Let’s see a demo of how the stack is built and destroyed during function calls, on a Linux machine using GCC.

Consider this C code

```
int mult(int a, int b) {
        int c, d = 20, e = 30, f;
        f = add(d, e);
        c = a * b + f;
        return c;
}
int add(int x, int y) {
        int z;
        z = x + y;
        return z;
}
```

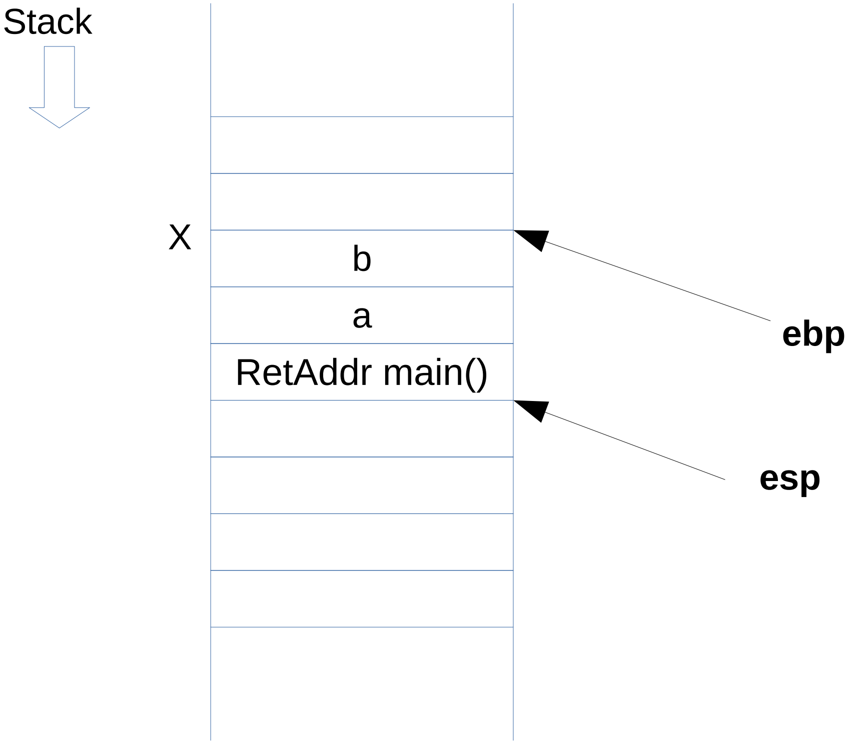
Translated to assembly as:

add:

```
        pushl   %ebp
        movl    %esp, %ebp
        subl    $16, %esp
        movl    8(%ebp), %edx
        movl    12(%ebp), %eax
        addl    %edx, %eax
        movl    %eax, -4(%ebp)
        movl    -4(%ebp), %eax
        leave
        ret
```

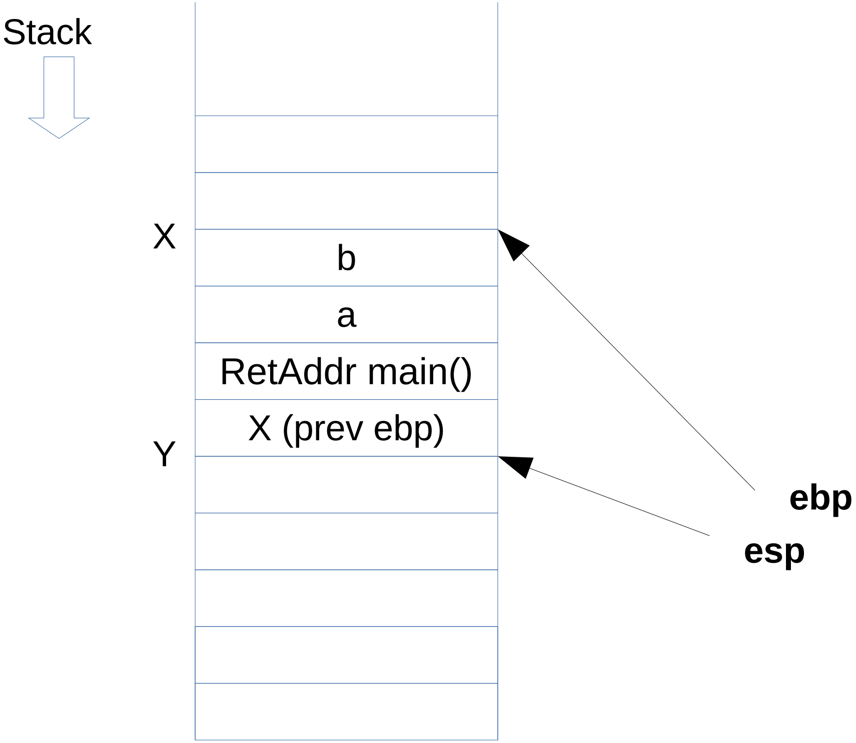
mult:

```
        pushl   %ebp
        movl    %esp, %ebp
        subl    $24, %esp
        movl    $20, -24(%ebp)
        movl    $30, -20(%ebp)
        subl    $8, %esp
        pushl   -20(%ebp)
        pushl   -24(%ebp)
        call    add
        addl    $16, %esp
        movl    %eax, -16(%ebp)
        movl    8(%ebp), %eax
        imull   12(%ebp), %eax
        movl    %eax, %edx
        movl    -16(%ebp), %eax
        addl    %edx, %eax
        movl    %eax, -12(%ebp)
        movl    -12(%ebp), %eax
        leave
        ret
```



```
/* Control is here */
int mult(int a, int b) {
        int c, d = 20, e = 30, f;
        f = add(d, e);
        c = a * b + f;
        return c;
}
int add(int x, int y) {
        int z;
        z = x + y;
        return z;
}
```

```
* Control is here */
mult:
        pushl   %ebp
        movl    %esp, %ebp
        subl    $24, %esp
        movl    $20, -24(%ebp)
        movl    $30, -20(%ebp)
        subl    $8, %esp
        pushl   -20(%ebp)
        pushl   -24(%ebp)
        call    add
```



Stack

X

b

a

RetAddr main()

X (prev ebp)

