HW 6

Turn in a .txt, .pdf or image file showing the state of the queues after each step or fill in this, scan it and turn it in.

This homework very much based on the example at
http://stackoverflow.com/questions/37026/java-notify-vs-notifyall-all-over-again

It contains a detailed explanation of what happens -- look at it and the solution *after* doing this yourself

- In this homework you will show the status of the program as *wait*, *notify* and *notifyAll* calls are made. Positions in the *wait* and *blocked queue* do not matter.
- This homework will demonstrate how threads wait on locks, how *wait*, *notify* and *notifyAll* work, and why you need a *while* loop to recheck a condition.

wait, notify and notifyAll
Let L be the lock

notify

If one or more threads are in the *wait queue*, wake one up and place it into the *blocked queue*. The thread to be woken up is picked arbitrarily. The thread woken up must acquire *L* before continuing. This is done automatically when in a synchronized method. The thread executing *notify* must hold the lock *L* and continues to hold it until it reaches the end of the synchronized block.

notifyAll

If one or more threads are in the *wait queue*, wake all of them up. All woken up threads will be placed into the *blocked queue* and attempt to acquire *L* when it is released by the thread executing the *notifyAll*. At most one will get the lock, all others will continue to be in the *blocked queue* (not the *wait queue*!) The thread executing *notifyAll* must hold the lock *L* and continues to hold it until it reaches the end of the synchronized block.

