Example

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- Sketch the various stages involved in inserting the following keys, in the order given, into an AVL tree:

- 342, 206, 444, 523, 607, 301, 142, 183, 102, 157, 149

- First try to do it by yourself, and check with the soluton.

342 (0)

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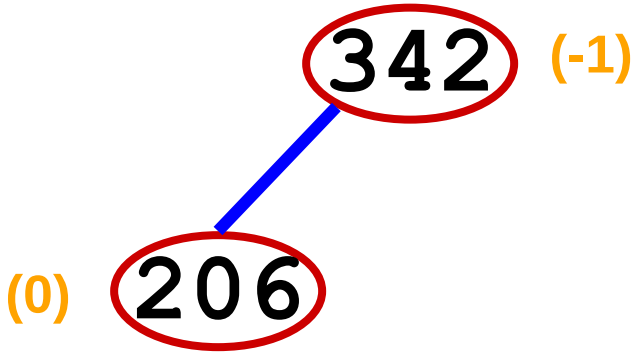

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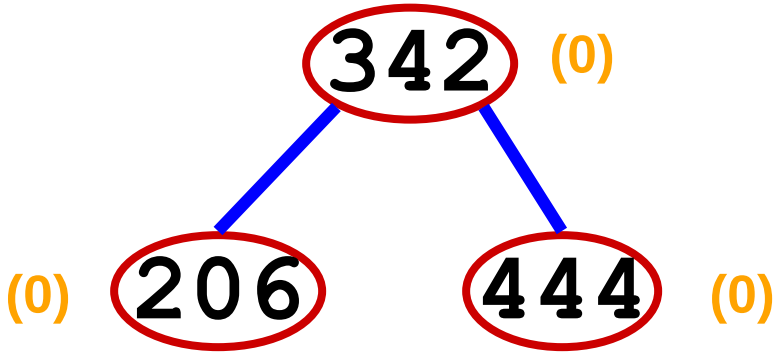
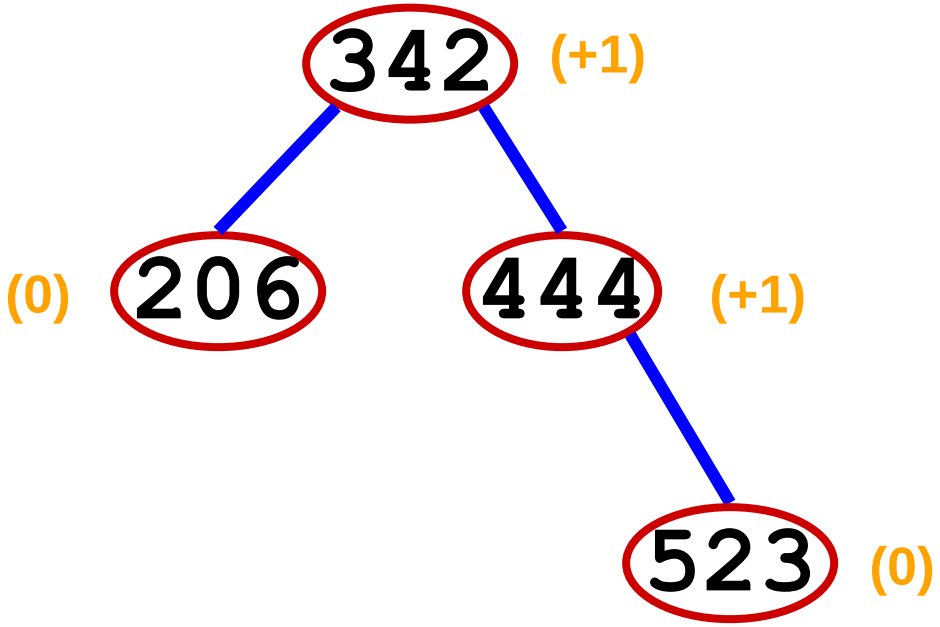
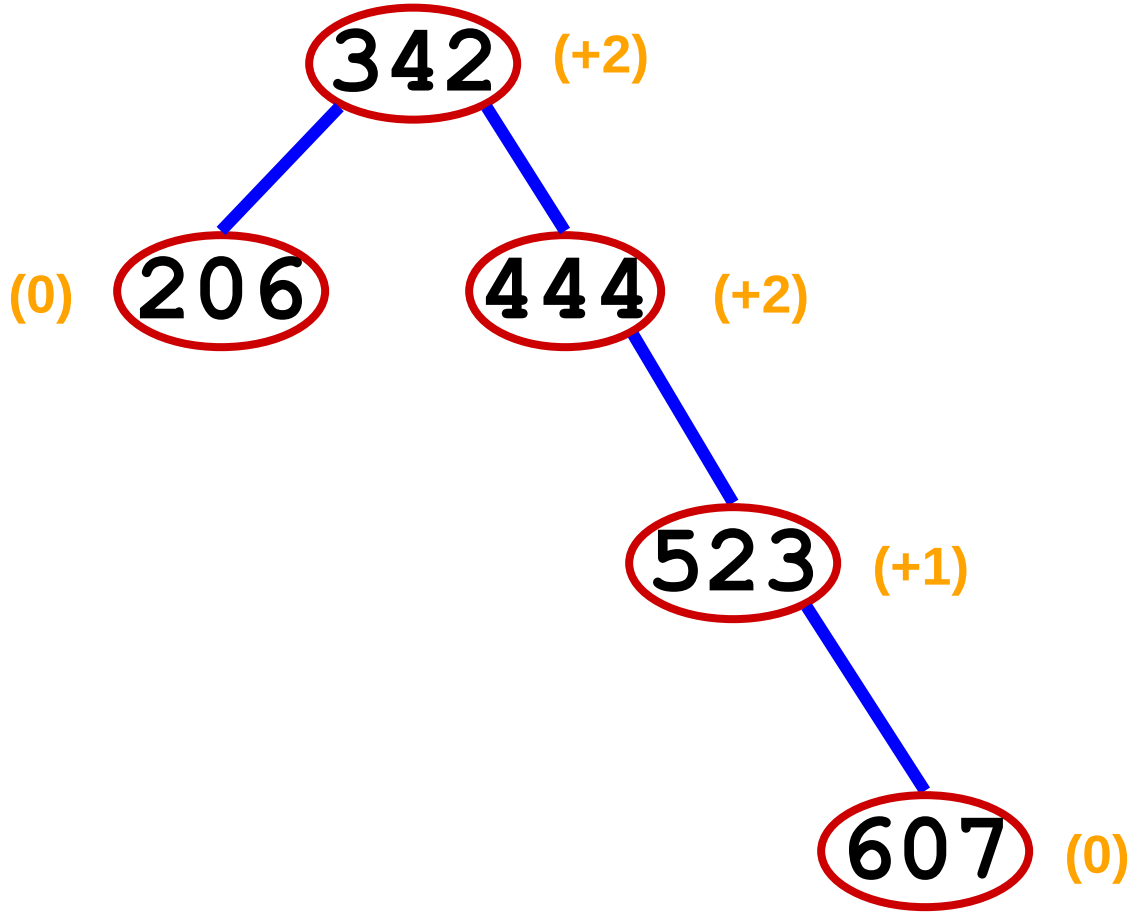


UNIVERSITY OF CALGARY



UNIVERSITY OF CALGARY



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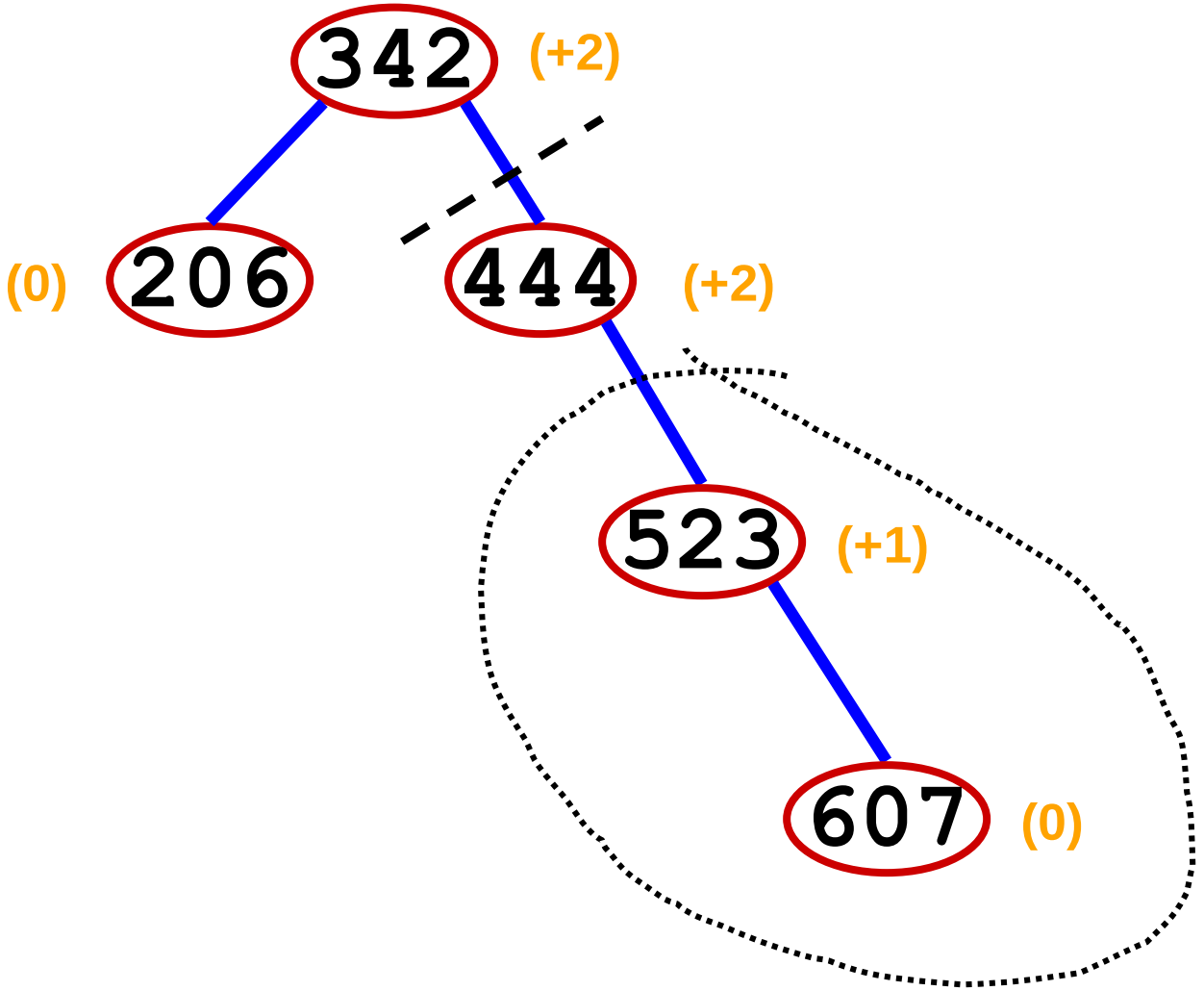
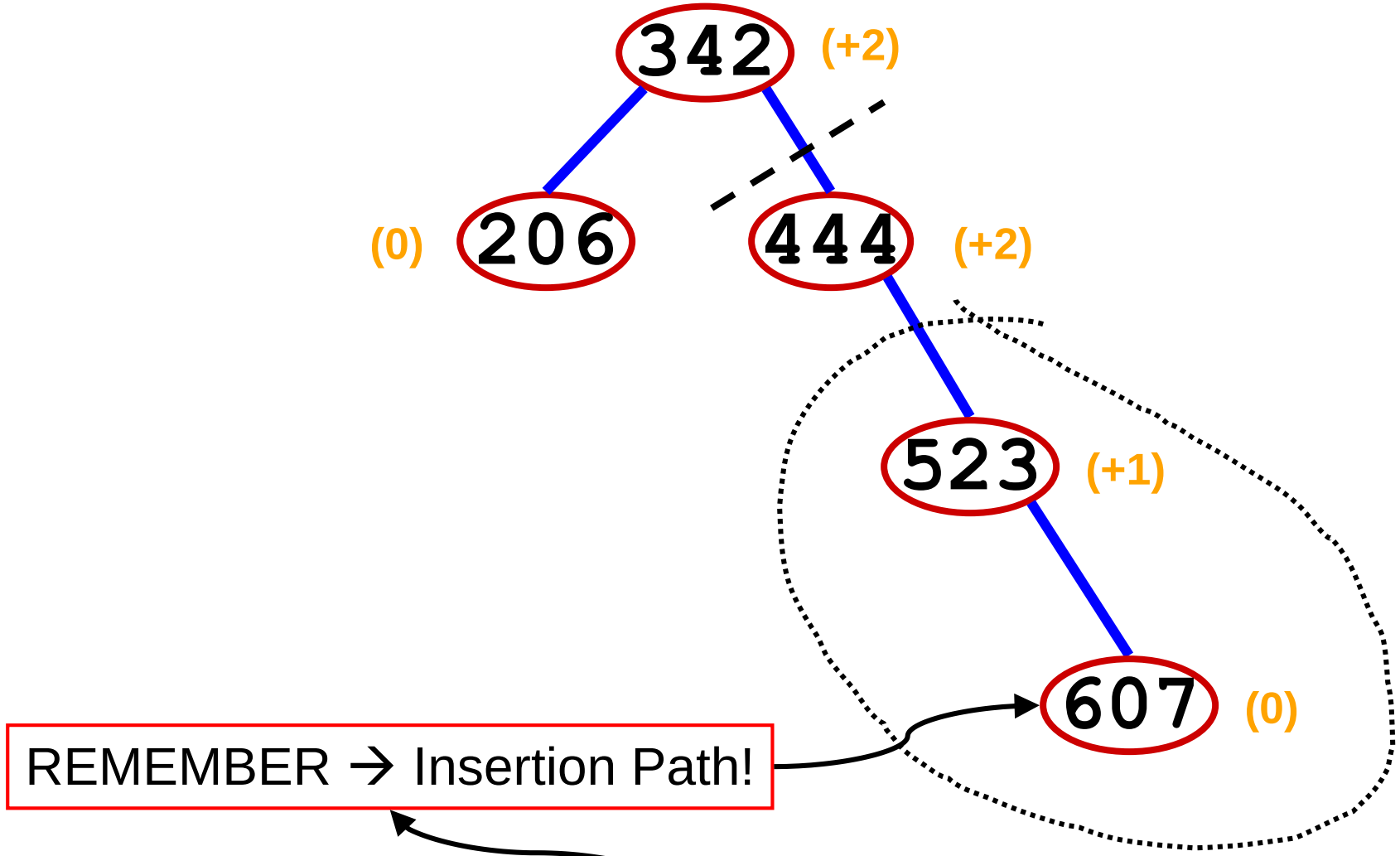
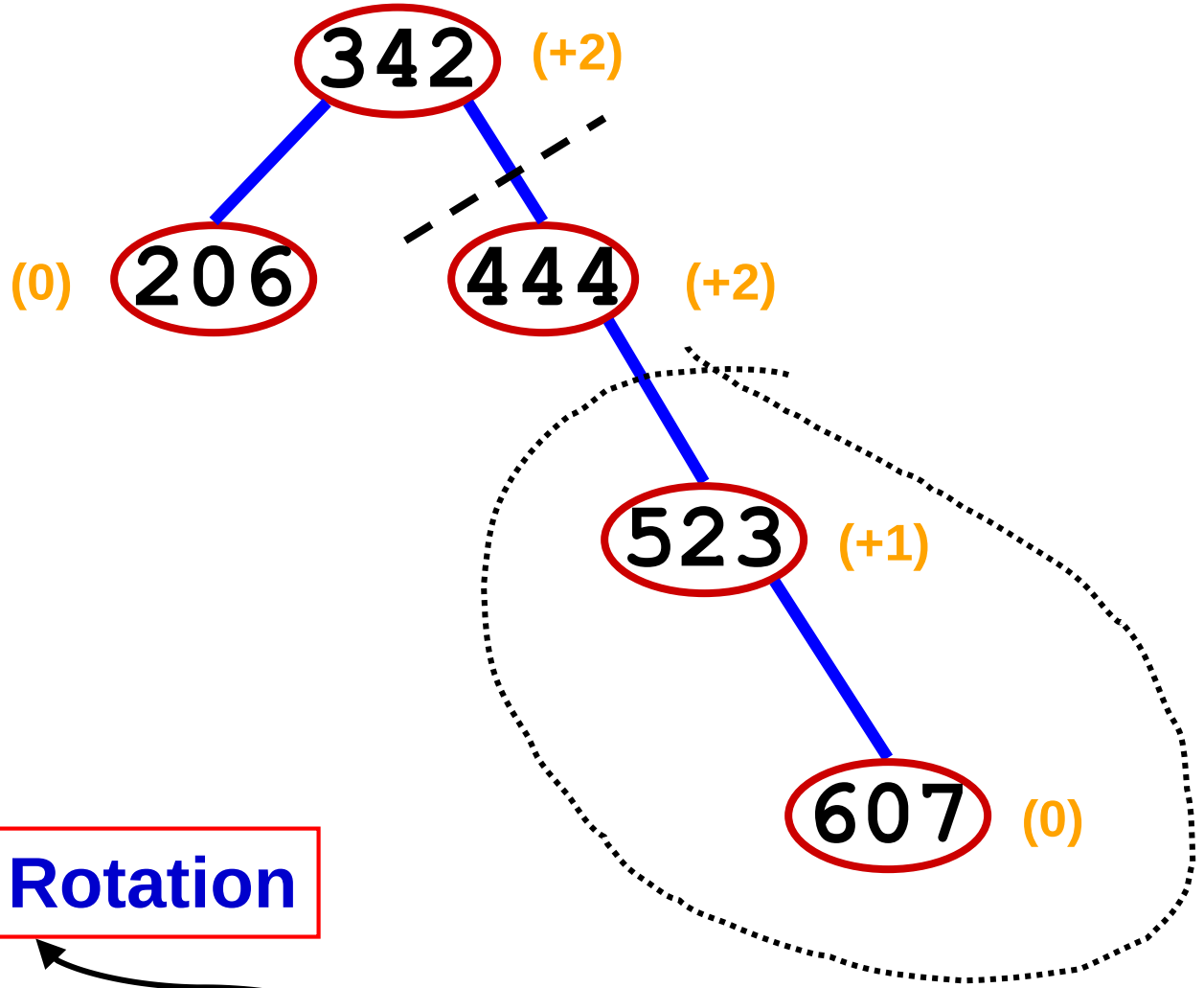


