

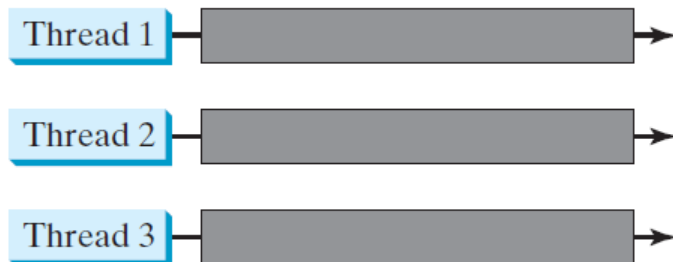


Multi-Thread Programming

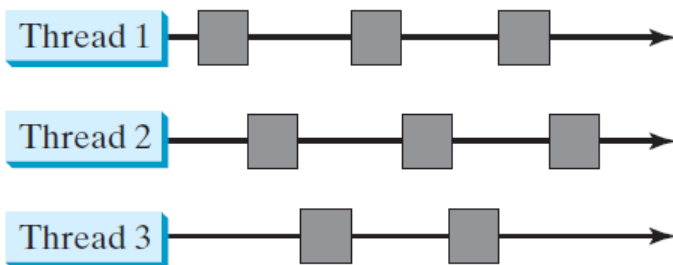
CSGE601021 Dasar-Dasar Pemrograman 2
Fakultas Ilmu Komputer Universitas Indonesia

Threads Concept

Multiple
threads on
multiple
CPUs

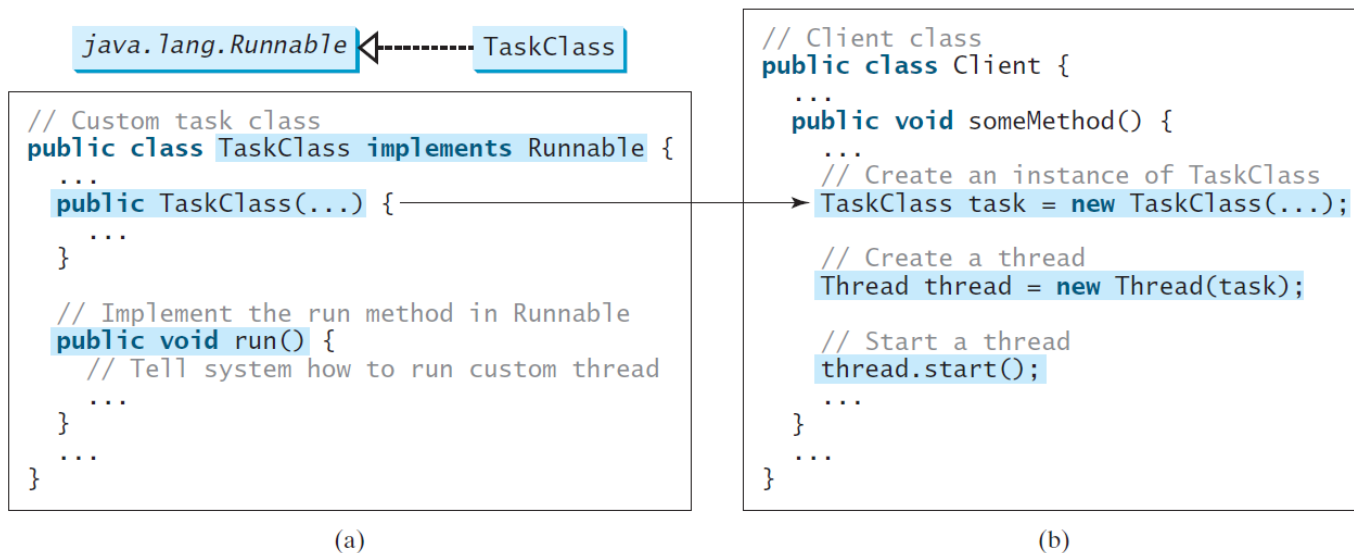


Multiple
threads
sharing a
single CPU



Creating Tasks and Threads

- Tasks are objects and to create tasks, you have to first define a class for tasks, which implements the Runnable interface
- A task must be executed in a thread.



Example: Using the Runnable Interface to Create and Launch Threads

- Objective: Create and run three threads:
 - The first thread prints the letter *a* 100 times.
 - The second thread prints the letter *b* 100 times.
 - The third thread prints the integers 1 through 100.

```
public class TaskThreadDemo {  
    public static void main(String[] args) {  
        // Create tasks  
        Runnable printA = new PrintChar('a', 100);  
        Runnable printB = new PrintChar('b', 100);  
        Runnable print100 = new PrintNum(100);  
  
        // Create threads  
        Thread thread1 = new Thread(printA);  
        Thread thread2 = new Thread(printB);  
        Thread thread3 = new Thread(print100);  
  
        // Start threads  
        thread1.start();  
        thread2.start();  
        thread3.start();  
    }  
}
```

Example: Using the Runnable Interface to Create and Launch Threads

```
class PrintChar implements Runnable {
    // The character to print
    private char charToPrint;
    private int times; // The times to repeat

    /** Construct a task with specified character
     * and number of times to print the character
     */
    public PrintChar(char c, int t) {
        charToPrint = c;
        times = t;
    }

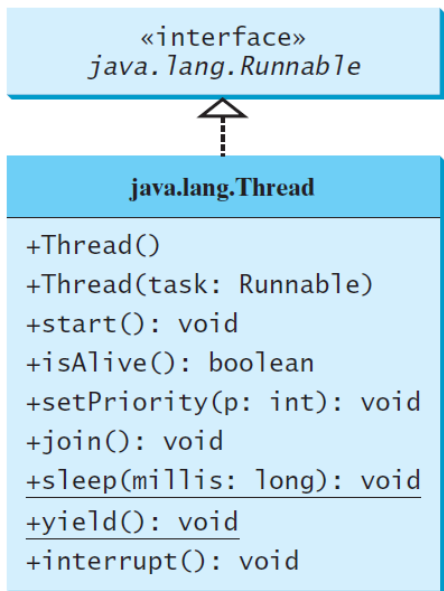
    @Override /** Override the run() method to tell
     * the system what the task to perform
     */
    public void run() {
        for (int i = 0; i < times; i++) {
            System.out.print(charToPrint);
        }
    }
}
```

```
class PrintNum implements Runnable {
    private int lastNum;

    /** Construct a task for printing 1, 2, ... i */
    public PrintNum(int n) {
        lastNum = n;
    }

    @Override /** Tell the thread how to run */
    public void run() {
        for (int i = 1; i <= lastNum; i++) {
            System.out.print(" " + i);
        }
    }
}
```

The Thread Class



Creates an empty thread.

Creates a thread for a specified task.

Starts the thread that causes the `run()` method to be invoked by the JVM.

Tests whether the thread is currently running.

Sets priority `p` (ranging from 1 to 10) for this thread.

Waits for this thread to finish.

Puts a thread to sleep for a specified time in milliseconds.

Causes a thread to pause temporarily and allow other threads to execute.

Interrupts this thread.

The Static yield() Method

- You can use the yield() method to temporarily release time for other threads. For example, suppose you modify the code in Lines 53-57 in TaskThreadDemo.java as follows:

```
public void run() {  
    for (int i = 1; i <= lastNum; i++) {  
        System.out.print(" " + i);  
        Thread.yield();  
    }  
}
```

- Every time a number is printed, the print100 thread is yielded. So, the numbers are printed after the characters.

