Problem 2

The goal of this problem is to explore the effect of various process structures on a practical application - the searching of a list for 3 given indices, as well as determining the maximum element in the list.

In these problems, we assume that each process will search a sub-list consisting of at most 250 elements, except in the variation, in which we increase that number to 1000 per process.

Question 1

In this part, a single process is used to sequentially search the list for the 3 indices and the max. However, the process may not terminate as soon as the three elements are found; it must run until the end of the list, in order to determine with certainty the value of the maximum element in the list.

Based on the results in timeResults.txt, this method seems to be the fastest compared to the later variations. The reason for this is likely due to the massive overhead involved in forking new processes, which this part does not involve.

Question 2

In this part, a chain of processes is used to search the list for the 3 indices and the max. Because we are limited to only spawning a single process at a time, the structure of the process "tree" looks more like a linked list of processes.

Based on the results in timeResults.txt, this method seems to be the slowest compared to the later variations. The reason is simple: we are creating a massive chain of processes, each dependent on one another, and even though each is searching concurrently, the creation of a new process must wait for the previous process in the chain to finish being created. Thus, the large overhead that comes with forking is extremely detrimental to the runtime of this algorithm.

Additionally, on a list of size 1M, the program breaks as-is, because too many processes are spawned and the ulimit (31830 on the DSV system) is exceeded.

Question 3

In this part, a fanout tree of processes is used to search the list for the 3 indices and the max. Because each process can spawn at most X processes, the structure of the process tree consists of a root with at most X children, each of which may have at most X children of their own, and so on. This was by far the most challenging to code, as it involved some tricky recursion and very judicious maintaining of counters. Interprocess communication was achieved by creating a new pipe for each parent process and handing that pipe down to the children. Each child could then read from their own pipes and write to their parent's pipe.

Based on the results in timeResults.txt, this method seems to be second-worst. Again, we are creating a large number of processes, which takes considerable time. The only benefit of this method over the method in Question 2 is that now, we are no longer bottlenecked by each previous process when we fork. Forking is happening concurrently.

Increasing the value of X seems to increase the total amount of time the search takes, up to a certain threshold. This is likely because, as above, more unnecessary processes results in a longer overall search time.

Variation on the Question

In this part, we only need to search for the 3 indices. To achieve this, we use a single parent process to spawn a bunch of helper children that will search while the parent spawns more children, until there are enough children to cover the whole list. Additionally, we set the size of each sub-list that a process can search to be 1000 instead of the previous 250, to reduce the number of processes and increase the overall speed.

Based on the results in timeResults.txt, this variation runs quite quickly. However, it seems as though the true winner is still a single process, even for a very large (1M) size list.

Problem 2

To generate a list of n numbers to a file "arrayNums.txt":

```
make generate
```

```
./generate n
```

To run any question, please follow the instructions below.

To send the output to an output text file, please add

```
> output.txt
```

to the command that runs the program. This will redirect the standard output from the program into a text file of the given name.

Part 1:

After generating a list of size n, to run the single-process search:

```
make q1
```

```
./search n
```

Part 2:

After generating a list of size n, to run the multi-process DFS search:

```
make q2
```

```
./search n
```

Part 3:

After generating a list of size n, to run the multi-process BFS search:

```
make q3
```

```
./search n
```

