND: &
- bitwise OR: |
- bitwise XOR: ^
- bitwise NOT: ~
  - Not to be confused with logical NOT !

Memory

Case 1: When adjacent members are of the same type

Treat the size of original type as a unit

If member1 + member2 > size of original type => member2 will be stored in other unit.

If member1 + member2 < size of original type => m1, m2 are stored side by side

```
#include <stdio.h>
int main(){
    struct bs{
        unsigned m: 6;    // store in 4bytes
        unsigned n: 30;   // store in another 4 bytes
        unsigned p: 4;
    };
    printf("%zu\n", sizeof(struct bs));
    return 0;
}

/*
  m, n, p are unsigned int => 4 bytes = 32 bits
  6 + 12 + 4 < 32. they will be stored side by side.

  if n:30.
  6 + 30 > 32.  n will be stored in another 32 bits.

*/
```

```
#include <stdio.h>
int main(){
    struct bs{
        unsigned m: 6;
        unsigned n: 30;
        unsigned p: 4;

      // 6 + 30 + 4 = 40 bits
    };
    printf("%zu\n", sizeof(struct bs));
    return 0;
  // 12 bytes .... not good
}
```

Case 2: When the types of adjacent members are different, different compilers have different implementation schemes, GCC will compress storage, but VC/VS will not

Case 3:If non-bit field members are interspersed between members, no compression will be performed

```
#include <stdio.h>
int main(){
    struct bs{
        unsigned m: 12;
        unsigned ch;
        unsigned p: 4;
    };

    printf("%zu\n", sizeof(struct bs));
    return 0;
  // 12 bytes .... not good
}
```

(Last year, there an extension for one assignment...)

P4: Files in C

> ### 11.1.1 Streams and File Descriptors
>
> When you want to do input or output to a file, you have a choice of two basic mechanisms for representing the connection between your program and the file: file descriptors and streams. File descriptors are represented as objects of type `int`, while streams are represented as `FILE *` objects.

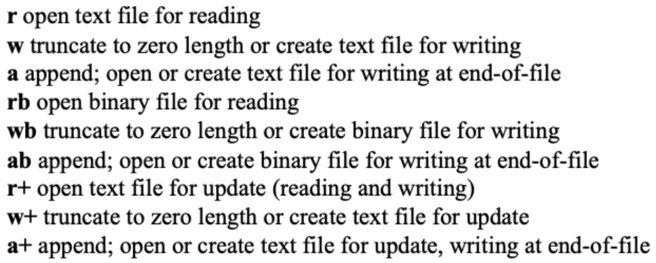
> File descriptors provide a primitive, low-level interface to input and output operations. Both file descriptors and streams can represent a connection to a device (such as a terminal), or a pipe or socket for communicating with another process, as well as a normal file. [...]

- How to operate file (Regular file)?
  - Open the file

    At this stage, get information about the file, such as file name, file status, current reading and writing position, etc., which will be saved in a **FILE type structure variable**

    ```
    // file function defined in <stdio.h>
    FILE *fopen(const char *path, const char *mode);
    ```

    ```
    FILE* myfile = fopen(“turtles.txt”, “w”); // "w" is the mode
    ```

    r open text file for reading
    w truncate to zero length or create text file for writing
    a append; open or create text file for writing at end-of-file
    rb open binary file for reading
    wb truncate to zero length or create binary file for writing
    ab append; open or create binary file for writing at end-of-file
    r+ open text file for update (reading and writing)
    w+ truncate to zero length or create text file for update
    a+ append; open or create text file for update, writing at end-of-file

    - Devices are often represented as files

      the keyboard is called the standard input file, scanf reads data from this file

      the monitor usually called the standard output file, and printf outputs data to this file

      ```
      fscanf(stdin, …) same as scanf(…)
      fprintf(stdout, …) same as printf(…)
      ```

    - Do some operations
        - Read/write file
    - Close the file

      Free the structure variable, and prohibit operations on the file at the same time

- To operate other files represents devices ---> `open` to get file descriptor (`open` is for Linux, not other systems)

> Q4 Together 5 min

Back at 5:18

Buffer

Buffer is **an area of memory used to temporarily store data** while it's being moved from one place to another.

Why buffer ?

Assuming you have some rubbish at home, do you directly throw it into the garbage room ?

Definitely not, you just throw it in your home rubbish bin until it's full. Then you throw all things to the garbage room.

Buffer is similar with "the home rubbish bin".

Buffer mechanism

- **No buffering**: When you write characters to an unbuffered stream, the operating system writes them to the file as soon as possible.
  - `stderr`

- **Full buffering:** When you write characters to a fully-buffered stream, the operating system writes them to the file in blocks of arbitrary size.

- **Line buffering**: When you write characters to a line-buffered stream, the operating system writes them to the file when it encounters a newline character.
  - `stdin/stdout`

When do we flush the buffer to do the real IO ?

- The buffer is full
- Execute `fflush`
- Close file

Example

> Demo

10: 20

> Week4/Q6, Q8, Q9, Q10

Q6

Back AT 5: 45

A special demo:

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

struct flexi_example
{
  int data;
  char arr[];
};

int main(){
    //  struct size is usually known at compile time
    printf("%zu\n", sizeof(struct flexi_example)); // 4

    struct flexi_example *obj;
    // achieve VLA
    obj = malloc(sizeof (struct flexi_example) + 5);
    free(obj);
}
```