CSO-Recitation 08

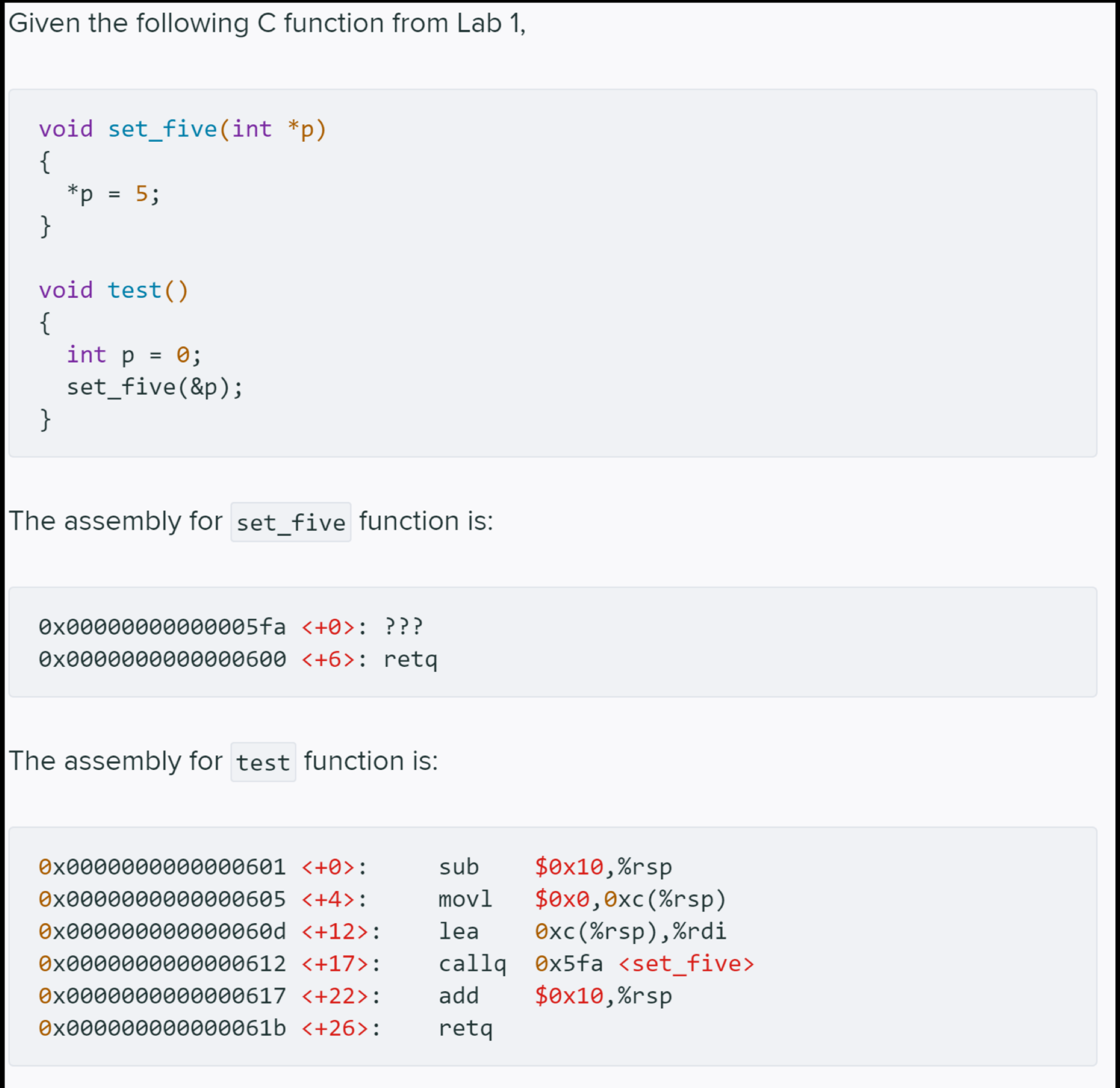
CSCI-UA 0201-007

R08: Assessment 07 & Assembly

Today’s Topics

- Assessment 07
- Some exercises
    - give some senses about lab3

Q1 Set_five



Given the following C function from Lab 1,

```
void set_five(int *p)
{
  *p = 5;
}

void test()
{
  int p = 0;
  set_five(&p);
}
```

The assembly for `set_five` function is:

```
0x00000000000005fa <+0>: ???
0x0000000000000600 <+6>: retq
```

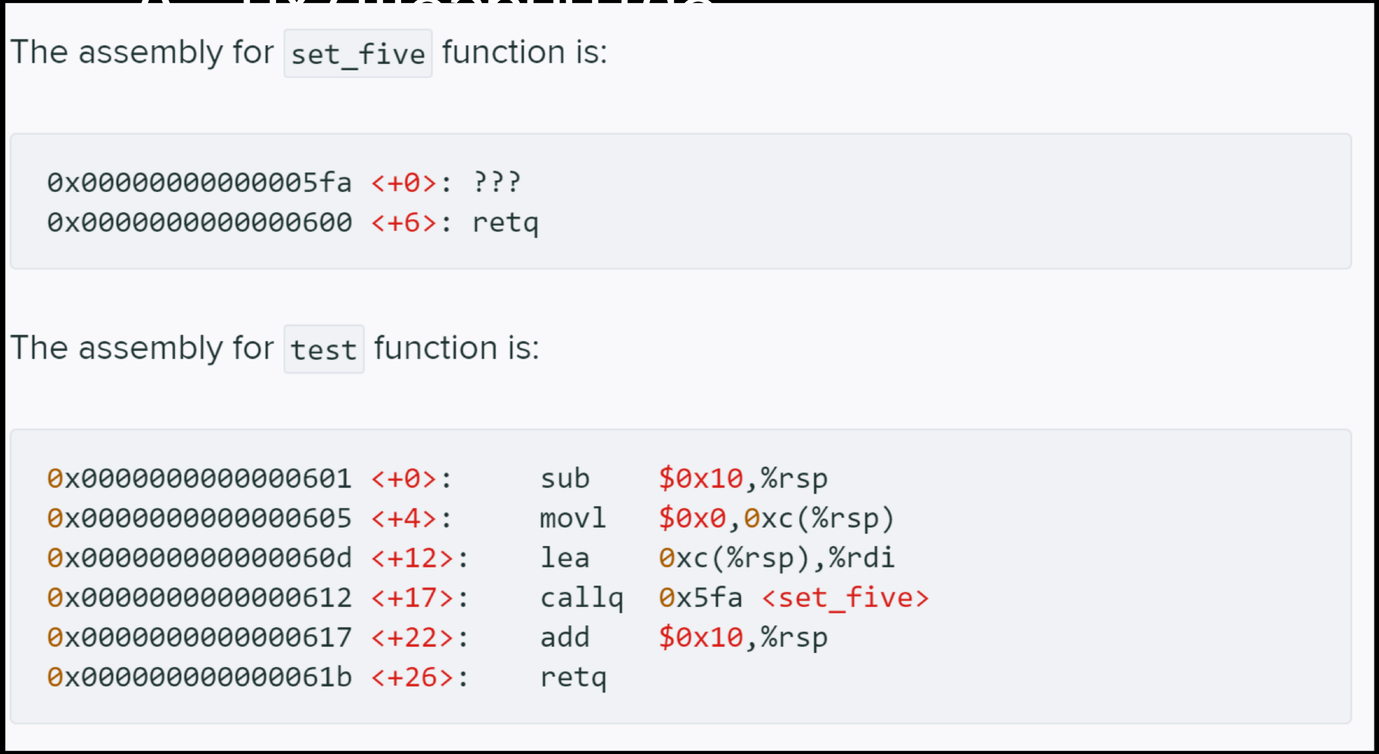
The assembly for `test` function is:

```
0x0000000000000601 <+0>:     sub    $0x10,%rsp
0x0000000000000605 <+4>:     movl   $0x0,0xc(%rsp)
0x000000000000060d <+12>:    lea    0xc(%rsp),%rdi
0x0000000000000612 <+17>:    callq  0x5fa <set_five>
0x0000000000000617 <+22>:    add    $0x10,%rsp
0x000000000000061b <+26>:    retq
```

Q1.1 %rsp

Under normal program execution, suppose the value of %rsp is `0x7fff856001d8` **just prior to** executing the first instruction of `test`. What is the value of %rsp just prior to executing the first instruction of `set_five`?

A. 0x7fff856001d8



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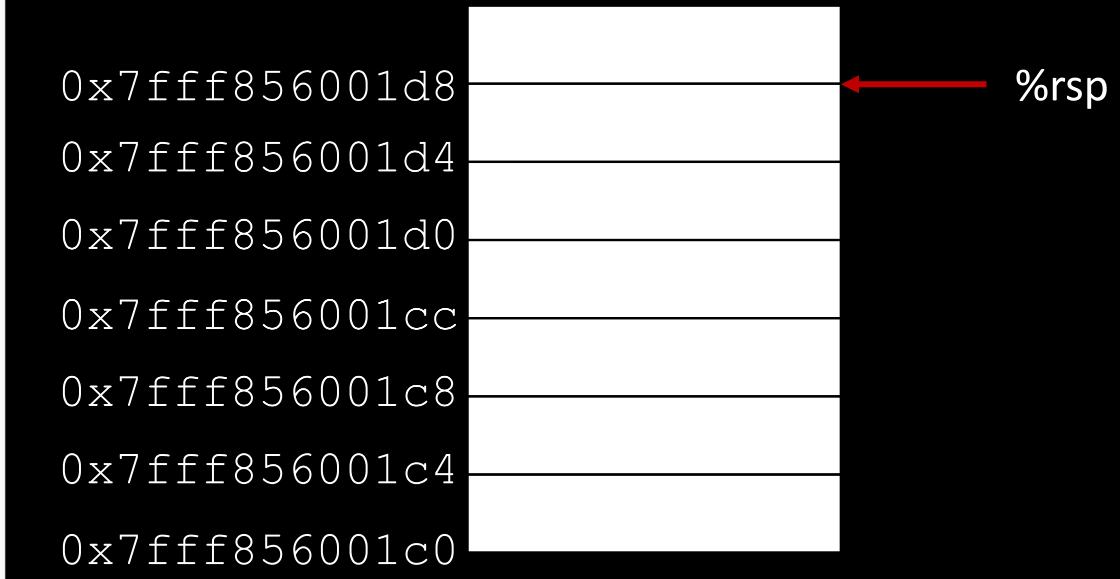
```



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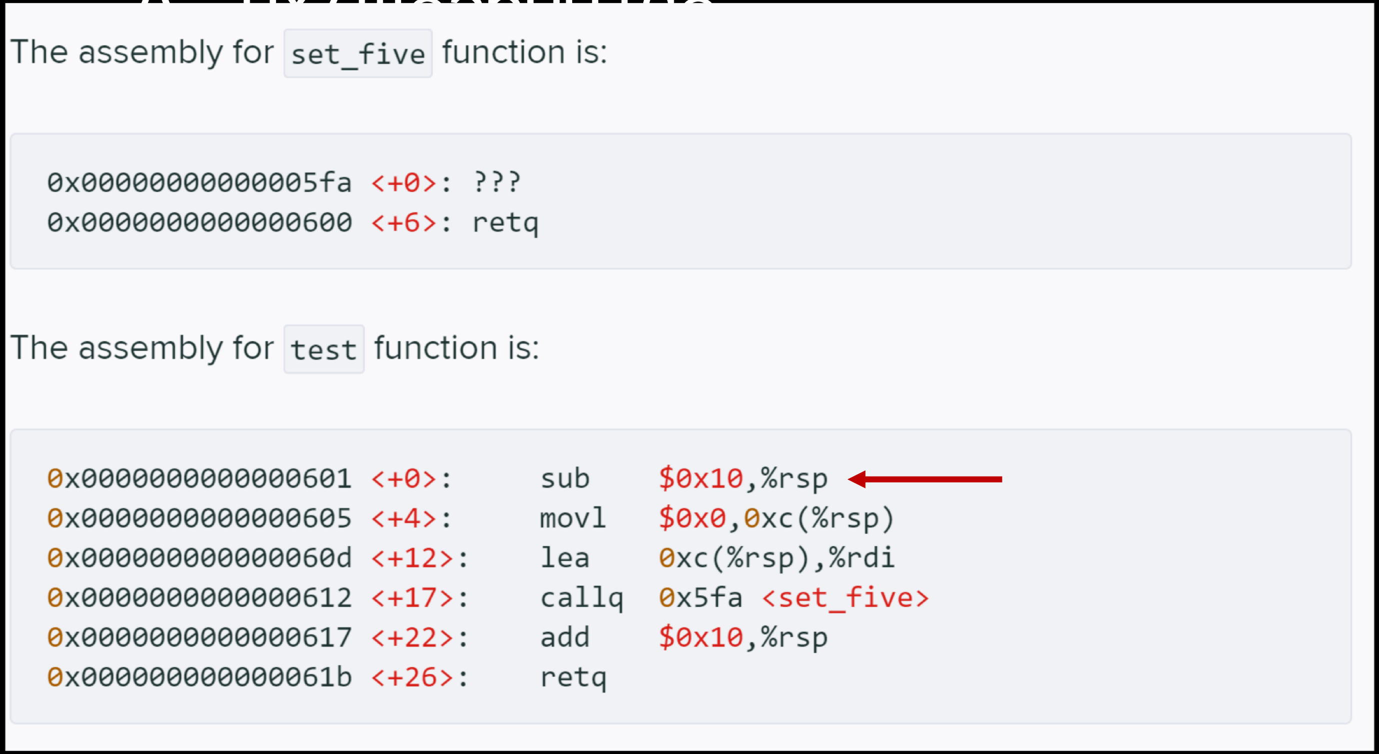

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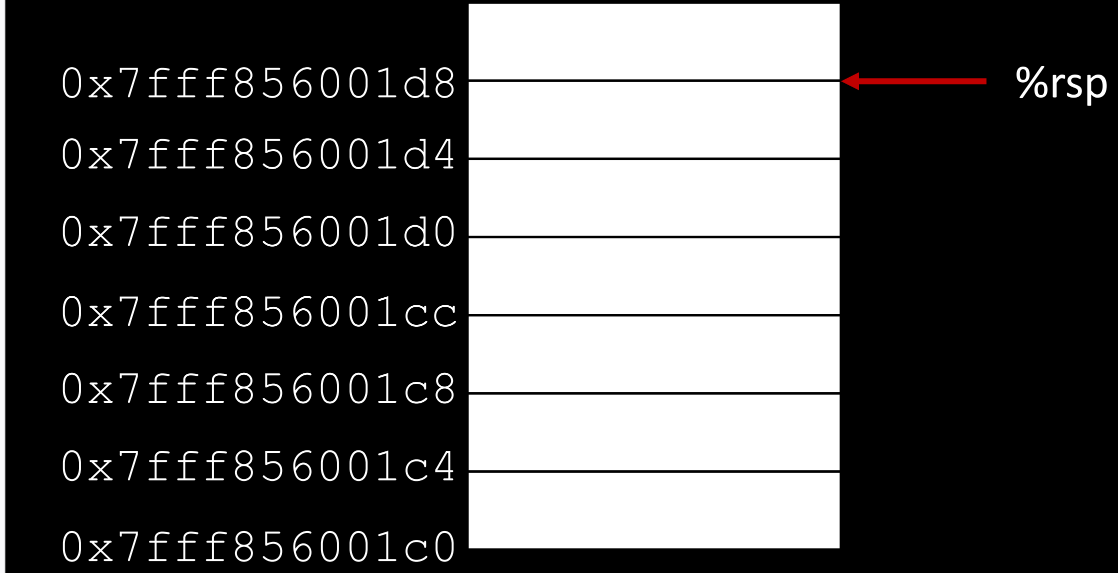
```



