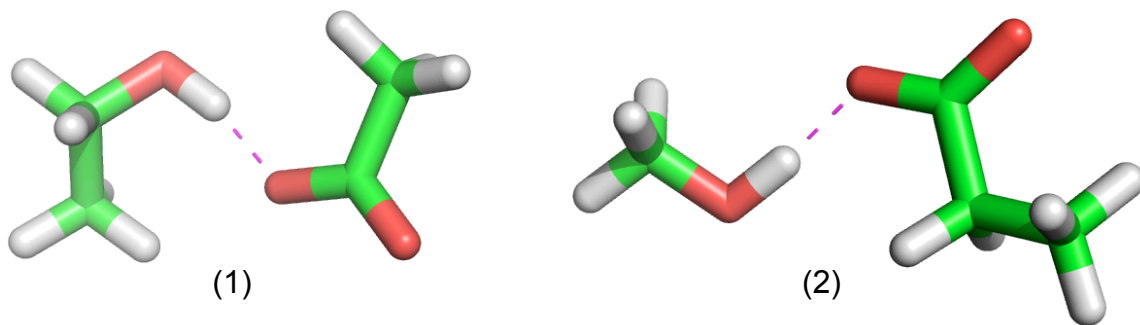
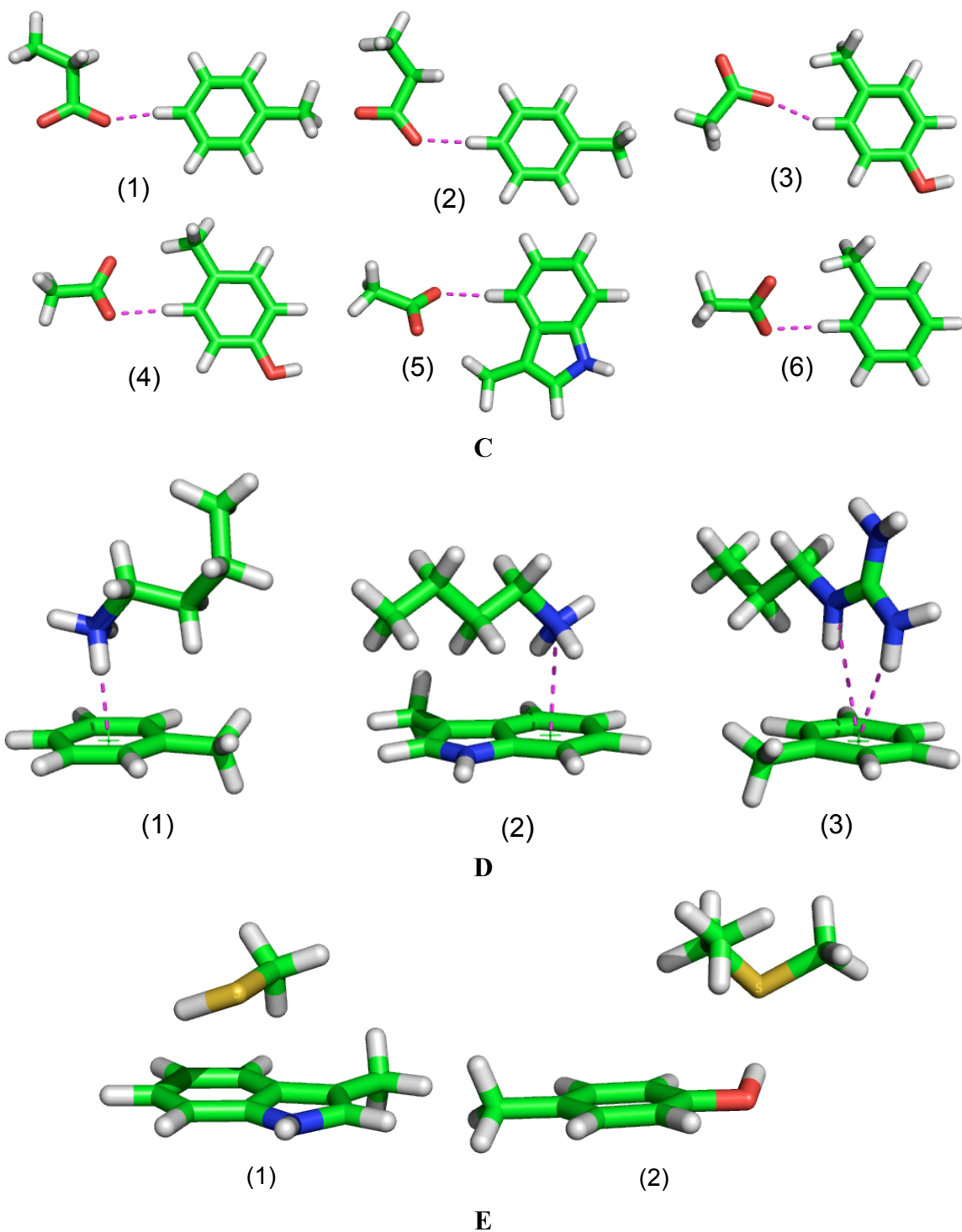


