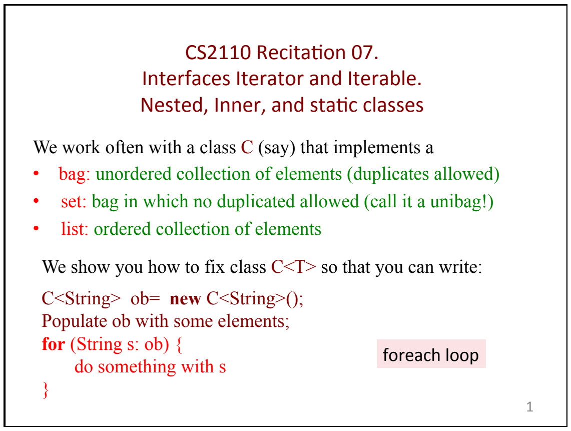


CS2110 Recitation 07.
Interfaces Iterator and Iterable.
Nested, Inner, and static classes

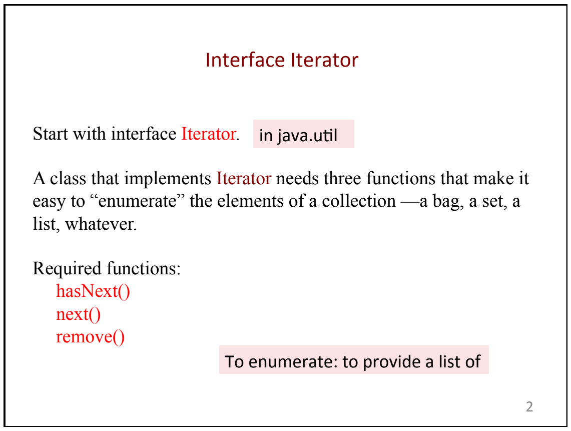
We work often with a class C (say) that implements a

- bag: unordered collection of elements (duplicates allowed)
- set: bag in which no duplicated allowed (call it a unibag!)
- list: ordered collection of elements

We show you how to fix class C<T> so that you can write:

```
C<String>  ob=  new C<String>();
Populate ob with some elements;
for (String s: ob) {
      do something with s
}
```

foreach loop



Interface Iterator

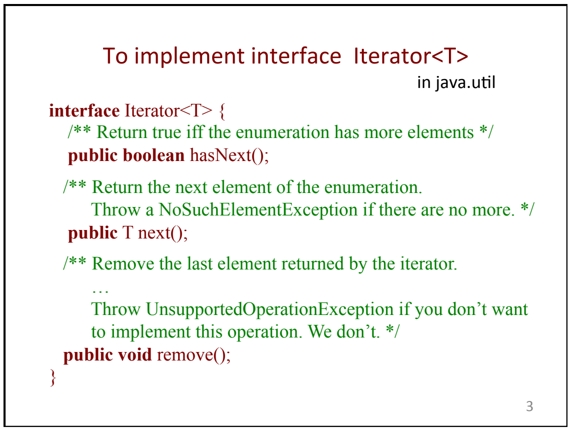
Start with interface Iterator.   in java.util

A class that implements Iterator needs three functions that make it easy to “enumerate” the elements of a collection —a bag, a set, a list, whatever.

Required functions:

```
    hasNext()
    next()
    remove()
```

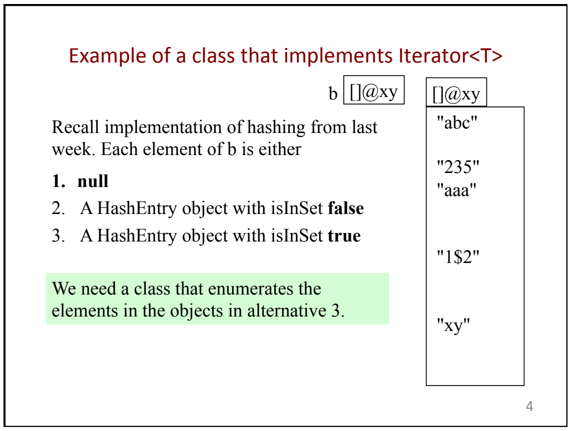
To enumerate: to provide a list of



To implement interface Iterator<T>

in java.util

```
interface Iterator<T> {
   /** Return true iff the enumeration has more elements */
   public boolean hasNext();
  /** Return the next element of the enumeration.
       Throw a NoSuchElementException if there are no more. */
   public T next();
  /** Remove the last element returned by the iterator.
       …
       Throw UnsupportedOperationException if you don’t want
       to implement this operation. We don’t. */
  public void remove();
}
```