607 causes RR imbalance at 444

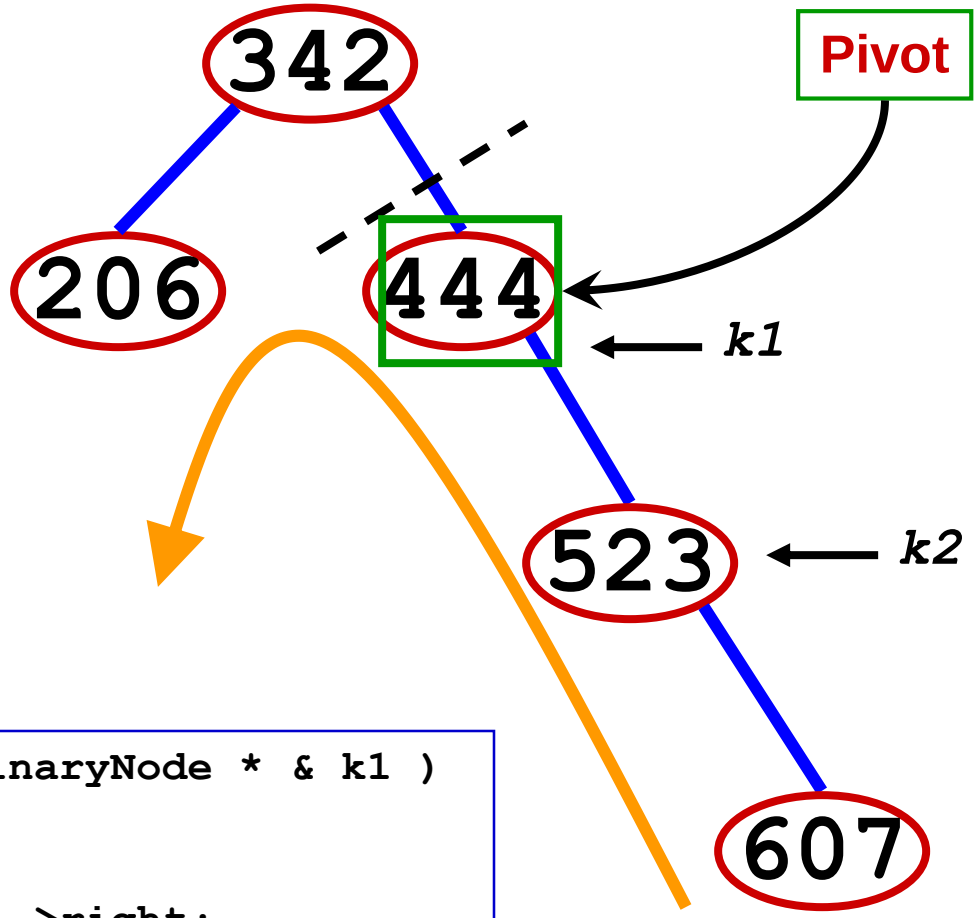


607 causes RR imbalance at 444

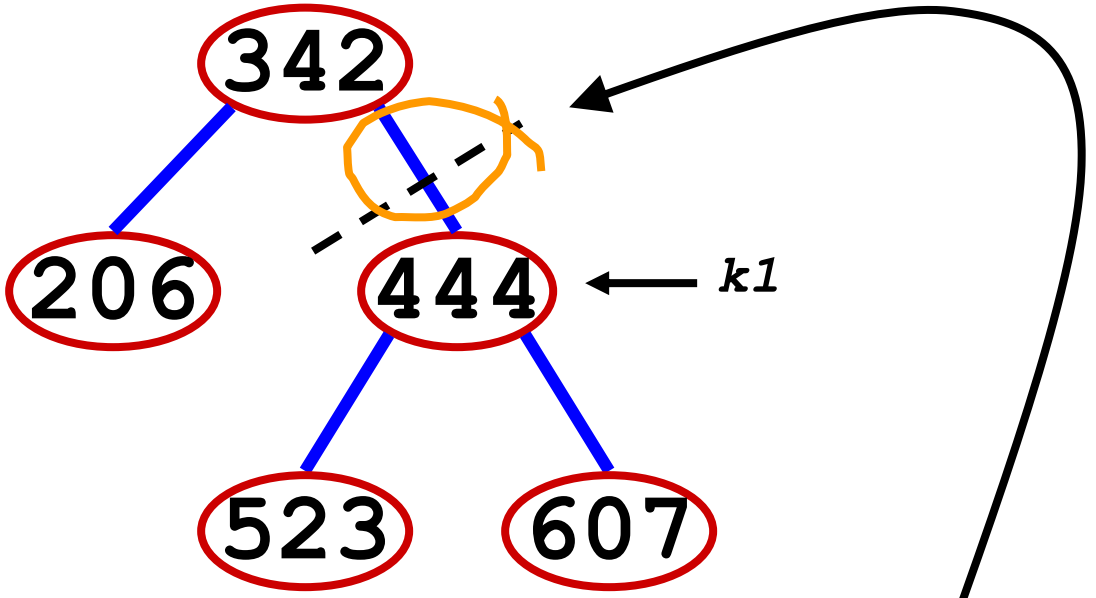


Single Rotation

607 causes RR imbalance at 444

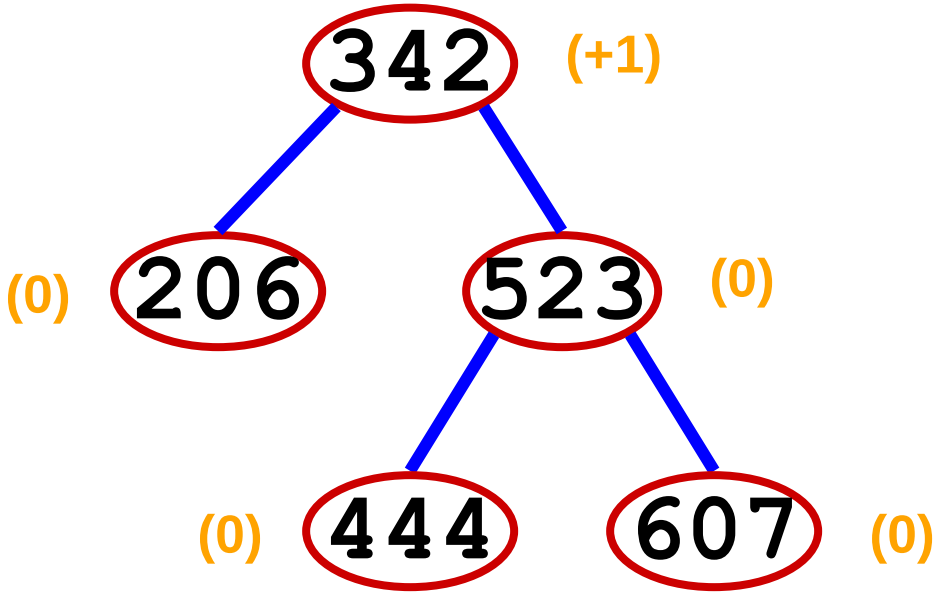



```
void LeftRotate( BinaryNode * & k1 )
{
BinaryNode *k2 = k1->right;
k1->right = k2->left;
k2->left = k1;
k1 = k2;
}
```




```
void LeftRotate( BinaryNode * & k1 )
{
BinaryNode *k2 = k1->right;
k1->right = k2->left;
k2->left = k1;
k1 = k2;
}
```

REMEMBER !
re-connect k1→node to the tree



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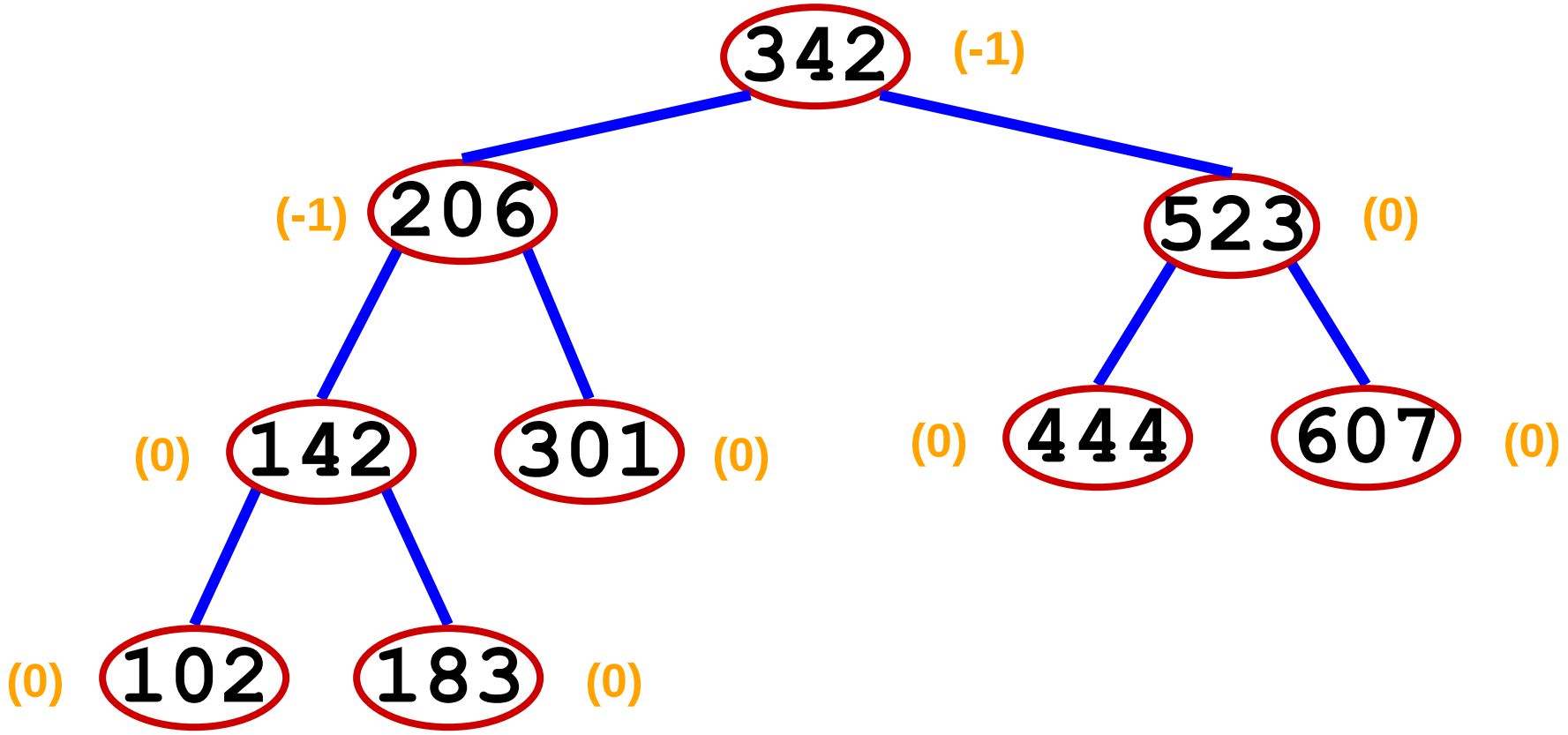
Check balance-factors…

