Function Pointers

FUNCTION POINTERS

- Sometimes we would like to choose different behaviors at different times in the same piece of code or function.
- For instance in a sorting routine, we want to allow the function's caller to choose the order in which the data is sorted
- We can use some functions as arguments to other functions through the function pointers.
- extern int f(); // f by itself is a pointer to a function. But it is illegal to assign a value to f (similar to int ar[5]; => ar is also a pointer, but it cannot be on the left-side of an assignment)
- Definition:
  - int **(*pf)**(); // pf is a pointer to a function returning an int.

Define and assign a value to a function pointer

- Definition:
  - **int (*pf)();** // pf is a pointer to a function returning an int.
  - The () around *pf are necessary for correct grouping. Without them: int *pf(); // this would be a function returning an int pointer
- Assigning value:
  - {
  -   extern int f1();
  -   int (*pf) (); // pf is a pointer to a function returning an int.
  -   pf=f1; // assign the address of f1 to pf
  -   pf=f1(); // ILLEGAL, f1 returns an int, but pf is a pointer
  -   pf=&f1(); //ILLEGAL, cannot take the address of a function result
  -   pf=&f1; // ILLEGAL, &f1 is a pointer to a pointer, but pf is a pointer to an int
  - }

Return type argument

```
extern int if1(), if2(), (*pif)();
extern float ff1(), (*pff)();
extern char cf1(), (*pcf)();

main()
{
  pif = if1; /* Legal -- types match */
  pif = cf1; /* ILLEGAL -- type mismatch */
  pff = if2; /* ILLEGAL -- type mismatch */
  pcf = cf1; /* Legal -- types match */
  if1 = if2; /* ILLEGAL -- Assign to a constant */
}
```

Calling a function using pointers

- Use the same syntax we use to declare the function pointer, include possible arguments. E.g.:
  - {
  - extern int f1();
  - int (*pf) ();
  - int answer;
  - pf=f1;
  - answer=(*pf)(a); // calls f1() with argument a => f1(a)
  - …
  - }

Example (check the whole code that was shown in the class)

- We would like to either add the values of all integers between x and y and return the sum; or want to add square of each integer between x and y.
- We will have one function to cumulatively sum the numbers.
- This function will take a pointer as one of its arguments. So that, user can decide if she wants to use find sum(i) or sum(i^2):

```
/*   Function returns the argument a. */
int self_i(int a)
{
            return a;
}
/*   Function returns the square of a. */
int square_i(int a)
{
            return a * a;
}
/*   Function sums values of *fp applied to
integers from x to y. */
int sum_generic(int (*fp)(), int x, int y)
{
            int i, cumsum = 0;
            for (i = x; i <= y; i++)
                        cumsum += (*fp)(i);
            return cumsum;
}
```

Structures & unions

Outline

- Structures
- Initialization
- Alignment of structure members
- Nested structures
- Bit fields
- Unions

Structures

- A structure is like an array except that each element can have a different data type. Moreover, elements in a structure have names instead of subscript values.

- Without structures, a single person's record would be declared as:

```
char name[20], tcno[11];
short day, month, year;
```

```
strcpy(name, "John Smith");
strcpy(tcno, "01322222654");
day=26;
month=11;
year=1957;
```

- What about multiple people's records?

```
char name[1000][20], tcno[1000][11];
short day[1000], month[1000], year[1000];
```

- Three ways to define a structure
  - using a TAG name
  - without a TAG name
  - using a typedef name

```
structure personalstat{
   char ps_name[20], ps_tcno[11];
   short ps_day, ps_month, ps_year;
};
// *Declare a variable from above template
struct personalstat ps;
struct personalstat psarr[1000], *ptrps;
ptrps=&psarr[10]; // e.g. use of pointers
```
1

```
// Define the template and var. together WITHOUT a tag name:
struct {
   char ps_name[20], ps_tcno[11];
   short ps_day, ps_month, ps_year;
} ps;
```
2

```
// Define the template and var. together WITH a tag name:
struct personalstat{
   char ps_name[20], ps_tcno[11];
   short ps_day, ps_month, ps_year;
} ps, psarr[1000], *ptrps;
```
1

```
typedef struct {
   char ps_name[20], ps_tcno[11];
   short ps_day, ps_month, ps_year;
} PERSONALSTAT;
// *Declare a variable from above template
PERSONALSTAT ps;
```
3