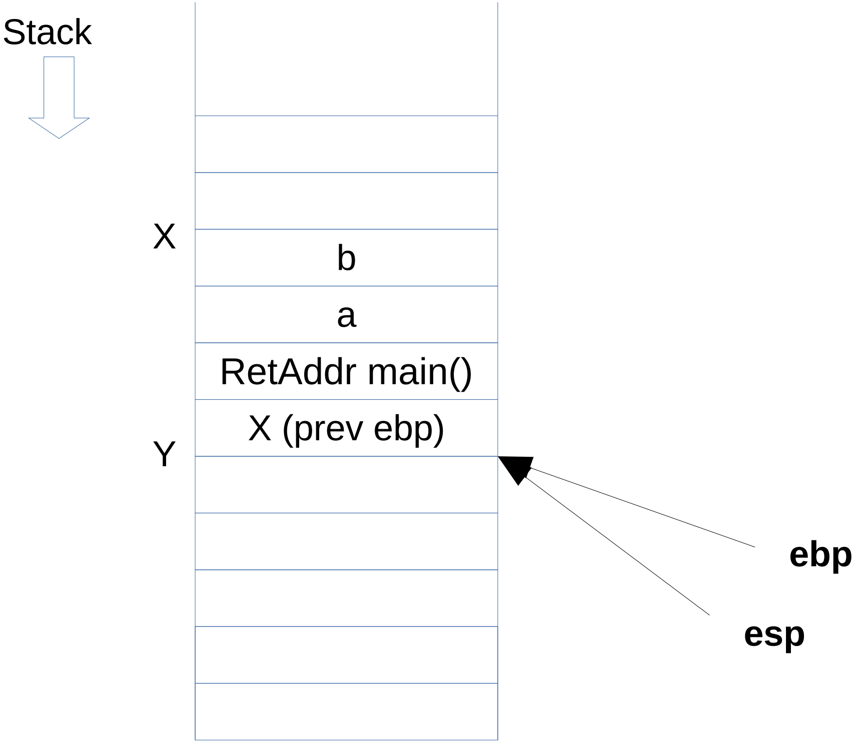
Y

ebp

esp

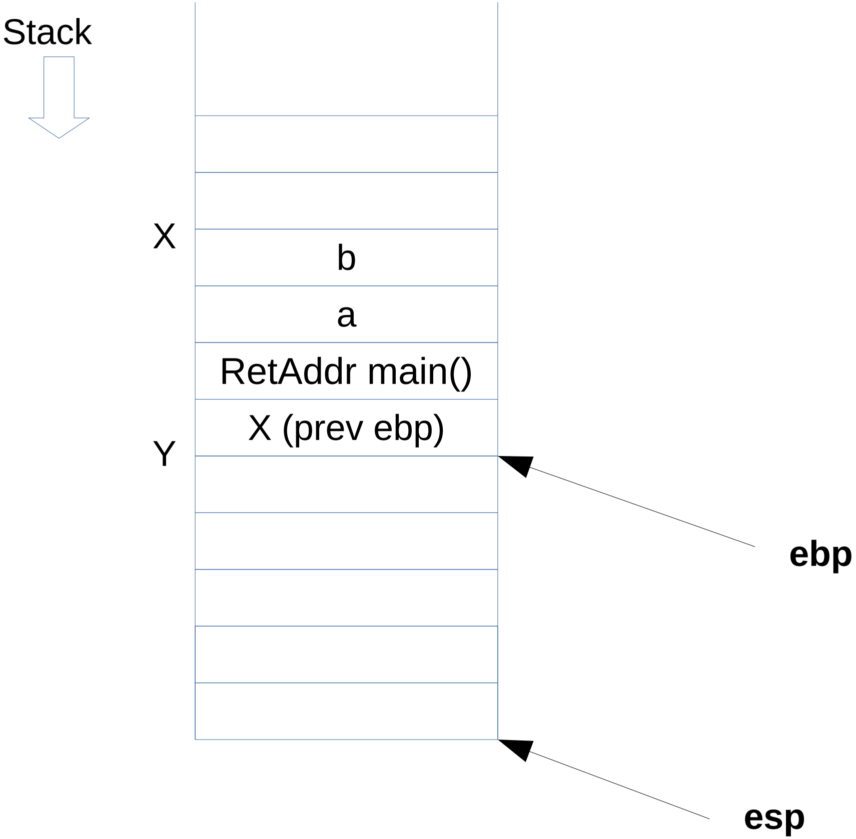
```
int mult(int a, int b) {
        int c, d = 20, e = 30, f;
        f = add(d, e);
        c = a * b + f;
        return c;
}
int add(int x, int y) {
        int z;
        z = x + y;
        return z;
}
```

```
mult:
        pushl   %ebp
        movl    %esp, %ebp
        subl    $24, %esp
        movl    $20, -24(%ebp)
        movl    $30, -20(%ebp)
        subl    $8, %esp
        pushl   -20(%ebp)
        pushl   -24(%ebp)
        call    add
```



```
int mult(int a, int b) {
        int c, d = 20, e = 30, f;
        f = add(d, e);
        c = a * b + f;
        return c;
}
int add(int x, int y) {
        int z;
        z = x + y;
        return z;
}
```

```
mult:
        pushl   %ebp
        movl    %esp, %ebp
        subl    $24, %esp
        movl    $20, -24(%ebp)
        movl    $30, -20(%ebp)
        subl    $8, %esp
        pushl   -20(%ebp)
        pushl   -24(%ebp)
        call    add
```



Stack

X

b

a

RetAddr main()

X (prev ebp)

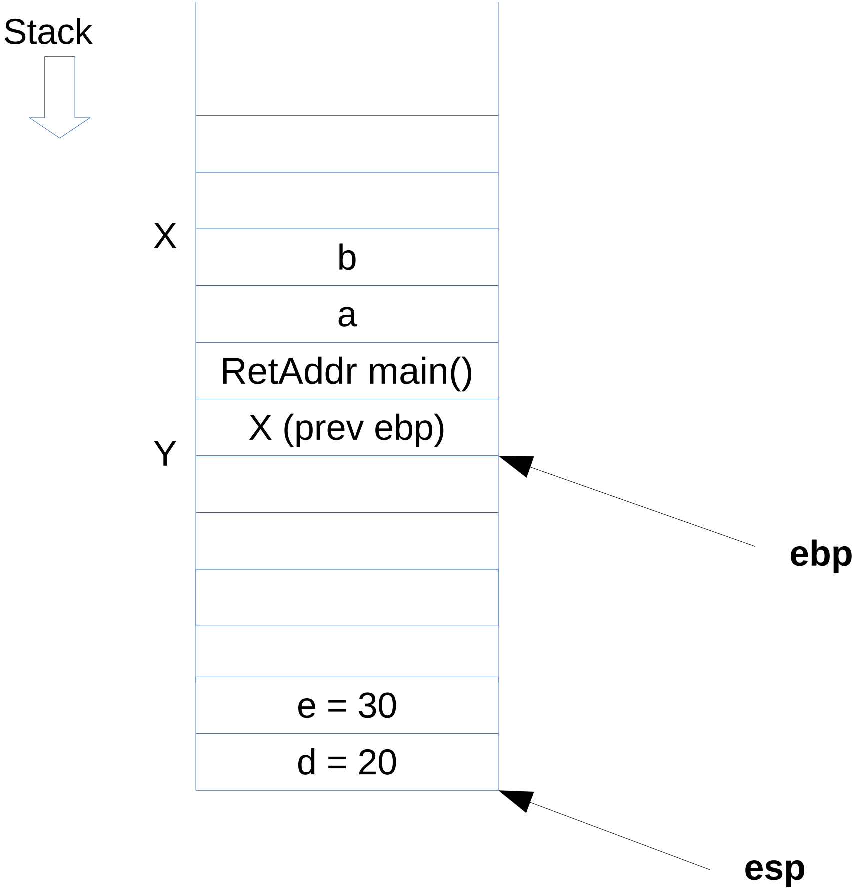
Y

ebp

esp

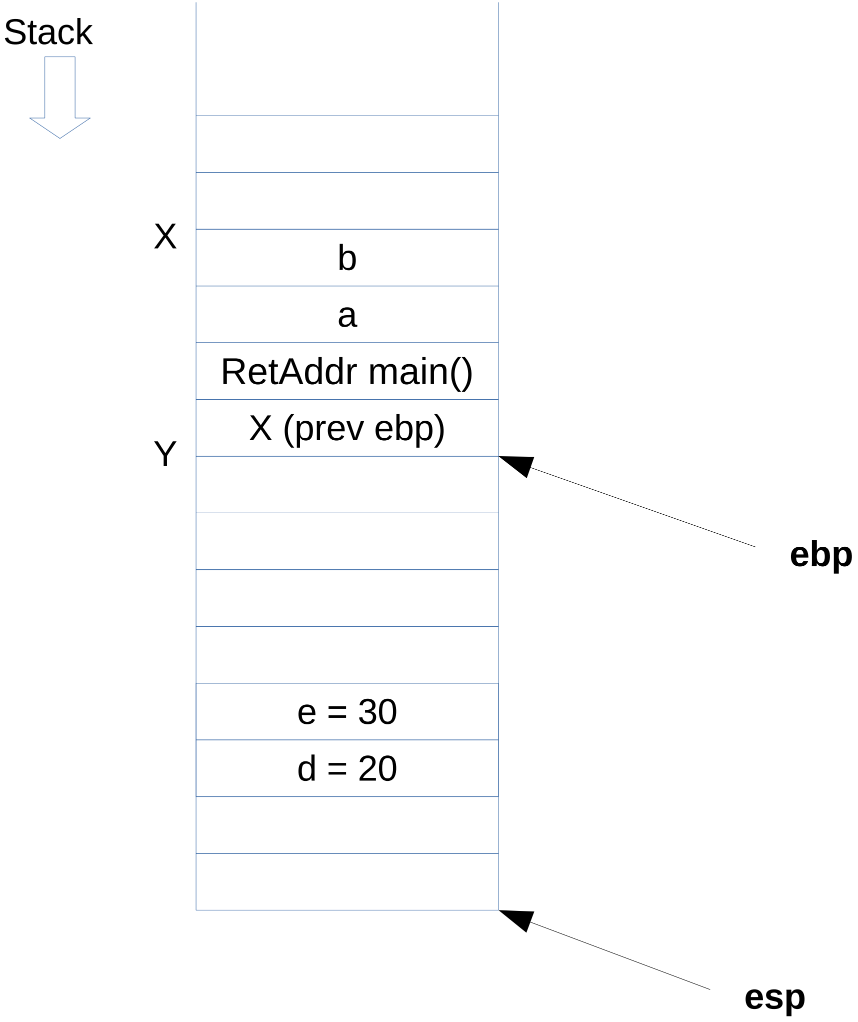
```
int mult(int a, int b) {
        int c, d = 20, e = 30, f;
        f = add(d, e);
        c = a * b + f;
        return c;
}
int add(int x, int y) {
        int z;
        z = x + y;
        return z;
}
```

```
mult:
    pushl   %ebp
    movl    %esp, %ebp
    subl    $24, %esp
    movl    $20, -24(%ebp)
    movl    $30, -20(%ebp)
    subl    $8, %esp
    pushl   -20(%ebp)
    pushl   -24(%ebp)
    call    add
```



