



Variables, Pointers, and Arrays

Prof. David August

COS 217

<http://www.cs.princeton.edu/courses/archive/fall07/cos217/>



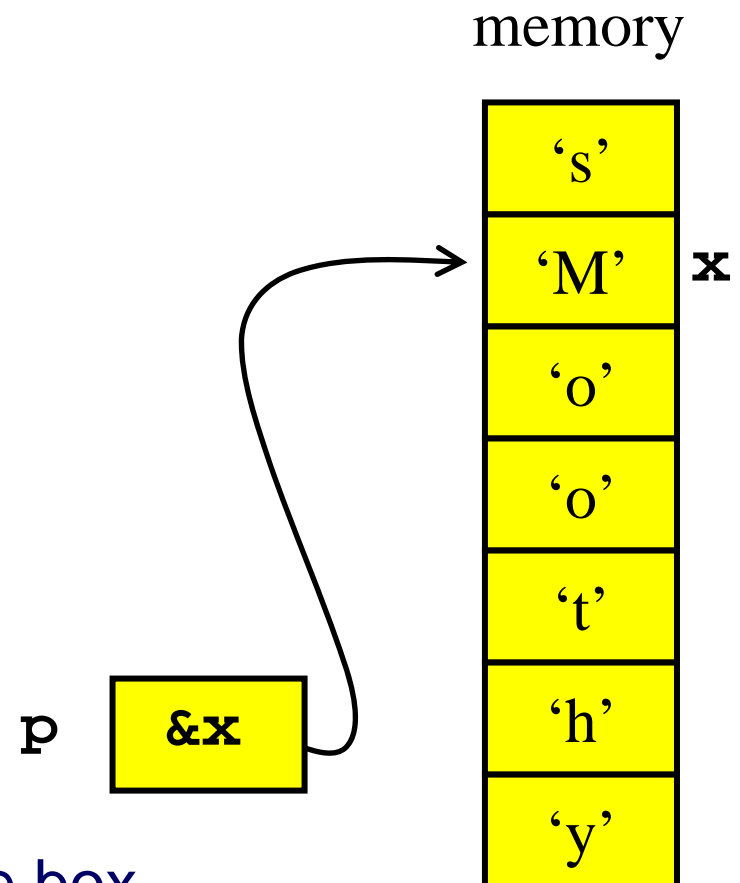
Overview of Today's Lecture

- **Pointers**
 - Differences between value, variable, and pointer
 - Using pointers to do call-by-reference in C
- **Struct**
 - Multiple values grouped together
 - Dereferencing to access individual elements
- **Arrays**
 - List of elements of the same type
 - Relationship between arrays and pointers
 - Example program to reverse an array
- **Strings**
 - Array of characters ending in '\0'

Values, Variables, and Pointers



- Value
 - E.g., 'M'
- Variable
 - A named box that holds a value
 - E.g., `char x = 'M';`
- Pointer value
 - Address of the box
 - E.g., `&x`
- Pointer variable
 - A box holding the address of the box
 - E.g., `char* p = &x;`





Example Program

```
#include <stdio.h>
int main(void) {
    char x = 'M';
    char* p = &x;
    printf("Value of x is %c\n", x);
    printf("Address of x is %u\n", p);
    printf("Address of p is %u\n," &p);
    return 0;
}
```

- Output

- Value of x is M
- Address of x is 4290770463
- Address of p is 4290770456



Values vs. Variables

```
int n;
```



```
n = 217;
```



```
n = n + 9;
```



```
3 = n;
```

??

```
&n
```

a pointer value

```
&3
```

??

What is this?

`*(&n)`



Call by Value is Not Enough

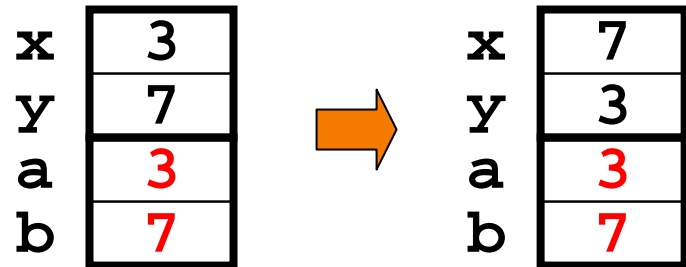
- Function parameters are transmitted by value
 - Values copied into “local variables”

```
void swap(int x, int y)
{
    int t;

    t = x;
    x = y;
    y = t;
}

int main(void) {
    ...
    swap(a,b);
    ...
}
```

No!



