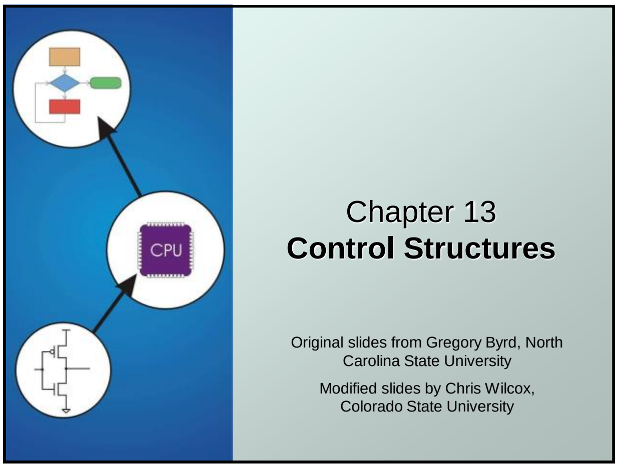
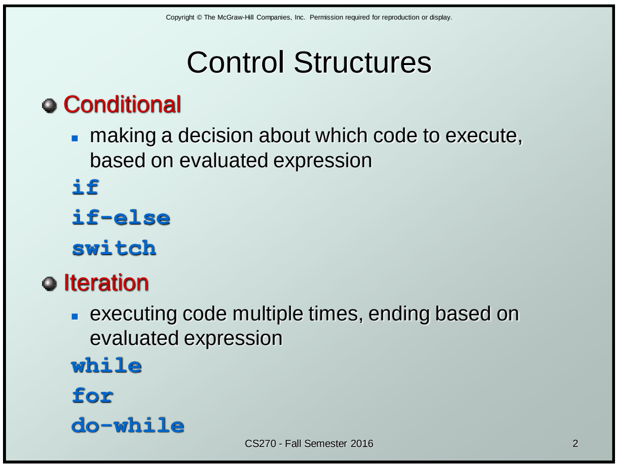


Chapter 13
Control Structures

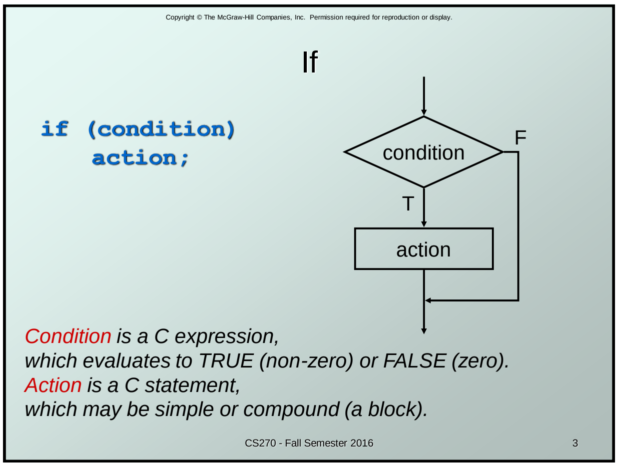
Original slides from Gregory Byrd, North Carolina State University

Modified slides by Chris Wilcox, Colorado State University



Control Structures

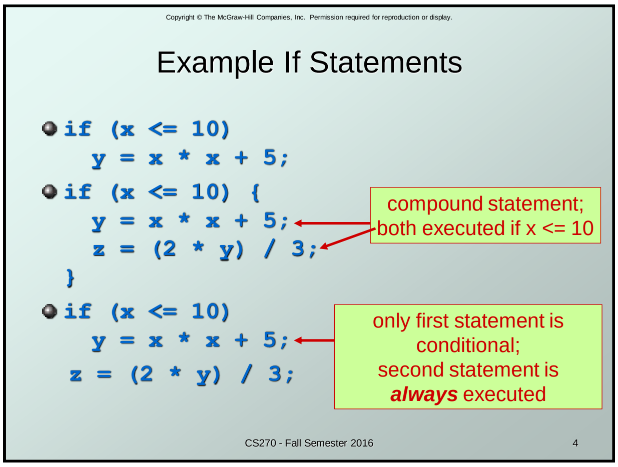
- Conditional
  - making a decision about which code to execute, based on evaluated expression
  - `if`
  - `if-else`
  - `switch`
- Iteration
  - executing code multiple times, ending based on evaluated expression
  - `while`
  - `for`
  - `do-while`



If

```
if (condition)
   action;
```

*Condition is a C expression,
which evaluates to TRUE (non-zero) or FALSE (zero).
Action is a C statement,
which may be simple or compound (a block).*



Example If Statements

```
if (x <= 10)
  y = x * x + 5;
if (x <= 10) {
  y = x * x + 5;
  z = (2 * y) / 3;
}
if (x <= 10)
  y = x * x + 5;
z = (2 * y) / 3;
```

compound statement; both executed if x <= 10

only first statement is conditional; second statement is ***always*** executed

More If Examples

- `if (0 <= age && age <= 11)`
  ```
  if (0 <= age && age <= 11)
     kids += 1;
  ```

-
  ```
  if (month == 4 || month == 6 ||
        month == 9 || month == 11)
     printf("The month has 30 days.\n");
  ```

-
  ```
  if (x = 2)
     y = 5;
  ```

always true,
so action is ***always*** executed!

A common programming error (= instead ==), not caught by compiler because it's syntactically correct.

If's Can Be Nested

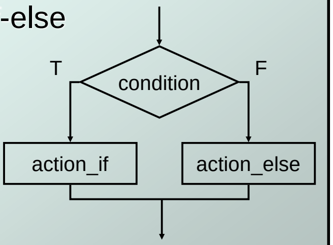
```
if (x == 3)
  if (y != 6)
  {
    z = z + 1;
    w = w + 2;
  }
```

is the same as...

```
if ((x == 3) && (y != 6))
{
  z = z + 1;
  w = w + 2;
}
```

If-else

```
if (condition)
   action_if;
else
   action_else;
```



Else allows choice between two mutually exclusive actions without re-testing condition.

Matching Else with If

- Else is always associated with *closest* unassociated if.

