Pointers

In this section of notes you will learn about another type of variable that stores addresses rather than data

Memory: What You Know

- Memory is analogous to a series of slots each of which can store a single piece of information.

1000 S.F. Adams 100	**1001** S. Bill 'j'	**1002** C. Brown
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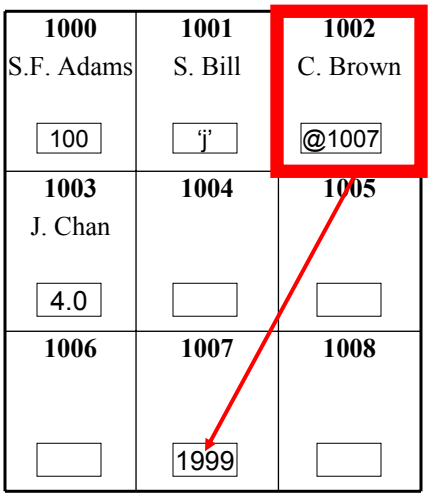
Memory: What You Will Learn

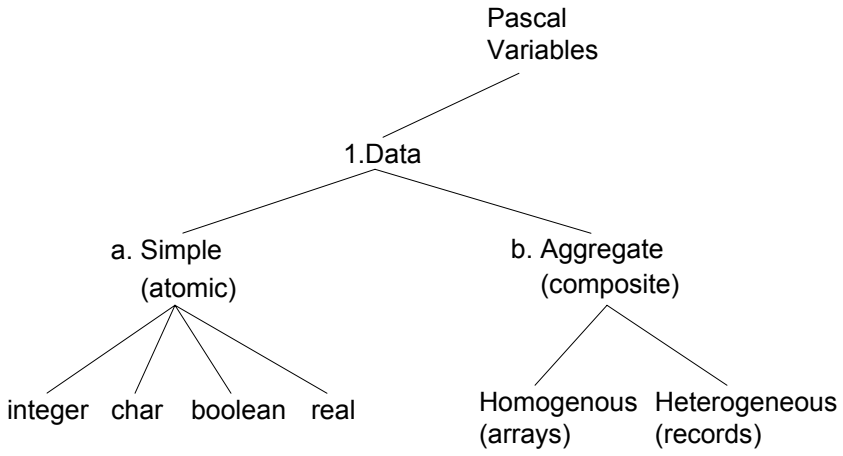
•How a memory location can contain the address of another location in memory.



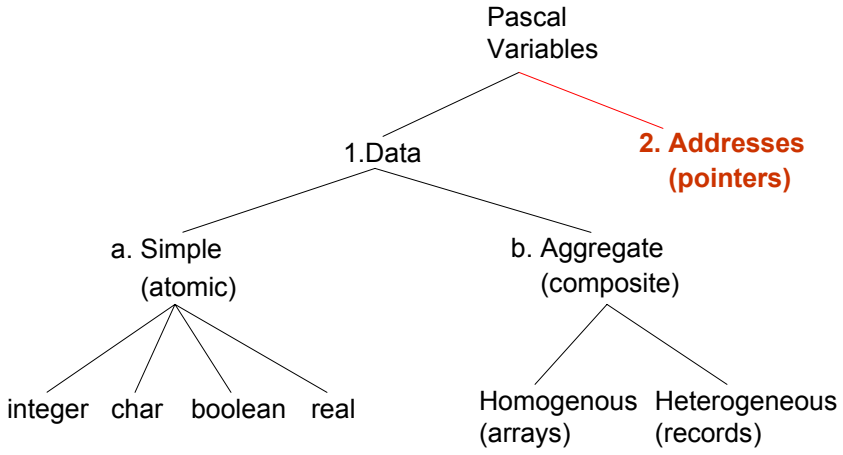
Why Bother With Pointers?

The answer to this question will be deferred until the next section of notes (linked lists).

