CS61B Lecture #5: Arrays and Objects

- Readings for next week: *Blue Reader* Chapter 6.
- Readings on language details: *Java Language Specification,* Chapter 10 (Arrays), Chapter 8 and 9. Again, this material is dense, and I don't want you to try to memorize. Do try to get as much out of it as you easily can, and save up questions to ask in lecture, discussion, or by e-mail. Feel free to ignore particularly mystifying sections, or things we aren't interested in just now: notably sections on **strictfp**, **volatile**, **transient**, **native**, **synchronized**, nested and inner classes, instance and static initializers (8.6–8.7), and enums (8.9).
- For faster response, please send urgent problems (like "the lab files don't compile") as mail to cs61b, rather than using class messages.

Arrays

- An array is structured container whose components are
  - **length**, a fixed integer.
  - a sequence of **length** simple containers of the same type, numbered from 0.
  - (.length field usually implicit in diagrams.)
- Arrays are anonymous, like other structured containers.
- Always referred to with pointers.
- For array pointed to by `A`,
  - Length is `A.length`
  - Numbered component i is `A[`i`]` (i is the *index*)
  - Important feature: index can be *any integer expression*.

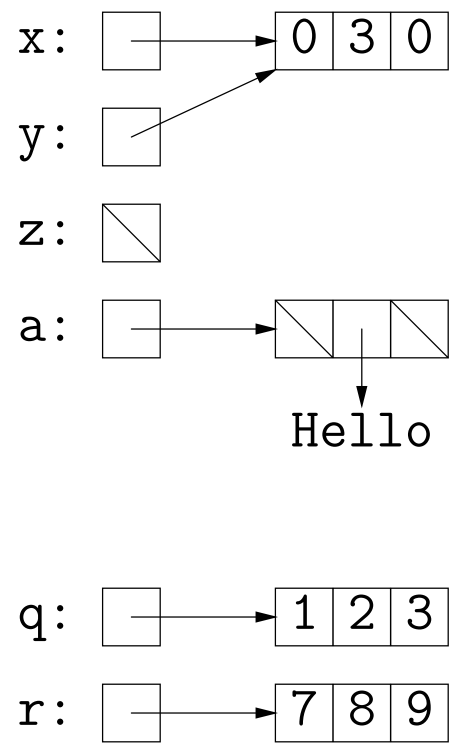
A Few Samples

Java

```
int[] x, y, z;
String[] a;
x = new int[3];
y = x;
a = new String[3];
x[1] = 2;
y[1] = 3;
a[1] = "Hello";

int[] q;
q = new int[] { 1, 2, 3 };
// Short form for declarations:
int[] r = { 7, 8, 9 };
```

Results



Example: Accumulate Values

Problem: Sum up the elements of array *A*.

```
static int sum (int[] A) {
  int N;
  N = 0;
  for (int i = 0; i < A.length; i += 1)
    N += A[i];
  return N;
}
```

```
// New (1.5) syntax
for (int x : A)
  N += x;
```

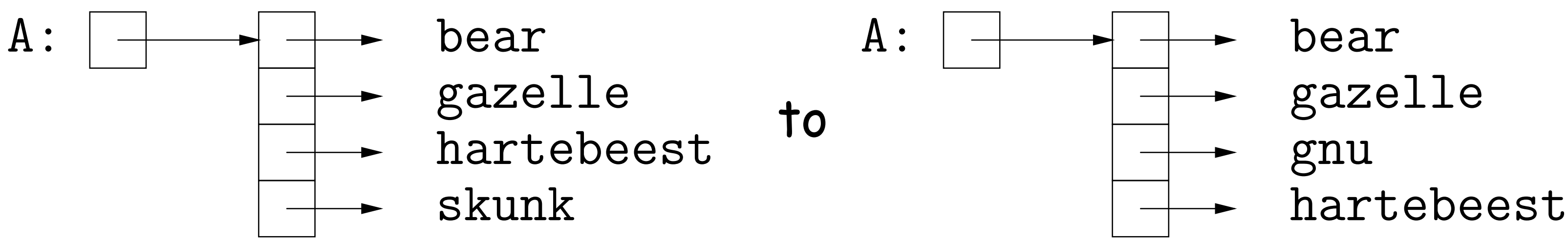
```
// For the hard-core: could have written

int N, i;
for (i=0, N=0; i<A.length; N += A[i], i += 1)
  { }   // or just ;

// But please don't: it's obscure.
```