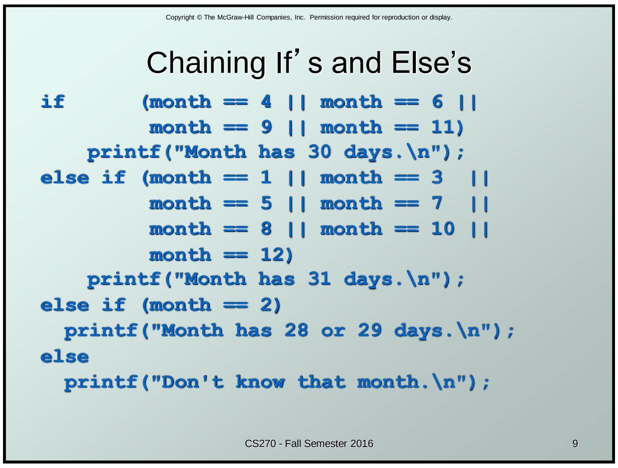
```
if (x != 10)
  if (y > 3)
    z = z / 2;
else
  z = z * 2;
```

is the same as...

```
if (x != 10) {
  if (y > 3)
    z = z / 2;
  else
    z = z * 2;
}
```

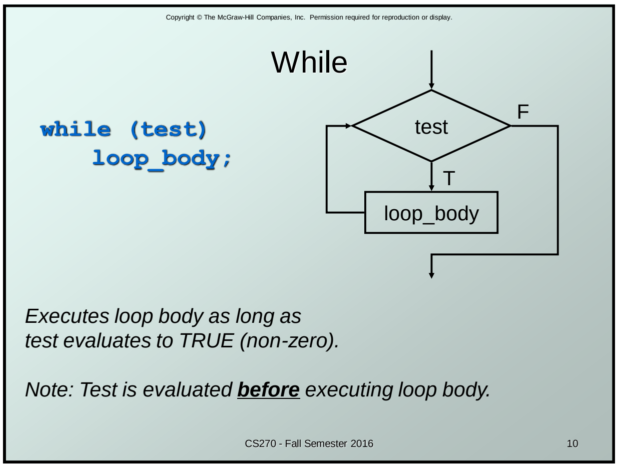
is NOT the same as...

```
if (x != 10) {
  if (y > 3)
    z = z / 2;
}
else
    z = z * 2;
```



Chaining If’ s and Else’s

```
if      (month == 4 || month == 6 ||
         month == 9 || month == 11)
   printf("Month has 30 days.\n");
else if (month == 1 || month == 3  ||
         month == 5 || month == 7  ||
         month == 8 || month == 10 ||
         month == 12)
   printf("Month has 31 days.\n");
else if (month == 2)
  printf("Month has 28 or 29 days.\n");
else
  printf("Don't know that month.\n");
```

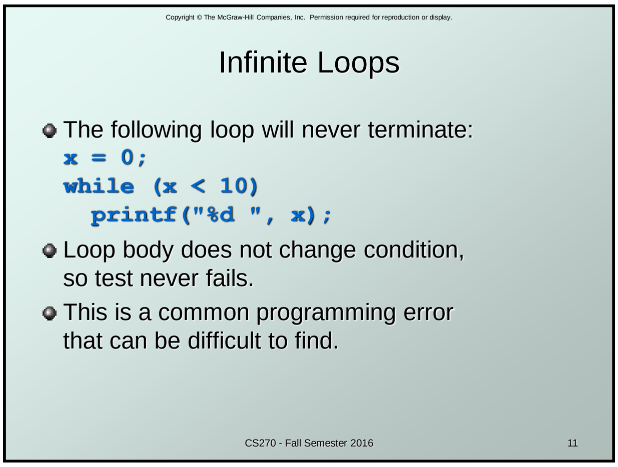


While

```
while (test)
    loop_body;
```

Executes loop body as long as test evaluates to TRUE (non-zero).

Note: Test is evaluated ***before*** *executing loop body.*

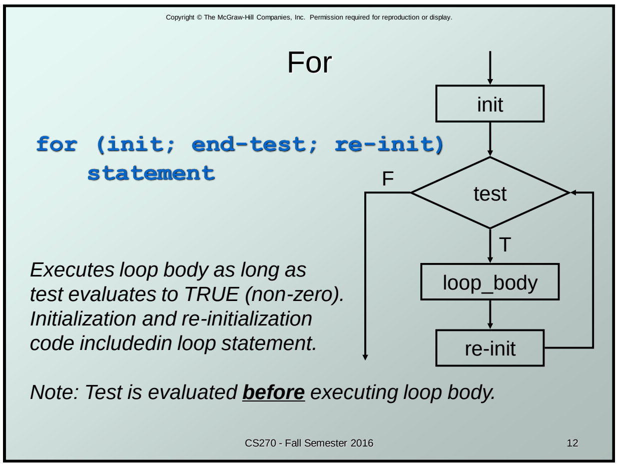


Infinite Loops

- The following loop will never terminate:

```
x = 0;
while (x < 10)
  printf("%d ", x);
```

- Loop body does not change condition, so test never fails.
- This is a common programming error that can be difficult to find.

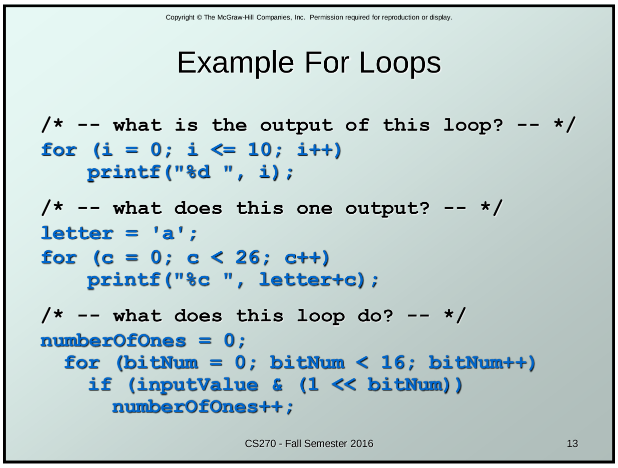


For

```
for (init; end-test; re-init)
    statement
```

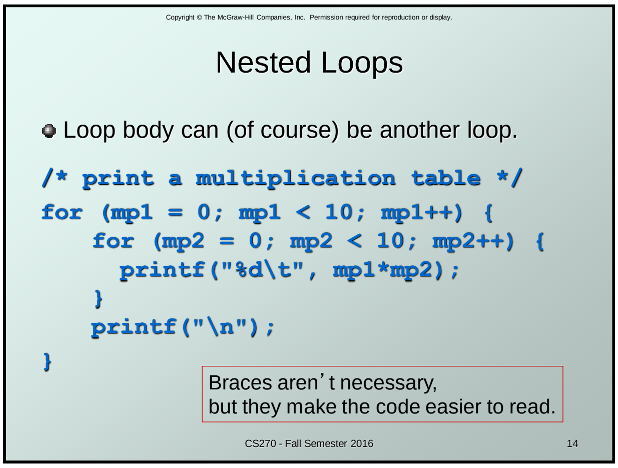
Executes loop body as long as test evaluates to TRUE (non-zero). Initialization and re-initialization code includedin loop statement.

