Outline

- In this lesson, we will:
  - See how arrays are passed to functions
    - The behavior may be unexpected
  - Learn that array identifiers themselves have a value
  - See how that corresponds with passing of arrays to functions
  - See that local arrays are treated as `const`, but parameter arrays are not

Arrays

- The previous topic covered arrays and their uses
  - Stores a fixed number of entries
  - Entries can be accessed with literal integers or integer data types
    - The index must be a value between `0` and `capacity - 1`
- This is sufficient for using arrays
- We will now investigate the implementation of arrays
  - This will lead to memory and addresses

Inability to assign arrays

- Unlike local variables of primitive data types, local arrays cannot be assigned to

```
#include <iostream>

// Function declarations
int main();

// Function definitions
int main() {
    int  first_array[10]{};
    int second_array[10]{};

    first_array = second_array;

    return 0;
}
```

It is as if arrays identifiers are declared `const`

```
example.cpp: In function 'int main()':
example.cpp:11:19: error: invalid array assignment
     first_array = second_array;
                   ^~~~~~~~~~~~
```

const arrays

- However, if an array is declared `const`,
  its *entries* cannot be changed after initialization

```
#include <iostream>

// Function declarations
int main();

// Function definitions
int main() {
    int const primes[10]{2, 3, 5, 7, 11, 13, 17, 19, 23, 25};

    primes[9] = 29;

    return 0;
}
```

```
example.cpp: In function 'int main()':
example.cpp:10:17: error: assignment of read-only
location 'primes[9]'
     primes[9] = 29;
                 ^~
```


Inability to assign arrays

- It is a design feature
  - The assumption is that local arrays are temporary
- If you want to copy all the entries from one array to another,
  you must use a for loop:

```
for ( int k{0}; k < capacity; ++k ) {
    first_array[k] = second_array[k];
}
```


Inability to return local arrays

- There is no mechanism to return a local array from a function

```
#include <iostream>

// Function declarations
int main();
int f()[5];

int f()[5] {
    int x[5]{3,4,5,6,7};
    return x;
}

// Function definitions
int main() {
    std::cout << f()[1] << std::endl;

    return 0;
}
```

```
example.cpp:5:10: error: 'f' declared as
function returning an array
 int f()[5];
          ^
example.cpp:7:10: error: 'f' declared as
function returning an array
 int f()[5] {
```


Local arrays

- Local arrays are meant to temporarily store information for the duration of a function
  - C++ never creates new arrays and copies the entries over for you
  - We cannot return the local array,
    as it was local to the function
  - Later, we will see how we can:
    create, manipulate and return persistent arrays

Passing arrays as arguments

- Local arrays can be passed as arguments to a function
  - You may expect notation a follows:

```
// Function declarations;
double average( double array[10] );
int main();
```

  - Solution: the array capacity must be passed as a separate argument

```
// Function declarations;
double average( double array[], unsigned int capacity );
int main();
```

The identifier of the array

The number of entries in the array

Passing arrays as arguments

- We calculate and print out the average:

```
double average( double array[], unsigned int capacity ) {
    double sum{0.0};

    for ( unsigned int k{0}; k < capacity; ++k ) {
        sum += array[k];
    }

    return sum/capacity;
}

int main() {
    double data[5]{ 103.8, 105.1, 102.6, 103.7, 104.9 };

    std::cout << average( data, 5 ) << std::endl;

    return 0;
}
```

Output:

```
104.02
```


Passing arrays as arguments

- One solution is to have a separate local variable store the capacity:

```
int main() {
    unsigned int const DATA_CAPACITY{5};
    double data[DATA_CAPACITY]{ 103.8, 105.1, 102.6, 103.7, 104.9 };

    std::cout << average( data, DATA_CAPACITY ) << std::endl;

    return 0;
}
```


Passing arrays as arguments

- This prints the entries of an array:

```
void print_array( double array[], unsigned int capacity ) {
    if ( capacity == 0 ) {
        return;
    }

    std::cout << array[0];

    for ( unsigned int k{1}; k < capacity; ++k ) {
        std::cout << ", " << array[k];
    }

    std::cout << std::endl;
}
```

Passing arrays as arguments

- This function converts an array into a string:

```
std::string to_string( double array[], unsigned int capacity ) {
    if ( capacity == 0 ) {
        return "";
    }

    std::string return_string{ std::to_string( array[0] ) };

    for ( unsigned int k{1}; k < capacity; ++k ) {
        return_string += ", " + std::to_string( array[k] );
    }

    return return_string;
}
```


Passing arrays as arguments

- Here we use that printing function:

```
int main() {
    unsigned int const DATA_CAPACITY{5};
    double data[DATA_CAPACITY]{ 103.8, 105.1, 102.6, 103.7, 104.9 };

    print_array( data, DATA_CAPACITY );
    std::cout << to_string( data, DATA_CAPACITY ) << std::endl;

    return 0;
}
```

Output:

```
103.8, 105.1, 102.6, 103.7, 104.9
103.800000, 105.100000, 102.600000, 103.700000
```


