BBM 101 – Introduction to Programming I

Fall 2014, Lecture 12

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Today

- Structures
  - Structure Definitions
  - Initializing Structures
  - Accessing Members of Structures
  - `typedef`
  - Using Structures With Functions
  - Structures and Pointers
  - Assignments
  - Arrays of Structures
- Linked Lists
- Unions
  - Union definitions
  - Union operations
- Enumeration Constants

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Structures

- Collections of related variables (aggregates) under one name
  - Can contain variables of different data types
- Commonly used to define records to be stored in files
- Combined with pointers, can create linked lists, stacks, queues, and trees

Structure Definitions

Example 1:

```
struct card {
    char *face;
    char *suit;
 };
```

- **`struct`** introduces the definition for structure **`card`**
- **`card`** is the structure name and is used to declare variables of the structure type
- **`card`** contains two members of type **`char *`**
  - These members are **`face`** and **`suit`**

Structure Definitions

- **`struct`** information
  - Can contain a member that is a pointer to the same structure type
  - A structure definition does not reserve space in memory
    - Instead creates a new data type used to define structure variables

- Definitions
  - Defined like other variables:

```
struct card oneCard, deck[ 52 ], *cPtr;
```

  - Can use a comma separated list:

```
struct card {
   char *face;
   char *suit;
} oneCard, deck[ 52 ], *cPtr;
```

Structure Definitions

Example 2:

```
struct point {
     int x;
     int y;
     };

struct point pt; /* defines a variable pt
                    which is a structure of
                    type struct point */

pt.x = 15;
pt.y = 30;
printf("%d, %d", pt.x, pt.y);
```

Structure Definitions

```
/* Structures can be nested. One representation of a
  rectangle is a pair of points that denote the
  diagonally opposite corners. */

struct rect {
     struct point pt1;
     struct point pt2;
};

struct rect screen;

/* Print the pt1 field of screen */
printf("%d, %d",screen.pt1.x,screen.pt1.y);

/* Print the pt2 field of screen */
printf("%d, %d",screen.pt2.x,screen.pt2.y);
```

Structure Operations

- Assigning a structure to a structure of the same type
- Taking the address (**`&`**) of a structure
- Accessing the members of a structure
- Using the **`sizeof`** operator to determine the size of a structure

Initializing Structures

- Initializer lists
  - Example:

```
struct card oneCard = { "Three", "Hearts" };
```

- Assignment statements
  - Example:

```
struct card threeHearts = oneCard;
```

  - Could also define and initialize **threeHearts** as follows:

```
struct card threeHearts;
threeHearts.face = “Three”;
threeHearts.suit = “Hearts”;
```

Accessing Members of Structures

- Dot operator (`.`) used with structure variables

```
struct card myCard;
printf( "%s", myCard.suit );
```

- Arrow operator (`->`) used with pointers to structure variables

```
struct card *myCardPtr = &myCard;
printf( "%s", myCardPtr->suit );
```

- **`myCardPtr->suit`** is equivalent to

```
( *myCardPtr ).suit
```

```c
#include <stdio.h>

/* card structure definition */
struct card {
   char *face; /* define pointer face */
   char *suit; /* define pointer suit */
}; /* end structure card */

int main() {
  struct card a;     /* define struct a */
  struct card *aPtr; /* define a pointer to card */
  /* place strings into card structures */
  a.face = "Ace";
  a.suit = "Spades";
  aPtr = &a; /* assign address of a to aPtr */
  printf( "%s%s%s\n%s%s%s\n%s%s%s\n", a.face, " of ", a.suit,
    aPtr->face, " of ", aPtr->suit, ( *aPtr ).face, " of ",
    ( *aPtr ).suit );

 return 0; /* indicates successful termination */
} /* end main */
```

Program Output

```
Ace of Spades
Ace of Spades
Ace of Spades
```

`typedef`

- Creates synonyms (aliases) for previously defined data types
- Use **`typedef`** to create shorter type names

