Outline

- Function parameter passing
- Array recap
- Array as a container: partially filled array
- Passing array to function
- Some common functions on arrays
- 2D (two dimensional) arrays

Function call: recap

- **Arguments vs Parameters**
  - Arguments: what are being passed in a function call
  - Parameters: those listed in function declaration/ definition
- Passing parameters: assigning actual arguments to corresponding parameters
  - pass-by-value: the value of actual argument is assigned to parameter
  - pass-by-reference: the address of actual argument (must be a variable) is assigned to parameter
    - the parameter refers to the argument

Function call: passing parameters

```
void borrow (int & x, int y, int amount);

int main ()
{
      int value1, value2;
      value1 = 2;
      value2 = 10;
      cout <<"value1=" << value1 << endl;
            << "value2=" << value2 <<endl;
      borrow (value1, value2, 3);  //Calling borro
value2
      cout <<"After function call: " ;
      cout <<"value1=" << value1 << endl;
            << "value2=" << value2 <<endl;

}

void borrow (int & x, int y, int amount)
{
     x-=amount;
     y+=amount;
}
```

- Which parameters are passed by value, by argument?
- Parameter y and amount are pass-by-value
  - int y = value2;
  - int amount = 3;
  - the value of actual argument is assigned to parameter
- Parameter x is pass-by-reference: address of actual argument, value1, is assigned to parameter
  - int & x = value1;// x refers to value1 in main
  - When x-=amount, it's modifying value1 in main!

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Array Syntax

SYNTAX 6.1 Defining an Array

Size must be a constant.

Ok to omit size if initial values are given.

Element type Name Size

```
double data[5] = { 32, 54, 67.5, 29, 35 };
```

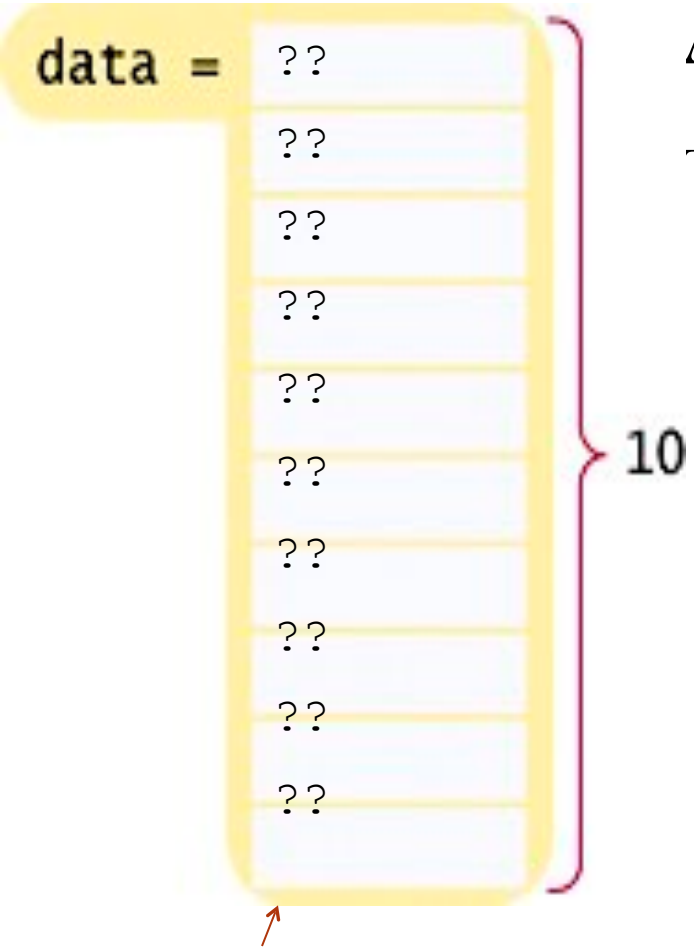
Optional list of initial values

Use brackets to access an element.

```
data[i] = 0;
```

The index must be ≥ 0 and < the size of the array.

