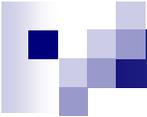# Dynamic Memory Allocation

Problem with Arrays

- Sometimes
  - □ Amount of data cannot be predicted beforehand
  - □ Number of data items keeps changing during program execution
- Example: Seach for an element in an array of N elements
- One solution: find the maximum possible value of N and allocate an array of N elements
  - □ Wasteful of memory space, as N may be much smaller in some executions
  - □ Example: maximum value of N may be 10,000, but a particular run may need to search only among 100 elements
    - Using array of size 10,000 always wastes memory in most cases

Better Solution

- Dynamic memory allocation
  - Know how much memory is needed after the program is run
    - Example: ask the user to enter from keyboard
  - Dynamically allocate only the amount of memory needed

- C provides functions to dynamically allocate memory
  - malloc, calloc, realloc

Memory Allocation Functions

- **malloc**
  - ☐ Allocates requested number of bytes and returns a pointer to the first byte of the allocated space

- **calloc**
  - ☐ Allocates space for an array of elements, initializes them to zero and then returns a pointer to the memory.

- **free**
  - ☐ Frees previously allocated space.

- **realloc**
  - ☐ Modifies the size of previously allocated space.

- We will only do **malloc** and **free**

Allocating a Block of Memory

- A block of memory can be allocated using the function malloc
  - Reserves a block of memory of specified size and returns a pointer of type void
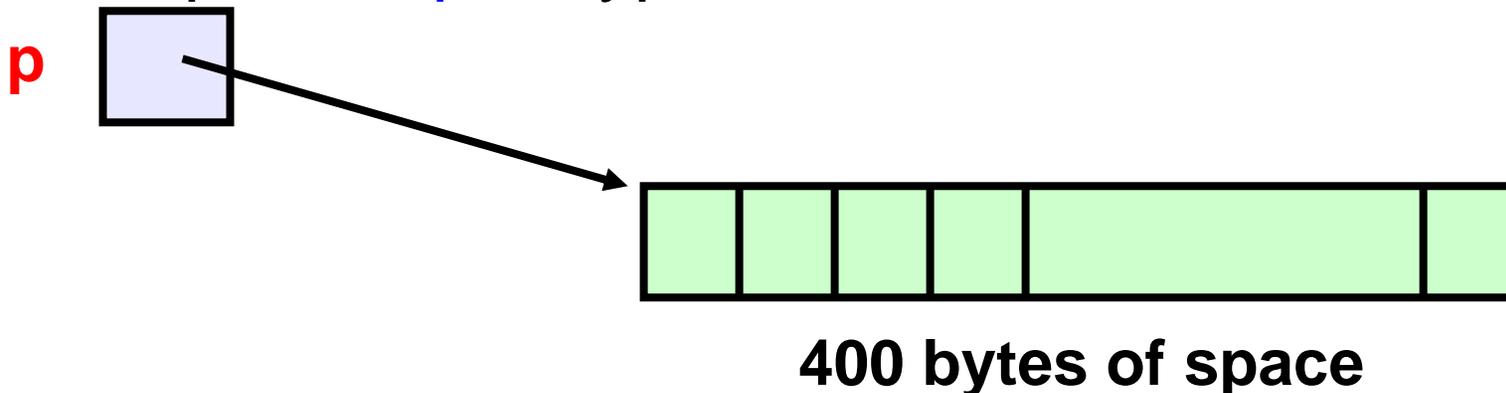 - The return pointer can be type-casted to any pointer type
- General format:

  type *p;

  p = (type *) malloc (byte_size);

Example

p = (int *) malloc(100 * sizeof(int));

☐ A memory space equivalent to 100 times the size of an int bytes is reserved

☐ The address of the first byte of the allocated memory is assigned to the pointer p of type int

p

400 bytes of space

Contd.

- cptr = (char *) malloc (20);

    Allocates 20 bytes of space for the pointer cptr of type char

- sptr = (struct stud *) malloc(10*sizeof(struct stud));

    Allocates space for a structure array of 10 elements. sptr points to a structure element of type struct stud

Always use sizeof operator to find number of bytes for a data type, as it can vary from machine to machine 7

Points to Note

- malloc always allocates a block of contiguous bytes
  - ☐ The allocation can fail if sufficient contiguous memory space is not available
  - ☐ If it fails, malloc returns NULL

```
if  ((p = (int *) malloc(100 * sizeof(int))) == NULL)
  {
      printf ("\n Memory cannot be allocated");
      exit();
  }
```
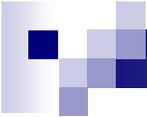
Using the malloc'd Array

- Once the memory is allocated, it can be used with pointers, or with array notation

- Example:

```
int *p, n, i;
scanf("%d", &n);
p = (int *) malloc (n * sizeof(int));
for (i=0; i<n; ++i)
    scanf("%d", &p[i]);
```

The n integers allocated can be accessed as *p, *(p+1), *(p+2),…, *(p+n-1) or just as p[0], p[1], p[2], …,p[n-1]

