Pointers and 2-D Arrays

Concept of pointer to pointer

- A pointer stores the memory address of a variable.
- The pointer itself is a variable, and is stored in memory.
- We can define a pointer to pointer, to store the memory address of a pointer variable.

Example 1

```
#include <stdio.h>
main()
{
    int var;     int *ptr;     int **pptr;
   var = 3000;
   ptr = &var;       // Points to "var"
   pptr = &ptr;      // Points to "ptr"
   printf ("Value of var = %d \n", var );
   printf ("Value available at *ptr = %d \n", *ptr );
   printf ("Value available at **pptr = %d \n", **pptr);
}
```

Output

```
Value of var = 3000
Value available at *ptr = 3000
Value available at **pptr = 3000
```

3

Example 2

```
#include <stdio.h>
main()
{
      int var;     int *ptr;     int **pptr;
      var = 3000;
      ptr = &var;
      pptr = &ptr;
      printf ("Address of var = %u \n", &var );
      printf ("Value of ptr = %u \n", ptr );
      printf ("Value stored at pptr = %u \n", *pptr);
}
```

Output

```
Address of var = 3974241144
Value of ptr = 3974241144
Value stored at pptr = 3974241144
```

4

What does array name mean in 2-D array?

```
int  a[10], b[5][3];
```

- We know that 'a' is a constant pointer whose value is the address of the 0th element of the array `a[10]`.
- Similarly, `a+i` is the address of the i^{th} element of the array.
- What is the meaning of '`b`' and what is its arithmetic?

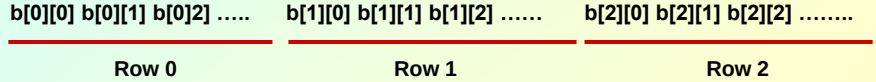
5

How is a 2-D array is stored in memory?

- Starting from a given memory location, the elements are stored *row-wise* in consecutive memory locations.
  - x: starting address of the array in memory
  - c: number of columns
  - k: number of bytes allocated per array element

```
int b[5][3];
```

Element `b[i][j]` :: allocated memory location at address `x+(i*c+j)*k`



6

Arithmetic of 'b'

```
int b[5][3];
```

b[0][0] b[0][1] b[0][2] ….. b[1][0] b[1][1] b[1][2] …… b[2][0] b[2][1] b[2][2] ……..

Row 0 Row 1 Row 2

- `b` is the starting address of the 0th row
- `b+1` is the starting address of the 1th row
- `b+2` is the starting address of the 2th row
- In general, `b+i` represents the starting address of the ith row
- The size of a row will be: `c × sizeof(int)` bytes, where `c` is the number of columns.

7

Example 3

```
#include <stdio.h>
int main()
{
   int a[10], b[3][5];
   printf ("a:   %u \t   b:   %u \n", a, b);
   printf ("a+1: %u \t b+1: %u \n", a+1, b+1);
   printf ("a+2: %u \t b+2: %u \n", a+2, b+2);
   printf ("a+3: %u \t b+3: %u \n", a+3, b+3);
}
```

Output

```
a:   3217738332  b:   3217738272
a+1: 3217738336  b+1: 3217738292
a+2: 3217738340  b+2: 3217738312
a+3: 3217738344  b+3: 3217738332
```

8

Type of 'b'

```
int b[3][5];
```

- 'b' is a pointer constant of type `int[][5]`, that is, a contiguous row of five integers.
- If such a pointer is incremented by one, it increases by `5 × sizeof(int)` bytes.

9

Arithmetic of *(b+i)

- If 'b' is the address of the 0th row, `*b` is the 0th row itself.
  - A row may be viewed as a 1-D array, so `*b` is the starting address of this 1-D array, i.e. address of the 0th element of the 0th row.
- Similarly, `b+i` is the address of the ith row, `*(b+i)` is the ith row.
  - So `*(b+i)` is the address of the 0th element of the ith row.

