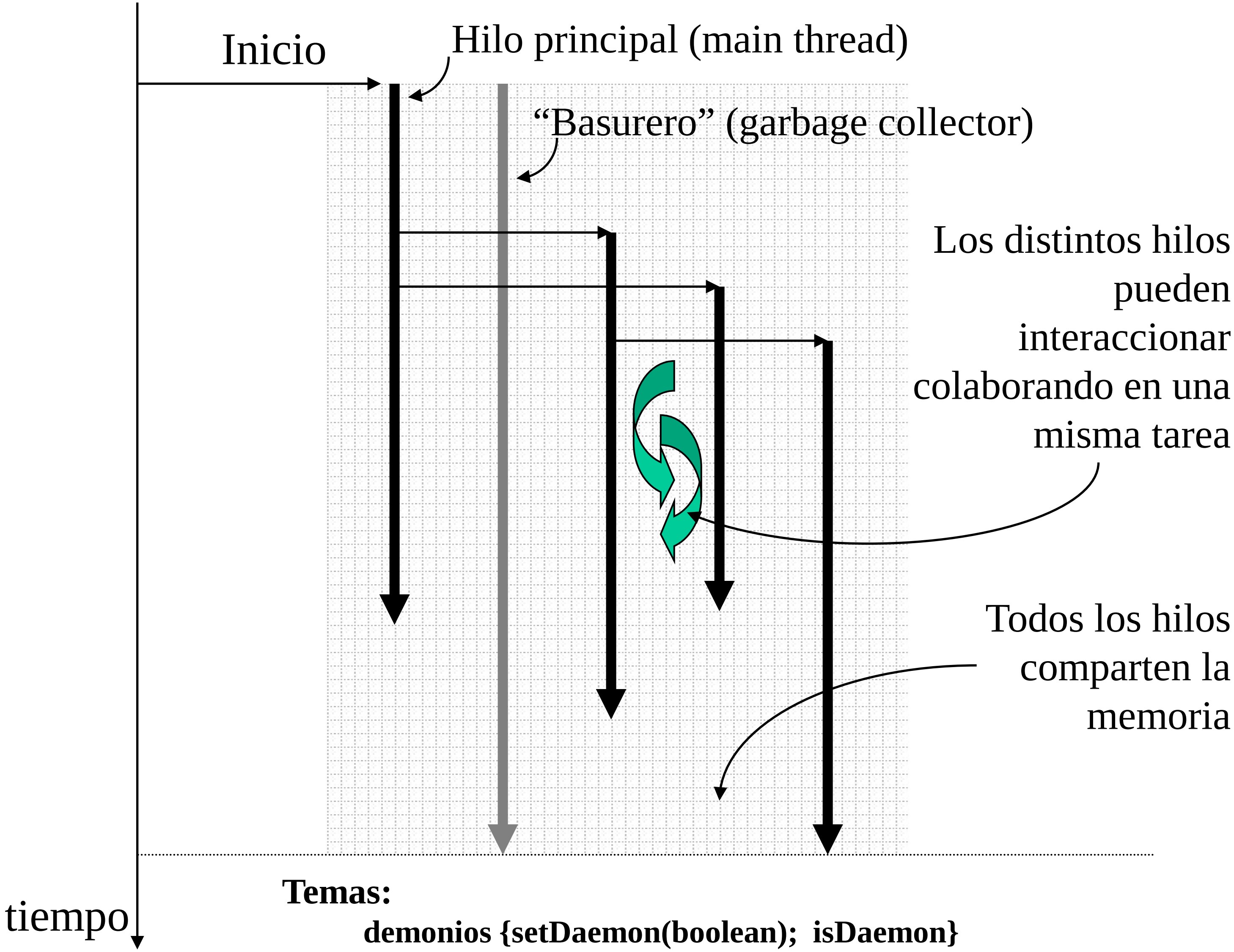
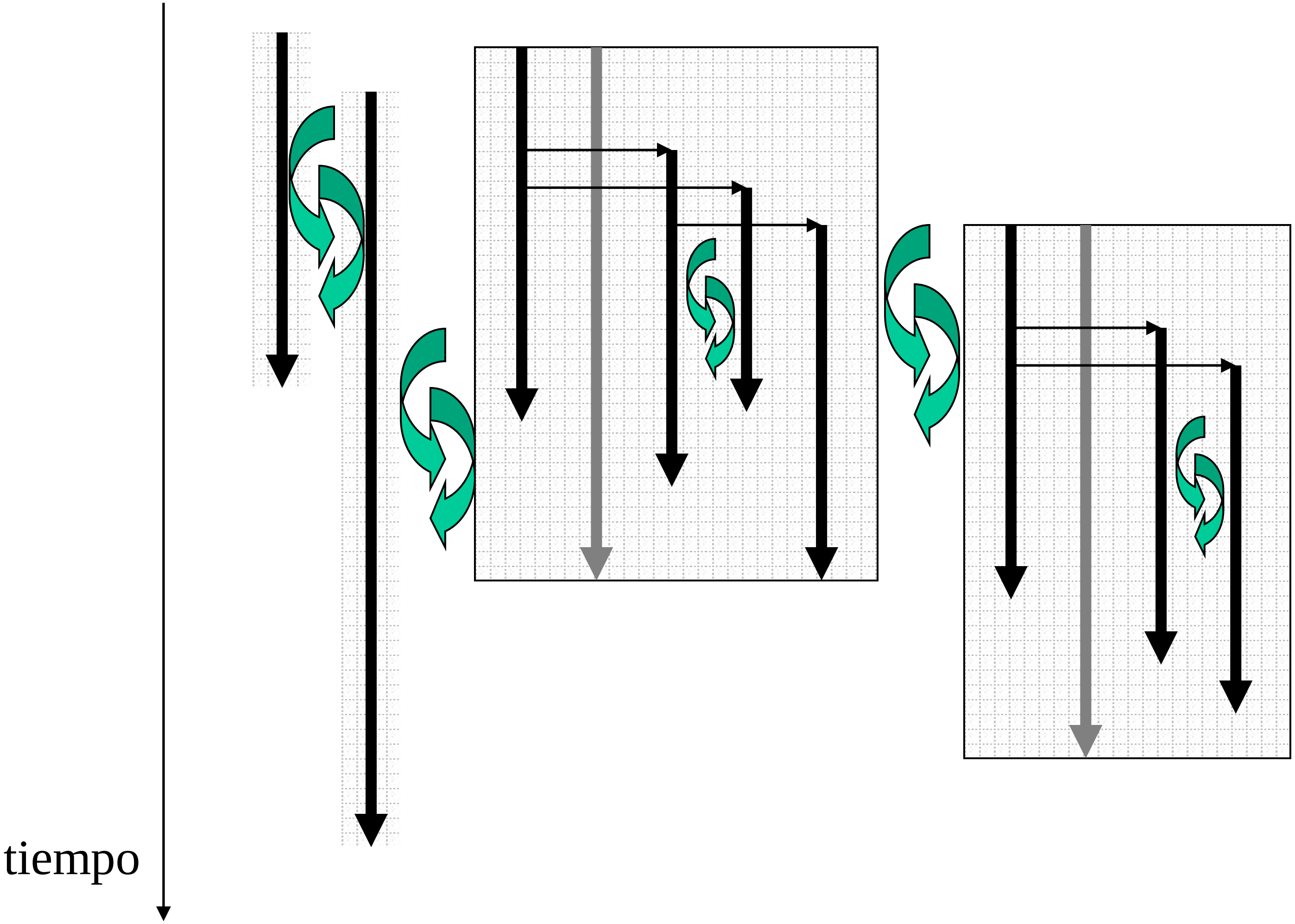
Threads (Hilos)

