

C++ For C Coders 5

Data Structures
C++ for C Coders

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dynamic memory allocation
new & delete operators

Three kinds of memory (or data)

- **Static memory**
 - where global and static variables live
 - allocated at compiler time
- **Heap memory**
 - dynamically allocated at execution time
 - "managed" memory accessed using pointers
 - explicitly allocated and deallocated using operators **new** and **delete** by programmer
- **Stack memory**
 - used by automatic variables
 - automatically created at function entry, resides in activation frame of the function, and is destroyed when returning from function

Static Memory

Global Variables

Static Variables

Heap Memory (or free store)

Dynamically Allocated Memory

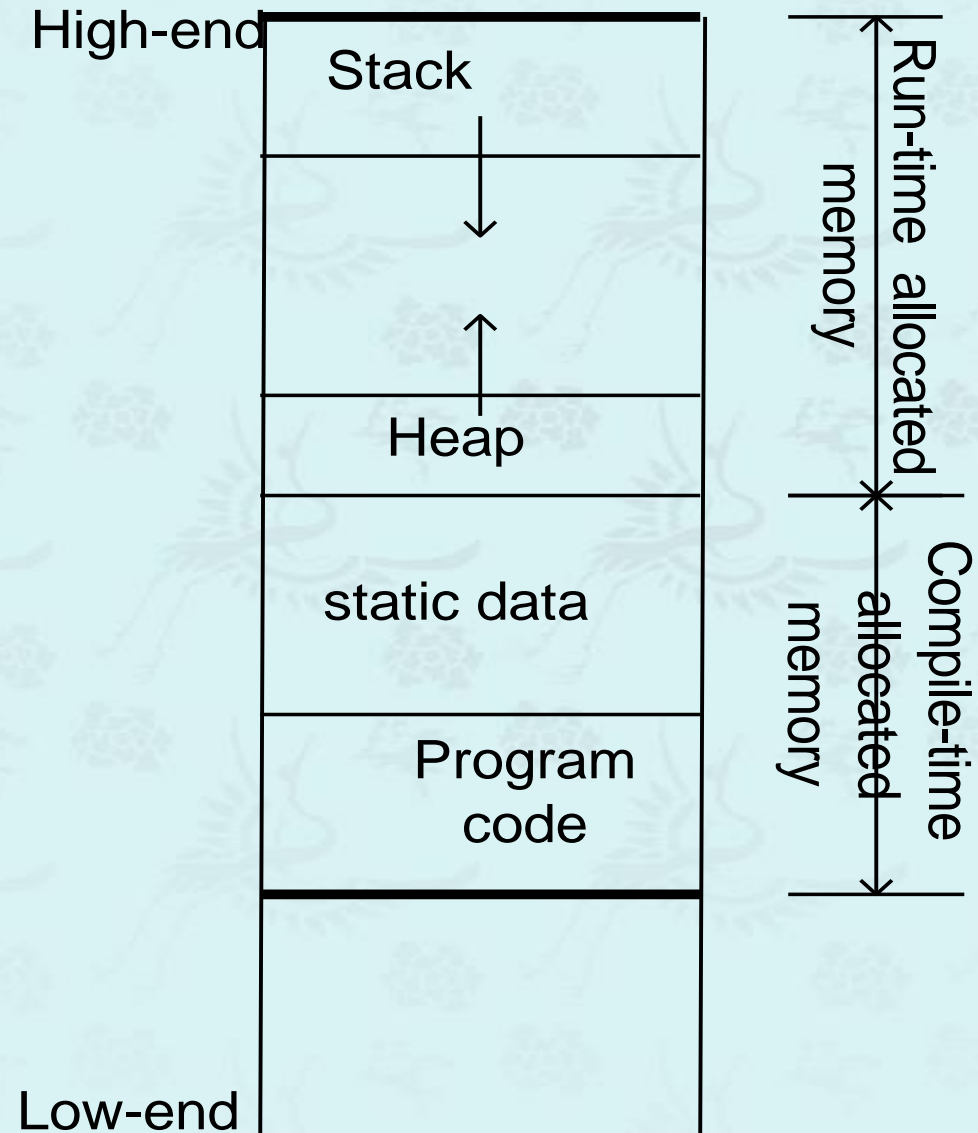
(Unnamed variables)

