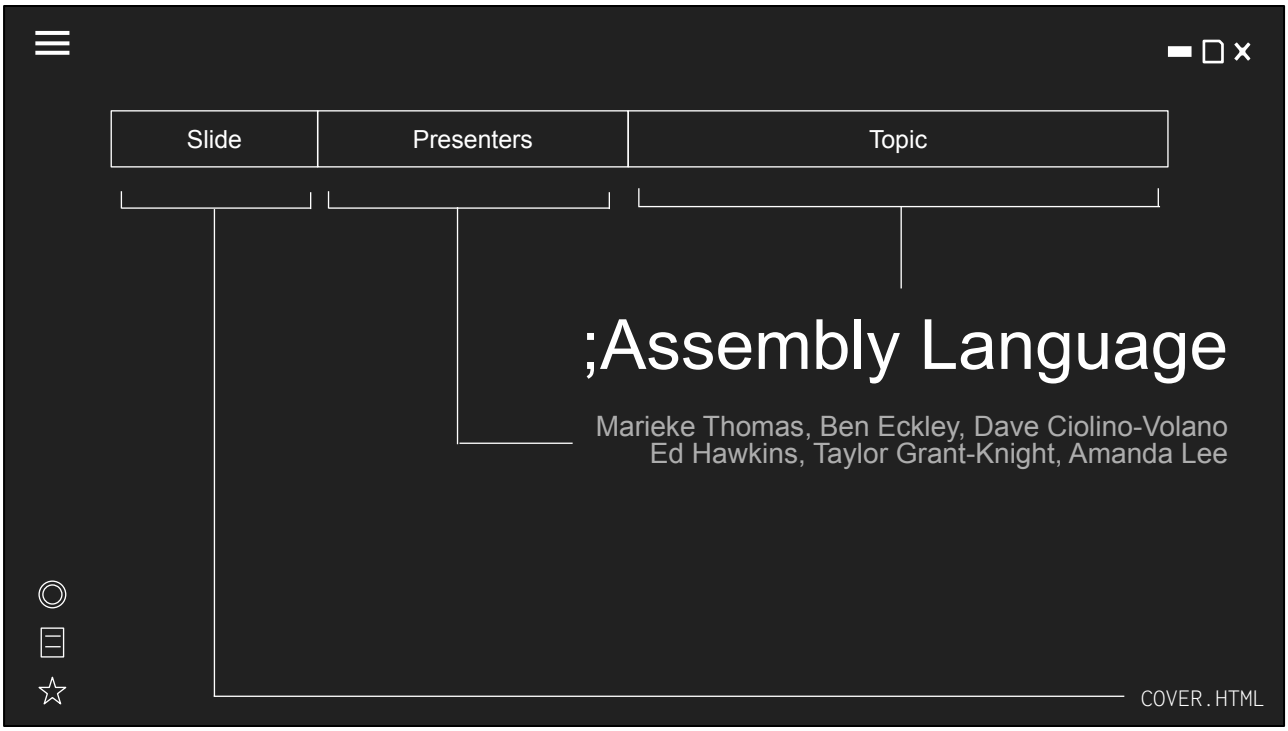

Slide
Presenters
Topic
;Assembly Language
Marieke Thomas, Ben Eckley, Dave Ciolino-Volano
Ed Hawkins, Taylor Grant-Knight, Amanda Lee
COVER.HTML

;Agenda

1. Intro
2. History of Assembly
3. Fundamentals of Assembly
4. Fun with Assembly! (Code Along)
5. More Fun with Assembly!!! (HW)
6. Additional Resources
7. Questions???
8. And now a word from next week's group…

AGENDA.HTML

Ed

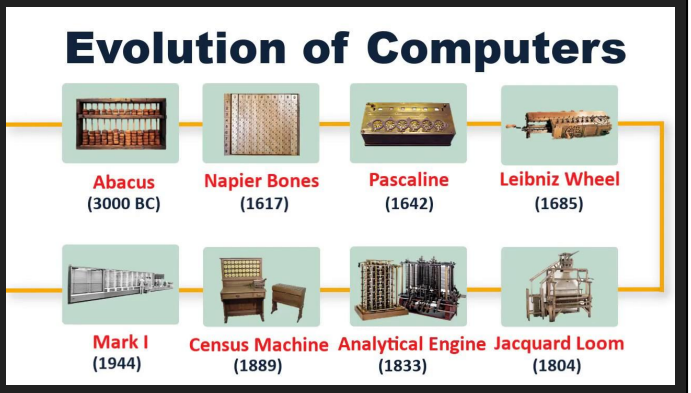
;Assembly: The code that tells your hardware what to do

Abstraction begets abstraction begets abstraction…turtles all the way down.

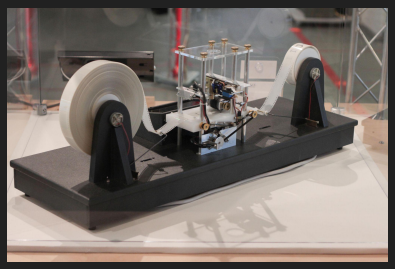
Mark 1: 5 tons, 816 cubic feet 1600 vacuum tubes, 5 horsepower (?!?!?)

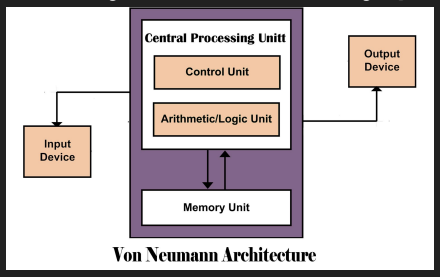
TRADIC: First transistorized computer, 800 transistors, only .13 horseys needed

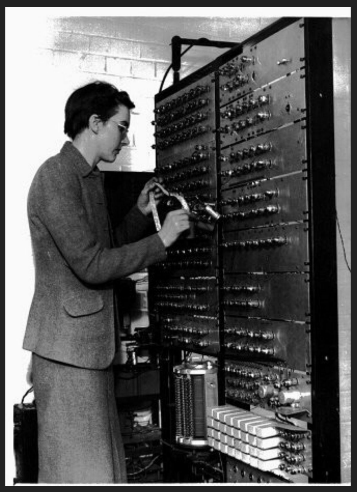
Modern CPU: ~290 million transistors and same # of horseys as TRADIC



An incredibly brief history of Assembly part 1





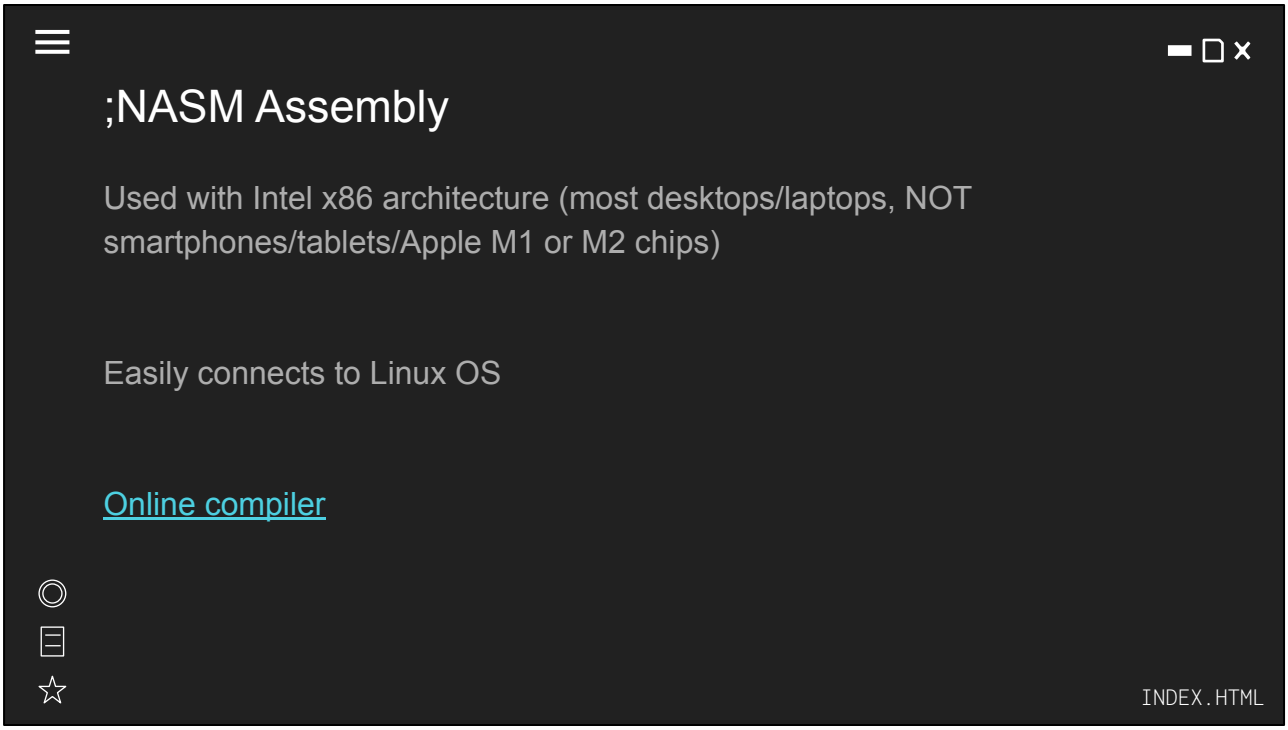


Turing to Von Neumann to Kathleen Booth…but boy oh boy it goes a lot further back than that.

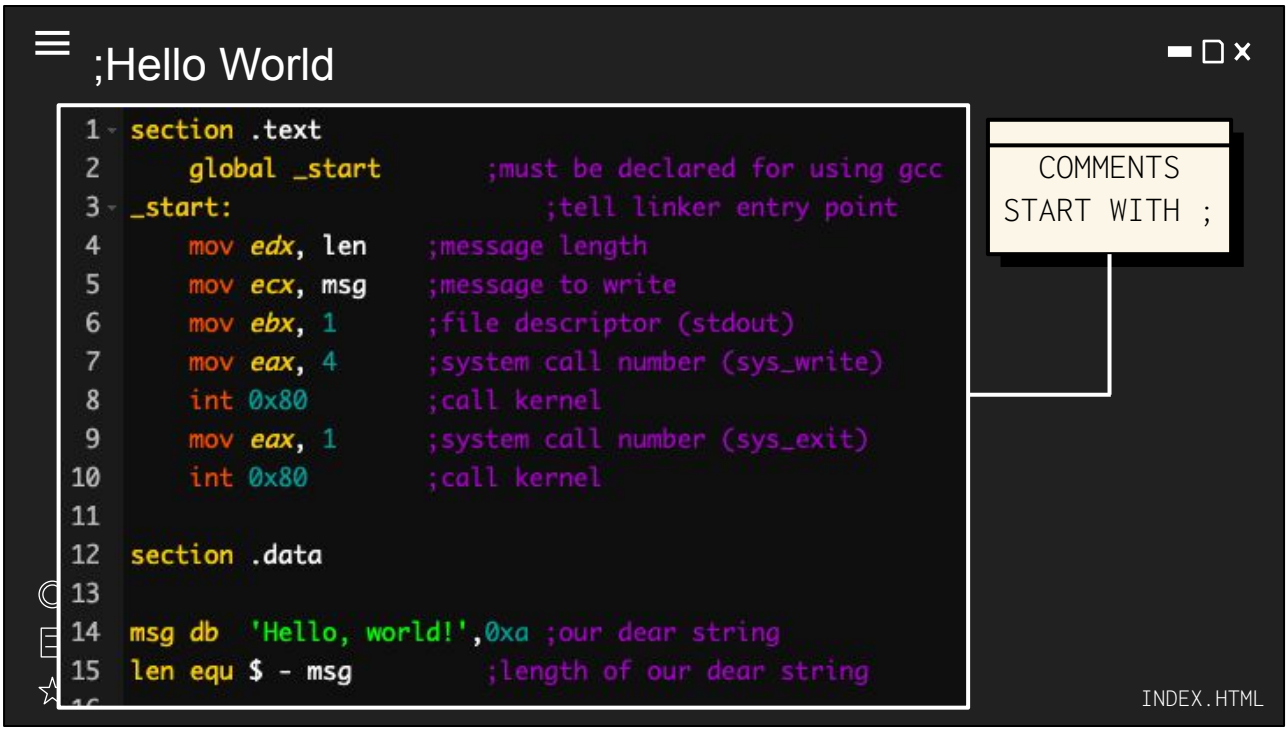
An incredibly brief history of Assembly part 2

Kathleen Booth's Contracted Notation

11)	$M \times R \rightarrow cA.$	Clear accumulator, multiply M by R and place L.H. 39 digits of answer in A and R.H. 39 digits in R.
12)	$A \div M \rightarrow cR.$	Clear register, divide A by M, leave quotient in R and remainder in A.
13)	$C \rightarrow M_l.$	
14)	$C \rightarrow M_r.$	
15)	$Cc \rightarrow M_l.$	If number in A $\geqslant 0$ shift control to $M_l.$
16)	$Cc \rightarrow M_r.$	
17)	$A \rightarrow M.$	

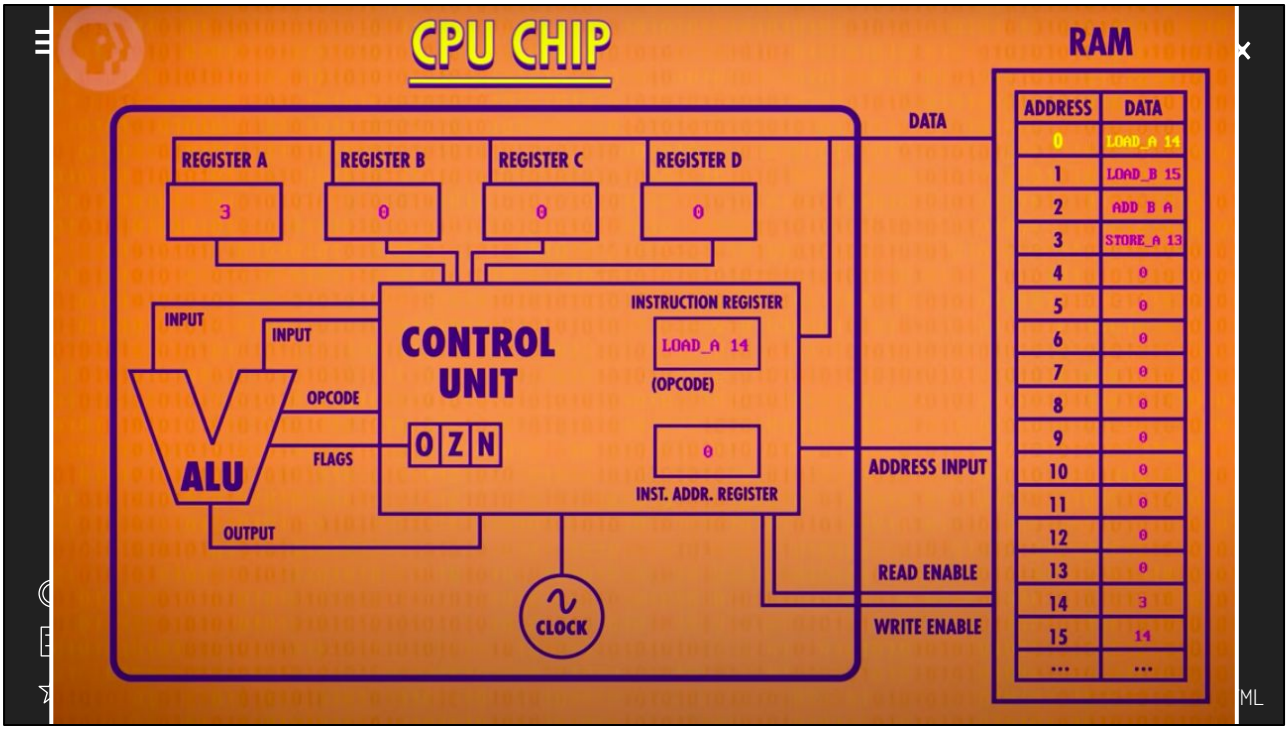


Ben
Assembly is hardware-specific. There are many different assembly languages. Today we will be programming in NASM assembly
Online compiler: https://www.tutorialspoint.com/compile_assembly_online.php

