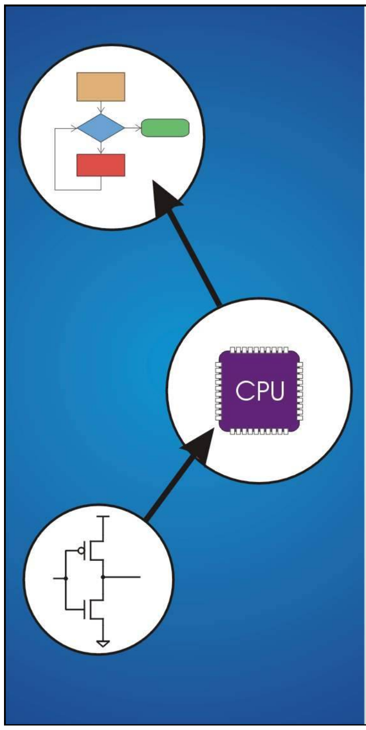


Chapter 13
Control Structures

Original slides from Gregory Byrd, North Carolina State University

Modified slides by C Wilcox, S Rajopadhye
Colorado State University

Control Structures

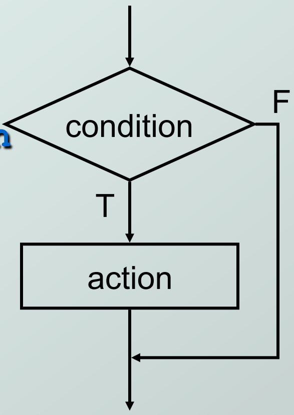
- Conditional
  - making a decision about which code to execute, based on evaluated expression

  `if`
  `if-else`
  `switch`
- Iteration
  - executing code multiple times, ending based on evaluated expression

  `while`
  `for`
  `do-while`

If

```
if (condition)
   statement;//action
```



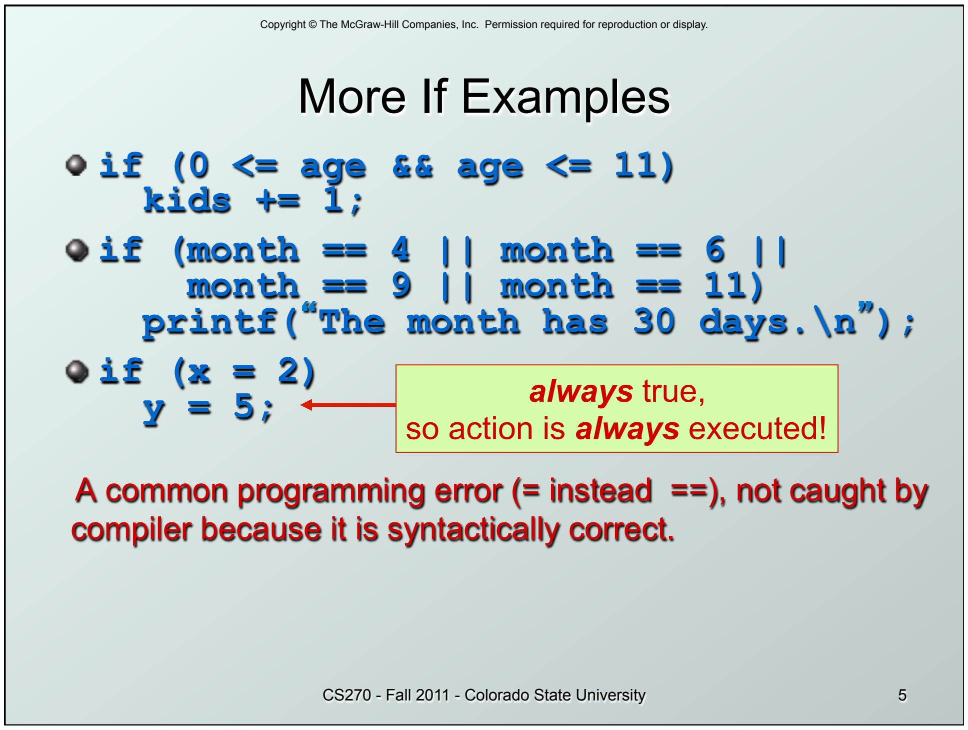
Condition is a C expression,
which evaluates to TRUE (non-zero) or FALSE (zero).
Action is a C statement,
which may be simple or compound (a block).

