Roadmap

C:

```
car *c = malloc(sizeof(car));
c->miles = 100;
c->gals = 17;
float mpg = get_mpg(c);
free(c);
```

Java:

```
Car c = new Car();
c.setMiles(100);
c.setGals(17);
float mpg =
    c.getMPG();
```

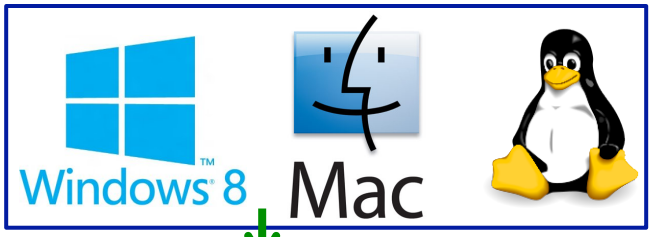
Assembly language:

```
get_mpg:
    pushq   %rbp
    movq    %rsp, %rbp
    ...
    popq    %rbp
    ret
```

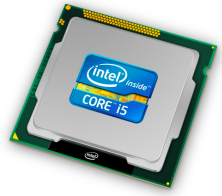
Machine code:

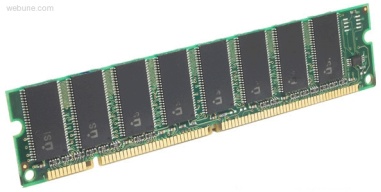
```
0111010000011000
100011010000010000000010
1000100111000010
11000001111110100011111
```

OS:



Computer system:





- Memory & data
- Integers & floats
- Machine code & C
- **x86 assembly**
- Procedures & stacks
- Arrays & structs
- Memory & caches
- Processes
- Virtual memory
- Memory allocation
- Java vs. C

Section 4: x86 Assembly Programming

- Move instructions, registers, and operands
- Memory addressing modes
- `swap` example: 32-bit vs. 64-bit
- Arithmetic operations
- Condition codes
- Conditional and unconditional branches
- Loops
- Switch statements

Three Basic Kinds of Instructions

- **Transfer data between memory and register**
  - *Load* data from memory into register
    - %reg = Mem[address]
  - *Store* register data into memory
    - Mem[address] = %reg

Remember: memory is indexed just like an array[]!

- **Perform arithmetic function on register or memory data**
  - c = a + b;

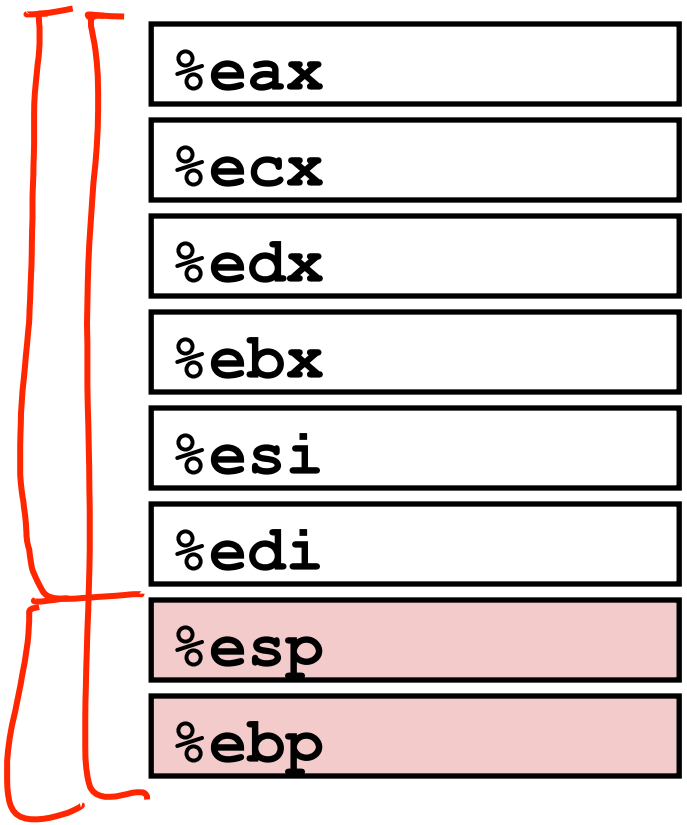
- **Transfer control**
  - Unconditional jumps to/from procedures
  - Conditional branches

Moving Data: IA32

- **Moving Data**
  - **`movx`** ***Source*, *Dest***
  - **`x`** is one of {**`b`**, **`w`**, **`l`**}

  - **`movl`** ***Source*, *Dest*:**
    Move 4-byte "long word"
  - **`movw`** ***Source*, *Dest*:**
    Move 2-byte "word"
  - **`movb`** ***Source*, *Dest*:**
    Move 1-byte "byte"

