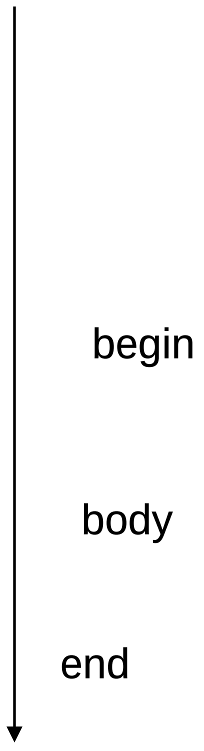
Multithreaded Programming in Java

Agenda

- Introduction
- Thread Applications
- Defining Threads
- Java Threads and States
- Examples

A single threaded program

```
class ABC
{
....
    public void main(..)
    {
    ...
    ..
    }
}
```

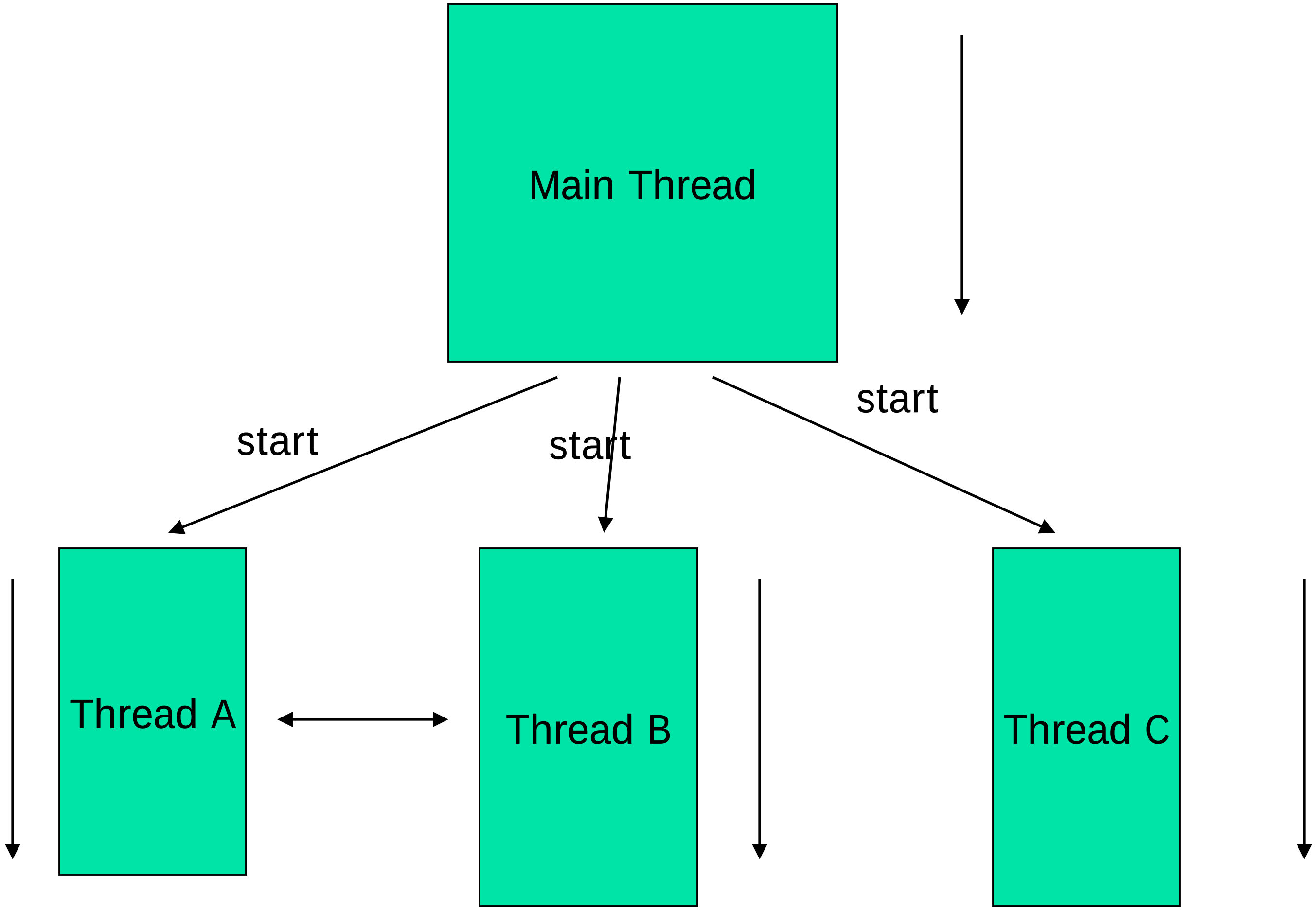


begin

body

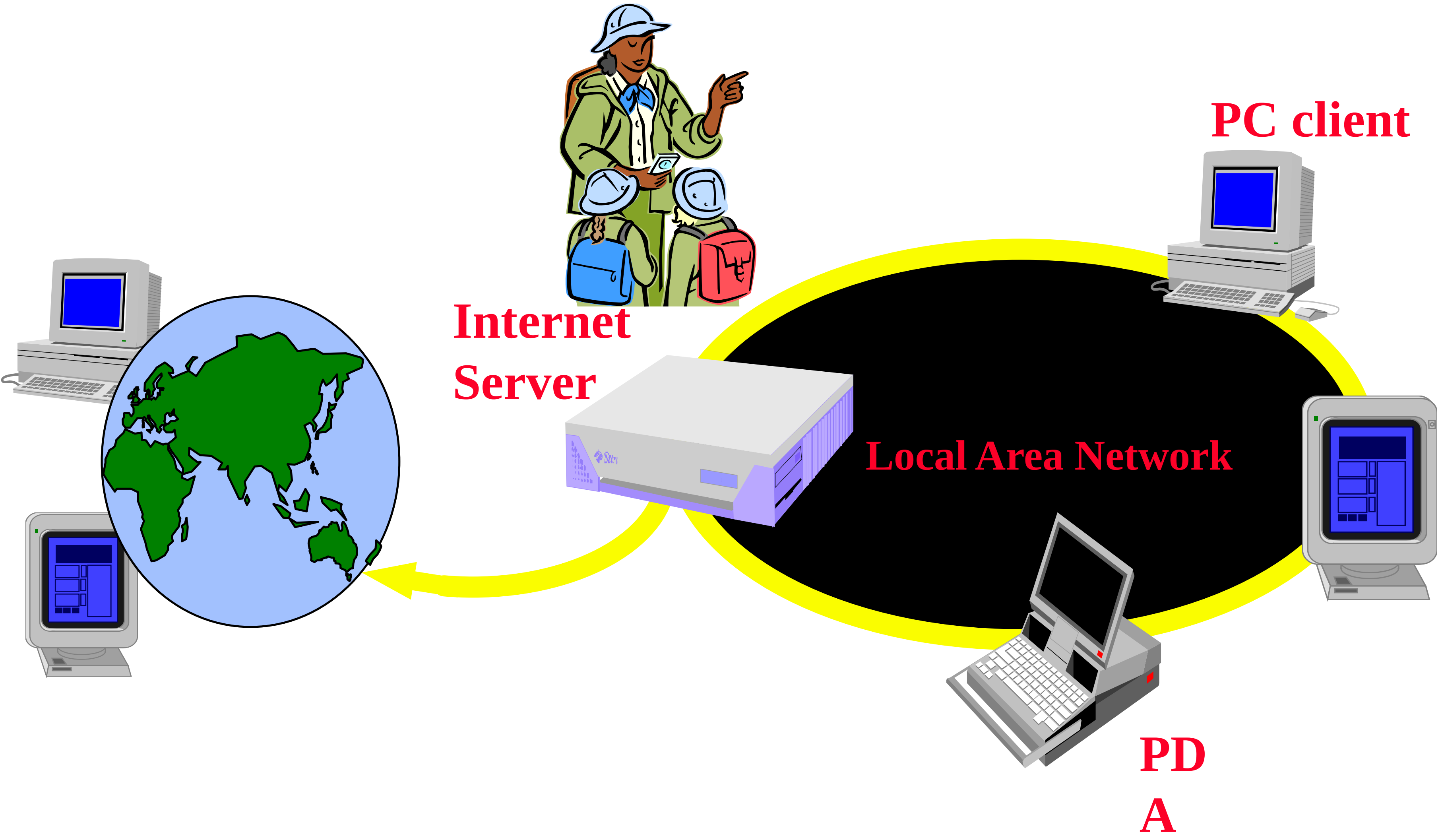
end

A Multithreaded Program

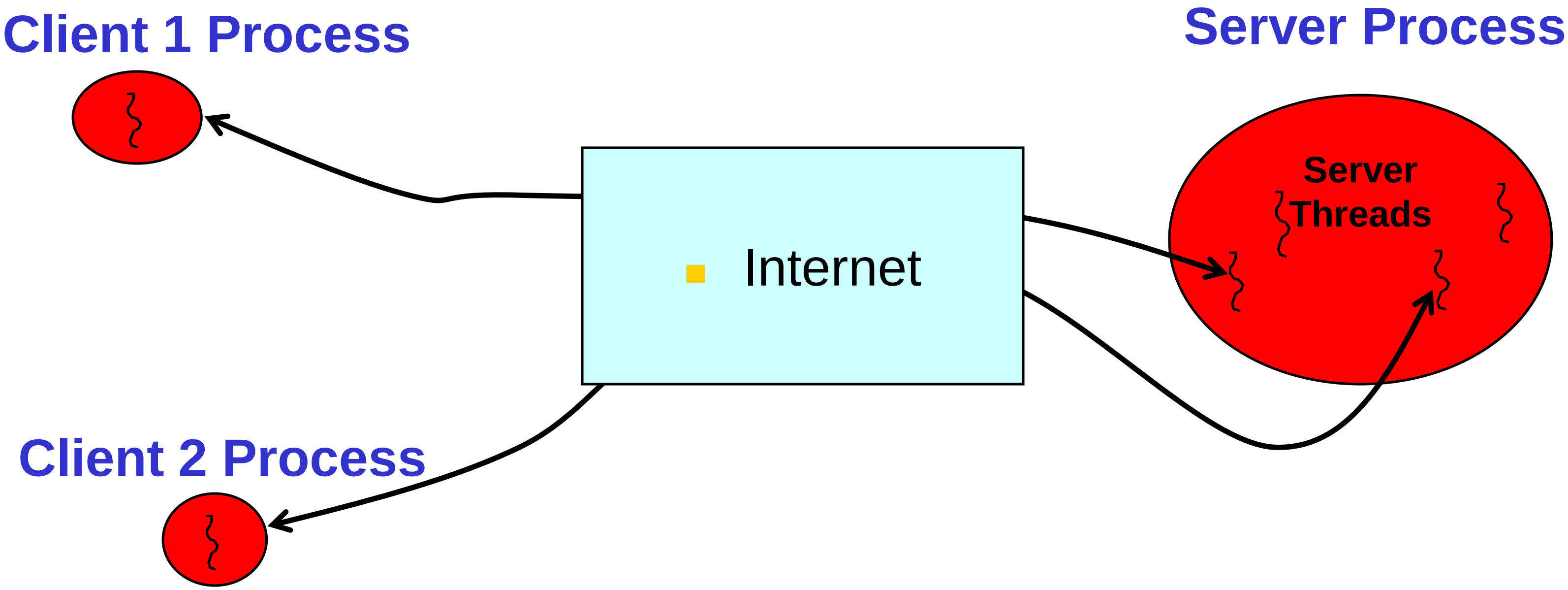


Threads may switch or exchange data/results

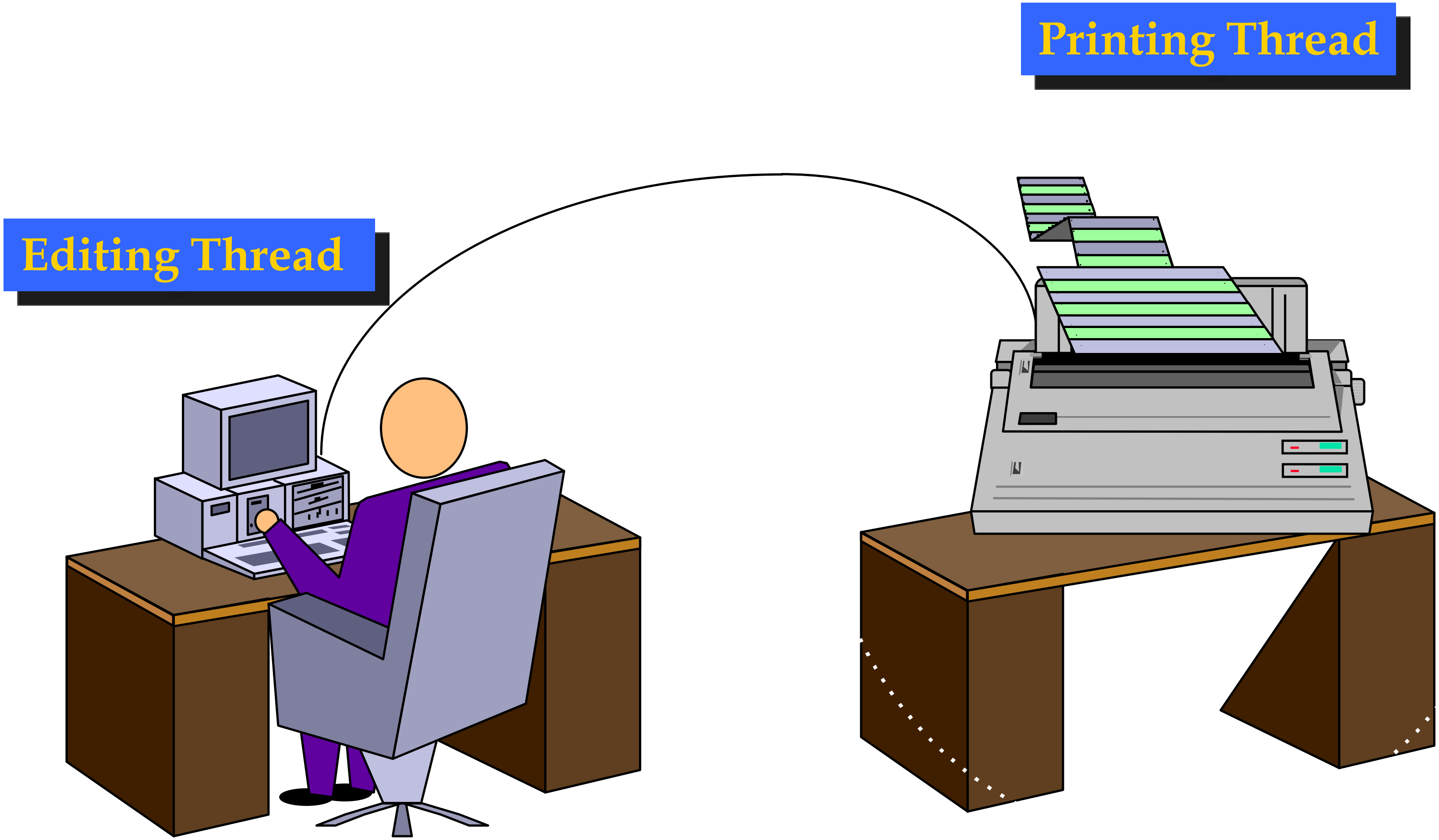
Web/Internet Applications: Serving Many Users Simultaneously