Stack Memory

Auto Variables

Function parameters

Dynamic Memory Allocation Diagram



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[IntialExpression]

- 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**

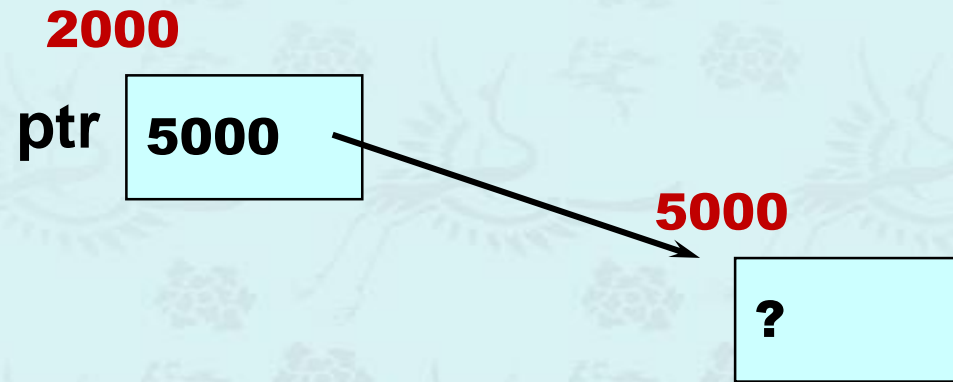
```
char *ptr;
```

➔

```
ptr = new char;
```

```
*ptr = 'B';
```

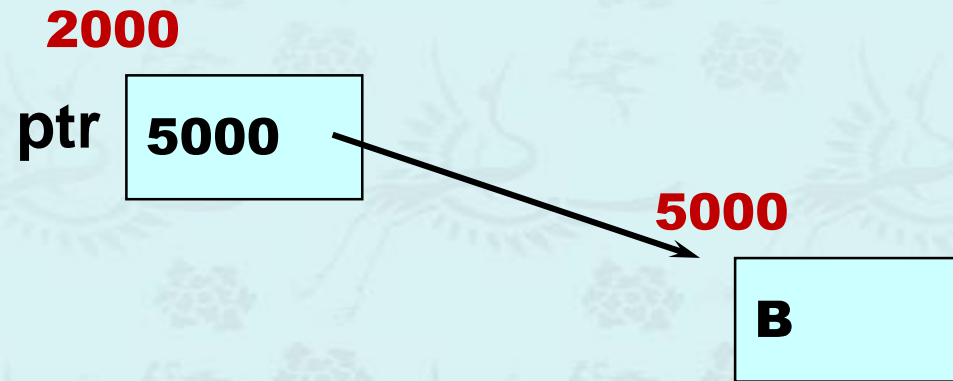
```
cout << *ptr;
```



NOTE: Dynamic data has no variable name

Operator **new**

```
char *ptr;  
  
ptr = new char;  
  
➔ *ptr = 'B';  
  
cout << *ptr;
```



NOTE: Dynamic data has no variable name

new vs. malloc()

- **new** is an operator.
- It calls the constructor.
- It returns exact data type if memory is available.
- It throws `bad_alloc` exception on failure. Use **nothrow** for **nullptr**.
- It can be overridden.
- In which memory allocated from the heap.
- Size is calculated by the compiler.
- **malloc** is a library function.
- It does not call the constructor.
- It returns the `void *` if memory is available.
- It returns **nullptr** on failure.
- It cannot be overridden.
- In which memory allocated from the heap.
- Need to pass the size.

NOTE: We learn how to use both `malloc()` as well as `new` first. Once we get familiar with them, then we rather start using **new** and **delete** operators **more and more later** in this course.