Call by Reference Using Pointers



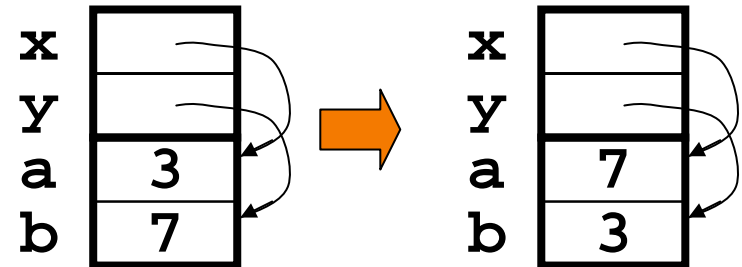
- Use pointers to pass variables “by reference”

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

    t = *x;
    *x = *y;
    *y = t;
}
```

Yes

```
int main(void) {
    ...
    swap(&a, &b);
    ...
}
```

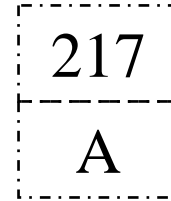




Structures

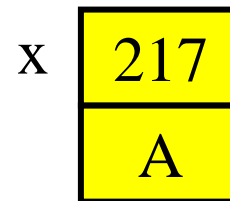
A struct value is a bunch of values glued together

```
struct pair {  
    int number;  
    char grade;  
};
```



A struct variable is a box holding a struct value

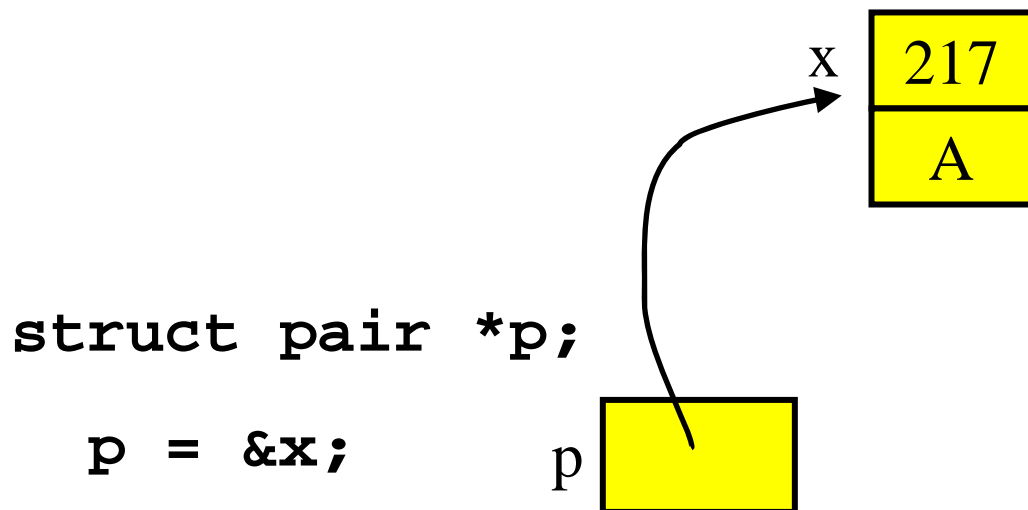
```
struct pair x;  
x.number = 217;  
x.grade = 'A';
```





Pointers to structs

