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ABSTRACTS

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The American Society for Clinical Laboratory Science serves as the voice of all clinical laboratory professionals, creating a vision for the advancement of the clinical laboratory practice field, and advocating the value and role of the profession ensuring safe, effective, efficient, equitable, and patient-centered healthcare.

ASCLS Core Values

Core Values include enhancing quality standards and patient safety; providing professional development opportunities; promoting expanded roles and contributions of clinical laboratory professionals to the healthcare team; increasing the diversity in the profession; and expanding the voice and role of under-represented individuals and groups.

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CONTINUING EDUCATION QUESTIONS
Reimbursement Concerns

KATHY HANSEN, DON LAVANTY

ASCLS, through the vigilance of its Government Affairs Committee (GAC) members, the legislative consultant, and the executive vice president, watches for changes and developments in payment policies for laboratory services that will be of concern to our members. ASCLS’ participation in collaborative efforts with other professional organizations, such as with the Clinical Laboratory Coalition, is another venue from which to watch for and comment on changes in reimbursement policy.

There are a number of areas of activity that are “heating up” at the moment, any of which could become an issue that would require a full-fledged advocacy effort by the ASCLS membership. Whether or not these are officially implemented remains to be seen, but they provide a snapshot of the type of activity that goes on continually and needs our attention.

Competitive bidding: One of the provisions of the Medicare Modernization Act (MMA) of 2004 was a Congressional mandate for the Center for Medicare and Medicaid Services (CMS) to conduct a competitive bidding project for clinical laboratory services. ASCLS has long vigorously opposed the concept of competitive bidding for laboratory services, holding that laboratory tests are services, not commodities. Quality and access are important features of laboratory testing and as important, or more important, than price.

To comply with the MMA legislation, CMS appointed a director of the project and hired a contractor, Research Triangle Institute, to plan and conduct the bidding process. The purpose of the demonstration is twofold:

• To determine whether competitive bidding can be used to provide Part B clinical laboratory services at fees below current Medicare reimbursement rates while simultaneously maintaining quality and access to care

• To gain valuable information on the relative costs of laboratory tests

The details of the competitive bidding demonstration project were outlined in the Washington Beat column in the Winter 2006 edition.

An initial report was due to Congress by December 31, 2005, but had not been published as of mid-February, 2006. The demonstration project was to last three years in order to allow time for analysis of the impact on quality, access, and savings. However, President Bush’s proposed 2007 budget (to be effective October 2006) calls for competitive bidding nationwide for Medicare outpatient laboratory services, without waiting for the results of a demonstration project.

The following wording is found in the administration’s budget proposal: “Competitive Bidding for Labs: CMS successfully tested a competitive bidding model for DME (durable medical equipment) in Polk County, Florida and San Antonio, Texas. Based on that success, MMA expanded DME competitive bidding nationwide and required a similar competitive process for outpatient drugs [Note: this refers to drugs administered during a clinic visit, not those purchased by the patient for home use.] The Budget proposes to build on these successful competition models by extending competitive bidding to Medicare laboratory services.”

Estimated savings are $1.43 billion over the period 2007-2011.

Implementation of nationwide competitive bidding could have a devastating effect on hospital outreach programs, many of which could be shut out of performing testing for Medicare beneficiaries. ASCLS will oppose this proposal.

Medically Unbelievable Edits: CMS proposes to implement new edits called Medically Unbelievable Edits (MUEs) as of July 1, 2006. These frequency edits would be added to the Correct Coding Initiative (CCI) edits already in place for
Analyzing Medicare outpatient claims. Previous CCI edits have looked at pairs of current procedural terminology codes and banned certain ones from being billed on the same date of service. For example, there is a CCI edit that prevents billing a hemoglobin on the same date of service as a hemogram, since the hemoglobin is part of the hemogram or complete blood count. This particular example can be problematic for a same-day surgery patient, for example, who may have a hemogram ordered pre-operatively, and then a hemoglobin rechecked later in the day post-op. The proposed MUEs go a step further and set limits for nearly every CPT code as to how many can be billed on one date of service. There are many examples that are creating concern in the laboratory community, such as:

88305 Level IV – Surgical pathology gross and microscopic examination. MUE limits to two per day. This code is used for many common types of biopsies such as skin biopsies or prostate needle biopsies, where many more than two distinct specimens are commonly taken at the same time. Some institutions estimate that 25% to 50% of their claims for this service would be denied under this MUE.

82784 Gammaglobulin, IgA, IgD, IgG, IgM, each. MUE limits to one per day. Accepted ordering practice is to order IgA, IgG, and IgM together on the same sample.

83896 Molecular diagnostics; nucleic acid probe, each. MUE limits to one per day. Most molecular assays use multiple probes, from as few as two to as many as 90 or more per sample to look for mutations. The MUE limit would mean that laboratories would lose money on all these tests.

ASCLS is preparing comments, due in March, about these edits. We feel strongly that these edits do not reflect current accepted (not excessive) ordering practices.

Clinical laboratory fee schedule: The Medicare laboratory fee schedule was developed in 1984. While there have been some inflationary updates, the relative pricing of laboratory services has not changed to keep pace with changes in technology that make some older tests less expensive to run, while expensive tests based on new technology are often not reimbursed adequately to cover costs. CMS and Congress recognize the limitations of the fee schedule, and this may be a reason why the laboratory is vulnerable to so many cuts.

ASCLS and CLMA have offered the time of laboratory professionals to develop an alternative logic for the fee schedule, possibly based on some sort of relative value unit system which is commonly used for other Medicare providers.

Advamed, the trade association representing the vendors of laboratory equipment and supplies, has developed a proposal to CMS which would establish an advisory group to deal specifically with reimbursement for molecular-based tests. ASCLS shares Advamed’s concerns about the inadequate process for evaluating new technology and establishing fair pricing. However, we are also concerned about carving out one particular segment of testing for attention, when we see the problems with the fee schedule as being much more extensive than this one area of testing.

State billing regulations: Pathology societies in a growing number of states are addressing the issue of markups added to pathology services provided by physician offices. The offices purchase tests and professional services from a laboratory on a client basis, then inflate that price when billing the patient or their insurance. Many consider this to be “fee-splitting” or fraudulent billing practice that drives up the cost of healthcare.

Some states have passed laws requiring that the laboratory bill the insurance company or other payer directly, rather than billing the physician office as a middle man. Others are working through their state board of medical practice to have the markups declared unethical. In some instances, the ban on markups has been limited to surgical pathology and cytology services; in others, all laboratory services have been included. In some states, ASCLS constituent societies have been asked to support direct billing initiatives.

These examples are only a sample of the issues that the GAC monitors on ASCLS members’ behalf. If you become aware of things that concern you, please contact a GAC member. Email addresses are on the ASCLS web site.
INDEX TERMS: bioterrorism; clinical laboratory.

