Chapter 16

Structures, Unions, and Enumerations

Structure Variables

- The properties of a ***structure*** are different from those of an array.
  - The elements of a structure (its ***members***) aren't required to have the same type.
  - The members of a structure have names; to select a particular member, we specify its name, not its position.
- In some languages, structures are called ***records,*** and members are known as ***fields.***

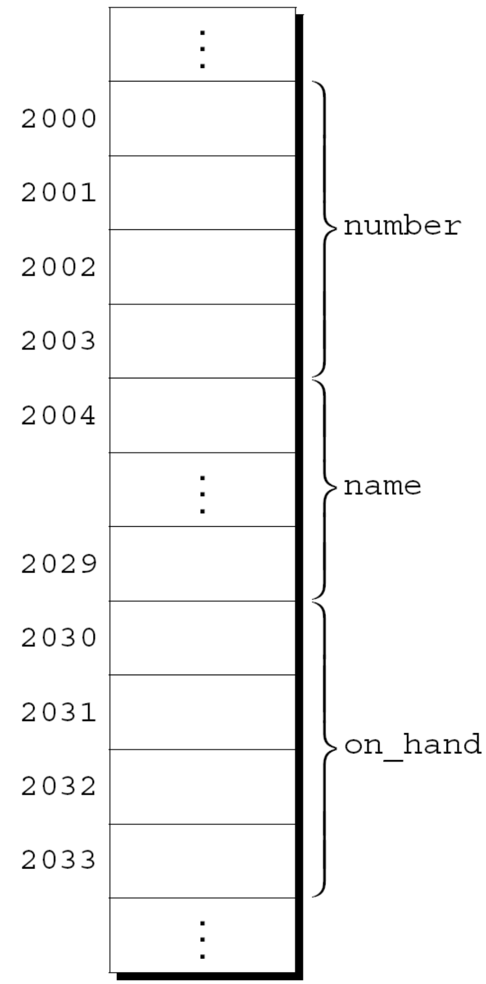
Declaring Structure Variables

- A structure is a logical choice for storing a collection of related data items.
- A declaration of two structure variables that store information about parts in a warehouse:

```
struct {
  int number;
  char name[NAME_LEN+1];
  int on_hand;
} part1, part2;
```

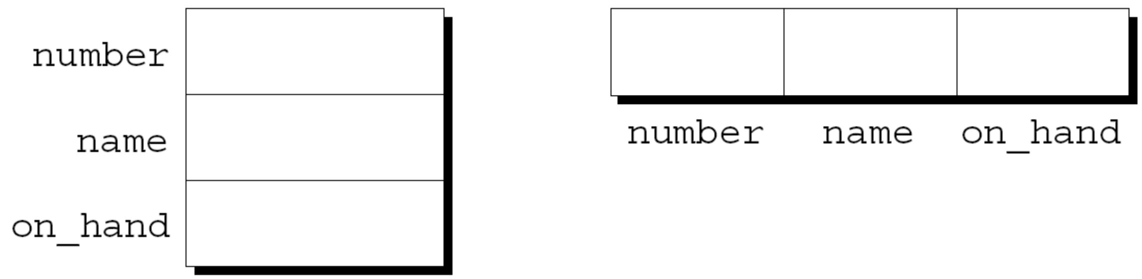
Declaring Structure Variables

- The members of a structure are stored in memory in the order in which they're declared.
- Appearance of `part1` →
- Assumptions:
  - `part1` is located at address 2000.
  - Integers occupy four bytes.
  - `NAME_LEN` has the value 25.
  - There are no gaps between the members.



Declaring Structure Variables

- Abstract representations of a structure:



- Member values will go in the boxes later.

Declaring Structure Variables

- Each structure represents a new scope.
- Any names declared in that scope won't conflict with other names in a program.
- In C terminology, each structure has a separate ***name space*** for its members.

Declaring Structure Variables

- For example, the following declarations can appear in the same program:

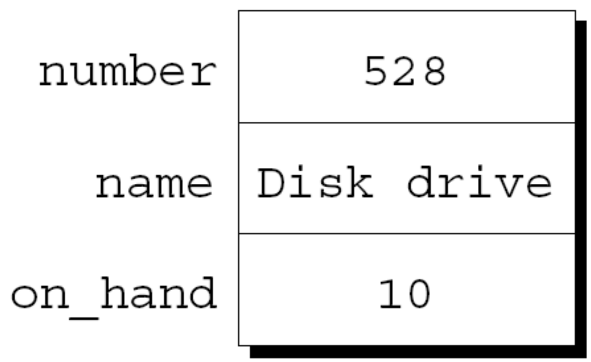
```
struct {
  int number;
  char name[NAME_LEN+1];
  int on_hand;
} part1, part2;

struct {
  char name[NAME_LEN+1];
  int number;
  char sex;
} employee1, employee2;
```

Initializing Structure Variables

- A structure declaration may include an initializer:

```
struct {
  int number;
  char name[NAME_LEN+1];
  int on_hand;
} part1 = {528, "Disk drive", 10},
  part2 = {914, "Printer cable", 5};
```

- Appearance of `part1` after initialization:



Initializing Structure Variables

- Structure initializers follow rules similar to those for array initializers.
- Expressions used in a structure initializer must be constant. (This restriction is relaxed in C99.)
- An initializer can have fewer members than the structure it's initializing.
- Any "leftover" members are given 0 as their initial value.