Initialization

```
PERSONALSTAT ps = { "George Smith", "002340671",
                    3, 5, 1946 };
```

```
PERSONALSTAT psarr[] = { {},
                         {}
};
```

```
typedef struct
{
    int a;
    float b;
} s = { 1, 1.0 };  /* Initializer is not allowed
                    * in a typedef
                    */
```

Referencing structure members & Arrays

- ps.ps_day=15;
- ps.ps_month=3;
- ps.ps_year=1987;

- If *ptrps is a pointer:
  - (*ptrps).ps_day
  - ptrps ->ps_day

- Array of structures is declared with structure's typedef name and array name:
- PERSONALSTAT psarr[10];

Array of Structures vs Pointer of Structures - I

```
#include "pstat.h" // contains declaration of
                         PERSONALSTAT typedef
//count the number of people in a certain age group
int agecount(PERSONALSTAT psarr[], int size, int
low_age, int high_age, int current_year){
    int i, age, count=0;
    for(i=0; i<size; i++){
        age=current_year - psarr[i].ps_year;
        if(age>=low_age && age<=high_age)
            count++;
    }
    return count;
}
```

```
#include "pstat.h" // contains declaration of
                         PERSONALSTAT typedef
//count the number of people in a certain age group
int agecount(PERSONALSTAT psarr[], int size, int
low_age, int high_age, int current_year){
    int i, age, count=0;
    for(i=0; i<size; ++psarr, i++){
        age=current_year - psarr->ps_year;
        if(age>=low_age && age<=high_age)
            count++;
    }
    return count;
}
```

Array of Structures vs Pointer of Structures-2

```
#include "pstat.h" // contains declaration of
                        PERSONALSTAT typedef
//count the number of people in a certain age group
int agecount(PERSONALSTAT psarr[], int size, int
low_age, int high_age, int current_year){
    int i, age, count=0;

    for(i=0; i<size; ++psarr, i++){
        age=current_year - psarr->ps_year;
        if(age>=low_age && age<=high_age)
            count++;
    }
    return count;
}
```

```
#include "pstat.h" // contains declaration of
                        PERSONALSTAT typedef
//count the number of people in a certain age group
int agecount(PERSONALSTAT psarr[], int size, int
low_age, int high_age, int current_year){
    int age, count=0;
    PERSONALSTAT *p=psarr, *plast=&psarr[size]
    for( ; p<plast; ++p){
        age=current_year - p->ps_year;
        if(age>=low_age && age<=high_age)
            count++;
    }
    return count;
}
```

Nested structures

```
typedef struct {
    char day;
    char month;
    short year;
} DATE;

typedef struct {
    char ps_name[20], ps_tcno[11];
    DATE ps_birth_date;
} PERSONALSTAT;

// *Declare an array from above definition:
PERSONALSTAT psarr[1000];
psarr[j].ps_birth_date.day=25;
```

- You are permitted to declare pointers to structures that have not yet been declared.
- This feature enables you to create self-referential structures and also to create mutually referential structures:

struct s1{
int a;
struct s2 *b;
};
	struct s2{
	int a;
	struct s1 *b;
	};

- This is known as forward referencing, is one of the few instances in C where you may use an identifier before it has been declared.
- Note that forward references are not permitted within typedefs. The following produces a syntax error:

