C Programming for Engineers

Data Structure & Object Oriented Programming

ICEN 200– Spring 2018

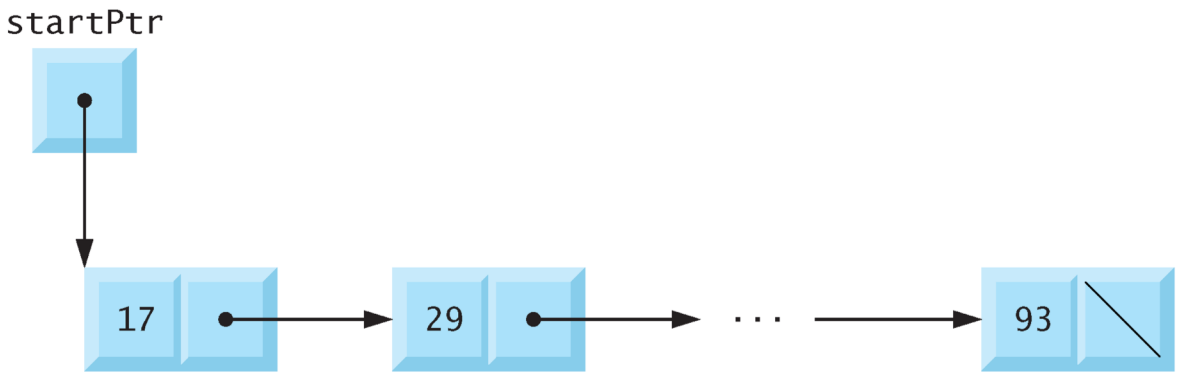
Prof. Dola Saha

Data Structures

- We've studied fixed-size data structures such as single-subscripted arrays, double-subscripted arrays and structs.
- This topic introduces dynamic data structures with sizes that grow and shrink at execution time.
  - Linked lists are collections of data items "lined up in a row"—insertions and deletions are made *anywhere* in a linked list.
  - Stacks are important in compilers and operating systems—insertions and deletions are made *only at one end* of a stack—its top.
  - Queues represent waiting lines; insertions are made *only at the back* (also referred to as the tail) of a queue and deletions are made *only from the front* (also referred to as the head) of a queue.
  - Binary trees facilitate high-speed searching and sorting of data, efficient elimination of duplicate data items, representing file system directories and compiling expressions into machine language.

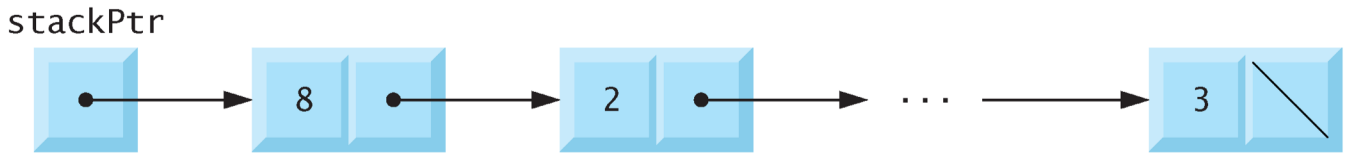
Linked List

- Linked lists are collections of data items "lined up in a row"—insertions and deletions are made *anywhere* in a linked list.
  - Linear Linked List
  - Doubly linked list
  - Circular linked list