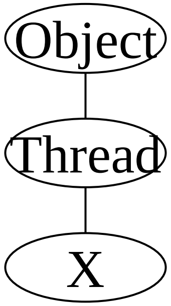

Inicio
Hilo principal (main thread)
“Basurero” (garbage collector)
Los distintos hilos pueden interaccionar colaborando en una misma tarea
Todos los hilos comparten la memoria
tiempo

Temas:

- **demonios {setDaemon(boolean); isDaemon}**
- **prioridades y “scheduling” {setPriority(int); getPriority()}**
- **secciones críticas {synchronized}**
- **sincronización**

Procesos en un S.O.





Object

Thread

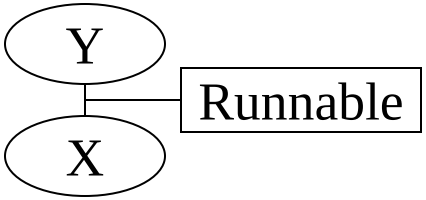
X

Objeto de
subclase de Thread

```
class X  extends Thread {
......

public void run()
 { // código origen del hilo
  }
}
```

```
X a = new X(); a.start();
```

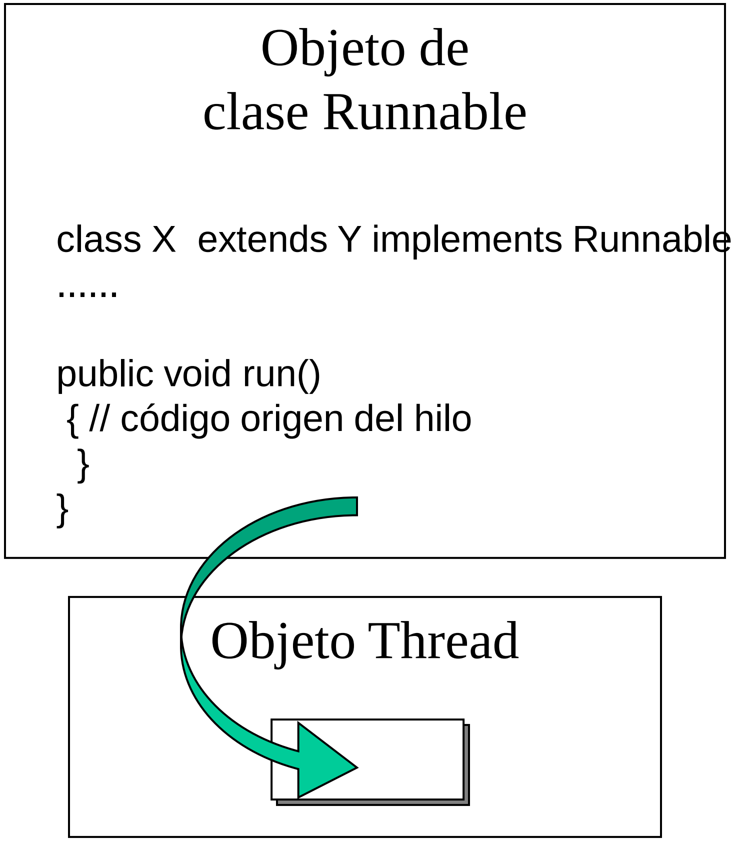
*El start() puede situarse en el constructor



Y

Runnable

X



Objeto de
clase Runnable

```
class X  extends Y implements Runnable {
......

public void run()
 { // código origen del hilo
  }
}
```

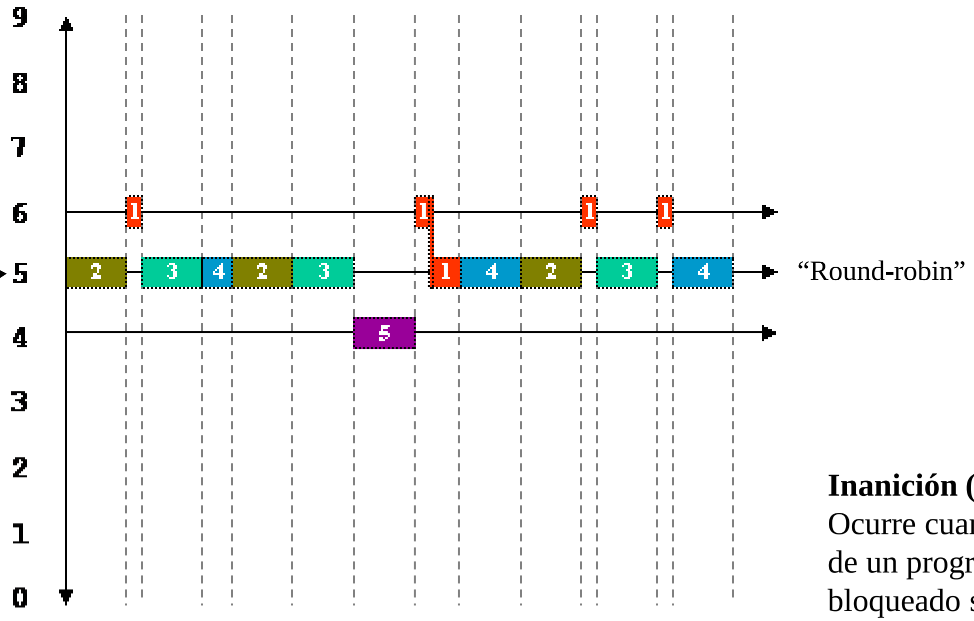
Objeto Thread

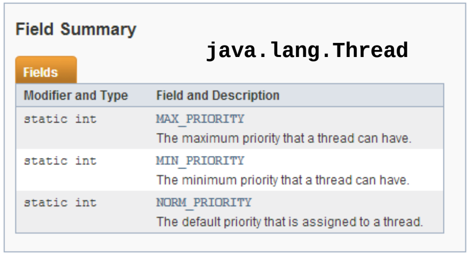
```
X a = new X(); Thread t=new Thread(a); t.start();
```

