YELLOWSTONE SCIENCE

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The Mystery of Protein Thermostability

Interview with Dr. John F. Burger

Roosevelt's 1903 Visit

A Ride to the Infernal Regions

The National Park Service is developing Research Learning Centers to encourage research and provide educational opportunities in the parks. As part of this service-wide initiative, the Greater Yellowstone Science Learning Center (GYSLC) includes personnel and facilities in the three parks that make up the Greater Yellowstone Inventory and Monitoring Network: Bighorn Canyon National Recreation Area, Grand Teton National Park, and Yellowstone National Park. This web site is a portal to detailed information about the natural and cultural resources at each of these parks and about the research projects underway there.

The primary focus of the GYSLC is to promote mission-oriented research in the network, explain the need for and results of research in the network to park managers, students, researchers, and the interested public, and to help develop the network's Vital Signs Monitoring Plan. The Research Learning Centers have been designed as public-private partnerships that involve a wide range of people and organizations, including researchers, universities, educators, and community groups. Through these partnerships the GYSLC seeks to link management decisions more closely with research results and build knowledge sharing relationships with educational institutions and the public.

Resource information available on the website includes the digital Yellowstone Atlas, a data-rich, visual display of information; the Resource Almanac, a one-page description of why the resource is important and its status and trends; an in-depth overview essay that details the background of the resource; a description of science and management projects; and links to articles, management documents, references, and other pertinent websites.

Science in the Greater Yellowstone

WITH THIS ISSUE, *Yellowstone Science* enters its 15th year in publication. Almost 250 articles on studies concerning the park's natural and cultural resources have been published in that time. The National Park Service has a research mandate and is required by law to use the highest quality science information to support park management decision-making. Yet researchers produce more than 200 papers, manuscripts, books, and book chapters *each year*. Park management is at a huge disadvantage when it comes to absorbing that volume of information. How can the park best collect, summarize, and make science information accessible?

We have been discussing this issue in the Yellowstone Center for Resources, as have many others throughout the National Park Service (NPS). The NPS has created 32 inventory and monitoring networks nationwide, challenged with the responsibility of preparing Vital Signs Monitoring plans. Park vital signs are selected physical, chemical, and biological elements and processes of park ecosystems that represent the overall health or condition of the park, known or hypothesized effects of stressors, or elements that have important human values. Vital signs monitoring is a key component in the Service's strategy to provide scientific data and information needed for management decision-making and education as well as to understand and measure performance regarding the condition of watersheds, landscapes, marine resources, and biological communities.

The NPS has also developed Research Learning Centers to facilitate research efforts and provide educational opportunities. They are places where science and education come together to preserve and protect areas of national significance. They have been designed as public-private partnerships that involve a wide range of people and organizations including researchers, universities, educators, and community groups.

Working together, the three park units in the Greater Yellowstone Inventory and Monitoring Network (Yellowstone and Grand Teton national parks and Bighorn Canyon National Recreation Area) have formed a Greater Yellowstone Science Learning Center, where information on natural and cultural resource topics can be made available. During the last year, with financial support from Canon U.S.A. through the Yellowstone Park Foundation, NPS staff have created a prototype website with new information products for a variety of resource topics.

We are looking for feedback on this new endeavor. Please visit the Greater Yellowstone Science Learning Center website at www.greateryellowstonescience.org, and send us your thoughts. Comments can be sent to Tami_Blackford@nps.gov or PO Box 168, Yellowstone National Park, WY 82190. We appreciate your input, and hope you enjoy this issue of *Yellowstone Science*.

www.greateryellowstonescience.org

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Submissions are welcome from all investigators conducting formal research in the Yellowstone area. To submit proposals for articles, to subscribe, or to send a letter to the editor, please write to the following address:
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on the cover:
Grand Prismatic Spring.
NPS Photo by Jim Peaco.


NPS

Old Faithful erupting behind President Gerald Ford, 1976.

FEATURES

DEPARTMENTS

NEWS & NOTES


NPS

2007 Winter Elk Count

The Northern Yellowstone Cooperative Wildlife Working Group conducted its annual winter survey of the northern Yellowstone elk population on December 30, 2006. A total of 6,738 elk were counted during good survey conditions. Approximately two-thirds of the observed elk were located within Yellowstone National Park, and one-third was located north of the park boundary. Biologists used three fixed-wing aircraft to count elk through the entire northern range during the one-day survey. The northern Yellowstone elk herd winters between the northeast entrance of Yellowstone National Park and Dome Mountain/Dailey Lake in the Paradise Valley.

This year's count of 6,738 elk was similar to the count of 6,588 elk in March 2006, but significantly lower than the 9,545 elk counted in January 2005. "This decrease in counted elk likely reflects the continuing effects of predation by wolves and other large carnivores, as well as decreased detection of elk within Yellowstone due to anti-predation behaviors such as smaller group sizes, increased dispersion of groups, and increased use of forested habitats, making them more difficult to locate," according to P.J. White, biologist for Yellowstone National Park.

"It appears that elk distribution has changed in recent years with elk numbers north of Yellowstone Park leveling off at between 3,200–4,000 elk, while elk numbers wintering inside the park may be decreasing," according to Tom Lemke, biologist for Montana Fish, Wildlife and Parks (FWP).

"In an effort to reduce hunter mortality on female elk, FWP has reduced the number of antlerless Late Elk Hunt permits over the last several years. For the last two years, only 100 antlerless permits have been issued," said Lemke. "At the current level of harvest, recreational hunting has very little impact on elk numbers in a population of several thousand animals. Hunting has basically been removed as a significant factor regulating northern Yellowstone elk numbers."

The State Elk Plan calls for a winter population objective of 3,000–5,000 elk north of Yellowstone with 2,000–3,000 of those animals wintering on or near the state-owned Dome Mountain Wildlife Management Area (WMA). In the last four years, an estimated total of 3,200–4,000 elk have wintered in the area with 2,100–2,800 elk using the Dome Mountain WMA. By the end of this winter, biologists expect elk numbers north of the park to remain within the management objectives. In contrast, during the late 1990s, 5,300–8,600 elk wintered north of the park with 3,500–4,500 elk in the Dome Mountain area. Wintering such large numbers of elk could lead to long-term habitat decline and increase the likelihood of game damage problems on private land.

"From a winter elk management perspective we are currently meeting State Elk Plan population objectives. The number of elk wintering north of Yellowstone Park has been within State Elk Plan objectives since 2003," added Lemke.

The working group will continue to monitor trends of the northern Yellowstone elk population and evaluate the relative contribution of various components of mortality, including predation, environmental factors, and hunting. The working group was formed in 1983 to cooperatively preserve and protect the long-term integrity of the northern Yellowstone winter range for wildlife species by increasing our scientific knowledge of the species and their habitats, promoting prudent land management activities, and encouraging an interagency approach to answering questions and solving problems. The working group is comprised of resource managers and biologists from Montana Fish, Wildlife and Parks; Yellowstone National Park; Gallatin National Forest; and U.S. Geological Survey–Northern Rocky Mountain Science Center.

John Varley Named Big Sky Institute Director

John Varley, former director of the Yellowstone Center for Resources at Yellowstone National Park, has been named executive director of the Big Sky Institute at Montana State University.

Varley, 65, began a three-year appointment on January 16. He follows Lisa Graumlich who resigned to become director of the School of Natural Resources at the University of Arizona in Tucson.

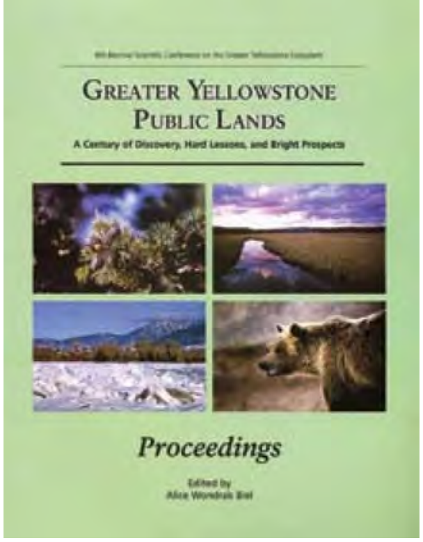
"We are delighted that John will be bringing his unique combination of gifts and experience to a leadership position at MSU," Provost and Vice President for Academic Affairs David Dooley said. "MSU, in part through its 'University of the Yellowstone' initiative and the Big Sky Institute, is poised to achieve new levels of excellence and John will help us attain our goals."

Varley, who moved to Bozeman after retiring from the National Park Service in February 2006, said, "I wasn't looking for another job. They thought I had some skills I could bring to MSU. It looked very exciting to me."

Varley said he and Graumlich have worked together closely over the years, including work on a joint Tanzania–Yellowstone wildlife research project.

In his new position, Varley said he will look at the Big Sky Institute's educational and science mission. He will continue to help develop the concept of MSU as the University of the Yellowstone.

Varley became director of the Yellowstone Center for Resources in 1993. During the 10 years before that, he was chief of the Division of Research at Yellowstone. He was a supervisory fisheries biologist in Idaho from 1980 to 1983, a fisheries biologist in Yellowstone from 1972 to 1980, and a fisheries research biologist in Utah from 1967 to 1972. He has been an adjunct professor at Ricks College in Rexburg, Idaho, the University of Wyoming in Laramie, Wyoming, and MSU in Bozeman, Montana.



Eighth Biennial Conference Proceedings Available

The proceedings from the Eighth Biennial Science Conference on the Greater Yellowstone Ecosystem, *Greater Yellowstone Public Lands: A Century of Discovery, Hard Lessons, and Bright Prospects*, is now available from the Yellowstone Center for Resources. The conference, which took place in October 2005, focused on the mandates, "cultures," relationships, and accomplishments of the numerous local, state, and federal management agencies responsible for Greater Yellowstone's public lands.

If you would like to receive a copy of the proceedings, please contact Virginia Warner at virginia_warner@nps.gov, or 307-344-2230. An electronic version is also available at www.nps.gov/yell/naturescience/conferencearchive.htm.

Gerald R. Ford, 1913–2006: Park Ranger, 38th President of the United States

Gerald R. Ford holds a special place in the heart of the National Park Service family. He will be remembered for his many accomplishments as president of the United States and his compassion in healing the nation's wounds following the war in Vietnam. For the National Park Service, he is considered one of our own; he is the only American president to have served as a park ranger in the National Park Service.

In 1936, Gerald Ford worked as a seasonal park ranger at Yellowstone National Park. Ford later recalled that time as one of the greatest summers of his life. According to his supervisor at Yellowstone, Canyon District Ranger Frank Anderson, Ford was "a darned good ranger." While serving in Yellowstone, one of Ford's assignments was as an armed guard on the bear-feeding truck. The National Park Service no longer feeds bears, but Ford always remembered that duty and often regaled his family with stories about the bear-feeding truck. During his summer at Yellowstone, Ford also worked in the Canyon Hotel and Lodge meeting and greeting VIPs, though he felt it was "undemocratic and un-American to give special attention to VIPs." According to Wayne Repogle, Ford's roommate that summer, one of the duties that Ford particularly enjoyed was the early morning check. From 5 AM to 7 AM each day, every automobile in camp had to be checked for make, model, state, and license number. Repogle indicated that the rangers had to run most of the time to get 150 to 200 licenses listed in two hours. As a football player, Ford was very fit and saw this duty as an opportunity to stay in shape. Repogle stated that Ford genuinely enjoyed "everything we rangers had to do."

NPS

President Gerald Ford in Yellowstone National Park, summer 1936.

As President of the United States, Ford oversaw an era when the National Park Service, under the leadership of Director Gary Everhardt, tightened the criteria for national parklands. Previously, for an area to be recommended for inclusion in the National Park System, it had to be considered nationally significant and lend itself to administration, preservation, and public use. The new emphasis would also consider whether the area was assured of adequate protection outside the National Park System and whether it would be available for public appreciation and use under such protection. During his time in office, President Ford added eighteen new areas to the National Park System.

The National Park Service family extends its heartfelt condolences to the Ford family at this difficult time and remembers one of its own fondly. We respect him as one of the pioneers in the field of rangering, and as a president that cared deeply for the National Park Service.

A New Prehistoric Source for Stone Tools

by Robin Szamuhel

In summer 2006, the archeology team revisited 248 sites to evaluate their current condition. The core team was composed of two volunteers (John Reynolds and myself) and an intern (Brian Quinn), with assistance from Yellowstone archeologist Ann Johnson. During these site visits, we came upon a stone source for prehistoric tools whose importance had been previously unappreciated. This site is enormous in both its size and its potential contribution to major archeological research questions in Yellowstone prehistory. With the help of aerial photographs and repeated visits to the site, the archeology team has been assessing the total size of the raw material source, and it appears to be more than 2,250,000 square meters.

During our initial survey, as we were looking for erosion or disturbances that might be damaging the site, we observed deep cuts in the bedrock made by early peoples, indicating quarrying activity or areas where stone had been removed. We could see where early people had dug into a cliff to follow a particularly good vein of raw material. There was also waste material, the stone left behind by prehistoric diggers. The debris on the ground was a spectrum of colors—translucent white, blue, green, purple, orange, red, brown, and everything in between. Someone had gone to the trouble of digging several large, fist- and head-sized chunks out of the bedrock, but the raw material had been left at the site. The color of these chunks was dramatic, with veins of crystalline material, speckles of black or white, or bands of different colors running through them. The colors and quality of the raw material will help us revise the interpretation of what raw materials were being brought into the park as tools, and what was being obtained locally.