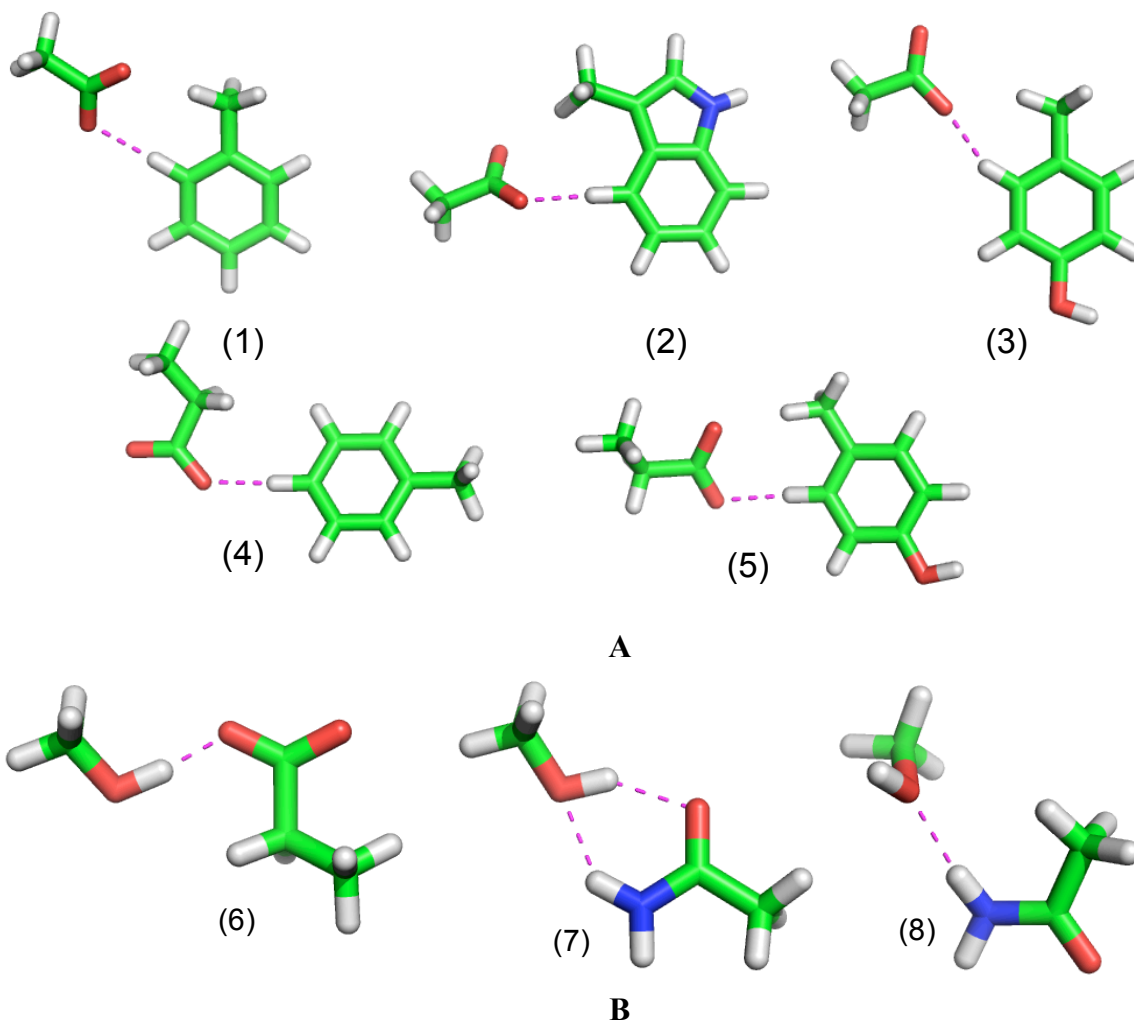
A



B



**Figure S1.** Representative structures of four types of outliers. **A:** stacked rings. (1) Trp\_Trp\_4, (2) Tyr\_Tyr\_3, (3) Tyr\_Trp\_2, (4) Phe\_Tyr\_7, (5) Phe\_Trp\_5, (6) Phe\_Trp\_1, (7) Phe\_Phe\_4, (8) Phe\_Trp\_4. **B:** Strong hydrogen bonds. (1) Thr\_Asp\_2, (2) Ser\_Glu\_2. **C:** ion-rings (in plane): (1) Glu\_Phe\_1, (2) Glu\_Phe\_5, (3) Asp\_Tyr\_4, (4) Asp\_Tyr\_1, (5) Asp\_Trp\_3, (6) Asp\_Phe\_1. **D:** ion-rings (off plane): (1) Lys\_Phe\_2, (2) Lys\_Trp\_4, (3) Arg\_Phe\_3. **E:** Sulfur-containing molecules: (1) Cys\_Trp\_2, (2) Met\_Tyr\_2.



**Figure S2.** Representative amino acid analog pairs that have strong  $n \rightarrow \sigma^*$  interactions. **A:** Hydrogen-bond-like interactions formed between an aromatic and a negatively charged residues: (1) Asp\_Phe\_1, (2) Asp\_Trp\_3, (3) Asp\_Tyr\_4, (4) Glu\_Phe\_5 and (5) Glu\_Tyr\_3. **B:** Hydrogen-bond interactions: (6) Ser\_Glu\_2, (7) Ser\_Asn\_1 and (8) Ser\_Asn\_2.