CSCE 121
Introduction to Program Design & Concepts

Dynamic Memory

Dr. Tim McGuire

Grateful acknowledgment to Dr. Philip Ritchey and Dr. Michael Moore for some of the material on which these slides are based.

Dynamic Memory Allocation

- Can allocate storage for a variable while program is running
- Computer returns address of newly allocated variable
- Uses `new` operator to allocate memory:

```
double *dptr = nullptr;
dptr = new double;
```

- `new` returns address of memory location

Dynamic Memory Allocation

- Can also use `new` to allocate array:

```
const int SIZE = 25;
arrayPtr = new double[SIZE];
```

- Can then use `[]` or pointer arithmetic to access array:

```
for(i = 0; i < SIZE; i++)
    arrayptr[i] = i * i;
```

or

```
for(i = 0; i < SIZE; i++)
    *(arrayptr + i) = i * i;
```

- Program will terminate if not enough memory available to allocate

Releasing Dynamic Memory

- Use `delete` to free dynamic memory:

```
delete fptr;
```

- Use `[]` to free dynamic array:

```
delete [] arrayptr;
```

- Only use `delete` with dynamic memory!

Recall: Memory Layout

Stack and heap
grow toward each other.

Stack

- Recall:
  - As stack grows / shrinks, items are automatically cleared from Memory
    - i.e. when a function ends,
      all of its objects (variables) are cleared from Memory

- Sometimes we want objects to live on after a function is finished.
  - Put on the Heap / Free Store

Heap aka Dynamic Memory

- How to use the heap?
  - Use '**new**'
    - Gets memory from the heap
    - Returns a pointer
  - Use '*' to dereference the pointer
  - Initialize with **nullptr** (i.e. 0) – *See Null Pointer note in zyBook.*

```
int i = 7; // put item on the stack
int* j = nullptr;
j = new int(11); // put item on the heap
cout << “Value in i: " << i << endl;
cout << "Address of i: " << &i << endl;
cout << “Value in j: " << j << endl;
cout << "Address of j: " << &j << endl;
cout << "*j (value at address pointed to in j): " << *j << endl;
int* k = new int[5]; // allocate an array on the heap
```

Heap

- If we put something on the heap we also have to remove it.
  - If we don't we might have a memory leak.
  - More on memory management / challenges with pointers later.

- How to remove from the heap?
  - Use '`delete`'
  - Use '`delete[]`' if deleting an array

```
delete j; // remove item from the heap
          // j still points to the memory in the heap
          // that can be a problem
```

Only use `delete` with dynamic memory!

Notes on new / delete

- If you delete memory that has already been deleted, then an exception will likely occur.
- If you delete a pointer that is set to **`nullptr`**, then no error occurs. (The **`delete`** operator is designed to have no effect when used on a null pointer.)
- If you try to dereference a pointer that has been deleted, then an exception will likely occur.
- So try to set the pointer to **`nullptr`** after you use delete.

Dynamic Memory Allocation

dynamicArray.cpp

```
1  // This program totals and averages the sales figures for any number of days.
2  // The figures are stored in a dynamically allocated array.
3  // Based on an original from Tony Gaddis
4
5  #include <iostream>
6  #include <iomanip>
7  using namespace std;
8
9  int main()
10 {
11     double *sales = nullptr,  // To dynamically allocate an array (must use *, not [])
12     total = 0.0,              // Accumulator
13     average;                  // To hold average sales
14     int numDays,              // To hold the number of days of sales
15         count;                // Counter variable
16
17
18     // Get the number of days of sales.
19     cout << "How many days of sales figures do you wish ";
20     cout << "to process? ";
21     cin >> numDays;
22
23     // Dynamically allocate an array large enough to hold
24     // that many days of sales amounts.
25     sales = new double[numDays];
```

Dynamic Memory Allocation

```
26
27      // Get the sales figures for each day.
28      cout << "Enter the sales figures below.\n";
29      for (count = 0; count < numDays; count++)
30      {
31      cout << "Day " << (count + 1) << ": ";
32      cin >> sales[count];
33      }
34
35      // Calculate the total sales
36      for (count = 0; count < numDays; count++)
37      {
38      total += sales[count];
39      }
40
41      // Calculate the average sales per day
42      average = total / numDays;
43
44      // Display the results
45      cout << fixed << showpoint << setprecision(2);
46      cout << "\n\nTotal Sales: $" << total << endl;
47      cout << "Average Sales: $" << average << endl;
48
49      // Free dynamically allocated memory
50      delete [] sales;
51      sales = nullptr;  // make sales a null pointer
52
53      return 0;
54  }
```

mcguire@CSCE-1PSF1G2: /mnt/c/windows/system32

```
Tue Oct 12 20:35:00 mcguire DynamicMemory$ g++ dynamicArray.cpp
Tue Oct 12 20:35:18 mcguire DynamicMemory$ ./a.out
How many days of sales figures do you wish to process? 5
Enter the sales figures below.
Day 1: 898.63
Day 2: 652.32
Day 3: 741.85
Day 4: 852.96
Day 5: 921.37


Total Sales: $4067.13
Average Sales: $813.43
Tue Oct 12 20:36:04 mcguire DynamicMemory$
```

Pointers to Structures

- A structure variable has an address
- Pointers to structures are variables that can hold the address of a structure:

```
Student *stuPtr;
```

- Can use `&` operator to assign address:

```
stuPtr = &stu1;
```

- Structure pointer can be a function parameter

Accessing Structure Members via Pointer Variables

- Must use `()` to dereference pointer variable, not field within structure:

```
cout << (*stuPtr).studentID;
```

- Can use structure pointer operator to eliminate `()` and use clearer notation:

```
cout << stuPtr->studentID;
```

Code Segment showing use of structure pointers

dynamicStructure.cpp

```
34  }
35
36  //***************************************************************
37  // Definition of function getData. Uses a pointer to a  *
38  // Student structure variable. The user enters student  *
39  // information, which is stored in the variable.        *
40  //***************************************************************
41
42  void getData(Student *s)
43  {
44     // Get the student name.
45     cout << "Student name: ";
46     getline(cin, s->name);
47
48     // Get the student ID number.
49     cout << "Student ID Number: ";
50     cin >> s->idNum;
51
52     // Get the credit hours enrolled.
53     cout << "Credit Hours Enrolled: ";
54     cin >> s->creditHours;
55
56     // Get the GPA.
57     cout << "Current GPA: ";
58     cin >> s->gpa;
59  }
```

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Memory Diagrams 4
How Dynamic Memory Works

