PRESIDENTIAL ADDRESS

Reflections on Science in South Dakota and on Vitamin B_{12}

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As I reviewed the previous Presidential addresses from the past decade, I found two themes that dominate the addresses — comments on the state of science in South Dakota and beyond and presentations on scientific subjects of interest to the President of the Academy. I have chosen to speak with respect to both of these subjects.

SCIENCE AND CHANGE IN SOUTH DAKOTA

Change is an inevitable event. The only thing certain is uncertainty. If you do not like the weather in South Dakota, give it an hour and it will change. Clichéd sayings yet appropriate ones for all of us.

As I sit and finalize my thoughts for this address, I have already had to change some of them, maybe many of them, even the ones that were written as recently as just a few days ago. A day does not seem to pass when what we knew yesterday is not what we know today, sometimes for the better, and sometimes for the worse.

Science in South Dakota, whether it is related to its teaching or its research, has changed considerably over the twelve plus years during which I have lived and worked in the State of South Dakota. The changes have been at the local, statewide, and global levels. I, as many of you, have experienced these changes, which are, in large part, the result of the explosive growth and development of our electronic technologies. These changes are guaranteed to continue.

We will soon be entering a new, possibly different, era of science and education in South Dakota. This era is one that will be mapped by a new official in the highest office of the state. For many of us, new officials at the local level will also map the direction within this new era. Personally, my institution, the South Dakota School of Mines and Technology (SDSM&T), is beginning to look at its next 10 to 20 years. Its executive officer, Dr. Richard Gowen, has given notification that he will be resigning during the summer of 2003, and now SDSM&T is considering its future. Other institutions in the state are facing similar situations as some of their high level administrators are considering career changes and moves.

I, as many of you, have experienced the highs and lows of education, particularly science education, in the state. I have met with satisfaction and frustration as I have performed my tasks and met my responsibilities as a member of one of the higher education institutions in the state. I have had to learn to adapt and change, sometimes as quickly as the proverbial overnight, to maintain a competency within my position.

The delivery of education, perhaps as recently as 10 years ago, was for many of us, the standard classroom setting in which traditional lecture was likely employed to deliver the material to the student. The student was required to supplement this material by reading an accompanying textbook, and the student's assessment was probably accomplished by traditional written examination. Since then, of course, many changes have occurred. Electronic methods of delivery and interaction have entered our classroom. The textbook is now complemented or even replaced by CD's and websites. Students bring their laptops to class for downloading of materials as opposed to transcribing the material given during the lecture, and in turn, they upload their completed assignments. Group learning, team teaching, and interdisciplinary subjects have entered the classroom. Assessment likely still includes written examinations but has been expanded to include oral examinations, traditional student portfolios, and electronic student portfolios. Delivery of course content has also evolved. First, it was the satellite uplink, then the videotape, and now on-line streaming of lecture material. These changes have permitted the expansion of the boundaries of our institutions and our state. Articulation agreements and cooperativity agreements have created new centers of education and new opportunities for students by which they can attain their higher education goals. These current trends are likely to be our future, especially the outsourcing of education to sites where traditional centers of learning do not exist.

Change is now prevalent in the ways scientists conduct their research and share their discovery. Scientists by nature are solitary creatures and often pursue their scientific inquiry on an individual basis, sometimes with the help of a body of research assistants. But this is changing and also will continue to change. The speed at which data is collected, analyzed, and reported is increasing almost on a daily basis and the single scientist is a diminishing entity. Partnerships, collaborations, and research teams are developing between faculty within departments, between departments, between institutions, and between even institutions in different countries. Similar couplings are happening between academia and industry. A review of the current scientific literature reveals a rapidly growing number of publications that are being submitted by multiple principal researchers and that are being submitted from multiple institutions. Within South Dakota, the Experimental Program to Stimulate Competitive Research (EPSCoR) and Small Business Innovation Research (SBIR) are two programs that have helped to foster the pursuit and establishment of many of these partnerships. A faculty member's survival, tenure, and promotion at many institutions rely on the ability to conduct some level of research or scholarly activity. Collaboration in research was at one time viewed with a negative attitude by evaluators of faculty performance, but now such teamwork is encouraged if not mandated. Finally, scientists are faced with the reinvention of themselves, often as the result of changes in their funding sources, and sometimes simply because of our inherent curiosity in the things that surround us. Research is being done still in the name of basic science and for the satisfaction of gaining knowledge, but more and more it is also being done for the sake of application, for profit, and for the support and benefit of the local and global communities.

As a closing note on science in South Dakota, I earned a Ph.D. in Inorganic Chemistry. My graduate education prepared me for a life of research and scientific inquiry. A postdoctoral experience further prepared me for this endeavor. However, I have often been the researcher last and everything else first, things for which I was never truly trained. It is hard to tell what it is that I am today, as I am the chair of my department, an educator of students, a mentor of graduate students, and an advisor of students and colleagues – I am an first administrator and a teacher, and then finally a researcher. But I am a scientist, and although what I was specifically prepared to do is not what I usually do each day, my training as a scientist did prepare me for the expected and frequently sudden changes that occur in my position and in my life. I believe I speak for many of us in that we are prepared for these changes because we are scientists. We are by nature the skeptic, and we are therefore always wary of the things that we observe, that we stand ready to always look at life with an open eye and mind, and that we respond quickly and correctly to the unexpected.