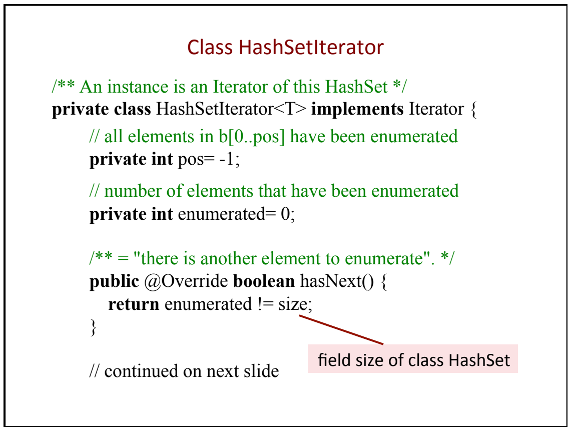
Example of a class that implements Iterator<T>

b
[]@xy
[]@xy
"abc"
"235"
"aaa"
"1$2"
"xy"

Recall implementation of hashing from last week. Each element of b is either

1. **null**
2. A HashEntry object with isInSet **false**
3. A HashEntry object with isInSet **true**

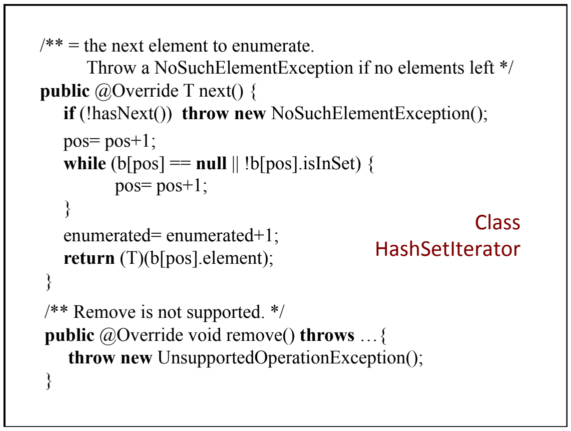
We need a class that enumerates the elements in the objects in alternative 3.



Class HashSetIterator

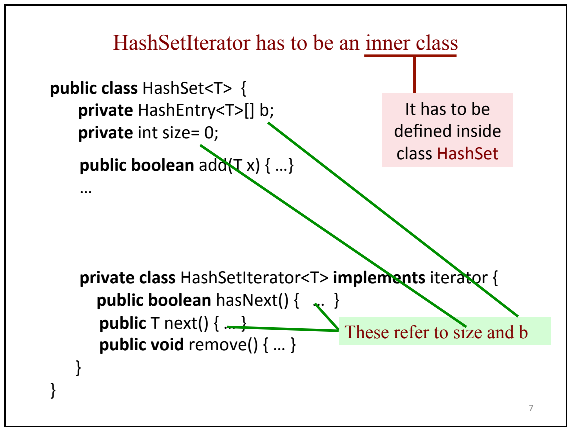
```
/** An instance is an Iterator of this HashSet */
private class HashSetIterator<T> implements Iterator {
      // all elements in b[0..pos] have been enumerated
      private int pos= -1;
      // number of elements that have been enumerated
      private int enumerated= 0;

      /** = "there is another element to enumerate". */
      public @Override boolean hasNext() {
         return enumerated != size;
      }

      // continued on next slide
```

field size of class HashSet



```
/** = the next element to enumerate.
        Throw a NoSuchElementException if no elements left */
public @Override T next() {
    if (!hasNext())  throw new NoSuchElementException();
    pos= pos+1;
    while (b[pos] == null || !b[pos].isInSet) {
            pos= pos+1;
    }
    enumerated= enumerated+1;
    return (T)(b[pos].element);
}
/** Remove is not supported. */
public @Override void remove() throws …{
    throw new UnsupportedOperationException();
}
```

Class HashSetIterator



HashSetIterator has to be an inner class

```
public class HashSet<T>  {
     private HashEntry<T>[] b;
     private int size= 0;

     public boolean add(T x) { …}
     …


     private class HashSetIterator<T> implements iterator {
        public boolean hasNext() {  …  }
        public T next() { … }
        public void remove() { … }
     }
}
```

