

Class Declaration

```
public class CashRegister
{
    private int itemCount;
    private double totalPrice;
    // Instance variables

    public void addItem(double price)
    {
        itemCount++;
        totalPrice = totalPrice + price;
    }
    // Method
    . . .
}
```

Selected Operators and Their Precedence

(See Appendix B for the complete list.)

[]	Array element access
++ -- !	Increment, decrement, Boolean <i>not</i>
* / %	Multiplication, division, remainder
+ -	Addition, subtraction
< <= > >=	Comparisons
== !=	Equal, not equal
&&	Boolean <i>and</i>
	Boolean <i>or</i>
=	Assignment

Conditional Statement

```
    Condition
    /
if (floor >= 13)
{
    actualFloor = floor - 1;
}
// Executed when condition is true
else if (floor >= 0)
{
    actualFloor = floor;
}
// Second condition (optional)
else
{
    System.out.println("Floor negative");
}
// Executed when all conditions are false (optional)
```

Loop Statements

```
    Condition
    /
while (balance < TARGET)
{
    year++;
    balance = balance * (1 + rate / 100);
}
// Executed while condition is true
```

```
    Initialization    Condition    Update
    /      /      /
for (int i = 0; i < 10; i++)
{
    System.out.println(i);
}
```

Variable and Constant Declarations

Type	Name	Initial value
int	cansPerPack	= 6;
final double	CAN_VOLUME	= 0.335;

Method Declaration

Modifiers	Return type	Parameter type and name
public static	double	cubeVolume(double sideLength)
{		
double volume = sideLength * sideLength * sideLength;		
return volume;		
}		

Exits method and returns result.

Mathematical Operations

Math.pow(x, y)	Raising to a power x^y
Math.sqrt(x)	Square root \sqrt{x}
Math.log10(x)	Decimal log $\log_{10}(x)$
Math.abs(x)	Absolute value $ x $
Math.sin(x)	Sine, cosine, tangent of x (x in radians)
Math.cos(x)	
Math.tan(x)	

String Operations

```
String s = "Hello";
int n = s.length(); // 5
char ch = s.charAt(1); // 'e'
String t = s.substring(1, 4); // "ell"
String u = s.toUpperCase(); // "HELLO"
if (u.equals("HELLO")) ... // Use equals, not ==
for (int i = 0; i < s.length(); i++)
{
    char ch = s.charAt(i);
    Process ch
}
```

```
do
{
    System.out.print("Enter a positive integer: ");
    input = in.nextInt();
}
while (input <= 0);
```

Loop body executed at least once

Set to a new element in each iteration

```
for (double value : values)
{
    sum = sum + value;
}
```

An array or collection

Executed for each element



If you want to write a program that collects objects (such as the stamps to the left), you have a number of choices. Of course, you can use an array list, but computer scientists have invented other mechanisms that may be better suited for the task. In this chapter, we introduce the collection classes and interfaces that the Java library offers. You will learn how to use the Java collection classes, and how to choose the most appropriate collection type for a problem.

15.1 An Overview of the Collections Framework

A collection groups together elements and allows them to be retrieved later.

When you need to organize multiple objects in your program, you can place them into a **collection**. The `ArrayList` class that was introduced in Chapter 7 is one of many collection classes that the standard Java library supplies. In this chapter, you will learn about the Java *collections framework*, a hierarchy of interface types and classes for collecting objects. Each interface type is implemented by one or more classes (see Figure 1).

At the root of the hierarchy is the `Collection` interface. That interface has methods for adding and removing elements, and so on. Table 1 on page 674 shows all the methods. Because all collections implement this interface, its methods are available for all collection classes. For example, the `size` method reports the number of elements in *any* collection.

The `List` interface describes an important category of collections. In Java, a *list* is a collection that remembers the order of its elements (see Figure 2). The `ArrayList` class implements the `List` interface. An `ArrayList` is simply a class containing an array that is expanded as needed. If you are not concerned about efficiency, you can use the `ArrayList` class whenever you need to collect objects. However, several common operations are inefficient with array lists. In particular, if an element is added or removed, the elements at larger positions must be moved.

The Java library supplies another class, `LinkedList`, that also implements the `List` interface. Unlike an array list, a linked list allows efficient insertion and removal of elements in the middle of the list. We will discuss that class in the next section.

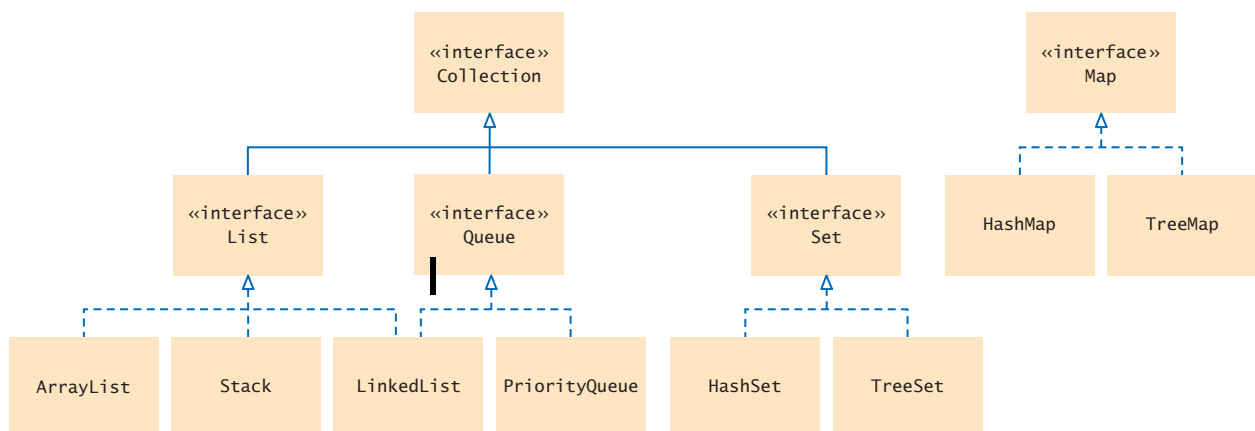


Figure 1 Interfaces and Classes in the Java Collections Framework

15.4 Maps

The `HashMap` and `TreeMap` classes both implement the `Map` interface.



A **map** allows you to associate elements from a *key set* with elements from a *value collection*. You use a map when you want to look up objects by using a key. For example, Figure 10 shows a map from the names of people to their favorite colors.

Just as there are two kinds of set implementations, the Java library has two implementations for the `Map` interface: `HashMap` and `TreeMap`.

After constructing a `HashMap` or `TreeMap`, you can store the reference to the map object in a `Map` reference:

```
Map<String, Color> favoriteColors = new HashMap<String, Color>();
```

Use the `put` method to add an association:

```
favoriteColors.put("Juliet", Color.RED);
```

You can change the value of an existing association, simply by calling `put` again:

```
favoriteColors.put("Juliet", Color.BLUE);
```

The `get` method returns the value associated with a key.

```
Color julietsFavoriteColor = favoriteColors.get("Juliet");
```

If you ask for a key that isn't associated with any values, then the `get` method returns `null`.

