Default and Copy Constructors

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Contents

1 The Default Constructor

The Default Constructor

The *default constructor* is a constructor that takes no arguments. This is the constructor you are calling when you declare an object with no parameters. E.g.,

```
std::string s;
```

. . . . . .

Declaring a Default Constructor

It might be declared like this

```
class Time {
public:
   Time();
    ⋮
```

or with defaults:

```
namespace std {
class string {
public:
    ⋮
   string(char* s = "");
   ⋮
```

Either way, we can *call* it with no parameters.

. . . . . .

Why 'default'?

- It's just an ordinary constructor
- But it is used (implicitly) to initialize elements of an array.
- It is also used (implicitly) in other ADTs' constructors when they do not explicitly initialize a data member.

. . . . . .

Implicit Use: Arrays

For example, if we declared:

```
std::string words[5000];
```

then each of the 5000 elements of this array will be initialized using the default constructor for `string`

. . . . . .

Implicit Use: Other Constructors

```
struct Bid {
  std::string bidderName;
  double amount;
  std::string itemName;
  Time bidPlacedAt;

   Bid();
};


Bid::Bid()
{
   amount = 0.0;
}
```

- `bidPlacedAt` is initialized using the `Time` default constructor.
- `bidderName` and `itemName` are initialized using the `string` default constructor.

.....

Explicit Construction in Other Constructors

If we *don't* want the default value, we need to explicitly perform some other initialization:

```
struct Bid {
  std::string bidderName;
  double amount;
  std::string itemName;
  Time bidPlacedAt;

   Bid();
};



Bid::Bid()
{
   amount = 0.0;
   bidPlacedAt = Time(8, 0, 0); // 8 AM
}
```

This actually constructs a `Time` object and then copies it.

- a bit inefficient

- C++ provides a special way to directly call constructors

. . . . . .

Explicit Construction: Initializer Lists

Alternate way to explicitly perform some other initialization:

```
Bid::Bid()
   : bidPlacedAt(8, 0, 0) // 8 AM
{
   amount = 0.0;
}
```

- Called an *initializer list*
- data member name fololowed by constructor arguments

. . . . . .

Initializer Lists

- *Can* be used to initialize any data member

```
struct Bid {
  std::string bidderName;
  double amount;
  std::string itemName;
  Time bidPlacedAt;

   Bid();
};


Bid::Bid()
   : bidderName(""), amount(0.0),
     itemName("knick-knack"), bidPlacedAt(8, 0, 0)
{
}
```

- *Must* be used to initialize data members that are

  - constants (`const`)
  - references
  - members of classes that have no default constructors

. . . . . .

The Helpful Compiler

If we create no constructors at all for a class, the compiler generates a default constructor for us.

- Initializes each data member using their data types' default constructors
- For primitives such as `int`, `double`, pointers, etc., this does nothing at all

. . . . . .

Example: Name

```
class Name {
public:
   string getGivenName();
   void setGivenName (string);

   string getSurName();
   void setSurName (string);
private:
   string givenName;
   string surName;
};
```

- Compiler will generate a default constructor `Name()`
- `givenName` and `surName` will be initialized using the default constructor of `string`
  - Probably just fine

. . . . . .

Example: Name 2

```
class Name {
public:
   Name (string gName, string sName)
     : givenName(gName), surName(sName) {}
```

```
   string getGivenName();
   void setGivenName (string);

   string getSurName();
   void setSurName (string);
private:
   string givenName;
   string surName;
};
```

- Compiler will *not* generate a default constructor `Name()` because we provided a different constructor
- If we want one, we have to write our own
  - If we don't, we cannot have arrays of `Names`

.....

Example: Name 3

```
class Name {
public:
   Name () {}

   Name (string gName, string sName)
     : givenName(gName), surName(sName) {}

   string getGivenName();
   void setGivenName (string);

   string getSurName();
   void setSurName (string);
private:
   string givenName;
   string surName;
};
```

.....

Example: BidCollectionBook implicit default constructor

```
struct BidCollection {
  int MaxSize;
  int size;
  Bid* elements; // array of bids

  /**
   * Read all bids from the indicated file
   */
  void readBids (std::string fileName);
};
```

- Compiler would generate a default constructor
  - that would leave random bits in all 3 data members

. . . . . .

Example: BidCollection explicit default constructor

```
struct BidCollection {
  int MaxSize;
  int size;
  Bid* elements; // array of bids

  BidCollection (int MaxBids = 1000);

  /**
   * Read all bids from the indicated file
   */
  void readBids (std::string fileName);
};
   :
BidCollection::BidCollection (int theMaxSize)
{
  MaxSize = theMaxSize;
  size = 0;
  elements = new Bid[MaxSize];
}
```

. . . . . .