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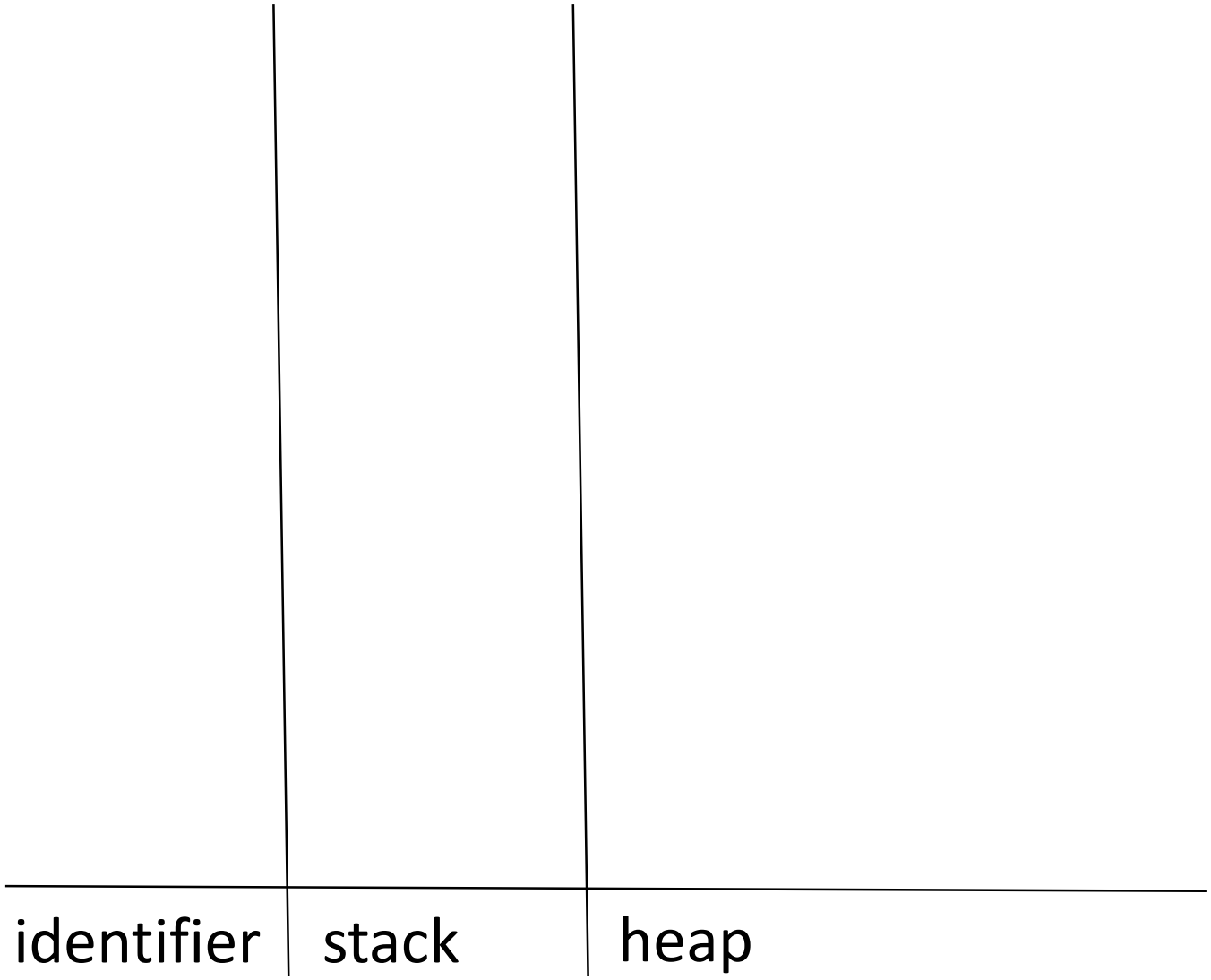
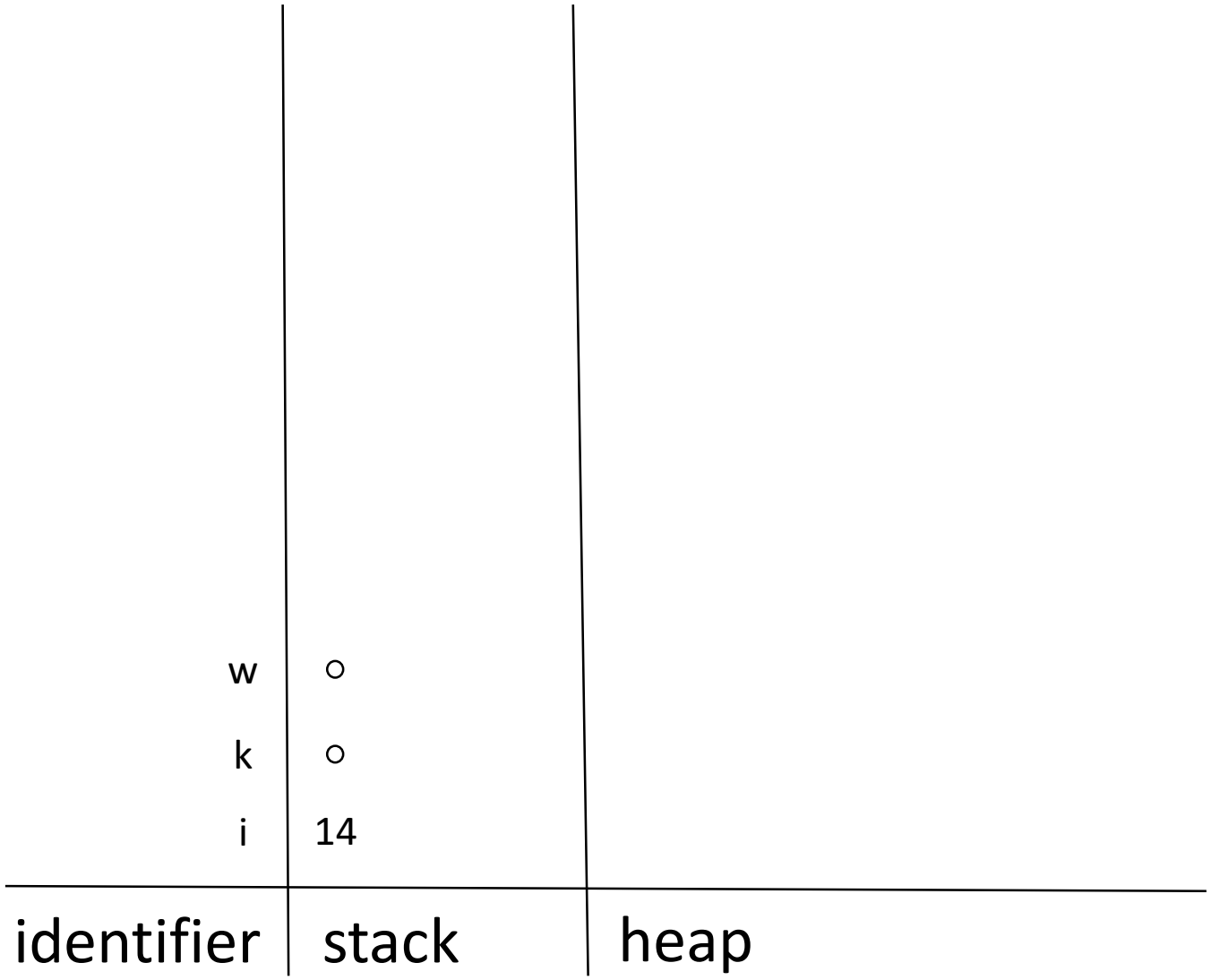
output



output

```
int main() {
    int i = 14;

    int* k = &i;

    k = new int(3);

    delete k;

    Date* w = new Date(7, 7, 2015);

    delete w;

    w = nullptr;
}
```



