CS 3330: C

25 August 2016

Layers of Abstraction

`x += y`	"Higher-level" language: C
add `%rbx, %rax`	Assembly: X86-64
60 03	Machine code: Y86
	(we'll talk later)
	Logic and Registers

Compilation Steps

compile:	`gcc -S file.c`	$\Rightarrow$	`file.s`
assemble:	`gcc -c file.s`	$\Rightarrow$	`file.o`
link:	`gcc -o file file.o`	$\Rightarrow$	`file` (exec.)
c+a:	`gcc -c file.c`	$\Rightarrow$	`file.o`
c+a+l:	`gcc -o file file.c`	$\Rightarrow$	`file` (exec.)

...

What's in those files?

hello.c

```
#include <stdio.h>
int main(void) {
  puts("Hello,␣World!");
  return 0;
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hello.s

```
    .text
main:
    sub  $8, %rsp
    mov  .Lstr, %rdi
    call puts
    xor  %eax, %eax
    add  $8, %rsp
    ret

    .data
.Lstr: .string "Hello,␣World!"
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text (code) segment:

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relocations:

take 0s at	*and replace with*
text, byte 6 ( )	data segment, byte 0
text, byte 10 ( )	address of puts

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symbol table:

main	text byte 0

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+ stdio.o

hello.exe

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```

hello.s

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data segment:

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48 65 6C 6C 6F 2C 20 57 6F 72 6C 00
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relocations:

take 0s at	*and replace with*
text, byte 6 ( )	data segment, byte 0
text, byte 10 ( )	address of puts

symbol table:

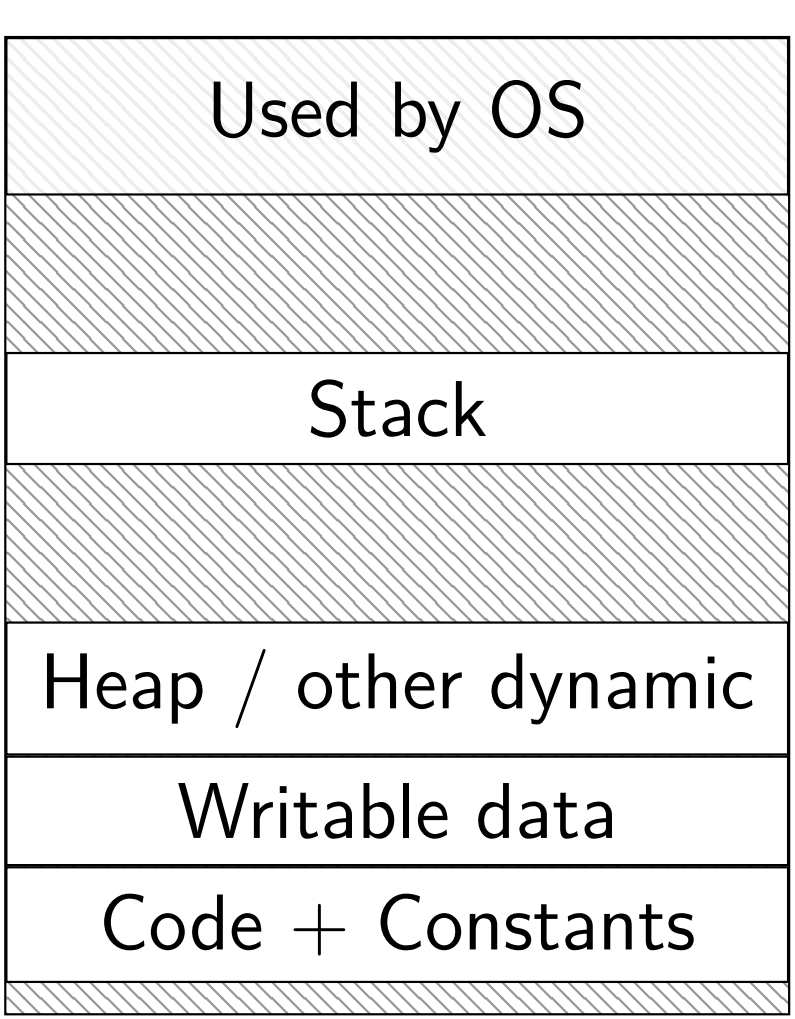
main	text byte 0

+ stdio.o

hello.exe

```
48 83 EC 08 BF A7 02 04 00
E8 08 4A 04 00 31 C0 48
83 C4 08 C3 …
…(code from stdio.o) …
48 65 6C 6C 6F 2C 20 57 6F
72 6C 00 …
…(data from stdio.o) …
```

Program Memory (x86-64 Linux)



