[DASF004-42]

Basis and Practice in Programming

(프로그래밍 기초와 실습)

Spring 2022

HYUNGJOON KOO

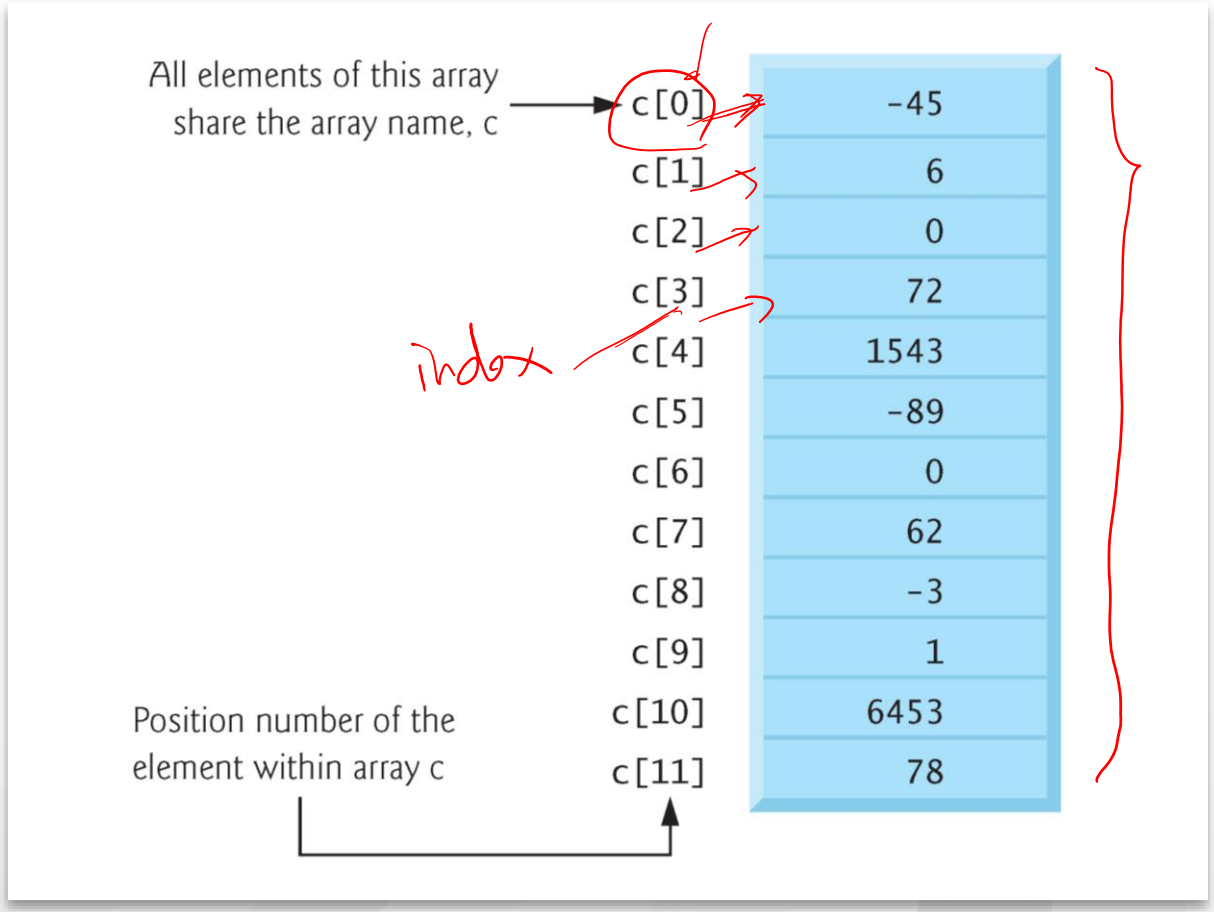
SUNG KYUN KWAN UNIVERSITY(SKKU)

Array Basics

Motivation

- **Get two numbers from a user**
  - `int a, b;`
- **Get 10 numbers from a user**
  - `int a, b, c, d, e, f, g, h, i, j;`
- **Get 100 numbers from a user**
  - `int a1, a2, a3, …. a100;`
- **Get N numbers from a user ?**

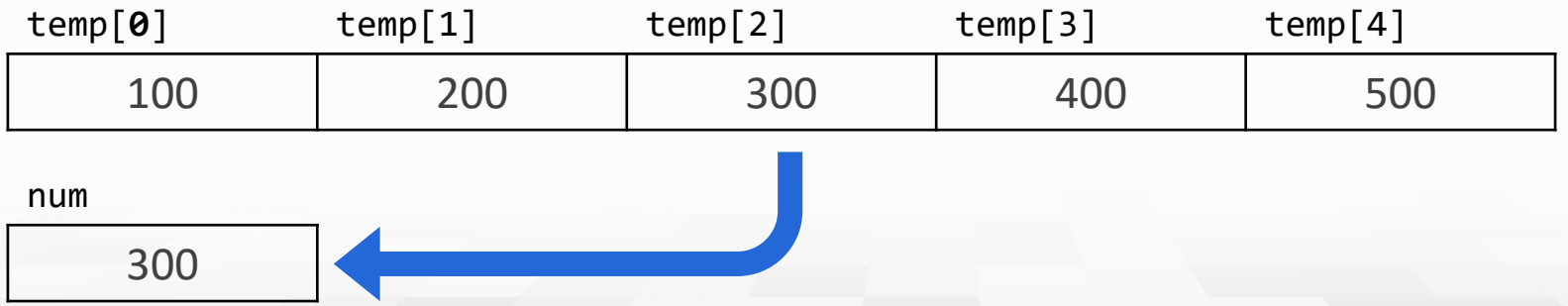
- A group of ***contiguous*** memory locations
- All elements have the same type.



Example of an array (Preview)

```
int temp[5] = {100, 200, 300, 400, 500};
int num = temp[2];   // num = 300;
```

- **Above code**
  - defines an array with squared brackets ([]) specifying the number of elements.
  - initializes the array with an initializer list within curly brackets ({}).
  - refers third element using the array's name followed by the position number in square brackets ([]).



