

Intermediate Programming

Day 7

Outline

- Function declarations
- Passing arrays to functions
- Recursion
- Review questions

Function declarations

Recall that if we (only) define a function after we use it, the compiler will complain.

```
#include <stdio.h>

int main( void )
{
    int a = 7;
    int b = foo(a);
    printf( "%d\n" , b );
    return 0;
}

int foo( int x )
{
    int y = 5;
    return x+y;
}
```

```
>> gcc foo.c
foo.c: In function 'main':
foo.c:7:10: warning: implicit declaration of function 'foo' [-Wimplicit-function-declaration]
   7 |   int b = foo( a );
     |             ^~~
>>
```

Function declarations

- We can declare a function before it is called and only define it after.
 - Note semicolon after parameter list
 - Declaration should appear before the first call to the function
 - A function declaration is also known as a *function prototype*
 - Names of parameters (e.g., `x`) are optional, but can be illuminating
 - It is recommended that you have them (and that they are meaningful) in your declarations so it's easier to understand what the function does and what to pass in.
 - Code tends to be more readable if functions are declared before `main` and defined after.

```
#include <stdio.h>
int foo( int );
int main( void )
{
    int a = 7;
    int b = foo(a);
    printf( "%d\n" , b );
    return 0;
}

int foo( int x )
{
    int y = 5;
    return x+y;
}
```

Function declarations

Creating an executable is done in three steps

1. Pre-processor:
Function declarations are brought in using `#include`, etc.
2. Compilation:
Functions are transformed from source code to object code
3. Linking:
Bring together relevant object code (e.g. if a function calls another function)

When compiling a function that invokes other functions, the compiler does not need to know what the other function does, only what it takes as input and returns as output.

⇒ The compiler only needs to know the declaration of the invoked functions.

Outline

- Function declarations
- **Passing arrays to functions**
- Recursion
- Review questions

Passing arrays to functions

Recall:

- Argument values in C are passed by value
 - ⇒ The function sees a copy of the value passed in as an argument
 - ⇒ Changes made to the argument within the function will not be seen when the function returns.

```
#include <stdio.h>
void increment( int i ) { i += 1; }
int main( void )
{
    int i = 1;
    printf( "i = %d\n" , i );
    increment( i );
    printf( "i = %d\n" , i );
    return 0;
}
```

```
>> gcc temp.c -std=c99 -pedantic -Wall -Wextra
>> ./a.out
i = 1
i = 1
>>
```

Passing arrays to functions

Recall:

- Argument values in C are passed by value
- The **sizeof** function returns the size of a type/variable

```
#include <stdio.h>
int main(void)
{
    int x = 75;
    printf( "Size of char: %d\n" , sizeof( char ) );
    printf( "Size of int: %d\n" , sizeof( x ) );
    return 0;
}
```

```
>> ./a.out
Size of char: 1
Size of int: 4
>>
```


Passing arrays to functions

Recall:

- Argument values in C are passed by value
- The **sizeof** function returns the size of a type/variable
- You can determine the size of a static array using the **sizeof** operator

```
#include <stdio.h>
int main(void)
{
    int values[] = { 0 , 130 };
    printf( "Array size: %d\n" , sizeof( values ) );
    return 0;
}
```

```
>> ./a.out
Array size: 8
>>
```

Passing arrays to functions

Recall:

- Argument values in C are passed by value
- The `sizeof` function returns the size of a type/variable
- You can determine the size of a static array using the `sizeof` operator

Disclaimer:

This is only partially true

Passing arrays to functions

As with other variables, you can pass an array as an argument to a function.

```
#include <stdio.h>

void print( int values[] , int sz )
{
    for( int i=0 ; i<sz ; i++ ) printf( " %d" , values[i] );
    printf( "\n" );
}

int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    int sz = (int)sizeof(v)/sizeof(int);
    print( v , sz );
    return 0;
}
```

```
>> ./a.out
 9 7 5 6 8 10
>>
```

Passing arrays to functions

However:

1. The function can change the contents of the array.

```
#include <stdio.h>

void print( int values[] , int sz )
{
    for( int i=0 ; i<sz ; i++ ) printf( " %d" , values[i] );
    printf( "\n" );
}

void setToZero( int values[] , int idx )
{
    values[idx] = 0;
}

int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    int sz = (int)sizeof(v)/sizeof(int);
    print( v , sz );
    setToZero( v , 1 );
    print( v , sz );
    return 0;
}
```

```
>> ./a.out
 9 7 5 6 8 10
 9 0 5 6 8 10
>>
```

Passing arrays to functions

However:

1. The function can change the contents of the array.
You can use the keyword **const** to indicate that your function will not change the contents of the array.

```
#include <stdio.h>

void print( const int values[] , int sz )
{
    for( int i=0 ; i<sz ; i++ ) printf( " %d" , values[i] );
    printf( "\n" );
}

void setToZero( int values[] , int idx )
{
    values[idx] = 0;
}

int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    int sz = (int)sizeof(v)/sizeof(int);
    print( v , sz );
    setToZero( v , 1 );
    print( v , sz );
    return 0;
}
```

```
>> ./a.out
 9 7 5 6 8 10
 9 0 5 6 8 10
>>
```

