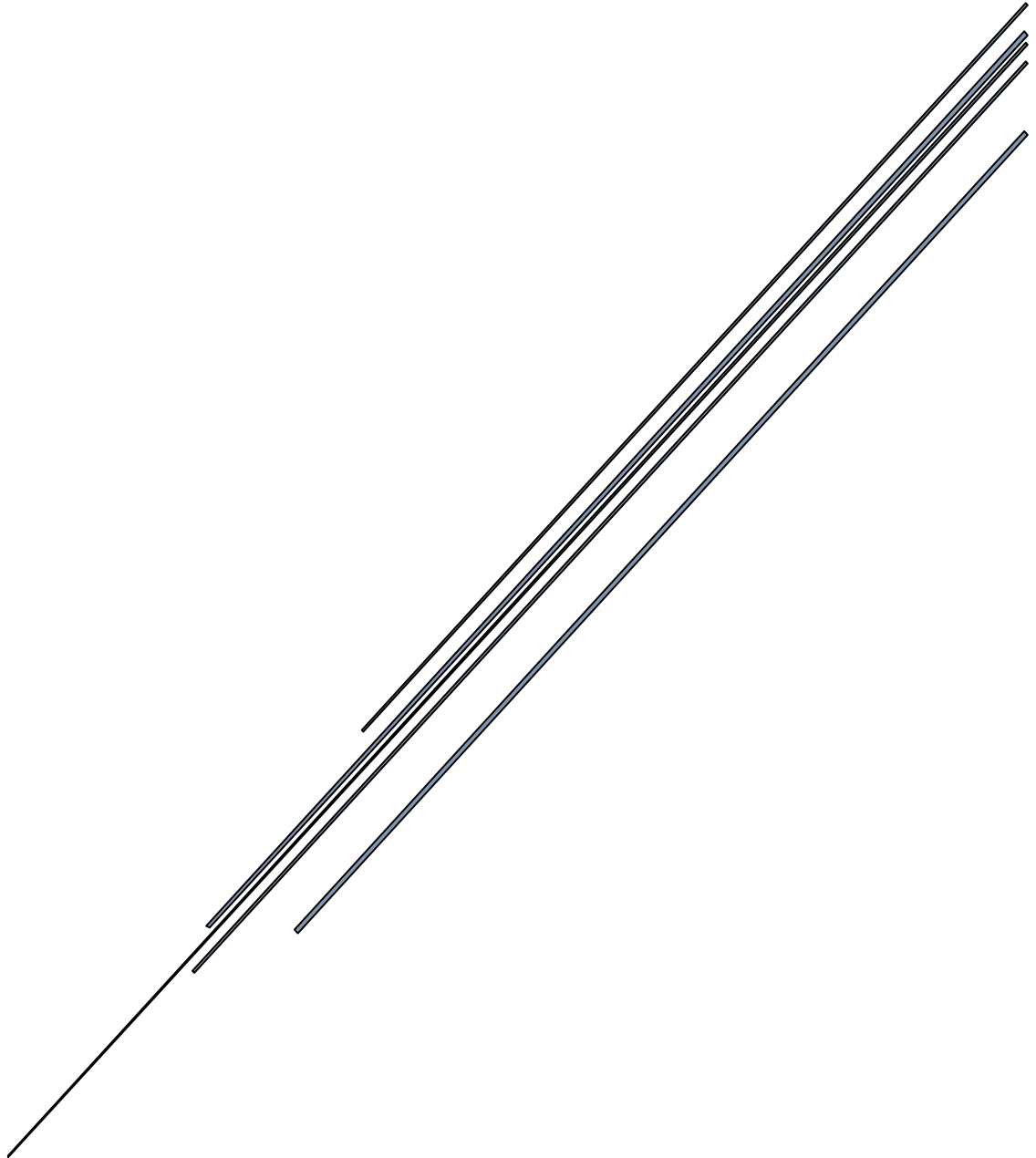


# CSEN 602: OPERATING SYSTEMS

## Project Report



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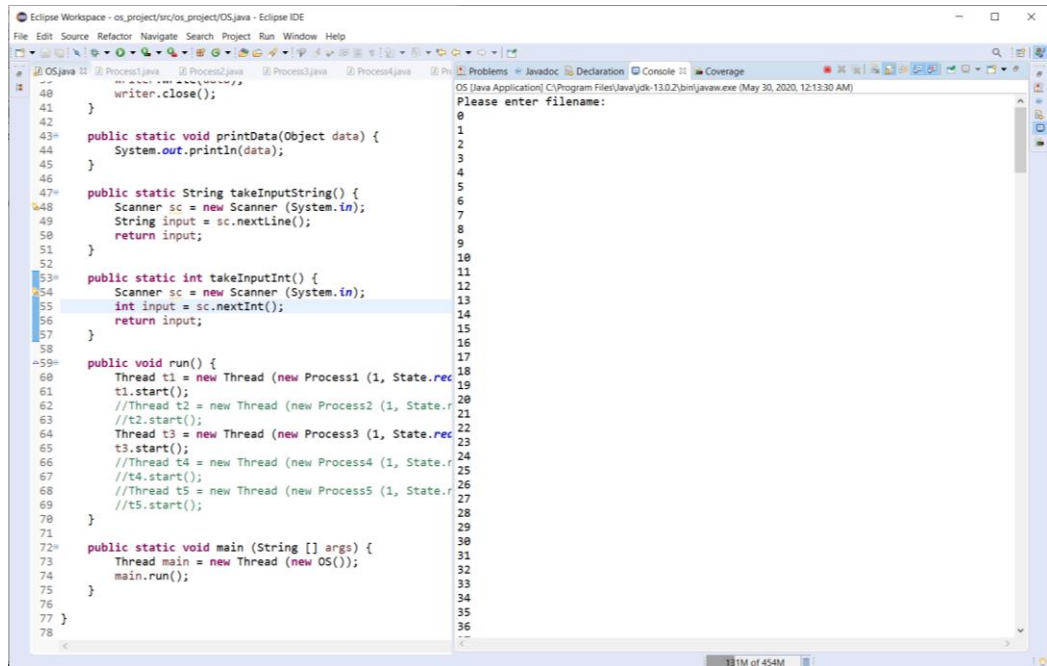
# **Milestone 1**

## **1. Implementation**

We divided the milestone into 7 classes; 5 of which are the processes required to implement, a process state enum class and an operating system class. The system calls were implemented in the OS class as separate, static methods to be able to call them from the process classes. Each process has its own class, named “Process(n)”. To be able to implement threading, each process class implements the interface “Runnable” and its function is defined in the “public void run()” method to be able to consecutively run all the process at once from the OS class. The OS class implements the interface “Runnable” as well but as the main thread. In its “run()” method we create five threads for each process and call their start() functions. Finally, in the main method of the class OS, we create a thread for our main thread (OS class) then call its “run()” method hence resulting in the consecutive running of all the five processes.

## 2. Screenshots of output

### a) Execute Process 1 and Process 3

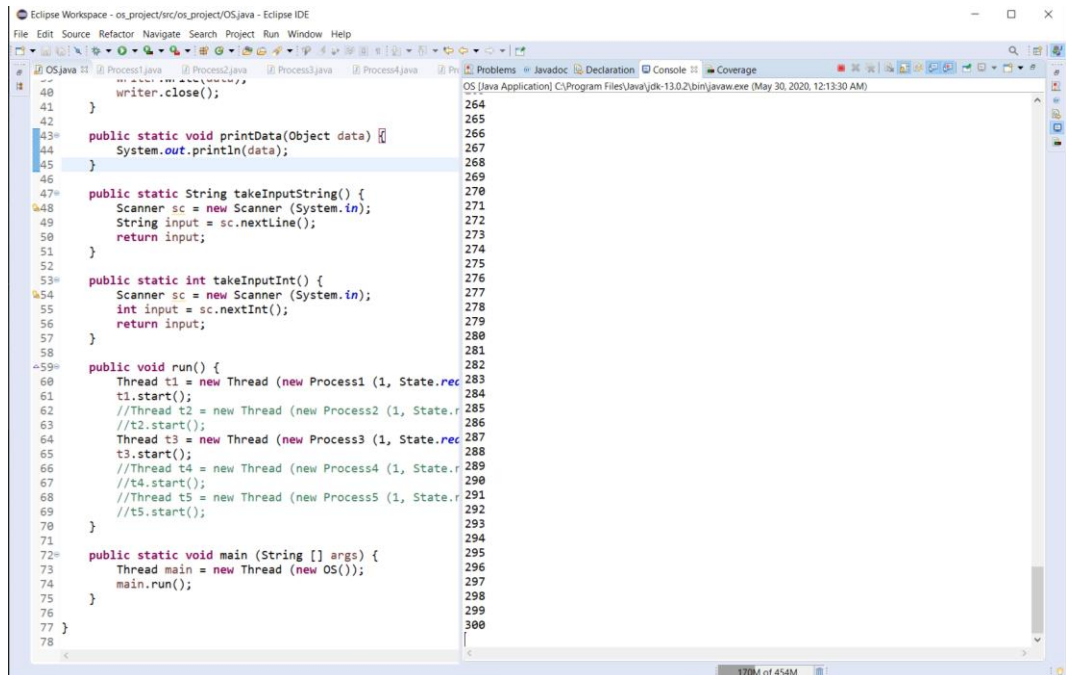


The screenshot shows the Eclipse IDE with the source code of `OS.java` on the left and the console output on the right. The code includes methods for printing data, taking string and integer input, and a `run` method that starts five threads (`Process1` through `Process5`). The console output shows the prompt "Please enter filename:" followed by a list of numbers from 0 to 36.

```

40      writer.close();
41    }
42
43    public static void printData(Object data) {
44      System.out.println(data);
45    }
46
47    public static String takeInputString() {
48      Scanner sc = new Scanner (System.in);
49      String input = sc.nextLine();
50      return input;
51    }
52
53    public static int takeInputInt() {
54      Scanner sc = new Scanner (System.in);
55      int input = sc.nextInt();
56      return input;
57    }
58
59    public void run() {
60      Thread t1 = new Thread (new Process1 (1, State.rec));
61      t1.start();
62      //Thread t2 = new Thread (new Process2 (1, State.r
63      //t2.start();
64      Thread t3 = new Thread (new Process3 (1, State.rec));
65      t3.start();
66      //Thread t4 = new Thread (new Process4 (1, State.r
67      //t4.start();
68      //Thread t5 = new Thread (new Process5 (1, State.r
69      //t5.start();
70    }
71
72    public static void main (String [] args) {
73      Thread main = new Thread (new OS());
74      main.run();
75    }
76
77  }
78
  
```

OS [Java Application] C:\Program Files\Java\jdk-13.0.2\bin\java.exe (May 30, 2020, 12:13:30 AM)  
 Please enter filename:  
 0  
 1  
 2  
 3  
 4  
 5  
 6  
 7  
 8  
 9  
 10  
 11  
 12  
 13  
 14  
 15  
 16  
 17  
 18  
 19  
 20  
 21  
 22  
 23  
 24  
 25  
 26  
 27  
 28  
 29  
 30  
 31  
 32  
 33  
 34  
 35  
 36

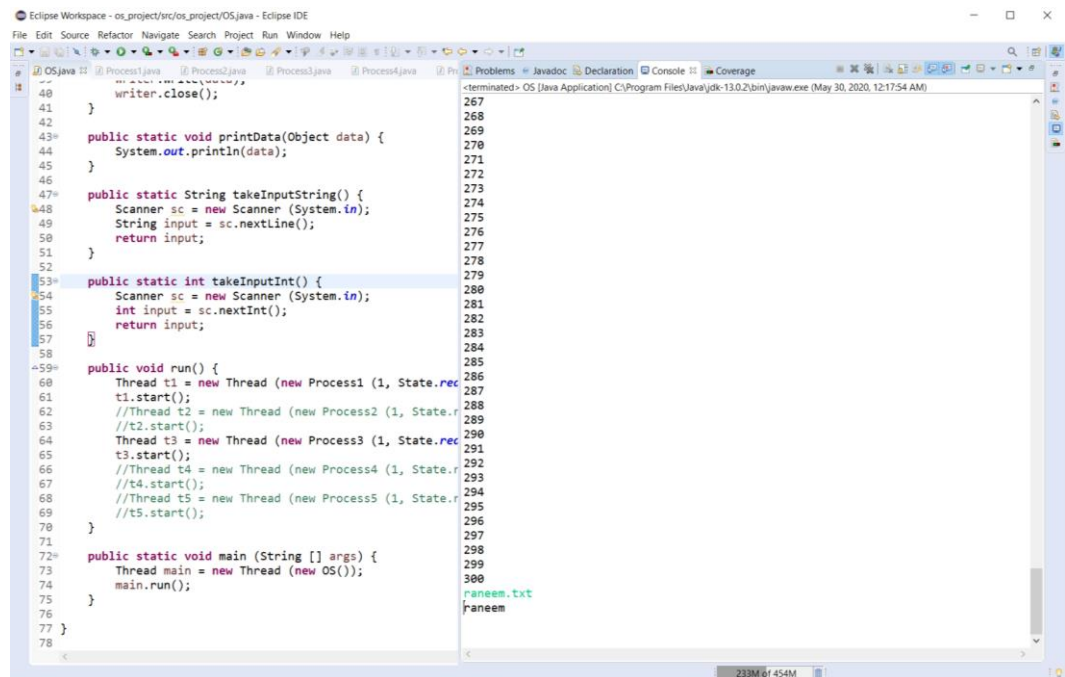


This screenshot is similar to the one above, showing the same source code in `OS.java`. The console output is truncated, showing numbers from 264 to 300.

```

40      writer.close();
41    }
42
43    public static void printData(Object data) {
44      System.out.println(data);
45    }
46
47    public static String takeInputString() {
48      Scanner sc = new Scanner (System.in);
49      String input = sc.nextLine();
50      return input;
51    }
52
53    public static int takeInputInt() {
54      Scanner sc = new Scanner (System.in);
55      int input = sc.nextInt();
56      return input;
57    }
58
59    public void run() {
60      Thread t1 = new Thread (new Process1 (1, State.rec));
61      t1.start();
62      //Thread t2 = new Thread (new Process2 (1, State.r
63      //t2.start();
64      Thread t3 = new Thread (new Process3 (1, State.rec));
65      t3.start();
66      //Thread t4 = new Thread (new Process4 (1, State.r
67      //t4.start();
68      //Thread t5 = new Thread (new Process5 (1, State.r
69      //t5.start();
70    }
71
72    public static void main (String [] args) {
73      Thread main = new Thread (new OS());
74      main.run();
75    }
76
77  }
78
  