Array Declaration

- **How to declare an array variable**
  - Similar to regular variables

```
int num;         // defining an integer variable
int numbers[10]; // defining an integer array with 10 elements
```

- **data type** must be firstly specified.
- **variable name** will follow.
- **squared brackets** make the variable an array variable.
- The **number of elements** will be placed within brackets.
  - » can be omitted with initialization.

- **Specifying the type and the number of elements makes the computer reserve the appropriate amount of memory.**

Initializing an Array in a Declaration

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- **Arrays are not automatically initialized.**
- **Uninitialized array elements contain garbage values.**
- **'Initializer list' or 'Array initializer'**
  - An array can be initialized with curly brackets({ }) following an equals sign (=).
  - Array initialization with curly brackets is permitted **only** in a declaration.
  - Not specified elements are initialized with zeroes.
  - The size of one-dimensional array is not necessarily specified.
    - » Only when the initialization is following

```
int n[5] = { 1, 2, 3, 4, 5 };

int n[5] = { 0 };              // unassigned elements
                               // have zeroes as values

int n[] = { 1, 2, 3, 4, 5 };   // unspecified size is set to
                               // the number of elements
```

Special case: char name[20]

- **String variables in C are with 'char array' data type.**
  - Use squared brackets after the variable name to specify the string length.
  - The size of the string MUST be greater than the actual string length.

- **In fact, "hello" is a character array with the size of six.**
  - The last element is a **null character (\0)**.

```
char str[6] = "hello";
char str[] = "hello";
char str[] = { 'h', 'e', 'l', 'l', 'o', '\0' };
```

  - Initialization with " " is also permitted **only** in a declaration.

- **char name[20] can have at most 19 alphabets.**

Special case: `char name[20]` (Supplementary slide)

- **Initialization with " " is permitted only in a declaration.**
- **A string of characters enclosed in " " is called a string literal**
  - a.k.a *string constant* or *constant string*
  - String literals are stored in C as an array of chars, terminated by a null byte.
  - They are constant, so string literals cannot be modified.
- **When an array is declared with a string literal,**
  - the computer assigns a certain size of memory for the array,
  - and it reads the string literal and copy the characters into that memory.
  - It is automatically done only with array declarations, so initialization cannot be done after declaration.
- **We will visit this slide again after learning pointers.**

Initializing an Array with a Loop

- **Arrays are not automatically initialized.**
- **Below code uses `for` statements to initialize the elements of a five-integer array `n` to zeros.**

```
int n[5];
for( size_t i=0; i<5; i++) {
    n[i] = 0;
}
```

- **size_t data type**
  - represents an unsigned integral type according to C standard.
  - is recommended for any variable representing an array's size or an array's indices.
  - is defined in header <stddef.h>, which is often included by other headers.

Array Indexing

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- **Referring to a particular location or element**
  - The position number within square brackets is called an **index**.
  - We must specify the array's name and the index.

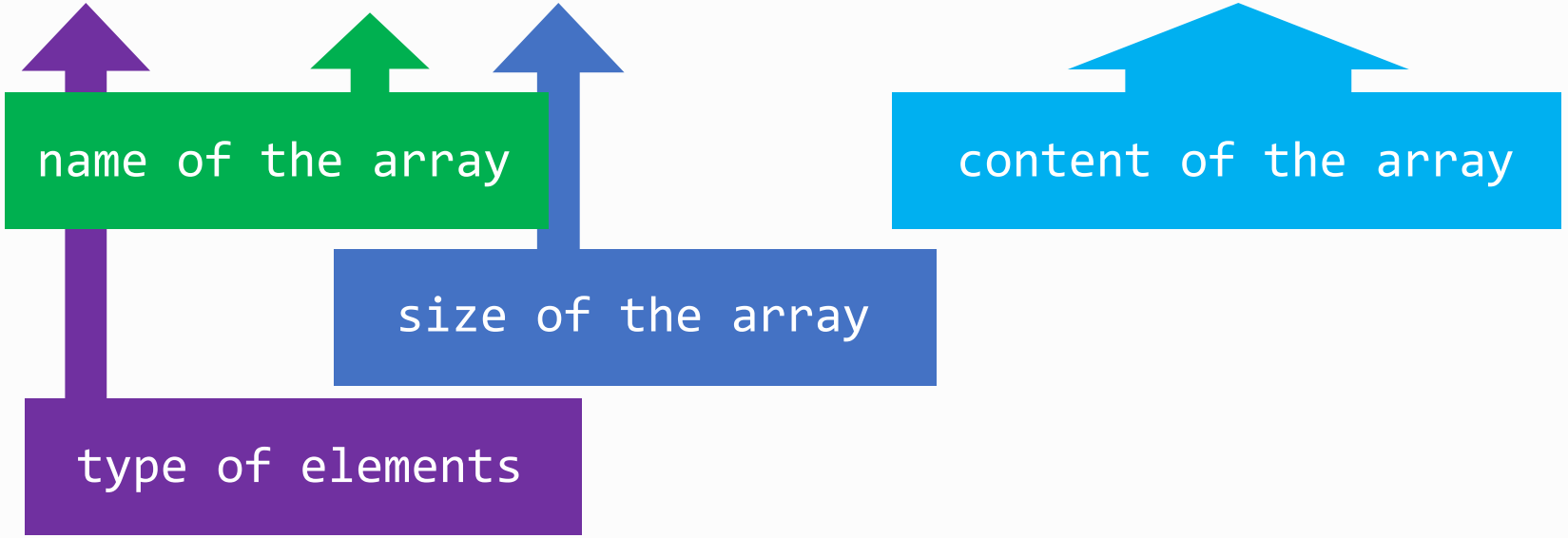
- **The first element in every array is the zeroth element.**
  - Zero-based numbering or zero indexed arrays

- **An index must be an integer or an integer expression.**
  - Example:

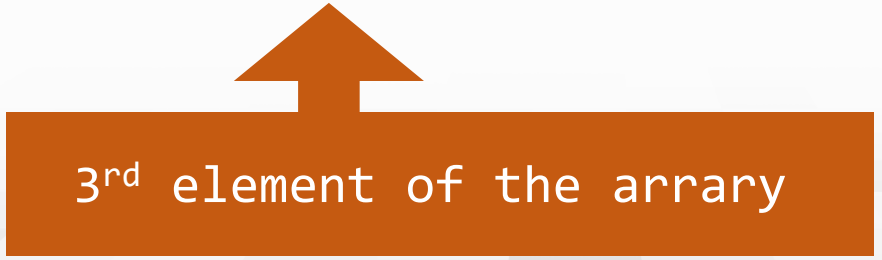
```
a=5, b=6;
c[11] = 2;        // an integer index
c[a+b] = 2;       // an integer expression index, same result
b = c[1];
```

