Concurrent Algorithms
Lecture 2 - Processes and Threads

Eugene Kenny

eugkenny.lit@gmail.com

Limerick Institute of Technology

September 17th 2015

Lecture Outline

- Java implementations of concurrency
- process and threads
- a simple `ParticleApplet` example
- ways of creating `Thread` objects in Java:
  - extending the `Thread` class; and
  - implementing the `Runnable` interface
- the lifecycle of a `Thread`:
  - starting a new `Thread`,
  - while the `Thread` is running; and
  - shutting it down

Implementations of Concurrency

We can distinguish two main types of implementations of concurrency:

- **shared memory:** the execution of concurrent processes by running them on one or more processors all of which access a shared memory – processes communicate by reading and writing shared memory locations; and
- **distributed processing:** the execution of concurrent processes by running them on separate processors which don't share memory – processes communicate by message passing.

Java Implementations of Concurrency

Java supports both shared memory and distributed processing implementations of concurrency:

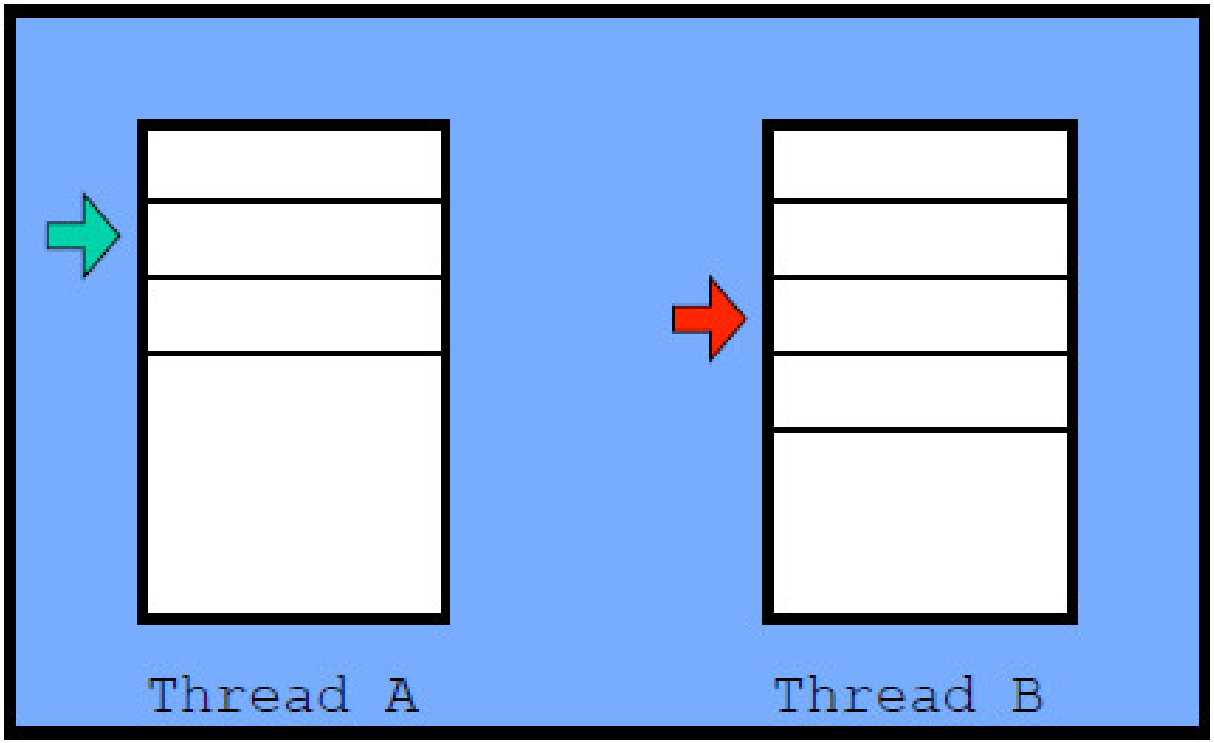
- **shared memory:** multiple user threads in a single Java Virtual Machine – threads communicate by reading and writing shared memory locations; and
- **distributed processing:** via the `java.net` and `java.rmi` packages – threads in different JVMs communicate by message passing or (remote procedure call)

Processes and Threads

- A *process* is any thread of execution or control, e.g.:
  - part of a concurrent program (lightweight process)
  - programs running in different address spaces on the same processor (heavyweight or OS processes)
  - running on a different processor or on a different computer
- A *thread* is a process which forms part of a concurrent program
  - threads execute within a *shared address space*
  - a *Java thread* is a process running within a JVM (JVM is generally run as a heavyweight or OS process)

