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Structures

Why Learning Structures

1. Arrays are used to store a collection of unrelated data items of the same data type.
2. C also provides a **data type** called *structure* that stores a collection of data items of different data types as a group. The individual components of a structure can be any valid data types.
3. In this chapter, we describe the **struct** data type.

Structures

- **Structure Declaration, Initialization and Operations**
- Arrays of Structures and Nested Structures
- Pointers to Structures
- Functions and Structures
- The typedef Construct

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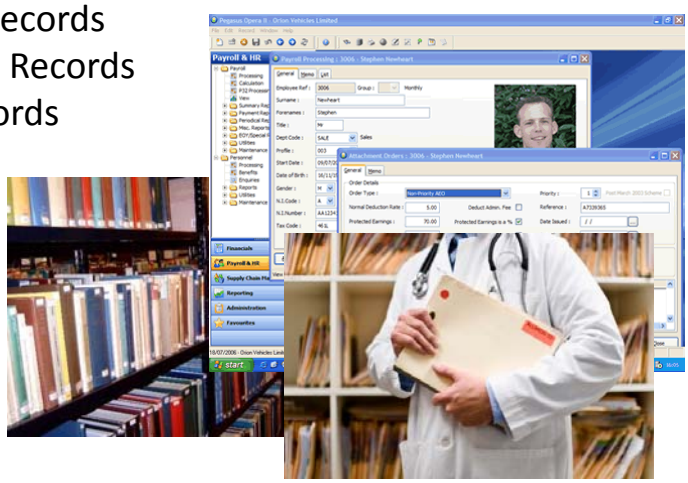
Structures

1. Here, we discuss structure declaration, initialization and operations.

Records

- Medical Records
- Employee Records
- Book Records
- Etc.



Note: Records usually contain data of **different types**.

Records

1. Records are used to keep related information of an object together.
2. There are many examples of records such as medical records, book records, employee records, etc.
3. Structure is similar to record in that it is used to keep related data together as a data type.

Structures

- Structure: an **aggregate** of **values**, components are **distinct**, and may possibly have different types.
- For example, a **record** about a book in a library may contain, i.e. book record:
  - **char** title[40];
  - **char** author[20];
  - **float** value;

[Note: may have **different** data types]

- Two steps in order to use a structure:
  1. Define a **structure template** (similar to a data type).
  2. Declare a **variable** on the structure template.

Structures

1. Structure is an aggregate of values. Their components are distinct, and may possibly have different types, including arrays and other structures.
2. For example, a book record may contain the title, author and book value.
3. We can create a **structure template**, which can be defined as a **data type** with different data members, to specify the book record. It tells the compiler the various components of a book record that make up the structure.
4. **Structure variables** can then be declared with the type of the structure.
5. Therefore, to use structure in a program, there are two steps:
   - Define a structure template (or data type).
   - Declare a variable based on the structure data type.

Defining a Structure Template

- A **structure template** is the master plan that describes how a structure is put together. To set up a structure template, e.g.

```
struct book {              /*template of book*/
  char title[40];
  char author[20];         /* members */
  float value;
};
```

  - **struct**: reserved keyword to introduce a structure
  - **book**: an **optional** **tag name** which follows the keyword struct to name the structure declared.
  - **title, author, value**: the **member** of the structure book.

- Note - The above declaration just declares a template, not a variable. **No memory space** is allocated.

Defining a Structure Template

1. A structure template (or data type) is the master plan that describes how a structure is put together.
2. A structure template can be set up as shown in **struct book**:

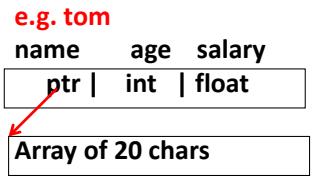
```
struct book {          /* struct book defines the template of book*/
    char title[40];    /* title, author, value are members of the structure */
    char author[20];
    float value;
};                     /* semicolon to end the definition */
```

2. The word **struct** is a reserved keyword to introduce a structure. The name **book** is an optional tag name that follows the keyword **struct** to name the structure declared. The **title**, **author** and **value** are the *members* of the structure **book**.
3. The members of a structure can be any of the valid C data types.
4. A semicolon after the closing brace ends the definition of the structure definition.
5. The declaration declares a template (or data type), not a variable. Therefore, no memory space is allocated. It only acts as a template for the named structure type. The tag name **book** can then be used for the declaration of variables.

Declaring Structure Variable: with Tag Name

- **With tag name**: separate the definition of structure template from the definition of structure variable.

```
struct person {
   char name[20];
   int age;
   float salary;
};
```




```
struct person tom, mary;
```

- With tag name – we can use the structure type subsequently in the program.

Declaring Structure Variable: with Tag Name

1. The structure name or tag is optional.
2. With structure tag, the definition of structure template can be separated from the definition of structure variables. As shown in the declaration **struct person**, a structure template **person** comprising three components **name**, **age** and **salary** is created.
2. **tom** and **mary** are two structure variables which are declared using the structure **person**.
3. With tag name, we can use the structure data type subsequently in the program.

Declaring Structure Variable: without Tag Name

- **Without tag name**: combine the definition of structure template with that of structure variable.

```
struct {
   char name[20];
   int age;
   float salary;
} tom, mary;
```

/* no tag – person is not used */

- Without tag name – we cannot use the structure type elsewhere in the program.

Declaring Structure Variable: without Tag Name

1. Without structure tag, the definition of structure template must be combined with that of structure variables.
2. As shown in the structure declaration, a structure template is created with three components: **name**, **age** and **salary**.
3. The variables **tom** and **mary** are then defined using this structure.
4. Without structure tag name, we cannot use the structure elsewhere in the program.
5. It is always a good idea to include a structure tag when defining a structure.