NPS PHOTOS

Colorful piece of raw material.

Multiple dense concentrations of flakes suggest workshop areas where people broke down chunks into smaller pieces to manufacture tools. Across the site, evidence of quarrying and manufacturing activities is so apparent that a vivid picture of prehistoric activity can be imagined. For example, a certain pile of flakes and debris suggests a prehistoric person perched on an adjacent outcrop, using a hammerstone to remove flake after flake from a chunk of translucent chalcedony in order to make a tool kit to take back to the camp.

We know that chert, chalcedony, and obsidian are three major lithic materials used by prehistoric people in Yellowstone to manufacture tools. Obsidian Cliff is the largest established material source in the park, and is the largest source of obsidian used in Yellowstone from the earliest occupations around 12,000 years ago to the time of first contact with Europeans. Obsidian Cliff obsidian has been found as far east as Ohio, as far northwest as Washington state, and as far south as Texas.

This new site has been named Robin's Quarry by park archeologist Ann Johnson. While not as large as Obsidian Cliff, the site may be comparable in its local importance as a source of raw material. The amazing and distinctive colors found at this site are recognizable as material previously observed at several occupation sites along the Yellowstone River and on the south shore of Yellowstone Lake. The possible local sourcing of these materials is significant to our interpretations of trade and migration patterns. If the material being harvested from this quarry site is the same material left behind as projectile points, hide scrapers, or flakes discarded by someone retouching a knife's edge, we can follow and assess the pattern of a group's movement in the park, and perhaps even possible trade patterns with neighboring groups. For example, if materials or tools from the quarry are located beyond the usual migration area of a group, this may suggest that trade was occurring, or that our concept of a group's seasonal round (yearly travels) may have to be revised.

Volunteer Robin Szamuhel.

It is important to note that while sourcing obsidian can be done by non-destructively examining the chemical composition of the material, chert cannot be sourced in the same manner. Therefore, establishing the source of a piece of chert presents an interesting challenge, and tracing chert tools and flakes back to this site will be a complex endeavor for the archeology team.

While much remains to be studied in order to understand the importance of this raw material source, the evidence suggests a site of great magnitude, and we are excited about its research potential. As a science, archeology relies on fact and physical evidence to re-create prehistoric lifeways and patterns, and depends on the formulation and testing of hypotheses. With the data from this site, we have an opportunity to pursue questions that had heretofore not been formulated, and to address the increasingly complex questions about selection of raw material for stone tools and their use through time. YS

Unfolding the Mystery of Protein Thermostability

John Peters, Brian Bothner, and Susan Kelly

Figure 1. Graduate student Josh Spuhler measures temperature and pH in some of Yellowstone's hottest thermal features while looking for organisms—and ultimately proteins—that thrive in temperatures over 80°C (176°F).

PHOTOS COURTESY THERMAL BIOLOGY INSTITUTE

VISITORS TO Yellowstone National Park are amazed and delighted by the many thermal features—the geysers, bubbling mud pots, and steam vents; the clouds of steam carrying the familiar "rotten eggs" odor of hydrogen sulfide gas; and the multicolored waters of the pools. Even more amazing is the sight of the algae mats and the awareness that a whole array of microbial life lives in these inhospitable environments. The visitor cannot help but wonder, how does anything live here? "Protein thermostability" seems a dry term to describe such wonders, but it is one of the keys to life in Yellowstone's extreme environments.

The organisms in Yellowstone's thermal features are *thermophiles*, heat-loving microorganisms that not only survive, but thrive, at temperatures above 45°C (113°F). Hyperthermophiles prefer temperatures even hotter; above 80°C (176°F) (Figure 1). In response to the extreme conditions, these organisms have evolved mechanisms to protect their structure from the effects of high temperatures. A key mechanism is the development of proteins that are *thermostable*, or able to operate effectively at high temperatures. Unraveling the mysteries behind the thermostability of proteins is a fascinating area of research that not only illuminates one of nature's wonders, but also offers scientific knowledge of industrial and biotechnological utility.

Building Blocks of the Cell: Polymers and Proteins

The fascinating complexity of the cell has awed philosophers and inspired scientists for hundreds of years. A cell is composed of small and large molecules, each with a distinct purpose. The molecules themselves are lifeless; however, when they occur in the right combination and under the proper conditions we know life emerges—the exact mechanics of how is of continuing and current interest, especially in light of the search for extraterrestrial life.

It is the very large molecules within the cell—*macromolecules*—that make up the cell structure, store information, and are responsible for the processes of life. Biological macromolecules are *polymers*; that is, they are composed of repeating or similar subunits linked into a chain by chemical bonds and further assembled into complex structures. Polymers can exist in long or short chains, and both biological organisms and synthetic chemists have used this property to their advantage, in that large-scale structures can be built from small molecules simply by making the chains very long. What makes biological polymers different from synthetic ones is that they are made up of many types of repeating subunits, rather than just one or two. Figure 2 illustrates the difference. Nylon and the common plastic polyethylene are both polymers, but they are composed of only one kind of very simple subunit; for example, the repeating ethylene unit in polyethylene. The three biological polymers collagen, protein, and cellulose, on the other hand, are shown to be complex molecules made up of large subunits that are themselves complex. Furthermore, long chains of biological polymers can adopt a variety of three-dimensional shapes, which in turn underlie a variety of functions. So, despite the fact that both synthetic and biological polymers are made up of carbon, nitrogen, oxygen, and hydrogen, the properties of the resulting molecules are very different. The greater variety of repeating units give biomolecules the flexibility, adaptability, and variety essential to the processes of life.

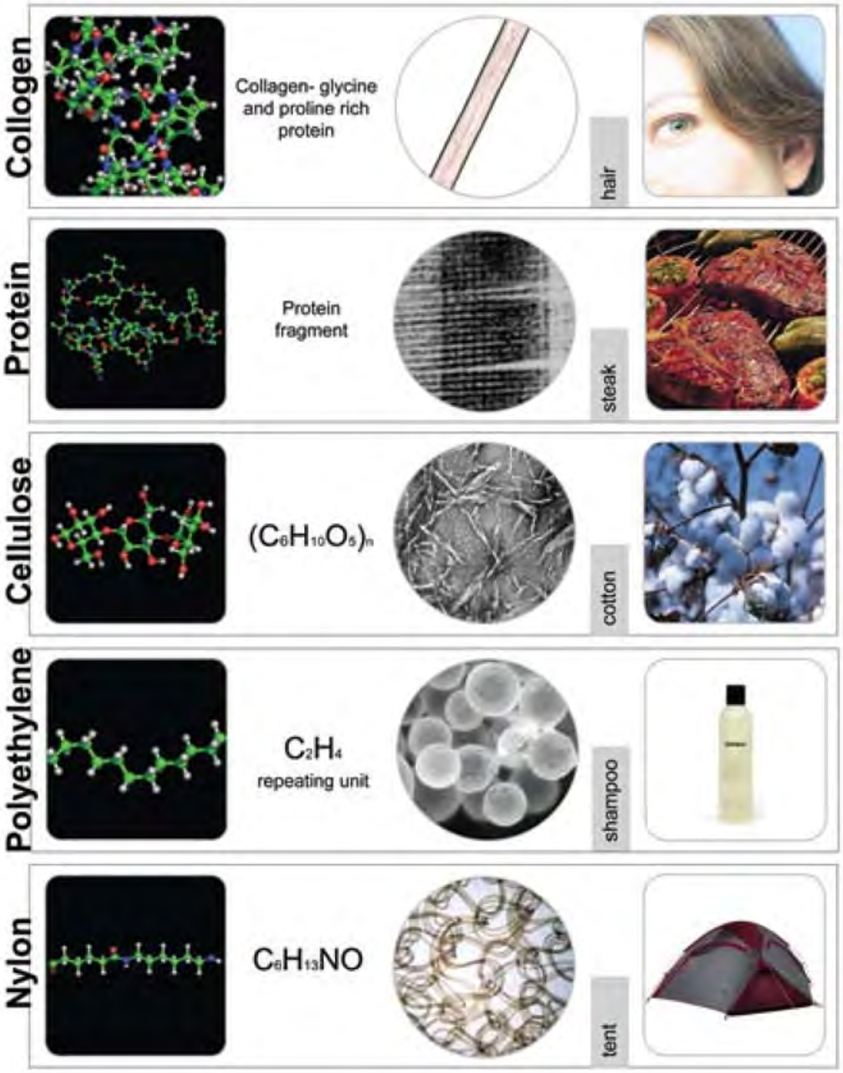


Figure 2. Biological and chemical polymers. Biology has made good use of polymers. Many of the most important biomolecules are polymers, including proteins (collagen), nucleic acids, lipids, and carbohydrates (cellulose). Like biomolecules, the synthetic polymers nylon and polyethylene are composed of repeating molecular units, but these are simpler and less varied than the subunits of biopolymers. Molecular components that make up the biological and synthetic polymers shown here include oxygen (red), nitrogen (blue), hydrogen (grey), and carbon (green).

Four major types of biopolymers are found in every living organism: polysaccharides, lipids, nucleic acids, and proteins. *Polysaccharides* are chains of carbohydrates (sugar, for example) and have highly diverse functional roles and sizes. In humans the polysaccharide glycogen, made up of repeating units of glucose, is used for short-term energy storage. The polysaccharide cellulose, the most abundant natural polymer on earth, is a structural component of plant cell walls. *Lipids,* like other polymers, are composed of a hydrocarbon chain. When attached to an acidic molecule, this chain forms a fatty acid, which is the major energy storage molecule in animals. The primary role of *nucleic acids* is to store genetic information. Deoxyribonucleic acid (DNA) stores heritable information that is passed from one generation to the next, while ribonucleic acid (RNA) stores information transiently as cellular components are assembled. RNA and DNA are polymers made up of four different units that can be linked in any order, thereby providing the basis for genetic diversity. The fourth and final class of biopolymers is the *proteins*, linear chains of 20 possible different amino acids linked together by peptide bonds. Proteins come in an enormous range of shapes, sizes, and structures, and it is their structure which underlies the vast range of functions they can adopt. The ability of Yellowstone thermophiles to withstand heat is intimately related to the structure of their proteins.

Functional Roles of Proteins

Proteins are the biological molecules responsible for the structure and function of cells and organisms. Just as there are thousands of genes in an organism, there are thousands of corresponding proteins, each with a unique function. Life, as we know it, depends on the orchestration of numerous types of proteins. As the primary agents of biological function, proteins carry out an array of jobs that includes chemical conversion, regulation, transport, and cell structure.

Each of the 20 different amino acids that make up proteins has its own chemical properties. As the composition and sequence of a protein varies, its physical character will change, leading to a nearly endless supply of diversity. For example, if three different amino acids are linked together, 8,000 (20^3) different sequences are possible. A small protein of 100 amino acids, therefore, can have 20^{100} different possible combinations—an enormous number! In fact, there is not nearly enough observable matter in the universe to make even a single copy of each possible sequence. The amino acid sequence dictates how the long chain folds up into a globular structure, and the resulting three-dimensional structure determines the function of a given protein in a cell.

The largest functional class of proteins is the *enzymes*, or biological catalysts. A *catalyst* is a molecule that speeds up, or catalyzes, the rate of chemical reactions in a *substrate,* the molecule acted upon. Enzymes are known to catalyze 4,000 different biochemical reactions. As biological catalysts, enzymes accelerate the rate of chemical reactions essential to life without undergoing any chemical change themselves. Since the enzyme remains unchanged, it can direct many iterations of the same chemical conversion of a given substrate. A single enzyme molecule can be responsible for thousands of conversions per second, making enzymes the most efficient catalysts known. Most enzymes are highly *specific*, acting upon only one substrate, but others have a very broad range of activity. An enzyme is usually named according to either its substrate or the chemical reaction it catalyzes, with the suffix *_ase* added. Lactase, for example, is a common digestive enzyme that breaks down lactose, the sugar in milk, and may be taken as a supplement by lactose-intolerant people. As another example, DNA polymerase catalyzes the reaction by which the DNA chain or polymer is built.


More than 70 research groups, including scientists from the Thermal Biology Institute, study some of Yellowstone's 14,000 estimated thermal features.

A second functional group is the *regulatory* proteins, which alter the function of other proteins without undergoing chemical modification themselves. Hormones such as insulin are a good example of this class. Regulatory proteins often bind to other protein molecules and change their shape, thus altering their function. The job of certain regulatory proteins is to bind to DNA, thereby altering gene expression. A third group of proteins help *transport* molecules; for example, proteins in the cell membrane are responsible for bringing nutrients into the cell, while others direct intracellular transport, moving nutrients, metabolites, hormones, or even regulatory proteins around the cell. Finally, proteins provide the *structural* scaffolding of the cell, which is a more passive function than their other, highly dynamic processes. Structural proteins are often composed of multiple polymers that are assembled in a hierarchal fashion. Common examples of structural proteins are keratin, found in hair, fingernails, and horns; and collagen, which holds us together via skin, tendons, and cartilage.