- **Lots of these in typical code**

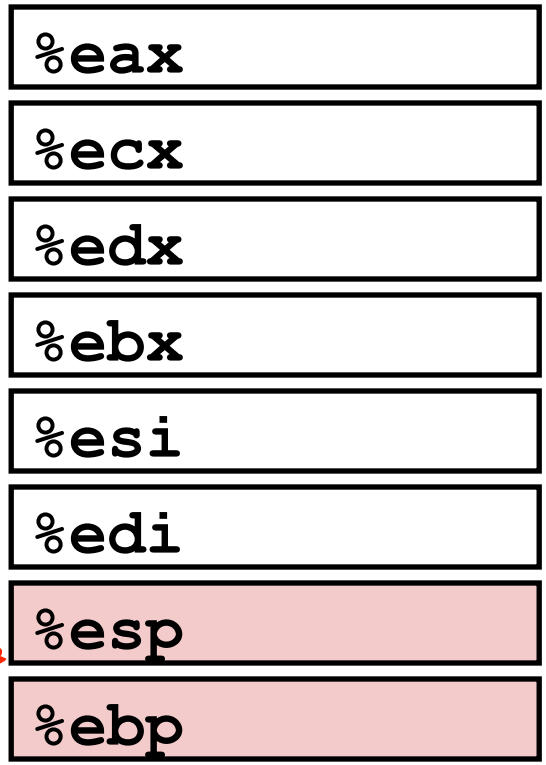


Moving Data: IA32

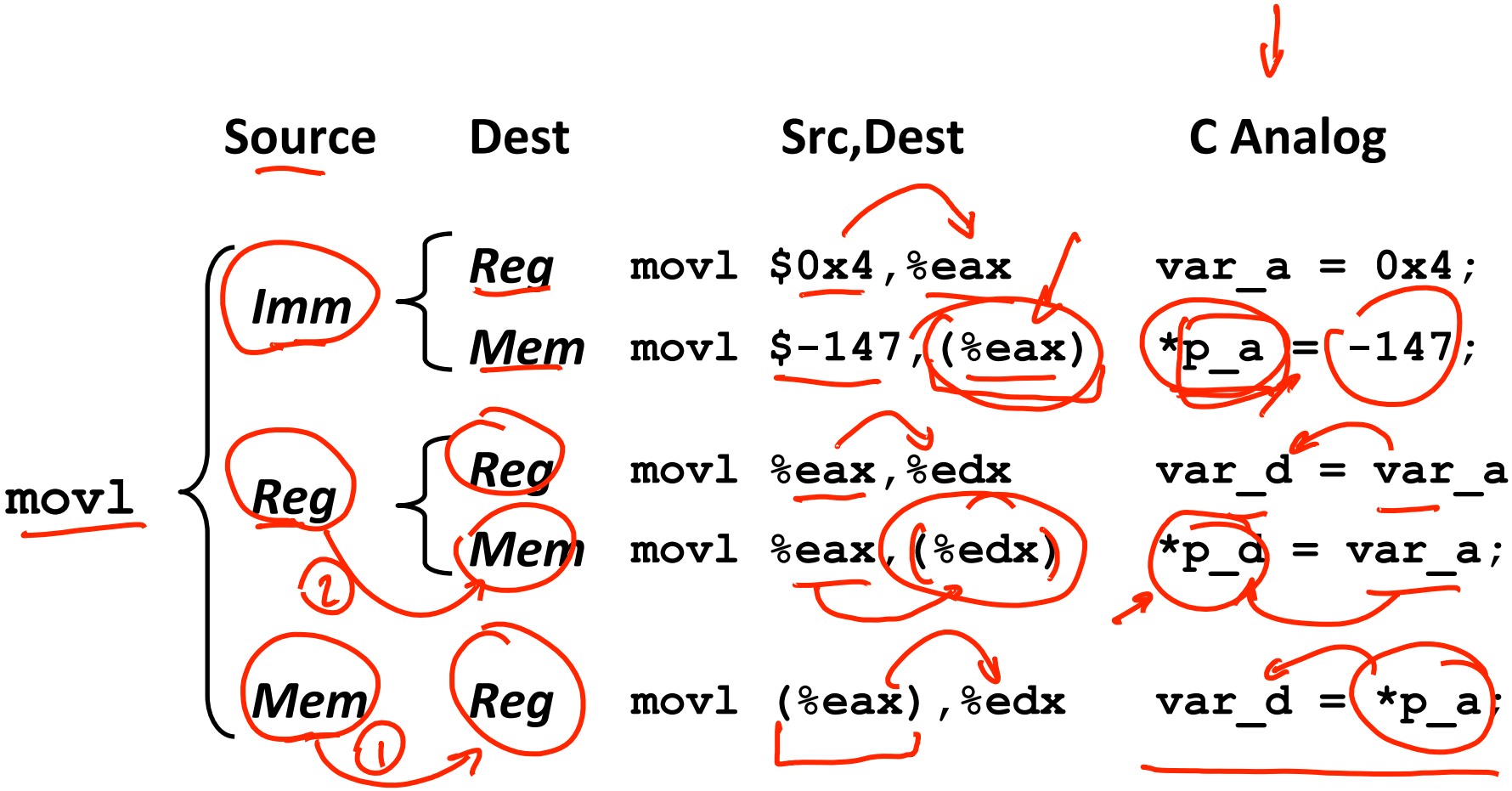
- **Moving Data**

  `movl` *Source*, *Dest*:

- **Operand Types**
  - ***Immediate:*** Constant integer data
    - Example: `$0x400`, `$-533`
    - Like C constant, but prefixed with `'$'`
    - Encoded with 1, 2, or 4 bytes
  - ***Register:*** One of 8 integer registers
    - Example: `%eax`, `%edx`
    - But `%esp` and `%ebp` reserved for special use
    - Others have special uses for particular instructions
  - ***Memory:*** 4 consecutive bytes of memory at address given by register
    - Simplest example: `(%eax)`
    - Various other "address modes"



`movl` Operand Combinations



Cannot do memory-memory transfer with a single instruction.

Memory Addressing Modes: Basic

- **Indirect (R) Mem[Reg[R]]**
  - Register R specifies the memory address

```
movl (%ecx),%eax
```

- **Displacement D(R) Mem[Reg[R]+D]**
  - Register R specifies a memory address
    - (e.g. the start of some memory region)
  - Constant displacement D specifies the offset from that address

```
movl 8(%ebp),%edx
```

%edx = Mem[%ebp + 8]

Using Basic Addressing Modes

```
void swap(int *xp, int *yp)
{
  int t0 = *xp;
  int t1 = *yp;
  *xp = t1;
  *yp = t0;
}
```

```
swap:
    pushl %ebp
    movl  %esp,%ebp
    pushl %ebx

    movl 12(%ebp),%ecx
    movl 8(%ebp),%edx
    movl (%ecx),%eax
    movl (%edx),%ebx
    movl %eax,(%edx)
    movl %ebx,(%ecx)

    movl -4(%ebp),%ebx
    movl %ebp,%esp
    popl %ebp
    ret
```

