



Lecture Set #9:

Arrays Intro

This lecture set:

- | Intro to arrays
- | Copying arrays and making arrays bigger
- | Array lengths and out-of-bounds indexing
- | Passing arrays and array elements to a function
- | Different levels of copy



Data Structures and Arrays

Data structures: mechanisms for storing data in a structured way

We have seen simple data structures implemented as classes:

`Rational.java`

- Rational number data stored as numerator / denominator pair

Arrays are a very useful data structure provided by Java and other programming languages

Array: sequence of variables of the same type

- homogeneous data structure
- size (quantity) fixed when space is allocated
- ordered

Individual elements of sequence can be referenced/updated/etc.

Arrays are objects (hence allocated on heap) with a reference on the stack

Like other objects, “instance variables” of array = cells in array are assigned default values (0 / null / etc.) when array created

Array Indexing



Java provides a special syntax for uniformly accessing cells in an array
Declaration of a:

```
int[] a;
```

Allocation of space for array named a:

```
a = new int[5]; // or combined: int[] a = new int[5];
```

This creates five `int` variables “named”::`a[0]`, `a[1]`, `a[2]`, `a[3]`, `a[4]`

To modify contents of cell #2 to 6 and cell #1 to 74:

```
a[2] = 6;
```

```
a[1] = 74;
```

To use the contents of cell #2 and cell #1 :

```
System.out.println("value = " + (a[1]-a[2]));
```

This access mechanism to the individual elements is called **array indexing**

In Java / C / C++, array cells are indexed beginning at 0 and going up to $n-1$ (where n is number of cells)

Beware: start at 0! and end at one less than the size!!

Square Brackets: [] and length



Three uses in Java:

Array variable declaration: `int[] a`

Array object creation: `new int[10]`

Array indexing: `a[0]`

array also has a `.length` holds the amount of space currently allocated for that array

Alternate Declaration Syntax

To maintain consistency with C / C++, following declaration of array variables also possible

- `int grade[];`

Compare to Java standard:

```
int[] grade;
```

Java standard generally preferred

“type[]” emphasizes array status

Alternative syntax sometimes handy:

```
int grade[], size, gpa[];
```

Declares two arrays of base type `int`: `grade`, `gpa`

Declares a single `int` variable: `size`

Summary of Arrays

Arrays are:

- Sequences of cells holding values of the same type (“base type”)

- Objects (hence created using new)

To define an array variable:

```
int[] a; // an array with base type int
```

To create an array object:

```
a = new int[10];
```

- Creates an array of 10 cells on the heap

- The base type is `int`

To access individual array cells: use indexing

```
a[0], a[1], ..., a[9]
```

- Cells are just like variables:

 - They may be read: `x = a[3];`

 - They may be written: `a[2] = 7;`

A Common Programming Idiom



To process all elements in array ...

Do the following:

- `for (int i = 0; i < a.length; i++){`
- `...process the one element at a[i]...`
- `}`

Use fresh loop counter to avoid overwriting another variable of same name elsewhere

Remember:

- Use `0` as one end of the array, not `1`
- Use `i < a.length` as the other end, not `i <= a.length`

Copying Arrays

Does the following copy a into b?

- `int[] a = new int[5];`
- `int[] b = a;`

No: a, b are aliases

How to make a copy?

```
int[] a = new int[5];  
int[] b = new int[a.length];  
for (int i = 0; i < a.length; i++){  
    b[i] = a[i];  
}
```


Making Arrays Bigger

Suppose we want to make an array bigger by adding an element.

Does the following work?

- `int[] a = new int[5];`
- `a.length++;`

No!

We get the following:

```
Exception in thread "main" java.lang.Error:  
Unresolved compilation problem:  
The final field array.length cannot be assigned  
at Sample.main(Sample.java:15)
```

`a.length` is immutable

No assignment to it is allowed

To Make an Array Bigger...

