Pointers

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

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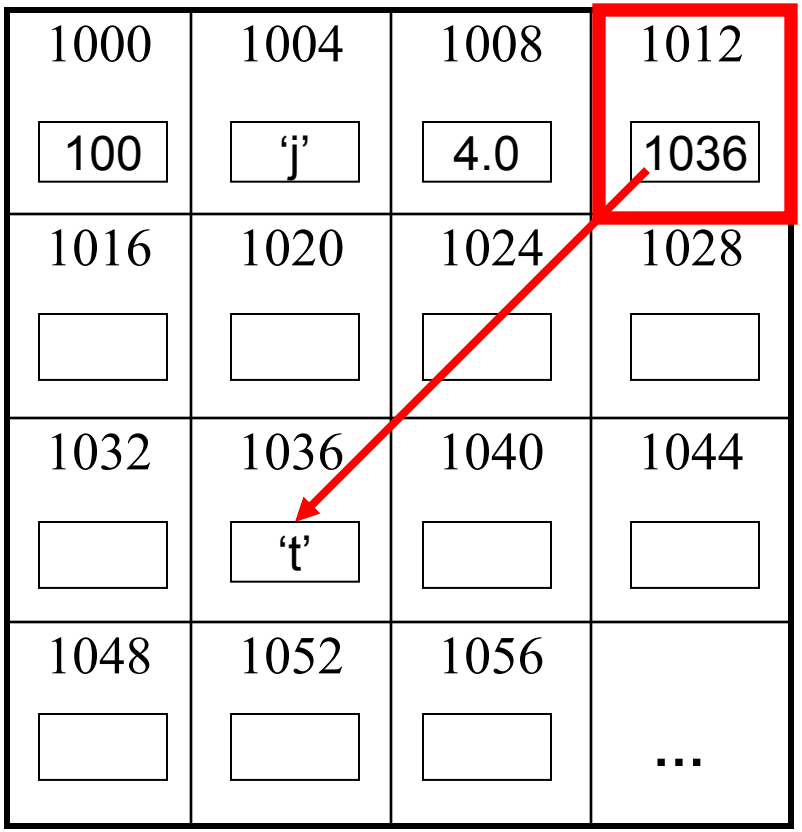
Memory: What You Know

