

Bryan Arnold

CSE 4300

3/23/18

Programming Assignment 2

## PART 1

This is the first part of the assignment with currentID. Here is the output:

```
Not my turn!
Not my turn!
Not my turn!
My turn!
Thread ID 1 printCount: 1
Not my turn!
Not my turn!
Not my turn!
My turn!
Thread ID 2 printCount: 1
Not my turn!
Not my turn!
Not my turn!
My turn!
Thread ID 3 printCount: 1
Not my turn!
Not my turn!
Not my turn!
My turn!
Thread ID 4 printCount: 1
Not my turn!
Not my turn!
Not my turn!
My turn!
Thread ID 1 printCount: 2
Not my turn!
Not my turn!
Not my turn!
My turn!
Thread ID 2 printCount: 2
Not my turn!
Not my turn!
Not my turn!
My turn!
Thread ID 3 printCount: 2
Not my turn!
Not my turn!
Not my turn!
```

My turn!  
Thread ID 4 printCount: 2  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Thread ID 1 printCount: 3  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Thread ID 2 printCount: 3  
Not my turn!  
Not my turn!  
My turn!  
Thread ID 3 printCount: 3  
Not my turn!  
My turn!  
Thread ID 4 printCount: 3  
Not my turn!  
Not my turn!  
My turn!  
Thread ID 1 printCount: 4  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Thread ID 2 printCount: 4  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Thread ID 3 printCount: 4  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Thread ID 4 printCount: 4  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Thread ID 1 printCount: 5  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Thread ID 2 printCount: 5  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!

Thread ID 3 printCount: 5  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Thread ID 4 printCount: 5  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Thread ID 1 printCount: 6  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Thread ID 2 printCount: 6  
Not my turn!  
Not my turn!  
My turn!  
Thread ID 3 printCount: 6  
Not my turn!  
My turn!  
Thread ID 4 printCount: 6  
Not my turn!  
Not my turn!  
My turn!  
Thread ID 1 printCount: 7  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Thread ID 2 printCount: 7  
Not my turn!  
Not my turn!  
My turn!  
Thread ID 3 printCount: 7  
Not my turn!  
My turn!  
Thread ID 4 printCount: 7  
Not my turn!  
Not my turn!  
My turn!  
Thread ID 1 printCount: 8  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Thread ID 2 printCount: 8  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!

```
Thread ID 3 printCount: 8
Not my turn!
Not my turn!
Not my turn!
Not my turn!
My turn!
Thread ID 4 printCount: 8
Not my turn!
Not my turn!
My turn!
Thread ID 1 printCount: 9
Not my turn!
Not my turn!
Not my turn!
My turn!
Thread ID 2 printCount: 9
Not my turn!
Not my turn!
Not my turn!
My turn!
Thread ID 3 printCount: 9
Not my turn!
Not my turn!
Not my turn!
Not my turn!
My turn!
Thread ID 4 printCount: 9
Not my turn!
Not my turn!
My turn!
Thread ID 1 printCount: 10
Not my turn!
Not my turn!
Not my turn!
My turn!
Thread ID 2 printCount: 10
Not my turn!
My turn!
Thread ID 3 printCount: 10
Not my turn!
My turn!
Thread ID 4 printCount: 10
Not my turn!
Thread number 1 printed 'Not my turn!' 25 times
Thread number 2 printed 'Not my turn!' 26 times
Thread number 3 printed 'Not my turn!' 27 times
Thread number 4 printed 'Not my turn!' 27 times
```

**This output is to display that each ID printed ‘My turn!’ 10 times. As indicated above, you can clearly see this is true.**

Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
My turn!

Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!  
My turn!  
Not my turn!  
Not my turn!

```
My turn!
Not my turn!
Not my turn!
Not my turn!
My turn!
Not my turn!
Not my turn!
My turn!
Not my turn!
My turn!
Not my turn!
Not my turn!
My turn!
Not my turn!
Not my turn!
Not my turn!
My turn!
Not my turn!
My turn!
Not my turn!
My turn!
Not my turn!
Thread number 1 printed 'Not my turn!' 20 times
Thread number 2 printed 'Not my turn!' 21 times
Thread number 3 printed 'Not my turn!' 22 times
Thread number 4 printed 'Not my turn!' 22 times
```

The number of times the ‘Not my turn!’ printed varied due to the fact the threads could arrive in an arbitrary order to the lock. Therefore, it varied from time to time. This is what the program looks like in default.

## SOURCE CODE PART 1

```
/*
 * Bryan Arnold *
 * CSE 4300 *
 * 3/23/18 *
 * Assignment2 *
 */

//PART 1 OF THE ASSIGNMENT

#include <stdio.h>
#include <stdlib.h>
#include <pthread.h>
#include <time.h>
```

```

int printCount[] = {0, 0, 0, 0}; //keep track of how many times each
thread's turn happens
int printCountFalse[] = {0, 0, 0, 0}; //keep track of how many times
each thread's turn doesn't happen
int currentID = 1; //currentID
pthread_mutex_t lock = PTHREAD_MUTEX_INITIALIZER; //lock mutex with
default initialization

void *run(void *arg); //Protoype header for the run function

// run Function
// This function is responsible for carrying out what each
// thread will be doing concurrently. Each thread is given an
// ID, and checks whether the gloab variable currentID is the same.
// If it is, print 'My turn!', increment the currentID by 1, then
check
// if the currentID > 4 and reset to 1 if so. If the currentID doesn't
// match the thread ID, print 'Not my turn!'. When each thread has
been printed
// 'My turn!' 10 times, quit the program.
void *run(void *arg){

    int threadID = (int)arg; //Thread ID for each thread passed as
arguments

    while(1){

        pthread_mutex_lock(&lock); //lock the data from other
threads accessing it

        if(threadID == currentID){ //If thread Id matches Current
ID

            printf("My turn!\n");
            currentID++;
            printCount[threadID - 1]++;
            //printf("Thread ID %d printCount: %d\n", threadID,
printCount[threadID - 1]);

            if(currentID > 4){ //If currentID > 4

                currentID = 1;

            }

        }

        pthread_mutex_unlock(&lock); //release data to other
threads

