Background on Concurrency & Parallelism in Java (Part 2)

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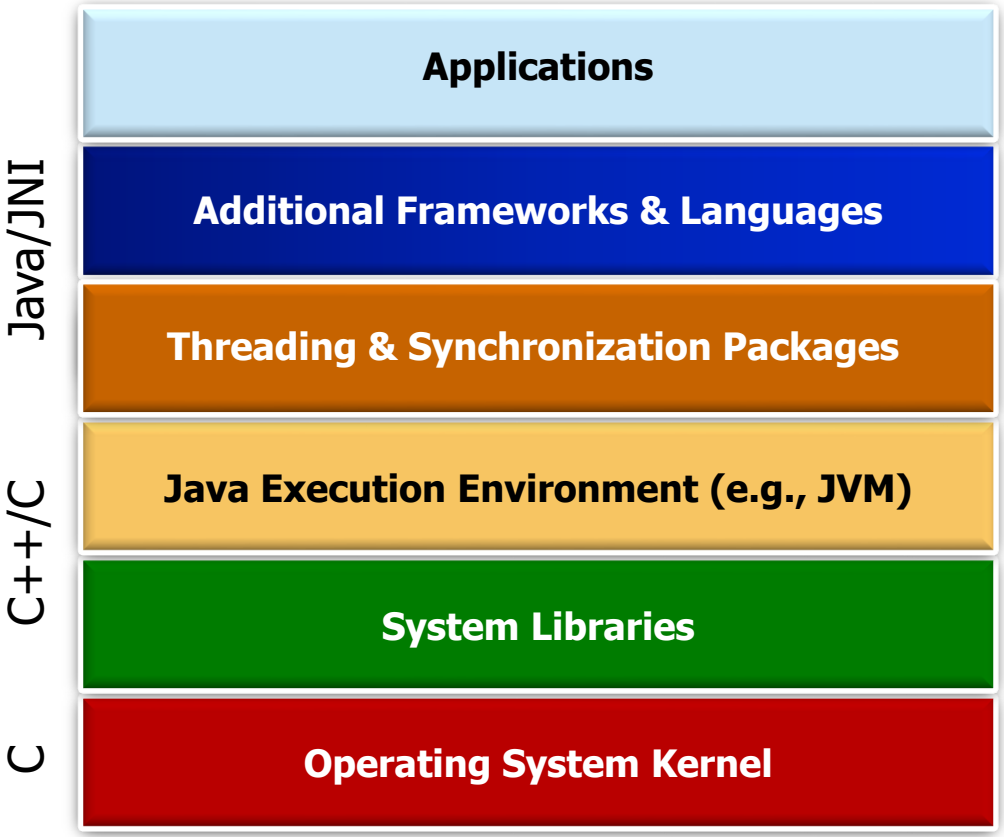
Learning Objectives in this Part of the Lesson

- Understand the meaning of the terms concurrency & parallelism
- Be aware of the history of Java concurrency & parallelism



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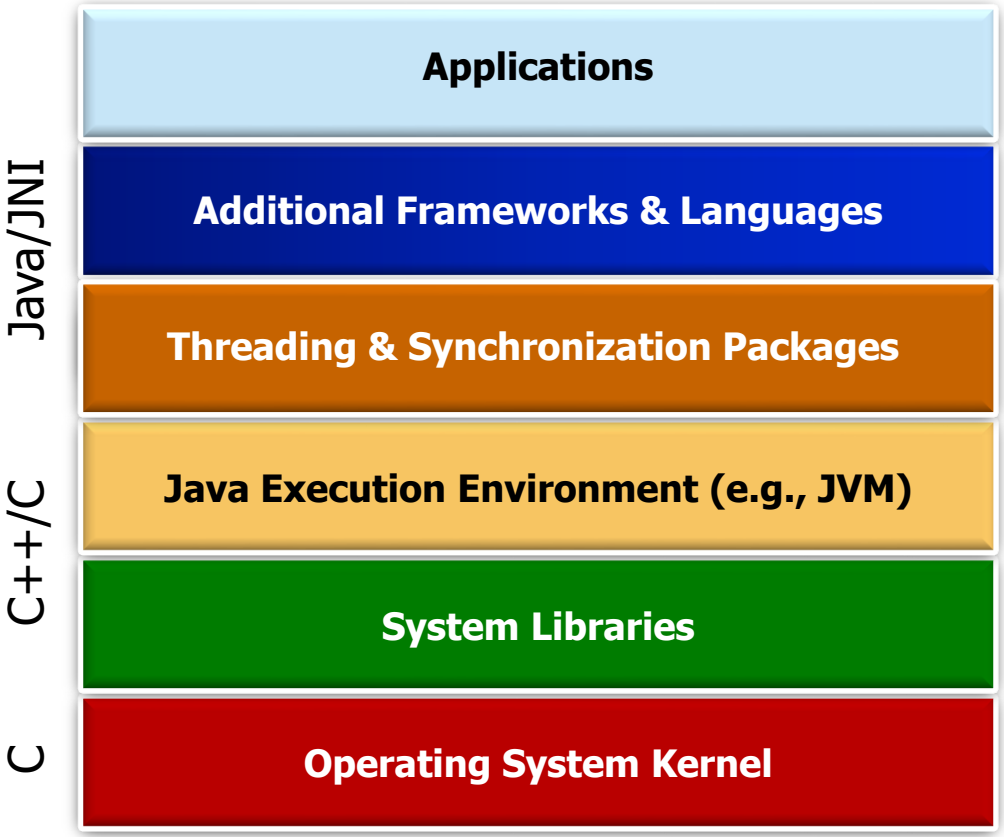


Hopefully, you'll already know some of this!!!

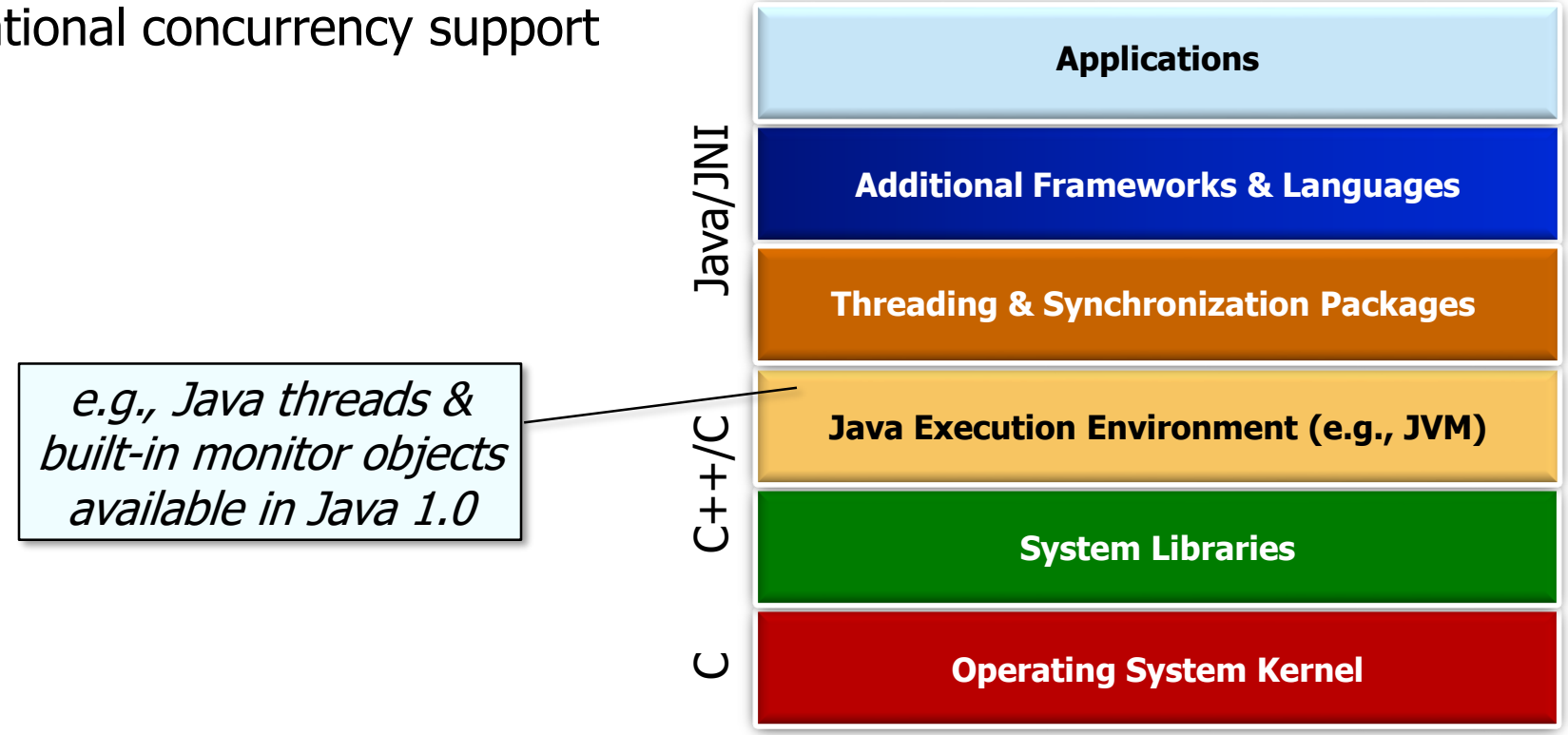
Learning Objectives in this Part of the Lesson

