Review of topics in concurrency

What is the smallest value of `counter`, among those listed, after the threads terminate?

```
int counter = 0;
```

thread t

```
int cnt;
for (int i = 0; i < 5; i++) {
  cnt = counter;
  counter = cnt + 1;
}
```

thread u

```
int cnt;
for (int i = 0; i < 5; i++) {
  cnt = counter;
  counter = cnt + 1;
}
```

1. 1
2. 5
3. 6
4. 10

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for (int i = 0; i < 5; i++) {
  cnt = counter;
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}
```

1. 1
2. 5
3. 6
4. 10

The final value of `counter` is `5` when both threads read `counter == 0`, one thread proceeds and increments it to `5`, and the other thread overwrites the same values up to `5`.

But there are schedules where there is an even more destructive interference between the two threads, so that the final value of `counter` can be as low as 2!

#	t'S LOCAL	u'S LOCAL	SHARED
1	$pc_t: 2$ $cnt_t: \bot$	$pc_u: 6$ $cnt_u: \bot$	counter: 0
2	$pc_t: 2$ $cnt_t: \bot$	$pc_u: 7$ $cnt_u: 0$	counter: 0
3	$pc_t: 3$ $cnt_t: 0$	$pc_u: 7$ $cnt_u: 0$	counter: 0
4	$pc_t: 3$ $cnt_t: 0$	$pc_u: 6$ $cnt_u: 0$	counter: 1
5	$pc_t: 3$ $cnt_t: 0$	$pc_u: 7$ $cnt_u: 1$	counter: 1
6	$pc_t: 3$ $cnt_t: 0$	$pc_u: 6$ $cnt_u: 1$	counter: 2
7	$pc_t: 3$ $cnt_t: 0$	$pc_u: 7$ $cnt_u: 2$	counter: 2
8	$pc_t: 3$ $cnt_t: 0$	$pc_u: 6$ $cnt_u: 2$	counter: 3
9	$pc_t: 3$ $cnt_t: 0$	$pc_u: 7$ $cnt_u: 3$	counter: 3
10	$pc_t: 3$ $cnt_t: 0$	$pc_u: 6$ $cnt_u: 3$	counter: 4
11	$pc_t: 2$ $cnt_t: 0$	$pc_u: 6$ $cnt_u: 3$	counter: 1
12	$pc_t: 2$ $cnt_t: 0$	$pc_u: 7$ $cnt_u: 1$	counter: 1
13	$pc_t: 3$ $cnt_t: 1$	$pc_u: 7$ $cnt_u: 1$	counter: 1
14	$pc_t: 2$ $cnt_t: 1$	$pc_u: 7$ $cnt_u: 1$	counter: 2
15	$pc_t: 3$ $cnt_t: 2$	$pc_u: 7$ $cnt_u: 1$	counter: 2
16	$pc_t: 2$ $cnt_t: 2$	$pc_u: 7$ $cnt_u: 1$	counter: 3
17	$pc_t: 3$ $cnt_t: 3$	$pc_u: 7$ $cnt_u: 1$	counter: 3
18	$pc_t: 2$ $cnt_t: 3$	$pc_u: 7$ $cnt_u: 1$	counter: 4
19	$pc_t: 3$ $cnt_t: 4$	$pc_u: 7$ $cnt_u: 1$	counter: 4
20	done	$pc_u: 7$ $cnt_u: 1$	counter: 5
21	done	done	counter: 2

What is the value of `n` after 8 concurrent threads terminate?

```
int n = 0; Semaphore s = new Semaphore(1); // capacity 1
```

thread t_k

```
int x;
1  s.down();
2  x = n;
3  n = x + 1;
4  s.up();
```

1. Between 1 and 8
2. Between 4 and 8
3. Always 4
4. Always 8

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```

1. Between 1 and 8
2. Between 4 and 8
3. Always 4
4. Always 8

What is the value of `n` after 8 concurrent threads terminate?

```
int n = 0; Semaphore s = new Semaphore(2); // capacity 2
```

thread t_k

```
int x;
1  s.down();
2  x = n;
3  n = x + 1;
4  s.up();
```

1. Between 1 and 8
2. Between 4 and 8
3. Always 4
4. Always 8

What is the value of `n` after 8 concurrent threads terminate?