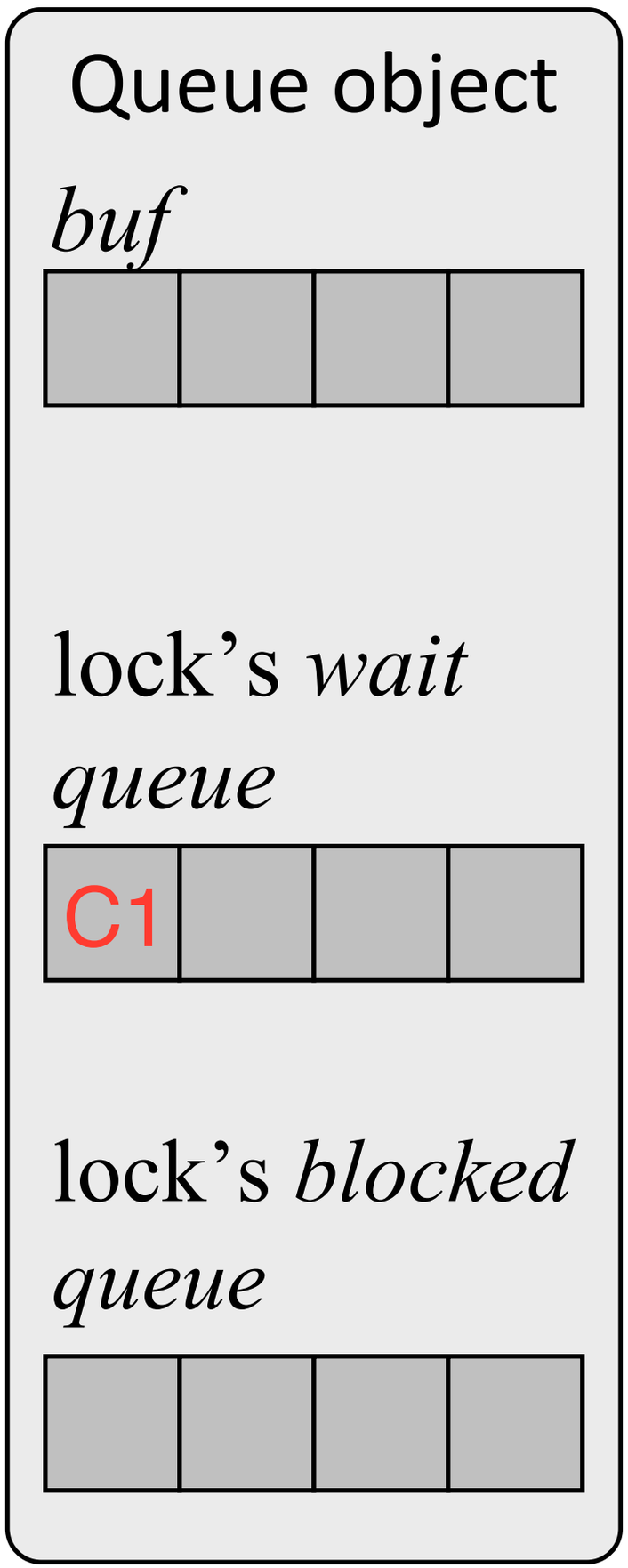
Wait

Put the thread executing *wait* into *L*'s wait queue. The thread executing wait must hold *L* and releases it when it executes *wait*.

First scenario -- this code is part of a class that implements a blocking queue

```
public synchronized void put(Object o) {
    while (buf.size()==MAX_SIZE) {
        wait(); // called if the buffer is full (try/catch removed
                // for brevity)
    }
    buf.add(o);
    notify(); // called in case there are any getters or putters waiting
}
```

```
public synchronized Object get() {
    // Y: this is where C2 tries to acquire the lock (i.e. at the
    // beginning of the method)
    while (buf.size()==0) {
        wait(); // called if the buffer is empty (try/catch removed
                // for brevity)
        // X: this is where C1 tries to re-acquire the lock (see below)
    }
    Object o = buf.remove(0);
    notify(); // called if there are any getters or putters waiting
    return o;
}
```

