Flattening and unflattening XML markup

A Zen garden of “raising” methods

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Flattening and raising

- We may use empty elements (*Trojan horse pairs* or [single] *milestones*) to work around overlap problems
- We may flatten container elements and raise empty ones to create or invert a hierarchy
- Fully inverting a hierarchy and raising scattered flattened elements may require different strategies

- **Example**
- We want to tag the splitting of an element, but we can't wrap an end tag followed by a start tag in a container
- This arises when we collate variant witnesses; we want to wrap each variant reading in the equivalent of TEI **<rdg>**

Flattening with intent to raise

Original content elements

```
<?xml version="1.0" encoding="UTF-8"?>
<p>
  <cit>
    <quote>
      <lg>
        <l>Like one who, on a lonely road,</l>
        <l>Doth walk in fear and dread,</l>
        <l>And, having once turn’d round, walks on,</l>
        <l>And turns no more his head;</l>
        <l>Because he knows a frightful fiend</l>
        <l>Doth close behind him tread*.</l>
      </lg>
    </quote>
    <note> *
      <bibl>Coleridge’s “Ancient Mariner.”</bibl>
    </note>
  </cit>
</p>
```

Collating *Frankenstein*

Q. How do you get a text-collation tool to tell you about differences in (say) paragraphing or lineation?

Q. How do you ensure that XML collation output with variants that span line boundaries is well-formed?

Answers:

- Treat XML markup as character data, not as markup.
- Transform the markup into **virtual elements**, so that when it is raised as XML again, you won't have overlapping hierarchies.

Flattening with intent to raise

...converted to virtual elements (*)

```
<?xml version="1.0" encoding="UTF-8"?><p
    xmlns:th="http://www.blackmesatech.com/2017/nss/trojan-horse">
  <cit xml:id="fThomas_C10-cit_1" th:sID="d1e3"/>
  <quote xml:id="fThomas_C10-quote_1" th:sID="d1e5"/>
  <lg xml:id="fThomas_C10-lg_1" th:sID="d1e7"/>
  <l xml:id="fThomas_C10-l_1" th:sID="d1e9"/>
      Like one who, on a lonely road, <l th:eID="d1e9"/>
  <l xml:id="fThomas_C10-l_2" th:sID="d1e12"/>
      Doth walk in fear and dread, <l th:eID="d1e12"/>
  <l xml:id="fThomas_C10-l_3" th:sID="d1e15"/>
      And, having once turn'd round, walks on, <l th:eID="d1e15"/>
  <l xml:id="fThomas_C10-l_4" th:sID="d1e18"/>
      And turns no more his head; <l th:eID="d1e18"/>
  <l xml:id="fThomas_C10-l_5" th:sID="d1e21"/>
      Because he knows a frightful fiend <l th:eID="d1e21"/>
  <l xml:id="fThomas_C10-l_6" th:sID="d1e25"/>
      Doth close behind him tread*. <l th:eID="d1e25"/>
  <lg th:eID="d1e7"/>
  <quote th:eID="d1e5"/>
  <note xml:id="fThomas_C10-note_1" th:sID="d1e30"/> *
  <bibl xml:id="fThomas_C10-bibl_1">
    Coleridge's "Ancient Mariner."
  </bibl>
  <note th:eID="d1e30"/>
  <cit th:eID="d1e3"/>
</p>
```

Context:

preparing for collation:

(we expect witnesses to alter line boundaries and structure)

What we want: virtual overlapping hierarchies

Context: "hotspot" variant location markers inserted in edition files following the collation process

```
<lg xml:id="novel1_letter4_chapter4_div4_div4_p8_cit1_quote1_lg1">
   <l xml:id="novel1_letter4_chapter4_div4_div4_p8_cit1_quote1_lg1_l1"> Like
     <seg xml:id="C10_app435-f1818_end"/>one
     <seg xml:id="C10_app437-f1818_start"/>who,
     <seg xml:id="C10_app437- f1818_end"/>on a
     <seg xml:id="C10_app439-f1818_start"/>lonely road,</l>
    <l xml:id="novel1_letter4_chapter4_div4_div4_p8_cit1_quote1_lg1_l2">
       Doth <seg xml:id="C10_app439-f1818_end"/>walk in fear and
       <seg xml:id="C10_app441-f1818_start"/>dread,</l>
    <l xml:id="novel1_letter4_chapter4_div4_div4_p8_cit1_quote1_lg1_l3">
       And, <seg xml:id="C10_app441-f1818_end"/>having once
       <seg xml:id="C10_app443-f1818_start"/>turn'd
       <seg xml:id="C10_app443-f1818_end"/>
       <seg xml:id="C10_app444-f1818_start"/>round, walks on,</l>
    <l xml:id="novel1_letter4_chapter4_div4_div4_p8_cit1_quote1_lg1_l4">
     And <seg xml:id="C10_app444-f1818_end"/>turns no more his
<seg xml:id="C10_app446-f1818_start"/>head;</l>
    <l xml:id="novel1_letter4_chapter4_div4_div4_p8_cit1_quote1_lg1_l5">
      Because <seg xml:id="C10_app446-f1818_end"/>he knows a frightful
     <seg xml:id="C10_app448-f1818_start"/>fiend</l>
   <l xml:id="novel1_letter4_chapter4_div4_div4_p8_cit1_quote1_lg1_l6">
      Doth <seg xml:id="C10_app448-f1818_end"/>close behind him
      <seg xml:id="C10_app450-f1818_start"/>tread*.</l>
</lg>
```

The problem in a nutshell

Given Trojan Horse* elements of the form

```
... <e th:sID="x"/> ... <e th:eID="x"/> ..
```

produce

```
... <e> ... </e> ..
```

* DeRose 2004 “Markup overlap: a review and a horse,” Extreme Markup Languages 2004.

Preliminary thoughts about raising

- Change the element structure (thinking in nodes)
- Change the tags (thinking in strings)

XML processing and raising

XML processing may involve

1. Reading the serialization (string)
2. Parsing the input to identify events (SAX / event)
3. Building (and using) a tree (DOM)

Each of these stages can be accessed for raising

Seven* raising solutions: a zen garden walk**

- Thinking in strings
  - Regular expression matching
  - pulldom (Python)
- Thinking in nodes
  - Right-sibling traversal (XSLT/XQuery)
  - Inside-out recognition (XSLT/XQuery)
  - Outside-in recognition (XSLT/XQuery)
  - Accumulators (XSLT 3.0)
  - Tumbling Windows (XQuery 3.1)

* Actually, there are more, but seven may be enough.

** We only have time to visit five of these on our short walk today. For the others, read our paper / come talk to us afterwards!

For each solution. . .

- How does it work?
- How are pairs recognized?
- In what order are pairs raised to elements?

String methods

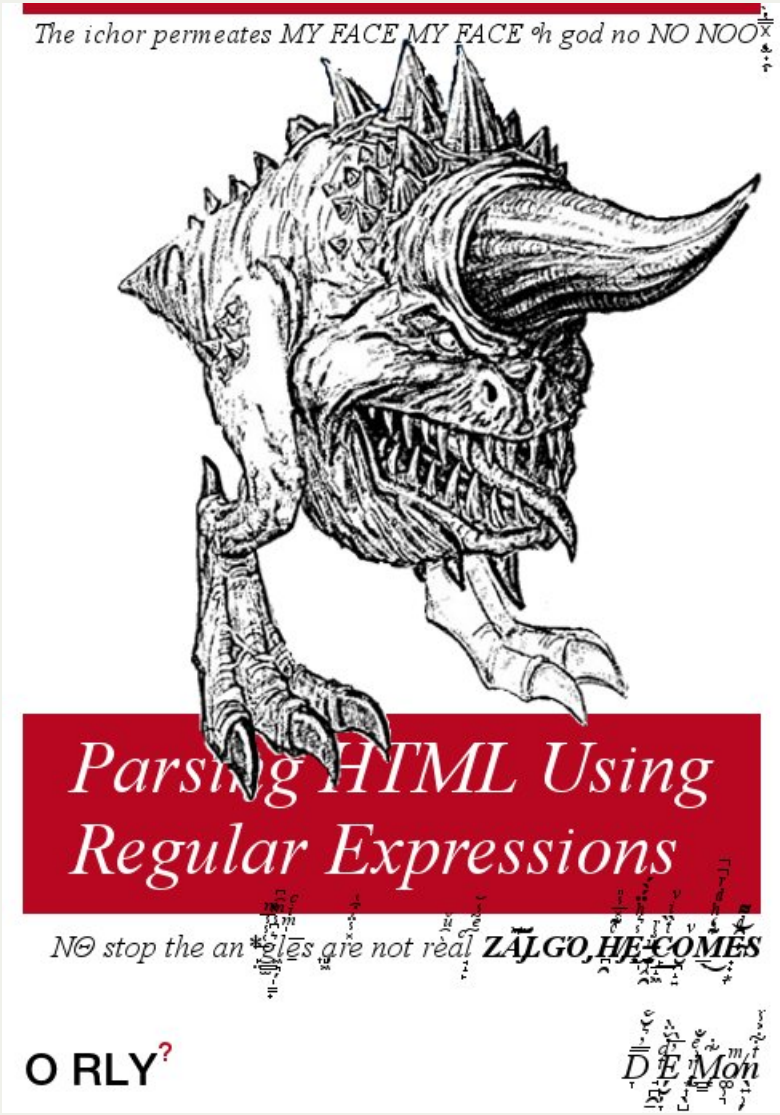
- regular expression matching
- python (pulldom and minidom)

Regular expression matching

- XML is not a *regular language*
- But matching tags as strings is not the same as parsing XML

```
(<[^>]+?)th:sID\s*=\s*['"]\w+?['"](.*?)\/(>)
```

- Dot-matches-all mode
- Watch for the element end-delimiter
- Match non-greedily
- Use **\s+** (not space) for whitespace
- (Canonicalize the XML first)



Python XML processing

Input: pulldom (SAX-like event processor)

String output

- Construct tags (not elements) on element-start and element-end events
- Easy to create malformed output (esp. attribute value quoting)

XML output

- minidom (or lxml)
  - minidom (or lxml or xml.sax.saxutils.XMLGenerator())
  - Add nodes to the tree
  - Maintain context on a stack
- Only partially namespace-aware

A Python pulldom application

SAX-like event interface, with ability to pull in DOM-like subtrees.

- When you see a start-marker,
  - start an element,
  - push it on a stack,
  - start collecting content for it.

```
<lg th:sID="id1"/>
```

```
<lg th:eID="id1"/>
```

- When you see an end-marker,
  - stop collecting content (close the element)
  - pop the stack

- When you see anything else,
  - add it as last child of the element on top of the stack.

pulldom source

```
for event, node in parseString(input.read()):
        if (event == START_ELEMENT
           and not node.hasAttribute('th:eID')):
            # This is a start-marker.
            # Prune attributes ... (not shown)
            open_elements.peek().appendChild(clone)
            open_elements.push(clone)
        elif (event == END_ELEMENT
            and not node.hasAttribute('th:sID')):
            # This is an end-marker.
            open_elements.pop()
        elif event == CHARACTERS:
            t = d.createTextNode(node.data)
            open_elements.peek().appendChild(t)
        else:
            continue

result = open_elements[0].toxml()
```

The core of the Python app

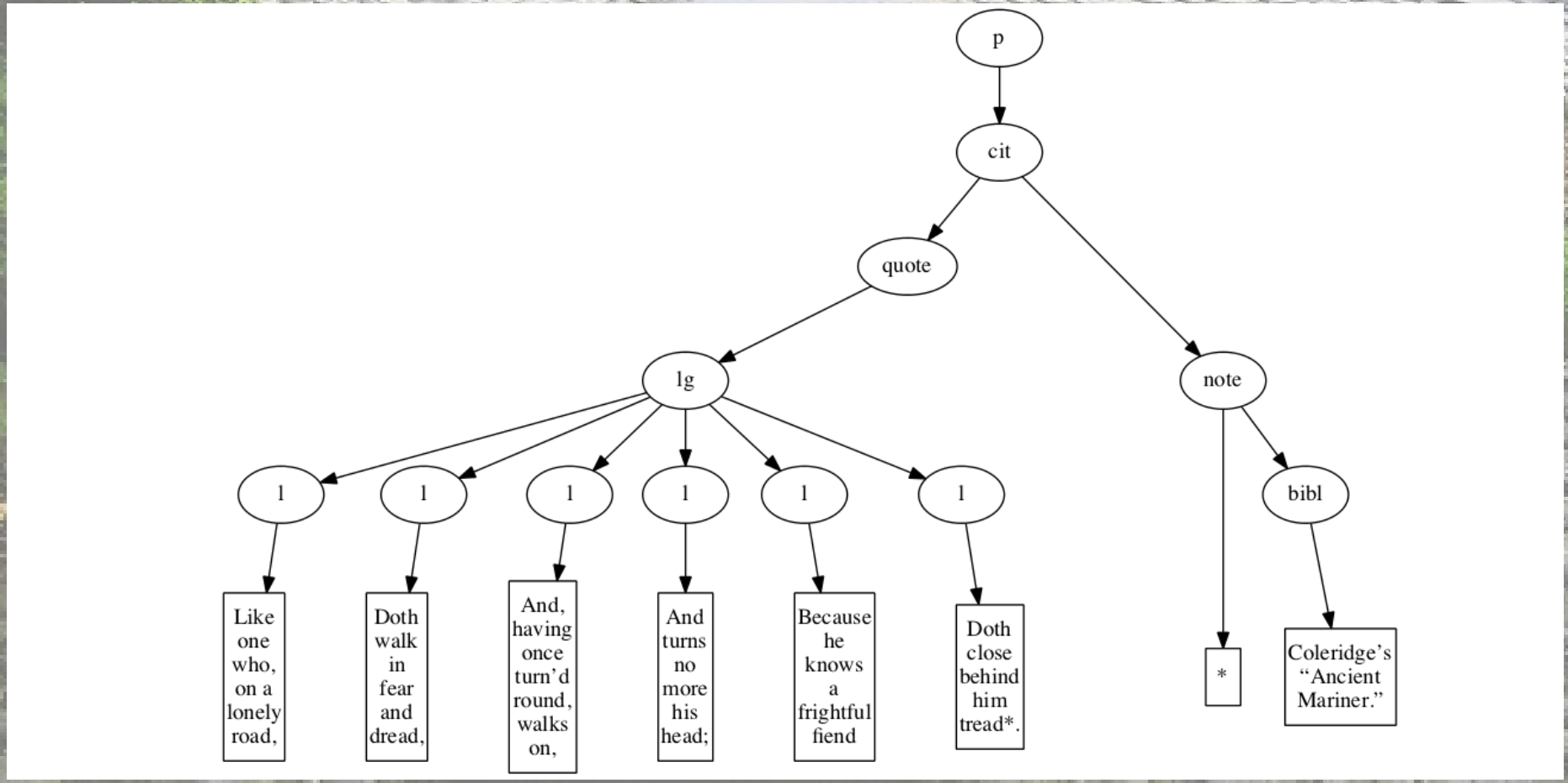
Inside out

- Scales poorly for large documents
- Exit condition requires careful attention

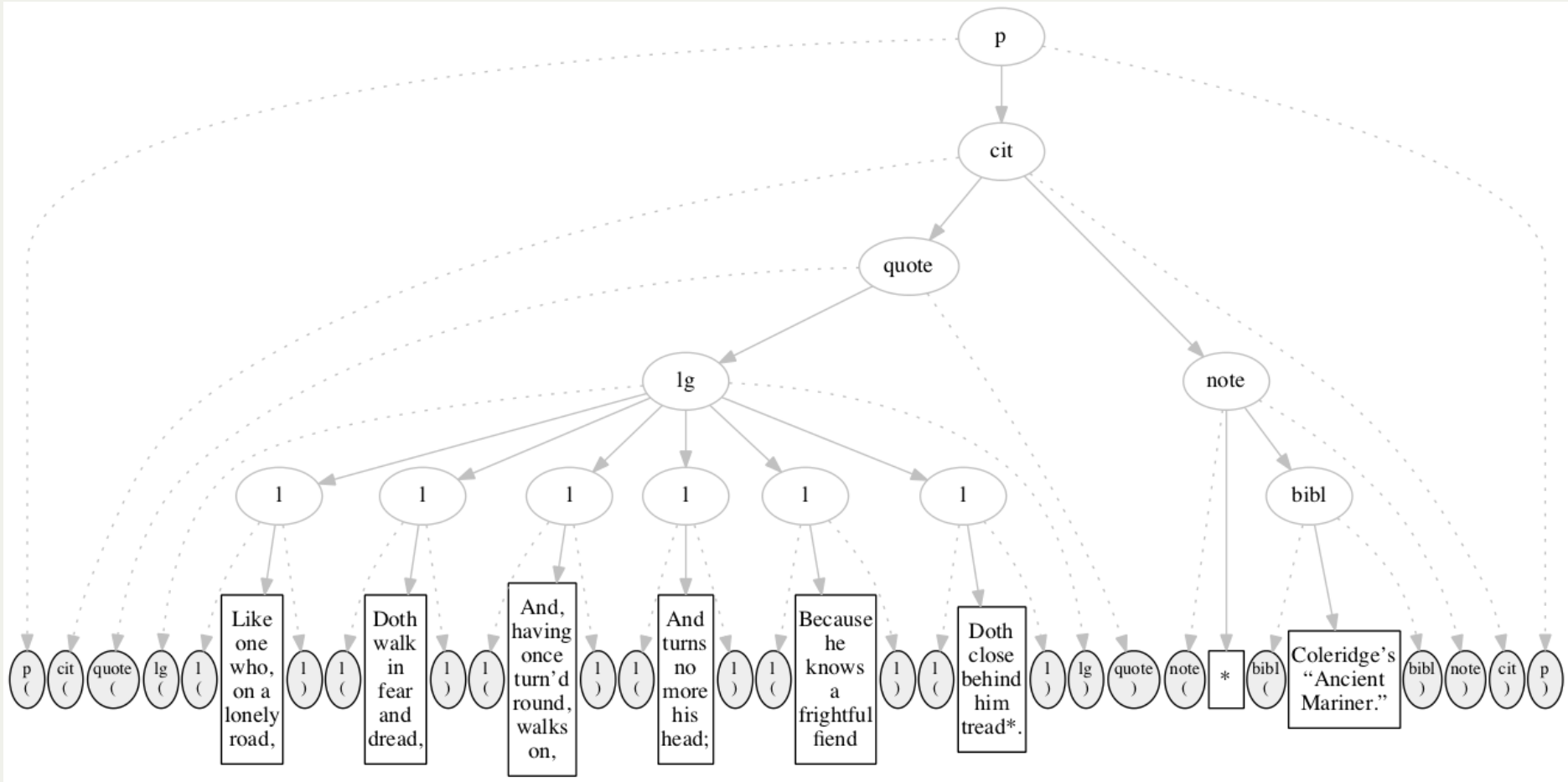
Raising with XSLT

- left-to-right
- inside-out
- outside-in
- accumulators

From flattened to raised, via nodes:

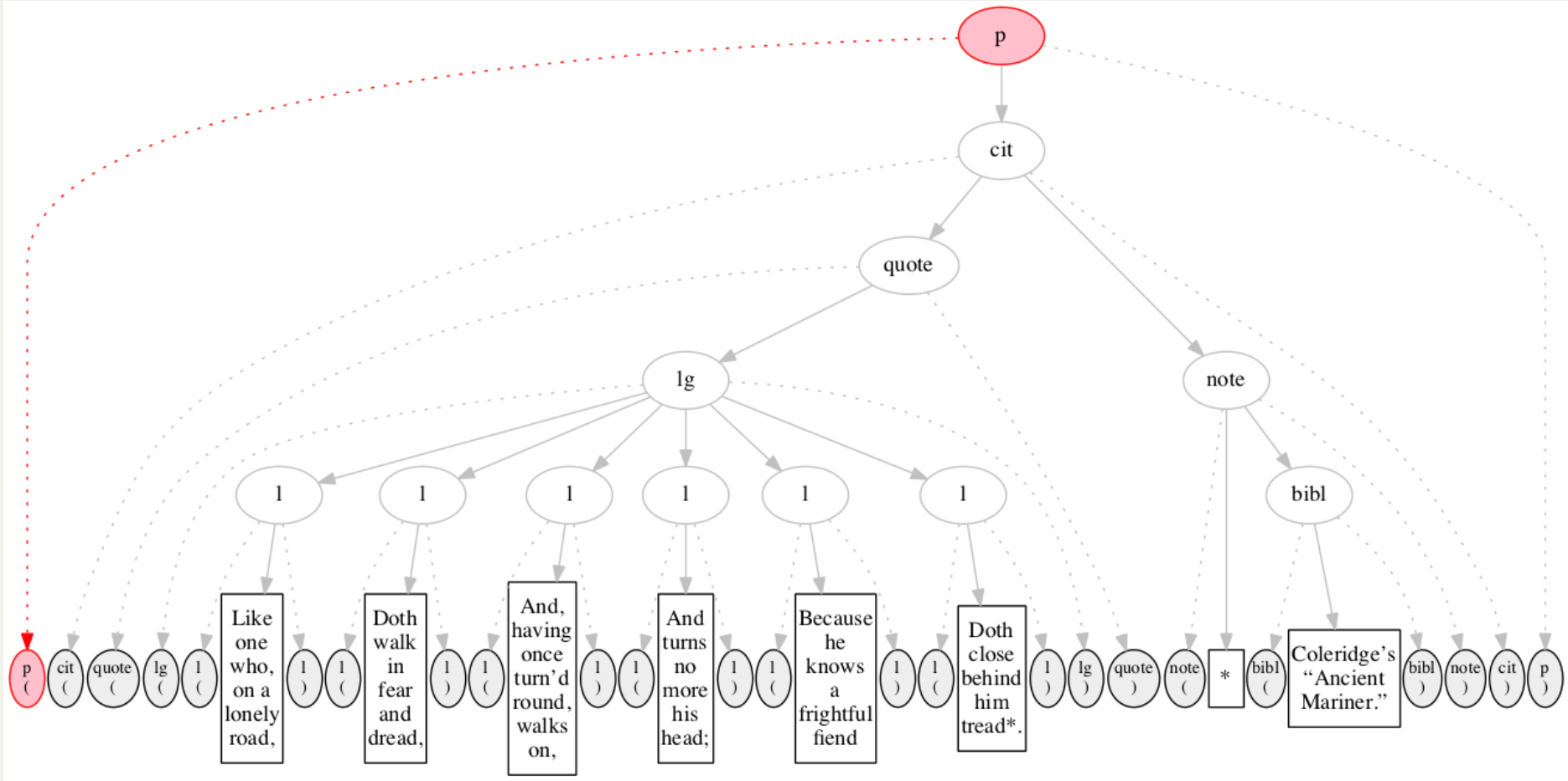


Left to right



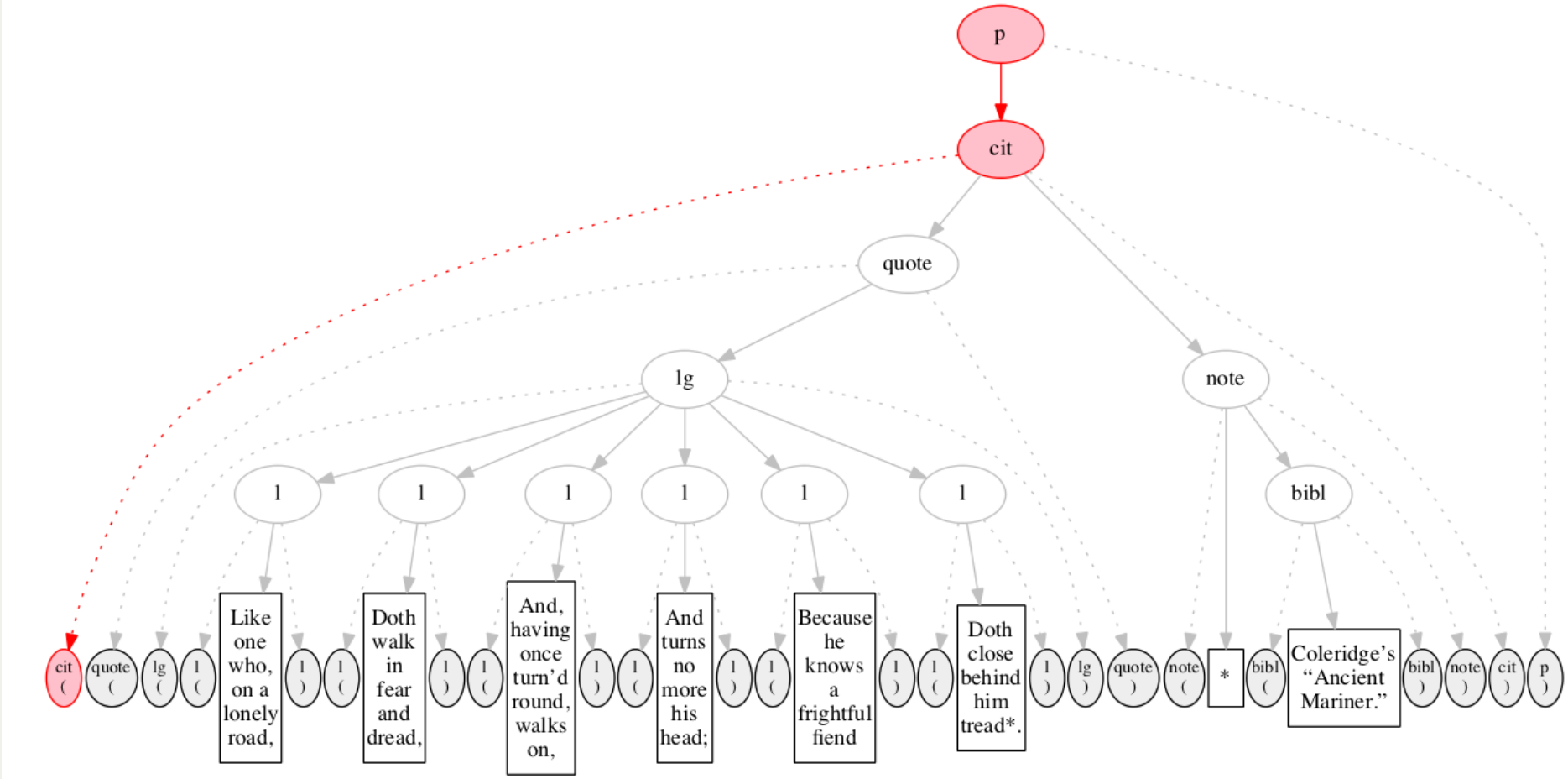
At the outset, we have a flat sequence of nodes.

Left to right



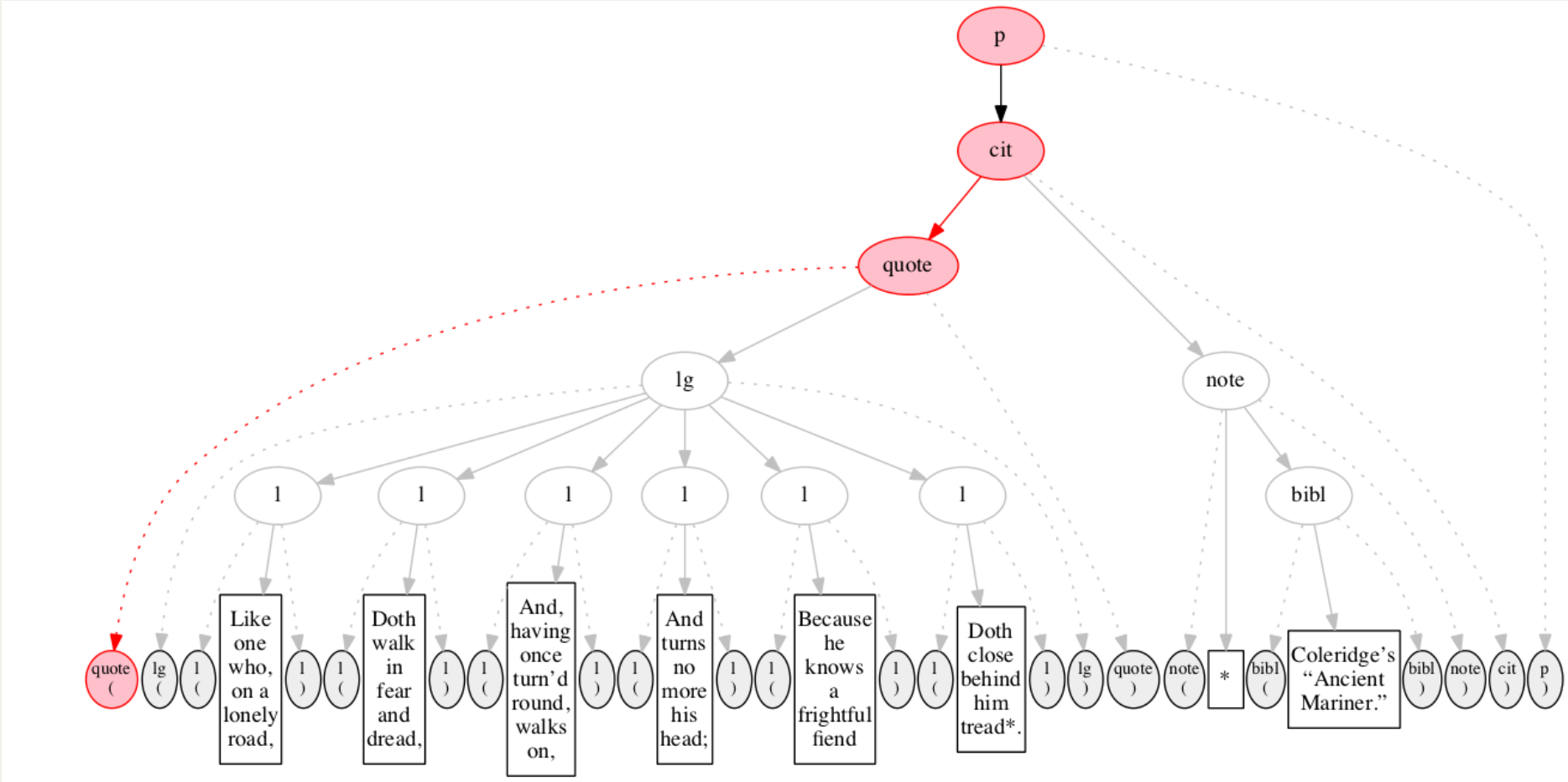
We first encounter the start-marker for the paragraph.

