# Dynamic Memory Allocation

# Basic Idea

- Many a time we face situations where data is dynamic in nature.
  - Amount of data cannot be predicted beforehand.
  - Number of data items keeps changing during program execution.

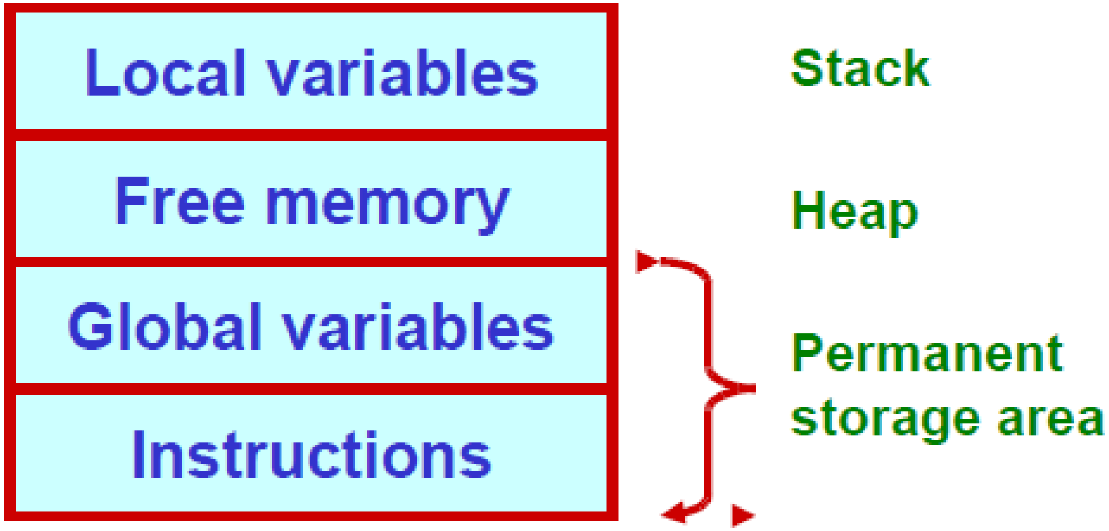
- Such situations can be handled more easily and effectively using dynamic memory management techniques.

# Contd.

- C language requires the number of elements in an array to be specified at compile time.
  - Often leads to wastage or memory space or program failure.

- Dynamic Memory Allocation
  - Memory space required can be specified at the time of execution.
  - C supports allocating and freeing memory dynamically using library routines.

# Memory Allocation Process in C



Local variables

Free memory

Global variables

Instructions

Stack

Heap

Permanent storage area

# Contd.

- The program instructions and the global variables are stored in a region known as *permanent storage area*.

- The local variables are stored in another area called *stack*.

- The memory space between these two areas is available for dynamic allocation during execution of the program.
  - This free region is called the *heap*.
  - The size of the heap keeps changing.

# 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.

# 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:

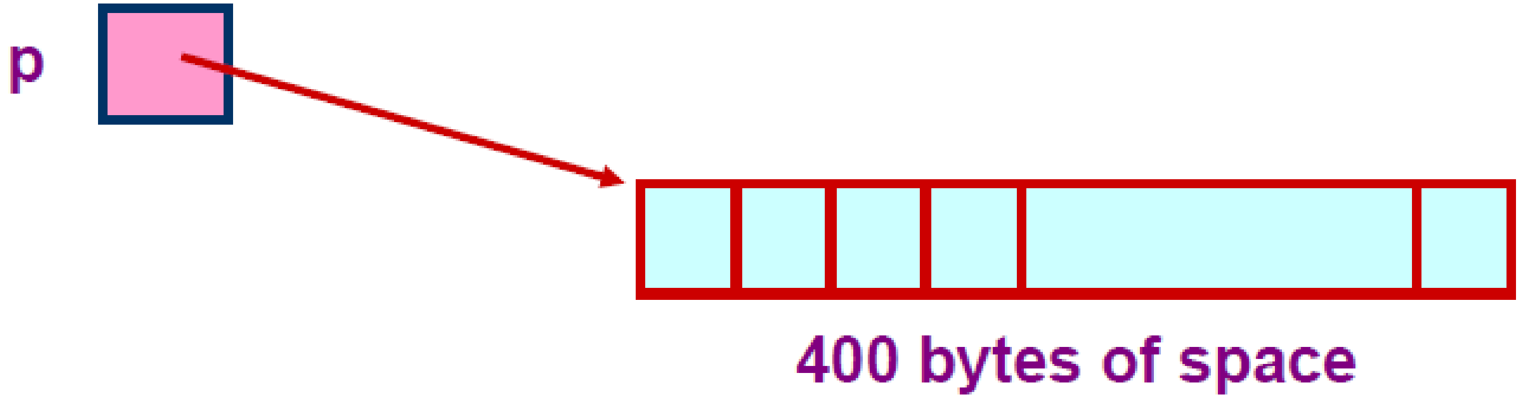
```
ptr =  (type *) malloc (byte_size);
```

# Contd.

- Examples

```
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`.



# 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`".

# 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();
  }
```

# Example

```
#include <stdio.h>

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));
```

```
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);
}
```

# Releasing the Used Space

- When we no longer need the data stored in a block of memory, we may release the block for future use.

- How?
  - 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`.

# Altering the Size of a Block

- Sometimes we need to alter the size of some previously allocated memory block.
  - More memory needed.
  - Memory allocated is larger than necessary.

- How?
  - By using the `realloc` function.

- If the original allocation is done as:

  ```
      ptr = malloc (size);
  ```

  then reallocation of space may be done as:

  ```
      ptr = realloc (ptr, newsize);
  ```

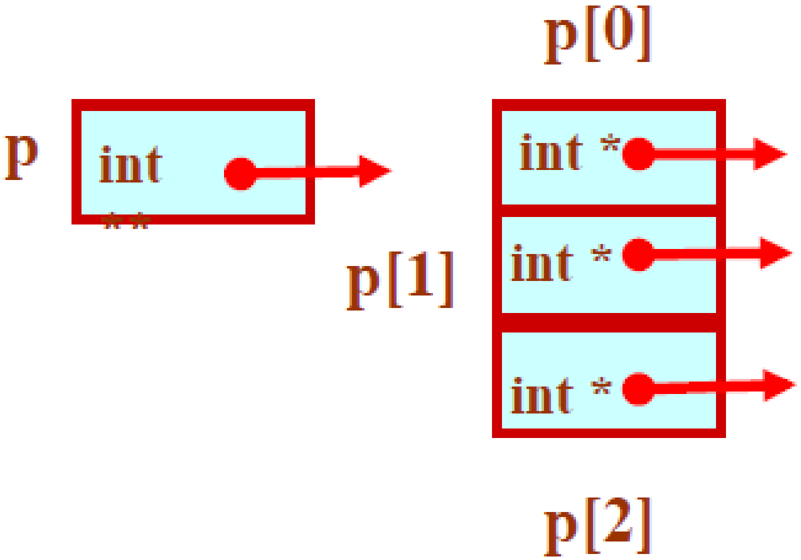
# Contd.

- The new memory block may or may not begin at the same place as the old one.
  - If it does not find space, it will create it in an entirely different region and move the contents of the old block into the new block.
- The function guarantees that the old data remains intact.
- If it is unable to allocate, it returns `NULL` and frees the original block.

# Pointer to Pointer

- **Example:**

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



# 2-D Array Allocation

```
#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

```
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]);
 }
```

Elements accessed like 2-D array elements.

# 2-D Array: Contd.

```
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");
    }
}
```

```
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
```

```
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);
}
```