`0xFFFF FFFF FFFF FFFF`

`0xFFFF 8000 0000 0000`

`0x7F…`

`0x0000 0000 0040 0000`

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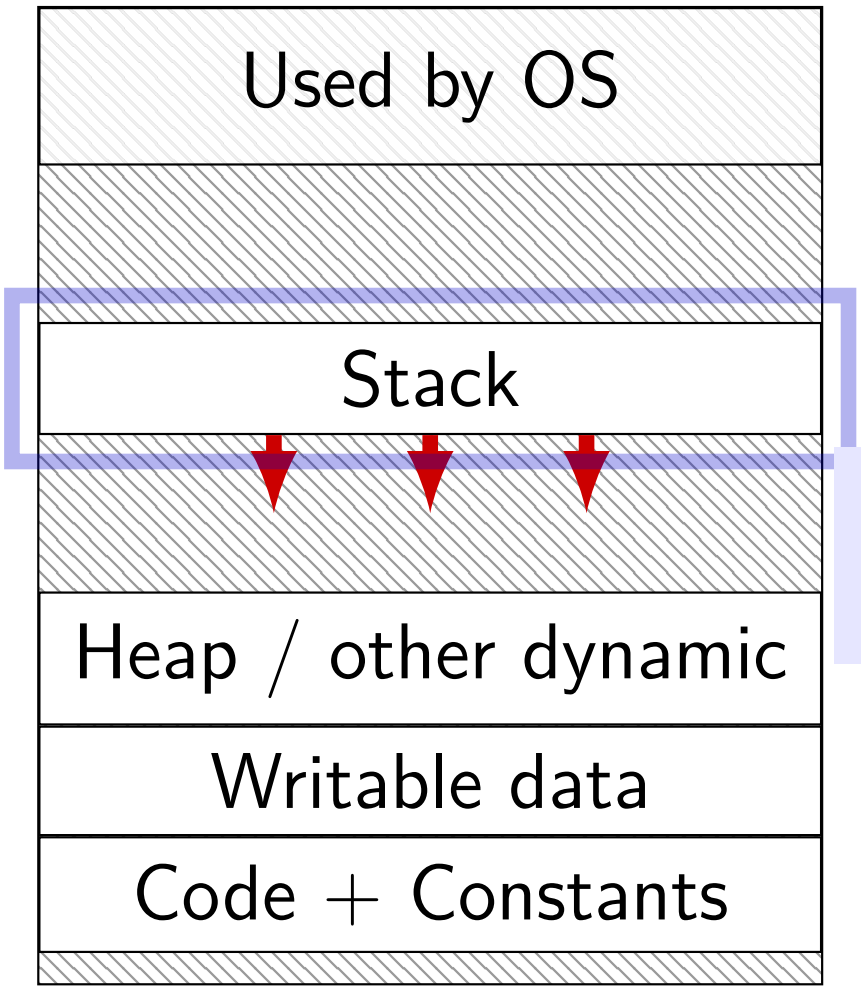

0xFFFF FFFF FFFF FFFF

0xFFFF 8000 0000 0000

0x7F…

stack grows down
"top" has smallest address

0x0000 0000 0040 0000

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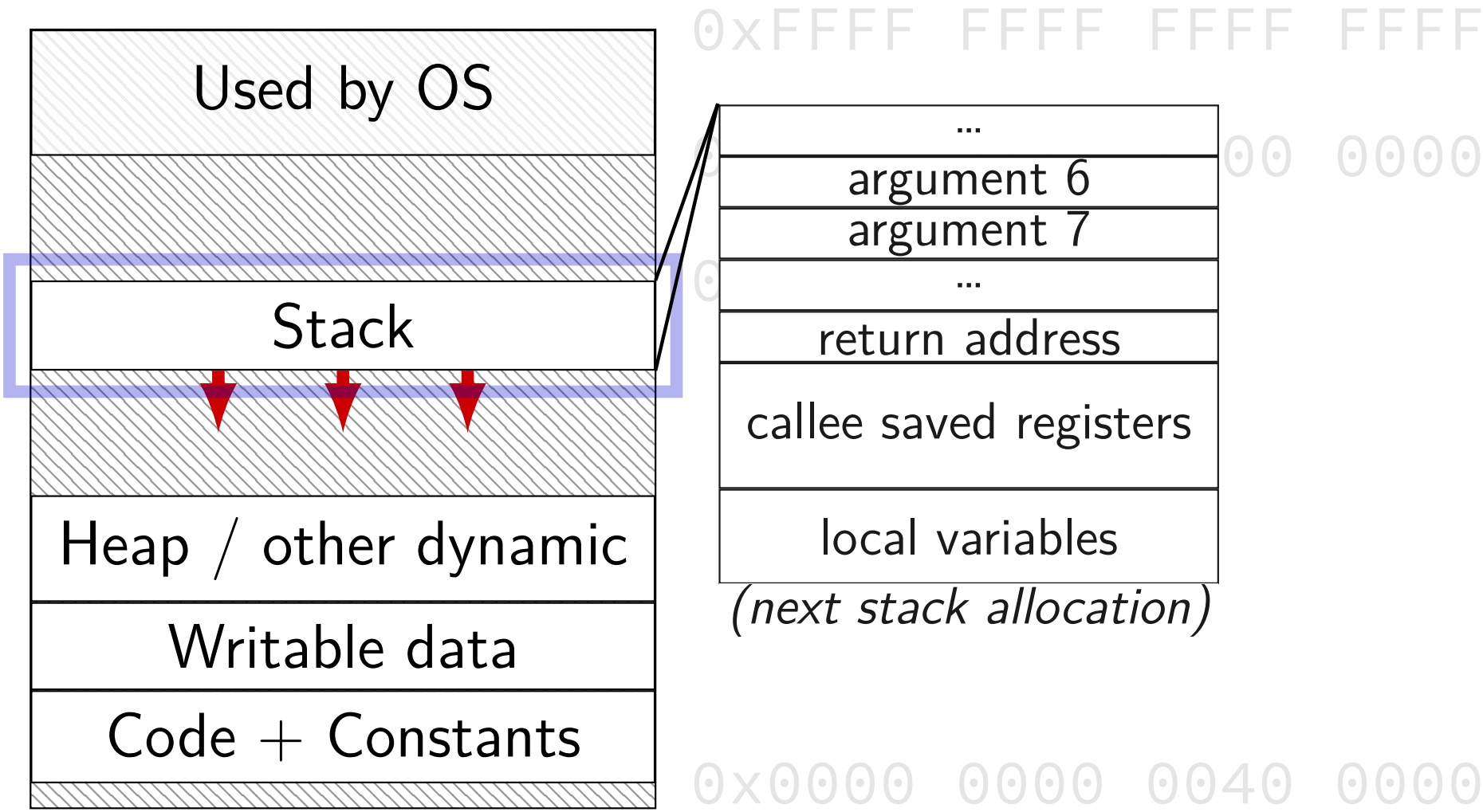

