Overview of Sequential Programming Concepts

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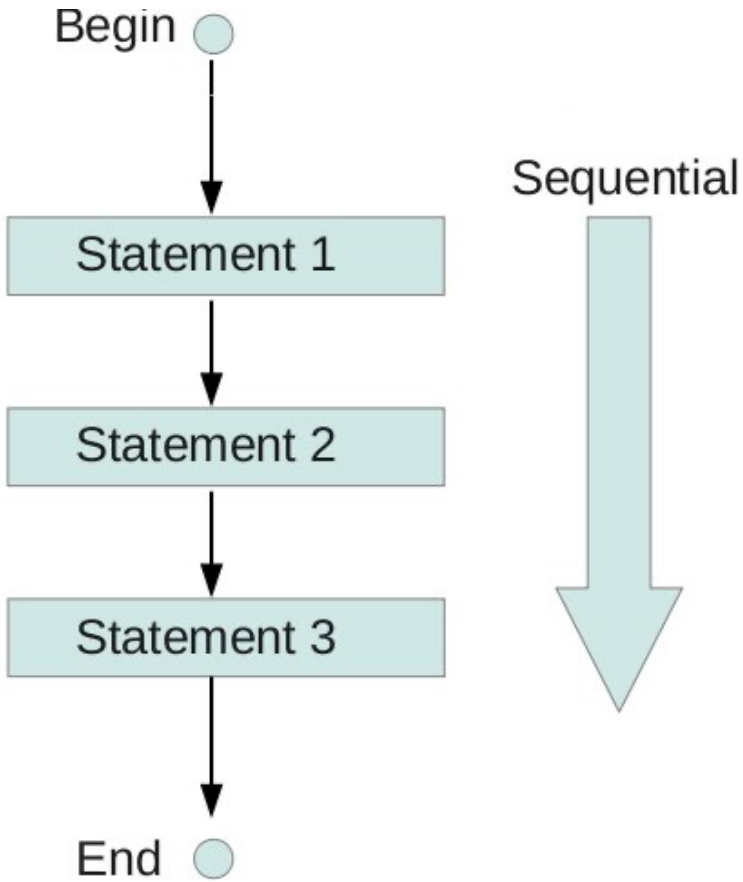
Learning Objectives in this Lesson

- Understand the meaning of key concepts associated with sequential programming
  - e.g., each step in a program is executed in order one at a time



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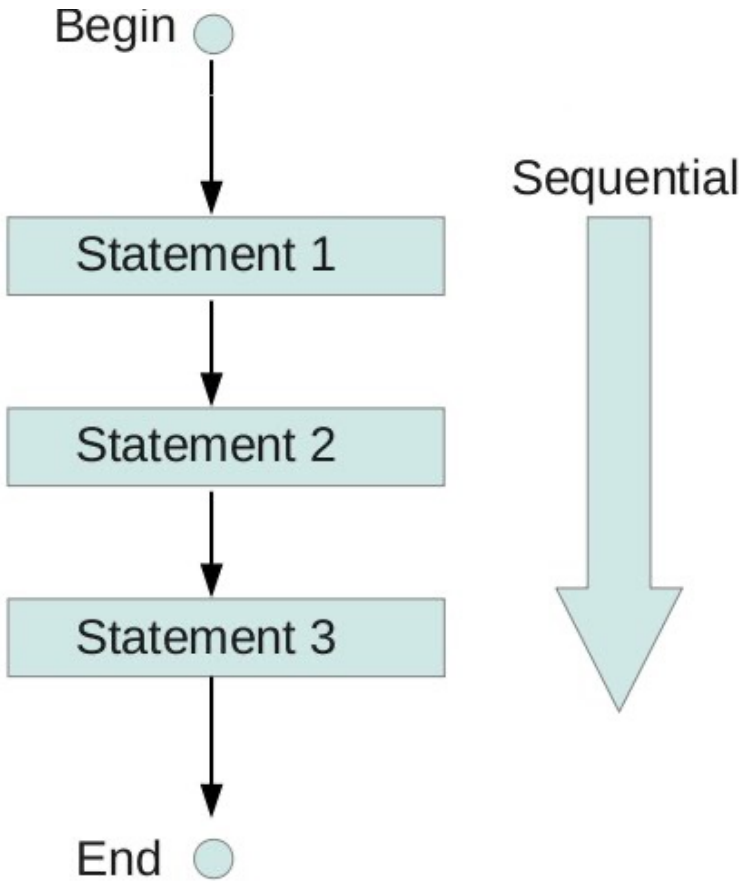
  - e.g., each step in a program is executed in order one at a time

