Bill gave a puppy to John.
It bit him.
He gave it back to him.

Tree Search:

Step 1: Start at the NP for *it*,
Step 2: go up to the S. Node X = S and the path = S-NP.
Step 3: There are no branches to the left of node X, so
Step 4: go back to the previous tree. Search in this order, until you get to something that works for *it*. S, NP, VP, proper noun, verb, NP.

Step 1: Start at the NP for *him*
Step 2: go up to the S. Node X = S and the path = S-VP-NP.
Step 3: Traverse the nodes below X to the left of the path. NP (doesn’t agree), verb, pronoun. Nothing works.
Step 4: Traverse the previous tree in the same order as before. This time, stop at the first NP, *Bill*.

At the third sentence:
Step 1: Start at the NP for *he*
Step 2: go up to the S.
Step 3: There are no nodes to the left of this path.
Step 4: Look back the next sentence. Traverse like so: S, NP (doesn’t agree), VP, pronoun, verb, NP.

The process for the pronoun *it* works just like *him* for the previous sentence, but now it matches *it* (or *the puppy*).
Discourse Coherence

Let’s establish the coherence of the following discourse, and determine the pronoun reference while we’re at it.

The discourse:

(1) John ate Bill’s peaches.
(2) He went ballistic.

The general coherence axioms:

If one utterance results from another, there’s a coherence relation:
(3) \( \forall e_i, e_j \ \text{Result}(e_i, e_j) \Rightarrow \text{CoherenceRel}(e_i, e_j) \)

If one utterance causes another, that second one results from the first:
(4) \( \forall e_i, e_j \ \text{cause}(e_i, e_j) \Rightarrow \text{Result}(e_i, e_j) \)

Causation is transitive:
(5) \( \forall e_1, e_2, e_3 \ \text{cause}(e_i, e_j) \land \text{cause}(e_j, e_k) \Rightarrow \text{cause}(e_i, e_k) \)

Real-world axioms:

If somebody has peaches, they want to eat them:
(6) \( \forall e_i, x, y \ \text{Have}(e_i, x, y) \land \text{Peaches}(y) \Rightarrow \exists e_j \text{ Want}(e_j, x, e_k) \land \text{Eat}(e_k, x, y) \)

If somebody eats something, that causes it to be gone:
(7) \( \forall e_i, x, y \ \text{Eat}(e_i, x, y) \Rightarrow \exists e_j \ \text{Gone}(e_j, y) \land \text{cause}(e_i, e_j) \)

If something is gone, that makes it impossible to eat it:
(8) \( \forall e_i, x, y \ \text{Gone}(e_i, x) \land \text{Eat}(e_j, y, x) \Rightarrow \exists e_k \ \text{Impossible}(e_k, e_j) \land \text{cause}(e_i, e_k) \)

If somebody wants something that’s impossible, they go ballistic
(9) \( \forall e_i, x \ \text{Want}(e_i, x, e_j) \land \text{Impossible}(e_j) \Rightarrow \exists e_k \ \text{GoBallistic}(e_k, x) \land \text{cause}(e_j, e_k) \)

The content of the utterances themselves:

From (1):
(10) \( \text{Eat}(e_1, \text{John}, p) \land \text{Peaches}(p) \land \text{Have}(e_2, \text{Bill}, p) \)

From (2):
(11) \( \text{GoBallistic}(e_3, \text{he}) \)

Begin hypothesizing (abduction):
Assume we have a Coherence relation:
(12) Coherence(e₁, e₃)

From (12) & (3), we can hypothesize a Result relation:
(13) Result(e₁, e₃)

From (13) & (4), hypothesize that (1) caused (2)
(14) cause(e₁, e₃)

Start making deductions:

From (10) & (6), deduce that Bill wants to eat the peaches:
(15) Want(e₄, Bill, e₅) ∧ Eat(e₅, Bill, p)

From (7) & (10), deduce that the peaches are gone:
(16) Gone(e₆, p) ∧ cause(e₁, e₆)

From (8) and (16), deduce that it is impossible for Bill to eat the peaches:
(17) Impossible(e₇, e₅) ∧ cause(e₆, e₇)

From (5), (16) & (17), deduce that John’s eating the peaches caused it to be impossible for Bill to eat them:
(18) cause(e₁, e₇)

From (9), (15) & (17), deduce that Bill goes ballistic:
(19) GoBallistic(e₈, Bill) ∧ cause(e₇, e₈)

From (5), (18) & (19), deduce that John’s eating the peaches caused Bill to go Ballistic:
(20) cause(e₁, e₈)

If we replace he in (11) with Bill, we can assert that e₃ = e₈, and recast (19):
(21) GoBallistic(e₃, Bill) ∧ cause(e₁, e₃)

Which is proof of what we hypothesized, establishing a coherence relation given a particular resolution for the pronoun he.