Types Of Variables: What You Know



Types Of Variables: What You Will Learn



Declaration Of Pointer Variables

Format:

```
type
    type name = ^ type pointed to[1];
        :                :
begin
    var pointer name : type name;
```

Example:

```
type
    IntegerPointer = ^integer;
        :                :
begin
    var numPtr1 : IntegerPointer;
```

1 An alternative is to use the "at-sign" @ instead of the "up-arrow" ^ to declare a pointer variable (*not recommended*)

Allocating Memory For Pointers

- It involves reserving some dynamic memory and having the pointer point to that memory.

Format

```
new (pointer name);
```

Example

```
new (numPtr1);
```

De-Allocating Memory For Pointers

- Returning back the dynamically allocated memory (if it's needed it can then be re-used for something else).

Format

dispose (*pointer name*);

Example

dispose (numPtr1);

De-Allocating Memory For Pointers: Followup

- Should also be followed by having the pointer no longer point to the memory that has just been de-allocated

Format:

pointer name := NIL;

Example:

numPtr1 := NIL;

Using Pointers

Important! Are you dealing with the pointer or what the pointer is pointing to (allocated memory)?

•Pointer name

•Pointer name ^ (de-reference pointer)

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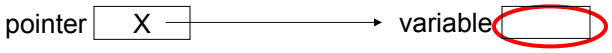


Accessing Pointers

Format:

(Pointer)

pointer name

(Memory pointed to)

pointer name ^

Accessing Pointers (2)

Example:

```
type
   IntegerPointer = ^integer;
         :                :
begin
    var numPtr1 : IntegerPointer;
     new(numPtr1);

   (Pointer)
   writeln(numPtr1);


  (Memory pointed to)
  writeln(numPtr1^);
```

Accessing Pointers (2)

Example:

```
type
   IntegerPointer = ^integer;
         :                :
begin
    var numPtr1 : IntegerPointer;
     new(numPtr1);

   (Pointer)
   writeln(numPtr1);


   (Memory pointed to)
   writeln(numPtr1^);
```


Accessing Memory Allocated Through A Pointer

Normally memory is accessed through a variable name:

```
var num : integer;
num := 12;
```

A pointer is a variable and the pointer can be accessed through the name of the pointer:

```
type
   IntegerPointer = ^integer;
begin
    var numPtr : IntegerPointer;
    new(numPtr);
```

However the memory allocated through the pointer (referred to by the pointer) can only be accessed through the pointer

Accessing Memory Allocated Through A Pointer (2)

- In a similar fashion if you have the address of a location in memory then it may be accessed or modified without using a variable name.
- This is precisely how variable parameters (pass by reference) are implemented!

Using Pointers : Allowable Operations

Assignment :=

Relational

- Equality =
- Inequality <>

Using Pointers : Assignment

Format:

(Pointer)

pointer name := *pointer name*;

(Memory pointed to)

pointer name ^ := *expression*;

Example:

(Pointer)

numPtr1 := numPtr2;

(Memory pointed to)

numPtr1^ := 100;

Using Pointers : Allowable Operations (Equality)

Format:

(Pointer)

if (*pointer name 1* = *pointer name 2*) then

(Memory pointed to)

if (*pointer name 1*^ = *pointer name 2*^) then

Example:

(Pointer)

if (numPtr1 = numPtr2) then

(Memory pointed to)

if (numPtr1^ = numPtr2^) then

Using Pointers : Allowable Operations (Inequality)

Format:

(Pointer)

if (*pointer name 1 <> pointer name 2*) then

(Memory pointed to)

if (*pointer name 1^ <> pointer name 2^*) then

Example:

(Pointer)

if (numPtr1 <> numPtr2) then

(Memory pointed to)

if (numPtr1^ <> numPtr2^) then

Pointers : First Example

```
program pointer1 (output);
type
  IntegerPointer = ^integer;
begin
  var num       : integer;
  var numPtr1 : IntegerPointer;
  var numPtr2 : IntegerPointer;
  writeln('Example 1');
  num := 10;
  new(numPtr1);
  new(numPtr2);
  numPtr1^ := 100;
  numPtr2^ := 100;
  writeln('num = ':11, num:3);
  writeln('numPtr1^ = ':11, numPtr1^:3);
  writeln('numPtr2^ = ':11, numPtr2^:3);
```