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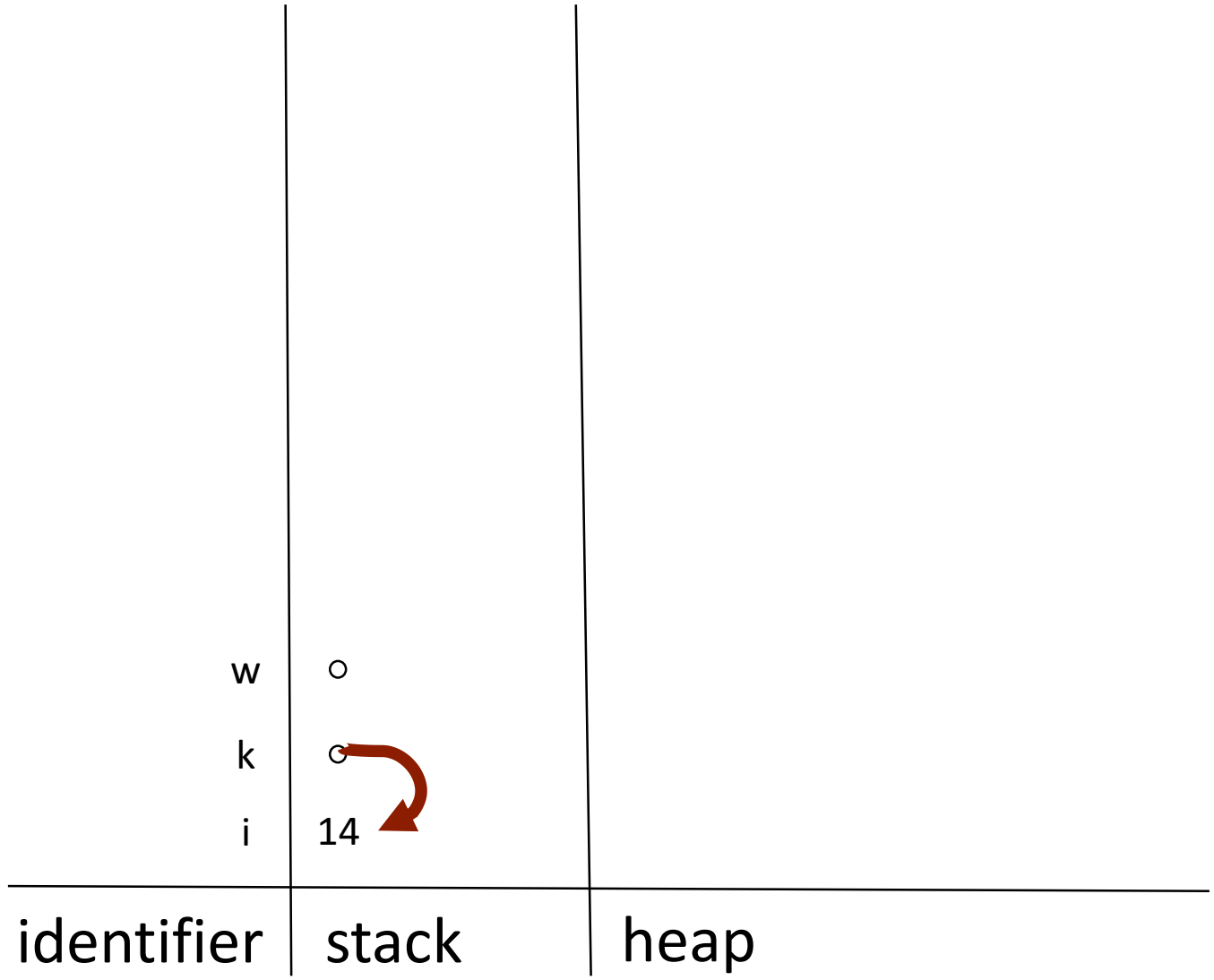

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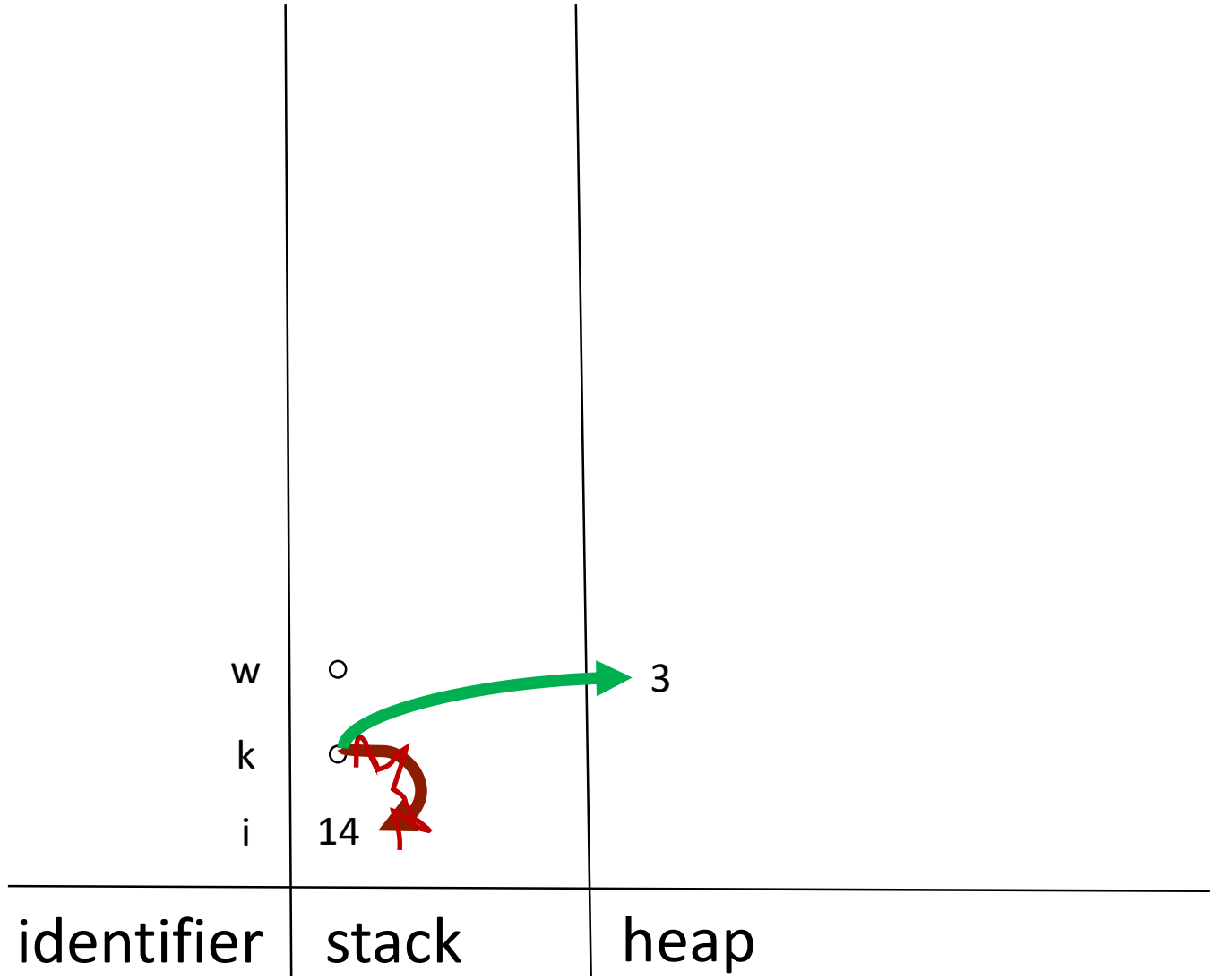

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    k = new int(3);