Passing arrays as arguments

- Here is an interesting function:

```
void reset( double array[], unsigned int capacity ) {
    for ( unsigned int k{0}; k < capacity; ++k ) {
        array[k] = 0.0;
    }
}

int main() {
    unsigned int const DATA_CAPACITY{5};
    double data[DATA_CAPACITY]{ 103.8, 105.1, 102.6, 103.7, 104.9 };

    reset( data, DATA_CAPACITY );
    print_array( data, DATA_CAPACITY );

    return 0;
}
```

Output:

```
0, 0, 0, 0, 0
```


Passing arrays as arguments

- Aren't parameters passed by value?
  - Shouldn't a copy of the array be sent?
- Problems:
  - Imagine copying an array with 1000 entries...
- Observation:
  - Like references, when passed, arrays cannot be part of an arithmetic or logical expression
  - You can only pass the array identifier
    - Consequently, differing behaviors should be expected

Passing arrays as arguments

- Question: what is passed?

```
#include <iostream>

void some_function( double array[], unsigned int capacity ) {
    std::cout << array << std::endl;
}

int main() {
    double data[5]{ 103.8, 105.1, 102.6, 103.7, 104.9};
    std::cout << data << std::endl;
    some_function( data, 5 );

    return 0;
}
```

Output:

```
0xffffcb80
0xffffcb80
```


Passing arrays as arguments

- Note that:
  - These seem to be hexadecimal numbers
  - The "values" of the local array and the parameter array are equal:

```
0xffffcb80
```

- You may get different hexadecimal numbers, but both will be the same number

Array values

- Recall that an array of capacity *n* stores entries of the given type
  - Each entry occupies a fixed number of bytes
- Thus, the following arrays occupy:

```
int array_1[10];    //  10 x 4 =  40 bytes
double array_2[7];  //   7 x 8 =  56 bytes
bool array_3[100];  // 100 x 1 = 100 bytes
```

- The value of the array variable is the address of the first byte
  - It is the address in main memory

Array values

- Consider the following:

```
#include <iostream>

int main();

int main() {
    int array_1[12]; //  48 bytes = 0x30 bytes
    int array_2[20]; //  80 bytes = 0x50 bytes
    int array_3[52]; // 208 bytes = 0xd0 bytes

    std::cout << array_1 << std::endl;
    std::cout << array_2 << std::endl;
    std::cout << array_3 << std::endl;

    return 0;
}
```

```
53237253
53237297
53237140
```

The output is

```
0xffffcbd0
0xffffcb80
0xffffcab0
```

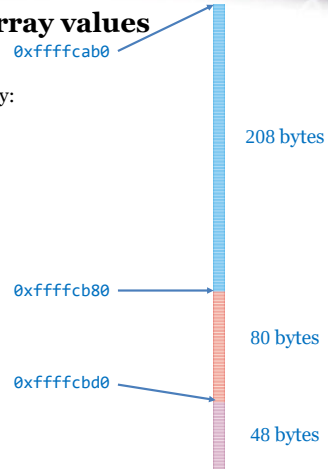
```
0xffffcab0
+ ________d0
0xffffcb80

0xffffcb80
+ ________50
0xffffcbd0
```

Array values

- Looking at this graphically:

The output is
0xffffcbd0
0xffffcb80
0xffffcab0



Array addresses are passed by value

- When an array is passed as an argument, the value of the address is passed:

```
void f( int param[], unsigned int capacity ) {
    int local[5]{ 1, 10, 100, 1000, 10000 };
    std::cout << "param = " << param << std::endl;
    std::cout << "local = " << local << std::endl;
    std::cout << "param[3] = " << param[3] << std::endl;
    std::cout << "Assigning param = local;" << std::endl;
    param = local;
    std::cout << "param = " << param << std::endl;
    std::cout << "local = " << local << std::endl;
    std::cout << "param[3] = " << param[3] << std::endl;
}

int main() {
    int data[4]{ 2, 3, 5, 7 };
    std::cout << "data  = " << data << std::endl;
    f( data, 4 );
    std::cout << "data  = " << data << std::endl;
    return 0;
}
```

Output:

```
data  = 0xffffcbf0
param = 0xffffcbf0
local = 0xffffcba0
param[3] = 7
Assigning param = local;
param = 0xffffcba0
local = 0xffffcba0
param[3] = 1000
data  = 0xffffcbf0
```


Summary

- Following this lesson, you now
  - Understand that arrays store an address in memory
    - It is at that address that the array is stored
  - Understand that arrays, when passed to functions, are passed by this address value
  - A change to an entry in a parameter array changes the corresponding entry in the argument array
  - While local array identifiers cannot be assigned to, parameter array identifiers can be

References

[1] No references?

Colophon

These slides were prepared using the Georgia typeface. Mathematical equations use Times New Roman, and source code is presented using `Consolas`.

The photographs of lilacs in bloom appearing on the title slide and accenting the top of each other slide were taken at the Royal Botanical Gardens on May 27, 2018 by Douglas Wilhelm Harder. Please see

https://www.rbg.ca/

for more information.



Disclaimer

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