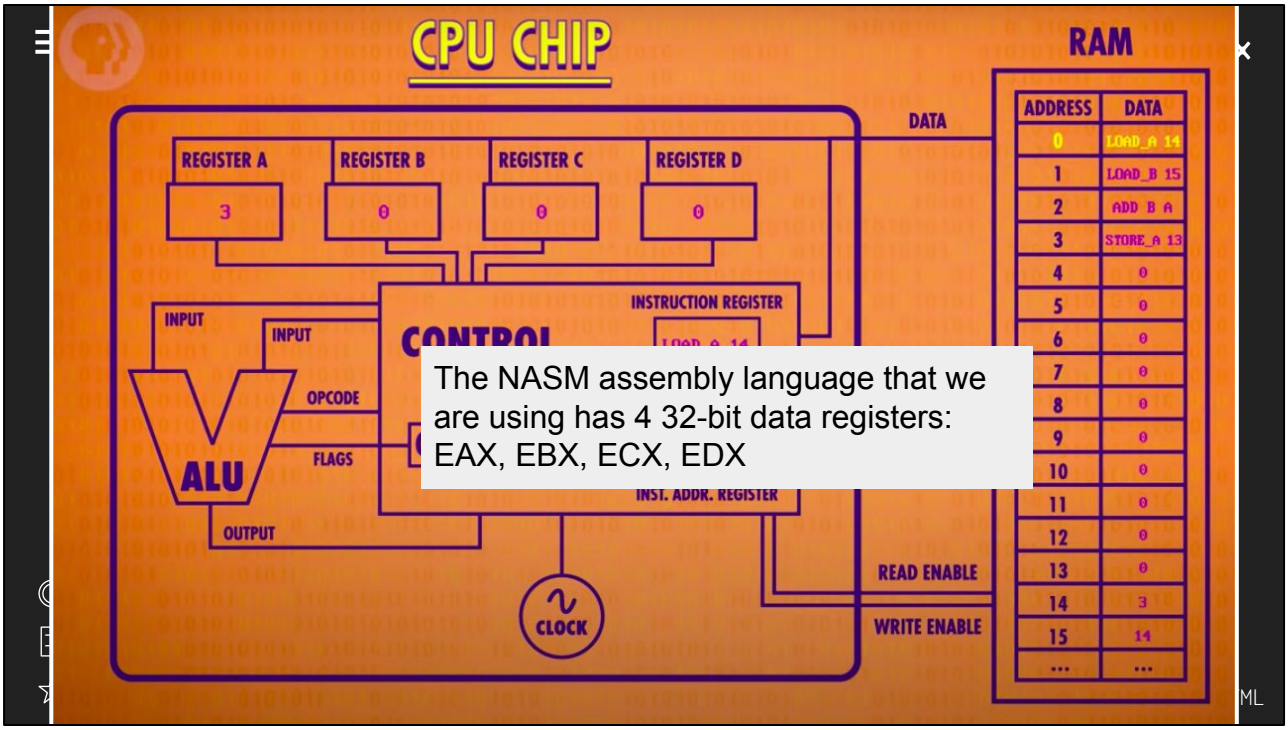


Taylor/Amanda
Link: https://www.tutorialspoint.com/compile_assembly_online.php
Presentation: Give link to the compiler. Introduce sections (.text, .data, .bss not shown), explain that all this is for Hello World. Marieke will walk through what “mov” command is. After that, we will walk through each line of code.

Taylor/Amanda



Marieke RAM stores data (BOTH the instructions/code, and the info we want to remember, like strings). Inside the CPU is a very small amount of memory in the form of registers. The data stored in the registers can be accessed much more quickly than the data in RAM, so it's common for a program to load data from RAM into the registers, do something with it, and then store the result back in RAM. We do this using the mov operation



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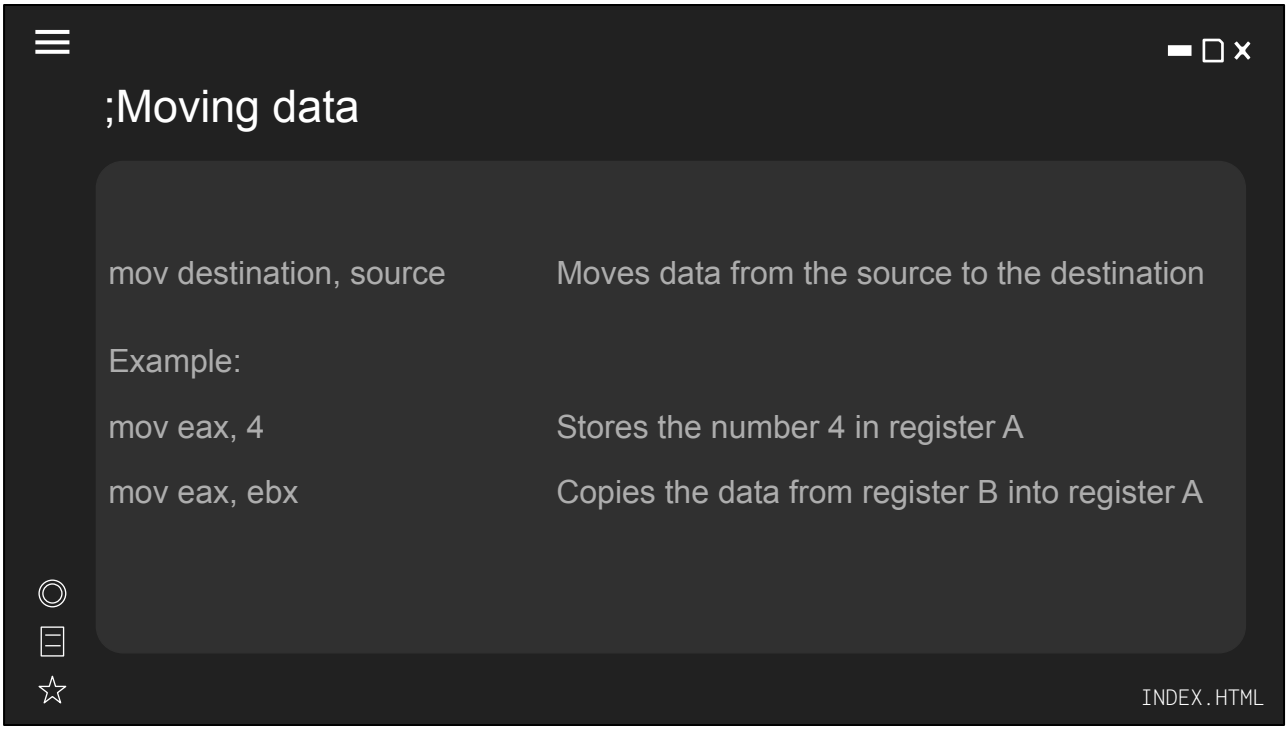
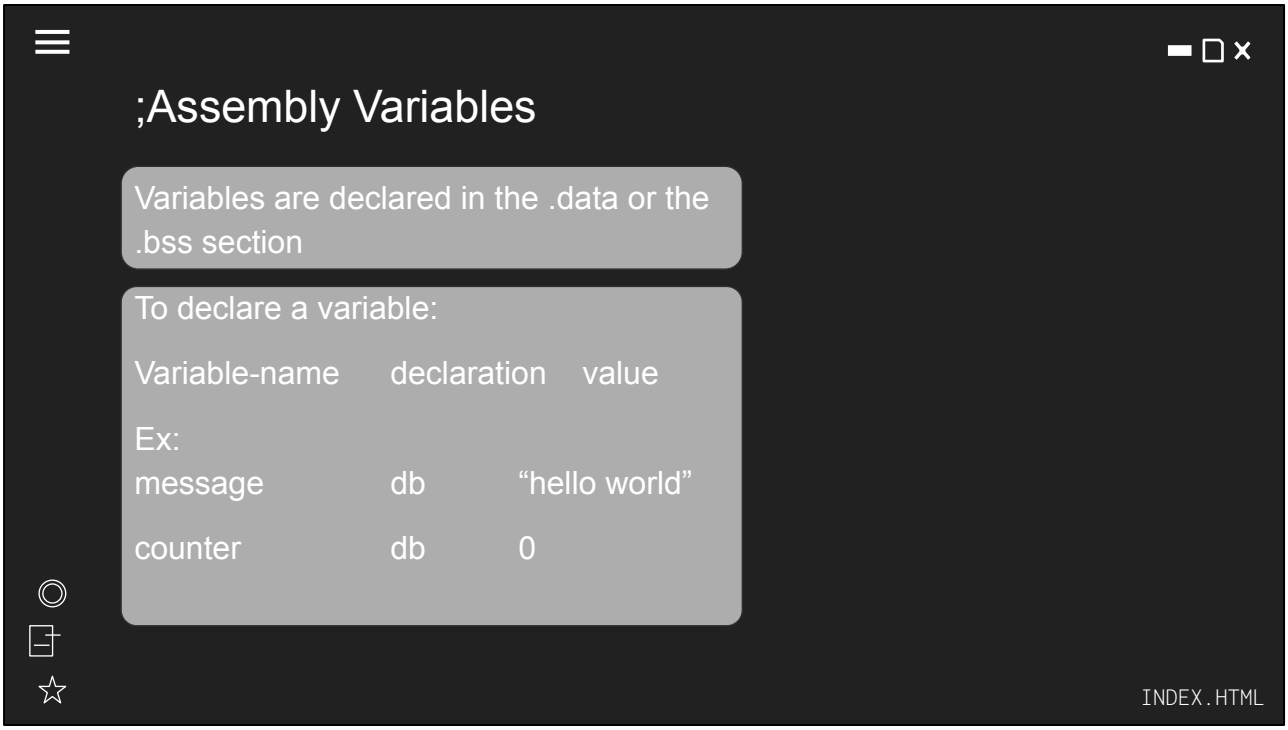

;Moving data
mov destination, source
Moves data from the source to the destination
Example:
mov eax, 4
Stores the number 4 in register A
mov eax, ebx
Copies the data from register B into register A
INDEX.HTML

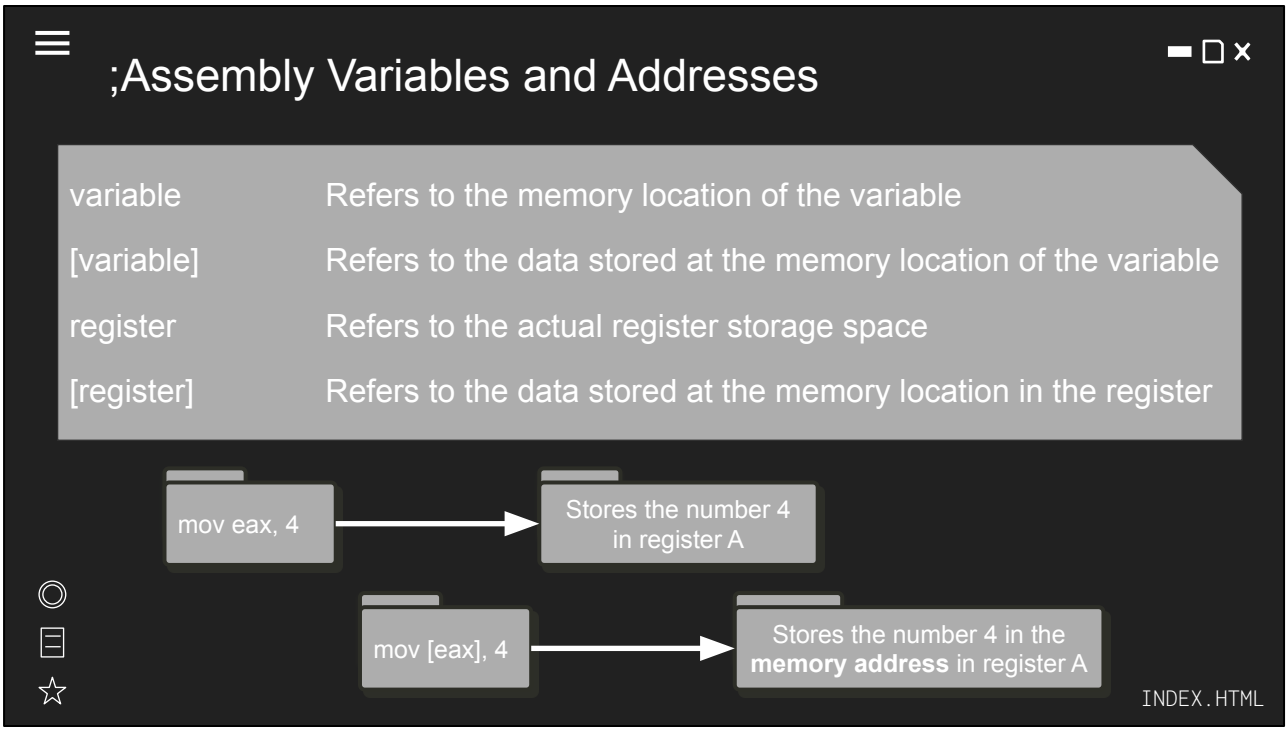
Marieke



Marieke

Db = define byte

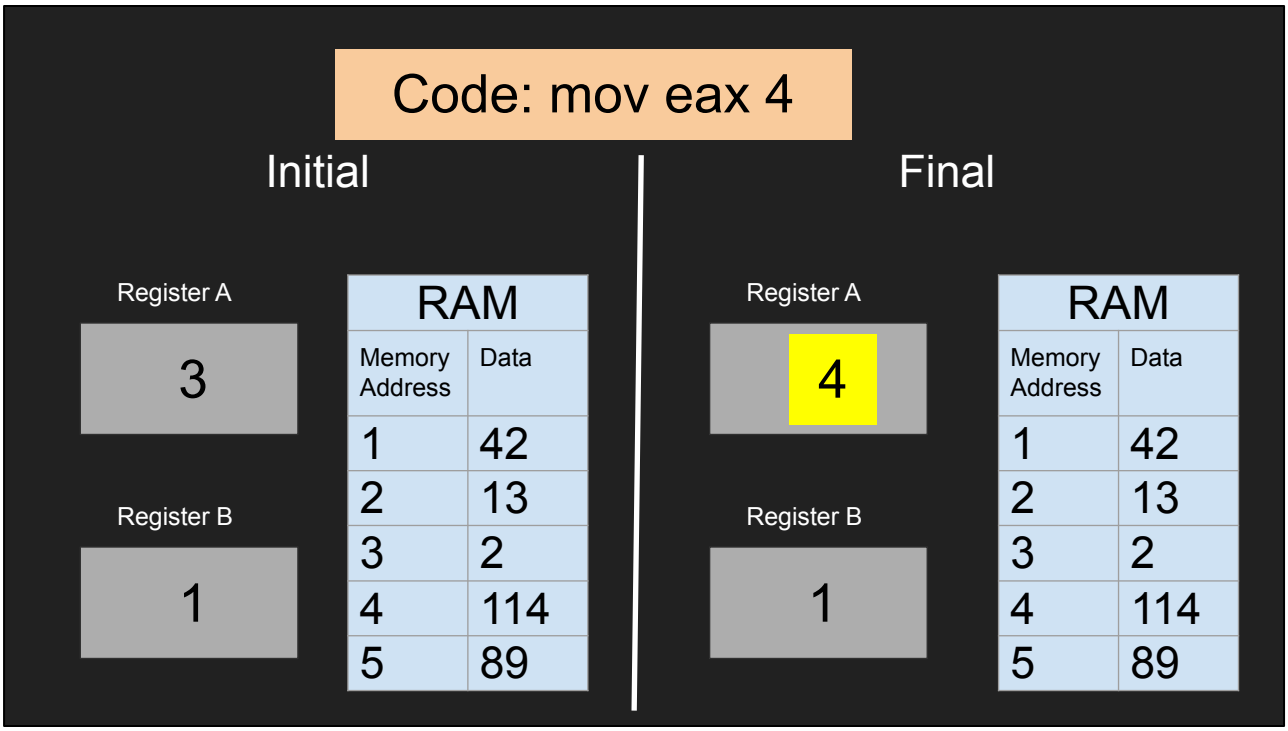
I found this thread helpful for figuring out the differences:
https://stackoverflow.com/questions/48608423/what-do-square-brackets-mean-in-x86-assembly