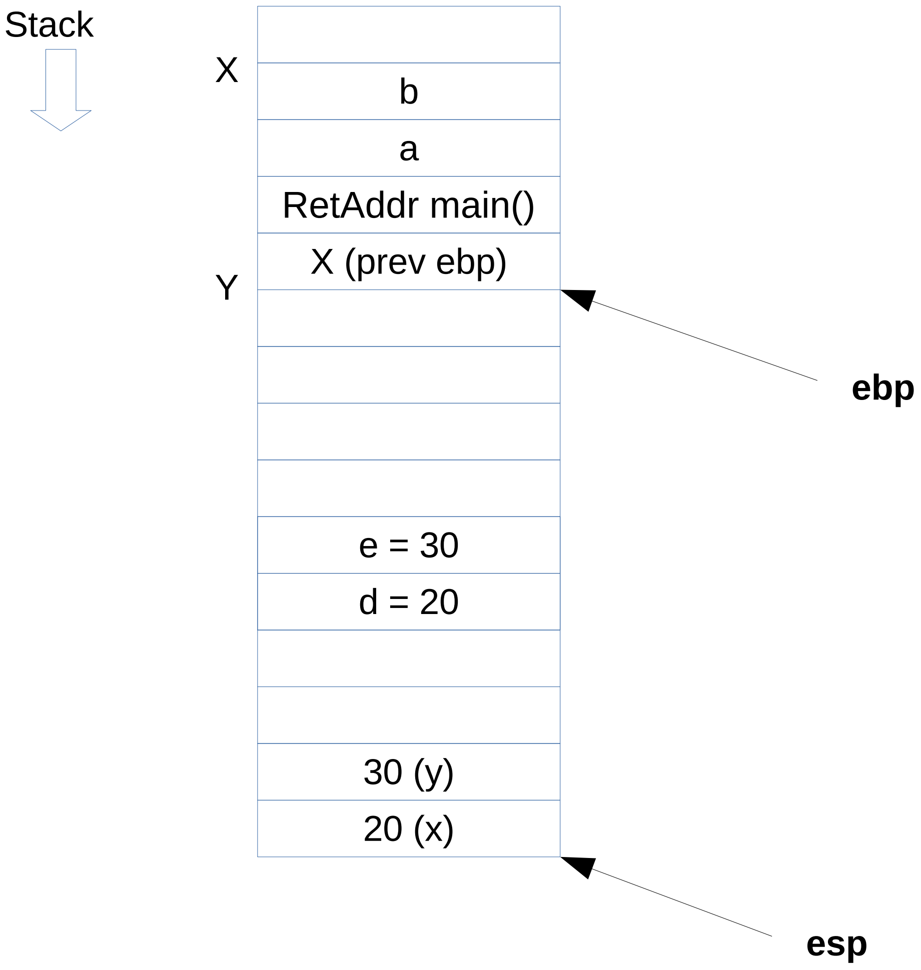
```
int mult(int a, int b) {
        int c, d = 20, e = 30, f;
        f = add(d, e);
        c = a * b + f;
        return c;
}
int add(int x, int y) {
        int z;
        z = x + y;
        return z;
}
```

```
mult:
        pushl   %ebp
        movl    %esp, %ebp
        subl    $24, %esp
        movl    $20, -24(%ebp)
        movl    $30, -20(%ebp)
        subl    $8, %esp
        pushl   -20(%ebp)
        pushl   -24(%ebp)
        call    add
```



```
int mult(int a, int b) {
        int c, d = 20, e = 30, f;
        f = add(d, e);
        c = a * b + f;
        return c;
}
int add(int x, int y) {
        int z;
        z = x + y;
        return z;
}
```

```
mult:
        pushl   %ebp
        movl    %esp, %ebp
        subl   $24, %esp
        movl    $20, -24(%ebp)
        movl    $30, -20(%ebp)
        subl    $8, %esp
        pushl   -20(%ebp)
        pushl   -24(%ebp)
        call    add
```



Stack

X

b

a

RetAddr main()

X (prev ebp)

Y

e = 30

d = 20

30 (y)

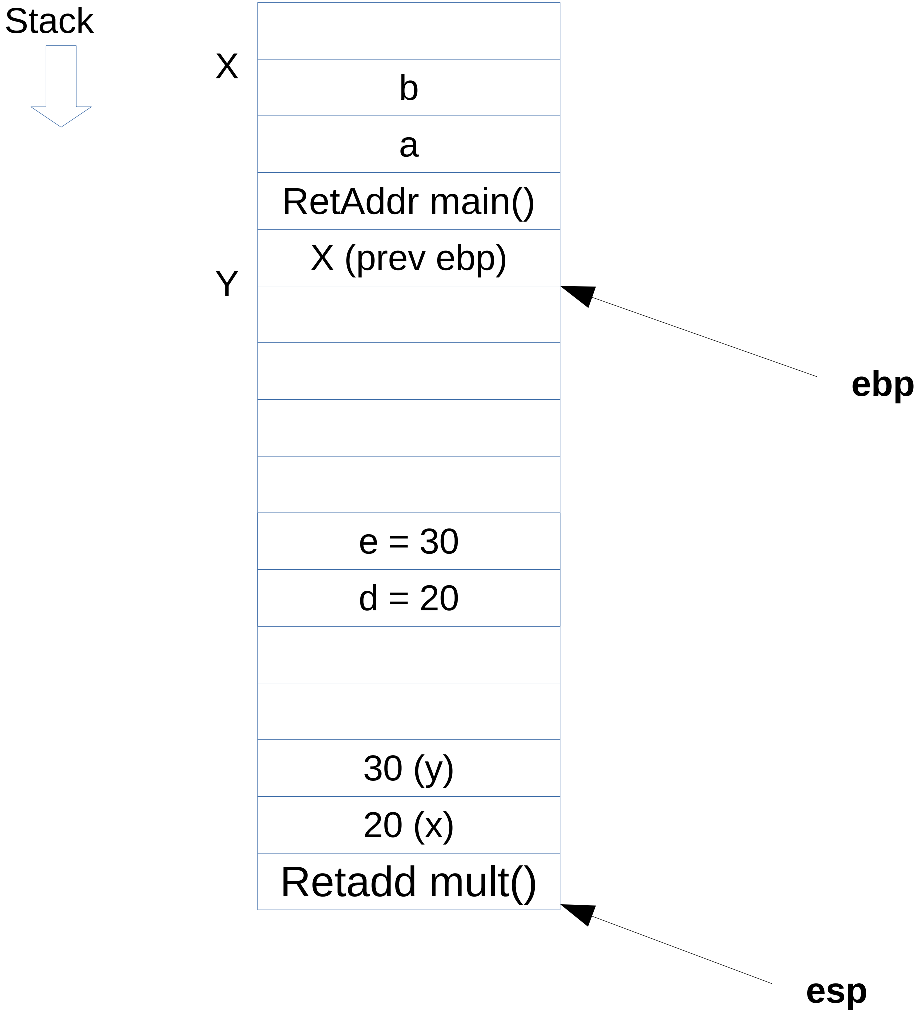
20 (x)

ebp

esp

```
int mult(int a, int b) {
        int c, d = 20, e = 30, f;
        f = add(d, e);
        c = a * b + f;
        return c;
}
int add(int x, int y) {
        int z;
        z = x + y;
        return z;
}
```

```
mult:
        pushl   %ebp
        movl    %esp, %ebp
        subl    $24, %esp
        movl    $20, -24(%ebp)
        movl    $30, -20(%ebp)
        subl    $8, %esp
        pushl   -20(%ebp)
        pushl   -24(%ebp)
        call    add
```



Stack

X

b

a

RetAddr main()

Y

X (prev ebp)

e = 30

d = 20

30 (y)

20 (x)

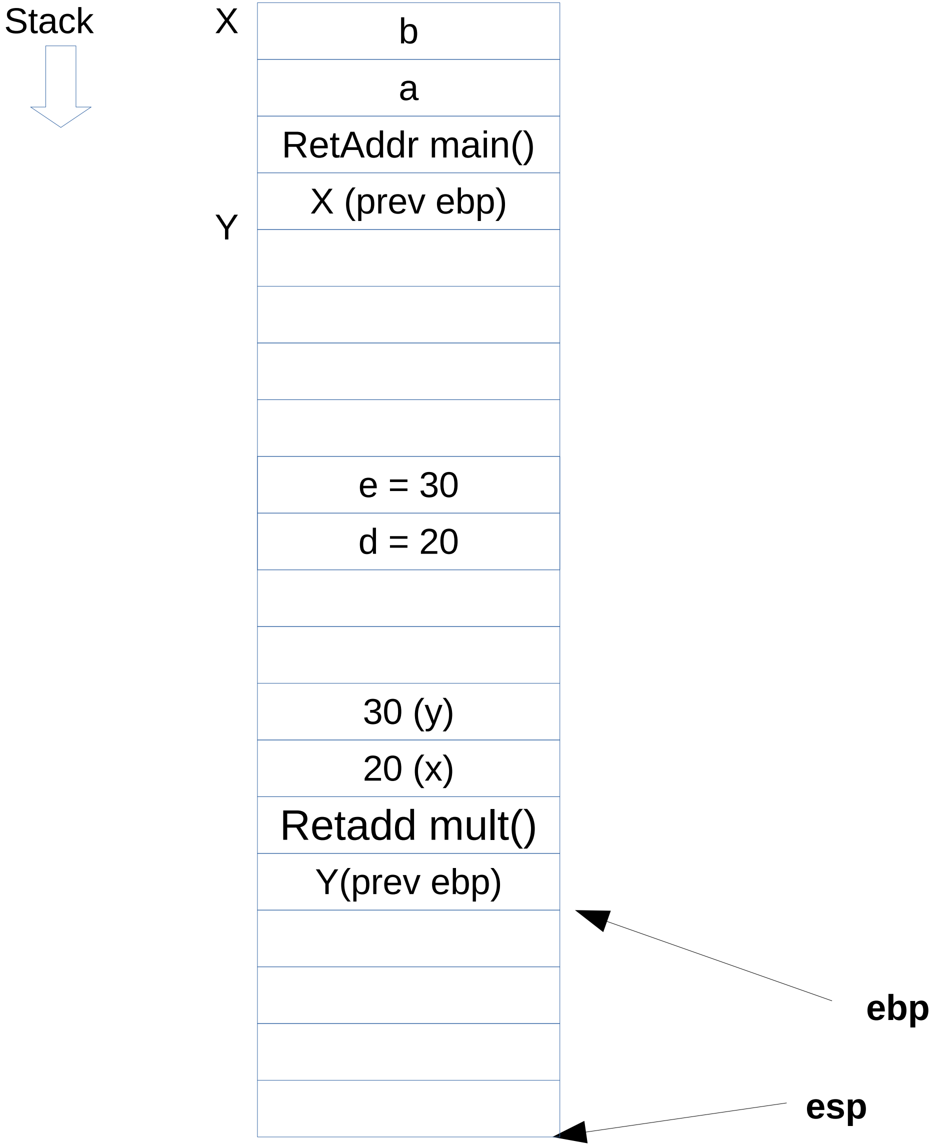
Retadd mult()