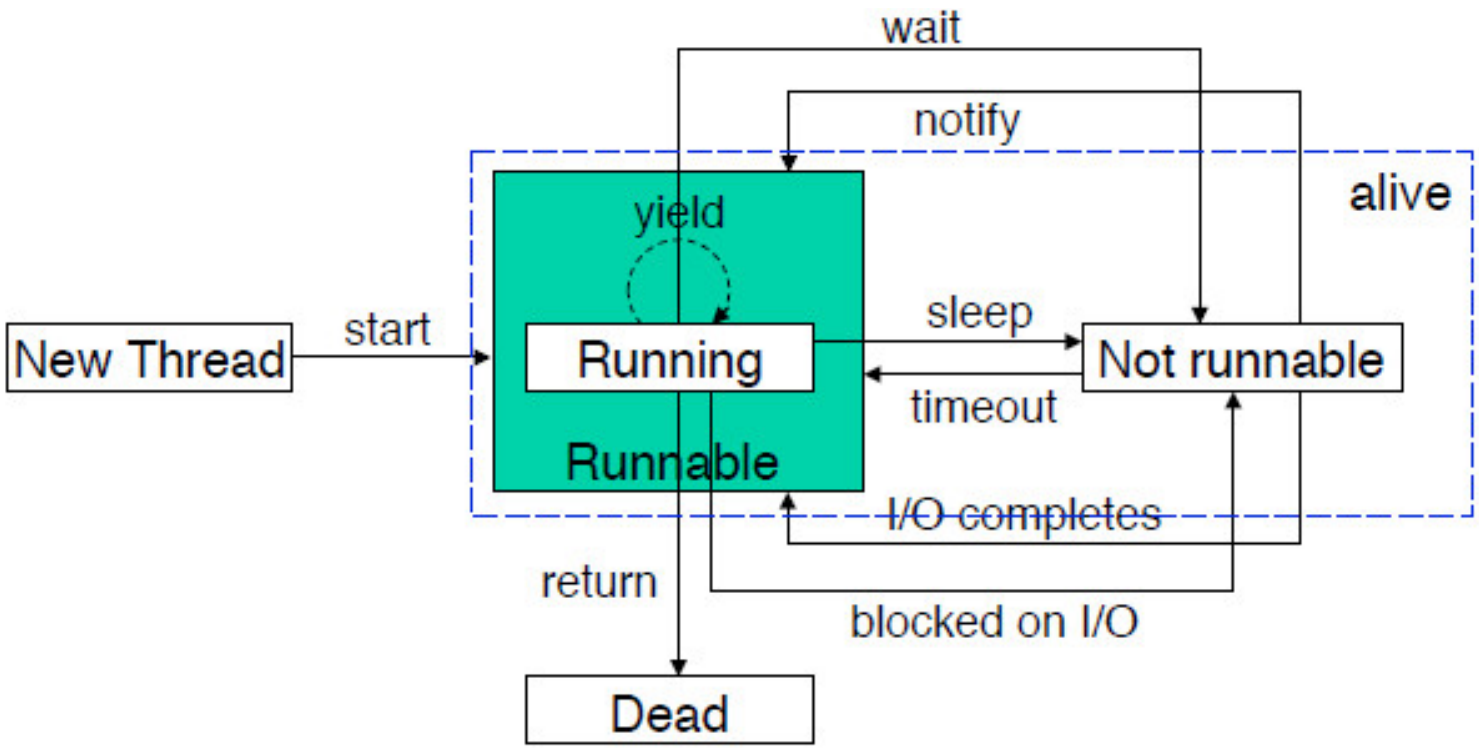
Threads in Java

A *thread* is a single sequential flow of control within a Java program.



Within the JVM, the *threads* comprising a Java program are represented by instances of the `Thread` class.

Thread lifecycle



A Simple Example: `ParticleApplet`

`ParticleApplet` creates *n* `Particle` objects, sets each particle in autonomous 'continuous' motion, and periodically updates the display to show their current positions:

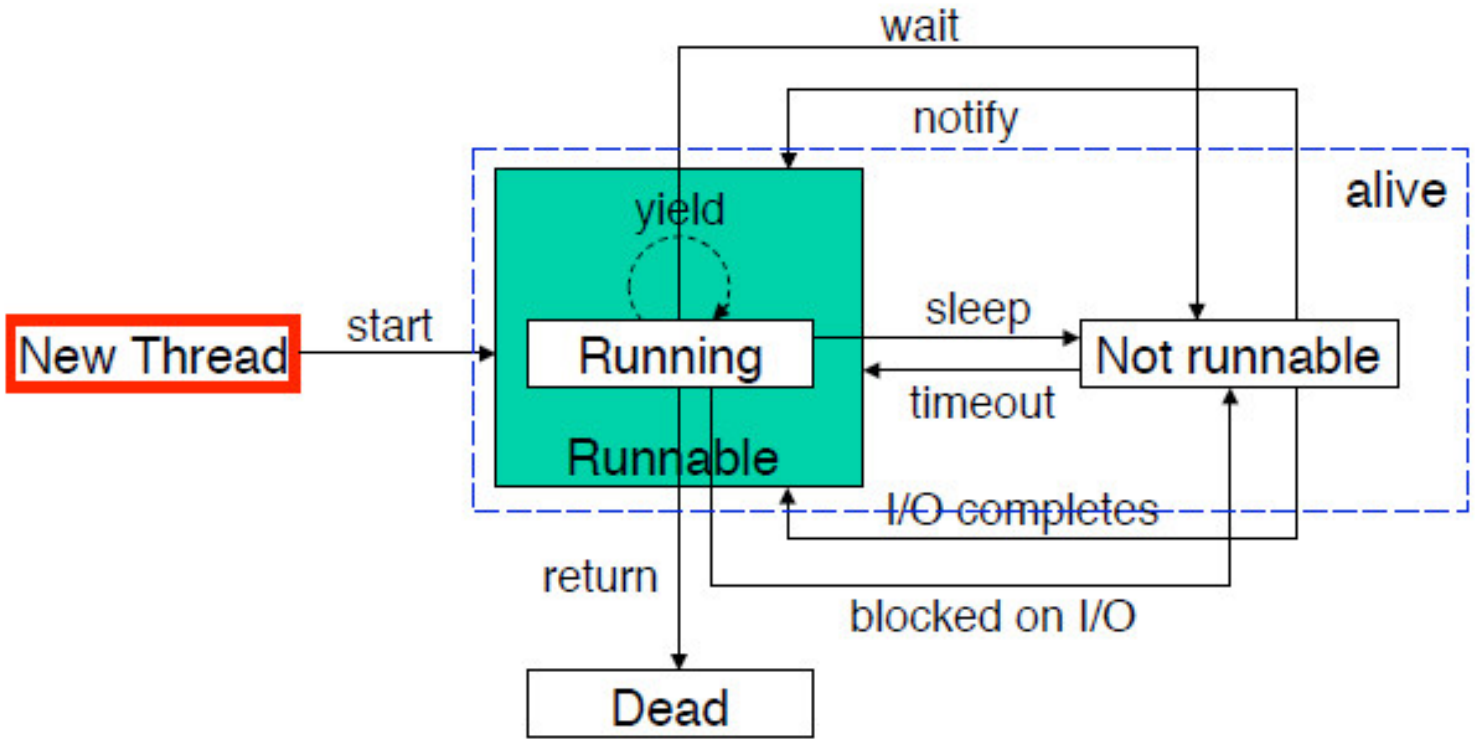
- each `Particle` runs in its own Java `Thread` which computes the position of the particle; and
- an additional `ParticleCanvas` `Thread` periodically checks the positions of the particles and draws them on the screen.
- in this example there are at least 12 threads and possibly more, depending on how the browser handles applets.