Top government and public health officials have reported that the United States’ investment of $20 billion in bioterrorism preparedness since 2001 has left the US dolefully unprepared to respond to a bioterrorism attack. Critics such as Irwin Redlener from the National Center for Disaster Preparedness at Columbia University contend that bioterrorism preparedness programs are not operated in an effective manner, thus wasting billions of dollars.

Bioterrorism preparedness is the primary responsibility of the Department of Health and Human Services (DHHS). The department’s responsibilities include stocking antibiotics, sharing information among laboratories and hospitals, and assisting communities in response in the event of an emergency. This is an overwhelming responsibility even for the federal government. While the government has made advances in addressing this responsibility, problems exist with some of these efforts. For example, a national stockpile of medical equipment and supplies has been amassed and can be delivered to any city within 12 hours of an attack. Unfortunately, once the cities receive the supplies they have not developed the infrastructure to deliver these supplies to their citizens in a time frame that would save lives. While the location and exact contents of the stockpile are secret, DHHS reports that there is enough smallpox vaccine for every US resident and enough antibiotics to treat 60 million people who might be exposed the most viral form of anthrax.

In 2003 President Bush announced an initiative titled Project BioShield. The project is a $5.6 billion research effort intended to spur the development of vaccines and antidotes over a ten year period by pharmaceutical companies. The intent is to encourage these pharmaceutical companies to develop new drugs and antidotes of which the government would purchase most of the drugs if they meet specified standards. Despite the availability of a large pot of funding, pharmaceutical companies have not shown much interest due to liability concerns.

In 2004 a 21 city program titled Cities Readiness Initiative was launched by DHHS aimed at encouraging officials in the targeted 21 cities to develop plans for deploying supplies received from the national stockpile (Figure 1). As of yet no city has developed a workable plan that would get supplies to the public in time to counter the effects of the bioterrorism agent. A proposal to use the US Postal Service to distribute supplies from the airport to the community has been put forth. This would have to be agreed to by both the postal service and its workers and numerous issues remain unresolved.

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Cities are to develop plans to distribute vaccines and antibiotics in the event of a bioterrorism attack. Distribution of funds is based on population and geography.
The role of the clinical laboratory in bioterrorism has received no attention, yet the laboratory is a pivotal point in the preparedness strategy. In the event of an attack and before supplies arrive, physicians and nurses will be faced with massive numbers (hundreds to thousands) of patients presenting with various symptoms, which will require supportive therapy. It is reasonable to expect exposed patients to experience vomiting, diarrhea, dehydration, and numerous other symptoms depending on the toxin they have been exposed to. Treatment providers will require substantial laboratory work to appropriately treat patients. Tests such as electrolytes, basic chemistries (glucose, renal, and liver function tests), CBCs, and cultures are minimal essentials needed to make objective medical decisions. After treatment supplies arrive from the federal government, and patients are treated, these same basic tests will be required plus other tests necessary to monitor patients.

As in so many other situations, the laboratory is overlooked or simply forgotten in planning for a response to bioterrorism. Yet it is clear that this could be a major barrier to a successful bioterrorism response. Laboratory directors and managers must consider these potential scenarios and begin working with city officials to assure laboratory preparedness in the event of a bioterrorism attack.

Opinions expressed herein are solely those of the author.

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A Brief Survey of Aquaporins and Their Implications for Renal Physiology

WAYNE GADE, BROOKE ROBINSON

Aquaporins (AQP) are an important family of proteins that efficiently channel water through the cell membranes. Although water can diffuse across biological membranes at measurable rates, physiologists had long predicted the existence of channels to facilitate rapid reabsorption of water by renal tubular cells. With AQP's present, water can “gush” through the membrane at the extraordinary rate of three billion water molecules per second per aquaporin channel. In their absence, water only trickles across the hydrophobic lipid bilayers of cell membranes.

Aquaporins have fascinated researchers over the last decade, culminating in the 2003 Nobel Prize for Chemistry given to their discoverer, Dr. Peter Agre. During the 1990s, scientists identified and characterized members of the mammalian aquaporin family, now designated as AQP0 through AQP10. AQP's are also found in many plant and bacterial species. However, their relevance to the clinical laboratory is only recently emerging. Dr. Agre's Nobel symposium address provides an excellent mini-review of aquaporins in medicine.1

Our understanding of renal physiology and pathophysiology has advanced greatly as we account for the subtle implications of various AQP systems. For example, nephrogenic diabetes insipidus (NDI), the inability to produce concentrated urine, can result from several different malfunctions in the AQP2 system controlled by anti-diuretic hormone (ADH).

Virtually all mammalian cells incorporate aquaporins into their cell membranes, and many cells produce multiple aquaporins, each with a specific function. It is therefore not surprising that malfunctions have important clinical conditions. The present article discusses the implications of aquaporins for renal physiology, while the accompanying article is focused on the clinical aspects of aquaporins.

ABBREVIATIONS: ADH = anti-diuretic hormone; AQP = aquaporin; AMP = adenosine monophosphate; cAMP = cyclic AMP; CD = collecting duct; cDNA = complementary DNA; CHF = congestive heart failure; DCT = distal convoluted tube; NDI = nephrogenic diabetes insipidus; PCT = proximal convoluted tubule; RBC = red blood cells; RT-PCR = reverse transcription-polymerase chain reaction.

INDEX TERMS: aquaporins; diabetes insipidus; nephrogenic diabetes insipidus; renal physiology.

Clin Lab Sci 2006;19(2):70

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HISTORICAL PERSPECTIVE

Diffusion is defined as the passive movement of molecules from a high concentration to an area of lower concentration, and osmosis specifically indicates the movement of water across a semipermeable membrane.2 For decades, the mechanism of rapid osmosis in renal cell membranes had puzzled scientists, with predictions that water channels must be involved as early as the 1950s.1,3 Predictions were based on calculated energy requirements for unaided osmosis versus osmosis through channels, as shown in Figure 1. In the 1970s, the fluid mosaic model of membranes provided insights into the membrane environment,4 but also underscored the difficulty hydrophilic molecules would encounter when crossing the hydrophobic bilayer.5 By the 1980s, detailed studies of many transport proteins had added depth to our understanding of membrane structure and organization. However, until...
the early 1990s, the mechanism of rapid osmosis was still not adequately explained. Since their discovery in 1988, the family of known aquaporins has grown to include AQP0-AQP10. More than 200 similar water channels are known to exist in microorganisms as well as plant and animal cells. The scientific importance of aquaporins was further validated when Peter Agre, credited with their discovery, was awarded the 2003 Nobel Prize for Chemistry.

In the decade following their discovery, scores of researchers have made remarkable progress toward defining the molecular mechanisms of the aquaporin family and demonstrating their association with a wide range of clinical conditions. The accompanying article describes the clinical relevance of a wide range of diseases associated with dysfunction of various aquaporin systems.

