15213 Recitation Section C

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Outline

- Last week's exercise
- Function and stack
- Array
- Struct and linked-list

Last Week’s Final Example

```
int func5(int x){ ??? }
```

```
0x80483c0     push %ebp
0x80483c1     mov  %esp,%ebp
0x80483c3     mov  0x8(%ebp),%ecx
0x80483c6     xor  %eax,%eax
0x80483c8     xor  %edx,%edx
0x80483ca     cmp  %ecx,%edx
0x80483cc     jge  0x80483d7
0x80483ce     mov  %esi,%esi
0x80483d0     add  %edx,%eax
0x80483d2     inc  %edx
0x80483d3     cmp  %ecx,%edx
0x80483d5     jl   0x80483d0
0x80483d7     mov  %ebp,%esp
0x80483d9     pop  %ebp
0x80483da     ret
```

$\left.\begin{array}{l} \text{0x80483c3 … 0x80483d5} \end{array}\right\}$ *Body*

Write Comments

```
int func5(int x){ ??? }
```

```
0x80483c3   mov   0x8(%ebp),%ecx
0x80483c6   xor   %eax,%eax
0x80483c8   xor   %edx,%edx
0x80483ca   cmp   %ecx,%edx
0x80483cc   jge   0x80483d7
0x80483ce   mov   %esi,%esi
0x80483d0   add   %edx,%eax
0x80483d2   inc   %edx
0x80483d3   cmp   %ecx,%edx
0x80483d5   jl    0x80483d0
0x80483d7   ……
```

```
ecx = x
eax = 0
edx = 0
if (edx>=x)
  goto L1
nop
L2:eax += edx
edx ++
if (edx<x)
  goto L2
L1:
```

Name the variables

- eax– result, edx--i

```
0x80483c3   mov   0x8(%ebp),%ecx
0x80483c6   xor   %eax,%eax
0x80483c8   xor   %edx,%edx
0x80483ca   cmp   %ecx,%edx
0x80483cc   jge   0x80483d7
0x80483ce   mov   %esi,%esi
0x80483d0   add   %edx,%eax
0x80483d2   inc   %edx
0x80483d3   cmp   %ecx,%edx
0x80483d5   jl    0x80483d0
0x80483d7   ……
```

```
ecx = x;
result = 0;
i = 0;
if (i>=x)
  goto L1;

L2:result += i;
   i++;
if (i<x)
  goto L2;
L1:
```

Loop

```
result = 0;
i = 0;
if (i>=x)
  goto L1;

L2:result += i;
    i++;
if (i<x)
  goto L2;
L1:
```

```
result = 0; i = 0;
if (i>=x)  goto L1;
do {
    result += i;
    i++;
}while (i<x);
L1:
```

```
result = 0; i = 0;
While (i<x){
    result += i;
    i++;
}
```

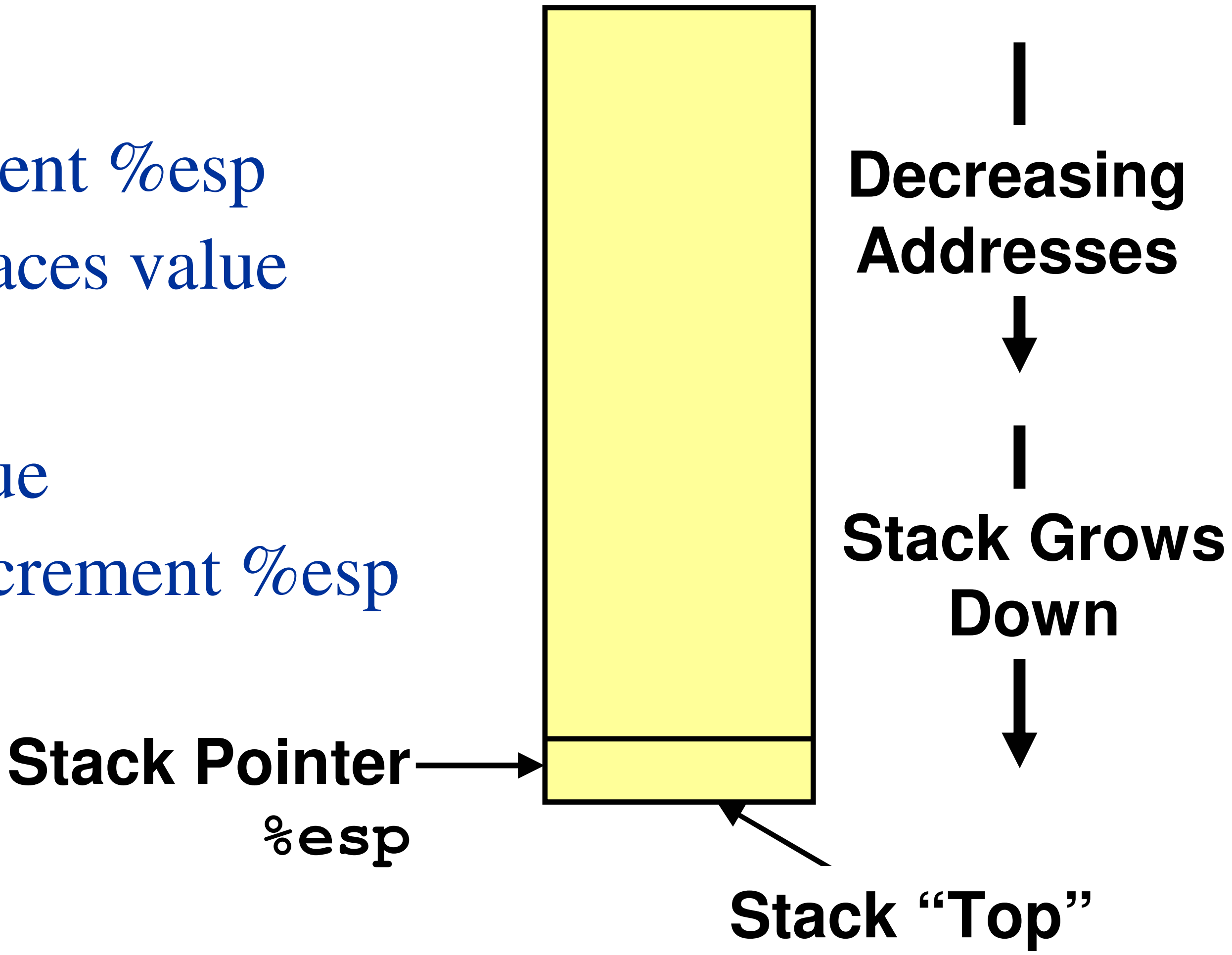
```
result = 0;
for (i=0; i<x; i++)
    result += i;
```

