

Chapter 13 Control Structures

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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

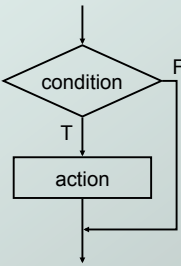
while
for
do-while

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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).

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Example If Statements

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

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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

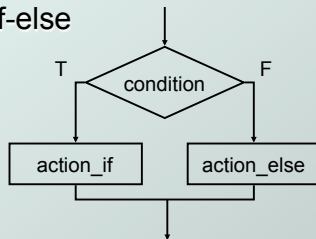
```
if (x == 3)
  if (y != 6)
  {
    z = z + 1;
    w = w + 2;
  }
```

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");

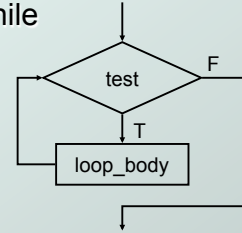
```

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);

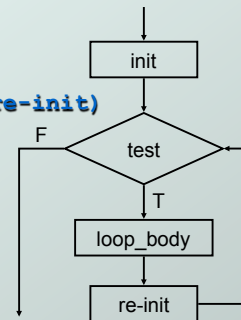
```
- Loop body does not change condition, so test never fails.
- This is a common programming error that can be difficult to find.

For

```

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

```



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

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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.

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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

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Problem 1: Calculating Pi

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

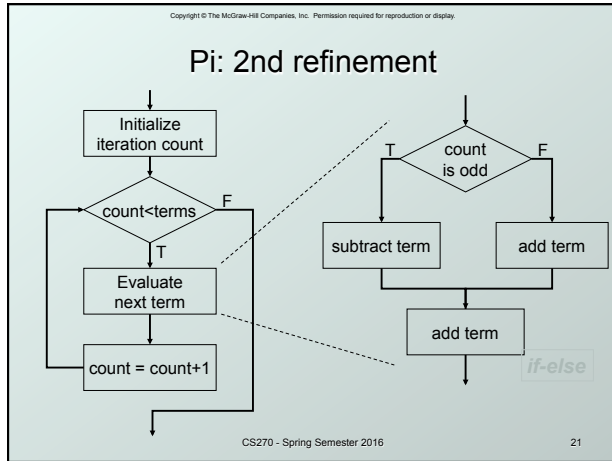
$$\pi = 4 - \frac{4}{3} + \frac{4}{5} - \frac{4}{7} + \dots + (-1)^{n-1} \frac{4}{2n+1} + \dots$$

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Pi: 1st refinement

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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.

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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;
}
  
```

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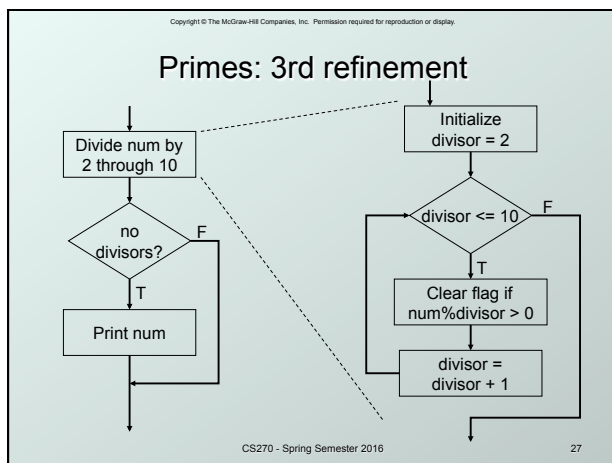
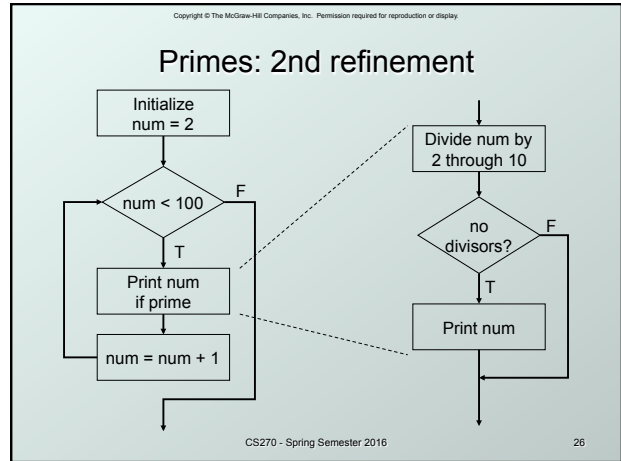
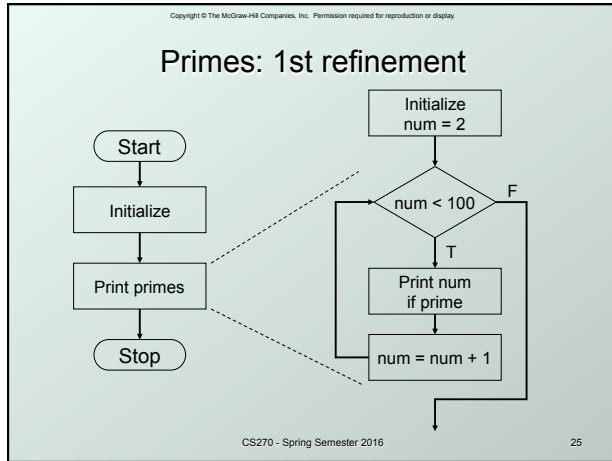
Problem 2: Finding Prime Numbers

- 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.

```

graph TD
    Start([Start]) --> Init[Initialize]
    Init --> Print[Print primes]
    Print --> Stop([Stop])
  
```

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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`.

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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)

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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.

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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");
}

```

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More About Switch

- Case expressions must be constant.
- If no break, then next case is also executed.

```

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

```

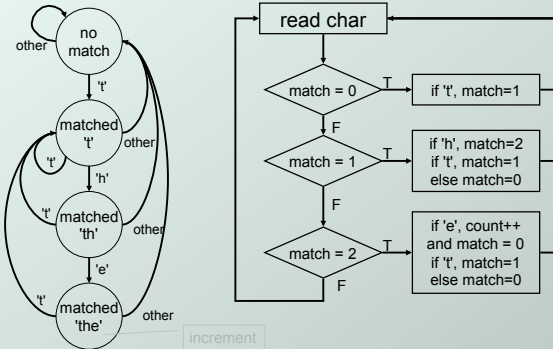
If a is 1, prints "ABC".
If a is 2, prints "BC".
Otherwise, prints "C".

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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>

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
```