Structures in C

Heterogeneous Data

- A piece of information that describe the characteristics of an entity (object, person, company, etc.) are grouped together in a user-defined data type called struct (stands for structure).
- Imagine writing a program dealing with student data
- Each student record would consist of
  - last name
  - first name
  - an ID number
  - Gender
  - phone Number
  - Etc.
- It allows groups of data to be passed around in a single variable
  - It is also know as an abstract data type
  - This is the first step of data abstraction, which is encapsulation of a group of related data in one entity.

Defining Structure Types in C

- The syntax for a struct ***definition*** (not declaration) is as follows:

  struct [tag_name] {member_declaration_list};

- In other words:

```
struct Struct_Name
{
    <dataType1> identifier1;
    <dataType2> identifier2;
    ...
    <dataTypeN> identifierN;
};
```

Don't forget the semi-colon. This is part of the syntax!

- The new type is called `Struct_Name` and contains ***data members*** (or ***member variables***) named `identifier1`, `identifier2`, etc.

Defining Structure Types in C

- To illustrate, here's the definition of a struct to hold a student record

```
struct studentRecord
{
    char firstName[30];
    char lastName[30];
    int idNum;
    char gender;
    char phoneNumber[20];
};
```

The studentRecord struct contains seven data members.

- This is only a definition; it does not allocate space for a variable structure type.

Using Structure Types in C

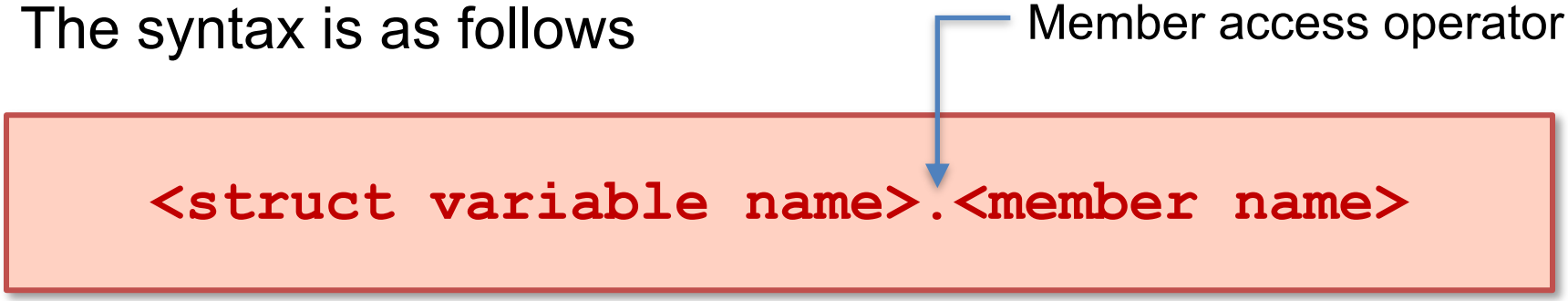
- Struct definitions generally go either outside the functions and at the top of the program or go into a header file:

```
#include <stdio.h>

struct Name
{
   char firstName [30];
   char middleInitial;
   char lastName [30];
};

void PrintName( struct Name name );

int main()
{
  struct Name myName;
  strcut Name herName;
  struct Name x, y, z;
   ...
}
```

- As function prototype and main function show, you can declare **struct** variables like any other primary data types:

Accessing Struct Data

- To access the members of a struct, use a period (“.”) which is called the ***member access operator***, also called the ***dot operator***
  - In ENGG 233 we have seen this with strings and vectors:
- The syntax is as follows



- Notice that we do not include the struct type, but rather the ***name of a variable*** whose type is a struct.
- Example:

```
struct Name theName;
theName.middleInitial = 'S';
```

- How the firstName and the lastName must be assigned?

