hashCode and compareTo

hashCode()

- if you override **`equals()`** you must override **`hashCode()`**
  - otherwise, the hashed containers won't work properly
    - recall that we did not override **`hashCode()`** for **`PhoneNumber`**

```
// client code somewhere
PhoneNumber pizza = new PhoneNumber(416, 967, 1111);

HashSet<PhoneNumber> h = new HashSet<PhoneNumber>();
h.add(pizza);
System.out.println( h.contains(pizza) );       // true

PhoneNumber pizzapizza =
                    new PhoneNumber(416, 967, 1111);
System.out.println( h.contains(pizzapizza) );  // false
```


[notes 2.3.5]

Arrays as Containers

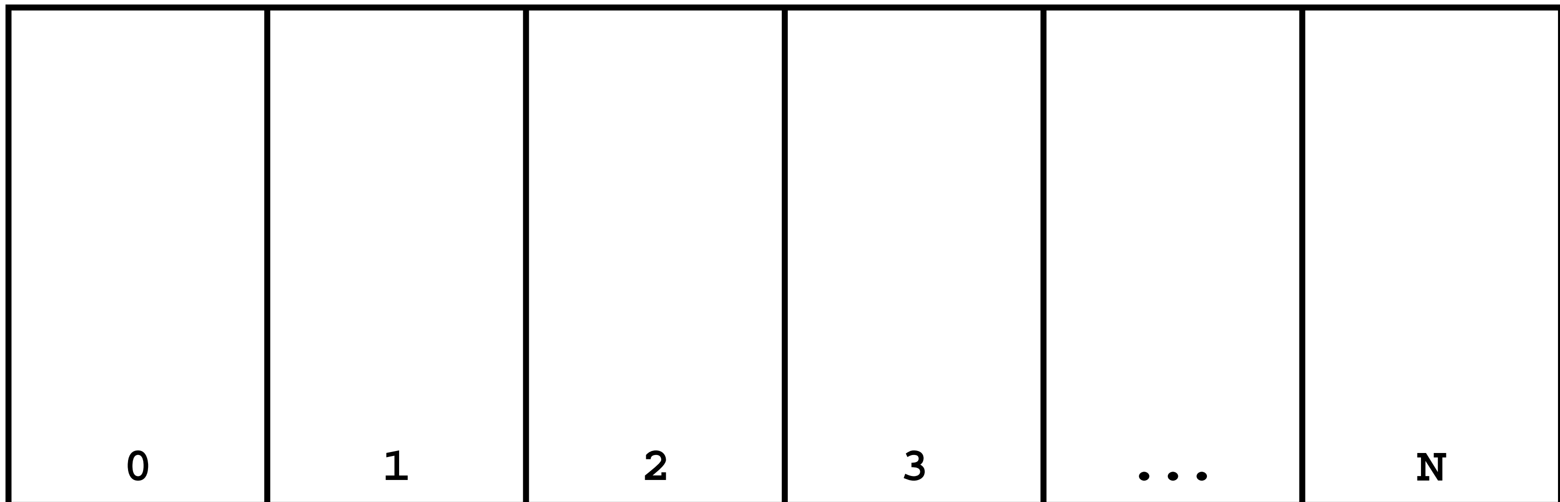
- suppose you have an array of unique **`PhoneNumbers`**
  - how do you compute whether or not the array contains a particular **`PhoneNumber`**?

```
public static boolean
       hasPhoneNumber(PhoneNumber p,
                      PhoneNumber[] numbers)
{
  if (numbers != null) {
    for( PhoneNumber num : numbers ) {
      if (num.equals(p)) {
        return true;
      }
    }
  }
  return false;
}
```

- called *linear search* or *sequential search*
  - doubling the length of the array doubles the amount of searching we need to do
- if there are **`n PhoneNumber`**s in the array:
  - best case
    - the first **`PhoneNumber`** is the one we are searching for
      - 1 call to **`equals()`**
  - worst case
    - the **`PhoneNumber`** is not in the array
      - n calls to **`equals()`**
  - average case
    - the **`PhoneNumber`** is somewhere in the middle of the array
      - approximately (n/2) calls to **`equals()`**

