Syntax of Programming Languages

Syntax and Semantics of Expressions

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- The Lisp expression `(– (– 2 3) 4)` and the Java expression `2 – 3 – 4` have the *same semantics* but have *different syntax*.

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Examples

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- + is a ternary operator whose operands are (– x y), 3, and (* z z).

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In Lisp, a function call is written as a list whose ***first*** element is the function name.

Now consider a notation we’ll call ***rpnLisp*** that’s the same as Lisp except in that a function call is written as a list whose ***last*** element is the function name.

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Thus the Lisp expression (+ (- 1 2) (* 3 4 5) 6)
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Rules 2 – 5 give decompositions of e into two (rules 4 & 5) or three (rule 2 & 3) substructures, but some of these decompositions may ***violate*** the following important principle of syntax specification:

- ***The semantics of a structure should be easily definable in terms of the semantics of its syntactic substructures.***

Example of How the Principle May be Violated

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(i) e_1 = x **op** = – e_2 = y * z + w

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- ***The semantics of a structure should be easily definable in terms of the semantics of its syntactic substructures.***

Let e be the following Java expression: x – y * z + w

Then 3. e = e_1 **op** e_2 where each of e_1 and e_2 is an s.v.i.e. and **op** is a binary operator.

gives the following decompositions of e:

(i)	e_1 = x	**op** = –	e_2 = y * z + w
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- Sec. 2.5 of Sethi (assigned reading after Exam 1) gives another way to specify syntactically valid infix expressions ***that does not have this drawback***.

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Key Question: How can we determine which operator of e should be applied **last**?

How to Determine Which Operator of an Infix Expression e Should be Applied Last

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(a) **and**

(b)

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(c)

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If no precedence and associativity rules for the operators have been given, then when an expression has more than one top level operator it will ***not*** be possible to uniquely determine which operator should be applied last!

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However, the designer of an infix notation will usually give ***precedence and associativity rules*** for the operators that:

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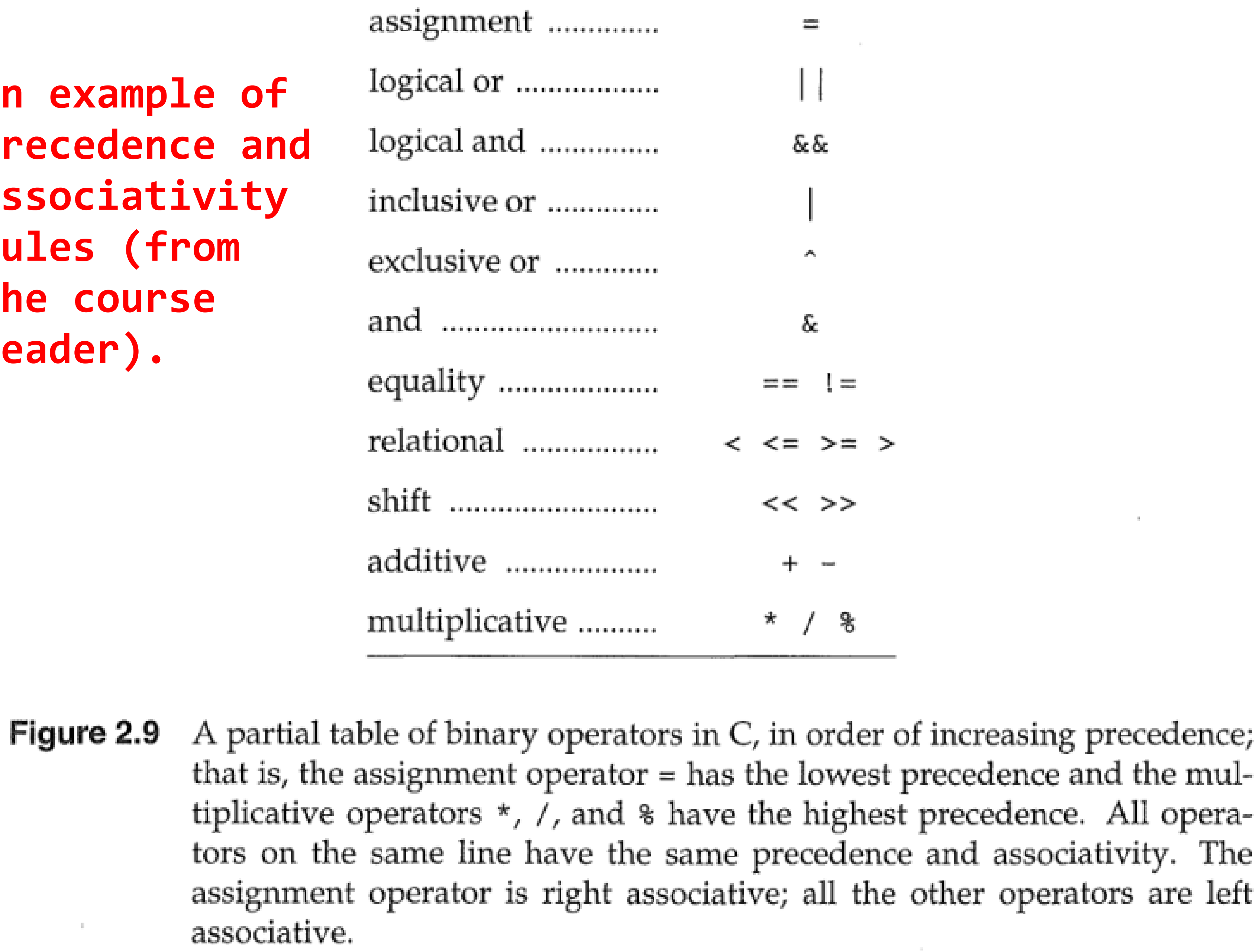
(ii) specify, for each class, whether the class is ***left***-associative (= ***left-to-right*** associative) or ***right***-associative (= ***right-to-left*** associative).

