

RNA Free Energy: Stacking Energies

The purpose of this interactive is to teach how to use the Turner Energy Rules to determine the total Free Energy of a given RNA structure. The lowest free energy structure is the preferred prediction, since it is the most theoretically stable structure. In this exercise, you learn how to use the rule to figure out the energy of just one possible structure. Often there would be multiple possible structures for the same sequence and the lowest free energy “wins”!

The upper table shows the free energies of base pairs stacked on top of one another.

Turner Energy Rules

		TOP					
		AU	CG	GC	UA	GU	UG
B O T T O M	AU	-0.9	-1.8	-2.3	-1.1	-0.5	-0.7
	CG	-2.1	-2.9	-3.4	-2.3	-1.5	-1.5
	GC	-1.7	-2	-2.9	-1.8	-1.3	1.9
	UA	-0.9	-1.7	-2.1	-0.9	-0.7	-0.5
	GU	-0.9	-1.7	-2.1	-0.9	-0.5	-0.5
	UG	-0.9	-1.7	-2.1	-0.9	0.6	-0.5

Bases in Loop	Internal Loop	Bulge Loop	Hairpin Loop
1	0	3.3	0
2	0.8	5.2	0
3	1.3	6	7.4
4	1.7	6.7	5.9
5	2.1	7.4	4.4
6	2.5	8.2	4.3
7	2.6	9.1	4.1
8	2.8	10	4.1

Reset
Quiz Mode

AA
4.3

G G A
-2.3

G G
2.5

GC
-1.7

C C
-2.1

G A
-0.9

C U
-0.5

AU
5.2

GC
-0.9

UA
5.2

GU
-0.9

G |
-0.9

U |
5.2

AU
-0.9

A |
5.2

A |
-0.9

UA
-0.9

UG
-0.9

3'U
G5'
RNA Free Energy:

7.9

Energy of A-U pair “stacked” over a G-C pair

RNA Free Energy: Other structural elements

This method works best for predicting hairpin RNA structures. Note how there is a loop at the top of the structure of unpaired bases. Hairpin loops, bulges and internal loops tend to “destabilize” the structure and raise the free energy. Notice all the positive numbers in the lower table.

Turner Energy Rules

		TOP					
		AU	CG	GC	UA	GU	UG
BOTTOM	AU	-0.9	-1.8	-2.3	-1.1	-0.5	-0.7
	CG	-2.1	-2.9	-3.4	-2.3	-1.5	-1.5
	GC	-1.7	-2	-2.9	-1.8	-1.3	1.9
	UA	-0.9	-1.7	-2.1	-0.9	-0.7	-0.5
	GU	-0.9	-1.7	-2.1	-0.9	-0.5	-0.5
	UG	-0.9	-1.7	-2.1	-0.9	0.6	-0.5

	Internal Loop	Bulge Loop	Hairpin Loop
1	0	3.3	0
2	0.8	5.2	0
3	1.3	6	7.4
4	1.7	6.7	5.9
5	2.1	7.4	4.4
6	2.5	8.2	4.3
7	2.6	9.1	4.1
8	2.8	10	4.1

Reset Quiz Mode

AA
G A
G G

4.3

GC
C C
G A
C U

-2.3
2.5

G
U

5.2

AU	-1.7
GC	-2.1
UA	-0.9
GU	-0.5

G	5.2
U	5.2

AU	-0.9
A	5.2
A	5.2
UA	-0.9
UG	-0.9

3'U G5' RNA Free Energy:

7.9

The lower table shows the free energies of other RNA structural elements.

This is a 6-base hairpin loop

6-base internal loop

2-base bulge (very unstable)

RNA Free Energy: Final Free Energy

The example below shows how the stacking energy is calculated AROUND a 2-base bulge. Use the same approach for internal loops.

The total Free Energy for the given structure is the SUM of all the free energies for every element in the structure.

Turner Energy Rules

		TOP					
		AU	CG	GC	UA	GU	UG
B O T T O M	AU	-0.9	-1.8	-2.3	-1.1	-0.5	-0.7
	CG	-2.1	-2.9	-3.4	-2.3	-1.5	-1.5
	GC	-1.7	-2	-2.9	-1.8	-1.3	1.9
	UA	-0.9	-1.7	-2.1	-0.9	-0.7	-0.5
	GU	-0.9	-1.7	-2.1	-0.9	-0.5	-0.5
	UG	-0.9	-1.7	-2.1	-0.9	-0.5	-0.5

Bases in Loop	Internal Loop		
1	0	3.3	0
2	0.8	5.2	0
3	1.3	6	7.4
4	1.7	6.7	5.9
5	2.1	7.4	4.4
6	2.5	8.2	4.3
7	2.6	9.1	4.1
8	2.8	10	4.1

Reset Quiz Mode

RNA Free Energy: 7.9

This is the free energy of the base pairs (G-U and A-U) stacked around a 2-base bulge.

RNA Free Energy: This is the total (SUM) for the entire structure.