Array definition and indexing (Summary)


```
int array_temp[5] = {100, 200, 300, 400, 500};
```




```
int num = array_temp[2];
```



Array Initializer Example

- **Two arrays with initializer lists are used in the example.**
  - Without the initializer, we can see garbage values.
  - What happens when the initializer has more elements than the size?
  - We will check different ways of initializing a string variable.

```
#include <stdio.h>
int main() {
     int numbers[10];
     //int numbers[10] = {0};
     for(int i=0; i<10; i++)
          printf("%d ", numbers[i]);
     printf("\n");
     char hello[6] = "hello";
     printf("%s\n", hello);
     return 0;
}
```

Initializing an Array With a Loop Example

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- **An integer array is initialized with a loop.**
  - We can use int data type instead of size_t. What's the difference?

```
#include <stdio.h>
int main() {
     int n[5];
     for( size_t i=0; i<5; i++) {
          n[i] = 0;
     }
     for( size_t i=0; i<5; i++) {
          printf("%d ", n[i]);
     }
     printf("\n");
     return 0;
}
```

Array Examples with Various Usages

An example of array definition

```
int b[100], x[27];
```

- Above definition reserves 100 elements for integer array b and 27 elements for integer array x.
  - Indices lie in the ranges 0–99 and 0–26, respectively.

An example of array indexing

- Printing the sum of the values contained in the first three elements of array c

```
printf("%d", c[0] + c[1] + c[2]);
```

Exercise: Reversing an array

- Fill in the empty box to print elements in a reverse order.

```
#define N 10
int a[N], i;
for (i = 0; i < N; i++)
    a[i] = 1;                  // initializes a

for (i = 0; i < N; i++)
    scanf("%d", &a[i]);        // reads data into a

for (?????;?????;?????)
    printf("%d ", a[i]);
printf("\n");
```

Exercise: Reversing an array (Solution)

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- Fill in the empty box to print elements in a reverse order.

```
#define N 10
int a[N], i;
for (i = 0; i < N; i++)
    a[i] = 1;              // initializes a

for (i = 0; i < N; i++)
    scanf("%d", &a[i]);    // reads data into a

for (i = N-1; i>=0; i--)
    printf("%d ", a[i]);
printf("\n");
```

Reading Materials

- Arrays are data structures consisting of related data items of the same type. Later, we discuss C's notion of struct (structure)—a data structure consisting of related data items of possibly different types. Arrays and structures are "static" entities in that they remain the same size throughout program execution.

- An array is a group of contiguous memory locations that all have the same type. To refer to a particular location or element in the array, we specify the array's name and the position number of the particular element in the array.

- Any element in an array be referred to by giving the array's name followed by the position number of the particular element in square brackets ([]). The first element in every array is the zeroth element. An array name, like other identifiers, can contain only letters, digits and underscores and cannot begin with a digit. The position number within square brackets is called an index or subscript. An index must be an integer or an integer expression.

Symbolic Constants

Symbolic Constant

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- **Symbolic constant**
  - The #define preprocessor directive is used for defining symbolic constants.
  - A symbolic constant is an identifier that's replaced with replacement text by the C preprocessor before the program is compiled.
  - When the program is preprocessed, all occurrences of the symbolic constant are replaced with the replacement text following the constant.

- **For arrays, using symbolic constants to specify array sizes makes programs more modifiable.**

Symbolic Constant for Better Modifiability

- A program that fills the array with calculation and prints the elements of the array in tabular form without a symbolic constant.

```
#include <stdio.h>

int main()
{
  int s[5];

  for(size_t i = 0; i < 5; i++) {
    s[i] = 2 + 2 * i;
  }

  printf("%s%13s\n", "Element", "Value");

  for(size_t i = 0; i < 5; i++) {
    printf("%7lu%13d\n", i, s[i]);
  }

  return 0;
}
```

```
Element        Value
      0            2
      1            4
      2            6
      3            8
      4           10
```

Symbolic Constant for Better Modifiability

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```c
#include <stdio.h>

int main()
{
  int s[5];

  for(size_t i = 0; i < 5; i++) {
    s[i] = 2 + 2 * i;
  }

  printf("%s%13s\n", "Element", "Value");

  for(size_t i = 0; i < 5; i++) {
    printf("%7lu%13d\n", i, s[i]);
  }

  return 0;
}
```

- **When the number of items is increased or decreased, we'd have to change the program in three separate places.**
- **We can do that in a different way with a symbolic constant.**
  - Without symbolic constants, we'd have to change the program in three separate places.

Symbolic Constant for Better Modifiability

- A program that fills the array with calculation and prints the elements of the array in tabular form with a symbolic constant.

```
#include <stdio.h>
#define SIZE 5

int main()
{
  int s[SIZE];

  for(size_t i = 0; i < SIZE; i++) {
    s[i] = 2 + 2 * i;
  }

  printf("%s%13s\n", "Element", "Value");

  for(size_t i = 0; i < SIZE; i++) {
    printf("%7lu%13d\n", i, s[i]);
  }

  return 0;
}
```

```
Element        Value
      0            2
      1            4
      2            6
      3            8
      4           10
```

Symbolic Constant for Better Modifiability

```c
#include <stdio.h>
#define SIZE 5

int main()
{
  int s[SIZE];

  for(size_t i = 0; i < SIZE; i++) {
    s[i] = 2 + 2 * i;
  }

  printf("%s%13s\n", "Element", "Value");

  for(size_t i = 0; i < SIZE; i++) {
    printf("%7lu%13d\n", i, s[i]);
  }

  return 0;
}
```

- **We could have the first for loop fill a 1000-element array by simply changing the value of SIZE in the #define directive from 5 to 1000.**

- **Common mistake**
  - Adding a semicolon can become a habit.
  - Accidentally, you can terminate the #define preprocessor with a semicolon.
  - Then, the preprocessor replaces all occurrences of the symbolic constant SIZE in the program with the text 5;.

Array Example with Symbolic Constant

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- **Symbolic constant**
  - The #define preprocessor directive is used for defining symbolic constants.
  - A symbolic constant is an identifier that's replaced with replacement text by the C preprocessor before the program is compiled.
  - All occurrences of the symbolic constant are replaced with the replacement text following the constant.

