Intro to C++

Introductions

- Who we are
  - proprietary trading (trading uses the firm's capital)
  - institutional brokerage (routing and executing client firms' trades)
  - not providing software as a product or service
  - ~150 people in Chicago, New York, London (Singapore coming soon!)
- Who I am
  - Andrew Wonnacott — Developer — Princeton COS '19
  - C++ / Python
  - core equities & futures trading system pipeline
  - genderfluid; he/him for tonight

Introductions

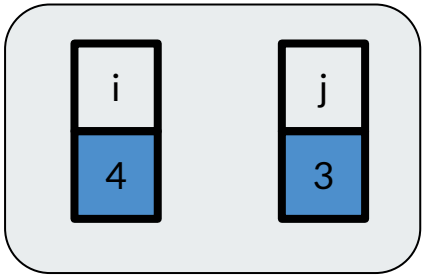
- What we do
  - Securities arbitrage (our trades are observations of mispricings, not term-based predictions of price movement)
  - ETFs, equity, commodity, bonds, fx, futures & options, etc...
  - essentially any electronic market with central clearing
- Who we're looking for
  - Full-time hires starting in 2022
  - Talented software developers who want to build systems
  - Awareness of the forest while building the trees
  - Also hiring traders & quants (contact our recruiting team)

Java quiz!

```
int i = 3;

int j = i;

i++;

System.out.println(j);
```

Java quiz!

```
int i = 3;

int j = i;

i++;

System.out.println(j); // 3
```

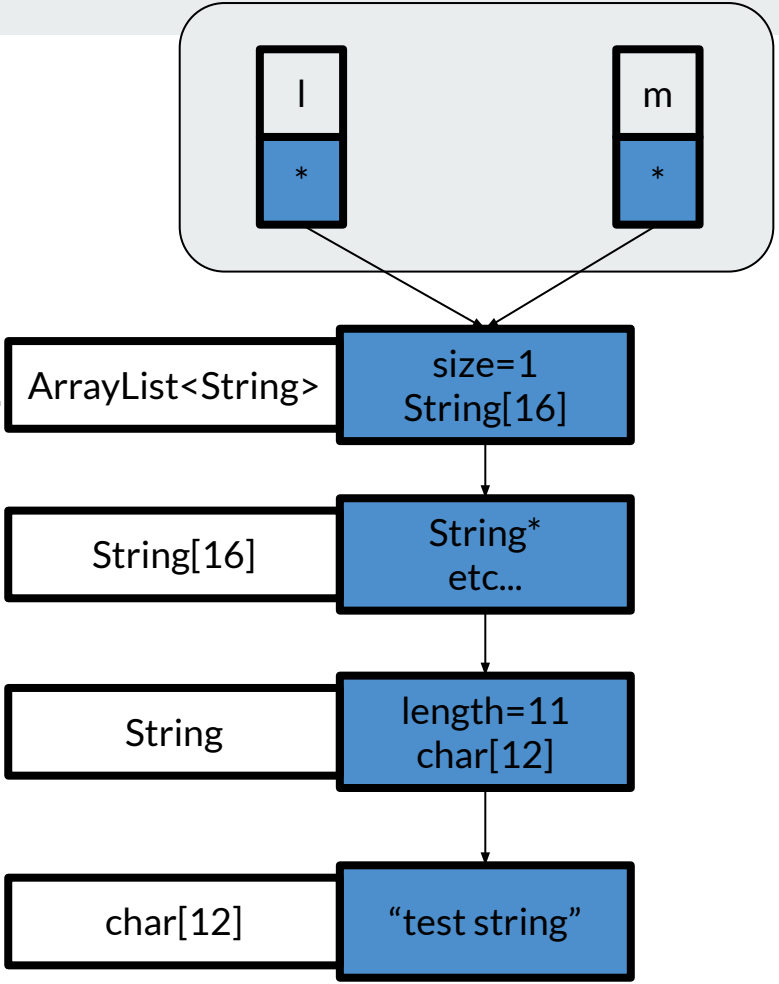


Java quiz!

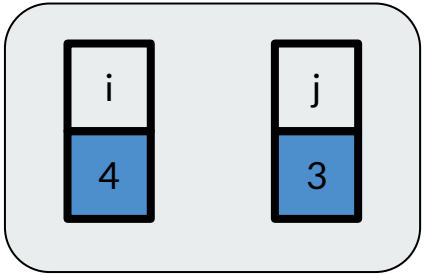
```
ArrayList<String> l = new ArrayList<String>();

ArrayList<String> m = l;

l.add(“test string”);

System.out.println(m);
```

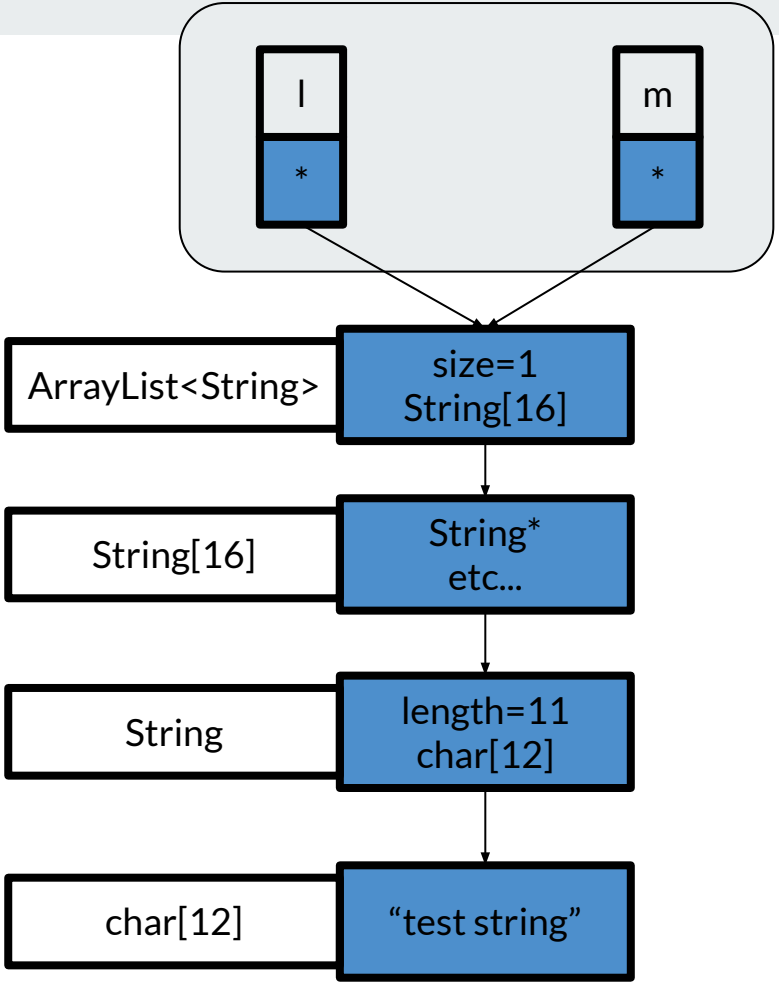
Java quiz!

```
ArrayList<String> l = new ArrayList<String>();

ArrayList<String> m = l;

l.add("test string");

System.out.println(m); // ["test string"]
```



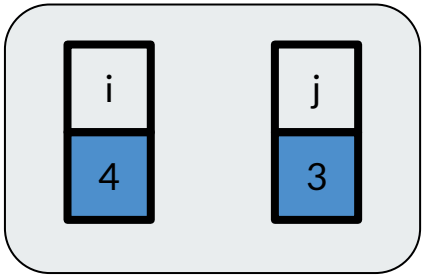
References vs values



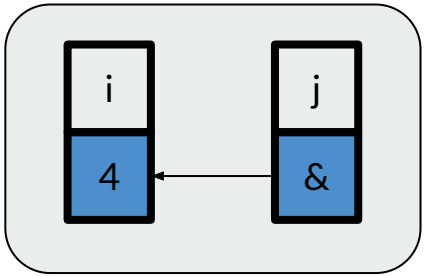


References vs values: primitives, idea

```
int i = 3;

int j = i;

i++;

println(j);
```