Example Accessing Struct Data

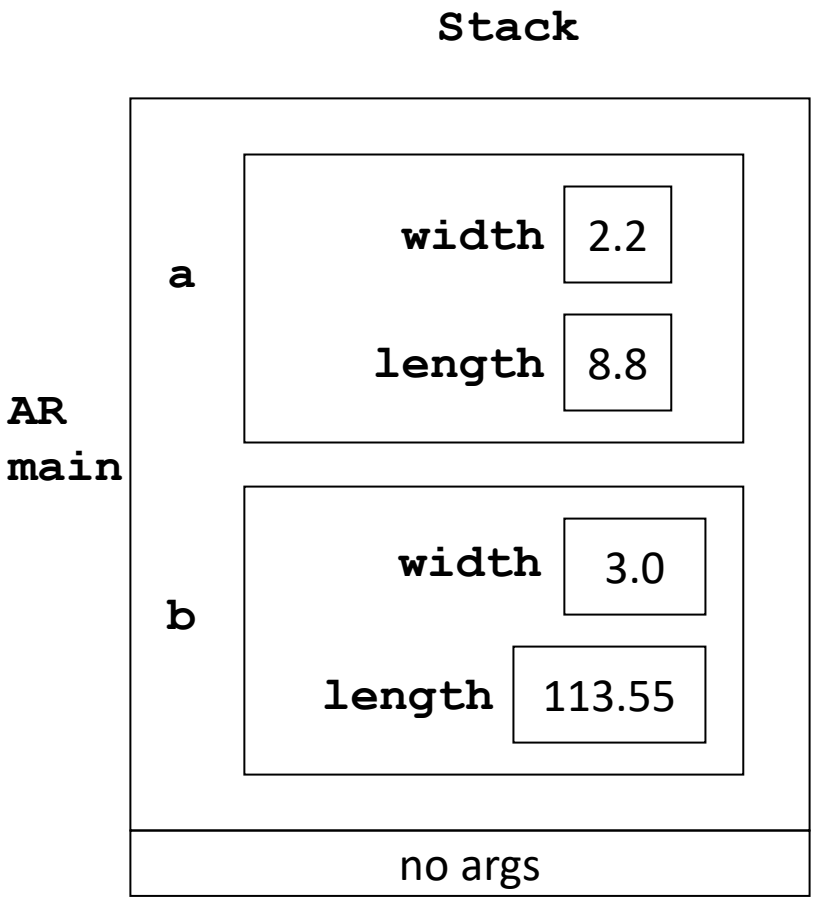
```
struct Complex_number{
    double real;
    double imag;
};

int main(void){
  struct Complex_number cplx  ;

  printf("Enter the real part of a complex number: ");
  scanf("%lf", &cplx.real);

  printf("Enter the imaginary part of a complex number: ");
  scanf("%lf", &cplx.imag);

  printf("The real part is: %f and the imaginary part is: %f\n",
                                          cplx.real, cplx.imag);
  return 0;
}
```

Structure Instance on the Memory

- Every instance of a structure type has its own set of member variables on the memory:

```
struct Rectangle {
    double width;
    double length;
};

int main(void) {
   struct Rectangle a;
   struct Rectangle b;
   a.width = 2.2;
   a.length = 8.8;
   b.width = 3.0;
   b.length = 113.55;

   // point 1

   return 0;
}
```

Point 1



Pointer to Structure Type

Pointers to User-defined Data Types

- A pointer in C can point to any addressable memory location, including user-defined data types such as structures.
- Consider the following definition of structure Point:

```
struct Point {
   double x;      // Point's x-coordinate
   double y;     // Point's y-coordinate
   char label;
};
```

- Consider the following statements:

```
struct Point centre;
struct Point *pst; // pointer to struct Point
pst = &centre;      // pst pointing to centre
```

Pointers to User-defined Data Types

- To access the structure's data members via a pointer, you need to dereference the pointer first and then access the member:

```
(*pst).x = 57.66;
(*pst).y = 99.00;
(*pst).label = 'A';
```

Note: The parentheses are required because dot operator has higher precedence

- A better and possibly easier option is to use an arrow operator **->** (a dash followed by greater sign)

```
pst -> x = 57.66;
pst -> y = 99.00;
pst -> label = 'A';
```

