



# Variables, Pointers, and Arrays

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COS 217

<http://www.cs.princeton.edu/courses/archive/fall06/cos217/>



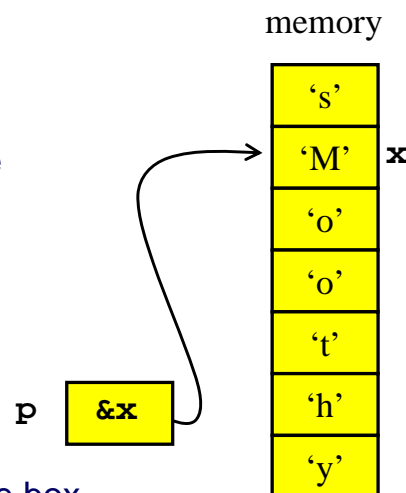
# Overview of Today's Lecture

- 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 ?

`n = 217;`      n 217

`n = n + 9;`      n 226

`3 = n;`      ??  
`&n`      a pointer value  
`&3`      ??

What is this?  
\*(&n)

# Call by Value is Not Enough



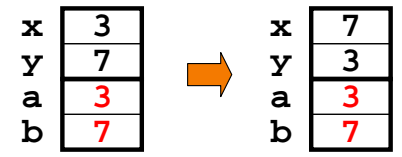
- Function parameters are transmitted by value
  - Values copied into "local variables"

```
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



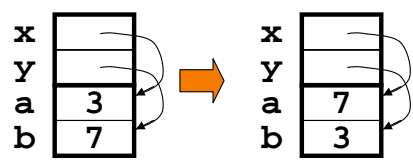
- Use pointers to pass variables "by reference"

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

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

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

*Yes*

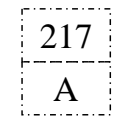


# Structures



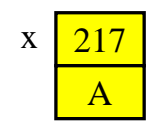
A struct value is a bunch of values glued together

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



A struct variable is a box holding a struct value

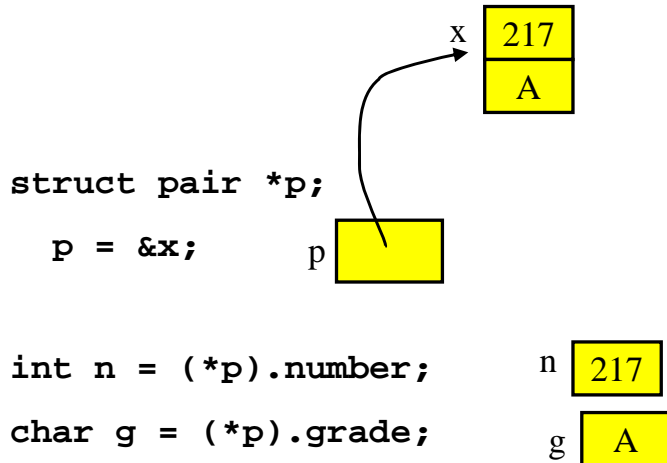
```
struct pair x;
x.number = 217;
x.grade = 'A';
```



## Pointers to structs



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

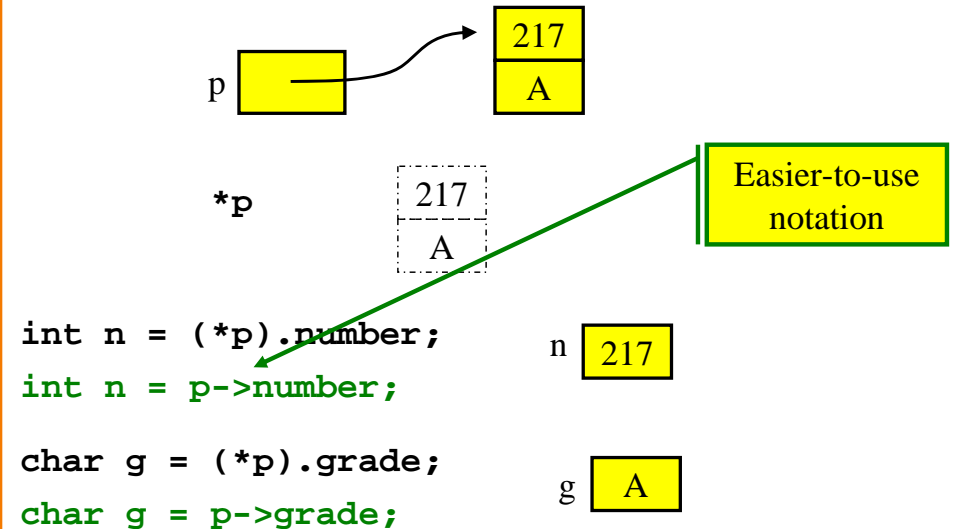


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## Dereferencing Fields



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

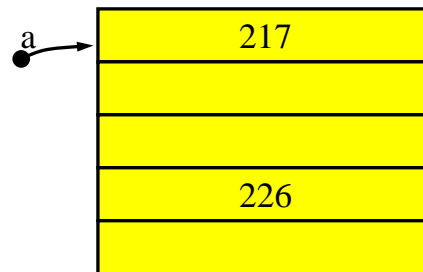


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## Arrays in C



```
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!