Hash Tables

- you can think of a hash table as being an array of buckets where each bucket holds the stored objects



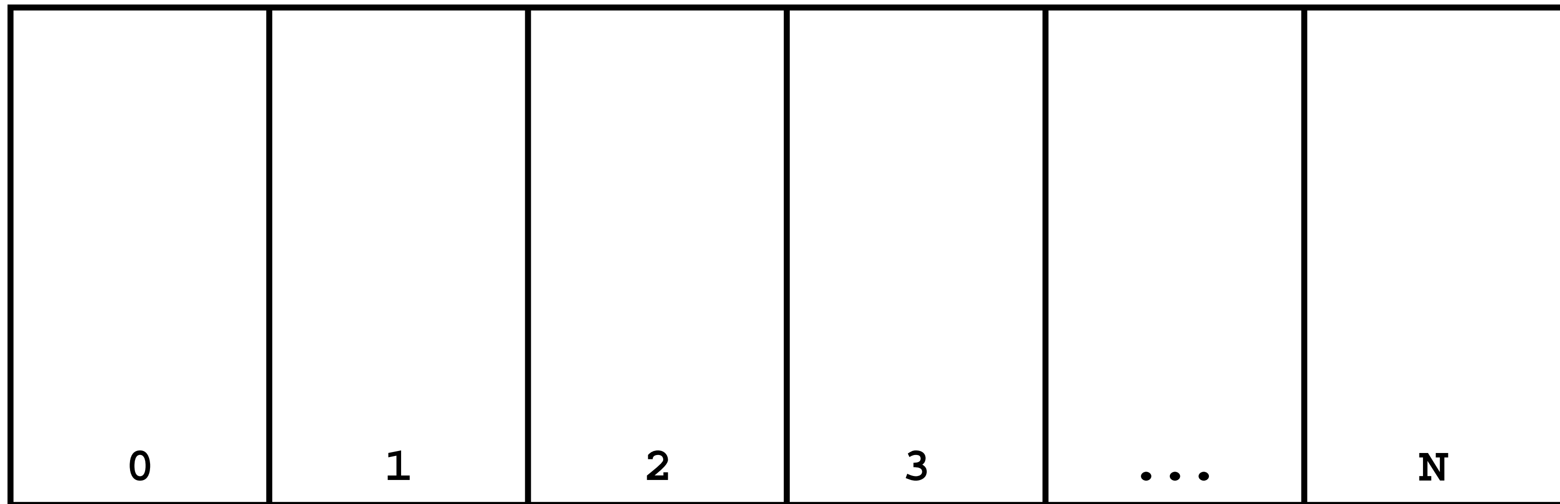
Insertion into a Hash Table

- to insert an object **`a`**, the hash table calls **`a.hashCode()`** method to compute which bucket to put the object into

