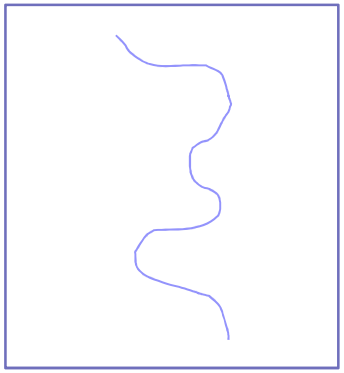
Basics of programming 3

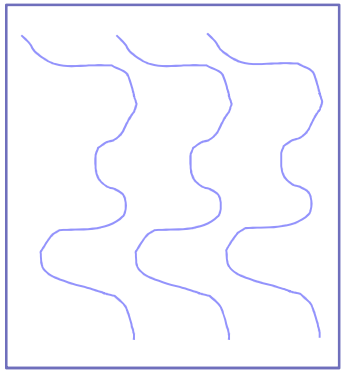
Multithreading in Java

Thread basics

- Motivation
  - in most cases sequential (single threaded) applications are not adequate
  - it's easier to decompose tasks into separate instruction sequences
  - e.g.: keyboard handling and graphical update



single threaded

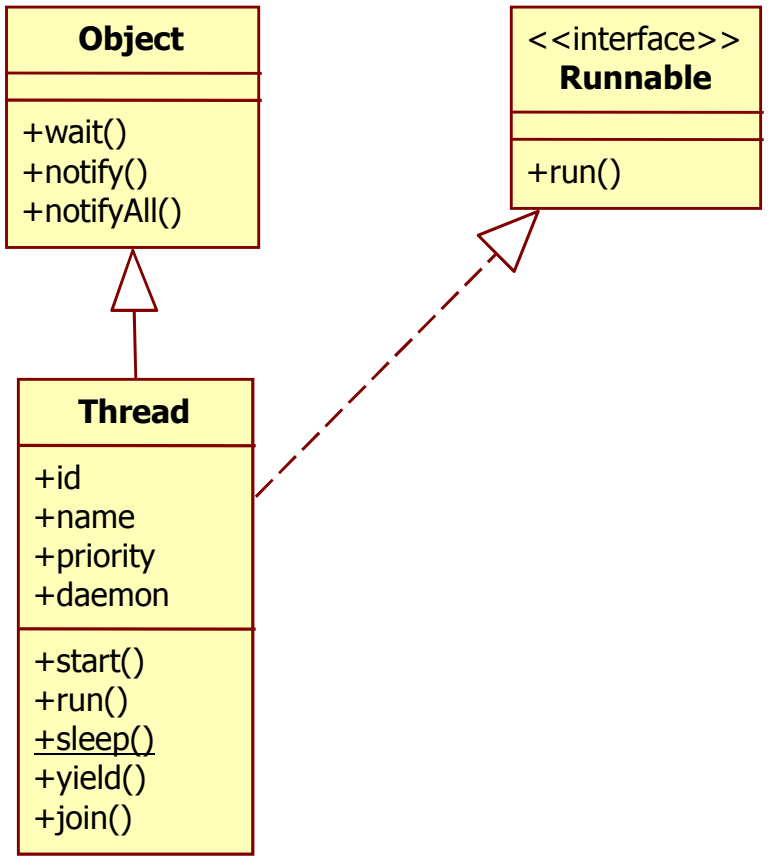


multithreaded

Java thread basics

- Implicit thread handling
  - class *Thread*, interface *Runnable*
  - threads share all memory
    - can have static thread-specific data
  - threads execute methods
  - each thread executing (mostly) independently
  - synchronization by object access (monitors)
  - non-strict priority scheduling

java.lang.Thread



Java thread basics

- Entry point: *run*
  - every thread must have a *void run()* method
  - in this method all Java features can be used
- Starting point
  - every thread has a *start* method
  - it has to be called to start the thread
  - starts a new execution thread and calls *run*
- Creating a thread
  - inheritance (*Thread*) or delegation (*Runnable*)