ParticleApplet

There are three classes:

- `Particle`: represents the position and behaviour of a particle and can draw the particle at its current position;
- `ParticleCanvas`: provides a drawing area for the `Particles`, and periodically asks the `Particles` to draw themselves; and
- `ParticleApplet`: creates the `Particles` and the canvas and sets the `Particles` in motion.

Thread lifecycle: creation



Creating Threads

There are two ways to create a thread:

- extending the `Thread` class and overriding its `run()` method; or
- defining a class which implements the `Runnable` interface and its `run()` method and passing the `Runnable` object to the `Thread` constructor.

```
public interface java.lang.Runnable{
  void run();
}
```

The Thread class implements the `Runnable` interface.

Extending the Thread class

```
class Particle extends Thread{

  protected int x, y;
  protected final random rng = new Random(this.hashCode());

  // constructor etc

  public void run(){
    try{
      for(;;){
        move();
        sleep(100);
      }
    }catch (InterruptedException e){
      return;
    }
  }
// other methods ...
```

Particle class continued

```
    public synchronized void move(){
      x += (rng.nextInt() % 10);
      y += (rng.nextInt() % 10);
    }

    public void draw(Graphics g) {
      int lx, ly;
      synchronized(this) { lx = x; ly = y; }
      g.drawRect(lx, ly, 10, 10);
    }
}
```

Implementing Runnable

```
class ParticleCanvas extends Canvas implements Runnable{
  private Particle[] particles = new Particle[0];

  // constructor etc ...

  public void run(){
    try{
      for(;;){
        repaint();
        Thread.sleep(100);
      }
    }
    catch (InterruptedException e) { return; }
  }

  // other methods ...
```

ParticleCanvas class continued

```
  protected synchronized void getParticles(){
    return particles;
  }

  // called by Canvas.repaint();

  public void paint(Graphics g){
    Particle[] ps = getParticles();
    for (int i = 0; i < ps.length(); i++)
      ps[i].draw(g);
  }
}
```

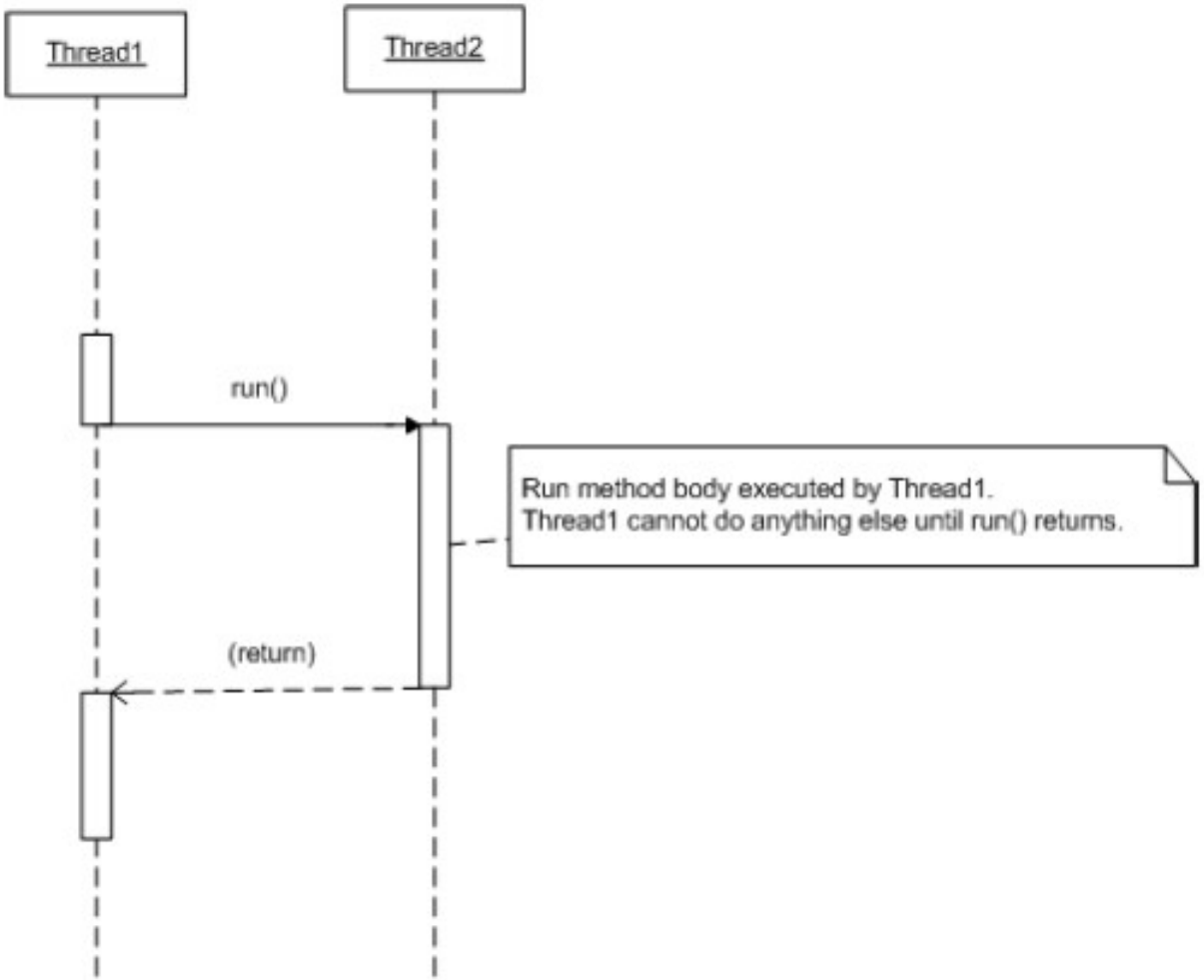
Particle threads

```
public class ParticleAppletA extends Applet{

  protected final ParticleCanvas canvas = new ParticleCanvas(400)
      ;
  protected Particle[] particles; // null when not running
  protected Thread canvasThread;

  // ParticleApplet start method
  public synchronized void start() {
    int n = 10; // just for demo
    if (particles == null){ // bypass if already started
      particles = new Particle[n];
      for (int i = 0; i < n; ++i){
        particles[i] = new Particle(200, 200);
        particles[i].setName("Particle Thread " + i);
        particles[i].start();
      }
      canvas.setParticles(particles);
      // continued ...
```