Mastering these concepts is essential before trying to learn more advanced concurrent & parallel programming concepts



An Overview of Sequential Programming

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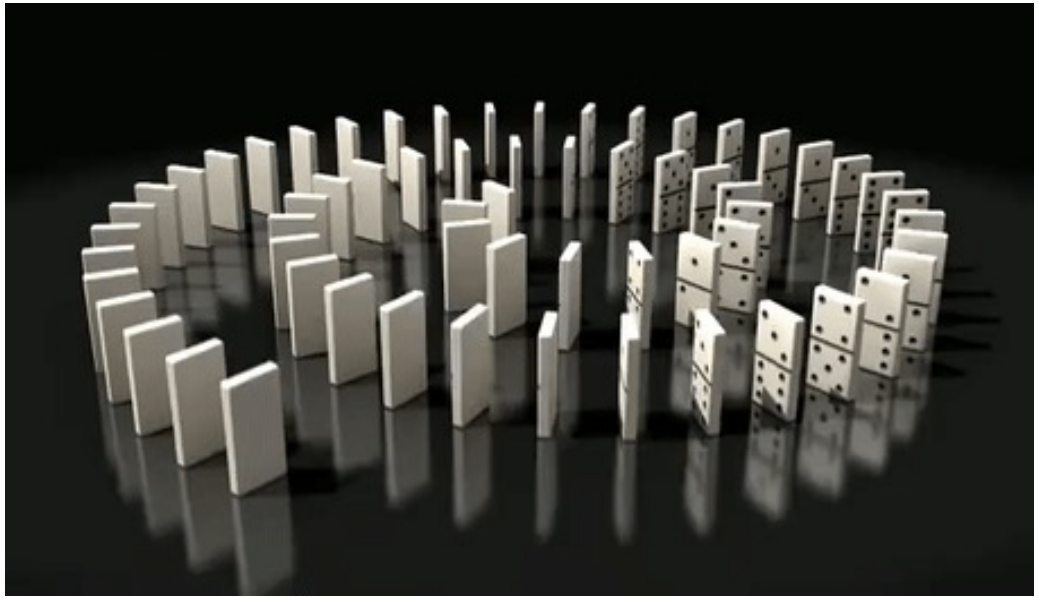
- Sequential programming is a form of computing that executes the same sequence of instructions & always produces the same results
  - i.e., execution is *deterministic*



See en.wikipedia.org/wiki/Sequential_algorithm

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- Sequential programming is a form of computing that executes the same sequence of instructions & always produces the same results
  - i.e., execution is *deterministic*

Given a certain input, the same output will always be produced in the same order

See en.wikipedia.org/wiki/Deterministic_algorithm

An Overview of Sequential Programming

- The deterministic behavior of sequential programs assumes no deliberate use of randomness, of course