An example of precedence and associativity rules (from the course reader).



assignment	=
logical or	||
logical and	&&
inclusive or	|
exclusive or	^
and	&
equality	== !=
relational	< <= >= >
shift	<< >>
additive	+ -
multiplicative	* / %

Figure 2.9 A partial table of binary operators in C, in order of increasing precedence; that is, the assignment operator = has the lowest precedence and the multiplicative operators *, /, and % have the highest precedence. All operators on the same line have the same precedence and associativity. The assignment operator is right associative; all the other operators are left associative.

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Using these rules, ***we can find the operator of*** e ***that should be applied last as follows***:

Follow These Steps to Determine Which Operator of an Infix Expression e Should be Applied Last:

1.

2.

2.1

2.2

2.3

Follow These Steps to Determine Which Operator of an Infix Expression e Should be Applied Last:

1. If e is of the form (e′), then the operator that should be applied last in e′ is also the operator that should be applied last in e.

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Example: Find the operator that should be applied last in this C expression: x * (y + (z + 3) – 2) + w – u / t

Solution: There are 4 top-level operators, namely the 4 **black** operators in: x ***** (y + (z + 3) – 2) **+** w **–** u **/** t

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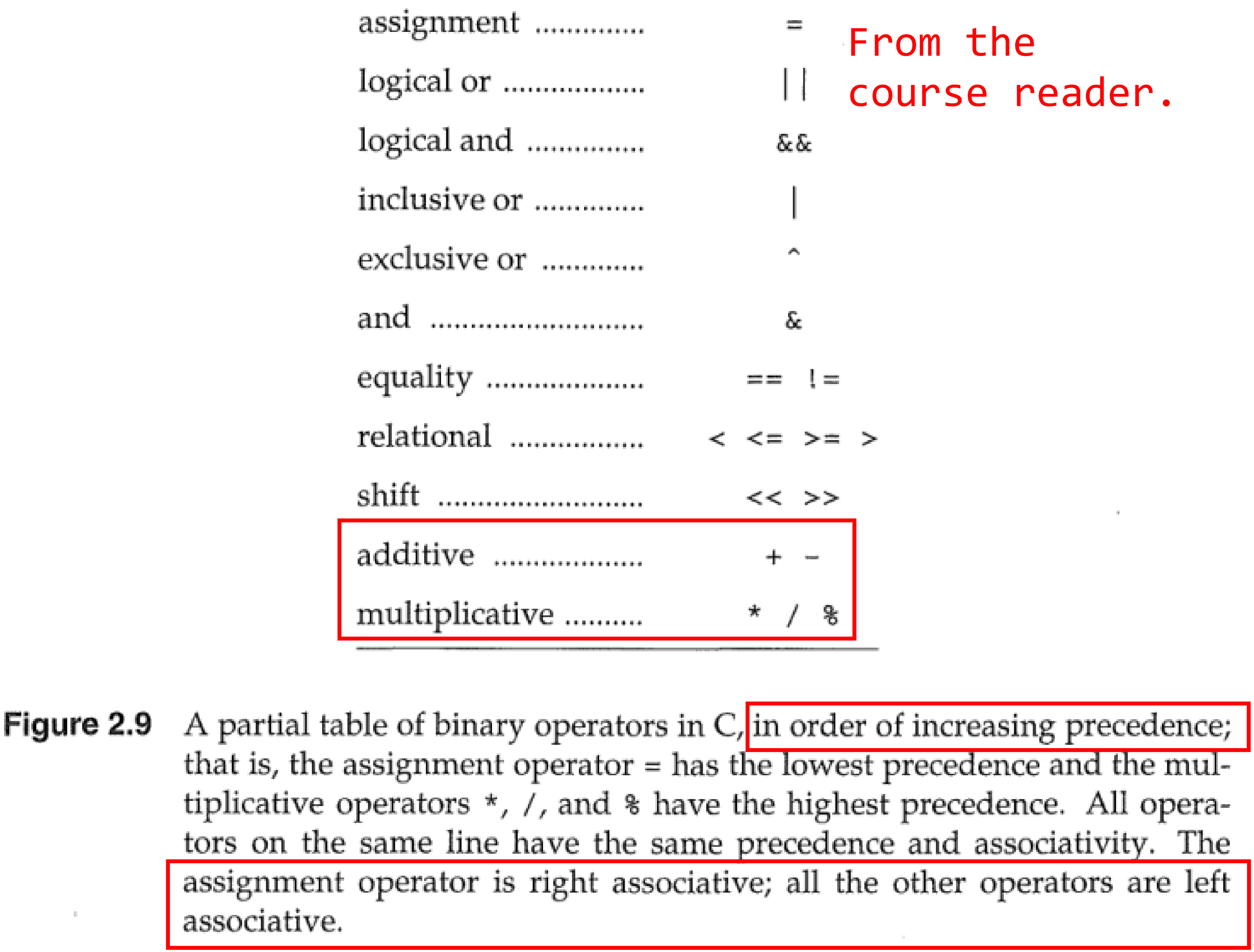
Step 2.3:



assignment	=
logical or	||
logical and	&&
inclusive or	|
exclusive or	^