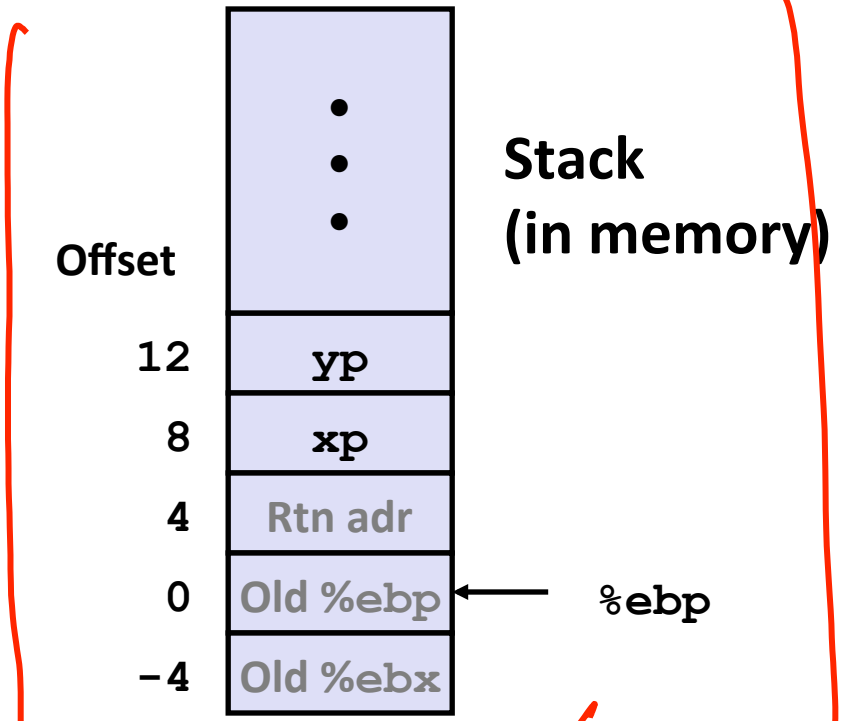
Set Up

Body

Finish

Understanding Swap

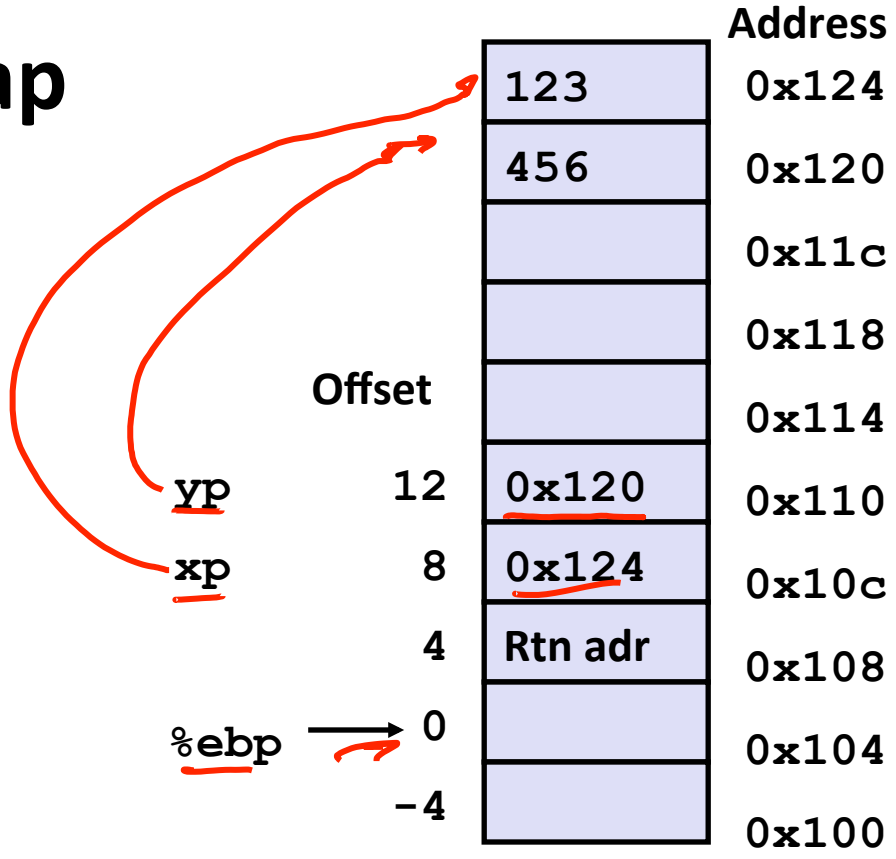
```
void swap(int *xp, int *yp)
{
  int t0 = *xp;
  int t1 = *yp;
  *xp = t1;
  *yp = t0;
}
```



Register	Value
%ecx	yp
%edx	xp
%eax	t1
%ebx	t0

```
movl 12(%ebp),%ecx   # ecx = yp
movl 8(%ebp),%edx    # edx = xp
movl (%ecx),%eax     # eax = *yp (t1)
movl (%edx),%ebx     # ebx = *xp (t0)
movl %eax,(%edx)     # *xp = eax
movl %ebx,(%ecx)     # *yp = ebx
```

