Procedures I

CSE 351 Winter 2024

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Senior Oops Engineer @ReinH · Feb 28, 2019

I am a full stack engineer which means if you give me one more task my stack will overflow

Relevant Course Information

- Lab 2 due next Friday (2/2)
  - Can start in earnest after today's lecture!
  - See GDB Tutorial Lesson and and Phase 1 walkthrough in Section 4 Lesson
- Midterm (take home, 2/8–2/10)
  - Make notes and use the midterm reference sheet
  - Form study groups and look at past exams!

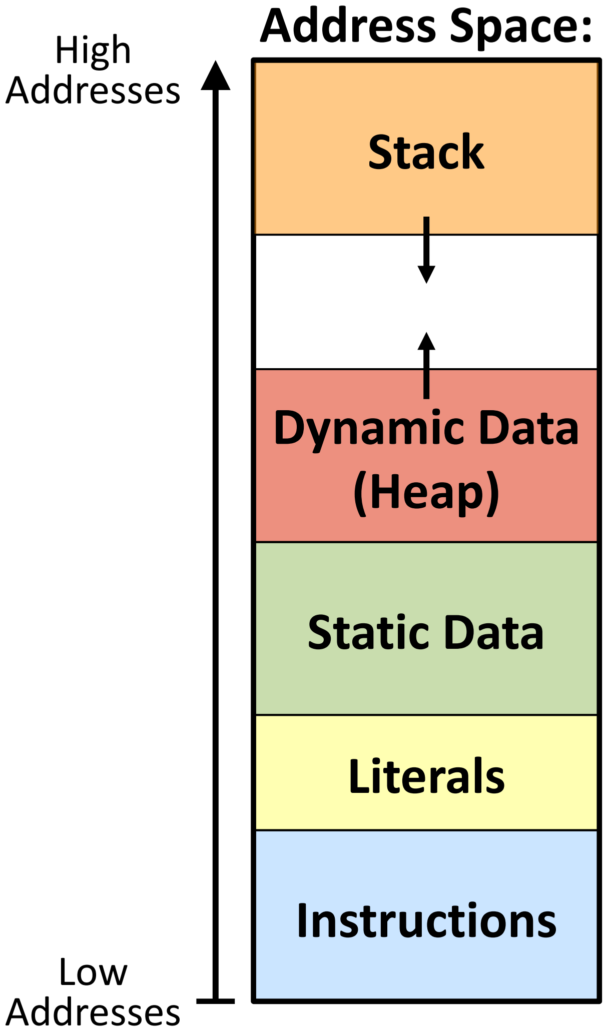
Procedures I

Lesson Summary (1/3)

- Memory is organized into 5 segments based on data declaration and lifetime
  - Goals: maximize use of space, manage data differently, apply separate permissions

- A **segmentation fault** is caused by an impermissible memory access

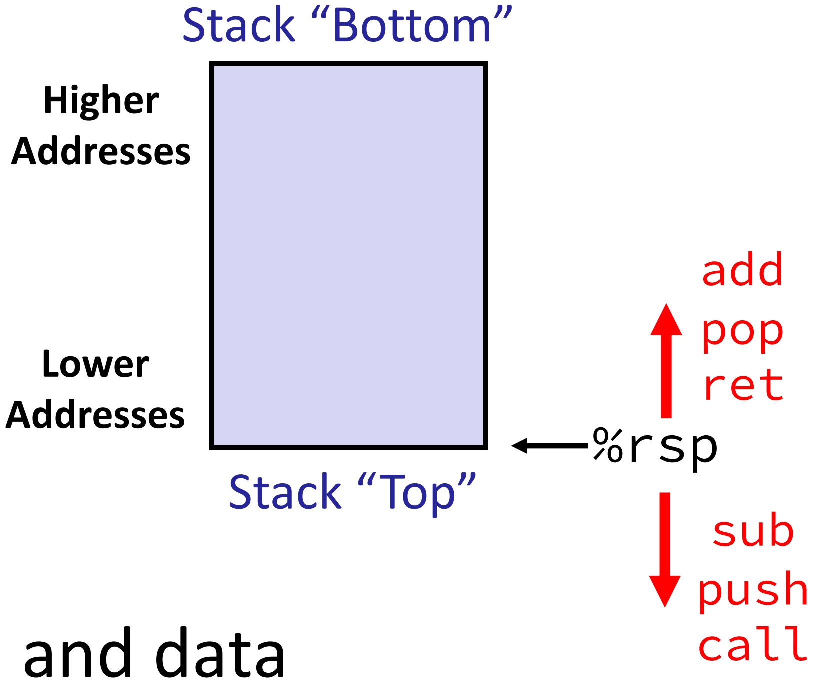
Address Space:



Segment	Contents	Permissions
Stack	Local variables and procedure context	Writable; not executable
Dynamic Data (Heap)	Variables allocated with `new` or `malloc`	Writable; not executable
Static Data	*Static* variables (*e.g.*, global variables)	Writable; not executable
Literals	Immutable literals (*e.g.*, `"example"`)	Read-only; not executable
Instructions	Program code	Read-only; executable

Lesson Summary (2/3)

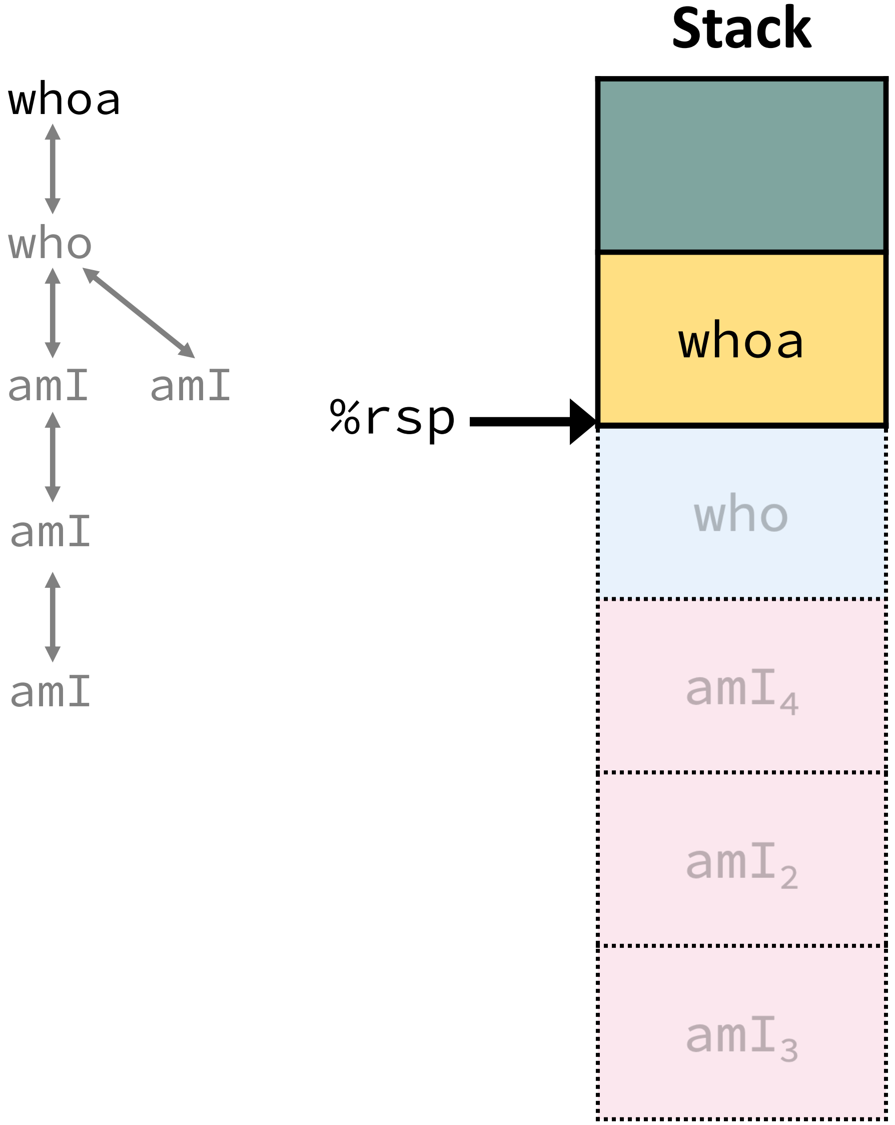
- **The Stack** is the memory segment with the highest addresses and grows downward
  - Stack "top" (lowest address) is defined by the value of the stack pointer (`%rsp`)
  - Can manipulate using `add`, `sub`, `push`, and `pop`



