Computer Science & Engineering 150A
Problem Solving Using Computers

Lecture 04 - Conditionals

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(Adapted from Christopher M. Bourke)

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Notes

- Control Structure
- Conditions
- `if` statements

Notes

Control Structure

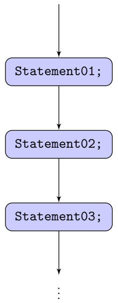
- **Control structures**:
  - Control the flow of execution in a program or function.
  - Enable you to combine individual instructions into a single logical unit with one entry point (i.e. `int main(void) {`) and one exit point (`return 0; }`).
- Three kinds of structures to control execution flow:
  - Sequence
  - Selection
  - Repetition

Notes

Sequential Flow

Compound statement:

- Written as a group of statements
- Bracketed by { and }
- Used to specify sequential flow
- All statements are unconditionally executed
- Order is important

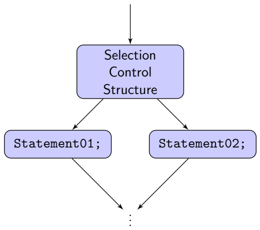


Notes

Selection Flow

Selection control structure:

- Evaluates criteria to determine which alternative "path" to follow.
- A *control structure* determines which statement(s) to execute
- Statements are mutually exclusive



Notes

Selection Flow – Conditions

Definition

A *condition* is an expression that is either `true` or `false`.

A program chooses alternative paths of computation by testing one or more conditions.

- (ConditionEval `==` 1) → `true`,
- (ConditionEval `==` 0) → `false`.
- The resting heart rate is a good indicator of health
- `if` (resting_heart_rate $<$ 75) *then* you are in good health.
  - if resting heart rate is 80, ConditionEval is `false`.
  - if resting heart rate is 50, ConditionEval is `true`.
  - if resting heart rate is 75, what is ConditionEval?

Notes

Relational and Equality Operators

Operator	Meaning	Type
<	less than	relational
>	greater than	relational
<=	less than or equal to	relational
>=	greater than or equal to	relational
==	equal to	equality
!=	*not* equal to	equality

Table: Relational and Equality Operators in C

Notes

Relational and Equality Operators

Conditions come in four forms:

- `variable` *relational-operator* `variable`
- Example: `if(numberOfStudents > numberOfSeats)`
- `variable` *relational-operator* `CONSTANT`
- Example: `if(numberOfStudents < 5)`
- `variable` *equality-operator* `variable`
- Example: `if(numberOfStudents == numberOfSeats)`
- `variable` *equality-operator* `CONSTANT`
- Example: `if(averageGrade == 75.0)`

What about more than one condition? (Example: $0 \leq x \leq 10$)

Notes

Logical Operators

Logical Operators: Operators that can combine conditions to make more complicated selection statements.

C Syntax	Meaning	True When
&&	logical AND	Both are true
||	logical OR	Either is true
!	logical NOT (*negation*)	False

Table: Logical Operators in C

Notes

Logical Operators

Logical Expressions - expressions that involve conditional statement(s) and logical operator(s).

Examples:

- `(x >= 0 && x <=10)`
- `(temperature > 90.0 && humidity > 0.90)`
- `!(x >= 0 && x <=10)`

What about the following: Are we going to go or not?

`(go || !go)`

Notes

Tautologies & Contradictions

- A *tautology* is a logical expression that is *always* true
  - Any non-zero constant (`1, 1.5, 8`, etc.)
  - An expression that, when simplified, always ends up being true
    - `(go || !go)` is always true
- A *contradiction* is a logical expression that is *always* false
  - The zero constant (`0`)
  - An expression that, when simplified, always ends up being false
    - `(go && !go)` is always false

Notes

Distributivity

- The logical AND can be *distributed* over a logical expression just as multiplication can be over an algebraic expression.
  - $a(b + c) = ab + ac$
  - `a && (b || c)` is same as `(a && b) || (a && c)`
    - (Here, `a`, `b`, and `c` are relations like `x < 5`)
- When distributing the logical NOT, AND and OR are reversed!
- Example:
  - `!(x >= 0 && x <=10)`
  - `(!(x >= 0) || !(x <=10))`
  - `((x < 0) || (x > 10))`

Best to simplify logical expressions as much as possible, but more important to keep code readable.

