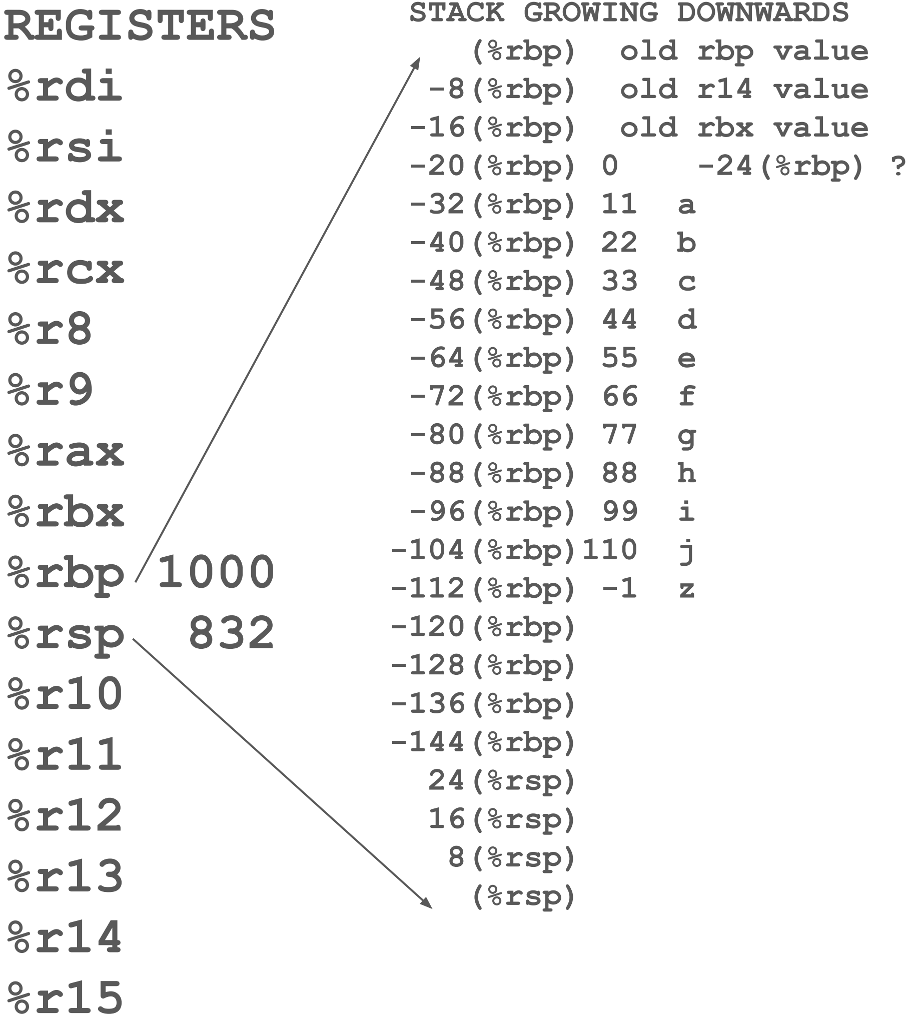
# Stack Frame Tracing

```c
#include <stdio.h>  // program to be compiled to X86-64
long test();

int main(void)
{ long a=11; long b=22; long c= 33; long d= 44; long e= 55; long f= 66;
  long g= 77; long h= 88; long i= 99; long j= 110;  long z = -1;
  z=test(a,b,c,d,e,f,g,h,i,j);
  printf("z=%ld\n",z);return 1;
}

long test(long a, long b, long c, long d, long e, long f, long g, long h, long i, long j){
    long x =  a+b+c+d+e+f+g+h+i+j;
    long y =  a+b+c+d+e;
    long z =  x-y;
    return z;
}
```



# REGISTERS

%rdi
%rsi
%rdx
%rcx
%r8
%r9
%rax
%rbx
%rbp 1000
%rsp 832
%r10
%r11
%r12
%r13
%r14
%r15

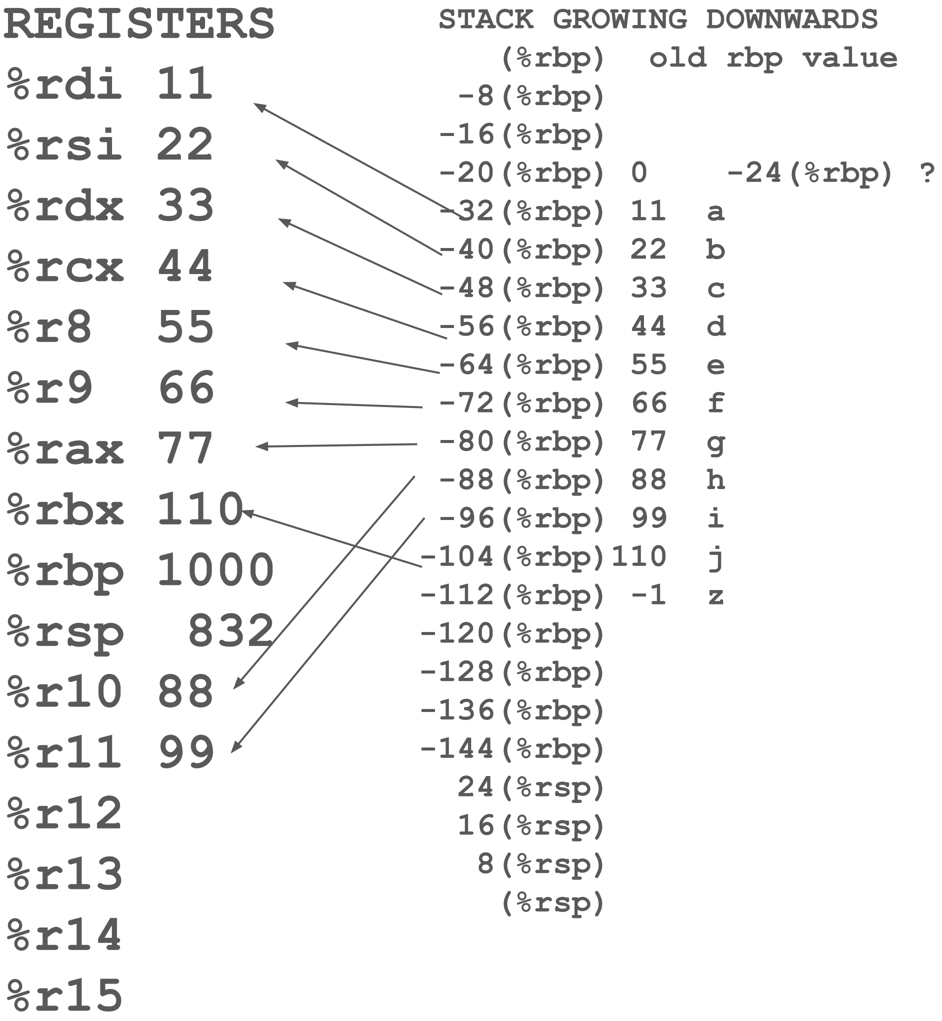
## STACK GROWING DOWNWARDS

| | | | |
|---|---|---|---|
| (%rbp) | old rbp value | | |
| -8(%rbp) | old r14 value | | |
| -16(%rbp) | old rbx value | | |
| -20(%rbp) | 0 | -24(%rbp) | ? |
| -32(%rbp) | 11 | a | |
| -40(%rbp) | 22 | b | |
| -48(%rbp) | 33 | c | |
| -56(%rbp) | 44 | d | |
| -64(%rbp) | 55 | e | |
| -72(%rbp) | 66 | f | |
| -80(%rbp) | 77 | g | |
| -88(%rbp) | 88 | h | |
| -96(%rbp) | 99 | i | |
| -104(%rbp) | 110 | j | |
| -112(%rbp) | -1 | z | |
| -120(%rbp) | | | |
| -128(%rbp) | | | |
| -136(%rbp) | | | |
| -144(%rbp) | | | |
| 24(%rsp) | | | |
| 16(%rsp) | | | |
| 8(%rsp) | | | |
| (%rsp) | | | |

```
int main(void)
{ long a=11; long b=22; long c= 33; long d= 44; long e= 55; long f= 66;
  long g= 77; long h= 88; long i= 99; long j= 110;  long z = -1;
  z=test(a,b,c,d,e,f,g,h,i,j);
  printf("z=%ld\n",z);return 1;
}
```

```
_main:                              ## @main
## %bb.0:          ## PROLOGUE
pushq %rbp         ## push base of previous frame into stack
movq  %rsp, %rbp   ## store rsp as base of current frame
pushq %r14         ## store callee saved registers
pushq %rbx         ## that are used below
subq  $144, %rsp ## CREATE STACK FRAME (18 longs)

        movl  $0, -20(%rbp)
        movq  $11, -32(%rbp)
        movq  $22, -40(%rbp)
        movq  $33, -48(%rbp)
        movq  $44, -56(%rbp)
        movq  $55, -64(%rbp)
        movq  $66, -72(%rbp)
        movq  $77, -80(%rbp)
        movq  $88, -88(%rbp)
        movq  $99, -96(%rbp)
        movq  $110, -104(%rbp)
        movq  $-1, -112(%rbp)
```



