Don't Start with Dekker's Algorithm: Top-Down Introduction of Concurrency

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Multicore Programming Education Workshop
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Bottom-Up Concurrency

- AKA Concurrency for Wizards
- Usually taught in the OS course
  - Dekker's algorithm
  - Peterson's algorithm
  - (maybe) Lamport's bakery and fast (no contention) locks
  - TAS
  - T&TAS
  - (maybe) MCS
  - semaphores, monitors, (maybe) CCRs

But...

- Where did the threads come from?
- Why do I care?
  (What are they *for*?)
- Can mere mortals make
  any of this work?

Concurrency First?

- Sequentiality as a special case
  - » See Arvind's talk after lunch
  - » A backlash, perhaps, against concurrency for wizards
- I'm going to suggest an intermediate approach
  - » Learn what you need when you need it
  - » "Top-down", but not "concurrency first"

Suggested Principles

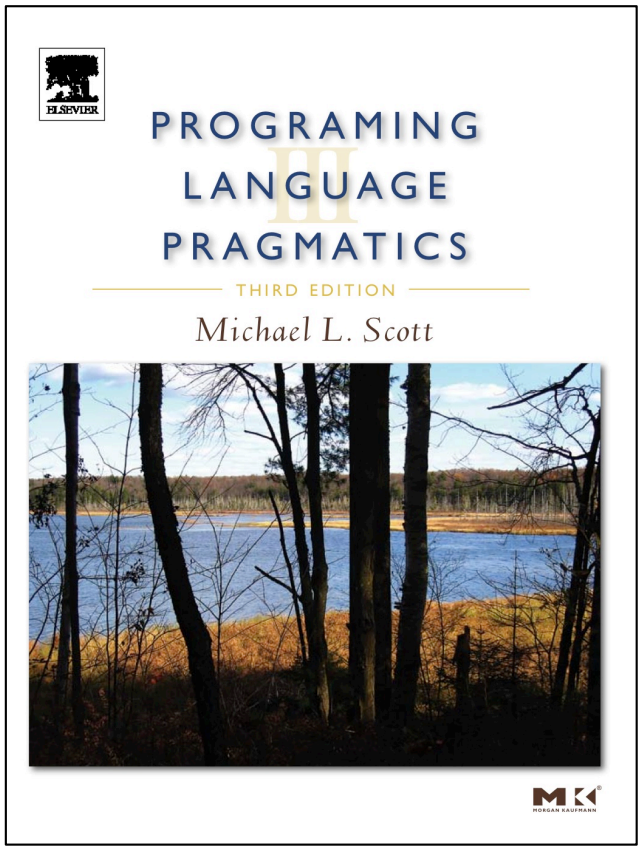
- Integrate parallelism & concurrency into the whole curriculum
- Introduce it gradually where it naturally fits
- Provide clear motivation *and payoff* at each step
- Recognize that
  - » everybody needs benefits from multicore
  - » many need to deal with events (concurrency)
  - » some need to develop concurrent data structures
  - » few need to implement synchronization mechanisms or other race-based code

