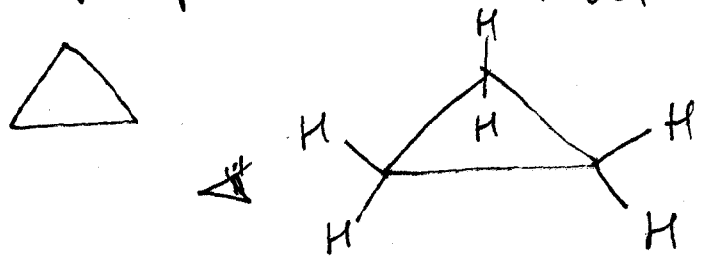
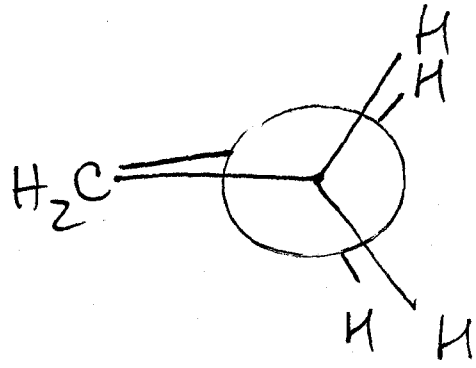
cyclopropane – flat.





all eclipsed

very strained molecule

What is "ring strain"?

Two components.

1. angle strain – caused by distortion of bond angles away from tetrahedral.
   (cyclopropane: 60° vs 109.5°)
2. steric strain – caused by eclipsing hydrogens / substituents

how can we quantify this?

we can measure the heat of combustion for straight-chain alkanes. For every CH_2 added to the chain, $\Delta H°$ increases by about 157 kcal/mol.

propane: $\Delta H = -530.6$

butane: -687.4

pentane: -845.2

Since cyclic alkanes have formula $(CH_2)_n$ we should be able to predict ΔH for combustion

Ring	Predicted	Observed	Δ
cyclopropane	−472.2 kcal/mol	−499.8	27.6 kcal/mol
cyclobutane	−629.6	−655.9	26.3
cyclohexane	−944.4	−944.5	0.1

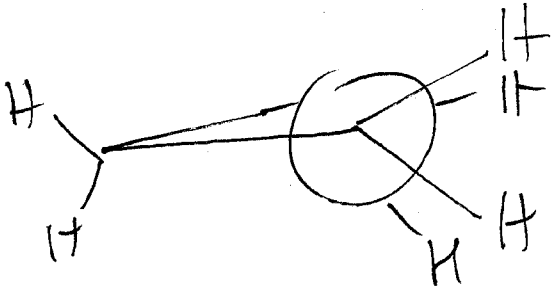
↑ ring strain

Look @ lots of examples:

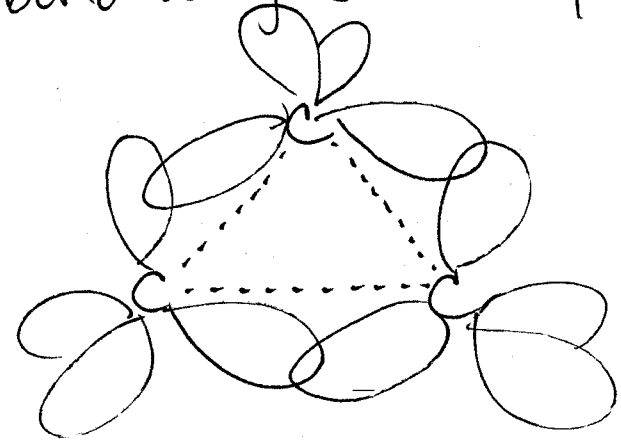
- small rings (3,4) – highly strained
- common rings (5,6,7) – little strain
- medium rings (8-12) – strained
- large rings (>12) – little strain

---

cyclopropane



60° bond angles – very distorted.



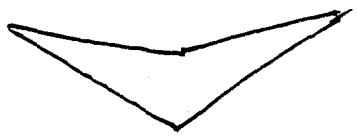
"banana bonds"

C-C bonds in cyclopropane are relatively weak (not formed by max. orbital overlap)

ΔH° (bond strength) = 65 kcal/mol

Compare: 90 kcal/mol in ethane

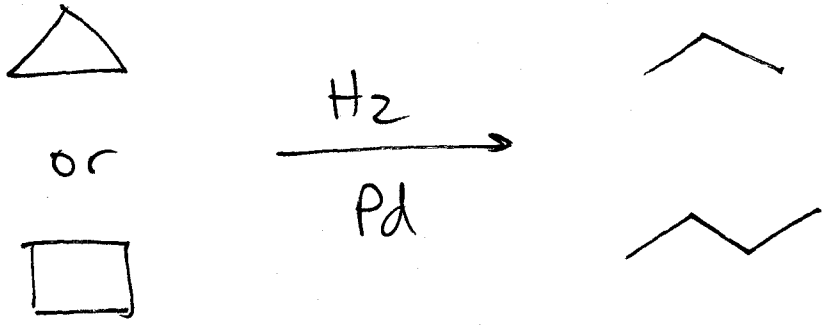
cyclobutane - not planar - puckered



bent 26° out of planarity.

