Proteins stepping on 'landmines': How they survive the immense heat they create

December 10 2014

Steve Presse, Ph.D. is an assistant professor of physics in the School of Science at Indiana University-Purdue University Indianapolis. Credit: School of Science at Indiana University-Purdue University Indianapolis

How do some proteins survive the extreme heat generated when they catalyze reactions that can happen as many as a million times per second? Work by researchers from Indiana University-Purdue University Indianapolis (IUPUI) and the University of California Berkeley published online on Dec. 10 in *Nature* provides an explosive answer to this important question.

Proteins are essential to the human body, doing the bulk of the work within cells. Proteins are large molecules responsible for the structure, function, and regulation of tissues and organs. Enzymes—special proteins that catalyze chemical reactions within cells—are critical to every bodily function from breathing to walking. Some enzymes produce a lot of heat per reaction. Enough heat, in fact, that if that heat were to be injected in another protein, that protein would overheat and unfold. So, how do enzymes expel that heat without overheating and self-destructing?

Steve Pressé, Ph.D., assistant professor of physics in the School of Science at IUPUI, led the study's theoretical arm. He is co-corresponding author of the *Nature* study by Riedel et al. along with Howard Hughes Medical Institute investigator Carlos Bustamante, Ph.D., of the University of California Berkley, who led the experimental research arm of the study in close collaboration with Susan Marqusee, M.D., Ph.D., also of UC Berkeley.

"A critical goal in improving human health will be to understand how a protein recovers from a reaction and, ultimately, how to speed up its activity," said Pressé, a biophysicist at IUPUI.

"We have discovered a key fact that explains how enzymes recover from a reaction: enzymes dissipate heat by very rapidly accelerating immediately following the reaction. This finding has very deep implications regarding how heat flows in living systems."

To illustrate how this heat transfer appears to occur, Pressé refers to an observation made by Alexander Graham Bell in the 19th century, which lead to the discovery of the 'photoacoustic effect'. Noting that metal—when exposed to sun then to shade—emitted a ringing sound, Bell concluded that heat from light expanded the metal that then recontracted in the shade. In doing so, the metal sent audible pressure waves out into the air.

Similarly, Pressé explains, enzymes respond to the energy released during catalytic reactions by expanding and contracting which in turn violently propels the enzyme and generates a pressure wave—the study authors call it a chemoacoustic wave—because it is caused by the heat of a chemical reaction.

"Think of proteins as stepping on landmines. We asked how does a protein avoid damage from the enormous amounts of heat released and not break apart? Now we have shown that they cope with this heat assault by pushing that energy outwards from the reaction site as chemoacoustic waves and propelling themselves away in the meanwhile," said Pressé.

The Pressé, Bustamante and Marquesee labs plan to continue investigating this puzzling 'chemoacoustic effect' on a number of other proteins using a variety of experimental and theoretical methods.

More information: The Heat Released During Catalytic Turnover Enhances the Diffusion Of An Enzyme, *Nature*, DOI: 10.1038/nature14043

Provided by Indiana University-Purdue University Indianapolis School of Science