Dynamic Memory Allocation

- *In C*, functions such as `malloc()` and `free()` are used to dynamically allocate and deallocate 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**

The NULL/nullptr Pointer

- There is a pointer constant called the “null pointer” denoted by NULL/nullptr.
- NULL is int type 0 in C/C++, but nullptr is std::nullptr_t type.
- **NOTE:** It is an error to dereference a pointer whose value is NULL or nullptr. Such an error may cause your program to crash, or behave erratically. It is the programmer's job to check for this.

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

Operator **delete** Syntax

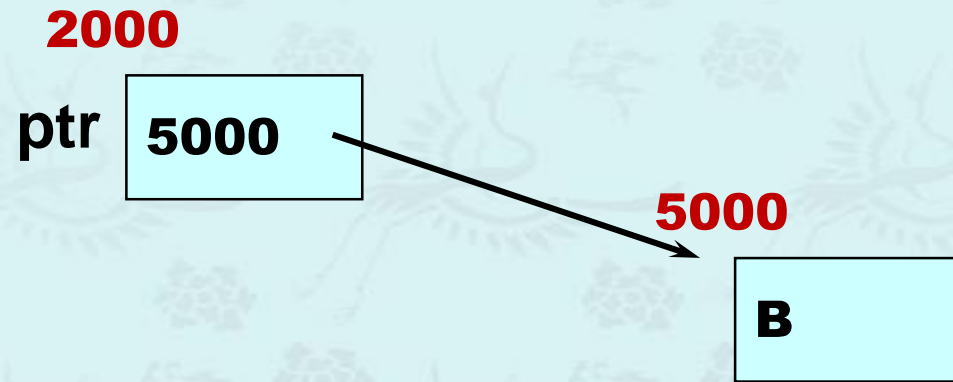
```
delete PointerVariable
```

```
delete [] PointerVariable
```

- 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 nullptr.
- Square brackets are used with delete to deallocate a dynamically allocated array.

Operator delete

```
char *ptr;  
  
ptr = new char;  
  
➔ *ptr = 'B';  
  
delete ptr;
```



NOTE: **delete** deallocates the memory pointed to by **ptr**

Operator **delete**

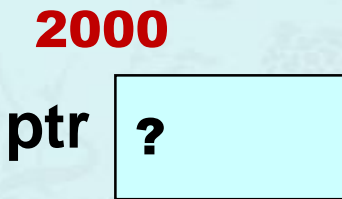
```
char *ptr;
```

```
ptr = new char;
```

```
*ptr = 'B';
```

