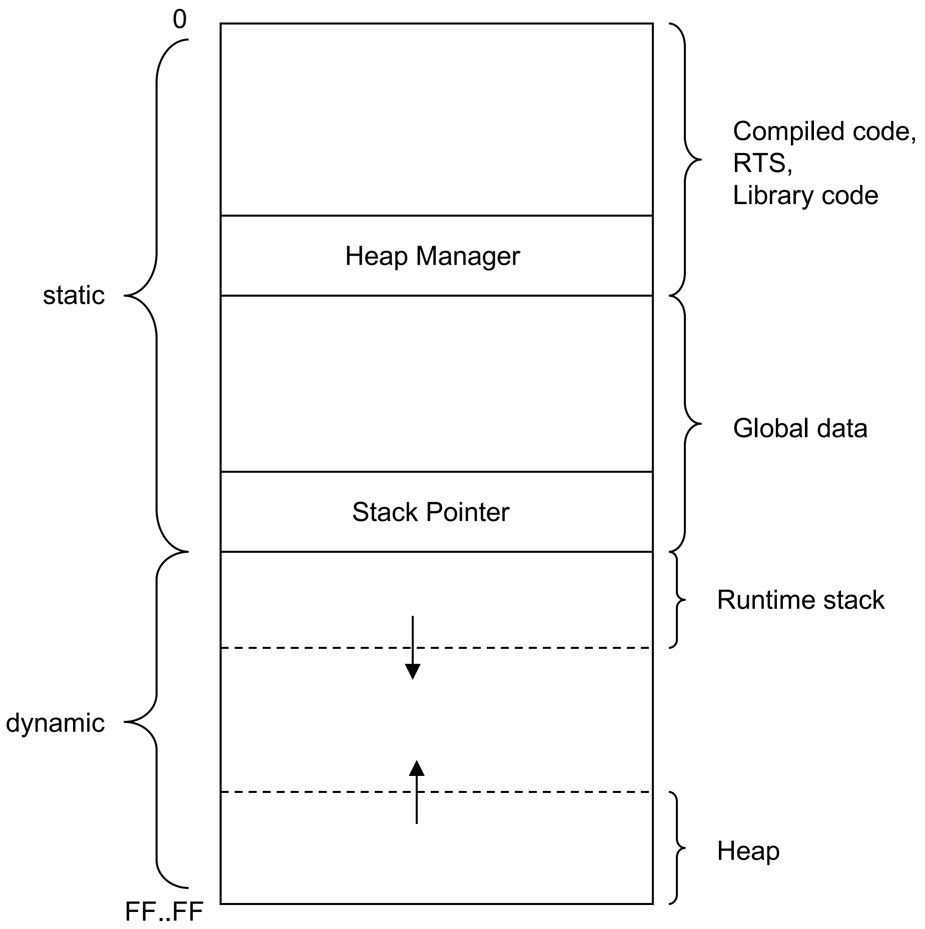
Memory Management

For most programming languages memory management has two parts:

(1) Static - global data, compiled code, runtime system
(2) Dynamic - runtime stack (activation record stack), heap (!)

Typical Memory Layout



A typical memory layout for languages such as C and Java

NOTE: if the runtime stack and the heap meet ⇒ out of memory

The Heap

Runtime systems allocate dynamically created objects on the heap by a call to the heap manager.

In Java the heap manager is called with the new keyword.

In C the heap manager is called using the malloc function.

Observation:
In languages like Java and ML heap memory is reclaimed by the heap manager automatically via garbage collection when it is no longer used.

In C the programmer has to explicitly manage heap memory with malloc/free function calls. This is error prone and leads to the (in)famous dangling pointer reference (free called too early) and the memory leak (free never called) problems.

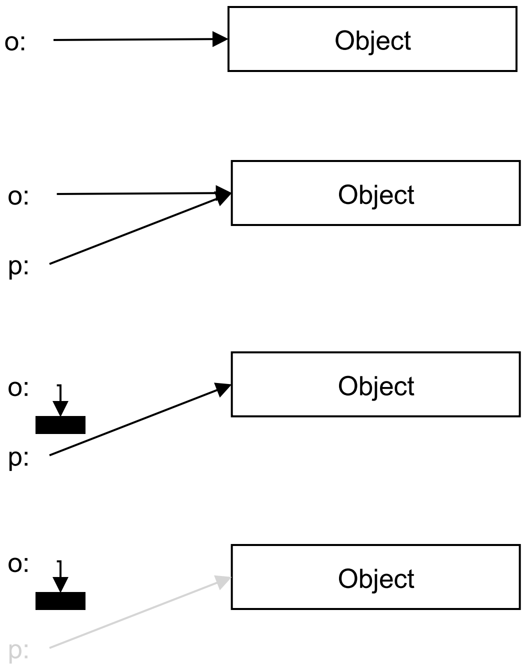
Example C (Memory Leak)

