8. Sequence Data I

11. Sequences

Sequences

```
#include <iostream>
int main() {
   double n1, n2, n3, n4, n5;
   std::cout << "Please enter five numbers: ";
   std::cin >> n1 >> n2 >> n3 >> n4 >> n5;
   std::cout << "The average of " << n1 << ", " << n2 << ", "
      << n3 << ", " << n4 << ", " << n5 << " is "
      << (n1 + n2 + n3 + n4 + n5)/5 << '\n';
}
-------------------------------------------------------------------
#include <iostream>
int main() {
   double sum = 0.0, num;   const int NUMBER_OF_ENTRIES = 5;
   std::cout << "Please enter " << NUMBER_OF_ENTRIES << " numbers: ";
   for (int i = 0; i < NUMBER_OF_ENTRIES; i++) {
      std::cin >> num;
      sum += num;
   }
   std::cout << "The average of " << NUMBER_OF_ENTRIES << " values is "
      << sum/NUMBER_OF_ENTRIES << '\n';
}
```

Vectors (1)

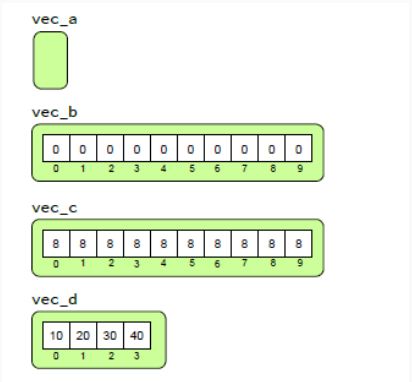
- Sequences: vectors and arrays
  - `std::vector, std::array`

- Nonempty sequence
  - Every nonempty sequence has a unique first element.
  - Every nonempty sequence has a unique last element.
  - Every element in a nonempty sequence except for the first element has a unique predecessor element.
  - Every element in a nonempty sequence except for the last element has a unique successor element.

- Vector is a template class in STL (Standard Template Library) of C++ programming language. C++ vectors are sequence containers that store elements.

Vectors (2)

```
#include <vector>

using std::vector;

std::vector<int> vec_a;
std::vector<int> vec_b(10); // All elements are zero by default.
std::vector<int> vec_c(10, 8);
std::vector<int> vec_d{10, 20, 30, 40, 50};
```



Vectors (3)

```
vector<int> list(3);
list[0] = 5;
list[1] = -3;
list[2] = 12;

std::cout << list[1] << '\n'; // list[1] : int variable

std::vector<int> list;
std::vector<double> collection{ 1.0, 3.5, 0.5, 7.2 };
std::vector<char> letters{ 'a', 'b', 'c' };

std::vector<double> nums(10);
int i = 3;
nums[1] = 2.4;
nums[i] = 2.1;
nums[i*2-1] = 2.2;     // nums[a[i]], a[max(x,y)]
std::cout << nums << '\n';
nums[10] = 5.1;        // memory access error, nums[-1]
nums[1.5] = 2.2;       // 1.5 --> 1
```


Vectors (4)

```
#include <iostream>
#include <vector>
int main() {
   double sum = 0.0;
   const int NUMBER_OF_ENTRIES = 5;
   std::vector<double> numbers(NUMBER_OF_ENTRIES);
   std::cout << "Please enter " << NUMBER_OF_ENTRIES << " numbers: ";
   for (int i = 0; i < NUMBER_OF_ENTRIES; i++) {
      std::cin >> numbers[i];
      sum += numbers[i];
   }
   std::cout << "The average of ";
   for (int i = 0; i < NUMBER_OF_ENTRIES - 1; i++)
      std::cout << numbers[i] << ", ";
   std::cout "The average is " << sum/NUMBER_OF_ENTRIES << '\n';
}
```

Vector Methods (1)

- push_back
  - —inserts a new element onto the back of a vector
- pop_back
  - —removes the last element from a vector
- operator[]
  - —provides access to the value stored at a given index within the vector
- at
  - —provides bounds-checking access to the value stored at a given position within the vector
- size
  - —returns the number of values currently stored in the vector
- empty
  - —returns true if the vector contains no elements; returns false if the vector contains one or more elements
- clear
  - —makes the vector empty.

A method in object-oriented programming is a procedure associated with a class.

