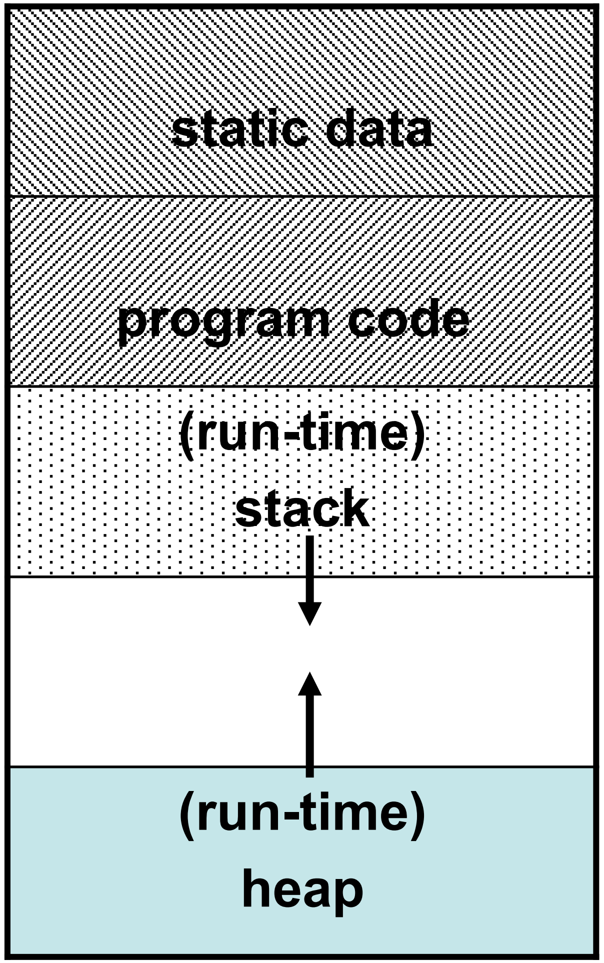
COMP2012H

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("Brokeback");

   // 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.

