Recall that . . .

char str [8];

- **str** is the base address of the array.
- We say **str** is a pointer because its value is an address.
- It is a pointer constant because the value of **str** itself cannot be changed by assignment. It "points" to the memory location of a `char`.

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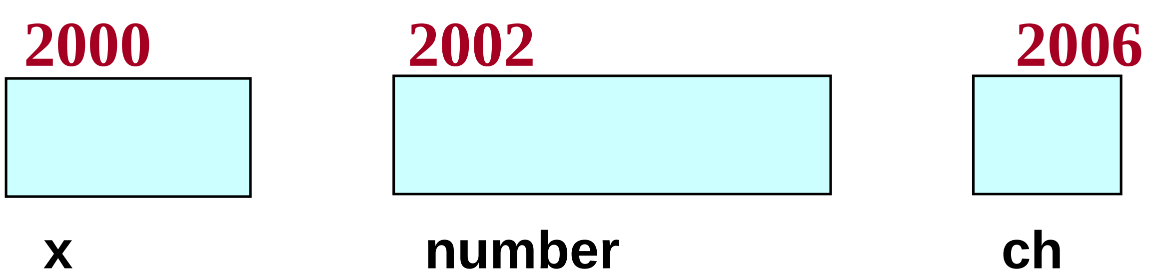
'H'	'e'	'l'	'l'	'o'	'\0'		
str [0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]

Addresses in Memory

- When a variable is declared, enough memory to hold a value of that type is allocated for it at an unused memory location. This is the address of the variable

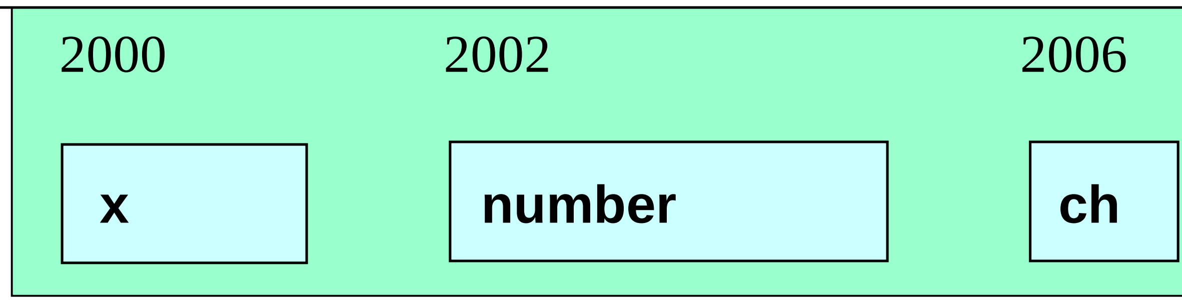
```
int      x;
float    number;
char     ch;
```



Obtaining Memory Addresses

- The address of a *non-array variable* can be obtained by using the address-of operator &

```
int     x;
float   number;
char    ch;
```




```
cout << “Address of x is “ << &x << endl;

cout << “Address of number is “ << &number << endl;

cout << “Address of ch is “ << &ch << endl;
```

What is a pointer variable?

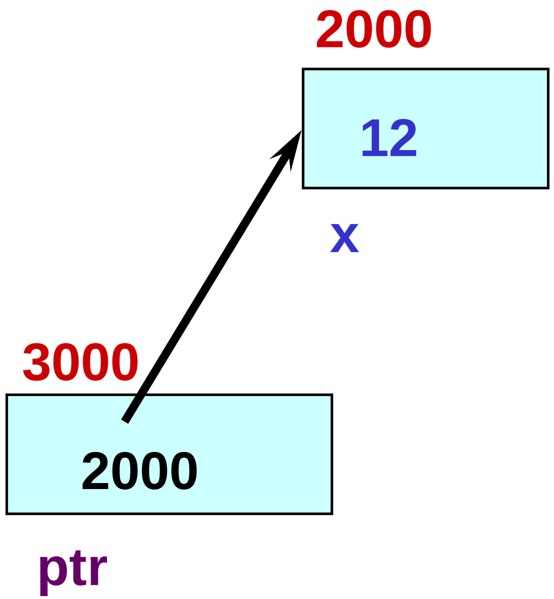
- A pointer variable is a variable whose value is the address of a location in memory.