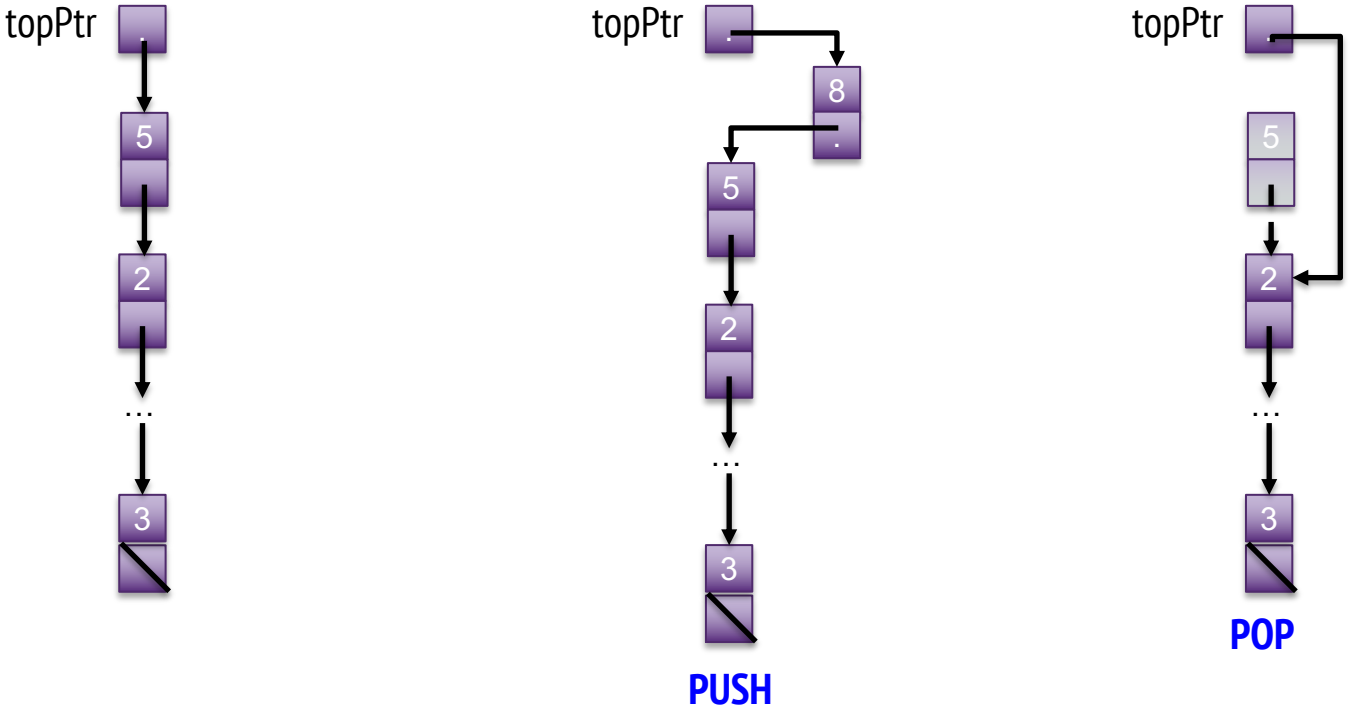


Stacks

- Stacks are important in compilers and operating systems—insertions and deletions are made *only at one end* of a stack—its top.
- Stack is referred to as LIFO (last-in-first-out).
- PUSH
- POP