```



```

        if(threadID != currentID){ //if thread ID doesn't match
currentID

                printf("Not my turn!\n");
                printCountFalse[threadID - 1]++;
                usleep(1);

        }

        if(printCount[threadID - 1] == 10){ //If all threads have
matched the ID 10 times

                break;

        }

    }

    return arg; //exit run
}

// Main Function
// This is where the program will run.
// It creates the threads, pointer for return,
// and any integer tracker value variables.
// The threads are created, returned into the pointer,
// then the number of times each thread printed
// 'Not my turn!' are displayed.
int main(){

    //Threads, variables for tracking, etc.
    pthread_t t[4];
    void* ptr;
    int i;
    int id = 1;
    int checker = 1;

    for(i = 0; i < 4; i++){ //Create 4 threads and make them run the
run function

        checker = pthread_create(&t[i], NULL, run, (void *)id);

        if(checker != 0){

            printf("Error creating thread\n");
            exit(1);

        }

    }

```

```

        id++;

    }

    for(i = 0; i < 4; i++){ //Wait for all threads to finish

        pthread_join(t[i], &ptr);

    }

    for(i = 0; i < 4; i++){ //Display how many times 'Not my turn!'
printed
        printf("Thread number %d printed 'Not my turn!' %d
times\n", i + 1, printCountFalse[i]);

    }

    return 0; //exit program
}

```

## PART 2

This is the second part of the assignment with the producer consumer problem. Here is the output for the queue size being 5:

```

Producer number 2 produced item number: 1
Producer number 1 produced item number: 1
Consumer number 1 consumed item number: 1
Consumer number 2 consumed item number: 1
Producer number 1 produced item number: 2
Producer number 2 produced item number: 2
Consumer number 1 consumed item number: 2
Producer number 1 produced item number: 3
Consumer number 2 consumed item number: 3
Producer number 2 produced item number: 3
Producer number 1 produced item number: 4
Consumer number 1 consumed item number: 4
Consumer number 2 consumed item number: 3
Producer number 2 produced item number: 4
Producer number 1 produced item number: 5
Consumer number 1 consumed item number: 5
Producer number 1 produced item number: 6
Producer number 2 produced item number: 5
Consumer number 2 consumed item number: 5
Producer number 1 produced item number: 7
Producer number 2 produced item number: 6
Producer number 2 produced item number: 7

```

Consumer number 2 consumed item number: 7  
Consumer number 1 consumed item number: 6  
Producer number 1 produced item number: 8  
Producer number 2 produced item number: 8  
Producer number 2 produced item number: 9  
Consumer number 2 consumed item number: 9  
Consumer number 1 consumed item number: 8  
Producer number 1 produced item number: 9  
Producer number 2 produced item number: 10  
Producer number 1 produced item number: 10  
Consumer number 2 consumed item number: 10  
Consumer number 1 consumed item number: 10  
Producer number 2 produced item number: 11  
Producer number 1 produced item number: 11  
Producer number 2 produced item number: 12  
Consumer number 2 consumed item number: 12  
Producer number 1 produced item number: 12  
Producer number 2 produced item number: 13  
Consumer number 1 consumed item number: 13  
Producer number 1 produced item number: 13  
Consumer number 2 consumed item number: 13  
Producer number 1 produced item number: 14  
Consumer number 1 consumed item number: 14  
Producer number 2 produced item number: 14  
Consumer number 1 consumed item number: 14  
Producer number 1 produced item number: 15  
Consumer number 2 consumed item number: 15  
Producer number 2 produced item number: 15  
Consumer number 2 consumed item number: 15  
Producer number 1 produced item number: 16  
Consumer number 1 consumed item number: 16  
Producer number 2 produced item number: 16  
Consumer number 1 consumed item number: 16  
Producer number 1 produced item number: 17  
Consumer number 2 consumed item number: 17  
Producer number 2 produced item number: 17  
Consumer number 1 consumed item number: 17  
Producer number 1 produced item number: 18  
Consumer number 2 consumed item number: 18  
Producer number 2 produced item number: 18  
Consumer number 2 consumed item number: 18  
Producer number 1 produced item number: 19  
Consumer number 1 consumed item number: 19  
Producer number 2 produced item number: 19  
Consumer number 2 consumed item number: 19  
Producer number 1 produced item number: 20  
Consumer number 1 consumed item number: 20  
Producer number 2 produced item number: 20  
Consumer number 2 consumed item number: 20  
Producer number 1 produced item number: 21  
Consumer number 1 consumed item number: 21  
Producer number 2 produced item number: 21