Example If Statements

-
  ```
  if (x <= 10)
     y = x * x + 5;
  ```

-
  ```
  if (x <= 10) {
     y = x * x + 5;
     z = (2 * y) / 3;
  }
  ```
  compound statement; both executed if x <= 10

-
  ```
  if (x <= 10)
     y = x * x + 5;
  z = (2 * y) / 3;
  ```
  only first statement is conditional; second statement is ***always*** executed



More If Examples

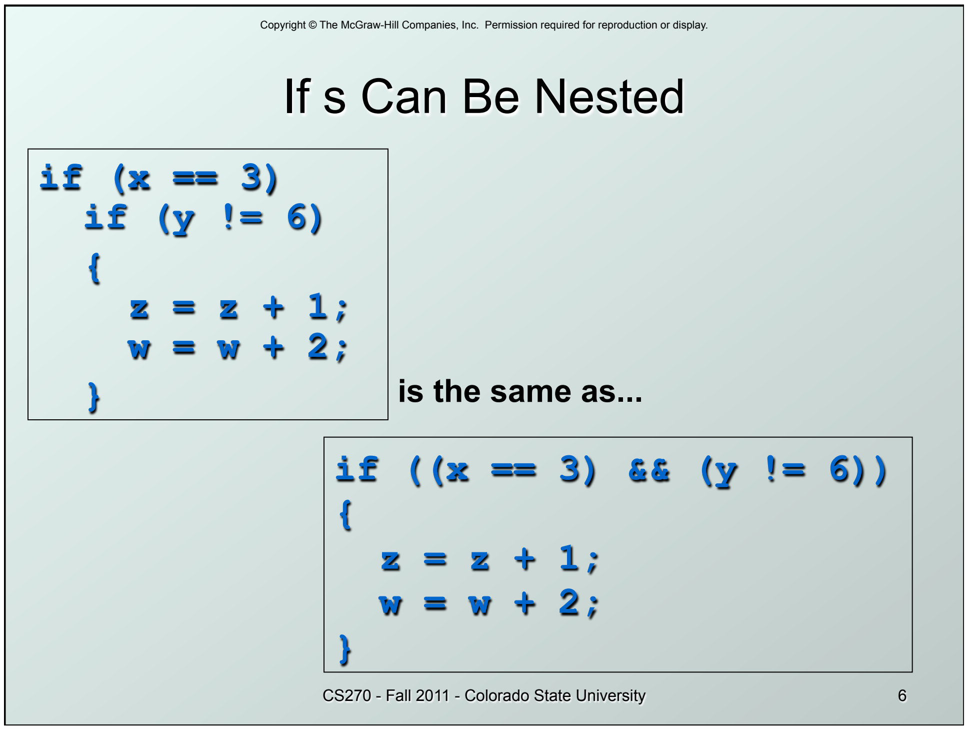
-
  ```
  if (0 <= age && age <= 11)
     kids += 1;
  ```

-
  ```
  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 is syntactically correct.



If s Can Be Nested

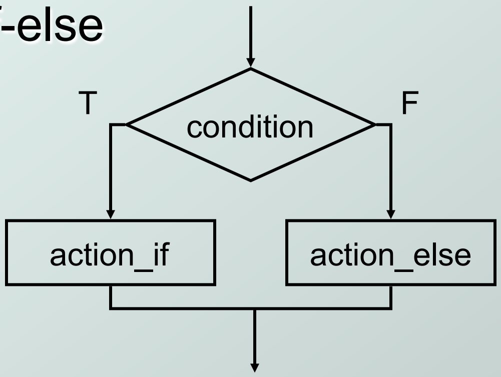
```
if (x == 3)
   if (y != 6)
   {
      z = z + 1;
      w = w + 2;
   }
```

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...

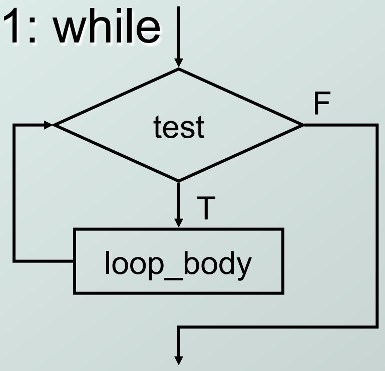
```
if (x != 10) {
  if (y > 3)
    z = z / 2;
}
else
    z = z * 2;
```

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”);
```