Hilos – “Scheduling”
asignación de tiempos y Prioridades

Prioridad

Nivel por defecto




Field Summary

`java.lang.Thread`

Fields

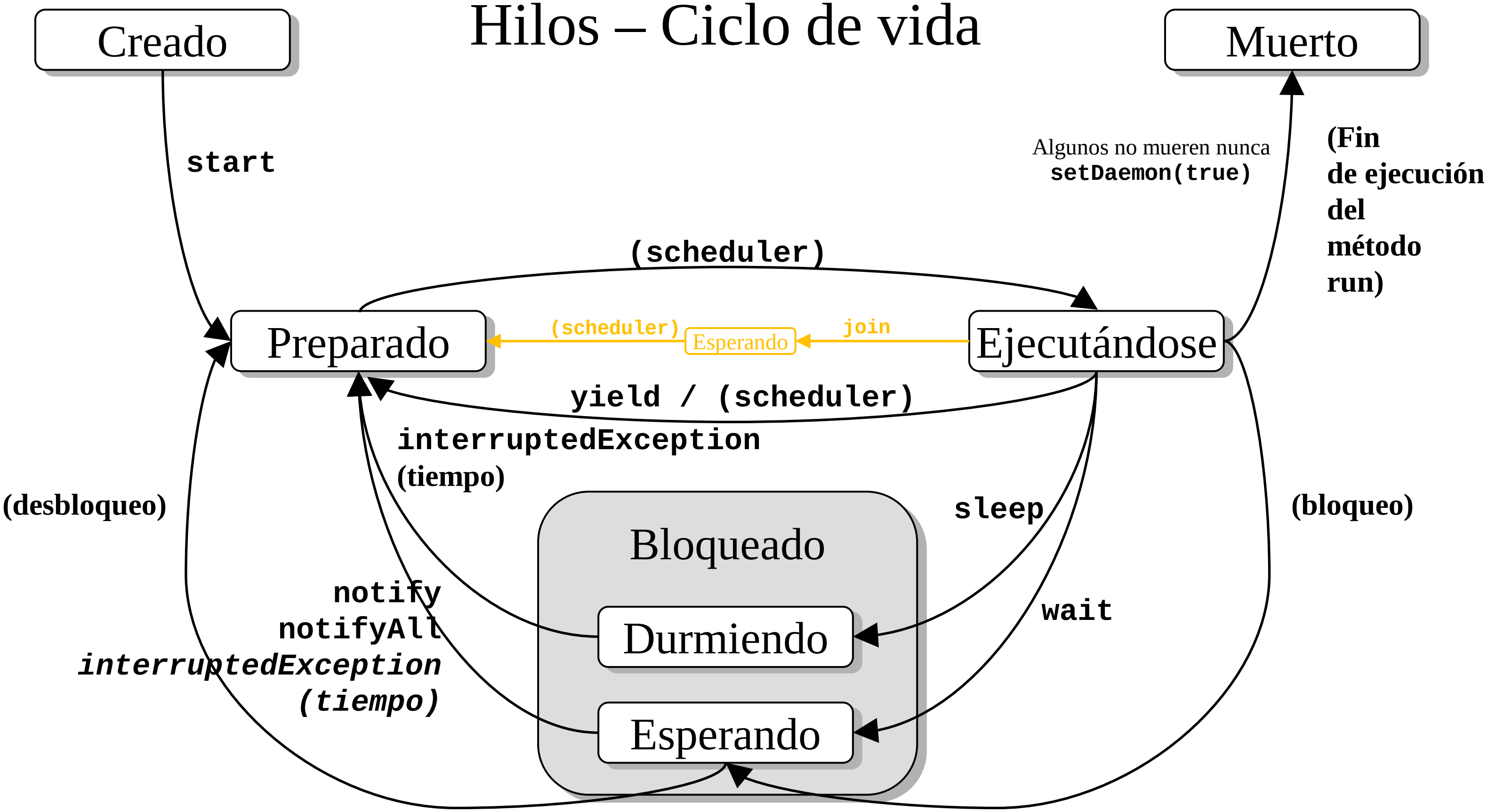
Modifier and Type	Field and Description
`static int`	`MAX_PRIORITY` The maximum priority that a thread can have.
`static int`	`MIN_PRIORITY` The minimum priority that a thread can have.
`static int`	`NORM_PRIORITY` The default priority that is assigned to a thread.

```
java.lang.Thread

        •public final void setPriority(int newPriority)
        •public final int getPriority()
```

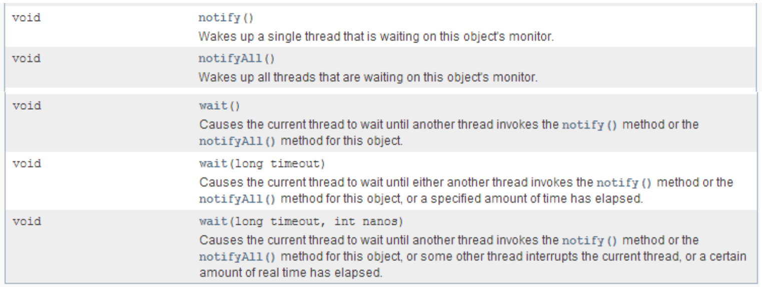
Inanición (starvation) ⚠

Ocurre cuando uno o más hilos de un programa ven siempre bloqueado su acceso a un recurso y por tanto no pueden progresar