Define Arrays



An "array of double"

Ten elements of **`double`** type can be stored in this array named data

```
double data[10];
```

type of each element

# of elements, i.e. the "size" of the array

Must be a constant

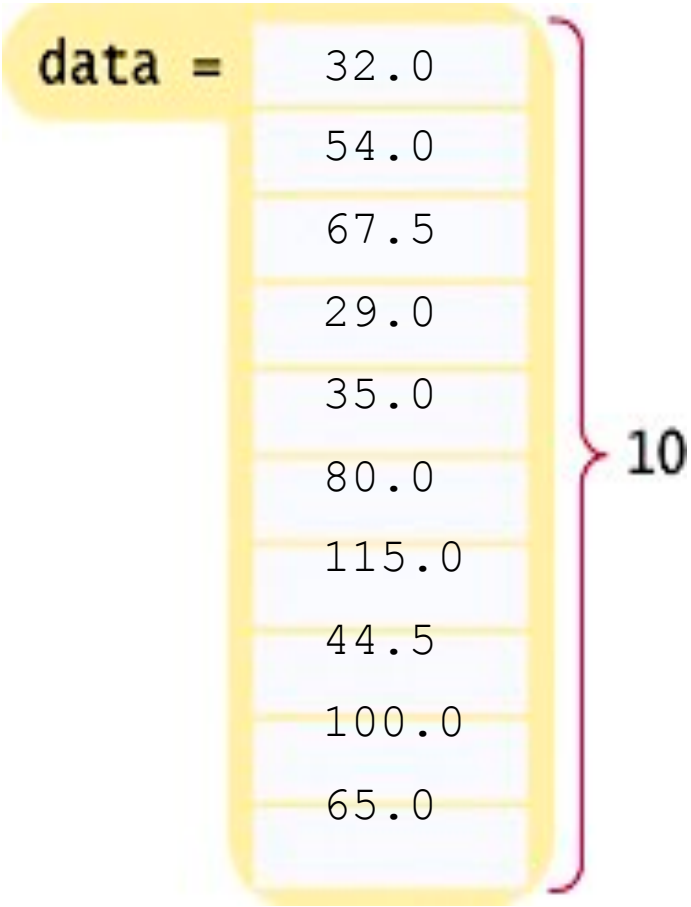
The elements have random values!

Define Arrays with initial values

define an array while specifying initial values:

```
double data[] = { 32, 54, 67.5, 29, 35, 80, 115, 44.5, 100, 65 };
```