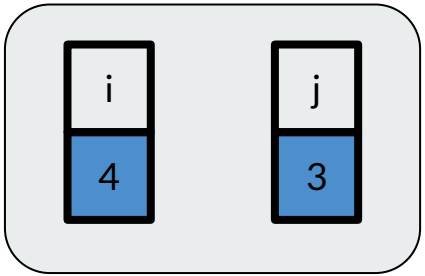



```
int i = 3;

int& j = i;

i++;

println(j);
```

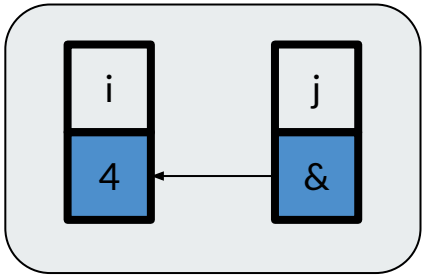


References vs values: primitives, C++

```
int i = 3;

int j = i;

i++;

cout << j << endl; // 3
```




```
int i = 3;

int& j = i;

i++;

cout << j << endl; // 4
```



References vs values: objects

```
array_list<string> l =
array_list<string>();

array_list<string> m = l;

l.add(“test string”);

cout << m; // []
```

```
array_list<string> l =
array_list<string>();

array_list<string>& m = l;

l.add(“test string”);

cout << m; // [“test string”]
```

References vs values: objects

```
array_list<string> l =
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array_list<string> m = l;

l.add("test string");

cout << m;
```

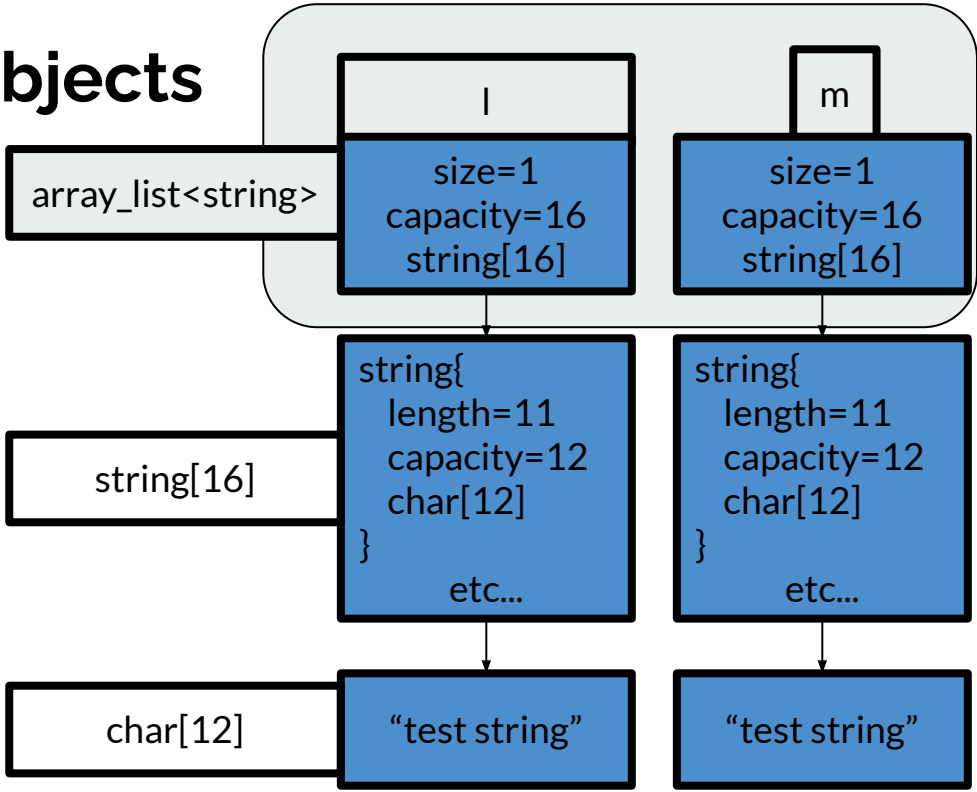

References vs values: objects

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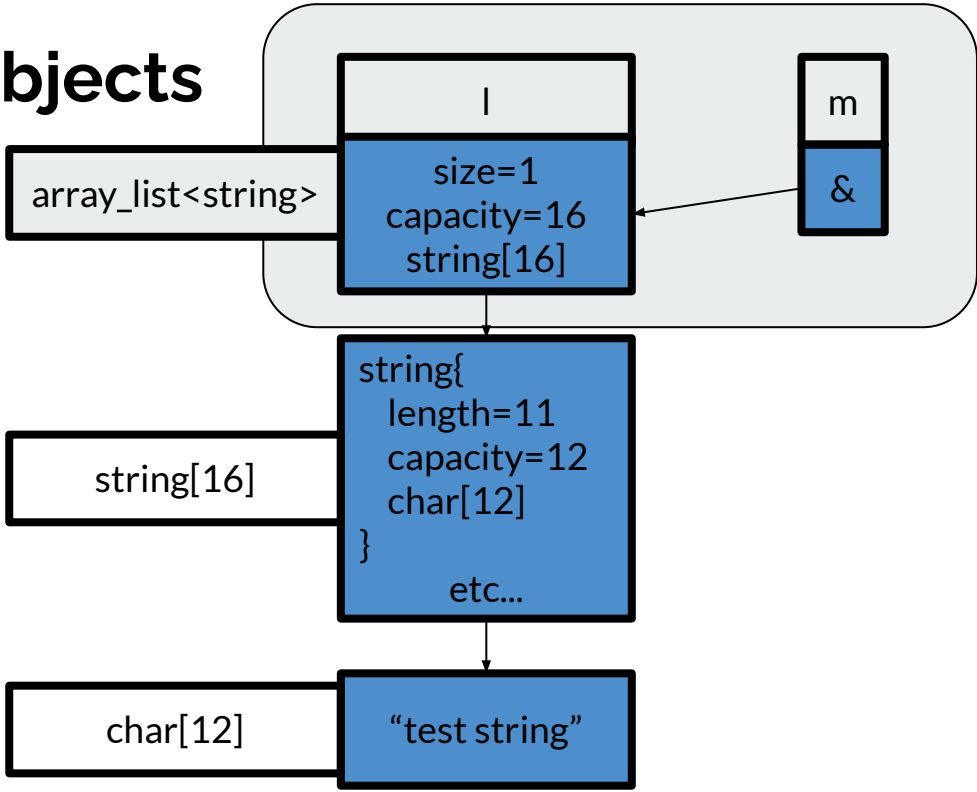
cout << m;
```



References vs values: objects