Consumer number 1 consumed item number: 21  
Producer number 1 produced item number: 22  
Consumer number 2 consumed item number: 22  
Producer number 2 produced item number: 22  
Consumer number 1 consumed item number: 22  
Producer number 1 produced item number: 23  
Consumer number 2 consumed item number: 23  
Producer number 2 produced item number: 23  
Consumer number 1 consumed item number: 23  
Producer number 2 produced item number: 24  
Consumer number 2 consumed item number: 24  
Producer number 1 produced item number: 24  
Consumer number 1 consumed item number: 24  
Producer number 2 produced item number: 25  
Consumer number 2 consumed item number: 25  
Producer number 1 produced item number: 25  
Consumer number 1 consumed item number: 25  
Producer number 2 produced item number: 26  
Consumer number 2 consumed item number: 26  
Producer number 1 produced item number: 26  
Consumer number 1 consumed item number: 26  
Producer number 2 produced item number: 27  
Consumer number 2 consumed item number: 27  
Producer number 1 produced item number: 27  
Consumer number 1 consumed item number: 27  
Producer number 1 produced item number: 28  
Consumer number 2 consumed item number: 28  
Producer number 2 produced item number: 28  
Consumer number 2 consumed item number: 28  
Producer number 1 produced item number: 29  
Consumer number 1 consumed item number: 29  
Producer number 2 produced item number: 29  
Consumer number 2 consumed item number: 29  
Producer number 1 produced item number: 30  
Consumer number 1 consumed item number: 30  
Producer number 2 produced item number: 30  
Consumer number 2 consumed item number: 30  
Producer number 1 produced item number: 31  
Consumer number 1 consumed item number: 31  
Producer number 2 produced item number: 31  
Consumer number 2 consumed item number: 31  
Producer number 1 produced item number: 32  
Consumer number 1 consumed item number: 32  
Producer number 2 produced item number: 32  
Consumer number 2 consumed item number: 32  
Producer number 1 produced item number: 33  
Consumer number 1 consumed item number: 33  
Producer number 2 produced item number: 33  
Consumer number 2 consumed item number: 33  
Producer number 1 produced item number: 34  
Consumer number 1 consumed item number: 34  
Producer number 1 produced item number: 35

Consumer number 2 consumed item number: 35  
Producer number 2 produced item number: 34  
Consumer number 2 consumed item number: 34  
Producer number 1 produced item number: 36  
Consumer number 1 consumed item number: 36  
Producer number 2 produced item number: 35  
Consumer number 1 consumed item number: 35  
Producer number 1 produced item number: 37  
Consumer number 2 consumed item number: 37  
Producer number 2 produced item number: 36  
Consumer number 1 consumed item number: 36  
Producer number 1 produced item number: 38  
Consumer number 2 consumed item number: 38  
Producer number 2 produced item number: 37  
Consumer number 1 consumed item number: 37  
Consumer number 2 consumed item number: 12  
Producer number 2 produced item number: 38  
Producer number 1 produced item number: 39  
Consumer number 1 consumed item number: 39  
Consumer number 2 consumed item number: 38  
Producer number 2 produced item number: 39  
Producer number 1 produced item number: 40  
Consumer number 1 consumed item number: 40  
Producer number 2 produced item number: 40  
Consumer number 2 consumed item number: 40  
Producer number 1 produced item number: 41  
Consumer number 1 consumed item number: 41  
Producer number 2 produced item number: 41  
Consumer number 1 consumed item number: 41  
Producer number 1 produced item number: 42  
Consumer number 2 consumed item number: 42  
Producer number 2 produced item number: 42  
Consumer number 1 consumed item number: 42  
Producer number 1 produced item number: 43  
Consumer number 2 consumed item number: 43  
Producer number 2 produced item number: 43  
Consumer number 1 consumed item number: 43  
Producer number 1 produced item number: 44  
Consumer number 1 consumed item number: 44  
Producer number 2 produced item number: 44  
Consumer number 2 consumed item number: 44  
Producer number 1 produced item number: 45  
Consumer number 2 consumed item number: 45  
Producer number 2 produced item number: 45  
Consumer number 1 consumed item number: 45  
Producer number 1 produced item number: 46  
Consumer number 2 consumed item number: 46  
Producer number 1 produced item number: 47  
Consumer number 1 consumed item number: 47  
Producer number 2 produced item number: 46  
Consumer number 2 consumed item number: 46  
Producer number 1 produced item number: 48

Consumer number 2 consumed item number: 48  
Producer number 2 produced item number: 47  
Consumer number 1 consumed item number: 47  
Producer number 1 produced item number: 49  
Consumer number 2 consumed item number: 49  
Producer number 2 produced item number: 48  
Consumer number 1 consumed item number: 48  
Producer number 1 produced item number: 50  
Consumer number 1 consumed item number: 50  
Producer number 2 produced item number: 49  
Consumer number 2 consumed item number: 49  
Producer number 1 produced item number: 51  
Consumer number 1 consumed item number: 51  
Producer number 2 produced item number: 50  
Consumer number 2 consumed item number: 50  
Producer number 1 produced item number: 52  
Consumer number 1 consumed item number: 52  
Producer number 2 produced item number: 51  
Consumer number 2 consumed item number: 51  
Producer number 1 produced item number: 53  
Consumer number 1 consumed item number: 53  
Producer number 2 produced item number: 52  
Consumer number 2 consumed item number: 52  
Producer number 1 produced item number: 54  
Consumer number 1 consumed item number: 54  
Producer number 2 produced item number: 53  
Consumer number 1 consumed item number: 53  
Producer number 1 produced item number: 55  
Consumer number 2 consumed item number: 55  
Producer number 2 produced item number: 54  
Consumer number 1 consumed item number: 54  
Producer number 1 produced item number: 56  
Consumer number 2 consumed item number: 56  
Producer number 2 produced item number: 55  
Consumer number 1 consumed item number: 55  
Producer number 1 produced item number: 57  
Consumer number 2 consumed item number: 57  
Producer number 2 produced item number: 56  
Consumer number 1 consumed item number: 56  
Producer number 1 produced item number: 58  
Consumer number 2 consumed item number: 58  
Producer number 2 produced item number: 57  
Consumer number 1 consumed item number: 57  
Producer number 1 produced item number: 59  
Consumer number 2 consumed item number: 59  
Producer number 2 produced item number: 58  
Consumer number 1 consumed item number: 58  
Producer number 1 produced item number: 60  
Consumer number 2 consumed item number: 60  
Producer number 2 produced item number: 59  
Consumer number 1 consumed item number: 59  
Producer number 1 produced item number: 61

```
Consumer number 1 consumed item number: 61
Producer number 2 produced item number: 60
Consumer number 2 consumed item number: 60
Producer number 1 produced item number: 62
Consumer number 1 consumed item number: 62
Producer number 2 produced item number: 61
Consumer number 2 consumed item number: 61
Producer number 2 produced item number: 62
Consumer number 1 consumed item number: 62
Producer number 1 produced item number: 63
Consumer number 2 consumed item number: 63
Producer number 2 produced item number: 63
Consumer number 1 consumed item number: 63
Producer number 1 produced item number: 64
Consumer number 2 consumed item number: 64
Producer number 2 produced item number: 64
Consumer number 1 consumed item number: 64
Producer number 1 produced item number: 65
Consumer number 2 consumed item number: 65
Producer number 2 produced item number: 65
Consumer number 2 consumed item number: 65
Producer number 2 produced item number: 66
Number of times producers put to sleep: 126
Number of times consumers put to sleep: 121
```