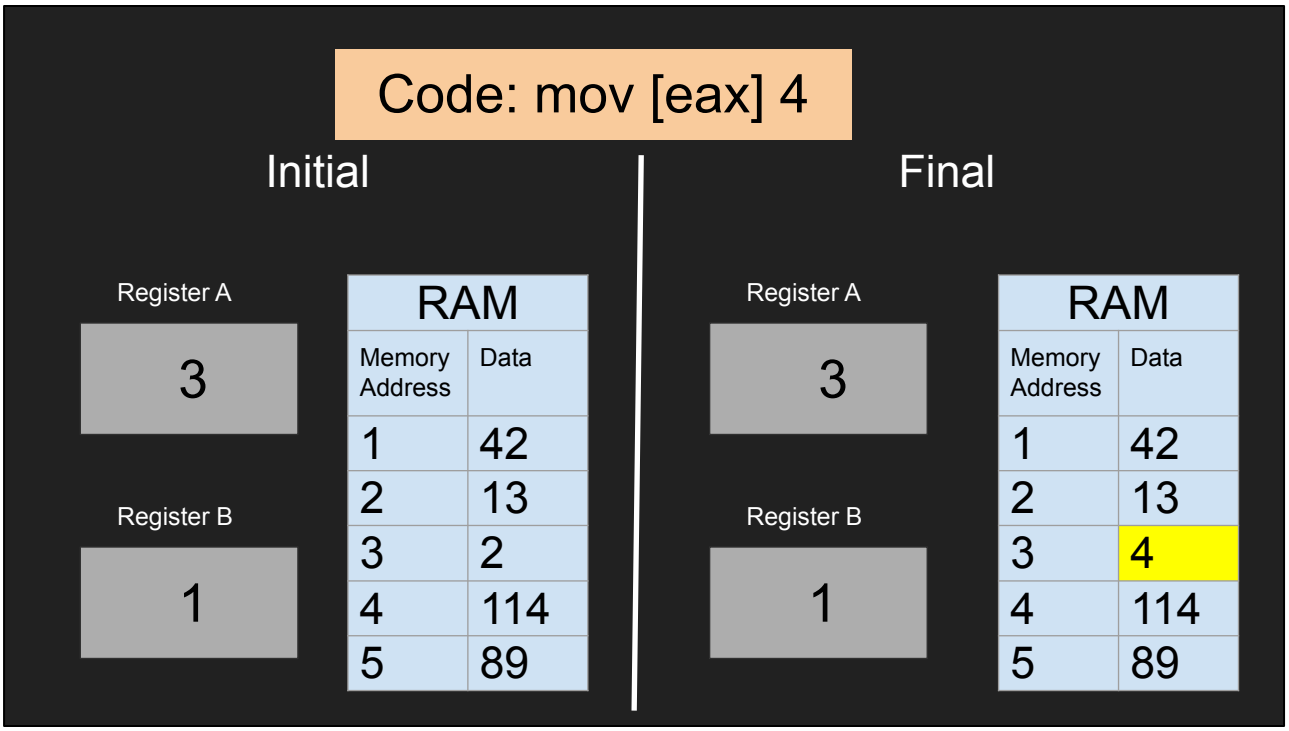
Marieke

A variable doesn't actually store your data. It stores the location in RAM where the data is located.

I found this thread helpful for figuring out the differences: https://stackoverflow.com/questions/48608423/what-do-square-brackets-mean-in-x86-assembly


Code: mov eax 4
Initial
Final
Register A
3
Register B
1
RAM
Memory Address
Data
1 42
2 13
3 2
4 114
5 89
Register A
4
Register B
1
RAM
Memory Address
Data
1 42
2 13
3 2
4 114
5 89

Marieke


Code: mov [eax] 4
Initial
Register A
3
Register B
1
RAM
Memory Address
Data
1
42
2
13
3
2
4
114
5
89
Final
Register A
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Register B
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RAM
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Data
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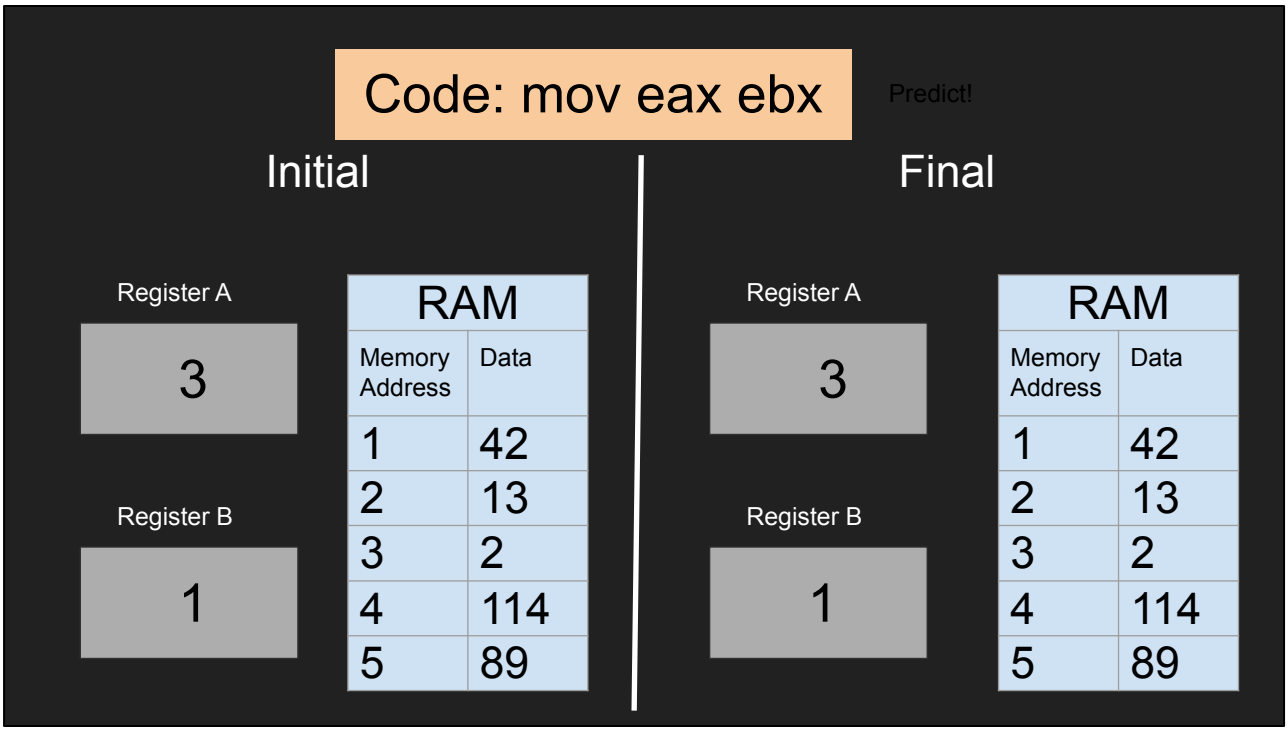
42
2
13
3
4
4
114
5
89

