Software Security
COSC 466/566
Spring 2023

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THE UNIVERSITY OF
TENNESSEE

I

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To: Kim, Doowon

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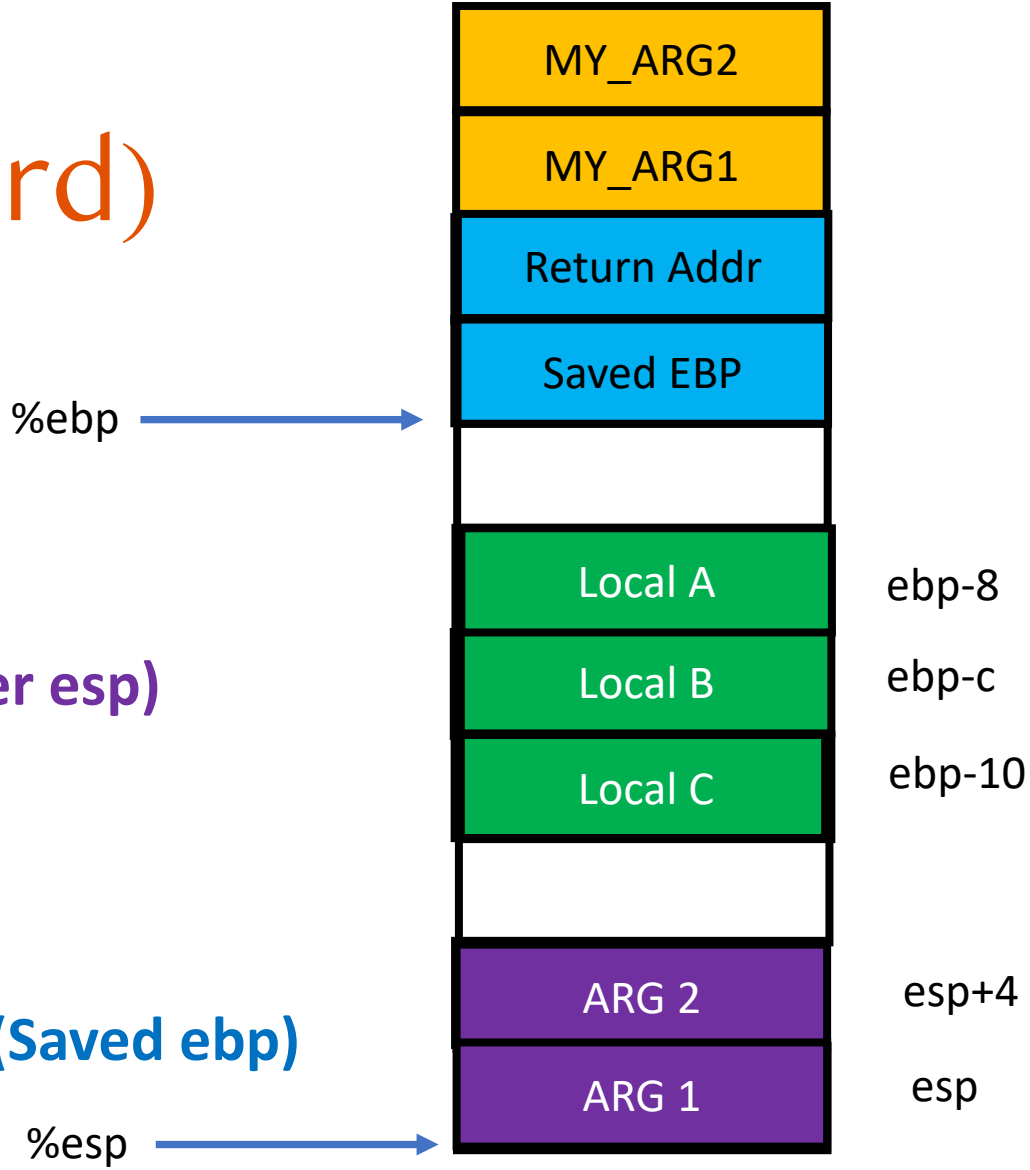
Stack (Grows Downward)

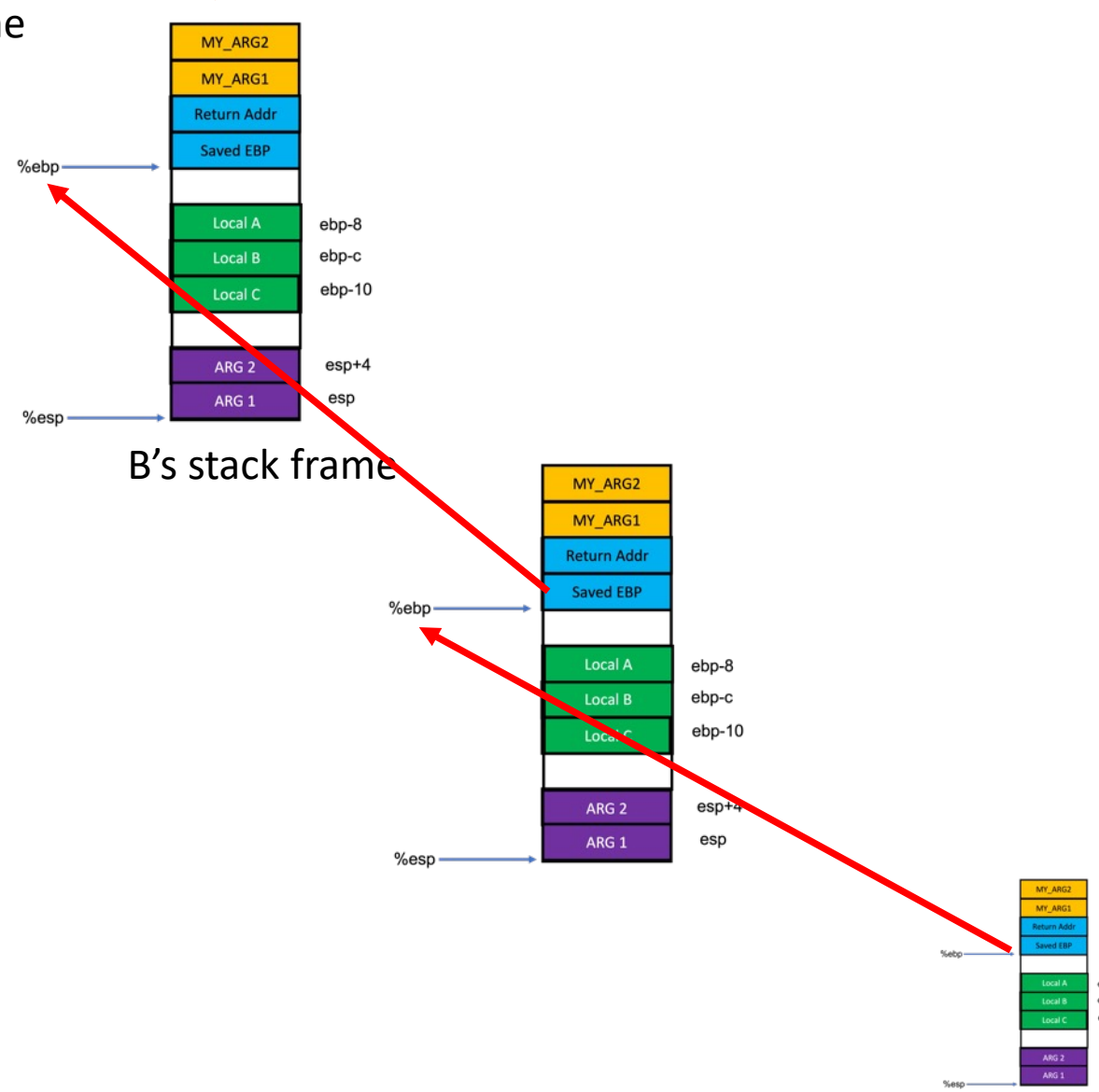
- Defines a variable scope of a function
  - **Local variables (negative index over ebp)**
  - **Arguments (positive index over ebp)**
  - **Function call arguments (positive index over esp)**
- Maintains nested function calls
  - **Return target (return address)**
  - **Local variables of the upper level function (Saved ebp)**
- Starts at `%ebp` (bottom), ends at `%esp` (top)

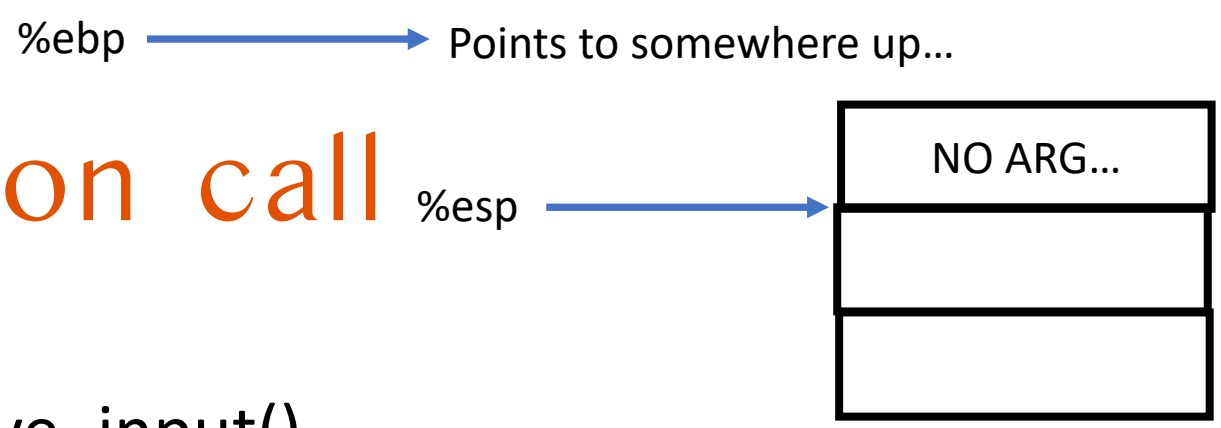


Stack (Grows Downward)

If a() calls b() and then b() calls c()….

When it returns, we restore ebp!





Example – Function call

- In bof-level0, main() calls receive_input()
  - `call   0x8048570 <receive_input>`
  - `0x0804866b <+11>:    xor    %eax,%eax`
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  - `0x08048570 <+0>:push   %ebp`
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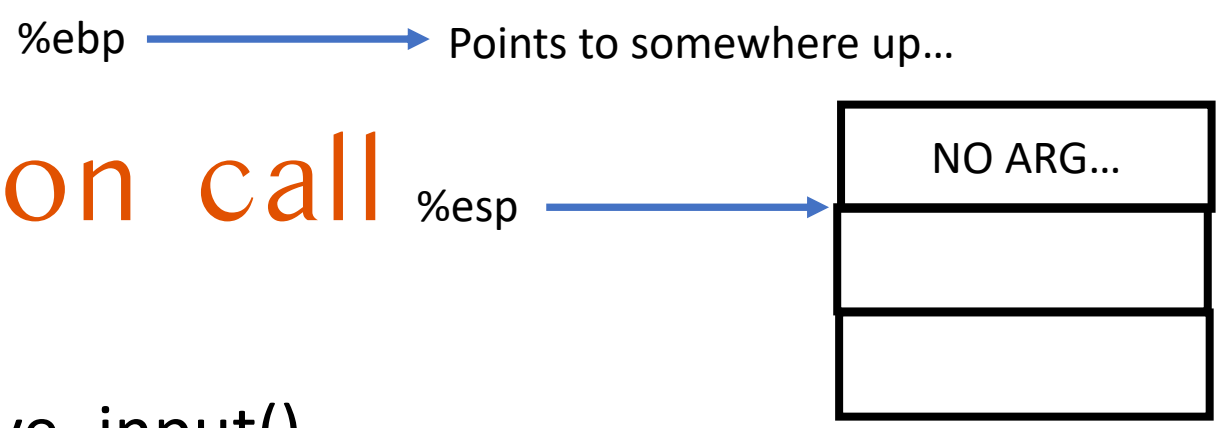

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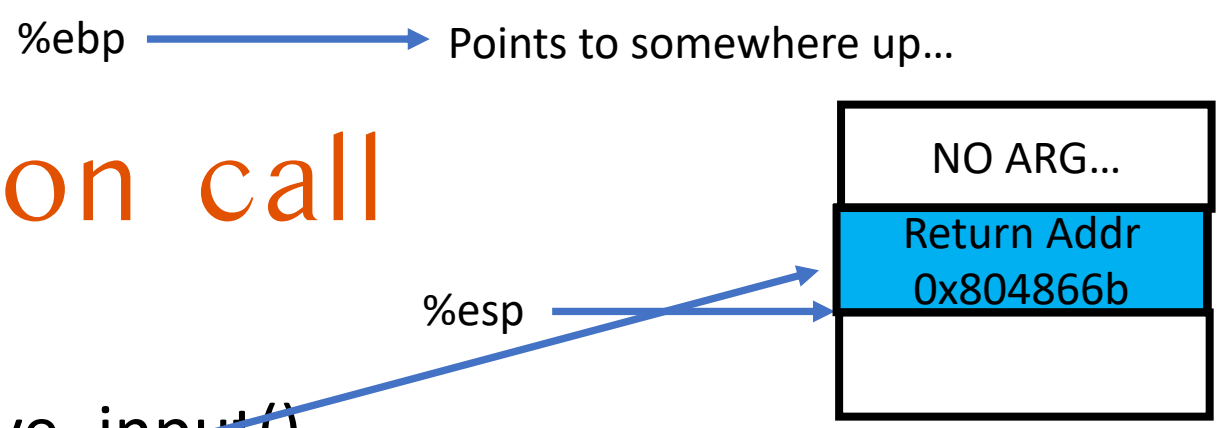

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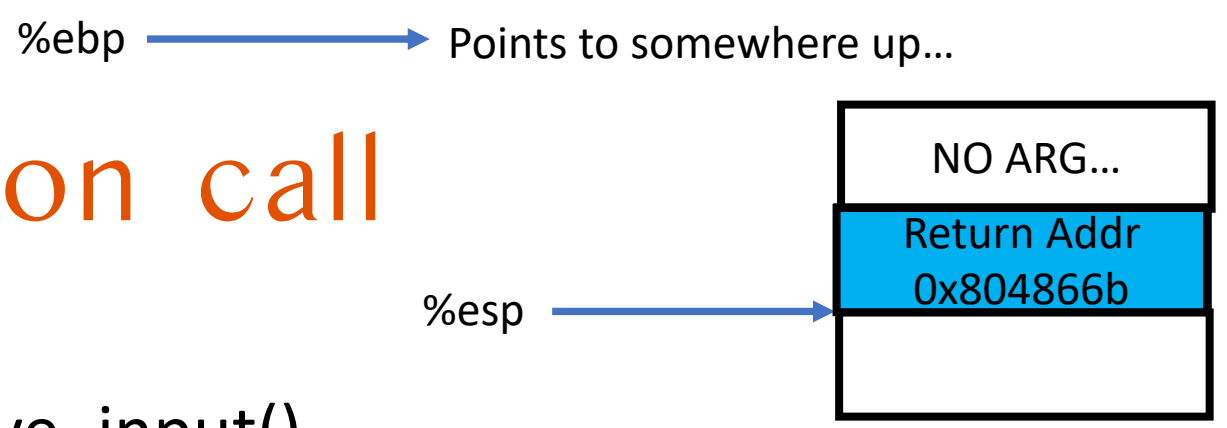
Call: push the address to return to the stack, then jump!

```
push %eip   -- points the next instruction
jmp 0x8048570 <receive_input>
```



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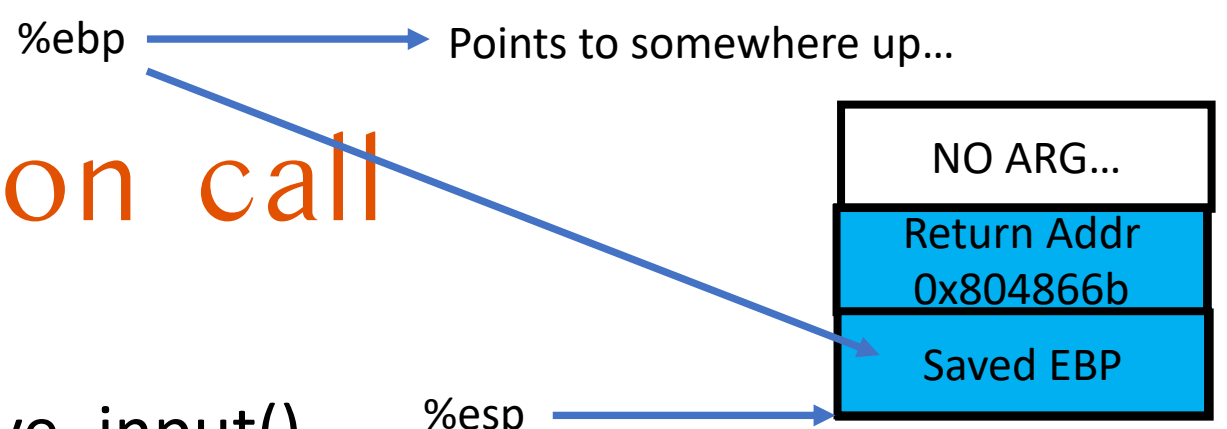

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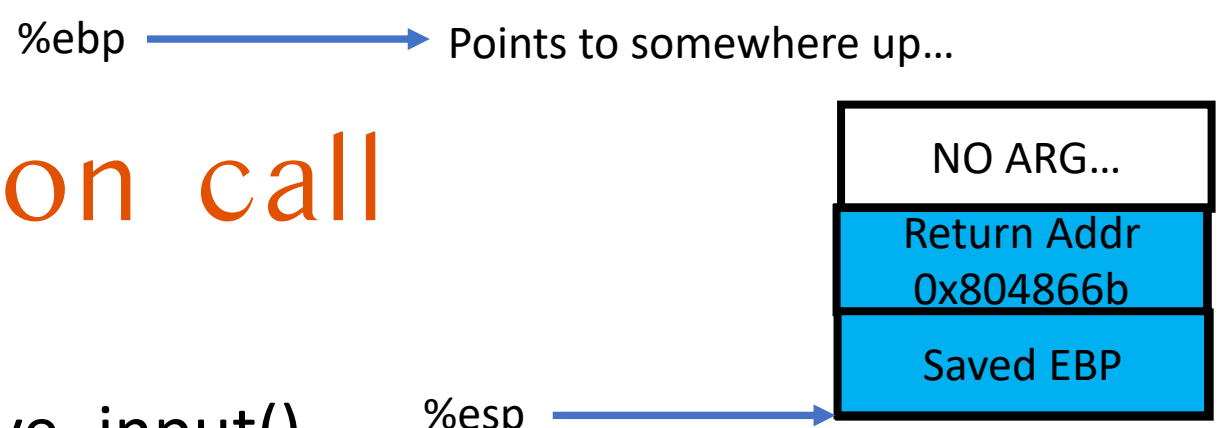

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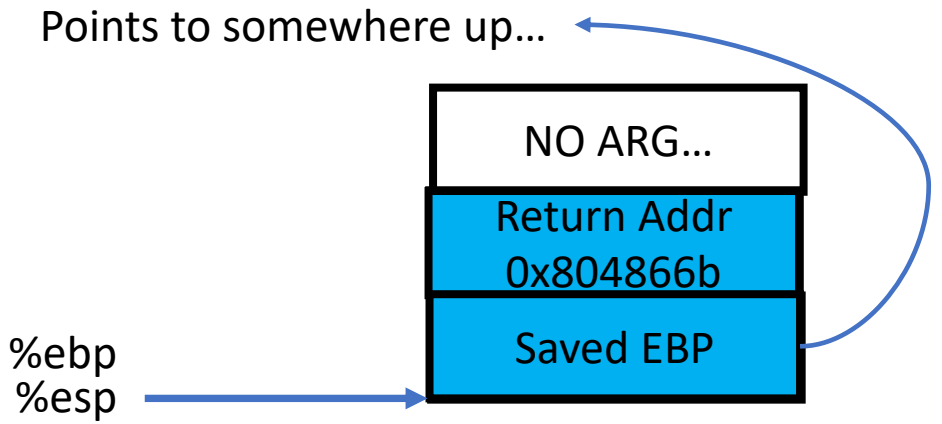

