RNA Tertiary Structure prediction: Deep Learning vs. Statistical Force field

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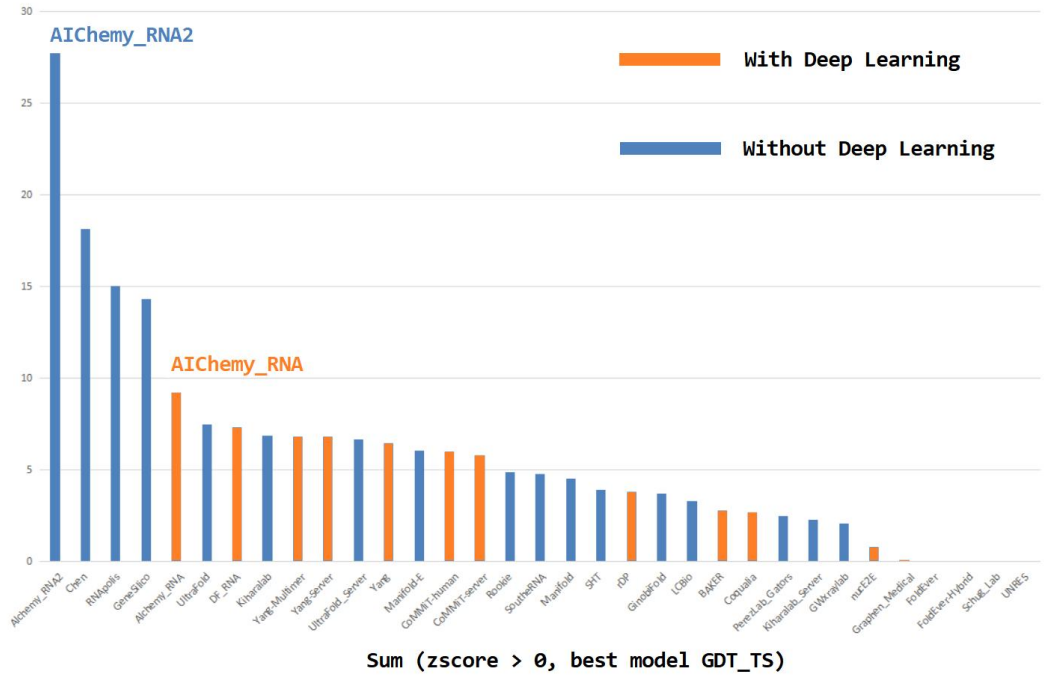
Outline

- Introduction to RhoFold
- Basic ideas behind BRiQ
- Compare between BRiQ and AMBER



