Exercise 1.

1. state after \texttt{let r = ref 5 and s = ref 3 and t = r}:

2. state after subsequently executing \texttt{incr r}:

3. state after subsequently executing \texttt{incr t}:

Exercise 2. in-place list reversal

State before the loop:

State after the loop:

Loop invariant:

Exercise 3. length of mutable list using a while loop

State before the loop:

State after the loop:

Picture describing the state during the loop:

Try to state a loop invariant. What do you need?

Exercise 4. generalize MList to define \( p \leadsto \text{MListSeg} q L \), where \( L \) denotes the list of items in the list segment from \( p \) (inclusive) to \( q \) (exclusive):

\[ p \leadsto \text{MListSeg} q L \equiv \]

Exercise 5. length of mutable list using a while loop and MListSeg

Loop invariant: \( \exists q, L_1, L_2, \ldots \)

Instantiate \( q, L_1, L_2 \) before the loop:

Instantiate \( q, L_1, L_2 \) after the loop:
Exercise 6. define the representation predicate $p \rightsquigarrow \text{Queue } L$.

Exercise 7. define the representation predicate $p \rightsquigarrow \text{Mtree } T$.

Exercise 8. define $p \rightsquigarrow \text{MtreeDepth } n T$ by generalizing $p \rightsquigarrow \text{Mtree } T$.

Exercise 9. give an alternative definition of “$p \rightsquigarrow \text{MtreeDepth } n T$”, this time by reusing the definition of $p \rightsquigarrow \text{Mtree } T$ without modification.

Exercise 10. define a predicate $p \rightsquigarrow \text{MtreeComplete } T$ for describing a mutable complete binary tree, of some unspecified depth.

Exercise 11. define a predicate $p \rightsquigarrow \text{MsearchTree } E$ for describing a mutable binary search tree storing the set of elements $E$.

Exercise 12. specify the primitive operations on references.

\[
\begin{align*}
\text{(ref } v) \\
\text{(!} r) \\
\text{r := v)}
\end{align*}
\]

Exercise 13. Give specifications for:

\[
\begin{align*}
\text{(Array.get i p)} \\
\text{(Array.set i p v)} \\
\text{(Array.length p)} \\
\text{(Array.create n v)}
\end{align*}
\]

Exercise 14. What is the natural specification of function \textit{myref}? What is missing from our current interpretation of triple?