size is omitted, as compiler can count…

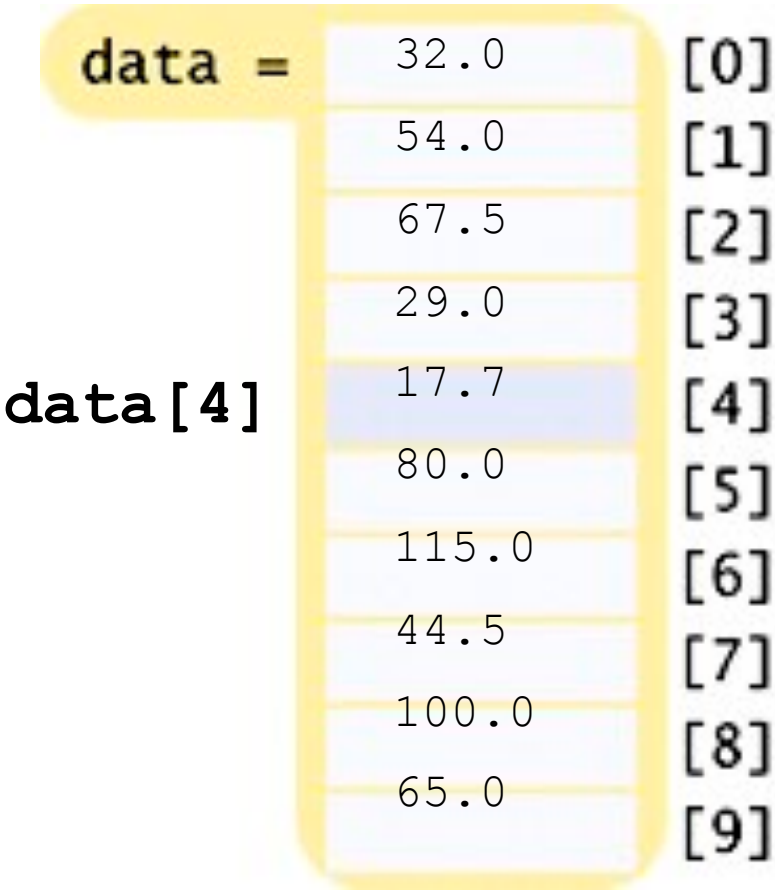


Practice: declare an array and store names of all US coins in the array

Practice: declare an array of char to store characters 'a', 'b', 'c', 'd', 'e'.

Access Array Element

```
double data[] = { 32, 54, 67.5, 29, 35, 80,
115, 44.5, 100, 65 };
```



- To access an array element:

  `data[i]`

- where **`i`** is the *index*.

- In C++ and most computer languages, index starts with **`0`**.

Visiting All Elements

To visit all elements of an array, use a variable for index.

```
double data[] = { 32, 54, 67.5, 29, 35, 80, 115, 44.5,
100, 65 };
```

```
for (int i = 0; i < 10; i++)
{
    cout << data[i] << endl;

}
```

When `i` is `0`, `data[i]` is `data[0]`, the first element.

When `i` is `1`, `data[i]` is `data[1]`, the second element.

…When `i` is `9`, `data[i]` is `data[9]`, the *last legal* element.

Bounds Error

A *bounds* error occurs when you access an element outside the legal set of indices:

```
cout << data[10];
```

Doing this can corrupt data or cause your program to terminate.

DANGER!!!

DANGER!!!

DANGER!!!

Table 1 Defining Arrays

`int numbers[10];`	An array of ten integers.
`const int SIZE = 10;` `int numbers[SIZE];`	It is a good idea to use a named constant for the size.
`int size = 10;` `int numbers[size];`	**Error:** The size must be a constant.
`int squares[5] = { 0, 1, 4, 9, 16 };`	An array of five integers, with initial values.
`int squares[] = { 0, 1, 4, 9, 16 };`	You can omit the array size if you supply initial values. The size is set to the number of initial values.
`int squares[5] = { 0, 1, 4 };`	If you supply fewer initial values than the size, the remaining values are set to 0. This array contains 0, 1, 4, 0, 0.
`string names[3];`	An array of three strings.

Use array to build a table

- How to display a date using English name for month?

```
int month;
…
if (month==1)
    cout <<"Jan";
else if (month==2)
        cout <<"Feb";
else if (month==3)
      cout << "Mar";
...
```

very long code!

Usage of array

- We can simplify the code using a table that maps 1 to Jan, 2 to Feb, 3 to Mar, …
- How ?
  - String month_names[12]={"Jan", "Feb", "Mar", "Apr", "May", "Jun", "July", "Aug", "Sep", "Oct", "Nov", "Dec"};
  - cout << month_names[month];
  - Not quite, this maps 0 to Jan, 1 to Feb, ..
  - To fix: cout << month_names[month-1];

Usage of array

- We can simplify the code using a table that maps 1 to Jan, 2 to Feb, 3 to Mar, …
- Alternatively:
  - String month_names[13]={"","Jan", "Feb", "Mar", "Apr", "May", "Jun", "July", "Aug", "Sep", "Oct", "Nov", "Dec"};
  - cout << month_names[month];

- one liner versus if/elseif statement with 12 cases !

DataChecker function

- Create and use a table that maps month to the number of days in the month
  - 1: 31
  - 2: 28 or 29
  - 3: 31
  - 4: 30
  - 5: 31
  - …
- What to do with Feb?