Multithreaded Server: For Serving Multiple Clients Concurrently



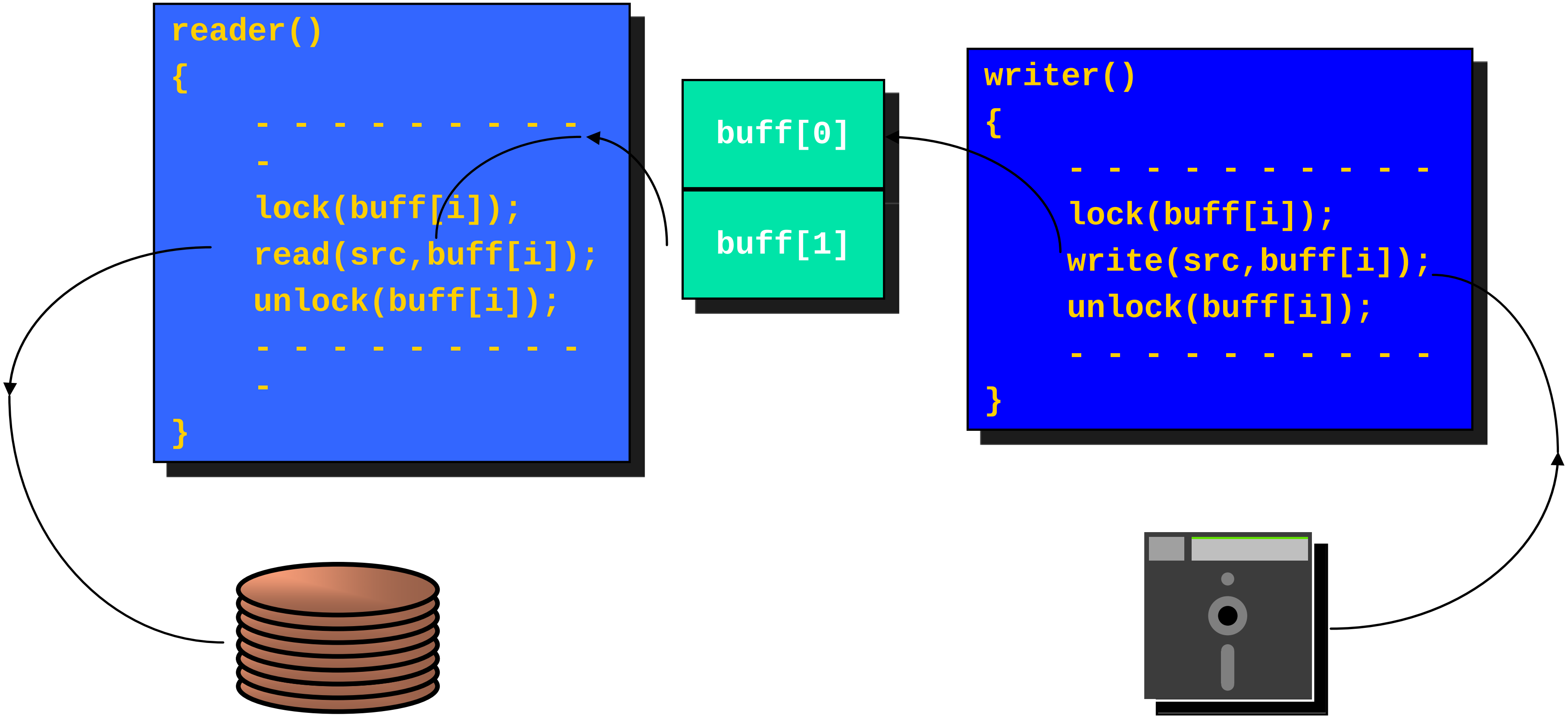
Modern Applications need Threads (ex1): Editing and Printing documents in background.



Printing Thread

Editing Thread

Multithreaded/Parallel File Copy

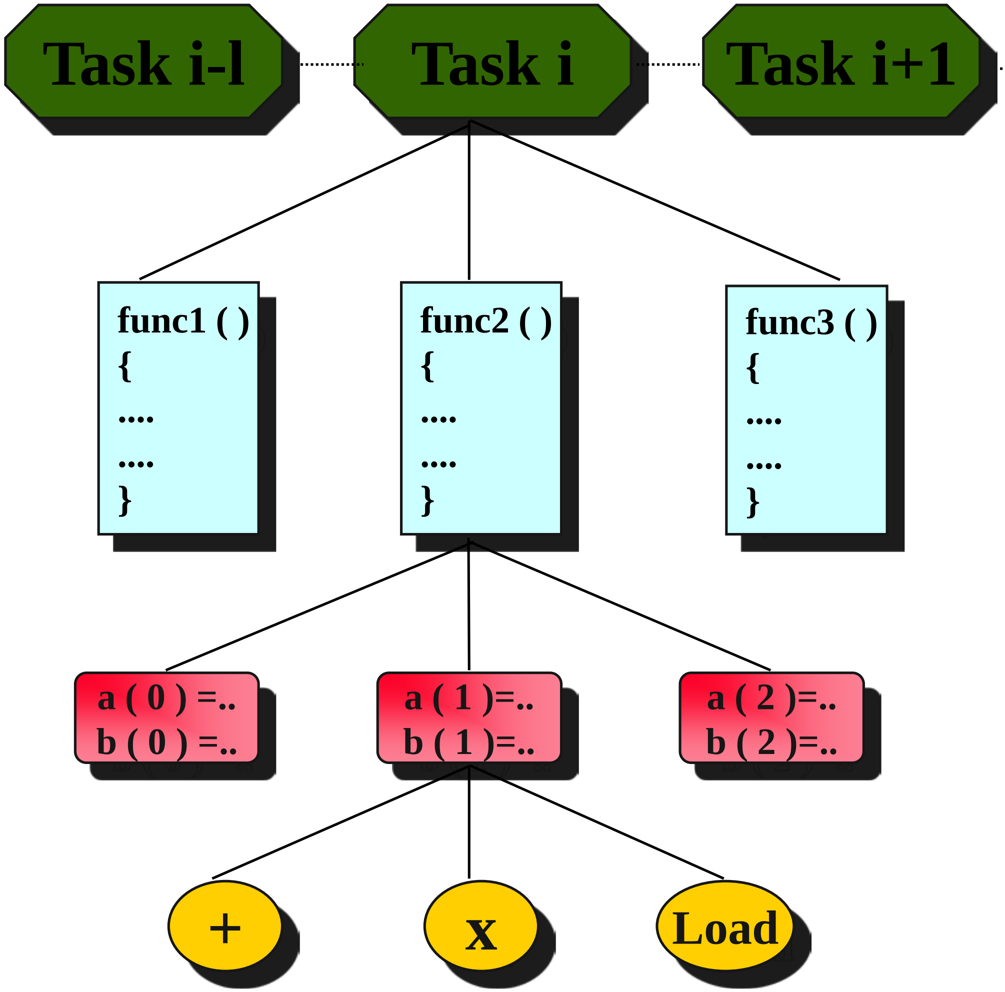


```
reader()
{
    - - - - - - - - - -
    -
    lock(buff[i]);
    read(src,buff[i]);
    unlock(buff[i]);
    - - - - - - - - - -
    -
}
```

```
writer()
{
    - - - - - - - - - -
    lock(buff[i]);
    write(src,buff[i]);
    unlock(buff[i]);
    - - - - - - - - - -
}
```

Cooperative Parallel Synchronized Threads

Levels of Parallelism



Sockets/
PVM/MPI

Task i-l   Task i   Task i+1

Threads

```
func1 ( )
{
....
....
}
```

```
func2 ( )
{
....
....
}
```

```
func3 ( )
{
....
....
}
```

Compilers

a (0) =..
b (0) =..

a (1)=..
b (1)=..

a (2)=..
b (2)=..