Hilos – Ciclo de vida

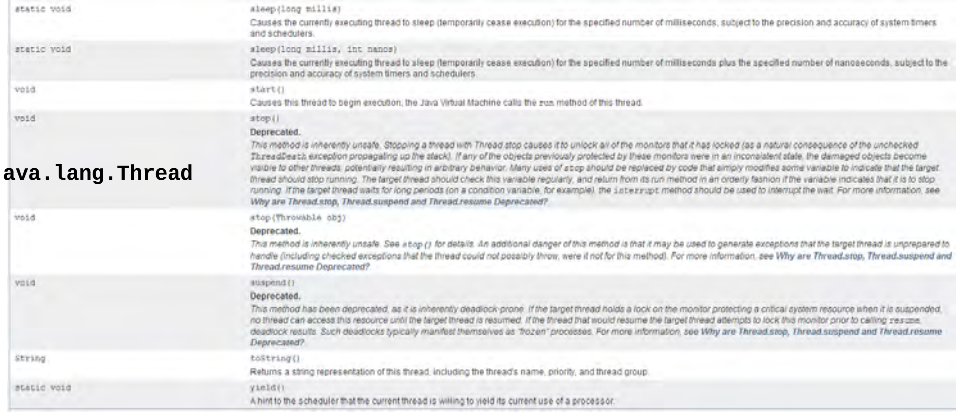


java.lang.Object



void	notify() Wakes up a single thread that is waiting on this object's monitor.
void	notifyAll() Wakes up all threads that are waiting on this object's monitor.
void	wait() Causes the current thread to wait until another thread invokes the notify() method or the notifyAll() method for this object.
void	wait(long timeout) Causes the current thread to wait until either another thread invokes the notify() method or the notifyAll() method for this object, or a specified amount of time has elapsed.
void	wait(long timeout, int nanos) Causes the current thread to wait until another thread invokes the notify() method or the notifyAll() method for this object, or some other thread interrupts the current thread, or a certain amount of real time has elapsed.

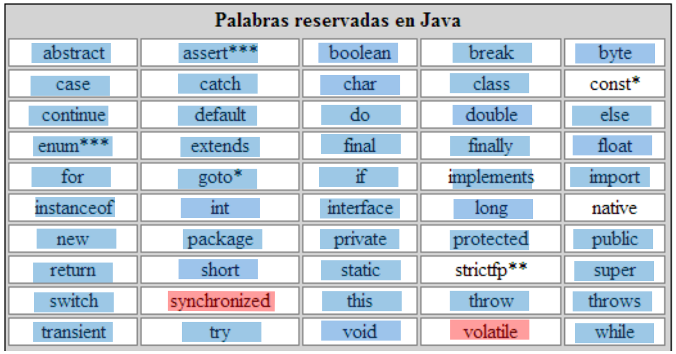
java.lang.Thread



static void	sleep(long millis) Causes the currently executing thread to sleep (temporarily cease execution) for the specified number of milliseconds, subject to the precision and accuracy of system timers and schedulers.
static void	sleep(long millis, int nanos) Causes the currently executing thread to sleep (temporarily cease execution) for the specified number of milliseconds plus the specified number of nanoseconds, subject to the precision and accuracy of system timers and schedulers.
void	start() Causes this thread to begin execution; the Java Virtual Machine calls the run method of this thread.
void	stop() **Deprecated.** *This method is inherently unsafe. Stopping a thread with Thread.stop causes it to unlock all of the monitors that it has locked (as a natural consequence of the unchecked ThreadDeath exception propagating up the stack). If any of the objects previously protected by these monitors were in an inconsistent state, the damaged objects become visible to other threads, potentially resulting in arbitrary behavior. Many uses of stop should be replaced by code that simply modifies some variable to indicate that the target thread should stop running. The target thread should check this variable regularly, and return from its run method in an orderly fashion if the variable indicates that it is to stop running. If the target thread waits for long periods (on a condition variable, for example), the interrupt method should be used to interrupt the wait. For more information, see **Why are Thread.stop, Thread.suspend and Thread.resume Deprecated?***
void	stop(Throwable obj) **Deprecated.** *This method is inherently unsafe. See stop() for details. An additional danger of this method is that it may be used to generate exceptions that the target thread is unprepared to handle (including checked exceptions that the thread could not possibly throw, were it not for this method). For more information, see **Why are Thread.stop, Thread.suspend and Thread.resume Deprecated?***
void	suspend() **Deprecated.** *This method has been deprecated, as it is inherently deadlock-prone. If the target thread holds a lock on the monitor protecting a critical system resource when it is suspended, no thread can access this resource until the target thread is resumed. If the thread that would resume the target thread attempts to lock this monitor prior to calling resume, deadlock results. Such deadlocks typically manifest themselves as "frozen" processes. For more information, see **Why are Thread.stop, Thread.suspend and Thread.resume Deprecated?***
String	toString() Returns a string representation of this thread, including the thread's name, priority, and thread group.
static void	yield() A hint to the scheduler that the current thread is willing to yield its current use of a processor.

