Pointers

Topics

- Pointers
- Problem Solving and Testing Strategy

Pointers

- Pointers is not a so hard to understand
- Think of the concept of Pointers before thinking of how to code it
- Pointers enable very sophisticated operations
- First, we need to learn about l and r values.

Lvalues And Rvalues

- C Supports Two Kinds Of Expressions
- Lvalues (L for left side of assignment)
  – expressions which can be evaluated and modified
- Rvalues (R for right side of assignment)
  – expressions which can only be evaluated

Lvalue And Rvalue Examples

- Lvalue Examples:
  - A Variable Name `int a;`
  - An Array Index `array[0]`
- Rvalue Examples:
  - Literal Constants `5.14e4`
  - Arithmetic Expressions `5 * a`

Lvalue And Rvalue Examples

- Lvalue Examples:
  - A Variable Name `int a;`
  - An Array Index `array[0]`
- Rvalue Examples:
  - Literal Constants `5.14e4`
  - Arithmetic Expressions `5 * a`

Can not change (5*a) unless you change a, but you can not use: 5*a = ….

Lvalues

- An lvalue actually refers to a location in memory
  - We conveniently refer it by name

```
int a = 12;
```

Lvalues

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  - We conveniently refer it by name

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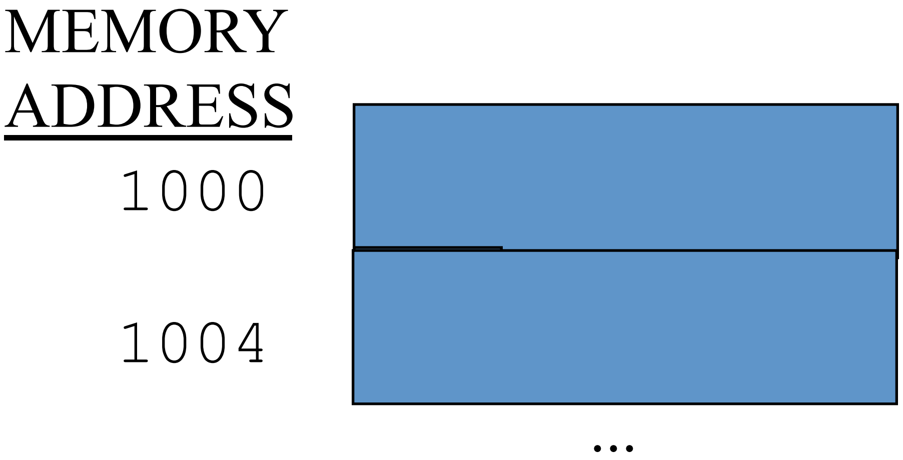
```



MEMORY
ADDRESS

1000

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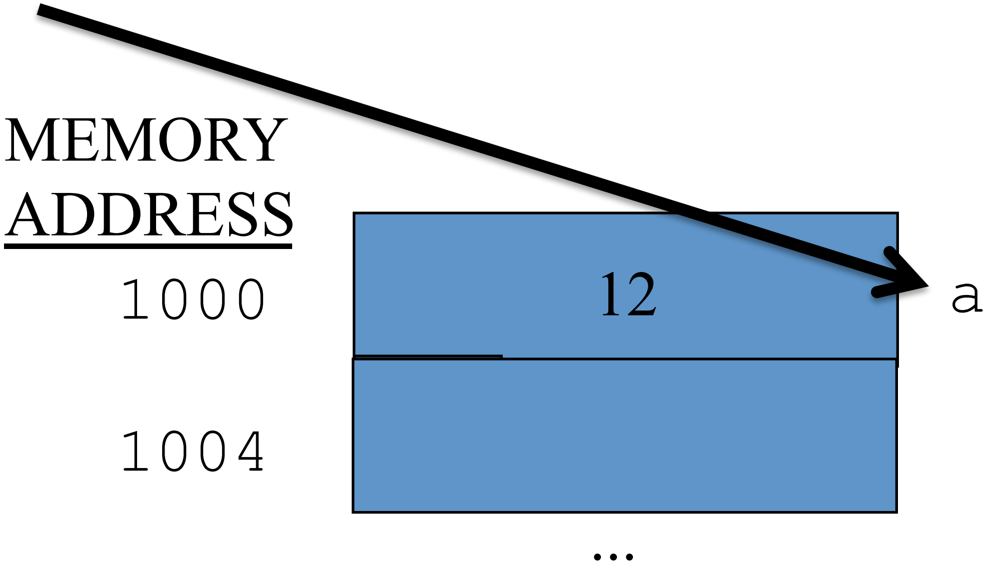
…

Lvalues

- An lvalue actually refers to a location in memory
  - We conveniently refer it by name

```
int a = 12;
```



Pointer Variables

- A pointer is a variable that contains the address of another variable

Pointer Variables

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```
int a = 12;
int* intPtr;
//
//


//
//
```

Pointer Variables

- A pointer is a variable that contains the address of another variable

```
int a = 12;
int* intPtr;
// intPtr is a variable that will
// contain a memory address of an int
// marked by * after int


//
//
```

Pointer Variables

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Pointer Variables

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intPtr = &a;
//intPtr contains the address of var a
```

Pointer Variables

- A pointer is a variable that contains the address of another variable

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int a = 12;
int* intPtr;
// intPtr is a variable that will
// contain a memory address
// marked by * after int
intPtr = &a;
//intPtr contains the address of var a
//a’s address not content because of &
```

Pointer Variables

- A pointer is a variable that contains the address of another variable

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int a = 12;
int* intPtr;
// intPtr is a variable that will
// contain a memory address
// marked by * after int
intPtr = &a;
//intPtr contains the address of a
// address not content because of &
```

Pointer Variables

- A pointer is a variable that contains the address of another variable

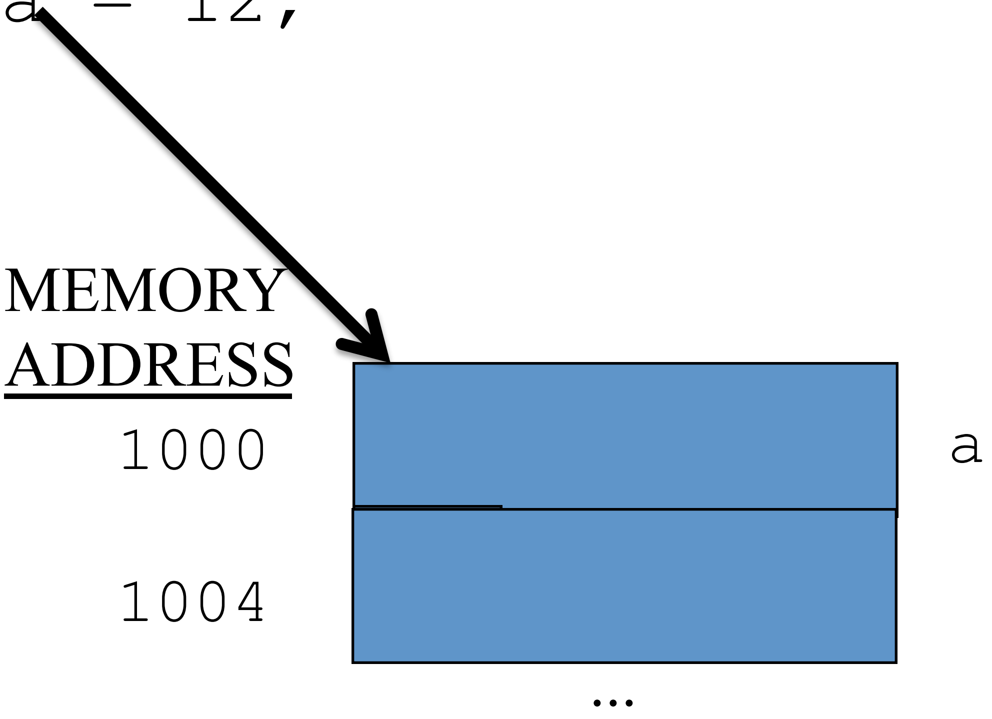
```
int a = 12;
// means a in RAM should contain 12
//
```

…

Pointer Variables

- A pointer is a variable that contains the address of another variable

```
int a = 12;
//
//
```

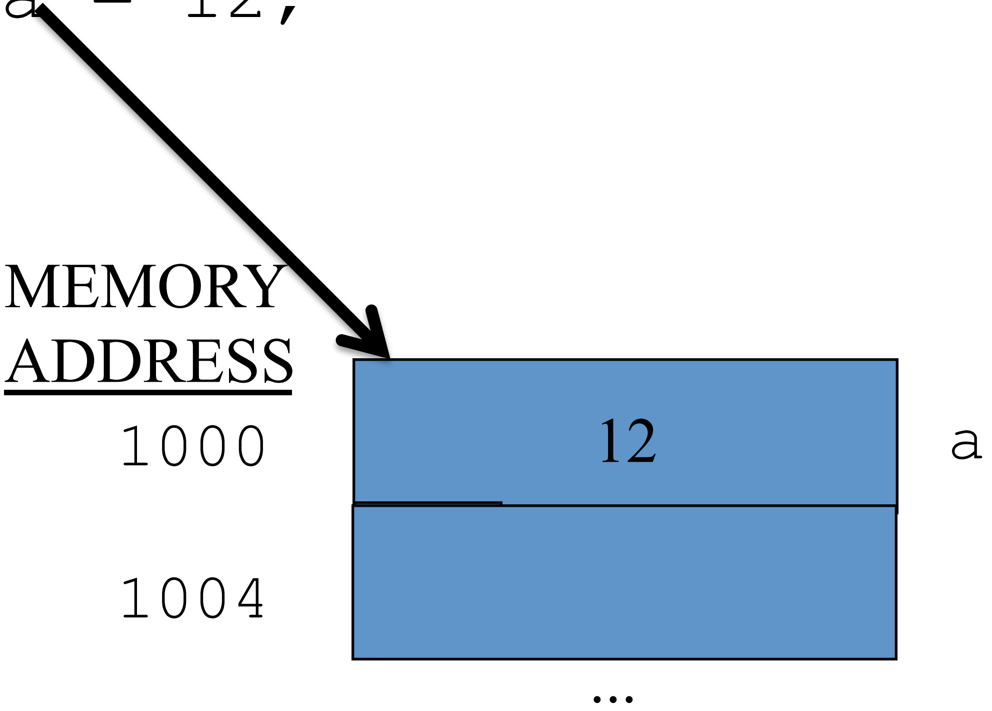


MEMORY ADDRESS

Pointer Variables

- A pointer is a variable that contains the address of another variable