Structure "Fold" Defines Function

The function of a protein in general, and of an enzyme specifically, is defined by its three-dimensional structure or what is sometimes termed the "fold." Protein structure is most often described in terms of levels of structural complexity. The first level, called the primary structure, refers to the sequence of amino acids in a continuous chain. The chain of amino acids, or *polypeptide*, can vary in length from about 50 to more than 2,000 amino acids linked together by peptide bonds. A functional protein is a polypeptide consisting of one or more of these chains folded in a well-defined way. Proteins are synthesized within the aqueous environment of a cell, and it is the presence of water that helps direct the folding of an extended polypeptide chain into a compact functional protein. Some of the amino acids that make up the polypeptide chain are *hydrophilic*, meaning that they bond well with water molecules, while others are *hydrophobic* and reject water molecules. The protein is driven toward its final structure by the propensity of the hydrophobic amino acids to aggregate and prevent interactions with water by burying themselves in the protein interior, a phenomenon referred to as the *hydrophobic effect.*

The final active form of the protein is also held together by other forces such as electrostatic interactions, which are the attractive forces of positive and negative charges. An additional interaction that is observed infrequently but which contributes significantly to the stability of a protein is *disulfide bonding*, occurring when a pair of amino acids bond together via two sulfur atoms. The hydrophobic effect as well as these other interactions together stabilize the protein fold. The variety of interactions afforded by the diversity of amino acid structures can create regions of the protein that are rigid and other regions that are more flexible. Given that there are 20 common amino acids, the number of different combinations or sequences possible for an average-sized protein (~400 amino acids) is astronomical, introducing the possibility of different structures that could contribute to thermostability.

Enzymes Increase the Rate of Chemical Reactions

Sustaining a living cell requires an array of coordinated chemical events. When we consume carbohydrates, proteins, and/or fats in our diet these relatively large molecules are broken down to produce energy and synthesize components of new cells via complex pathways of reactions. These processes can occur spontaneously, but without an appropriate catalyst they would occur too slowly to sustain life. The rate of the reaction, or how fast a reactant is converted to a product, is determined by *activation energy*, the quantity of energy needed to get the reaction started; that is, to overcome the *activation barrier* (Figure 3). Enzymes catalyze biological reactions by lowering the activation barrier. The site at which rate enhancement or catalysis occurs on the enzyme is called the *active site*. This site is often chemically complementary to the reactant, and the elaborate protein architecture of the enzyme allows for this complementary site to be maintained but also allows for structural changes that lower the energy of key intermediate states. The structure of an enzyme defines its function and specificity in a biochemical reaction.

Enzymes are amazingly efficient biological catalysts, but they work optimally at defined temperatures. For example, most enzymes present in our bodies are most efficient near normal body temperature, 37°C (98.6°F). These enzymes are inactivated and destroyed if exposed to high temperatures because the overall three-dimensional structure or fold of the protein is permanently altered under extreme conditions. Enzymes in other life forms, such as the thermophiles of Yellowstone's thermal springs or those associated with deep sea thermal vents, have adapted to environments where temperatures can approach the boiling point of water. In response to the extreme conditions, thermophilic enzymes have evolved thermostability as a mechanism to protect their structure from the effects of high temperatures.

Chemistry and Life at High Temperatures

Life is very different in high-temperature environments. All life depends on a flow of electrons for energy production, but the mechanisms by which life in Yellowstone's extreme environments obtain energy is often very different from those of more familiar plants and animals, largely because of the unusual chemical environment. The superheated water in Yellowstone's thermal springs percolates throughout an extensive plumbing system, leaching metals and minerals from the subsurface rock. Frequent earthquake activity further mixes these mineral-rich waters, bringing them into contact with other rocks and minerals, so the composition of water in thermal springs varies dramatically. Most life exists in a neutral pH range, and some Yellowstone hot springs do maintain a neutral pH. However, many others exist at distinctly high pH (basic) or low pH (acidic) values (Figure 4). Essentially, many

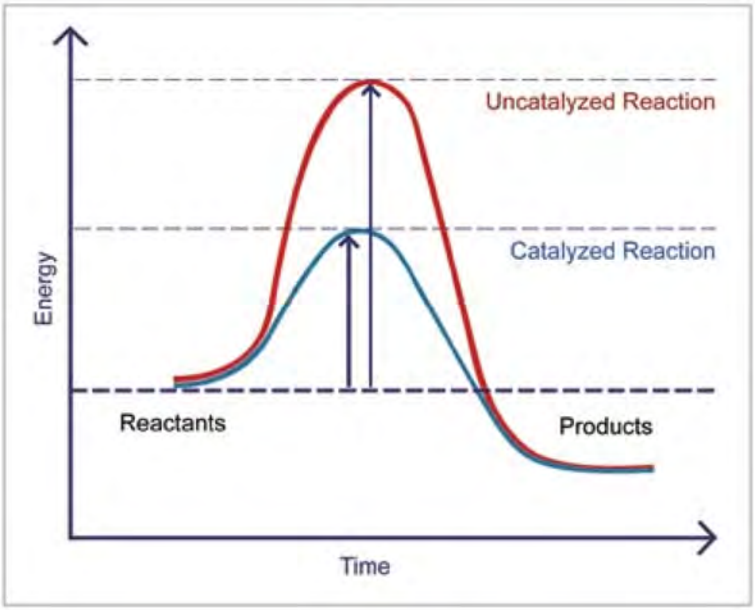


Figure 3. A reaction coordinate representing the energy over the course of a chemical reaction showing the difference in activation energy in uncatalyzed (red) and catalyzed (blue) reactions.

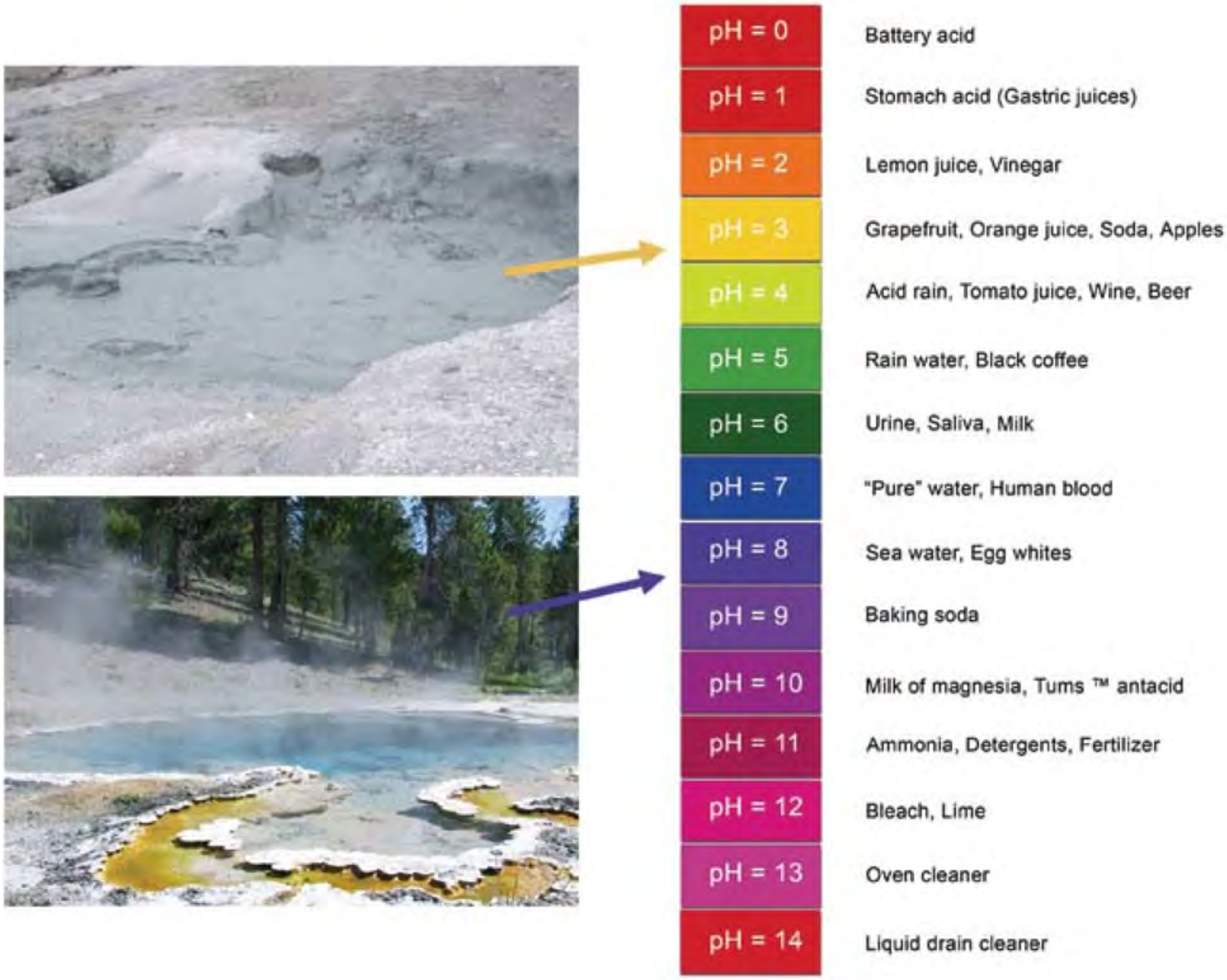


Figure 4. Yellowstone thermal features exhibit an astonishing range of chemical environments. The pH scale (1–14), is a measurement of the acidity of a solution and is defined in terms of the concentration of hydrogen ions (H+). A pH lower than 7 is considered acidic, while a pH higher than 7 is considered basic or alkaline; pH of 7 is neutral. On the pH scale, a shift up by one number represents a ten-fold decrease in hydrogen concentration. For example, a shift in pH from 2 to 3 (toward relatively less acidity) represents a decrease in total concentration of hydrogen by ten times. Thermal Biology Institute (TBI) researchers study features across a wide pH range—from less than pH 3 in some Norris Geyser Basin features (top) to as high as pH 10; Octopus Spring, pH 8, shown here (bottom).

Yellowstone thermophiles are living in pools of boiling acid.

Animals typically gain energy by *oxidation*, a process that strips electrons from organic compounds such as carbohydrates, proteins, and fats (the *electron donors*), and *respiration*, the process by which electrons are finally transferred to oxygen, the final *electron acceptor*. This type of energy metabolism for sustaining life requires oxygen, but in many of the thermal environments in the park oxygen is not present at all, or only in vanishingly small amounts. Furthermore, organic carbon, an essential element of typical electron donors, is usually not abundant in thermal environments. Consequently, to survive in hot springs thermophilic organisms have evolved alternative mechanisms for energy production in which inorganic compounds such as hydrogen and hydrogen sulfide gases can serve as electron donors, and metals like iron and arsenic can serve as terminal electron acceptors.

Nonetheless, despite the unusual alternative mechanisms that thermophiles have developed to survive in extreme environments, there remains a common thread among all living things. All life is dependent on coordinated sets of chemical reactions catalyzed by enzymes, but high temperature affects catalysis in two important ways. First, the rate of most chemical reactions is accelerated at higher temperatures, whether enzymes are present or not. However, enzymes are still required to achieve the reaction rates required to sustain life. Second, high temperatures affect the stability of proteins. Proteins that aren't adapted to high temperatures become nonfunctional very rapidly when exposed to heat. Heat is energy, and enough

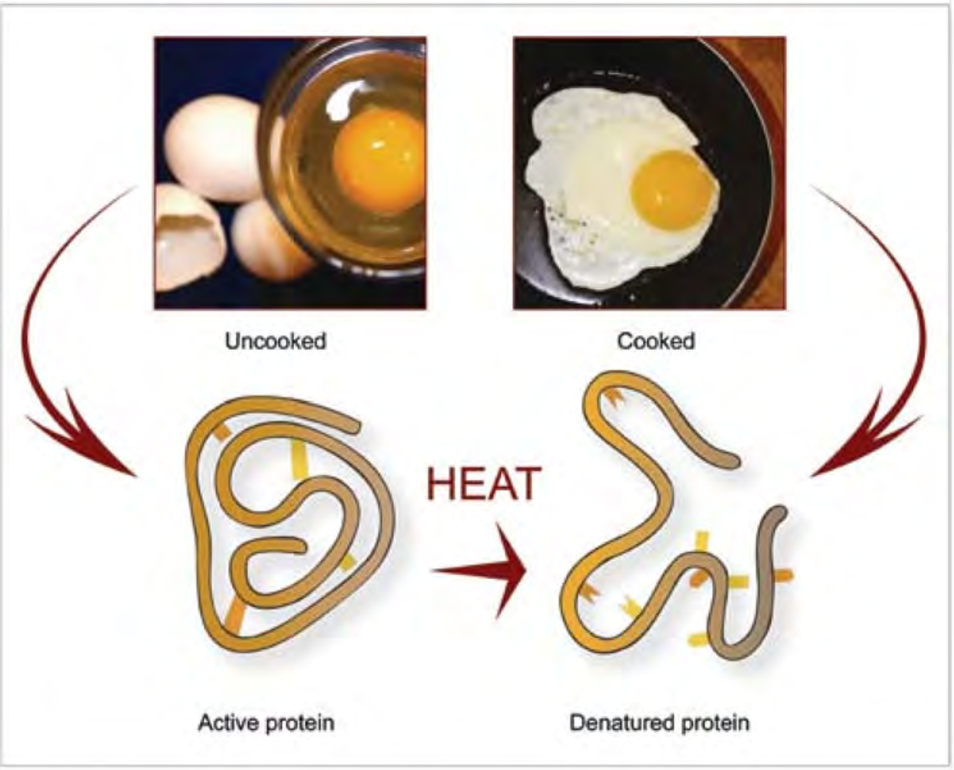


Figure 5. The changes a protein-rich food like an egg undergoes (left) when individual proteins are denatured or unfolded by heat (right).

