The University Of Michigan

EECS402 Lecture 14

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Revisiting Use Of:
Copy Constructors
Assignment Operators
Destructors

1

Problem Description

- Recall:
  - Copy ctors are used when a copy of an object needs to be made (most often via a pass-by-value parameter)
  - Assignment operators are used to assign one object's attributes to another object's
- Both of these do a "member-by-member copy"
  - Algorithm: For each data member of the right-hand-side object, copy its value into the corresponding member of the left-hand-side object
  - If the member is an integer, the 4 bytes containing the int are copied
  - If the member is a double, the 8 bytes containing the double are copied
  - If the member is a pointer, the 4* bytes containing the pointer are copied
    - NOTE: Only the 4* bytes of the pointer are copied, even if the pointer is pointing to an array of 100 values!

*: These days, pointers are usually 8 bytes, but I still talk about them like they're 4 bytes since it makes it easier to include in examples showing memory, etc.

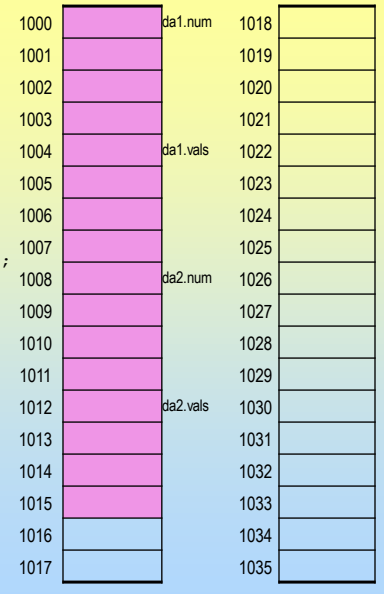
2

A Dynamic Array Class


```
class DynAryClass
{
  private:
    int num;
    char *vals; //Will point to
                //array of chars
  public:
    void setVals(char a, char b,
                 char c)
    {
      num = 3;
      vals = new char[num];
      vals[0] = a;
      vals[1] = b;
      vals[2] = c;
    }

    void setVals(char a, char b,
                 char c, char d)
    {
      num = 4;
      vals = new char[num];
      vals[0] = a;
      vals[1] = b;
      vals[2] = c;
      vals[3] = d;
    }

    void changeVal(int index, char c)
    {
      if (index >= 0 && index < num)
      {
        vals[index] = c;
      }
      else
      {
        cout << "Out of range" << endl;
      }
    }

    void printInfo() const
    {
      int i;
      for (i = 0; i < num; i++)
      {
        cout << vals[i];
      }
      cout << endl;
    }
};
```


Use Of The DynAryClass, p.1


```
int main()
{
  DynAryClass da1;
  DynAryClass da2;

  da1.setVals('d', 'r', 'e', 'w');
  cout << "da1: ";
  da1.printInfo();
  da2 = da1;
  cout << "da2 after assigning to da1: ";
  da2.printInfo();
  cout << "Change da1 drew => draw" << endl;
  da1.changeVal(2, 'a');
  cout << "da1: ";
  da1.printInfo();
  cout << "da2: ";
  da2.printInfo();

  return 0;
}
```

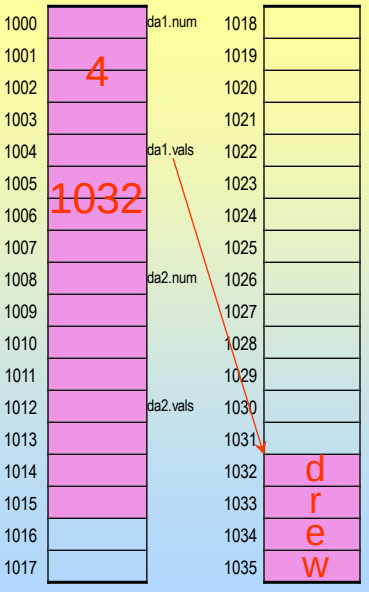


Notes:

- Red arrow indicates which instructions have been executed
- Purple filled cells indicate that memory has been allocated by the program for its use

Use Of The DynAryClass, p.2


```
int main()
{
  DynAryClass da1;
  DynAryClass da2;

  da1.setVals('d', 'r', 'e', 'w');
  cout << "da1: ";
  da1.printInfo();
  da2 = da1;
  cout << "da2 after assigning to da1: ";
  da2.printInfo();
  cout << "Change da1 drew => draw" << endl;
  da1.changeVal(2, 'a');
  cout << "da1: ";
  da1.printInfo();
  cout << "da2: ";
  da2.printInfo();

  return 0;
}
```