```
array_list<string>* l = new
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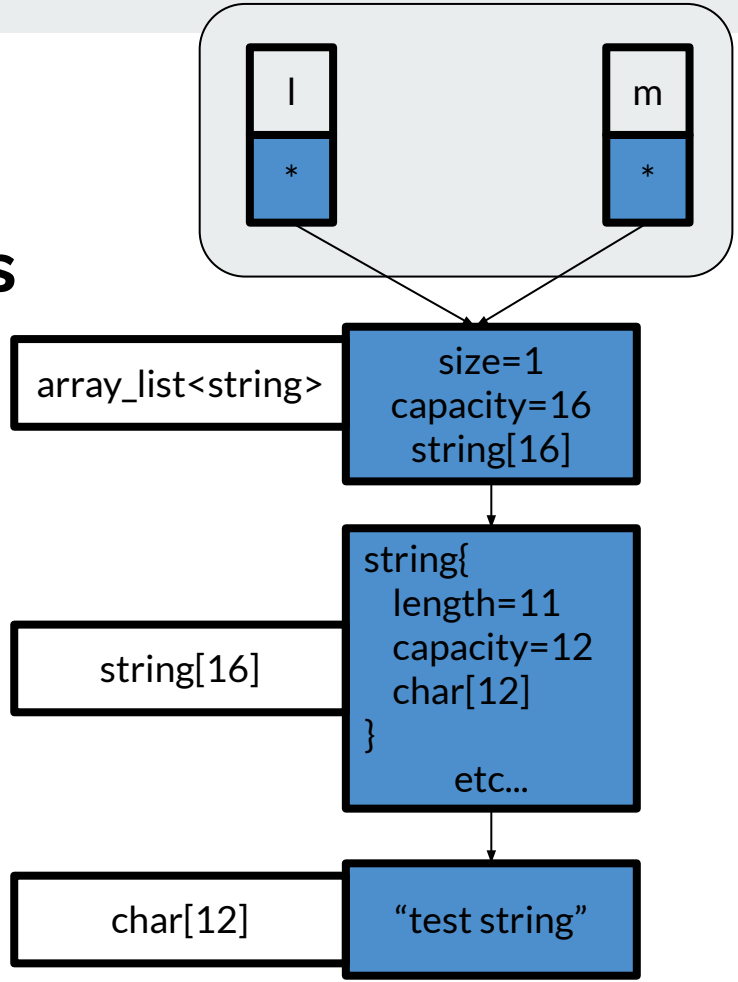
array_list<string>* m = l;

(*l).add("test string");

cout << *m;
```



Java quiz 2! Garbage collection

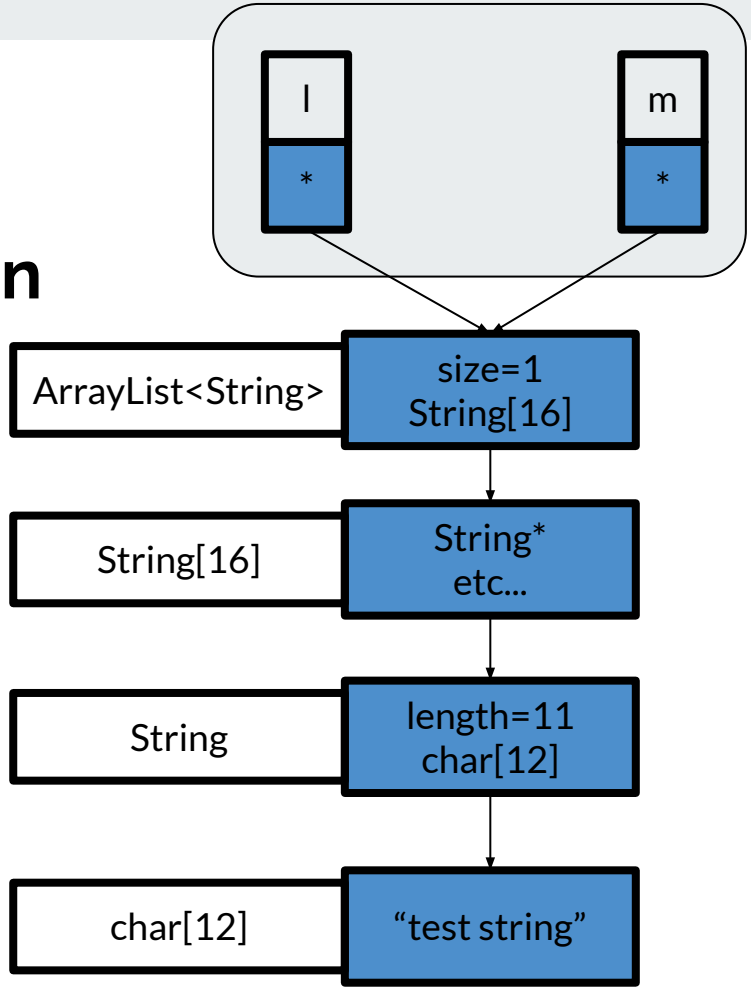
```
ArrayList<String> l = new ArrayList<String>();

ArrayList<String> m = l;

l.add("test string");

System.out.println(m);

return;
```



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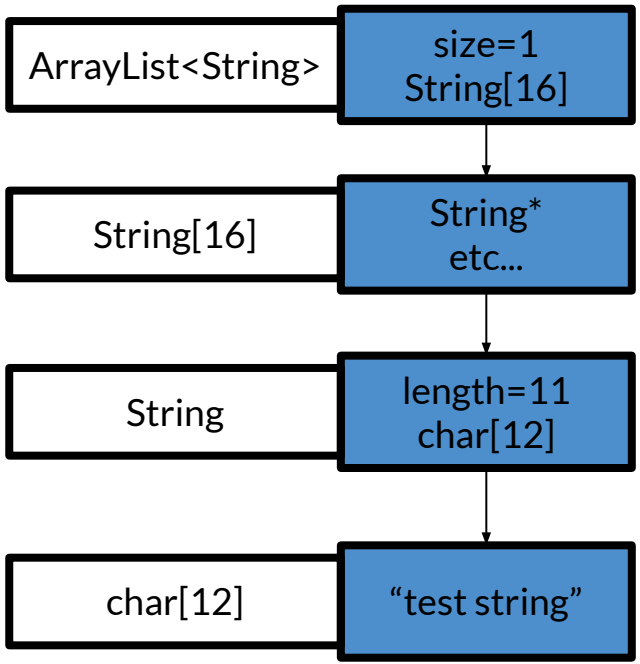

Java quiz 2! Garbage collection

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ArrayList<String> m = l;

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C++ quiz! Garbage collection

```
array_list<string>* l = new
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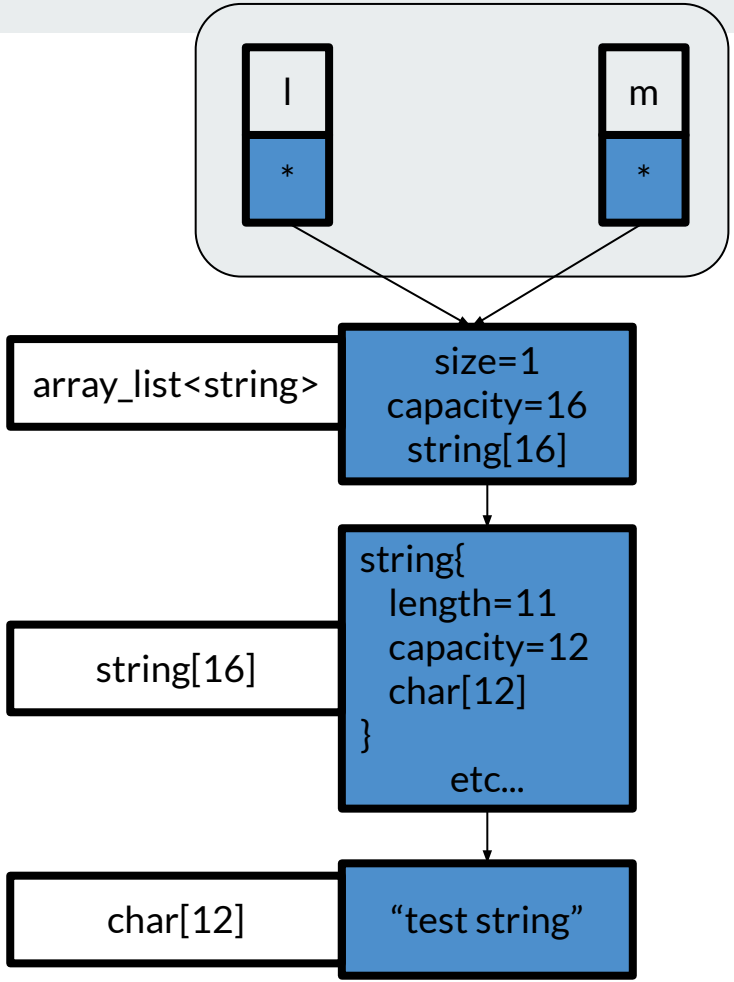
array_list<string>* m = l;