Thinking about Parallelism

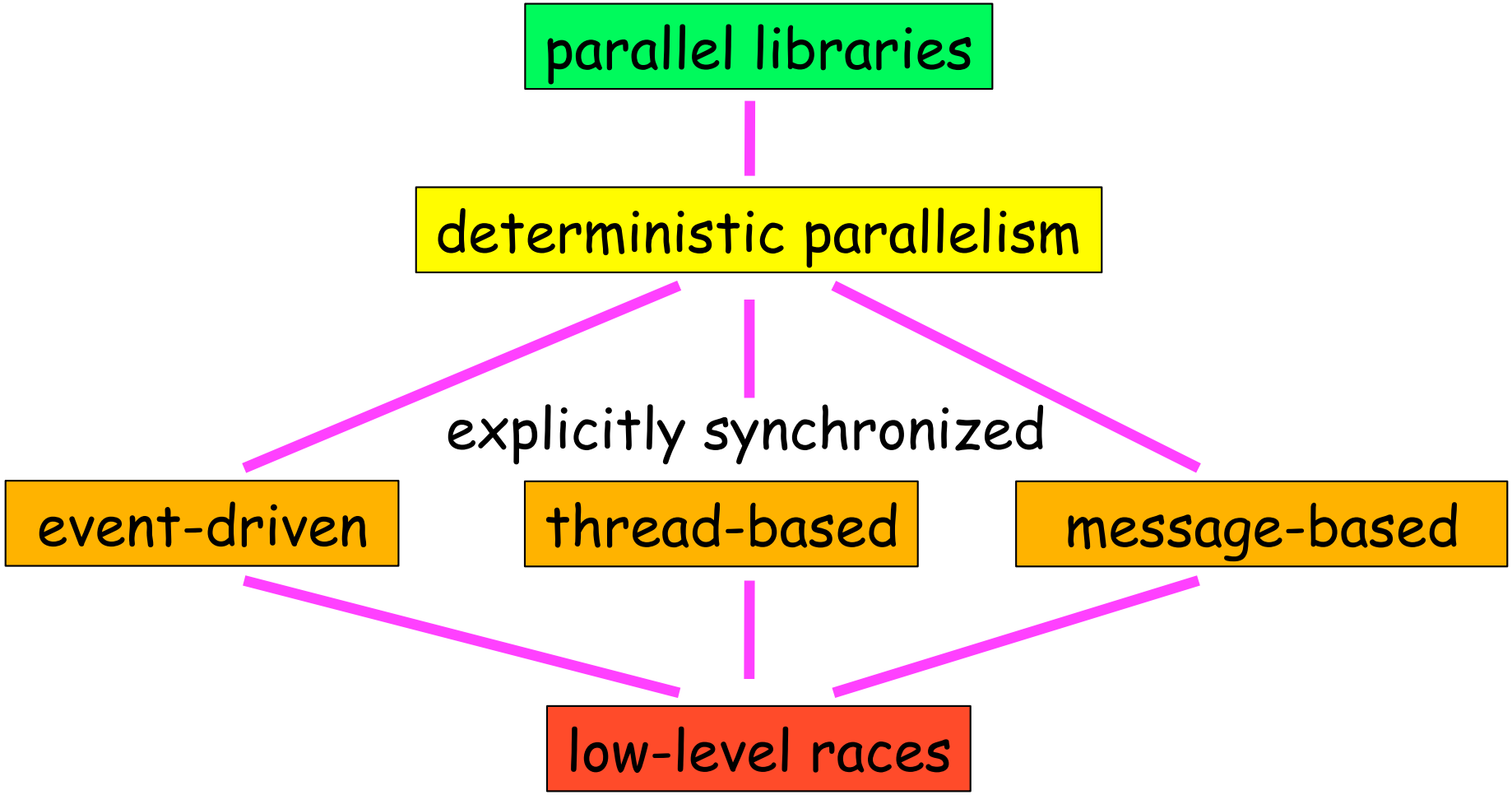
- Is it more or less fundamental than sequentiality?
- May be a silly question
  - » Dependences among algorithm steps form a partial order
  - » I don't care if you call it
    - a restriction of the empty order
    - or a relaxation of some total order
- Both are ways of thinking about the ordering of algorithmic steps (state transformers)