C Code

```
int func5(int x)
{
        int result=0;
        int i;
        for (i=0; i<x; i++)
            result += i;
        return result;
}
```

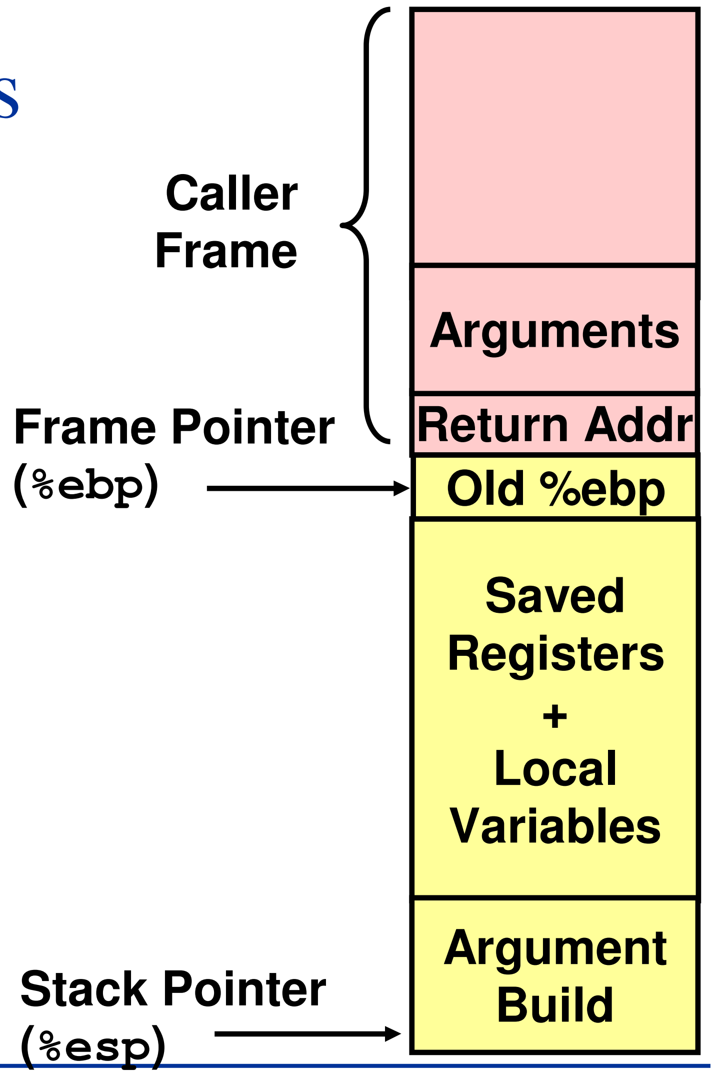
Stack Basics

- push
  - decrement %esp
  - then places value
- pop
  - get value
  - then increment %esp