The number of producers is closest to consumers here, as the queue size cannot store that many before they are consumed. Next, the output for the queue size 15, then 30.

```
Producer number 2 produced item number: 1
Producer number 1 produced item number: 1
Consumer number 1 consumed item number: 1
Consumer number 2 consumed item number: 1
Producer number 1 produced item number: 2
Producer number 2 produced item number: 2
Consumer number 1 consumed item number: 2
Producer number 1 produced item number: 3
Consumer number 2 consumed item number: 3
Producer number 2 produced item number: 3
Producer number 1 produced item number: 4
Consumer number 1 consumed item number: 4
Consumer number 2 consumed item number: 3
Producer number 2 produced item number: 4
Producer number 1 produced item number: 5
Producer number 2 produced item number: 5
Consumer number 1 consumed item number: 5
Producer number 1 produced item number: 6
Consumer number 2 consumed item number: 6
Producer number 1 produced item number: 7
Producer number 2 produced item number: 6
Consumer number 1 consumed item number: 6
```

Consumer number 2 consumed item number: 7  
Producer number 2 produced item number: 7  
Producer number 1 produced item number: 8  
Producer number 2 produced item number: 8  
Consumer number 1 consumed item number: 8  
Consumer number 2 consumed item number: 8  
Producer number 2 produced item number: 9  
Producer number 1 produced item number: 9  
Consumer number 1 consumed item number: 9  
Producer number 2 produced item number: 10  
Producer number 1 produced item number: 10  
Consumer number 2 consumed item number: 10  
Producer number 2 produced item number: 11  
Producer number 1 produced item number: 11  
Consumer number 1 consumed item number: 11  
Producer number 2 produced item number: 12  
Producer number 1 produced item number: 12  
Consumer number 2 consumed item number: 12  
Producer number 2 produced item number: 13  
Producer number 1 produced item number: 13  
Consumer number 1 consumed item number: 13  
Producer number 2 produced item number: 14  
Producer number 1 produced item number: 14  
Producer number 1 produced item number: 15  
Consumer number 2 consumed item number: 15  
Producer number 2 produced item number: 15  
Consumer number 1 consumed item number: 15  
Producer number 2 produced item number: 16  
Producer number 1 produced item number: 16  
Consumer number 2 consumed item number: 16  
Consumer number 1 consumed item number: 16  
Producer number 2 produced item number: 17  
Producer number 2 produced item number: 18  
Producer number 1 produced item number: 17  
Consumer number 2 consumed item number: 17  
Consumer number 1 consumed item number: 18  
Producer number 2 produced item number: 19  
Producer number 1 produced item number: 18  
Consumer number 2 consumed item number: 18  
Producer number 2 produced item number: 20  
Producer number 1 produced item number: 19  
Consumer number 2 consumed item number: 19  
Producer number 1 produced item number: 20  
Consumer number 1 consumed item number: 20  
Producer number 2 produced item number: 21  
Consumer number 2 consumed item number: 21  
Producer number 1 produced item number: 21  
Consumer number 1 consumed item number: 21  
Producer number 2 produced item number: 22  
Consumer number 2 consumed item number: 22  
Producer number 1 produced item number: 22  
Consumer number 1 consumed item number: 22



Producer number 2 produced item number: 23  
Consumer number 2 consumed item number: 23  
Producer number 1 produced item number: 23  
Consumer number 1 consumed item number: 23  
Producer number 2 produced item number: 24  
Consumer number 2 consumed item number: 24  
Producer number 1 produced item number: 24  
Consumer number 1 consumed item number: 24  
Producer number 2 produced item number: 25  
Consumer number 2 consumed item number: 25  
Producer number 1 produced item number: 25  
Consumer number 1 consumed item number: 25  
Producer number 2 produced item number: 26  
Consumer number 2 consumed item number: 26  
Producer number 1 produced item number: 26  
Consumer number 1 consumed item number: 26  
Producer number 2 produced item number: 27  
Consumer number 2 consumed item number: 27  
Producer number 1 produced item number: 27  
Consumer number 1 consumed item number: 27  
Producer number 2 produced item number: 28  
Consumer number 2 consumed item number: 28  
Producer number 1 produced item number: 28  
Consumer number 1 consumed item number: 28  
Producer number 2 produced item number: 29  
Consumer number 2 consumed item number: 29  
Producer number 1 produced item number: 29  
Consumer number 1 consumed item number: 29  
Producer number 1 produced item number: 30  
Consumer number 2 consumed item number: 30  
Producer number 2 produced item number: 30  
Consumer number 1 consumed item number: 30  
Producer number 1 produced item number: 31  
Consumer number 2 consumed item number: 31  
Consumer number 1 consumed item number: 20  
Producer number 1 produced item number: 32  
Producer number 2 produced item number: 31  
Consumer number 2 consumed item number: 31  
Producer number 1 produced item number: 33  
Consumer number 1 consumed item number: 33  
Producer number 2 produced item number: 32  
Consumer number 2 consumed item number: 32  
Producer number 2 produced item number: 33  
Consumer number 1 consumed item number: 33  
Producer number 1 produced item number: 34  
Consumer number 1 consumed item number: 34  
Producer number 2 produced item number: 34  
Consumer number 2 consumed item number: 34  
Producer number 1 produced item number: 35  
Consumer number 1 consumed item number: 35  
Producer number 1 produced item number: 36  
Consumer number 2 consumed item number: 36