Note: Test is evaluated ***before*** *executing loop body.*



Example For Loops

```
/* -- what is the output of this loop? -- */
for (i = 0; i <= 10; i++)
    printf("%d ", i);

/* -- what does this one output? -- */
letter = 'a';
for (c = 0; c < 26; c++)
    printf("%c ", letter+c);

/* -- what does this loop do? -- */
numberOfOnes = 0;
  for (bitNum = 0; bitNum < 16; bitNum++)
    if (inputValue & (1 << bitNum))
      numberOfOnes++;
```

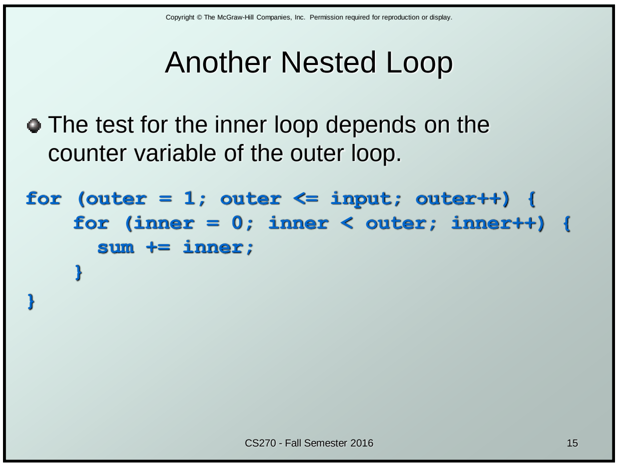


Nested Loops

- Loop body can (of course) be another loop.

```
/* print a multiplication table */
for (mp1 = 0; mp1 < 10; mp1++) {
    for (mp2 = 0; mp2 < 10; mp2++) {
      printf("%d\t", mp1*mp2);
    }
    printf("\n");
}
```

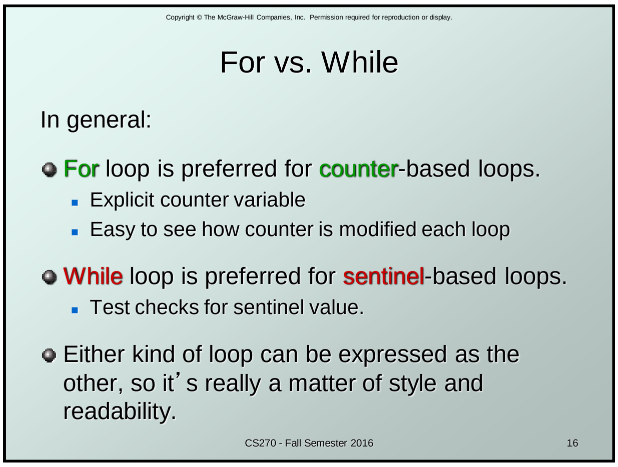
Braces aren't necessary,
but they make the code easier to read.



Another Nested Loop

- The test for the inner loop depends on the counter variable of the outer loop.

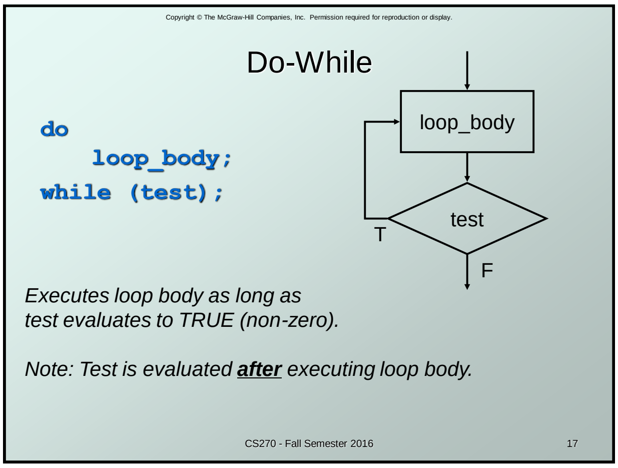
```
for (outer = 1; outer <= input; outer++) {
    for (inner = 0; inner < outer; inner++) {
      sum += inner;
    }
}
```



For vs. While

In general:

- For loop is preferred for counter-based loops.
  - Explicit counter variable
  - Easy to see how counter is modified each loop
- While loop is preferred for sentinel-based loops.
  - Test checks for sentinel value.
- Either kind of loop can be expressed as the other, so it's really a matter of style and readability.



Do-While

```
do
    loop_body;
while (test);
```

loop_body

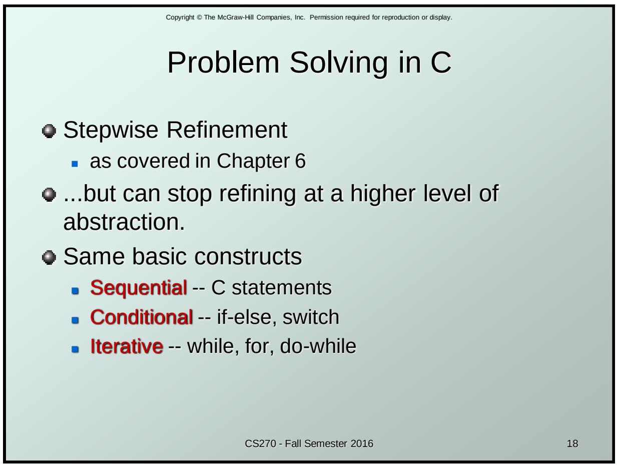
test

T

F

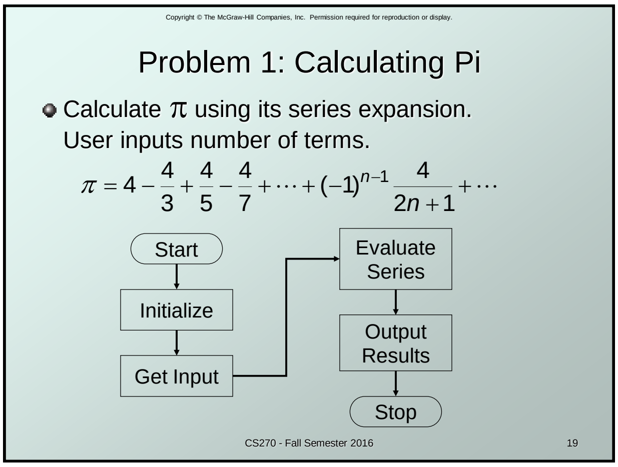
Executes loop body as long as test evaluates to TRUE (non-zero).