Pointers to User-defined Data Types

- The following statements produce the same output:

```
printf("label = %c  x = %f  y= %f.",
                    centre.label, centre.x, centre.y);

printf("label = %c  x = %f  y= %f.",
                      pst -> label, pst->x, pst ->y);

printf("label = %c  x = %f  y= %f.",
                    (*pst).label,(*pst).x, (*pst).y);
```

- You may also assign a pointer to any members of a C structure:

```
double *pd;
char *pc;
pd = &centre.x;
pc = &centre.label;
printf("label = %c  x = %f.", *pc, *pd);
```

Passing Structure as Arguments of a Function

Structure Types as a Function Argument

- Like any other data types in C, a structure data type can be passed to a function either **by value**, or by its **address**.
- Consider the following definition of structure type Staff and the given main function:

```
struct Staff {
   char Fname [30];
   char Lname [30];
   int age;
   double salary;
};

// prototype of function print goes here
int main(){
  struct Staff st = { "Judy", " Moor", 45, 3000.00};
  print (&st);
  return 0;
}
```

- Further details on initializing structures will be discussed later in this set of slides.
- Now lets write the implementation and the prototype of function print.

Structure Types as a Function Argument

- Here is the prototype of the function print

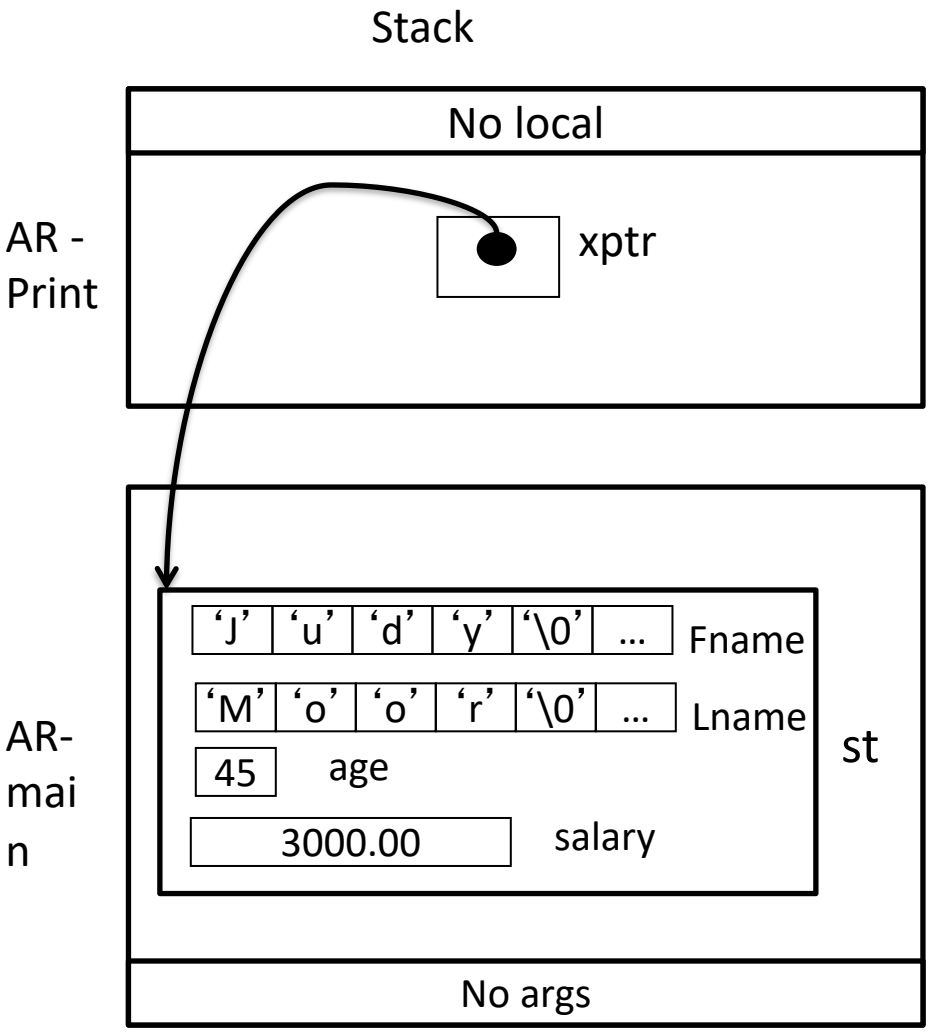
```
void print ( const struct Staff *xptr);
```