```
(Somewhere in the code)
#define NUM 10          // defining symbolic constant before using it

...

(Somewhere below in the code)
printf("%d\n", NUM);     // OK. NUM is replaced with text '10'
printf("NUM\n");         // 'NUM' will be printed instead of '10'
printf("%s\n", NUM);     // ERROR.'%s' is for strings not for integers
```

Array Example with Symbolic Constant

- **Specifying an Array's Size with a Symbolic Constant**
  - Useful when the target array size is fixed during the execution.

```
#define N 10

int a[N], i;
for (i = 0; i < N; i++)
    a[i] = 1;                       // initializes a

for (i = 0; i < N; i++)
    scanf("%d", &a[i]);             // reads data into a

for (i = 0; i < N; i++)
    sum += a[i];                    // sums the elements of a
```

- **for loops are a well-match to array operations.**
  - It naturally supplies indexes for the array.

- **Arrays**
  - A group of contiguous memory locations
  - All elements have the same type.

- **Declaration and initialization**
  - Squared brackets ([]) specifies that the variable is for an array. (with its size)
  - You can initialize an array with an initializer list within curly brackets ({}) while declaring it.
  - A loop is a good choice for initializing or accessing the array.

Hands-on Lab

- arr_noinit.c
- arr_init.c
- arr_print.c
- arr_print_symbolic_constant.c
- arr_print_reverse.c

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Example Program with an Array (1)

Using Arrays to Summarize Survey Results

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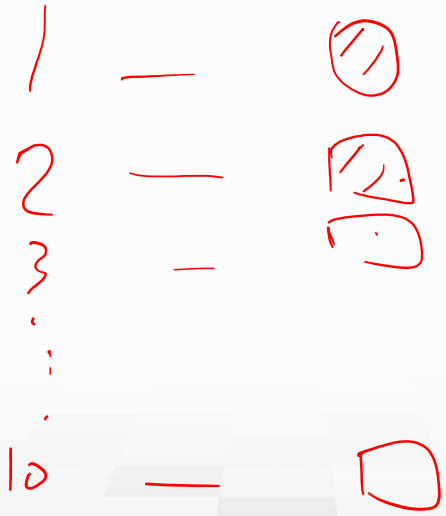
- **Problem statement**
  - Forty students were asked to rate the quality of the food in the student cafeteria on a scale of 1 to 10 (1 means awful and 10 means excellent). Place the 40 responses in an integer array and summarize the results of the poll.

- **We wish to summarize the number of responses of each type (i.e., 1 through 10).**



Using Arrays to Summarize Survey Results

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- Source code

```
#include <stdio.h>
#define RESPONSES_SIZE 40
#define FREQUENCY_SIZE 11

int main()
{
  int frequency[FREQUENCY_SIZE] = {0};

  int responses[RESPONSES_SIZE] = {1, 2, 6, 4, 8, 5, 9, 7, 8, 10,
       1, 6, 3, 8, 6, 10, 3, 8, 2, 7, 6, 5, 7, 6, 8, 6, 7, 5, 6, 6,
       5, 6, 7, 5, 6, 4, 8, 6, 8, 10};

  for(size_t answer = 0; answer < RESPONSES_SIZE; answer++) {
    frequency[responses[answer]]++;
  }

  printf("%s%17s\n", "Rating", "Frequency");

  for(size_t rating = 1; rating < FREQUENCY_SIZE; rating++) {
    printf("%6lu%17d\n", rating, frequency[rating]);
  }

  return 0;
}
```

Using Arrays to Summarize Survey Results

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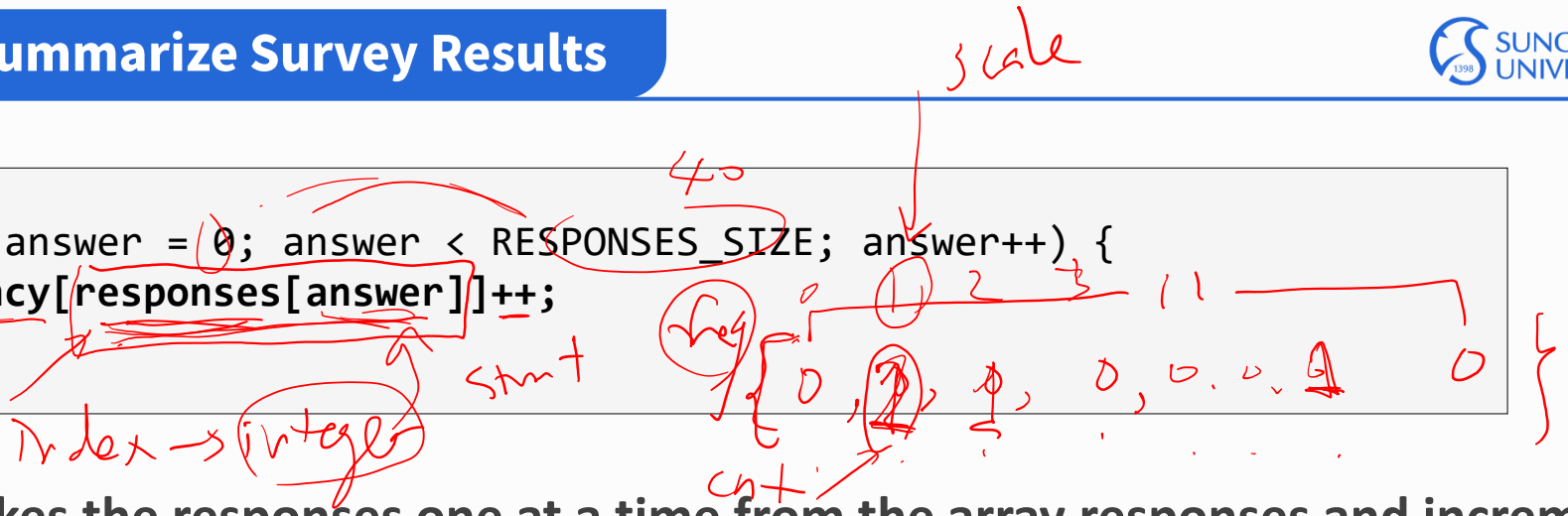
```
#include <stdio.h>
#define RESPONSES_SIZE 40
#define FREQUENCY_SIZE 11