How to convert to using vector?

```
int DaysInMonth[13]={0,31,28,31,30,31,30,31,31,30,31,30,31};
if (leap_year(yr))
    DaysInMonth[2]=29;
```

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Partially-Filled Arrays

- How to choose size for an array ?
  - pick a reasonable maximum number of elements
  - We call this quantity **capacity**, e.g.,

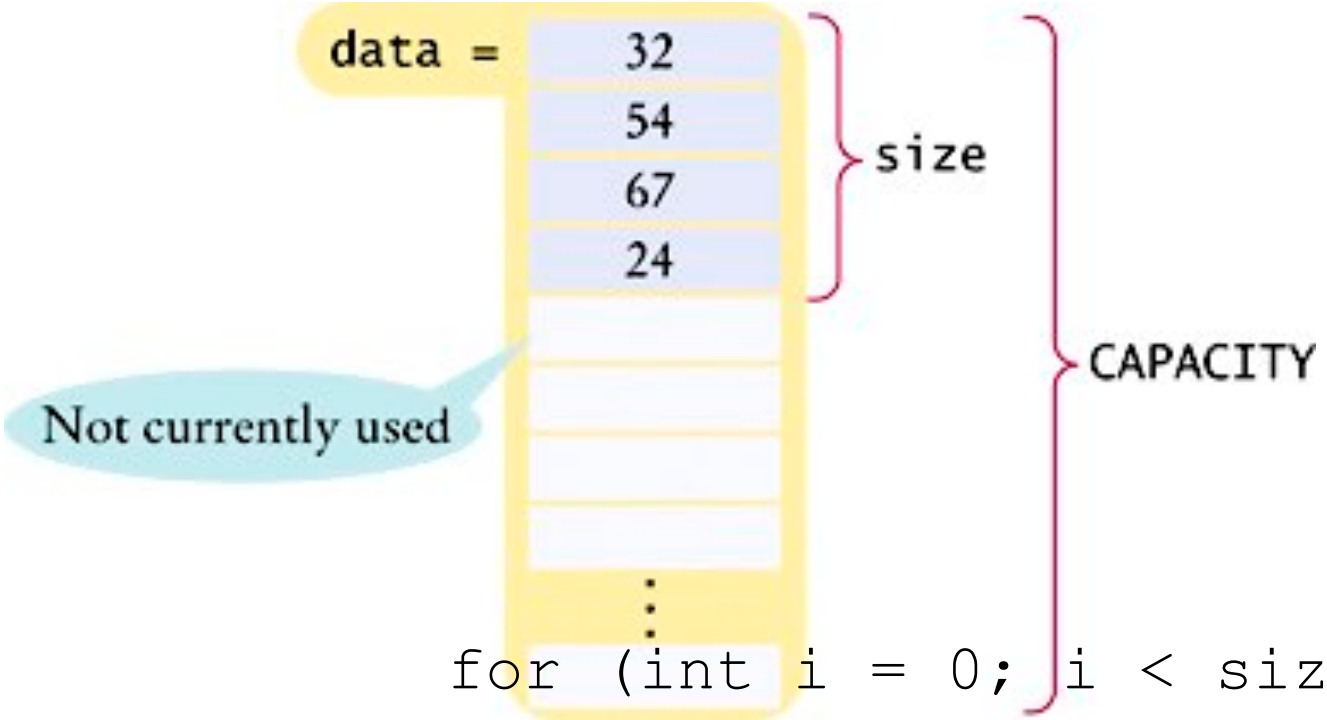
```
const int CAPACITY = 100;
double data[CAPACITY];
```

- This array usually has less than CAPACITY elements in it
  - array is **partially filled**
  - use a companion variable to keep track # of elements in array

```
int size = 0; // array is empty initially
```

Partially-Filled Arrays

If only four elements have been stored in the array:




```
for (int i = 0; i < size; i++)
{
    cout << data[i] << endl;
}
```

Partially-Filled Array

```
const int CAPACITY = 100;
double data[CAPACITY];
int size = 0;

double input;
while (cin >> input)
{
   if (size < CAPACITY)
   {
      data[size] = x;
      size++;
   }
}
```