- And, here is the implementation of function print:

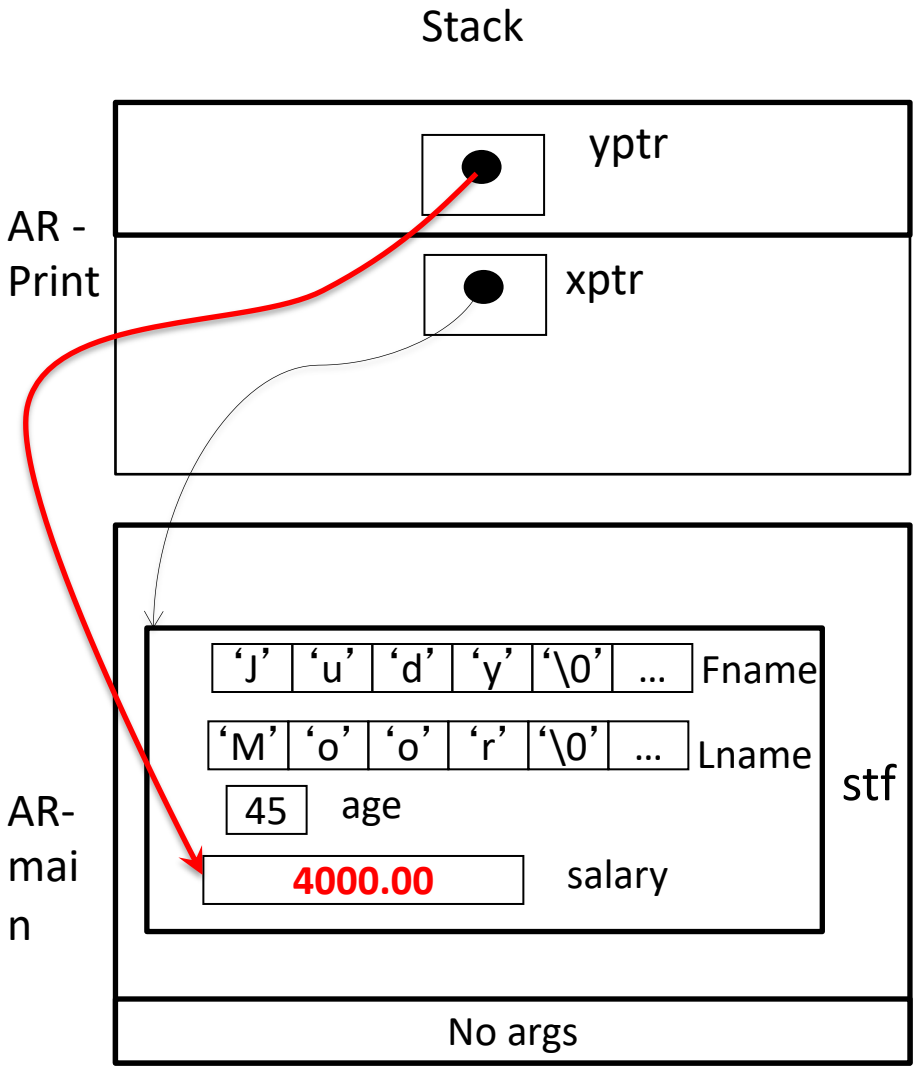
```
void print ( const struct Staff *xptr)
{
 // point one
 printf("%s", xptr -> Fname);
 printf("%s", xptr -> Fname
 printf("%d", xptr -> age);
 printf("%f", xptr -> salary);
 double *yptr = &(xptr -> salary);
 *yptr = 4000.00;
 // point two
}
```