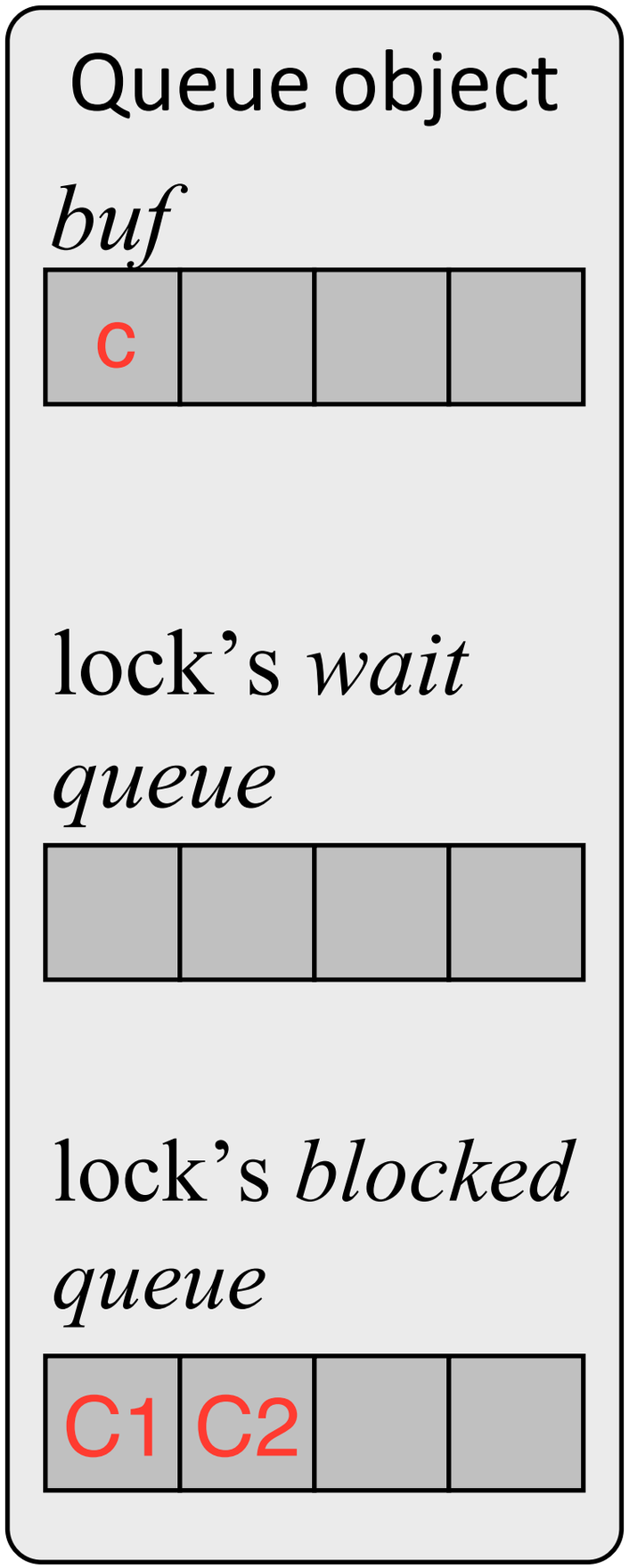


There are two kinds of threads -- consumer threads *C1, C2*, ..., that remove characters from *buf*, and producer threads *P1, P2*, ..., that add characters to *buf*. For our purposes, *buf.size( )* returns the number of characters in the buffer.

The buffer *buf* is initially empty.

1. Consumer *C1* enters the synchronized block for the *get* method
2. *buf.size( ) == 0* is true
3. *wait( )* is executed, placing *C1* on the lock's *wait queue*

Show the status of *buf*, lock's *wait queue* and lock's *blocked queue.*

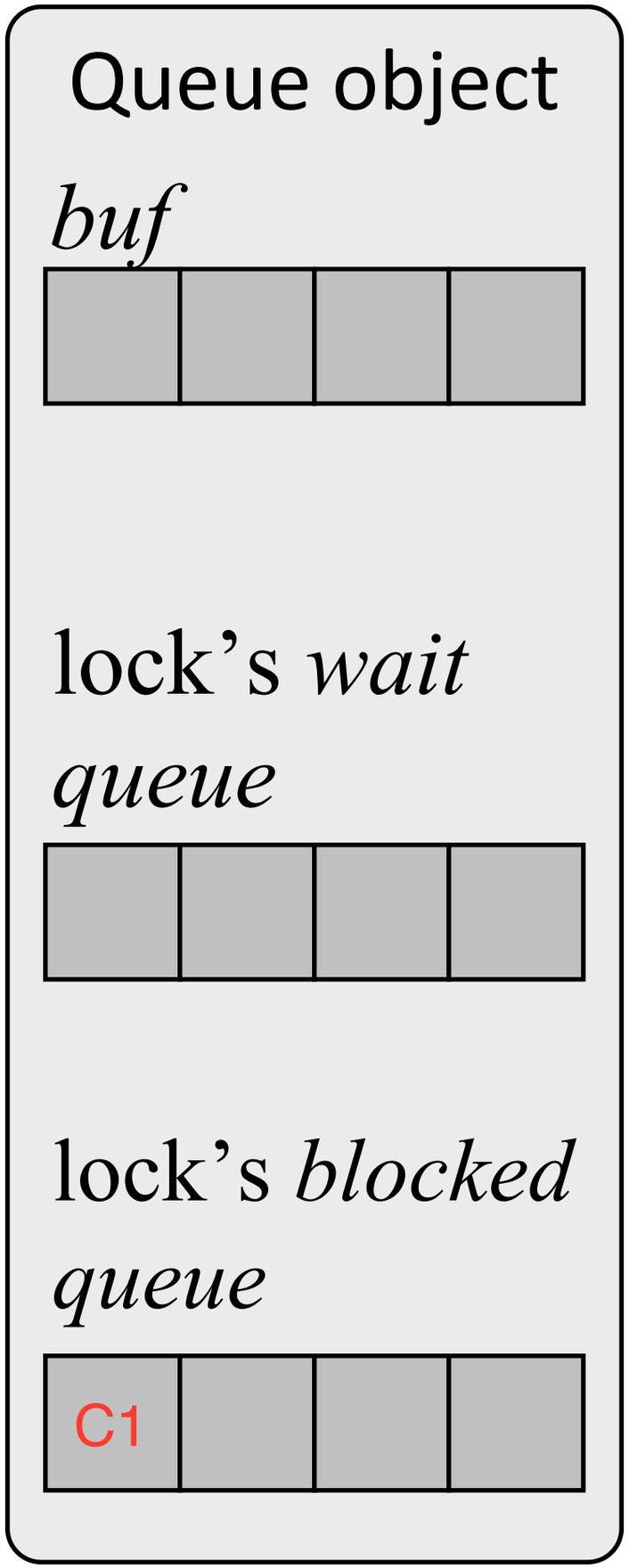


1. Consumer 2 (*C2*) is just about to enter the synchronized block for the *get* method, but has not acquired the lock.

2. Producer *P1* enters the synchronized method *put*, acquires the lock, places the character "*c*" into *buf*, and calls *notify( )*.