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}
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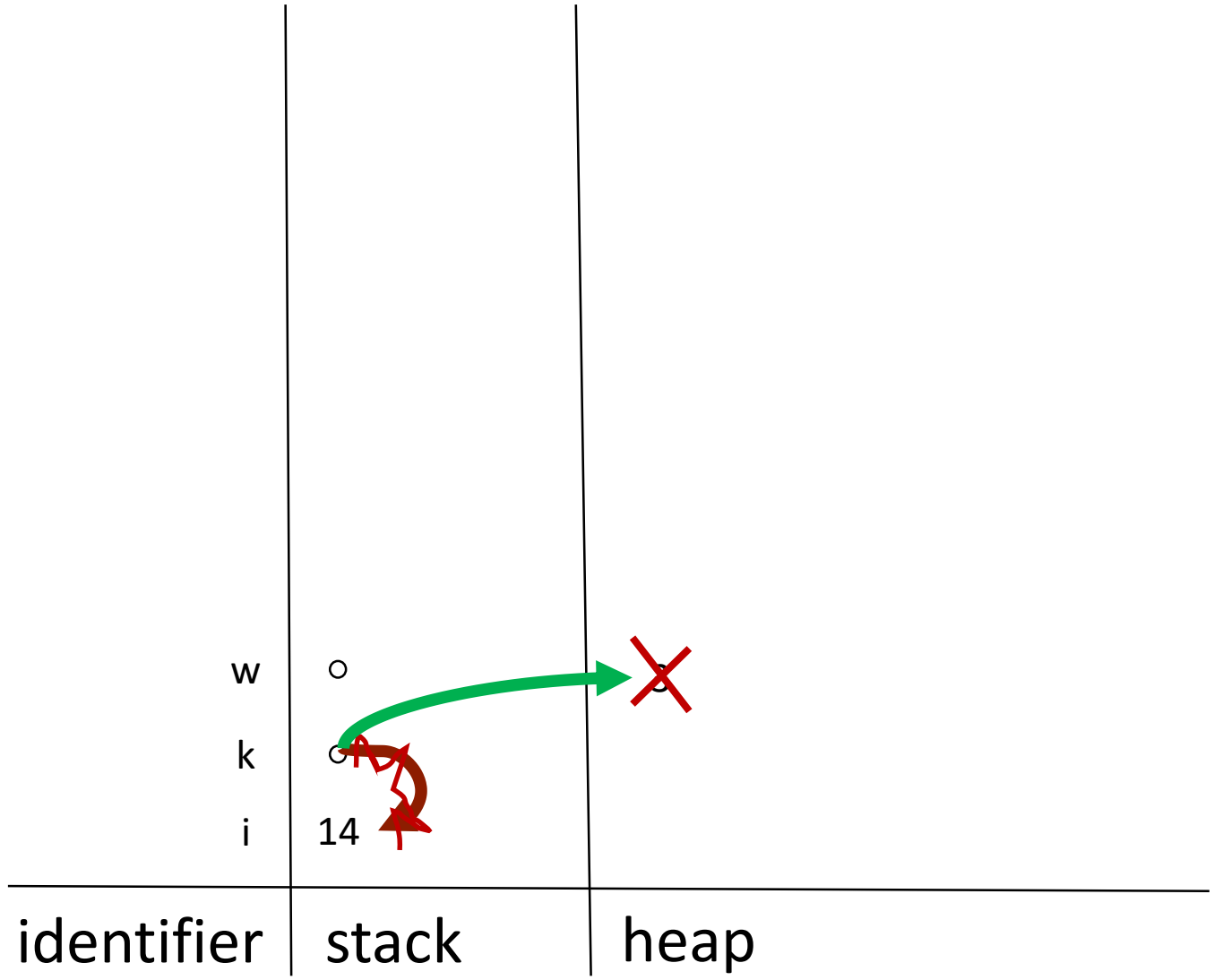

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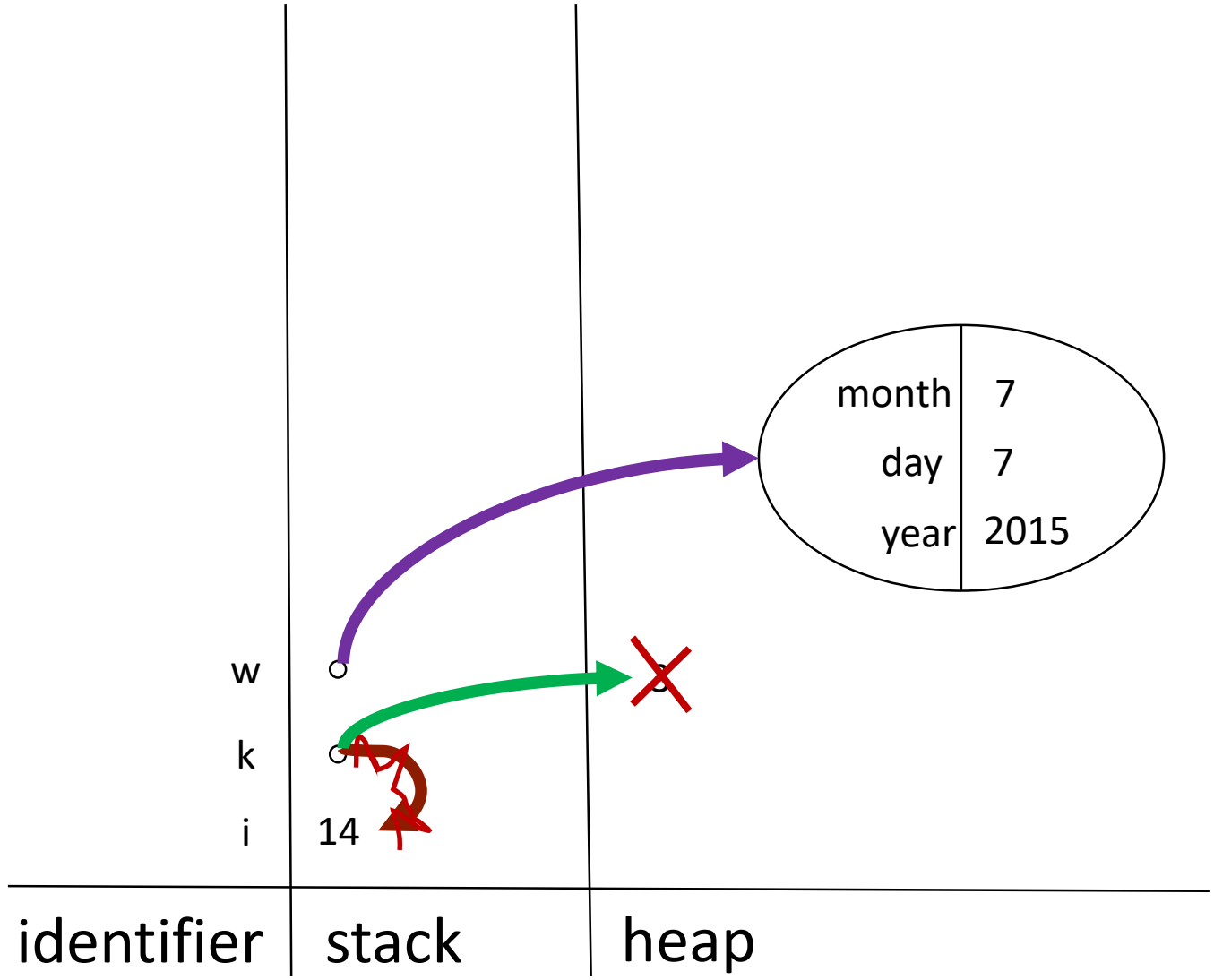