Notes:

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- Purple filled cells indicate that memory has been allocated by the program for its use

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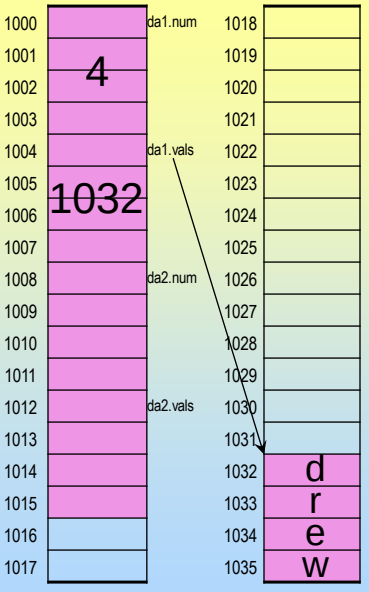
Use Of The DynAryClass, p.3


```
int main()
{
  DynAryClass da1;
  DynAryClass da2;

  da1.setVals('d', 'r', 'e', 'w');
  cout << "da1: ";
  da1.printInfo();
  da2 = da1;
  cout << "da2 after assigning to da1: ";
  da2.printInfo();
  cout << "Change da1 drew => draw" << endl;
  da1.changeVal(2, 'a');
  cout << "da1: ";
  da1.printInfo();
  cout << "da2: ";
  da2.printInfo();

  return 0;
}
```

da1: drew



Notes:

- Red arrow indicates which instructions have been executed
- Purple filled cells indicate that memory has been allocated by the program for its use

6

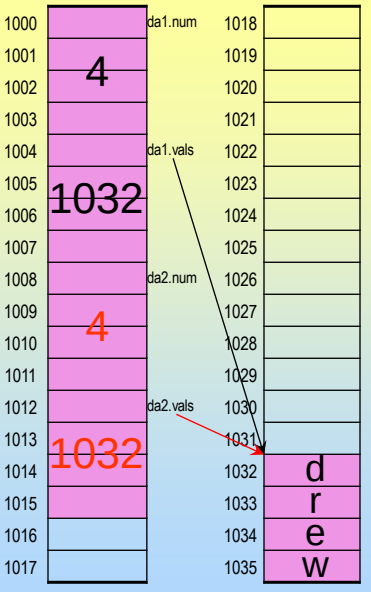
Use Of The DynAryClass, p.4


```
int main()
{
  DynAryClass da1;
  DynAryClass da2;

  da1.setVals('d', 'r', 'e', 'w');
  cout << "da1: ";
  da1.printInfo();
  da2 = da1;
  cout << "da2 after assigning to da1: ";
  da2.printInfo();
  cout << "Change da1 drew => draw" << endl;
  da1.changeVal(2, 'a');
  cout << "da1: ";
  da1.printInfo();
  cout << "da2: ";
  da2.printInfo();

  return 0;
}
```

da1: drew



Notes:

- Red arrow indicates which instructions have been executed
- Purple filled cells indicate that memory has been allocated by the program for its use

7

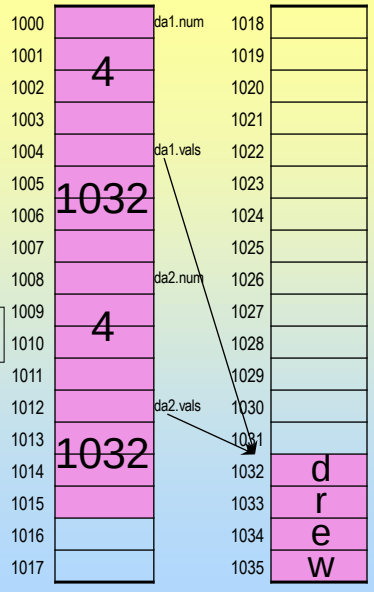
Use Of The DynAryClass, p.5


```
int main()
{
  DynAryClass da1;
  DynAryClass da2;

  da1.setVals('d', 'r', 'e', 'w');
  cout << "da1: ";
  da1.printInfo();
  da2 = da1;
  cout << "da2 after assigning to da1: ";
  da2.printInfo();
  cout << "Change da1 drew => draw" << endl;
  da1.changeVal(2, 'a');
  cout << "da1: ";
  da1.printInfo();
  cout << "da2: ";
  da2.printInfo();

  return 0;
}
```

da1: drew
da2 after assigning to da1: drew



Notes:

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Use Of The DynAryClass, p.6


```
int main()
{
  DynAryClass da1;
  DynAryClass da2;

  da1.setVals('d', 'r', 'e', 'w');
  cout << "da1: ";
  da1.printInfo();
  da2 = da1;
  cout << "da2 after assigning to da1: ";
  da2.printInfo();
  cout << "Change da1 drew => draw" << endl;
  da1.changeVal(2, 'a');
  cout << "da1: ";
  da1.printInfo();
  cout << "da2: ";
  da2.printInfo();

  return 0;
}
```

da1: drew
da2 after assigning to da1: drew
Change da1 drew => draw

Notes:
- Red arrow indicates which instructions have been executed
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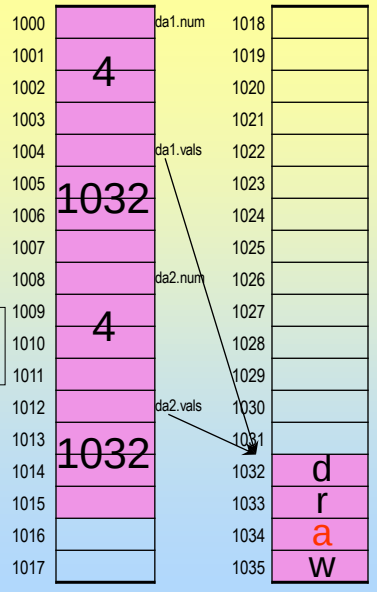

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Use Of The DynAryClass, p.7

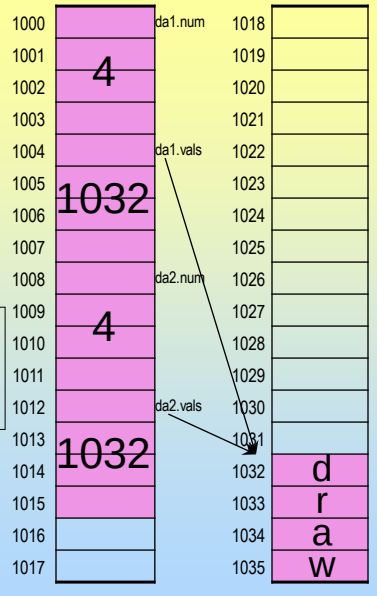

```
int main()
{
  DynAryClass da1;
  DynAryClass da2;

  da1.setVals('d', 'r', 'e', 'w');
  cout << "da1: ";
  da1.printInfo();
  da2 = da1;
  cout << "da2 after assigning to da1: ";
  da2.printInfo();
  cout << "Change da1 drew => draw" << endl;
  da1.changeVal(2, 'a');
  cout << "da1: ";
  da1.printInfo();
  cout << "da2: ";
  da2.printInfo();

  return 0;
}
```

da1: drew
da2 after assigning to da1: drew
Change da1 drew => draw
da1: draw
da2: draw

da2 seems to have changed, but code only changed da1!!



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Problem Solution

- The member-by-member assignment operator copied only the pointer value
  - This results in multiple objects pointing to the same physical memory location
  - When one object changes the memory, change is seen on other objects since that memory is "shared" between the objects
- Programmer must override the default assignment behavior to prevent this, if it is a problem!
  - Provide your own implementation of the assignment operator that does more than a member-by-member copy
  - Create a whole new array for the left-hand-side object and copy the contents over
- Most often, when you overload the assignment operator in this way, you will want to overload the copy ctor too
  - Default copy ctor has same problem since it does a member-by-member copy as well

Added DynAryClass Functionality

```
class DynAryClass
{
 private:
   int num;
   char *vals; //Will pt to array of chars
 public:
   //---No changes to other functions---
   //Overloaded assignment operator
   void operator=(const DynAryClass &rhs)
   {
     int i;
     num = rhs.num; //Just copy the static vars
     vals = new char[num];
     for (i = 0; i < num; i++)
     {
       vals[i] = rhs.vals[i]; //Copy ary contents
     }
   }
   //Copy ctor implementation
   DynAryClass(const DynAryClass &rhs)
   {
     int i;
     num = rhs.num; //Just copy the static vars
     vals = new char[num];
     for (i = 0; i < num; i++)
     {
       vals[i] = rhs.vals[i]; //Copy ary contents
     }
   }
   DynAryClass():num(0), vals(0)
   { ; }
};
```

Remember – when you provide a constructor, the "implicit default ctor" is no longer available! Therefore, when adding the copy ctor, another ctor must be overloaded as well to allow construction of new objects.