Iteration 1: 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

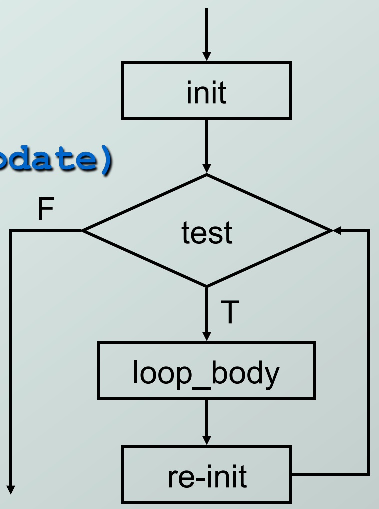
- The following loop will never terminate:

```
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; update)
    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 make the code more readable. Also avoids bugs when editing

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;
    }
  }
```

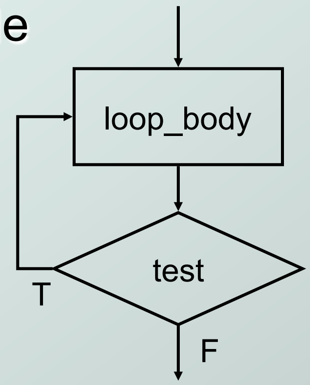
For vs. While

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);
```



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

Note: Test is evaluated ***after*** *executing loop body. So* loop_body *is executed* ***at least once***

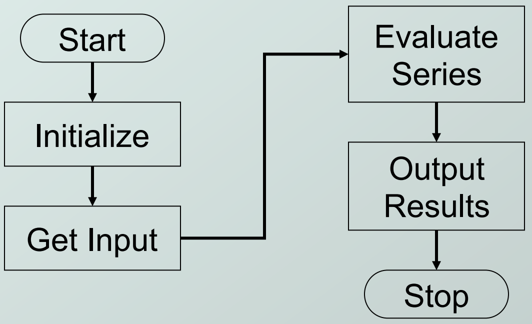
Problem Solving in C

- 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

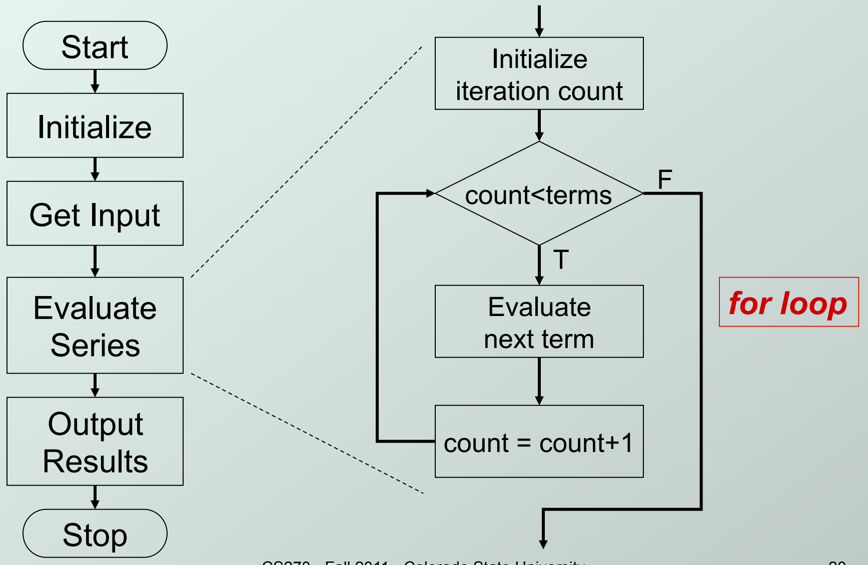
Problem 1: Calculating Pi