3. *C1* is woken up by the notify and must reacquire the lock before proceeding. Thus both *C1* and *C2* are competing for the lock.

Show the status of *buf*, lock's *wait queue* and lock's *blocked queue.*



1. One of *C1* and *C2* is non-deterministically chosen to get the lock. Let's say *C2* gets the lock. It gets to enter the method since *C1* is awake it is put on the *blocked queue*, not back on the *wait queue*.

2. *C2* gets the character and releases the lock which is then acquired by *C1*.

Is there a character in *buf* for *C1* to get?

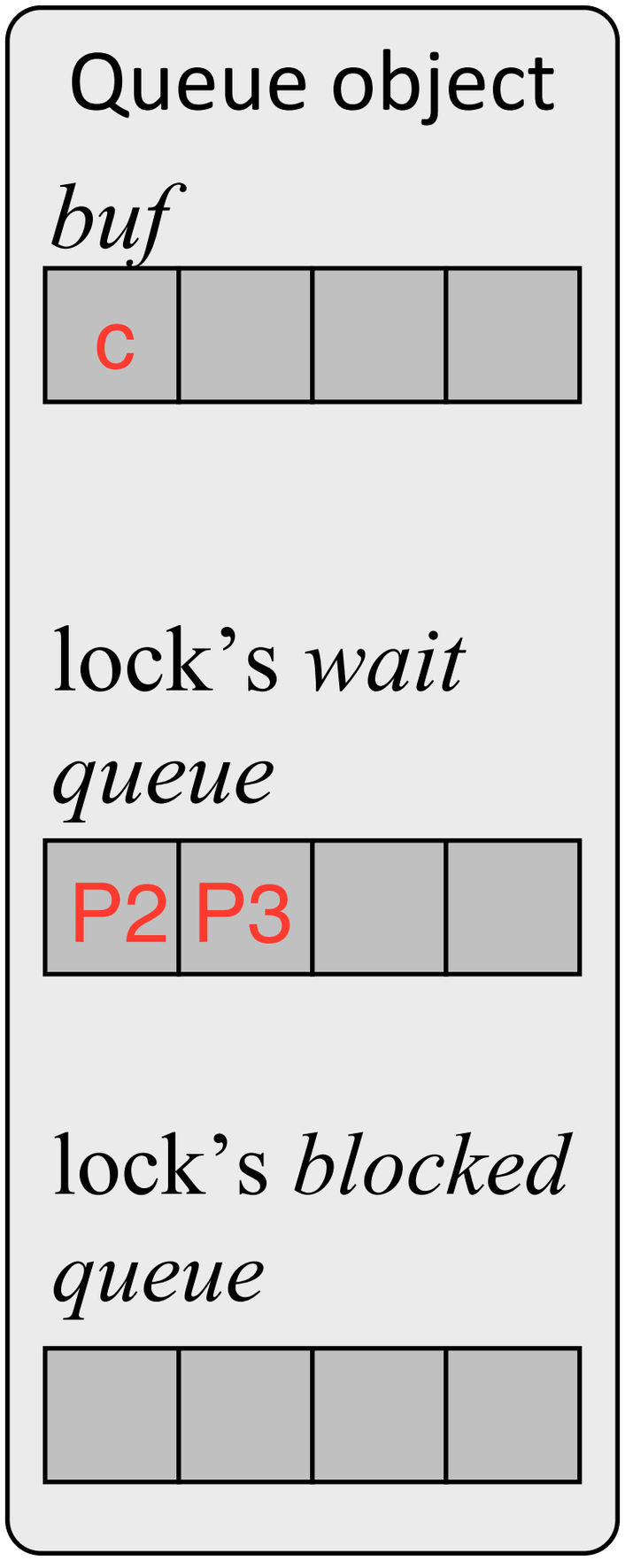
No, C2 already got the character. Therefore it is removed from buf

What will happen in the program as written?