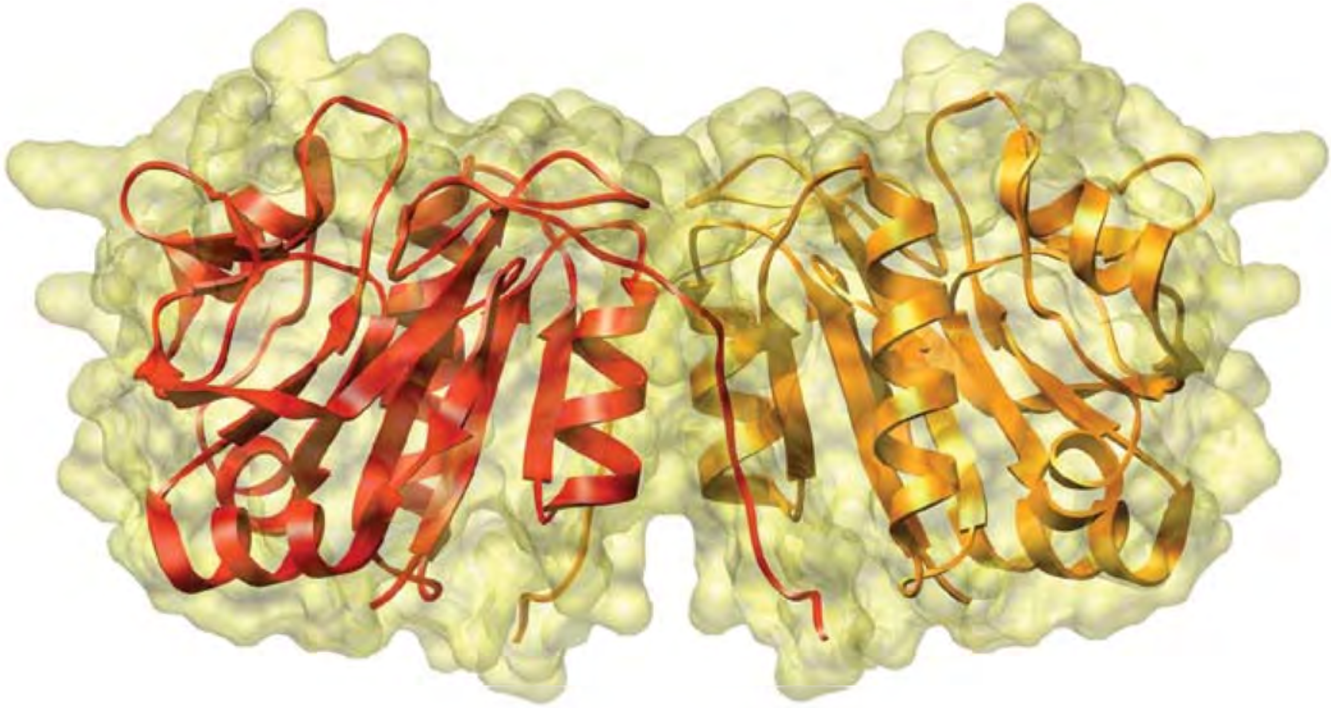


Figure 6. A structural model of an enzyme involved with the transfer of sugars. This glycosyl-transferase was isolated from a thermophilic virus found in the Rabbit Creek area of Yellowstone. The three-dimensional surface of the enzyme has a butterfly shape and is shown in transparency. The protein backbone is represented with red and yellow ribbons. Typical of proteins that have evolved to function at high temperatures, it has a compact structure with short loops connecting the amino acid strands (arrows) and helices (spirals). The model is based on X-ray crystallography data from the lab of TBI researcher Martin Lawrence published in the *Journal of Virology* 80(15), August 2006.

energy is capable of breaking the interactions that control and stabilize the protein fold, thus breaking down the specific structure that is required for function. In the case of enzymes that are not adapted to high temperatures, it is the catalytic function that is inactivated. The heat-induced unfolding or *denaturation* of a protein is often an irreversible process. A classic example of this phenomenon occurs in the cooking of an egg. As the egg cooks, you actually observe the proteins present in the clear liquid egg white denature, forming a white solid (Figure 5). The protein structure is irreversibly changed into another form incapable of carrying out the life-supporting functions of a cell.

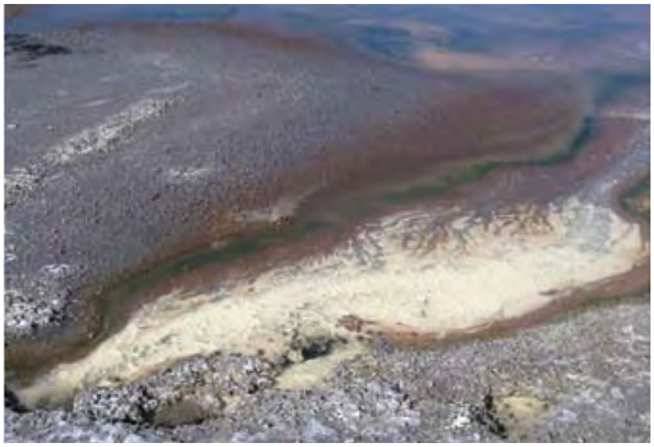
What Gives a Protein Thermostability?

Fundamentally, there are few differences between the enzymes that catalyze reactions under moderate conditions, such as those in our bodies, and those found in thermophiles. The mechanisms used to catalyze the chemical reactions are the same, but certain differences at the molecular level allow heat-tolerant proteins to maintain their structures at temperatures that approach the boiling point of water. Intramolecular interactions are the foundation of protein fold and function, and studies of the mechanism of thermal adaptation have revealed that thermally tolerant proteins have a more numerous and extensive set of internal interactions. These proteins are also more compact and generally lack regions such as exposed loops or extended ends. Such loops and ends are typically floppy and represent regions where the stabilizing interactions are vulnerable (Figure 6). Thermophilic proteins don't have as many of these floppy regions and thus resist unfolding. The interior of thermostable proteins is denser than that of proteins adapted for ambient temperatures. In fact, a thermostable protein may be essentially impenetrable to water, thus preventing water from competing for interaction sites that stabilize the fold.

So why aren't all proteins or enzymes built to be stable? The key to this very important question lies in the overall adaptability of a protein that is ultimately stable. Proteins and especially those that function as enzymes are involved in mediating and facilitating dynamic processes and thus are most effective if they can function dynamically. Enzymes that are thermostable are often less effective at accelerating their specific reactions, a necessary tradeoff in high-temperature environments. At moderate temperatures, however, the flexibility and catalytic efficiency of less stable enzymes are of the highest priority.

Can We Put Thermostable Proteins to Use?

The ability of enzymes to accelerate chemical reaction rates up to a million times while maintaining high substrate specificity far exceeds the capabilities of manmade catalysts. However, the conditions under which industrial chemical reactions occur are generally far more harsh than those inside a cell.



Yellowstone thermal areas are teeming with life. Thermal Biology Institute scientists and others who investigate the mystery of thermal stability have a variety of thermal environments to choose from. Hot features near Porcelain Basin (above) are home to acid-loving microbes that obtain energy by oxidizing the minerals sulfur and iron.

Microbial streamers—millions of microorganisms connected in long chains—flow in the thermal runoff along Rabbit Creek.

Mud pots are acid hot springs with a limited water supply. While mud pot activity varies with precipitation and the seasons, they are excellent places to look for thermophiles and their proteins.

If enzymes are to be used to improve the efficiency of industrial reactions they must be able to tolerate such harsh conditions. Naturally, scientists have turned to thermostable enzymes for use in industrial applications.

Thermostable enzymes are a mainstay for the starch industry, which yields products for baking, brewing, detergents, and other applications from starches such as maltose and glucose syrups. The breakdown of starch requires multiple enzymes called amylases. Since starch is soluble in water only at high temperatures, thermostable amylases are essential to this huge industry, which accounts for 30% of the world's industrial use of enzymes.

During the processing and bleaching of wood for paper, xylan and lignin (complex carbohydrates abundant in plant cell walls and wood) must be broken down without degrading the cellulose fibers that go into paper. Enzymes with specific activity for xylan and lignin are advantageous in pulp and paper manufacture; however, they must be able to withstand the high temperature and high (basic) pH conditions used to process wood. Thermostable xylanases are now used in the Kraft process, the most common method of producing paper pulp. Their bleaching properties reduce the need for chlorine, offering a significant environmental benefit. As worldwide demand for paper increases, the use of enzymes reduces the release of halogenated organic compounds, a serious environmental pollutant.

Cellulose, the major component of plant cell walls, is the most abundant natural material on earth. It can be used to produce fuel, fiber, animal feed, and chemicals. However, cellulose is difficult to digest and requires a group of enzymes for complete degradation of the carbohydrate chains. In fact, the most costly step in the production of ethanol from plant material is generating the enzymes that are used. Cellulases are used in color-brightening detergents, cotton production, extracting color from juices, and improving animal feed. All of these processes could benefit from increased thermostability of the enzymes, since the cellulases currently used operate optimally at 50–55°C (122–131°F), while many of the processes require higher temperatures.


Chemotrophic microorganisms—organisms that make a living on chemical energy—can be invisible to the naked eye, but are found in deep, clear pools like these along White Creek.

Chitin, one of the most abundant polymers in nature, can be processed to yield chitosan, a biological resource with many industrial, agricultural, dietary, and medical uses. Chitin is found in the exoskeletons of all crustaceans (shellfish) and insects, as well as in fungi. Thermostable chitinases are valuable in catalyzing the reactions that break down chitin into chitosan. In developing countries along the Pacific Rim,

Applications from Yellowstone organisms are found in the following processes:

- Heat-stable enzymes are used in laundry detergents to break down protein and fat stains on clothing.
- Heat-tolerant microorganisms are being studied to identify enzymes that can degrade alkaline materials including pesticides and explosives like TNT.
- An enzyme from a Yellowstone bacterium is being used to clean up industrial wastewater from hydrogen peroxide bleaching processes used to whiten and disinfect products.
- New thermal-tolerant enzymes from a Yellowstone organism can reproduce DNA more accurately and without the equipment necessary in the current DNA fingerprinting process.
- Metal-containing proteins are being studied for the potential production of hydrogen fuel.
- Enzymes that help speed up the fermentation process and convert plant material like corn into ethanol are being studied for potential biofuel applications.
- Enzymes have been discovered that break down starch at high temperature into the sweeteners trehalose and saccharide, used in processed foods, cosmetics, and pharmaceutical products.

thermostable enzymes could be used to reduce some of the millions of tons of crab and shrimp waste produced each year and return a value-added material in the form of chitosan.

The class of enzymes with the greatest market share in industry are the proteases, which cleave the peptide bond between amino acids and thus break down proteins. One of the most familiar uses of proteases is in enzyme-based stain removers, which use proteases to break down protein-based stains such as blood as well as many other compounds. Industrial uses include leather processing and food and pharmaceutical production.

Our examination of the commercial uses for thermostable enzymes is by no means complete, and many other industries are benefiting from the use of such enzymes in chemical processes. There are a few basic requirements that determine the feasibility of using an enzyme instead of a synthetic catalyst. For use in large-scale industry, an enzyme must be available in large quantities for a reasonable price and should be stable for the duration of the process. Because thermostable enzymes have increased stability at moderate temperatures, they can be more cost effective than other enzymes, even when the maximum temperature of a process does not require use of a thermostable form. Enzymes can also substantially reduce waste products from industrial processes, particularly for reactions in which a heavy-metal catalyst can be replaced with a protein.

Yellowstone's Most Famous Enzyme

Thermus aquaticus is an aerobic bacterium first discovered in 1966 in Mushroom Pool in Yellowstone National Park, and now known to be found in thermal areas worldwide. At that time, *T. aquaticus* was a remarkable discovery because its optimum temperature for growth lay between 70°C and 75°C (158°F to 167°F), near the upper limits for life. This otherwise unremarkable organism was added to a microbial culture collection by microbiologist and early park researcher Thomas Brock.