- https://www.cplusplus.com/reference/vector/vector/

Vector Methods (2)

```
std::vector<int> list;          // Declare list to be a vector
list.push_back(5);              // Add 5 to the end of list
list.push_back(-3);             // Add -3 to the end of the list
list.push_back(12);             // Add 12 to the end of list
list.pop_back();                // Removes 12 from the list
list.pop_back();                // Removes -3 from the list
std::cout << list.size() << std::endl;       // 1

// reference operator[](size_type position);
// const_reference operator[](size_type position) const;
std::vector<int> vec = {10, 20, 30};
vec.operator[](2) = 3;
std::cout << vec[2] << std::endl;     // 3
vec[2] = 4;
std::cout << vec[2] << std::endl;     // 4
vec.at(2) = 5;
std::cout << vec[2] << std::endl;     // 5
```

Vector Methods (3)

```
for(type elementVariable : vectorVariable)   // c++11
   statement;
-----------------------------------------------------------------
#include <iostream>
#include <vector>
int main() {
   std::vector<double> vec(10);
   std::cout << "Please enter 10 numbers: ";

   for (double& elem : vec)
      std::cin >> elem;

   for (double elem : vec)
      std::cout << elem << '\n';
}
// for (unsigned i = 0; i < vec.size(); i++)
//   std::cout << vec[i] << '\n';
```


Vectors and Functions (1)

```
returnType functionName(std::vector<type> variableName)
-----------------------------------------------------------------
#include <iostream>
#include <vector>
void print(std::vector<int> v) {
   for (int elem : v) std::cout << elem << " ";
   std::cout << '\n';
}
void square(std::vector<int>& v) {
   for (int& elem : v) elem *= elem;
}
int sum(std::vector<int> v) {
   int result = 0;
   for (int elem : v) result += elem;
   return result;
}
int main() {
   std::vector<int> list{ 2, 4, 6, 8, };
   print(list);         std::cout << sum(list) << '\n';
   square(list);        print(list);    std::cout << sum(list) << '\n';
}
```

Vectors and Functions (2)

```
void make_random(std::vector<int>& v, int size)
// size is maximum size
{
   v.clear();

   int n = rand() % size + 1;
   for (int i = 0; i < n; i++)
      v.push_back(rand());
}
```


Vectors and Functions (3)

```
std::vector<type> functionName(parameterList)
----------------------------------------------------------------------
…
std::vector<int> primes(int begin, int end) {
   std::vector<int> result;
   for (int i = begin; i <= end; i++)
      if (is_prime(i))   result.push_back(i);
   return result;      // deep copy
}
int main() {
   int low, high;
   std::cout << "Please enter lowest and highest values in "
      << "the range: ";
   std::cin >> low >> high;
   std::vector<int> prime_list = primes(low, high);
   print(prime_list);
}
```

Multidimensional Vectors (1)

```
std::vector<std::vector<type>> a(size2, std::vector<type>(size1));
-------------------------------------------------------------------
std::vector<std::vector<int>> a(2, std::vector<int>(3));
a[0][0] = 5;
a[0][1] = 19;
a[0][2] = 3;
a[1][0] = 22;
a[1][1] = -8;
a[1][2] = 10;

std::vector<std::vector<int>> a{{ 5, 19, 3}, {22, -8, 10}};
```


Multidimensional Vectors (2)

```
void print(const std::vector<std::vector<double>>& m) {
   for (unsigned row = 0; row < m.size(); row++) {
      for (unsigned col = 0; col < m[row].size(); col++)
         std::cout << std::setw(5) << m[row][col];
      std::cout << '\n';
   }
}

-------------------------------------------------------------------

void print(const std::vector<std::vector<double>>& m) {
   for (const std::vector<double> row : m) {  // auto row
      for (int elem : row)                    // auto elem
         std::cout << std::setw(5) << elem;
      std::cout << '\n';
   }
}
```

Static Arrays (1)

```
dataType arrayName[size];
dataType arrayName[size] = {value1, value2, … };
dataType arrayName[] = {value1, value2, … };

arrayName[index] // [0, size-1]

returnType functionName(datatype arrayName[], const int size)
```


Static Arrays (2)

```
void print(int a[], int n) {
   for (int i = 0; i < n; i++)
      std::cout << a[i] << " ";
   std::cout << '\n';
}
int main() {
   int list[] = { 2, 4, 6, 8 };
   print(list, 4);     // sizeof(list)/sizeof(int)
   std::cout << sum(list, 4) << '\n';
   for (int i = 0; i < 4; i++)
      list[i] = 0;

   print(list, 4);
}
```

Static Arrays (3)

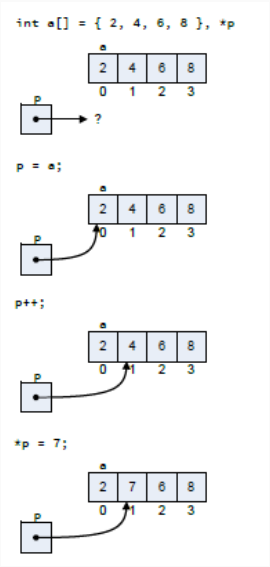
```
void print(int a[], int n) {
   for (int i = 0; i < n; i++)
      std::cout << a[i] << " ";
   std::cout << '\n';
}
void clear(int a[], int n)  // void clear(int* a, int n)
{
   for (int i = 0; i < n; i++) a[i] = 0;
}
int main() {
   int list[] = { 2, 4, 6, 8 };
   print(list, 4); // print(&list[0], 4);
   clear(list, 4);
   print(list, 4);
}
```


