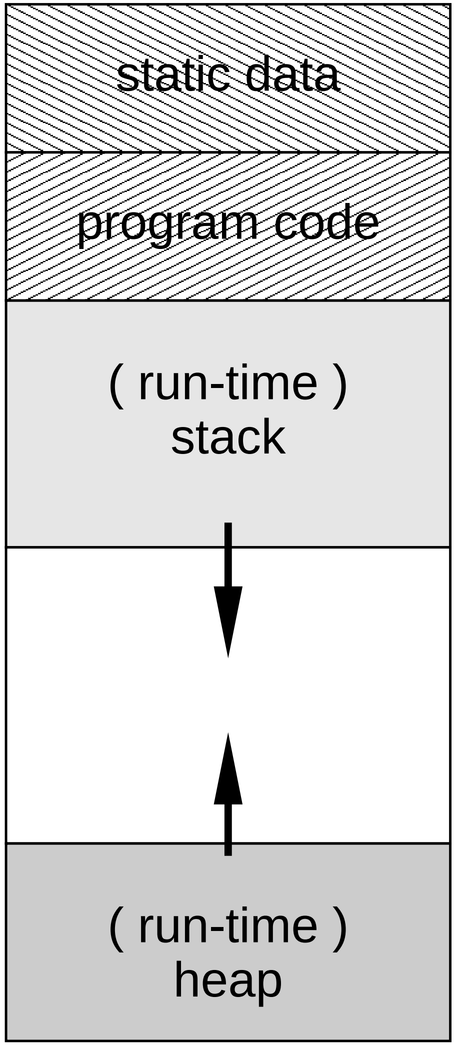
# Comp151

# Garbage Collection & Destructors

# Memory Layout of a Running Program

```
void f()
{
    // x, y are local variables
    // on the runtime stack
    int x = 4;
    Word y("Titanic");

    // p is another local variable
    // on the runtime stack.
    // But the array of 100 int
    // that p points to
    // is on the heap
    int* p = new int [100];
}
```




[ ... , local variables, temporary variables, passed arguments ]

[ objects dynamically allocated by "new" ]

# Memory Usage on Runtime Stack and Heap

- Local variables are *constructed* (created) when they are defined in a function/block on the run-time stack.
- When the function/block terminates, the local variables inside and the CBV arguments will be *destructed* (and removed) from the run-time stack.
- Both construction and destruction of variables are done automatically by the compiler by calling the appropriate constructors and destructors.
- BUT, dynamically allocated memory remains after function/block terminates, and it is the user's responsibility to return it back to the heap for recycling; otherwise, it will stay until the program finishes.

# Garbage and Memory Leak

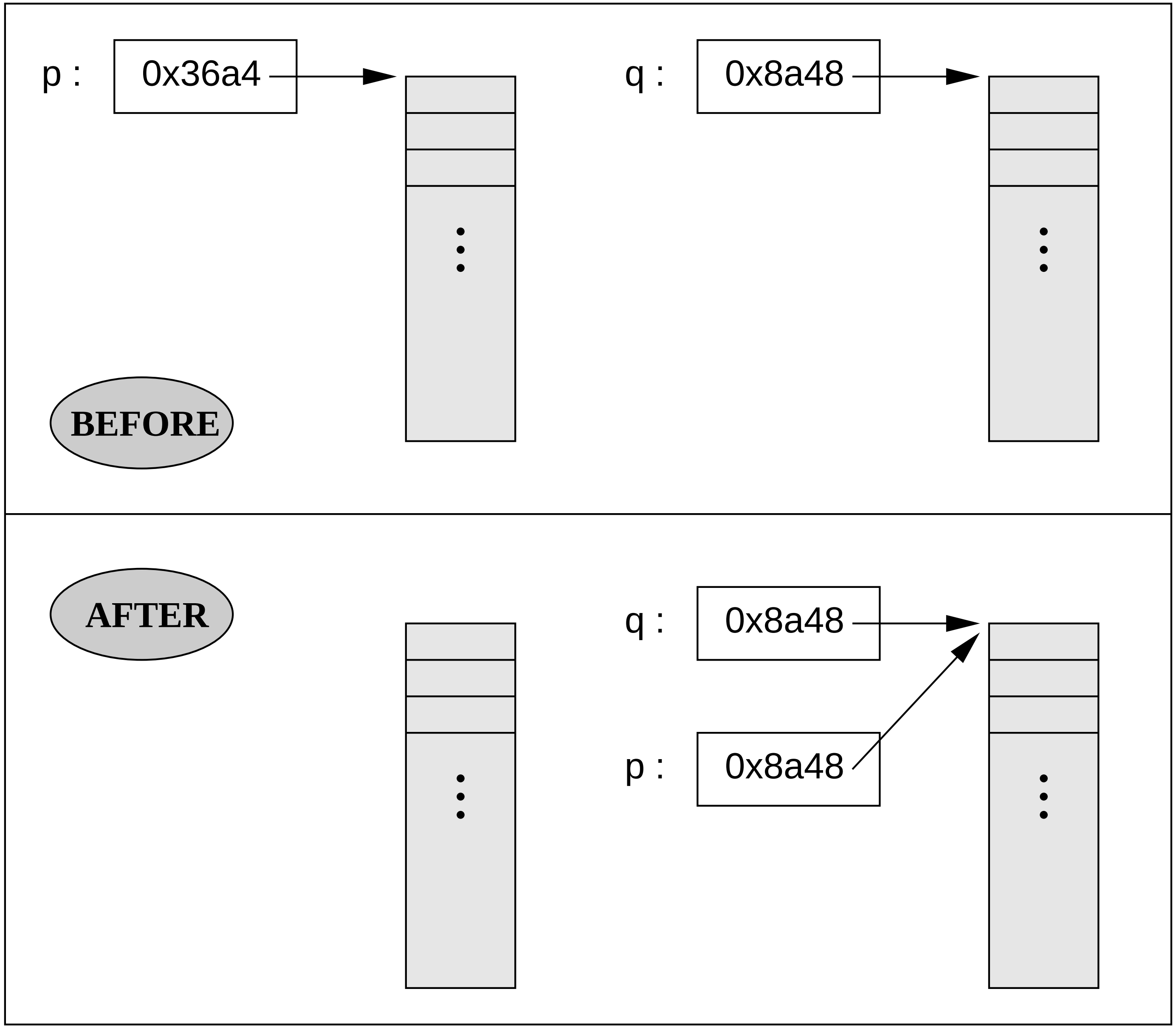


```
main()
{
    for (int j = 1; j ≤ 10000; j++)
    {
        int* snoopy = new int [100];
        int* vampire = new int [100];
        snoopy = vampire;            // Now snoopy becomes vampire
        ...                          // Where is the old snoopy?
    }
}
```