Creating and starting a thread

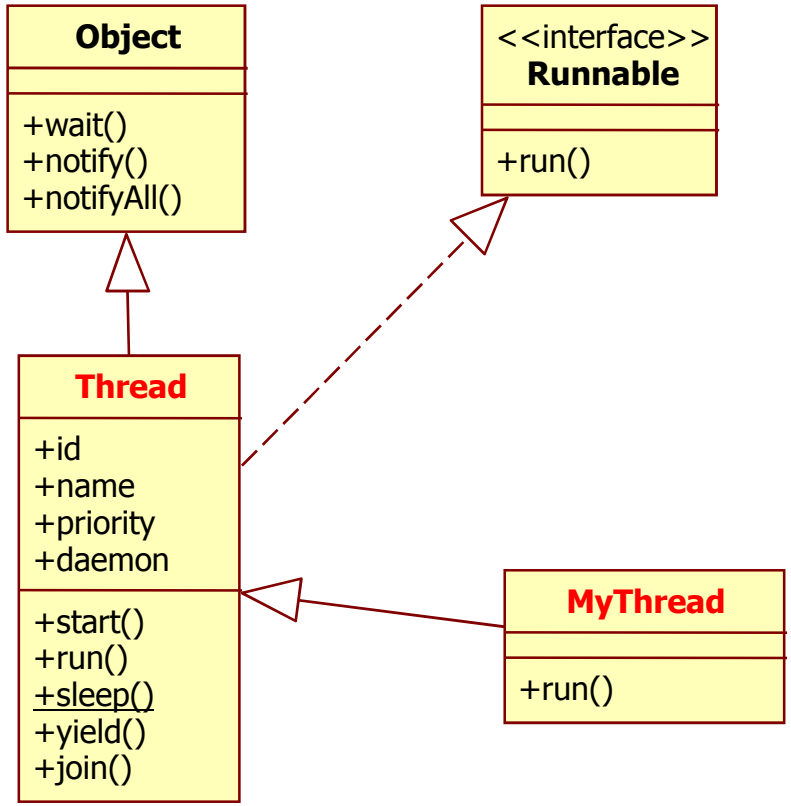
- Inheritance: extending class `Thread`

```
public class MyThread extends Thread {
  int a;
  int b;
  public MyThread(int i) { b=i; }
  public void run() {
    for (a = 0; a < b; a++) { System.out.println(a); }
  }
}
```

```
MyThread mt = new MyThread(1000);
mt.start();
...
```

Creating thread: inheritance

- Extending class *Thread*



Creating and starting a thread

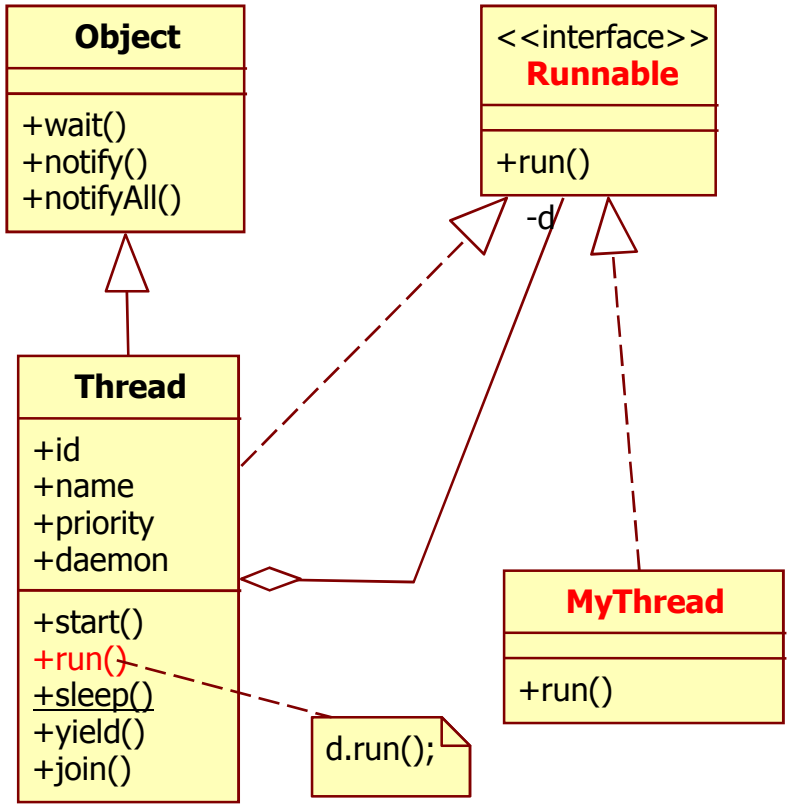
- Delegation: implementing if. `Runnable`

```
public class MyThread implements Runnable {
   int a;
   int b;
   public MyThread(int i) { b=i; }
   public void run() {
     for (a = 0; a < b; a++) { System.out.println(a); }
   }
}
```

```
MyThread mt = new MyThread(1000);
Thread t = new Thread(mt); // kell egy szál, ami futtat
t.start();
...
```