Designated Initializers (C99)

- C99's designated initializers can be used with structures.
- The initializer for `part1` shown in the previous example:

```
{528, "Disk drive", 10}
```

- In a designated initializer, each value would be labeled by the name of the member that it initializes:

```
{.number = 528, .name = "Disk drive", .on_hand = 10}
```

- The combination of the period and the member name is called a ***designator.***

Designated Initializers (C99)

- Designated initializers are easier to read and check for correctness.
- Also, values in a designated initializer don't have to be placed in the same order that the members are listed in the structure.
  - The programmer doesn't have to remember the order in which the members were originally declared.
  - The order of the members can be changed in the future without affecting designated initializers.

Designated Initializers (C99)

- Not all values listed in a designated initializer need be prefixed by a designator.
- Example:

```
{.number = 528, "Disk drive", .on_hand = 10}
```

  The compiler assumes that `"Disk drive"` initializes the member that follows `number` in the structure.
- Any members that the initializer fails to account for are set to zero.

Operations on Structures

- To access a member within a structure, we write the name of the structure first, then a period, then the name of the member.
- Statements that display the values of `part1`'s members:

```
printf("Part number: %d\n", part1.number);
printf("Part name: %s\n", part1.name);
printf("Quantity on hand: %d\n", part1.on_hand);
```

Operations on Structures

- The members of a structure are lvalues.
- They can appear on the left side of an assignment or as the operand in an increment or decrement expression:

```
part1.number = 258;
  /* changes part1's part number */
part1.on_hand++;
  /* increments part1's quantity on hand */
```

Operations on Structures

- The period used to access a structure member is actually a C operator.
- It takes precedence over nearly all other operators.
- Example:

```
scanf("%d", &part1.on_hand);
```

The `.` operator takes precedence over the `&` operator, so `&` computes the address of `part1.on_hand`.

Operations on Structures

- The other major structure operation is assignment:

```
part2 = part1;
```

- The effect of this statement is to copy `part1.number` into `part2.number`, `part1.name` into `part2.name`, and so on.

Operations on Structures

- Arrays can't be copied using the = operator, but an array embedded within a structure is copied when the enclosing structure is copied.
- Some programmers exploit this property by creating "dummy" structures to enclose arrays that will be copied later:

```
struct { int a[10]; } a1, a2;
a1 = a2;
  /* legal, since a1 and a2 are structures */
```

Operations on Structures

- The = operator can be used only with structures of ***compatible*** types.
- Two structures declared at the same time (as `part1` and `part2` were) are compatible.
- Structures declared using the same "structure tag" or the same type name are also compatible.
- Other than assignment, C provides no operations on entire structures.
- In particular, the == and != operators can't be used with structures.

Structure Types

- Suppose that a program needs to declare several structure variables with identical members.
- We need a name that represents a *type* of structure, not a particular structure *variable*.
- Ways to name a structure:
  - Declare a "structure tag"
  - Use `typedef` to define a type name

Declaring a Structure Tag

- A ***structure tag*** is a name used to identify a particular kind of structure.
- The declaration of a structure tag named `part`:

```
struct part {
  int number;
  char name[NAME_LEN+1];
  int on_hand;
};
```

- Note that a semicolon must follow the right brace.

Declaring a Structure Tag

- The `part` tag can be used to declare variables:

```
struct part part1, part2;
```

- We can't drop the word `struct`:

```
part part1, part2;   /*** WRONG ***/
```

  `part` isn't a type name; without the word `struct`, it is meaningless.

- Since structure tags aren't recognized unless preceded by the word `struct`, they don't conflict with other names used in a program.

Declaring a Structure Tag

- The declaration of a structure *tag* can be combined with the declaration of structure *variables:*

```
struct part {
  int number;
  char name[NAME_LEN+1];
  int on_hand;
} part1, part2;
```

Declaring a Structure Tag

- All structures declared to have type `struct part` are compatible with one another:

```
struct part part1 = {528, "Disk drive", 10};
struct part part2;

part2 = part1;
  /* legal; both parts have the same type */
```

Defining a Structure Type

- As an alternative to declaring a structure tag, we can use `typedef` to define a genuine type name.
- A definition of a type named `Part`:

```
typedef struct {
  int number;
  char name[NAME_LEN+1];
  int on_hand;
} Part;
```

- `Part` can be used in the same way as the built-in types:

```
Part part1, part2;
```

Defining a Structure Type

- When it comes time to name a structure, we can usually choose either to declare a structure tag or to use `typedef`.
- However, declaring a structure tag is mandatory when the structure is to be used in a linked list (Chapter 17).