```
struct pair {int number; char grade;};  
struct pair x;    x.number=217;    x.grade='A';
```



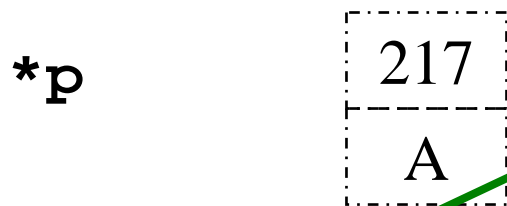
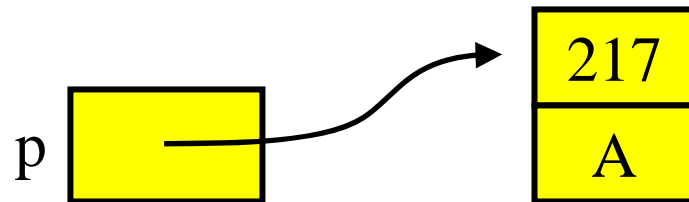
```
int n = (*p).number;  
char g = (*p).grade;
```

The diagram shows the result of dereferencing the pointer `p`. The variable `n` is shown as a yellow box containing the value `217`, and the variable `g` is shown as a yellow box containing the character `A`.



Dereferencing Fields

```
struct pair {int number; char grade;} *p;
```



Easier-to-use notation

```
int n = (*p).number;
```



```
int n = p->number;
```

```
char g = (*p).grade;
```

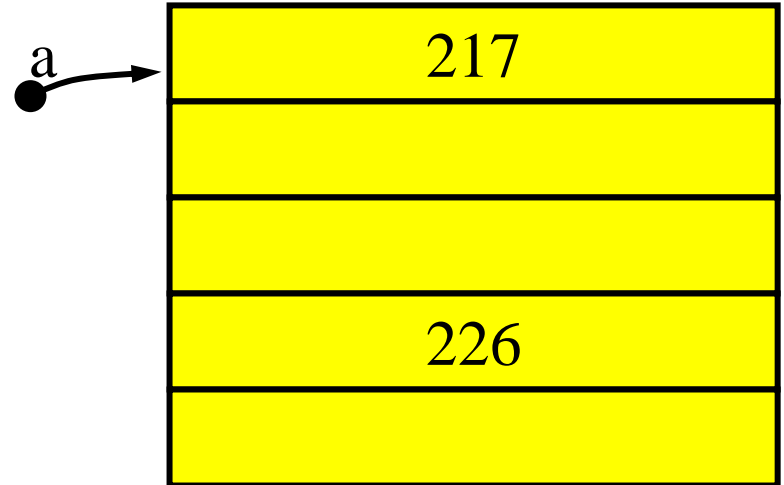


```
char g = p->grade;
```

Arrays in C



```
int a[5];
```



a is a *value* of type “pointer to int”

What is “**a**” in the picture above?

a is the pointer *constant*, not the five consecutive memory locations!

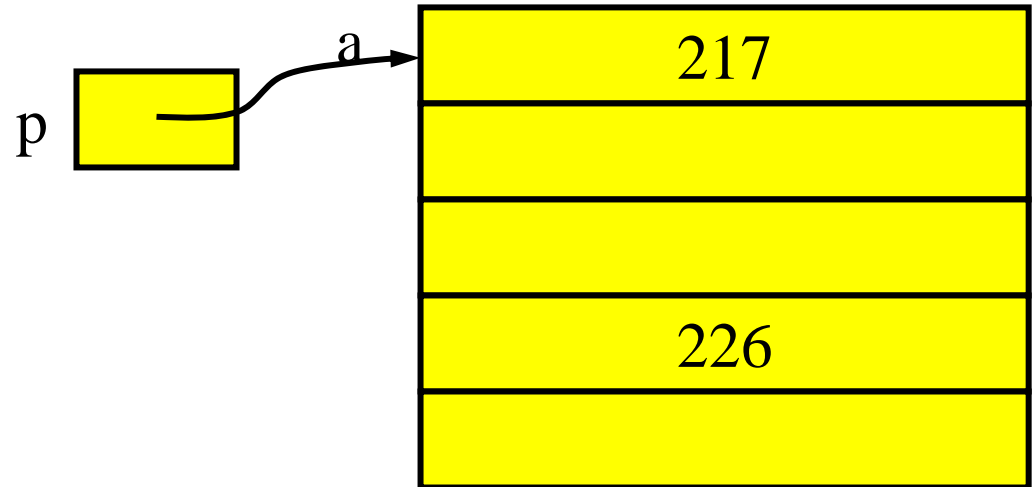


Arrays and Pointers

```
int a[5];
```

```
int *p;
```

```
p = a;
```



a is a *value* of type “pointer to int” (int *)

p is a *variable* of type “pointer to int” (int *)

OK: `p = a; if (a == p)...; a[i] = p[j];`

Wrong: `a = p; 3 = i;`

C Does Not Do Bounds Checking!