(*l).add("test string");

cout << *m;

return;
```



C++ quiz! Garbage collection

```
array_list<string>* l = new
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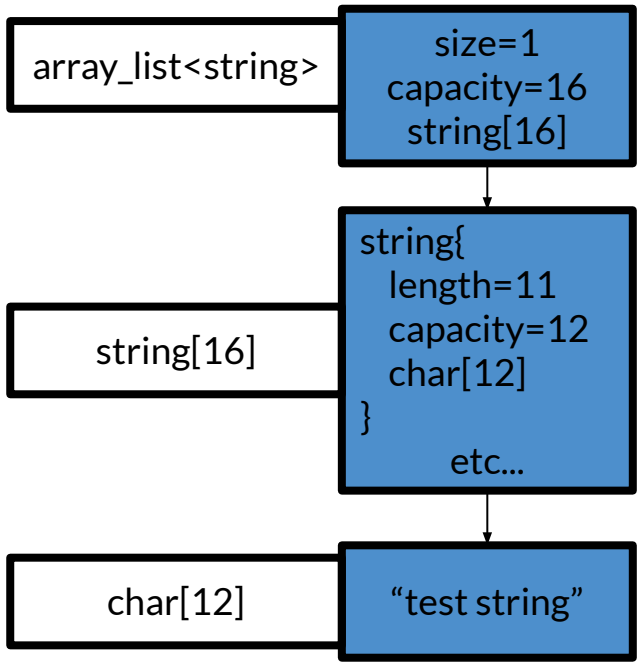
array_list<string>* m = l;

(*l).add("test string");

cout << *m;

return;
```



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(*l).add("test string");

cout << *m;

return;
```
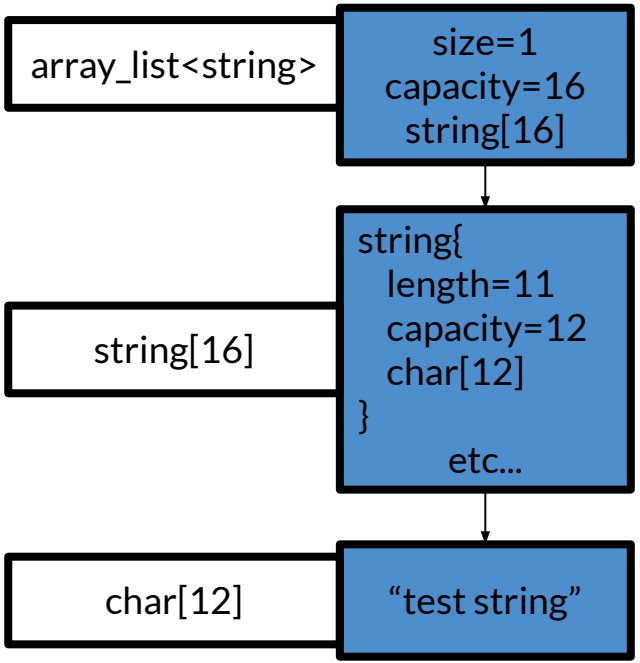
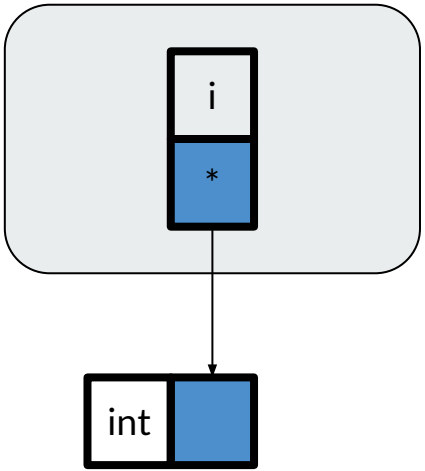



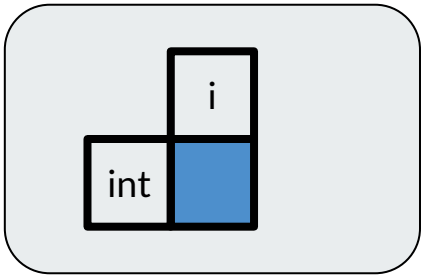
A simple class: C++ and Java

```
class Integer {
     private int i;
     public Integer(int i) {
          this.i = i;
     }
     public int get() {
          return i;
     }
}
```



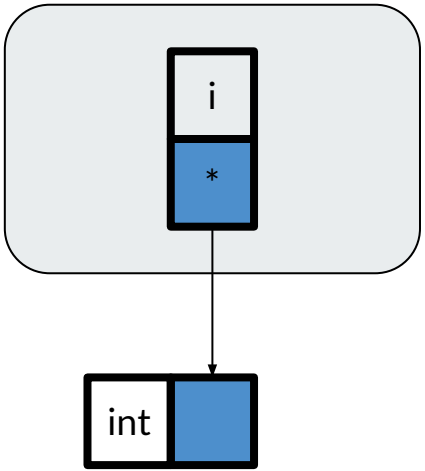
A simple class: C++ and Java

```
class Integer {
private:
     int _i;
public:
     Integer(int i) {
          _i = i;
     }
     int get() {
          return _i;
     }
}
```



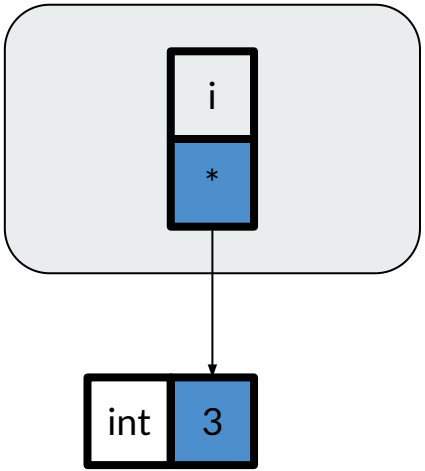
A simple class: C++ and Java

```
class Integer {
private:
     int* _i;
public:
     Integer(int i) {
          _i = new int(i);
     }
     int& get() {
          return *_i;
     }
}
```



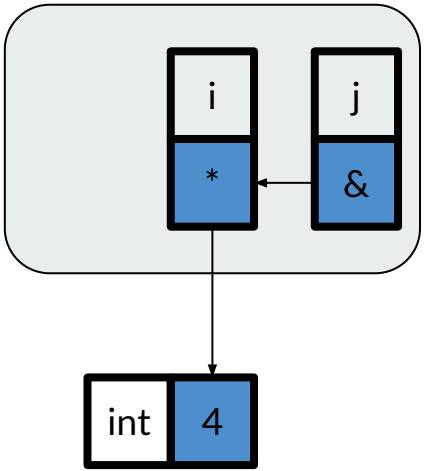
A simple class: C++ and Java

```
Integer i = Integer(3);
cout << i.get() << endl; // 3
```



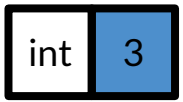
A simple class: C++ and Java

```
Integer i = Integer(3);
Integer& j = i;
i.get()++;
cout << j.get() << endl; // 4
```