OK



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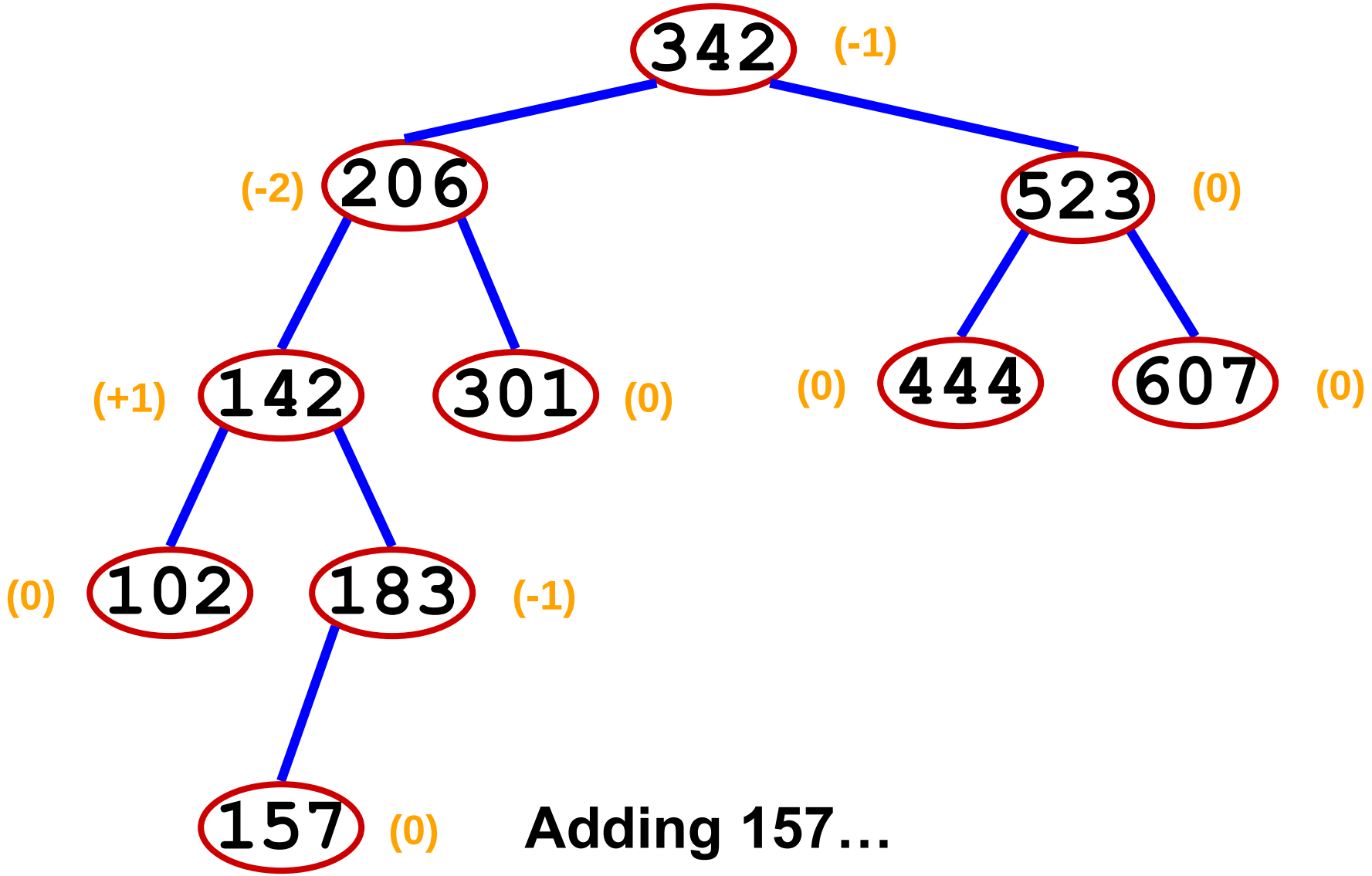
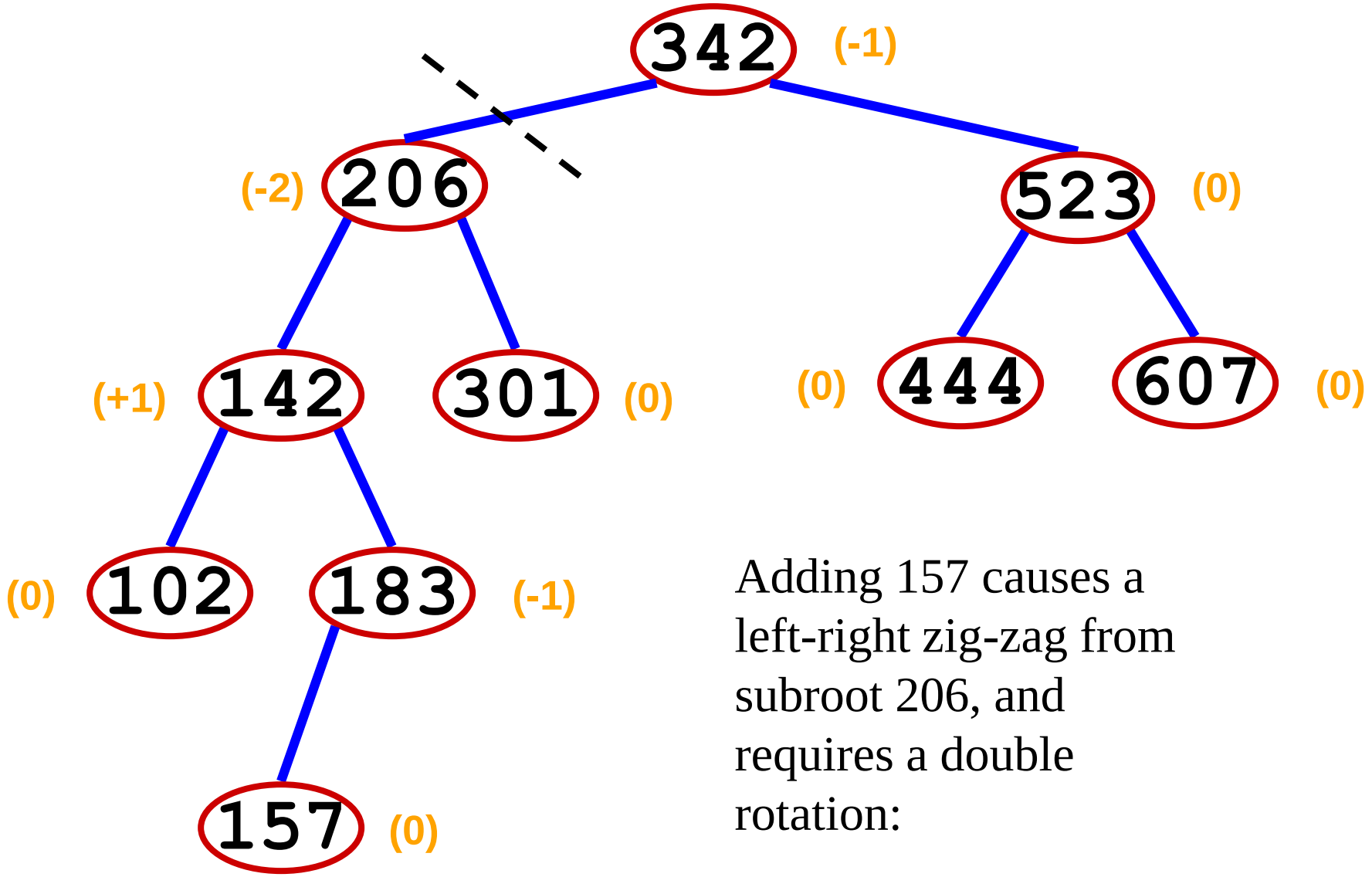
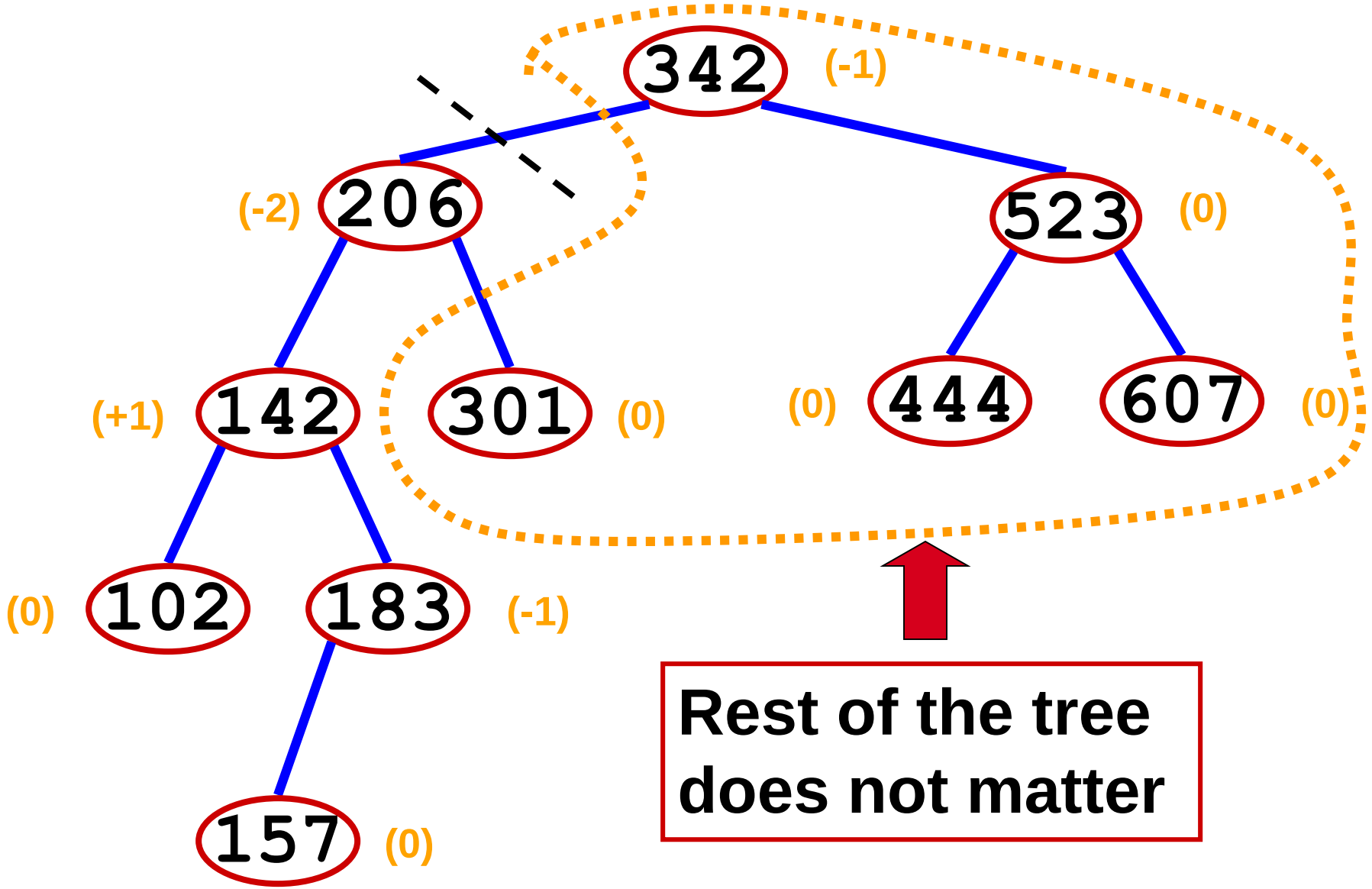
So far so good…

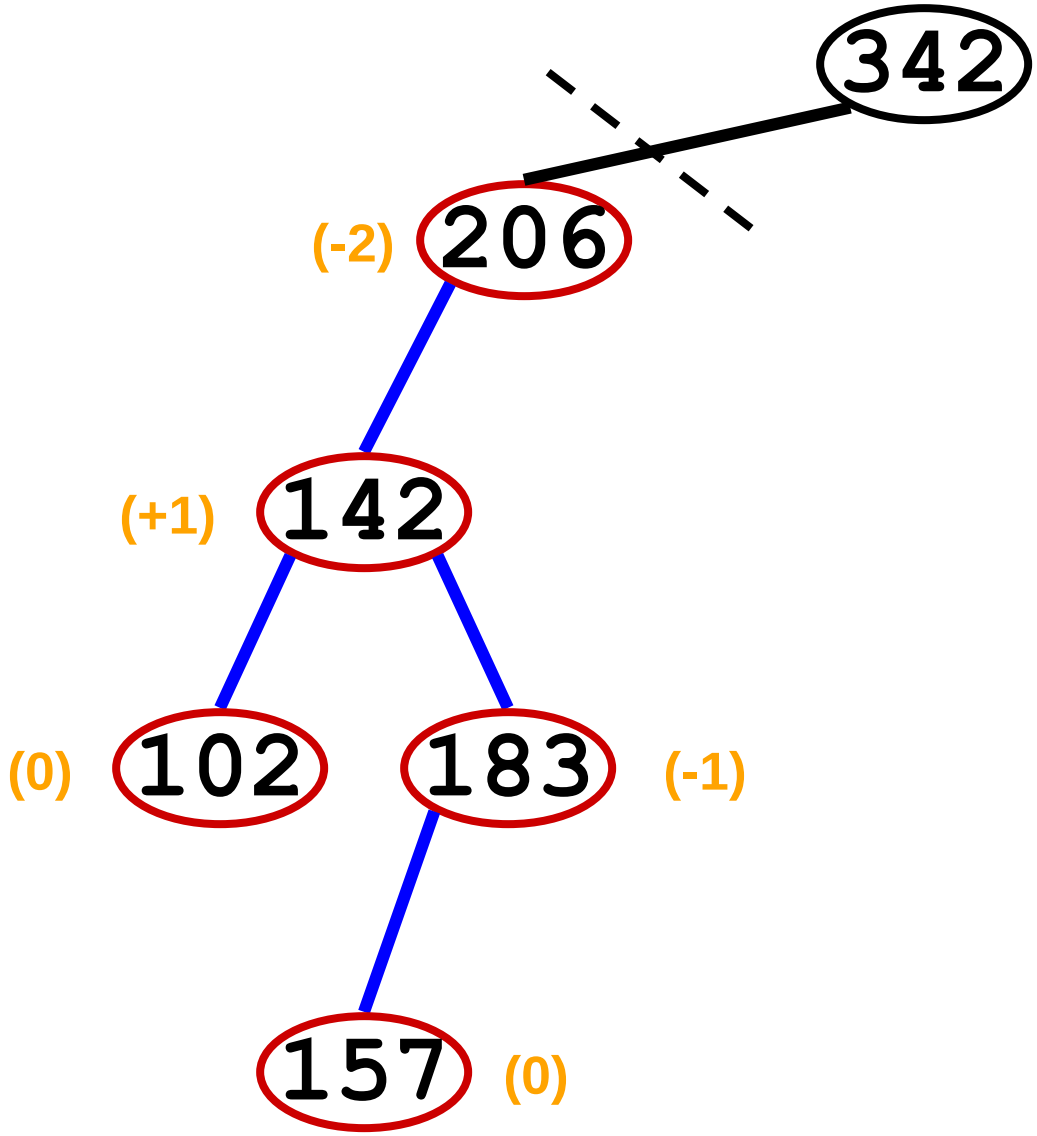

342
(-1)
(-2)
206
523
(0)
(+1)
142
301
(0)
(0)
444
607
(0)
(0)
102
183
(-1)
157
(0)
Adding 157…



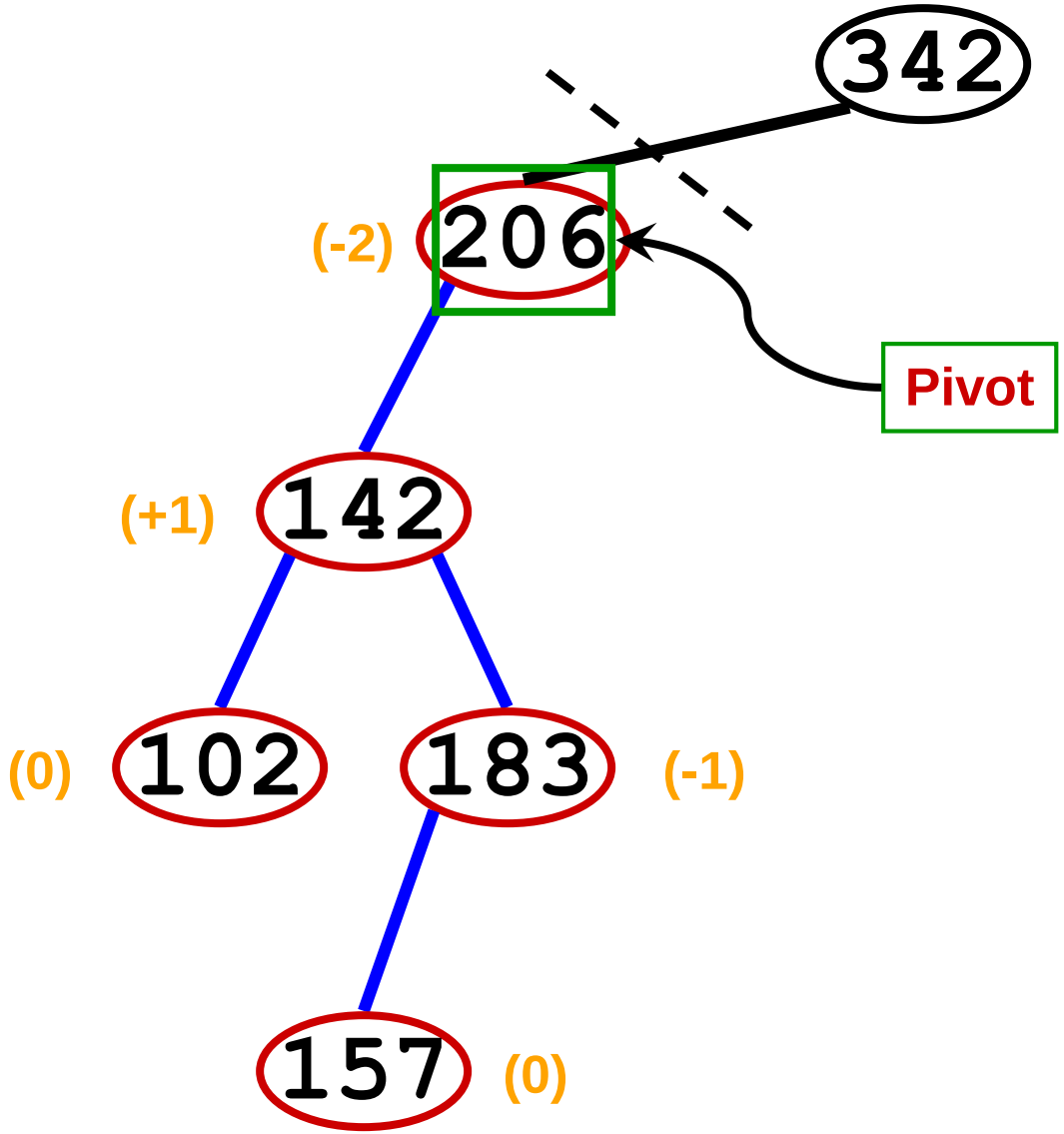
Adding 157 causes a left-right zig-zag from subroot 206, and requires a double rotation:

Make 183 the new subroot

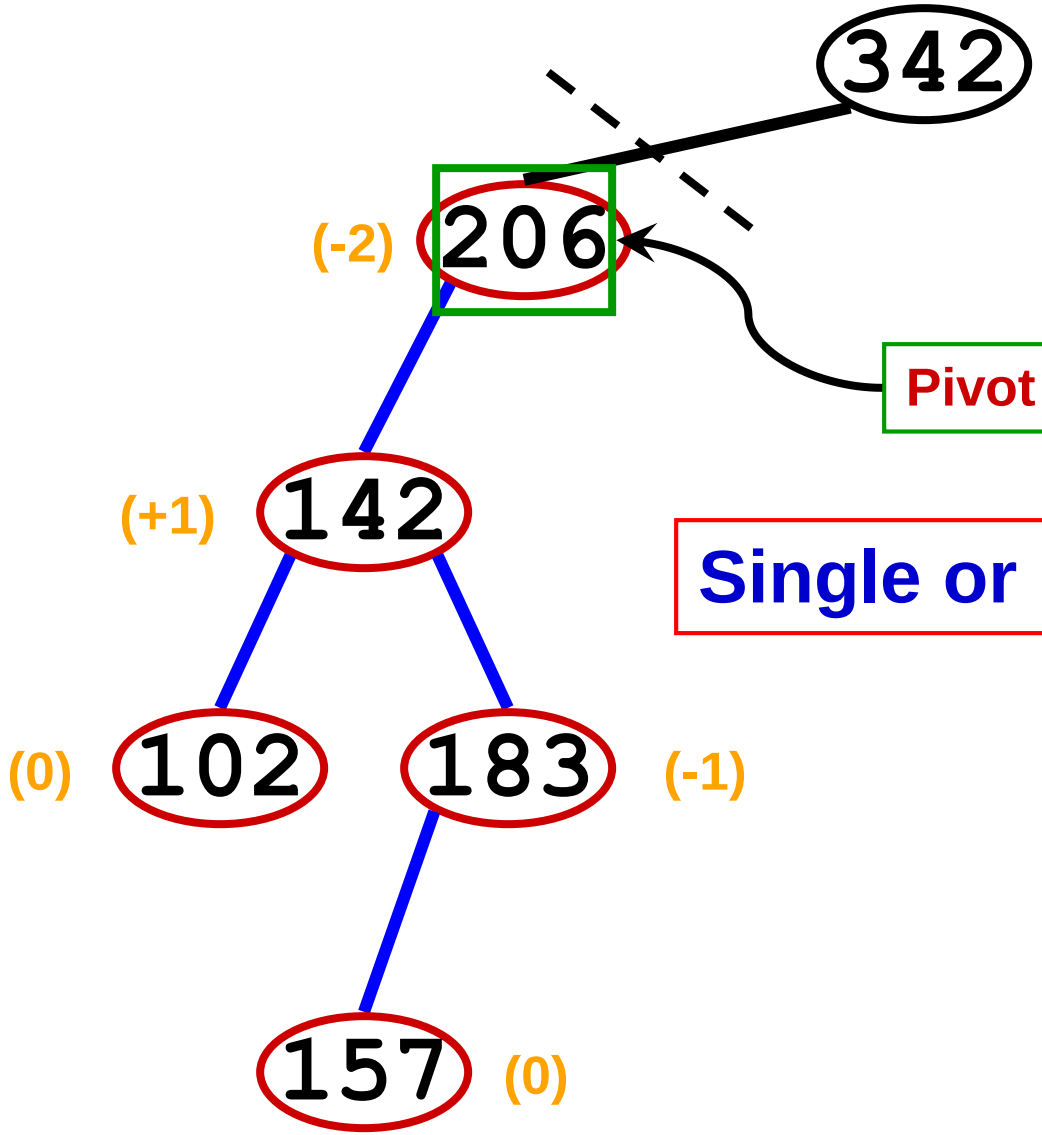

342
(-1)
(-2)
206
523
(0)
(+1)
142
301
(0)
(0)
444
607
(0)
(0)
102
183
(-1)
157
(0)
Rest of the tree does not matter



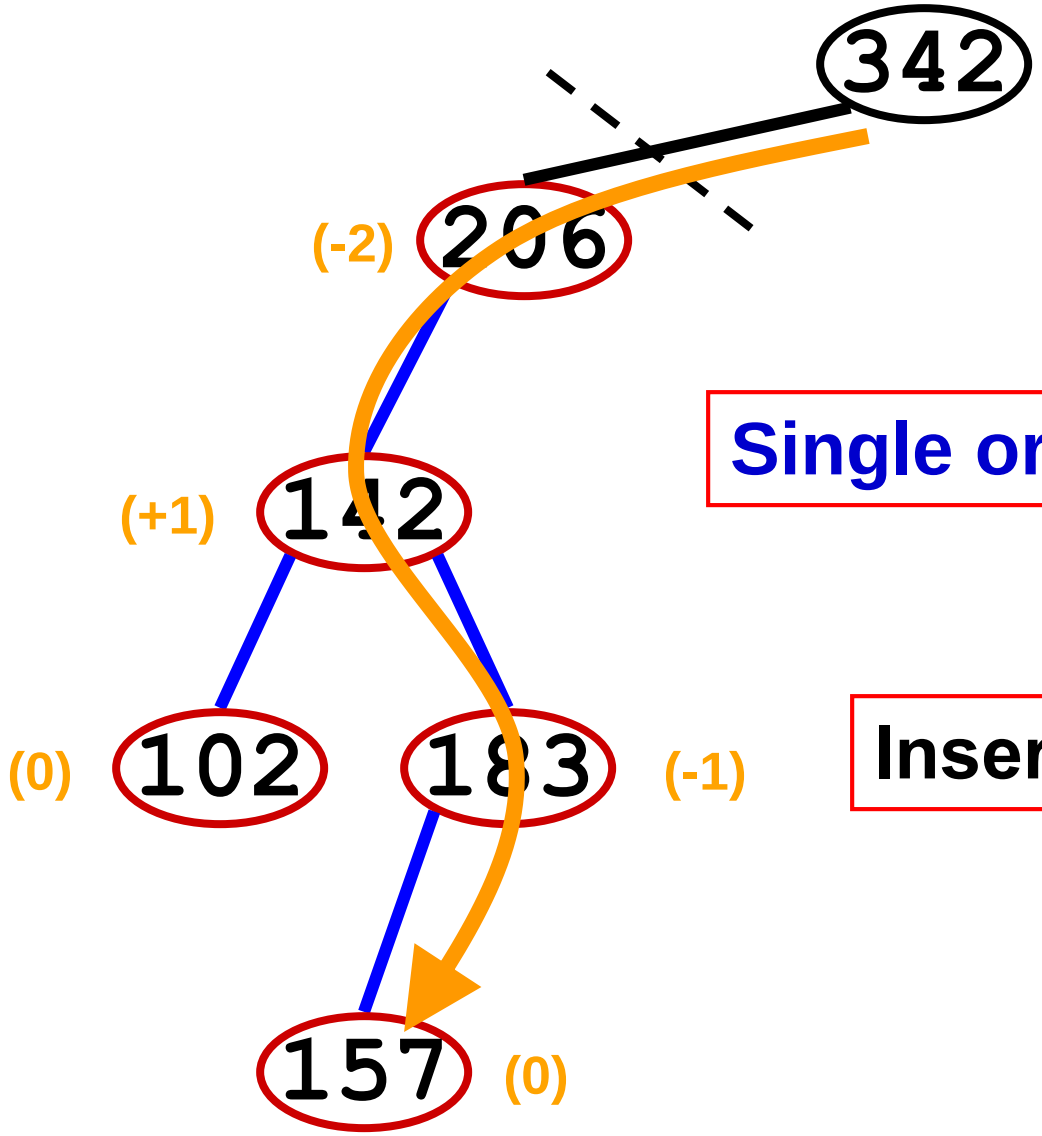
UNIVERSITY OF CALGARY



UNIVERSITY OF CALGARY

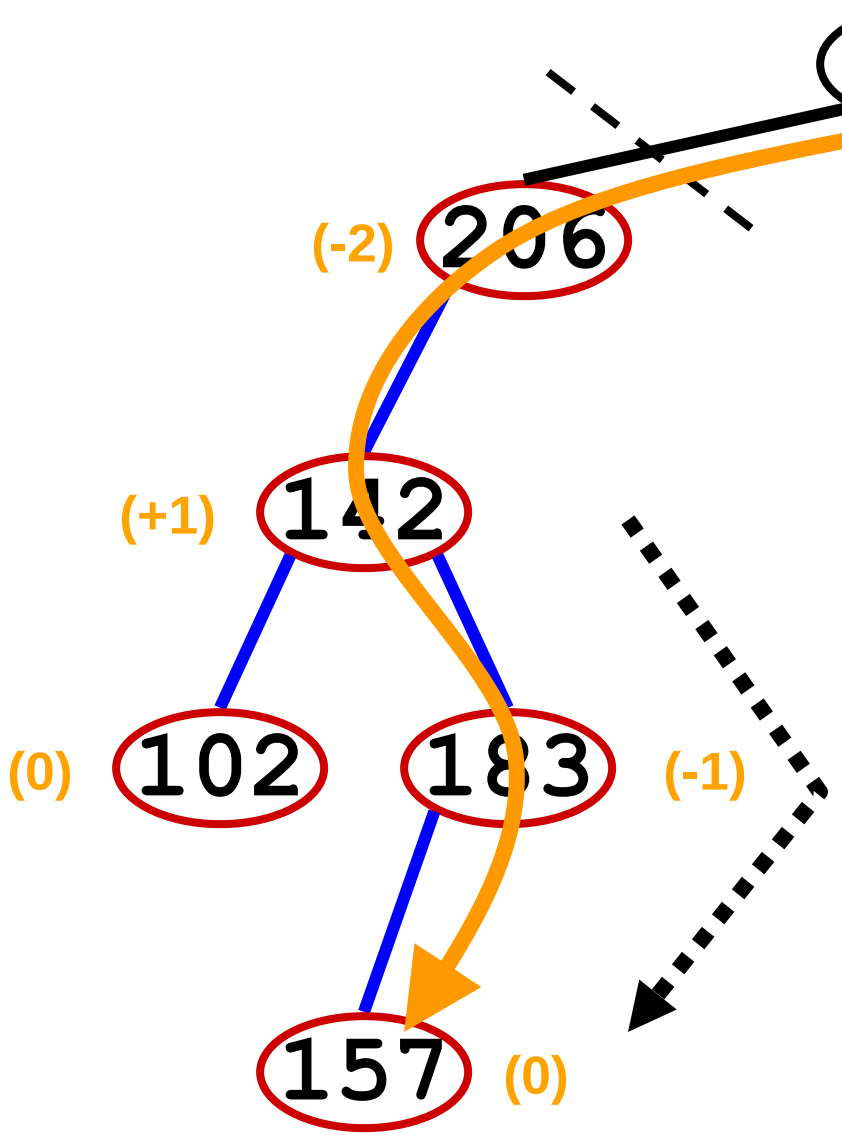


Single or Double Rotation?



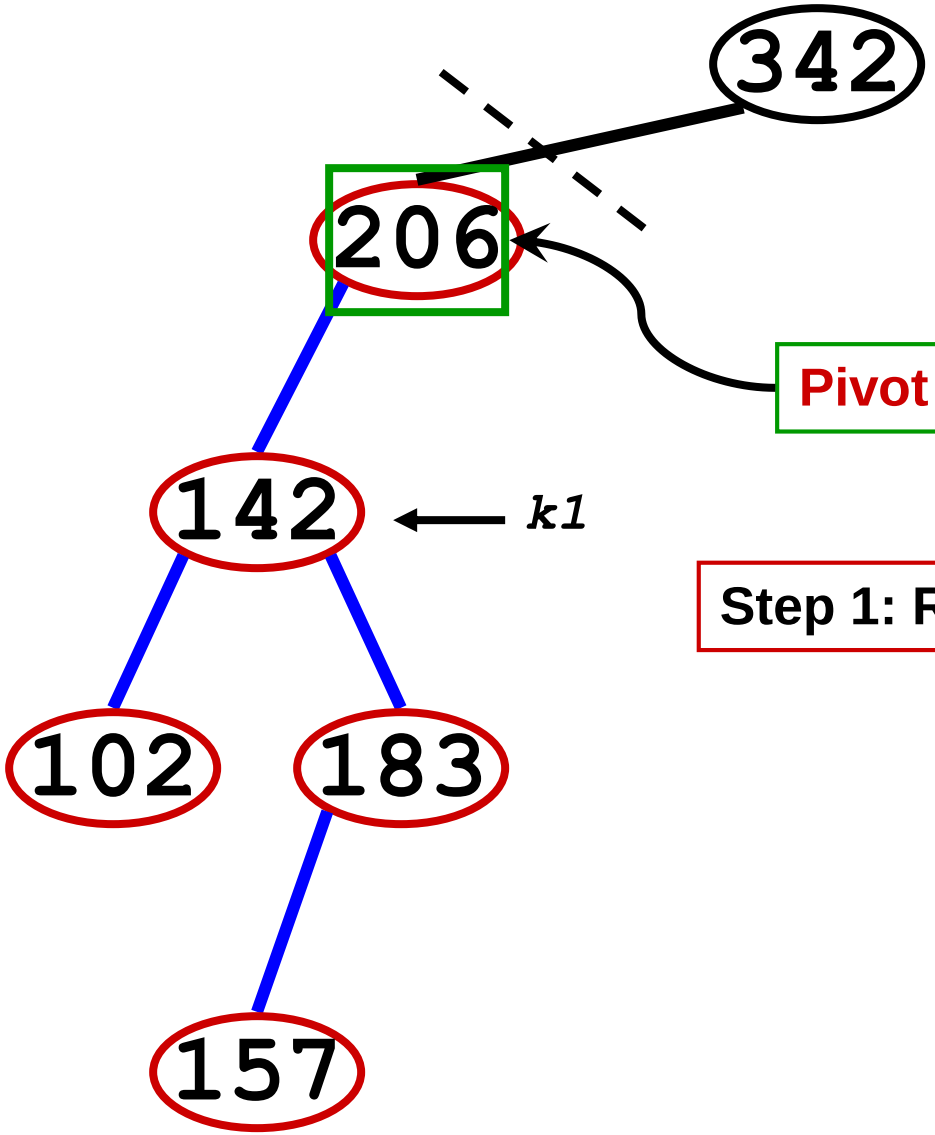
Single or Double Rotation?

Insertion Path…



zig-zag formation

Double Rotation

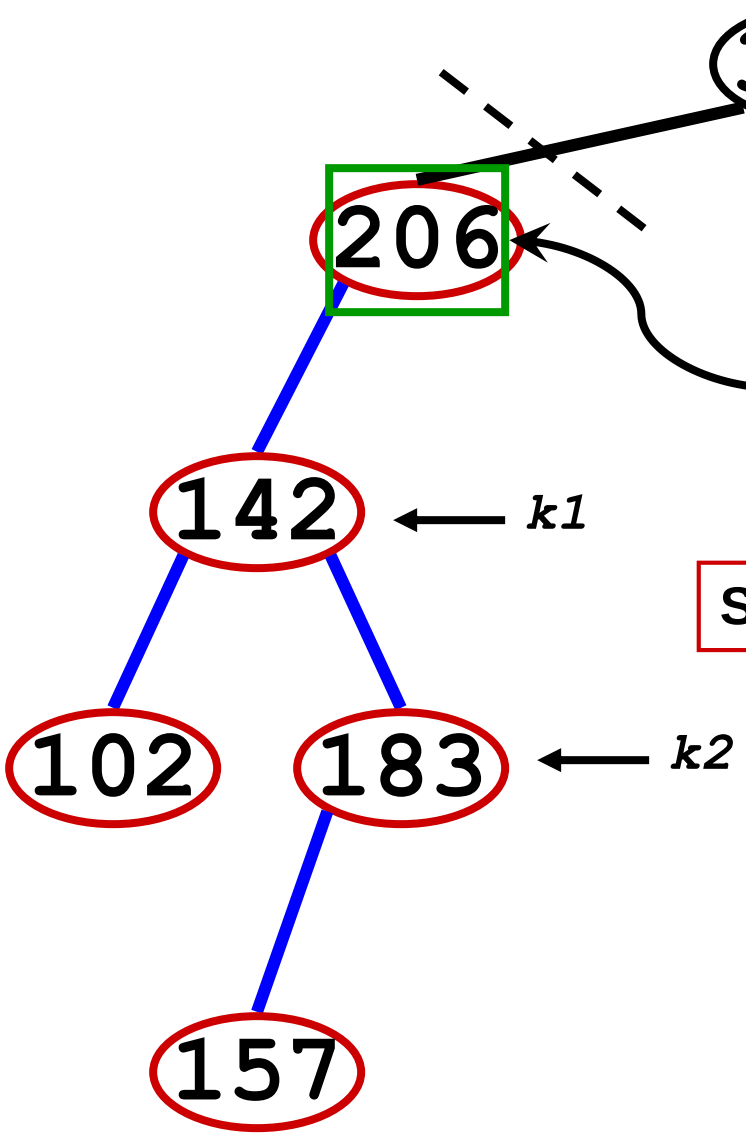


Double Rotation

Step 1: Rotate child and grandchild

RIGHT rotation

```
BinaryNode *k2 = k1->right;
k1->right = k2->left;
k2->left = k1;
k1 = k2;
```