- Garbage is a piece of storage that is part of a program but there are no more references to it in the program.
- Memory Leak occurs when there is garbage.

Question: What happens if garbages are huge or continuously created inside a big loop?!

# Example: Before and After p = q



# delete: To Remove Garbage

```
main() {
    Stack* p = new Stack(9);        // A dynamically allocated stack object
    int* q = new int [100];   // A dynamically allocated array of integers
    ...
    delete p;                                         // delete an object
    delete [ ] q;                           // delete an array of objects
    p = 0;                // It is a good practice to set a pointer to NULL
    q = 0;                            // when it is not pointing to anything
}
```

- Explicitly remove a single garbage object by calling **delete** on a pointer to the object.
- Explicitly remove an array of garbage objects by calling **delete [ ]** on a pointer to the first object of the array.
- Notice that **delete** ONLY puts the dynamically allocated memory back to the heap, and the local variables (p and q above) stay behind on the run-time stack until the function terminates.

# Dangling References and Pointers

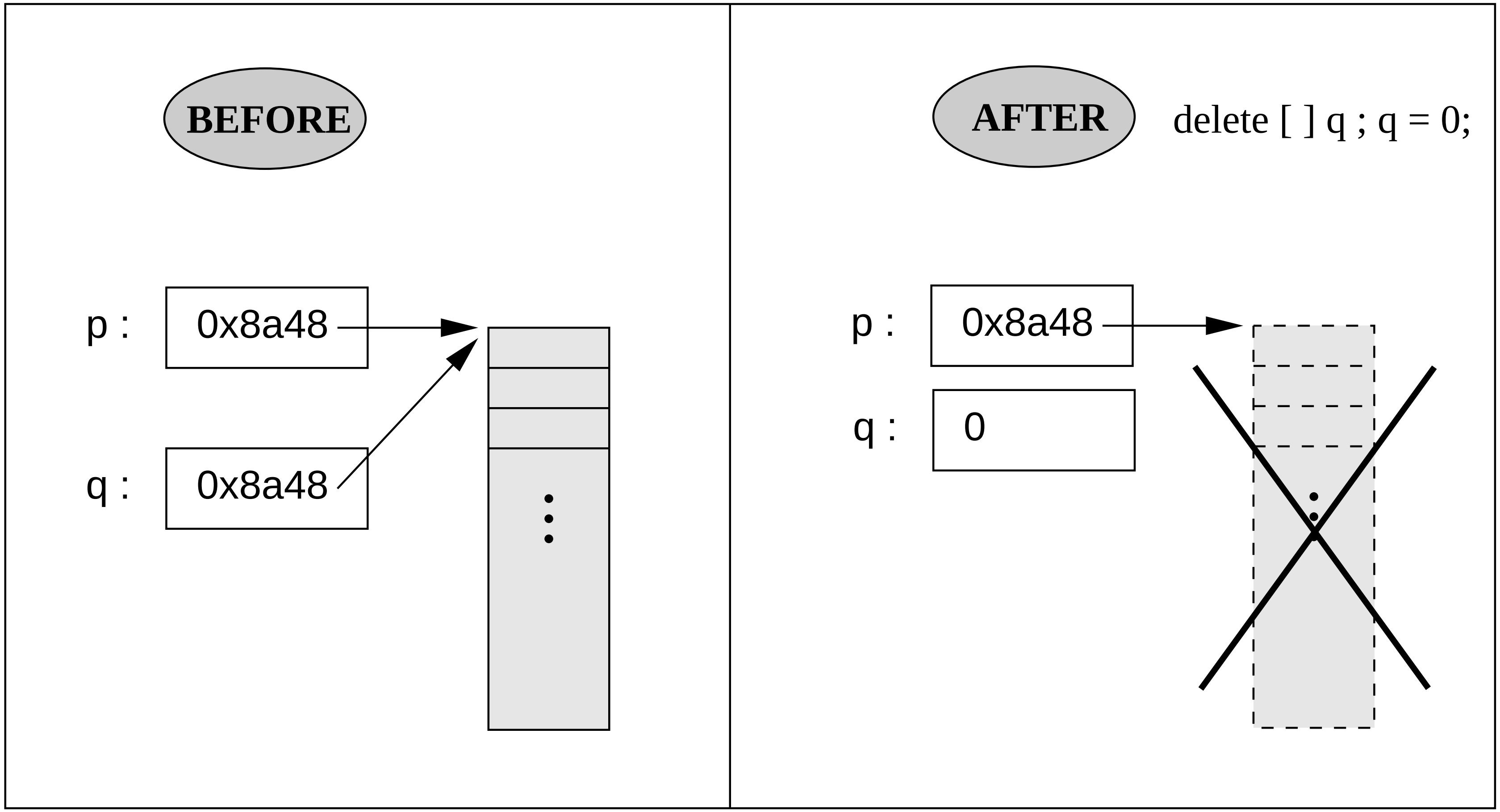
However, careless use of **delete** may cause dangling references.

```
main()
{
    char* p;
    char* q = new char [128];          // Dynamically allocate a char buffer
    ...
    p = q;                             // p and q now points to the same char buffer
    delete [ ] q; q = 0;               // delete the char buffer
    /* Now p is a dangling pointer! */
    p[0] = 'a';                        // Error: possibly segmentation fault
    delete [ ] p;                      // Error: possibly segmentation fault
}
```

- A dangling reference is created when memory pointed by a pointer is deleted but the user thinks that the address is still valid.
- Dangling references are due to carelessness and pointer aliasing — an object is pointed to by *more* than *one* pointer.