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

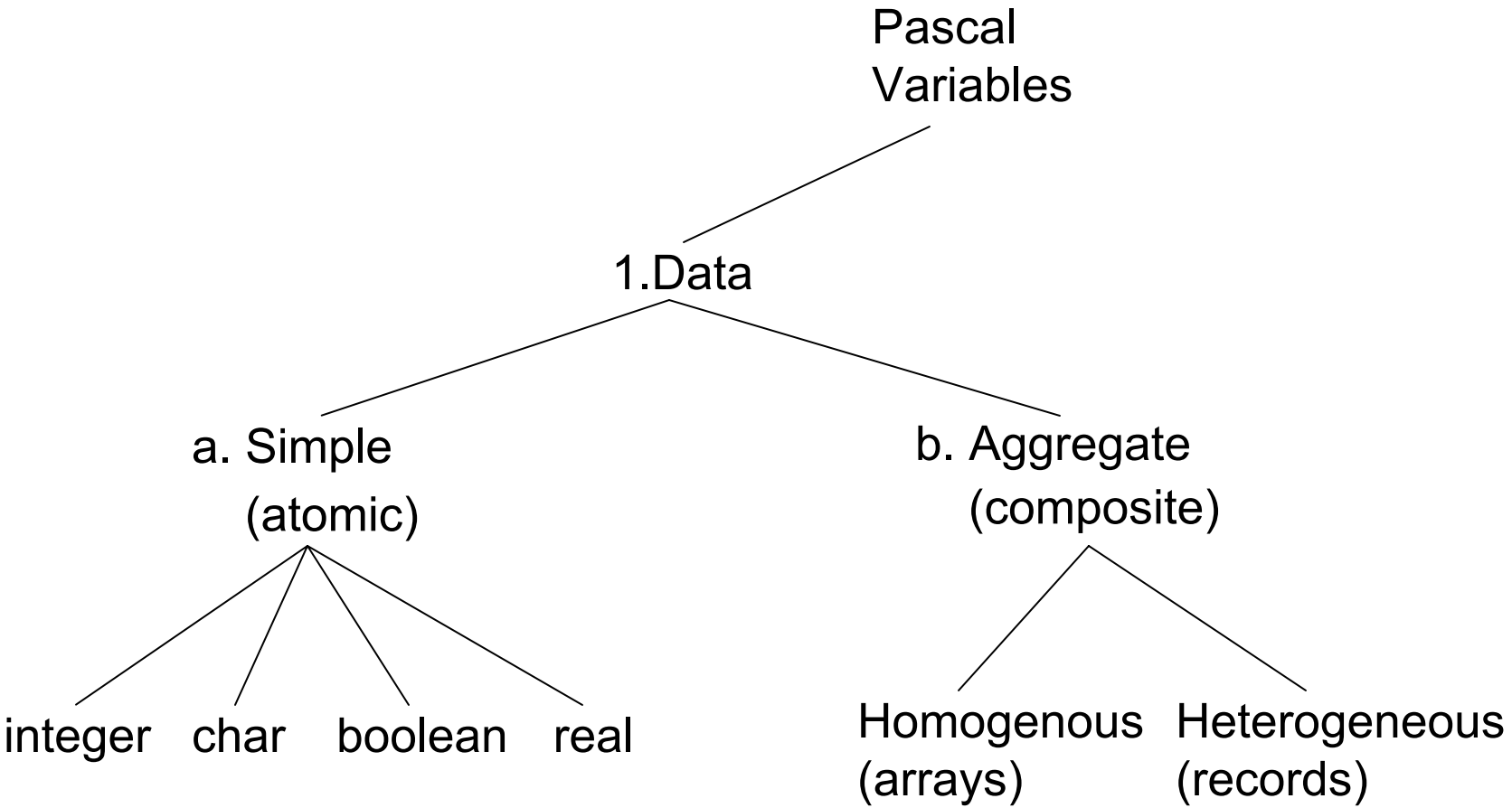
1000	1004	1008	1012
100	'j'	4.0	
1016	1020	1024	1028
1032	1036	1040	1044
1048	1052	1056	
			...