Example:

```
typedef struct point pixel;
```

- Defines a new type name **`pixel`** as a synonym for type **`struct point`**

```
typedef struct Card *CardPtr;
```

- Defines a new type name **CardPtr** as a synonym for type **struct Card ***

- **`typedef`** does not create a new data type
  - Only creates an alias

Using Structures With Functions

- Passing structures to functions
  - Pass entire structure
    - Or, pass individual members
  - Both pass call by value

- To pass structures call-by-reference
  - Pass its address
  - Pass reference to it

- To pass arrays call-by-value
  - Create a structure with the array as a member
  - Pass the structure

Using Structures with Functions 1

```
#include<stdio.h> /* Demonstrates passing a structure to a function */

struct data{
    int amount;
    char fname[30];
    char lname[30];
}rec;

void printRecord(struct data x){
   printf("\nDonor %s %s gave $%d", x.fname, x.lname, x.amount);
}

int main(void){
      printf("Enter the donor's first and last names\n");
      printf("separated by a space:  ");
      scanf("%s %s",rec.fname, rec.lname);
      printf("Enter the donation amount:   ");
      scanf("%d",&rec.amount);
      printRecord(rec);
      return 0;}
```

Using Structures with Functions 2

```
/* Make a point from x and y components. */
struct point makepoint (int x, int y)
{
        struct point temp;

        temp.x = x;
        temp.y = y;
        return (temp);

}
/* makepoint can now be used to initialize a
   structure */
struct rect screen;
struct point middle;

screen.pt1 = makepoint(0,0);
screen.pt2 = makepoint(50,100);
middle = makepoint((screen.pt1.x + screen.pt2.x)/2,
                   (screen.pt1.y + screen.pt2.y)/2);
```

```
/* add two points */

struct point addpoint (struct point p1, struct point
p2)
{
      p1.x += p2.x;
      p1.y += p2.y;
      return p1;
}
```

Both arguments and the return value are structures in the function addpoint.

Structures and Pointers

```
struct point *p;  /* p is a pointer to a structure
                     of type struct point */
struct point origin;

p = &origin;
printf("Origin is (%d, %d)\n", (*p).x, (*p).y);
```

- Parenthesis are necessary in **`(*p).x`** because the precedence of the structure member operator (dot) is higher than *.
- The expression **`*p.x`** ≡ **`*(p.x)`** which is illegal because **`x`** is not a pointer.

Structures and Pointers

- Pointers to structures are so frequently used that an alternative is provided as a shorthand.
- If **`p`** is a pointer to a structure, then

```
p -> field_of_structure
```

  refers to a particular field.
- We could write

```
printf("Origin is (%d %d)\n", p->x, p->y);
```

Structures and Pointers

- Both `.` and `->` associate from left to right
- Consider

```
struct rect r, *rp = &r;
```

- The following 4 expressions are equivalent.

```
r.pt1.x
rp -> pt1.x
(r.pt1).x
(rp->pt1).x
```

```
struct rect {
      struct point pt1;
      struct point pt2;
};
```

Assignments

```
struct student {
    char *last_name;
    int student_id;
    char grade;
};
struct student temp, *p = &temp;

temp.grade = 'A';
temp.last_name = "Casanova";
temp.student_id = 590017;
```

Expression	Equiv. Expression	Value
`temp.grade`	`p -> grade`	`A`
`temp.last_name`	`p -> last_name`	`Casanova`
`temp.student_id`	`p -> student_id`	`590017`
`(*p).student_id`	`p -> student_id`	`590017`

Arrays of Structures

- Usually a program needs to work with more than one instance of data.
- For example, to maintain a list of phone #s in a program, you can define a structure to hold each person’s name and number.

```
struct entry {
        char fname[10];
        char lname[12];
        char phone[8];
};
```