0x7fff856001d8

0x7fff856001d4

0x7fff856001d0

0x7fff856001cc

0x7fff856001c8

0x7fff856001c4

0x7fff856001c0

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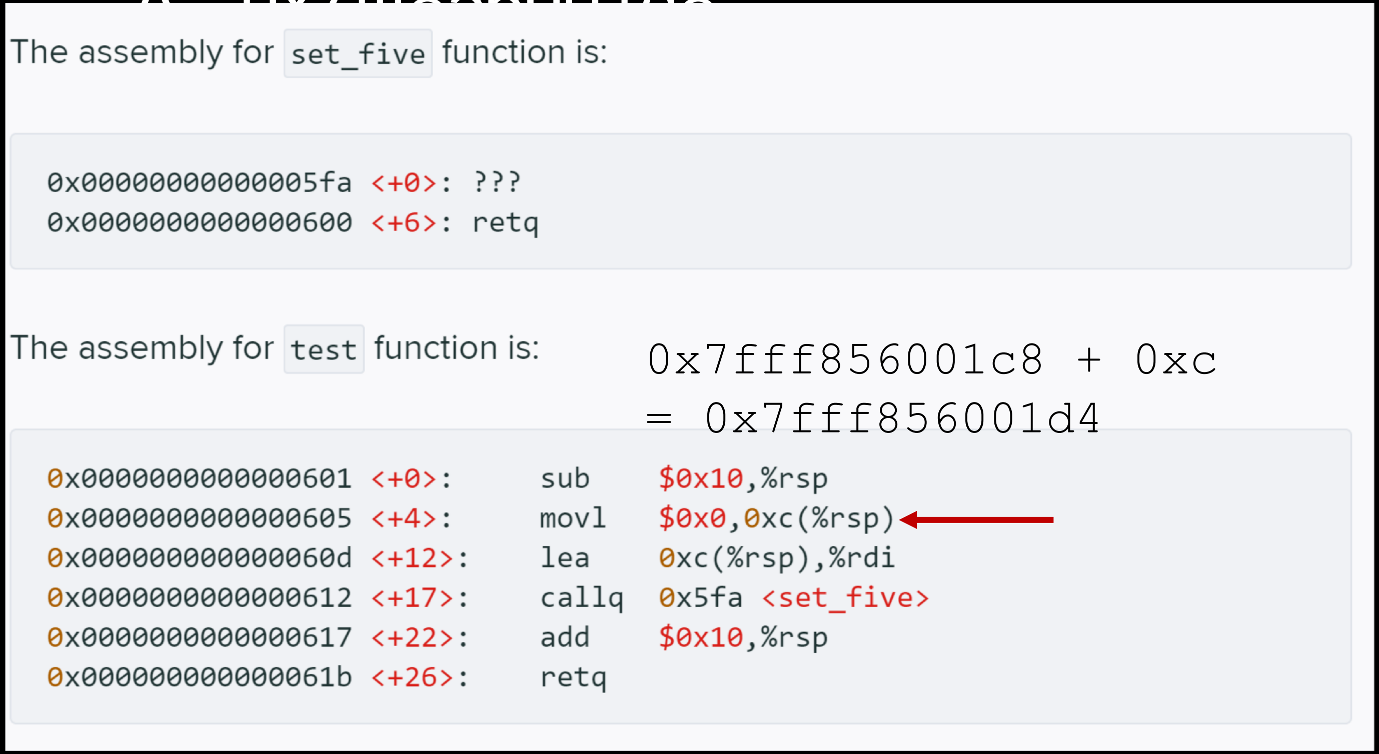

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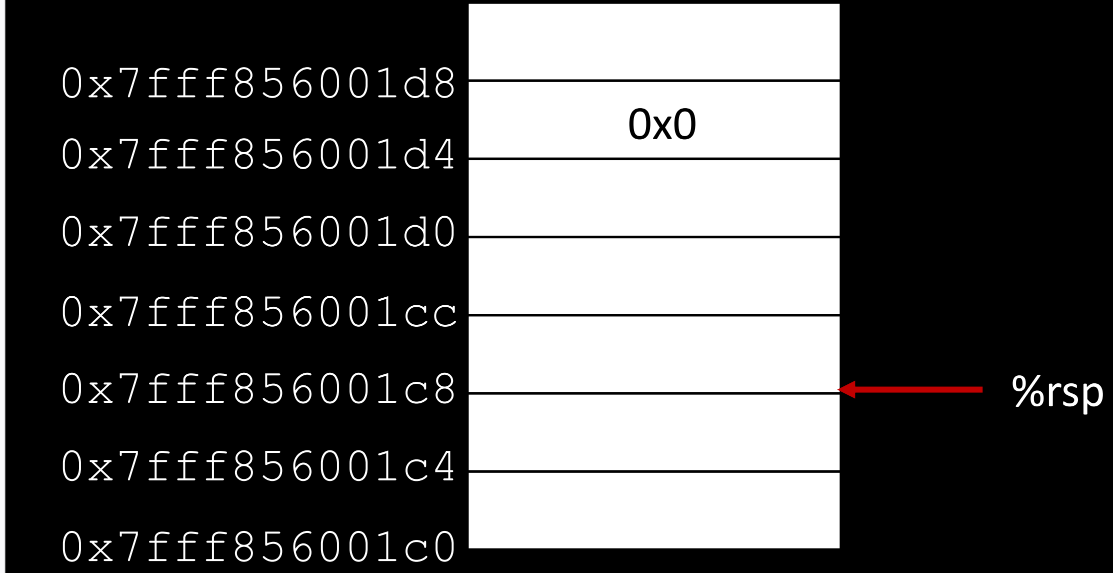
0x0000000000000617 <+22>:    add    $0x10,%rsp
0x000000000000061b <+26>:    retq
```

`0x7fff856001c8 + 0xc`
`= 0x7fff856001d4`



0x7fff856001d8
0x7fff856001d4 0x0
0x7fff856001d0
0x7fff856001cc
0x7fff856001c8 %rsp
0x7fff856001c4
0x7fff856001c0

Q1.1 %rsp

Under normal program execution, suppose the value of %rsp is `0x7fff856001d8` **just prior to** executing the first instruction of `test`. What is the value of %rsp just prior to executing the first instruction of `set_five`?

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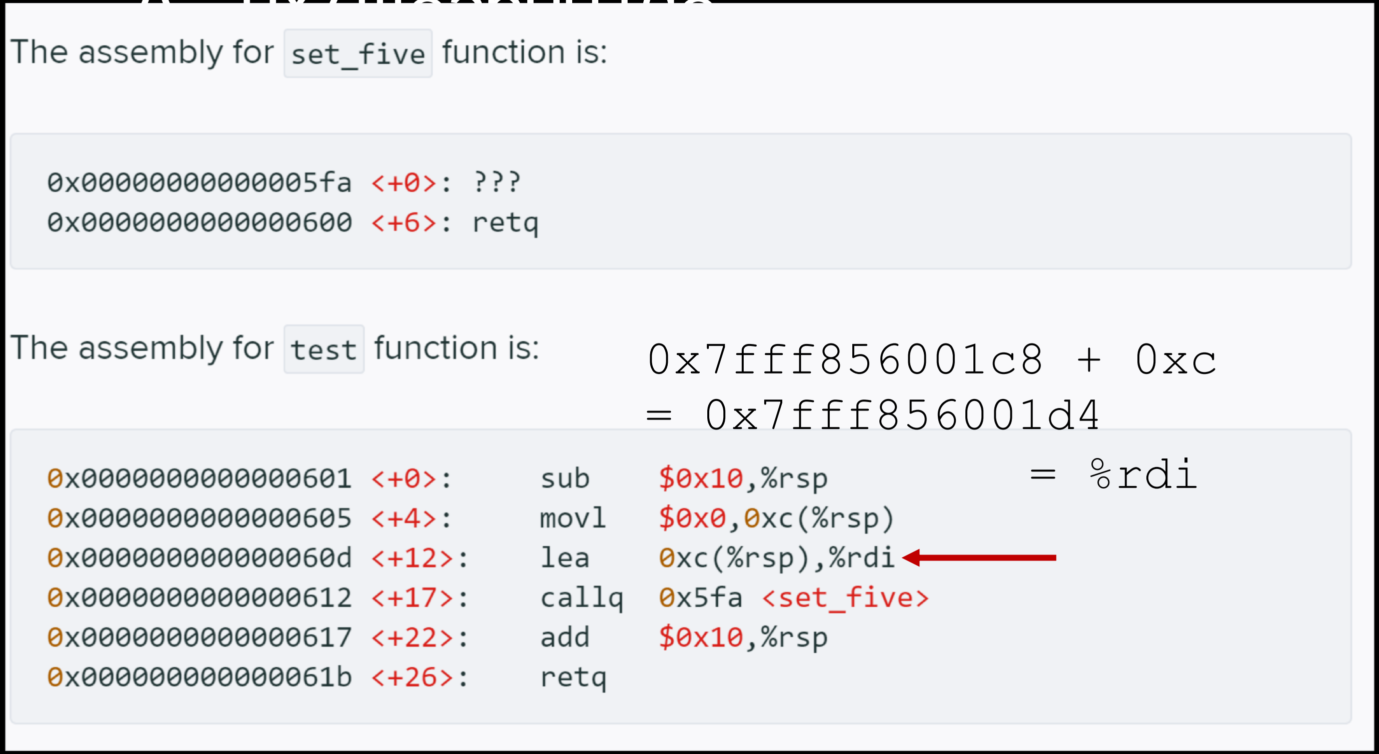

The assembly for `set_five` function is:

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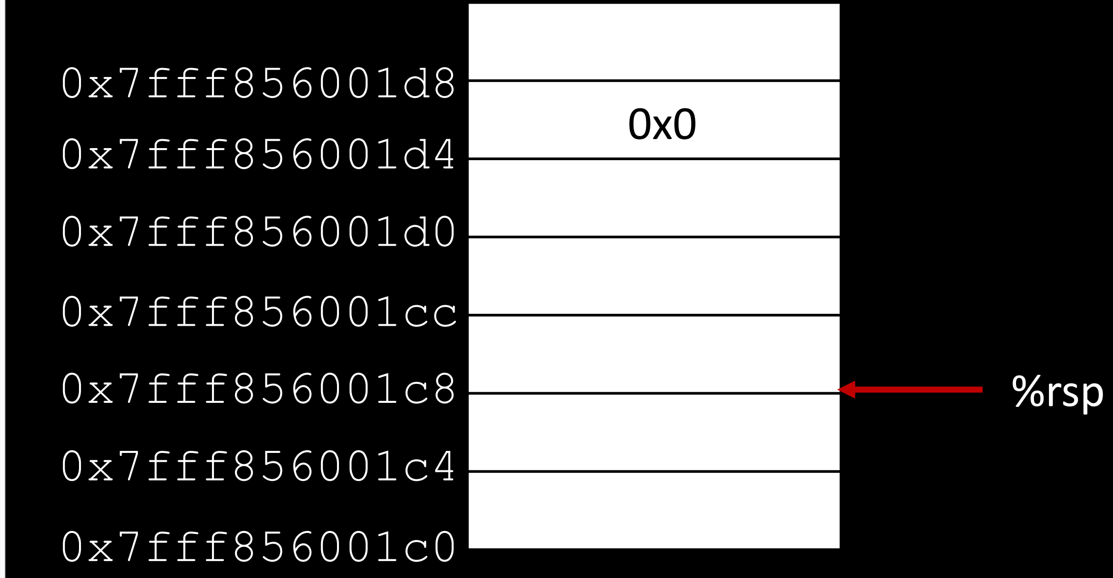
0x0000000000000612 <+17>:    callq  0x5fa <set_five>
0x0000000000000617 <+22>:    add    $0x10,%rsp
0x000000000000061b <+26>:    retq
```