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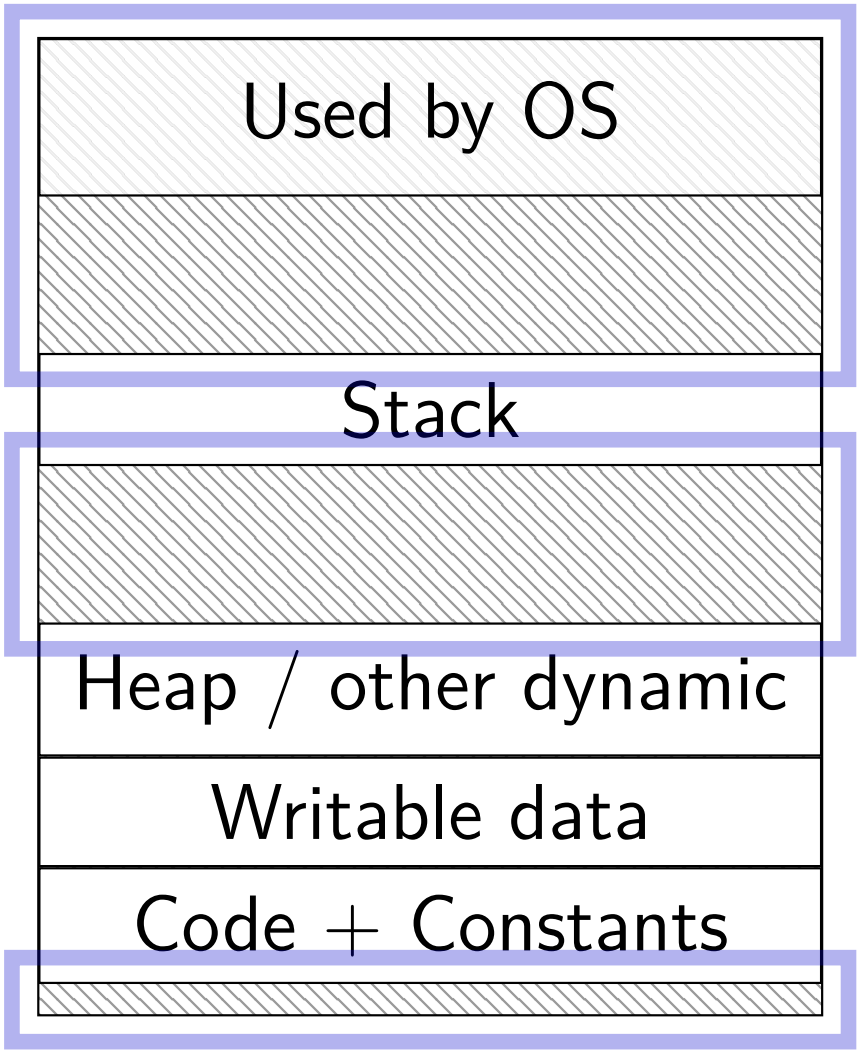

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C Data Types

Varies between machines(!). For this course:

type	size (bytes)
`char`	1
`short`	2
`int`	4
`long`	8

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`char`	1
`short`	2
`int`	4
`long`	8
`float`	4
`double`	8
`void *`	8
`anything *`	8