Passing arrays to functions

However:

1. The function can change the contents of the array.
You can use the keyword **const** to indicate that your function will not change the contents of the array.

```
#include <stdio.h>

void print( const int values[] , int sz )
{
    for( int i=0 ; i<sz ; i++ ) printf( " %d" , values[i] );
    printf( "\n" );
}

void setToZero( const int values[] , int idx )
{
    values[idx] = 0;
}

int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    int sz = (int)sizeof(v)/sizeof(int);
```

```
>> gcc ...
foo.c: In function 'setToZero':
foo.c:10:14: error: assignment of read-only location '*(values + (sizetype)((long unsigned int)idx * 4))'
   10 |     values[idx] = 0;
      |             ^
>>
```

Passing arrays to functions

However:

1. The function can change the contents of the array.
2. If you pass an array to a function and call the **sizeof** function on it, you will not get the size of the array.

```
#include <stdio.h>

int arraySize( const int values[] )
{
    return sizeof( values );
}

int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    printf( "%d %d\n" , sizeof( v ) , arraySize( v ) );
    return 0;
}
```

```
>> ./a.out
24 8
>>
```

Passing arrays to functions

- If function **func1** calls **func2**:
 - ✓ If you declare an array in the body of **func1**, you can pass it as an argument to **func2** (which can then pass it on to another function, etc.)

```
#include <stdio.h>

void swap( int values[] , int idx1 , int idx2 )
{
    int tmp = values[ idx1 ];
    values[ idx1 ] = values[ idx2 ];
    values[ idx2 ] = tmp;
}

void reverse( int values[] , int sz )
{
    for( int i=0 ; i<sz/2 ; i++ ) swap( values , i , sz-1-i );
}

void print( const int values[] , int sz )
{
    for( int i=0 ; i<sz ; i++ ) printf( " %d" , values[i] );
    printf( "\n" );
}

int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    int sz = (int)sizeof(v)/sizeof(int);
    print( v , sz );
    reverse( v , sz );
    print( v , sz );
    return 0;
}
```

```
>> ./a.out
 9 7 5 6 8 10
10 8 6 5 7 9
>>
```


Passing arrays to functions

- If function **func1** calls **func2**:
 - ✓ If you declare an array in the body of **func1**, you can pass it as an argument to **func2**
 - ✗ If you declare an array in the body of **func2**, you cannot return it to **func1** (yet).

```
#include <stdio.h>

int *reverse( const int values[] , int sz )
{
    int rev_values[sz];
    for( int i=0 ; i<sz ; i++ ) rev_values[i] = values[sz-1-i];
    return rev_values;
}

void print( const int values[] , int sz )
{
    for( int i=0 ; i<sz ; i++ ) printf( " %d" , values[i] );
    printf( "\n" );
}

int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    int sz = (int)sizeof(v)/sizeof(int);
    print( v , sz );
    int *rev_v = reverse( v , sz );
    print( rev_v , sz );
    return 0;
}
```

```
>> ./a.out
 9 7 5 6 8 10
Segmentation fault (core dumped)
>>
```

Outline

- Function declarations
- Passing arrays to functions
- **Recursion**
- Review questions

Recursion

We've already seen that a function can call other functions within its body.

```
#include <stdio.h>

void printReverse( const int values[] , int sz )
{
    for( int i=0 ; i<sz ; i++ ) printf( " %d" , values[sz-1-i] );
    printf( "\n" );
}

int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    int sz = (int)sizeof(v)/sizeof(int);
    printReverse( v , sz );
    return 0;
}
```

```
>> ./a.out
    10 8 6 5 7 9
>>
```

Recursion

We've already seen that a function can call other functions within its body.

A function can also call itself.

```
#include <stdio.h>

void printReverse( const int values[] , int sz )
{
    if( !sz ) printf( "\n" );
    else
    {
        printf( " %d" , values[sz-1] );
        printReverse( values , sz-1 );
    }
}

int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    int sz = (int)sizeof(v)/sizeof(int);
    printReverse( v , sz );
    return 0;
}
```

```
>> ./a.out
  9 7 5 6 8 10
>>
```

Recursion

Like a *while* loop, a recursive function call can go on indefinitely.

```
#include <stdio.h>

void printReverse( const int values[] , int sz )
{
    if( !sz ) printf( "\n" );
    else
    {
        printf( " %d" , values[sz-1] );
        printReverse( values , sz-1 );
    }
}

int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    int sz = (int)sizeof(v)/sizeof(int);
    printReverse( v , sz );
    return 0;
}
```

```
>> ./a.out
  9 7 5 6 8 10
>>
```

Recursion

Like a *while* loop, a recursive function call can go on indefinitely.