AIChemy_RNA RhoFold: end-to-end deep learning method

AIChemy_RNA2 BRiQ: modeling with statistical force field

Architecture of RhoFold

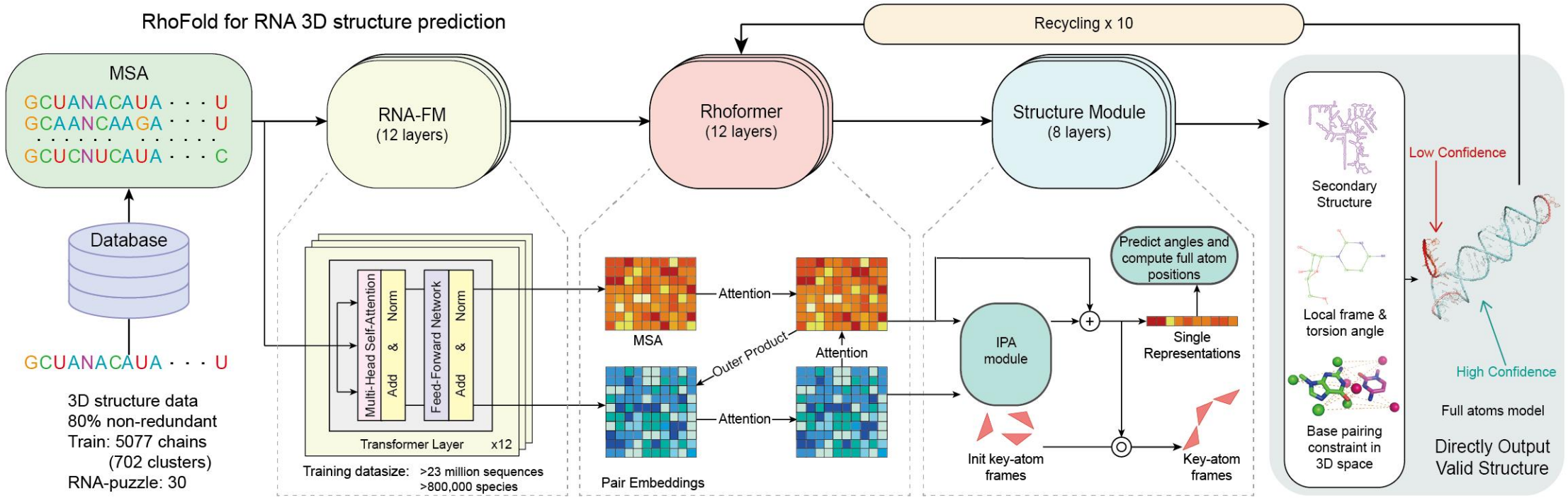
Learned from AlphaFold2

Challenge: Insufficient structure data

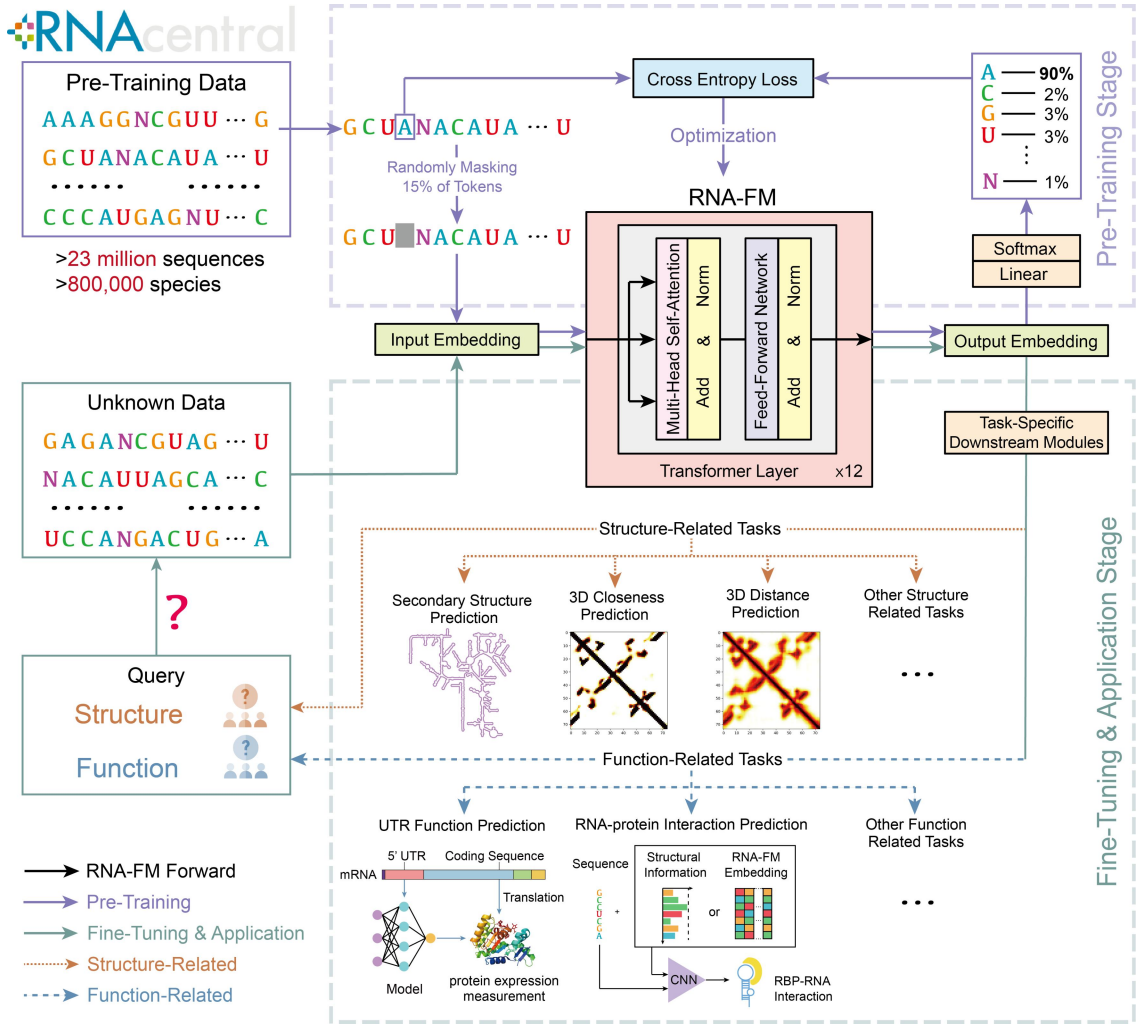
Structures in PDB

Protein: 194,832

RNA: 6,520

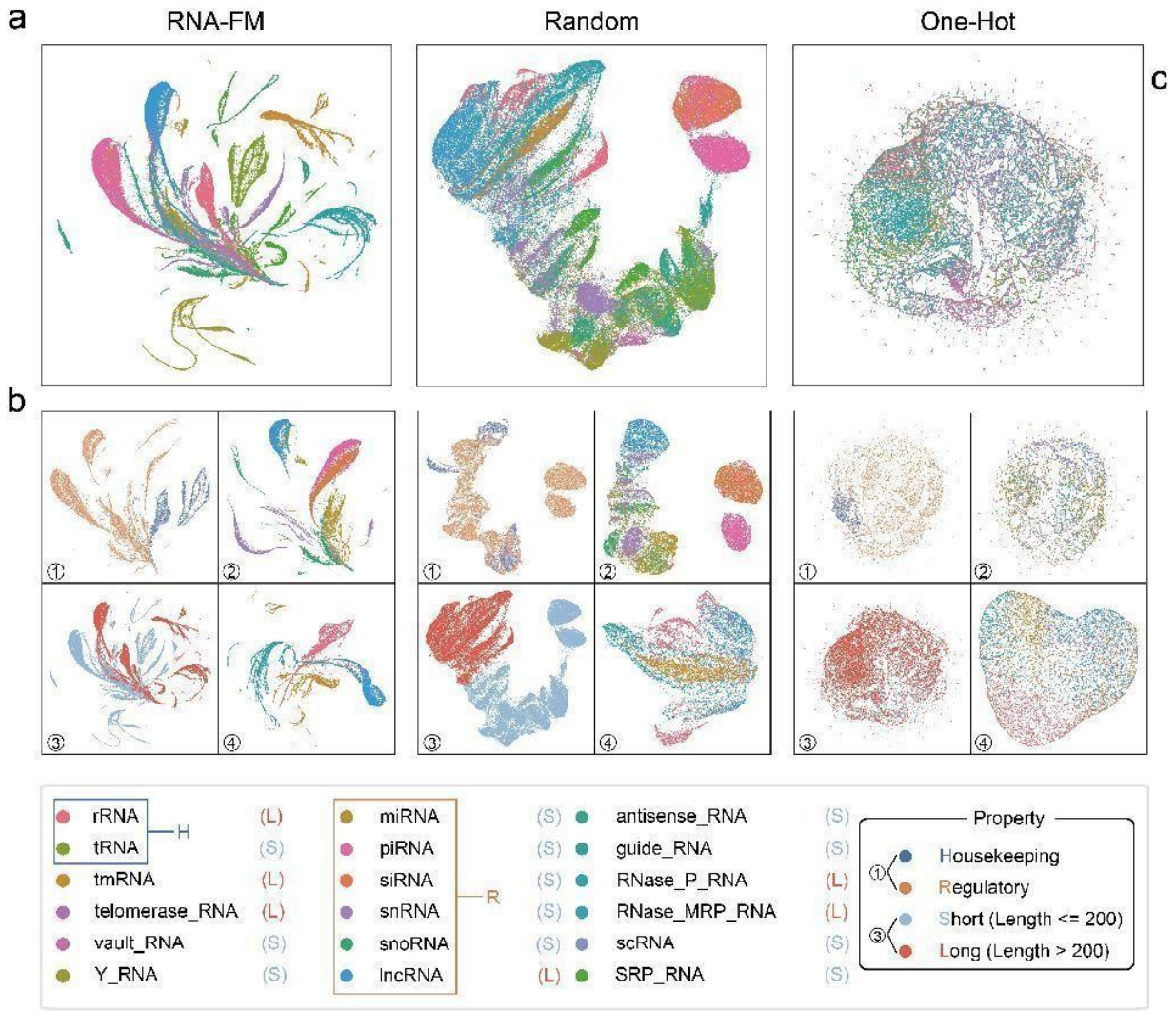


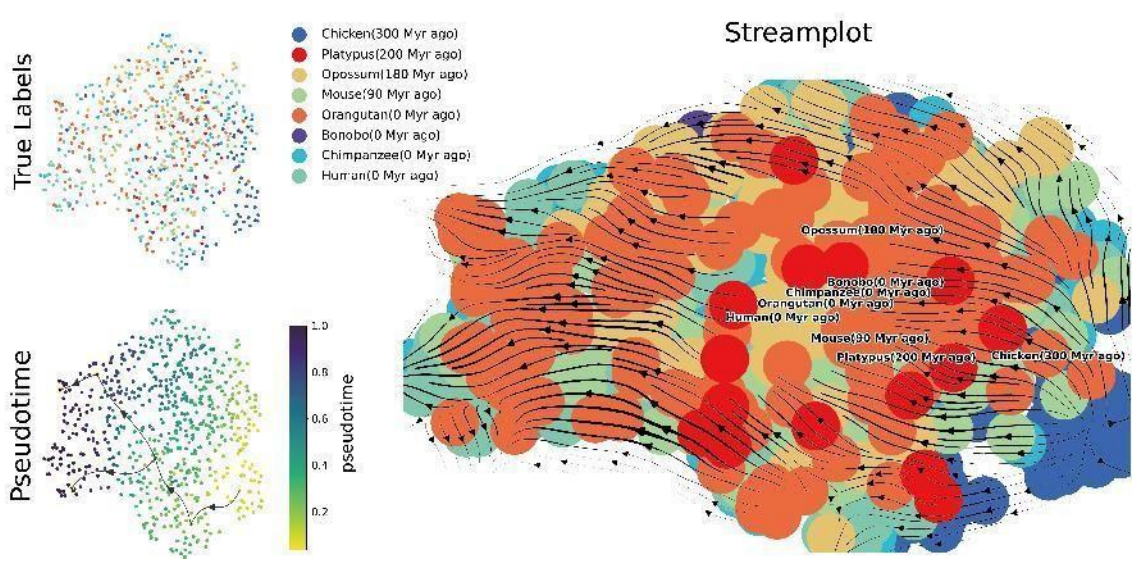
RNA foundation model (RNA-FM)



- Only use sequence information
- Self-supervised trained on all the RNA central ncRNA sequences (23 million)
- After trained, the model can output representations of input sequences