0x7fff856001c8 + 0xc
= 0x7fff856001d4
= %rdi



Q1.1 %rsp

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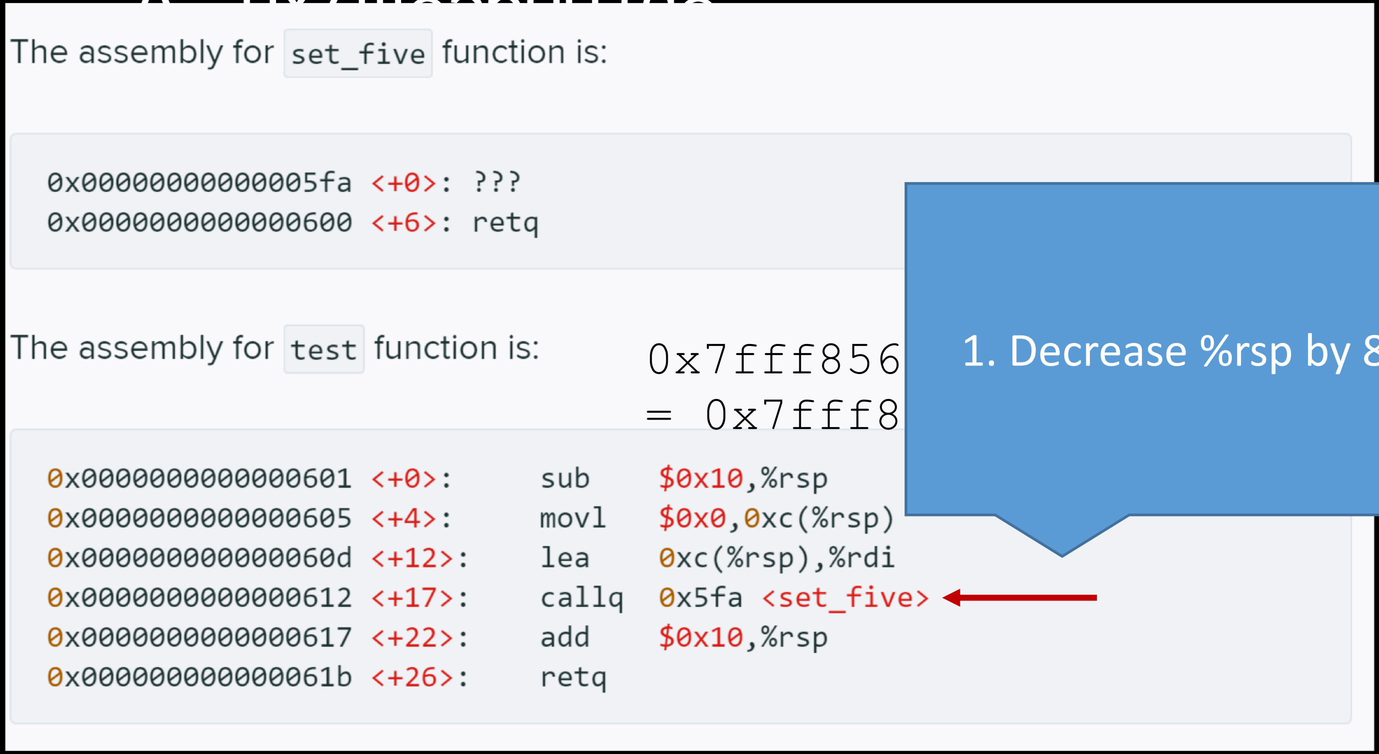

The assembly for `set_five` function is:

```
0x00000000000005fa <+0>: ???
0x0000000000000600 <+6>: retq
```

The assembly for `test` function is:

```
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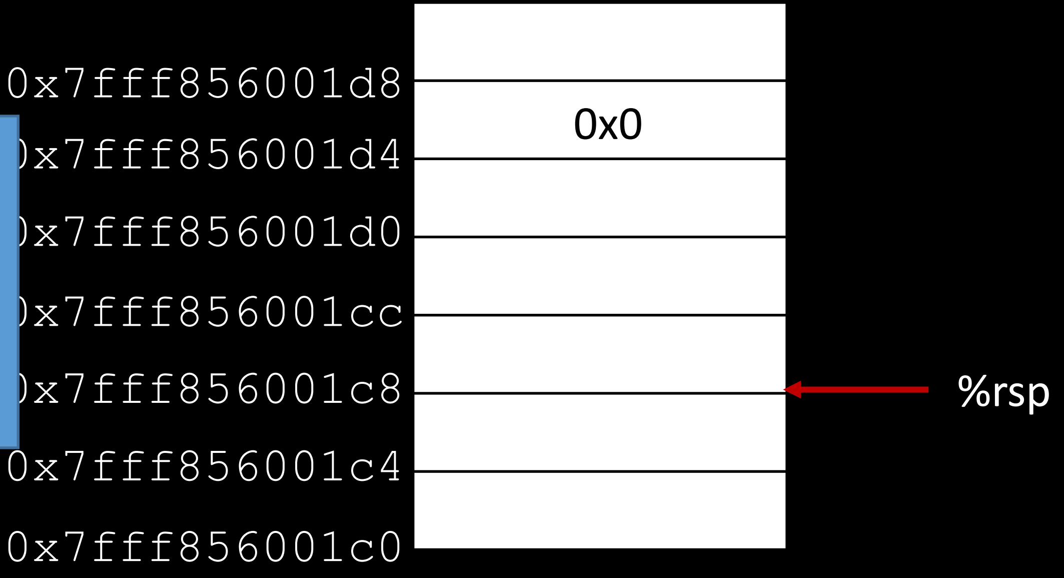
0x0000000000000605 <+4>:     movl   $0x0,0xc(%rsp)
0x000000000000060d <+12>:    lea    0xc(%rsp),%rdi
0x0000000000000612 <+17>:    callq  0x5fa <set_five>
0x0000000000000617 <+22>:    add    $0x10,%rsp
0x000000000000061b <+26>:    retq
```

0x7fff856
= 0x7fff8

1. Decrease %rsp by 8



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Under normal program execution, suppose the value of %rsp is `0x7fff856001d8` **just prior to** executing the first instruction of `test`. What is the value of %rsp just prior to executing the first instruction of `set_five`?

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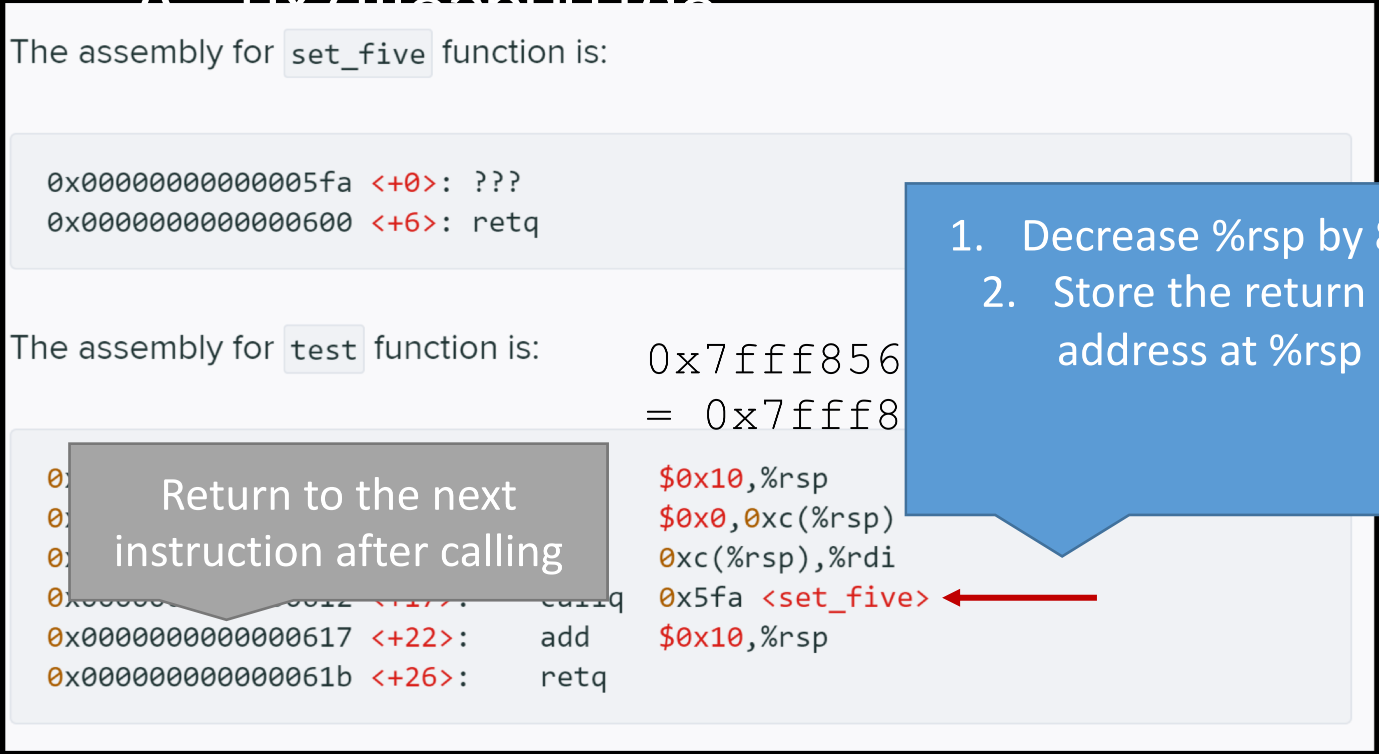


The assembly for `set_five` function is:

```
0x00000000000005fa <+0>: ???
0x0000000000000600 <+6>: retq
```

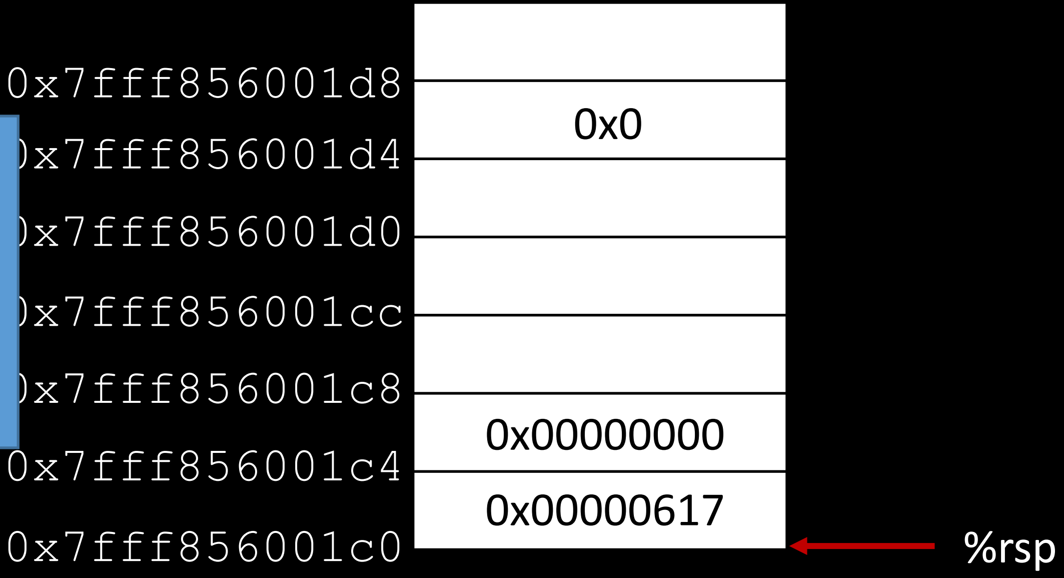
The assembly for `test` function is:

```
0x                                        $0x10,%rsp
0x                                        $0x0,0xc(%rsp)
0x                                        0xc(%rsp),%rdi
0x        0612 <+17>:          callq      0x5fa <set_five>
0x0000000000000617 <+22>:      add        $0x10,%rsp
0x000000000000061b <+26>:      retq
```

Return to the next instruction after calling

0x7fff856
= 0x7fff8

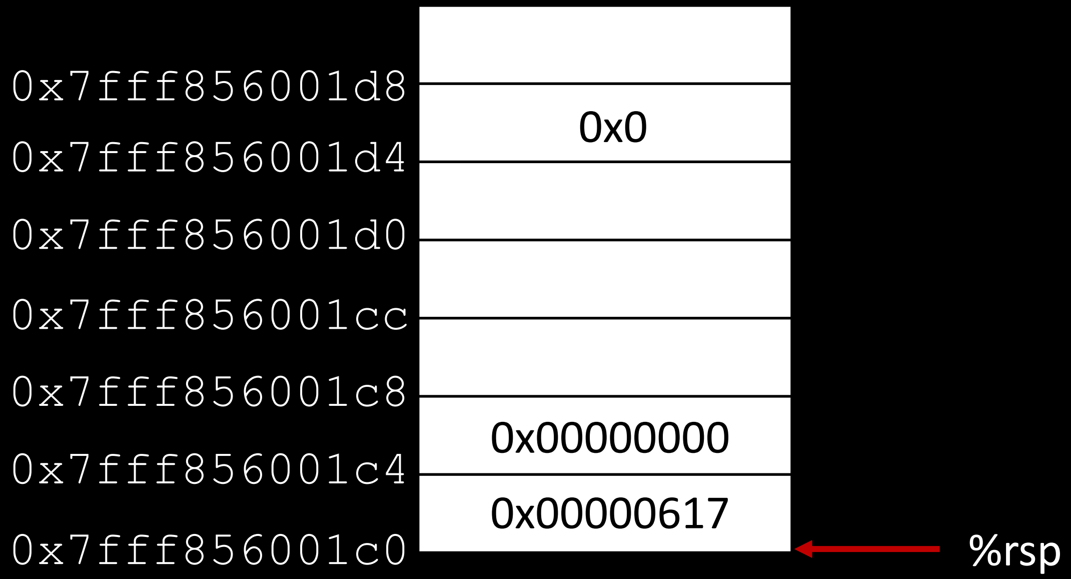
1. Decrease %rsp by 8
2. Store the return address at %rsp



Q1.1 %rsp

Under normal program execution, suppose the value of %rsp is `0x7fff856001d8` **just prior to** executing the first instruction of `test`. What is the value of %rsp just prior to executing the first instruction of `set_five`?