*Note: Test is evaluated **after** executing loop body.*



Problem Solving in C

- Stepwise Refinement
  - as covered in Chapter 6
- ...but can stop refining at a higher level of abstraction.
- Same basic constructs
  - Sequential -- C statements
  - Conditional -- if-else, switch
  - Iterative -- while, for, do-while



Problem 1: Calculating Pi

- Calculate π using its series expansion. User inputs number of terms.

$$\pi = 4 - \frac{4}{3} + \frac{4}{5} - \frac{4}{7} + \cdots + (-1)^{n-1}\frac{4}{2n+1} + \cdots$$

Start

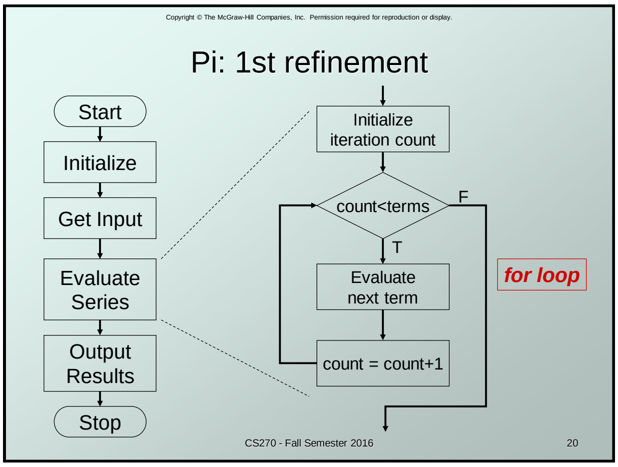
Initialize

Get Input

Evaluate Series

Output Results

Stop



Pi: 1st refinement

Start

Initialize

Get Input

Evaluate Series

Output Results

Stop

Initialize iteration count

count<terms

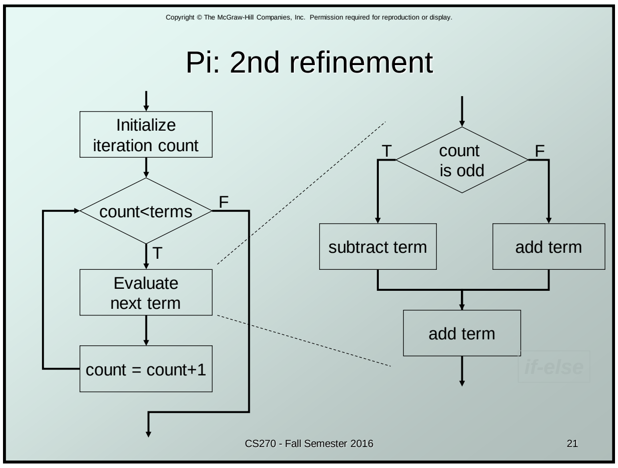
F

T

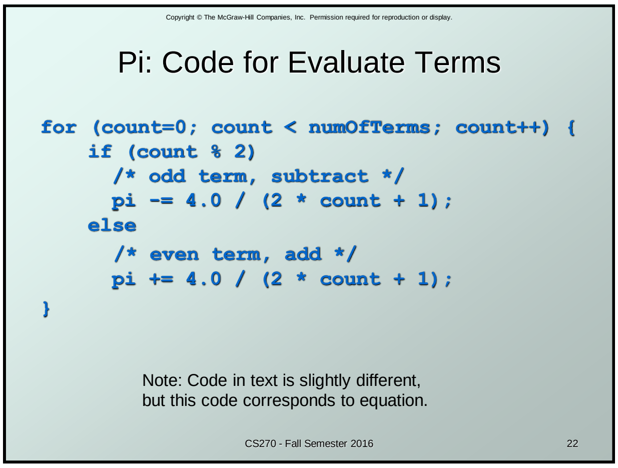
Evaluate next term

count = count+1

for loop



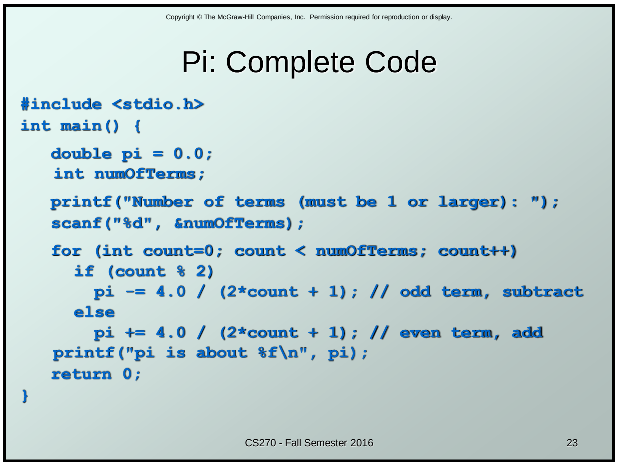
Pi: 2nd refinement



Pi: Code for Evaluate Terms

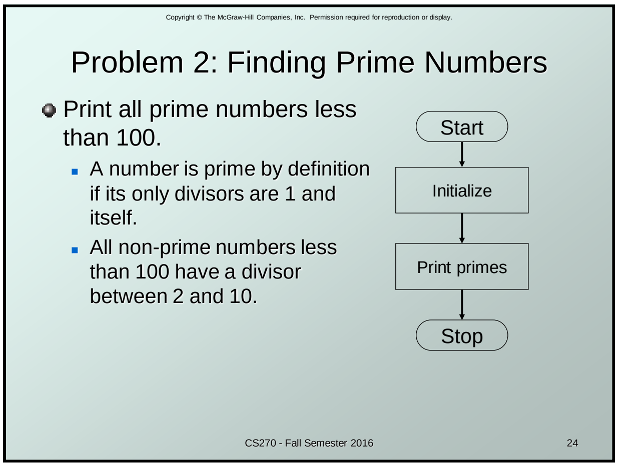
```
for (count=0; count < numOfTerms; count++) {
    if (count % 2)
      /* odd term, subtract */
      pi -= 4.0 / (2 * count + 1);
    else
      /* even term, add */
      pi += 4.0 / (2 * count + 1);
}
```

Note: Code in text is slightly different,
but this code corresponds to equation.