Accessing Structure Members

- The notation required to reference the members of a structure is

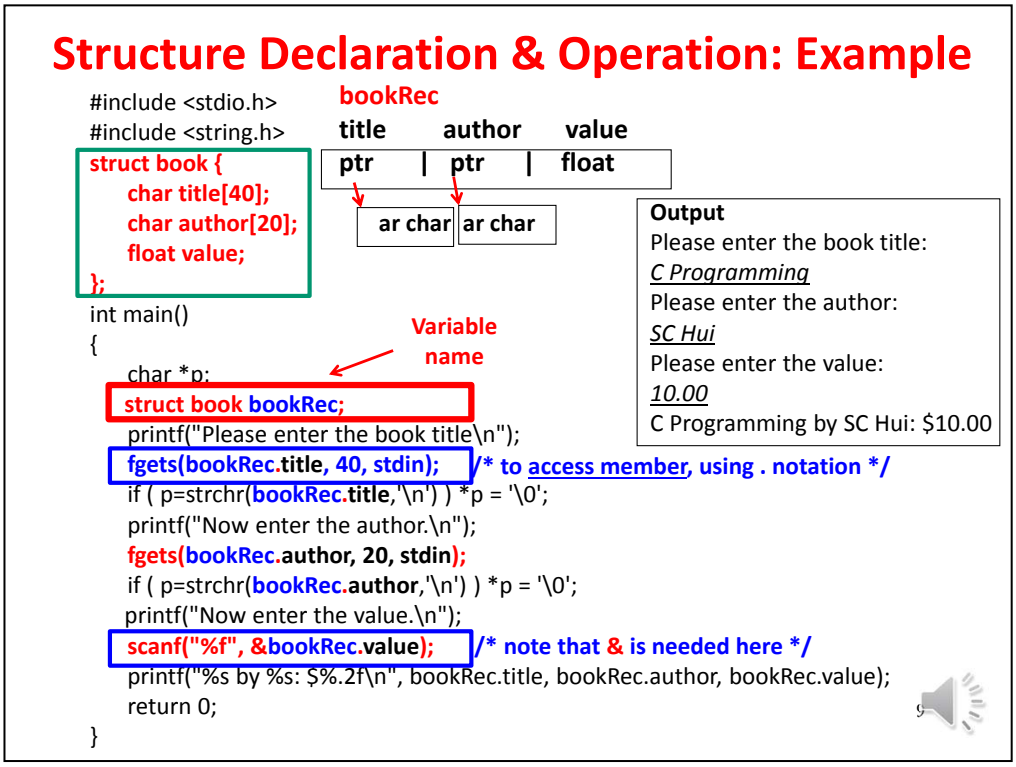
  structureVariableName.memberName

- The "**.**" (dot notation) is a member access operator known as the **member operator.**

- For example, to access the member **age** of the variable **tom** from the struct person, we have **tom.age**.

Accessing Structure Members

1. The notation required to access a member of a structure is **structureVariableName.memberName**
2. The "**.**" is an access operator known as the **member operator**. The member operator has the highest (or equal) priority among the operators in the operator precedence table.
3. For example, to access the member **age** of the variable **tom** from the structure **person**, we have **tom.age**



Structure Declaration and Operation: Example

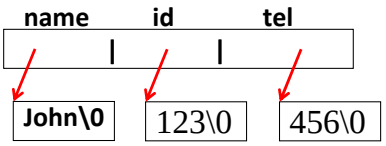
1. In the program, it defines the structure template (or data type) **book** and the declaration of a structure variable **bookRec**.
2. The structure definition can be placed inside a function or outside a function. If it is defined inside the function, the definition can only be used by that function.
3. In the program, the structure template **struct book** is defined outside the **main()** function. It is a global declaration, and all the functions following the definition can use the template.
4. In the **main()** function, it declares a variable **bookRec** of type **struct book**. The storage space is then allocated for the variable.
5. The **fgets()** function is used to read the user input on title and author which are character strings: To access a member of a structure, we use the dot notation such as **bookRec.title** and **bookRec.author**.
5. The **scanf()** statement **scanf("%f", &bookRec.value);** will read the user input on book value which is of data type **float**.
6. After reading the user input, the book title, author and book value will be printed on the screen.

Structure Variable: Initialization

- Syntax for initializing structure variable is similar to that for initializing array variable.
- When there are **insufficient** values assigned to all members of the structure, remaining members are assigned zero by default.
- Initialization of variables can only be performed with **constant values** or **constant expressions** which deliver a value of the required type.

```
struct personTag{
        char    name[20];
        char    id[20];
        char    tel[20];
}student = {"John", "123", "456"};

printf("%s %s %s\n", student.name, student.id, student.tel);
```



using . notation

Output
John 123 456

Structure Variable: Initialization

1. The syntax for initializing structures is similar to that of initializing arrays. When there are insufficient values to be assigned to all members of the structure, the remaining members are assigned to zero by default.
2. The structure variable **student** is declared, and followed by an assignment symbol and a list of values defined within braces: **student = {"John", "123", "456"};**
3. Initialization of variables can only be performed with constant values or constant expressions that deliver a value of the required type. The initial values are assigned to the individual members of the structure in the order in which the members occur. The **name** member of **student** is assigned with "**John**", the **id** member is assigned with **"123"**, and the **tel** member is assigned with **"456"**.
4. The **printf()** statement prints the data of the structure variable **student** using dot notation to access the member of structure: **student.name, student.id, student.tel**.

Structure Assignment

- The values in one structure can be assigned to another:

```
struct personTag newmember;
newmember = student;
```

- This has the effect of copying the entire contents of the structure variable **student** to the structure variable **newmember**. Each member of the **newmember** variable is assigned with the value of the corresponding member in the **student** variable.

Analogy (using primitive data type):

```
int num=10;
int member;
member = num;
```

Structure Assignment

1. The value of one structure variable can be assigned to another structure variable of the same type using the assignment operator.
2. First, we define a new variable **newmember** under the data type **struct personTag**: **struct personTag newmember;**
3. Then, we can assign the **struct personTag** variable **student** to **newmember**: **newmember = student;**
4. This has the effect of copying the entire contents of the structure variable **student** to the structure variable **newmember**. Each member of the **newmember** variable is assigned with the value of the corresponding member in the **student** variable.
5. The structure assignment operation is similar to primitive variable assignment operation.

Structures

- Structure Declaration, Initialization and Operations
- **Arrays of Structures and Nested Structures**
- Pointers to Structures
- Functions and Structures
- The typedef Construct

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Structures

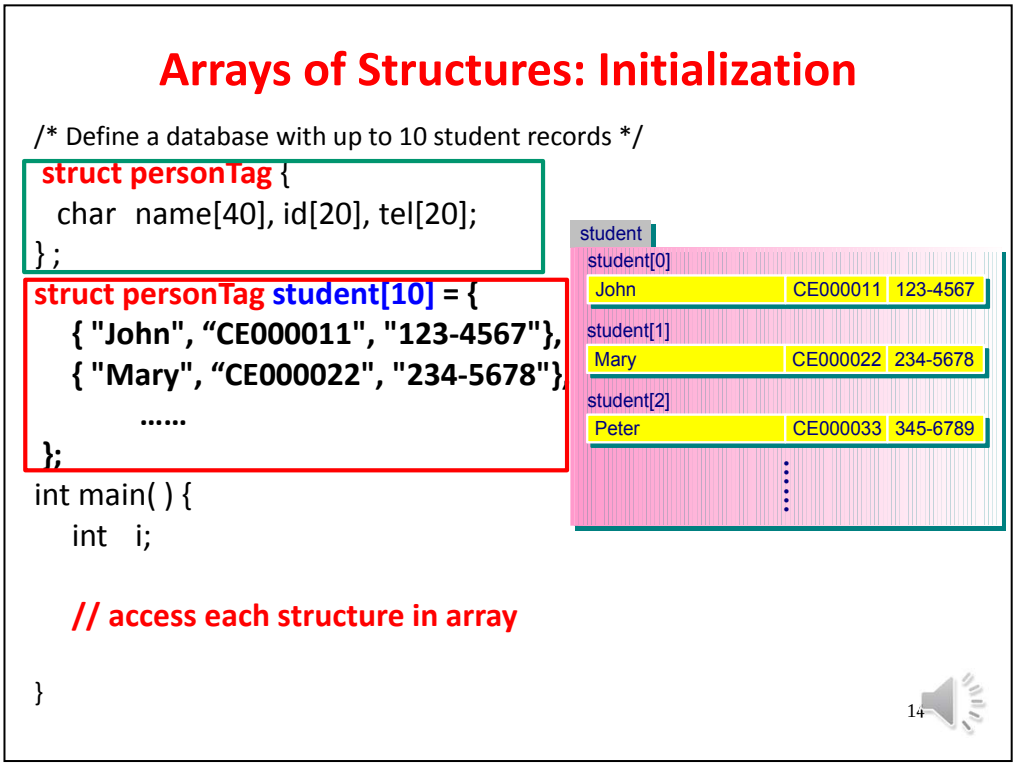
1. Here, we discuss arrays of structures and nested structures.