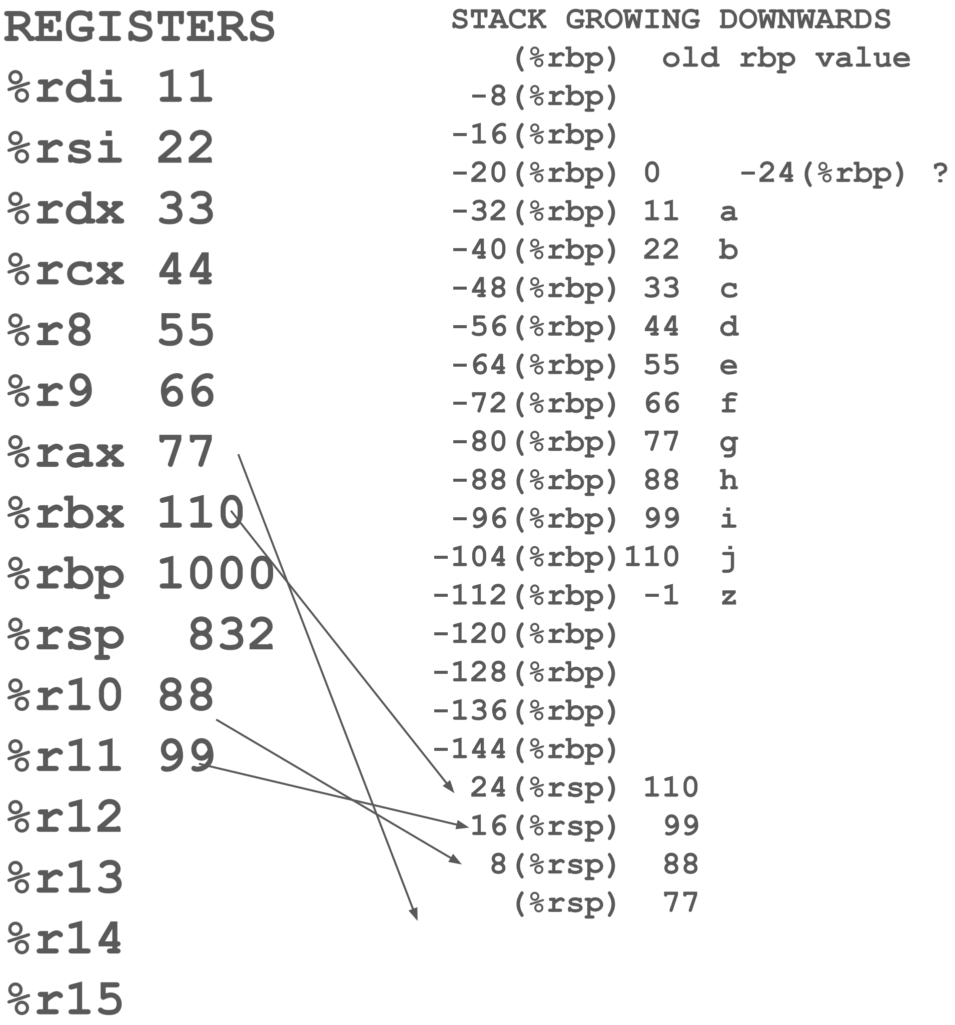
## REGISTERS

| | |
|---|---|
| %rdi | 11 |
| %rsi | 22 |
| %rdx | 33 |
| %rcx | 44 |
| %r8 | 55 |
| %r9 | 66 |
| %rax | 77 |
| %rbx | 110 |
| %rbp | 1000 |
| %rsp | 832 |
| %r10 | 88 |
| %r11 | 99 |
| %r12 | |
| %r13 | |
| %r14 | |
| %r15 | |

## STACK GROWING DOWNWARDS

| | | | |
|---|---|---|---|
| (%rbp) | old rbp value | | |
| -8(%rbp) | | | |
| -16(%rbp) | | | |
| -20(%rbp) | 0 | | -24(%rbp) ? |
| -32(%rbp) | 11 | a | |
| -40(%rbp) | 22 | b | |
| -48(%rbp) | 33 | c | |
| -56(%rbp) | 44 | d | |
| -64(%rbp) | 55 | e | |
| -72(%rbp) | 66 | f | |
| -80(%rbp) | 77 | g | |
| -88(%rbp) | 88 | h | |
| -96(%rbp) | 99 | i | |
| -104(%rbp) | 110 | j | |
| -112(%rbp) | -1 | z | |
| -120(%rbp) | | | |
| -128(%rbp) | | | |
| -136(%rbp) | | | |
| -144(%rbp) | | | |
| 24(%rsp) | | | |
| 16(%rsp) | | | |
| 8(%rsp) | | | |
| (%rsp) | | | |

```
int main(void)
{ long a=11; long b=22; long c= 33; long d= 44; long e= 55; long f= 66;
  long g= 77; long h= 88; long i= 99; long j= 110;  long z = -1;
  z=test(a,b,c,d,e,f,g,h,i,j);
  printf("z=%ld\n",z);return 1;
}
 # move params from stack to registers
          movq  -32(%rbp), %rdi
          movq  -40(%rbp), %rsi
          movq  -48(%rbp), %rdx
          movq  -56(%rbp), %rcx
          movq  -64(%rbp), %r8
          movq  -72(%rbp), %r9
          movq  -80(%rbp), %rax
          movq  -88(%rbp), %r10
          movq  -96(%rbp), %r11
          movq  -104(%rbp), %rbx
```



```
REGISTERS
%rdi  11
%rsi  22
%rdx  33
%rcx  44
%r8   55
%r9   66
%rax  77
%rbx  110
%rbp  1000
%rsp   832
%r10  88
%r11  99
%r12
%r13
%r14
%r15
```

```
STACK GROWING DOWNWARDS
    (%rbp)  old rbp value
  -8(%rbp)
 -16(%rbp)
 -20(%rbp)  0     -24(%rbp)  ?
 -32(%rbp)  11  a
 -40(%rbp)  22  b
 -48(%rbp)  33  c
 -56(%rbp)  44  d
 -64(%rbp)  55  e
 -72(%rbp)  66  f
 -80(%rbp)  77  g
 -88(%rbp)  88  h
 -96(%rbp)  99  i
-104(%rbp)110   j
-112(%rbp)  -1  z
-120(%rbp)
-128(%rbp)
-136(%rbp)
-144(%rbp)
  24(%rsp)  110
  16(%rsp)   99
   8(%rsp)   88
    (%rsp)   77
```

```
int main(void)
{ long a=11; long b=22; long c= 33; long d= 44; long e= 55; long f= 66;
  long g= 77; long h= 88; long i= 99; long j= 110;  long z = -1;
  z=test(a,b,c,d,e,f,g,h,i,j);
  printf("z=%ld\n",z);return 1;
}

#  set up arguments for the call
          movq      %rax, (%rsp)
          movq      %r10, 8(%rsp)
          movq      %r11, 16(%rsp)
          movq      %rbx, 24(%rsp)
          callq     _test
```

First six arguments are in registers,
Last 4 are passed on the stack

## REGISTERS

| | |
|---|---|
| %rdi | 11 |
| %rsi | 22 |
| %rdx | 33 |
| %rcx | 44 |
| %r8 | 55 |
| %r9 | 66 |
| %rax | 77 |
| %rbx | 110 |
| %rbp | 824 |
| %rsp | 816 |
| %r10 | 88 |
| %r11 | 99 |
| %r12 | |
| %r13 | |
| %r14 | |
| %r15 | |