- Procedure calling conventions for passing control and data
  - `call` and `ret` pass control using `%rip` and a return address on the stack
  - Arguments: `%rdi`, `%rsi`, `%rdx`, `%rcx`, `%r8`, `%r9`, Stack
  - Return value: `%rax`

Lesson Summary (3/3)

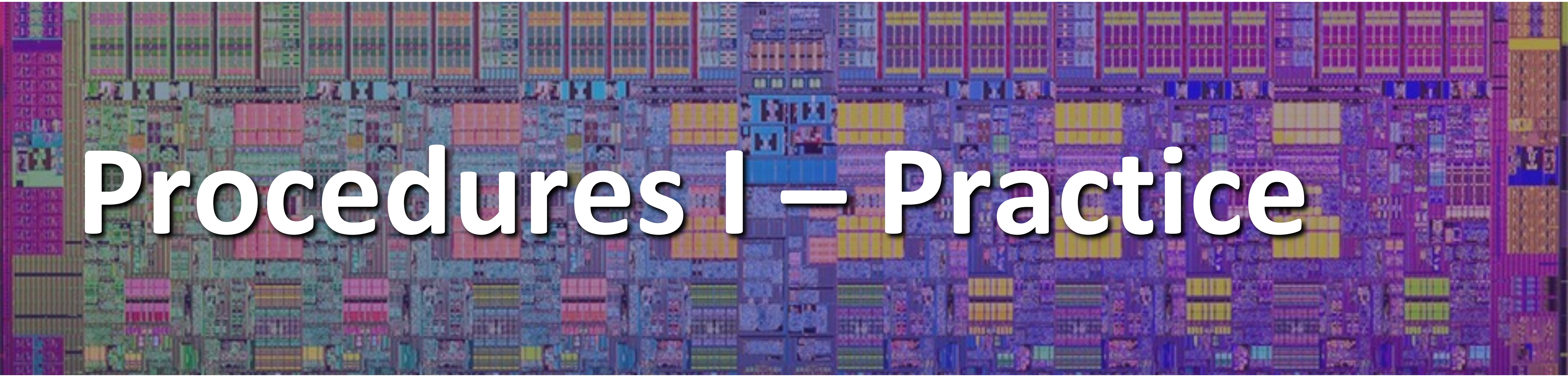
- Stack organized into **stack frames** that hold a procedure instance's data
  - Size will vary based on procedure specifics
  - Space gets allocated as procedure executes, deallocated by the time it returns



Lesson Q&A

- Learning Objectives:
  - Determine the location/segment in memory that a piece of data will be stored based on the nature of that data (*i.e.*, static, literals, etc.).
  - Trace stack frame movement and creation.

- What lingering questions do you have from the lesson?
  - Chat with your neighbors about the lesson for a few minutes to come up with questions



Procedures I – Practice

Practice Questions (1/2)

- How does the stack change after executing the following instructions?

```
pushq  %rbp
subq   $0x18, %rsp
```

8B

add to stack

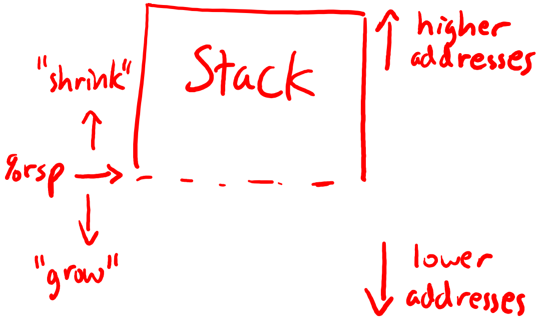
lower address

0x18 = 24

grow 8 B

grow 24 B

grow by 32 B



- For the following function, which registers do we know *must* be used?

```
void* memset(void* ptr, int value, size_t num);
```

return value in %rax

arguments in %rdi, %rsi, and %rdx

%rsp changed by call & ret

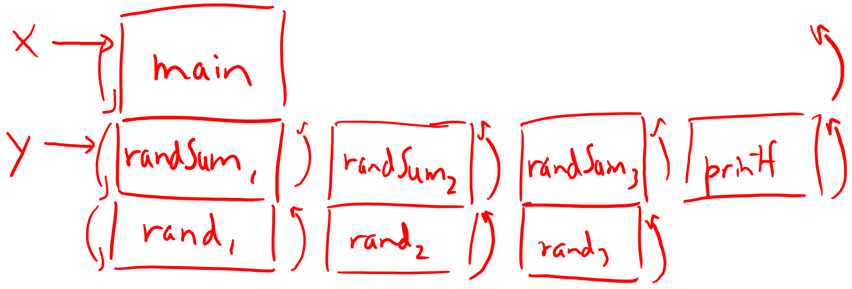
%rip changed while executing instructions