Pointers : First Example (2)

```
if (numPtr1 = numPtr2) then
  writeln('Same memory')
else
  writeln('Separate memory');
if (numPtr1 ^= numPtr2^) then
  writeln('Same data')
else
  writeln('Different data');
(* Not allowed *)
(*writeln('numPtr1=',numPtr1); *)

writeln('Example 2');
num := numPtr1^;
writeln('num = ':11, num:3);
writeln('numPtr1^ = ':11, numPtr1^:3);
num := 33;
writeln('num = ':11, num:3);
writeln('numPtr1^ = ':11, numPtr1^:3);
writeln;
```


Pointers: First Example (3)

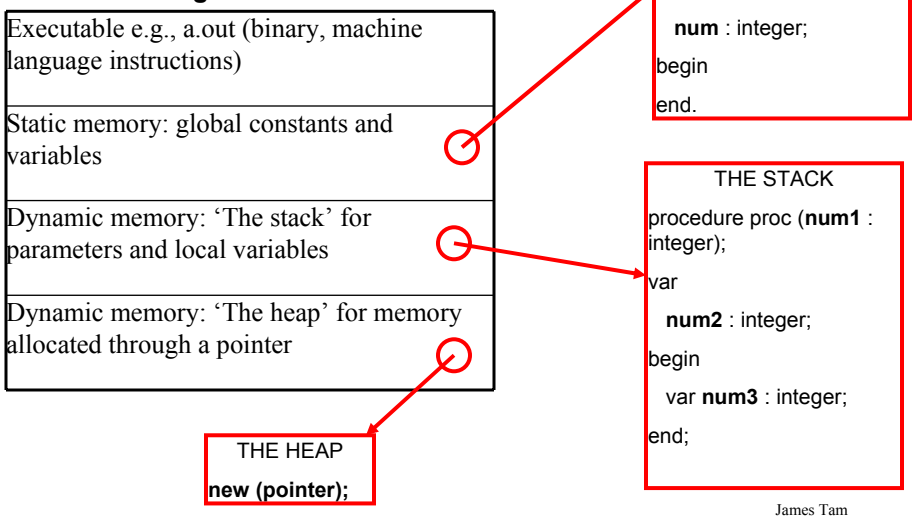
```
writeln('Example 3');
numPtr2 ^ := 66;
numPtr1 := numPtr2;
if (numPtr1 = numPtr2) then
  writeln('Same memory')
else
  writeln('Separate memory');
numPtr2^ := 33;
writeln('numPtr1^ = ':11, numPtr1^);
writeln('numPtr2^ = ':11, numPtr2^);

dispose(numPtr1);
(*   dispose(numPtr2); *)

(* Indicating that neither pointer points to any memory *)
numPtr1 := NIL;
numPtr2 := NIL;
end.
```

RAM: How Things Are Divided Up

Memory that's allocated for programs that are running



Pointers And Parameter Passing

Value parameters

- In the call to the module what's passed in is a copy of the value stored in the parameter.
- The header for the module declares the name of the *local identifier/local variable used to store the value stored in the parameter*.

Variable parameters

- In the call to the module what's passed in is the address of the variable.
- The header for the module declares the name of the *local pointer that is used to store the address of the parameter*.
- The pointer is automatically de-referenced (to change the original parameter) whenever the local identifier is accessed.

Pointers And Parameter Passing (2)

```
program parameters (output);

procedure proc (      num1 : integer;
                    var num2 : integer);
begin
  num1 := 10;
  num2 := 20;
end;

begin
  var num1 : integer;
  var num2 : integer;
  num1 := 1;
  num2 := 2;
  proc(num1,num2);
end.
```


Parameter Passing: Rules Of Thumb You Should Know For Data Parameters

Value parameters

- Data: What's passed in *cannot* change (changes are made to a local copy).