- Understand the meaning of the terms concurrency & parallelism
- Be aware of the history of Java concurrency & parallelism
- Know which Java mechanism(s) to understand & apply

A Brief History of Concurrency & Parallelism in Java

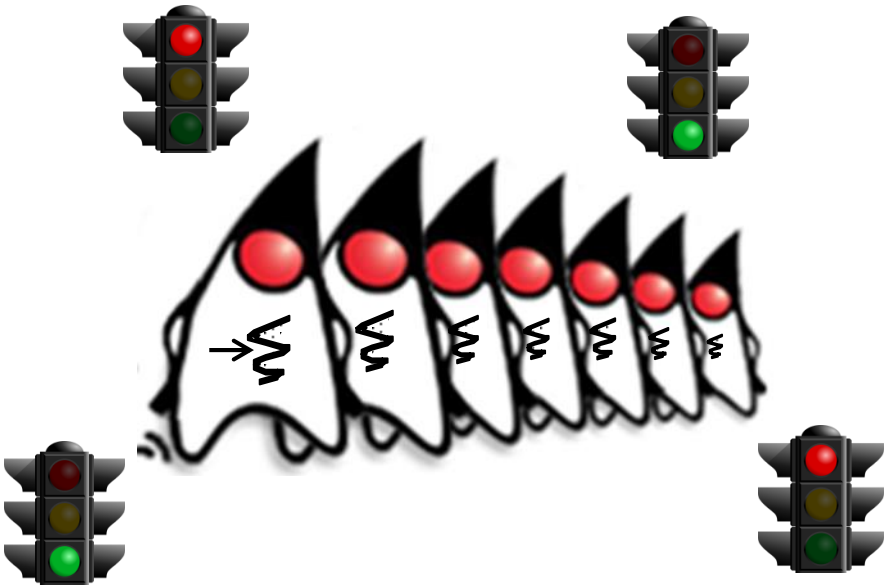
A Brief History of Concurrency & Parallelism in Java

- Foundational concurrency support



A Brief History of Concurrency & Parallelism in Java

- Foundational concurrency support
  - Focus on basic multi-threading & synchronization primitives



See docs.oracle.com/javase/tutorial/essential/concurrency

A Brief History of Concurrency & Parallelism in Java

- Foundational concurrency support
  - Focus on basic multi-threading & synchronization primitives

Allow multiple threads to communicate via a bounded buffer

```
SimpleBlockingBoundedQueue<Integer>
   simpleQueue = new
     SimpleBlockingBoundedQueue<>();

Thread[] threads = new Thread[] {
   new Thread(new Producer<>
                    (simpleQueue)),
   new Thread(new Consumer<>
                    (simpleQueue))
};

for (Thread thread : threads)
   thread.start();

for (Thread thread : threads)
   thread.join();
```

See github.com/douglascraigschmidt/LiveLessons/tree/master/SimpleBlockingQueue

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```

Start & join these multiple threads

See github.com/douglascraigschmidt/LiveLessons/tree/master/SimpleBlockingQueue

A Brief History of Concurrency & Parallelism in Java

- Foundational concurrency support
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```
class SimpleBlockingBoundedQueue
                                        <E> {
  public E take() ...{
    synchronized(this) {
      while (mList.isEmpty())
        wait();

      notifyAll();

      return mList.poll();
    }
  }
```

Built-in monitor object mutual exclusion & coordination primitives

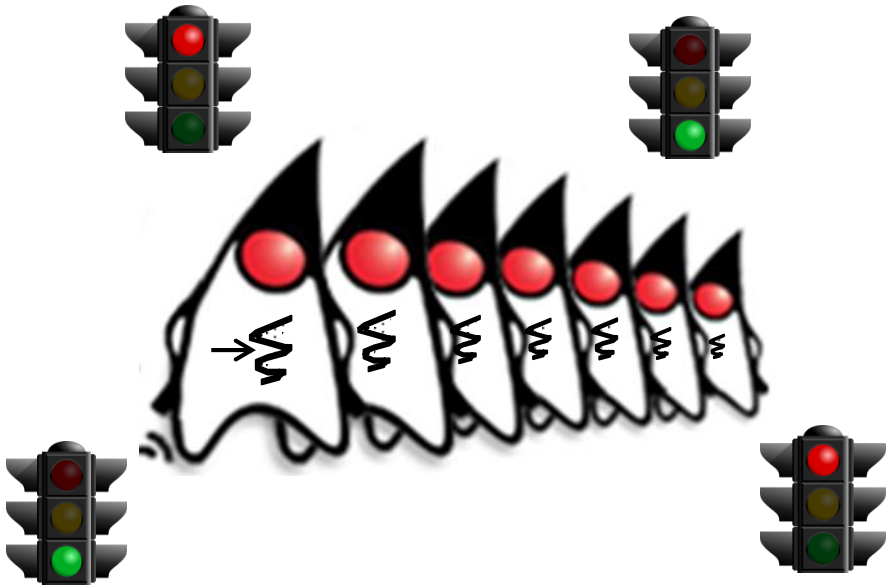
See github.com/douglascraigschmidt/LiveLessons/tree/master/SimpleBlockingQueue

A Brief History of Concurrency & Parallelism in Java

- Foundational concurrency support
  - Focus on basic multi-threading & synchronization primitives
  - Efficient, but low-level & very limited in capabilities

A Brief History of Concurrency & Parallelism in Java

- Foundational concurrency support
  - Focus on basic multi-threading & synchronization primitives
  - Efficient, but low-level & very limited in capabilities
    - Many accidental complexities



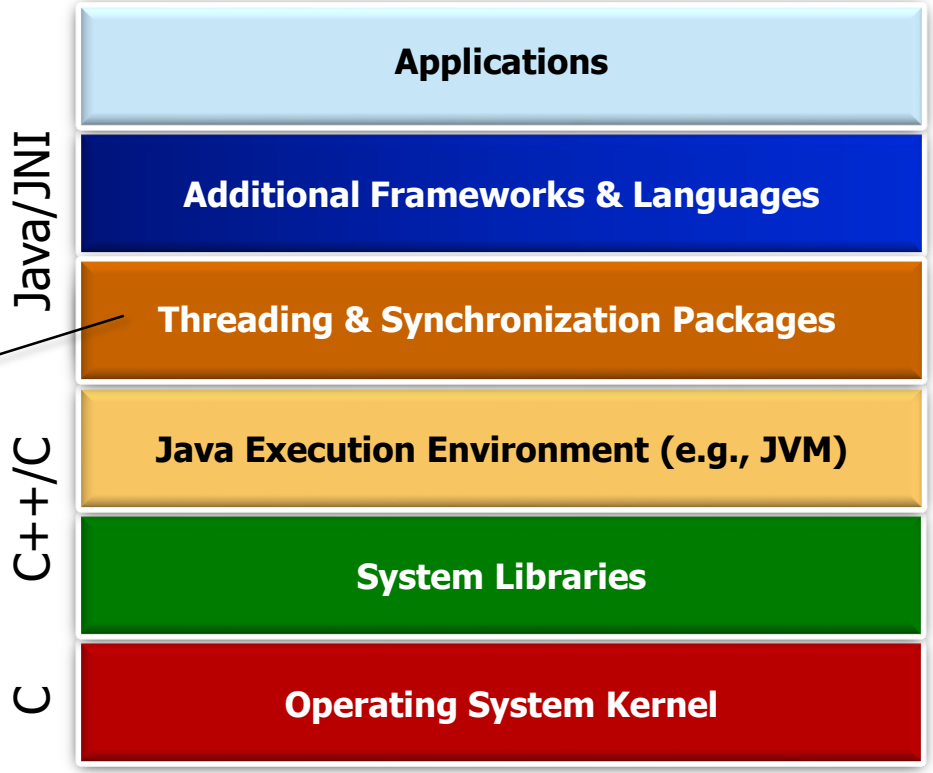
Accidental complexities arise from limitations with software techniques, tools, & methods

See en.wikipedia.org/wiki/No_Silver_Bullet

A Brief History of Concurrency & Parallelism in Java

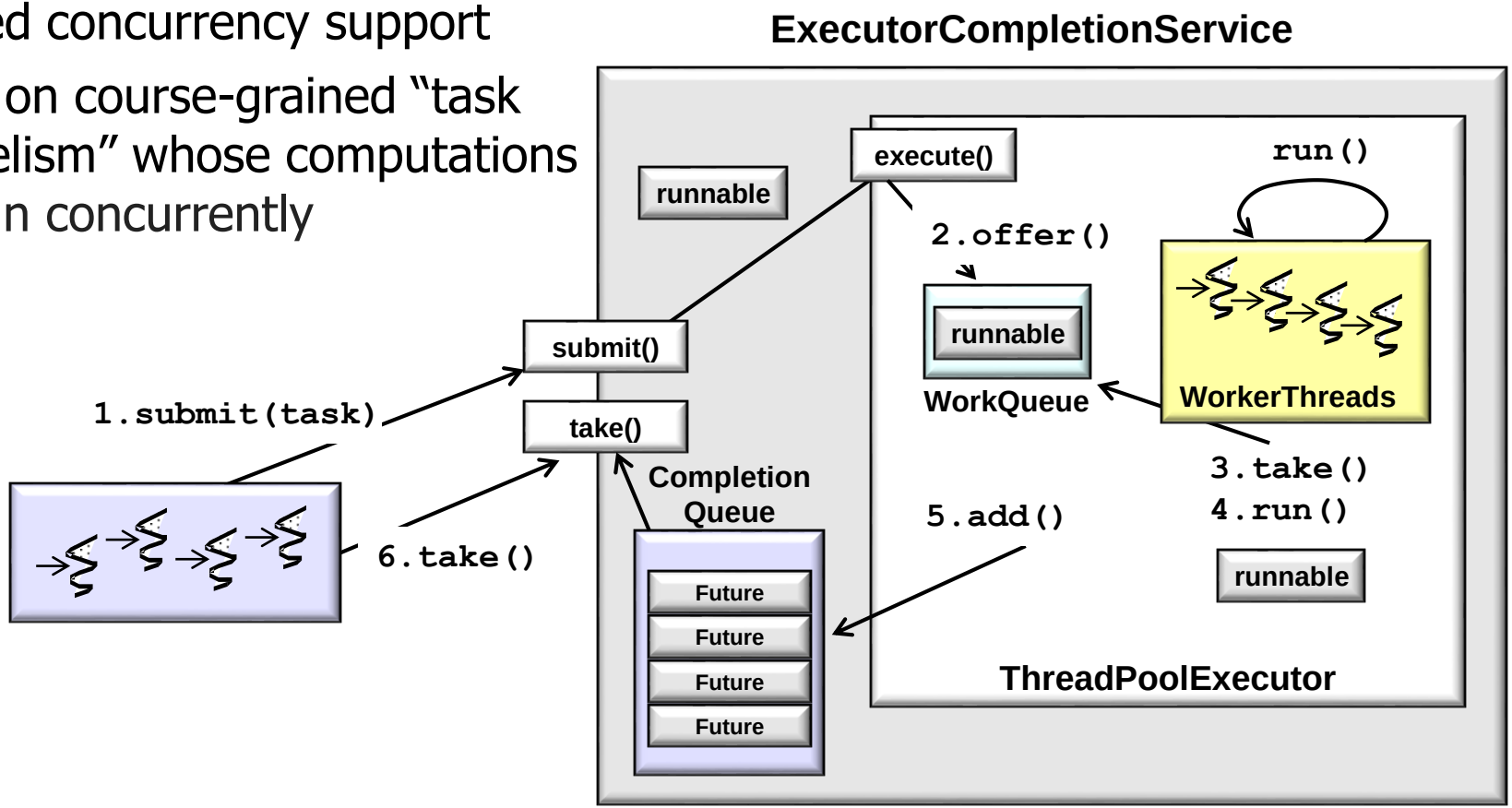
- Advanced concurrency support

e.g., Java executor framework, synchronizers, blocking queues, atomics, & concurrent collections available in Java 1.5+



A Brief History of Concurrency & Parallelism in Java

- Advanced concurrency support
  - Focus on course-grained "task parallelism" whose computations can run concurrently



See en.wikipedia.org/wiki/Task_parallelism

A Brief History of Concurrency & Parallelism in Java

- Advanced concurrency support
  - Focus on course-grained "task parallelism" whose computations can run concurrently