Practice Questions (2/2)

- Answer the following questions about when `main()` is run (assume `x` and `y` stored on the Stack):

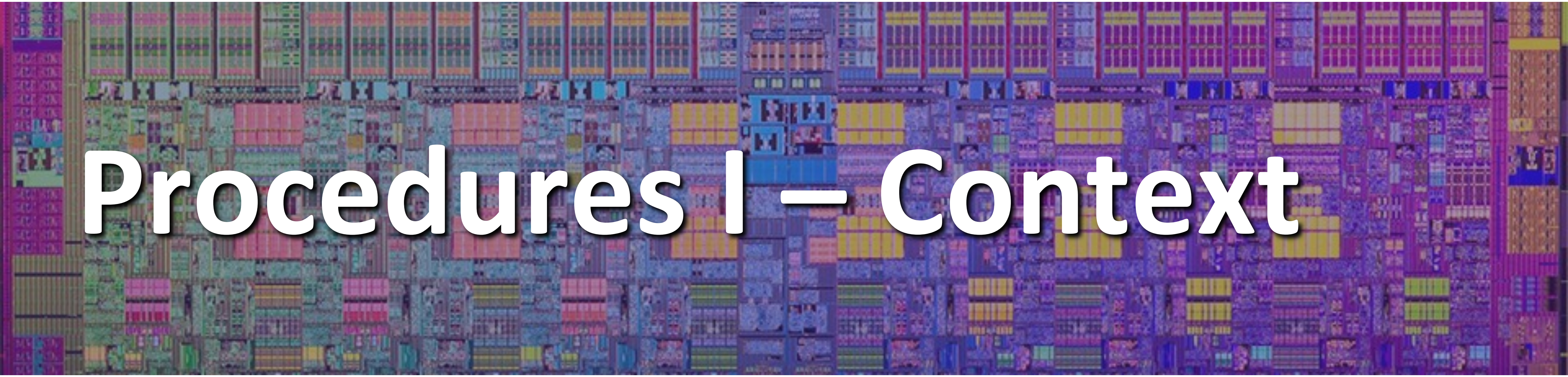
```c
int main() {
    int i, x = 0;
    for(i=0;i<3;i++)
        x = randSum(x);
    printf("x = %d\n",x);
    return 0;
}
```

```c
int randSum(int n) {
    int y = rand()%20;
    return n+y;
}
```



