CSE 333 24sp Section 2

Debugging and Structs

UNIVERSITY of WASHINGTON

Checking In & Logistics

- Exercise 3:
  - Due **Friday (Tomorrow!) @ 10:00am (6/28)**
- Homework 1:
  - Due **Friday next week @ 11:00pm (7/05)**
  - Start Early!

Any questions, comments, or concerns?

- Exercises going ok?
- Lectures making sense?

Structs and Typedef Review

Defining Structs

- To define a struct, we use the `struct` statement, which typically has a name (a tag) and must have one or more data members
  - This defines a new data type!

```
struct simplestring_st {
  char* word;
  int   length;
};
struct simplestring_st my_word;
```

Typedef

- The C Programming language provides the keyword `typedef`, which defines an alias (alternate name) for an existing data type
  - This can be used in combination with a `struct` statement

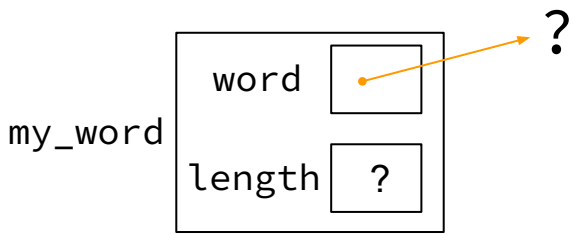
```
struct simplestring_st {
  char* word;
  int   length;
};
typedef struct simplestring_st SimpleString;
SimpleString my_word;
```

```
typedef struct simplestring_st {
  char* word;
  int   length;
} SimpleString;
SimpleString my_word;
```

Structs and Memory Diagrams

- `struct` instance is a box, with individual boxes for fields inside of it, labelled with field names
  - Even though we know that field ordering is guaranteed, we can be loose with where we place the fields in our diagram

```
typedef struct simplestring_st {
  char* word;
  int   length;
} SimpleString;
SimpleString my_word;
```



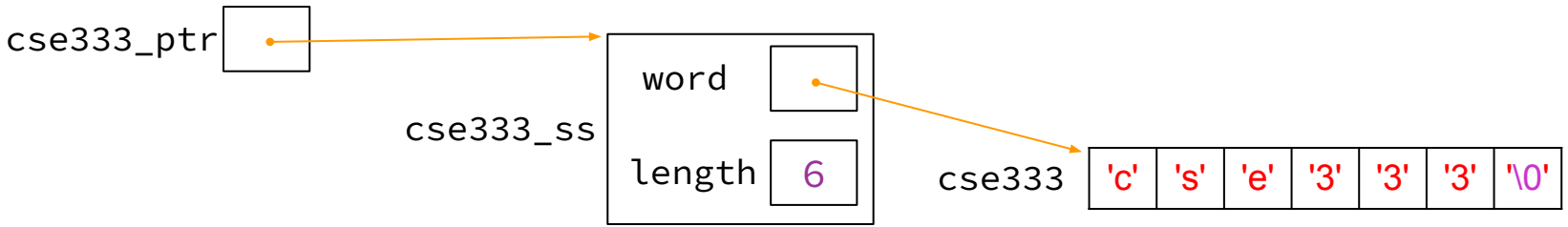
Structs and Pointers

- "`.`" to access field from `struct` instance
- "`->`" to access field from `struct` pointer

```
typedef struct simplestring_st {
  char* word;
  int   length;
} SimpleString;
```

```
char cse333[] = "cse333";
SimpleString  cse333_ss;
SimpleString* cse333_ptr = &cse333_ss;

cse333_ss.word = cse333;
cse333_ptr->length = strlen(cse333);
```



Passing Structs as Parameters

- Assignment copies over all of the field values
  - Unlike reference copying in Java

- Structs are *pass-by-copy* (as arguments and return values)
  - Can imitate pass-by-reference by passing pointer to struct instance instead

Debugging Tools

Debugging

- ✨ **Debugging is a skill that you will need throughout your career!** ✨
- The 333 projects are big with lots of potential for bugs
  - Learning to use the debugging tools will make your life a lot easier
  - Course staff will help you learn the tools in office hours, too
- Debugging tool output can be scary at first, but extremely useful once you know how to parse it

Debugging Strategies

Many debugging strategies exist but here's a simple 5 step process!