C1 will go back to waiting because buf.size() will be 0

What would have happened if the *while* loop was not in the *get( )* method?

C1 would've tried to remove a character not in buf, resulting in an out of bounds error, or another error.

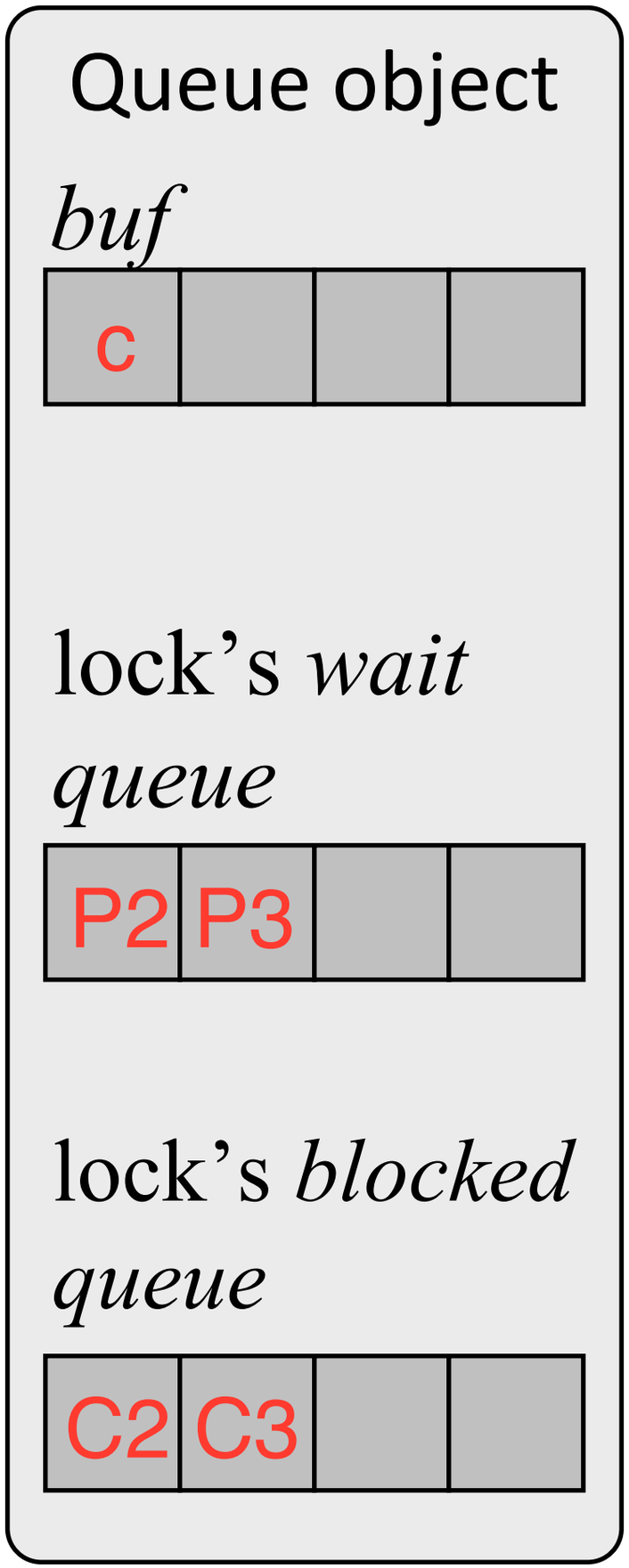


Let's look at a scenario that shows the need for notifyAll instead of notify in the code.

To make this easy, assume a buffer size of *1*. Producer and consumer threads are named as before. *buf* is initially empty.