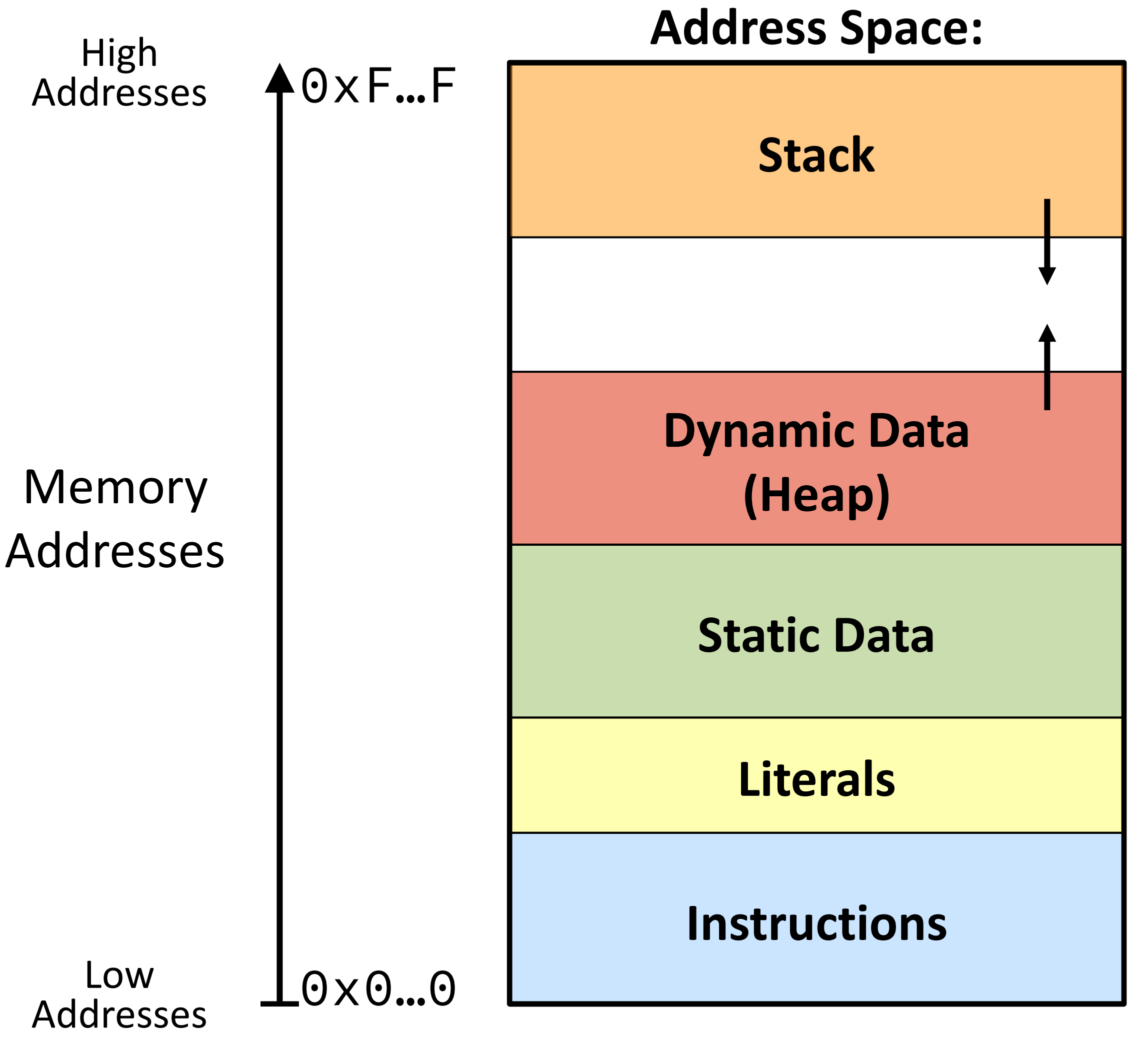
- *Higher/larger address*: [✓ x] or y?
- How many total stack frames are *created*? 8
- What is the maximum *depth* (# of frames) of the Stack?

A. 1 B. 2 [✓ C. 3] D. 4



Procedures I – Context

Simplified Memory Layout



What Goes Here:

Local variables and procedure context

Variables allocated with new or `malloc`

Static variables (including global variables)