```
int a[5];
```

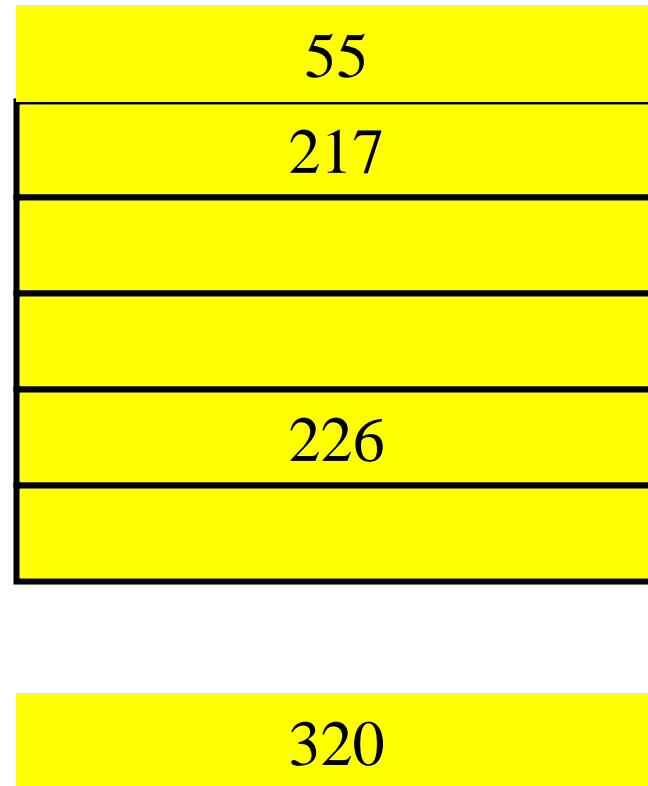
```
a[0] = 217;
```

```
a[3] = 226;
```

```
a[-1] = 55;
```

```
a[7] = 320;
```

a



Unpleasant if you happened to have another variable before the array variable `a`, or after it!



Arrays and Pointers