Variable parameters

- Data: What's passed in *can* change (changes are made to the original parameter)

Parameter Passing: Rules Of Thumb You Should Learn For Pointer Parameters

Value parameters (pointer parameter)

- Pointers: What's passed in (a pointer) *cannot* change (changes are made to a local copy of the pointer).

Variable parameters (pointer parameter)

- Pointers: What's passed in (a pointer) *can* change (changes are made to the original pointer parameter)

Value or variable parameters (what the pointer parameter points to)

- Value parameter:
  - A local copy of the pointer is made for the module which contains the address of a data variable.
  - *This allows the data referred to by the pointer to be changed.*
- Variable parameter:
  - The address of the pointer parameter is passed to another local pointer (pointer to a pointer).
  - *Again this allows the data referred to by the pointer to be changed.*

Pointers As Value Parameters

Need to define a type for the pointer first!

Format (defining a type for the pointer):

type
<pointer name> = ^ *<type pointed to>*;

Format (passing pointer):

procedure *procedure name* (*pointer name (1)* : *type of pointer (1*);
pointer name (2) : *type of pointer (2)*;
: **:**
pointer name (n) : *type of pointer (n)*);

function *function name* (*pointer name (1)* : *type of pointer (1*);
pointer name (2) : *type of pointer (2)*;
: **:**
pointer name (n) : *type of pointer (n)*);

Pointers As Value Parameters (2)

Example (defining a type for the pointer)

```
type
  CharPointer = ^char;
```

Example (passing pointer):

```
procedure proc1 (aCharPointer : CharPointer );
begin
        :           :
end;
```


Pointers As Variable Parameters

Need to define a type for the pointer first!

Format (defining a type for the pointer):

type

<pointer name> = ^ *<type pointed to>*;

Format (passing pointer):

procedure *procedure name* (var *pointer name (1)* : *type of pointer (1*);
var *pointer name (2)* : *type of pointer (2)*;
: **:**
var *pointer name (n)* : *type of pointer (n)*);

function *function name* (var *pointer name (1)* : *type of pointer (1*);
var *pointer name (2)* : *type of pointer (2)*;
: **:**
var *pointer name (n)* : *type of pointer (n)*);

Pointers As Variable Parameters

Need to define a type for the pointer first!

Example (defining a type for the pointer)

```
type
  CharPointer = ^char;
```

Example (passing pointer):

```
  procedure proc1 (var aCharPointer : CharPointer );
  begin
        :          :
  end;
```


Pointers: Second Example

A full version of this program can be found in Unix under:
/home/231/examples/pointers/pointer2.p

```
program pointer2 (output);
type
  CharPointer = ^char;

procedure proc1 (charPtr : CharPointer);
var
  temp    : CharPointer;
begin
  writeln;
  writeln(‘Proc1');
  new(temp);
  temp^ := 'A';
  charPtr := temp;
  writeln('temp^ = ', temp^);
  writeln('charPtr^ = ', charPtr^);
end;
```

Pointers: Second Example (2)

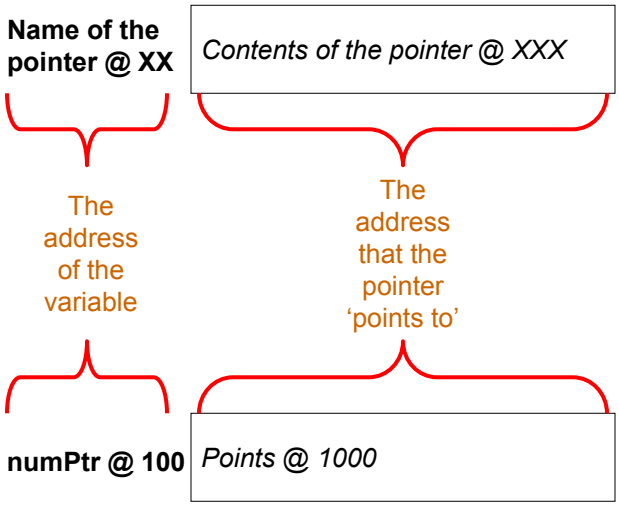
```
procedure proc2 (var charPtr : CharPointer);
var
  temp : CharPointer;
begin
  writeln;
  writeln(‘Proc2');
  new(temp);
  temp^ := 'A';
  charPtr := temp;
  writeln('temp^ = ', temp^);
  writeln('charPtr^ = ', charPtr^);
end;
```