Structures as Arguments and Return Values

- Functions may have structures as arguments and return values.
- A function with a structure argument:

```
void print_part(struct part p)
{
  printf("Part number: %d\n", p.number);
  printf("Part name: %s\n", p.name);
  printf("Quantity on hand: %d\n", p.on_hand);
}
```

- A call of `print_part`:

```
print_part(part1);
```

Structures as Arguments and Return Values

- A function that returns a `part` structure:

```
struct part build_part(int number,
                       const char *name,
                       int on_hand)
{
  struct part p;

  p.number = number;
  strcpy(p.name, name);
  p.on_hand = on_hand;
  return p;
}
```

- A call of `build_part`:

```
part1 = build_part(528, "Disk drive", 10);
```

Structures as Arguments and Return Values

- Passing a structure to a function and returning a structure from a function both require making a copy of all members in the structure.
- To avoid this overhead, it's sometimes advisable to pass a pointer to a structure or return a pointer to a structure.
- Chapter 17 gives examples of functions that have a pointer to a structure as an argument and/or return a pointer to a structure.

Structures as Arguments and Return Values

- There are other reasons to avoid copying structures.
- For example, the `<stdio.h>` header defines a type named `FILE`, which is typically a structure.
- Each `FILE` structure stores information about the state of an open file and therefore must be unique in a program.
- Every function in `<stdio.h>` that opens a file returns a pointer to a `FILE` structure.
- Every function that performs an operation on an open file requires a `FILE` pointer as an argument.

Structures as Arguments and Return Values

- Within a function, the initializer for a structure variable can be another structure:

```
void f(struct part part1)
{
  struct part part2 = part1;
  …
}
```

- The structure being initialized must have automatic storage duration.

Compound Literals (C99)

- Chapter 9 introduced the C99 feature known as the ***compound literal.***
- A compound literal can be used to create a structure "on the fly," without first storing it in a variable.
- The resulting structure can be passed as a parameter, returned by a function, or assigned to a variable.

Compound Literals (C99)

- A compound literal can be used to create a structure that will be passed to a function:

```
print_part((struct part) {528, "Disk drive", 10});
```

  The compound literal is shown in **bold**.

- A compound literal can also be assigned to a variable:

```
part1 = (struct part) {528, "Disk drive", 10};
```

- A compound literal consists of a type name within parentheses, followed by a set of values in braces.
- When a compound literal represents a structure, the type name can be a structure tag preceded by the word `struct` or a `typedef` name.

Compound Literals (C99)

- A compound literal may contain designators, just like a designated initializer:

```
print_part((struct part) {.on_hand = 10,
                          .name = "Disk drive",
                          .number = 528});
```

- A compound literal may fail to provide full initialization, in which case any uninitialized members default to zero.

Nested Arrays and Structures

- Structures and arrays can be combined without restriction.
- Arrays may have structures as their elements, and structures may contain arrays and structures as members.

Nested Structures

- Nesting one structure inside another is often useful.
- Suppose that `person_name` is the following structure:

```
struct person_name {
  char first[FIRST_NAME_LEN+1];
  char middle_initial;
  char last[LAST_NAME_LEN+1];
};
```

Nested Structures

- We can use `person_name` as part of a larger structure:

```
struct student {
  struct person_name name;
  int id, age;
  char sex;
} student1, student2;
```

- Accessing `student1`'s first name, middle initial, or last name requires two applications of the . operator:

```
strcpy(student1.name.first, "Fred");
```

Nested Structures

- Having `name` be a structure makes it easier to treat names as units of data.
- A function that displays a name could be passed one `person_name` argument instead of three arguments:

```
display_name(student1.name);
```

- Copying the information from a `person_name` structure to the `name` member of a student structure would take one assignment instead of three:

```
struct person_name new_name;
…
student1.name = new_name;
```

Arrays of Structures

- One of the most common combinations of arrays and structures is an array whose elements are structures.
- This kind of array can serve as a simple database.
- An array of `part` structures capable of storing information about 100 parts:

```
struct part inventory[100];
```

Arrays of Structures

- Accessing a part in the array is done by using subscripting:

```
print_part(inventory[i]);
```

- Accessing a member within a `part` structure requires a combination of subscripting and member selection:

```
inventory[i].number = 883;
```

- Accessing a single character in a part name requires subscripting, followed by selection, followed by subscripting:

```
inventory[i].name[0] = '\0';
```

Initializing an Array of Structures

- Initializing an array of structures is done in much the same way as initializing a multidimensional array.
- Each structure has its own brace-enclosed initializer; the array initializer wraps another set of braces around the structure initializers.