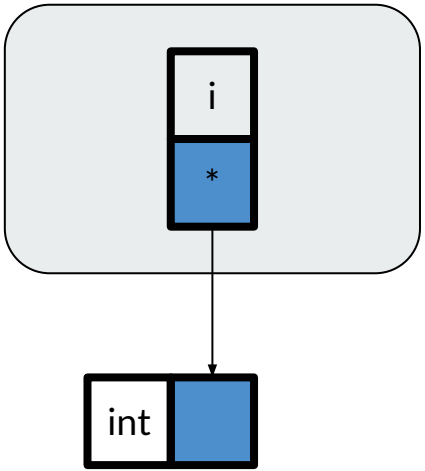


A simple class: C++ and Java

```
Integer i = Integer(3);
cout << i.get() << endl;
// 💣 leaking memory
```

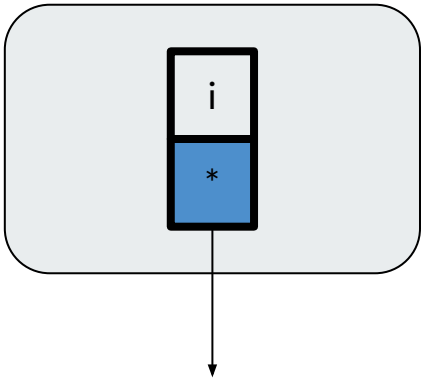


```
class Integer {
private:
     int *_i;
public:
     Integer(int i) {
          _i = new int(i);
     }
     ~Integer() {
          delete _i;
     }
     int& get() {
          return *_i;
     }
}
```



A simple class: C++ and Java

```
Integer i;
cout << i.get() << endl; // 💣
```



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class Integer {
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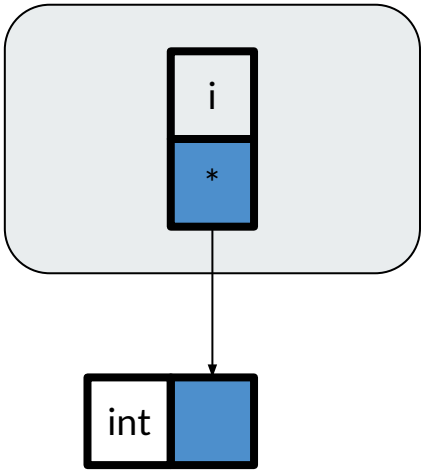
     ~Integer() {
          delete _i;
     }
     int& get() {
          return *_i;
     }
}
```



A simple class: C++ and Java

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Integer i = Integer(3);
Integer j = i;
i.get()++;
cout << j.get() << endl; // 4
```
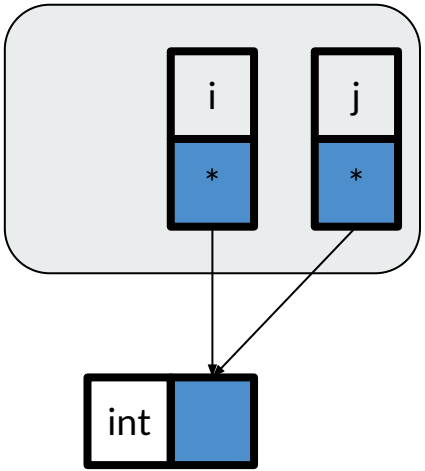
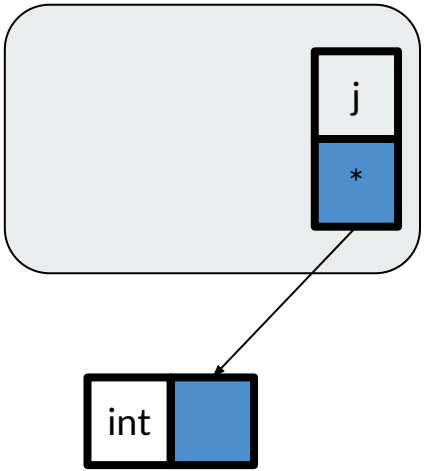



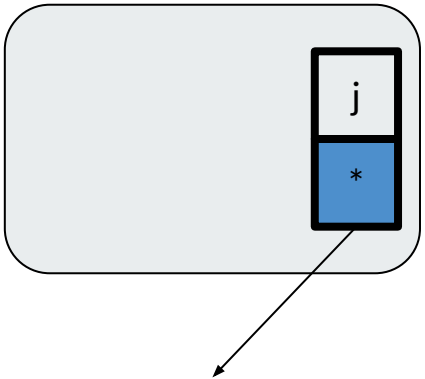
A simple class: C++ and Java

```
Integer i = Integer(3);
Integer j = i;
i.get()++;
cout << j.get() << endl;
```

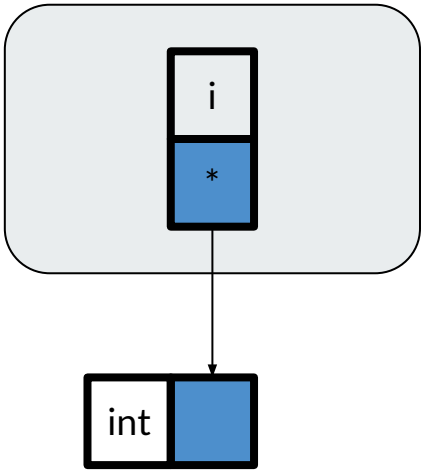


A simple class: C++ and Java

```
Integer i = Integer(3);
Integer j = i;
i.get()++;
cout << j.get() << endl;
// 💣 “double free” (deleting twice)
```

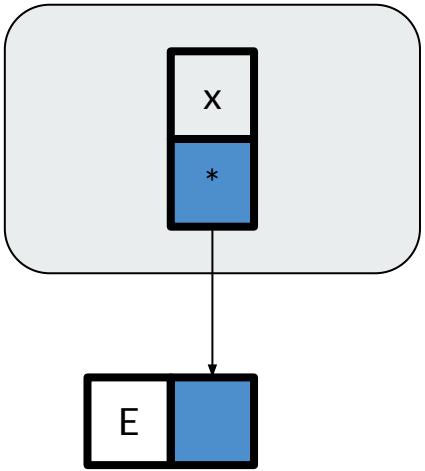


```
class Integer {
private:
     int *_i;
public:
     Integer() {
          _i = new int();
     }
     Integer(int i) {
          _i = new int(i);
     }
     Integer(Integer& o) {
          _i = new int(o.get());
     }
     ~Integer() {
          delete _i;
     }
     int& get() {
          return *_i;
     }
}
```

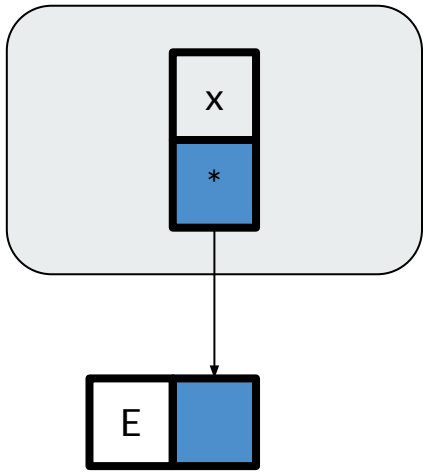


A box

```
class Box<E> {
     private E e;
     public Box(E e) {
          this.e = e;
     }
     public E get() {
          return e;
     }
}
```



```
template <class E> class Box {
private:
     E *_e;
public:
     Box() {
          _e = new E();
     }
     Box(E& e) {
          _e = new E(e);
     }
     Box(Box& o) {
          _i = new E(o.get());
     }
     ~Box() {
          delete _e;
     }
     E& get() {
          return *_e;
     }
}
```



Why is the box useful? Why is C++ useful?