- In general passing by address is preferred

AR for Point One in function print



AR at Point Two function print



Copying Structure Instances

- You are allowed to assign structure variables of the ***same* type**:

```
struct Rectangle box1, box2;
struct Point centre, corner;

box1.width = 10;
box1.length = pow( box1.width, 3 );

// copy the first box object
box2 = box1;
// WARNING: BAD STATEMENTS
box2 = centre;      // Type mismatch: Different types!
corner = box1;      // Type mismatch: Different types!
```

Functions Returning Structure Data Type

- C function can also return a structure data type.
- The following function returns a point object that represents a point in the middle of two points:

```
struct Point mid_point(const struct Point *a,
                       const struct Point *b)
{
    struct Point middle;
    middle.x = (a -> x + b ->x) / 2;
    middle.y = (a -> y + b ->y) / 2;
    middle.lable = 'M';
    return middle;
}
```

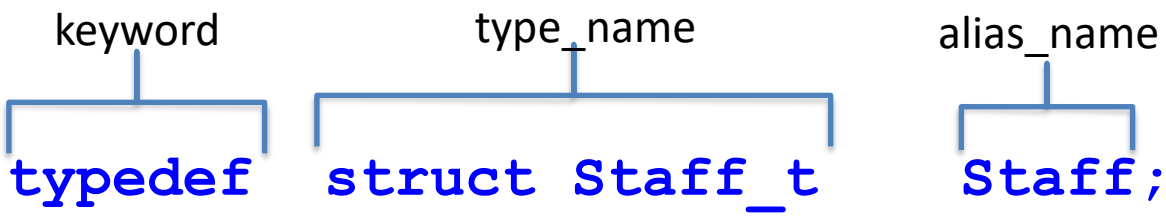
Using typedef

Using Typedef with Structure Types

- In C, you can use **typedef** to simplify the declaration of structure types.
- General format is:

typedef type_name alias_name;

```
struct Staff_t {
    char Fname[SIZE];          // First Name
    char Lname[SIZE];          // Last Name
    int age;
    double salary;
};
```



Using Typedef with Structure Types

- Now, you can use Both Staff and struct Staff_t as a type to declare your variables:

```
Staff x, y, z;
Staff *p;
struct Staff_t  w, *p2;
```

- You can also use typedef with the definition of the structure:

```
typedef struct Staff_t {
    char  Fname[SIZE];          // First Name
    char Lname[SIZE];           // Last Name
    int age;
    double salary;
} Staff;
```

Initializing Structure Instances

- You can initialize a structure type as follows:

```
int main()
{
   struct Name x, y;
   struct Name z = {“Bill”, ‘S’, “Horstmann”};
   return 0;
}
```

- The initialization of structure type follows the usual initialization rules:
  - automatic storage class: member will have indeterminate initial.
  - static storage: initial values will be zero, and pointers will be null pointer.
- Notice that initialization is allowed only at the time declaration. The following assignment is NOT allowed;

```
struct Name w;
W = {“Judy”, ‘E’, “Moor”};   // ERROE
```

Initializing Structures Instances

- You may also specify fewer initializer than the number of data member. In this case any remaining member are initialized to zero:
- Example:

```
typedef struct Point {
   double x_coordinate;
   double y_coordinate;
   char label;
} Point;

Point centre = { 100 };
```

  – X_coordinate is initialized to 100 and two other members y_coordinate and label to zero.

