Tutorial exercise 1 – note on solutions

- Grammar:

```
Program -> ‘program’ string statement
Statement -> ‘turn’ number ‘degrees’ |
             ‘forward’ number |
             ‘times’ number ‘do’ statement |
             ‘begin’ statementlist
Statement-list -> ‘end’ |
                  statement ‘;’ statement-list
```

Move fast

Get an idea of the big picture

Then go to the gaps and work backwards

Turtle.java

```
static StatementTree parseStatement(Lexer lex) throws IOException
  {
    Token t = lex.nextToken();
    switch (t.tokenId) {
    case Token.TURN:
      lex.match(Token.NUMBER);
      int degrees = lex.getLastToken().intValue;
      lex.match(Token.DEGREES);
      return new TurnNode(degrees);

    case Token.FORWARD:
          ??
          ??
          ??
```

Turtle.java

```
static StatementTree parseStatement(Lexer lex) throws IOException
  {
    Token t = lex.nextToken();
    switch (t.tokenId) {
    case Token.TURN:
      lex.match(Token.NUMBER);
      int degrees = lex.getLastToken().intValue;
      lex.match(Token.DEGREES);
      return new TurnNode(degrees);

    case Token.FORWARD:
      lex.match(Token.NUMBER);
      int distance = lex.getLastToken().intValue;
      return new ForwardNode(distance);
```

Turtle.java

```
static StatementTree parseStatement(Lexer lex) throws IOException
  {
    Token t = lex.nextToken();
    switch (t.tokenId) {
    case Token.TURN:
       …
    case Token.FORWARD:
       …
    case Token.TIMES:
       ??
       ??
       ??
       ??
       ??
```

Turtle.java

```
static StatementTree parseStatement(Lexer lex) throws IOException
  {
    Token t = lex.nextToken();
    switch (t.tokenId) {
    case Token.TURN:
       …

    case Token.FORWARD:
       …
    case Token.TIMES:
       lex.match(Token.NUMBER);
       int count = lex.getLastToken().intValue;
       lex.match(Token.DO);
       ??
       ??
```

Turtle.java

```
static StatementTree parseStatement(Lexer lex) throws IOException
  {
    Token t = lex.nextToken();
    switch (t.tokenId) {
    case Token.TURN:
      …
    case Token.FORWARD:
      …
    case Token.TIMES:
      lex.match(Token.NUMBER);
      int count = lex.getLastToken().intValue;
      lex.match(Token.DO);
      StatementTree body = ??
      return new TimesNode(count, body);
```

Turtle.java

```
static StatementTree parseStatement(Lexer lex) throws IOException
  {
    Token t = lex.nextToken();
    switch (t.tokenId) {
    case Token.TURN:
      …

    case Token.FORWARD:
      …
    case Token.TIMES:
      lex.match(Token.NUMBER);
      int count = lex.getLastToken().intValue;
      lex.match(Token.DO);
      StatementTree body = parseStatement(lex);
      return new TimesNode(count, body);
```

InterpretVisitor.java

```
public class InterpretVisitor extends TreeVisitor {
    void visitStatementList(StatementTree first,
                            StatementTreeList rest) {
        first.Accept(this);
        if (rest != null) {
            rest.Accept(this);
        }
    }
    void visitTurnNode(int degrees) {
        System.out.println("Please turn "+degrees+" degrees");
    }
    void visitForwardNode(int distance) {
        ??
    }
    void visitTimesNode(int count, StatementTree body) {
        ??
        ??
        ??
    }
    void visitBeginNode(StatementTreeList body) {
        body.Accept(this);
    }
}
```

InterpretVisitor.java

```
public class InterpretVisitor extends TreeVisitor {
    void visitStatementList(StatementTree first,
                            StatementTreeList rest) {
        first.Accept(this);
        if (rest != null) {
            rest.Accept(this);
        }
    }
    void visitTurnNode(int degrees) {
        System.out.println("Please turn "+degrees+" degrees");
    }
    void visitForwardNode(int distance) {
        System.out.println("Please move forward "+distance);
    }
    void visitTimesNode(int count, StatementTree body) {
        ??
        ??
        ??
    }
    void visitBeginNode(StatementTreeList body) {
        body.Accept(this);
    }
}
```

InterpretVisitor.java

```
public class InterpretVisitor extends TreeVisitor {
    void visitStatementList(StatementTree first,
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        first.Accept(this);
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    void visitTurnNode(int degrees) {
        System.out.println("Please turn "+degrees+" degrees");
    }
    void visitForwardNode(int distance) {
        System.out.println("Please move forward "+distance);
    }
    void visitTimesNode(int count, StatementTree body) {
        for (int i=0; i<count; ++i) {
            body.Accept(this);
        }
    }
    void visitBeginNode(StatementTreeList body) {
        body.Accept(this);
    }
}
```

Visitors

- The turtle interpreter was implemented using a “visitor”
- Visitor is an example of a “design pattern”
- Visitor is a common technique to simplify traversal of a tree or graph
- What is the alternative?