Producer number 2 produced item number: 35  
Consumer number 1 consumed item number: 35  
Producer number 1 produced item number: 37  
Consumer number 2 consumed item number: 37  
Producer number 2 produced item number: 36  
Consumer number 1 consumed item number: 36  
Producer number 1 produced item number: 38  
Consumer number 2 consumed item number: 38  
Producer number 2 produced item number: 37  
Consumer number 1 consumed item number: 37  
Producer number 1 produced item number: 39  
Consumer number 2 consumed item number: 39  
Producer number 2 produced item number: 38  
Consumer number 1 consumed item number: 38  
Producer number 1 produced item number: 40  
Consumer number 2 consumed item number: 40  
Producer number 2 produced item number: 39  
Consumer number 1 consumed item number: 39  
Producer number 1 produced item number: 41  
Consumer number 2 consumed item number: 41  
Producer number 2 produced item number: 40  
Consumer number 1 consumed item number: 40  
Producer number 1 produced item number: 42  
Consumer number 2 consumed item number: 42  
Producer number 2 produced item number: 41  
Consumer number 1 consumed item number: 41  
Producer number 1 produced item number: 43  
Consumer number 2 consumed item number: 43  
Producer number 1 produced item number: 44  
Consumer number 1 consumed item number: 44  
Producer number 2 produced item number: 42  
Consumer number 2 consumed item number: 42  
Producer number 1 produced item number: 45  
Consumer number 1 consumed item number: 45  
Producer number 2 produced item number: 43  
Consumer number 2 consumed item number: 43  
Producer number 1 produced item number: 46  
Consumer number 1 consumed item number: 46  
Producer number 2 produced item number: 44  
Consumer number 2 consumed item number: 44  
Producer number 1 produced item number: 47  
Consumer number 1 consumed item number: 47  
Consumer number 2 consumed item number: 32  
Producer number 2 produced item number: 45  
Producer number 1 produced item number: 48  
Consumer number 1 consumed item number: 48  
Consumer number 2 consumed item number: 45  
Producer number 1 produced item number: 49  
Consumer number 1 consumed item number: 49  
Producer number 2 produced item number: 46  
Producer number 1 produced item number: 50  
Consumer number 2 consumed item number: 50

Producer number 2 produced item number: 47  
Consumer number 1 consumed item number: 47  
Producer number 1 produced item number: 51  
Consumer number 1 consumed item number: 51  
Producer number 2 produced item number: 48  
Consumer number 2 consumed item number: 48  
Producer number 1 produced item number: 52  
Consumer number 1 consumed item number: 52  
Producer number 1 produced item number: 53  
Consumer number 2 consumed item number: 53  
Producer number 2 produced item number: 49  
Consumer number 2 consumed item number: 49  
Producer number 1 produced item number: 54  
Consumer number 1 consumed item number: 54  
Producer number 2 produced item number: 50  
Consumer number 2 consumed item number: 50  
Producer number 1 produced item number: 55  
Consumer number 1 consumed item number: 55  
Producer number 2 produced item number: 51  
Consumer number 2 consumed item number: 51  
Producer number 1 produced item number: 56  
Consumer number 1 consumed item number: 56  
Producer number 2 produced item number: 52  
Consumer number 2 consumed item number: 52  
Producer number 1 produced item number: 57  
Consumer number 1 consumed item number: 57  
Producer number 2 produced item number: 53  
Consumer number 2 consumed item number: 53  
Producer number 1 produced item number: 58  
Consumer number 1 consumed item number: 58  
Producer number 2 produced item number: 54  
Consumer number 2 consumed item number: 54  
Producer number 1 produced item number: 59  
Consumer number 1 consumed item number: 59  
Producer number 2 produced item number: 55  
Consumer number 2 consumed item number: 55  
Producer number 2 produced item number: 56  
Consumer number 1 consumed item number: 56  
Producer number 1 produced item number: 60  
Consumer number 2 consumed item number: 60  
Producer number 2 produced item number: 57  
Consumer number 1 consumed item number: 57  
Producer number 1 produced item number: 61  
Consumer number 2 consumed item number: 61  
Producer number 2 produced item number: 58  
Consumer number 1 consumed item number: 58  
Producer number 1 produced item number: 62  
Consumer number 2 consumed item number: 62  
Producer number 2 produced item number: 59  
Consumer number 1 consumed item number: 59  
Producer number 1 produced item number: 63  
Consumer number 2 consumed item number: 63

Producer number 2 produced item number: 60  
Consumer number 1 consumed item number: 60  
Producer number 1 produced item number: 64  
Consumer number 2 consumed item number: 64  
Producer number 2 produced item number: 61  
Consumer number 1 consumed item number: 61  
Producer number 1 produced item number: 65  
Consumer number 1 consumed item number: 65  
Producer number 2 produced item number: 62  
Consumer number 2 consumed item number: 62  
Producer number 1 produced item number: 66  
Consumer number 2 consumed item number: 66  
Producer number 2 produced item number: 63  
Consumer number 1 consumed item number: 63  
Producer number 1 produced item number: 67  
Consumer number 2 consumed item number: 67  
Producer number 1 produced item number: 68  
Consumer number 1 consumed item number: 68  
Producer number 2 produced item number: 64  
Consumer number 2 consumed item number: 64  
Producer number 2 produced item number: 65  
Consumer number 1 consumed item number: 65  
Producer number 1 produced item number: 69  
Consumer number 2 consumed item number: 69  
Producer number 2 produced item number: 66  
Consumer number 1 consumed item number: 66  
Producer number 1 produced item number: 70  
Number of times producers put to sleep: 148  
Number of times consumers put to sleep: 121