Pointers and Arrays (1)

```
#include <iostream>
int main() {
   int a[] = { 2, 4, 6, 8, 10, 12, 14, 16, 18, 20 }, *p;
   p = &a[0]; // p points to first element of array a

   for (int i = 0; i < 10; i++) {
      std::cout << *p << ' ';
      p++;  // +1 ?
      // std::cout << *p++ << ' ';    // a[i], i=i+1
      // std::cout << (*p)++ << ' '; // a[0]++
   }

   std::cout << '\n';
}
```

Pointers and Arrays (2)

```
#include <iostream>
int main() {
   int a[] = { 2, 4, 6, 8, 10, 12, 14, 16, 18, 20 },
      *begin, *end, *cursor;
   begin = a;
   end = a + 10;

   cursor = begin;
   while (cursor != end) {
      std::cout << *cursor << ' ';
      cursor++;
   }
   std::cout << '\n';
}
```



Pointers and Arrays (3)

```
#include <iostream>
void iterative_print(const int *a, int n) {
   for (int i = 0; i < n; i++)
      std::cout << a[i] << ' ';
}
void recursive_print(const int *a, int n) {
   if (n > 0) {
      std::cout << *a << ' ';
      recursive_print(a + 1, n - 1);
   }
}
int main() {
   int list[] = { 23, -3, 4, 215, 0, -3, 2, 23, 100, 88, -10 };
   iterative_print(list, 11);
   recursive_print(list, 11);
}
```

Pointers and Arrays (4)

```
void print(int *begin, int *end)
// end points just past the end of the array
{
   for (int *elem = begin; elem != end; elem++)
      std::cout << *elem << ' ';
   std::cout << '\n';
}
```


Pointers and Arrays (5)

```
#include <iostream>
int main() {
   int arr[] = {10, 20, 30, 40, 50};
   int *p = arr;
   std::cout << *p << '\n';   // 10
   std::cout << p[0] << '\n'; // 10
   std::cout << p[1] << '\n'; // 20
   std::cout << *p << '\n';   // 10
   p++; // Advances p to the next element
   std::cout << *p << '\n';   // 20
   p += 2; // Advance p two places
   std::cout << *p << '\n';   // 40
   std::cout << p[0] << '\n'; // 40
   std::cout << p[1] << '\n'; // 50
   p--;
   std::cout << *p << '\n';
}
```

Dynamic Arrays (1)

```
#include <iostream>
const int MAX_NUMBER_OF_ENTRIES = 1000000;
double numbers[MAX_NUMBER_OF_ENTRIES];
int main() {
   int size;
   std::cin >> size;
   if (size > 0) {
      for (int i = 0; i < size; i++)
         std::cin >> numbers[i];

      for (int i = 0; i < size; i++)
         std::cout << numbers[i] << '\n';
   }
}
```


Dynamic Arrays (2)

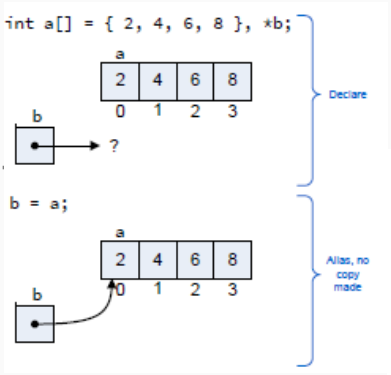
```
#include <iostream>
int main() {
   double *numbers;
   int size;
   std::cin >> size;
   if (size > 0) {
      numbers = new double[size];     // numbers = new double;
      for (int I = 0; I < size; i++)
         std::cin >> numbers[i];

      for (int I = 0; I < size; i++)
         std::cout << numbers[i] << '\n';

      delete [] numbers;              // delete numbers;
   }
}

// local variables: stack, global variables: static memory
// dynamic memory: heap.
```