Left to right



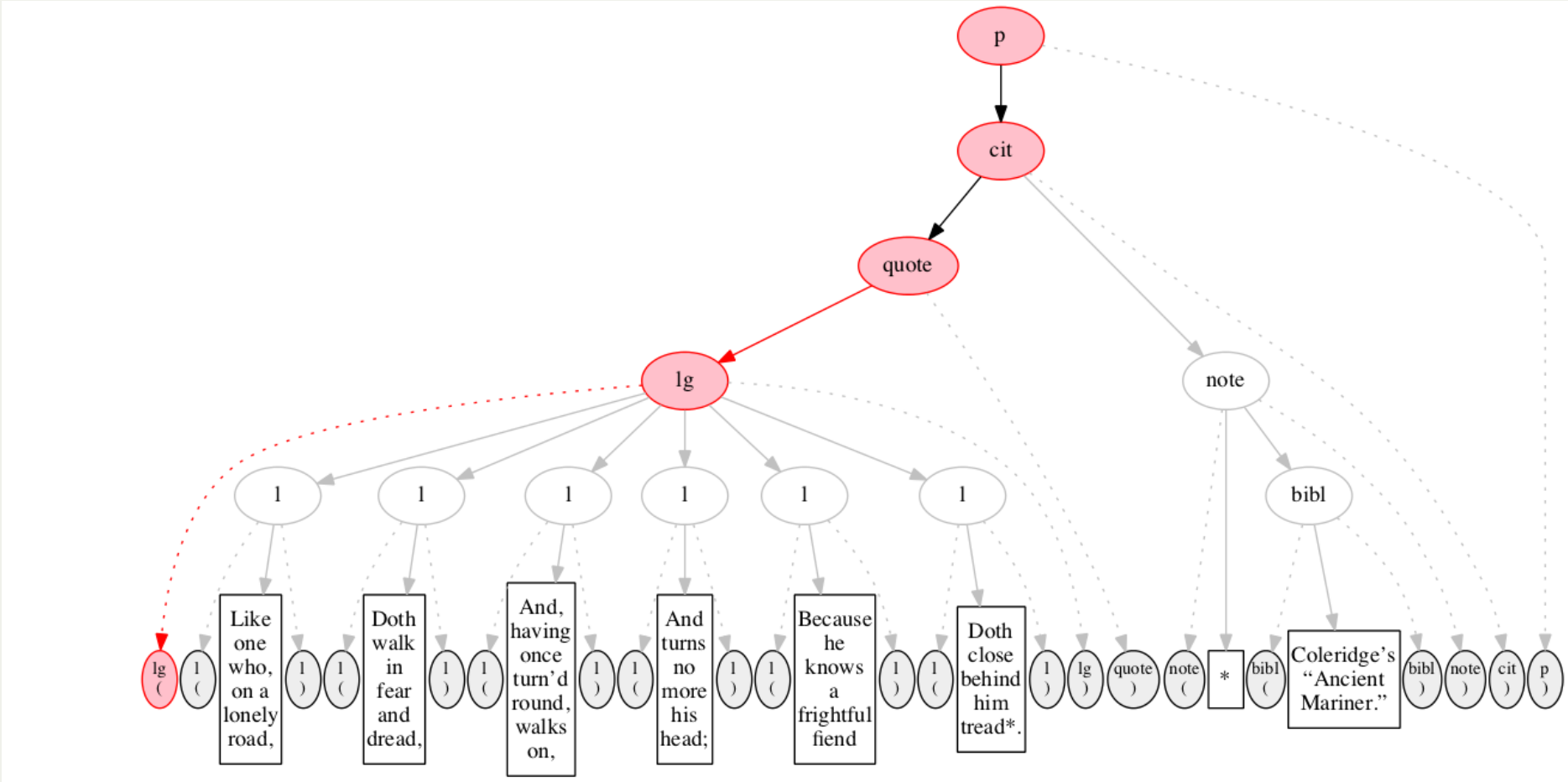
We then encounter a start-marker for a citation. The paragraph has been started but not finished.

Left to right



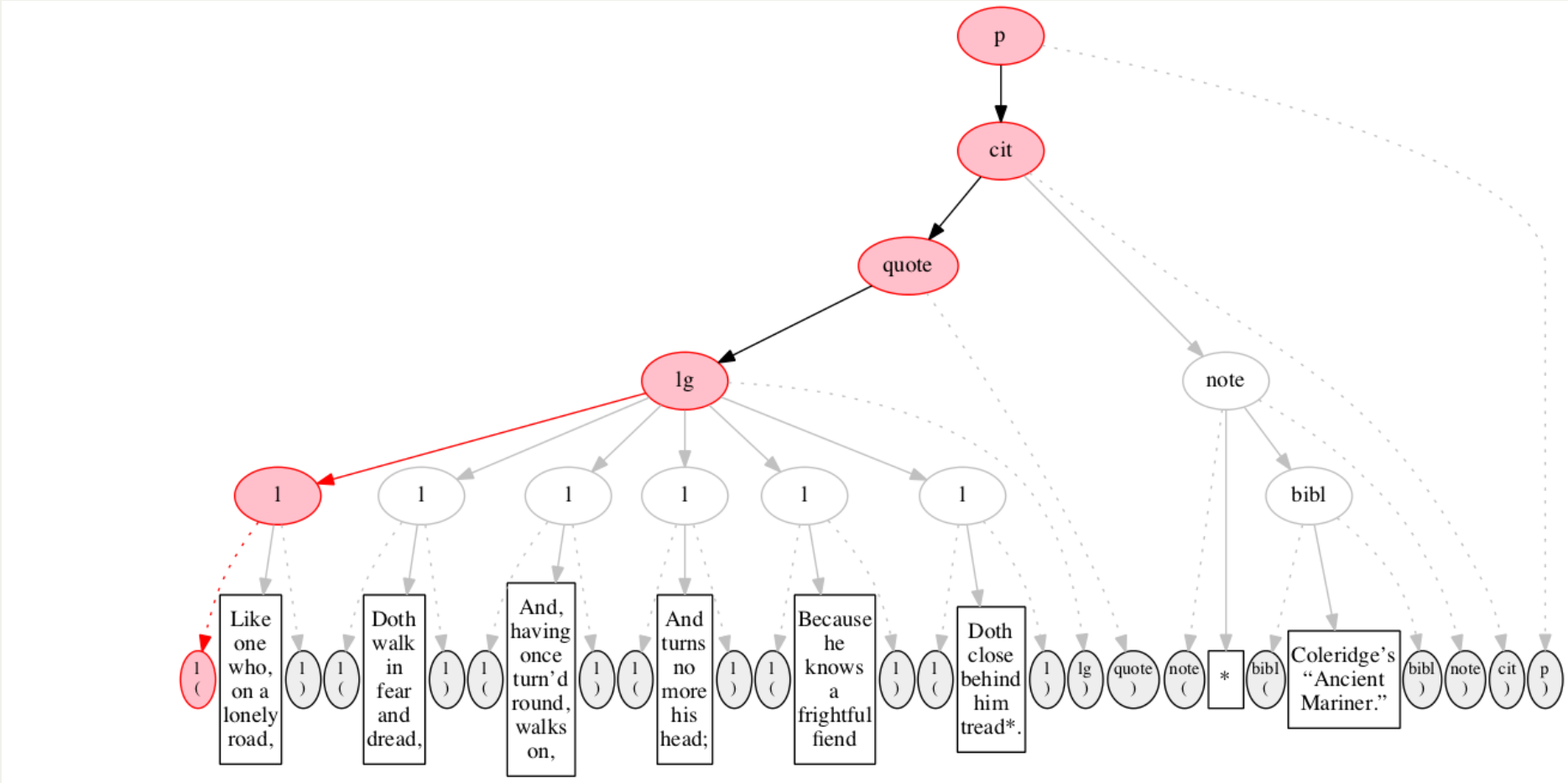
We then encounter a start-marker for a quotation.

Left to right



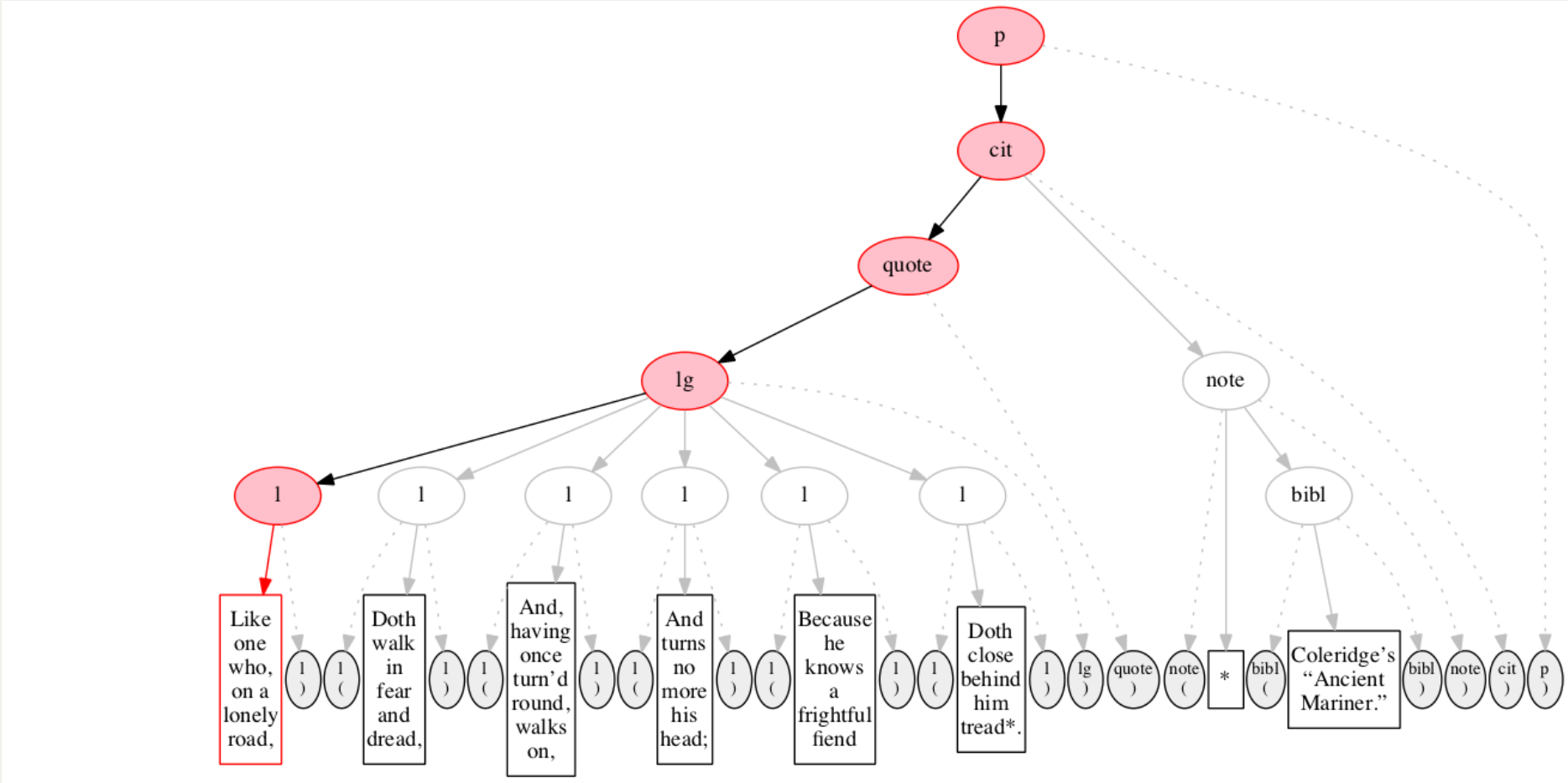
We then encounter a start-marker for a line group.

Left to right



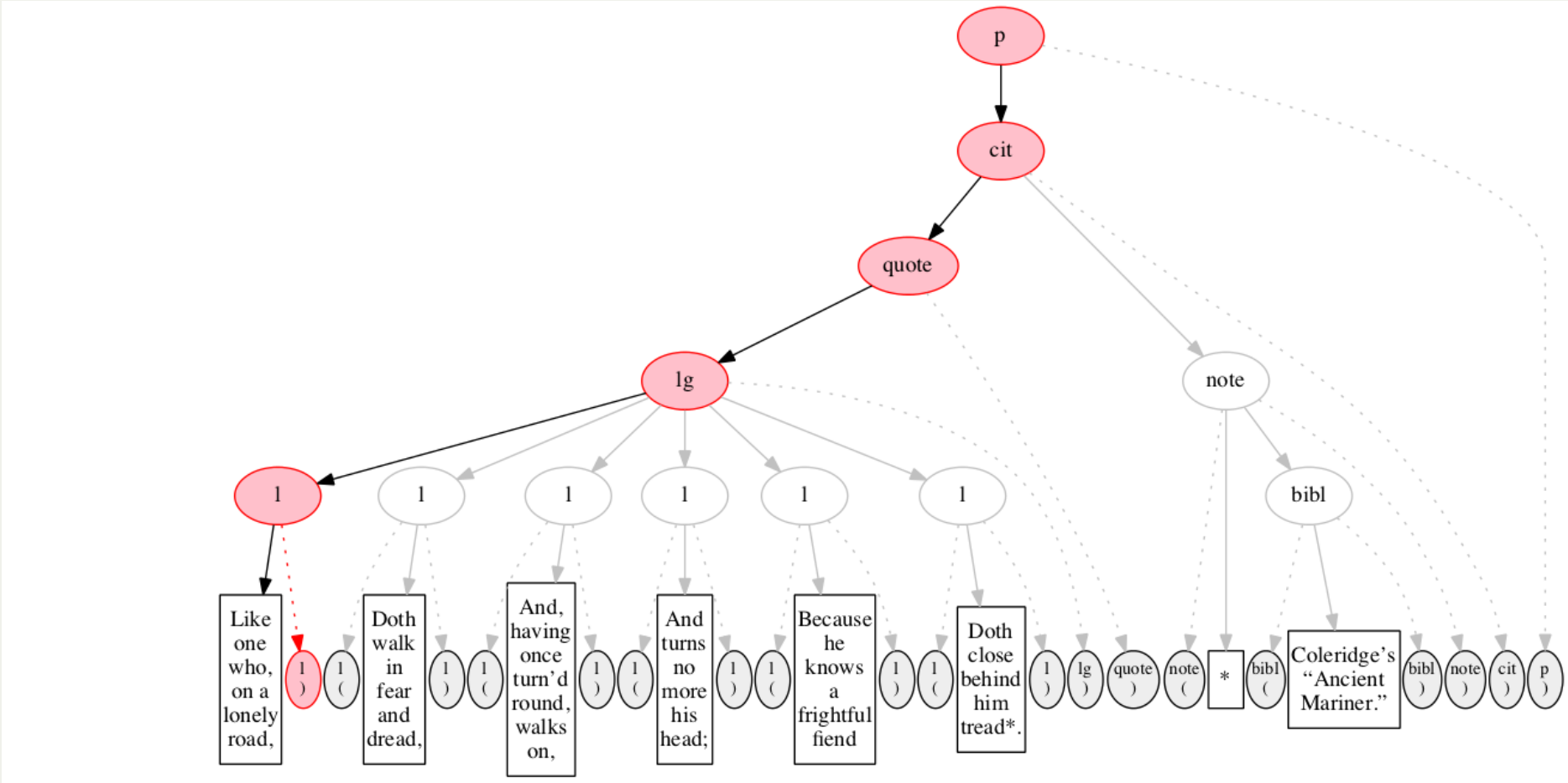
We then encounter a start-marker for the first line of verse.

Left to right



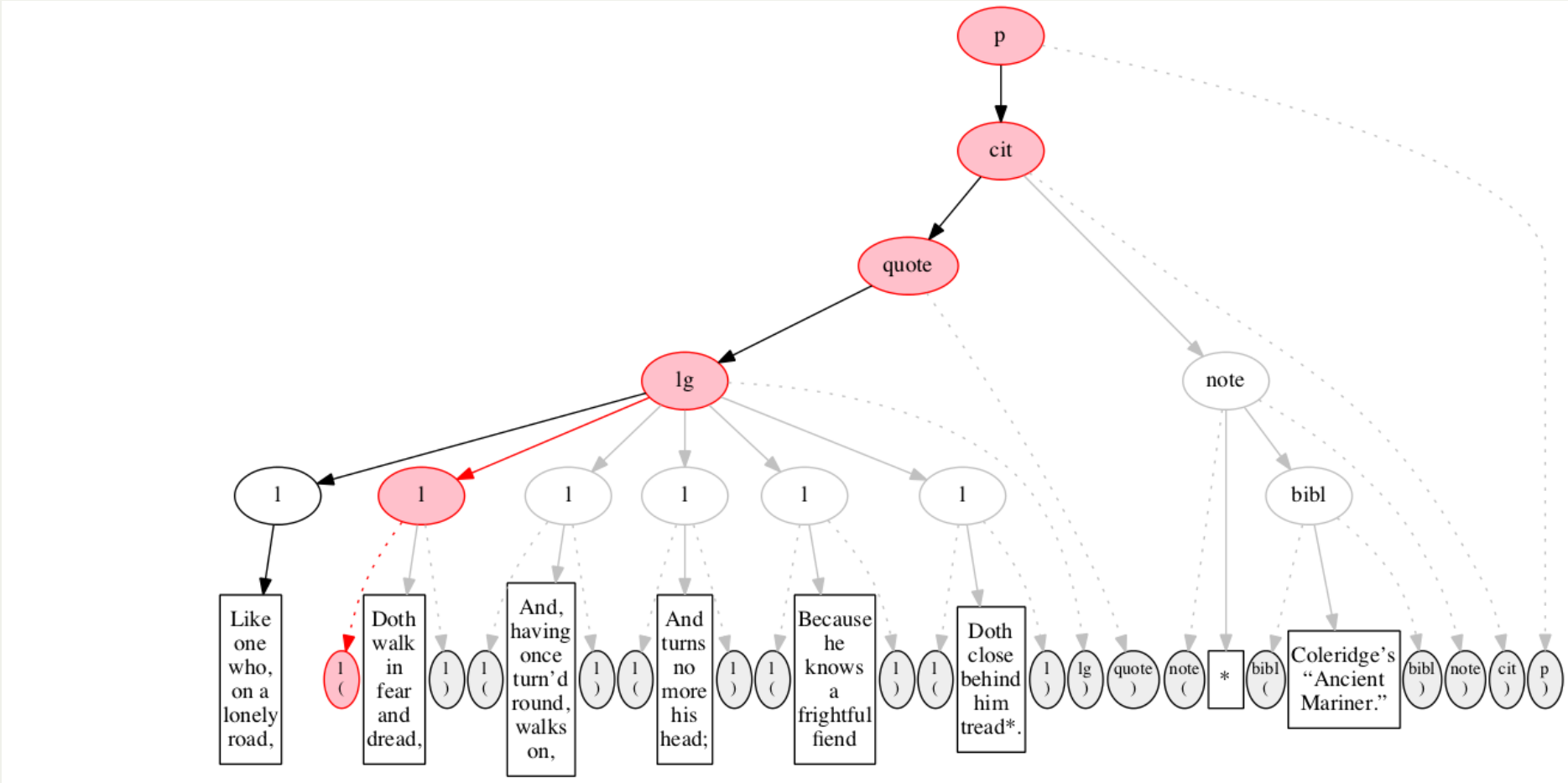
And finally some text data: the text of the first line of verse.

Left to right



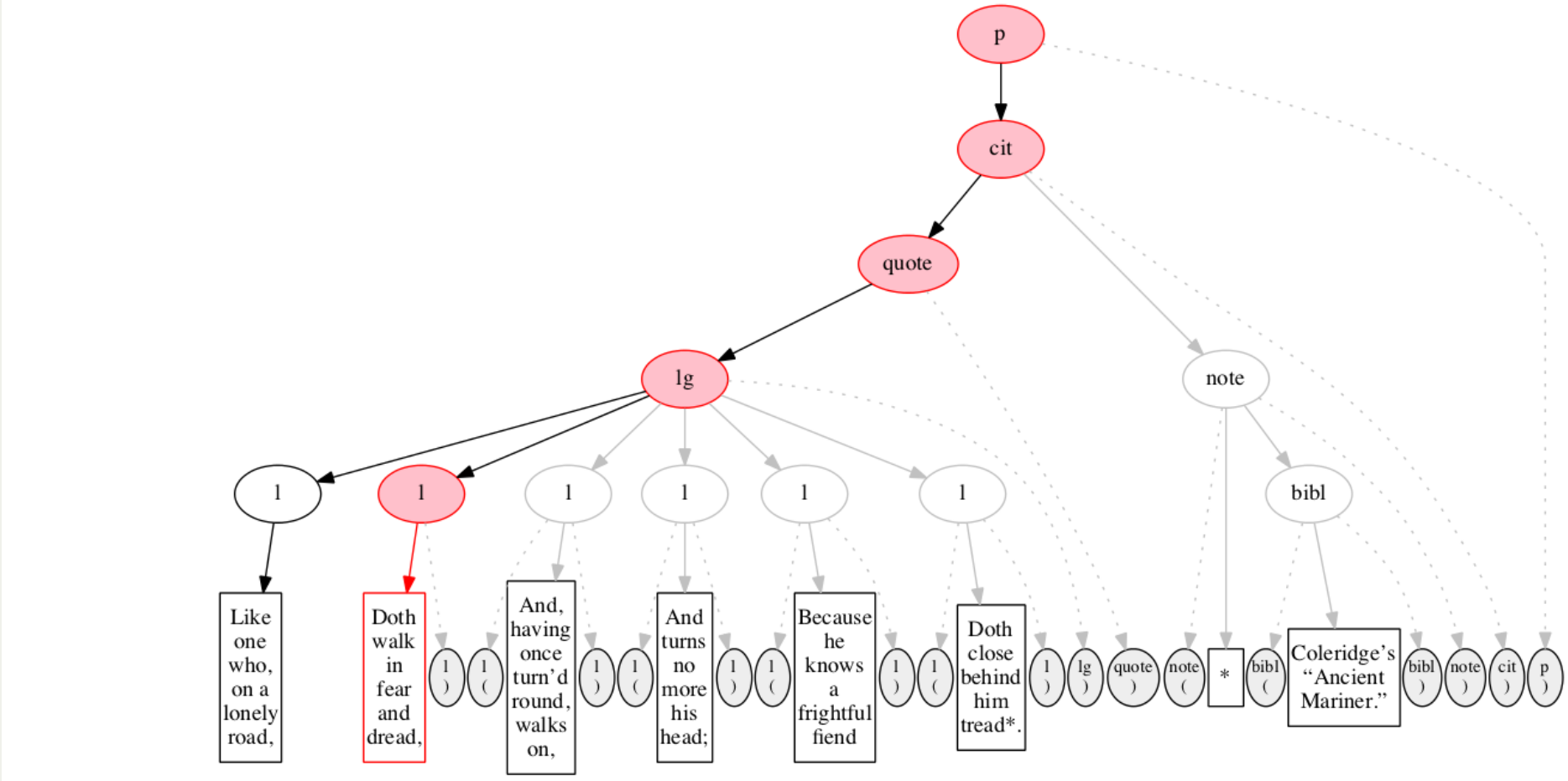
End-marker for the first line.

Left to right



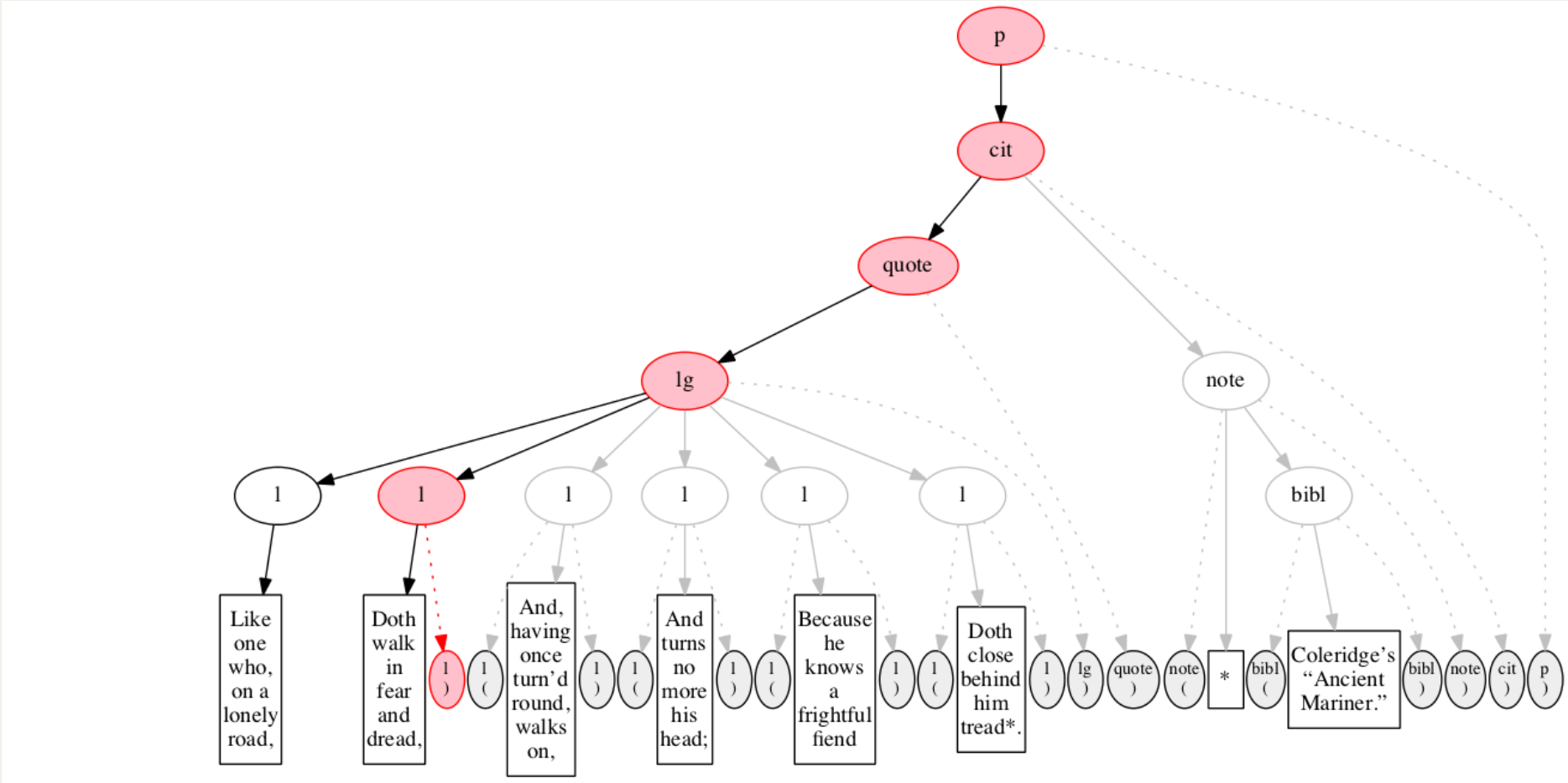
We then encounter a start-marker for the second line of verse. The first line is now finished (as signaled by the change in color).

Left to right



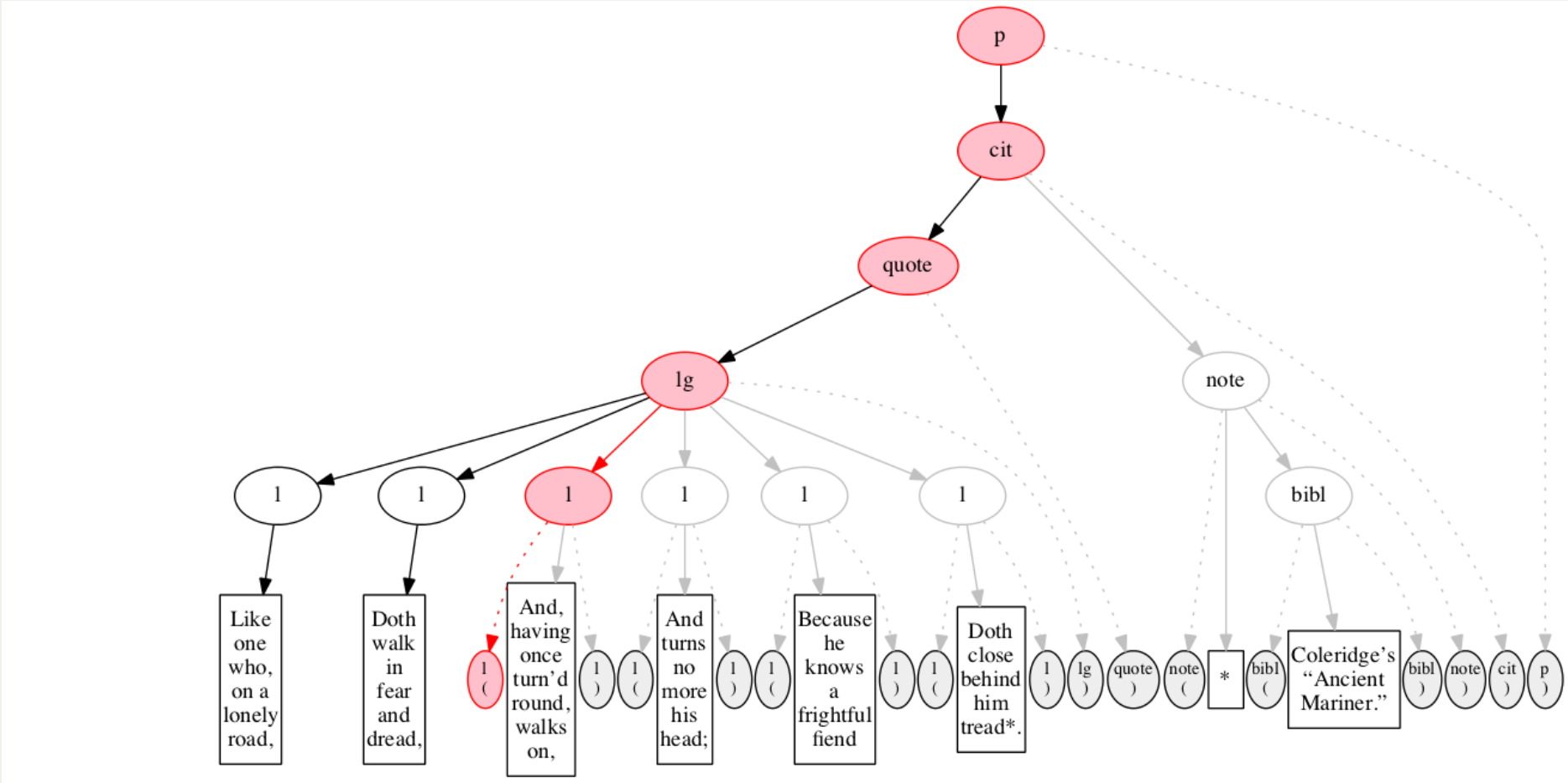
The text of the second line of verse.

