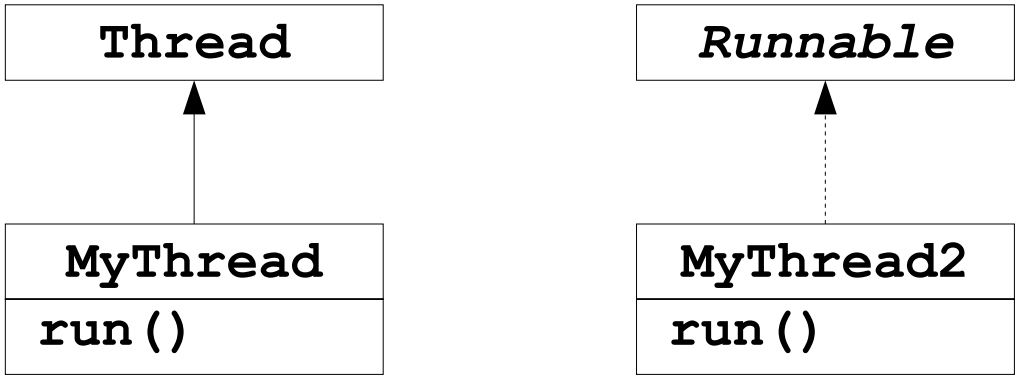
Concurrency

- Advantages and disadvantages of threads
- Java threads
  - Class **`java.lang.Thread`**
  - Interface **`java.lang.Runnable`**
- Also called *multithreaded* programming



Thread

- *Definition*: A thread is a single sequential flow of control within a program (also called *lightweight process*).

- Each thread acts like its own sequential program
  - Underlying mechanism divides up CPU between multiple threads.

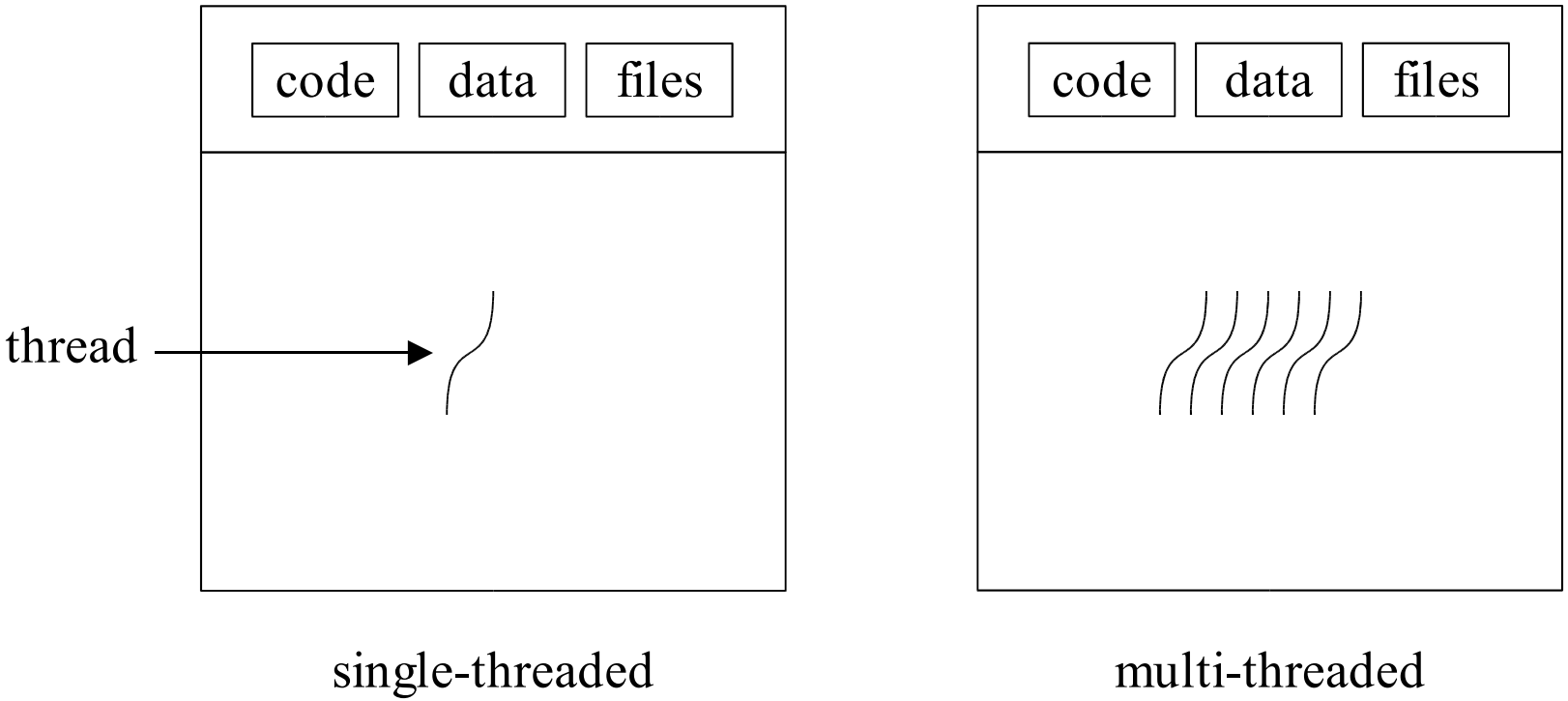
- Two types of multithreaded applications
  - Make many threads that do many tasks in parallel, i.e., no communication between the threads (GUI).
  - Make many threads that do many tasks concurrently, i.e., communication between the threads (data access).