2 Copy Constructors

Copy Constructors

The copy constructor for a class `Foo` is the constructor of the form:

```
Foo (const Foo& oldCopy);
```

. . . . . .

2.1 Where Do We Use a Copy Constructor?

Where Do We Use a Copy Constructor?

The copy constructor gets used in 5 situations:

1. When you declare a new object as a copy of an old one:

   ```
   Time time2 (time1);
   ```

   or

   ```
   Time time2 = time1;
   ```

2. When a function call passes a parameter "by copy" (i.e., the formal parameter does not have a &):

   ```
   void foo (Time b, int k);
     ⋮

   Time noon (12, 0, 0);
   foo (noon, 0);    // foo actually gets a copy of noon
   ```

3. When a function returns an object:

   ```
   Time foo (int k);
   {
     Time t (k, 0, 0);
     ⋮
     return t;
   }
   ```

4. When explicitly invoked in another constructor's initialization list:

   ```
   Name (string gName, string sName)
     : givenName(gName), surName(sName) {}
   ```

5. When an object is a data member of another class for which the compiler has generated its own copy constructor.

. . . . . .

2.2 Compiler-Generated Copy Constructors

Compiler-Generated Copy Constructors

If we do not create a copy constructor for a class, the compiler generates one for us.

- copies each data member via *their* individual copy constructors.
  - For primitive types (int, double, pointers, etc.), just copies the bits.

. . . . . .

2.3 Example: Bid: Compiler-Generated Copy Constructor

Example: Bid: Compiler-Generated Copy Constructor

```
struct Bid {
  std::string bidderName;
  double amount;
  std::string itemName;
  Time bidPlacedAt;

};
```

`Bid` does not provide a copy constructor, so the compiler generates one for us, just as if we had written:

```
struct Bid {
  std::string bidderName;
  double amount;
  std::string itemName;
  Time bidPlacedAt;

  Bid (const Bid&);
};
  ⋮
Bid::Bid (const Bid& b)
  : bidderName(b.bidderName), amount(b.amount),
    itemName(b.itemName), bidPlacedAt(b.bidPlacedAt)
{}
```

and that's probably just fine.

. . . . . .

2.4 Example: BidCollection: Compiler-Generated Copy Constructor

Example: BidCollection: Compiler-Generated Copy Constructor

```
struct BidCollection {
  int MaxSize;
  int size;
  Bid* elements; // array of bids

  /**
   * Create a collection capable of holding the indicated number of bids
   */
  BidCollection (int MaxBids = 1000);

  ~BidCollection ();

  /**
   * Read all bids from the indicated file
   */
  void readBids (std::string fileName);
};
```

`BidCollection` does not provide a copy constructor, so the compiler generates one for us, just as if we had written:

```
struct BidCollection {
  int MaxSize;
  int size;
  Bid* elements; // array of bids

  /**
   * Create a collection capable of holding the indicated number of bids
   */
  BidCollection (int MaxBids = 1000);
   BidCollection (const BidCollection&);
};
  :
BidCollection::BidCollection (const BidCollection& bc)
  : MaxSize(bc.MaxSize), size(bc.size),
    elements(bc.elements)
{}
```

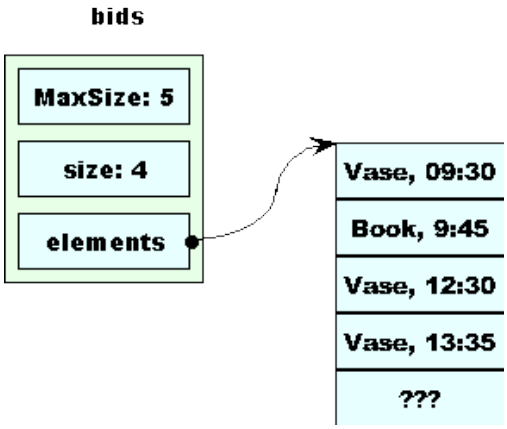
which is not good at all!