See en.wikipedia.org/wiki/Randomized_algorithm

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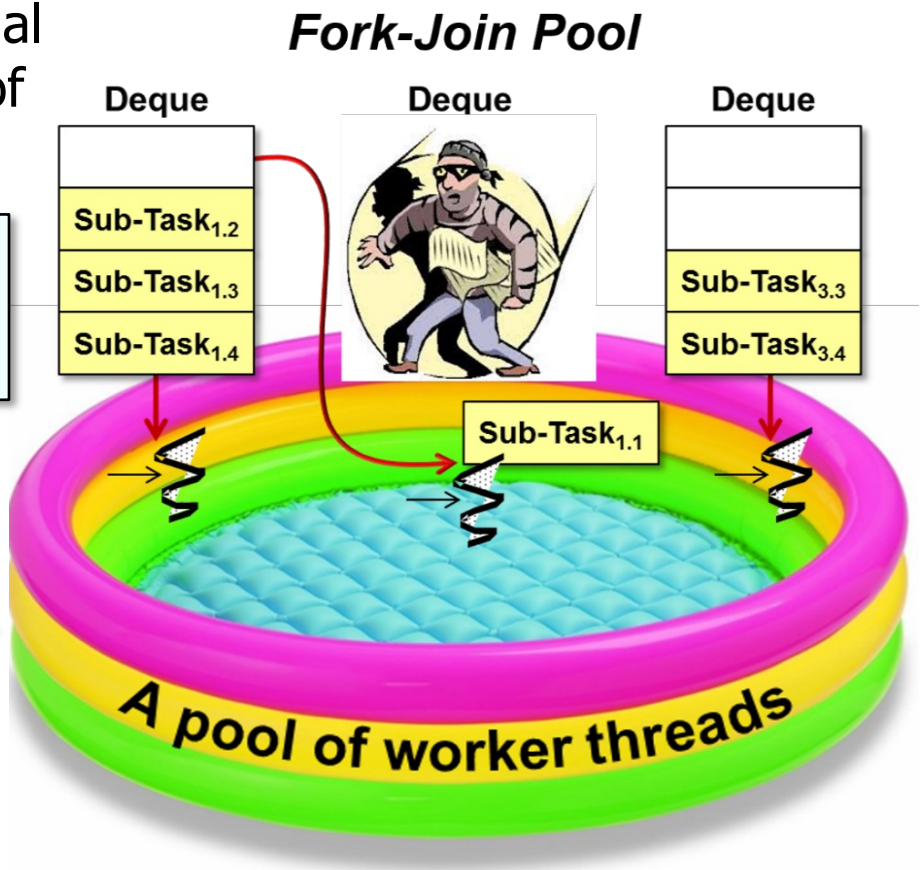
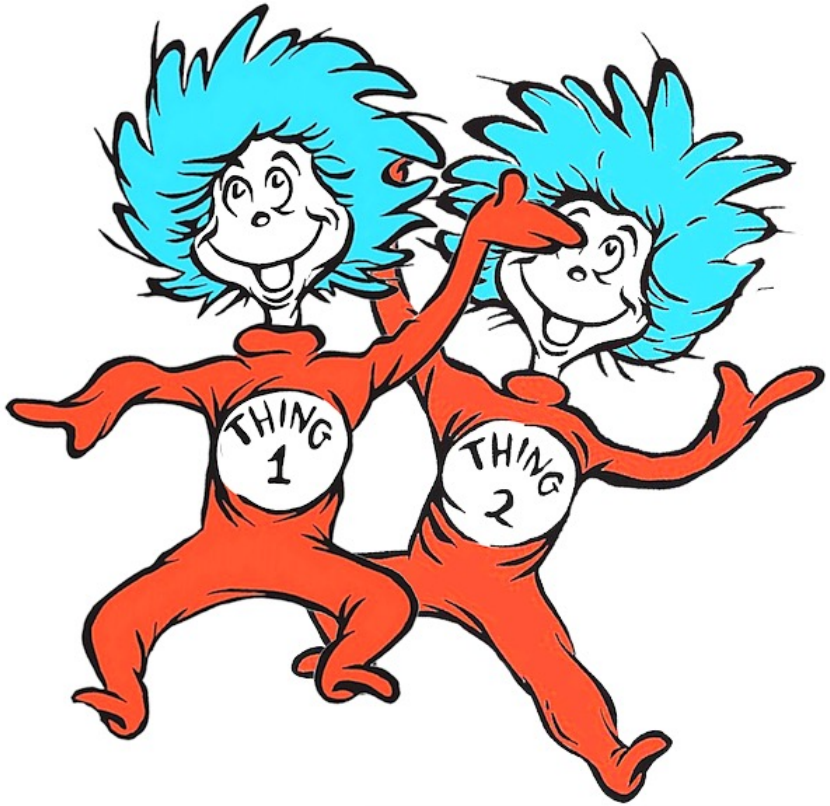
See upcoming lessons on the Java Fork-Join framework for coverage of how randomness is applied in concurrent & parallel programs