Memory: What You Will Learn

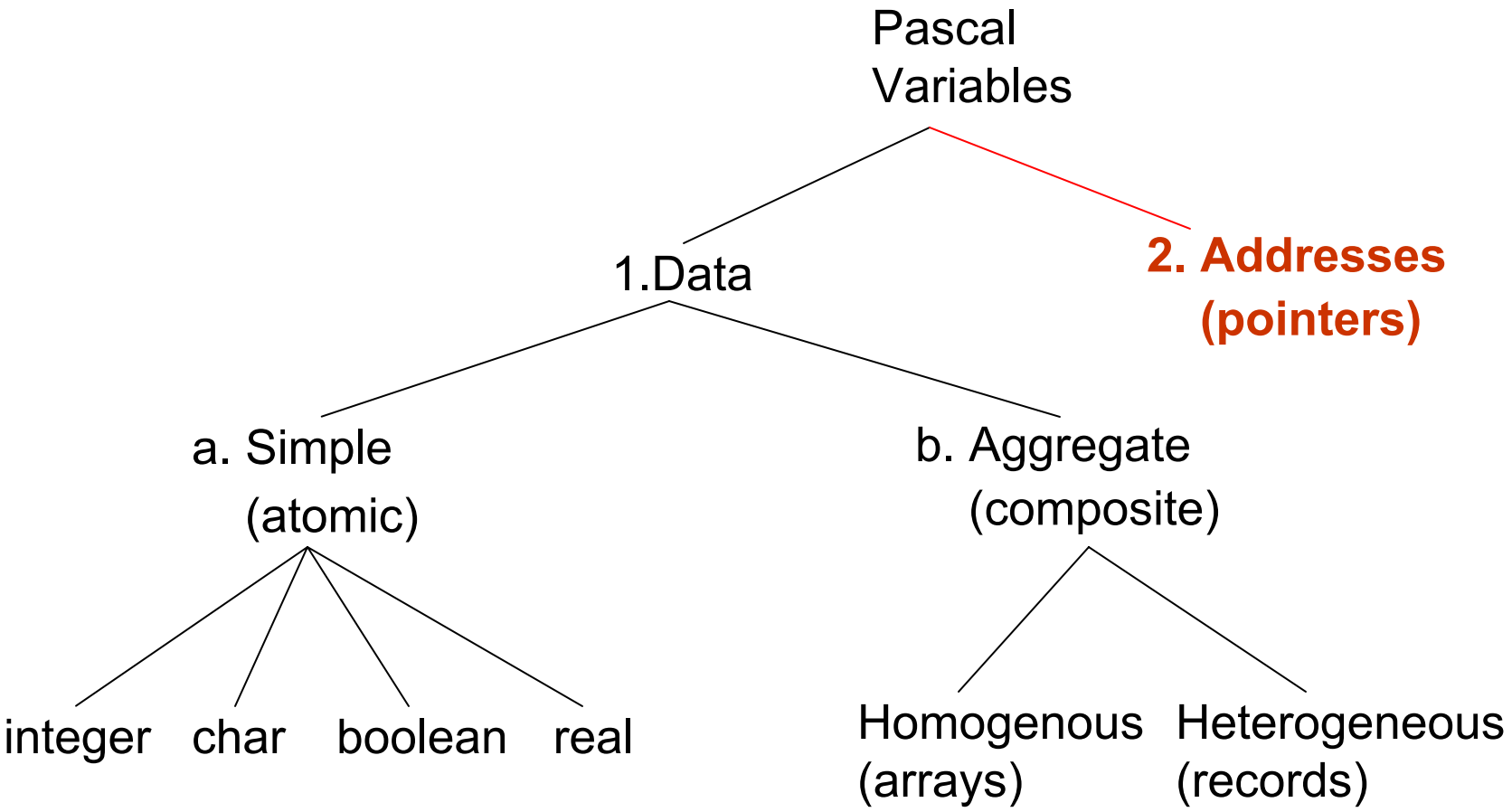
- Memory can also contain the address of another slot



Types Of Variables



Types Of Variables



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

Static vs. dynamic memory

- Arrays

Allocating dynamic memory

- Reserving some dynamic memory and having the pointer point to it.

Format

new (*pointer name*);

Example

new (numPtr1);

De-Allocating Memory For Pointers

De-allocating memory

- Returning back the dynamically allocated memory

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)

Using Pointers

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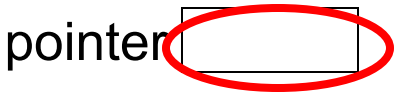
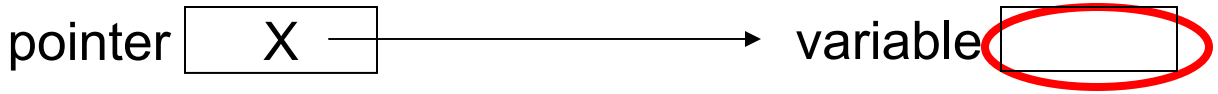
- Pointer name



- Pointer name ^ (de-reference pointer)



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^);
```

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

A full version of this example can be found in Unix under:
/home/231/examples/pointers/pointer1.p

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

Pointers : First Example (2)

```
writeln('num = ':11, num:3);
writeln('numPtr1^ = ':11, numPtr1^:3);
writeln('numPtr2^ = ':11, numPtr2^:3);
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); *)
```

Pointers: First Example (3)

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

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

Pointers: First Example (4)

```
  writeln('Example 4');
  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);
  numPtr1 := NIL;
  numPtr2 := NIL;
end.
```

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;
```