1. **Observation**: Something is wrong with your program!
2. **Hypothesis**: What do you think is going wrong?
3. **Experiment**: Use debuggers and other tools to verify the problem
4. **Analyze**: Identify and implement a fix to the problem.
5. Repeat steps 1-4 until *bug free*!

Key debugging skills to master

1. Stop at “interesting” places
   - Debug after a crash or segfault
   - Use breakpoints to stop during execution

1. Look around when stopped
   - Print values of variables
   - Look at source code
   - Look up/down call chain

1. Resume execution
   - Incrementally, step at a time
   - Until next breakpoint
   - Until finished

333 Debugging Options

- `gdb` (GNU Debugger) is a general-purpose debugging tool
  - Stops at breakpoints and program crashes
  - Lots of helpful features for tracing code, checking current expression values, and examining memory
- `valgrind` specifically check for memory errors
  - Great for catching non-crashing odd behavior (*e.g.*, using uninitialized values, memory leaks on the heap)
  - If your code uses `malloc`, should use `--leak-check=full` option

Basic Functions in GDB

- Setting breakpoints:
  - `break <filename>:<line#>`
- Advancing
  - `step` – into functions
  - `next` – over functions
  - `continue` – to next break
- Reading Values
  - `print` – evaluate expression once
  - `display` – keep evaluating expression
- Examining memory
  - `x` – dereference provided address
  - `bt` – backtracing
- Reference Card: https://courses.cs.washington.edu/courses/cse333/24sp/resources/gdb-refcard.pdf

Common Errors

```
Hello World!
Segmentation fault (core dumped)
```

- **Misusing Functions**: Read documentation (online, through man pages, or the `.h` files for your homework) for function parameters and function purpose
  - Oftentimes, this leads to unexpected results!

- **Segmentation Fault**: Dereferencing an uninitialized pointer, `NULL`, a previously-freed pointer, or many other things.
  - GDB automatically halts execution when `SIGSEGV` is received, useful for debugging

- **Memory “Errors”**: Many possible errors, commonly use of uninitialized memory or “memory leaks” (data allocated on heap that does not get free’d).
  - Use `valgrind` to help catch memory errors!

Trying to Run `reverse.c`

We have a program *`reverse.c`* that accepts a string from the user and reverses it!

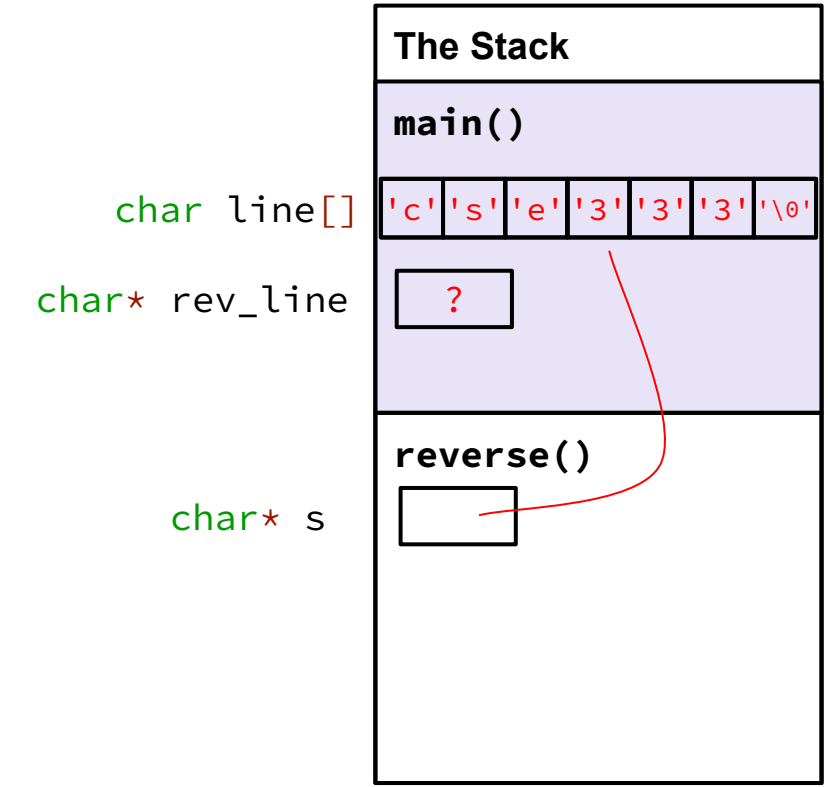
But it has a few problems… let's take a look!