- Combined with rMSA, extracting more evolutionary information

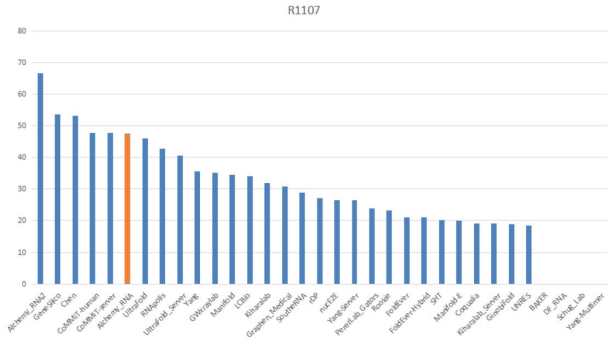
RNA foundation model (RNA-FM)



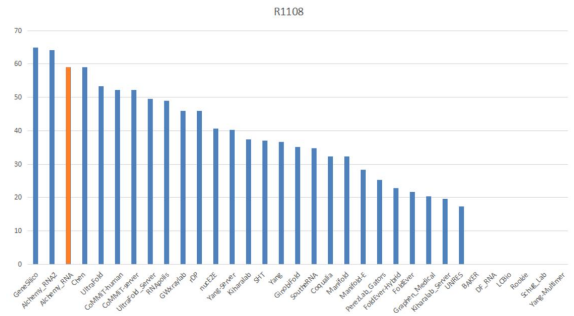


RNA-FM extracts the sequence pattern and evolutionary information

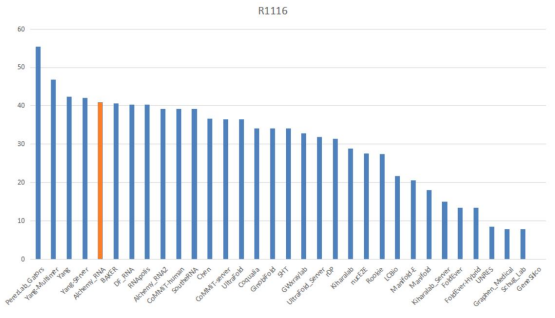
Performance of RhoFold (GDT_TS of best model)



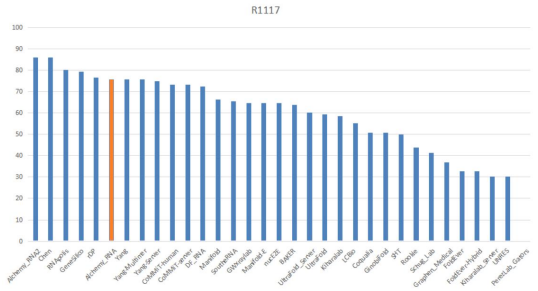
R1107



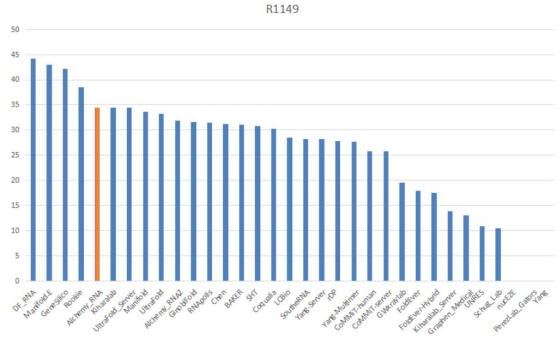
R1108



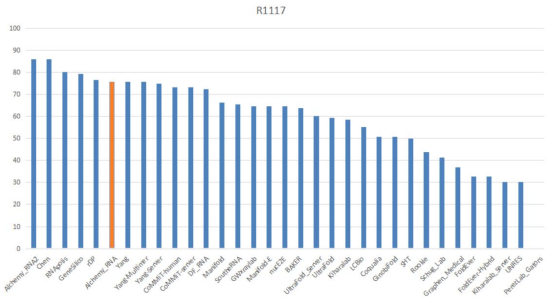
R1116



R1117



R1149



R1156

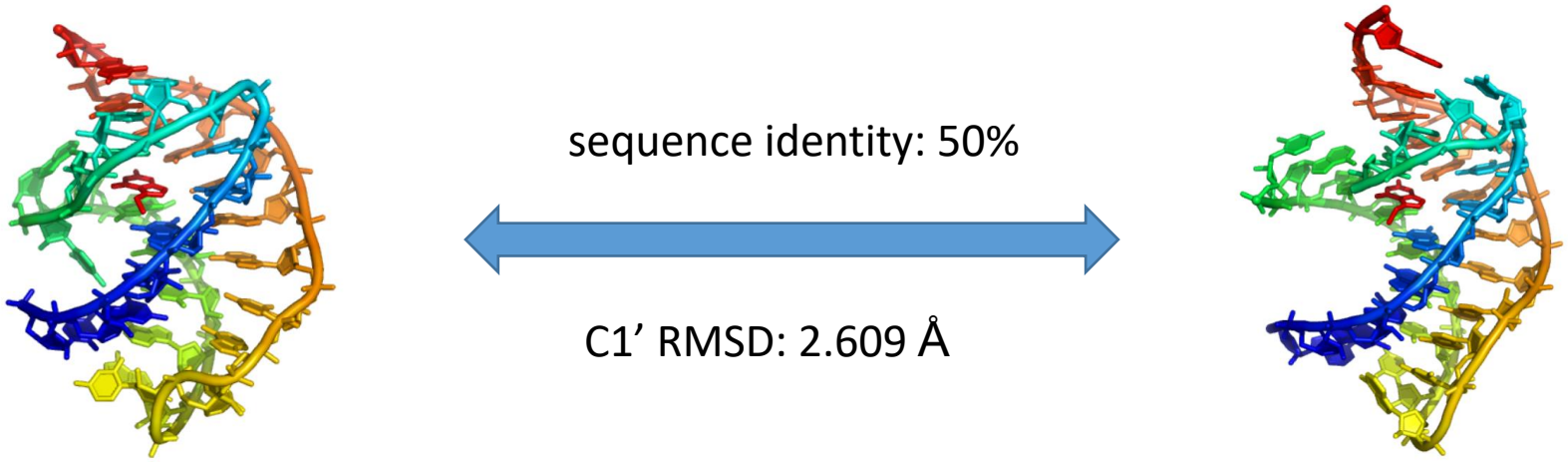
Comparable to other top groups on these 6 targets