Whenever size of the array changes we update this variable

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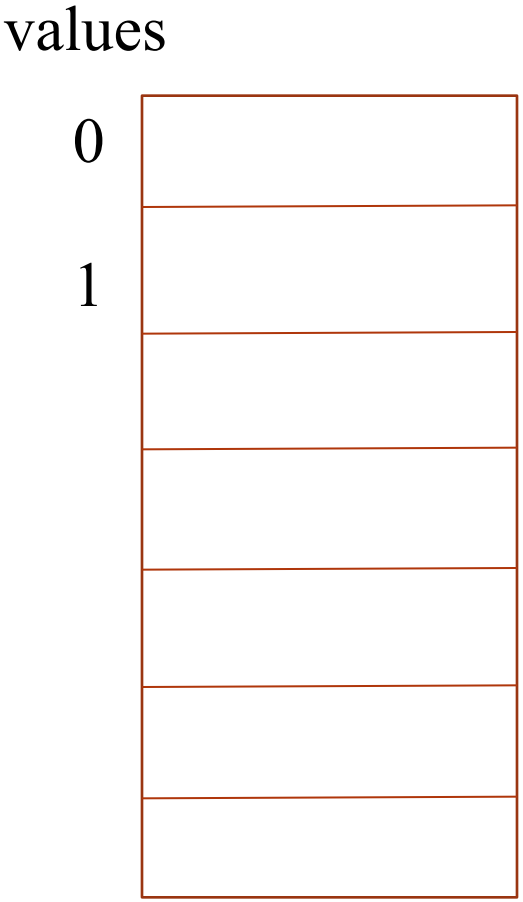
Arrays

- a lower level structure
  - contiguous memory that holds multiple elements of same type
  - actually pointer variable, storing <u>address of first (0th) element</u>
- Programmers
  - use companion variables to keep track part of array is filled
    - If array is always filled from top, size
    - Sometimes, use two indices, start, end



Array Parameter

- When passing array to a function …
  - use an empty pair of square brackets after parameter name to indicate it's an array.
  - Pass size of array (# of elements)

```
 // calculate the sum of elements in an array
double sum(double data[], int size)
 {
    double total = 0;
    for (int i = 0; i < size; i++)
    {
       total = total + data[i];
    }
    return total;
 }
```

Exercise

- Write a function that calculate the average of values in the array of int

Array Parameters

- changes to array parameter are made to actual parameter, i.e., the array the caller passed to function:

```
void Initialize(double data[], int size)
{
   for (int i = 0; i < size; i++)
   {
      data[i] = 0;
   }
}
```

This works! But why?

```
 in caller,

  double my_array[20];
  Initialize (my_array, 20);
```

Array Parameters

- **data** is passed by value,
  - At function call, parameter variable (data) is initialized with value of actual parameter (my_array)
  - Key: recall array variable is a pointer (addr of first element of array)

```
void Initialize(double data[], int size)
 {
    for (int i = 0; i < size; i++)
    {
       data[i] = 0;
    }
 }
…
double my_array[20];
Initialize (my_array, 20);
```

Array Parameter

And writing an ampersand is *always* an error:

```
void multiply1(double& data[], int size, double factor)
{
    for (int i = 0; i < size; i++)
    {
        data[i] = data[i] * factor;
    }
}
void multiply2(double data[]&, int size, double factor)
{
    for (int i = 0; i < size; i++)
    {
        data[i] = data[i] * factor;
    }
}
```