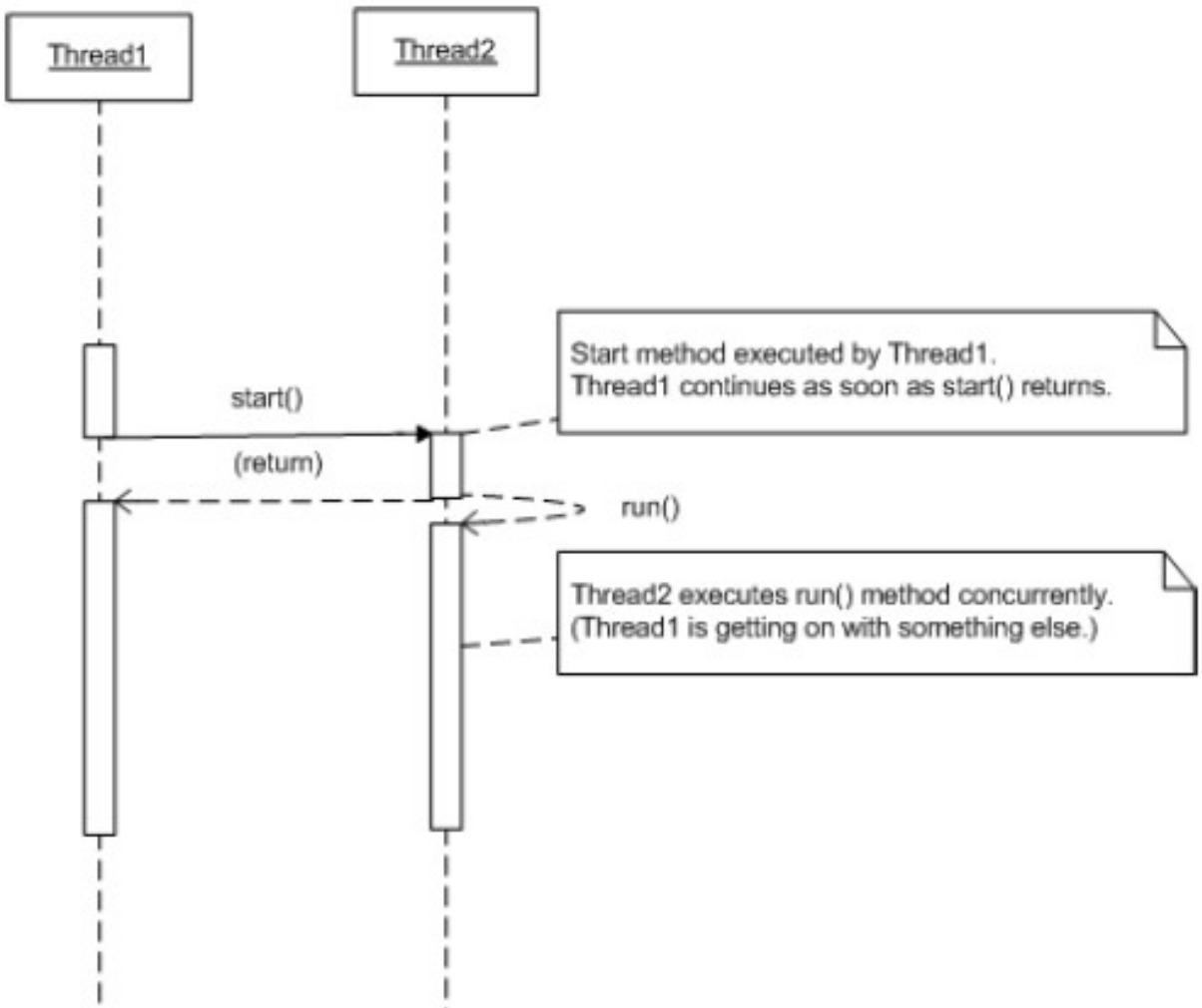
ParticleCanvas thread

```
public class ParticleAppletA extends Applet{

  protected final ParticleCanvas canvas = new ParticleCanvas(400)
      ;
  protected Particle[] particles; // null when not running
  protected Thread canvasThread;

  // ParticleApplet start method ...
  public synchronized void start() {
    int n = 10; // just for demo
    if (particles == null){ // bypass if already started

      // code to start particles omitted
      canvasThread = new Thread(canvas);
      canvasThread.setName("Canvas Thread");
      canvasThread.start();
    }
  }
```