To remove an association, call the `remove` method with the key:

```
favoriteColors.remove("Juliet");
```

Table 5 Working with Maps

<pre>Map<String, Integer> scores;</pre>	Keys are strings, values are <code>Integer</code> wrappers. Use the interface type for variable declarations.
<pre>scores = new TreeMap<String, Integer>();</pre>	Use a <code>HashMap</code> if you don't need to visit the keys in sorted order.
<pre>scores.put("Harry", 90); scores.put("Sally", 95);</pre>	Adds keys and values to the map.
<pre>scores.put("Sally", 100);</pre>	Modifies the value of an existing key.
<pre>int n = scores.get("Sally"); Integer n2 = scores.get("Diana");</pre>	Gets the value associated with a key, or <code>null</code> if the key is not present. <code>n</code> is 100, <code>n2</code> is <code>null</code> .
<pre>System.out.println(scores);</pre>	Prints <code>scores.toString()</code> , a string of the form <code>{Harry=90, Sally=100}</code>
<pre>for (String key : scores.keySet()) { Integer value = scores.get(key); . . . }</pre>	Iterates through all map keys and values.
<pre>scores.remove("Sally");</pre>	Removes the key and value.

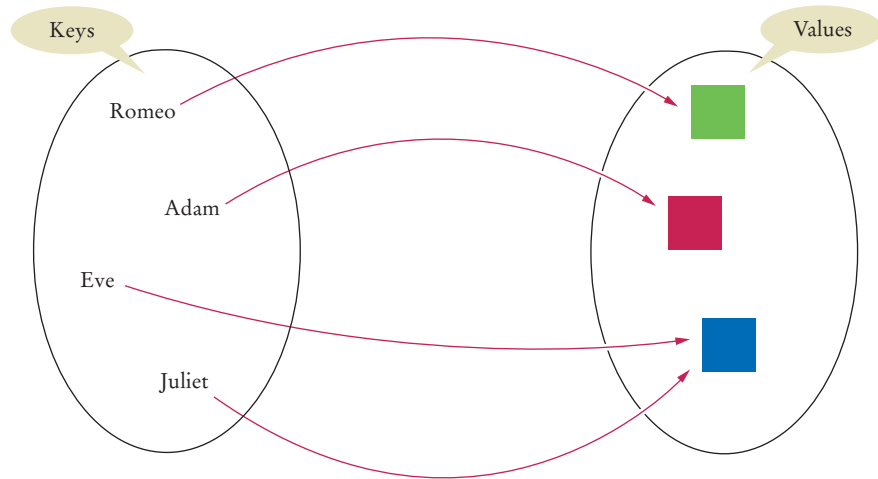


Figure 10 A Map

To find all keys and values in a map, iterate through the key set and find the values that correspond to the keys.

Sometimes you want to enumerate all keys in a map. The `keySet` method yields the set of keys. You can then ask the key set for an iterator and get all keys. From each key, you can find the associated value with the `get` method. Thus, the following instructions print all key/value pairs in a map `m`:

```
Set<String> keySet = m.keySet();
for (String key : keySet)
{
    Color value = m.get(key);
    System.out.println(key + "->" + value);
}
```

This sample program shows a map in action:

section_4/MapDemo.java

```
1 import java.awt.Color;
2 import java.util.HashMap;
3 import java.util.Map;
4 import java.util.Set;
5
6 /**
7  * This program demonstrates a map that maps names to colors.
8  */
9 public class MapDemo
10 {
11     public static void main(String[] args)
12     {
13         Map<String, Color> favoriteColors = new HashMap<String, Color>();
14         favoriteColors.put("Juliet", Color.BLUE);
15         favoriteColors.put("Romeo", Color.GREEN);
16         favoriteColors.put("Adam", Color.RED);
17         favoriteColors.put("Eve", Color.BLUE);
18
19         // Print all keys and values in the map
20
21         Set<String> keySet = favoriteColors.keySet();
```

```

22     for (String key : keySet)
23     {
24         Color value = favoriteColors.get(key);
25         System.out.println(key + " : " + value);
26     }
27 }
28 }

```

Program Run

```

Juliet : java.awt.Color[r=0,g=0,b=255]
Adam   : java.awt.Color[r=255,g=0,b=0]
Eve    : java.awt.Color[r=0,g=0,b=255]
Romeo  : java.awt.Color[r=0,g=255,b=0]

```

SELF CHECK

16. What is the difference between a set and a map?
17. Why is the collection of the keys of a map a set and not a list?
18. Why is the collection of the values of a map not a set?
19. Suppose you want to track how many times each word occurs in a document. Declare a suitable map variable.
20. What is a `Map<String, HashSet<String>>`? Give a possible use for such a structure.

Practice It Now you can try these exercises at the end of the chapter: R15.17, E15.4, E15.5.

HOW TO 15.1**Choosing a Collection**

Suppose you need to store objects in a collection. You have now seen a number of different data structures. This How To reviews how to pick an appropriate collection for your application.

**Step 1** Determine how you access the values.

You store values in a collection so that you can later retrieve them. How do you want to access individual values? You have several choices:

- Values are accessed by an integer position. Use an `ArrayList`.
- Values are accessed by a key that is not a part of the object. Use a map.
- Values are accessed only at one of the ends. Use a queue (for first-in, first-out access) or a stack (for last-in, first-out access).
- You don't need to access individual values by position. Refine your choice in Steps 3 and 4.

Step 2 Determine the element types or key/value types.

For a list or set, determine the type of the elements that you want to store. For example, if you collect a set of books, then the element type is `Book`.

Similarly, for a map, determine the types of the keys and the associated values. If you want to look up books by ID, you can use a `Map<Integer, Book>` or `Map<String, Book>`, depending on your ID type.

Step 3 Determine whether element or key order matters.

When you visit elements from a collection or keys from a map, do you care about the order in which they are visited? You have several choices:

- Elements or keys must be sorted. Use a `TreeSet` or `TreeMap`. Go to Step 6.
- Elements must be in the same order in which they were inserted. Your choice is now narrowed down to a `LinkedList` or an `ArrayList`.
- It doesn't matter. As long as you get to visit all elements, you don't care in which order. If you chose a map in Step 1, use a `HashMap` and go to Step 5.

Step 4 For a collection, determine which operations must be efficient.

You have several choices:

- Finding elements must be efficient. Use a `HashSet`.
- It must be efficient to add or remove elements at the beginning, or, provided that you are already inspecting an element there, another position. Use a `LinkedList`.
- You only insert or remove at the end, or you collect so few elements that you aren't concerned about speed. Use an `ArrayList`.

Step 5 For hash sets and maps, decide whether you need to implement the `hashCode` and `equals` methods.

- If your elements or keys belong to a class that someone else implemented, check whether the class has its own `hashCode` and `equals` methods. If so, you are all set. This is the case for most classes in the standard Java library, such as `String`, `Integer`, `Rectangle`, and so on.
- If not, decide whether you can compare the elements by identity. This is the case if you never construct two distinct elements with the same contents. In that case, you need not do anything—the `hashCode` and `equals` methods of the `Object` class are appropriate.
- Otherwise, you need to implement your own `equals` and `hashCode` methods—see Section 9.5.2 and Special Topic 15.1.