Exercise 1

Complete the Memory Diagram

```
int main() {
char line[MAX_STR];
char* rev_line;

printf("Please enter a string: ");
fgets(line, MAX_STR, stdin);
rev_line = reverse(line);
    .
    .
    .
```

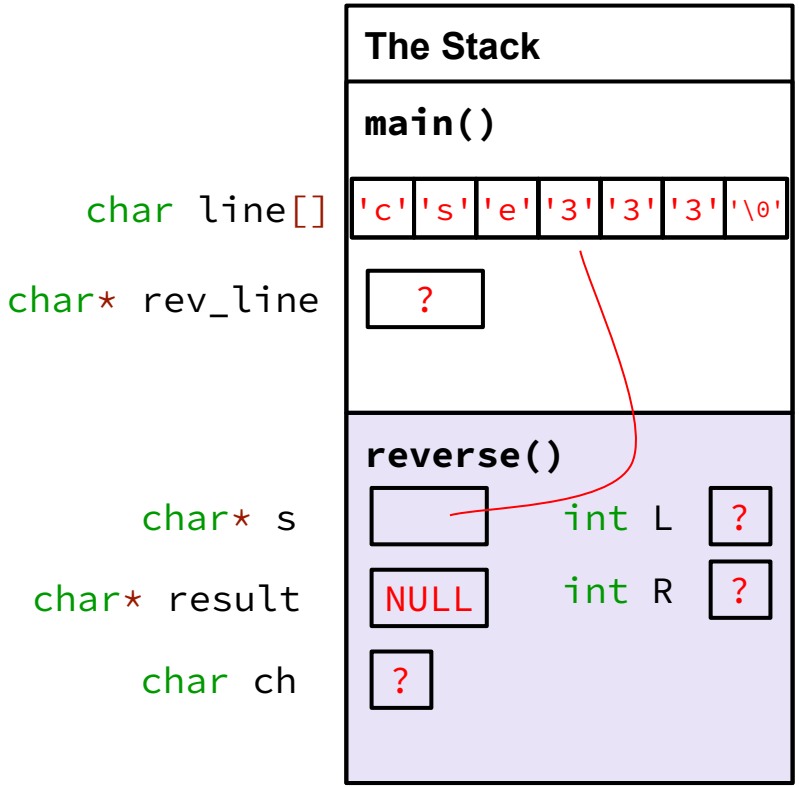


*unreached code omitted for space

Complete the Memory Diagram

```
 char* reverse(char* s) {
➡char* result = NULL;
➡int L, R;
➡char ch;

➡strcpy(result, s);
    •
    •
    •
```