- To declare a pointer variable, you must specify the type of value that the pointer will point to, for example,

```
int*   ptr; // ptr will hold the address of an int

char*  q;   // q will hold the address of a char
```

Using a Pointer Variable

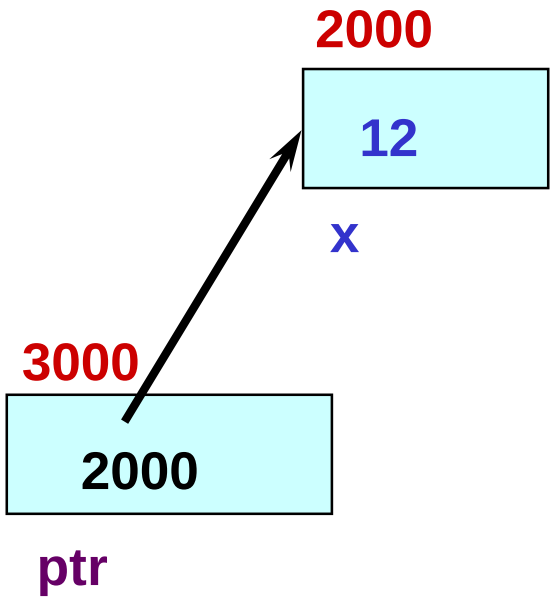
```
int  x;
x = 12;

int*  ptr;
ptr = &x;
```



NOTE: **Because ptr holds the address of x, we say that ptr "points to" x**

*: dereference operator

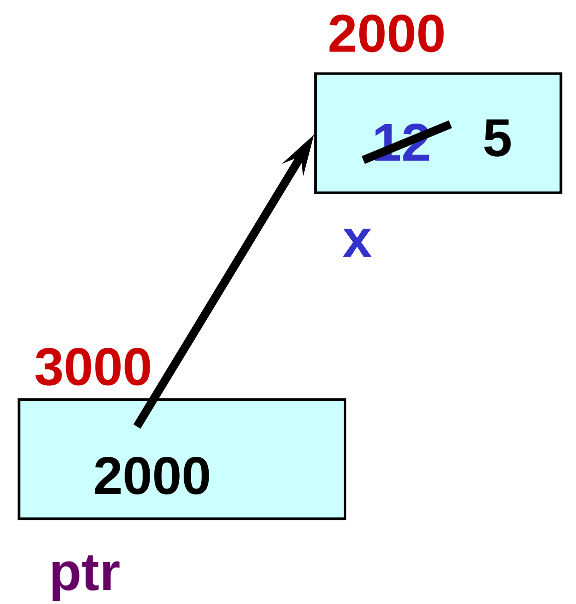
```
int  x;
x = 12;


int*  ptr;
ptr = &x;

cout  <<  *ptr;
```



NOTE: **The value pointed to by ptr is denoted by *ptr**

Using the Dereference Operator

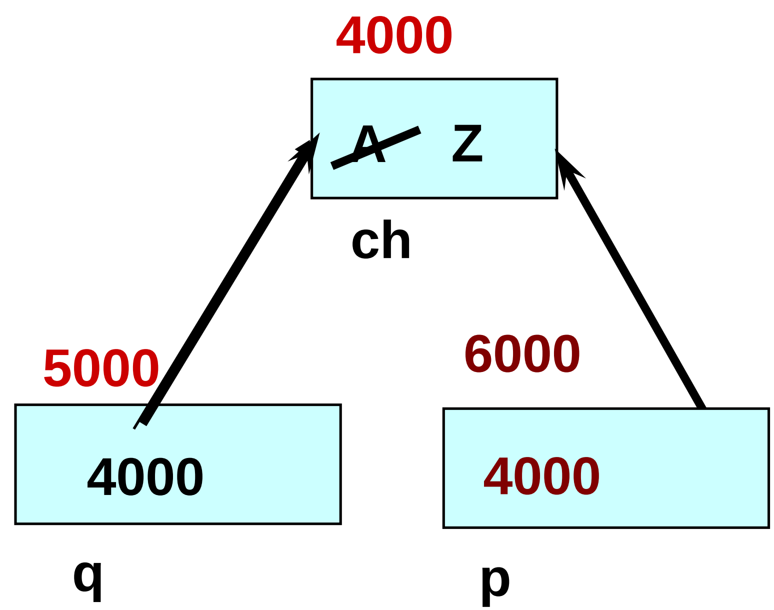
```
int  x;
x = 12;


int*  ptr;
ptr = &x;

*ptr = 5;
```




```
// changes the value at the
   address ptr points to 5
```