Creating threads: delegation

- Implementing interface *Runnable*



java.lang.Thread

- `run()`
  - entry point of the thread (like *main* for an application)
- `start()`
  - starts the thread, calls *run()*
- `sleep(long millis [, int nanos])`
  - thread waits for the given time
- `join([long millis [,int nanos]])`
  - waits for the given thread (for a given time)

java.lang.Thread

- `yield()`
  - gives CPU usage to next thread
- `interrupt()`
  - interrupts the thread when it's waiting
  - eg. for *wait*, *sleep*, etc. `InterruptedException`
- `setDaemon(boolean on)`
- `boolean isDaemon()`
  - sets daemon flag
  - when JVM stops, it stops all daemon threads
  - non-daemon threads are waited for

java.lang.Thread

- `int getState()`
  - returns state (runnable, waiting, etc, *see later*)
- `int getId()`
  - returns thread id
- `set/getName()`
  - thread's name
- `set/getPriority()`
  - thread's priority
  - is it daemon?

java.lang.Thread

- `boolean isAlive()`
  - does is still run?
- `static Thread currentThread()`
  - reference to the running thread object
  - for accessing the thread executing current code
- `ThreadGroup getThreadGroup()`
  - returns threadgroup
- `static int activeCount()`
  - number of active threads in the threadgroup

java.lang.Thread

- Stopping a thread
  - *Thread.stop()* method is deprecated

```
private volatile boolean stopSignal;
MyThread(){ stopSignal = false; }
public void stop() { stopSignal = true; }
public void run() {
    while (!stopSignal) {
        do a step or two...
    }
}
```

