Hyung-Sin Kim

Computing Foundations for Data Science

Graduate School of Data Science, Seoul National University



You already know what functions are.

Today we focus more on what happens when you call a function in C



- Declaration (function prototype)
 - Informs the compiler about relevant properties
 - Name, data type of return value, and type of input arguments

```
#include <stdio.h>
int Factorial(int n);
int main(void) {
  int number;
  int answer;
   printf("Input a number: ");
   scanf("%d", &number);
   answer = Factorial(number);
   printf("The factorial of %d is %d\n", number, answer);
int Factorial(int n) {
  int result = 1;
  for (int i=1; i <=n; i++)
     result += 1;
  return result:
```

- Declaration (function prototype)
 - Informs the compiler about relevant properties
 - Name, data type of return value, and type of input arguments
- Call
 - The caller must transmit proper arguments (number, type) to the callee
 - Calling is possible only when the callee is **declared** before

```
#include <stdio.h>
int Factorial(int n);
int main(void) {
  int number;
  int answer;
  printf("Input a number: ");
  scanf("%d", &number);
  answer = Factorial(number);
  printf("The factorial of %d is %d\n", number, answer);
int Factorial(int n) {
  int result = 1:
  for (int i=1; i <=n; i++)
     result += 1;
  return result:
```



- Declaration (function prototype)
 - Informs the compiler about relevant properties
 - Name, data type of return value, and type of input arguments
- Call
 - The caller must transmit proper arguments (number, type) to the callee
 - Calling is possible only when the callee is **declared** before
- Definition
 - Formal parameter list, initialized by the argument values passed by the caller
 - Any variable declared in the body is **local** to the function

```
#include <stdio.h>
int Factorial(int n);
int main(void) {
  int number;
  int answer;
  printf("Input a number: ");
  scanf("%d", &number);
  answer = Factorial(number);
  printf("The factorial of %d is %d\n", number, answer);
int Factorial(int n) {
  int result = 1:
```

for (int i=1; i <=n; i++)

result += 1; return result:



- Declaration (function prototype)
 - Informs the compiler about relevant properties
 - Name, data type of return value, and type of input arguments
- Call
 - The caller must transmit proper arguments (number, type) to the callee
 - Calling is possible only when the callee is **declared** before
- Definition
 - Formal parameter list, initialized by the argument values passed by the caller
 - Any variable declared in the body is **local** to the function
 - Return value goes back to the caller
 - If there is no return, return type is **void**

```
#include <stdio.h>
int Factorial(int n);
int main(void) {
  int number;
  int answer;
  printf("Input a number: ");
  scanf("%d", &number);
  answer = Factorial(number);
  printf("The factorial of %d is %d\n", number, answer);
int Factorial(int n) {
  int result = 1:
  for (int i=1; i <=n; i++)
     result += 1;
  return result:
```

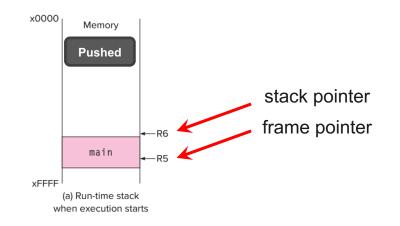


Function Implementation in C - Example

```
int main(void) {
  int a;
  int b;
  b = Watt(a);
                   // main calls Watt first
  b = Volt(a, b); // then calls Volt
int Watt(int a) {
  int w;
  w = Volt(w, 10); // Watt calls Volt
  return w;
int Volt(int q, int r) {
  int k;
  int m;
  return k;
```

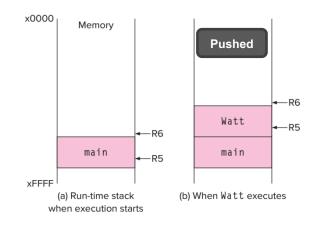


```
int main(void) {
  int a;
  int b;
                   // main calls Watt first
  b = Volt(a, b); // then calls Volt
int Watt(int a) {
  int w;
  w = Volt(w, 10); // Watt calls Volt
  return w;
int Volt(int q, int r) {
  int k;
  int m;
  return k;
```