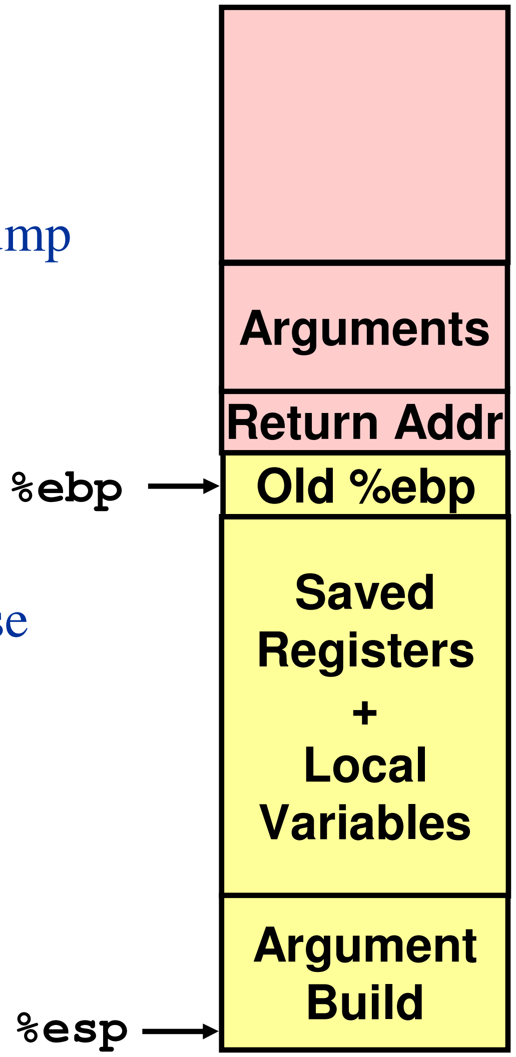
Function Stack Frames

- A caller function calls a callee function



Making a Call

- Caller:
  - "push" arguments (*in what order?*)
  - "call": put *return address* onto stack, jump to the start of callee function
- Callee:
  - save (caller's) %ebp
  - set up stack frame
  - save *callee-saved* registers if want to use
    - %ebx, %esi, %edi
  - put return value in %eax
  - restore %ebp and %esp
  - "ret" to jump to the "Return Addr"



Example 1

- Please draw the stack at the marked points
- Write C code for the assembly code
  - **(gdb) x/s 0x8048478**

  0x8048478 <_IO_stdin_used+4>: "%d\n"

```
int example_1 (int x, int y)
```

```
0x80483e4     push    %ebp
0x80483e5     mov     %esp,%ebp
0x80483e7     mov     0xc(%ebp),%eax
0x80483ea     add     0x8(%ebp),%eax
0x80483ed     mov     %ebp,%esp
0x80483ef     pop     %ebp
0x80483f0     ret
```

2.Stack?

ASM of main()

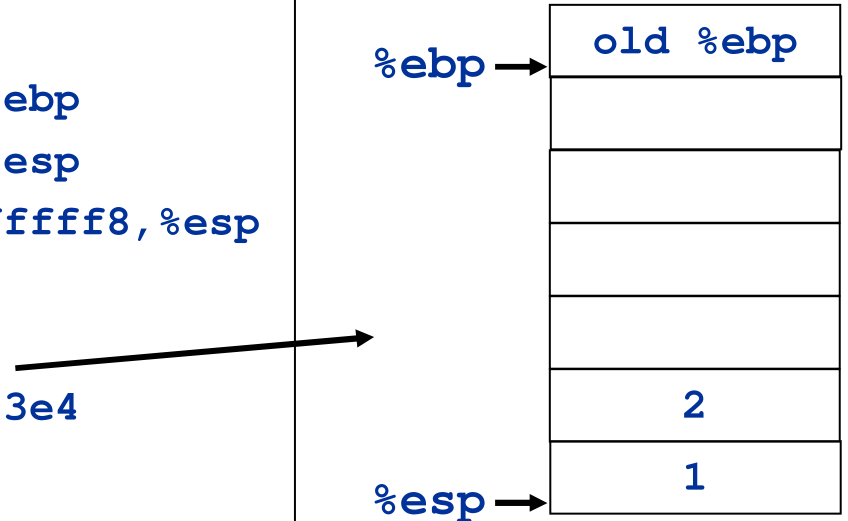
```
0x80483f4    push    %ebp
0x80483f5    mov     %esp,%ebp
0x80483f7    sub     $0x8,%esp
0x80483fa    add     $0xfffffff8,%esp
0x80483fd    push    $0x2
0x80483ff    push    $0x1
0x8048401    call    0x80483e4 <example_1>
0x8048406    add     $0xfffffff8,%esp
0x8048409    push    %eax
0x804840a    push    $0x8048478
0x804840f    call    0x8048308 <printf>
0x8048414    xor     %eax,%eax
0x8048416    mov     %ebp,%esp
0x8048418    pop     %ebp
0x8048419    ret
```

1.Stack?

3.Stack?

