Lecture 5 - Selection Statements

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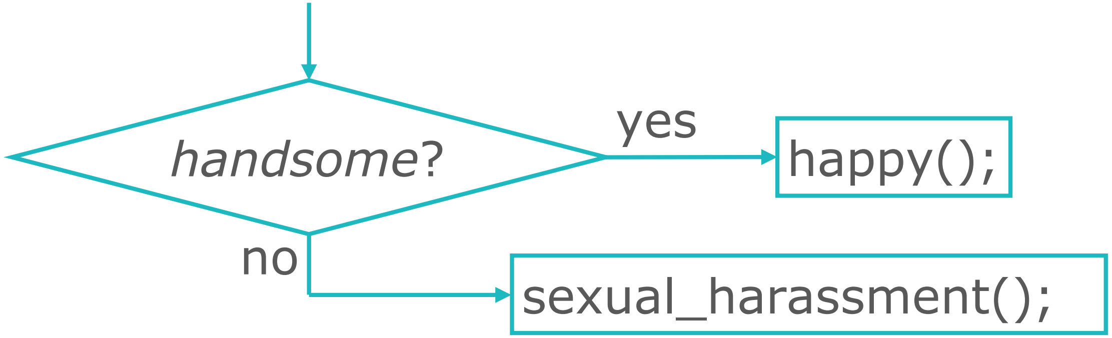
```
if(handsome)
  happy();
else
  sexual_harassment();
```



handsome?

yes

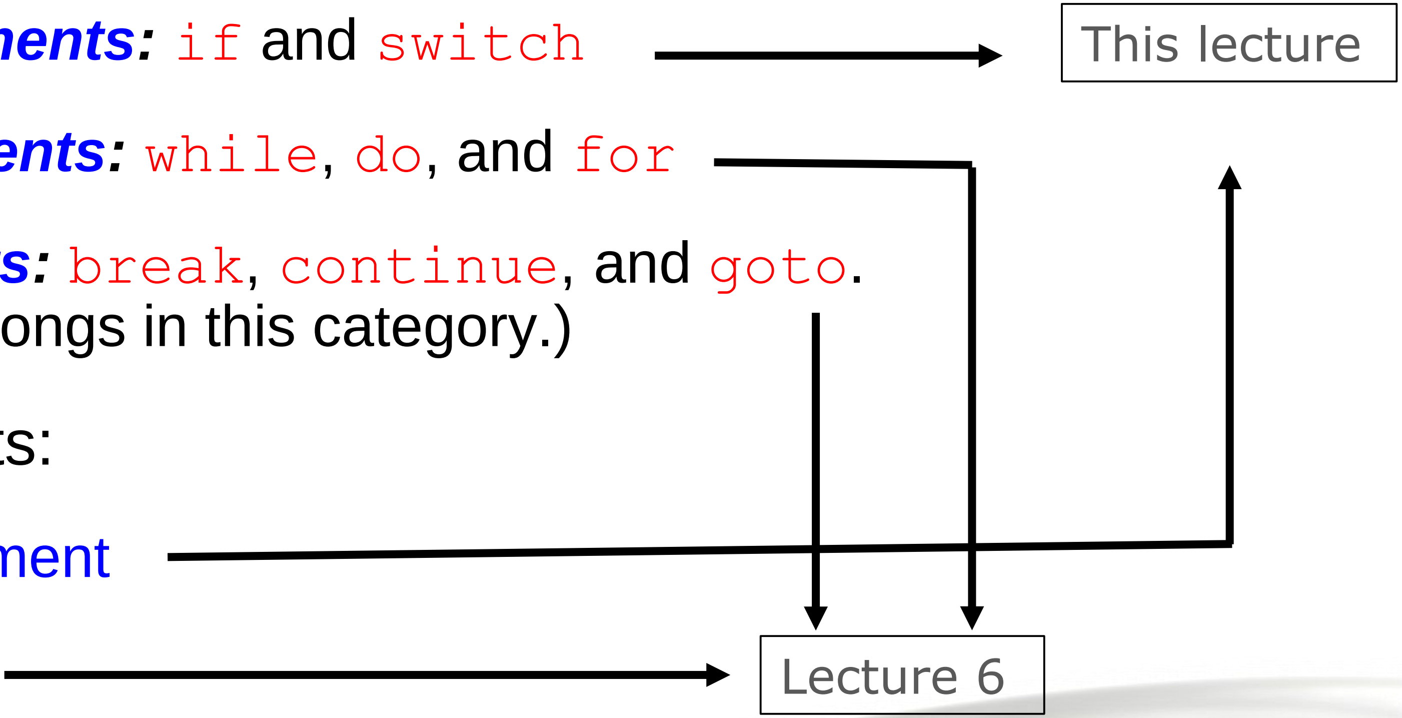
happy();