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

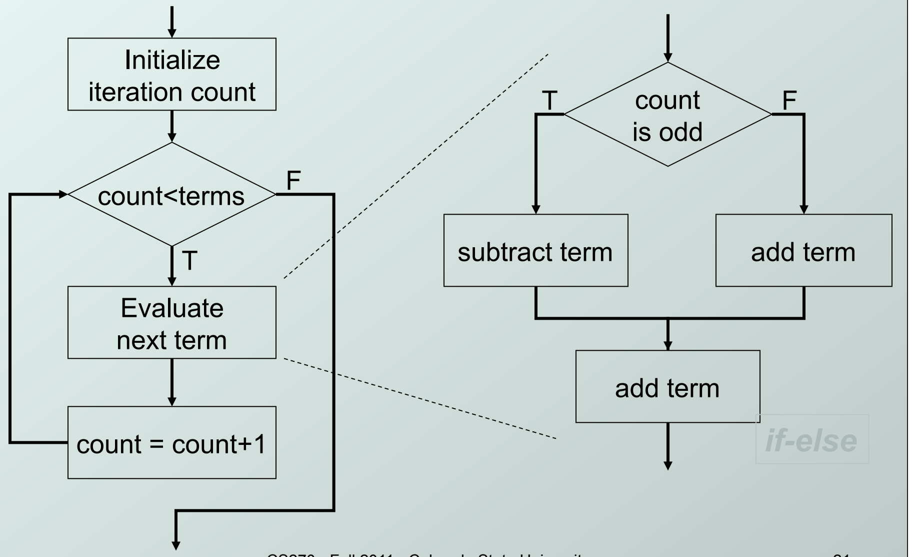
$$\pi = 4 - \frac{4}{3} + \frac{4}{5} - \frac{4}{7} + \cdots + (-1)^{n-1}\frac{4}{2n+1} + \cdots$$



Pi: 1st refinement



Pi: 2nd refinement



Pi: Code for "Evaluate next Term"

```
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);
  }
```

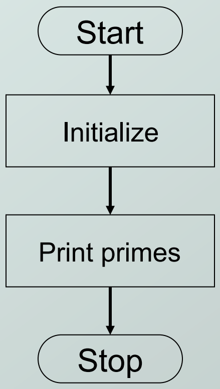
Note: Code in text is slightly different,
but this code corresponds to equation.

Pi: Complete Code

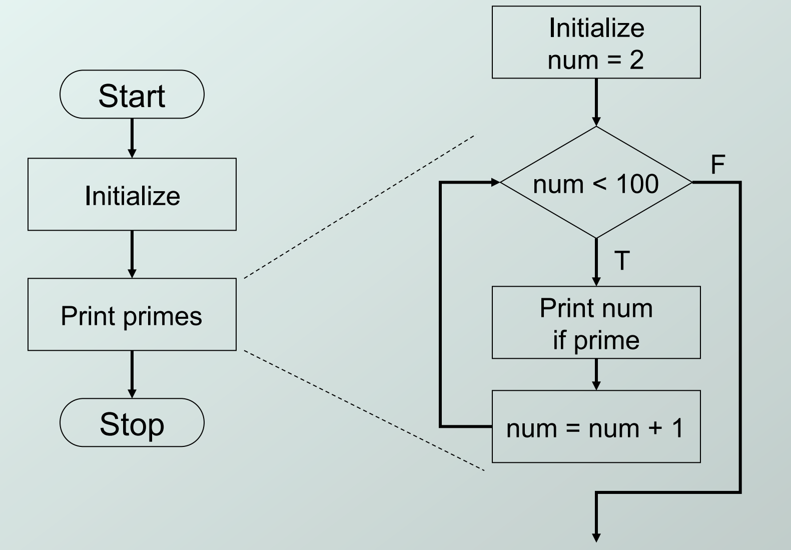
```
#include <stdio.h>
int main(int argc, char *argv[]) {
    double pi = 0.0;
    int numOfTerms, count;
    printf("Number of terms (must be 1 or larger) : ");
    scanf("%d", &numOfTerms);
    for (count=0; count < numOfTerms; count++) {
    if (count % 2) {
      pi -= 4.0 / (2 * count + 1); // odd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

