Smart Pointers

Object-Oriented Programming with C++

std smart pointers

- Standard library holder for raw pointers on stack
  - `std::unique_ptr`
  - `std::shared_ptr`
  - `std::weak_ptr`
  - `std::auto_ptr` (deprecated in C++11)
  - …

Putting it all together

Templates

Inheritance

Reference Counting

Smart Pointers

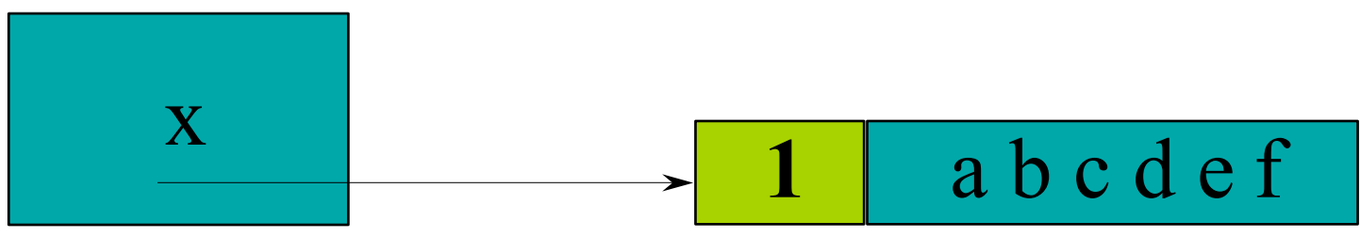
Reference: *C++ Strategies and Tactics*, Robert Murray, 1993

Goals

- Introduce the code for maintaining reference counts
  – A reference count is a count of the number of times an object is shared
  – Pointer manipulations have to maintain the count
- Class UCObject holds the count
  –"Use-counted object"
- UCPointer is a *smart pointer* to a UCObject
  – A smart pointer is an object defined by a class
  – Implemented using a template
  – Overloads `operator->` and unary `operator*`