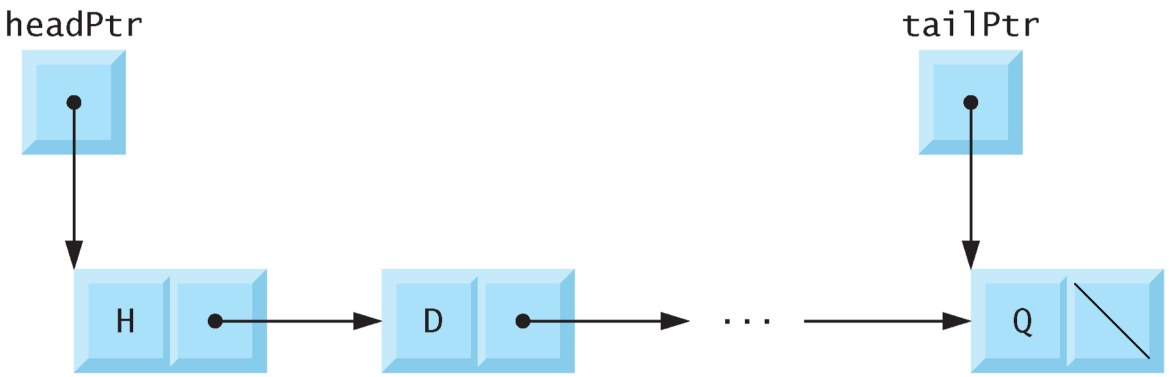


Stack – PUSH & POP



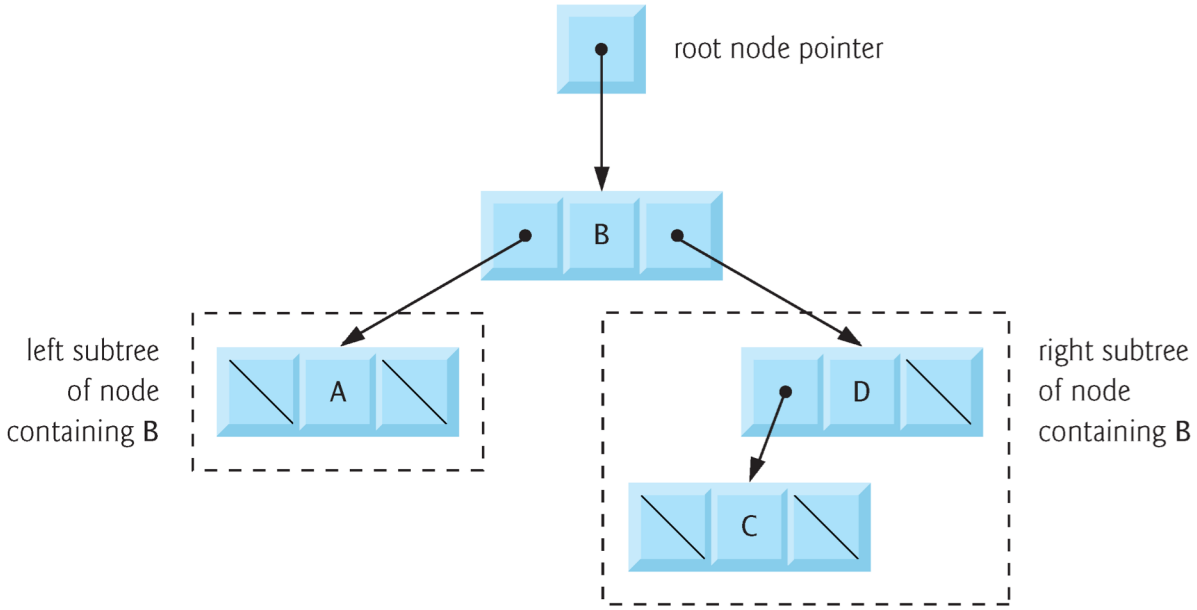
Queues

- Queues represent waiting lines; insertions are made *only at the back* (also referred to as the tail) of a queue and deletions are made *only from the front* (also referred to as the head) of a queue.
- Used in networking when packets are queued to move from one layer to another.
- Enqueue
- Dequeue



Trees

- A tree is a *nonlinear, two-dimensional data structure* with special properties.
- Tree nodes contain *two or more* links.
- Binary trees facilitate high-speed searching and sorting of data, efficient elimination of duplicate data items, representing file system directories and compiling expressions into machine language.