`b.hashCode()` ➡ **`0`**

`a.hashCode()` ➡ **`2`**

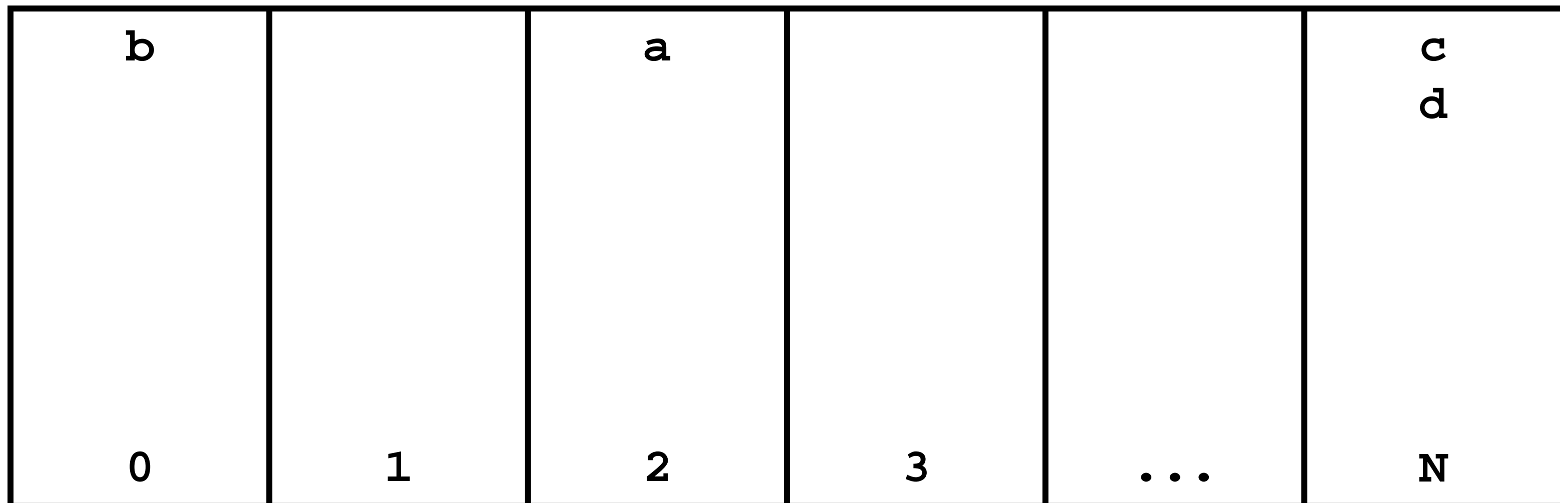
`c.hashCode()` ➡ **`N`**
`d.hashCode()` ➡ **`N`**



➡ means the hash table takes the hash code and does something to it to make it fit in the range **`0—N`**

Insertion into a Hash Table

- to insert an object **`a`**, the hash table calls **`a.hashCode()`** method to compute which bucket to put the object into



Search on a Hash Table

- to see if a hash table contains an object **`a`**, the hash table calls **`a.hashCode()`** method to compute which bucket to look for **`a`** in

`z.hashCode()` ➔ N

`a.hashCode()` ➔ 2

b		a.equals(a) true		z.equals(c) z.equals(d) false	
0	1	2	3	...	N

Search on a Hash Table

- to see if a hash table contains an object **`a`**, the hash table calls **`a.hashCode()`** method to compute which bucket to look for **`a`** in

- searching a hash table is usually much faster than linear search
  - doubling the number of elements in the hash table usually does not noticably increase the amount of search needed
- if there are **`n PhoneNumber`**s in the hash table:
  - best case
    - the bucket is empty, or the first **`PhoneNumber`** in the bucket is the one we are searching for
      - 0 or 1 call to **`equals()`**
  - worst case
    - all **`n`** of the **`PhoneNumber`**s are in the same bucket
      - n calls to **`equals()`**
  - average case
    - the **`PhoneNumber`** is in a bucket with a small number of other **`PhoneNumbers`**
      - a small number of calls to **`equals()`**

`Object hashCode()`

- if you don't override **`hashCode()`**, you get the implementation from **`Object.hashCode()`**
  - **`Object.hashCode()`** uses the memory address of the object to compute the hash code

```
// client code somewhere
PhoneNumber pizza = new PhoneNumber(416, 967, 1111);

HashSet<PhoneNumber> h = new HashSet<PhoneNumber>();
h.add(pizza);

PhoneNumber pizzapizza = new PhoneNumber(416, 967, 1111);
System.out.println( h.contains(pizzapizza) );  // false
```

- note that **`pizza`** and **`pizzapizza`** are distinct objects
  - therefore, their memory locations must be different
    - therefore, their hash codes are different (probably)
    - therefore, the hash table looks in the wrong bucket (probably) and does not find the phone number even though **`pizzapizza.equals(pizza)`** *

* unless you're from Naples

A Bad (but legal) **`hashCode()`**

```
public final class PhoneNumber {
  // attributes, constructors, methods ...

  @Override public int hashCode()
  {
    return 1;  // or any other constant int
  }
}
```

- this will cause a hashed container to put all **`PhoneNumber`**s in the same bucket

A Slightly Better `hashCode()`

```
public final class PhoneNumber {
  // attributes, constructors, methods ...

  @Override public int hashCode()
  {
    return (int)(this.getAreaCode() +
                 this.getExchangeCode() +
                 this.getStationCode());
  }
}
```