Example: BidCollection is hard to copy

To see why, suppose we had some application code:

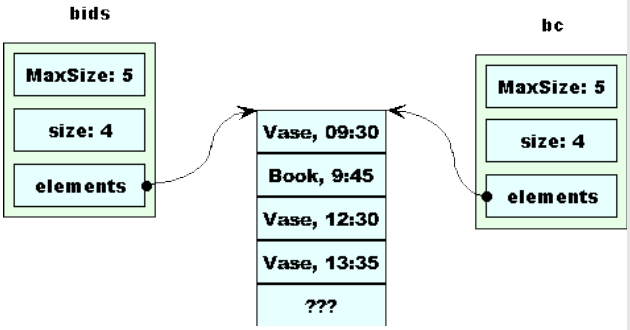
```
BidCollection removeLate (BidCollection bc, Time t)
{
  for (int i = 0; i < x.size;)
    {
     if (bc.elements[i].bidPlacedAt.noLaterThan(t))
        ++i;
     else
        removeElement (elements, size, i);
    }
  return bc;
}
    <:::>
BidCollection afterNoonBids =
   removeLate (bids, Time(12,0,0));
```

Assume we start with this in `bids`.



2.5

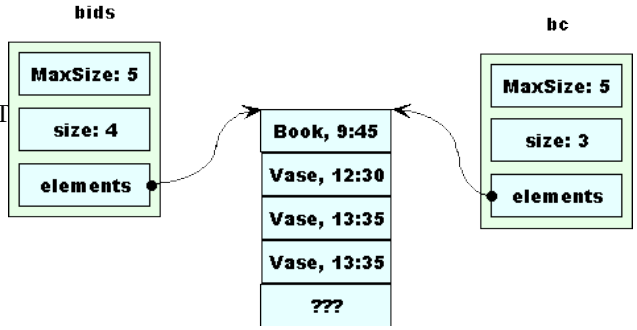
When `removeLate` is called, we get a copy of `bids`.

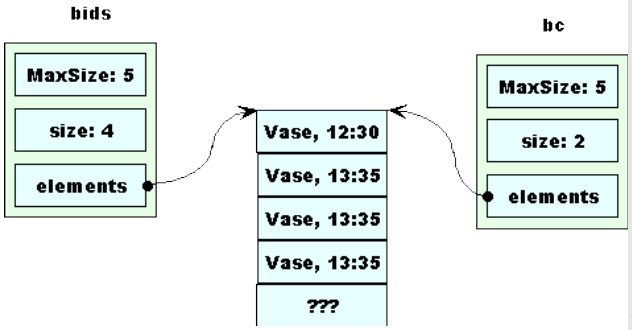



```
BidCollection removeLate (BidCollection bc, Time t)
{
  for (int i = 0; i < x.size;)
    {
     if (bc.elements[i].bidPlacedAt.noLaterThan(t))
        ++i;
     else
        removeElement (elements, size, i);
    }
  return bc;
}
    ⋮
BidCollection afterNoonBids =
   removeLate (bids, Time(12,0,0));
```

`removeLate` removes the first morning bid from `bc`.

```
BidCollection removeLate (BidCollection bc, Time t)
{
  for (int i = 0; i < x.size;)
    {
     if (bc.elements[i].bidPlacedAt.noLaterT
        ++i;
     else
        removeElement (elements, size, i);
    }
  return bc;
}
    ⋮
BidCollection afterNoonBids =
   removeLate (bids, Time(12,0,0));
```



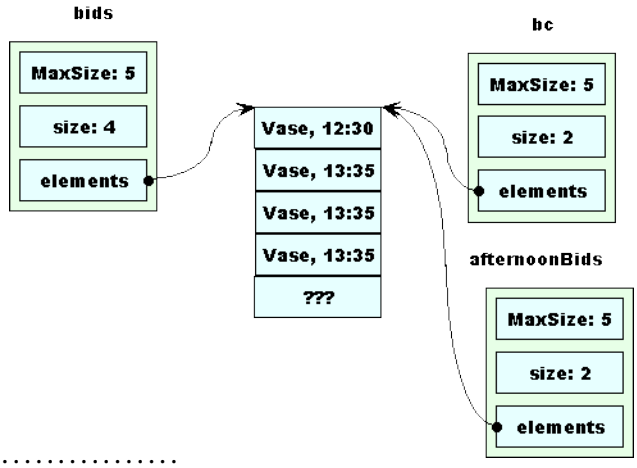


Then `removeLate` removes the remaining morning bid from `bc`.

```
BidCollection removeLate (BidCollection bc, Time t)
{
  for (int i = 0; i < x.size;)
    {
     if (bc.elements[i].bidPlacedAt.noLaterThan(t))
        ++i;
     else
        removeElement (elements, size, i);
    }
  return bc;
}
   ⋮
BidCollection afterNoonBids =
   removeLate (bids, Time(12,0,0));
```