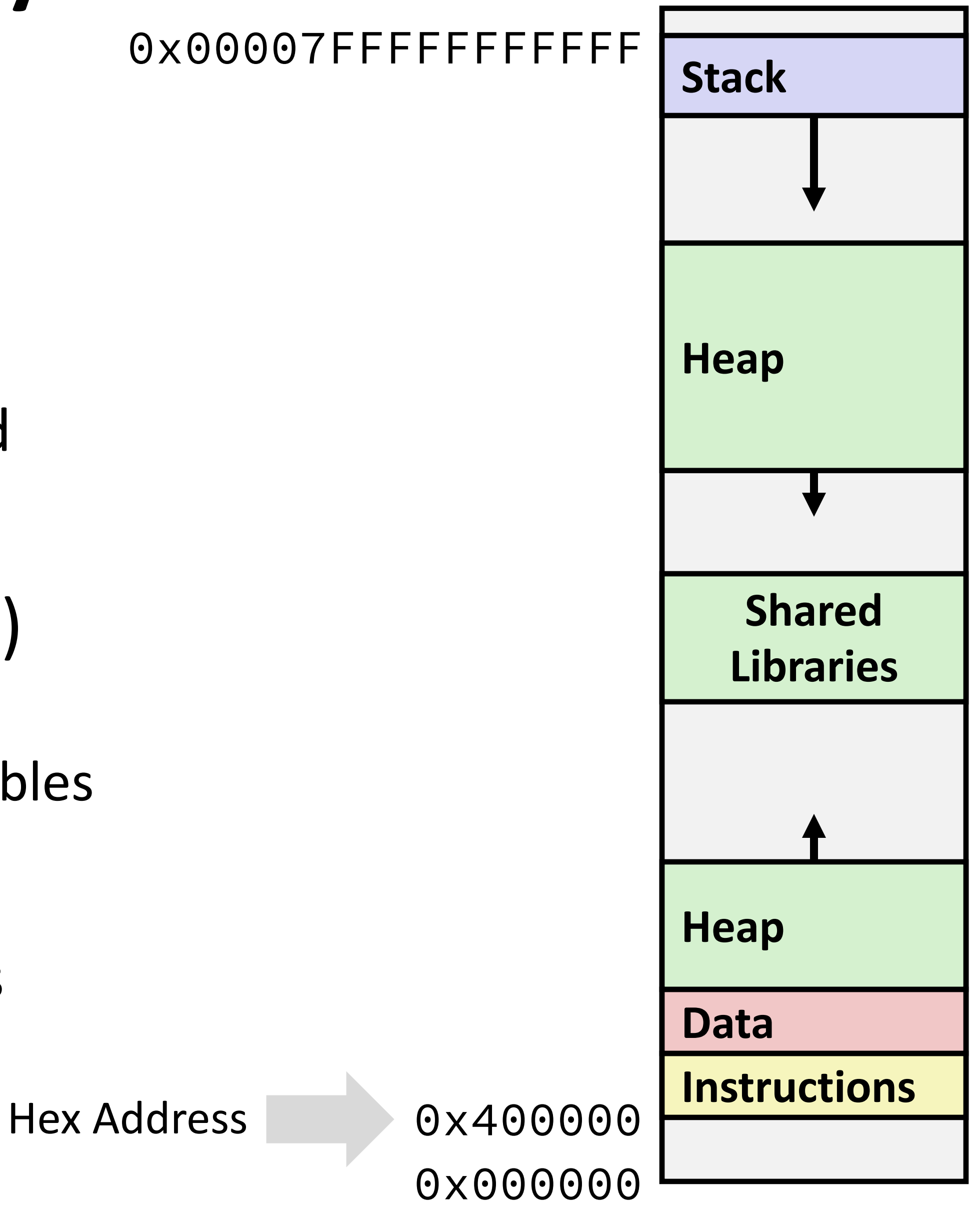
Immutable literals/constants (*e.g.*, `"example"`)

Program code

x86-64 Linux Memory Layout

This is extra (non-testable) material

- Stack
  - Runtime stack has 8 MiB limit
- Heap
  - Dynamically allocated as needed
  - `malloc()`, `calloc()`, `new`, …
- Statically allocated data (Data)
  - Read-only: string literals
  - Read/write: global arrays and variables
- Code / Shared Libraries
  - Executable machine instructions
  - Read-only



Stack Overflow

- When the stack pointer exceeds the stack bounds (segmentation fault)
  - In theory: when it collides with the Heap
  - In x86-64 Linux, when it exceeds 8 MiB limit

- Causes?
  - Infinite/deep recursion
  - Very large local variables

- Fixes?
  - Use iterative solution, compiler tail-call optimization
  - Allocate large variables elsewhere (more on the Heap later this quarter)

Aside: Stack Overflow

- Has nothing to do with actual stack overflow – named based on poll of blog users; some of the non-winning options:
  - algorithmical
  - bitoriented
  - dereferenced
  - fellowhackers
  - humbleprogrammers
  - privatevoid
  - shiftleft1
  - understandrecursion
- Crowd-sourced their logo for $512

Discussion Questions

- Discuss the following question(s) in groups of 3-4 students
  - I will call on a few groups afterwards so please be prepared to share out
  - Be respectful of others' opinions and experiences

- Naming/etymology plays a big role in learning
  - Which new terms <u>in this class</u> have been the most intuitive for you to learn vs. the most difficult?
  - What do you think goes into a good vs. bad name more generally in computer science?

Group Work Time

- During this time, you are encouraged to work on the following:
  1) If desired, continue your discussion
  2) Work on the homework problems
  3) Work on the lab (if applicable)

- Resources:
  - You can revisit the lesson material
  - Work together in groups and help each other out
  - Course staff will circle around to provide support