For it to terminate, you need:

1. A base case

The parameters are “so simple” that the function can solve the problem directly, without recursion

```
#include <stdio.h>
```

```
void printReverse( const int values[] , int sz )  
{
```

```
    if( !sz ) printf( "\n" );
```

```
    else
```

```
    {
```

```
        printf( " %d" , values[sz-1] );
```

```
        printReverse( values , sz-1 );
```

```
    }
```

```
}
```

```
int main( void )
```

```
{
```

```
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
```

```
    int sz = (int)sizeof(v)/sizeof(int);
```

```
    printReverse( v , sz );
```

```
    return 0;
```

```
}
```

```
>> ./a.out
```

```
9 7 5 6 8 10
```

```
>>
```

Recursion

Like a *while* loop, a recursive function call can go on indefinitely.

For it to terminate, you need:

1. A base case

The parameters are “so simple” that the function can solve the problem directly, without recursion

2. Progress towards the base case

When invoked recursively, the parameters become “simpler”

```
#include <stdio.h>
```

```
void printReverse( const int values[] , int sz )  
{
```

```
    if( !sz ) printf( "\n" );
```

```
    else
```

```
    {
```

```
        printf( " %d" , values[sz-1] );
```

```
        printReverse( values , sz-1 );
```

```
    }
```

```
}
```

```
int main( void )
```

```
{
```

```
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
```

```
    int sz = (int)sizeof(v)/sizeof(int);
```

```
    printReverse( v , sz );
```

```
    return 0;
```

```
}
```

```
>> ./a.out
```

```
9 7 5 6 8 10
```

```
>>
```

Recursion

When you invoke a function, the execution “jumps” from where you are in the code to where the function is in the code.

In order to be able to track where to go back to after the function is invoked, you need to store (among many other things) where you were when you called the function.

A *stack frame* stores this information for a given function call.

The collection of stack frames generated by all the function calls so far is stored on the *call stack*.

```
#include <stdio.h>

void printReverse( const int values[] , int sz )
{
    if( !sz ) printf( "\n" );
    else
    {
        printf( " %d" , values[sz-1] );
        printReverse( values , sz-1 );
    }
}

int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    int sz = (int)sizeof(v)/sizeof(int);
    printReverse( v , sz );
    return 0;
}
```


Recursion

The downside of recursion is that every time you recurse, you need to add another stack frame to the call stack.

⇒ Recursive function calls come with a compute/memory overhead.

```
#include <stdio.h>

void printReverse( const int values[] , int sz )
{
    if( !sz ) printf( "\n" );
    else
    {
        printf( " %d" , values[sz-1] );
        printReverse( values , sz-1 );
    }
}

int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    int sz = (int)sizeof(v)/sizeof(int);
    printReverse( v , sz );
    return 0;
}
```

Recursion

The downside of recursion is that every time you recurse, you need to add another stack frame to the call stack.

⇒ Recursive function calls come with a compute/memory overhead.

```
#include <stdio.h>

void printReverse( const int values[] , int sz )
{
    if( !sz ) printf( "\n" );
    else
    {
        printf( " %d" , values[sz-1] );
        printReverse( values , sz-1 );
    }
}

int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    int sz = (int)sizeof(v)/sizeof(int);
    printReverse( v , sz );
    return 0;
}
```

Diagram illustrating the recursive call process:

- A box labeled **sz=6** is connected by an arrow to the `printReverse` function call in the code.
- A box labeled **>> ./a.out** is connected by a line to the `main` function call in the code.

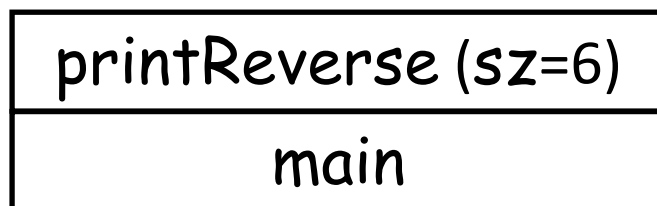
main

call stack

Recursion

The downside of recursion is that every time you recurse, you need to add another stack frame to the call stack.

⇒ Recursive function calls come with a compute/memory overhead.



call stack

```
#include <stdio.h>

void printReverse( const int values[] , int sz )
{
    if( !sz ) printf( "\n" );
    else
    {
        printf( " %d" , values[sz-1] );
        printReverse( values , sz-1 );
    }
}

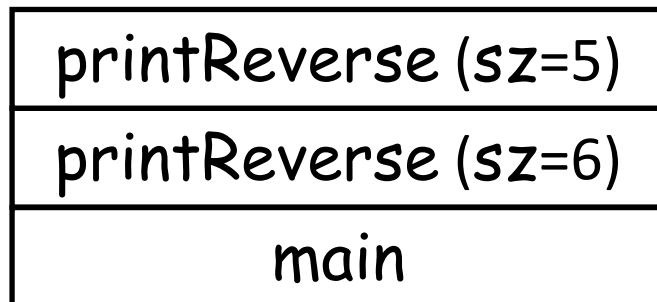
int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    int sz = (int)sizeof(v)/sizeof(int);
    printReverse( v , sz );
    return 0;
}
```

```
>> ./a.out
10
```

Recursion

The downside of recursion is that every time you recurse, you need to add another stack frame to the call stack.

