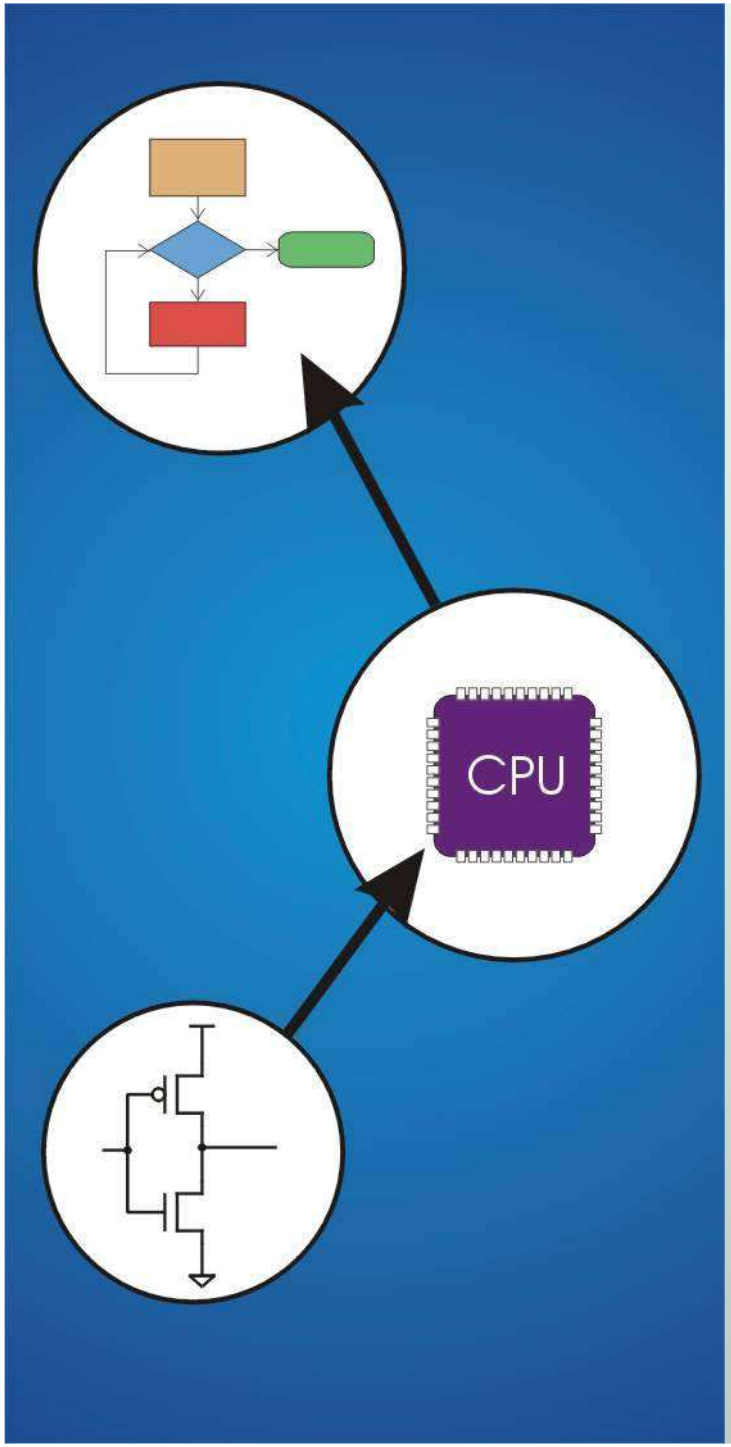

Chapter 13
Control Structures

Original slides from Gregory Byrd, North Carolina State University

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Control Structures

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

  `if`

  `if-else`

  `switch`

We will also see
Problem solving: stepwise refinements
Examples

- Iteration
  - executing code multiple times, ending based on evaluated expression