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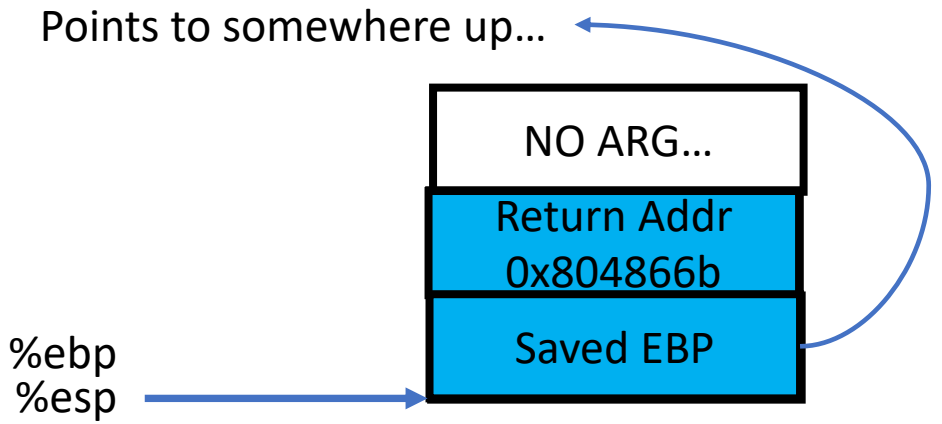

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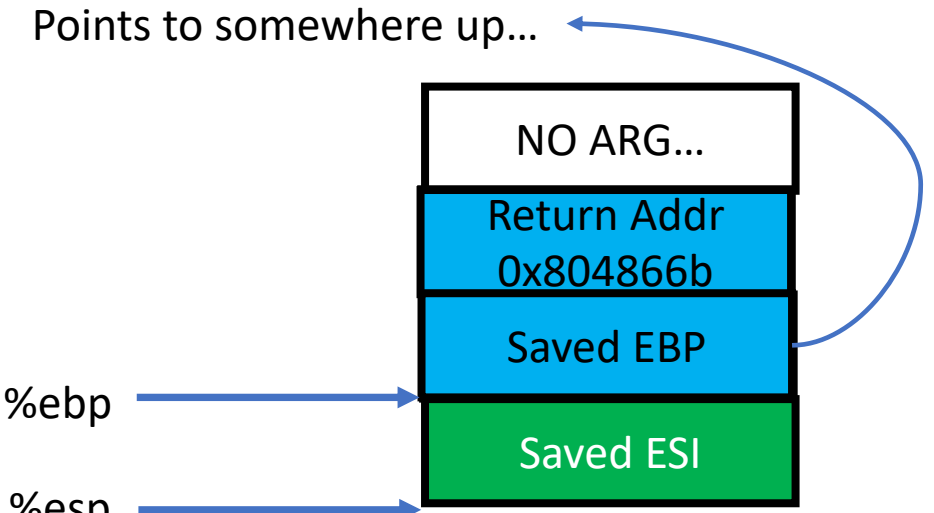

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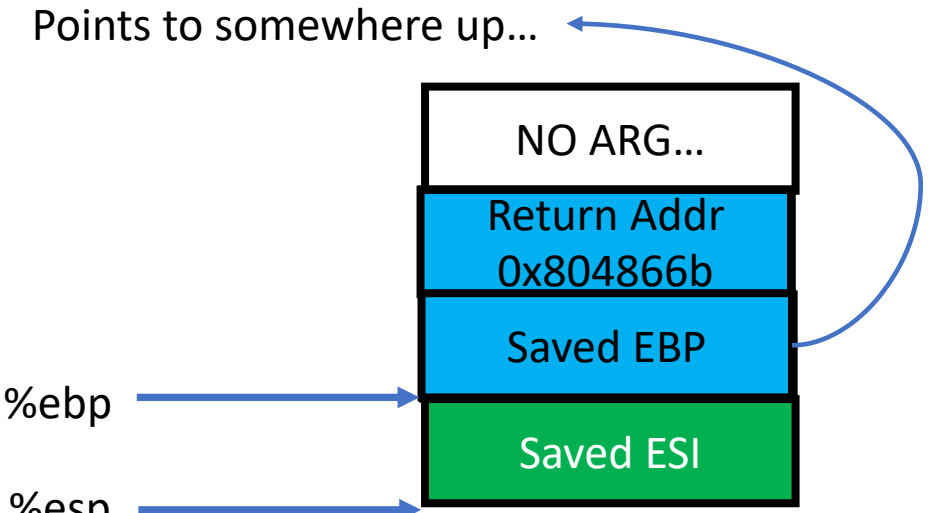

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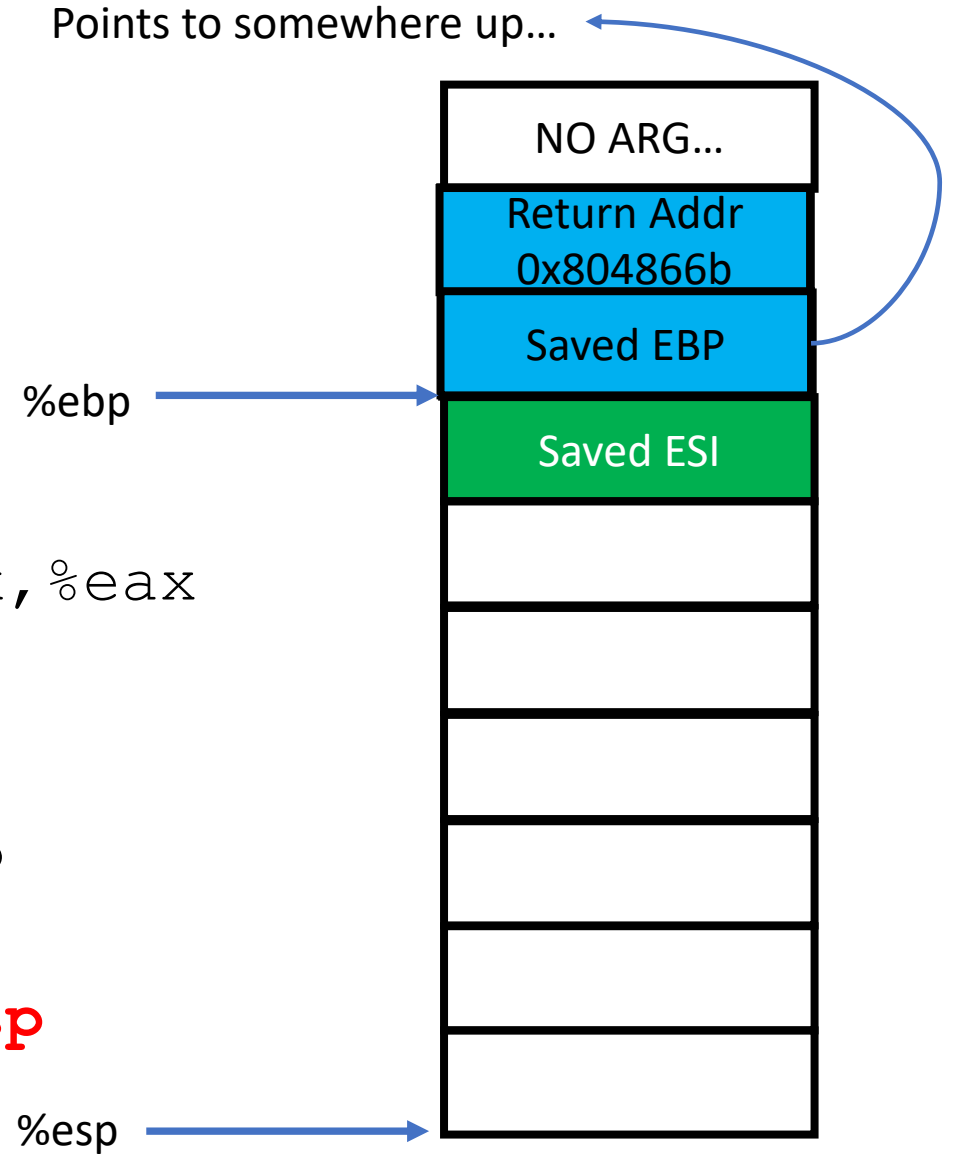

Example – Function call

- Call printf?

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movl    $0x41414141,-0x8(%ebp)
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lea     0x8048727,%eax
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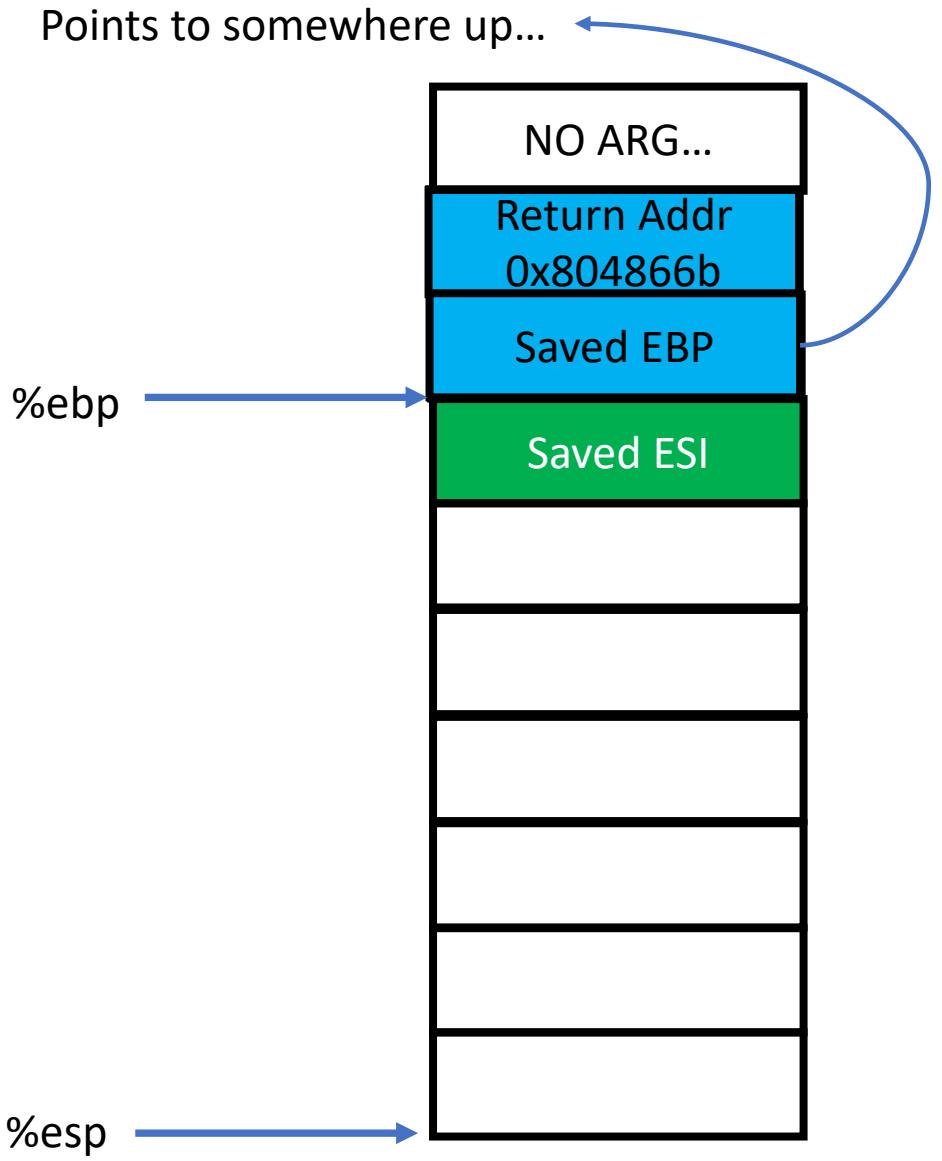

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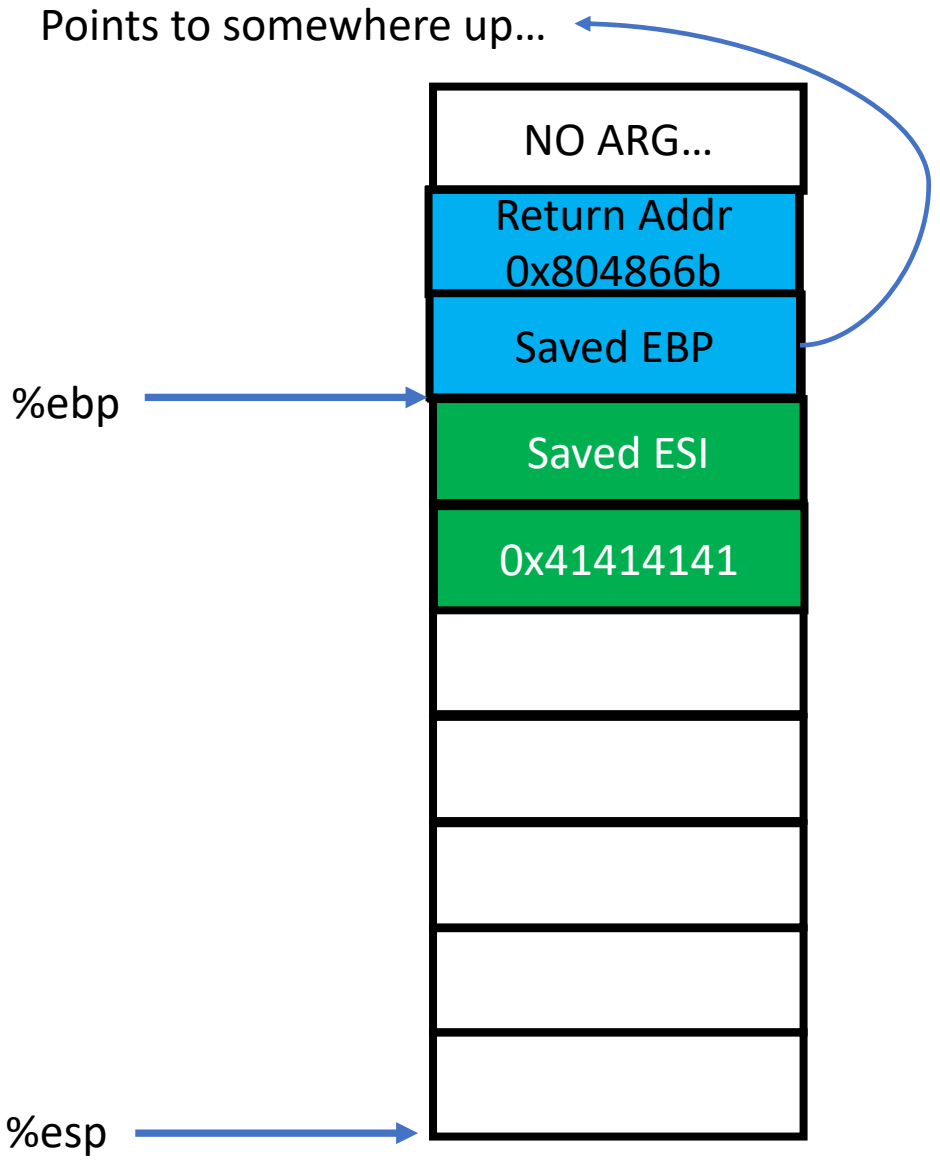

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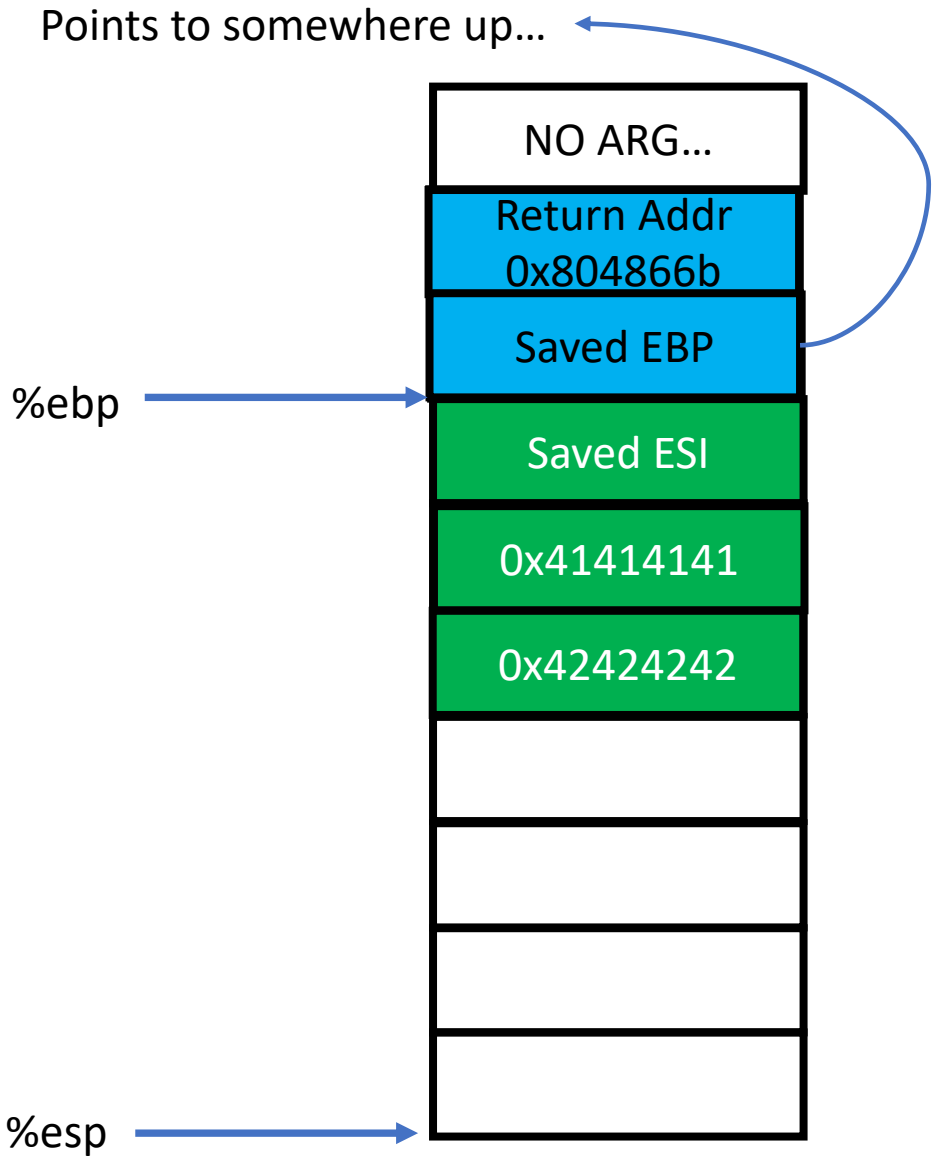