10

For the array b[3][5]

- If *b is the address of the 0th element of the 0th row, *b+1 is the address of the 1th element of the 0th row.
- Similarly, *b+j is the address of the jth element of the 0th row.
- The difference between b+1 and b is 20 bytes, but the difference between *b+1 and *b is the `sizeof(int)`, that is, 4 bytes.

11

- So, *(b+i) is the address of the 0th element of the ith row.
- Thus, *(b+i)+j is the address of the jth element of the ith row.
  - That is, same as `&b[i][j]`.

```
*(b+i)+j is equivalent to &b[i][j]
```

12

Some Equivalences

```
*(b + i) + j   ⟹   &b[i][j]

*(*(b + i) + j) ⟹   b[i][j]

   b[i] + j    ⟹   &b[i][j]

 *(b[i] + j)   ⟹   b[i][j]

(*(b + i))[j]  ⟹   b[i][j]
```

13

Calculation of the address of `b[i][j]`

```
int  b[3][5]
```

- The C compiler can calculate the address of the j^{th} element of the i^{th} row using the following formula:

  `b + k (5i + j)`

  where `k = sizeof(int)`.

- The compiler needs the following:
  - Value of row and column indices
  - The number of columns
  - The size of the data type.

14

Passing 2-D Arrays to functions (recap)

1-D Array and Formal Parameter

- Consider the declaration: `int a[10];`
  - The array name 'a' is a constant pointer.
  - The formal parameter: `int x[]` or `int *x` is a pointer variable of the corresponding type, where the address of an array location is copied into the function.

```
void sort (int n, int x[]);

void sort (int n, int *x);
```

  - These two information are sufficient for the compiler to calculate the address of `x[i]`.

Formal parameter for 2-D Array

- Consider the declaration: `int b[ROW][COL];`
  - The C compiler needs the following information to calculate the address of `b[i][j]` (given i and j):
    - Starting address '`b`'
    - The data type of the array elements, that is, '`int`'
    - The number of columns '`COL`'
- Example:

```
void matadd (int row, int col, int a[][10],
                        int b[][10], int c[][10]);
```

17

An example

```
#include <stdio.h>

void transpose (int x[][3],
                        int n)
{
   int  p, q, t;

   for (p=0; p<n; p++)
     for (q=p; q<n; q++)
      {
         t = x[p][q];
         x[p][q] = x[q][p];
         x[q][p] = t;
       }
}
```

```
main()
{
  int a[3][3], p, q;

  for (p=0; p<3; p++)
    for (q=0; q<3; q++)
      scanf ("%d", &a[p][q]);
  transpose (a, 3);
  for (p=0; p<3; p++)
  {
    printf ("\n");
    for (q=0; q<3; q++)
       printf ("%d  ", a[p][q]);
  }
}
```

18

Dynamically Allocating 2-D Arrays

You may recall ….

- We have discussed earlier the issue of dynamically allocating space for 1-D arrays.
  - Using `malloc()` library function.
- Pros and cons of this approach:
  - The space gets allocated in global data area called heap (not on the stack), and hence does not evaporate at the end of function call.
  - The conventional method allocates space in the stack as part of the activation record, and so is not available across function calls.

Looking back at pointer arithmetic

```
int  *p, (*q)[5], *r[3], **s;
```

- Variable '`p`' can be used to point to an integer.
  Thus, `p+i` will mean: `p + i * sizeof(int)`
- Variable '`q`' can be used to point to an integer array of size 5.
  Hence, `q+i` will mean: `q + i*5*sizeof(int)`
- '`r`' is not a variable but a constant pointer (name of an array, each element of the array is an `int*`).
  So, `r+i` will mean: `r + i * sizeof(int*)`
- Variable '`s`' can be used to point to a location of type `int*` .
  Thus, `s+i` will mean: `s + i*sizeof(int*)`

21

Some typical values ….

```
sizeof(int):              4
sizeof(int *):            8
sizeof(int [5]):          20
sizeof(int (*)[5]):       8
sizeof(int **):      8
```

22

How was 1-D array dynamically allocated?