See gee.cs.oswego.edu/dl/papers/fj.pdf

An Overview of Sequential Programming

- Sequential programs have two main characteristics



See www.doc.ic.ac.uk/~jnm/concurrency/online/concurrent/tsld007.htm

An Overview of Sequential Programming

- Sequential programs have two main characteristics:
  - The textual order of statements specifies their order of execution

```
public E get(int index) {
   rangeCheck(index);

   return elementData
                    (index);
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```
public E get(int index) {
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e.g., chaos & insanity will occur in Java's ArrayList get() method if rangeCheck() is not called before elementData()!!!

See src/share/classes/java/util/ArrayList.java

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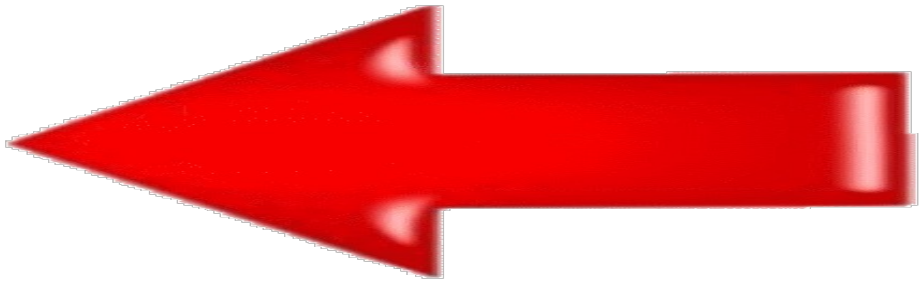
- Sequential programs have two main characteristics:
  - The textual order of statements specifies their order of execution
  - Successive statements must execute without any temporal overlap *visible* to programs

Consider the code sequence

```
a = b + c
d = e - a
```



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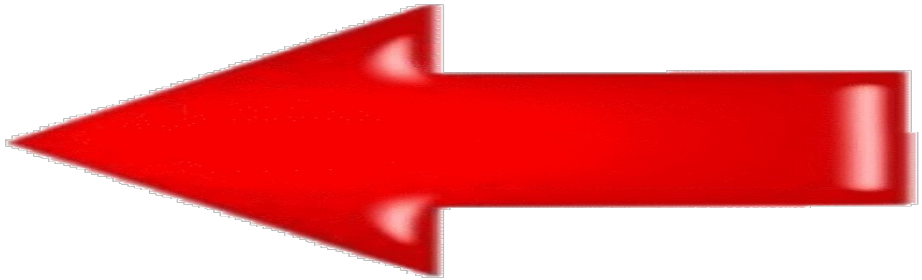
The value of 'a' must be assigned before the value of 'd' is assigned



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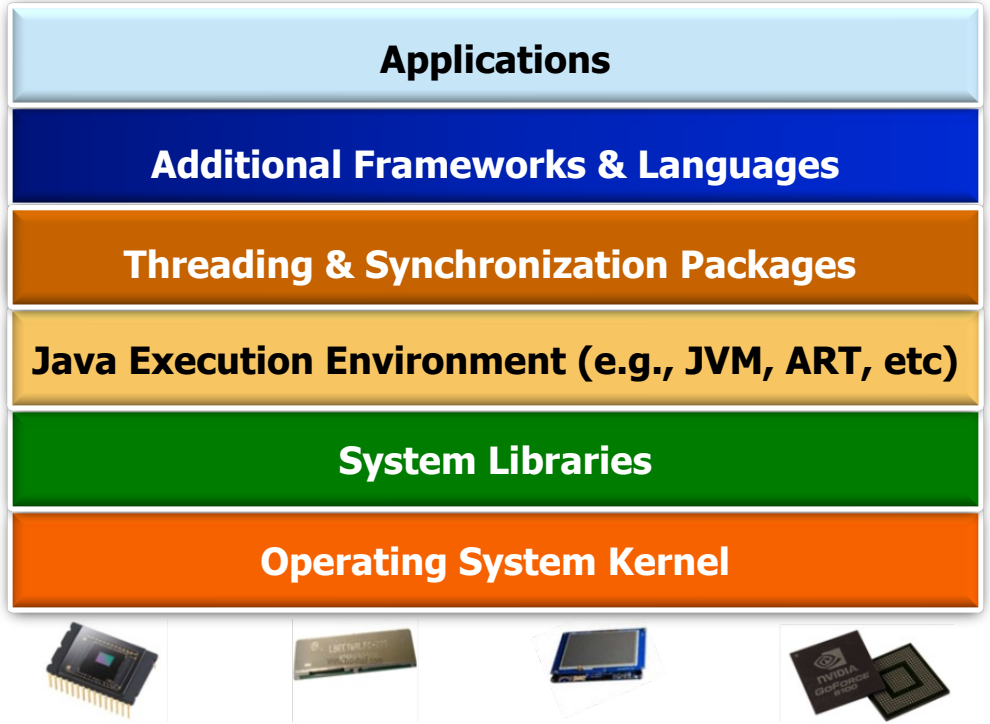

See en.wikipedia.org/wiki/Solution_stack

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e.g., out-of-order execution is used to avoid "pipeline stalls" that delay instruction execution

Consider the code sequence

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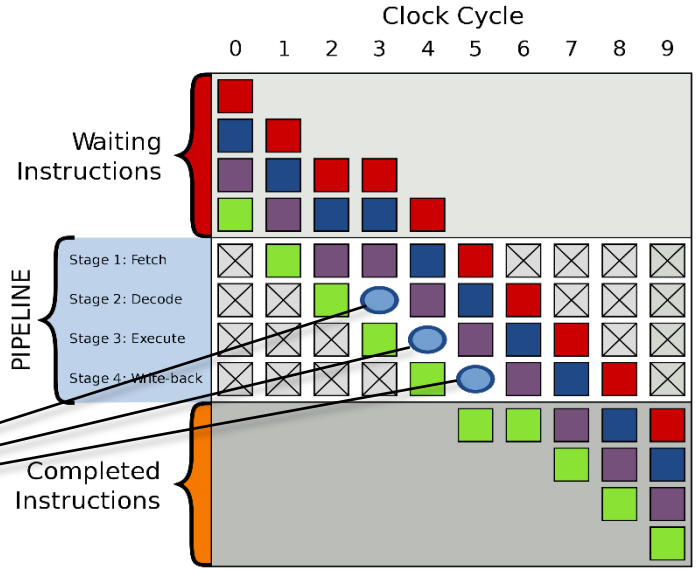
Assuming a, b, c, d, & e are in memory & loads/stores take one clock cycle out-of-order, then instruction scheduling eliminates pipeline stalls



See en.wikipedia.org/wiki/Out-of-order_execution & en.wikipedia.org/wiki/Pipeline_stall

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Original code with stalls:

```
LD   Rb, b
LD   Rc, c
  stall
ADD  Ra, Rb, Rc
SD   Ra, a
LD   Re, e
  stall
SUB  Rd, Re, Ra
SD   Rd, d
```

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```

Scheduled code without stalls:

```
LD    Rb, b
LD    Rc, c
LD    Re, e
ADD   Ra, Rb, Rc
SD    Ra, a
SUB   Rd, Re, Ra
SD    Rd, d
```

See en.wikipedia.org/wiki/Instruction_scheduling

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  - The textual order of statements specifies their order of execution
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  - However, lower layers in the solution stack can reorder instructions transparently
    - Mercifully these optimizations occur ”under the hood”!!

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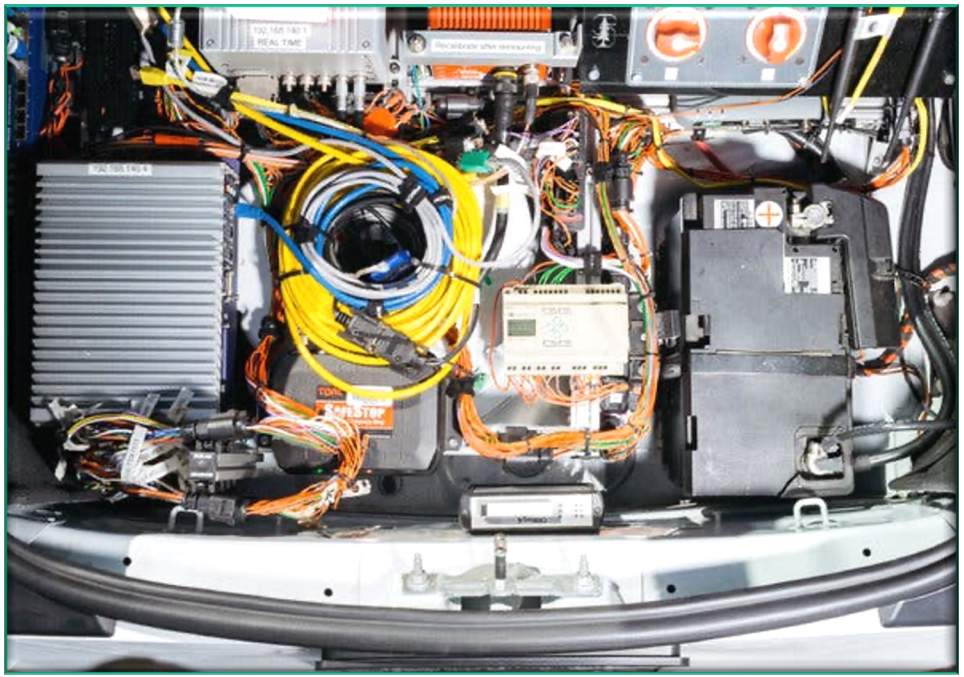

See www.nytimes.com/2015/09/27/business/complex-car-software-becomes-the-weak-spot-under-the-hood.html

End of Overview of Sequential Programming Concepts