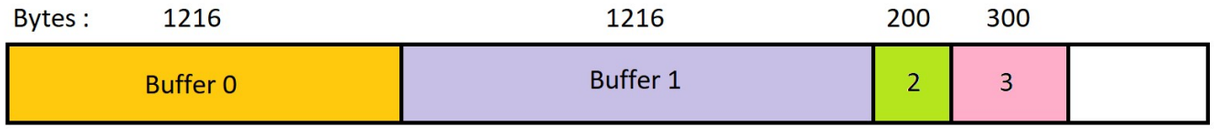
By studying the SDCC library source code for the 8051 and writing your own test code, learn the details of how SDCC does heap management, specifically for the `malloc()` and `free()` functionality. Given the program described in Required Element 17, evaluate how the heap is managed for the following sequence:
Step 1) The heap is created with 3200 bytes. Step 2) Buffers 0 and 1 are created with 1200 bytes each. Step 3) Buffer 2 of 200 bytes is created using the '+' command. Step 4) Buffer 3 of 300 bytes is created using the '+' command. Step 5) Buffer 2 is deleted using the '-' command.

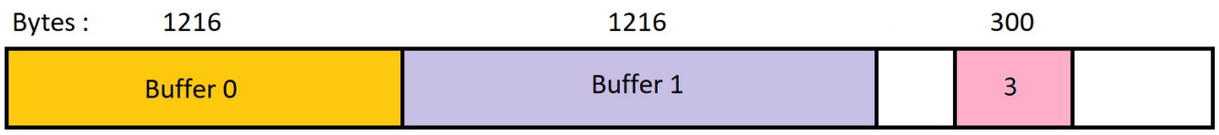
```
Monish Nene ESD Spring 2018 Lab 3
Enter the size for buffer 0 and buffer 1 between 32 to 3200 bytes and a multiple of 32:1200
invalid number.
Re-enter number:
Enter the size for buffer 0 and buffer 1 between 32 to 3200 bytes and a multiple of 32:1216
Created Buffer 0 with 1216 bytes
Created Buffer 1 with 1216 bytes
'+' Add Buffer, '-' Delete Buffer, '=' Dump Buffer 0, '?' Buffer Query, '@' Reset Code
Enter the size for buffer 2 between 20 to 400 bytes:200
Created Buffer 2 with 200 bytes
Enter the size for buffer 3 between 20 to 400 bytes:300
Created Buffer 3 with 300 bytes
Buffer number = 3
Buffer Start Address = 2649
Buffer End Address = 2949
Allocated Space= 300 bytes
Used Space = 0 bytes
Unused Space = 300 bytes
Buffer number = 2
Buffer Start Address = 2445
Buffer End Address = 2645
Allocated Space= 200 bytes
Used Space = 0 bytes
Unused Space = 200 bytes
Buffer number = 1
Buffer Start Address = 1225
Buffer End Address = 2441
Allocated Space= 1216 bytes
Used Space = 0 bytes
Unused Space = 1216 bytes
Buffer number = 0
Buffer Start Address = 5
Buffer End Address = 1221
Allocated Space= 1216 bytes
Used Space = 0 bytes
Unused Space = 1216 bytes
```

What does the heap free memory pool look like after the sequence above?

Before step 5



After step 5

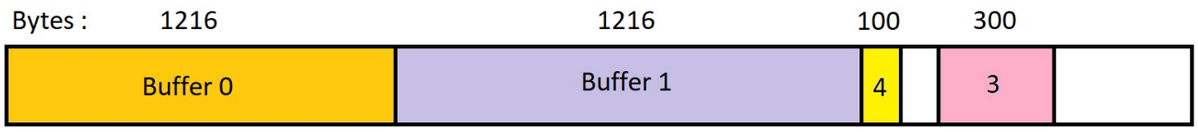


Describe what would happen for the three following possible cases:

Note: Each buffer has a 5 byte header. Size 1216 was used instead of 1200 as it is divisible by 32.

a. If Step 6 of the sequence was to create a buffer of 100 bytes, where would it be allocated?
Answer : The New Buffer is created with the same start address as the Previous one.