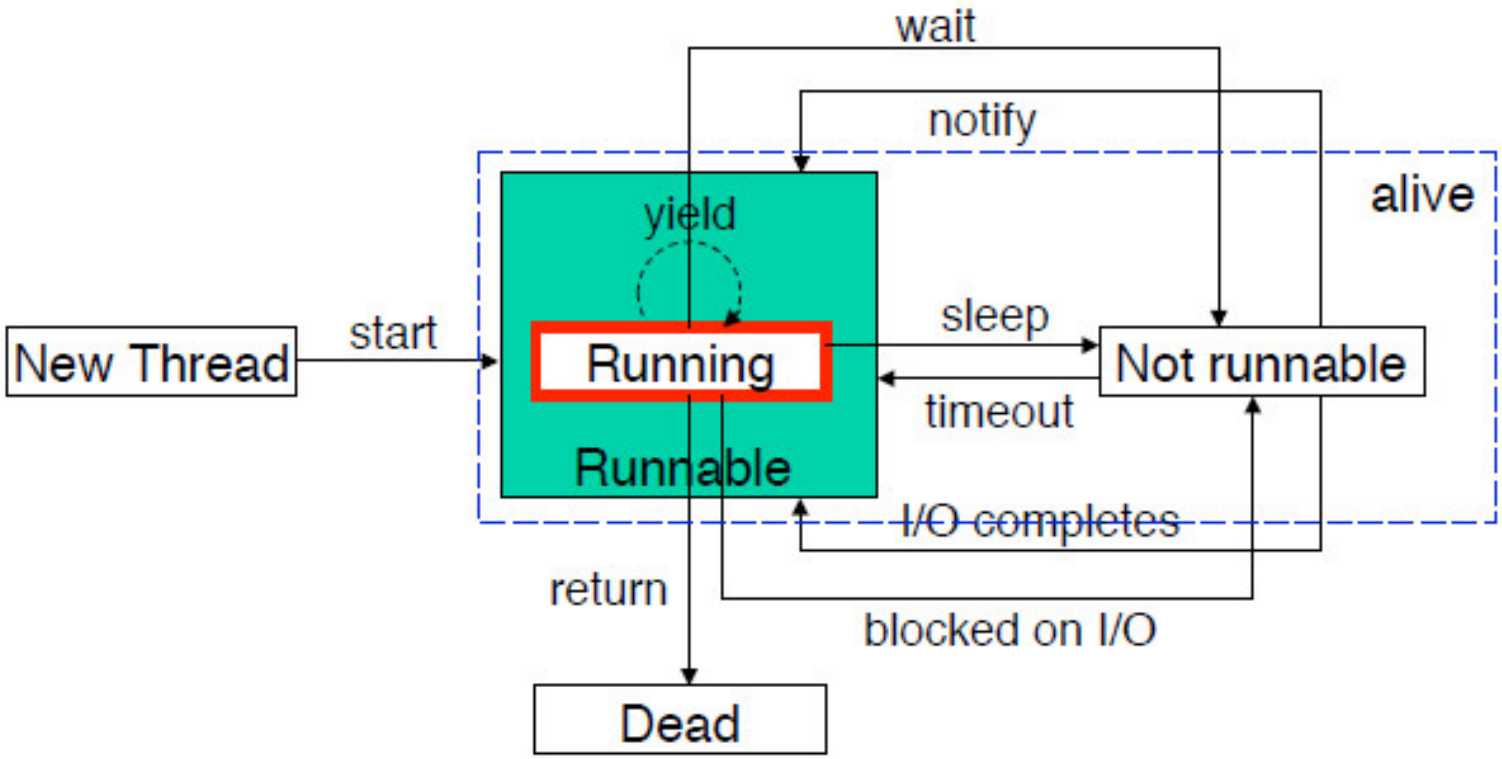
Calling `run()` ... (wrong!)



Calling `start()` ... (right!)