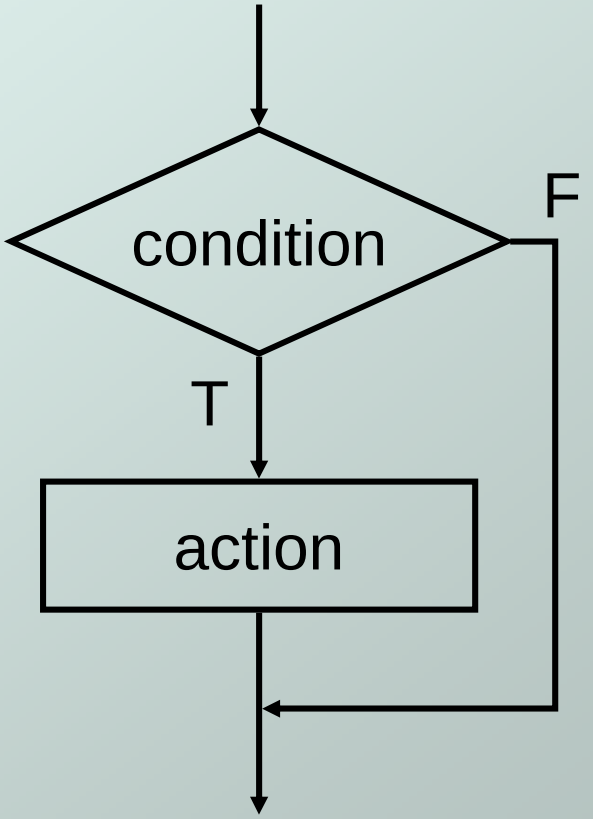
  `while`

  `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;
}
```

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's syntactically correct.

If's Can Be Nested

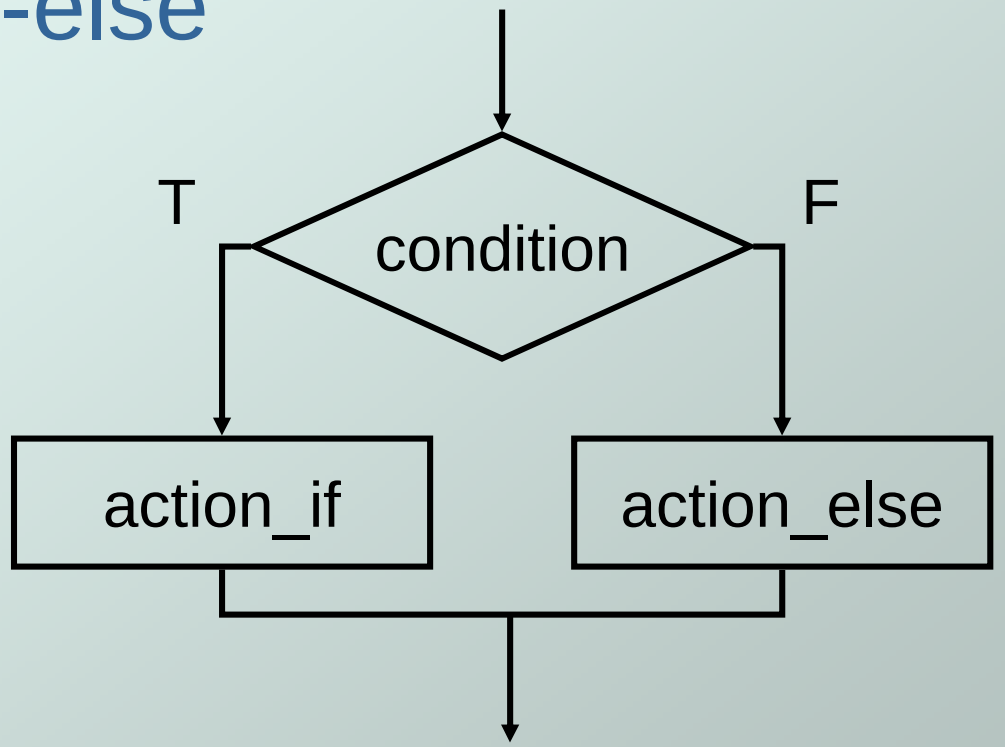
```
if (x == 3)
   if (y != 6)
   {
      z = z + 1;
      w = w + 2;
   }
```

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...

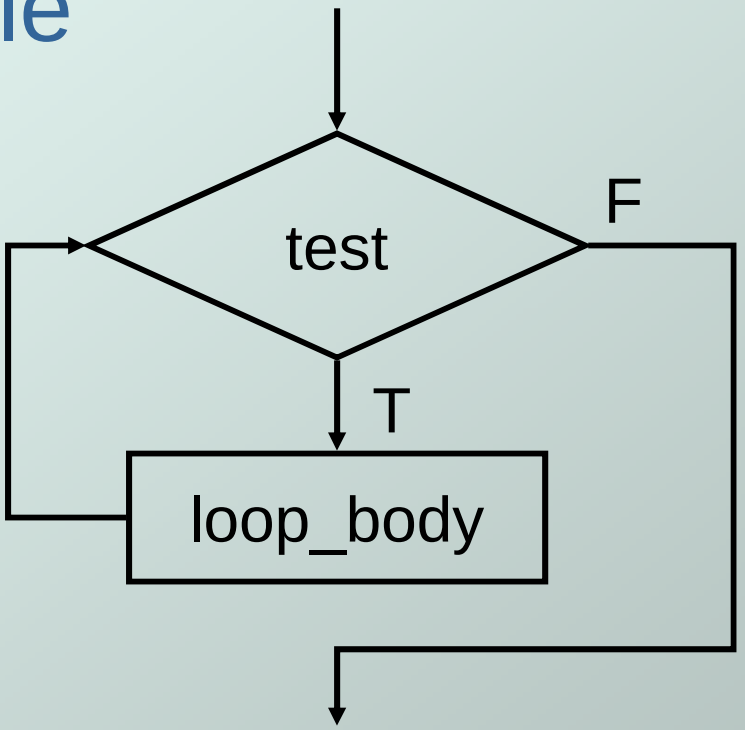
```
if (x != 10) {
  if (y > 3)
    z = z / 2;
}
else
    z = z * 2;
```

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

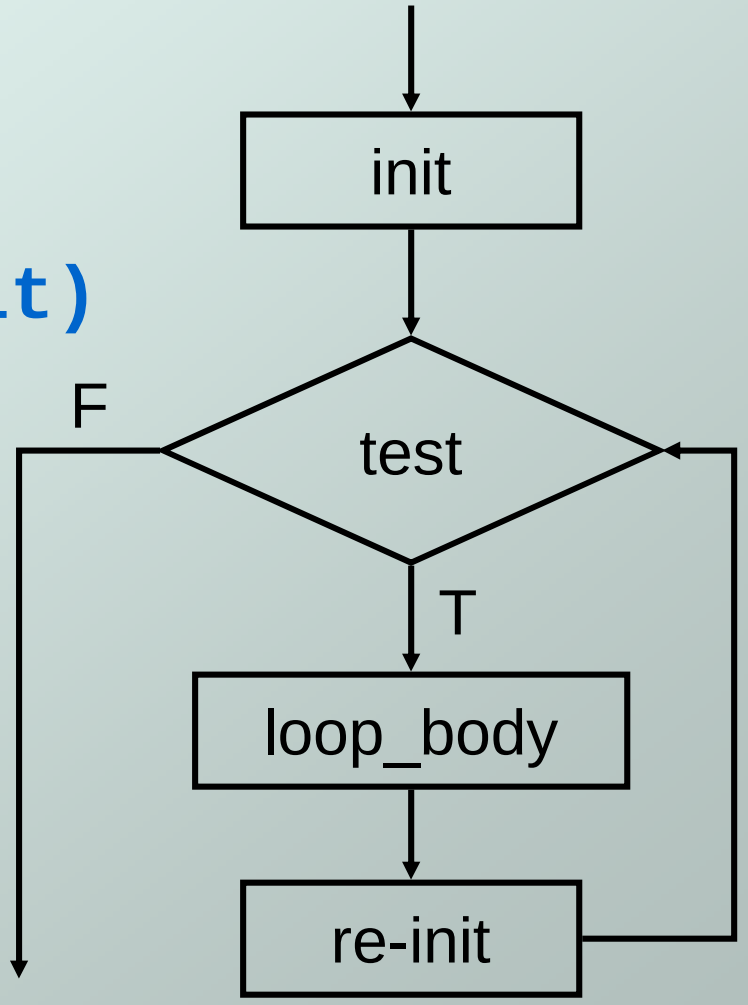
- The following loop will never terminate:

```
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; 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++) {

}
```

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;
    }
  }
```

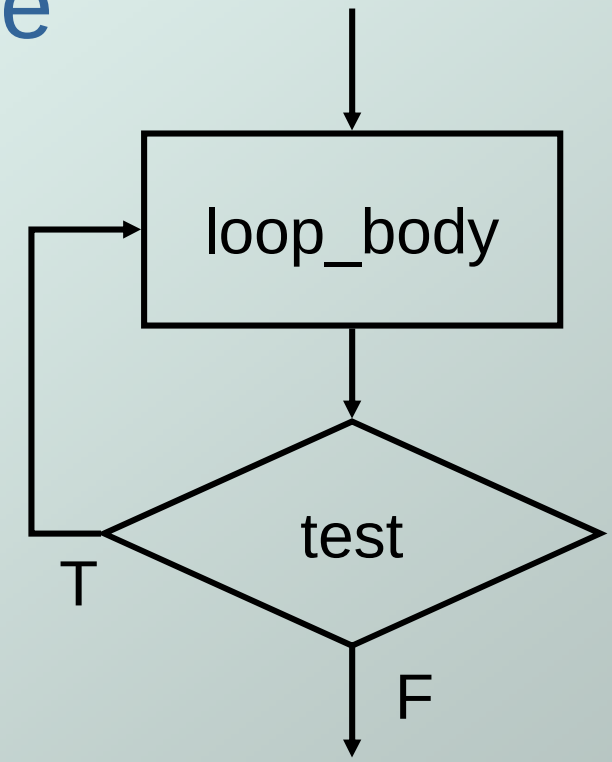
For vs. While

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);
```



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

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

Problem Solving in C

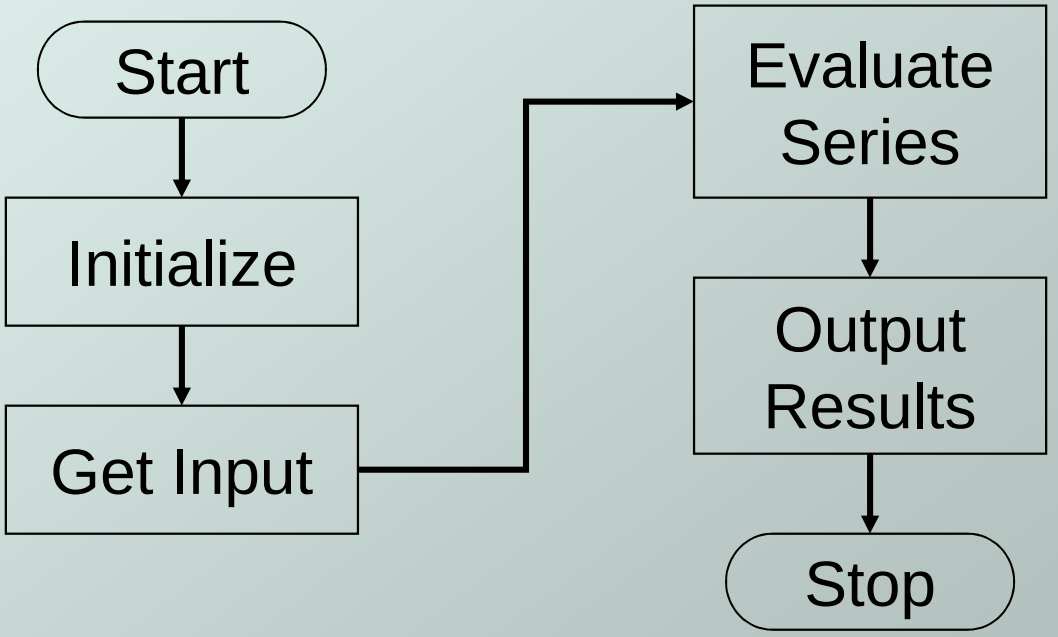
- Stepwise Refinement
  - as covered in Chapter 6
- ...but can stop refining at a higher level of abstraction.