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Example functions on array

Search array for an element

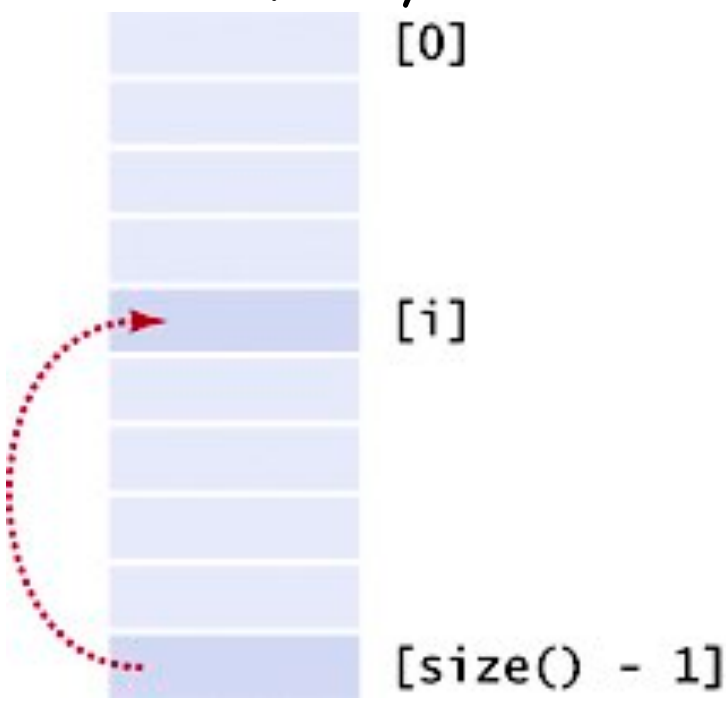
```
/** search for value x in an array
@param values: array of ints
@param size: length of values
@param x: the value to look for
@return -1 if x is not in the array, otherwise, return the index */
int search ( int values[ ], int size, int x)
{



}
```

Removing an Element*

- Suppose you want to remove the element at index i.
- If elements in the array are not in any particular order
  - Overwrite the element to be removed with the last element, then shrink the size by one



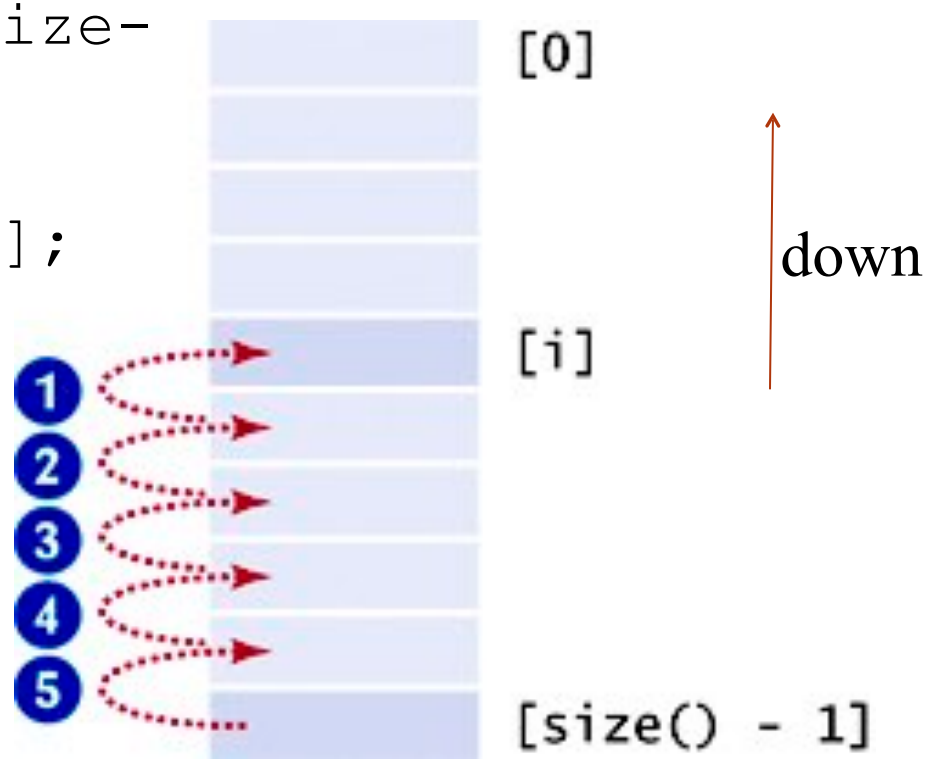

```
int last_pos = size - 1;
data[i] = data[last_pos];
size --;
```