Failed on 4 synthetic RNAs and 2 protein-RNA complexes

Conclusion of Deep Learning method

Currently, our deep learning method didn’t outperform state-of-art structure modeling methods relying on scoring functions

This result is a bit different from what we saw on RNA puzzle tests



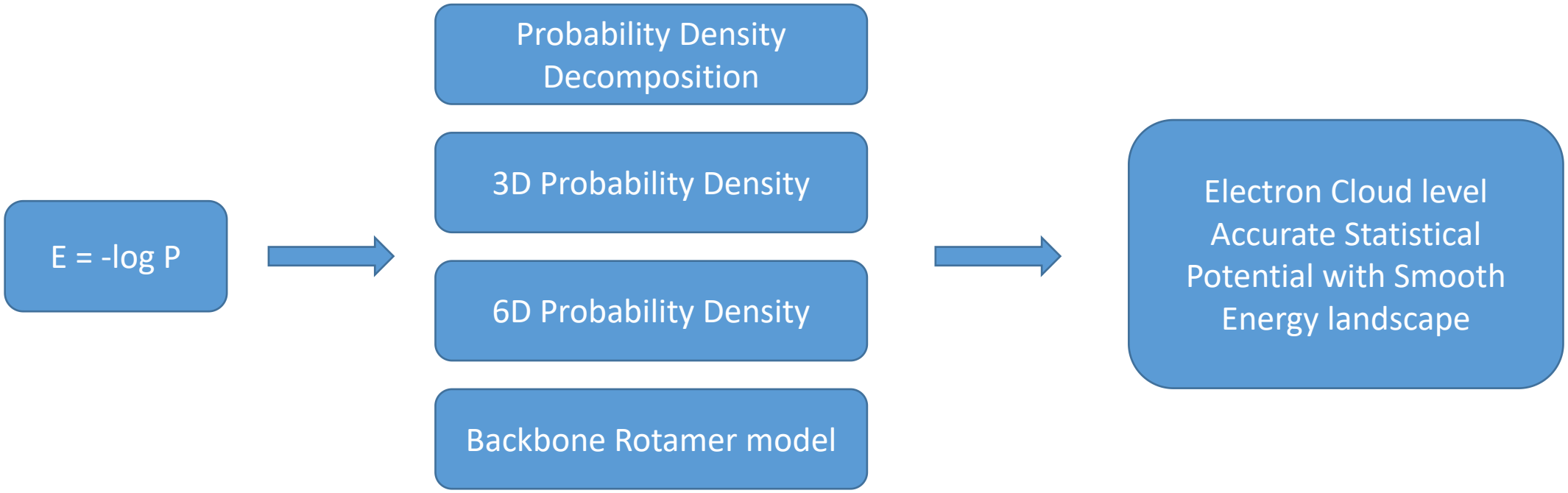
Target R1117

PDB: 3fu2_A

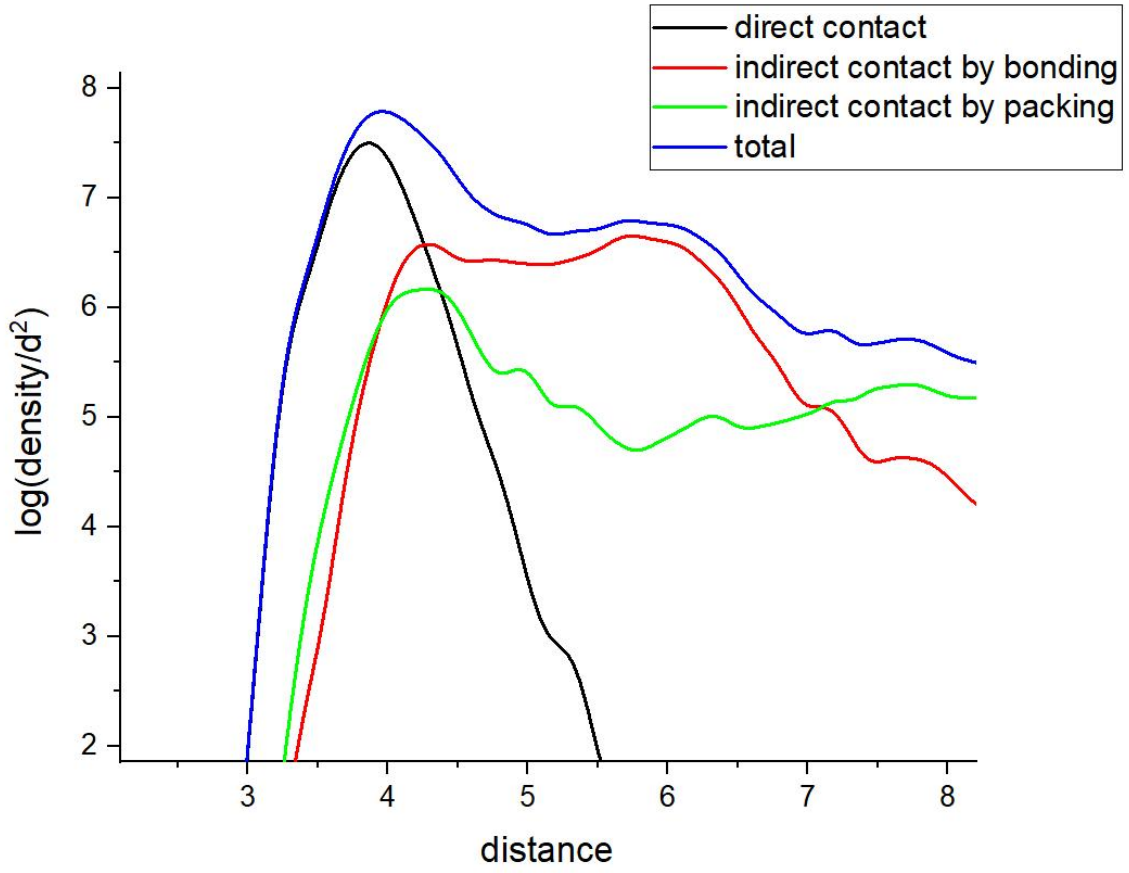
The **80%** sequence identity cutoff is widely used to divide training set and test set