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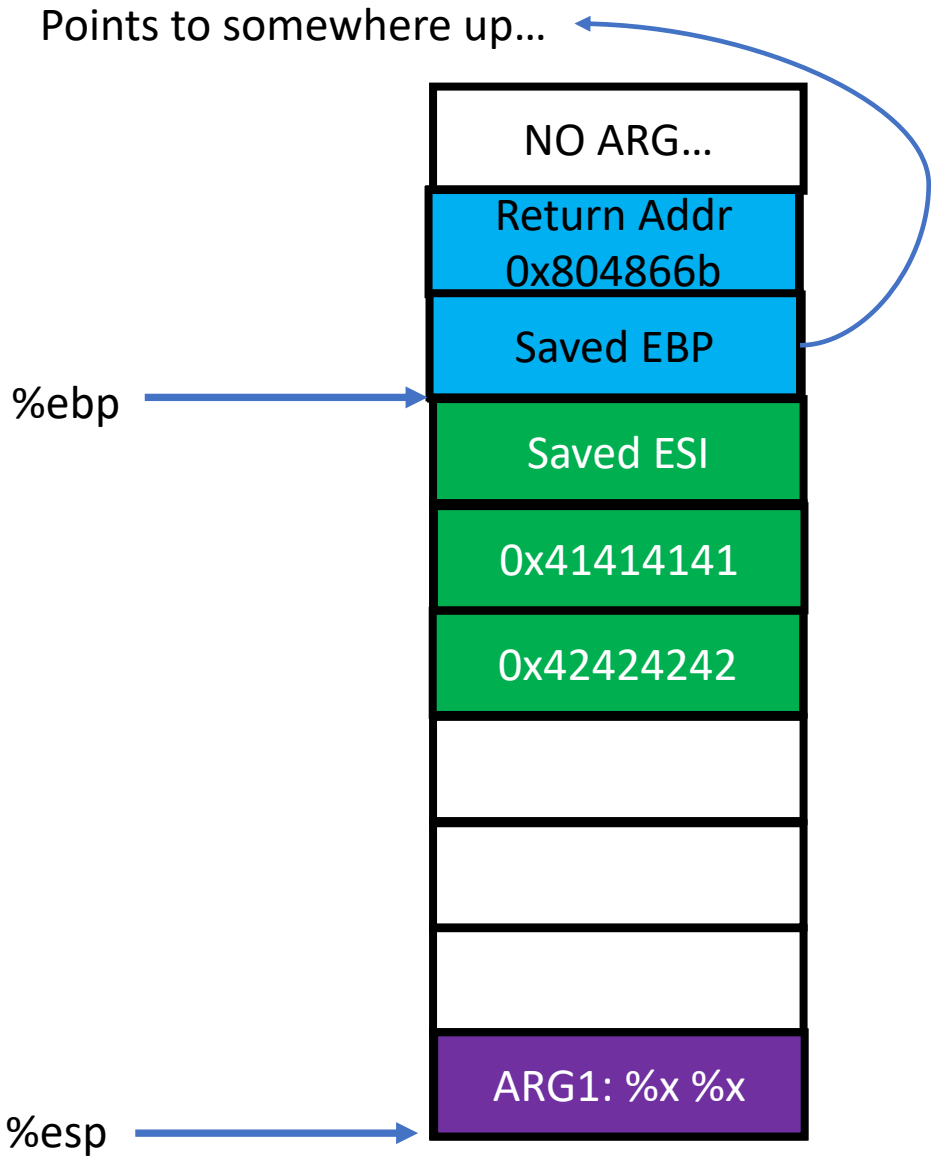

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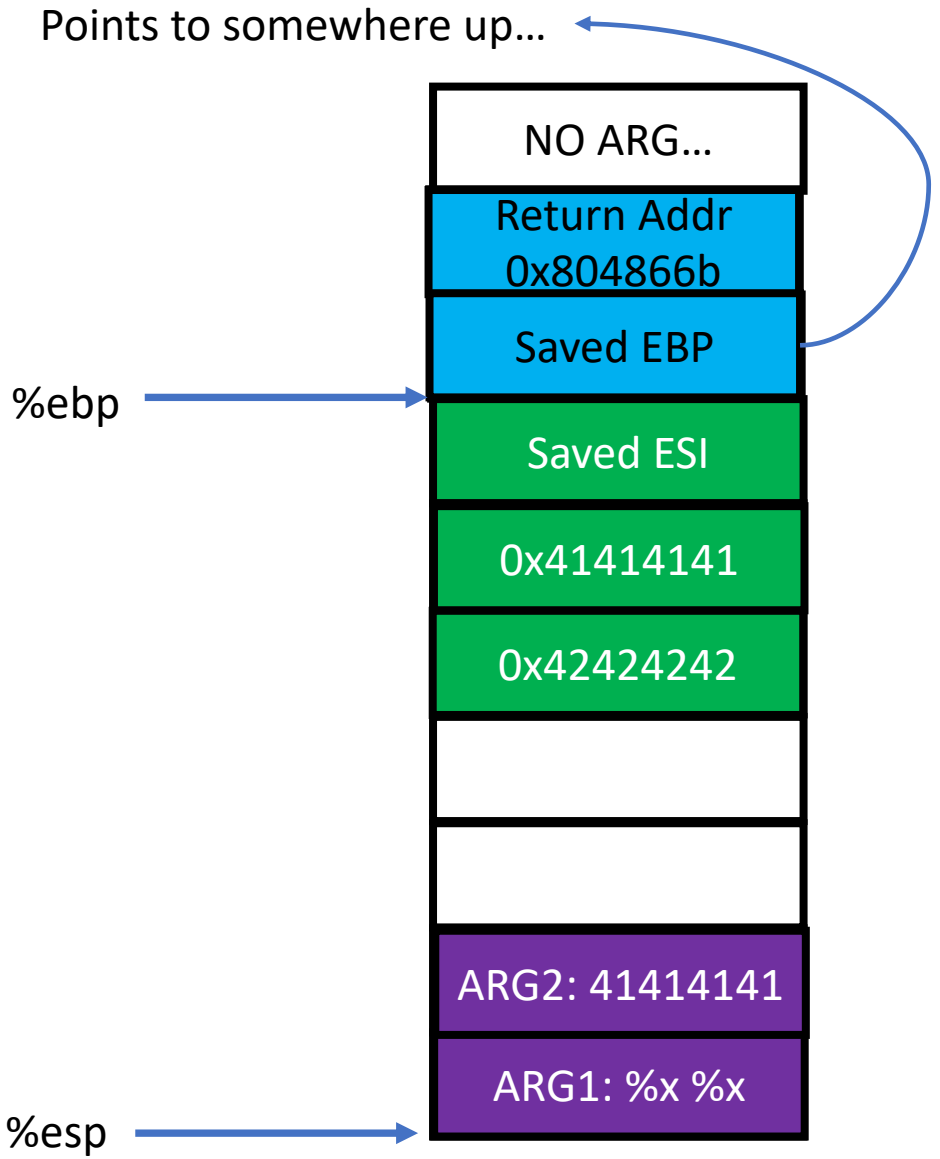

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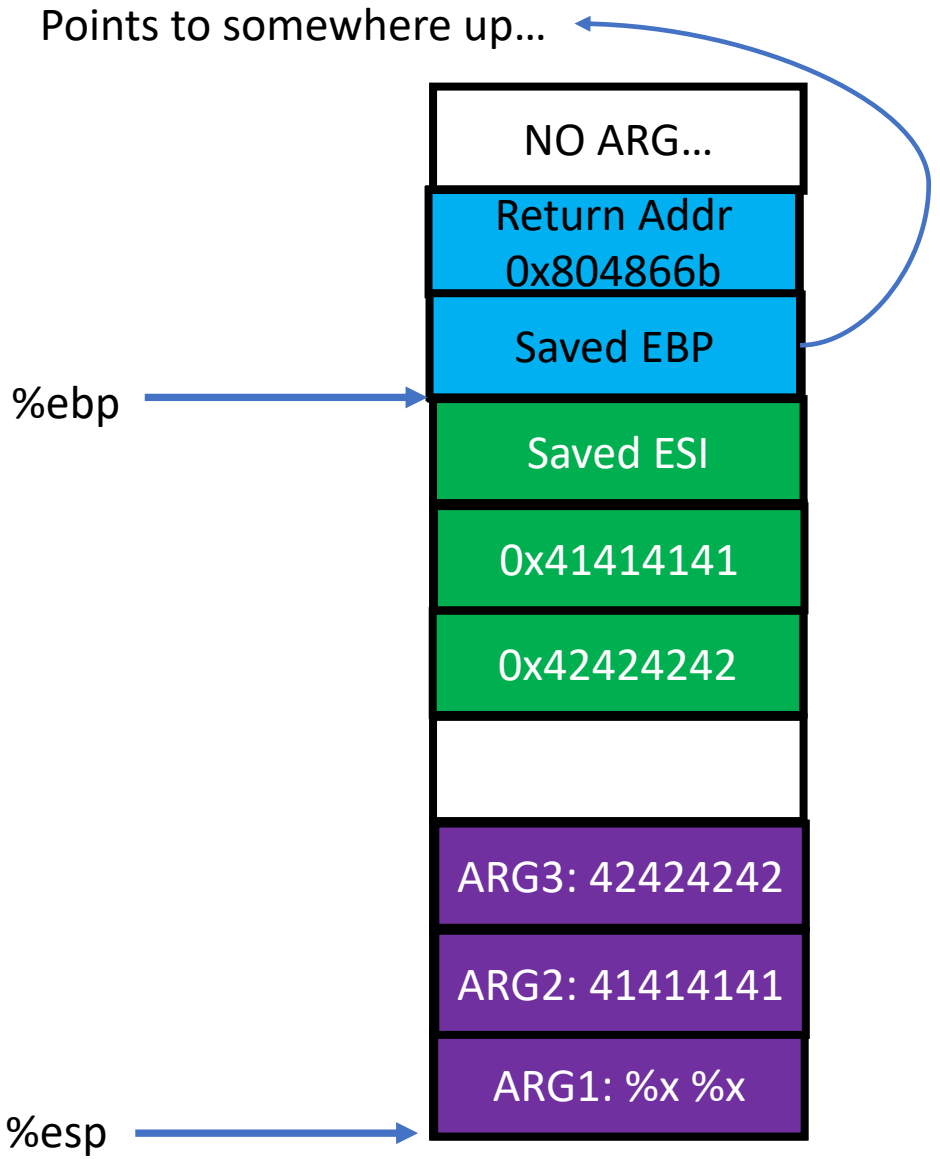

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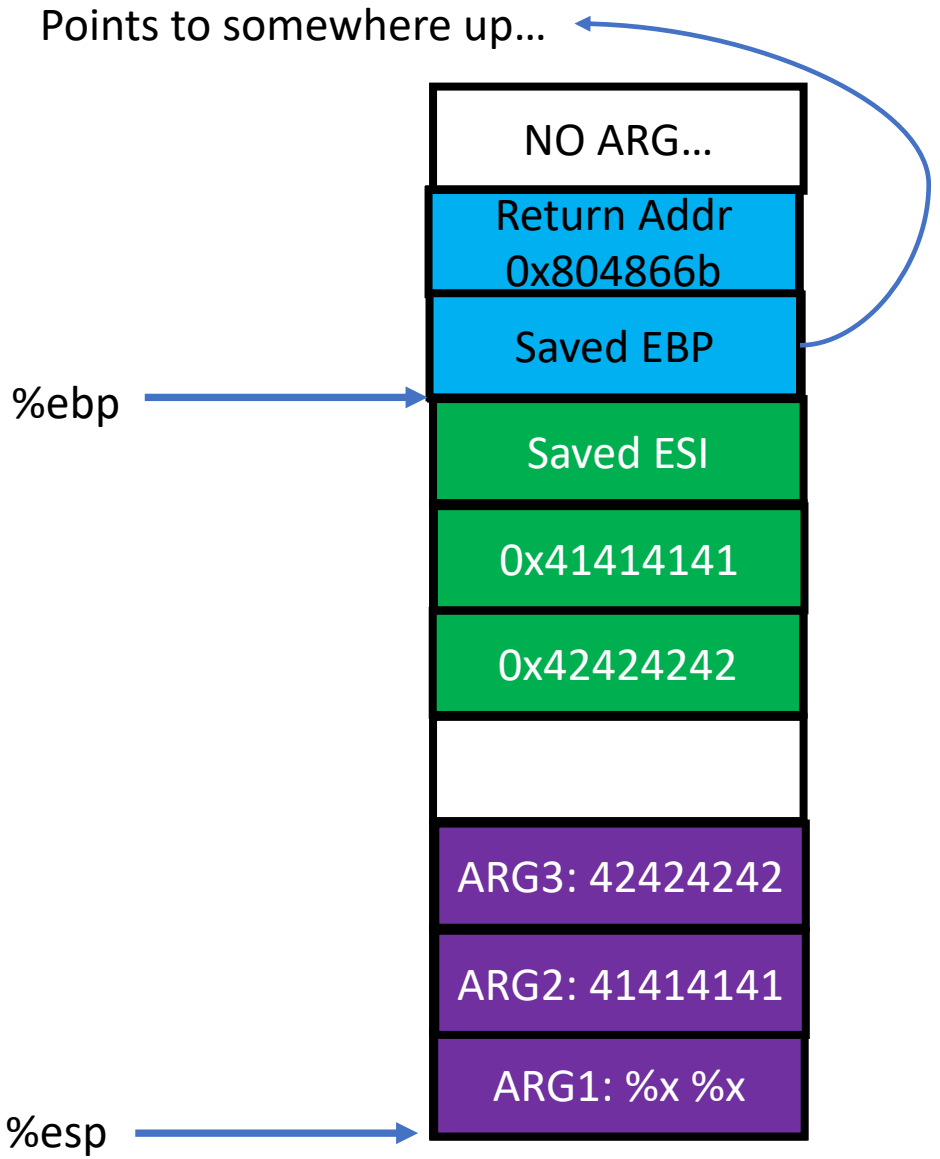

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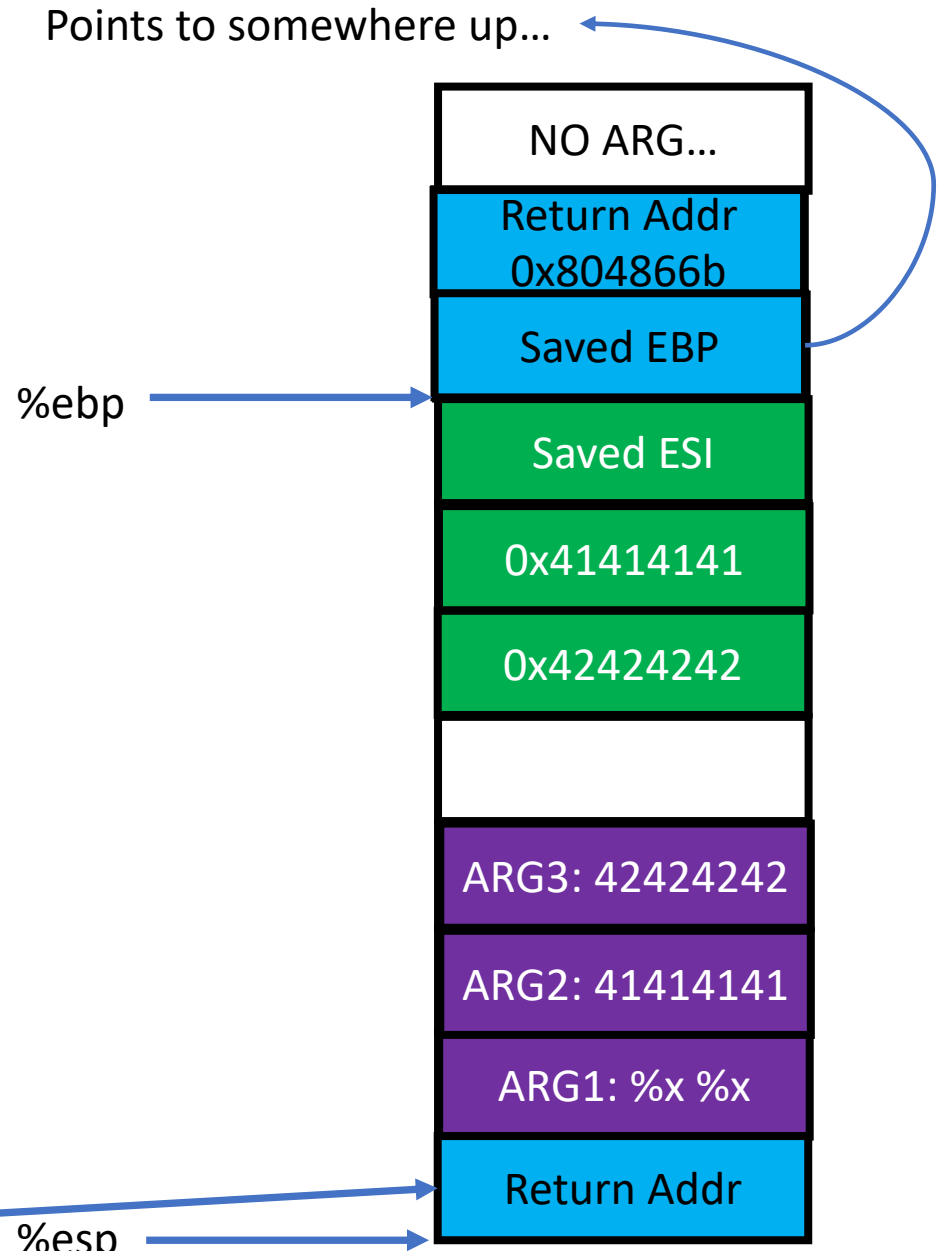

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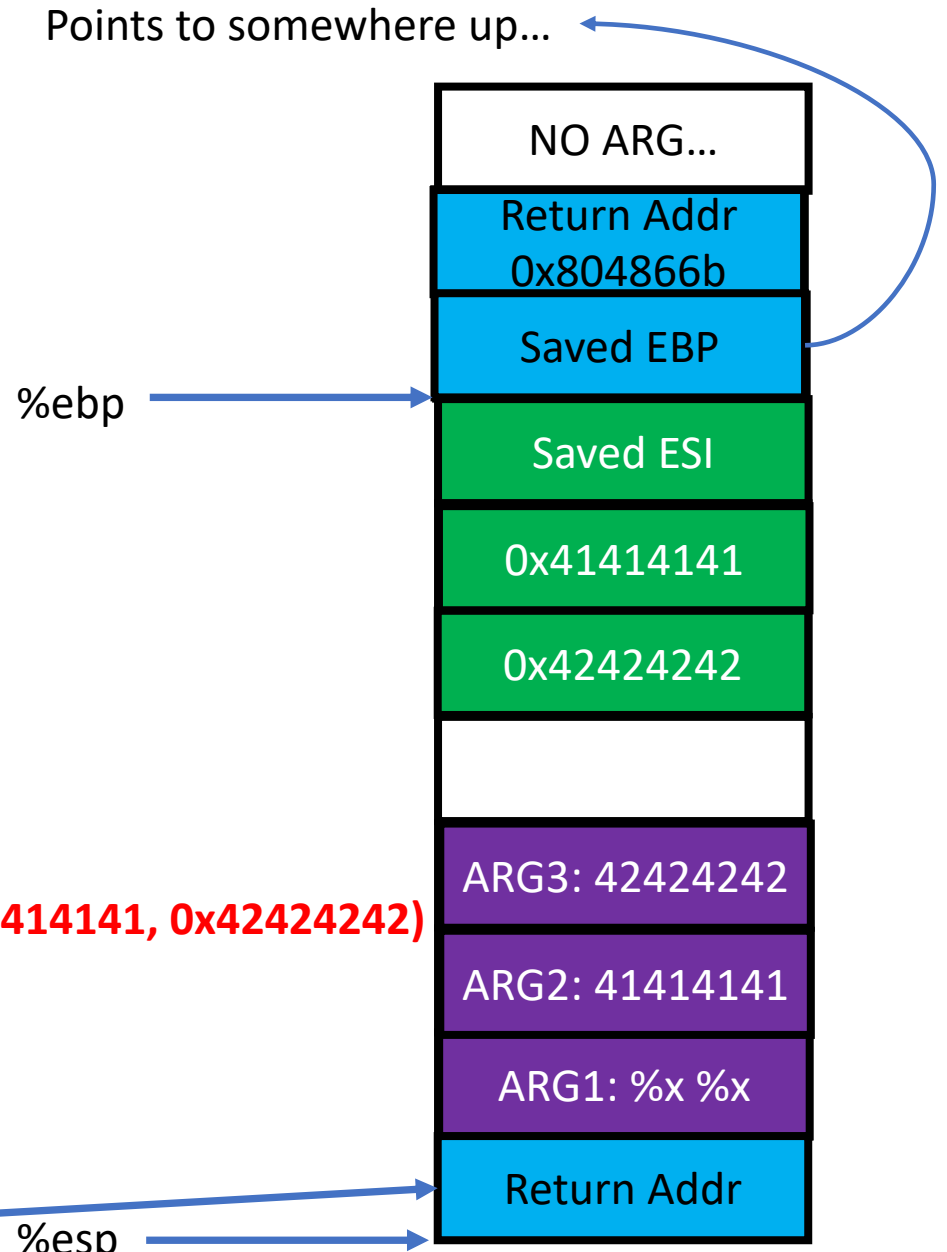
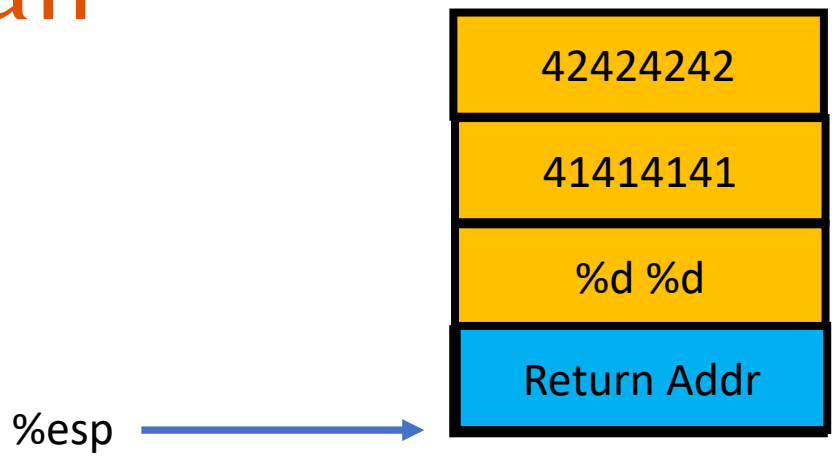
Calls printf("%x %x", 0x41414141, 0x42424242)



Example – Function call

- What printf will see?