```

OS [Java Application] C:\Program Files\Java\jdk-13.0.2\bin\java.exe (May 30, 2020, 12:13:30 AM)  
 264  
 265  
 266  
 267  
 268  
 269  
 270  
 271  
 272  
 273  
 274  
 275  
 276  
 277  
 278  
 279  
 280  
 281  
 282  
 283  
 284  
 285  
 286  
 287  
 288  
 289  
 290  
 291  
 292  
 293  
 294  
 295  
 296  
 297  
 298  
 299  
 300

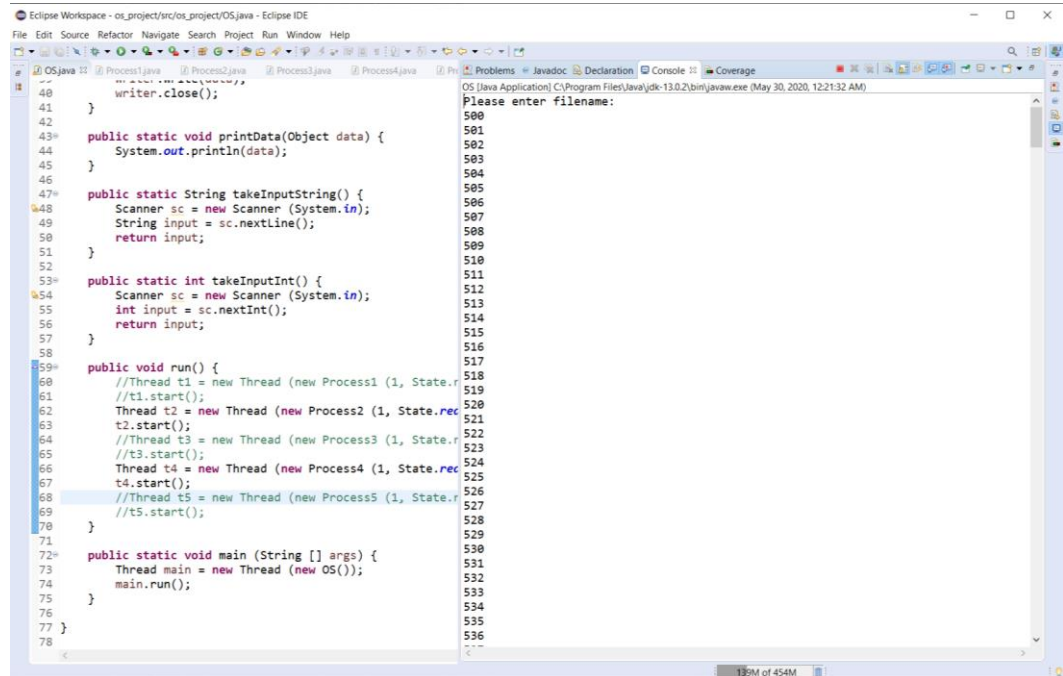


```

Eclipse Workspace - os_project/src/os_project/OS.java - Eclipse IDE
File Edit Source Refactor Navigate Search Project Run Window Help
OS.java Process1.java Process2.java Process3.java Process4.java Problems Javadoc Declaration Console Coverage
40 writer.close();
41 }
42
43 public static void printData(Object data) {
44     System.out.println(data);
45 }
46
47 public static String takeInputString() {
48     Scanner sc = new Scanner(System.in);
49     String input = sc.nextLine();
50     return input;
51 }
52
53 public static int takeInputInt() {
54     Scanner sc = new Scanner(System.in);
55     int input = sc.nextInt();
56     return input;
57 }
58
59 public void run() {
60     Thread t1 = new Thread(new Process1(1, State.rec));
61     t1.start();
62     //Thread t2 = new Thread(new Process2(1, State.rec));
63     //t2.start();
64     Thread t3 = new Thread(new Process3(1, State.rec));
65     t3.start();
66     //Thread t4 = new Thread(new Process4(1, State.rec));
67     //t4.start();
68     //Thread t5 = new Thread(new Process5(1, State.rec));
69     //t5.start();
70 }
71
72 public static void main(String[] args) {
73     Thread main = new Thread(new OS());
74     main.run();
75 }
76
77 }
78
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
raneem.txt
raneem
  
```

As evident from the above screenshots, the two processes started simultaneously. Process 3 counted from 0 to 300 while Process 1 waited for a user to input the filename. After inputting the filename “raneem.txt”, Process 1 outputted its contents and the main method terminated.

## b) Execute Process 2 and Process 4

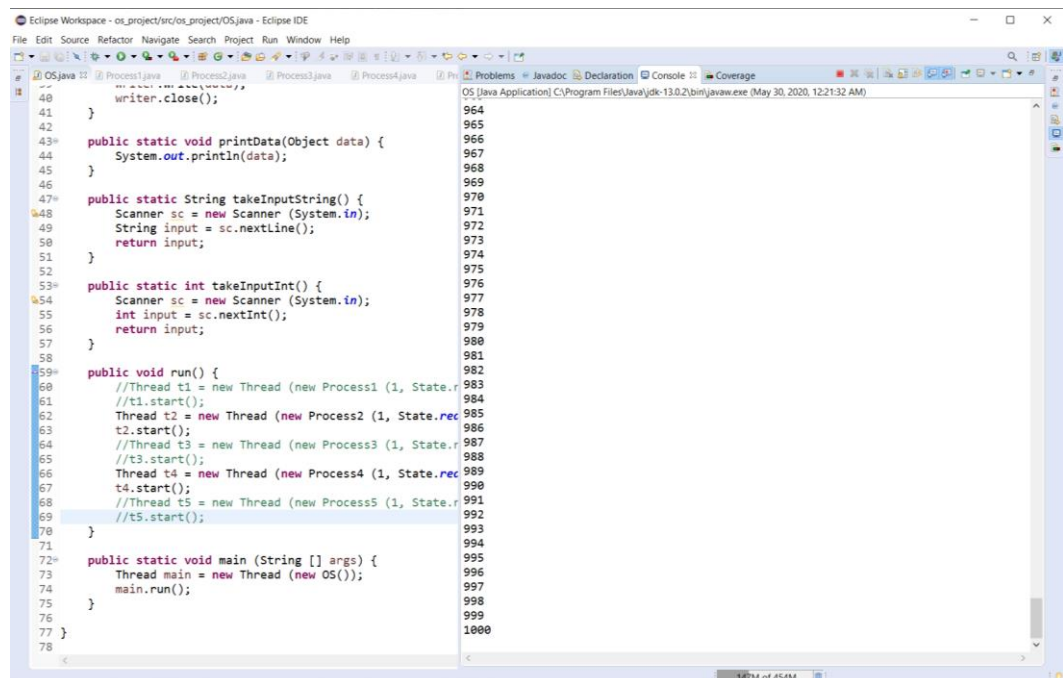


```

Eclipse Workspace - os_project/src/os_project/OS.java - Eclipse IDE
File Edit Source Refactor Navigate Search Project Run Window Help
OS.java Process1.java Process2.java Process3.java Process4.java
writer.close();
}
}
public static void printData(Object data) {
    System.out.println(data);
}
}
public static String takeInputString() {
    Scanner sc = new Scanner(System.in);
    String input = sc.nextLine();
    return input;
}
}
public static int takeInputInt() {
    Scanner sc = new Scanner(System.in);
    int input = sc.nextInt();
    return input;
}
}
public void run() {
    //Thread t1 = new Thread (new Process1 (1, State.rec
    //t1.start();
    Thread t2 = new Thread (new Process2 (1, State.rec
    t2.start();
    //Thread t3 = new Thread (new Process3 (1, State.rec
    //t3.start();
    Thread t4 = new Thread (new Process4 (1, State.rec
    t4.start();
    //Thread t5 = new Thread (new Process5 (1, State.rec
    //t5.start();
}
}
public static void main (String [] args) {
    Thread main = new Thread (new OS());
    main.run();
}
}
}
}

Please enter filename:
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
136M of 454M

```

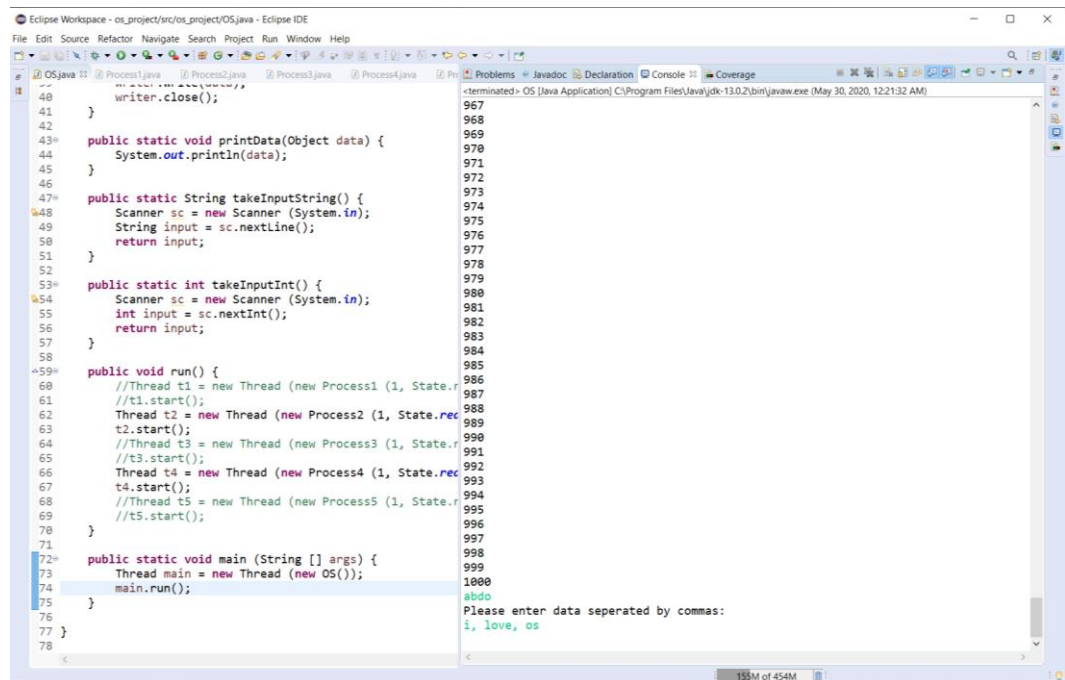


```

Eclipse Workspace - os_project/src/os_project/OS.java - Eclipse IDE
File Edit Source Refactor Navigate Search Project Run Window Help
OS.java Process1.java Process2.java Process3.java Process4.java
writer.close();
}
}
public static void printData(Object data) {
    System.out.println(data);
}
}
public static String takeInputString() {
    Scanner sc = new Scanner(System.in);
    String input = sc.nextLine();
    return input;
}
}
public static int takeInputInt() {
    Scanner sc = new Scanner(System.in);
    int input = sc.nextInt();
    return input;
}
}
public void run() {
    //Thread t1 = new Thread (new Process1 (1, State.rec
    //t1.start();
    Thread t2 = new Thread (new Process2 (1, State.rec
    t2.start();
    //Thread t3 = new Thread (new Process3 (1, State.rec
    //t3.start();
    Thread t4 = new Thread (new Process4 (1, State.rec
    t4.start();
    //Thread t5 = new Thread (new Process5 (1, State.rec
    //t5.start();
}
}
public static void main (String [] args) {
    Thread main = new Thread (new OS());
    main.run();
}
}
}
}

964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
147M of 454M

```



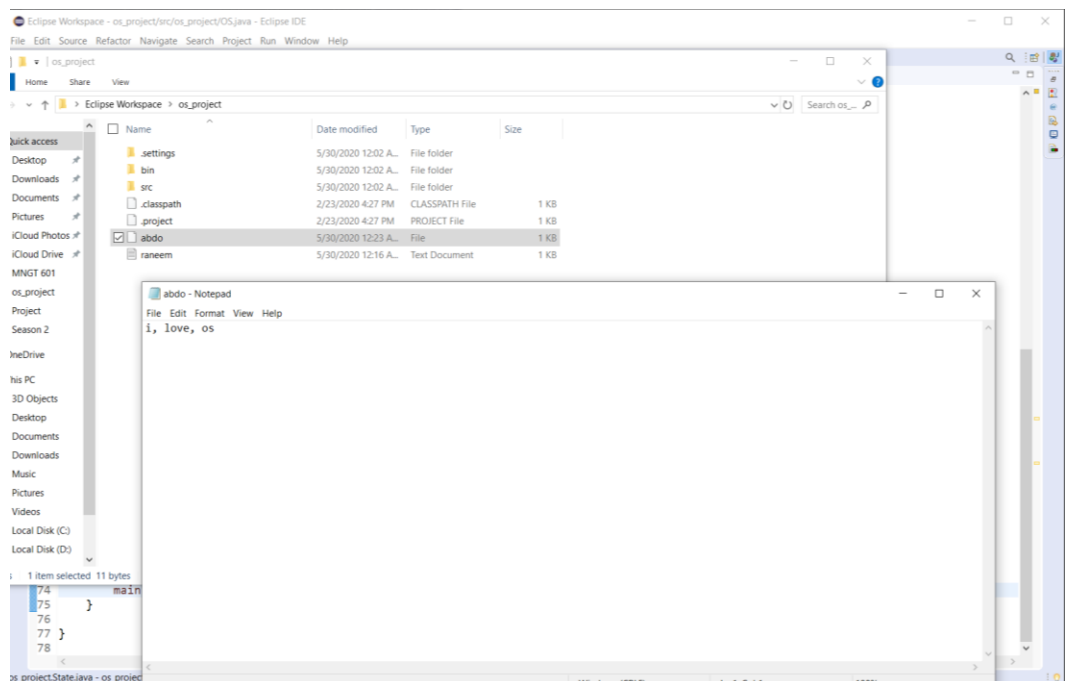
```

40      writer.close();
41  }
42
43  public static void printData(Object data) {
44      System.out.println(data);
45  }
46
47  public static String takeInputString() {
48      Scanner sc = new Scanner(System.in);
49      String input = sc.nextLine();
50      return input;
51  }
52
53  public static int takeInputInt() {
54      Scanner sc = new Scanner(System.in);
55      int input = sc.nextInt();
56      return input;
57  }
58
59  public void run() {
60      //Thread t1 = new Thread (new Process1 (1, State.r
61      //t1.start();
62      Thread t2 = new Thread (new Process2 (1, State.r
63      t2.start();
64      //Thread t3 = new Thread (new Process3 (1, State.r
65      //t3.start();
66      Thread t4 = new Thread (new Process4 (1, State.r
67      t4.start();
68      //Thread t5 = new Thread (new Process5 (1, State.r
69      //t5.start();
70  }
71
72  public static void main (String [] args) {
73      Thread main = new Thread (new OS());
74      main.run();
75  }
76
77  }
78
  
