Putting it All Together

Templates

Inheritance

Reference Counting

Smart Pointers

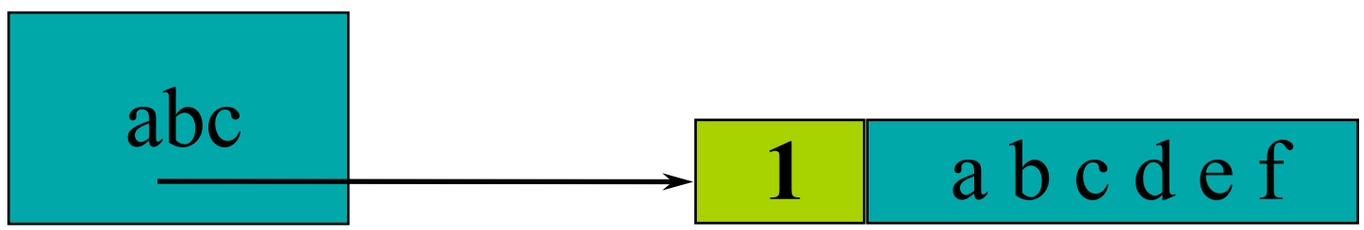
Reference: *C++ Strategies and Tactics*, Robert Murray, 1993

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

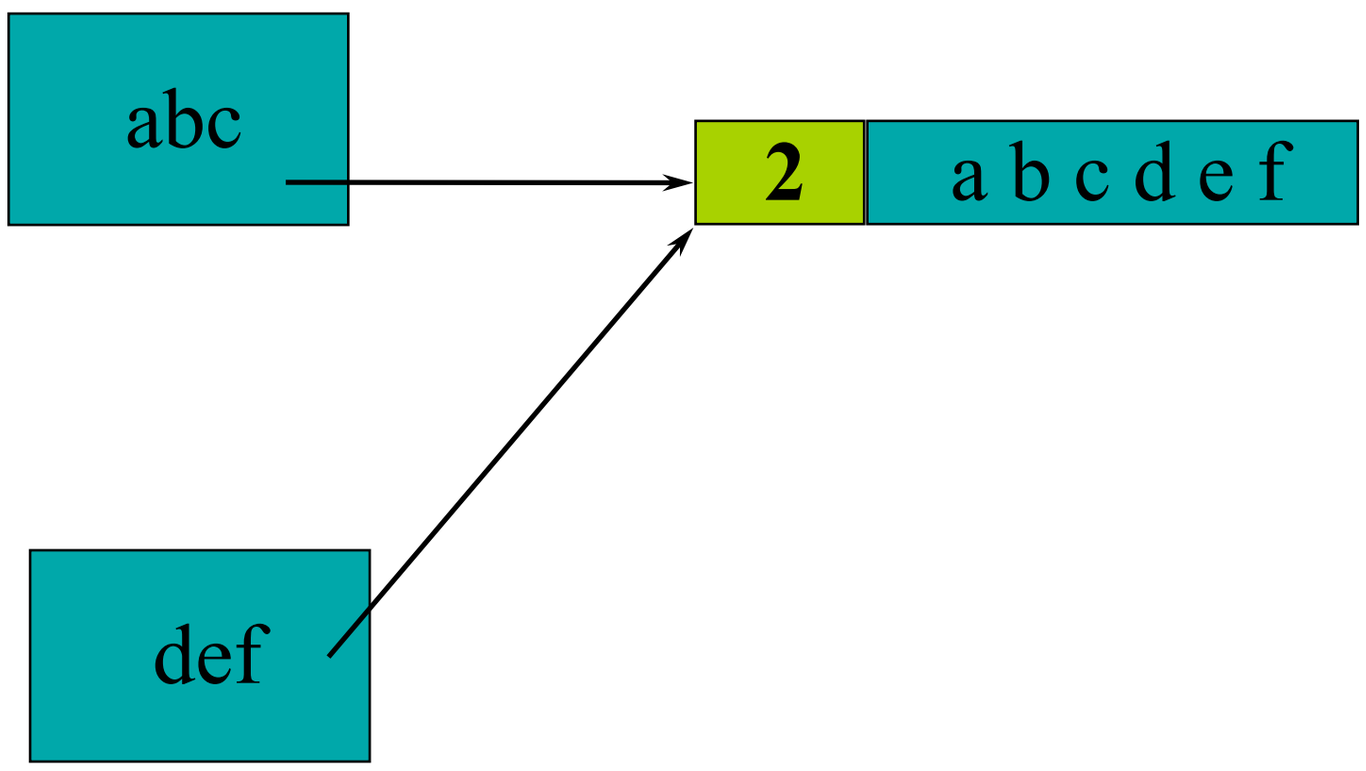
```
String abc("abcdef");
```



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

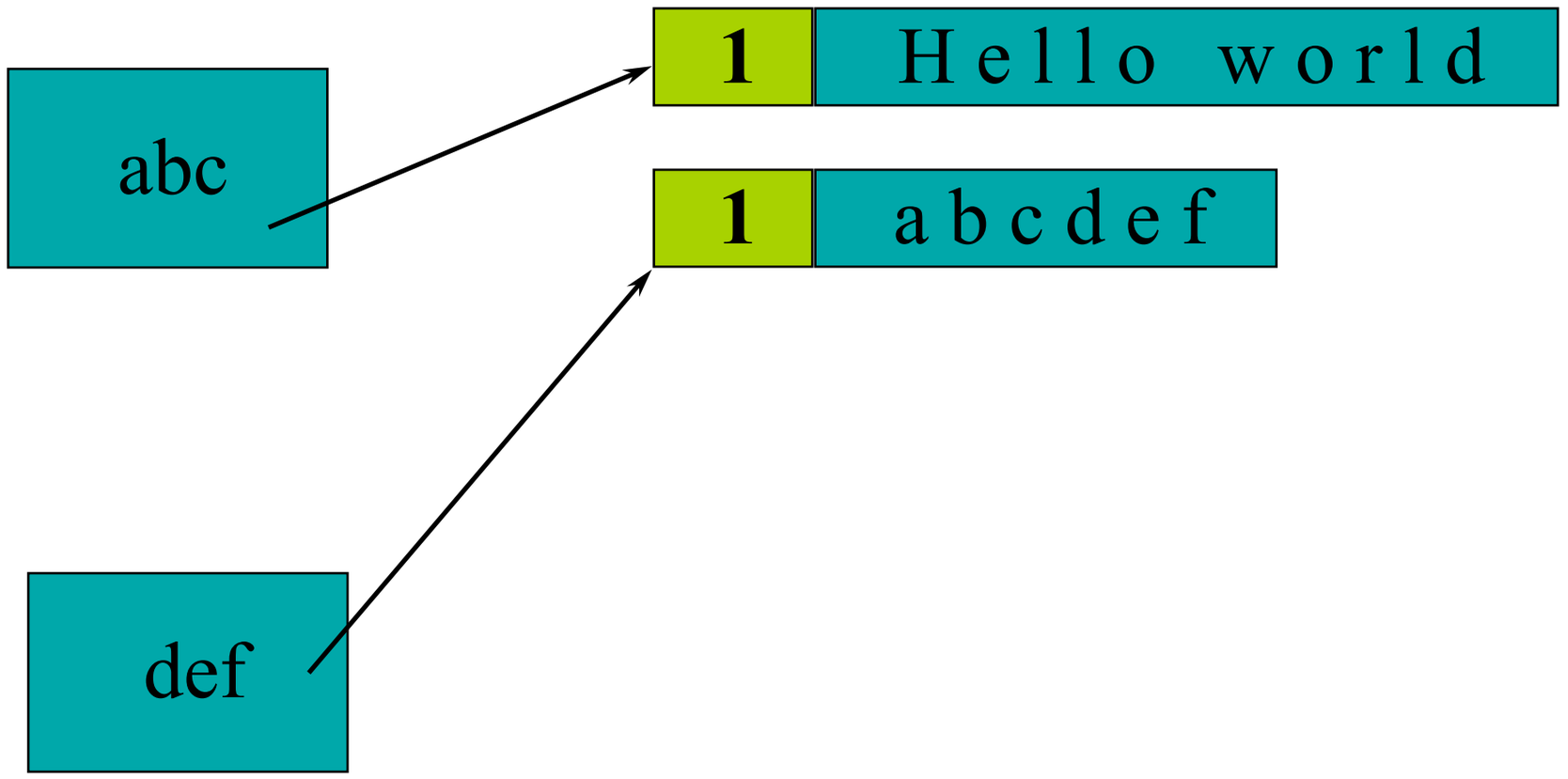
Reference counts in action

```
String abc("abcdef");
String def = abc; // shallow copy of abc
```