Reference counts in action

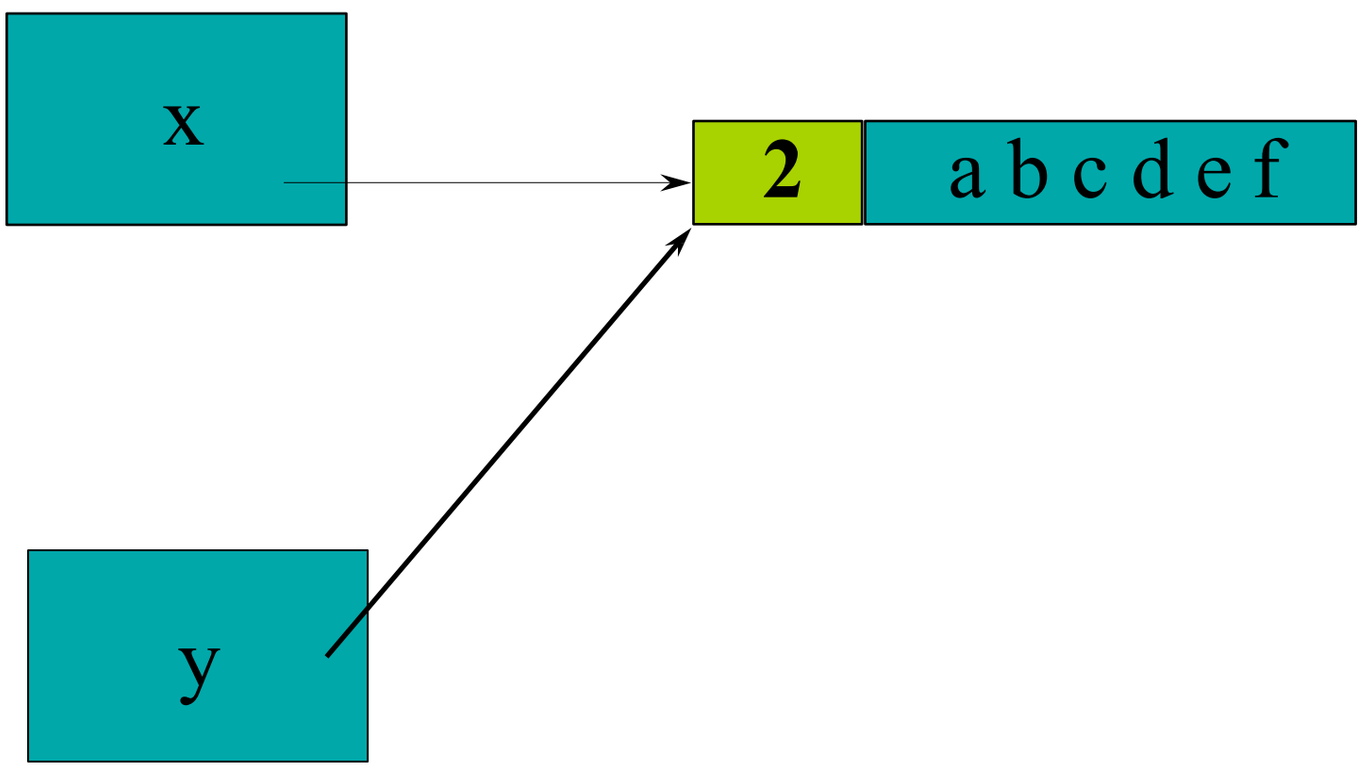
```
String x("abcdef");
```



Shared memory maintains a count of how many times it is shared

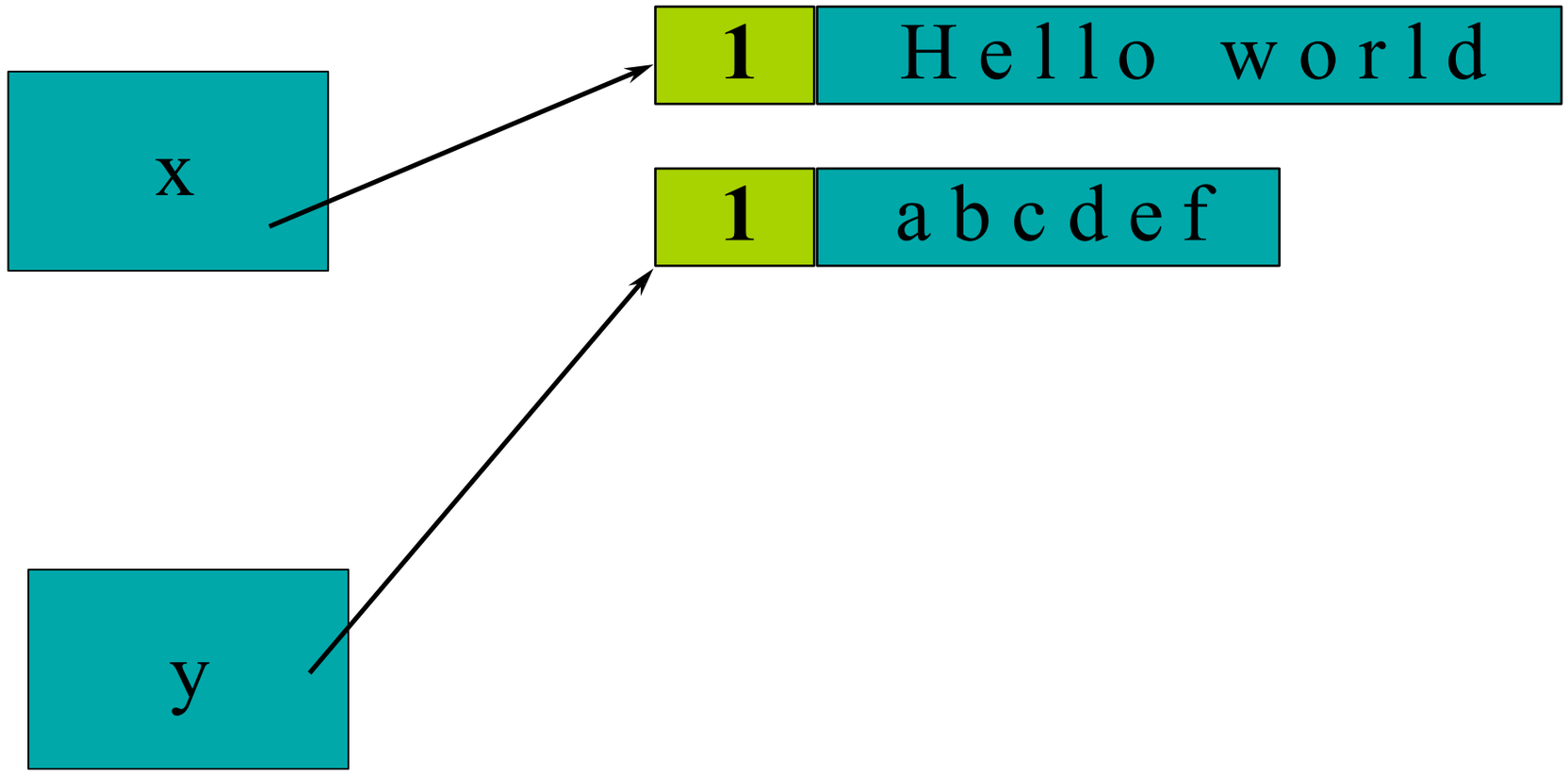
Reference counts in action

```
String x("abcdef");
String y = x; // shallow copy of x
```