```
ExecutorService executor =
  Executors.newFixedThreadPool
    (numOfBeings,
     mThreadFactory);
...
CyclicBarrier entryBarrier =
  new CyclicBarrier(numOfBeings+1);

CountDownLatch exitBarrier =
  new CountDownLatch(numOfBeings);

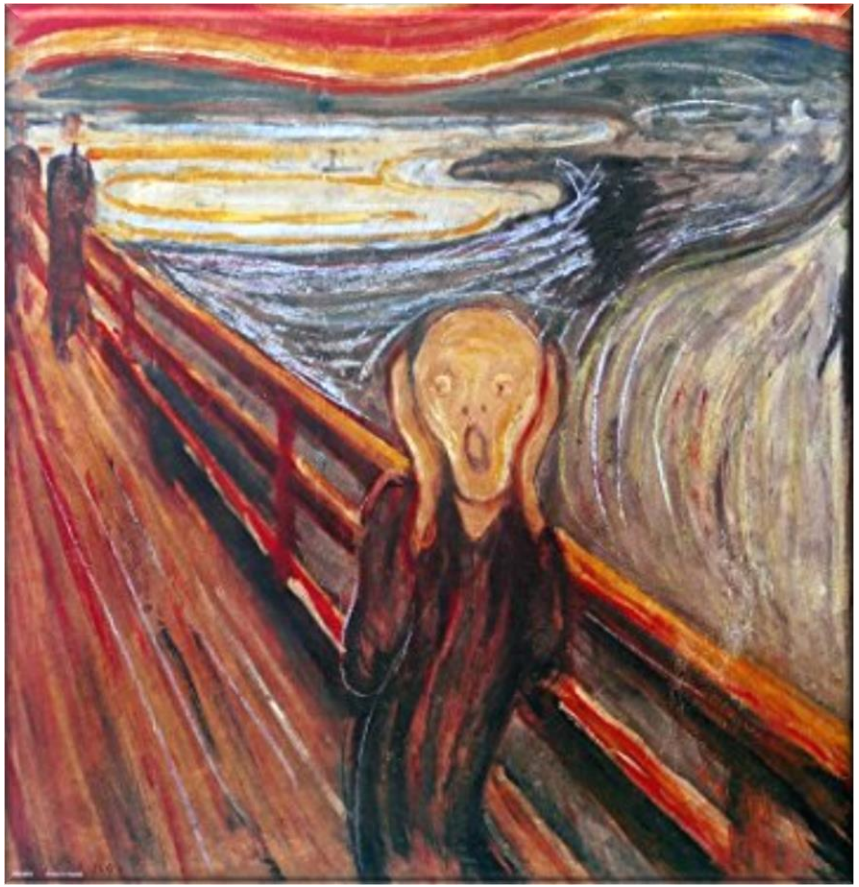
for (int i=0; i < beingCount; ++i)
  executor.execute
    (makeBeingRunnable(i,
     entryBarrier,
     exitBarrier));
```

Create a fixed-sized thread pool & also coordinate the starting & stopping of multiple tasks that acquire/release shared resources

See github.com/douglascraigschmidt/LiveLessons/tree/master/PalantiriManagerApplication

A Brief History of Concurrency & Parallelism in Java

- Advanced concurrency support
  - Focus on course-grained "task parallelism" whose computations can run concurrently
  - Feature-rich & optimized, but also tedious & error-prone to program



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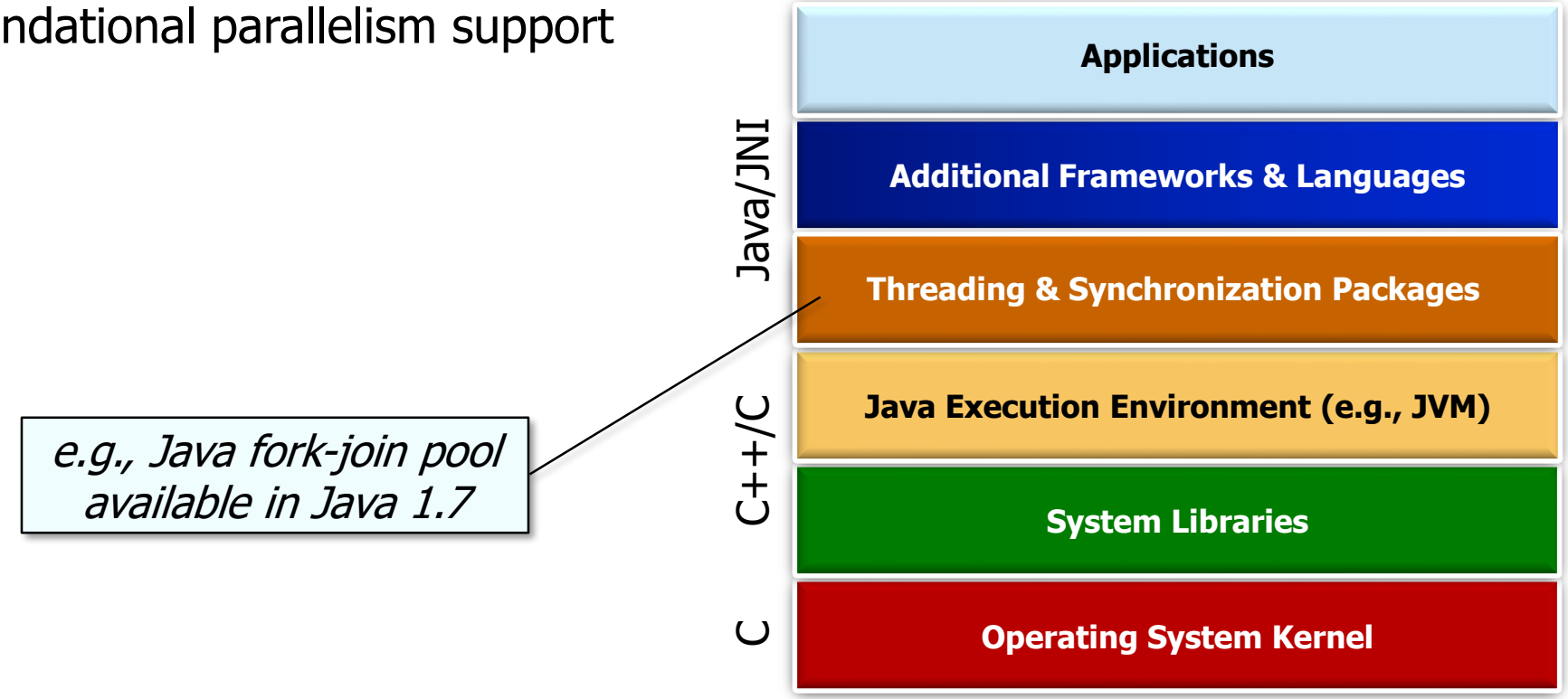