Passive diffusion and osmosis
Water is small enough to allow passive diffusion (without energy expenditure) across cell membranes, driven solely by a concentration gradient. A gradient, or osmotic pressure, results from unequal solute concentrations on the two sides of a membrane. Whenever a gradient in solutes exists, water responds by diffusing toward the side with higher solute concentrations. Thus, water’s “urge to dilute” reduces the osmotic pressure until the concentration gradient is eliminated.

Kidney reabsorption illustrates the concept that, when given the opportunity, osmosis can effectively eliminate concentration gradients (Figure 2). As the urine filtrate passes through the proximal convoluted tubule (PCT), two thirds of the electrolytes and greater than 99% of most metabolites are reabsorbed. Yet the osmolality remains virtually unchanged because water follows the reabsorbed ions and metabolites. Thus, as shown in Figure 2, the filtrate volume is reduced approximately 70%, with minimal change in osmolality. For example, with a normal filtration rate of 100 mL/min, the PCT cells must reabsorb 70 mL/min. The transient solute gradients can drive unaided osmosis, but this model simply could not account for the speed of renal reabsorption.

Unaided osmosis left questions
The observed speed of water reabsorption in the PCT was one of several questions. Can water possibly diffuse through hydrophobic membranes fast enough to account for the PCT’s reabsorption rates? Also, as the filtrate descends through the loop of Henle into the hyperosmotic medulla, water is reabsorbed, but what prevents a flow reversal as the filtrate turns and ascends toward the renal cortex? If water diffuses through descending loop membranes so freely, how do the membranes in the ascending loop prevent diffusion? Finally, how can the collecting duct (CD) cells vary their water permeability, depending on hormonal control?

The hormone exerting control in the CD has multiple names. Clinical practitioners most frequently use anti-diuretic hormone (ADH). However, most researchers refer to this hormone as vasopressin, or arginine-vasopressin (AVP). For the purposes of this article, we will use ADH.

Evidence suggested the existence of aquaporins
Although water diffuses at an appreciable rate through biological or artificial membranes, calculations suggested that the rapid osmosis observed in the PCT would require a transporter molecule. For example, Chandy and coworkers had estimated that an activation energy of >10 kcal/mol is required for unaided osmosis across a hydrophobic lipid bilayer. Such an energy requirement would preclude the rapid transport seen in the renal tubules. The activation

Figure 1. A generalized representation of water diffusing across a membrane

The below illustrates two possible modes of water diffusing across the membrane barrier. On the right, a water molecule is shown crossing the membrane by simple unaided diffusion. In order to accomplish this, the water molecule must temporarily break numerous hydrogen bonds that can form in solution, so that it can cross the hydrophobic membrane. Calculations show that the activation energy required for this unassisted diffusion is > 10 kcal/mole. On the left, water molecules are seen crossing through an aquaporin channel, with this passage requiring < 5 kcal/mole of activation energy. This reduction in activation energy enables water to cross the membrane more than 100 times faster when aquaporins are present.
energy for diffusion across red blood cell membranes was calculated to be <5 kcal/mol, or roughly the equivalent of water diffusion within a solution. This suggested that water channels must lower the energy requirement for osmosis through the hydrophobic membrane, as shown in Figure 1. However, proving the existence of transporters was complicated by the background of unaided diffusion that exists even without aquaporins. For comparison, unaided osmosis occurs at a rate approximately $10^3$ times faster than glycerol or urea and $10^5$ times faster than glucose. The observed reversible inhibition of osmosis by HgCl$_2$ further suggested involvement of a transport protein that requires an active cysteine residue. Also, increases in water permeability were shown to correspond with the appearance of membrane proteins, with no observed changes in lipid composition.

**Figure 2.** A “stretched-out” nephron is shown indicating water reabsorption and osmolality in various portions

As the filtrate moves through the PCT, approximately 70% of Na$^+$ and water and 99% of metabolites are reabsorbed. As the remaining filtrate descends into the hyperosmolar medulla, more water is removed without Na$^+$ reabsorption. In both of these segments AQP1 is primarily responsible for water reabsorption. As the filtrate ascends toward the renal cortex, NaCl is reabsorbed without water reabsorption, because the ascending loop cells lack AQPs. In the DCT and DC, reabsorption of Na$^+$ and water are under hormonal control. Sodium reabsorption is controlled in the DCT by the Renin-Angiotensin-Aldosterone system, while water is controlled by ADH in the CD. ADH signals for AQP2 insertion into CD cell membranes and facilitation of water reabsorption as the filtrate exits through the hyperosmolar medulla.

**Demonstration of AQP1’s role as a water channel**

Karl Windhager proposed an invaluable strategy for confirming the aquaporin role through insertion of CHIP28 into *Xenopus laevis* oocytes. The complementary DNA (cDNA) for CHIP28 was obtained, and CHIP28 was incorporated into the oocyte membranes. Native oocytes are normally unresponsive to osmotic changes; however, once their membranes contained CHIP28, a dramatic 100-fold increase in water permeability caused cells to swell rapidly and burst. Reversible inhibition by HgCl$_2$, helped confirm that CHIP28 was indeed a water channel and the source of the new osmotic responsiveness. Similarly, embryonic rat cells lack osmotic responsiveness until they begin inserting aquaporins after birth. Additional studies using synthetic liposomes and reconstitution...
of CHIP28 from RBCs demonstrated that insertion of the protein led specifically to increased water permeability.21,22 Once CHIP28 was confirmed as a water channel, and several similar channels had been described, the aquaporin terminology was adopted, and CHIP28 was renamed AQP1.

Sequence homologies helped identify new aquaporins
Once their existence and functional role were demonstrated, researchers surveyed various cells for related aquaporin genes.1,8-16 Probes of cDNA from known aquaporins were used to search for similar genes with sequence homologies.16 The aquaporin family of proteins contains a pair of unique and highly conserved sequences in the gene, which helped researchers construct valuable cDNA probes.16 Using this strategy to survey the human genome, the aquaporin family grew rapidly and now includes AQP0-10.12,17

Molecular techniques used in aquaporin research
Since the isolation of cDNA to CHIP28,20 cloning of each of the AQP genes has been undertaken using a multitude of molecular techniques. These techniques include: cloning the DNA into a variety of vectors, PCR, reverse transcription-PCR (RT-PCR), electrophoresis followed by all three common forms of blots (Southern, Northern, Western), immunohistochemical analysis, in vitro transcription and translation, differential centrifugations, enzyme immunoassay, and many other methods.23,24 A concise summary of these techniques is available,4 and a more detailed compilation of these techniques is also available.25

Assessment of gene expression
Since all somatic cells contain each aquaporin gene, the expression of a specific aquaporin in a particular tissue helps to determine its functional role. Gene expression or the presence of messenger RNA is demonstrated through the use of RT-PCR.16,26-28 The appearance of the protein products is then confirmed using immunohistochemical methods and is related to AQP function. Once gene expression is demonstrated in a tissue, its developmental timing and the impact of physiological conditions can yield insights into its functional role.26-28 Such studies have implicated the increased expression of AQP2 in the pathogenesis of several conditions of volume overload, including congestive heart failure (CHF), pulmonary edema, and liver cirrhosis.11,12 In addition to ADH effects, conditions that alter AQP2 expression include: lithium treatments, hypokalemia, hypercalcemia, chronic renal failure, ischemic renal failure, cirrhosis, mephitic syndrome, and seemingly unrelated conditions such as a low protein diet or exposure to high altitudes.11,12 Physiologic conditions such as exercise, fasting, or starvation are known to alter the expression of AQP7 and AQP9.27,28 Correlating the changes in AQP expression in response to physiological or pharmacological conditions often suggests the AQP functional role.1,8-10 Altered AQP expression following drug treatments also helps differentiate between strategies likely to have beneficial or detrimental results. For example, lithium treatment causes a downregulation of AQP2 expression in CD cells,26 and explains why many patients on lithium develop transient NDI. Such knowledge may suggest corrective measures for future treatments.