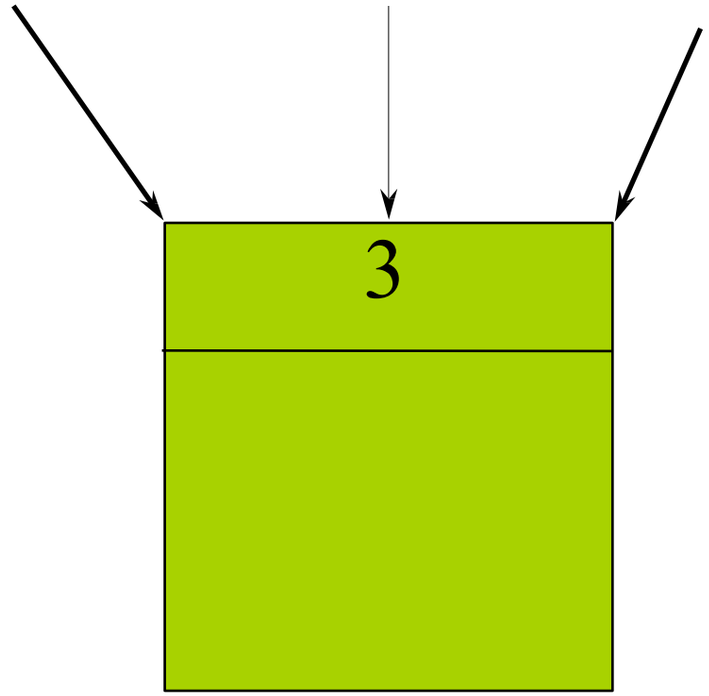


Reference counts in action

```
String x("abcdef");
String y = x; // shallow copy of x
x = "Hello world";  // copy on write
```