If you don’t use a visitor…

```
public class TurnNode extends StatementTree {
    int degrees;

    TurnNode(int d) {
        degrees = d;
    }
    public void print() {
        System.out.println("turn "+degrees+" degrees");
    }
    public void interpret() {
        System.out.println("please turn "+degrees);
    }

}
```

- The simplest way to implement the interpreter is to have an “interpret()” method for each of the AST’s node types – as shown above for “TurnNode”

If you don’t use a visitor…

```
public class TurnNode extends StatementTree {
    int degrees;

    TurnNode(int d) {
        degrees = d;
    }
    public void print() {
        System.out.println("turn "+degrees+" degrees");
    }
    public void interpret() {
        System.out.println("please turn "+degrees);
    }
    public void inFrench() {
        System.out.println(“tournez "+degrees);
    }
}
```

- We need to add a method for each operation that involves a traversal of the AST

Using a visitor…

```
public class TurnNode extends StatementTree {
    int degrees;

    TurnNode(int d) {
        degrees = d;
    }
public void Accept(TreeVisitor v) {
        v.visitTurnNode(degrees);
    }
}
```

- With a visitor the AST node types just have one Accept method

```
public class InterpretVisitor extends TreeVisitor {
    void visitStatementList(StatementTree first,
                            StatementTreeList rest) {
        first.Accept(this);
        if (rest != null) {
            rest.Accept(this);
        }
    }
    void visitTurnNode(int degrees) {
        System.out.println("Please turn "+degrees+" degrees");
    }
    void visitForwardNode(int distance) {
        System.out.println("Please move forward "+distance);
    }
    void visitTimesNode(int count, StatementTree body) {
        for (int i=0; i<count; ++i) {
            body.Accept(this);
        }
    }
    void visitBeginNode(StatementTreeList body) {
        body.Accept(this);
    }
}
```

- Now we can encapsulate all the interpreter code in a single file
- And we can write a “print” traversal in a similar, single file

Parse tree

You should be able to draw the parse tree for a given input, based on a specified grammar

Here we work through drawing the parse tree for the turtle language example in Tutorial 1

The main thing to notice is that the parse tree is *strictly* derived from the grammar – you have no choice

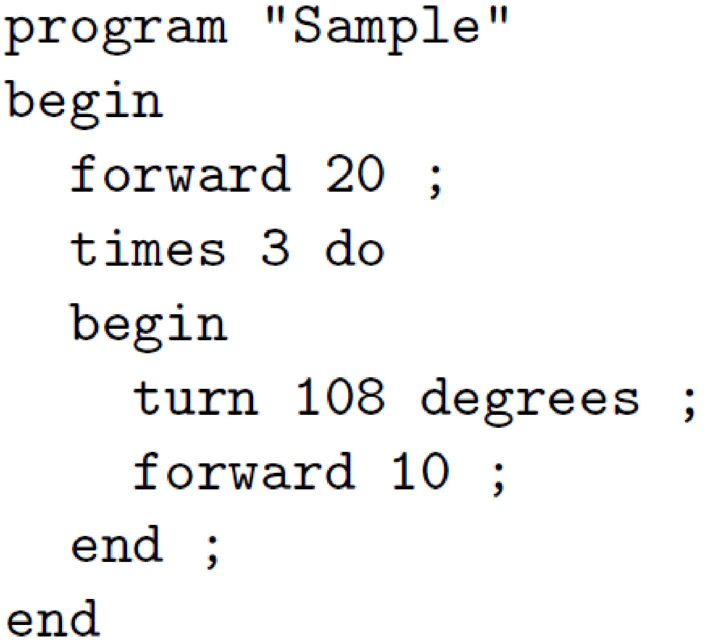
In contrast, your compiler will build an abstract syntax tree – which you will design

Warm-up: drawing the parse tree

- Grammar:

```
Program -> ‘program’ string statement
Statement -> ‘turn’ number ‘degrees’ |
             ‘forward’ number |
             ‘times’ number ‘do’ statement |
             ‘begin’ statementlist
Statement-list -> ‘end’ |
                  statement ‘;’ statement-list
```

- Input:



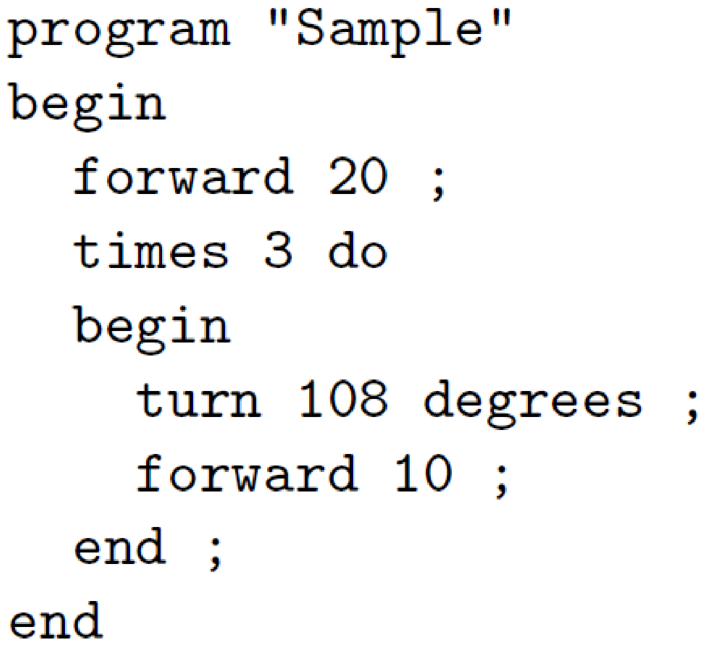
```
program "Sample"
begin
  forward 20 ;
  times 3 do
  begin
    turn 108 degrees ;
    forward 10 ;
  end ;
end
```