Concurrency as Control Flow

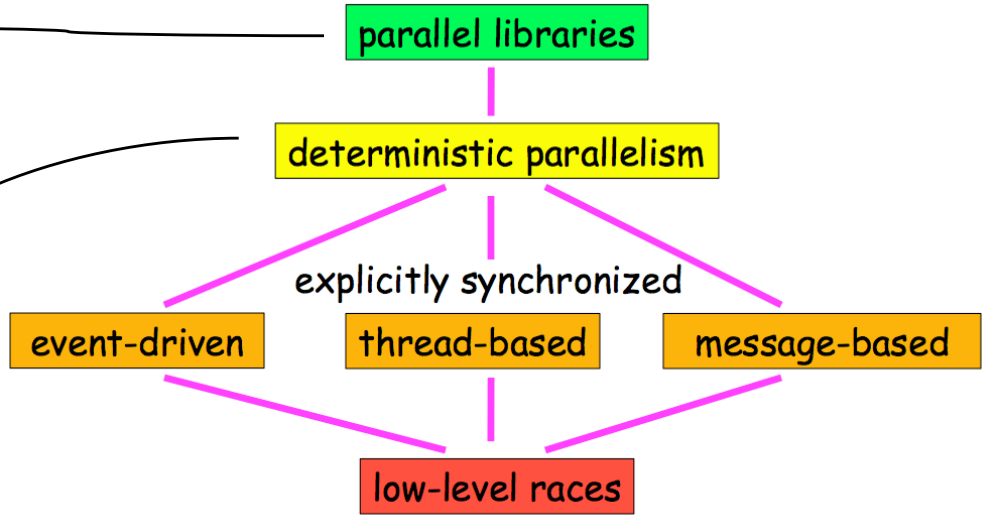
- My languages text/course talks about
  - sequencing
  - selection
  - iteration
  - procedural abstraction
  - recursion
  - concurrency
  - exception handling and speculation
  - nondeterminacy