```

Console Output:

```

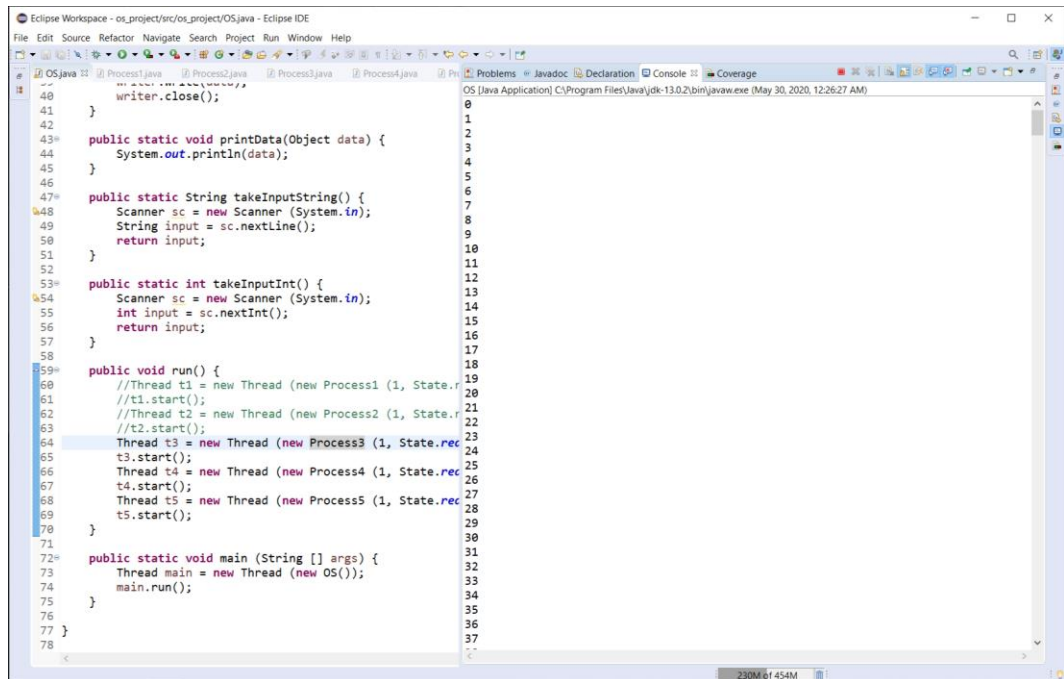
<terminated> OS (Java Application) C:\Program Files\Java\jdk-13.0.2\bin\javaw.exe (May 30, 2020, 12:21:32 AM)
1000
abdo
Please enter data seperated by commas:
i, love, os
  
```



As evident from the above screenshots, the two processes started simultaneously. Process 4 counted from 500 to 100 while Process 2 waited for a user to input the filename. After inputting

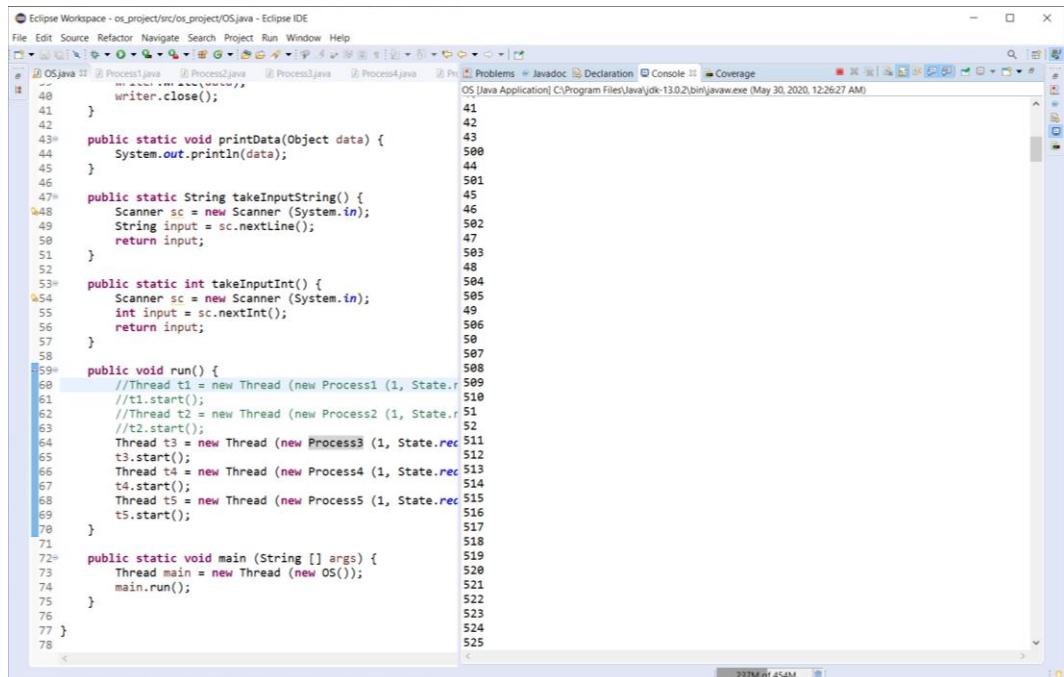
the filename and the required data, Process 2 wrote the data to the specified file.

### c) Execute Process 5, Process 3, and Process 4



```

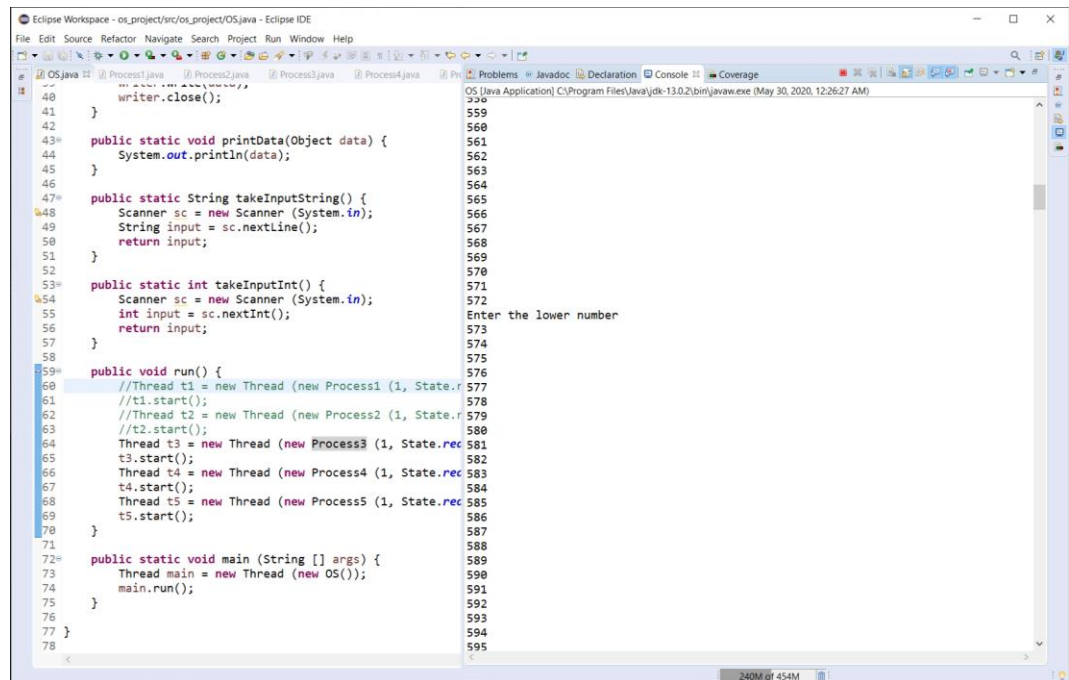
40      writer.close();
41    }
42
43    public static void printData(Object data) {
44        System.out.println(data);
45    }
46
47    public static String takeInputString() {
48        Scanner sc = new Scanner (System.in);
49        String input = sc.nextLine();
50        return input;
51    }
52
53    public static int takeInputInt() {
54        Scanner sc = new Scanner (System.in);
55        int input = sc.nextInt();
56        return input;
57    }
58
59    public void run() {
60        //Thread t1 = new Thread (new Process1 (1, State.r
61        //t1.start();
62        //Thread t2 = new Thread (new Process2 (1, State.r
63        //t2.start();
64        Thread t3 = new Thread (new Process3 (1, State.rec
65        t3.start();
66        Thread t4 = new Thread (new Process4 (1, State.rec
67        t4.start();
68        Thread t5 = new Thread (new Process5 (1, State.rec
69        t5.start();
70    }
71
72    public static void main (String [] args) {
73        Thread main = new Thread (new OS());
74        main.run();
75    }
76
77 }
78
  
```



```

40      writer.close();
41    }
42
43    public static void printData(Object data) {
44        System.out.println(data);
45    }
46
47    public static String takeInputString() {
48        Scanner sc = new Scanner (System.in);
49        String input = sc.nextLine();
50        return input;
51    }
52
53    public static int takeInputInt() {
54        Scanner sc = new Scanner (System.in);
55        int input = sc.nextInt();
56        return input;
57    }
58
59    public void run() {
60        //Thread t1 = new Thread (new Process1 (1, State.r
61        //t1.start();
62        //Thread t2 = new Thread (new Process2 (1, State.r
63        //t2.start();
64        Thread t3 = new Thread (new Process3 (1, State.rec
65        t3.start();
66        Thread t4 = new Thread (new Process4 (1, State.rec
67        t4.start();
68        Thread t5 = new Thread (new Process5 (1, State.rec
69        t5.start();
70    }
71
72    public static void main (String [] args) {
73        Thread main = new Thread (new OS());
74        main.run();
75    }
76
77 }
78
  
```





The screenshot shows the Eclipse IDE with the file `OS.java` open. The code defines a class `OS` with several static methods and a `run` method. The `run` method creates five threads: `Process1`, `Process2`, `Process3`, `Process4`, and `Process5`. The console output shows the execution of the program, including the prompt "Enter the lower number" and the output of the threads.

```

40      writer.close();
41  }
42
43  public static void printData(Object data) {
44      System.out.println(data);
45  }
46
47  public static String takeInputString() {
48      Scanner sc = new Scanner (System.in);
49      String input = sc.nextLine();
50      return input;
51  }
52
53  public static int takeInputInt() {
54      Scanner sc = new Scanner (System.in);
55      int input = sc.nextInt();
56      return input;
57  }
58
59  public void run() {
60      //Thread t1 = new Thread (new Process1 (1, State.r
61      //t1.start();
62      //Thread t2 = new Thread (new Process2 (1, State.r
63      //t2.start();
64      Thread t3 = new Thread (new Process3 (1, State.rec
65      t3.start();
66      Thread t4 = new Thread (new Process4 (1, State.rec
67      t4.start();
68      Thread t5 = new Thread (new Process5 (1, State.rec
69      t5.start();
70  }
71
72  public static void main (String [] args) {
73      Thread main = new Thread (new OS());
74      main.run();
75  }
76
77 }
78

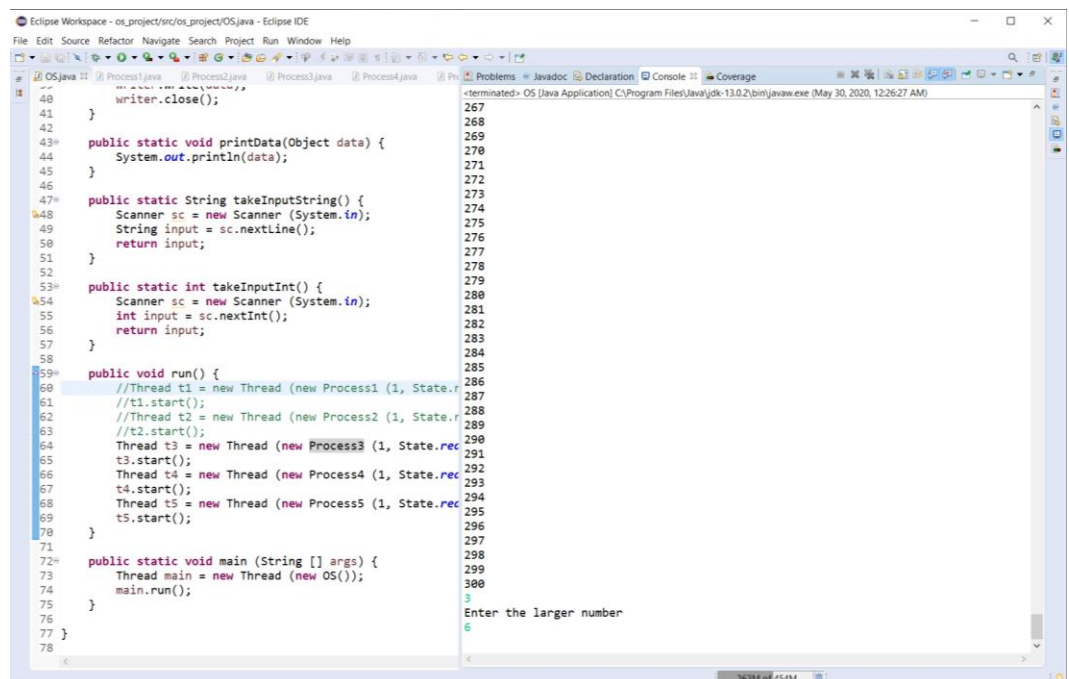
```

Console Output:

```

OS [Java Application] C:\Program Files\Java\jdk-13.0.2\bin\javaw.exe (May 30, 2020, 12:26:27 AM)
559
560
561
562
563
564
565
566
567
568
569
570
571
572 Enter the lower number
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595