Example – Function Return

- Function return of receive_input

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add     $0x54,%esp
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pop     %ebp
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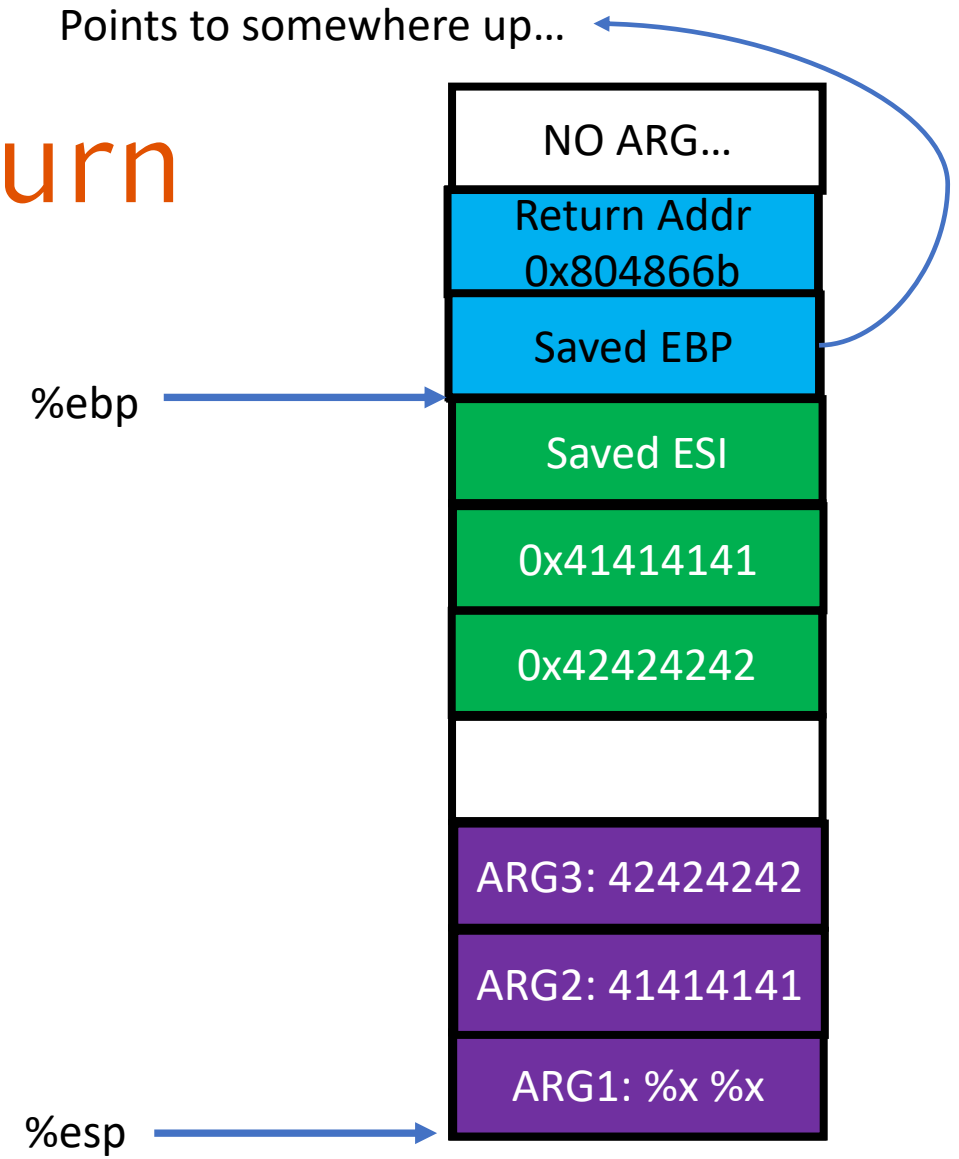

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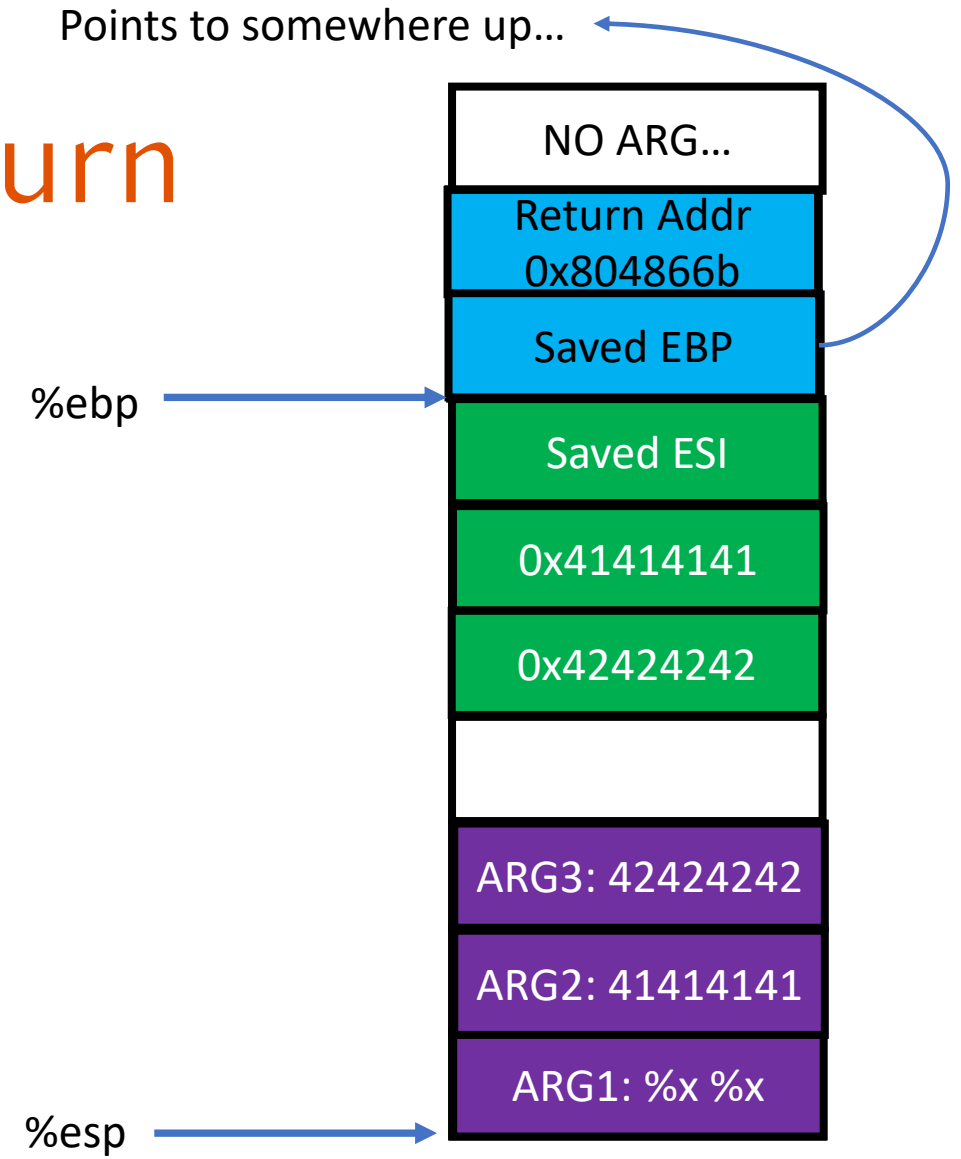

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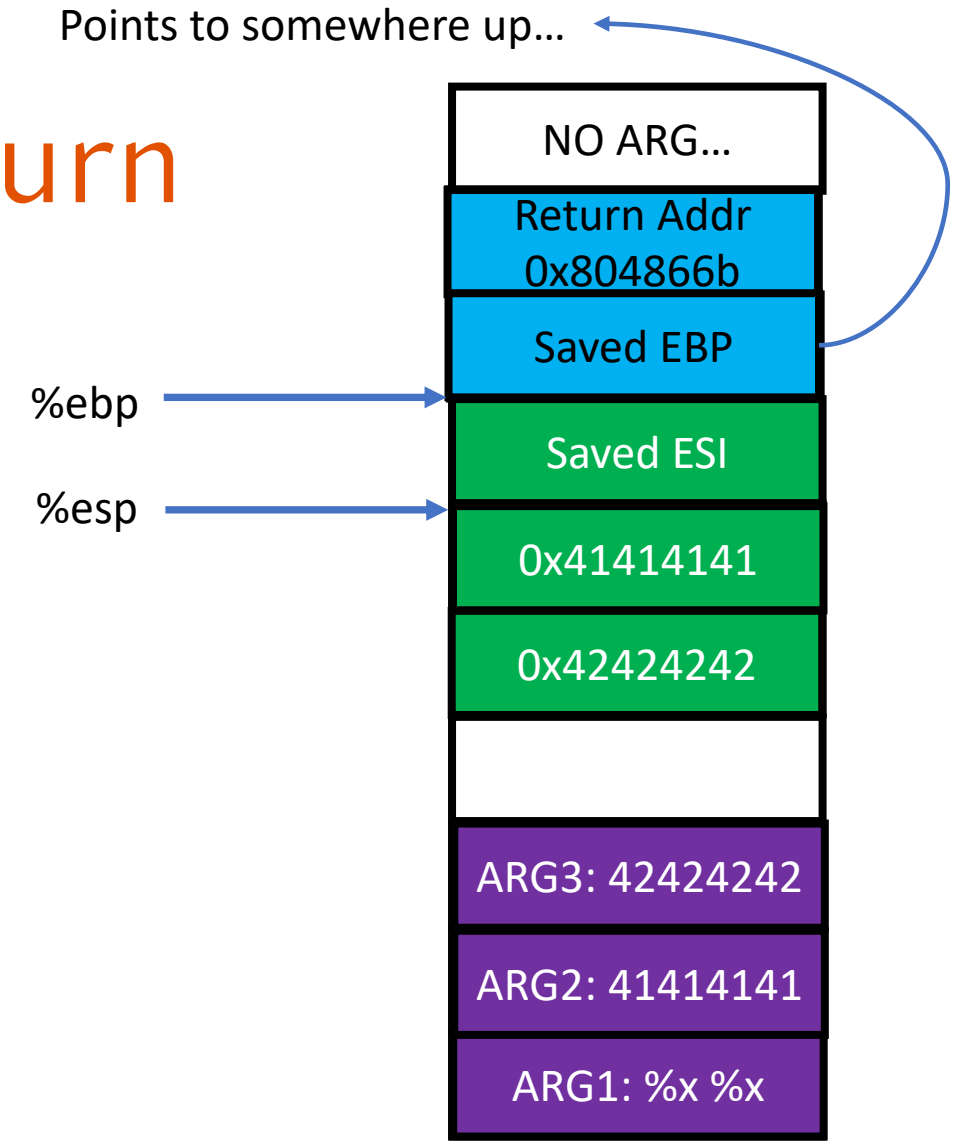

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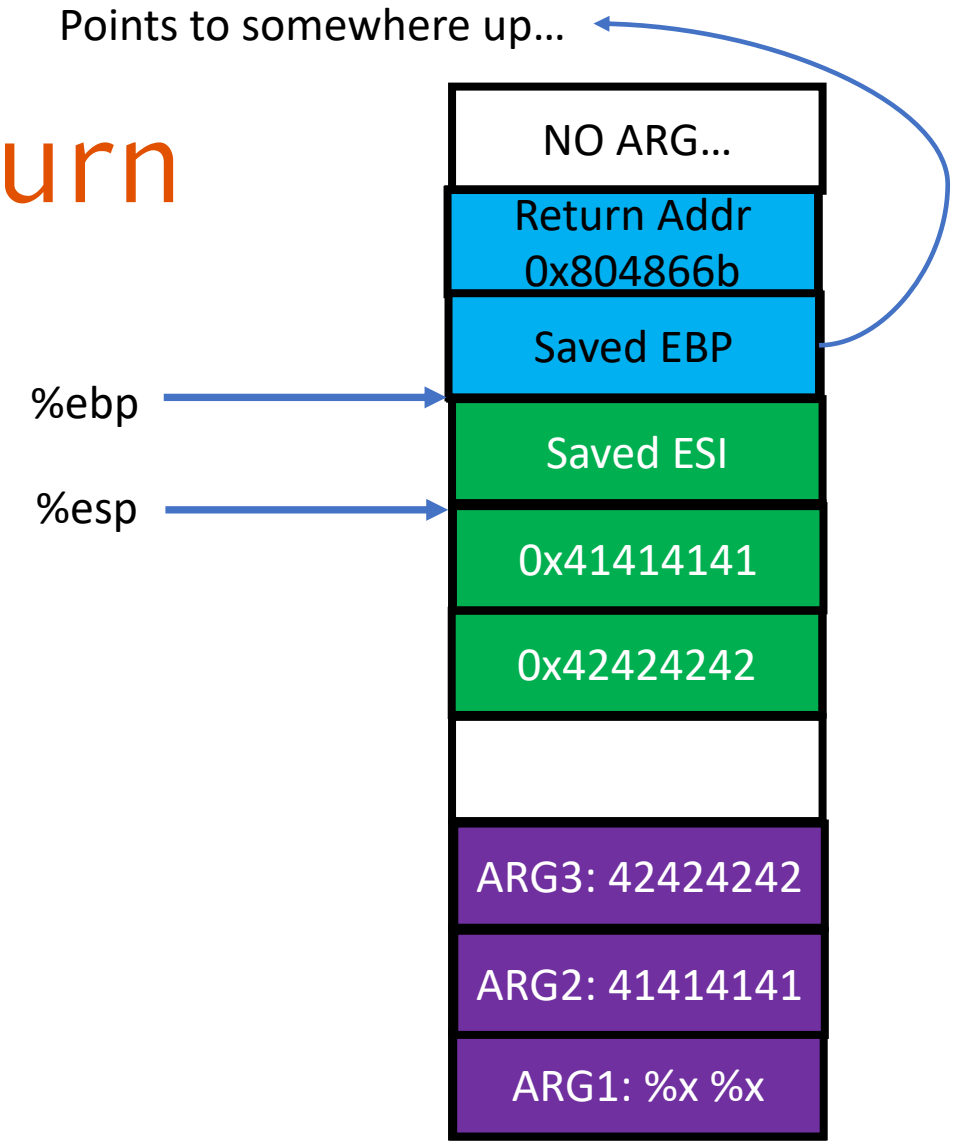