Left to right



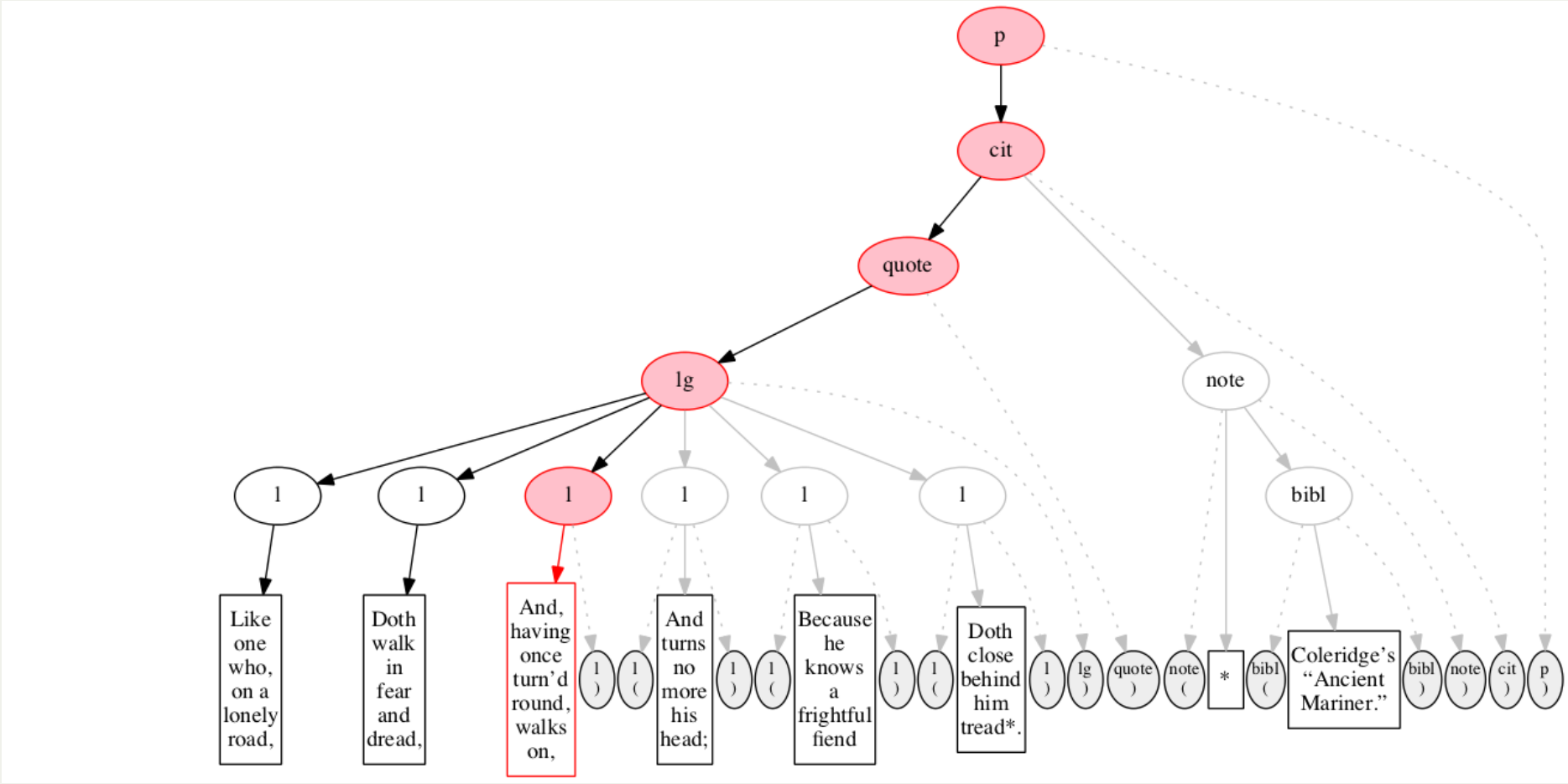
End-marker for the second line.

Left to right



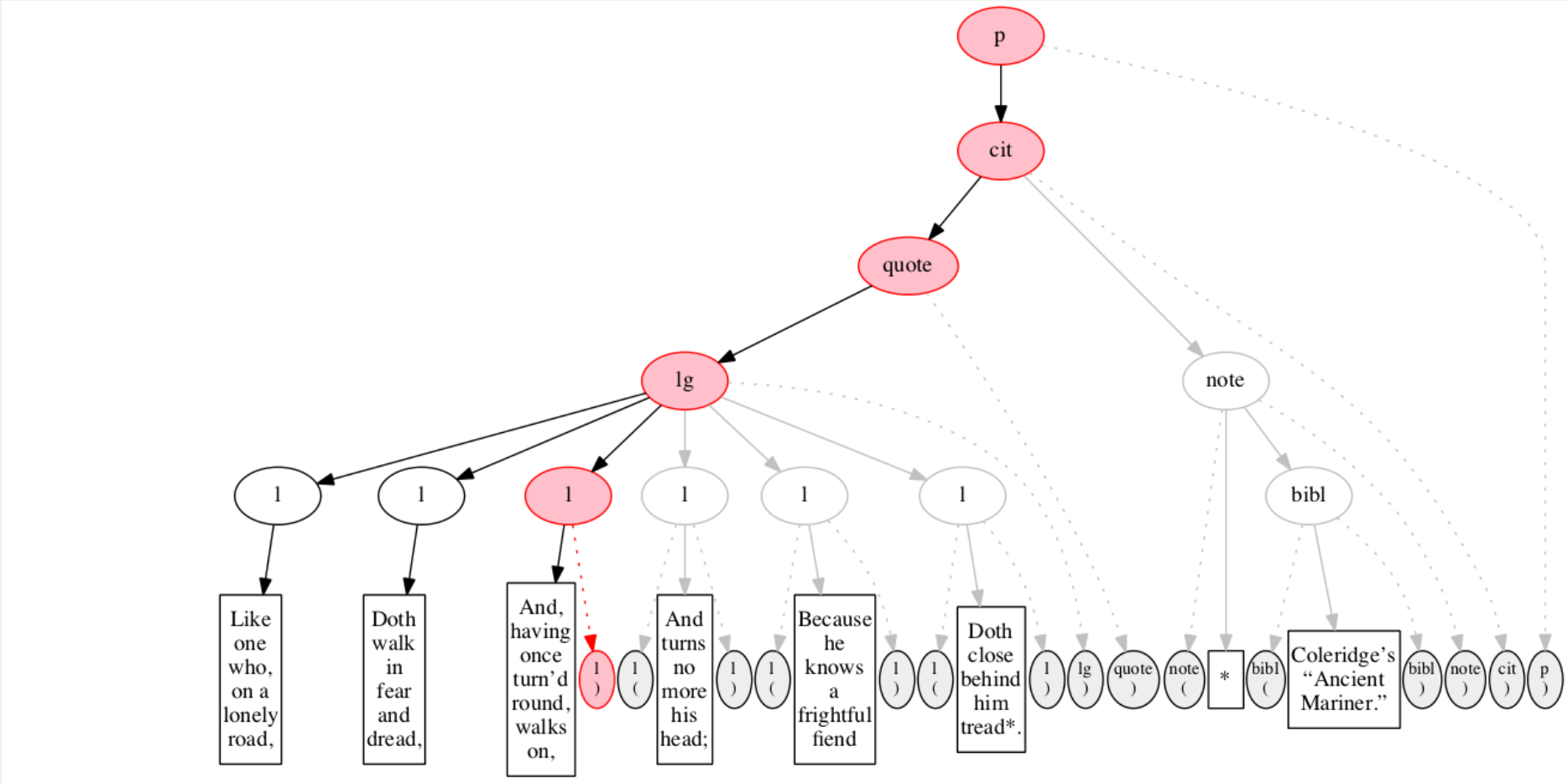
Start-marker for the third line of verse.

Left to right



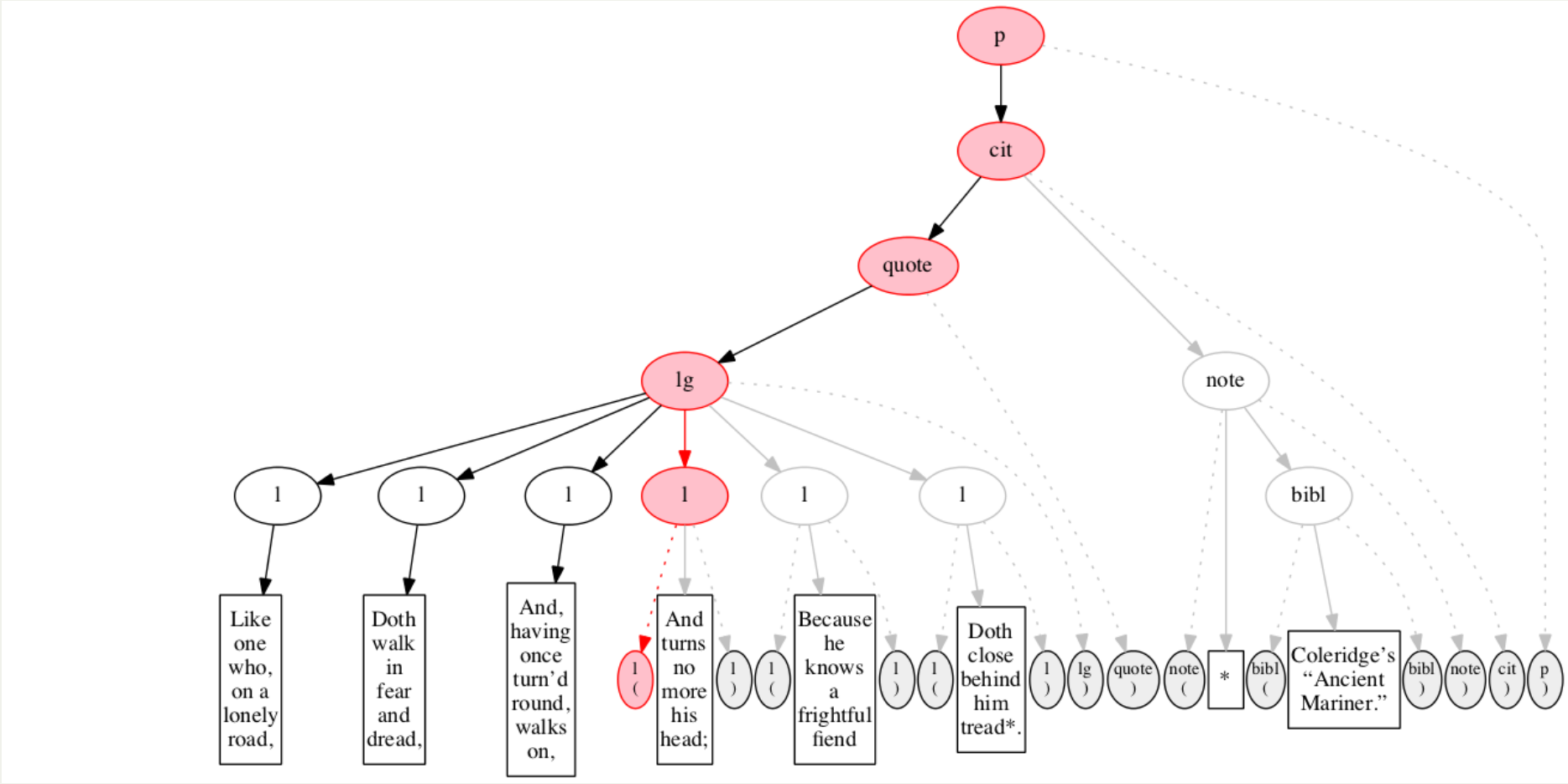
Text of the line.

Left to right



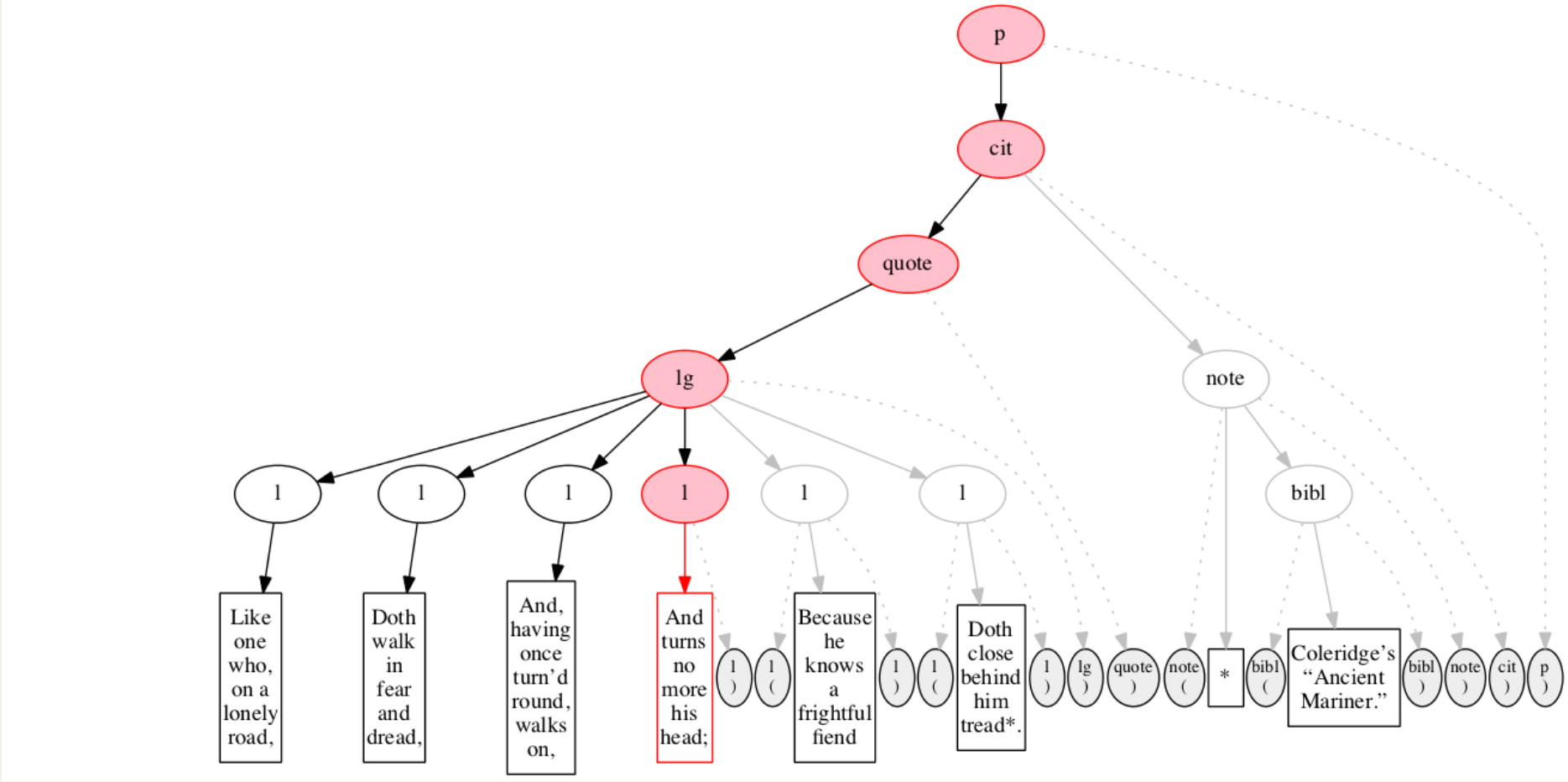
End-marker for the line.

Left to right



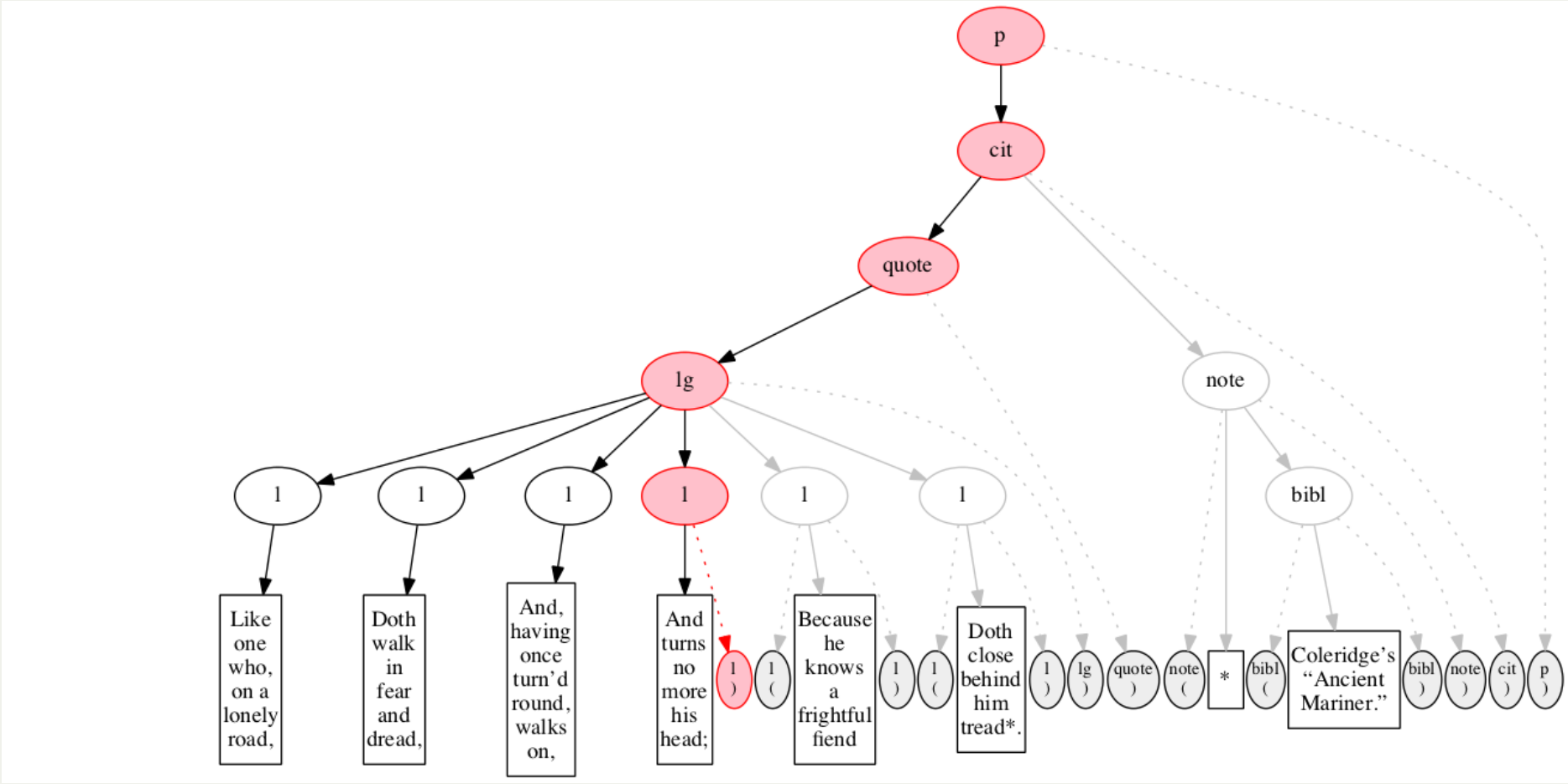
Start-marker for the fourth line of verse.

Left to right



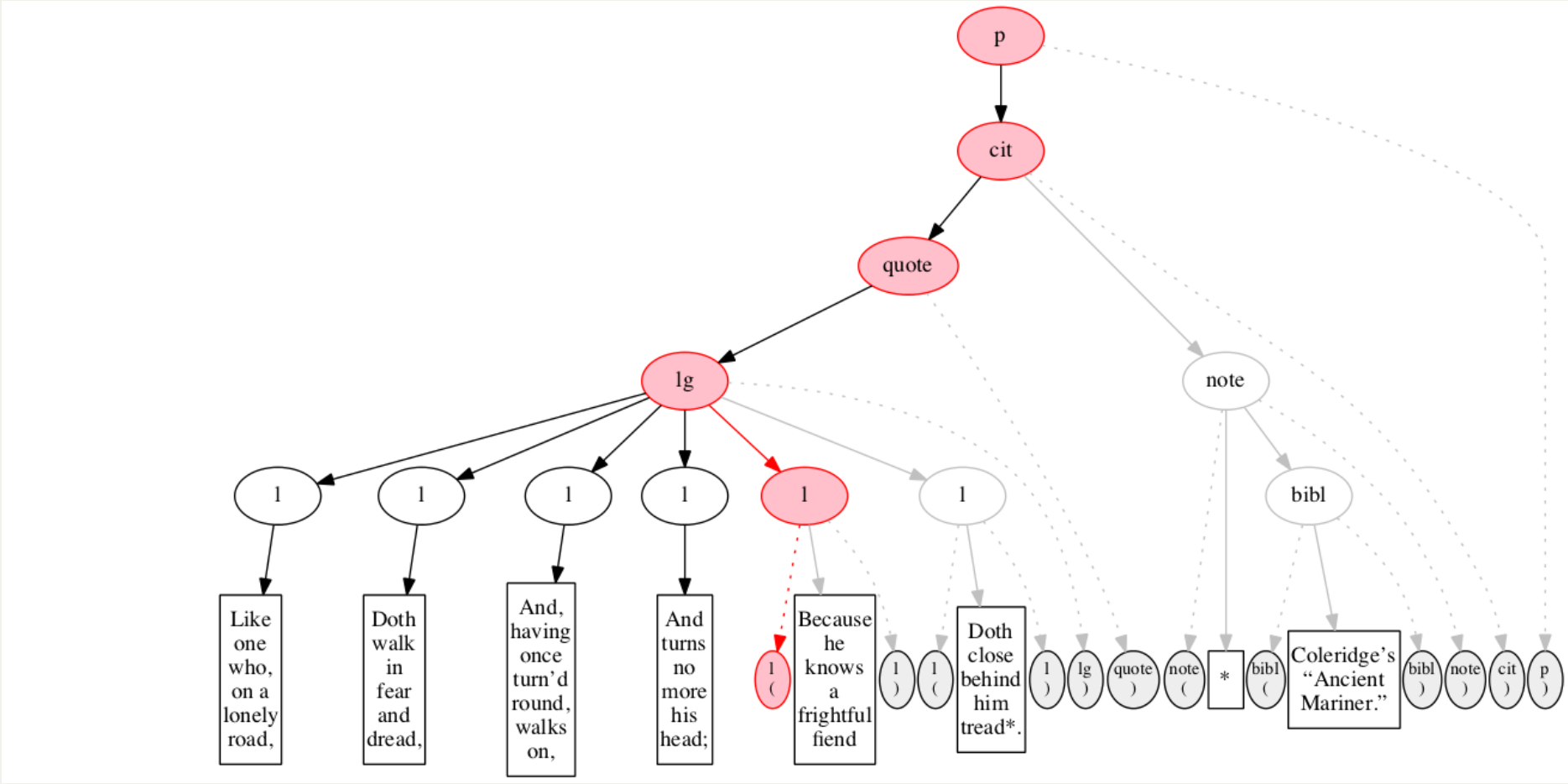
Text of the line.

Left to right



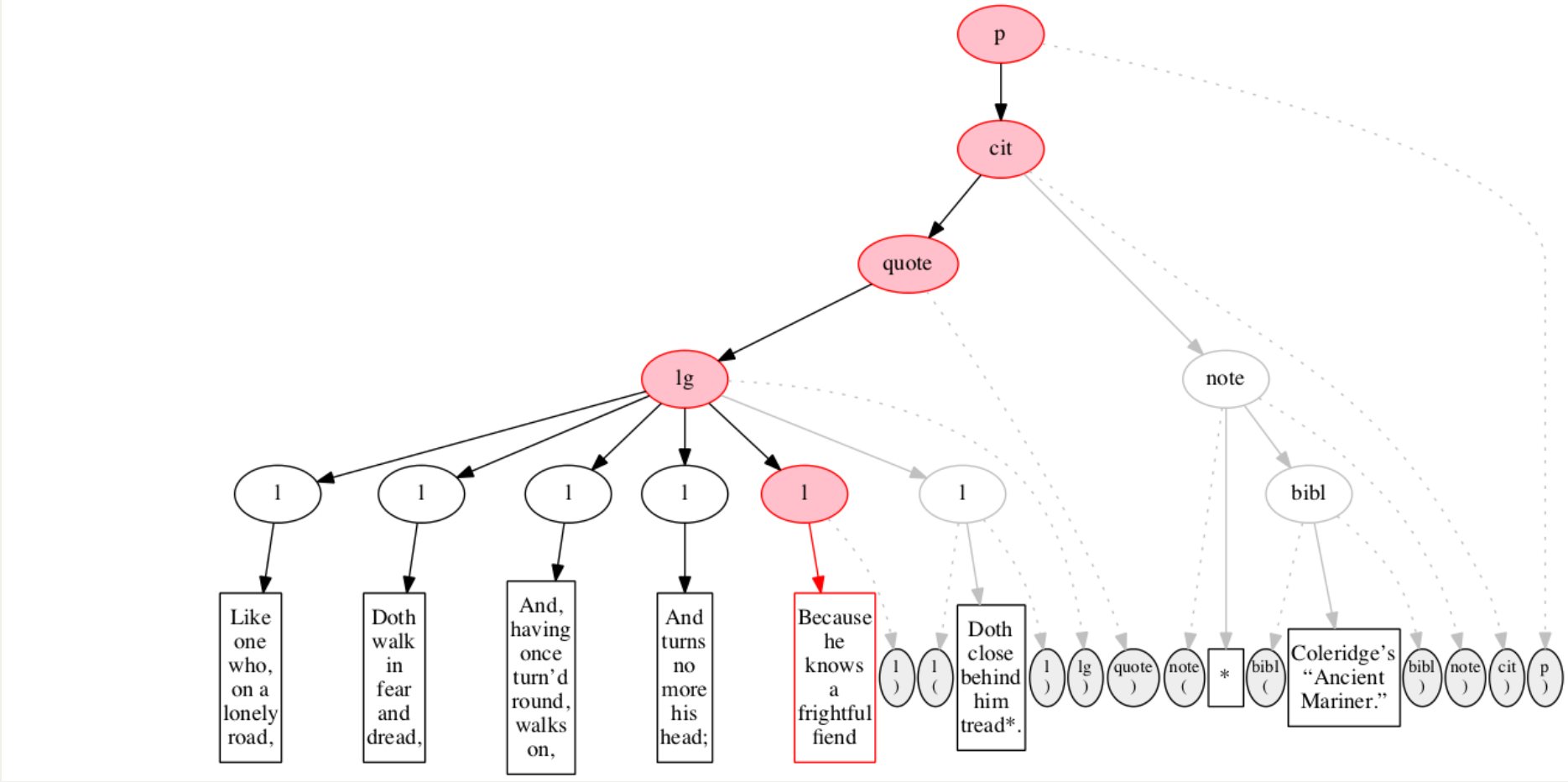
End-marker for the fourth line.

Left to right



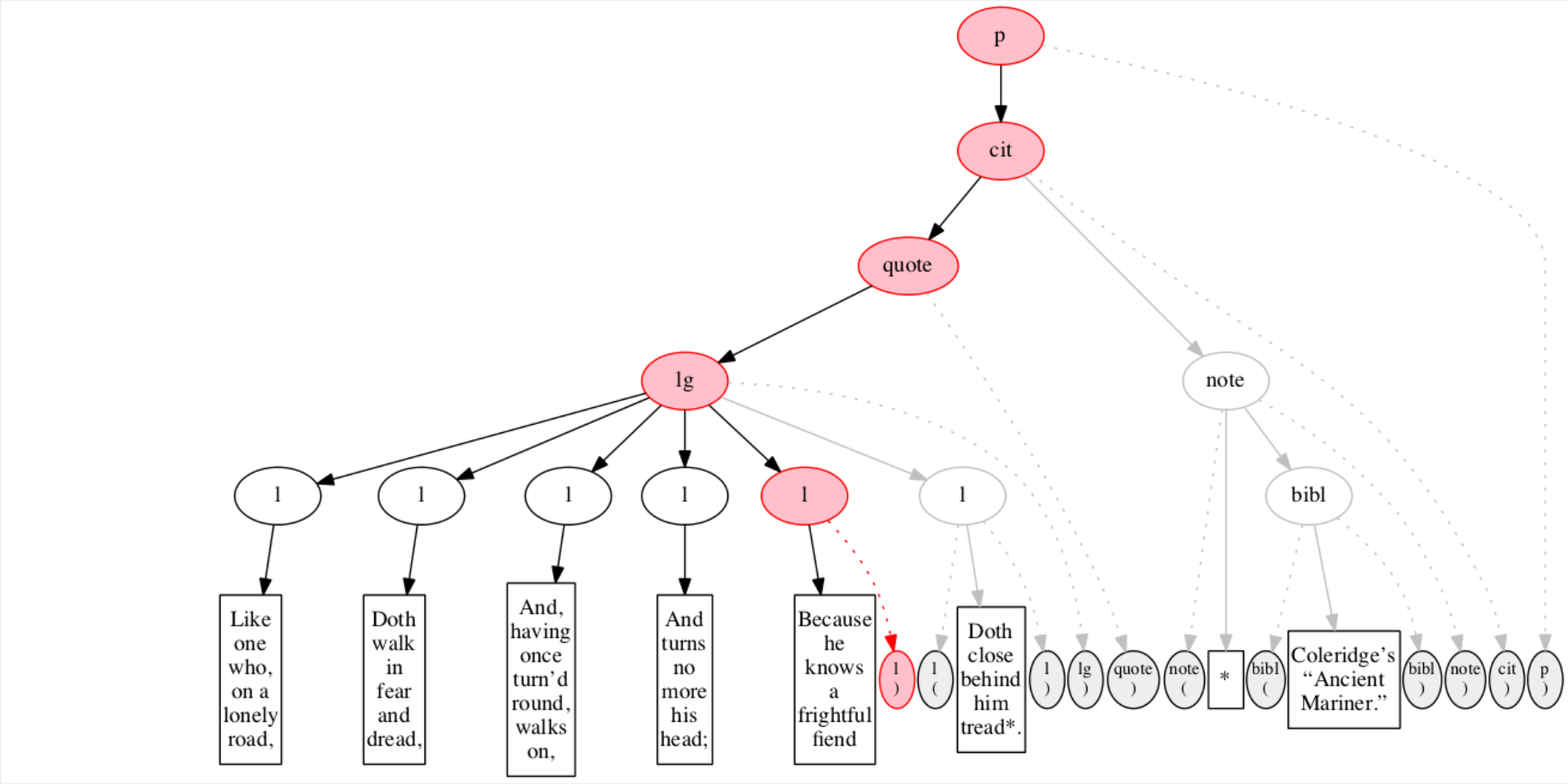
Start-marker for the fifth line of verse.