Arrays of Structures

- **Record -** A structure variable can be seen as a record, e.g. the structure variable **student** in the previous example is a student record with the information of a student name, id, tel, ...
- **Database -** When structure variables of the same type are grouped together, we have a database of that structure type.
- **Array of Structures** - One can create a database by defining an **array** of certain structure type.

Arrays of Structures

1. A structure variable can be seen as a **record**. For example, the structure variable **student** is a student record with the information of a student name, identity and telephone number.
2. When structure variables of the same type are grouped together, we can form a **database** of that structure type.
3. Therefore, we can create a database by defining an **array of structures**.



Arrays of Structures: Initialization

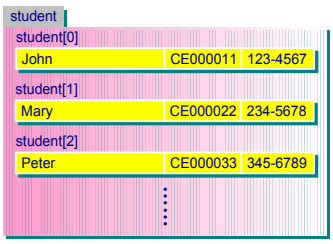
1. In the program, the variable **student** defines an array of structures, which is a database of student records.
2. Each element of the array is of **struct personTag**. It means each array element contains three members, namely **name**, **id** and **telephone**, of the structure.
3. The syntax for declaring an array of structures is **struct personTag student[10];** where it starts with the keyword **struct** and followed by the name of the structure **personTag** that identifies the data type. This is then followed by the name of the array, **student**. The values specified within the square brackets specify the total number of elements in the array.
4. Array of structures can be initialized as shown. The initializers for each element are enclosed in braces, and each member is separated by a comma. An example is given as follows:

```
struct personTag student[10] = {
    {"John", "CE000011", "123-4567"},    /* for student[0] */
    {"Mary", "CE000022", "234-5678"},    /* for student[1] */
    {"Peter", "CE000033", "345-6789"},   /* for student[2] */
    …
};
```

Arrays of Structures: Operation

```
/* Define a database with up to 10 student records */
struct personTag {
  char  name[40], id[20], tel[20];
} ;
struct personTag student[10] = {
   { "John", "CE000011", "123-4567"},
   { "Mary", "CE000022", "234-5678"},
        ……
};
int main( ) {
   int   i;
   for (i=0; i<10; i++)
        printf("Name: %s,  ID: %s, Tel: %s\n",
           student[i].name, student[i].id, student[i].tel);
}
```

using array index and . operator



Output

Name: John ID: CE000011 Tel: 123-4567
Name: Mary ID: CE000022
Tel: 234-5678

Arrays of Structures: Operation

1. Array index is used when accessing individual elements of an array of structures.
2. We use **student[i]** to denote the $(i+1)^{th}$ record. The first element starts with index 0.
3. To access a member of a specific element, we use **student[i].name** which denotes a member of the $(i+1)^{th}$ record.
4. Therefore, to access each array element, we use a **for** loop to traverse the array.
5. The array index is used to traverse the array, and the member (or dot) operator is used to access each member of the structure in the array element (e.g. **student[i].name, student[i].id, student[i].tel**).

Nested Structures

- A structure can also be **included** in other structures.
- For example, to keep track of the course history of a student, one can use a structure (**without** any nested structures) such as:

```
struct studentTag { // without any nested structures
    char name[40];
    char id[20];                                   (1) Student information
    char tel[20];
    int   SC101Yr;  /* the year when SC101 is taken * /
    int   SC101Sr;  /* the semester when SC101 is taken */     (2) Course: SC101
    char SC101Grade;  /* the grade obtained for SC101 */
    int   SC102Yr;  /* the year when SC102 is taken */
    int   SC102Sr;  /* the semester when SC102 is taken */     (3) Course: SC102
    char SC102Grade;  /* the grade obtained for SC102 */
};
struct studentTag student[1000];
  // student – array of 1000 student records
```

