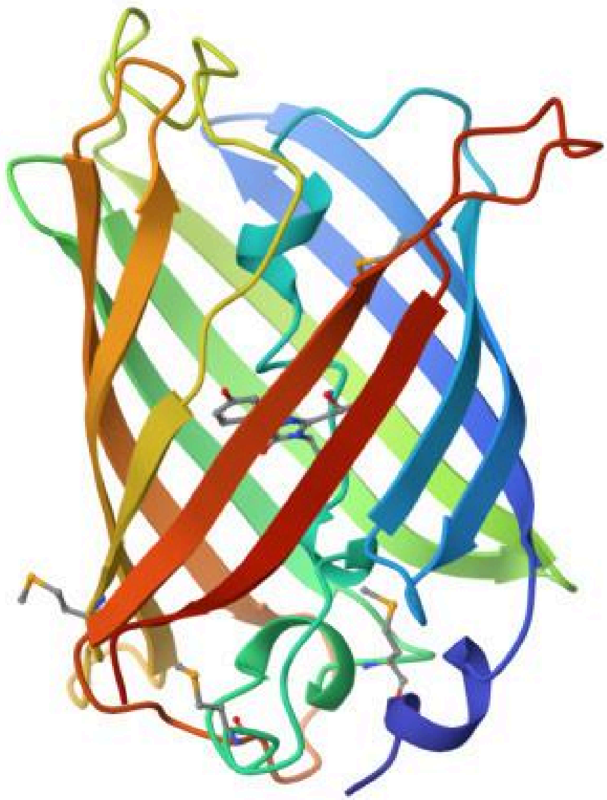
Exploring Green Fluorescent Protein

Tutorial



Green Fluorescent Protein (GFP) is a well-studied protein that exhibits fluorescence when exposed to ultraviolet or blue light, making it a powerful tool in molecular biology and biotechnology.

Learn how to explore GFP using tools from the RCSB PDB with this tutorial.

RCSB PDB-101

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RCSB PDB PROTEIN DATA BANK

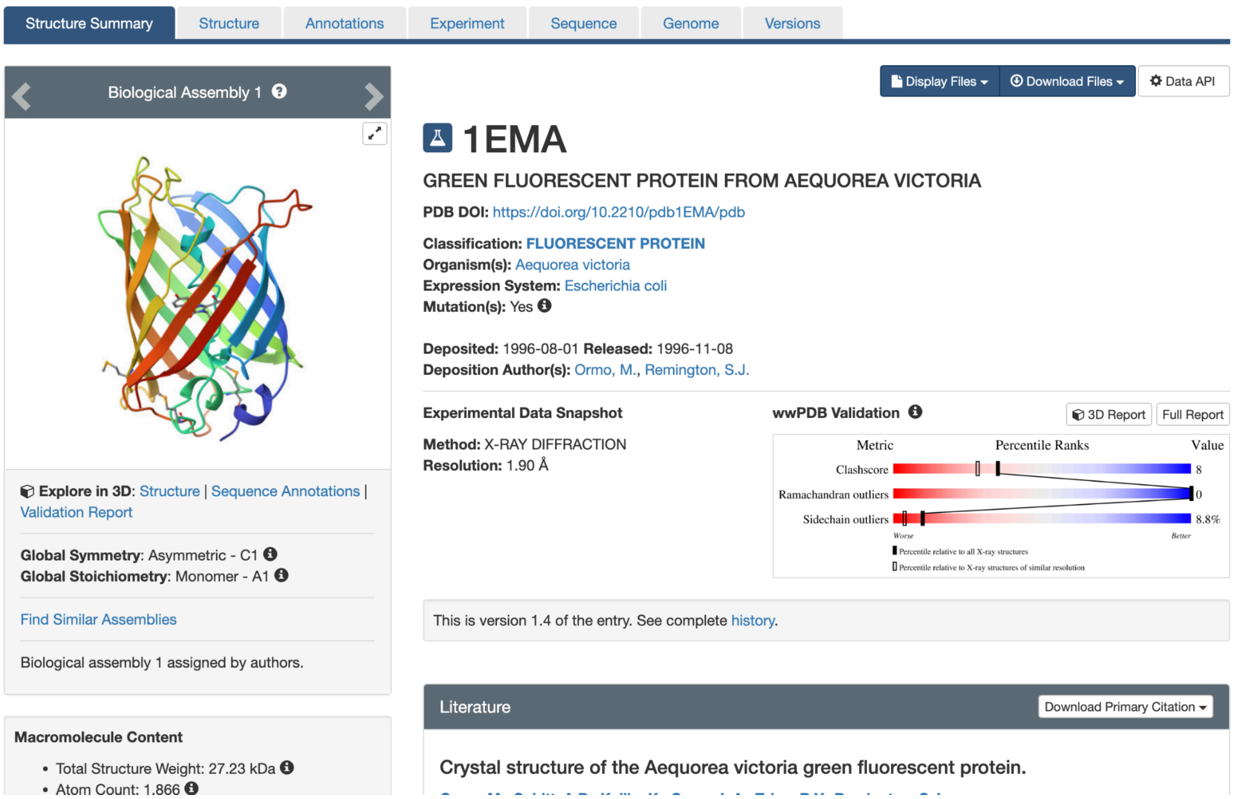
Tutorial Tasks:

Task 1: Find structures of green fluorescent protein at the RCSB PDB website

1. Go to the RCSB PDB website to begin.
2. Search by typing the phrase "green fluorescent protein" in the text box on the search bar at the top of the home page.
3. Select "green fluorescent protein" from the "in UniProt Molecule Name" list.
4. The results page will contain a list of entries related to GFP.

Task 2: Explore the details of entry 1ema

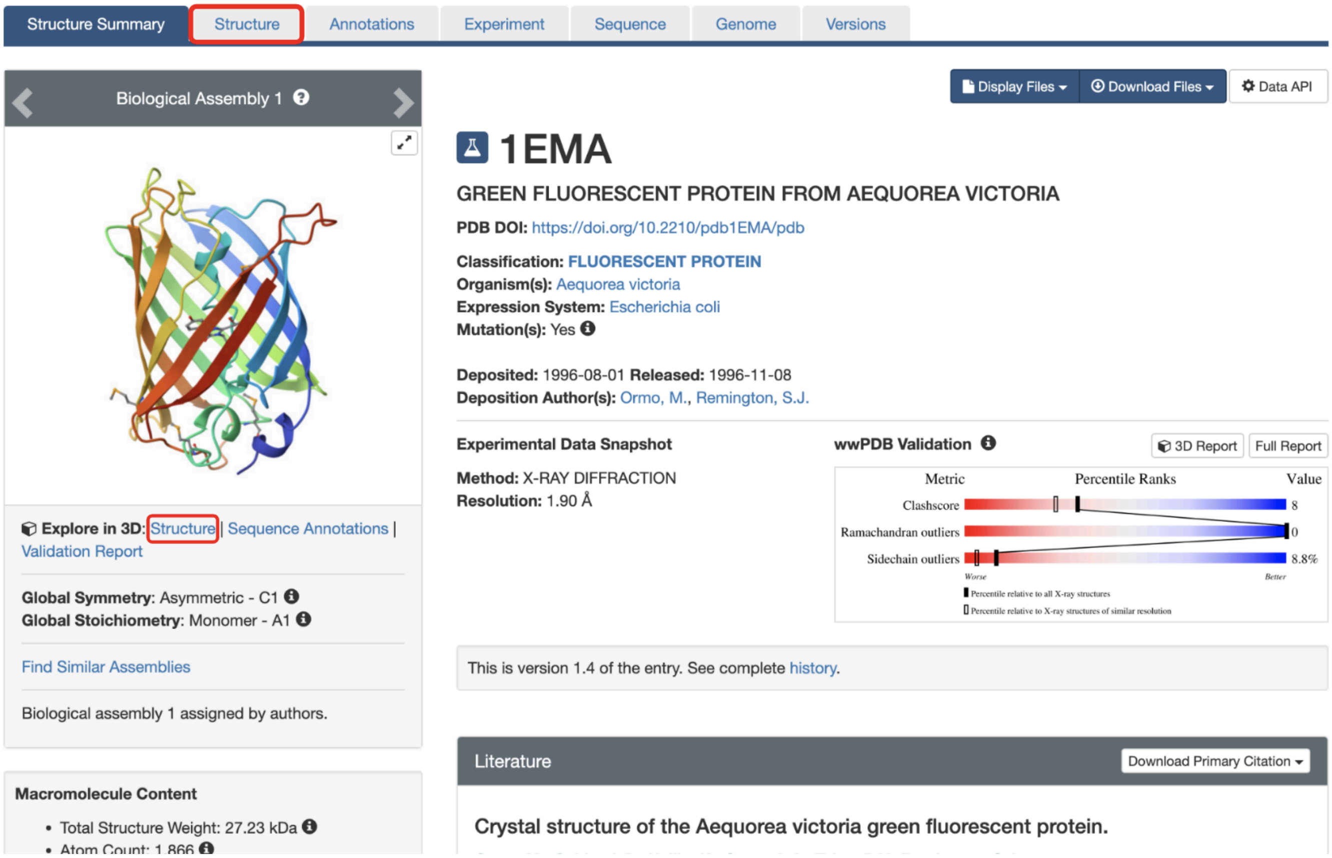
1. Scroll down the list to entry **1ema** and click on the title, PDB ID, or image to view the protein's details on the **Structure Summary Page**. This entry contains a protein that was taken from the jellyfish *Aequorea victoria* with PDB ID **1ema**[1]. You can also enter the ID **1ema** directly into the search bar.
2. This will take you to the **Structure Summary page**. In this page, you will find:
   - Basic Information: protein name, organism, structure resolution, etc.
   - Structure Image: a 3D image of the protein.
   - Experimental Details: information about how the structure was determined.
   - Related Literature: links to publications associated with the structure.
   - Download Options: download the structure (coordinate) file for further analysis.