- Sample code segment:

```
int *p, n, i;
scanf ("%d", &n);
p = (int *) malloc (n * sizeof(int));
```

- Array elements can be accessed equivalently as:

```
p[i] = 20;
*(p+i) = 20;
```

23

Methods to allocate space for 2-D array

1. Variable number of rows, fixed number of columns
2. Variable number of columns, but fixed number of rows
3. Both number of rows and columns variable

24

Dynamically Allocating 2-D Arrays

Variable number of rows
Fixed number of columns

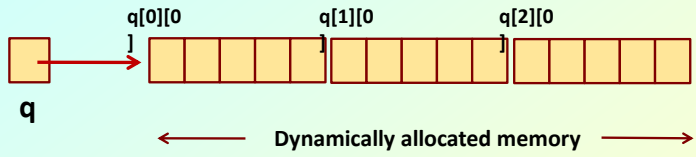
25

1:: Allocating space for 2-D array *n* ×*5*

- We can use a pointer of type `(*q)[5]` to allocate space for the array of n rows and 5 columns.

```
int  (*q)[5], n;
printf("Enter nos. of rows:");
scanf("%d", &n);
q = (int (*)[5]) malloc(n*5*sizeof(int));
```

26



27

```
#include <stdio.h>
#include <stdlib.h>
int main()
{
   int (*q)[5],rows,i,j;
   printf("Enter the number of Rows: ") ;
     scanf("%d", &rows);

   q = (int (*)[5]) malloc (rows*5*sizeof(int));

   for(i=0; i<rows; ++i)
     for(j=0; j<5; ++j)
         q[i][j]=2*i+3*j;
   for(i=0; i<rows; ++i) {
     for(j=0; j<5; ++j)
         printf("%d ", q[i][j]);
     printf("\n");
   }
   return 0;
}
```

```
Enter the number of Rows: 3
0 3 6 9 12
2 5 8 11 14
4 7 10 13 16
```

28

- **Some observations:**
  - '`q`' points to the 0th row of a 5-element array
  - '`q+i`' points to the ith row of a 5-element array
  - `*q` is the address of `q[0][0]`, that is, `&q[0][0]`
  - `*q+j` is the address of `q[0][j]`, that is, `&q[0][j]`
  - `*(q+i)+j` is address of `q[i][j]`, that is, `&q[i][j]`
  - `**q` is `q[0][0]`
  - `*(*q+j)` is `q[0][j]`
  - `*(*(q+i)+j)` is `q[i][j]`

29

Dynamically Allocating 2-D Arrays

Fixed number of rows
Variable number of columns

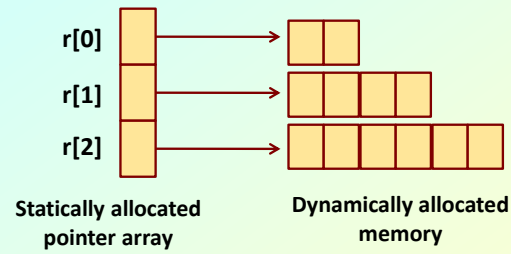
30

2:: Allocating space for 2-D array *3 × m*

- We can use a pointer array of size 3, where the `i`th element of the array will point to the `i`th row of length `m`.
  - Possible to have different number of elements in different rows.

```
int  *r[3], i, c;
printf("Enter nos. of columns:");
scanf("%d", &c);
for (i=0;i<3;i++)
  r[i] = (int *) malloc (c*sizeof(int));
```

31



32

```
#include <stdio.h>
#include <stdlib.h>
int main()
{
  int *r[3], i, j, col;
  for(i=0; i<3; ++i) {
    col = 2 * (i+1);
    r[i] = (int *) malloc (col*sizeof(int));
    for(j=0; j<col; ++j)
      r[i][j] = i + j;
  }
 for(i=0; i<3; ++i) {
    col = 2 * (i+1);
    for(j=0; j<col; ++j)
       printf("%d ", r[i][j]);
    printf("\n");
  }
  return 0;
}
```

```
0 1
1 2 3 4
2 3 4 5 6 7
```

33

- **Some observations:**
  - `r[i]` is the i^{th} pointer, which stores the address of the 0^{th} element of the i^{th} row.
  - So, `r[i]+j` is the address of the j^{th} element of the i^{th} row.
  - `*(r[i]+j)`, same as `r[i][j]`, is the j^{th} element of the i^{th} row.