Notes

True and False

C Convention

- For convenience when writing we identify zero with `false` and one with `true`
- C does not recognize the words `true, false`
- C has no built-in *Boolean* type!
- Instead, zero is identified with `false`
- *Any* non-zero value is identified with `true`
- Example: `-1, 0.01, 386` are all `true`

Notes

Operator Tables

Logical AND

The result of taking a logical AND with two operands is true if and only if *both* operands are `true`. Otherwise it is `false`.

Operand A	Operand B	Result
0	0	0
0	1	0
1	0	0
1	1	1

Notes

Operator Tables

Logical AND

The result of taking a logical OR with two operands is true if and only if *at least one* of the operands is `true`. Otherwise it is `false`.

Operand A	Operand B	Result
0	0	0
0	1	1
1	0	1
1	1	1

Notes

Operator Tables

Logical AND

You can only apply a logical NOT to a single operand. The result is that `true` gets flipped to `false` and vice versa.

Operand	Result
0	1
1	0

Notes

Operator Precedence

Order of precedence for operators

Precedence	Operator
High	Function calls
	`! + - &` (unary)
	`* / %`
	`+ -` (binary)
	`< <= >= >`
	`== !=`
	`&&`
	`||`
Low	`=`

Table: Order of Precedence for Operators

Notes

Short-Circuiting

- If the first operand of a logical OR is true, the whole expression is true regardless of the second operand.
- Similarly, if the first operand of a logical AND is false, the whole expression is false regardless of the second operand.
  - `(true || anything)` is `true`
  - `(false && anything)` is `false`
- By convention, in either case C does not bother to evaluate the second operand.
- This is known as *short-circuiting*

Notes

Programming Tip

- Writing pseudocode will help you to write logical expressions in plain English.
- Translate the expressions into valid C syntax
- Be sure that the original and the translation are logically *equivalent*
- You can use a `int` type to store true/false:
  `int someBoolean = 0;`

Notes

Comparing Characters

- Recall that C uses *partially weak typing*
- C treats characters as integers in the range $[0, 255]$
- Thus, it makes sense that we can compare characters using relational and equality operators.
- Comparisons are based on the values used to encode letters (typically ASCII; Appendix A)
- Example: `'a' < 'e'` is true since (in ASCII) $97 < 101$

Notes

Comparing Characters

Exercise

Assuming ASCII encoding, what are the values of the following character comparisons?

1. `'B' <= 'A'`
2. `'Z' == 'z'`
3. `'A' < 'a'`
4. `'5' <= '7'`

Answer:

Notes

Comparing Characters

CSCE150A

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Answer:

1. false since $66 > 65$

Notes

Comparing Characters

CSCE150A

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2. false since $90 \neq 122$

Notes

Comparing Characters

CSCE150A

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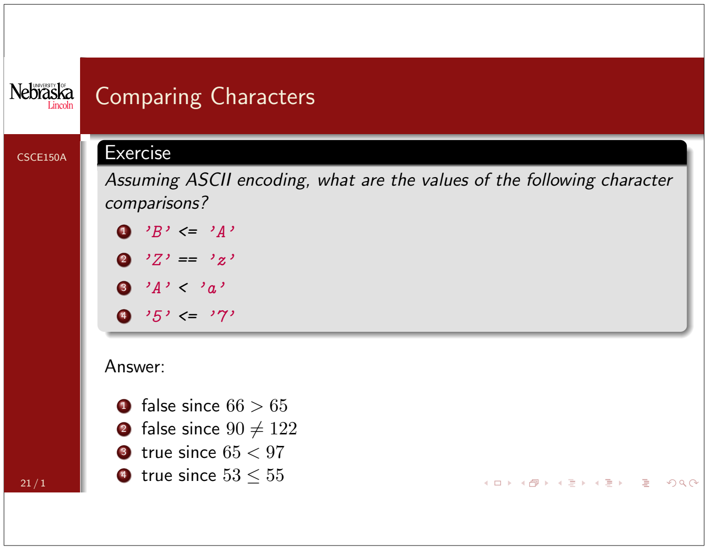
1. false since $66 > 65$
2. false since $90 \neq 122$
3. true since $65 < 97$