Warm-up: drawing the parse tree

- Grammar:

```
Program -> ‘program’ string statement
Statement -> ‘turn’ number ‘degrees’ |
             ‘forward’ number |
             ‘times’ number ‘do’ statement |
             ‘begin’ statementlist
Statement-list -> ‘end’ |
                  statement ‘;’ statement-list
```

- Input:



```
program "Sample"
begin
  forward 20 ;
  times 3 do
  begin
    turn 108 degrees ;
    forward 10 ;
  end ;
end
```

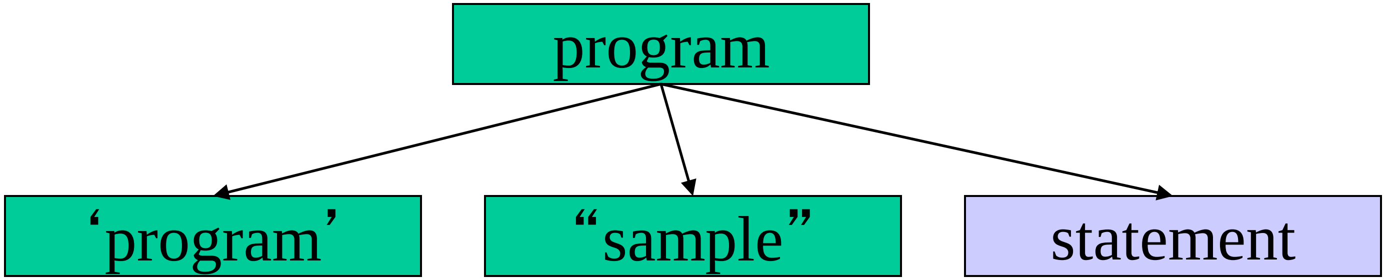
Warm-up: drawing the parse tree

- Grammar:

```
Program -> ‘program’ string statement
Statement -> ‘turn’ number ‘degrees’ |
             ‘forward’ number |
             ‘times’ number ‘do’ statement |
             ‘begin’ statementlist
Statement-list -> ‘end’ |
                  statement ‘;’ statement-list
```

- Stick to a simple rule:
  - Start by drawing the start symbol “program” at the top of the page
  - Draw three arrows, one for each item on the right hand side:
    - `‘program’ string statement`