Producer number 2 produced item number: 1  
Consumer number 1 consumed item number: 1  
Producer number 1 produced item number: 1  
Consumer number 2 consumed item number: 1  
Producer number 1 produced item number: 2  
Producer number 2 produced item number: 2  
Consumer number 1 consumed item number: 2  
Producer number 1 produced item number: 3  
Consumer number 2 consumed item number: 3  
Producer number 2 produced item number: 3  
Producer number 1 produced item number: 4  
Consumer number 1 consumed item number: 4  
Consumer number 2 consumed item number: 3  
Producer number 2 produced item number: 4  
Producer number 1 produced item number: 5  
Consumer number 1 consumed item number: 5  
Producer number 2 produced item number: 5  
Producer number 1 produced item number: 6  
Consumer number 2 consumed item number: 6  
Producer number 2 produced item number: 6

Producer number 1 produced item number: 7  
Producer number 1 produced item number: 8  
Consumer number 2 consumed item number: 8  
Consumer number 1 consumed item number: 7  
Producer number 2 produced item number: 7  
Producer number 1 produced item number: 9  
Producer number 1 produced item number: 10  
Consumer number 2 consumed item number: 10  
Consumer number 1 consumed item number: 9  
Producer number 2 produced item number: 8  
Producer number 1 produced item number: 11  
Producer number 2 produced item number: 9  
Consumer number 2 consumed item number: 9  
Consumer number 1 consumed item number: 11  
Producer number 1 produced item number: 12  
Producer number 2 produced item number: 10  
Producer number 1 produced item number: 13  
Consumer number 2 consumed item number: 13  
Producer number 2 produced item number: 11  
Producer number 1 produced item number: 14  
Consumer number 1 consumed item number: 14  
Producer number 2 produced item number: 12  
Producer number 2 produced item number: 13  
Producer number 1 produced item number: 15  
Consumer number 2 consumed item number: 15  
Consumer number 1 consumed item number: 13  
Producer number 2 produced item number: 14  
Producer number 1 produced item number: 16  
Consumer number 2 consumed item number: 16  
Producer number 1 produced item number: 17  
Producer number 2 produced item number: 15  
Consumer number 1 consumed item number: 15  
Consumer number 2 consumed item number: 17  
Producer number 1 produced item number: 18  
Producer number 2 produced item number: 16  
Producer number 1 produced item number: 19  
Consumer number 1 consumed item number: 19  
Consumer number 2 consumed item number: 16  
Producer number 2 produced item number: 17  
Producer number 1 produced item number: 20  
Consumer number 1 consumed item number: 20  
Producer number 2 produced item number: 18  
Producer number 1 produced item number: 21  
Producer number 1 produced item number: 22  
Consumer number 2 consumed item number: 22  
Consumer number 1 consumed item number: 21  
Producer number 2 produced item number: 19  
Producer number 1 produced item number: 23  
Producer number 2 produced item number: 20  
Producer number 1 produced item number: 24  
Consumer number 2 consumed item number: 24  
Consumer number 1 consumed item number: 20

Producer number 2 produced item number: 21  
Producer number 2 produced item number: 22  
Producer number 1 produced item number: 25  
Consumer number 2 consumed item number: 25  
Consumer number 1 consumed item number: 22  
Producer number 2 produced item number: 23  
Producer number 2 produced item number: 24  
Producer number 1 produced item number: 26  
Consumer number 2 consumed item number: 26  
Producer number 2 produced item number: 25  
Consumer number 1 consumed item number: 25  
Producer number 2 produced item number: 26  
Producer number 1 produced item number: 27  
Producer number 1 produced item number: 28  
Consumer number 2 consumed item number: 28  
Consumer number 1 consumed item number: 27  
Producer number 2 produced item number: 27  
Producer number 1 produced item number: 29  
Producer number 2 produced item number: 28  
Consumer number 1 consumed item number: 28  
Producer number 2 produced item number: 29  
Producer number 1 produced item number: 30  
Consumer number 2 consumed item number: 30  
Producer number 2 produced item number: 30  
Producer number 1 produced item number: 31  
Consumer number 1 consumed item number: 31  
Producer number 2 produced item number: 31  
Consumer number 2 consumed item number: 31  
Producer number 1 produced item number: 32  
Consumer number 1 consumed item number: 32  
Producer number 1 produced item number: 33  
Producer number 2 produced item number: 32  
Consumer number 2 consumed item number: 32  
Producer number 2 produced item number: 33  
Producer number 1 produced item number: 34  
Consumer number 1 consumed item number: 34  
Producer number 2 produced item number: 34  
Producer number 2 produced item number: 35  
Producer number 1 produced item number: 35  
Consumer number 2 consumed item number: 35  
Consumer number 1 consumed item number: 35  
Producer number 2 produced item number: 36  
Producer number 1 produced item number: 36  
Producer number 2 produced item number: 37  
Consumer number 2 consumed item number: 37  
Producer number 1 produced item number: 37  
Consumer number 1 consumed item number: 37  
Producer number 1 produced item number: 38  
Consumer number 2 consumed item number: 38  
Producer number 2 produced item number: 38  
Consumer number 1 consumed item number: 38  
Producer number 1 produced item number: 39

