Overview of Concurrent Programming Concepts

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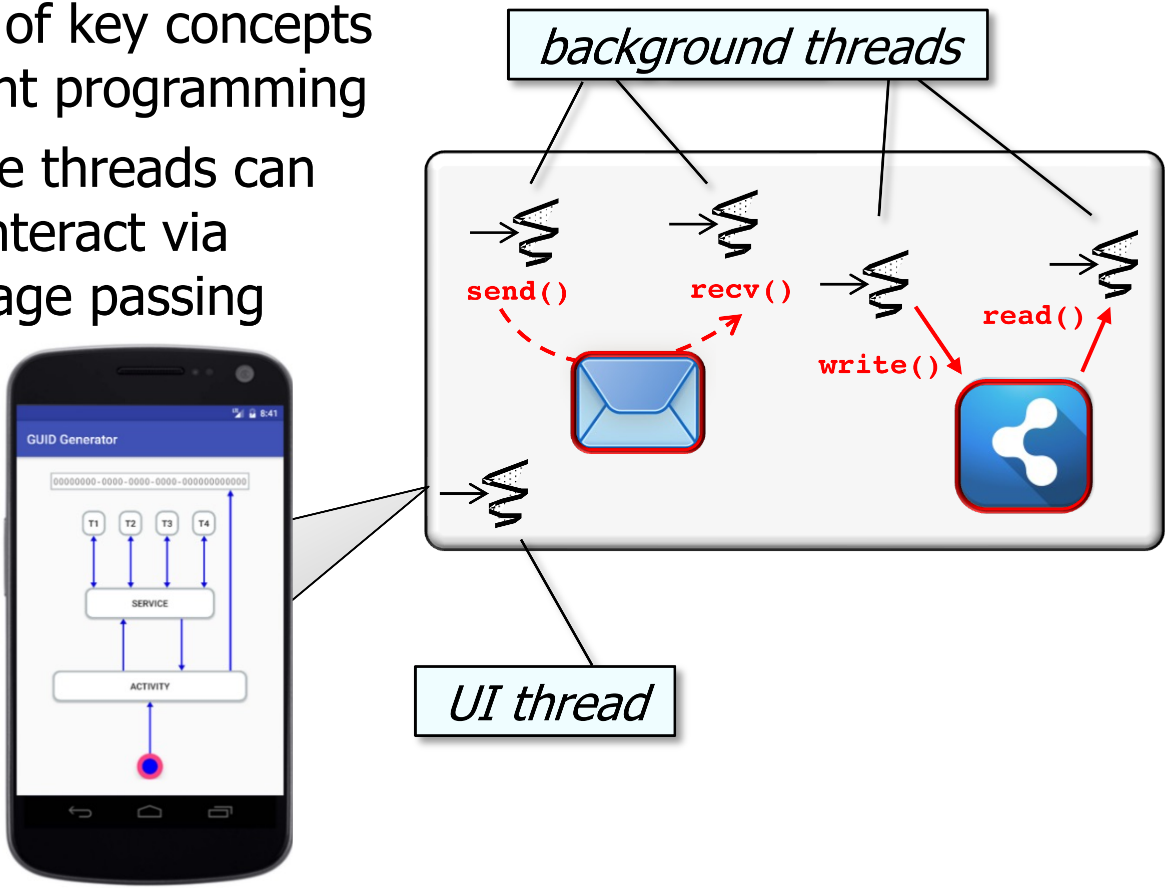
Learning Objectives in this Part of the Lesson

- Understand the meaning of key concepts associated with concurrent programming
  - e.g., where two or more threads can run simultaneously & interact via shared objects & message passing