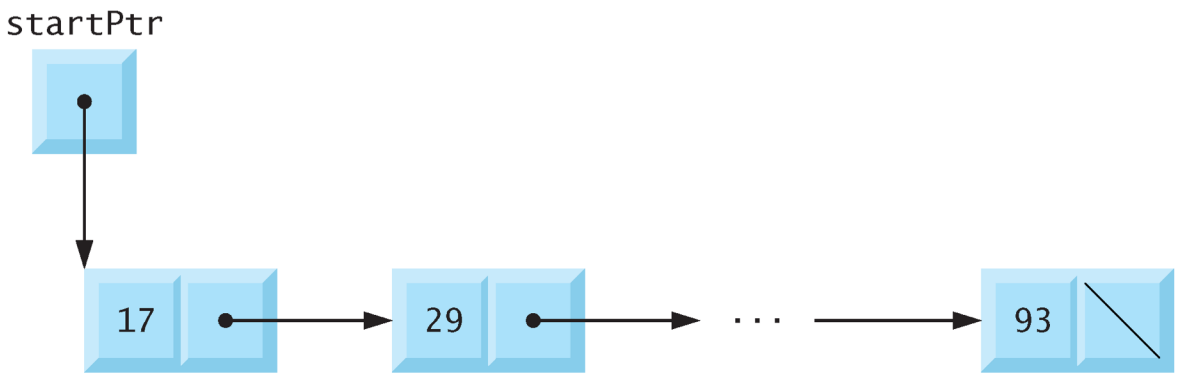


Self Referencing Structures

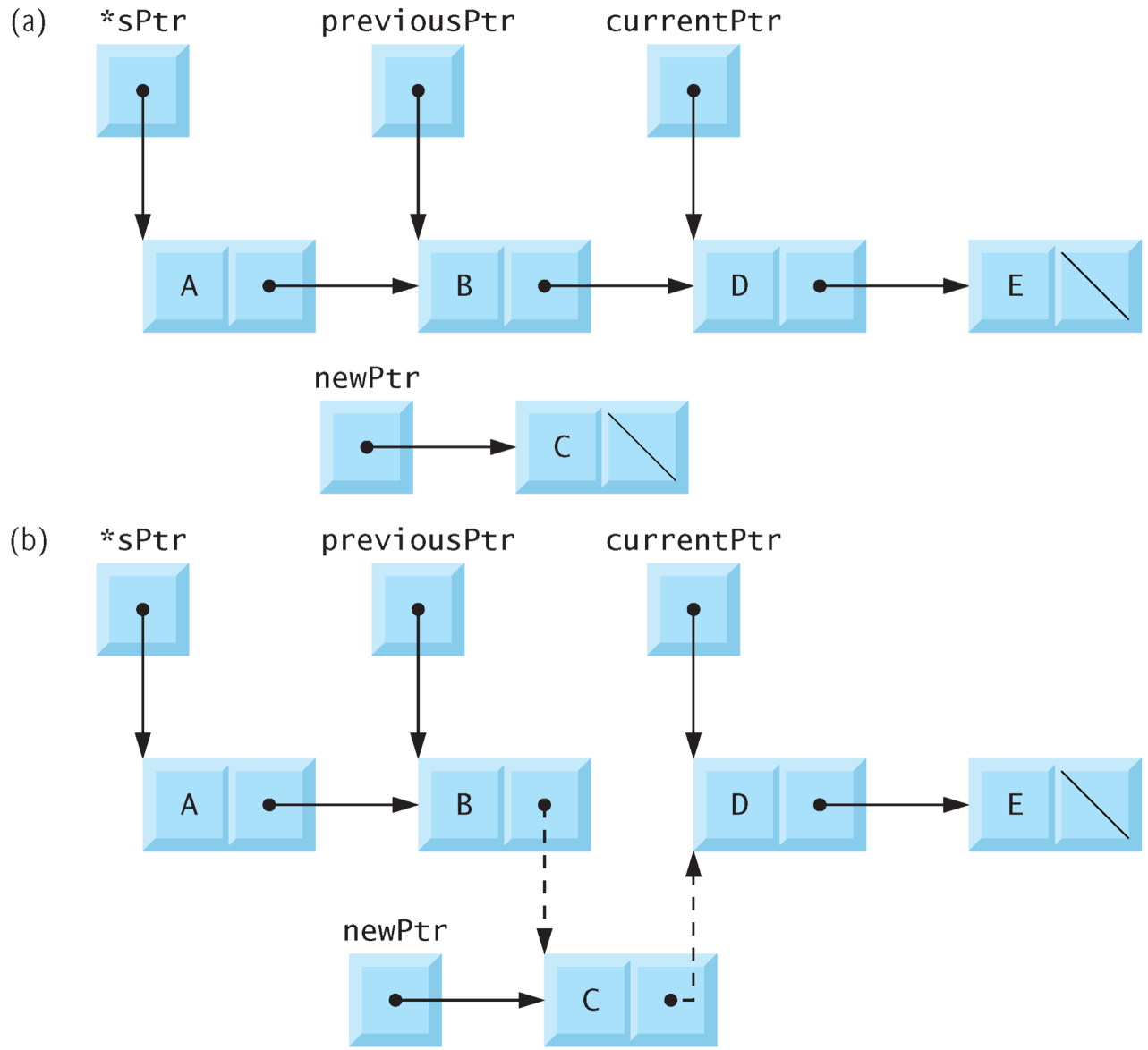
- A *self-referential structure* contains a pointer member that points to a structure of the *same* structure type.
- Example:
  - ```
    struct node {
        int data;
        struct node *nextPtr;
    };
    ```

  defines a type, `struct node`.
