Recall: 'H NMR spectroscopy → signals for all 'H atoms in a molecule: VERY powerful for organic molecule structure determination.

Key question — for a given pair (or larger set) of 'H's — one NMR signal vs. multiple signals??

To answer: Learn to class 'H's w/in a molecule as §10.8. Equivalent vs. Non-equivalent (Homo, Enantiom & Diastereotopic)

Illustrative examples:
1. CH₃CH₃ — All 'H's equivalent to one another (one 'H NMR signal)

   "Substitution test"

   \[
   \begin{array}{c}
   H \quad H \\
   / \quad / \\
   1 \quad 1 \\
   H \quad H
   \end{array}
   \]

   \[
   \begin{array}{c}
   F \quad H \\
   / \quad / \\
   1 \quad 1 \\
   H \quad H
   \end{array}
   \] vs. H-C-C-H vs. etc.

2. Propane = CH₃CH₂CH₃

   2 kinds of 'H's — CH₃ vs. CH₂

   All 6 methyl 'H's are enantiotopic. Both methylene 'H's are enantiotopic & CH₃ 'H's non-equivalent to CH₂ 'H's.
Predict 2°H NMR signals.

3. Butane = CH₃CH₂CH₂CH₃
   2 Kinds of H, CH₃ vs. CH₂
   All CH₃ H's (6) Homotopic
   CH₃ non-equivalent to CH₂
   H's on each CH₂ are enantiotopic.

Relationship between "enantiotopic" & "# of NMR signals"?
If environment (e.g., solvent) is achiral ⇒ Enantiotopic H's are NMR equivalent.

4. H₃C-C-CH₂CH₃ ⇒ 5 Kinds of H
   - 3 H's on C₁ are homotopic
   - 3 H's on C₄ are homotopic
   - C₁ H's non-equiv. rel to C₄
- Lone H on C2 is unique.
  The 2 H's on C3 are diastereotopic — non-equivalent in 1H NMR spectrum.

Cholesterol: 36 different kinds of H's!
- 5 CH3 groups are non-equivalent to one another
  [Note: CH3's at right side are diastereotopic]
- 11 CH2 groups; in every case, the two H's are diastereotopic.

What does NMR measure?
⇒ Nuclear spin.
Nuclei are charged (+); spin leads to magnetic field.
For 1H nuclei, 2 spin states, +1/2 vs. -1/2.
Usually, these two states are indistinguishable (same energy).
But, in a strong magnetic field, the two spin states have different energies → leads to possibility of NMR

Graphical convention:

\[ E \uparrow \uparrow \uparrow \uparrow \uparrow \ \\
\text{Apply \ strong \ mag. \ field} \ \\
\text{6 H nuclei w/ spin field} \ \\
+\frac{1}{2} (\uparrow) \text{ or } -\frac{1}{2} (\downarrow) \ (\text{mag. field} (B_0)) \ \\
\]

NMR measurement — determine energy (radio freq. range) required for "spin flip" of nuclei (\( \uparrow \rightarrow \downarrow \))
Abs. of radio freq. radiation by the sample (requires ext. mag. field)—"nuclear magnetic resonance"
Non-equiv. H's w/in a molecule experience different local magnetic environments → different energies (spin flip)