Create a new larger array object

Copy old array contents into new object

Assign address of new object to variable

- `int[] a = new int[5];`
- `{`
- `int[] temp = new int[a.length + 1];`
- `for (int i = 0; i < a.length; i++){`
- `temp[i] = a[i];`
- `}`
- `a = temp;`
- `}`

New variable temp created to hold copy

New block created to ensure temp does not interfere with another variable of the same name

Previous contents of a become garbage

Arrays As Arguments

Arrays = objects

Array variables = references

Array cells = variables of the base type (references or primitives depending on what that base type is)

Both can be used as arguments to methods

Array cells: passed just like the variables of that base type

Array arguments: passed just like objects

- Reference to array is passed in
- If the method expects an array of doubles, an array of doubles **of any size** can be passed
- **Promotion does not apply.** You cannot pass an int array when an array of doubles is expected

Array Initializers

Arrays may be initialized at declaration time!

```
int[] a = {5, 0, 1, 2};
```

Java:

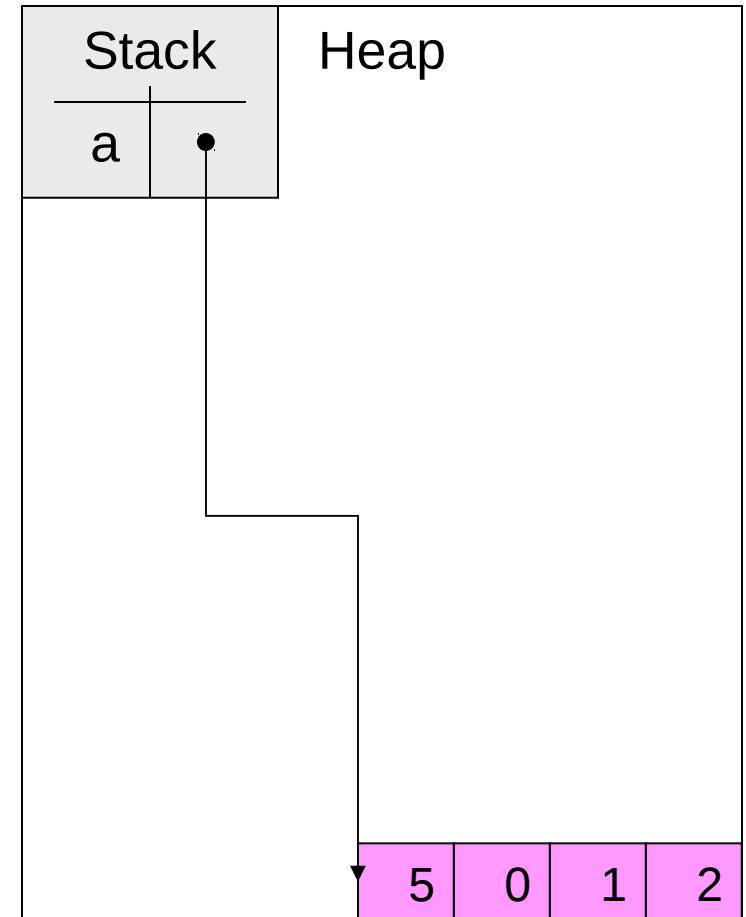
- counts elements (here, 4);

- creates correct size of array

- copies elements into array

- returns reference to array

See Array Example 3



Arrays of Objects

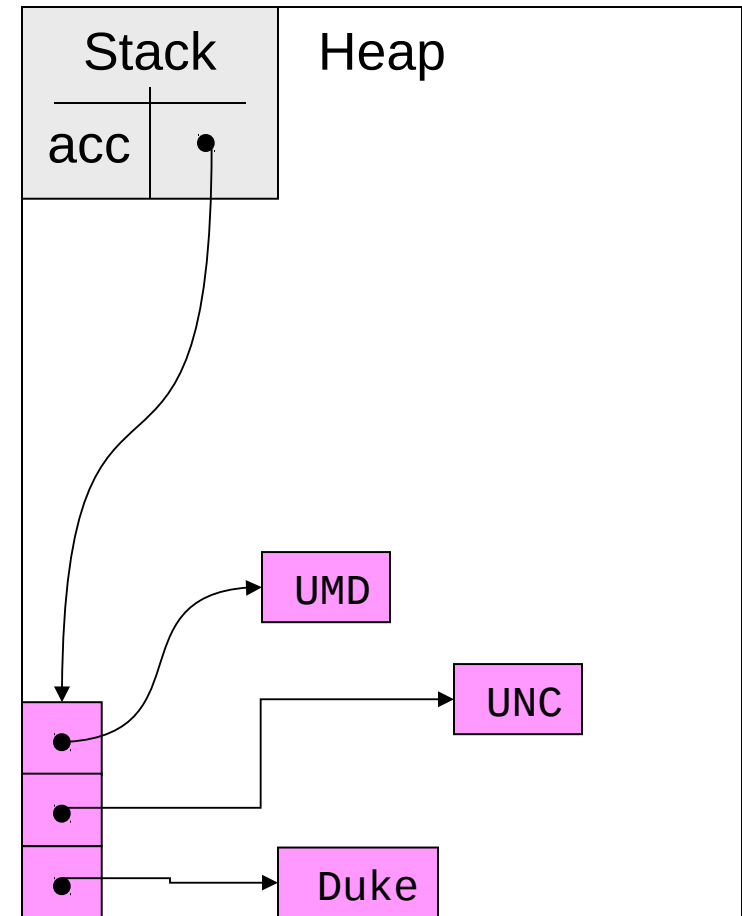
Class types can also be base types of arrays
e.g.