- A structure of type `struct node` has two members – integer member `data` and pointer member `nextPtr`.
    ```

Linked List graphical representation



Insert a node in order in a list



Insert a node – C code

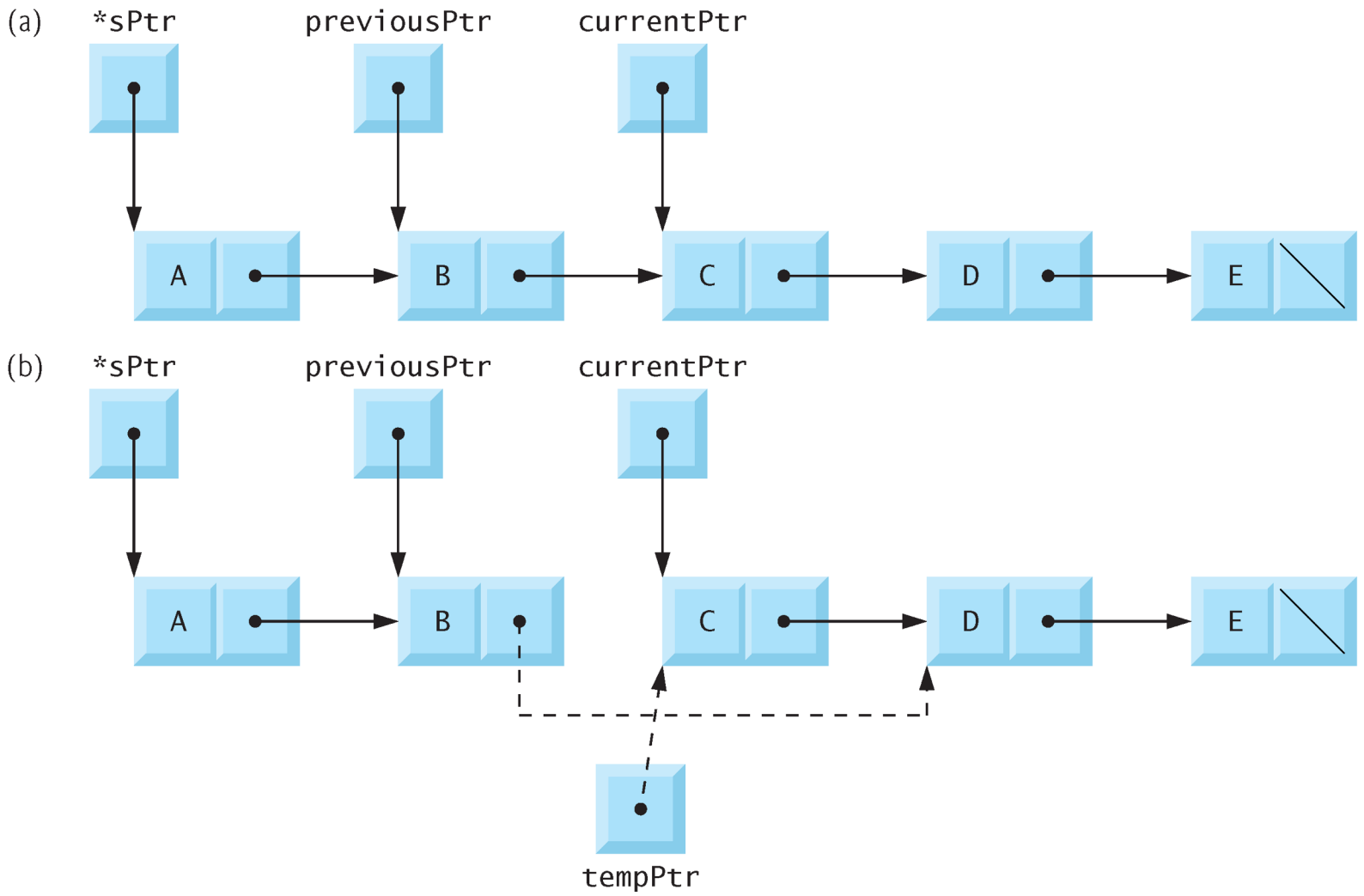
```
void insert(ListNodePtr *sPtr, char value)
{
   ListNodePtr newPtr = malloc(sizeof(ListNode)); // create node