Self –Test on Pointers

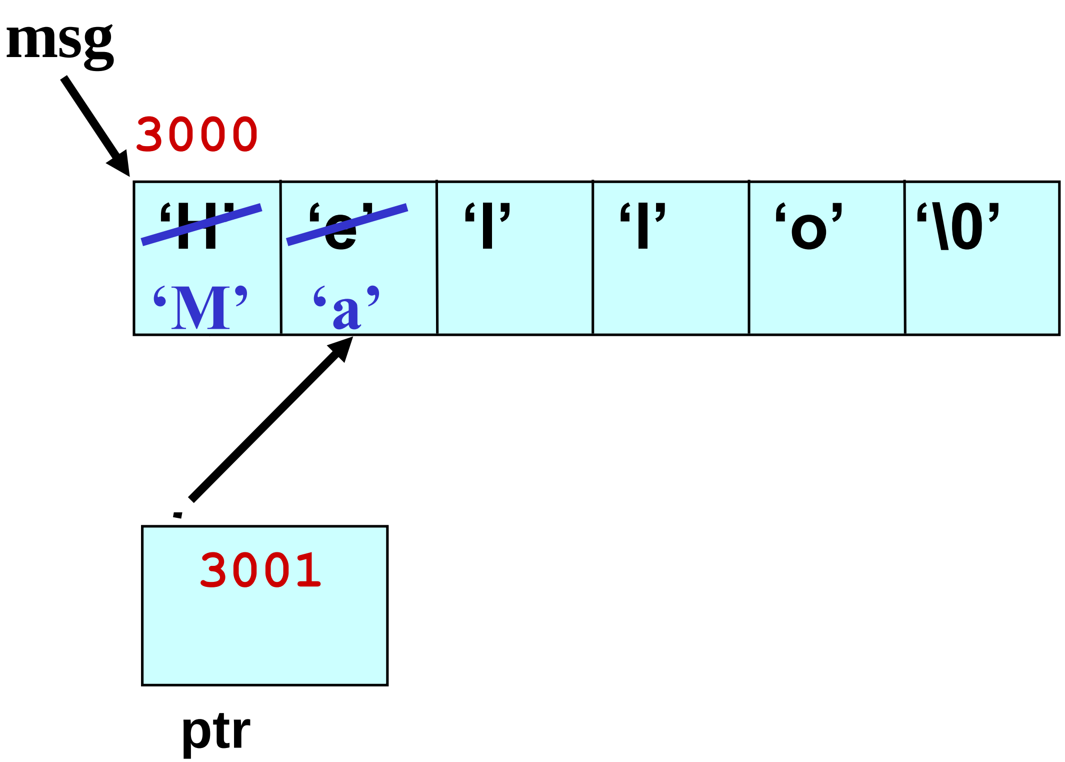
```
char  ch;
ch =  'A';

char*  q;
q  = &ch;

*q = 'Z';
char*  p;
p = q;
```




```
// the rhs has value 4000
// now p and q both point to ch
```

Using a Pointer to Access the Elements of a String

```
char   msg[ ] =“Hello”;
char*  ptr;
ptr  =  msg;
*ptr  = ‘M’ ;
ptr++;
*ptr = ‘a’;
```



Reference Variables

Reference variable = ***alias for another variable***

- Contains the address of a variable (like a pointer)
- No need to perform any dereferencing (unlike a pointer)
- Must be initialized when it is declared

```
int x = 5;
int &z = x;            // z is another name for x
int &y ;               //Error: reference must be initialized
cout << x << endl;     -> prints 5
cout << z << endl;     -> prints 5

z = 9;                 // same as x = 9;

cout << x << endl;     -> prints 9
cout << z << endl;     -> prints 9
```

Why Reference Variables

- Are primarily used as function parameters

- Advantages of using references:
  - you don't have to pass the address of a variable
  - you don't have to dereference the variable inside the called function