NOTE: This should have been done earlier anyhow, since pointers should be initialized to 0 (NULL) and this didn't happen in the earlier versions of the program in this lecture!

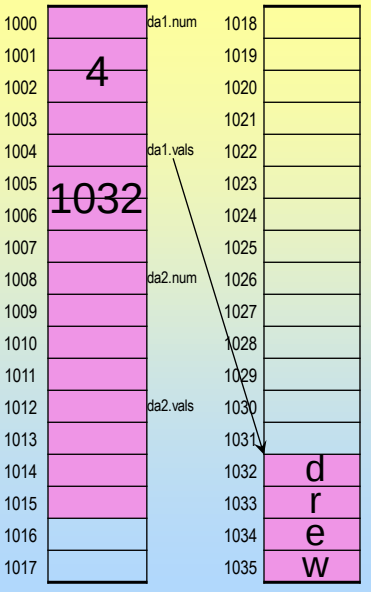
Using The New DynAryClass, p.1


```
int main()
{
  DynAryClass da1;
  DynAryClass da2;

  da1.setVals('d', 'r', 'e', 'w');
  cout << "da1: ";
  da1.printInfo();
  da2 = da1;
  cout << "da2 after assigning to da1: ";
  da2.printInfo();
  cout << "Change da1 drew => draw" << endl;
  da1.changeVal(2, 'a');
  cout << "da1: ";
  da1.printInfo();
  cout << "da2: ";
  da2.printInfo();

  return 0;
}
```

da1: drew



Notes:

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13

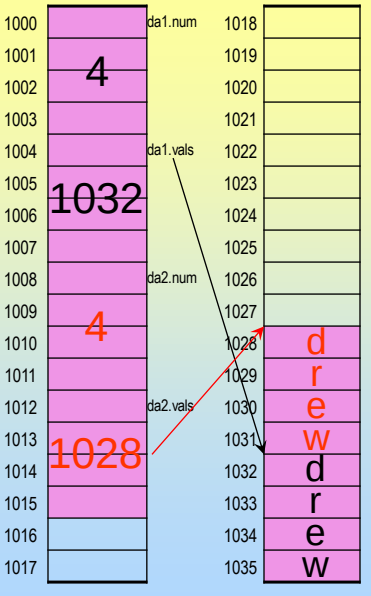
Using The New DynAryClass, p.2


```
int main()
{
  DynAryClass da1;
  DynAryClass da2;

  da1.setVals('d', 'r', 'e', 'w');
  cout << "da1: ";
  da1.printInfo();
  da2 = da1;
  cout << "da2 after assigning to da1: ";
  da2.printInfo();
  cout << "Change da1 drew => draw" << endl;
  da1.changeVal(2, 'a');
  cout << "da1: ";
  da1.printInfo();
  cout << "da2: ";
  da2.printInfo();

  return 0;
}
```

da1: drew



Notes:

- Red arrow indicates which instructions have been executed
- Purple filled cells indicate that memory has been allocated by the program for its use

14

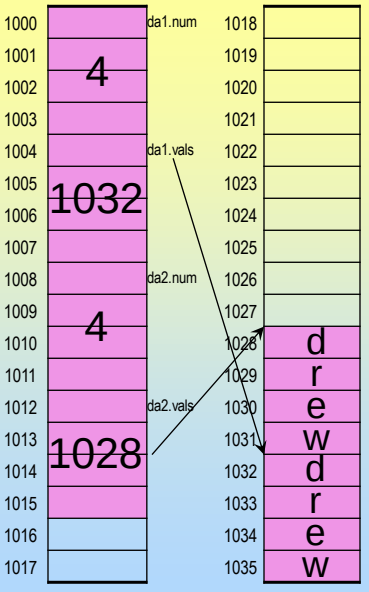
Using The New DynAryClass, p.3


```
int main()
{
  DynAryClass da1;
  DynAryClass da2;

  da1.setVals('d', 'r', 'e', 'w');
  cout << "da1: ";
  da1.printInfo();
  da2 = da1;
  cout << "da2 after assigning to da1: ";
  da2.printInfo();
  cout << "Change da1 drew => draw" << endl;
  da1.changeVal(2, 'a');
  cout << "da1: ";
  da1.printInfo();
  cout << "da2: ";
  da2.printInfo();

  return 0;
}
```

da1: drew
da2 after assigning to da1: drew



Notes:
- Red arrow indicates which instructions have been executed
- Purple filled cells indicate that memory has been allocated by the program for its use