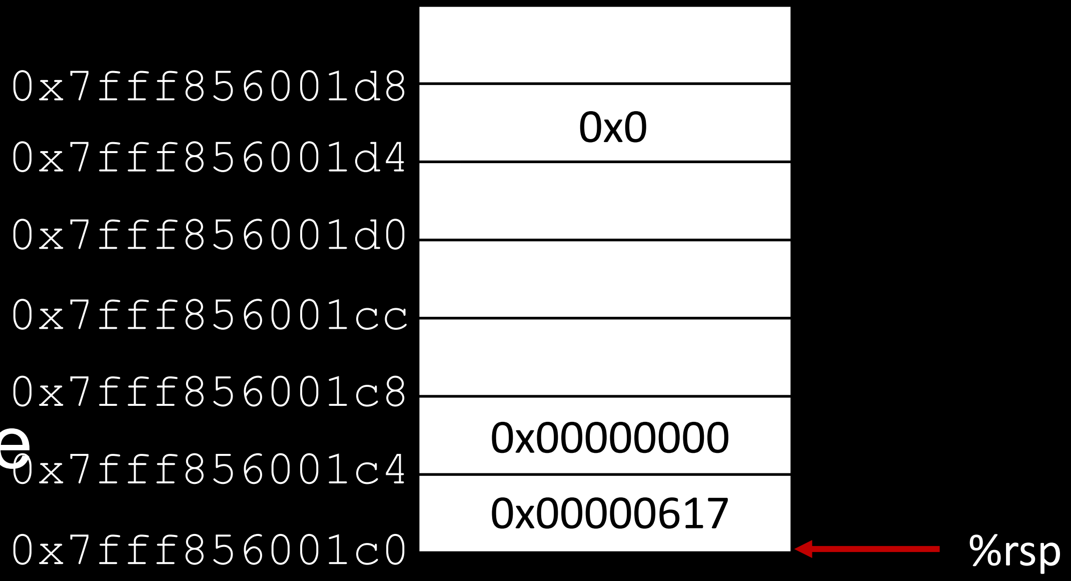
A. 0x7fff856001d8
B. 0x7fff856001c8
C. 0x7fff856001e8
[✓ D. 0x7fff856001c0]
E. 0x7fff856001d0
F. 0x7fff856001c4
G. 0x7fff856001cc
H. None of the above



Q1.2

Under normal program execution, what is the 8-byte value stored under the address specified by %rsp **just prior to** executing the first instruction of `set_five`?

A. 0x7fff856001d8
B. 0x7fff856001c0
C. 0x000000000000060d
D. 0x0000000000000612
[✓ E. 0x0000000000000617]
F. It could be any arbitrary 8-byte value

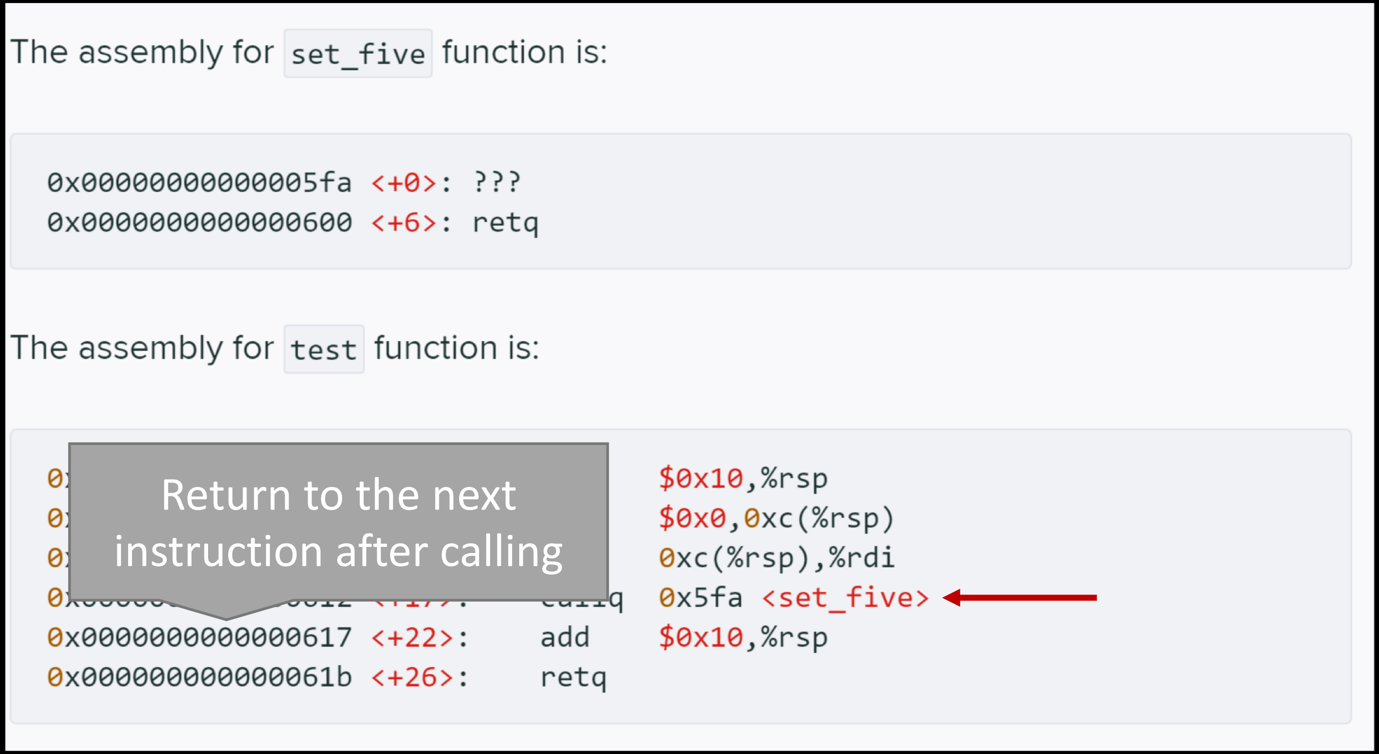


0x7fff856001d8
0x0
0x7fff856001d4
0x7fff856001d0
0x7fff856001cc
0x7fff856001c8
0x00000000
0x7fff856001c4
0x00000617
0x7fff856001c0
%rsp

Q1.3

After executing instruction 0x0000000000000600 <+6>: retq in set_five, what's new %rip value?

A. 0x000000000000060d



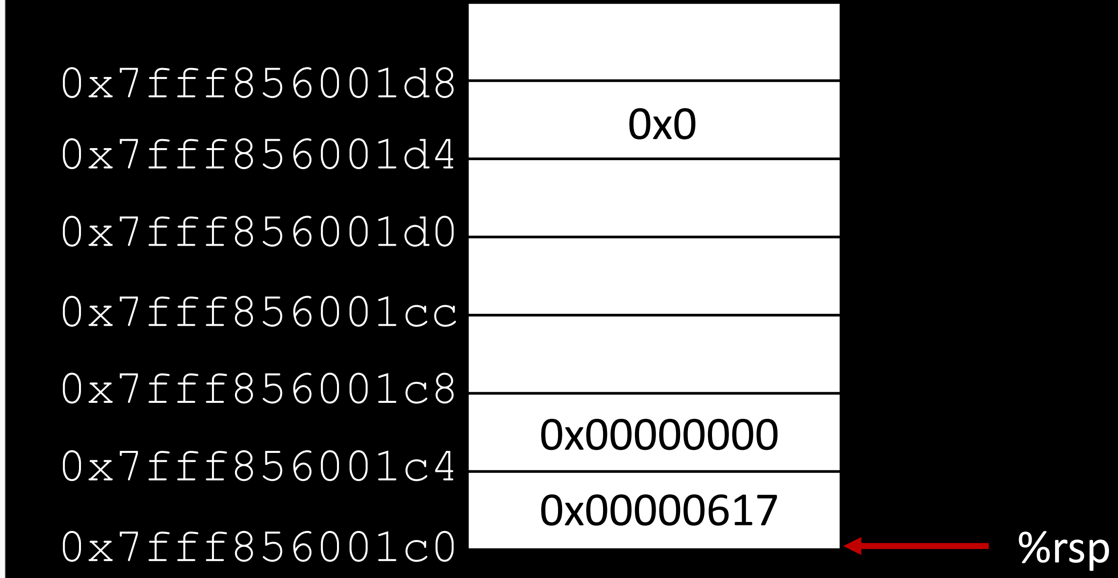
The assembly for `set_five` function is:

```
0x00000000000005fa <+0>: ???
0x0000000000000600 <+6>: retq
```

The assembly for `test` function is:

```
0x                                  $0x10,%rsp
0x                                  $0x0,0xc(%rsp)
0x                                  0xc(%rsp),%rdi
0x                          callq   0x5fa <set_five>
0x0000000000000617 <+22>:   add     $0x10,%rsp
0x000000000000061b <+26>:   retq
```

Return to the next instruction after calling



0x7fff856001d8	
0x7fff856001d4	0x0
0x7fff856001d0	
0x7fff856001cc	
0x7fff856001c8	
0x7fff856001c4	0x00000000
0x7fff856001c0	0x00000617

Q1.3

After executing instruction 0x0000000000000600 <+6>: retq in set_five, what's new %rip value?

A. 0x000000000000060d

B. 0x0000000000000612

[✓ C. 0x0000000000000617]

D. 0x0000000000000604

E. 0x0000000000000608

Q1.4 p's location (WI

Where is the local variable p stor

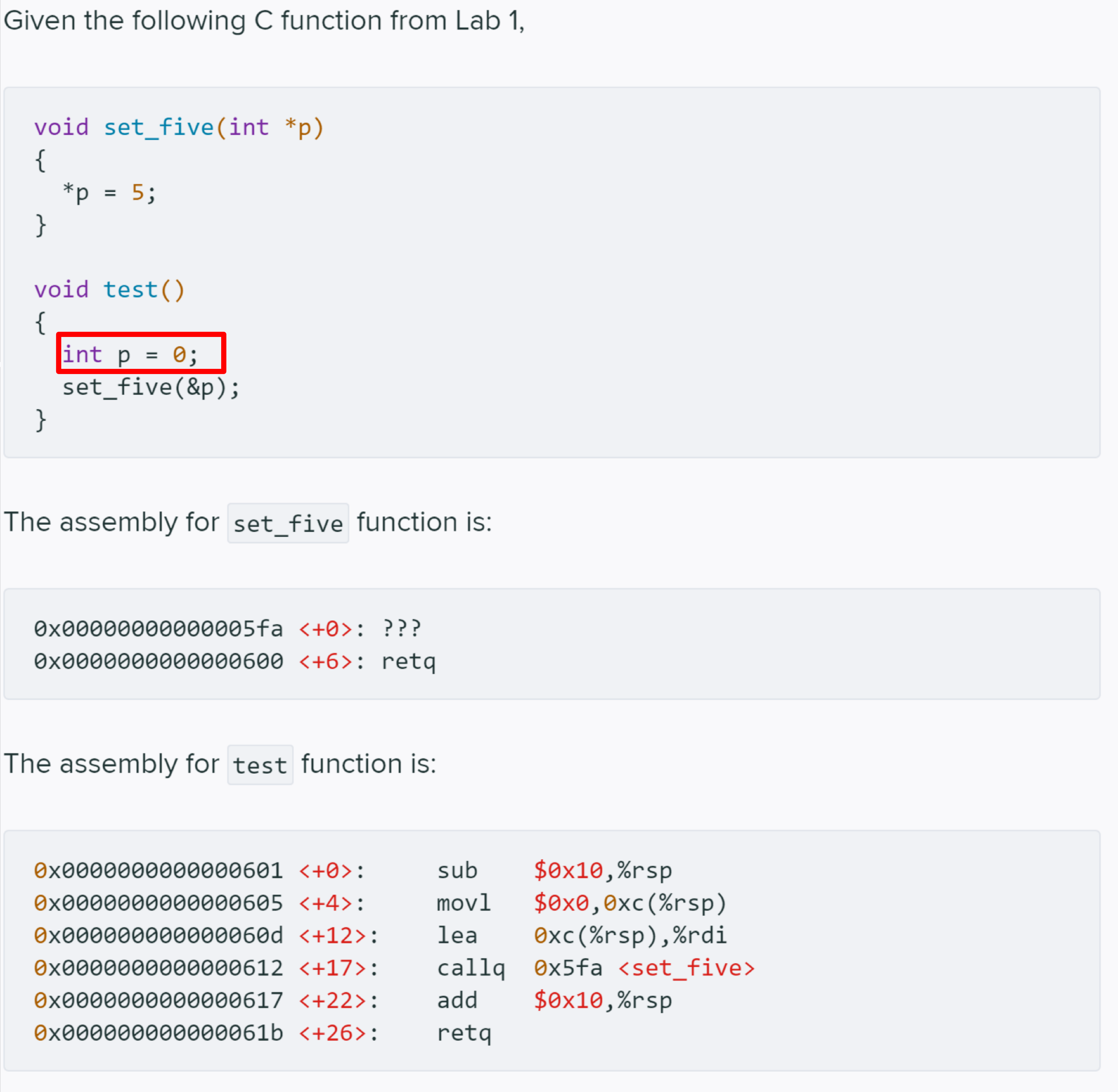
A. some register

B. memory (data segment)

[✓ C. memory (stack)]

D. memory (heap)

- char, int, long, … (primitive data types) =>
  - use registers whenever possible
  - stack otherwise
- local array/struct variables => stack



Given the following C function from Lab 1,

```
void set_five(int *p)
{
  *p = 5;
}

void test()
{
  int p = 0;
  set_five(&p);
}
```

The assembly for `set_five` function is:

```
0x00000000000005fa <+0>: ???
0x0000000000000600 <+6>: retq
```