Program

```
struct Object * o;

void f()
{
    o = malloc(sizeof(struct Object));



    struct Object * p = o;



    o = NULL;



}
```

(pop activation record off the runtime stack)

Heap Manager



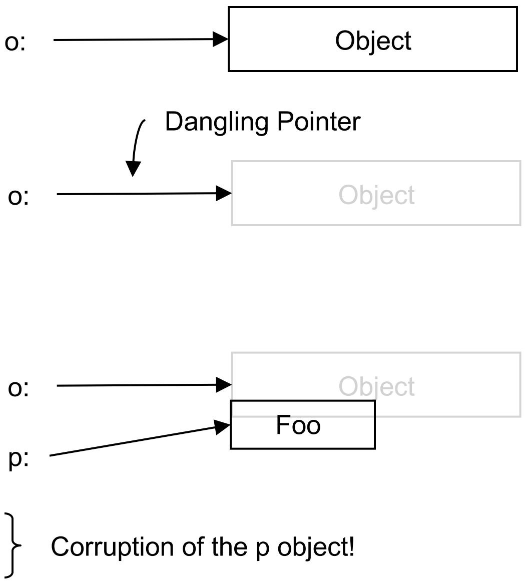
Note: the heap manager has not way of knowing that this memory is no longer used ⇒memory leak

Example C (Dangling Pointer)

Program

```
void f()
{
   struct Object * o = malloc(sizeof(struct Object));

   free(o);

   struct Foo  * p = malloc(sizeof(struct Foo));

    o->ObjectAttribute = value;

    p->Print();
    free(p);
}
```

Heap Manager



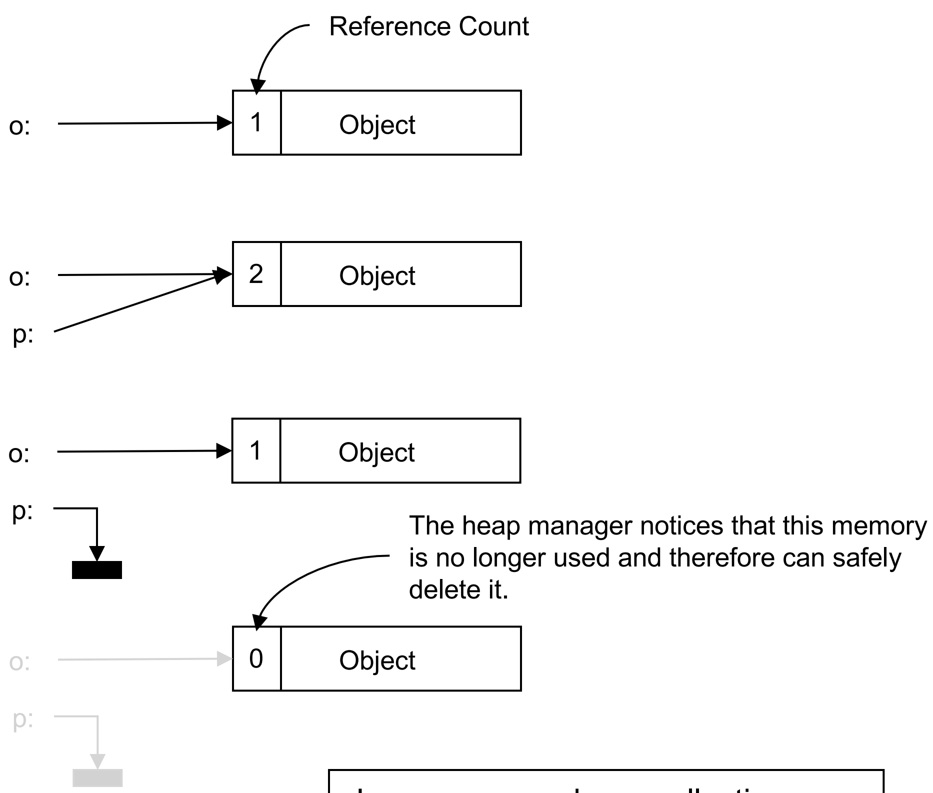
Corruption of the p object!

Example Java (Garbage Collection)

Program

```
void f()
{
   Object o = new Object();



   Object p = o;



   p = null;


}

(pop activation record off the runtime stack)
```

Heap Manager



The heap manager notices that this memory is no longer used and therefore can safely delete it.

Java uses a garbage collection technique called reference counting.