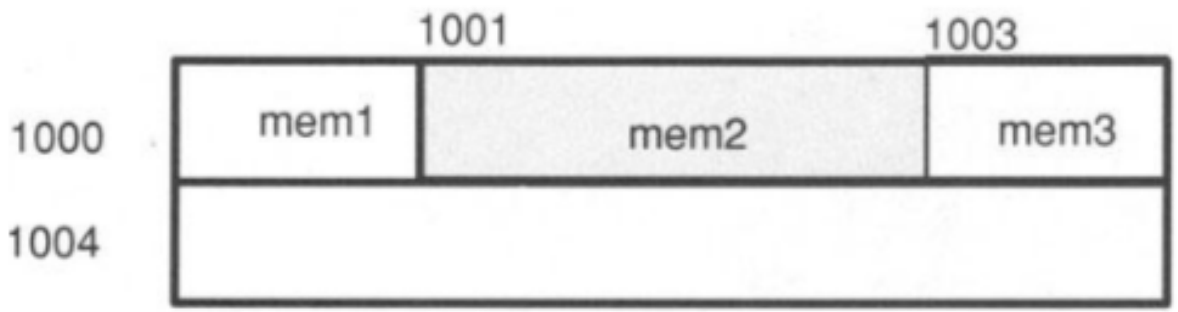
```
typedef struct {
    int a;
    FOO *ptr; // ERROR: FOO is not yet declared
} FOO;
```

Alignment of structure members

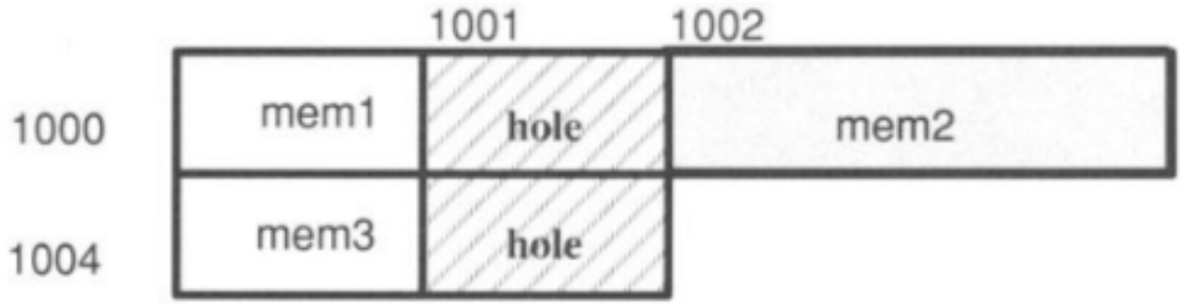
- Some computers require that any data object larger than a char must be assigned an address that is a multiple of a power of 2 (all objects > than a char be stored at even addresses.
- Normally, these alignment restrictions are invisible to the programmer. However, they can create holes, or gaps, in structures.
- Consider how a compiler would allocate memory for the following structure:

```
structure ALIGN_EXAMP{
    char mem1;
    short mem2;
    char mem3;
} s1;
```

If the computer has no alignment restrictions, s1 would be stored as:



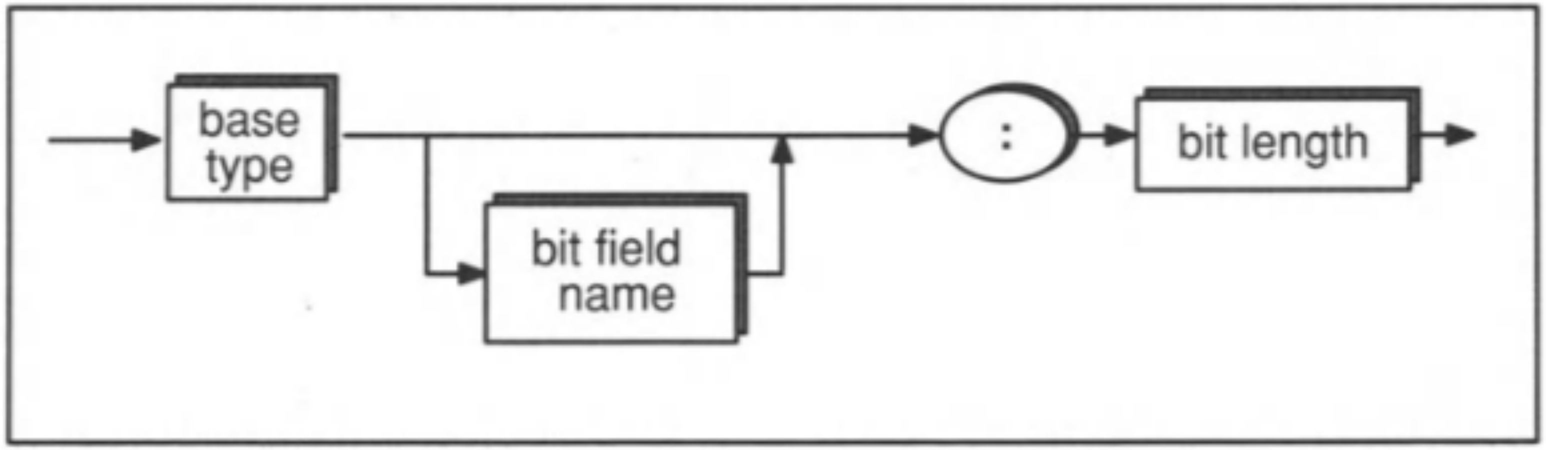
If the computer requires objects > a char to be stored at even addresses, s1 would be stored as:



*This storage arrangement results in a 1-byte hole between mem1 and mem2 and following mem3.

Bit fields

- The smallest data type that C supports is char(8 bits)
- But in structures, it is possible to declare a smaller object called a *bitfield*.
- Bit fields behave like other int variables, except that:
  - You cannot take the address of a bit field and
  - You cannot declare an array of bit fields.
- Syntax:



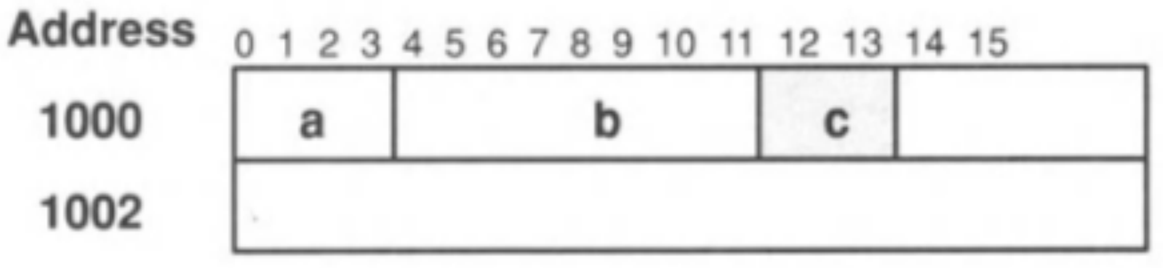
- The base type may be **int, unsigned int**, or **signed int**.
- If the bit field is declared as int, the implementation is free to decide whether it is an unsigned int or a signed int (**For portable code, use the signed or unsigned qualifier**).
- The *bit length* is an integer constant expression that may not exceed the length of an int.
- On machines where ints are 16 bits long, e.g. the following is illegal: int too_long: 17;

Bit fields -2

- Assuming your compiler allocates 16-bits for a bit field, the following declarations would cause *a, b,* and *c* to be packed into a single 16-bit object

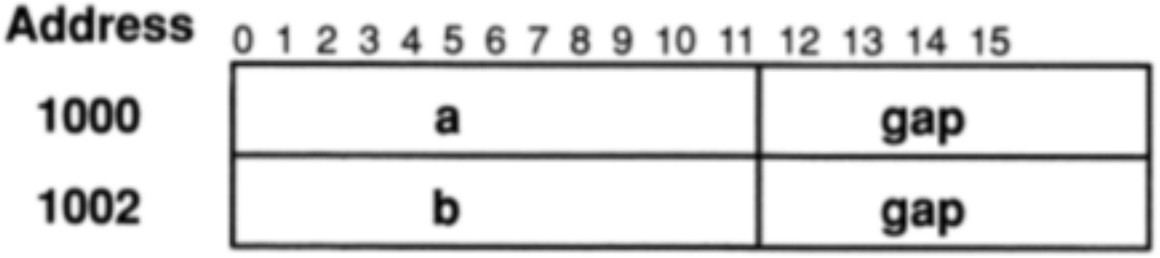
```
struct
{
   int a : 3;
   int b : 7;
   int c : 2;
} s;
```

Each implementation is free to arrange the bit fields within the object in either increasing or decreasing order