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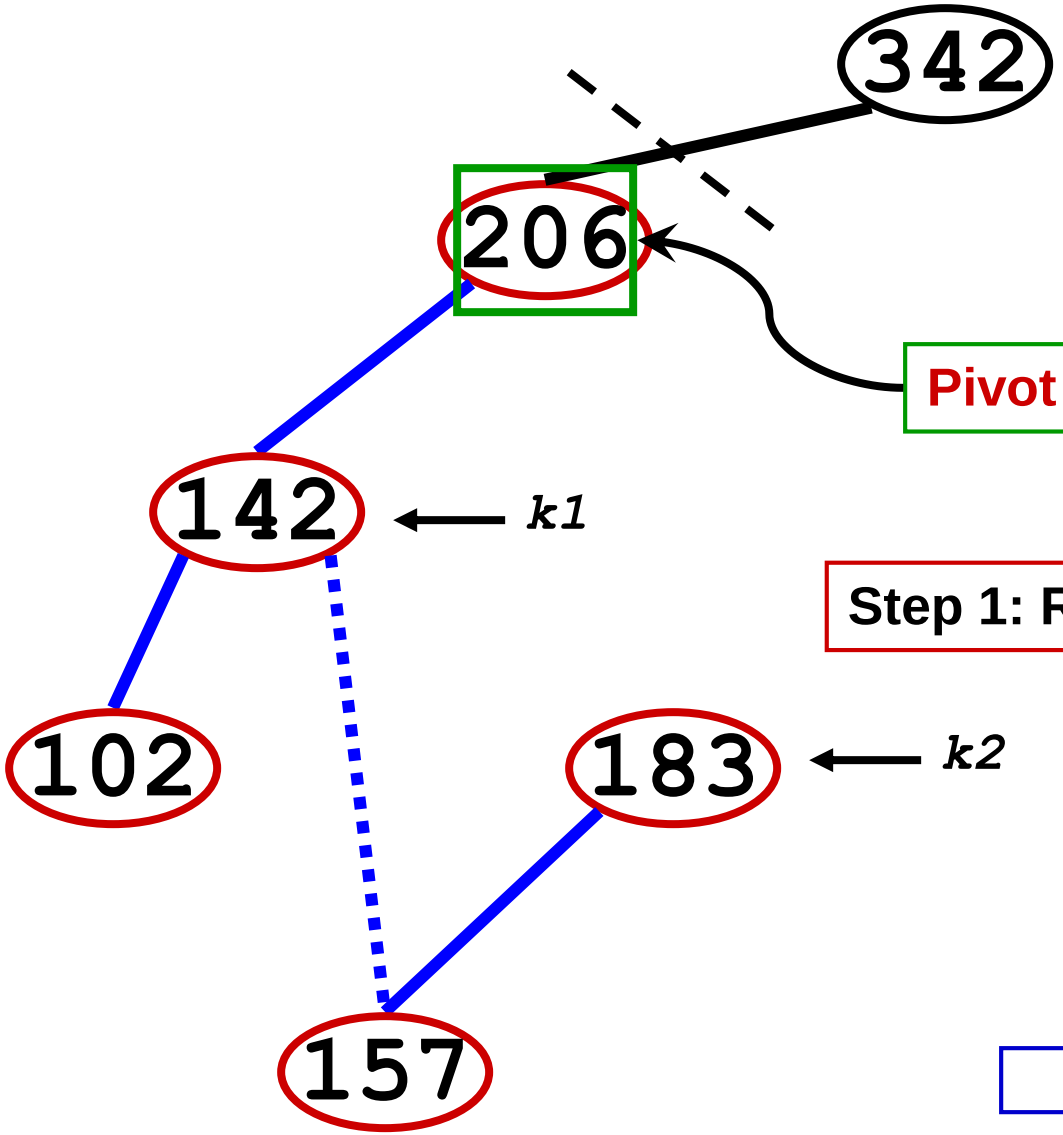

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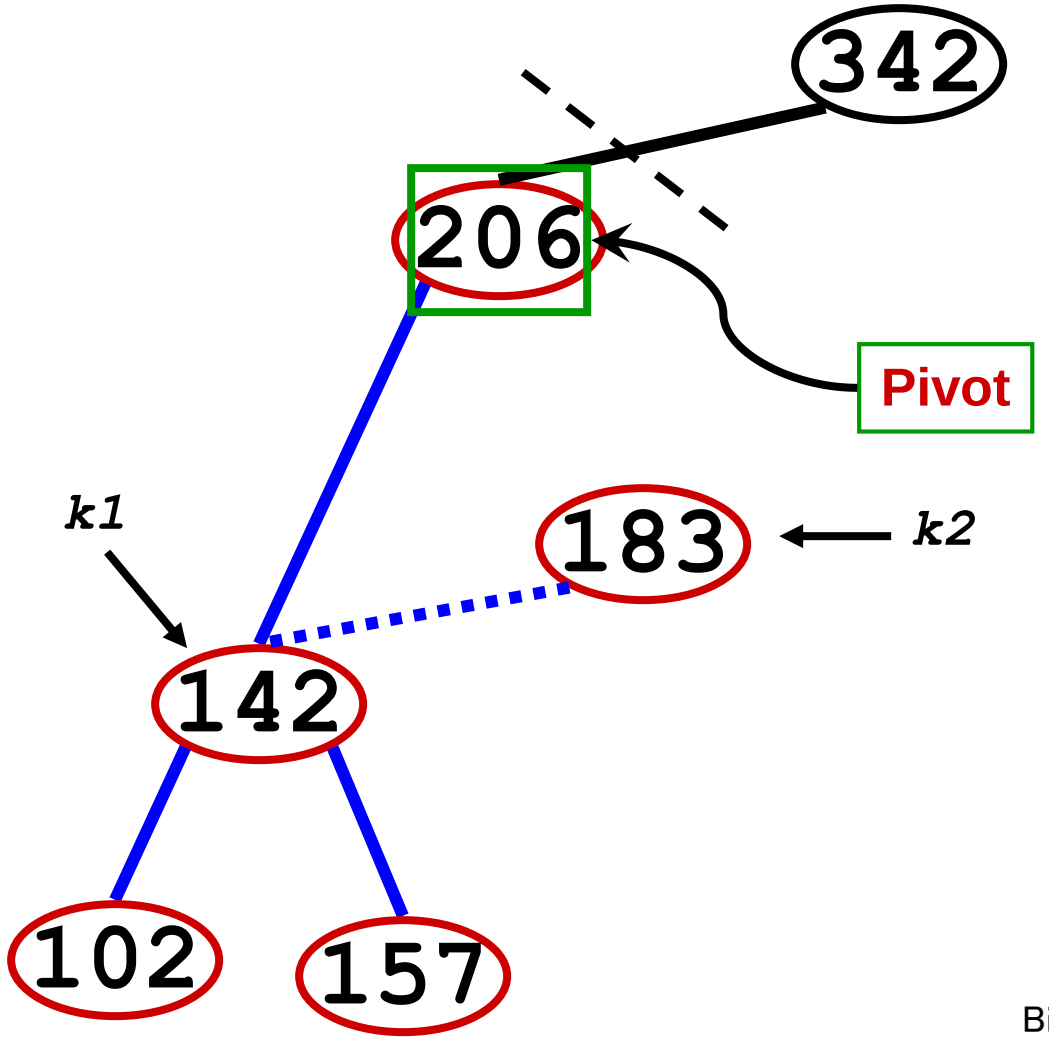

Double Rotation

RIGHT rotation

```
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k2->left = k1;
k1 = k2;
```