Removing an Element (cont'd)*

If array is sorted

move all elements following the i-th element "down" (to a lower index), and then shrink the size by one

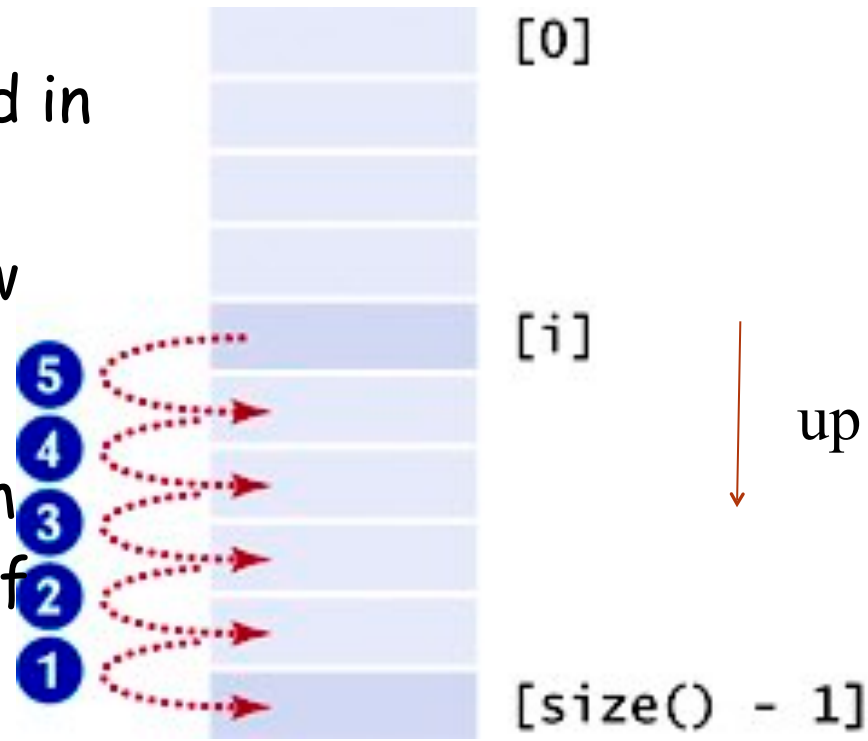
```
for (int j = pos; j < size-
  1; j++)
{
   data[j] = data[j + 1];
}
size --;
```



Inserting an Element*

- Insert a new element into array
- array[size] = data;
- size++;

- If elements need to be sorted in order
  - find position to insert new value
  - Move up all elements from that location to the end of array
  - Insert the new element at now vacant position [i].



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Two-Dimensional Arrays

- Collections of values that have a two-dimensional layout
  - E.g., multiplication table
  - E.g., configuration of game board (tic-tac-toe, chess…)
- Each element accessed with *rows and columns* index
  - ***two-dimensional array***, or a ***matrix***

x	0	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	1	2	3	4	5	6	7	8	9	10	11	12
2	0	2	4	6	8	10	12	14	16	18	20	22	24
3	0	3	6	9	12	15	18	21	24	27	30	33	36
4	0	4	8	12	16	20	24	28	32	36	40	44	48
5	0	5	10	15	20	25	30	35	40	45	50	55	60
6	0	6	12	18	24	30	36	42	48	54	60	66	72
7	0	7	14	21	28	35	42	49	56	63	70	77	84
8	0	8	16	24	32	40	48	56	64	72	80	88	96
9	0	9	18	27	36	45	54	63	72	81	90	99	108
10	0	10	20	30	40	50	60	70	80	90	100	110	120
11	0	11	22	33	44	55	66	77	88	99	110	121	132
12	0	12	24	36	48	60	72	84	96	108	120	132	144

TWO-DIMENSIONAL ARRAY

- Declare a 2D array:

```
const int ROWS_NUM = 10;
 const int COLS_NUM = 10;
 double multi_table[ROWS_NUM][COLS_NUM];
```

As with one-dimensional arrays, size in both dimension decided at compilation time, cannot be changed …