Top-Down Concurrency

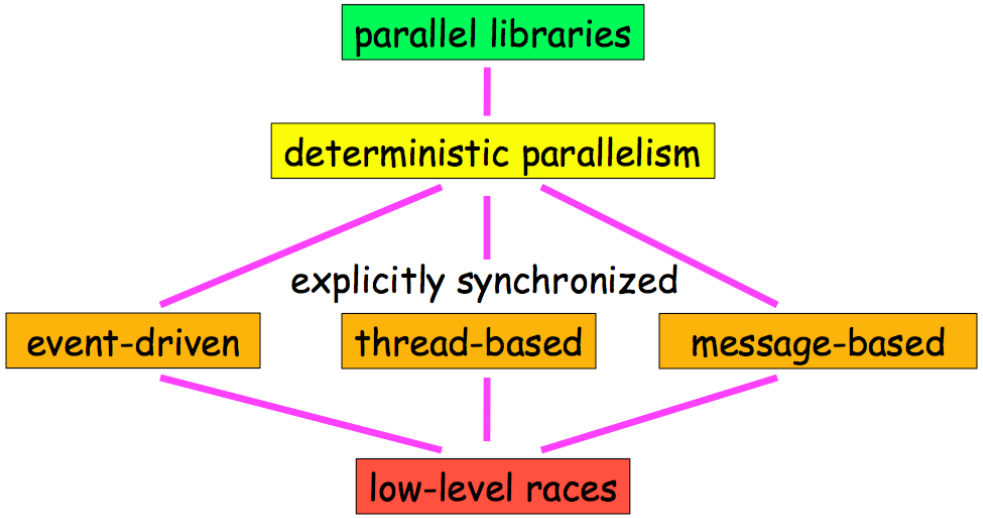


- Straightforward



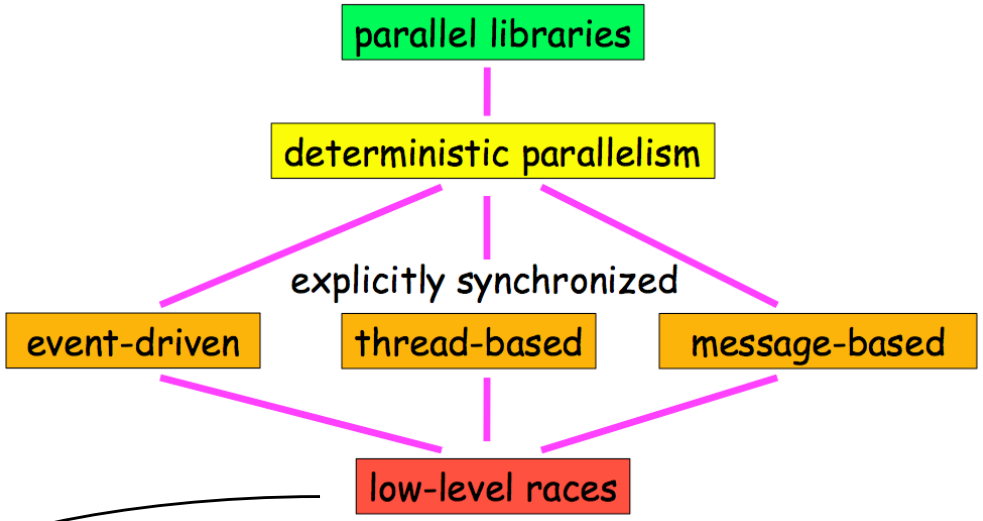
- Use
  - » par-do or spawn/sync w/compiler-enforced dynamic separation
  - » speculation in sequential programs
  - » futures in pure functional languages
  - » safe futures in impure languages
- And maybe
  - » par-do, spawn/sync, or unsafe futures, w/out enforced separation
  - » HPF for-all

- Consider
  - » locality
  - » granularity
  - » load balance
  - » design patterns



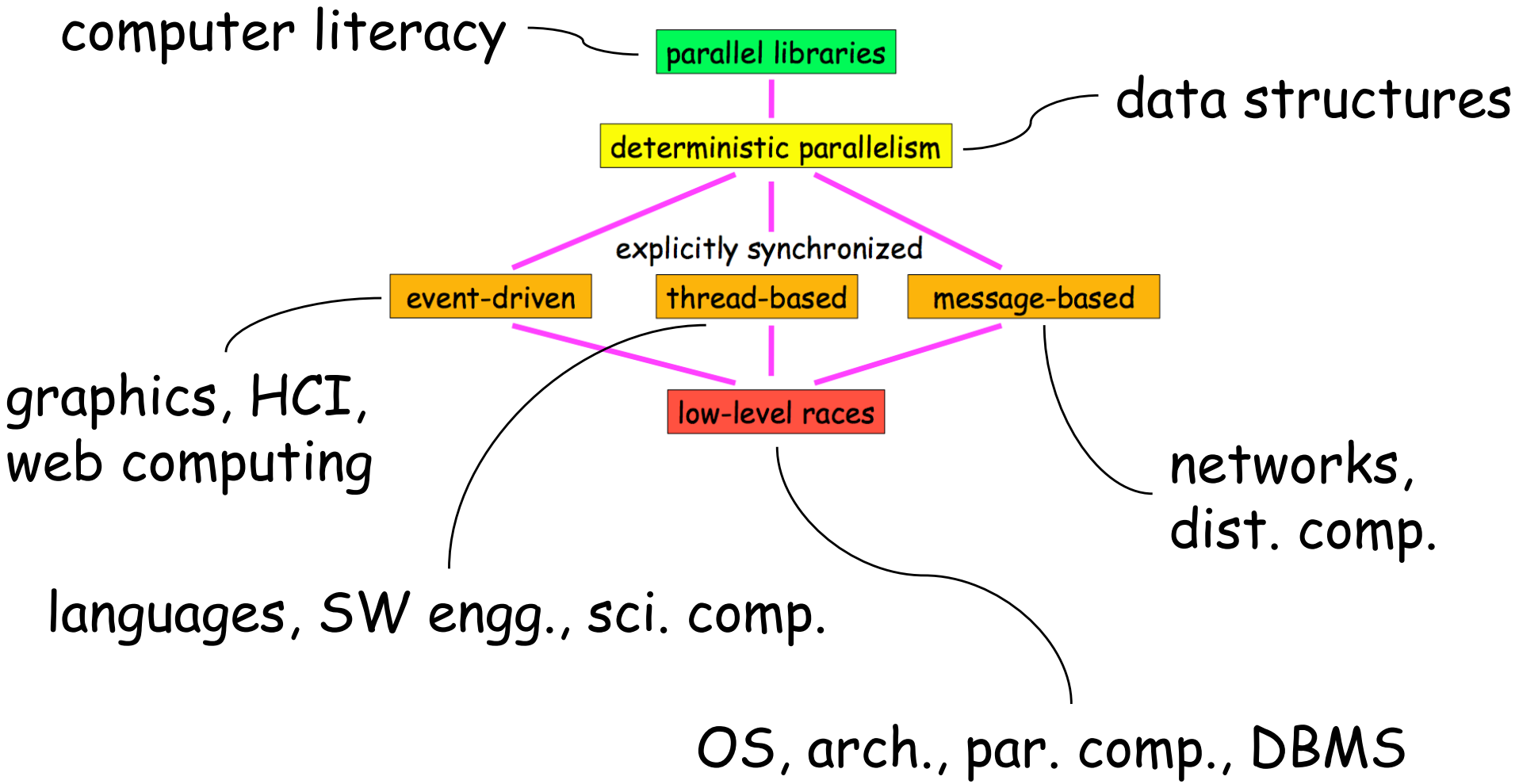
- Use
  - atomic blocks
  - PO-iterators
  - loop post-wait
  - map-reduce
  - condition sync
  - locks, monitors, CCRs
  - send/receive/rendezvous