⇒ Recursive function calls come with a compute/memory overhead.



call stack

```
#include <stdio.h>

void printReverse( const int values[] , int sz )
{
    if( !sz ) printf( "\n" );
    else
    {
        printf( " %d" , values[sz-1] );
        printReverse( values , sz-1 );
    }
}

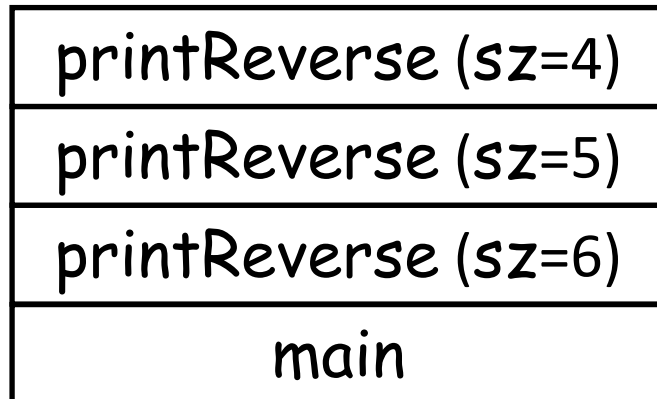
int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    int sz = (int)sizeof(v)/sizeof(int);
    printReverse( v , sz );
    return 0;
}
```

```
>> ./a.out
10 8
```

Recursion

The downside of recursion is that every time you recurse, you need to add another stack frame to the call stack.

⇒ Recursive function calls come with a compute/memory overhead.



call stack

```
#include <stdio.h>

void printReverse( const int values[] , int sz )
{
    if( !sz ) printf( "\n" );
    else
    {
        printf( " %d" , values[sz-1] );
        printReverse( values , sz-1 );
    }
}

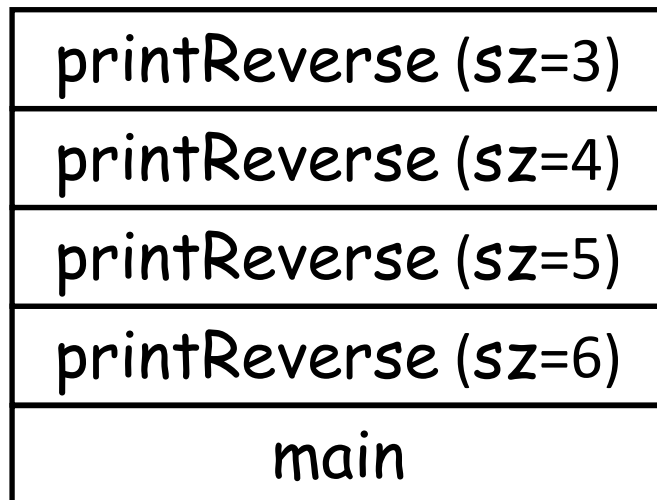
int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    int sz = (int)sizeof(v)/sizeof(int);
    printReverse( v , sz );
    return 0;
}
```

```
>> ./a.out
10 8 6
```

Recursion

The downside of recursion is that every time you recurse, you need to add another stack frame to the call stack.

⇒ Recursive function calls come with a compute/memory overhead.



call stack

```
#include <stdio.h>

void printReverse( const int values[] , int sz )
{
    if( !sz ) printf( "\n" );
    else
    {
        sz=2
        printf( " %d" , values[sz-1] );
        printReverse( values , sz-1 );
    }
}

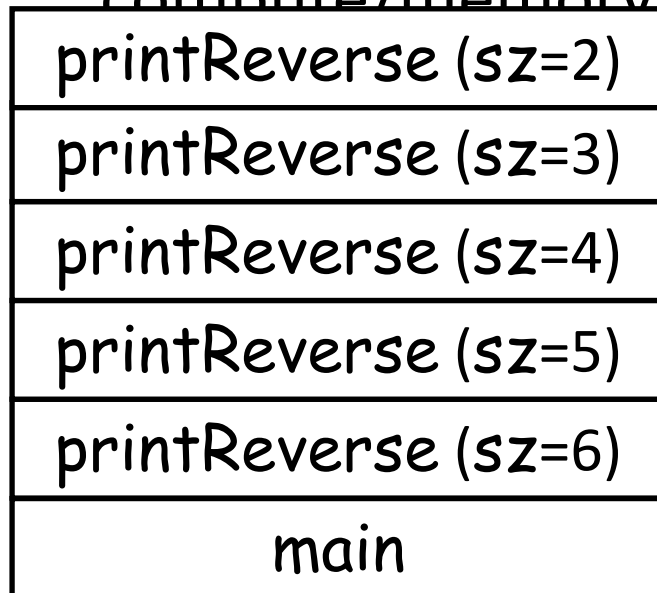
int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    int sz = (int)sizeof(v)/sizeof(int);
    printReverse( v , sz );
    return 0;
}
```

```
>> ./a.out
10 8 6 5
```

Recursion

The downside of recursion is that every time you recurse, you need to add another stack frame to the call stack.