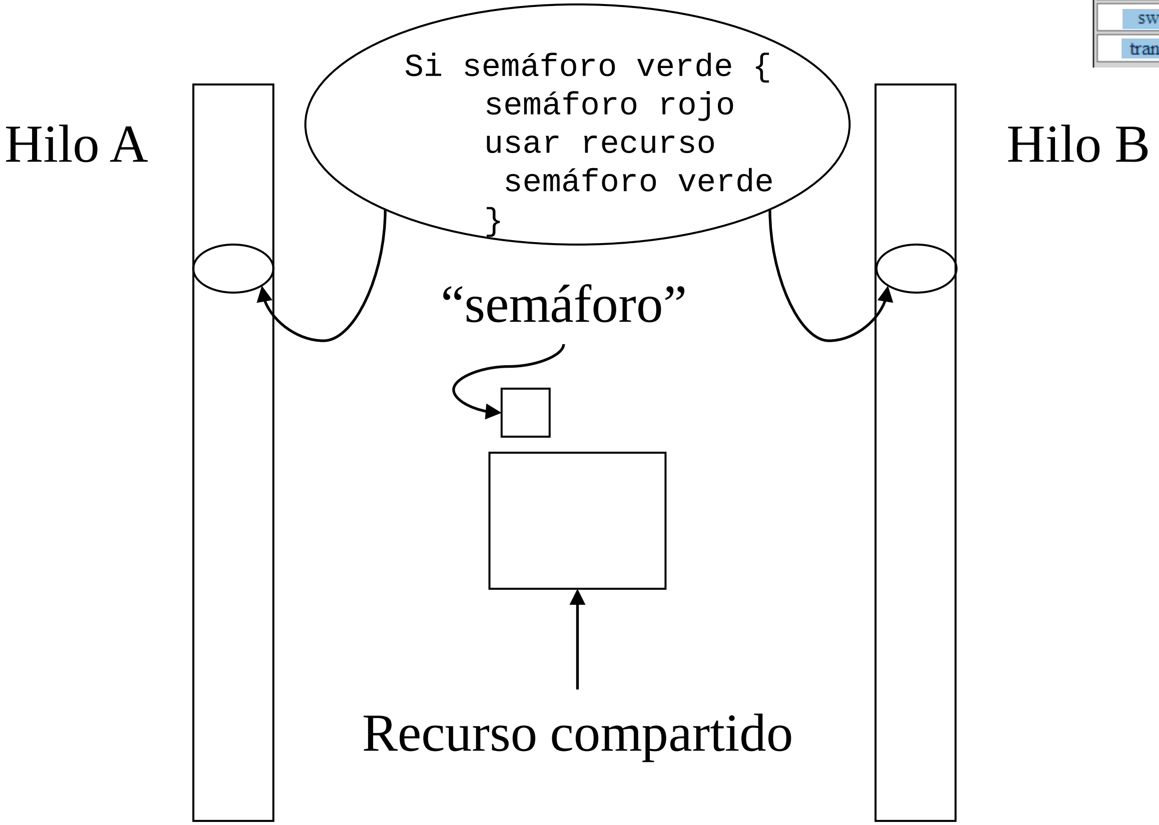
Mecanismos proporcionados por Java para el entorno multi-hilo

- Exclusión mutua (secciones criticas)
- Bloqueo de recursos



Palabras reservadas en Java

abstract	assert***	boolean	break	byte
case	catch	char	class	const*
continue	default	do	double	else
enum***	extends	final	finally	float
for	goto*	if	implements	import
instanceof	int	interface	long	native
new	package	private	protected	public
return	short	static	strictfp**	super
switch	synchronized	this	throw	throws
transient	try	void	volatile	while



Hilo A

```
Si semáforo verde {
    semáforo rojo
    usar recurso
     semáforo verde
    }
```

Hilo B

“semáforo”

Recurso compartido

Interbloqueo (deadlock)

Es una forma “terminal” de inanición. Ocurre cuando dos o más hilos esperan a una condición que no puede satisfacerse. El interbloqueo más habitual consiste en que dos (o más) hilos esperan a que otro haga algo de un modo circular.

Sincronizando un contador

```java
package edu.upvehu.gbg.docencia.volatil;

import java.util.concurrent.atomic.AtomicInteger;

public class ContandoConHilos {
   private static final int TOP_COUNT=1_000_000;

   public static void main(String[] args) throws InterruptedException {
      Counter counter;
      Thread t1,t2;

      //Los dos hilos "contra" un contador no Thread Safe
      counter=new NoTSCounter();
      t1=new Barrido(counter,TOP_COUNT); t2=new Barrido(counter,TOP_COUNT);
      t1.start();t2.start(); t1.join(); t2.join();
      System.out.println("Contador no Thread Safe: "+counter.getCount());

      //Los dos hilos "contra" un contador Thread Safe mediante sincronización
      counter=new synchronizedCounter();
      t1=new Barrido(counter,TOP_COUNT); t2=new Barrido(counter,TOP_COUNT);
      t1.start();t2.start(); t1.join(); t2.join();
      System.out.println("Contador Thread Safe: "+counter.getCount());

      //Los dos hilos "contra" un contador volatil mediante sincronización
      counter=new volatileCounter();
      t1=new Barrido(counter,TOP_COUNT); t2=new Barrido(counter,TOP_COUNT);
      t1.start();t2.start(); t1.join(); t2.join();
      System.out.println("Contador volatil: "+counter.getCount());

      //Los dos hilos "contra" un contador atómico
      counter=new AtomicCounter();
      t1=new Barrido(counter,TOP_COUNT); t2=new Barrido(counter,TOP_COUNT);
      t1.start();t2.start(); t1.join(); t2.join();
      System.out.println("Contador atómico: "+counter.getCount());

   }
}

//Hilo que "barre" un contador de cero hasta un máximo
class Barrido extends Thread{
   Counter counter;   int topCount;

   public Barrido(Counter counter, int topCount) {this.counter = counter;  this.topCount=topCount; }

   @Override public void run() { for (int i = 0; i < topCount; i++) counter.increment();}
}
```

```java
//Interfaz del concepto "contador"
interface Counter {
   public  void increment();
   public  int getCount();
}
```

```java
//Contador no Thread Safe
class NoTSCounter implements Counter {
   private int count = 0;

   @Override public  void increment() { count++; }
   @Override public  int getCount() { return count; }
}
```

```java
//Contador Thread Safe
class synchronizedCounter implements Counter {
   private int count = 0;

   @Override public synchronized void increment() { count++; }
   @Override public synchronized int getCount() { return count; }
}
```

```java
//Contador volatil (no es TS porque count++ no es atómica)
class volatileCounter implements Counter {
   private volatile int count = 0;

   @Override public void increment() { count++; }
   @Override public int getCount() { return count; }
}
```