Left to right



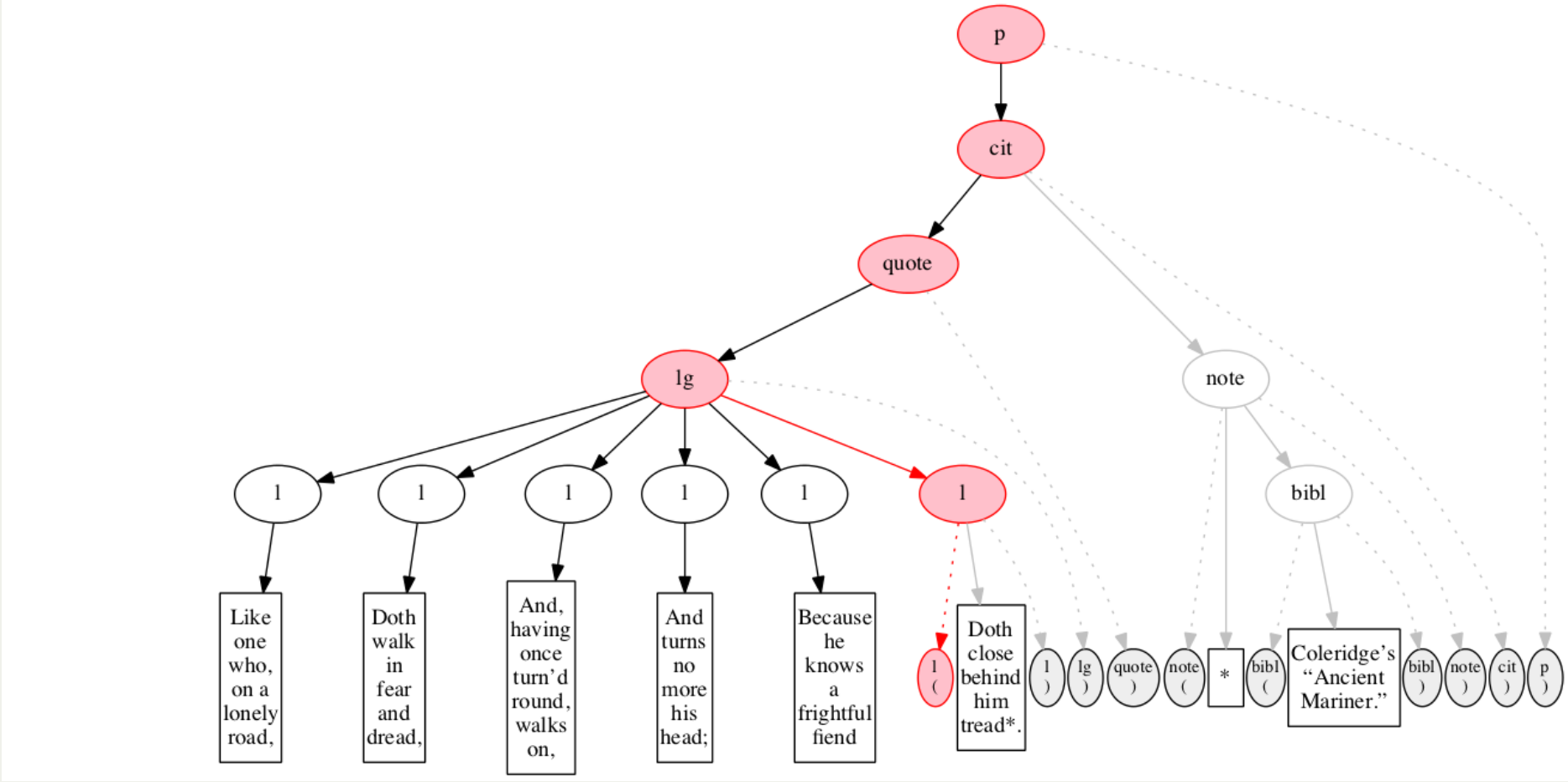
Text of the line.

Left to right



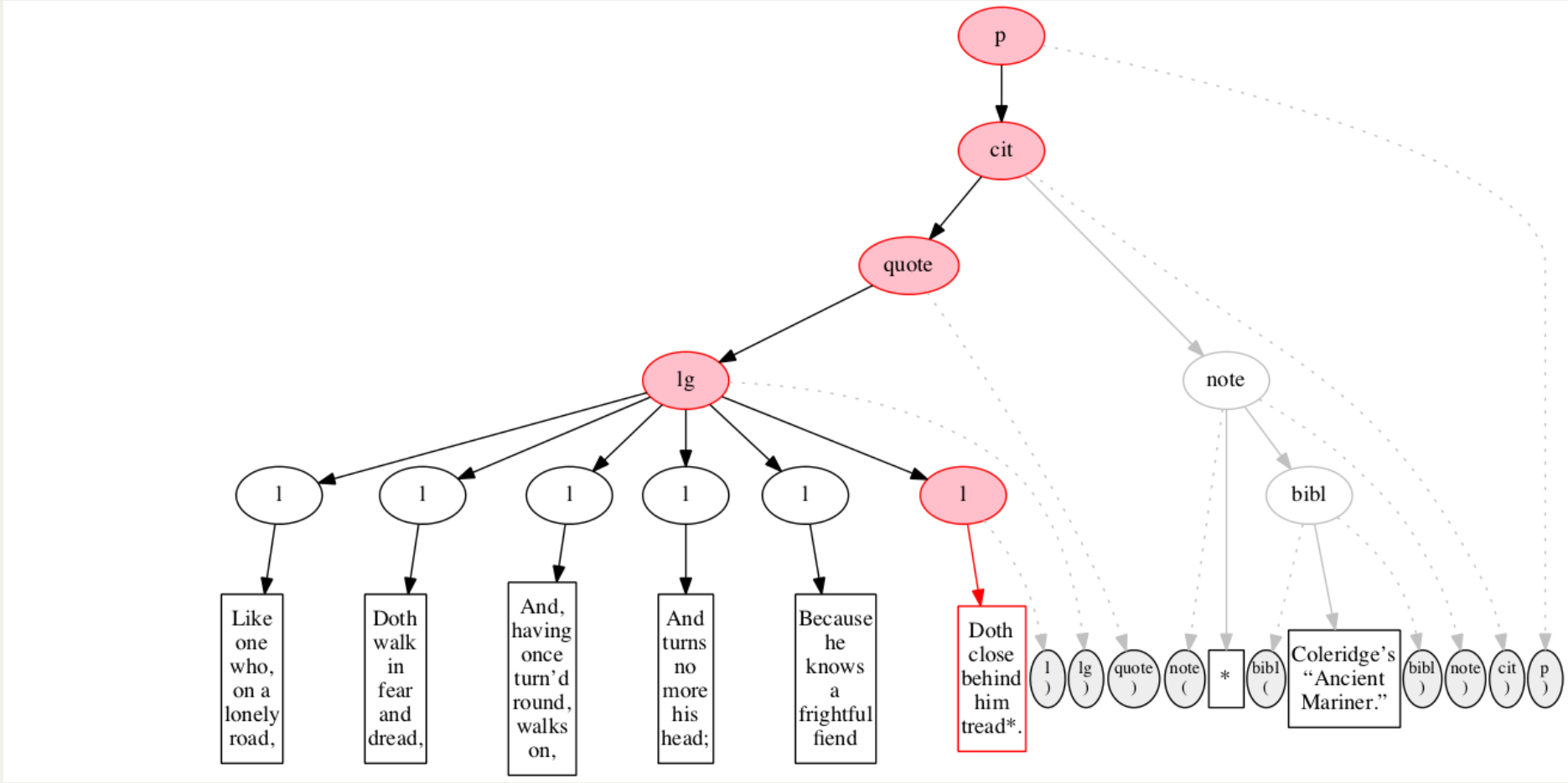
End-marker for the fifth line.

Left to right



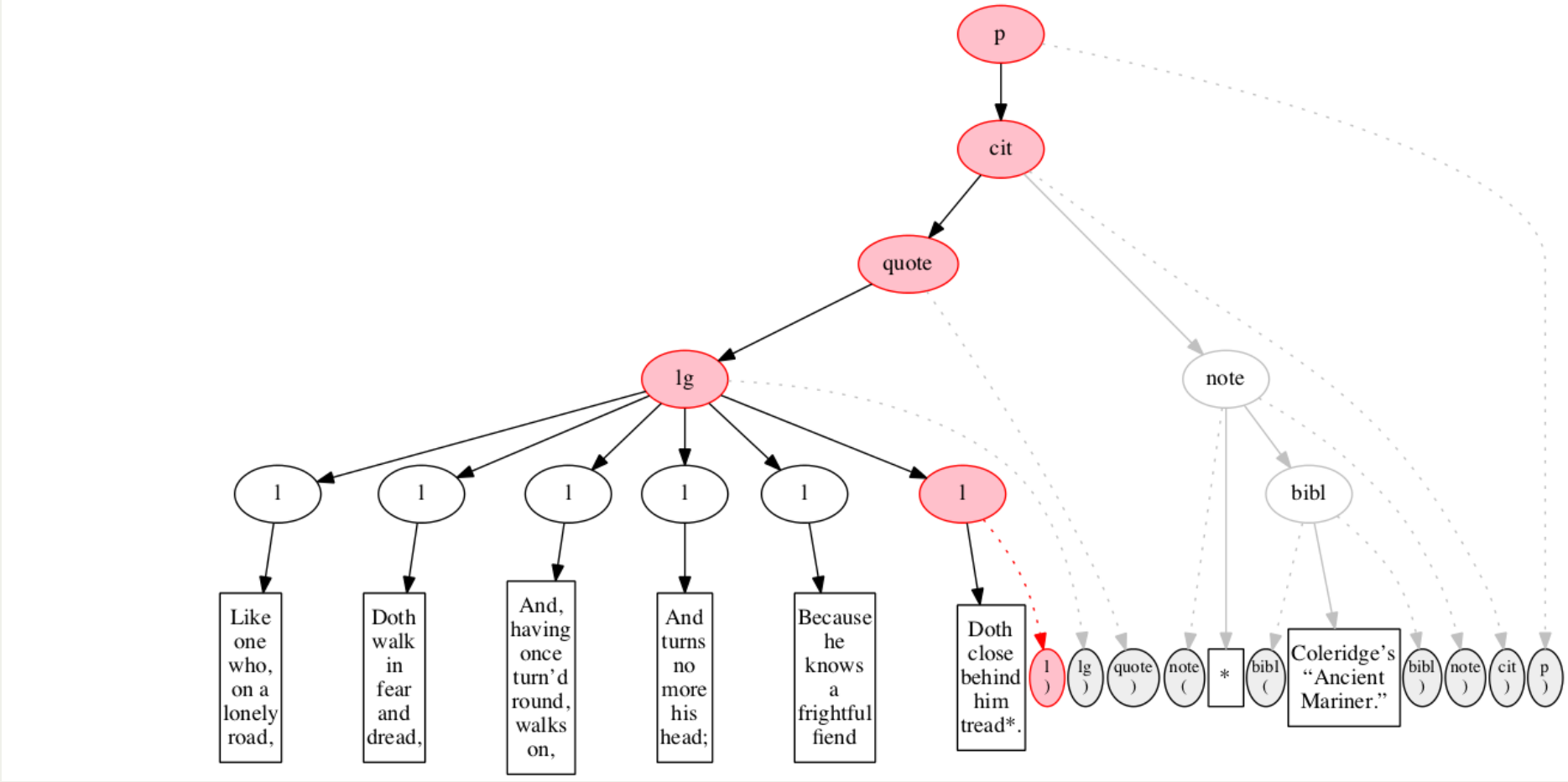
Start-marker for the last line of verse.

Left to right



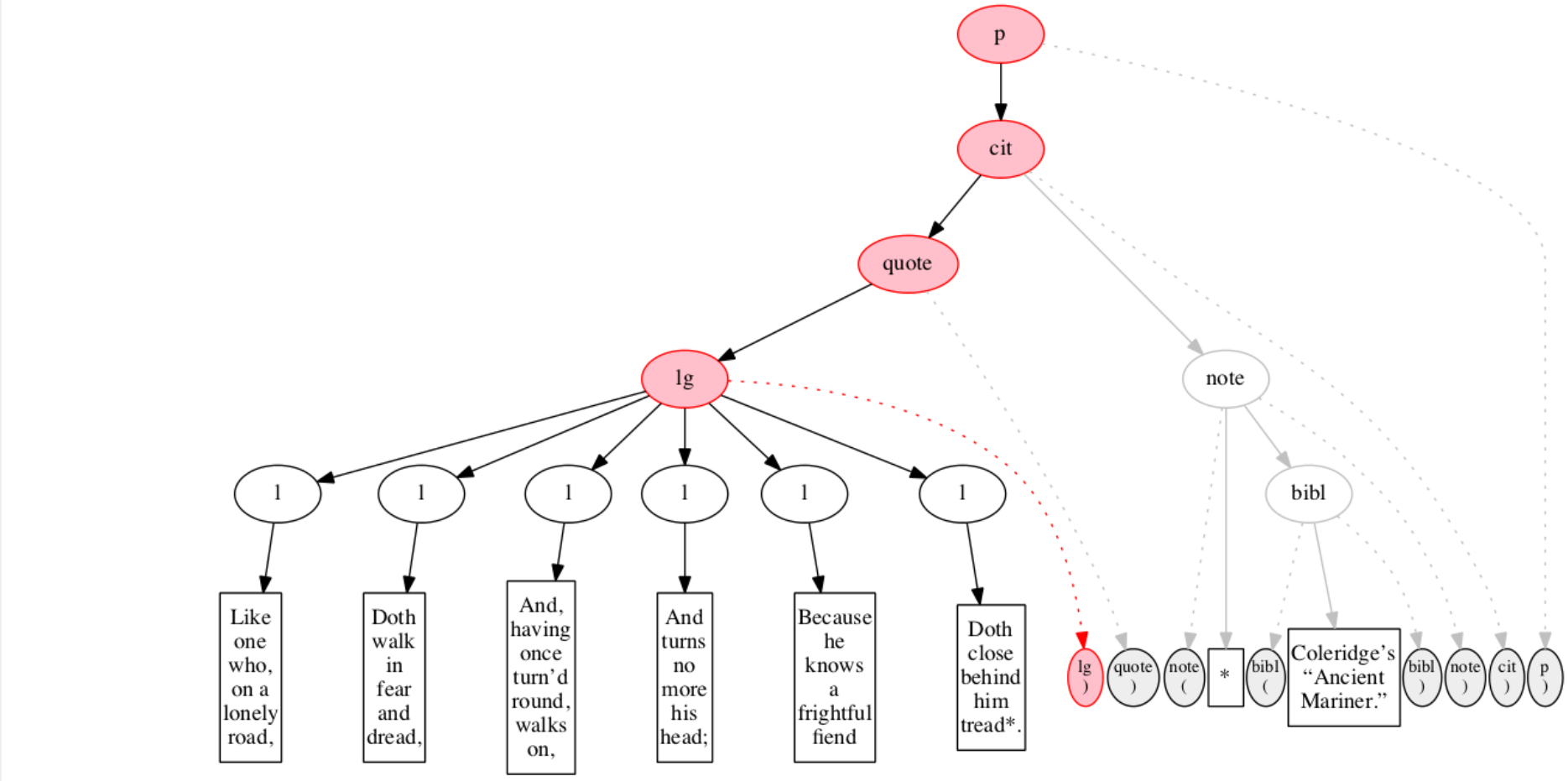
Text of the line.

Left to right



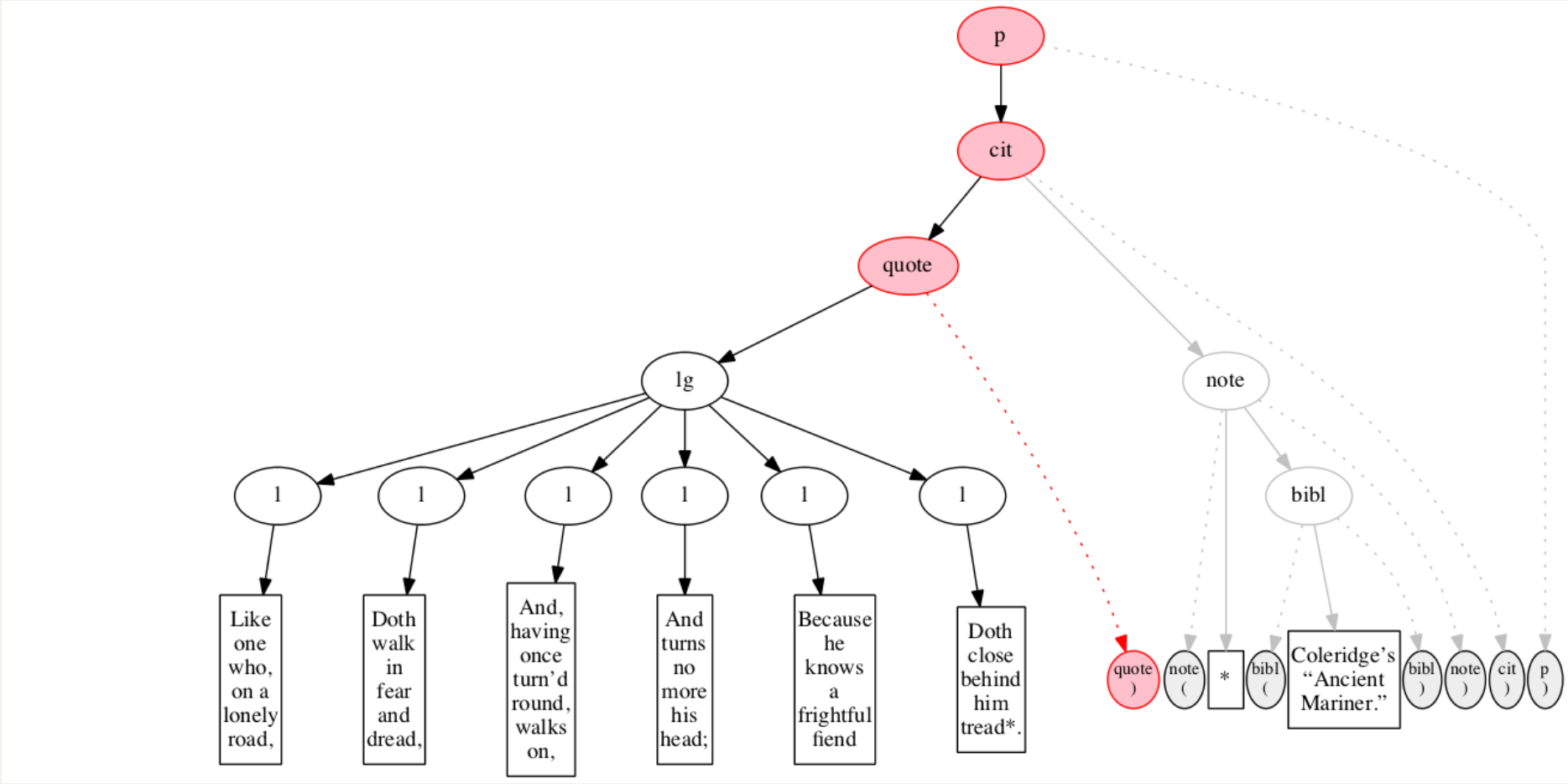
End-marker for the line.

Left to right



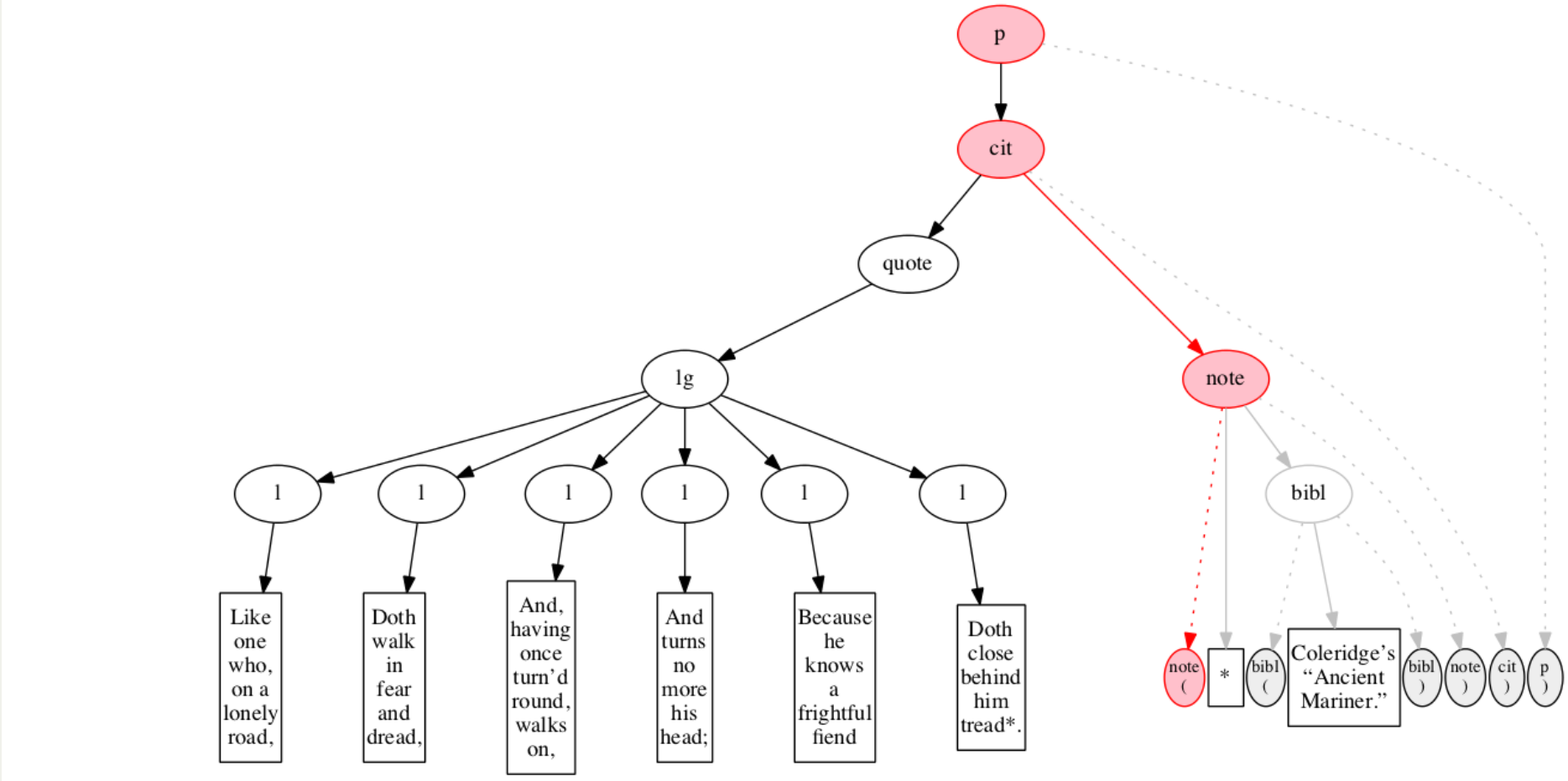
The end-marker for the line group.

Left to right



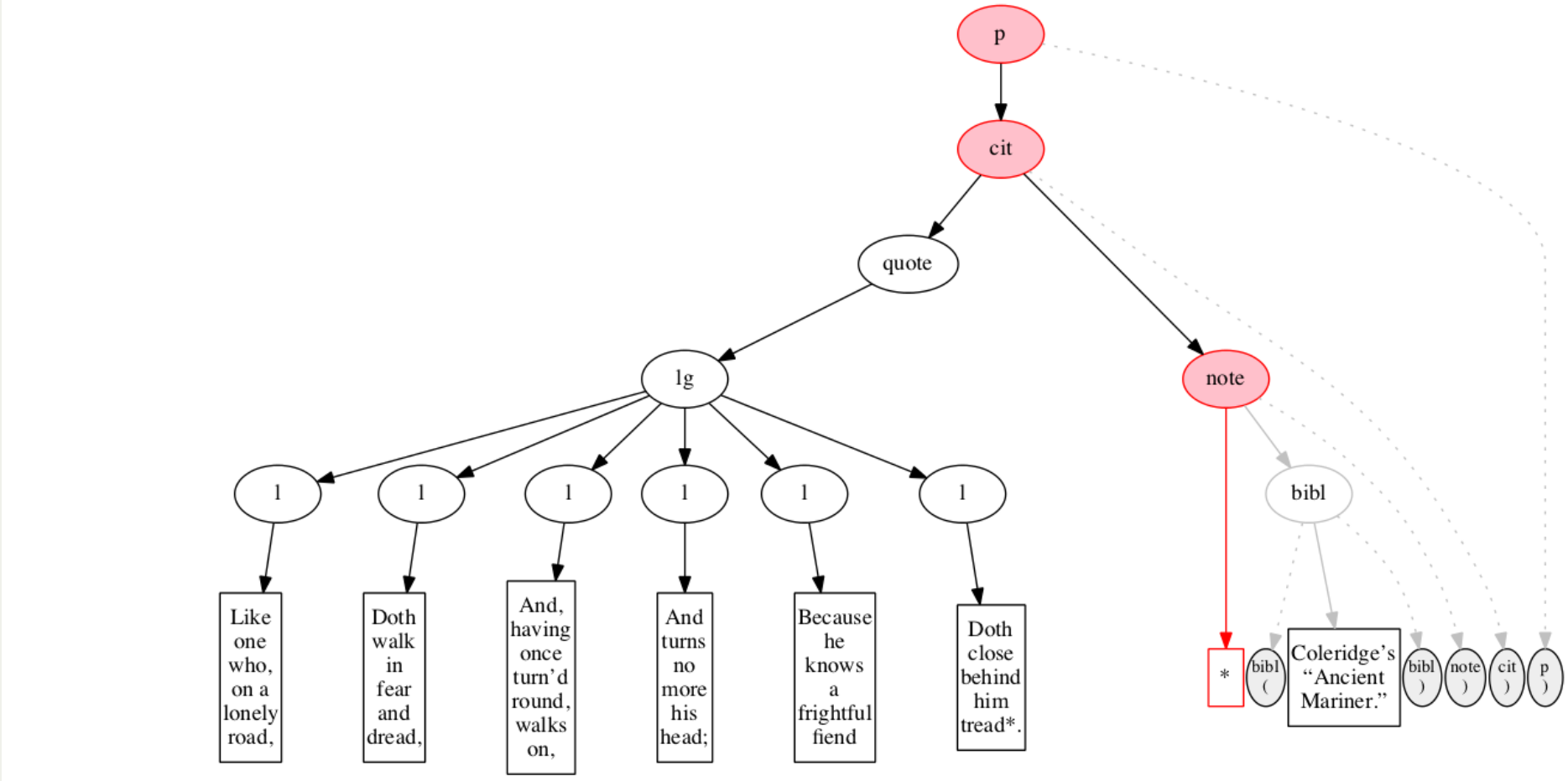
End-marker for the quotation.

Left to right



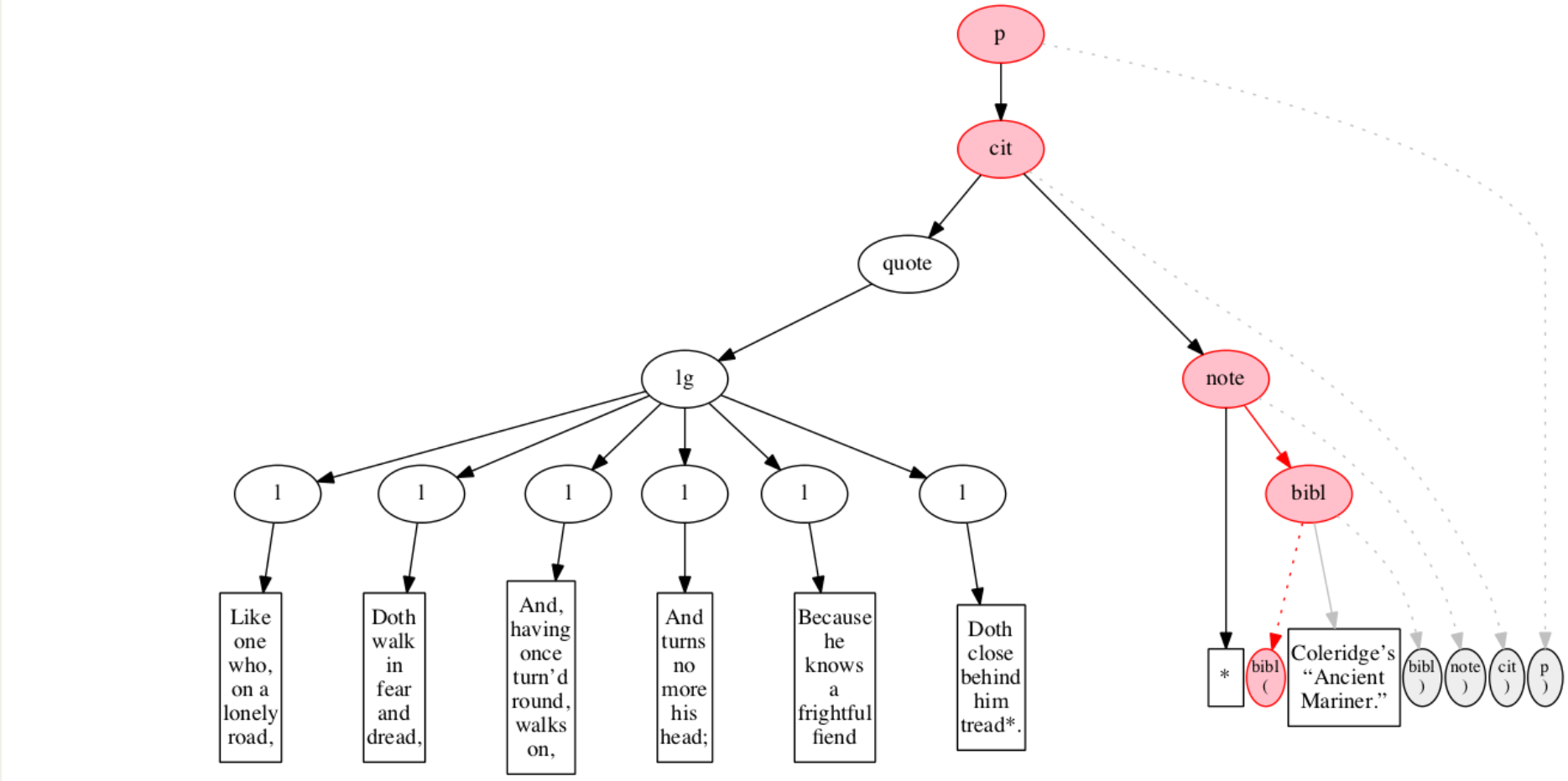
Start-marker for the note attributing the quotation.