int main()
{
  int frequency[FREQUENCY_SIZE] = {0};

  int responses[RESPONSES_SIZE] = {1, 2, 6, 4, 8, 5, 9, 7, 8, 10,
       1, 6, 3, 8, 6, 10, 3, 8, 2, 7, 6, 5, 7, 6, 8, 6, 7, 5, 6, 6,
       5, 6, 7, 5, 6, 4, 8, 6, 8, 10};
```

- **The array responses is a 40-element array of the students' responses.**
- **We use an 11-element array frequency to count the number of occurrences of each response.**
  - We ignore frequency[0] because it's logical to have response 1 increment frequency[1] rather than frequency[0].
  - This allows us to use each response directly as the index in the frequency array.

Using Arrays to Summarize Survey Results

```
for(size_t answer = 0; answer < RESPONSES_SIZE; answer++) {
    frequency[responses[answer]]++;
}
```



- **The for loop takes the responses one at a time from the array responses and increments one of the 10 counters (frequency[1] to frequency[10]) in the frequency array.**
- **The key statement in the loop is the bold line which increments the appropriate frequency counter depending on the value of responses[answer].**

```
int responses[RESPONSES_SIZE] = {1, 2, 6, 4, 8, … , 10};
```

- When answer is 2, responses[answer] is 6, so ++frequency[responses[answer]]; is interpreted as ++frequency[6]; which increments array element six, and so on.
- Regardless of the number of responses processed in the survey, only an 11-element array is required (ignoring element zero) to summarize the results.

Using Arrays to Summarize Survey Results

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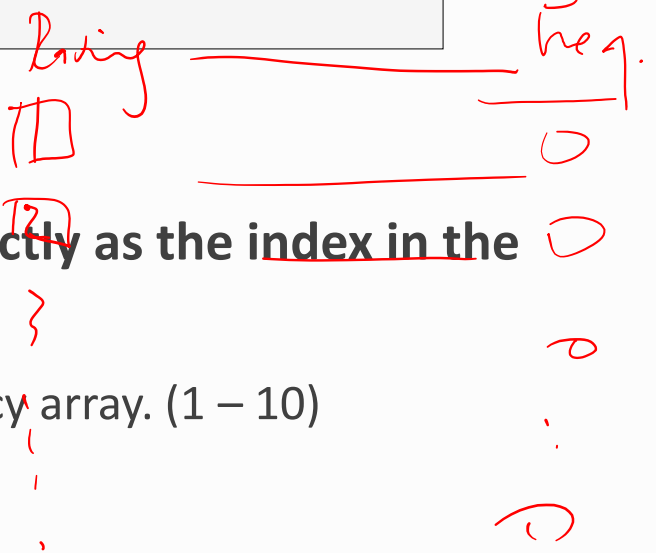
```
printf("%s%17s\n", "Rating", "Frequency");

for(size_t rating = 1; rating < FREQUENCY_SIZE; rating++) {
    printf("%6lu%17d\n", rating, frequency[rating]);
}
```

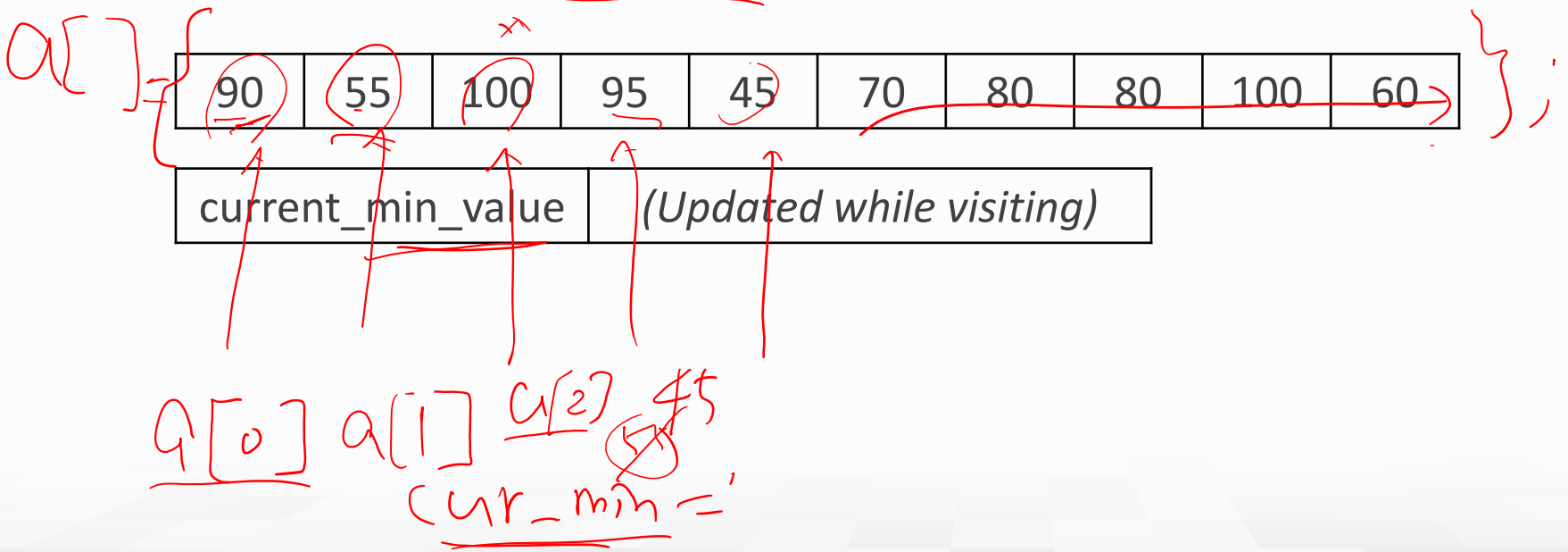


- **Above part is for summarizing the survey results.**
- **Check that the for loop uses the loop controlling variable directly as the index in the frequency array.**
  - FREQUENCY_SIZE is 11, so we can visit all elements in the frequency array. (1 – 10)
- **Follow-up question: How can we make the program to print the average, min and max rating?**

Example Program with an Array (2)

Q: What is the minimum value of an array?

- **For a given data, the max or min value is commonly asked.**
- **How can we get the max or min value?**
  - We need to visit all elements.
  - We need a temporal variable for storing current max/min value.



Algorithm for Min/Max

1 Declare a variable

2 Initialize it with an upper/lower bound of data

- It is OK or even better to initialize the min/max variable as the first value of the array.