Understanding Swap




```
movl 12(%ebp),%ecx      # ecx = yp
movl 8(%ebp),%edx       # edx = xp
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movl (%edx),%ebx        # ebx = *xp (t0)
movl %eax,(%edx)        # *xp = eax
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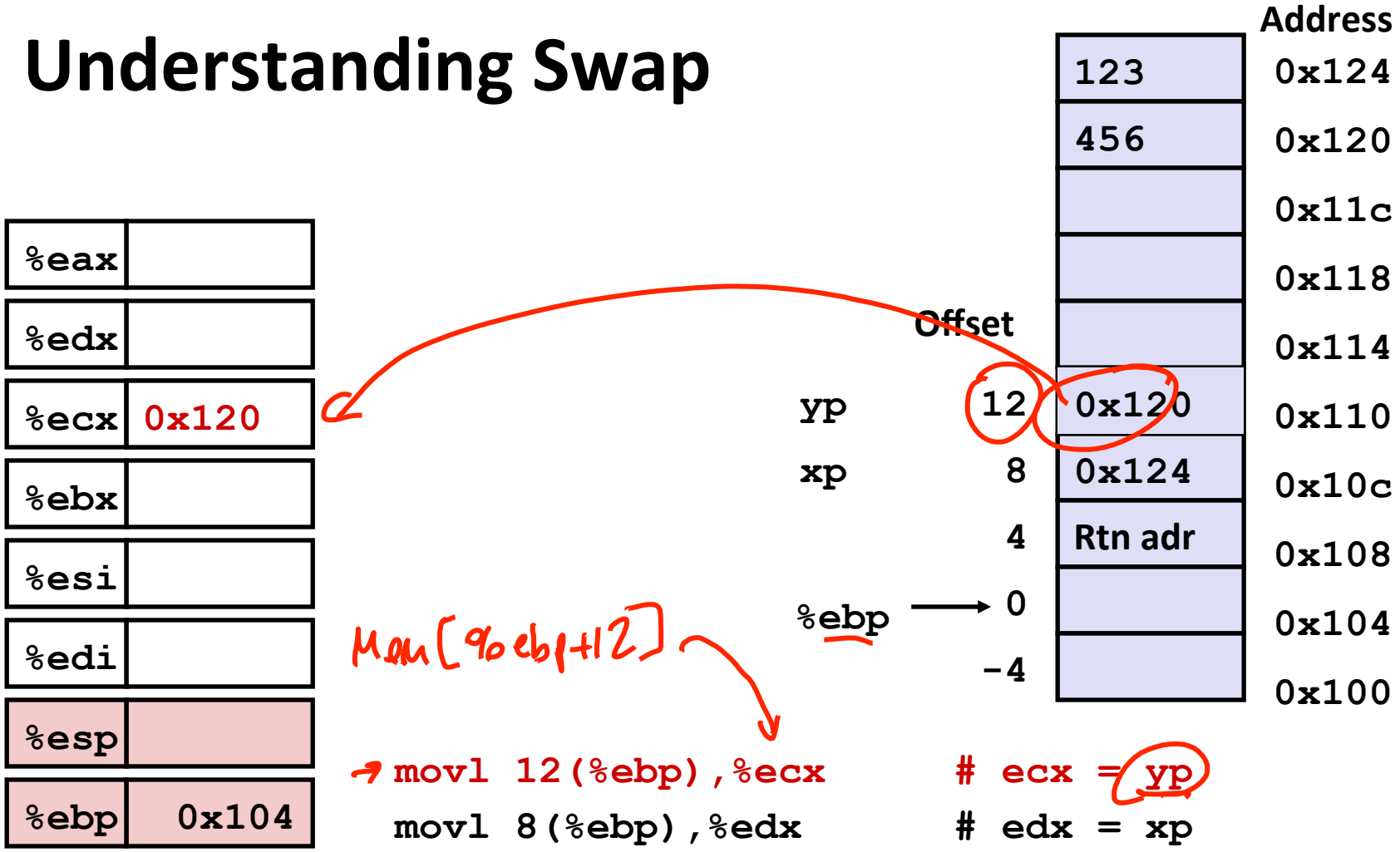
Understanding Swap

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movl (%ecx),%eax        # eax = *yp (t1)
movl (%edx),%ebx        # ebx = *xp (t0)
movl %eax,(%edx)        # *xp = eax
movl %ebx,(%ecx)        # *yp = ebx
```
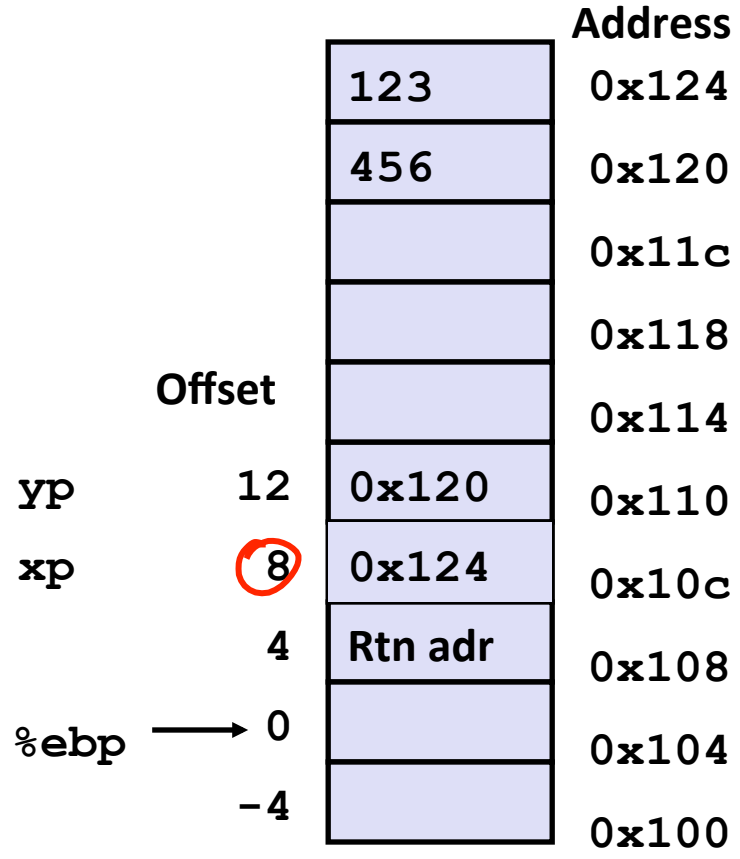