Pi: Complete Code

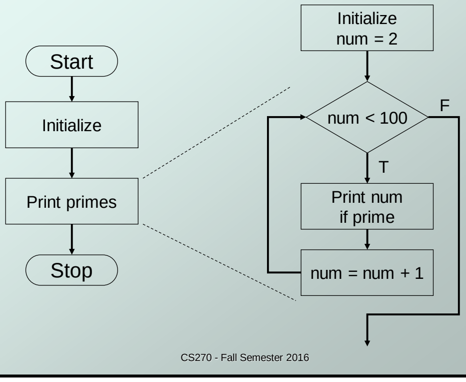
```
#include <stdio.h>
int main() {
   double pi = 0.0;
   int numOfTerms;
   printf("Number of terms (must be 1 or larger): ");
   scanf("%d", &numOfTerms);
   for (int count=0; count < numOfTerms; count++)
     if (count % 2)
       pi -= 4.0 / (2*count + 1); // odd term, subtract
     else
       pi += 4.0 / (2*count + 1); // even term, add
   printf("pi is about %f\n", pi);
   return 0;
}
```



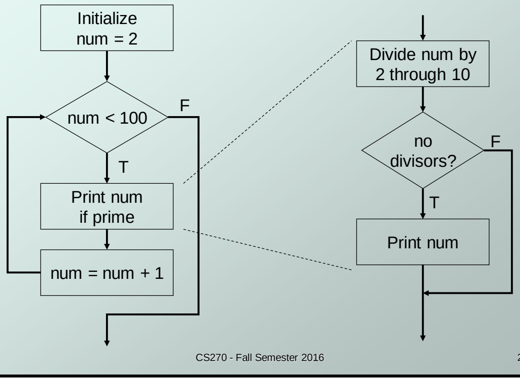
Problem 2: Finding Prime Numbers

- Print all prime numbers less than 100.
  - A number is prime by definition if its only divisors are 1 and itself.
  - All non-prime numbers less than 100 have a divisor between 2 and 10.

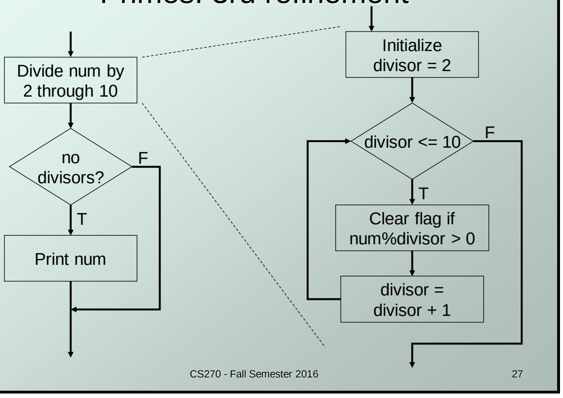
Primes: 1st refinement



Primes: 2nd refinement



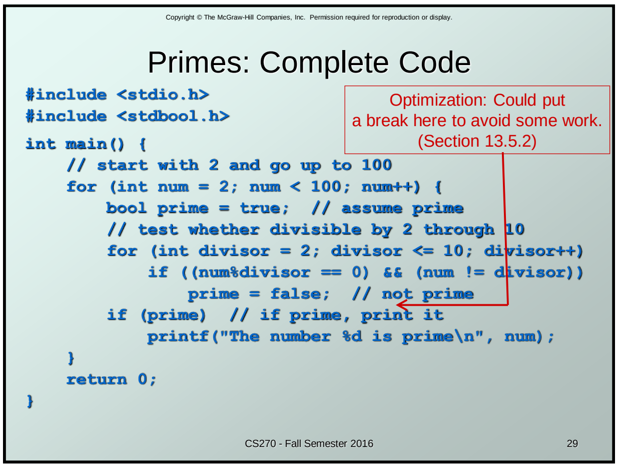
Primes: 3rd refinement



Primes: Using a Flag Variable

- To keep track of whether number was divisible, we use a boolean “flag” variable.
  - Set prime = true, assuming that number is prime.
  - If a divisor divides number evenly, set prime = false.

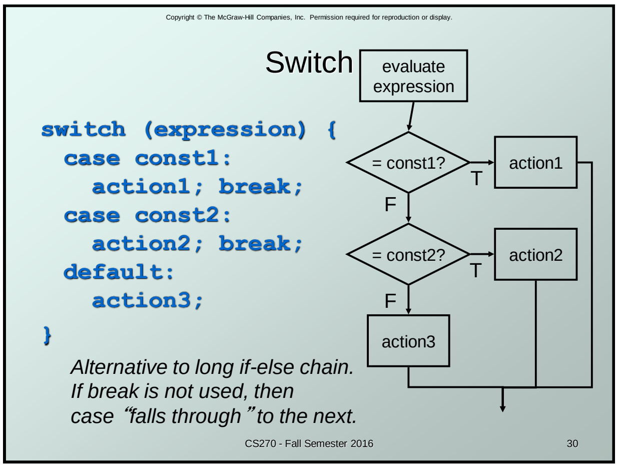
    Once it is set to false, it stays false.
  - After all divisors are checked, number is prime if the flag variable is still true.
- Use <stdbool.h>, which defines the type bool, and the constants true & false.



Primes: Complete Code

```
#include <stdio.h>
#include <stdbool.h>

int main() {
    // start with 2 and go up to 100
    for (int num = 2; num < 100; num++) {
        bool prime = true;  // assume prime
        // test whether divisible by 2 through 10
        for (int divisor = 2; divisor <= 10; divisor++)
            if ((num%divisor == 0) && (num != divisor))
                prime = false;  // not prime
        if (prime)  // if prime, print it
            printf("The number %d is prime\n", num);
    }
    return 0;
}
```

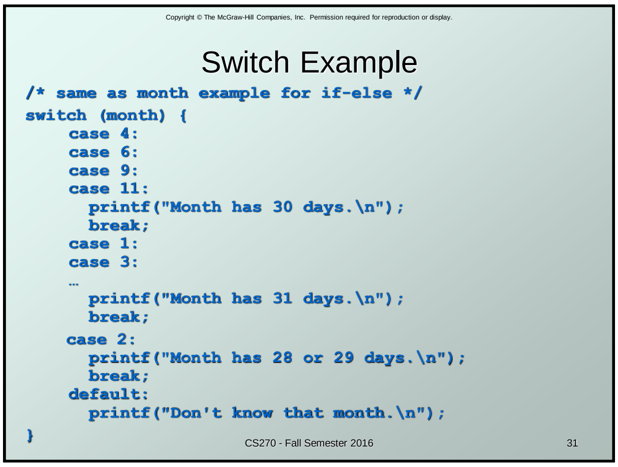
Optimization: Could put a break here to avoid some work. (Section 13.5.2)