no

sexual_harassment();

Statements

- So far, we’ve used `return` statements and expression statements.
- Most of C’s remaining statements fall into three categories:
  - ***Selection statements:*** `if` and `switch`
  - ***Iteration statements:*** `while`, `do`, and `for`
  - ***Jump statements:*** `break`, `continue`, and `goto`. (`return` also belongs in this category.)
- Other C statements:
  - Compound statement
  - Null statement



This lecture

Lecture 6

Logical Expressions

- Several of C’s statements must test the value of an expression to see if it is “true” or “false.”
- For example, an `if` statement might need to test the expression `i < j`; a true value would indicate that `i` is less than `j`.
- In many programming languages, an expression such as `i < j` would have a special “Boolean” or “logical” type.
- In C, a comparison such as `i < j` yields an integer: either 0 (false) or 1 (true).

Relational Operators

- C’s ***relational operators:***

`<`	less than
`>`	greater than
`<=`	less than or equal to
`>=`	greater than or equal to

- These operators produce 0 (false) or 1 (true) when used in expressions.

- The relational operators can be used to compare integers and floating-point numbers, with operands of mixed types allowed.

- The precedence of the relational operators is lower than that of the arithmetic operators.
  - For example, `i + j < k - 1` means `(i + j) < (k - 1).`

Relational Operators (cont.)

- The relational operators are left associative.
- The expression

  ```
  i < j < k
  ```

  is legal, but does not test whether `j` lies between `i` and `k`.
- Since the `<` operator is left associative, this expression is equivalent to

  ```
  (i < j) < k
  ```

  The 1 or 0 produced by `i < j` is then compared to `k`.
- The correct expression is `i < j && j < k`.

Equality Operators

- C provides two ***equality operators:***

  ```
  ==   equal to
  !=   not equal to
  ```

- The equality operators are left associative and produce either 0 (false) or 1 (true) as their result.

- The equality operators have lower precedence than the relational operators, so the expression

  ```
  i < j == j < k
  ```

  is equivalent to

  ```
  (i < j) == (j < k)
  ```

Logical Operators

- More complicated logical expressions can be built from simpler ones by using the ***logical operators:***

<table>
<tr><td>!</td><td>logical negation</td></tr>
<tr><td>&&</td><td>logical <i>and</i></td></tr>
<tr><td>||</td><td>logical <i>or</i></td></tr>
</table>

- The `!` operator is unary, while `&&` and `||` are binary.
- The logical operators produce 0 or 1 as their result.
- The logical operators treat any nonzero operand as a true value and any zero operand as a false value.

Logical Operators (cont.)

- Behavior of the logical operators:

  !*expr* has the value 1 if *expr* has the value 0.

  expr1 && *expr2* has the value 1 if the values of *expr1* and *expr2* are both nonzero.

  expr1 || *expr2* has the value 1 if either *expr1* or *expr2* (or both) has a nonzero value.

- In all other cases, these operators produce the value 0.

Logical Operators (cont.)

- Both `&&` and `||` perform “short-circuit” evaluation: they first evaluate the left operand, then the right one.
- If the value of the expression can be deduced from the left operand alone, the right operand isn’t evaluated.
- Example: `(i != 0) && (j / i > 0)`

  `(i != 0)` is evaluated first.
- If `i` isn’t equal to 0, then `(j / i > 0)` is evaluated.
- If `i` is 0, the entire expression must be false, so there’s no need to evaluate `(j / i > 0)`. Without short-circuit evaluation, division by zero would have occurred.