Example: Insert into an Array

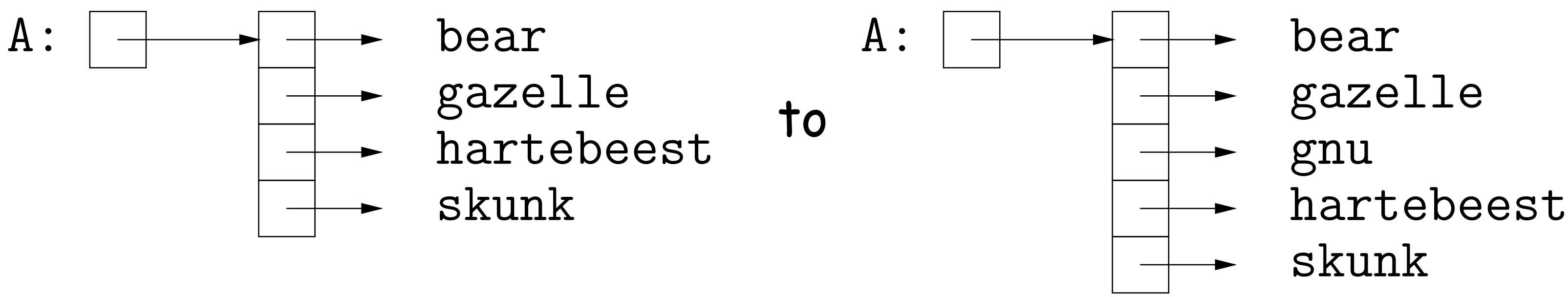
Problem: Want a call like `insert (A, 2, "gnu")` to convert (destructively)




```
/** Insert X at location K in ARR, moving items
 *  K, K+1, ... to locations K+1, K+2, ....
 *  The last item in ARR is lost. */
static void insert (String[] arr, int k, String x) {
  for (int i = arr.length-1; i > k; i -= 1) // Why backwards?
    arr[i] = arr[i-1];
  // Alternative to this loop:
  //    System.arraycopy ( arr, k,  arr, k+1,  arr.length-k-1);
  //                       from     to         # to copy
  arr[k] = x;
}
```

Growing an Array

Problem: Suppose that we want to change the description above, so that `A = insert2 (A, 2, "gnu")` does *not* shove "skunk" off the end, but instead "grows" the array.