1. *P1* puts a "c" into the buffer.
2. *P2* attempts a put, checks the while loop and performs a *wait( )*
3. *P3* attempts a put, checks the *while* loop and performs a *wait( )*

Show the status of *buf*, lock's *wait queue* and lock's *blocked queue.*



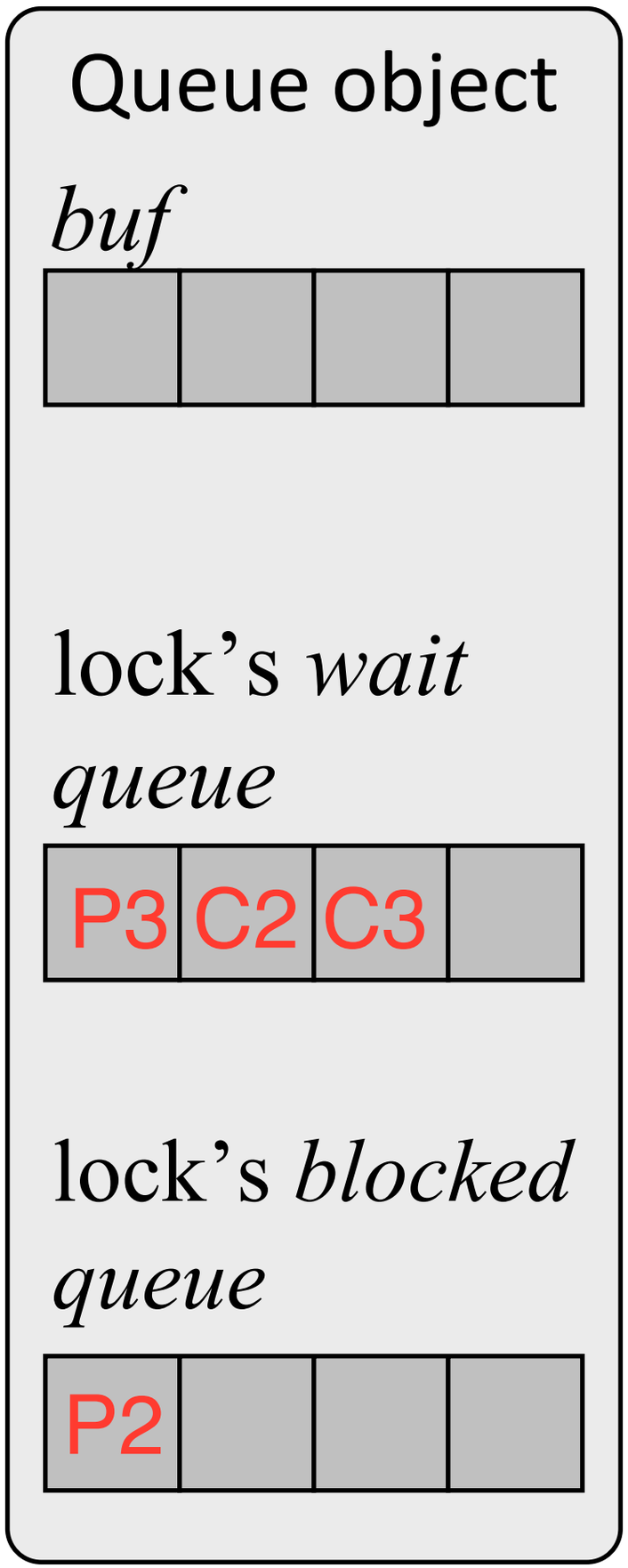
4. The following happen at time step 4:

   a. *C1* attempt to get 1 character and enters the *get* method;

   b. *C2* attempts to get 1 character but blocks on entry to the *get* method;

   c. *C3* attempts to get 1 character but blocks on entry to the *get* method;

Show the status of *buf*, lock's *wait queue* and lock's *blocked queue.*



5. The following happen at time step 5.

   a. *C1* is executing the *get* method, gets the character, calls *notify* and exits the method (releasing the lock and giving *C2* and *C3* a chance to acquire it);

