Red-black tree updates
- black
- red

Insert: $\circ$ root $\rightarrow$ $\bullet$

recolor

possibly nonterminating

\[ \begin{align*}
\text{possibly nonterminating} \\
\end{align*} \]
Delete short node (all paths down lack one black node)
- red or black node (color preserved)
- root

creates a terminating case

Nonterminating if original root is black

O(log n) recolorings; 0, 1, 2, or 3 rotations

O(1) amortized recoloring time for insert/delete:

\[ \Phi = 2 \text{ for } \begin{array}{c} \text{ } \\ \text{ } \end{array}, \quad 1 \text{ for } \begin{array}{c} \text{ } \\ \text{ } \end{array} \]