Left to right



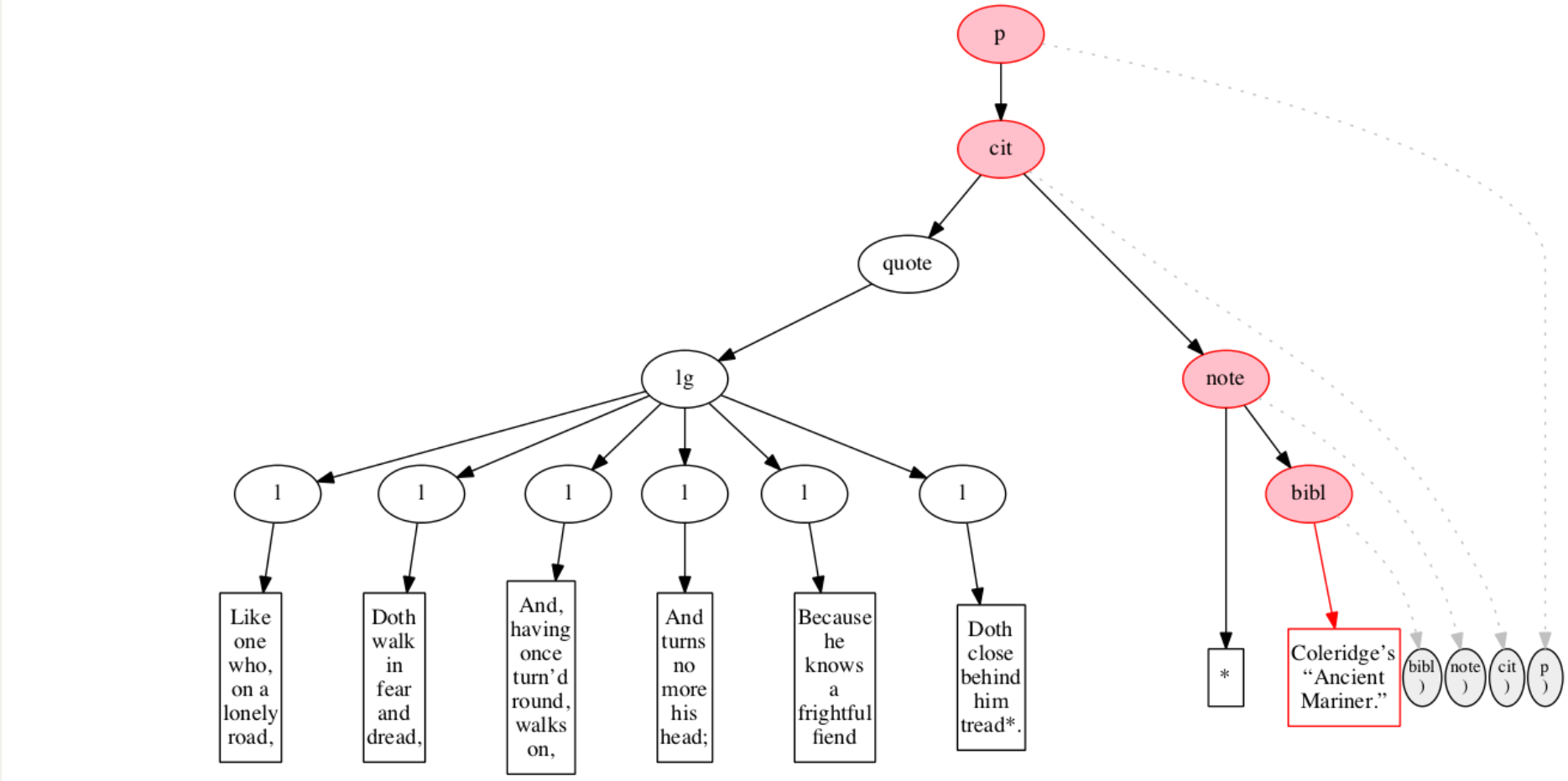
Text directly within the note.

Left to right



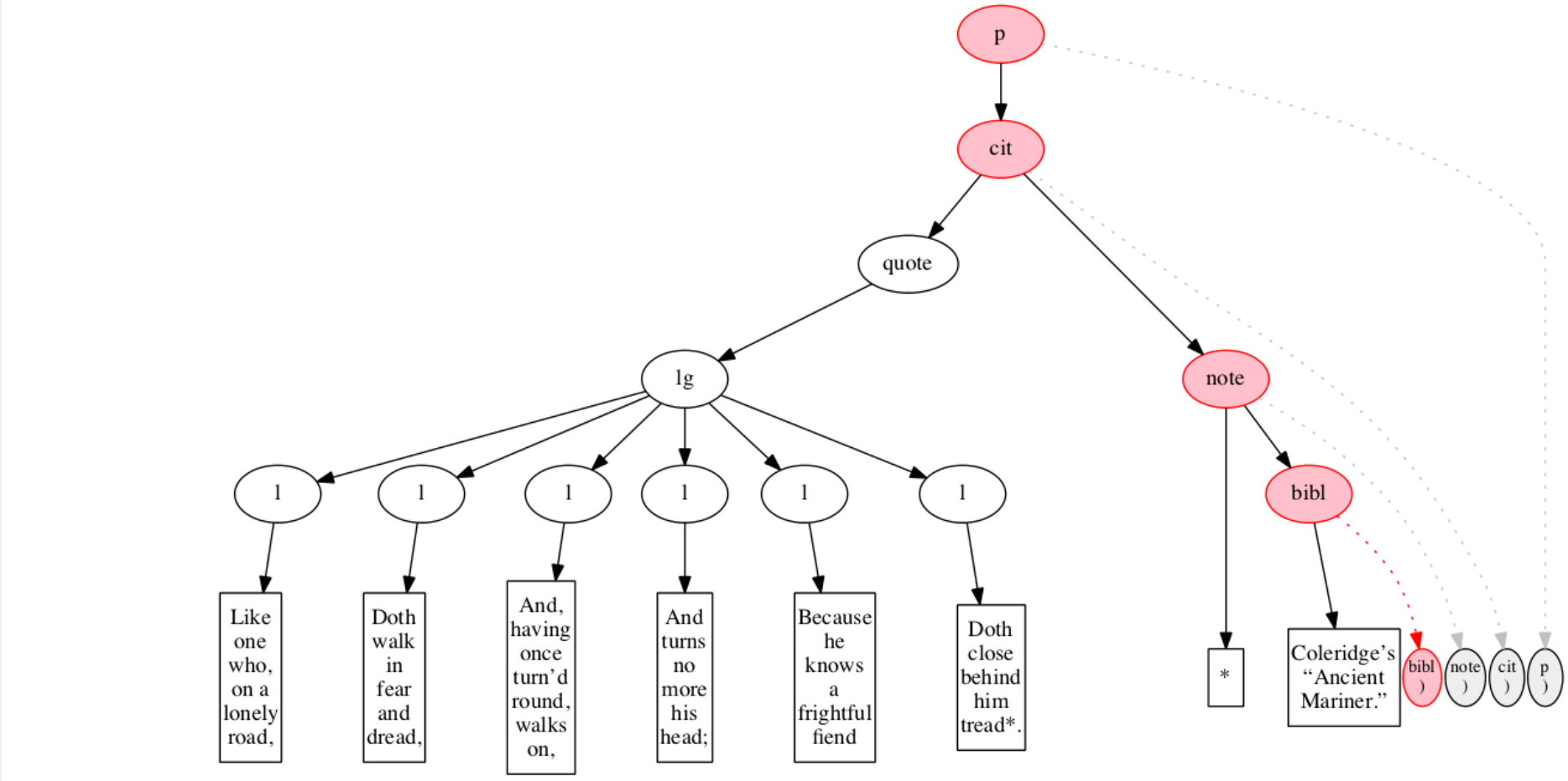
Start-marker for bibliographic reference.

Left to right



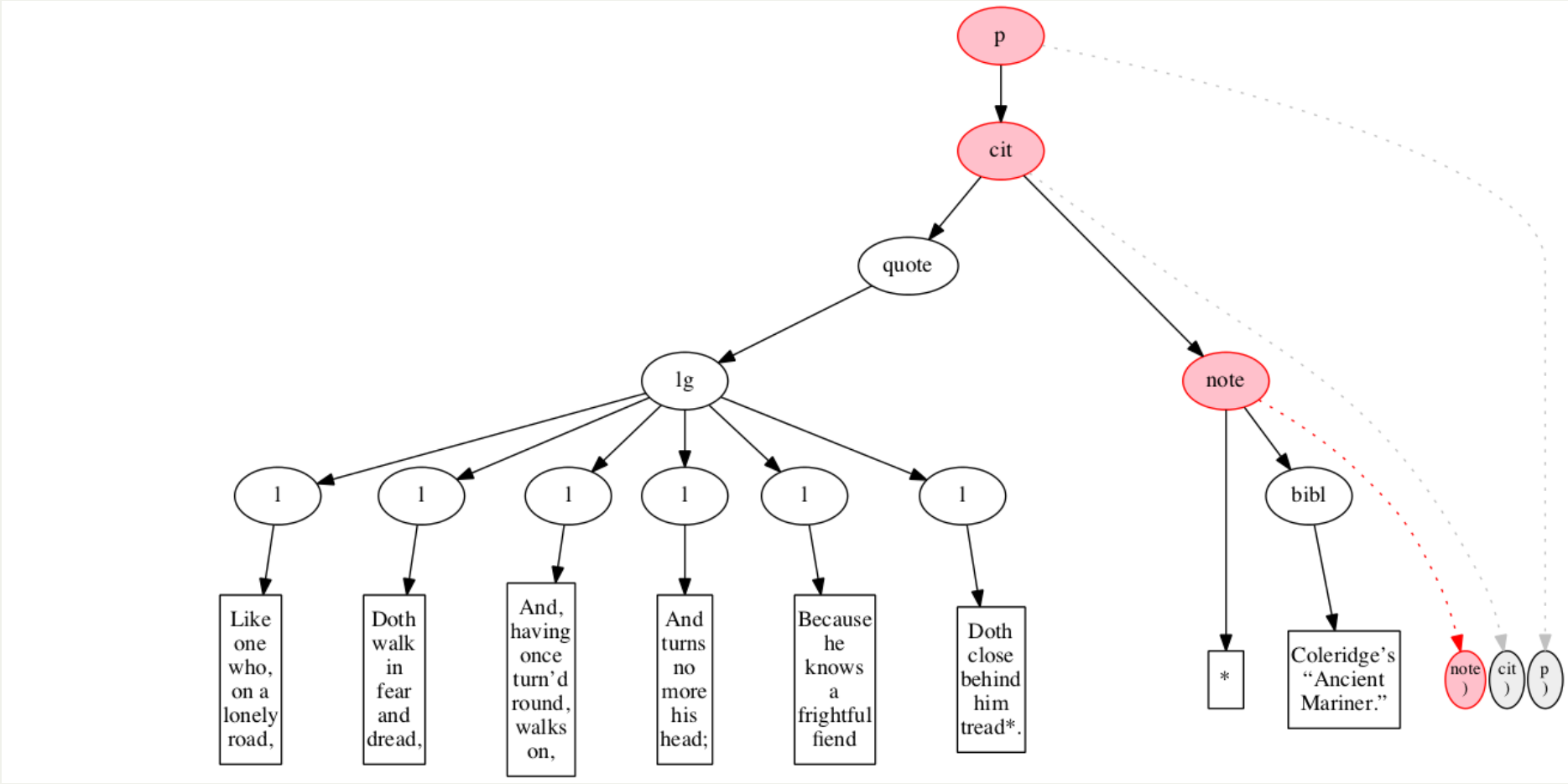
Text of the bibliographic reference.

Left to right



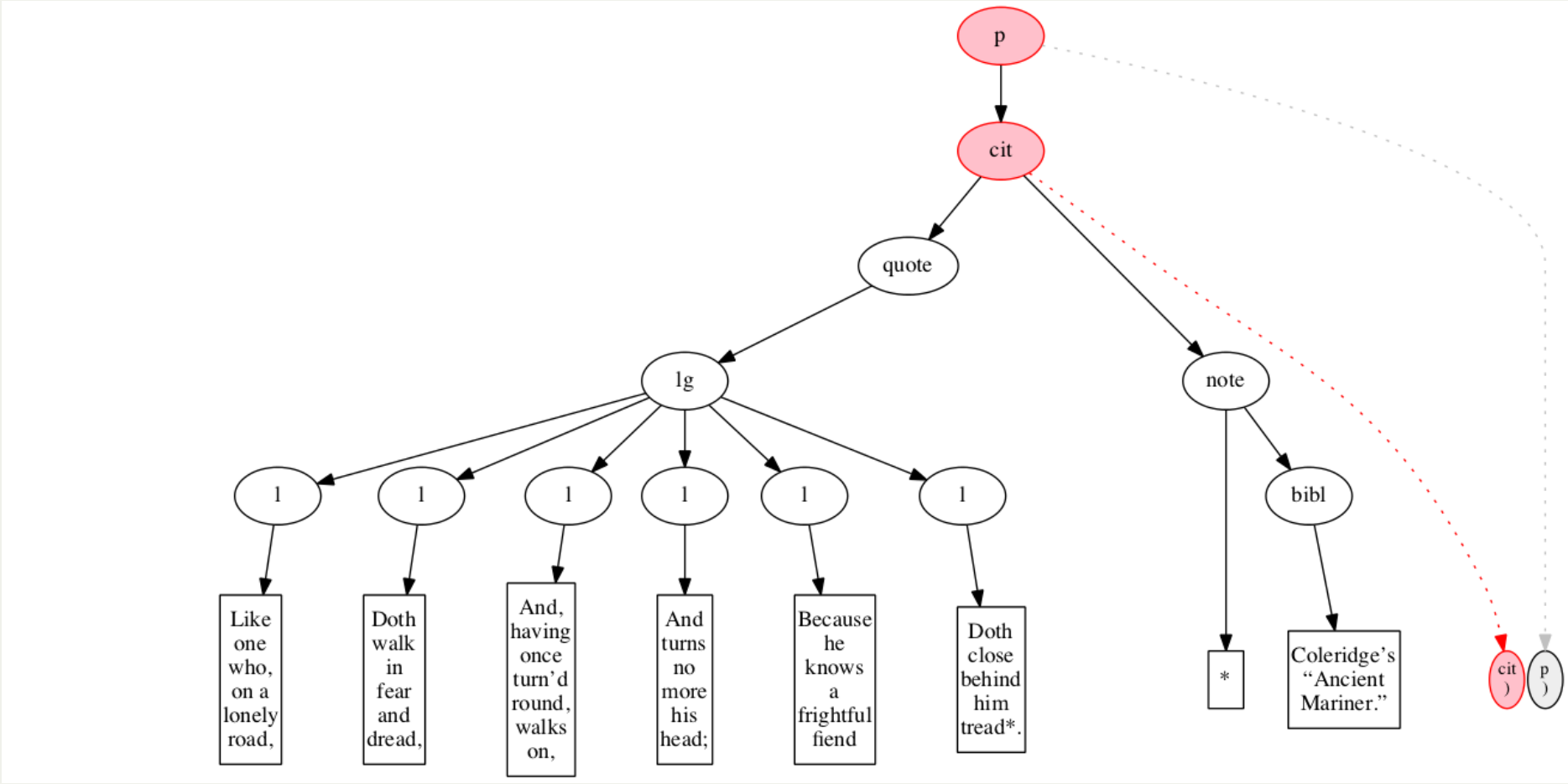
End-marker for the bibliographic reference.

Left to right



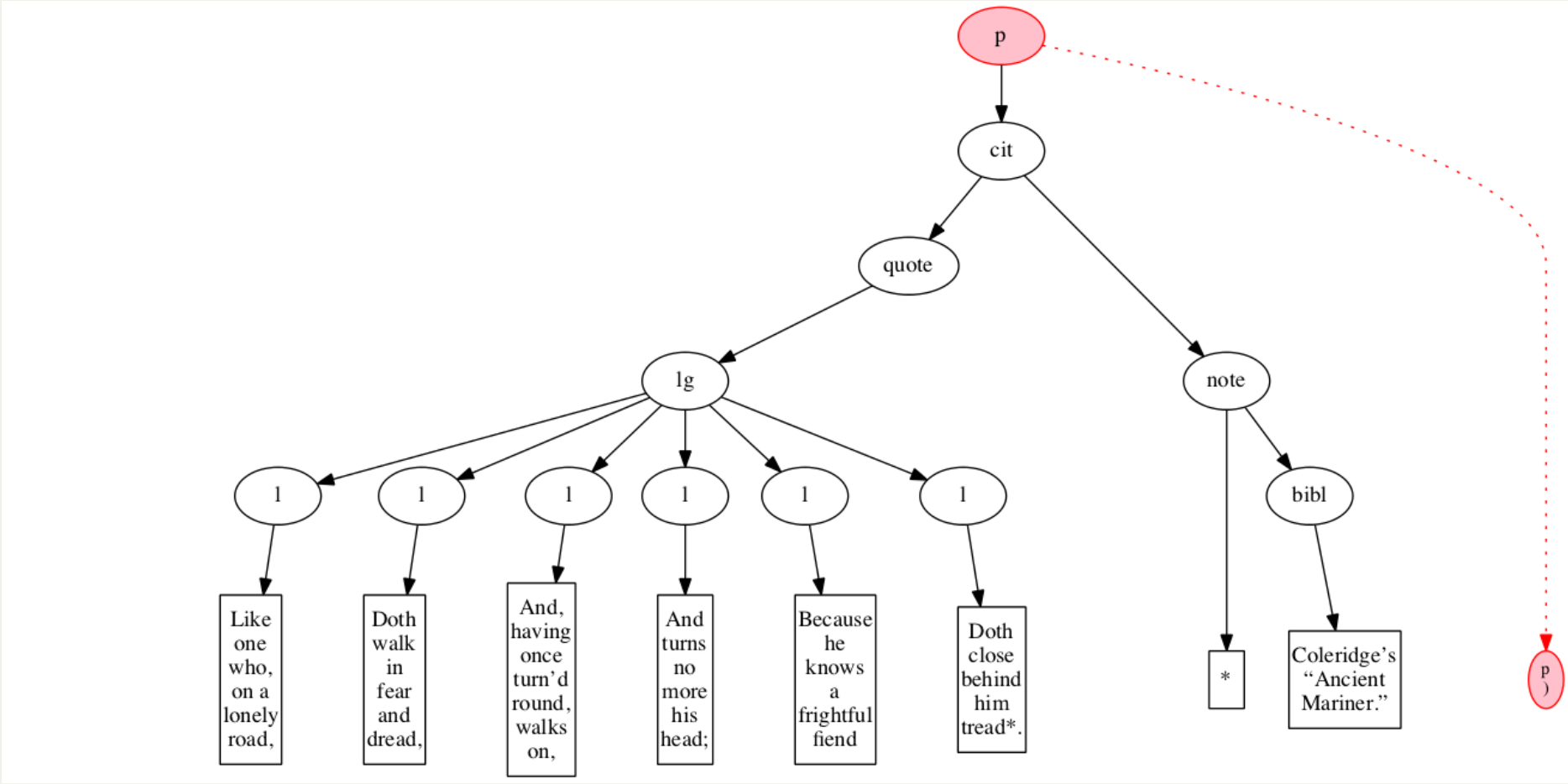
End-marker for the note.

Left to right



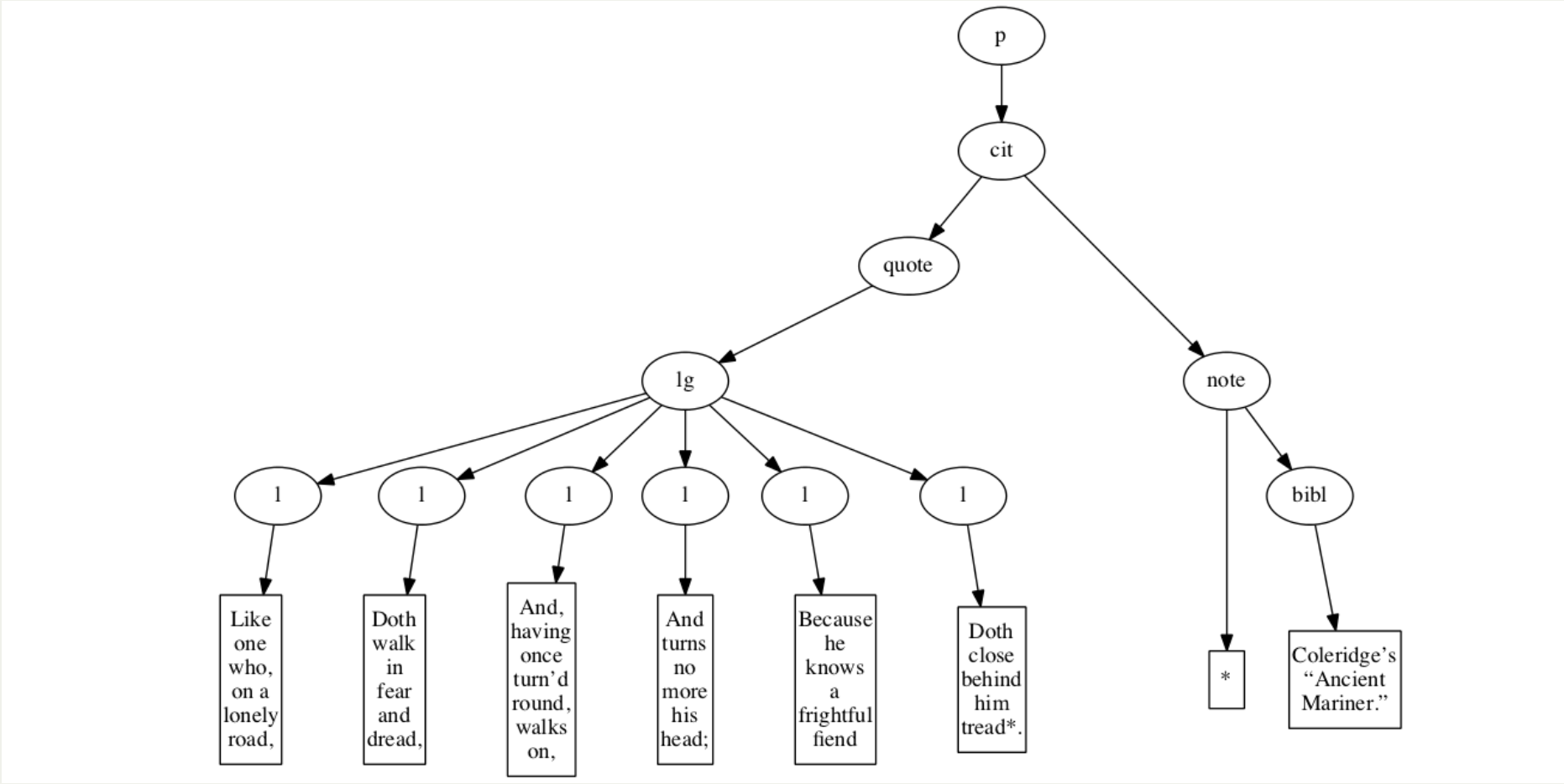
End-marker for the citation.

Left to right



End-marker for the paragraph.

Left to right



Final raised state.

Left-to-right traversal

- Single pass over input
- Useful but unusual idiom in XSLT

  - Call apply-templates on one node at a time
  - On start-marker:
    - copy the element
    - process the immediate right sibling as child
    - After element closes, continue with the immediate right sibling of the end-marker
  - On end-marker: Stop.
  - On anything else: Copy to output.

Left-to-right traversal code

On start-marker

```
<xsl:template match="*[th:is-start-marker(.)]" mode="raisin

    <!--* 1: handle this element *-->
    <xsl:copy copy-namespaces="no">
      <xsl:copy-of select="@* except @th:*"/>
      <xsl:apply-templates select="following-sibling::node(
                           mode="raising">
      </xsl:apply-templates>
    </xsl:copy>

    <!--* 2: continue after this element *-->
    <xsl:apply-templates select="th:matching-end-marker(.)
                                 /following-sibling::node()
                         mode="raising">
    </xsl:apply-templates>
  </xsl:template>
```

Left-to-right traversal code

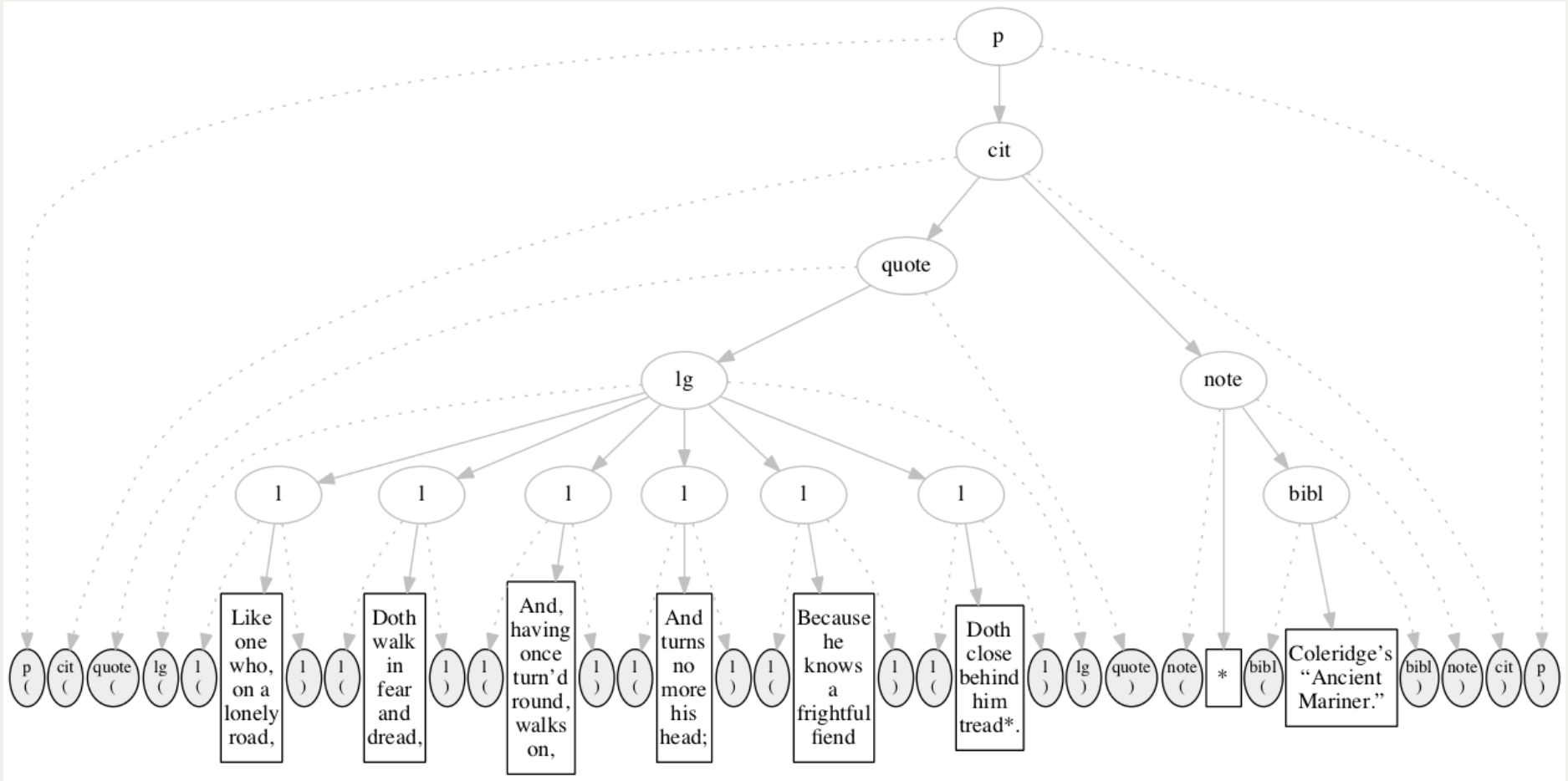
On end-marker

```
<xsl:template match="*[th:is-end-marker(.)]" mode="raising">

   <!--* no action necessary *-->
   <!--* we do NOT recur to our right.  We leave it to our parent to
       that. *-->

 </xsl:template>
```