```



The screenshot shows the Eclipse IDE with the file `OS.java` open. The code is the same as in the previous screenshot. The console output shows the execution of the program, including the prompt "Enter the larger number" and the output of the threads.

```

40      writer.close();
41  }
42
43  public static void printData(Object data) {
44      System.out.println(data);
45  }
46
47  public static String takeInputString() {
48      Scanner sc = new Scanner (System.in);
49      String input = sc.nextLine();
50      return input;
51  }
52
53  public static int takeInputInt() {
54      Scanner sc = new Scanner (System.in);
55      int input = sc.nextInt();
56      return input;
57  }
58
59  public void run() {
60      //Thread t1 = new Thread (new Process1 (1, State.r
61      //t1.start();
62      //Thread t2 = new Thread (new Process2 (1, State.r
63      //t2.start();
64      Thread t3 = new Thread (new Process3 (1, State.rec
65      t3.start();
66      Thread t4 = new Thread (new Process4 (1, State.rec
67      t4.start();
68      Thread t5 = new Thread (new Process5 (1, State.rec
69      t5.start();
70  }
71
72  public static void main (String [] args) {
73      Thread main = new Thread (new OS());
74      main.run();
75  }
76
77 }
78

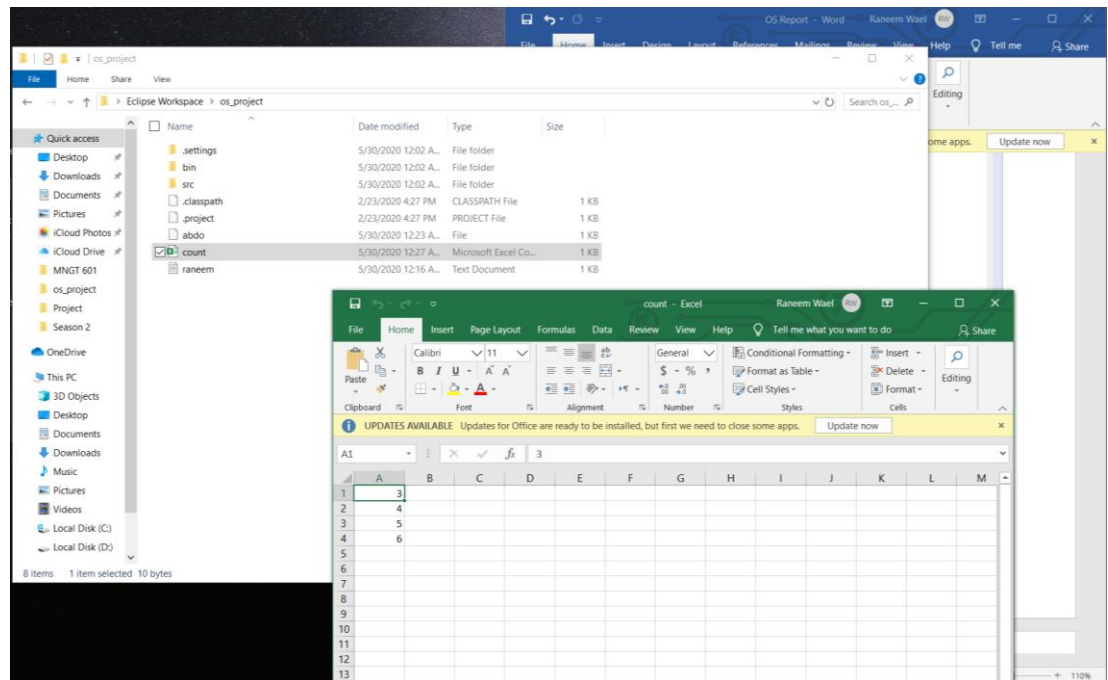
```

Console Output:

```

<terminated> OS [Java Application] C:\Program Files\Java\jdk-13.0.2\bin\javaw.exe (May 30, 2020, 12:26:27 AM)
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
3 Enter the larger number
6

```



As evident from the above screenshots, Process 3 started, then Process 4 started as well, and finally Process 5. Process 3 and 4 were running consecutively till the inputs to Process 5 where inputted and the file “count” was created.

### **3. Questions**

a) What are system calls? And why do we need them?

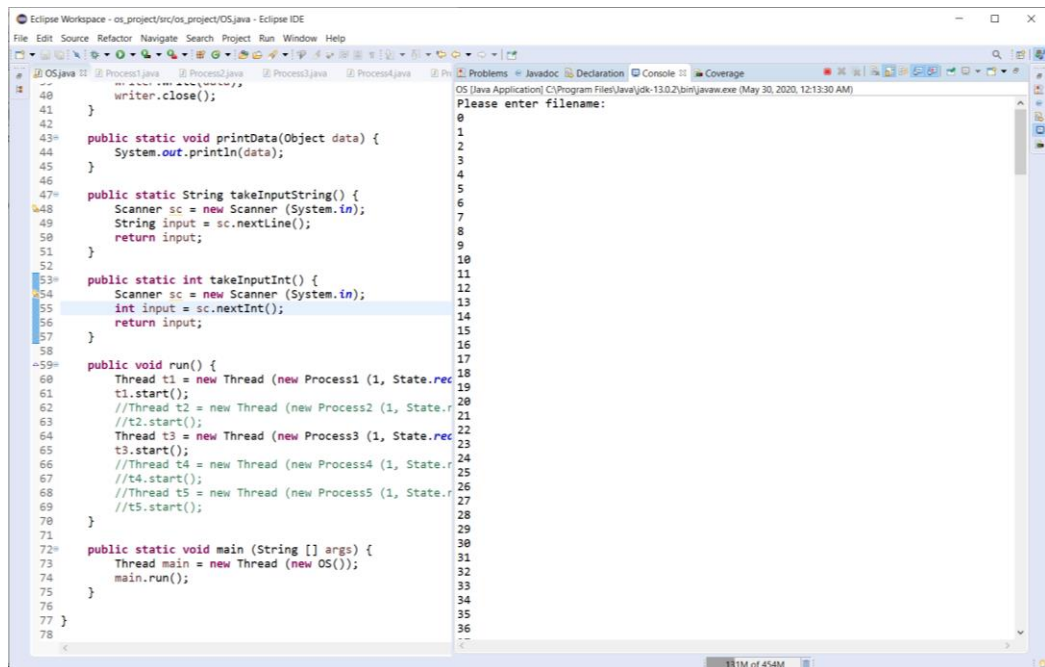
A system call is the programmatic way in which a process requests a service from the kernel of the operating system (hence why we included them in the operating system class and made

them static so the processes could be able to call them) it is executed on. We need them to be able to collect information from the user, print output to the printer, and read and write data from and to files.

b) Give an overview of your team's implementation, how you implemented the OS and processes?

Answered in the presentation.

c) What happens when you run process 1 and process 3 at the same time? (Show us the output)



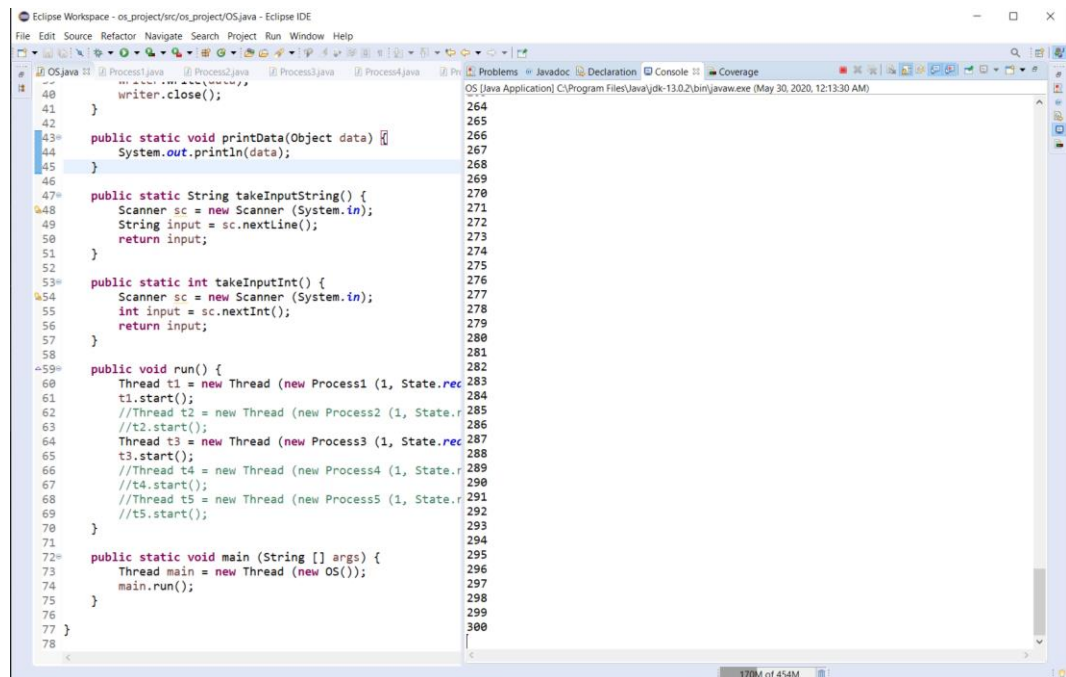
The screenshot shows the Eclipse IDE with a Java project named 'os\_project'. The main file 'OS.java' is open, showing a multi-threaded application. The code defines several static methods: `printData`, `takeInputString`, `takeInputInt`, and `run`. The `run` method creates five threads: `Process1`, `Process2`, `Process3`, `Process4`, and `Process5`. The `main` method starts a `Thread` named `main` with a new `OS` object.

The console output shows the execution of the program. It starts with a prompt 'Please enter filename:' followed by a series of numbers (0 to 36) representing the output of the processes. The output is as follows:

```

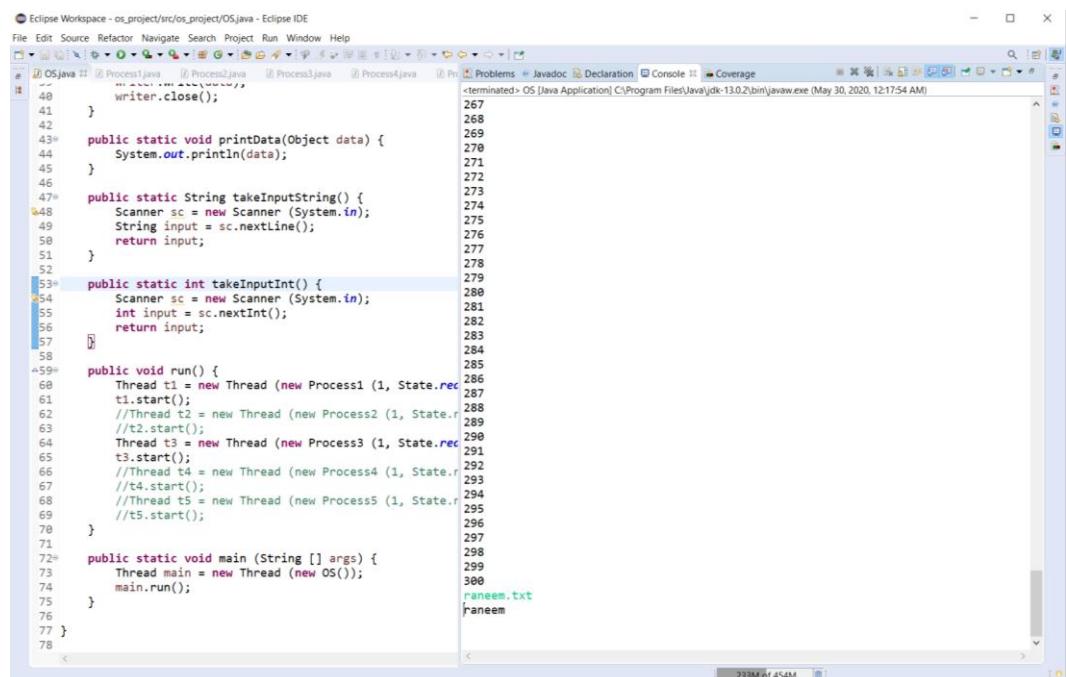
OS [Java Application] C:\Program Files\Java\jdk-13.0.2\bin\java.exe (May 30, 2020, 12:13:30 AM)
Please enter filename:
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36

```



```

40      writer.close();
41  }
42  }
43  public static void printData(Object data) {
44      System.out.println(data);
45  }
46  }
47  public static String takeInputString() {
48      Scanner sc = new Scanner (System.in);
49      String input = sc.nextLine();
50      return input;
51  }
52  }
53  public static int takeInputInt() {
54      Scanner sc = new Scanner (System.in);
55      int input = sc.nextInt();
56      return input;
57  }
58  }
59  public void run() {
60      Thread t1 = new Thread (new Process1 (1, State.rec
61      t1.start();
62      //Thread t2 = new Thread (new Process2 (1, State.r
63      //t2.start();
64      Thread t3 = new Thread (new Process3 (1, State.rec
65      t3.start();
66      //Thread t4 = new Thread (new Process4 (1, State.r
67      //t4.start();
68      //Thread t5 = new Thread (new Process5 (1, State.r
69      //t5.start();
70  }
71  }
72  public static void main (String [] args) {
73      Thread main = new Thread (new OS());
74      main.run();
75  }
76  }
77  }
78  }
  
```



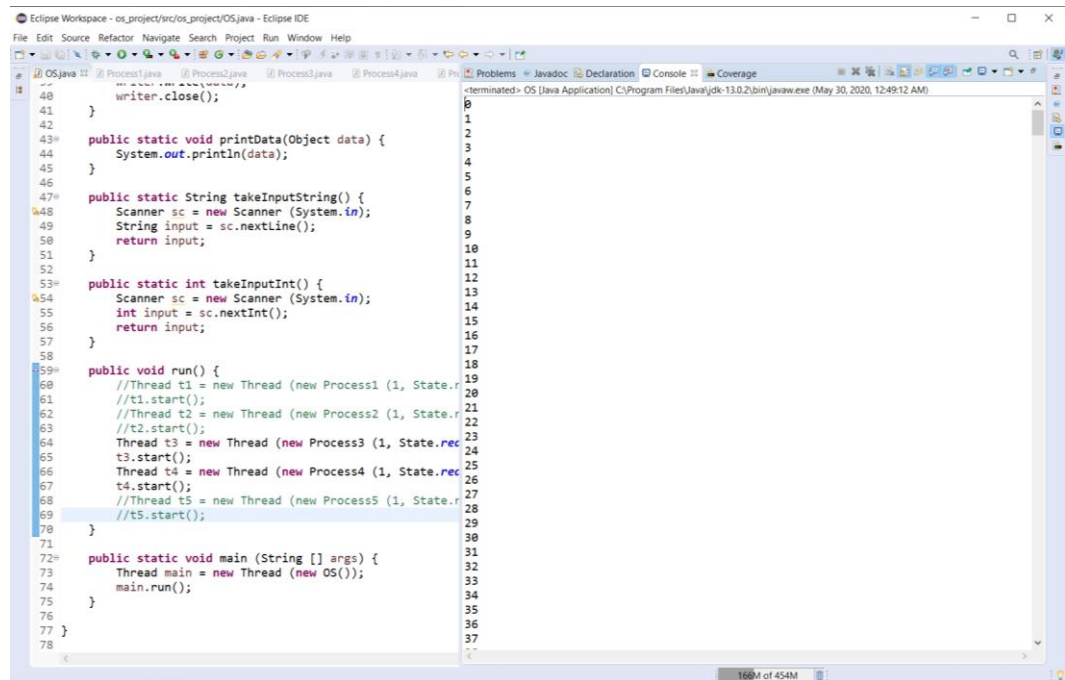
```

267      <terminated> OS [Java Application] C:\Program Files\Java\jdk-13.0.2\bin\javaw.exe (May 30, 2020, 12:17:54 AM)
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300
  
```

As evident from the above screenshots, the two processes started simultaneously. Process 3 counted from 0 to 300 while Process 1 waited for a user to input the filename. After inputting

the filename “raneem.txt”, Process 1 outputted its contents and the main method terminated.

d) What happens when you run process 3 and process 4 together? (Show us the output)