- `String[] acc = new String[3];`

Array cells store references to objects

Array initializers can also be used

```
String[] acc = {"UMD", "UNC",  
"Duke"};
```



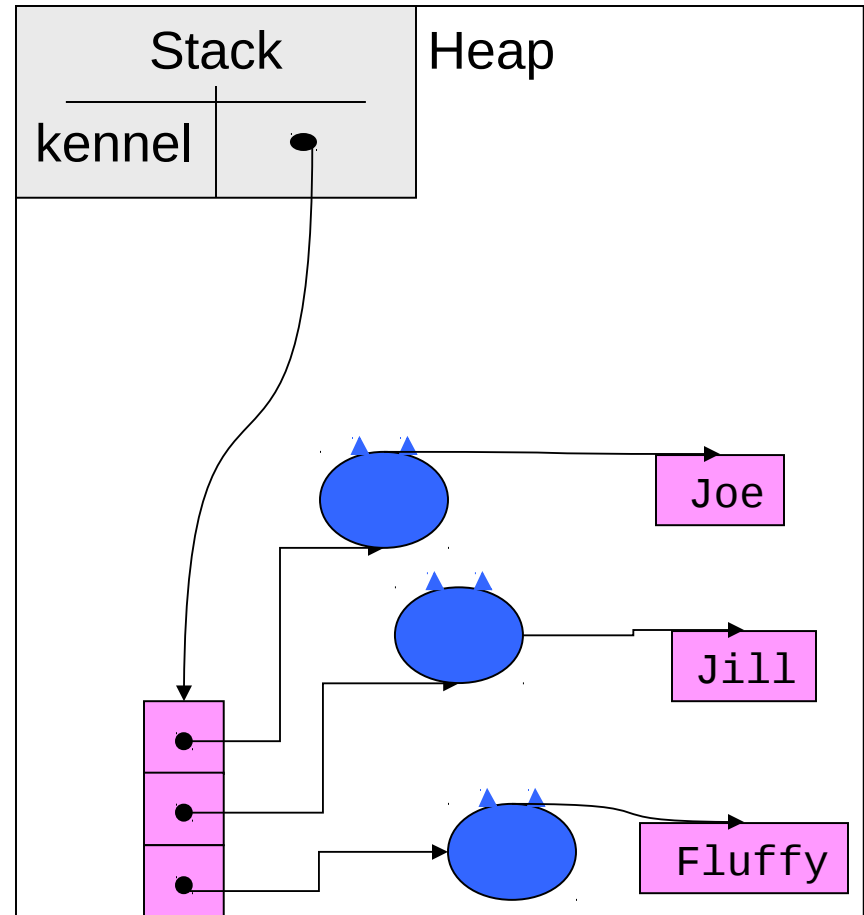
Arrays of Objects (continued)

More complicated example than strings:

Cat objects

Expressions can also appear in initializers

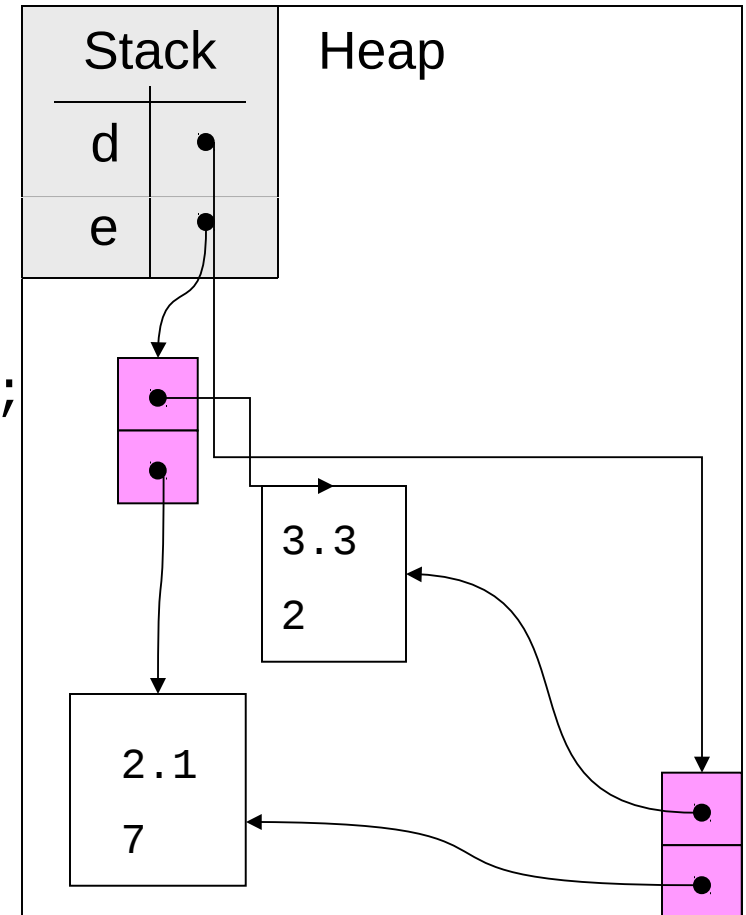
```
Cat[] kennel = {
    new Cat("Joe"),
    new Cat("Jill"),
    new Cat("Fluffy")
};
```



Shallow Copying

```
Person[] d = {
    new Person(2.1, 7, ...),
    new Person(3.3, 2, ...)
};
```

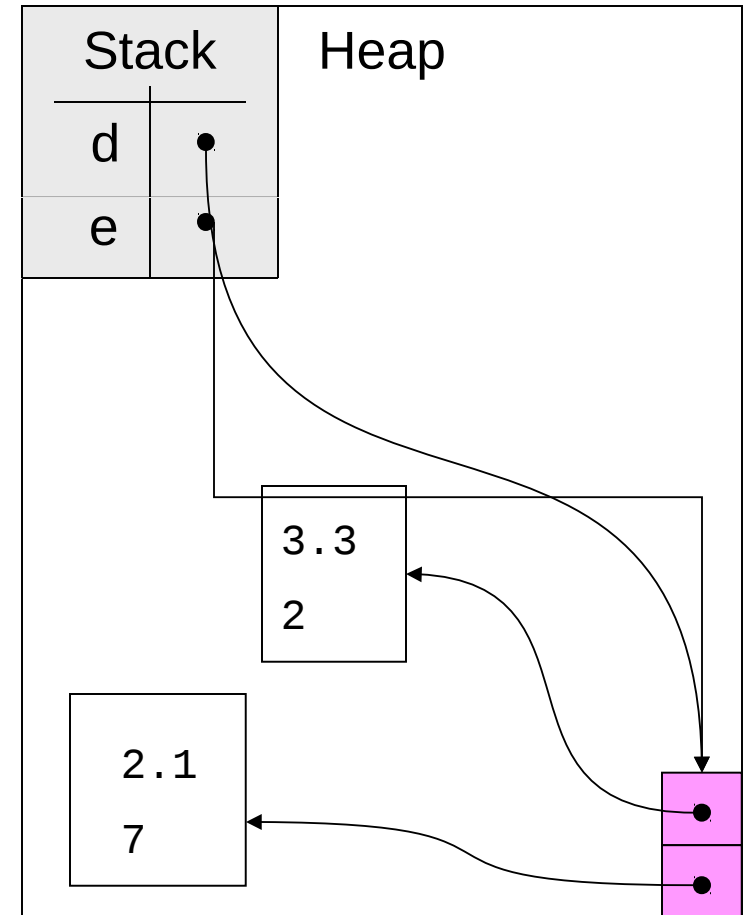
```
Person[] e = new Person[d.length];
for (int i=0; i < d.length, i++){
    e[i] = d[i];
}
```



Reference Copying

```
Person[] d = {
    new Person(2.1, 7, ...),
    new Person(3.3, 2, ...)
};
```