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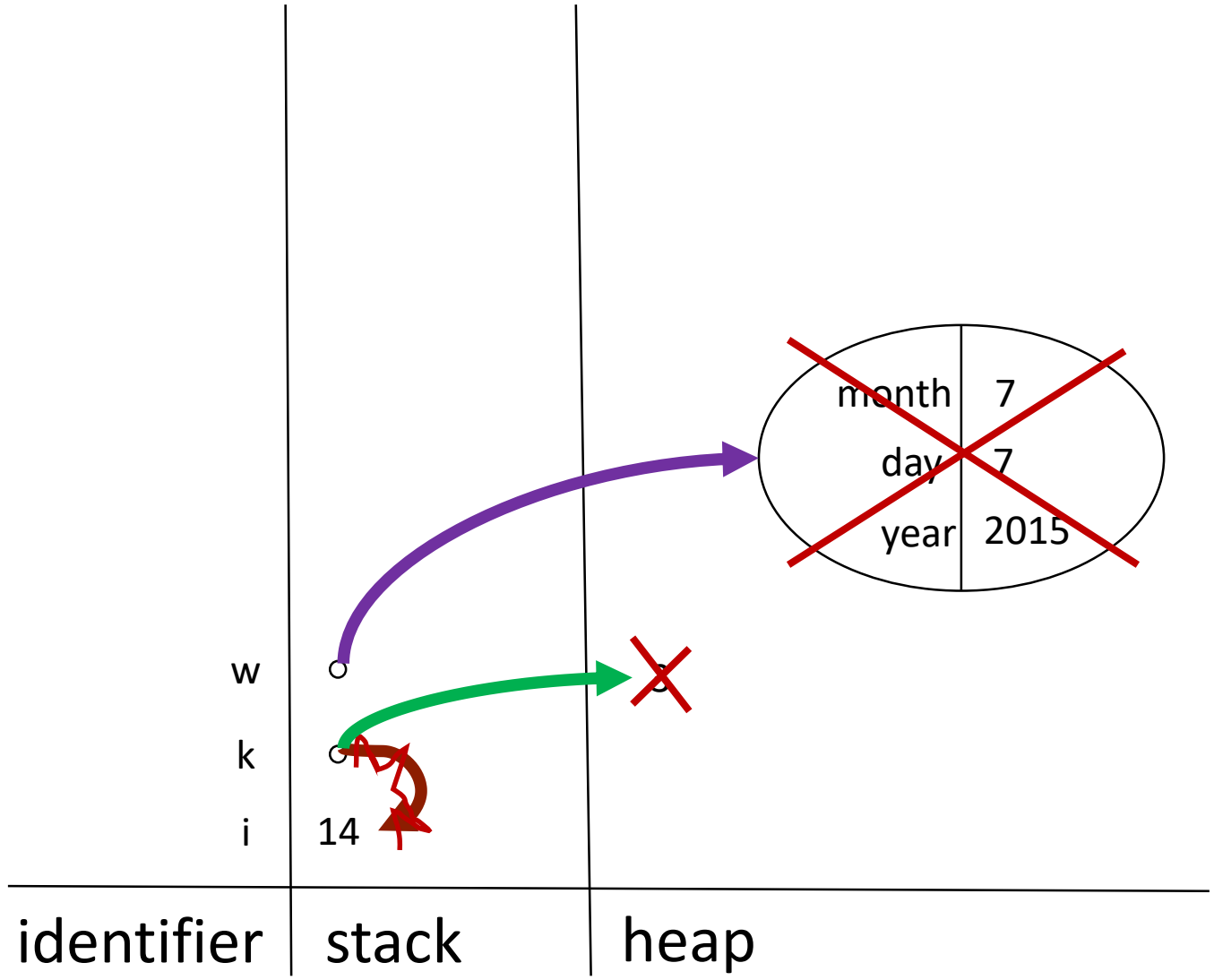

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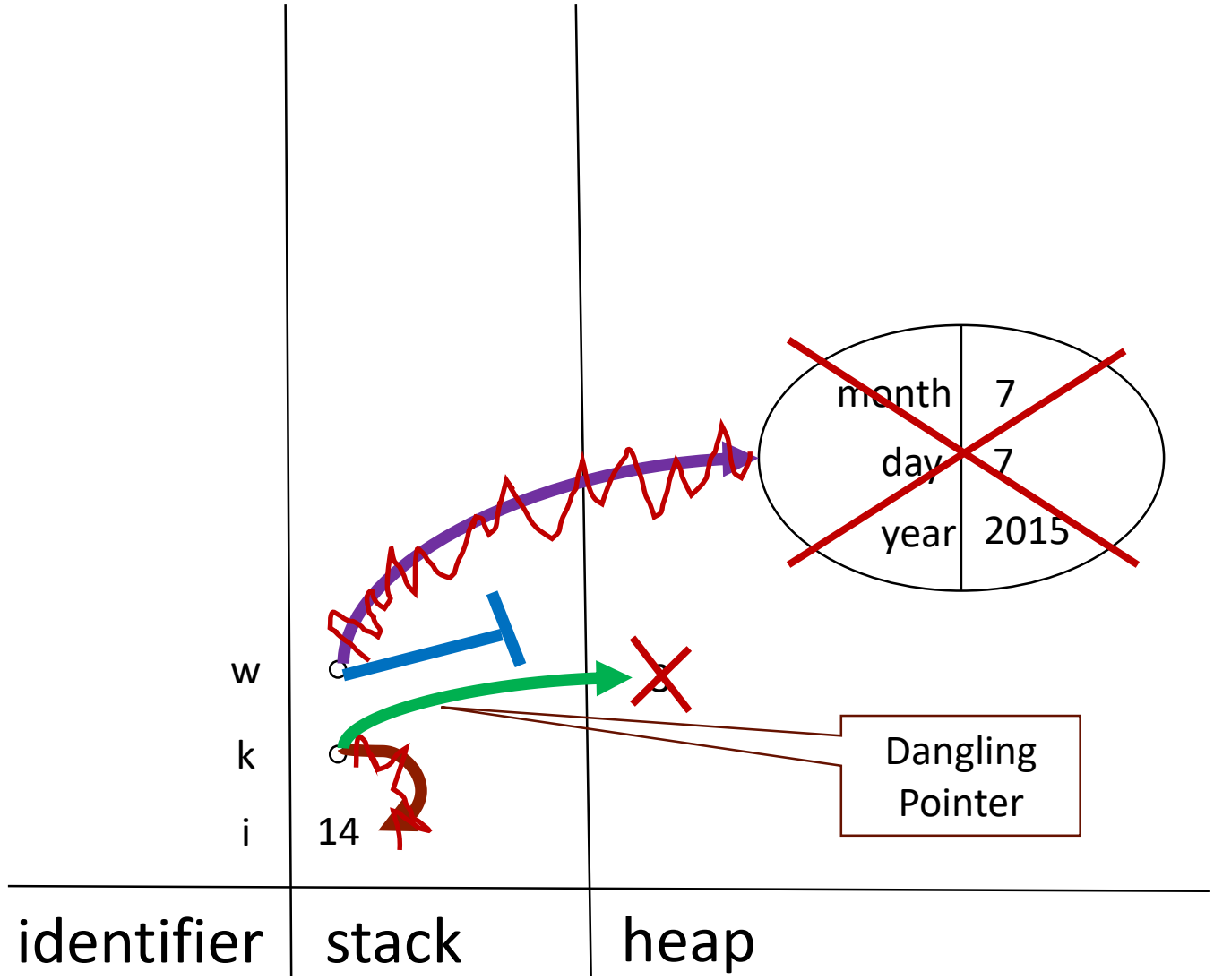

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Dynamic Memory Management

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Memory Leaks

- Lose access to memory allocated on the heap.
  - Easy to lose when dealing with pointers
- We want to avoid!!!
- Sometimes conflated with poor memory management.

Managing Memory

- Programmer gets memory from the heap
- Programmer must free it when done
  - Commonly referred to as **garbage collection**.

- Good exam question
  - What are specific scenarios that can result in a memory leak?
  - Think about the definition of a memory leak as we continue to discuss dynamic memory management.