- Same basic constructs
  - Sequential -- C statements
  - Conditional -- if-else, switch
  - Iterative -- while, for, do-while

Problem solving: stepwise refinements
- Calculating π
- Prime numbers
- Substring searching

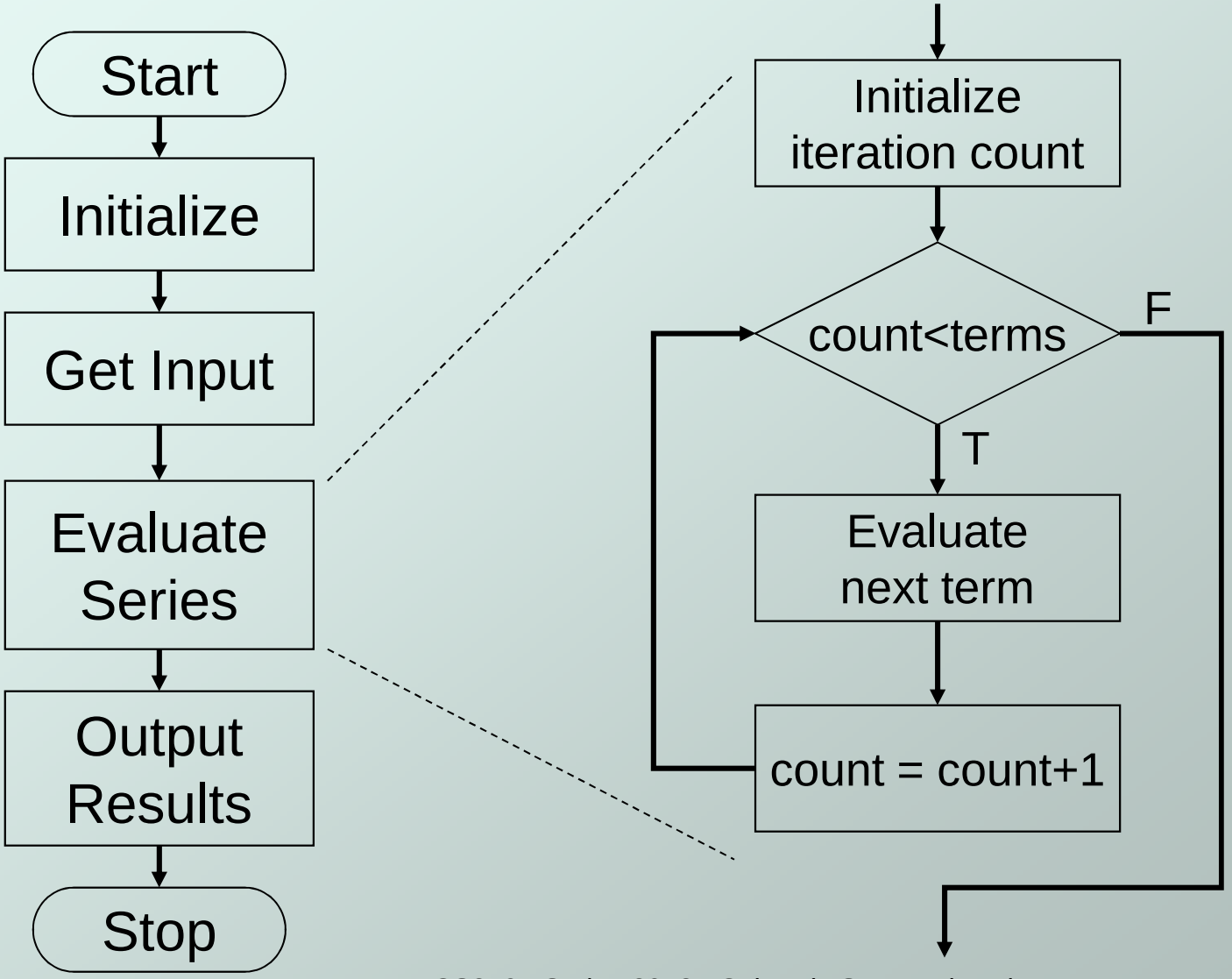
Problem 1: Calculating Pi

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

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

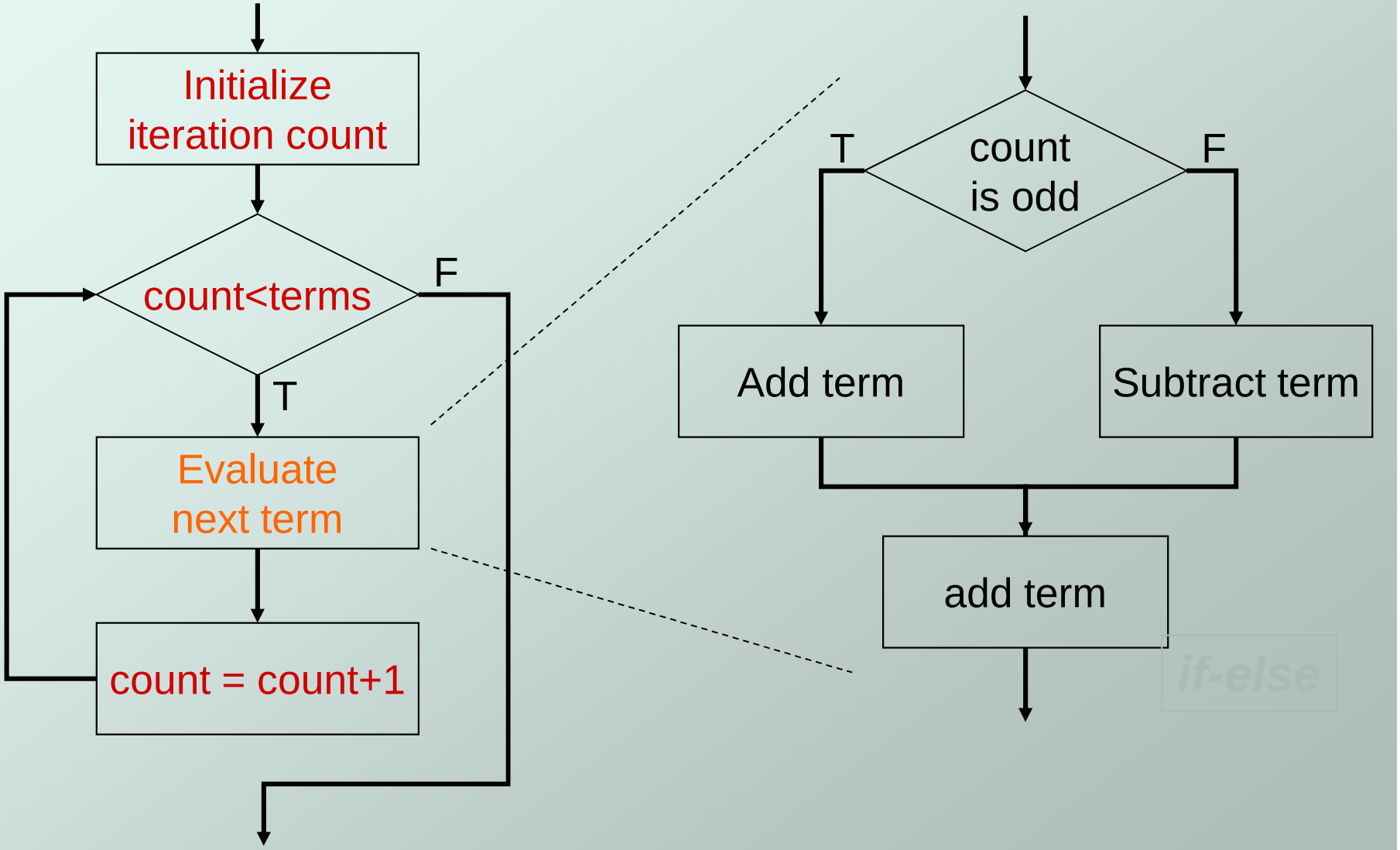


Pi: 1st refinement



for loop

Pi: 2nd refinement



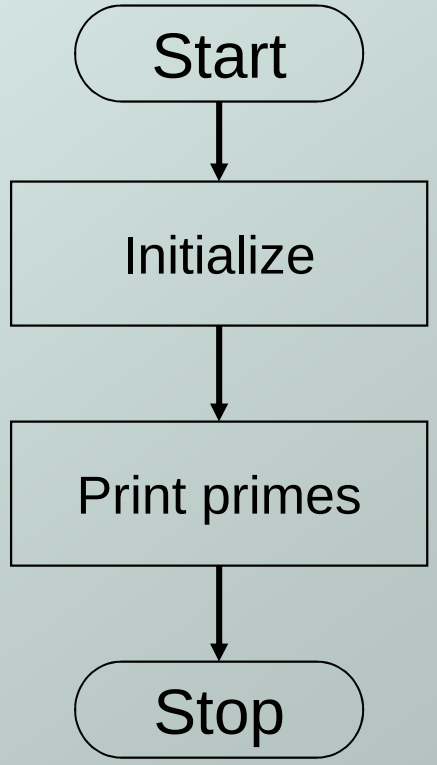
Pi: Complete Code