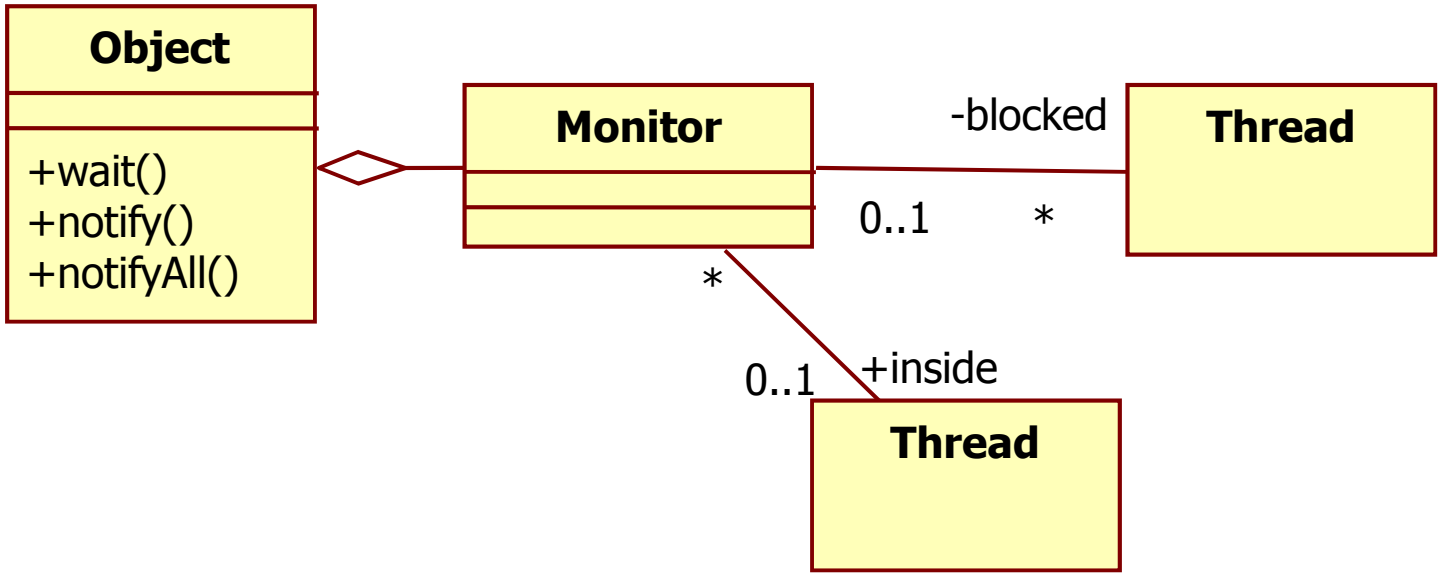
Theads vs. Objects

- Objects have
  - state (attributes, associations)
  - behaviour (methods)
- Threads do
  - execute statements described in methods
  - have *Thread* objects referring to them
    - c.f. *Thread.getCurrentThread()*
    - OO API for thread handling