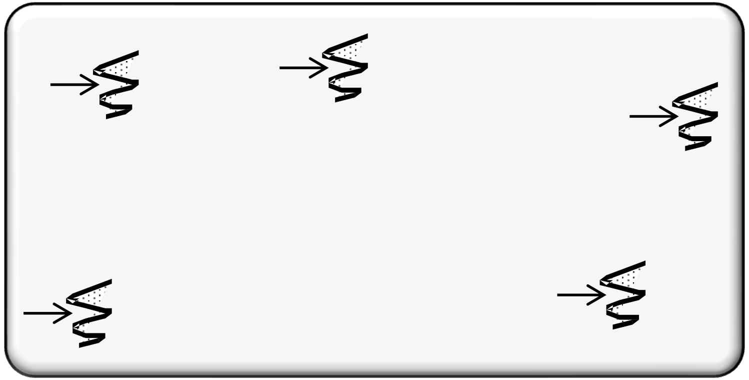


Concurrent programming helps address ‘cons’ of sequential programming

An Overview of Concurrent Programming

An Overview of Concurrent Programming

- Concurrent programming is a form of computing where two or more threads can run simultaneously

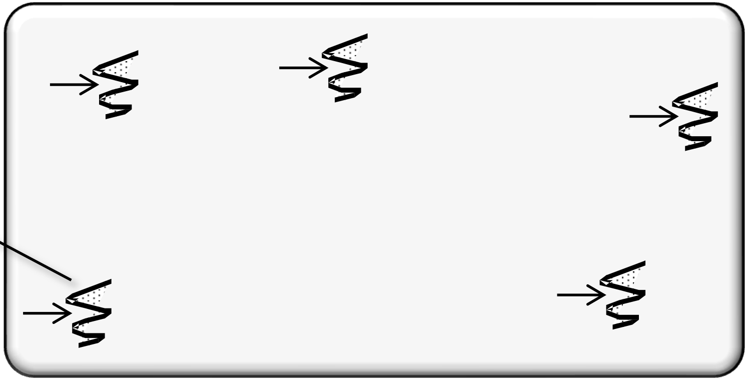


See en.wikipedia.org/wiki/Concurrency_(computer_science)

An Overview of Concurrent Programming

- Concurrent programming is a form of computing where two or more threads can run simultaneously

A thread is a unit of execution for a stream of instructions that can run concurrently on one or more processor cores over its lifetime



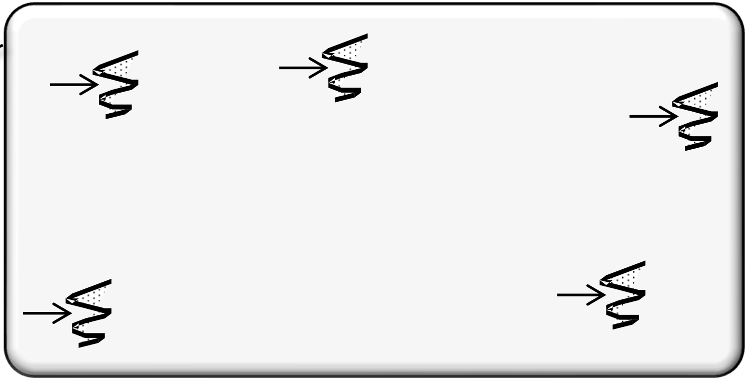
Processor cores

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

An Overview of Concurrent Programming

- Concurrent programming is a form of computing where two or more threads can run simultaneously

A thread typically runs in a process, which allocates & manages resources (e.g., files, memory, & network connections) & prevents corruption from threads in other processes



Processor cores

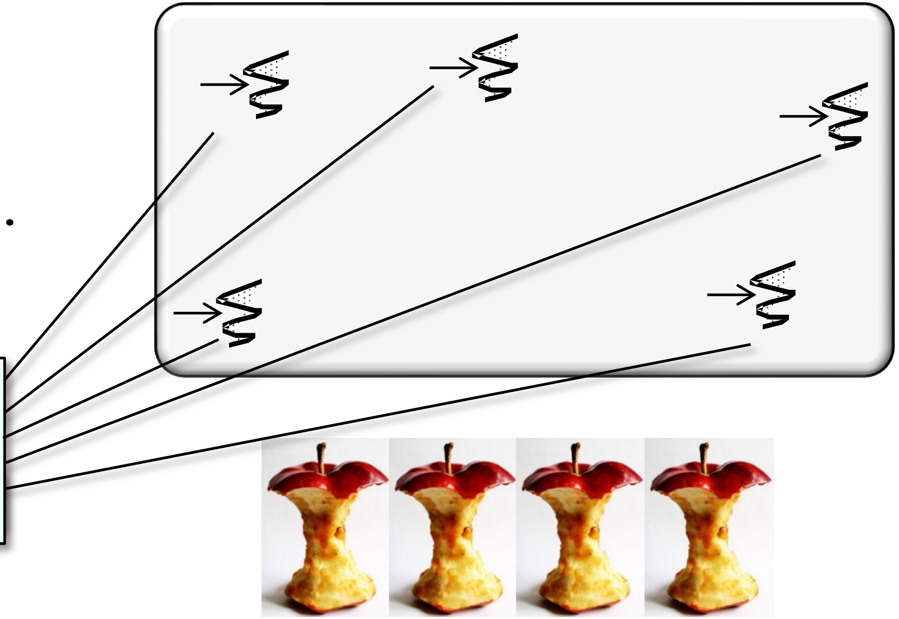
See en.wikipedia.org/wiki/Process_(computing)