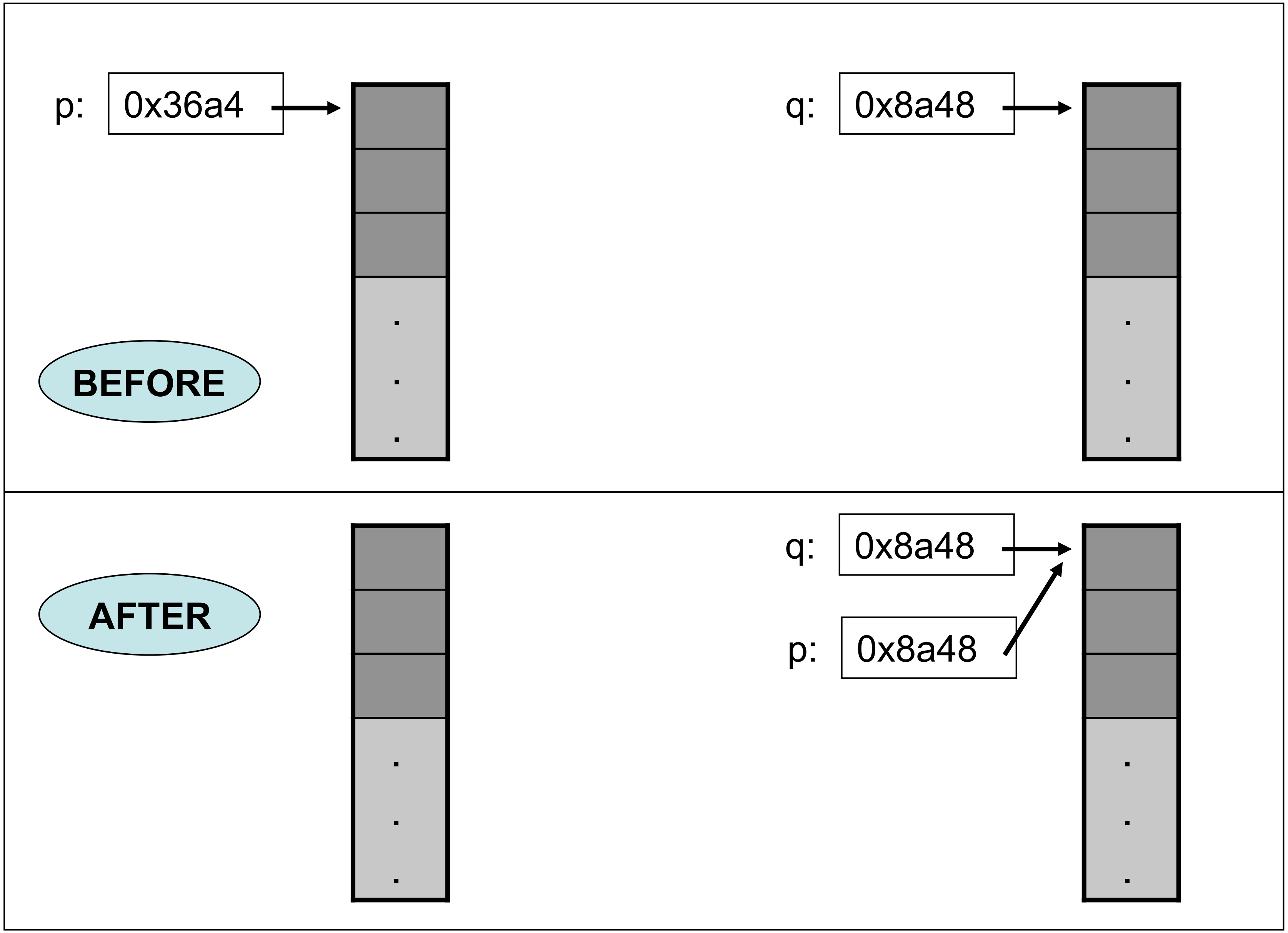
Garbage and Memory Leaks

```
int 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 was created (allocated) by a program, where there are no more pointers/references to it.
- A memory leak occurs when there is garbage.

Question: What happens if there is a huge piece of garbage, or garbage is continuously created inside a big loop?!

Example: Before and After p = q



`delete`: to prevent garbage