It has to be defined inside class HashSet

These refer to size and b

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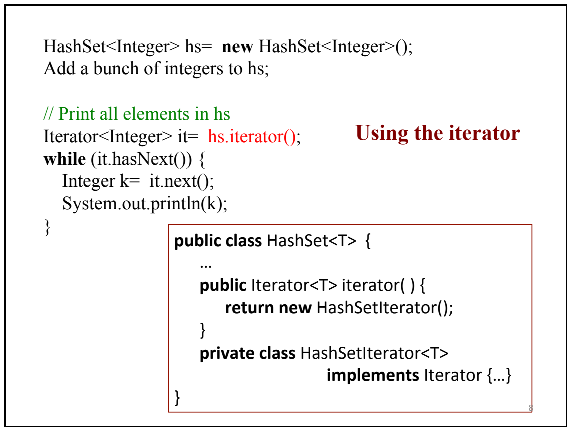

```
HashSet<Integer> hs=  new HashSet<Integer>();
Add a bunch of integers to hs;

// Print all elements in hs
Iterator<Integer> it=  hs.iterator();
while (it.hasNext()) {
    Integer k=  it.next();
    System.out.println(k);
}
```

Using the iterator

```
public class HashSet<T>  {
     …
     public Iterator<T> iterator( ) {
         return new HashSetIterator();
     }
     private class HashSetIterator<T>
                          implements Iterator {…}
}
```

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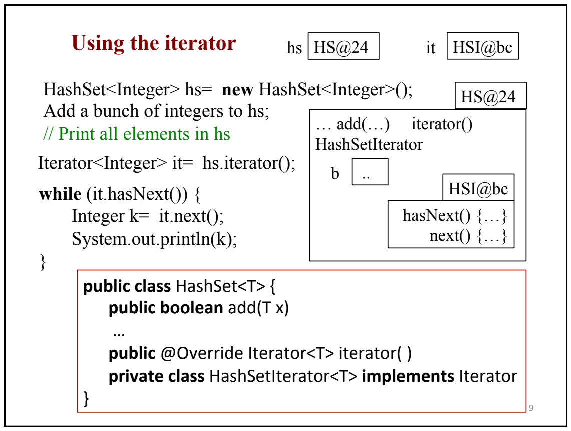

Using the iterator

```
HashSet<Integer> hs=  new HashSet<Integer>();
Add a bunch of integers to hs;
// Print all elements in hs
Iterator<Integer> it=  hs.iterator();
while (it.hasNext()) {
     Integer k=  it.next();
     System.out.println(k);
}
```

```
public class HashSet<T> {
     public boolean add(T x)
     …
     public @Override Iterator<T> iterator( )
     private class HashSetIterator<T> implements Iterator
}
```

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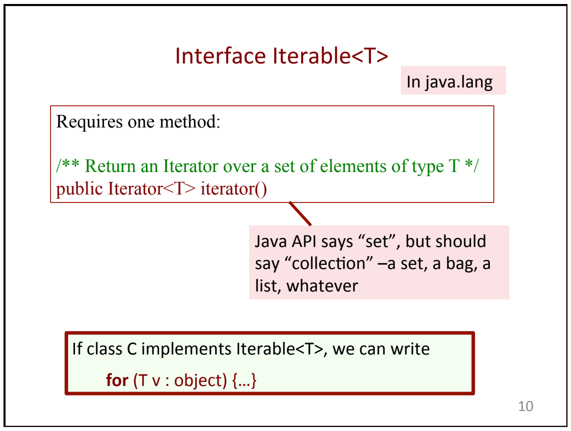

Interface Iterable<T>

In java.lang

Requires one method:

```
/** Return an Iterator over a set of elements of type T */
public Iterator<T> iterator()
```

Java API says "set", but should say "collection" –a set, a bag, a list, whatever

If class C implements Iterable<T>, we can write

```
    for (T v : object) {…}
```

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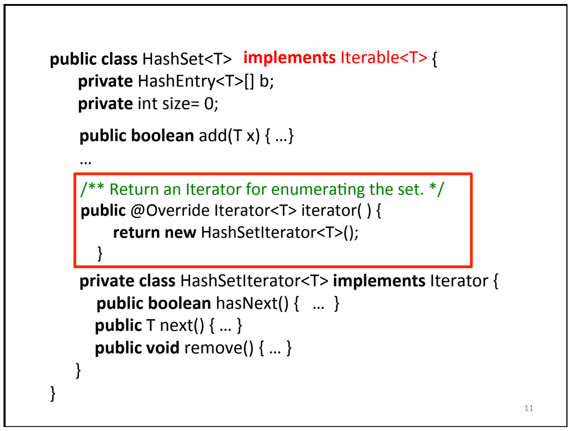

```
public class HashSet<T>  implements Iterable<T> {
     private HashEntry<T>[] b;
     private int size= 0;

     public boolean add(T x) { …}
     …
     /** Return an Iterator for enumerating the set. */
     public @Override Iterator<T> iterator( ) {
          return new HashSetIterator<T>();
      }
     private class HashSetIterator<T> implements Iterator {
        public boolean hasNext() {  …  }
        public T next() { … }
        public void remove() { … }
     }
}
```