Step 6 If you use a tree, decide whether to supply a comparator.

Look at the class of the set elements or map keys. Does that class implement the `Comparable` interface? If so, is the sort order given by the `compareTo` method the one you want? If yes, then you don't need to do anything further. This is the case for many classes in the standard library, in particular for `String` and `Integer`.

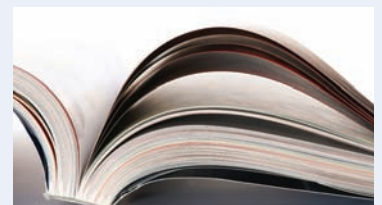
If not, then your element class must implement the `Comparable` interface (Section 10.3), or you must declare a class that implements the `Comparator` interface (see Special Topic 14.5).



WORKED EXAMPLE 15.1

Word Frequency

Learn how to create a program that reads a text file and prints a list of all words in the file in alphabetical order, together with a count that indicates how often each word occurred in the file. Go to wiley.com/go/javaexamples and download Worked Example 15.1.



Special Topic 15.1



Hash Functions

If you use a hash set or hash map with your own classes, you may need to implement a hash function. A **hash function** is a function that computes an integer value, the **hash code**, from an object in such a way that different objects are likely to yield different hash codes. Because hashing is so important, the `Object` class has a `hashCode` method. The call

```
int h = x.hashCode();
```

computes the hash code of any object `x`. If you want to put objects of a given class into a `HashSet` or use the objects as keys in a `HashMap`, the class should override this method. The method should be implemented so that different objects are likely to have different hash codes.

For example, the `String` class declares a hash function for strings that does a good job of producing different integer values for different strings. Table 6 shows some examples of strings and their hash codes.

It is possible for two or more distinct objects to have the same hash code; this is called a *collision*. For example, the strings "Ugh" and "VII" happen to have the same hash code, but these collisions are very rare for strings (see Exercise P15.4).

The `hashCode` method of the `String` class combines the characters of a string into a numerical code. The code isn't simply the sum of the character values—that would not scramble the character values enough. Strings that are permutations of another (such as "eat" and "tea") would all have the same hash code.

Here is the method the standard library uses to compute the hash code for a string:

```
final int HASH_MULTIPLIER = 31;
int h = 0;
for (int i = 0; i < s.length(); i++)
{
    h = HASH_MULTIPLIER * h + s.charAt(i);
}
```

For example, the hash code of "eat" is

$$31 * (31 * 'e' + 'a') + 't' = 100184$$



A good hash function produces different hash values for each object so that they are scattered about in a hash table.

A hash function computes an integer value from an object.

A good hash function minimizes *collisions*—identical hash codes for different objects.

Table 6 Sample Strings and Their Hash Codes	
String	Hash Code
"eat"	100184
"tea"	114704
"Juliet"	−2065036585
"Ugh"	84982
"VII"	84982

CHAPTER SUMMARY

Understand the architecture of the Java collections framework.

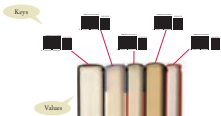
- A collection groups together elements and allows them to be retrieved later.
- A list is a collection that remembers the order of its elements.
- A set is an unordered collection of unique elements.
- A map keeps associations between key and value objects.

Understand and use linked lists.

- A linked list consists of a number of nodes, each of which has a reference to the next node.
- Adding and removing elements at a given position in a linked list is efficient.
- Visiting the elements of a linked list in sequential order is efficient, but random access is not.
- You use a list iterator to access elements inside a linked list.

Choose a set implementation and use it to manage sets of values.

- The HashSet and TreeSet classes both implement the Set interface.
- Set implementations arrange the elements so that they can locate them quickly.
- You can form hash sets holding objects of type String, Integer, Double, Point, Rectangle, or Color.
- You can form tree sets for any class that implements the Comparable interface, such as String or Integer.
- Sets don't have duplicates. Adding a duplicate of an element that is already present is ignored.
- A set iterator visits the elements in the order in which the set implementation keeps them.
- You cannot add an element to a set at an iterator position.

**Use maps to model associations between keys and values.**

- The HashMap and TreeMap classes both implement the Map interface.
- To find all keys and values in a map, iterate through the key set and find the values that correspond to the keys.
- A hash function computes an integer value from an object.
- A good hash function minimizes *collisions*—identical hash codes for different objects.
- Override hashCode methods in your own classes by combining the hash codes for the instance variables.
- A class's hashCode method must be compatible with its equals method.



Use the Java classes for stacks, queues, and priority queues.



- A stack is a collection of elements with “last-in, first-out” retrieval.
- A queue is a collection of elements with “first-in, first-out” retrieval.
- When removing an element from a priority queue, the element with the most urgent priority is retrieved.



Solve programming problems using stacks and queues.



- A stack can be used to check whether parentheses in an expression are balanced.
- Use a stack to evaluate expressions in reverse Polish notation.
- Using two stacks, you can evaluate expressions in standard algebraic notation.
- Use a stack to remember choices you haven't yet made so that you can backtrack to them.

STANDARD LIBRARY ITEMS INTRODUCED IN THIS CHAPTER

```
java.util.Collection<E>
    add
    contains
    iterator
    remove
    size
java.util.HashMap<K, V>
java.util.HashSet<K, V>
java.util.Iterator<E>
    hasNext
    next
    remove
java.util.LinkedList<E>
    addFirst
    addLast
    getFirst
    getLast
    removeFirst
    removeLast
java.util.List<E>
    listIterator
```

```
java.util.ListIterator<E>
    add
    hasPrevious
    previous
    set
java.util.Map<K, V>
    get
    keySet
    put
    remove
java.util.Queue<E>
    peek
java.util.PriorityQueue<E>
    remove
java.util.Set<E>
java.util.Stack<E>
    peek
    pop
    push
java.util.TreeMap<K, V>
java.util.TreeSet<K, V>
```

REVIEW QUESTIONS

- ■ **R15.1** An invoice contains a collection of purchased items. Should that collection be implemented as a list or set? Explain your answer.
- ■ **R15.2** Consider a program that manages an appointment calendar. Should it place the appointments into a list, stack, queue, or priority queue? Explain your answer.
- ■ ■ **R15.3** One way of implementing a calendar is as a map from date objects to event objects. However, that only works if there is a single event for a given date. How can you use another collection type to allow for multiple events on a given date?



In the supermarket, a generic product can be sourced from multiple suppliers. In computer science, generic programming involves the design and implementation of data structures and algorithms that work for multiple types. You have already seen the generic `ArrayList` class that can be used to collect elements of arbitrary types. In this chapter, you will learn how to implement your own generic classes and methods.

18.1 Generic Classes and Type Parameters

Generic programming is the creation of programming constructs that can be used with many different types. For example, the Java library programmers who implemented the `ArrayList` class used the technique of generic programming. As a result, you can form array lists that collect elements of different types, such as `ArrayList<String>`, `ArrayList<BankAccount>`, and so on.

