CSCI 262
Data Structures

17 – The "Big 3"

CS@Mines

What are…

THE BIG 3

CS@Mines 2

The Big 3

Three (optional) methods for your class:

- Copy constructor: creates copies of object
  - When passing by value
  - When used in variable initializer
- Assignment operator: copies object over existing object in assignment
- Destructor: called when object goes out of scope or is deleted

C++ provides default behaviors for each of these…
(but we'll want to override the defaults!)

CS@Mines 3

Copy Constructor

Used to create a *new* object as a copy of another:

```
foo x;
foo y(x);        // y is created as
                 // copy of x
```

or:

```
foo y = x;       // also uses copy
                 // constructor, not
                 // assignment operator
```

Also called when:

- Passed by value into function
- Returned (by value) from function

CS@Mines 4

Assignment Operator

Used when assigning using *existing* objects:

```
foo x, y;
x = y;      // x already existed as
            // an object of type foo
```

CS@Mines 5

Destructor

Applied automatically when:

- Object goes out of scope
- Object is deleted

E.g.,

```
foo *p = new foo;
delete p;        // *p is deleted
```

Or

```
while (true) {
      foo f;
      break;
}
// f is now out of scope
```

CS@Mines 6

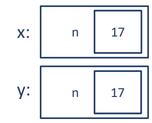
DEFAULT BEHAVIORS

Default Behavior: Copy and Assignment

Simply copies instance variables…

```
class foo {
public:
        int n;
};

foo x;
x.n = 42;
foo y(x);      // y.n also now equals 42
x.n = 17;
y = x;         // y.n also now equals 17
```



This is typically the behavior we want! However…

Copy Default Behavior: with Dynamically Allocated Memory

Example:

```
class number {
public:
        number(int n) { ptr = new int(n); }
private:
        int* ptr;
};

number x(42);
number y = x;
```

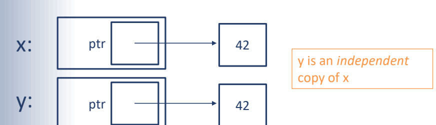
Problem: we only copied the *pointer* – x and y now "share" memory

Copy Default Behavior: with Dynamically Allocated Memory

Example, illustrated:

```
number x(42);
number y = x;
```

What we want to happen:

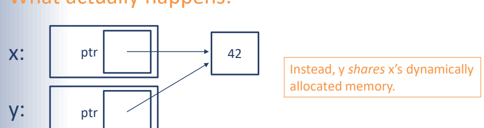


Copy Default Behavior: with Dynamically Allocated Memory

Example, illustrated:

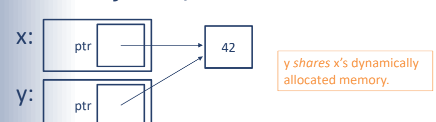
```
number x(42);
number y = x;
```

What actually happens:



Why Is This a Problem?

```
number x(42);
number y = x;
```



What if we had a setter for the value, and changed x (or y)?

Deep Copy

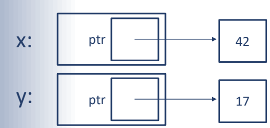
- The default behavior is called a *shallow copy*
- The behavior we want is called a *deep copy*
  - Copy memory pointed to by member pointer variables
    - Where appropriate – it isn't always correct to do so
    - May need to allocate/reallocate
  - Copy member non-pointer variables recursively

Assignment Default Behavior: with Dynamically Allocated Memory

Example of assignment:

```
number x(42), y(17);
```

Initially:

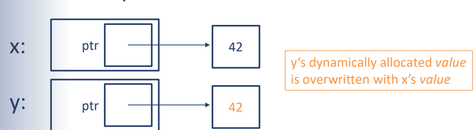


Assignment Default Behavior: with Dynamically Allocated Memory

Example of assignment:

```
number x(42), y(17);
y = x;
```

What we expect:

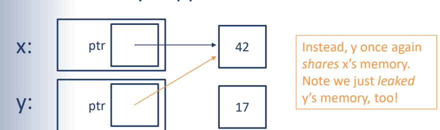


Assignment Default Behavior: with Dynamically Allocated Memory

Example of assignment:

```
number x(42), y(17);
y = x;
```

What actually happens:



Destructor Default Behavior: with Dynamically Allocated Memory

The default destructor:

- Call destructors of each member variable
- Does nothing to primitive types (and pointers)

While this is generally appropriate, it will result in a memory leak for our number class.