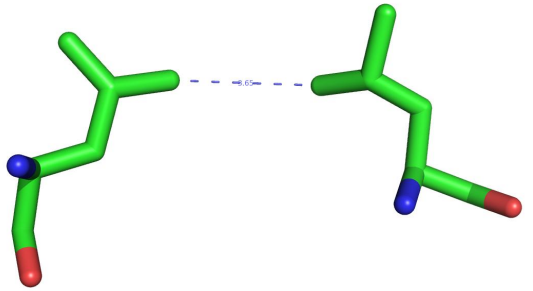
Basic ideas behind BRiQ

Try to learn physics from structure database

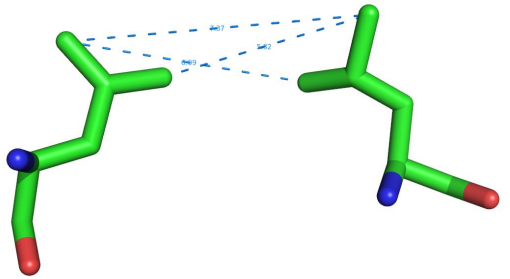


Probability density decomposition

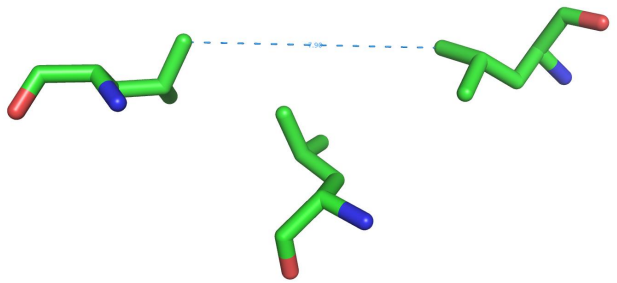




direct contact

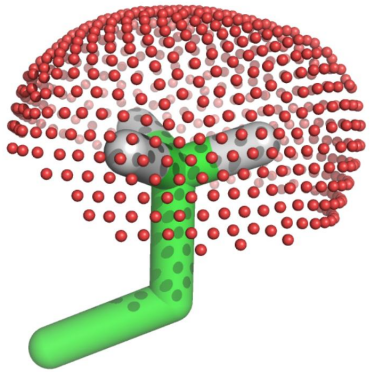


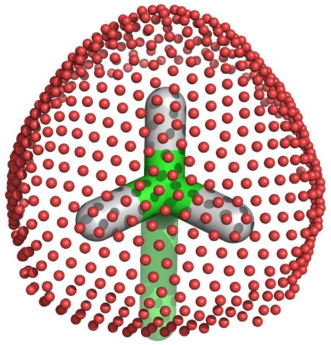
indirect contact by bonding



indirect contact by packing

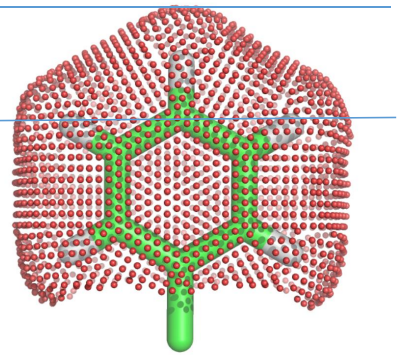
1D to 3D, draw electron cloud surface of chemical groups