- decreases bond angles (thereby increases that component of ring strain)
- lets H's get away from being eclipsed (decreases the steric/torsional strain)

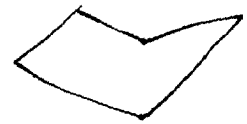
$\Delta H^\circ = 63 \text{ kcal/mol}$



Cyclopentane

might be expected to be planar (108° bond angles) – but the steric/torsional strain would be very high.

Instead, it is also puckered.



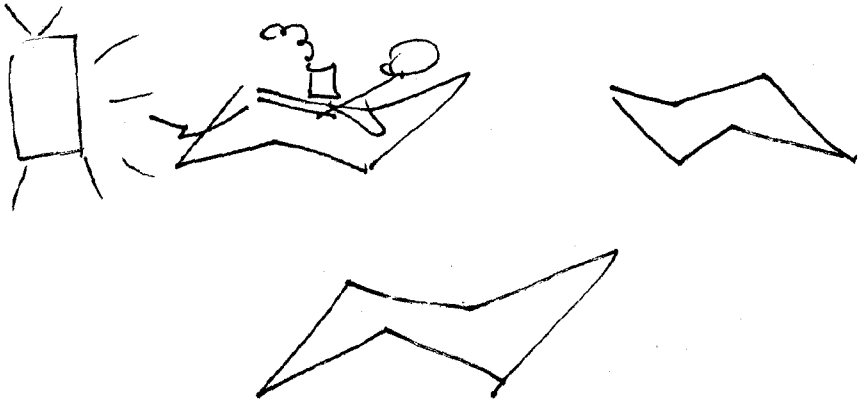
This increases the angle strain somewhat, but greatly decreases the steric strain.

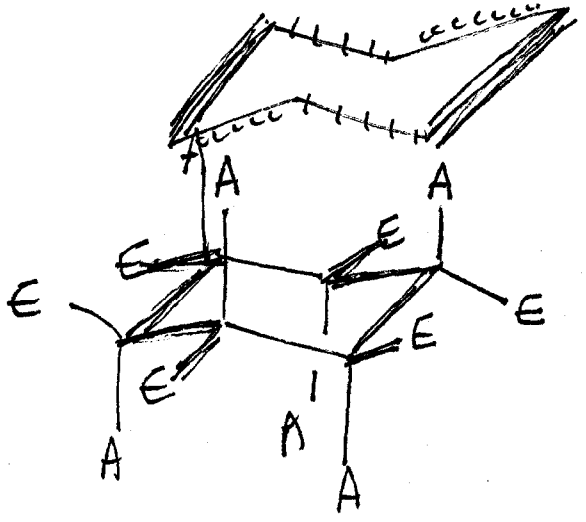
Overall – very little strain.

Cyclohexane

Strain-Free

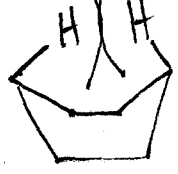
most stable conformation called "chair" –
tetrahedral bond angles
zero eclipsing interactions.

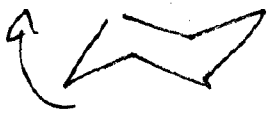




conformational change -

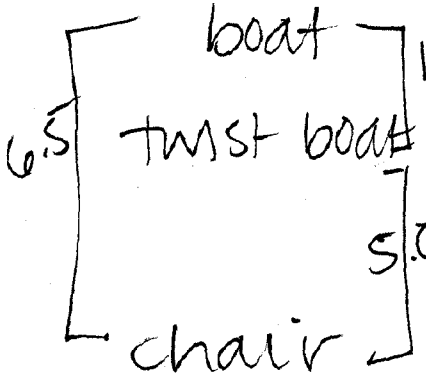
chair → boat



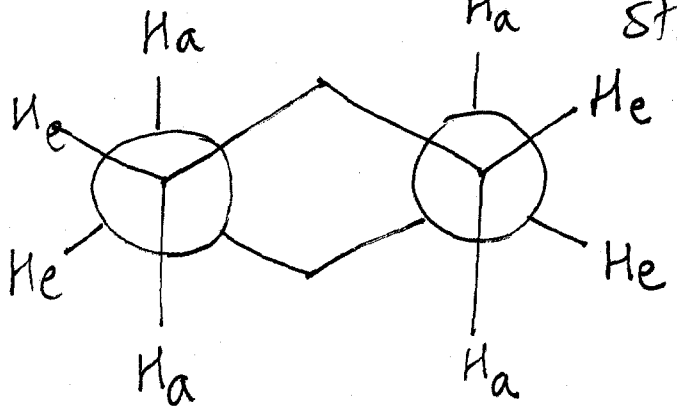


bowsprit H's -

steric problems. (transannular strain)

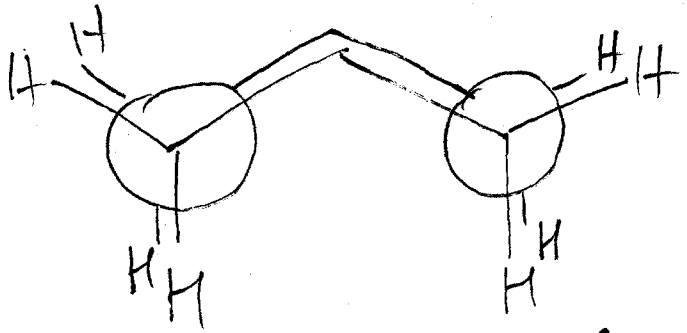


chair →



all staggered

boat →



all eclipsed

"ring flip" - convert one chair into the other

this interconverts axial + equat