```
#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=1; count <= numOfTerms; count++) {
    if (count % 2) {
      pi += 4.0 / (2 * count - 1); // odd term, add
    } else {
      pi -= 4.0 / (2 * count - 1); // even term, subtract
    }
   }
    printf("The approximate value of pi is %f\n", pi);
}
```

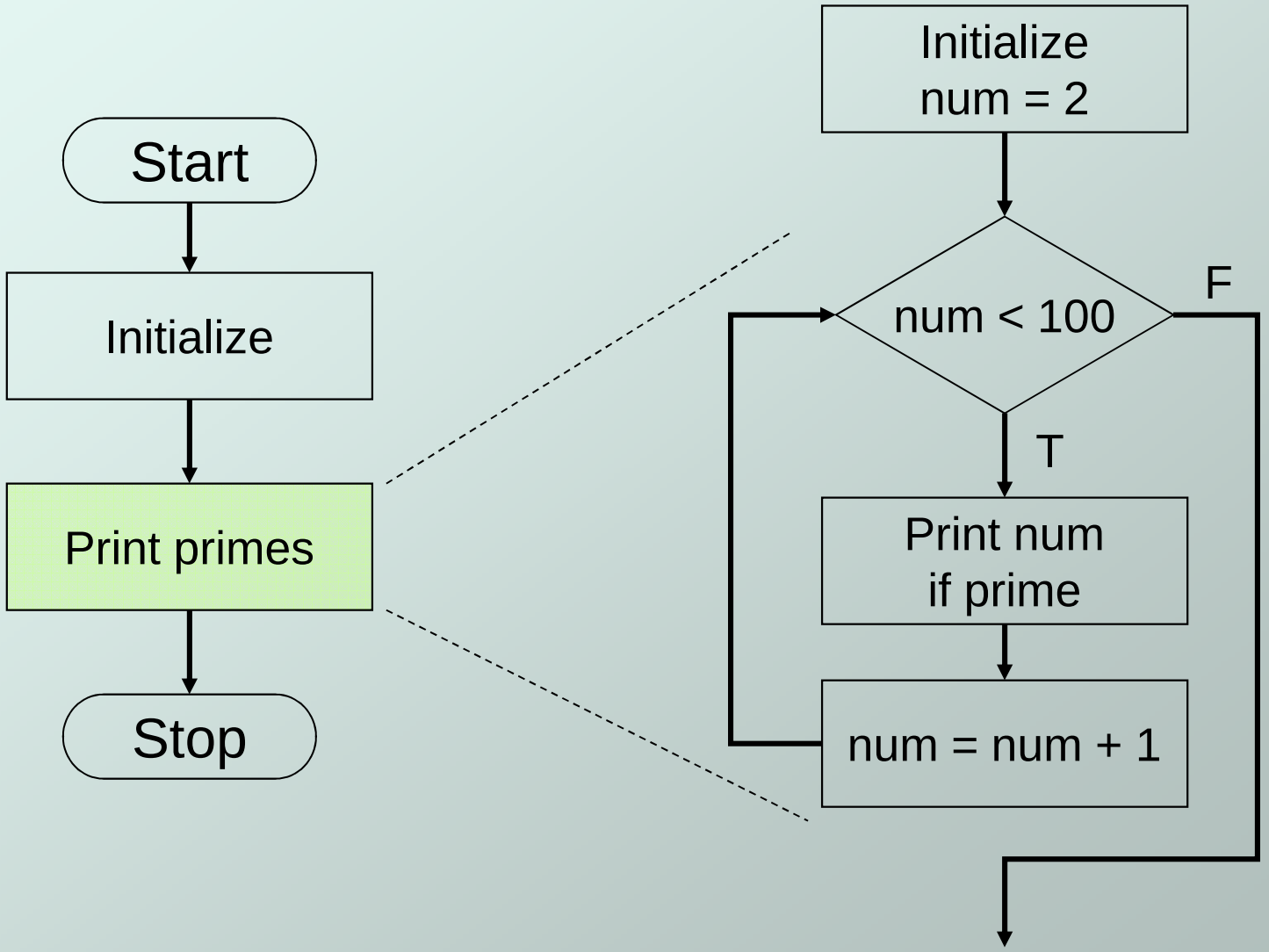
Note: First term is term 1