⇒ Recursive function calls come with a ~~compute~~/memory overhead.



call stack

```
#include <stdio.h>

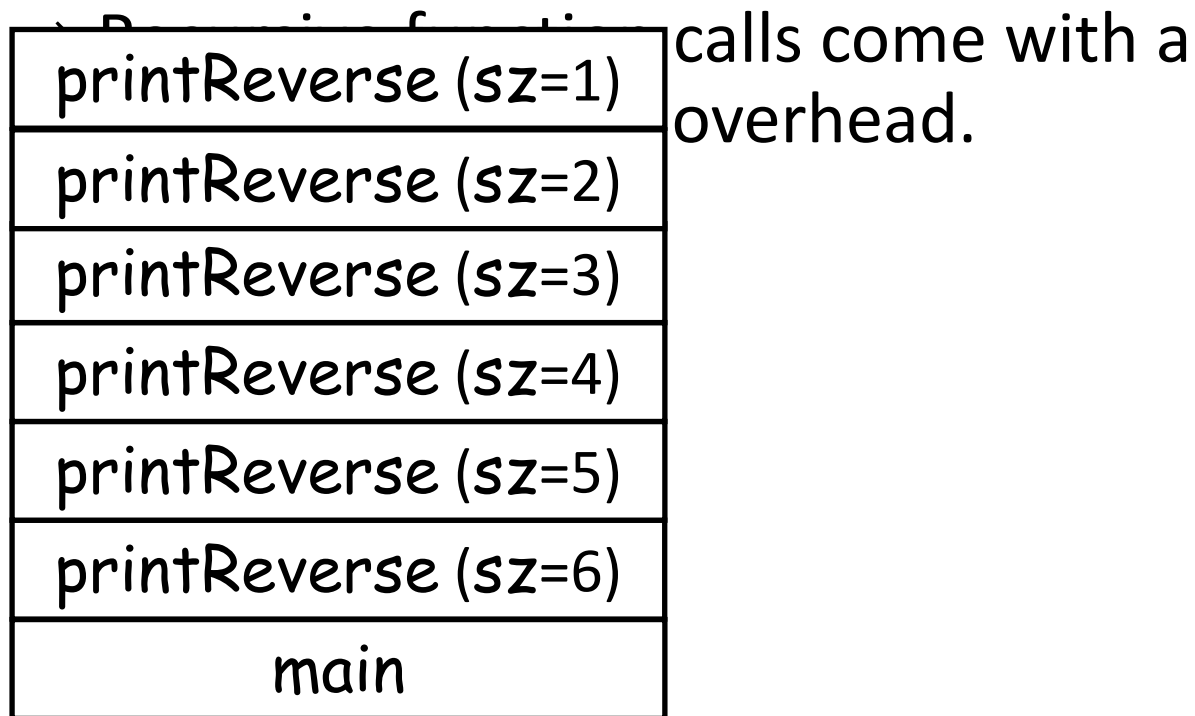
void printReverse( const int values[] , int sz )
{
    if( !sz ) printf( "\n" );
    else
    {
        sz=1
        printf( " %d" , values[sz-1] );
        printReverse( values , sz-1 );
    }
}

int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    int sz = (int)sizeof(v)/sizeof(int);
    printReverse( v , sz );
    return 0;
}
```

```
>> ./a.out
10 8 6 5 7
```

Recursion

The downside of recursion is that every time you recurse, you need to add another stack frame to the call stack.



call stack

```
#include <stdio.h>

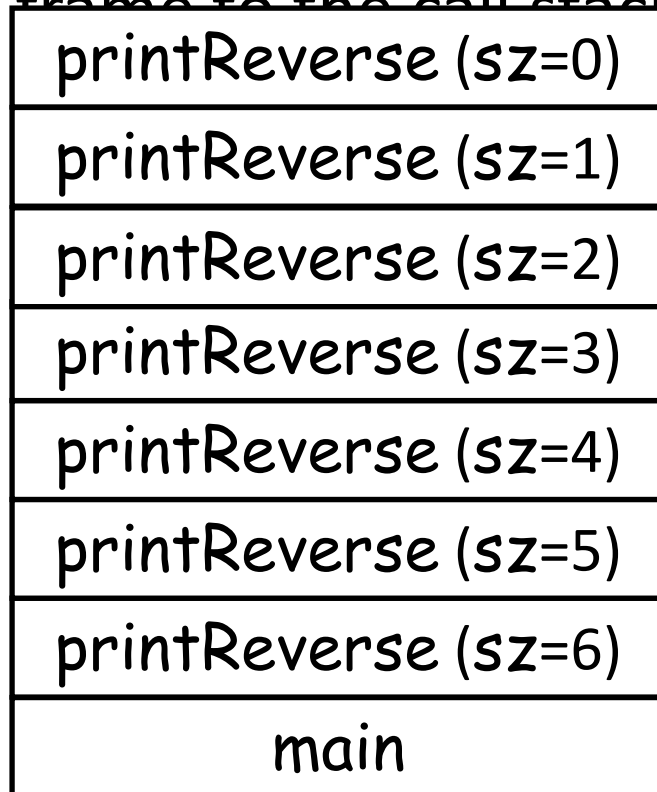
void printReverse( const int values[] , int sz )
{
    if( !sz ) printf( "\n" );
    else
    {
        printf( " %d" , values[sz-1] );
        printReverse( values , sz-1 );
    }
}

int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    int sz = (int)sizeof(v)/sizeof(int);
    printReverse( v , sz );
    return 0;
}
```

```
>> ./a.out
10 8 6 5 7 9
```