Initializing an Array of Structures

- One reason for initializing an array of structures is that it contains information that won't change during program execution.
- Example: an array that contains country codes used when making international telephone calls.
- The elements of the array will be structures that store the name of a country along with its code:

```
struct dialing_code {
  char *country;
  int code;
};
```

Initializing an Array of Structures

```
const struct dialing_code country_codes[] =
  {{"Argentina",            54}, {"Bangladesh",      880},
   {"Brazil",               55}, {"Burma (Myanmar)",  95},
   {"China",                86}, {"Colombia",         57},
   {"Congo, Dem. Rep. of", 243}, {"Egypt",            20},
   {"Ethiopia",            251}, {"France",           33},
   {"Germany",              49}, {"India",            91},
   {"Indonesia",            62}, {"Iran",             98},
   {"Italy",                39}, {"Japan",            81},
   {"Mexico",               52}, {"Nigeria",         234},
   {"Pakistan",             92}, {"Philippines",      63},
   {"Poland",               48}, {"Russia",            7},
   {"South Africa",         27}, {"South Korea",      82},
   {"Spain",                34}, {"Sudan",           249},
   {"Thailand",             66}, {"Turkey",           90},
   {"Ukraine",             380}, {"United Kingdom",   44},
   {"United States",         1}, {"Vietnam",          84}};
```

- The inner braces around each structure value are optional.

Initializing an Array of Structures

- C99's designated initializers allow an item to have more than one designator.
- A declaration of the `inventory` array that uses a designated initializer to create a single part:

```
struct part inventory[100] =
  {[0].number = 528, [0].on_hand = 10,
   [0].name[0] = '\0'};
```

The first two items in the initializer use two designators; the last item uses three.

Program: Maintaining a Parts Database

- The `inventory.c` program illustrates how nested arrays and structures are used in practice.
- The program tracks parts stored in a warehouse.
- Information about the parts is stored in an array of structures.
- Contents of each structure:
  - Part number
  - Name
  - Quantity

Program: Maintaining a Parts Database

- Operations supported by the program:
  - Add a new part number, part name, and initial quantity on hand
  - Given a part number, print the name of the part and the current quantity on hand
  - Given a part number, change the quantity on hand
  - Print a table showing all information in the database
  - Terminate program execution

Program: Maintaining a Parts Database

- The codes `i` (insert), `s` (search), `u` (update), `p` (print), and `q` (quit) will be used to represent these operations.
- A session with the program:

```
Enter operation code: i
Enter part number: 528
Enter part name: Disk drive
Enter quantity on hand: 10

Enter operation code: s
Enter part number: 528
Part name: Disk drive
Quantity on hand: 10
```

Program: Maintaining a Parts Database

```
Enter operation code: s
Enter part number: 914
Part not found.

Enter operation code: i
Enter part number: 914
Enter part name: Printer cable
Enter quantity on hand: 5

Enter operation code: u
Enter part number: 528
Enter change in quantity on hand: -2
```

Program: Maintaining a Parts Database

```
Enter operation code: s
Enter part number: 528
Part name: Disk drive
Quantity on hand: 8

Enter operation code: p
Part Number   Part Name                  Quantity on Hand
    528       Disk drive                        8
    914       Printer cable                     5

Enter operation code: q
```

Program: Maintaining a Parts Database

- The program will store information about each part in a structure.
- The structures will be stored in an array named `inventory`.
- A variable named `num_parts` will keep track of the number of parts currently stored in the array.

Program: Maintaining a Parts Database

- An outline of the program's main loop:

```
for (;;) {
  prompt user to enter operation code;
  read code;
  switch (code) {
    case 'i': perform insert operation; break;
    case 's': perform search operation; break;
    case 'u': perform update operation; break;
    case 'p': perform print operation; break;
    case 'q': terminate program;
    default:  print error message;
  }
}
```

Program: Maintaining a Parts Database

- Separate functions will perform the insert, search, update, and print operations.
- Since the functions will all need access to `inventory` and `num_parts`, these variables will be external.
- The program is split into three files:
  - `inventory.c` (the bulk of the program)
  - `readline.h` (contains the prototype for the `read_line` function)
  - `readline.c` (contains the definition of `read_line`)