An Overview of Concurrent Programming

- Concurrent programming is a form of computing where two or more threads can run simultaneously

```
for (int i = 0; i < 5; i++)
  new Thread(() ->
             someComputation()).
             start();
```

This code snippet creates/starts 5 Java Thread objects that run someComputation concurrently across 4 processor cores



Processor cores

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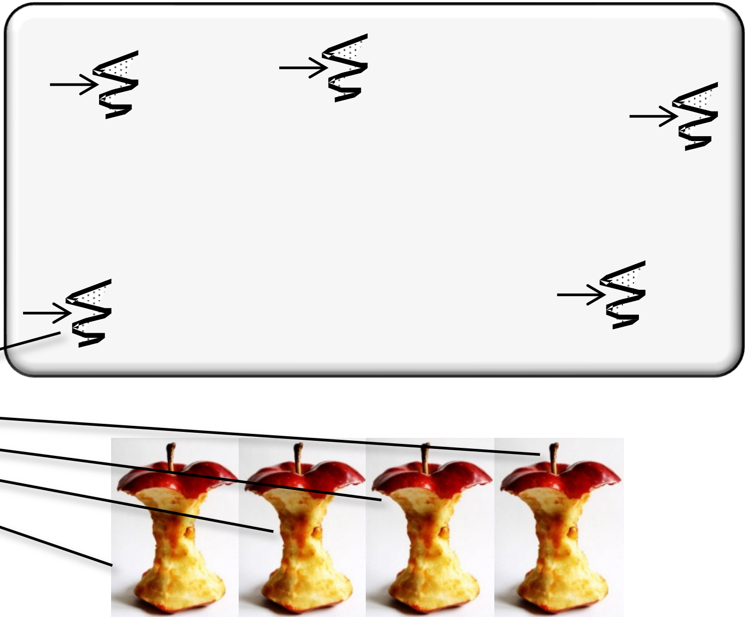
A Java Thread object needn't run on the same core throughout its lifetime, but instead it can be "multiplexed" across multiple cores via "time-slicing"



Processor cores

See scalibq.wordpress.com/2012/06/01/multi-core-and-multi-threading

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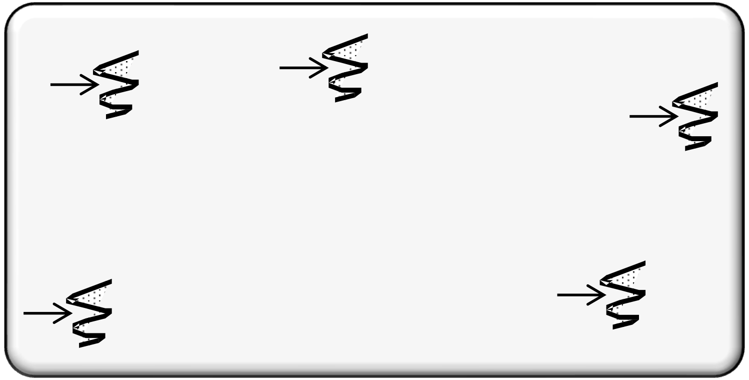
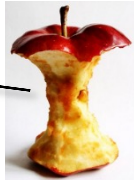