FIX IT!

Fixing the Defaults

We can override the defaults by defining our own copy constructor, destructor, and assignment operator:

```
class number {
public:
    number(int n) { ptr = new int(n); }
    number(const number& num);     // copy constructor
    ~number();                     // destructor
                                   // assignment op.
    number& operator=(const number& num);
private:
    int* ptr;
};
```


Fixing the Copy Constructor

```
number::number(const number& num) {
    ptr = new int;
    *ptr = *(num.ptr);
}
```

Note: must be passed by reference! (Why?)

Step 1: copy non-pointer member variables

Step 2: *allocate* our own memory

Step 3: *copy* value (not pointer!)

Fixing the Assignment Operator

Similar to copy constructor… but different.

```
number& number::operator=(const number& num) {
        if (this == &num) return *this;  // self assignment

        // no need to allocate/deallocate, we're the same size
        *ptr = *(num.ptr);
        return *this;
}
```

Step 1: check for self-assignment
Step 2: copy non-pointer member variables
Step 3: allocate/de-allocate (if necessary)
Step 4: copy value
Step 5: return *this

Fixing the Destructor

Just need to clean up our memory…

```
number::~number() {
    delete ptr;
}
```


Adding the "Big 3" to

ARRAY LIST

Array List Class

```
class array_list {
public:
        array_list();
        int size();
        int get(int index);
        void set(int index, int val);
        …
private:
        int*   _arr;
        int    _size;
        int    _capacity;
        void   _resize();
};
```

Array List Class + Big 3

```
class array_list {
public:
        array_list();
        array_list(const array_list& lst);
        ~array_list();

        array_list& operator=(const array_list& lst);

        int size();
        int get(int index);
        void set(int index, int val);
        …
private:
        int*  _arr;
        int   _size;
        int   _capacity;
        void  _resize();
};
```


Array List: Copy Constructor

```
array_list::array_list(const array_list& src) {
        _capacity = src._capacity;    // same cap.
        _size = src._size;            // same size
        _arr = new int[_capacity];    // allocate
        for (int j = 0; j < _size; j++) {
                _arr[j] = src._arr[j];  // copy
        }
}
```


Array List: Assignment Operator

```
array_list& array_list::operator=(const array_list& src)
{
        if (this == &src) return *this;  // self-assign chk
        delete[] _arr;                   // clean up old
        _capacity = src._capacity;       // copy non-ptr
        _size = src._size;               // member vars
        _arr = new int[_capacity];       // allocate
        for (int j = 0; j < _size; j++) {
                _arr[j] = src._arr[j];   // copy
        }
        return *this;                    // return *this
}
```


Refactoring Opportunity

```
array_list& array_list::operator=(const array_list& src)
{
        if (this == &src) return;
        delete[] _arr;
        _capacity = src._capacity;
        _size = src._size;
        _arr = new int[_capacity];
        for (int j = 0; j < _size; j++) {
                _arr[j] = src._arr[j];
        }
        return *this;
}
```


Array List Refactoring

```
void array_list::deep_copy(const array_list& src) {
        _capacity = src._capacity;
        _size = src._size;
        _arr = new int[_capacity];
        for (int j = 0; j < _size; j++) {
                _arr[j] = src._arr[j];
        }
}

array_list::array_list(const array_list& src) {
        deep_copy(src);
}

array_list& array_list::operator=(const array_list& src) {
        if (this == &src) return;
        delete[] _arr;
        deep_copy(src);
        return *this;
}
```


Array List Destructor

```
array_list::~array_list() {
        delete[] _arr;
}
```

Up Next

- Reading for Wednesday: Chapter 13.3
- Wednesday, April 3
  - Templates
  - Read Chapter 16 (16.5 is optional)
- Friday, April 5
  - Lab 11 – Queue, part 2
- Monday, April 8
  - Binary Trees
  - Lab 11 due

CS@Mines 31