Recursion

The downside of recursion is that every time you recurse, you need to add another stack frame to the call stack.



call stack

calls come with a overhead.

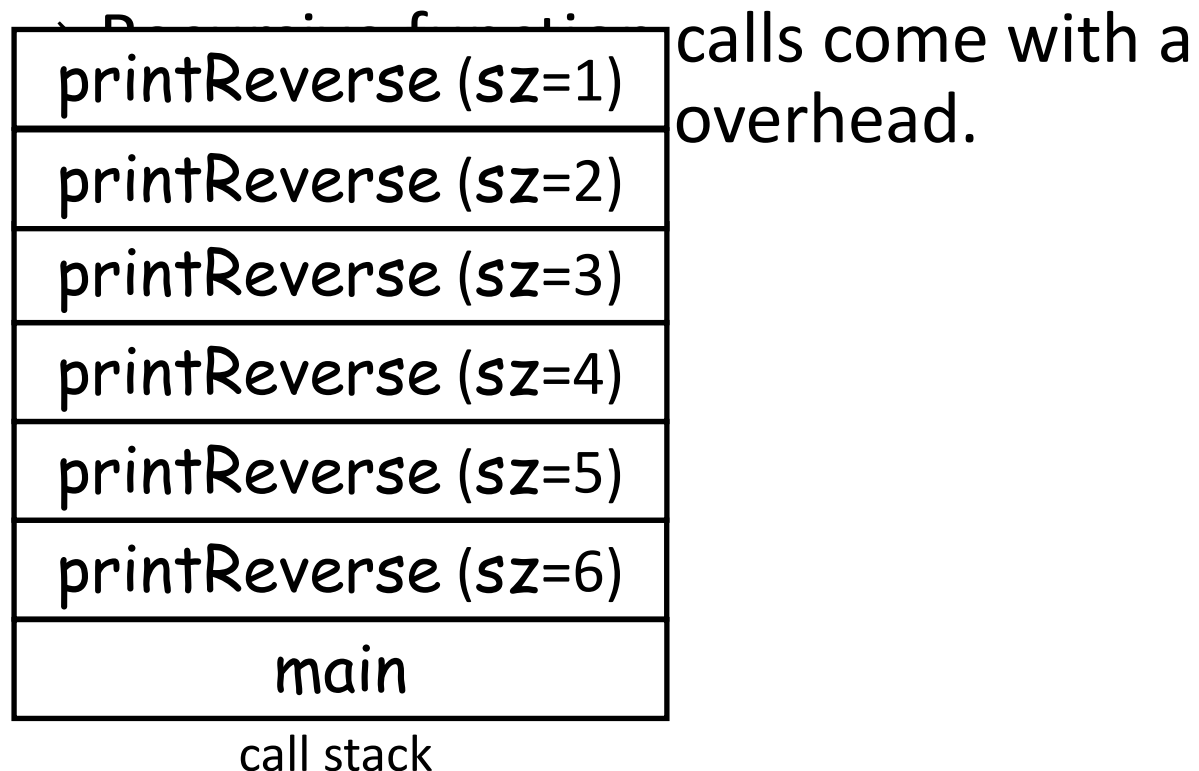
```
#include <stdio.h>
```

```
void printReverse( const int values[] , int sz )  
{  
    if( !sz ) printf( "\n" );  
    else  
    {  
        printf( " %d" , values[sz-1] );  
        printReverse( values , sz-1 );  
    }  
}  
  
int main( void )  
{  
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };  
    int sz = (int)sizeof(v)/sizeof(int);  
    printReverse( v , sz );  
    return 0;  
}
```

```
>> ./a.out  
10 8 6 5 7 9
```

Recursion

The downside of recursion is that every time you recurse, you need to add another stack frame to the call stack.



```
#include <stdio.h>
```