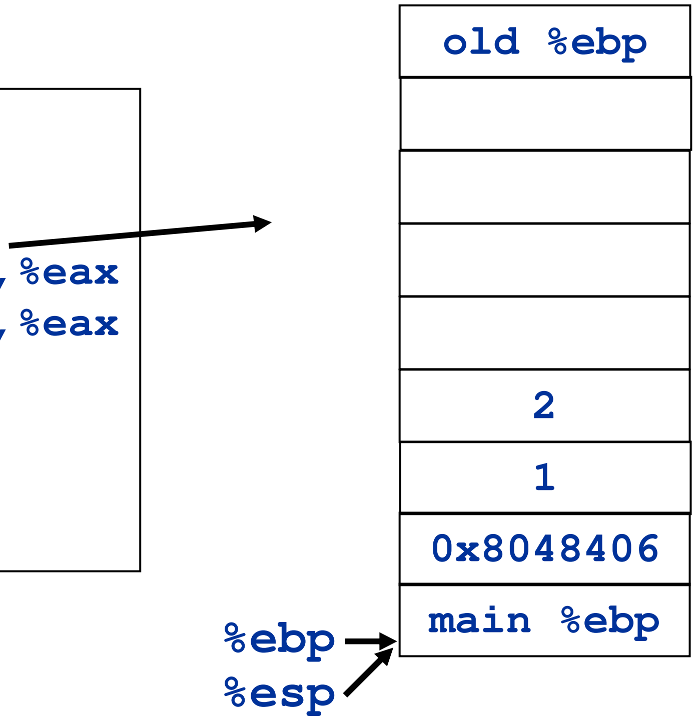
Stack at Point 1

```
<main>
0x80483f4    push    %ebp
0x80483f5    mov     %esp,%ebp
0x80483f7    sub     $0x8,%esp
0x80483fa    add     $0xfffffff8,%esp
0x80483fd    push    $0x2
0x80483ff    push    $0x1
0x8048401    call    0x80483e4
   <example_1>
0x8048406    …………
```



Stack at Point 2

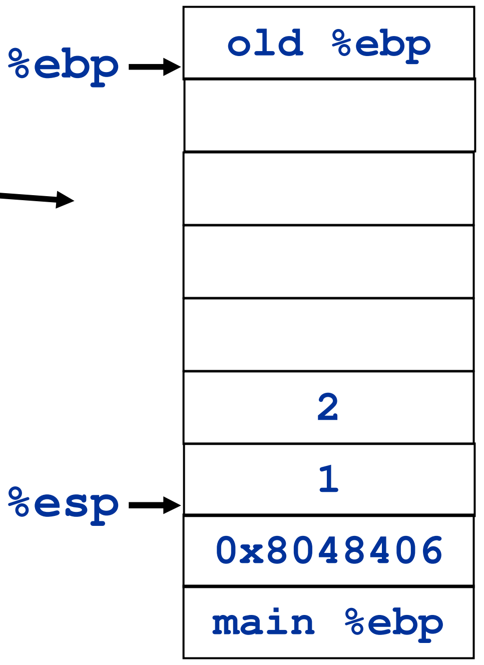
```
<example_2>
0x80483e4     push   %ebp
0x80483e5     mov    %esp,%ebp
0x80483e7     mov    0xc(%ebp),%eax
0x80483ea     add    0x8(%ebp),%eax
0x80483ed     mov    %ebp,%esp
0x80483ef     pop    %ebp
0x80483f0     ret
```



Stack at Point 3

```
<main>
0x80483ff    .........
0x8048401    call 0x80483e4 <example_1>
0x8048406    ............
```

```
<example_2>
0x80483e4     push    %ebp
0x80483e5     mov     %esp,%ebp
0x80483e7     mov     0xc(%ebp),%eax
0x80483ea     add     0x8(%ebp),%eax
0x80483ed     mov     %ebp,%esp
0x80483ef     pop     %ebp
0x80483f0     ret
```



Write Comments

```
int example_1 (int x, int y)
```

```
0x80483e4     push    %ebp
0x80483e5     mov     %esp,%ebp
0x80483e7     mov     0xc(%ebp),%eax
0x80483ea     add     0x8(%ebp),%eax
0x80483ed     mov     %ebp,%esp
0x80483ef     pop     %ebp
0x80483f0     ret
```

```
eax=y
eax+=x
```

main()

```
0x80483f4   push   %ebp
0x80483f5   mov    %esp,%ebp
0x80483f7   sub    $0x8,%esp
0x80483fa   add    $0xfffffff8,%esp
0x80483fd   push   $0x2
0x80483ff   push   $0x1
0x8048401   call   0x80483e4 <example_1>
0x8048406   add    $0xfffffff8,%esp
0x8048409   push   %eax
0x804840a   push   $0x8048478
0x804840f   call   0x8048308 <printf>
0x8048414   xor    %eax,%eax
0x8048416   mov    %ebp,%esp
0x8048418   pop    %ebp
0x8048419   ret
```

```
example_1(1,2)


printf("%d\n",
result_example_1)

return 0;
```