Understanding Swap

%eax	
%edx	0x124
%ecx	0x120
%ebx	
%esi	
%edi	
%esp	
%ebp	0x104

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movl 8(%ebp),%edx       # edx = xp
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movl %eax,(%edx)        # *xp = eax
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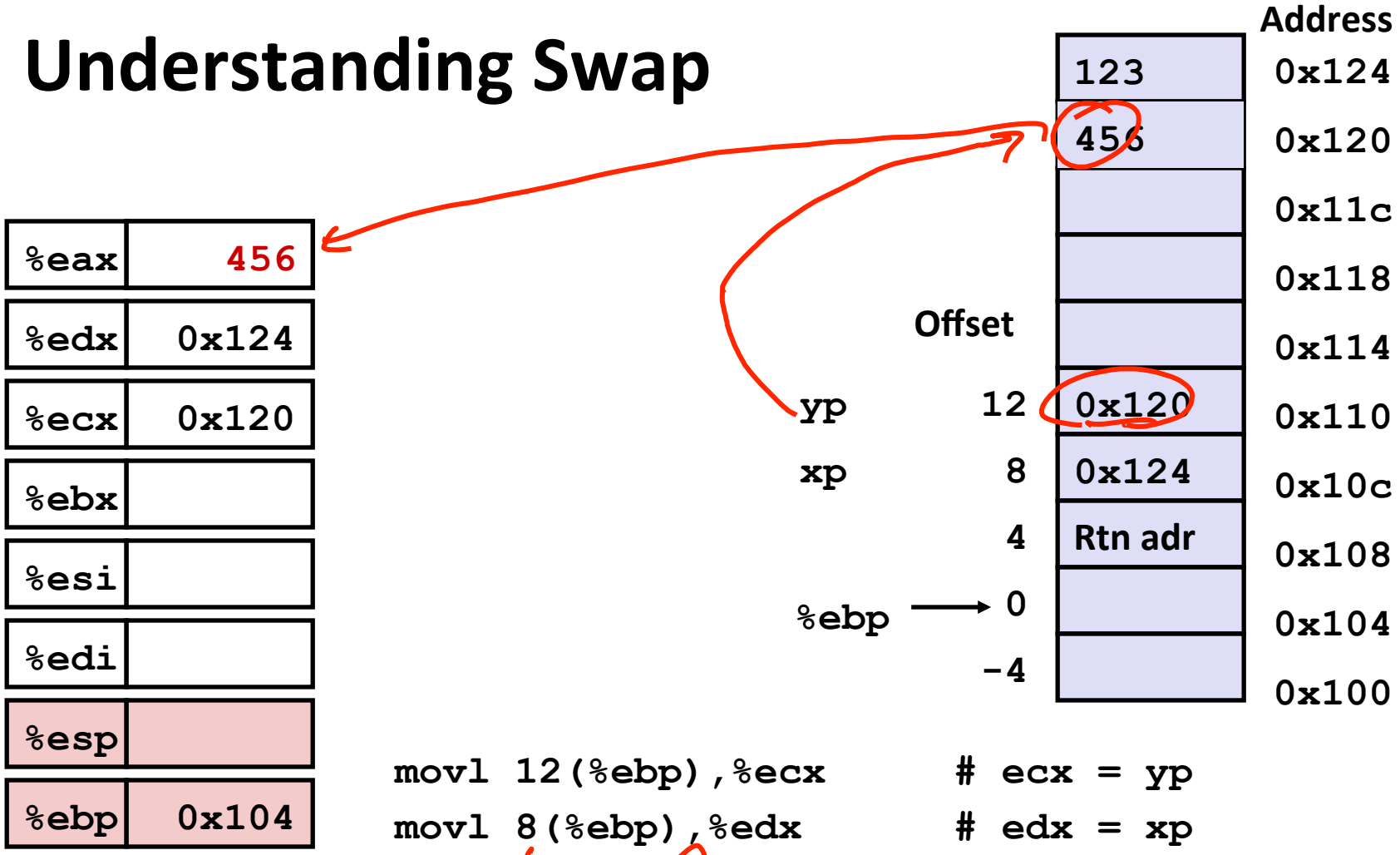
```

Understanding Swap