   if (newPtr != NULL) { // is space available?
      newPtr->data = value; // place value in node
      newPtr->nextPtr = NULL; // node does not link to another node

      ListNodePtr previousPtr = NULL;
      ListNodePtr 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
      }

      // insert new node at beginning of list
      if (previousPtr == NULL) {
         newPtr->nextPtr = *sPtr;
         *sPtr = newPtr;
      }
      else { // insert new node between previousPtr and currentPtr
         previousPtr->nextPtr = newPtr;
         newPtr->nextPtr = currentPtr;
      }
   }
   else {
      printf("%c not inserted. No memory available.\n", value);
   }
}
```

Delete a node from list



Delete a node – C code

```
// delete a list element
char delete(ListNodePtr *sPtr, char value)
{
   // delete first node if a match is found
   if (value == (*sPtr)->data) {
      ListNodePtr tempPtr = *sPtr; // hold onto node being removed
      *sPtr = (*sPtr)->nextPtr; // de-thread the node
      free(tempPtr); // free the de-threaded node
      return value;
   }
   else {
      ListNodePtr previousPtr = *sPtr;
      ListNodePtr currentPtr = (*sPtr)->nextPtr;

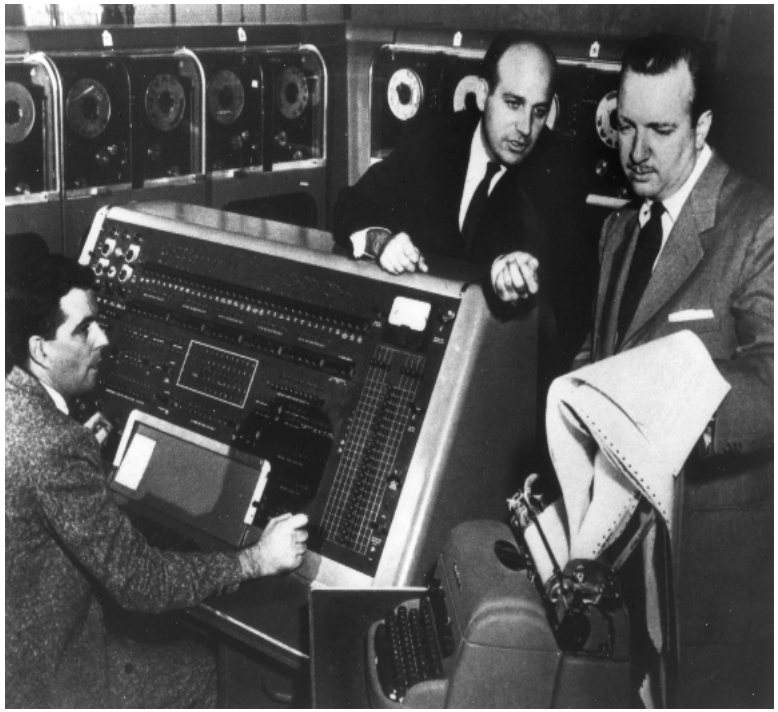
      // loop to find the correct location in the list
      while (currentPtr != NULL && currentPtr->data != value) {
         previousPtr = currentPtr; // walk to ...
         currentPtr = currentPtr->nextPtr; // ... next node
      }

      // delete node at currentPtr
      if (currentPtr != NULL) {
         ListNodePtr tempPtr = currentPtr;
         previousPtr->nextPtr = currentPtr->nextPtr;
         free(tempPtr);
         return value;
      }
   }

   return '\0';
}
```

Evolution of computers

- Early computers were far less complex than today's computers
- Modern computers are smaller, but more complex



Objects

- Computer scientists have introduced the notion of ***objects*** and ***object-oriented programming*** to help manage the growing complexity of modern computers.
- Object is anything that can be represented by data in computer's memory

Properties

- The data that represent the object are organized into a set of **properties**.
- The values stored in an object's properties at any one time form the **state** of an object.

Name:	PA 3794
Owner:	US Airlines
Location:	39 52′ 06″ N 75 13′ 52″ W
Heading:	271°
Altitude:	19 m
AirSpeed:	0
Make:	Boeing
Model:	737
Weight:	32,820 kg

Methods

- In object-oriented programming, the programs that manipulate the properties of an object are the object's **methods**.

- We can think of an object as *a collection of properties and the methods* that are used to manipulate those properties.

Class

- A ***class*** is a group of objects with the same properties and the same methods.

Class
<CAR>

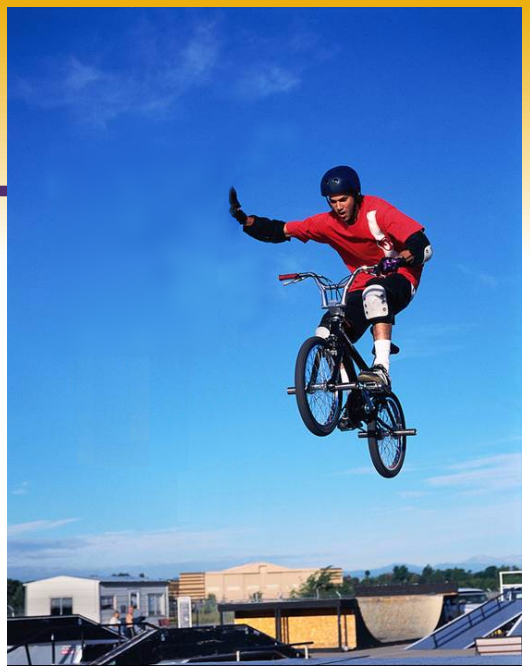
Object
<7_series_BMW>

Object
<Ford_Mustang>

Object
<VW_Beetle>

Instance

- Each copy of an object from a particular class is called an ***instance*** of the object.
- The act of creating a new instance of an object is called **instantiation.**
- Two different instances of the same class will have the **same properties, but different values** stored in those properties.



Terminology

Object

Property

The same terminology is used in most object-oriented programming languages.

Method

Instantiation

Class

Instance

State

First OOP in C++