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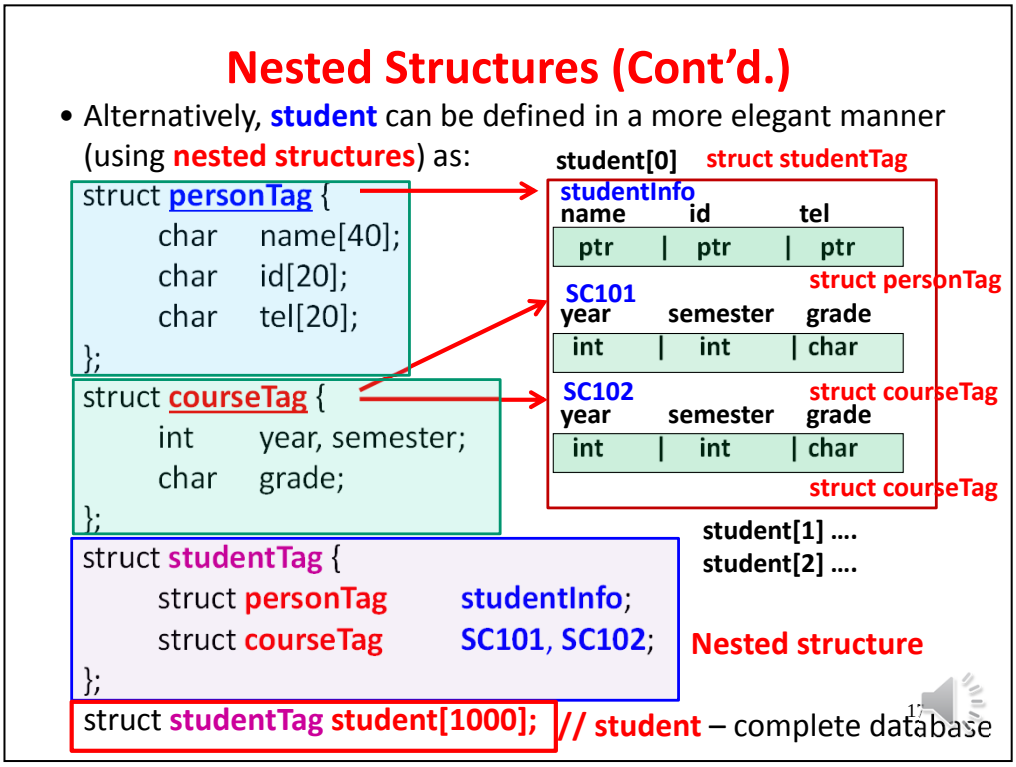
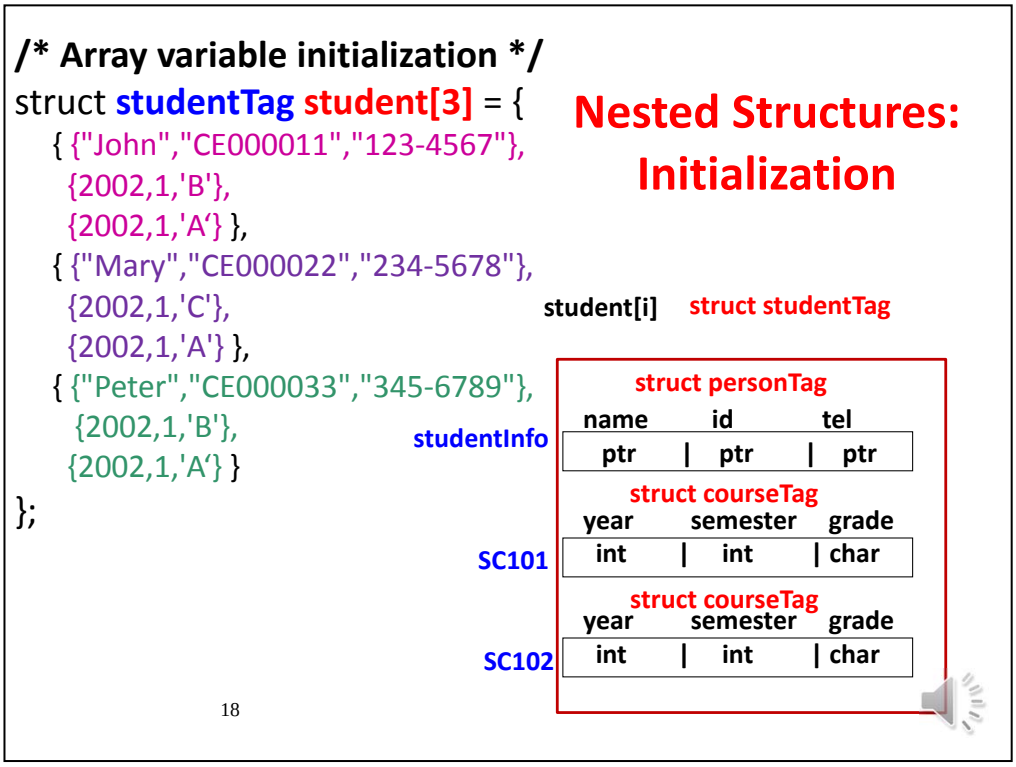
Nested Structures

1. In nested structures, a structure can also be included in other structures.
2. For example, to keep track of the course history of a student, one can define a structure (without any nested structures) as shown in **struct studentTag**:
2. In the structure template definition **struct studentTag**, the members are student information including **name**, **id** and **tel**. In addition, it also includes the courses (i.e. SC101 and SC102) that are taken by the student.
3. Once the **struct studentTag** is defined, an array variable **student** of 1000 elements of type **struct studentTag** is created.



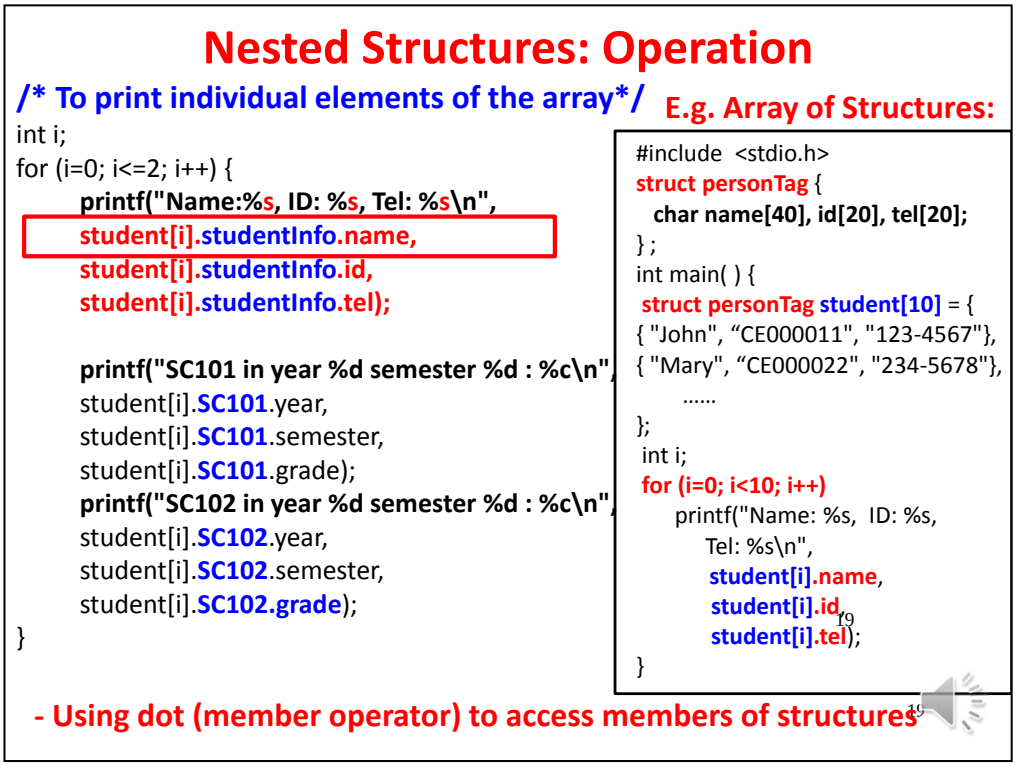
Nested Structures

1. Alternatively, the variable **student** can be defined in a more elegant manner using nested structures.
2. We create a structure template called **personTag** to contain the student information which has three members, namely **name**, **id** and **tel**, of array of characters.
3. We also create a structure template called **courseTag** to contain the course information which has three members, namely **year** and **semester** of type **int**, and **grade** of type **char.**
4. Then, we define the nested structure **studentTag** which has three members:
   - **studentInfo** which is a structure of **personTag**;
   - **SC101** and **SC102** which are structures of **courseTag**.
7. Note that the structure definition of **personTag** and **courseTag** must appear before the definition of structure **studentTag**.



Nested Structures: Initialization

1. In this program, after defining the nested structure **studentTag** and the array of structures variable **student**, we initialize the variable **student** with initial data.
2. The initialization is very similar to that of initializing multi-dimensional arrays.

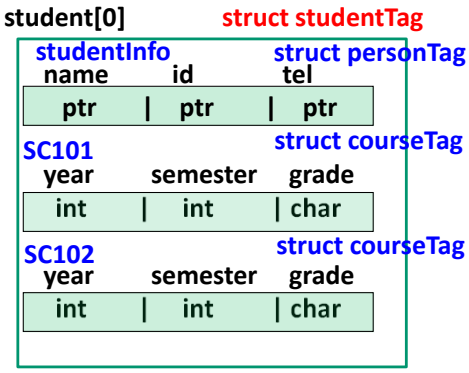


Nested Structures: Operation

1. To access each array element, we use a **for** loop to traverse the array.
2. The array notation and member operator are used for accessing each array element and structure member. The data can then be processed and printed on the screen.