Consumer number 2 consumed item number: 39  
Producer number 2 produced item number: 39  
Consumer number 1 consumed item number: 39  
Producer number 1 produced item number: 40  
Consumer number 2 consumed item number: 40  
Producer number 2 produced item number: 40  
Consumer number 1 consumed item number: 40  
Producer number 1 produced item number: 41  
Consumer number 1 consumed item number: 41  
Producer number 2 produced item number: 41  
Consumer number 2 consumed item number: 41  
Producer number 1 produced item number: 42  
Consumer number 1 consumed item number: 42  
Producer number 2 produced item number: 42  
Consumer number 2 consumed item number: 42  
Producer number 1 produced item number: 43  
Consumer number 1 consumed item number: 43  
Consumer number 2 consumed item number: 36  
Producer number 1 produced item number: 44  
Producer number 2 produced item number: 43  
Consumer number 1 consumed item number: 43  
Consumer number 2 consumed item number: 44  
Producer number 1 produced item number: 45  
Producer number 2 produced item number: 44  
Consumer number 1 consumed item number: 44  
Producer number 1 produced item number: 46  
Consumer number 2 consumed item number: 46  
Producer number 2 produced item number: 45  
Consumer number 1 consumed item number: 45  
Producer number 1 produced item number: 47  
Consumer number 1 consumed item number: 47  
Producer number 2 produced item number: 46  
Consumer number 2 consumed item number: 46  
Producer number 1 produced item number: 48  
Consumer number 1 consumed item number: 48  
Producer number 2 produced item number: 47  
Consumer number 2 consumed item number: 47  
Producer number 1 produced item number: 49  
Consumer number 1 consumed item number: 49  
Producer number 2 produced item number: 48  
Consumer number 1 consumed item number: 48  
Producer number 1 produced item number: 50  
Consumer number 2 consumed item number: 50  
Producer number 2 produced item number: 49  
Consumer number 2 consumed item number: 49  
Producer number 1 produced item number: 51  
Consumer number 1 consumed item number: 51  
Producer number 2 produced item number: 50  
Consumer number 2 consumed item number: 50  
Producer number 2 produced item number: 51  
Consumer number 1 consumed item number: 51  
Producer number 1 produced item number: 52

Consumer number 2 consumed item number: 52  
Producer number 2 produced item number: 52  
Consumer number 2 consumed item number: 52  
Producer number 1 produced item number: 53  
Consumer number 1 consumed item number: 53  
Producer number 2 produced item number: 53  
Consumer number 2 consumed item number: 53  
Producer number 1 produced item number: 54  
Consumer number 1 consumed item number: 54  
Producer number 2 produced item number: 54  
Consumer number 1 consumed item number: 54  
Producer number 1 produced item number: 55  
Consumer number 2 consumed item number: 55  
Producer number 2 produced item number: 55  
Consumer number 1 consumed item number: 55  
Producer number 1 produced item number: 56  
Consumer number 2 consumed item number: 56  
Producer number 2 produced item number: 56  
Consumer number 1 consumed item number: 56  
Producer number 1 produced item number: 57  
Consumer number 2 consumed item number: 57  
Producer number 2 produced item number: 57  
Consumer number 1 consumed item number: 57  
Producer number 1 produced item number: 58  
Consumer number 2 consumed item number: 58  
Producer number 2 produced item number: 58  
Consumer number 1 consumed item number: 58  
Producer number 1 produced item number: 59  
Consumer number 1 consumed item number: 59  
Producer number 2 produced item number: 59  
Consumer number 2 consumed item number: 59  
Producer number 1 produced item number: 60  
Consumer number 1 consumed item number: 60  
Producer number 2 produced item number: 60  
Consumer number 2 consumed item number: 60  
Producer number 1 produced item number: 61  
Consumer number 1 consumed item number: 61  
Producer number 2 produced item number: 61  
Consumer number 2 consumed item number: 61  
Producer number 1 produced item number: 62  
Consumer number 1 consumed item number: 62  
Producer number 2 produced item number: 62  
Consumer number 2 consumed item number: 62  
Producer number 1 produced item number: 63  
Consumer number 1 consumed item number: 63  
Producer number 2 produced item number: 63  
Consumer number 2 consumed item number: 63  
Producer number 1 produced item number: 64  
Consumer number 1 consumed item number: 64  
Producer number 2 produced item number: 64  
Consumer number 2 consumed item number: 64  
Producer number 1 produced item number: 65



```
Consumer number 1 consumed item number: 65
Producer number 2 produced item number: 65
Consumer number 1 consumed item number: 65
Producer number 1 produced item number: 66
Consumer number 2 consumed item number: 66
Producer number 2 produced item number: 66
Consumer number 1 consumed item number: 66
Producer number 1 produced item number: 67
Consumer number 2 consumed item number: 67
Producer number 1 produced item number: 68
Consumer number 1 consumed item number: 68
Producer number 2 produced item number: 67
Consumer number 2 consumed item number: 67
Producer number 1 produced item number: 69
Consumer number 1 consumed item number: 69
Producer number 2 produced item number: 68
Consumer number 2 consumed item number: 68
Producer number 1 produced item number: 70
Consumer number 1 consumed item number: 70
Producer number 2 produced item number: 69
Consumer number 2 consumed item number: 69
Producer number 1 produced item number: 71
Consumer number 2 consumed item number: 71
Producer number 1 produced item number: 72
Consumer number 1 consumed item number: 72
Producer number 2 produced item number: 70
Consumer number 2 consumed item number: 70
Producer number 2 produced item number: 71
Consumer number 1 consumed item number: 71
Producer number 1 produced item number: 73
Consumer number 2 consumed item number: 73
Producer number 2 produced item number: 72
Consumer number 1 consumed item number: 72
Producer number 1 produced item number: 74
Consumer number 2 consumed item number: 74
Producer number 2 produced item number: 73
Consumer number 1 consumed item number: 73
Producer number 1 produced item number: 75
Consumer number 2 consumed item number: 75
Producer number 1 produced item number: 76
Consumer number 1 consumed item number: 76
Producer number 2 produced item number: 74
Consumer number 2 consumed item number: 74
Producer number 1 produced item number: 77
Number of times producers put to sleep: 151
Number of times consumers put to sleep: 121
```

Notice how the number of producers begins to get further away from the number of consumers. This makes sense due to the fact the queue size for items has

increased, furthering the rate in which producers can output. Note: the reason why consumers and producers consume/produce items of the same number twice, is because each consumer/producer create or consumes their own items. So, in total the number of items exceeds 100, but it doesn't appear this way.