- If a bit field would located in an **int** boundary, a new memory area may be allocated, depending on your compiler. For instance, the declaration might cause a new 16-bit area of memory to be allocated for *b:*

```
struct
{
   int a : 10;
   int b : 10;
} s;
```



Bit fields -3

- Consider *DATE* structure example:

```
struct DATE{
   unsigned int day : 5;
   unsigned int month : 4;
    unsigned int year : 11;
};
```

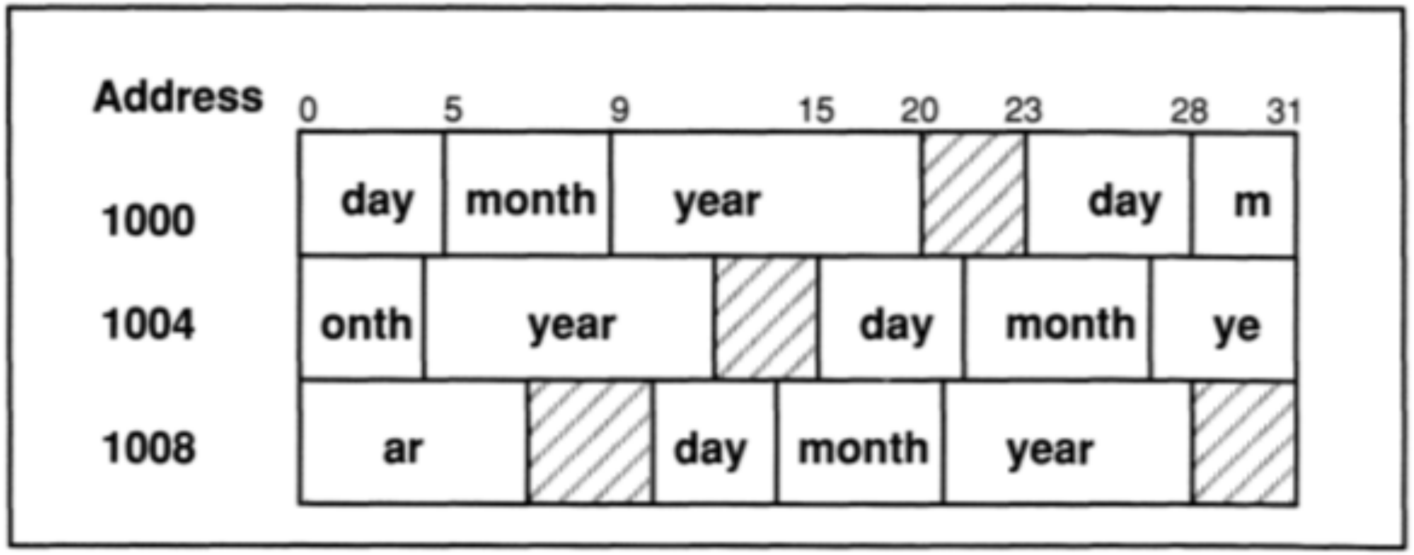
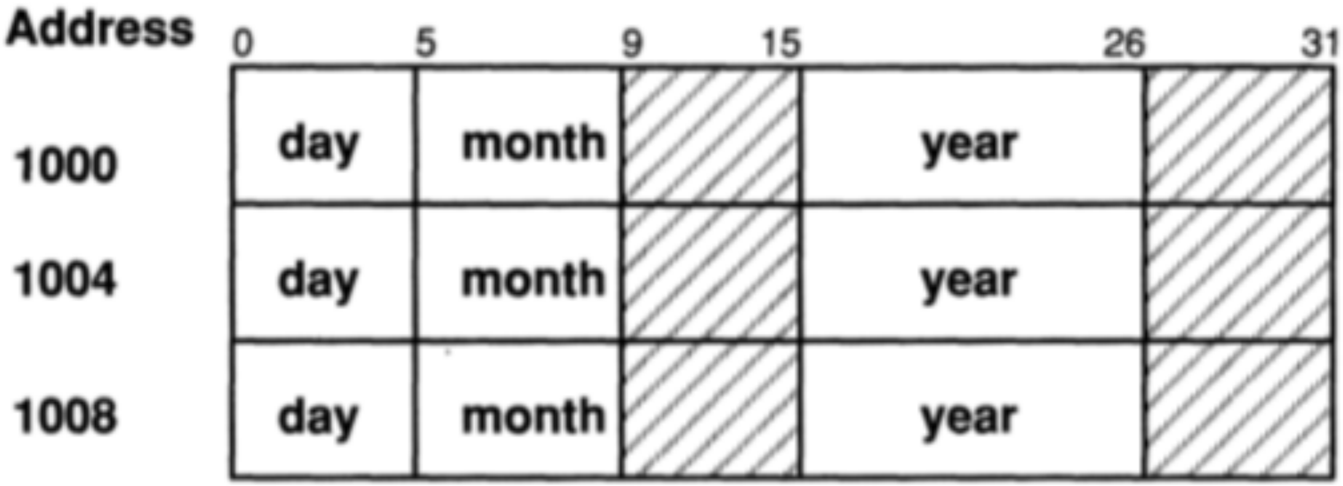