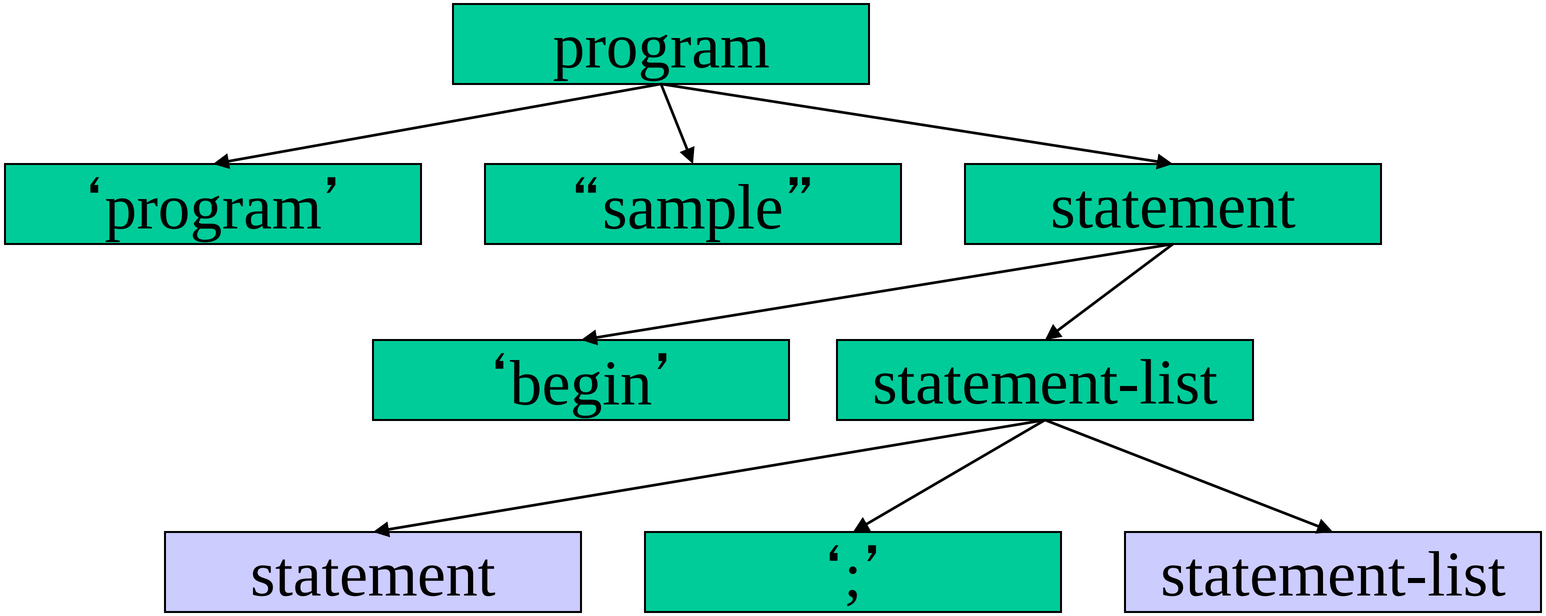
Drawing the parse tree



- Grammar:

```
Program -> ‘program’ string statement
```

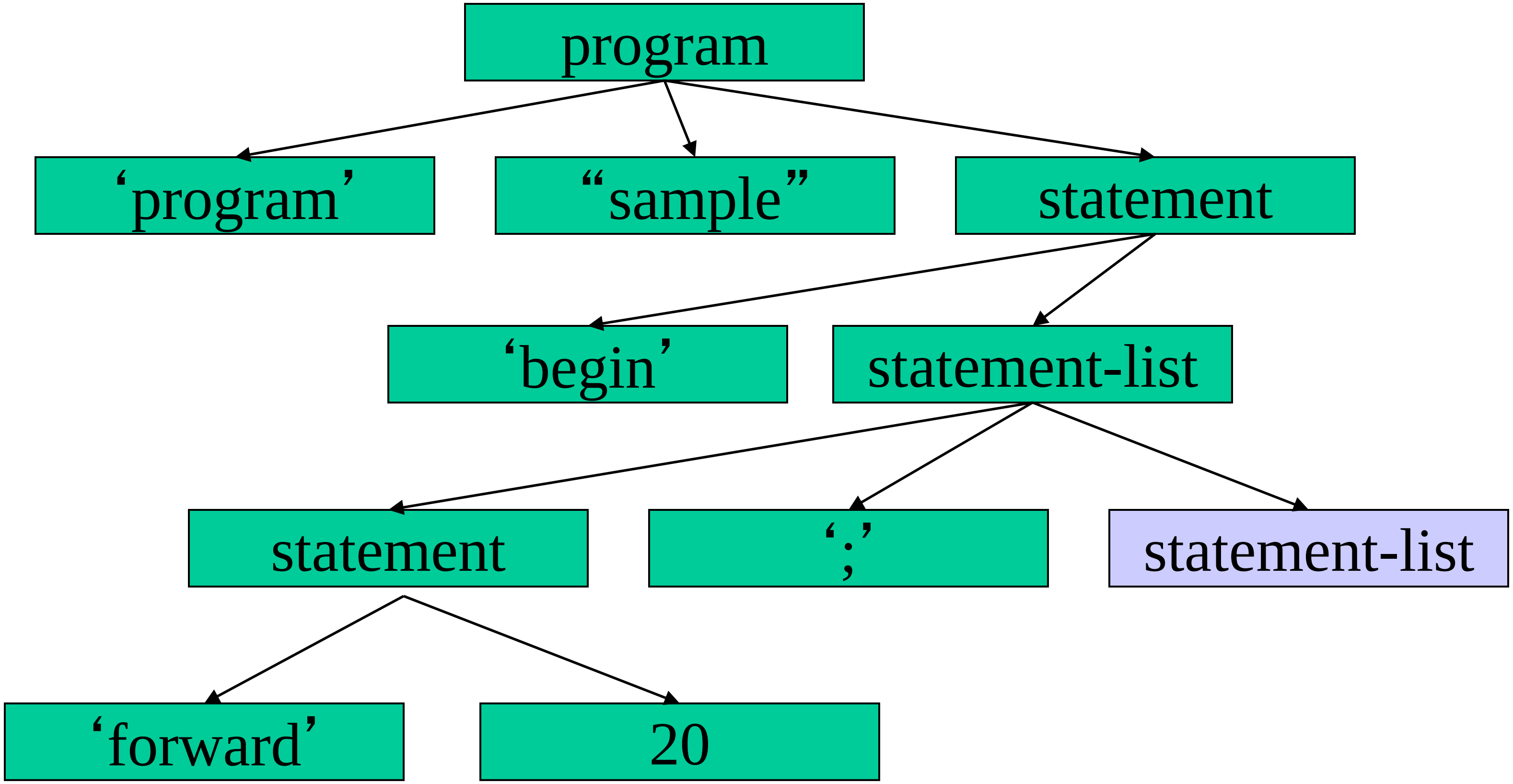
Drawing the parse tree



- Grammar:

```
Statement -> 'turn' number 'degrees' |
                     'forward' number |
                     'times' number 'do' statement |
                     'begin' statementlist
Statement-list -> 'end' |
                  statement ';' statement-list
```