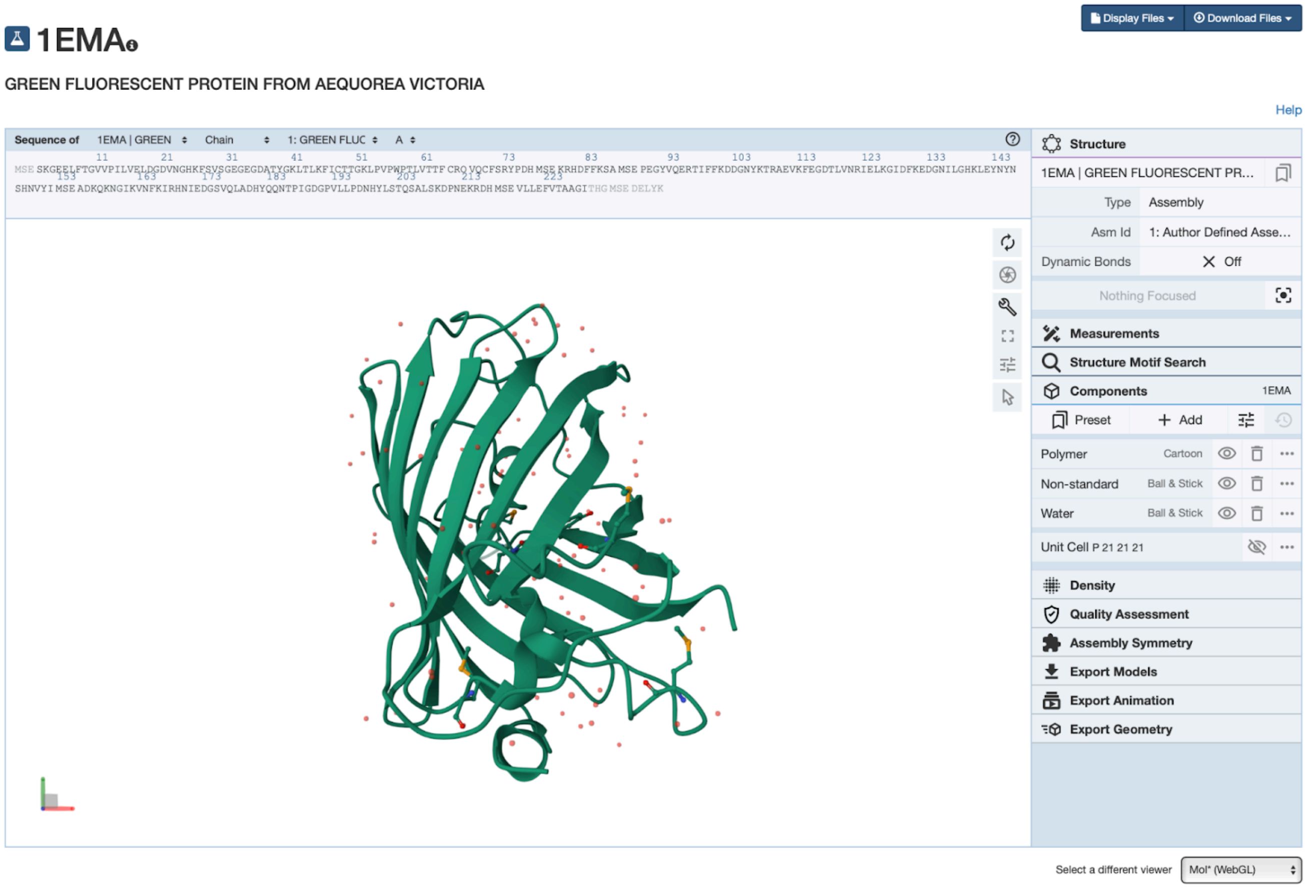
Task 3: Explore the GFP structure using Mol*