```
int a = 12;
//
//
```



Pointer Variables

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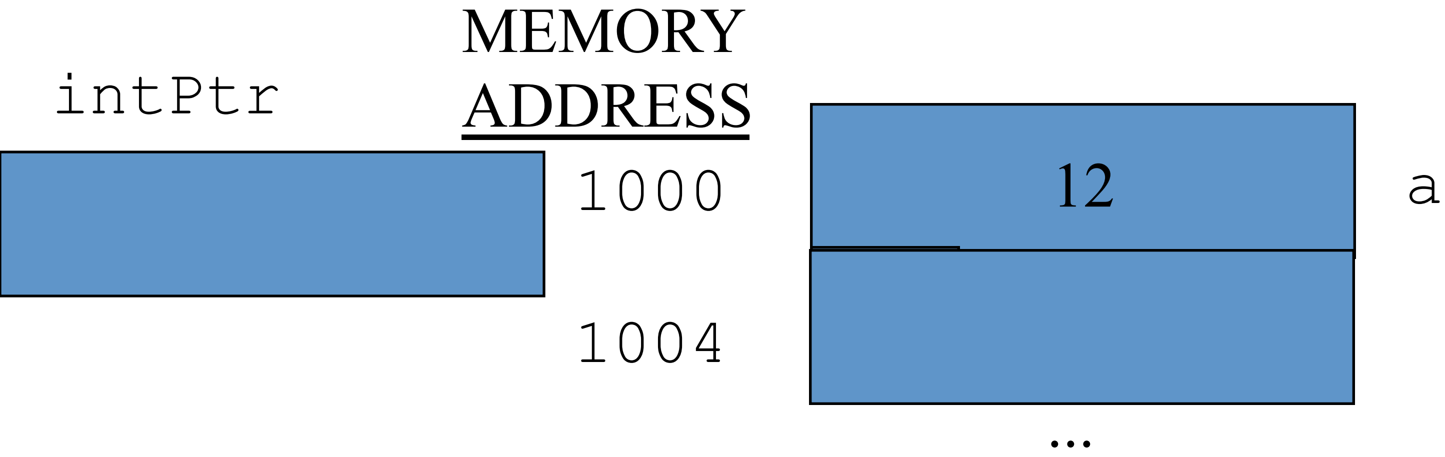
int* intPtr;
intPtr = &a;
```



intPtr

MEMORY ADDRESS

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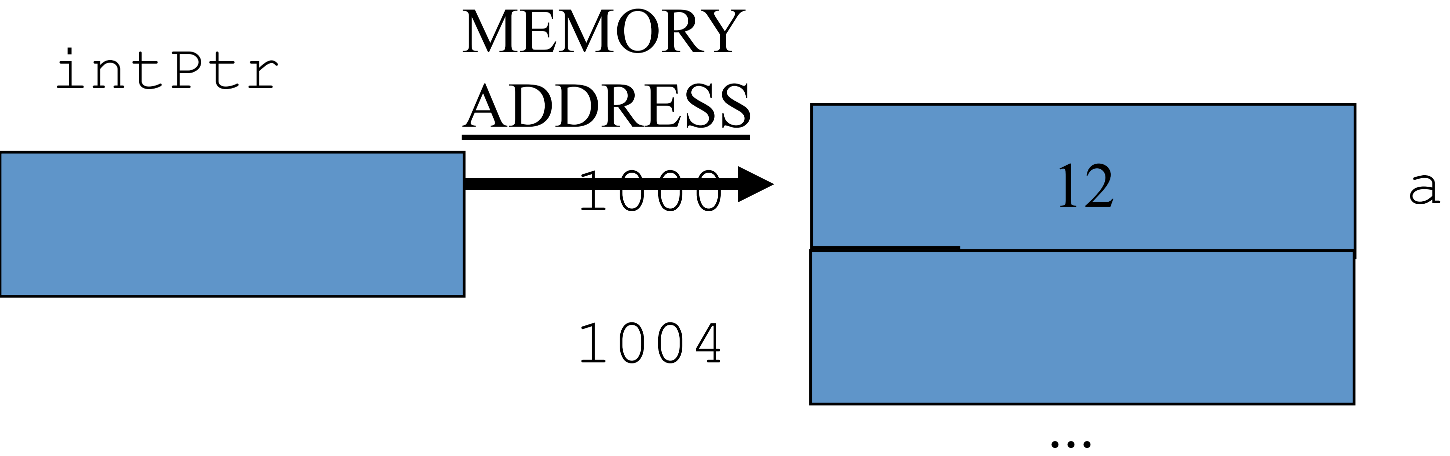
Pointer Variables

- A pointer is a variable that contains the address of another variable

```
int a = 12;
int* intPtr;
intPtr = &a;
```



Pointer Variables

- Like any kind of variable, pointers must be declared: `typename* varname;`
- Once declared, you can change the address the pointer contains by assigning it using the address of operator &
- To change the content of the address the pointer contains you use the *

Pointer Variables

- Declare: `int* intP;`
- Assign the address of another variable to intP:
  `intP = &x;` //x must be same type
- To change the content of x:
  *intP = 5 //x now contains 5

Pointer Variables

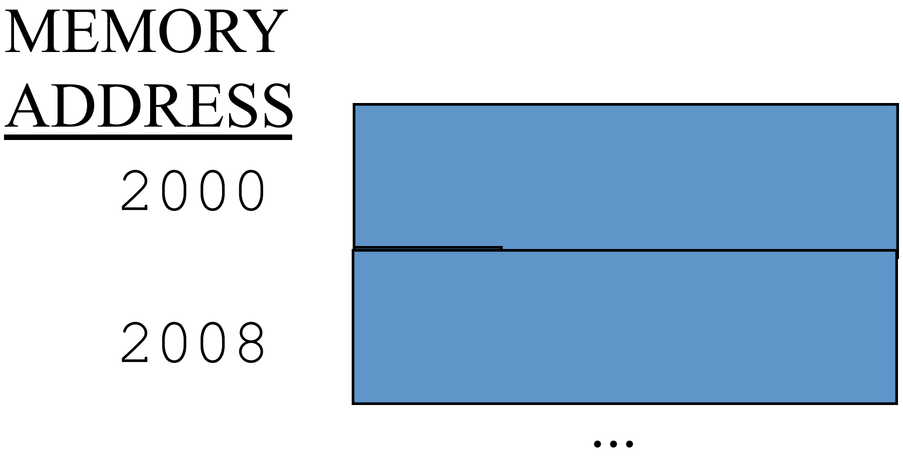
- Like Any Kind Of Variable, Pointers Must Be Declared: *`typename* varName;`*

```
double d = 13.1;
double* dPtr; // to declare
dPtr = &d;    // to assign
```

Pointer Variables

- Like Any Kind Of Variable, Pointers Must Be Declared: *`typename* varName;`*

```
double d = 13.1;
double* dPtr;
dPtr = &d;
```



MEMORY
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Pointer Variables

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double d = 13.1;
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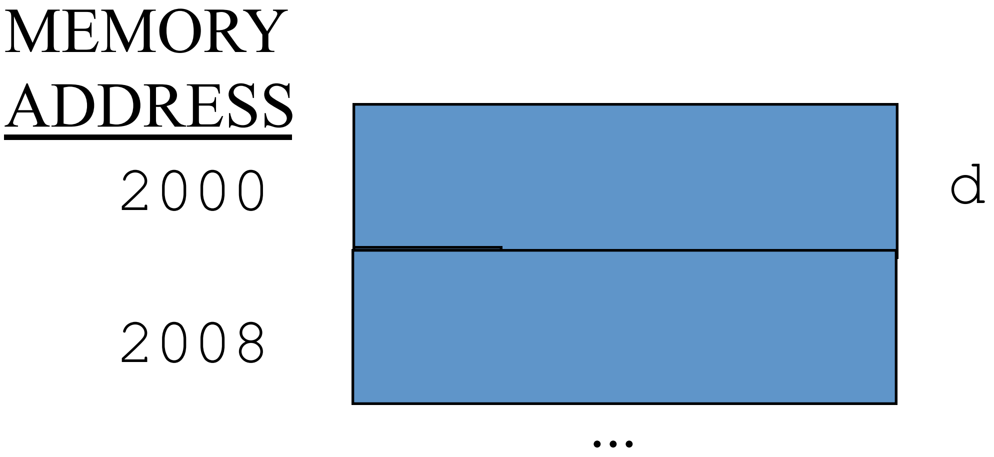