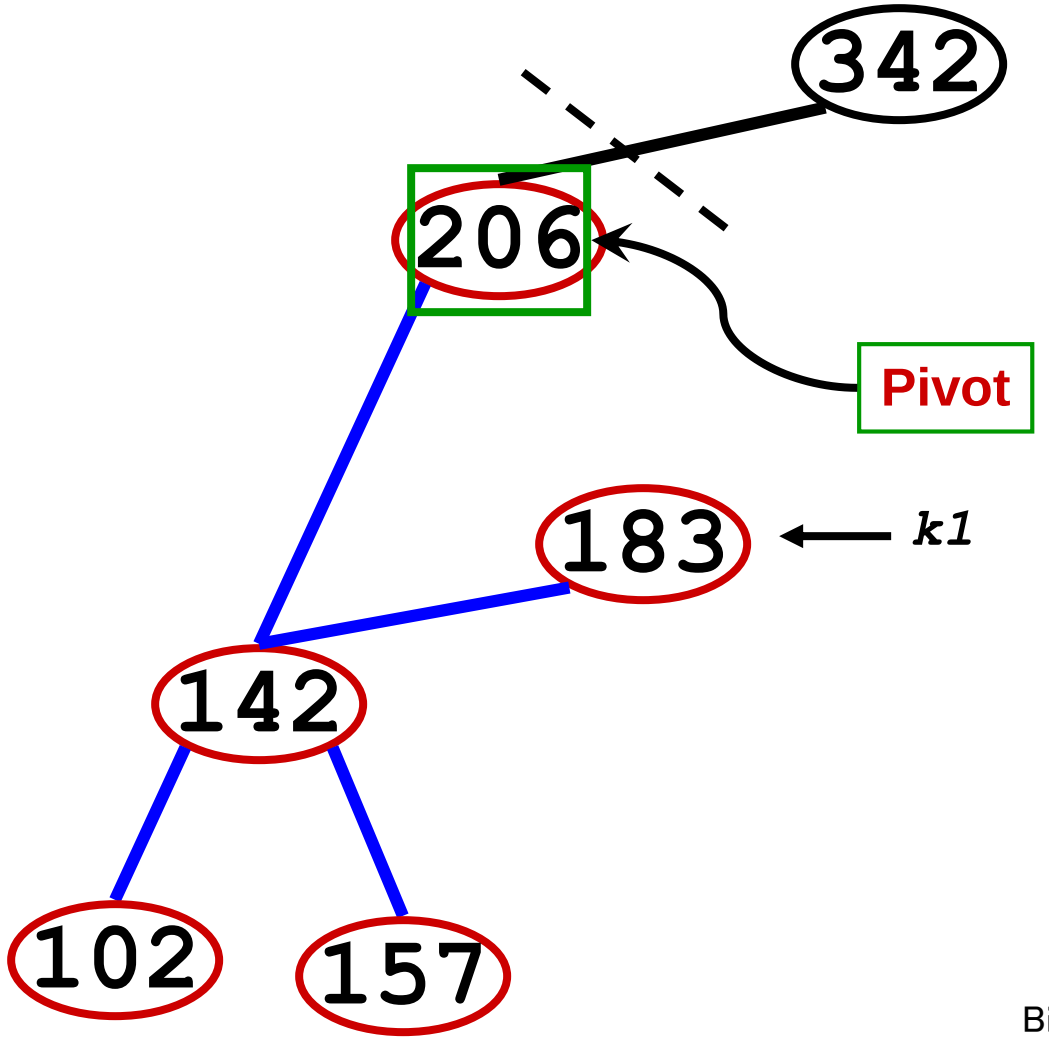

Double Rotation

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k2->left = k1;
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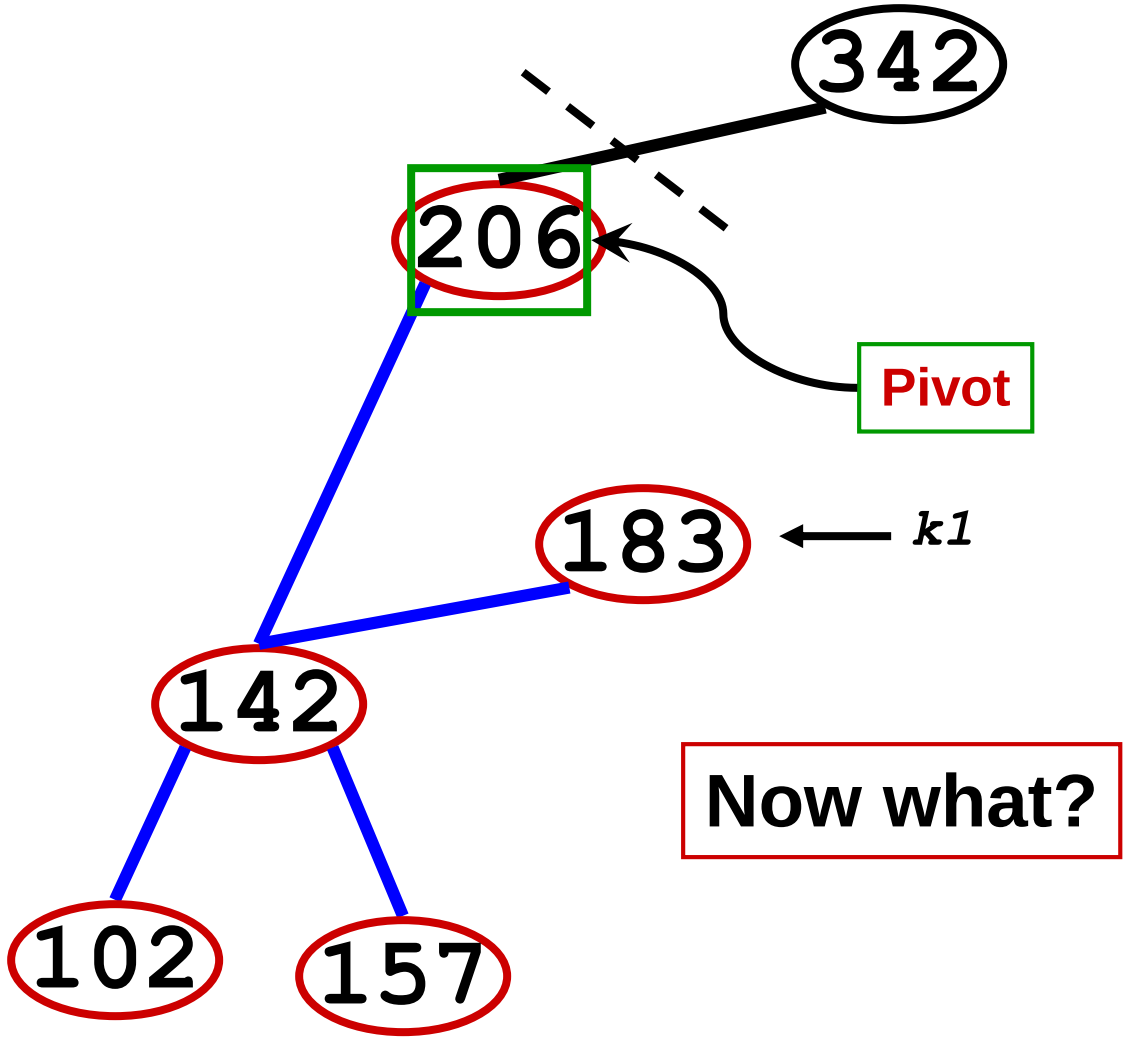
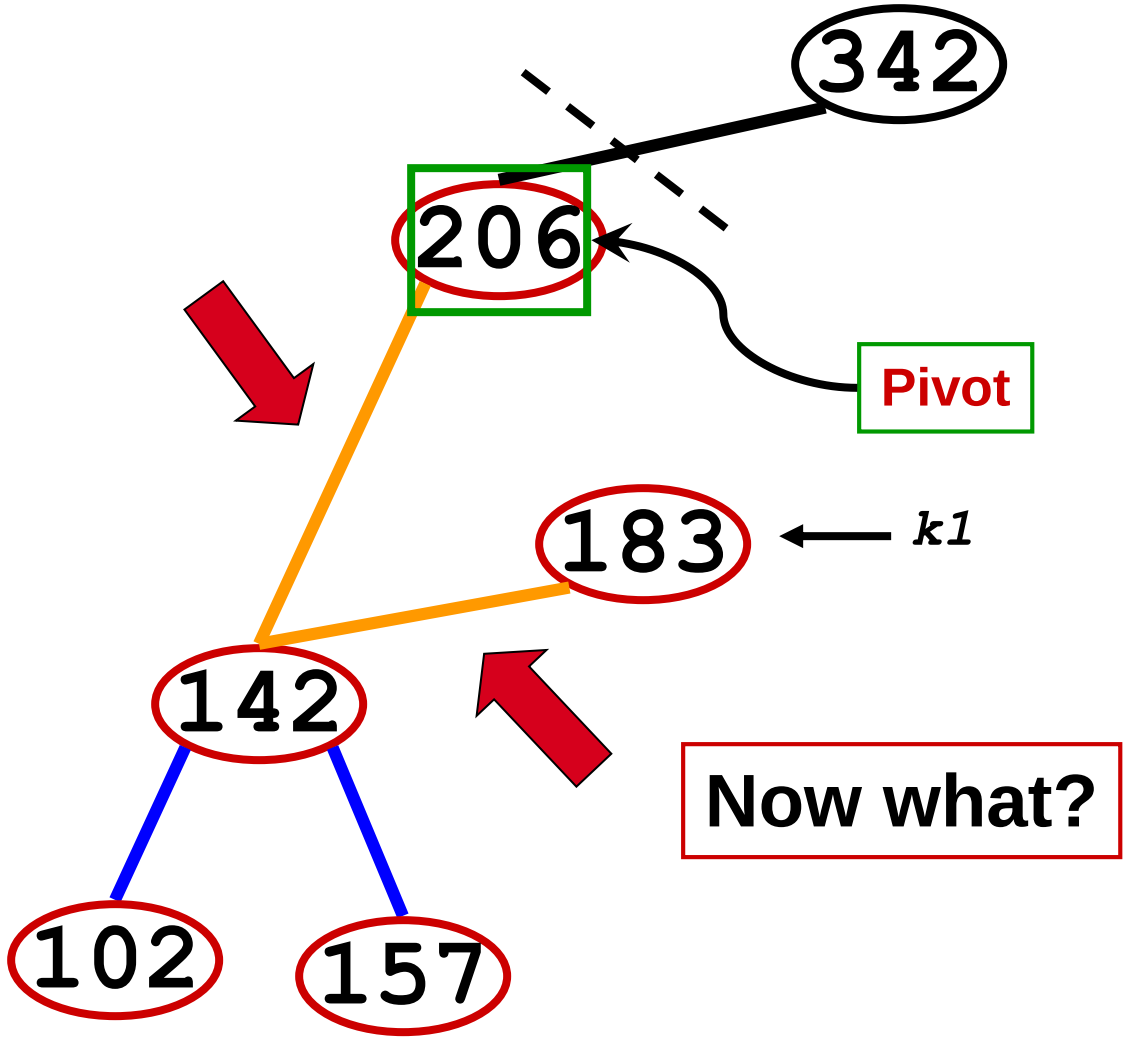
```



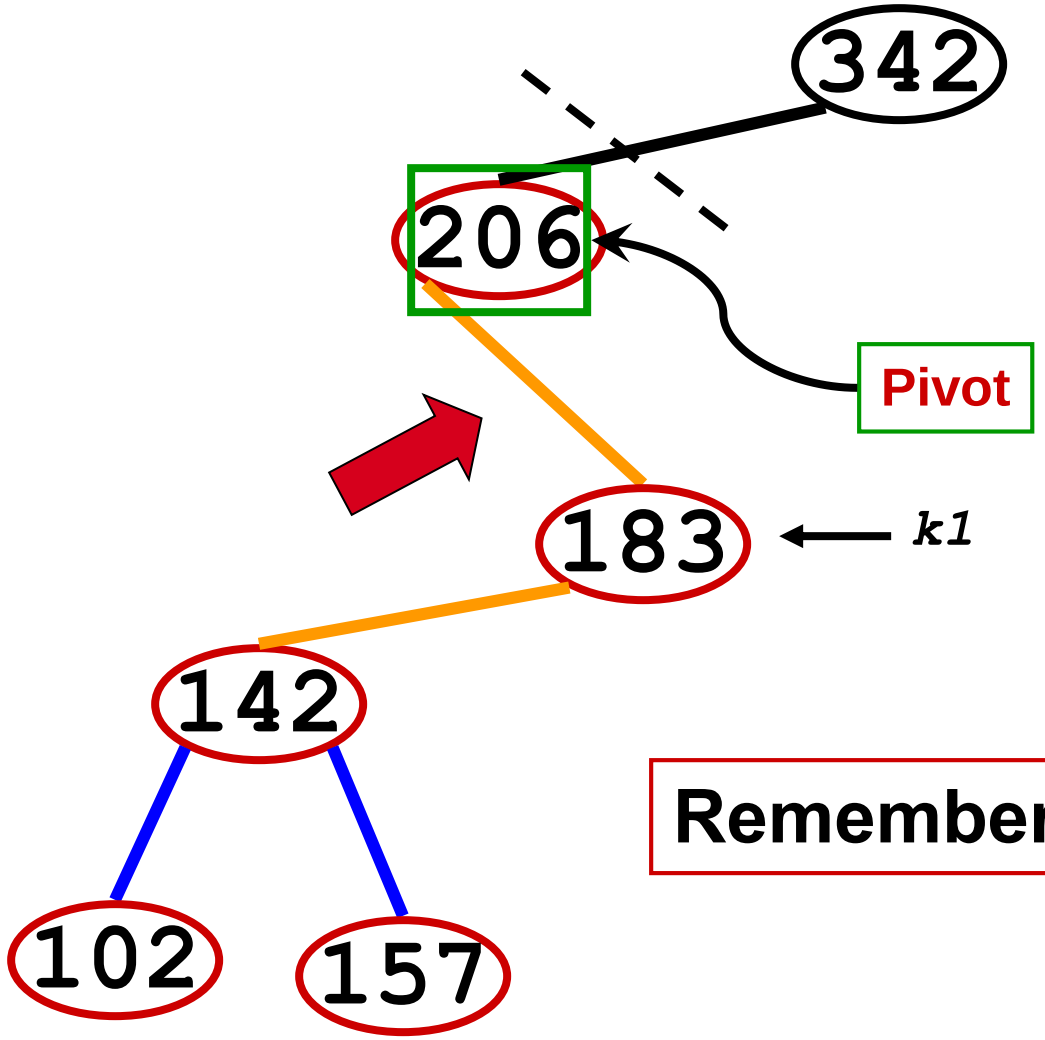
Double Rotation

Now what?



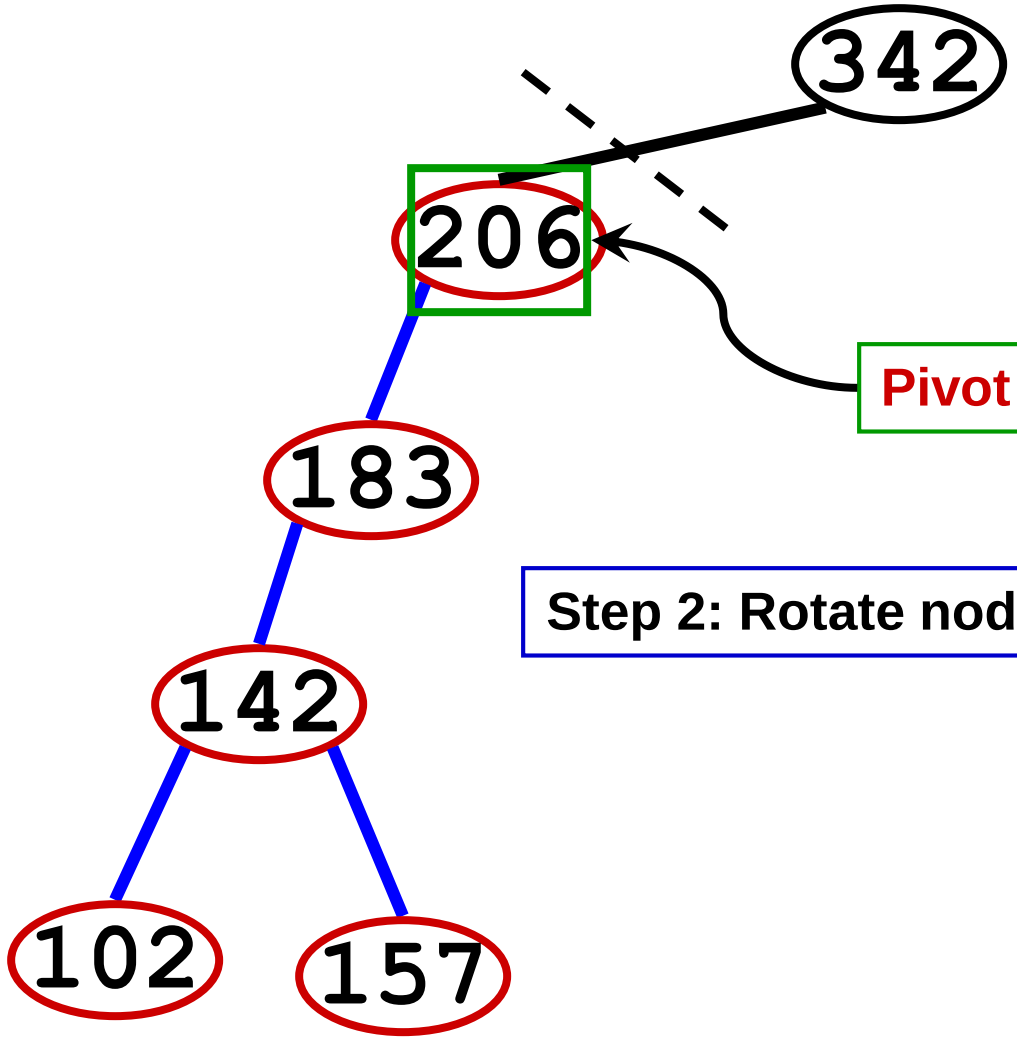
Double Rotation

Now what?



Double Rotation

Remember that…

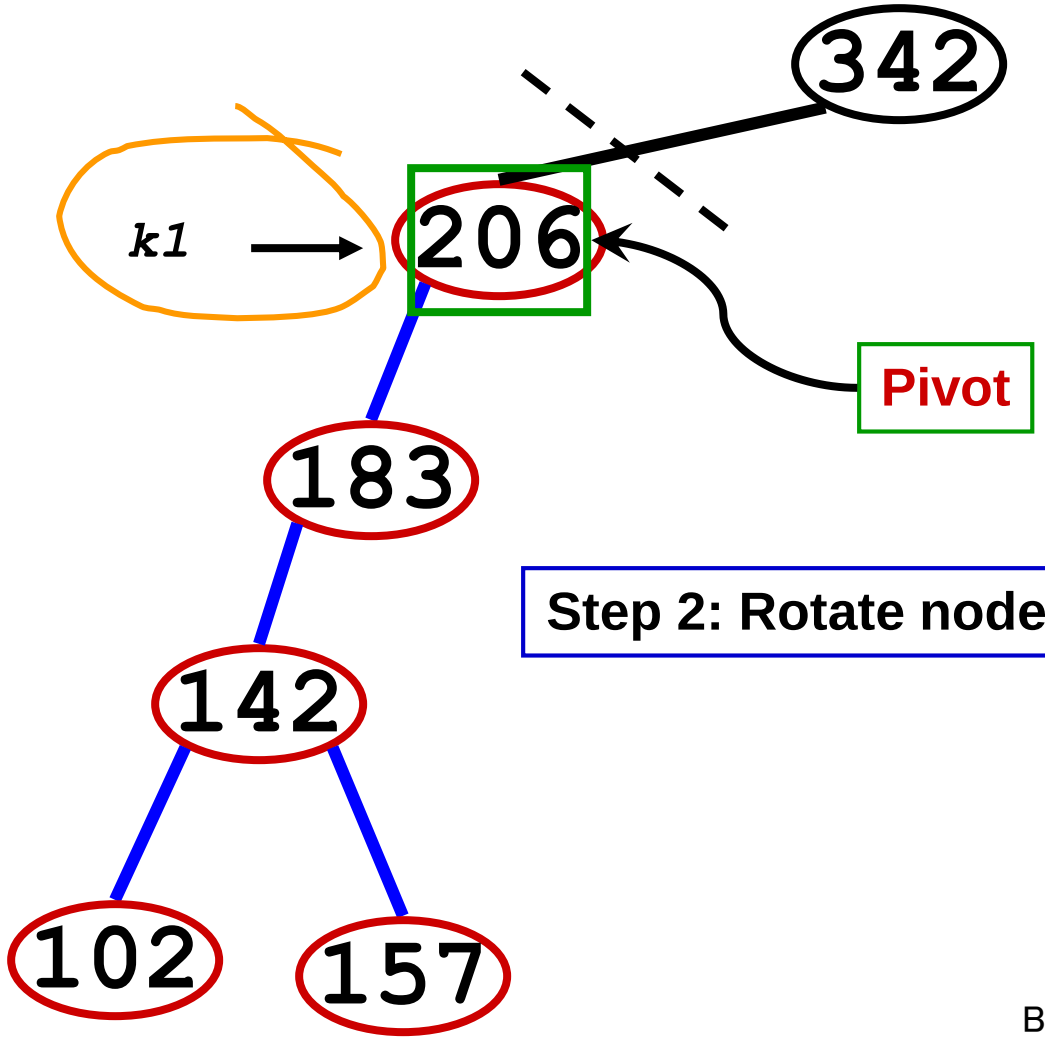


Double Rotation

Step 2: Rotate node and new child (AVL)

LEFT rotation