Now, let's take a look at the GFP structure in close detail.

To launch **Mol***, click on **Structure** in the **Explore in 3D** section below the image or the **Structure** tab at the top of the page.

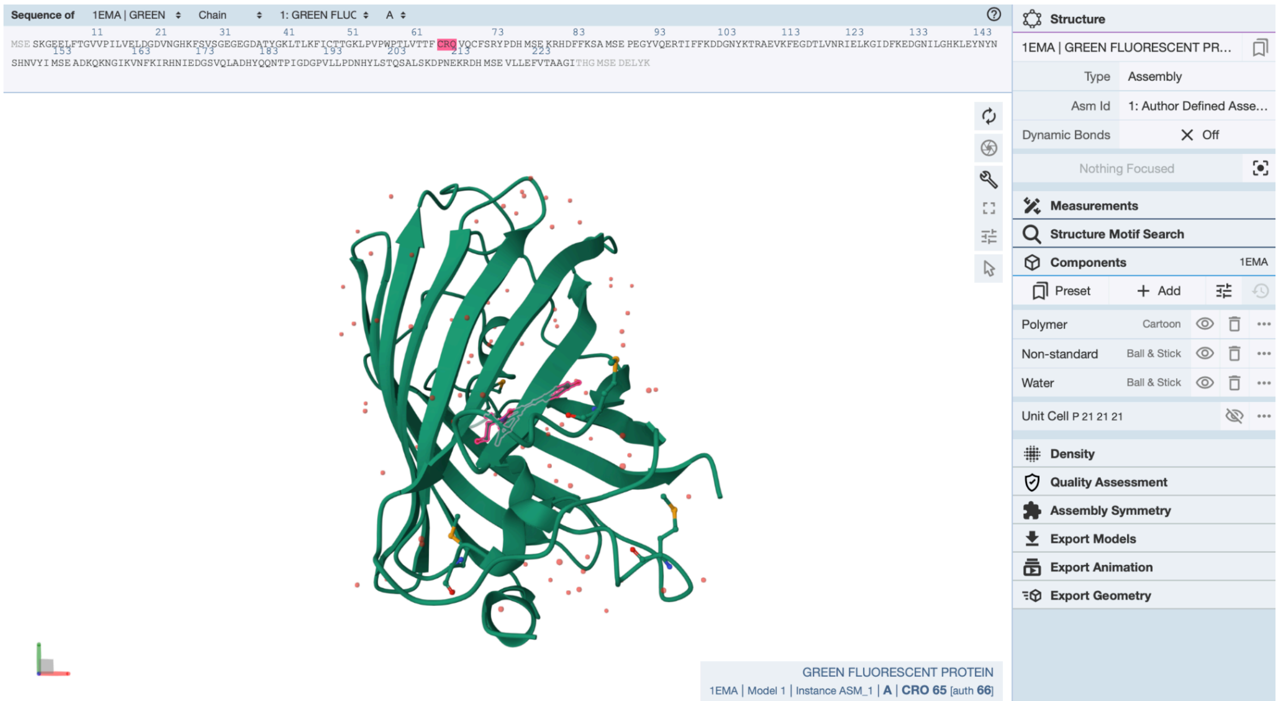


This will open the Mol* interactive viewer and interface.



At the top of the viewer, just above the 3D molecular image, you will find a display of the amino acid sequence. When you click on an amino acid residue in the sequence at the top, the corresponding residue in the 3D structure will be highlighted. This allows you to easily navigate between the sequence and structure to see exactly where specific residues are located in the folded protein.

For example, if you click on **CRO 65** in the sequence, you'll see the corresponding residue in the 3D structure highlighted, allowing you to explore its position relative to other residues.