On other nodes

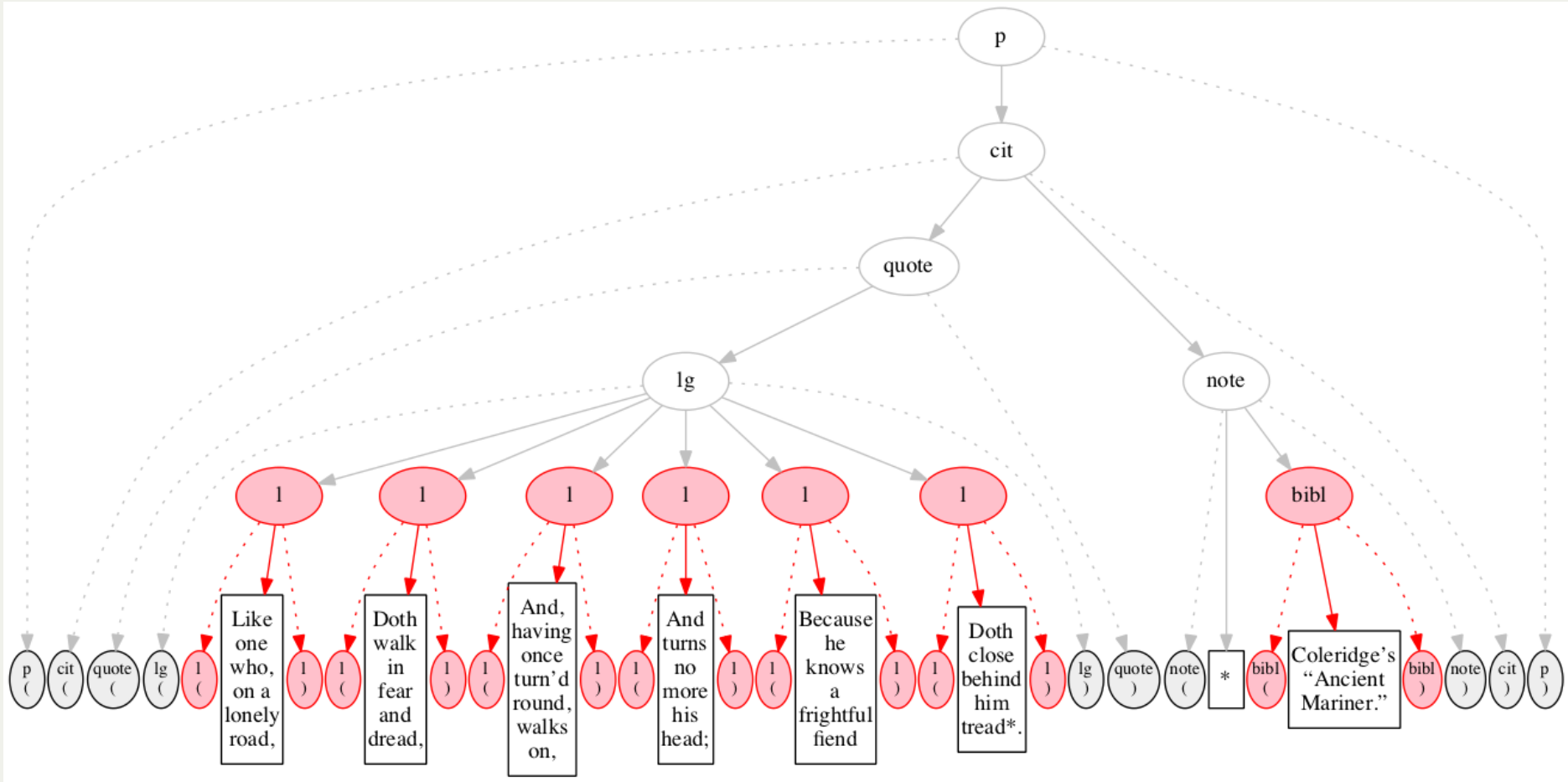
```
  <xsl:template match="text() | comment() | processing-instructio
                mode="raising">
    <xsl:copy/>
    <xsl:apply-templates select="following-sibling::node()[1]"
                         mode="raising"/>
  </xsl:template>
```

Inside out



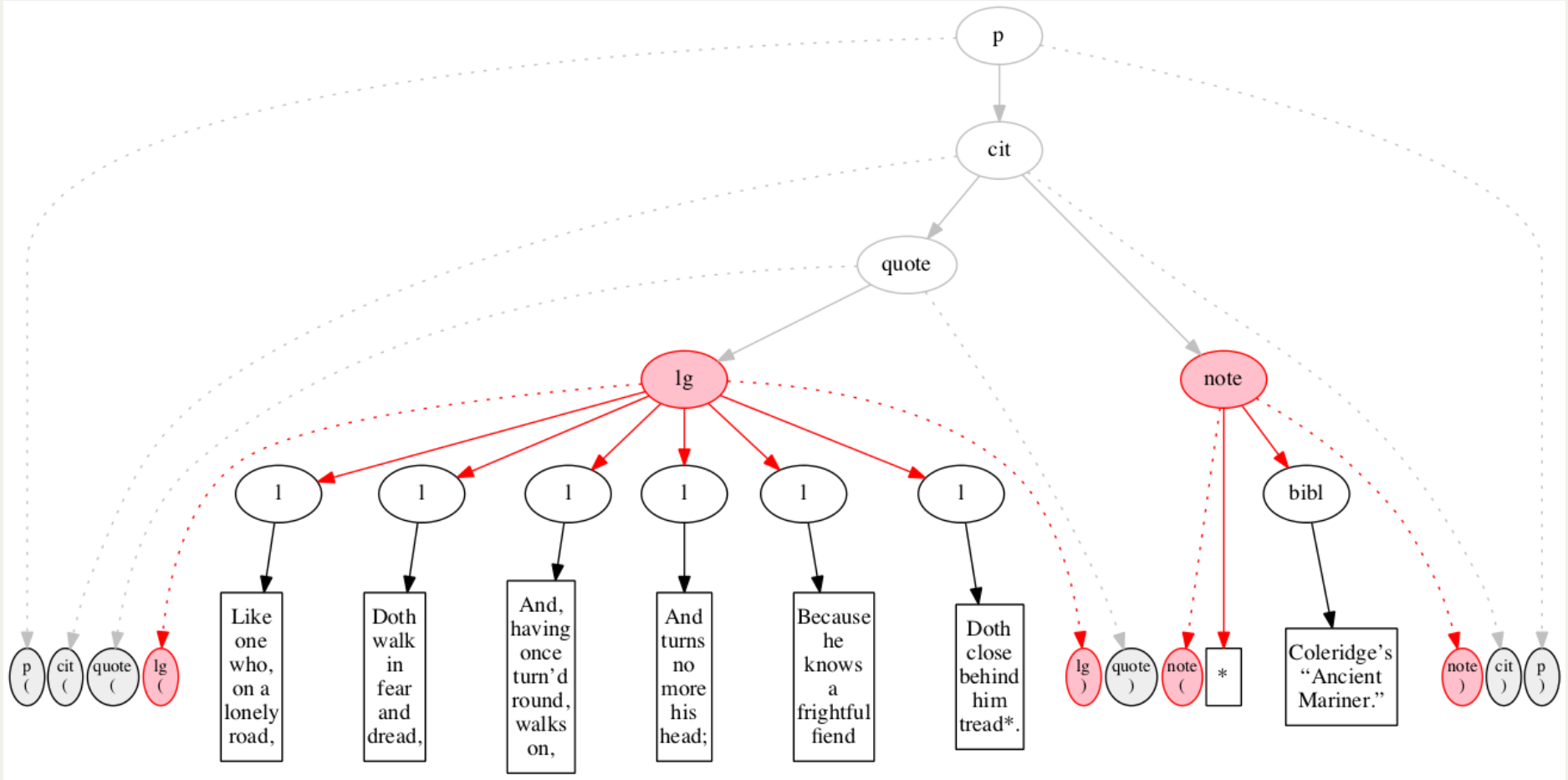
At the outset, we have a flat sequence of nodes.

Inside out



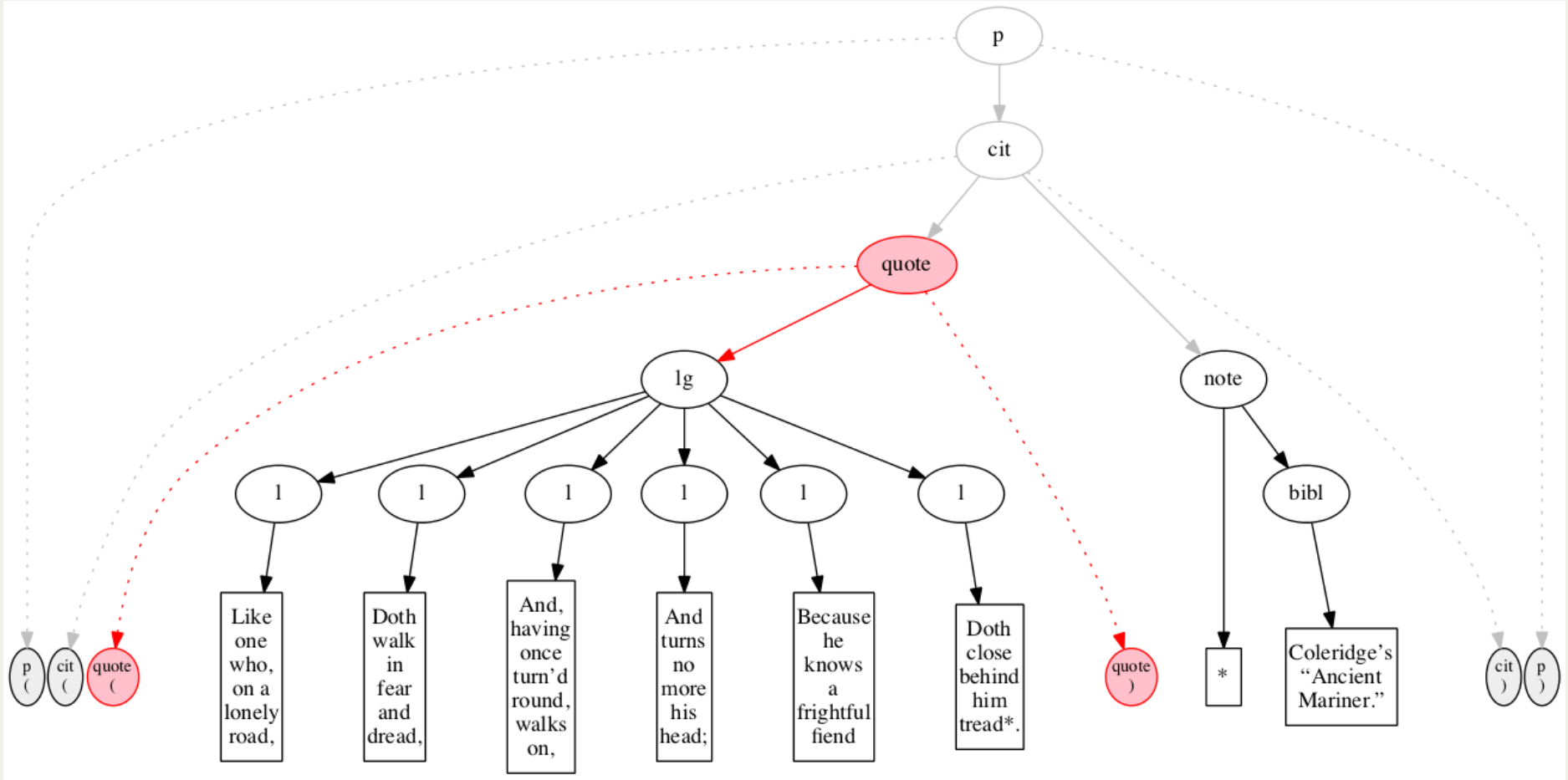
On the first pass we raise all character-only elements.

Inside out



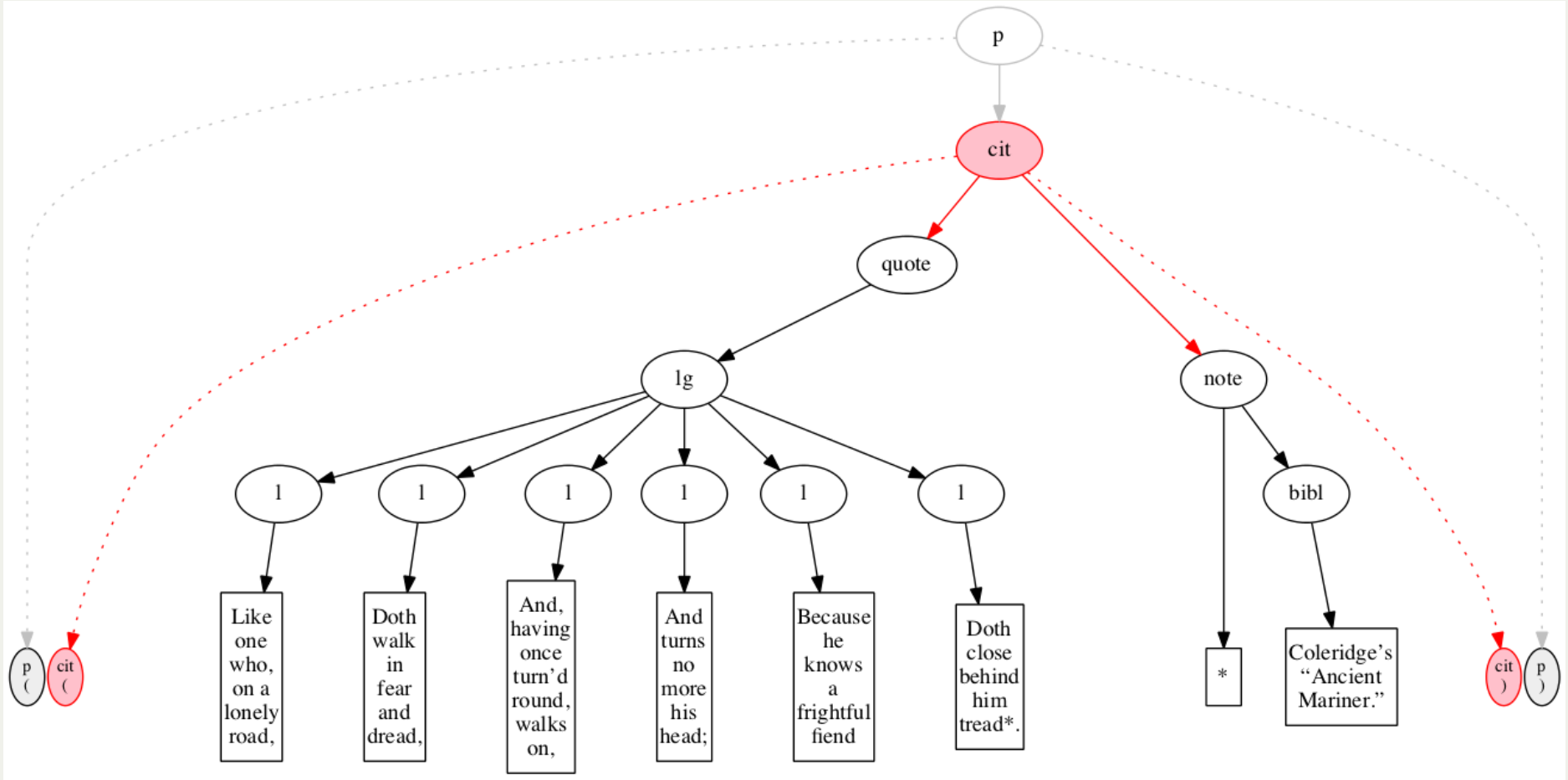
On the second pass, we raise the line group and the note.

Inside out



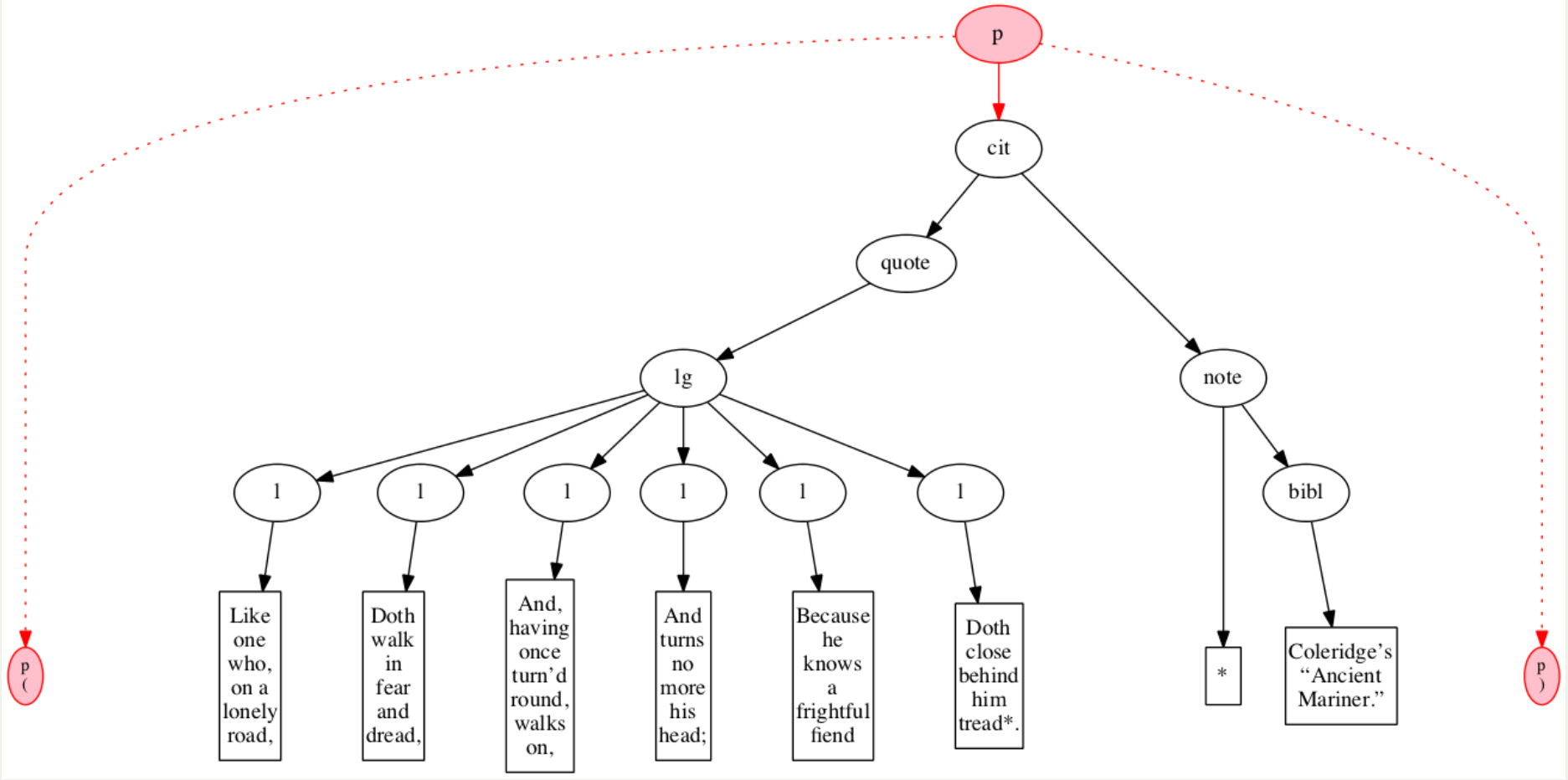
On the third pass, we raise the quote element.

Inside out



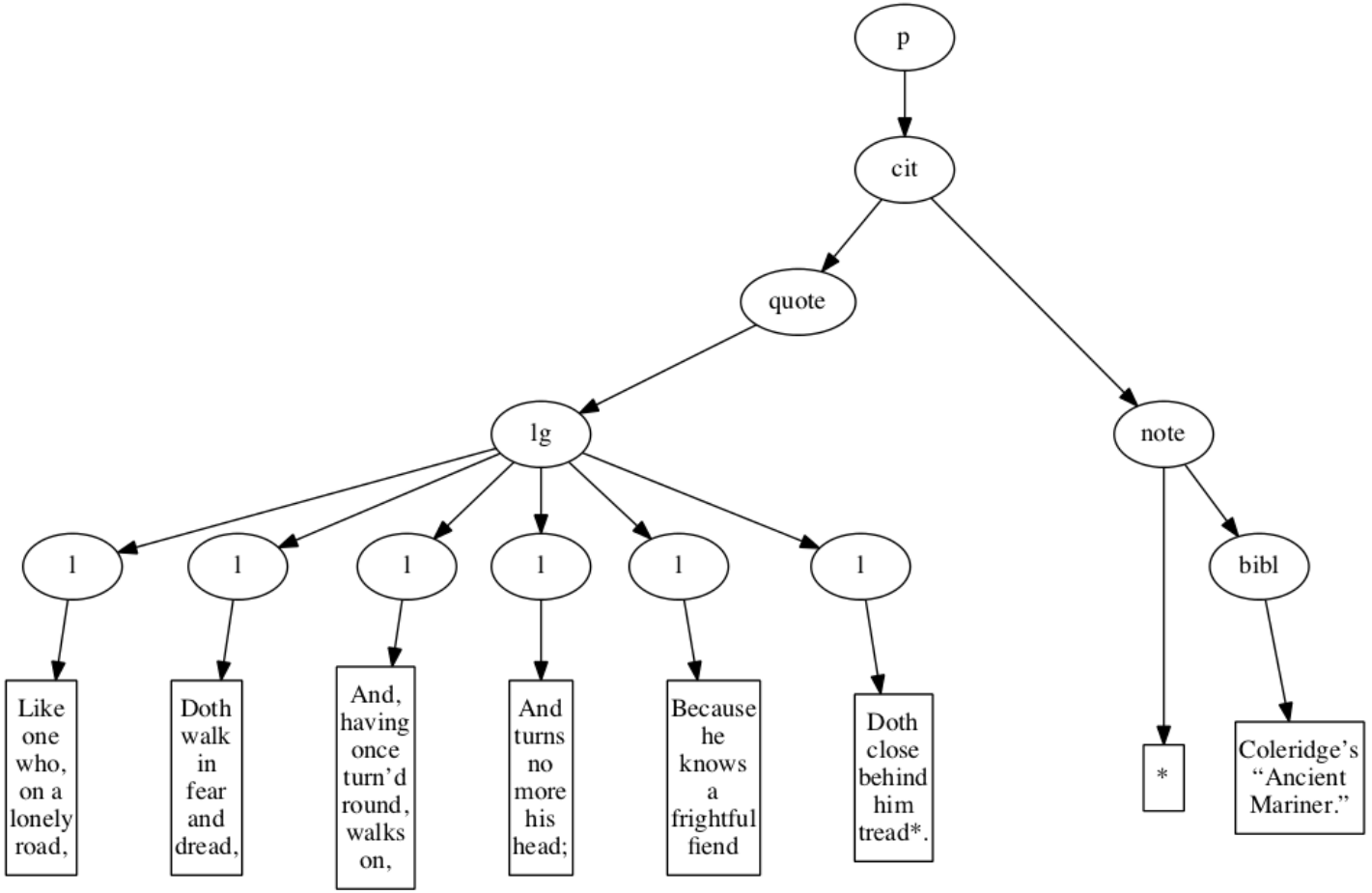
On the fourth pass, the citation element.

Inside out



On the fifth and final pass, we raise the paragraph.

Inside out



Final state. Number of passes = depth of tree.

Inside out construction

- Multiple passes
- On each pass:
  - Locate all the (would-be) innermost virtual elements
  - raise them
- If no more nodes to process, return the result
- If more nodes to process, make another pass (recursion)

Inside-out: code

Initiation: call th:raise() on the document node:

```
<xsl:template match="/">
        <xsl:sequence select="th:raise(.)"/>
    </xsl:template>
```

raise() function: either applies templates and then recurs, or it stops:

```
<xsl:function name="th:raise">
    <xsl:param name="input" as="document-node()"/>
    <xsl:choose>
        <xsl:when test="exists($input//*[@th:sID eq
            following-sibling::*[@th:eID][1]/@th:eID])">
            <!-- If we have more work to do, do it -->
            <xsl:variable name="result" as="document-node()">
                <xsl:document>
                    <xsl:apply-templates select="$input" mode="loop"/>
                </xsl:document>
            </xsl:variable>
            <xsl:sequence select="th:raise($result)"/>
        </xsl:when>
        <xsl:otherwise>
            <!-- We have no more work to do, return the input unchanged. -
            <xsl:sequence select="$input"/>
        </xsl:otherwise>
    </xsl:choose>
</xsl:function>
```

Inside-out: code

Matching the virtual innermost pairs

```
<xsl:template match="*[@th:sID eq
      following-sibling::*[@th:eID][1]/@th:eID]" priority="1">
      <xsl:copy copy-namespaces="no">
          <xsl:copy-of select="@* except @th:sID"/>
          <xsl:variable name="end-marker" as="element()"
                        select="following-sibling::*[@th:eID][1]
          <xsl:copy-of select="following-sibling::node()
                        [. << $end-marker]"/>
      </xsl:copy>
  </xsl:template>
```

If the first end-marker we see after a start-marker matches, we have a virtual innermost pair. Raise it!

Inside-out: code

Ignore anything inside a virtual innermost pair:

```
<xsl:template
        match="node()
            [preceding-sibling::*[@th:sID][1]/@th:sID
            eq
            following-sibling::*[@th:eID][1]/@th:eID]"
        priority="1"/>
```

Suppress the end-marker:

```
<xsl:template match="*
        [@th:eID eq preceding-sibling::*[@th:sID][1]/@th:sID]"
        priority="1"/>
```

Copy anything outside an innermost pair:

```
 <!-- identity template (all modes) -->
    <xsl:template match="@* | node()" mode="#all">
        <xsl:copy>
            <xsl:apply-templates select="@* | node()"/>
        </xsl:copy>
    </xsl:template>
```

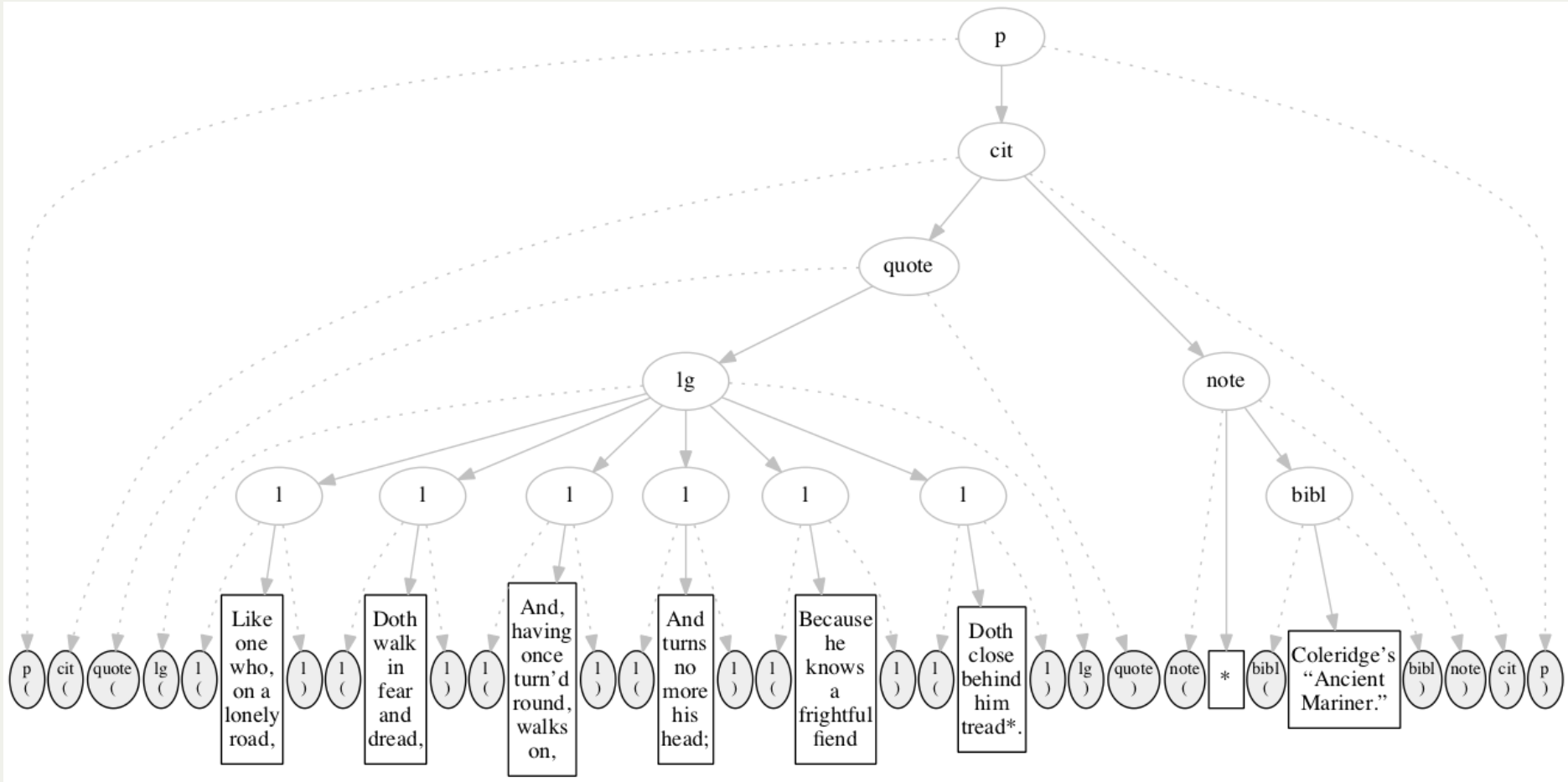
Outside in

Q: Can we make a mirror-image of inside-out from the other way around?

A: Sort of. . .

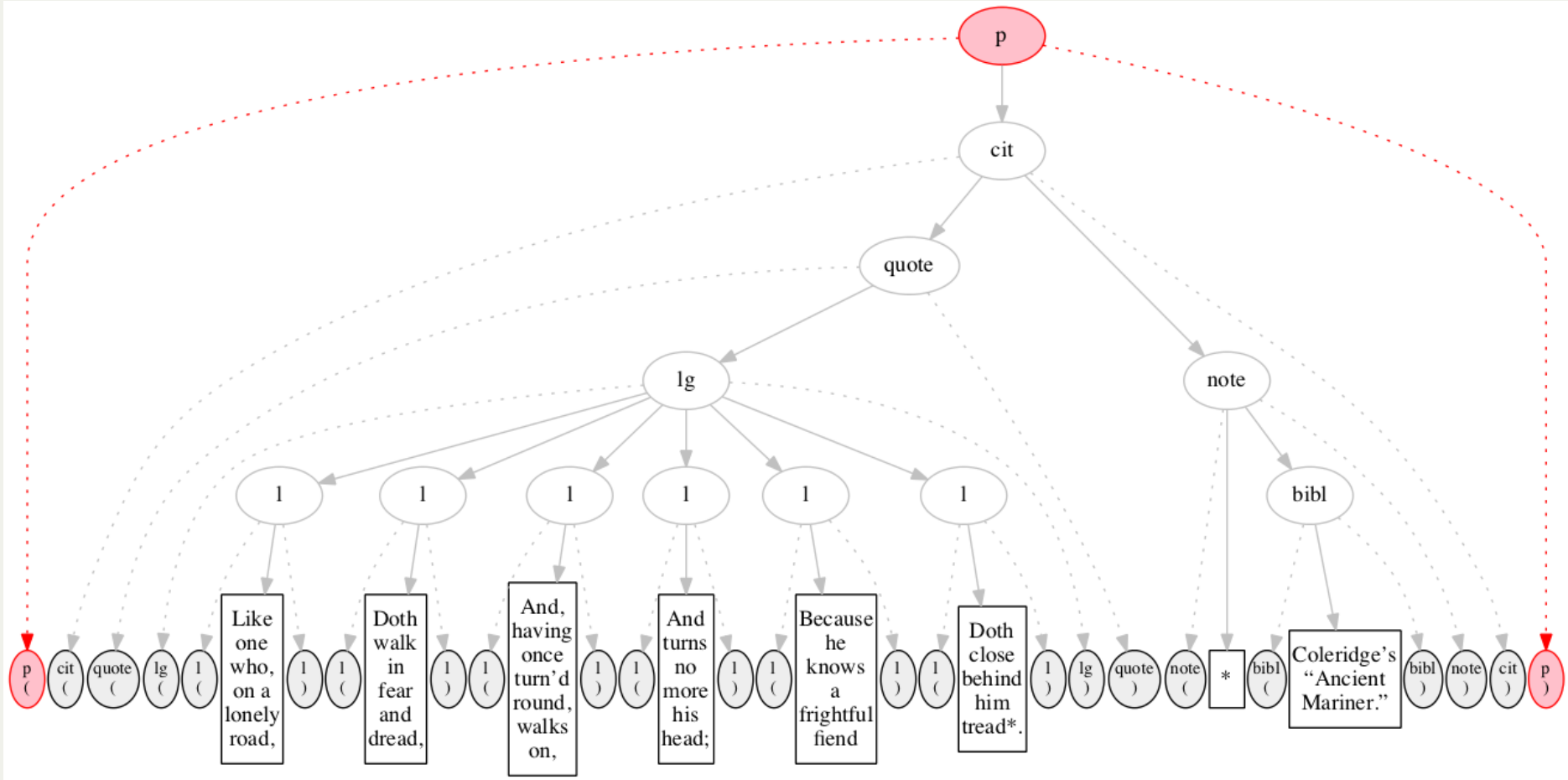
- First recognize left-most outermost pair and handle it, then recur to handle next pair.
- To handle any pair, make element, then recur on (virtual) children.
- Length of argument sequence will be smaller on each call. So: faster than inside-out?
- Two recursive calls for each virtual element. So: slower than inside-out?