The `LinkedList` class that we implemented in Section 16.1 is also an example of generic programming—you can store objects of any class inside a `LinkedList`. That `LinkedList` class achieves genericity by using *inheritance*. It uses references of type `Object` and is therefore capable of storing objects of any class. For example, you can add elements of type `String` because the `String` class extends `Object`. In contrast, the `ArrayList` and `LinkedList` classes from the standard Java library are **generic classes**. Each of these classes has a **type parameter** for specifying the type of its elements. For example, an `ArrayList<String>` stores `String` elements.

When declaring a generic class, you supply a variable for each type parameter. For example, the standard library declares the class `ArrayList<E>`, where `E` is the **type variable** that denotes the element type. You use the same variable in the declaration of the methods, whenever you need to refer to that type. For example, the `ArrayList<E>` class declares methods

```
public void add(E element)
public E get(int index)
```

You could use another name, such as `ElementType`, instead of `E`. However, it is customary to use short, uppercase names for type variables.

In order to use a generic class, you need to *instantiate* the type parameter, that is, supply an actual type. You can supply any class or interface type, for example

```
ArrayList<BankAccount>
ArrayList<Measurable>
```

However, you cannot substitute any of the eight primitive types for a type parameter. It would be an error to declare an `ArrayList<double>`. Use the corresponding wrapper class instead, such as `ArrayList<Double>`.

When you instantiate a generic class, the type that you supply replaces all occurrences of the type variable in the declaration of the class. For example, the `add` method for `ArrayList<BankAccount>` has the type variable `E` replaced with the type `BankAccount`:

```
public void add(BankAccount element)
```

Contrast that with the `add` method of the `LinkedList` class in Chapter 16:

```
public void add(Object element)
```

In Java, generic programming can be achieved with inheritance or with type parameters.

A generic class has one or more type parameters.

Type parameters can be instantiated with class or interface types.

**FULL CODE EXAMPLE**

Go to wiley.com/go/javacode to download programs that demonstrate safety problems when using collections without type parameters.

Type parameters make generic code safer and easier to read.

The `add` method of the generic `ArrayList` class is safer. It is impossible to add a `String` object into an `ArrayList<BankAccount>`, but you can accidentally add a `String` into a `LinkedList` that is intended to hold bank accounts:

```
ArrayList<BankAccount> accounts1 = new ArrayList<BankAccount>();
LinkedList accounts2 = new LinkedList(); // Should hold BankAccount objects
accounts1.add("my savings"); // Compile-time error
accounts2.addFirst("my savings"); // Not detected at compile time
```

The latter will result in a class cast exception when some other part of the code retrieves the string, believing it to be a bank account:

```
BankAccount account = (BankAccount) accounts2.getFirst(); // Run-time error
```

Code that uses the generic `ArrayList` class is also easier to read. When you spot an `ArrayList<BankAccount>`, you know right away that it must contain bank accounts. When you see a `LinkedList`, you have to study the code to find out what it contains.

In Chapters 16 and 17, we used inheritance to implement generic linked lists, hash tables, and binary trees, because you were already familiar with the concept of inheritance. Using type parameters requires new syntax and additional techniques—those are the topic of this chapter.

SELF CHECK

1. The standard library provides a class `HashMap<K, V>` with key type `K` and value type `V`. Declare a hash map that maps strings to integers.
2. The binary search tree class in Chapter 17 is an example of generic programming because you can use it with any classes that implement the `Comparable` interface. Does it achieve genericity through inheritance or type parameters?
3. Does the following code contain an error? If so, is it a compile-time or run-time error?

```
ArrayList<Integer> a = new ArrayList<Integer>();
String s = a.get(0);
```

4. Does the following code contain an error? If so, is it a compile-time or run-time error?

```
ArrayList<Double> a = new ArrayList<Double>();
a.add(3);
```

5. Does the following code contain an error? If so, is it a compile-time or run-time error?

```
LinkedList a = new LinkedList();
a.addFirst("3.14");
double x = (Double) a.removeFirst();
```

Practice It Now you can try these exercises at the end of the chapter: R18.4, R18.5, R18.6.

18.2 Implementing Generic Types

In this section, you will learn how to implement your own generic classes. We will write a very simple generic class that stores *pairs* of objects, each of which can have an arbitrary type. For example,

```
Pair<String, Integer> result = new Pair<String, Integer>("Harry Morgan", 1729);
```

- ■ **E18.9** Provide suitable `hashCode` and `equals` methods for the `Pair` class of Section 18.2 and implement a `HashMap` class, using a `HashSet<Pair<K, V>>`.
- ■ ■ **E18.10** Implement a generic version of the permutation generator in Section 13.4. Generate all permutations of a `List<E>`.
- ■ **E18.11** Write a generic static method `print` that prints the elements of any object that implements the `Iterable<E>` interface. The elements should be separated by commas. Place your method into an appropriate utility class.
- ■ **E18.12** Turn the `MinHeap` class of Chapter 17 into a generic class. As with the `TreeSet` class of the standard library, allow a `Comparator` to compare elements. If no comparator is supplied, assume that the element type implements the `Comparable` interface.
- ■ **E18.13** Make the `Measurer` interface from Chapter 10 into a generic class. Provide a static method `T max(T[] values, Measurer<T> meas)`.
- **E18.14** Provide a static method `void append(ArrayList<T> a, ArrayList<T> b)` that appends the elements of `b` to `a`.
- ■ **E18.15** Modify the method of Exercise E18.14 so that the second array list can contain elements of a subclass. For example, if `people` is an `ArrayList<Person>` and `students` is an `ArrayList<Student>`, then `append(people, students)` should compile but `append(students, people)` should not.
- ■ **E18.16** Modify the method of Exercise E18.14 so that it leaves the first array list unchanged and returns a new array list containing the elements of both array lists.
- ■ **E18.17** Modify the method of Exercise E18.16 so that it receives and returns arrays, not array lists. *Hint: Arrays.copyOf.*
- **E18.18** Provide a static method that reverses the elements of a generic array list.
- **E18.19** Provide a static method that returns the reverse of a generic array list, without modifying the original list.
- ■ **E18.20** Provide a static method that checks whether a generic array list is a palindrome; that is, whether the values at index `i` and `n - 1 - i` are equal to each other, where `n` is the size of the array list.
- ■ **E18.21** Provide a static method that checks whether the elements of a generic array list are in increasing order. The elements must be comparable.

PROGRAMMING PROJECTS

- ■ **P18.1** Write a static generic method `PairUtil.minmax` that computes the minimum and maximum elements of an array of type `T` and returns a pair containing the minimum and maximum value. Require that the array elements implement the `Measurable` interface of Chapter 10.
- ■ **P18.2** Repeat Exercise P18.1, but require that the array elements implement the `Comparable` interface.
- ■ ■ **P18.3** Repeat Exercise P18.2, but refine the bound of the type parameter to extend the generic `Comparable` type.