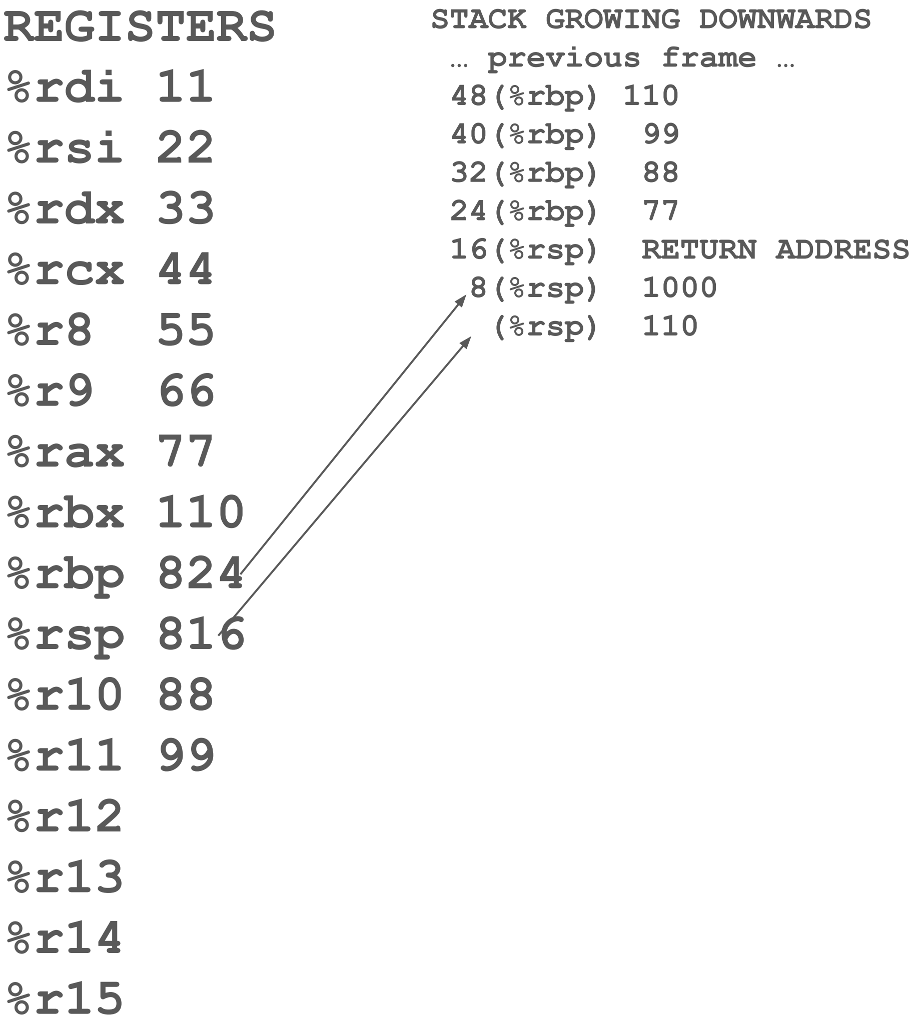
## STACK GROWING DOWNWARDS

… previous frame …

| | |
|---|---|
| 32(%rsp) | 110 |
| 24(%rsp) | 99 |
| 16(%rsp) | 88 |
| 8(%rsp) | 77 |
| (%rsp) | RETURN ADDR |

```
long test(long a, long b, long c, long d, long e, long f, long g, long h, long i, long j){
   long x =  a+b+c+d+e+f+g+h+i+j;
   long y =  a+b+c+d+e;
   long z =  x-y;
   return z;
}
```

PUSH the Return Address on the Stack and jump to the code for the new function!



## REGISTERS

| | |
|---|---|
| %rdi | 11 |
| %rsi | 22 |
| %rdx | 33 |
| %rcx | 44 |
| %r8 | 55 |
| %r9 | 66 |
| %rax | 77 |
| %rbx | 110 |
| %rbp | 824 |
| %rsp | 816 |
| %r10 | 88 |
| %r11 | 99 |
| %r12 | |
| %r13 | |
| %r14 | |
| %r15 | |

## STACK GROWING DOWNWARDS

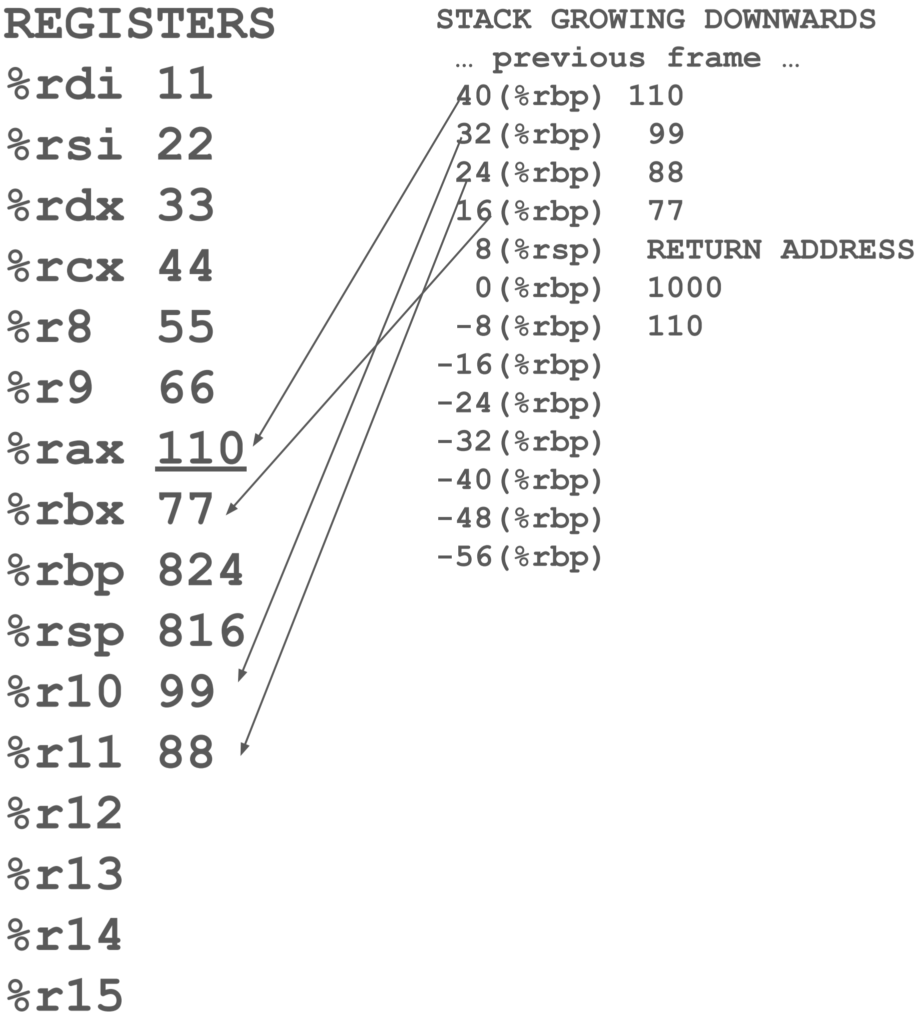
… previous frame …

| | |
|---|---|
| 48(%rbp) | 110 |
| 40(%rbp) | 99 |
| 32(%rbp) | 88 |
| 24(%rbp) | 77 |
| 16(%rsp) | RETURN ADDRESS |
| 8(%rsp) | 1000 |
| (%rsp) | 110 |

```
long test(long a, long b, long c, long d, long e, long f, long g, long h, long i, long j){
    long x =  a+b+c+d+e+f+g+h+i+j;
    long y =  a+b+c+d+e;
    long z =  x-y;
    return z;
}
```

PUSH old frame pointer onto the stack
Set new frame pointer to point to that cell
Push rbx onto the stack

```
#Prologue
_test:
pushq   %rbp
movq    %rsp, %rbp
pushq   %rbx
```



REGISTERS

| | |
|---|---|
| %rdi | 11 |
| %rsi | 22 |
| %rdx | 33 |
| %rcx | 44 |
| %r8 | 55 |
| %r9 | 66 |
| %rax | 110 |
| %rbx | 77 |
| %rbp | 824 |
| %rsp | 816 |
| %r10 | 99 |
| %r11 | 88 |
| %r12 | |
| %r13 | |
| %r14 | |
| %r15 | |

STACK GROWING DOWNWARDS

… previous frame …

| | |
|---|---|
| 40(%rbp) | 110 |
| 32(%rbp) | 99 |
| 24(%rbp) | 88 |
| 16(%rbp) | 77 |
| 8(%rsp) | RETURN ADDRESS |
| 0(%rbp) | 1000 |
| -8(%rbp) | 110 |
| -16(%rbp) | |
| -24(%rbp) | |
| -32(%rbp) | |
| -40(%rbp) | |
| -48(%rbp) | |
| -56(%rbp) | |