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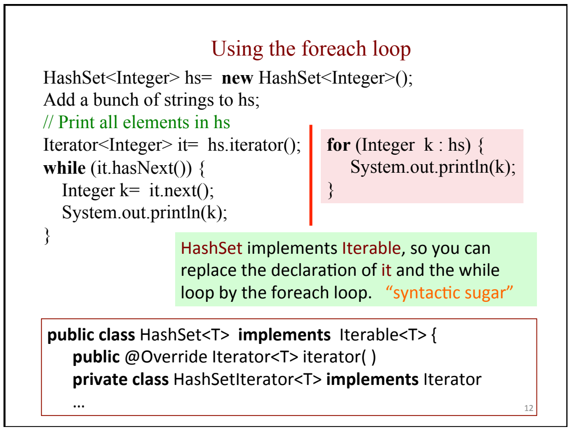

Using the foreach loop

```
HashSet<Integer> hs=  new HashSet<Integer>();
Add a bunch of strings to hs;
// Print all elements in hs
Iterator<Integer> it=  hs.iterator();
while (it.hasNext()) {
    Integer k=  it.next();
    System.out.println(k);
}
```

```
for (Integer  k : hs) {
    System.out.println(k);
}
```

HashSet implements Iterable, so you can replace the declaration of it and the while loop by the foreach loop. "syntactic sugar"

```
public class HashSet<T>  implements  Iterable<T> {
     public @Override Iterator<T> iterator( )
     private class HashSetIterator<T> implements Iterator
     …
```

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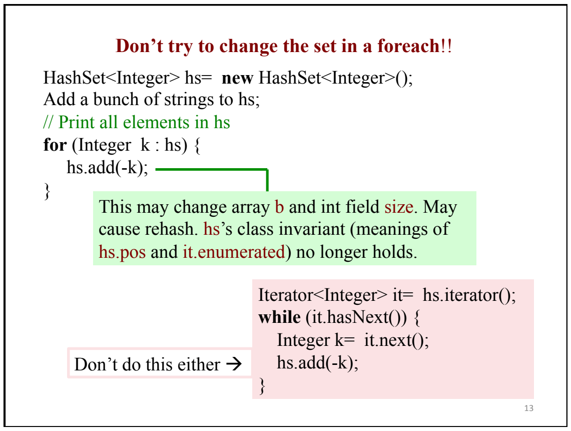

Don't try to change the set in a foreach!!

```
HashSet<Integer> hs=  new HashSet<Integer>();
Add a bunch of strings to hs;
// Print all elements in hs
for (Integer  k : hs) {
    hs.add(-k);
}
```

This may change array b and int field size. May cause rehash. hs's class invariant (meanings of hs.pos and it.enumerated) no longer holds.

Don't do this either →

```
Iterator<Integer> it=  hs.iterator();
while (it.hasNext()) {
    Integer k=  it.next();
    hs.add(-k);
}
```

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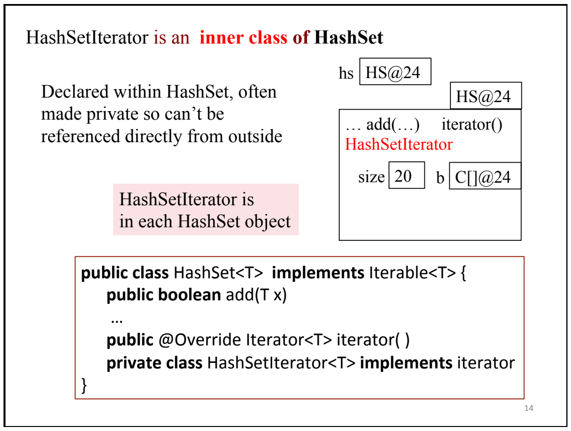

HashSetIterator is an inner class of HashSet

Declared within HashSet, often made private so can't be referenced directly from outside

HashSetIterator is in each HashSet object

```
public class HashSet<T>  implements Iterable<T> {
    public boolean add(T x)
    …
    public @Override Iterator<T> iterator( )
    private class HashSetIterator<T> implements iterator
}
```