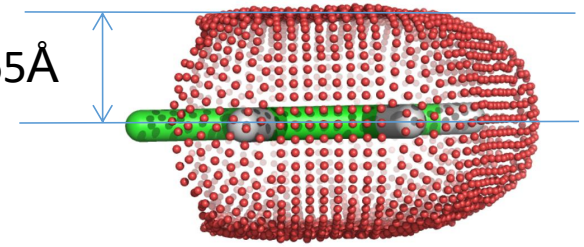


ILE-CD

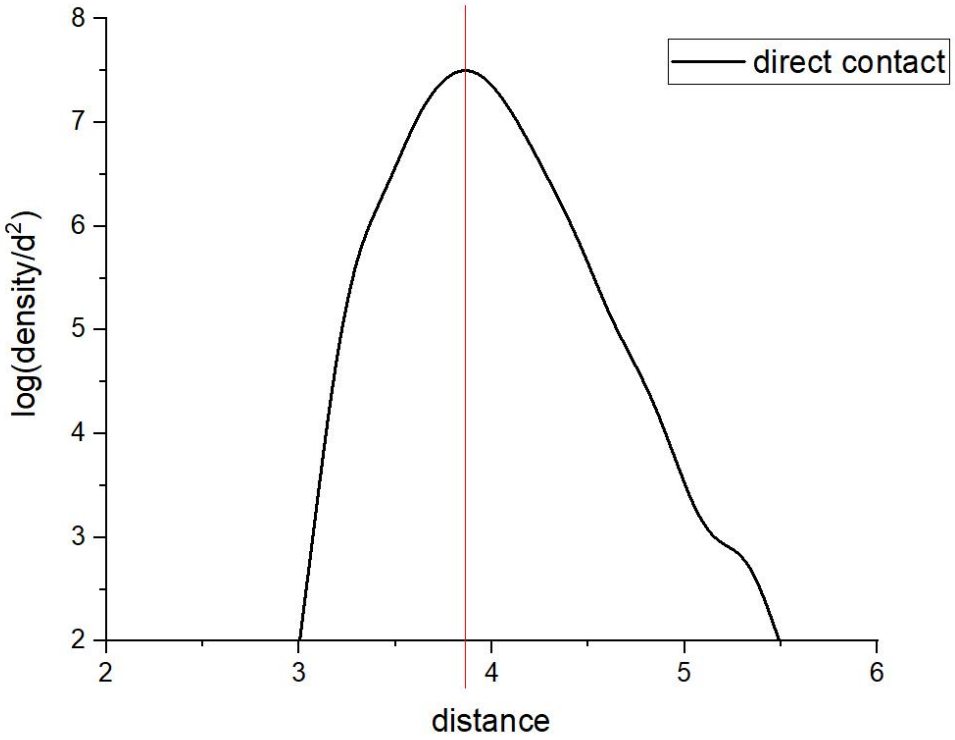
1.95Å



1.65Å

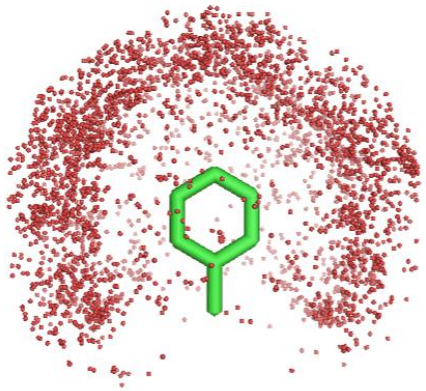


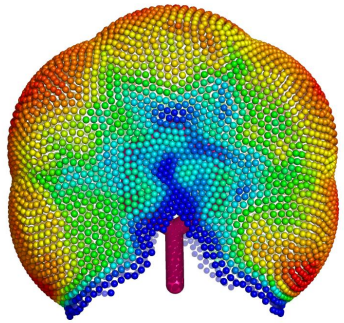
PHE

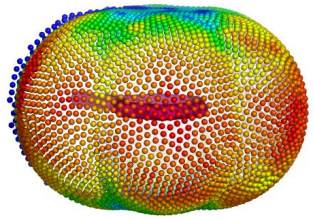


Charge distribution of polar groups to 3D energy

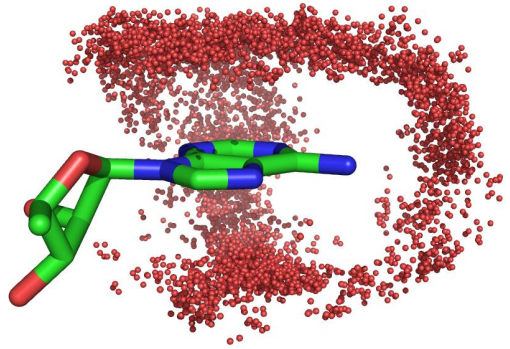
Density of GLU-OE atoms in the local frame of PHE

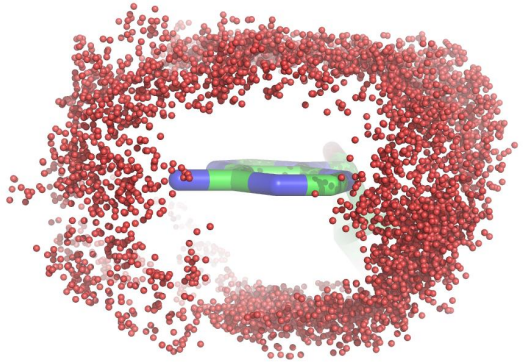




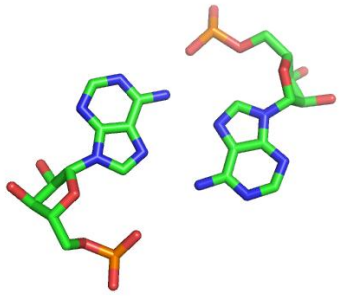


Density of ribose O4’ atoms in the local frame of Base A

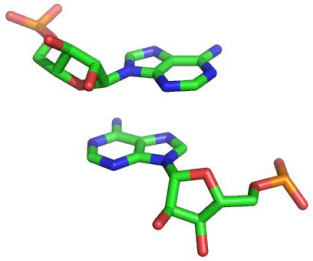




6D energy for base-base interactions



base pairing



base stacking

Divide the orientation space into 9 billion conformations

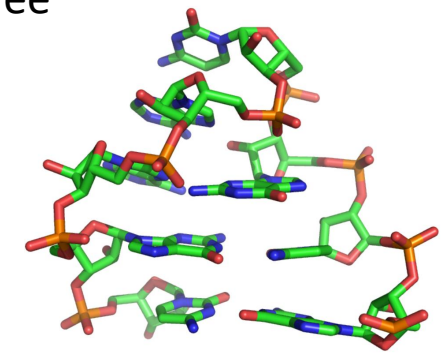
About 5 million effective conformations

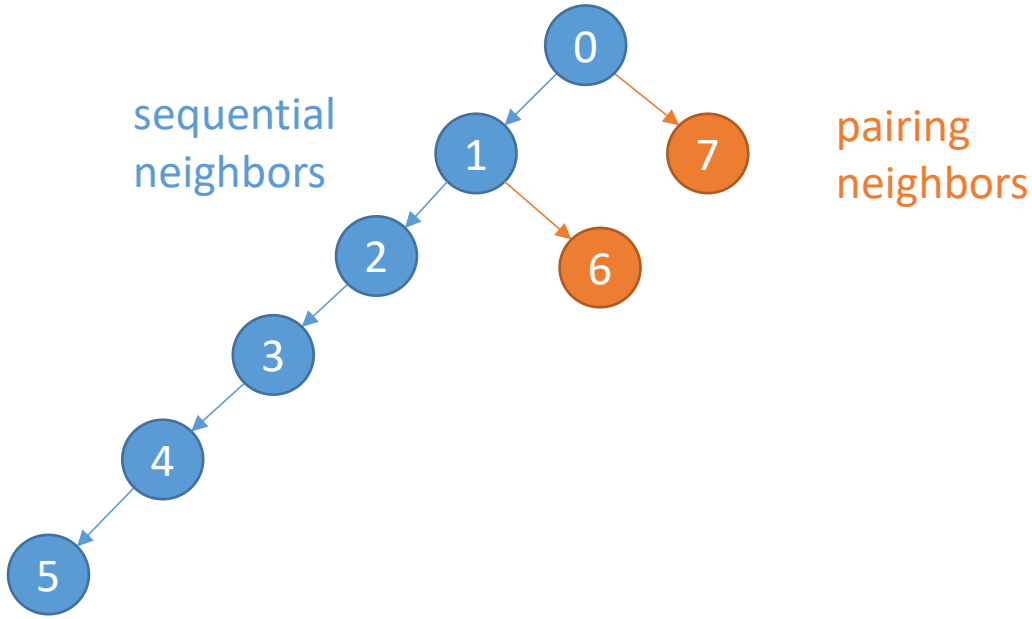
Get the energy of each conformation from 6D density and QM calculation