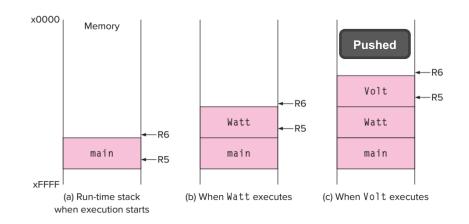


```
int main(void) {
  int a;
  int b;
  b = Watt(a);
                   // main calls Watt first
  b = Volt(a, b); // then calls Volt
int Watt(int a) {
  int w;
  w = Volt(w, 10);
                     // Watt calls Volt
  return w;
int Volt(int q, int r) {
  int k;
  int m;
  return k;
```



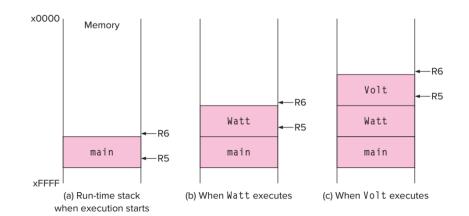


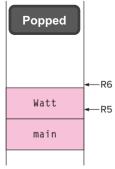
```
int main(void) {
  int a;
  int b;
  b = Watt(a);
                    // main calls Watt first
  b = Volt(a, b); // then calls Volt
int Watt(int a) {
  int w;
  w = Volt(w, 10);
                      // Watt calls Volt
  return w;
int Volt(int q, int r) {
  int k;
  int m;
  return k;
```



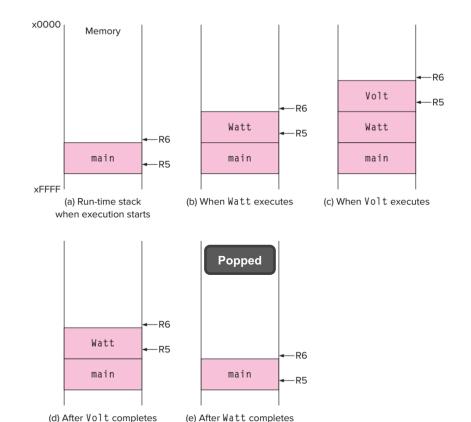


```
int main(void) {
  int a;
  int b;
  b = Watt(a);
                   // main calls Watt first
  b = Volt(a, b); // then calls Volt
int Watt(int a) {
  int w;
  w = Volt(w. 10): // Watt calls Volt
  return w.
int Volt(int q, int r) {
  int k;
  int m;
  return k;
```



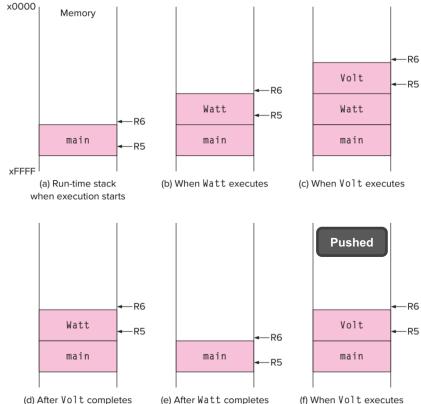


```
int main(void) {
  int a;
  int b;
                    // main calls Watt first
  b = Volt(a, b);
                    // then calls Volt
int Watt(int a) {
  int w;
  w = Volt(w, 10); // Watt calls Volt
  return w;
int Volt(int q, int r) {
  int k;
  int m;
  return k;
```





```
int main(void) {
  int a;
  int b;
  b = Watt(a);
                   // main calls Watt first
  b = Volt(a, b); // then calls Volt
int Watt(int a) {
  int w;
  w = Volt(w, 10); // Watt calls Volt
  return w;
int Volt(int q, int r) {
  int k;
  int m;
  return k;
```