Patient with AQP deficiencies and “knockout mice”
Much valuable information can be gained from observing the pathophysiologic results when either patients or animal models lack functional AQPs.29-32 Ma and coworkers have provided a good summary of their protocol for inserting defective genes to produce “knockout mice”.29 Patients with an inability to make AQP1 have been extensively studied.31 Given the importance of AQP1 in the PCT reabsorption of water, it was initially surprising that these patients had only mildly defective urine concentrating ability.31 However, further research has suggested that other AQPs are present in the PCT. More dramatic forms of NDI have been seen in patients with deficiencies in AQP2 or the ADH-receptors.30,34 These two conditions are more thoroughly described in the accompanying article.

The effect of a defective AQP4 gene was observed in “knockout mice” to gain information about the functional role of the gene product.29 AQP4 is expressed in the CD cells, and facilitates water’s exit from the basolateral membranes after AQP2 has facilitated uptake into the cells. These mice had a four-fold decrease in ADH-stimulated reabsorption.29 However, AQP4 is most strongly expressed in the brain, and a major role in osmoregulation had been proposed. In this study, the AQP4-deficient mice demonstrated no gross neuromuscular abnormalities or obvious problems with osmoregulation.29

Immunohistochemical methods establish cellular localizations
The cellular or subcellular location of aquaporins also leads to understanding their physiological role. Most often, immunohistoassays use microscopic visualization of fluorescent labeled anti-AQP antibodies in tissues or specific membranes.24,27,30,32,33 Figure 3 shows the specific locations of various AQPs in renal cells that were established using microscopy and immunoassays. Traditional cellular fractionations based on centrifugation have been useful to quantify which cell fractions contain the AQP.
Complex questions require multiple techniques
As research questions become more sophisticated, many answers require a combination of multiple techniques to detect gene expression, cellular locations, and regulation of gene expression. In hormonally regulated systems, a pathologic condition may result from complications with several factors of the multi-step process. For example, NDI can result from AQP2 gene mutations, malfunction of ADH receptors, changes in gene expression, or trafficking malfunctions (the process of folding and transporting of newly synthesized AQP to the cell membrane). Sorting through these complex physiological systems requires a combination of the above techniques to separate individual parts of the system.

AQUAPORINS SOLVE MANY BIOCHEMICAL PUZZLES
As with any quantum leap in science, the discovery of aquaporins not only offers simplified explanations of basic phenomena, such as cellular swelling in hypoosmotic environments, but it also helps explain more complex phenomena. Such phenomena include the hormonally regulated reabsorption in the renal CD, stimulation of transient secretions in salivary and lacrimal glands, the pathophysiology of NDI, development of various forms of edema, and possibly the regulation of plasma osmolality.

Water and the central puzzle
Prior to the discovery of aquaporins, scientists were perplexed by how easily water permeated the hydrophobic barrier of a lipid bilayer. Why should water, the very molecule used to define our concept of hydrophobicity, be the primary exception to the rule that hydrophilic molecules cannot cross hydrophobic membranes without help?

Many cells have modest osmotic needs. If not involved with reabsorption or secretion, they can rely on unaided osmosis. However, even steep osmotic gradients are simply insufficient to drive water over the large energy hill required for unaided osmosis with the reabsorption rates observed in the PCT (Figure 1). Thus, renal physiologists were left to struggle with several complex puzzles. If membranes of the PCT and descending loop of Henle reabsorb 80% of the urine filtrate, at “gushing” rates of 80 mL to 120 mL per minute, why are neighboring ascending loop membranes almost impermeable to water? On the molecular level, how can one membrane allow rapid osmosis, while others block this seemingly inevitable flow? And finally, what on/off switch enables CD cells to regulate osmosis based on the presence or absence of ADH?

Figure 3. Distribution of aquaporins (AQP1, AQP2, and AQP3) in membranes of renal tubules
Note that AQP1 is present in large quantities in both the apical and basal membranes of the cells of the proximal tubules and descending loop of Henle (panel 3A). Similarly, AQP3 is present in the basal and lateral membranes of the principle cells in the collecting duct (panel 3B). Both AQP1 and AQP3 channels are always present in these membranes. However, AQP2 channels are only inserted into the apical membrane of the collecting duct cells following a signal from ADH.

3A
Proximal tubules,
descending thin limbs

3B
Collecting duct,
principal cells

Renal physiology revisited, accounting for aquaporins

The original renal puzzle was unanswerable as previously stated: If most membranes freely allow osmosis, then what prevents osmosis through ascending loop cell membranes? The answer became obvious with the realization that membranes normally restrict osmosis, unless aquaporins are present.

Renal reabsorption of water and NaCl is illustrated in Figure 2. Approximately 70% of both water and Na⁺ are reabsorbed in the PCT, without changing the osmolality. As the filtrate descends into the medullary region in the descending loop of Henle, another ten percent of original filtrate volume is reabsorbed as the hyperosmolality of the medulla provides a steep concentration gradient and “sucks” water out. Such rapid reabsorption in the PCT and descending loop of Henle is facilitated by a high density of AQP1 and AQP3 (Figure 3A).¹¹,¹²,¹⁵ Permeability studies with AQP1 present demonstrate that water can “gush” at the phenomenal rate of 10⁷ water molecules/second/channel.²¹,²³

However, as the filtrate ascends toward the cortex, the filtrate is hyperosmolar compared to the decreasing solute concentrations during the ascent toward the renal cortex. Logically, water flow should reverse and re-enter the tubule. Why does flow reversal not happen? If AQP1-mediated osmosis explains the remarkable reabsorption rates in the PCT membranes, its absence also explains the impermeability of the ascending loop membranes. The membranes of ascending loop cells simply lack any AQPs, meaning that no magical bilayer reconstruction or lipid reformulations are required to reduce osmosis to a trickle.