15

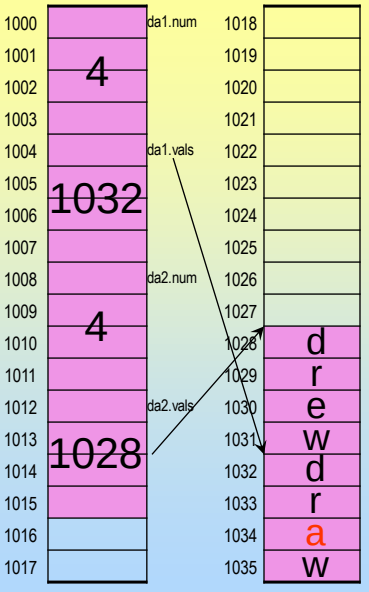
Using The New DynAryClass, p.4


```
int main()
{
  DynAryClass da1;
  DynAryClass da2;

  da1.setVals('d', 'r', 'e', 'w');
  cout << "da1: ";
  da1.printInfo();
  da2 = da1;
  cout << "da2 after assigning to da1: ";
  da2.printInfo();
  cout << "Change da1 drew => draw" << endl;
  da1.changeVal(2, 'a');
  cout << "da1: ";
  da1.printInfo();
  cout << "da2: ";
  da2.printInfo();

  return 0;
}
```

da1: drew
da2 after assigning to da1: drew
Change da1 drew => draw



Notes:
- Red arrow indicates which instructions have been executed
- Purple filled cells indicate that memory has been allocated by the program for its use

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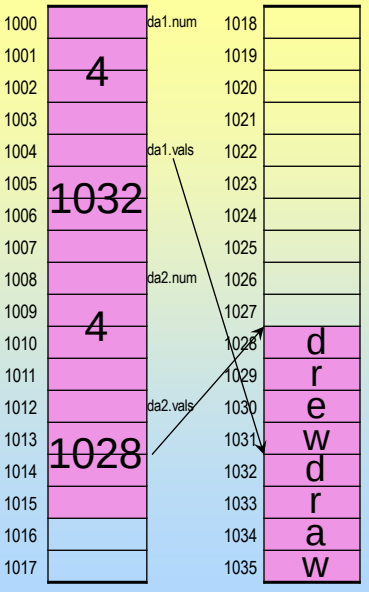
Using The New DynAryClass, p.5


```
int main()
{
  DynAryClass da1;
  DynAryClass da2;

  da1.setVals('d', 'r', 'e', 'w');
  cout << "da1: ";
  da1.printInfo();
  da2 = da1;
  cout << "da2 after assigning to da1: ";
  da2.printInfo();
  cout << "Change da1 drew => draw" << endl;
  da1.changeVal(2, 'a');
  cout << "da1: ";
  da1.printInfo();
  cout << "da2: ";
  da2.printInfo();

  return 0;
}
```

```
da1: drew
da2 after assigning to da1: drew
Change da1 drew => draw
da1: draw
da2: drew
```



Notes:

- Red arrow indicates which instructions have been executed
- Purple filled cells indicate that memory has been allocated by the program for its use

General Rule, Version 1

- When a class you write contains data members that will point to dynamically allocated memory:
  - Override the assignment operator so that a full copy of the object (and all dynamic memory associated with it) is made when assigning
    - This will take the place of (override) the default assignment operator that performs a shallow copy
  - Override the copy constructor so that a full copy of the object (and all dynamic memory associated with it) is made when copying
    - This will take the place of (override) the default copy ctor that performs a shallow copy
  - Overload another constructor (default or otherwise) so that objects can be constructed with something other than the copy ctor
  - Initialize the pointer members to 0 (NULL) in the ctors