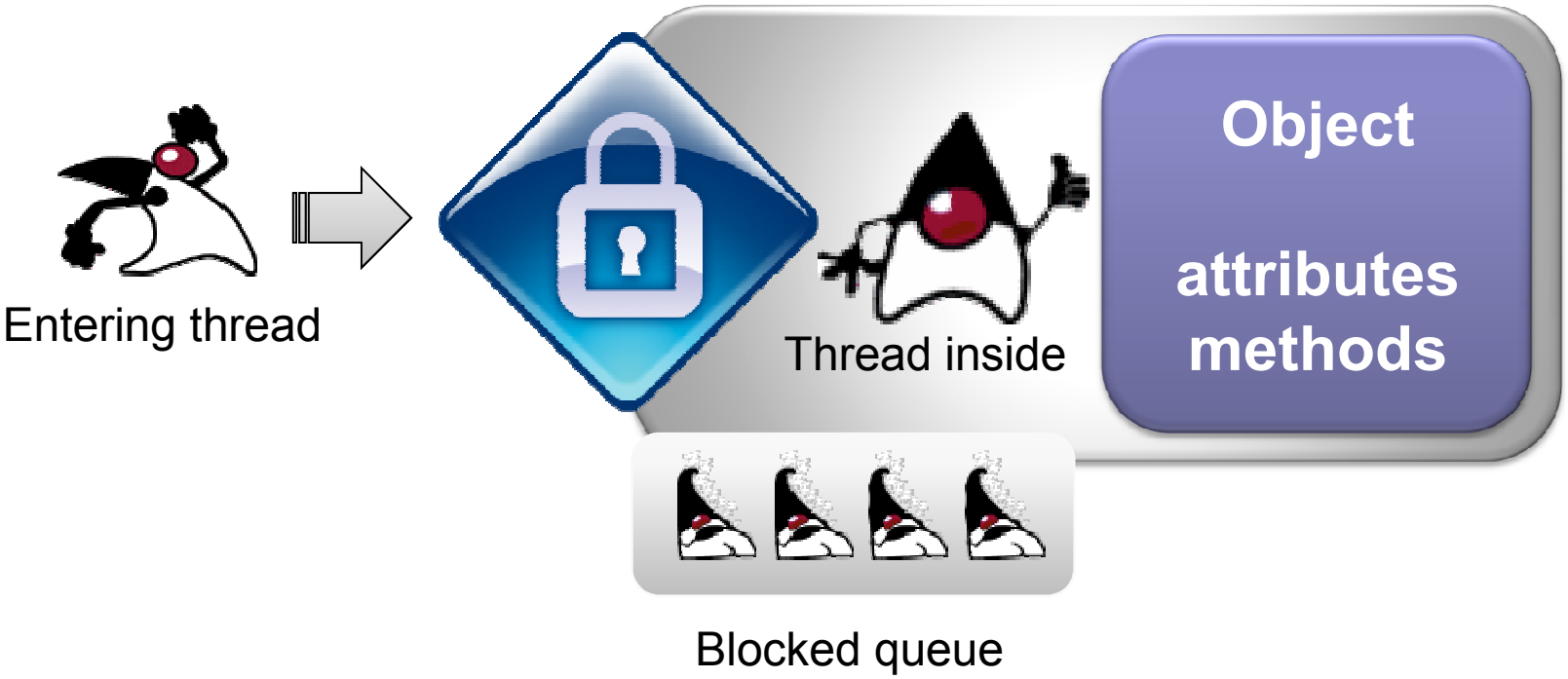
Mutual exclusion

- Motivation
  - some resources should be accessed by just a single thread at a time
- Every object has its own monitor
  - only one thread allowed inside the monitor
  - other threads must wait in the monitor queue
  - recursive entry is allowed
- **`static boolean holdsLock(Object obj)`**
  - checks if actual thread is inside monitor of *obj*

Mutual exclusion: monitor



Objects' monitors explained



Mutual exclusion

- Entering the monitor with `synchronized`

```
Hashtable<String, Integer> ht = ...;
public void increment(String s) {
        ...
        synchronized (ht) {
                int i = ht.get(s);
                i++;
                ht.put(s,i);
        }
        ...
}
```

Mutual exclusion

- `synchronized`
  - before a block
    - needs an object reference parameter
  - before a method
    - monitor is that of the object whose method is called
    - equivalent to a method wide synchronized block

```
void foo() {
        synchronized(this) {
                ...
        }
}
```

```
synchronized void foo() {

        ...

}
```

Thread signalling

- **`Object.wait([long millis [,int nanos]])`**
  - if called, the thread will wait for signals for the specified time
  - thread must be inside the monitor of the object
  - during wait it leaves the monitor temporarily