```
int n = 0; Semaphore s = new Semaphore(2); // capacity 2
```

thread t_k

```
int x;
1 s.down();
2 x = n;
3 n = x + 1;
4 s.up();
```

1. Between 1 and 8
2. Between 4 and 8
3. Always 4
4. Always 8

The value 1 occurs if one thread t reads 0 initially, and then waits inside its critical section, while the other threads go through their critical section in mutual exclusion. Then, t finishes by writing 1, thus overwriting the increments of all other threads.

What do threads continuously calling `x()` and `y()` print?

```
monitor class CountPrint {
  private Condition isX = new Condition();
  private Condition isY = new Condition();
  public void x()
  { isX.wait(); System.out.print("X"); isY.signal(); }
  public void y()
  { isY.wait(); System.out.print("Y"); isX.signal(); }
}
```

1. A sequence of alternating `X` and `Y`.
2. The first answer, if the monitor uses “signal and wait”.
3. The first answer, if the monitor uses “signal and continue”.
4. The program deadlocks.

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What do threads continuously calling `x()` and `y()` print?

```
monitor class CountPrint {
  private Condition isY = new Condition();
  public void x()
  { System.out.print("X"); isY.signal(); }
  public void y()
  { isY.wait(); System.out.print("Y"); }
}
```

1. A sequence with at least one `X` between every pair of `Y`.
2. The first answer, if the monitor uses “signal and wait”.
3. The first answer, if the monitor uses “signal and continue”.
4. The program deadlocks.

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2. The first answer, if the monitor uses “signal and wait”.
3. The first answer, if the monitor uses “signal and continue”.
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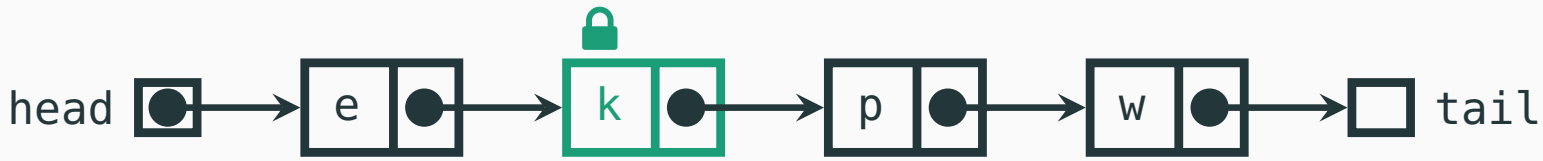
Under “signal and continue”, it is possible that two unblocked calls to `y()` get in the entry queue and then execute one after another.

Thread `t` is adding a node `m` while locking node `k`. How can this operation go wrong?



1. Another thread may add a node `l` before `m`
2. Another thread may add a node `g` before `k`
3. Another thread may remove node `k`
4. Another thread may invalidate node `k`

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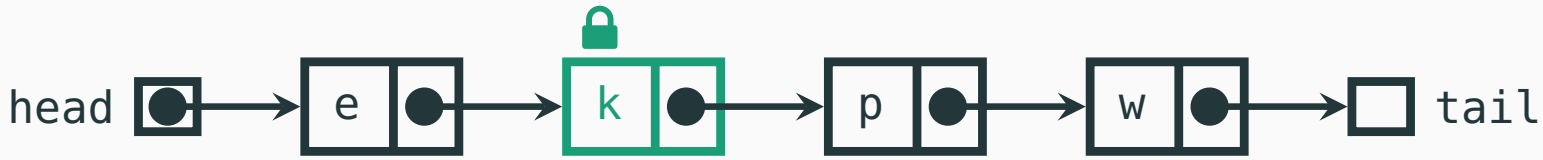

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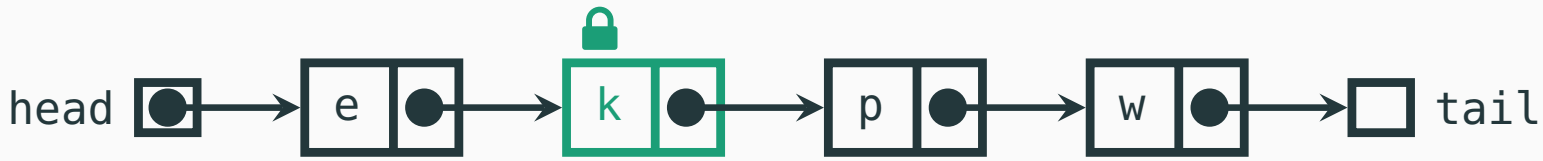
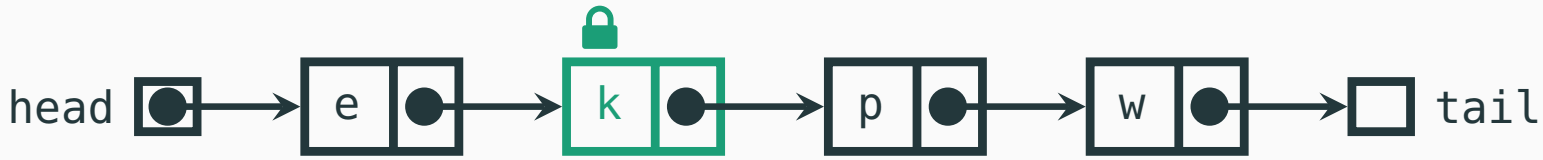
Thread `t` is removing node `p` while locking node `k`. How can this operation go wrong?



1. Another thread may add a node `m` after `k`
2. Another thread may add a node `q` after `p`
3. Another thread may remove node `w`
4. Another thread may add a node `g` before `k`

Thread `t` is removing node `p` while locking node `k`. How can this operation go wrong?



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What does `twice([1,2,3,4])` return?