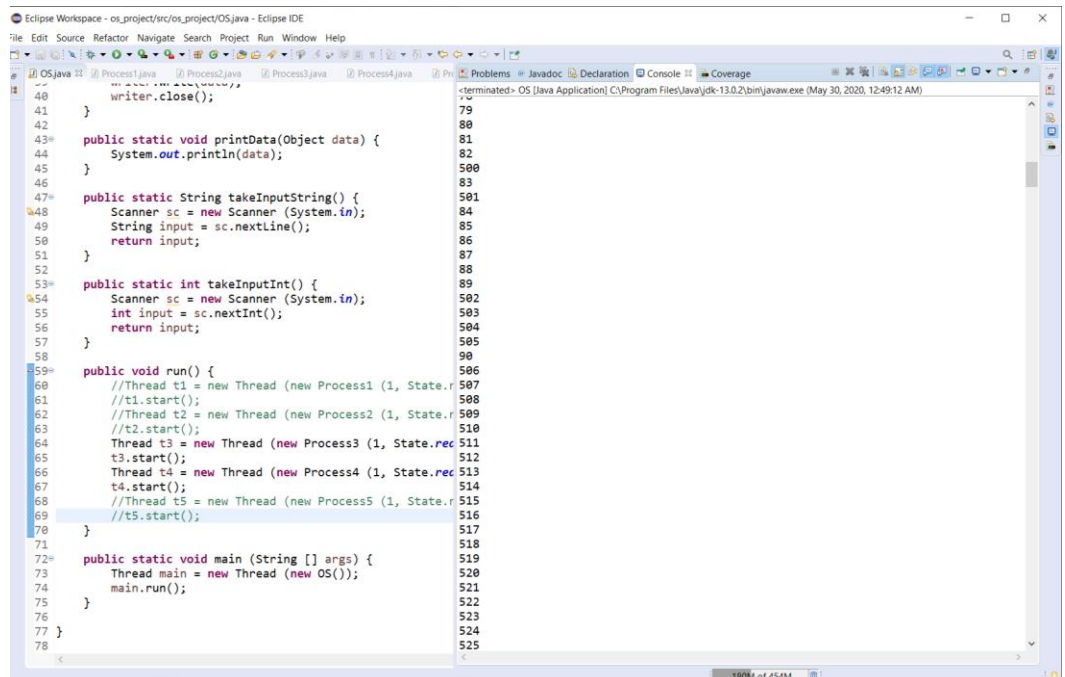


The screenshot shows the Eclipse IDE with the file `OS.java` open. The code defines a `run()` method that creates and starts five threads: `Process1`, `Process2`, `Process3`, `Process4`, and `Process5`. The `main` method creates a `Thread` object for `OS` and calls `run()`. The console on the right shows the output of the program, which includes the contents of `raneem.txt` and the termination of the main method.

```

40      writer.close();
41    }
42
43    public static void printData(Object data) {
44      System.out.println(data);
45    }
46
47    public static String takeInputString() {
48      Scanner sc = new Scanner(System.in);
49      String input = sc.nextLine();
50      return input;
51    }
52
53    public static int takeInputInt() {
54      Scanner sc = new Scanner(System.in);
55      int input = sc.nextInt();
56      return input;
57    }
58
59    public void run() {
60      //Thread t1 = new Thread (new Process1 (1, State.r
61      //t1.start();
62      //Thread t2 = new Thread (new Process2 (1, State.r
63      //t2.start();
64      Thread t3 = new Thread (new Process3 (1, State.rec
65      t3.start();
66      Thread t4 = new Thread (new Process4 (1, State.rec
67      t4.start();
68      //Thread t5 = new Thread (new Process5 (1, State.r
69      //t5.start();
70    }
71
72    public static void main (String [] args) {
73      Thread main = new Thread (new OS());
74      main.run();
75    }
76  }
77 }
78

```

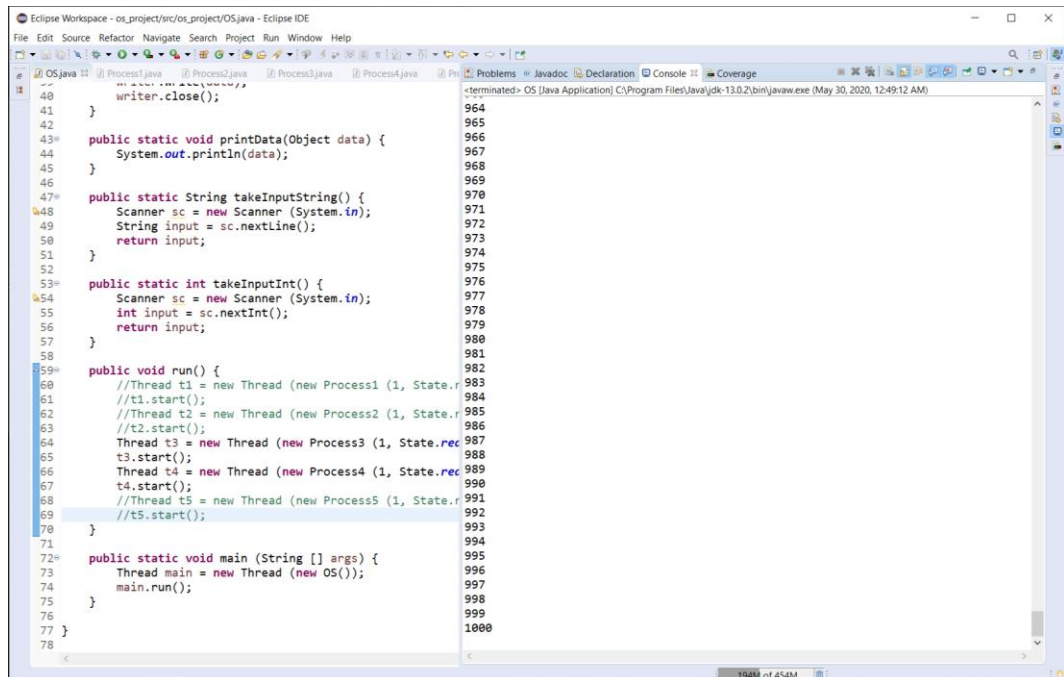


This screenshot is similar to the one above, showing the same `OS.java` code. The console output on the right is more extensive, showing the execution of the threads and the termination of the main method.

```

40      writer.close();
41    }
42
43    public static void printData(Object data) {
44      System.out.println(data);
45    }
46
47    public static String takeInputString() {
48      Scanner sc = new Scanner(System.in);
49      String input = sc.nextLine();
50      return input;
51    }
52
53    public static int takeInputInt() {
54      Scanner sc = new Scanner(System.in);
55      int input = sc.nextInt();
56      return input;
57    }
58
59    public void run() {
60      //Thread t1 = new Thread (new Process1 (1, State.r
61      //t1.start();
62      //Thread t2 = new Thread (new Process2 (1, State.r
63      //t2.start();
64      Thread t3 = new Thread (new Process3 (1, State.rec
65      t3.start();
66      Thread t4 = new Thread (new Process4 (1, State.rec
67      t4.start();
68      //Thread t5 = new Thread (new Process5 (1, State.r
69      //t5.start();
70    }
71
72    public static void main (String [] args) {
73      Thread main = new Thread (new OS());
74      main.run();
75    }
76  }
77 }
78

```



```

40      writer.close();
41    }
42
43    public static void printData(Object data) {
44        System.out.println(data);
45    }
46
47    public static String takeInputString() {
48        Scanner sc = new Scanner (System.in);
49        String input = sc.nextLine();
50        return input;
51    }
52
53    public static int takeInputInt() {
54        Scanner sc = new Scanner (System.in);
55        int input = sc.nextInt();
56        return input;
57    }
58
59    public void run() {
60        //Thread t1 = new Thread (new Process1 (1, State.r
61        //t1.start();
62        //Thread t2 = new Thread (new Process2 (1, State.r
63        //t2.start();
64        Thread t3 = new Thread (new Process3 (1, State.rec
65        t3.start();
66        Thread t4 = new Thread (new Process4 (1, State.rec
67        t4.start();
68        //Thread t5 = new Thread (new Process5 (1, State.r
69        //t5.start();
70    }
71
72    public static void main (String [] args) {
73        Thread main = new Thread (new OS());
74        main.run();
75    }
76
77 }
78

```

As evident from the above screenshots, process 3 started counting then process 4 started as well and then they both consecutively continued to run till they both finished counting and the main method terminated.



## **Milestone 2**

### **1. Implementation**

We used the solution code for milestone 1, not ours as it was implemented slightly differently, therefore all that is related to milestone is not the same as what was explained above.

We removed the “p.start();” in the “createProcess(int ProcessID)” method as that would start all processes one after the other and disregard the scheduler. We also added a readyQueue to the OperatingSystem class where we added every newly created process to it using “readyQueue.add(Process p)”.

In a new method name “fcfsScheduler()” we implemented a First Come First Serve scheduler, therefore we didn’t really use the semaphores however we still implemented them in a separate class which I will explain later. Regarding the scheduler method; we first check if the readyQueue is not empty and start the process on top then, in a do while loop, we keep checking the state of the process till its state is set to “Terminated” (otherwise we let it continue) then we start the next process in the readyQueue, this keeps looping while the readyQueue size is greater than 0. Therefore, implementing the FCFS algorithm

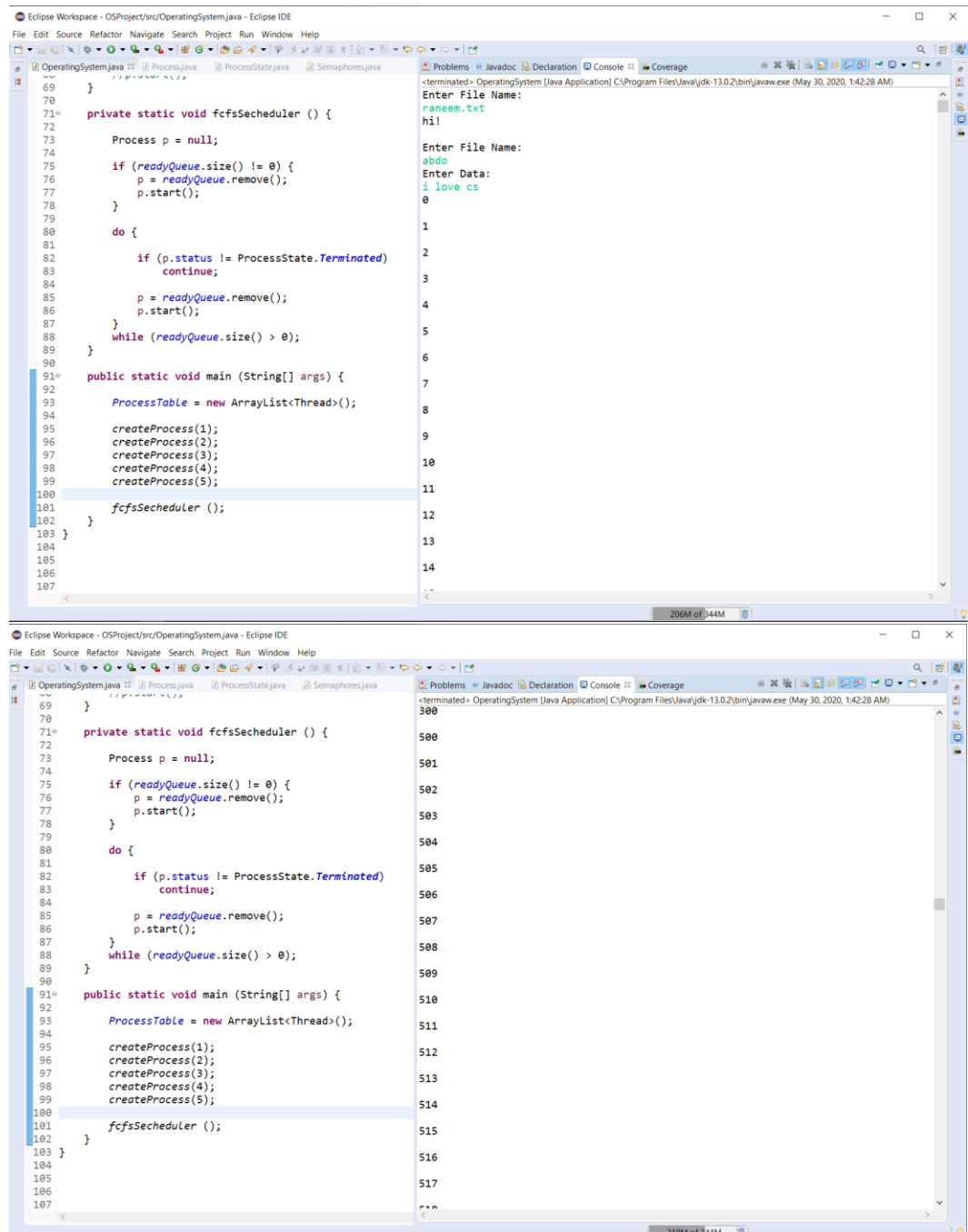
where the first created process runs from start to finish and then the second one starts and so on. In regards to the implementation of semaphores; we created a class name “Semaphores” that is made up of 4 semaphores and 4 queues, one for each. Each semaphore has two methods; “sem(Name)Wait(Process p)” which checks the availability of the semaphore and either lets the process run or suspends it and adds it to the queue, the “sem(Name)Post()” however, returns the semaphore to available and checks whether the queue contains and processes or not, if it does then it adds the first one to the readyQueue and resumes it.

We also modified the Process class to support the use of semaphores and scheduling. For instance, whenever a process is run, we remove it from the readyQueue to not interfere with the scheduling algorithm. Whenever a process tries to use any of the OS’s system calls, we call the “wait(Process P)” method of the semaphore to check it’s availability and when the process is done using it, we release the semaphore using its Post() method. Finally, in the OperatingSystem class’s main method, we create the processes and call the method fcfsScheduler() to schedule the order in which the processes are executed.