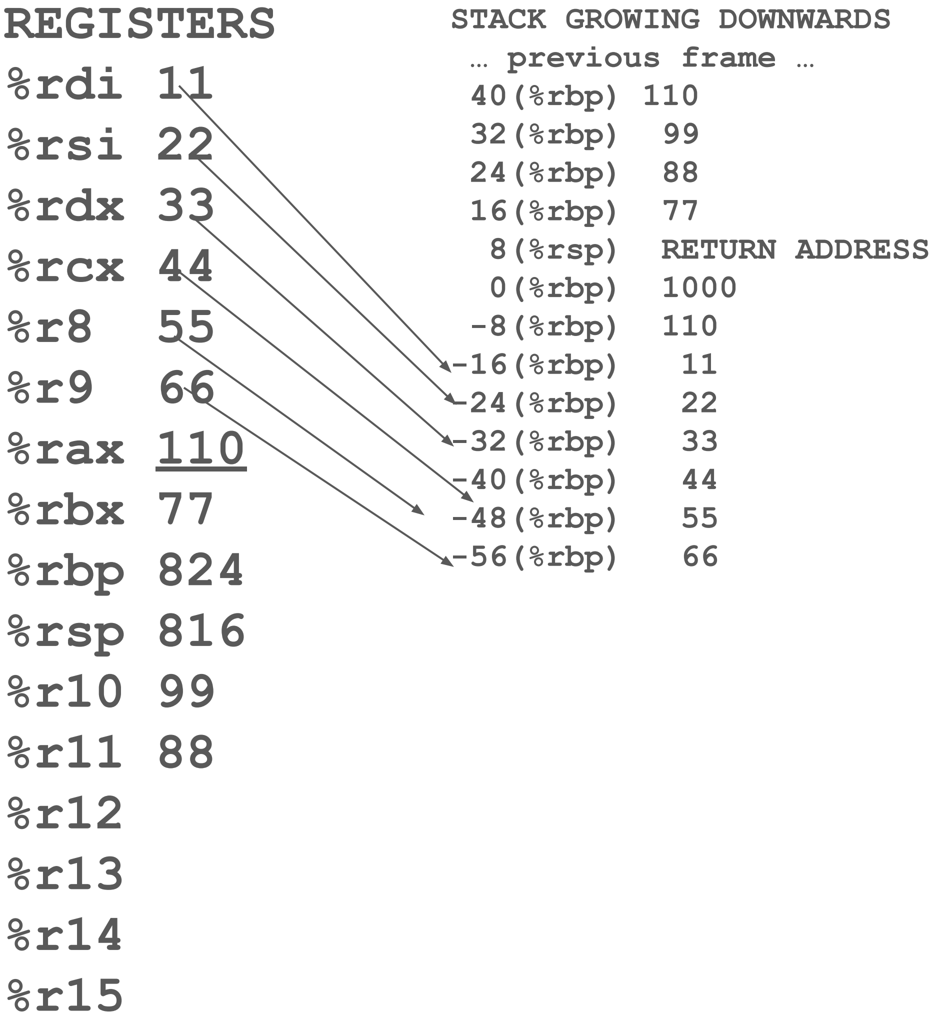
```
long test(long a, long b, long c, long d, long e, long f, long g, long h, long i, long j){
    long x =  a+b+c+d+e+f+g+h+i+j;
    long y =  a+b+c+d+e;
    long z =  x-y;
    return z;
}
```

We now show the stack locations with respect to %rbp
The pointer for the current frame

Then we copy the parameters from the stack into registers

```
movq    40(%rbp), %rax
movq    32(%rbp), %r10
movq    24(%rbp), %r11
movq    16(%rbp), %rbx

movq    %rdi, -16(%rbp)
movq    %rsi, -24(%rbp)
movq    %rdx, -32(%rbp)
movq    %rcx, -40(%rbp)
movq    %r8, -48(%rbp)
movq    %r9, -56(%rbp)
```



## REGISTERS

| | |
|---|---|
| %rdi | 11 |
| %rsi | 22 |
| %rdx | 33 |
| %rcx | 44 |
| %r8 | 55 |
| %r9 | 66 |
| %rax | 110 |
| %rbx | 77 |
| %rbp | 824 |
| %rsp | 816 |
| %r10 | 99 |
| %r11 | 88 |
| %r12 | |
| %r13 | |
| %r14 | |
| %r15 | |

## STACK GROWING DOWNWARDS

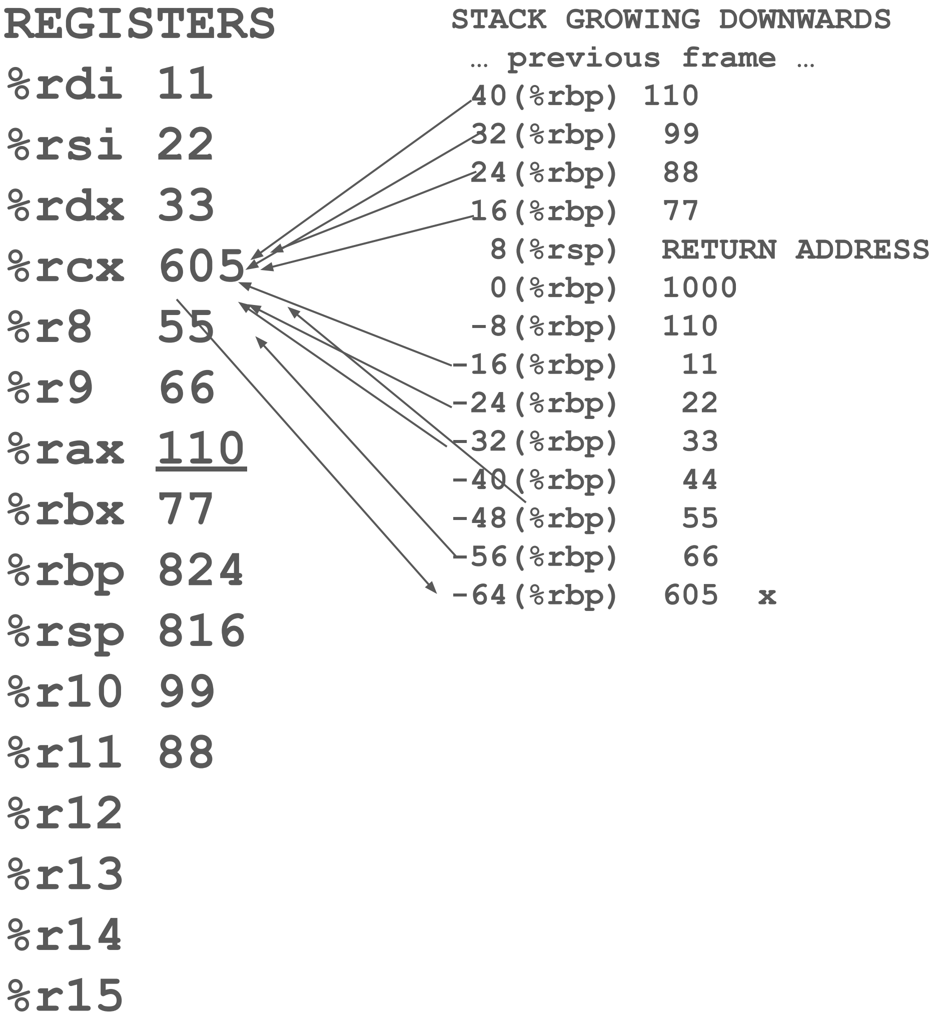
… previous frame …

| | |
|---|---|
| 40(%rbp) | 110 |
| 32(%rbp) | 99 |
| 24(%rbp) | 88 |
| 16(%rbp) | 77 |
| 8(%rsp) | RETURN ADDRESS |
| 0(%rbp) | 1000 |
| -8(%rbp) | 110 |
| -16(%rbp) | 11 |
| -24(%rbp) | 22 |
| -32(%rbp) | 33 |
| -40(%rbp) | 44 |
| -48(%rbp) | 55 |
| -56(%rbp) | 66 |

```
long test(long a, long b, long c, long d, long e, long f, long g, long h, long i, long j){
    long x =  a+b+c+d+e+f+g+h+i+j;
    long y =  a+b+c+d+e;
    long z =  x-y;
    return z;
}
```

```
# Copy parameters from registers into the stack

movq    %rdi, -16(%rbp)
movq    %rsi, -24(%rbp)
movq    %rdx, -32(%rbp)
movq    %rcx, -40(%rbp)
movq    %r8, -48(%rbp)
movq    %r9, -56(%rbp)
```



## REGISTERS

| | |
|---|---|
| %rdi | 11 |
| %rsi | 22 |
| %rdx | 33 |
| %rcx | 605 |
| %r8 | 55 |
| %r9 | 66 |
| %rax | 110 |
| %rbx | 77 |
| %rbp | 824 |
| %rsp | 816 |
| %r10 | 99 |
| %r11 | 88 |
| %r12 | |
| %r13 | |
| %r14 | |
| %r15 | |