Pointers: Second Example (4)

```
begin                   (* Main program *)
  var charPtr : CharPointer;
  new (charPtr);
  charPtr^ := 'a';
  writeln;
  writeln(‘Main program.');
  writeln('charPtr^ = ', charPtr^);
  proc1(charPtr);
  writeln('After proc1');
  writeln('charPtr^ = ', charPtr^);
  proc2(charPtr);
  writeln('After proc2');
  writeln('charPtr^ = ', charPtr^);
  writeln;
end.                    (* End of main program *)
```

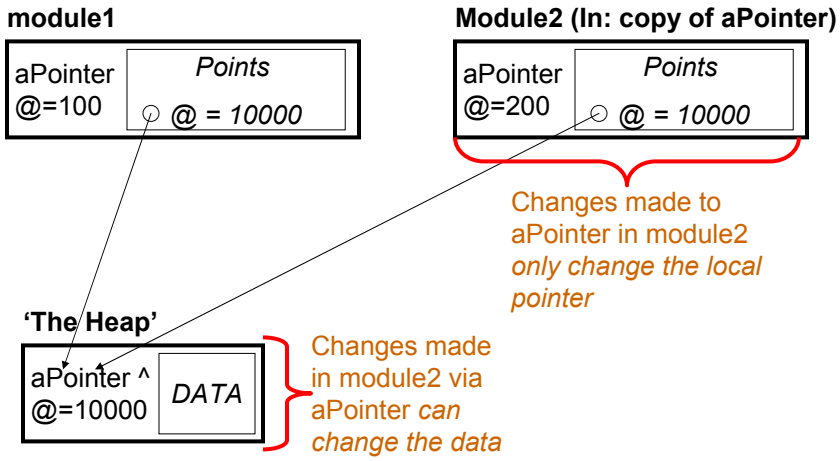
Summary: Passing Pointers As Parameters

Reminder of the notation



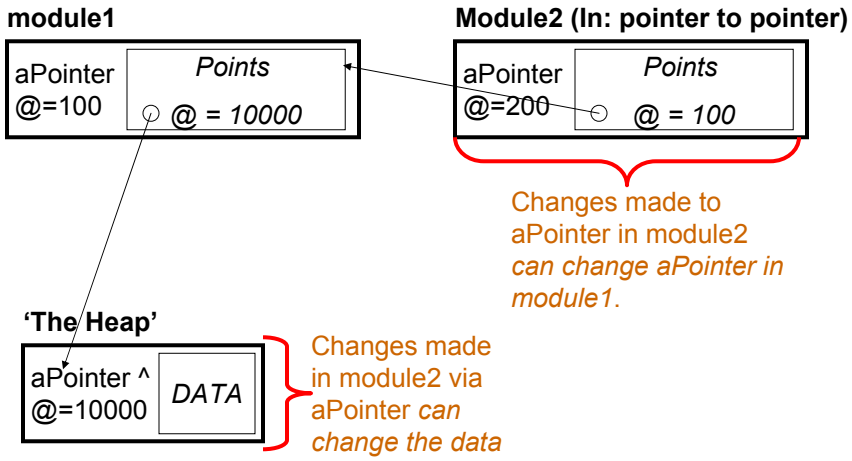
Summary: Passing Pointers As Value Parameters

Module1 calls Module2 and passes 'aPointer' as a value parameter e.g., 'proc1'in the previous example