34

Dynamically Allocating 2-D Arrays

Both number of rows and columns are variable

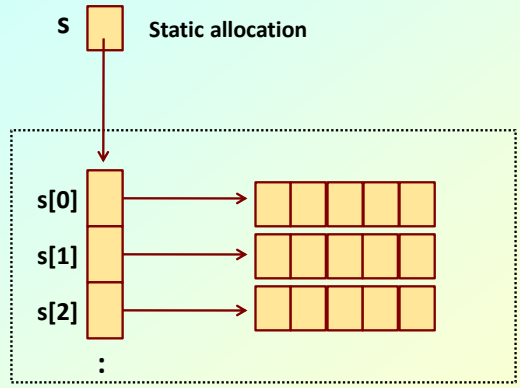
35

3: Dynamic allocation of $r \times c$ array

- We can allocate a 2-D array of variable number of rows and columns, where both the number of rows and the number of columns as inputs.

```
int  **s, r, c;
printf("Enter nos. of rows, columns:");
scanf("%d %d", &r, &c);
s = (int **) malloc(r * sizeof(int *));
for (i=0;i<r;i++)
  s[i] = (int *) malloc(c * sizeof(int));
```

36



37

```
#include <stdio.h>
#include <stdlib.h>
int main()
{
  int **s, row, column, i, j;
  printf("Enter Row & Column:\n");
    scanf("%d %d", &row, &column);
  s = (int **) malloc(row*sizeof(int *));
  for(i=0; i<row; ++i) {
    s[i] = (int *) malloc(column*sizeof(int));
    for(j=0; j<column; ++j)
      s[i][j] = i+j ;
  }
 for(i=0; i<row; ++i) {
    for(j=0; j<column; ++j)
      printf("%d ", s[i][j]);
    printf("\n");
  }
  return 0;
}
```

```
Enter Row and Column:
3 5
0 1 2 3 4
1 2 3 4 5
2 3 4 5 6
```

38

- **Some observations:**
  - `s+i` is the address of the `i`th element of the pointer array.
  - `*(s+i)`, which is the same as `s[i]`, is the `i`th element of the pointer array that stores the address of the 0th element of the `i`th row.
  - `s[i]+j` is the address of the `j`th element of the `i`th row.
  - `*(s[i]+j)`, which is the same as `s[i][j]`, is the `j`th element of the `i`th row.

39

Example with 2-D Array

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

int **allocate (int h, int w)
    {
      int **p;
      int i, j;

      p = (int **) calloc (h, sizeof(int *) );
      for (i=0;i<h;i++)
        p[i] = (int *) calloc (w,sizeof(int));
      return(p);
    }
```

Allocate array of pointers

Allocate array of integers for each row

40

```
void read_data (int **p, int h, int w)
  {
      int i, j;
      for (i=0;i<h;i++)
        for (j=0;j<w;j++)
          scanf ("%d", &p[i][j]);
  }

void print_data (int **p, int h, int w)
  {
     int i, j;
      for (i=0;i<h;i++)
      {
      for (j=0;j<w;j++)
        printf ("%5d ", p[i][j]);
       printf ("\n");
      }
}
```

Elements accessed like 2-D array elements.

41

```
main()
{
   int **p;
   int M, N;

   printf ("Give M and N \n");
   scanf ("%d%d", &M, &N);
   p = allocate (M, N);
   read_data (p, M, N);
   printf ("\nThe array read as \n");
   print_data (p, M, N);
}
```

```
Give M and N
3 3
1 2 3
4 5 6
7 8 9
The array read as
    1     2     3
    4     5     6
    7     8     9
```

42