The return statement makes a copy of `bc`, which is stored in `afterNoonBids`
`removeLate` removes the remaining morning bid from `bc`.

```
BidCollection removeLate (BidCollection bc,
{
    ⋮
  return bc;
}
    ⋮
BidCollection afterNoonBids =
   removeLate (bids, Time(12,0,0));
```

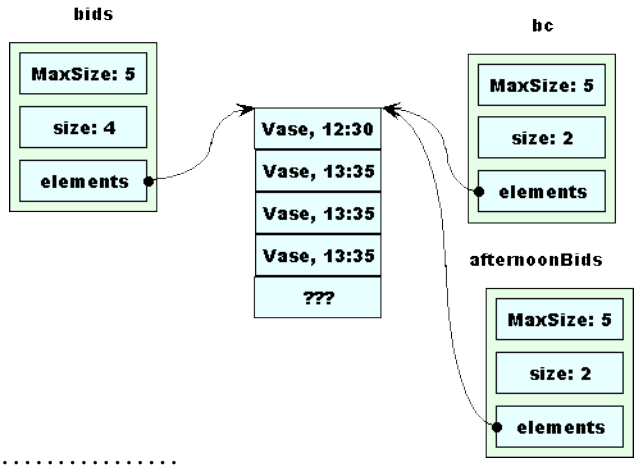


.....

Trouble: bids is corrupted

Note that we have corrupted the original collection, `bids`

- It thinks it has more (according to `size`) bids than are left in the array
- The bids that it has are now changed



.....

That's not the worst of it!

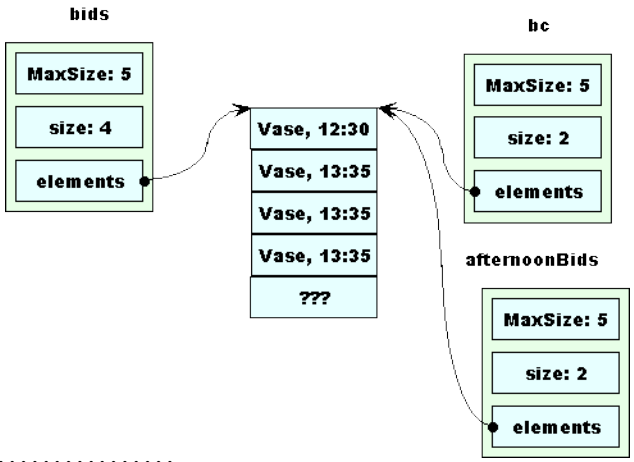
When we exit `removeLate`,

```
BidCollection removeLate (BidCollection bc, Time t)
{
  for (int i = 0; i < x.size;)
    {
     if (bc.elements[i].bidPlacedAt.noLaterThan(t))
        ++i;
     else
        removeElement (elements, size, i);
    }
  return bc;
}
```

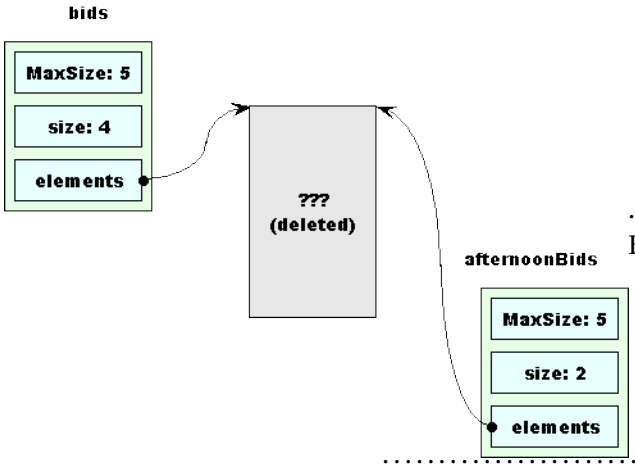
the destructor for `BidCollection` is called on `bc`

```
BidCollection::~BidCollection()
{
  delete [] elements;
}
```

Taking us from this...



What a Mess!