inventory.c

```
/* Maintains a parts database (array version) */

#include <stdio.h>
#include "readline.h"

#define NAME_LEN 25
#define MAX_PARTS 100

struct part {
  int number;
  char name[NAME_LEN+1];
  int on_hand;
} inventory[MAX_PARTS];

int num_parts = 0;   /* number of parts currently stored */

int find_part(int number);
void insert(void);
void search(void);
void update(void);
void print(void);
```

```
/**********************************************************
 * main: Prompts the user to enter an operation code,     *
 *       then calls a function to perform the requested   *
 *       action. Repeats until the user enters the        *
 *       command 'q'. Prints an error message if the user *
 *       enters an illegal code.                          *
 **********************************************************/
int main(void)
{
  char code;
  for (;;) {
    printf("Enter operation code: ");
    scanf(" %c", &code);
    while (getchar() != '\n')   /* skips to end of line */
      ;
```

```
      switch (code) {
        case 'i': insert();
                  break;
        case 's': search();
                  break;
        case 'u': update();
                  break;
        case 'p': print();
                  break;
        case 'q': return 0;
        default:  printf("Illegal code\n");
      }
      printf("\n");
    }
  }
```

```
/*********************************************************
 * find_part: Looks up a part number in the inventory     *
 *            array. Returns the array index if the part  *
 *            number is found; otherwise, returns -1.     *
 *********************************************************/
int find_part(int number)
{
  int i;

  for (i = 0; i < num_parts; i++)
    if (inventory[i].number == number)
      return i;
  return -1;
}
```

```
/**********************************************************
 * insert: Prompts the user for information about a new   *
 *         part and then inserts the part into the        *
 *         database. Prints an error message and returns  *
 *         prematurely if the part already exists or the  *
 *         database is full.                              *
 **********************************************************/
void insert(void)
{
  int part_number;

  if (num_parts == MAX_PARTS) {
    printf("Database is full; can't add more parts.\n");
    return;
  }
```

```
  printf("Enter part number: ");
  scanf("%d", &part_number);
  if (find_part(part_number) >= 0) {
    printf("Part already exists.\n");
    return;
  }

  inventory[num_parts].number = part_number;
  printf("Enter part name: ");
  read_line(inventory[num_parts].name, NAME_LEN);
  printf("Enter quantity on hand: ");
  scanf("%d", &inventory[num_parts].on_hand);
  num_parts++;
}
```

```
/**********************************************************
 * search: Prompts the user to enter a part number, then  *
 *         looks up the part in the database. If the part *
 *         exists, prints the name and quantity on hand;  *
 *         if not, prints an error message.               *
 **********************************************************/
void search(void)
{
  int i, number;

  printf("Enter part number: ");
  scanf("%d", &number);
  i = find_part(number);
  if (i >= 0) {
    printf("Part name: %s\n", inventory[i].name);
    printf("Quantity on hand: %d\n", inventory[i].on_hand);
  } else
    printf("Part not found.\n");
}
```

```
/**********************************************************
 * update: Prompts the user to enter a part number.      *
 *         Prints an error message if the part doesn't   *
 *         exist; otherwise, prompts the user to enter   *
 *         change in quantity on hand and updates the    *
 *         database.                                     *
 **********************************************************/
void update(void)
{
  int i, number, change;

  printf("Enter part number: ");
  scanf("%d", &number);
  i = find_part(number);
  if (i >= 0) {
    printf("Enter change in quantity on hand: ");
    scanf("%d", &change);
    inventory[i].on_hand += change;
  } else
    printf("Part not found.\n");
}
```

```
/**********************************************************
 * print: Prints a listing of all parts in the database,  *
 *        showing the part number, part name, and         *
 *        quantity on hand. Parts are printed in the      *
 *        order in which they were entered into the       *
 *        database.                                       *
 **********************************************************/
void print(void)
{
  int i;

  printf("Part Number   Part Name                  "
         "Quantity on Hand\n");
  for (i = 0; i < num_parts; i++)
    printf("%7d       %-25s%11d\n", inventory[i].number,
           inventory[i].name, inventory[i].on_hand);
}
```

Program: Maintaining a Parts Database

- The version of `read_line` in Chapter 13 won't work properly in the current program.
- Consider what happens when the user inserts a part:

```
Enter part number: 528
Enter part name: Disk drive
```

- The user presses the Enter key after entering the part number, leaving an invisible new-line character that the program must read.
- When `scanf` reads the part number, it consumes the 5, 2, and 8, but leaves the new-line character unread.

Program: Maintaining a Parts Database

- If we try to read the part name using the original `read_line` function, it will encounter the new-line character immediately and stop reading.
- This problem is common when numerical input is followed by character input.
- One solution is to write a version of `read_line` that skips white-space characters before it begins storing characters.
- This solves the new-line problem and also allows us to avoid storing blanks that precede the part name.

readline.h

```
#ifndef READLINE_H
#define READLINE_H

/**********************************************************
 * read_line: Skips leading white-space characters, then  *
 *            reads the remainder of the input line and   *
 *            stores it in str. Truncates the line if its *
 *            length exceeds n. Returns the number of     *
 *            characters stored.                          *
 **********************************************************/
int read_line(char str[], int n);

#endif
```

readline.c

```
#include <ctype.h>
#include <stdio.h>
#include "readline.h"

int read_line(char str[], int n)
{
  int ch, i = 0;

  while (isspace(ch = getchar()))
    ;
  while (ch != '\n' && ch != EOF) {
    if (i < n)
      str[i++] = ch;
    ch = getchar();
  }
  str[i] = '\0';
  return i;
}
```

Unions

- A ***union***, like a structure, consists of one or more members, possibly of different types.
- The compiler allocates only enough space for the largest of the members, which overlay each other within this space.
- Assigning a new value to one member alters the values of the other members as well.