Reference Variables Example

```
#include <iostream.h>

// Function prototypes
   (required in C++)

void p_swap(int *, int *);
void r_swap(int&, int&);

int main (void){
 int v = 5, x = 10;
 cout << v << x << endl;
 p_swap(&v,&x);
 cout << v << x << endl;
 r_swap(v,x);
 cout << v << x << endl;
 return 0;
}
```

```
void p_swap(int *a, int *b)
{
  int temp;
   temp = *a;     (2)
   *a = *b;             (3)
   *b = temp;
}
```

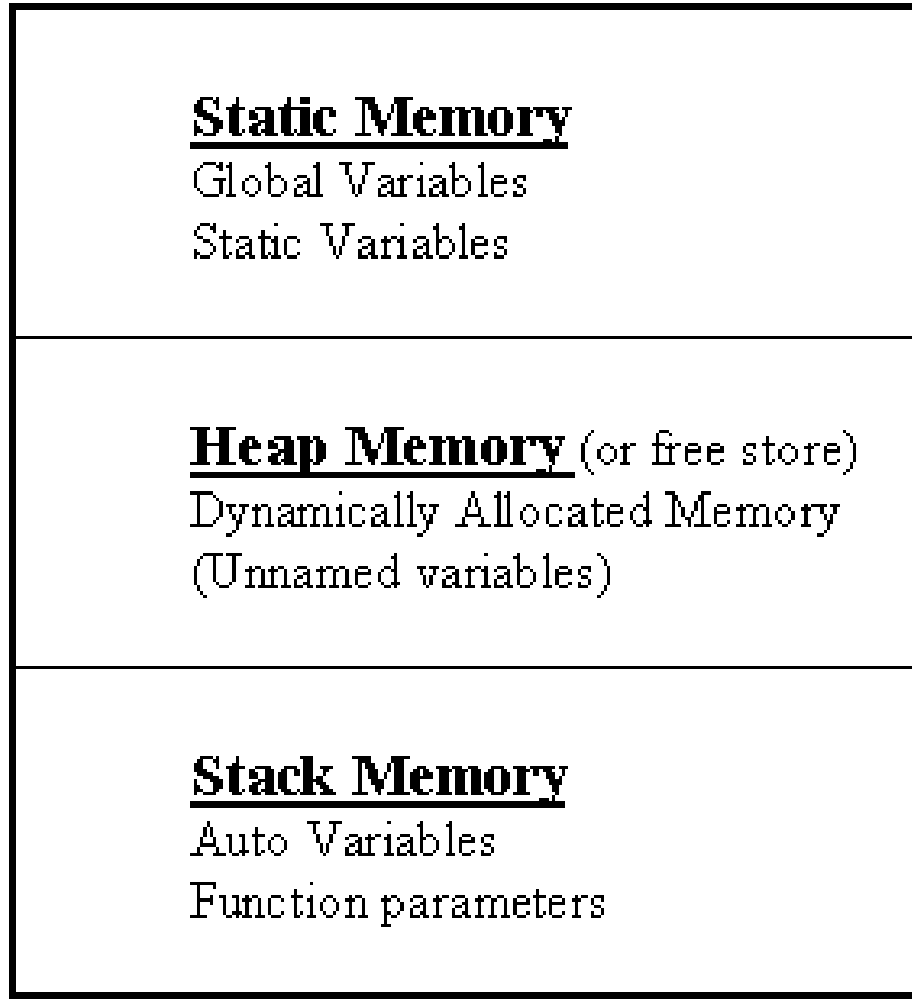
```
void r_swap(int &a, int &b)
{
 int temp;
 temp = a;              (2)
 a = b;        (3)
 b = temp;
}
```

Dynamic Memory Allocation

In C and C++, three types of memory are used by programs:

- **Static memory** - where global and static variables live
- **Heap memory** - dynamically allocated at execution time

  - "managed" memory accessed using pointers
- **Stack memory** - used by automatic variables



3 Kinds of Program Data

- STATIC DATA: Allocated at compiler time
- DYNAMIC DATA: explicitly allocated and deallocated during program execution by C++ instructions written by programmer using operators **`new`** and **`delete`**
- AUTOMATIC DATA: automatically created at function entry, resides in activation frame of the function, and is destroyed when returning from function