Problem 2: Finding Prime Numbers

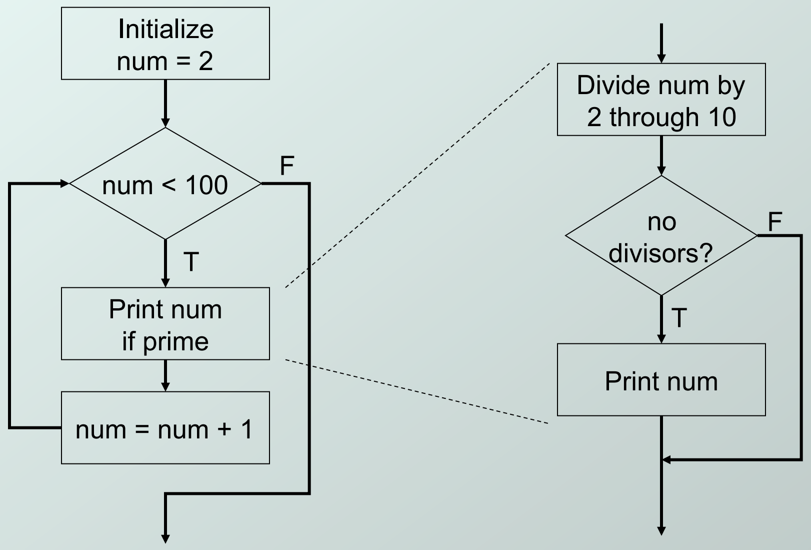
- Print all prime numbers less than 100.
  - A number is prime by definition if its only divisors are 1 and itself.
  - All non-prime numbers less than 100 have a divisor between 2 and 10.



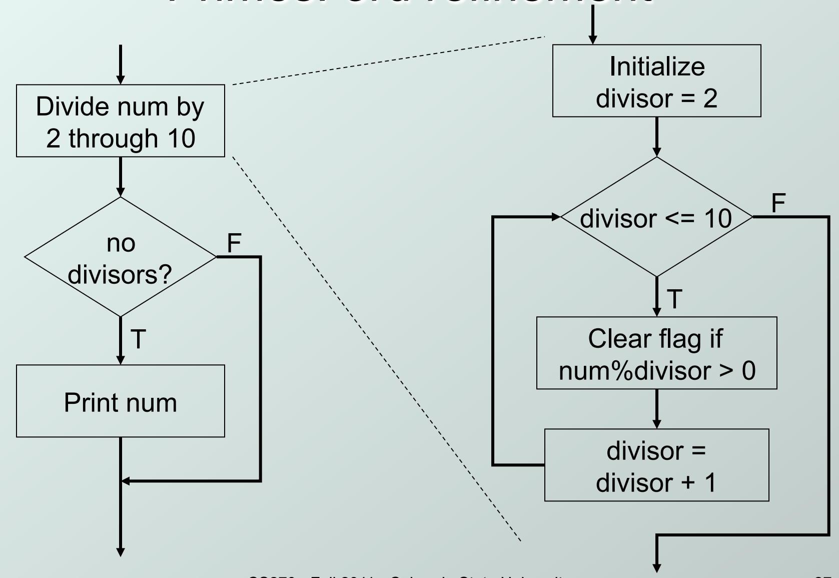
Primes: 1st refinement



Primes: 2nd refinement



Primes: 3rd refinement



Primes: Using a Flag Variable

- To keep track of whether number was divisible, we use a "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 macros to help readability.

```
#define TRUE  1
#define FALSE 0
```