Problem 2: Finding Prime Numbers

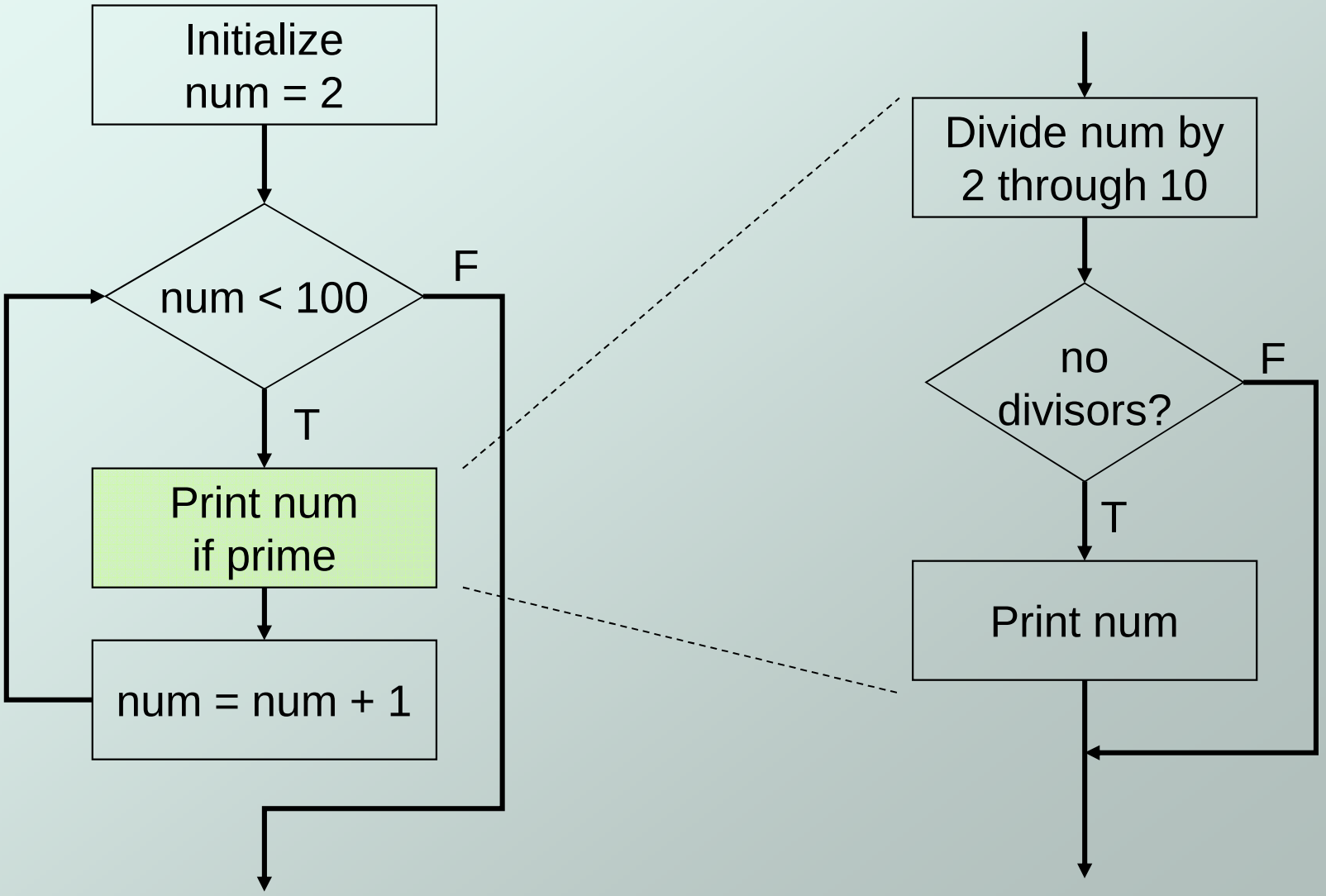
- Print all prime numbers less than 100.
  - A number is prime by definition if its only divisors are 1 and itself.
  - All non-prime numbers less than 100 have a divisor between 2 and 10.



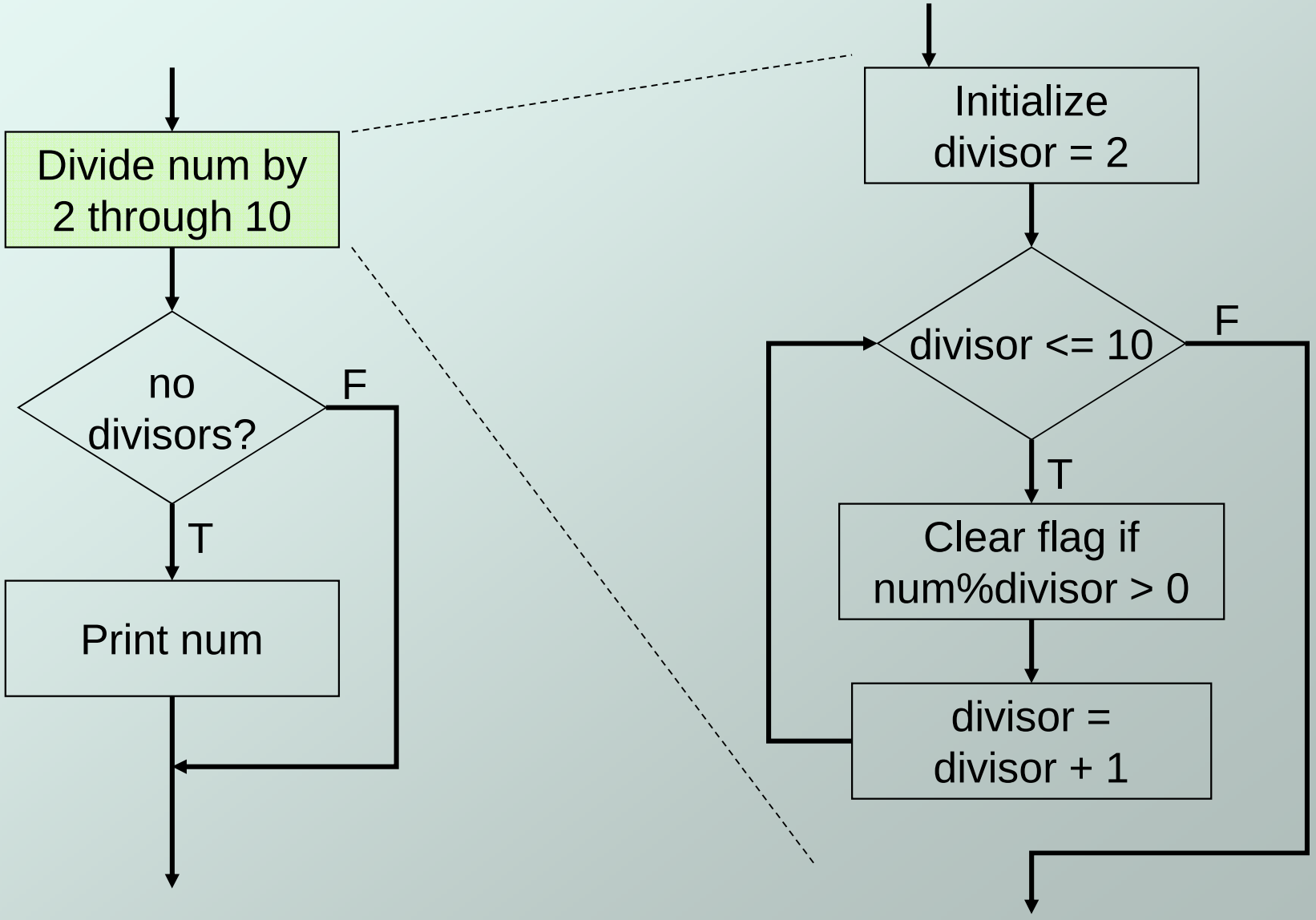
Primes: 1st refinement



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
```