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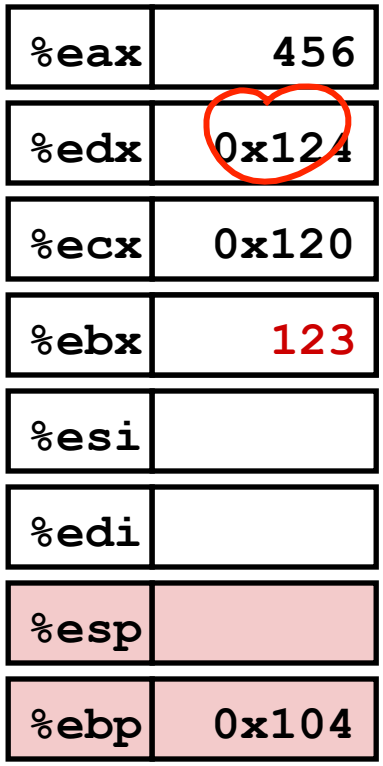
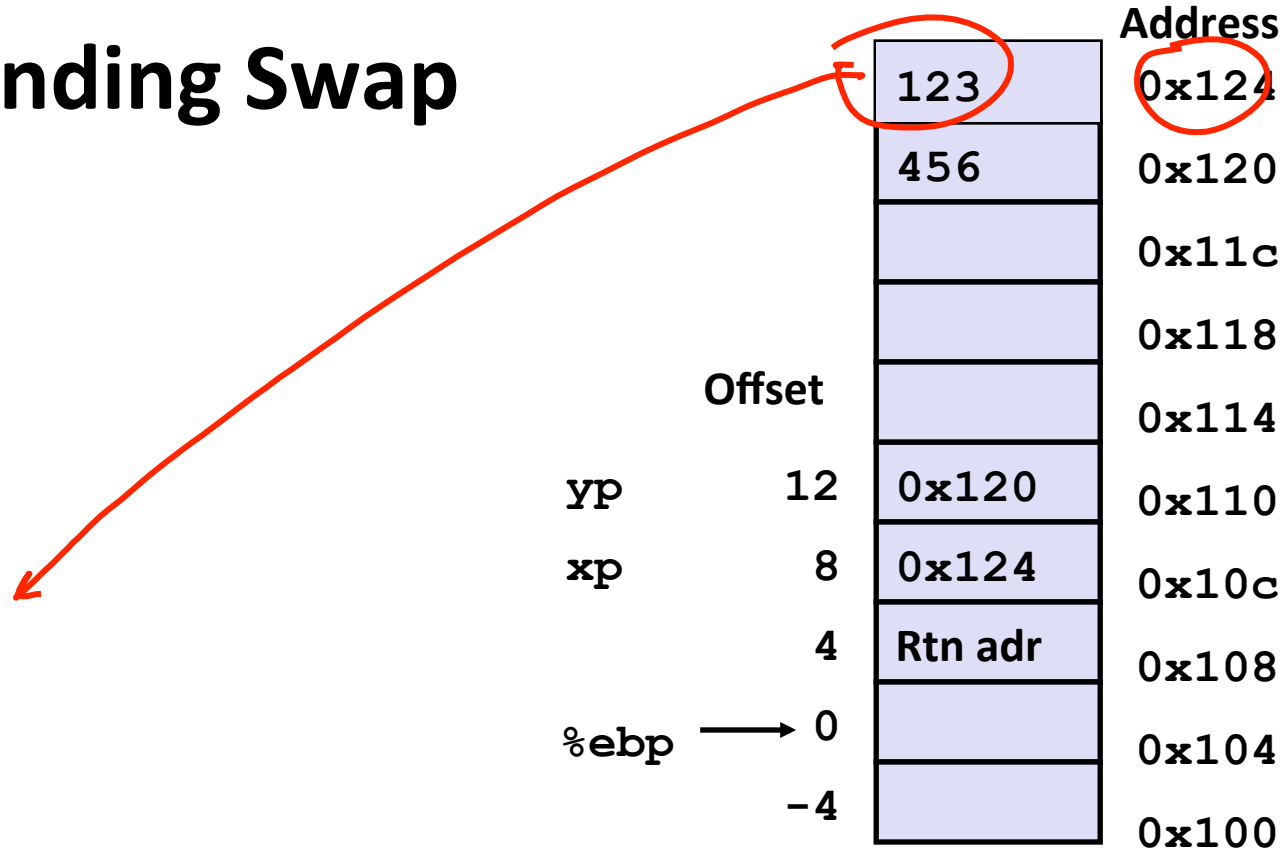
Understanding Swap



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movl (%edx),%ebx        # ebx = *xp (t0)
movl %eax,(%edx)        # *xp = eax
movl %ebx,(%ecx)        # *yp = ebx
```
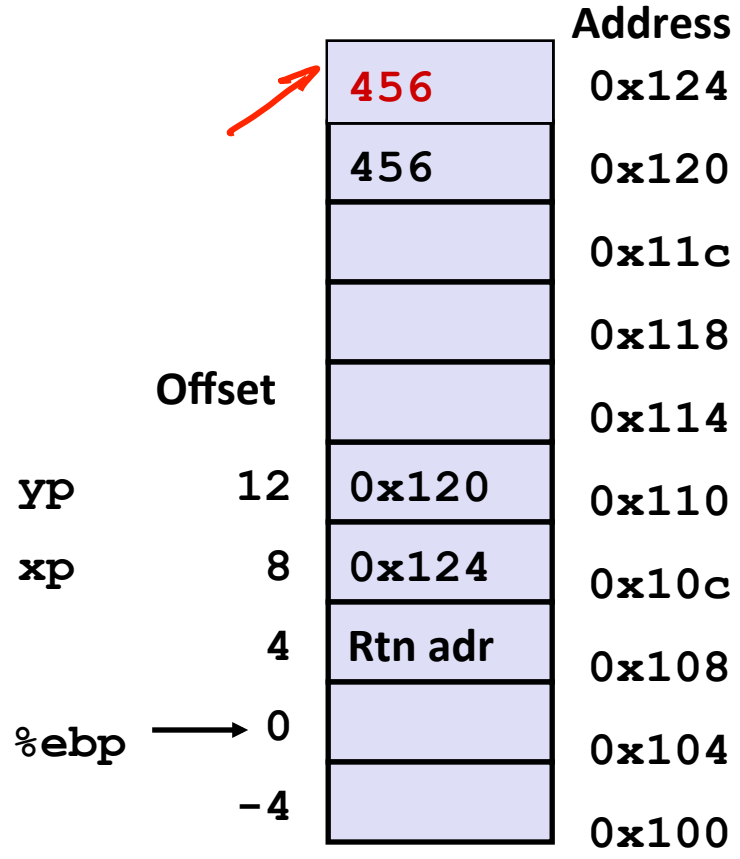