C Code

```
int example_1 (int x, int y)
{
        return x+y;
}

int main ()
{
        int result;

        result = example_1 (1, 2);
        printf ("%d\n", result);

        return 0;
}
```

Example 2: Recursion

- Please write C code for the assembly code
- Draw the stack changes of calling **`example_2(3)`**

`int example_2 (int x)`

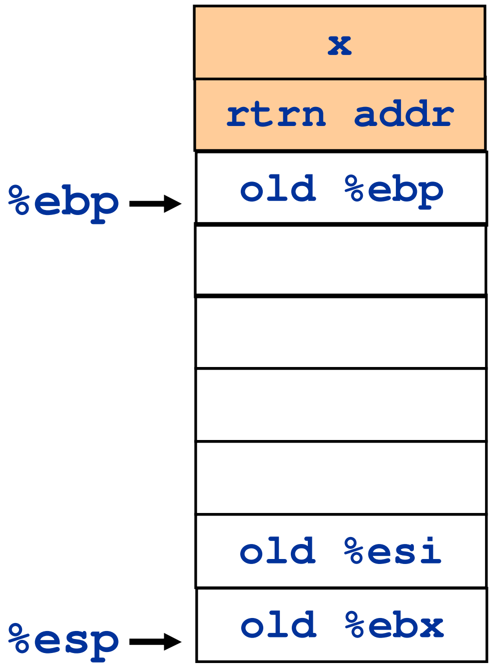
```
0x8048420   push   %ebp
0x8048421   mov    %esp,%ebp
0x8048423   sub    $0x10,%esp
0x8048426   push   %esi
0x8048427   push   %ebx
0x8048428   mov    0x8(%ebp),%ebx
0x804842b   cmp    $0x2,%ebx
0x804842e   jg     0x8048437
0x8048430   mov    $0x1,%eax
0x8048435   jmp    0x8048453
```

Example 2 Cont'd

```
0x8048437    add     $0xfffffff4,%esp
0x804843a    lea     0xfffffffe(%ebx),%eax
0x804843d    push    %eax
0x804843e    call    0x8048420 <example_2>
0x8048443    mov     %eax,%esi
0x8048445    add     $0xfffffff4,%esp
0x8048448    lea     0xffffffff(%ebx),%eax
0x804844b    push    %eax
0x804844c    call    0x8048420 <example_2>
0x8048451    add     %esi,%eax
0x8048453    lea     0xffffffe8(%ebp),%esp
0x8048456    pop     %ebx
0x8048457    pop     %esi
0x8048458    mov     %ebp,%esp
0x804845a    pop     %ebp
0x804845b    ret
```

Stack Frame

```
<example_2>
0x8048420   push   %ebp
0x8048421   mov    %esp,%ebp
0x8048423   sub    $0x10,%esp
0x8048426   push   %esi
0x8048427   push   %ebx

. . . . . .

0x8048453   lea    0xffffffe8(%ebp),%esp
0x8048456   pop    %ebx
0x8048457   pop    %esi
0x8048458   mov    %ebp,%esp
0x804845a   pop    %ebp
0x804845b   ret
```