MEMORY

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d

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Pointer Variables

- Like Any Kind Of Variable, Pointers Must Be Declared: *`typename* varName;`*

```
double d = 13.1;
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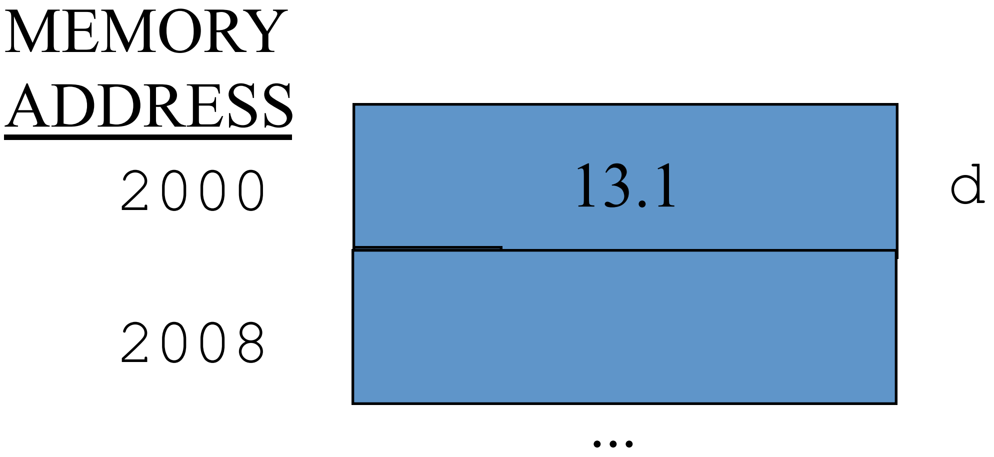

MEMORY ADDRESS

2000 13.1 d

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…

Pointer Variables

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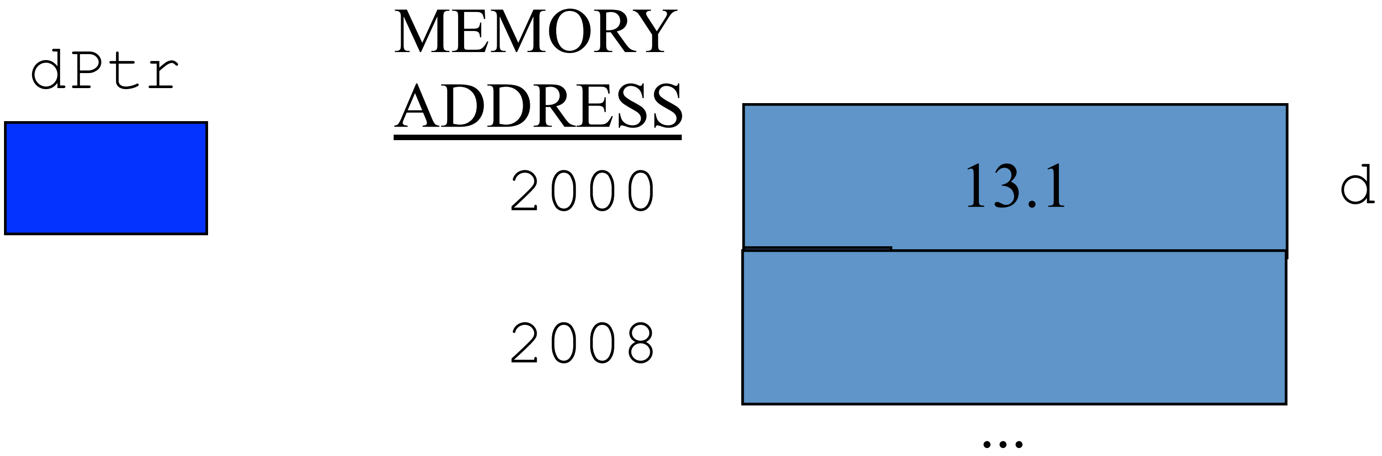

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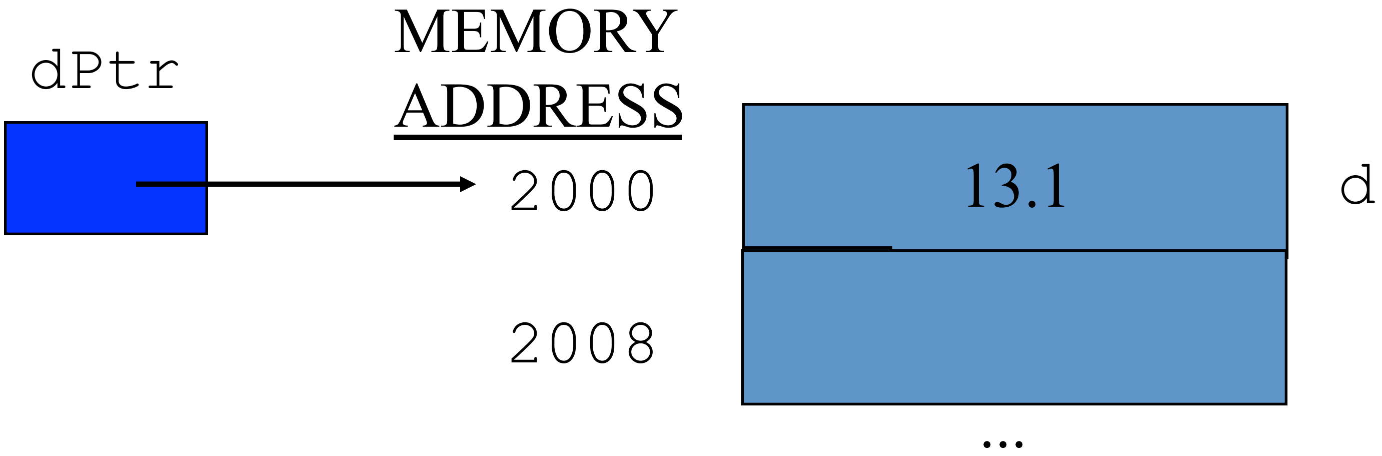

Pointer Variables

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double d = 13.1;
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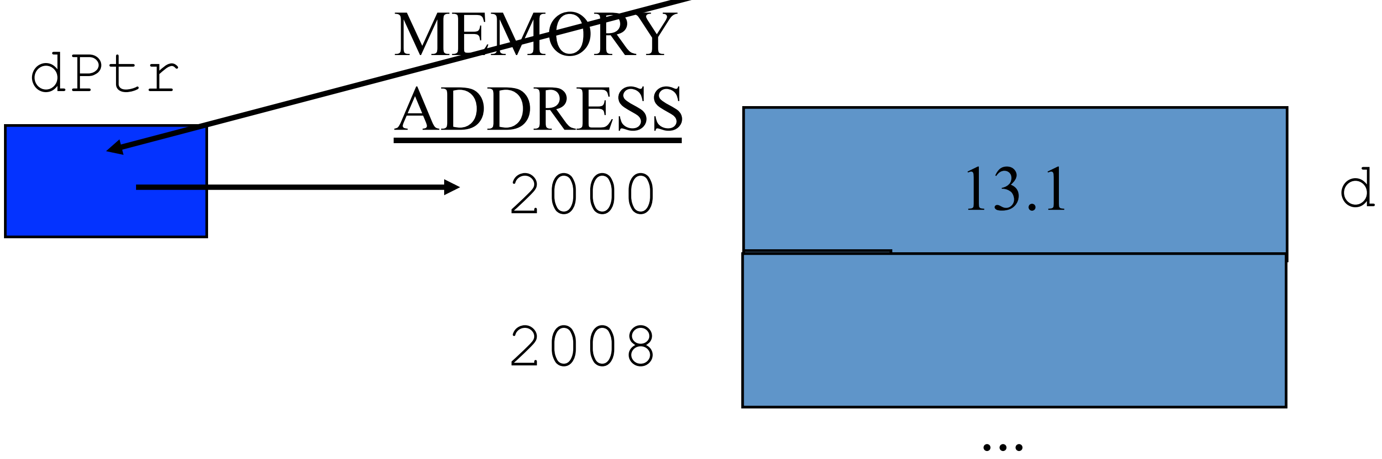
The Pointer Is An Address We Can Change



dPtr

MEMORY ADDRESS

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13.1

d

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...

Pointer Variables

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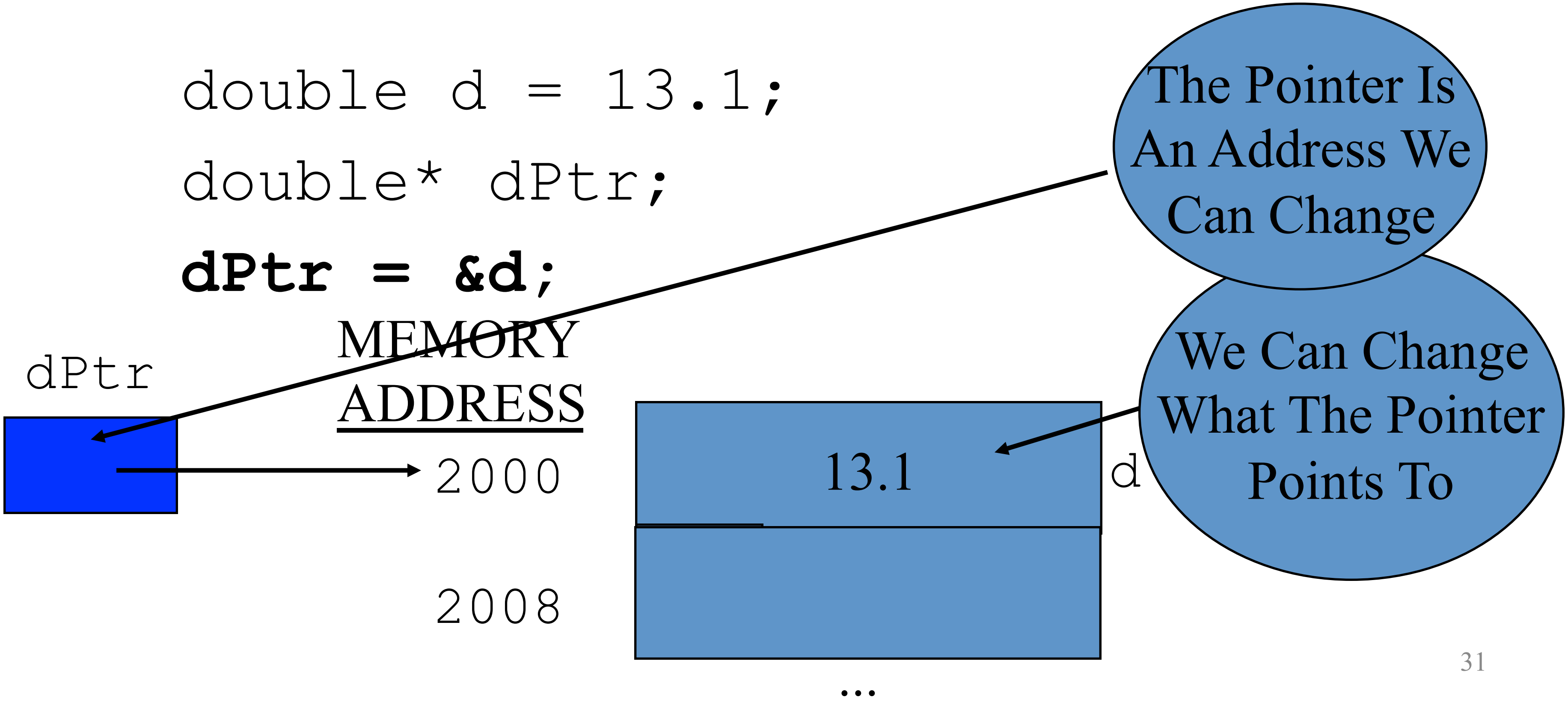


The Pointer Is An Address We Can Change

We Can Change What The Pointer Points To

Pointer Variables

- Once declared, a pointer points to variables of the same pointer’s declared type

  For example:

```
double d = 13.1; // d is double
double* dPtr; // dPtr to a double
```

- After all the pointer “points to” a RAM address that contains a value, which must be of some type

Pointer Variables

- Once declared, a pointer points to variables of the same pointer’s declared
- For example:

```
double d = 13.1; // d is double
double* dPtr; // dPtr to a double
dPtr = &d; // dPtr points to d
```

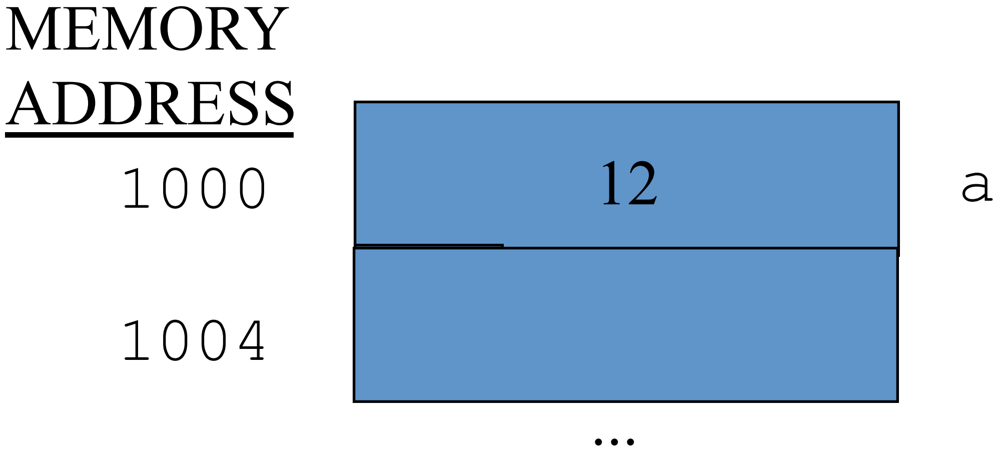
Pointer Variables

- The variable the pointer points to is called its' ***referent***
  - *In the previous example, d is the referent*
- The content of the pointer is another RAM address
- That RAM address may contain a value that can be changed just like we did before, using assignment statements

Pointer Dereferencing

- The Thing A Pointer Points To Can Be Manipulated By The Pointer Variable

```
int a = 12;
int* intPtr;
intPtr = &a;
*intPtr = 5;
```



Pointer Dereferencing

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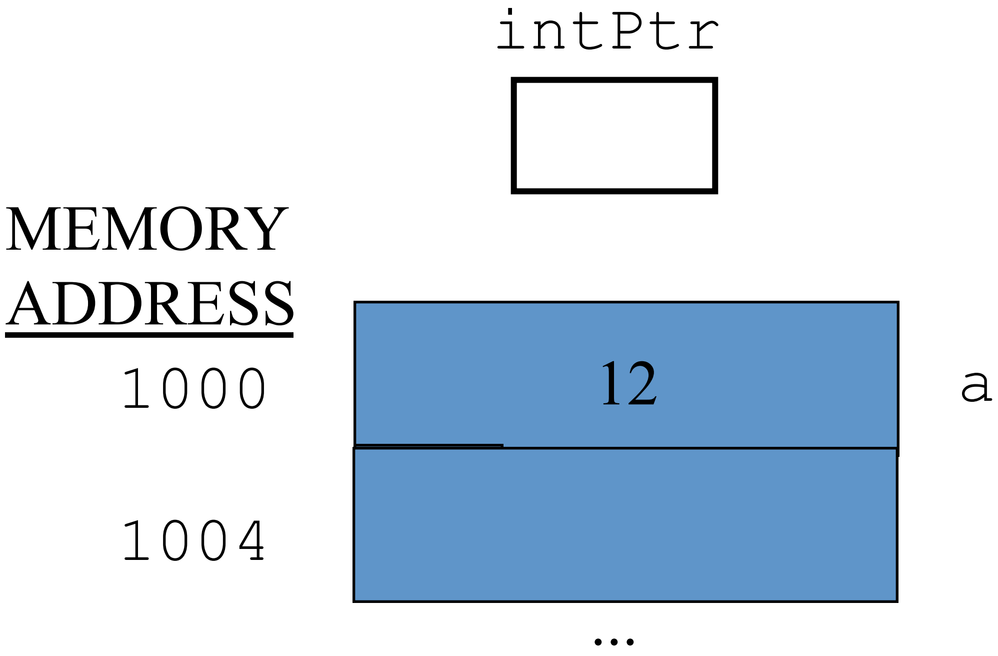

Pointer Dereferencing

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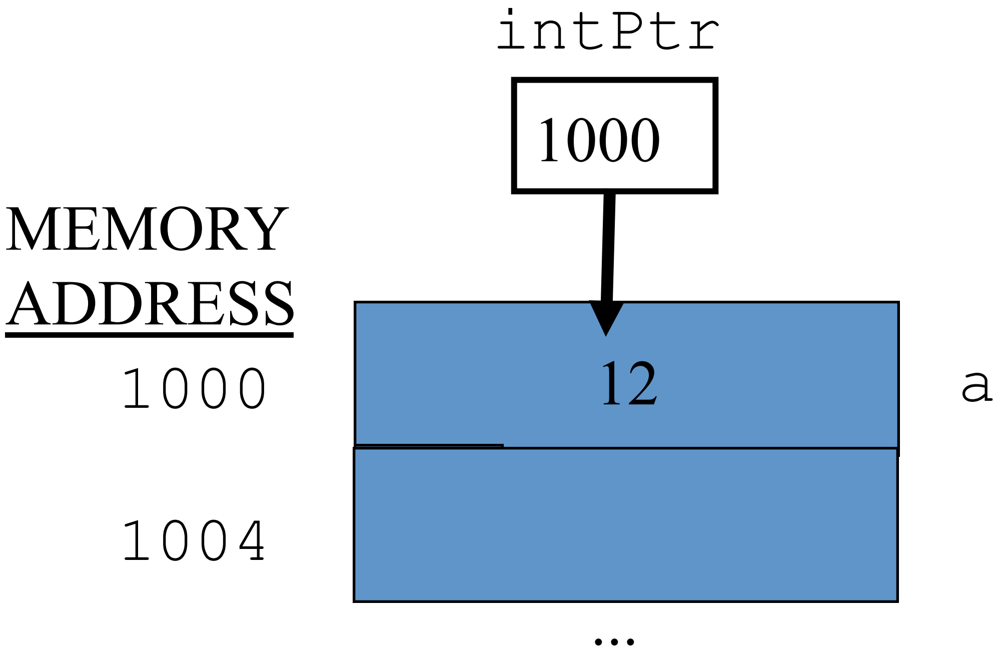

Pointer Dereferencing

- The Thing A Pointer Points To Can Be Manipulated By The Pointer Variable