Regulated transport systems

Two basic mechanisms of regulated passive transport have been described. First, gated systems use transporters that open and close, as commonly seen with ion transporters of the neuronal or neuromuscular systems. Second, sequestered transporters remain in intracellular vesicles until a specific signal promotes transport. Insulin-based regulation of glucose transport in muscle and fat cells illustrates the second mechanism.²⁴ In muscle or fat cells, an intracellular pool of glucose transporters is unavailable, except following the binding of insulin to its receptor.²⁴ Thus, glucose uptake by these cells only occurs after a meal and subsequent to the secretion of insulin.

The ADH-controlled reabsorption in the CD is analogous to this second mechanism, with a intracellular pool of presynthesized AQP2. In the absence of ADH, these AQP2 channels reside in intracellular vesicles and do not facilitate water reabsorption. When ADH is present, AQP2 channels are inserted into the cell’s luminal surface, and water enters the CD cells (as illustrated in Figure 3B), driven by the concentration gradient in the hypertonic medulla. Other AQP channels, designated AQP3 and AQP4, are always present (constitutive) on the plasma side of the CD cells and facilitate the unregulated exodus of water from these cells (Figure 3B). Reabsorption occurs only when ADH binds its receptor, signals for AQP2 insertion, and water to be allows water into the cell. Finally, AQP3 and AQP4 allow water to be drawn out of the opposite cell membrane.¹,⁸-¹⁷ Figure 2 illustrates the difference in osmolality and volume of urine produced with and without ADH present. Thus, both diabetes mellitus and diabetes insipidus relate to a malfunction of two analogous transport systems.

Summary of renal reabsorption

Note that knowledge of the existence of AQPs does not change the basic observations of renal reabsorption as described in introductory classes.¹⁸,³⁵ However, the molecular-level explanations of the phenomena are infinitely more satisfying. Furthermore, diagnostic assessment and therapies will no doubt be altered by our newer, more sophisticated model of renal physiology. Examples of the pathophysiology of several diseases and clinical applications are described in the accompanying article.

Molecular mechanism of aquaporins

The primary questions concerning the aquaporin mechanism were: 1) What causes the pore’s impressive selectivity, while allowing incredibly rapid diffusion of water? 2) How are H₂O⁺ ions excluded, while allowing very similar H₂O molecules rapid transit? 3) How is the observed HgCl₂ inhibition explained?

Molecular details of the common mechanism of the aquaporin family are elucidated in several excellent reviews.³⁶-⁴⁴ The folded protein contains four identical subunits that form funnel-shaped entrances from both sides of the membrane with a narrow central constriction that restricts all but the smallest molecules.¹,³⁶-⁴² Small ions, such as sodium, cannot shed their shell of water molecules and so are excluded from the pore. The H₂O⁺ ions, are excluded by positively charged amino acids in the heart of the pore. Finally, the water molecules must successfully re-orient themselves in different directions as they traverse the aquaporin “gauntlet”.³⁷-⁴⁴

In most (but not all) AQPs, a critical cysteine residue reacts with mercury ions and thus accounts for the reversible inhi-
bition of aquaporins by heavy metal ions. The Hg-sensitive cysteine residue is near the constriction, and reaction with mercury effectively blocks the pore.\textsuperscript{37-44} Interestingly, before the advent of loop diuretics, mercuric compounds were used to produce a profound diuresis,\textsuperscript{1} presumably by specific inhibition of the renal AQPs.

### Table 1. Characteristics of the family of aquaporins

<table>
<thead>
<tr>
<th>Aquaporin</th>
<th>Cellular location</th>
<th>Characteristics and/or role</th>
</tr>
</thead>
<tbody>
<tr>
<td>AQP0</td>
<td>Eye lenses, also called MIP (major intrinsic protein)</td>
<td>Comprises 50% of lens membrane proteins, removes excess water from lens</td>
</tr>
<tr>
<td>AQP1</td>
<td>Many cells, including RBCs, renal cells, eye cells, respiratory tissues</td>
<td>Major water channel of renal reabsorption, control of pulmonary edema</td>
</tr>
<tr>
<td>AQP2</td>
<td>Renal collecting duct cells (luminal surface)</td>
<td>Hormonally-regulated (ADH) reabsorption in kidney, Intracellular until cAMP-induced relocalization</td>
</tr>
<tr>
<td>AQP3</td>
<td>RBCs, renal cells, eyes, and brain cells</td>
<td>Unregulated kidney reabsorption, also transports glycerol</td>
</tr>
<tr>
<td>AQP4</td>
<td>Many parts of brain (center of osmoregulation), eye, and respiratory tissues</td>
<td>Possibly involved with osmoregulation and release retinal cells of ADH, control</td>
</tr>
<tr>
<td>AQP5</td>
<td>Eyes (lacrimal glands), salivary glands, other secretory glands, and respiratory tissues</td>
<td>Regulated water transport like AQP2, secretion of water from respiratory epithelial and gland cells</td>
</tr>
<tr>
<td>AQP6</td>
<td>Intercalated cells of renal collecting duct</td>
<td>Also a gated-ion channel, internalized in cells, possibly involved with plasma pH regulation</td>
</tr>
<tr>
<td>AQP7</td>
<td>Adipose tissue</td>
<td>Transports glycerol in addition to water, release of glycerol during metabolism of triglycerides</td>
</tr>
<tr>
<td>AQP8</td>
<td>Hepatocytes and pancreatic ducts</td>
<td>Localized in intracellular vesicles, cAMP-induced relocalization may control water in bile secretions</td>
</tr>
<tr>
<td>AQP9</td>
<td>Hepatocytes</td>
<td>Transports glycerol in addition to water, uptake of glycerol for use in gluconeogenesis</td>
</tr>
<tr>
<td>AQP10</td>
<td>Reported in kidney</td>
<td>Function unknown</td>
</tr>
</tbody>
</table>
Survey of variations within the aquaporin family

Presently, the human AQP family contains AQP0-AQP10, with different cellular locations and specificities as illustrated in Table 1. Logically, each of these AQP variations probably serves a unique physiologic function. However, the significance of many of the subtle differences is currently unknown and investigations continue.

Aquaporins as blood group antigens

As mentioned above, the discovery of CHIP28 (AQP1) occurred during a study of Rh antigens of RBCs. Although AQP1 has been shown to contain glycosylation corresponding to the ABO system, an AQP1 deficiency does not affect a person’s ABO type. ABO blood groups result from the presence or absence of two transglycosidases that modify the terminal residues of “glycosylation trees” on various molecules.

The Colton blood group antigen corresponds to a unique amino acid sequence near the N-terminus of AQP1. A mutation at residue number 45 substitutes an alanine for a valine and causes a non-functional AQP1. Patients with the mutation will produce antibodies to the normal Colton sequence following exposure to this antigen from a transfusion or pregnancy. An interesting case described in accompanying article involves a female patient whose AQP1-deficiency was only discovered when a prenatal screen detected anti-Colton (AQP1) antibodies during her second pregnancy. Her primary symptom, aside from the complications of the Colton blood group, was a subclinical NDI that was only obvious following stress.