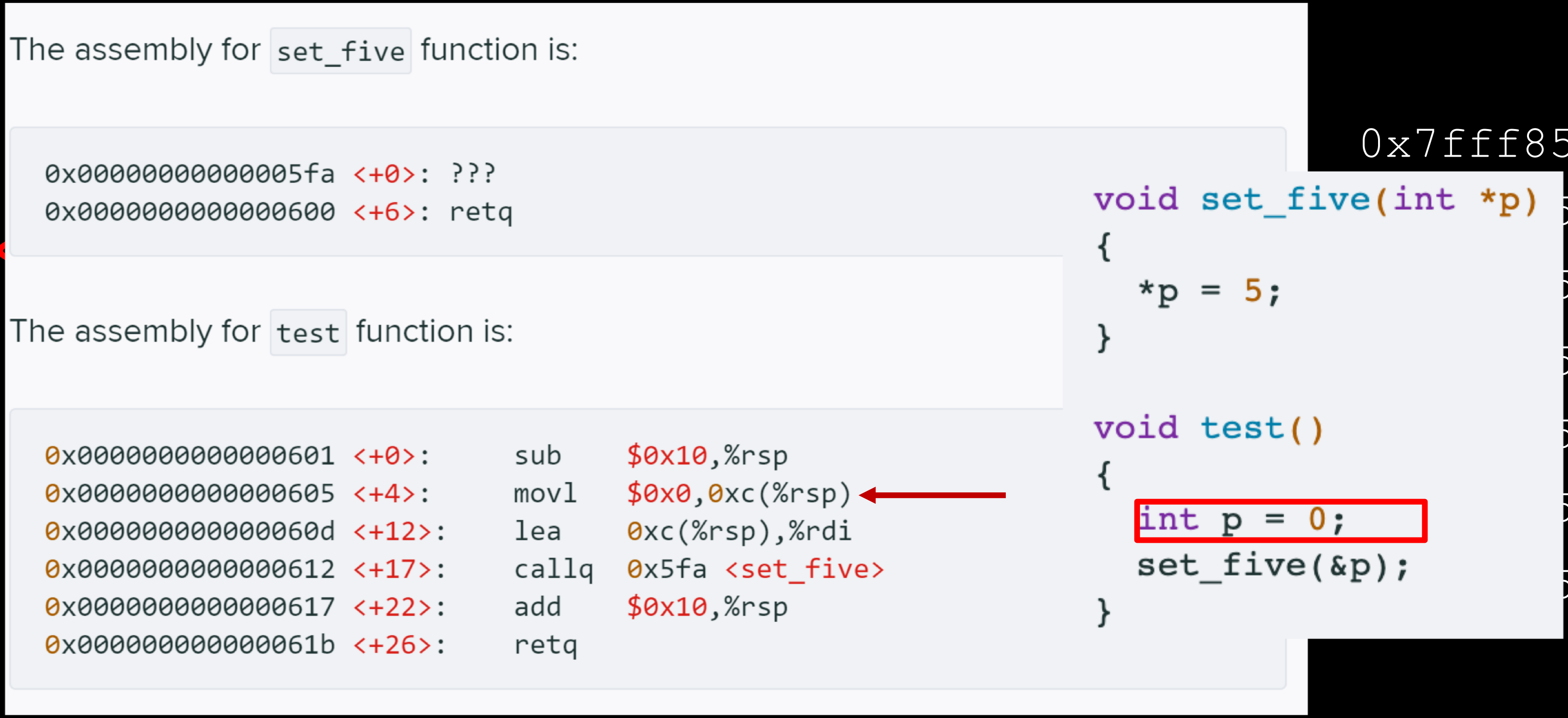
The assembly for `test` function is:

```
0x0000000000000601 <+0>:     sub    $0x10,%rsp
0x0000000000000605 <+4>:     movl   $0x0,0xc(%rsp)
0x000000000000060d <+12>:    lea    0xc(%rsp),%rdi
0x0000000000000612 <+17>:    callq  0x5fa <set_five>
0x0000000000000617 <+22>:    add    $0x10,%rsp
0x000000000000061b <+26>:    retq
```

Register or stack? Look at the code.
‘&p’ => p is on memory => stack

Q1.5 p's location

If your answer of 1.4 is memory, where in memory (aka what address) is p stored (assuming the value of %rsp is 0x7fff856001d8 just prior to executing the first instruction of test)?



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```

```
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  *p = 5;
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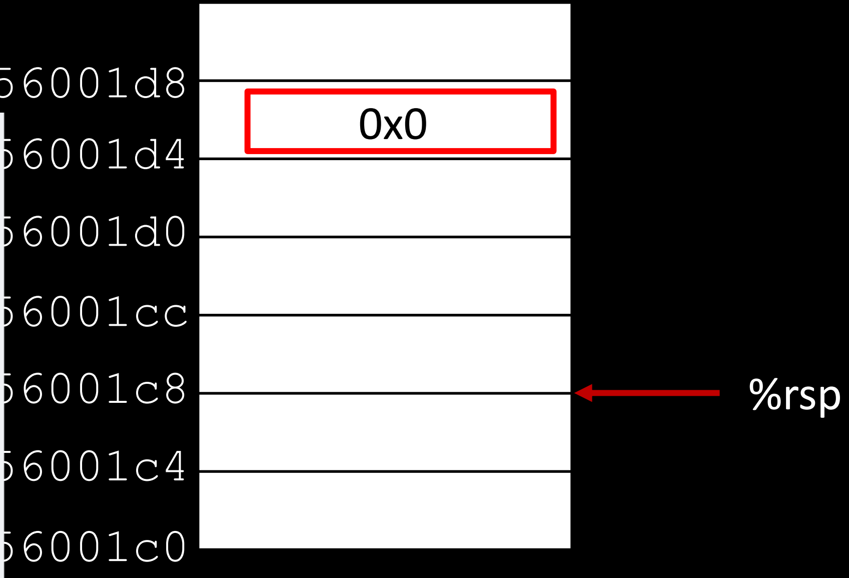

Q1.5 p's location

If your answer of 1.4 is memory, where in memory (aka what address) is p stored (assuming the value of %rsp is 0x7fff856001d8 just prior to executing the first instruction of test)?

A. 0x7fff856001d8

B. 0x7fff856001c8

[✓ C. 0x7fff856001d4]

D. 0x7fff856001d0

E. 0x7fff856001cc

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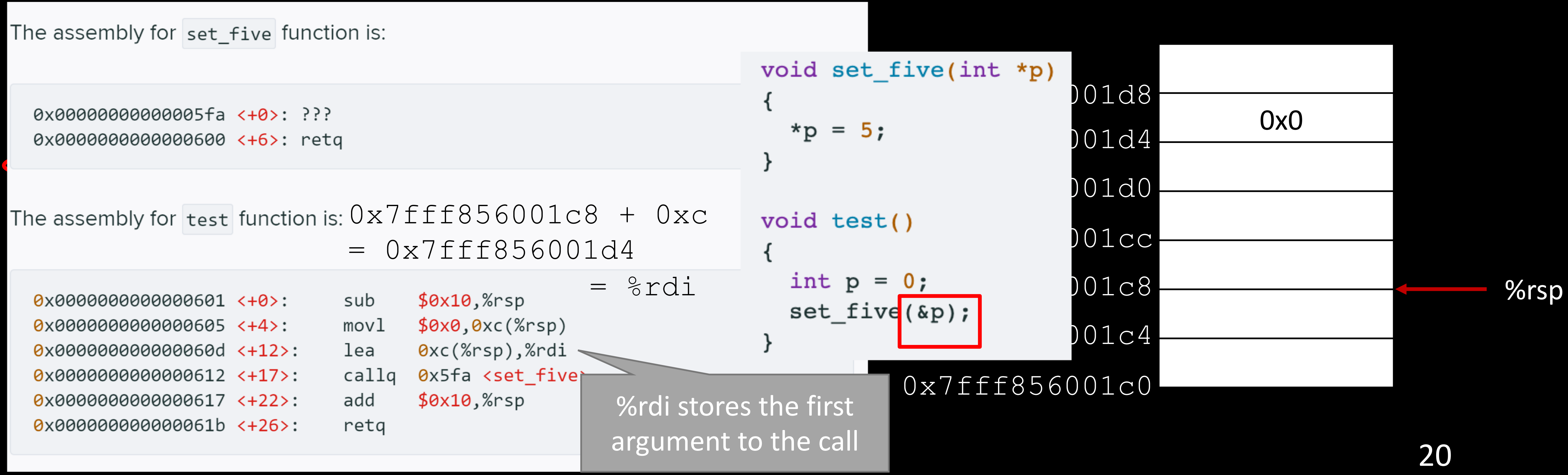
If your answer of 1.4 is memory, where in memory (aka what address) is p stored (assuming the value of %rsp is 0x7fff856001d8 just prior to executing the first instruction of test)?



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0x0000000000000612 <+17>:    callq  0x5fa <set_five>
0x0000000000000617 <+22>:    add    $0x10,%rsp
0x000000000000061b <+26>:    retq
```

```
void set_five(int *p)
{
  *p = 5;
}

void test()
{
  int p = 0;
  set_five(&p);
}
```

0x7fff856001c8 + 0xc
= 0x7fff856001d4
= %rdi

%rdi stores the first argument to the call

Q1.5 p's location

If your answer of 1.4 is memory, where in memory (aka what address) is p stored (assuming the value of %rsp is 0x7fff856001d8 just prior to executing the first instruction of test)?

A. 0x7fff856001d8

B. 0x7fff856001c8

[✓ C. 0x7fff856001d4]

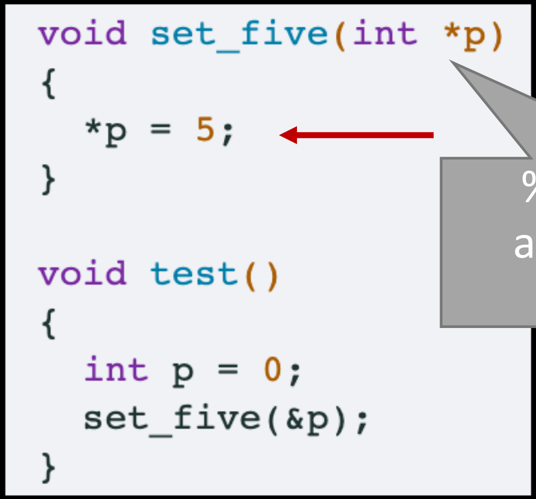
D. 0x7fff856001d0

E. 0x7fff856001cc

Q1.6 set_five

What's the missing first instruction of set_five (aka the instruction corresponding to ???)

A. `movl $0x5,(%rdi)`



```
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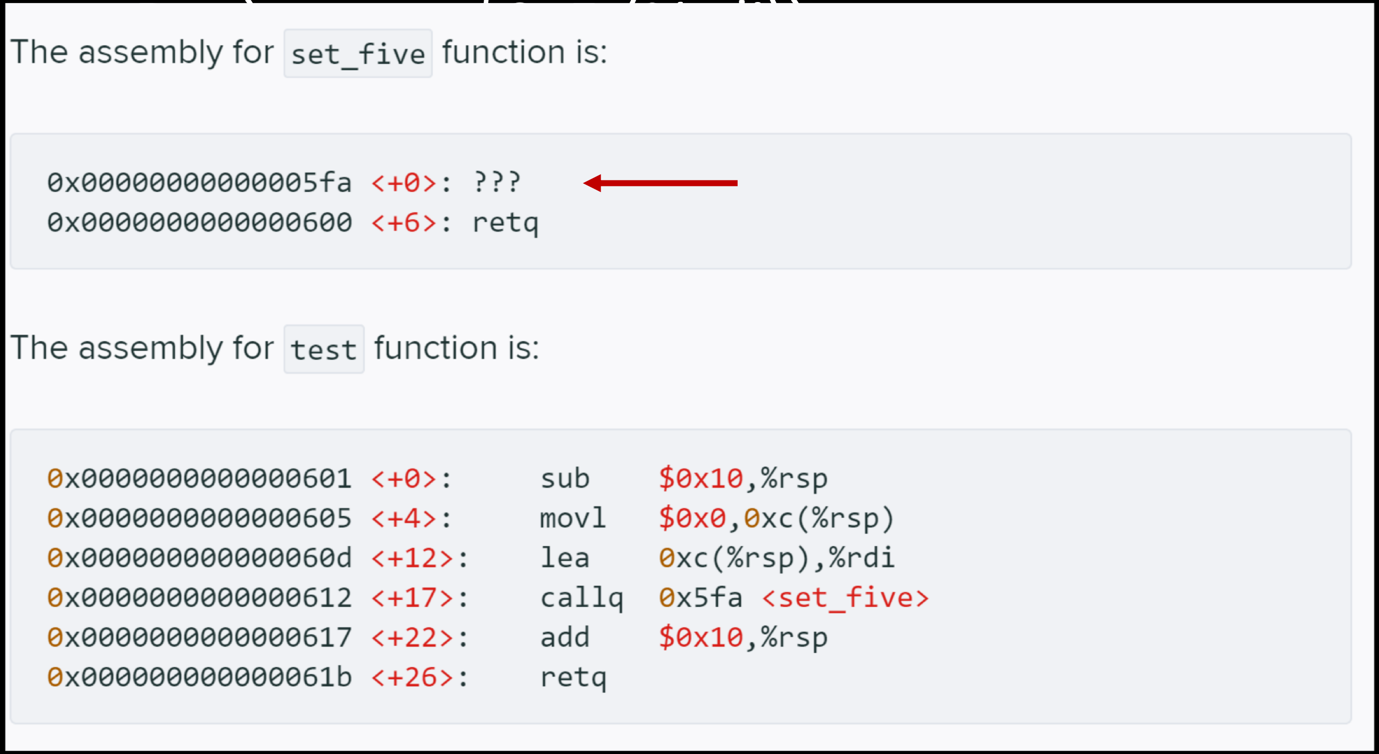
%rdi stores the first argument to the call
%rdi=p



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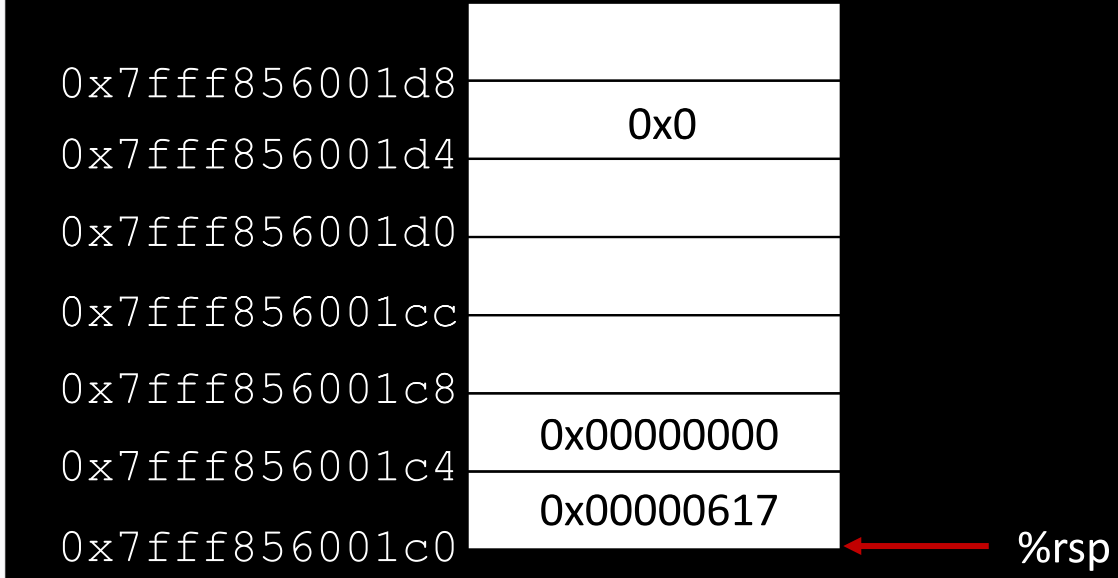
```



0x7fff856001d8	
0x7fff856001d4	0x0
0x7fff856001d0	
0x7fff856001cc	
0x7fff856001c8	
0x7fff856001c4	0x00000000
0x7fff856001c0	0x00000617

Q1.6 set_five

What's the missing first instruction of set_five (aka the instruction corresponding to ???)