## 2. Screenshots of output

a) Execute all the processes using the implemented scheduling algorithm



The top screenshot shows the Eclipse IDE with the file `OperatingSystem.java` open. The code defines a `fcfsScheduler` method and a `main` method that creates five processes. The console output shows the program starting and the first process printing "hi!".

```

69
70
71 private static void fcfsScheduler () {
72
73     Process p = null;
74
75     if (readyQueue.size() != 0) {
76         p = readyQueue.remove();
77         p.start();
78     }
79
80     do {
81
82         if (p.status != ProcessState.Terminated)
83             continue;
84
85         p = readyQueue.remove();
86         p.start();
87     }
88     while (readyQueue.size() > 0);
89
90 }
91
92 public static void main (String[] args) {
93     ProcessTable = new ArrayList<Thread>();
94
95     createProcess(1);
96     createProcess(2);
97     createProcess(3);
98     createProcess(4);
99     createProcess(5);
100
101     fcfsScheduler ();
102 }
103
104
105
106
107

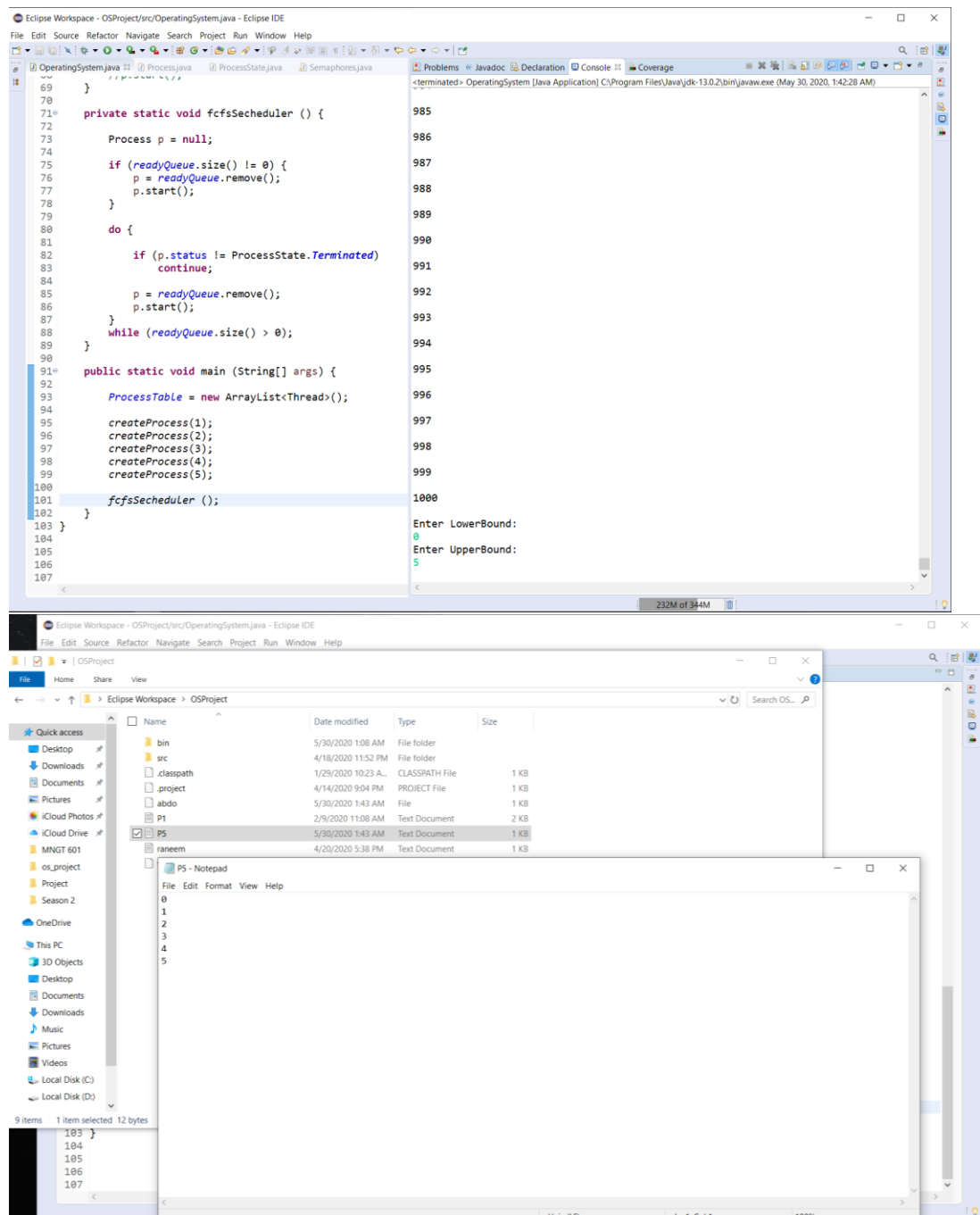
```

The bottom screenshot shows the same code, but the console output is scrolled down to show the execution of five processes. The output shows the program starting and the first process printing "hi!".

```

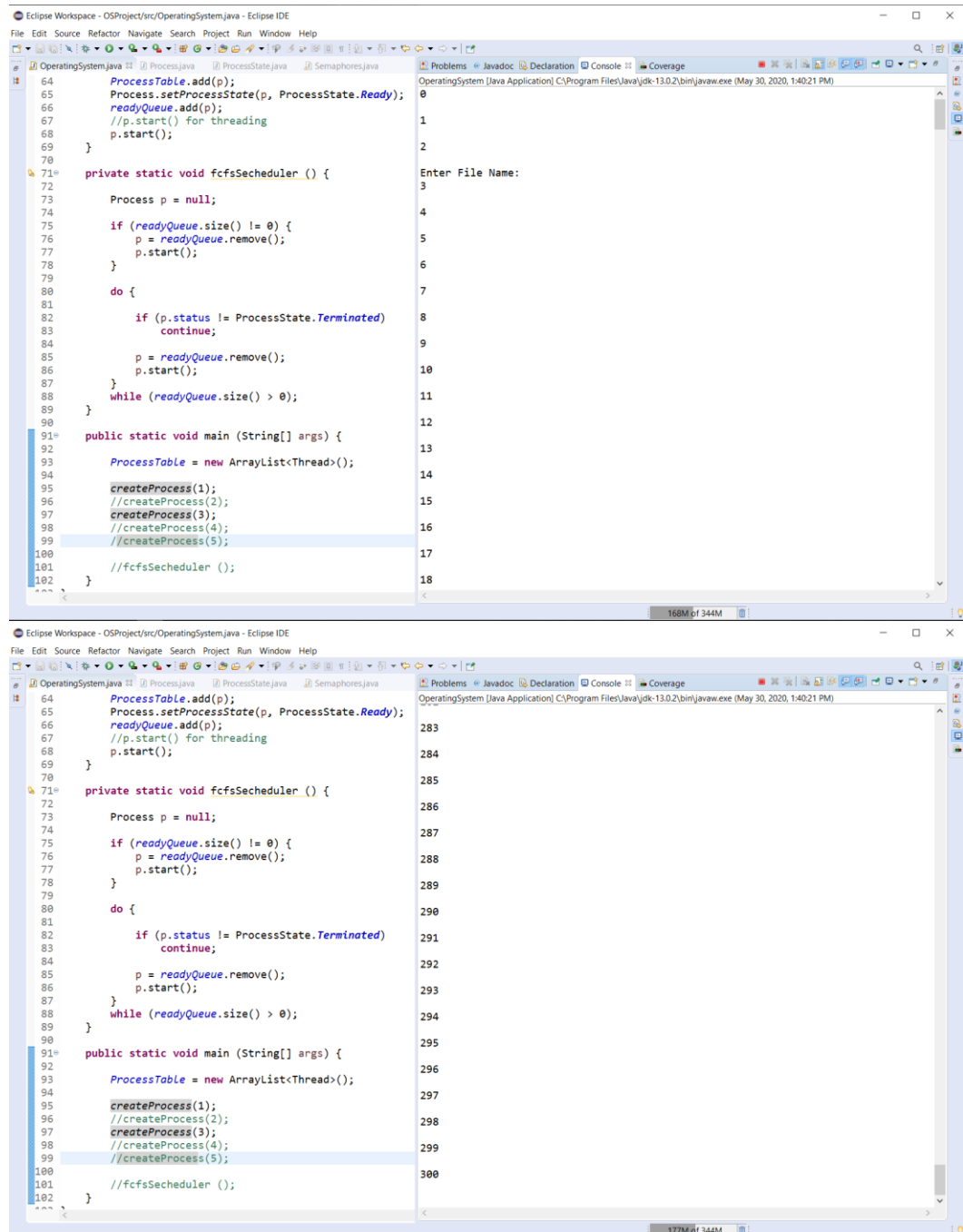
<terminated> OperatingSystem [Java Application] C:\Program Files\Java\jdk-13.0.2\bin\javaw.exe (May 30, 2020, 1:42:28 AM)
Enter File Name:
raneem.txt
hi!
Enter File Name:
abdo
Enter Data:
i love cs
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1
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```



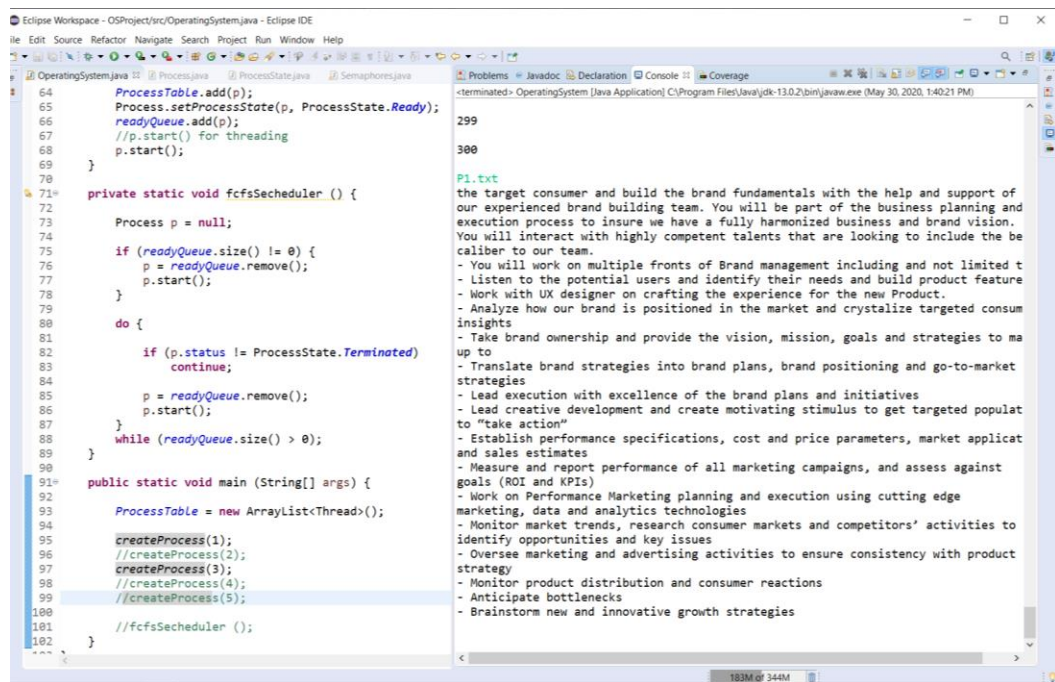
As is evident from the above screenshots, the process where executed in order of their creation and each process finishes before the next starts.

## b) Execute Process 1 and Process 3 without the scheduling algorithm



```

Eclipse Workspace - OSProject/src/OperatingSystem.java - Eclipse IDE
File Edit Source Refactor Navigate Search Project Run Window Help
OperatingSystem.java Process.java ProcessState.java Semaphores.java
64 ProcessTable.add(p);
65 Process.setProcessState(p, ProcessState.Ready);
66 readyQueue.add(p);
67 //p.start() for threading
68 p.start();
69 }
70
71 private static void fcfsSecheduler () {
72     Process p = null;
73
74     if (readyQueue.size() != 0) {
75         p = readyQueue.remove();
76         p.start();
77     }
78
79     do {
80         if (p.status != ProcessState.Terminated)
81             continue;
82
83         p = readyQueue.remove();
84         p.start();
85     } while (readyQueue.size() > 0);
86 }
87
88 public static void main (String[] args) {
89     ProcessTable = new ArrayList<Thread>();
90
91     createProcess(1);
92     //createProcess(2);
93     createProcess(3);
94     //createProcess(4);
95     //createProcess(5);
96
97     //fcfsSecheduler ();
98 }
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```



```

64 ProcessTable.add(p);
65 Process.setProcessState(p, ProcessState.Ready);
66 readyQueue.add(p);
67 //p.start() for threading
68 p.start();
69 }
70
71 private static void fcfsScheduler () {
72     Process p = null;
73
74     if (readyQueue.size() != 0) {
75         p = readyQueue.remove();
76         p.start();
77     }
78
79     do {
80         if (p.status != ProcessState.Terminated)
81             continue;
82
83         p = readyQueue.remove();
84         p.start();
85     } while (readyQueue.size() > 0);
86 }
87
88 public static void main (String[] args) {
89     ProcessTable = new ArrayList<Thread>();
90
91     createProcess(1);
92     //createProcess(2);
93     createProcess(3);
94     //createProcess(4);
95     //createProcess(5);
96
97     //fcfsScheduler ();
98 }
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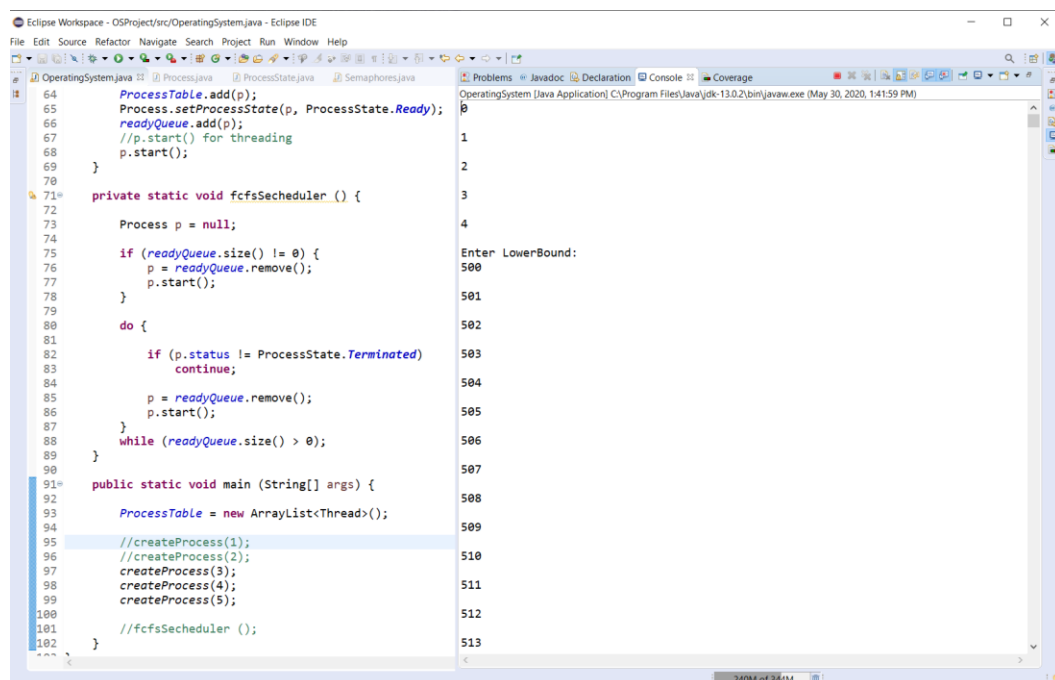
```

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P1.txt  
the target consumer and build the brand fundamentals with the help and support of our experienced brand building team. You will be part of the business planning and execution process to insure we have a fully harmonized business and brand vision. You will interact with highly competent talents that are looking to include the be caliber to our team.