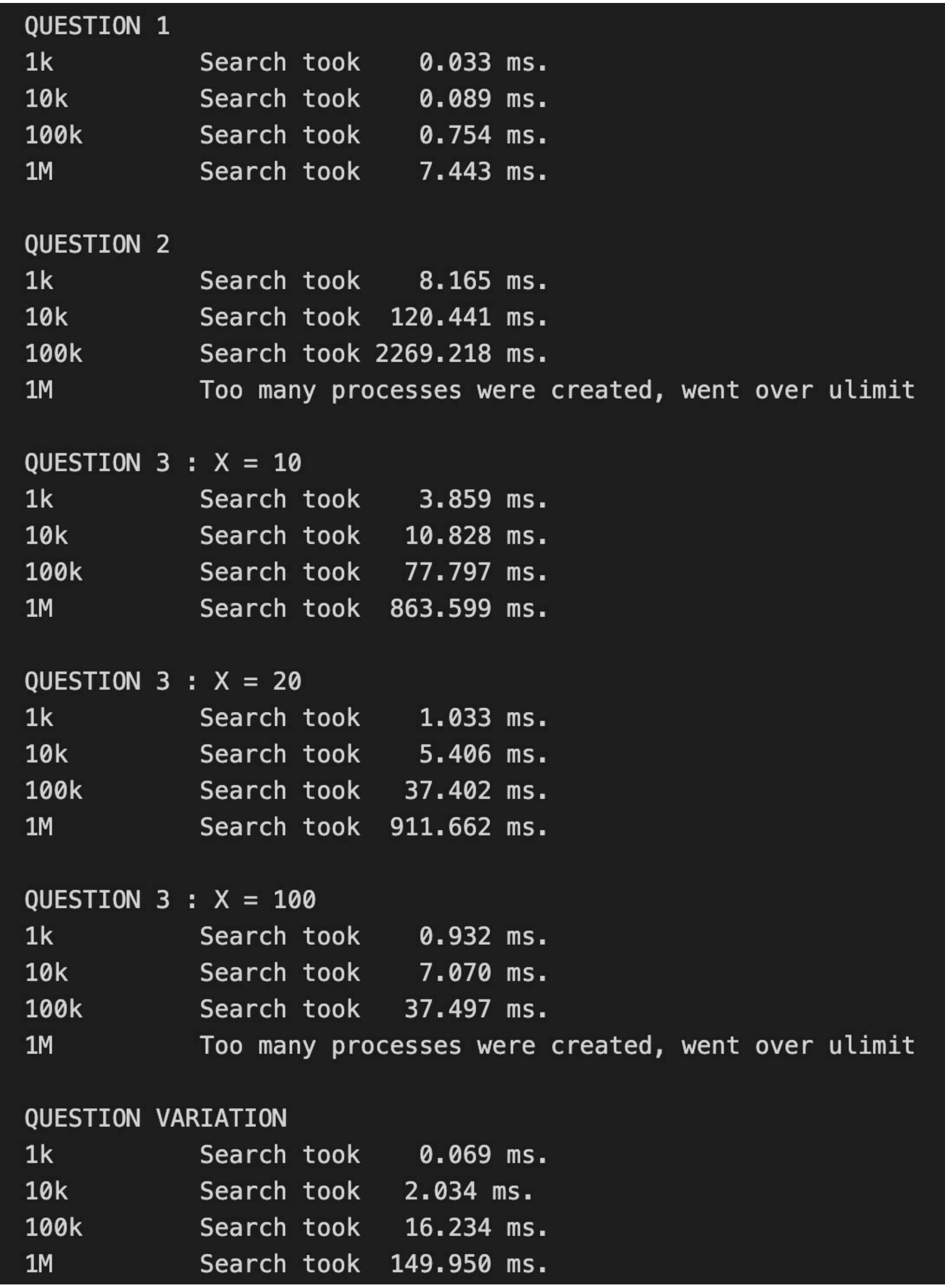
Note: the value of X can be specified in the Definition at the top of the search_3.c file: X_PROCS, by default set to 10.

Variation on the Problem:

After generating a list of size n, to run the variation on the problem:

```
make qvar
```

```
./search n
```



```
QUESTION 1
1k          Search took    0.033 ms.
10k         Search took    0.089 ms.
100k        Search took    0.754 ms.
1M          Search took    7.443 ms.

QUESTION 2
1k          Search took    8.165 ms.
10k         Search took  120.441 ms.
100k        Search took 2269.218 ms.
1M          Too many processes were created, went over ulimit

QUESTION 3 : X = 10
1k          Search took    3.859 ms.
10k         Search took   10.828 ms.
100k        Search took   77.797 ms.
1M          Search took  863.599 ms.

QUESTION 3 : X = 20
1k          Search took    1.033 ms.
10k         Search took    5.406 ms.
100k        Search took   37.402 ms.
1M          Search took  911.662 ms.

QUESTION 3 : X = 100
1k          Search took    0.932 ms.
10k         Search took    7.070 ms.
100k        Search took   37.497 ms.
1M          Too many processes were created, went over ulimit

QUESTION VARIATION
1k          Search took    0.069 ms.
10k         Search took   2.034 ms.
100k        Search took   16.234 ms.
1M          Search took  149.950 ms.
```