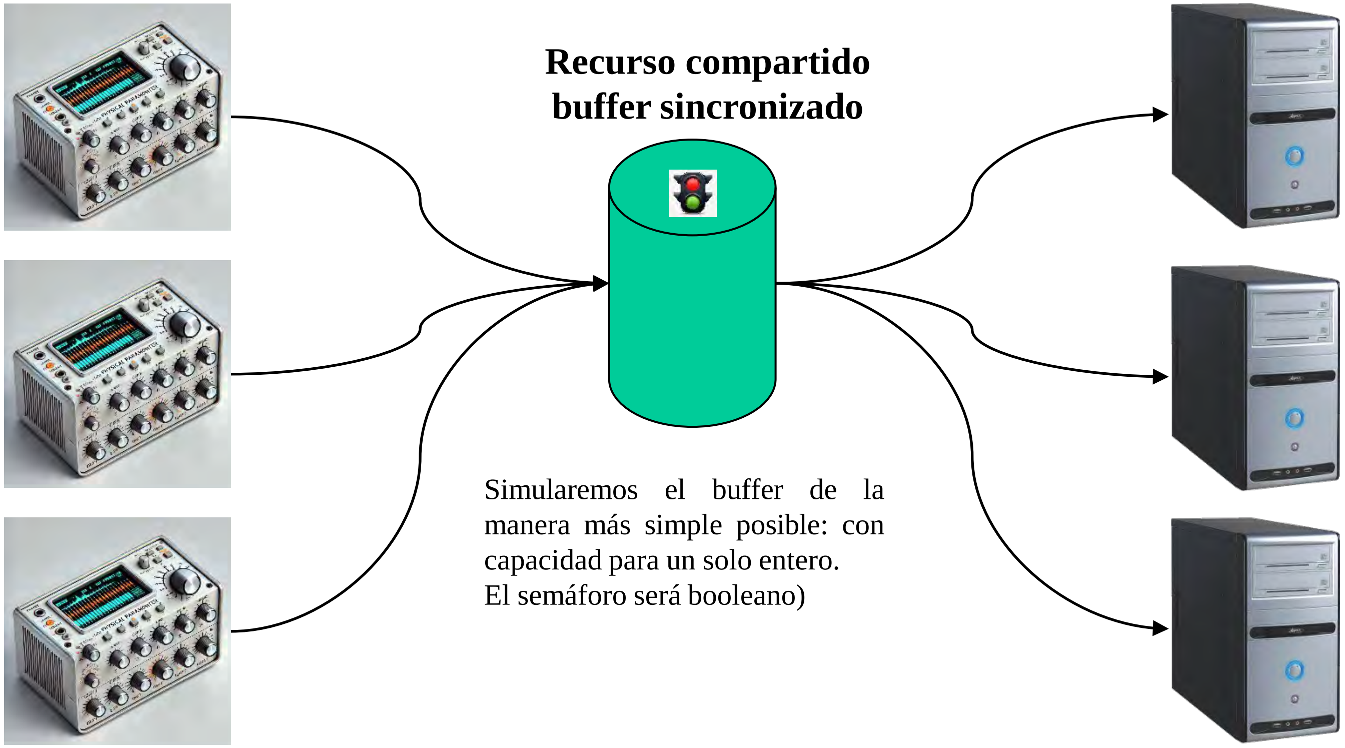
```java
//Contador atómico (es TS –la atomicidad lo asegura-)
class AtomicCounter implements Counter {
   private final AtomicInteger count = new AtomicInteger(0);

   @Override public void increment() { count.incrementAndGet(); }
   @Override public int getCount() { return count.get(); }
}
```

```
german@Raskolnikov:Java -jar ContandoConHilos.jar
Contador no Thread Safe: 1060434
Contador Thread Safe: 2000000
Contador volatil: 1220971
Contador atómico: 2000000
```

Carreras críticas y problemas de visibilidad

Carreras críticas

Desarrollo de un ejemplo con hilos en colaboración



Hilos productores de datos

Recurso compartido buffer sincronizado

Hilos consumidores de datos

Simularemos el buffer de la manera más simple posible: con capacidad para un solo entero.
El semáforo será booleano)

Simularemos los productores como generadores de una serie enteros (de 0 a 9) en intervalos de tiempo aleatorios.

Simularemos los consumidores únicamente para recoger los datos. Estarán siempre dispuestos a recoger un dato.

```
public class Cubiculo {
            private int contenido;
            private boolean disponible = false;

            public synchronized int get() {
                ...
            }

            public synchronized void put(int valor) {
                ...
            }
        }
```

Sección crítica

Un método sincronizado es una “sección crítica” de código. Toma en propiedad el objeto, de modo que otro hilo no puede acceder simultáneamente a cualquier otro método sincronizado.

(es vital que los campos “críticos” sean privados y sólo accedidos desde métodos sincronizados)

wait / notify

Un hilo puede esperar a que algo suceda mediante un “wait”, y retomar su ejecución cuando sea notificado (“notify”)

```
public synchronized int get() {
  while (!disponible) {
   // esperar a que el productor genere un valor
    try { wait();} catch (InterruptedException e) {}
  }
  disponible = false;
  // notificar al productor que el valor ha sido recogido
  notifyAll();
  return contenido;
  }

public synchronized void put(int valor) {
  while (disponible) {
    // esperar a que el consumidor recoja un valor
    try { wait(); } catch (InterruptedException e) {}
  }
  contenido = valor;
  disponible = true;
  // notificar al consumidor que el valor ha sido generado
  notifyAll();
}
```

En nuestro ejemplo se notifica a todos los hilos (notifyAll) porque así eliminamos la posibilidad de que al pasar a preparado sólo uno resulte ser del mismo tipo (consumidor → consumidor, o productor→ productor)