ebp

esp

```
int mult(int a, int b) {
        int c, d = 20, e = 30, f;
        f = add(d, e);
        c = a * b + f;
        return c;
}
int add(int x, int y) {
        int z;
        z = x + y;
        return z;
}
```

```
mult:
        pushl   %ebp
        movl    %esp, %ebp
        subl    $24, %esp
        movl    $20, -24(%ebp)
        movl    $30, -20(%ebp)
        subl    $8, %esp
        pushl   -20(%ebp)
        pushl   -24(%ebp)
        call    add
```



Stack

X

b

a

RetAddr main()

X (prev ebp)

Y

e = 30

d = 20

30 (y)

20 (x)

Retadd mult()

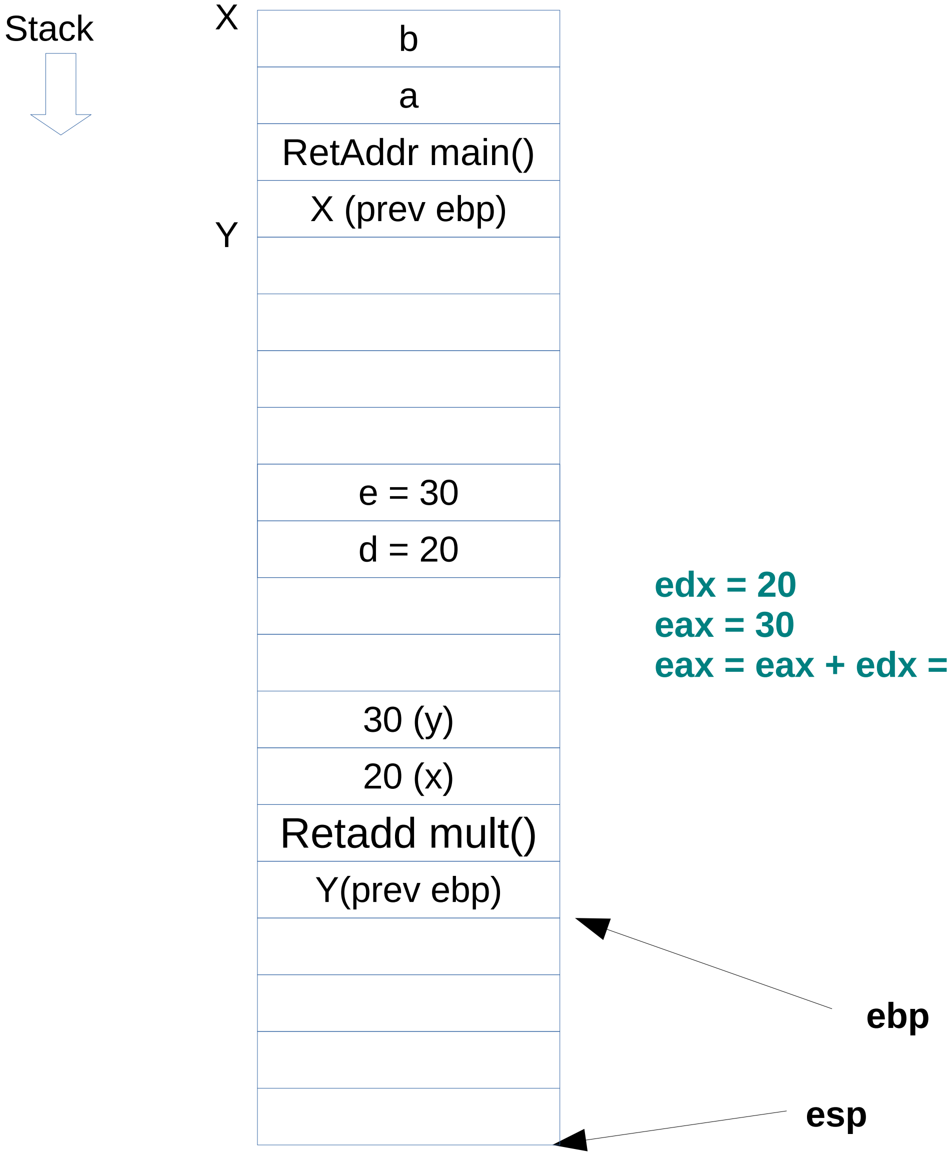
Y(prev ebp)

ebp

esp

```
int mult(int a, int b) {
        int c, d = 20, e = 30, f;
        f = add(d, e);
        c = a * b + f;
        return c;
}
int add(int x, int y) {
        int z;
        z = x + y;
        return z;
}
```

```
add:
        pushl   %ebp
        movl    %esp, %ebp
        subl    $16, %esp
        movl    8(%ebp), %edx
        movl    12(%ebp), %eax
        addl    %edx, %eax
        movl    %eax, -4(%ebp)
        movl    -4(%ebp), %eax
        leave
        ret
```



Stack

X

Y

b

a

RetAddr main()

X (prev ebp)

e = 30

d = 20

30 (y)

20 (x)

Retadd mult()

Y(prev ebp)

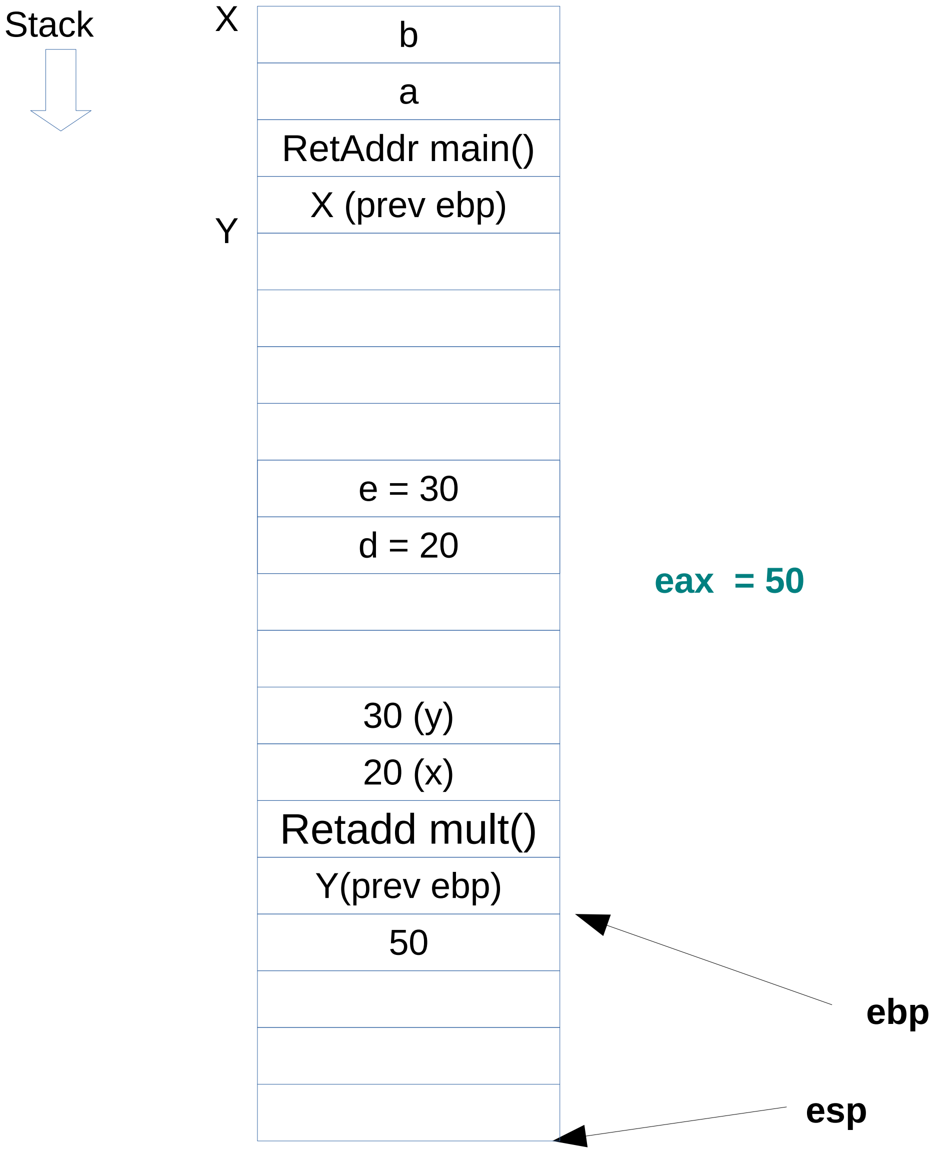
ebp

esp

edx = 20
eax = 30
eax = eax + edx = 50

```
int mult(int a, int b) {
        int c, d = 20, e = 30, f;
        f = add(d, e);
        c = a * b + f;
        return c;
}
int add(int x, int y) {
        int z;
        z = x + y;
        return z;
}
```

```
add:
        pushl   %ebp
        movl    %esp, %ebp
        subl    $16, %esp
        movl    8(%ebp), %edx
        movl    12(%ebp), %eax
        addl    %edx, %eax
        movl    %eax, -4(%ebp)
        movl    -4(%ebp), %eax
        leave
        ret
```