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How Memory Leaks Work with Memory Diagram

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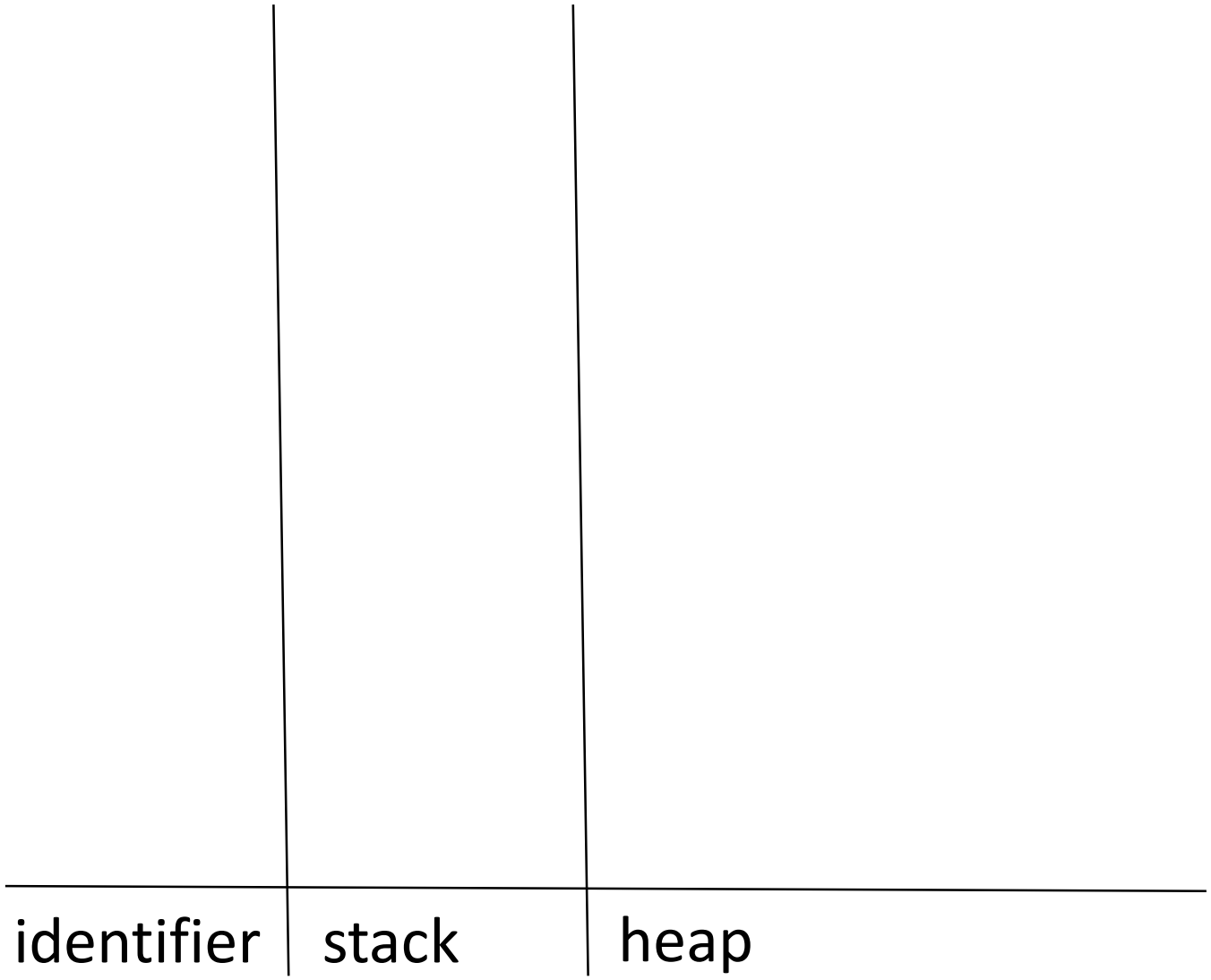
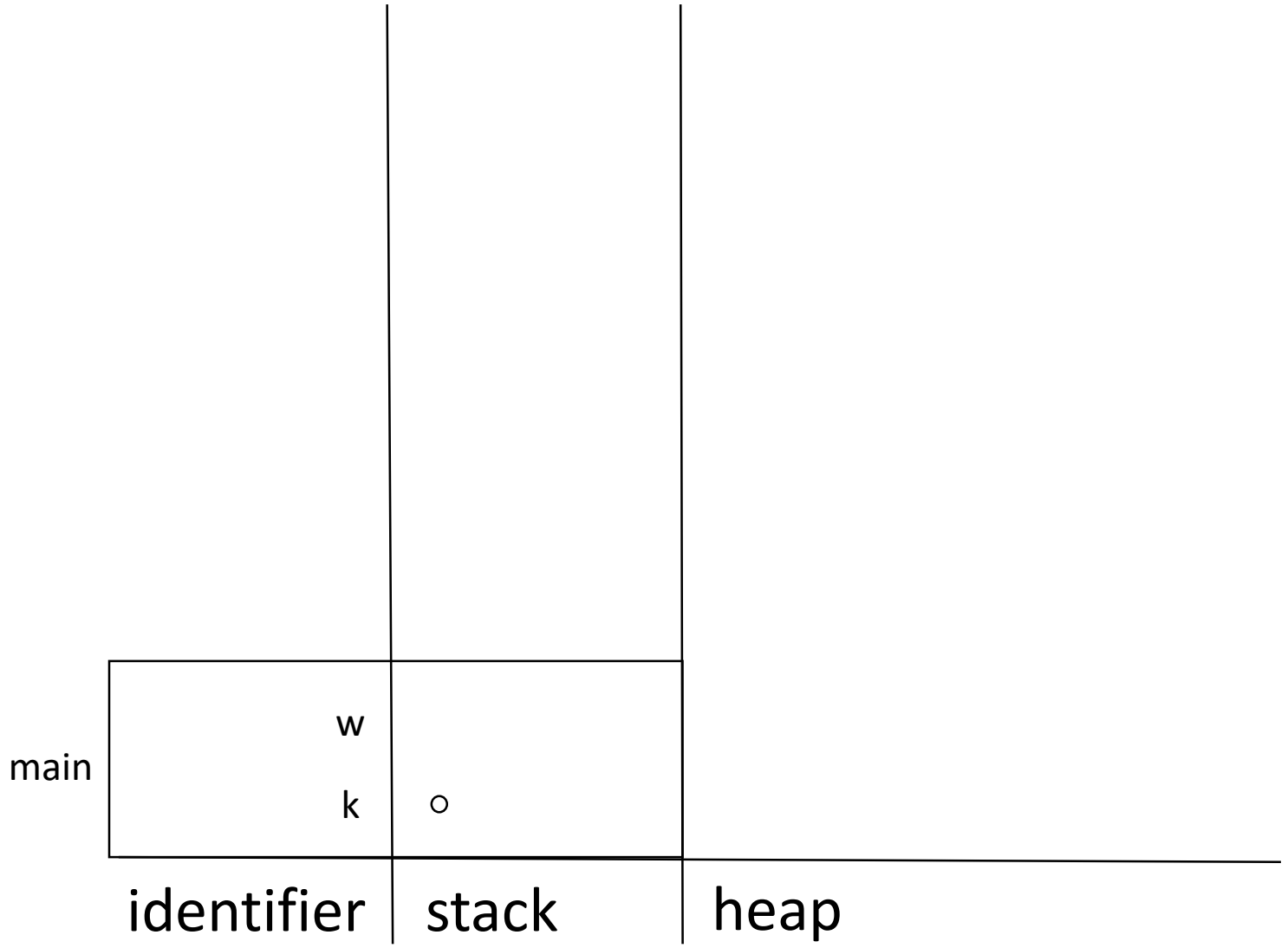
output



output

```
int getANumber() {
    int* z = new int(15);
    return *z;
}
int main() {
    int* k = new int(3);
    k = new int (7);
    int w = getANumber();
}
```