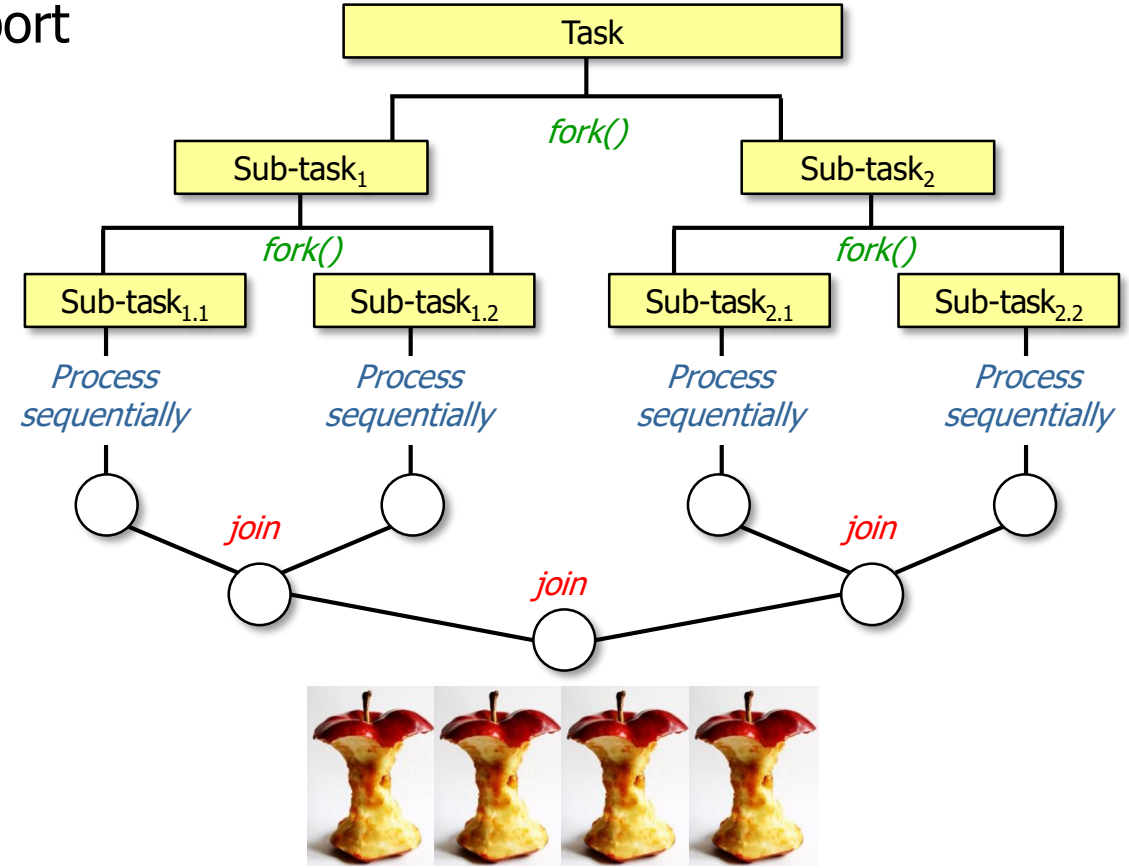
- Foundational parallelism support



A Brief History of Concurrency & Parallelism in Java

- Foundational parallelism support
  - Focus on data parallelism that runs the same task on different data elements



See en.wikipedia.org/wiki/Data_parallelism

A Brief History of Concurrency & Parallelism in Java

- Foundational parallelism support
  - Focus on data parallelism that runs the same task on different data elements

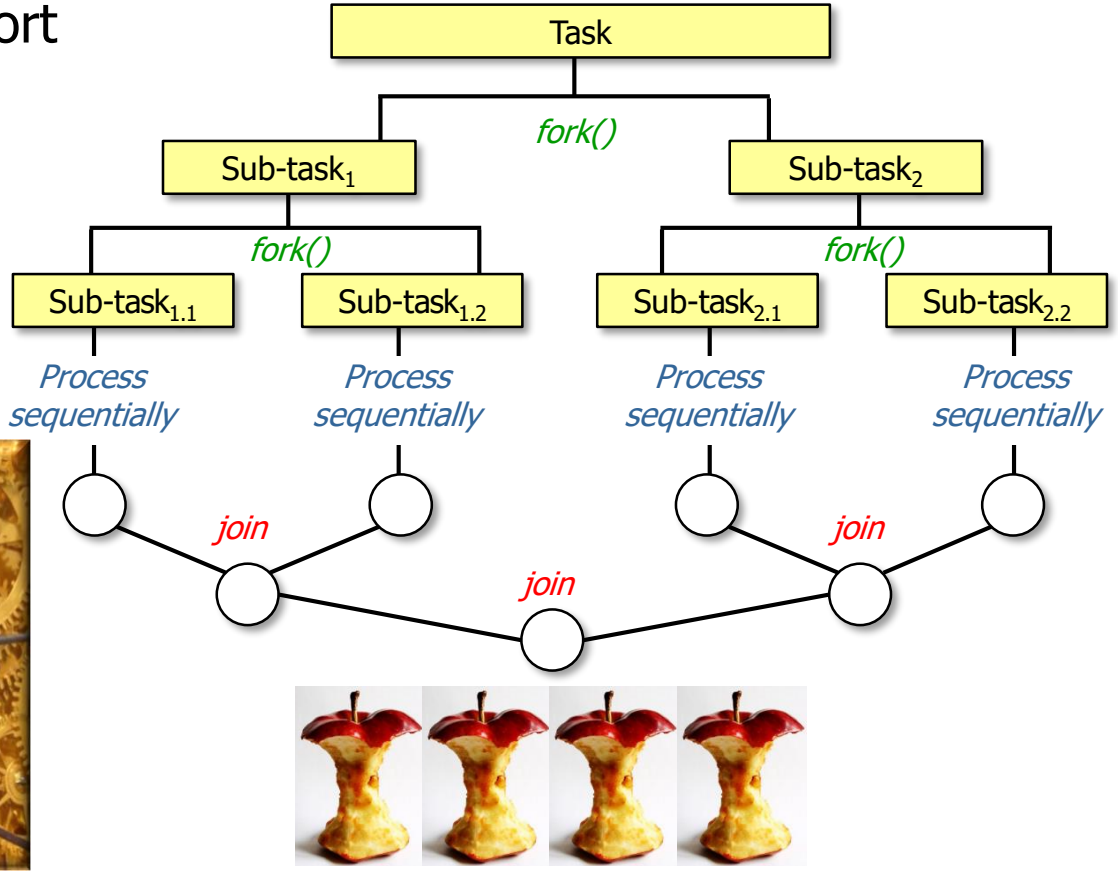
```
List<List<SearchResults>>
  listOfListOfSearchResults =
    ForkJoinPool
      .commonPool()
      .invoke(new
        SearchWithForkJoinTask
          (inputList,
           mPhrasesToFind, ...));
```

Use a common fork-join pool to search input strings to locate phrases that match

See github.com/douglascraigschmidt/LiveLessons/tree/master/SearchForkJoin

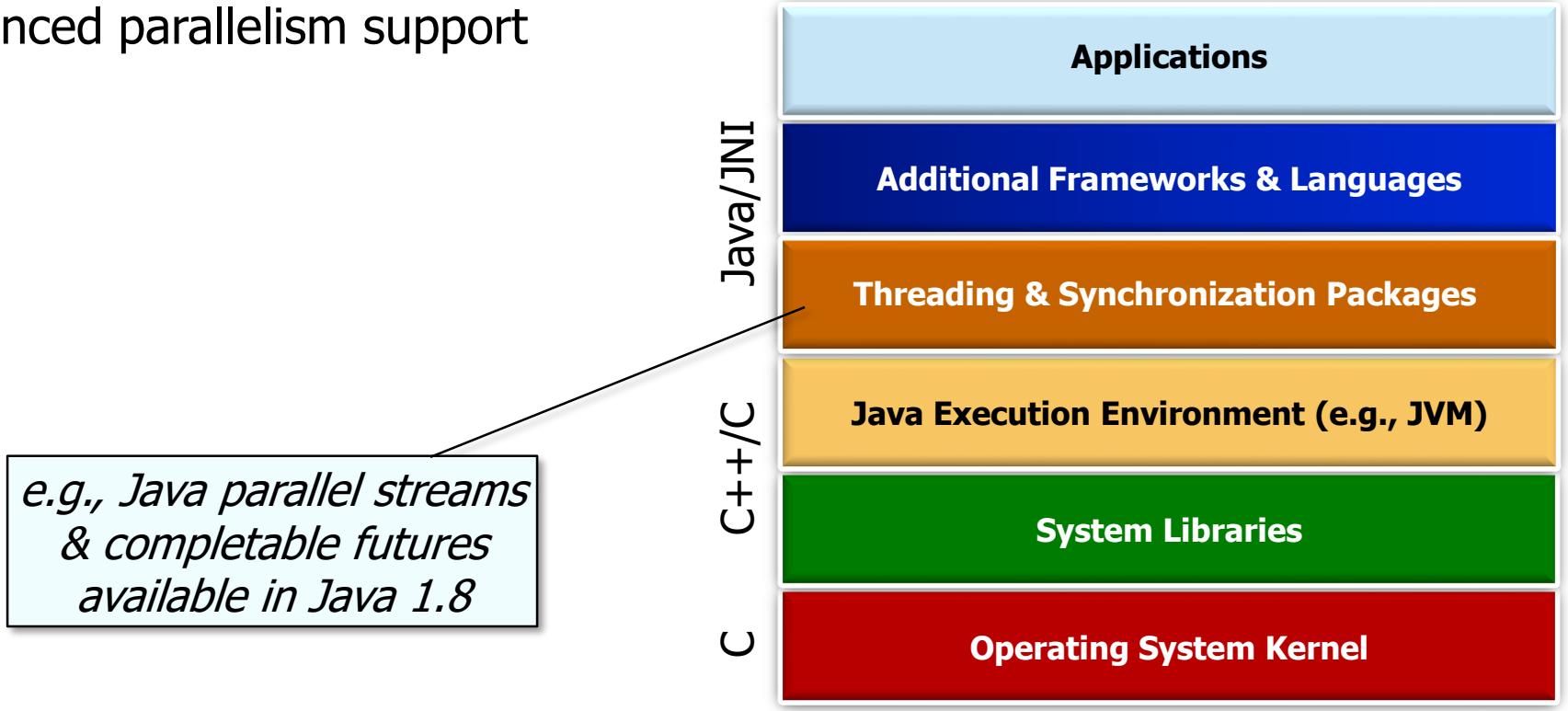