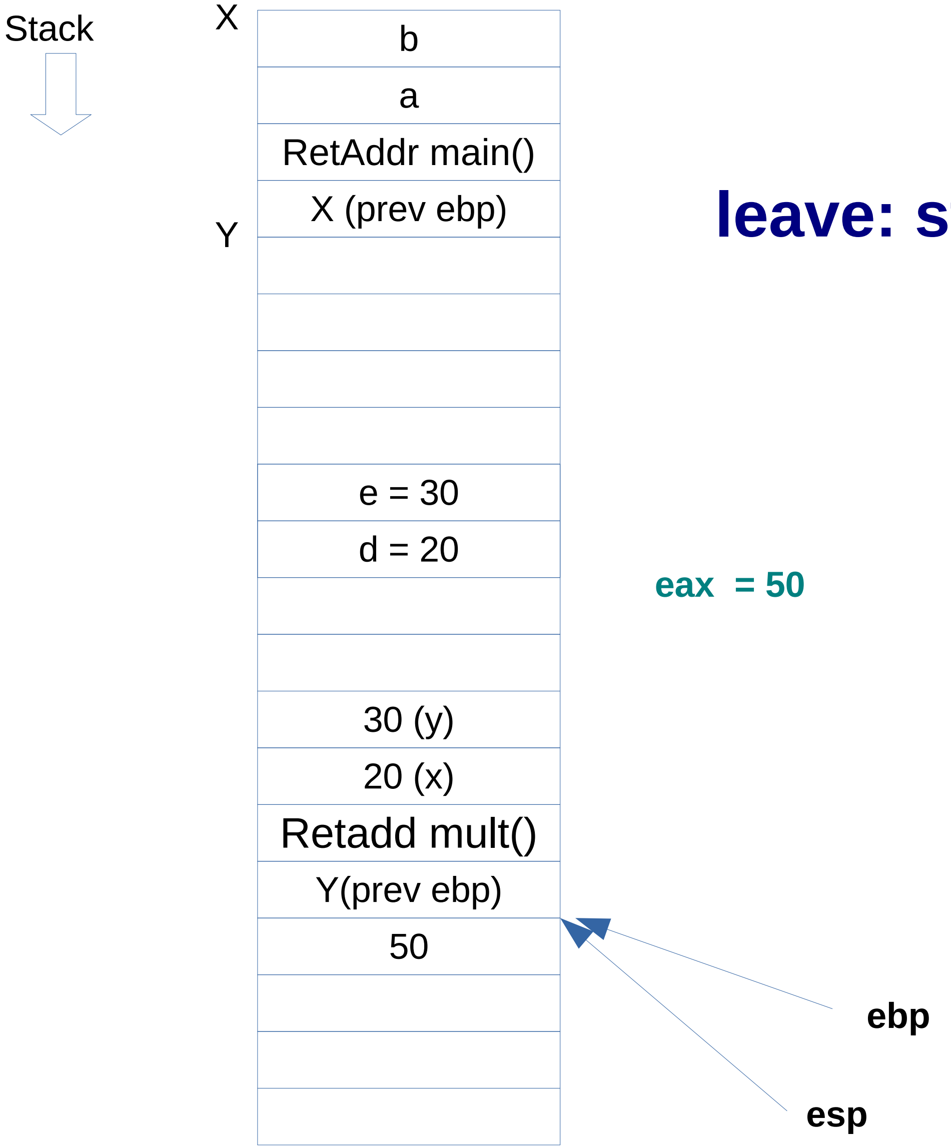


```
int mult(int a, int b) {
        int c, d = 20, e = 30, f;
        f = add(d, e);
        c = a * b + f;
        return c;
}
int add(int x, int y) {
        int z;
        z = x + y;
        return z;
}
```

```
add:
        pushl   %ebp
        movl    %esp, %ebp
        subl   $16, %esp
        movl    8(%ebp), %edx
        movl    12(%ebp), %eax
        addl   %edx, %eax
        movl    %eax, -4(%ebp)
        movl    -4(%ebp), %eax
        leave
        ret
```

Some redundant code generated here.
Before “leave”. Result is in eax

leave: step 1

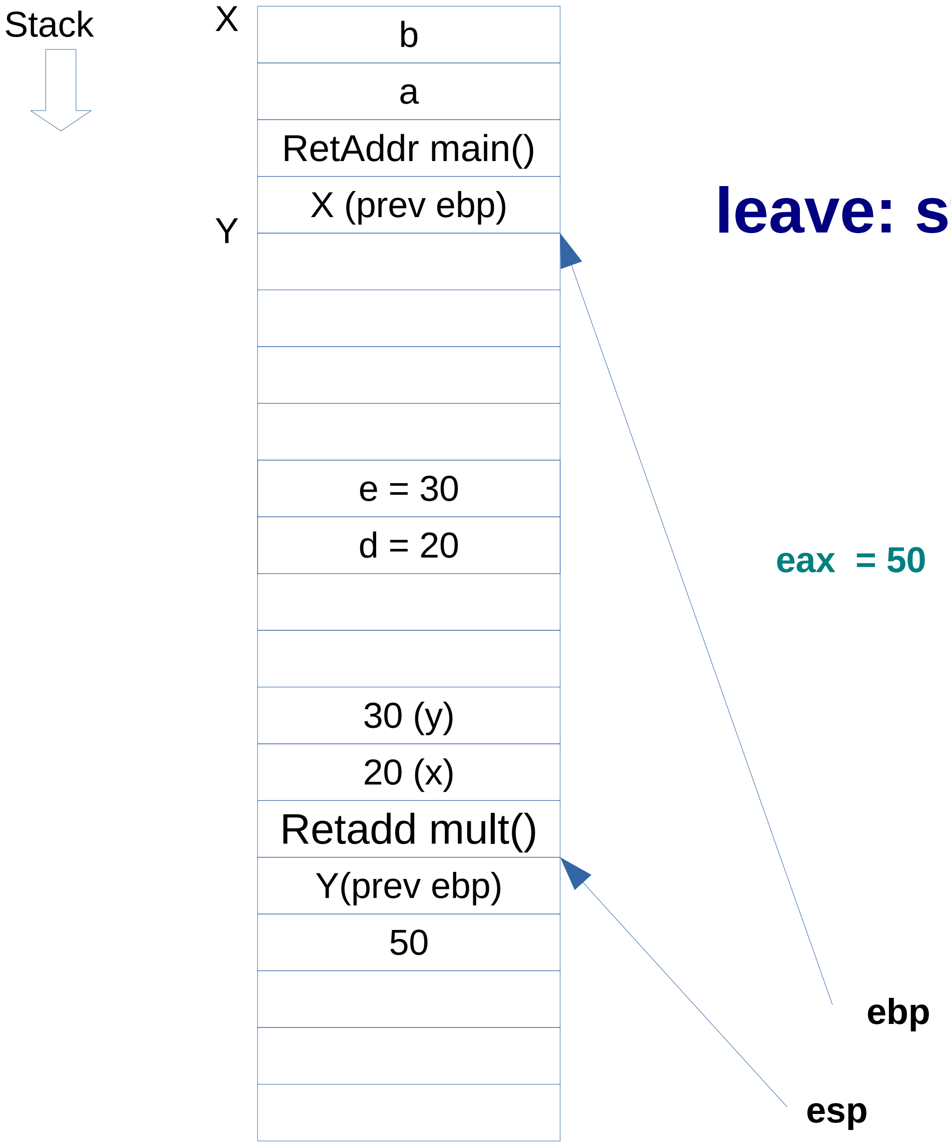


eax = 50

```
int mult(int a, int b) {
        int c, d = 20, e = 30, f;
        f = add(d, e);
        c = a * b + f;
        return c;
}
int add(int x, int y) {
        int z;
        z = x + y;
        return z;
}
```

```
add:
        pushl   %ebp
        movl    %esp, %ebp
        subl    $16, %esp
        movl    8(%ebp), %edx
        movl    12(%ebp), %eax
        addl    %edx, %eax
        movl    %eax, -4(%ebp)
        movl    -4(%ebp), %eax
          leave # # Set ESP to EBP,
then pop EBP.
        ret
```