In the early 1980s Kary Mullis, a scientist with Cetus Corporation, found a use for a heat-tolerant enzyme from *Thermus aquaticus* in the *polymerase chain reaction* or PCR method, a procedure Mullis developed to replicate DNA sequences. The PCR process requires heating the DNA to be copied. However, the DNA polymerase first used in this procedure—the enzyme responsible for copying a DNA molecule—denatured at temperatures greater than 60°C (140°F), making the PCR method slow and arduous because more enzyme had to be added each time the DNA was copied. The DNA polymerase from *Thermus aquaticus* (Taq DNA polymerase) is heat stable, allowing multiple rounds of DNA replication to be performed in a test tube without addition of more enzyme. The use of Taq DNA polymerase led to the automation of PCR and the development of a multimillion-dollar industry devoted to the amplification of tiny amounts of DNA, with applications for basic research, drug discovery, and forensics. For his brilliant idea, Dr. Mullis received the 1993 Nobel Prize in Medicine.

Today, PCR is an important technique used by a wide array of researchers in the park, whether they are studying microbial communities or lake trout populations. PCR is used to amplify tiny bits of DNA found in hair or other biological samples, allowing species such as grizzly bears, wolves, and bison to be identified, thereby providing valuable information about population numbers, distribution, and behavior to park managers and researchers. The discovery

Thermal Biology Institute Research Associate Sarah Korf tests the thermal waters in the Broad Creek area in an effort to better understand how thermophilic bacteria and archaea make a living.

> A thermophile is a heat-loving microorganism that not only survives, but thrives, at temperatures above 45°C (113°F). Hyperthermophiles prefer temperatures even hotter; above 80°C (176°F).

of a heat-stable enzyme from a Yellowstone microorganism brings the idea of resource protection full circle. Protection of Yellowstone resources allowed for the discovery of an organism that is now helping with the management and further protection of this unique ecosystem. Ongoing research in Yellowstone is exploring the use of Yellowstone thermal proteins for a variety of everyday applications.

Yellowstone's Future

Yellowstone truly has something for everyone, first-time visitor and world-famous researcher alike. It is often noted that Yellowstone was established in 1872 for its unusual geology—its geysers, hot springs, and mud pots. Yet we continue to discover and redefine the exact nature and significance of this grand act of preservation. Predecessors would never have suspected the park's significance today as a Biosphere Reserve and World Heritage site. Early park promoters and enthusiasts could not have foreseen the significance of preserving clean air, natural quiet, or nighttime darkness, let alone microbial life and the thermal-stable proteins within. For the scientist most significantly, the park contains vast pristine microbial habitats not duplicated anywhere else on Earth. Preserving these crucial environments is of utmost priority. For this reason, scientists of the Montana State University Thermal Biology Institute work closely with the National Park Service to conduct their research using "leave no trace" practices so that basic and applied research can be conducted without compromising other values—known and unknown. We can only wonder at the vast potential for future discovery. YS

Acknowledgements

Special thanks to Monica Chodkiewicz for help with the figures and to Connie Bollinger and Ellen Petrick for editing and review.

John Peters (left) is the Director of the Thermal Biology Institute (TBI) at Montana State University–Bozeman, where he studies the protein structure and function of thermal enzymes. His research is focused on metal-containing enzymes from Yellowstone microorganisms involved with nitrogen metabolism, hydrogen metabolism, and metal reduction, with potential applications tied to bioremediation of metals and clean energy production of hydrogen fuel. **Brian Bothner** (right), Assistant Professor of Biochemistry, is a new member of TBI. His research interests include proteomics and virology. A particular focus of his research is characterizing viruses isolated from Yellowstone thermal features and elucidating the biology of viral infection in Archaeal species such as *Sulfolobus solfataricus*. **Susan Kelly** (center) is the Coordinator of Outreach and Education for TBI. The Institute's outreach activities target the scientific community, the general public, and K–12 audiences.

Colorful microbial mats form in some Yellowstone thermal features. Microbial communities are defined by temperature and chemical composition of thermal waters; thermally adapted proteins allow organisms to thrive in seemingly inhospitable environments.

(More information about TBI, its activities, and applications of Yellowstone thermophiles is posted at www.tbi.montana.edu.)

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PHOTOS COURTESY OF JOHN BURGER

Burns, Bugs, and Bites

The YS *Interview with Dr. John F. Burger*

DR. JOHN F. BURGER *is a zoology professor at the University of New Hampshire who has been coming to Yellowstone since 1956. He specializes in blood-feeding flies, on which he has written two articles for* Yellowstone Science *(issues 3:2 and 4:4). His current research in Yellowstone focuses on using photography to document the natural succession of vegetation following wildfires. Roy Renkin, Vegetation Management Specialist, and Tami Blackford,* Yellowstone Science *Editor, sat down with John on August 7, 2006, during his annual visit to the park.*

Becoming an Entomologist

Yellowstone Science (YS): What made you want to be an entomologist?

John Burger (JB): I think the first thing was probably summer camp in Michigan, where one of the activities was making a butterfly collection. That's where a lot of people get interested, even though they may not maintain that interest; collecting butterflies is one of the neat things to do when you're a kid. They encouraged us not only to collect but also to learn how to mount them properly, as well as how to frame them in cotton and put them up on the wall. I did all of that. Unfortunately, I didn't know anything about putting moth crystals in there to keep out the dermestid beetles. After a couple of years, the bodies of some of my best butterflies were basically dusty powder, and it turned out to be a real mess. But I certainly learned about dermestid beetles—the hard way! Any museum collection has to be concerned about them. When I was down at the Yellowstone Heritage and Research Center, they showed me some of the collections I had done back in the 1960s. I was curious about how they were being housed, and I noticed they were being really careful about museum pests.

The second thing that set me on the entomology path was a college class I took in my junior year, taught by my major professor, Kenneth Christiansen, who is a worldwide specialist with *Collembola*—springtails, small arthropods that live in soil, leaf litter, and caves. He specialized in cave *Collembola*. He was a fantastic teacher; the reason I went into biology was because he taught the general biology course. He triggered my interest in insects; after I graduated I had a long talk with him and decided that was what I wanted to specialize in. I ended up getting both a Master's and PhD in insect biosystematics.

Contracting Yellowstone-itis

YS: How did you get interested in Yellowstone?

JB: That started in 1956 when I was 16. Dale Nuss organized a summer camp called Camp Trails that I attended. We spent the summer on horseback tracing the Bannock Trail and the Nez Perce route, following the Howard Eaton trail system. We would ride from point A to point B, spend the night, and then go somewhere else the next day—for the entire summer. I guess that was when I was infected by a virulent virus known as Yellowstone-itis. I understand other people have been infected by it. At that age, having an experience like that—spending the whole summer in the wilderness—had a major impact on me.

When I started college I discovered that a lot of students work in national parks in the summer. I applied, and the Yellowstone Park Company hired me. I was assigned to the Fishing Bridge cafeteria as a dishwasher in 1959, the year of the Hebgen Lake earthquake. You got five days on, two days off. It was such a wonderful experience that I came back in 1960 and '61. In 1961 I cooked trout for the people who caught them from Fishing Bridge. Back then, there were wall-to-wall people fishing from the bridge.

I finished my Master's degree at the University of Arizona in 1965 and went on to the University of California–Berkeley. At the time, my major professor was working on insects associated with cattle, and I wondered about the difference between flies that might be on cattle and flies that might be on bison. Bison are native; cattle are not. Were the flies on cattle originally on native animals? My professor thought this was interesting, and I suggested that I go to Yellowstone and do a survey of the insects associated with bison in order to compare them with what was found on cattle. So in 1966 I came to Yellowstone, based out of the Lamar Buffalo Ranch, which is where the research people were then. I spent the whole summer there, working mainly in the Lamar backcountry. I also wanted to know what was on cattle near the park, so I went down to Gardiner and started inquiring about where there might be some cows whose flies I could compare with what was up in the park. They told me a man named Scotty Chapman had some cows at his place on the river, so I went to see him. He found out I was working on insects and got all excited. I spent the summers of 1966 and '67 looking both at flies on cattle at Scotty's place and on bison in the park. I published some papers on that and got the Yellowstone-itis going again.

I had a side study on moose that turned out to be extremely interesting. There is a particular fly that feeds on the blood of moose and nothing else, which is very unusual for a fly. It's related to a fly that feeds on cattle and lays its eggs in cattle excrement, the hornfly. The so-called moosefly does exactly the same thing on moose. The adults stay on the moose, and—I was actually able to observe this with a spotting scope down at Pelican Valley—when the moose poops, some of the females will lay eggs in the moose droppings for about 5 to 10 minutes. After about 10 minutes there are no longer any flies there.

YS: Did you incubate moose droppings?

JB: I'd take them back to Lamar and put them in containers, then wait until the adult flies came out. Nobody had ever really done any studies on the biology of this fly, but I spent both summers figuring out its biology and behavior, and published a fairly large paper on it. That got me permanently interested in Yellowstone. Then I got married and had kids, and went away for a long time.

Arnica cordifolia along the Hoodoo Basin Trail, in a severe burn area, July 1990 (two years after the Clover Mist fire).

Changes in Post-fire Vegetation

YS: Your current work in the park is in post-fire photography, looking at photographs and interpreting change.

JB: Yes. It wasn't until after the fires of 1988 that I began to think about all the years I'd spent here taking pictures of places all around the park. I had slides from 1959 through 1967. It struck me that it would be interesting to go back and compare the areas post-fire, and thought it would be even more interesting to see how areas exposed to different fire intensities responded over time and what vegetational changes there might be.

Every summer since 1990, I've gone back and re-photographed exactly the same spots either every year or every three years so that I can look at vegetation changes over time. I tried to pick areas that were lightly burned versus those that were completely burned. Now I do it by GPS coordinates, so not only can I go back, but if anybody else wanted to go back, say 50 years from now, they could find the exact spot. I have about 5,000–6,000 slides.

YS: Are you seeing what you expected to see?

JB: I didn't know what I expected to see. I do remember that everything was pretty black in 1990. I wish I'd come back right after the fires, but the idea didn't hit me right away. One of the things that was really impressive after the 1988 fires, as I went into the Lamar backcountry, was the arnica. It was just a sea of yellow. I had never seen that much arnica before. But after two or three years, the flowers were pretty much gone. Arnica must really respond after a fire. It's things like that that really fascinate me. Another thing that really impressed me

Lamar River Trail looking up Cache-Calfee Ridge pre-fire, 1966.

Lamar River Trail looking up Cache-Calfee Ridge, July 1997.

after the East and Grizzly fires in 2003 was that as I was walking the Thorofare Trail from the Nine Mile trailhead, everything looked black, but when I dug down below that black area, I didn't go more than a centimeter or two before I found perfectly unburned soil. I did a little cross-section and took pictures to show where the soot was and where the unburned soil was. I told my students, this looks really awful, but a lot of plants have underground parts. However bad it looks on the surface, underground—unless it was something like the Norris blowdown area, where the fire sat and really cooked everything—there's no problem.

YS: Many resource specialists predicted the Norris blowdown would not support much vegetation of any kind for decades following the 1988 fires because all of the organic material in the soil was consumed by the fire. Contrary to expectations, the area proved to be optimal for lodgepole pine seed germination, and the growth rate of established trees is far greater than adjacent stands that burned but were not affected by the wind storm.

JB: I looked at growth rates in various places, too. I did a series of measurements on tree height and looked at the distance between the branches. There was one particular tree just south of Norris Junction that I couldn't measure any more because I couldn't get my measuring tool up to the top of the tree. I finally had to give up when it was 22.77 feet tall, and it couldn't have been from before 1988.

I was also looking at onset of reproduction. How old the trees were when they first started to produce cones. I was seeing them as early as seven years post-fire. I've been told that lodgepole has what's called a weedy growth habit. It begins to reproduce very quickly compared to a lot of other conifers.

YS: In your work, do you see successional changes in taxa or insect functional groups similar to those seen by botanists as some plants dominate at one point and then give way to others?

JB: I don't think we really know. I have been asked how the fires in 1988 affected flying insects like horseflies. I honestly don't know. I suppose smoke and fire would have killed some of them, but I have no idea what effect, if any, that's going to have on insect populations over the long term. Obviously, the types of plants that are available after a fire will be utilized by the types of insects that can utilize them. As there are changes in flora over time, I suspect there will be changes maybe not in species, but certainly in populations of insects.

Landscape Changes

YS: After coming here for so long, what are the most significant long-term trends you've noticed?

JB: I wasn't thinking very ecologically when I was working at Fishing Bridge. But I think what's most impressed me about change in the park is the difference between how the forest looks now and how it looked back in the 1950s and 1960s, when almost the entire park was closed canopy lodgepole, particularly down in the interior, and almost nothing was growing on the forest floor.

The other thing that really impressed me was looking at the forest from the air. It was a total revelation—not just the burn mosaic, but also flying over unburned areas and seeing different age classes in stands. You're thinking this is a lodgepole pine forest—and it is—but it's not even-aged forest. It's a whole mosaic of different age groups, and you can see that from the air. You may not be able to determine exactly how old each patch is, but you can tell that one patch over here is much older than another over there. I have some beautiful pictures showing these old, scraggly trees and then there's this big patch of brighter green, younger trees in amongst all the old ones.

YS: There's phenomenal growth in some of these trees. In some areas, the densities are as high as 50,000 trees per acre. They're stacked in like sardines.