CPU

+   x   Load

Code-Granularity

Code Item

Large grain
(task level)
Program

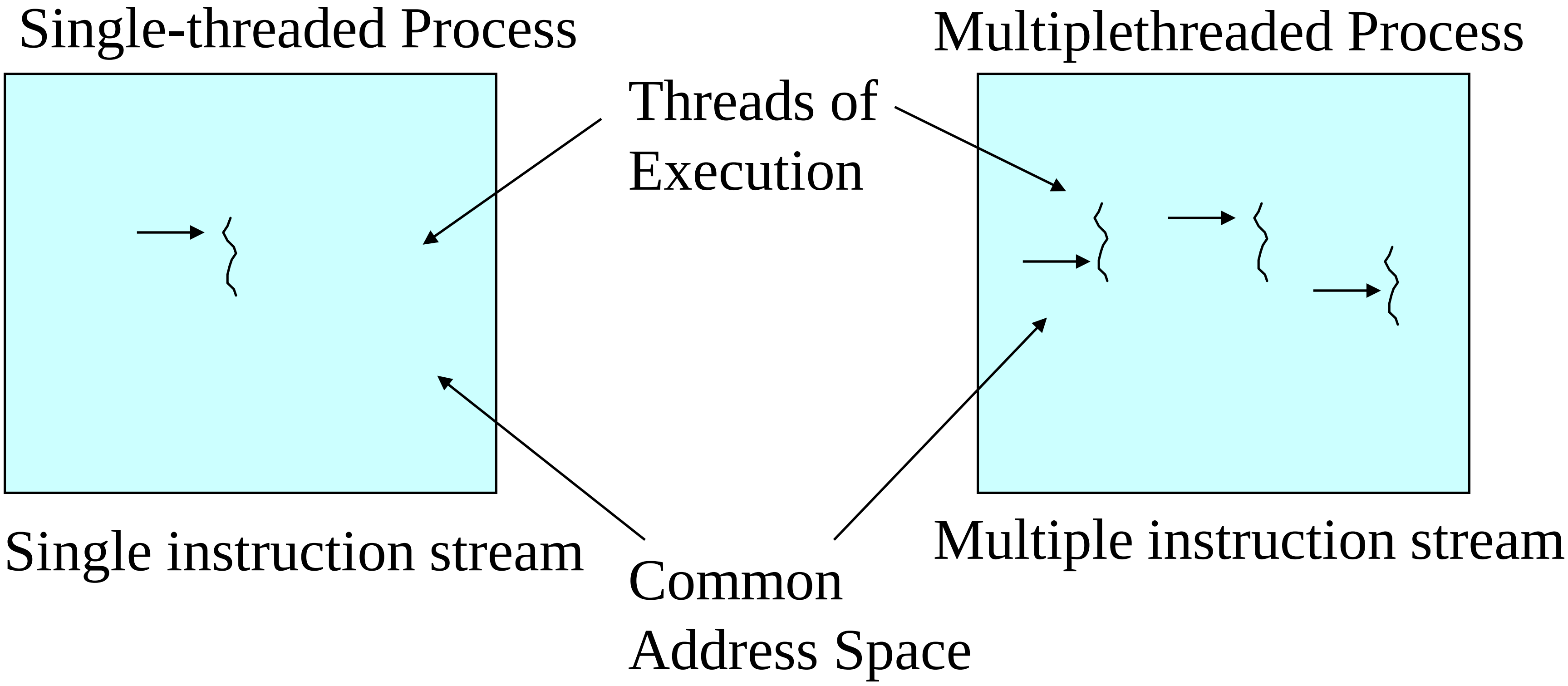
Medium grain
(control level)
Function (thread)

Fine grain
(data level)
Loop (Compiler)