The Static sleep(milliseconds) Method

- The sleep(long mills) method puts the thread to sleep for the specified time in milliseconds. For example, suppose you modify the code in Lines 53-57 in TaskThreadDemo.java as follows:

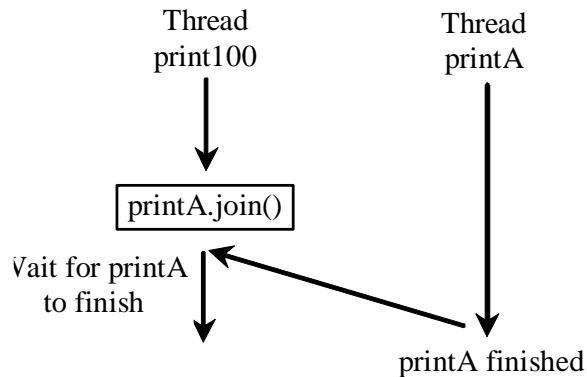
```
public void run() {  
    for (int i = 1; i <= lastNum; i++) {  
        System.out.print(" " + i);  
        try {  
            if (i >= 50) Thread.sleep(1);  
        }  
        catch (InterruptedException ex) {  
        }  
    }  
}
```

- Every time a number (≥ 50) is printed, the print100 thread is put to sleep for 1 millisecond.

The join() Method

- You can use the join() method to force one thread to wait for another thread to finish. For example, suppose you modify the code in Lines 53-57 in TaskThreadDemo.java as follows:

```
public void run() {  
    Thread thread4 = new Thread(  
        new PrintChar('c', 40));  
    thread4.start();  
    try {  
        for (int i = 1; i <= lastNum; i++) {  
            System.out.print(" " + i);  
            if (i == 50) thread4.join();  
        }  
    }  
    catch (InterruptedException ex) {  
    }  
}
```



- The numbers after 50 are printed after thread printA is finished.

isAlive(), interrupt(), and isInterrupted()

- The **isAlive()** method is used to find out the state of a thread. It returns true if a thread is in the Ready, Blocked, or Running state; it returns false if a thread is new and has not started or if it is finished.
- The **interrupt()** method interrupts a thread in the following way: If a thread is currently in the Ready or Running state, its interrupted flag is set; if a thread is currently blocked, it is awakened and enters the Ready state, and an `java.io.InterruptedExceptio`n is thrown.
- The **isInterrupted()** method tests whether the thread is interrupted.

The deprecated stop(), suspend(), and resume() Methods

NOTE: The Thread class also contains the stop(), suspend(), and resume() methods. As of Java 2, these methods are *deprecated* (or *outdated*) because they are known to be inherently unsafe. You should assign null to a Thread variable to indicate that it is stopped rather than use the stop() method.

Thread Priority

- Each thread is assigned a default priority of `Thread.NORM_PRIORITY`. You can reset the priority using `setPriority(int priority)`.
- Some constants for priorities include
`Thread.MIN_PRIORITY`
`Thread.MAX_PRIORITY`
`Thread.NORM_PRIORITY`

Example: Flashing Text (JavaFX)

```
public class FlashText extends Application {
    private String text = "";

    @Override
    public void start(Stage primaryStage) {
        StackPane pane = new StackPane();
        Label lblText = new Label("Programming is fun");
        pane.getChildren().add(lblText);

        new Thread(new Runnable() {
            @Override
            public void run() {
                try {
                    while (true) {
                        if (lblText.getText().trim().length() == 0)
                            text = "Welcome";
                        else
                            text = "";

                        Platform.runLater(new Runnable() {
                            @Override
                            public void run() {
                                lblText.setText(text);
                            }
                        });
                    }
                }
            }
        });
    }
}
```

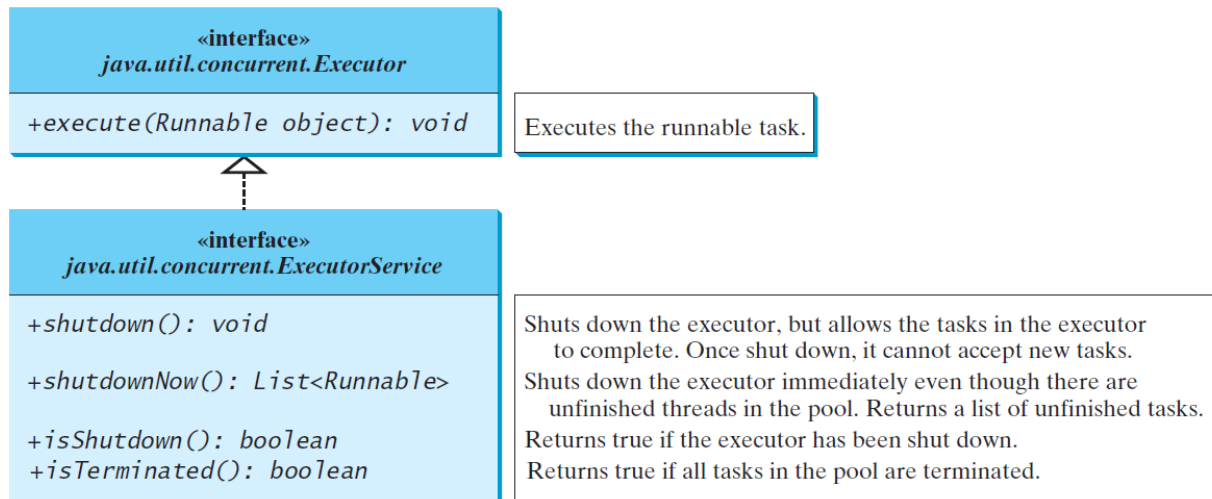
```
        Thread.sleep(200);
    }
}
catch (InterruptedException ex) {
}
}
}).start();

// Create a scene and place it in the stage
Scene scene = new Scene(pane, 200, 50);
primaryStage.setTitle("FlashText"); // stage title
primaryStage.setScene(scene); // Place the scene
primaryStage.show(); // Display the stage
}

/** The main method is only needed for the IDE with
 * limited JavaFX support. Not needed for running
 * from the command line. */
public static void main(String[] args) {
    launch(args);
}
}
```

Thread Pools

- Starting a new thread for each task could limit throughput and cause poor performance. A thread pool is ideal to manage the number of tasks executing concurrently. JDK 1.5 uses the `Executor` interface for executing tasks in a thread pool and the `ExecutorService` interface for managing and controlling tasks. `ExecutorService` is a subinterface of `Executor`.



Creating Executors

- To create an Executor object, use the static methods in the Executors class.

java.util.concurrent.Executors

```
+newFixedThreadPool(numberOfThreads:  
int): ExecutorService
```

```
+newCachedThreadPool():  
ExecutorService
```

Creates a thread pool with a fixed number of threads executing concurrently. A thread may be reused to execute another task after its current task is finished.