- Consider
  - progress
  - happens-before
  - data race freedom
  - 2-phase commit
  - consensus, self-stabilization, Byzantine agreement, etc.



- Build
  - » implementation of threads, locks, monitors, transactions, etc.
  - » nonblocking data structures
  - » non-DRF algorithms
- Consider
  - » memory models/ consistency
  - » linearizability, serializability
  - » consensus hierarchy

Where in the Curriculum?



Motivation and Rewards

- Need clear payoff, at each step of the way, to motivate further investment/refinement
  - » speedup (even if modest, e.g., on 2-core machine)
  - » clarity (for event-driven and naturally multithreaded code)
- Will benefit greatly from access to parallel machines
  - » Simulators are lousy motivation
  - » Niagara boxes are cheap
-

What Language Do We Use?

- Lamport: This is the wrong question.
  - » "Imagine an art historian answering 'how would you describe impressionist painting?' by saying 'in French'."
- MLS: This is the wrong analogy.
  - » Imagine an art teacher answering "how would you introduce pointillism?" by saying "in oils".
- Notation matters!

Algol 68

```
[]REAL M = (0.0, 0.0);
...
BEGIN
    M[0] := f(M[0]),          # note comma
    M[1] := g(M[1])
END
```

Java 5

```
static class A implements Runnable {
    double M[];
    A(double m[]) {M = m;}
    public void run () {
        M[0] = f(M[0]);
    }
}
```

```
static class B implements Runnable {
    double M[];
    B(double m[]) {M = m;}
    public void run () {
        M[1] = g(M[1]);
    }
}
```

```
...
double M[] = new double[2];
ExecutorService pool = Executors.newFixedThreadPool(2);
pool.execute(new A(M));
pool.execute(new B(M));
pool.shutdown();
try {
    boolean finished = pool.awaitTermination(10, TimeUnit.SECONDS);
} catch (InterruptedException e) { }
```

C# 3.0

```
double[] M = new double[2];
Parallel.Do(
    delegate { M[0] = f(M[0]); },
    delegate { M[1] = g(M[1]); }
);
```

- Where are the other options?
  - » production quality (with good IDE)
  - » widely used (for practical-minded students)

Summary Recap

- Integrate parallelism & concurrency into the whole curriculum
- Introduce it gradually where it naturally fits
- Provide clear motivation *and payoff* at each step
- Assign projects on real machines
- In real programming languages

www.cs.rochester.edu/research/synchronization/