Example

```c
int main()
{
  int i,N;
  float *height;
  float sum=0,avg;

  printf("Input no. of students\n");
  scanf("%d", &N);


  height = (float *)
       malloc(N * sizeof(float));
```

```c
printf("Input heights for %d
students \n",N);
  for (i=0; i<N; i++)
   scanf ("%f", &height[i]);


  for(i=0;i<N;i++)
    sum += height[i];


  avg = sum / (float) N;


  printf("Average height = %f \n",
              avg);
  free (height);
  return 0;
}
```
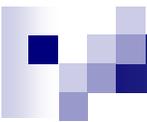
Releasing the Allocated Space: free

- An allocated block can be returned to the system for future use by using the free function
- General syntax:

      free (ptr);

  where ptr is a pointer to a memory block which has been previously created using malloc
- Note that no size needs to be mentioned for the allocated block, the system remembers it for each pointer returned

Can we allocate only arrays?

- malloc can be used to allocate memory for single variables also
  - p = (int *) malloc (sizeof(int));
  - Allocates space for a single int, which can be accessed as *p
- Single variable allocations are just special case of array allocations
  - Array with only one element

malloc( )-ing array of structures

```c
typedef  struct{
        char name[20];
        int roll;
        float SGPA[8], CGPA;
    } person;
void main()
 {
    person *student;
    int i,j,n;
    scanf("%d", &n);
    student = (person *)malloc(n*sizeof(person));
    for (i=0; i<n; i++) {
        scanf("%s", student[i].name);
        scanf("%d", &student[i].roll);
        for(j=0;j<8;j++) scanf("%f", &student[i].SGPA[j]);
        scanf("%f", &student[i].CGPA);
    }
 }
```

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Static array of pointers

```c
#define  N   20
#define  M  10
int main()
{
    char word[N], *w[M];
    int i, n;
    scanf("%d",&n);
    for (i=0; i<n; ++i) {
        scanf("%s", word);
        w[i] = (char *) malloc ((strlen(word)+1)*sizeof(char));
        strcpy (w[i], word) ;
    }
    for (i=0; i<n; i++) printf("w[%d] = %s \n",i,w[i]);
    return 0;
}
```
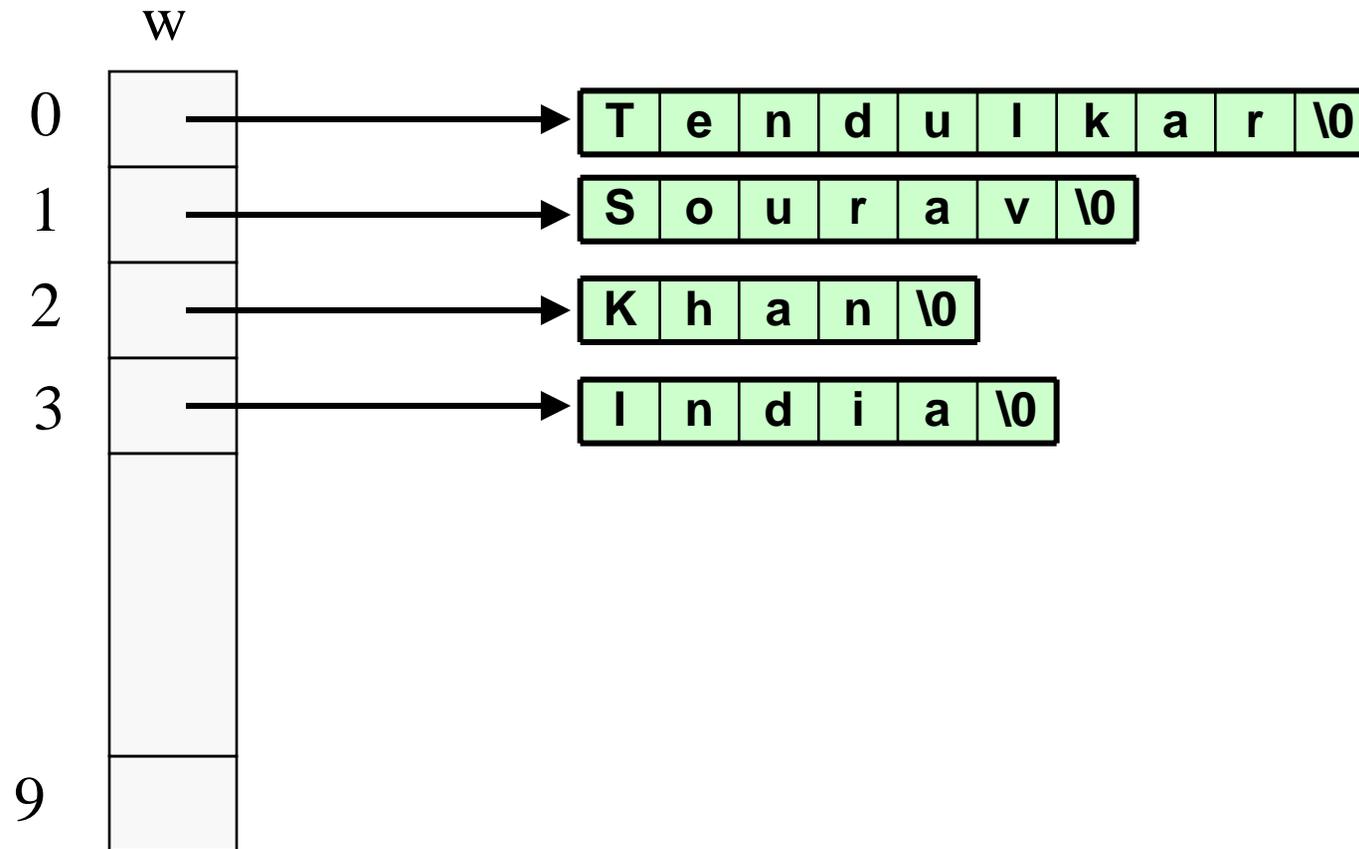
Static array of pointers

```c
#define  N   20
#define  M  10
int main()
{
    char word[N], *w[M];
    int i, n;
    scanf("%d",&n);
    for (i=0; i<n; ++i) {
        scanf("%s", word);
        w[i] = (char *) malloc ((strlen(word)+1)*sizeof(char));
        strcpy (w[i], word) ;
    }
    for (i=0; i<n; i++) printf("w[%d] = %s \n",i,w[i]);
    return 0;
}
```