Unions

- An example of a union variable:

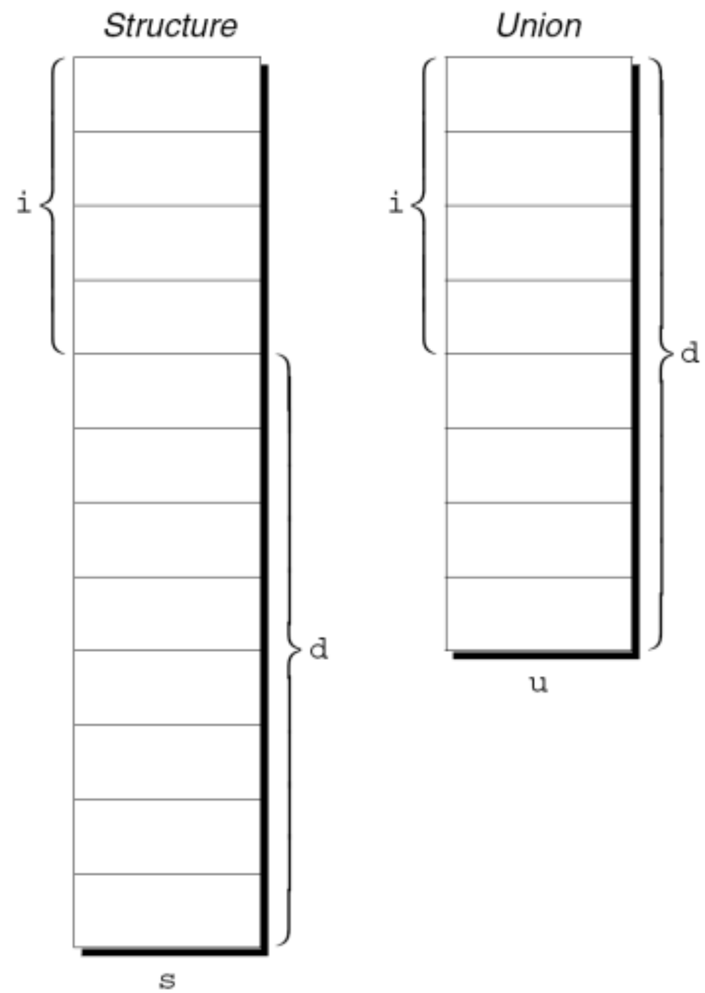
```
union {
  int i;
  double d;
} u;
```

- The declaration of a union closely resembles a structure declaration:

```
struct {
  int i;
  double d;
} s;
```

Unions

- The structure `s` and the union `u` differ in just one way.
- The members of `s` are stored at different addresses in memory.
- The members of `u` are stored at the same address.



Unions

- Members of a union are accessed in the same way as members of a structure:

```
u.i = 82;
u.d = 74.8;
```

- Changing one member of a union alters any value previously stored in any of the other members.
  - Storing a value in `u.d` causes any value previously stored in `u.i` to be lost.
  - Changing `u.i` corrupts `u.d`.

Unions

- The properties of unions are almost identical to the properties of structures.
- We can declare union tags and union types in the same way we declare structure tags and types.
- Like structures, unions can be copied using the = operator, passed to functions, and returned by functions.

Unions

- Only the first member of a union can be given an initial value.
- How to initialize the `i` member of `u` to 0:

```
union {
  int i;
  double d;
} u = {0};
```

- The expression inside the braces must be constant. (The rules are slightly different in C99.)

Unions

- Designated initializers can also be used with unions.
- A designated initializer allows us to specify which member of a union should be initialized:

```
union {
  int i;
  double d;
} u = {.d = 10.0};
```

- Only one member can be initialized, but it doesn't have to be the first one.

Unions

- Applications for unions:
  - Saving space
  - Building mixed data structures
  - Viewing storage in different ways (discussed in Chapter 20)

Using Unions to Save Space

- Unions can be used to save space in structures.
- Suppose that we're designing a structure that will contain information about an item that's sold through a gift catalog.
- Each item has a stock number and a price, as well as other information that depends on the type of the item:

  Books: Title, author, number of pages

  Mugs: Design

  Shirts: Design, colors available, sizes available

Using Unions to Save Space

- A first attempt at designing the `catalog_item` structure:

```
struct catalog_item {
  int stock_number;
  double price;
  int item_type;
  char title[TITLE_LEN+1];
  char author[AUTHOR_LEN+1];
  int num_pages;
  char design[DESIGN_LEN+1];
  int colors;
  int sizes;
};
```

Using Unions to Save Space

- The `item_type` member would have one of the values `BOOK`, `MUG`, or `SHIRT`.
- The `colors` and `sizes` members would store encoded combinations of colors and sizes.
- This structure wastes space, since only part of the information in the structure is common to all items in the catalog.
- By putting a union inside the `catalog_item` structure, we can reduce the space required by the structure.