JB: They finally put up those signs saying, "naturally reseeded by fire in 1988." In 1990, a lot of people were appalled because there was almost nothing there at that time. Or they were shaking their heads, saying, how could they let this happen? It's terrible. I don't hear that anymore. The landscape is so different now, even than it was 5 or 10 years ago, that people are beginning to be a little bit more impressed. The other thing that they want to know is how much work it must have been to replant all the trees. You get tired of saying, no we're not the U.S. Forest Service; we're not going in and reseeding.

Biting Flies

YS: We'd like to talk about insects. You've already written two insect articles for *Yellowstone Science.*

JB: I wrote those two on my specialty, biting flies. I was out in Lamar [in summer 2006] talking with ranger Brian Chan and he said they were just awful. [Former Yellowstone biologist] Mary Meagher said that up in Cinnabar Basin she didn't even want to go outside this summer because they were so bad.

YS: They bite people's hands.

JB: Snipe flies like the wrists and between the fingers. Some people call them sticky flies. Some people call them buffalo flies. There's a fellow out at Silvertip Ranch who called them "those little gray bastards."

YS: It was just miserable about the second or third week of July this year.

JB: That's about the time when they seem to be the worst. The second summer I was out in Lamar, 1967, it was a horrible year. I'd go up to Cold Creek, then head up to upper Lamar and run into bands of them. They'd be there, then they'd go away for a while, then they'd come back again further down the trail.

YS: What do we know about their life cycle?

JB: In the immature stages, they're in the soil, but there's not a lot known about exactly what sorts of habitats they prefer. It's really like a black hole as far as the immature stages go. Nobody really knows where the eggs are laid, whether on the ground or in low vegetation. I've seen articles suggesting that they prefer moderately damp soil, often associated with the understory of various trees. For example, out at Lamar, you might find them underneath aspen groves, where there's some moisture. I spent the better part of a week in various areas around the Buffalo Ranch trying to find immature stages. I never found any, but it's like looking for a needle in a haystack. Horseflies are much easier. They like the margins of ponds, so you can dig there and find those with no problem. Snipe flies are terrestrial. The immature stages are predators, feeding on other small invertebrates—as far as we know.

They go through a single generation each year. The adults come out in late spring or early summer. Like most of the so-called lower flies, the males don't bite—only the females. Males probably live only for a week or two. Nobody knows anything about mating behavior, but afterward, the females will search for blood. They probably feed primarily on the larger mammals—elk, deer, whatever else might be around—bison and people. Deer are just tormented by these things. We have a tail-flicking index. You can tell the severity of biting flies by the number of ear flicks or tail switches per minute. You can drive by an area and, depending on what the tails are doing, you can determine what the situation is out there. At Mammoth, in the evening, sometimes the ears on the elk are just going a mile a minute. That's a good index for activity.


John Burger collecting black flies.

These periodic population irruptions are strange. One or two other people and I have tried to puzzle out what sort of combination of environmental factors might contribute to the occasional really large population. In most years, it seems like they're around but not a problem. People have tried to look for patterns—whether it's "x" number of years in between, for instance. The most important thing, in my opinion, is some combination of environmental features in a particular year. One idea was that the climatic conditions in the previous fall, when the immature stages are developing, might be important: a dry fall followed by a wet spring, or a wet fall followed by a dry spring. The only way to know for sure would be to go back and look really closely at climatic records. But I don't think it's ever really been done.

YS: The years 1967, 1994 (when you wrote the *Yellowstone Science* article), and 2006 were really bad. It seems like once a decade they really catch people's attention.

JB: They're always there. It's when you get the swarms that everybody seems to notice and complain about it. Is it snowpack? Moisture in the soil? Who knows? They belong to an insect family called Rhagionidae, almost all of which are non-biting. The only two genera that feed on blood are this one and a genus called *Spaniopsis,* which occurs in South Africa. There's a very large variety of genera in that family. I've seen quite a few in Yellowstone in the past; some of them have an alternating color pattern and some are very colorful, with orange thoraxes or black-and-white abdomens. There are three major species in this area. One is sort of grey, with three yellowish-brown stripes on the thorax. The other one is a darker grey, almost brown. Then there's a black one that you usually find at higher elevations. It's not nearly as abundant. The grayish one with the stripy thorax is found at lower elevations, like Lamar. The greyish-brownish fly tends to occur at higher elevations, like 7,000–8,000 ft. The black one tends to occur, for example, on Parker Peak. I used to see them up on the eastern boundary there, the shiny black ones.

YS: The genus is widespread.

JB: It's worldwide, but is primarily in North America.

YS: After the adult females get a blood meal, that helps them complete the reproductive cycle?

JB: Right. After the females of most of these kinds of flies—including mosquitoes, black flies, and horseflies—have mated, the ovaries go through a series of stages, 1–5, with 1 being the initial state of the ovary and stage 5 being the fully formed egg. The ovary is divided into many different sections called ovarioles. Each ovariole eventually will develop an egg. After the ovaries reach a certain point between stages 1 and 2, they arrest—just sit there and do nothing. This triggers all sorts of hormonal mechanisms that in turn trigger the host-seeking behavior. They look for movement. Once they get a complete blood meal, then each of the eggs will begin to go through the various stages. At stage 5, the eggs are ready to be deposited.

YS: Once the female deposits the eggs, does she die?

JB: It depends. Most of the work has been done with mosquitoes, some of which tend to be fairly short-lived. They may go through one or two ovarian cycles. A much lower percentage of females manage to get through three or four cycles. It's a pretty dangerous world out there. Climate, predators, birds, diseases, parasites; all sorts of things can affect their survival. The record number of cycles that I remember seeing for mosquitoes is about five. That's really rare; it'd have to be a darned lucky female. That has not really been studied in snipe flies, so I am not certain whether there is a more finite number of possible ovarian cycles in snipe flies.

Insect Repellant

YS: Is there any form of insect repellent that's effective against these flies? Even DEET doesn't seem to work.

JB: I've actually worked on that a little bit out in Lamar. I have all these herbal, natural compounds that supposedly work better than DEET. And they're not toxic. DEET is nasty, if only because it's a plasticizer, and if you have it on your hands and touch something that's vinyl or has plastic in it—like the dashboard of a car—you stick to it. One thing I tried in Lamar that actually worked fairly well, but only for a short time, was citronella. There are a number of repellents that have citronella oil in them. I'd sit out behind the residence at Rose Creek, which is a great place for snipe flies, and I'd put DEET on one arm and citronella on the other. The citronella would work really well for half an hour, maybe 45 minutes. After that, they started coming again, but it did work to a point. There are a number of natural repellents that have come on the market in the last 10–15 years, some with oil of peppermint or oil of cloves. They're called aromatic oils, and they appear to have some effectiveness. A new material that's been out in Europe for 5–10 years is called picaridin. It's supposed to be as good as DEET if not better, without the plasticizing effect and unpleasant odor. It's becoming available, but is still hard to find.

YS: Aren't there are also health concerns associated with DEET? It seems like most of the supposedly strong repellents these days are only maybe 30–32% DEET.

JB: I used to know of some products that were 95% DEET. They were recommended for people who had to be out in the woods all day long, exposed to high concentrations of whatever biting insects were out there. Those products are extremely unpleasant for a number of reasons. Number one, again, is that if you touch anything, you're going to make a big mess. Second is that I saw some studies indicating that they cause numbness in some people—sensory effects. The other thing is that exposure to mucus membranes—your eyes, mouth, nose—is painful. If you have it on your hands and you rub your eye, it's just absolutely horrible. Twenty-eight percent is about as high as you want to go, and I would recommend even lower concentrations.

Human Health and Wildlife Diseases

YS: Are there any human health concerns associated with any of those biting insects?

JB: A species that's a vector of West Nile Virus occurs in the park, *Culex tarsalis*. But I'm not certain how abundant it is in the park. I did find it in Frying Pan Spring one year. Some of the pools there aren't as hot as some of the others, but I remember thinking, mosquito larvae in Frying Pan Spring? I mean, whoa! But that's what it turned out to be—*Culex tarsalis*. Rocky Mountain Spotted Fever might be another thing, depending on whether ticks are enough of a problem here.

YS: Every now and then you see a deer in hunting season [October] that's really loaded with ticks.

JB: Oh, winter ticks—*Dermacentor albipictus*. That's a really interesting beast because unlike most ticks, which feed and then drop off, that tick actually stays on the animal through all of its life cycle, from larva to adult. Not only that, but the deer also can go through areas and pick up really large numbers of them. I've seen masses of those things on elk, for example.

YS: Here in the park?

JB: Yeah, in Lamar. Sometimes they get so bad that they actually cause the animal's hair to drop out; it's almost like scabies, really nasty. They can get enormous numbers, and I strongly suspect that that may be a real problem in terms of energy drain, particularly in the winter when animals are stressed anyway. There has been some indication that winter stress also may be a factor in the numbers that you find on the animals. Some people have said that animals that are in poor condition tend to move around less. Because they lie around more, they may be more susceptible to getting ticks on them, and so tick numbers sometimes correlate with an animal's condition. So you could say, aha, the animal's in poor condition because of all the ticks! But maybe there are a lot of ticks because the animal's already in poor condition. So we don't really know for sure.

> [O]ften when I'm coming back from hiking in Pelican Valley, people are asking, "did you see any animals?" I say, "lots of animals." "Oh, what did you see?" "Well, butterflies, bees, flies." "Oh. Okay." And they walk off.

YS: How about wildlife diseases?

JB: There's plague, which of course you get periodic outbreaks of in ground squirrels and prairie dogs. I've never heard of plague up here, but it's possible it could be endemic. It certainly is established in large areas of the West, and every once in a while you hear about occasional human cases that pop up here and there.

One thing I studied while I was here was face flies (*Musca autumnalis*), an introduced fly from Europe that came into eastern North America in the early 1950s and spread across the entire country. They were associated with cattle, initially. The flies gather around the eyes and other mucous membranes, and feed on secretions around the eyes, mouth, and nose. In addition to looking at bison here, I went up to the national bison range in Moiese, Montana, and looked at flies on the bison up there, because that's a captive, or at least fenced, population. They were having severe face fly problems up there; in fact, they actually had bison whose eyeballs were erupting because of the irritation from a fly-transmitted bacterium that infects the eye. The animals go blind. And so I said, okay, I've got to find out if this fly has reached Yellowstone or not. So I started looking for it, and eventually I found it. It was way up on the Cache-Calfee Ridge, up in the Lamar backcountry. There would always be a group of maybe 50 to 75 bison that would hang out up on the eastern boundary most of the summer when it was hot down below, and I got several specimens of face fly in 1967. So I knew the fly was at least in Yellowstone. The question was, would it become abundant enough to really become a serious problem, and as far as I know it hasn't.

Exotic Insects

YS: Do you think we have a lot of exotic insects here?

JB: You certainly do have some, because some of these insects are adaptable to different kinds of animals, ungulates particularly—you have cervids as well as bovids. The introduced insects probably came in back in the 1800s, but they're probably not of any real concern. I don't know if you have houseflies here, but that's an introduced species.

YS: What about ladybugs?

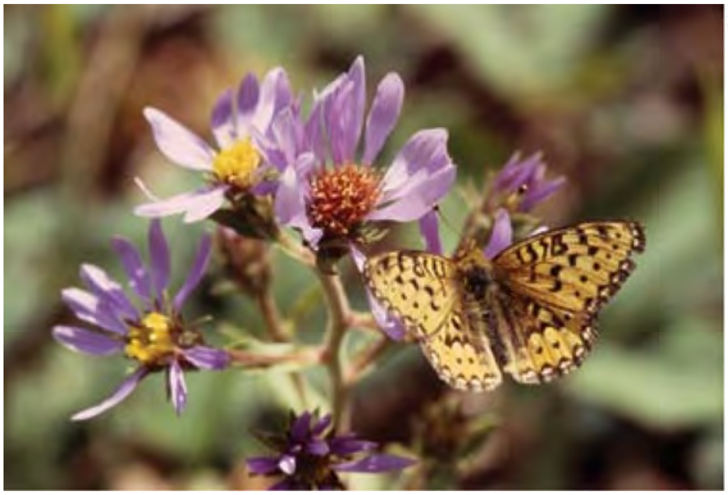
JB: I wouldn't be surprised. A lot of ladybugs were introduced intentionally in various areas and spread all around.

YS: There's been talk about introducing exotic insects for exotic weed control; do you have any thoughts on that?

JB: Well, okay, let's say you don't like thistle. You've got these nasty old thistles growing all over the place because horses have pooped all along the trails for however many years. We have this wonderful insect that really controls thistle well. Well, that's nice except what are you going to do when it goes from the introduced thistle to the native thistle? That is, once it

Burger at Lower Miller Creek cabin.

runs out of one thing to eat, what's it going to do? Is it going to die out, or is it going to move to something else? And quite frankly, sometimes we don't really know. Sometimes unintended consequences are very painful. There is an example in the east—I don't know if you've heard of the Halloween lady beetle (*Harmonia*) or not, but it is a species of lady beetle that was introduced to control aphids on various kinds of crops. They tried a number of times to get it to establish and apparently couldn't, but then finally, all of the sudden, it started appearing in larger and larger numbers until now the numbers are huge. And they have this tendency to go into people's houses in the wintertime by the thousands. And so you've got people calling up and saying, we've got thousands of these lady beetles in the house—what do we do? How do we get rid of them? And apparently they have adversely affected some of the native lady beetle species in terms of competition. And so again, you've got a situation where, number one, they're actually a pest in terms of humans in some cases, and in others they are apparently decimating the native lady beetle populations. So we've solved our problem with pea aphids—sure, okay. Now what?