- the basic idea is generate a hash code using the attributes of the object
- it would be nice if two distinct objects had two distinct hash codes
  - but this is not required; two different objects can have the same hash code
- it is required that:
  1. if **`x.equals(y)`** then **`x.hashCode() == y.hashCode()`**
  2. **`x.hashCode()`** always returns the same value if **`x`** does not change its state

Something to Think About

- what do you need to be careful of when putting a mutable object into a **`HashSet`**?
  - can you avoid the problem by using immutable objects?

compareTo

Comparable Objects

- many value types have a natural ordering
  - that is, for two objects **`x`** and **`y`**, **`x`** is less than **`y`** is meaningful
    - **`Short`**, **`Integer`**, **`Float`**, **`Double`**, etc
    - **`String`**s can be compared in dictionary order
    - **`Date`**s can be compared in chronological order
    - you might compare **`Vector2D`**s by their length
    - **`Die`**s can be compared by their face value
- if your class has a natural ordering, consider implementing the **`Comparable`** interface
  - doing so allows clients to sort arrays or **`Collection`**s of your object

Interfaces

- an interface is (usually) a group of related methods with empty bodies
  - the **`Comparable`** interface has just one method

```
public interface Comparable<T>
{
  int compareTo(T t);
}
```

- a class that implements an interfaces promises to provide an implementation for every method in the interface

`compareTo()`

- Compares this object with the specified object for order. Returns a negative integer, zero, or a positive integer as this object is less than, equal to, or greater than the specified object.
- Throws a **`ClassCastException`** if the specified object type cannot be compared to this object.

Die compareTo()

```
public class Die implements Comparable<Die> {
  // attributes, constructors, methods ...


  public int compareTo(Die other) {
    int result = 0;
    if (this.getValue() < other.getValue()) {
      result = -1;
    }
    else if (this.getValue() > other.getValue()) {
      result = 1;
    }
    return result;
  }
}
```

Die compareTo()

- the following also works for the Die class, but is dangerous in general:

```
public int compareTo(Die other) {
  int result = this.getValue() - other.getValue();
  return result;
}
```

Comparable Contract

1. the sign of the returned **`int`** must flip if the order of the two compared objects flip
   - if **`x.compareTo(y) > 0`** then **`y.compareTo(x) < 0`**
   - if **`x.compareTo(y) < 0`** then **`y.compareTo(x) > 0`**
   - if **`x.compareTo(y) == 0`** then **`y.compareTo(x) == 0`**

Comparable Contract

2. **`compareTo()`** must be transitive
   - if `x.compareTo(y) > 0 && y.compareTo(z) > 0` then `x.compareTo(z) > 0`
   - if `x.compareTo(y) < 0 && y.compareTo(z) < 0` then `x.compareTo(z) < 0`
   - if `x.compareTo(y) == 0 && y.compareTo(z) == 0` then `x.compareTo(z) == 0`

Comparable Contract

3. if `x.compareTo(y) == 0` then the signs of `x.compareTo(z)` and `y.compareTo(z)` must be the same

Consistency with equals

- an implementation of **`compareTo()`** is said to be consistent with **`equals()`** when

  if **`x.compareTo(y) == 0`** then
  `x.equals(y) == true`

  - and

  if **`x.equals(y) == true`** then
  `x.compareTo(y) == 0`

Not in the Comparable Contract

- it is not required that **`compareTo()`** be consistent with **`equals()`**
  - that is

    if **`x.compareTo(y) == 0`** then

    `x.equals(y) == false` is acceptable
  - similarly

    if **`x.equals(y) == true`** then

    `x.compareTo(y) != 0` is acceptable

- try to come up with examples for both cases above

Implementing **`compareTo`**

- implementing **`compareTo`** is similar to implementing equals
- you need to compare all of the fields
  - starting with the field that is most significant for ordering purposes and working your way down