```
…
int min_score = 100; // Upper bound is 100 for scores
for (int i = 0; i < 10; i++) // Assuming 10 students
    if (min_score > scores[i])
        min_score = scores[i];
…
```

- **CHECKPOINT: Why upper bound for min and lower bound for max?**

Using Arrays to Summarize Survey Results (re-visited)

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```
printf("%s%17s\n", "Rating", "Frequency");

for(size_t rating = 1; rating < FREQUENCY_SIZE; rating++) {
    printf("%6lu%17d\n", rating, frequency[rating]);
}
```

- Above part is for summarizing the survey results.
- Check that the for loop uses the loop controlling variable directly as the index in the frequency array.
  - FREQUENCY_SIZE is 11, so we can visit all elements in the frequency array. (1 – 10)

- **Follow-up question: How can we make the program to print the average, min and max rating?**

Exercise: Min, Max, Avg for Survey Results

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- Modify the program to print min, max and average values of the survey.

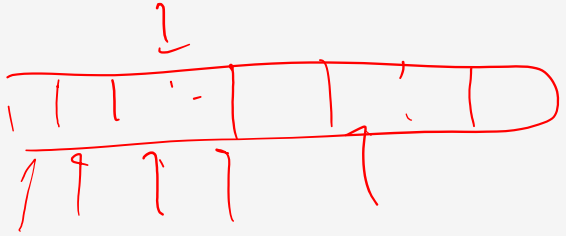
```c
#include <stdio.h>
#define RESPONSES_SIZE 40
#define FREQUENCY_SIZE 11

int main()
{
  int frequency[FREQUENCY_SIZE] = { };

  int responses[RESPONSES_SIZE] = {1, 2, 6, 4, 8, 5, 9, 7, 8, 10,
       1, 6, 3, 8, 6, 10, 3, 8, 2, 7, 6, 5, 7, 6, 8, 6, 7, 5, 6, 6,
       5, 6, 7, 5, 6, 4, 8, 6, 8, 10};

  for(size_t answer = 0; answer < RESPONSES_SIZE; answer++) {
    frequency[responses[answer]]++;
  }

  printf("%s%17s\n", "Rating", "Frequency");

  for(size_t rating = 1; rating < FREQUENCY_SIZE; rating++) {
    printf("%6lu%17d\n", rating, frequency[rating]);
  }

  return 0;
}
```

```
Rating        Frequency
     1                2
     2                2
     3                2
     4                2
     5                5
     6               11
     7                5
     8                7
     9                1
    10                3

Min: 1, Max: 10, Avg: 6.025
```

Exercise: Min, Max, Avg for Survey Results (Solution)

- Modify the program to print min, max and average values of the survey.

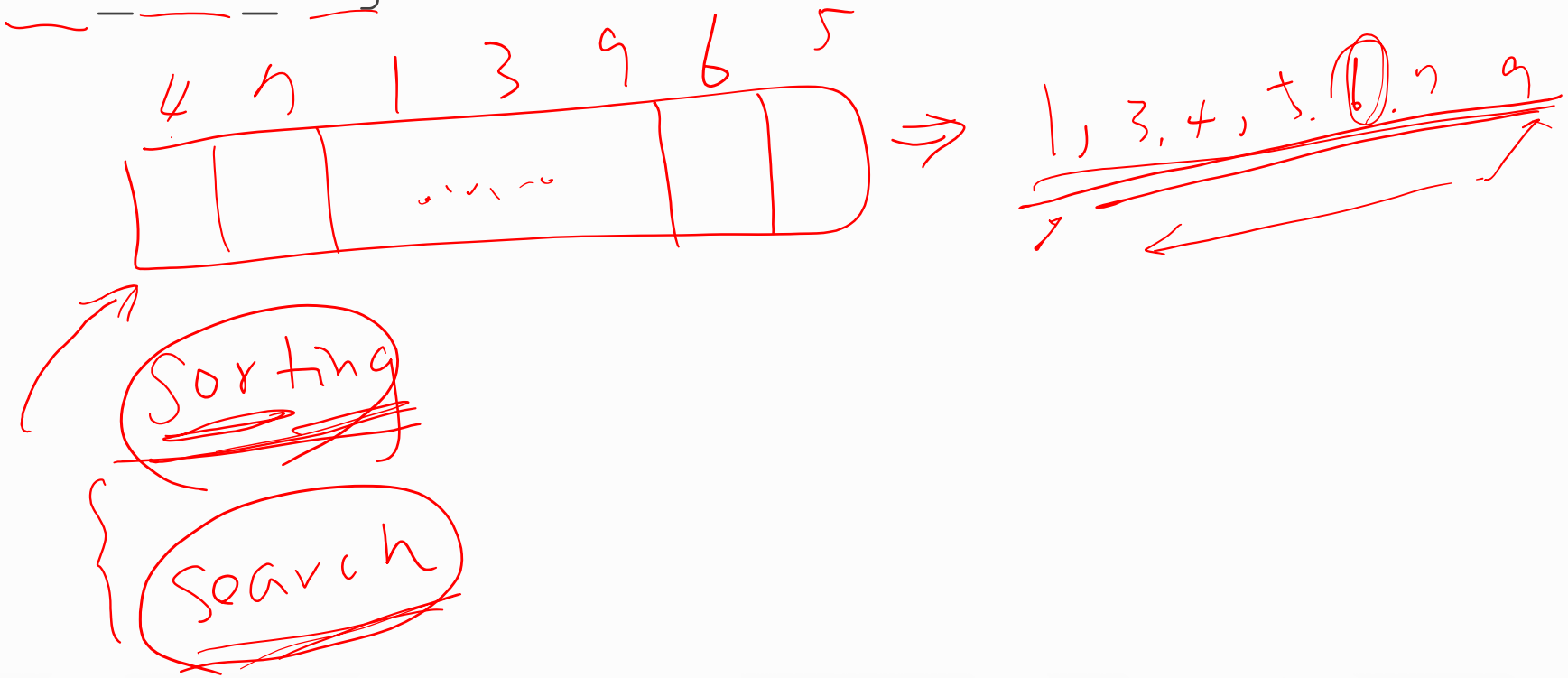
```
...
int min = 10, max = 1, sum = 0;

for(size_t answer = 0; answer < RESPONSES_SIZE; answer++) {
  frequency[responses[answer]]++;
  if(responses[answer] > max) {
    max = responses[answer];
  }
  if(responses[answer] < min) {
    min = responses[answer];
  }
  sum += responses[answer];
}

printf("%s%17s\n", "Rating", "Frequency");
for(size_t rating = 1; rating < FREQUENCY_SIZE; rating++) {
  printf("%6lu%17d\n", rating, frequency[rating]);
}
printf("\nMin: %d, Max: %d, Avg: %.3lf\n", min, max, (double)sum/RESPONSES_SIZE);
return 0;
}
```