## STACK GROWING DOWNWARDS

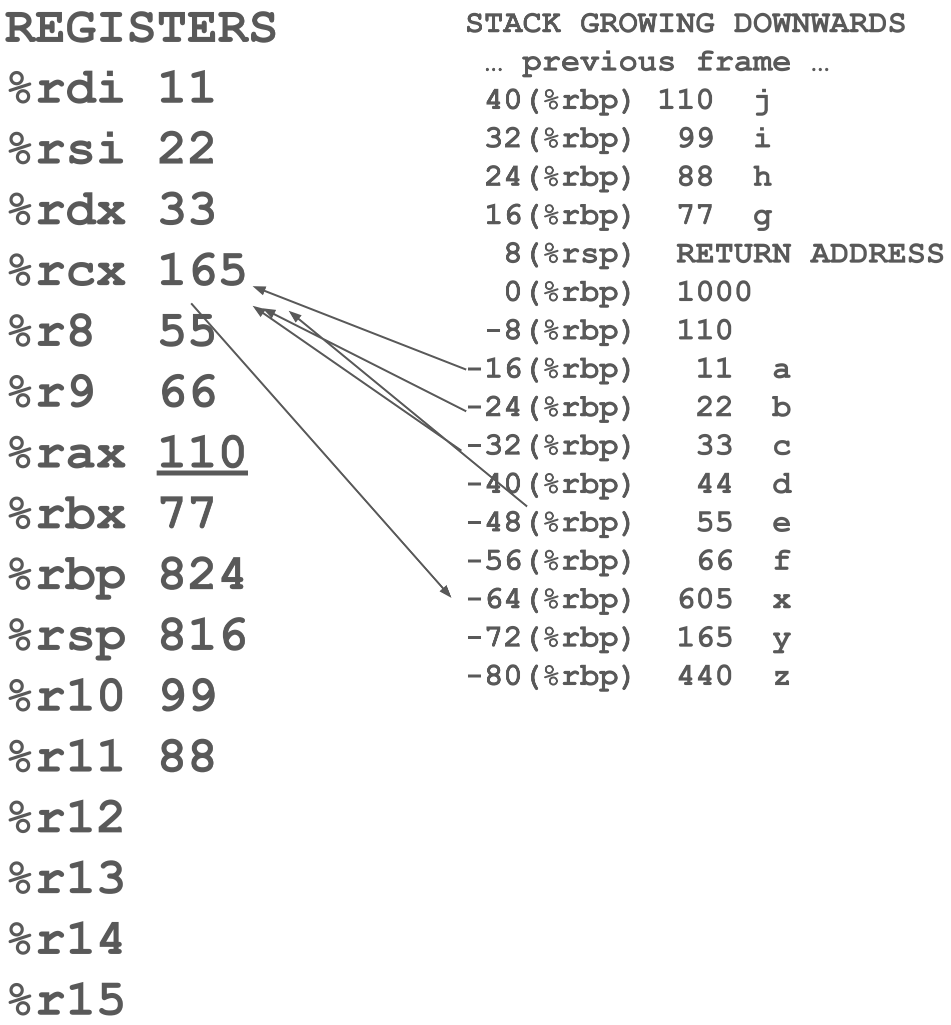
… previous frame …

| | | |
|---|---|---|
| 40(%rbp) | 110 | |
| 32(%rbp) | 99 | |
| 24(%rbp) | 88 | |
| 16(%rbp) | 77 | |
| 8(%rsp) | RETURN ADDRESS | |
| 0(%rbp) | 1000 | |
| -8(%rbp) | 110 | |
| -16(%rbp) | 11 | |
| -24(%rbp) | 22 | |
| -32(%rbp) | 33 | |
| -40(%rbp) | 44 | |
| -48(%rbp) | 55 | |
| -56(%rbp) | 66 | |
| -64(%rbp) | 605 | x |

```
long test(long a, long b, long c, long d, long e, long f, long g, long h, long i, long j){
    long x =  a+b+c+d+e+f+g+h+i+j;
    long y =  a+b+c+d+e;
    long z =  x-y;
    return z;
}
```

Next we calculate x which is the sum the values of the parameters. Ths sum is accumulated in rcx and then stored the result in the stack

```
movq    -16(%rbp), %rcx
addq    -24(%rbp), %rcx
addq    -32(%rbp), %rcx
addq    -40(%rbp), %rcx
addq    -48(%rbp), %rcx
addq    -56(%rbp), %rcx
addq    16(%rbp), %rcx
addq    24(%rbp), %rcx
addq    32(%rbp), %rcx
addq    40(%rbp), %rcx
movq    %rcx, -64(%rbp)
```



## REGISTERS

| | |
|---|---|
| %rdi | 11 |
| %rsi | 22 |
| %rdx | 33 |
| %rcx | 165 |
| %r8 | 55 |
| %r9 | 66 |
| %rax | 110 |
| %rbx | 77 |
| %rbp | 824 |
| %rsp | 816 |
| %r10 | 99 |
| %r11 | 88 |
| %r12 | |
| %r13 | |
| %r14 | |
| %r15 | |

## STACK GROWING DOWNWARDS

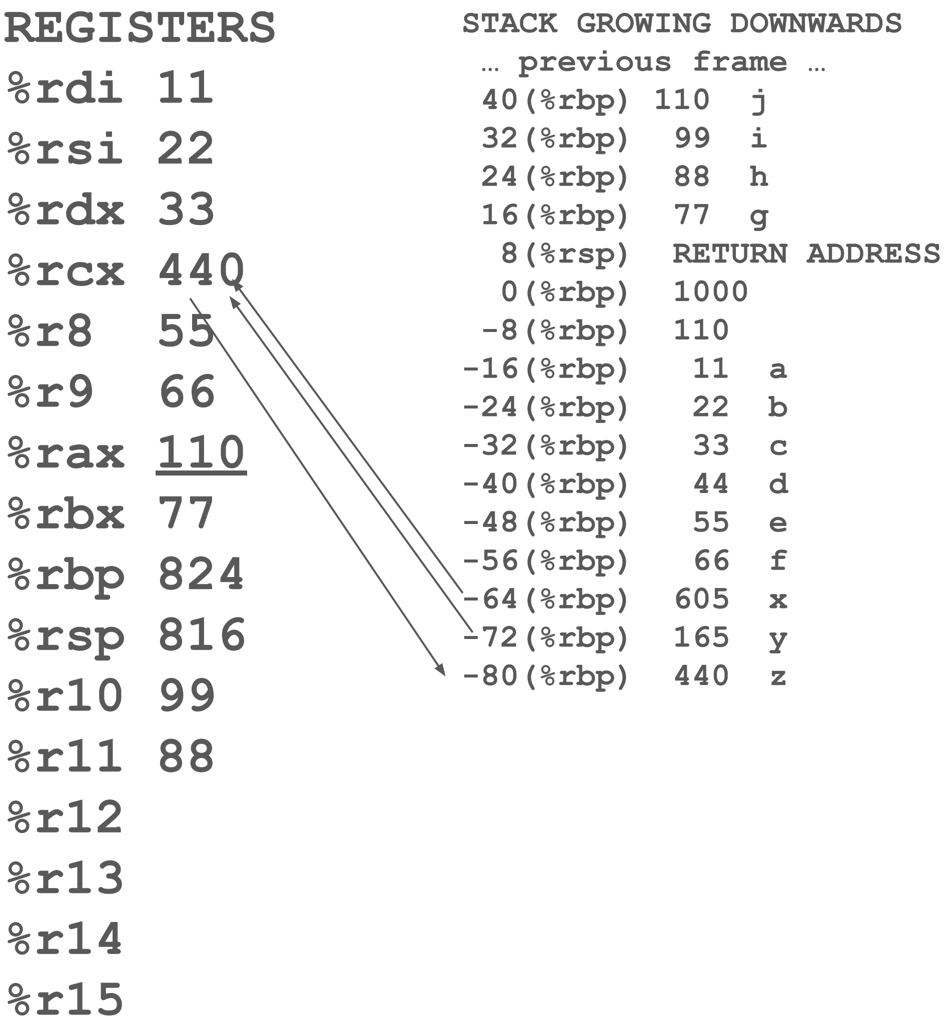
… previous frame …

| | | |
|---|---|---|
| 40(%rbp) | 110 | j |
| 32(%rbp) | 99 | i |
| 24(%rbp) | 88 | h |
| 16(%rbp) | 77 | g |
| 8(%rsp) | RETURN ADDRESS | |
| 0(%rbp) | 1000 | |
| -8(%rbp) | 110 | |
| -16(%rbp) | 11 | a |
| -24(%rbp) | 22 | b |
| -32(%rbp) | 33 | c |
| -40(%rbp) | 44 | d |
| -48(%rbp) | 55 | e |
| -56(%rbp) | 66 | f |
| -64(%rbp) | 605 | x |
| -72(%rbp) | 165 | y |
| -80(%rbp) | 440 | z |

```
long test(long a, long b, long c, long d, long e, long f, long g, long h, long i, long j){
    long x =  a+b+c+d+e+f+g+h+i+j;
    long y =  a+b+c+d+e;
    long z =  x-y;
    return z;
}
```

Next we calculate y = a+b+c+d+e and store it in the stack

```
movq      -16(%rbp), %rcx
addq      -24(%rbp), %rcx
addq      -32(%rbp), %rcx
addq      -40(%rbp), %rcx
addq      -48(%rbp), %rcx
movq      %rcx, -72(%rbp)
```