Logical Operators (cont.)

- Thanks to the short-circuit nature of the && and || operators, side effects in logical expressions may not always occur.
- Example:
- i > 0 && ++j > 0
- If i > 0 is false, then ++j > 0 is not evaluated, so j isn’t incremented.
- The problem can be fixed by changing the condition to ++j > 0 && i > 0 or, even better, by incrementing j separately.

Logical Operators (cont.)

- The `!` operator has the same precedence as the unary plus and minus operators.
- The precedence of `&&` and `||` is lower than that of the relational and equality operators.
  - For example, `i < j && k == m` means `(i < j) && (k == m)`.
- The `!` operator is right associative; `&&` and `||` are left associative.

The `if` Statement

- The `if` statement allows a program to choose between two alternatives by testing an expression.
- In its simplest form, the `if` statement has the form

  `if (` *expression* `)` *statement*

- When an `if` statement is executed, *expression* is evaluated; if its value is nonzero, *statement* is executed.
- Example:

```
if (line_num == MAX_LINES)
  line_num = 0;
```

The `if` Statement (cont.)

- Confusing `==` (equality) with `=` (assignment) is perhaps the most common C programming error.
- The statement

```
    if (i == 0) …
```

tests whether `i` is equal to 0.

- The statement

```
    if (i = 0) …
```

assigns 0 to `i`, then tests whether the result is nonzero.

The `if` Statement (cont.)

- Often the expression in an `if` statement will test whether a variable falls within a range of values.
- To test whether 0 ≤ `i` < `n`:

```
if (0 <= i && i < n) …
```

- To test the opposite condition (`i` is outside the range):

```
if (i < 0 || i >= n) …
```

Compound Statements

- In the `if` statement template, notice that *statement* is singular, not plural:

  `if (` *expression* `)` *statement*

- To make an `if` statement control two or more statements, use a ***compound statement.***
- A compound statement has the form

  `{` *statements* `}`

- Putting braces around a group of statements forces the compiler to treat it as a single statement.

Compound Statements (cont.)

- Example:

```
{ line_num = 0; page_num++; }
```

- Example of a compound statement used inside an `if` statement:

```
if (line_num == MAX_LINES) {
  line_num = 0;
  page_num++;
}
```

- Each inner statement still ends with a semicolon, but the compound statement itself does not.
- Compound statements are also common in loops and other places where the syntax of C requires a single statement.

The `else` Clause

- An `if` statement may have an `else` clause:

  `if (` *expression* `)` *statement* `else` *statement*

- The statement that follows the word `else` is executed if the expression has the value 0.

```
if (i > j)
   max = i;
else
   max = j;
```

- Inner statements are usually indented, but if they're short they can be put on the same line as the `if` and `else`:

```
if (i > j) max = i;
else max = j;
```

The **`else`** Clause (cont.)

- It’s not unusual for `if` statements to be nested inside other `if` statements:

```
if (i > j)
  if (i > k)
    max = i;
  else
    max = k;
else
  if (j > k)
    max = j;
  else
    max = k;
```

- Aligning each `else` with the matching `if` makes the nesting easier to see.

The **`else`** Clause (cont.)

- To avoid confusion, don’t hesitate to add braces:

```
if (i > j) {
  if (i > k)
    max = i;
  else
    max = k;
} else {
  if (j > k)
    max = j;
  else
    max = k;
}
```

```
if (i > j) {
  if (i > k) {
    max = i;
  } else {
    max = k;
  }
} else {
  if (j > k) {
    max = j;
  } else {
    max = k;
  }
}
```

The `else` Clause (cont.)

- Advantages of using braces even when they’re not required:
  - Makes programs easier to modify, because more statements can easily be added to any `if` or `else` clause.
  - Helps avoid errors that can result from forgetting to use braces when adding statements to an `if` or `else` clause.