...to this.
Both collections have "dangling pointers"

Avoiding this Problem

We could

- Decide never to pass a `BidCollection` by copy, never return one from a function, never to create a new `BidCollection` as a copy of an old one
  - We would have to remember this in all future applications
- or, write our own copy constructor that actually works
  - Every `BidCollection` should have its own unique array

2.6 Writing a BidCollection Copy Constructor

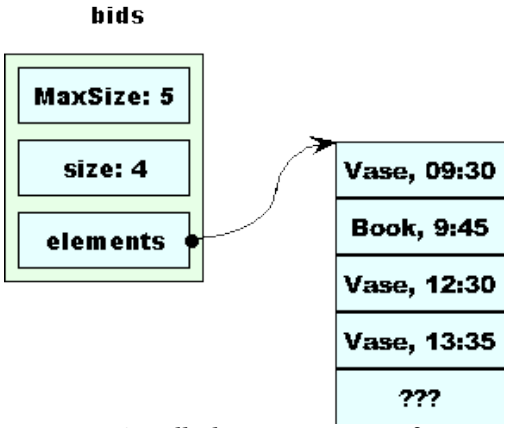
Writing a BidCollection Copy Constructor

```
BidCollection::BidCollection (const BidCollection& bc)
  : MaxSize (bc.MaxSize), size (bc.size)
{
  elements = new Bid[MaxSize];
  for (int i = 0; i < size; ++i)
    elements[i] = bc.elements[i];
}
```

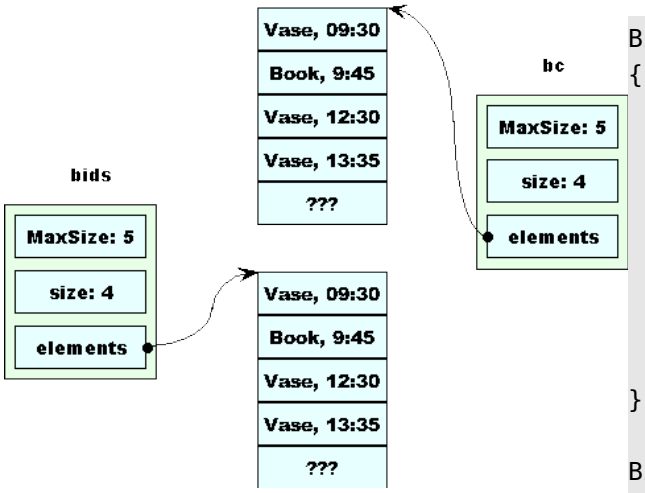
.....

Once More, With Feeling!

With this copy constructor in place, things should go much more smoothly.



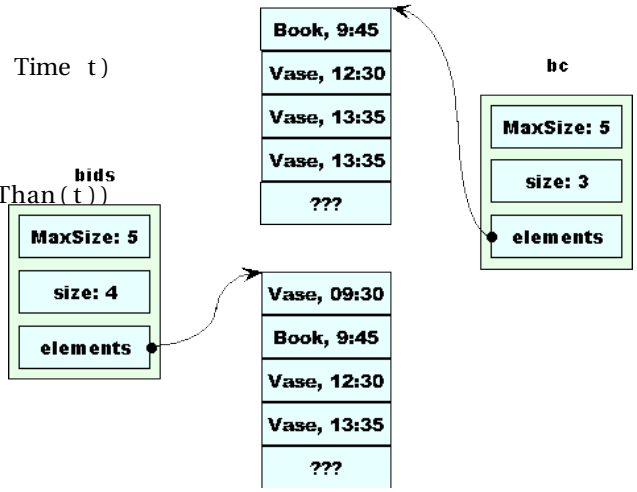
When `removeLate` is called, we get a copy of `bids`.



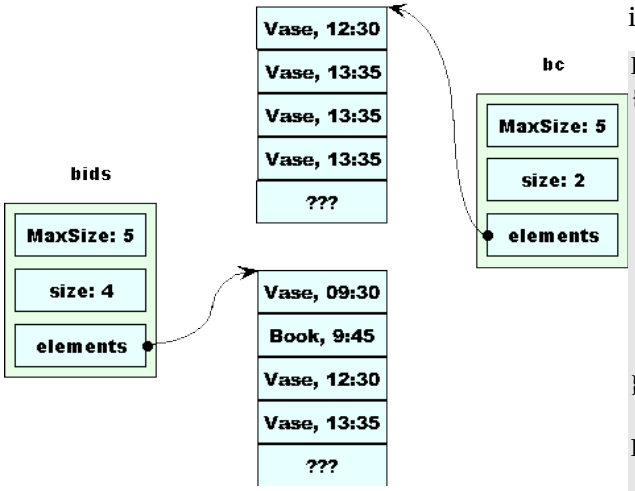

```
BidCollection removeLate (BidCollection bc, Time t)
{
  for (int i = 0; i < x.size;)
    {
     if (bc.elements[i].bidPlacedAt.noLaterThan(t))
        ++i;
     else
        removeElement (elements, size, i);
    }
  return bc;
}
    <:::>
BidCollection afterNoonBids =
   removeLate (bids, Time(12,0,0));
```