Advantages and disadvanteages

- Advantages
  - Responsiveness, e.g., of user interfaces
  - Resource sharing
  - Economy
  - Utilization of multiprocessor hardware architectures

- Disadvantages
  - More complicated code
  - Deadlocks (very hard to debug logical program errors)

Single and Multithreaded Processes



single-threaded

multi-threaded

User and Kernel Threads

- Thread management done by user-level threads library.
  - Examples
    - POSIX *Pthreads* (e.g., Linux and NT)
    - Mach *C-threads* (e.g., MacOS and NeXT)
    - Solaris *threads*
- Supported by the kernel
  - Examples
    - Windows 95/98/NT/2000/XP
    - Solaris
    - TRU64 (one of HP's UNIX)

Java Threads

- Java threads may be created by
  - Extending **`Thread`** class
  - Implementing the **`Runnable`** interface

Class **`Thread`**

- The simplest way to make a thread
- Treats a thread as an object
- Override the **`run()`** method, i.e., the thread's "main"
  - Typically a loop
  - Continues for the life of the thread
- Create **`Thread`** object, call method **`start()`**
- Performs initialization, call method **`run()`**
- Thread terminates when **`run()`** exits.

Extending the **Thread** Class

```
class Worker extends Thread {
   public void run() {
       System.out.println("I\'m a worker thread");
    } // thread is dead
}


public class First{
    public static void main (String args[]){
          Worker runner = new Worker();
          runner.start();
          System.out.println("I\'m the main thread");
    } // main thread alive until all children are dead
}
```

Extending the **`Thread`** Class, cont.

```
class SimpleThread extends Thread {
   public SimpleThread(String str) {
         super(str);
     }
     public void run() {
         for (int i = 0; i < 10; i++) {
             System.out.println(i + " " + getName());
             try {
                 sleep((long)(Math.random() * 1000));
             } catch (InterruptedException e) {}
         }
         System.out.println("DONE! " + getName());
     }
}
public class TwoThreadsDemo {
   public static void main (String[] args) {
   new SimpleThread("Jamaica").start();
   new SimpleThread("Fiji").start();
   }
}
```

[Source: java.sun.com]

Sharing Resources

- *Single threaded programming*: you own everything, no problem with sharing
- *Multi-threaded programming*: more than one thread may try to use a shared resource at the same time
  - Add and withdraw from a bank account
  - Using the speakers at the same time, etc.

- Java provides locks, i.e., monitors, for objects, so you can wrap an object around a ressource
  - First thread that acquires the lock gains control of the object, and the other threads cannot call synchronized methods for that object.

Locks

- One lock pr. object for the object's methods.
- One lock pr. class for the class' static methods.