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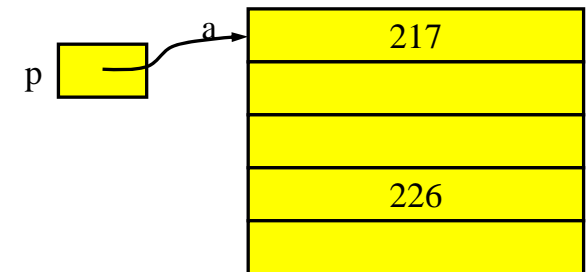
## Arrays and Pointers



```
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];`

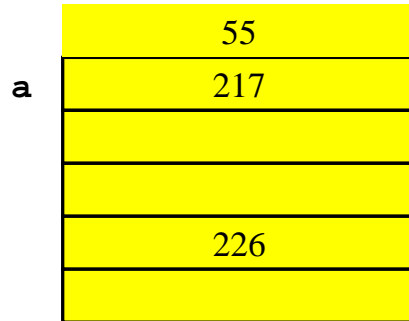
Wrong: `a = p;`     `3 = i;`

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# C Does Not Do Bounds Checking!



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



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

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

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

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



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

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# Arrays and Pointers



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

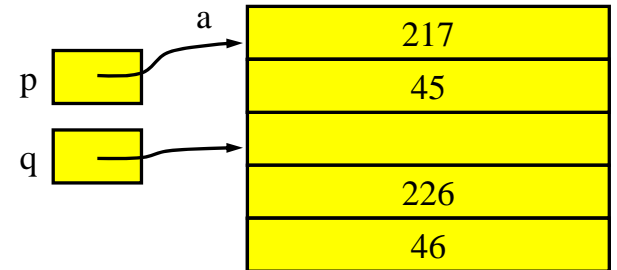
```
int *p, *q;
```

```
p = a;
```

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

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

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

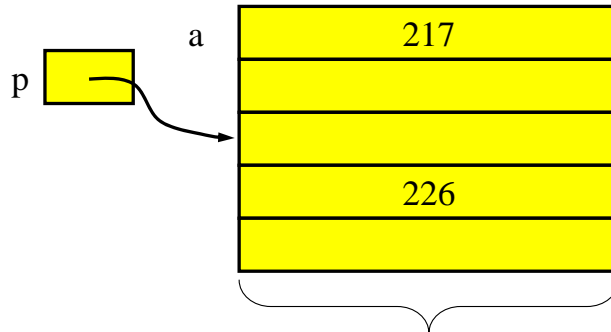


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# Pointer Arithmetic



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



Subscript: **a[i]** “means” **\*(a+i)**

```
int *p;
```

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

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

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# 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];
```

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## 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);
}
```

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## 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!

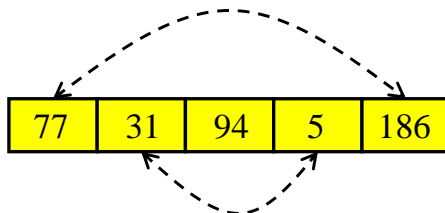
```
int main(void) {
    printArray(fib, 5);
}
```

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## 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
  - ...



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## 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);
}
```

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# 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
```

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# Char Array and Pointer Manipulation



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

mystring J e l l y \0

yourstring [ ] → C e l l o \0

```
mystring[0] = 'J';
yourstring[0] = 'C';
yourstring = mystring;
yourstring[4] = 'y';
mystring = yourstring;
```

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# 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);
```

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# 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?*

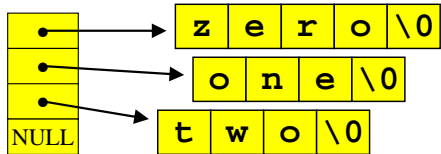
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## Boxes and Arrows



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*

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## Summary of Today's Class



- C variables
  - Pointer
  - Struct
  - Array
  - String
- Readings
  - See Course Schedule on Web page!

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