Truth

~~`bool`~~

Truth

~~`bool`~~

`x == 4` is an **`int`**

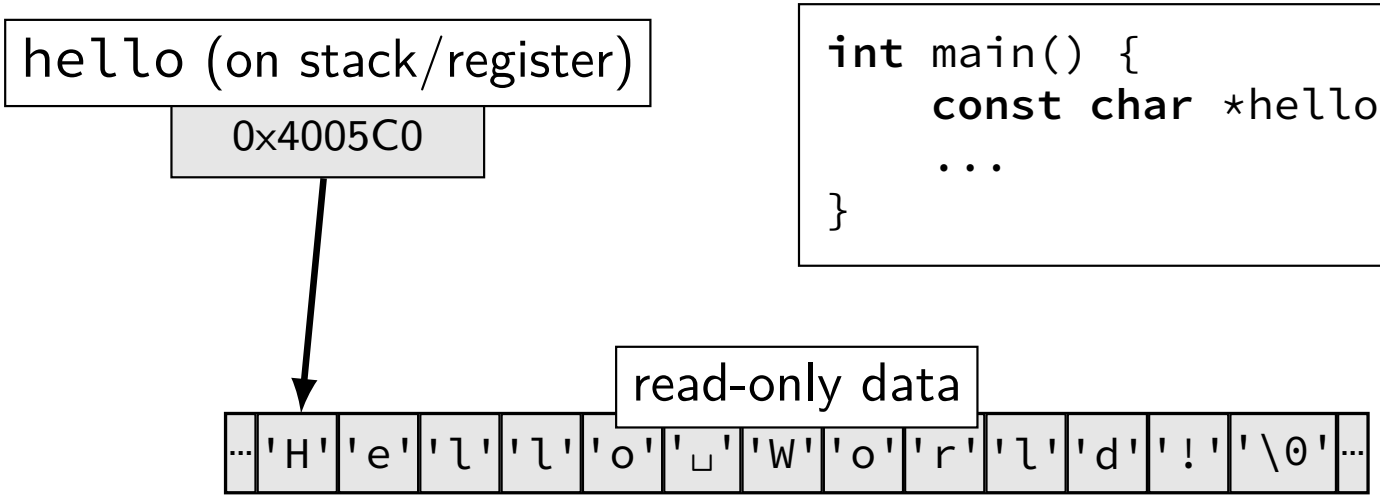
`1` if true; `0` if false

False values in C

`0`

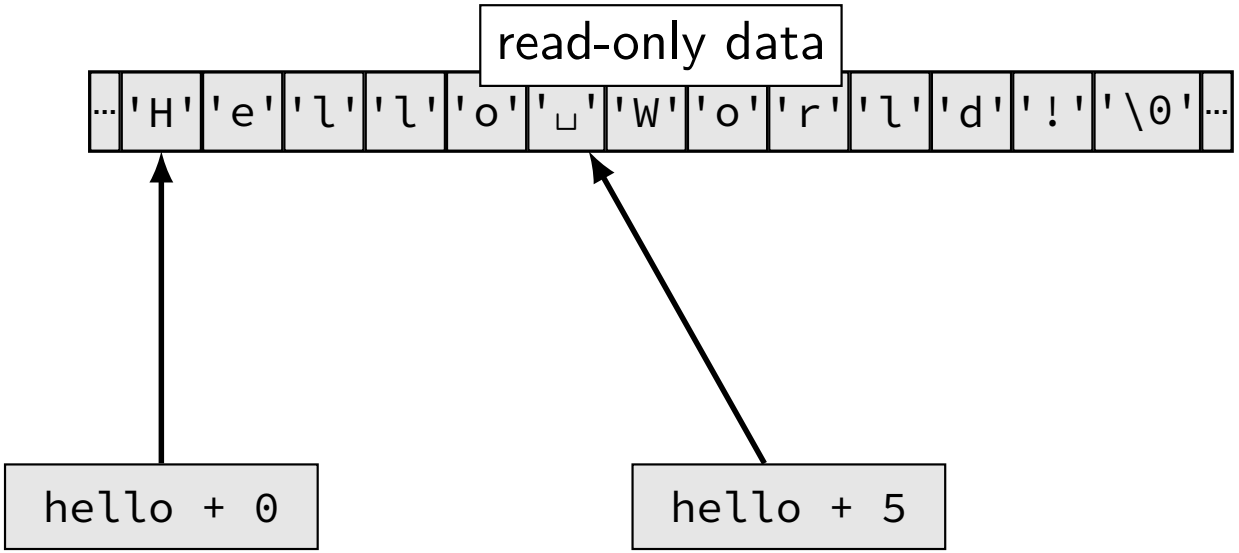
including null pointers — `0` cast to a pointer

Strings in C




```
int main() {
    const char *hello = "Hello␣World!";
    ...
}
```