Creates a thread pool that creates new threads as needed, but will reuse previously constructed threads when they are available.

```
import java.util.concurrent.*;  
  
public class ExecutorDemo {  
    public static void main(String[] args) {  
        // Create a fixed thread pool with maximum three threads  
        ExecutorService executor = Executors.newFixedThreadPool(3);  
  
        // Submit runnable tasks to the executor  
        executor.execute(new PrintChar('a', 100));  
        executor.execute(new PrintChar('b', 100));  
        executor.execute(new PrintNum(100));  
  
        // Shut down the executor  
        executor.shutdown();  
    }  
}
```

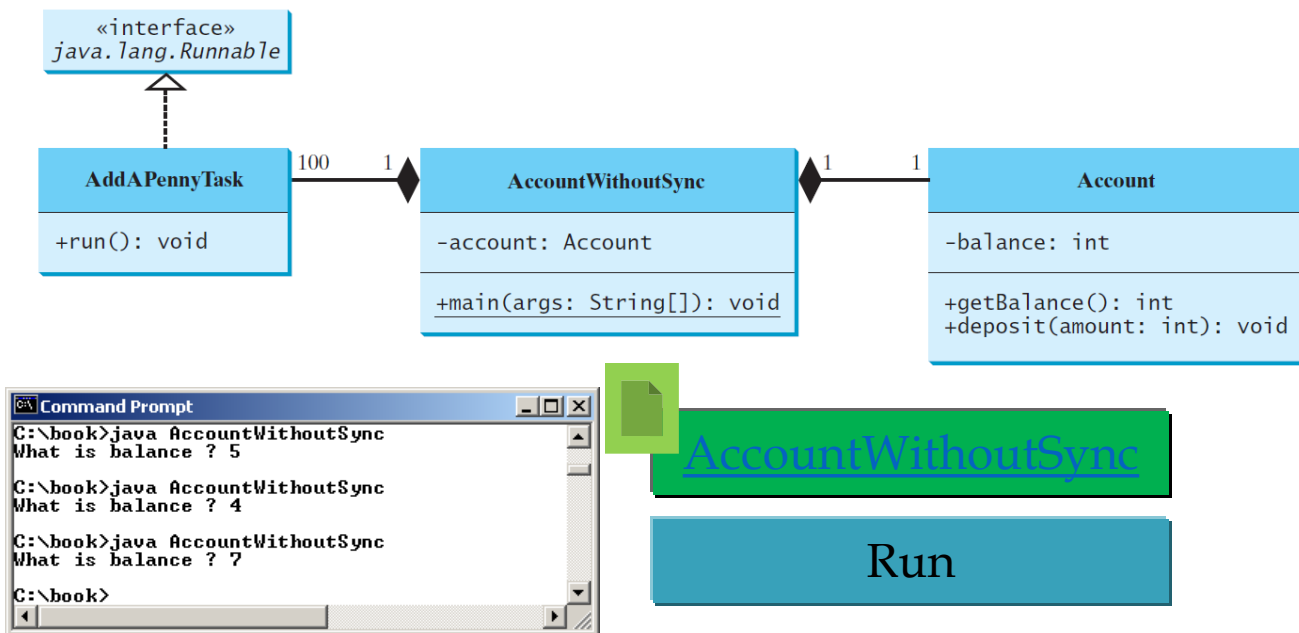
Thread Synchronization

- A shared resource may be corrupted if it is accessed simultaneously by multiple threads. For example, two unsynchronized threads accessing the same bank account may cause conflict.

Step	balance	thread[i]	thread[j]
1	0	<code>newBalance = bank.getBalance() + 1;</code>	
2	0		<code>newBalance = bank.getBalance() + 1;</code>
3	1	<code>bank.setBalance(newBalance);</code>	
4	1		<code>bank.setBalance(newBalance);</code>

Example: Showing Resource Conflict

- Objective: Write a program that demonstrates the problem of resource conflict. Suppose that you create and launch one hundred threads, each of which adds a penny to an account. Assume that the account is initially empty.



Race Condition

- What, then, caused the error in the example? Here is a possible scenario:

Step	balance	Task 1	Task 2
1	0	newBalance = balance + 1;	
2	0		newBalance = balance + 1;
3	1	balance = newBalance;	
4	1		balance = newBalance;

- The effect of this scenario is that Task 1 did nothing, because in Step 4 Task 2 overrides Task 1's result.
- Obviously, the problem is that Task 1 and Task 2 are accessing a common resource in a way that causes conflict.
- This is a common problem known as a *race condition* in multithreaded programs.
- A class is said to be *thread-safe* if an object of the class does not cause a race condition in the presence of multiple threads.
- As demonstrated in the preceding example, the Account class is not thread-safe.

The synchronized keyword

- To avoid race conditions, more than one thread must be prevented from simultaneously entering certain part of the program, known as critical region.
- The critical region in the Listing 30.5 is the entire deposit method.
- You can use the synchronized keyword to synchronize the method so that only one thread can access the method at a time.
- There are several ways to correct the problem in Listing 30.5, one approach is to make Account thread-safe by adding the synchronized keyword in the deposit method in Line 45 as follows:

```
public synchronized void deposit(double amount)
```

Synchronizing Instance Methods and Static Methods

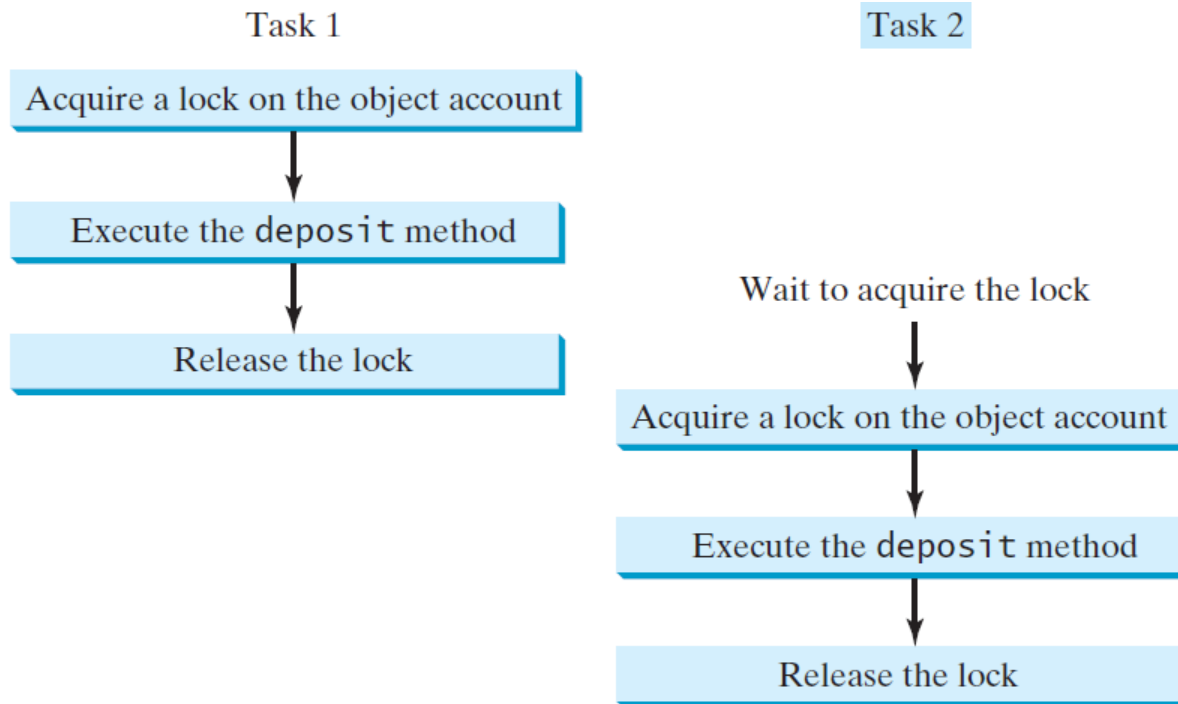
- A synchronized method acquires a lock before it executes. In the case of an instance method, the lock is on the object for which the method was invoked.
- In the case of a static method, the lock is on the class. If one thread invokes a synchronized instance method (respectively, static method) on an object, the lock of that object (respectively, class) is acquired first, then the method is executed, and finally the lock is released.
- Another thread invoking the same method of that object (respectively, class) is blocked until the lock is released.