Multiple threads can also be multi-plexed over a single-core processor



See en.wikipedia.org/wiki/Single-core

An Overview of Concurrent Programming

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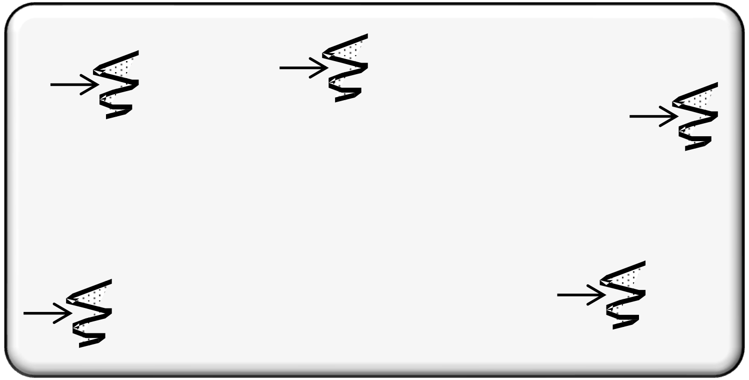
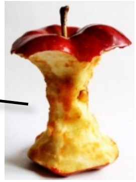


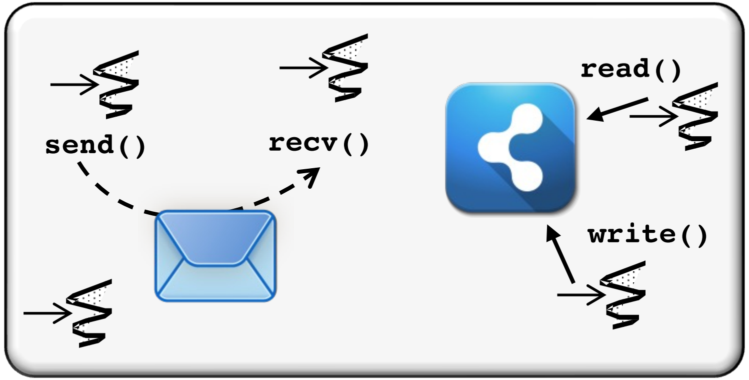
However, single-core processors are becoming rare for general-purpose computing devices..



See www.quora.com/Are-single-core-CPUs-still-produced

An Overview of Concurrent Programming

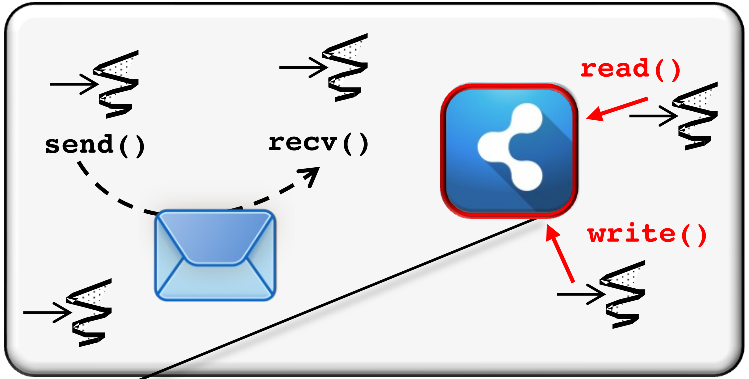
- Threads can interact via shared objects (synchronizers) & message passing



See upcoming lesson on "*Overview of How Concurrent Programs are Developed in Java*"

An Overview of Concurrent Programming

- Threads can interact via shared objects (synchronizers) & message passing



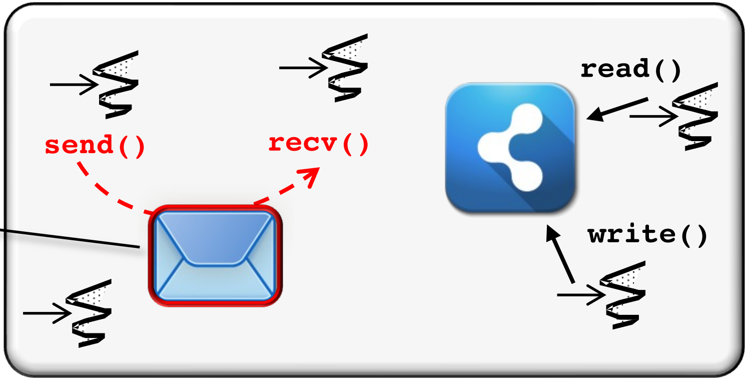
Shared objects (synchronizers) can be used to ensure mutual exclusion between—& coordination amongst—multiple threads