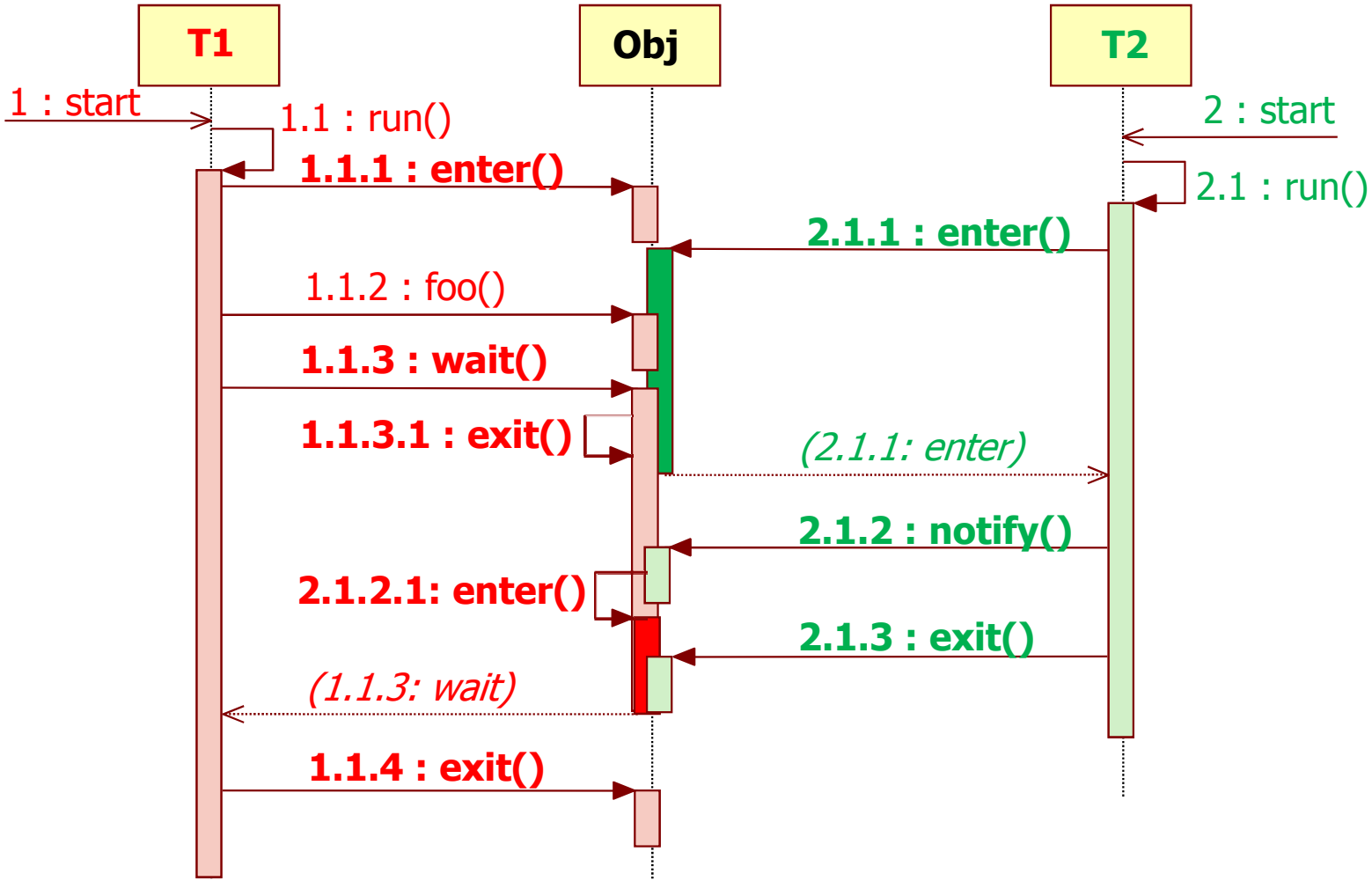
```
synchronized (obj) {
    ...
    try {
        obj.wait(); // temporarily leaving monitor
    } catch (InterruptedException ie) {...}
    ...
}
```

Thread signalling

- **`Object.notify()`**
  - notifies a thread that waits on the objects
  - thread must be inside the monitor of the object
  - notified thread enters the monitor queue of the object
- **`Object.notifyAll()`**
  - same as above, but notifies all waiting threads

```
synchronized (obj) {
        obj.notify(); // wakes a waiting thread
}
```