Synchronizing Instance Methods and Static Methods

- With the deposit method synchronized, the preceding scenario cannot happen. If Task 2 starts to enter the method, and Task 1 is already in the method, Task 2 is blocked until Task 1 finishes the method.

Step	Balance	Task 1	Task 2
1	0	<code>newBalance = balance + 1;</code>	
2	0		<code>newBalance = balance + 1;</code>
3	1	<code>balance = newBalance;</code>	
4	1		<code>balance = newBalance;</code>

Synchronizing Tasks



Synchronizing Statements

- Invoking a synchronized instance method of an object acquires a lock on the object, and invoking a synchronized static method of a class acquires a lock on the class.
- A synchronized statement can be used to acquire a lock on any object, not just *this* object, when executing a block of the code in a method.
- This block is referred to as a *synchronized block*. The general form of a synchronized statement is as follows:

```
synchronized (expr) {  
    statements;  
}
```

- The expression *expr* must evaluate to an object reference.
- If the object is already locked by another thread, the thread is blocked until the lock is released.
- When a lock is obtained on the object, the statements in the synchronized block are executed, and then the lock is released.

Synchronizing Statements vs. Methods

Any synchronized instance method can be converted into a synchronized statement. Suppose that the following is a synchronized instance method:

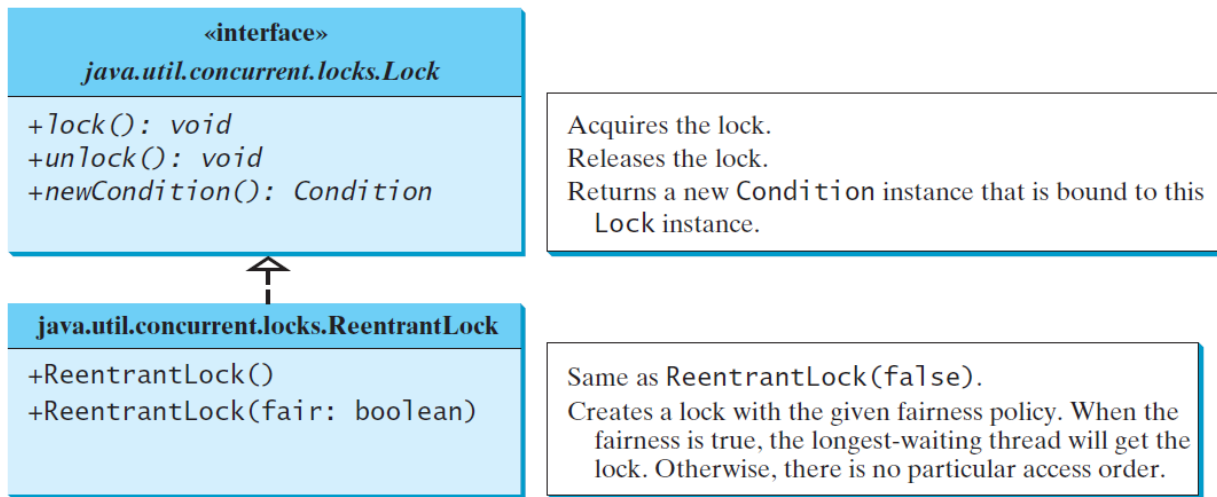
```
public synchronized void xMethod() {  
    // method body  
}
```

This method is equivalent to

```
public void xMethod() {  
    synchronized (this) {  
        // method body  
    }  
}
```


Synchronization Using Locks

- A synchronized instance method implicitly acquires a lock on the instance before it executes the method.
- JDK 1.5 enables you to use locks explicitly.
 - The new locking features are flexible and give you more control for coordinating threads
 - A lock is an instance of the Lock interface, which declares the methods for acquiring and releasing locks
 - A lock may also use the [newCondition\(\)](#) method to create any number of Condition objects, which can be used for thread communications



Fairness Policy

- **ReentrantLock** is a concrete implementation of Lock for creating mutual exclusive locks.
- You can create a lock with the specified fairness policy.
- True fairness policies guarantee the **longest wait** thread to obtain the lock first.
- **False fairness** policies grant a lock to a waiting thread without any access order.
- Programs using fair locks accessed by many threads may have **poor overall performance** than those using the default setting, but have **smaller variances** in times to obtain locks and guarantee lack of starvation.

Example: Using Locks (AccountWithSyncUsingLock.java)

```
public class AccountWithSyncUsingLock {
    private static Account account = new Account();

    public static void main(String[] args) {
        ExecutorService executor =
Executors.newCachedThreadPool();

        // Create and launch 100 threads
        for (int i = 0; i < 100; i++) {
            executor.execute(new AddAPennyTask());
        }

        executor.shutdown();

        // Wait until all tasks are finished
        while (!executor.isTerminated()) {
        }

        System.out.println("What is balance ? " +
            account.getBalance());
    }

    // A thread for adding a penny to the account
    public static class AddAPennyTask implements Runnable {
        public void run() {
            account.deposit(1);
        }
    }
}
```

```
public static class Account {
    private static Lock lock = new ReentrantLock();
    private int balance = 0;

    public int getBalance() {
        return balance;
    }

    public void deposit(int amount) {
        lock.lock(); // Acquire the lock

        try {
            int newBalance = balance + amount;

            // This delay is added to magnify the
            // data-corruption problem.
            Thread.sleep(5);

            balance = newBalance;
        }
        catch (InterruptedException ex) {
        }
        finally {
            lock.unlock(); // Release the lock
        }
    }
}
```

Cooperation Among Threads

- The **conditions** can be used to facilitate communications among threads
- A thread can specify what to do under a certain condition
- Conditions are objects created by invoking the `newCondition()` method on a `Lock` object
- Once a condition is created, you can use its `await()`, `signal()`, and `signalAll()` methods for thread communications
- The `await()` method causes the current thread to wait until the condition is signaled
- The `signal()` method wakes up one waiting thread, and the `signalAll()` method wakes all waiting threads

«interface»

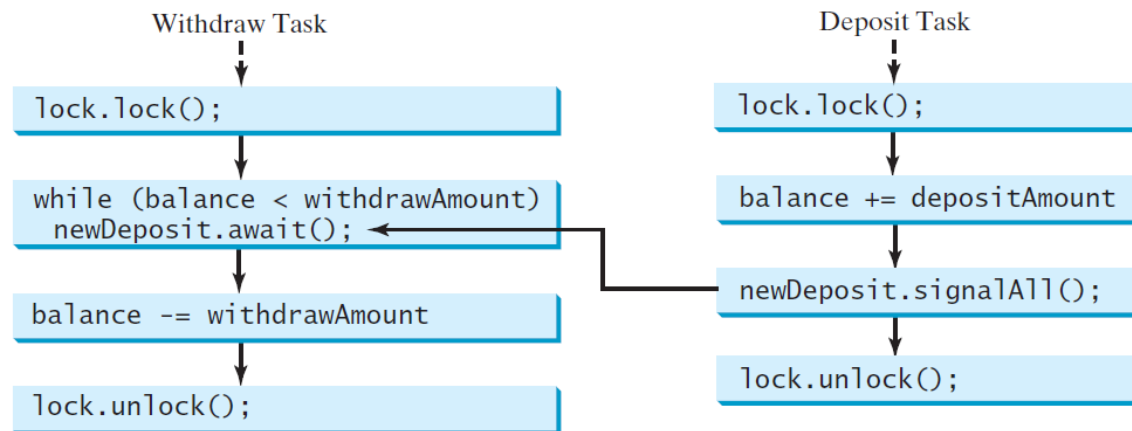
java.util.concurrent.Condition

```
+await(): void  
+signal(): void  
+signalAll(): Condition
```

Causes the current thread to wait until the condition is signaled.
Wakes up one waiting thread.
Wakes up all waiting threads.