See upcoming lesson on "*Overview of How Concurrent Programs are Developed in Java*"

An Overview of Concurrent Programming

- Threads can interact via shared objects (synchronizers) & message passing

Multiple threads can pass messages via queues that are properly synchronized



See upcoming lesson on "*Overview of How Concurrent Programs are Developed in Java*"

An Overview of Concurrent Programming

- Unlike sequential programming, different executions of a concurrent program may produce different orderings of instructions:

See earlier lesson on "*Overview of Sequential Programming Concepts*"

An Overview of Concurrent Programming

- Unlike sequential programming, different executions of a concurrent program may produce different orderings of instructions:
  - The textual order of the source code doesn't define the order of execution

```
new Thread(() ->
               computationA()).
               start();

new Thread(() ->
               computationB()).
               start();

new Thread(() ->
               computationC()).
               start();
```

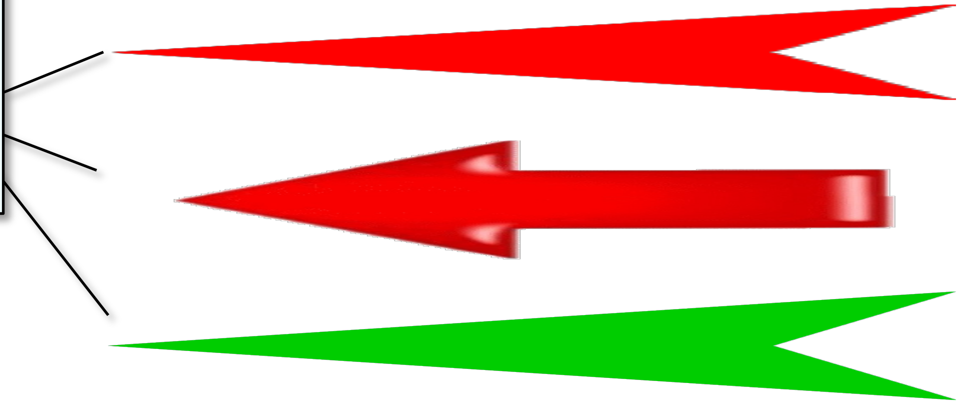
computationA(), computationB(), & computationC() can run in any order after their threads start up

See en.wikipedia.org/wiki/Indeterminacy_in_concurrent_computation

An Overview of Concurrent Programming

- Unlike sequential programming, different executions of a concurrent program may produce different orderings of instructions:
  - The textual order of the source code doesn't define the order of execution
  - Operations are permitted to overlap in time across multiple cores