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}

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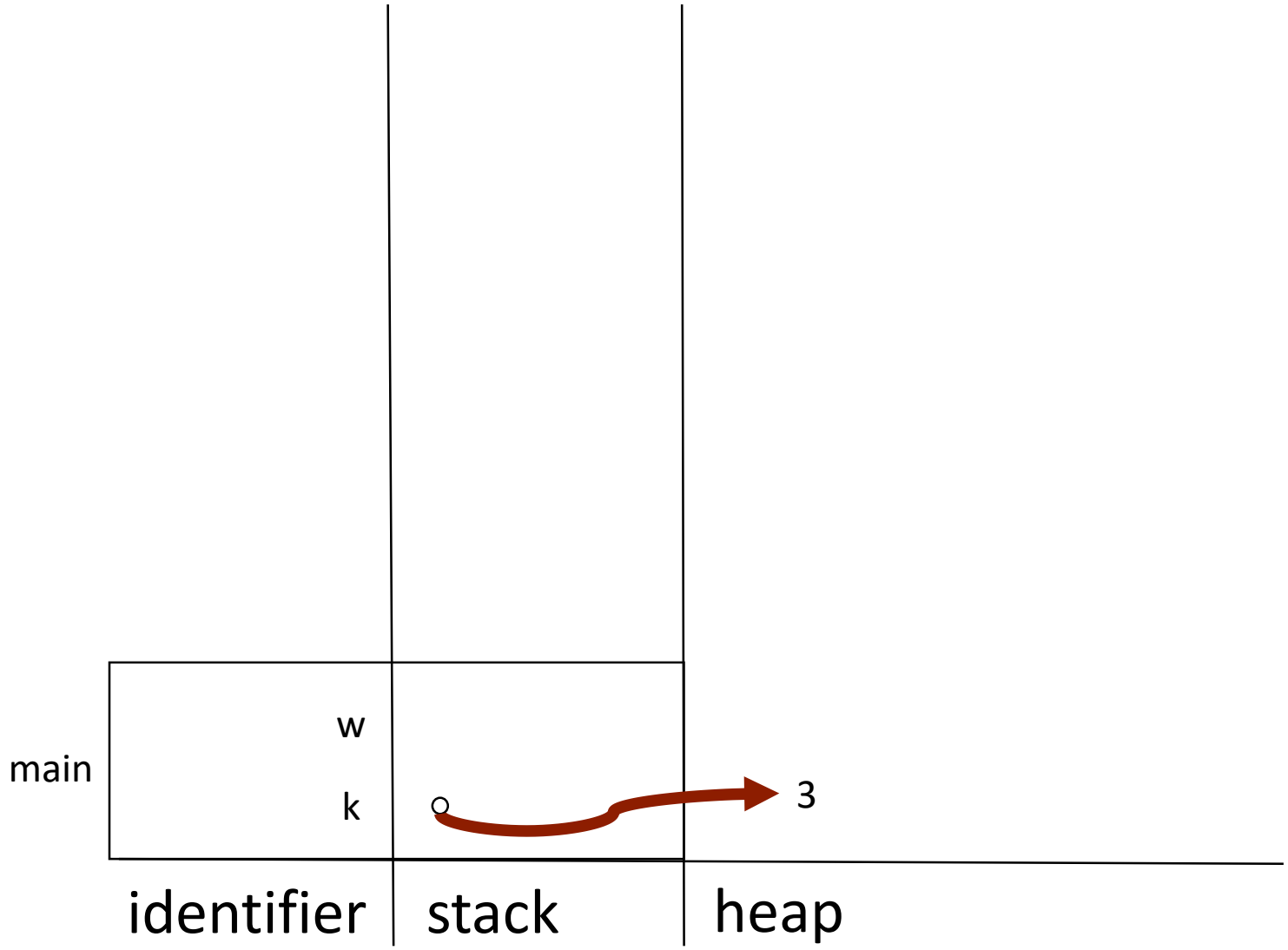

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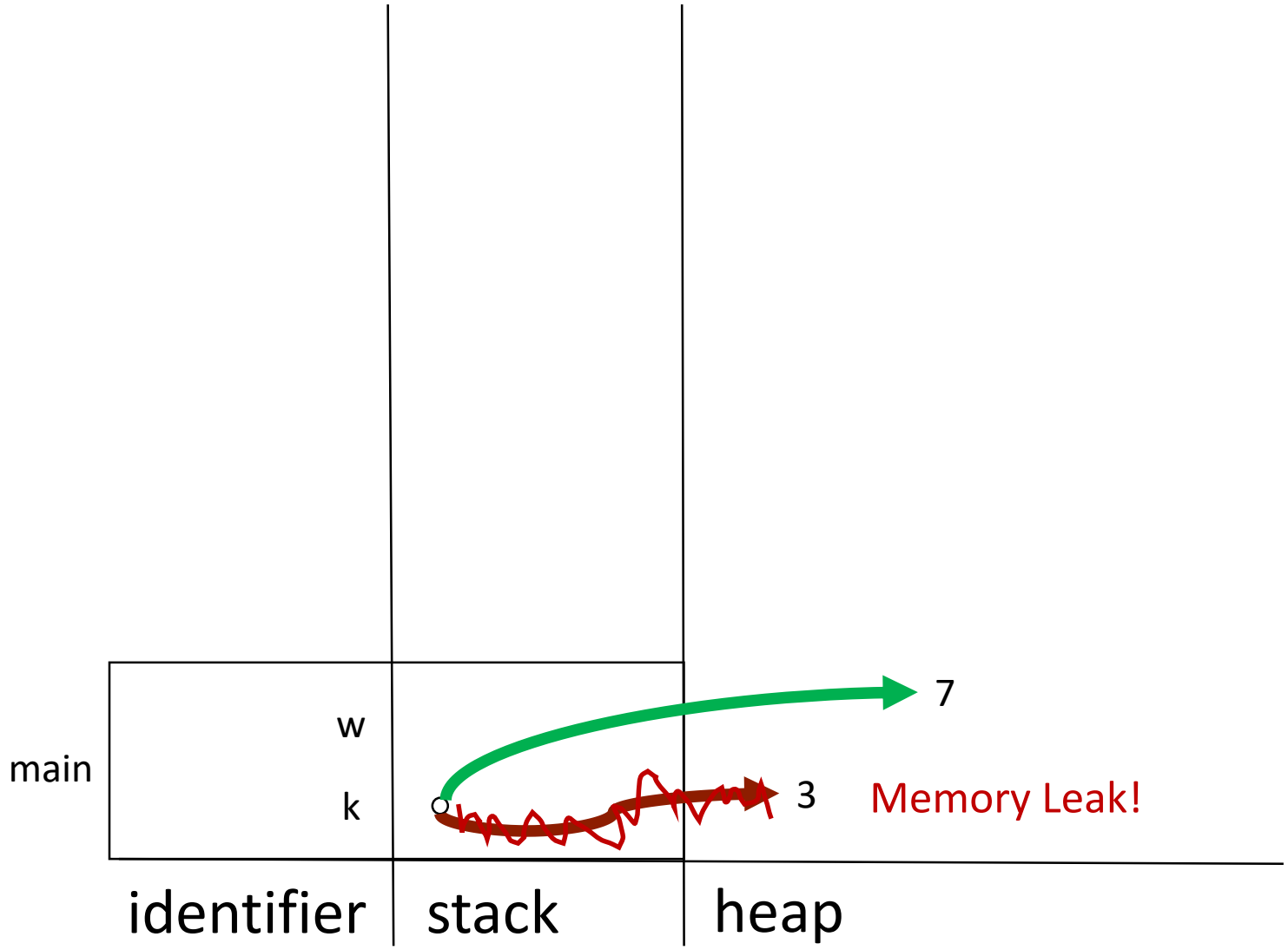