- ■ **P18.4** Make the `Measurable` interface from Chapter 10 into a generic class. Provide a static method that returns the largest element of an `ArrayList<T>`, provided that the elements are instances of `Measurable<T>`. Be sure to return a value of type `T`.
- ■ ■ **P18.5** Enhance Exercise P18.4 so that the elements of the `ArrayList<T>` can implement `Measurable<U>` for appropriate types `U`.

ANSWERS TO SELF-CHECK QUESTIONS

1. `HashMap<String, Integer>`
2. It uses inheritance.
3. This is a compile-time error. You cannot assign the `Integer` expression `a.get(0)` to a `String`.
4. This is a compile-time error. The compiler won't convert `3` to a `Double`. *Remedy:* Call `a.add(3.0)`.
5. This is a run-time error. `a.removeFirst()` yields a `String` that cannot be converted into a `Double`. *Remedy:* Call `a.addFirst(3.14)`;
6. `new Pair<String, String>("Hello", "World")`
7. `new Pair<String, Integer>("Hello", 1729)`
8. An `ArrayList<Pair<String, Integer>>` contains multiple pairs, for example `[(Tom, 1), (Harry, 3)]`. A `Pair<ArrayList<String>, Integer>` contains a list of strings and a single integer, such as `[(Tom, Harry), 1]`.
9.

```
public static Pair<Double, Double> roots(
    Double x)
{
    if (x >= 0)
    {
        double r = Math.sqrt(x);
        return new Pair<Double, Double>(r, -r);
    }
    else { return null; }
}
```
10. You have three type parameters: `Triple<T, S, U>`. Add an instance variable `U third`, a constructor argument for initializing it, and a method `U getThird()` for returning it.
11. The output depends on the implementation of the `toString` method in the `BankAccount` class.
12. No—the method has no type parameters. It is an ordinary method in a generic class.
13. `fill(a, "**")`
14. You get a compile-time error. An integer cannot be converted to a string.
15. You get a run-time error. Unfortunately, the call compiles, with `T = Object`. This choice is justified because a `String[]` array is convertible to an `Object[]` array, and `42` becomes `new Integer(42)`, which is convertible to an `Object`. But when the program tries to store an `Integer` in the `String[]` array, an exception is thrown.
16.

```
public class BinarySearchTree<E
    extends Comparable<E>>
or, if you read Special Topic 18.1,
public class BinarySearchTree<E
    extends Comparable<? superE>>
```
17.

```
public static <E extends Measurable> E min(
    ArrayList<E> objects)
{
    E smallest = objects.get(0);
    for (int i = 1; i < objects.size(); i++)
    {
        E obj = objects.get(i);
        if (obj.getMeasure()
            < smallest.getMeasure())
        {
            smallest = obj;
        }
    }
    return smallest;
}
```
18. No. As described in Common Error 18.1, you cannot convert an `ArrayList<BankAccount>` to an `ArrayList<Measurable>`, even if `BankAccount` implements `Measurable`.
19. Yes, but this method would not be as useful. Suppose `accounts` is an array of `BankAccount` objects. With this method, `min(accounts)` would return a result of type `Measurable`, whereas the generic method yields a `BankAccount`.

Step 7 Supply any needed helper methods.

Your bean can have methods that are not property getters and setters. For example, the Time-ZoneBean has helper methods to look up the time zone for a city.

25.5 JSF Components

There are JSF components for text input, choices, buttons, and images.

The value attribute of an input component denotes the value that the user supplies.

In this section, you will see the most useful user-interface components that you can place on a JSF form. Table 1 shows a summary. (For a comprehensive discussion of all JSF components, see *Core JavaServer Faces*, 3rd ed., by David Geary and Cay Horstmann (Sun Microsystems Press/Prentice Hall, 2010)).

Each component has a value attribute that allows you to connect the component value with a bean property, for example

```
<h:inputSecret value="#{user.password}"/>
```

The h:inputTextArea component has attributes to specify the rows of text and columns of characters, such as

```
<h:inputTextArea value="#{user.comment}" rows="10" cols="40"/>
```

Table 1 Common JSF Components

Component	JSF Tag	Common Attributes	Example
Text Field	h:inputText	value	<input type="text" value="12345678901234567890"/>
Password Field	h:inputSecret	value	<input type="password" value="*****"/>
Text Area	h:inputTextArea	value rows cols	<div>line one line two line three</div>
Radio Button Group	h:selectOneRadio	value layout	<input type="radio"/> Cheese <input checked="" type="radio"/> Pickle <input type="radio"/> Mustard <input type="radio"/> Lettuce <input type="radio"/> Onions
Checkbox	h:selectOneCheckbox	value	Receive email: <input checked="" type="checkbox"/>
Checkbox Group	h:selectManyCheckbox	value layout	<input checked="" type="checkbox"/> Cheese <input type="checkbox"/> Pickle <input checked="" type="checkbox"/> Mustard <input type="checkbox"/> Lettuce <input type="checkbox"/> Onions
Menu	h:selectOneMenu h:selectManyMenu	value	<div>Cheese Pickle Mustard Lettuce</div>
Image	h:graphicImage	value	
Submit Button	h:commandButton	value action	<input type="button" value="press me"/>

The radio button and checkbox groups allow you to specify horizontal or vertical layout:

```
<h:selectOneRadio value="#{burger.topping}" layout="lineDirection">
```

In European languages, `lineDirection` means horizontal and `pageDirection` means vertical. However, in some languages, lines are written top-to-bottom, and the meanings are reversed.

Button groups and menus are more complex than the other user-interface components. They require you to specify two properties:

- the collection of possible choices
- the actual choice

The `value` attribute of the component specifies the actual choice to be displayed. The collection of possible choices is defined by a nested `f:selectItems` tag, like this:

```
<h:selectOneRadio value="#{creditCardBean.expirationMonth}"
    layout="pageDirection">
    <f:selectItems value="#{creditCardBean.monthChoices}"/>
</h:selectOneRadio>
```

Use an `f:selectItems` tag to specify all choices for a component that allows selection from a list of choices.

When you use the `f:selectItems` tag, you need to add the namespace declaration

```
xmlns:f="http://java.sun.com/jsf/core"
```

to the `html` tag at the top of your JSF page.

The value of the `f:selectItems` tag must have a type that can describe a list of choices. There are several types that you can use, but the easiest—and the only one that we will discuss—is a `Map`. The keys of the map are the *labels*—the strings that are displayed next to each choice. The corresponding map values are the *label values*—the values that correspond to the selection. For example, a choice map for months would map January to 1, February to 2, and so on:

```
public class CreditCardBean
{
    . . .
    public Map<String, Integer> getMonthChoices()
    {
        Map<String, Integer> choices = new LinkedHashMap<String, Integer>();
        choices.put("January", 1);
        choices.put("February", 2);
        . . .
        return choices;
    }
}
```

Here, we use a `LinkedHashMap` because we want to visit entries in the order in which they are inserted. This is more useful than a `HashMap`, which would visit the labels in random order or a `TreeMap`, which would visit them in alphabetical order (starting with April!).