Aquaglyceroporins and metabolism

Three members of the aquaporin family, AQP3, AQP7, and AQP9, allow efficient diffusion of glycerol, in addition to water. This seemingly curious specificity correlates well with their apparent physiological function, since fat and liver cells, known to import and export glycerol, express these glycerol-transporting aquaporins. AQP9 facilitates glycerol uptake by hepatocytes, where glycerol contributes carbons for gluconeogenesis. Glycerol, lactate, and amino acids are used for gluconeogenesis, which is essential for the liver’s maintenance of blood glucose levels during fasting or starvation. Fat cells use AQP7 to export glycerol produced during mobilization of triglycerides. Thus, both tissues depend on aquaglyceroporins during fasting or starvation conditions, and it is not surprising that both AQP7 and AQP9 are up-regulated during these conditions. Although AQP3 has similar ability to promote glycerol diffusion, its expression in numerous cells not involved with gluconeogenesis suggests that its primary role involves osmosis.

Conditions affecting glycerol metabolism also alter expression of AQP 7 and AQP9. For example, fasting, starvation, uncontrolled diabetes, and exercise all cause a marked increase in AQP9 expression. As obesity reaches epidemic proportions in the US population and Type II diabetes, insulin-resistance, and metabolic syndrome become popular “buzz words”, many unanswered questions remain concerning this newly appreciated aspect of our metabolism. For example, what consequences would result from AQP7 or AQP9 malfunctions? Can medications which alter their expression be useful in controlling these common metabolic conditions?

Intracellular AQP6 and the renal H+ ATPase

Transport of H+ ions is uniquely characteristic of AQP6, which associates with the H+-specific ATPase pump known to acidify urine in the CD. In addition, AQP6 apparently resides exclusively in intracellular vesicles of the intercalated cells in the CD. Molecular details and physiologic significance of AQP6’s odd specificity for transport of acids are not yet established.

Regulated osmosis and AQP2 and AQP5

Most osmosis is not directly regulated and is always driven by concentration gradients, even when facilitated by AQPs. However, the body must regulate osmosis in certain situations. As mentioned above, ADH regulates water reabsorption by controlling the insertion of AQP2 into the CD cell membranes. Receptor binding of ADH causes an increase in cyclic AMP (cAMP) and activates a protein kinase, which phosphorylates a specific serine residue on AQP2. Phosphorylation ultimately leads to AQP2 insertion into CD cell membranes.

Secretory glands and lung tissues apparently control fluid secretion through analogous regulation of AQP5. Lungs tissues, secretory glands such as the salivary and lacrimal, and ducts of the pancreas and bile are all known to contain AQP5. See Figure 2 in the accompanying article. Salivation, crying, and many other secretions are neither constant nor random, but are closely controlled by nerve stimulation. Interestingly, AQP5 resides in intracellular vesicles and contains a potential phosphorylation site homologous to the control site on AQP2, suggesting that these secretions are controlled by a similar mechanism.
CONCLUSION AND SUMMARY

Aquaporins are a family of channel proteins that facilitate osmosis, or the rapid movement of water, across virtually every cell membrane in our bodies. Although water slowly crosses hydrophobic membranes without aquaporins, many physiological systems demand much more rapid osmosis. In the renal PCT and descending loop of Henle, where 80% of renal filtrate is reabsorbed, osmosis occurs at rates approaching 100 mL per minute. AQP1 was first isolated from RBCs and the PCT, and facilitates reabsorption by increasing membrane water permeability by 100-fold. In fact, calculations place the rate of diffusion through these membrane channels at a phenomenal rate of $10^8$ water molecules/second/channel. Despite this amazing rate, most AQPs are extremely water-specific, effectively excluding ions or small neutral molecules such as glucose.

Two AQPs help control water transport in response to hormonal or neuronal signals. In the renal CD, pre-synthesized AQP2 remains internalized in vesicles until ADH signals for the vesicles to fuse with the cell membrane, which inserts AQP2 and increases reabsorption. A similar mechanism apparently controls AQP5 function in lung epithelial cells and various secretory glands. Another interesting subclass of AQPs involves AQP 3, AQP7, and AQP9, called aquaglyceroporins, because they transport both glycerol and water. These AQPs are found in fat cells and hepatocytes and are responsive to insulin and such physiological conditions as exercise and fasting, suggesting that their primary physiological role involves glycerol transport and control of gluconeogenesis.

Aquaporins are implicated, either as the primary lesion or secondarily, in numerous diseases. For example, NDI results from an ineffective AQP2 response to ADH signals aimed at stimulating water reabsorption. AQP2 is also indirectly involved in edematous conditions such as CHF, cfrhis, pulmonary edemas, while AQP4 may be involved with cerebral edema. Additional examples of clinical implications are described in the accompanying article.

The use of probes to screen the genome for homologous sequences has allowed researchers to identify the likely members of the aquaporin family. However, investigations into the expression of various AQPs remain an active and fertile area of research. Once the expression of a particular AQP is established, and its precise cellular location is determined, investigations focus on regulators of its expression to help elucidate its physiological role. Pathophysioalogic observations of animals and patients with defined mutations to AQP genes are also pointing to new directions for clinical research. Clinical applications are continually expanding with increased understanding of disease processes and exploration of possible therapeutic interventions.

As science gains insights into the AQP family and their clinical correlations, several commercialized version of research assays may soon arrive for routine clinical use. For example, elevated urinary AQP2 levels, as detected by EIA procedures, are associated with such conditions as diabetes insipidus, CHF, and liver cirrhosis. These procedures will likely be commercialized once the clinical significance has been established. Numerous immunoassays using antibodies to variant AQPs and nucleic acid probes to normal and variant AQP genes also have exciting potential for development into clinical markers.

REFERENCES

Virtually all human cells incorporate aquaporins, or water channel proteins, into their cell membrane. Indeed, many cells produce several aquaporins, each adapted for a specific physiologic function. Thus, it is not surprising that aquaporin malfunctions are associated with numerous important clinical conditions. This article describes the clinical aspects of malfunctions in aquaporins or their regulation.

Although water can diffuse across biological membranes (osmosis) without the aid of a transport system, researchers had predicted for decades that rapid reabsorption by renal tubule cells must be aided by a channel or pore. Yet, not until the 1990s were the first members of the aquaporin (AQP) family identified. Led by Dr. Peter Agre, recipient of the 2003 Nobel Prize in Chemistry, researchers have since amassed an astounding amount of information about AQPs and their function. For example, the flow rate of water through AQP1 is an extraordinary three billion water molecules per second per aquaporin channel, while a relative trickle of water crosses the hydrophobic lipid bilayer of cell membranes devoid of AQPs.