Fritillary (*Nymphalidae* family) on aster.

NPS

Insect Inventory and Monitoring

YS: Here in Yellowstone, there's been lots of work done in relation to the larger mammals, but less on insects, especially given their numbers and diversity. Can you address what it is we think we know or, more importantly, what we don't know about insects in this part of the world?

JB: I've thought about that a lot. When you come to Yellowstone you think elk, bison, bears, wolves. This happens very frequently—often when I'm coming back from hiking in Pelican Valley, people are asking, "did you see any animals?" I say, "lots of animals." "Oh, what did you see?" "Well, butterflies, bees, flies." "Oh. Okay." And they walk off. I think most people who come here just visiting have heard about the charismatic megafauna, and that's what almost all people focus on. But if you look at ecosystems, you start thinking about how many insects there are in Yellowstone relative to other animals. We probably don't know even within an order of magnitude how many there are. If you were to ask me for a number, I would say many thousands, but that would just be a guess. I usually try to be fairly observant when I'm out hiking, particularly when there are lots of flowers out, because there's all sorts of insect activity. Black horseflies circling around. Stuff flying around and landing on flowers. Snapping grasshoppers. Somebody asked me the other day why they make that noise. I get asked that fairly frequently. I said, you know, I'm not sure anybody knows whether it's an alarm or whether it's something else. I've heard a couple of explanations. In some years you get huge numbers of Mormon crickets. Like a lot of other insect populations, they sort of fluctuate over time.

I sometimes wonder if it's possible to get any reasonable estimate of diversity here. I suppose you could, but it would be a big, big job. You'd almost need a group of people to do a "bioblitz" [a rapid assessment of as many species from as many taxonomic groups living in a particular area at a given point in time as possible, often conducted over a 24-hour period by scientists and volunteer members of the public] to try to catalog numbers in a particular geographic area. Those are becoming more and more popular. Acadia National Park has had a number of those over the years. Each year they'll pick a certain order of insects, whether it's beetles or flies or bees and wasps, and they'll get as many specialists as they can to come in and spend about five days intensively looking at everything. It's similar to a Christmas Bird Count, but much more challenging.

YS: Are there key insect species that you think we should be monitoring, so that in 10 years we don't look back and say, gosh, we wish we had some data on that?

JB: It would have to be something that is relatively sensitive to whatever changes are of concern here.

YS: Having an inventory might be a first good step.

JB: There was a fellow from England, Adrian Pont, who came to Yellowstone and the Tetons one summer and was so enamored that he came back for several summers. He happens to specialize in muscid flies, which are not very well known or well studied, and he gave me a list that's about 25 pages long of all the species that he found in both parks.

YS: Great Smoky Mountains National Park recently started an all-taxa biological inventory.

JB: I've been involved in it. I've done all the horseflies. Here in Yellowstone, there are representatives of all the species I've collected down in the HRC collection. In fact, they even put my name on one of the drawers. But I have all the mosquito species, all the horseflies, deerflies, and snipe flies.

YS: How many mosquito species did you collect?

JB: There are more than 30 species known in the park; I probably collected two-thirds of them at one time or another. Or they collected me! I collected larvae, too, when I got here early enough in the spring. They're actually easier to identify than the adults are.

Simple Answers

YS: You mentioned grasshoppers. Given the rich history of grazing issues about how many elk the northern range can support, it's mind-boggling to think about the biomass of grasshoppers out there and how much plant matter they consume.

JB: It's huge. All you have to do to realize it is walk along for five minutes and count the number of grasshoppers that are only on the trail. Never mind how many are out there that you don't see. I saw some speculation about the amount of plant material consumed by grasshoppers relative to elk or bison. And they're not taking a huge volume, but it's the numbers that add up. What if you heard somebody say, "There's too many grasshoppers; we're going to have to cull the grasshopper population"?

YS: Plants obviously can't get up and run away from an herbivore, but they can do some really unique things. What have we learned about how plants respond or react to insects by creating chemical defenses against herbivory?

JB: Insects can stimulate plant defenses—for example, the production of certain types of toxic molecules that prevent most insects from feeding on certain kinds of plants. In most cases that I'm aware of, at least a few insects manage to somehow circumvent that plant defense. In fact, one of the ideas involving what people sometimes call co-evolution is that there is a sort of arms race going on with insects evading a particular response from a specific plant. The plant responds either by producing more or different compounds that make it unpalatable. Then the insects somehow evade or detoxify the materials. It's a little bit like insecticide resistance. In terms of large herbivores, the underground parts of the plant are often adapted to grazing and, in fact, grazing actually stimulates plant growth.

John Burger on Parker Peak, his favorite spot in the park.

All these people who say the northern range is overgrazed, what does that mean, exactly? What criteria do you use? Some people say, well, there aren't as many willows as there used to be. You go down to Pelican Creek where it goes into the lake, and there are no willows at all. I have pictures, taken in 1960, of two great big moose feeding on these enormous willows growing all along Pelican Creek. What happened to the willows? Overgrazing? It turns out that the caldera is tilting, and the water levels are going up in some areas and down in others. The water levels and the flow there are completely different than they were in 1960. Looks to me like the willows have simply been drowned out. No willows, no moose.

YS: It seems like more and more people are beginning to recognize that landscape changes are often the result of things like hydrological, climatic, or geological shifts, instead of more obvious, visible drivers like elk grazing—that identifying the reasons for landscape change is more complex than simply comparing a couple of photos.

> People want to try to reduce things to simple factors, and I'm a process person. I'm always wary of what I call simple answers to questions that may not be so simple.

JB: Wolves are the other visible driver that people like to point to. We're seeing more willows now. Why is that? A simple explanation is that elk never had anything to worry about in terms of predators, but now they have to worry about wolves, so they're not spending as much time grazing the willows as they used to. So the wolves are responsible for the new willow growth that we're seeing. People want to try to reduce things to simple factors, and I'm a process person. I'm always wary of what I call simple answers to questions that may not be so simple. It's interesting to think that those things might be happening, but I'm always a little wary about saying, "that's the answer."

YS: Is there anything else we should know about insects in Yellowstone?

JB: One thing I've always been intrigued by is that you're not allowed to kill animals in the park; does that include mosquitoes? Does it include snipe flies? Horseflies?

YS: Do you plan to continue coming back to the park?

JB: As long as I can get around! It's going to be pretty hard to keep me away from here as long as I can walk on two legs.

YS

Trailing Theodore Roosevelt Through Yellowstone

The Written and Visual Records of Roosevelt's 1903 Yellowstone Visit

Jeremy Johnston

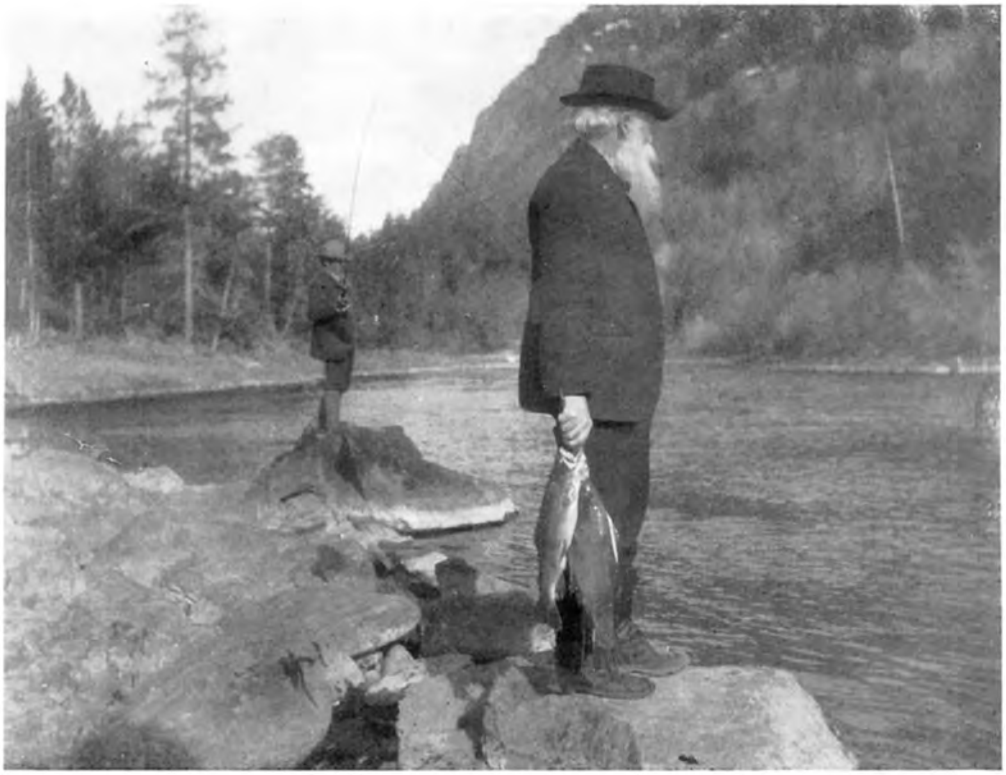
THE PRESIDENT, MR. BURROUGHS AND "BILLY" HOFER ON THE TRAIL FROM HELL ROARING TO STERN CREEK.
Copyright, 1903, by The Illustrated Sporting News.

Theodore Roosevelt, John Burroughs, and Elwood "Billy" Hofer near Hellroaring Creek. This image appeared in *The Illustrated Sporting News* in an article by Lindsay Denison.

THEODORE ROOSEVELT'S VISIT to Yellowstone National Park in 1903 marked the most extensive presidential visit to the region, yet only four detailed primary narratives and very few visual images recount Roosevelt's extended visit within the park boundaries. A number of photos and press accounts covered Roosevelt's arrival and the famous dedication of what would become known as the Roosevelt Arch; however, due to Roosevelt's desire to escape the public's prying eyes while he camped within Yellowstone, Major John Pitcher and the soldiers under his command greatly limited any public access to Roosevelt's campsites. As a result, no newspaper reporters or bystanders managed to witness Roosevelt enjoying his private camping trip through the park. Roosevelt and his companions, who included John Burroughs, Elwood Hofer, and Major John Pitcher, did write first-hand accounts of their visit, and a number of these have been reprinted in various formats, all of which offer a good literary narrative of the visit. Yet surprisingly, very few photos were taken of Roosevelt and his colleagues camping in the park, and only a minute number of these images have been circulated to a wide audience.

In 1906, John Burroughs, a famed naturalist writer, published his first-hand account, "Camping with Roosevelt," for *The Atlantic Monthly*. In 1907, Burroughs published this same narrative with an additional account of his other encounters with Roosevelt in the book, *Camping and Tramping with Roosevelt*. Both John Pitcher and Elwood Hofer, who previously guided Roosevelt through the Yellowstone region in 1891, wrote very brief accounts of the president's visit. Hofer's account, "The President's Park Trip," appeared in *Forest and Stream* on June 13, 1903. Pitcher kept a diary of the trip and allowed it to be published in an article for the *Avant Courier* on May 8, 1903. Pitcher's diary of the trip was again published in 1910 in a book by Addison C. Thomas, *Roosevelt Among the People*, which covered Roosevelt's entire 1903 nationwide trip. In 1904, The Boone and Crockett Club first published Roosevelt's account of his visit to Yellowstone, "The Wilderness Reserves." This article appeared in *American Big Game In its Haunts*, a collection of various hunting narratives written by Boone and Crockett Club members. The periodical, *Forestry and Irrigation*, reprinted Roosevelt's story in June 1904 and it appeared in print again with Roosevelt's book, *Outdoor*

PRESIDENT ROOSEVELT AND MAJOR PITCHER.



"OOM JOHN."

The pictures above appeared in *American Big Game In Its Haunts*. *Top:* Roosevelt in camp with Major John Pitcher. *Above:* John Burroughs with a fishing companion. Roosevelt affectionately referred to Burroughs as "Oom John" (*oom* is Dutch for "uncle").

Pastimes of an American Hunter, published in 1905.

Due to the Major John Pitcher's efforts to fulfill Roosevelt's request of being isolated from the public and the press during his visit, only a few images of Roosevelt's visit to the park exist and very few of these images have been reprinted. It appears that Major John Pitcher was the only photographer during Roosevelt's private trip through Yellowstone. According to a letter written by B. E. Parke to the Roosevelt Memorial Association, he "was told that each of the party received prints [of Pitcher's photos] after which the negative was destroyed" (Theodore Roosevelt Collection, Harvard University).


A HARD TRIP THROUGH THE SNOW.

Copyright, 1903, by The Illustrated Sporting News.

Roosevelt (at the front with the sleigh driver), John Burroughs, and H. W. Child (at the back of the sleigh). During the sleigh ride, Roosevelt bolted from the sled and captured a mouse under his hat, believing it to be an unknown species.