Output

```
4
Tendulkar
Sourav
Khan
India
w[0] = Tendulkar
w[1] = Sourav
w[2] = Khan
w[3] = India
```

How it will look like

w

0	→ T e n d u l k a r \0
1	→ S o u r a v \0
2	→ K h a n \0
3	→ I n d i a \0
9	

Pointers to Pointers

- Pointers are also variables (storing addresses), so they have a memory location, so they also have an address

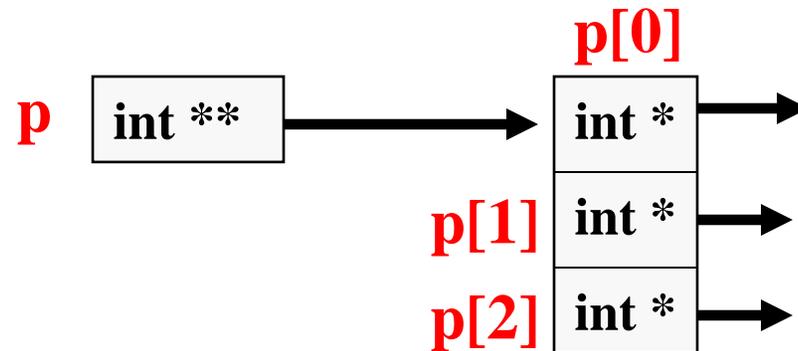- Pointer to pointer – stores the address of a pointer variable

```
int x = 10, *p, **q;
p = &x;
q = &p;
printf("%d  %d  %d", x, *p, *(*q));

will print 10  10  10 (since *q = p)
```
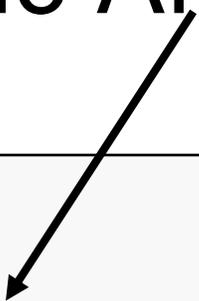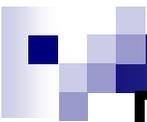
Allocating Pointer to Pointer

int **p;

p = (int **) malloc(3 * sizeof(int *));

Dynamic Arrays of pointers

```c
int main()
{
  char word[20], **w;  /*  "**w" is a pointer to a pointer array */
  int i, n;
  scanf("%d",&n);
  w = (char **) malloc (n * sizeof(char *));
  for (i=0; i<n; ++i) {
    scanf("%s", word);
    w[i] = (char *) malloc ((strlen(word)+1)*sizeof(char));
    strcpy (w[i], word) ;
  }
  for (i=0; i<n; i++) printf("w[%d] = %s \n",i, w[i]);
  return 0;
}
```

Dynamic Arrays of pointers

```
int main()
{
  char word[20], **w;  /* "**w" is a pointer to a pointer array */
  int i, n;
  scanf("%d",&n);
  w = (char **) malloc (n * sizeof(char *));
  for (i=0; i<n; ++i) {
    scanf("%s", word);
    w[i] = (char *) malloc ((strlen(word)+1)*sizeof(char));
    strcpy (w[i], word) ;
  }
  for (i=0; i<n; i++) printf("w[%d] = %s \n",i, w[i]);
  return 0;
}
```

Output

```
5
India
Australia
Kenya
NewZealand
SriLanka
w[0] = India
w[1] = Australia
w[2] = Kenya
w[3] = NewZealand
w[4] = SriLanka
```

How this will look like

w → 0 → | I | n | d | i | a | \0 |

1 → | A | u | s | t | r | a | l | l | a | \0 |

2 → | K | e | n | y | a | \0 |

3 → | N | e | w | Z | e | a | l | a | n | d | \0 |

4 → | S | r | i | L | a | n | k | a | \0 |