# Example: Dangling References





## Other Solutions: Garbage, Dangling References



Garbage and dangling references are due to careless pointer manipulation and pointer aliasing.

- Some languages provide automatic garbage collection facility which stops a program from running from time to time, checks for garbages, and puts them back to the heap for recycling.
- Some languages do *not* have pointers at all!
  (It was said that most program bugs are due to pointers.)

# Destructors: Introduction

```
void Example()
{
    Word x("bug", 4);
    ...
}

int main() { Example(); .... }
```

- On return from Example(), the local Word object "x" of Example() is destroyed from the run-time stack of Example(). i.e. the memory space of (int) x.frequency and (char*) x.str are released.

Quiz: How about the dynamically allocated memory for the string, "bug" that x.str points to?

# Destructors



C++ supports a more general mechanism for user-defined destruction of class objects through destructor member functions.

```
~Word() { delete [ ] str; }
```

- A *destructor* of a class X is a special member function with the name X::~X( ).
- A destructor takes no arguments, and has no return type — thus, there can only be ONE destructor for a class.
- The destructor of a class is invoked automatically whenever its object goes out of scope — out of a function/block.
- If not defined, the compiler will generate a default destructor of the form X::~X( ) { } which does nothing.

# Example: Destructors

```
class Word {
    int frequency;
    char* str;
  public:
    Word() : frequency(0), str(0) {};
    Word(const char* s, int k = 0) { ... }
    ~Word() { delete [ ] str; }
};

int main() {
    Word* p = new Word("Titanic");
    Word* x = new Word [5];

    ...

    delete p;                    // destroy a single object
    delete [ ] x;                // destroy an array of objects
}
```

# Bug: Default Assignment

```
void Bug(Word& x)
{
    Word bug("bug", 4);
    x = bug;
}

int main()
{
    Word movie("Titanic");              // which constructor?
    Bug(movie);
}
```

Quiz: What is movie.str after returning from the call Bug(movie)?