You can select a range of residues in the sequence, and the corresponding region of the protein will be highlighted in the 3D viewer. This is particularly useful if you want to focus on specific regions of the protein, such as the chromophore pocket or an active site.

The 3D structure will be shown in parallel with the sequence, allowing the observation of how the linear sequence folds into its three-dimensional structure. This helps in understanding how certain motifs or specific residues (such as the chromophore-forming residues) play a role in the protein's function.

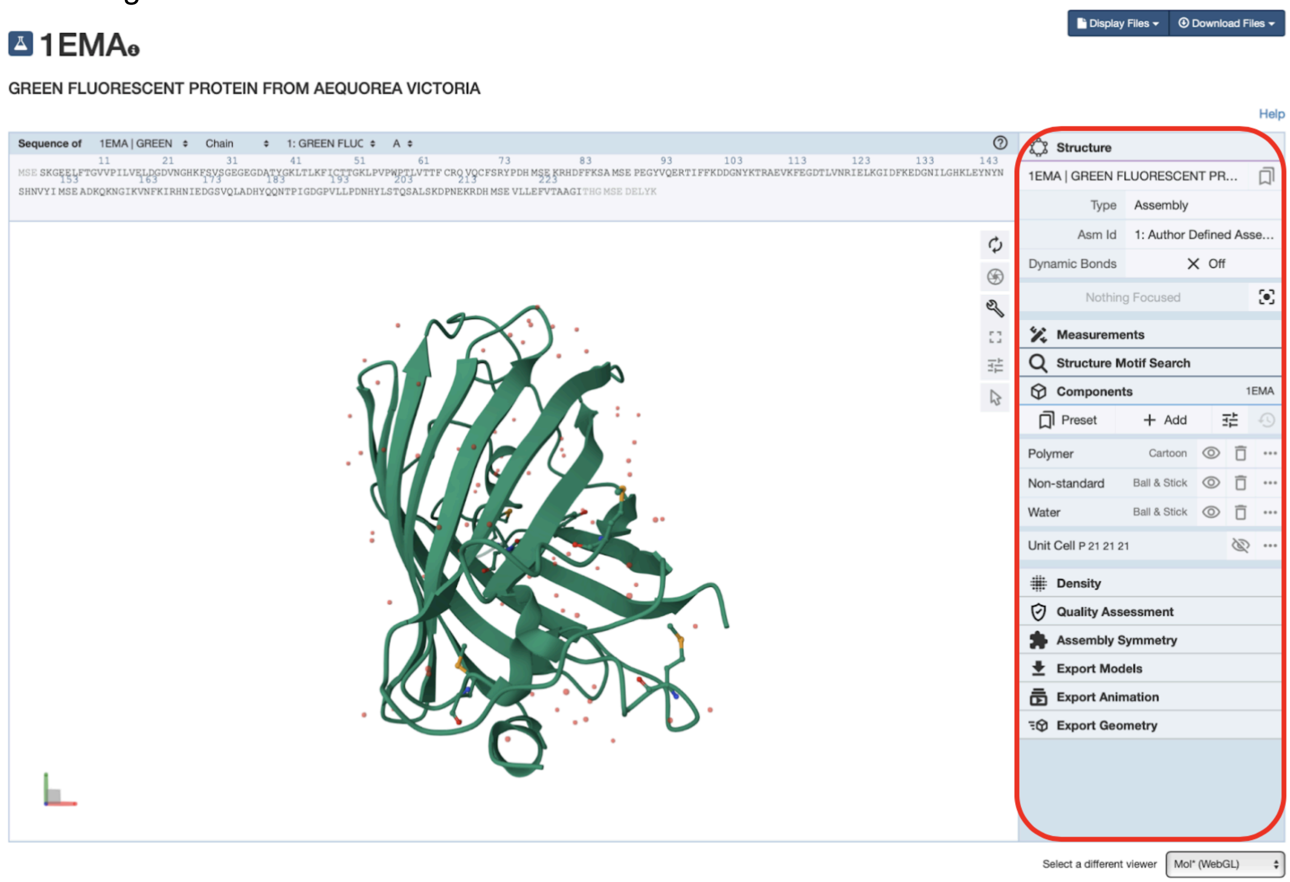
Mol* automatically displays a ribbon representation of the protein structure. This representation represents the polypeptide chain of the protein, but uses flat arrows to show beta strands and curly ribbons to show alpha helices.