Outside in



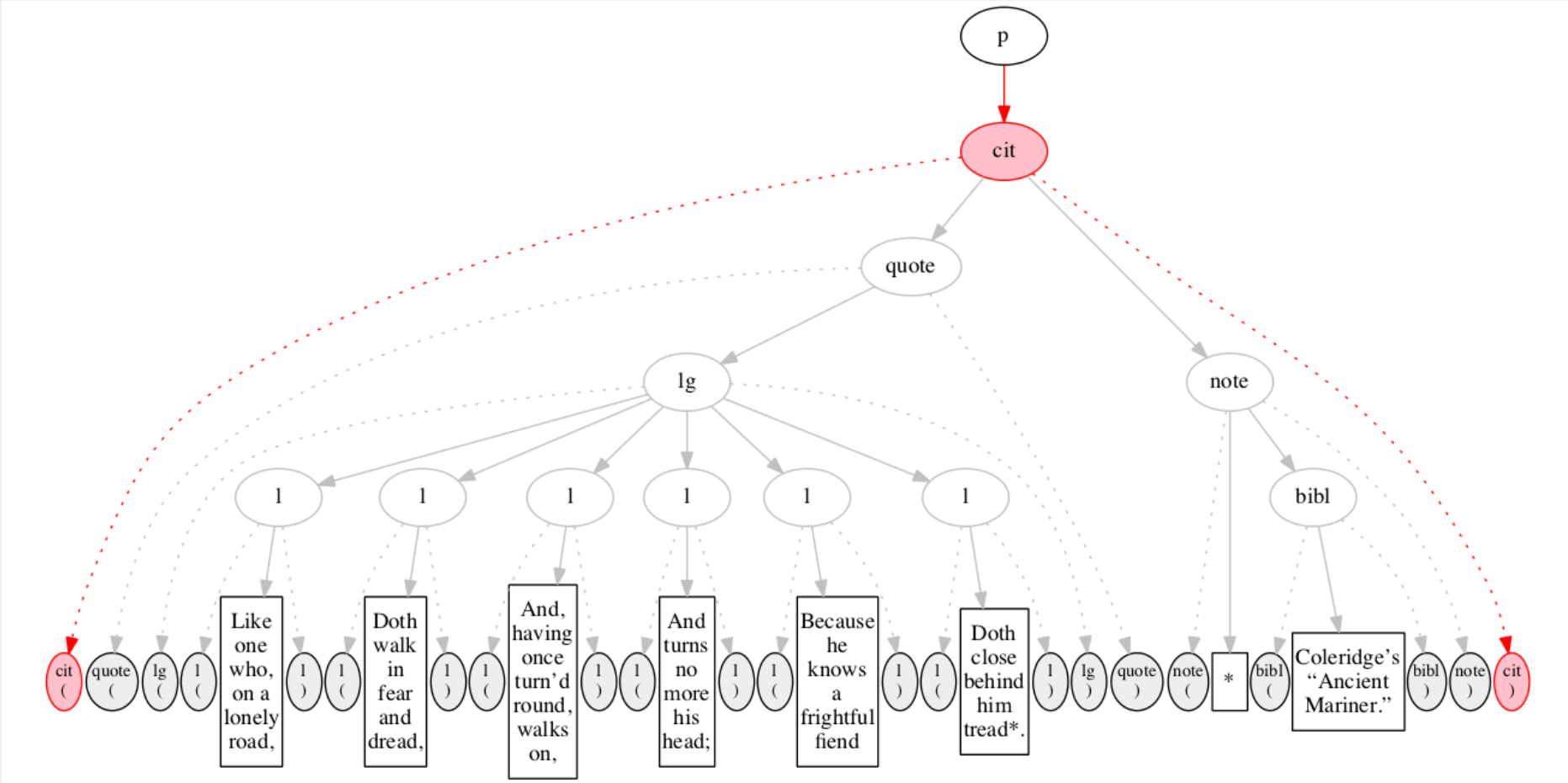
At the outset, we have a flat sequence of nodes.

Outside in



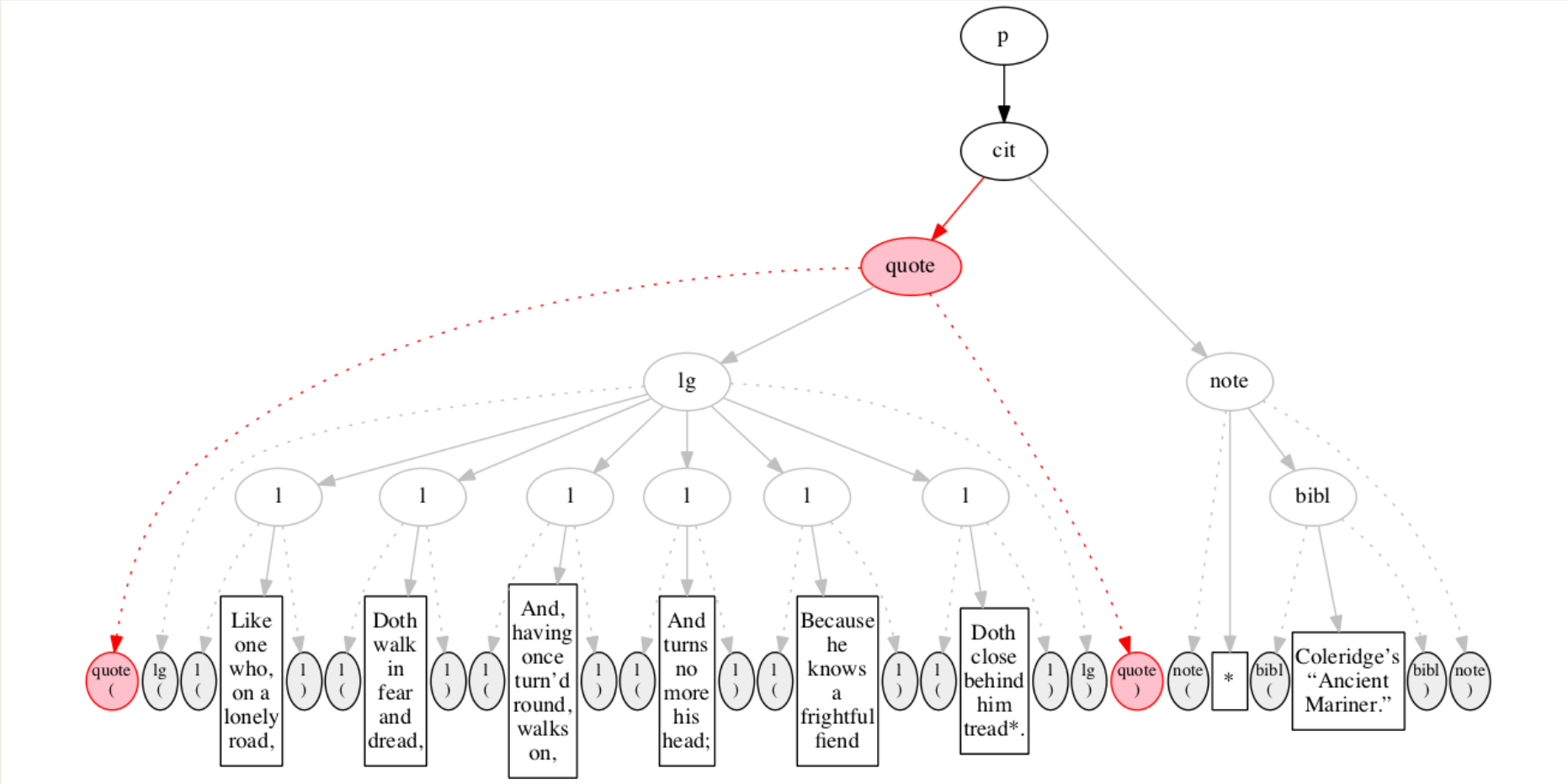
On the first pass we raise the outermost element, the <p>.

Outside in



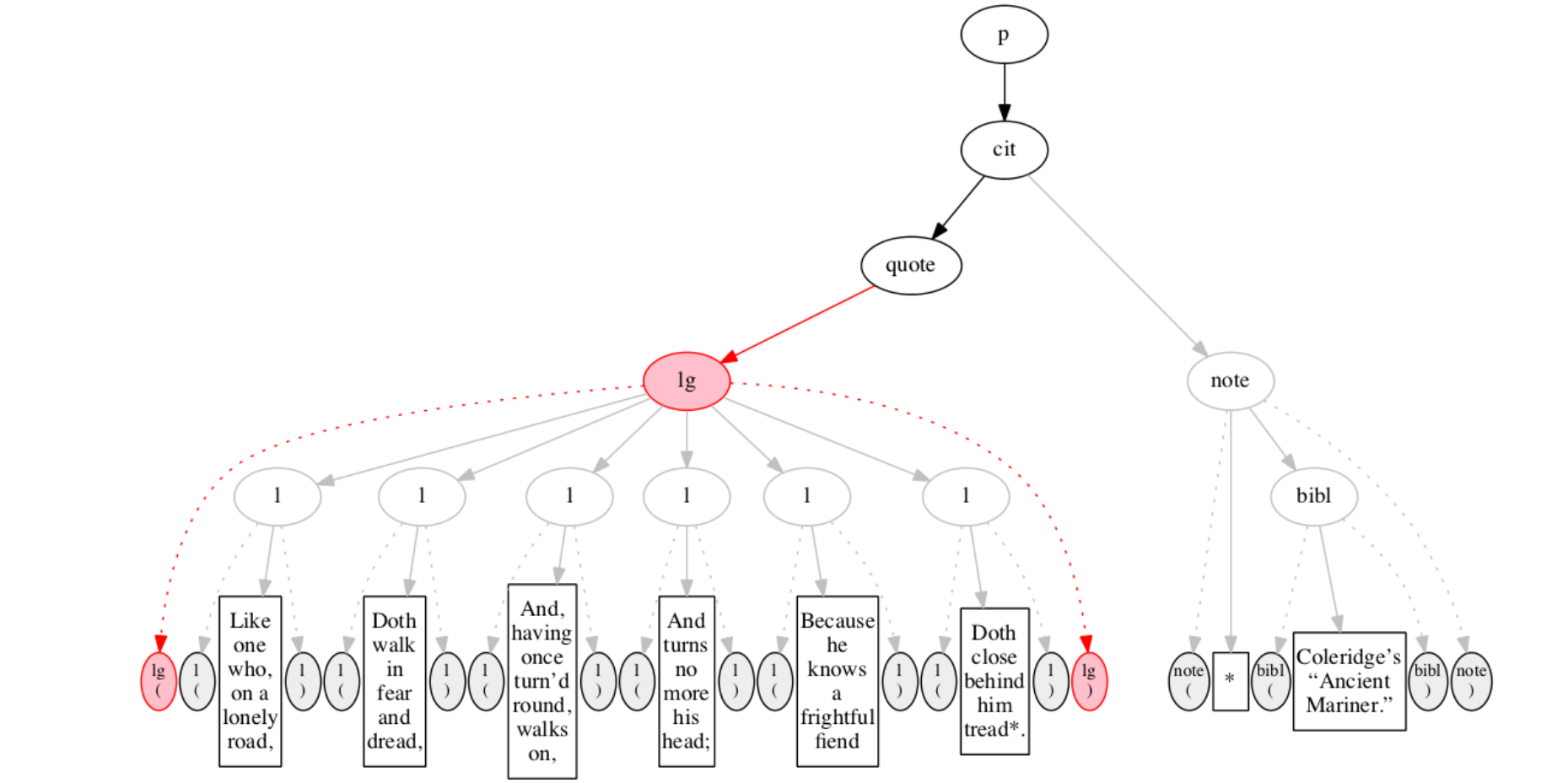
On the second pass, we raise the citation element. The <p> element is finished, though its children are still in process.

Outside in



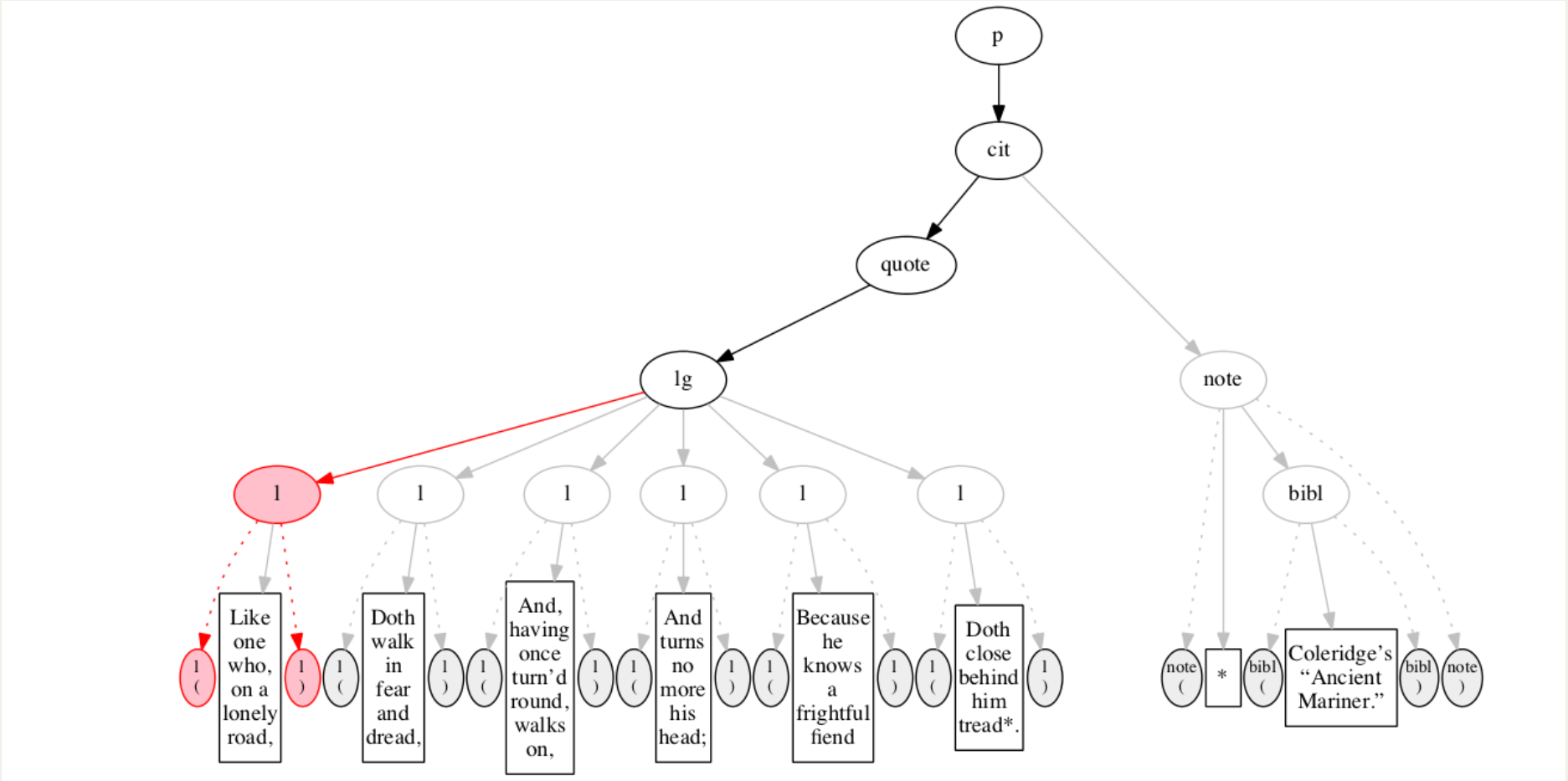
On the third pass, we raise the <quote> element, but we don't know how to raise the <note> at the same time.

Outside in



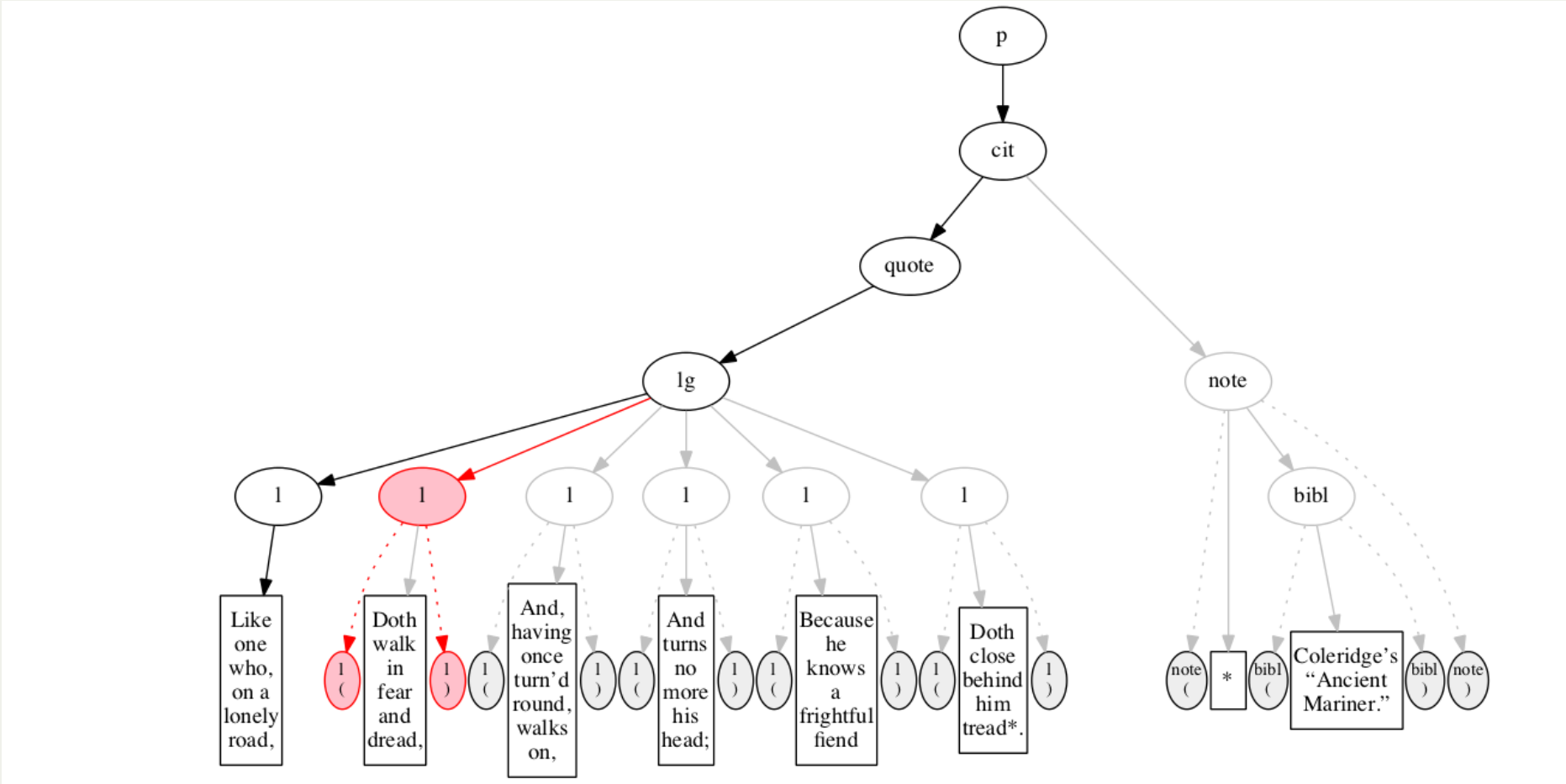
On the fourth pass, we recur on the content of the quotation and raise the line group.

Outside in



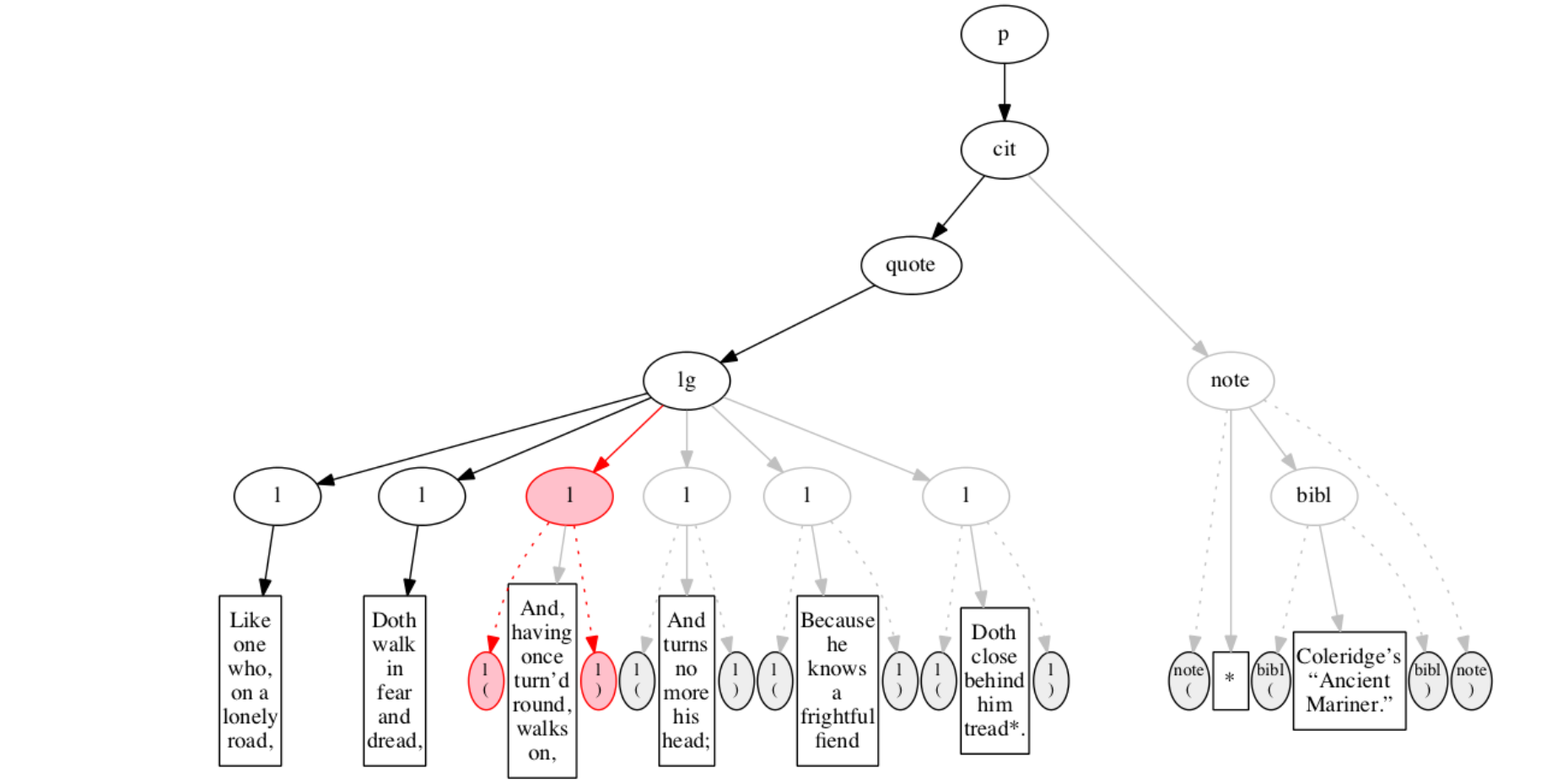
On the fifth pass, we raise the first line.

Outside in



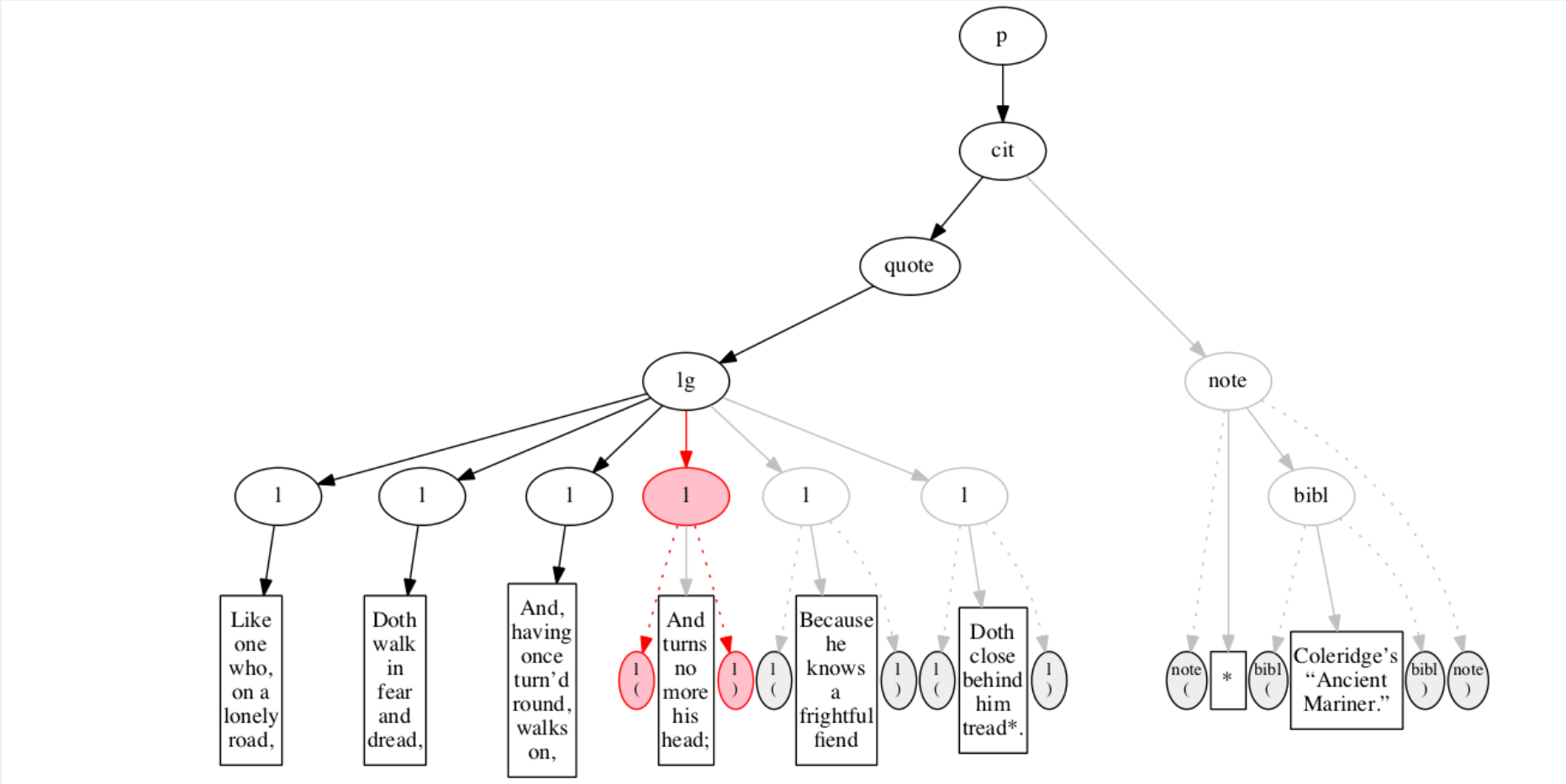
We raise the second line (6th pass).