```
BinaryNode *k2 = k1->left;
k1->left = k2->right;
k2->right = k1;
k1 = k2;
```



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```

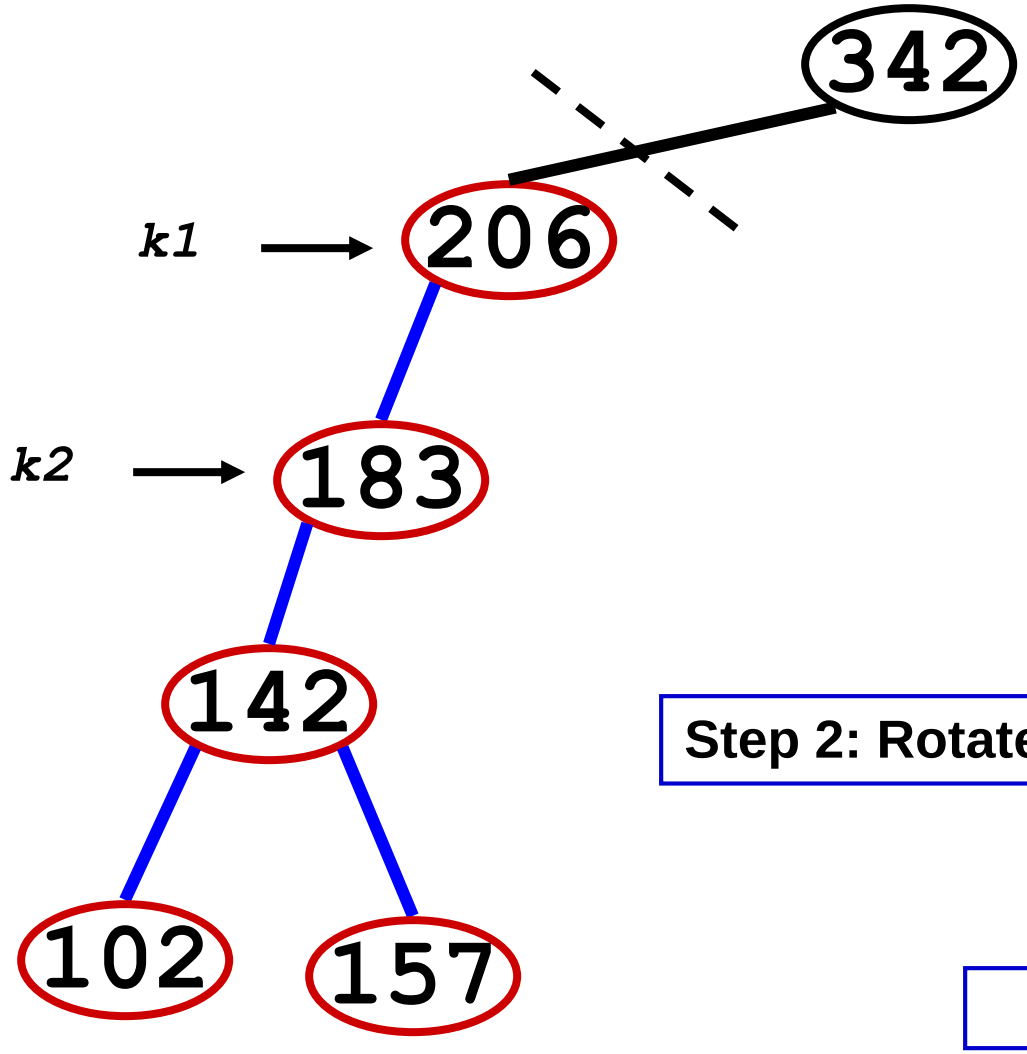

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LEFT rotation

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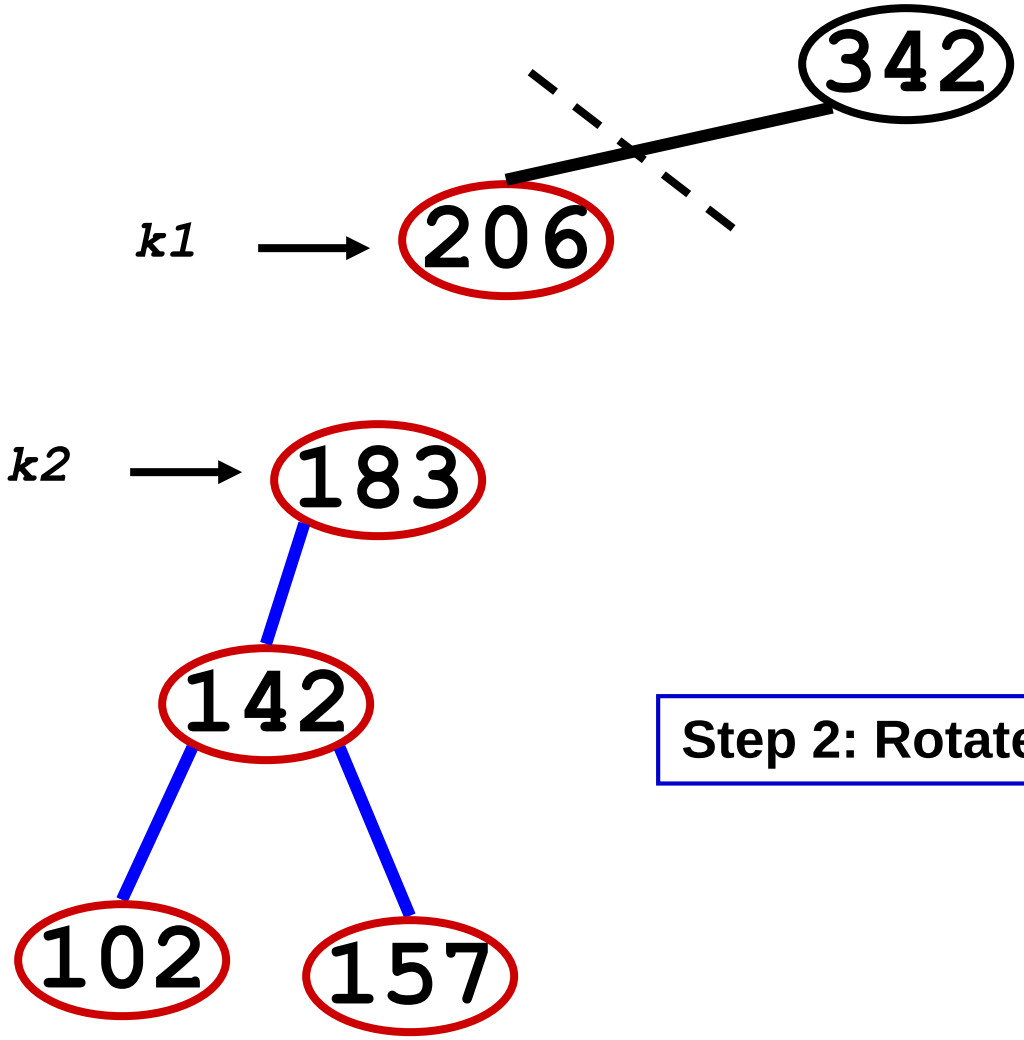
```



Double Rotation

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k1->left = k2->right;
k2->right = k1;
k1 = k2;
```

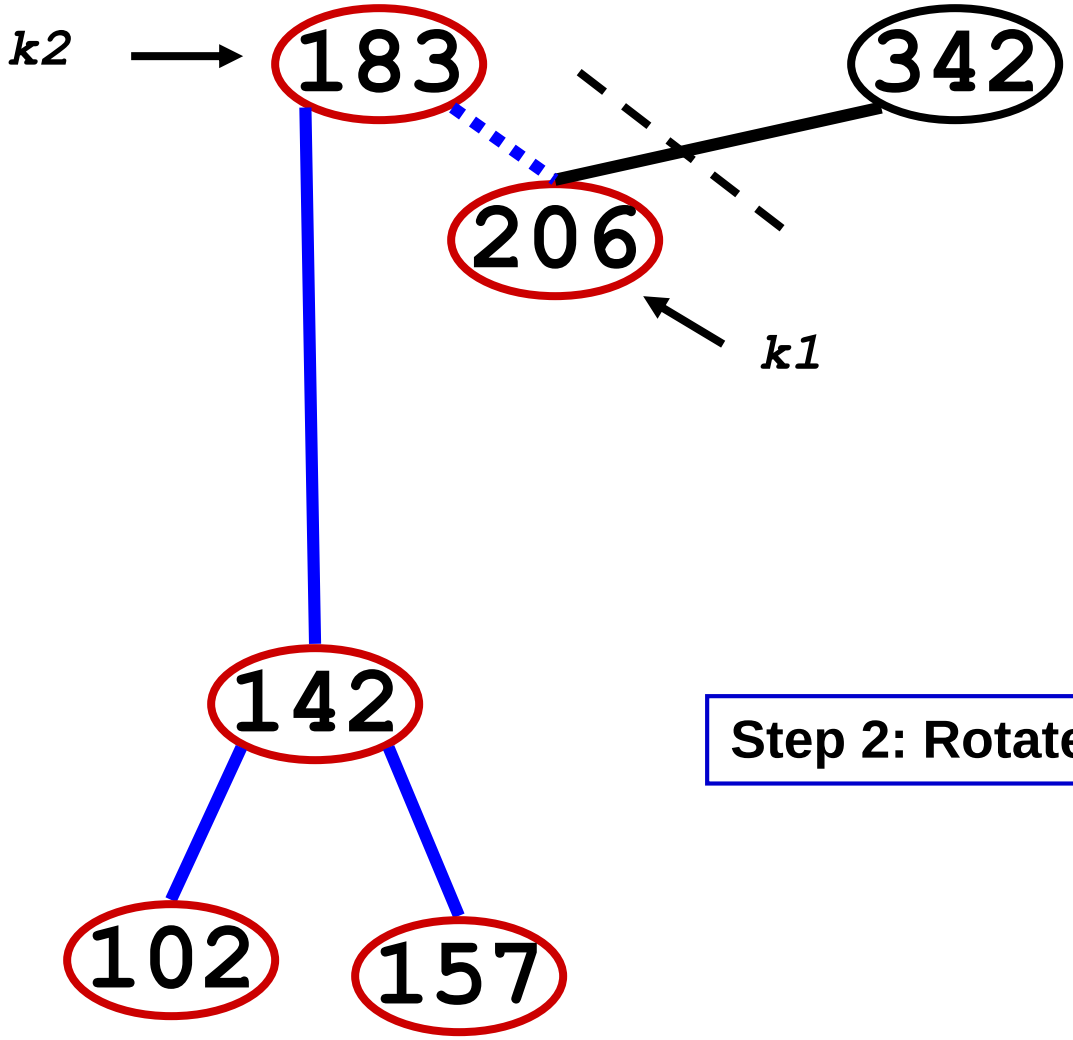

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Double Rotation

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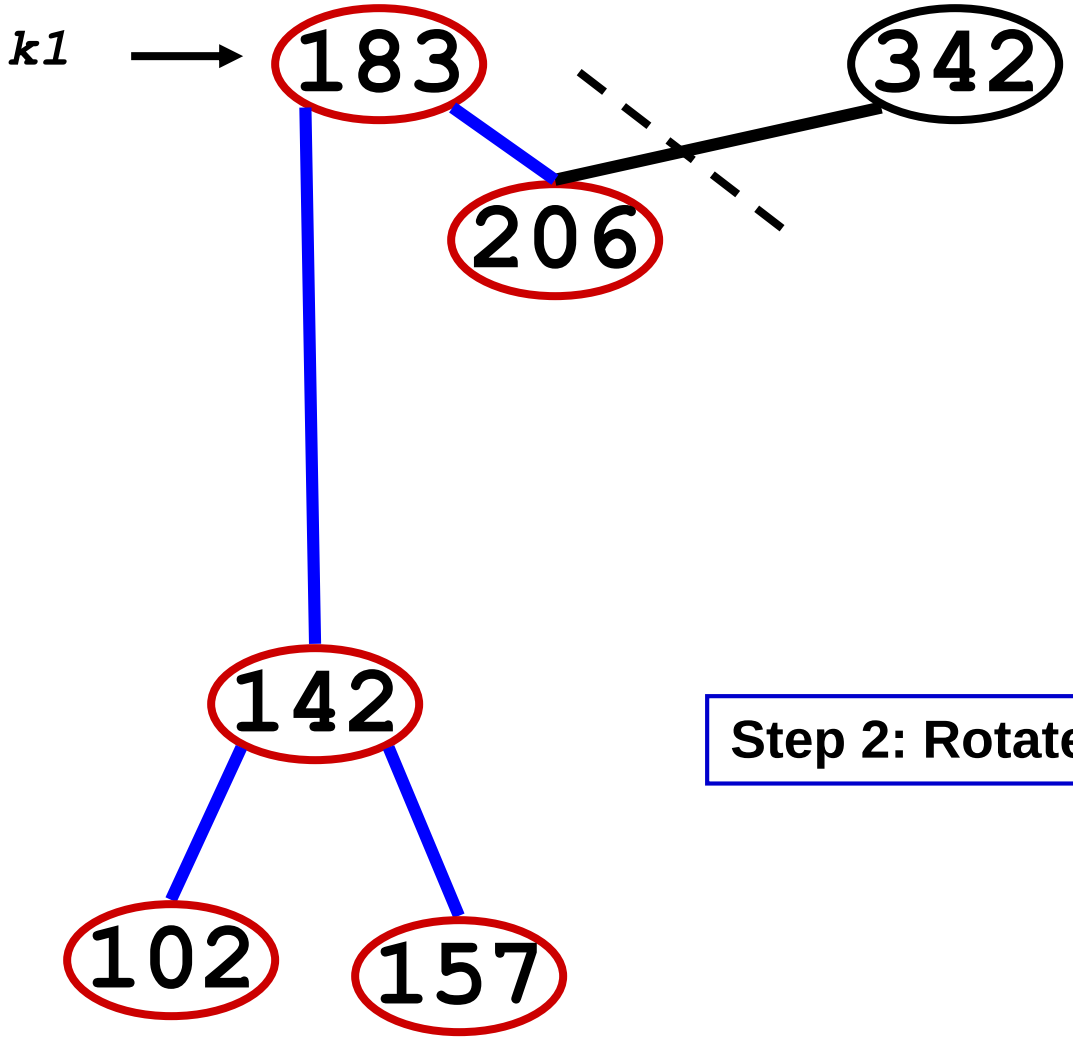
LEFT rotation