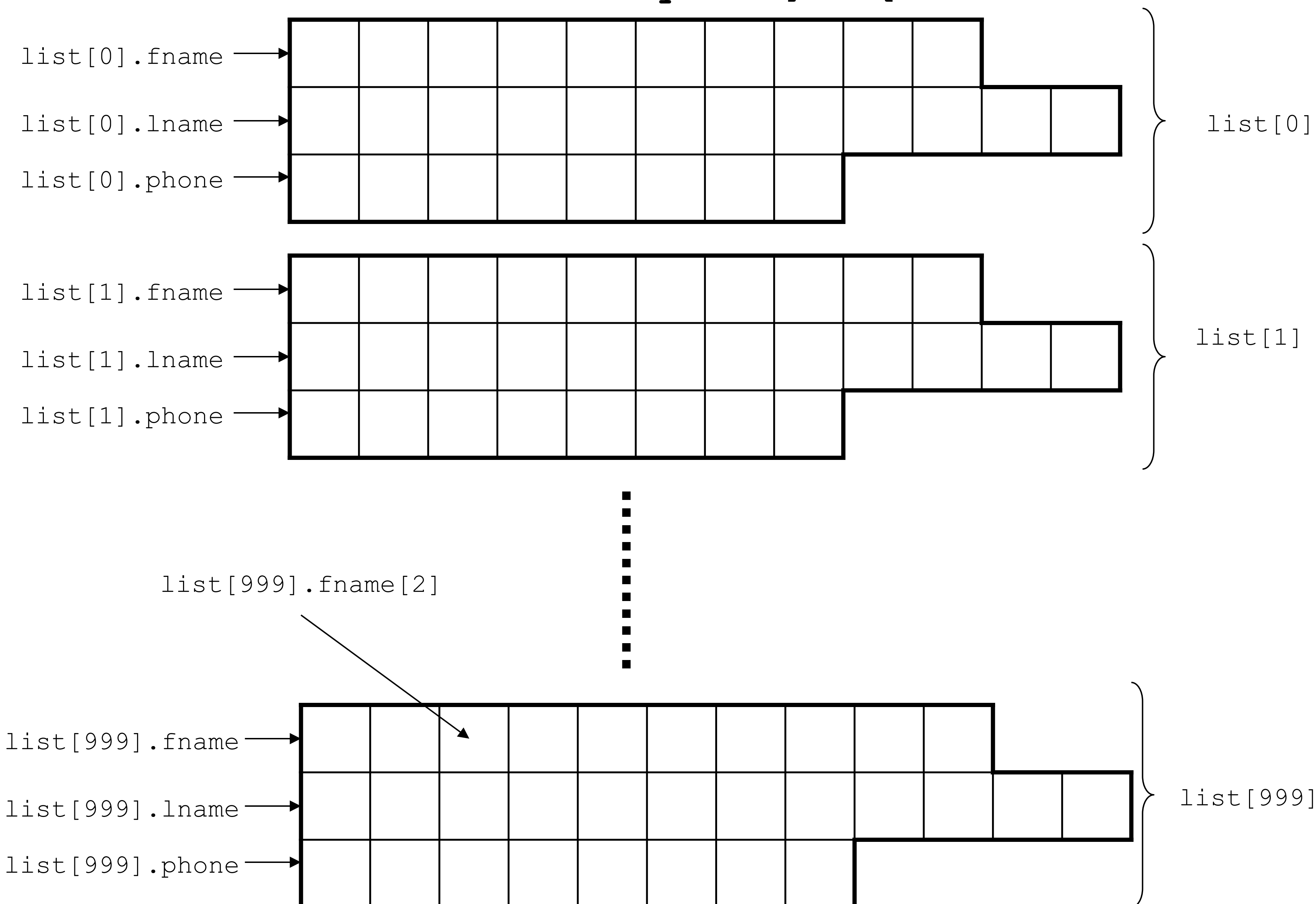
Arrays of Structures

- A phone list has to hold many entries, so a single instance of the entry structure isn't of much use. What we need is an array of structures of type entry.