```
1  // Fig. 3.1: fig03_01.cpp
2  // Define class GradeBook with a member function displayMessage,
3  // create a GradeBook object, and call its displayMessage function.
4  #include <iostream>
5  using namespace std;
6
7  // GradeBook class definition
8  class GradeBook
9  {
10 public:
11    // function that displays a welcome message to the GradeBook user
12    void displayMessage() const
13    {
14       cout << "Welcome to the Grade Book!" << endl;
15    } // end function displayMessage
16 }; // end class GradeBook
17
18 // function main begins program execution
19 int main()
20 {
21    GradeBook myGradeBook; // create a GradeBook object named myGradeBook
22    myGradeBook.displayMessage(); // call object's displayMessage function
23 } // end main
```

```
Welcome to the Grade Book!
```

Access Specifier: Public & Private

- Keyword public or private is an access specifier.
- Access specifiers are always followed by a colon (:)

- Public:
  - Accessible to public—that is, it can be called by other functions in the program (such as main), and by member functions / methods of other classes (if there are any).
- Private:
  - Accessible only to member functions / methods of the class for which they are declared.

Passing value

```
1  // Fig. 3.3: fig03_03.cpp
2  // Define class GradeBook with a member function that takes a parameter,
3  // create a GradeBook object and call its displayMessage function.
4  #include <iostream>
5  #include <string> // program uses C++ standard string class
6  using namespace std;
7
8  // GradeBook class definition
9  class GradeBook
10 {
11 public:
12    // function that displays a welcome message to the GradeBook user
13    void displayMessage( string courseName ) const
14    {
15       cout << "Welcome to the grade book for\n" << courseName << "!"
16          << endl;
17    } // end function displayMessage
18 }; // end class GradeBook
19
20  // function main begins program execution
21  int main()
22  {
23     string nameOfCourse; // string of characters to store the course name
24     GradeBook myGradeBook; // create a GradeBook object named myGradeBook
25
26     // prompt for and input course name
27     cout << "Please enter the course name:" << endl;
28     getline( cin, nameOfCourse ); // read a course name with blanks
29     cout << endl; // output a blank line
30
31     // call myGradeBook's displayMessage function
32     // and pass nameOfCourse as an argument
33     myGradeBook.displayMessage( nameOfCourse );
34  } // end main
```

Example object with properties & methods (1)

```
1  // Fig. 3.5: fig03_05.cpp
2  // Define class GradeBook that contains a courseName data member
3  // and member functions to set and get its value;
4  // Create and manipulate a GradeBook object with these functions.
5  #include <iostream>
6  #include <string> // program uses C++ standard string class
7  using namespace std;
8
9  // GradeBook class definition
10 class GradeBook
11 {
12 public:
13    // function that sets the course name
14    void setCourseName( string name )
15    {
16       courseName = name; // store the course name in the object
17    } // end function setCourseName
18
19    // function that gets the course name
20    string getCourseName() const
21    {
22       return courseName; // return the object's courseName
23    } // end function getCourseName
```

Example object with properties & methods (2)

```
24
25       // function that displays a welcome message
26       void displayMessage() const
27       {
28          // this statement calls getCourseName to get the
29          // name of the course this GradeBook represents
30          cout << "Welcome to the grade book for\n" << getCourseName() << "!"
31             << endl;
32       } // end function displayMessage
33    private:
34       string courseName; // course name for this GradeBook
35    }; // end class GradeBook
36
37    // function main begins program execution
38    int main()
39    {
40       string nameOfCourse; // string of characters to store the course name
41       GradeBook myGradeBook; // create a GradeBook object named myGradeBook
42
43       // display initial value of courseName
44       cout << "Initial course name is: " << myGradeBook.getCourseName()
45          << endl;
```

Example object with properties & methods (3)

```
46
47      // prompt for, input and set course name
48      cout << "\nPlease enter the course name:" << endl;
49      getline( cin, nameOfCourse ); // read a course name with blanks
50      myGradeBook.setCourseName( nameOfCourse ); // set the course name
51
52      cout << endl; // outputs a blank line
53      myGradeBook.displayMessage(); // display message with new course name
54   } // end main
```

```
Initial course name is:

Please enter the course name:
CS101 Introduction to C++ Programming

Welcome to the grade book for
CS101 Introduction to C++ Programming!
```

Constructor and Destructor

- A **constructor** is a special function that gets called automatically when the object of a class is created.

- A **destructor** is a special function that gets called automatically when an object is deleted.

Constructor Example