```
int 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 = NULL;        // it is good practice to set a pointer to 0
   q = NULL;        //   when it is not pointing to anything
}
```

- Explicitly deallocate the memory for a single object by calling `delete` on a pointer to the object.
- Explicitly deallocate the memory for 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.

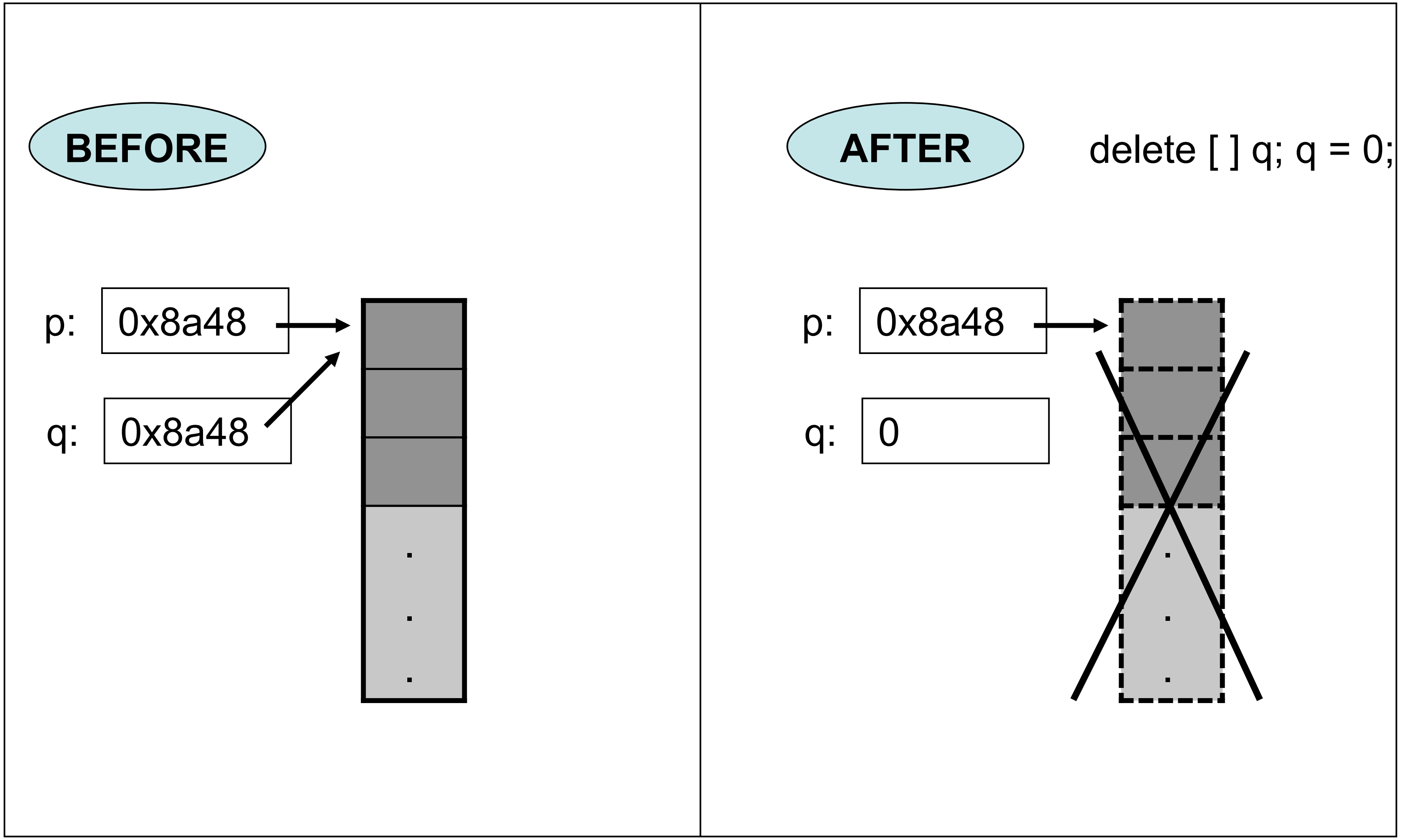
Dangling References and Pointers

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

```
int 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 to by a pointer is deleted but the user thinks that the address is still valid.
- Dangling references are due to carelessness and pointer aliasing — where an object is pointed to by *more* than *one* pointer.

Example: Dangling References



Other Solutions: Garbage, Dangling References

Memory leaks and dangling references are due to careless pointer manipulation, especially in situations where there is pointer aliasing.

- Some languages provide automatic garbage collection facility which stops a program from running from time to time, checks for garbage, and puts that memory back in the heap for recycling.
  - e.g.: Lisp, Scheme, Java, C#, .NET …

- Some languages do *not* have explicit pointers at all!

  (The large majority of program bugs are due to pointers.)

- However, you pay a performance penalty for such solutions.

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 <u>destructor member functions</u>.

~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 <u>ONE</u> destructor for a class.
- The destructor of a class is invoked <u>automatically</u> whenever its object goes out of scope – out of a function/block.
- If not defined, the compiler will generate a <u>default destructor</u> 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("Brokeback Mountain");
    Word* x = new Word [5];
    …
    delete p;      // destroy a single object
    delete [ ] x;  // destroy an array of objects
}
```

Bug: Default Assignment

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

int main()
{
    Word movie("Brokeback Mountain");   // which constructor?
    buggy(movie);
}
```

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