Initializing Structures

- C99 standard also allows us to explicitly initialize certain members of a structure type:

```
Point center = {.x = 100.05, .y = 205.00};
```

Note: you cannot initialize the structure data members at the time of definition. The following definition and initialization is **NOT** allowed:

```
struct Point {
   double x = 100;
   double y = 100;
   char label = ' ';
   };
```

Structures and Arrays

```
#define SIZE 20

typedef struct Staff {
                char Fname[SIZE];          // First Name
                 char Lname[SIZE];          // Last Name
                int age;
                double salary;
 } Staff;
```

- Array Declaration

```
Staff a[100];
```

  - Declares an array with 100 elements of struct variable.
  - All the rules that applies to arrays of simple data types, applies to an array of structure too.
    - Use index number to access each element:

```
printf ("%d" a[i].age);// prints the value of age
```

The name of an array of structure holds the address of the first element.

Initialization of Array of Structures

- You can initialize array of structures, as follows:

```
Staff arr [3] = {
                {“Judy”, “Moore”, 18, 2450.00},
                {“Jack”, “Wong”, 19, 3450.00},
                {“Tim”, “Lewis”, 21, 1450.00}
};
```

- To display the second character in the first element of array **arr**, we can use the following syntax. **What is the output**?

```
printf(“%c”, arr[1].Lname[0]);
```

Reading Data into Members of Structure

- You can use scanf to read values from keyboard into the data members of an struct variable:

```
Staff x;

printf (“Enter your first name: );
scanf(“%s”, x.Fname);

printf (“Enter your last name: );
scanf(“%s”, x.Lname);

printf (“Enter your age: );
scanf(“%d”, &x.age);

printf (“Enter your salary: );
scanf(“%lf”, &x.salary);
```

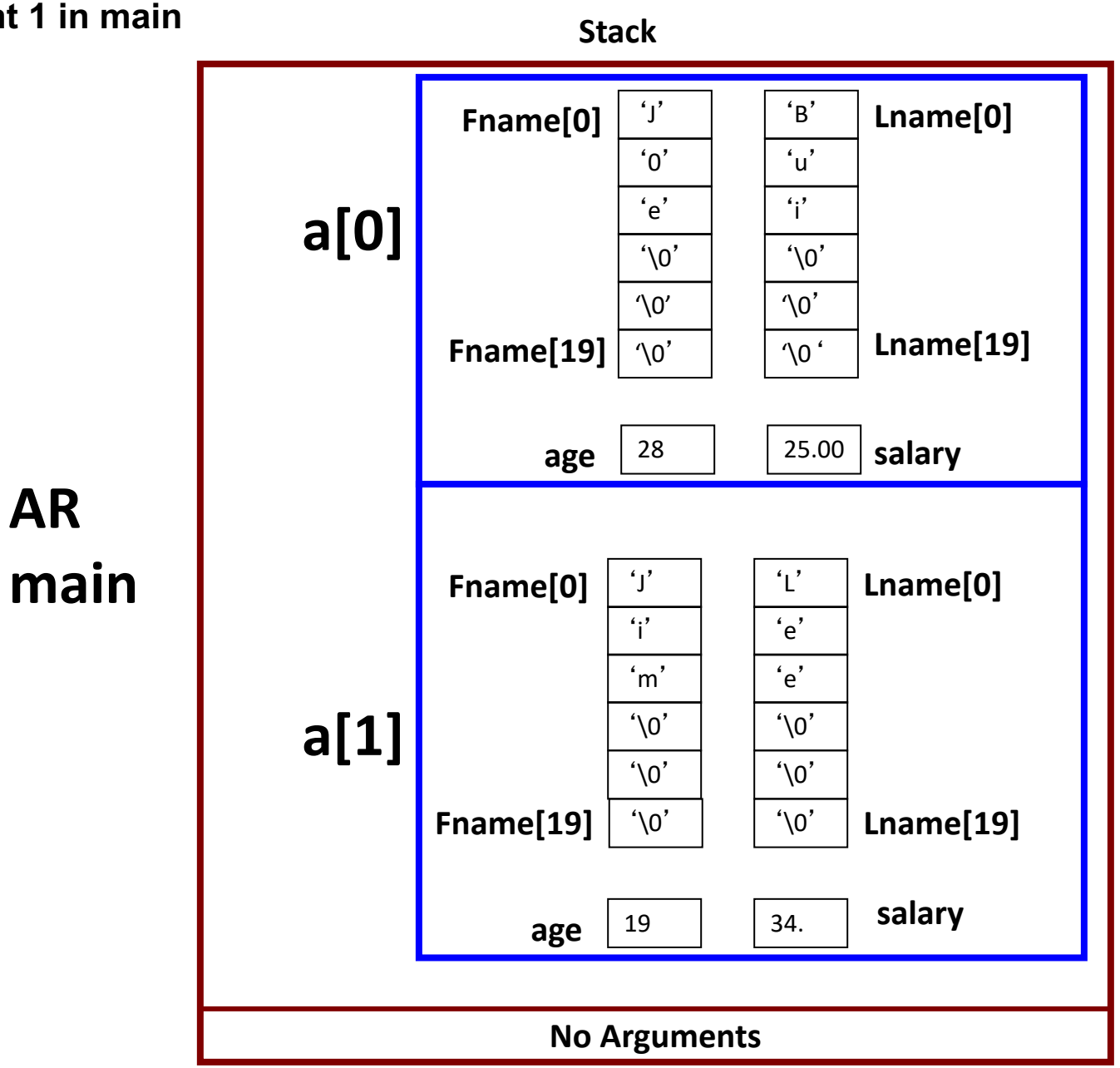
- Notice the & (address operator) in front of the numeric variable names, but not string variables.