Very fine grain
(multiple issue)
With hardware

Single and Multithreaded Processes

threads are light-weight processes within a process



Single-threaded Process

Multiplethreaded Process

Threads of Execution

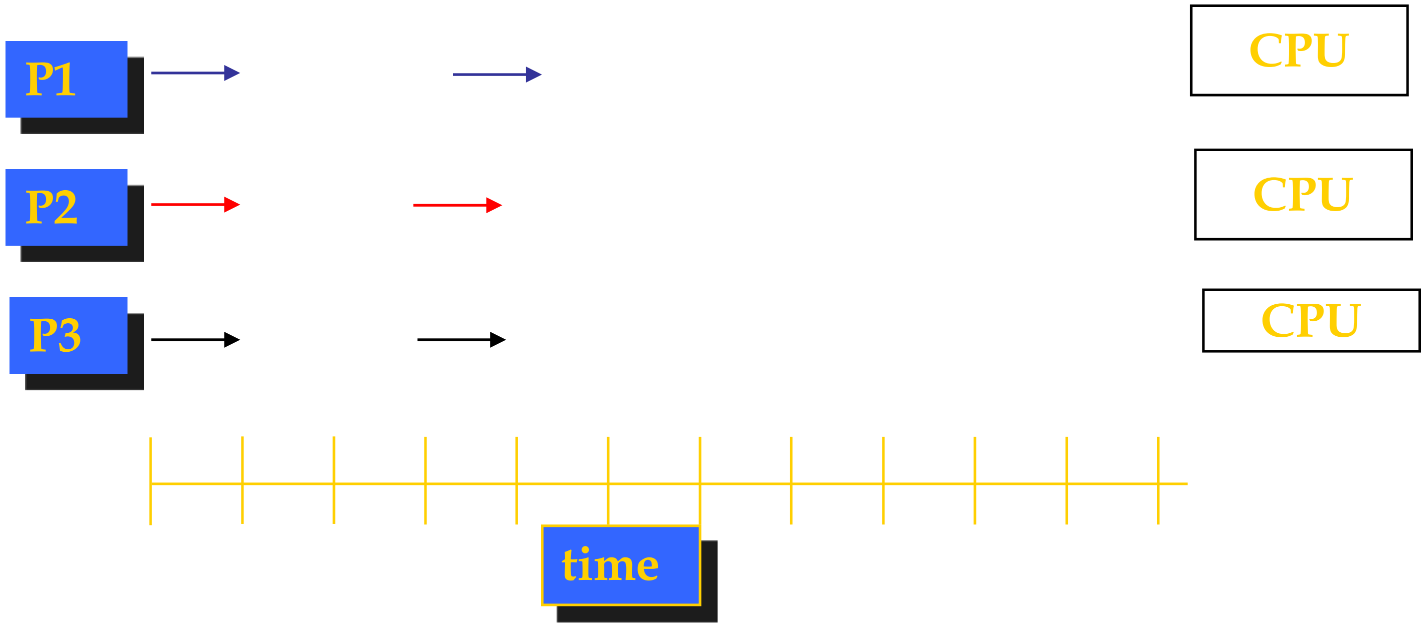
Single instruction stream

Common Address Space

Multiple instruction stream

Multithreading - Multiprocessors

Process Parallelism

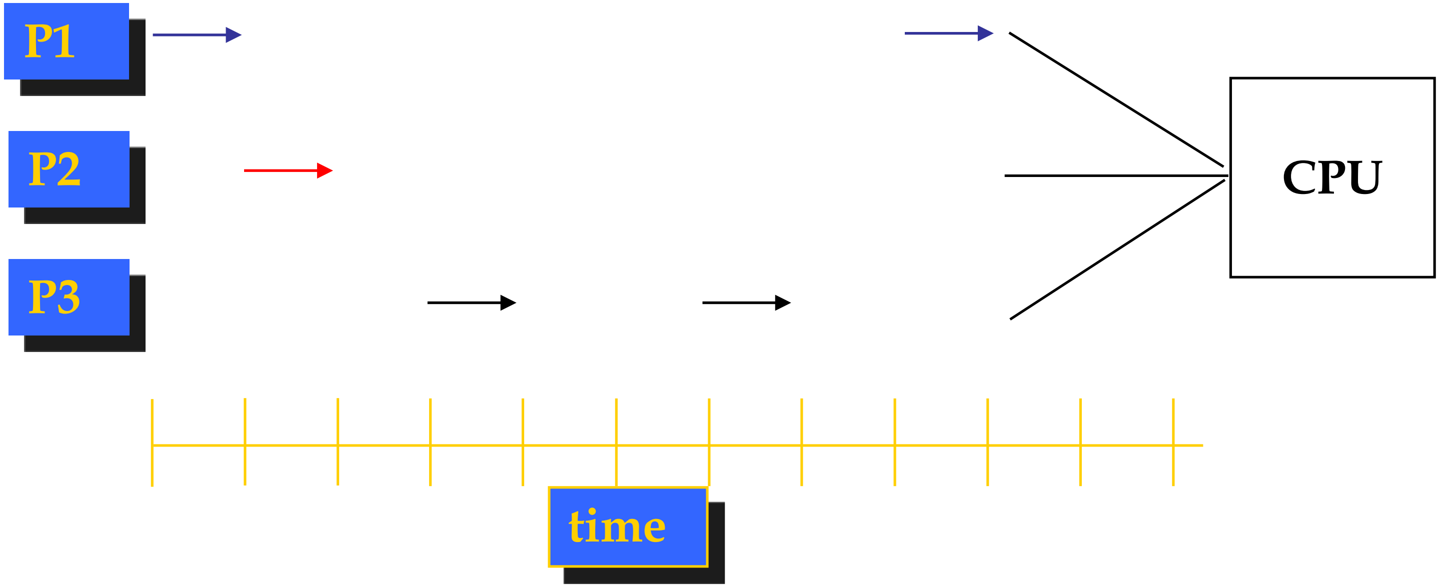


No of execution process more the number of CPUs

Multithreading on Uni-processor

- Concurrency Vs Parallelism

😐 **Process Concurrency**



P1

P2

P3

CPU

time

Number of Simultaneous execution units > number of CPUs

What are Threads?

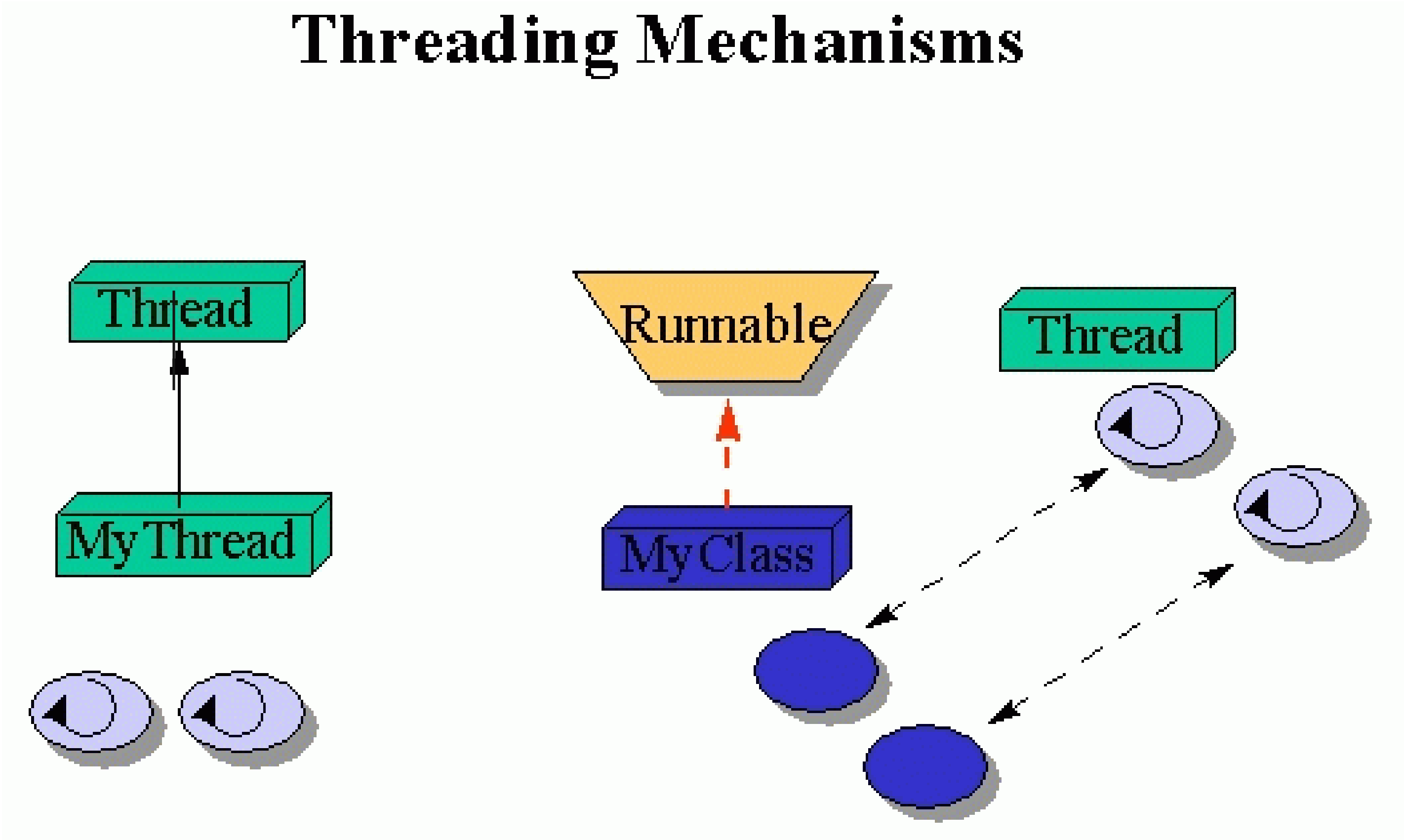
- A piece of code that run in concurrent with other threads.
- Each thread is a statically ordered sequence of instructions.
- Threads are being extensively used express concurrency on both single and multiprocessors machines.
- Programming a task having multiple threads of control – Multithreading or Multithreaded Programming.

Java Threads

- Java has built in thread support for Multithreading
- Synchronization
- Thread Scheduling
- Inter-Thread Communication:
  - currentThread start setPriority
  - yield run getPriority
  - sleep stop suspend
  - resume
- Java Garbage Collector is a low-priority thread

Threading Mechanisms...