Notes



Comparing Characters

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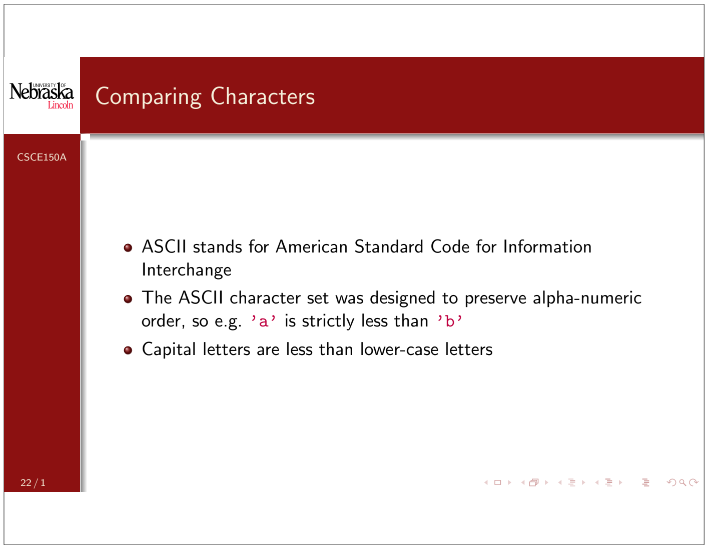
4. `'5' <= '7'`

Answer:

1. false since $66 > 65$
2. false since $90 \neq 122$
3. true since $65 < 97$
4. true since $53 \leq 55$

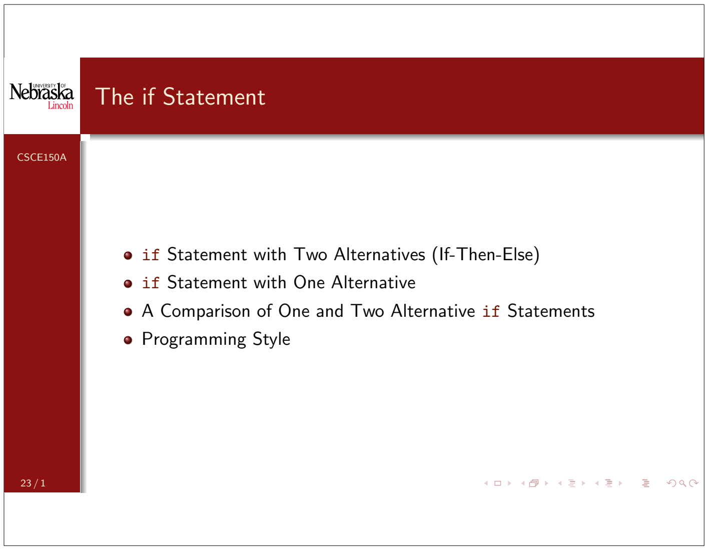
Notes



Comparing Characters

- ASCII stands for American Standard Code for Information Interchange
- The ASCII character set was designed to preserve alpha-numeric order, so e.g. `'a'` is strictly less than `'b'`
- Capital letters are less than lower-case letters

Notes



The if Statement

- `if` Statement with Two Alternatives (If-Then-Else)
- `if` Statement with One Alternative
- A Comparison of One and Two Alternative `if` Statements
- Programming Style