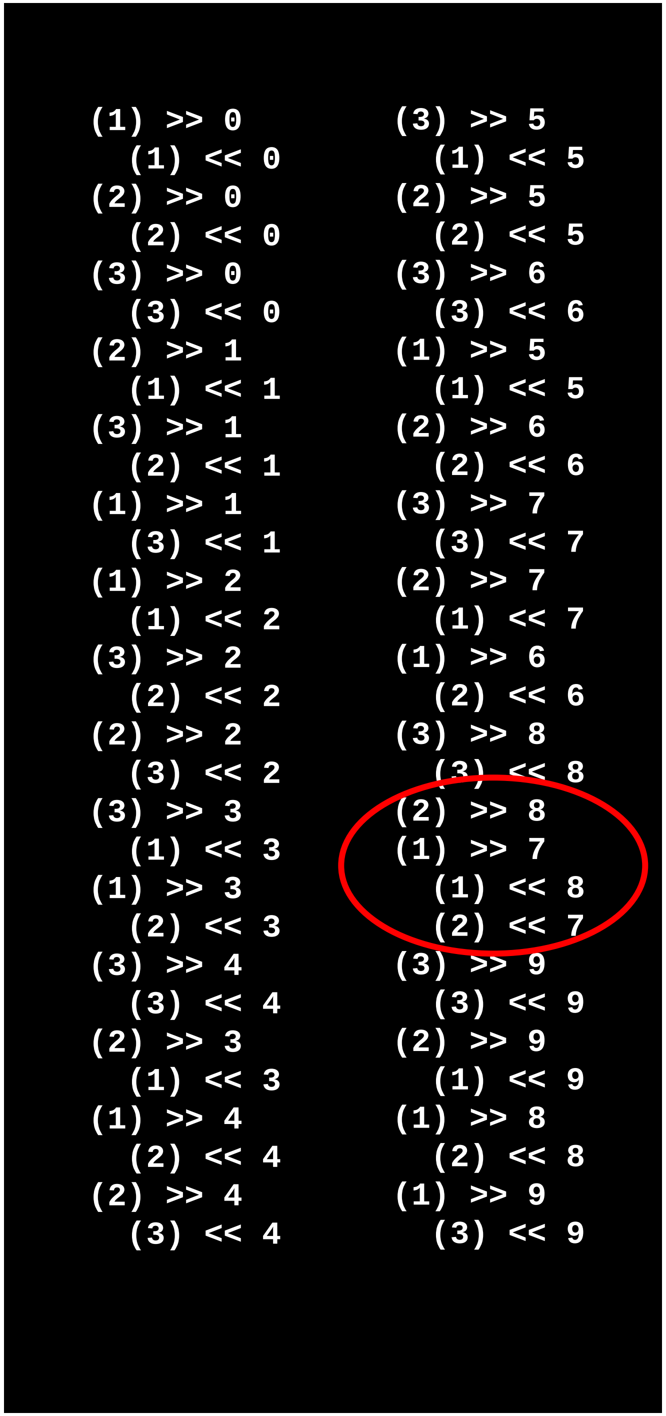
Productor / consumidor

```java
public class Productor extends Thread {
    private Cubiculo cubiculo;
    private int numero;

    public Productor(Cubiculo c, int numero) {
        cubiculo = c; this.numero = numero;
    }

    public void run() {
        for (int i = 0; i < 10; i++) {
            cubiculo.put(i);
            System.out.println("("+numero+ ") >> " + i);
            //Usamos un sleep en un ciclo por claridad, pero es mala práctica
            try {
                    Thread.sleep((int)(Math.random() * 100));
            } catch (InterruptedException e) { }
        }
    }
}
```

```java
public class Consumidor extends Thread {
    private Cubiculo cubiculo;
    private int numero;

    public Consumidor(Cubiculo c, int numero) {
        cubiculo = c; this.numero = numero;
        setDaemon(true);
    }

    public void run() {
        int valor = 0;
        while (true) {
            valor = cubiculo.get();
            System.out.println("  (" + numero+ ") << " + valor);
            Thread.yield();
        }
    }
}
```

Comprobando el funcionamiento

```
public class MainProdCons extends Object {

  public static void main (String args[]) {
    Cubiculo cubiculo=new Cubiculo();
    Productor p1=new Productor(cubiculo,1);
    Productor p2=new Productor(cubiculo,2);
    Productor p3=new Productor(cubiculo,3);
    Consumidor c1=new Consumidor(cubiculo,1);
    Consumidor c2=new Consumidor(cubiculo,2);
    Consumidor c3=new Consumidor(cubiculo,3);

    p1.start();
    p2.start();
    p3.start();
    c1.start();
    c2.start();
    c3.start();
    }
}
```



```
(1) >> 0        (3) >> 5
  (1) << 0        (1) << 5
(2) >> 0        (2) >> 5
  (2) << 0        (2) << 5
(3) >> 0        (3) >> 6
  (3) << 0        (3) << 6
(2) >> 1        (1) >> 5
  (1) << 1        (1) << 5
(3) >> 1        (2) >> 6
  (2) << 1        (2) << 6
(1) >> 1        (3) >> 7
  (3) << 1        (3) << 7
(1) >> 2        (2) >> 7
  (1) << 2        (1) << 7
(3) >> 2        (1) >> 6
  (2) << 2        (2) << 6
(2) >> 2        (3) >> 8
  (3) << 2        (3) << 8
(3) >> 3        (2) >> 8
  (1) << 3      (1) >> 7
(1) >> 3          (1) << 8
  (2) << 3        (2) << 7
(3) >> 4        (3) >> 9
  (3) << 4        (3) << 9
(2) >> 3        (2) >> 9
  (1) << 3        (1) << 9
(1) >> 4        (1) >> 8
  (2) << 4        (2) << 8
(2) >> 4        (1) >> 9
  (3) << 4        (3) << 9
```