Switch

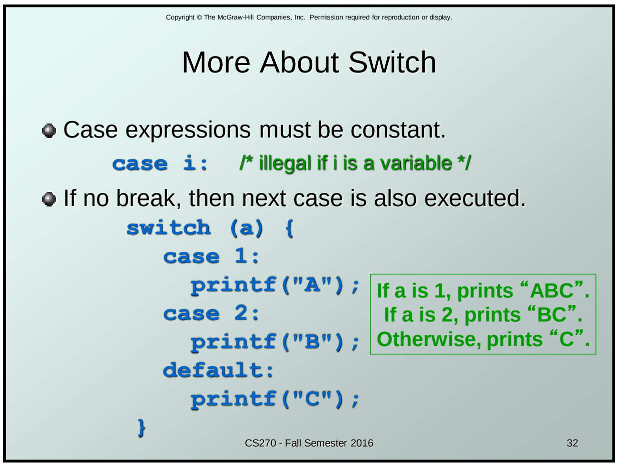
```
switch (expression) {
  case const1:
    action1; break;
  case const2:
    action2; break;
  default:
    action3;
}
```

Alternative to long if-else chain. If break is not used, then case "falls through" to the next.



Switch Example

```
/* same as month example for if-else */
switch (month) {
    case 4:
    case 6:
    case 9:
    case 11:
      printf("Month has 30 days.\n");
      break;
    case 1:
    case 3:
    …
      printf("Month has 31 days.\n");
      break;
    case 2:
      printf("Month has 28 or 29 days.\n");
      break;
    default:
      printf("Don't know that month.\n");
}
```



More About Switch

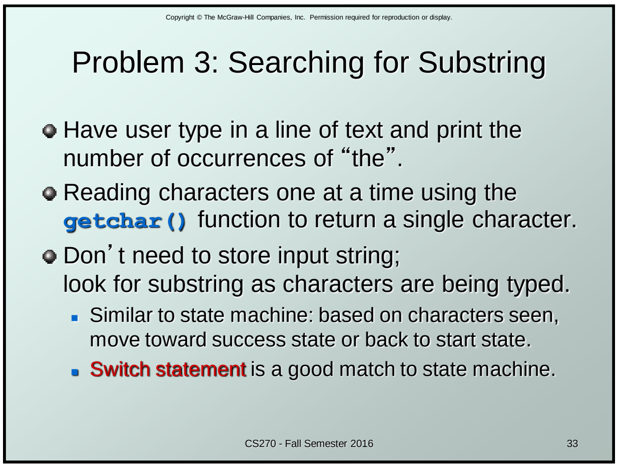
- Case expressions must be constant.

```
case i:   /* illegal if i is a variable */
```

- If no break, then next case is also executed.

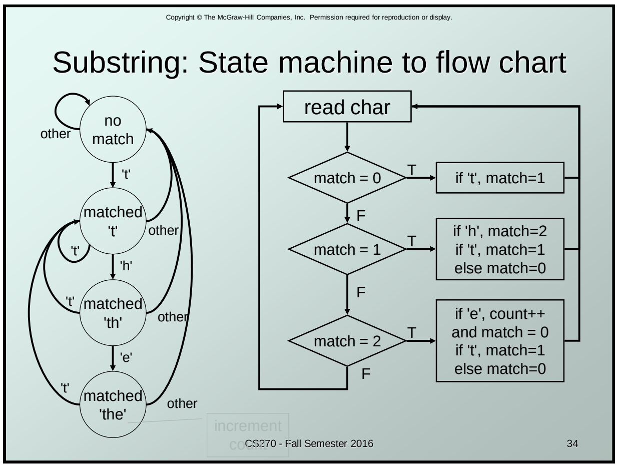
```
switch (a) {
  case 1:
    printf("A");
  case 2:
    printf("B");
  default:
    printf("C");
}
```

If a is 1, prints "ABC". If a is 2, prints "BC". Otherwise, prints "C".



Problem 3: Searching for Substring

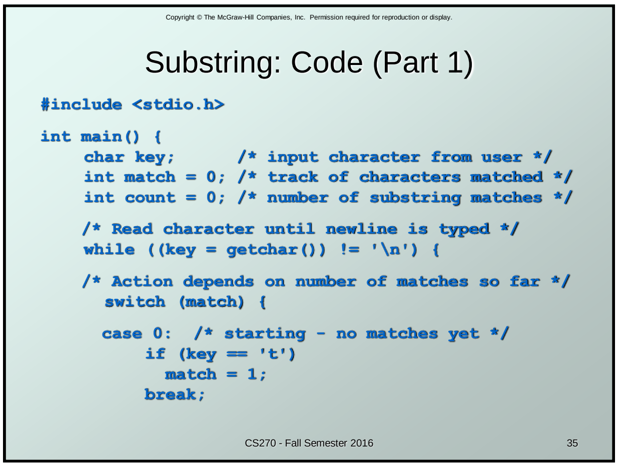
- Have user type in a line of text and print the number of occurrences of “the”.
- Reading characters one at a time using the **`getchar()`** function to return a single character.
- Don’t need to store input string; look for substring as characters are being typed.
  - Similar to state machine: based on characters seen, move toward success state or back to start state.
  - Switch statement is a good match to state machine.