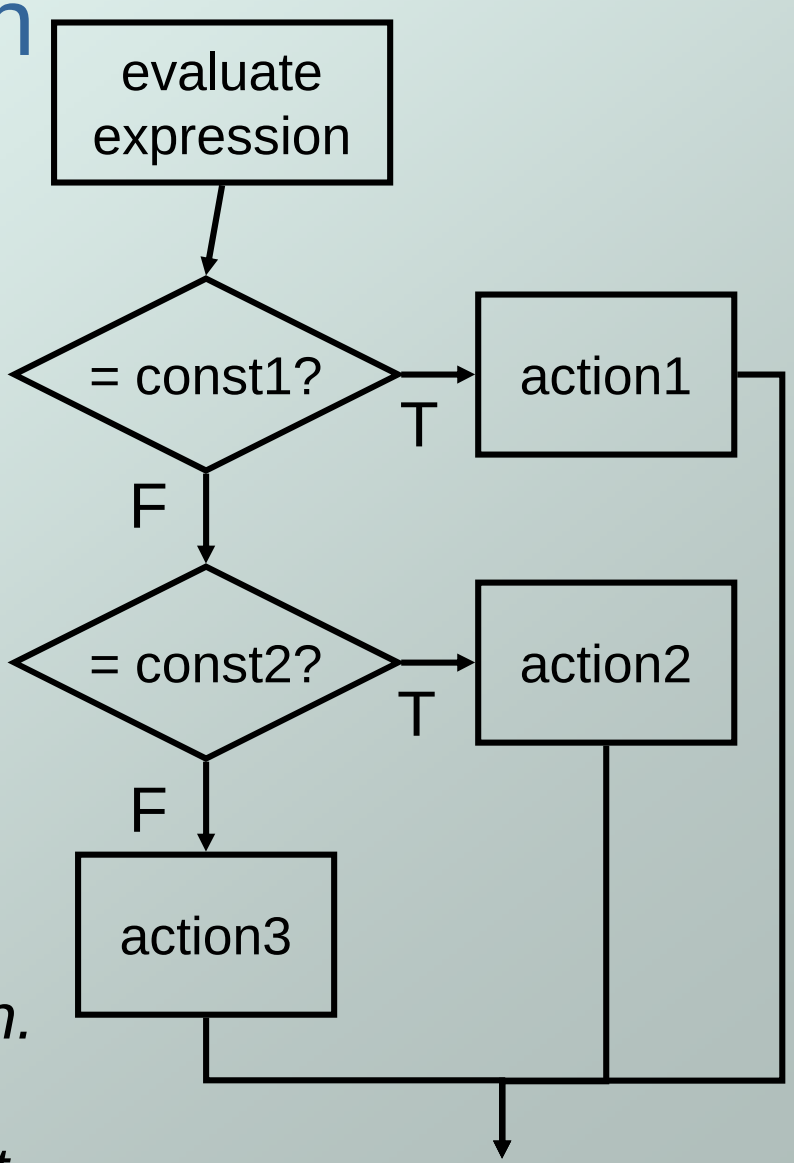
Primes: Complete Code

```
#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.

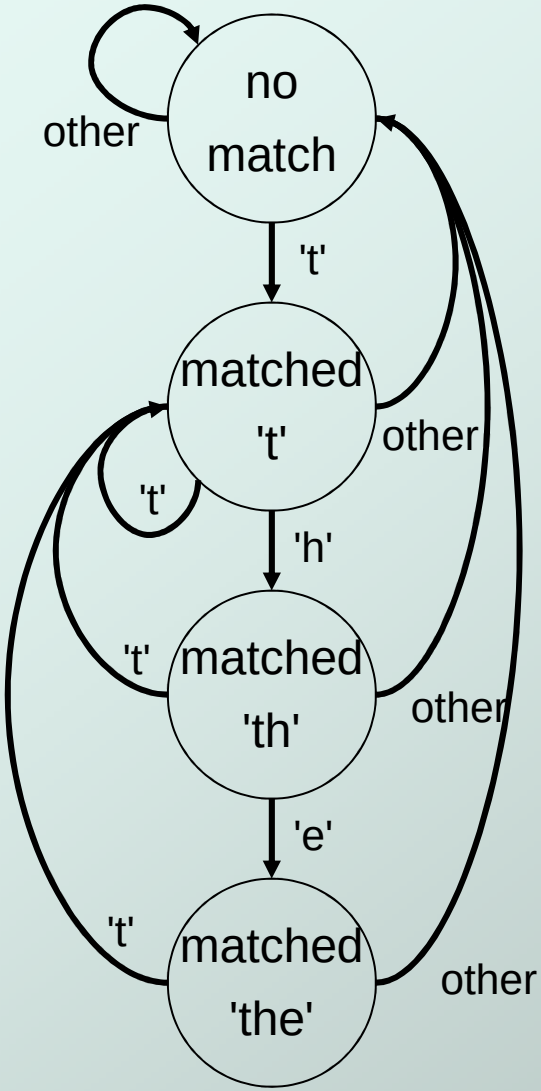
```
switch (a) {
   case 1:
     printf("A");
   case 2:
     printf("B");
   default:
     printf("C");
 }
```

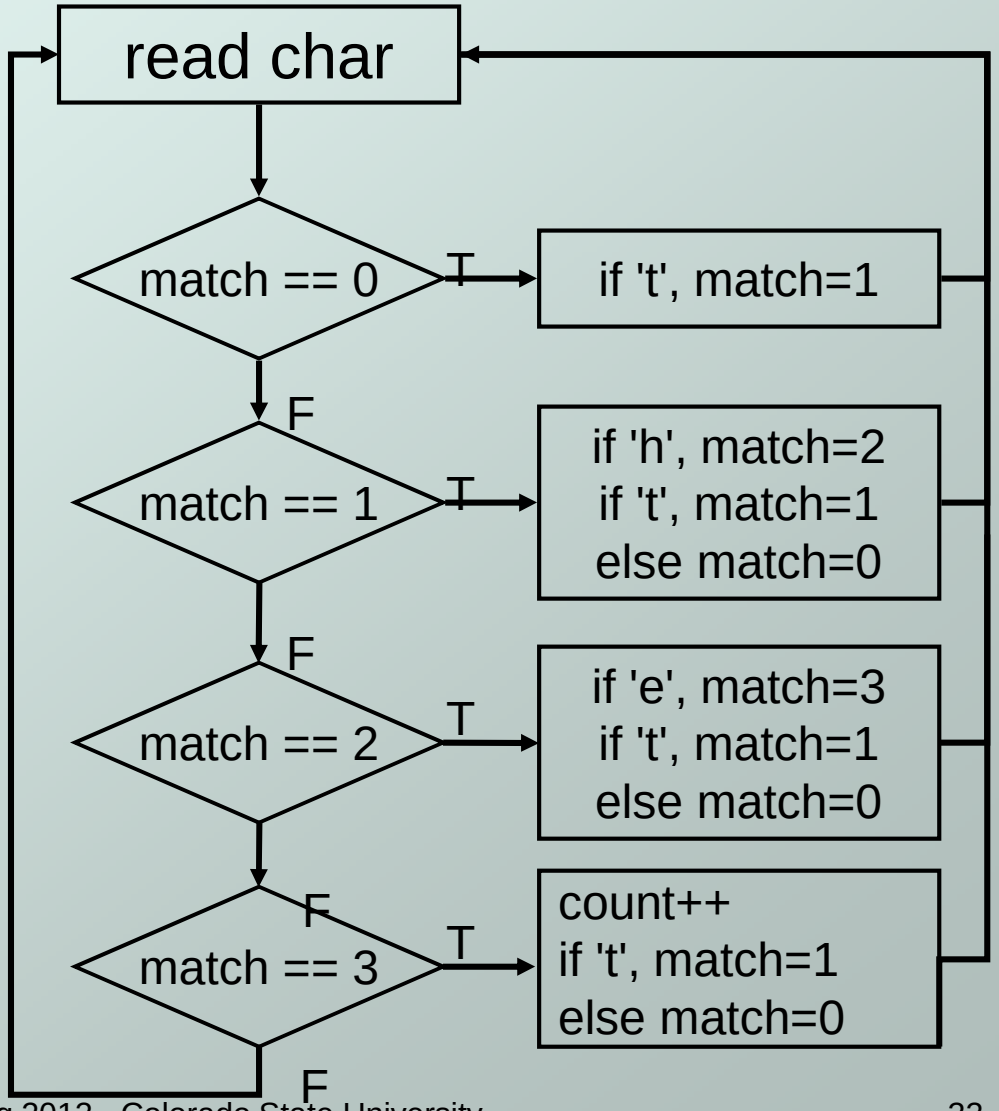
If a is 1, prints "ABC".
If a is 2, prints "BC".
Otherwise, prints "C".

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;
case 2:  /* 'th' has been matched */
    if (key == 'e') {
      match = 3;
    } else if (key == 't') {
      match = 1;
    } else { match = 0; }
    break;
```

Substring: Code (Part 3)

```
      case 3:  /* 'the' has been matched */
           count++;   /* increment count */
           if (key == 't') {
             match = 1;
           } else {
             match = 0;
           }
           break;
       }
    }
    // When we detected a newline,
    // if we had just seen a "the" then increment
    if (match==3) { count++; }
     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`**?