The type of the value property of the component enclosing the `f:selectItems` tag must match the type of the map value. For example, `creditCardBean.expirationMonth` must be an integer, not a string. If multiple selections are allowed, the type of the value property must be a list or array of matching types. For example, if one could choose multiple months, a `selectManyRadio` component would have a value property with a type such as `int[]` or `ArrayList<Integer>`.

STANDARD LIBRARY ITEMS INTRODUCED IN THIS CHAPTER

```
java.text.DateFormat
    format
    getTimeInstance
    setTimeZone
java.util.LinkedHashMap
```

```
java.util.TimeZone
    getAvailableIDs
    getTimeZone
javax.sql.DataSource
    getConnection
```

REVIEW QUESTIONS

- **R25.1** Most web browsers have a command to “view the source” of a web page. Load the page <http://horstmann.com> into your browser and view the source. What is the “language” used for formatting the source? What images, links, bullets, and input elements can you find?
- **R25.2** Have a closer look at the HTTP POST request on page W1056. Where is the data that the user provided? What does `login=Log%20in` mean? (The code `%20` denotes a space in the “URL encoding” scheme.)
- **R25.3** What is the difference between a JSF page and a JSF container?
- **R25.4** What is a bean?
- **R25.5** What is a bean property?
- **R25.6** Is a `JButton` a bean? Why or why not?
- **R25.7** What is the software engineering purpose of using beans in conjunction with JSF pages?
- **R25.8** How are variables in the JSF expression language different from variables in Java programs?
- **R25.9** When is a bean constructed in a JSF application? Can you have two different instances of a bean that are active at the same time?
- **R25.10** How can you implement error checking in a JSF application? Explain, using a login page as an example.
- **R25.11** What input elements can you place on a JSF form? What are their Swing equivalents?
- **R25.12** What is the difference between a client-server application and a three-tier application?

PRACTICE EXERCISES

- **E25.1** Write a JSF application that reports the values of the following system properties of the web server:
 - The Java version (`java.version`)
 - The operating system name (`os.name`)
 - The operating system version (`os.version`)

Supply a bean that uses the `getProperties` method of the `System` class.

```

    java.util.LinkedList<E> implements List<E>, Queue<E>, Serializable
    java.util.ArrayList<E> implements List<E>, Serializable
    java.util.AbstractQueue<E>
    java.util.PriorityQueue<E> implements Serializable
    java.util.AbstractSet<E>
    java.util.HashSet<E> implements Serializable, Set<E>
    java.util.TreeSet<E> implements Serializable, SortedSet<E>
    java.util.AbstractMap<K, V>
    java.util.HashMap<K, V> implements Map<K, V>, Serializable
    java.util.LinkedHashMap<K, V>
    java.util.TreeMap<K, V> implements Serializable, Map<K, V>
    java.util.Arrays
    java.util.Collections
    java.util.Calendar
    java.util.GregorianCalendar
    java.util.Date implements Serializable
    java.util.Dictionary<K, V>
    java.util.Hashtable<K, V>
    java.util.Properties implements Serializable
    java.util.EventObject implements Serializable
    java.awt.AWTEvent
    java.awt.event.ActionEvent
    java.awt.event.ComponentEvent
    java.awt.event.InputEvent
    java.awt.event.KeyEvent
    java.awt.event.MouseEvent
    javax.swing.event.ChangeEvent
    java.util.Random implements Serializable
    java.util.Scanner
    java.util.TimeZone implements Serializable
    java.util.concurrent.locks.ReentrantLock implements Lock, Serializable
    java.util.logging.Level implements Serializable
    java.util.logging.Logger
    javax.swing.ButtonGroup implements Serializable
    javax.swing.ImageIcon implements Serializable
    javax.swing.KeyStroke implements Serializable
    javax.swing.Timer implements Serializable
    javax.swing.border.AbstractBorder implements Serializable
    javax.swing.border.EtchedBorder
    javax.swing.border.TitledBorder
    javax.xml.parsers.DocumentBuilder
    javax.xml.parsers.DocumentBuilderFactory
    javax.xml.xpath.XPathFactory
    java.lang.Comparable<T>
    java.lang.Runnable
    java.sql.Connection
    java.sql.ResultSet
    java.sql.ResultSetMetaData
    java.sql.Statement
    java.sql.PreparedStatement
    java.util.Collection<E>
    java.util.List<E>
    java.util.Set<E>
    java.util.SortedSet<E>
    java.util.Comparator<T>
    java.util.EventListener
    java.awt.event.ActionListener
    java.awt.event.KeyListener
    java.awt.event.MouseListener
    javax.swing.event.ChangeListener

```

Class java.util.GregorianCalendar

- **GregorianCalendar()**
This constructs a calendar object that represents the current date and time.
- **GregorianCalendar(int year, int month, int day)**
This constructs a calendar object that represents the start of the given date.
Parameters: year, month, day The given date

Class java.util.HashMap<K, V>

- **HashMap<K, V>()**
This constructs an empty hash map.

Class java.util.HashSet<E>

- **HashSet<E>()**
This constructs an empty hash set.

Class java.util.InputMismatchException

This exception is thrown if the next available input item does not match the type of the requested item.

Interface java.util.Iterator<E>

- **boolean hasNext()**
This method checks whether the iterator is past the end of the list.
Returns: true if the iterator is not yet past the end of the list
- **E next()**
This method moves the iterator over the next element in the linked list. This method throws an exception if the iterator is past the end of the list.
Returns: The object that was just skipped over
- **void remove()**
This method removes the element that was returned by the last call to next or previous. This method throws an exception if there was an add or remove operation after the last call to next or previous.

Class java.util.LinkedHashMap<K, V>

- **LinkedHashMap<K, V>()**
This constructs an empty linked hash map. The iterator of a linked hash map visits the entries in the order in which they were added to the map.

Class java.util.LinkedList<E>

- **void addFirst(E element)**
- **void addLast(E element)**
These methods add an element before the first or after the last element in this list.
Parameters: element The element to be added

I-10 Index

grep program, 526
Grid bag layout, 843
Grid layout, 843
GridLayout constructor, 843, A-15
Grouping radio buttons, 852–853
grow method, java.awt.Rectangle class, A-15
GUI (Graphical User Interface), components. *See also* Layout management; *specific components*.
default size, 845
making selections. *See* Check boxes; Combo boxes; Radio buttons.
GUI builders, 862
Gutenberg project, 454