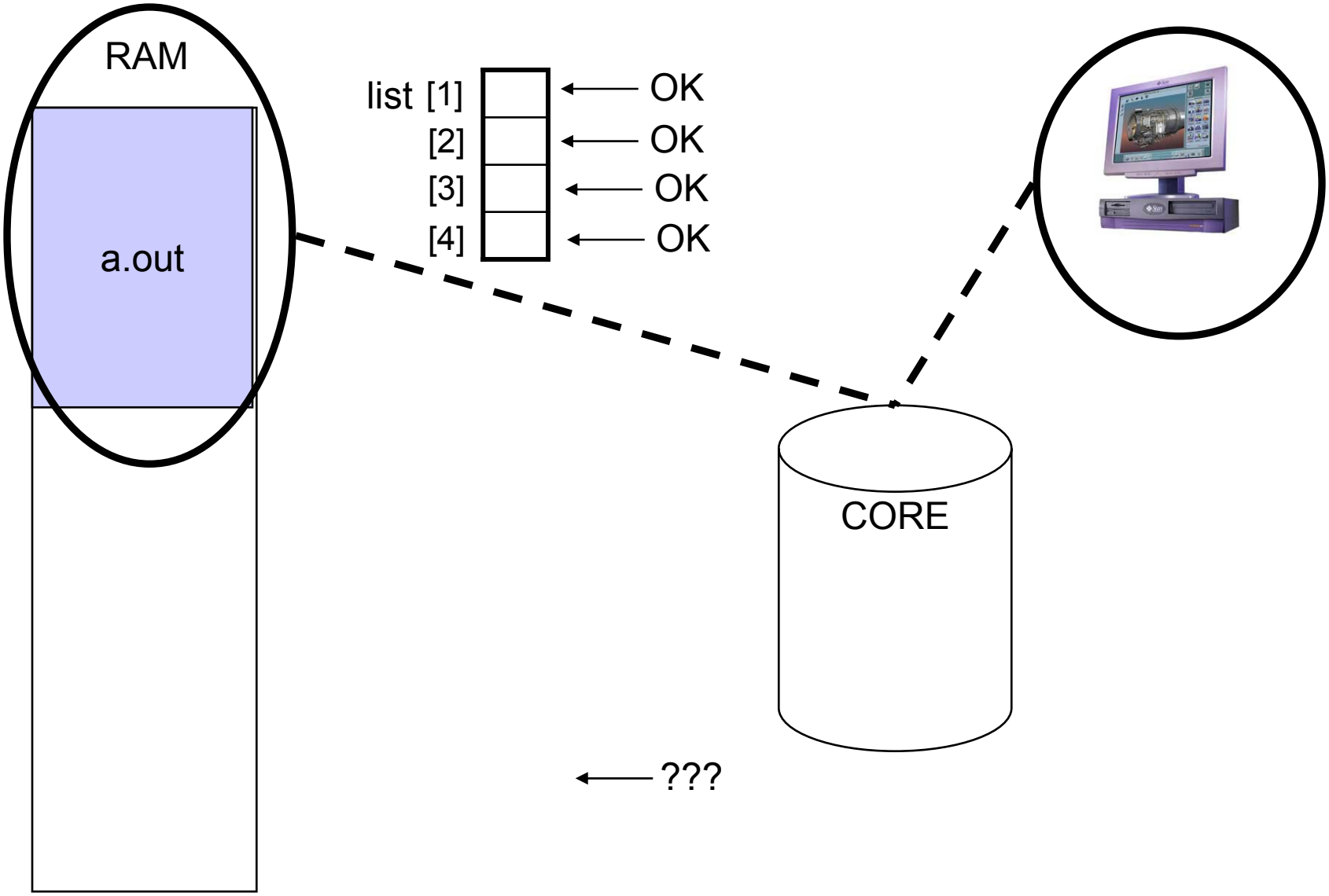
Pointers: Second Example (2)

```
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 *)
```

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.
```

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