Cascaded **`if`** Statements

- A “cascaded” `if` statement is often the best way to test a series of conditions, stopping as soon as one of them is true.
- Example:

```
if (n < 0)
  printf("n is less than 0\n");
else
  if (n == 0)
    printf("n is equal to 0\n");
  else
    printf("n is greater than 0\n");
```

Cascaded **`if`** Statements (cont.)

- Aligning each `else` with the original `if` avoids the problem of excessive indentation when the number of tests is large:

```
if ( expression )
  statement
else if ( expression )
  statement
…
else if ( expression )
  statement
else
  statement
```

```
if (n < 0)
  printf("n is less than 0\n");
else if (n == 0)
  printf("n is equal to 0\n");
else
  printf("n is greater than 0\n");
```

Program: Calculating a Broker's Commission

- When stocks are sold or purchased through a broker, the broker's commission often depends upon the value of the stocks traded.

- Suppose that a broker charges the amounts shown in the table:

Transaction size	*Commission rate*
Under $2,500	$30 + 1.7%
$2,500–$6,250	$56 + 0.66%
$6,250–$20,000	$76 + 0.34%
$20,000–$50,000	$100 + 0.22%
$50,000–$500,000	$155 + 0.11%
Over $500,000	$255 + 0.09%

- The minimum charge is $39.
- The `broker.c` program asks the user to enter the amount of the trade, then displays the amount of the commission:

```
Enter value of trade: 30000
Commission: $166.00
```

- The heart of the program is a cascaded `if` statement that determines which range the trade falls into.

Program: Calculating a Broker’s Commission (cont.)

broker.c

```c
#include <stdio.h>
int main(void)
{
  float commission, value;
  printf("Enter value of trade: ");
  scanf("%f", &value);

  if (value < 2500.00f)
   commission = 30.00f + .017f * value;
  else if (value < 6250.00f)
   commission = 56.00f + .0066f * value;
  else if (value < 20000.00f)
   commission = 76.00f + .0034f * value;
  else if (value < 50000.00f)
   commission = 100.00f + .0022f * value;
  else if (value < 500000.00f)
   commission = 155.00f + .0011f * value;
  else
   commission = 255.00f + .0009f * value;
  if (commission < 39.00f)
    commission = 39.00f;

  printf("Commission: $%.2f\n",
     commission);
  return 0;
}
```

The "Dangling else" Problem

- When `if` statements are nested, the "dangling else" problem may occur:

```
if (y != 0)
   if (x != 0)
      result = x / y;
else
   printf("Error: y is equal to 0\n");
```

- The indentation suggests that the else clause belongs to the outer if statement.
- However, C follows the rule that an else clause belongs to the nearest if statement that hasn't already been paired with an else.

The “Dangling **else**” Problem (cont.)

- To make the `else` clause part of the outer `if` statement, we can enclose the inner `if` statement in braces:

```
if (y != 0) {
  if (x != 0)
    result = x / y;
} else
  printf("Error: y is equal to 0\n");
```

- Using braces in the original `if` statement would have avoided the problem in the first place.

Conditional Expressions

- C's ***conditional operator*** allows an expression to produce one of two values depending on the value of a condition.
- The conditional operator consists of two symbols (`?` and `:`), which must be used together:

  expr1 `?` *expr2* `:` *expr3*

- The expression is evaluated in stages: *expr1* is evaluated first;
  - if its value isn't zero, then *expr2* is evaluated, and its value is the value of the entire conditional expression.
  - if the value is zero, then the value of *expr3* is the value of the conditional.
- The conditional operator requires three operands, so it is often referred to as a ***ternary*** operator.

Conditional Expressions (cont.)

- Example:

```
int i, j, k;
i = 1;
j = 2;
k = i > j ? i : j;           /* k is now 2 */
k = (i >= 0 ? i : 0) + j;    /* k is now 3 */
```

- The parentheses are necessary, because the precedence of the conditional operator is less than that of the other operators discussed so far, with the exception of the assignment operators.
- Conditional expressions tend to make programs shorter but harder to understand, so it’s probably best to use them sparingly.
- Conditional expressions are often used in `return` statements:

```
return i > j ? i : j;
```

Conditional Expressions (cont.)