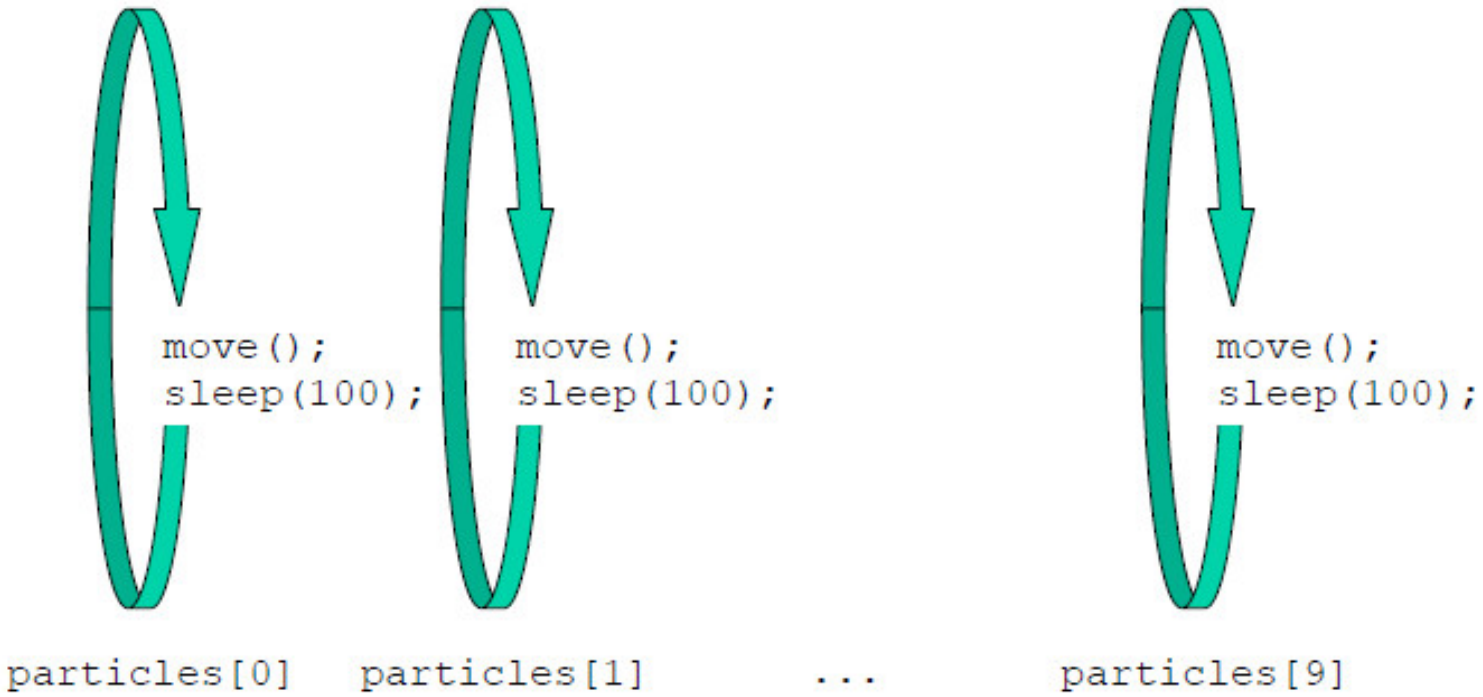
Thread lifecycle: running



Particle.run()

```
class Particle extends Thread{
  // fields, constructor etc
  public void run(){
    try{
      for(;;){
        move();
        sleep(100);
      }
    }
    catch (InterruptedException e) { return; }
  }
  // other methods
}
```