Reference counts in action

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



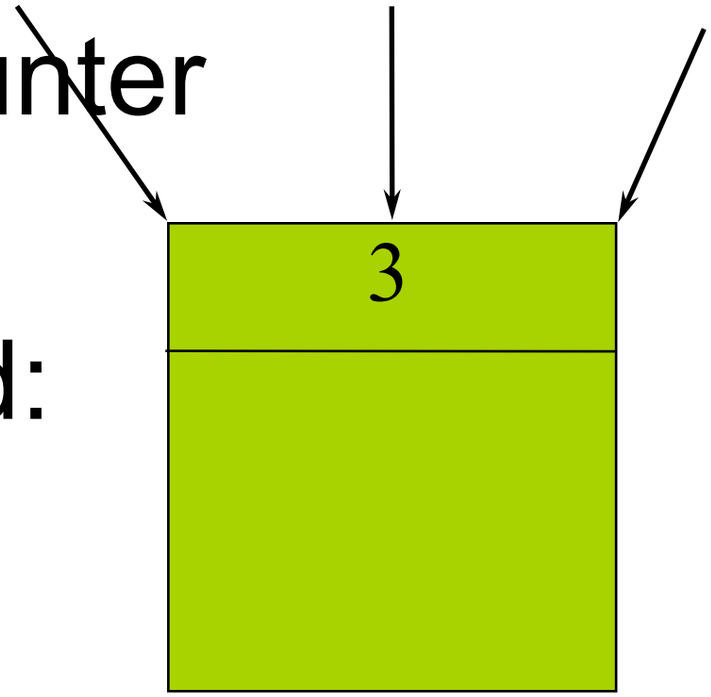
Reference counting

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

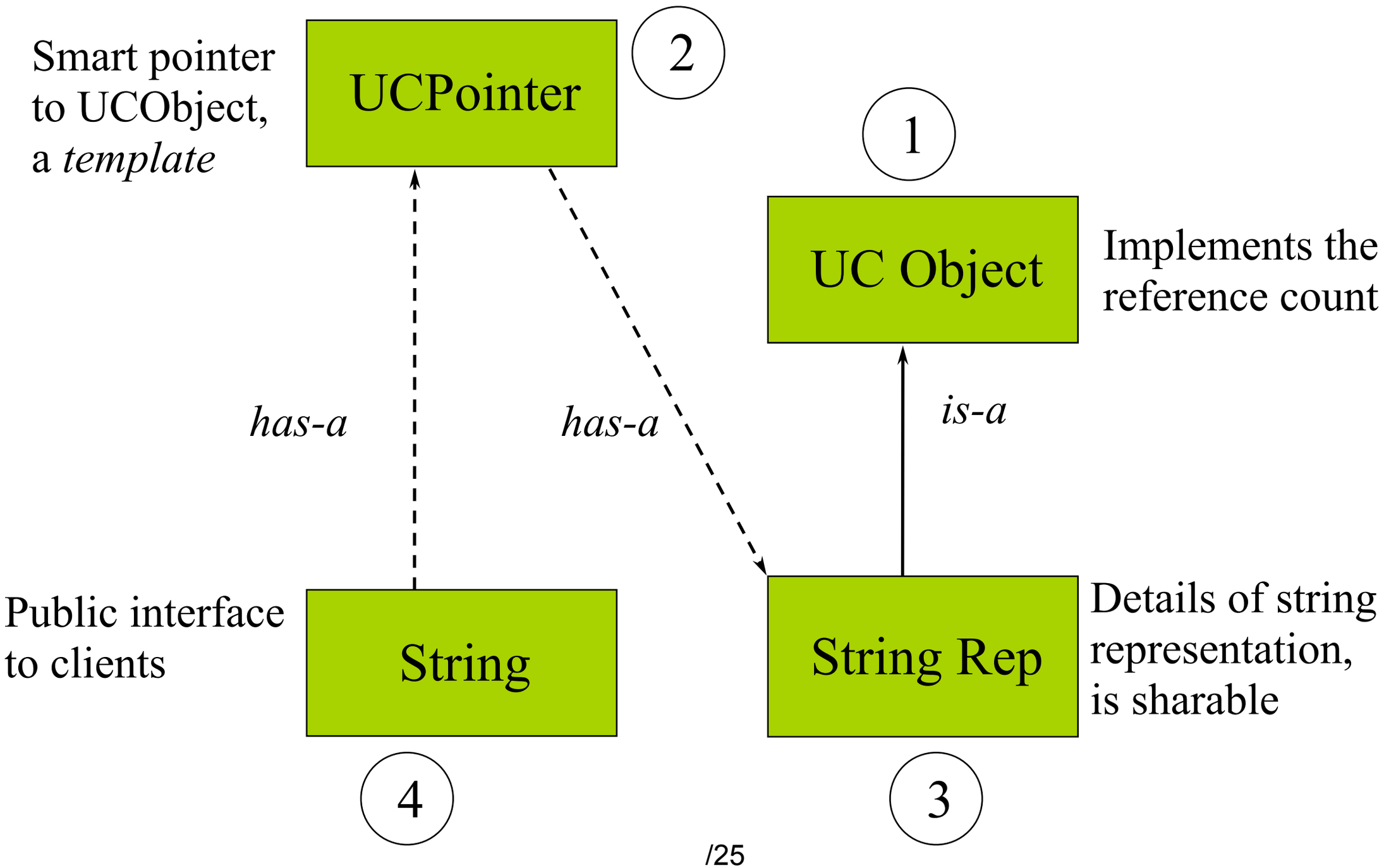
```
p = q;
```

- Have to do the following

```
p->decrement(); // p's count will decrease
p = q;
q->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
  - –But don't use *this* afterwards!

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 constructor

```
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;
}
```

The -> Operator

- `operator->`() is a unary operator
  - Result must support the -> operation
- C++ allows you to overload
  - [] -- subscripting
  - () -- "function call"
  - ->() -- pointer chasing
  - *() -- unary pointer dereference

The UCPointer -> operator

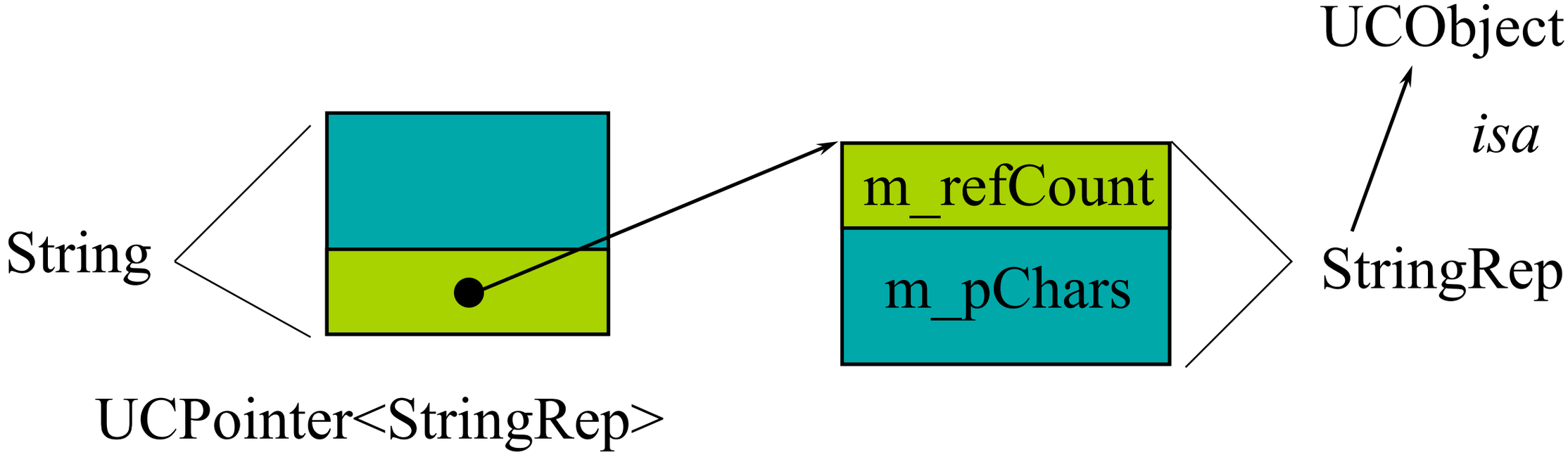
```
template<class T>
T* UCPointer<T>::operator->() const {
   return m_pObj;
}
```

- Example: Shape inherits from UCObject.

```
Ellipse elly(200F, 300F);
UCPointer<Shape> p(&elly);
p->render(); // calls Ellipse::render() on
elly!
```

Envelope and Letter

- Envelope provides protection
- Letter contains the contents



String Class

```
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;
    // reference semantics -- no assignment op!
    void operator=(const StringRep&) { }
};
```

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(0) {
  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;
}
```

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();
}
```

Critique

- UCPointer maintains reference counts
- UCObject hides the details of the count String is very clean
- StringRep deals only with string storage and manipulation
- UCObject and UCPointer are reusable
- Objects with cycles of UCPointer will never be deleted

Other smart pointers

- Standard library holder for raw pointers on stack
- Releases resource when destroyed (latest)

```
template <class X> std::auto_ptr {
public:
  explicit auto_ptr(X* = 0) throw();
  auto_ptr(auto_ptr&) throw();
  auto_ptr& operator=(auto_ptr&) throw();
  ~auto_ptr();
  X& operator*() const throw();
  X* operator->() const throw();
  ...
};
```