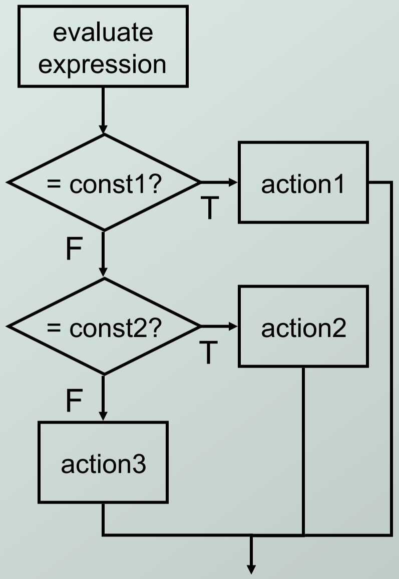
Primes: Complete Code

```
#include <stdio.h>
#define TRUE  1
#define FALSE 0
  int main (int argc, char*argv[]) {
    int num, divisor, prime;
    /* start with 2 and go up to 100 */
    for (num = 2; num < 100; num ++ ) {
      prime = TRUE;  /* assume prime */
      /* test whether divisible by 2 through 10 */
      for (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);
    }
  }
```

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.

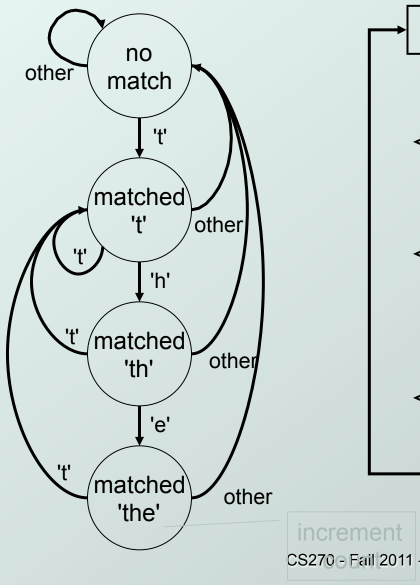
```
switch (a) {
   case 1:
     printf("A");
   case 2:
     printf("B");
   default:
     printf("C");
}
```

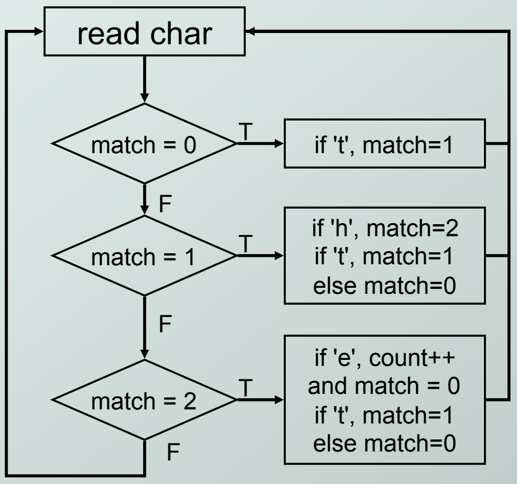
If a is 1, prints "ABC".
If a is 2, prints "BC".
Otherwise, prints "C".