Nested Structures: Notations

- **student[i]** denotes the *i+1*th array record. It consists of three members: studentInfo, SC101, SC102.
- **student[i].studentInfo** denotes the personal information in the *i+1*th record. It conssits of three members: name, id, tel.
- **student[i].studentInfo.name** denotes the student name in this record.
- **student[i].studentInfo.name[j]** denotes a single character value.
- **student[i].SC101, student[i].SC102** denote the course information in the *i+1*th record. Each consists of three members: year, semester, grade.



Nested Structures: Notations

1. In the nested structure variable **student**, we note the following notations:
   - **student**, which denotes the complete array (i.e. the database);
   - **student[i]**, which denotes the $(i+1)^{th}$ record;
   - **student[i].studentInfo**, which denotes the personal information in the $(i+1)^{th}$ record;
   - **student[i].studentInfo.name**, which denotes the student name in the $(i+1)^{th}$ record; and
   - **student[i].studentInfo.name[j]**, which denotes a single character value in the $(i+1)^{th}$ record.

Structures

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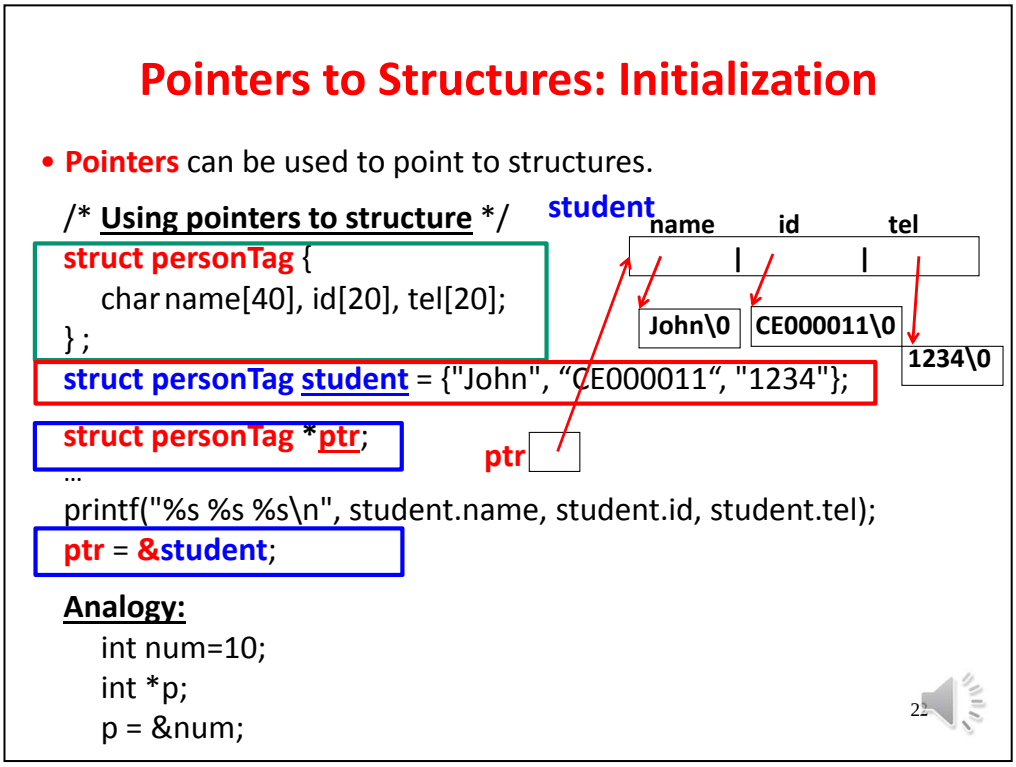
Structures

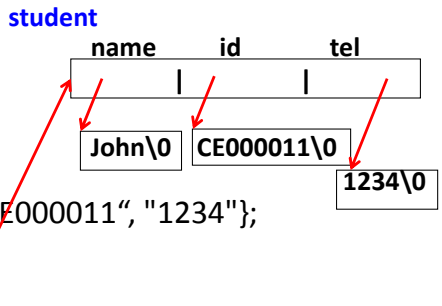
1. Here, we discuss pointers to structures.



Pointers to Structures: Initialization

1. Pointers can be used to point to structures.
2. The variable **student** of **struct personTag** is declared with initialization: **struct personTag student={"John","CE011","1234"};**
2. Next, we create a pointer **ptr** to the structure **personTag**: **struct personTag *ptr;**
3. Then, we use the address operator (**&**) to obtain the address of a structure variable, and then assign the address to the pointer: **ptr = &student;**
4. As such, we can use the pointer variable **ptr** to access the contents in the structure variable **student**.

Pointers to Structures: Operation




```
/* Using pointers to structure */
struct personTag {
    char name[40], id[20], tel[20];
} ;
struct personTag student = {"John", "CE000011", "1234"};
struct personTag *ptr;
...
printf("%s %s %s\n", student.name, student.id, student.tel);
ptr = &student;

printf("%s %s %s\n", (*ptr).name, (*ptr).id, (*ptr).tel );

/* Why is the round brackets around *ptr needed?
  – op precedence */
```

Pointers to Structures: Operation

1. The **indirection operator** (*****) can be used to access a member of a structure via a pointer to the structure.
2. Since **ptr** points to the structure **student**, the notations **(*ptr).name**, **(*ptr).id** and **(*ptr).tel**, return the value of the member **name**, **id** and **tel** of **student** respectively.
3. Note that the parentheses are necessary to enclose ***ptr** as the member operator (**.**) has higher operator precedence than the indirection operator (*****).

Pointers to Structures: Operation (Cont'd.)

printf("%s %s %s\n", **(*ptr).name**, (*ptr).id, (*ptr).tel);

Or it can also be written as:

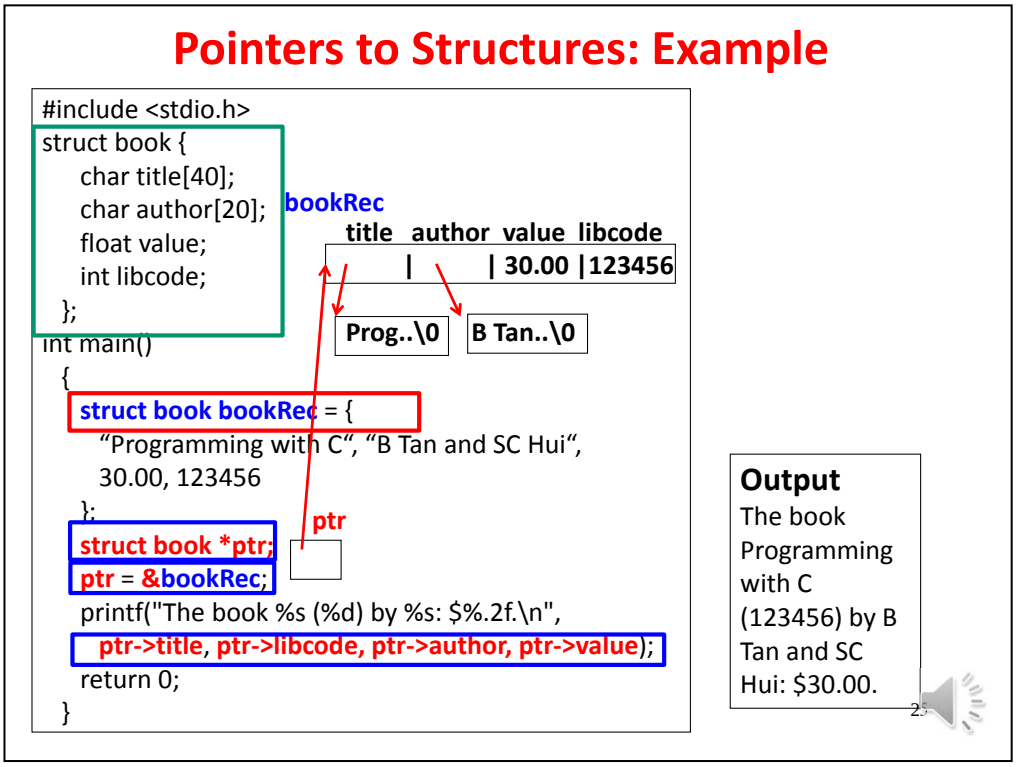
printf("%s %s %s\n", **ptr->name**, **ptr->id**, **ptr->tel**);

Note

- The operator **->** is called the **structure pointer operator** reserved for a pointer pointing to a structure.
- Less typing is needed if one compares **ptr->tel** to **(*ptr).tel**.
- It is quite common to use the structure pointer operator (**->**) instead of the indirection operator (*****) in pointers to structures.

Pointers to Structures: Operation

1. Since dereferencing is very common in pointer to structure, C provides an operator called the **structure pointer operator** (**->**) for a pointer pointing to a structure. There is no whitespace between the symbols (**-**) and (**>**).
2. We can use the notations **ptr->name**, **ptr->id** and **ptr->tel** to obtain the values of the members of the structure **student**.
3. It takes less typing when **ptr->tel** is compared with **(*ptr).tel**, though they have exactly the same meaning.
4. It is quite common to use the structure pointer operator (**->**) instead of the indirection operator (*****) in pointers to structures.



Pointers to Structures: Example

1. We can use the structure variable to access each member of the structure. We can also use pointer variable to access each member of the structure.
2. In the program, we define a structure called **book** with four members: **title**, **author**, **value** and **libcode**.
3. After that, we define a structure variable called **bookRec**, and initialize it with values.
4. We then define the pointer variable **ptr** to the **struct book** type: **struct book *ptr;**
5. We assign the address of the structure variable **bookRec** to the pointer variable **ptr**: **ptr = &bookRec;** Therefore, the pointer variable contains the address of **bookRec**.
6. As a result, we may access the members of **bookRec** via **ptr**.
7. In the **printf()** statement, it uses structure pointer operator to access each individual member of the **bookRec** structure and prints each member information of **bookRec**.

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- **Functions and Structures**
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Structures

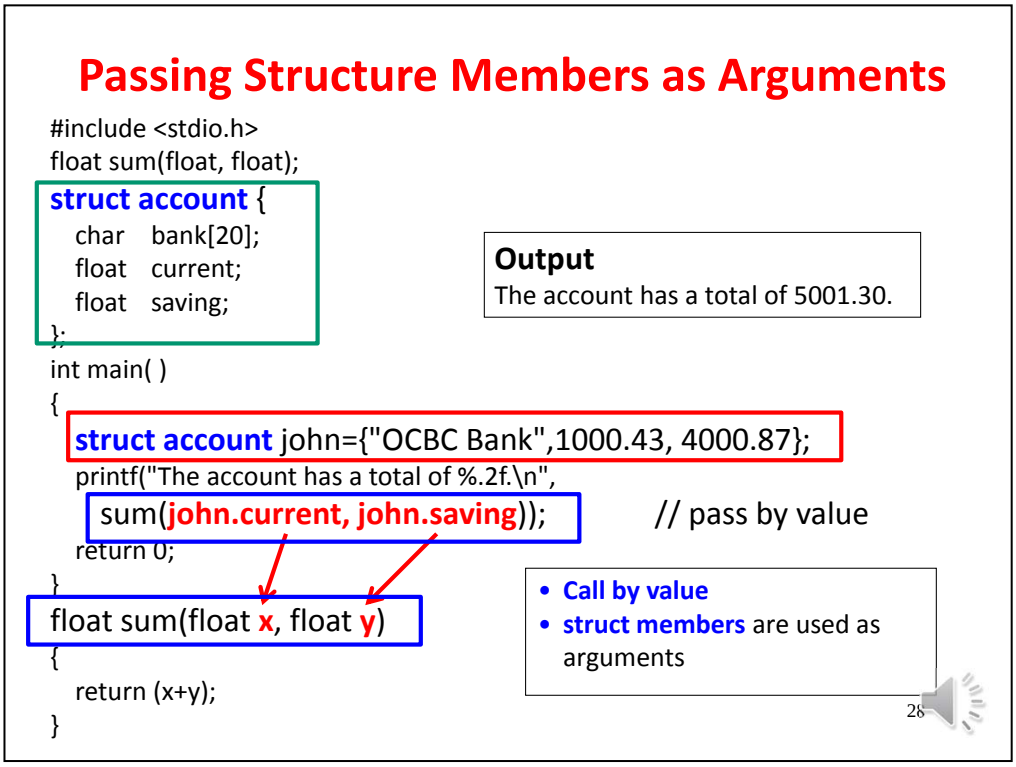
1. Here, we discuss functions and structures.

Functions and Structures

- **Four** ways to pass structure information to a function:
  1. Passing **structure members** as arguments using call by value, or call by reference;
  2. Passing **structures** as arguments;
  3. Passing **pointers to structures** as arguments; and
  4. Passing by **returning structures**.
- Basically, parameter passing between functions using structure is **similar** to other basic data types such as int, float, etc.

