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

- Example: initializing 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 is
    - Part number
    - Name
    - Quantity

Program: Maintaining a Parts Database

- Operations supported by the program
  - Add a new part:
    - part number
    - part name
    - 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 will be as follow:

```
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 not 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 does not      *
 *         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 will not 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')
  { 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

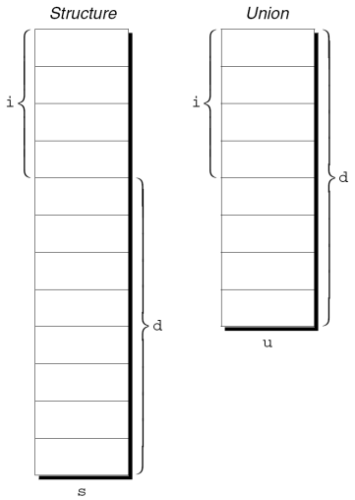
```
union
{ int i;
  double d;
} u;
```

- 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

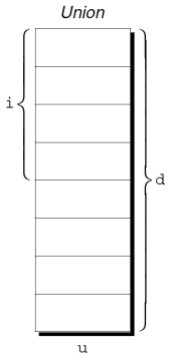


Unions

- 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

- *By default,* the *first member* of a union can be *given* an *initial value*
- Here it is 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

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 does not have to be the first one*

Unions

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

Using Unions to Save Space

- Unions can be used to save space in structures
- Suppose that we are designing a structure that will contain information about an item that is 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);
```

```
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);
```

```
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

- 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 is 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 is 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 the tag field is to remind us what is currently stored in the union
- `item_type` served this purpose in the `catalog_item` structure

```
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;
};
```

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 will 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;
```

An example that assigns a value to the `d` member of `u`

```
n.kind = DOUBLE_KIND;
n.u.d = 7.65;
```

`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 will 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 not tell that `s` has only four possible values
  - The significance of `2` is not 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 is no indication to someone reading the program that the macros represent values of the same "*type*"
  - The names `CLUBS`, `DIAMONDS`, `HEARTS`, and `SPADES` will be removed by the preprocessor, so they will not be available during debugging

Enumerations

- C provides a special kind of type which 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 are declared in a similar way

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

- Enumeration constants are *similar* to constants created with the `#define` directive, but they are *not equivalent*
  - If an enumeration is declared inside a function, its constants will not 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`
- Enumeration tags resemble structure and union tags

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

- `enum 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 is 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`
  - `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 is convenient to be able to use an enumeration value as an integer, it is dangerous to use an integer as an enumeration value
- For example, we might accidentally store the number `4` into `s`, which does not correspond to any suit

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

s = SPADES;    /* s is now 3              */
s++;           /* s is now 4, legal, but*/
               /* logically incorrect    */
```

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
- The new structure makes it obvious that `kind` has only two possible values:
  - `INT_KIND` and
  - `DOUBLE_KIND`