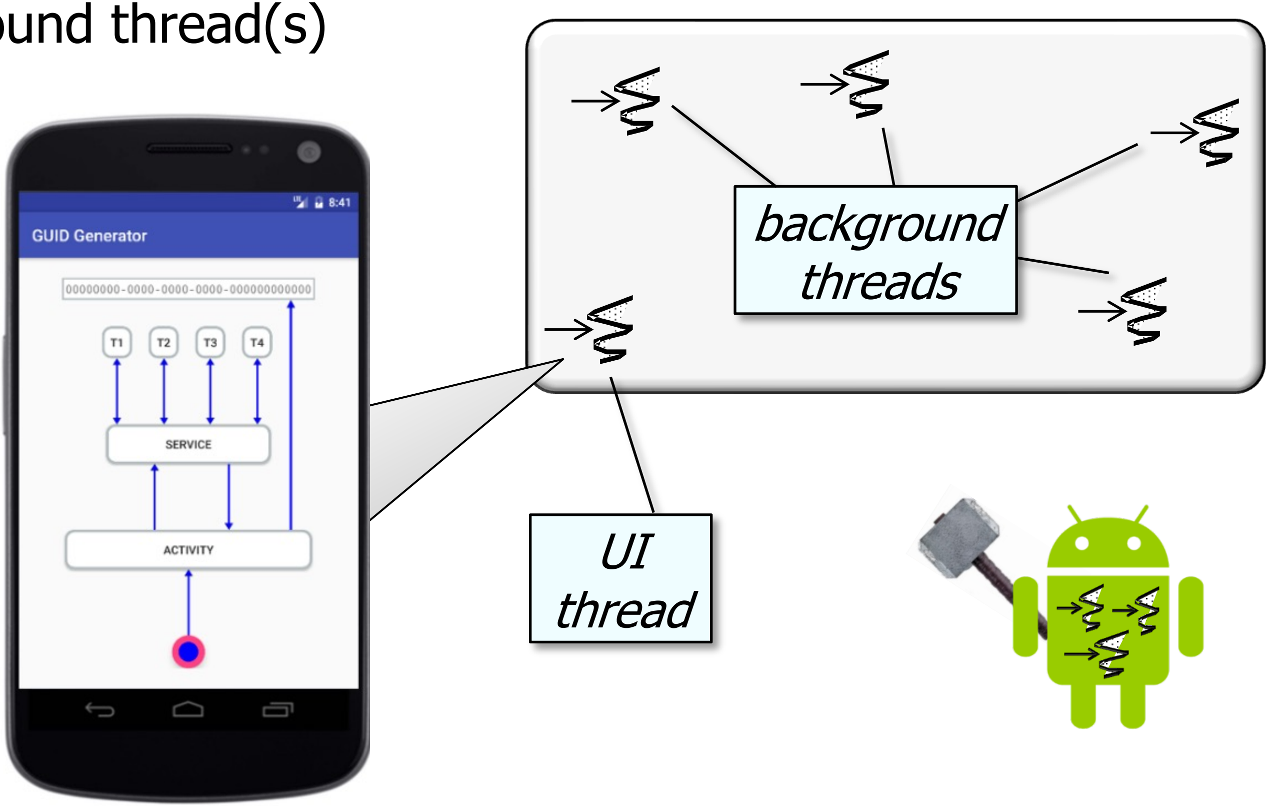
Multiple computations can execute concurrently (during overlapping time periods) instead of sequentially (with one completing before the next starts)



See en.wikipedia.org/wiki/Concurrent_computing

An Overview of Concurrent Programming

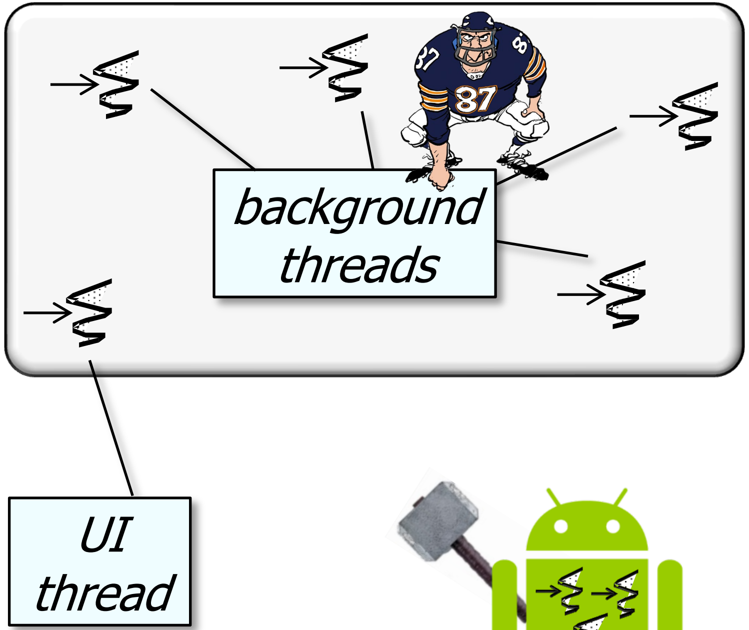
- Concurrent programming can offload work from the user interface (UI) thread to background thread(s)