Write Comments For Body

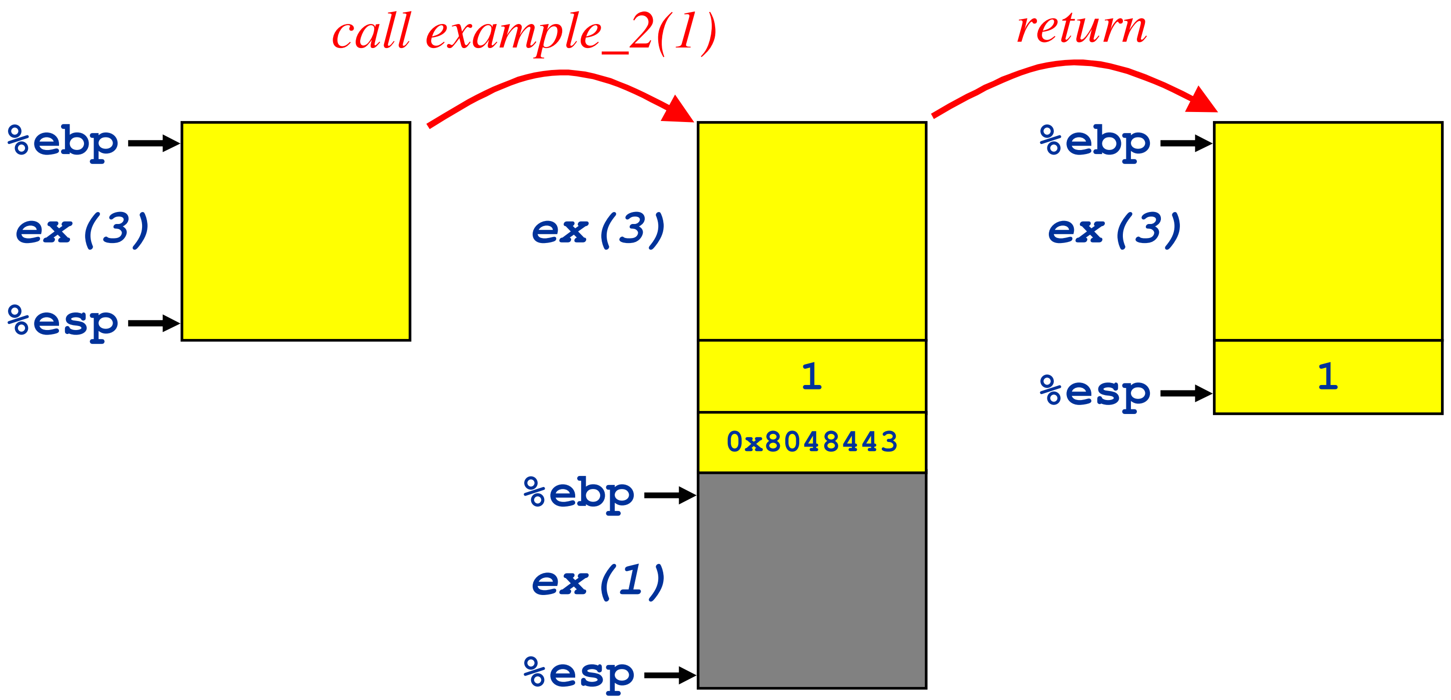
```
0x8048428   mov    0x8(%ebp),%ebx             ebx=x
0x804842b   cmp    $0x2,%ebx                  if (x>2)
0x804842e   jg     0x8048437                    goto L1
0x8048430   mov    $0x1,%eax                  eax=1
0x8048435   jmp    0x8048453                  goto L2
0x8048437   add    $0xfffffff4,%esp           L1:
0x804843a   lea    0xfffffffe(%ebx),%eax
0x804843d   push   %eax                       push x-2
0x804843e   call   0x8048420 <example_2>      example_2
0x8048443   mov    %eax,%esi                  esi=eax
0x8048445   add    $0xfffffff4,%esp
0x8048448   lea    0xffffffff(%ebx),%eax
0x804844b   push   %eax                       push x-1
0x804844c   call   0x8048420 <example_2>      example_2
0x8048451   add    %esi,%eax                  eax+=esi
0x8048453   . . .                             L2:
```

C Code

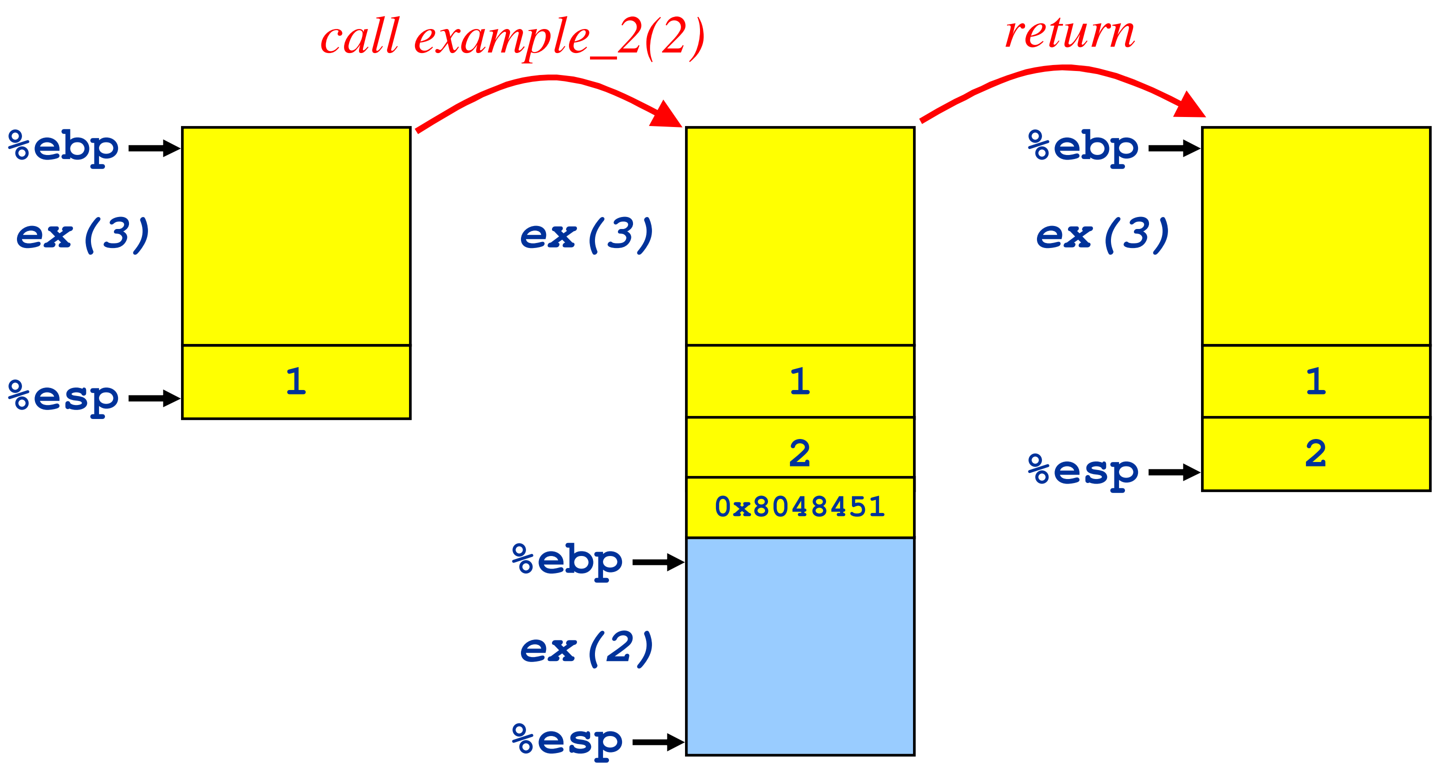
```
int example_2 (int n)
{int result;

   if (n <= 2)
     result = 1;
   else
     result = example_2(n-2)
            + example_2(n-1);

   return result;
}
```