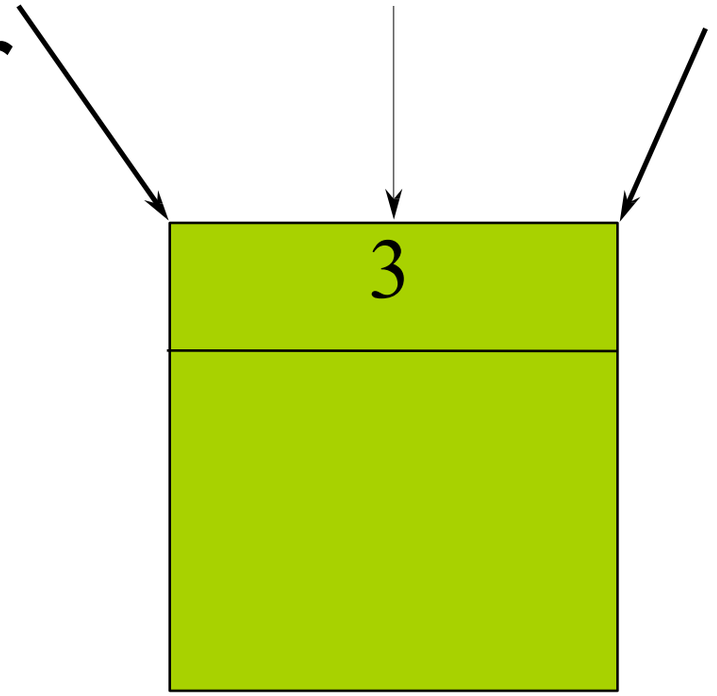


Reference counting



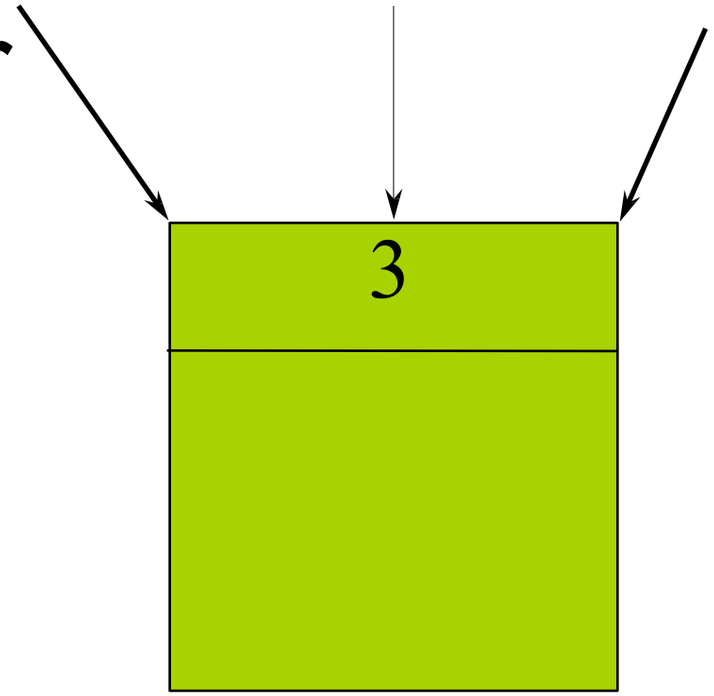
Reference counting

- Each shareable object has a counter



Reference counting

- Each shareable object has a counter
- Initial value is 0



Reference counting

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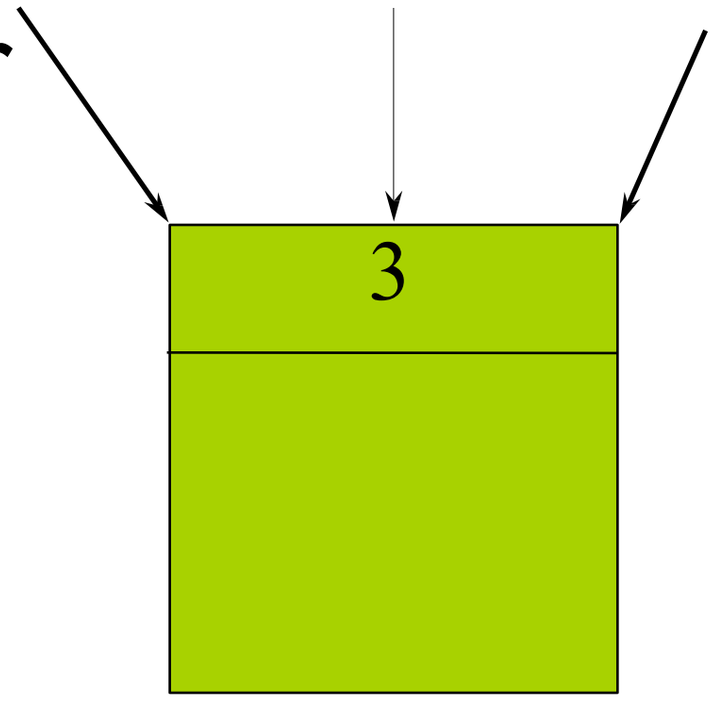
- Initial value is 0
- Whenever a pointer is assigned:

```
p = q;
```