Pointer Arithmatic



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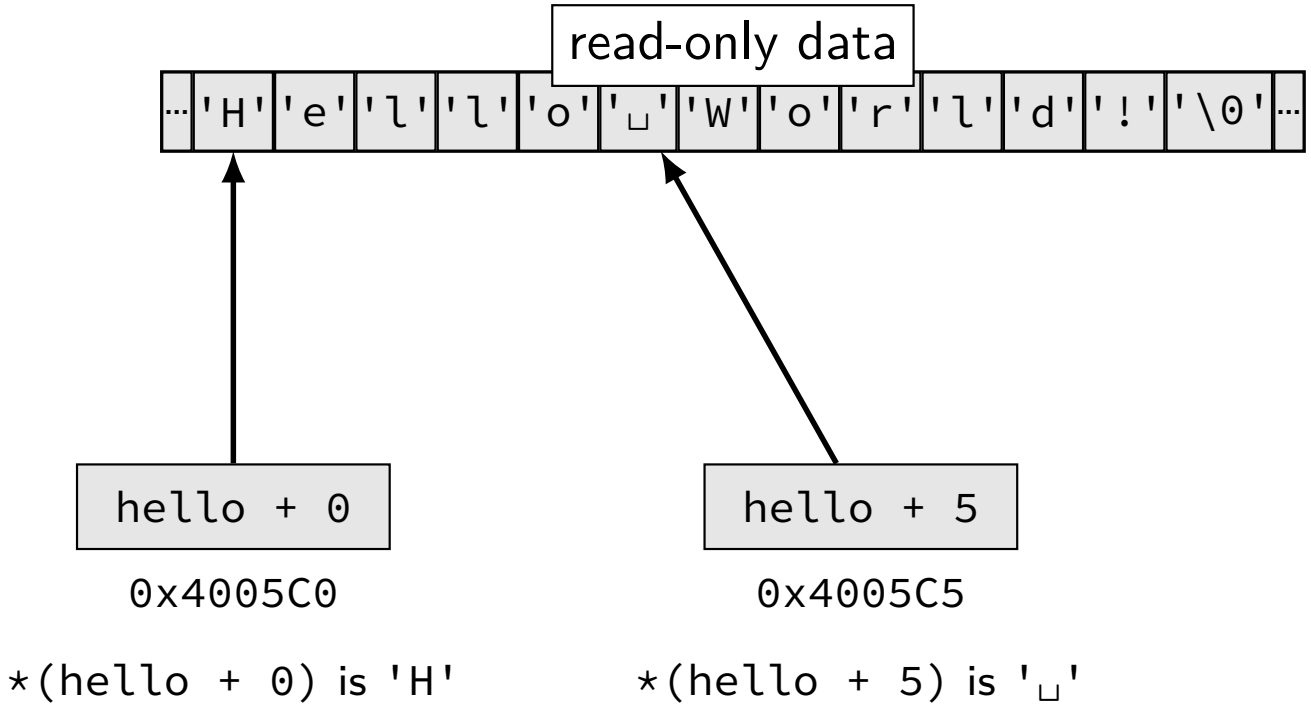
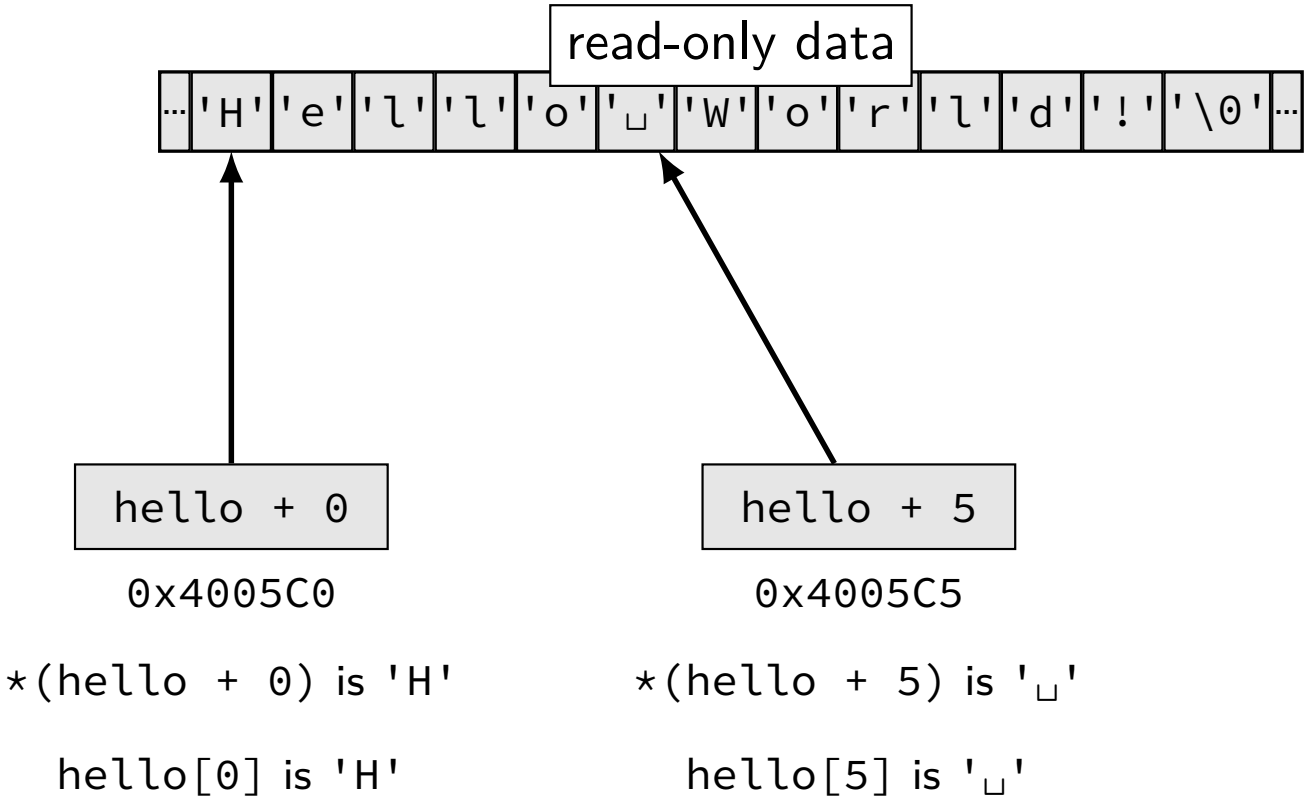