- Create a class that extends the Thread class
- Create a class that implements the Runnable interface



1st method: Extending Thread class

- Threads are implemented as objects that contains a method called run()

```
class MyThread extends Thread
{
    public void run()
    {
        // thread body of execution
    }
 }
```

- Create a thread:

```
MyThread thr1 = new MyThread();
```

- Start Execution of threads:

```
thr1.start();
```

An example

```
class MyThread extends Thread {     / / the thread
        public void run() {
                System.out.println(" this thread is running ... ");
        }
} // end class MyThread

class ThreadEx1 {                            / / a program that utilizes the thread
        public static void main(String [] args  ) {
             MyThread t = new MyThread();
             // due to extending the Thread class (above)
             // I can call start(), and this will call
             // run(). start() is a method in class Thread.
             t.start();
       } // end main()
}        // end class ThreadEx1
```

2nd method: Threads by implementing Runnable interface

```
class MyThread implements Runnable
{
  .....
  public void run()
  {
     // thread body of execution
  }
}
```

- Creating Object:

  ```
  MyThread myObject = new MyThread();
  ```

- Creating Thread Object:

  ```
  Thread thr1 = new Thread( myObject );
  ```

- Start Execution:

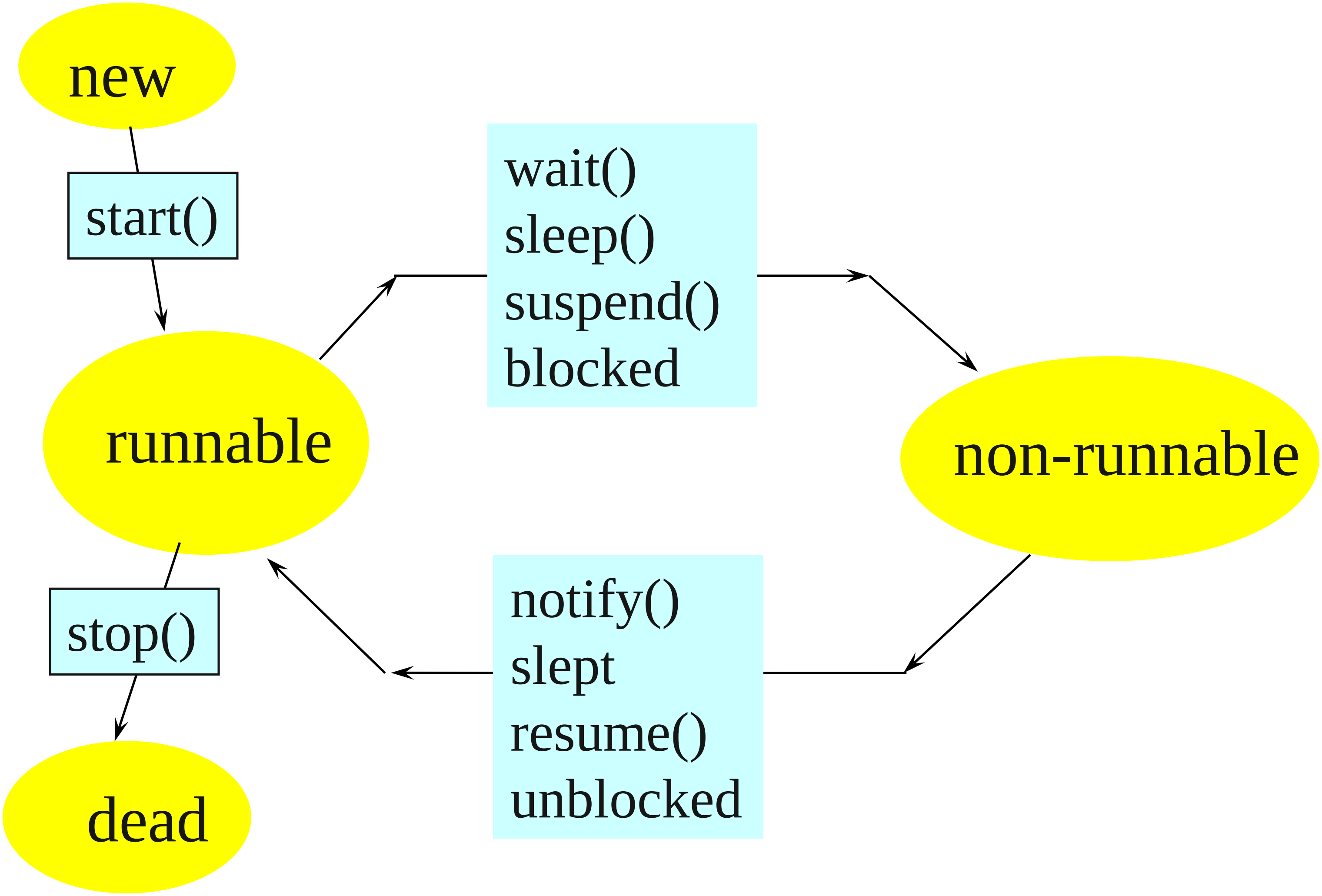
  ```
  thr1.start();
  ```

An example

```
class MyThread implements Runnable  {
        public void run() {
                System.out.println(" this thread is running ... ");
        }
} // end class MyThread

class ThreadEx2 {
        public static void main(String [] args  ) {
                Thread t = new Thread(new MyThread());
                            // due to implementing the Runnable interface
                           // I can call start(), and this will call run().
                t.start();
        } // end main()
}        // end class ThreadEx2
```

Life Cycle of Thread



new

start()

runnable

wait()
sleep()
suspend()
blocked

non-runnable

notify()
slept
resume()
unblocked

stop()

dead

A Program with Three Java Threads

- Write a program that creates 3 threads

Three threads example

```
class A extends Thread
{
     public void run()
       {
          for(int i=1;i<=5;i++)
            {
                System.out.println("\t From ThreadA: i= "+i);
            }

              System.out.println("Exit from A");
       }

}

class B extends Thread
{
     public void run()
       {

          for(int j=1;j<=5;j++)
            {
                System.out.println("\t From ThreadB: j= "+j);
            }

              System.out.println("Exit from B");
       }

}
```

```
class C extends Thread
{
     public void run()
       {

           for(int k=1;k<=5;k++)
             {
                  System.out.println("\t From ThreadC: k= "+k);
             }

              System.out.println("Exit from C");
       }

}


class ThreadTest
{
       public static void main(String args[])

        {
               new A().start();
               new B().start();
               new C().start();

        }



}
```

Run 1

```
[raj@mundroo] threads [1:76] java ThreadTest
      From ThreadA: i= 1
      From ThreadA: i= 2
      From ThreadA: i= 3
      From ThreadA: i= 4
      From ThreadA: i= 5
Exit from A
      From ThreadC: k= 1
      From ThreadC: k= 2
      From ThreadC: k= 3
      From ThreadC: k= 4
      From ThreadC: k= 5
Exit from C
      From ThreadB: j= 1
      From ThreadB: j= 2
      From ThreadB: j= 3
      From ThreadB: j= 4
      From ThreadB: j= 5
Exit from B
```