Store the pre-calculated energies into a hash table

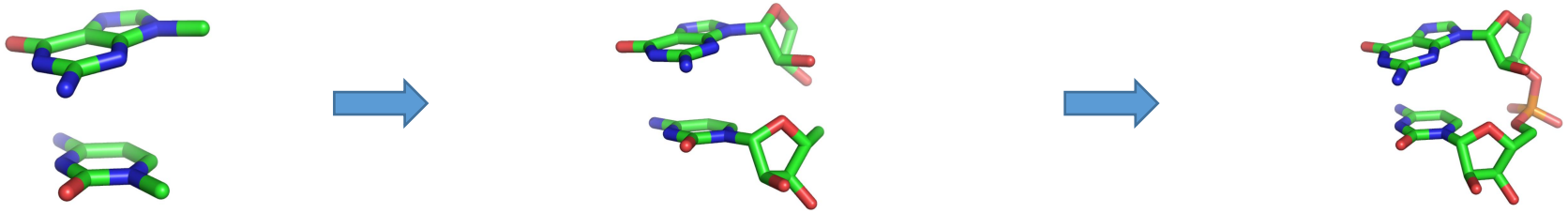
Monte Carlo sampling

base folding tree

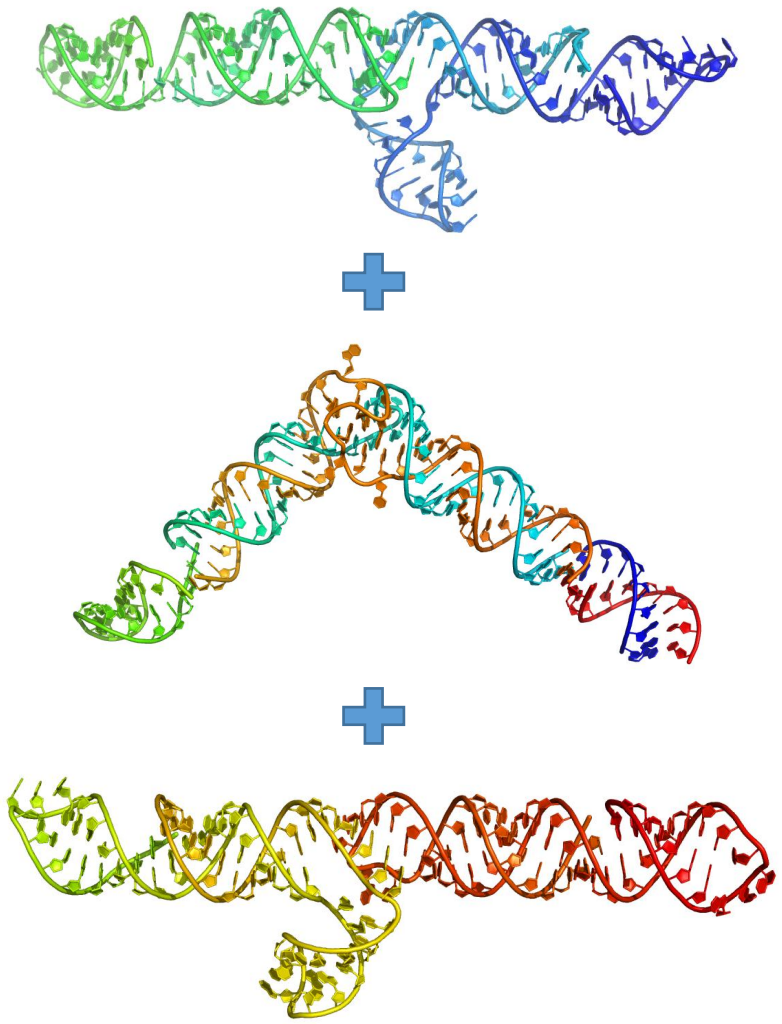




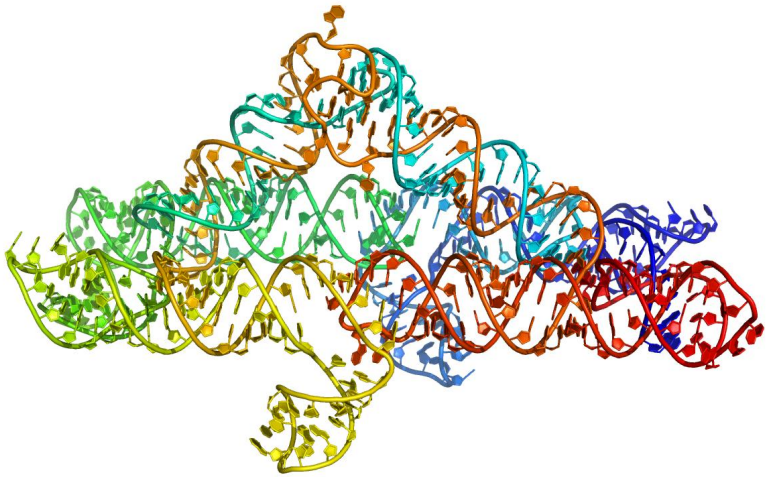
modeling order



Motif assembling (R1126)



assembling

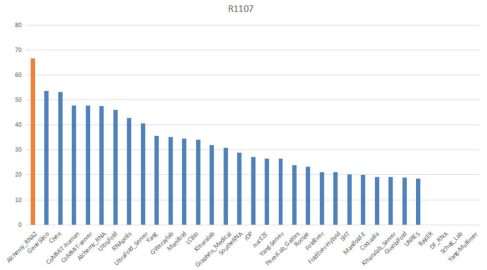


global refinement

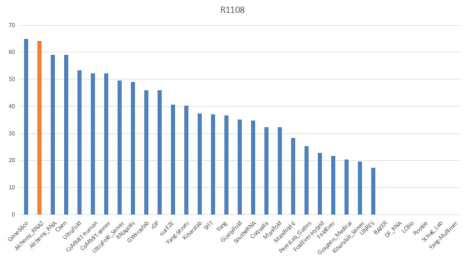
BRiQ vs. AMBER

	BRiQ	AMBER
non-polar interactions	Electron cloud surface Empirical score	Lennard-Jonse potential
polar interactions	3D statistical energy 6D statistical energy	Coulomb interactions Partial charge model
bonded interactions	Backbone rotamer energy Statistical torsion energy	Energy for bond length, bond Angle and dihedral angle
solvation	not considered	Explicit solvation model
differentiable	no	yes
structure sampling	Monte Carlo sampling	Molecular dynamics sampling

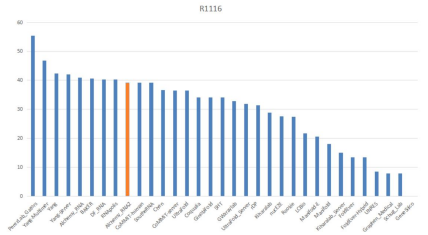
Performance of BRiQ (GDT_TS of best model)