Outside in



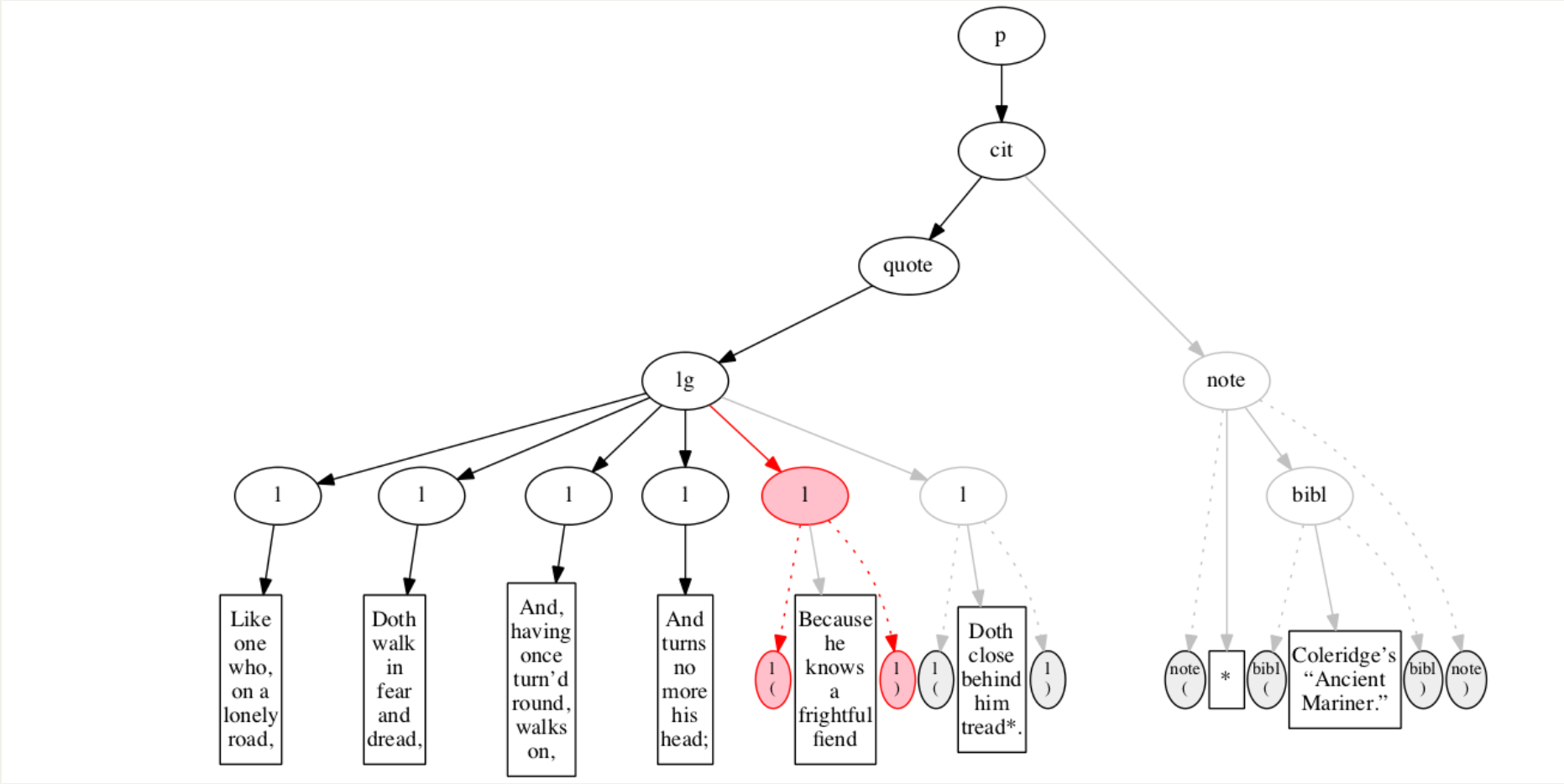
Third line (7th pass).

Outside in



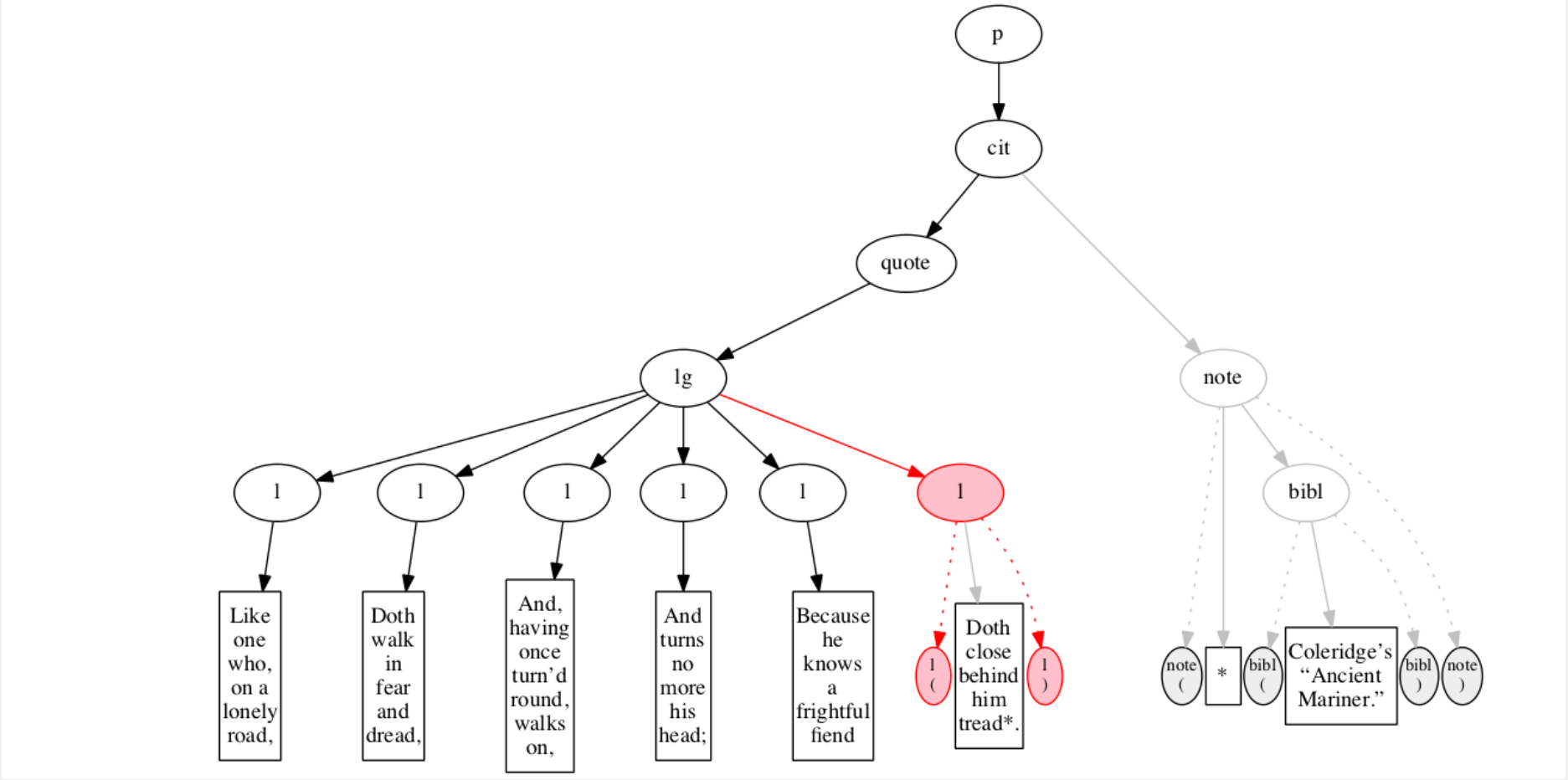
Fourth line (8th pass).

Outside in



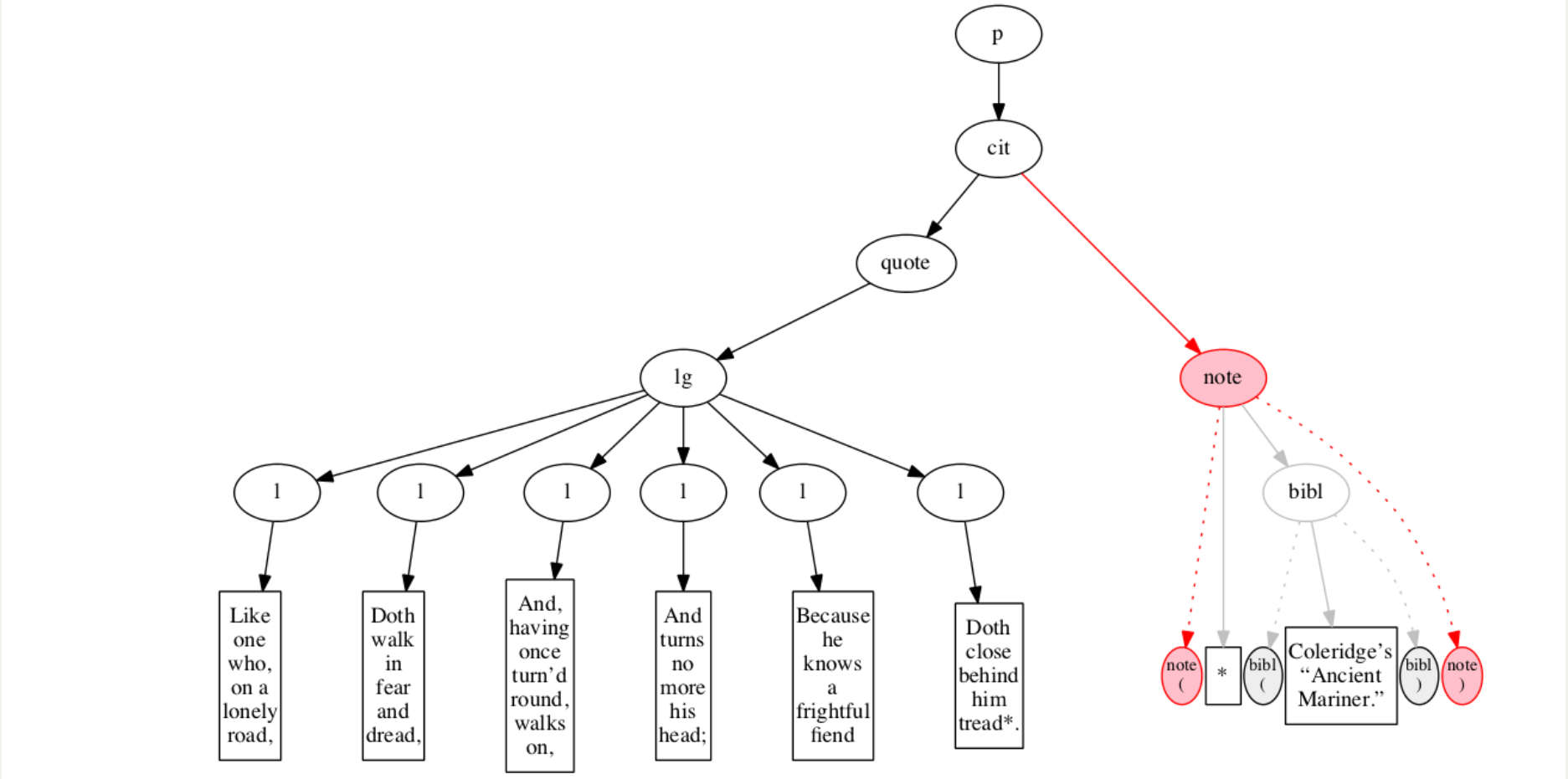
Fifth line (9th pass).

Outside in



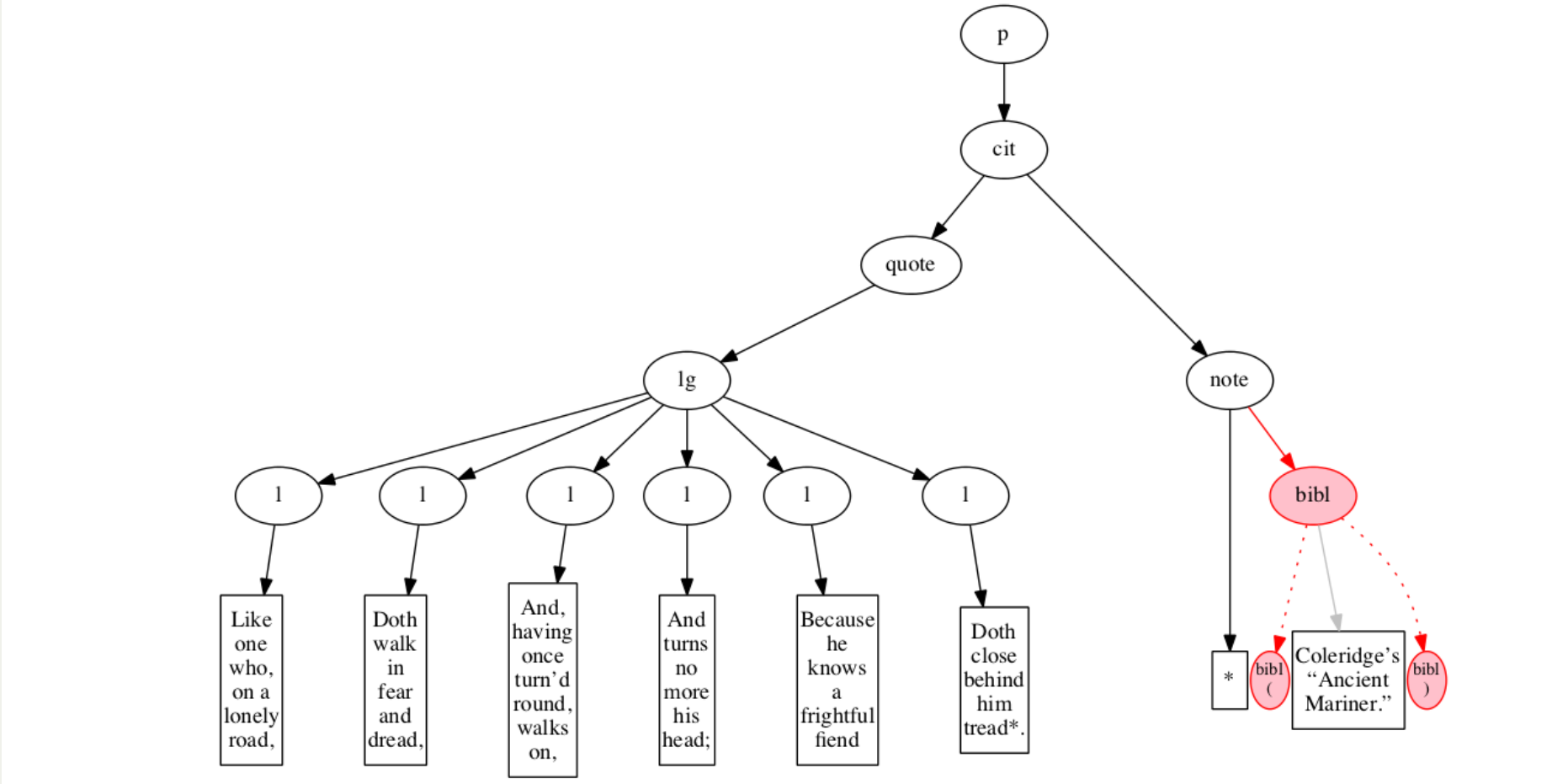
Sixth line (10th pass)

Outside in



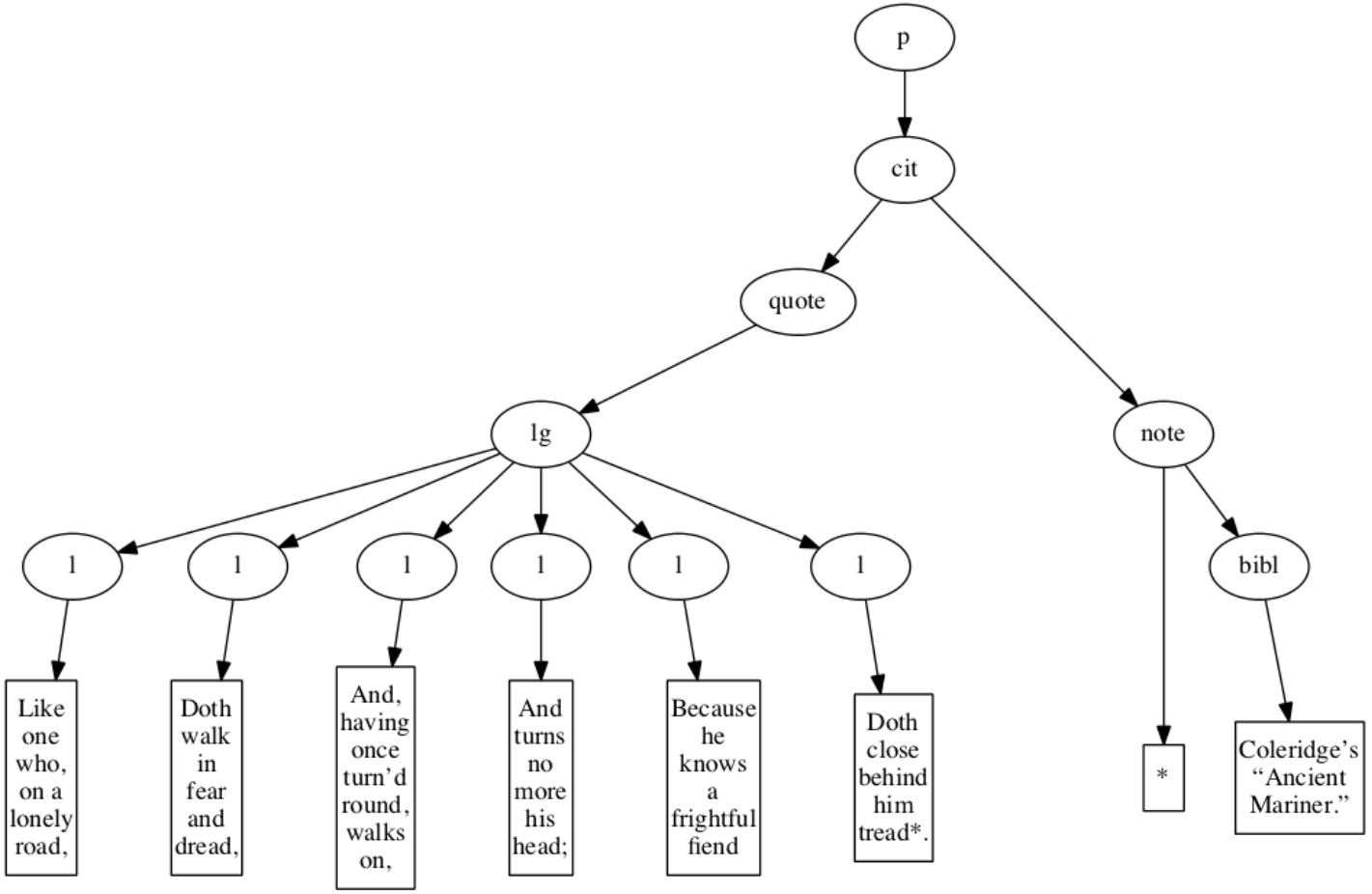
Now we finally make it to the note. (11th pass)

Outside in



On the 12th and final pass, we raise the bibliographic reference within the note.

Outside in



Final raised state.

Outside-in construction

On any content element, check for markers and raise them:

```
<xsl:template match="*[exists(node())]">
    <xsl:copy>
      <xsl:sequence select="@*, th:raise-sequence(child::node())"/>
    </xsl:copy>
  </xsl:template>
```

Outside-in th:raise sequence

The th:raise-sequence() function checks for matching start-/end-marker pairs. If none, it terminates, returning its input. Otherwise, it has work to do.

```
<xsl:function name="th:raise-sequence" as="node()*">
  <xsl:param name="ln" as="node()*"/>

  <!--* lidStarts, lidEnds:  lists of IDs for start- and end-markers *-->
  <xsl:variable name="lidStarts" as="xs:string*"
                select="for $n in $ln[th:start-marker(.)]
                        return th:id($n)"/>
  <xsl:variable name="lidEnds" as="xs:string*"
                select="for $n in $ln[th:end-marker(.)]
                        return th:id($n)"/>

  <xsl:choose>
    <!--* base case:  no start-marker / end-marker pairs present *-->
    ...
    <!--* 'normal' case: take first start-marker with matching end-marker *-->
    ...
  </xsl:choose>
</xsl:function>
```

Outside-in: base case

If there are no matching markers present, we're done.

```
<!--* base case:  no start-marker / end-marker pairs present *-->
    <xsl:when test="empty($lidStarts[. = $lidEnds])">
      <!--* The sequence may contain elements with markers inside,
          * so we apply templates, instead of just returning $ln *-->
      <xsl:apply-templates select="$ln"/>
    </xsl:when>
```

Outside-in: normal case

In the normal case, we

1. Find the first start-marker with a matching end-marker.
   Divide the sequence into left, center, right subsequences.
2. Apply templates to left subsequence.
3. Make element from start-marker.
4. Recur on center subsequence (children of new element).
5. Recur on right subsequence.

Outside-in: find the left-most start marker

Find the first start-marker with a matching end-marker. Then divide the sequence into left, center, right subsequences.

```
<!--* 'normal' case: take first start-marker with matching end-marker *-->
    <xsl:otherwise>
      <!--* find ID of first start-marker with matching end-marker *-->
      <xsl:variable name="id" as="xs:string"
                    select="$lidStarts[. = $lidEnds][1]"/>
      <!--* find position of start- and end-markers with that ID *-->
      <xsl:variable name="posStartEnd" as="xs:integer+"
                    select="for $i in 1 to count($ln) return
                            if ($ln[$i][(th:start-marker(.)
                                or th:end-marker(.))
                                and th:id(.) eq $id])
                                then $i else ()"/>
      <xsl:variable name="posStart" as="xs:integer"
                    select="$posStartEnd[1]"/>
      <xsl:variable name="posEnd" as="xs:integer"
                    select="$posStartEnd[2]"/>
```

Outside-in: lean to the left, lean to the right...

Apply templates to left subsequence.

```
<!--* Apply templates to all items to left of start. These may
      * include markers, but if so they are not matched and not
      * raisable. They may also include elements which contain
      * markers, so we need to apply templates, not just return
      * them. *-->
    <xsl:apply-templates select="$ln[position() lt $posStart]"/>
```

Outside-in: raise one element

Make element from start-marker; recur on center subsequence (as children of new element).

```
<!--* Raise the element and call raise-sequence() on its
          * content. *-->
      <xsl:copy select="$ln[$posStart]">
        <!--* copy the attributes (filtering as needed) *-->
        <xsl:sequence
            select="$ln[$posStart]/(@* except @th:*)"/>

        <!--* handle children *-->
        <xsl:sequence select="th:raise-sequence(
                                $ln[position() gt $posStart
                                and position() lt $posEnd]
                              )"/>
      </xsl:copy>
```

Outside-in:

Recur to find the next outermost pair

Recur, moving to the right subsequence:

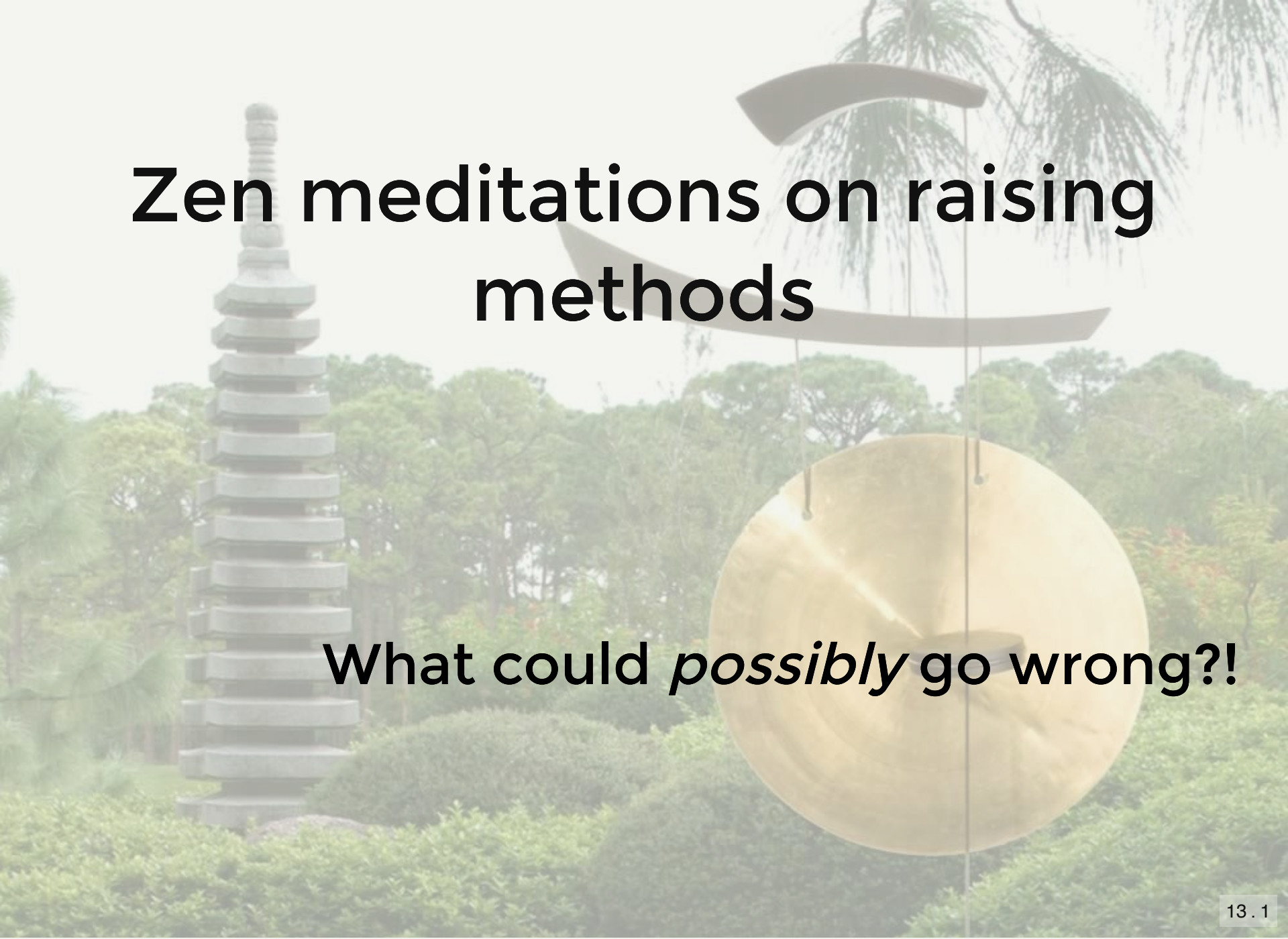
```
<!--* call raise-sequence() on all items to right of end *-->
       <xsl:sequence select="th:raise-sequence(
                                 $ln[position() gt $posEnd]
                             )"/>
     </xsl:otherwise>
```

Accumulators

- Another left-right single-pass process.
- Streamable.
- Slightly spooky action at a distance.
- Algorithm resembles pulldom rules:
  - For start-marker: push marker onto stack.
  - For text nodes, comments: append to top sequence in stack.
  - For end-marker: make element, pop stack, append to (new) top sequence in stack.

Tumbling windows

- Another grouping construct, can be based on a count (e.g. every pair of markers)
- Can be written inside-out or outside-in.

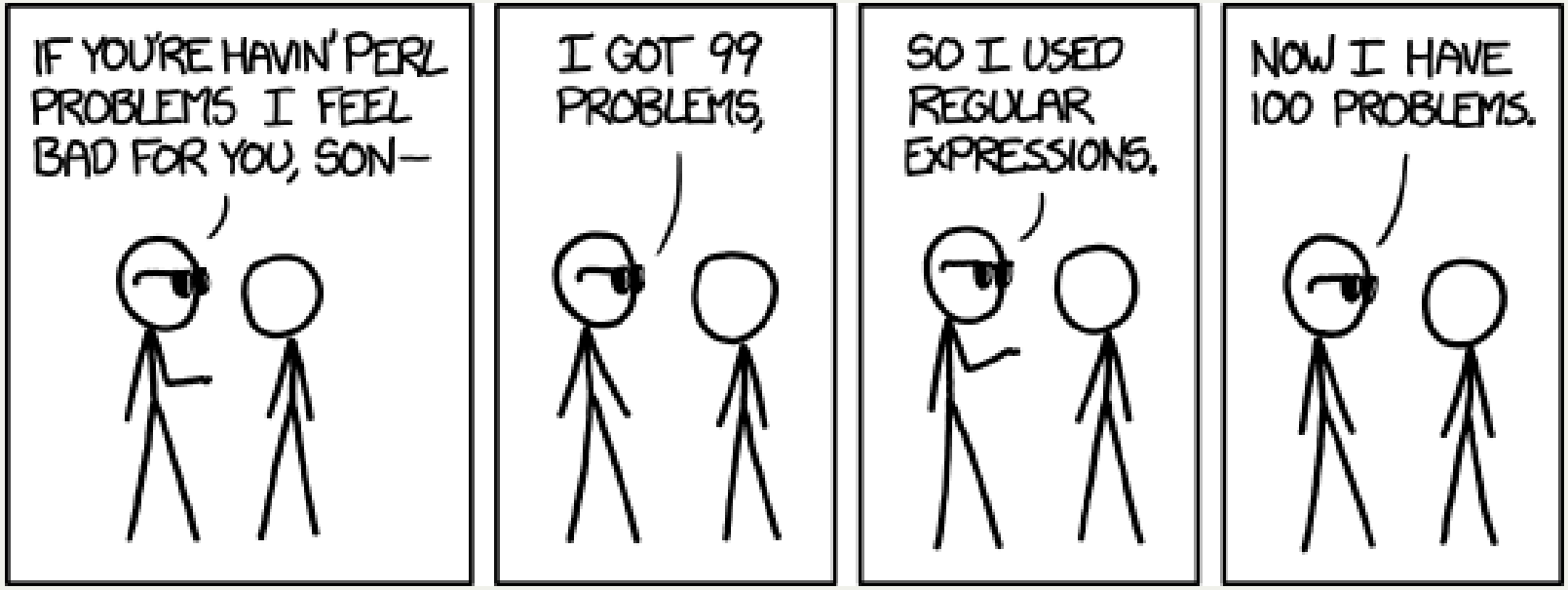


Zen meditations on raising methods

What could *possibly* go wrong?!

String-processing tags

- Pro: quick, light-weight
- Con: brittle



Pull parsing in Python

- Writing XML output as a string
  - too easy to generate overlapping tags and ill-formed attribute values
- Writing XML output as XML: more robust, but potentially confusing
  - Be careful of removing attributes from the START_ELEMENT event, since you need them to find the END_ELEMENT!
  - pulldom has a different sense of START_ELEMENT and END_ELEMENT events. Trojan markers qualify as both, and can double the number of tags.
  - Namespaces!
    - Processing namespaced Trojan markers: It matters whether the namespace information is expressed in declarations on elements or as prefixes

Left to right sibling traversal

- Easy to forget to look for the *first* following sibling and select following-sibling::node() instead of following-sibling::node()[1]
  - makes for gigantically enlarged output!
- Easy to forget to apply the @mode = "raising"
  - causes loss of input nodes (reduced output)

Inside-out recursion

- Double processing
  - must remember to suppress nodes that are being copied, since these are also candidates for applying templates
  - don't forget to set empty <xsl:template/> rules!
- Endless looping
  - To prevent: test for nodes that can be raised without breaking hierarchy

Accumulators

- Be sure your Saxon processor is fully XSLT 3.0.
  - Don't try this with Saxon HE 9.6.0.5
- Don't forget to specify @use-accumulators= "stack" on default mode declaration.

For further investigation

- Performance analysis
  - Memory usage? Stack space?
  - Are functions faster than named templates? Slower? Indifferent?
  - Are patterns of performance constant across processors?
  - Do XQuery function implementations of inside-out and outside-in show same performance patterns?
  - Why is outside-in tumbling window performance so bad in preliminary tests?
- More solutions?