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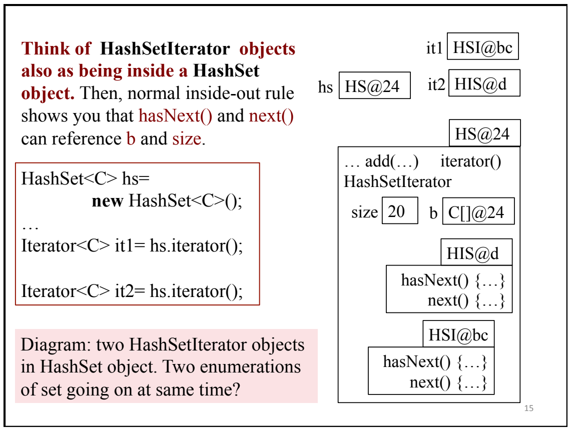

Think of HashSetIterator objects also as being inside a HashSet object. Then, normal inside-out rule shows you that hasNext() and next() can reference b and size.

```
HashSet<C> hs=
           new HashSet<C>();
…
Iterator<C> it1= hs.iterator();

Iterator<C> it2= hs.iterator();
```

Diagram: two HashSetIterator objects in HashSet object. Two enumerations of set going on at same time?

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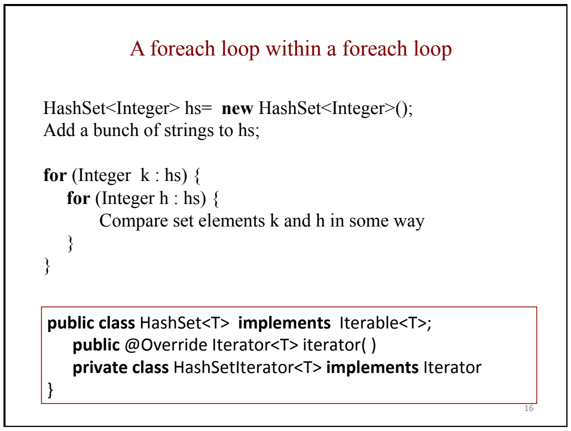

A foreach loop within a foreach loop

```
HashSet<Integer> hs=  new HashSet<Integer>();
Add a bunch of strings to hs;

for (Integer  k : hs) {
    for (Integer h : hs) {
        Compare set elements k and h in some way
    }
}
```

```
public class HashSet<T>  implements  Iterable<T>;
    public @Override Iterator<T> iterator( )
    private class HashSetIterator<T> implements Iterator
}
```

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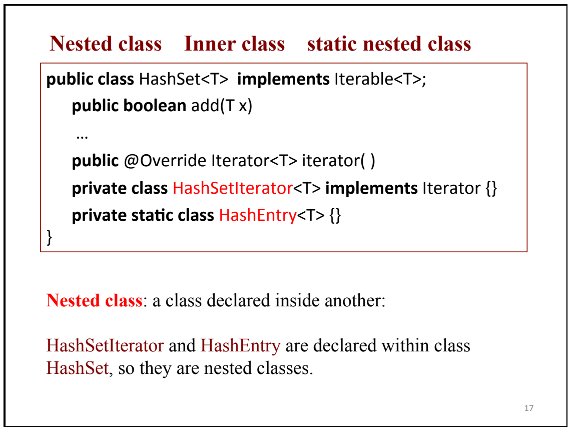

Nested class   Inner class   static nested class

```
public class HashSet<T>  implements Iterable<T>;
    public boolean add(T x)
     …
    public @Override Iterator<T> iterator( )
    private class HashSetIterator<T> implements Iterator {}
    private static class HashEntry<T> {}
}
```

Nested class: a class declared inside another:

HashSetIterator and HashEntry are declared within class HashSet, so they are nested classes.

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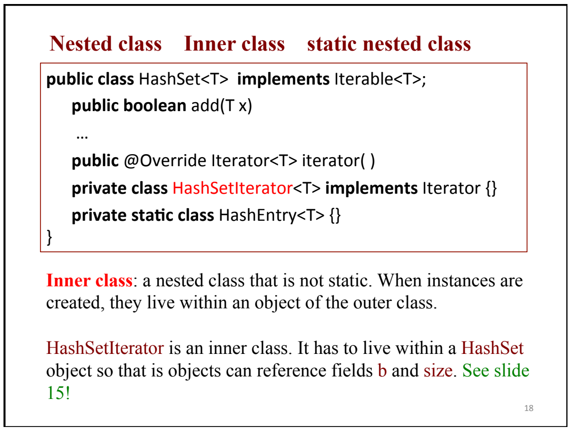

Nested class   Inner class   static nested class

```
public class HashSet<T>  implements Iterable<T>;
    public boolean add(T x)
     …
    public @Override Iterator<T> iterator( )
    private class HashSetIterator<T> implements Iterator {}
    private static class HashEntry<T> {}
}
```

Inner class: a nested class that is not static. When instances are created, they live within an object of the outer class.