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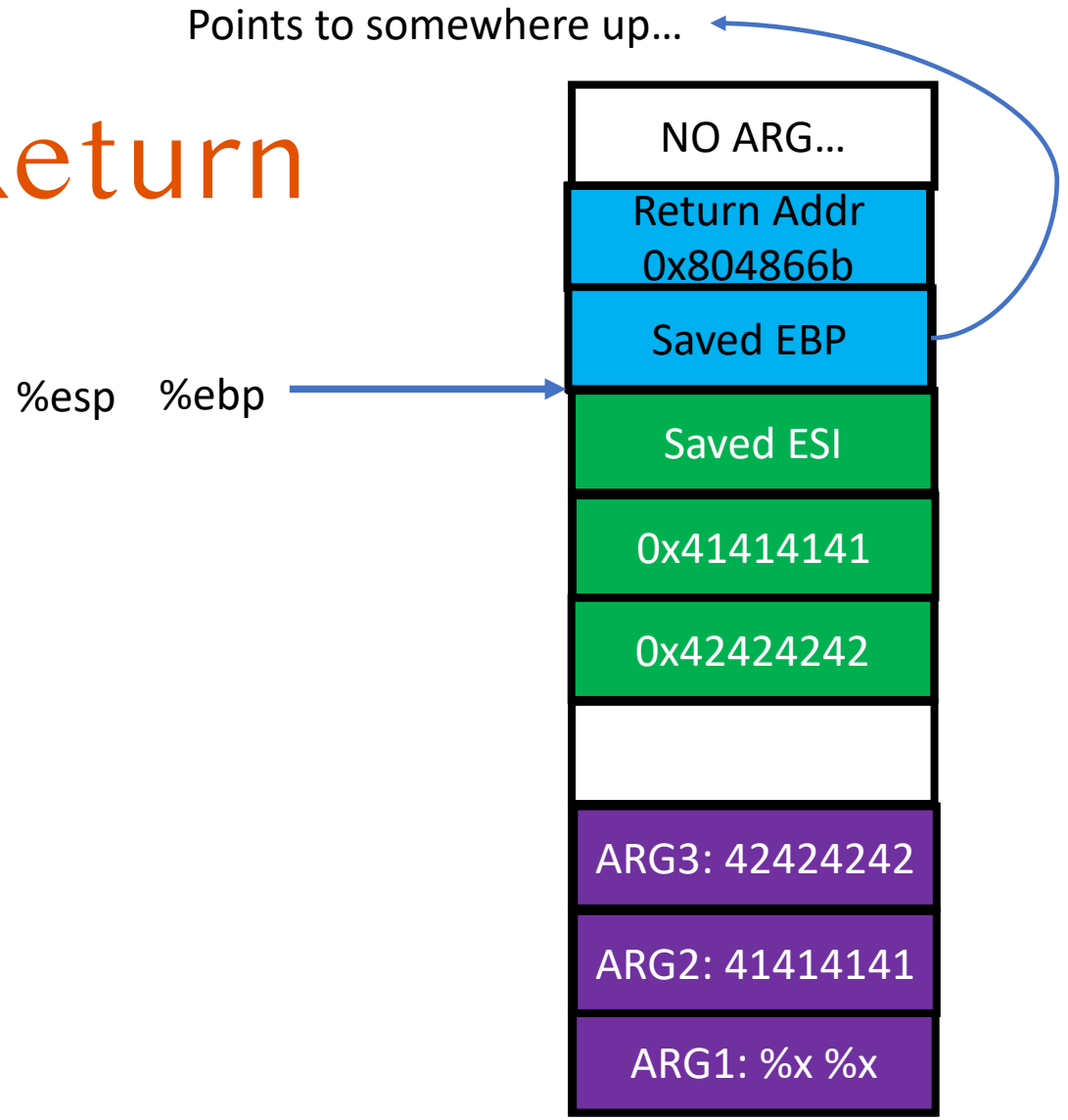
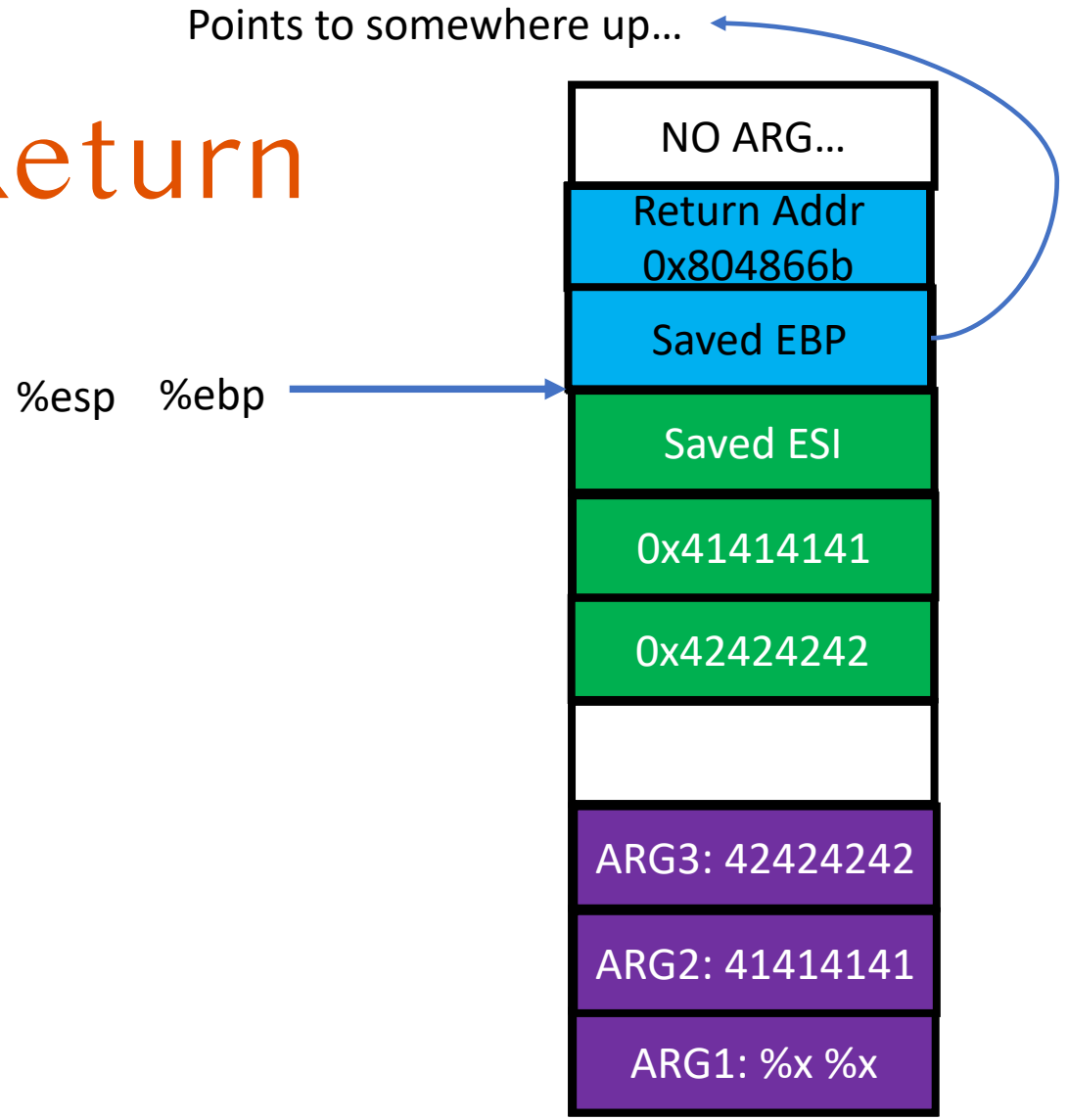


Example – Function Return

- Function return of receive_input

```
add     $0x54,%esp
pop     %esi
pop     %ebp
ret
```



Example – Function Return

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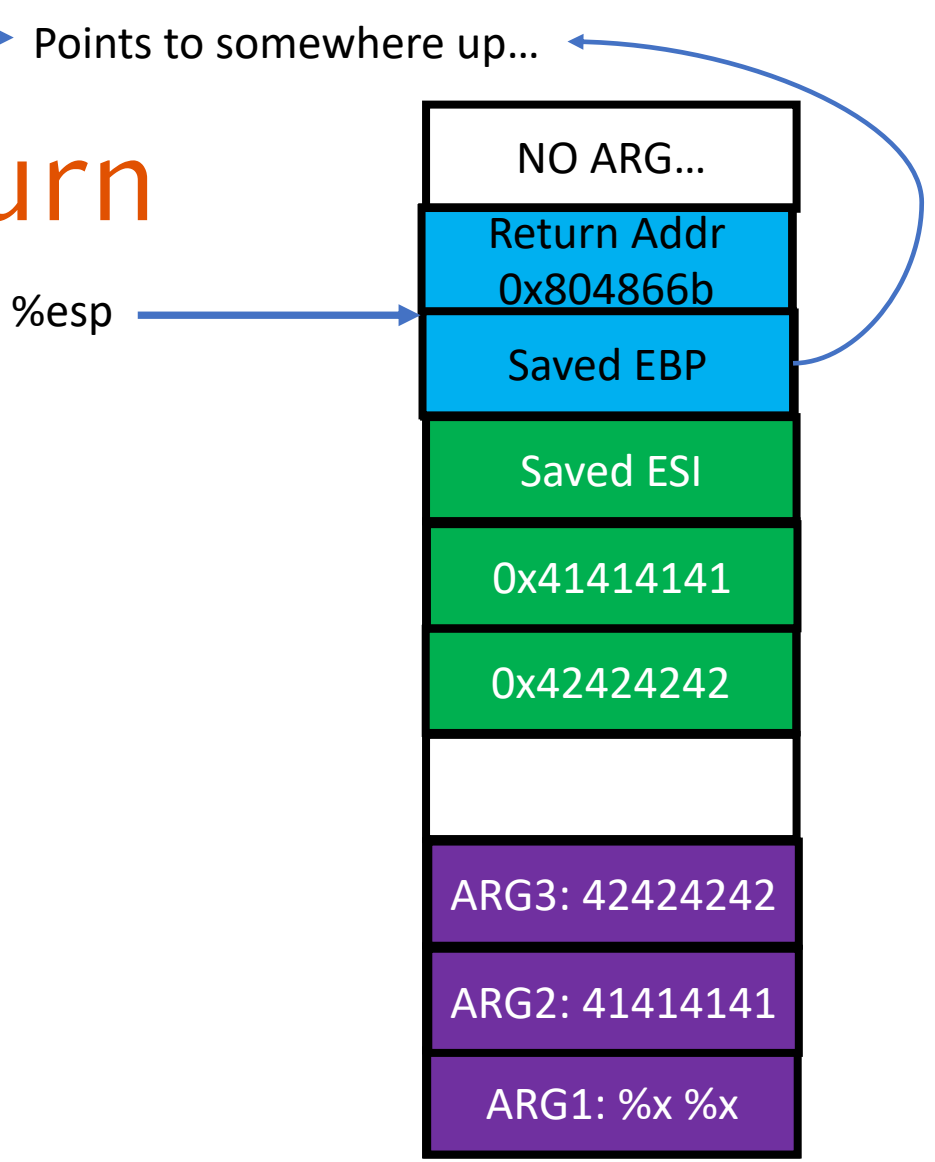
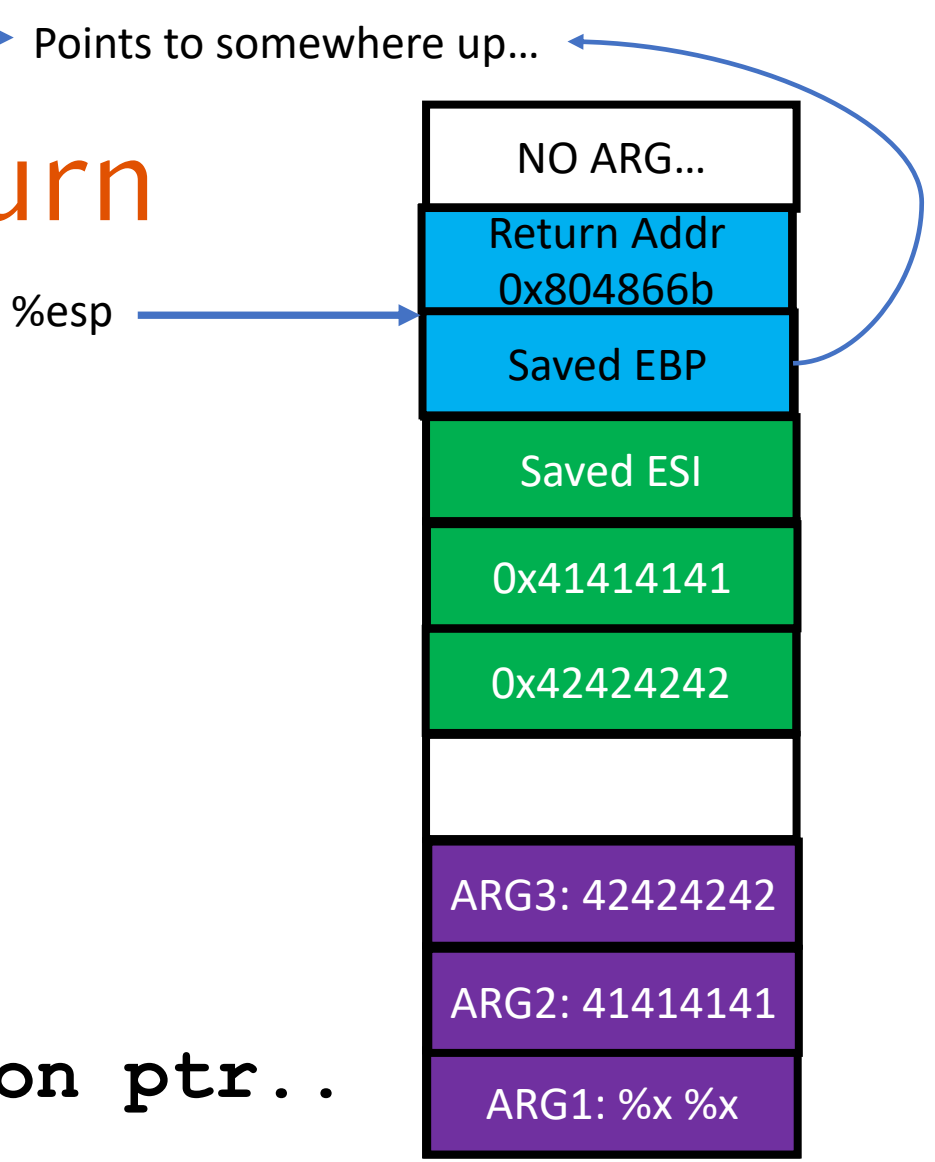


Example – Function Return



- Function return of receive_input

```
add     $0x54,%esp
pop     %esi
pop     %ebp
ret
```

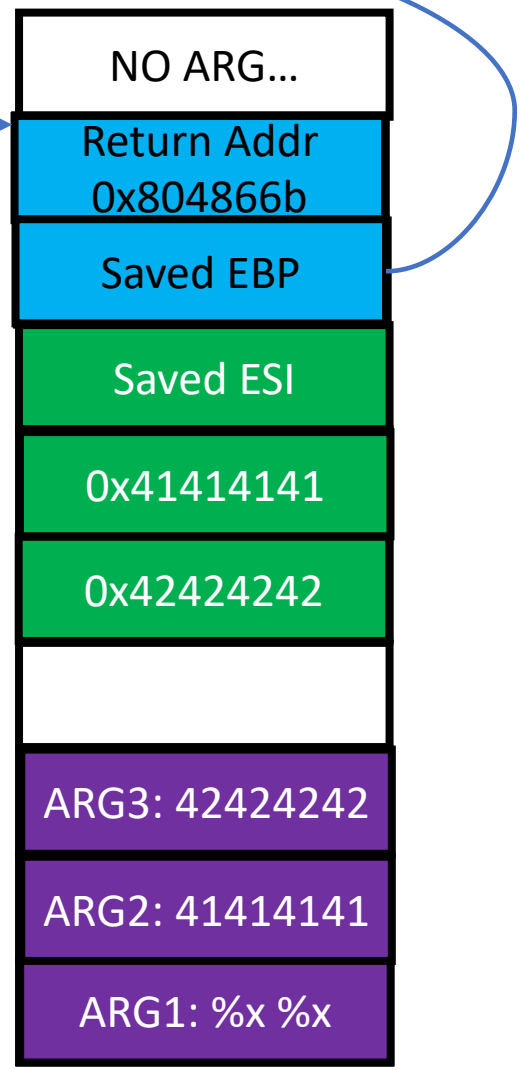
ret: pop %eip, change instruction ptr..

Example – Function Return

- Function return of receive_input

```
add     $0x54,%esp
pop     %esi
pop     %ebp
ret
```

```
call   0x8048570 <receive_input>
0x0804866b <+11>:       xor    %eax,%eax
```



Buffer Overflow

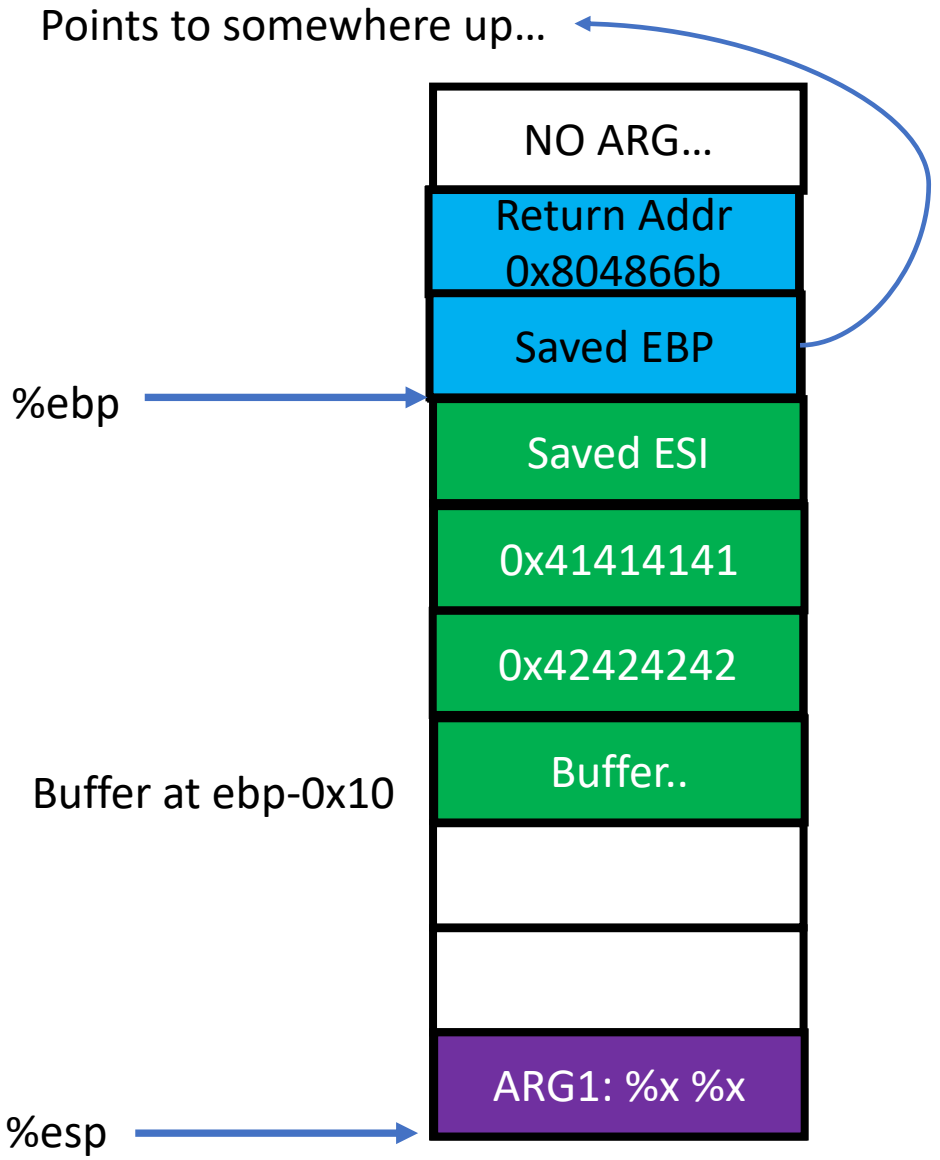
- Example

```
void receive_input() {
    int a = 0x41414141, b = 0x42424242;
    char buf[20];

    printf("Values in two local variables are:\n"
           "a = 0x%08x and b = 0x%08x\n", a, b);

    printf("Can you change these values to:\n"
           "a = 0x48474645 and b = 0x44434241?\n");

    printf("Type YES if you agree with this... "
           "(a fake message, you may overflow the input buffer).\n");
    fgets(buf, 128, stdin);
```

- char buf[20];
- fgets(buf, 128, stdin);

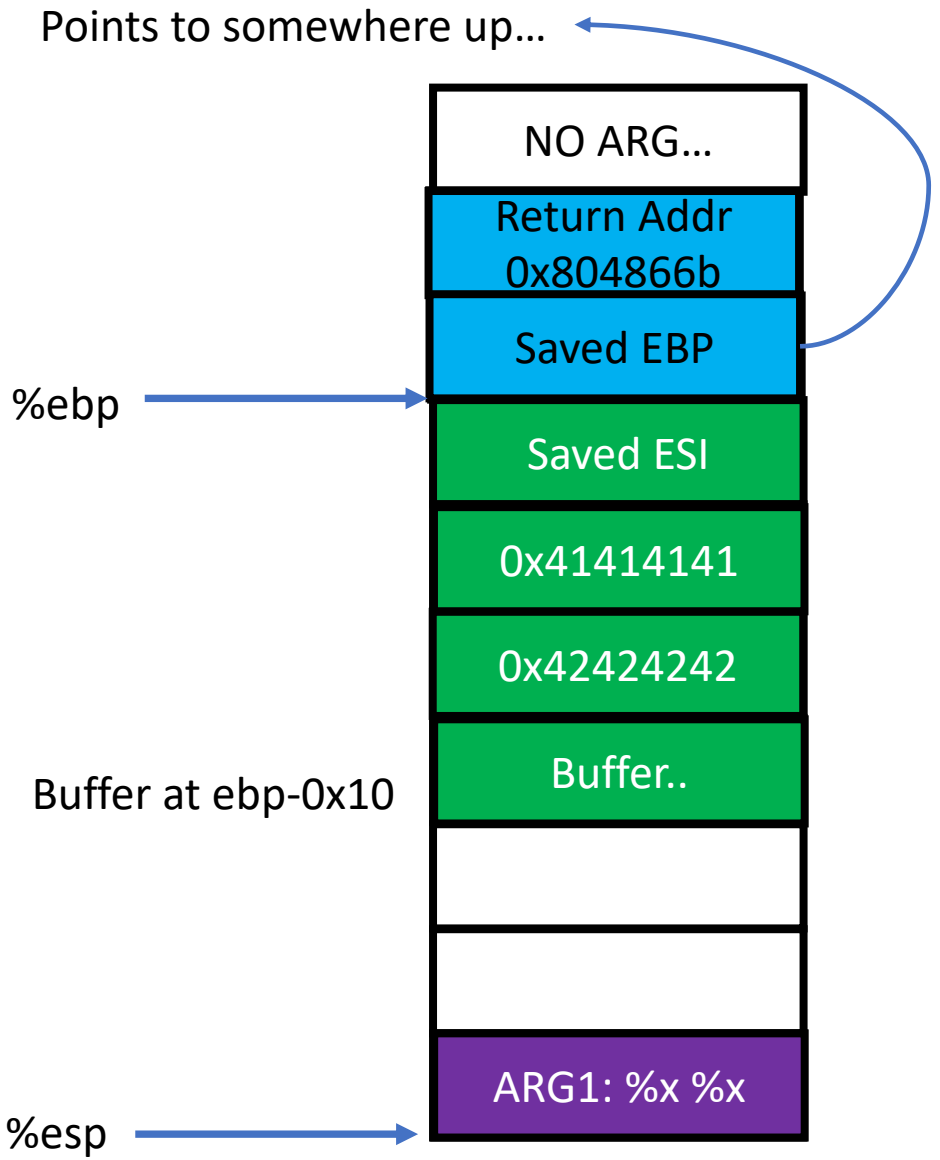
Buffer Overflow

- Overwrite values in stack by overflowing
  - A local variable buffer
- Suppose we have char buffer[4];
  - -0x8(%ebp) stores 0x41414141
  - -0xc(%ebp) stroes 0x42424242
  - **-0x10(%ebp) is a buffer, size 4 byte.**
- Program gets input from you via
  - `fgets(buffer, 128, stdin);`
  - Read **128** bytes..
- What if you type “1111aaaabbbb”?