Understanding Swap

%eax	456
%edx	0x124
%ecx	0x120
%ebx	123
%esi	
%edi	
%esp	
%ebp	0x104

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movl 12(%ebp),%ecx      # ecx = yp
movl 8(%ebp),%edx       # edx = xp
movl (%ecx),%eax        # eax = *yp (t1)
movl (%edx),%ebx        # ebx = *xp (t0)
movl %eax,(%edx)        # *xp = eax
movl %ebx,(%ecx)        # *yp = ebx
```

Understanding Swap

%eax	456
%edx	0x124
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%esi	
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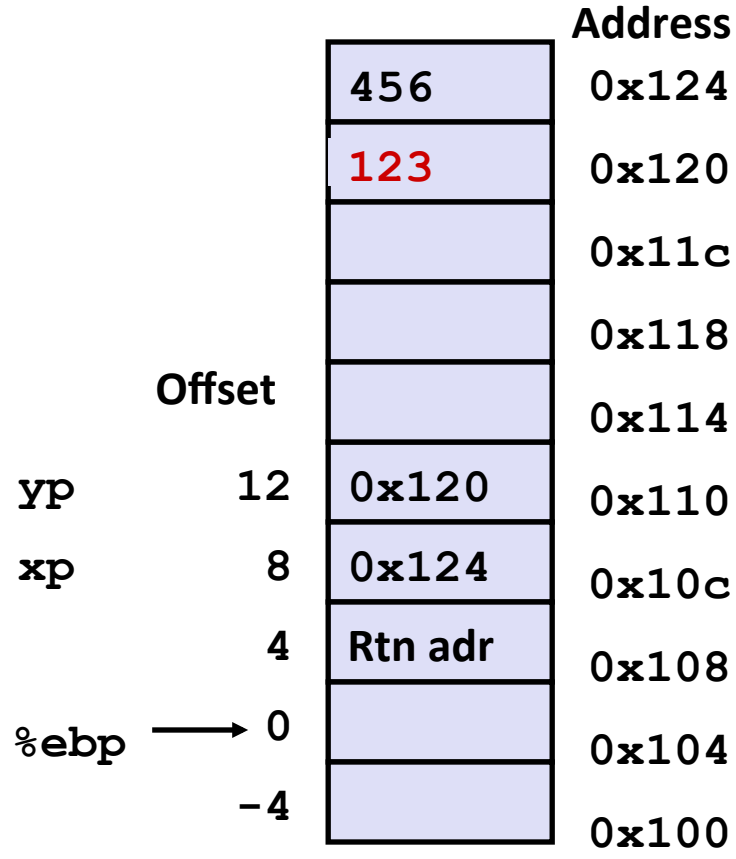


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movl 8(%ebp),%edx       # edx = xp
movl (%ecx),%eax        # eax = *yp (t1)
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movl %eax,(%edx)        # *xp = eax
movl %ebx,(%ecx)        # *yp = ebx
```