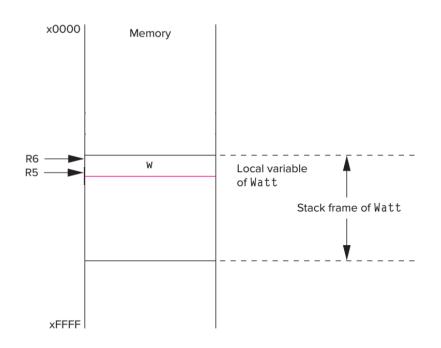
Let's see what happens during a function's lifetime

(1) Calling (Passing arguments to the function)

- (2) Start Callee (Reserve stack for the function)
 - (3) End Callee (Return)
 - (4) Return to Caller



```
int main(void) {
  int a;
  int b;
  b = Watt(a);
                   // main calls Watt first
  b = Volt(a, b); // then calls Volt
int Watt(int a) {
  int w;
  w = Volt(w, 10);
                      // Watt calls Volt
  return w;
int Volt(int q, int r) {
  int k;
  int m;
  return k;
```





```
int main(void) {
  int a;
  int b;
                                                                             x0000
                                                                                             Memory
  b = Watt(a);
                 // main calls Watt first
  b = Volt(a, b); // then calls Volt
                                                                                                                 Parameters
int Watt(int a) {
                                                                                                                 for Volt
                                                                         R6 ---
                                                                                                10
  int w;
                                                                                                W
                                                                                                                 Local variable
                                                                         R5 ---
                                                                                                                 of Watt
                    // Watt calls Volt
  w = Volt(w, 10);
                                                                                                                             Stack frame of Watt
  return w;
int Volt(int q, int r) {
                            (1) Decrement R6 and Push 10
  int k;
  int m;
                                                                              xFFFF
```



return k;

```
int main(void) {
  int a;
  int b;
                                                                            x0000
                                                                                            Memory
  b = Watt(a);
                 // main calls Watt first
  b = Volt(a, b); // then calls Volt
                                                                         R6 ---
                                                                                           value of W
                                                                                                                Parameters
int Watt(int a) {
                                                                                                                for Volt
                                                                                               10
  int w;
                                                                                               W
                                                                                                                Local variable
                                                                        R5 -
                                                                                                                of Watt
                    // Watt calls Volt
  w = Volt(w, 10);
                                                                                                                            Stack frame of Watt
  return w;
int Volt(int q, int r) {
                            (1) Decrement R6 and Push 10
  int k;
  int m;
                                                                             xFFFF
                           (2) Decrement R6 and Push w value
```



return k;

```
int main(void) {
  int a;
  int b;
                                                                             x0000
                                                                                            Memory
                 // main calls Watt first
  b = Watt(a);
  b = Volt(a, b); // then calls Volt
                                                                         R6 ---
                                                                                           value of W
                                                                                                                 Parameters
int Watt(int a) {
                                                                                                                 for Volt
                                                                                               10
  int w;
                                                                                                W
                                                                                                                 Local variable
                                                                         R5 -
                                                                                                                 of Watt
                    // Watt calls Volt
  w = Volt(w, 10);
                                                                                                                            Stack frame of Watt
  return w;
int Volt(int q, int r) {
                            (1) Decrement R6 and Push 10
  int k;
  int m;
                                                                             xFFFF
                            (2) Decrement R6 and Push w value
  return k;
                            (3) Pass the control to Volt
```



Let's see what happens during a function's lifetime

(1) Calling (Passing arguments to the function)

(2) Start Callee (Reserve stack for the function)