A Brief History of Concurrency & Parallelism in Java

- Foundational parallelism support
  - Focus on data parallelism that runs the same task on different data elements
  - Powerful & scalable, but tedious to program directly



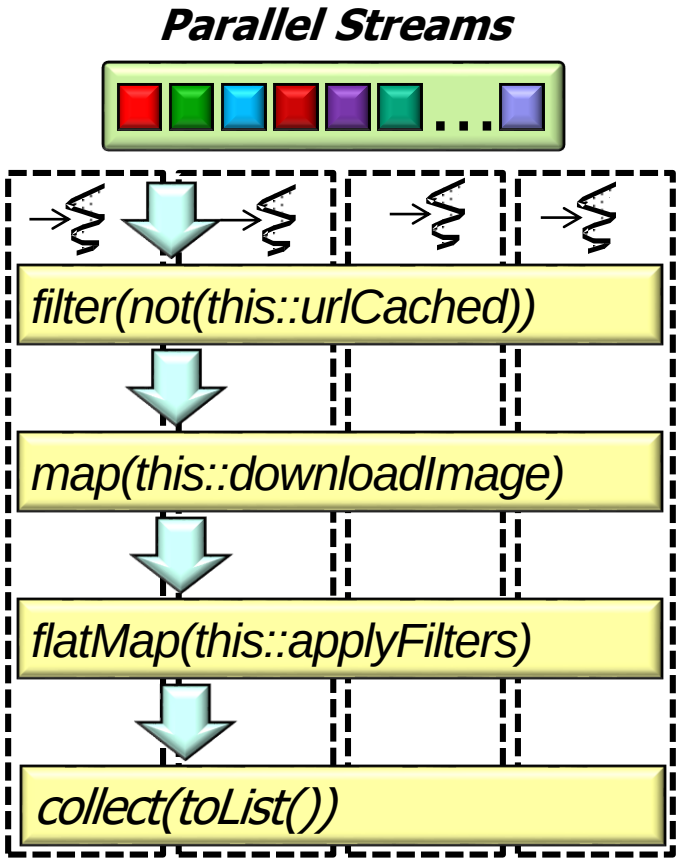
A Brief History of Concurrency & Parallelism in Java

- Advanced parallelism support



A Brief History of Concurrency & Parallelism in Java

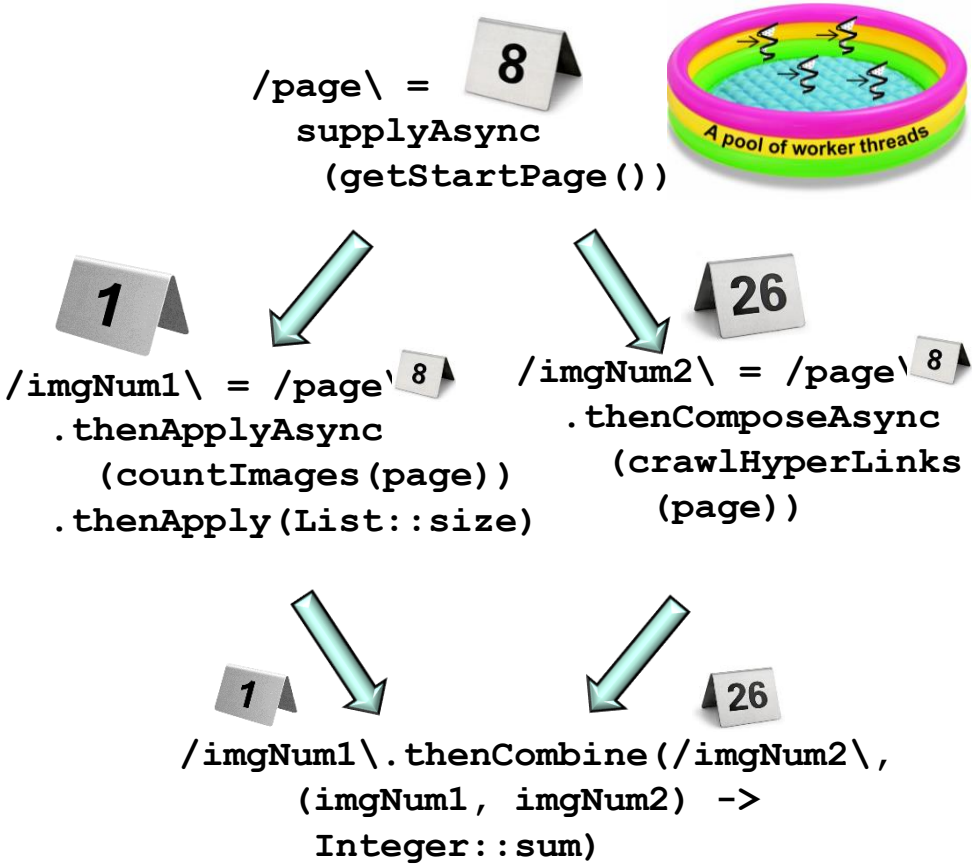
- Advanced parallelism support
  - Focus on functional programming for data parallelism



See en.wikipedia.org/wiki/Data_parallelism

A Brief History of Concurrency & Parallelism in Java

- Advanced parallelism support
  - Focus on functional programming for data parallelism & reactive asynchrony



See gist.github.com/staltz/868e7e9bc2a7b8c1f754

A Brief History of Concurrency & Parallelism in Java

- Advanced parallelism support
  - Focus on functional programming for data parallelism & reactive asynchrony