Notes

If-Then-Else Statement

- Conditions are used to assign **boolean** (T,F) values to variables
- Example: senior_citizen = (age >= 65)
- 0 or 1 is assigned to senior_citizen depending on the value of age
- More often, conditions are used to make a choice between alternatives, through the if statement.
- If the condition is true, one statement is executed, otherwise, another statement is executed.

```
if (!senior_citizen)
   printf("Your hamburger is $3.50\n");
else
   printf("Your hamburger is $2.50\n");
```

Notes

if Statement with One Alternative

- It is not necessary to specify an alternative (else statement)
- An if statement can determine to execute a statement or not

```
if(senior_citizen)
   price = price - 1.0;
```

Notes

Programming Tip

- Recall that division by zero is undefined (and dangerous)
- You can use an if statement to avoid such errors

```
if(x != 0)
   quotient = quotient / x;
```

Notes

Program Style

- Statements following the `if` statements should be indented
- `else` statement is at the same indentation as the `if` statement
- Statements following the `else` statements should be indented

Notes

Programming Tip

Pitfall: Do *not* end an `if` statement with a semi-colon:

```
if(price < 0);
   printf("The product is free!\n");
```

- Syntactically correct; program will compile
- Essentially like `if(price<0){};`
- Will *not* give expected results
- The `if` statement is ended by the semicolon
- Thus, “`The product is free!`” will be printed regardless of the value of `price`

Notes

if Statement with Compound Statements

- In previous slides, `if` and `else` statements have performed only one operation
- C always assumes that each `if` or `else` statement will be followed by one operation
- If more than one statement needs to be done for an `if` or `else`, we use {} to group a set of statements into one compound statement

Notes

if Statement with Compound Statements

```c
if(pop_today > pop_yesterday)
{
   growth = pop_today - pop_yesterday;
   growth_pct = 100.0 * growth / pop_yesterday;
   printf("Growth percentage = %.2f.\n", growth_pct);
}
```

Notes

Another Example

```c
if (crash_test_rating_index <= MAX_SAFE_CTRI)
{
   printf("Car #%d: safe\n", auto_id);
   numOfSafeCars = numOfSafeCars + 1;
}
else
{
   printf("Car #%d: unsafe\n", auto_id);
   numOfUnsafeCars = numOfUnsafeCars + 1;
}
```

If you omit the braces, what happens?

Notes

Tracing an if Statement

- Verifying the correctness of a C statement before running the program
- Catching logical errors will save a lot of time in debugging.
- A *hand trace* or *desk check* is a step-by-step simulation of each step of the program, as well as how the values of the variables change at each step.

Notes

Nested if Statements and Multiple-Alternative Decisions

- No decisions: Sequential program
- One decision: `if-then` (One alternative)
  - `if(cond) statement;`
- Decision between two alternatives: `if-then-else` (Two alternative statements)
  - `if(cond) statement; else statement2;`
- Decisions between many alternatives
  - School level

Notes

Nested if Statements and Multiple-Alternative Decisions

```
if (x <= 0)
    pre_school = pre_school + 1;
else
    if (x <= 12)
        public_school = public_school + 1;
    else
        univ = univ + 1;
```

Notes

Nested ifs vs. Sequence of ifs I

Can instead use a sequence of `if` statements

```
if(x <= 0)
   pre_school = pre_school + 1;
if(x <= 12 && x > 0)
   public_school = public_school + 1;
if(x > 12)
   univ = univ + 1;
```

Notes

Nested ifs vs. Sequence of ifs II

- Not as readable: since the sequence does not clearly show that exactly one of the three assignment statements is executed for a particular x.
- Less efficient because all three of the conditions are always tested. In the nested if statement, only the first condition is tested when x is not positive.
- Can lead to logical errors

Notes

Nested ifs vs. Sequence of ifs III

```
if(score >= 90)
   grade = 'A';
if(score >= 80)
   grade = 'B';
if(score >= 70)
   grade = 'C';
```

What happens when `score = 95`?