- Typically data is private, only accessed through methods.
  - Must be private to be protected against concurrent access
- If a method is synchronized, entering that method acquires the lock.
  - No other thread can call *any* synchronized method for that object until the lock is released.

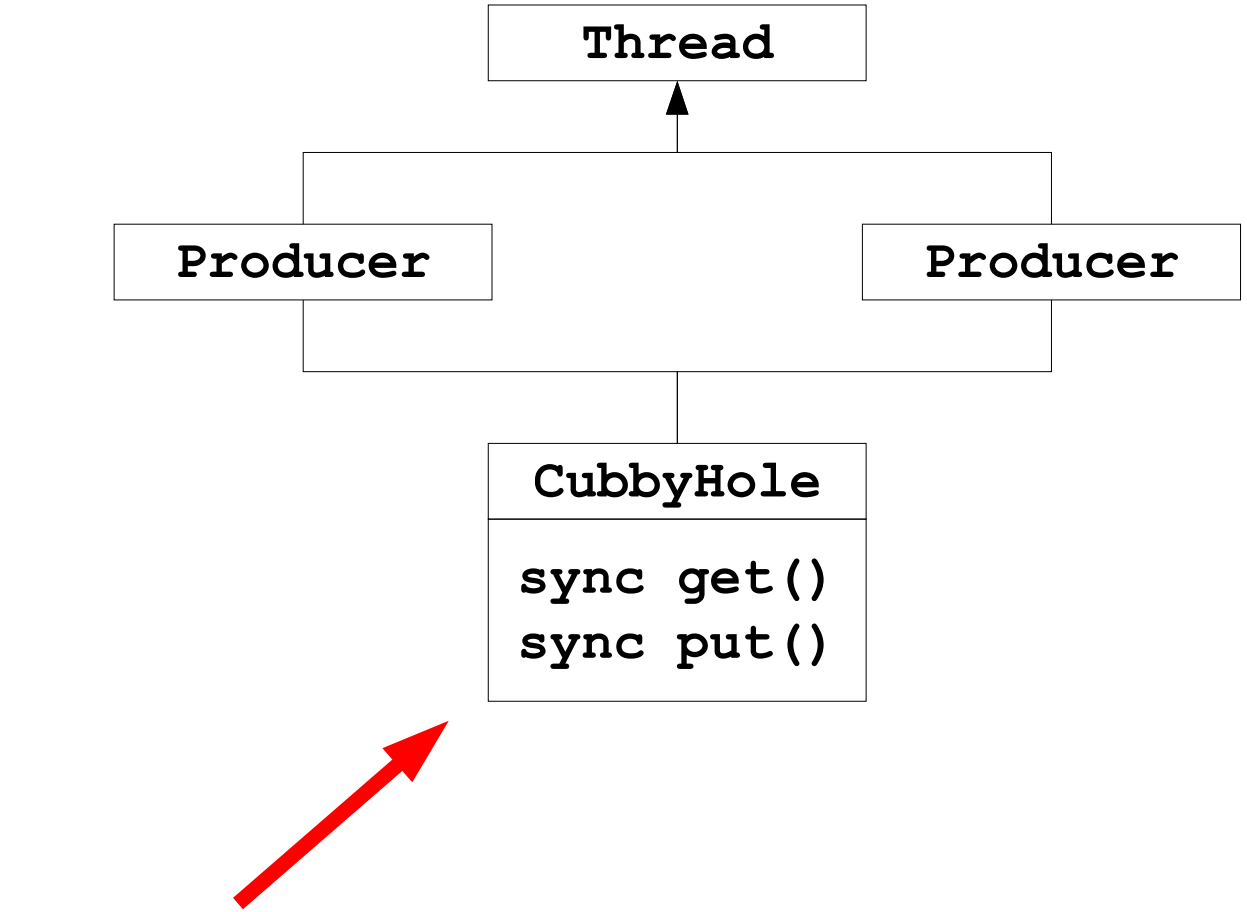
Sharing Resources, cont.

- Only one synchronized method can be called at any time for a particular object

```
synchronized void foo() {/*..*/}
synchronized void bar() {/*..*/}
```

- Efficiency
  - Memory: Each object has a lock implemented in **`Object`**
  - Speed: JavaSoft: 6x method call overhead. Theoretical minimum 4x overhead
    - Older standard Java libraries used synchronized a lot, did not provide any alternatives.