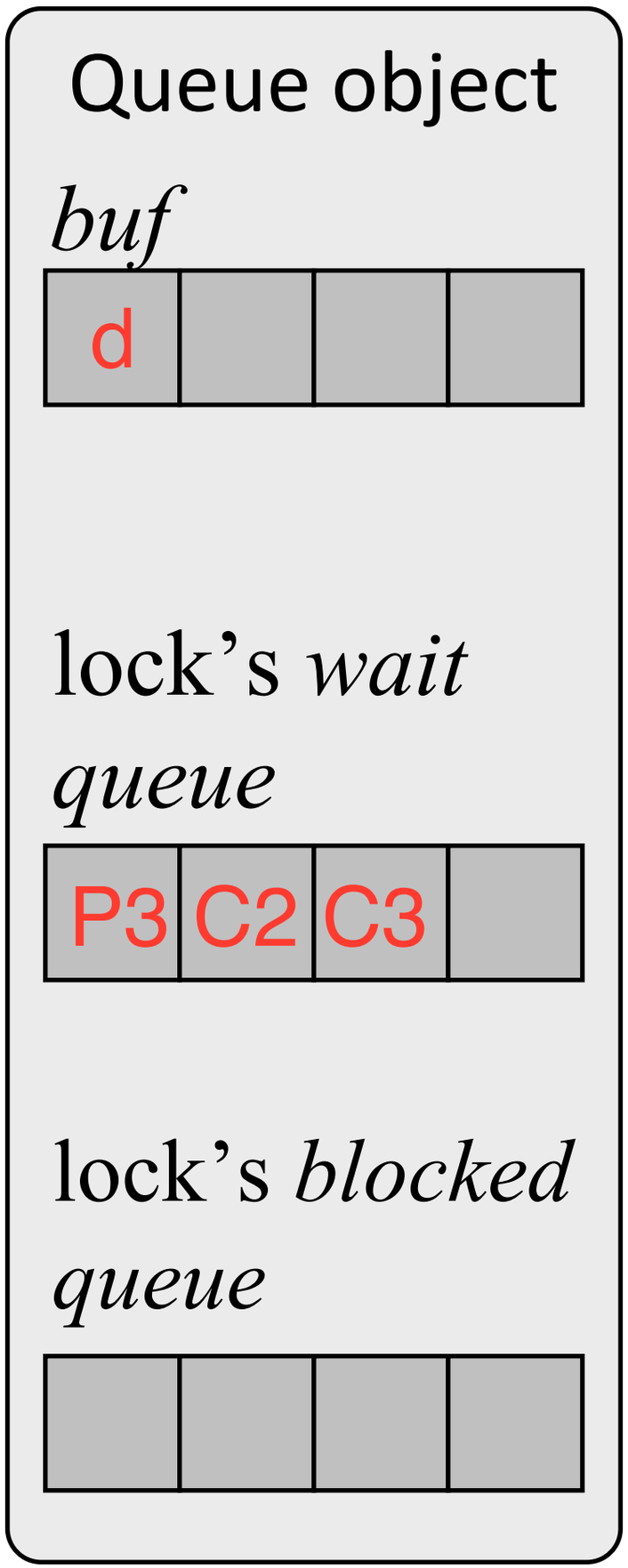
   b. The *notify* wakes up *P2*

   c. BUT, *C2* enters the method before *P2* can (*P2* must reacquire the lock), so *P2* blocks on entry to the put method;

   d. *C2* checks the wait loop, sees there are no more characters in the buffer and so it waits (releasing the lock in the process)

   e. *C3* enters the method after *C2*, but before *P2*, checks the wait loop, sees there are no more characters in the buffer, and so it waits