Our understanding of renal physiology and pathophysiology has advanced greatly as we account for the subtle implications of various AQP systems. For example, nephrogenic diabetes insipidus (NDI), the inability to produce concentrated urine, can result from several different malfunctions in the hormonally controlled AQP2 system. The list of diseases known to involve AQPs now includes: early onset of cataracts, Sjogren’s syndrome, cerebral and pulmonary edemas, cirrhotic liver development of ascites, and congestive heart failure (CHF).

**ABBREVIATIONS:** ADH = anti-diuretic hormone; AQP = aquaporin; cAMP= cyclic adenosine monophosphate; CDI = central diabetes insipidus; CHF = congestive heart failure; MIP = major intrinsic protein; NDI = nephrogenic diabetes insipidus; PCT = proximal convoluted tubule; RT-PCR = reverse transcription - polymerase chain reaction; SS = Sjogren’s syndrome; SIADH = syndrome of inappropriate ADH secretion.

**INDEX TERMS:** aquaporins; diabetes insipidus; nephrogenic diabetes insipidus; renal physiology.

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The first aquaporin, originally called CHIP28, was accidentally discovered during an investigation of Rh antigens, and the authors suggested it was part of the red cell cytoskeleton.\(^1,2\) Elegant demonstration that the CHIP28 protein was indeed a water channel occurred when its insertion into frog oocyte membranes conferred a rapid response to hypotonic (low solute) conditions. Normally, these frog eggs respond very sluggishly in hypotonic buffer, but oocytes expressing CHIP28 rapidly swelled and exploded when placed in a hypoosmolar buffer.\(^3\)

Since this 1991 demonstration, aquaporin research has similarly “exploded” with reports of 11 different AQPs, several thousand AQP articles in the scientific literature, and the 2003 Nobel Prize for Chemistry for their discoverer, Dr. Peter Agre.\(^1\) Hundreds of AQP researchers have purified, characterized, and successfully cloned aquaporins designated AQP0-AQP10.\(^4-9\) Detailed molecular mechanisms of several
AQP1s are known, enabling researchers to relate structural
details to their function.6,8,9 Subtle differences in AQP
activities and different tissue localizations have suggested
specialized functional roles.5-9 A more complete description
of aquaporin research and methodologies is included in the
accompanying article.

A thorough understanding of renal physiology now explains
the very rapid reabsorption of water in the proximal con-
volved tubule (PCT) by acknowledging the presence of
plethora of AQP1 channels in the membranes.10-13 The rela-
tive water impermeability of cells of the ascending limb of
the loop of Henle, which was previously mysterious, is now
simply explained by their lack of AQPs. Hormonal control
of water reabsorption by cells in the collecting duct is known to
depend on insertion of an intracellular pool of AQP2 chan-
nels following the binding of anti-diuretic hormone (ADH)
to the cell surface receptor.10-13 A more complete description
of this system is given in the accompanying article.

Basic science research directed at cell biology inevitably an-
swers many clinical questions, as well as uncovering many
more unanswered questions. The list of associations between
diseases or pathophysiologic conditions and AQP system
malfunctions is constantly expanding.4-9 Within the next few
years, an understanding of AQPs will become an essential
part of laboratory medicine. This article will survey diseases
associated with AQP defects and provide several case stories
to illustrate the pathophysiology.

Table 1. Clinical applications of aquaporins

<table>
<thead>
<tr>
<th>Disease or condition</th>
<th>AQP involved</th>
<th>Malfunctions and symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renal diseases - NDI</td>
<td>AQP2 or receptors</td>
<td>Inability to concentrate urine, polyuria, lack of ADH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(vasopressin) response</td>
</tr>
<tr>
<td>Subclinical NDI</td>
<td>AQP1 deficiency</td>
<td>Subclinical NDI, symptomatic after osmotic stress</td>
</tr>
<tr>
<td>Sjogren's syndrome</td>
<td>AQP5, AQP1</td>
<td>Chronically dry mouth, eyes, and lungs. Deficiency or inappropriate signaling of AQP5 suspected.</td>
</tr>
<tr>
<td>Eye diseases (cataracts)</td>
<td>AQP0 (MIP)</td>
<td>Inappropriate removal of water from lens</td>
</tr>
<tr>
<td>CHF and liver cirrhosis</td>
<td>AQP2 elevation</td>
<td>Changes in aquaporin patterns</td>
</tr>
<tr>
<td>Pulmonary edema</td>
<td>AQP2 elevation</td>
<td>Changes in aquaporin patterns</td>
</tr>
<tr>
<td>Cerebral edema</td>
<td>AQP4</td>
<td>Malfunction of osmoregulation involving AQP4 suspected. Changes in aquaporin patterns, astrocytes</td>
</tr>
<tr>
<td>Colton blood groups</td>
<td>AQP1</td>
<td>Rare blood group related to mutation, produces no functional AQP1*, HDN-complicated pregnancies</td>
</tr>
</tbody>
</table>

*Surprisingly, patients without functional AQP1 have only subclinical renal symptoms in absence of stress. Under stressed conditions, these patients can exhibit a severe inability to concentrate their urine appropriately.25
CLINICAL METHODOLOGIES OF AQUAPORIN RESEARCH

Although AQP assays have not yet entered the routine clinical arena, their arrival is imminent as research assays are commercialized. A brief review of the wide array of research methods is included in the accompanying article.

Traditional protein biochemistry techniques have been combined with techniques of molecular biology, such as reverse transcription - polymerase chain reaction (RT-PCR) to convert cellular mRNAs back into DNA for cloning the AQP genes. In addition, quantitation of mRNAs leads to understanding of cellular expression and factors that mediate up- or down-regulation of various AQPs. The frog oocyte system described above remains a valuable tool to demonstrate water channel activities of normal and mutant genes which are inserted into transgenic mice and laboratory animal models. Others have identified and studied AQP-related mutations from actual patients. Tsukaguchi and others have evaluated the function of mutations in AQP and ADH receptors by inserting them into oocytes. These and other studies have demonstrated adverse effects in receptor binding and protein processing or trafficking, in addition to actual AQP dysfunctions.

Immunostaining, using antibodies to specific AQPs, has been instrumental in establishing tissue localization and in some cases intracellular localization.

Several research assays for urinary AQP2 are in the enzyme immunoassay format and could be added to the arsenal of clinical assays, once the clinical utility of detecting elevated levels of AQP2 has been established. Elevations in urinary AQP2 are found in CHF patients and those with liver cirrhosis, and AQP2 expression is known to be affected by numerous physiologic and pharmacologic factors.

Finally, as DNA probes become more commonplace in the clinical laboratory, the probes used to identify AQP mutations and assess levels of gene expression may present exciting diagnostic possibilities.

CLINICAL RELEVANCE OF AQUAPORINS

A summary of a range of aquaporin-related diseases can be found in Table 1. While renal diseases are the best characterized conditions resulting from compromised AQP systems, the following discussions will illustrate the mounting evidence for AQP involvement in many diverse pathologies.