- You will work on multiple fronts of Brand management including and not limited to
- Listen to the potential users and identify their needs and build product feature to "take action"
- Analyze how our brand is positioned in the market and crystalize targeted consum insights
- Take brand ownership and provide the vision, mission, goals and strategies to ma up to
- Translate brand strategies into brand plans, brand positioning and go-to-market strategies
- Lead execution with excellence of the brand plans and initiatives
- Lead creative development and create motivating stimulus to get targeted populat
- Establish performance specifications, cost and price parameters, market applicat and sales estimates
- Measure and report performance of all marketing campaigns, and assess against goals (ROI and KPIs)
- Work on Performance Marketing planning and execution using cutting edge marketing, data and analytics technologies
- Monitor market trends, research consumer markets and competitors' activities to identify opportunities and key issues
- Oversee marketing and advertising activities to ensure consistency with product strategy
- Monitor product distribution and consumer reactions
- Anticipate bottlenecks
- Brainstorm new and innovative growth strategies

## c) Execute Process 5, Process3 and Process 4 without the scheduling algorithm

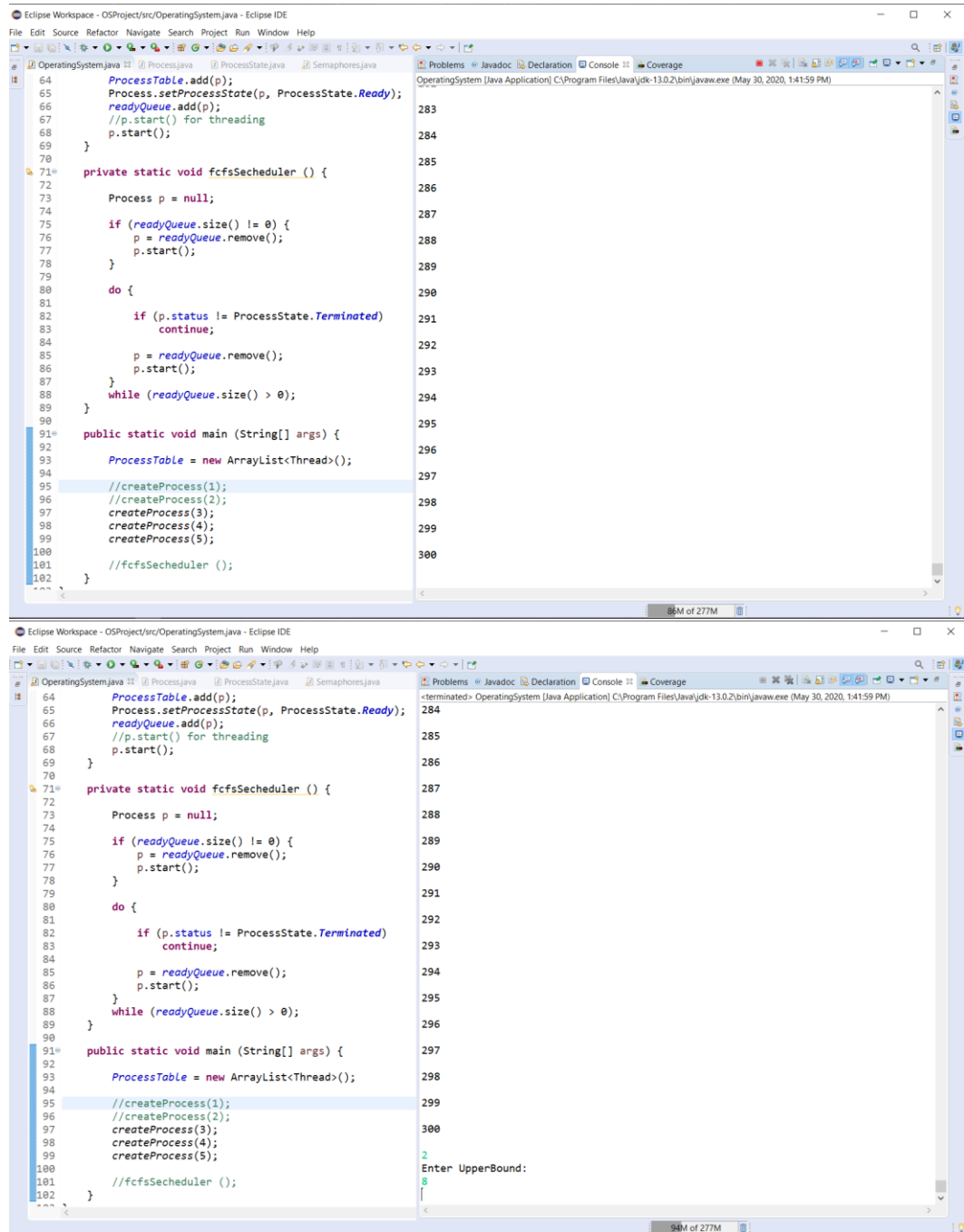


```

64 ProcessTable.add(p);
65 Process.setProcessState(p, ProcessState.Ready);
66 readyQueue.add(p);
67 //p.start() for threading
68 p.start();
69 }
70
71 private static void fcfsScheduler () {
72     Process p = null;
73
74     if (readyQueue.size() != 0) {
75         p = readyQueue.remove();
76         p.start();
77     }
78
79     do {
80         if (p.status != ProcessState.Terminated)
81             continue;
82
83         p = readyQueue.remove();
84         p.start();
85     } while (readyQueue.size() > 0);
86 }
87
88 public static void main (String[] args) {
89     ProcessTable = new ArrayList<Thread>();
90
91     //createProcess(1);
92     //createProcess(2);
93     createProcess(3);
94     createProcess(4);
95     createProcess(5);
96
97     //fcfsScheduler ();
98 }
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The image displays two screenshots of the Eclipse IDE, showing the same Java code for a process scheduler. The code is located in the file `OperatingSystem.java` within the project `OSProject\src\OperatingSystem.java`.

**Top Screenshot:** The code is shown in the editor. The `main` method is at line 91, and the `fcfsScheduler` method is at line 71. The `main` method creates a `ProcessTable` and calls `createProcess` for five processes. The `fcfsScheduler` method is a private static void method that manages the process queue.

```

64  ProcessTable.add(p);
65  Process.setProcessState(p, ProcessState.Ready);
66  readyQueue.add(p);
67  //p.start() for threading
68  p.start();
69  }
70
71  private static void fcfsScheduler () {
72
73      Process p = null;
74
75      if (readyQueue.size() != 0) {
76          p = readyQueue.remove();
77          p.start();
78      }
79
80      do {
81
82          if (p.status != ProcessState.Terminated)
83              continue;
84
85          p = readyQueue.remove();
86          p.start();
87      }
88      while (readyQueue.size() > 0);
89  }
90
91  public static void main (String[] args) {
92
93      ProcessTable = new ArrayList<Thread>();
94
95      //createProcess(1);
96      //createProcess(2);
97      createProcess(3);
98      createProcess(4);
99      createProcess(5);
100
101      //fcfsScheduler ();
102  }

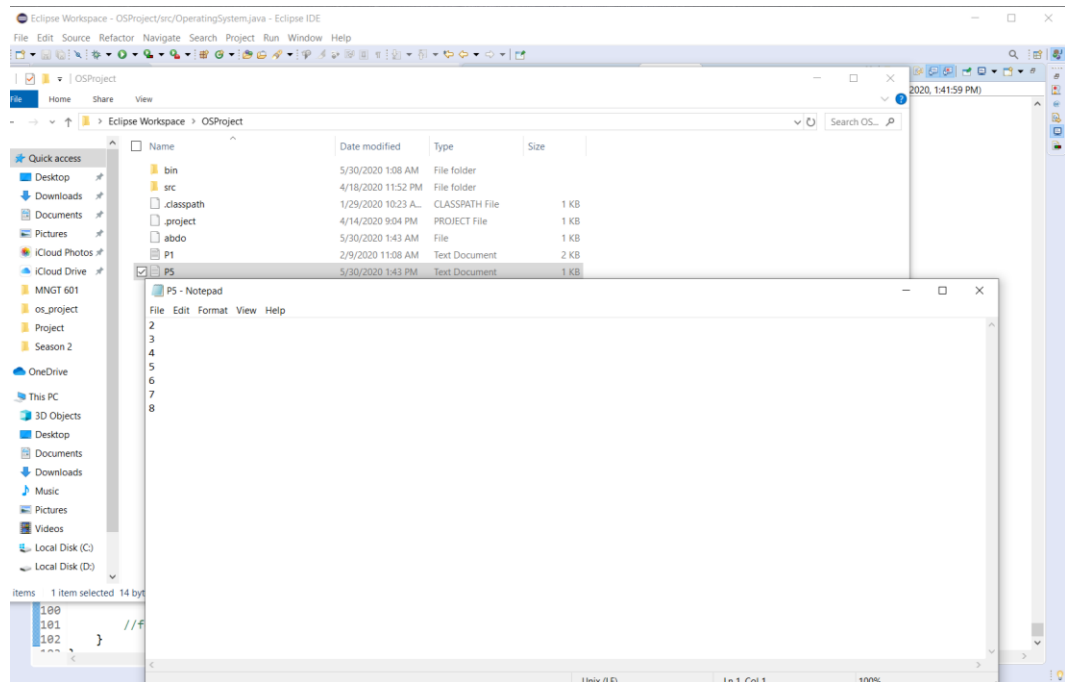
```

**Bottom Screenshot:** The code is the same, but the console output shows the execution results. The output indicates that the process has terminated and the user has entered the upper bound.

```

<terminated> OperatingSystem [Java Application] C:\Program Files\Java\jdk-13.0.2\bin\javaw.exe (May 30, 2020, 1:41:59 PM)
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Enter UpperBound:
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```



### 3. Questions

a) Why are semaphores important to have? Why did we need to use them?

Semaphores are important as they control access to a common resource used by multiple process at the same time. They prevent the arise of problems of more than one process trying to access the resource simultaneously which may result in data coherence or a race condition.

We used them in the project to prevent such problems from happening as we use threading and therefore the processes run simultaneously

and might need the same resource at the same time.

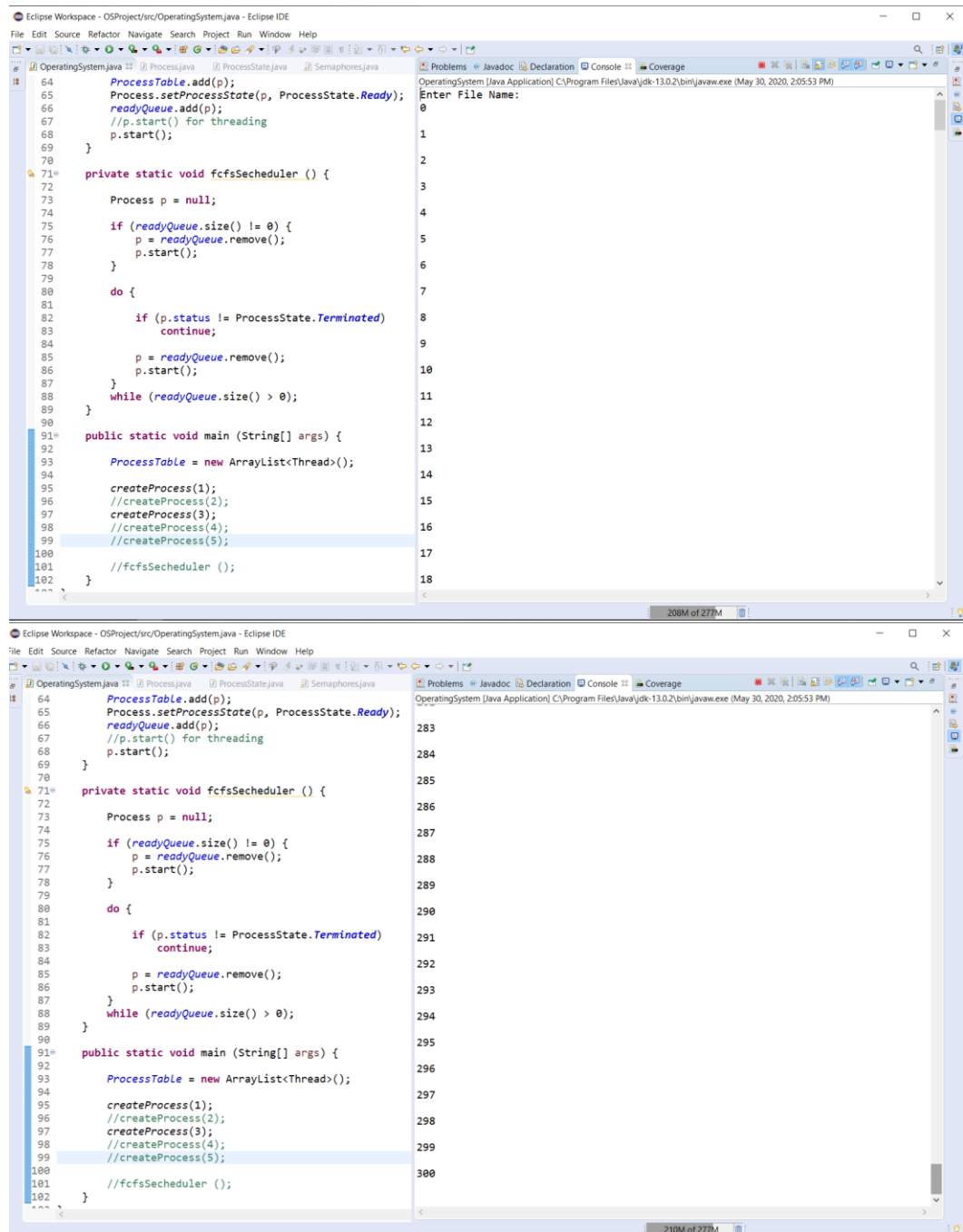
b) What do we achieve by using semaphores?

A semaphore implements synchronization and mutual exclusion therefore, making us achieve concurrency or multithreading.

c) Why does a process change its state?