Array of Structure on the Memory

```
int main(){

  Staff a[2] =
                  {
                     {“Joe”, “Bui”, 28, 25},
                     {“Jim”, “Lee”, 19, 34}

                   };

  // point 1
   return o;
}
```

- See the AR diagram for this program in the next slide

AR Diagram – Point 1 in main



Nested Structure

Nested Structures

- A structure may have another structure object as one of its members.
- Consider the definitions of struct Date and struct Person in a header files called date.h, and person.h.
- Notice how an instance or a pointer of type Date is defined in struct Person.

Header file date.h	Header file person.h
#ifndef nested_Structure_date_h #define nested_Structure_date_h typedef struct Date { int day, month, year; } Date; #endif	#ifndef nested_Structure_person_h #define nested_Structure_person_h #include "date.h" typedef struct Person{ char name[30]; Date birthday; Date* graduation_day; } Person; #endif

Using a Nested Structure

```
#include <stdio.h>
#include "person.h"
#include "date.h"

int main()
{
   Person p1 = {"Jack", 12, 12, 1983, NULL};
   Date d = {23, 11, 1972};
   Person p2 = {"Judy", 8, 10, 1982, NULL};
   p2.graduation_day = &d;

   printf("Person's name is: %s, birthday: %d-%d-%d, and graduation date:"
          " %d-%d-%d\n", p2.name, p2.birthday.day, p2.birthday.month,
       p2.birthday.year, p2.graduation_day->day, p2.graduation_day->month,
       p2.graduation_day->year);

   return 0;
}
```

Program's Output:

Person's name is: Judy, birthday: 8-10-1982, and graduation date: 23-11-1972

A structure that contains an array of another structure

Header file: department.h

```
#ifndef nested_Structure_department_h
#define nested_Structure_department_h

#include "person.h"

#define STAFF_SIZE 100
#define NAME_LENGTH 30

typedef struct Department
{

   char dept_name[NAME_LENGTH];
   Person staff_list[STAFF_SIZE];

} Department;

#endif
```

Implementation file: main.c

```
#include <stdio.h>
#include <string.h>
#include ”date.h"
#include "department.h”
// here is a simplified version of a possible main
// function that uses some of these structures
int main(void)
{
  Department dept;
  Date d;
  dept.staff_list[0].graduation_day = &d
  dept.staff_list[0].graduation_day->day = 20;

  dept.staff_list[0].birthday.day= 23;
  strcpy (dept.staff_list[0].name, "Julia");
  strcpy (dept.dept_name, "ABC Engineers");
  return 0;
}
```