- After the structure has been defined, you can define the array as follows:

```
struct entry list[1000];
```

struct entry list[1000]



- To assign data in one element to another array element, you write

```
list[1] = list[5];
```

- To move data between individual structure fields, you write

```
strcpy(list[1].phone, list[5].phone);
```

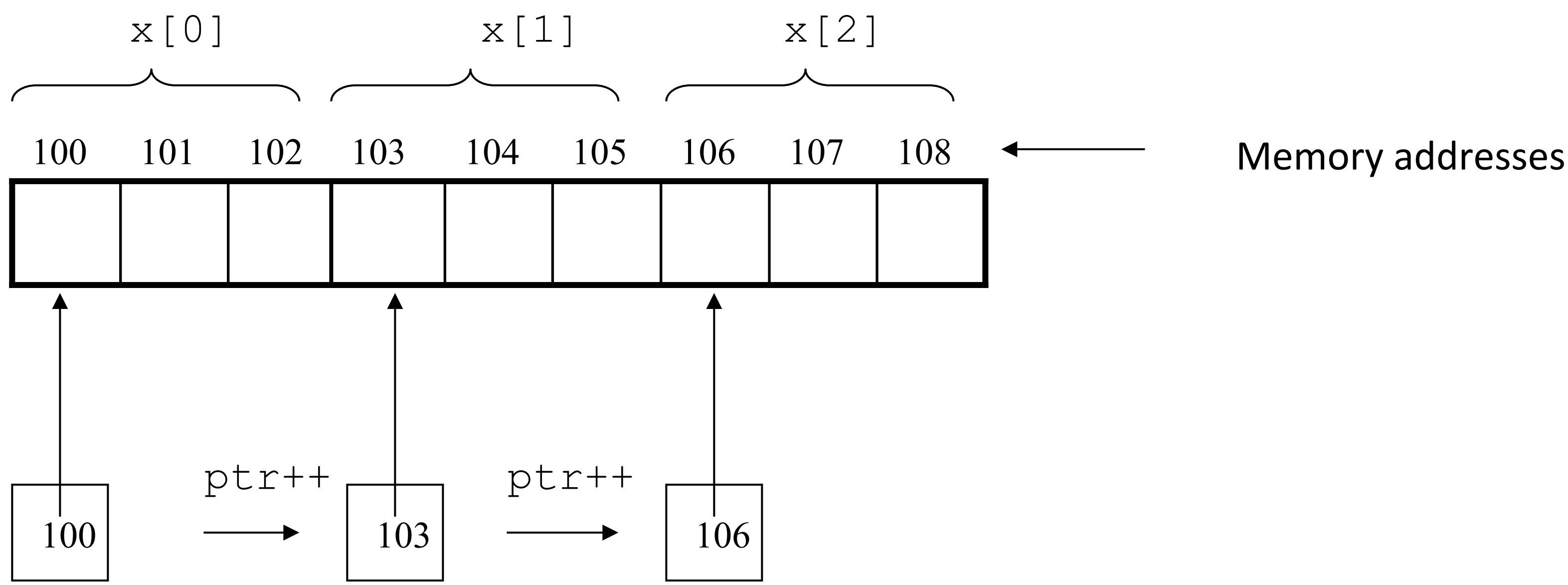
- To move data between individual elements of structure field arrays, you write

```
list[5].phone[1] = list[2].phone[3];
```

```
#define CLASS_SIZE 100

struct student {
        char *last_name;
        int student_id;
        char grade;
};
int main(void)
{
        struct student temp,
                class[CLASS_SIZE];
        ...
}
int countA(struct student class[])
{
        int i, cnt = 0;
        for (i = 0; i < CLASS_SIZE; ++i)
                cnt += class[i].grade == 'A';
        return cnt;
}
```

- Arrays of structures can be very powerful programming tools, as can pointers to structures.

```
struct part {
      int number;
      char name [10];
};

struct part data[100];
struct part *p_part;

p_part = data;
printf("%d %s", p_part->number, p_part ->
name);
```