Processes have 5 states; ready, new, waiting, running and terminated. The various states are important for identifying the current stage a process is at and helps the scheduling algorithm select one of the processes in the ready state to run. When a process is created, it is in the new state, it then goes to ready; signifying that it is ready to run. When a process needs a user input or when it is trying to use a resource that is not available (is being used by another process) it goes to the waiting stage. Finally, the terminated state is for when the process has finished executing.

d) Imagine a scenario where Process 1 arrives at T=0 and Process 3 arrives at T=1, show the output and explain what happens if you executing without the scheduling algorithm.



```

64     ProcessTable.add(p);
65     Process.setProcessState(p, ProcessState.Ready);
66     readyQueue.add(p);
67     //p.start() for threading
68     p.start();
69 }
70
71 private static void fcfsScheduler () {
72     Process p = null;
73
74     if (readyQueue.size() != 0) {
75         p = readyQueue.remove();
76         p.start();
77     }
78
79     do {
80         if (p.status != ProcessState.Terminated)
81             continue;
82
83         p = readyQueue.remove();
84         p.start();
85     } while (readyQueue.size() > 0);
86 }
87
88 public static void main (String[] args) {
89     ProcessTable = new ArrayList<Thread>();
90
91     createProcess(1);
92     //createProcess(2);
93     createProcess(3);
94     //createProcess(4);
95     //createProcess(5);
96
97     //fcfsScheduler ();
98 }
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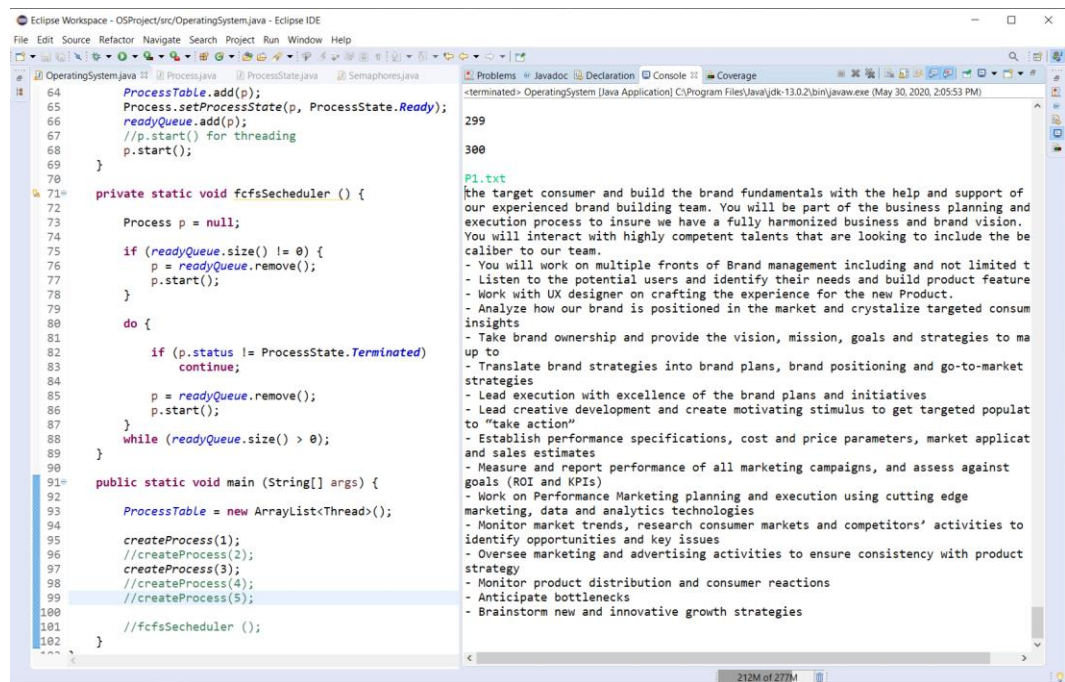
```

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```





The screenshot shows the Eclipse IDE with a Java project named 'OSProject'. The main editor displays the 'OperatingSystem.java' file. The code defines a 'ProcessTable' as an 'ArrayList<Thread>', a 'readyQueue' as an 'ArrayList<Process>', and a 'Process' class with a 'start()' method. The 'main' method creates five processes and starts a 'fcfsScheduler()' thread. The 'fcfsScheduler()' method processes the 'readyQueue' and prints the contents of 'P1.txt' to the console. The console output shows the execution of the processes and the printing of 'P1.txt'.

```

64 ProcessTable.add(p);
65 Process.setProcessState(p, ProcessState.Ready);
66 readyQueue.add(p);
67 //p.start() for threading
68 p.start();
69 }
70
71 private static void fcfsScheduler () {
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74     if (readyQueue.size() != 0) {
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79     do {
80         if (p.status != ProcessState.Terminated)
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83         p = readyQueue.remove();
84         p.start();
85     } while (readyQueue.size() > 0);
86
87     public static void main (String[] args) {
88         ProcessTable = new ArrayList<Thread>();
89
90         createProcess(1);
91         //createProcess(2);
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93         //createProcess(4);
94         //createProcess(5);
95
96         //fcfsScheduler ();
97     }
98 }
99
100
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```

Console Output:

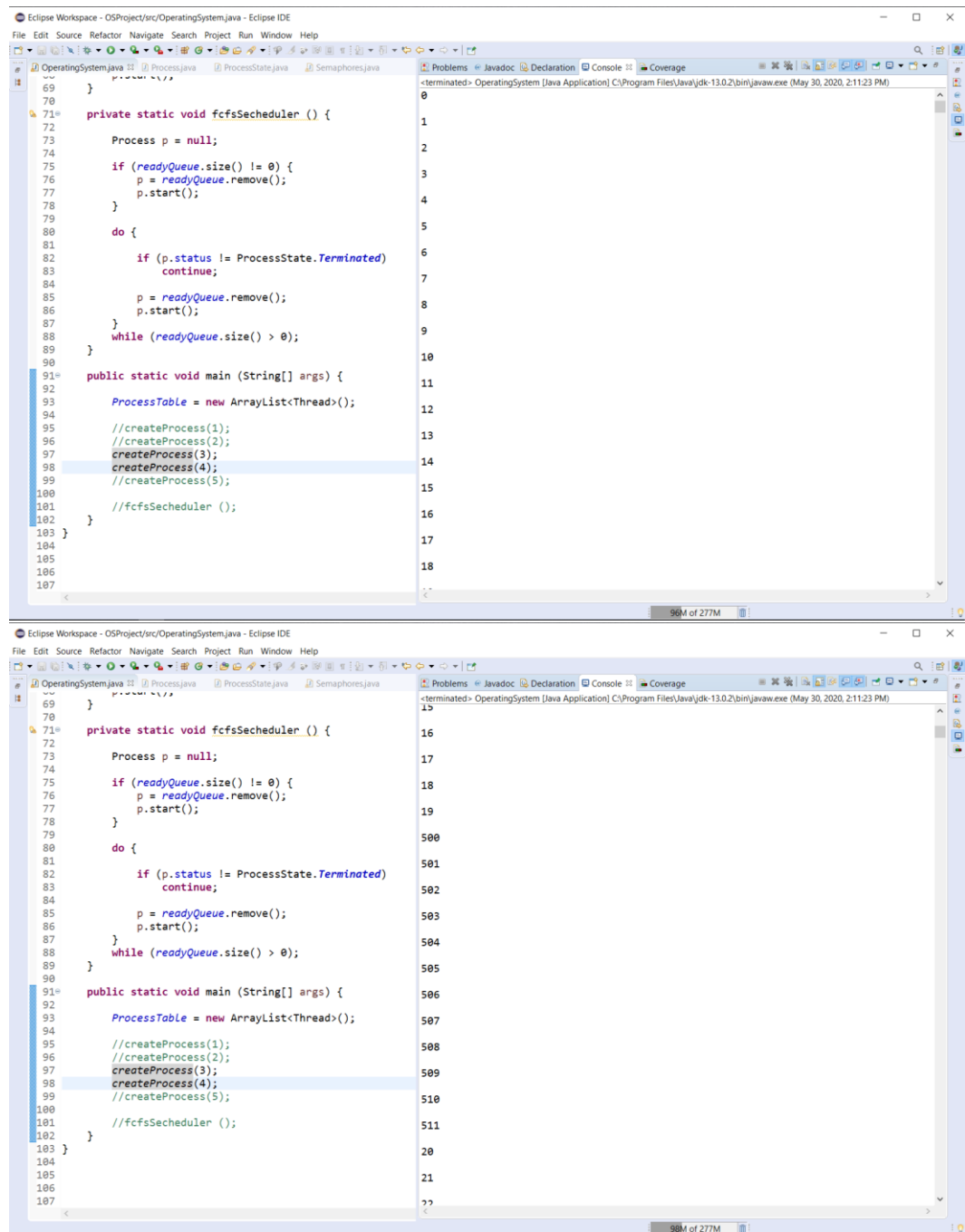
```

<terminated> OperatingSystem [Java Application] C:\Program Files\Java\jdk-13.0.2\bin\javaw.exe (May 30, 2020, 2:05:53 PM)
299
300
P1.txt
the target consumer and build the brand fundamentals with the help and support of
our experienced brand building team. You will be part of the business planning and
execution process to insure we have a fully harmonized business and brand vision.
You will interact with highly competent talents that are looking to include the be
caliber to our team.
- You will work on multiple fronts of Brand management including and not limited t
- Listen to the potential users and identify their needs and build product feature
- Work with UX designer on crafting the experience for the new Product.
- Analyze how our brand is positioned in the market and crystalize targeted consum
insights
- Take brand ownership and provide the vision, mission, goals and strategies to ma
up to
- Translate brand strategies into brand plans, brand positioning and go-to-market
strategies
- Lead execution with excellence of the brand plans and initiatives
- Lead creative development and create motivating stimulus to get targeted populat
to "take action"
- Establish performance specifications, cost and price parameters, market applicat
and sales estimates
- Measure and report performance of all marketing campaigns, and assess against
goals (ROI and KPIs)
- Work on Performance Marketing planning and execution using cutting edge
marketing, data and analytics technologies
- Monitor market trends, research consumer markets and competitors' activities to
identify opportunities and key issues
- Oversee marketing and advertising activities to ensure consistency with product
strategy
- Monitor product distribution and consumer reactions
- Anticipate bottlenecks
- Brainstorm new and innovative growth strategies

```

As evident from the above screenshots, Process 1 started first then Process 3 counted from 0 to 300 while Process 1 waited for a user to input the filename. After inputting the filename “P1.txt”, Process 1 outputted its contents and the main method terminated.

e) Imagine a scenario where Process 3 arrives at T=0 and Process 4 arrives at T=1, show the output and explain what happens if you executing without the scheduling algorithm.



```

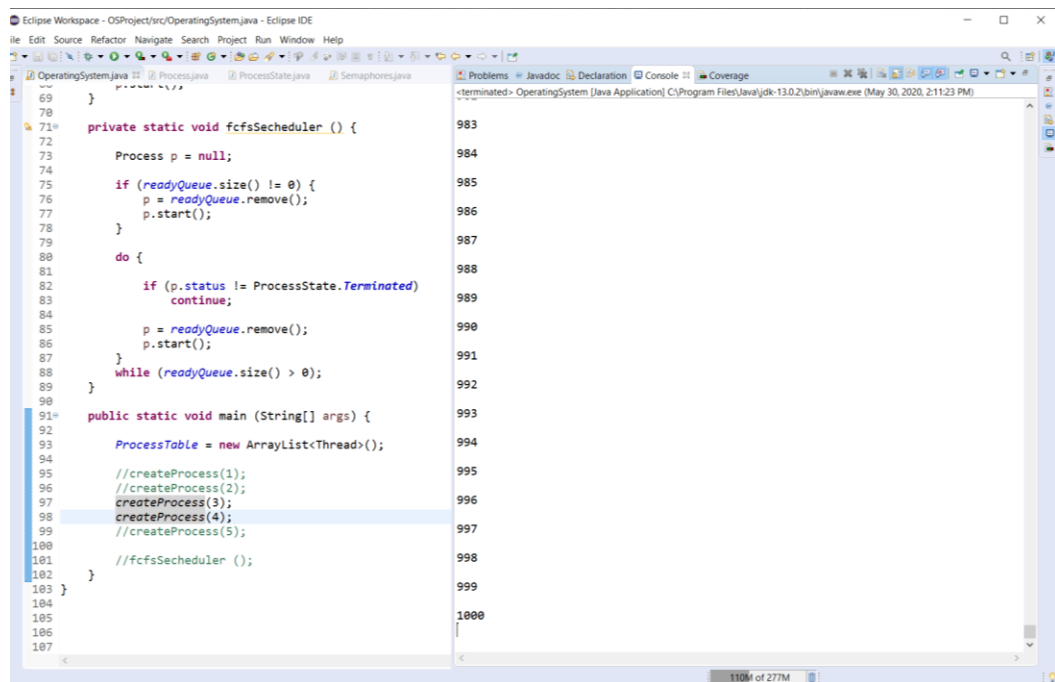
Eclipse Workspace - OSProject/src/OperatingSystem.java - Eclipse IDE
File Edit Source Refactor Navigate Search Project Run Window Help
OperatingSystem.java Process.java ProcessState.java Semaphores.java
Problems Javadoc Declaration Console Coverage
<terminated> OperatingSystem [Java Application] C:\Program Files\Java\jdk-13.0.2\bin\javaw.exe (May 30, 2020, 2:11:23 PM)

69 }
70
71 private static void fcfsScheduler () {
72     Process p = null;
73
74     if (readyQueue.size() != 0) {
75         p = readyQueue.remove();
76         p.start();
77     }
78
79     do {
80
81         if (p.status != ProcessState.Terminated)
82             continue;
83
84         p = readyQueue.remove();
85         p.start();
86     }
87     while (readyQueue.size() > 0);
88 }
89
90
91 public static void main (String[] args) {
92
93     ProcessTable = new ArrayList<Thread>();
94
95     //createProcess(1);
96     //createProcess(2);
97     createProcess(3);
98     createProcess(4);
99     //createProcess(5);
100
101     //fcfsScheduler ();
102 }
103 }
104
105
106
107

Eclipse Workspace - OSProject/src/OperatingSystem.java - Eclipse IDE
File Edit Source Refactor Navigate Search Project Run Window Help
OperatingSystem.java Process.java ProcessState.java Semaphores.java
Problems Javadoc Declaration Console Coverage
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100
101     //fcfsScheduler ();
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103 }
104
105
106
107

```



```

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96     createProcess(4);
97     //createProcess(5);
98
99     //fcfsScheduler ();
100 }
101
102
103 }
104
105
106
107
  
```

Console Output:

```

983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
  
```

As evident from the above screenshots, process 3 started counting then process 4 started as well and then they both consecutively continued to run till they both finished counting and the main method terminated.

#### f) Why is scheduling important?

Scheduling controls how processes are to be executed by processor(s) over time. Only one thread at a time can run in a single process. It is important as it improves processor efficiency, response time and throughput.

g) Explain the advantages and disadvantages of your team's implemented scheduling algorithm.

We used the FCFS (First Come First Serve) scheduling algorithm. When the currently running process has ceased to execute, the process that has been in the ready queue the longest is selected for running.

The main advantage of this algorithm would be that it is simple and easy to understand.

The disadvantages however include; suffering of processes with less execution time, meaning their waiting time is often quite long. Moreover, FCFS algorithm is particularly troublesome for time-sharing systems, where it is important that each user get a share of the CPU at regular intervals.

h) Imagine a scenario where Process 1 arrives at  $T=0$  and Process 3 arrives at  $T=1$ , show the output and explain what happens if you are executing with your implemented scheduling algorithm.

Answered in the presentation.