- Calls of `printf` can sometimes benefit from condition expressions. Instead of

```
if (i > j)
    printf("%d\n", i);
else
    printf("%d\n", j);
```

  we could simply write

```
printf("%d\n", i > j ? i : j);
```

- Conditional expressions are also common in certain kinds of macro definitions.

Boolean Values in C89

- For many years, the C language lacked a proper Boolean type, and there is none defined in the C89 standard.
- One way to work around this limitation is to declare an `int` variable and then assign it either 0 or 1:

```
int flag;

flag = 0;
…
flag = 1;
```

- Although this scheme works, it doesn’t contribute much to program readability.

Boolean Values in C89 (cont.)

- To make programs more understandable, C89 programmers often define macros with names such as `TRUE` and `FALSE`:

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

- Assignments to `flag` now have a more natural appearance:

```
flag = FALSE;
…
flag = TRUE;
```

Boolean Values in C89 (cont.)

- To test whether `flag` is true, we can write

  ```
      if (flag == TRUE) …
  ```

  or just

  ```
      if (flag) …
  ```

- The later also works correctly if `flag` has a value other than 0 or 1.

- To test whether `flag` is false, we can write

  ```
      if (flag == FALSE) …
  ```

  or

  ```
      if (!flag) …
  ```

Boolean Values in C89

- Carrying this idea one step further, we might even define a macro that can be used as a type:

```
#define BOOL int
```

- `BOOL` can take the place of `int` when declaring Boolean variables:

```
BOOL flag;
```

- It’s now clear that `flag` isn’t an ordinary integer variable, but instead represents a Boolean condition.

Boolean Values in C99 (cont.)

- C99 provides the `_Bool` type.
- A Boolean variable can be declared by writing

```
_Bool flag;
```

- `_Bool` is an integer type, so a `_Bool` variable is really just an integer variable in disguise.
- Unlike an ordinary integer variable, however, a `_Bool` variable can only be assigned 0 or 1.
- Attempting to store a nonzero value into a `_Bool` variable will cause the variable to be assigned 1:

```
flag = 5;   /* flag is assigned 1 */
```

Boolean Values in C99 (cont.)

- It’s legal (although not advisable) to perform arithmetic on `_Bool` variables.
- It’s also legal to print a `_Bool` variable (either 0 or 1 will be displayed).
- And, of course, a `_Bool` variable can be tested in an `if` statement:

```
if (flag)    /* tests whether flag is 1 */
  …
```

Boolean Values in C99 (cont.)

- C99's `<stdbool.h>` header makes it easier to work with Boolean values.
- It defines a macro, `bool`, that stands for `_Bool`.
- If `<stdbool.h>` is included, we can write

```
bool flag;    /* same as _Bool flag; */
```

- `<stdbool.h>` also supplies macros named `true` and `false`, which stand for 1 and 0, respectively, making it possible to write

```
flag = false;
…
flag = true;
```

The **switch** Statement

- A cascaded `if` statement can be used to compare an expression against a series of values:

```
if (grade == 4)
  printf("Excellent");
else if (grade == 3)
  printf("Good");
else if (grade == 2)
  printf("Average");
else if (grade == 1)
  printf("Poor");
else if (grade == 0)
  printf("Failing");
else
  printf("Illegal grade");
```

The **switch** Statement (cont.)

- The switch statement is an alternative:

```
switch (grade) {
  case 4:  printf("Excellent");
           break;
  case 3:  printf("Good");
           break;
  case 2:  printf("Average");
           break;
  case 1:  printf("Poor");
           break;
  case 0:  printf("Failing");
           break;
  default: printf("Illegal grade");
           break;
}
```

The **switch** Statement (cont.)