```
List<Image> images =
   urls
      .parallelStream()
      .filter(not(this::urlCached))
      .map(this::downloadImage)
      .flatMap(this::applyFilters)
      .collect(toList());
```

Synchronously download images that aren't already cached from a list of URLs & process/store the images in parallel

See github.com/douglascraigschmidt/LiveLessons/tree/master/ImageStreamGang

A Brief History of Concurrency & Parallelism in Java

- Advanced parallelism support
  - Focus on functional programming for data parallelism & reactive asynchrony

```
CompletableFuture<Stream<Image>>
  resultsFuture = urls
    .stream()
    .map(this::checkUrlCachedAsync)
    .map(this::downloadImageAsync)
    .flatMap(this::applyFiltersAsync)
    .collect(toFuture())
    .thenApply(stream ->
                 log(stream.flatMap
                   (Optional::stream),
                 urls.size()))
    .join();
```

Asynchronously download images that aren't already cached from a list of URLs & process/store the images in parallel

See github.com/douglascraigschmidt/LiveLessons/tree/master/ImageStreamGang

A Brief History of Concurrency & Parallelism in Java

- Advanced parallelism support
  - Focus on functional programming for data parallelism & reactive asynchrony
  - Strikes an effective balance between productivity & performance

A Brief History of Concurrency & Parallelism in Java

- Advanced parallelism support
  - Focus on functional programming for data parallelism & reactive asynchrony