and	&
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Step 2.3: These 2 operators **+** and **-** belong to a ***left-associative*** precedence class, so the rightmost of them (i.e., **-**) must be applied last.

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Example: In **Java**, arguments of functions or operators are evaluated in ***left-to-right*** order, so **/** is applied ***before*** **--** when evaluating the above expression. Thus

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Consider this C/C++ expression: `y / 2 * --y`

`/` and `*` belong to a ***left-associative*** precedence class, so the operator that should be applied ***last*** is: `*`

But a C or C++ compiler is free to generate code that applies `--` first or applies `/` first!

Note: In addition to precedence & associativity rules, a language may have *other* rules that govern the order in which operators in infix expressions are applied!

Example: In **Java**, arguments of functions or operators are evaluated in ***left-to-right*** order, so `/` is applied ***before*** `--` when evaluating the above expression. Thus

```
     int y = 4; System.out.println(y / 2 * --y);
```

prints 6 (not 3).

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Example: In **Java**, arguments of functions or operators are evaluated in ***left-to-right*** order, so **/** is applied ***before*** **--** when evaluating the above expression. Thus

```
     int y = 4; System.out.println(y / 2 * --y);
```

prints 6 (not 3). In C++ there's no left-to-right rule, so **int y = 4; cout << y / 2 * --y;** may print 3 or 6.