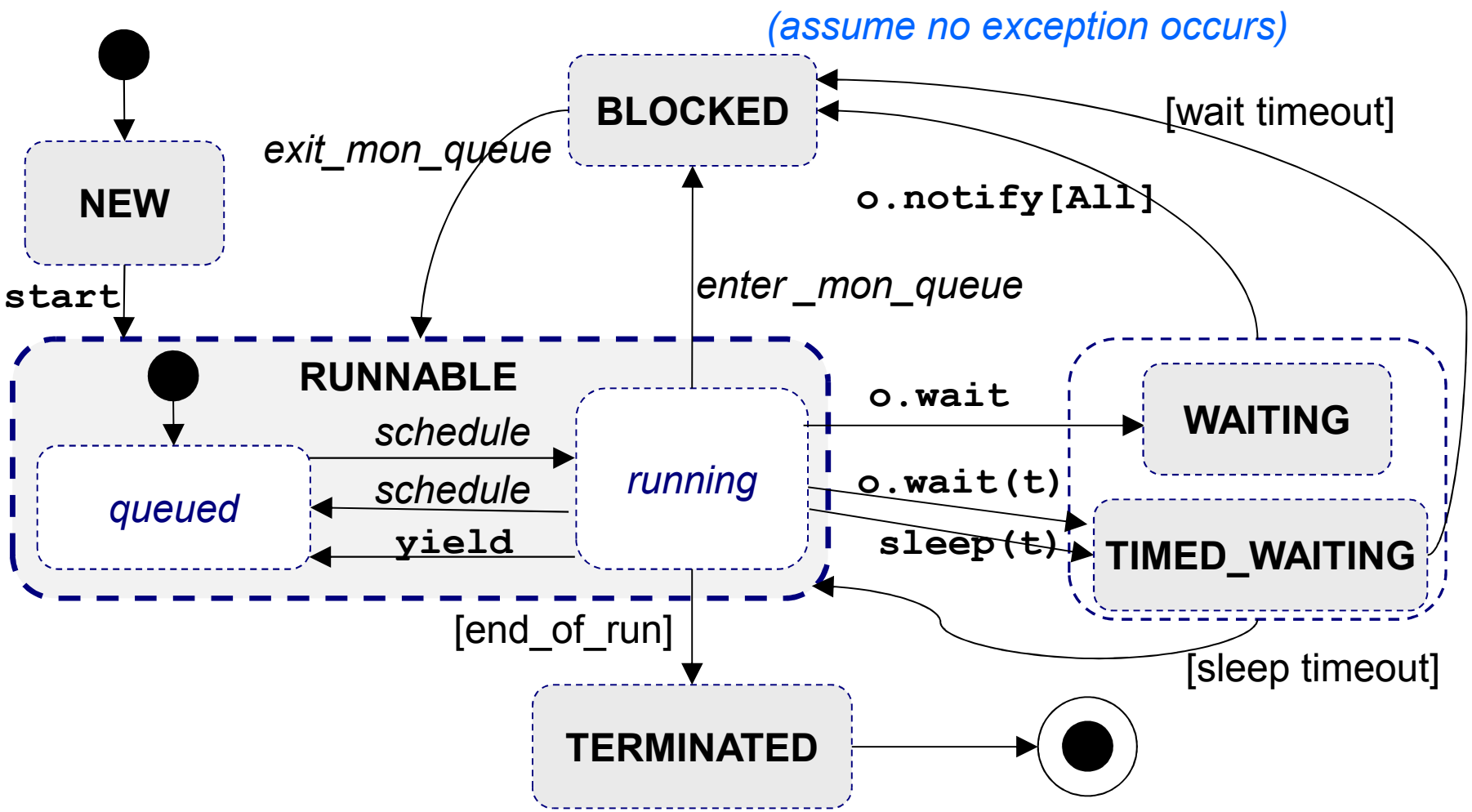
Monitors and wait-notify



States of the threads

- **`NEW`**
  - newly created, not yet started
- **`RUNNABLE`** ***`(+running)`***
  - runs or is able to run (already started)
- **`BLOCKED`**
  - waits for a monitor
- **`WAITING, TIMED_WAITING`**
  - waiting thread (***`Object.wait, Thread.sleep`***)
- **`TERMINATED`**
  - stopped, can not be restarted

Thread state diagram



Thread-safe collections

- Wrapper classes
  - Fabricated by class *Collections*
    - `public static <T> Collection<T> synchronizedCollection(Collection<T> c)`
    - also for List, Set, SortedSet, Map, SortedMap
  - Backed by original collection
    - Stands between client (caller) and collection
    - Underlying collection is modified, accessed, etc
    - Makes calls synchronized

Thread-safe collections

- Genuine thread-safe collection
  - In package *java.util.concurrent*
  - *ConcurrentHashMap*
    - Thread-safe *Map* implementation
  - *CopyOnWriteArrayList/Set*
    - Modification creates new array

      → modification are costly
    - Iterators are independent, but can not modify

Volatile

- Thread data is cached
  - Cache might be out-of-date
    - Update e.g. before/after synch block

      → attributes might differ in different caches
  - Keyword *volatile*
    - makes attributes's access atomic, synchronized
    - Useful for 2-word types as well (eg. *double*, *long*)
      - Makes data fetch atomic

Further thread features

- Interruption
  - *InterruptedException*, etc
- Per-thread data
  - *ThreadLocal<T>*
- Threadpools
  - *Callable* and *ExecutorService*
- Timed starts
  - *TimerTask*