H

Halt checker, 606
Halting problem, 606–607
Hand tracing
animation, 251
arithmetic operations, 154–156
description, 203–204
loops, 249–253
objects, 105–107
Hardware, definition, 2
“Has-a” relationships. *See* Aggregation.
Hash codes
collisions, 690–691
description, 690–691, 741
full code example, 691
Hash functions, 690–691
Hash tables, description, 741–742
Hash tables, implementing
adding/removing elements, 743–744
buckets, 742
collisions, 741
efficiency, 745*t*
finding elements, 743
hash codes, 741
iterating over hash tables, 744–749
linear probing, 749
open addressing, 742, 749
probing sequence, 749
sample code, 745–749
separate chaining, 742
hashCode method, 681
HashMap constructor, A-38
HashSet constructor, A-38
HashSetDemo.java class, 748–749
HashSet.java class, 745–748
hasNext method
java.util.Iterator<E> interface, 677, 682, A-38
java.util.Scanner class, A-41
hasNextDouble method, java.util.Scanner class, 219, A-41
hasNextInt method, java.util.Scanner class, 218–219, A-41
hasNextLine method, java.util.Scanner class, A-41
hasPrevious method, java.util.ListIterator<E> interface, 678, A-39
HeapDemo.java class, 802–803
Heaps. *See also* Binary search; Tree concepts.
adding nodes, 794–795. *See also* Heapsort algorithm.
definition, 793
removing nodes, 796–797. *See also* Heapsort algorithm.
sample code, 798–803
sorting nodes. *See* Heapsort algorithm.
storing in arrays, 798
Heapsort algorithm, 804–808
HeapSorter.java, 806–808
Height of trees, 763
“Hello, World” program
analyzing, 12–14
source code, 12
writing, 8–11
HelloPrinter.java class, 12
Help, online, 55. *See also* Documentation.
Hexadecimal numbers, A-73
High-level languages, 6
History of computers
Altair 8800, 406
Apple II, 406
Babbage's Difference Engine, 652
corporate monopolies, 60
first kit computer, 406
first programmer, 652
hardware evolution, 5
IBM, 60

microprocessors, 406
Microsoft, 60
personal computing, 406
standardization, 680
Turing machine, 606
Univac Corporation, 60
VisiCalc, 406

Hoff, Marcian E., 406
Houston, Frank, 359
HTML (Hypertext Markup Language)
attributes, A-88–89
entities, A-89–90
overview, A-86
tag summary, A-87–88
Huffman trees, 767, 770

I

IBM, history of computers, 60
IEEE floating-point numbers, A-72
IETF (Internet Engineering Task Force), 680
if statements. *See also* switch statements.
animation, 196, 200
dangling else problem, 204–205
definition, 180
duplicate code in branches, 186
ending with a semicolon, 184–185
flowchart for, 181
implementing (How To), 193–195
input validation, 218–220
multiple alternatives, 196–199
nesting, 200–203
sample program, 182–183
syntax, 182
IllegalArgumentException, 534–535, A-23
ImageIcon constructor, A-44
Immutable classes, 383–384
implements reserved word, 466–468
Implicit parameters, 110
import directive, 398–399, 401
Importing
classes from packages, 54
packages, 401
in method, java.lang.System class, 147
Income tax computation, 200–203
Income tax rate schedule, 200*t*
Indefinite loops, 254

- java.lang.Boolean class, method summary, A-22. *See also specific methods.*
- java.lang.Character class, method summary, A-22. *See also specific methods.*
- java.lang.Class class, method summary, A-22. *See also specific methods.*
- java.lang.Cloneable interface, summary, A-22
- java.lang.CloneNotSupportedException, A-22
- java.lang.Comparable<T> interface
 - full code example, 474
 - method summary, A-23. *See also specific methods.*
 - overview, 473–477
 - parameterized, 660–661
- java.lang.Double class, 162, A-23
- java.lang.Error class, summary, A-23
- java.lang.IllegalArgumentException, 537, A-23
- java.lang.IllegalStateException, summary, A-23
- java.lang.Integer class
 - converting strings to numbers, 162
 - method summary, A-23–24. *See also specific methods.*
 - minimum/maximum values, getting, 132
- java.lang.InterruptedException, A-24
- java.lang.Math class, method summary, 142, A-24–26. *See also specific methods.*
- java.lang.NullPointerException, 543, A-26
- java.lang.NumberFormatException, 537, A-26
- java.lang.Object class, method summary, A-26–27. *See also specific methods.*
- java.lang.Runnable interface, method summary, A-27. *See also specific methods.*
- java.lang.RuntimeException, 537, A-27
- java.lang.String class
 - charAt method, 158
 - compareTo method, 189
 - equals method, 188–190
 - length method, 43–44, 156
 - method summary, A-27–28. *See also specific methods.*
 - replace method, 46
 - substring method, 159–160
 - toUpperCase method, 43–44
- java.lang.System class, 147, A-28
- java.lang.Thread class, method summary, A-28–29. *See also specific methods.*
- java.lang.Throwable class, method summary, A-29. *See also specific methods.*
- java.math package, A-29
- java.math.BigDecimal class
 - add method, 138
 - method summary, A-29
 - multiply method, 138
 - subtract method, 138
- java.math.BigInteger class, A-29
 - add method, 138
 - multiply method, 138
 - subtract method, 138
- java.net package, A-30–31
- java.net.HttpURLConnection class, A-30
- java.net.ServerSocket class, A-30
- java.net.Socket class, A-30
- java.net.URL class, 517, A-31
- java.net.URLConnection class, A-31
- java.sql package, A-31–34
- java.sql.Connection interface, A-31–32
- java.sql.DriverManager class, A-32
- java.sql.PreparedStatement class, A-32
- java.sql.ResultSet class, A-32–A-33
- java.sql.ResultSetMetaData class, A-33–34
- java.sql.SQLException, A-34
- java.sql.Statement class, A-34
- java.text package, A-34–35
- java.text.DateFormat class, method summary, A-34–35
- java.util package, A-35–42
- java.util.ArrayList<E> class
 - add method, 348
 - get method, 348
 - method summary, A-35. *See also specific methods.*
 - remove method, 349
 - set method, 348–349
 - size method, 348
- java.util.Arrays class
 - copyOf method, 327–328
 - method summary, A-36. *See also specific methods.*
 - toStrings method, 323–324
- java.util.Calendar class, A-36
- java.util.Collection<E> interface, 674, A-36–37
- java.util.Collections class, A-37
- java.util.Comparator<T> interface, 661, A-37
- java.util.concurrent.locks package, A-42
- java.util.concurrent.locks.Condition class, A-42
- java.util.concurrent.locks.Lock class, A-42
- java.util.concurrent.locks.ReentrantLock class, A-42
- java.util.Date class, A-37
- java.util.EventObject class, A-37
- java.util.GregorianCalendar class, A-38
- java.util.HashMap<K, V> class, 690, A-38
- java.util.HashSet<E> class
 - description, 681–682
 - hash functions, 690–691
 - implementing sets, 681–682
 - interface references to, 685
- java.util.HashSet<E> class, method summary, A-38
- java.util.InputMismatchException, A-38
- java.util.Iterator<E> interface, 683, A-38
- java.util.LinkedHashMap<K, V> class, A-38
- java.util.LinkedList<E> class, A-38–39
- java.util.List<E> interface, 672, A-39
- java.util.ListIterator<E> interface, 683, A-39
- java.util.logging package, A-43