```
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int* intPtr;
intPtr = &a;
*intPtr = 5;
```
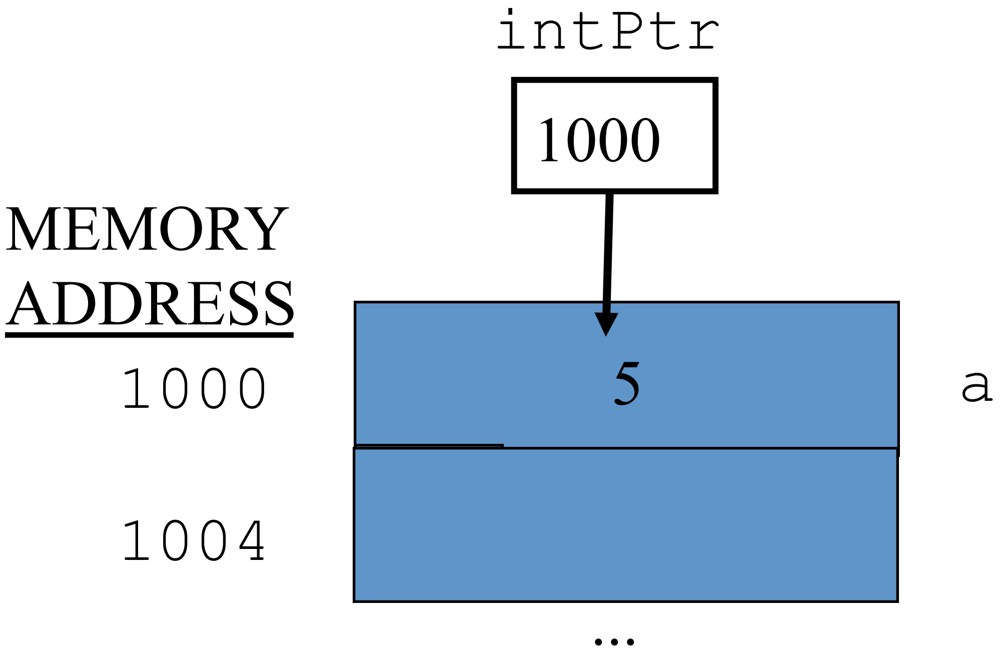
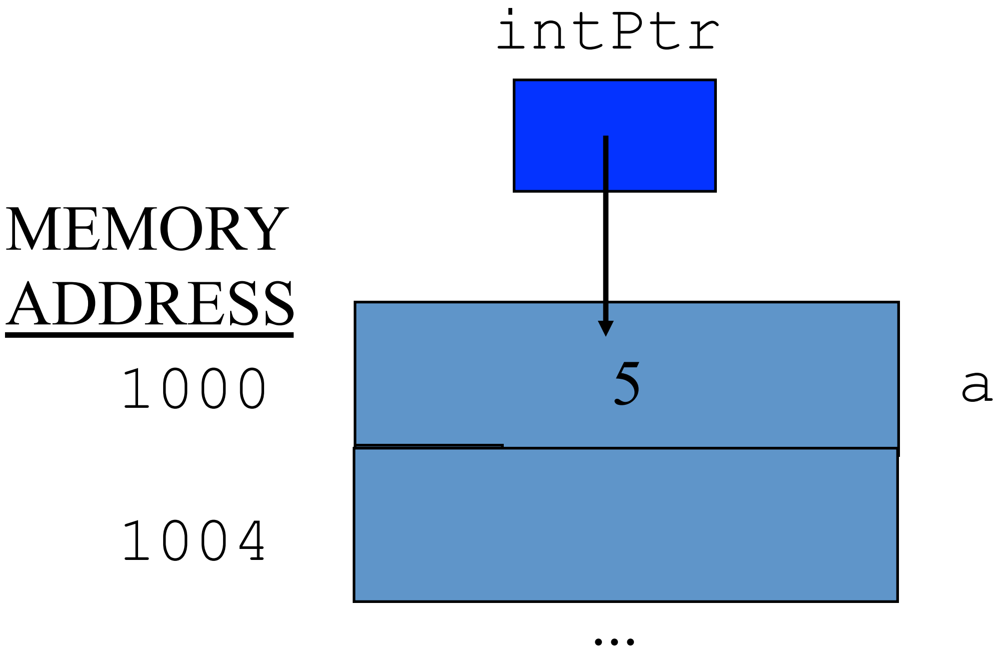



Pointer Dereferencing or Indirection

- The change the RAM content the pointer is pointing to, use an assignment statement, but add *
- * goes before the pointer variable.
- * is the dereference or indirection operator
  - It traverses the pointer to access what is being pointed to

Pointer Dereferencing

```
int a = 12;
int* intPtr;
intPtr = &a;
*intPtr = 5;
```



MEMORY ADDRESS

intPtr

1000

5

a

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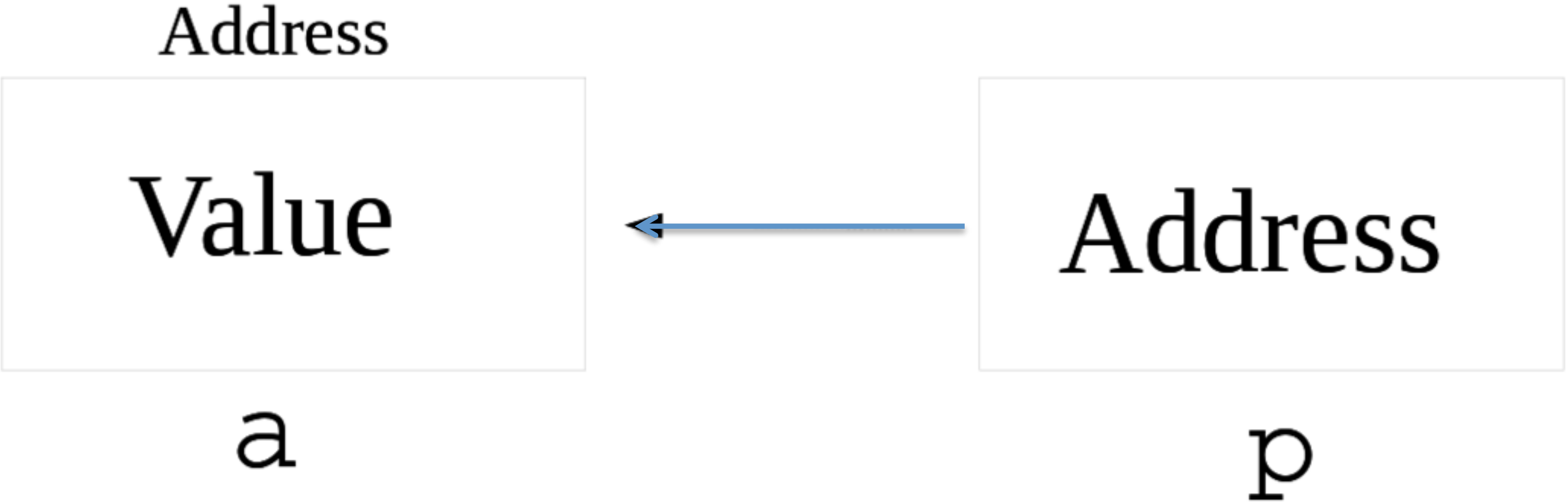
...

Stop Here – Read the Book

- Read section 25, 25.1, 25.2 (ignore structures)
- Carefully read 25.3 then stop.
- Image in 25.3 has a faint arrow:



Now Practice

- The code:

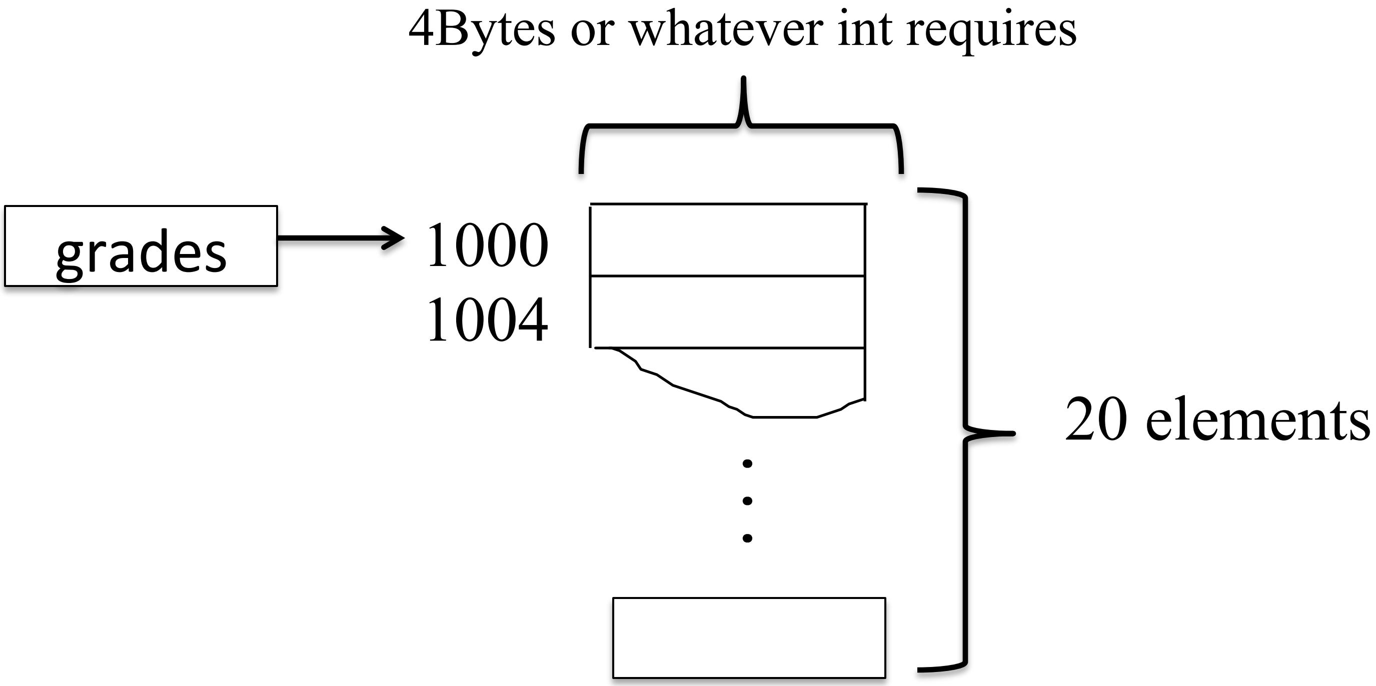
```
int x = 12;
  //use printf to print content of x
 int* intPtr;
 intPtr = &x;
 *intPtr = 5;
 //use printf to print content of x
```

Pointers and Arrays

- It sounds funny to differentiate a pointer from an array
- An array is a pointer!

Pointers and Arrays

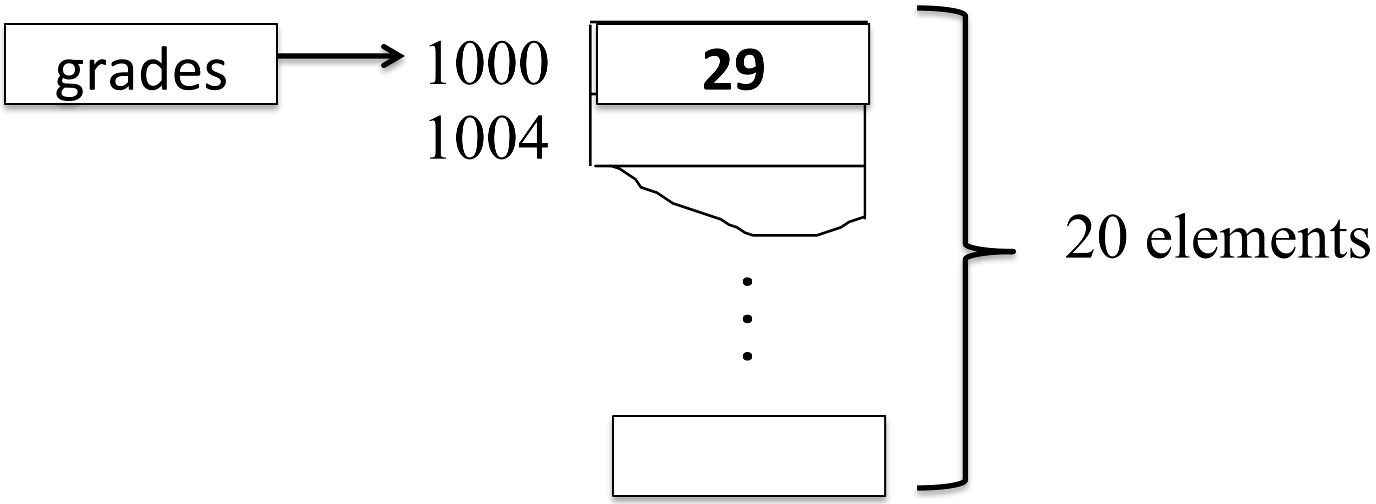
int grades[20]; //grades is a pointer to some RAM location



Pointers and Arrays