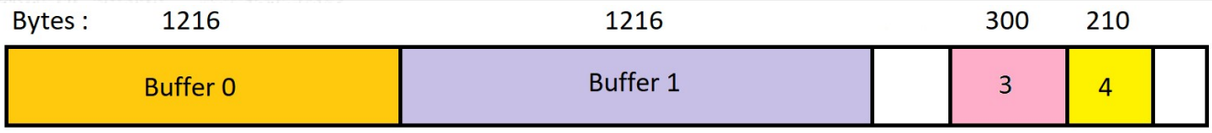
```
Monish Nene ESD Spring 2018 Lab 3
Enter the size for buffer 0 and buffer 1 between 32 to 3200 bytes and a multiple of 32:1216
Created Buffer 0 with 1216 bytes
Created Buffer 1 with 1216 bytes
'+' Add Buffer, '-' Delete Buffer, '=' Dump Buffer 0, '?' Buffer Query, '@' Reset Code
Enter the size for buffer 2 between 20 to 400 bytes:200
Created Buffer 2 with 200 bytes
Enter the size for buffer 3 between 20 to 400 bytes:300
Created Buffer 3 with 300 bytes
What is the buffer id of the buffer you want to delete?(Note: Buffer 0 can't be deleted.)2
Deleted Buffer 2
Enter the size for buffer 2 between 20 to 400 bytes:100
Created Buffer 2 with 100 bytes
Buffer number = 3
Buffer Start Address = 2649
Buffer End Address = 2949
Allocated Space= 300 bytes
Used Space = 0 bytes
Unused Space = 300 bytes
Buffer number = 2
Buffer Start Address = 2445
Buffer End Address = 2545
Allocated Space= 100 bytes
Used Space = 0 bytes
Unused Space = 100 bytes
Buffer number = 1
Buffer Start Address = 1225
Buffer End Address = 2441
Allocated Space= 1216 bytes
Used Space = 0 bytes
Unused Space = 1216 bytes
Buffer number = 0
Buffer Start Address = 5
Buffer End Address = 1221
Allocated Space= 1216 bytes
Used Space = 0 bytes
Unused Space = 1216 bytes
```



b. If Step 6 of the sequence was to create a buffer of 210 bytes, where would it be allocated?

Answer : The New Buffer is created after the buffer 3 end address in the heap.

```
Monish Nene ESD Spring 2018 Lab 3
Enter the size for buffer 0 and buffer 1 between 32 to 3200 bytes and a multiple of 32:1216
Created Buffer 0 with 1216 bytes
Created Buffer 1 with 1216 bytes
'+' Add Buffer, '-' Delete Buffer, '=' Dump Buffer 0, '?' Buffer Query, '@' Reset Code
Enter the size for buffer 2 between 20 to 400 bytes:200
Created Buffer 2 with 200 bytes
Enter the size for buffer 3 between 20 to 400 bytes:300
Created Buffer 3 with 300 bytes
What is the buffer id of the buffer you want to delete?(Note: Buffer 0 can't be deleted.)2
Deleted Buffer 2
Enter the size for buffer 2 between 20 to 400 bytes:210
Created Buffer 2 with 210 bytes
Buffer number = 3
Buffer Start Address = 2649
Buffer End Address = 2949
Allocated Space= 300 bytes
Used Space = 0 bytes
Unused Space = 300 bytes
Buffer number = 2
Buffer Start Address = 2953
Buffer End Address = 3163
Allocated Space= 210 bytes
Used Space = 0 bytes
Unused Space = 210 bytes
Buffer number = 1
Buffer Start Address = 1225
Buffer End Address = 2441
Allocated Space= 1216 bytes
Used Space = 0 bytes
Unused Space = 1216 bytes
Buffer number = 0
Buffer Start Address = 5
Buffer End Address = 1221
Allocated Space= 1216 bytes
Used Space = 0 bytes
Unused Space = 1216 bytes
```



c. If Step 6 of the sequence was to create a buffer of 400 bytes, where would it be allocated?
Answer : the memory allocation for the new buffer fails. There is no location in the heap with continuous 400 bytes + 5 bytes for header. The heap is fragmented with 205 bytes in middle and 350 bytes at end.

```
Monish Nene ESD Spring 2018 Lab 3
Enter the size for buffer 0 and buffer 1 between 32 to 3200 bytes and a multiple of 32:1216
Created Buffer 0 with 1216 bytes
Created Buffer 1 with 1216 bytes
'+' Add Buffer, '-' Delete Buffer, '=' Dump Buffer 0, '?' Buffer Query, '@' Reset Code
Enter the size for buffer 2 between 20 to 400 bytes:200
Created Buffer 2 with 200 bytes
Enter the size for buffer 3 between 20 to 400 bytes:300
Created Buffer 3 with 300 bytes
What is the buffer id of the buffer you want to delete?(Note: Buffer 0 can't be deleted.)2
Deleted Buffer 2
Enter the size for buffer 2 between 20 to 400 bytes:400
Memory Allocation failed for buffer 2
```