APPENDIX 2: Schematic Diagrams of Secondary and Tertiary Structure Elements

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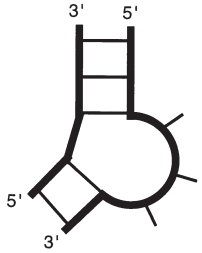
Figure 1 Elements of RNA secondary structure. A secondary structure can be divided into single-strand regions, helices, bulges, hairpin loops, internal loops, and junctions. The distinction between a single-strand region and a bulge, loop, or junction is that in a single strand the ends are not constrained. In contrast, the ends of bulges, loops, or junctions must be in a tightly limited volume. Single-strand regions next to helices are dangling ends; the dangling nucleotide may be on a 5′ end, or a 3′ end. A dangling mismatch is produced by apposing 5′ and 3′ dangling nucleotides. The figure is a slightly modified version of Figure 1, with permission from Nowakowski and Tinoco, *Seminars in Virology* **8:** 153–165 (1997).

single strand

A-form double helix

Double helix with
5'-dangling end

single nucleotide bulge

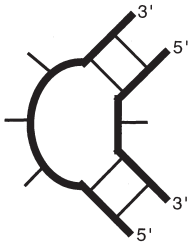


three nucleotide bulge

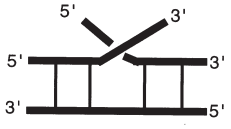
hairpin loop

mismatch pair
or, symmetric internal
loop of 2 nucleotides

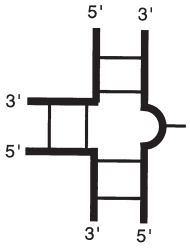
symmetric internal loop



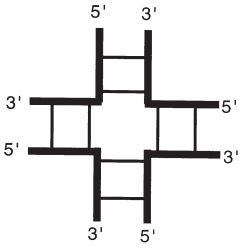
asymmetric internal loop



two-stem junction
or, coaxial stack



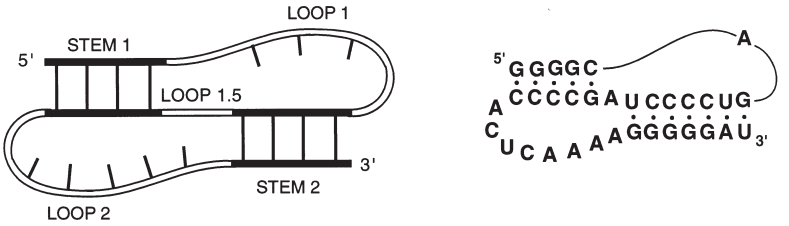
three-stem junction



four-stem junction

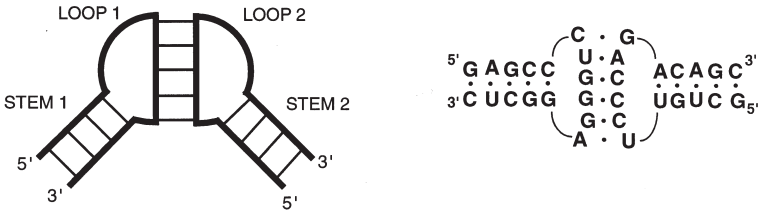
Figure 2 Some elements of RNA tertiary structure. Secondary structure elements can interact to form tertiary structure elements. (*a*) A pseudoknot is formed when a single strand folds to base-pair with a hairpin loop. In the pseudoknot shown (from mouse mammary tumor virus [Shen and Tinoco, *J. Mol. Biol.* **247:** 963–978 [1995]) both loop 1 and loop 1.5 consist of a single adenylate nucleotide. (*b*) Two hairpin loops can base-pair to form kissing hairpins; the kissing hairpin can be intramolecular or intermolecular. The sequence shown is the TAR loop from HIV-1 paired to a complementary loop (Chang and Tinoco, *J. Mol. Biol.* **269:** 52–66 [1997]). (*c*) A hairpin loop can interact with an internal loop as shown for the GAAA tetraloop docked into its receptor from the P4-P6 domain of the *Tetrahymena thermophyla* group I intron (Cate et al., *Science* **273:** 1678–1685 [1996]). The interaction involves stacking of the loop As on the A-platform of the receptor, plus base triple formation. The figure is a slightly modified version of Figure 2, with permission from Nowakowski and Tinoco, *Seminars in Virology* **8:** 153–165 (1997).

a)



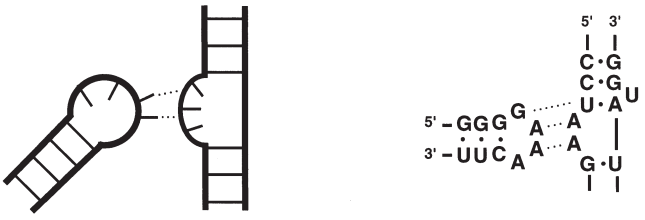
Pseudoknot

b)



Kissing hairpins

c)



Hairpin loop - bulge contact