Topics for Further Discussion

- Learn about the Green Fluorescent Protein featured in the Molecule of the Month section on the PDB-101 website.
- Build paper models of Green and Red Fluorescent Proteins and compare their structures.

Task 4: Different ways of looking at GFP in Mol*

On the right of the Mol* interface is the **Control Panel**.



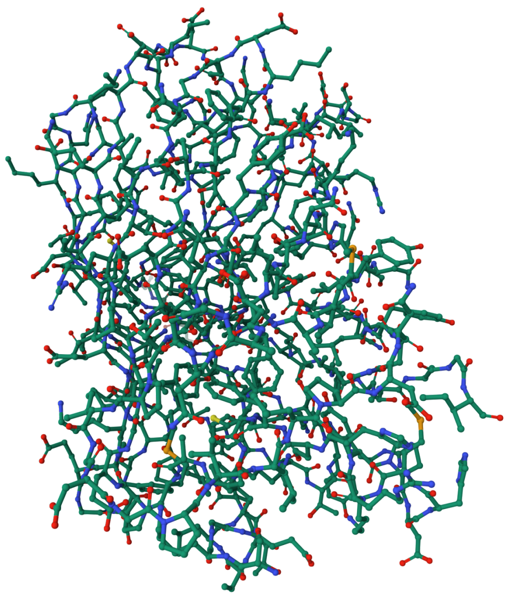
This panel controls the visual representation of the structure and includes options to change how the protein is displayed. It also provides access to important tools for highlighting and analyzing specific parts of the protein structure, making it easier to navigate and manipulate the 3D model.

Let's switch to a view that shows all atoms and bonds in a ball-and-stick representation.

1. In the **Control Panel**, locate the **Components** section.
2. In the **Non-standard** and **Water** components sections, click on the eye icons  . This will remove any non-standard molecules or water from the display, focusing on the main protein structure.
3. With the **Polymer** component remaining visible, look for the three dots next to it.
4. Click on the three dots to reveal a dropdown menu.
5. In the dropdown menu, select **Cartoon Representation** to expand another menu.
6. In the **Type** section, click on **Cartoon** to see that the default **Cartoon** representation is selected.
7. Select **Ball & Stick** from the dropdown to switch to a ball-and-stick view. This will display the atoms and bonds in a more detailed, atomic model representation.

8. Again in the Polymer component, select **Set Coloring** to reveal another dropdown menu.
9. In the dropdown menu, select **Atom Property** to bring up a further set of options.
10. Click on **Element Symbol**. This will color the atoms based on their element.