`removeLate` removes the first morning bid from `bc`.

```
BidCollection removeLate (BidCollection bc, Time t)
{
  for (int i = 0; i < x.size;)
    {
     if (bc.elements[i].bidPlacedAt.noLaterThan(t))
        ++i;
     else
        removeElement (elements, size, i);
    }
  return bc;
}
    ⋮
BidCollection afternoonBids =
   removeLate (bids, Time(12,0,0));
```



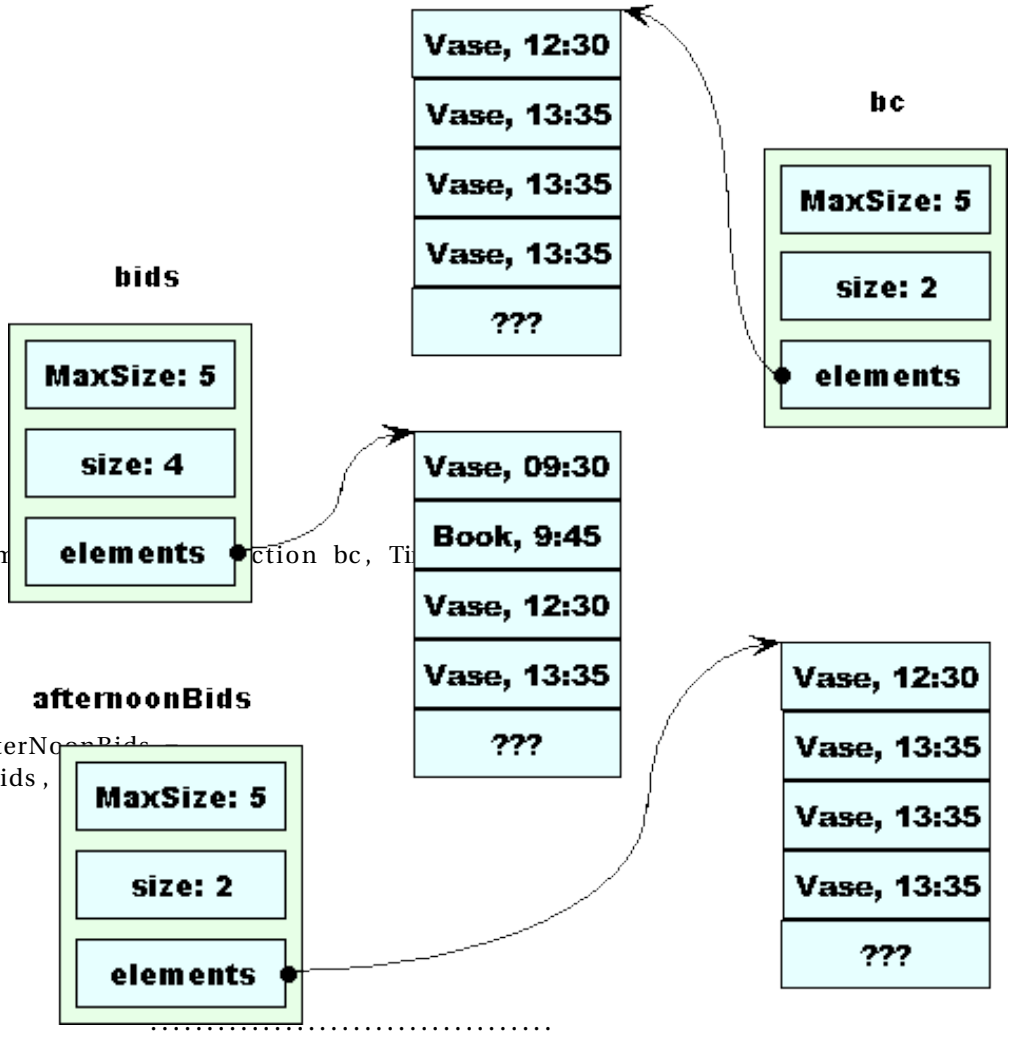
Then `removeLate` removes the remaining morning bid from `bc`.