Sharing Resources, Example



Sharing Resources, Example cont.

```
public class CubbyHole {
   private int contents;
   private boolean available = false;
   public synchronized int get() {
       while (available == false) {
              try { wait(); } ... }
       available = false;
       notifyAll();
       return contents;
   }
   public synchronized void put(int value) {
       while (available == true) {
              try { wait(); ...} }
       contents = value;
       available = true;
       notifyAll();
   }
}
```

Sharing Resources, Example cont.

```
public class Producer extends Thread {
   private CubbyHole cubbyhole;
   private int number;
   public Producer(CubbyHole c, int number) {
       cubbyhole = c;
       this.number = number;     }
   public void run() {
       for (int i = 0; i < 10; i++) {
         cubbyhole.put(i);
       System.out.println(
       "Producer #" + this.number + " put: " + i);
       try {sleep((int)(Math.random() * 100));
       } catch (InterruptedException e) { } }
   }
}
```

Sharing Resources, Example cont.

```
public class Consumer extends Thread {
   private CubbyHole cubbyhole;
   private int number;
   public Consumer(CubbyHole c, int number) {
       cubbyhole = c;
       this.number = number;
   }
   public void run() {
       int value = 0;
       for (int i = 0; i < 10; i++) {
         value = cubbyhole.get();
         System.out.println(
          "Consumer #" + this.number + " got: " + value);
       }
   }
}
```

Sharing Resources, Example cont.

```
public class ProducerConsumerTest {
   public static void main(String[] args) {
       CubbyHole c = new CubbyHole();
       Producer p1 = new Producer(c, 1);
       Consumer c1 = new Consumer(c, 1);
       p1.start();
       c1.start();
   }
}
```

The **`Runnable`** Interface

- To inherit from an exising object and make it a thread, implement the **`Runnable`** interface.
- A more classical, function-oriented way to use threads.

- *Rule of Thumb:* If your class must subclass some other class (the most common example being **`Applet`**), you should use **`Runnable`**.

```
public interface Runnable{
   public abstract void run();
}
```

The **Runnable** Interface, cont.

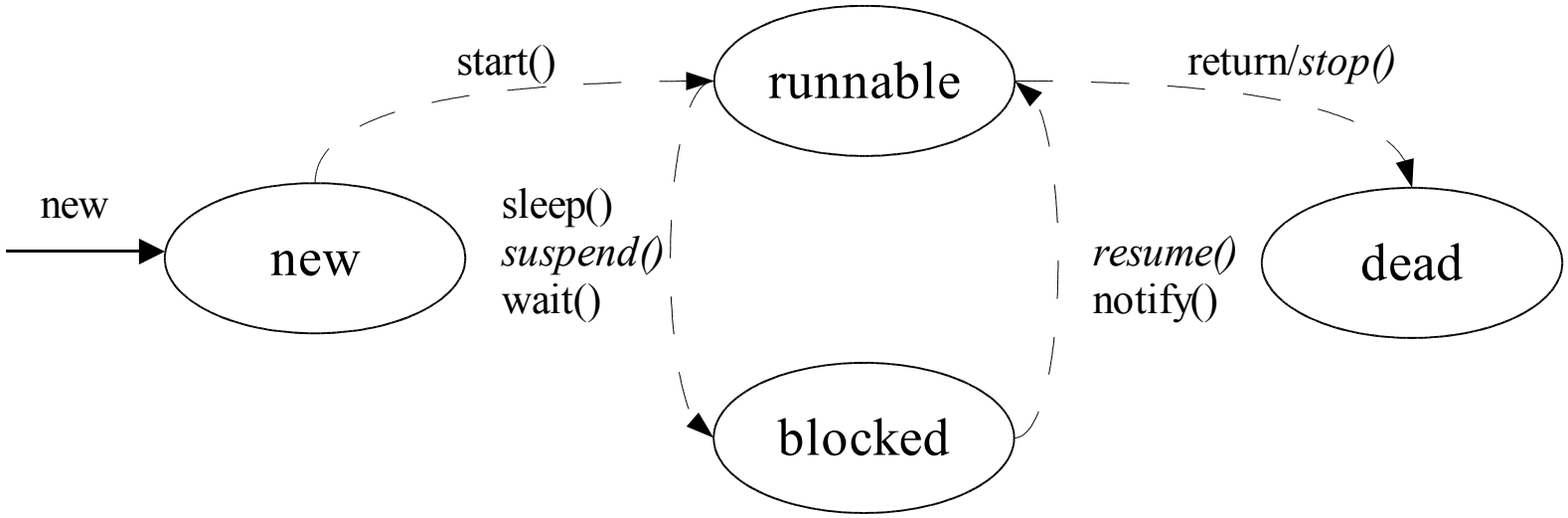
```
class Worker implements Runnable{
   public void run(){
       System.out.println("I\'m a worker thread");
   }
}

public class Second{
    public static void main(String args[]) {
          Runnable runner = new Worker();
          Thread thrd = new Thread(runner);
          thrd.start();
          System.out.println("I\'m the main thread");
    }
}
```