Once you've completed these steps, you should see the structure displayed with atoms as balls and bonds as sticks, with a color scheme highlighting the individual atoms. This will allow you to explore the detailed atomic structure more easily.



Each sphere represents an atom, and the lines between these atoms represent covalent bonds.

The colors of the atoms are as follows:

- Green is Carbon
- Blue is Nitrogen
- Red is Oxygen
- Yellow is Sulfur

Let's get a better look at the protein structure with all atoms and bonds shown. To do this we are going to zoom into the protein.

To adjust the view of the protein structure, you can use the following controls:

- **Rotate** the structure by pressing the left mouse and move, or use the Shift button + left mouse button and drag, allowing you to examine it from different angles.
- **Zoom** in and out by using the mouse scroll wheel. On a touchpad, use a two-finger drag. On a touchscreen device, pinch two fingers.
- **Pan** the structure by pressing the right mouse button and move, or use the Control button + the left mouse button and move. On a touchscreen device, use a two-finger drag.

The chromophore is difficult to spot with this representation—look for a five-membered ring connected to a six-membered ring, buried in the middle of the protein. The next exercise will show you an easy way to find the chromophore.

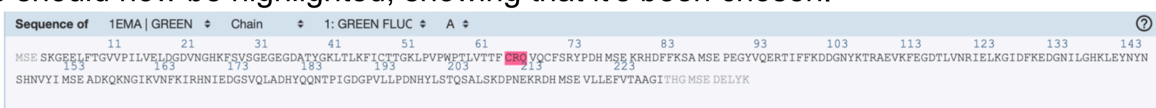
This representation displays all atoms and bonds, which provides a lot of detailed information. However, with so much data shown at once, it can become difficult to focus on specific structural features. To simplify the view, you may need to adjust the representation or focus on particular parts of the protein as demonstrated in the subsequent tasks.

Task 5: Exploring the chromophore with a combination of ribbon view with atom view

If we want to see how specific atoms interact with other parts of the protein, we need to be able to see secondary and tertiary structure as well as atom-level detail. This requires combining both atoms and ribbons.

1. Refresh the page to start fresh from the beginning.
2. Hide the **Non-standard** and **Water** components by clicking on the eye icons .
3. Click on the arrow icon to turn on **Toggle Selection Mode**. Check that the selection level is set to **Residue**. This ensures that you can select specific residues to highlight.

4. Click on **CRO 65** in the amino acid sequence panel to select the chromophore. This residue should now be highlighted, showing that it's been chosen.



5. Click on the box icon at the top to create a Component of Selection. This will generate a new component based on the selected residue (the chromophore), allowing it to be displayed separately.
6. In the dropdown options for the new component, click on the **< Create Later >** panel to the right of **Representation** and select **Ball & Stick**. This will display the chromophore in atomic detail using the ball-and-stick representation.
7. Click on **Options** for another dropdown menu. Under **Label**, click on the right side and name the component "chromophore".
8. Finally, click on **+ Create Component**.

Click on the eye icon next to the newly created chromophore component in the **Control Panel** to make the component appear or disappear. Rotate the structure to see how the chromophore fits within the overall shape of the protein. This will help you visualize its placement in the context of the entire structure.

Chromophore is not shown.