A. [✓ `movl   $0x5,(%rdi)`]

B. `movq   $0x5,(%rdi)`

C. `movl   $0x5,(%rsi)`

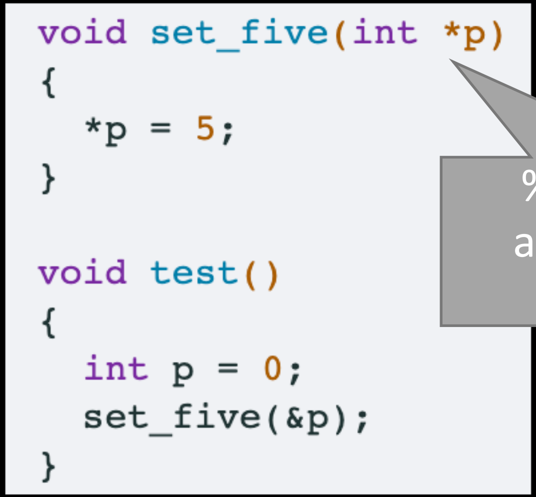
D. `movq   $0x5,(%rdi)`

E. `movl   $0x5, %edi`

F. `movq   $0x5, %rdi`

G. `movl   $0x5, %esi`

H. `movq   $0x5, %rsi`



```
void set_five(int *p)
{
  *p = 5;
}

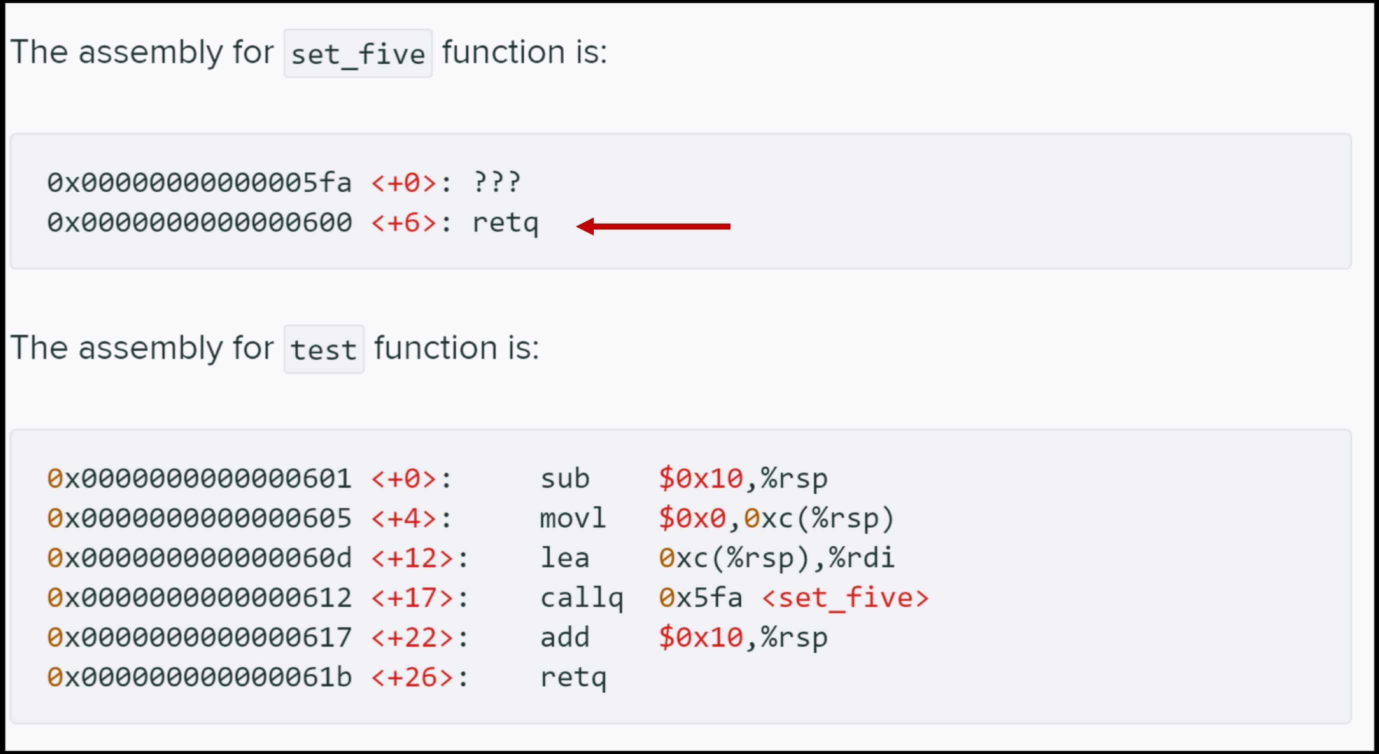
void test()
{
  int p = 0;
  set_five(&p);
}
```

%rdi stores the first argument to the call
%rdi=p

p: int * => movl
Pointer is 64-bit => %rdi

Question

- After executing instruction 0x0000000000000600 <+6>: retq in set_five, what's new %rsp value?



The assembly for `set_five` function is:

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The assembly for `test` function is:

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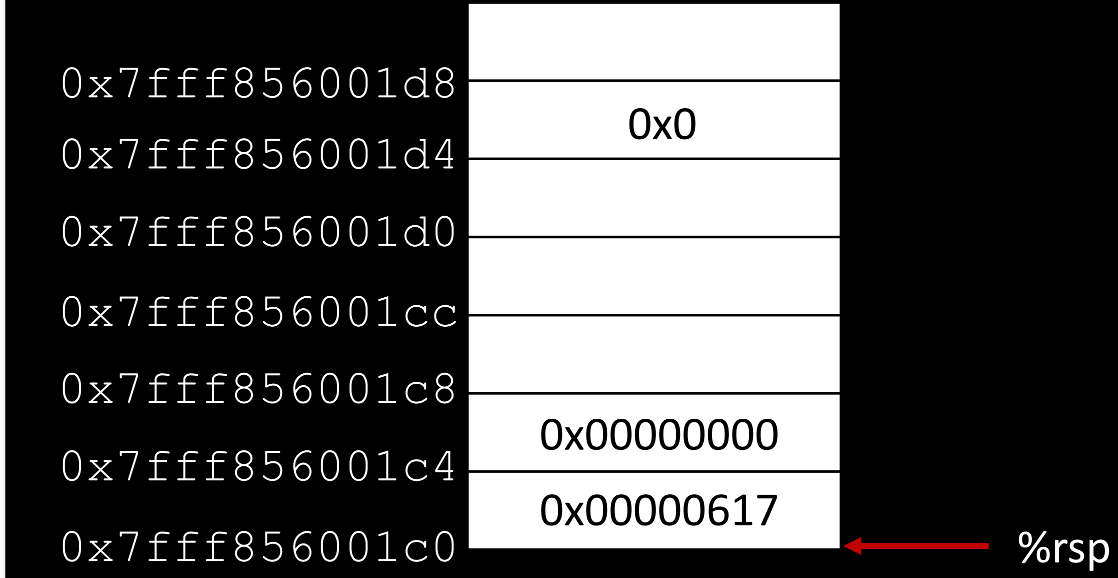
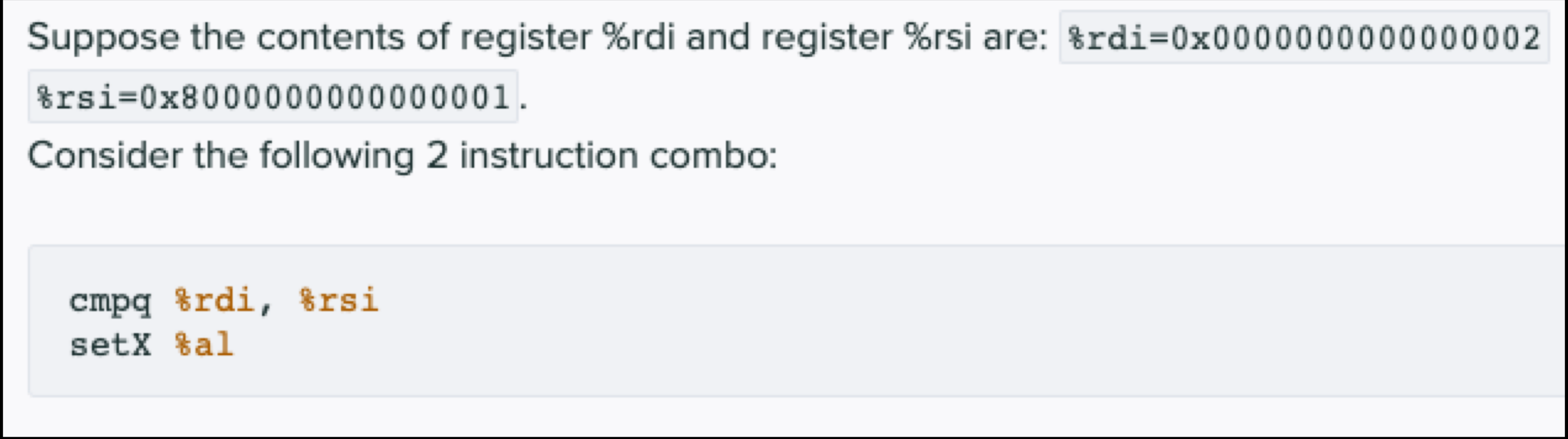


```
0x7fff856001d8
0x7fff856001d4   0x0
0x7fff856001d0
0x7fff856001cc
0x7fff856001c8
0x7fff856001c4   0x00000000
0x7fff856001c0   0x00000617   %rsp
```

Q2 cmp and set



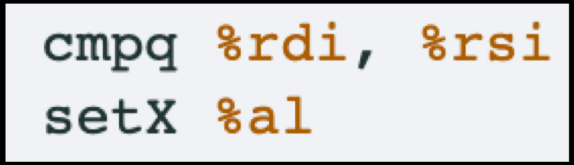
Suppose the contents of register %rdi and register %rsi are: `%rdi=0x0000000000000002` `%rsi=0x8000000000000001`.

Consider the following 2 instruction combo:

```
cmpq %rdi, %rsi
setX %al
```

Q2.1 RFLAGS

%rdi=0x0000000000000002
%rsi=0x8000000000000001



```
cmpq %rdi, %rsi
setX %al
```

In Q2, which of the following status flags are set after executing cmpq %rdi, %rsi (aka the rest are cleared)?

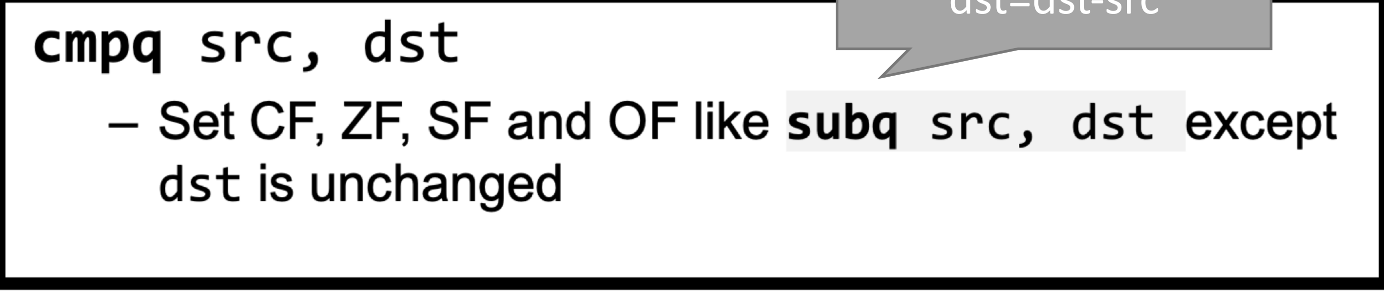
A. ZF

B. SF

C. CF

D. OF

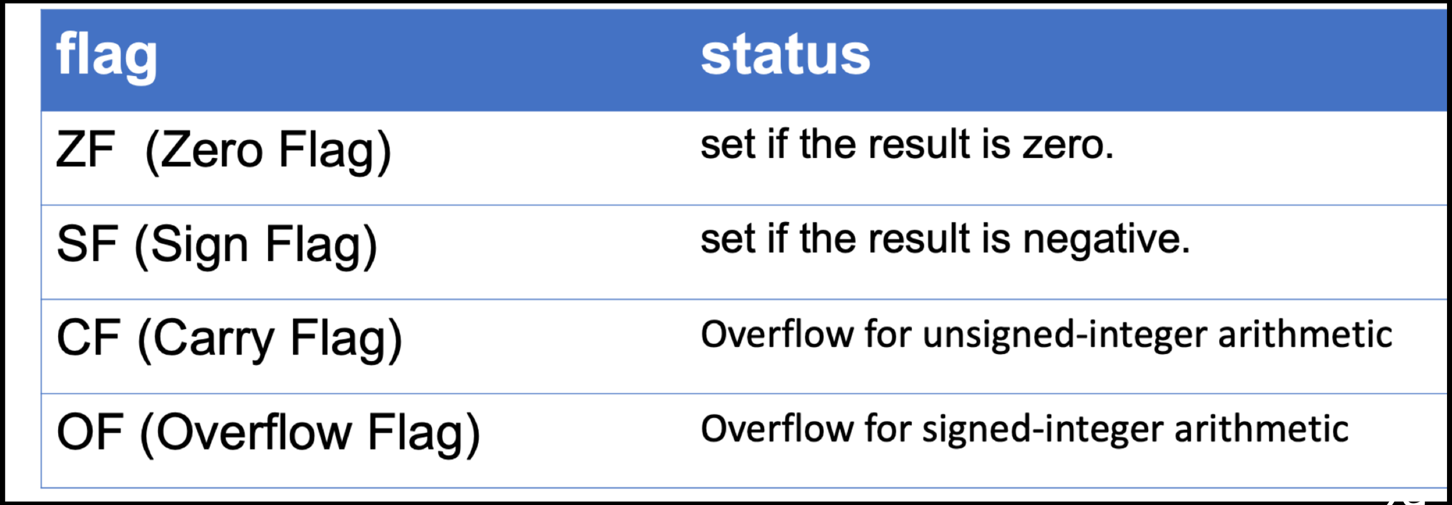
- %rsi-%rdi = 0x7fff…ff
- SF=MSB=0



cmpq src, dst

– Set CF, ZF, SF and OF like **subq** src, dst except dst is unchanged

dst=dst-src



flag	status
ZF (Zero Flag)	set if the result is zero.
SF (Sign Flag)	set if the result is negative.
CF (Carry Flag)	Overflow for unsigned-integer arithmetic
OF (Overflow Flag)	Overflow for signed-integer arithmetic

CF and OF

- The CPU doesn’t know if operands are signed or unsigned
- So, it calculates both the signed overflow (OF) and the unsigned overflow (CF) for each instruction
  - OF is set assuming both operands are signed
  - CF is set assuming both operands are unsigned

Q2.1 RFLAGS

In Q2, which of the following status flags are set after executing cmpq %rdi, %rsi (aka the rest are cleared)?