Cooperation Among Threads

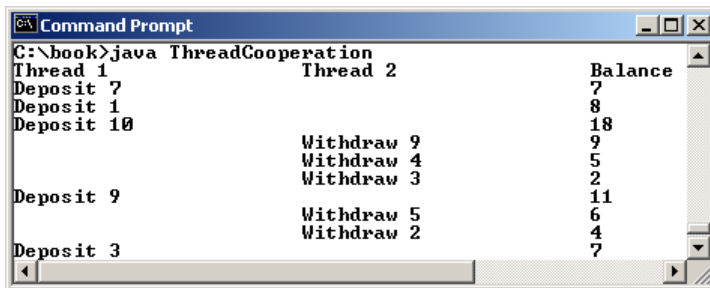
- To synchronize the operations, use a lock with a condition: newDeposit (i.e., new deposit added to the account).
- If the balance is less than the amount to be withdrawn, the withdraw task will wait for the newDeposit condition.
- When the deposit task adds money to the account, the task signals the waiting withdraw task to try again.



Example: Thread Cooperation

- Write a program that demonstrates thread cooperation.
- Suppose that you create and launch two threads, one deposits to an account, and the other withdraws from the same account.
- The second thread has to wait if the amount to be withdrawn is more than the current balance in the account.
- Whenever new fund is deposited to the account, the first thread notifies the second thread to resume.
- If the amount is still not enough for a withdrawal, the second thread has to continue to wait for more fund in the account.
- Assume the initial balance is 0 and the amount to deposit and to withdraw is randomly generated.

<https://liveexample.pearsoncmg.com/html/ThreadCooperation.html>



```
Command Prompt
C:\book>java ThreadCooperation
Thread 1          Thread 2          Balance
Deposit 7         Withdraw 9         7
Deposit 1         Withdraw 4         8
Deposit 10        Withdraw 3         18
                  Withdraw 5         9
                  Withdraw 2         5
Deposit 9         Withdraw 3         2
                  Withdraw 5         11
Deposit 3         Withdraw 2         6
                  Withdraw 2         4
                  Withdraw 2         7
```

Java's Built-in Monitors (Optional)

- Locks and conditions are new in Java 5. Prior to Java 5, thread communications are programmed using object's built-in monitors.
 - Locks and conditions are more powerful and flexible than the built-in monitor.
 - For this reason, this section can be completely ignored.
 - However, if you work with legacy Java code, you may encounter the Java's built-in monitor.
- A *monitor* is an object with mutual exclusion and synchronization capabilities.
 - Only one thread can execute a method at a time in the monitor.
 - A thread enters the monitor by acquiring a lock on the monitor and exits by releasing the lock.
 - *Any object can be a monitor.*
 - An object becomes a monitor once a thread locks it.
 - Locking is implemented using the synchronized keyword on a method or a block.
 - A thread must acquire a lock before executing a synchronized method or block.
 - A thread can wait in a monitor if the condition is not right for it to continue executing in the monitor.

wait(), notify(), and notifyAll()

- Use the wait(), notify(), and notifyAll() methods to facilitate communication among threads.
- The wait(), notify(), and notifyAll() methods must be called in a synchronized method or a synchronized block on the calling object of these methods. Otherwise, an IllegalMonitorStateException would occur.
- The wait() method lets the thread wait until some condition occurs. When it occurs, you can use the notify() or notifyAll() methods to notify the waiting threads to resume normal execution. The notifyAll() method wakes up all waiting threads, while notify() picks up only one thread from a waiting queue.

Example: Using Monitor

Task 1

```
synchronized (anObject) {  
    try {  
        // Wait for the condition to become true  
        while (!condition)  
            anObject.wait();  
        // Do something when condition is true  
    }  
    catch (InterruptedException ex) {  
        ex.printStackTrace();  
    }  
}
```

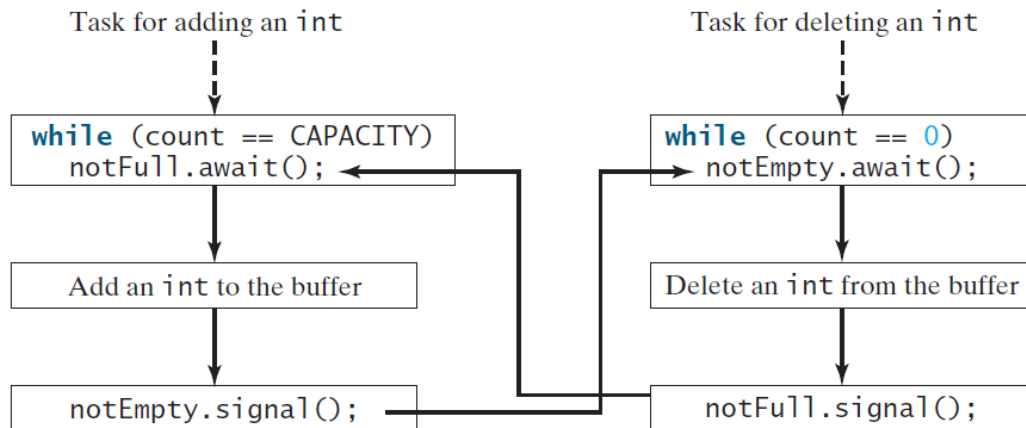
Task 2

```
synchronized (anObject) {  
    // When condition becomes true  
    anObject.notify(); or anObject.notifyAll();  
    ...  
}
```

- The `wait()`, `notify()`, and `notifyAll()` methods must be called in a synchronized method or a synchronized block on the receiving object of these methods. Otherwise, an `IllegalMonitorStateException` will occur.
- When `wait()` is invoked, it pauses the thread and simultaneously releases the lock on the object. When the thread is restarted after being notified, the lock is automatically reacquired.
- The `wait()`, `notify()`, and `notifyAll()` methods on an object are analogous to the `await()`, `signal()`, and `signalAll()` methods on a condition.

Case Study: Producer/Consumer (Optional)

- Consider the classic Consumer/Producer example.
- Suppose you use a buffer to store integers.
- The buffer size is limited. The buffer provides the method `write(int)` to add an `int` value to the buffer and the method `read()` to read and delete an `int` value from the buffer.
- To synchronize the operations, use a lock with two conditions: `notEmpty` (i.e., buffer is not empty) and `notFull` (i.e., buffer is not full).
- When a task adds an `int` to the buffer, if the buffer is full, the task will wait for the `notFull` condition.
- When a task deletes an `int` from the buffer, if the buffer is empty, the task will wait for the `notEmpty` condition.