- The above diagram shows an array named **x** that consists of 3 elements. The pointer **ptr** was initialized to point at **x[0]**. Each time **ptr** is incremented, it points at the next array element.

```
/* Array of structures */
#include <stdio.h>
#define MAX 4

struct part {
       int number;
       char name[10];
} data[MAX] = {1, “Smith”, 2, “Jones”, 3, “Adams”, 4,
               “Wilson”};

int main (void)
{
       struct part *p_part;
       int count;

       p_part = data;
       for (count = 0; count < MAX; count++) {
          printf(“\n %d %s”, p_part -> number, p_part -> name);
          p_part++;
       }
       return 0;}
```

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- **Linked Lists**
- Unions
  - Union definitions
  - Union operations
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Introduction

- Dynamic data structures
  - Data structures that grow and shrink during execution
- Linked lists
  - Allow insertions and removals anywhere
- Stacks
  - Allow insertions and removals only at top of stack
- Queues
  - Allow insertions at the back and removals from the front
- Binary trees
  - High-speed searching and sorting of data and efficient elimination of duplicate data items

Self-Referential Structures

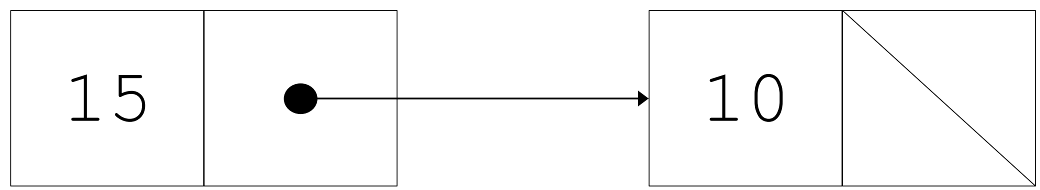
- Self-referential structures
  - Structure that contains a pointer to a structure of the same type
  - Can be linked together to form useful data structures such as lists, queues, stacks and trees
  - Terminated with a NULL pointer (**0**)

```
struct node {
   int data;
   struct node *nextPtr;
}
```

- **`nextPtr`**
  - Points to an object of type node
  - Referred to as a link
    - Ties one node to another **`node`**

Dynamic Memory Allocation

Two self-referential structures linked together



Dynamic Memory Allocation

- Dynamic memory allocation
  - Obtain and release memory during execution
- **`malloc`**
  - Takes number of bytes to allocate
    - Use **`sizeof`** to determine the size of an object
  - Returns pointer of type **`void *`**
    - A **`void *`** pointer may be assigned to any pointer
    - If no memory available, returns **`NULL`**
  - Example

```
newPtr = malloc( sizeof( struct node ) );
```

- **`free`**
  - Deallocates memory allocated by **`malloc`**
  - Takes a pointer as an argument
  - **`free ( newPtr );`**

Linked Lists

- Linked list
  - Linear collection of self-referential class objects, called nodes
  - Connected by pointer links
  - Accessed via a pointer to the first node of the list
  - Subsequent nodes are accessed via the link-pointer member of the current node
  - Link pointer in the last node is set to **`NULL`** to mark the list's end

- Use a linked list instead of an array when
  - You have an unpredictable number of data elements
  - Your list needs to be sorted quickly

Linked Lists

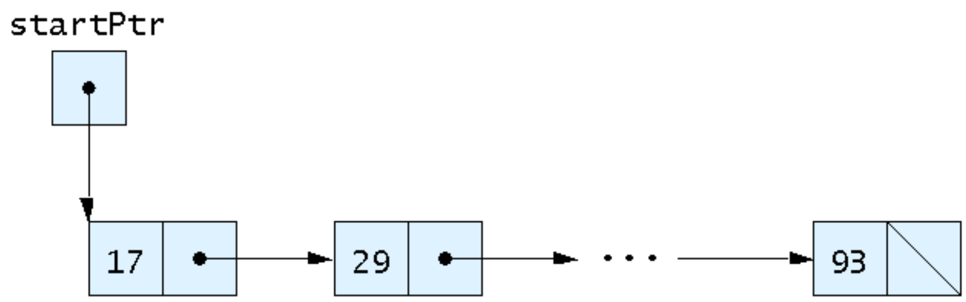


Fig. 12.2 A graphical representation of a linked list.

