These questions are intended for self-study, to help review and deepen your understanding of the lecture. Sample answers are available. There is nothing to hand in.

1. Using the typing rules on lecture 7a slide 8, write typing derivations for the following expressions, or else explain briefly why it is impossible to produce such a tree. In all cases, assume that the initial typing environment is the empty environment $\emptyset$.

(a) $(+ (+ 1 2) 3)$

(b) $(+ \times 1)$

(c) $(\text{let } x = 0 (\text{while } (<= x 10) (:= x (+ x 1))))$

(d) $(\text{let } x = (<= 0 1) (+ (\text{if } x 1 2) 3))$

(e) $(+ (\text{if } (<= 2 1) (<= 1 2) 3) 39)$

2. Recall from Lab 4 the expression form $(\text{before } e_1 e_2)$ whose informal semantics are as follows: evaluate $e_1$, remember the result value $v$, evaluate $e_2$, throw away the result value, and then yield $v$ as the overall value of the expression. For example, the expression $(\text{before } a (:= a 42))$ sets $a$ to 42 and yields the old value of $a$ as its result. Write down a static typing rule for before expressions in the style of slide 8.