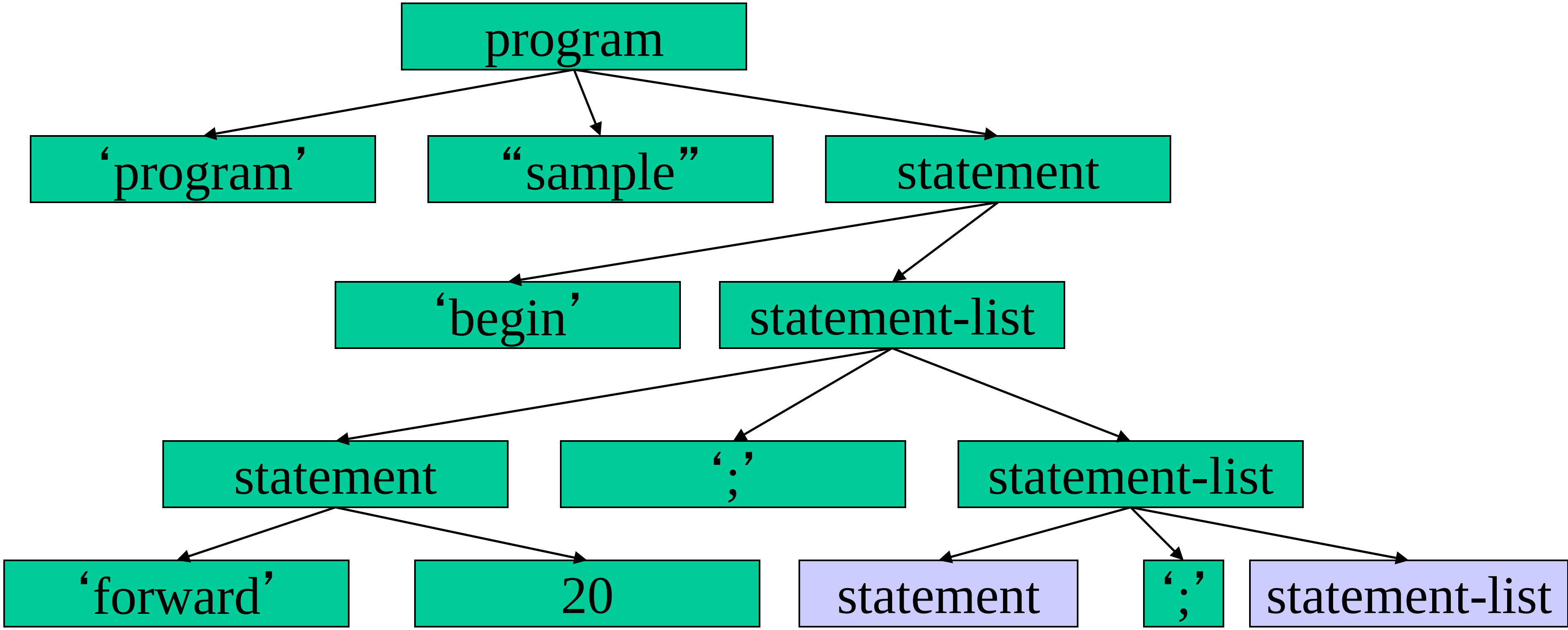
Drawing the parse tree



- Grammar:

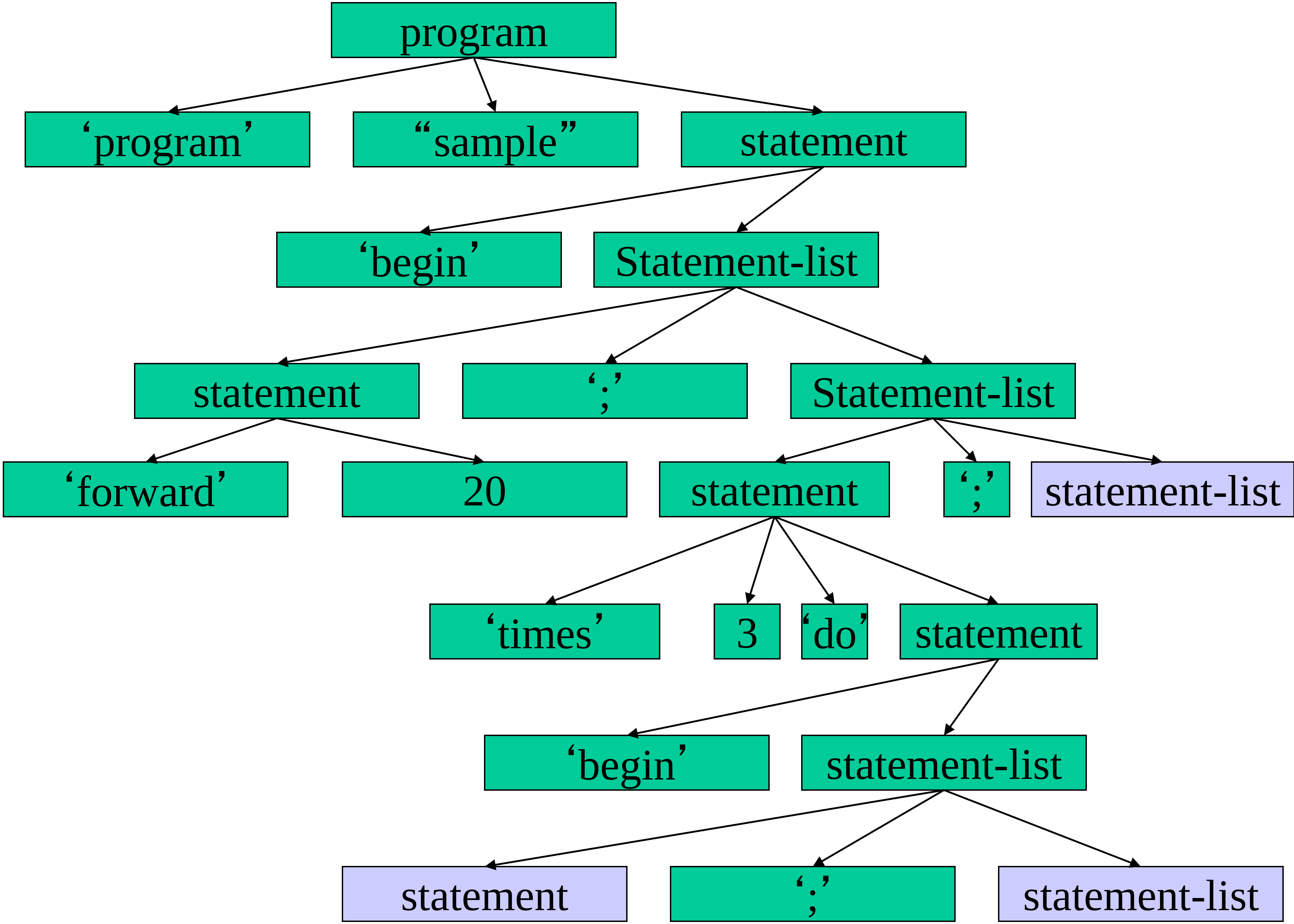
```
    Statement -> ‘turn’ number ‘degrees’ |
                       ‘forward’ number | …
                       ‘times’ number ‘do’ statement |
                       ‘begin’ statementlist
    Statement-list -> ‘end’ |
                    statement ‘;’ statement-list
```

Drawing the parse tree



- Grammar:

```
Statement-list -> ‘end’ |
                  statement ‘;’ statement-list
```



program

‘program’

“sample”

statement

‘begin’

Statement-list

statement

‘;’

Statement-list

‘forward’

20

statement

‘;’

statement-list

‘times’

3

‘do’

statement

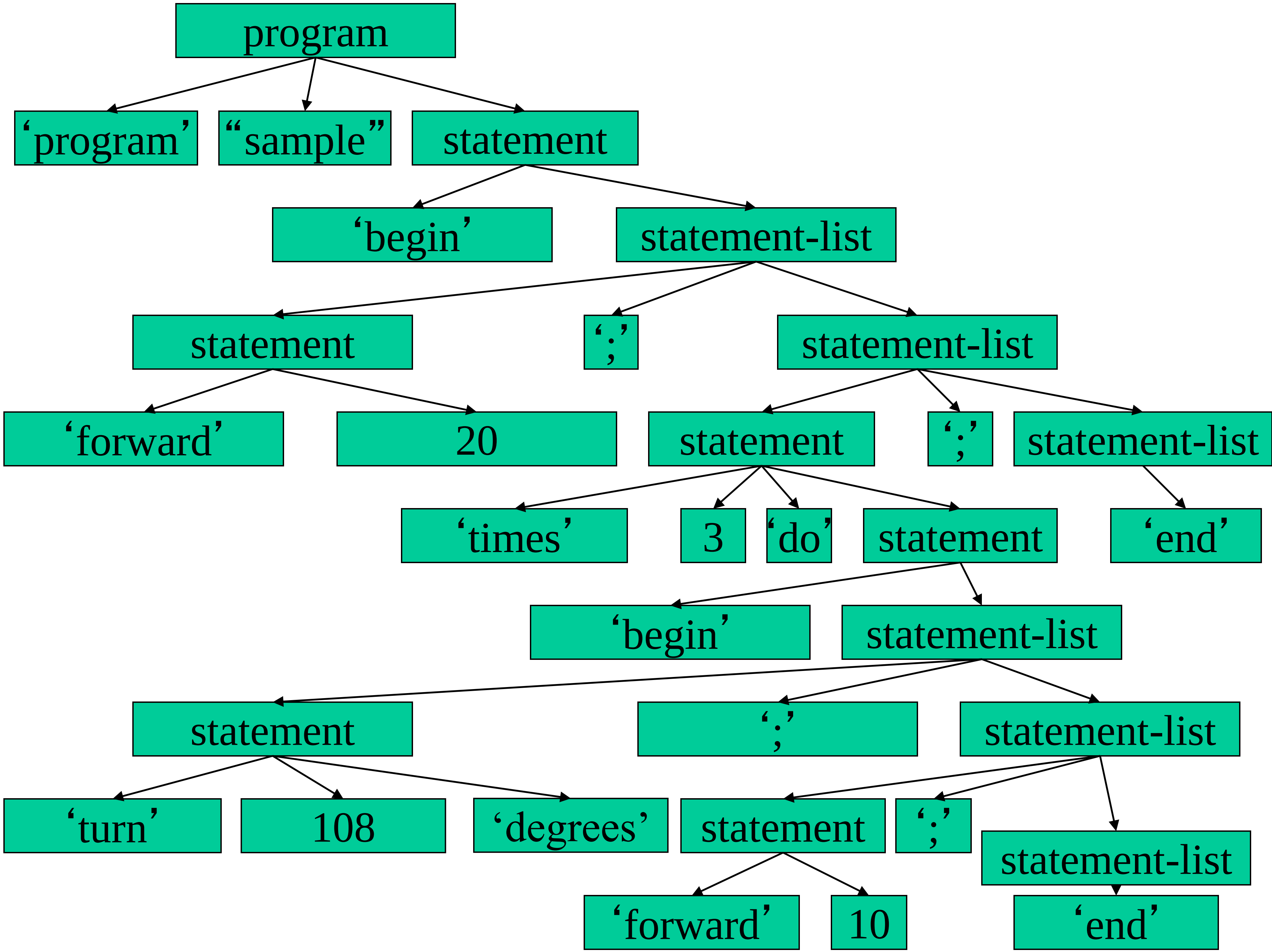
‘begin’