`*(hello + 0)` is `'H'`

`*(hello + 5)` is `'␣'`

Pointer Arithmatic



Arrays and Pointers

`*(foo + bar)` exactly the same as `foo[bar]`

arrays 'decay' into pointers

Exercise

```
1 char foo[4] = "foo";
2     // {'f', 'o', 'o', '\0'}
3 char *pointer;
4 pointer = foo;
5 *pointer = 'b';
6 pointer = pointer + 2;
7 pointer[0] = 'z';
8 *(foo + 1) = 'a';
```

Final value of `foo`?

A. `"fao"`

B. `"zao"`

C. `"baz"`

D. `"bao"`

E. something else/crash

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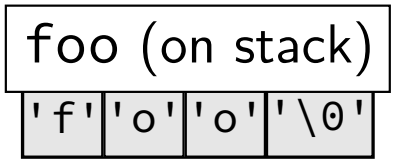

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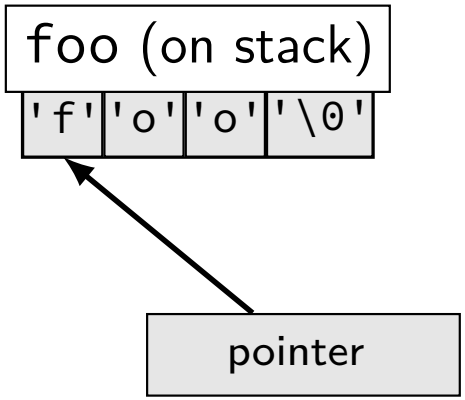

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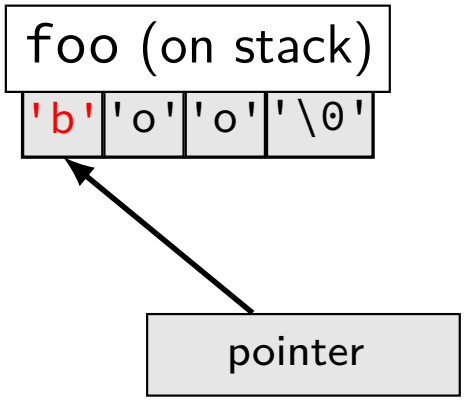

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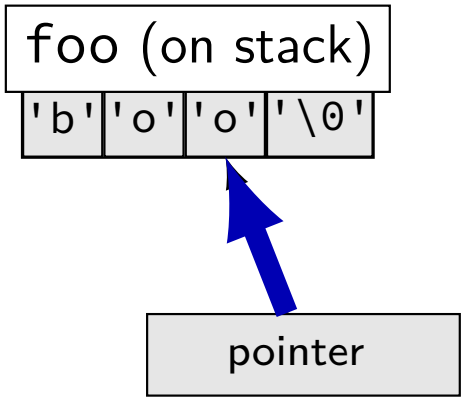

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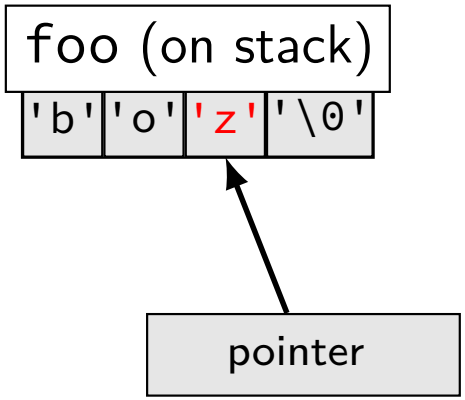

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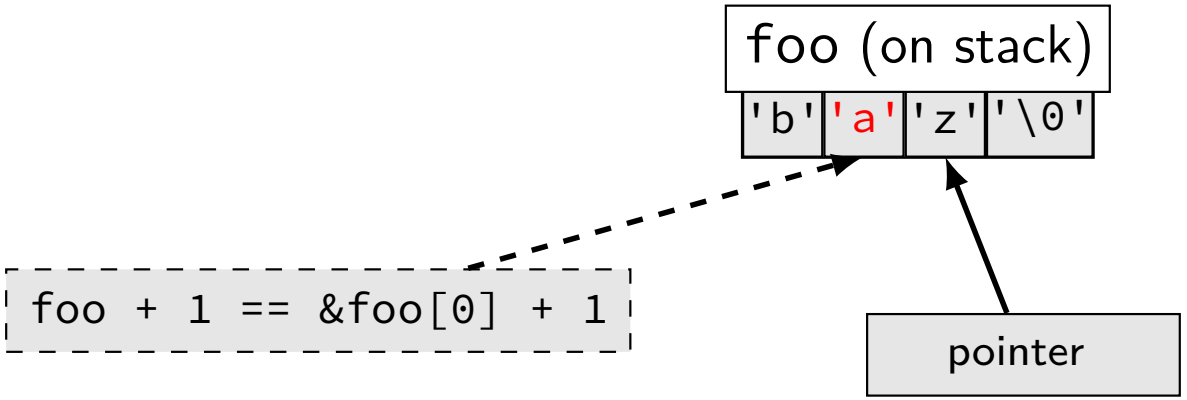