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

/* self-referential structure */
struct listNode {
   char data;                /* define data as char */
   struct listNode *nextPtr; /* listNode pointer */
}; /* end structure listNode */

typedef struct listNode ListNode;
typedef ListNode *ListNodePtr;

/* prototypes */
void insert( ListNodePtr *sPtr, char value );
char delete( ListNodePtr *sPtr, char value );
int isEmpty( ListNodePtr sPtr );
void printList( ListNodePtr currentPtr );
void instructions( void );
```

```
int main(){
        ListNodePtr startPtr = NULL; /* initialize startPtr */
        int choice;                     /* user's choice */
        char item;                      /* char entered by user */

        instructions(); /* display the menu */
        printf( "? " );
        scanf( "%d", &choice );

        /* loop while user does not choose 3 */
        while ( choice != 3 ) {
                switch ( choice ) {
                        case 1:
                                printf( "Enter a character: " );
                                scanf( "\n%c", &item );
                                insert( &startPtr, item );
                                printList( startPtr );
                                break;
                        case 2: ..
                        default:
                                printf( "Invalid choice.\n\n" );
                                break;
                } /* end switch */
               }
}
```

```
/* Insert a new value into the list in sorted order */
void insert( ListNodePtr *sPtr, char value )
{
      ListNodePtr newPtr;      /* pointer to new node */
      ListNodePtr previousPtr; /* pointer to previous node in
list */
      ListNodePtr currentPtr;  /* pointer to current node in
list */

      newPtr = malloc( sizeof( ListNode ) );

      if ( newPtr != NULL ) {     /* is space available */
       newPtr->data = value;
       newPtr->nextPtr = NULL;
       previousPtr = NULL;
       currentPtr = *sPtr;

       /* loop to find the correct location in the list */
       while ( currentPtr != NULL && value > currentPtr->data ) {
              previousPtr = currentPtr;          /* walk to ...   */
              currentPtr = currentPtr->nextPtr;  /* ... next node */
       } /* end while */
```

```
/* insert newPtr at beginning of list */
if ( previousPtr == NULL ) {
       newPtr->nextPtr = *sPtr;
       *sPtr = newPtr;
} /* end if */
else { /* insert newPtr between previousPtr and currentPtr */
       previousPtr->nextPtr = newPtr;
       newPtr->nextPtr = currentPtr;
} /* end else */
```

```
Enter your choice:
   1 to insert an element into the list.
   2 to delete an element from the list.
   3 to end.
? 1
Enter a character: B
The list is:
B --> NULL