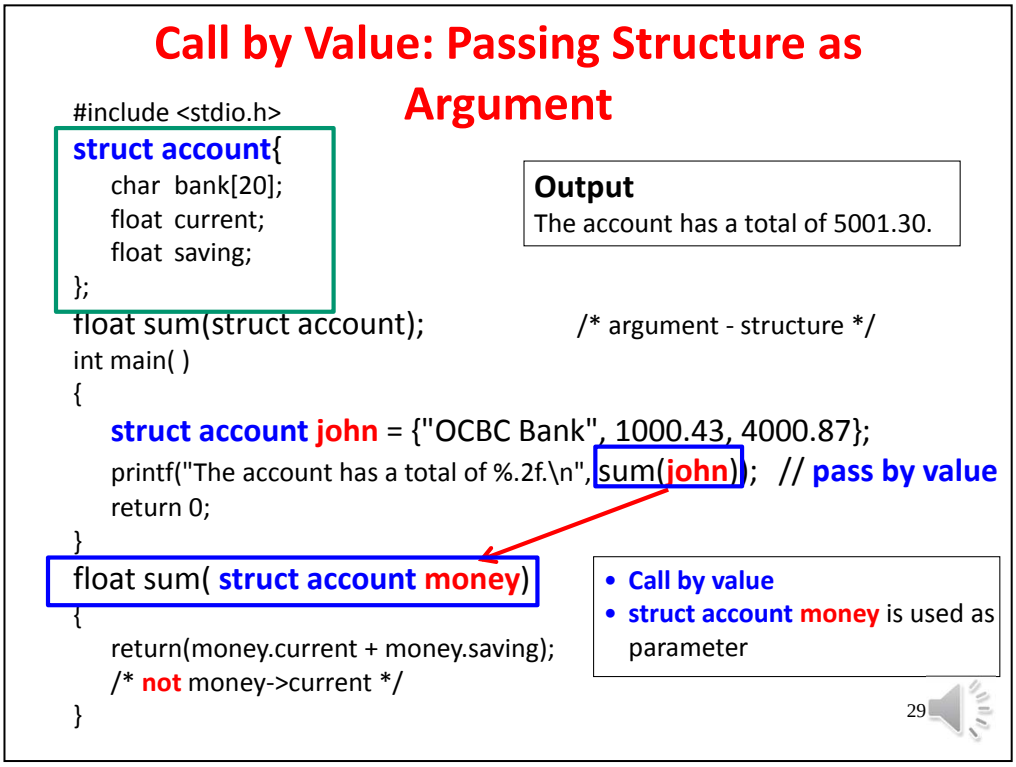
Functions and Structures

1. It is often necessary to pass structure information to a function. In C, there are four ways to pass structure information to a function:
   1) Passing structure members as arguments using call by value, or call by reference;
   2) Passing structures as arguments;
   3) Passing pointers to structures as arguments; and
   4) Passing by returning structures.
2. Basically, parameter passing between functions using structure is similar to other basic data types such as **int**, **float**, etc.



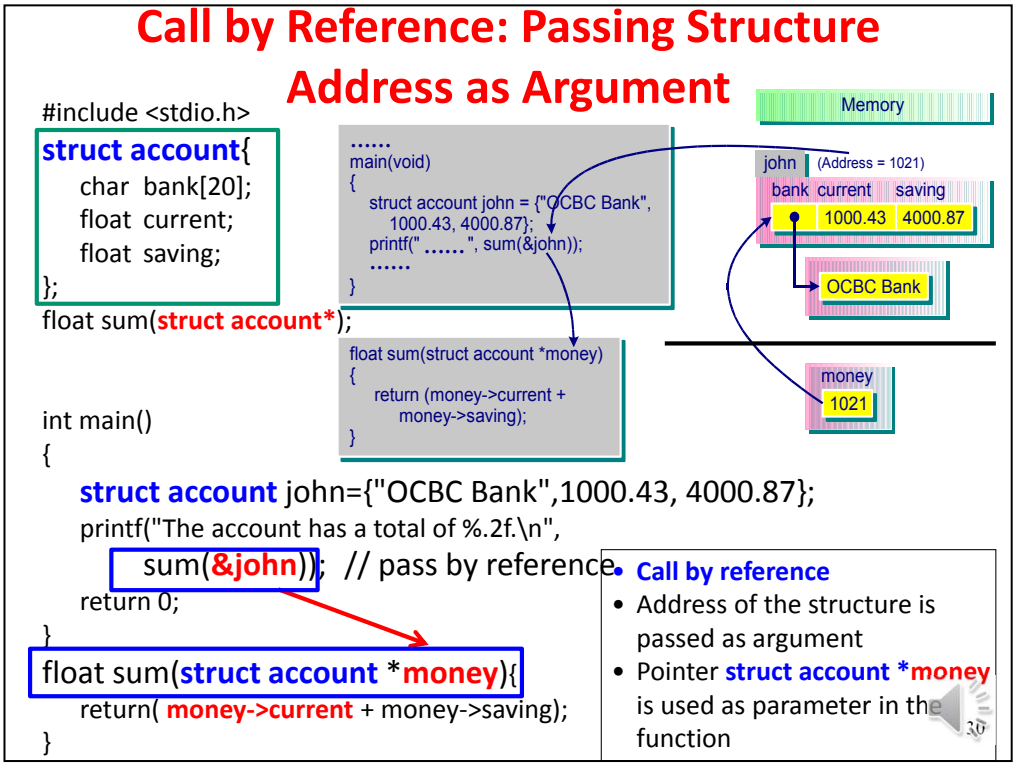
Structures and Functions: Passing Structure Members as Arguments

1. In the program, a structure template **account** is defined with three members: **bank**, **current** and **saving**.
2. In the **main()** function, an **account** structure variable **john** is declared with initial values. The structure members **john.current** and **john.saving** are passed to the function **sum()** when it is called.
3. The function **sum()** is used to compute the total amount from the saving and current accounts. It has two parameters, **x** and **y**, of type **float**. When it is called, the structure members **john.current** and **john.saving** are passed to the parameters **x** and **y** respectively. Then, it computes the sum of **x** and **y**, and returns the result to the calling **main()** function.



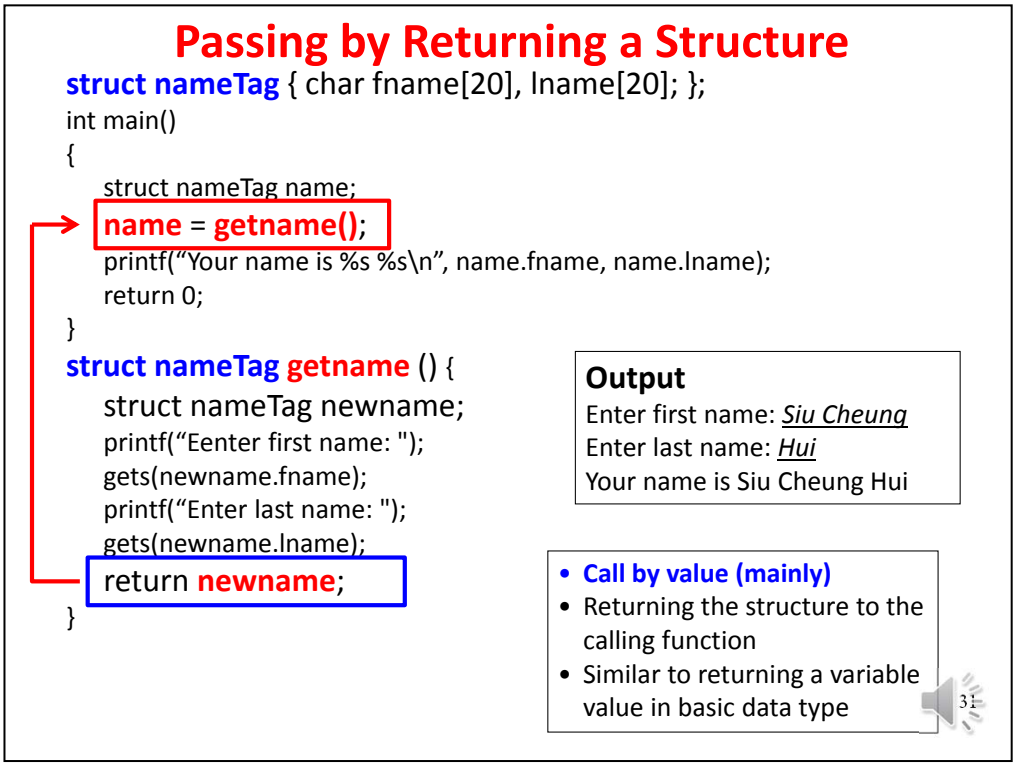
Structures and Functions: Using Call be Value by Passing Structures as Arguments