- (3) End Callee (Return)
 - (4) Return to Caller

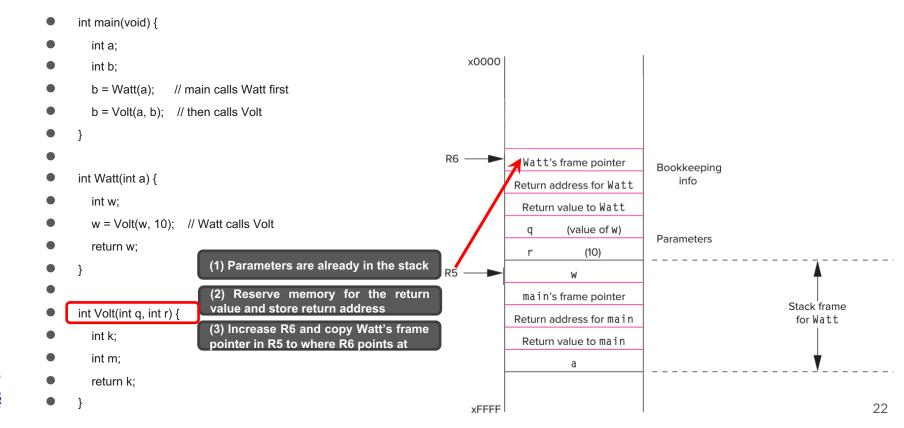


```
int main(void) {
  int a;
                                                                            x0000
  int b;
  b = Watt(a);
                  // main calls Watt first
  b = Volt(a, b); // then calls Volt
int Watt(int a) {
  int w;
  w = Volt(w, 10); // Watt calls Volt
                                                                        R6
                                                                                               (value of w)
                                                                                                                 Parameters
  return w;
                                                                                                   (10)
                          (1) Parameters are already in the stack
                                                                       R5
                                                                                       main's frame pointer
                                                                                                                                           Stack frame
int Volt(int q, int r) {
                                                                                     Return address for main
                                                                                                                                            for Watt
  int k;
                                                                                       Return value to main
  int m;
                                                                                                 a
  return k;
                                                                                                                                                            20
                                                                             xFFFF
```



```
int main(void) {
  int a;
                                                                          x0000
  int b;
  b = Watt(a);
                  // main calls Watt first
  b = Volt(a, b); // then calls Volt
                                                                                                               Bookkeeping
int Watt(int a) {
                                                                                                                   info
                                                                                   Return address for Watt
  int w;
                                                                                     Return value to Watt
  w = Volt(w, 10); // Watt calls Volt
                                                                                             (value of W)
                                                                                                               Parameters
  return w;
                                                                                                 (10)
                         (1) Parameters are already in the stack
                             Reserve memory for the return
                                                                                     main's frame pointer
                         value and store return address
                                                                                                                                        Stack frame
int Volt(int q, int r) {
                                                                                   Return address for main
                                                                                                                                         for Watt
  int k:
                                                                                     Return value to main
  int m;
                                                                                              a
  return k;
                                                                                                                                                        21
                                                                           xFFFF
```







```
int main(void) {
  int a;
                                                                         x0000
  int b;
  b = Watt(a):
                 // main calls Watt first
  b = Volt(a, b); // then calls Volt
                                                                                   Watt's frame pointer
                                                                                                            Bookkeeping
int Watt(int a) {
                                                                                                                info
                                                                                 Return address for Watt
  int w;
                                                                                   Return value to Watt
  w = Volt(w, 10); // Watt calls Volt
                                                                                           (value of W)
                                                                                                            Parameters
  return w;
                                                                                              (10)
                        (1) Parameters are already in the stack
                             Reserve memory for the return
                                                                                   main's frame pointer
                        value and store return address
                                                                                                                                     Stack frame
int Volt(int q, int r) {
                                                                                 Return address for main
                                                                                                                                      for Watt
                        (3) Increase R6 and copy Watt's frame
  int k:
                        pointer in R5 to where R6 points at
                                                                                   Return value to main
  int m;
                         (4) Increase R6 and move the frame
                                                                                            a
                        point (R5) to R6
  return k;
                                                                                                                                                    23
                                                                         xFFFF
```



```
int main(void) {
  int a;
                                                                       x0000
  int b;
  b = Watt(a);
                 // main calls Watt first
  b = Volt(a, b); // then calls Volt
                                                                   R6 —
                                                                                           m
                                                                                                          Local variables
                                                                   R5 —
                                                                                  Watt's frame pointer
                                                                                                           Bookkeeping
int Watt(int a) {
                                                                                                               info
                                                                                Return address for Watt
  int w;
                                                                                  Return value to Watt
  w = Volt(w, 10); // Watt calls Volt
                                                                                          (value of W)
                                                                                                           Parameters
  return w;
                                                                                             (10)
                        (1) Parameters are already in the stack
                            Reserve memory for the return
                                                                                  main's frame pointer
                        value and store return address
                                                                                                                                   Stack frame
int Volt(int q, int r) {
                                                                                Return address for main
                                                                                                                                    for Watt
                        (3) Increase R6 and copy Watt's frame
  int k:
                        pointer in R5 to where R6 points at
                                                                                  Return value to main
  int m;
                        (4) Increase R6 and move the frame
                                                                                           a
                        point (R5) to R6
  return k;
                        (5) Reserve memory for Volt's local
                                                                                                                                                   24
                                                                        xFFFF
                        variables
```