- Expressive: allows control of low-level behavior like memory layout
  - don’t want to store a large object on the stack
- Modular: encapsulates low level operations in a reusable, compact way
  - we avoid 💣 code using the box
- Performant: no garbage collection needed
  - we know exactly what our code does

We need our trading system to be all of these

Okay, but is the box useful?

- We can store a big object on the heap with a Box on the stack
- But we need to copy it (expensive) whenever we copy the Box
- Let’s do something different...

“lvalues” and “rvalues”

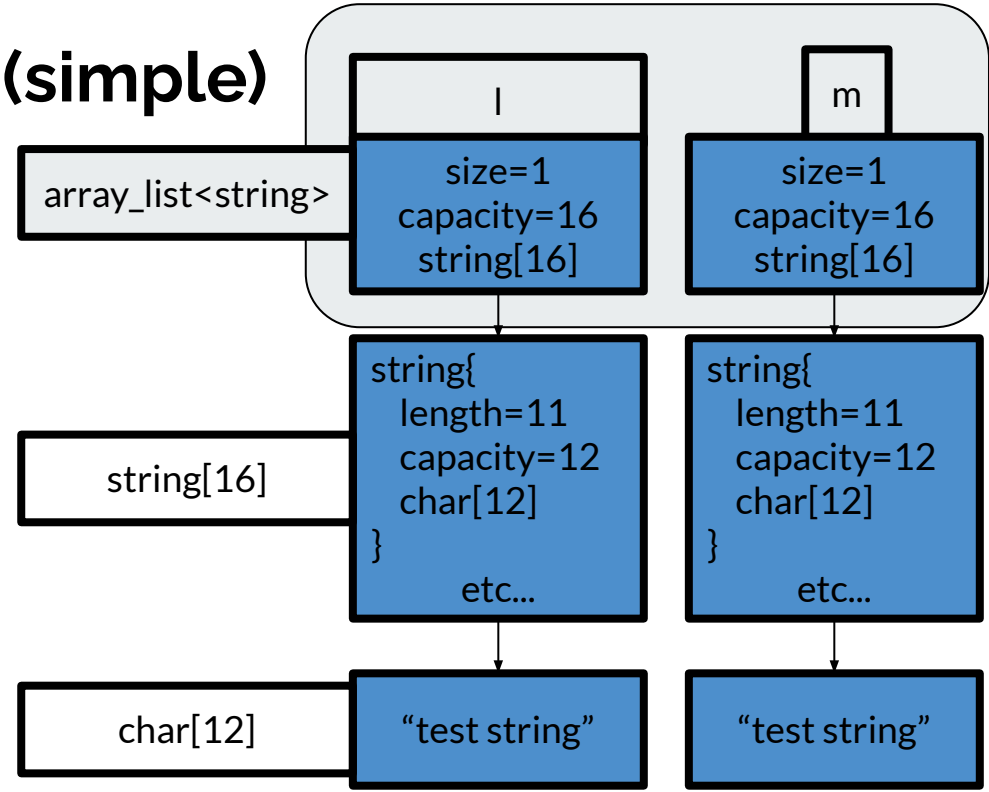
- left-hand side of =
- lvalues outlive the expression
  - have a name
- examples
  - variables
  - function return references

- right-hand side of =
- rvalues are temporary
  - no name
- examples
  - literal expressions
  - function return values

unclear? I’ll demonstrate...

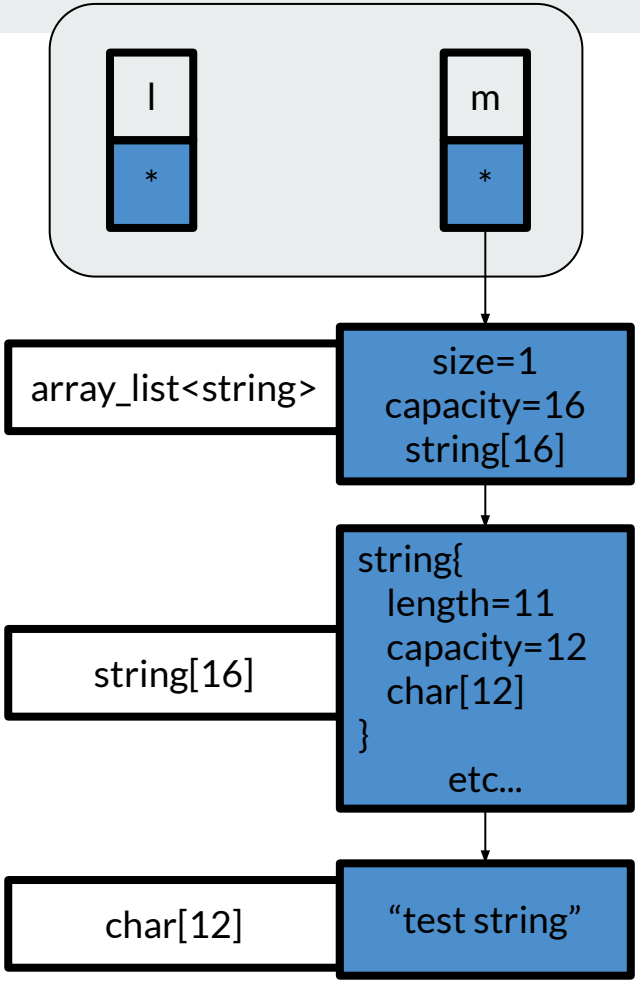
We want code like this (simple)

```
array_list<string> l =
array_list<string>();

array_list<string> m = l;

l.add("test string");

cout << m;
```



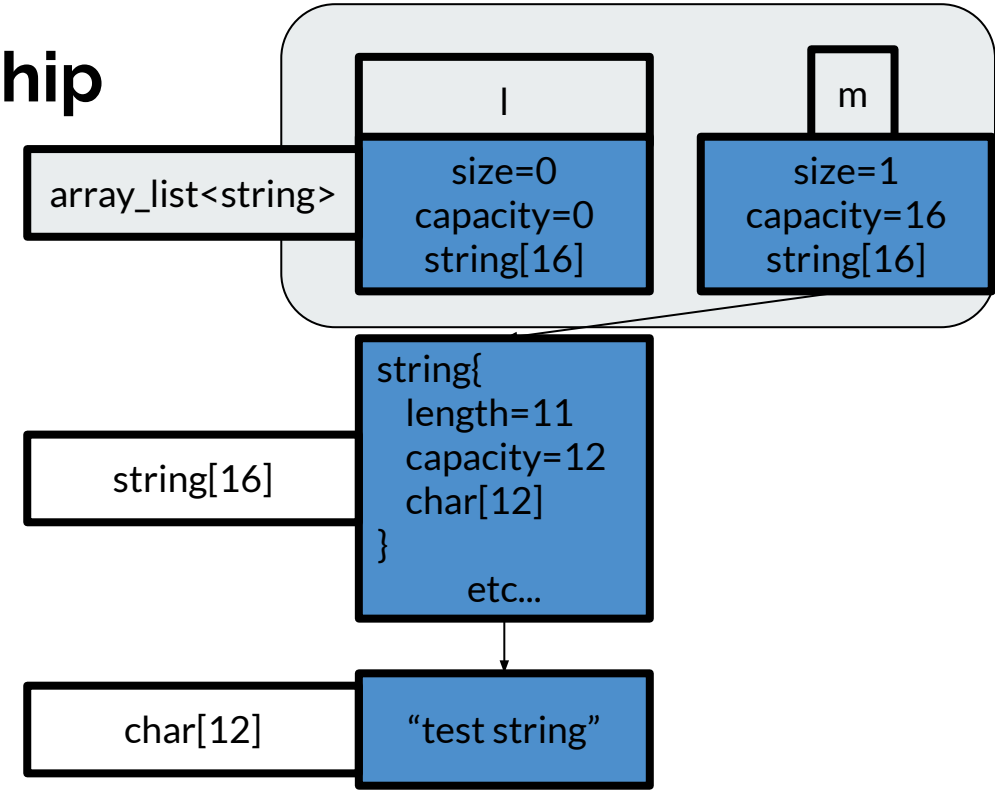
to get a result like this (gifting)

```
array_list<string>* l = new
array_list<string>();

array_list<string>* m = l;

l = null;

(*m).add("test string");

cout << *m;
```