Marieke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Predict!
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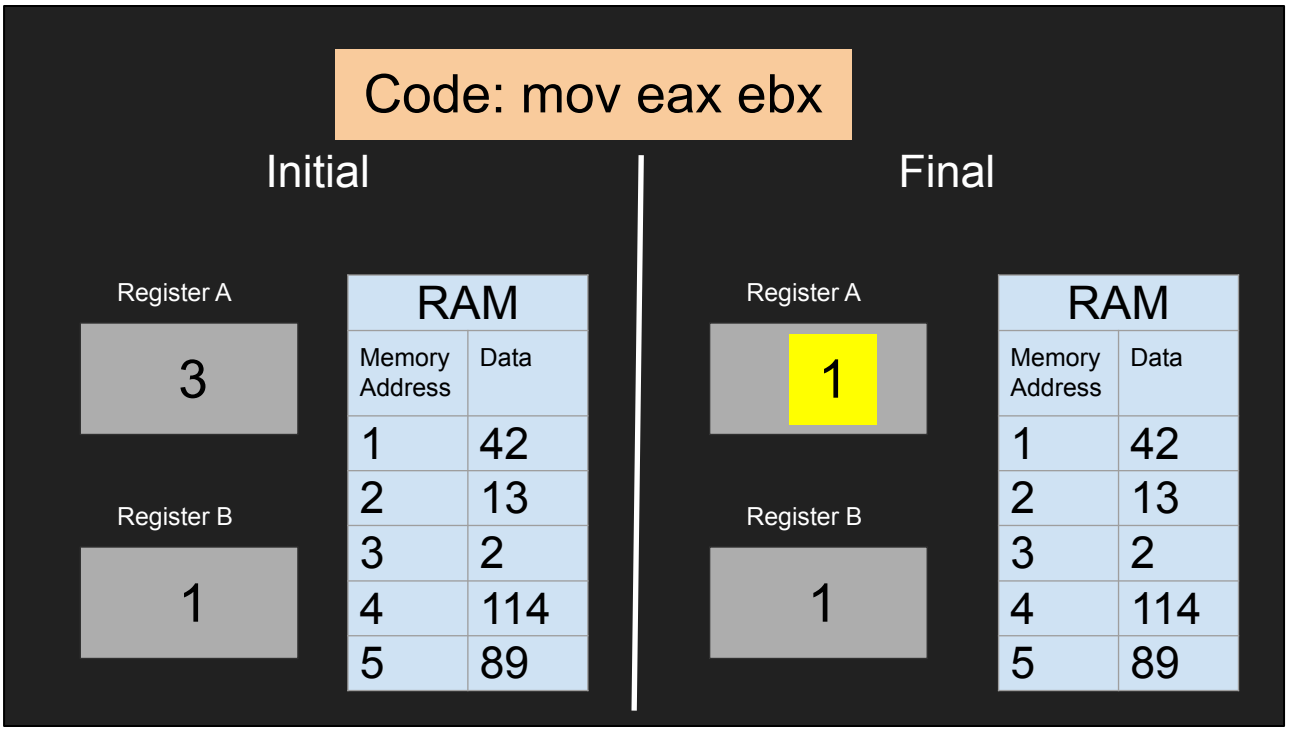
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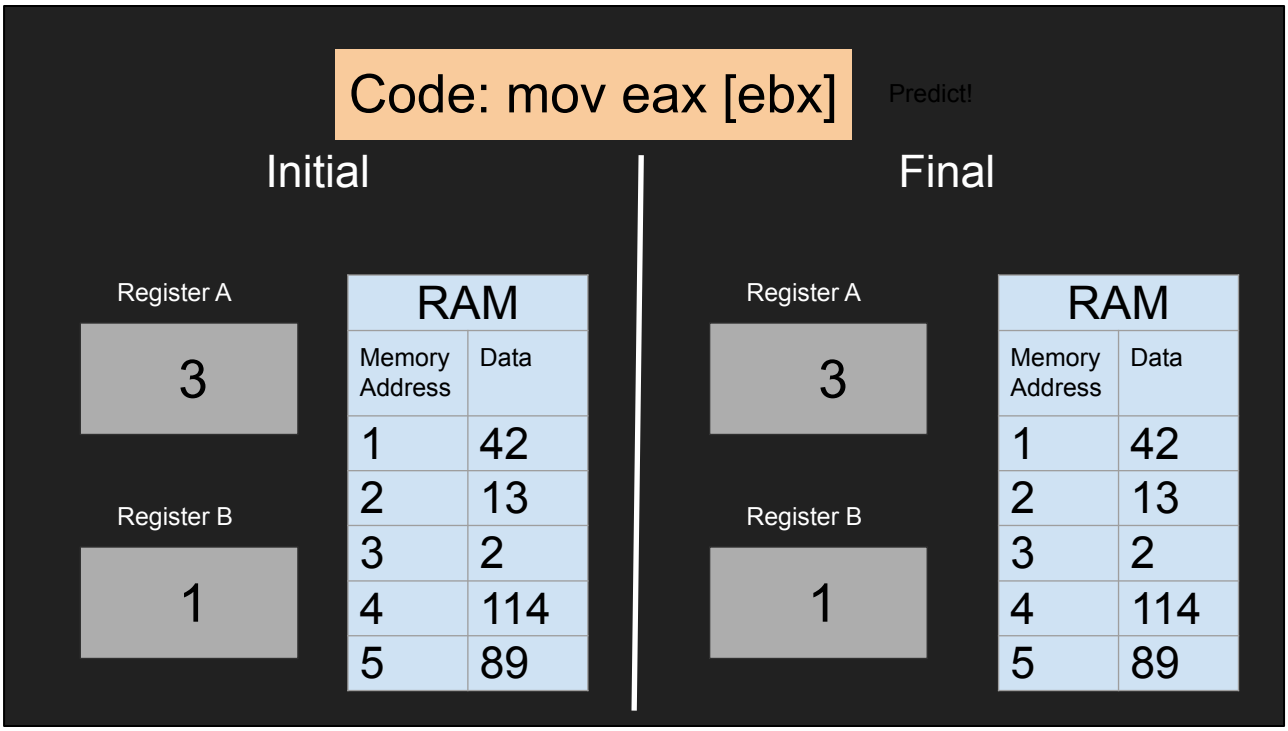
Code: mov eax [ebx]
Predict!
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Final
Register A
3
Register B
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Memory Address
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Register A
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Memory Address
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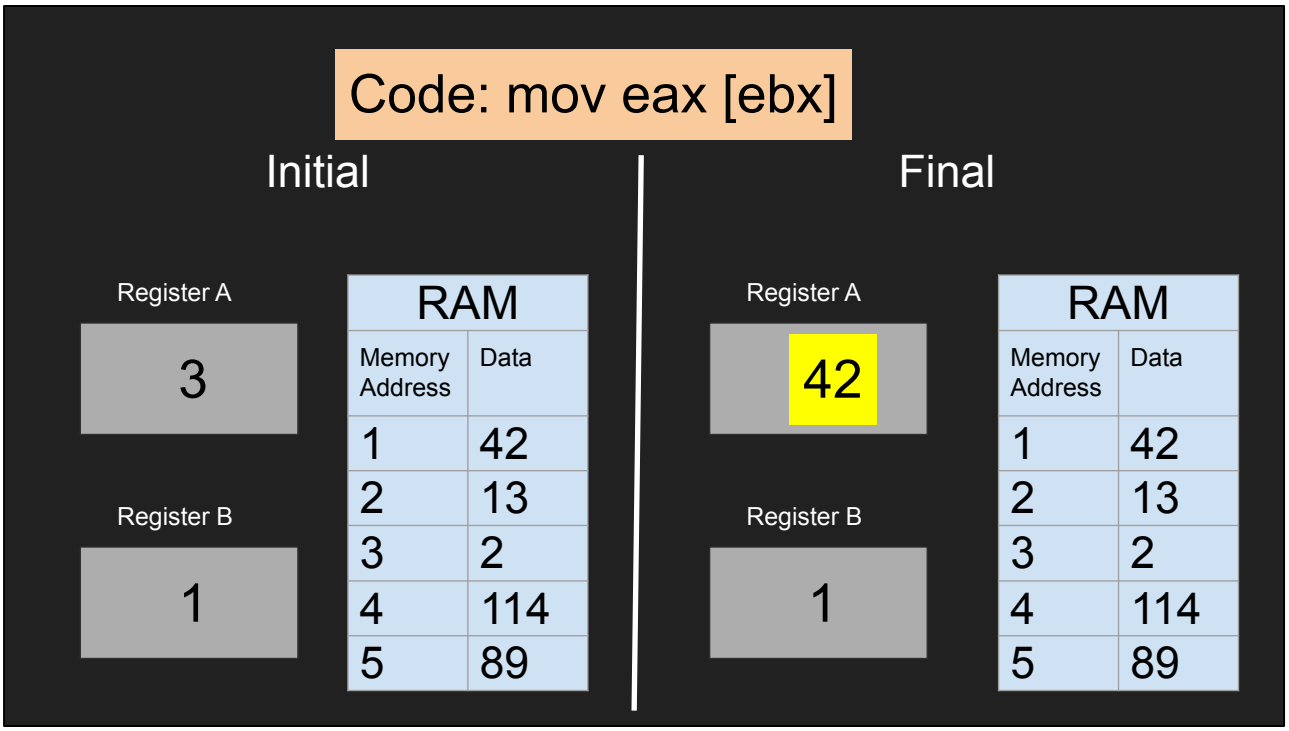
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Register A
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Register B
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RAM
Memory Address
Data
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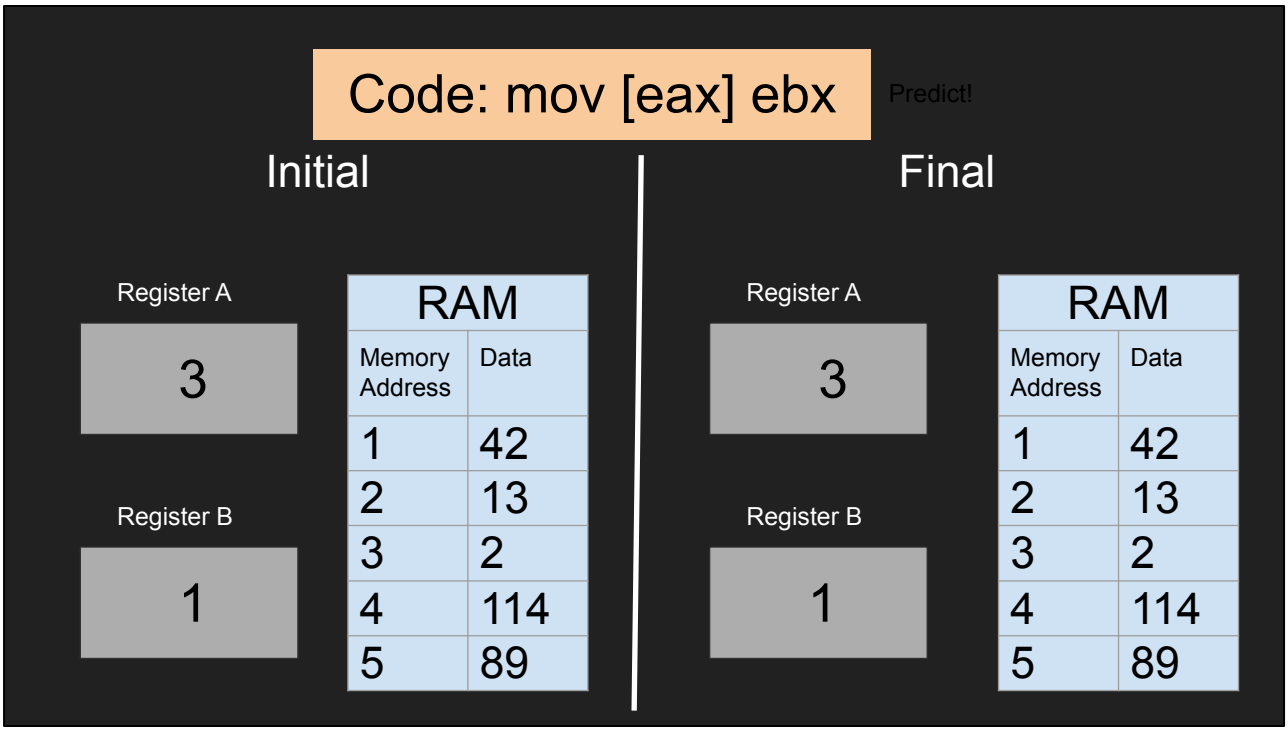
3 2
4 114
5 89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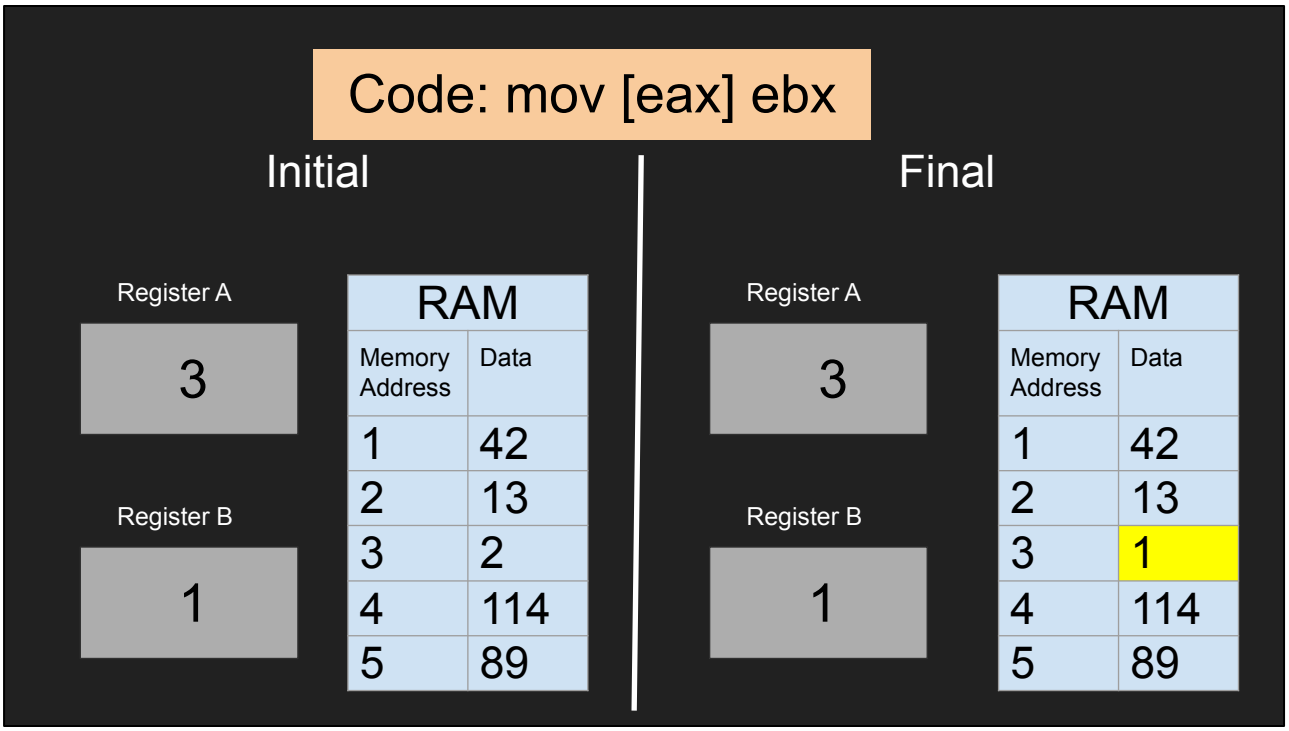
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Memory Address
Data
1
42
2
13
3
2
4
114
5
89
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Register A
3
Register B
1
RAM
Memory Address
Data
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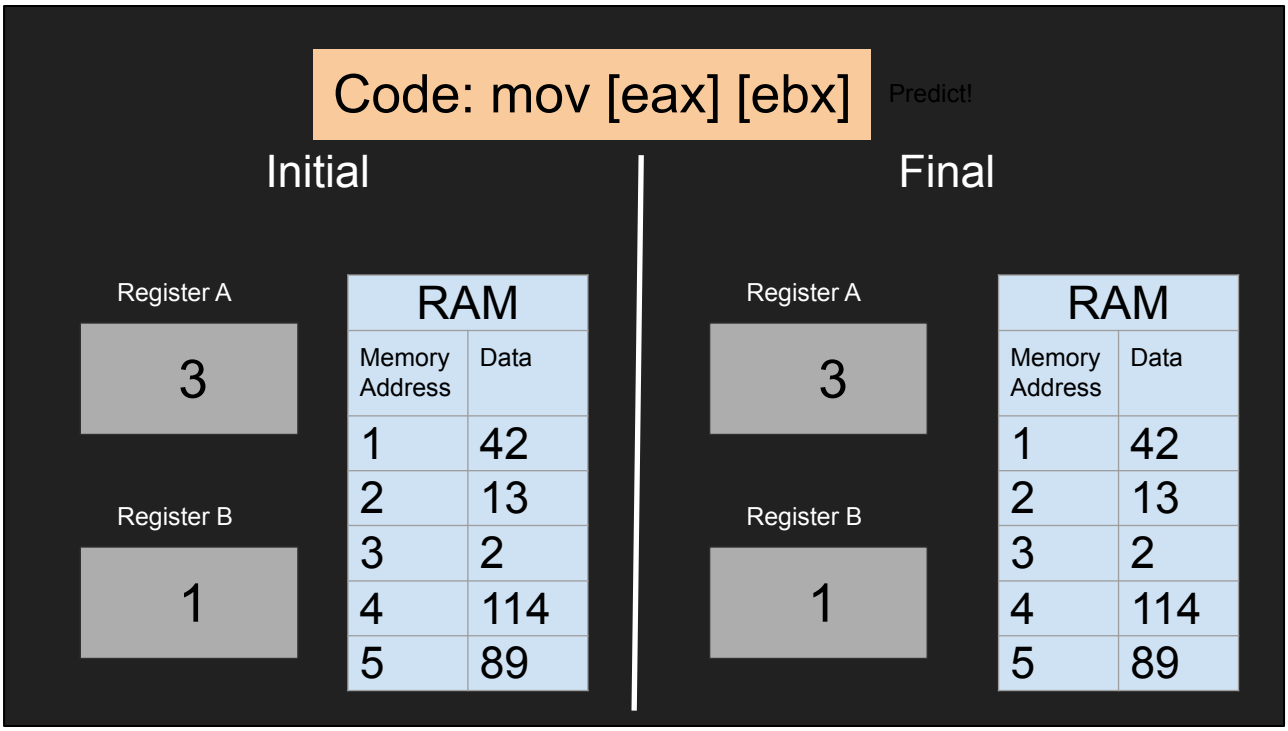
42
2
13
3
1
4
114
5
89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Register A
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Register B
1
RAM
Memory Address
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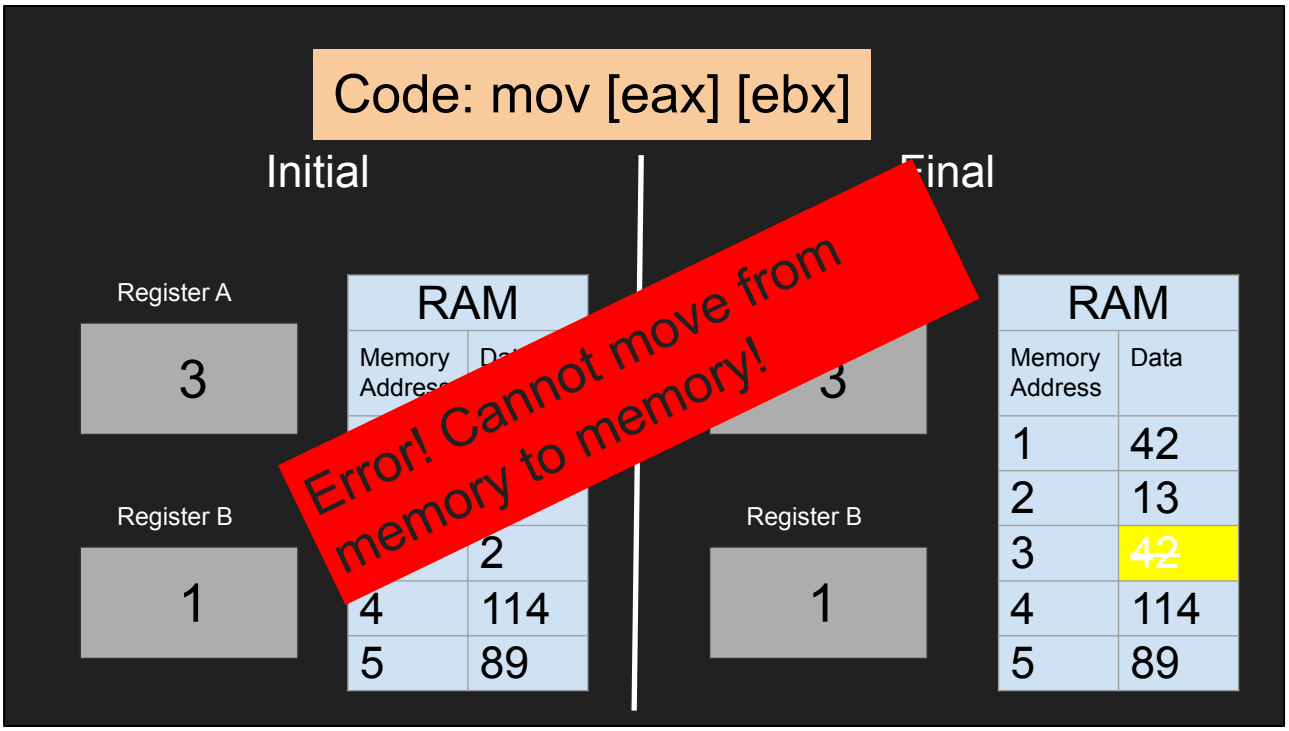
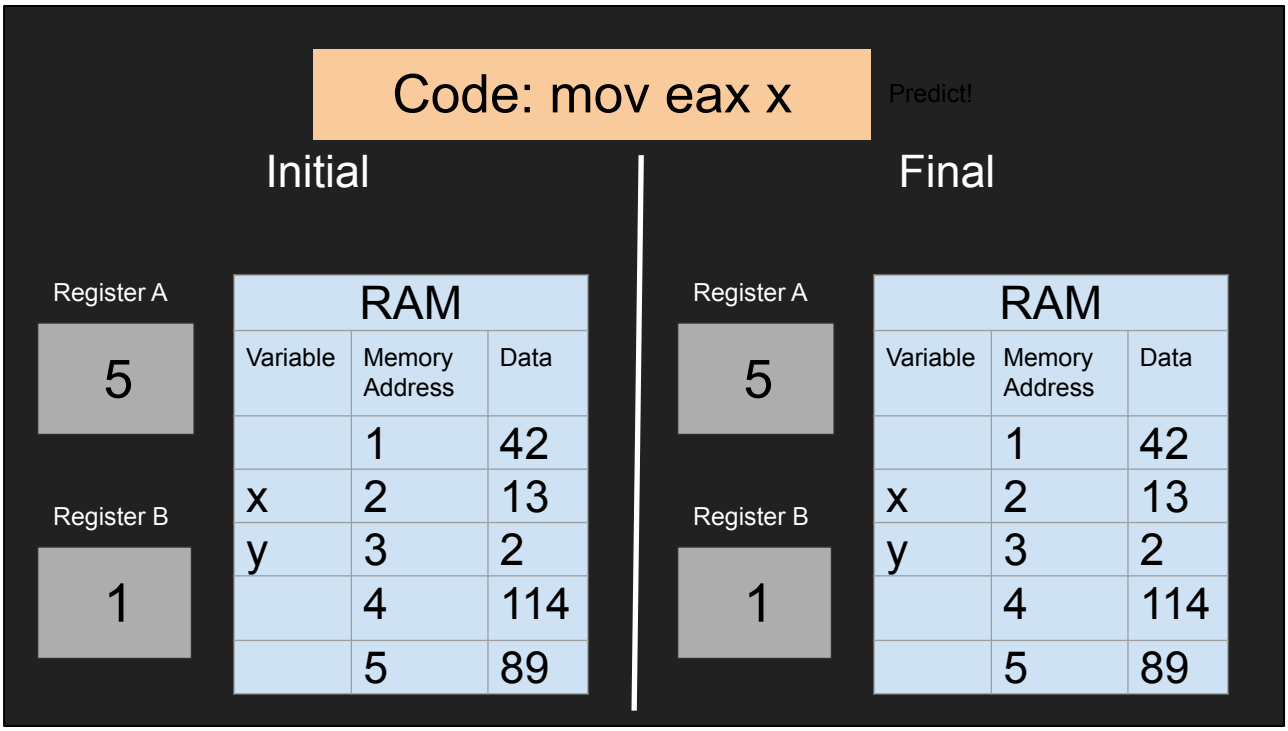
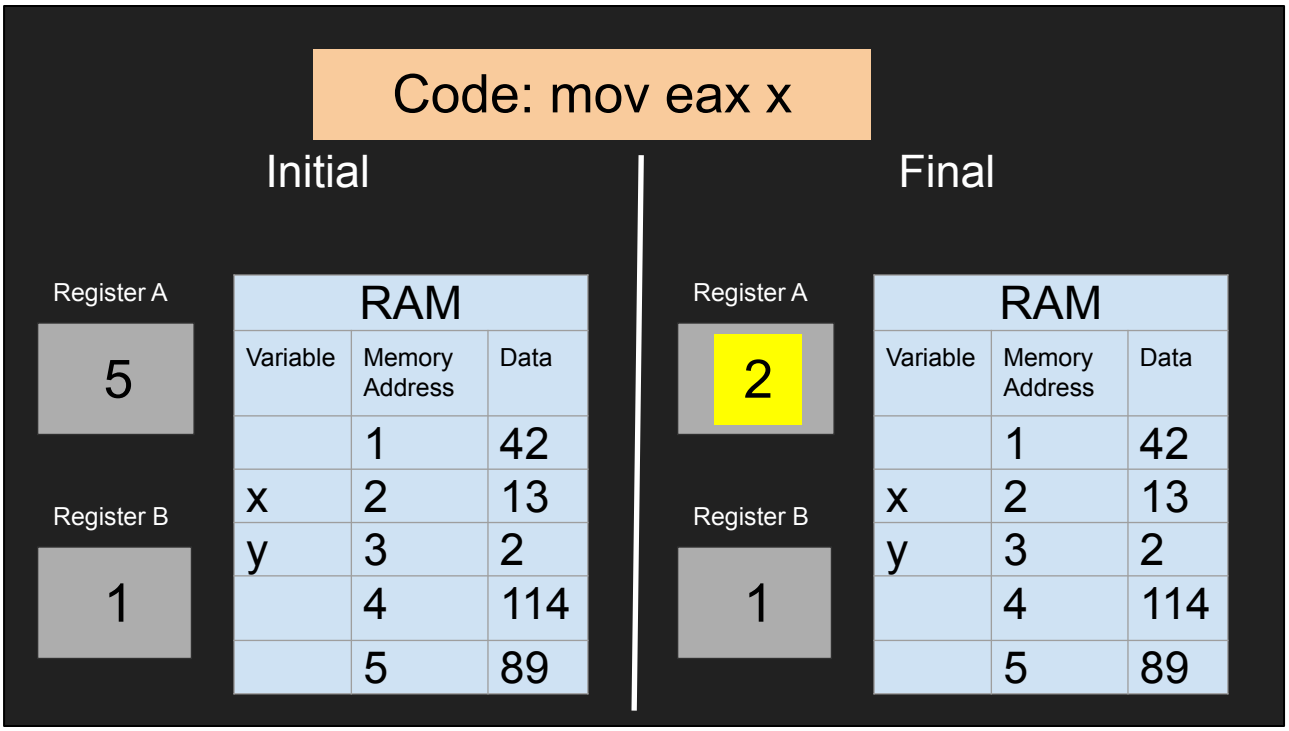