- A `switch` statement may be easier to read than a cascaded `if` statement.
- `switch` statements are often faster than `if` statements.
- Most common form of the `switch` statement:

```
switch ( expression ) {
  case constant-expression : statements
  …
  case constant-expression : statements
  default : statements
}
```

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The **`switch`** Statement (cont.)

- The word `switch` must be followed by an integer expression—the ***controlling expression***—in parentheses.
- Characters are treated as integers in C and thus can be tested in `switch` statements.
- Floating-point numbers and strings don’t qualify, however.

The **`switch`** Statement (cont.)

- Each case begins with a label of the form

  `case` *constant-expression* `:`

- A ***constant expression*** is much like an ordinary expression except that it can't contain variables or function calls.
  - `5` is a constant expression, and `5 + 10` is a constant expression, but `n + 10` isn't a constant expression (unless `n` is a macro that represents a constant).
- The constant expression in a case label must evaluate to an integer (characters are acceptable).

The `switch` Statement (cont.)

- After each case label comes any number of statements.
- No braces are required around the statements.
- The last statement in each group is normally `break`.

The **`switch`** Statement (cont.)

- Duplicate case labels aren’t allowed.
- The order of the cases doesn’t matter, and the `default` case doesn’t need to come last.
- Several case labels may precede a group of statements:

```
switch (grade) {
  case 4:
  case 3:
  case 2:
  case 1:   printf("Passing");
            break;
  case 0:   printf("Failing");
            break;
  default: printf("Illegal grade");
            break;
}
```

The **switch** Statement (cont.)

- To save space, several case labels can be put on the same line:

```
switch (grade) {
  case 4: case 3: case 2: case 1:
           printf("Passing");
           break;
  case 0:  printf("Failing");
           break;
  default: printf("Illegal grade");
           break;
}
```

- If the `default` case is missing and the controlling expression’s value doesn’t match any case label, control passes to the next statement after the `switch`.

The Role of the `break` Statement

- Executing a `break` statement causes the program to "break" out of the `switch` statement; execution continues at the next statement after the `switch`.
- The `switch` statement is really a form of "computed jump."
- When the controlling expression is evaluated, control jumps to the case label matching the value of the `switch` expression.
- A case label is nothing more than a marker indicating a position within the `switch`.

The Role of the **`break`** Statement (cont.)

- Without `break` (or some other jump statement) at the end of a case, control will flow into the next case.

- Example:

```
switch (grade) {
  case 4:  printf("Excellent");
  case 3:  printf("Good");
  case 2:  printf("Average");
  case 1:  printf("Poor");
  case 0:  printf("Failing");
  default: printf("Illegal grade");
}
```

- If the value of `grade` is 3, the message printed is

```
GoodAveragePoorFailingIllegal grade
```

The Role of the **`break`** Statement (cont.)

- Omitting `break` is sometimes done intentionally, but it's usually just an oversight.
- It's a good idea to point out deliberate omissions of `break`:

```
switch (grade) {
  case 4: case 3: case 2: case 1:
          num_passing++;
          /* FALL THROUGH */
  case 0: total_grades++;
          break;
}
```

- Although the last case never needs a `break` statement, including one makes it easy to add cases in the future.

Program: Printing a Date in Legal Form

- Contracts and other legal documents are often dated in the following way:

```
Dated this __________ day of __________ , 20__ .
```

- The `date.c` program will display a date in this form after the user enters the date in month/day/year form:

```
Enter date (mm/dd/yy): 7/19/14
Dated this 19th day of July, 2014.
```

- The program uses `switch` statements to add "th" (or "st" or "nd" or "rd") to the day, and to print the month as a word instead of a number.