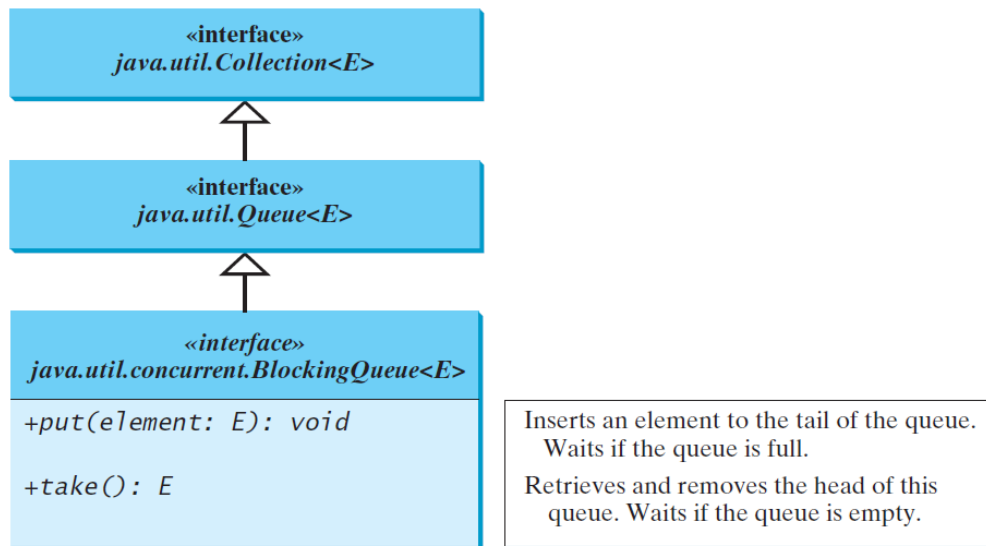
Case Study: Producer/Consumer (Optional)

<https://liveexample.pearsoncmg.com/html/ConsumerProducer.html>

- Listing above presents the complete program. The program contains the Buffer class (lines 50-101) and two tasks for repeatedly producing and consuming numbers to and from the buffer (lines 16-47). The write(int) method (line 62-79) adds an integer to the buffer. The read() method (line 81-100) deletes and returns an integer from the buffer.
- For simplicity, the buffer is implemented using a linked list (lines 52-53). Two conditions notEmpty and notFull on the lock are created in lines 59-60. The conditions are bound to a lock. A lock must be acquired before a condition can be applied. If you use the wait() and notify() methods to rewrite this example, you have to designate two objects as monitors.

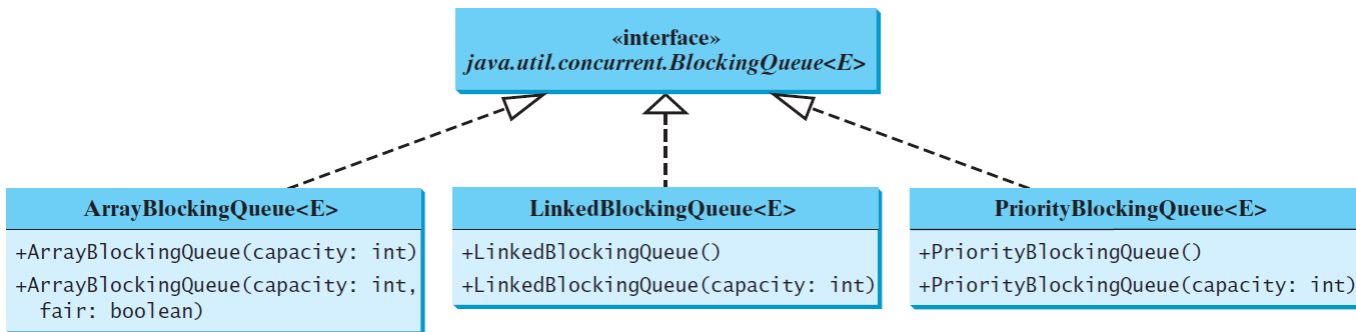
Blocking Queues (Optional)

- Previously we have discussed queues and priority queues.
- A *blocking queue* causes a thread to block when you try to add an element to a full queue or to remove an element from an empty queue.



Concrete Blocking Queues

- Three concrete blocking queues `ArrayBlockingQueue`, `LinkedBlockingQueue`, and `PriorityBlockingQueue` are supported in JDK 1.5.
- All are in the `java.util.concurrent` package.
 - `ArrayBlockingQueue` implements a blocking queue using an array. You have to specify a capacity or an optional fairness to construct an `ArrayBlockingQueue`.
 - `LinkedBlockingQueue` implements a blocking queue using a linked list. You may create an unbounded or bounded `LinkedBlockingQueue`.
 - `PriorityBlockingQueue` is a priority queue. You may create an unbounded or bounded priority queue.



Producer/Consumer Using Blocking Queues

- The program gives an example of using an ArrayBlockingQueue for the Consumer/Producer problem.

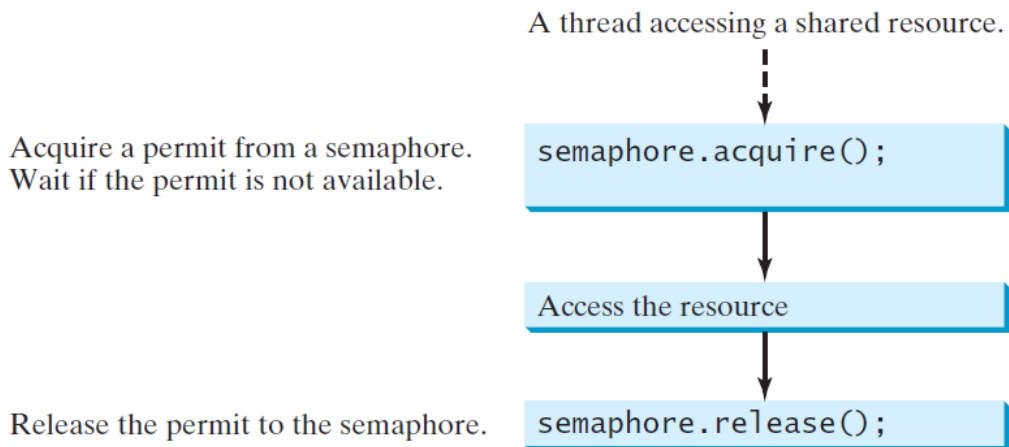
```
import java.util.concurrent.*;
```

```
public class ConsumerProducerUsingBlockingQueue {  
    private static ArrayBlockingQueue<Integer> buffer =  
        new ArrayBlockingQueue<>(2) ;  
  
    public static void main(String[] args) {  
        // Create a thread pool with two threads  
        ExecutorService executor =  
        Executors.newFixedThreadPool(2);  
        executor.execute(new ProducerTask());  
        executor.execute(new ConsumerTask());  
        executor.shutdown();  
    }  
  
    // A task for adding an int to the buffer  
    private static class ProducerTask implements Runnable {  
        public void run() {  
            try {  
                int i = 1;  
                while (true) {  
                    System.out.println("Producer writes " + i);  
                    buffer.put(i++); // Add any value to the buffer  
                    // Put the thread into sleep  
                    Thread.sleep((int) (Math.random() * 10000));  
                }  
            }  
        }  
    }  
}
```

```
        catch (InterruptedException ex) {  
            ex.printStackTrace();  
        }  
    }  
}  
  
    // A task for reading & deleting an int from the buffer  
    private static class ConsumerTask implements Runnable {  
        public void run() {  
            try {  
                while (true) {  
                    System.out.println("\t\t\tConsumer reads " +  
                    buffer.take());  
                    // Put the thread into sleep  
                    Thread.sleep((int) (Math.random() * 10000));  
                }  
            }  
            catch (InterruptedException ex) {  
                ex.printStackTrace();  
            }  
        }  
    }  
}
```

Semaphores (Optional)

- Semaphores can be used to restrict the number of threads that access a shared resource.
 - Before accessing the resource, a thread must acquire a permit from the semaphore.
 - After finishing with the resource, the thread must return the permit back to the semaphore.