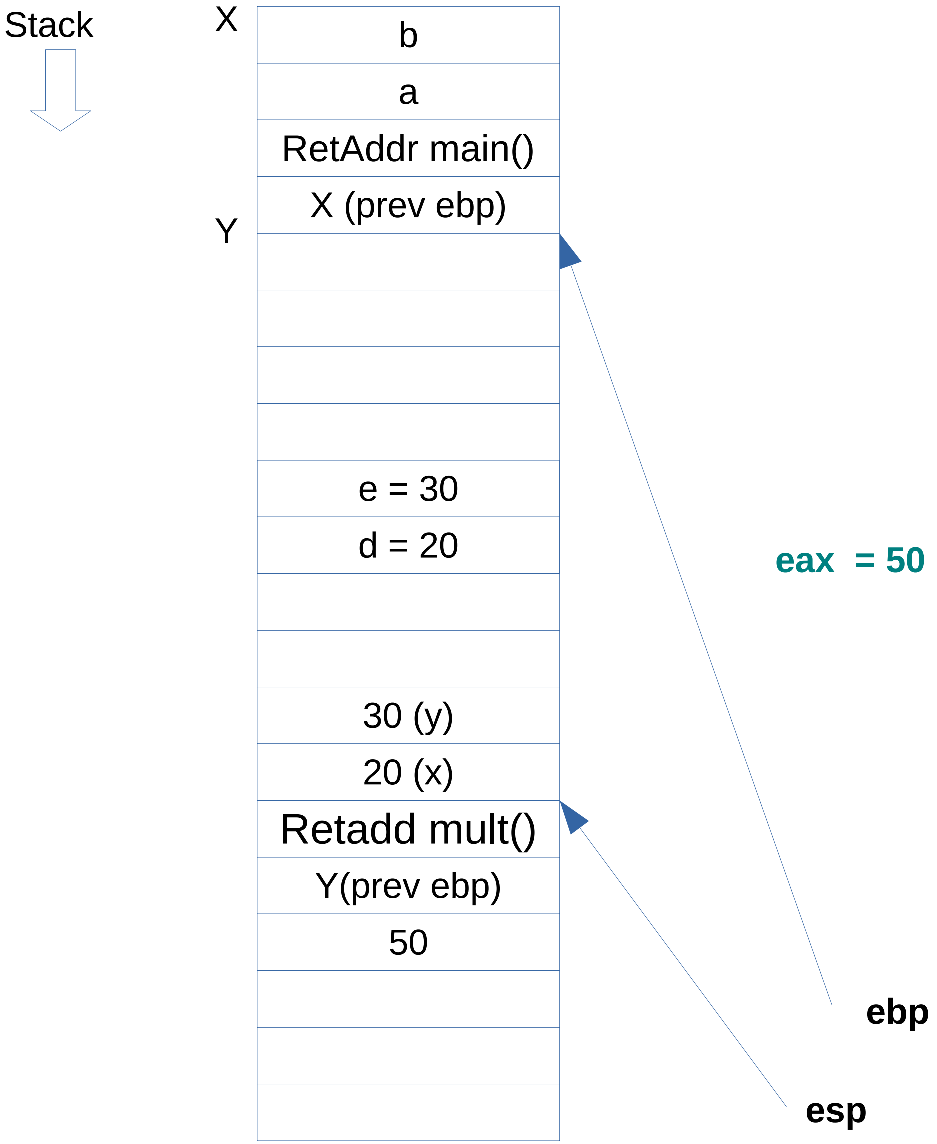
leave: step 2



eax = 50

```
int mult(int a, int b) {
        int c, d = 20, e = 30, f;
        f = add(d, e);
        c = a * b + f;
        return c;
}
int add(int x, int y) {
        int z;
        z = x + y;
        return z;
}
```

```
add:
        pushl   %ebp
        movl    %esp, %ebp
        subl    $16, %esp
        movl    8(%ebp), %edx
        movl    12(%ebp), %eax
        addl    %edx, %eax
        movl    %eax, -4(%ebp)
        movl    -4(%ebp), %eax
          leave # # Set ESP to EBP,
then pop EBP.
        ret
```



b

a

RetAddr main()

X (prev ebp)

e = 30

d = 20

30 (y)

20 (x)

Retadd mult()

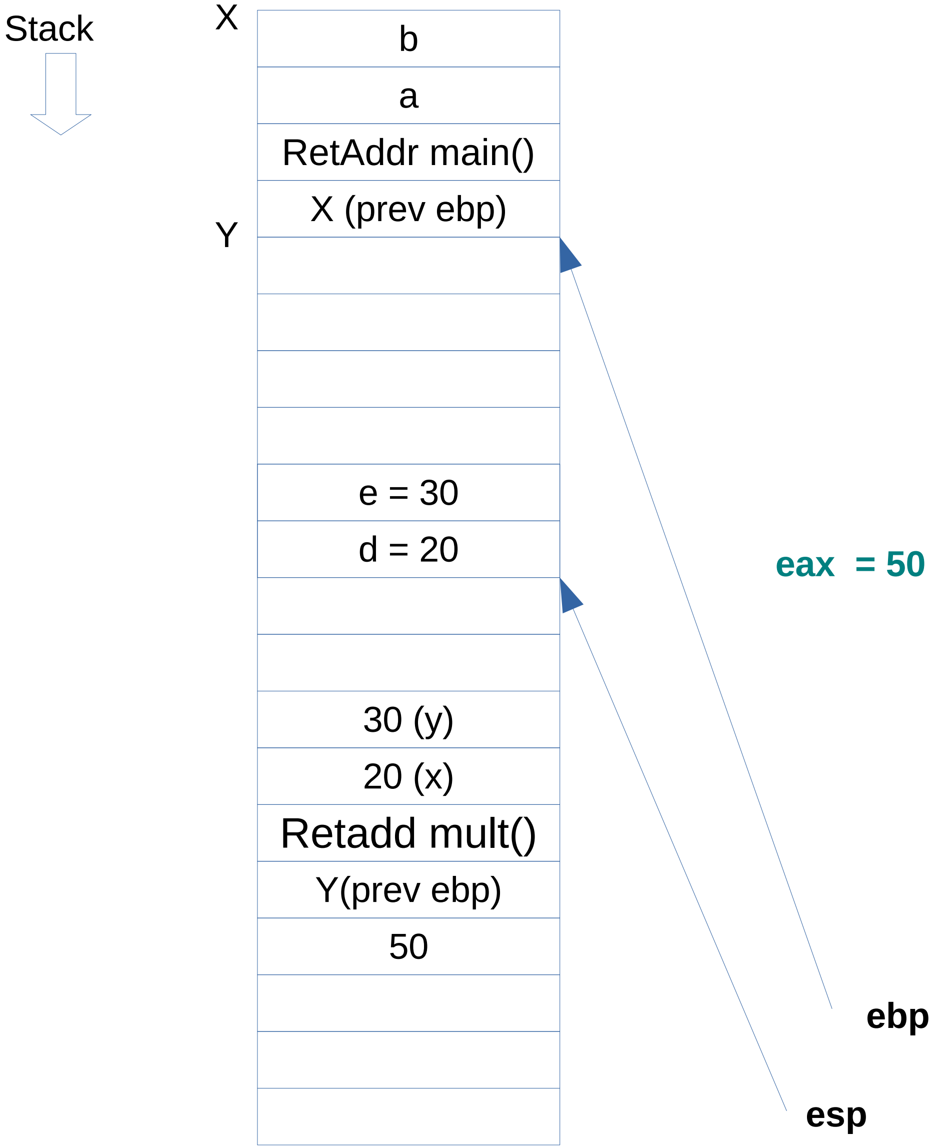
Y(prev ebp)

50

eax = 50

```
int mult(int a, int b) {
        int c, d = 20, e = 30, f;
        f = add(d, e); // here
        c = a * b + f;
        return c;
}
int add(int x, int y) {
        int z;
        z = x + y;
        return z;
}
```

```
add:
        pushl   %ebp
        movl    %esp, %ebp
        subl    $16, %esp
        movl    8(%ebp), %edx
        movl    12(%ebp), %eax
        addl    %edx, %eax
        movl    %eax, -4(%ebp)
        movl    -4(%ebp), %eax
          leave # # Set ESP to EBP,
then pop EBP.
        ret
```



Stack

X

b

a

RetAddr main()

X (prev ebp)

Y

e = 30

d = 20

30 (y)

20 (x)

Retadd mult()

Y(prev ebp)