HashSetIterator is an inner class. It has to live within a HashSet object so that is objects can reference fields b and size. See slide 15!

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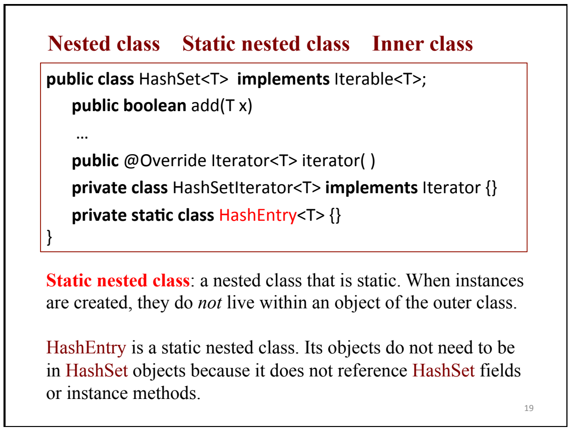
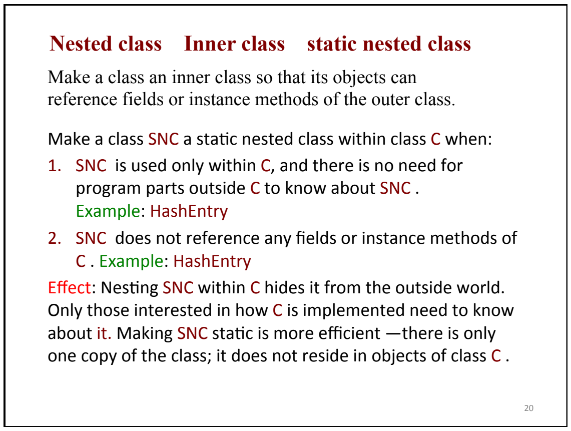


Nested class Static nested class Inner class

```
public class HashSet<T>  implements Iterable<T>;
    public boolean add(T x)
     …
    public @Override Iterator<T> iterator( )
    private class HashSetIterator<T> implements Iterator {}
    private static class HashEntry<T> {}
}
```

Static nested class: a nested class that is static. When instances are created, they do *not* live within an object of the outer class.

HashEntry is a static nested class. Its objects do not need to be in HashSet objects because it does not reference HashSet fields or instance methods.



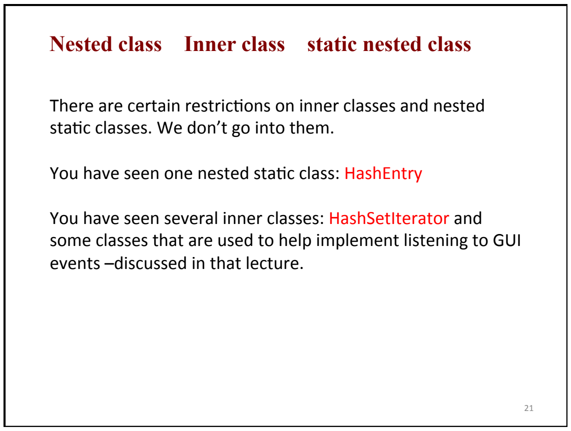
Nested class Inner class static nested class

Make a class an inner class so that its objects can reference fields or instance methods of the outer class.

Make a class SNC a static nested class within class C when:

1. SNC is used only within C, and there is no need for program parts outside C to know about SNC . Example: HashEntry
2. SNC does not reference any fields or instance methods of C . Example: HashEntry

Effect: Nesting SNC within C hides it from the outside world. Only those interested in how C is implemented need to know about it. Making SNC static is more efficient —there is only one copy of the class; it does not reside in objects of class C .



Nested class Inner class static nested class

There are certain restrictions on inner classes and nested static classes. We don’t go into them.

You have seen one nested static class: HashEntry

You have seen several inner classes: HashSetIterator and some classes that are used to help implement listening to GUI events –discussed in that lecture.