See developer.android.com/topic/performance/threads.html

An Overview of Concurrent Programming

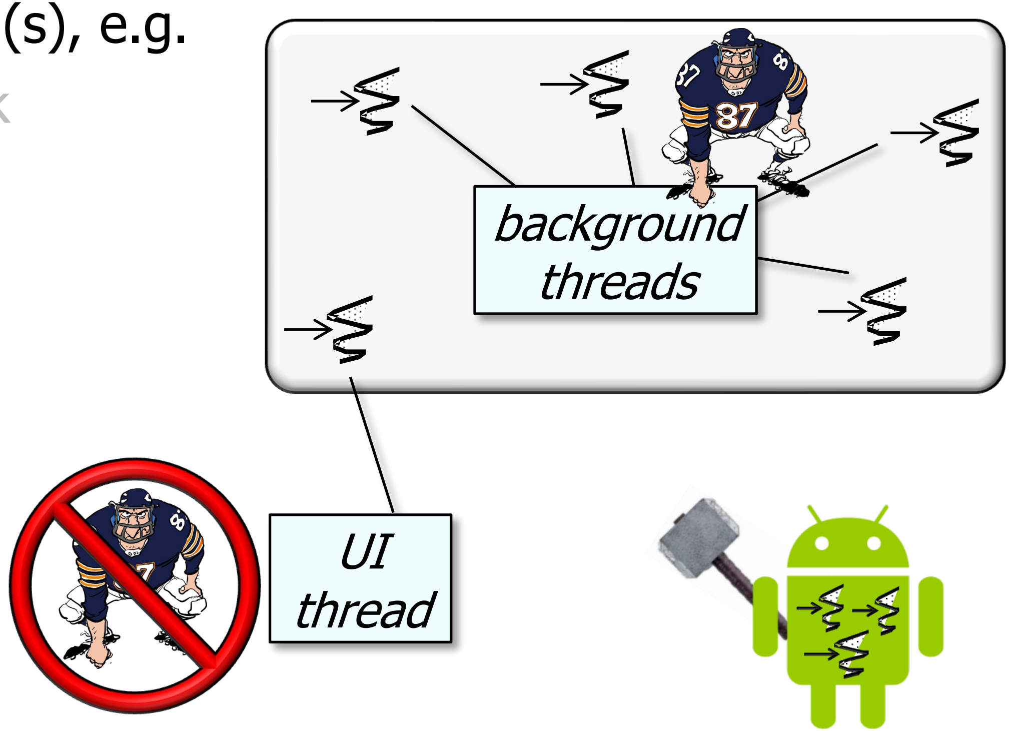
- Concurrent programming can offload work from the user interface (UI) thread to background thread(s), e.g.
  - Background thread(s) can block



See developer.android.com/training/multiple-threads/communicate-ui.html

An Overview of Concurrent Programming

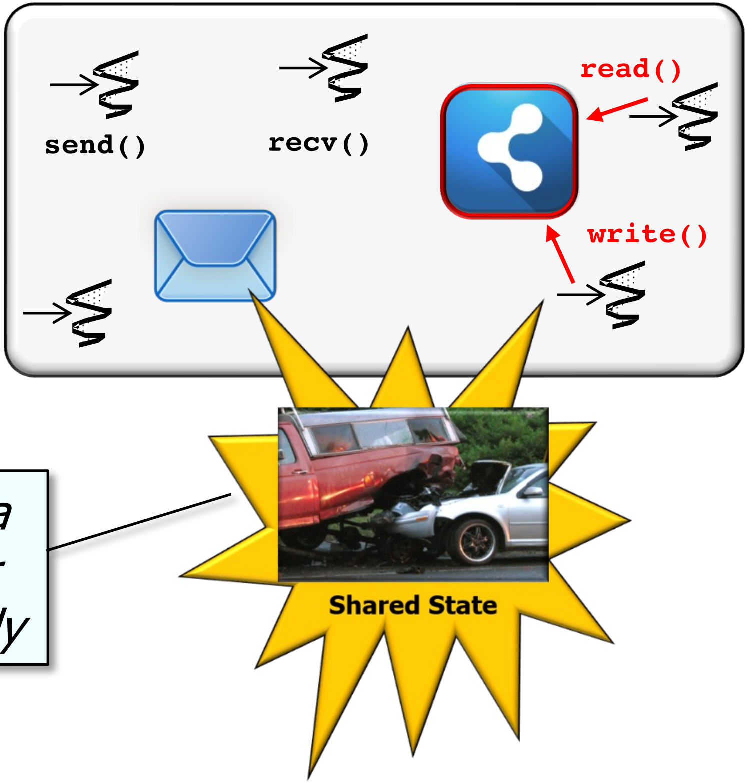
- Concurrent programming can offload work from the user interface (UI) thread to background thread(s), e.g.
  - Background thread(s) can block
  - The UI thread does not block