Program: Printing a Date in Legal Form (cont.)

date.c

```
#include <stdio.h>
int main(void)
{
  int month, day, year;

  printf("Enter date (mm/dd/yy): ");
  scanf("%d /%d /%d", &month,
   &day, &year);

  printf("Dated this %d", day);
  switch (day) {
    case 1: case 21: case 31:
      printf("st"); break;
    case 2: case 22:
      printf("nd"); break;
    case 3: case 23:
      printf("rd"); break;
    default: printf("th"); break;
  }
  printf(" day of ");
  switch (month) {
    case 1:  printf("January");   break;
    case 2:  printf("February");  break;
    case 3:  printf("March");     break;
    case 4:  printf("April");     break;
    case 5:  printf("May");       break;
    case 6:  printf("June");      break;
    case 7:  printf("July");      break;
    case 8:  printf("August");    break;
    case 9:  printf("September"); break;
    case 10: printf("October");   break;
    case 11: printf("November");  break;
    case 12: printf("December");  break;
  }

  printf(", 20%.2d.\n", year);
  return 0;
}
```

```
Enter date (mm/dd/yy): 7/19/14
Dated this 19th day of July, 2014.
```

A Quick Review to This Lecture

- `if` statements
  - `if (` *expression* `)` *statement*
    `if (` *expression* `)` `{`*statements*`}`
  - `if (` *expression* `)` *statement* `else` *statement*
    `if (` *expression* `)` `{`*statements*`}` `else` `{`*statements*`}`
- Logical Expression
  - yields an integer: either 0 (false) or 1 (true).
  - Relational Operators: < > <= >=
  - Equality Operators: == !=
  - Logical Operators: ! && ||

left associative

right associative and unary

A Quick Review to This Lecture (cont.)

- To test whether `j` lies between `i` and `k`, use

  `i < j && j < k` instead of `i < j < k` ✖

- Logical operators treat any nonzero operand as a true value and any zero operand as a false value.

- Both `&&` and `||` perform “short-circuit” evaluation:

  `(i != 0) && (j / i > 0)`

  If the value of the expression can be deduced from the left operand alone, the right operand isn’t evaluated.

- Confusing `==` with `=` is perhaps the most common error.

  `if (i == 0) …` tests whether `i` is equal to 0.
  `if (i = 0) …` assigns 0 to `i`, then tests `i` (zero/nonzero)

A Quick Review to This Lecture (cont.)

Nested `if` statement

```
if (i > j) {
  if (i > k) {
    max = i;
  } else {
    max = k;
  }
} else {
  if (j > k) {
    max = j;
  } else {
    max = k;
  }
}
```

Cascaded `if` statement

```
if (n < 0)
  printf("n is less than 0\n");
else if (n == 0)
  printf("n is equal to 0\n");
else if (n <= 1)
  printf("n is between 0 and 1\n");
else
  printf("n is greater than 1\n");
```

A Quick Review to This Lecture (cont.)

- the “dangling else” problem (using braces to avoid it)

```
if (y != 0)
   if (x != 0)
      result = x / y;
else
   printf("Error: y is equal to 0\n");
```

- Conditional Expressions

```
k = (i > j) ? i : j;
```

A Quick Review to This Lecture (cont.)

- Boolean Values
  - Using macro

```
#define BOOL int
#define TRUE 1
#define FALSE 0

BOOL flag;
flag = TRUE;
if (flag == FALSE) …    /* or if(!flag) */
```

  - Using _Bool

```
#define TRUE 1
#define FALSE 0

_Bool flag;
flag = TRUE;
if (flag == FALSE) …    /* or if(!flag) */
```

A Quick Review to This Lecture (cont.)

- Include <stdbool.h>

```
#include <stdbool.h>
bool flag;
flag = true;
if (flag == false) …    /* or if(!flag) */
```

- `switch` Statement (faster and easier to read than cascaded `if`)

No variables or function calls

integer (or character) expression

```
switch ( expression ) {
   case constant-expression : statements
   …
   case constant-expression : statements
   default : statements
}
```

A Quick Review to This Lecture (cont.)

- Without `break` (or some other jump statement) at the end of a case, control will flow into the next case.

```
switch (grade) {
  case 4: case 3: case 2: case 1:
      num_passing++;
      /* FALL THROUGH */
  case 0: total_grades++;
      break;
}
```

- A case label is nothing more than a marker indicating a position within the `switch`.

- If the `default` case is missing and the controlling expression’s value doesn’t match any case label, control passes to the next statement after the `switch`.