A. ZF

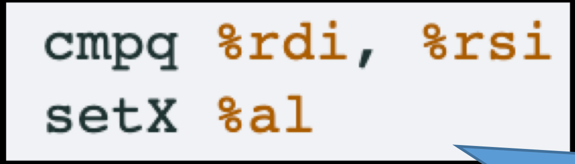
B. SF

C. CF

[✓ D. OF]

- %rsi-%rdi = 0x7fff…ff
- SF=MSB=0, not set
- CF: treat as unsigned
  - => no overflow, not set
- OF: treat as signed =>
  - => overflow, set

%rdi=0x0000000000000002
%rsi=0x8000000000000001



```
cmpq %rdi, %rsi
setX %al
```

Unsigned range: 0 ~ 2^64 - 1
%rdi = 2
%rsi = 2^63 + 1
%rsi - %rdi = 2^63 – 1: in the range

Signed range: -2^63 ~ 2^63 - 1
%rdi = 2
%rsi = -2^63 + 1
%rsi - %rdi = -2^63 – 1: out of the range

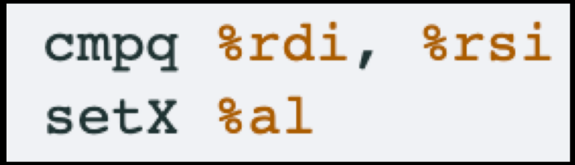
Tricks to quickly decide whether the signed/unsigned computation is overflow: see the previous recitation slides.

How to decide whether there is overflow?

- Machine:
    - Unsigned: there is a carry/borrow of the MSB
    - Signed:
        - if there is carry-in but no carry-out of MSB
        - or, there is no carry-in but there’s carry out of MSB

Q2.2 Set instruction

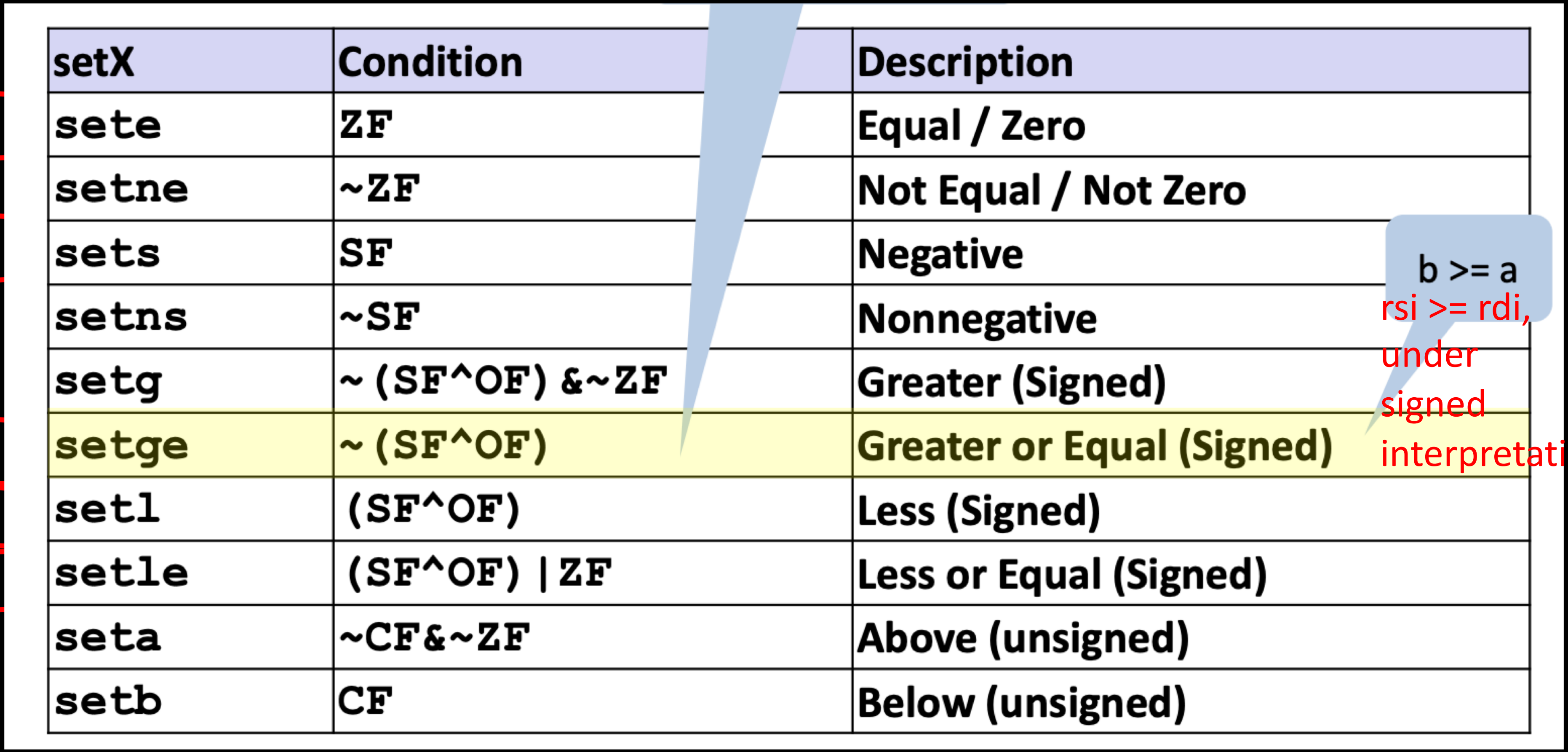
%rdi=0x0000000000000002
%rsi=0x8000000000000001



```
cmpq %rdi, %rsi
setX %al
```

In Q2, which of the following setX instruction would result in register %al being 1 after execution?

A. sete %al
[✓ B. setne %al]
C. sets %al
[✓ D. setns %al]
E. setg %al
F. setge %al
[✓ G. setl %al]
[✓ H. setle %al]
[✓ I. seta %al]
J. setb %al



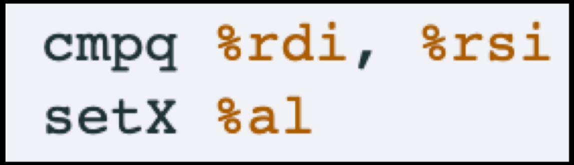
setX	Condition	Description
sete	ZF	Equal / Zero
setne	~ZF	Not Equal / Not Zero
sets	SF	Negative
setns	~SF	Nonnegative
setg	~(SF^OF)&~ZF	Greater (Signed)
setge	~(SF^OF)	Greater or Equal (Signed)
setl	(SF^OF)	Less (Signed)
setle	(SF^OF)|ZF	Less or Equal (Signed)
seta	~CF&~ZF	Above (unsigned)
setb	CF	Below (unsigned)

b >= a

rsi >= rdi, under signed interpretation

Exercise

%rdi=0x8000000000000002
%rsi=0x8000000000000001



```
cmpq %rdi, %rsi
setX %al
```

Which of the following status flags are set after executing cmpq %rdi, %rsi (aka the rest are cleared)?

A. ZF

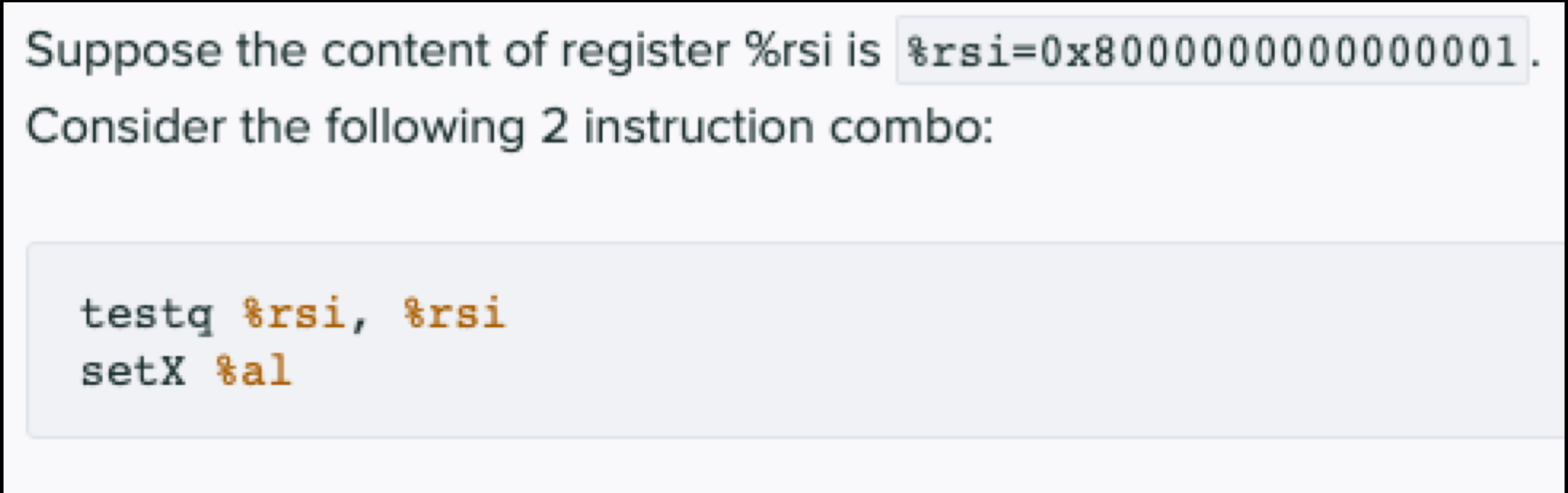
B. SF

C. CF

D. OF

%rsi - %rdi = 0xffffffffffffffff
SF = MSB = 1
CF = 1

Q3 Test and set

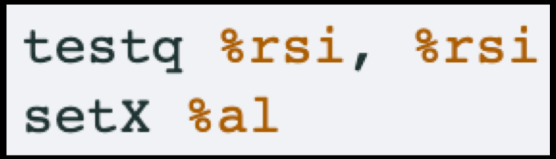


Suppose the content of register %rsi is `%rsi=0x8000000000000001`.

Consider the following 2 instruction combo:

```
testq %rsi, %rsi
setX %al
```

%rsi=0x8000000000000001



```
testq %rsi, %rsi
setX %al
```

Q3.1 RFLAGS

In Q3, which of the following status flags are set after executing testq %rsi, %rsi (aka the rest are cleared)?

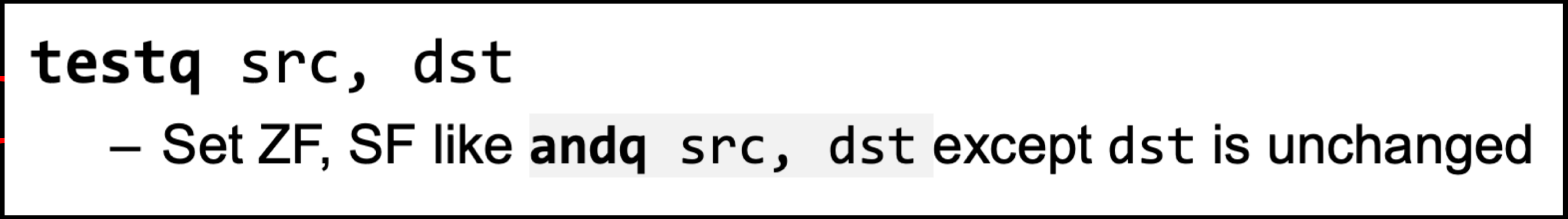
A. ZF

[✓ B. SF]

C. CF

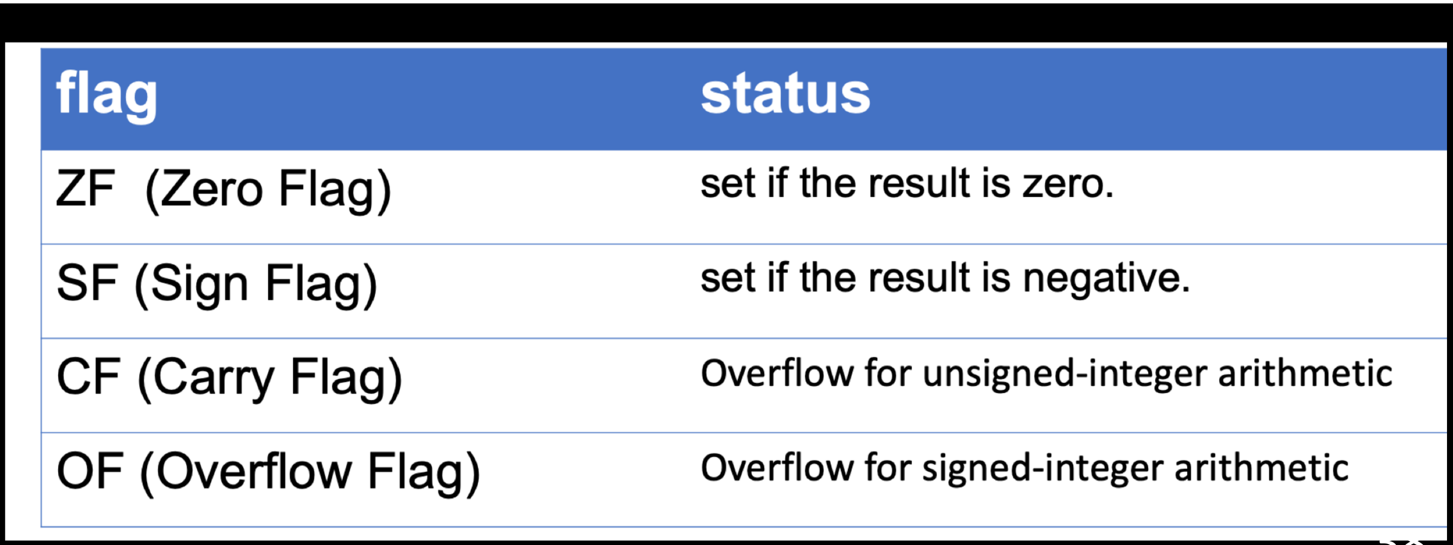
D. OF

- %rsi and %rdi =0x80…01
- SF=MSB=1
- CF, OF: test/and clears CF, OF



testq src, dst

– Set ZF, SF like `andq src, dst` except `dst` is unchanged



flag	status
ZF (Zero Flag)	set if the result is zero.
SF (Sign Flag)	set if the result is negative.
CF (Carry Flag)	Overflow for unsigned-integer arithmetic
OF (Overflow Flag)	Overflow for signed-integer arithmetic

Q3.2 Set instruction

ZF=0, SF=1, CF=0, OF=0

- In Q3, which of the following setX instruction would result in register %al being 1 after execution?