See developer.android.com/training/multiple-threads/communicate-ui.html

An Overview of Concurrent Programming

- Concurrent programming can offload work from the user interface (UI) thread to background thread(s), e.g.
  - Background thread(s) can block
  - The UI thread does not block
  - Any mutable state shared between these threads must be protected to avoid concurrency hazards



e.g., a "race condition" can occur when a program depends upon the sequence or timing of threads for it to operate properly

See upcoming lesson on "*Overview of Concurrency in Java*"

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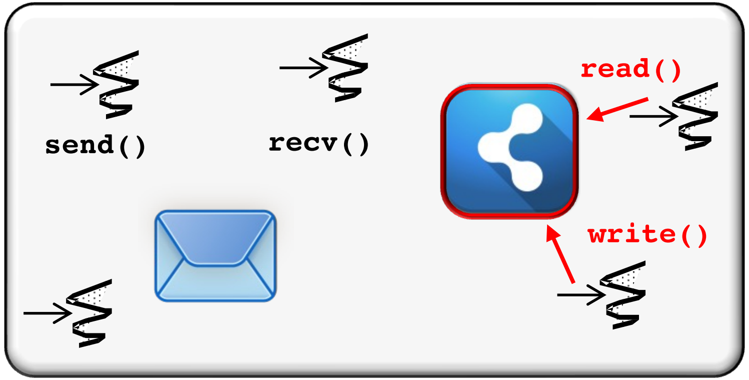
  - The UI thread does not block
  - Any mutable state shared between these threads must be protected to avoid concurrency hazards
    - Motivates the need for various types of Java synchronizers



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

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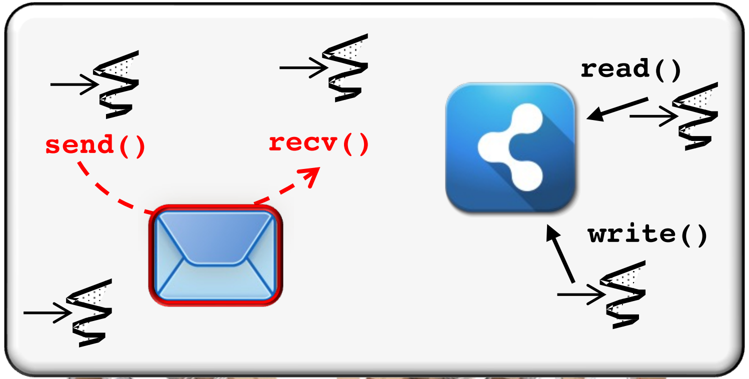
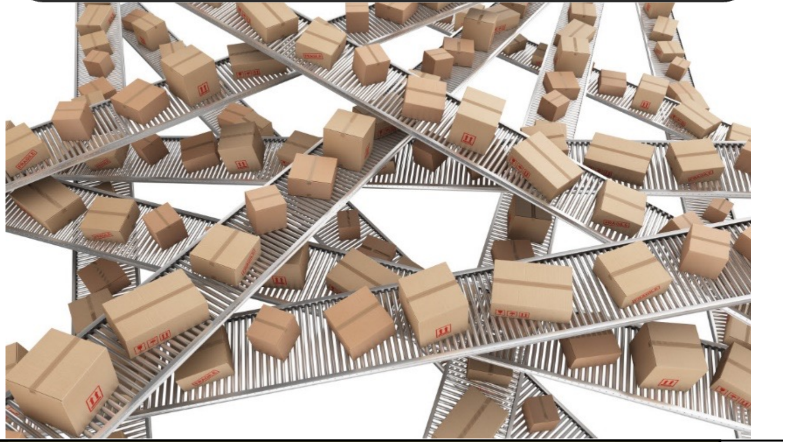
  - Any mutable state shared between these threads must be protected to avoid concurrency hazards
  - Message passing mechanisms can be used to avoid sharing state across multiple threads





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End of Overview of Concurrent Programming Concepts