```
int grades[20];
```

grades[0]=29;

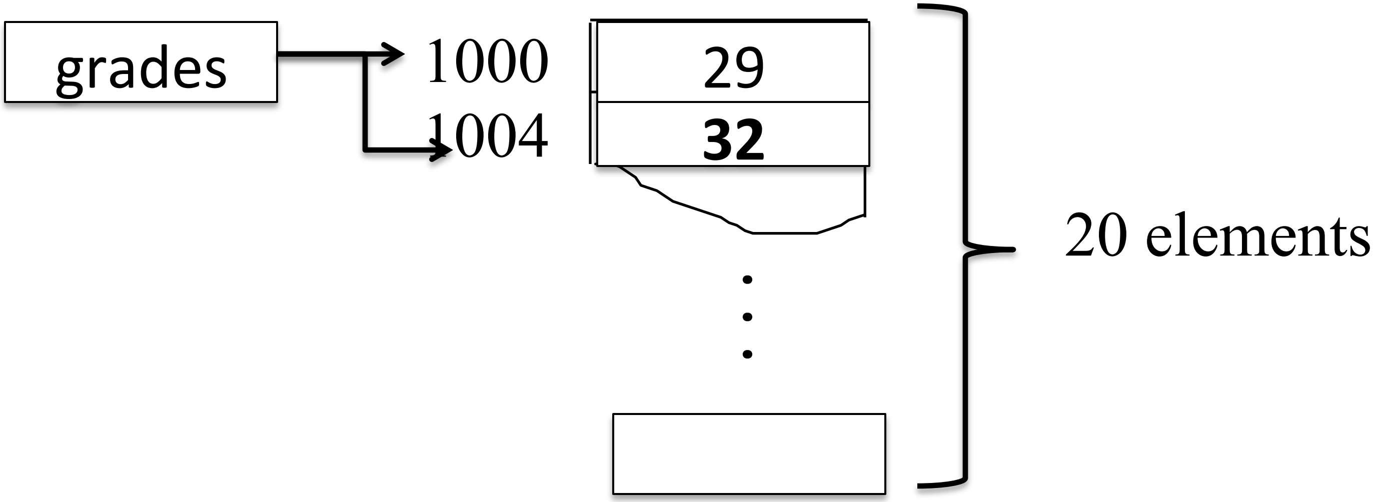


Pointers and Arrays

```
int grades[20];
grades[0]=29;
```

grades[1]=32; //note the arrow moved to next location

grades[n] works by starting from address 1000, then adding n locations. Again, grades always points to [0].



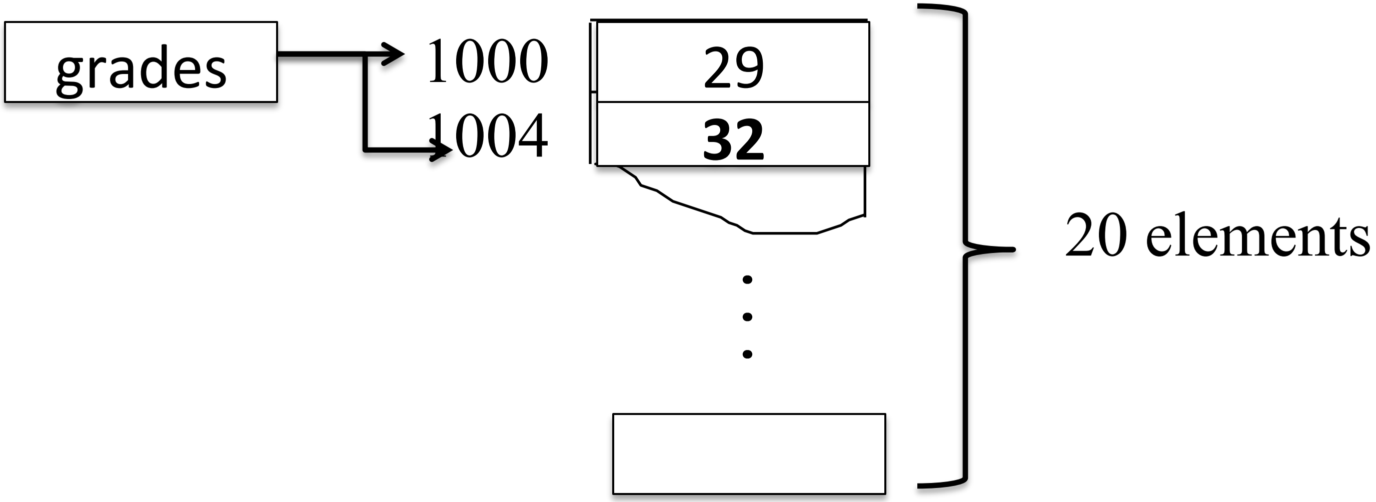
Pointers and Arrays

int grades[20];

grades[0]=29;

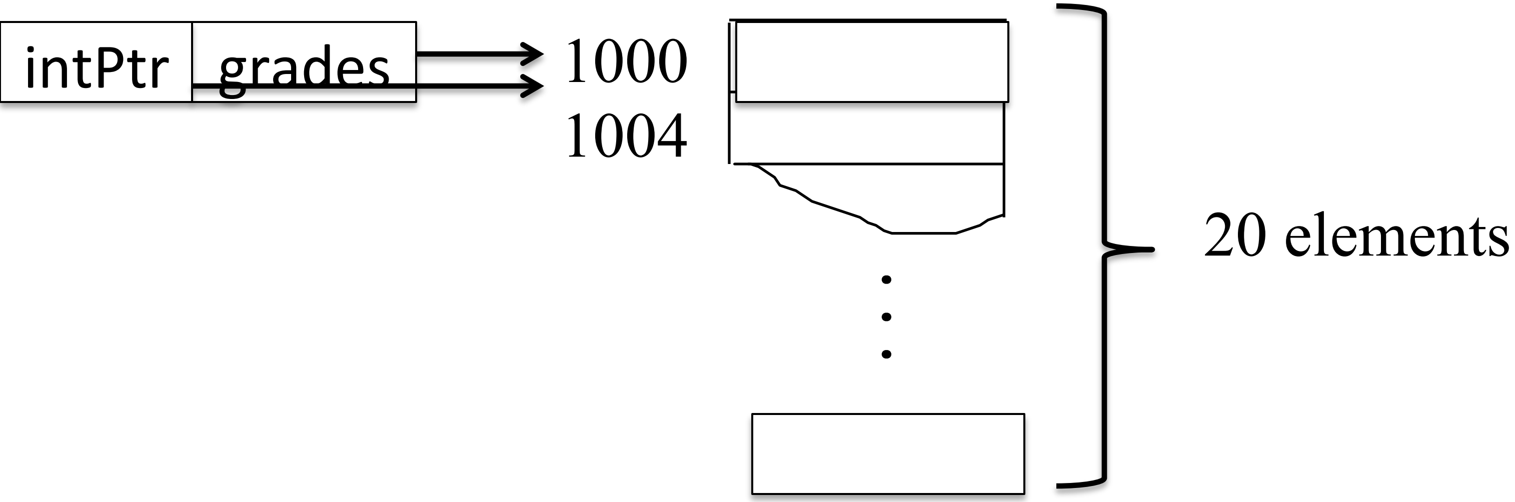
grades[1]=32; //note the arrow moved to next location

Another way to view grades[n] is: *(grades+n)
But we find grades[n] to be easier to use



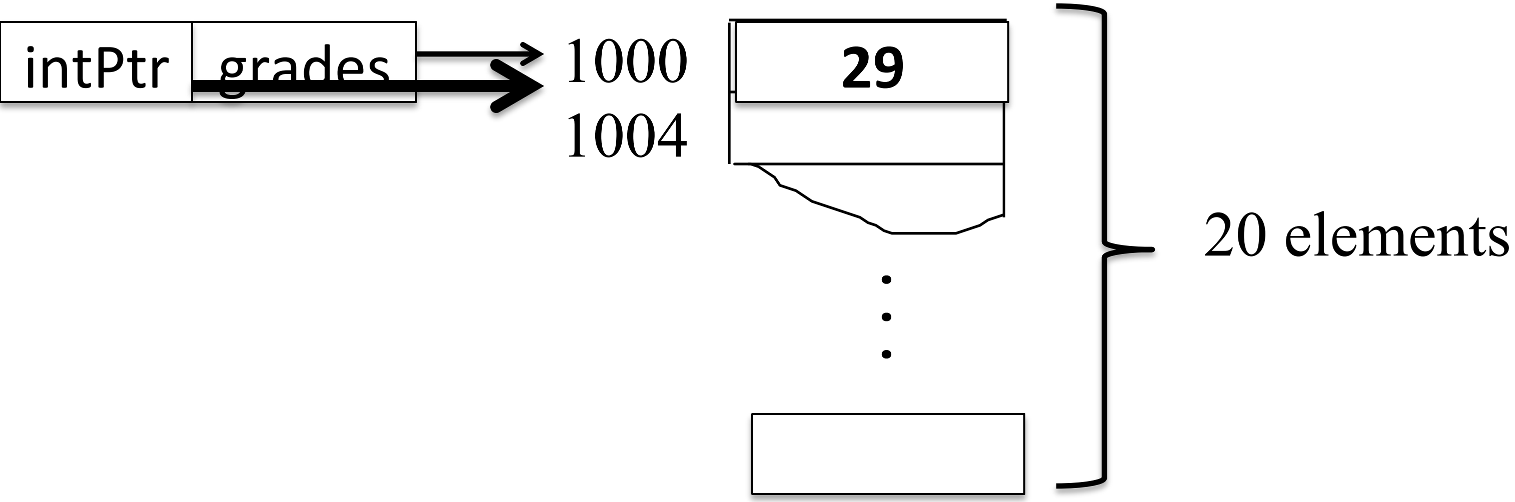
Pointers and Arrays