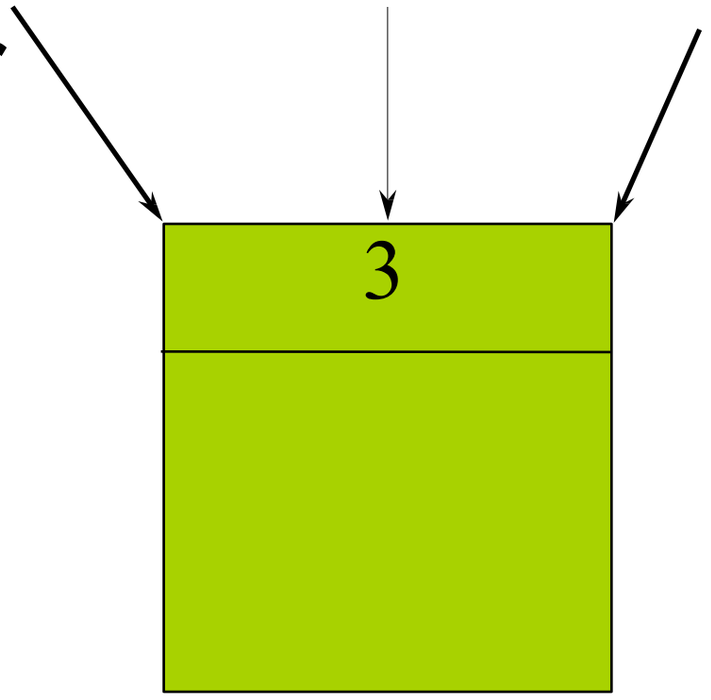
Reference counting

- Each shareable object has a counter
- Initial value is 0
- Whenever a pointer is assigned:

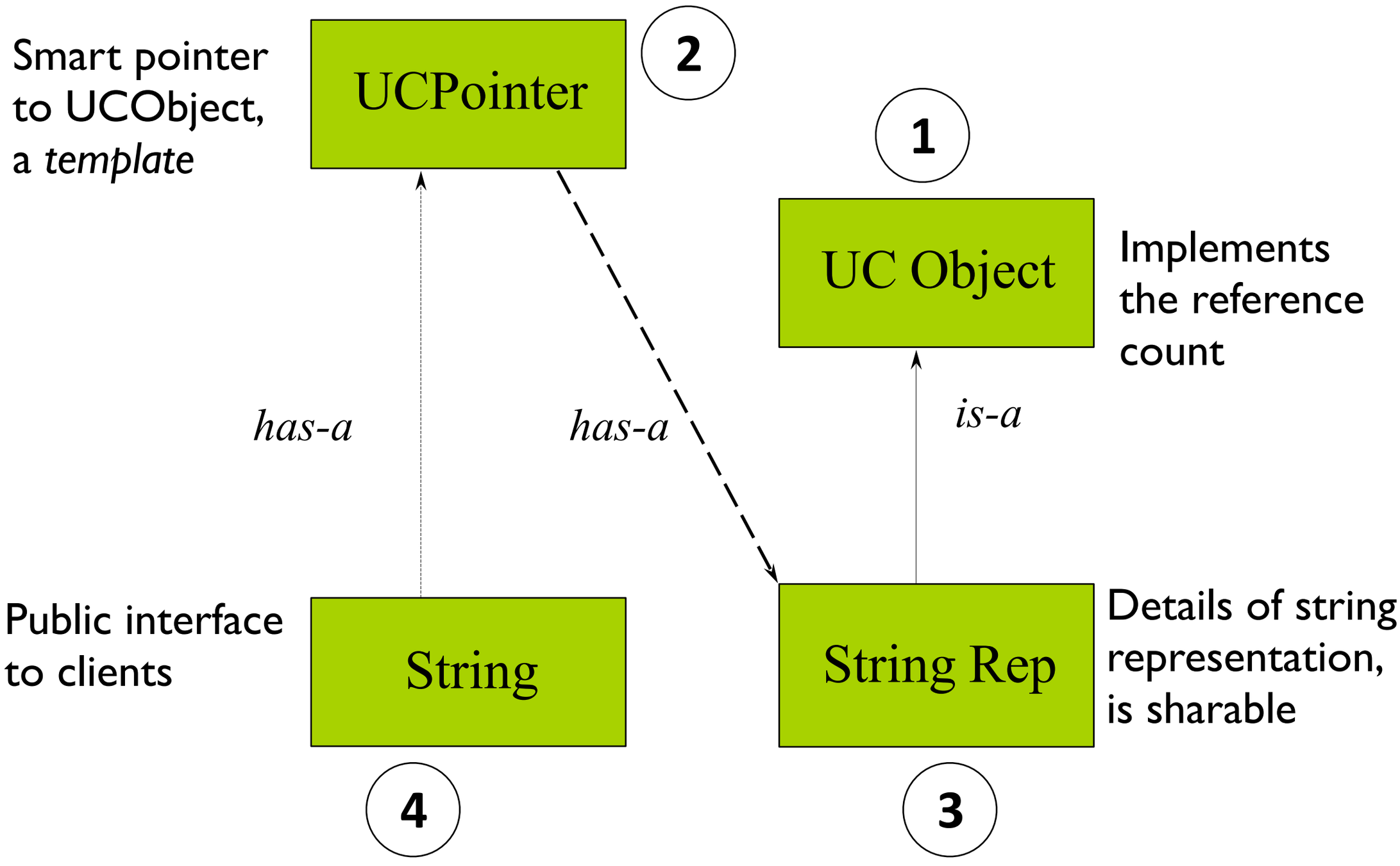
```
p = q;
```

- Have to do the following

```
p->decrement(); // p's count will decrease
  p = q;
p->increment(); // q/p's count will increase
```



The four classes involved



Reusing reference counting

```
#include <assert.h>
class UCObject {
public:
     UCObject() : m_refCount(0) { }
     virtual ~UCObject() { assert(m_refCount == 0); }
     UCObject(const UCObject&) : m_refCount(0) { }
     void incr() { m_refCount++; }
     void decr();
     int references() { return m_refCount; }
private:
     int m_refCount;
};
```

UCObject continued

```
inline void UCObject::decr(){
   m_refCount -= 1;
   if (m_refCount == 0) {
      delete this;
   }
}
```

- "delete this" is legal on heap object

–But don't use it on stack!

Class UCPointer

```
template <class T>
class UCPointer {
private:
     T* m_pObj;
     void increment() { if (m_pObj) m_pObj->incr(); }
     void decrement() { if (m_pObj) m_pObj->decr(); }
public:
     UCPointer(T* r = 0): m_pObj(r) { increment(); }
     ~UCPointer() { decrement(); };
     UCPointer(const UCPointer<T> & p);
     UCPointer& operator=(const UCPointer<T> &);
     T* operator->() const;
     T& operator*() const { return *m_pObj; }
};
```