➔

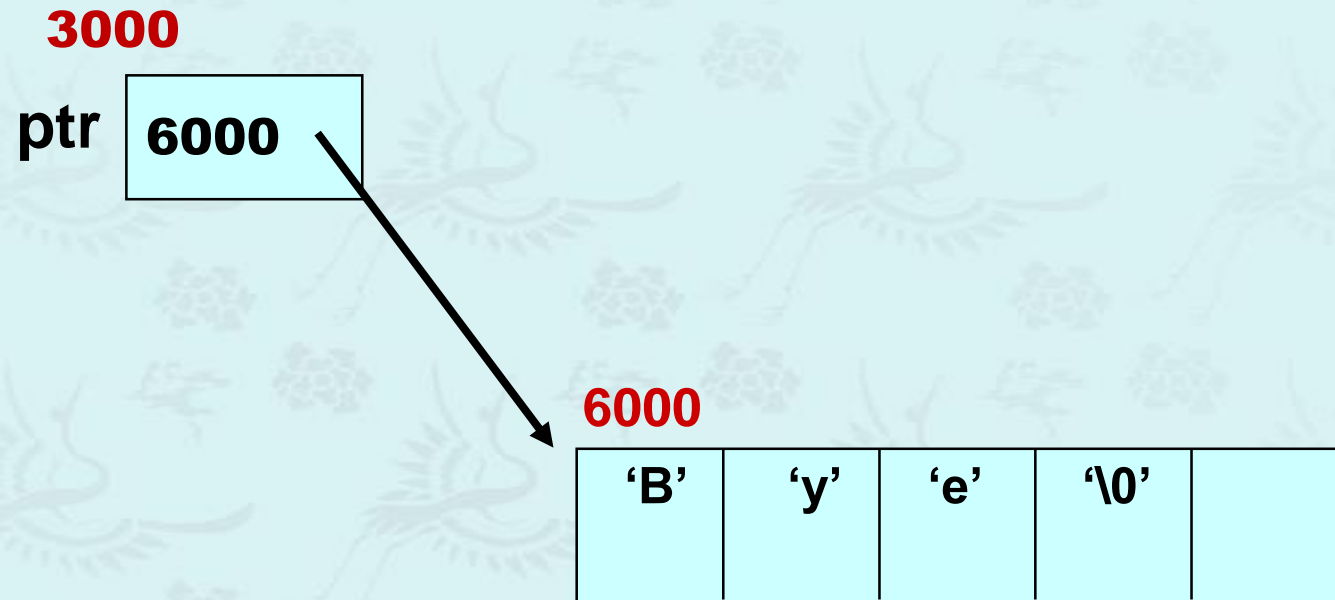
```
delete ptr;
```



NOTE: **delete** deallocates the memory pointed to by ptr

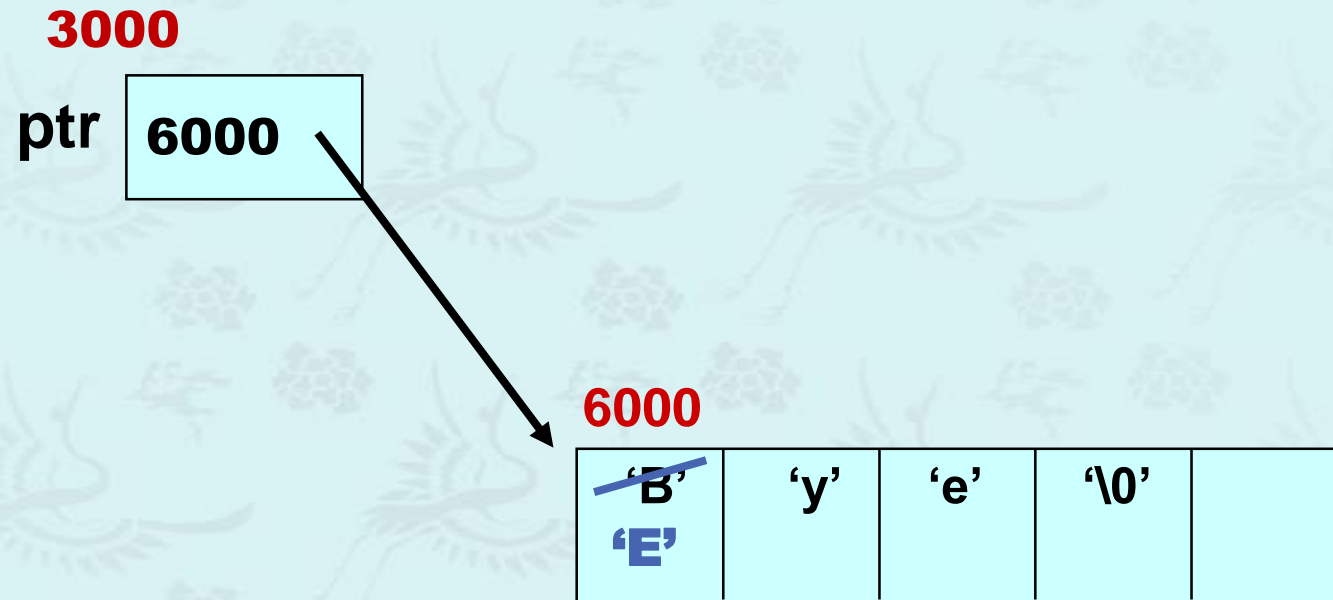
Example: Operator **delete**

```
char *ptr;  
  
ptr = new char[5];  
→ strcpy(ptr, "Bye");  
  
ptr[0] = 'E';  
  
delete [] ptr;  
  
ptr = nullptr;
```



