**Lab 5 - Chris Park**

**Problem 1 Output:**

```
desolis@blues:~/Dropbox/Ubuntu Transfer/Operating Systems/Lab5$ ./a.out
goodbye from thread 6
hello from thread 5
goodbye from thread 4
hello from thread 3
goodbye from thread 2
hello from thread 1
desolis@blues:~/Dropbox/Ubuntu Transfer/Operating Systems/Lab5$ ./a.out
goodbye from thread 6
hello from thread 5
goodbye from thread 4
hello from thread 3
goodbye from thread 2
hello from thread 1
desolis@blues:~/Dropbox/Ubuntu Transfer/Operating Systems/Lab5$ ./a.out
goodbye from thread 4
goodbye from thread 6
hello from thread 5
hello from thread 3
goodbye from thread 2
hello from thread 1
desolis@blues:~/Dropbox/Ubuntu Transfer/Operating Systems/Lab5$ ./a.out
hello from thread 5
goodbye from thread 4
goodbye from thread 6
hello from thread 3
goodbye from thread 2
hello from thread 1
desolis@blues:~/Dropbox/Ubuntu Transfer/Operating Systems/Lab5$
```

**Problem 2 Output & Answers:**

```
desolis@blues:~/Dropbox/Ubuntu Transfer/Operating Systems/Lab5$ ./a.out 10 5thread 0 is filling
array element 0 with 100
thread 1 is filling array element 1 with 101
thread 2 is filling array element 2 with 102
thread 3 is filling array element 3 with 103
thread 4 is filling array element 4 with 104
thread 0 is filling array element 5 with 105
thread 1 is filling array element 6 with 106
thread 2 is filling array element 7 with 107
thread 3 is filling array element 8 with 108
thread 4 is filling array element 9 with 109
desolis@blues:~/Dropbox/Ubuntu Transfer/Operating Systems/Lab5$
```

a) this value is a pointer to a buffer used for the created thread, and stores the thread ID. This is used for subsequent calls that refer to the thread.
b) pthread_join waits for the thread given as an argument to terminate, and cleans up resources used by the thread. This can lead to undefined behavior if multiple threads try to join simultaneously.

c) It is not required if you do not intend for the thread to terminate. If this is the case, then clean up is handles by the OS itself, which is probably a poor idea unless a situation specifically calls for the thread to continue and not rejoin. Perhaps running the thread detached would be the best choice in such a situation.

d) The tid represents a pointer to the buffer in use by the pthread with that ID.

e) I suppose you could pass any tid, so long as that thread actually exists. If it doesn't then it would try to access random memory and would likely segfault.

**Problem 3 Output & Answers:**

```
desolis@blues:~/Dropbox/Ubuntu Transfer/Operating Systems/Lab5$ ./a.out
producer locking critical region
producer producing 0
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing 1
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing 2
buffer not empty, producer sleeping
consumer locking critical region
consumer consuming 1
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing 3
buffer not empty, producer sleeping
consumer consuming 2
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing 4
buffer not empty, producer sleeping
consumer consuming 3
```

consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing 5
buffer not empty, producer sleeping
consumer consuming 4
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing 6
buffer not empty, producer sleeping
consumer consuming 5
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing 7
buffer not empty, producer sleeping

**Q) In your own words, explain what pthread_cond_wait does.**

pthread_condition_wait tells a calling thread to go to sleep dependent on a condition variable, and releases a mutex, which must be locked prior to eh wait call, to let other processes continue. The thread remains asleep until a signal call to the state of the condition variable is sent.

A) The first parameter is the same as the process to be slept. If it were the reverse the producer would be locking down the consumer and vice versa, which will result in a deadlock.

**Problem 4 Output & Answers:**

desolis@blues:~/Dropbox/Ubuntu Transfer/Operating Systems/Lab5$ ./a.out
consumer locking critical region
consumer consuming 1
buffer is empty, consumer sleeping
producer locking critical region
producer producing 0
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
buffer is empty, consumer sleeping

producer producing 1
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming 2
buffer is empty, consumer sleeping
producer producing 2
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming 3
buffer is empty, consumer sleeping
producer producing 3
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming 4
buffer is empty, consumer sleeping
producer producing 4
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming 5
buffer is empty, consumer sleeping
producer producing 5
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming 6
buffer is empty, consumer sleeping

**Q) Did switching those two lines make a difference?**

A) In problem 3 the producer only ever wakes up and produces one number at a time, and the consumer

never sleeps, it just waits for a lock on its critical region and consumes another, this always leaves the consumer a step behind the producer. By having the consumer run first in this problem, it immediately sleeps after consuming the only number in the buffer. This puts the producer and the consumer in a alternating operation, with the producer producer one number, and sleeping long enough for the consumer to wake up and consume that number and return to sleep again. If the joins are switched it results in the consumer having the same behavior as the producer in the previous problem. It only ever wakes up to consume one number at a time, while the producer never sleeps. It appears that the initally created thread never sleeps because the second thread is always joined before the initial. Putting it in a kind of closed loop.

**Problem 5 Output:**

```
consumer consuming element 0
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
buffer is empty, consumer sleeping
producer producing element 0
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 1
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 2
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 3
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 4
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 5
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 6
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 7
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
```

consumer consuming element 8
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 7
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 6
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 5
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 4
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 3
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 2
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 1
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 0
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
buffer is empty, consumer sleeping
producer producing element 0
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 1
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 2
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region

producer producing element 3
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 4
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 5
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 6
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 7
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 8
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 9
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 10
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 11
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 12
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 13
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 14
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 15

producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 16
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 17
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 18
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
consumer consuming element 19
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 18
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 17
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 16
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 15
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 14
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 13
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 12
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 11
consumer signaling producer to wake up

consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 10
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 9
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 8
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 7
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 6
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 5
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 4
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 3
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 2
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 1
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
consumer consuming element 0
consumer signaling producer to wake up
consumer releasing lock on critical region
consumer locking critical region
buffer is empty, consumer sleeping
producer producing element 0
producer signaling consumer to wake up

producer releasing lock on critical region
producer locking critical region
producer producing element 1
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 2
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 3
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 4
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 5
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 6
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 7
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 8
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 9
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 10
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 11
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 12
producer signaling consumer to wake up
producer releasing lock on critical region

producer locking critical region
producer producing element 13
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 14
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 15
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 16
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 17
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 18
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 19
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 20
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 21
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 22
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 23
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 24
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region

producer producing element 25
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 26
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 27
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 28
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 29
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 30
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 31
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 32
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 33
producer signaling consumer to wake up
producer releasing lock on critical region
producer locking critical region
producer producing element 34
producer signaling consumer to wake up
producer releasing lock on critical region

**Problem 6 Output & Answers:**

consumer consuming element 100
consumer signaling producer(s) to wake up
consumer releasing lock on critical region
producer2 producing element 99
producer2 signaling consumer to wake up
producer2 releasing lock on critical region
producer2 locking critical region

buffer not empty, producer2 sleeping
buffer not empty, producer sleeping
consumer locking critical region
consumer consuming element 100
consumer signaling producer(s) to wake up
consumer releasing lock on critical region
producer producing element 99
producer signaling consumer to wake up
producer releasing lock on critical region
buffer not empty, producer2 sleeping
producer locking critical region
buffer not empty, producer sleeping
consumer locking critical region
consumer consuming element 100
consumer signaling producer(s) to wake up
consumer releasing lock on critical region
producer producing element 99
producer signaling consumer to wake up
producer releasing lock on critical region
buffer not empty, producer2 sleeping
producer locking critical region
buffer not empty, producer sleeping
consumer locking critical region
consumer consuming element 100
consumer signaling producer(s) to wake up
consumer releasing lock on critical region
producer2 producing element 99
producer2 signaling consumer to wake up
producer2 releasing lock on critical region
producer2 locking critical region
buffer not empty, producer2 sleeping
buffer not empty, producer sleeping
consumer locking critical region
consumer consuming element 100
consumer signaling producer(s) to wake up
consumer releasing lock on critical region
producer producing element 99
producer signaling consumer to wake up
producer releasing lock on critical region
buffer not empty, producer2 sleeping
producer locking critical region
buffer not empty, producer sleeping
consumer locking critical region
consumer consuming element 100
consumer signaling producer(s) to wake up
consumer releasing lock on critical region
producer producing element 99
producer signaling consumer to wake up
producer releasing lock on critical region

buffer not empty, producer2 sleeping
producer locking critical region
buffer not empty, producer sleeping
consumer locking critical region
consumer consuming element 100
consumer signaling producer(s) to wake up
consumer releasing lock on critical region
producer2 producing element 99
producer2 signaling consumer to wake up
producer2 releasing lock on critical region
producer2 locking critical region
buffer not empty, producer2 sleeping
buffer not empty, producer sleeping
consumer locking critical region
consumer consuming element 100
consumer signaling producer(s) to wake up
consumer releasing lock on critical region
producer producing element 99
producer signaling consumer to wake up
producer releasing lock on critical region
buffer not empty, producer2 sleeping
producer locking critical region
buffer not empty, producer sleeping
consumer locking critical region
consumer consuming element 100
consumer signaling producer(s) to wake up
consumer releasing lock on critical region
producer producing element 99
producer signaling consumer to wake up
producer releasing lock on critical region
buffer not empty, producer2 sleeping
producer locking critical region
buffer not empty, producer sleeping
consumer locking critical region
consumer consuming element 100
consumer signaling producer(s) to wake up
consumer releasing lock on critical region

**Q) Comment on behavior. Was it expected? Where there problems? Could the consumer keep up?**

For the most part the behavior of the output is what I expected to be. I didn't have any problems adding the code for the second producer. I just added new function calls and variables for the new producer. I'm not sure if the order of creation/join on the threads has any effect here. The producers definitely overpowers the consumer in this problem. They ended up spending most of their time sleeping as they filled the buffer quickly and kept it there. A strange printing, most likely from a variable that is off in counting shows up. Where the consumer consumes element 100. There is no element 100 in the array. It should have stopped at 99.