## REGISTERS

| | |
|---|---|
| %rdi | 11 |
| %rsi | 22 |
| %rdx | 33 |
| %rcx | 440 |
| %r8 | 55 |
| %r9 | 66 |
| %rax | 110 |
| %rbx | 77 |
| %rbp | 824 |
| %rsp | 816 |
| %r10 | 99 |
| %r11 | 88 |
| %r12 | |
| %r13 | |
| %r14 | |
| %r15 | |

## STACK GROWING DOWNWARDS

… previous frame …

| | | |
|---|---|---|
| 40(%rbp) | 110 | j |
| 32(%rbp) | 99 | i |
| 24(%rbp) | 88 | h |
| 16(%rbp) | 77 | g |
| 8(%rsp) | RETURN ADDRESS | |
| 0(%rbp) | 1000 | |
| -8(%rbp) | 110 | |
| -16(%rbp) | 11 | a |
| -24(%rbp) | 22 | b |
| -32(%rbp) | 33 | c |
| -40(%rbp) | 44 | d |
| -48(%rbp) | 55 | e |
| -56(%rbp) | 66 | f |
| -64(%rbp) | 605 | x |
| -72(%rbp) | 165 | y |
| -80(%rbp) | 440 | z |

```
long test(long a, long b, long c, long d, long e, long f, long g, long h, long i, long j){
    long x =  a+b+c+d+e+f+g+h+i+j;
    long y =  a+b+c+d+e;
    long z =  x-y;
    return z;
}
```

Then we calculate z = x-y and store it in the stack

```
        movq      -64(%rbp), %rcx
        subq      -72(%rbp), %rcx
        movq      %rcx, -80(%rbp)
```

And we move it back to the register (not optimial1)

```
        movq      -80(%rbp), %rcx
```

## REGISTERS

| | |
|---|---|
| %rdi | 11 |
| %rsi | 22 |
| %rdx | 33 |
| %rcx | 440 |
| %r8 | 55 |
| %r9 | 66 |
| %rax | 110 440 |
| %rbx | 77 |
| %rbp | 824 |
| %rsp | 816 |
| %r10 | 99 |
| %r11 | 88 |
| %r12 | |
| %r13 | |
| %r14 | |
| %r15 | |

## STACK GROWING DOWNWARDS

… previous frame …

| | | |
|---|---|---|
| 40(%rbp) | 110 | j |
| 32(%rbp) | 99 | i |
| 24(%rbp) | 88 | h |
| 16(%rbp) | 77 | g |
| 8(%rbp) | RETURN ADDRESS | |
| 0(%rbp) | 1000 | |
| -8(%rbp) | 110 | |
| -16(%rbp) | 11 | a |
| -24(%rbp) | 22 | b |
| -32(%rbp) | 33 | c |
| -40(%rbp) | 44 | d |
| -48(%rbp) | 55 | e |
| -56(%rbp) | 66 | f |
| -64(%rbp) | 605 | x |
| -72(%rbp) | 165 | y |
| -80(%rbp) | 440 | z |
| -88(%rbp) | 110 | |

```
long test(long a, long b, long c, long d, long e, long f, long g, long h, long i, long j){
    long x =  a+b+c+d+e+f+g+h+i+j;
    long y =  a+b+c+d+e;
    long z =  x-y;
    return z;
}
```

Then we store the return value in rax
(but first move the current value into the stack, in case we need it later)

```
        movq      %rax, -88(%rbp)       ## 8-byte Spill
        movq      %rcx, %rax
```

# REGISTERS

| | |
|---|---|
| %rdi | 11 |
| %rsi | 22 |
| %rdx | 33 |
| %rcx | 440 |
| %r8 | 55 |
| %r9 | 66 |
| %rax | 440 |
| %rbx | 110 |
| %rbp | 1000 |
| %rsp | 816 |
| %r10 | 99 |
| %r11 | 88 |
| %r12 | |
| %r13 | |
| %r14 | |
| %r15 | |

## STACK GROWING DOWNWARDS

… previous frame …

| | | |
|---|---|---|
| 32(%rsp) | 110 | j |
| 24(%rsp) | 99 | i |
| 16(%rsp) | 88 | h |
| 8(%rsp) | 77 | g |
| 0(%rsp) | RETURN ADDRESS | |

```
long test(long a, long b, long c, long d, long e, long f, long g, long h, long i, long j){
   long x =  a+b+c+d+e+f+g+h+i+j;
   long y =  a+b+c+d+e;
   long z =  x-y;
   return z;
}
```

And we reset the value of rbx (a callee save register)

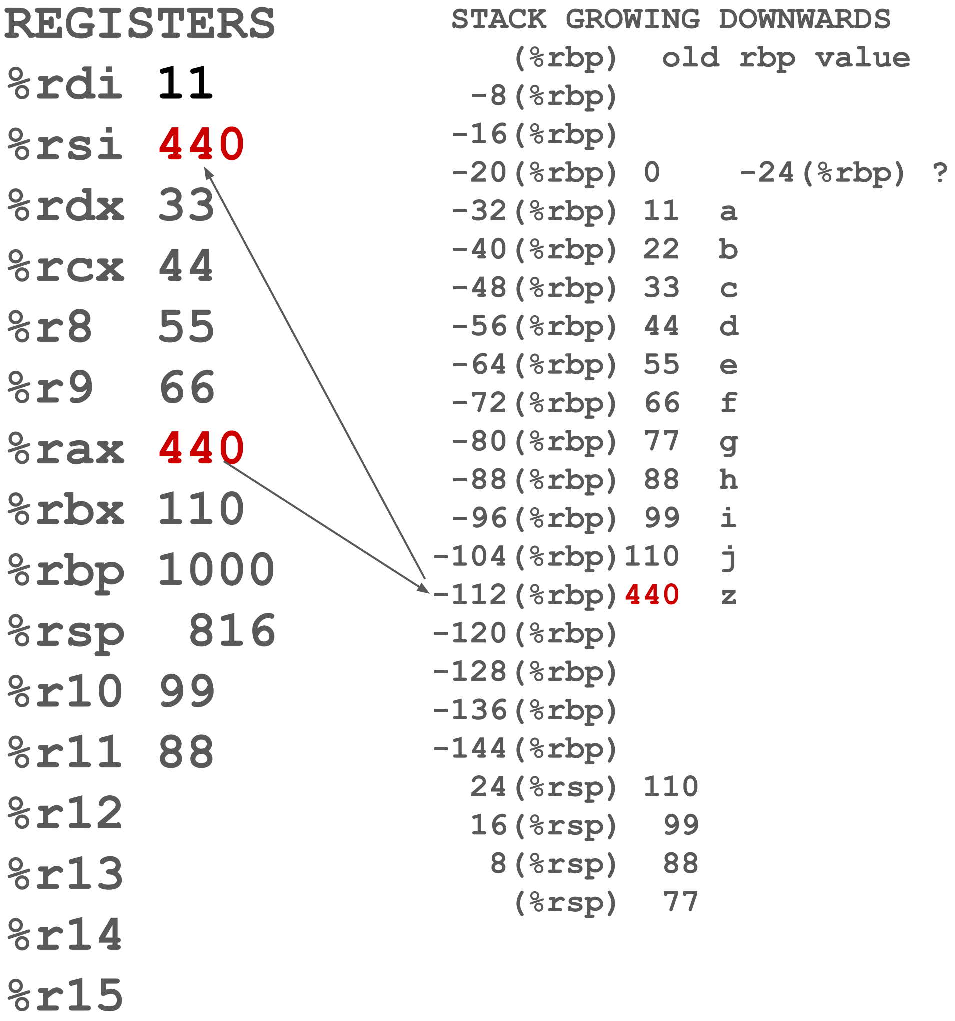
```
            popq        %rbx
```

And we reset the frame pointer to point to the beginning of the previous frqame

```
            popq        %rbpreturn
```

We have now also reset the stack pointer %rsp
So we can use the RETURN ADDRESS at (%rsp)
To get back to the previous function

```
            retq
```



## REGISTERS

| | |
|---|---|
| %rdi | 11 |
| %rsi | 440 |
| %rdx | 33 |
| %rcx | 44 |
| %r8 | 55 |
| %r9 | 66 |
| %rax | 440 |
| %rbx | 110 |
| %rbp | 1000 |
| %rsp | 816 |
| %r10 | 99 |
| %r11 | 88 |
| %r12 | |
| %r13 | |
| %r14 | |
| %r15 | |