UCPointer copy ctor

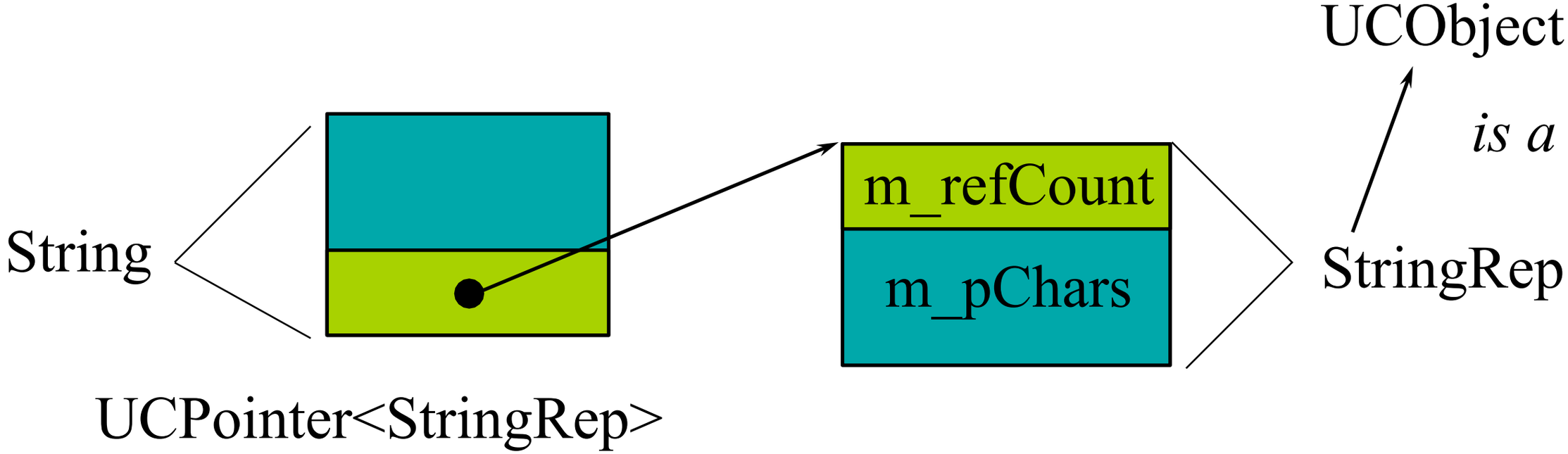
```
template <class T>
UCPointer<T>::UCPointer(const UCPointer<T> & p) {
   m_pObj = p.m_pObj;
   increment();
}
```

UCPointer assignment

```
template <class T>
UCPointer<T>&
UCPointer<T>::operator=(const UCPointer<T>& p) {
  if (m_pObj != p.m_pObj) {
    decrement();
    m_pObj = p.m_pObj;
    increment();
  }
  return *this;
}
```

Envelope and Letter

- Envelope provides protection
- Letter contains the contents



Class String

```
class String {
public:
    String(const char *);
    ~String();
    String(const String&);
    String& operator=(const String&);
    int operator==(const String&) const;
    String operator+(const String&) const;
    int length() const;
    operator const char*() const;
private:
    UCPointer<StringRep> m_rep;
};
```

Class StringRep

```
class StringRep : public UCObject {
public:
    StringRep(const char *);
    ~StringRep();
    StringRep(const StringRep&);
    int length() const{ return strlen(m_pChars); }
    int equal(const StringRep&) const;
private:
    char *m_pChars;
};
```

StringRep implementation

```
StringRep::StringRep(const char *s) {
    if (s) {
        int len = strlen(s) + 1;
        m_pChars = new char[len];
        strcpy(m_pChars , s);
    } else {
        m_pChars = new char[1];
        *m_pChars = '\0';
    }
}
StringRep::~StringRep() {
    delete [] m_pChars ;
}
```

StringRep implementation

```
StringRep::StringRep(const StringRep& sr) {
   int len = sr.length();
   m_pChars = new char[len + 1];
   strcpy(m_pChars , sr.m_pChars );
}
```

```
int StringRep::equal(const StringRep& sp)
const {
   return (strcmp(m_pChars, sp.m_pChars) == 0);
}
```

String implementation

```
String::String(const char *s)
    : m_rep(new StringRep(s)) {}

String::~String() {}

// Again, note constructor for rep in list.
String::String(const String& s) : m_rep(s.m_rep) {}

String&
String::operator=(const String& s) {
    m_rep = s.m_rep; // let smart pointer do work!
    return *this;
}
```

In such case, the implementation of ctor and operator= can be *ignored*.

String implementation

```
int
String::operator==(const String& s) const {
    // overloaded -> forwards to StringRep
    return m_rep->equal(*s.m_rep); // smart ptr *
}
```

```
int
String::length() const {
    return m_rep->length();
}
```

Dispatch to the real meat StringRep…

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- StringRep deals only with string storage and manipulation
- UCObject and UCPointer are reusable
- Slower than raw pointers
- Invasive design
  - see `std::shared_ptr` for non-intrusive design