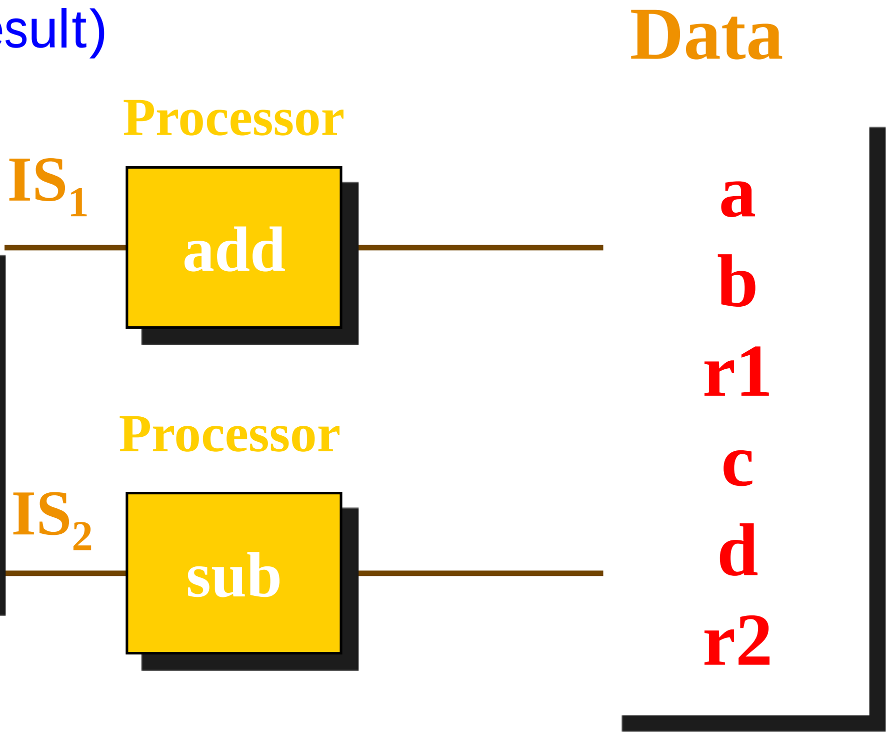
Run2

```
[raj@mundroo] threads [1:77] java ThreadTest
         From ThreadA: i= 1
         From ThreadA: i= 2
         From ThreadA: i= 3
         From ThreadA: i= 4
         From ThreadA: i= 5
         From ThreadC: k= 1
         From ThreadC: k= 2
         From ThreadC: k= 3
         From ThreadC: k= 4
         From ThreadC: k= 5
Exit from C
         From ThreadB: j= 1
         From ThreadB: j= 2
         From ThreadB: j= 3
         From ThreadB: j= 4
         From ThreadB: j= 5
Exit from B
Exit from A
```

Process Parallelism

- int add (int a, int b, int & result)
- // function stuff
- int sub(int a, int b, int & result)
- // function stuff

```
pthread t1, t2;
pthread-create(&t1, add, a,b, & r1);
pthread-create(&t2, sub, c,d, & r2);
pthread-par (2, t1, t2);
```



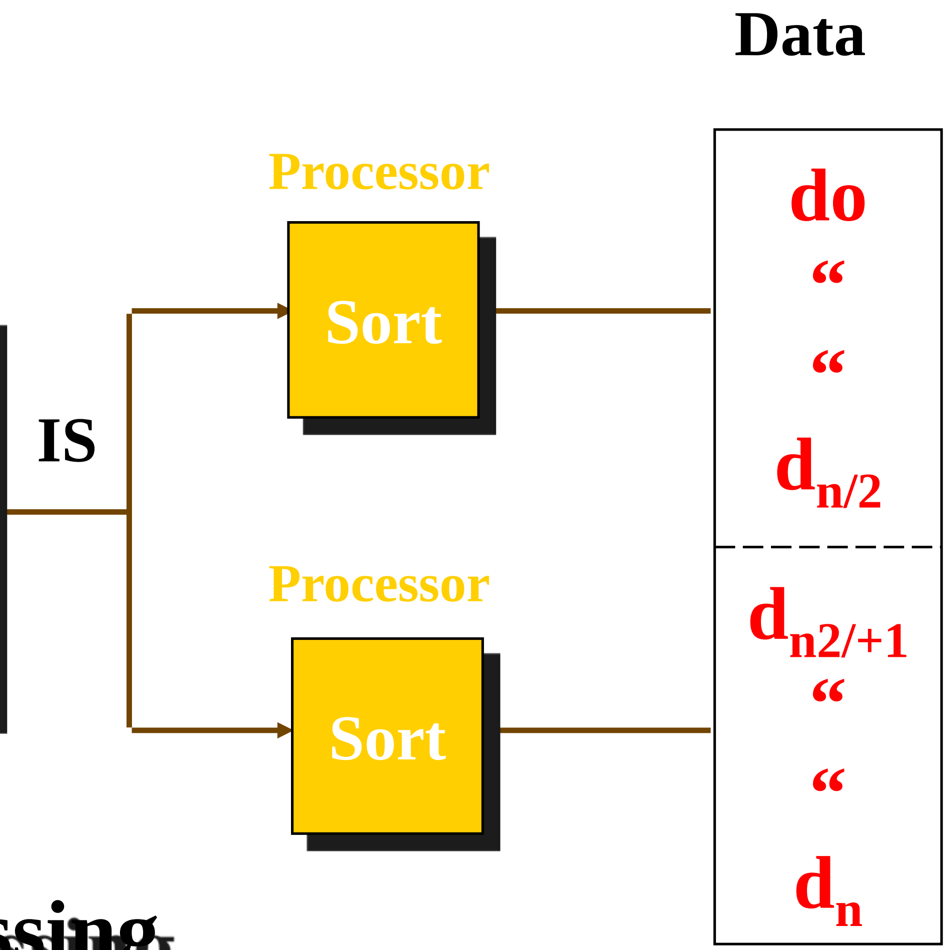
MISD and MIMD Processing

MISD and MIMD Processing

Data Parallelism

- sort(int *array, int count)
- //......
- //......

```
pthread-t, thread1, thread2;
“
“
pthread-create(& thread1, sort, array, N/2);
pthread-create(& thread2, sort, array, N/2);
pthread-par(2, thread1, thread2);
```