50

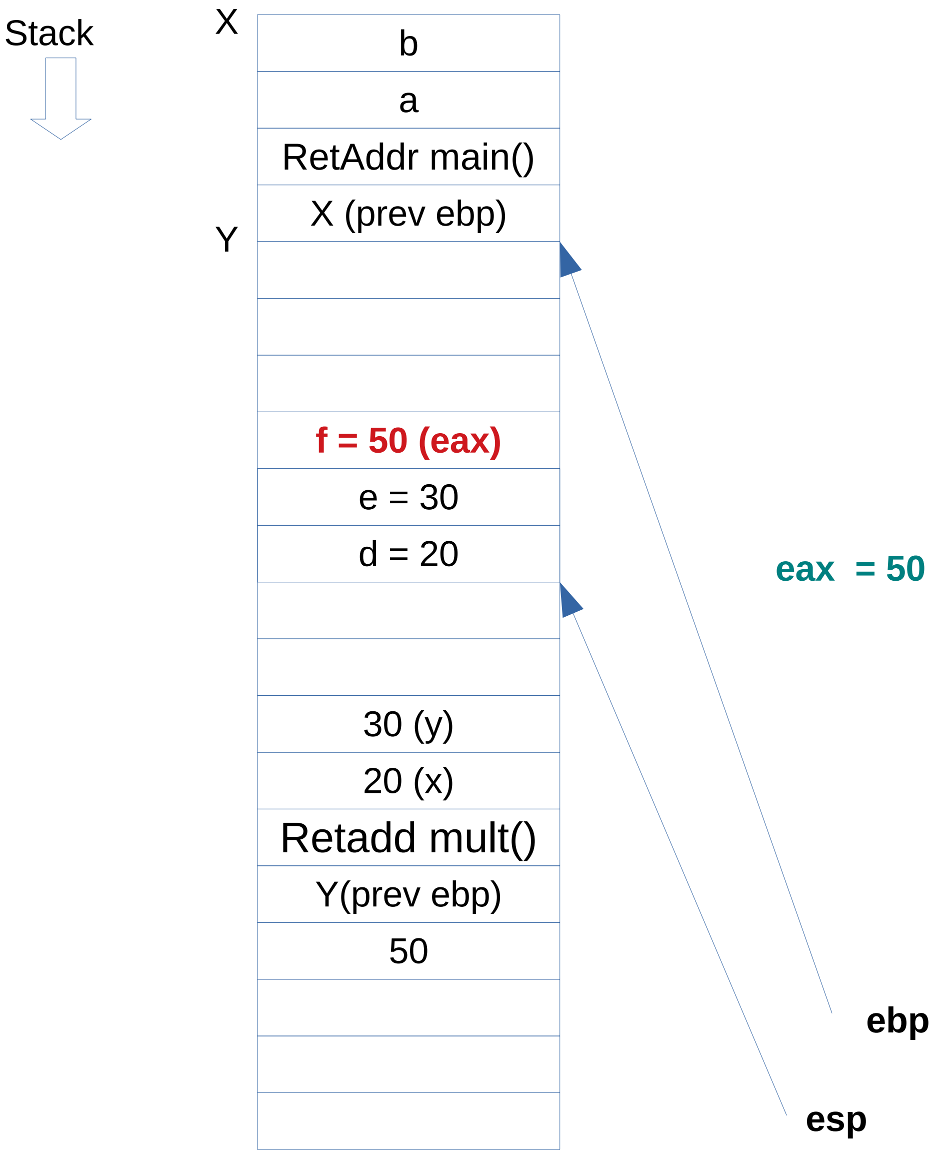
eax = 50

ebp

esp

```
int mult(int a, int b) {
        int c, d = 20, e = 30, f;
        f = add(d, e); // here
        c = a * b + f;
        return c;
}
int add(int x, int y) {
        int z;
        z = x + y;
        return z;
}
```

```
Mult:
    ....
      call    add
    addl    $16, %esp
    movl    %eax, -16(%ebp)
    movl    8(%ebp), %eax
    imull   12(%ebp), %eax
    movl    %eax, %edx
    movl    -16(%ebp), %eax
    addl    %edx, %eax
    movl    %eax, -12(%ebp)
    movl    -12(%ebp), %eax
    leave
    ret
```



Stack

X

b

a

RetAddr main()

X (prev ebp)

Y

f = 50 (eax)

e = 30

d = 20

30 (y)

20 (x)

Retadd mult()

Y(prev ebp)

50

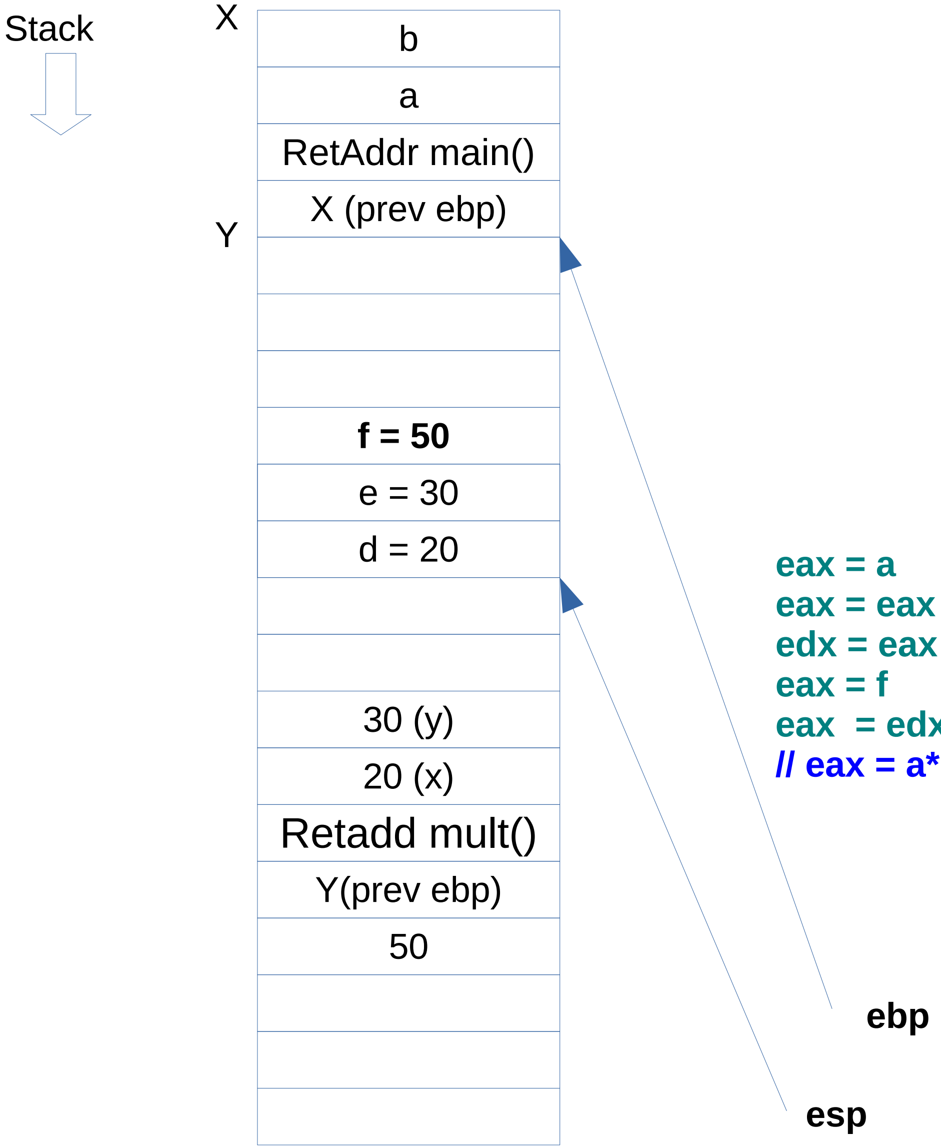
eax = 50

ebp

esp

```
int mult(int a, int b) {
        int c, d = 20, e = 30, f;
        f = add(d, e);
        c = a * b + f;
        return c;
}
int add(int x, int y) {
        int z;
        z = x + y;
        return z;
}
```

```
Mult:
        ....
          call    add
        addl    $16, %esp
        movl    %eax, -16(%ebp)
        movl    8(%ebp), %eax
        imull   12(%ebp), %eax
        movl    %eax, %edx
        movl    -16(%ebp), %eax
        addl    %edx, %eax
        movl    %eax, -12(%ebp)
        movl    -12(%ebp), %eax
        leave
        ret
```