Arrays of non-bytes

`array[2]` and `*(array + 2)` still the same

```
1 int numbers[4] = {10, 11, 12, 13};
2 int *pointer;
3 pointer = numbers;
4 *pointer = 20;  // numbers[0] = 20;
5 pointer = pointer + 2;
6 /* adds 8 (2 ints) to address */
7 *pointer = 30;  // numbers[2] = 30;
8 // numbers is {20, 11, 30, 13}
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Arrays: not quite pointers (1)

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int *pointer;
```

Legal: `pointer = array;`

same as `pointer = &(array[0]);`

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Illegal: ~~`array = pointer;`~~

Arrays: not quite pointers (2)

```
int array[100];
int *pointer = array;

sizeof(array) == 400
```

size of all elements

Arrays: not quite pointers (2)

```
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int *pointer = array;

sizeof(array) == 400
```

size of all elements

```
sizeof(pointer) == 8
```

size of address

Arrays: not quite pointers (2)

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int array[100];
int *pointer = array;

sizeof(array) == 400
```

size of all elements

```
sizeof(pointer) == 8
```

size of address

```
sizeof(&array[0]) == ???
```

(`&array[0]` same as `&(array[0])`)

Interlude: Command Line Tips

```
cr4bd@reiss-lenovo:~$ man man
```

man man

```
File  Edit  View  Search  Terminal  Help
MAN(1)                          Manual pager utils                          MAN(1)

NAME
       man - an interface to the on-line reference manuals

SYNOPSIS
       man  [-C  file]  [-d]  [-D]  [--warnings[=warnings]] [-R encoding] [-L locale] [-m sys-
       tem[,...]]  [-M  path]  [-S  list]  [-e  extension]  [-i|-I]  [--regex|--wildcard]
       [--names-only]  [-a]  [-u]  [--no-subpages]  [-P  pager] [-r prompt] [-7] [-E encoding]
       [--no-hyphenation] [--no-justification] [-p  string]  [-t]  [-T[device]]  [-H[browser]]
       [-X[dpi]] [-Z] [[section] page ...] ...
       man -k [apropos options] regexp ...
       man -K [-w|-W] [-S list] [-i|-I] [--regex] [section] term ...
       man -f [whatis options] page ...
       man -l [-C file] [-d] [-D] [--warnings[=warnings]] [-R encoding] [-L locale] [-P pager]
       [-r prompt] [-7] [-E encoding] [-p string] [-t]  [-T[device]]  [-H[browser]]  [-X[dpi]]
       [-Z] file ...
       man -w|-W [-C file] [-d] [-D] page ...
       man -c [-C file] [-d] [-D] page ...
       man [-?V]

DESCRIPTION
       man is the system's manual pager.  Each page argument given to man is normally the name
       of a program, utility or function.  The manual page associated with each of these argu-
       ments  is  then  found  and displayed.  A section, if provided, will direct man to look
       only in that section of the manual.  The default action is to  search  in  all  of  the
       available sections following a pre-defined order ("1 n l 8 3 2 3posix 3pm 3perl 5 4 9 6
       7" by default, unless overridden by the SECTION directive in /etc/manpath.config),  and
       to show only the first page found, even if page exists in several sections.

 Manual page man(1) line 1 (press h for help or q to quit)
```

man man

```
File  Edit  View  Search  Terminal  Help
EXAMPLES
       man ls
           Display the manual page for the item (program) ls.

       man -a intro
           Display,  in  succession,  all of the available intro manual pages contained within
           the manual.  It is possible to quit between successive  displays  or  skip  any  of
           them.

       man -t alias | lpr -Pps
           Format the manual page referenced by `alias', usually a shell manual page, into the
           default troff or groff format and pipe it to the printer  named  ps.   The  default
           output  for groff is usually PostScript.  man --help should advise as to which pro-
           cessor is bound to the -t option.

       man -l -Tdvi ./foo.1x.gz > ./foo.1x.dvi
           This command will decompress and format the nroff source  manual  page  ./foo.1x.gz
           into  a device independent (dvi) file.  The redirection is necessary as the -T flag
           causes output to be directed to stdout with no pager.  The output could  be  viewed
           with  a  program  such as xdvi or further processed into PostScript using a program
           such as dvips.

       man -k printf
           Search the short descriptions and manual page names for the keyword printf as regu-
           lar expression.  Print out any matches.  Equivalent to apropos printf.

       man -f smail
           Lookup the manual pages referenced by smail and print out the short descriptions of
           any found.  Equivalent to whatis smail.

 Manual page man(1) line 68 (press h for help or q to quit)
```

man chmod

```
File  Edit  View  Search  Terminal  Help
CHMOD(1)                          User Commands                          CHMOD(1)

NAME
       chmod - change file mode bits

SYNOPSIS
       chmod [OPTION]... MODE[,MODE]... FILE...
       chmod [OPTION]... OCTAL-MODE FILE...
       chmod [OPTION]... --reference=RFILE FILE...