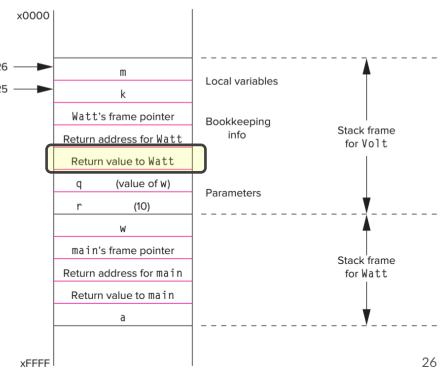


Let's see what happens during a function's lifetime

- (1) Calling (Passing arguments to the function)
- (2) Start Callee (Reserve stack for the function)
 - (3) End Callee (Return)
 - (4) Return to Caller



```
int main(void) {
  int a;
                                                                            x0000
  int b;
  b = Watt(a);
                  // main calls Watt first
  b = Volt(a, b); // then calls Volt
                                                                        R6 -
                                                                                                 m
                                                                        R5 -
int Watt(int a) {
  int w;
  w = Volt(w, 10); // Watt calls Volt
  return w;
                             (1) Store the return value in R5+3
int Volt(int q, int r) {
  int k:
  int m;
                                                                                                 a
  return k;
                                                                             xFFFF
```





```
int main(void) {
  int a;
                                                                            x0000
  int b;
  b = Watt(a):
                  // main calls Watt first
  b = Volt(a, b); // then calls Volt
                                                                                                                 Local variables
                                                                       R5 -
                                                                       R6 —
                                                                                       Watt's frame pointer
                                                                                                                 Bookkeeping
int Watt(int a) {
                                                                                                                                           Stack frame
                                                                                                                     info
                                                                                     Return address for Watt
                                                                                                                                            for Volt
  int w;
                                                                                       Return value to Watt
  w = Volt(w, 10); // Watt calls Volt
                                                                                               (value of W)
                                                                                                                 Parameters
  return w;
                                                                                                  (10)
                             (1) Store the return value in R5+3
                             (2) Pop the local variables
                                                                                       main's frame pointer
                             (increase R6 by 2)
                                                                                                                                           Stack frame
int Volt(int q, int r) {
                                                                                     Return address for main
                                                                                                                                            for Watt
  int k:
                                                                                       Return value to main
  int m;
                                                                                                a
  return k;
                                                                            xFFFF
```