- How To, 859–861
 - layout managers, 842
 - nesting panels, 843–844
 - panels, 842
 - Layout managers, 842
 - Leaf nodes, 763
 - Lenat, Douglas, 221
 - length method
 - java.io.RandomAccessFile class, 888–892, A-21
 - java.lang.String class, 43–44, 156, A-27
 - Less than, equal (`<=`), relational operator, 187*t*
 - Less than (`<`), relational operator, 187*t*
 - Lexicographic ordering, 189
 - Library. *See* Java library.
 - Licklider, J.C.R., 454
 - LIFO (last in, first out), 692
 - Line breaks, 158
 - Line2D.Double constructor, A-17
 - Linear probing, 749
 - Linear searching, 648–649
 - LinearSearcher.java class, 648–649
 - LineItem.java class, 578
 - Lines (graphic), drawing, 67
 - Lines (of text), reading, 521–522
 - Linked lists. *See also* java.util.
 - LinkedList<E> class.
 - animation, 677
 - definition, 675
 - doubly linked, 678
 - implementing queues as, 737–738
 - implementing stacks as, 735–737
 - list iterators, 677–679
 - nodes, 675–676
 - sample code, 679
 - structure of, 675–676
 - Linked lists, implementing
 - adding/removing elements, 717–718, 720–723
 - advancing an iterator, 719–720
 - doubly-linked lists (How To), 730
 - efficiency, 723–726, 726*t*
 - full code example, 729
 - inner classes, 716–717
 - Iterator class, 718–719
 - LinkedListIterator class, 718–719, 730
 - ListIterator class, 718–719
 - Node class, 716–717
 - sample code, 726–730
 - setting element values, 723
 - static classes, 730
 - LinkedHashMap constructor, A-38
 - LinkedListIterator class, 718–719, 730
 - LinkedList.java class, 726–729
 - LinkedListStack.java class, 736–737
 - ListDemo.java class, 679
 - Listeners. *See* Event listeners.
 - ListIterator class, 718–719
 - listIterator method, java.util.
 - LinkedList<E> class, 677
 - listIterator method, java.util.
 - List<E> interface, A-39
 - ListIterator.java, 729–730
 - Lists, definition, 672–673
 - Literals, string, 156
 - load method, java.util.Properties class, A-40
 - Local variables
 - declaring instance variables in, 108
 - definition, 107
 - duplicate names, 206
 - full code example, 107
 - garbage collection, 107
 - initializing, 107
 - lock method, java.util.concurrent.
 - locks.Lock class, A-42
 - log method, java.lang.Math class, 142*t*, A-25
 - log10 method, java.lang.Math class, 142*t*, A-25
 - Logging messages, 212–213
 - Logic errors, 15
 - Loma Prieta earthquake, 196
 - long data type, 132*t*, 133
 - Loop and a half problem, 266–267
 - LoopFib.java class, 601–602
 - Loops
 - animation, 251, 255
 - asymmetric bounds, 260
 - Boolean variables, 266
 - bounds, choosing, 260
 - break statements, 267–268
 - common errors, 247–249
 - continue statements, 267–268
 - count-controlled, 254
 - counting iterations, 260
 - credit card processing (Worked Example), 279
 - definite, 254
 - definition, 242
 - do loops, 262–263
 - enhanced for loop, 321–322
 - event-controlled, 254
 - flowcharting, 263
 - full code example, 262, 321–322
 - hand tracing, 249–253
 - improving recursion efficiency, 602–603
 - indefinite, 254
 - infinite, 248
 - loop and a half problem, 266–267
 - for loops, 254–259, 261
 - manipulating pixel images (Worked Example), 282
 - nesting, 279–282
 - off-by-one errors, 248–249
 - post-test, 262
 - pre-test, 262
 - redirecting input/output, 266
 - sentinel values, 263–266
 - while loops, 242–247
 - writing (How To), 276–279
 - Loops, common algorithms
 - averages, computing, 272
 - comparing adjacent values, 275–276
 - counters, 272–273
 - finding first match, 273
 - full code example, 275
 - maximum/minimum values, finding, 274
 - prompting for first match, 274
 - totals, computing, 272
 - Luggage handling system, 195
- M**
- Machine code, 6
 - Magic numbers, 139
 - main method, 12, 527–529
 - Managing object properties, common class patterns, 392
 - MapDemo.java class, 687–688
 - Maps
 - animation, 686
 - definition, 673–674
 - description, 686–688
 - Matrices, 340–346

Input

```
Scanner in = new Scanner(System.in);  
// Can also use new Scanner(new File("input.txt"));
```

```
int n = in.nextInt();  
double x = in.nextDouble();  
String word = in.next();  
String line = in.nextLine();
```

```
while (in.hasNextDouble())  
{  
    double x = in.nextDouble();  
    Process x  
}
```

Output

```
System.out.print("Enter a value: ");
```

Does not advance to new line.

Use + to concatenate values.

```
System.out.println("Volume: " + volume);
```

```
System.out.printf("%-10s %10d %10.2f", name, qty, price);
```

Field width Precision
Left-justified string Integer Floating-point number

```
PrintWriter out = new PrintWriter("output.txt");
```

```
out.close();
```

Use print/println/printf to write output to file.

Remember to close output file.

Arrays

```
Element type      Element type      Length  
int[] numbers = new int[5];  
int[] squares = { 0, 1, 4, 9, 16 };  
int[][] magicSquare =  
{  
    { 16, 3, 2, 13 },  
    { 5, 10, 11, 8 },  
    { 9, 6, 7, 12 },  
    { 4, 15, 14, 1 }  
};
```

All elements are zero.

```
for (int i = 0; i < numbers.length; i++)  
{  
    numbers[i] = i * i;  
}
```

```
for (int element : numbers)  
{  
    Process element  
}
```

```
System.out.println(Arrays.toString(numbers));  
// Prints [0, 1, 4, 9, 16]
```

Array Lists

```
Element type      Initially empty      Use wrapper type, Integer, Double, etc., for primitive types.  
ArrayList<String> names = new ArrayList<String>();  
  
names.add("Ann");  
names.add("Cindy"); // [Ann, Cindy], names.size() is now 2  
  
names.add(1, "Bob"); // [Ann, Bob, Cindy]  
names.remove(2); // [Ann, Bob]  
names.set(1, "Bill"); // [Ann, Bill]  
  
String name = names.get(0); // Gets "Ann"  
System.out.println(names); // Prints [Ann, Bill]
```

Add elements to the end

Linked Lists, Sets, and Iterators

```
LinkedList<String> names = new LinkedList<String>();  
names.add("Bob"); // Adds at end
```

```
ListIterator<String> iter = names.listIterator();  
iter.add("Ann"); // Adds before current position
```

```
String name = iter.next(); // Returns "Ann"  
iter.remove(); // Removes "Ann"
```

```
Set<String> names = new HashSet<String>();  
names.add("Ann"); // Adds to set if not present  
names.remove("Bob"); // Removes if present
```

```
Iterator<String> iter = names.iterator();  
while (iter.hasNext())  
{  
    Process iter.next()  
}
```

Maps

```
Key type      Value type  
Map<String, Integer> scores = new HashMap<String, Integer>();  
  
scores.put("Bob", 10);  
Integer score = scores.get("Bob");  
  
for (String key : scores.keySet())  
{  
    Process key and scores.get(key)  
}
```

Returns null if key not present