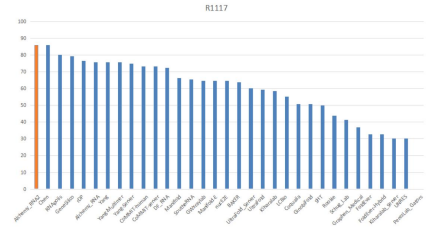
R1107



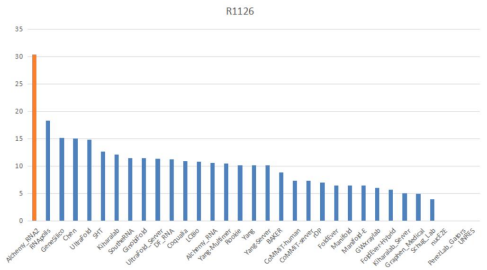
R1108



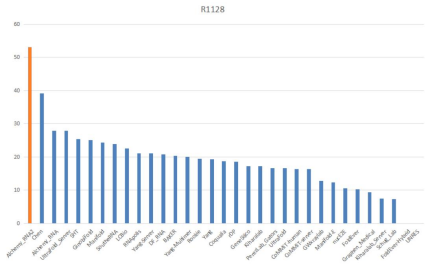
R1116



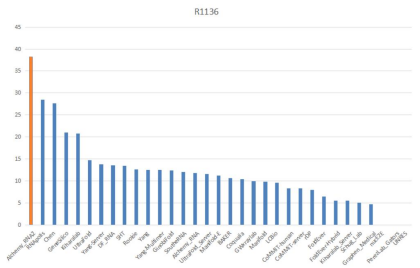
R1117



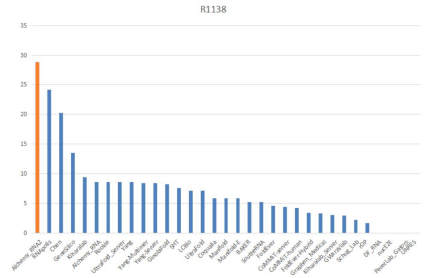
R1126



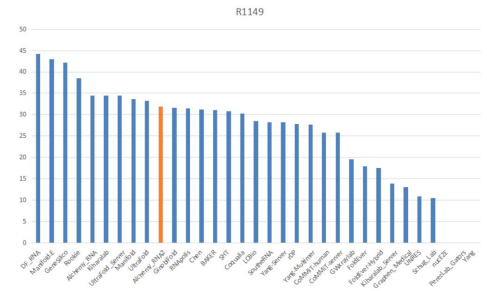
R1128



R1136



R1138



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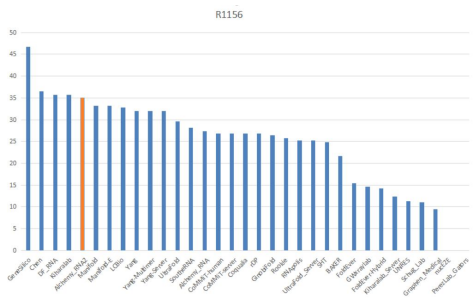
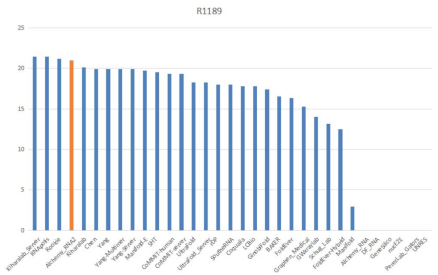
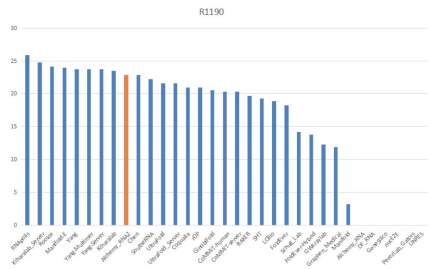


R1156



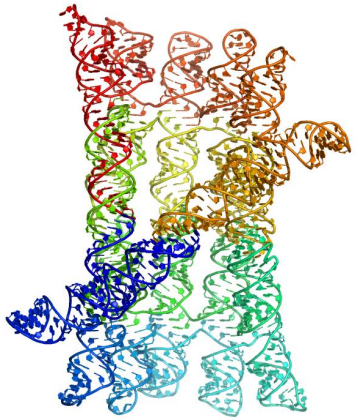
R1189

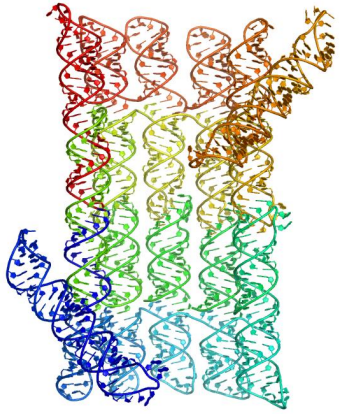


R1190

R1138

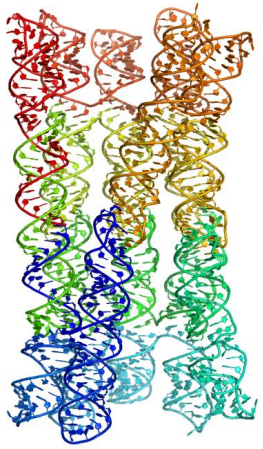
Young

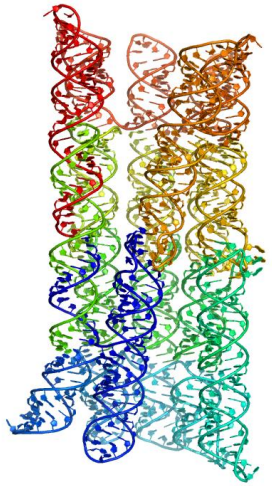




It’s more like a infant model

Mature

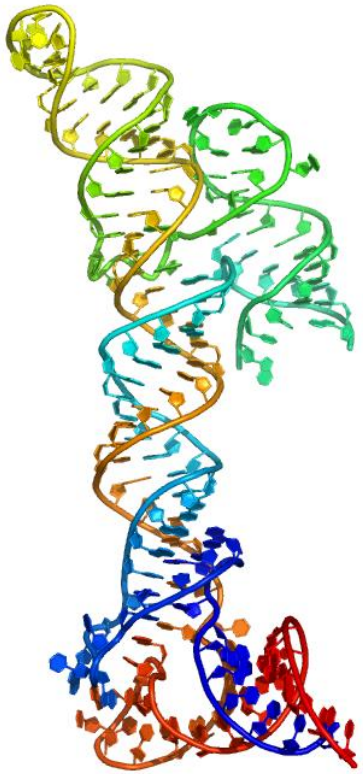




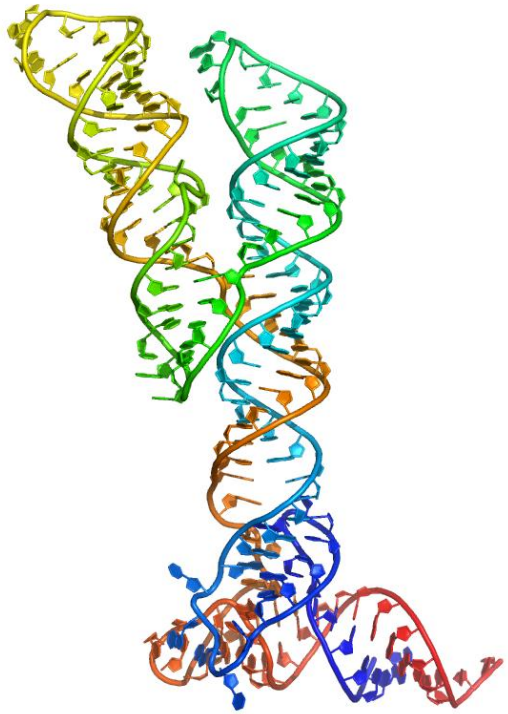
EM models

predicted models

R1116



Our energy function can’t distinguish these two topologies



X-Ray Crystal model

predicted model

Acknowledgment

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Prof. Zhou Yaoqi

Zelixir cofounders