A number of Pitcher's photographic images were first printed in an article by reporter Lindsay Denison, "The President in Yellowstone Park," which appeared in the short-lived sporting magazine *The Illustrated Sporting News*, which remained in print only from the year 1903 to 1906. According to Denison's article, Pitcher gave permission to reprint the images appearing in the article solely to *The Illustrated Sporting News*. Due to the short run of this magazine and its limited audience, Denison's article containing Pitcher's photos remained relatively unknown to researchers. Today, only a few original copies of this article exist in archival repositories. Both Roosevelt's and Burroughs' accounts also contained a few more of Pitcher's photographic images detailing Roosevelt's trip, including some of the same photos that were printed in *The Illustrated Sporting News*. Another small group of Pitcher's photos are housed in the Theodore Roosevelt Collection at Harvard University and many of these images have never been published.

Another collection of photos from Roosevelt's trip were published by Doris Whithorn in her book, *Twice Told on the Upper Yellowstone*, volume I. Whithorn writes, "contrary to orders, an enlisted man accompanying the presidential party to the camp near Tower Falls, carried a camera and used it. The negatives were entrusted to the Mammoth storekeeper, Ole


THE PRESIDENT PREPARING FOR A TRAMP IN THE WOODS.

Copyright, 1903, by The Illustrated Sporting News.


PASSING THROUGH THE GOLDEN GATE.

Copyright, 1903, by The Illustrated Sporting News.

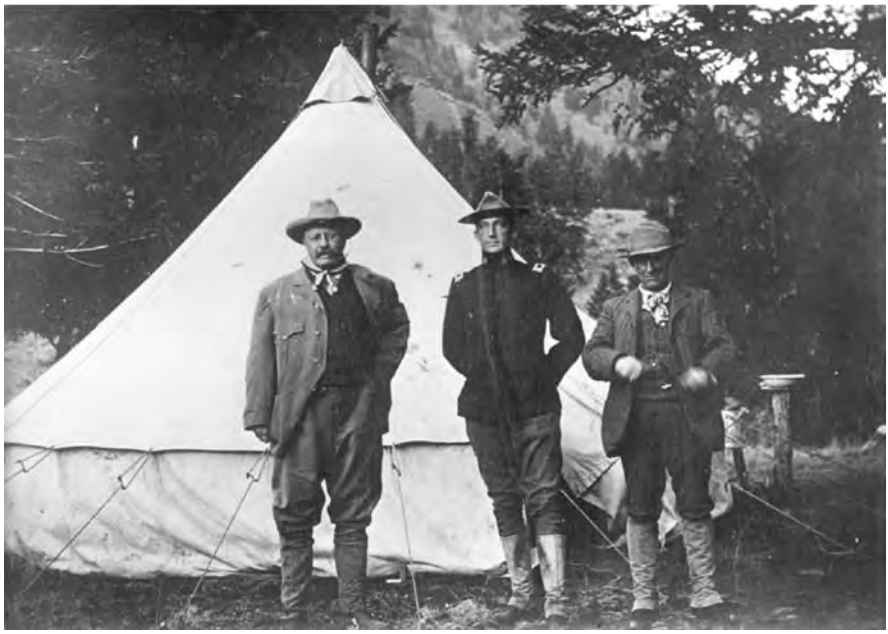
Left: Roosevelt hiked many miles to view wildlife during this 1903 trip. On one occasion, he hiked 18 miles solo, causing Pitcher much worry. *Above:* The group walks a dry segment of road in the Golden Gate area. The images on this page first appeared in *The Illustrated Sporting News*.

THEODORE ROOSEVELT COLLECTION, HARVARD COLLEGE LIBRARY

Roosevelt, dressed for a hiking trip.

NPS

In *Twice Told on the Upper Yellowstone,* by Doris Whithorn, Major Pitcher (left) was mistakenly identified as Theodore Roosevelt. It's likely this photo was taken with Pitcher's camera, not by an enlisted man, as Whithorn suggested.



THEODORE ROOSEVELT COLLECTION, HARVARD COLLEGE LIBRARY

Left to right: Theodore Roosevelt, Lieutenant Dorsey H. Cullen, and Elwood Hofer. Lt. Cullen served during the Spanish American War and fought in the Philippine Insurrection, and was honored to accompany Roosevelt in Yellowstone.

Anderson, but were never reclaimed. Ole's son gave them to Clarence Scoyen, and he loaned them to Bill Whithorn for producing the first prints in 1975." (Whithorn, page 37). It is the opinion of this researcher that Whithorn's images were also taken by Major Pitcher's camera and not that of an enlisted man's, especially since Pitcher, who is mistakenly identified by Whithorn as Roosevelt, appears in one of the photos. Due to the strict nature of the isolation provided to Roosevelt by Pitcher, it is unlikely that any secret camera was used by a soldier to take an unauthorized photo, especially of the commanding officer who issued the restrictions. For some unknown reason, Pitcher must have left these images with Anderson who then passed them on to his son. Since many of these photos included Roosevelt's companions posed with elk antlers and a bear skin rug, Roosevelt and Burroughs would not have wished to use them to illustrate their narratives. Both men cautiously avoided any slight suggestion that Roosevelt hunted any wildlife in the park in his isolation due to the president's advisors worrying about any possible public outcry that would taint Roosevelt's visit.

Reprinted here are the photographic images taken by Major John Pitcher that first appeared in the article by Lindsay Denison and in Burroughs' and Roosevelt's accounts. Also included are the previously unpublished photos from the Theodore Roosevelt Collection located at the Houghton Library at Harvard University. Many of these images have not been seen by the general public since they appeared in their original publications. The combined collection of these images offers the most complete presentation of Pitcher's photos documenting Roosevelt's visit to Yellowstone. Together, they offer a rare and intimate perspective of Roosevelt and his fellow companions relaxing in Yellowstone National Park.

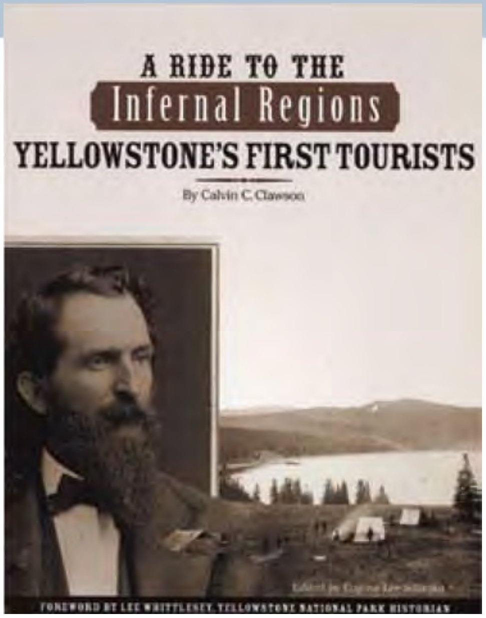
YS

Acknowledgments

The author extends his appreciation to Wallace Fine Dailey, the curator of the Theodore Roosevelt Collection at Harvard University, and George Rugg, the Curator of Special Collections at the University of Notre Dame, for providing many of the images reprinted here.

Jeremy M. Johnston was born and raised in Powell, Wyoming. He received his BA and MA from the University of Wyoming. His master's thesis is entitled, "Presidential Preservation: Theodore Roosevelt and Yellowstone National Park." Jeremy teaches Wyoming and Western history, including a college level course on the history of Yellowstone National Park, at Northwest College. His writings have been published in *Readings in Wyoming History*, *The George Wright Forum*, *Yellowstone Science*, *Points West*, and various regional newspapers.

BOOK REVIEW



A Ride to the Infernal Regions: Yellowstone's First Tourists

by Calvin C. Clawson, Edited by Lee Silliman

Tamsen Emerson Hert

(Helena, MT: Riverbend Publishing, 2003. 136 pages, 13 photos, 1 map. ISBN 1-931832-18-8.)

THE ASTONISHING FEATURES of what was to become Yellowstone National Park were described by such men as Jim Bridger and John Colter. Their stories of the Yellowstone, considered "tall tales," were finally verified by scientific explorations in 1869, 1870, and 1871. In 1871, Calvin C. Clawson of Deer Lodge, Montana, and five of his associates decided to see the wonders for themselves. This group of six unwittingly became the first tourists in the world's first national park.

Members of the party included C. C. Clawson of Deer Lodge, Montana, and editor of the town newspaper; Rossiter W. Raymond, editor of the *Engineering and Mining Journal* and U.S. Commissioner of Mines and Mineral Statistics; Frederic A. Eilers, Deputy Mining Commissioner; Josiah S. Daugherty of Wabash, Indiana; Gilman Sawtell, resident of the north shore of Henry's Lake, Idaho (15 miles from the present boundary of Yellowstone National Park), and the guide for the group; and Augustus F. Thrasher of Deer Lodge, Montana, photographer. As stated in the introduction "…their avowed goal was to see the 'Spouting Geysers…the lake, canyon, cataracts, and hot-springs of the Yellowstone' that others before them had amply described—rather than explore new territory or further establish the veracity of the their predecessors…" With the Hayden Expedition still in the park at the time of the group's departure, there were no maps available to show them the way. No map is mentioned in their accounts. They did have a description of the Upper Geyser Basin from Nathaniel Langford's articles published in *Scribner's Monthly*.

Interestingly, the group missed the Upper Geyser Basin, viewing only the Lower Geyser Basin before heading across country to Yellowstone Lake and then on to the Grand Canyon of the Yellowstone. Along the route they did encounter Gustavus Doane of the Hayden Expedition who directed them to the Upper Geyser Basin, which they visited on their return to Virginia City. Another interesting note is that A. F. Thrasher was the photographer; yet the volume is not illustrated with any of his photographs. In fact, none have been found, or it is likely that his early images of the Yellowstone would be comparable to those of William Henry Jackson, whose photographs are used to illustrate this work.

Lee Silliman discovered a gem when he unearthed the account of this 1871 visit in the Deer Lodge, Montana, *New North West* newspaper. This rare account of the journey has not been republished since its original appearance in seventeen installments between September 9, 1871, and June 1, 1872. The reprinting of the installments here attempts to reflect the original newspaper format.

More than the simple reprinting of a series of newspaper articles, Mr. Silliman enhances the value of this account with his annotations and supplemental material. The lengthy introduction gives the reader background on the trip; biographical material on the six travelers; details about the route; and describes the party's encounters with wildlife as well as their thoughts about Native Americans.

The text itself is divided into the

Hayden survey in "earthquake camp" on the east side of Yellowstone Lake. On the night of August 19, 1871, slight tremors were felt. Photo by William Henry Jackson.

installments as they originally appeared under four separate titles: "Notes on the Way to Wonderland: A Ride to the Infernal Regions"; "In the Region of the Wonderful Lake"; "In Wonderland: The Region of the Wonderful Lake"; and "In Wonderland: The Region of the Enchanted Lake." Throughout the text Silliman provides valuable information through the use of footnotes. Unlike the typical format, where footnotes are printed at the bottom of the page, here the footnotes are printed in a column which parallels the text. This makes it exceptionally easy to check the footnote and not lose your place—very easy to read!

The reader will learn a great deal about the early days of Yellowstone as Clawson describes the travel, geography, thermal features, and more. In many instances the text is clarified or enhanced by the comments in the notes. For example, in using "Wonderland" in the title of the installments, the reader learns from Silliman that this is the first public use of that term in describing the Yellowstone region. It is equally interesting to read Clawson's comments on the commercial value he sees in some of the thermal features—a topic that is being discussed in present day.

But this is more than Clawson's account of the trip. Silliman included additional material in five appendices that are accounts by other trip members, Rossiter W. Raymond and A. F. Thrasher, as well as an editorial presumed to be written by Clawson in support of the bill proposing the establishment of Yellowstone as a national park. This additional commentary fills in some of the gaps in Clawson's text.

The only criticism I have for the work is the lack of one additional map. It would have been nice to have a map of the route from Virginia City to Henry's Lake to the Madison River. I pulled out a Montana highway map to locate Deer Lodge and the approximate route to the park. Finally, in the bibliography there are a couple of errors. One is the repeated entry of one citation, and the other is that some of the sources cited in the footnotes were not listed in the bibliography.

This is an excellent read for anyone with an interest in Yellowstone. Historians as well as geyser gazers and everyone in between will be intrigued by the descriptions provided here. So, follow Lee Whittlesey's recommendation in the foreword, "…curl up somewhere in a warm place, pretend it is 1871 and enjoy C. C. Clawson's fascinating tale of pre-stagecoach Yellowstone."

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Tamsen Emerson Hert is the Wyoming Bibliographer at the University of Wyoming Libraries. Her article, *Luxury in the Wilderness, Yellowstone's Grand Canyon Hotel, 1911–1960,* which appeared in *Yellowstone Science* 13(3), won the Wyoming State Historical Society award for best article.

FROM THE ARCHIVES

THE PRESIDENT AND MR. BURROUGHS NEAR A GEYSER.

Copyright, 1903, by The Illustrated Sporting News.

Theodore Roosevelt with naturalist John Burroughs observing a geyser. This image appeared with Lindsay Denison's article for *The Illustrated Sporting News*.

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