Rating	Frequency
1	2
2	2
3	2
4	2
5	5
6	11
7	5
8	7
9	1
10	3

Min: 1, Max: 10, Avg: 6.025

- survey.c
- survey_min_max_avg.c



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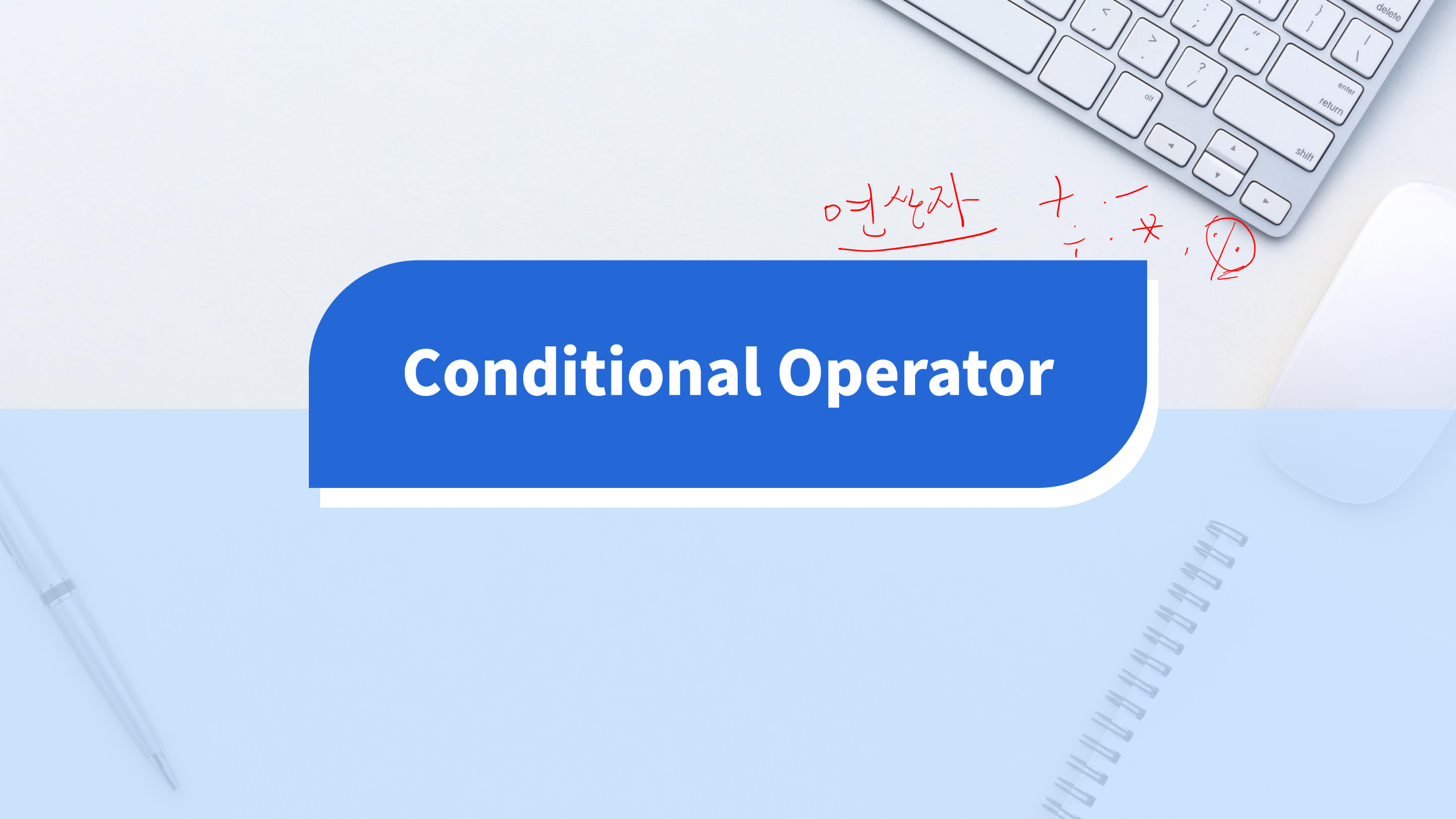
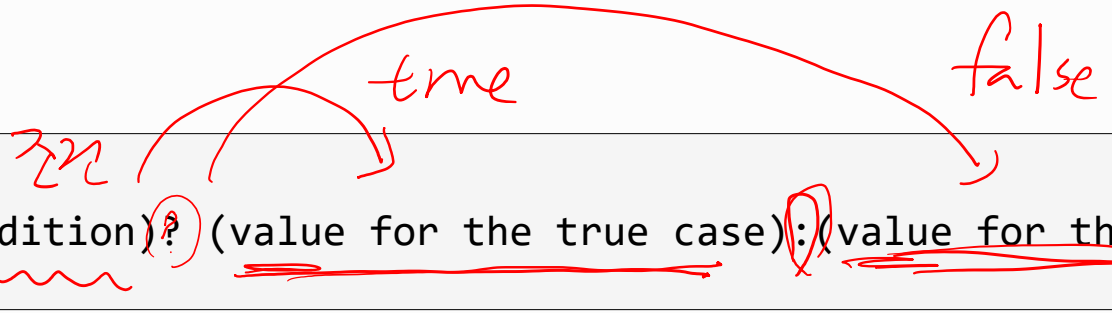