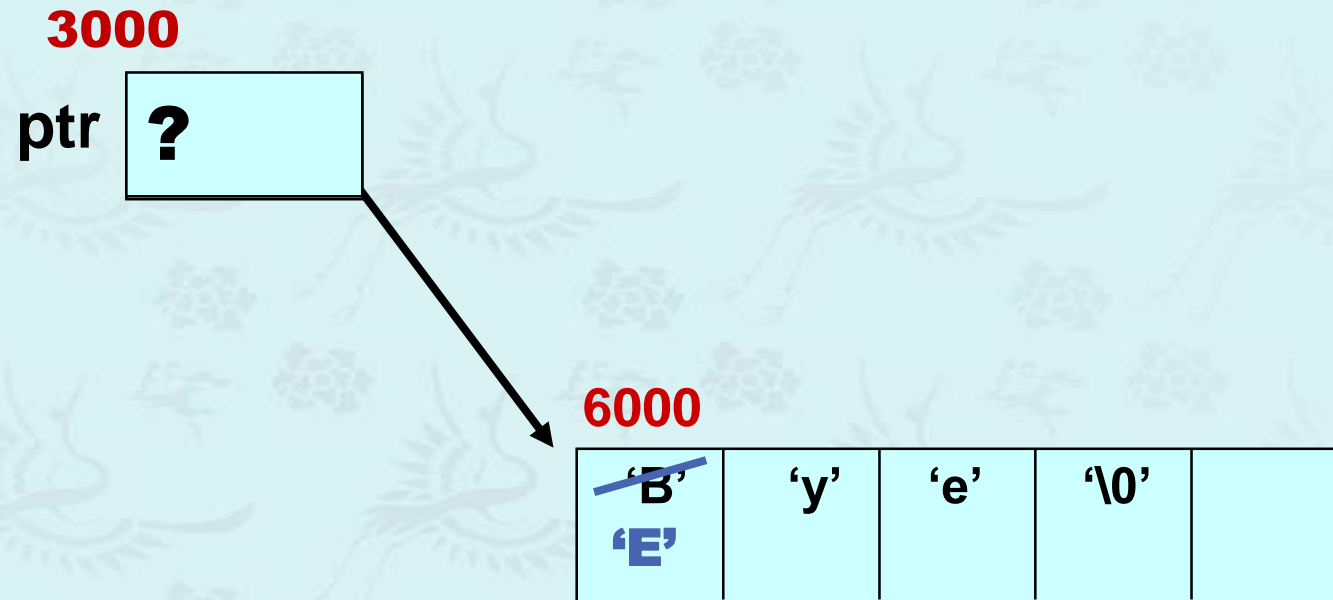
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Example: Operator **delete**

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→ delete [] ptr;  
  
ptr = nullptr;
```



NOTE:

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

Example: Operator **delete**

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char *ptr;  
  
ptr = new char[5];  
  
strcpy(ptr, "Bye");  
  
ptr[0] = 'E'  
  
delete [] ptr;  
  
→ ptr = nullptr;
```

3000
ptr **NULL**

NOTE:

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

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 nullptr before accessing it.
For example,

```
char *ptr = new char[5];  
assert(ptr != nullptr);
```



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 nullptr before accessing it.
For example,

```
char *ptr = new char[5];  
assert(ptr != nullptr);
```



```
char *ptr = new (nothrow) char[5];  
assert(ptr != nullptr);
```

Quiz 1

```
#include <iostream>
using namespace std;

int main() {
    int *pi;
    *pi = 17;
    cout << "i = " << *pi << endl;
    return 0;
}
```

- What type of an error?
 1. a link error
 2. a run-time error
 3. a syntax error
 4. a logic error
- Fix the code such that it outputs "i = 17".
 1. Adding two lines
 2. Using new and delete

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