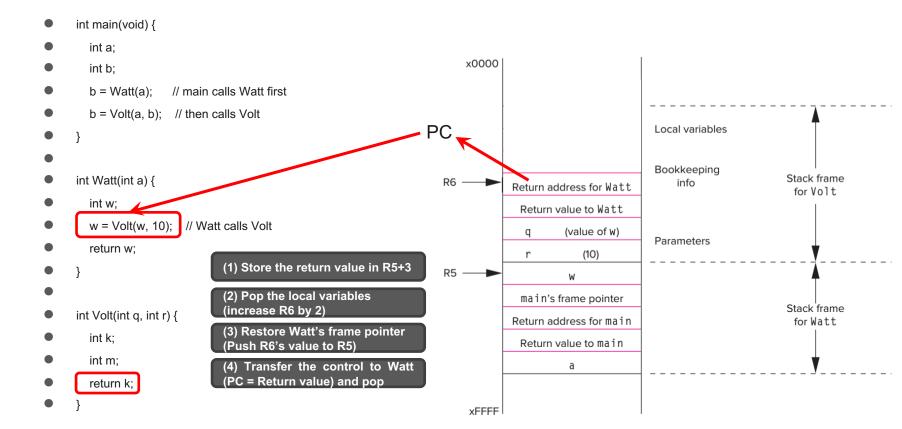


```
int main(void) {
  int a;
                                                                           x0000
  int b;
  b = Watt(a);
                  // main calls Watt first
  b = Volt(a, b); // then calls Volt
                                                                                                               Local variables
                                                                      R6 —
                                                                                     Watt's frame pointer
                                                                                                               Bookkeeping
                                                                                                                                         Stack frame
int Watt(int a) {
                                                                                                                   info
                                                                                    Return address for Watt
                                                                                                                                          for Volt
  int w;
                                                                                     Return value to Watt
  w = Volt(w, 10); // Watt calls Volt
                                                                                              (value of W)
                                                                                                               Parameters
  return w;
                                                                                                 (10)
                            (1) Store the return value in R5+3
                                                                      R5
                            (2) Pop the local variables
                                                                                     main's frame pointer
                            (increase R6 by 2)
                                                                                                                                         Stack frame
int Volt(int q, int r) {
                                                                                    Return address for main
                                                                                                                                          for Watt
                            (3) Restore Watt's frame pointer
  int k:
                                                                                     Return value to main
                            (Push R6's value to R5) and pop
  int m;
                                                                                               a
  return k;
                                                                           xFFFF
```

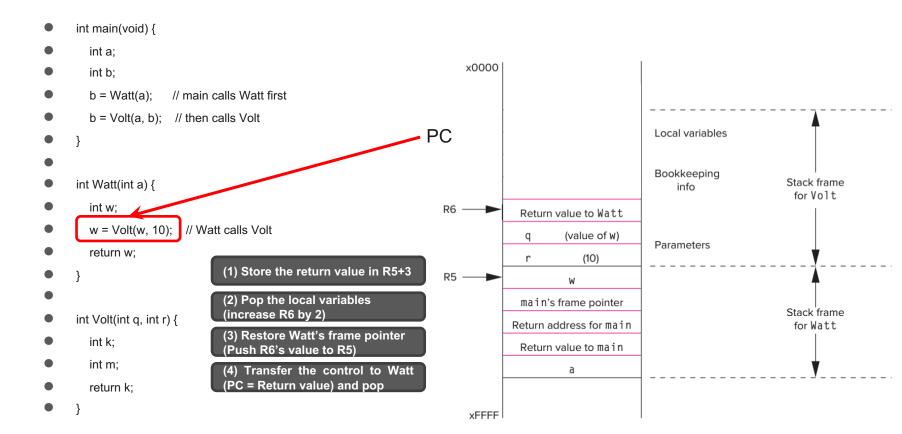


```
int main(void) {
  int a;
                                                                           x0000
  int b;
  b = Watt(a);
                  // main calls Watt first
  b = Volt(a, b); // then calls Volt
                                                                                                               Local variables
                                                                                                               Bookkeeping
                                                                                                                                         Stack frame
int Watt(int a) {
                                                                      R6 —
                                                                                                                   info
                                                                                    Return address for Watt
                                                                                                                                          for Volt
  int w;
                                                                                     Return value to Watt
  w = Volt(w, 10); // Watt calls Volt
                                                                                              (value of W)
                                                                                                               Parameters
  return w;
                                                                                                 (10)
                            (1) Store the return value in R5+3
                                                                      R5
                            (2) Pop the local variables
                                                                                     main's frame pointer
                            (increase R6 by 2)
                                                                                                                                         Stack frame
int Volt(int q, int r) {
                                                                                    Return address for main
                                                                                                                                          for Watt
                            (3) Restore Watt's frame pointer
  int k:
                                                                                     Return value to main
                            (Push R6's value to R5) and pop
  int m;
                                                                                               a
  return k;
                                                                           xFFFF
```