? 1
Enter a character: A
The list is:
A --> B --> NULL

? 1
Enter a character: C
The list is:
A --> B --> C --> NULL
```

Linked Lists

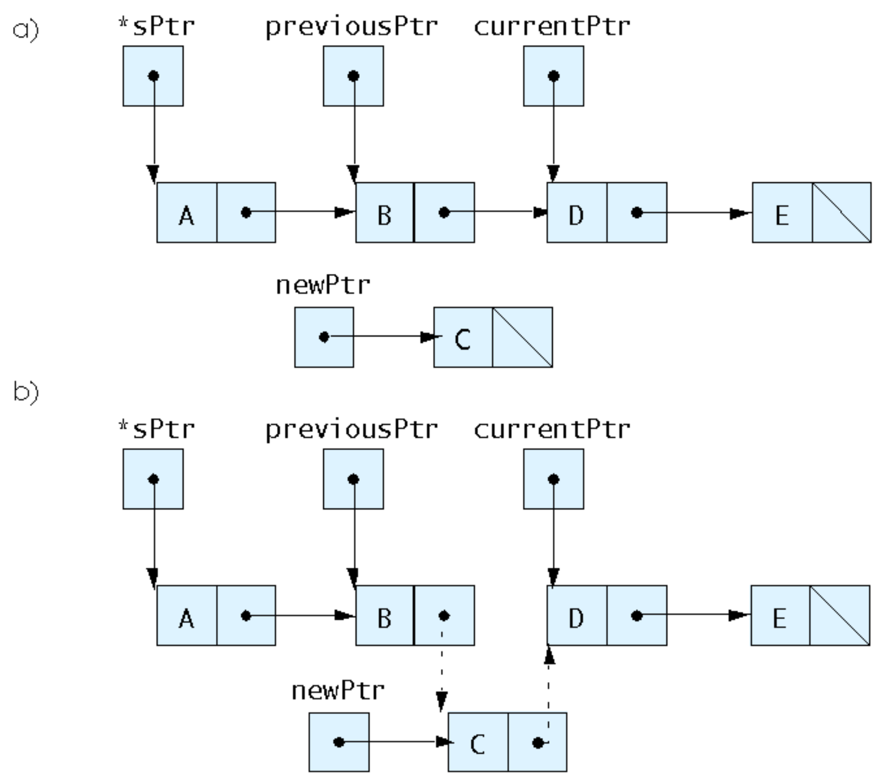


Fig. 12.5 Inserting a node in order in a list.

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Unions

- `union`
  - Memory that contains a variety of objects over time
  - Only contains one data member at a time
  - Members of a union share space
  - Conserves storage
  - Only the last data member defined can be accessed

- `union` definitions
  - Same as `struct`

```
union Number {
  int x;
  float y;
};
union Number value;
```

Unions

- Valid **`union`** operations
  - Assignment to union of same type: **`=`**
  - Taking address: **`&`**
  - Accessing union members: **`.`**
  - Accessing members using pointers: **`->`**

```
#include <stdio.h>

/* number union definition */
union number {
        int x;    /* define int x */
       double y; /* define double y */
}; /* end union number */

int main(){
        union number value; /* define union value */
        value.x = 100; /* put an integer into the union */
        printf( "%s\n%s\n%s%d\n%s%f\n\n",
       "Put a value in the integer member",  "and print both members.",
       "int:   ", value.x, "double:\n", value.y );
        value.y = 100.0; /* put a double into the same union */
        printf( "%s\n%s\n%s%d\n%s%f\n",
         "Put a value in the floating member", "and print both
members.",
               "int:   ", value.x, "double:\n", value.y );
         return 0; /* indicates successful termination */
} /* end main */
```

```
Put a value in the integer member
and print both members.
int:   100
double:
-92559592117433136000000000000000000000000000
0000000000000000000.000000

Put a value in the floating member
and print both members.
int:   0
double:
100.000000
```

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- **Enumeration Constants**

Enumeration Constants

- Enumeration
  - Set of integer constants represented by identifiers
  - Enumeration constants are like symbolic constants whose values are automatically set
    - Values start at 0 and are incremented by 1
    - Values can be set explicitly with =
    - Need unique constant names
  - Example:

```
enum Months { JAN = 1, FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP,
  OCT, NOV, DEC};
```

    - Creates a new type **`enum`** Months in which the identifiers are set to the integers 1 to 12

```c
#include <stdio.h>

/* enumeration constants represent months of the year */
enum months { JAN = 1, FEB, MAR, APR, MAY, JUN,
                  JUL, AUG, SEP, OCT, NOV, DEC };

int main()
{
      enum months month; /* can contain any of the 12 months */
      const char *monthName[] = { "", "January", "February", "March",
       "April", "May", "June", "July", "August", "September",
"October”, "November", "December" };

      for ( month = JAN; month <= DEC; month++ )
       printf( "%2d%11s\n", month, monthName[ month ] );

       return 0; /* indicates successful termination */
} /* end main */
```

1	January
2	February
3	March
4	April
5	May
6	June
7	July
8	August
9	September
10	October
11	November
12	December

Summary

- Structures
- Linked Lists
- Unions
- Enumeration Constants

Next week

- File Input and Output
- Strings