we can “move” ownership

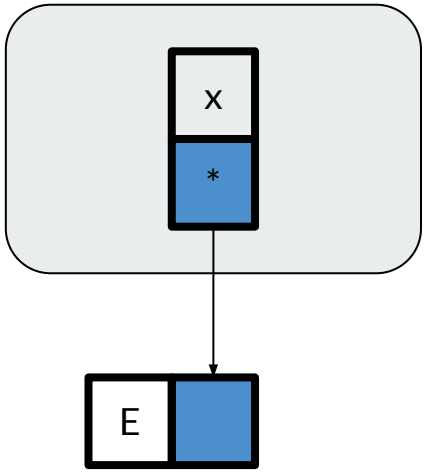
```
array_list<string> l =
array_list<string>();

array_list<string> m = move(l);

l.add(“test string”);

cout << m;
```



“move” turns an lvalue into an rvalue

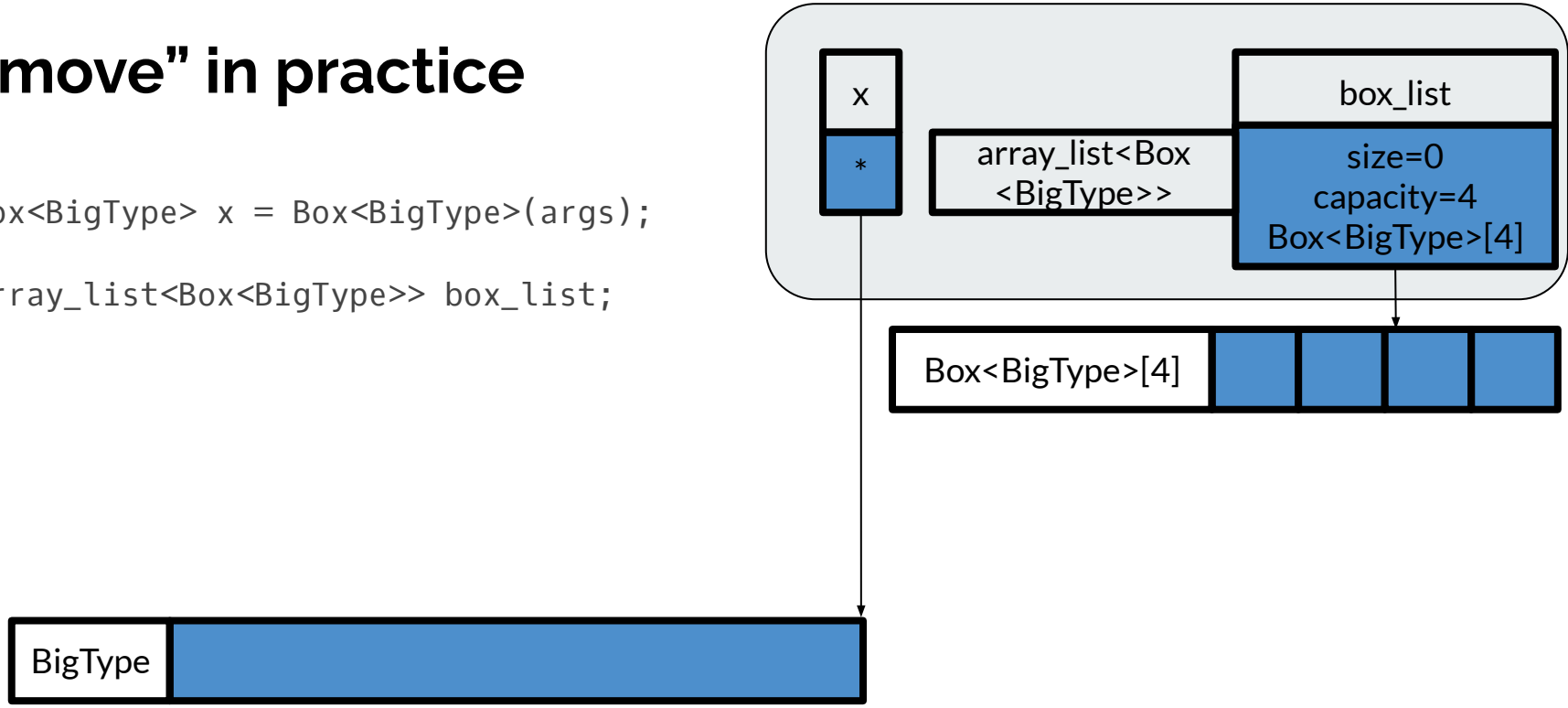
```
template <class E> class Box {
private:
     E *_e;
public:
     Box() {
          _e = new E();
     }
     Box(E& e) {
          _e = new E(e);
     }
     Box(Box& o) {
          _i = new E(o.get());
     }
}
```

```
E& get() {
     return *_e;
}
~Box() {
     if (_e != null) delete _e;
}
Box(E&& e) {
     _e = new E(move(e));
}
Box(Box&& o) {
     _e = o._e; o._e = null;
}
```



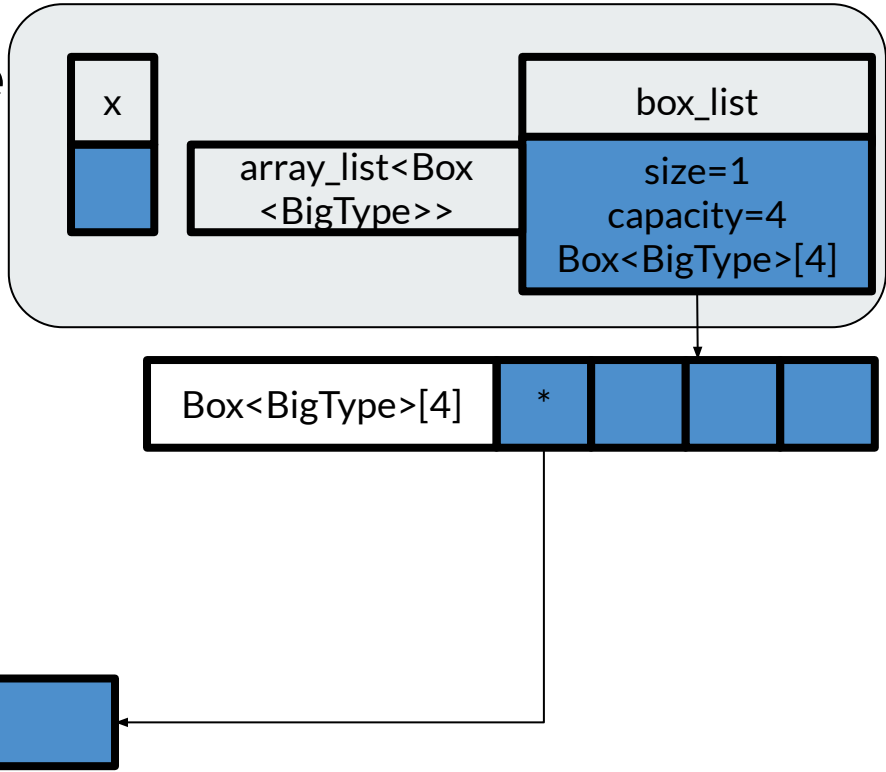
“move” in practice

```
Box<BigType> x = Box<BigType>(args);

array_list<Box<BigType>> box_list;
```