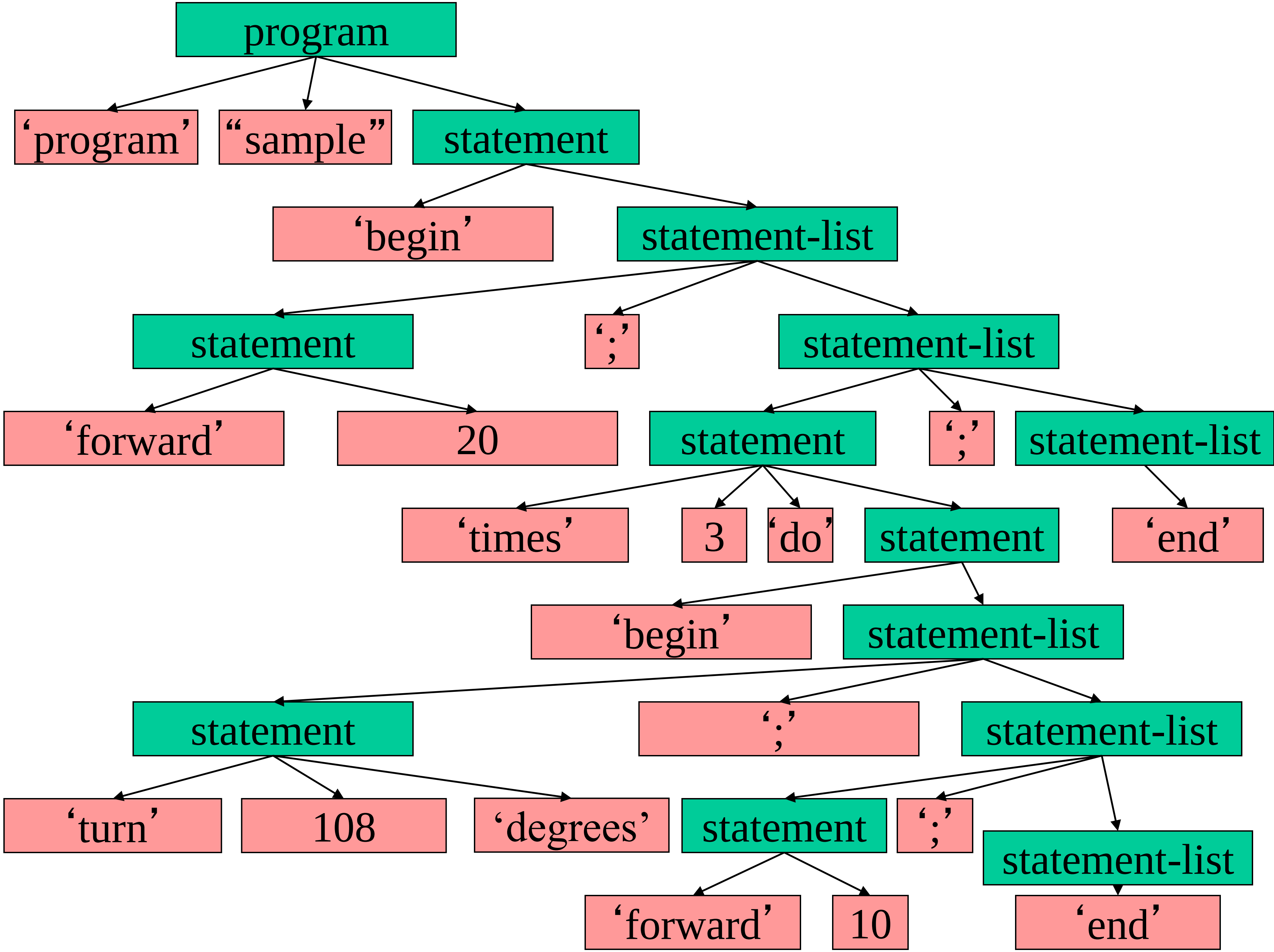
statement-list

statement

‘;’