Fibonacci Numbers

Stack Changes of example_2(3)



Stack Changes of example_2(3)



Arrays

- Allocated as contiguous blocks of memory
- Address Computation Example

```
int cmu[5];      /* at address 'addr' */
cmu[0]                addr+0
cmu[3]                addr+3*sizeof(int)
cmu[-1]               addr+(-1)*sizeof(int)
```

Example 3 Write C Code

```
0x80483f0    push    %ebp
0x80483f1    mov     %esp,%ebp
0x80483f3    push    %ebx
0x80483f4    mov     0x8(%ebp),%ebx
0x80483f7    mov     0xc(%ebp),%ecx
0x80483fa    xor     %eax,%eax
0x80483fc    xor     %edx,%edx
0x80483fe    cmp     %ecx,%eax
0x8048400    jge     0x804840a
0x8048402    add     (%ebx,%edx,4),%eax
0x8048405    inc     %edx
0x8048406    cmp     %ecx,%edx
0x8048408    jl      0x8048402
0x804840a    pop     %ebx
0x804840b    mov     %ebp,%esp
0x804840d    pop     %ebp
0x804840e    ret
```

Write Comments

```
0x80483f0    push %ebp
0x80483f1    mov  %esp,%ebp
0x80483f3    push %ebx
0x80483f4    mov  0x8(%ebp),%ebx
0x80483f7    mov  0xc(%ebp),%ecx
0x80483fa    xor  %eax,%eax
0x80483fc    xor  %edx,%edx
0x80483fe    cmp  %ecx,%eax
0x8048400    jge  0x804840a
0x8048402    add  (%ebx,%edx,4),%eax
0x8048405    inc  %edx
0x8048406    cmp  %ecx,%edx
0x8048408    jl   0x8048402
0x804840a    pop  %ebx
0x804840b    mov  %ebp,%esp
0x804840d    pop  %ebp
0x804840e    ret
```

```
ebx=arg1
ecx=arg2
eax=0
edx=0
if (0>=arg2)
  goto L1
L2:eax+=arg1[edx]
edx++
if (edx<arg2)
  goto L2
L1:
```

Write Comments

```
0x80483f0    push %ebp
0x80483f1    mov  %esp,%ebp
0x80483f3    push %ebx
0x80483f4    mov  0x8(%ebp),%ebx
0x80483f7    mov  0xc(%ebp),%ecx
0x80483fa    xor  %eax,%eax
0x80483fc    xor  %edx,%edx
0x80483fe    cmp  %ecx,%eax
0x8048400    jge  0x804840a
0x8048402    add  (%ebx,%edx,4),%eax
0x8048405    inc  %edx
0x8048406    cmp  %ecx,%edx
0x8048408    jl   0x8048402
0x804840a    pop  %ebx
0x804840b    mov  %ebp,%esp
0x804840d    pop  %ebp
0x804840e    ret
```

```
arg1:x, arg2:num
edx:i, eax:result
```

```
ebx=x
ecx=num
result=0
i=0
if (0>=num)
  goto L1
L2:result+=x[i]
i++
if (i<num)
  goto L2
L1:
```

Loop + Array

```
int example_3 (int x[], int num)
{
    int i, result;

    result = 0;
    for (i=0; i<num; i++)
        result += x[i];

    return result;
}
```

Struct and Linked List

-
  ```
  struct a_struct {
          int     a;
          float  b;
          char   c[20];
  };
  ```

-
  ```
  struct b_struct {
        . . .
        struct b_struct *link;
        . . .
  };
  ```