Using Unions to Save Space

```
struct catalog_item {
  int stock_number;
  double price;
  int item_type;
  union {
    struct {
      char title[TITLE_LEN+1];
      char author[AUTHOR_LEN+1];
      int num_pages;
    } book;
    struct {
      char design[DESIGN_LEN+1];
    } mug;
    struct {
      char design[DESIGN_LEN+1];
      int colors;
      int sizes;
    } shirt;
  } item;
};
```

Using Unions to Save Space

- If `c` is a `catalog_item` structure that represents a book, we can print the book's title in the following way:

```
printf("%s", c.item.book.title);
```

- As this example shows, accessing a union that's nested inside a structure can be awkward.

Using Unions to Save Space

- The `catalog_item` structure can be used to illustrate an interesting aspect of unions.
- Normally, it's not a good idea to store a value into one member of a union and then access the data through a different member.
- However, there is a special case: two or more of the members of the union are structures, and the structures begin with one or more matching members.
- If one of the structures is currently valid, then the matching members in the other structures will also be valid.

Using Unions to Save Space

- The union embedded in the `catalog_item` structure contains three structures as members.
- Two of these (`mug` and `shirt`) begin with a matching member (`design`).
- Now, suppose that we assign a value to one of the `design` members:

```
strcpy(c.item.mug.design, "Cats");
```

- The `design` member in the other structure will be defined and have the same value:

```
printf("%s", c.item.shirt.design);
  /* prints "Cats" */
```

Using Unions to Build Mixed Data Structures

- Unions can be used to create data structures that contain a mixture of data of different types.
- Suppose that we need an array whose elements are a mixture of `int` and `double` values.
- First, we define a union type whose members represent the different kinds of data to be stored in the array:

```
typedef union {
  int i;
  double d;
} Number;
```

Using Unions to Build Mixed Data Structures

- Next, we create an array whose elements are `Number` values:

```
Number number_array[1000];
```

- A `Number` union can store either an `int` value or a `double` value.
- This makes it possible to store a mixture of `int` and `double` values in `number_array`:

```
number_array[0].i = 5;
number_array[1].d = 8.395;
```

Adding a "Tag Field" to a Union

- There's no easy way to tell which member of a union was last changed and therefore contains a meaningful value.
- Consider the problem of writing a function that displays the value stored in a `Number` union:

```
void print_number(Number n)
{
  if (n contains an integer)
    printf("%d", n.i);
  else
    printf("%g", n.d);
}
```

There's no way for `print_number` to determine whether `n` contains an integer or a floating-point number.

Adding a "Tag Field" to a Union

- In order to keep track of this information, we can embed the union within a structure that has one other member: a "tag field" or "discriminant."
- The purpose of a tag field is to remind us what's currently stored in the union.
- `item_type` served this purpose in the `catalog_item` structure.

Adding a "Tag Field" to a Union

- The `Number` type as a structure with an embedded union:

```
#define INT_KIND 0
#define DOUBLE_KIND 1

typedef struct {
  int kind;   /* tag field */
  union {
    int i;
    double d;
  } u;
} Number;
```

- The value of `kind` will be either `INT_KIND` or `DOUBLE_KIND`.

Adding a "Tag Field" to a Union

- Each time we assign a value to a member of `u`, we'll also change `kind` to remind us which member of `u` we modified.
- An example that assigns a value to the `i` member of `u`:

```
n.kind = INT_KIND;
n.u.i = 82;
```

  `n` is assumed to be a `Number` variable.

Adding a "Tag Field" to a Union

- When the number stored in a `Number` variable is retrieved, `kind` will tell us which member of the union was the last to be assigned a value.
- A function that takes advantage of this capability:

```
void print_number(Number n)
{
  if (n.kind == INT_KIND)
    printf("%d", n.u.i);
  else
    printf("%g", n.u.d);
}
```

Enumerations

- In many programs, we'll need variables that have only a small set of meaningful values.
- A variable that stores the suit of a playing card should have only four potential values: "clubs," "diamonds," "hearts," and "spades."

Enumerations

- A "suit" variable can be declared as an integer, with a set of codes that represent the possible values of the variable:

```
int s;    /* s will store a suit */
…
s = 2;    /* 2 represents "hearts" */
```

- Problems with this technique:
  - We can't tell that `s` has only four possible values.
  - The significance of 2 isn't apparent.