The **Runnable** Interface, cont.

```
class SimpleRunnable implements Runnable {
   private String myName;    private Thread t;
   SimpleRunnable (String name) {
        myName = name; t = new Thread(this); t.start();
   }
   public void run() {
        for (int i = 0; i < 10; i++) {
           System.out.println(i + " " + myName);
           try {
                t.sleep((long)(Math.random() * 1000));
             } catch (InterruptedException e) {}
         }
         System.out.println("DONE! " + myName);
     }
}
public class TwoRunnableDemo {
   public static void main (String[] args)
   {        SimpleRunnable runner1 = new SimpleRunnable
   ("Jamaica");         SimpleRunnable runner2 = new
   SimpleRunnable("Fiji");     }
}
```

Java Thread Management

- *suspend()* – suspends execution of the currently running thread.
- *sleep()* – puts the currently running thread to sleep for a specified amount of time.
- *resume()* – resumes execution of a suspended thread.
- *stop()* – stops execution of a thread.



Synchronized Fields and Constructors

- Class or object fields cannot be synchronized.

```
public class DataFields{
  /** A synchronized object field not allowed */
  private synchronized int x;
  /** A synchronized class field not allowed */
  public static synchronized int y;
}
```

- Constructors cannot be synchronized.

```
public class DataFields{
  public synchronized DataFields(){// not allowed }
  public static synchronized void staticMethod(){
    System.out.println("I'm in sync"); // allowed
  }
}
```

Other Issues

- Thread priority
- Thread groups
- Daemon (unix term)
  - similar to a service (on Win32)
- Deadlock
  - Very hard to detect logical errors in programs

Deadlocks

```
public class TwoResources {
   private int contentsA = 10;
   private int contentsB = 20;
   private boolean availableA = true;
   private boolean availableB = true;
   public synchronized int getA() {
       while (availableA == false) {
             try { wait(); } ... }
       // snip see CubbyHole
}
   public synchronized void putA(int value) {
       while (availableA == true) {
             try { wait(); ...} }
       // snip see CubbyHole
   }
    // ditto for B resource
}
```

Deadlocks, cont.

```
public class TRConsumer extends Thread {
  // start thread in constructor
  private TwoResources tr;
  public void getAthenB(){
    int a = tr.getA();  sleepy(2000);
    int b = tr.getB();
  }
  public void getBthenA(){
    int b = tr.getB(); sleepy(2000);
    int a = tr.getA();
  }
  public static void createDeadlock(){
    TwoResources tr = new TwoResources();
    TRConsumer one = new TRConsumer(tr, "A"); // A B
    TRConsumer two = new TRConsumer(tr, "B"); // B A
  }
}
```

Summary

- *Single-threaded programming*: live by all by your self, own everything, no contention for resources.

- *Multithreading programming*: suddenly ”others” can have collisions and destroy information, get locked up over the use of resources.

- Multithreading is built-into the Java programming language.
- Multithreading makes Java programs complicated
  - Multithreading is by nature difficult, e.g., deadlocks.

Solaris 2 Threads