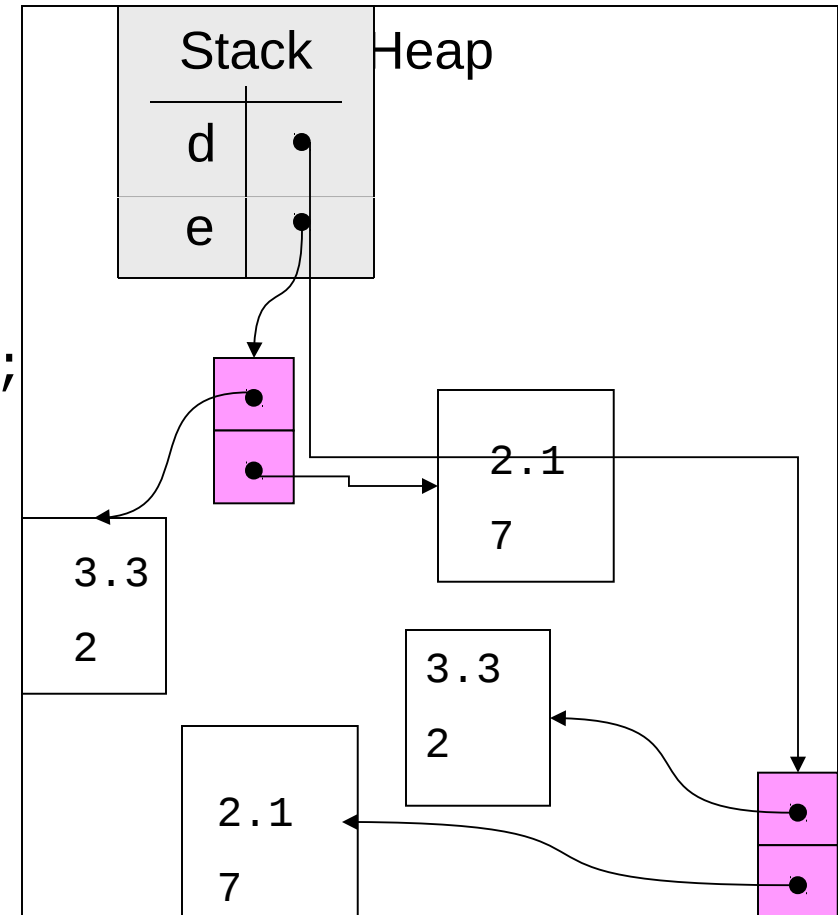
```
Person[] e = d;
```



Deep Copying

```
Person[] d = {
    new Person(2.1, 7, ...),
    new Person(3.3, 2, ...)
};
```

```
Person[] e = new Person[d.length];
for (int i=0; i<d.length; i++) {
    e[i] = new Person(d[i]);
}
```



Three Ways of Copying



CDCollector contains an array of CD's;
ReCDCollector contains an array of rewritableCD's;

Reference copy

```
public ReCD[] getCDsReferenceCopy() {  
    return myFavorites;  
}
```

Shallow copy

```
public ReCD[] getCDsShallowCopy() {  
    ReCD[] copy = new ReCD[myFavorites.length];  
    for (int i = 0; i < copy.length; i++)  
        copy[i] = myFavorites[i];  
    return copy;  
}
```

Deep copy

```
public ReCD[] getCDsDeepCopy() {  
    ReCD[] copy = new ReCD[myFavorites.length];  
    for (int i = 0; i < copy.length; i++)  
        copy[i] = new ReCD(myFavorites[i]);  
    return copy;  
}
```

```
ReCDCollectionOwner p =  
    new RECD...;  
ReCD[] a = p.getCD...();  
a[0] = otherCDalreadycreated;  
a[0].rewrite("other", "name");
```

When To Use What Kind of Copying?



Reference copying is usually a bad idea (not always but realize what you are doing)

Deep copying provides maximal protection against aliasing (but takes a lot of time and space if it was not necessary)

Storage space and time used

Reference: least

Shallow: middle

Deep: most

If the class is mutable, aliasing is something to be avoided and you must have true copies to prevent privacy leaks and modifications outside.

If you know the class is immutable, aliasing doesn't hurt but neither does making true copies (except wasted space and time).

If storage is an issue, aliasing problems may be worth copying with but must be well documented.