Figure 8-8. Storage of the DATE *Structure with Bit Fields. This figure assumes that the compiler packs bit fields to the nearest* **char** *and allows fields to span* **int** *boundaries.*



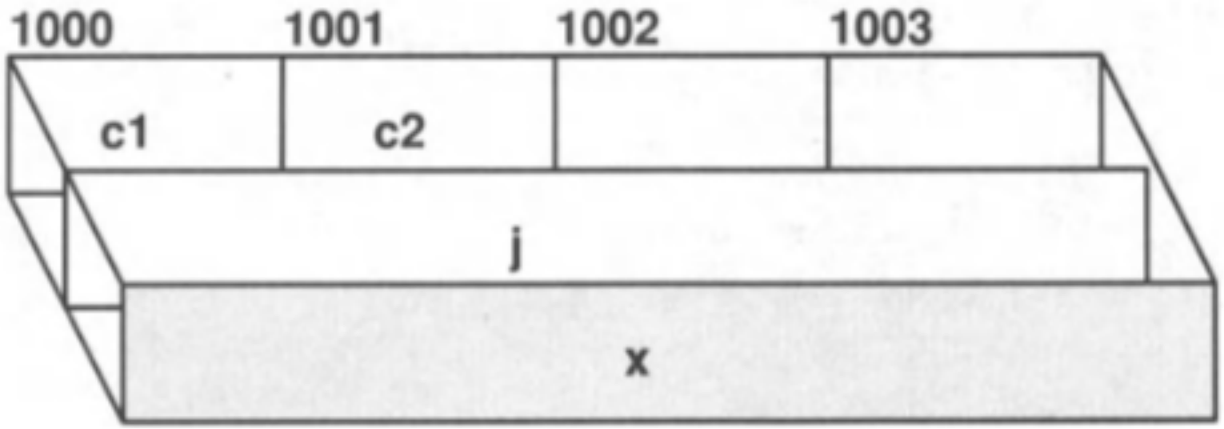
Alternative Storage of the DATE Structure with Bit Fields. This figure assumes that the compiler packs bit fields to the nearest **short** and **does not allow fields to span int boundaries**.

Unions

- Unions are similar to structures except that the members are overlaid one on top of another, so members share the same memory.
- There are two basic applications for unions:
  - Interpreting the same memory in different ways.
  - Creating flexible structures that can hold different types of data.
- Example:

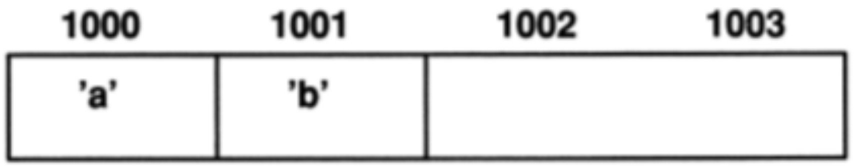
```
typedef union
{
   struct
   {
      char c1, c2;
   } s;
   long j;
   float x;
} U;

U example;
```



- Usage:

```
example.s.c1 = 'a';
example.s.c2 = 'b';
```



* If you make the assignment:
example.j = 5; // it overwrites the 2 chars, using all 4 bytes to store value 5.

linked list – next week