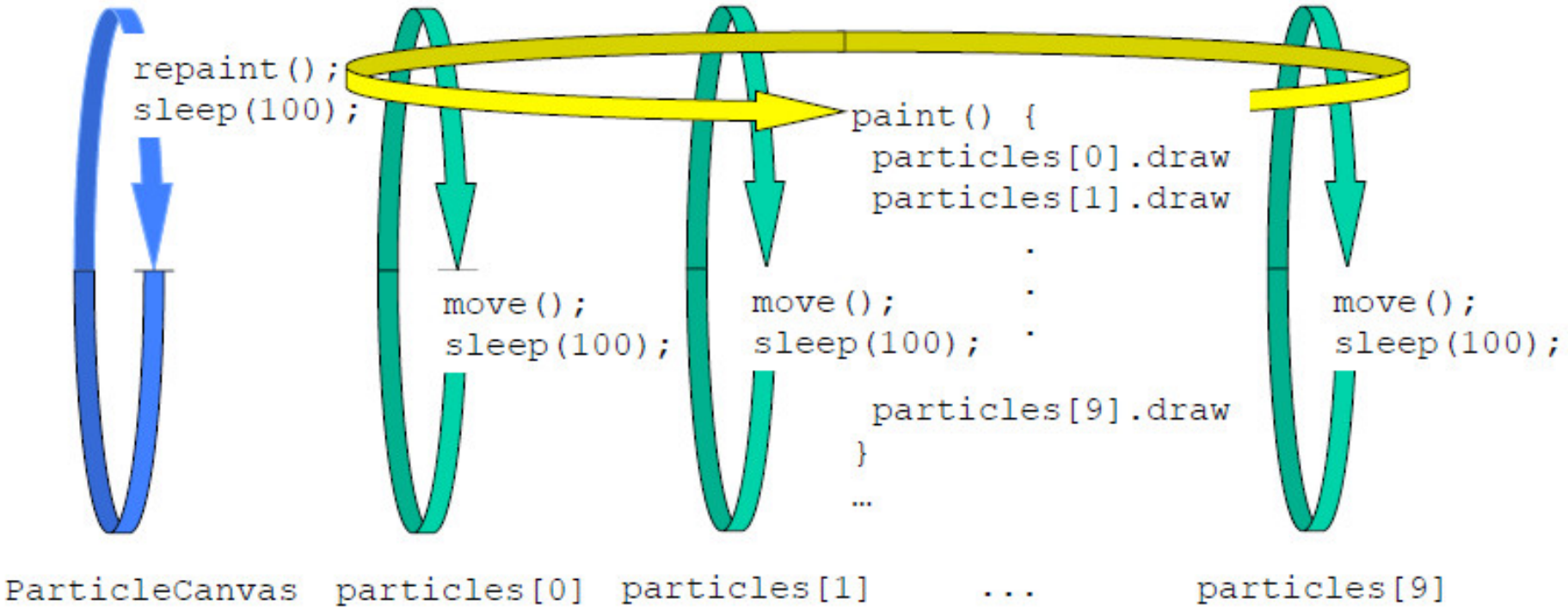
Particle threads



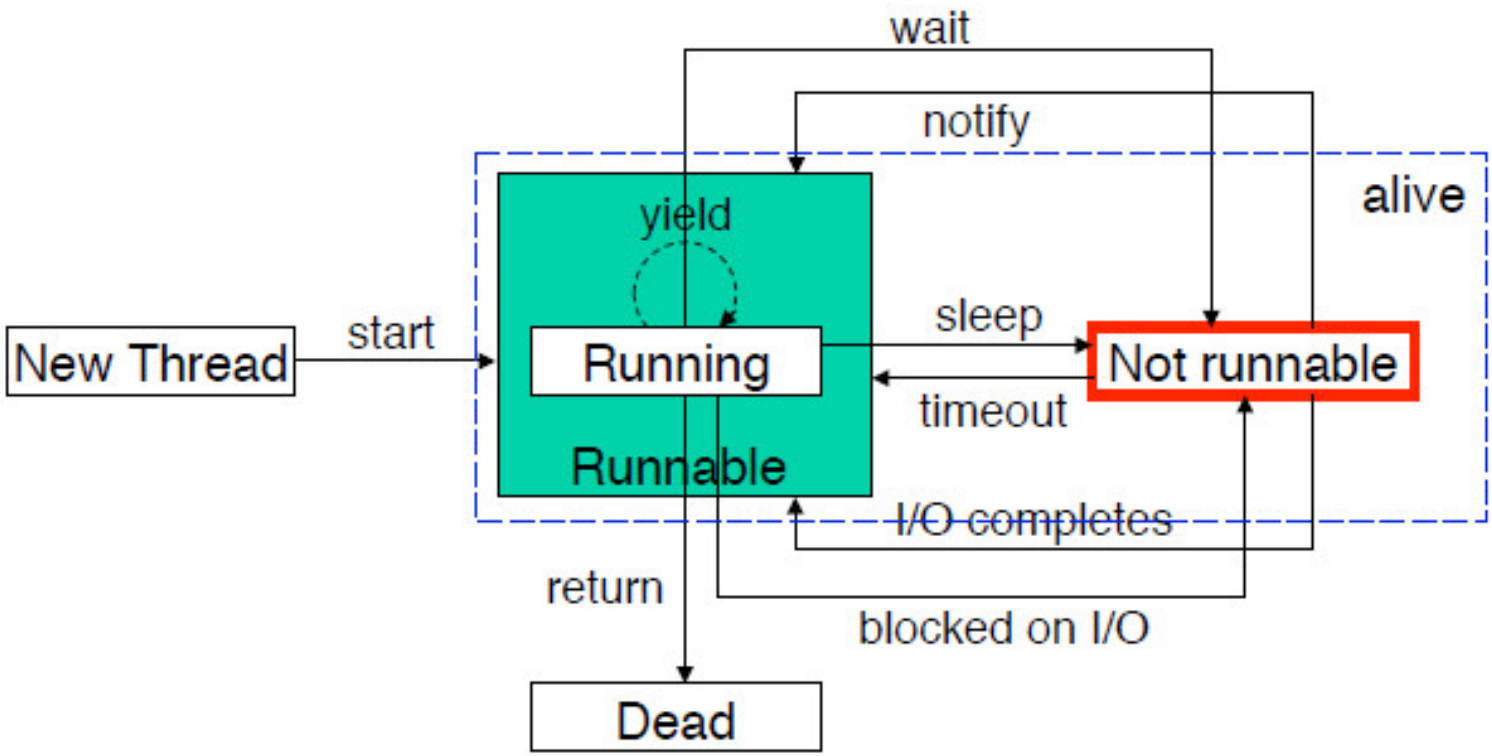
ParticleCanvas.run()

```
class ParticleCanvas extends Canvas implements Runnable{

  // fields, constructor etc
  public void run(){
    try{
      for(;;){
        repaint();
        Thread.sleep(100);
      }
    }
    catch (InterruptedException e) { return; }
  }
  // other methods
}
```

ParticleCanvas & AWT event threads



Thread lifecycle: not runnable



The not runnable state

A running `Thread` becomes not runnable when:

- it calls `sleep()` to tell the scheduler that it no longer wants to run;
- it blocks for I/O; or
- it blocks in `wait()`for condition synchronisation.

Examples of not runnable

- `Particle` threads become not runnable when they `sleep()`
- the `ParticleCanvas` thread becomes not runnable when it calls `sleep()`
- we'll return to `wait()` and condition synchronisation in later lectures

Scheduling methods

The `Thread` class provides the following **static** scheduling methods:

- `sleep(`**long** `msecs)`: causes the current thread to suspend for at least `msecs` milliseconds.
- `yield()`: requests that the JVM to run any other runnable but nonrunning thread rather than the current thread.