```
int a[5];
```

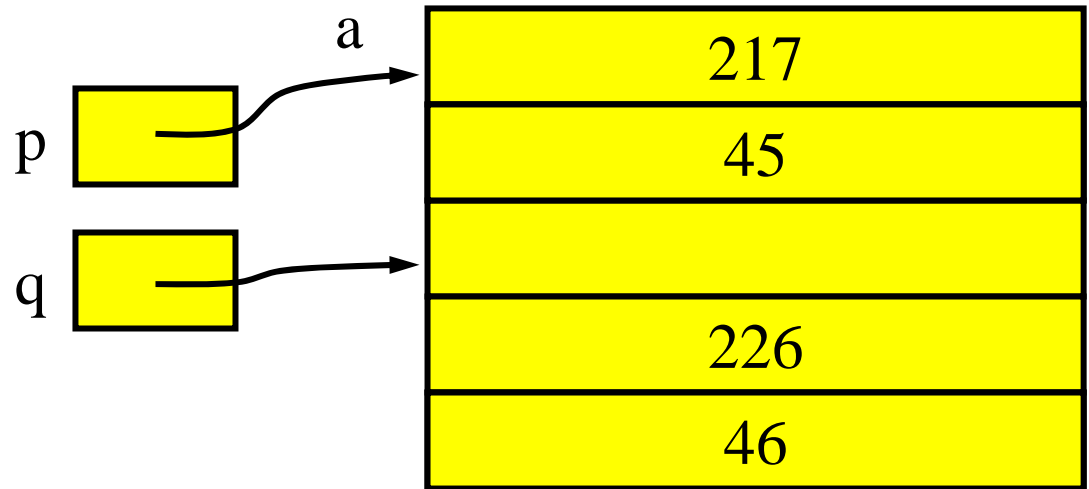
```
int *p, *q;
```

```
p = a;
```

```
p[1] = 44;
```

```
q = p + 2;
```

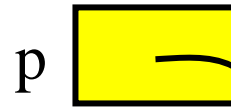
```
q[-1] = 45; q[2] = 46;
```



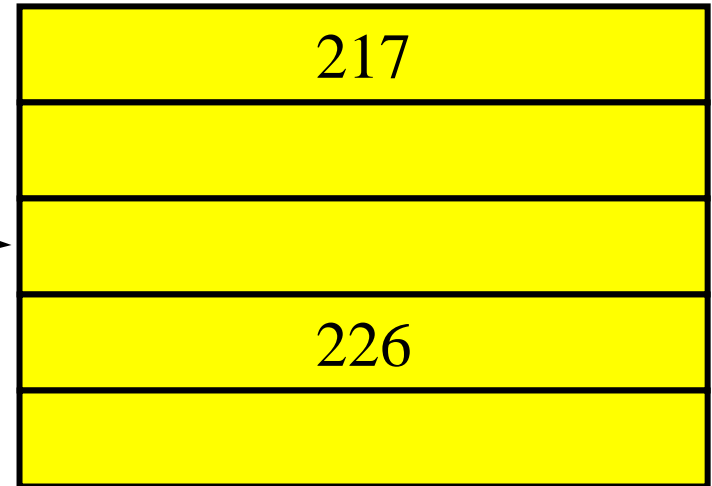


Pointer Arithmetic

```
int a[5];
```



a



4 bytes

Subscript: $a[i]$ “means” $*(a+i)$

```
int *p;
```

```
p = a + 2;
```

Note: arithmetic scales by data size (e.g., int of 4 bytes)

Quaint usage of pointer arithmetic



Add up the elements of an array:

```
int a[100];  
int sum, *p;  
...  
for (p=a; p<a+100; p++)  
    sum += *p;
```

More straightforwardly:

```
int a[100];  
int sum, i;  
...  
for (i=0; i<100; i++)  
    sum += a[i];
```




Array Parameters to Functions

```
void printArray(int *p, int n) {  
    int i;  
    for (i=0; i<n; i++)  
        printf("%d\n",p[i]);  
}  
  
int fib[5] = {1, 1, 2, 3, 5};  
  
int main(void) {  
    printArray(fib, 5);  
}
```



Array Params \equiv Pointer Params

```
void printArray(int *p, int n) { ... }
```

```
void printArray(int p[5], int n) { ... }
```

```
void printArray(int p[ ], int n) { ... }
```

```
void printArray(int p[1000], int n) { ... }
```

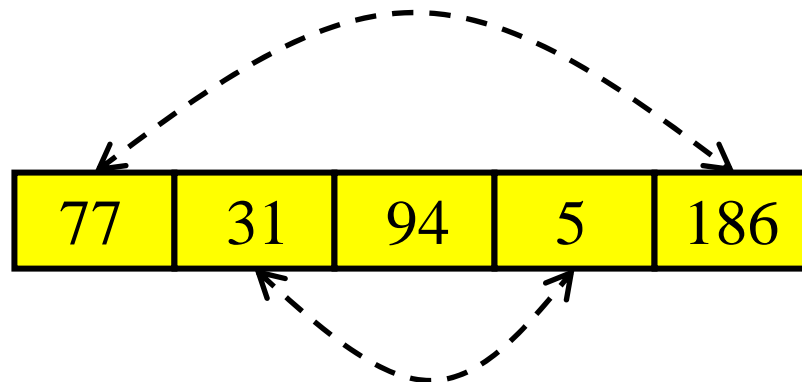
All these declarations are equivalent!

```
int main(void) {  
    printArray(fib, 5);  
}
```

Example Program: Reverse Array



- Reverse the values in an array
 - Inputs: integer array a , and number of elements n
 - Output: values of a stored in reverse order
- Algorithm
 - Swap the first and last elements in the array
 - Swap the second and second-to-last elements
 - ...





Example of Array by Reference

```
void reverse (int a[], int n) {
    int l, r, temp;
    for (l=0, r=n-1; l<r; l++, r--) {
        temp = a[l];
        a[l] = a[r];
        a[r] = temp;
    }
}

int main(void) {
    reverse(fib, 5);
}
```

Strings



A string is just an array of characters (pointer to character), terminated by a '\0' char (a null, ASCII code 0).