Code: mov [eax] [ebx]
Initial
Final
Register A
3
Register B
1
RAM
Memory Address
Data
2
4
114
5
89
Error! Cannot move from memory to memory!
3
Register B
1
RAM
Memory Address
Data
1
42
2
13
3
42
4
114
5
89


Code: mov eax x
Predict!
Initial
Final
Register A
5
Register B
1
RAM
Variable
Memory Address
Data
1 42
x 2 13
y 3 2
4 114
5 89
Register A
5
Register B
1
RAM
Variable
Memory Address
Data
1 42
x 2 13
y 3 2
4 114
5 89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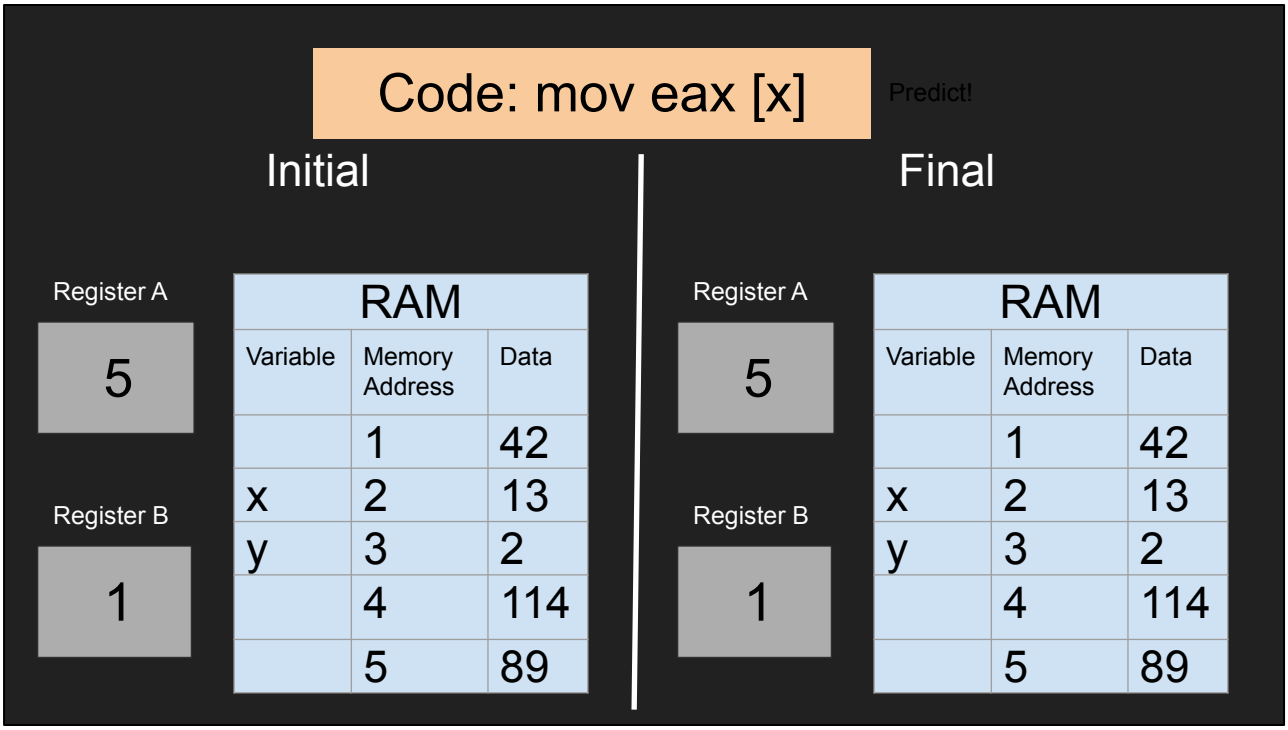
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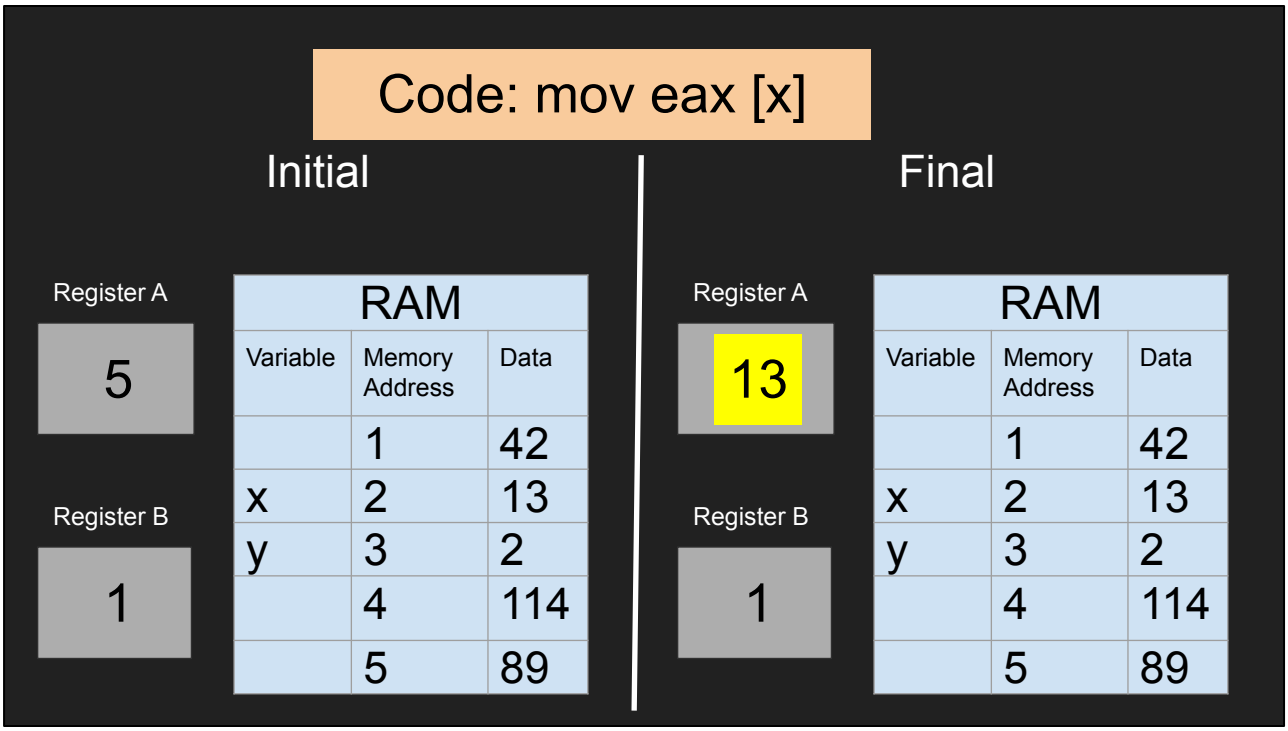
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Register B
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Variable
Memory Address
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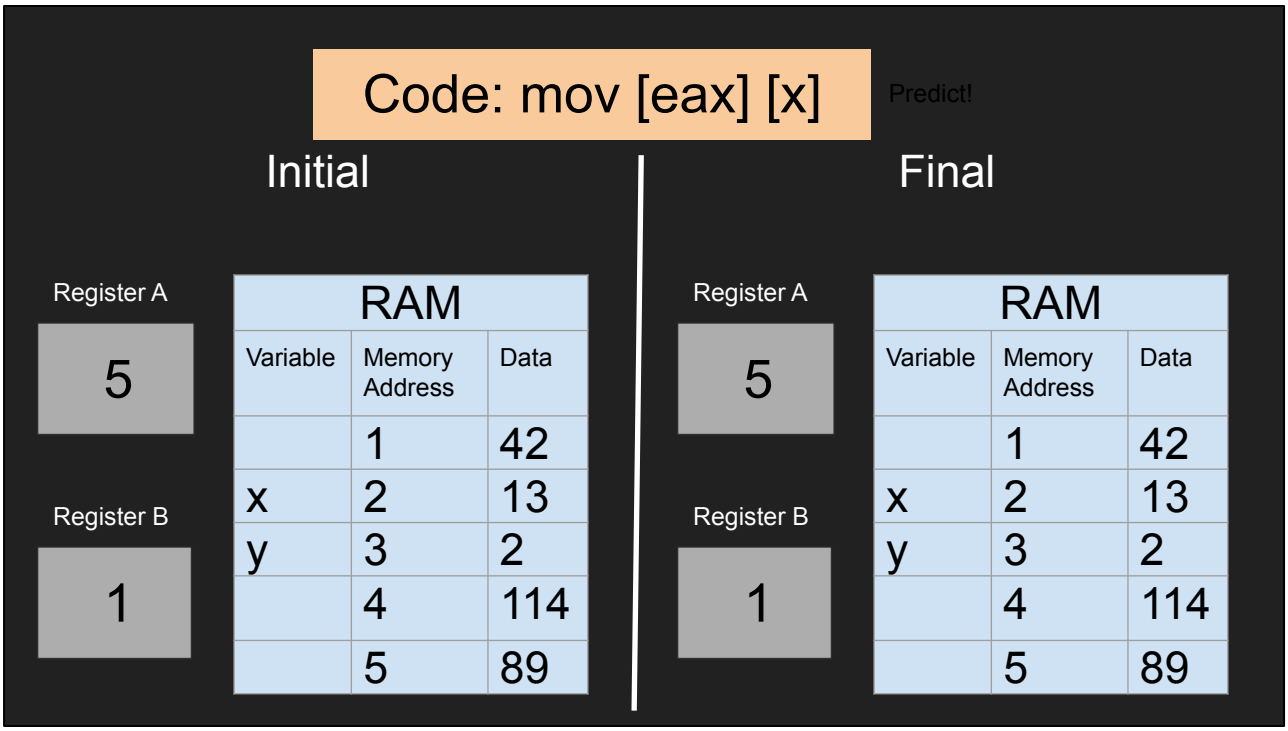
Code: mov [eax] [x]
Predict!
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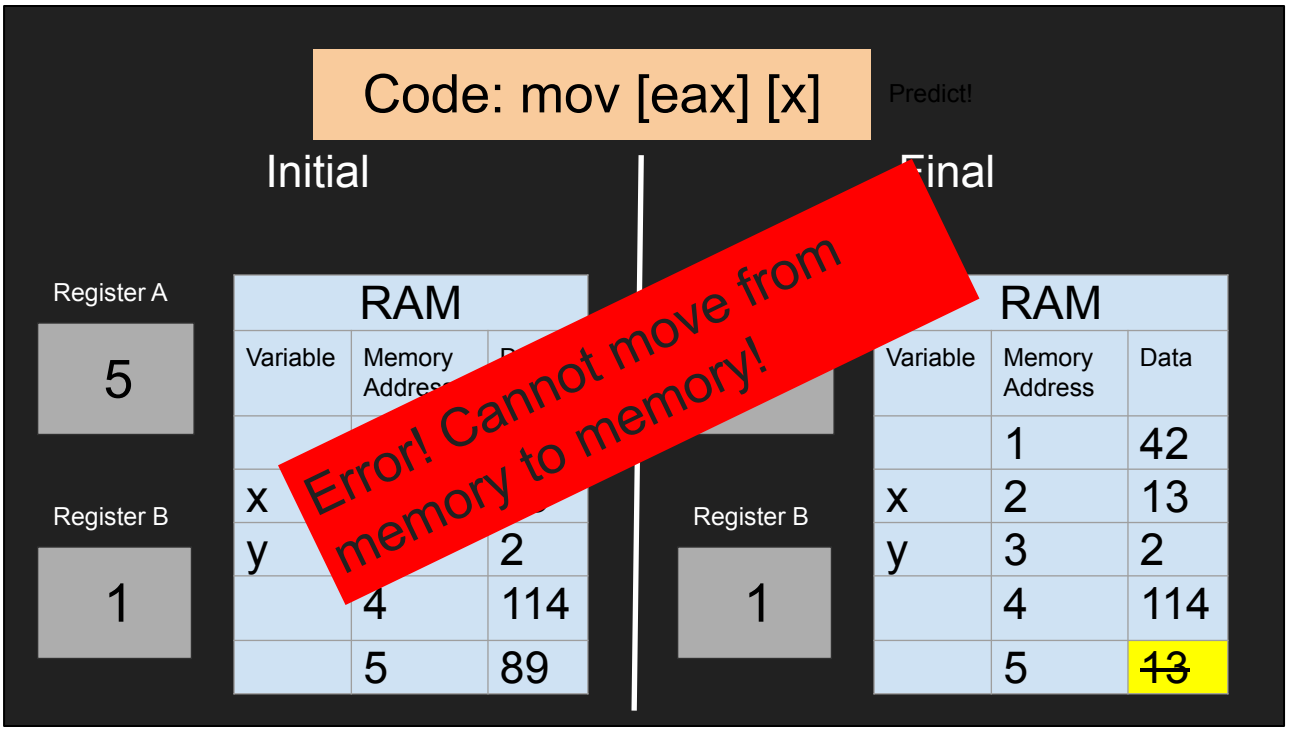