Show the status of *buf*, lock's *wait queue* and lock's *blocked queue.*

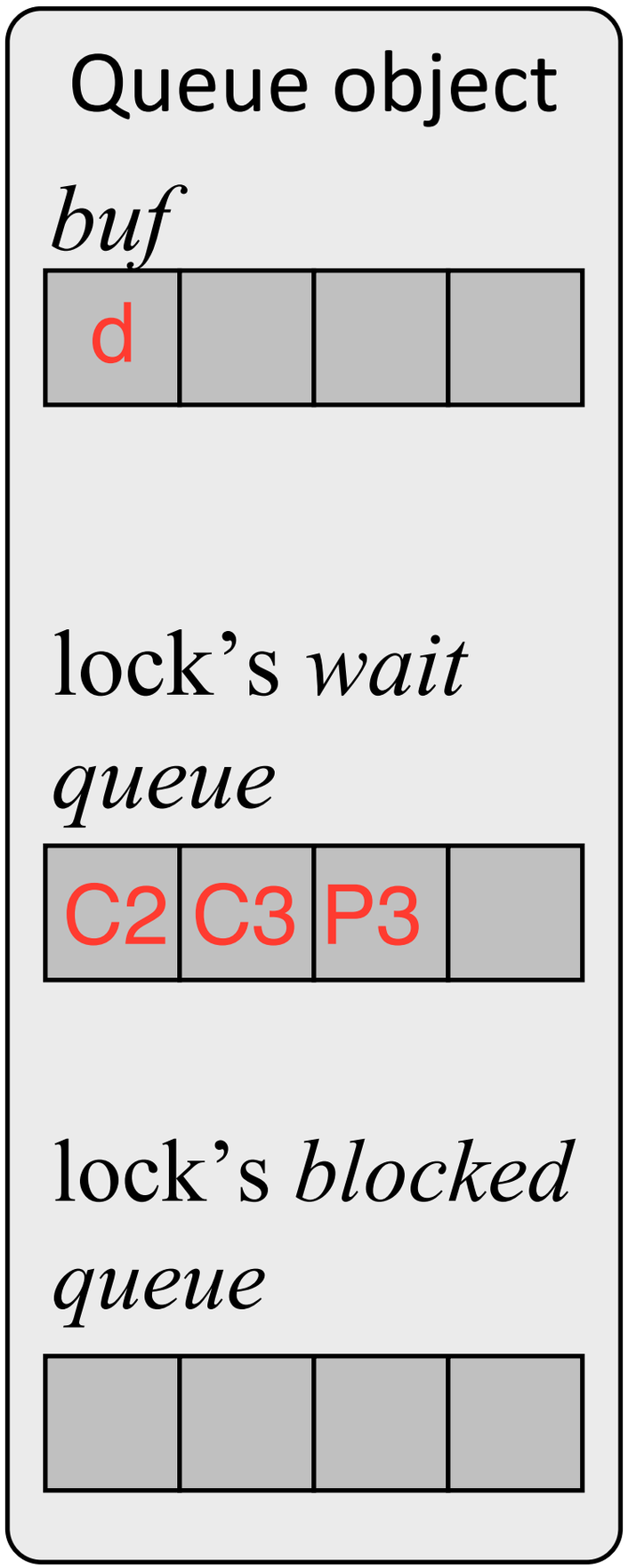


6. The following happen at time step 6.

   a. Now *P3*, *C2* and *C3* are all waiting!

   b. *P2* acquires the lock, puts a "*d*" in the buffer, calls *notify* and exits the method

Show the status of *buf*, lock's *wait queue* and lock's *blocked queue.*



7. The following happens at time step 7.

   a. *P2*'s notification wakes up *P3* (any thread can be woken up)

   b. *P3* checks the wait loop condition. There is already a character ("*d*") in the buffer and so it waits.

Show the status of *buf*, lock's *wait queue* and lock's *blocked queue.*

Is it possible for any thread to be woken up by another notify? It is not possible with the threads that are in the lock's wait queue. A new thread would have to be added which would then call notify() P3.

What would have happened if in 6b a notifyAll( ) was called? It will release the 3 threads that are waiting.

The correct code. Always use *notifyAll* unless there is a good reason not to.

```
public synchronized void put(Object o) {
    while (buf.size()==MAX_SIZE) {
        wait(); // called if the buffer is full (try/catch removed
                // for brevity)
    }
    buf.add(o);
    notifyAll(); // called in case any getters or putters waiting
}
```

```
public synchronized Object get() {
    // Y: this is where C2 tries to acquire the lock (i.e. at the
    // beginning of the method)
    while (buf.size()==0) {
        wait(); // called if the buffer is empty (try/catch removed
                // for brevity)
        // X: this is where C1 tries to re-acquire the lock (see below)
    }
    Object o = buf.remove(0);
    notifyAll(); // called in case any getters or putters waiting
    return o;
}
```