- Individual elements are accessed by double subscripts: multi_table[i][j]
  - multi_table[3][4] = 3*4;
  - **Use separate brackets!** , not multi_table[3,4] (wrong)

FILLING IN DATA

- To fill a two-dimensional array, use nested loops:

```
for (int i = 0; i < ROWS_NUM; i++)
    for (int j = 0; j < COLS_NUM; j++)
        multi_table[i][j] = i*j;
```

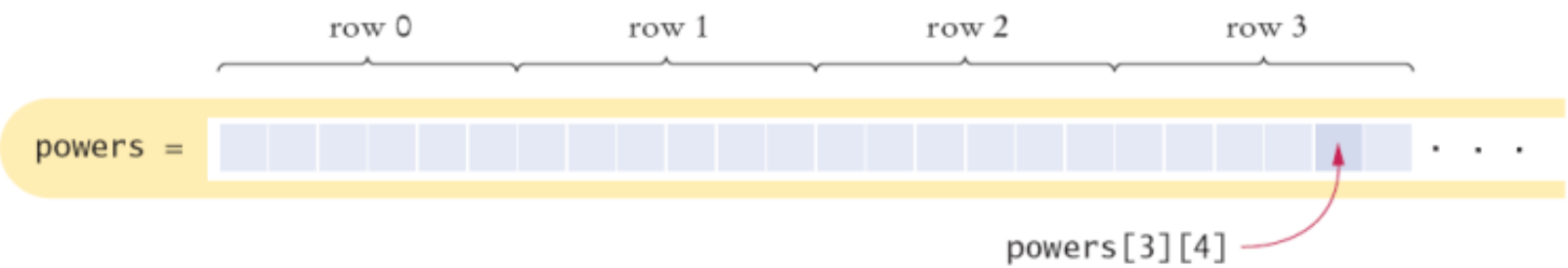
Computing Row and Column Totals

- A common task is to compute row or column totals.
- Row total:

```
for (int i=0; i< ROWS_NUM;i++)
{
    total = 0;
    for (int j=0; j < COLS_NUM, j++)
        total += multi_table[i][j];
    cout << " sum of row " << i <<" is " << total;
}
```

How is 2D array stored?

- Like 1D array, 2D array is also a low-level construct
  - 2D array stored in a contiguous block of memory: first row 0 elements, then row 1 elements, …
- Compiler finds multi_table[i][j] by computing offset:
  - i * COLS_NUM + j // there are i rows before me
  - Compiler needs to know COLS_NUM => COLS_NUM must be a const



PASSING TO FUNCTIONS

- Specify number of columns when declaring 2D array parameter

```
void print_table(double table[][COLS_NUM], int table_rows)
{
  const int WIDTH = 10;
  cout << fixed << setprecision(2);
  for (int i = 0; i < table_rows; i++)
  {
     for (int j = 0; j < COLS_NUM; j++)
        cout << setw(WIDTH) << table[i][j];
     cout << "\n";
  }
}
```

When calling this function, passing the name of the array `print_table (power_table, 4);`

Common Error

Leaving out the columns value is a very common error.

```
int row_total(int table[][], int row)
...
```

The compiler doesn't know how "long" each row is!

Example

Putting a value for the rows is not an error.

```
int row_total(int table[17][COLUMNS], int
row)
...
```

The compiler just ignores whatever you place there.

2D Array Parameters

- Following function works only for 2D arrays with 6 columns.

  const int POWERS_COL=6;

  void print_table(const double table[][POWERS_COLS], int table_rows)

- To process 2D array with different column numbers:
  - A different function:

```
const int COLUMNS_2 = 4;
int print_table_4(int table[][COLUMNS_2], int row)
{
 ….
}
```

SUMMARY

- Array
  - Declaration, fixed size at compilation time
  - Use of an int variable to store its size
  - Array assignment
  - Use array in function
    - Return an array
    - As parameter , need to pass the size …
- 2D array accessed with two subscripts: row and column
  - Stored as 1D array
  - Compiler calculate index from row and column indices