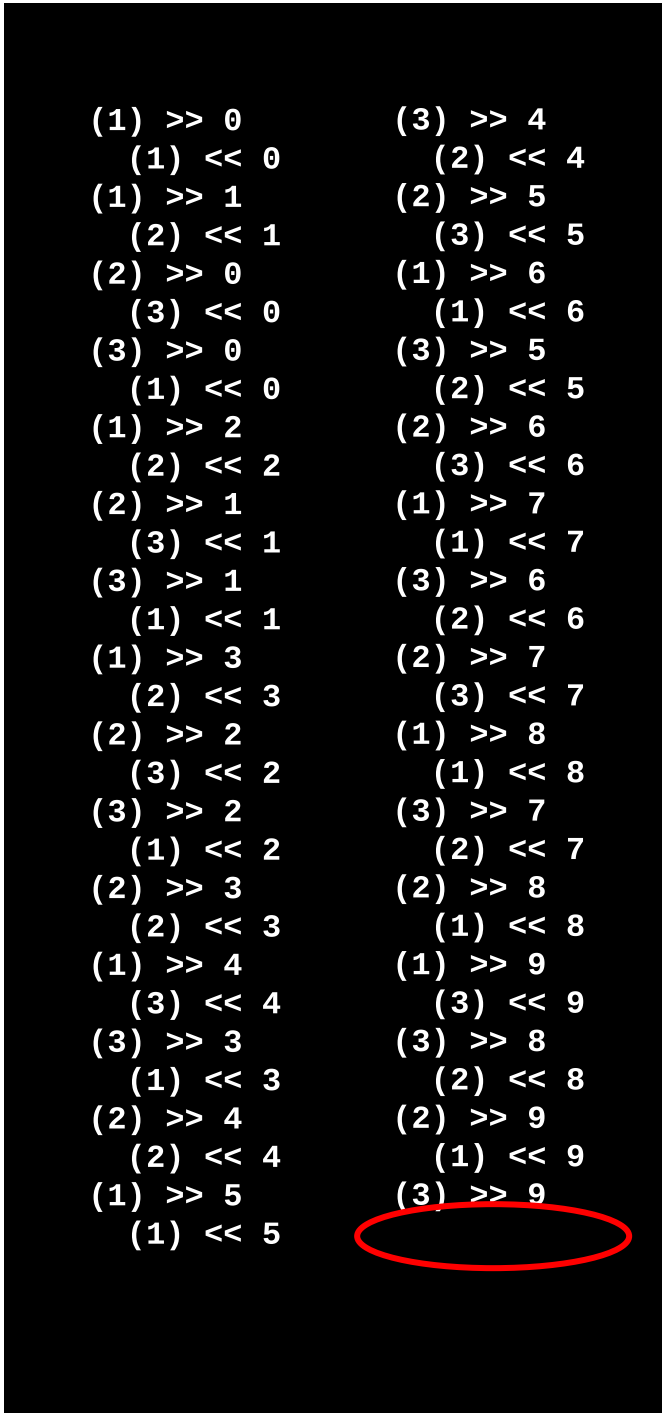
Ojo!. Algo va mal

Arreglado... (no todo)

```java
public void run() {
  for (int i = 0; i < 10; i++) {
    synchronized(cubiculo){
      cubiculo.put(i);
      System.out.println("("+numero+ ") >> " + i);
    }
    try {
      sleep((int)(Math.random() * 100));
    } catch (InterruptedException e) { }
  }
}
```

Productor / consumidor

```java
public void run() {
  int valor = 0;
  while (true) {
    synchronized(cubiculo) {
      valor = cubiculo.get();
      System.out.println("  (" + numero+ ") << " + valor);
    }
    yield();
  }
}
```



```
(1) >> 0          (3) >> 4
  (1) << 0          (2) << 4
(1) >> 1          (2) >> 5
  (2) << 1          (3) << 5
(2) >> 0          (1) >> 6
  (3) << 0          (1) << 6
(3) >> 0          (3) >> 5
  (1) << 0          (2) << 5
(1) >> 2          (2) >> 6
  (2) << 2          (3) << 6
(2) >> 1          (1) >> 7
  (3) << 1          (1) << 7
(3) >> 1          (3) >> 6
  (1) << 1          (2) << 6
(1) >> 3          (2) >> 7
  (2) << 3          (3) << 7
(2) >> 2          (1) >> 8
  (3) << 2          (1) << 8
(3) >> 2          (3) >> 7
  (1) << 2          (2) << 7
(2) >> 3          (2) >> 8
  (2) << 3          (1) << 8
(1) >> 4          (1) >> 9
  (3) << 4          (3) << 9
(3) >> 3          (3) >> 8
  (1) << 3          (2) << 8
(2) >> 4          (2) >> 9
  (2) << 4          (1) << 9
(1) >> 5          (3) >> 9
  (1) << 5
```

Ojo!. Algo va mal

La solución definitiva?

Esperar en main() a la terminación de los productores con join() y dar un tiempo extra.

Aprovechamos para introducir la existencia de **ThreadGroup**

En vez de usar join(), monitorizaremos la finalización del grupo.

```
public class MainProdCons {

    public static void main (String args[]) {
        Cubiculo cubiculo=new Cubiculo();

        ThreadGroup productores=new ThreadGroup("productores");
        ThreadGroup consumidores=new ThreadGroup("consumidores");

        Productor p1=new Productor(productores,cubiculo,"1");
        Productor p2=new Productor(productores,cubiculo,"2");
        Productor p3=new Productor(productores,cubiculo,"3");
        Consumidor c1=new Consumidor(consumidores,cubiculo,"1");
        Consumidor c2=new Consumidor(consumidores,cubiculo,"2");
        Consumidor c3=new Consumidor(consumidores,cubiculo,"3");
        c1.start(); c2.start(); c3.start();
        c1.start(); c2.start(); c3.start();

        int n;
        while ((n=productores.activeCount())!=0) {
            System.out.println("Productores Activos= "+n);
        try { Thread.sleep(500); } catch (InterruptedException e) {}
        }
        try { Thread.sleep(100); } catch (InterruptedException e) {}
            System.out.println("Productores Activos= "+n);
        }
}
```

```
Productores Activos= 3
(1) >> 0
  (1) << 0
(3) >> 0
  (2) << 0
(1) >> 1
  (3) << 1
(1) >> 2
  (1) << 2
(2) >> 0
  (2) << 0
(3) >> 1
  (3) << 1
```

```
(2) >> 1
  (1) << 1
(1) >> 3
  (2) << 3
(2) >> 2
  (3) << 2
(3) >> 2
  (1) << 2
(1) >> 4
  (2) << 4
(3) >> 3
  (3) << 3
(2) >> 3
```

```
  (1) << 3
(3) >> 4
  (2) << 4
Productores Activos= 3
(1) >> 5
  (3) << 5
(2) >> 4
  (1) << 4
(1) >> 6
  (2) << 6
(3) >> 5
  (3) << 5
(2) >> 5
```

```
    (1) << 5
(1) >> 7
  (2) << 7
(2) >> 6
  (3) << 6
(3) >> 6
  (1) << 6
(1) >> 8
Productores Activos= 3
  (2) << 8
(2) >> 7
  (3) << 7
(3) >> 7
  (1) << 7
(1) >> 9
  (2) << 9
(2) >> 8
  (3) << 8
(3) >> 8
  (1) << 8
(2) >> 9
  (2) << 9
(3) >> 9
  (3) << 9
Productores Activos= 0
```

Productor / consumidor

```java
public class Productor extends Thread {
   private Cubiculo cubiculo;

   public Productor(ThreadGroup tg, Cubiculo c, String id) {
      super(tg,id); cubiculo = c;
   }

   public void run() {
      for (int i = 0; i < 10; i++) {
         synchronized(cubiculo){
            cubiculo.put(i);
            System.out.println("("+getName()+ ") >> " + i);
         }
         try {sleep((int)(Math.random() * 100));
         } catch (InterruptedException e) { }
      }
   }
}
```

```java
public class Consumidor extends Thread {
   private Cubiculo cubiculo;

   public Consumidor(ThreadGroup tg, Cubiculo c, String id) {
      super(tg,id); cubiculo = c; setDaemon(true);
   }

   public void run() {
      int valor = 0;
      while (true) {
         synchronized(cubiculo){
            valor = cubiculo.get();
            System.out.println("  (" + getName()+ ") << " + valor);
         }
         yield();
      }
   }
}
```