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



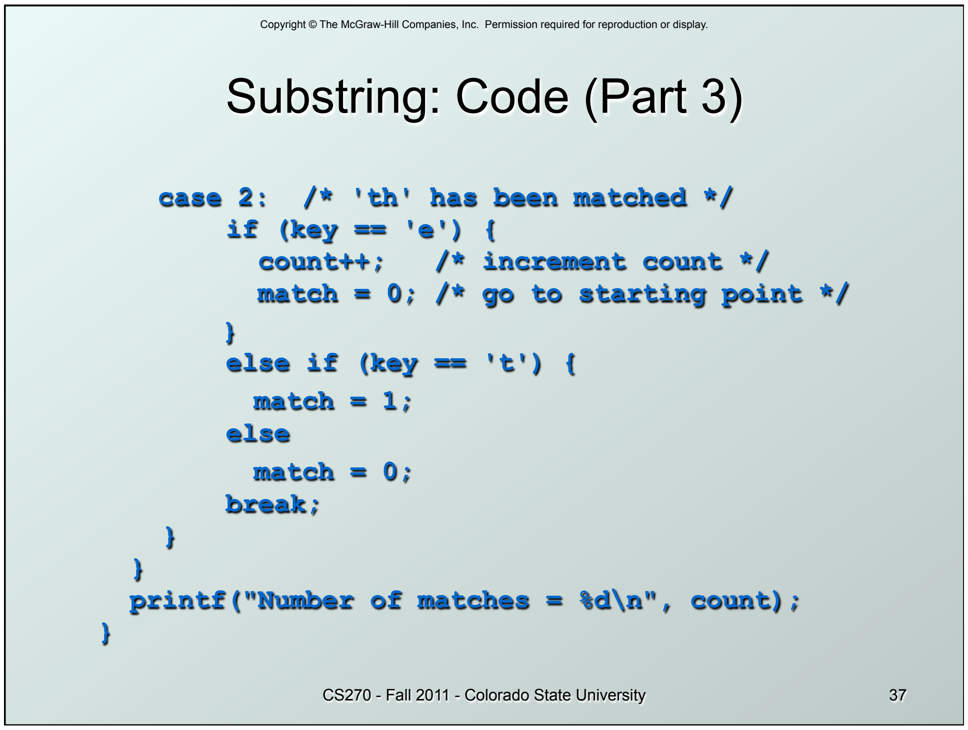


Substring: Code (Part 1)

```
#include <stdio.h>

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;
```

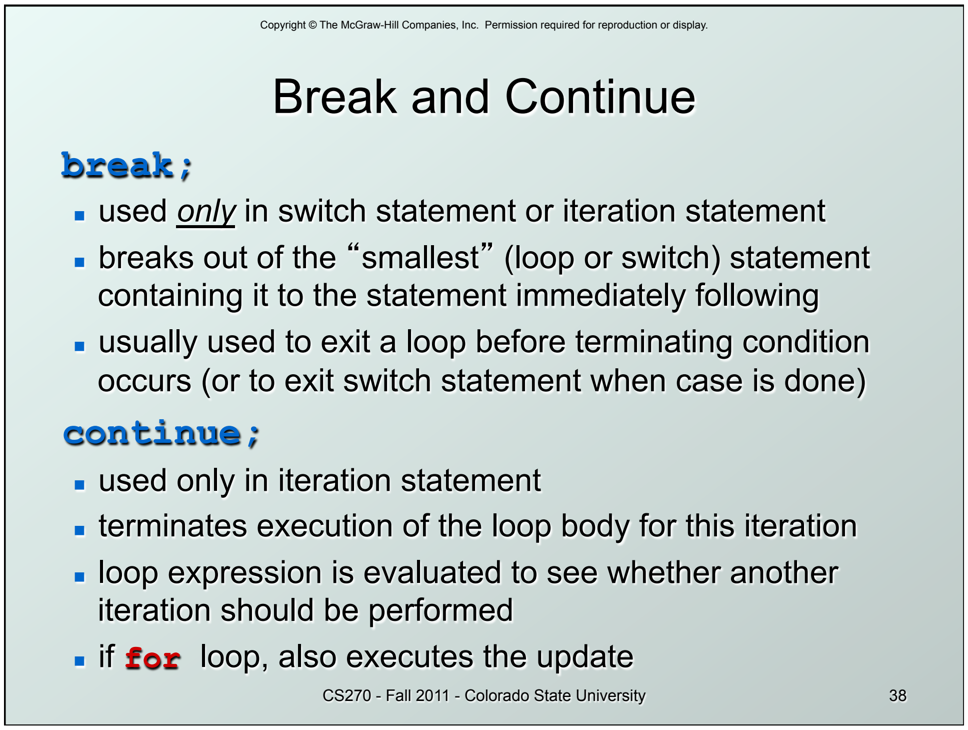
Substring: Code (Part 2)

```
       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 update

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