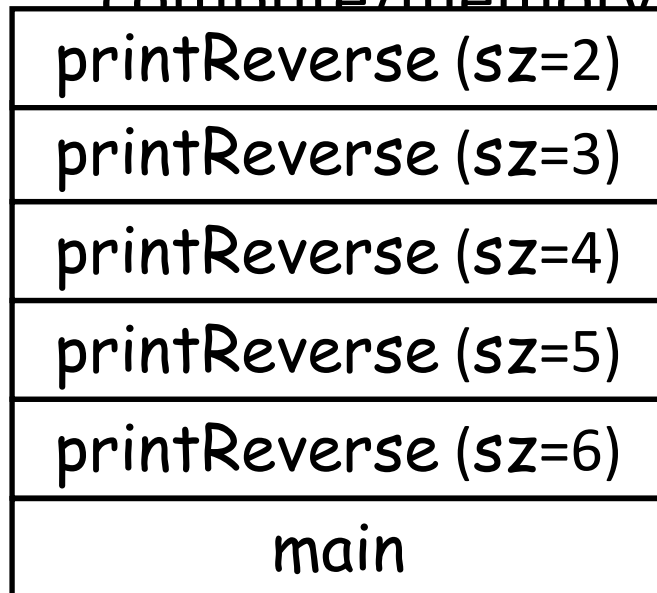
```
void printReverse( const int values[] , int sz )  
{  
    if( !sz ) printf( "\n" );  
    else  
    {  
        printf( " %d" , values[sz-1] );  
        printReverse( values , sz-1 );  
    }  
}  
  
int main( void )  
{  
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };  
    int sz = (int)sizeof(v)/sizeof(int);  
    printReverse( v , sz );  
    return 0;  
}
```

```
>> ./a.out  
10 8 6 5 7 9
```

Recursion

The downside of recursion is that every time you recurse, you need to add another stack frame to the call stack.

⇒ Recursive function calls come with a ~~compute~~/memory overhead.



call stack

```
#include <stdio.h>

void printReverse( const int values[] , int sz )
{
    if( !sz ) printf( "\n" );
    else
    {
        printf( " %d" , values[sz-1] );
        printReverse( values , sz-1 );
    }
}

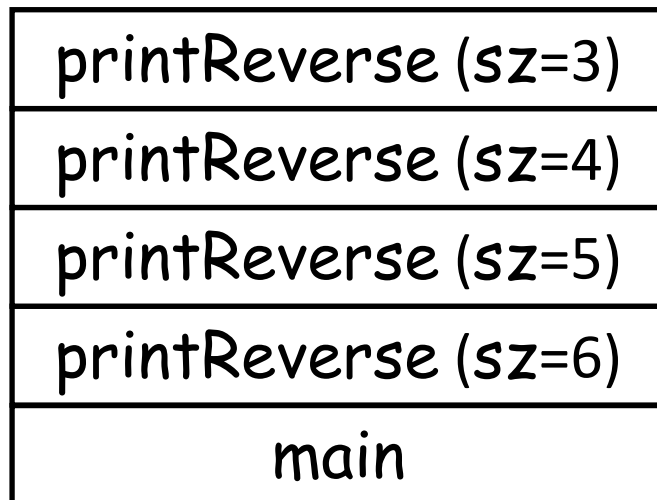
int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    int sz = (int)sizeof(v)/sizeof(int);
    printReverse( v , sz );
    return 0;
}
```

```
>> ./a.out
10 8 6 5 7 9
```

Recursion

The downside of recursion is that every time you recurse, you need to add another stack frame to the call stack.

⇒ Recursive function calls come with a compute/memory overhead.



call stack

```
#include <stdio.h>

void printReverse( const int values[] , int sz )
{
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    else
    {
        printf( " %d" , values[sz-1] );
        printReverse( values , sz-1 );
    }
}

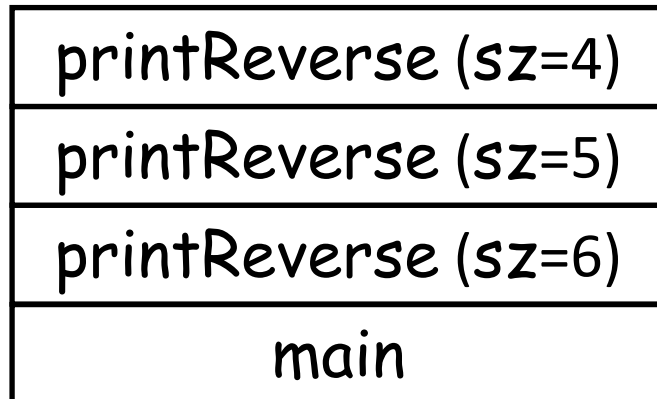
int main( void )
{
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };
    int sz = (int)sizeof(v)/sizeof(int);
    printReverse( v , sz );
    return 0;
}
```

```
>> ./a.out
10 8 6 5 7 9
```