THE COBALAMINS – THE INORGANIC VITAMINS

Vitamins are vital chemical and biochemical species that are required in small or trace amounts to maintain a healthy life in the higher animals. The animals that require them do not make such species, nor do they store these vitamins in their bodies for extended periods of time. Commonly known vitamins include Vitamin C (ascorbic acid), Vitamin E (a-tocopherol), Vitamin B_1 (thiamine hydrochloride), and Niacin (nicotinic acid). Unique among the vitamins is Vitamin B_{12}, owing to the fact that it is considered to be inorganic in its composition and function. The other vitamins are considered organic in their composition and nature.

Vitamin B_{12} and its related compounds are collectively known as the cobalamins, a name that is derived from the shortening of the expression "cobalt vitamin". It is the presence of cobalt within these compounds that makes it inorganic, makes it unique among the vitamins, and permits it to perform its vital and life-sustaining transformations within the higher animals. Without the presence of the cobalt, the vitamin is non-functional and is of no worth to a living system.

In its biochemistry, Vitamin B_{12} does not function independently. As such, it is therefore biologically designated as a coenzyme, meaning that it acts in concert with other biological molecules to complete its designated function. As already mentioned, it is a species that is not produced by the animals that require it and plants also do not produce it. It is only produced by microorganisms (anaerobic bacteria) that are typically found in the intestinal tract of animals. Humans and other animals acquire their daily dose of Vitamin B_{12} through a diet that includes products such as meat, milk, cheese, and eggs.

Vitamins typically are classified as fat or water soluble, based upon where the vitamin is stored by the body. Vitamin B_{12} is one of the water-soluble vitamins and is widely found throughout the body in locations such as the blood, brain, milk, spleen, and kidney. A healthy person needs to ingest and uptake but a trace of the vitamin on a daily basis — only 10 μg. One of its most essential roles is in the production of healthy red blood cells. Deficiency of Vitamin B12 in the blood is responsible for the disease called known as pernicious anemia.

There are currently six forms of Vitamin B_{12} that can be isolated from biological sources. Prior to the late 1960s, there were only five forms that could be isolated. The first to be isolated and characterized was cyanocobalamin, which is commonly given the name Vitamin B_{12}. Standard multivitamins and Vitamin B_{12} supplements contain the cyanocobalamin form. Other forms that were eventually isolated and characterized are adenosylcobalamin (coenzyme B_{12}), methylcobalamin, aquacobalamin, hydroxo(y)cobalamin, and most recently, sulfitocobalamin. The last is now considered to be technological artifact of modern food preserving practices. It is often found in fish products, which are frequently treated with sulfur dioxide (SO_2) as a preservative. SO_2 reacts with natural hydroxo(y)cobalamin in the fish to produce the sulfitocobalamin. Although all forms can be isolated from biological sources, only the adenosylcobalamin and the methylcobalamin are biochemically active and useful.

The history of Vitamin B_{12} begin in the mid-1920s when sufferers of the disease pernicious anemia were treated by a regular ingestion of 1 pound of raw (not cooked) liver, a dosage that varied with the severity of the patient's condition. In 1948, the first form of Vitamin B_{12} — the anti-pernicious anemia factor — was isolated and crystallized from liver and its structure was determined in 1956. Unfortunately, what was isolated and later structurally characterized is an anomaly and it was not the truly active form of Vitamin B_{12}. The biologically active forms, adenosylcobalamin and methylcobalamin, are destroyed upon exposure to light and are converted to aquacobalamin and hydroxo(y)cobalamin. The latter two species are in turn converted to cyanocobalamin upon exposure to cyanide ion, which was one of the reagents used in the original experiment to isolate the species from liver. The active forms were later isolated from both human and microbial material and clearly shown to be $AdoB_{12}$ and MeB_{12} but the name Vitamin B_{12} had already been attached to the anomalous form of cyanocobalamin.

Pernicious anemia, which has been mentioned several times, is a disease that results from insufficient levels of Vitamin B_{12} in the blood. This deficiency can be the result of lifestyle choice (vegetarian/ vegan, alcoholism), temporary physiological changes (pregnancy), and biochemical breakdowns (inability to form the coenzyme B_{12}, lack of enzymes and related species for uptake and transport). In most instances, supplements can overcome the deficiency; however, in the case of a lack of Intrinsic Factor, the glycoprotein responsible for the uptake of Vitamin B_{12} from the intestine, supplements are usually ineffective and direct delivery of Vitamin B_{12} into the blood is sometimes necessary. Symptoms of a Vitamin B_{12} deficiency are manifested in the neurological and the physical. For the former, symptoms include apathy, irritability, memory defects, dementia, emotional instability, depression, and psychosis. The latter symptoms include fatigue, indigestion, burning sensation on tongue, pale or yellowish complexion, and gastric cancer. Most of the symptoms can be reversed by treatment with Vitamin B_{12} but without treatment, death is the eventual outcome of a deficiency of the vitamin.

As a closing note on the cobalamins, exactly why does Vitamin B_{12} exist and what does it do. There are many reasons and I give just a few examples. The active forms of Vitamin B_{12} are responsible for the production of healthy red blood cells and several important biochemical transformation functions. Adenosylcobalamin is a catalyst for numerous biological transformations of the isomerase and mutase type, reactions in which organic molecules are converted from less useful to more useful forms by simple rearrangement of their constituent nuclei. Methylcobalamin is a methyl transfer agent and among its many roles is its use as a detoxification agent by anaerobic bacteria, where a need exists for the conversion of toxic elemental mercury to water-soluble methylmercury compounds. The latter compounds are readily eliminated by the bacteria whereas the elemental mercury is not and it remains within the organism.

CLOSING COMMENTS

I thank you for your time in listening to the thoughts of one scientist and educator in the State of South Dakota. I solicit your responses to my thoughts and welcome a dialogue on them. I would also like to thank Dr. Daniel L. Heglund for his valuable assistance in the preparation of this address.