```
BinaryNode *k2 = k1->left;
k1->left = k2->right;
k2->right = k1;
k1 = k2;
```



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Double Rotation

Step 2: Rotate node and new child (AVL)

LEFT rotation

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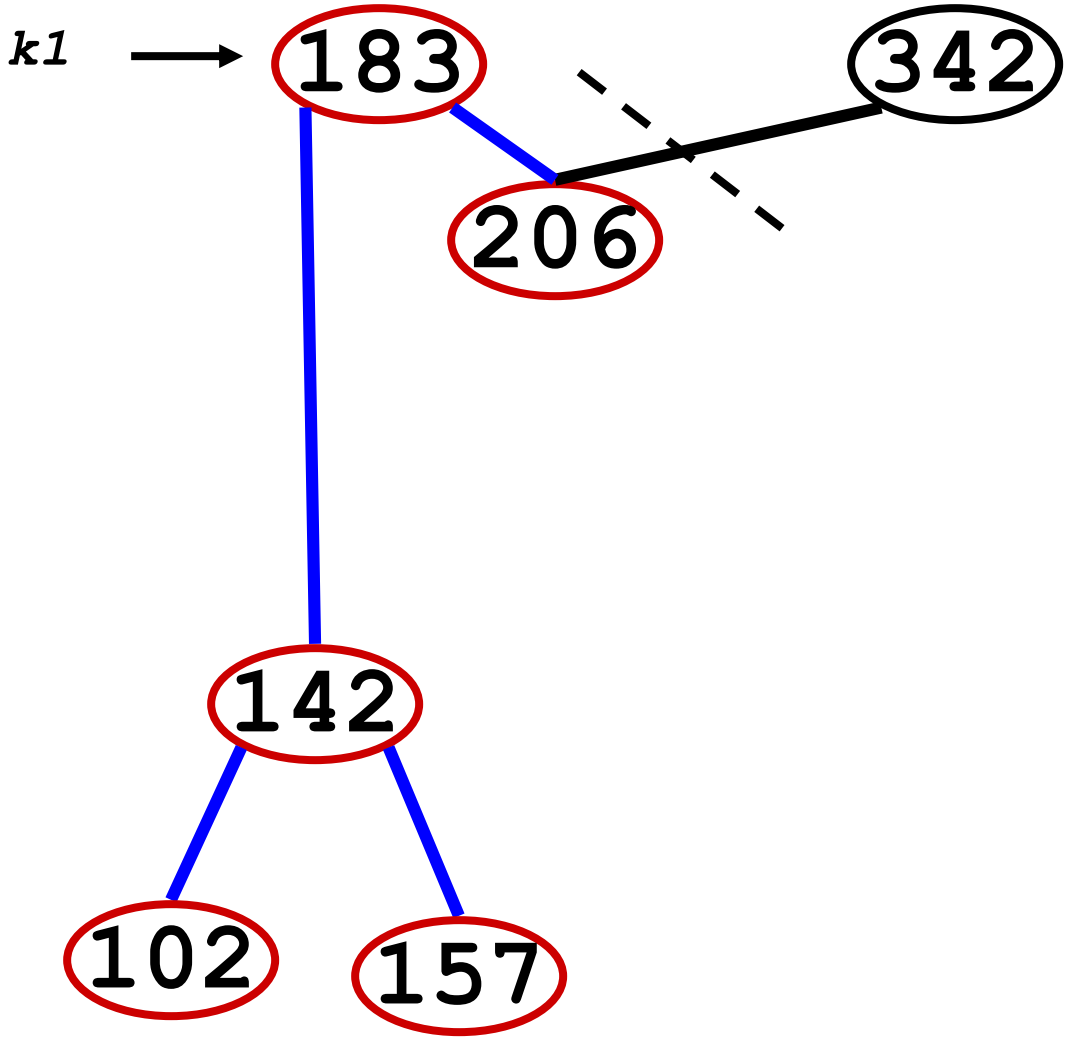
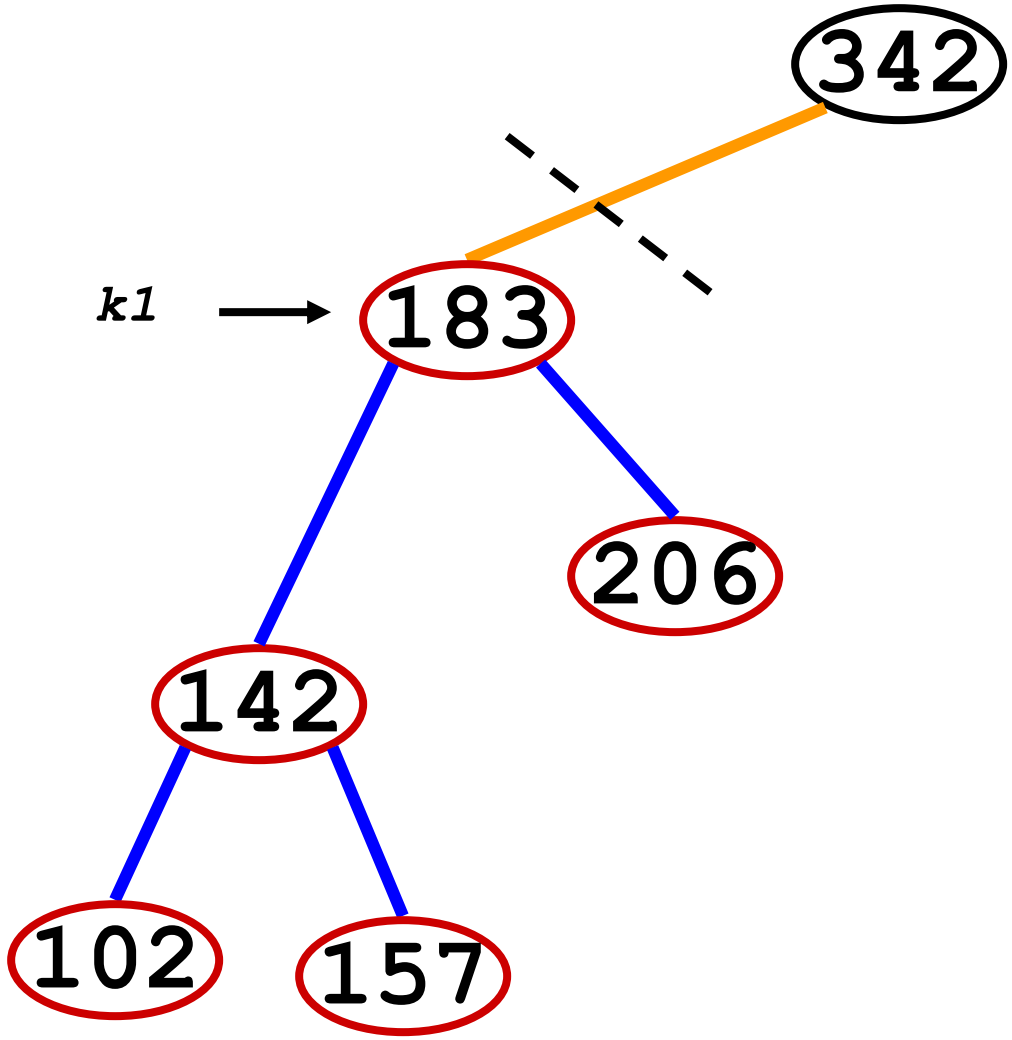
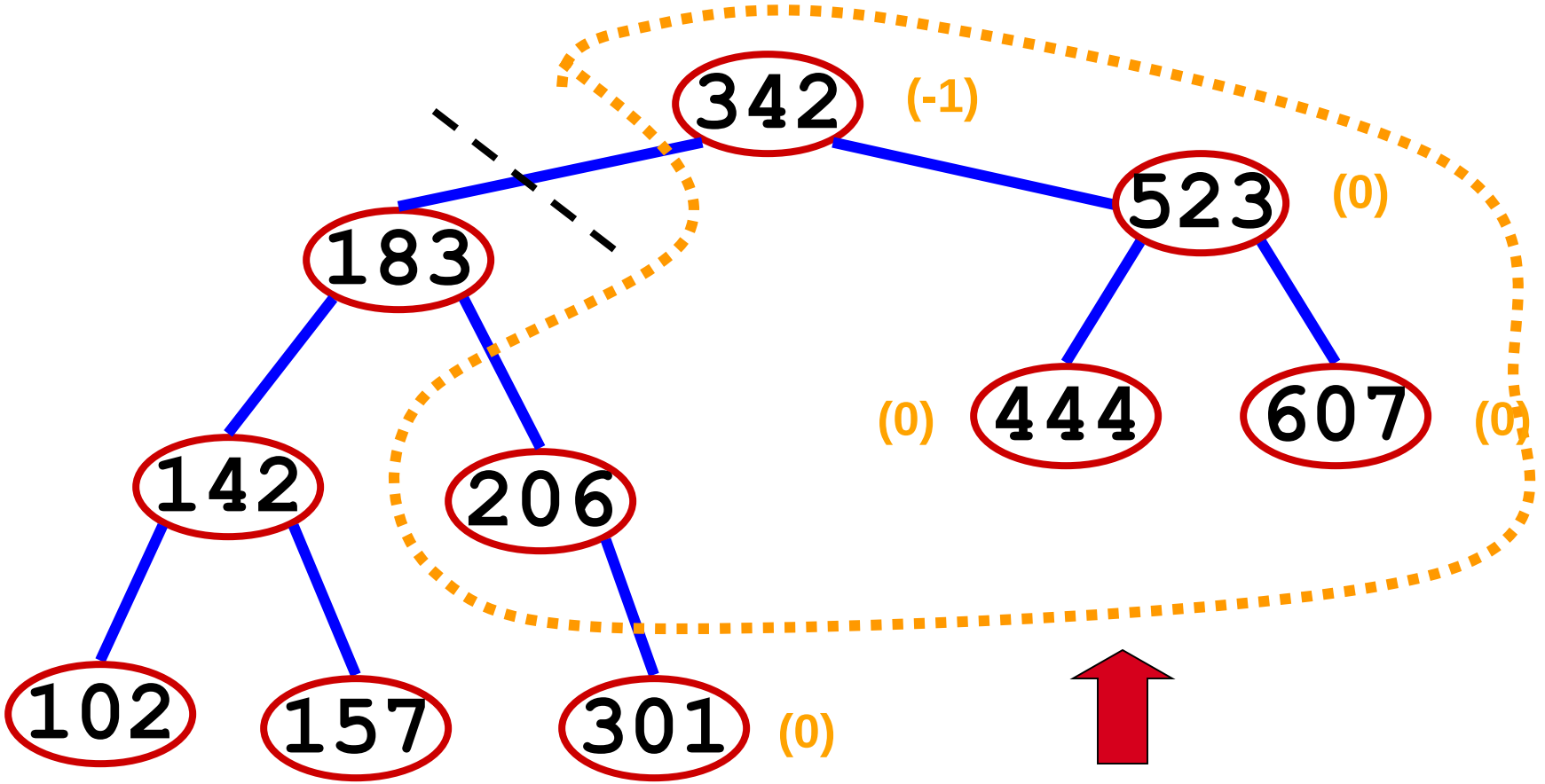


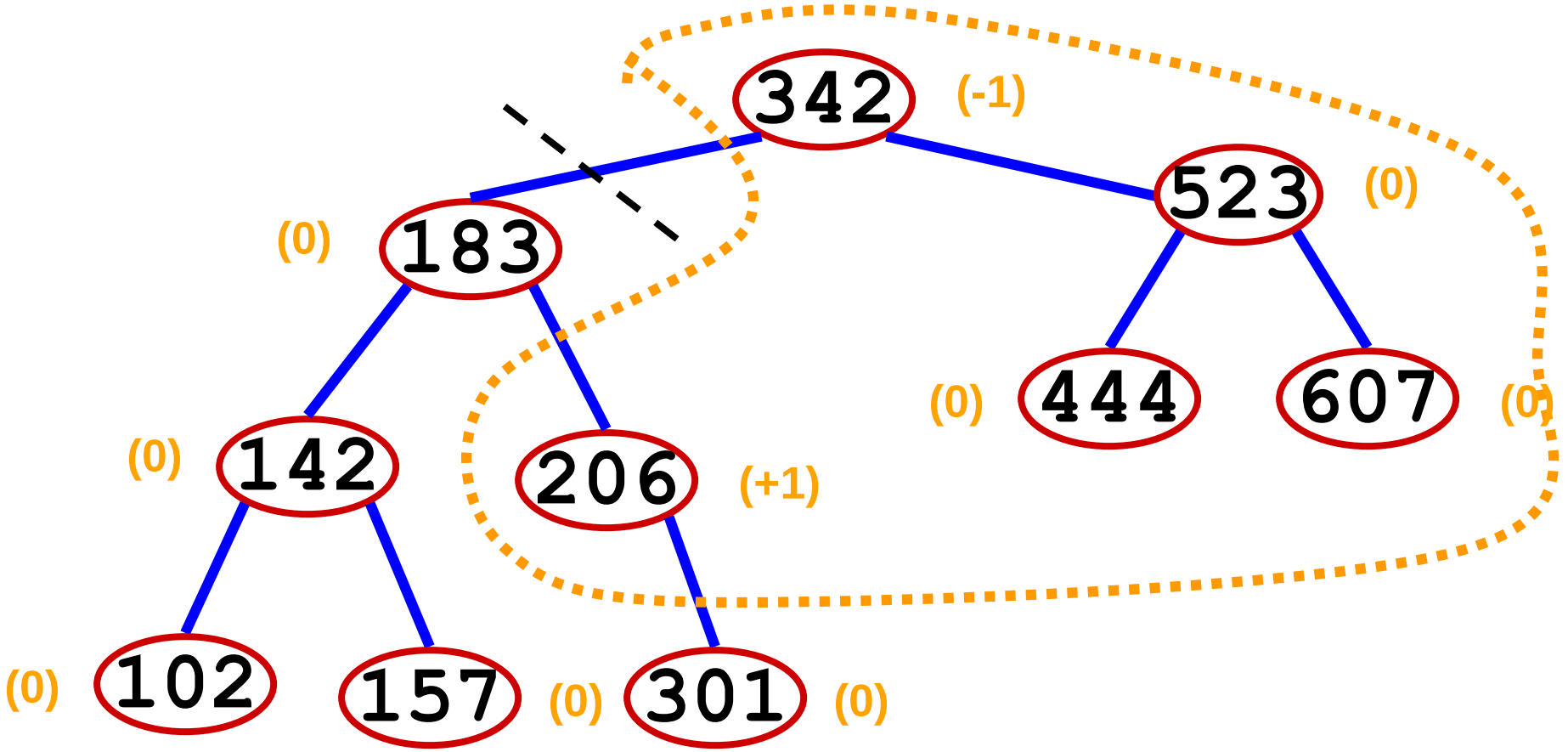
UNIVERSITY OF CALGARY



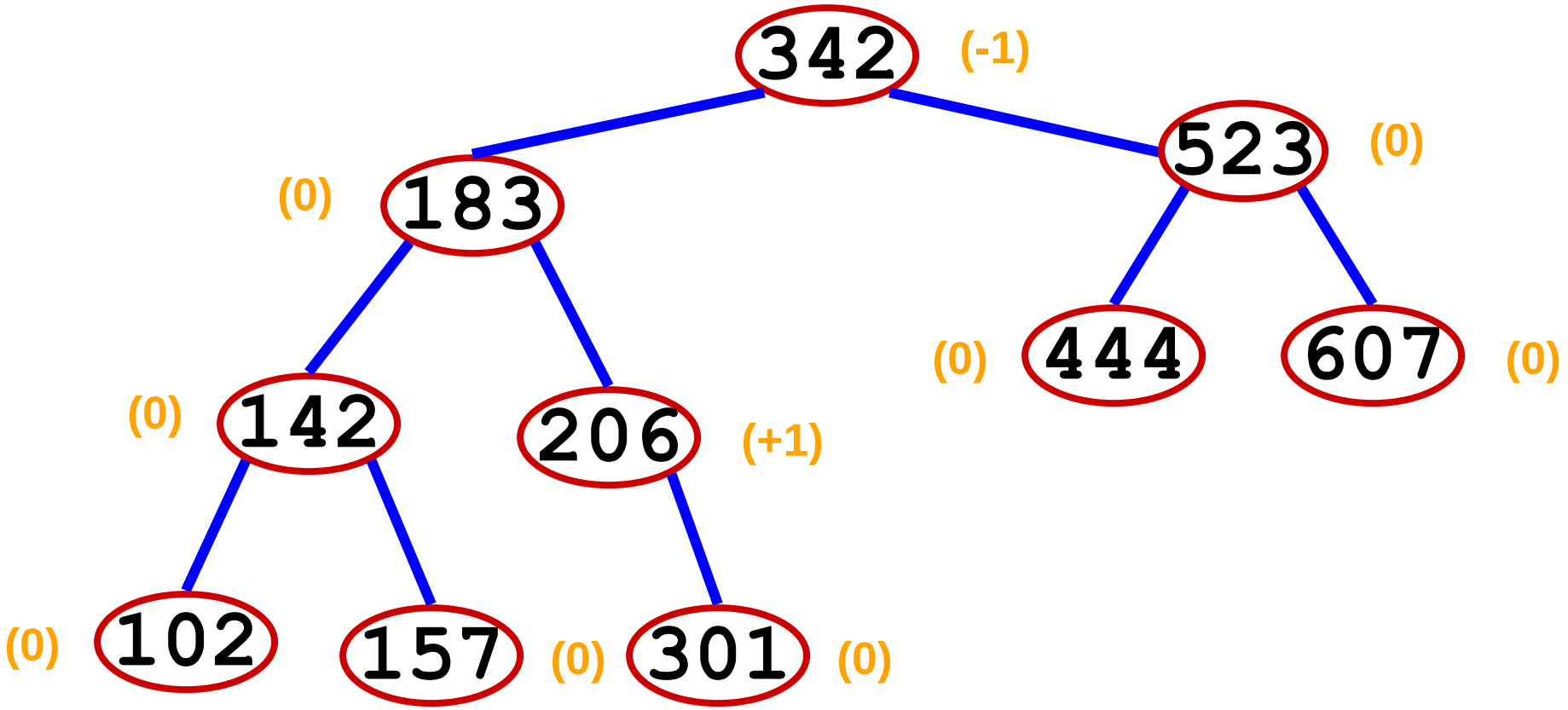
UNIVERSITY OF CALGARY



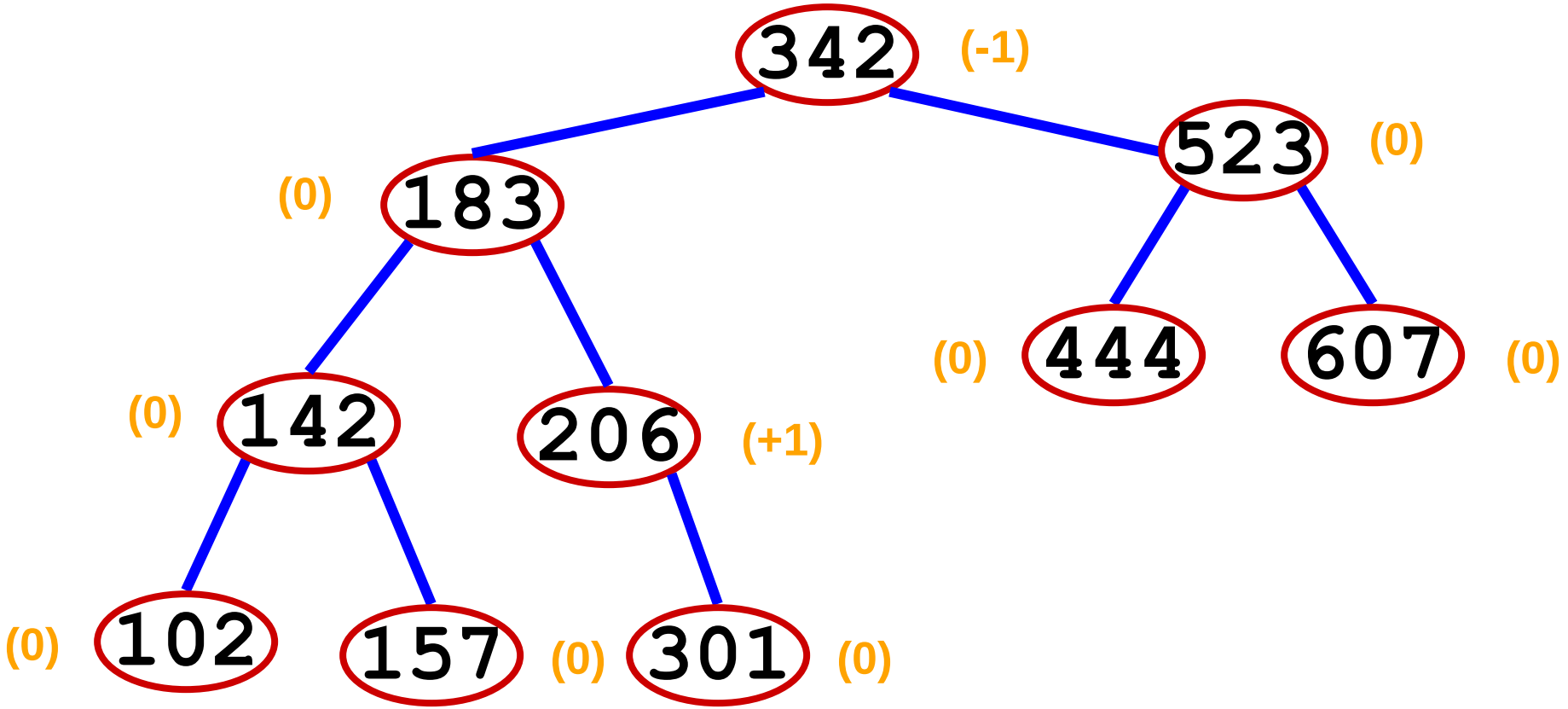
Back to the rest of the tree…



New factors …



Left hand subtree is now almost perfectly balanced


342
(-1)
523
(0)
(0)
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(0)
444
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(0)
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102
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