1. We can pass a structure as an argument to a function using the **call by value** method.
2. In the **main()** function, the structure variable **john** is passed as an argument to the function **sum()**.
3. The members of the structure parameter **money** in the function **sum()** are initialized with local copies. The function can only modify the local copies. Note that we simply use the member operator (**.**) to access the individual members of the structure variable.
4. The advantage of using this method is that the function cannot modify the members of the original structure variables, which is safer than working with the original variables.
5. However, this method is quite inefficient to pass large structures to functions. In addition, it also takes time and additional storage to make a local copy of the structure.



Structures and Functions: Using Call by Reference by Passing Structure Address as Argument

1. We can also pass the address of the structure as an argument to a function using the **call by reference** method.
2. In the **main()** function, the address of the structure variable **john** is passed as an argument to the function **sum()**.
3. In the function **sum()**, the pointer parameter **money** is used to point to the structure **john**. The structure pointer operator (**->**) is then used to access the members of the structure **account** to obtain the values of **john.current** and **john.saving**. This allows the function to access the structure variable and to modify its content.
4. This is a better approach than passing structures as arguments.



Structures and Functions: Passing by Returning a Structure

1. The function **getname()** returns a structure **nameTag**.
2. To call this function, the calling **main()** function must declare a variable of type **struct nameTag** in order to receive the result from **getname().**
3. It assigns the returned structure data to the variable **name** in the **main()** function.

Structures

- Structure Declaration, Initialization and Operations
- Arrays of Structures and Nested Structures
- Pointers to Structures
- Functions and Structures
- **The typedef Construct**

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Structures

1. Here, we discuss the **typedef** construct.

The typedef Construct

- **typedef** provides an elegant way in structure declaration. For example, having

```
struct date { int day, month, year; };
```

- One can define a **new data type** **Date** as

```
typedef struct date Date;
```

- Variables can be declared either as

```
struct date   today, yesterday;   or
Date          today, yesterday;
```

- When **typedef** is used, **tag name** is **redundant**, thus:

```
typedef struct {
        int   day,month,year;
} Date;
Date  today, yesterday;
```

No tag name – date

Define variables

Note: It is similar to define a new data type with record members

The typedef Construct

1. **typedef** provides an elegant way in structure declaration.
2. The general syntax for the **typedef** statement is **typedef dataType UserProvidedName;** The **typedef** keyword is followed by the data type and the user provided name for the data type.
2. It is very useful for creating simple names for complex structures.
3. For example, if we have defined the structure **struct date**, we can define a new data type **Date** as **typedef struct date Date;**
3. Variables can then be declared either as

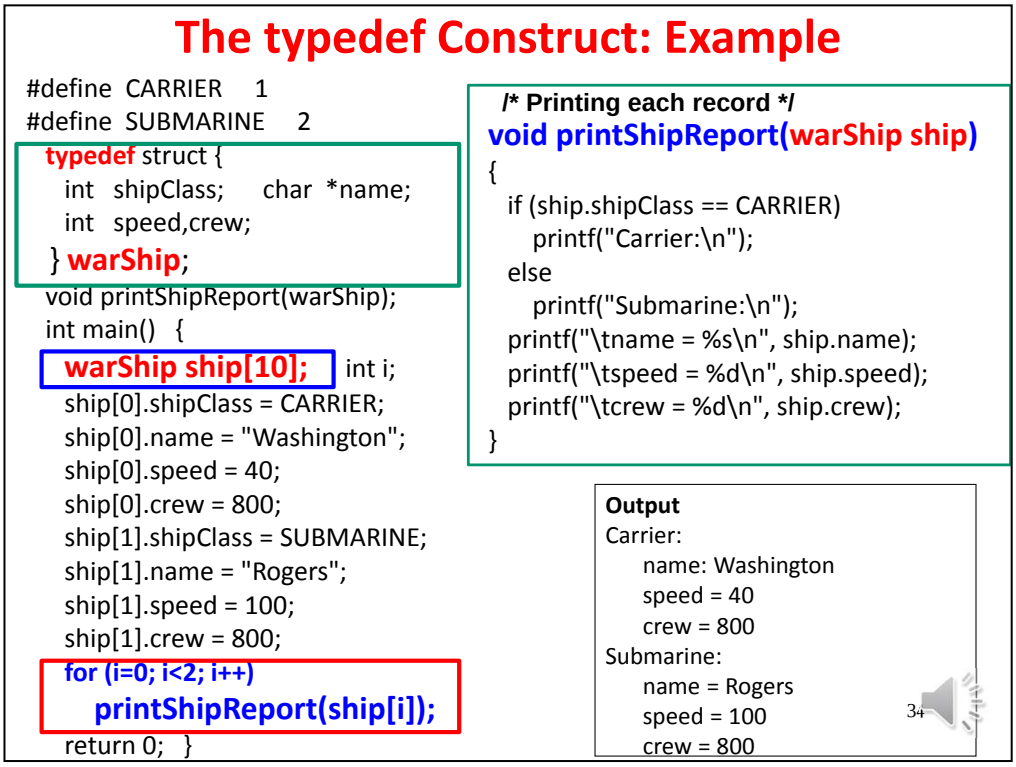
   struct date today, yesterday; or

   Date today, yesterday;
4. We can also use the type **Date** in function prototypes and function definitions.
5. When **typedef** is used, tag name is redundant. Therefore, we can declare

```
typedef struct {
    int   day, month, year;
} Date;
Date today, yesterday;
```

6. There are a number of advantages of using **typedef**. It enhances program

documentation by using meaningful names for data types in the programs. It makes the program easier to read and understand. Another advantage is to define simpler data types for complex declarations such as structures.



The typedef Construct: Example

1. In this program, we use **typedef** to define a new structure type **warship** as shown:

```
typedef struct {
    int shipClass;
    char *name;
    int speed,crew;
} warShip;
```

2. In the **main()** function, we declare an array of **warShip** structures variable called **ship**. A **for** loop is used to print the member information of the variable **ship** by calling the function **printShipReport()**.
3. The function **printShipReport()** is used for printing the member information of the **warShip** structure.

Thank you !!!