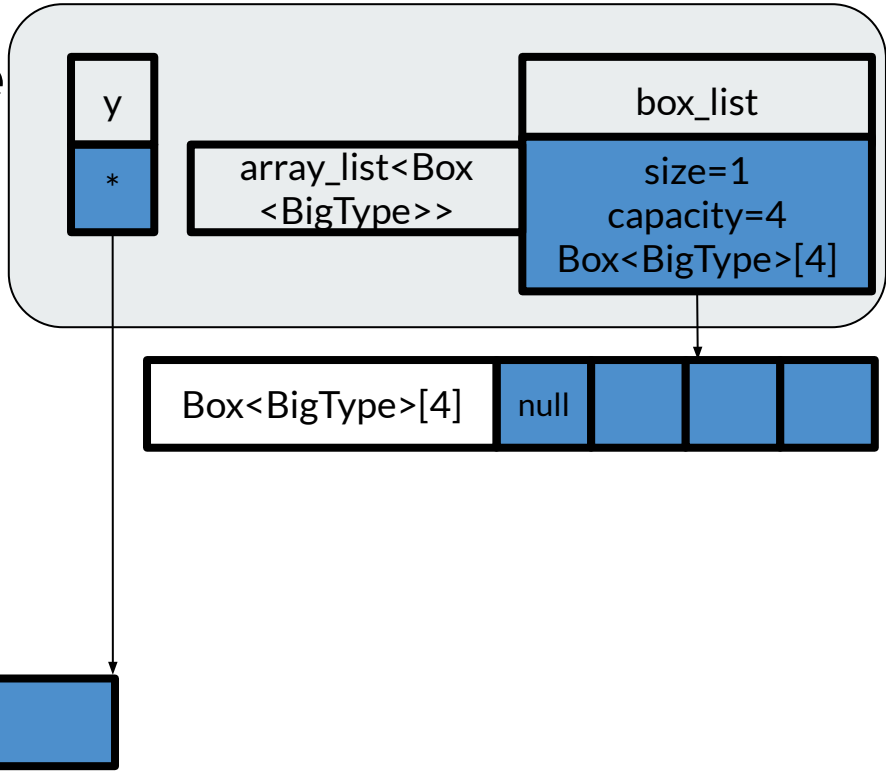
no reallocation of BigType

```
Box<BigType> x = Box<BigType>(args);

array_list<Box<BigType>> box_list;

box_list.add(move(x));
```



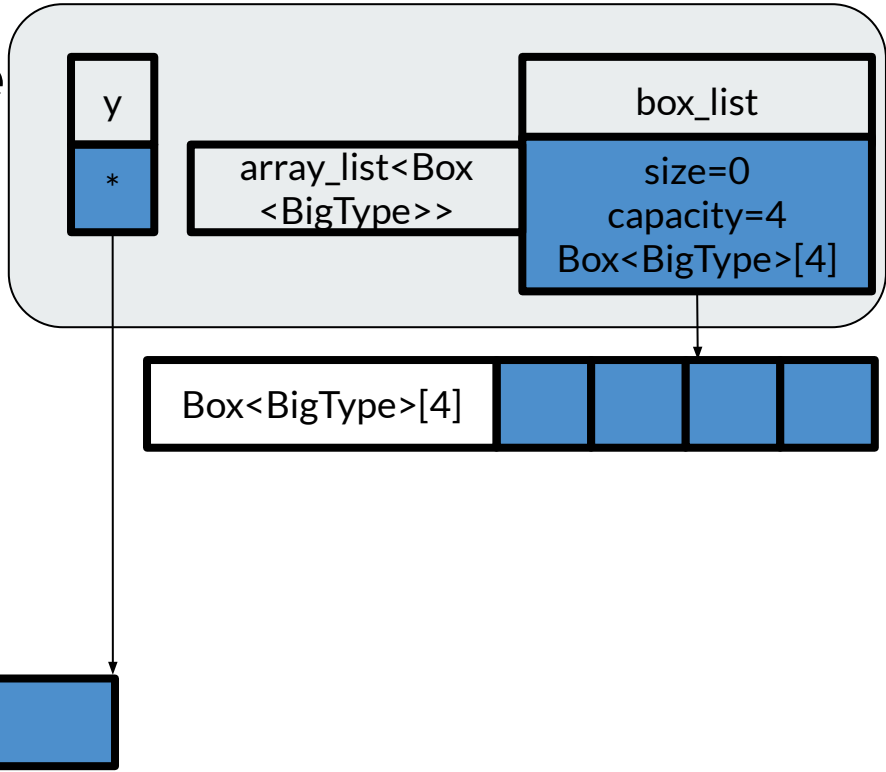
no reallocation of BigType

```
array_list<Box<BigType>> box_list;

// ... much later ...

Box<BigType> y = move(box_list[0]);
```



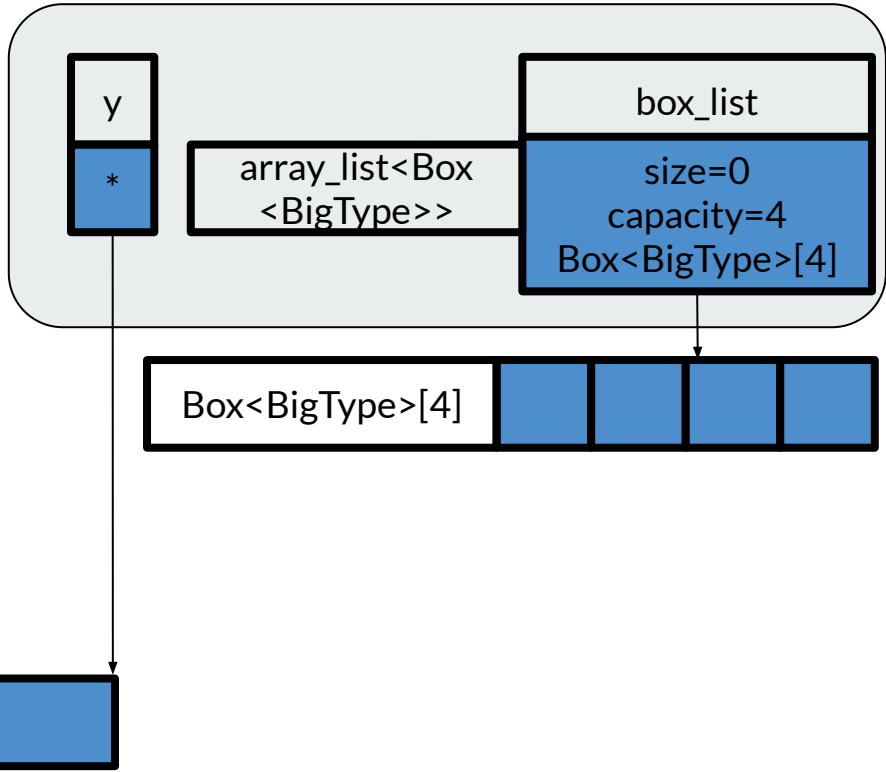
no reallocation of BigType

```
array_list<Box<BigType>> box_list;

// ... much later ...

Box<BigType> y = move(box_list[0]);

box_list.pop_back();
```



no memory management in client code

```
array_list<Box<BigType>> box_list;

// ... much later ...

Box<BigType> y = move(box_list[0]);

box_list.pop_back();
```



Questions?

- Email Andrew — address has been removed for upload technology questions

- Email Kyle, Joe, and Jeremy — recruiting@oldmissioncapital.com recruiting questions