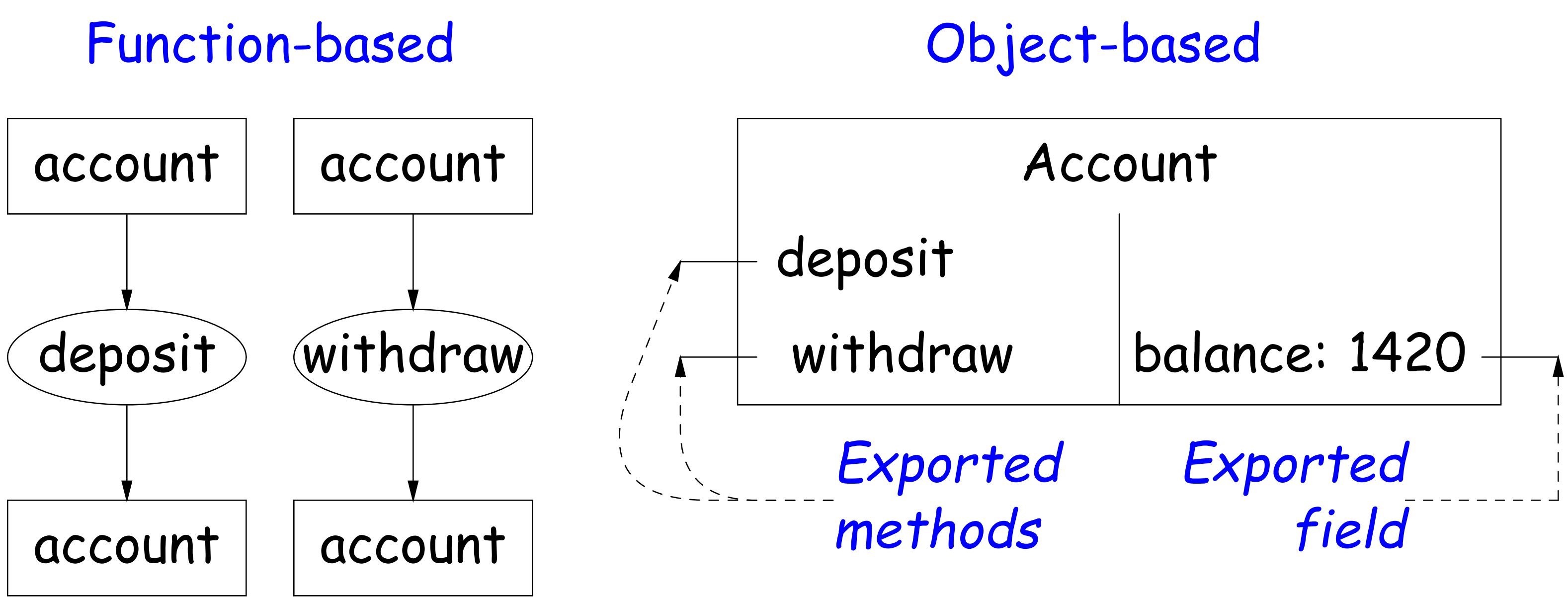

```
/** Return array, r, where r.length = ARR.length+1; r[0..K-1]
 *  the same as ARR[0..K-1], r[k] = x, r[K+1..] same as ARR[K..]. */
static String[] insert2 (String[] arr, int k, String x) {
  String[] result = new String[arr.length + 1];
  System.arraycopy (arr, 0, result, 0, k);
  System.arraycopy (arr, k, result, k+1, arr.length-k);
  result[k] = x;
  return result;
}
```

- Why do we need a different return type from `insert`??

Object-Based Programming

Basic Idea.

- *Function-based programs* are organized primarily around the functions (methods, etc.) that do things. Data structures (objects) are considered separate.
- *Object-based programs* are organized around the *types of objects* that are used to represent data; methods are grouped by type of object.
- Simple banking-system example:



Philosophy

- Idea (from 1970s and before): *An abstract data type* is
  - a set of possible values (a *domain*), plus
  - a set of *operations* on those values (or their containers).
- In `IntList`, for example, the domain was a *set of pairs:* `(head,tail)`, where `head` is an `int` and `tail` is a pointer to an `IntList`.
- The `IntList` operations consisted only of assigning to and accessing the two fields (`head` and `tail`).
- In *general*, prefer a purely *procedural interface,* where the functions (methods) do everything—no outside access to fields.
- That way, implementor of a class and its methods has complete control over behavior of instances.
- In Java, the preferred way to write the "operations of a type" is as *instance methods.*

You Saw It All in CS61A: The Account class

```scheme
(define-class (account balance0)
  (instance-vars (balance 0))
  (initialize
    (set! balance balance0))

  (method (deposit amount)
    (set! balance (+ balance amount))
    balance)
  (method (withdraw amount)
    (if (< balance amount)
      (error "Insufficient funds")
      (begin
        (set! balance (- balance amount))
        balance))) )
```

```scheme
(define my-account
  (instantiate account 1000))
(ask my-account 'balance)
(ask my-account 'deposit 100)
(ask my-account 'withdraw 500)
```

```java
public class Account {
  public int balance;
  public Account (int balance0) {
    balance = balance0;
  }
  public int deposit (int amount) {
    balance += amount; return balance;
  }
  public int withdraw (int amount) {
    if (balance < amount)
      throw new IllegalStateException
         ("Insufficient funds");
    else balance -= amount;
    return balance;
  }
}
```

```java
Account myAccount = new Account (1000);
myAccount.balance
myAccount.deposit (100);
myAccount.withdraw(500);
```

The Pieces

- Class declaration defines a *new type of object*, i.e., new type of structured container.
- **Instance variables** such as `balance` are the simple containers within these objects (*fields* or *components*).
- **Instance methods**, such as `deposit` and `withdraw` are like ordinary (static) methods that take an invisible extra parameter (called **this**).
- The **new** operator creates (*instantiates*) new objects, and initializes them using constructors.
- **Constructors** such as the method-like declaration of `Account` are special methods that are used only to initialize new instances. They take their arguments from the **new** expression.
- **Method selection** picks methods to call. For example,

  ```
  myAccount.deposit(100)
  ```

  tells us to call the method named `deposit` that is defined for the object pointed to by `myAccount`.

