CISC 372: Parallel Computing
Threads, part 4: barrier and reduction implementations

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Now let's generalize. . .

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Analysis

- (+) only 1 flag per thread
- (-) contention on shared variable counter (and its lock)
- (-) $O(n)$ due to last thread's protocol

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- see `coordinator_barrier.c`

Analysis of coordinator barrier

- (+) avoids memory contention
- (-) requires an extra thread
- (-) $O(n)$: execution time is proportional to n
  - what if $n = 10^6$?

Combining binary tree barrier

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- organizes workers in tree
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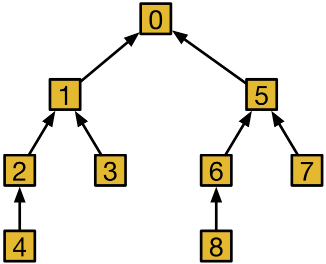
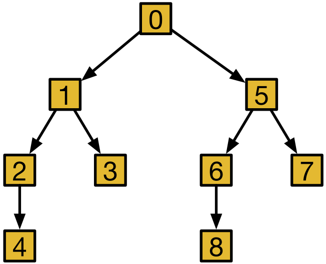
- flow of signals
  - send arrive signals up the tree
  - send depart signals down the tree
- sequence of events
  - worker waits for all children to arrive
  - then tells parent it has arrived
  - when root learns that its children have arrived
  - it knows all procs have arrived
  - then root tells its children to depart
  - when a worker is told to depart, it tells its children to depart, . . .





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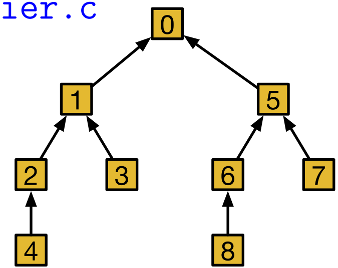
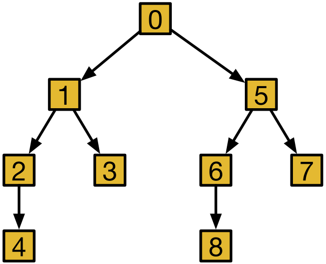
- protocol for leaf node *L*
  1. raise `arrive`[*L*]
  2. lower `depart`[*L*]
- protocol for interior node *I*
  1. lower `arrive`[*left*]
  2. lower `arrive`[*right*]
  3. raise `arrive`[*I*]
  4. lower `depart`[*I*]
  5. raise `depart`[*left*]
  6. raise `depart`[*right*]
- protocol for root node *R*
  1. lower `arrive`[*left*]
  2. lower `arrive`[*right*]
  3. raise `depart`[*left*]
  4. raise `depart`[*right*]





Analysis of combining tree barrier

- time is $O(\log(n))$
  - no loops $1..n$
  - each row in the tree can execute in parallel
- different procs execute different code
- leaf and root execute fewer instructions
  - could lead to inefficiency
- increases complexity

Symmetric barriers

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- common structure: solutions are constructed from pairs of 2-process barriers
  - Thread 1
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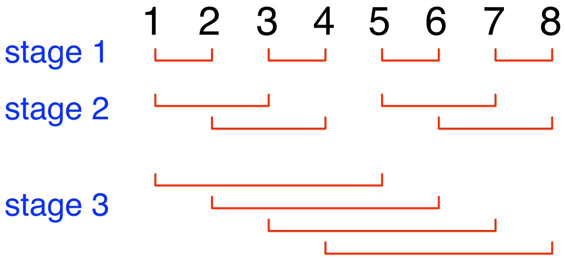

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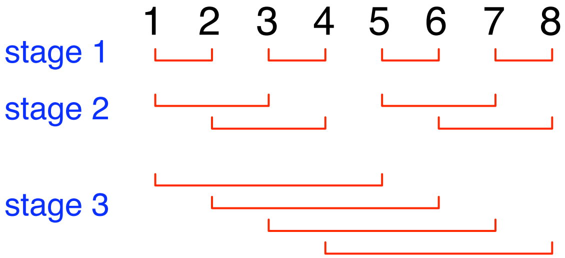

- butterfly: $O(\log(n))$ time and symmetric
- requires n to be power of 2

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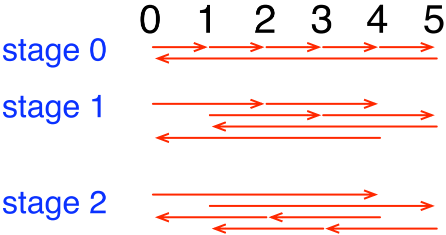
- dissemination barrier works for any n
- uses cyclic order of threads
- two flags (`a` and `b`) for each thread, in each stage
- in stage i each thread
  - synchs with thread 2^i to the right using `a` and `b` flags of that thread
  - synchs with thread 2^i to the left using its `a` and `b` flags
- stages: $0 \leq i < \lceil \log_2 n \rceil$



Dissemination barrier: code

```
for (int stage=0, i=1; stage<nstages; stage++, i*=2) {
  flag_raise(&bs->a[stage][(tid+i)%nthreads]);
  flag_lower(&bs->a[stage][tid]);
  flag_raise(&bs->b[stage][tid]);
  flag_lower(&bs->b[stage][(tid+i)%nthreads]);
}
```

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  - root gets the global sum and can assign it to a global variable
  - allows reduction without all threads contending for a single mutex

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  - for portable code: know how to write your own barrier
- `pthread_barrier_t` : type of a barrier object
- `pthread_barrier_init(...)`
  - `pthread_barrier_t *`
    - pointer to barrier object to initialize
  - `pthread_barrierattr_t *`
  - `unsigned int count`
    - number of threads that will participate in this barrier
- `pthread_barrier_destroy(pthread_barrier_t *)`
- `pthread_barrier_wait(pthread_barrier_t *)`