```
twice([]) -> [];
twice([H|T]) -> [2*H|twice(T)].
```

1. `[1,2,3,4]`
2. `[4,3,2,1]`
3. `[2,4,6,8]`
4. `[2,2,2,2]`

What does `twice([1,2,3,4])` return?

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```

1. `[1,2,3,4]`
2. `[4,3,2,1]`
3. `[2,4,6,8]`
4. `[2,2,2,2]`

What does `mtwice([1,2,3,4])` return?

```
mtwice(L) -> map(fun (X) -> 2*X end, L).
```

1. `[2,4,6,8]`
2. `[2,2,2,2]`
3. The list `[2,4,6,8]` with the elements in any order
4. The list `[1,2,3,4]` with the elements in any order

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What does process `Q` print?

process `P`

```
p() ->  % Q is Q's pid
  Q ! {self(), 1},
  Q ! {self(), 2},
  Q ! {self(), 3}.
```

process `Q`

```
q() ->  % P is P's pid
  receive {P, N} ->
    io:format("~p", [2*N]) end,
  q().
```

1. The numbers `1`, `2`, `3` in any order
2. The numbers `2`, `4`, `6` in any order
3. The numbers `1`, `2`, `3` in this order
4. The numbers `2`, `4`, `6` in this order

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  Q ! {self(), 1},
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What does process R print?

---

process P

```
p() ->
  R ! x,
  p().
```

process Q

```
q() ->
  R ! y,
  q().
```

process R

```
r() ->
  receive
    x -> io.format("X");
    y -> io.format("Y")
  end,
  r().
```

1. The sequence XYXYXY...
2. The sequence YXYXYX...
3. Any sequence of letters X and Y.
4. Any sequence of uppercase letters.

What does process R print?

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```
p() ->
  R ! x,
  p().
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q() ->
  R ! y,
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r() ->
  receive
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What does `ptwice([1,2,3,4], [], 4)` return?

```
ptwice([], R, 0) ->
  R;
ptwice([], R, N) ->
  receive X -> ptwice([], [X|R], N-1) end;
ptwice([H|T], R, N) ->
  Me = self(),
  spawn(fun ()-> Me ! 2*H end),
  ptwice(T, R, N).
```

1. `[2,4,6,8]`
2. `[8,6,4,2]`
3. The list `[2,4,6,8]` with the elements in any order
4. The list `[1,2,3,4]` with the elements in any order

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  receive X -> ptwice([], [X|R], N-1) end;
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2. `[8,6,4,2]`
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4. The list `[1,2,3,4]` with the elements in any order

Each send is executed by a different spawned process; hence there is no guarantee on the receiving order.