```
1  // Fig. 3.7: fig03_07.cpp
2  // Instantiating multiple objects of the GradeBook class and using
3  // the GradeBook constructor to specify the course name
4  // when each GradeBook object is created.
5  #include <iostream>
6  #include <string> // program uses C++ standard string class
7  using namespace std;
8
9  // GradeBook class definition
10 class GradeBook
11 {
12 public:
13    // constructor initializes courseName with string supplied as argument
14    explicit GradeBook( string name )
15       : courseName( name ) // member initializer to initialize courseName
16    {
17       // empty body
18    } // end GradeBook constructor
19
```

Constructor Example

```
20      // function to set the course name
21      void setCourseName( string name )
22      {
23         courseName = name; // store the course name in the object
24      } // end function setCourseName
25
26      // function to get the course name
27      string getCourseName() const
28      {
29         return courseName; // return object's courseName
30      } // end function getCourseName
31
32      // display a welcome message to the GradeBook user
33      void displayMessage() const
34      {
35         // call getCourseName to get the courseName
36         cout << "Welcome to the grade book for\n" << getCourseName()
37            << "!" << endl;
38      } // end function displayMessage
```

Constructor Example

```
39   private:
40      string courseName; // course name for this GradeBook
41   }; // end class GradeBook
42
43   // function main begins program execution
44   int main()
45   {
46      // create two GradeBook objects
47      GradeBook gradeBook1( "CS101 Introduction to C++ Programming" );
48      GradeBook gradeBook2( "CS102 Data Structures in C++" );
49
50      // display initial value of courseName for each GradeBook
51      cout << "gradeBook1 created for course: " << gradeBook1.getCourseName()
52         << "\ngradeBook2 created for course: " << gradeBook2.getCourseName()
53         << endl;
54   } // end main
```

```
gradeBook1 created for course: CS101 Introduction to C++ Programming
gradeBook2 created for course: CS102 Data Structures in C++
```

Separate Function definition & declaration

```
#include <string> // program uses C++ standard string class
#include <iostream>
using namespace std;

// GradeBook class definition
class GradeBook
{
public:
   // constructor initializes course name and instructor name
   GradeBook( std::string, std::string );
   void setCourseName( std::string ); // function to set the course name
   std::string getCourseName(); // function to retrieve the course name
   void setInstructorName( std::string ); // function to set instructor name
   std::string getInstructorName(); // function to retrieve instructor name
   void displayMessage(); // display welcome message and instructor name
private:
   std::string courseName; // course name for this GradeBook
   std::string instructorName; // instructor name for this GradeBook
}; // end class GradeBook
```

Separate Function definition & declaration

```
// constructor initializes courseName and instructorName
// with strings supplied as arguments
GradeBook::GradeBook( string course, string instructor )
{
   setCourseName( course ); // initializes courseName
   setInstructorName( instructor ); // initializes instructorName
} // end GradeBook constructor

// function to set the course name
void GradeBook::setCourseName( string name )
{
   courseName = name; // store the course name
} // end function setCourseName

// function to retrieve the course name
string GradeBook::getCourseName()
{
   return courseName;
} // end function getCourseName

// function to set the instructor name
void GradeBook::setInstructorName( string name )
{
   instructorName = name; // store the instructor name
} // end function setInstructorName

// function to retrieve the instructor name
string GradeBook::getInstructorName()
{
   return instructorName;
} // end function getInstructorName

// display a welcome message and the instructor's name
void GradeBook::displayMessage()
{
   // display a welcome message containing the course name
   cout << "Welcome to the grade book for\n" << getCourseName() << "!"
      << endl;

   // display the instructor's name
   cout << "This course is presented by: " << getInstructorName() << endl;
} // end function displayMessage
```

Separate Function definition & declaration

```
// function main begins program execution
int main()
{
   // create a GradeBook object; pass a course name and instructor name
   GradeBook gradeBook(
      "CS101 Introduction to C++ Programming", "Professor Smith" );

   // display initial value of instructorName of GradeBook object
   cout << "gradeBook instructor name is: "
      << gradeBook.getInstructorName() << "\n\n";

   // modify the instructorName using set function
   gradeBook.setInstructorName( "Assistant Professor Bates" );

   // display new value of instructorName
   cout << "new gradeBook instructor name is: "
      << gradeBook.getInstructorName() << "\n\n";

   // display welcome message and instructor's name
   gradeBook.displayMessage();
} // end main
```