PhoneNumber compareTo()

```
public class PhoneNumber implements Comparable<PhoneNumber> {
  // attributes, constructors, methods ...


  public int compareTo(PhoneNumber other) {
    int result = 0;
    result = this.getAreaCode() - other.getAreaCode();
    if (result == 0) {
      result = this.getExchangeCode() - other.getExchangeCode();
    }
    if (result == 0) {
      result = this.getStationCode() - other.getStationCode();
    }
    return result;
  }
}
```

Implementing **`compareTo`**

- if you are comparing fields of type **`float`** or **`double`** you should use **`Float.compare`** or **`Double.compare`** instead of **`<`**, **`>`**, or **`==`**

- if your **`compareTo`** implementation is broken, then any classes or methods that rely on **`compareTo`** will behave erratically
  - **`TreeSet`**, **`TreeMap`**
  - many methods in the utility classes **`Collections`** and **`Arrays`**

Mixing Static and Non-Static

`static` Fields

- a field that is **`static`** is a per-class member
  - only one copy of the field, and the field is associated with the class
    - every object created from a class declaring a static field shares the same copy of the field
- static fields are used when you really want only one common instance of the field for the class
  - less common than non-static fields

Example

- a textbook example of a static field is a counter that counts the number of created instances of your class

```
// adapted from Sun's Java Tutorial
public class Bicycle {
  // some other fields here...
  private static int numberOfBicycles = 0;

  public Bicycle() {
    // set some attributes here...
    Bicycle.numberOfBicycles++;
  }

  public static int getNumberOfBicyclesCreated() {
    return Bicycle.numberOfBicycles;
  }
}
```

note:
not this.numberOfBicycles++

- another common example is to count the number of times a method has been called

```
public class X {

  private static int numTimesXCalled = 0;
  private static int numTimesYCalled = 0;

  public void xMethod() {
    // do something... and then update counter
    ++X.numTimesXCalled;
  }

  public void yMethod() {
    // do something... and then update counter
    ++X.numTimesYCalled;
  }
}
```

Mixing Static and Non-static Fields

- a class can declare static (per class) and non-static (per instance) fields
- a common textbook example is giving each instance a unique serial number
  - the serial number belongs to the instance
    - therefore it must be a non-static field

```
public class Bicycle {
  // some attributes here...
  private static int numberOfBicycles = 0;

  private int serialNumber;

  // ...
```

- how do you assign each instance a unique serial number?
  - the instance cannot give itself a unique serial number because it would need to know all the currently used serial numbers
- could require that the client provide a serial number using the constructor
  - instance has no guarantee that the client has provided a valid (unique) serial number

- the class can provide unique serial numbers using static fields
  - e.g. using the number of instances created as a serial number

```
public class Bicycle {
  // some attributes here...

  private static int numberOfBicycles = 0;
  private int serialNumber;

  public Bicycle() {
    // set some attributes here...
    this.serialNumber = Bicycle.numberOfBicycles;
    Bicycle.numberOfBicycles++;
  }
}
```

- a more sophisticated implementation might use an object to generate serial numbers

```
public class Bicycle {

  // some attributes here...
  private static int numberOfBicycles = 0;

  private static final
    SerialGenerator serialSource = new SerialGenerator();

  private int serialNumber;

  public Bicycle() {
    // set some attributes here...
    this.serialNumber = Bicycle.serialSource.getNext();
    Bicycle.numberOfBicycles++;
  }
}
```

Static Methods

- recall that a **`static`** method is a per-class method
  - client does not need an object to invoke the method
  - client uses the class name to access the method
- a **`static`** method can only use **`static`** fields of the class
  - **`static`** methods have no **`this`** parameter because a **`static`** method can be invoked without an object
  - without a **`this`** parameter, there is no way to access non-static fields
- non-static methods can use all of the fields of a class (including **`static`** ones)

```
public class Bicycle {
  // some attributes, constructors, methods here...

  public static int getNumberCreated()
  {
    return Bicycle.numberOfBicycles;
  }

  public int getSerialNumber()
  {
    return this.serialNumber;
  }

  public void setNewSerialNumber()
  {
    this.serialNumber = Bicycle.serialSource.getNext();
  }
}
```

static method
can only use
static attributes

non-static method
can use
non-static attributes

and static attributes