Exercise 1.

Nussinov SCFG

a) Formulate the inside and outside algorithm for the Nussinov SCFG.

b) Show how to use your inside and outside variables to calculate the probability that positions $i$ and $j$ are base-paired, summed over all structures.

Exercise 2.

Covariance models

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a) Build a covariance model for the alignment of RNAs. Visualize it as a tree, like presented in the lecture.

b) Analyze the runtime and memory consumption of the CYK for CM database search.

Exercise 3.

CNF

Convert the production rule $W \rightarrow aWbWWc$ ($a, b, c$ terminal symbols) into Chomsky normal form. If the probability of of the original production is $p$, show the probabilities for the productions in normal form.

Exercise 4.

Minimal Resolved Match Refinement

Prove the following Lemma:

**Lemma 1.** There exists a unique resolved refinement $\bar{S}$ of $S$ of minimal cardinality.

**Proof:** Sketch: Consider two different resolved refinements $S_1$ and $S_2$ of $S$, both of minimal cardinality. Divide proof into two cases. 1) $(supp_A(S_1) \neq supp_A(S_2))$ 2) $supp_A(S_1) = supp_A(S_2)$, $supp_B(S_1) = supp_B(S_2)$