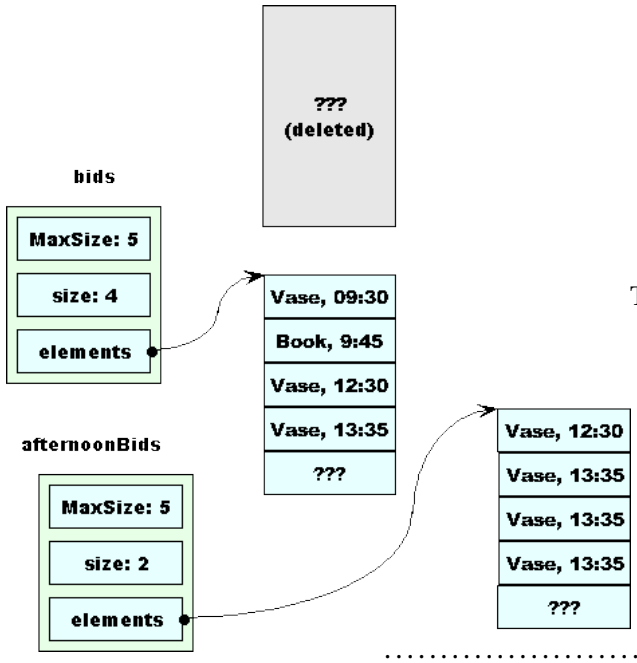

```
BidCollection removeLate (BidCollection bc, Time t)
{
  for (int i = 0; i < x.size;)
    {
     if (bc.elements[i].bidPlacedAt.noLaterThan(t))
        ++i;
     else
        removeElement (elements, size, i);
    }
  return bc;
}
    ⋮
BidCollection afternoonBids =
   removeLate (bids, Time(12,0,0));
```

The return statement makes a copy of `bc`, which is stored in `afterNoonBids`. `removeLate` removes the remaining morning bid from `bc`.

```
BidCollection rem                    ction bc, Ti
{
    ⋮
  return bc;
}
    ⋮
BidCollection afterNoonBids =
   removeLate (bids,
```



Much Nicer



The destructor for `BidCollection` is called on `bc`

- Both remaining collections are OK.

. . . . . .

2.7 Shallow & Deep Copying

If We Never Write Our Own

If our data members do not have explicit copy constructors (and their data members do not have explicit copy constructors, and . . .) then the compiler-provided copy constructor amounts to a bit-by-bit copy.

. . . . . .

Shallow vs Deep Copy

Copy operations are distinguished by how they treat pointers:

- In a *shallow copy*, all pointers are copied.
  - Leads to shared data on the heap.
- In a *deep copy*, objects pointed to are copied, then the new pointer set to the address of the copied object.
  - Copied objects keep exclusive access to the things they point to.

. . . . . .

Shallow copy is wrong when...

- Your ADT has pointers among its data members, and
- You don't want to share the objects being pointed to.

. . . . . .

Compiler-generated copy constructors are wrong when...

- Your ADT has pointers among its data members, and
- You don't want to share the objects being pointed to.

. . . . . .

3 Assignment

Assignment

Copy constructors are not the only way we make copies of data.

- Even more common is the use of assignment:

```
time2 = time1;
```

- Assignment is so common that it can be hard to imagine programming without it
  - though in rare conditions we will do so
  - E.g., you cannot assign `istream`s and `ostream`s
    - You cannot copy them by constructor either
- So the compiler will try to be helpful again

. . . . . .

3.1 Compiler-Generated Assignment Ops

Compiler-Generated Assignment Ops

If you don't provide your own assignment operator for a class, the compiler generates one automatically.

- assigns each data member in turn.
- If none of the members have programmer-supplied assignment ops, then this is a *shallow copy*

. . . . . .

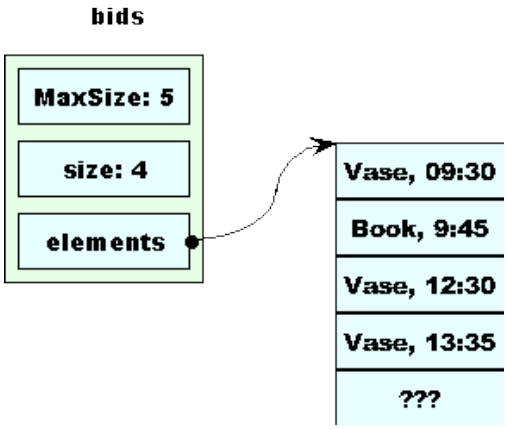
Example: BidCollection: Guess what happens

Our `BidCollection` class has no assignment operator, so the code below uses the compiler-generated version. To see why, suppose we had some application code:

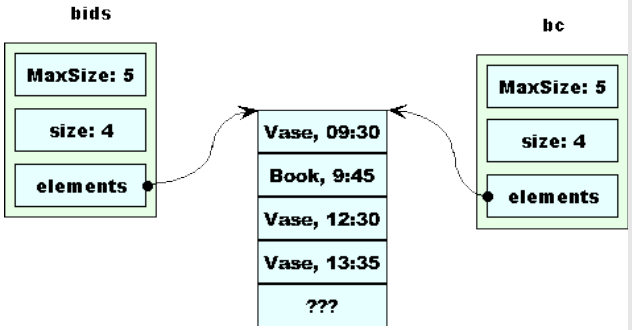
```
BidCollection bids;
  ⋮
BidCollection bc;
Time t (12, 0, 0);
bc = bids;
for (int i = 0; i < x.size;)
  {
   if (bc.elements[i].bidPlacedAt.noLaterThan(t))
      ++i;
   else
      removeElement (elements, size, i);
  }

BidCollection bc;
Time t (12, 0, 0);
bc = bids;
for (int i = 0; i < x.size;)
  {
   if (bc.elements[i].bidPlacedAt.noLaterThan(t))
      ++i;
   else
      removeElement (elements, size, i);
  }
```

Assume we start with this in `bids`.



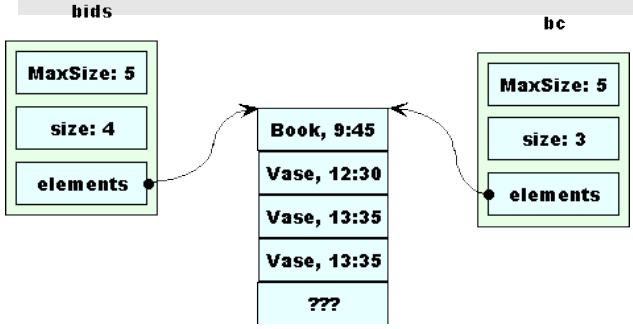
After the assignment, we have copied `bids`, bit-by-bit, into `bc`.

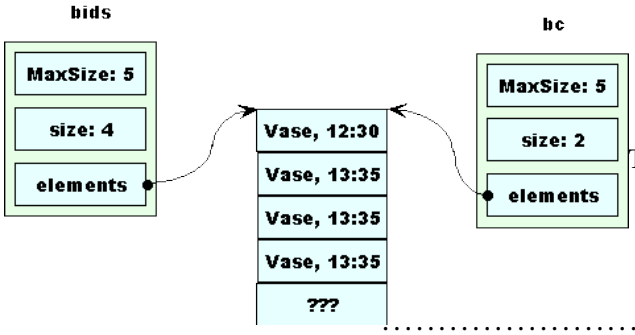



```
BidCollection bids;
  ⋮
BidCollection bc;
Time t (12, 0, 0);
bc = bids;
for (int i = 0; i < x.size;)
  {
   if (bc.elements[i].bidPlacedAt.noLaterThan(t))
      ++i;
   else
      removeElement (elements, size, i);
  }

BidCollection bc;
Time t (12, 0, 0);
bc = bids;
for (int i = 0; i < x.size;)
  {
   if (bc.elements[i].bidPlacedAt.noLaterThan(t))
      ++i;
   else
      removeElement (elements, size, i);
  }
```

We remove the first morning bid from `bc`.



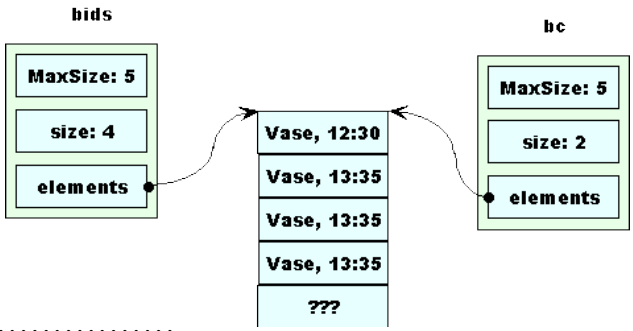


Then remove the remaining morning bid from `bc`.

Again: bids is corrupted

Note that we have corrupted the original collection, `bids`

- It thinks it has more (according to `size`) bids than are left in the array
- The bids that it has are now changed



Avoiding this Problem

We could

- Decide never to assign one `BidCollection` to another
  - We would have to remember this in all future applications
- or, write our own assignment that actually works
  - We'll look at how to do this later when we study *operator overloading*