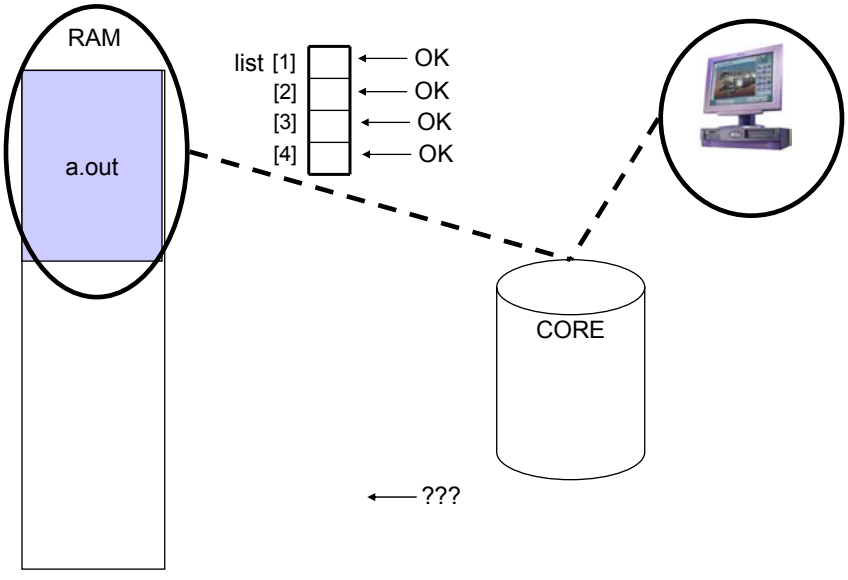


Summary: Passing Pointers As Variable Parameters

Module1 calls Module2 and passes 'aPointer' as a variable parameter e.g., 'proc2' in the previous example



What You Know: How Segmentation Faults Are Caused By Indexing Beyond The Array Bounds



What You Will Learn: How Segmentation Faults (Possibly Bus Errors) Can Be Caused By Incorrect Pointer Dereferencing

A full version of this program can be found in Unix under:
/home/231/examples/pointers/pointer3.p

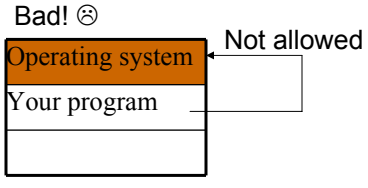
```
program pointer3 (output);

type
  IntegerPointer = ^ integer;

begin
  var numPtr1 : IntegerPointer;
  writeln('1');
  numPtr1^ := 100;
  writeln('2');
  numPtr1 := NIL;
  writeln('3');
  numPtr1^ := 100;
end.
```

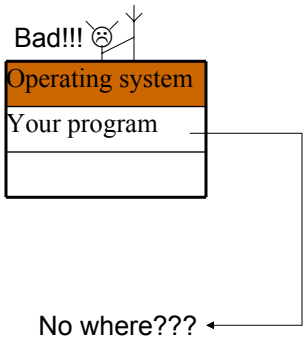

Segmentation Fault

- A 'memory access violation' (an attempt is made to access a part of memory that is 'forbidden' to a program).
- Can be caused be programs that index beyond the bounds of an array.
- Can also be caused by programs that improperly de-referenced pointers.



Bus Error

- Caused by a ‘faulty memory access’.
- May occur when a program tries to access a non-existent memory address.
- Could also be triggered by accessing beyond the bounds of an array or improperly de-referenced pointers.



You Should Now Know

- How to declare new types that are pointers to data
- How to declare variables that are pointers
- The difference between static and dynamically allocated memory
- How to dynamically allocate memory
- How to de-allocate memory
- Why and when to set pointers to NIL
- How to access a pointer and how to access what the pointer points to
- How to assign values to a pointer and how to assign values to what the pointer points to
- What operations can be performed on pointers and how does each one work
- How to pass pointers as value and variable parameters
- How incorrect pointer usage results in problems with memory accesses such as segmentation faults and bus errors