Let's see what happens during a function's lifetime

- (1) Calling (Passing arguments to the function)
- (2) Start Callee (Reserve stack for the function)
 - (3) End Callee (Return)
 - (4) Return to Caller



Function Implementation in C - Return to Caller

```
int main(void) {
  int a;
                                                                            x0000
  int b;
  b = Watt(a);
                  // main calls Watt first
  b = Volt(a, b); // then calls Volt
                                                                                                                Local variables
                                                                                                                 Bookkeeping
int Watt(int a) {
                                                                                                                                           Stack frame
                                                                                                                     info
                                                                                                                                            for Volt
  int w;
                                                                       R6 ---
                                                                                       Return value to Watt
  w = Volt(w, 10); // Watt calls Volt
                                                                                               (value of W)
                                                                                                                 Parameters
  return w;
                                                                                                  (10)
                                                                       R5 -
                            (1) Load the return value (R6) to
                                                                                       main's frame pointer
                            w and pop
                                                                                                                                           Stack frame
int Volt(int q, int r) {
                                                                                     Return address for main
                                                                                                                                            for Watt
  int k:
                                                                                       Return value to main
  int m;
                                                                                                a
  return k;
                                                                            xFFFF
```



Function Implementation in C - Return to Caller

```
int main(void) {
  int a;
                                                                            x0000
  int b;
  b = Watt(a);
                  // main calls Watt first
  b = Volt(a, b); // then calls Volt
                                                                                                                Local variables
                                                                                                                 Bookkeeping
int Watt(int a) {
                                                                                                                                           Stack frame
                                                                                                                     info
                                                                                                                                            for Volt
  int w;
  w = Volt(w, 10); // Watt calls Volt
                                                                       R6
                                                                                               (value of W)
                                                                                                                 Parameters
  return w;
                                                                                                  (10)
                                                                       R5 -
                            (1) Load the return value (R6) to
                                                                                       main's frame pointer
                            w and pop
                                                                                                                                           Stack frame
int Volt(int q, int r) {
                                                                                     Return address for main
                                                                                                                                            for Watt
  int k:
                                                                                       Return value to main
  int m;
                                                                                                a
  return k;
                                                                            xFFFF
```



```
int main(void) {
  int a;
                                                                           x0000
  int b;
  b = Watt(a);
                  // main calls Watt first
  b = Volt(a, b); // then calls Volt
int Watt(int a) {
  int w;
  w = Volt(w, 10); // Watt calls Volt
  return w;
                                                                       R6
                            (1) Load the return value (R6) to
                                                                                      main's frame pointer
                            w and pop
                                                                                                                                          Stack frame
int Volt(int q, int r) {
                                                                                    Return address for main
                                                                                                                                           for Watt
  int k;
                            (2) Pop the arguments
                                                                                      Return value to main
  int m;
                                                                                               a
  return k;
                                                                            xFFFF
```



Questions?



Thanks!