Example 4: Write C Code

```
0x8048434   push   %ebp
0x8048435   mov    %esp,%ebp
0x8048437   mov    0x8(%ebp),%edx
0x804843a   xor    %eax,%eax
0x804843c   test   %edx,%edx
0x804843e   je     0x8048449
0x8048440   add    0x4(%edx),%eax
0x8048443   mov    (%edx),%edx
0x8048445   test   %edx,%edx
0x8048447   jne    0x8048440
0x8048449   mov    %ebp,%esp
0x804844b   pop    %ebp
0x804844c   ret
```

Hint: the code visits a linked list

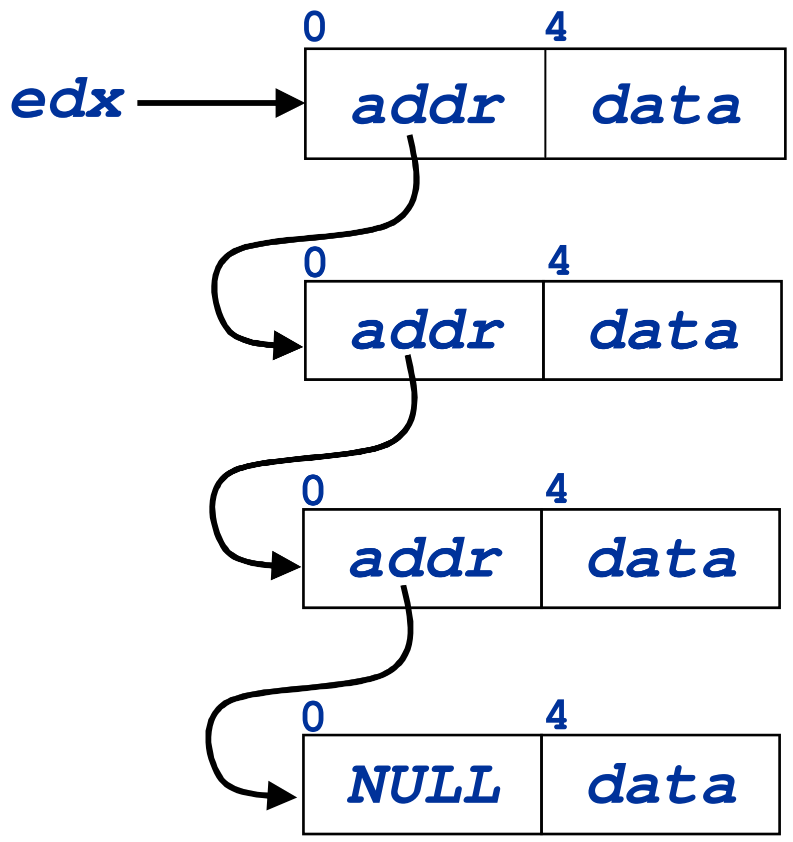
Write Comments

```
0x8048434    push %ebp
0x8048435    mov  %esp,%ebp
0x8048437    mov  0x8(%ebp),%edx
0x804843a    xor  %eax,%eax
0x804843c    test %edx,%edx
0x804843e    je   0x8048449
0x8048440    add  0x4(%edx),%eax
0x8048443    mov  (%edx),%edx
0x8048445    test %edx,%edx
0x8048447    jne  0x8048440
0x8048449    mov  %ebp,%esp
0x804844b    pop  %ebp
0x804844c    ret
```

```
edx=arg1
eax=0
if (edx == 0)
  goto L1
L2:eax += *(edx+4)
edx = *(edx)
if (edx != 0)
  goto L2
L1:
```

Understand the Loop

- *edx is an address*



```
edx=arg1
eax=0
if (edx == 0)
   goto L1
L2:eax += *(edx+4)
edx = *(edx)
if (edx != 0)
   goto L2
L1:
```

Name the Variables

- *arg1: head*
- *eax: result*
- *edx: p*
- **(edx+4): p->data*
- **(edx): p->next*
- *NULL is 0*

```
edx=arg1
eax=0
if (edx == 0)
  goto L1
L2:eax += *(edx+4)
edx = *(edx)
if (edx != 0)
  goto L2
L1:
```

Name the Variables

- *arg1: head*
- *eax: result*
- *edx: p*
- **(edx+4): p->data*
- **(edx): p->next*
- *NULL is 0*

```
p=head
result=0
if (p == NULL)
  goto L1
L2:result += p->data
p = p->next
if (p != NULL)
  goto L2
L1:
```

C Code

```
Struct linked_list {
  struct linked_list *next;
  int                   data;
};

int example_4 (struct linked_list *head)
{
   int result;
   struct linked_list *p;

   result = 0; p = head;
   while (p != NULL) {
      result += p->data;
      p = p->next;
   }
   return result;
}
```