Dynamic Memory Allocation

- *In C*, functions such as malloc() are used to dynamically allocate memory from the **Heap**.
- *In C++*, this is accomplished using the **new** and **delete** operators
- **new** is used to allocate memory during execution time
  – returns a pointer to the address where the object is to be stored
  – always returns a pointer to the type that follows the **new**

Operator `new` Syntax

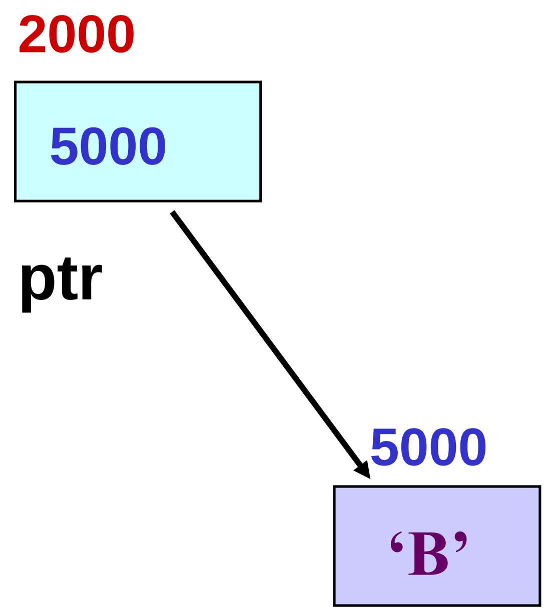
new DataType

new DataType [IntExpression]

- If memory is available, in an area called the heap (or free store) new allocates the requested object or array, and returns a pointer to (address of) the memory allocated.
- Otherwise, program terminates with error message.
- The dynamically allocated object exists until the delete operator destroys it.

Operator *new*

```
char*  ptr;

ptr = new char;

*ptr = 'B';

cout  <<  *ptr;
```



NOTE: Dynamic data has no variable name

The **`NULL`** Pointer

- There is a pointer constant called the "null pointer" denoted by NULL
- But NULL is not memory address 0.

- NOTE: It is an error to dereference a pointer whose value is NULL. Such an error may cause your program to crash, or behave erratically. It is the programmer's job to check for this.

```
while (ptr != NULL) {
      . . .            // ok to use *ptr here
}
```

Operator `delete` Syntax

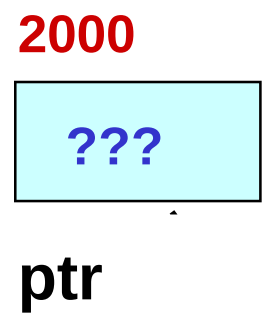
delete Pointer

delete [ ] Pointer

- The object or array currently pointed to by Pointer is deallocated, and the value of Pointer is undefined. The memory is returned to the free store.
- Good idea to set the pointer to the released memory to NULL
- Square brackets are used with delete to deallocate a dynamically allocated array.

Operator **delete**

```
char*  ptr;


ptr = new char;

*ptr = 'B';

cout  <<  *ptr;

delete  ptr;
```

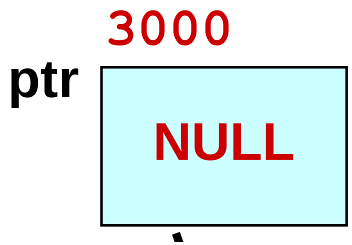


NOTE:

delete deallocates the memory pointed to by ptr

Example

```
char  *ptr ;

ptr  =  new  char[ 5 ];

strcpy( ptr, “Bye” );

ptr[ 0 ] =
‘u’;

delete [] ptr;

ptr = NULL;
```



// deallocates the array pointed to by ptr
// ptr itself is not deallocated
// the value of ptr becomes undefined

Pointers and Constants

```
char* p;
p = new char[20];

char c[] = “Hello”;
const char* pc = c; //pointer to a constant
pc[2] = ‘a’; // error
pc = p;

char  *const cp = c; //constant pointer
cp[2] = ‘a’;
cp = p; // error

const char *const cpc = c; //constant pointer to a const
cpc[2] = ‘a’; //error
cpc = p; //error
```

Take Home Message

- Be aware of where a pointer points to, and what is the size of that space.
- Have the same information in mind when you use reference variables.
- Always check if a pointer points to NULL before accessing it.