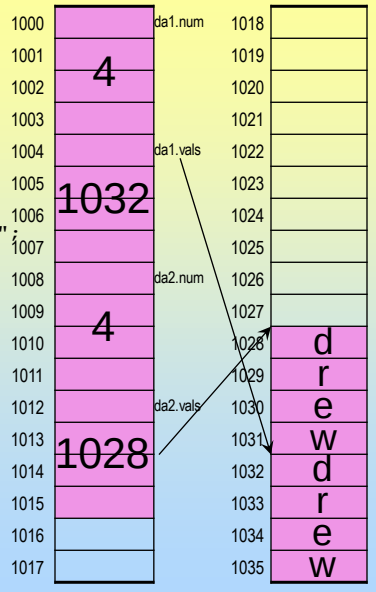
Yet Another Problem, p.1


```
int main()
{
  DynAryClass da1;
  DynAryClass da2;

  da1.setVals('d', 'r', 'e', 'w');
  cout << "da1: ";
  da1.printInfo();
  da2 = da1;
  cout << "da2 after assigning to da1: ";
  da2.printInfo();
  da1.setVals('h', 'i', '!');
  cout << "newly set da1: ";
  da1.printInfo();
  da2.setVals('a', 'b', 'c');
  cout << "newly set da2: ";
  da2.printInfo();

  return 0;
}
```

da1: drew
da2 after assigning to da1: drew



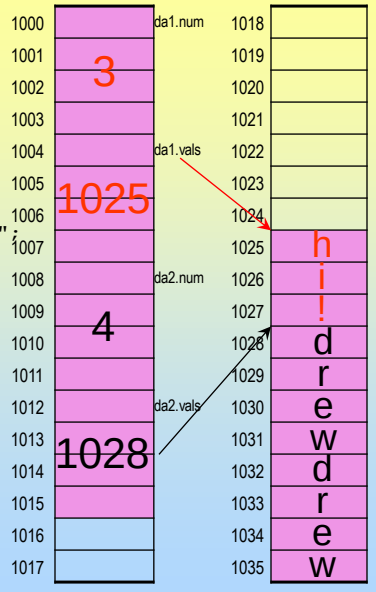
Yet Another Problem, p.2


```
int main()
{
  DynAryClass da1;
  DynAryClass da2;

  da1.setVals('d', 'r', 'e', 'w');
  cout << "da1: ";
  da1.printInfo();
  da2 = da1;
  cout << "da2 after assigning to da1: ";
  da2.printInfo();
  da1.setVals('h', 'i', '!');
  cout << "newly set da1: ";
  da1.printInfo();
  da2.setVals('a', 'b', 'c');
  cout << "newly set da2: ";
  da2.printInfo();

  return 0;
}
```

da1: drew
da2 after assigning to da1: drew
newly set da1: hi!



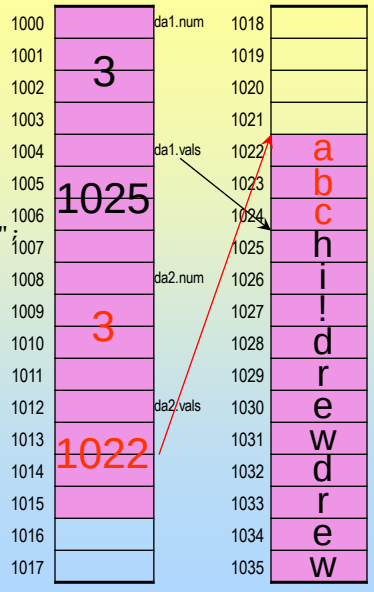
Yet Another Problem, p.3


```
int main()
{
  DynAryClass da1;
  DynAryClass da2;

  da1.setVals('d', 'r', 'e', 'w');
  cout << "da1: ";
  da1.printInfo();
  da2 = da1;
  cout << "da2 after assigning to da1: ";
  da2.printInfo();
  da1.setVals('h', 'i', '!');
  cout << "newly set da1: ";
  da1.printInfo();
  da2.setVals('a', 'b', 'c');
  cout << "newly set da2: ";
  da2.printInfo();

  return 0;
}
```