DESCRIPTION
       This  manual page documents the GNU version of chmod.  chmod changes the file mode bits
       of each given file according to mode, which can be either a symbolic representation  of
       changes to make, or an octal number representing the bit pattern for the new mode bits.

       The  format  of a symbolic mode is [ugoa...][[-+=][perms...]...], where perms is either
       zero or more letters from the set rwxXst, or a single letter from the set ugo.   Multi-
       ple symbolic modes can be given, separated by commas.

       A  combination  of  the  letters  ugoa controls which users' access to the file will be
       changed: the user who owns it (u), other users in the file's group (g), other users not
       in  the  file's group (o), or all users (a).  If none of these are given, the effect is
       as if (a) were given, but bits that are set in the umask are not affected.

       The operator + causes the selected file mode bits to be added to the existing file mode
       bits  of  each  file;  -  causes  them to be removed; and = causes them to be added and
       causes unmentioned bits to be removed except that a directory's  unmentioned  set  user
       and group ID bits are not affected.

       The  letters  rwxXst select file mode bits for the affected users: read (r), write (w),
 Manual page chmod(1) line 1/125 27% (press h for help or q to quit)
```

chmod

```
chmod --recursive og-r /home/USER
```

chmod

```
chmod  --recursive  og-r  /home/USER
```

others and group (student)

– remove

read

chmod

```
chmod  --recursive  og-r  /home/USER
```

user (yourself) / group / others

– remove / + add

read / write / execute or search

tar

the standard Linux/Unix file archive utility

Table of contents: `tar tf filename.tar`

eXtract: `tar xvf filename.tar`

Create: `tar cvf filename.tar directory`

(`v`: verbose; `f`: file — default is tape)

Tab completion and history

Back To C

stdio.h

C does not have `<iostream>`

Instead `<stdio.h>`

stdio

```
cr4bd@power1
: /if22/cr4bd ; man stdio

…
STDIO(3)                Linux Programmer's Manual                STDIO(3)

NAME
       stdio - standard input/output library functions

SYNOPSIS
       #include <stdio.h>

       FILE *stdin;
       FILE *stdout;
       FILE *stderr;

DESCRIPTION
       The  standard  I/O  library  provides  a  simple  and  efficient
       buffered stream I/O interface.  Input and output is mapped  into
       logical  data  streams  and the physical I/O characteristics are
       concealed.  The functions and  macros  are  listed  below;  more
       information is available from the individual man pages.
```

stdio

```
STDIO(3)                Linux Programmer's Manual               STDIO(3)

NAME
       stdio - standard input/output library functions


…

   List of functions
       Function      Description
     ------------------------------------------------------------
       clearerr      check and reset stream status
       fclose        close a stream


…

       printf        formatted output conversion


…
```

printf

```
int custNo = 1000;
const char *name = "Jane␣Smith"
printf("Customer␣#%d:␣%s\n",
       custNo, name);
// "Customer #1000: Jane Smith"
// same as:
cout << "Customer␣#" << custNo
     << ":␣" << name << endl;
```

printf

```
int custNo = 1000;
const char *name = "Jane␣Smith"
printf("Customer␣#%d:␣%s\n",
       custNo, name);
// "Customer #1000: Jane Smith"
// same as:
cout << "Customer␣#" << custNo
     << ":␣" << name << endl;
```

printf

```
int custNo = 1000;
const char *name = "Jane␣Smith"
printf("Customer␣#%d:␣%s\n",
       custNo, name);
// "Customer #1000: Jane Smith"
// same as:
cout << "Customer␣#" << custNo
     << ":␣" << name << endl;
```

printf

```
int custNo = 1000;
const char *name = "Jane␣Smith"
printf("Customer␣#%d:␣%s\n",
       custNo, name);
// "Customer #1000: Jane Smith"
// same as:
cout << "Customer␣#" << custNo
     << ":␣" << name << endl;
```

format string must match types of argument

printf formats quick reference

Specifier	Argument Type	Example(s)
%s	char *	Hello, World!
%p	any pointer	0x4005d4
%d	int/short/char	42
%u	unsigned int/short/char	42
%x	unsigned int/short/char	2a
%ld	long	42
%f	double/float	42.000000
		0.000000
%e	double/float	4.200000e+01
		4.200000e-19
%g	double/float	42, 4.2e-19
%%	(no argument)	%

printf formats quick reference

Specifier	Argument Type	Example(s)
%s	char *	Hello, World!
%p	any pointer	0x4005d4
%d	int/short/char	42
%u	[illegible]	[illegible]
%x	[illegible]	[illegible]
%ld	long	42
%f	double/float	42.000000 0.000000
%e	double/float	4.200000e+01 4.200000e-19
%g	double/float	42, 4.2e-19
%%	(no argument)	%

detailed docs: `man 3 printf`

goto

```
    for (...) {
      for (...) {
        if (thingAt(i, j)) {
          goto found;
        }
      }
    }
    printf("not␣found!\n");
    return;
found:
    printf("found!\n");
```

goto

```
for (...) {
  for (...) {
    if (thingAt(i, j
      goto found;
    }
  }
}
printf("not␣found!\n");
return;
found:
printf("found!\n");
```

assembly:
`jmp found`

assembly:
`found:`