```
int grades[20];
int* intPtr;
intPtr = &grades;
```



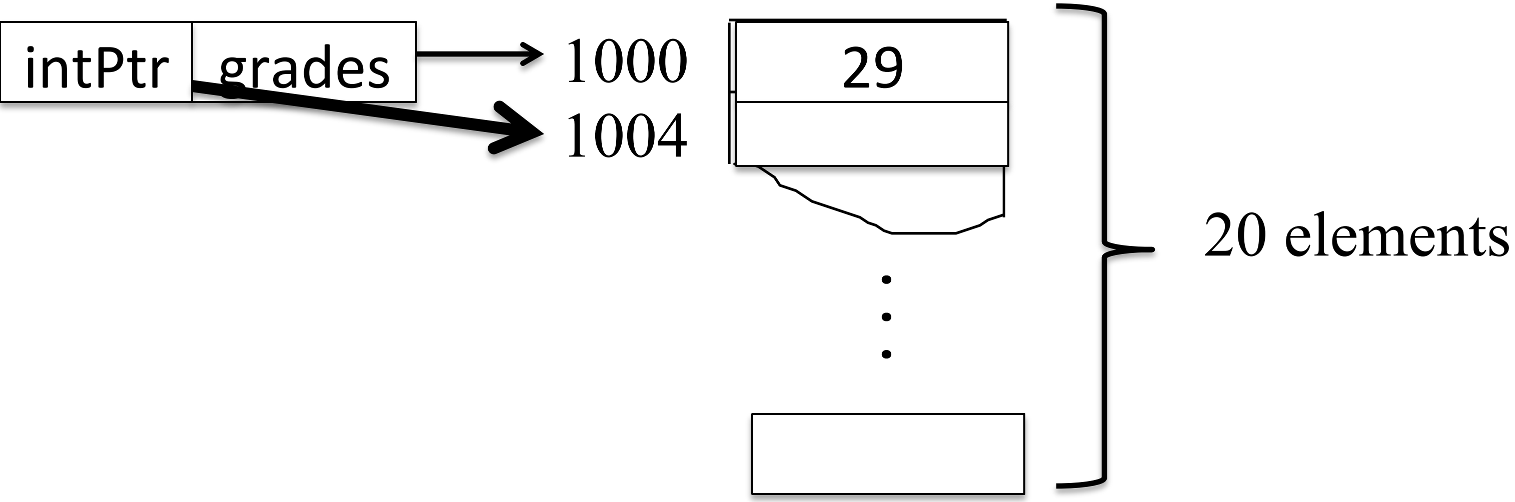
Pointers and Arrays

```
int grades[20];
int* intPtr;
intPtr = &grades;
```
***intPtr = 29;**



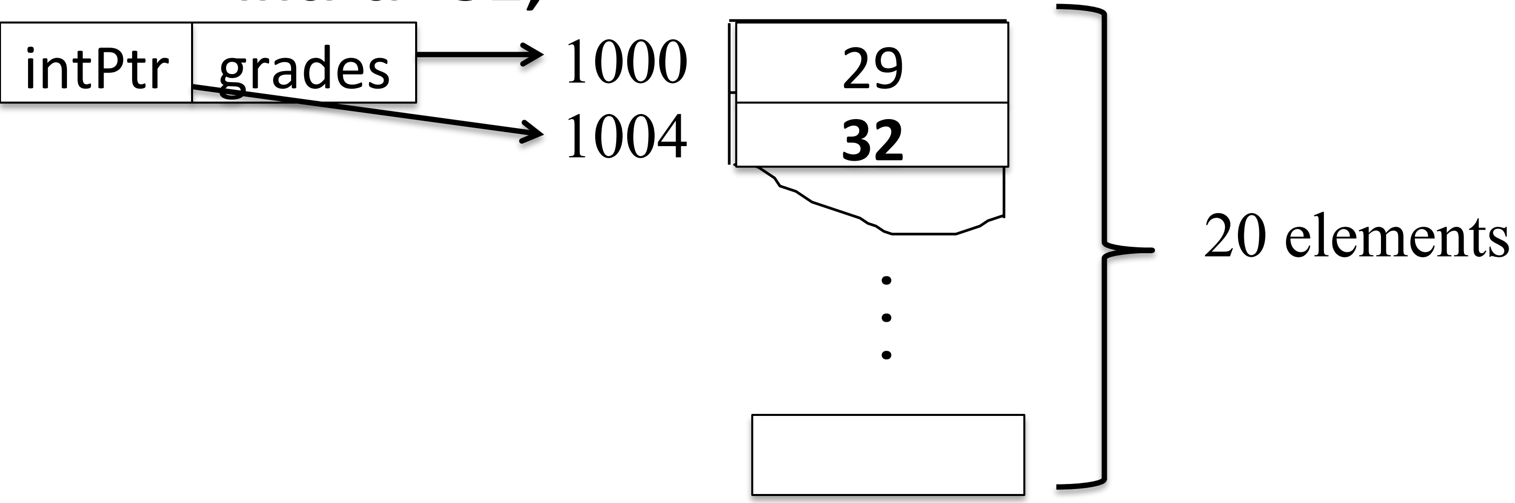
Pointers and Arrays

```
int grades[20];
int* intPtr;
intPtr = &grades;
*intPtr = 29;
```
intPtr++;



Pointers and Arrays

```
int grades[20];
int* intPtr;
intPtr = &grades;
*intPtr = 29;
intPtr++;
*intPtr=32;
```



Pointers and Arrays

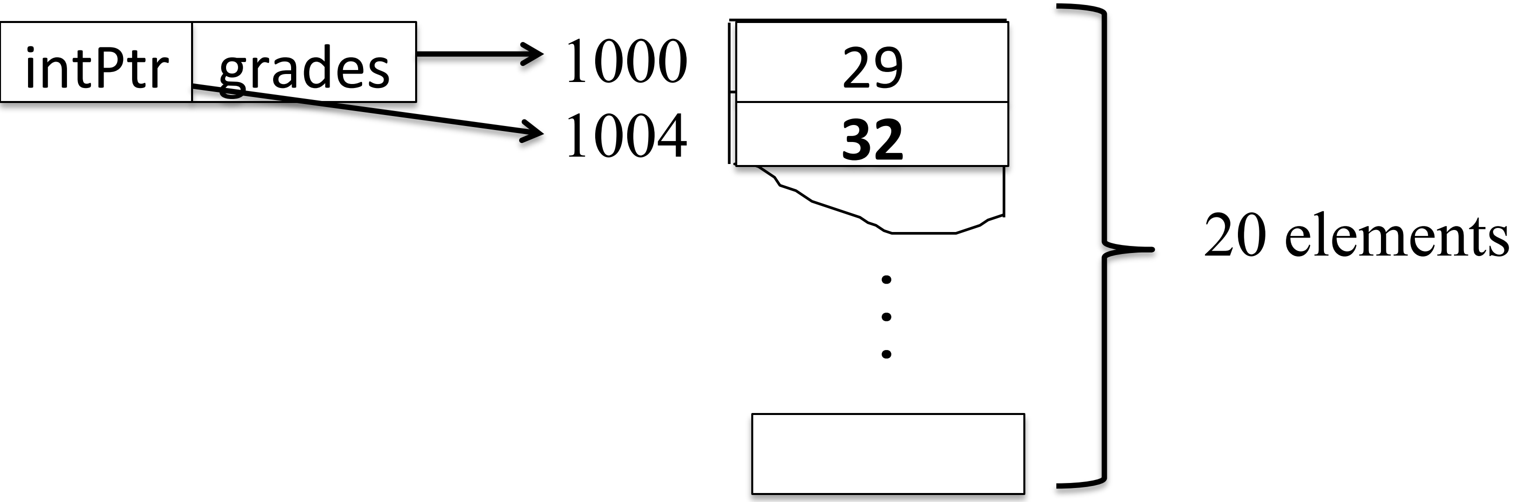
int grades[20];

int* intPtr;

intPtr = &grades;

*intPtr = 29;

*(intPtr**+1**)=32; **//You can also do this instead**



So far

- Declare the pointer as a type
- The pointer can only point to other variables of its same type
- You can assign using the address of
- You can change the content the pointer points to using *

Additionally

- Declare the pointer as a type
- The pointer can only point to other variables of its same type
- You can assign using the address of
- You can change the content the pointer points to using *
- **To change the content of the pointer (where it is point to), use regular assignment and math** (e.g. pointing to arrays)

More on Pointers - FYI

- Dynamic Arrays − filled with fun and danger!
- Covered in CS 52 (C++)
- Mostly done to manage RAM − hence most O.S. are written in C or C++
- involves malloc, free, and sizeof functions

Parameter Passing

- So far, our functions cannot alter their parameters
  - Referred to as “pass-by-value”
  - These functions can only provide a single output value
- However, there is another kind of parameter passing scheme that involves pointer variables
  - Referred to as “pass-by-reference”

Parameter Passing

- Passing by reference means that the argument address in RAM is passed into the parameter.
- Recall that passing by value, which we used all along, means that the argument content (literal) is copied into the parameter.

Parameter Passing

- Reference parameters are not copies of the argument, but “point to the same thing” the argument contains in RAM.
- Hence, a reference parameter is the argument itself
- Parameter must be a variable
- Specified when the prototype uses the syntax:

  ```
  type *
  ```
- Caller needs to send the data by saying:

  ```
     & variable
  ```
- Code will clarify in the next slides

Parameter Passing

- Anytime you want a function to change the caller's variable, you need to use pointers and pass-by-reference in C
- We've already seen this with `scanf(…)`
- After you type input, scanf assigns the RAM location of the &variable to the input

Parameter Passing

- Anytime you want a function to change the caller's variable, you need to use pointers and pass-by-reference in C
- We' ve already seen this with `scanf(…)`

```
int i;
scanf( &i );
```

Parameter Passing

- We had to say `&i` because we want `scanf( … )` to change our value of `i`.
  - This requires pass-by-reference
- The `&i` creates a pointer to an `int`
- Officially, `&` is the "address operator" and gets its memory location
  - A pointer variable holds the address of another variable (an l-value)

Parameter Passing

- Reference Parameter Example:

```
void swap(int * x, int * y) {
  int temp = *x;
//temp contains whatever x points to
 *x = *y; //x and y point to same thing
  *y = temp; //so x will change?
  }
```

- Legal Invocation???

```
int i=0, j=20;
swap( &i, &j );
 //print i and j here, did they change?
```

Parameter Passing

- Reference Parameter Example:

```
void swap(int * x, int * y) {
  int temp = *x;
  *x = *y;
  *y = temp;
}
```

- Legal Invocation??? Why?

```
int i=0, j=20;
swap( i, j++ );
```

Parameter Passing

- Reference Parameter Example:

```
void swap(int * x, int * y) {
   int temp = *x;
   *x = *y;
   *y = temp;
}
```

- Legal Invocation??? Why?