Creating Semaphores

- To create a semaphore, you have to specify the number of permits with an optional fairness policy.
- A task acquires a permit by invoking the semaphore's `acquire()` method and releases the permit by invoking the semaphore's `release()` method.
- Once a permit is acquired, the total number of available permits in a semaphore is reduced by 1.
- Once a permit is released, the total number of available permits in a semaphore is increased by 1.

`java.util.concurrent.Semaphore`

```
+Semaphore(numberOfPermits: int)
+Semaphore(numberOfPermits: int, fair:
  boolean)
+acquire(): void
+release(): void
```

Creates a semaphore with the specified number of permits. The fairness policy is false.

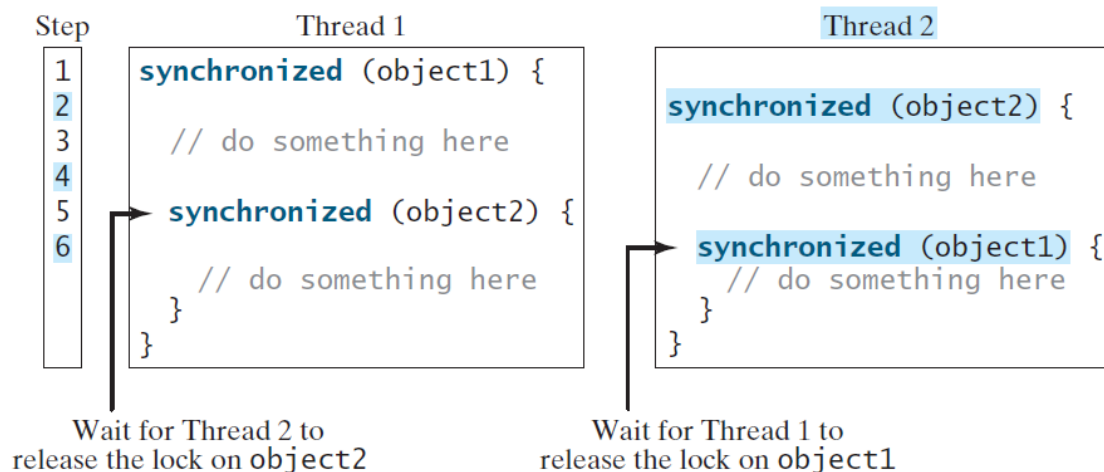
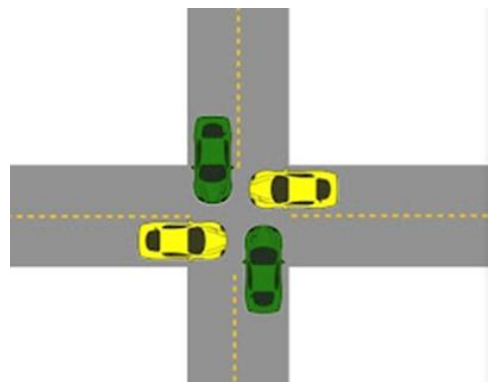
Creates a semaphore with the specified number of permits and the fairness policy.

Acquires a permit from this semaphore. If no permit is available, the thread is blocked until one is available.

Releases a permit back to the semaphore.

Deadlock

- Sometimes two or more threads need to acquire the locks on several shared objects.
 - This could cause *deadlock*, in which each thread has the lock on one of the objects and is waiting for the lock on the other object.
 - Consider the scenario with two threads and two objects. Thread 1 acquired a lock on object1 and Thread 2 acquired a lock on object2.
 - Now Thread 1 is waiting for the lock on object2 and Thread 2 for the lock on object1.
 - The two threads wait for each other to release the in order to get the lock, and neither can continue to run.

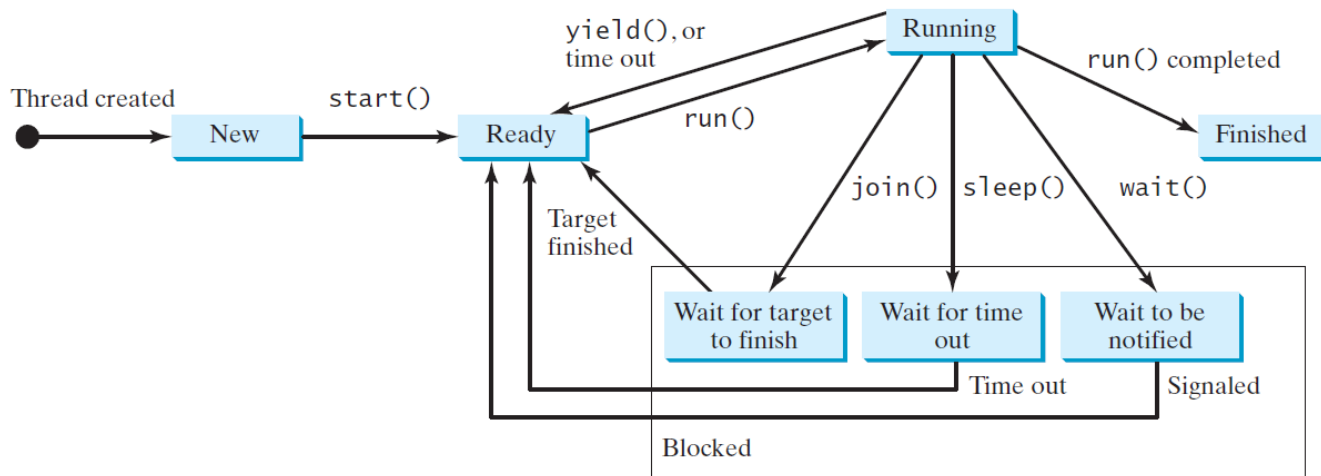


Preventing Deadlock

- Deadlock can be easily avoided by using a simple technique known as resource ordering.
- With this technique, you assign an order on all the objects whose locks must be acquired and ensure that each thread acquires the locks in that order.
- For the example, suppose the objects are ordered as object1 and object2.
 - Using the resource ordering technique, Thread 2 must acquire a lock on object1 first, then on object2.
 - Once Thread 1 acquired a lock on object1, Thread 2 has to wait for a lock on object1.
 - So Thread 1 will be able to acquire a lock on object2 and no deadlock would occur.

Thread States

A thread can be in one of five states: New, Ready, Running, Blocked, or Finished.



Synchronized Collections

- The classes in the Java Collections Framework are not thread-safe, i.e., the contents may be corrupted if they are accessed and updated concurrently by multiple threads. You can protect the data in a collection by locking the collection or using synchronized collections.
- The Collections class provides six static methods for wrapping a collection into a synchronized version. The collections created using these methods are called *synchronization wrappers*.

`java.util.Collections`

```
+synchronizedCollection(c: Collection): Collection  
+synchronizedList(list: List): List  
+synchronizedMap(m: Map): Map  
+synchronizedSet(s: Set): Set  
+synchronizedSortedMap(s: SortedMap): SortedMap  
+synchronizedSortedSet(s: SortedSet): SortedSet
```

Returns a synchronized collection.

Returns a synchronized list from the specified list.

Returns a synchronized map from the specified map.