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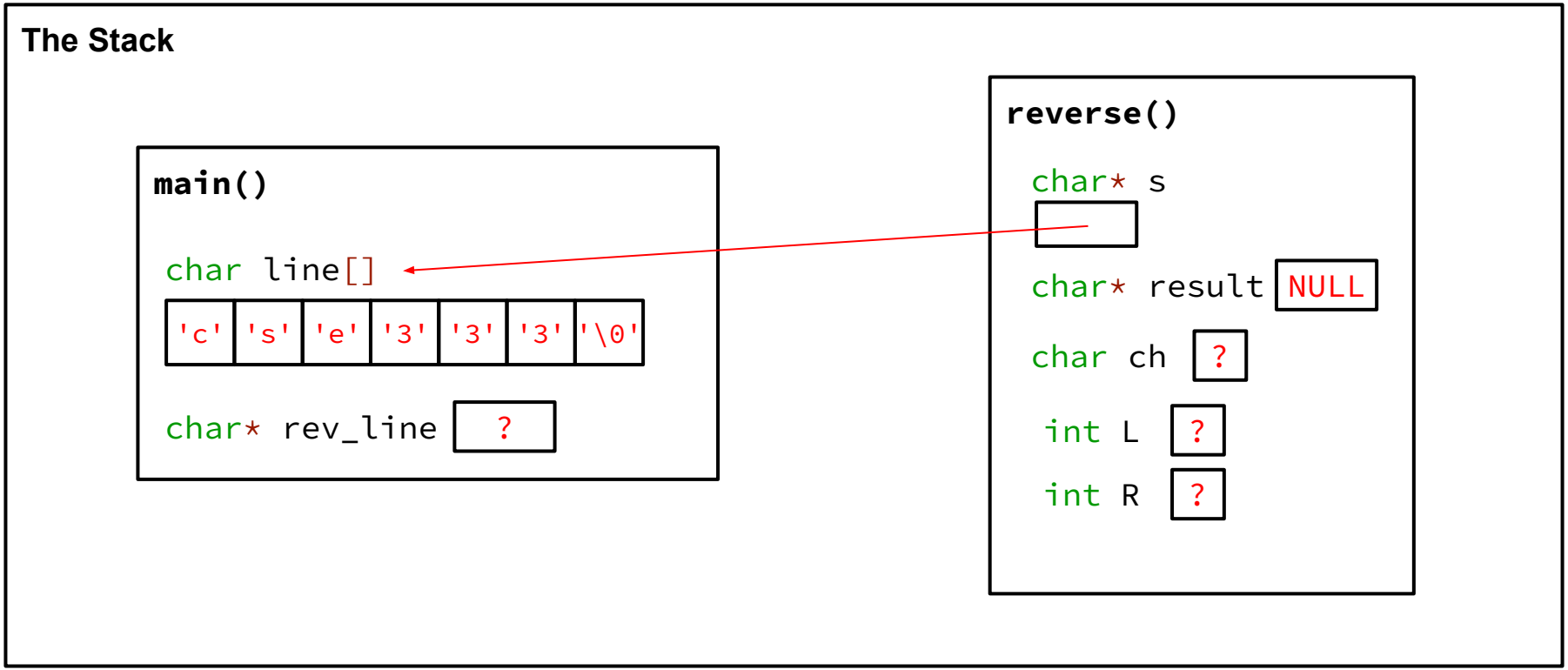
Completed Memory Diagram



Exercise 2 & 3

Fix 1: Segfault

- Tool help: `run` in `gdb` to find segfault, `man` for `strncpy`, `bt` to find segfault occurrence
- Old version:

```
result = NULL;
strcpy(result, s);
```

- New version:

```
result = (char*) malloc(strsize);
strncpy(result, s, strsize);
```

Fix 2: Doesn't reverse string

- Tool help: run in `gdb`, break on `reverse()`, step through code, `print /s word` at end of function (prints as string)
- Old version:

```
char ch;
int L = 0, R = strlen(result);
```

- New version:

```
char ch;
int L = 0, R = strlen(result) - 1;
```

Fix 3: Memory leaks

- Tool help: run under `valgrind`, identify un-freed allocation line numbers

- Old version:

```
char* reverse(char* s) { ...
return result; }
```

- New version:

```
char* reverse(char* s) { ...
return result; }
At end of main:   free(rev_line);
```

Style Fixes

- Tool help: None? Lecture slides! Google C++ Style Guide!
- `malloc` error checking:

```
result = (char*) malloc(strsize);
if (result == NULL) {
  // sample error checking. Read the spec on the requirements
  // for handling malloc!
  exit(EXIT_FAILURE);
}
```

- Remember to do this for the sake of code style! Malloc errors are rare, but we still check for failure to keep our code consistent