```
int i=0, j=20;
swap( &7-10, &i/j );
```

Function Call And Return

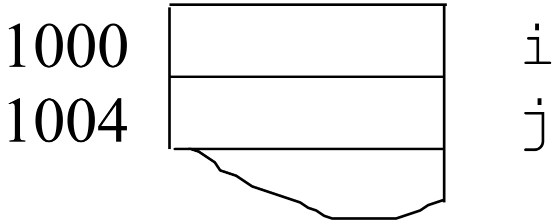
```
void swap( int *x, int *y);
main( )
```

```
int i = 0, j = 20;

swap( &i, &j );

return 0;
```

```
void swap( int* x,
           int* y)
```

```
int *temp = *x;
*x = *y;
*y = *temp;
```

Memory Model



Function Call And Return

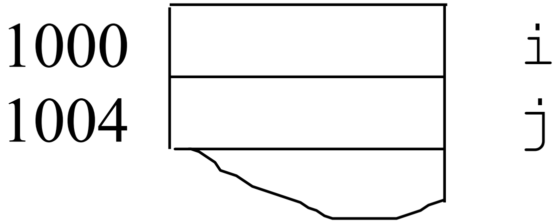
```
  void swap( int *x, int *y);
→ main( )
```

```
int i = 0, j = 20;

swap( &i, &j );

return 0;
```

```
void swap( int* x,
           int* y)
```

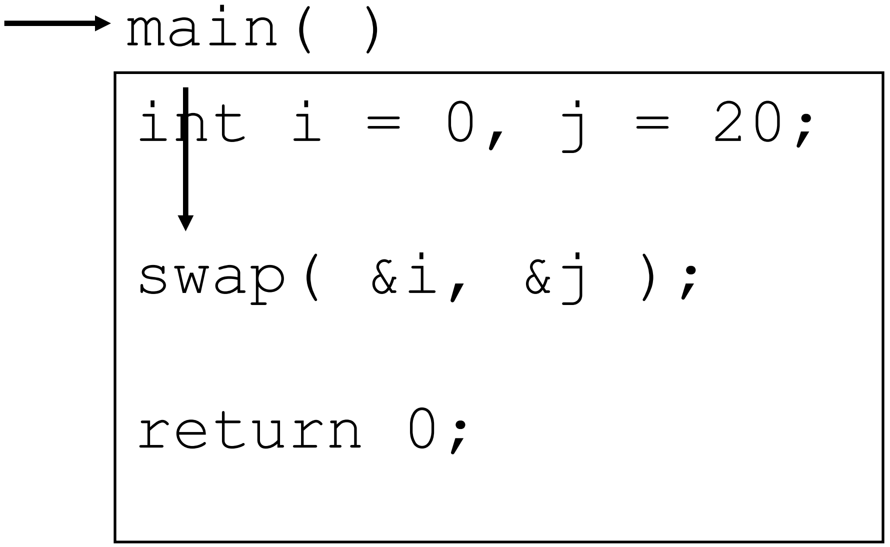
```
int *temp = *x;
*x = *y;
*y = *temp;
```

Memory Model



Function Call And Return

```
void swap( int *x, int *y);
```



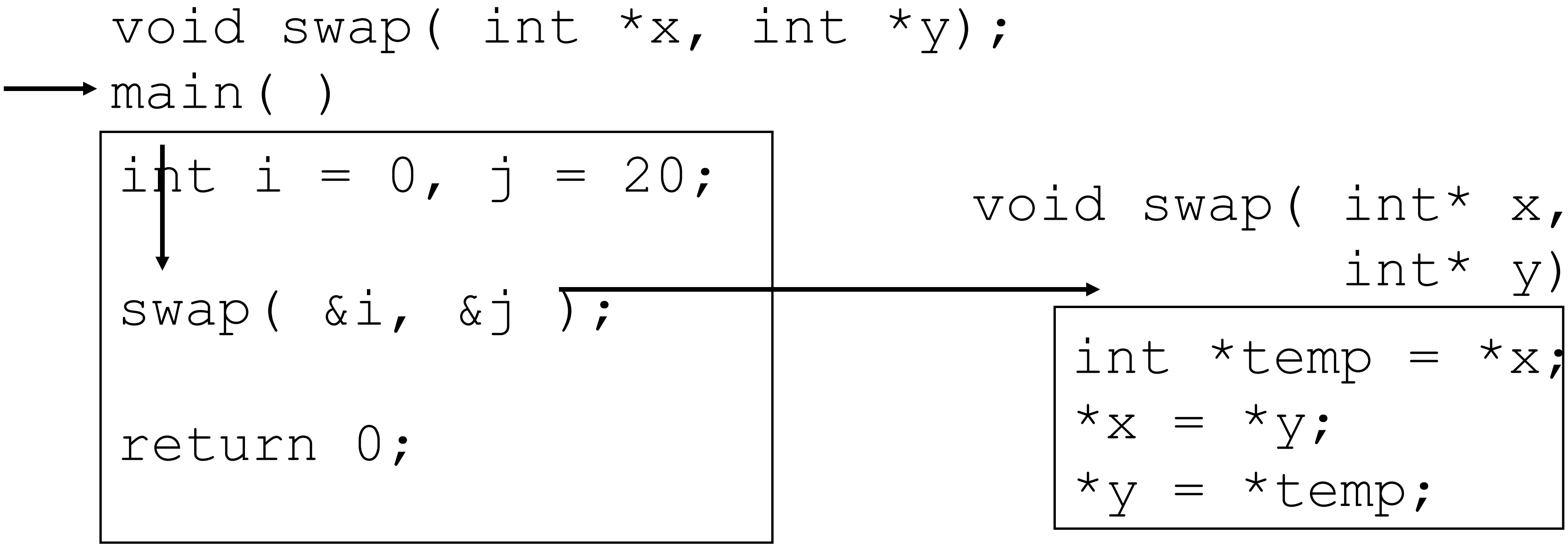
```
main( )
int i = 0, j = 20;

swap( &i, &j );

return 0;
```

```
void swap( int* x,
           int* y)
int *temp = *x;
*x = *y;
*y = *temp;
```

Memory Model

1000	0	i
1004	20	j

Function Call And Return



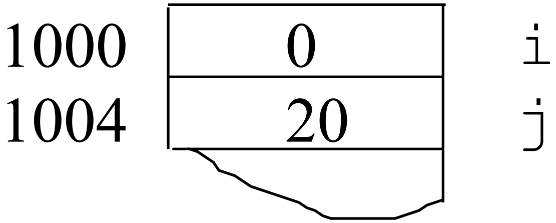
```
void swap( int *x, int *y);
main( )
```

```
int i = 0, j = 20;

swap( &i, &j );

return 0;
```

```
void swap( int* x,
           int* y)
```

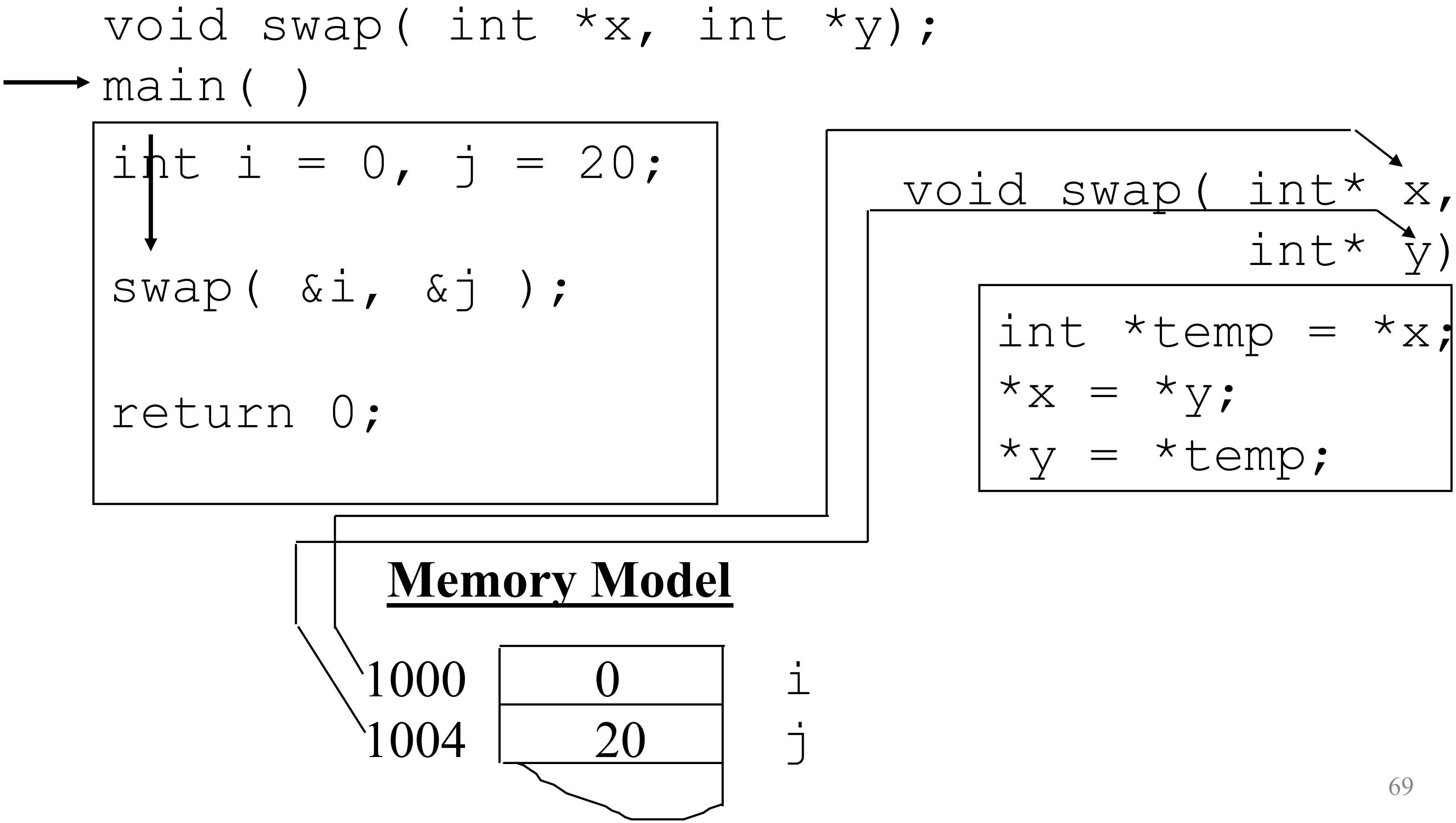
```
int *temp = *x;
*x = *y;
*y = *temp;
```

Memory Model



1000	0	i
1004	20	j

Function Call And Return



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void swap( int *x, int *y);
main( )
int i = 0, j = 20;

swap( &i, &j );

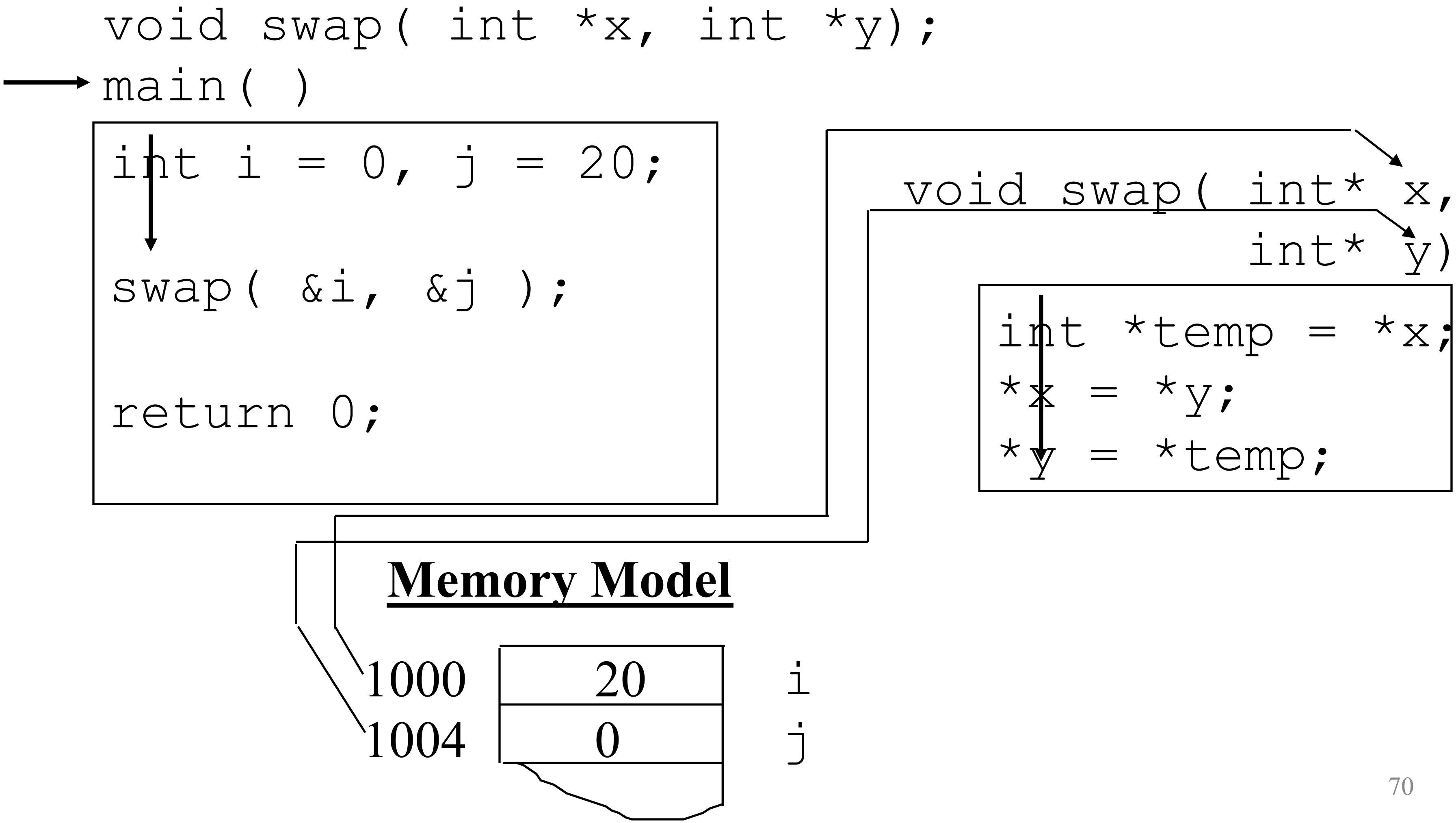
return 0;
```

```
void swap( int* x,
           int* y)
int *temp = *x;
*x = *y;
*y = *temp;
```