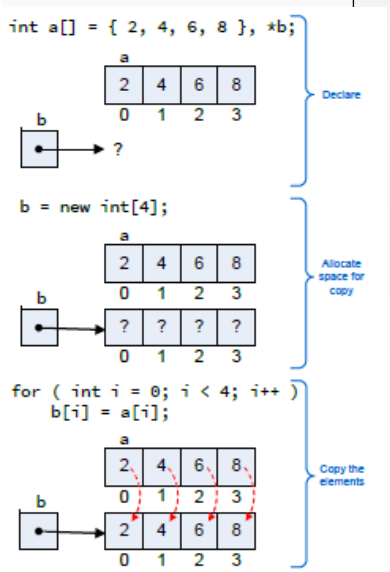
Copying an Array

```
int a[10], b[10];
for (int i = 0; i < 10; i++)
   a[i] = i;
b = a;
```

```
int a[10], *b;
for (int i = 0; i < 10; i++)
   a[i] = i;
b = a;
```

```
int a[10], *b;
b = new int[10];
for (int i = 0; i < 10; i++)
  b[i] = a[i];
```





Multidimensional Arrays (1)

```
dataType array[size2][size1];
dataType array[size2][size1] = {{…}, {…}, …};
dataType array[][size1] = {{…}, {…}, …};
dataType array[size2][size1] = {…};

array[index2][index1]
array[index2] // ?
```

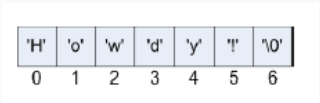
```
int m[3][2] = {{1}, {21, 22}, {31, 32}};
```

Multidimensional Arrays (2)

```
#include <iostream>
#include <iomanip>
const int ROWS = 3, COLUMNS = 5;
using Matrix = double[ROWS][COLUMNS];
// typedef double Matrix[ROWS][COLUMNS];
// void print_matrix(const double m[ROWS][COLUMNS])
// const double m[][COLUMNS], const double (*m)[COLUMNS]
void print_matrix(const Matrix m){
   for (int row = 0; row < ROWS; row++) {
      for (int col = 0; col < COLUMNS; col++)
         std::cout << std::setw(5) << m[row][col];
      std::cout << '\n';
   }
}
int main() {
   double mat[ROWS][COLUMNS] = {{1, 2, 3, 4, 5}, {11, 12, 13, 14, 15},
      {21, 22, 23, 24, 25}}; // Matrix mat = {…};
   print_matrix(mat);
}
```

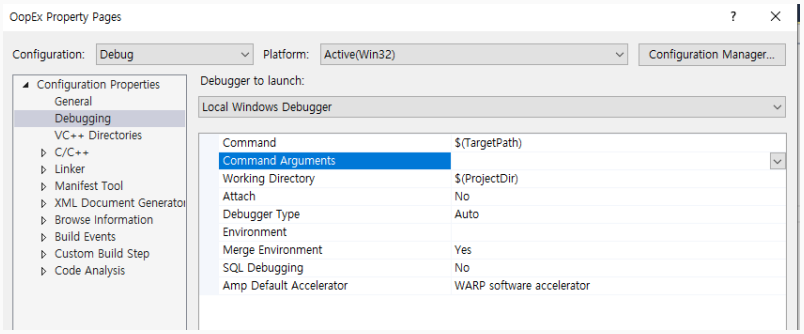

C String

```
char *word = "Howdy!";
std::cout << word << '\n';

char word[256];
std::cin >> word;

char word[10];
fgets(word, 10, stdin);       // #include <cstdio>
std::cout << word << '\n';

// <cstring>
int strlen(const char *s);
char *strcpy(char *s, const char *t);
int strcmp(const char *s, const char *t);
```



Command-line Arguments

```
>> copy count.cpp count2.cpp

-----------------------------------------------------------------------

#include <iostream>
int main(int argc, char *argv[]) {
   for (int i = 0; i < argc; i++)
      std::cout << '[' << argv[i] << "]\n";
}
```



Vectors vs. Arrays (1)

```
#include <iostream>
#include <vector>
#include <array>
int main() {
   std::vector<int> v(10);
   std::cout << v[0] << std::endl;

   std::array<int, 10> a;
   std::cout << a[0] << std::endl;

   int arr[10];
   std::cout << arr[0] << std::endl;

   int x = int();
   std::cout << x << std::endl;
}
```

Vectors vs. Arrays (2)

```
std::vector<int> vec = {10, 20, 30};

std::cout << *vec.begin() << std::endl;
std::cout << *(vec.end()-1) << std::endl;

int *cursor = &vec[0];
int *end = &vec[0] + vec.size();
while (cursor != end) {
   std::cout << *cursor << ' ';
   cursor++;
}
```


Vectors vs. Arrays (3)

	Vector	Array
Memory	Occupy more memory than array	Memory-efficient
Length	Variable length	Fixed-size length
Usage	Frequent insertion and deletion	Frequent element access
Resize	Dynamic	Resizing arrays is expensive
Indexing	Non-index based	Zero-based indexing
Access	Time-consuming	Constant time