A. sete %al

[✓ B. setne %al]

[✓ C. sets %al]

D. setns %al

E. setg %al

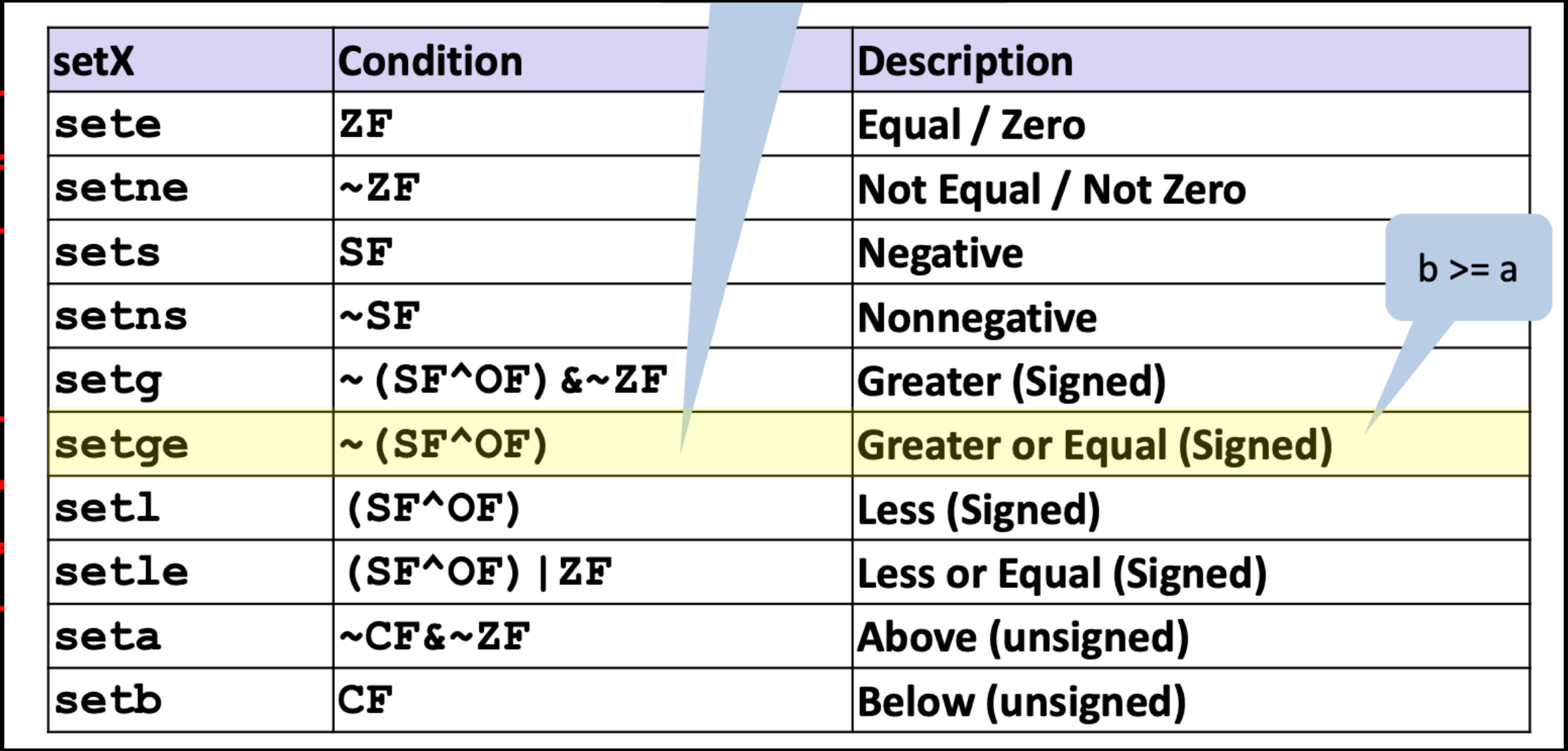
F. setge %al

[✓ G. setl %al]

[✓ H. setle %al]

[✓ I. seta %al]

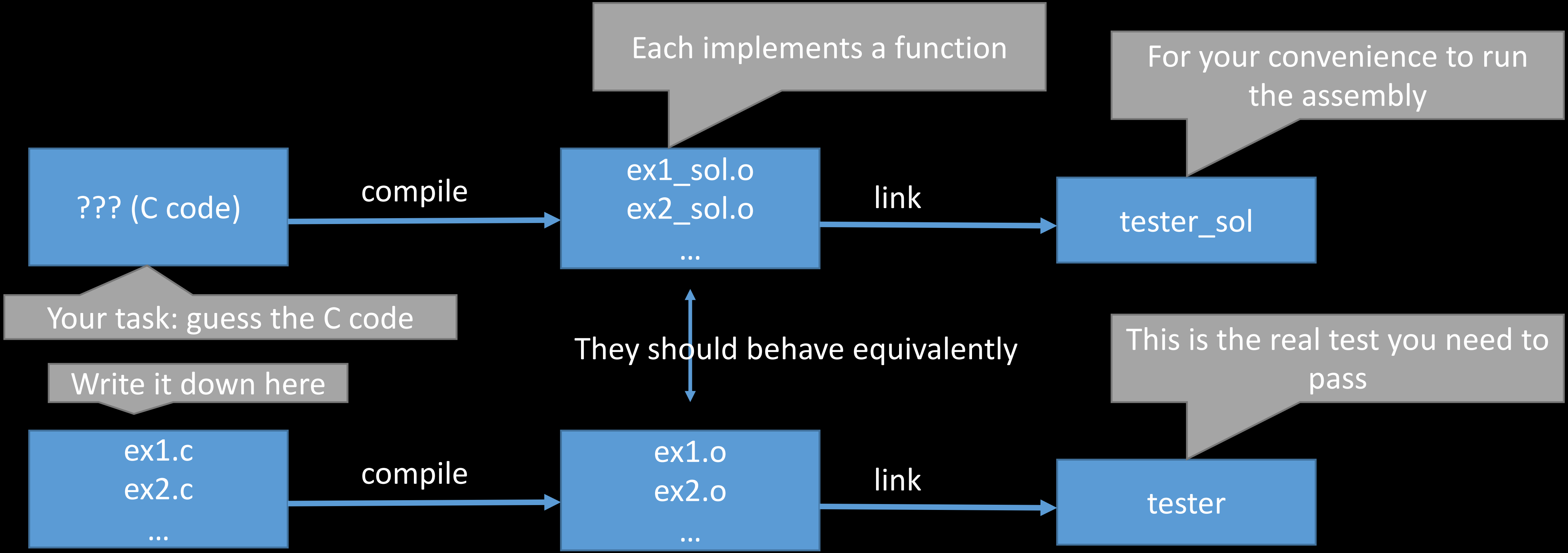
J. setb %al



setX	Condition	Description
sete	ZF	Equal / Zero
setne	~ZF	Not Equal / Not Zero
sets	SF	Negative
setns	~SF	Nonnegative
setg	~(SF^OF)&~ZF	Greater (Signed)
setge	~(SF^OF)	Greater or Equal (Signed)
setl	(SF^OF)	Less (Signed)
setle	(SF^OF)|ZF	Less or Equal (Signed)
seta	~CF&~ZF	Above (unsigned)
setb	CF	Below (unsigned)

b >= a

Lab3 -- Uncover the mystery



Each implements a function
For your convenience to run the assembly
??? (C code)
compile
ex1_sol.o
ex2_sol.o
…
link
tester_sol
Your task: guess the C code
They should behave equivalently
Write it down here
This is the real test you need to pass
ex1.c
ex2.c
…
compile
ex1.o
ex2.o
…
link
tester

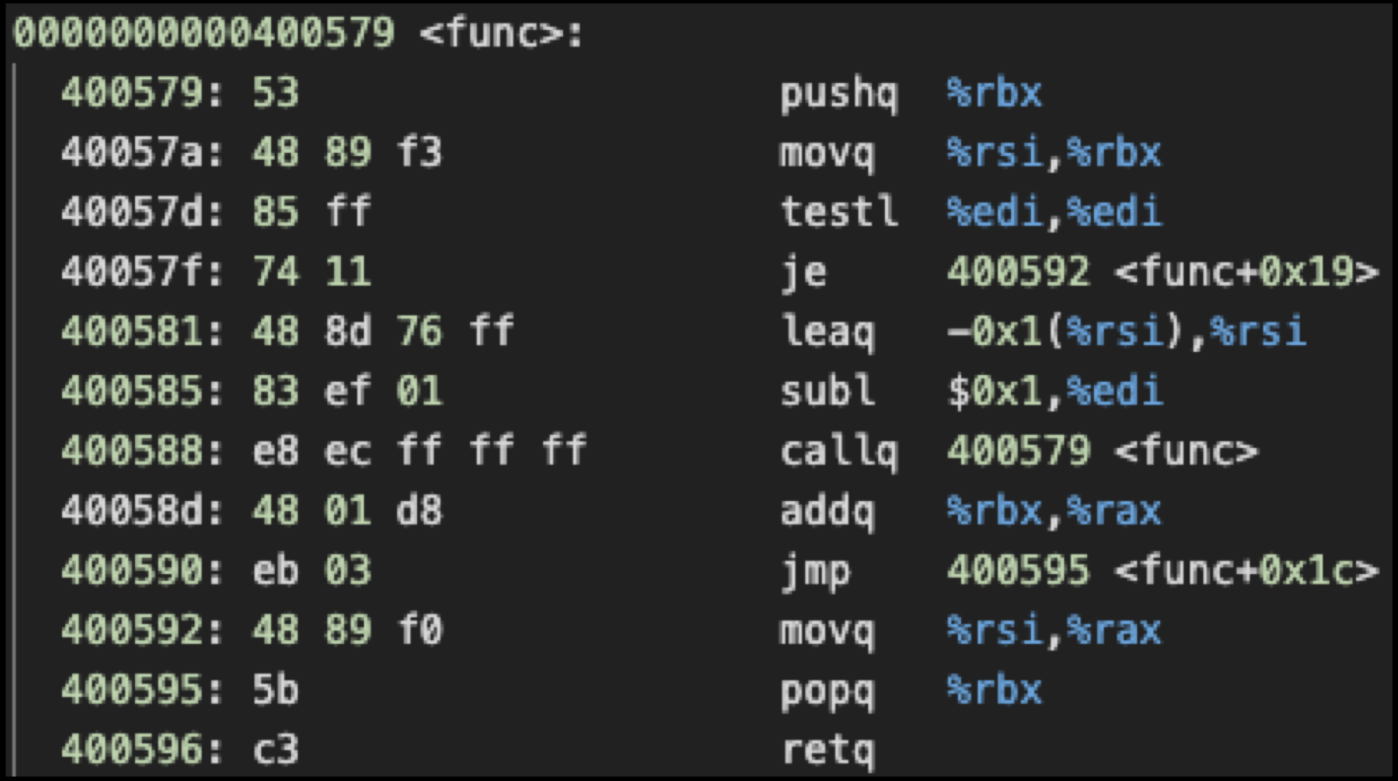
To view assembly code: objdump -d -M suffix ./tester_sol > tester_sol.s

Search for function label <ex1>

Exercise

Hint:
??? func(??? x, ??? y)
{
???
}

- Guess what's the C code for function func
- git clone https://github.com/lazycal/test.git



```
0000000000400579 <func>:
  400579: 53                      pushq  %rbx
  40057a: 48 89 f3                movq   %rsi,%rbx
  40057d: 85 ff                   testl  %edi,%edi
  40057f: 74 11                   je     400592 <func+0x19>
  400581: 48 8d 76 ff             leaq   -0x1(%rsi),%rsi
  400585: 83 ef 01                subl   $0x1,%edi
  400588: e8 ec ff ff ff          callq  400579 <func>
  40058d: 48 01 d8                addq   %rbx,%rax
  400590: eb 03                   jmp    400595 <func+0x1c>
  400592: 48 89 f0                movq   %rsi,%rax
  400595: 5b                      popq   %rbx
  400596: c3                      retq
```

Solution

```
long func(int x, long y)
{
if (x == 0) return y;
return func(x - 1, y - 1) + y;
}
```

Exercise

- After running `cmpl %eax %ebx`, what are the status of CF and OF?

eax	ebx	CF	OF
0x7fffffff	0x00000000	1	0
0x7fffffff	0xffffffff	0	0
0x80000000	0x00000000	1	1
0x80000000	0x80000000	0	0

Exercise

- Guess what's the C code for function m
- wget https://raw.githubusercontent.com/DingDTest/Recitation-examples/main/r08/example_func2