Memory Model

1000	0	i
1004	20	j

Function Call And Return



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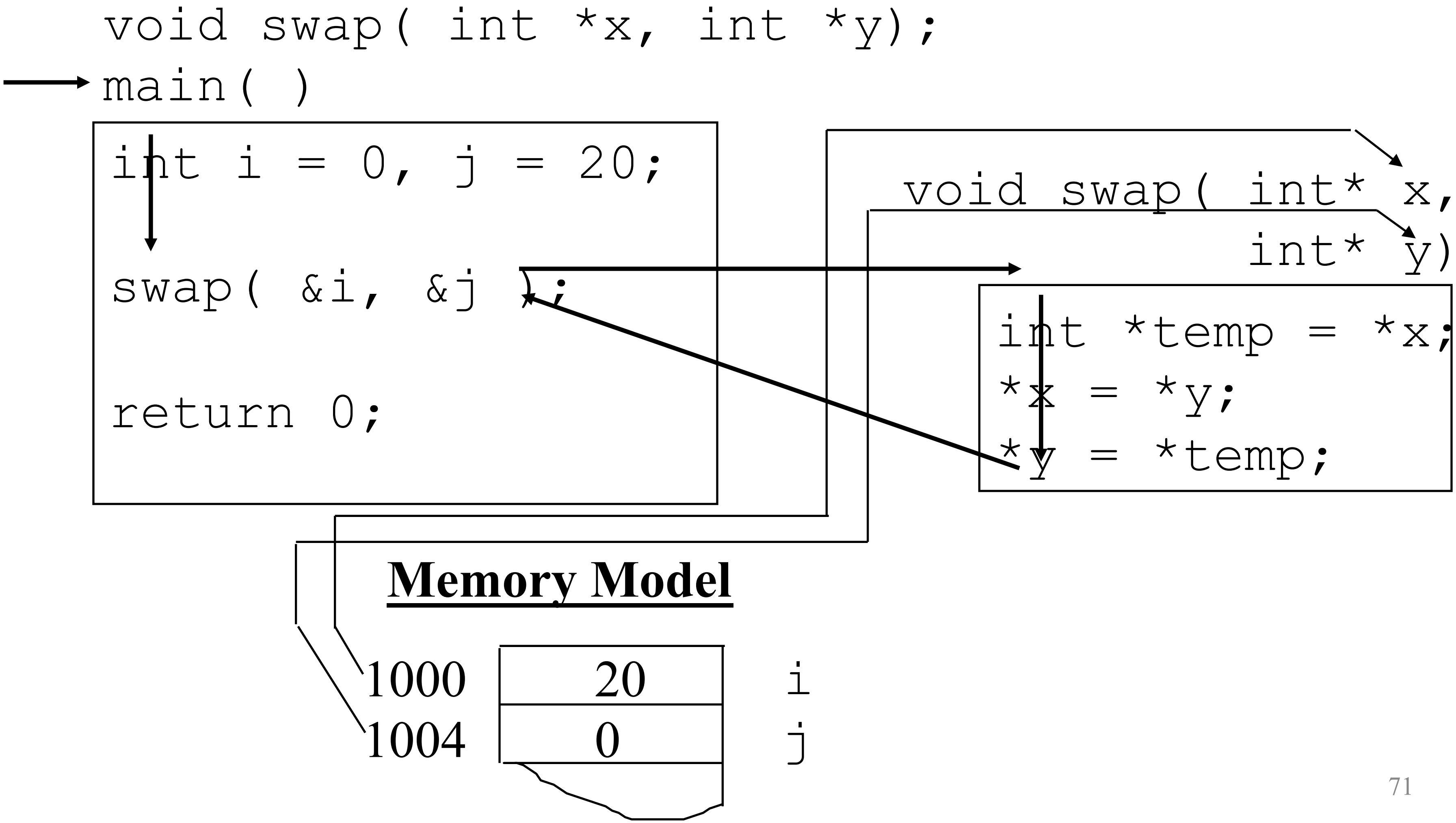

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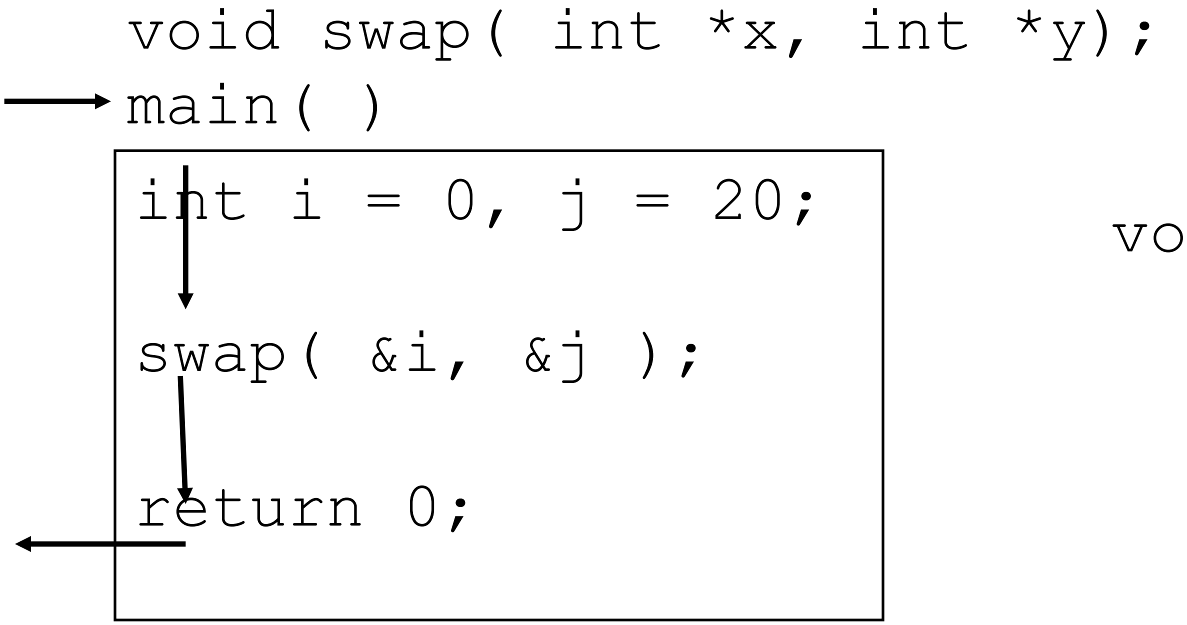
Function Call And Return



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```

Memory Model

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Summarizing Parameter Passing

- The caller passes the address of actual reference parameters to invoked functions

Summary of Operations with Pointers

- Point to another variable using address of: **&**
- Change the content of other variables using: *
- In place of an **array** − or as an array: pointer variable points to array name − then instead of using an array index, advance the pointer
- In functions where more than one value is to be returned. Pass arguments **by reference**.

Swap Demo

```
#include <stdio.h>

/*  In C, you pass parameters to a function using a
pass-by-reference scheme by using pointers which are
declared using *.  Reference  parameters are ones such
that if the function changes it value, the caller will see
those changes.  As a result, the "real" value is  passed
to the function, rather than a copy, as would occur
when passing
  by value as we learned to do originally.

  Reference parameters are used when a function
wants to change a
  value and wants to be sure the driver code "sees" that
changed
  value.
 */

void swapper( int * i, int * j );
```

```
int main( ) {
    int i, j;

    printf( "Please supply two ints to swap...\n" );
    scanf( "%d %d", &i, &j );
    printf( "Before swapping, i = %d and j = %d\n", i, j );
    /*
      You send reference parameters similar to the way
      we use scanf, by prefacing the variables with the
      &.  This address operator converts a variable into its
      address or location.
   */
    swapper( &i, &j );
    printf( "After swapping, i = %d and j = %d\n", i, j );
    return( 0 );
}

void swapper( int * i, int * j ) {
    int temp = * i;
    *i = *j;
    *j = temp;
}
```

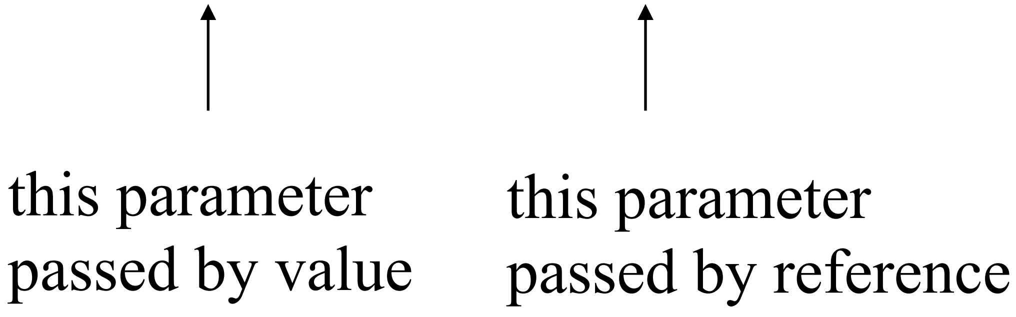
Summarizing Swap

- Pass-by-value results in copies being made of every argument
  - This might have a performance impact on your code
- However, pass-by-reference makes things more complex
  - Your function may have unintended side effects, since it can change values inside the caller' s world

Mixing Parameter Types

- A function may use both kinds of parameter passing schemes in one prototype

```
void process( int input, int* output );
```



this parameter
passed by value

this parameter
passed by reference

Done This Before

- Reminder of Problem Solving and Testing Strategy

Problem Solving Strategy

- One big problem is harder to solve than many smaller problems
- Understand the problem
  - what result is expected
  - what process can provide these results
  - what parameters are needed for these processes
  - write function descriptions in english telling what the function should do

Problem Solving Strategy

- C Syntax Typically Obscures Understanding
  - write out your solution on paper FIRST
  - use flow charts or pseudocode
  - translate to C syntax on paper
  - try not to compose code at a terminal
- Great Answers Don' t Come The First Time
  - iteratively refine and enhance partial solutions

Testing Strategy

- How Do You Test Functions?
  - Test One Function At A Time
  - Display Intermediate Results
  - You May Need To Create Test Data To Use Via “Driver Programs”
  - If The Function Being Tested Calls Other Functions, Create “Stubs”
  - Try Varying One Thing At A Time
    - if something goes wrong, you know what changed

Testing Strategy

- Drivers
  - allows you to test a function without all the rest of a program
  - just to execute the function and show its results
  - often, provides a loop to retest the function on different arguments

Testing Strategy

- Stubs
  - simplified version of a function not written or tested yet
  - often used when testing another function
  - does not necessarily deliver correct values
  - works best when stubs are replaced by actual functions, one at a time

Summary

- Pointers
- Parameter Passing Mechanisms
- Problem Solving and Testing Strategy