Buffer Overflow

- 4 byte buffer…
- What if you type “1111aaaabbbb”?



ASCII CODE

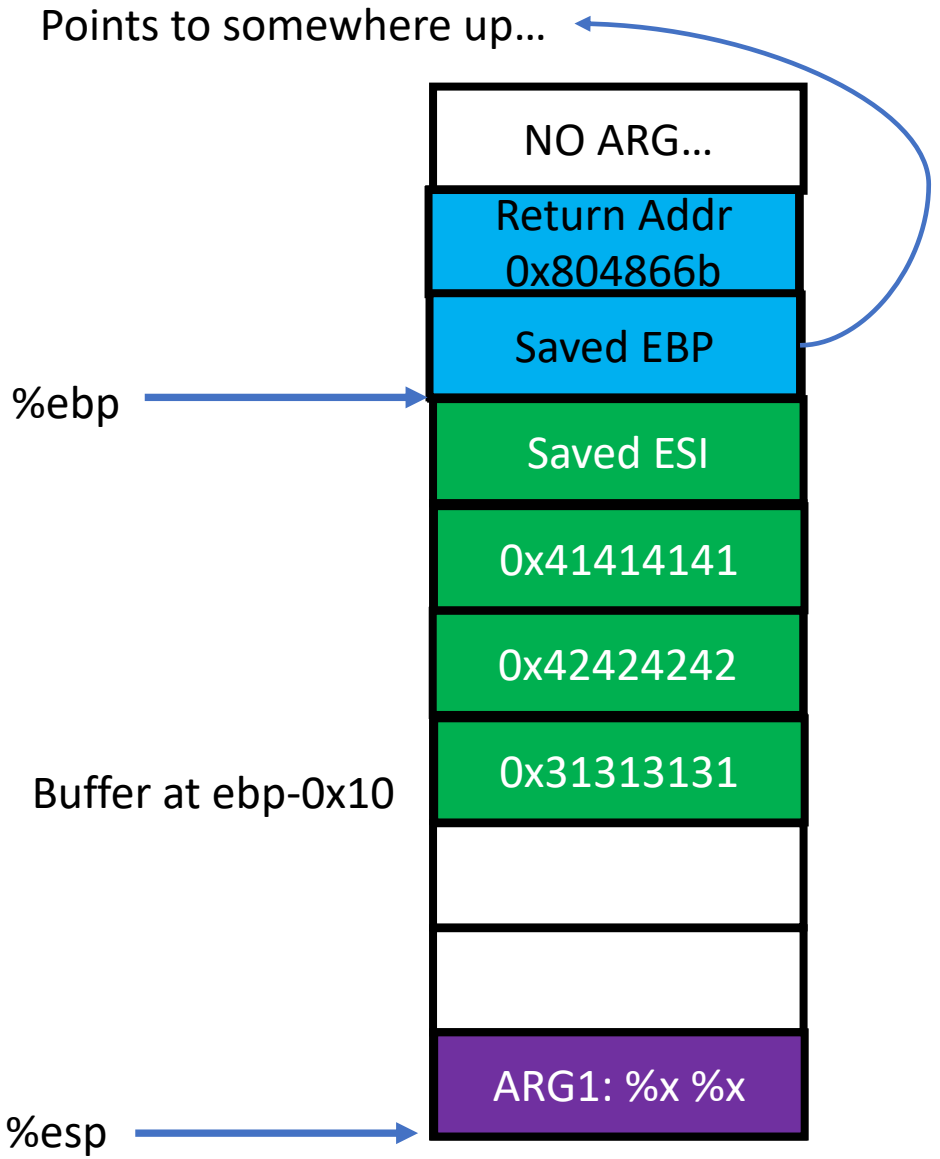
Dec	Hx	Oct	Char	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL (null)	32	20	040		Space	64	40	100	@	@	96	60	140	`	`
1	1	001	SOH (start of heading)	33	21	041	!	!	65	41	101	A	A	97	61	141	a	a
2	2	002	STX (start of text)	34	22	042	"	"	66	42	102	B	B	98	62	142	b	b
3	3	003	ETX (end of text)	35	23	043	#	#	67	43	103	C	C	99	63	143	c	c
4	4	004	EOT (end of transmission)	36	24	044	$	$	68	44	104	D	D	100	64	144	d	d
5	5	005	ENQ (enquiry)	37	25	045	%	%	69	45	105	E	E	101	65	145	e	e
6	6	006	ACK (acknowledge)	38	26	046	&	&	70	46	106	F	F	102	66	146	f	f
7	7	007	BEL (bell)	39	27	047	'	'	71	47	107	G	G	103	67	147	g	g
8	8	010	BS (backspace)	40	28	050	(	(	72	48	110	H	H	104	68	150	h	h
9	9	011	TAB (horizontal tab)	41	29	051	)	)	73	49	111	I	I	105	69	151	i	i
10	A	012	LF (NL line feed, new line)	42	2A	052	*	*	74	4A	112	J	J	106	6A	152	j	j
11	B	013	VT (vertical tab)	43	2B	053	+	+	75	4B	113	K	K	107	6B	153	k	k
12	C	014	FF (NP form feed, new page)	44	2C	054	,	,	76	4C	114	L	L	108	6C	154	l	l
13	D	015	CR (carriage return)	45	2D	055	-	-	77	4D	115	M	M	109	6D	155	m	m
14	E	016	SO (shift out)	46	2E	056	.	.	78	4E	116	N	N	110	6E	156	n	n
15	F	017	SI (shift in)	47	2F	057	/	/	79	4F	117	O	O	111	6F	157	o	o
16	10	020	DLE (data link escape)	48	30	060	0	0	80	50	120	P	P	112	70	160	p	p
17	11	021	DC1 (device control 1)	49	31	061	1	1	81	51	121	Q	Q	113	71	161	q	q
18	12	022	DC2 (device control 2)	50	32	062	2	2	82	52	122	R	R	114	72	162	r	r
19	13	023	DC3 (device control 3)	51	33	063	3	3	83	53	123	S	S	115	73	163	s	s
20	14	024	DC4 (device control 4)	52	34	064	4	4	84	54	124	T	T	116	74	164	t	t
21	15	025	NAK (negative acknowledge)	53	35	065	5	5	85	55	125	U	U	117	75	165	u	u
22	16	026	SYN (synchronous idle)	54	36	066	6	6	86	56	126	V	V	118	76	166	v	v
23	17	027	ETB (end of trans. block)	55	37	067	7	7	87	57	127	W	W	119	77	167	w	w
24	18	030	CAN (cancel)	56	38	070	8	8	88	58	130	X	X	120	78	170	x	x
25	19	031	EM (end of medium)	57	39	071	9	9	89	59	131	Y	Y	121	79	171	y	y
26	1A	032	SUB (substitute)	58	3A	072	:	:	90	5A	132	Z	Z	122	7A	172	z	z
27	1B	033	ESC (escape)	59	3B	073	;	;	91	5B	133	[	[	123	7B	173	{	{
28	1C	034	FS (file separator)	60	3C	074	<	<	92	5C	134	\	\	124	7C	174			|
29	1D	035	GS (group separator)	61	3D	075	=	=	93	5D	135	]	]	125	7D	175	}	}
30	1E	036	RS (record separator)	62	3E	076	>	>	94	5E	136	^	^	126	7E	176	~	~
31	1F	037	US (unit separator)	63	3F	077	?	?	95	5F	137	_	_	127	7F	177	&#127;	DEL

Source: www.LookupTables.com

- Image from: https://cs.smu.ca/~porter/csc/ref/ascii.html and www.LookupTables.com

Buffer Overflow

- 4 byte buffer…
- What if you type “1111aaaabbbb”?



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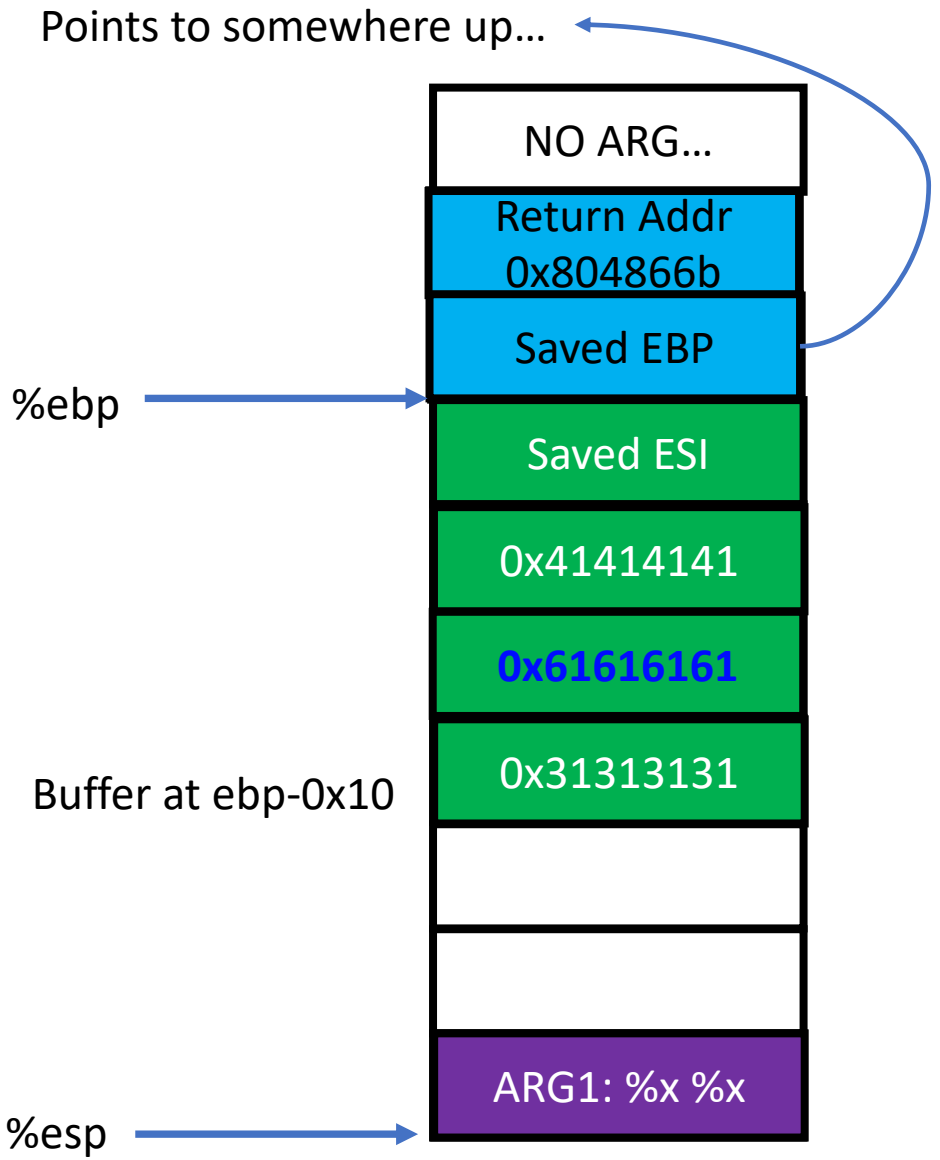

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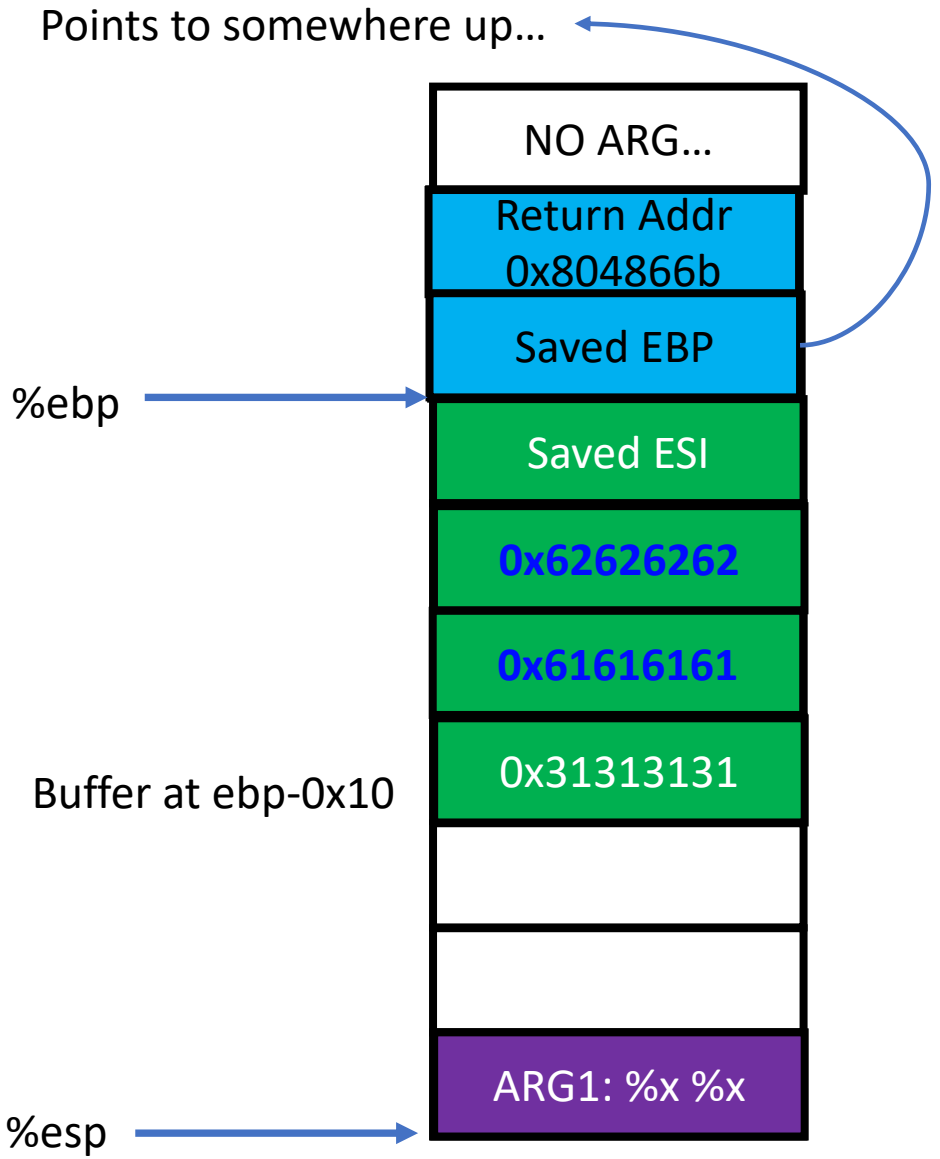
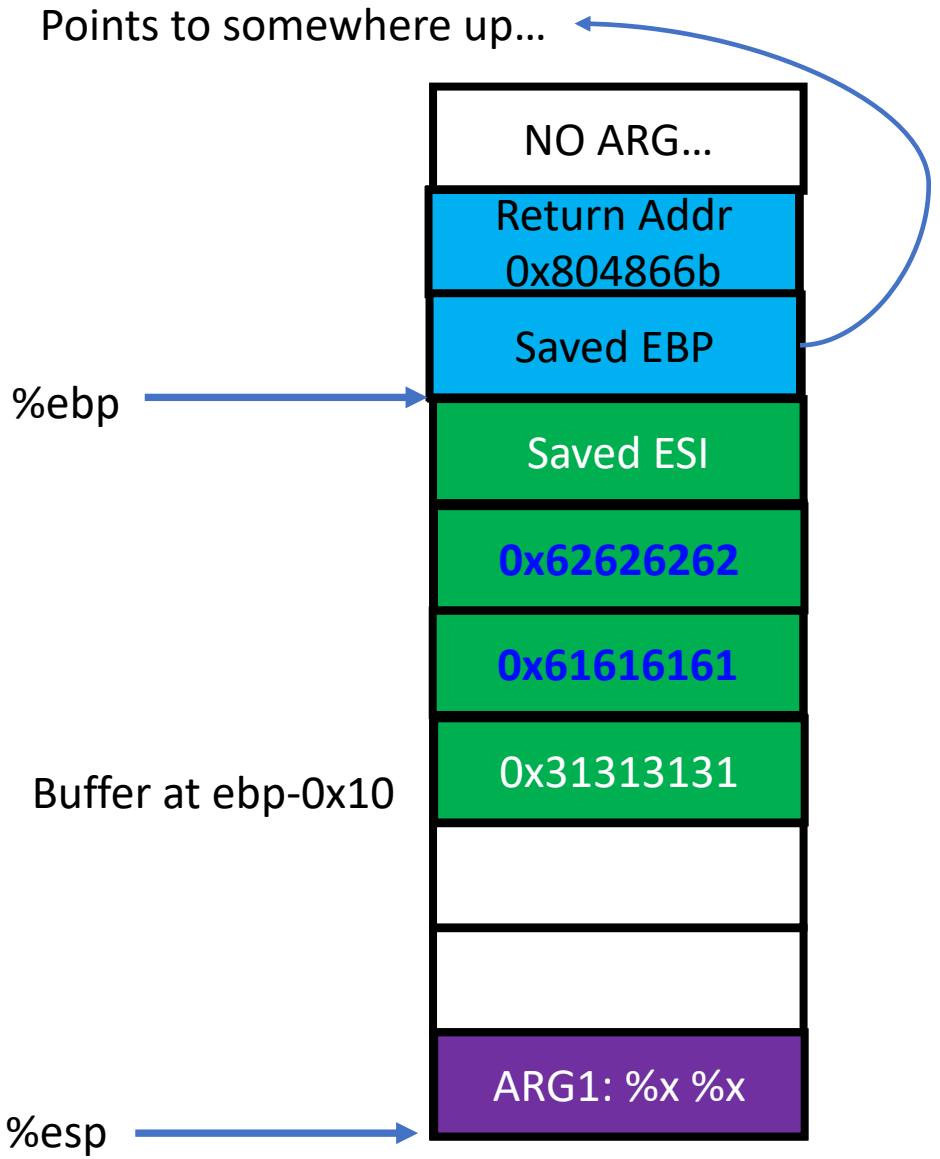