Stack

X

Y

b
a
RetAddr main()
X (prev ebp)

f = 50
e = 30
d = 20

30 (y)
20 (x)
Retadd mult()
Y(prev ebp)
50

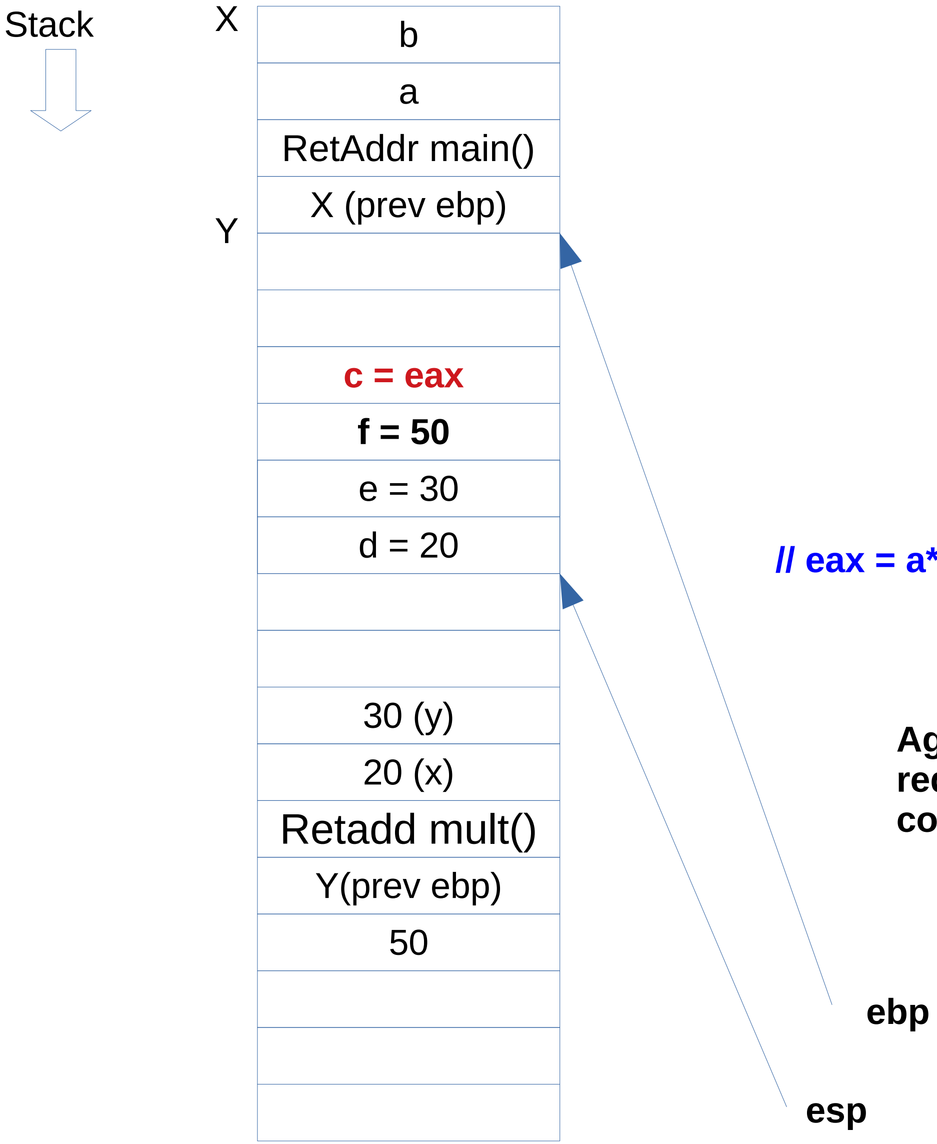
ebp

esp

```
int mult(int a, int b) {
        int c, d = 20, e = 30, f;
        f = add(d, e);
        c = a * b + f;
        return c;
}
int add(int x, int y) {
        int z;
        z = x + y;
        return z;
}
```

```
eax = a
eax = eax * b
edx = eax
eax = f
eax  = edx + eax
// eax = a*b + f
```

```
Mult:
        ....
          call    add
        addl    $16, %esp
        movl     %eax, -16(%ebp)
        movl     8(%ebp), %eax
        imull   12(%ebp), %eax
        movl     %eax, %edx
        movl     -16(%ebp), %eax
        addl    %edx, %eax
        movl    %eax, -12(%ebp)
        movl    -12(%ebp), %eax
        leave
        ret
```

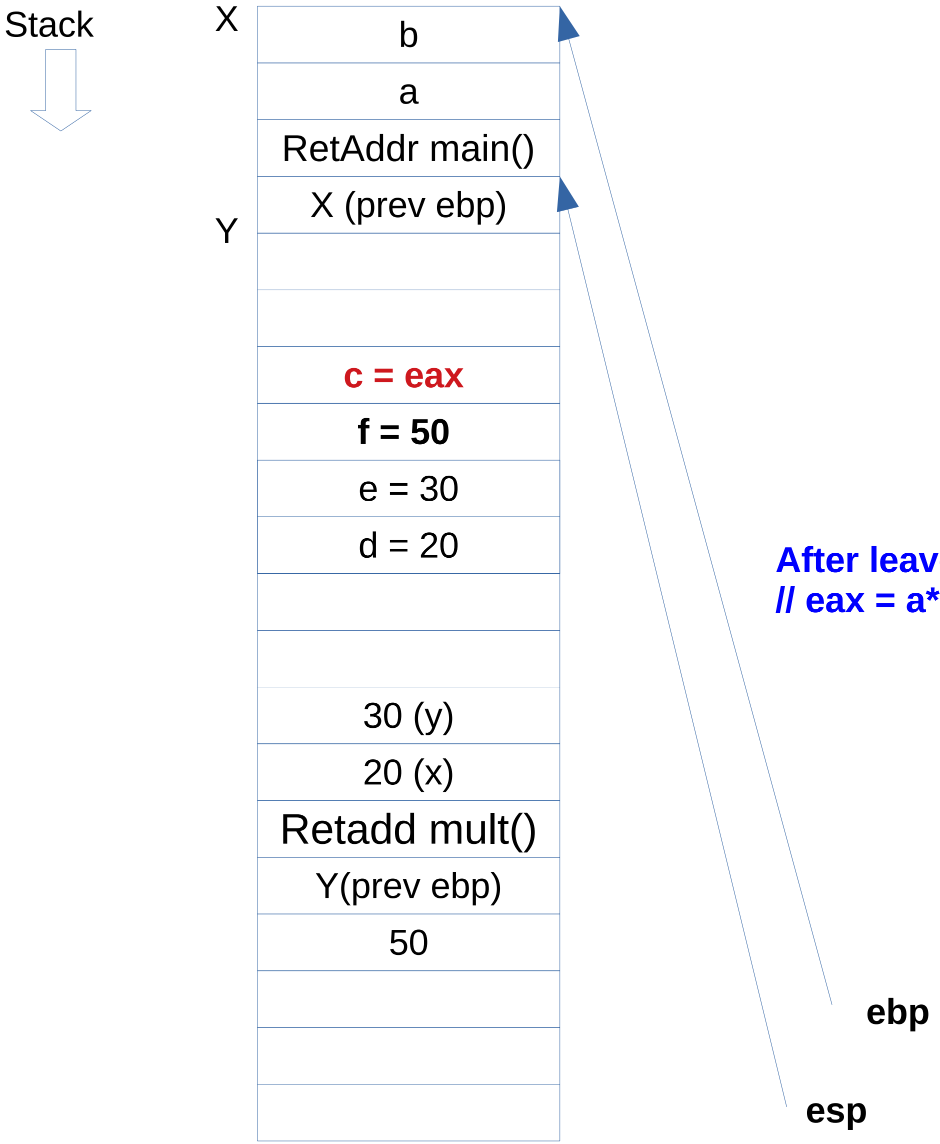


// eax = a*b + f

Again some redundant code

```
int mult(int a, int b) {
        int c, d = 20, e = 30, f;
        f = add(d, e);
        c = a * b + f;
        return c;
}
int add(int x, int y) {
        int z;
        z = x + y;
        return z;
}
```

```
Mult:
        ....
          call    add
        addl    $16, %esp
        movl    %eax, -16(%ebp)
        movl    8(%ebp), %eax
        imull   12(%ebp), %eax
        movl    %eax, %edx
        movl    -16(%ebp), %eax
        addl    %edx, %eax
        movl    %eax, -12(%ebp)
        movl    -12(%ebp), %eax
        leave
        ret
```



Stack

X
b
a
RetAddr main()
X (prev ebp)

Y

c = eax
f = 50
e = 30
d = 20

30 (y)
20 (x)
Retadd mult()
Y(prev ebp)
50

ebp

esp

After leave
// eax = a*b + f

```
int mult(int a, int b) {
        int c, d = 20, e = 30, f;
        f = add(d, e);
        c = a * b + f;
        return c;
}
int add(int x, int y) {
        int z;
        z = x + y;
        return z;
}
```

```
Mult:
        ....
          call    add
        addl    $16, %esp
        movl     %eax, -16(%ebp)
        movl    8(%ebp), %eax
        imull   12(%ebp), %eax
        movl    %eax, %edx
        movl    -16(%ebp), %eax
        addl    %edx, %eax
        movl    %eax, -12(%ebp)
        movl    -12(%ebp), %eax
        leave
        ret
```

Lessons

- Calling function (caller)
  - Pushes arguments on stack , copies values
- On call
  - Return IP is pushed
- Initially in called function (callee)
  - Old ebp is pushed
  - ebp = stack
  - Stack is decremented to make space for local variables

Lessons

- **Before Return**
  - **Ensure that result is in ‘eax**
- **On Return**
  - **stack = ebp**
  - **Pop ebp (ebp = old ebp)**
- **On ‘ret’**
  - **Pop ‘return IP’ and go back in old function**

Lessons

- This was a demonstration for a
  - User program, compiled with GCC, On Linux
  - Followed the conventions we discussed earlier
- Applicable to
  - C programs which work using LIFO function calls
- Compiler can’t be used to generate code using this mechanism for
  - Functions like fork(), exec(), scheduler(), etc.
  - Boot code of OS