Recursion

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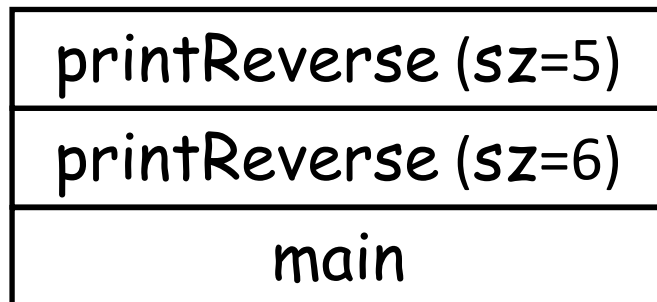
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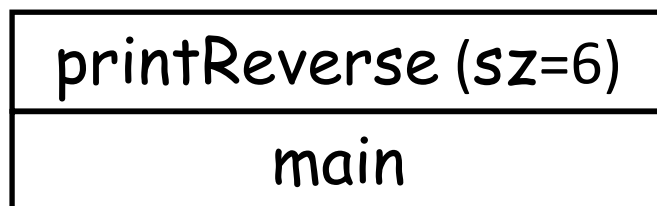
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{
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    int sz = (int)sizeof(v)/sizeof(int);
    printReverse( v , sz );
    return 0;
}
```

```
>> ./a.out
10 8 6 5 7 9
```

Recursion

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⇒ Recursive function calls come with a compute/memory overhead.

```
#include <stdio.h>
```

```
void printReverse( const int values[] , int sz )  
{  
    if( !sz ) printf( "\n" );  
    else  
    {  
        printf( " %d" , values[sz-1] );  
        printReverse( values , sz-1 );  
    }  
}  
  
int main( void )  
{  
    int v[] = { 9 , 7 , 5 , 6 , 8 , 10 };  
    int sz = (int)sizeof(v)/sizeof(int);  
    printReverse( v , sz );  
    return 0;  
}
```

```
>> ./a.out  
10 8 6 5 7 9
```

main

call stack

Recursion

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    int sz = (int)sizeof(v)/sizeof(int);
    printReverse( v , sz );
    return 0;
}
```

```
>> ./a.out
    10 8 6 5 7 9
>>
```

Recursion

The downside of recursion is that every time you recurse, you need to add another stack frame to the call stack.

⇒ Recursive function calls come with a compute/memory overhead.

⇒ If you recurse too deeply, you will run out of memory on the call stack.

```
#include <stdio.h>

void printReverse( const int values[] , int sz )
{
    if( !sz ) printf( "\n" );
    else
    {
        printf( " %d" , values[sz-1] );
        printReverse( values , sz-1 );
    }
}

int main( void )
{
    int v[300000] = { 0 };
    int sz = (int)sizeof(v)/sizeof(int);
    printReverse( v , sz );
    return 0;
}
```

```
>> ./a.out
.. Segmentation fault (core dumped)
>>
```

Recursion

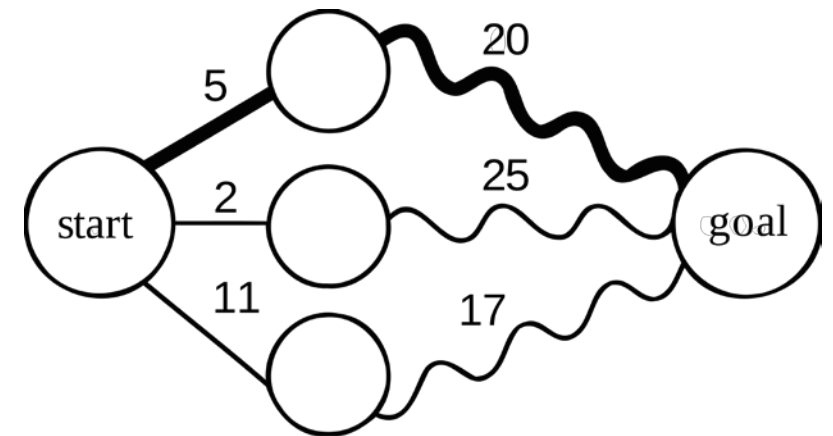
Recursion can be the natural for problems where:

- The algorithm uses a “divide and conquer” approach
- The data structure is recursive

Example:

Given a (positively) weighted graph, find a shortest path from the start to the goal:

- Iterate over the neighbors,
 - Compute the shortest path from the neighbor to the goal,
 - Sum the distance to the neighbor and the length of its shortest path
- Return the path with smallest sum



https://en.wikipedia.org/wiki/Dynamic_programming

Outline

- Function declarations
- Passing arrays to functions
- Recursion
- Review questions

Review questions

1. How do you get the size of an integer array?

Review questions

2. Is the size of a string array the same as the string length?

Review questions

3. What is the difference between a function declaration and a function definition?

Review questions

4. Can you have two functions with the same function name in a program?

Review questions

5. How does passing an integer array to a function differs from passing a single integer variable into a function?

Review questions

6. How can you make an array that is passed into a function not modifiable?

Review questions

7. What is the down-side to recursion?

Exercise 3-1

- Website -> Course Materials -> Ex3-1