## SOURCE CODE PART 2

```
/******
 * Bryan Arnold *
 *   CSE 4300   *
 *   2/24/18    *
 * Assignment1  *
 *****/

//PART 2 OF ASSIGNMENT

#include <stdlib.h>
#include <stdio.h>
#include <pthread.h>
#include <semaphore.h>

pthread_mutex_t lock = PTHREAD_MUTEX_INITIALIZER; //lock mutex with
default initialization
sem_t lineFull, lineEmpty; //Two semaphores, one for tracking empty or
full lines of items

typedef int queue; //queue structure, the size of the queue of items
queue line[30]; //default queue size is 30

int counter = 0; //Track what's in queue
int pSleep = 0; //How many times producer's had to sleep
int cSleep = 0; //How many times consumers had to sleep
queue item = 0;

// Producer Function
// This function is responsible for how the producer
// threads will operate. They enter the function,
// are assigned a thread ID. They will then infinitely
// do the producer protocol, with sleeping before they act.
// If the semaphore blocks, increment the sleep count.
// Now, use the mutex to lock data from other producer,
// add onto the queue, release the data and semaphore, and finally
// continue.
void *producer(void *arg) {

    int pid = (int)arg + 1; //Producer number
```

```

while(1) { //run forever until producing > 100

    int waitTime = rand() / 1000000000 + 1; //Number from 1-3
    sleep(waitTime); //Sleep to allow queues to fill up
    item++; //Increase item number

    if (sem_wait(&lineEmpty) == 0){ //Sleep, so increment

        pSleep++;

    }

    pthread_mutex_lock(&lock); //Lock item data

    if(addNewItem(item)) { //If failure to produce

        printf("Producer failed to produce an item\n");

    } else { //Item produced, so displayed

        printf("Producer number %d produced item number:
%d\n", pid, item);

    }

    pthread_mutex_unlock(&lock); //release data
    sem_post(&lineFull); //Increment semaphore

    }

}

// addNewItem Function
// This function is responsible for adding new items onto the queue.
// If the queue isn't full, add item onto queue, otherwise error.
int addNewItem(queue item) {

    if(counter < 30) { //Queue can acquire new item

        line[counter] = item;
        counter++;
        return 0;

    } else { //Queue can't add new item

        return -1;

    }

}

// Consumer Function

```

```

// This function is responsible for how the consumer
// threads will operate. They enter the function,
// are assigned a thread ID. They will then infinitely
// do the consumer protocol, with sleeping before they act.
// If the semaphore blocks, increment the sleep count.
// Now, use the mutex to lock data from other consumer,
// take from the queue, release the data and semaphore, and finally
// continue.
void *consumer(void *arg) {

    int cid = (int)arg + 1; //Thread ID assigned to each thread

    while(1) { //Runs forever until consumed > 100

        int waitTime = rand() / 1000000000 + 2; //Random number,
        slightly longer than producer, to reflect how this problem works in
        real life
        sleep(waitTime); //Sleep

        if(sem_wait(&lineFull) == 0){ //Increment sleep counter for
consumers

            cSleep++;

        }

        pthread_mutex_lock(&lock); //Protect data from other thread

        if(consumeOldItem(&item)) { //Failed consumption of item

            printf("Consumer failed to consume an item\n");

        } else { //Item consumed, display

            printf("Consumer number %d consumed item number:
%d\n", cid, item);

        }

        pthread_mutex_unlock(&lock); //Release data to other thread
        sem_post(&lineEmpty); //Release semaphore

    }

}

// addNewItem Function
// This function is responsible for removing old items from the queue.
// If the queue isn't empty, remove the item first put into the queue,
otherwise error.
int consumeOldItem(queue *item) {

```

```

        if(counter > 0) { //Queue not empty, so remove oldest one

            *item = line[(counter-1)];
            counter--;
            return 0;

        } else { //Otherwise error

            return -1;

        }

    }

}

// Main Function
// This runs the entire program. Creates threads,
// initializes semaphore, and terminates when the number
// of produced and consumed are over 120.
int main(int argc, char *argv[]) {

    int i; // Increment variable

    pthread_t tidP[2]; //Producer threads
    pthread_t tidC[2]; //Consumer threads
    sem_init(&lineFull, 0, 0); //Empty semaphore
    sem_init(&lineEmpty, 0, 30); //Full semaphore

    for(i = 0; i < 2; i++) { //Create producers

        pthread_create(&tidP[i], NULL, producer, (void*)i);

    }

    for(i = 0; i < 2; i++) { //Create consumers

        pthread_create(&tidC[i], NULL, consumer, (void*)i);

    }

    while(1){ //Loop forever

        if(pSleep && cSleep > 120){ //If consumed/produced both
over 120, break loop

            break;

        }

    }

    printf("Number of times producers put to sleep: %d\n", pSleep);
//Display number of times slept

```

```
    printf("Number of times consumers put to sleep: %d\n", cSleep);  
    //Display number of times slept  
  
    return 0; //Exit program  
  
}
```