statement-list


program
'program'
"sample"
statement
'begin'
statement-list
statement
';'
statement-list
'forward'
20
statement
';'
statement-list
'times'
3
'do'
statement
'end'
'begin'
statement-list
statement
';'
statement-list
'turn'
108
'degrees'
statement
';'
statement-list
'forward'
10
'end'



program

‘program’ “sample” statement

‘begin’ statement-list

statement ‘;’ statement-list

‘forward’ 20 statement ‘;’ statement-list

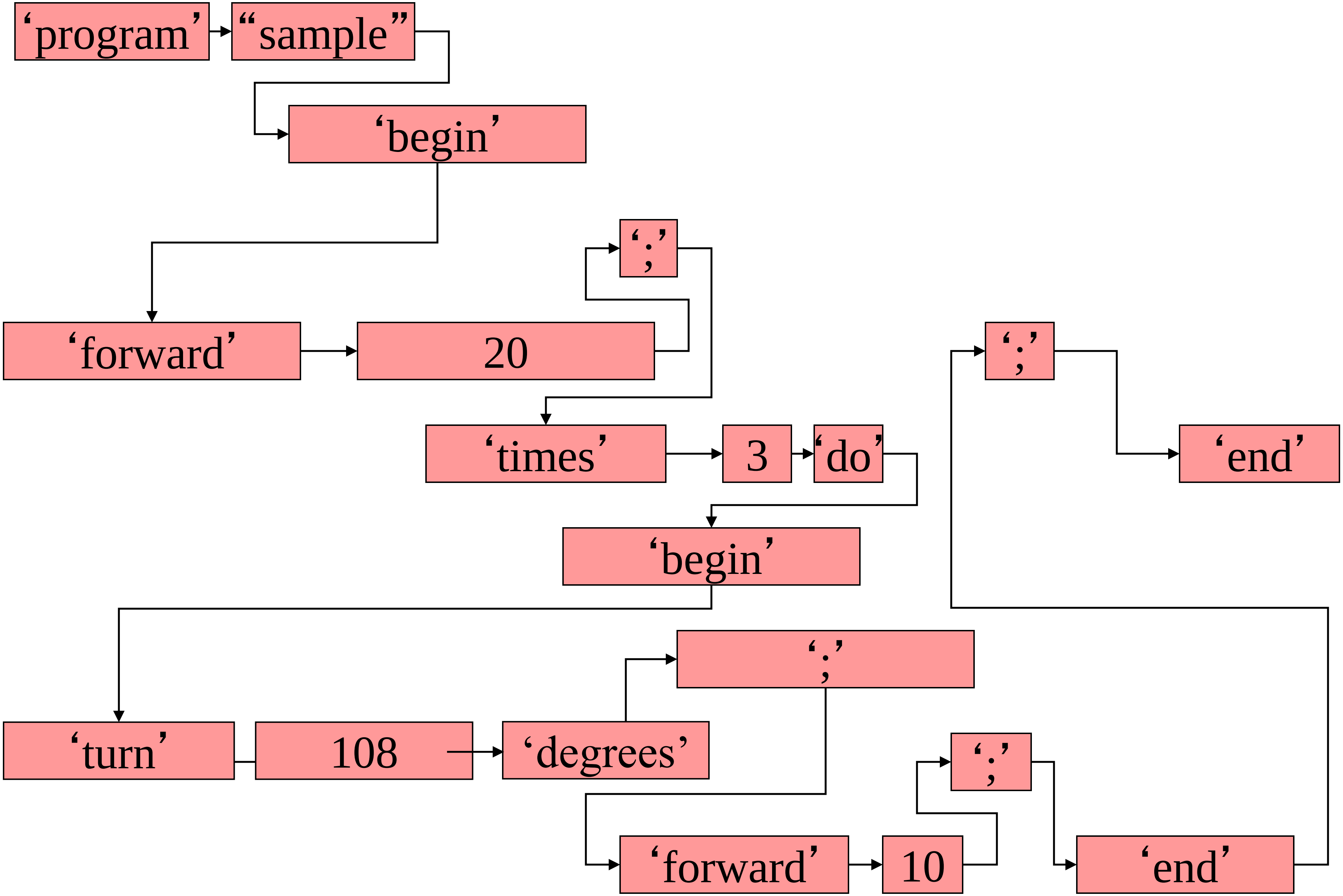
‘times’ 3 ‘do’ statement ‘end’

‘begin’ statement-list

statement ‘;’ statement-list

‘turn’ 108 ‘degrees’ statement ‘;’ statement-list

‘forward’ 10 ‘end’



‘program’

“sample”

‘begin’

‘forward’

20

‘;’

‘times’

3

‘do’

‘begin’

‘turn’

108

‘degrees’

‘;’

‘forward’

10

‘;’

‘end’

‘;’

‘end’