Conditional Operator

Conditional Operator

- C provides the **conditional operator** (**?:**) which is closely related to the `if…else` statement.
- The conditional operator is C's only ternary operator—it takes *three* operands.
  - The first operand is a *condition*.
  - The second operand is the value for the entire conditional expression if the condition is *true*.
  - The third operand is the value for the entire conditional expression if the condition is *false*.




```
(condition)? (value for the true case):(value for the false case)
```

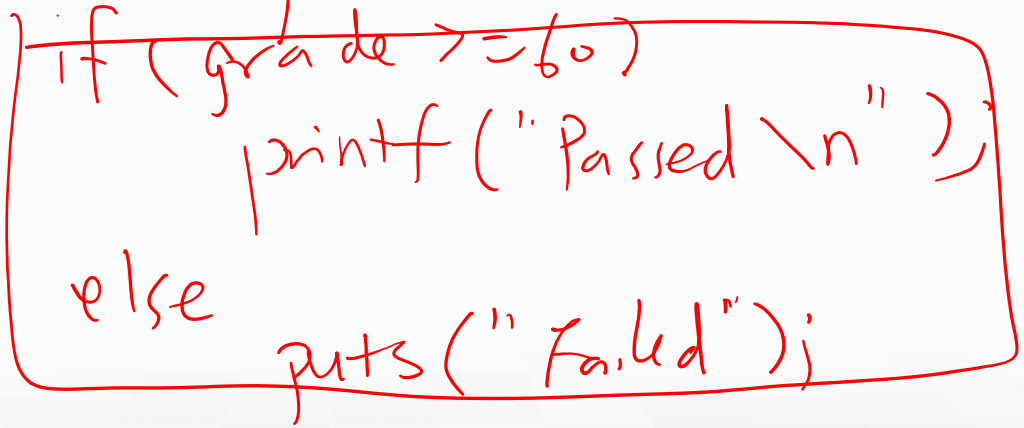
Conditional Operator

- For example, the puts statement

```
puts( grade >= 60 ? "Passed" : "Failed" );
```

contains as its second argument a conditional expression that evaluates to the string "Passed" if the condition `grade >= 60` is true and to the string "Failed" if the condition is false.

- The puts statement performs in essentially the same way as the preceding `if...else` statement.



Conditional Operator

- The second and third operands in a conditional expression can also be actions to be executed.

- For example, the conditional expression

```
grade >= 60 ? puts( "Passed" ) : puts( "Failed" );
```

  is read, "If `grade` is greater than or equal to `60` then puts("`Passed`"), otherwise `puts( "Failed" )`." This, too, is comparable to the preceding `if…else` statement.

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Conditional operator example

- Check that no comparison operators are used in the condition part.
- We have three or more different ways to show the same result.

```c
#include <stdio.h>
int main() {
  int num;
  scanf("%d", &num);
  num%2? printf("Odd\n"):printf("Even\n");     // or, printf(num%2? "Odd\n":"Even\n");
                                                // or, if(num % 2) { printf("Odd\n"); }
                                                //       else { printf("Even\n"); }

  return 0;
}
```

Comma Operator

Comma operator (,)

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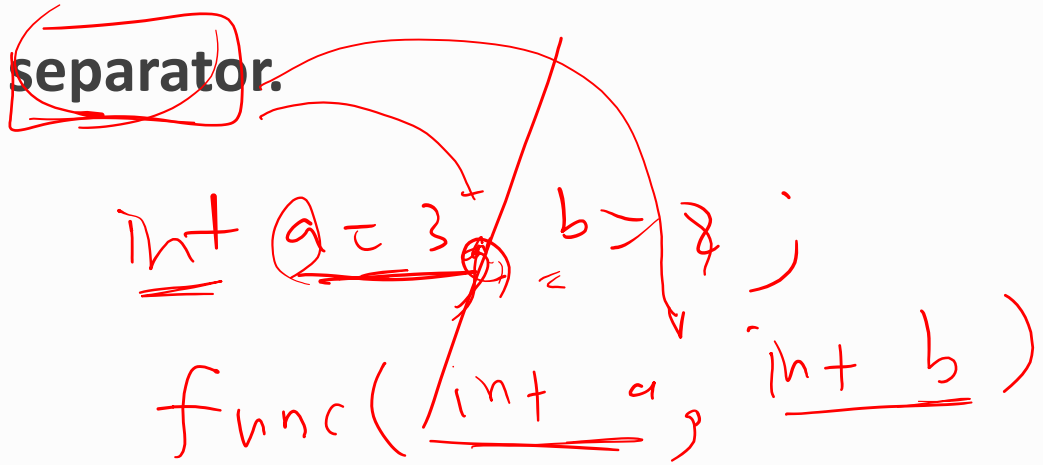
- **A binary operator**
  - The first operand is evaluated, and the result is discarded.
  - Then it evaluates the second operand and returns this value (and type).

- **It is distinct from using it as a separator.**
  - function calls and definitions
  - variable declarations
  - enum declarations



Usages of Comma

- Comma operator VS Comma separator?

	Operator or Separator?	Value of i
`int a=1, b=2, c=5;`		N/A
`int i = (a, b);`		2
`i = a, b;`		1
`i = (a += 1, a + b);`		4
`i = a += 1, a + b;`		3
`i = a, b, c;`		3
`i = (a, b, c);`		5

Common Mistake

- The programmer intended to print 'true' with 1, 2 or 3.
- What will be the result?

```
#include <stdio.h>

int main()
{
    int num;
    scanf("%d", &num);

    if(num == 1,2,3) {
        printf("true");
    } else {
        printf("false");
    }
}
```

(num==1) || (num==2) || (num==3)

|| OR, && AND

Hands-on Lab

- cond_oper1.c
- cond_oper2.c
- cond_oper3.c
- comma_oper.c
- comma_oper2.c