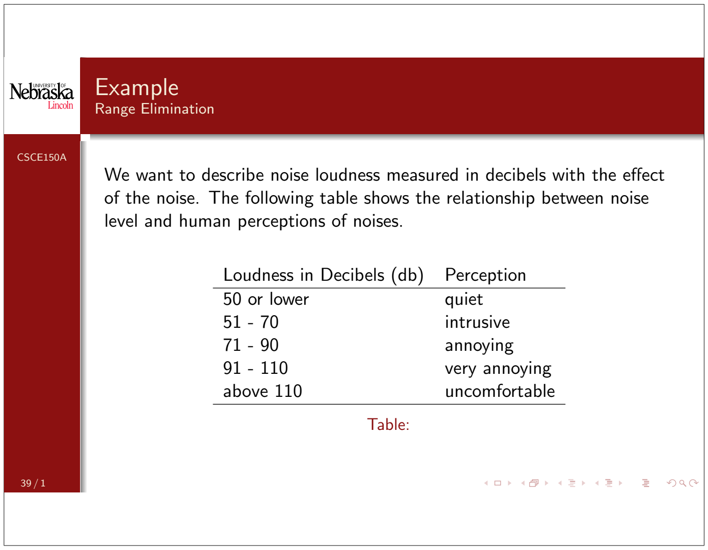
Notes

if-else-if Statement

Better solution: the if-else-if statement

```
if ( condition_1 )
   statement_1
else if ( condition_2 )
   statement_2
.
.
else if ( condition_n )
   statement_n
else
   statement_e
```

Notes



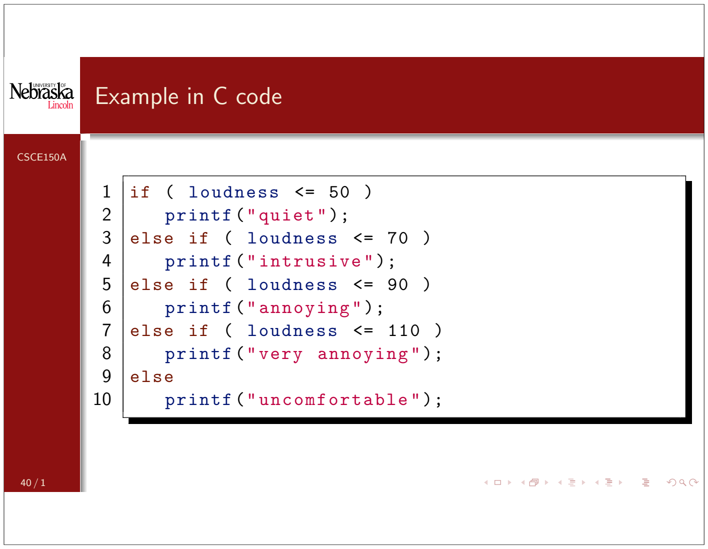
Example
Range Elimination

We want to describe noise loudness measured in decibels with the effect of the noise. The following table shows the relationship between noise level and human perceptions of noises.

Loudness in Decibels (db)	Perception
50 or lower	quiet
51 - 70	intrusive
71 - 90	annoying
91 - 110	very annoying
above 110	uncomfortable

Table:

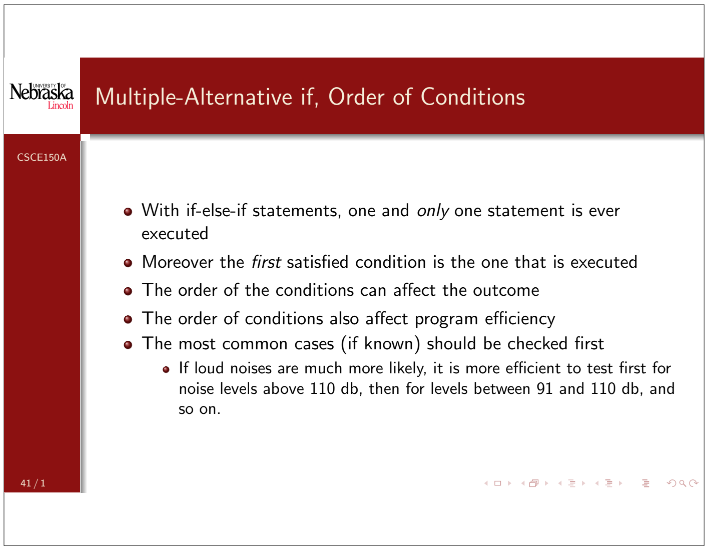
Notes



Example in C code

```
if ( loudness <= 50 )
   printf("quiet");
else if ( loudness <= 70 )
   printf("intrusive");
else if ( loudness <= 90 )
   printf("annoying");
else if ( loudness <= 110 )
   printf("very annoying");
else
   printf("uncomfortable");
```

Notes



Multiple-Alternative if, Order of Conditions

- With if-else-if statements, one and *only* one statement is ever executed
- Moreover the *first* satisfied condition is the one that is executed
- The order of the conditions can affect the outcome
- The order of conditions also affect program efficiency
- The most common cases (if known) should be checked first
  - If loud noises are much more likely, it is more efficient to test first for noise levels above 110 db, then for levels between 91 and 110 db, and so on.

Notes

Code Exercise

CSCE150A

Exercise

The Department of Defense would like a program that identifies **single males** *between the* **ages of 18 and 26**, *inclusive. Design a logical expression that captures this.*

Notes

Answer

CSCE150A

```
/* Print a message if all criteria are met.*/
if ( marital_status == ’S’ )
   if ( gender == ’M’ )
      if ( age >= 18 && age <= 26 )
         printf("All criteria are met.\n");
```

Can this be improved?

Notes

Better Solution

CSCE150A

```
if ( maritial_status == ’S’ &&
     gender == ’M’ &&
     age >= 18 &&
     age <= 26 )
   printf("All criteria are met.\n");
```

Avoids overhead of executing the “then” part of each `if` statement in previous solution

Notes

Switch

- The `switch` statement is similar to a multiple-alternative `if` statement, but can be used only for type `char` or type `int` expressions.
- Useful when the selection depends on the value of a single variable (called the *controlling variable*)
- Expressions in the `switch` statement must cover all possible values of the controlling variable.
  - Each viable expression → `case` statement
  - All other values → *fall-through* (`default:`) statement.

Notes

Switch Example

```
#include <stdio.h>
int main(void)
{
char class;
scanf("%c", &class);
switch (class)
  {
    case 'B':
    case 'b':
      printf("Battleship\n");
      break;
    case 'C':
    case 'c':
      printf("Cruiser\n");
      break;
    default:
      printf("Unknown ship class%c\n", class);
  }
return 0;
}
```

Notes

Common Errors

- You *cannot* use a **string** such as `"Cruiser"` or `"Frigate"` as a case label.
- The omission of the `break` statement at the end of an alternative causes the execution to “fall through” into the next alternative.
- Forgetting the closing brace of the `switch` statement body.

Notes

Nebraska Lincoln

Nested if versus switch

- A nested `if` is more general then a `switch` statement
  - `if`: Can check any number of any data type variables vs. one value for `int` or `char` data type.
- `if`: Can use a range of values, such as < 100
- `switch`: More readable
- `switch`: Can not compare strings or `double` types
- `switch`: Can not handle a range of values in one case label
- Use the switch whenever there are ten or fewer case labels
- Use the default label whenever possible

Notes

Nebraska Lincoln

Common Programming Errors I

- `(0 <= x <= 4)` is **always** `true`
  - Associativity: first `0 <= x` is evaluated (true or false)
  - Thus, it evaluates to either 1 or and 0
  - In either case, both are less than 4
  - Thus the entire expression is true *regardless* of the value of `x`
- `if(x = 10)` is **always** true: the assignment operator is evaluated and `x` is given a value of 10, which is true

Notes

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Common Programming Errors II