How can we put a 13 into memory address 5?

Instead of: ~~mov [eax] [x]~~
mov ebx [x]
mov [eax] ebx

Register A

5

Register B

1

RAM		
Variable	Memory Address	Data
	1	42
x	2	13
y	3	2
	4	114
	5	89

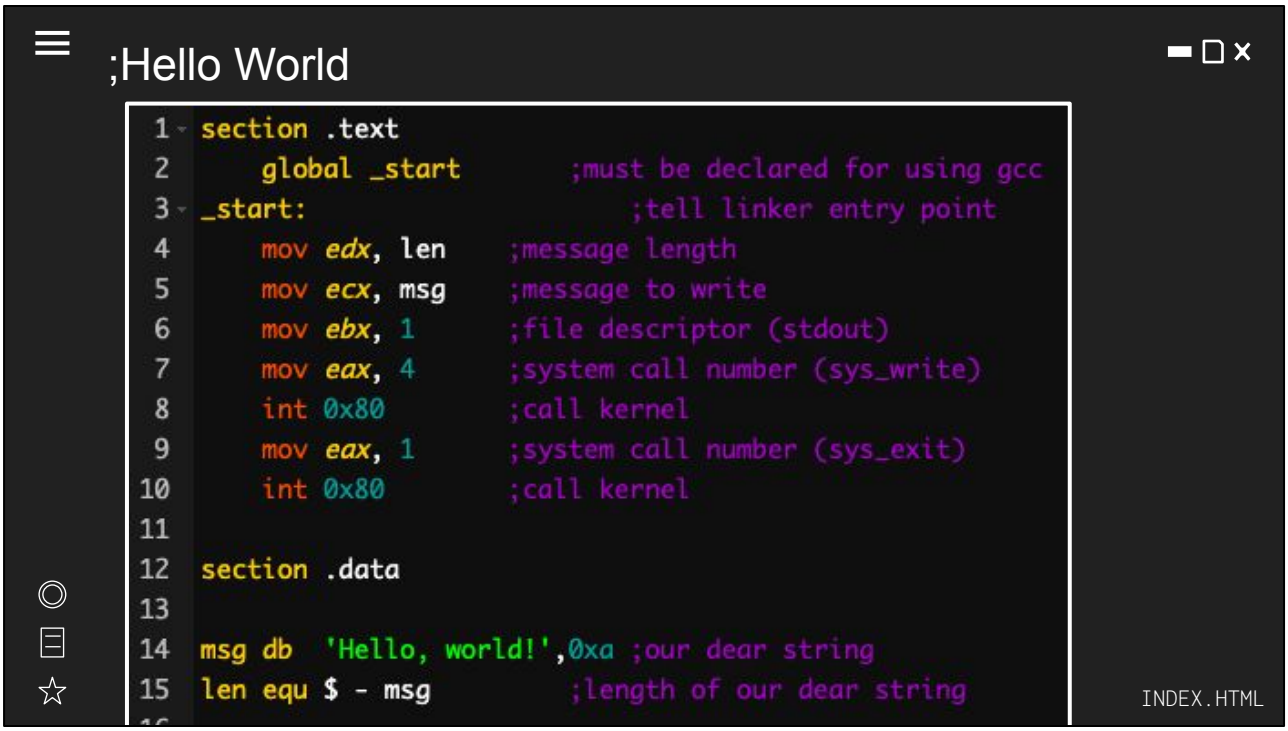
Register A

5

Register B

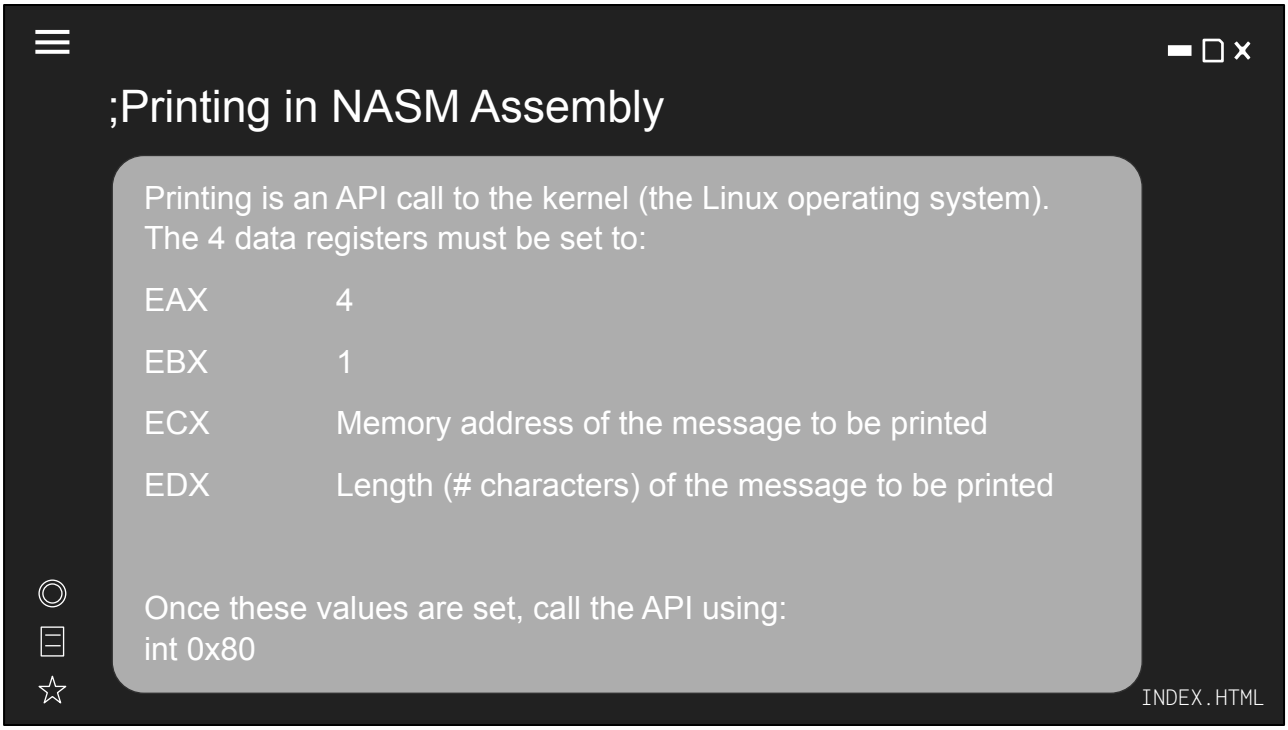
13

RAM		
Variable	Memory Address	Data
	1	42
x	2	13
y	3	2
	4	114
	5	13

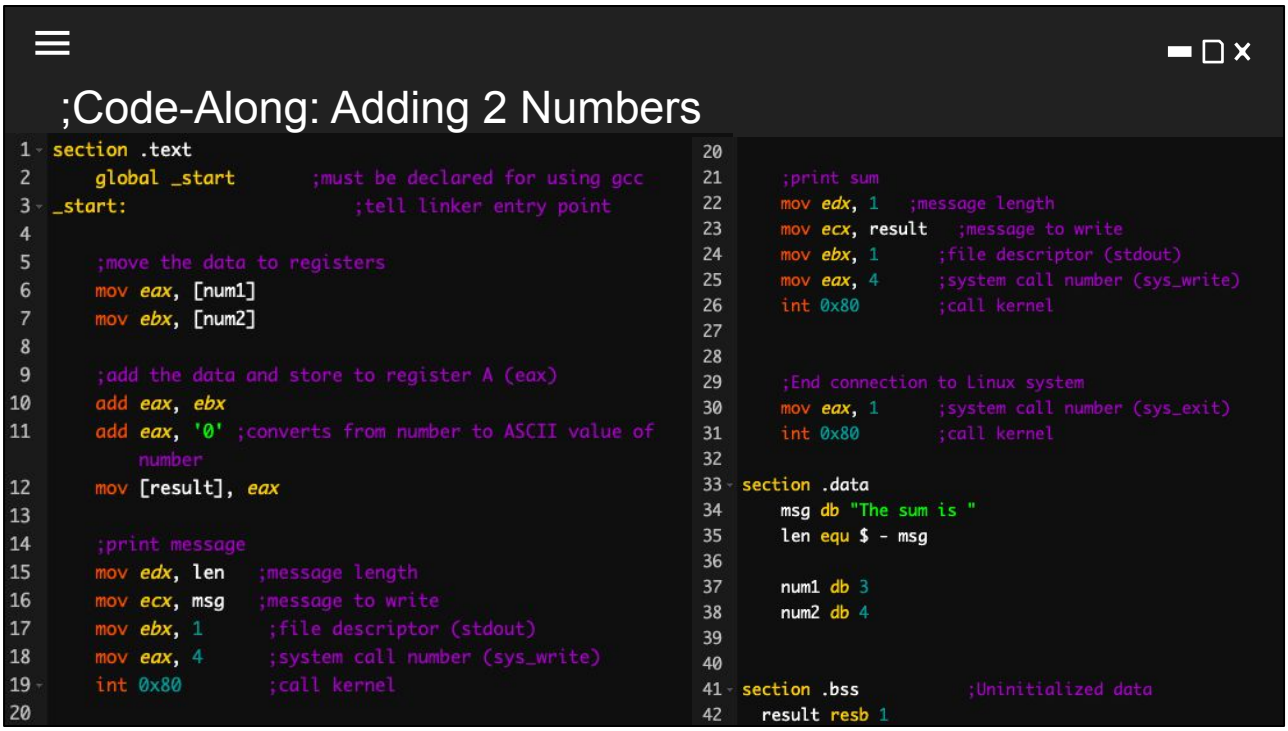


Taylor/Amanda
Printing (lines 4-8) is essentially an API call with 4 parameters, that need to be stored in the 4 registers (EAX, EBX, ECX, and EDX).

db = define byte
0xa = hex new line character
$ = the current location
0 stdin, 1 stdout and 2 stderr
https://stackoverflow.com/questions/17074663/need-guidance-on-understanding-basic-assembly