Getter Methods

- Slight problem with Java version of `Account`: anyone can assign to the `balance` field
- This reduces the control that the implementor of Account has over possible values of the balance.
- Solution: allow public access only through methods:

```
public class Account {
  private int balance;
  ...
  public int balance () { return balance; }
  ...
}
```

- Now the `balance` field cannot be directly referenced outside of `Account`.
- (OK to use name `balance` for both the field and the method. Java can tell which is meant by syntax: `A.balance` vs. `A.balance()`.)

Class Variables and Methods

- Suppose we want to keep track of the bank's total funds.
- This number is not associated with any particular Account, but is common to all—it is *class-wide*.
- In Java, "class-wide" $\equiv$ `static`

```
public class Account {
  ...
  private static int funds = 0;
  public int deposit (int amount) {
    balance += amount; funds += amount;
    return balance;
  }
  public static int funds () {
    return funds;
  }
  ...  // Also change withdraw.
}
```

- From outside, can refer to either `Account.funds()` or `myAccount.funds()` (same thing).

Instance Methods

- Instance method such as

```
int deposit (int amount) {
  balance += amount; funds += amount;
  return balance;
}
```

behaves sort of like a static method with hidden argument:

```
static int deposit (final Account this, int amount) {
  this.balance += amount; funds += amount;
  return this.balance;
}
```

- NOTE: Just explanatory: Not real Java (not allowed to declare 'this'). (`final` *is* real Java; means "can't change once set.")
- Likewise, the instance-method call `myAccount.deposit (100)` is like a call on this fictional static method:

```
Account.deposit (myAccount, 100);
```

- Inside method, as a convenient abbreviation, can leave off leading '`this.`' on field access or method call if not ambiguous.

‘Instance’ and ‘Static’ Don’t Mix

- Since real static methods don’t have the invisible `this` parameter, makes no sense to refer directly to instance variables in them:

```
public static int badBalance (Account A) {
   int x = A.balance;  // This is OK (A tells us whose balance)
   return balance;  // WRONG! NONSENSE!
}
```

- Reference to `balance` here equivalent to `this.balance`,
- But this is meaningless (*whose* balance?)
- However, it makes perfect sense to access a static (class-wide) field or method in an instance method or constructor, as happened with `funds` in the `deposit` method.
- There’s only one of each static field, so don’t need to have a ‘this’ to get it. Can just name the class.

Constructors

- To completely control objects of some class, you must be able to set their initial contents.
- A *constructor* is a kind of special instance method that is called by the **new** operator right after it creates a new object, as if

L = new IntList(1,null) $\Longrightarrow$
```
tmp = pointer to [0|\];
tmp.IntList(1, null);
L = tmp;
```

- Instance variables initializations are moved inside constructors:

```
class Foo {
  int x = 5;
  Foo () {
    DoStuff ();
  }
  ...
}
```

$\Longleftrightarrow$

```
class Foo {
  int x;
  Foo () {
    x = 5;
    DoStuff ();
  }
  ...
}
```

- In absence of any explicit constructor, get *default constructor:* `public Foo() { }`.
- Multiple *overloaded* constructors possible (different parameters).

Summary: Java vs. CS61A OOP in Scheme

Java	CS61A OOP
class Foo ...	(define-class (Foo *args*)...
int x = ...;	(instance-vars (x ...))
Foo(*args*) {...}	(initialize ...)
int f(...) {...}	(method (f ...) ...)
static int y = ...;	(class-vars (y ...))
static void g(...) {...}	(define (g...)...)
aFoo.f (...)	(ask aFoo 'f ...)
aFoo.x	(ask aFoo 'x)
new Foo (...)	(instantiate Foo ...)
this	self