1. (20 points) A protein structure can be described at four levels: a) primary structure, b) secondary structure, c) tertiary structure, and d) quaternary structure. Provide a brief definition for each level.

2. (30 points) The backbone conformation of a protein structure can be defined by three main chain torsional angles (also known as dihedral angles) $\phi$, $\psi$, and $\omega$.
   a) Illustrate the backbone dihedral angles ($\phi$, $\psi$, and $\omega$) using schematic drawing of a tripeptide.
   b) Name two or more secondary structures in proteins. Discuss their main structural features and stabilizing factors.
   c) The Ramachandran diagram plots the backbone dihedral angles ($\phi$, $\psi$) of a protein structure. On a $\phi$–$\psi$ plot (provided in Fig. 1), label the preferred regions corresponding to two types of secondary structures named in 2b).

3. (25 points) Name three major experimental techniques that have been used to determine protein structures. Discuss the strengths and limitations of each method.

4. (25 points) Write a paragraph that best describes the protein structure complex represented by ribbon diagrams in two different views in Fig. 2, including protein fold(s) and secondary structures in each subunits as well as structural arrangement of subunits in the 3D space.

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Fig. 1. Distribution of backbone torsional angles ($\phi$, $\psi$) of all residues but Gly (blue dots) in 207 high-resolution protein structures from PDB. Green shaded regions outline allowed regions.

Fig. 2. Ribbon diagram of the crystal structure of transducin ($\beta$ subunit in green; $\gamma$ subunit in cyan) in complex with its regulator (in magenta). PDB ID: 2TRC. Left: the front view; right: the side view as indicated by the shaded arrow.