Enumerations

- Using macros to define a suit "type" and names for the various suits is a step in the right direction:

```
#define SUIT     int
#define CLUBS    0
#define DIAMONDS 1
#define HEARTS   2
#define SPADES   3
```

- An updated version of the previous example:

```
SUIT s;
…
s = HEARTS;
```

Enumerations

- Problems with this technique:
  - There's no indication to someone reading the program that the macros represent values of the same "type."
  - If the number of possible values is more than a few, defining a separate macro for each will be tedious.
  - The names `CLUBS`, `DIAMONDS`, `HEARTS`, and `SPADES` will be removed by the preprocessor, so they won't be available during debugging.

Enumerations

- C provides a special kind of type designed specifically for variables that have a small number of possible values.
- An ***enumerated type*** is a type whose values are listed ("enumerated") by the programmer.
- Each value must have a name (an ***enumeration constant***).

Enumerations

- Although enumerations have little in common with structures and unions, they're declared in a similar way:

```
enum {CLUBS, DIAMONDS, HEARTS, SPADES} s1, s2;
```

- The names of enumeration constants must be different from other identifiers declared in the enclosing scope.

Enumerations

- Enumeration constants are similar to constants created with the `#define` directive, but they're not equivalent.
- If an enumeration is declared inside a function, its constants won't be visible outside the function.

Enumeration Tags and Type Names

- As with structures and unions, there are two ways to name an enumeration: by declaring a tag or by using `typedef` to create a genuine type name.
- Enumeration tags resemble structure and union tags:

```
enum suit {CLUBS, DIAMONDS, HEARTS, SPADES};
```

- `suit` variables would be declared in the following way:

```
enum suit s1, s2;
```

Enumeration Tags and Type Names

- As an alternative, we could use `typedef` to make `Suit` a type name:

```
typedef enum {CLUBS, DIAMONDS, HEARTS, SPADES} Suit;
Suit s1, s2;
```

- In C89, using `typedef` to name an enumeration is an excellent way to create a Boolean type:

```
typedef enum {FALSE, TRUE} Bool;
```

Enumerations as Integers

- Behind the scenes, C treats enumeration variables and constants as integers.
- By default, the compiler assigns the integers 0, 1, 2, … to the constants in a particular enumeration.
- In the `suit` enumeration, `CLUBS`, `DIAMONDS`, `HEARTS`, and `SPADES` represent 0, 1, 2, and 3, respectively.

Enumerations as Integers

- The programmer can choose different values for enumeration constants:

```
enum suit {CLUBS = 1, DIAMONDS = 2,
           HEARTS = 3, SPADES = 4};
```

- The values of enumeration constants may be arbitrary integers, listed in no particular order:

```
enum dept {RESEARCH = 20,
           PRODUCTION = 10, SALES =
25};
```

- It's even legal for two or more enumeration constants to have the same value.

Enumerations as Integers

- When no value is specified for an enumeration constant, its value is one greater than the value of the previous constant.
- The first enumeration constant has the value 0 by default.
- Example:

```
enum EGA_colors {BLACK, LT_GRAY = 7,
                 DK_GRAY, WHITE = 15};
```

`BLACK` has the value 0, `LT_GRAY` is 7, `DK_GRAY` is 8, and `WHITE` is 15.

Enumerations as Integers

- Enumeration values can be mixed with ordinary integers:

```
int i;
enum {CLUBS, DIAMONDS, HEARTS, SPADES} s;

i = DIAMONDS;    /* i is now 1              */
s = 0;           /* s is now 0 (CLUBS)      */
s++;             /* s is now 1 (DIAMONDS)   */
i = s + 2;       /* i is now 3              */
```

- `s` is treated as a variable of some integer type.
- `CLUBS`, `DIAMONDS`, `HEARTS`, and `SPADES` are names for the integers 0, 1, 2, and 3.

Enumerations as Integers

- Although it's convenient to be able to use an enumeration value as an integer, it's dangerous to use an integer as an enumeration value.
- For example, we might accidentally store the number 4—which doesn't correspond to any suit—into `s`.

Using Enumerations to Declare "Tag Fields"

- Enumerations are perfect for determining which member of a union was the last to be assigned a value.
- In the `Number` structure, we can make the `kind` member an enumeration instead of an `int`:

```
typedef struct {
  enum {INT_KIND, DOUBLE_KIND} kind;
  union {
    int i;
    double d;
  } u;
} Number;
```

Using Enumerations to Declare "Tag Fields"

- The new structure is used in exactly the same way as the old one.
- Advantages of the new structure:
  - Does away with the `INT_KIND` and `DOUBLE_KIND` macros
  - Makes it obvious that `kind` has only two possible values: `INT_KIND` and `DOUBLE_KIND`