da1: drew
da2 after assigning to da1: drew
newly set da1: hi!
newly set da2: abc



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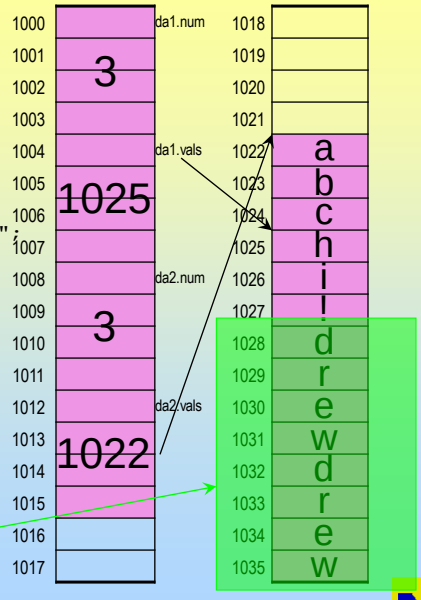
Yet Another Problem, p.4


```
int main()
{
  DynAryClass da1;
  DynAryClass da2;

  da1.setVals('d', 'r', 'e', 'w');
  cout << "da1: ";
  da1.printInfo();
  da2 = da1;
  cout << "da2 after assigning to da1: ";
  da2.printInfo();
  da1.setVals('h', 'i', '!');
  cout << "newly set da1: ";
  da1.printInfo();
  da2.setVals('a', 'b', 'c');
  cout << "newly set da2: ";
  da2.printInfo();

  return 0;
}
```

This memory has been "leaked".
There is no way to access it!!! The pointers that used to point to it have changed.



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Plugging The Memory Leak

- You must be sure to delete memory when you will no longer use it!
- Use the delete operator to free up memory before re-allocating new memory

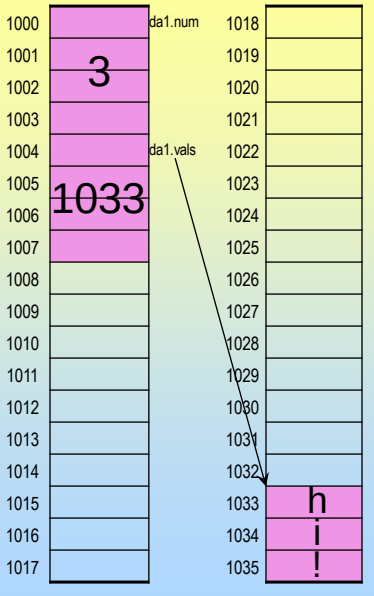
```
void setVals(char a, char b,
             char c)
{
  num = 3;
  delete [] vals;
  vals = new char[num];
  vals[0] = a;
  vals[1] = b;
  vals[2] = c;
}
void setVals(char a, char b,
             char c, char d)
{
  num = 4;
  delete [] vals;
  vals = new char[num];
  vals[0] = a;
  vals[1] = b;
  vals[2] = c;
  vals[3] = d;
}
```

Recall that using delete on a null pointer will have no effect (and will not seg fault). Using delete on a pointer that points to memory not owned by your program WILL cause a seg fault.

Therefore, it is important that the "vals" member be initialized to NULL so that the first time these functions are used, vals is a null pointer and the delete operator will not cause a seg fault.

One Final Problem, p.1


```
//Notes: Not a member function!
//       da is passed-by-value
void globalPrintDynAry(DynAryClass da)
{
  cout << "Global Print: ";
  da.printInfo();
}

int main()
{
  DynAryClass da1;
  DynAryClass da2;

  da1.setVals('h', 'i', '!');
  cout << "newly set da1: ";
  da1.printInfo();
  globalPrintDynAry(da1);

  return 0;
}
```

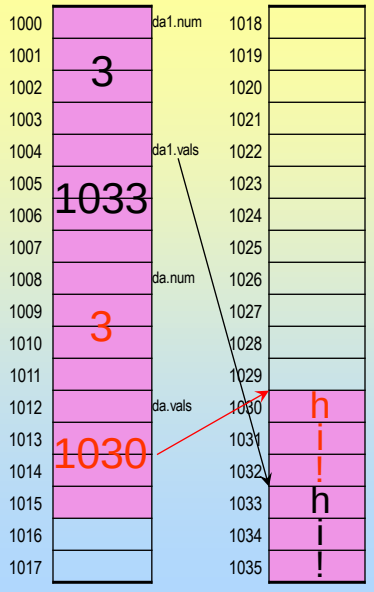


One Final Problem, p.2


```
//Notes: Not a member function!
//       da is passed-by-value
void globalPrintDynAry(DynAryClass da)
{
  cout << "Global Print: ";
  da.printInfo();
}

int main()
{
  DynAryClass da1;
  DynAryClass da2;

  da1.setVals('h', 'i', '!');
  cout << "newly set da1: ";
  da1.printInfo();
  globalPrintDynAry(da1);

  return 0;
}
```

newly set da1: hi!