Buffer Overflow

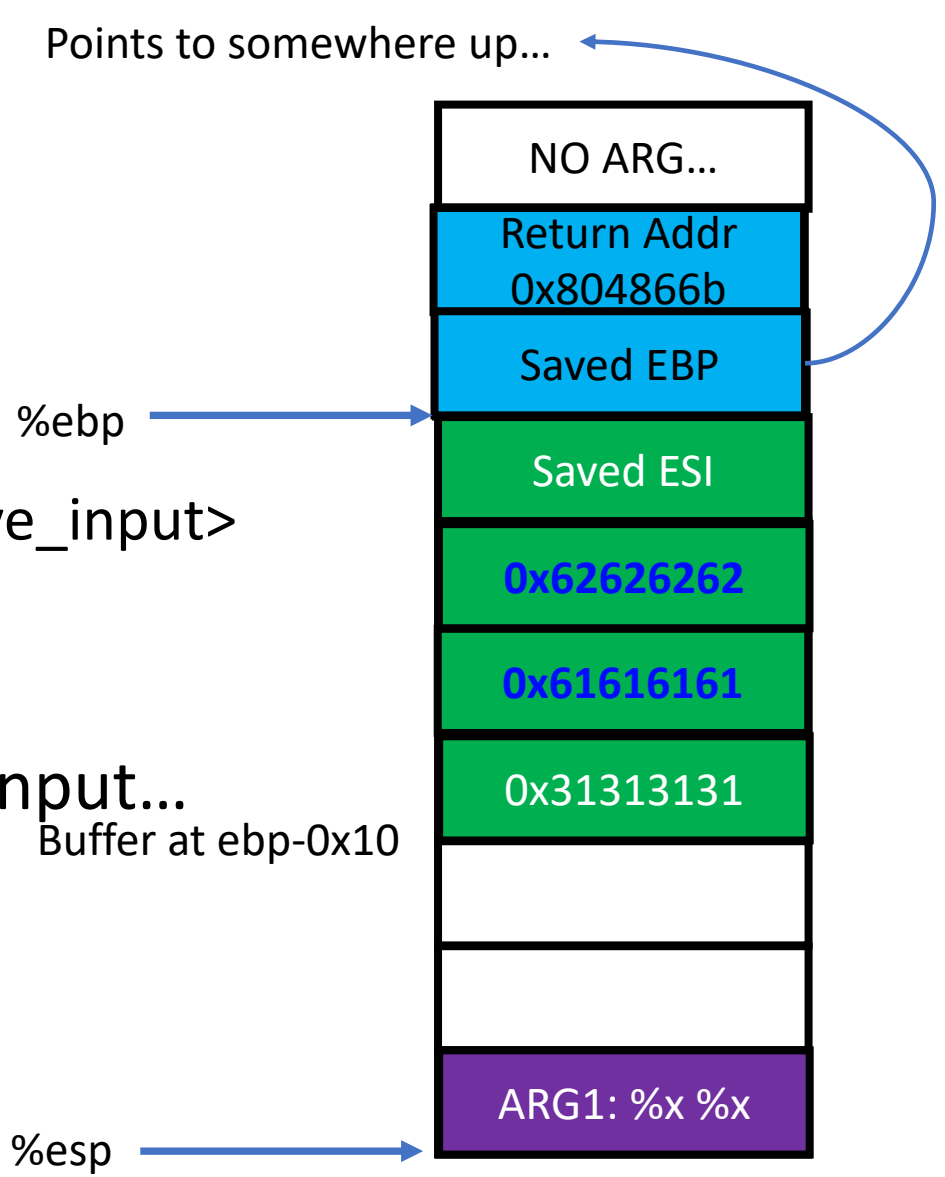
- 4 byte buffer…
- What if you type “1111aaaabbbb”?

- You can change variables!



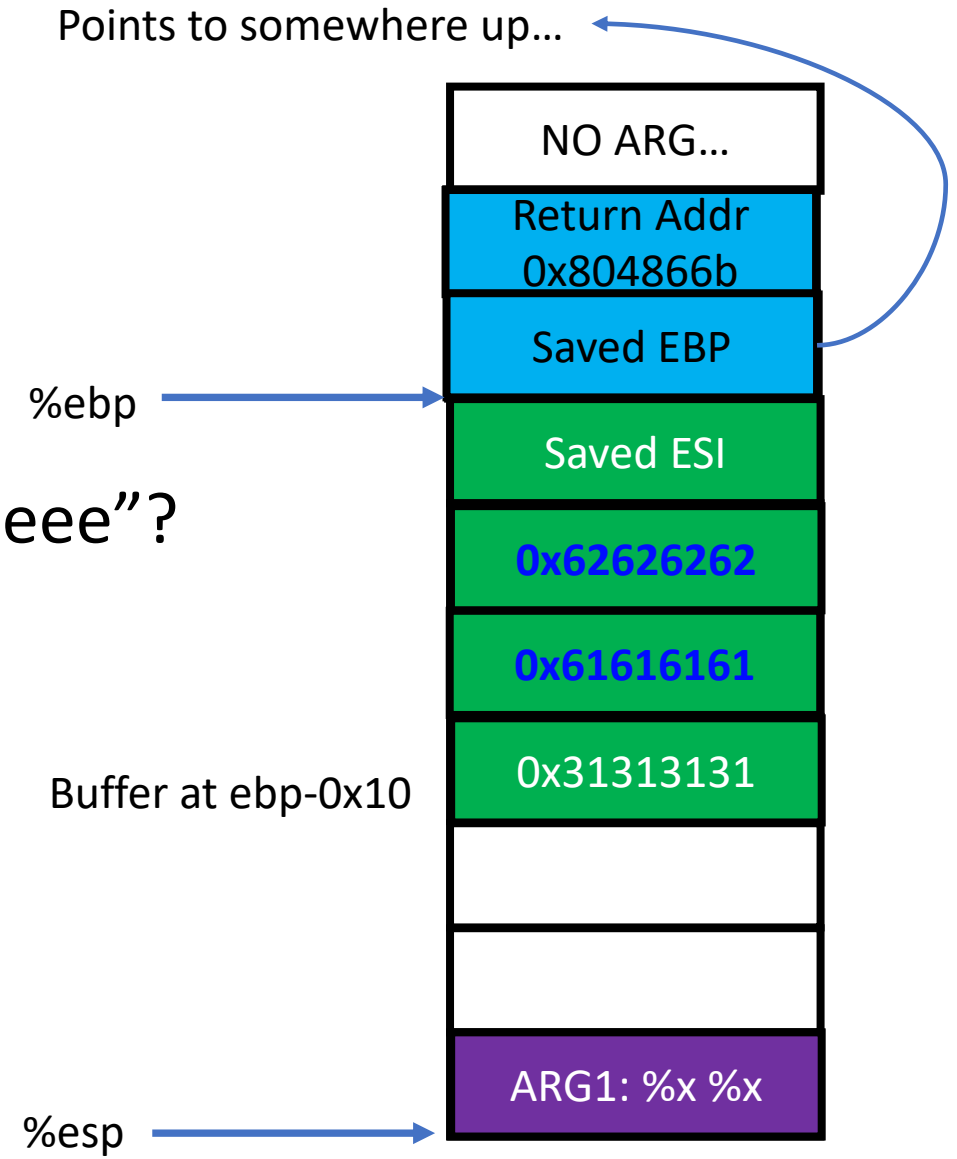
Return Address

- Store the execution points after the call
  - 0x08048666 <+6>: call 0x8048570 <receive_input>
  - 0x0804866b <+11>: xor %eax,%eax
- Should store 0x804866b on calling receive_input…



Buffer Overflow

- 4 byte buffer…
- What if you type “1111aaaabbbbccccddddeeee”?



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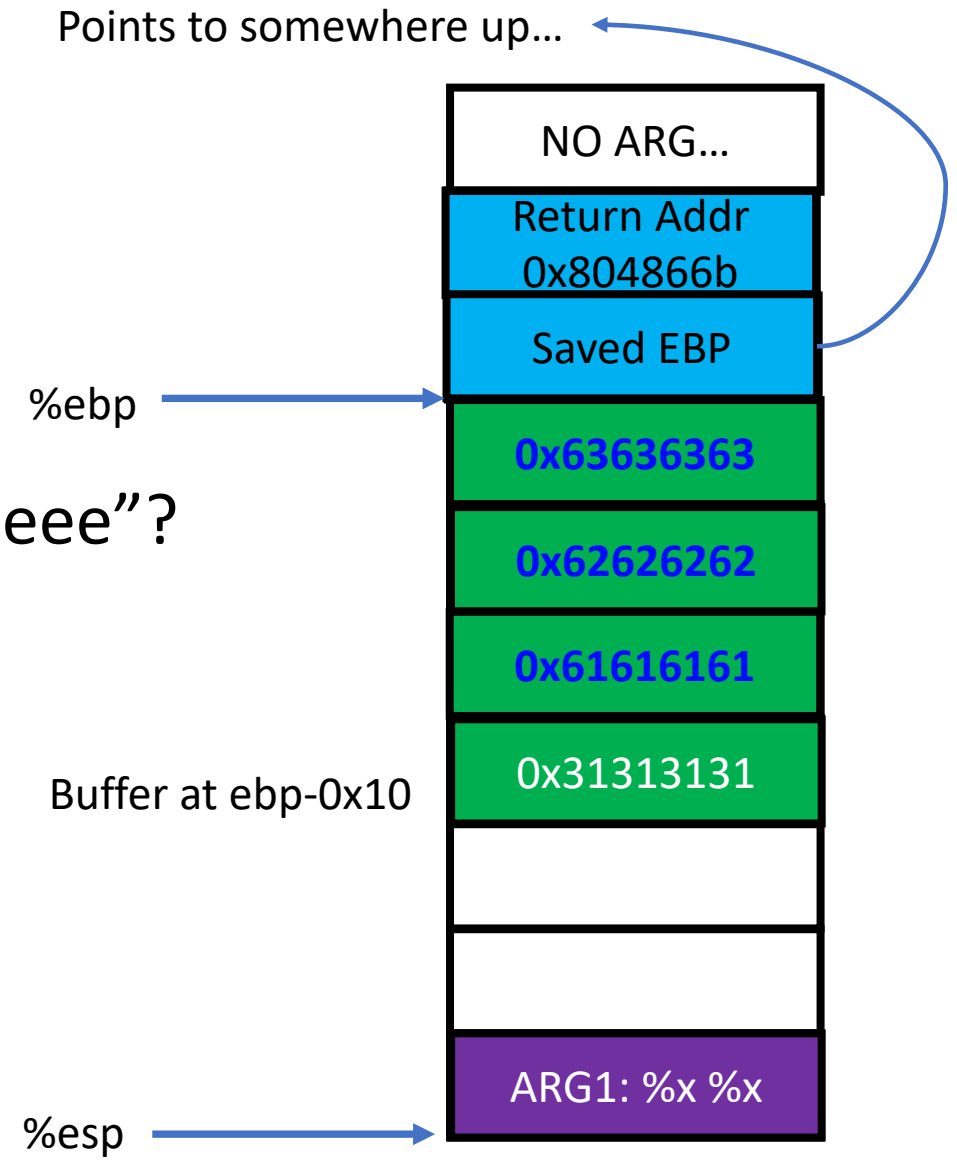

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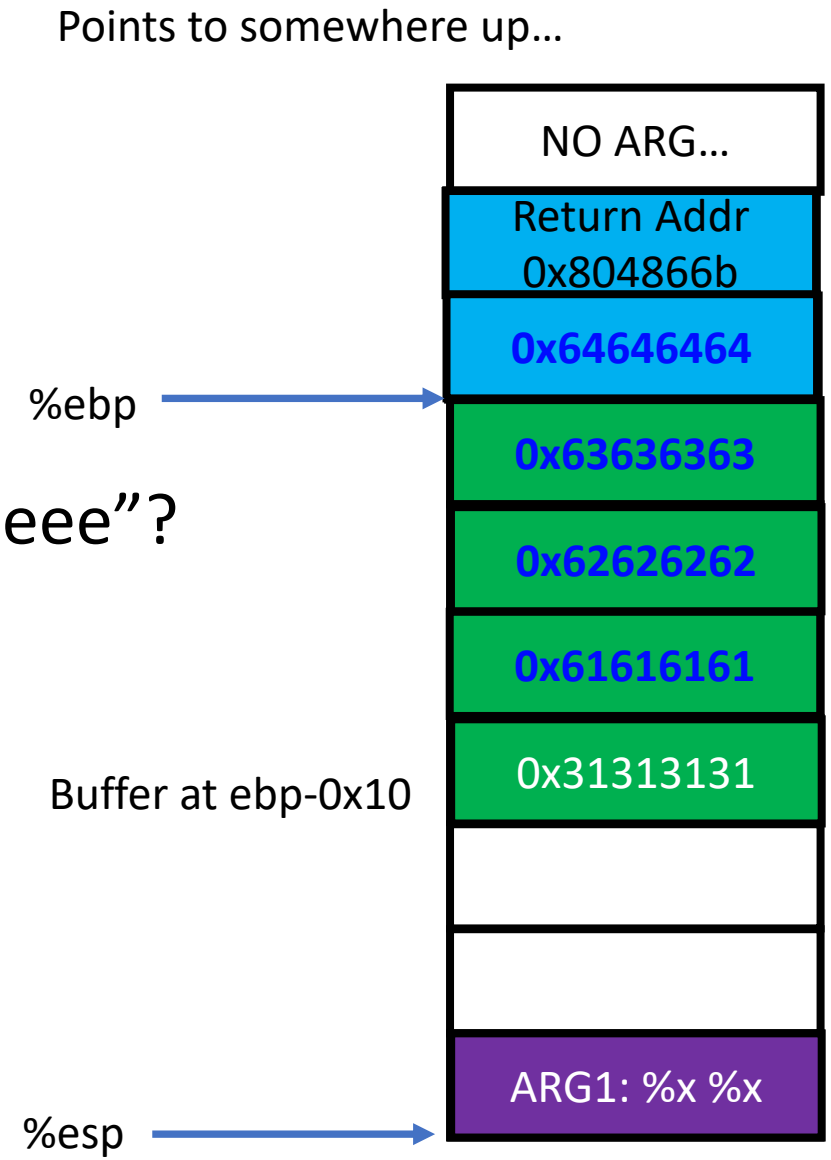

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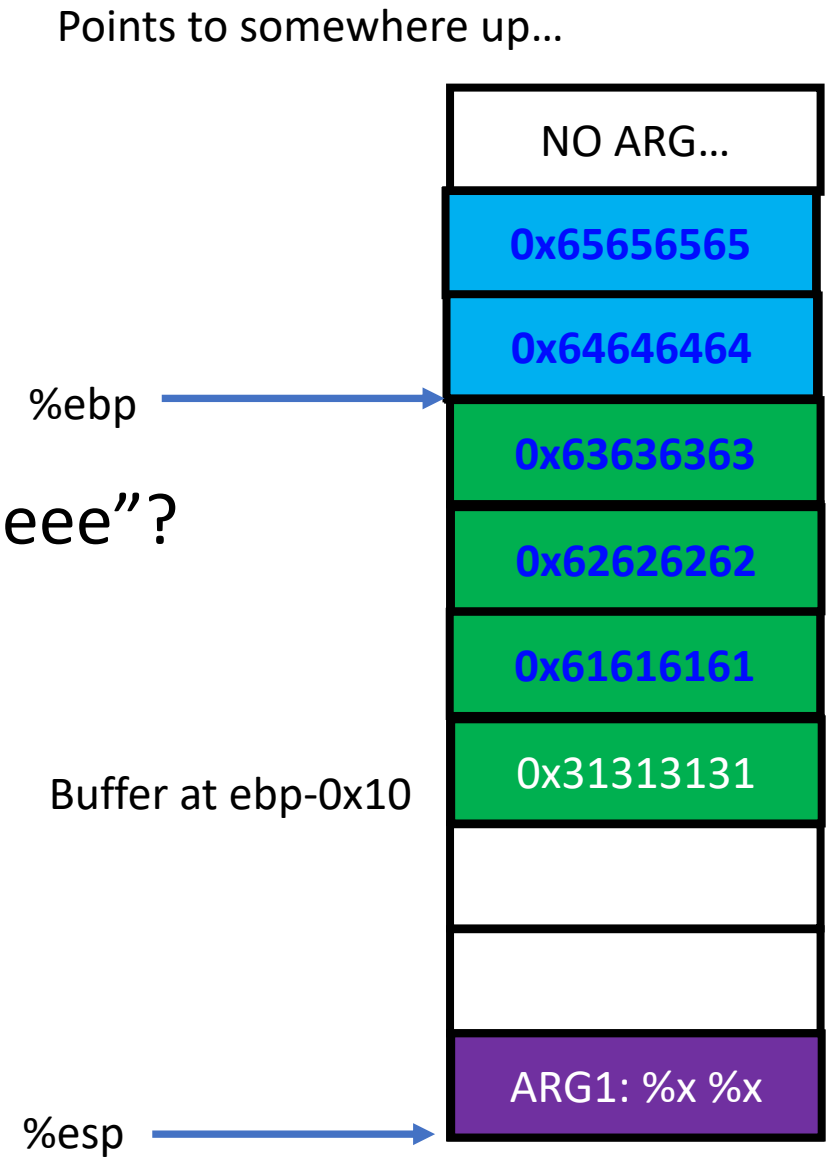
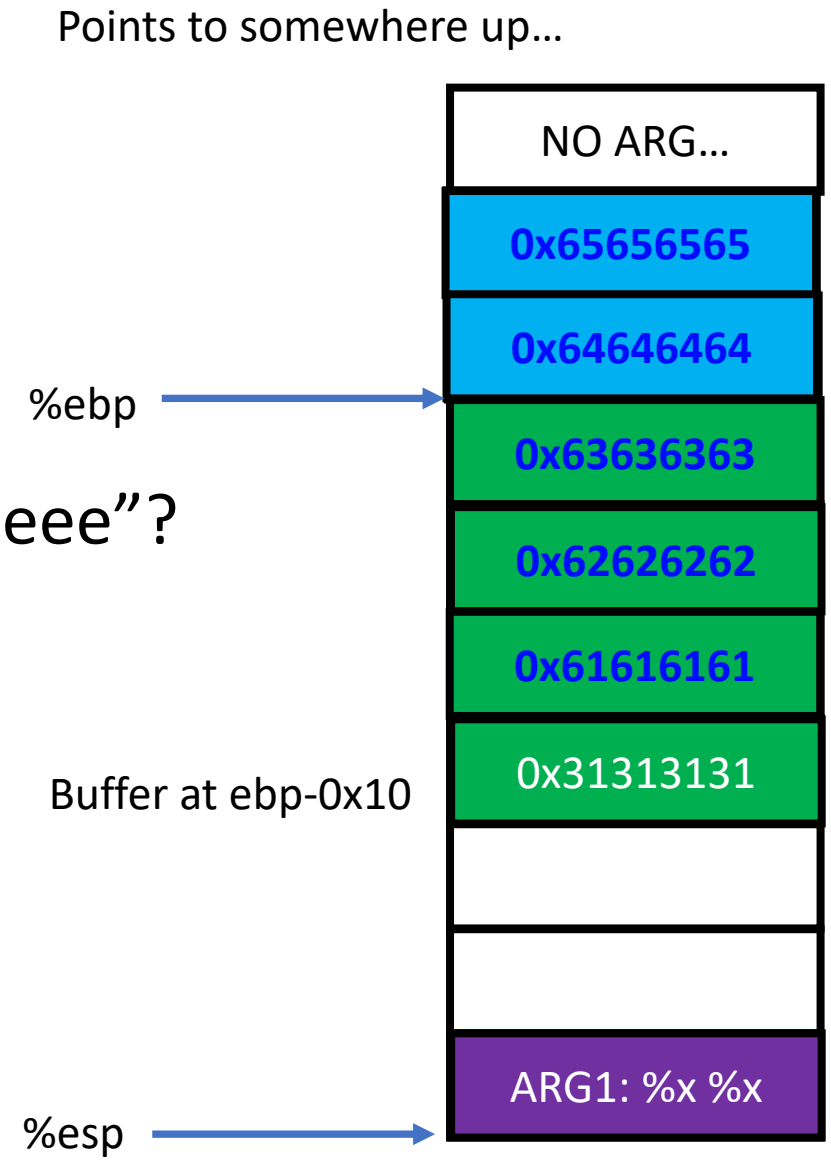


Buffer Overflow

- 4 byte buffer…
- What if you type “1111aaaabbbbccccddddeeee”?

