Example 5.11: The S-attributed definition in Fig. 5.10 constructs syntax trees for a simple expression grammar involving only the binary operators $+$ and $-$. As usual, these operators are at the same precedence level and are jointly left associative. All nonterminals have one synthesized attribute *node*, which represents a node of the syntax tree.

Every time the first production $E \rightarrow E_1 + T$ is used, its rule creates a node with $'+'$ for *op* and two children, $E_1.node$ and $T.node$, for the subexpressions. The second production has a similar rule.

	PRODUCTION	SEMANTIC RULES
1)	$E \to E_1 + T$	$E.node$ = **new** $Node('+', E_1.node, T.node)$
2)	$E \to E_1 - T$	$E.node$ = **new** $Node('-', E_1.node, T.node)$
3)	$E \to T$	$E.node = T.node$
4)	$T \to (E)$	$T.node = E.node$
5)	$T \to$ **id**	$T.node$ = **new** $Leaf$(**id**, **id**.$entry$)
6)	$T \to$ **num**	$T.node$ = **new** $Leaf$(**num**, **num**.val)

Figure 5.10: Constructing syntax trees for simple expressions

For production 3, $E \to T$, no node is created, since $E.node$ is the same as $T.node$. Similarly, no node is created for production 4, $T \to (E)$. The value of $T.node$ is the same as $E.node$, since parentheses are used only for grouping; they influence the structure of the parse tree and the syntax tree, but once their job is done, there is no further need to retain them in the syntax tree.

The last two T-productions have a single terminal on the right. We use the constructor *Leaf* to create a suitable node, which becomes the value of $T.node$.

Figure 5.11 shows the construction of a syntax tree for the input $a - 4 + c$. The nodes of the syntax tree are shown as records, with the *op* field first. Syntax-tree edges are now shown as solid lines. The underlying parse tree, which need not actually be constructed, is shown with dotted edges. The third type of line, shown dashed, represents the values of $E.node$ and $T.node$; each line points to the appropriate syntax-tree node.

At the bottom we see leaves for a, 4 and c, constructed by *Leaf*. We suppose that the lexical value **id**.*entry* points into the symbol table, and the lexical value **num**.*val* is the numerical value of a constant. These leaves, or pointers to them, become the value of $T.node$ at the three parse-tree nodes labeled T, according to rules 5 and 6. Note that by rule 3, the pointer to the leaf for a is also the value of $E.node$ for the leftmost E in the parse tree.

Rule 2 causes us to create a node with *op* equal to the minus sign and pointers to the first two leaves. Then, rule 1 produces the root node of the syntax tree by combining the node for $-$ with the third leaf.

If the rules are evaluated during a postorder traversal of the parse tree, or with reductions during a bottom-up parse, then the sequence of steps shown in Fig. 5.12 ends with p_5 pointing to the root of the constructed syntax tree. □

With a grammar designed for top-down parsing, the same syntax trees are constructed, using the same sequence of steps, even though the structure of the parse trees differs significantly from that of syntax trees.