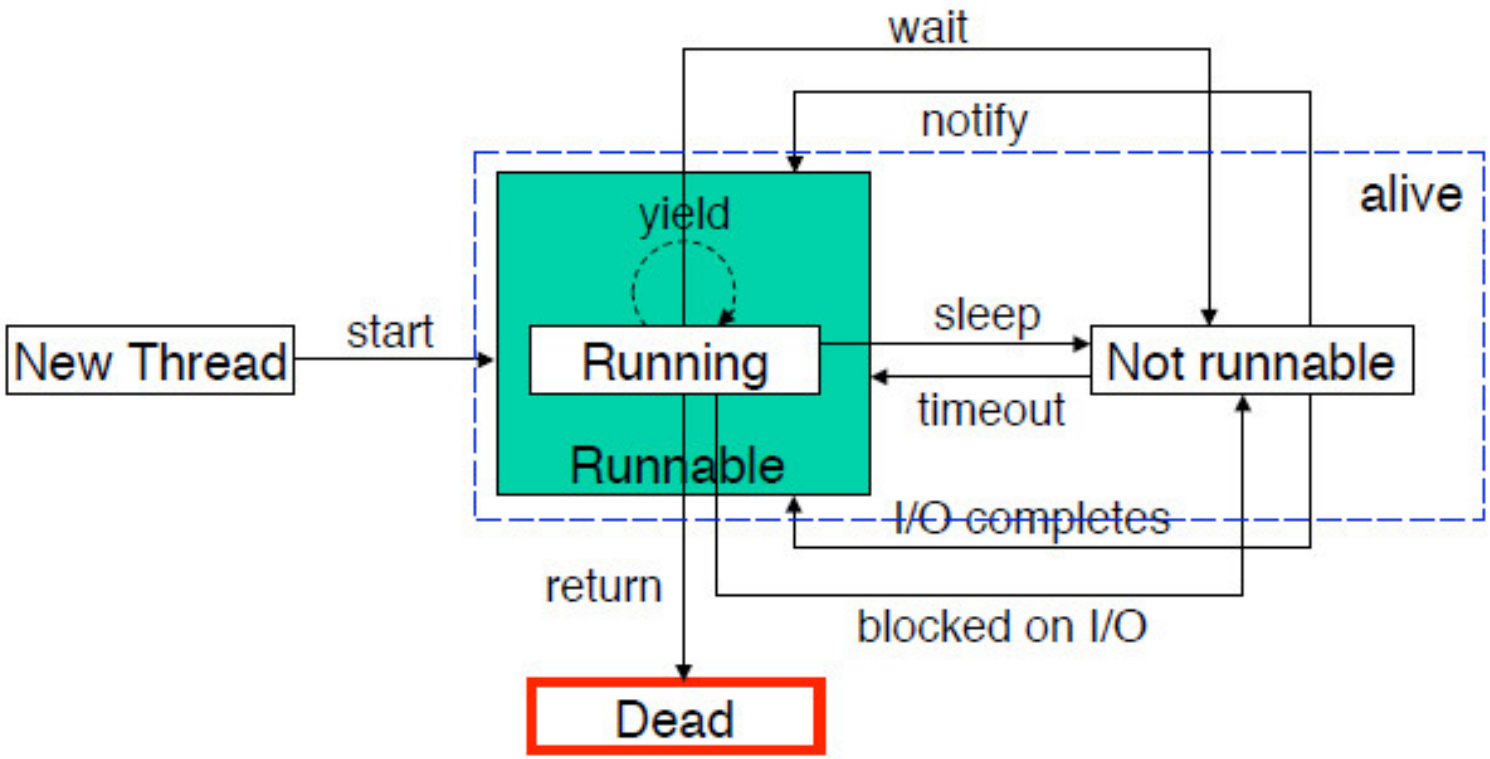
Thread priorities

Threads have *priorities* which heuristically influence schedulers:

- each thread has a priority in the range `Thread.MIN_PRIORITY` to `Thread.MAX_PRIORITY`
- by default, each new thread has the same priority as the thread that created it – the initial thread associated with a main method by default has priority `Thread.NORM_PRIORITY`
- the current priority of a thread can be accessed by the method `getPriority` and set via the method `setPriority`.

When there are more runnable threads than CPUs, a scheduler is generally biased in favour of threads with higher priorities.

Thread lifecycle: cancellation



Thread termination

A thread terminates when its `run()` method completes:

- either by returning normally; or
- by throwing an unchecked exception (`RuntimeException`, `Error` or one of their subclasses)

`Threads` are not restartable – invoking `start()` more than once results in an `InvalidThreadStateException`.

Thread cancellation

There are several ways to get a thread to stop:

- when the thread's `run()` method returns;
- call `Thread.stop()` – *this is a bad idea*, as it doesn't allow the thread to clean up before it dies; or
- `interrupt()` the thread.

Interrupting a Thread

Each `Thread` object has an associated boolean interruption status:

- `interrupt()`: sets a running thread's interrupted status to *true*
- `isInterrupted()`: returns *true* if the thread has been interrupted by `interrupt()`

A thread can periodically check its interrupted status, and if it is *true*, clean up and exit.

Thread (checked) exceptions

Threads which are blocked in calls `wait()` and `sleep()` aren't runnable, and can't check the value of the interrupted flag

- interrupting a thread which is waiting or sleeping aborts the thread and throws an `InterruptedException`
- if the interrupt flag is set *before* entering `sleep` or `wait` the thread immediately throws an `InterruptedException`

```
synchronized <method or block>
  try{
    wait()|sleep()
  } catch (InterruptedException e){
    // clean up and return (interrupted status false)
  }
```

Stopping the ParticleApplet

```
// ParticleApplet stop method (not Thread.stop)
public synchronized void stop(){
// Bypass if already stopped
  if (particles != null){
    for (int i = 0; i < particles.length; ++i)
      particles[i].interrupt();
    particles = null;
    canvasThread.interrupt();
    canvasThread = null;
  }
}
```

Stopping the Particles

```
// Particle run method
public void run(){
  try{
    for(;;){
      move();
      sleep(100);
    }
  }
  catch (InterruptedException e) { return; }
}
```

Suggested Reading:

- Andrews (2000), chapter 2, sections 2.1, chapter 3, section 3.1;
- Ben-Ari (1982), chapter 2.