Substring: State machine to flow chart

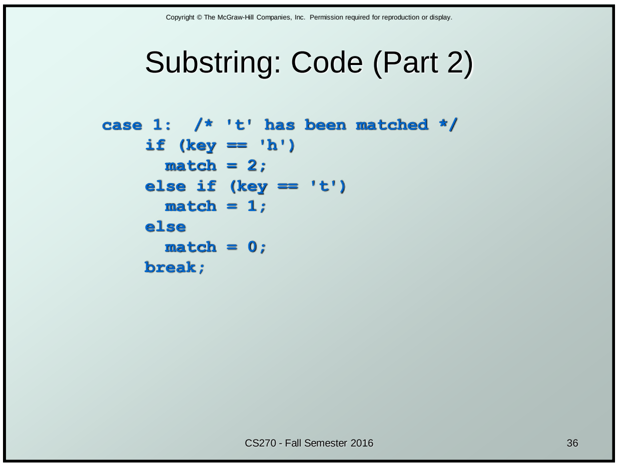
other
no match
't'
matched 't'
other
't'
'h'
't'
matched 'th'
other
'e'
't'
matched 'the'
other
increment count

read char
match = 0
T
if 't', match=1
F
match = 1
T
if 'h', match=2
if 't', match=1
else match=0
F
match = 2
T
if 'e', count++
and match = 0
if 't', match=1
else match=0
F



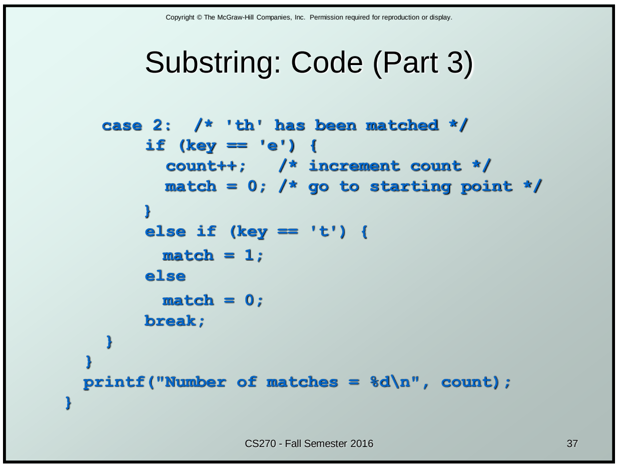
Substring: Code (Part 1)

```
#include <stdio.h>

int main() {
    char key;      /* input character from user */
    int match = 0; /* track of characters matched */
    int count = 0; /* number of substring matches */

    /* Read character until newline is typed */
    while ((key = getchar()) != '\n') {

    /* Action depends on number of matches so far */
      switch (match) {

      case 0:  /* starting - no matches yet */
          if (key == 't')
            match = 1;
          break;
```



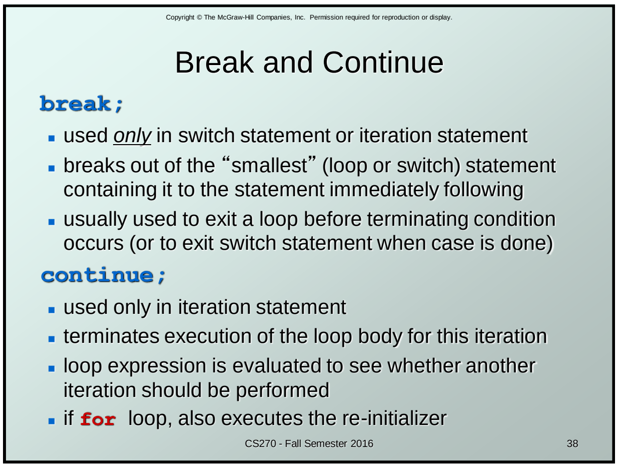
Substring: Code (Part 2)

```
case 1:  /* 't' has been matched */
    if (key == 'h')
      match = 2;
    else if (key == 't')
      match = 1;
    else
      match = 0;
    break;
```



Substring: Code (Part 3)

```
    case 2:  /* 'th' has been matched */
        if (key == 'e') {
          count++;   /* increment count */
          match = 0; /* go to starting point */
        }
        else if (key == 't') {
          match = 1;
        else
          match = 0;
        break;
    }
  }
  printf("Number of matches = %d\n", count);
}
```



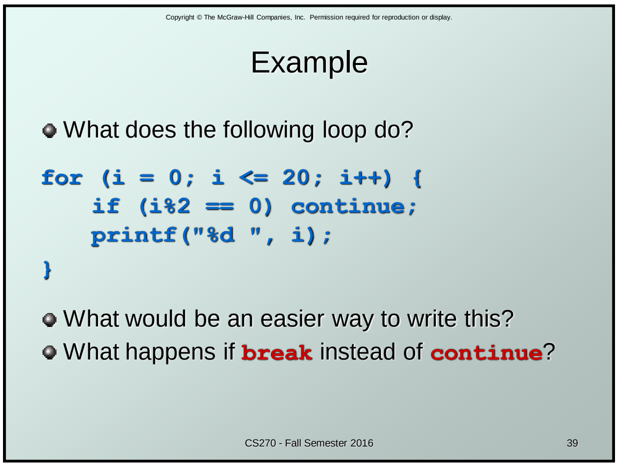
Break and Continue

`break;`

- used *only* in switch statement or iteration statement
- breaks out of the “smallest” (loop or switch) statement containing it to the statement immediately following
- usually used to exit a loop before terminating condition occurs (or to exit switch statement when case is done)

`continue;`

- used only in iteration statement
- terminates execution of the loop body for this iteration
- loop expression is evaluated to see whether another iteration should be performed
- if **`for`** loop, also executes the re-initializer

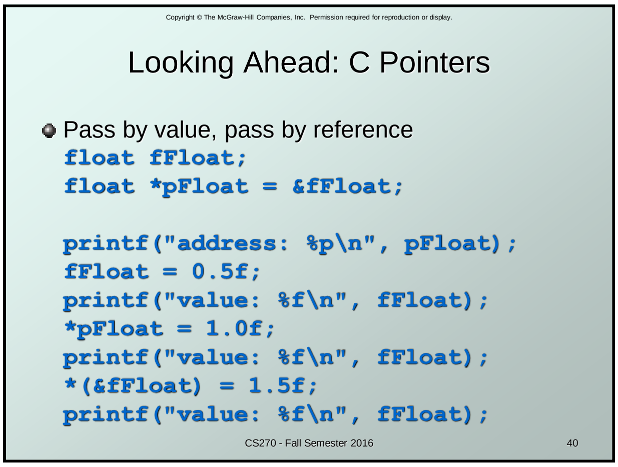


Example

- What does the following loop do?

```
for (i = 0; i <= 20; i++) {
    if (i%2 == 0) continue;
    printf("%d ", i);
}
```

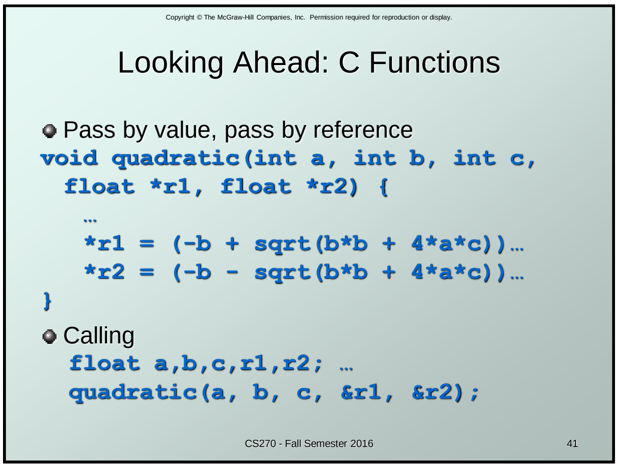
- What would be an easier way to write this?
- What happens if **`break`** instead of **`continue`**?



