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Proteopedia: A Collaborative, Virtual 3D Web-resource for Protein and Biomolecule Structure and Function

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Protein structures are hard to represent on paper. They are large, complex, and three-dimensional (3D)—four-dimensional if conformational changes count! Unlike most of their substrates, which can easily be drawn out in full chemical formula, drawing every atom in a protein would usually be a mess. Simplifications like showing only the surface of the protein or showing only a trace between its alpha carbons are preferred methods for representing the overall structure of a protein, and zoomed-in views showing all of the atoms in a certain part of the protein can highlight important residues. Unfortunately, even these simplifications can look confusing when flattened into two-dimensional images as in printed textbooks and scientific publications. Some aspects of the relationship between 3D protein structure and protein function are more easily conveyed to students using 3D representations of proteins, such as physical models or computer-generated molecular visualizations.

Proteopedia (http:/www.proteopedia.org) is a new collaborative web resource with pages describing protein, nucleic acid, and other biomolecule structures—including complexes—in interactive, virtual 3D [1]. A typical page in *Proteopedia*, which strives for encyclopedia-style pages, shows a rotating 3D protein structure (using *Jmol*, [2]) adjacent to descriptive text containing hyperlinks called "scene links" that can be clicked to elicit a change in the 3D structure to illustrate a point made in the text. *Proteopedia* is a wiki, like Wikipedia, so every member of the scientific community with a user account can create and edit pages in the website, and its scene-authoring tools make it simple to add "scene links" to any page. To properly attribute both credit and responsibility to page-authors, the bottom of every page lists the users that have edited that page; each listed user name links to a biographical account page describing the user's educational and professional background to help the reader determine page reliability. There are more than 200 user-added pages and more than 65,000 automatically generated "seeded" pages representing every entry in the Protein Data Bank (PDB), updated weekly.

Educators have found *Proteopedia* to be a useful teaching tool, and several instructors have adopted *Proteopedia* into their classrooms. The most obvious use is viewing existing user-added pages on molecules of interest (*e.g*. mechanosensitive channels [3] and HIV-1 protease [4]). However, even if a specific protein lacks a user-added page in *Proteopedia*, if its structure has been solved then the structure at least has an automatically generated "seeded" page for its PDB entry with a rotatable 3D structure and useful information including the abstract from the publication describing the structure, automatically generated "scene links" for ligands in the structure, and coloring by evolutionary conservation [5] (*e.g*. luciferase, 2d1s [6]). Instructors have also created pages as tutorials to either project in class or assign for students to read (*e.g*. tutorials on structural templates [7], serine proteases [8], and Ramachandran plots [9]). On *Proteopedia*, these instructor-created tutorials can be shared with other educators, who can adapt them for use in their own classrooms, all while protecting the original tutorial from unwanted changes. Finally, several educators have assigned class projects involving the creation of *Proteopedia* pages on particular molecules of interest. The students learn through teaching, and they end up contributing to a scientific and educational resource (see undergraduate student-authored photosystem II page [10] and graduate student-authored triosephosphate isomerase page [11]).

BAMBED readers are invited to visit the *Proteopedia* website (http://www.proteopedia.org) and request a free user account.

Beginning with this issue of *BAMBED*, selected *Proteopedia* pages that review a specific topic, protein, or molecule and pass peer review will be published in a new subsection of the feature *Multimedia in Biochemistry and Molecular Biology Education*. The *Proteopedia* page featured in this issue of *BAMBED* also represents one of the winning pages in the *Proteopedia* "Page of the Year Competition" for 2009 [12]. Thirty-one pages were entered into the competition, which invited *Proteopedia* page-authors

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to enter their pages to be judged based on intuitive communication of the subject matter, creative use of "scene-links," accessibility to a diverse scientific audience, beginning with a concise introduction accessible to someone unfamiliar with the subject, proper use of references, accuracy of the content, and having links to other, relevant *Proteopedia* pages. The winning page, featured in this issue, describes the structure and function of the *Haloarcula marismortui* large ribosomal subunit.

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