- Overwrites the return address!

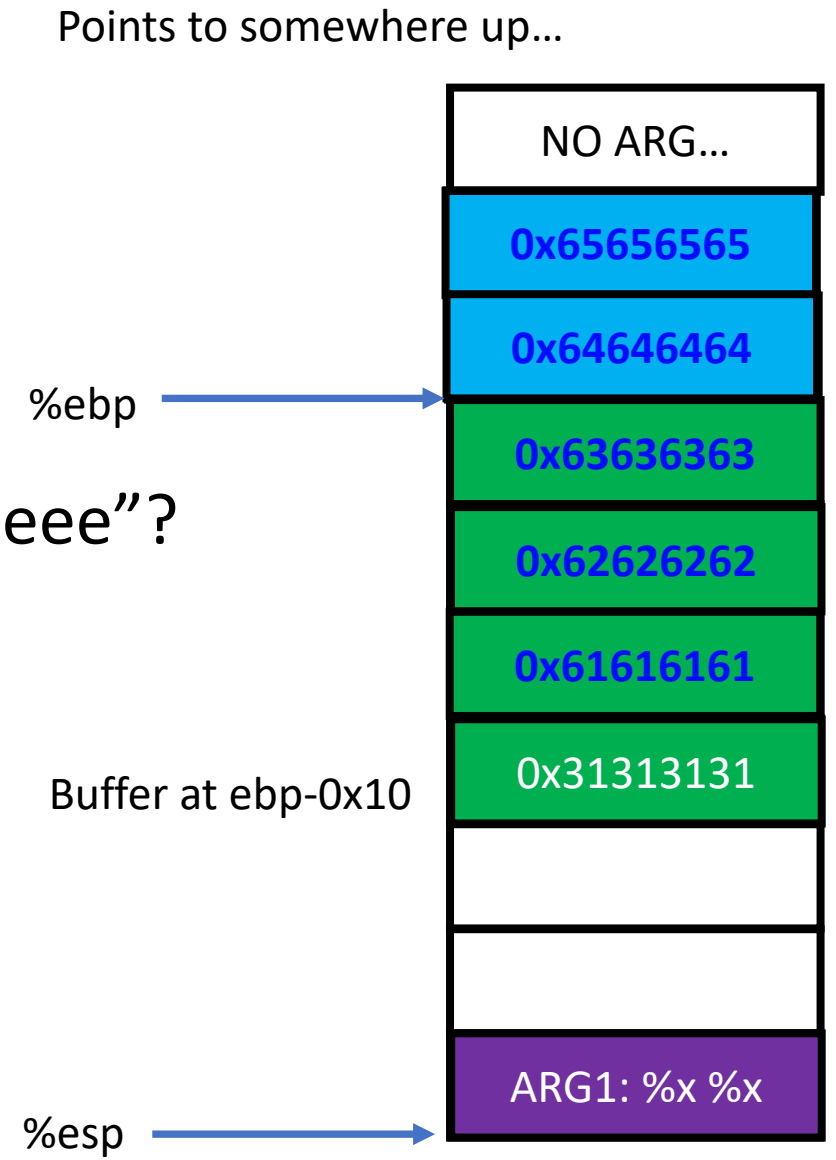


Buffer Overflow

- 4 byte buffer…
- What if you type “1111aaaabbbbccccddddeeee”?

- Overwrites the return address!

- Can you set that as the address of
  - get_a_shell()?



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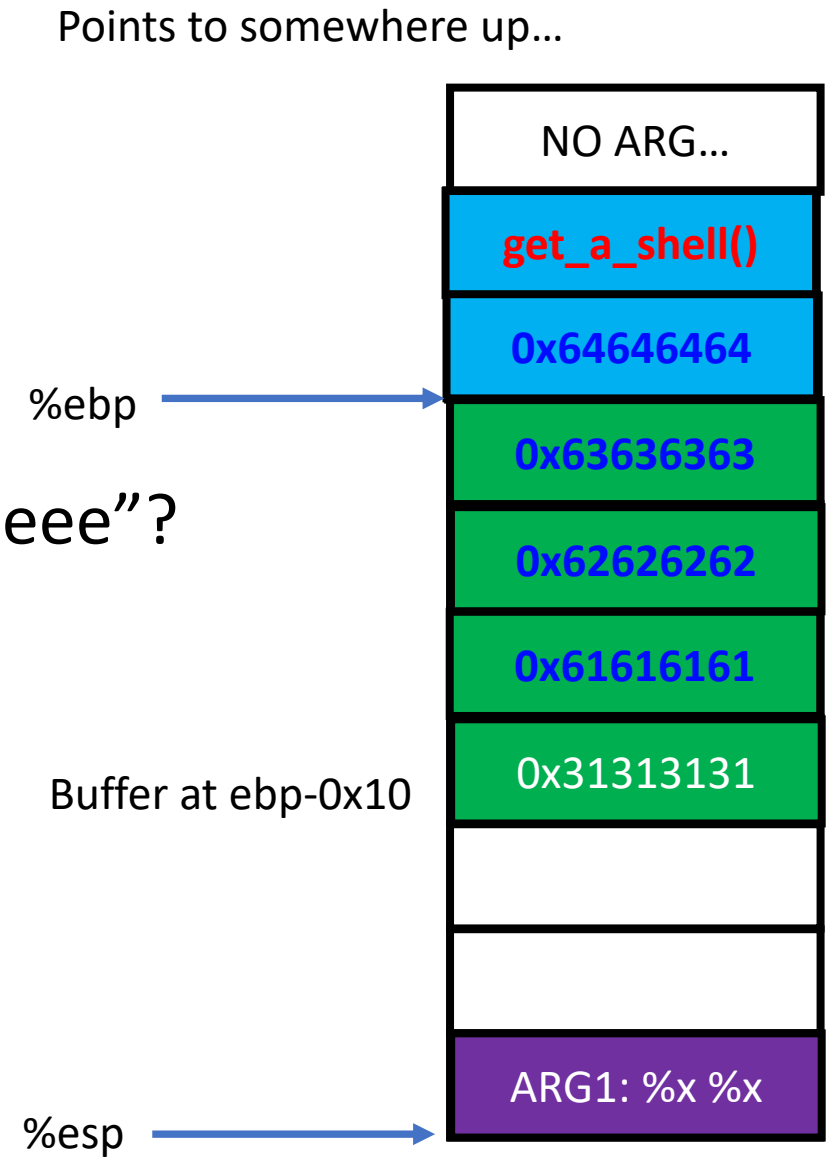

Buffer Overflow

- Function return of receive_input

```
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pop     %esi
pop     %ebp
ret
```

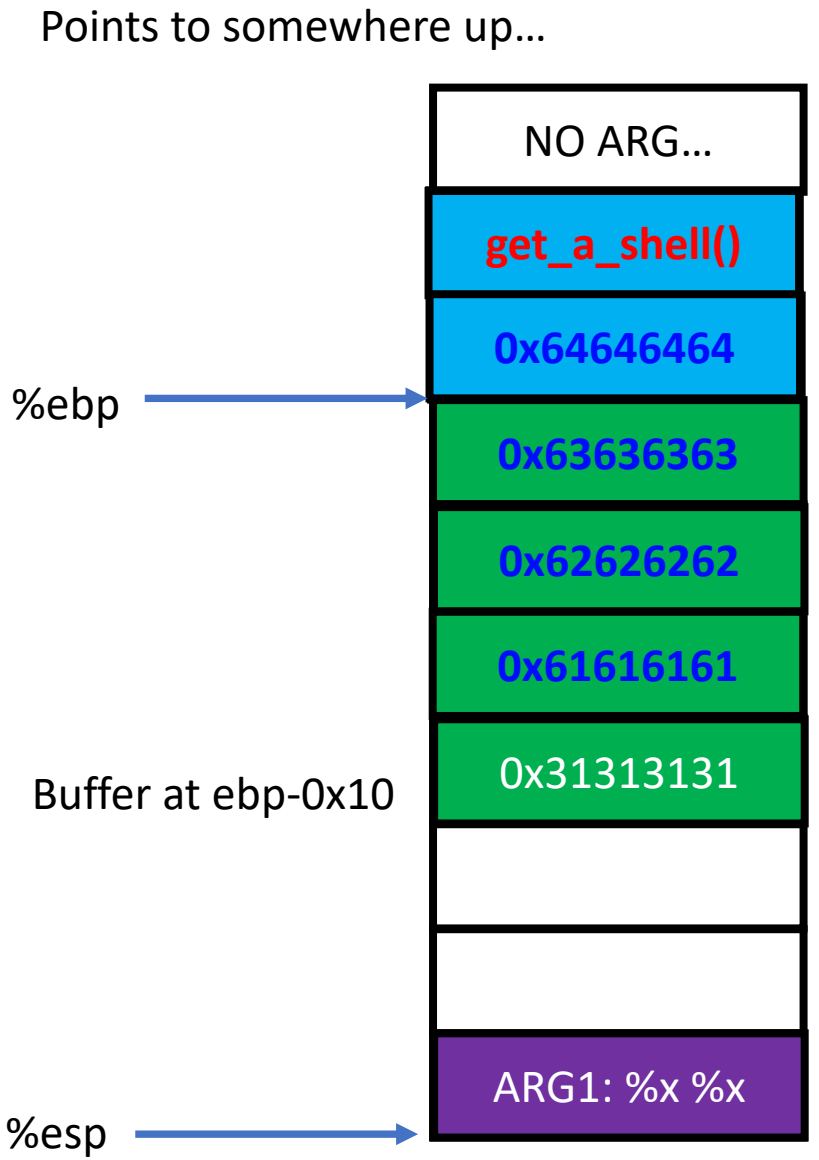

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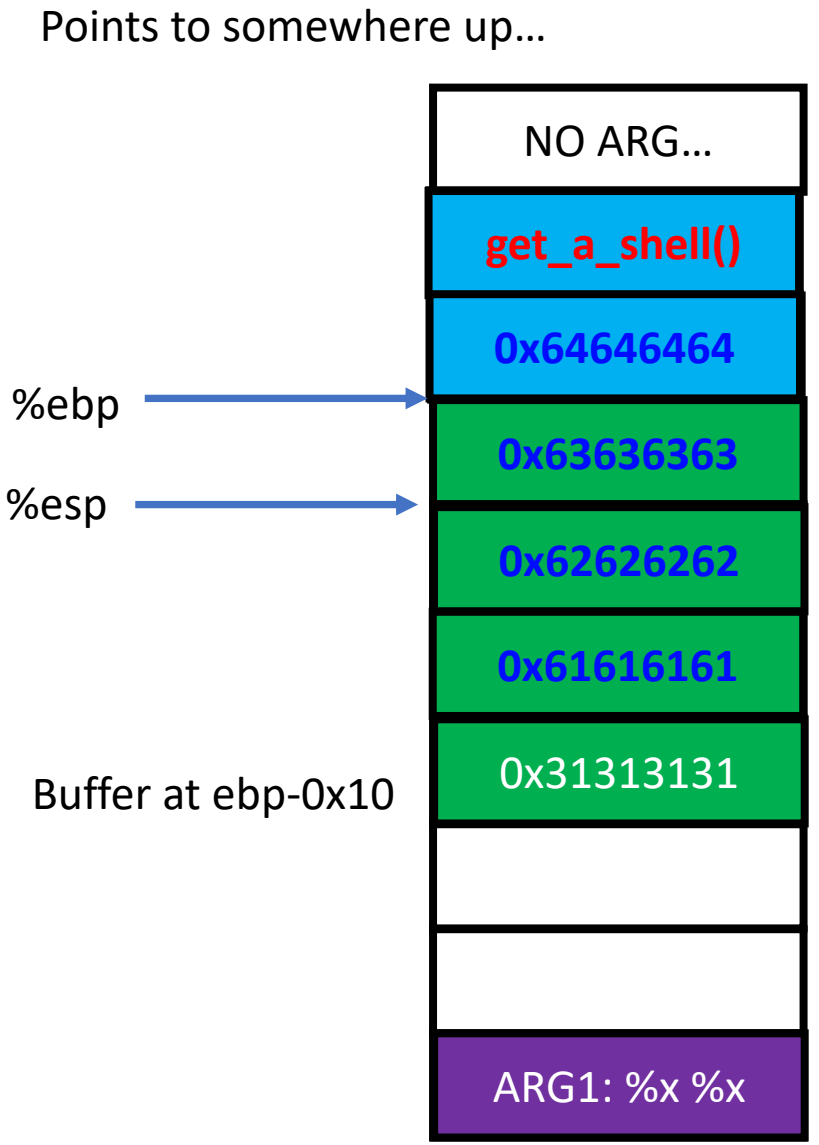

Buffer Overflow

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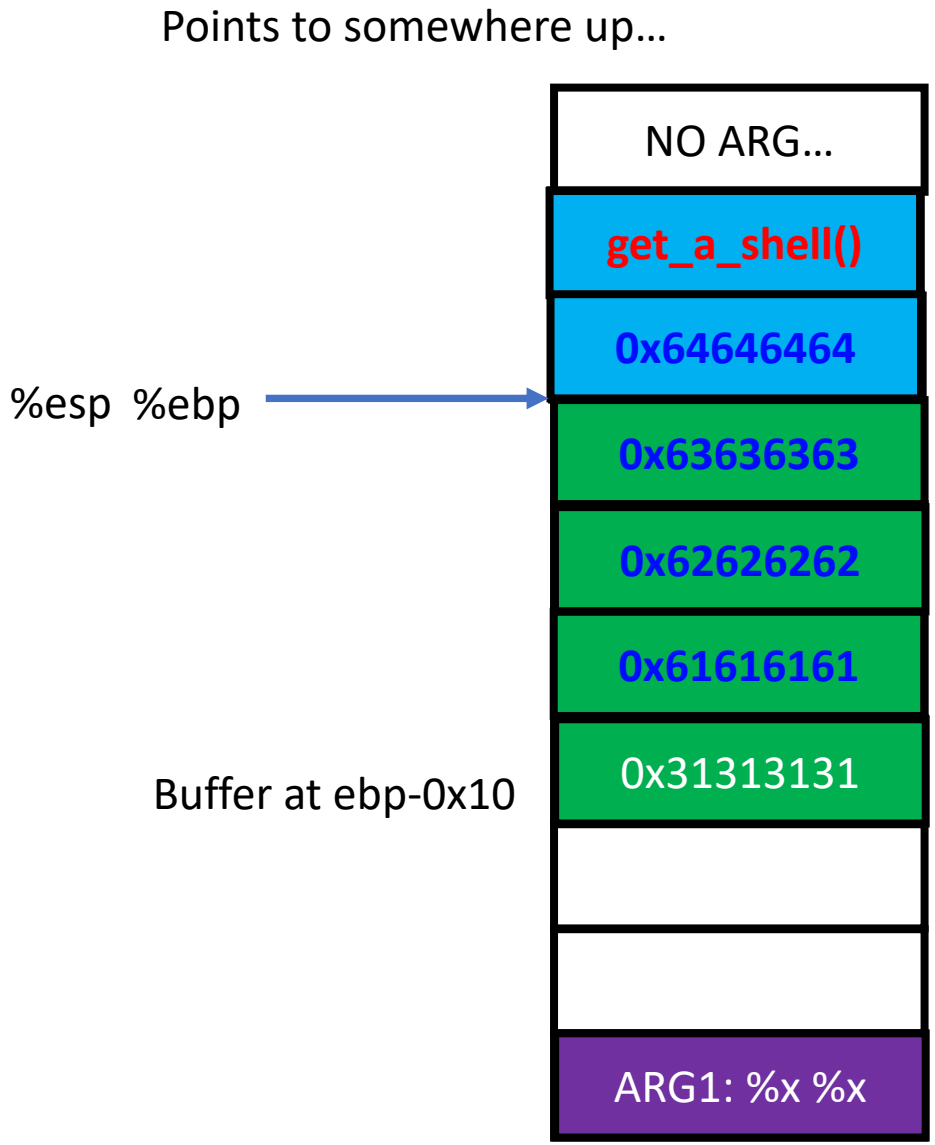

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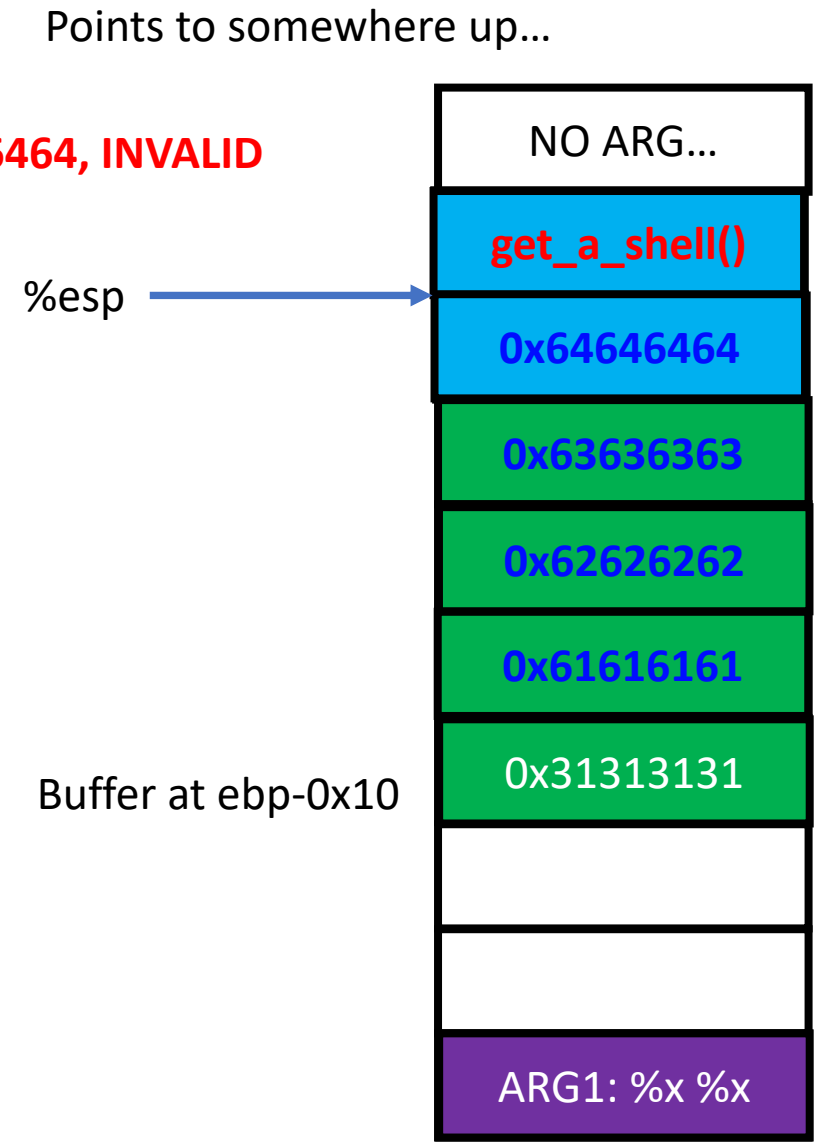

Buffer Overflow

- Function return of receive_input

```
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pop     %esi
pop     %ebp
ret
```

Run get_a_shell()!