```
char mystring[6] = {'H','e','l','l','o','\0'};
```

```
char mystring[6] = "Hello";
```

```
char mystring[] = "Hello";
```

} Equivalent

```
mystring
```

H	e	l	l	o	\0
---	---	---	---	---	----

```
char *yourstring = "Hello";
```

} Different

```
yourstring
```

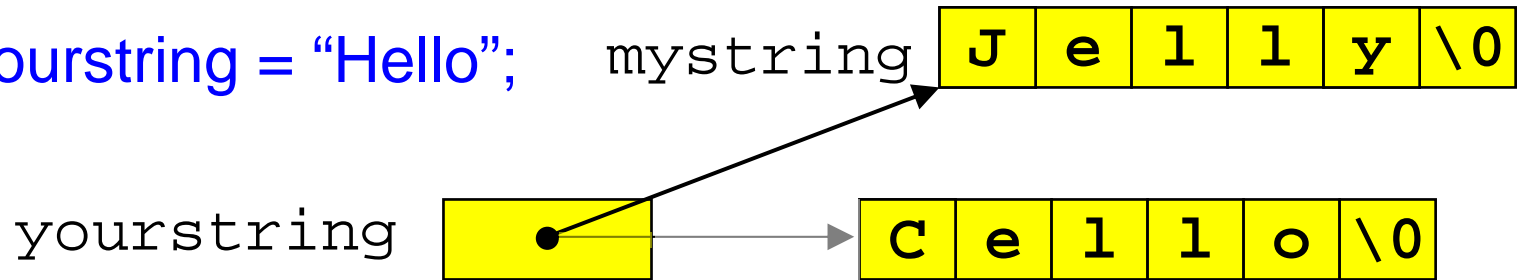
•	→	H	e	l	l	o	\0
---	---	---	---	---	---	---	----



Char Array and Pointer Manipulation

```
char mystring[] = "Hello";
```

```
char *yourstring = "Hello";
```



```
mystring[0] = 'J';
```

```
yourstring[0] = 'C';
```

```
yourstring = mystring;
```

```
yourstring[4] = 'y';
```

```
mystring = yourstring;
```



Printing a String

```
printf("%s",mystring);
```

mystring

H	e	l	l	o	\0
---	---	---	---	---	----

```
int i;
```

```
for (i=0; mystring[i]; i++)
```

```
    putchar(mystring[i]);
```

or,

```
char *p;
```

```
for (p=mystring; *p; p++)
```

```
    putchar(*p);
```



String termination

```
char mystring[] = "Hello";
```

mystring

H	e	x	l	o	!
---	---	---	---	---	---

```
mystring[2] = 0;      equivalently, mystring[2]='\0';
```

```
printf("%s\n",mystring);
```

He

```
mystring[2] = 'x'; mystring[5] = '!';
```

```
printf("%s\n",mystring);
```

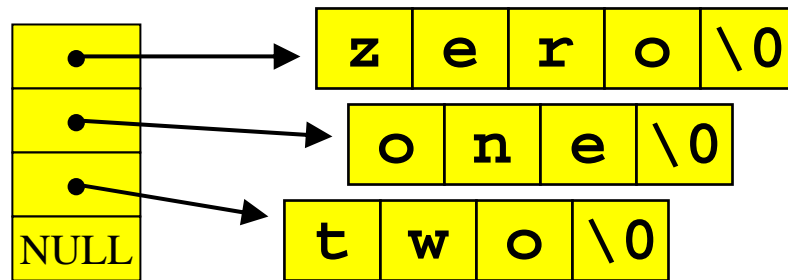
What will happen?



Boxes and Arrows

In designing and analyzing your data structures, draw pictures!

Example: you want an array of strings



```
char *query[4] =  
    {"zero", "one", "two", NULL};
```

*how to parse it: *(query[4])*

postfix operators bind tighter than prefix; whenever you're not sure, just put the parentheses in



Summary of Today's Class

- C variables
 - Pointer
 - Struct
 - Array
 - String

- Readings
 - See Course Schedule on Web page!