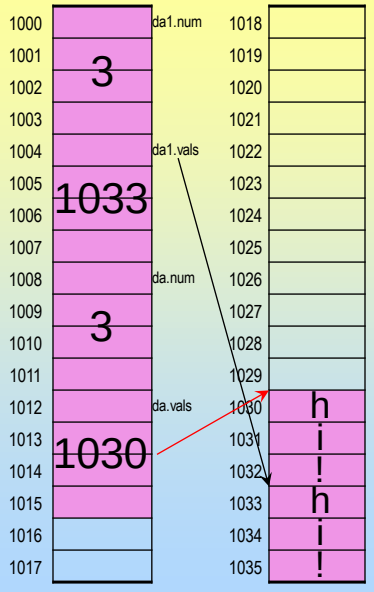
Pass-by-value param uses the (programmer-defined) copy ctor to make a full copy



One Final Problem, p.3


```
//Notes: Not a member function!
//       da is passed-by-value
void globalPrintDynAry(DynAryClass da)
{
  cout << "Global Print: ";
  da.printInfo();
}

int main()
{
  DynAryClass da1;
  DynAryClass da2;

  da1.setVals('h', 'i', '!');
  cout << "newly set da1: ";
  da1.printInfo();
  globalPrintDynAry(da1);

  return 0;
}
```

newly set da1: hi!
Global Print: hi!

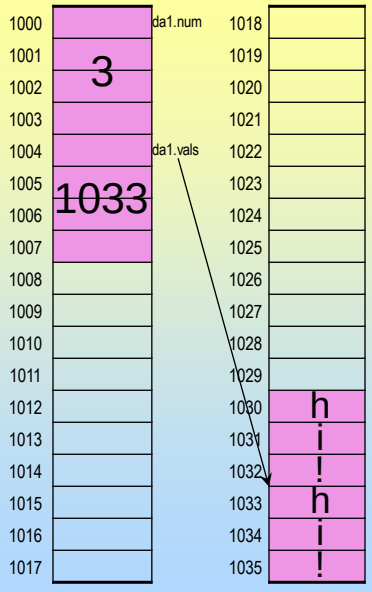


One Final Problem, p.4


```
//Notes: Not a member function!
//       da is passed-by-value
void globalPrintDynAry(DynAryClass da)
{
  cout << "Global Print: ";
  da.printInfo();
}

int main()
{
  DynAryClass da1;
  DynAryClass da2;

  da1.setVals('h', 'i', '!');
  cout << "newly set da1: ";
  da1.printInfo();
  globalPrintDynAry(da1);

  return 0;
}
```

newly set da1: hi!
Global Print: hi!

The value param "da" goes out of scope, and is therefore removed from memory. The dynamic memory it was pointing to remains though! This is another memory leak.



Plugging Memory Leak #2

- The memory leak was caused by an object being destroyed, but the dynamic memory associated with it remaining allocated
- Every time an object is destroyed, the destructor is called
- Solution: Provide a destructor that frees up dynamic memory associated with an object

```
class DynAryClass
{
 private:
   int num;
   char *vals; //Will pt to array of chars
 public:
   //---No changes to other functions---

   //Dtor - frees up dynamic memory associated with
   //the object being destroyed
   ~DynAryClass()
   {
     delete [] vals;
   }
};
```

General Rule, Version 2

- When a class you write contains data members that will point to dynamically allocated memory:
  - Override the assignment operator so that a full copy of the object (and all dynamic memory associated with it) is made when assigning
    - This will take the place of (override) the default assignment operator that performs a shallow copy
  - Override the copy constructor so that a full copy of the object (and all dynamic memory associated with it) is made when copying
    - This will take the place of (override) the default copy ctor that performs a shallow copy
  - Overload another constructor (default or otherwise) so that objects can be created with something other than the copy ctor
  - Initialize the pointer members to 0 (NULL) in the ctors
  - Provide a destructor so that dynamic memory used by an object is freed when the object is destroyed