  - Strikes an effective balance between productivity & performance
  - However, may be overly prescriptive

Which Java Mechanism(s) to Understand & Apply

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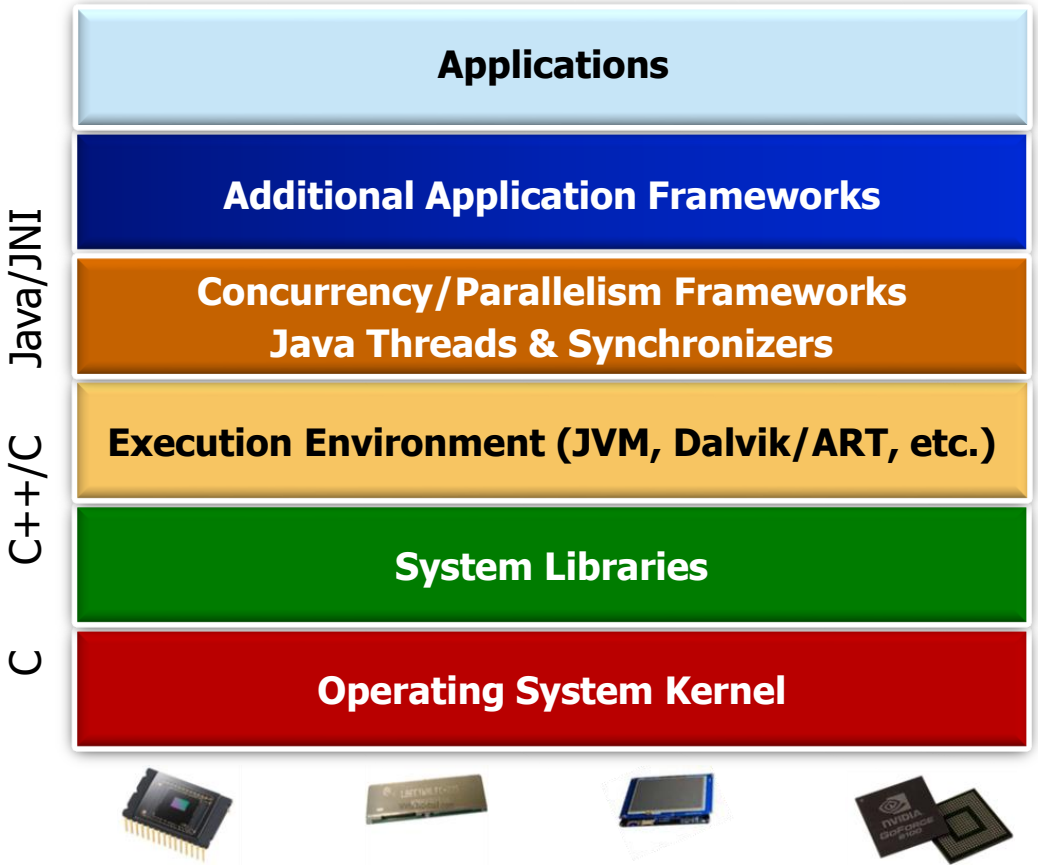
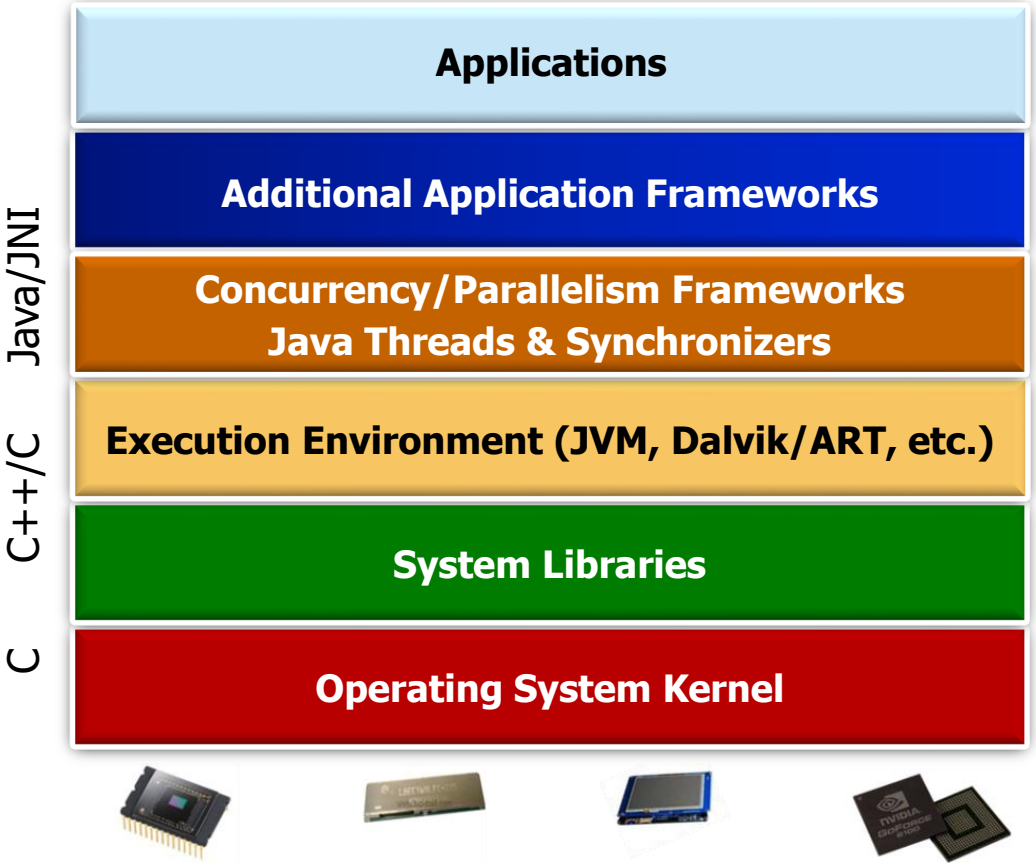
- Java's concurrency & parallelism mechanisms span multiple layers in the software stack



Which Java Mechanism(s) to Understand & Apply

- Java's concurrency & parallelism mechanisms span multiple layers in the software stack
  - Choosing best mechanism(s) depend on various factors

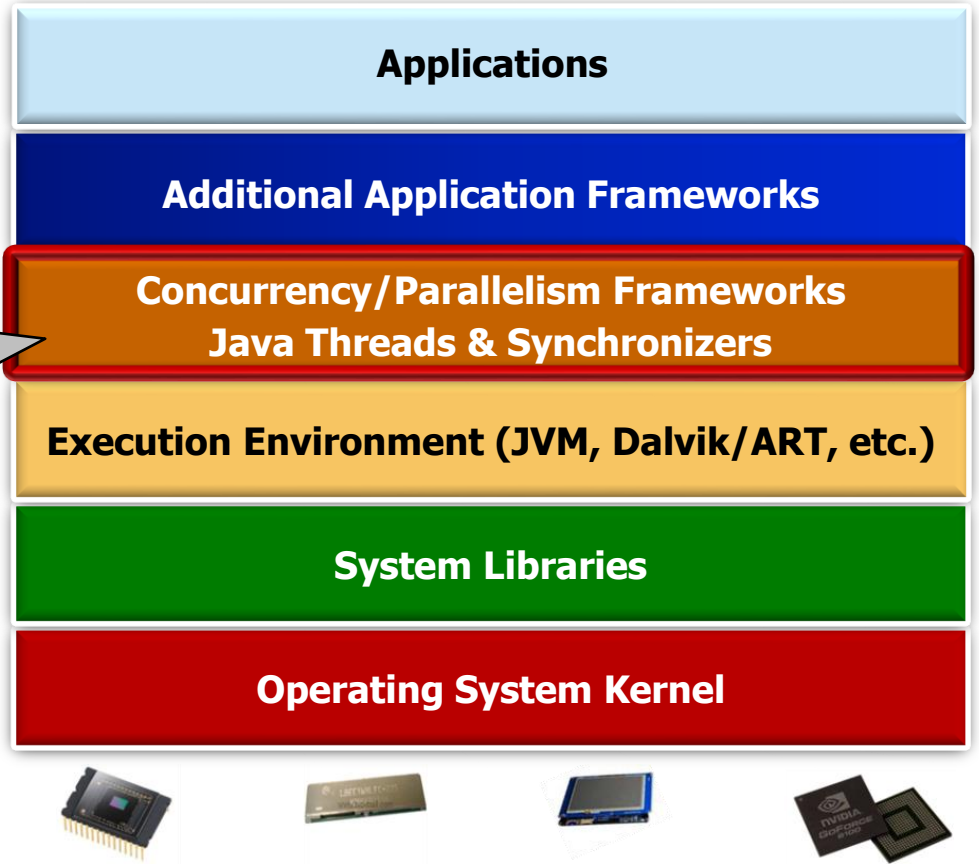


Which Java Mechanism(s) to Understand & Apply

- Developers of low-level classes & performance-sensitive apps may prefer shared object mechanisms

Package java.util.concurrent Description

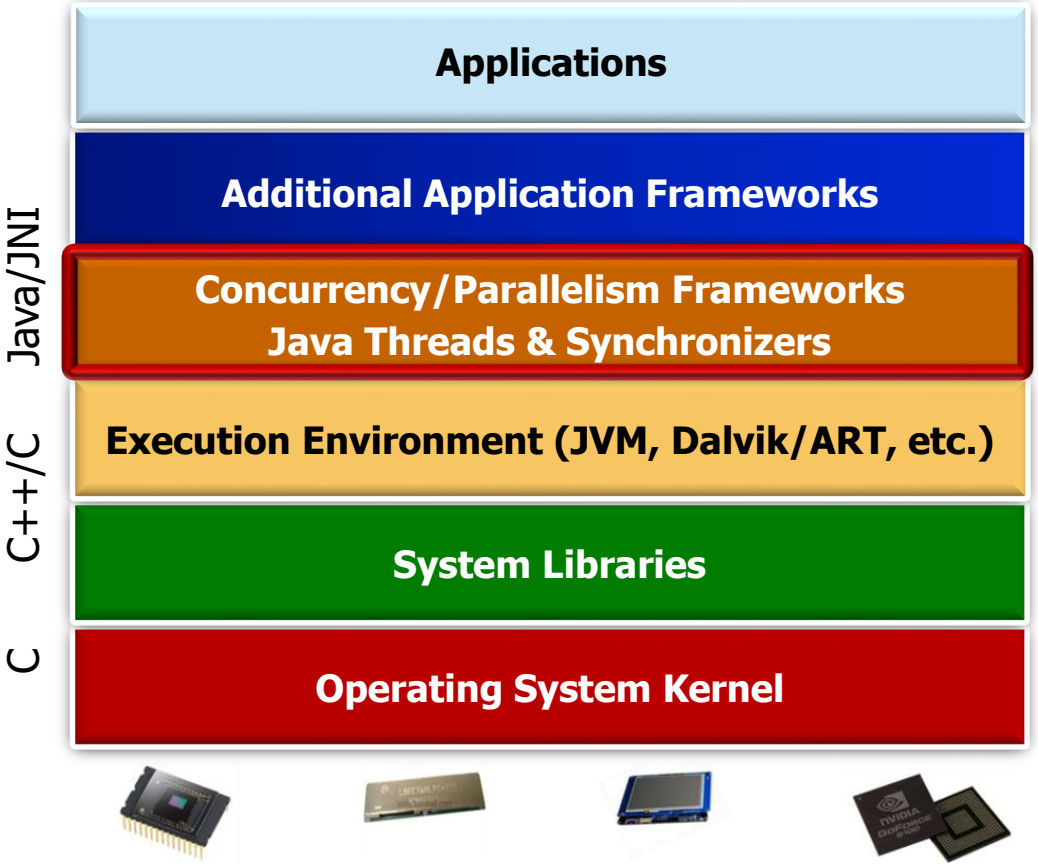
Utility classes commonly useful in concurrent programming. This package includes a few small standardized extensible frameworks, as well as some classes that provide useful functionality and are otherwise tedious or difficult to implement. Here are brief descriptions of the main components. See also the `java.util.concurrent.locks` and `java.util.concurrent.atomic` packages.



e.g., java.util.concurrent as per www.youtube.com/watch?v=sq0MX3fHkro

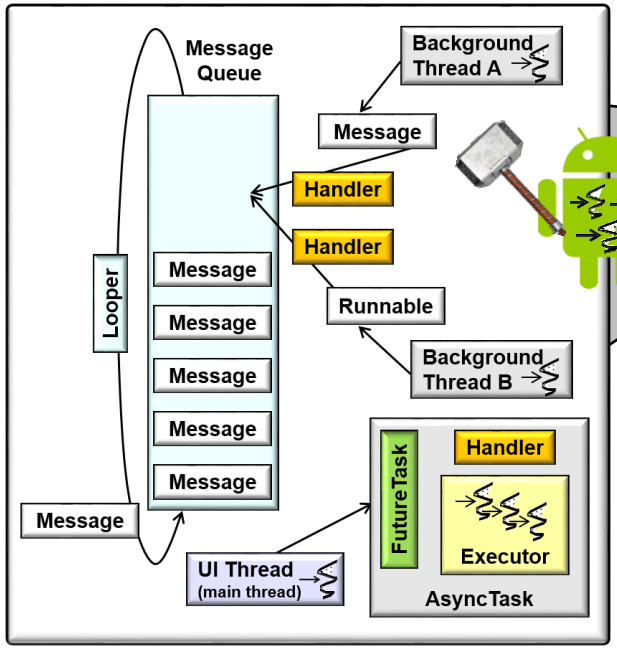
Which Java Mechanism(s) to Understand & Apply

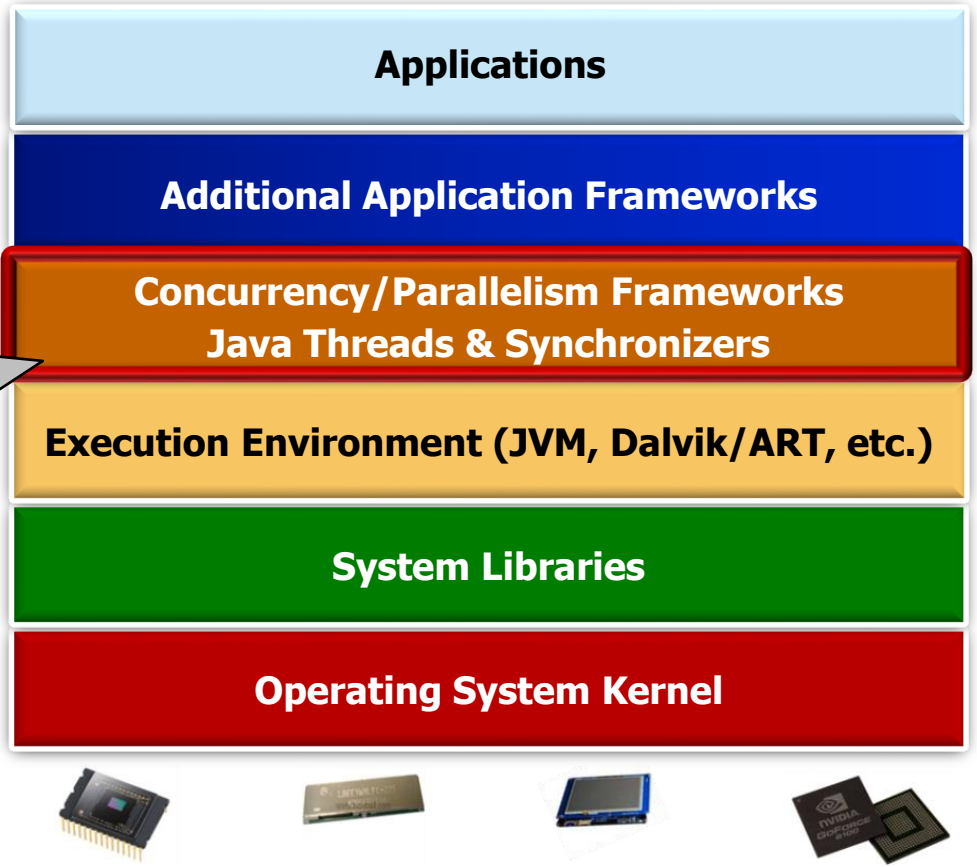
- Developers of low-level classes & performance-sensitive apps may prefer shared object mechanisms