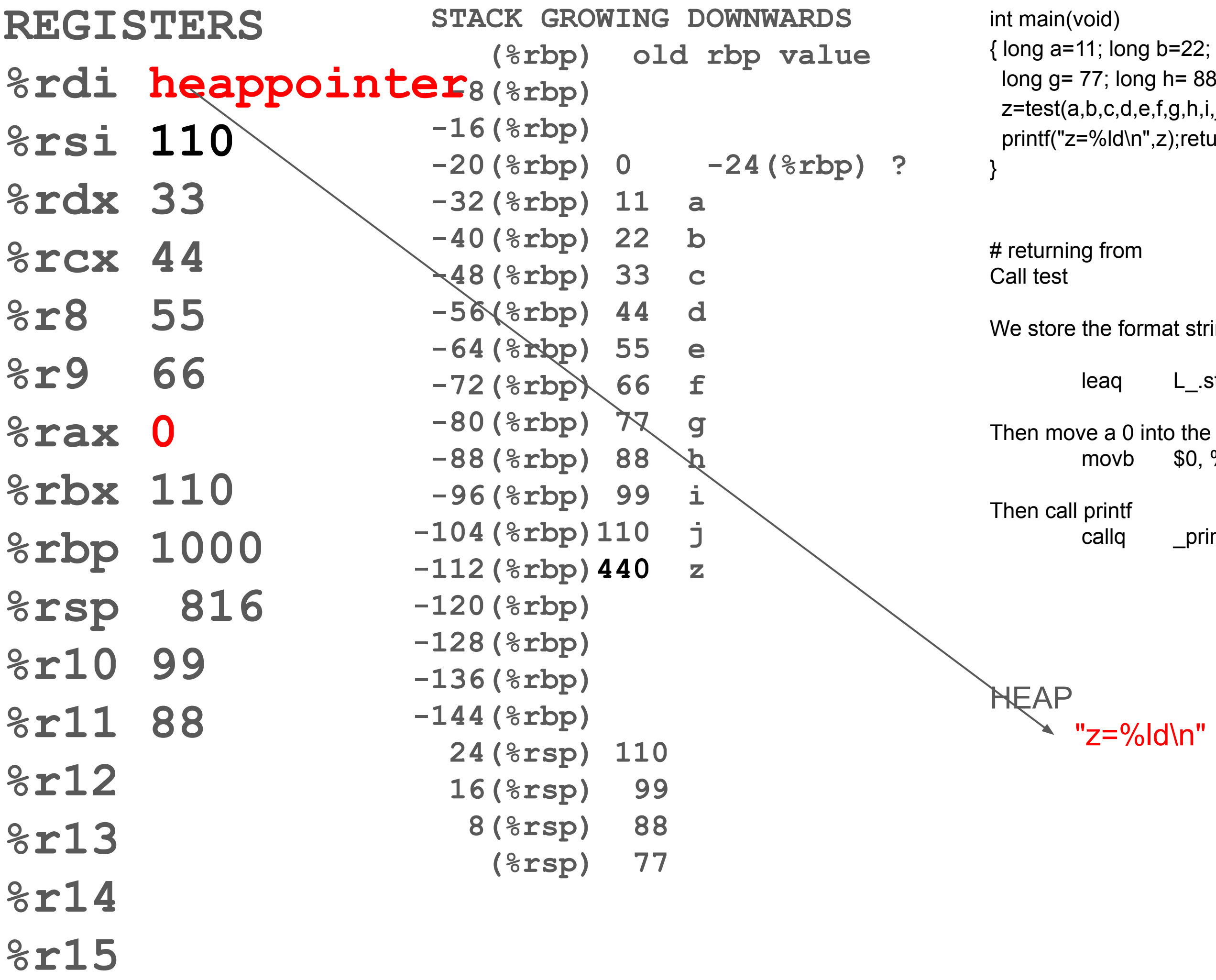
## STACK GROWING DOWNWARDS

| | | |
|---|---|---|
| (%rbp) | old rbp value | |
| -8(%rbp) | | |
| -16(%rbp) | | |
| -20(%rbp) | 0 | -24(%rbp) ? |
| -32(%rbp) | 11 | a |
| -40(%rbp) | 22 | b |
| -48(%rbp) | 33 | c |
| -56(%rbp) | 44 | d |
| -64(%rbp) | 55 | e |
| -72(%rbp) | 66 | f |
| -80(%rbp) | 77 | g |
| -88(%rbp) | 88 | h |
| -96(%rbp) | 99 | i |
| -104(%rbp) | 110 | j |
| -112(%rbp) | 440 | z |
| -120(%rbp) | | |
| -128(%rbp) | | |
| -136(%rbp) | | |
| -144(%rbp) | | |
| 24(%rsp) | 110 | |
| 16(%rsp) | 99 | |
| 8(%rsp) | 88 | |
| (%rsp) | 77 | |

```
int main(void)
{ long a=11; long b=22; long c= 33; long d= 44; long e= 55; long f= 66;
  long g= 77; long h= 88; long i= 99; long j= 110;  long z = -1;
  z=test(a,b,c,d,e,f,g,h,i,j);
  printf("z=%ld\n",z);return 1;
}
```

```
callq       _test  # We have just returned from this call

# store the return value in the stack
            movq       %rax, -112(%rbp)
# and copy it to rsi to set up for the PRINT call
            movq       -112(%rbp), %rsi
```



| REGISTERS | |
|---|---|
| %rdi | heappointer |
| %rsi | 110 |
| %rdx | 33 |
| %rcx | 44 |
| %r8 | 55 |
| %r9 | 66 |
| %rax | 0 |
| %rbx | 110 |
| %rbp | 1000 |
| %rsp | 816 |
| %r10 | 99 |
| %r11 | 88 |
| %r12 | |
| %r13 | |
| %r14 | |
| %r15 | |

STACK GROWING DOWNWARDS

| | | | | |
|---|---|---|---|---|
| (%rbp) | old rbp value | | | |
| -8(%rbp) | | | | |
| -16(%rbp) | | | | |
| -20(%rbp) | 0 | | -24(%rbp) | ? |
| -32(%rbp) | 11 | a | | |
| -40(%rbp) | 22 | b | | |
| -48(%rbp) | 33 | c | | |
| -56(%rbp) | 44 | d | | |
| -64(%rbp) | 55 | e | | |
| -72(%rbp) | 66 | f | | |
| -80(%rbp) | 77 | g | | |
| -88(%rbp) | 88 | h | | |
| -96(%rbp) | 99 | i | | |
| -104(%rbp) | 110 | j | | |
| -112(%rbp) | 440 | z | | |
| -120(%rbp) | | | | |
| -128(%rbp) | | | | |
| -136(%rbp) | | | | |
| -144(%rbp) | | | | |
| 24(%rsp) | 110 | | | |
| 16(%rsp) | 99 | | | |
| 8(%rsp) | 88 | | | |
| (%rsp) | 77 | | | |

```
int main(void)
{ long a=11; long b=22; long c= 33; long d= 44; long e= 55; long f= 66;
  long g= 77; long h= 88; long i= 99; long j= 110;  long z = -1;
  z=test(a,b,c,d,e,f,g,h,i,j);
  printf("z=%ld\n",z);return 1;
}
```

# returning from
Call test

We store the format string in the register to prepare for calling printf

```
        leaq     L_.str(%rip), %rdi
```