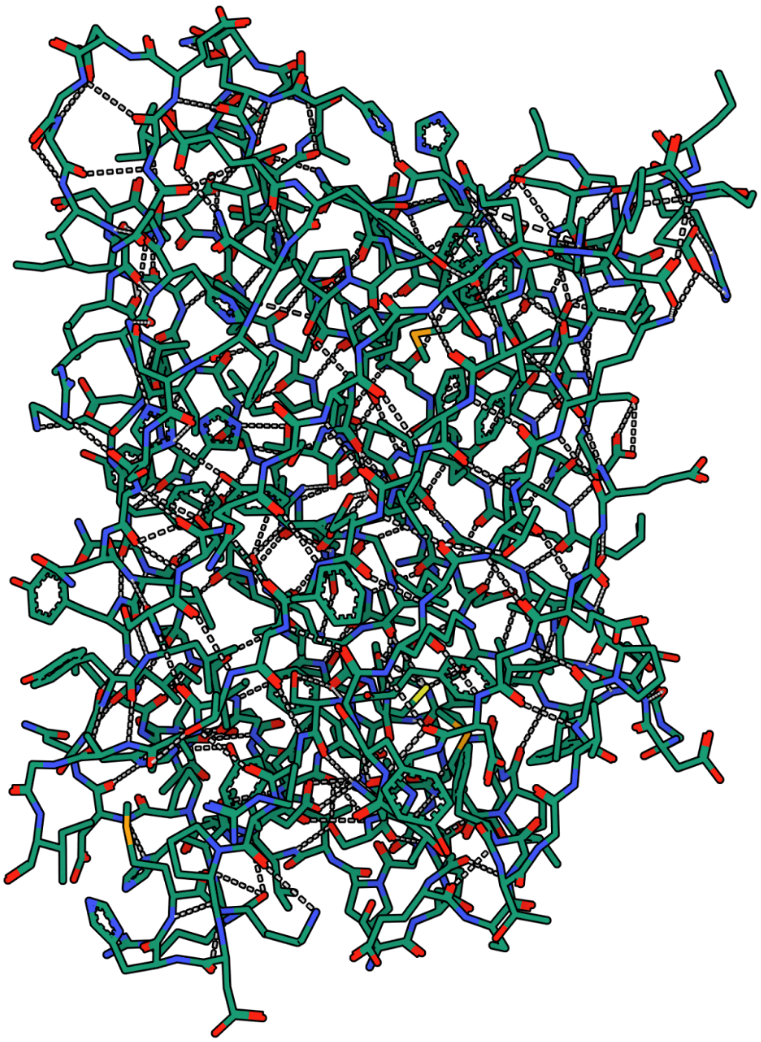
Chromophore shown in atoms and bonds.

Task 6: Visualize hydrogen bonds in proteins

The folded, secondary structures of proteins, like the beta sheets seen in GFP, are stabilized by hydrogen bonds. These hydrogen bonds are often formed between the N-H hydrogen atom and the C=O oxygen atom in the protein backbone. However, crystallographic structures typically do not include hydrogen atoms, so these bonds are not directly visible in most PDB structures. To see these hydrogen bonds, we can use Mol* for a more detailed view. In this task, we will visualize the hydrogen bonds in GFP (PDB ID: **1ema**).

1. Refresh the page to start fresh from the beginning.
2. In the **Control Panel**, click on the eye icons next to the **Water** and **Non-standard** components to hide them, so the view focuses on the protein structure.
3. Click on the three dots next to the **Polymer** component.
4. From the dropdown menu, select **Cartoon Representation**.
5. In the **Type** section, click on **Cartoon**.
6. Then, select **Line** from the dropdown to represent the protein as lines, making it easier to visualize hydrogen bonds.
7. To customize the appearance further, click on the three dots next to **Line** and select **Advanced Options** to reveal additional customization settings for the line representation.
8. Adjust the **Size Factor** to **4** to make the lines representing the covalent bonds in the structure more visible.
9. To view the additional hydrogen-bonding interactions, scroll up and click on **Add Representation** in the **Polymer** component dropdown.
10. From the dropdown menu, click on **Non-covalent Interactions** to display the interactions, including hydrogen bonds, between different parts of the structure. These interactions are shown as dashed lines. Feel free to go to advanced settings the same way as you did for the **Line Representation** to adjust the size or any other settings for better visualization.

11. To adjust the atom coloring, click on **Set Coloring** in the **Polymer** component dropdown.
12. From the dropdown, click on **Atom Property** and select **Element Symbol**.
13. You can rotate the GFP to see all of the hydrogen bonds.



By following these steps, you will be able to visualize the hydrogen bonds that stabilize the secondary structures of GFP and explore the atomic details of the protein.

Additional Activity: Hydrogen bonds are also important for stabilizing alpha helices. Try using Mol* to look at the hydrogen bonds in the hemoglobin structure with PDB ID **4hhb**.