Looking Ahead: C Pointers

- Pass by value, pass by reference

```
float fFloat;
float *pFloat = &fFloat;

printf("address: %p\n", pFloat);
fFloat = 0.5f;
printf("value: %f\n", fFloat);
*pFloat = 1.0f;
printf("value: %f\n", fFloat);
*(&fFloat) = 1.5f;
printf("value: %f\n", fFloat);
```



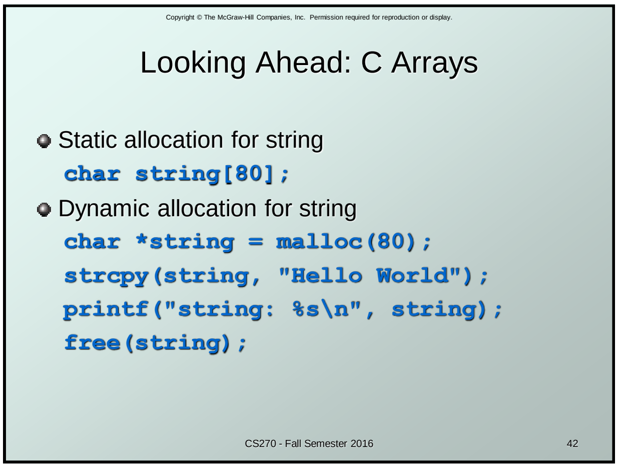
Looking Ahead: C Functions

- Pass by value, pass by reference

```
void quadratic(int a, int b, int c,
  float *r1, float *r2) {
   …
   *r1 = (-b + sqrt(b*b + 4*a*c))…
   *r2 = (-b - sqrt(b*b + 4*a*c))…
}
```

- Calling

```
  float a,b,c,r1,r2; …
  quadratic(a, b, c, &r1, &r2);
```



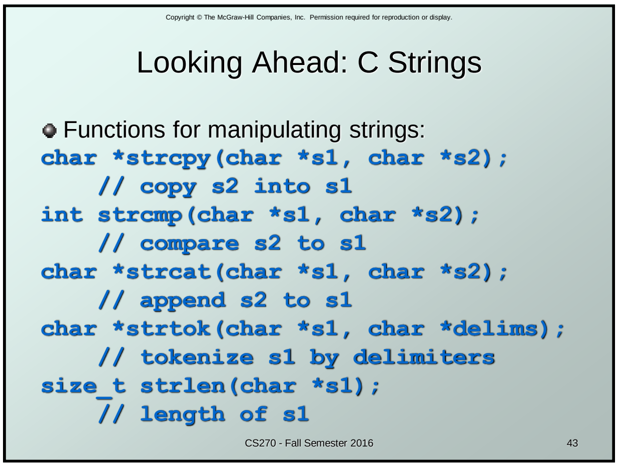
Looking Ahead: C Arrays

- Static allocation for string

```
char string[80];
```

- Dynamic allocation for string

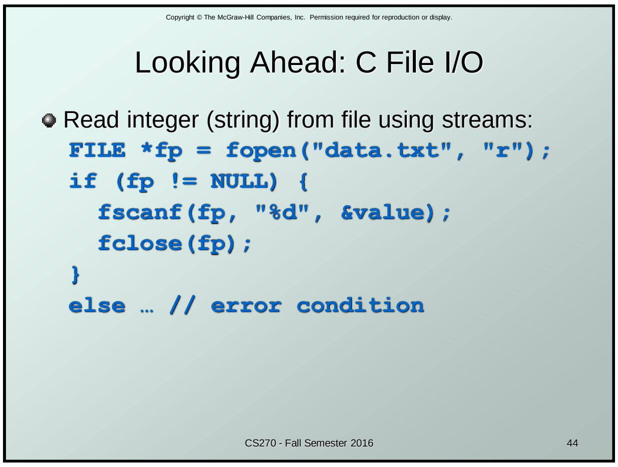
```
char *string = malloc(80);
strcpy(string, "Hello World");
printf("string: %s\n", string);
free(string);
```



Looking Ahead: C Strings

- Functions for manipulating strings:

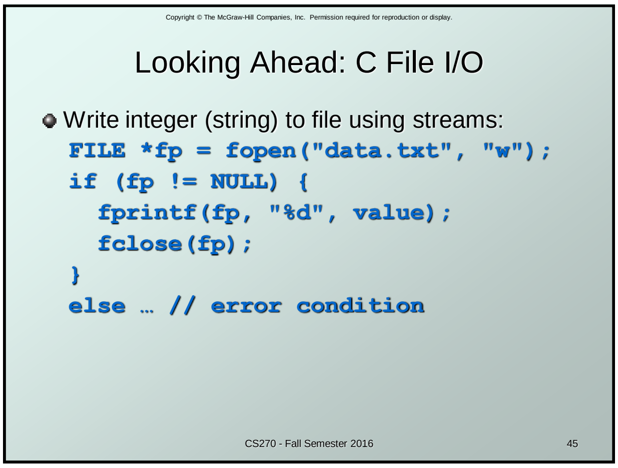
```
char *strcpy(char *s1, char *s2);
    // copy s2 into s1
int strcmp(char *s1, char *s2);
    // compare s2 to s1
char *strcat(char *s1, char *s2);
    // append s2 to s1
char *strtok(char *s1, char *delims);
    // tokenize s1 by delimiters
size_t strlen(char *s1);
    // length of s1
```



Looking Ahead: C File I/O

- Read integer (string) from file using streams:

```
FILE *fp = fopen("data.txt", "r");
if (fp != NULL) {
  fscanf(fp, "%d", &value);
  fclose(fp);
}
else … // error condition
```



Looking Ahead: C File I/O

- Write integer (string) to file using streams:

```
FILE *fp = fopen("data.txt", "w");
if (fp != NULL) {
  fprintf(fp, "%d", value);
  fclose(fp);
}
else … // error condition
```