- Don't forget to parenthesize the condition.
- Don't forget the opening and closing brackets, `{ }` if they are needed.
- When doing nested `if` statement, try to select conditions so that you can use the range-elimination multiple-alternative format.
- C matches each `else` with the closest unmatched `if`, so be careful so that you get the correct pairings of `if` and `else` statements.
  - Can insert curly braces to get the desired behavior

Notes

Common Programming Errors III

- In switch statements, make sure the controlling expression and case labels are of the same permitted type.
- Remember to include the default case for switch statements.
- Don't forget the opening and closing brackets, { } for the switch statement.
- Don't forget the break statement.

Notes

Conditionals: Review I

```
if (x == 0)
   statement_T;

if (x == 0)
   statement_T;
else
   statement_F;

if (x == 0) {
   statements_T;
}
```

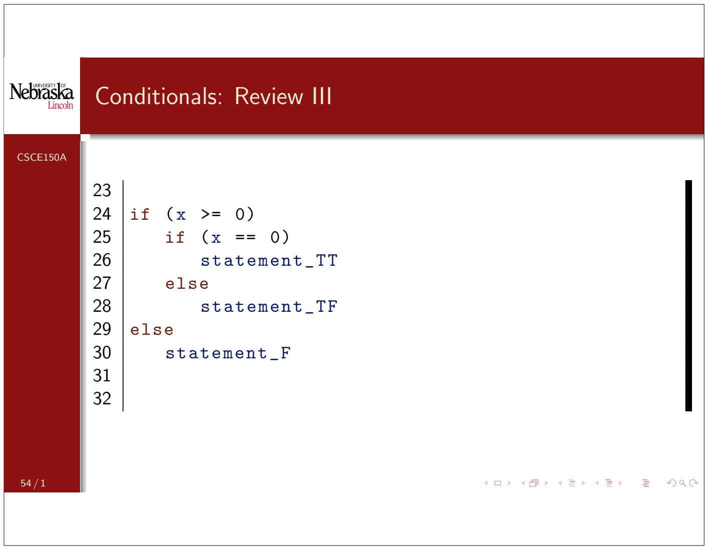
Notes

Conditionals: Review II

```

if (x == 0) {
   statements_T
}
else {
   statements_F
}
```

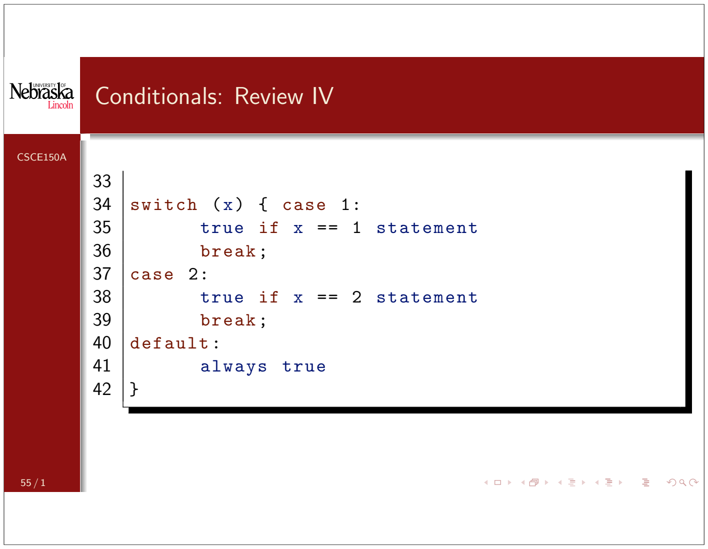
Notes



Conditionals: Review III

```
if (x >= 0)
   if (x == 0)
      statement_TT
   else
      statement_TF
else
   statement_F
```

Notes



Conditionals: Review IV

```
switch (x) { case 1:
      true if x == 1 statement
      break;
case 2:
      true if x == 2 statement
      break;
default:
      always true
}
```

Notes

Questions?

Notes