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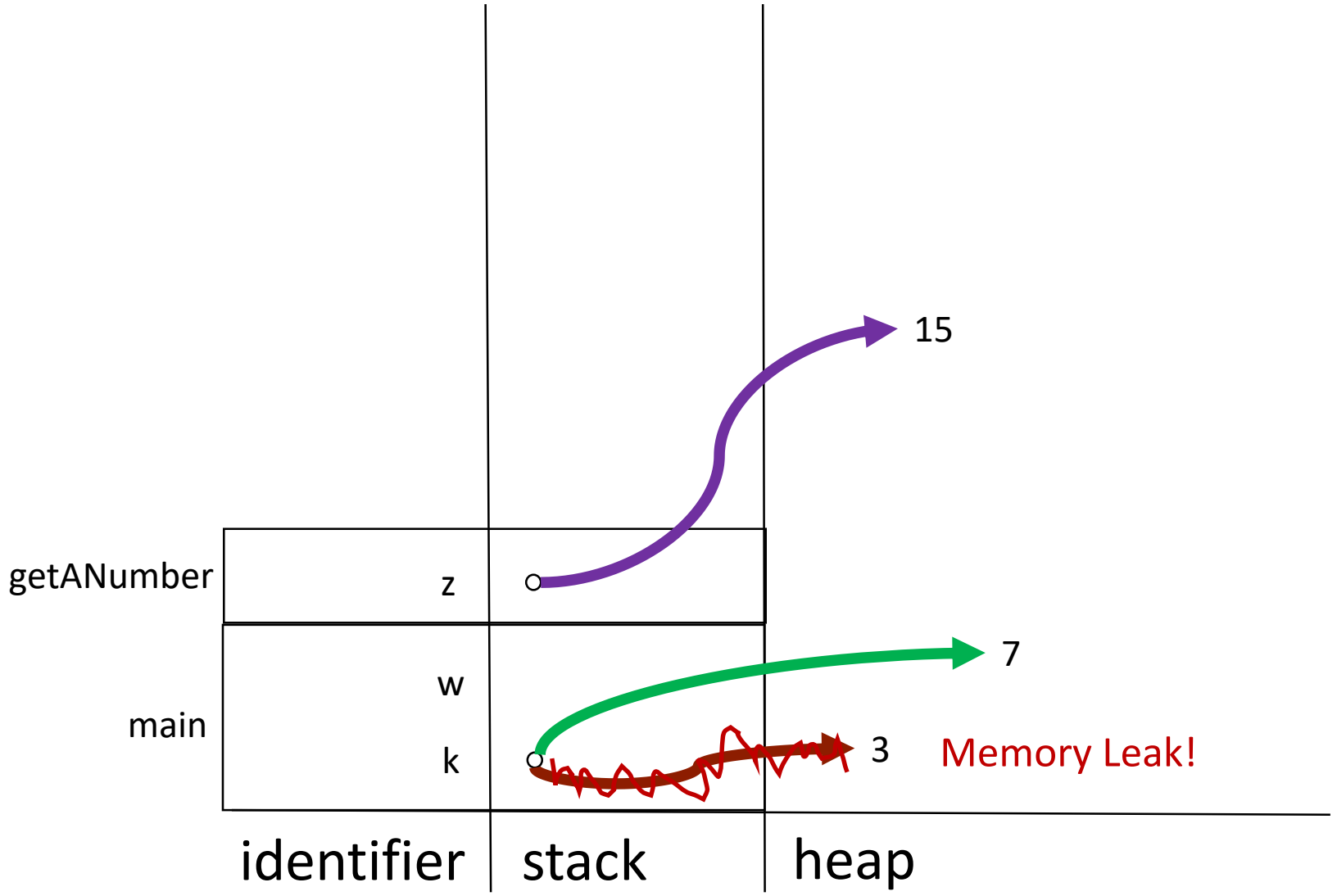

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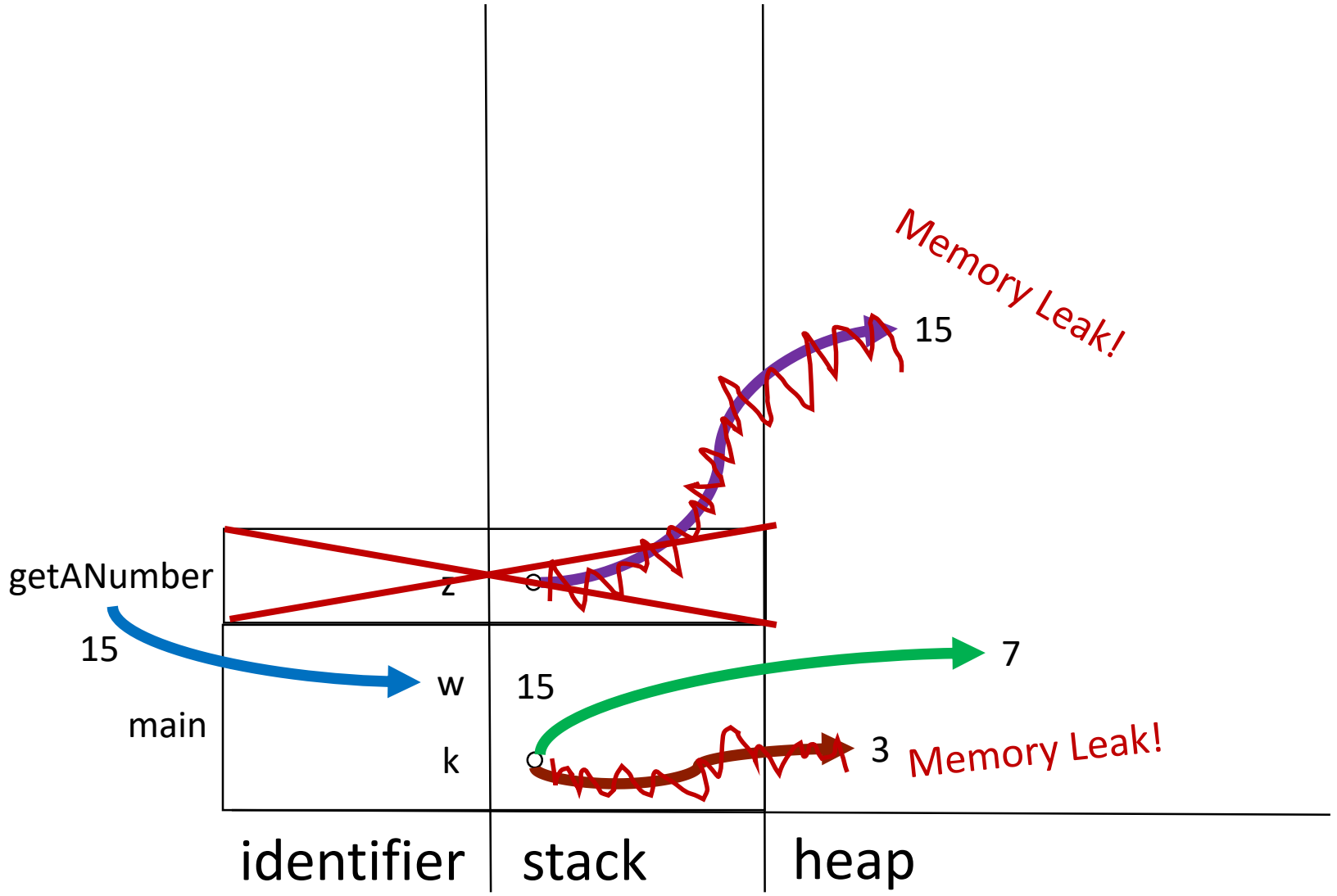

Resizing Arrays

For convenience, let’s put this in a struct

```
struct ResizableArray {
   int size;      // number of actual elements in the array
   int capacity; // the current capacity of the array
   int * data;   // data points to the array containing the data
};
```

We can initialize our resizeable array thus:

```
ResizableArray a;
a.size = 0;
a.capacity = INITIAL_SIZE;
a.data = new int[a.capacity];
```

Now, let's write code to add data to the array:

```
 if(a.size < a.capacity) {
    a.data[a.size] = val;
    a.size++;
}
//    but note that we have to handle the case if the array
//    becomes full
```

What do we do if the array becomes full?

- We have to resize it.
- That means allocate a new array and copy the original into it.

```
int *temp = new int[2 * a.capacity];
// copy the current values into the new array
for(int index = 0; index < a.size; index++)
   temp[index] = a.data[index];
// free the original array
delete [] a.data;
// make a.data point to the new array and update the capacity
a.data = temp;
a.capacity = 2 * a.capacity;
```

resize-array.cpp