Then move a 0 into the a register,  I don't know why

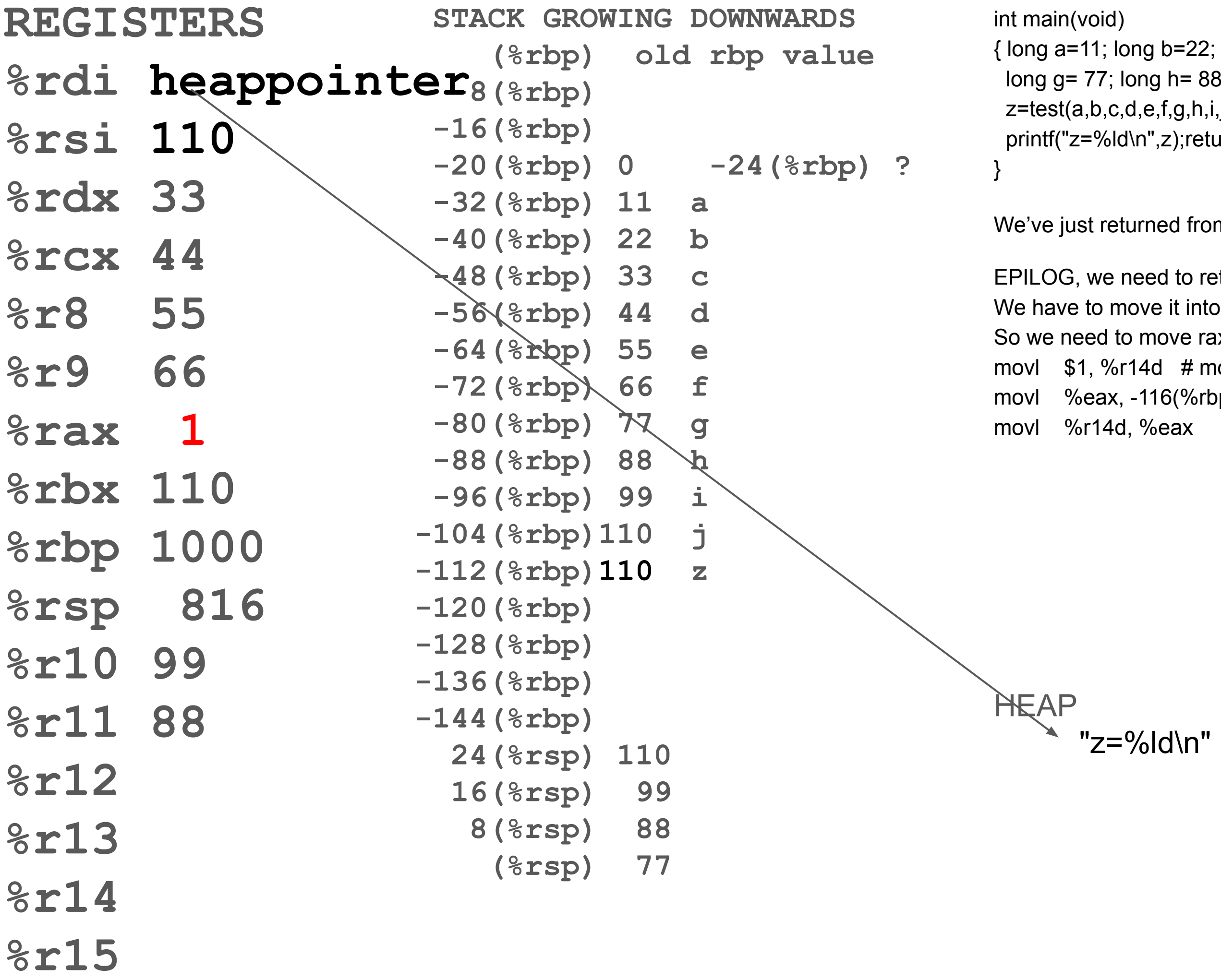
```
        movb     $0, %al
```

Then call printf

```
        callq    _printf
```

HEAP

"z=%ld\n"



## REGISTERS

| | |
|---|---|
| %rdi | heappointer |
| %rsi | 110 |
| %rdx | 33 |
| %rcx | 44 |
| %r8 | 55 |
| %r9 | 66 |
| %rax | 1 |
| %rbx | 110 |
| %rbp | 1000 |
| %rsp | 816 |
| %r10 | 99 |
| %r11 | 88 |
| %r12 | |
| %r13 | |
| %r14 | |
| %r15 | |

## STACK GROWING DOWNWARDS

| | | | |
|---|---|---|---|
| (%rbp) | old rbp value | | |
| -8(%rbp) | | | |
| -16(%rbp) | | | |
| -20(%rbp) | 0 | | -24(%rbp) ? |
| -32(%rbp) | 11 | a | |
| -40(%rbp) | 22 | b | |
| -48(%rbp) | 33 | c | |
| -56(%rbp) | 44 | d | |
| -64(%rbp) | 55 | e | |
| -72(%rbp) | 66 | f | |
| -80(%rbp) | 77 | g | |
| -88(%rbp) | 88 | h | |
| -96(%rbp) | 99 | i | |
| -104(%rbp) | 110 | j | |
| -112(%rbp) | 110 | z | |
| -120(%rbp) | | | |
| -128(%rbp) | | | |
| -136(%rbp) | | | |
| -144(%rbp) | | | |
| 24(%rsp) | 110 | | |
| 16(%rsp) | 99 | | |
| 8(%rsp) | 88 | | |
| (%rsp) | 77 | | |

HEAP

"z=%ld\n"

```
int main(void)
{ long a=11; long b=22; long c= 33; long d= 44; long e= 55; long f= 66;
  long g= 77; long h= 88; long i= 99; long j= 110;  long z = -1;
  z=test(a,b,c,d,e,f,g,h,i,j);
  printf("z=%ld\n",z);return 1;
}
```

We’ve just returned from the call to printf

EPILOG, we need to return 1, so
We have to move it into rax, but rax is a callee save
So we need to move rax into the stack first

```
movl    $1, %r14d   # move 1 to r14d
movl    %eax, -116(%rbp)
movl    %r14d, %eax
```

## REGISTERS

|  |  |
|---|---|
| %rdi | heappointer |
| %rsi | 110 |
| %rdx | 33 |
| %rcx | 44 |
| %r8 | 55 |
| %r9 | 66 |
| %rax | 1 |
| %rbx | 110 |
| %rbp | 1000 |
| %rsp | 1000 |
| %r10 | 99 |
| %r11 | 88 |
| %r12 |  |
| %r13 |  |
| %r14 |  |
| %r15 |  |

## STACK GROWING DOWNWARDS (%rsp)

```
int main(void)
{ long a=11; long b=22; long c= 33; long d= 44; long e= 55; long f= 66;
  long g= 77; long h= 88; long i= 99; long j= 110;  long z = -1;
  z=test(a,b,c,d,e,f,g,h,i,j);
  printf("z=%ld\n",z);return 1;
}
```

EPILOG, we need to return 1, so
We have to move it into rax, but rax is a callee save
So we need to move rax into the stack first

```
movl    $1, %r14d   # move 1 to r14d
movl    %eax, -116(%rbp)
movl    %r14d, %eax
```

Finally we reset the stack pointer,
Return the values of rbx, r14, and rbp and return to the Operating System

```
addq    $144, %rsp
popq    %rbx
popq    %r14
popq    %rbp
retq
```

HEAP

"z=%ld\n"

## REGISTERS

%rdi

%rsi

%rdx

%rcx

%r8

%r9

%rax

%rbx

%rbp

%rsp

%r10

%r11

%r12

%r13

%r14

%r15

## STACK GROWING DOWNWARDS

```
    (%rbp)
  -8(%rbp)
 -16(%rbp)
 -24(%rbp)
 -32(%rbp)
 -40(%rbp)
 -48(%rbp)
 -56(%rbp)
 -64(%rbp)
 -72(%rbp)
 -80(%rbp)
 -88(%rbp)
 -96(%rbp)
-104(%rbp)
-112(%rbp)
-120(%rbp)
-128(%rbp)
-136(%rbp)
-144(%rbp)
  24(%rsp)
  16(%rsp)
   8(%rsp)
    (%rsp)
```

## CODE:

## REGISTERS

%rdi
%rsi
%rdx
%rcx
%r8
%r9
%rax
%rbx
%rbp
%rsp
%r10
%r11
%r12
%r13
%r14
%r15

## STACK GROWING DOWNWARDS

```
    (%rbp)
  -8(%rbp)
 -16(%rbp)
 -24(%rbp)
 -32(%rbp)
 -40(%rbp)
 -48(%rbp)
 -56(%rbp)
 -64(%rbp)
 -72(%rbp)
 -80(%rbp)
 -88(%rbp)
 -96(%rbp)
-104(%rbp)
-112(%rbp)
-120(%rbp)
-128(%rbp)
-136(%rbp)
-144(%rbp)
  24(%rsp)
  16(%rsp)
   8(%rsp)
    (%rsp)
```

## CODE:

## REGISTERS

```
%rdi
%rsi
%rdx
%rcx
%r8
%r9
%rax
%rbx
%rbp
%rsp
%r10
%r11
%r12
%r13
%r14
%r15
```

## STACK GROWING DOWNWARDS

```
    (%rbp)
  -8(%rbp)
 -16(%rbp)
 -24(%rbp)
 -32(%rbp)
 -40(%rbp)
 -48(%rbp)
 -56(%rbp)
 -64(%rbp)
 -72(%rbp)
 -80(%rbp)
 -88(%rbp)
 -96(%rbp)
-104(%rbp)
-112(%rbp)
-120(%rbp)
-128(%rbp)
-136(%rbp)
-144(%rbp)
  24(%rsp)
  16(%rsp)
   8(%rsp)
    (%rsp)
```

## CODE:

## REGISTERS

%rdi

%rsi

%rdx

%rcx

%r8

%r9

%rax

%rbx

%rbp

%rsp

%r10

%r11

%r12

%r13

%r14

%r15

## STACK GROWING DOWNWARDS

```
    (%rbp)
  -8(%rbp)
 -16(%rbp)
 -24(%rbp)
 -32(%rbp)
 -40(%rbp)
 -48(%rbp)
 -56(%rbp)
 -64(%rbp)
 -72(%rbp)
 -80(%rbp)
 -88(%rbp)
 -96(%rbp)
-104(%rbp)
-112(%rbp)
-120(%rbp)
-128(%rbp)
-136(%rbp)
-144(%rbp)
  24(%rsp)
  16(%rsp)
   8(%rsp)
    (%rsp)
```

## CODE: