Exercises to the lecture
Concurrency Theory
Sheet 1

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Exercise 1.1 (Data Structures in Separation Logic)
Characterize data structures in separation logic. More precisely, define predicates llist(x), dllist(x), and tree(x), so that

- $\mathrm{llist}(x)$ means that x points to a linked list,
- $\mathrm{dllist}(x)$ points to a doubly linked list, and
- $\mathrm{tree}_{\mathrm{a,b}}(x)$ points to a binary search tree with values between a and b.

Exercise 1.2 (Formulas)
Prove the following properties of separation logic formulas:

- $*$ is commutative and associative and $(P * \mathrm{emp}) \Leftrightarrow P$
- If $(P \mathbin{-\!\circledast} Q)h$ is defined as $\exists\, h_1 . P h_1 \wedge Q(h \uplus h_1)$, then $(P \mathbin{-\!\circledast} Q)h \Leftrightarrow \neg(P \mathbin{-\!\!*} \neg Q)h$
- $P * (P \mathbin{-\!\!*} Q) \vdash Q$
- $10 \mapsto 20 \mathbin{-\!\!*} 10 \mapsto 20 \not\Leftrightarrow 10 \mapsto 20 \mathbin{-\!\circledast} 10 \mapsto 20$
- $\mathrm{ls}_\alpha(x, y) * \mathrm{ls}_\beta(y, z) \Rightarrow \mathrm{ls}_{\alpha\beta}(x, z)$

Exercise 1.3 (Sorting)
Using the syntax given in the lecture, present a program C that merges sorted lists (like in the Heapsort algorithm). Hence, given two sorted lists L_1 and L_2, the program returns a sorted list L containing precisely the elements from L_1 and L_2. Give formulas P and Q so that $\{P\}C\{Q\}$ holds.

Hint: To define P and Q, you can make use of the the list segment predicate ls_α from the lecture. Furthermore, you may have to introduce predicates that describe sorted lists and lists that are permutations of each other.

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