Taylor/Amanda

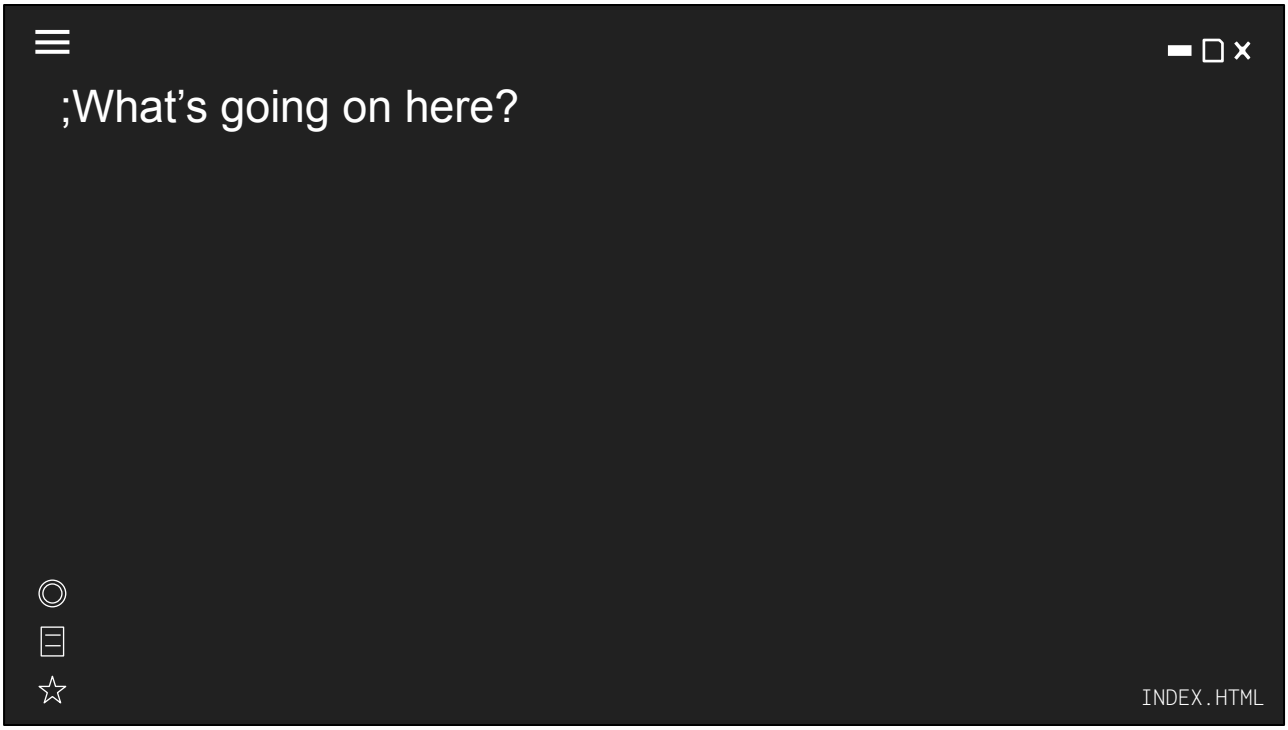


Marieke

Db = define byte (for constant)
Resb = reserve byte (for variable)

```
section .text
        global _start       ;must be declared for using gcc
_start:                     ;tell linker entry point

   ;move the data to registers
   mov eax, [num1]
   mov ebx, [num2]

   ;add the data and store to register A (eax)
   add eax, ebx
   add eax, '0'
   mov [result], eax

   ;print message
        mov     edx, len    ;message length
        mov     ecx, msg    ;message to write
        mov     ebx, 1      ;file descriptor (stdout)
        mov     eax, 4      ;system call number (sys_write)
        int     0x80        ;call kernel
```

```
    ;print sum
        mov     edx, 1   ;message length
        mov     ecx, result   ;message to write
        mov     ebx, 1      ;file descriptor (stdout)
        mov     eax, 4      ;system call number (sys_write)
        int     0x80        ;call kernel


        ;End connection to Linux system
        mov     eax, 1      ;system call number (sys_exit)
        int     0x80        ;call kernel

section .data
    msg db "The sum is "
    len equ $ - msg

    num1 db 3
    num2 db 4


section .bss          ;Uninitialized data
  result resb 1
```

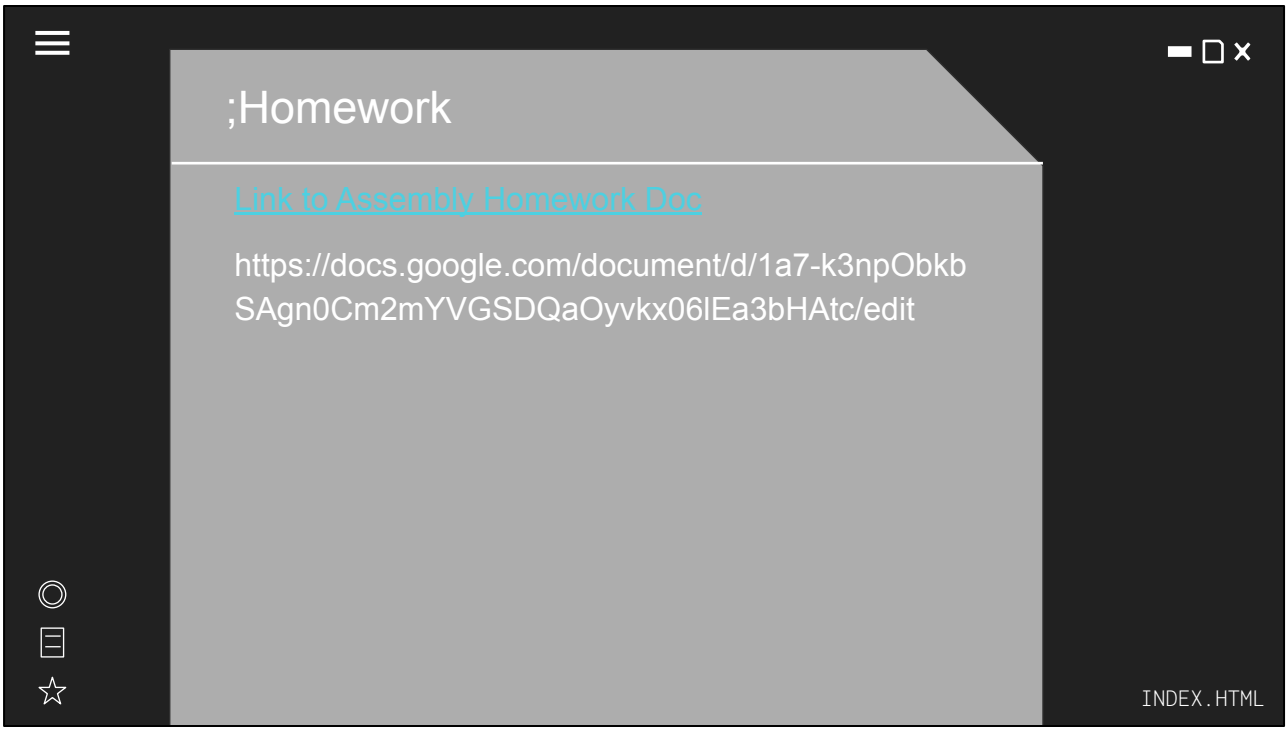


Taylor/Amanda

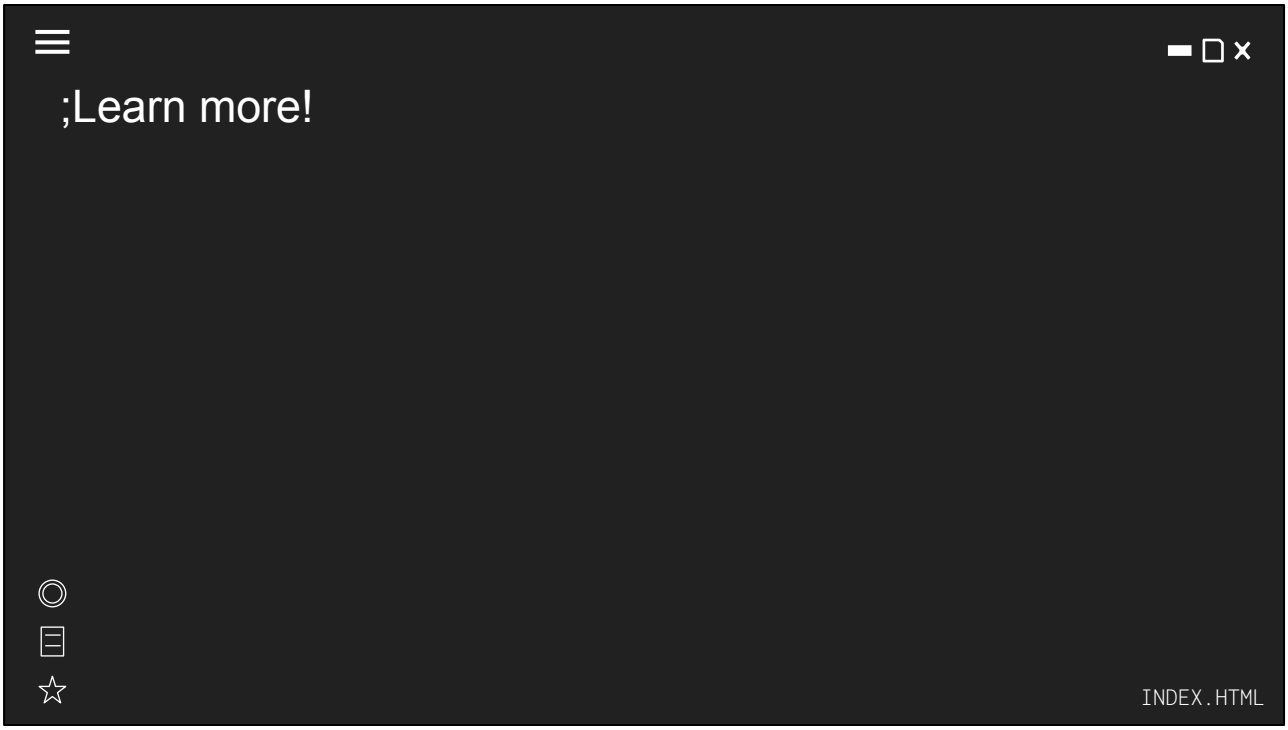
Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char
0	0	[NULL]	32	20	[SPACE]	64	40	@	96	60	`
1	1	[START OF HEADING]	33	21	!	65	41	A	97	61	a
2	2	[START OF TEXT]	34	22	"	66	42	B	98	62	b
3	3	[END OF TEXT]	35	23	#	67	43	C	99	63	c
4	4	[END OF TRANSMISSION]	36	24	$	68	44	D	100	64	d
5	5	[ENQUIRY]	37	25	%	69	45	E	101	65	e
6	6	[ACKNOWLEDGE]	38	26	&	70	46	F	102	66	f
7	7	[BELL]	39	27	'	71	47	G	103	67	g
8	8	[BACKSPACE]	40	28	(	72	48	H	104	68	h
9	9	[HORIZONTAL TAB]	41	29	)	73	49	I	105	69	i
10	A	[LINE FEED]	42	2A	*	74	4A	J	106	6A	j
11	B	[VERTICAL TAB]	43	2B	+	75	4B	K	107	6B	k
12	C	[FORM FEED]	44	2C	,	76	4C	L	108	6C	l
13	D	[CARRIAGE RETURN]	45	2D	-	77	4D	M	109	6D	m
14	E	[SHIFT OUT]	46	2E	.	78	4E	N	110	6E	n
15	F	[SHIFT IN]	47	2F	/	79	4F	O	111	6F	o
16	10	[DATA LINK ESCAPE]	48	30	0	80	50	P	112	70	p
17	11	[DEVICE CONTROL 1]	49	31	1	81	51	Q	113	71	q
18	12	[DEVICE CONTROL 2]	50	32	2	82	52	R	114	72	r
19	13	[DEVICE CONTROL 3]	51	33	3	83	53	S	115	73	s
20	14	[DEVICE CONTROL 4]	52	34	4	84	54	T	116	74	t
21	15	[NEGATIVE ACKNOWLEDGE]	53	35	5	85	55	U	117	75	u
22	16	[SYNCHRONOUS IDLE]	54	36	6	86	56	V	118	76	v
23	17	[END OF TRANS. BLOCK]	55	37	7	87	57	W	119	77	w
24	18	[CANCEL]	56	38	8	88	58	X	120	78	x
25	19	[END OF MEDIUM]	57	39	9	89	59	Y	121	79	y
26	1A	[SUBSTITUTE]	58	3A	:	90	5A	Z	122	7A	z
27	1B	[ESCAPE]	59	3B	;	91	5B	[	123	7B	{
28	1C	[FILE SEPARATOR]	60	3C	<	92	5C	\	124	7C	|
29	1D	[GROUP SEPARATOR]	61	3D	=	93	5D	]	125	7D	}
30	1E	[RECORD SEPARATOR]	62	3E	>	94	5E	^	126	7E	~
31	1F	[UNIT SEPARATOR]	63	3F	?	95	5F	_	127	7F	[DEL]

Taylor + Amanda

This program only handles the sum as a single digit ASCII value– if the sum is above 9, the program reads it as a different ASCII value for a punctuation mark
Could add 48 instead of adding “0” for the same effect



Ed
https://docs.google.com/document/d/1a7-k3npObkbSAgn0Cm2mYVGSDQaOyvkx06lEa3bHAtc/edit


;Learn more!
INDEX.HTML

;Repeating Code

Assembly language doesn’t contain *for* or *while* loops.

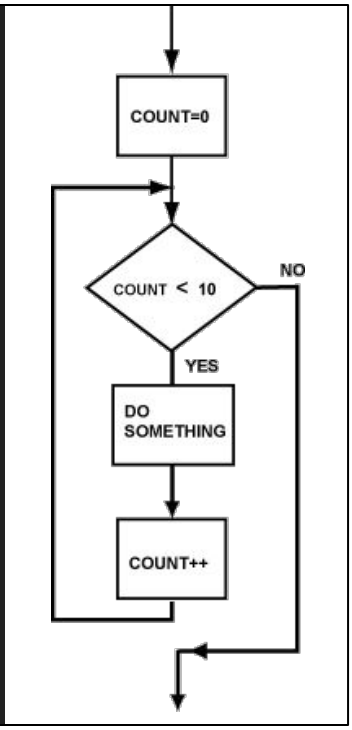
How can we repeat code in Assembly?

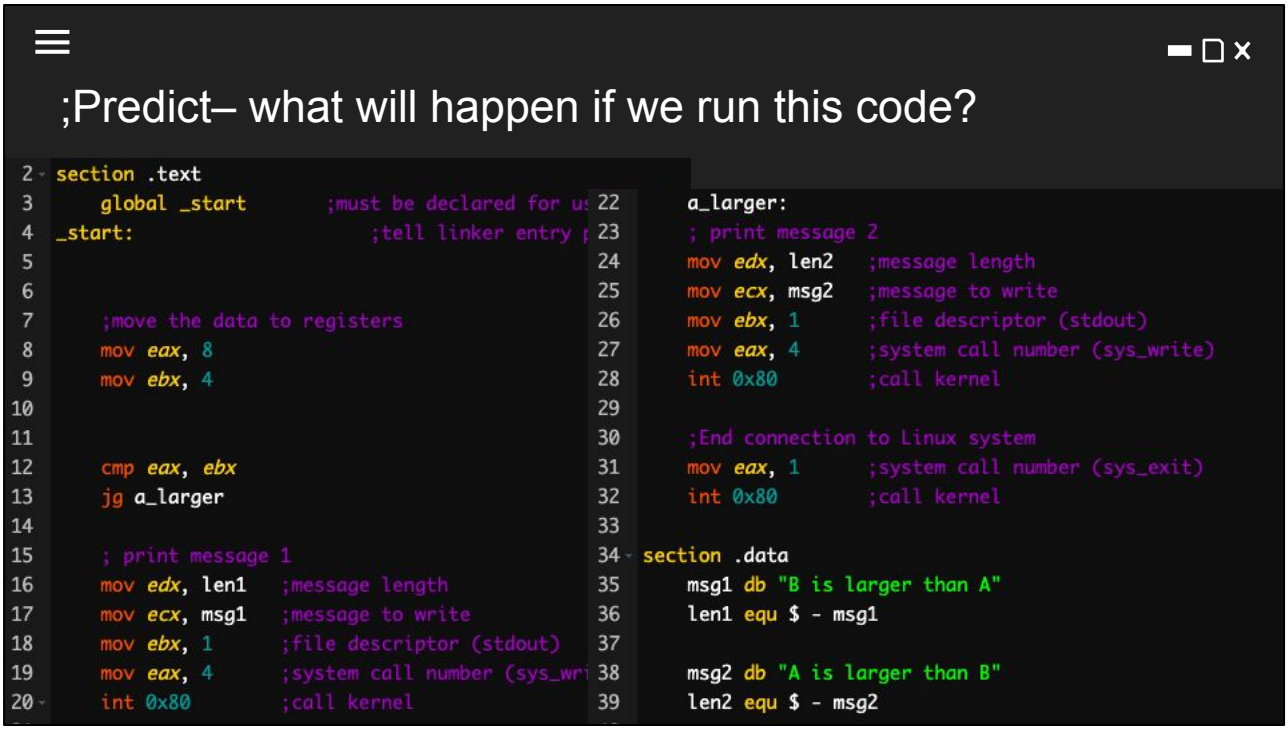
INDEX.HTML

;Jumps

To repeat code, we use jumps:

JMP	always jumps
JE	jumps if two values are equal
JG	jumps if the first value is greater than the second





Should print “A is larger than B”

```
section .text
        global _start       ;must be declared for using gcc
_start:                     ;tell linker entry point


    ;move the data to registers
    mov eax, 8
    mov ebx, 4


    cmp eax, ebx
    jg a_larger

    ; print message 1
        mov     edx, len1   ;message length
        mov     ecx, msg1   ;message to write
        mov     ebx, 1      ;file descriptor (stdout)
        mov     eax, 4      ;system call number (sys_write)
        int     0x80        ;call kernel

    a_larger:
    ; print message 2
```

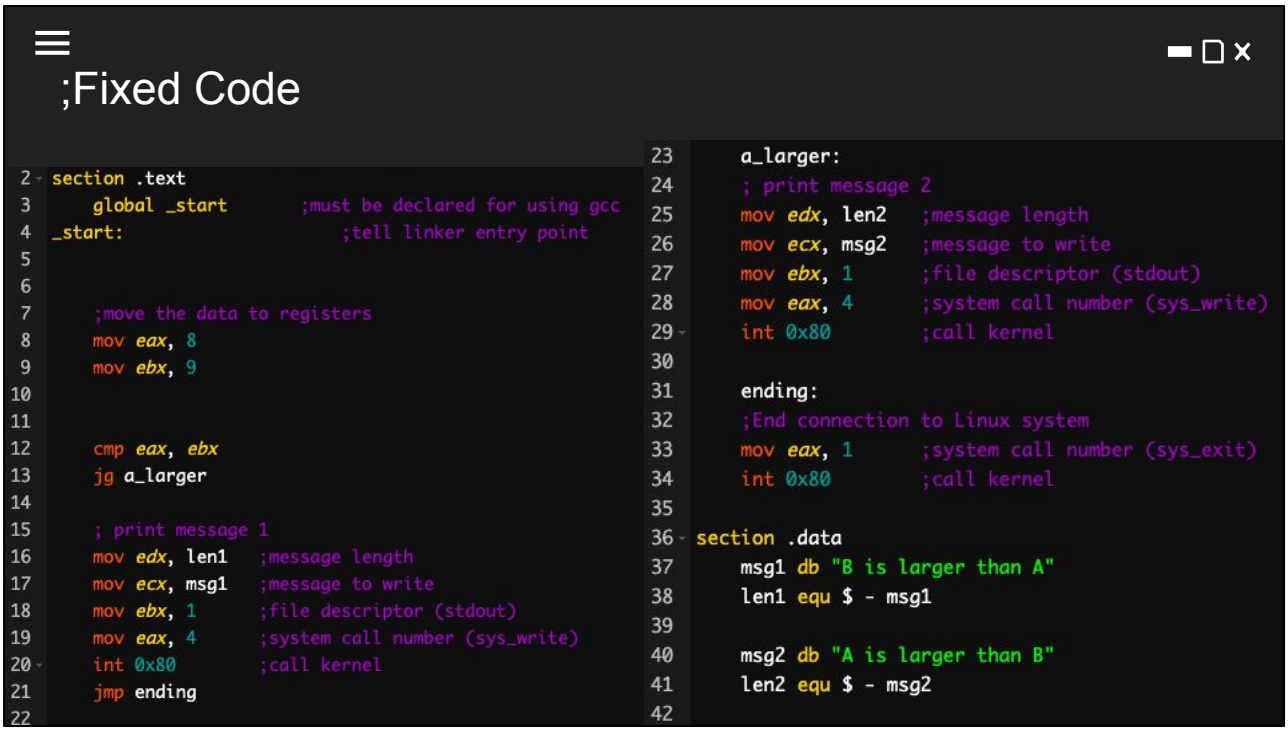
```
        mov     edx, len2   ;message length
        mov     ecx, msg2   ;message to write
        mov     ebx, 1      ;file descriptor (stdout)
        mov     eax, 4      ;system call number (sys_write)
        int     0x80        ;call kernel

        ;End connection to Linux system
        mov     eax, 1      ;system call number (sys_exit)
        int     0x80        ;call kernel

section .data
    msg1 db "B is larger than A"
    len1 equ $ - msg1

    msg2 db "A is larger than B"
    len2 equ $ - msg2
```

;What about now (changed row 9)?

```
2  section .text
3      global _start       ;must be declared for us
4  _start:                 ;tell linker entry p
5
6
7      ;move the data to registers
8      mov eax, 8
9      mov ebx, 9
10
11
12     cmp eax, ebx
13     jg a_larger
14
15     ; print message 1
16     mov edx, len1    ;message length
17     mov ecx, msg1    ;message to write
18     mov ebx, 1       ;file descriptor (stdout)
19     mov eax, 4       ;system call number (sys_wri
20     int 0x80         ;call kernel
```

```
22     a_larger:
23     ; print message 2
24     mov edx, len2    ;message length
25     mov ecx, msg2    ;message to write
26     mov ebx, 1       ;file descriptor (stdout)
27     mov eax, 4       ;system call number (sys_write)
28     int 0x80         ;call kernel
29
30     ;End connection to Linux system
31     mov eax, 1       ;system call number (sys_exit)
32     int 0x80         ;call kernel
33
34 section .data
35     msg1 db "B is larger than A"
36     len1 equ $ - msg1
37
38     msg2 db "A is larger than B"
39     len2 equ $ - msg2
```

Prints both messages, whoops. How do we fix it? Need to fix it by adding another jump after printing the first message, and adding a label in row 29 to jump to




```
;Program to compare 2 values
section .text
        global _start       ;must be declared for using gcc
_start:                     ;tell linker entry point


    ;move the data to registers
    mov eax, 8
    mov ebx, 9


    cmp eax, ebx
    jg a_larger

    ; print message 1
        mov     edx, len1   ;message length
        mov     ecx, msg1   ;message to write
        mov     ebx, 1      ;file descriptor (stdout)
        mov     eax, 4      ;system call number (sys_write)
        int     0x80        ;call kernel
    jmp ending

    a_larger:
    ; print message 2
```

```
        mov     edx, len2   ;message length
        mov     ecx, msg2   ;message to write
        mov     ebx, 1      ;file descriptor (stdout)
        mov     eax, 4      ;system call number (sys_write)
        int     0x80        ;call kernel

    ending:
        ;End connection to Linux system
        mov     eax, 1      ;system call number (sys_exit)
        int     0x80        ;call kernel

section .data
    msg1 db "B is larger than A"
    len1 equ $ - msg1

    msg2 db "A is larger than B"
    len2 equ $ - msg2
```

;Sample Code: Add 2 numbers from user

```
section .text
    global _start       ;must be declared for using gcc
_start:                     ;tell linker entry point
    ;Prints message
    mov edx, len1    ;message length
    mov ecx, msg1    ;message to write
    mov ebx, 1      ;file descriptor (stdout)
    mov eax, 4      ;system call number (sys_write)
    int 0x80        ;call kernel

    ;Read and store the user input
    mov edx, 2     ;stores up to 2 bytes of info
    mov ecx, num1   ;variable to store the info as
    mov ebx, 0      ;file descriptor (stdin)
    mov eax, 3      ;system call (sys_read)
    int 0x80        ;call kernel

    ;print
    mov edx, len2   ;message length
    mov ecx, msg2   ;message to write
    mov ebx, 1      ;file descriptor (stdout)
    mov eax, 4      ;system call number (sys_write)
    int 0x80        ;call kernel
```

```

    ;Read and store the user input
    mov edx, 2     ;stores up to 2 bytes of info
    mov ecx, num2   ;variable to store the info as
    mov ebx, 0      ;file descriptor (stdin)
    mov eax, 3      ;system call (sys_read)
    int 0x80        ;call kernel

    ;move the data to registers
    mov eax, [num1]
    sub eax, '0'
    mov ebx, [num2]
    sub ebx, '0'

    add eax, ebx
    add eax, '0'
    mov [result], eax

    ;print
    mov edx, len3   ;message length
    mov ecx, msg3   ;message to write
    mov ebx, 1      ;file descriptor (stdout)
    mov eax, 4      ;system call number (sys_write)
    int 0x80        ;call kernel
```

```
section      .text
       global _start       ;must be declared for using gcc
_start:                      ;tell linker entry point
       ;Prints message
       mov    edx, len1    ;message length
       mov    ecx, msg1    ;message to write
       mov    ebx, 1     ;file descriptor (stdout)
       mov    eax, 4     ;system call number (sys_write)
       int    0x80         ;call kernel

       ;Read and store the user input
    mov edx, 2     ;stores up to 2 bytes of info
    mov ecx, num1   ;variable to store the info as
    mov ebx, 0      ;file descriptor (stdin)
    mov eax, 3      ;system call (sys_read)
    int       0x80         ;call kernel

       ;print
       mov    edx, len2   ;message length
       mov    ecx, msg2   ;message to write
       mov    ebx, 1     ;file descriptor (stdout)
       mov    eax, 4     ;system call number (sys_write)
       int    0x80         ;call kernel

    ;Read and store the user input
    mov edx, 2     ;stores up to 2 bytes of info
    mov ecx, num2   ;variable to store the info as
    mov ebx, 0      ;file descriptor (stdin)
    mov eax, 3      ;system call (sys_read)
    int       0x80         ;call kernel
```

```
    ;move the data to registers
    mov eax, [num1]
    sub eax, '0'
    mov ebx, [num2]
    sub ebx, '0'

    add eax, ebx
    add eax, '0'
    mov [result], eax

    ;print
       mov    edx, len3   ;message length
       mov    ecx, msg3   ;message to write
       mov    ebx, 1     ;file descriptor (stdout)
       mov    eax, 4     ;system call number (sys_write)
       int    0x80        ;call kernel

    ;print
       mov    edx, 1   ;message length
       mov    ecx, result   ;message to write
       mov    ebx, 1     ;file descriptor (stdout)
       mov    eax, 4     ;system call number (sys_write)
       int    0x80        ;call kernel


       ;End connection to Linux system
       mov    eax, 1     ;system call number (sys_exit)
       int    0x80        ;call kernel

section      .data
    msg1 db "What is the first number? "
    len1 equ $ - msg1
    msg2 db "What is your second number? "
    len2 equ $ - msg2
    msg3 db "The sum is "
    len3 equ $ - msg3

    ; msg     db     'What is your name? ',0xa  ;our string
    ; len     equ    $ - msg                    ;length of our string (found
by taking the location of the byte after msg [$] and subtracting the location
of msg, which gives the bytes in msg)

    ; msg1    db     'Hello, '     ;our dear string
    ; len1    equ    $ - msg1      ;length of our dear string

section .bss           ;Uninitialized data
  num1 resb 2
  num2 resb 2
   result resb 1
```

;Sample Code: Add 2 numbers from user

```
24
25      ;Read and store the user input
26      mov edx, 2      ;stores up to 2 bytes of info
27      mov ecx, num2   ;variable to store the info as
28      mov ebx, 0      ;file descriptor (stdin)
29      mov eax, 3      ;system call (sys_read)
30      int 0x80        ;call kernel
31
32      ;move the data to registers
33      mov eax, [num1]
34      sub eax, '0'
35      mov ebx, [num2]
36      sub ebx, '0'
37
38      add eax, ebx
39      add eax, '0'
40      mov [result], eax
41
42      ;print
43      mov edx, len3   ;message length
44      mov ecx, msg3   ;message to write
45      mov ebx, 1      ;file descriptor (stdout)
46      mov eax, 4      ;system call number (sys_write)
47      int 0x80        ;call kernel
```

```
49      ;print
50      mov edx, 1   ;message length
51      mov ecx, result   ;message to write
52      mov ebx, 1      ;file descriptor (stdout)
53      mov eax, 4      ;system call number (sys_write)
54      int 0x80        ;call kernel
55
56
57      ;End connection to Linux system
58      mov eax, 1      ;system call number (sys_exit)
59      int 0x80        ;call kernel
60
61  section .data
62      msg1 db "What is the first number? "
63      len1 equ $ - msg1
64      msg2 db "What is your second number? "
65      len2 equ $ - msg2
66      msg3 db "The sum is "
67      len3 equ $ - msg3
68
69
70  section .bss           ;Uninitialized data
71    num1 resb 2
72    num2 resb 2
73    result resb 1
```

```
section     .text
        global _start       ;must be declared for using gcc
_start:                      ;tell linker entry point
        ;Prints message
        mov     edx, len1     ;message length
        mov     ecx, msg1     ;message to write
        mov     ebx, 1      ;file descriptor (stdout)
        mov     eax, 4      ;system call number (sys_write)
        int     0x80          ;call kernel

        ;Read and store the user input
    mov edx, 2      ;stores up to 2 bytes of info
    mov ecx, num1    ;variable to store the info as
    mov ebx, 0       ;file descriptor (stdin)
    mov eax, 3       ;system call (sys_read)
    int       0x80          ;call kernel

        ;print
        mov     edx, len2    ;message length
        mov     ecx, msg2    ;message to write
        mov     ebx, 1      ;file descriptor (stdout)
        mov     eax, 4      ;system call number (sys_write)
        int     0x80          ;call kernel

    ;Read and store the user input
    mov edx, 2      ;stores up to 2 bytes of info
    mov ecx, num2    ;variable to store the info as
    mov ebx, 0       ;file descriptor (stdin)
    mov eax, 3       ;system call (sys_read)
    int       0x80          ;call kernel
```

```
    ;move the data to registers
    mov eax, [num1]
    sub eax, '0'
    mov ebx, [num2]
    sub ebx, '0'

    add eax, ebx
    add eax, '0'
    mov [result], eax

    ;print
       mov    edx, len3   ;message length
       mov    ecx, msg3   ;message to write
       mov    ebx, 1     ;file descriptor (stdout)
       mov    eax, 4     ;system call number (sys_write)
       int    0x80        ;call kernel

    ;print
       mov    edx, 1   ;message length
       mov    ecx, result   ;message to write
       mov    ebx, 1     ;file descriptor (stdout)
       mov    eax, 4     ;system call number (sys_write)
       int    0x80        ;call kernel


       ;End connection to Linux system
       mov    eax, 1     ;system call number (sys_exit)
       int    0x80        ;call kernel

section      .data
    msg1 db "What is the first number? "
    len1 equ $ - msg1
    msg2 db "What is your second number? "
    len2 equ $ - msg2
    msg3 db "The sum is "
    len3 equ $ - msg3

    ; msg     db     'What is your name? ',0xa  ;our string
    ; len     equ    $ - msg                    ;length of our string (found
by taking the location of the byte after msg [$] and subtracting the location
of msg, which gives the bytes in msg)

    ; msg1    db     'Hello, '     ;our dear string
    ; len1    equ    $ - msg1      ;length of our dear string

section .bss           ;Uninitialized data
  num1 resb 2
  num2 resb 2
   result resb 1
```