SIMD Processing

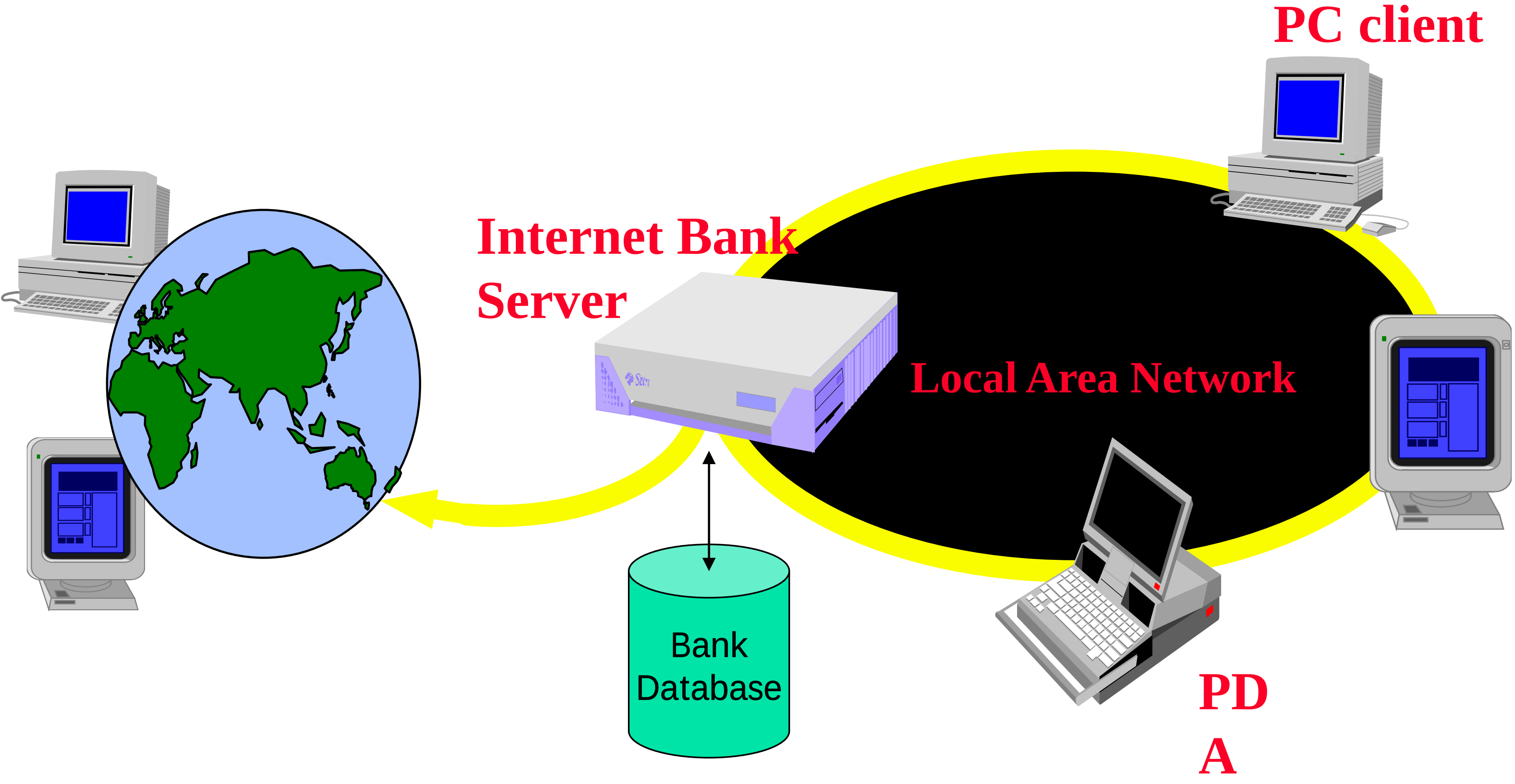
Next Class

- Thread Synchronisation
- Thread Priorities

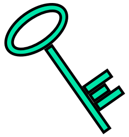
Accessing Shared Resources

- Applications Access to Shared Resources need to be coordinated.
  - Printer (two person jobs cannot be printed at the same time)
  - Simultaneous operations on your bank account

Online Bank: Serving Many Customers and Operations



Shared Resources



- If one thread tries to read the data and other thread tries to update the same date, it leads to inconsistent state.
- This can be prevented by synchronising access to data.
- In Java: “Synchronized” method:
  - syncronised void update()
  - {
    - …
  - }

the driver: 3rd Threads sharing the same object

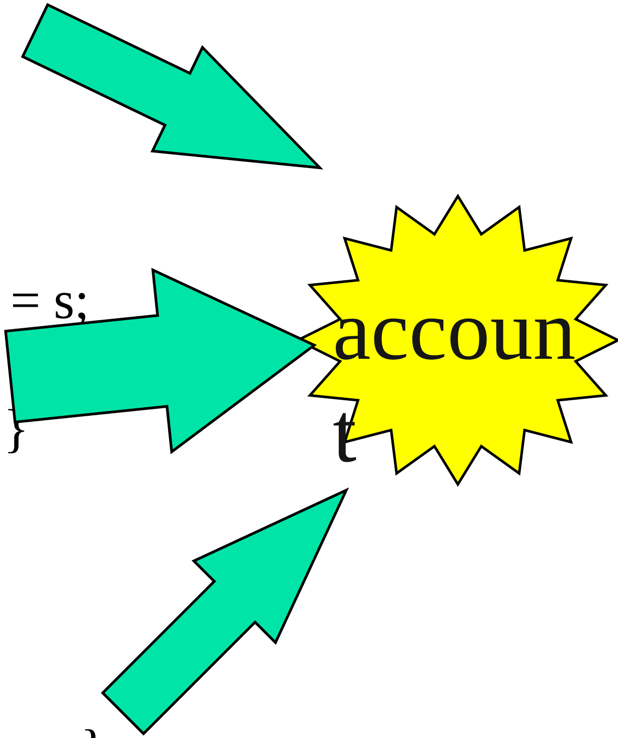
```
class InternetBankingSystem {
        public static void main(String [] args  ) {
            Account accountObject = new Account ();
            Thread t1 = new Thread(new MyThread(accountObject));
            Thread t2 = new Thread(new YourThread(accountObject));
            Thread t3 = new Thread(new HerThread(accountObject));
            t1.start();
            t2.start();
            t3.start();
          // DO some other operation
        } // end main()
}
```

Program with 3 threads and shared object

```
class MyThread implements Runnable  {
 Account account;
        public MyThread (Account s) {  account = s;}
        public void run() { account.deposit(); }
} // end class MyThread

class YourThread implements Runnable  {
 Account account;
        public YourThread (Account s) { account = s;
}
        public void run() { account.withdraw(); }
} // end class YourThread

class HerThread implements Runnable  {
 Account account;
        public HerThread (Account s) { account = s; }
        public void run() {account.enquire(); }
} // end class HerThread
```



account

Monitor (shared object) example

```
class Account {    // the 'monitor'
// DATA Members
  int balance;

// if 'synchronized' is removed, the outcome is unpredictable
 public synchronized void deposit( ) {
    // METHOD BODY : balance += deposit_amount;
  }

   public synchronized void withdraw( ) {
      // METHOD BODY: balance -= deposit_amount;
   }
   public synchronized void enquire( ) {
      // METHOD BODY: display balance.
   }
}
```

Thread Priority

- In Java, each thread is assigned priority, which affects the order in which it is scheduled for running. The threads so far had same default priority (ORM_PRIORITY) and they are served using FCFS policy.
  - Java allows users to change priority:
    - ThreadName.setPriority(intNumber)
      - MIN_PRIORITY = 1
      - NORM_PRIORITY=5
      - MAX_PRIORITY=10

Thread Priority Example

```
class A extends Thread
{
      public void run()
        {
            System.out.println("Thread A started");

            for(int i=1;i<=4;i++)
              {
                   System.out.println("\t From ThreadA: i= "+i);
              }

              System.out.println("Exit from A");
        }

}

class B extends Thread
{
      public void run()
        {
            System.out.println("Thread B started");

            for(int j=1;j<=4;j++)
              {
                   System.out.println("\t From ThreadB: j= "+j);
              }

              System.out.println("Exit from B");
        }

}
```

Thread Priority Example

```
class C extends Thread
{
    public void run()
     {
        System.out.println("Thread C started");

        for(int k=1;k<=4;k++)
         {
             System.out.println("\t From ThreadC: k= "+k);
         }
          System.out.println("Exit from C");
     }
}
class ThreadPriority
{
      public static void main(String args[])
       {
             A threadA=new A();
             B threadB=new B();
             C threadC=new C();

            threadC.setPriority(Thread.MAX_PRIORITY);
            threadB.setPriority(threadA.getPriority()+1);
            threadA.setPriority(Thread.MIN_PRIORITY);

            System.out.println("Started Thread A");
             threadA.start();

            System.out.println("Started Thread B");
             threadB.start();

            System.out.println("Started Thread C");
             threadC.start();

             System.out.println("End of main thread");
       }
}
```