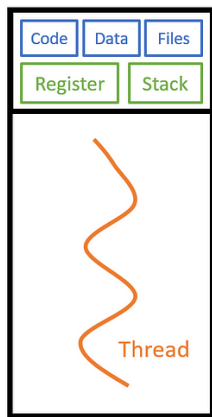
Returns a synchronized set from the specified set.

Returns a synchronized sorted map from the specified sorted map.

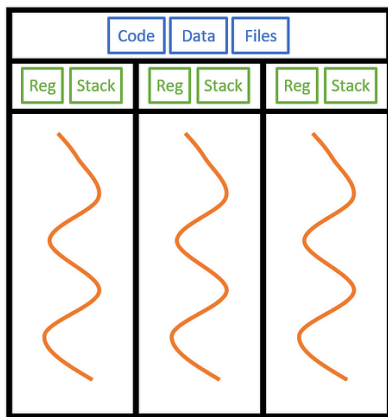
Returns a synchronized sorted set.

The Fork/Join Framework

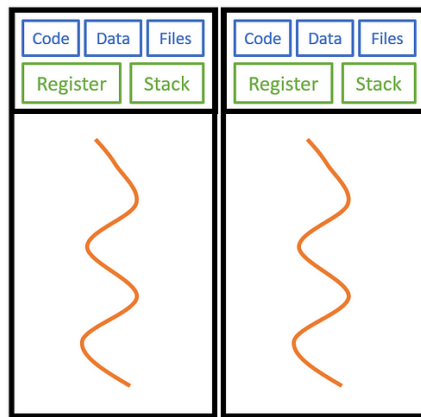
- The widespread use of multicore systems has created a revolution in software. In order to benefit from multiple processors, software needs to run in parallel.
- JDK 7 introduces the new Fork/Join Framework for parallel programming, which utilizes the multicore processors.



Single Processor Single Thread



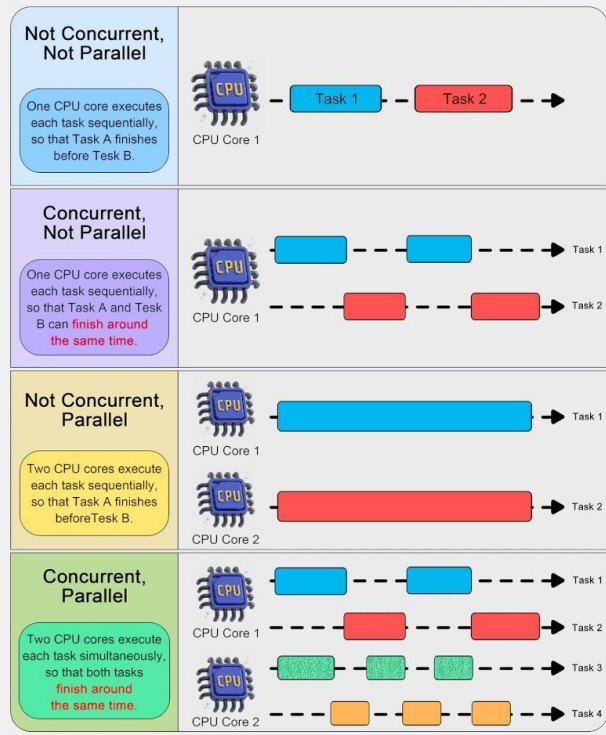
Single Processor Multithread



Multiprocessing

Concurrency is **Not** Parallelism

ByteByteGo



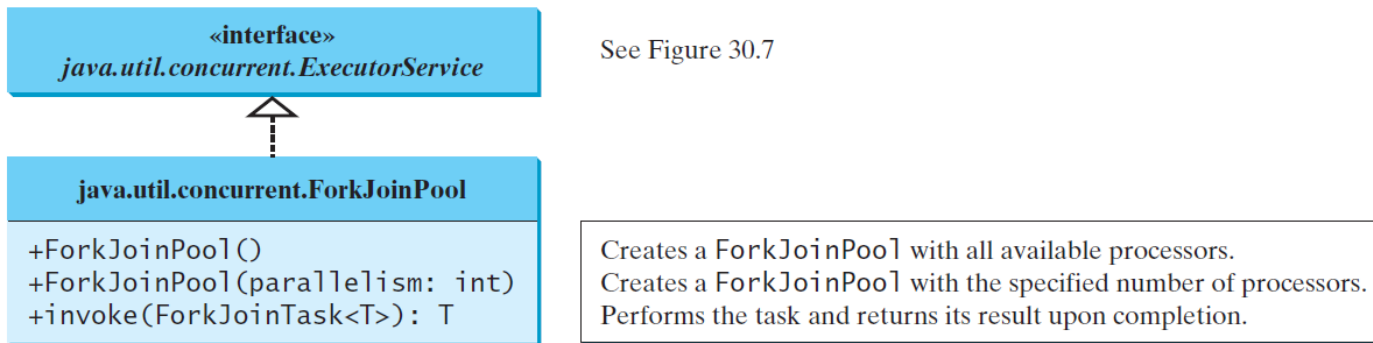
The Fork/Join Framework

- The Fork/Join Framework is used for parallel programming in Java.
- In JDK 7's Fork/Join Framework, a *fork* can be viewed as an independent task that runs on a thread.

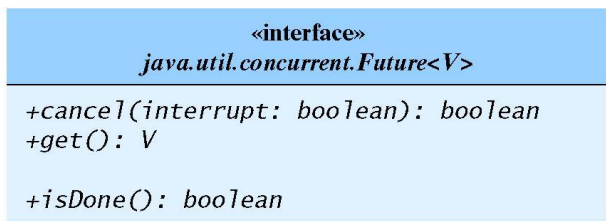


ForkJoinTask and ForkJoinPool

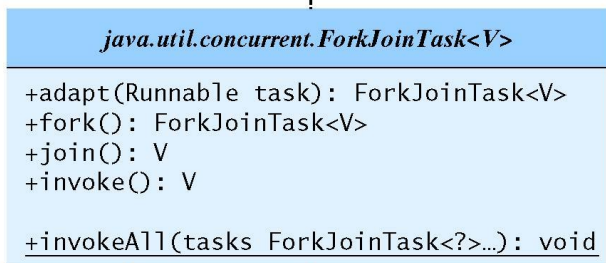
- The framework defines a task using the **ForkJoinTask** class, and executes a task in an instance of **ForkJoinPool**.



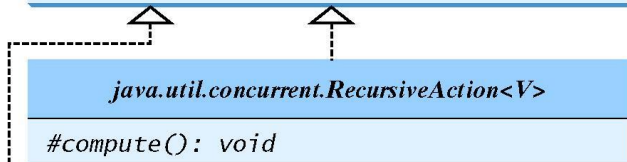
ForkJoinTask



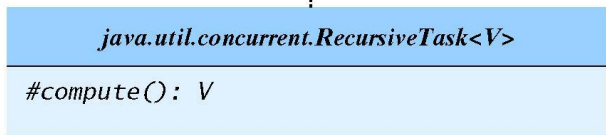
Attempts to cancel this task.
Waits if needed for the computation to complete and returns the result.
Returns true if this task is completed.



Returns a ForkJoinTask from a runnable task.
Arranges asynchronous execution of the task.
Returns the result of computations when it is done.
Performs the task and awaits for its completion, and returns its result.
Forks the given tasks and returns when all tasks are completed.



Defines how task is performed.



Defines how task is performed. Return the value after the task is completed.

.:END:.