  - **Pros**: Efficient & lightweight
  - **Cons**: Tedious & error-prone



Which Java Mechanism(s) to Understand & Apply

- Framework developers may want to use the Java message passing mechanisms

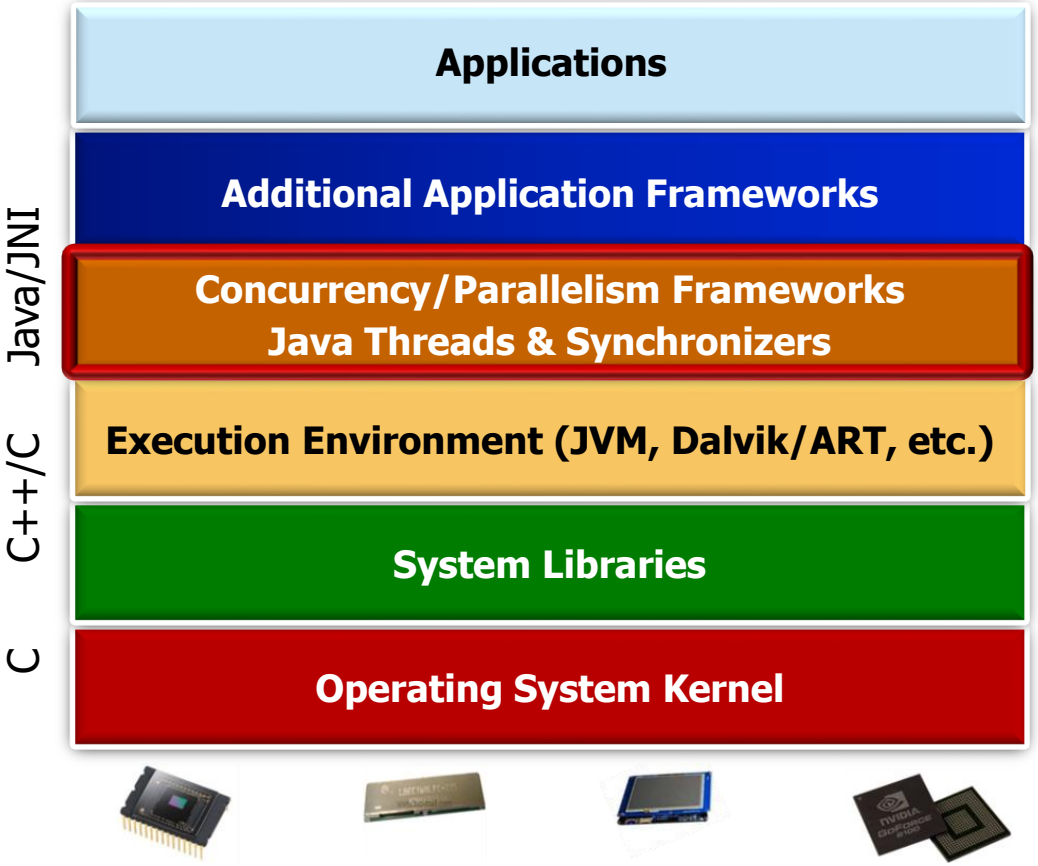




e.g., Android AsyncTask/HaMeR frameworks or Java ExecutorCompetionService

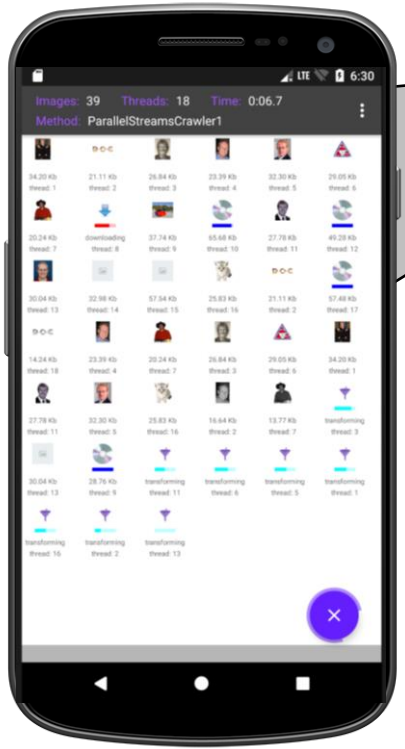
Which Java Mechanism(s) to Understand & Apply

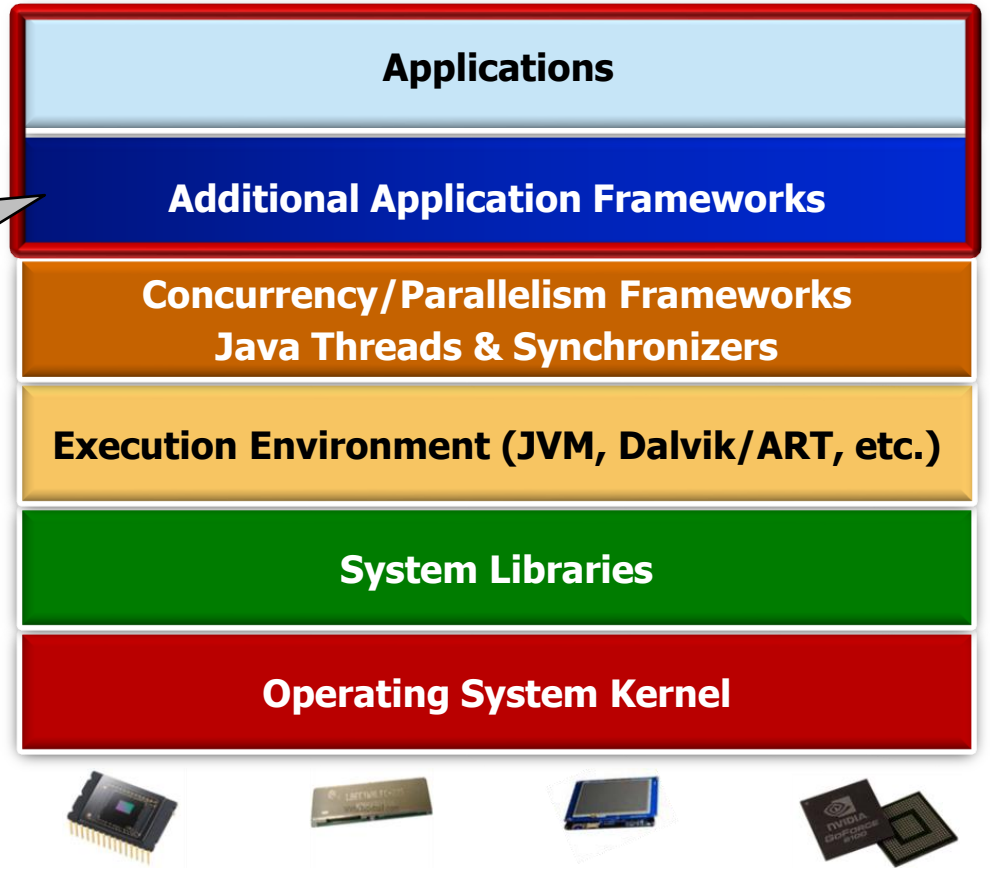
- Framework developers may want to use the Java message passing mechanisms
  - **Pros**: Flexible & decoupled
  - **Cons**: Time/space overhead



Which Java Mechanism(s) to Understand & Apply

- Mobile app developers may want to program w/higher-level frameworks

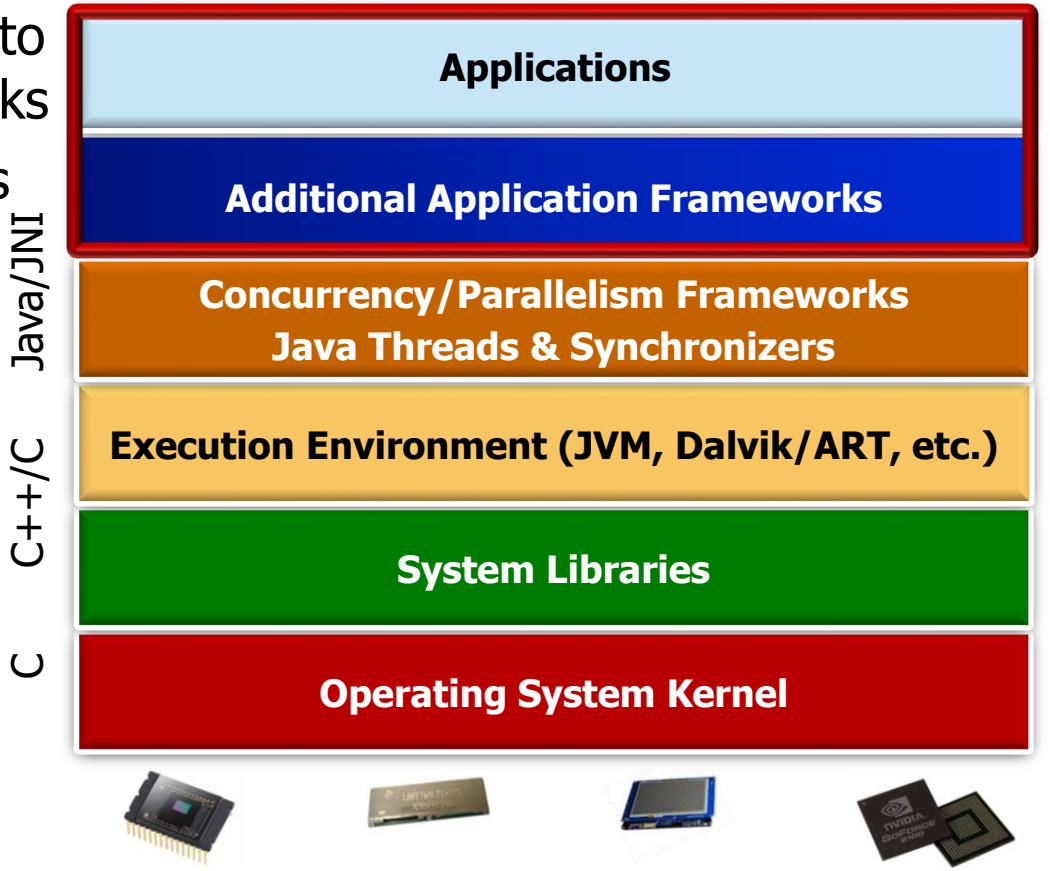




e.g., Java 8 parallel streams & completable futures, RxJava, etc.

Which Java Mechanism(s) to Understand & Apply

- Mobile app developers may want to program w/higher-level frameworks
  - **Pros**: Productivity & robustness
  - **Cons**: Time/space overhead & overly prescriptive



Which Java Mechanism(s) to Understand & Apply

C C++/C Java/JNI

- Applications
- Additional Application Frameworks
- Concurrency/Parallelism Frameworks
  Java Threads & Synchronizers
- Execution Environment (JVM, Dalvik/ART, etc.)
- System Libraries
- Operating System Kernel

"Full stack" developers should understand concepts & mechanisms at each layer

End of Background on Java Concurrency & Parallelism (Part 2)