Nephrogenic diabetes insipidus

Diabetes insipidus is defined by polyuria, even under conditions of dehydration, when ADH secretion normally maximizes water reabsorption. The inability to concentrate urine by reabsorbing water causes patients to produce 10-20L of very dilute urine per day. Inadequate secretion of ADH defines central diabetes insipidus (CDI), while the nephrogenic condition (NDI) results from an insufficient renal response to ADH. Recently, understanding of AQPs and the systems that control them has added greatly to our understanding of renal physiology and diseases.

The complex physiology of NDI starts with the ADH binding to its receptor and the response by CD cells, which requires several distinct steps. First, the cell-surface ADH receptors must specifically bind the ADH molecule. Binding to its receptors activates adenylate cyclase, an enzyme that catalyzes the synthesis of cyclic adenosine monophosphate (cAMP) and initiates the "second

Case 1. Congenital NDI*

A six month old male from a German family was diagnosed with congenital NDI following presentation with severe dehydration, hypernatremia, unexplained fever, vomiting, and failure to thrive. The child produced 1.1 L/day, 2-3x normal range. Other urine and serum chemistry levels are shown below, (normal ranges):

<table>
<thead>
<tr>
<th></th>
<th>Serum</th>
<th>Urine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osmolality (mOsm/kg)</td>
<td>316 (280-300)</td>
<td>104 (300-1000)</td>
</tr>
<tr>
<td>Sodium (mmol/L)</td>
<td>164 (135-145)</td>
<td>ND</td>
</tr>
<tr>
<td>Serum ADH (pg/ml)</td>
<td>35 (&lt; 2)</td>
<td>ND</td>
</tr>
<tr>
<td>Osmo (+Desmopressin)</td>
<td>no change</td>
<td>98 mOsmo/kg</td>
</tr>
</tbody>
</table>

Follow-up testing defined the cause of the NDI to be a mutation in the ADH receptor. The non-functional ADH receptor caused the patient’s renal function to be unresponsive to the very elevated levels of ADH shown above.

*Data extracted from a case originally described in Pasel.
messenger” system. Elevated cAMP levels lead to the phosphorylation of the pre-synthesized AQP2 channels, and signals for their insertion into the cell membrane.\textsuperscript{10-13} Elevated cAMP also increases AQP2 gene expression, promoting the synthesis of new AQP2 molecules. Once AQP2 molecules are inserted into the cell membrane, they will facilitate water reabsorption.

While malfunctions have been identified in each of these steps, most NDI cases have involved ADH-receptor mutations or disruption of the intracellular transport, rather than mutations of AQP2.\textsuperscript{22-24, 32-37} Case 1 describes a congenital NDI caused by an ADH receptor mutation.

**Acquired forms of NDI, including lithium treatment**

Acquired NDI can be caused by numerous nephrotoxic chemicals or drug treatments. For example, approximately 20% to 30% of patients treated with lithium become polyuric.\textsuperscript{22} Lithium’s therapeutic mode of action is unclear, but it has been speculated that lithium interferes with second messenger signals, such as cAMP. If this is true, lithium-induced NDI could result from disruption of the signal that normally results from ADH binding to its receptor. Without elevated cAMP, AQP2 is not inserted into the membrane, and water reabsorption is minimized.\textsuperscript{10-13}

Marples found that a 25 day course of lithium caused a 95% reduction in AQP2 in rats and the lithium-treated rats developed extreme polyuria,\textsuperscript{38} excreting urine volumes equal to their body weight each day. During lithium treatment, administration of ADH could not reverse the down-regulation of AQP2. However, AQP2 levels slowly returned to normal.

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**Case 2. Subclinical NDI caused by AQP1 deficiency**

A 37 year old woman was found to have antibodies against the Colton blood group during a routine prenatal screen. Follow-up testing showed the patient to be homozygous for a deletion in exon one of the AQP1 gene, making her incapable of producing any functional AQP1.

She had previously had a miscarriage during her first pregnancy, but gave birth to a healthy baby after 34 weeks of her second pregnancy. However, this infant suffered hemolytic disease of the newborn and required three neonatal transfusions. A subsequent pregnancy required five intrauterine and two neonatal transfusions. Fortunately, both children survived.

This woman had no other major medical problems, but occasionally experienced peripheral edema. She typically drank three to four liters of fluid per day and a subclinical polyuria. However, subsequent studies revealed that she lacked normal urine concentration capability that became obvious during periods of fluid deprivation. For example, following a 21 hour fluid deprivation, her serum and urine chemistry values were:

<table>
<thead>
<tr>
<th></th>
<th>Pre-restriction</th>
<th>Post-restriction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>serum</td>
<td>urine</td>
</tr>
<tr>
<td>Osmolality (mOsmo/kg)</td>
<td>280</td>
<td>230</td>
</tr>
<tr>
<td>ADH (pg/mL)</td>
<td>1.5</td>
<td>NA</td>
</tr>
</tbody>
</table>

The normal response to a 15 hour to 24 hour fluid deprivation would be a more concentrated urine (800-1300 mOsmo/kg), compared to this patient’s urine of 431 mOsmo/kg. In addition, urine osmolality remained at 400 mOsmo following infusions of hypertonic saline or desmopressin, an ADH agonist.

Following water loading, the patient produced appropriately dilute urine of ~ 80 mOsmo/kg. Immunoassays demonstrated appropriate levels of AQP2, but no AQP1 present. Thus, this patient’s chronic subclinical polyuria appears to be related to a less hypertonic medulla, which limited her ability to concentrate urine even during fluid restriction.

*Case was summarized from King.\textsuperscript{25}
normal following withdrawal of lithium.\textsuperscript{38} Interestingly, fluid deprivation increased AQP2 synthesis without increasing its insertion into the membrane,\textsuperscript{38} implying that a second regulatory mechanism exists for AQP2, in addition to ADH system.\textsuperscript{11,39}

Other forms of polyuria also appear to be associated with decreased AQP2 expression. Both hypokalemia (low serum potassium) and hypercalcemia (elevated serum calcium) are electrolyte imbalances known to be associated with ADH-resistant polyuria and polydipsia causing down-regulation of AQP2.\textsuperscript{5} The antibiotic Amphotericin B has also been shown to decrease AQP2.\textsuperscript{40}

**AQP1 deficiency and subclinical NDI**

As mentioned previously, AQP1 is present in many cells, including red blood cells, and is responsible for the majority of water reabsorbed in the PCT. Since approximately 75% of the filtrate is reabsorbed in the PCT, it is surprising that patients with a complete AQP1 deficiency have only a subclinical form of NDI.\textsuperscript{25} Since most of renal water reabsorption is facilitated by AQP1 in the PCT, one might expect a total deficiency of this aquaporin would lead to a devastating NDI and an anemia due to the lack of AQP1 in red blood cells. However, several known cases of AQP1 deficiency have presented with surprisingly mild renal concentration problems and no overt anemia.\textsuperscript{25} Cells in the straight portion of the proximal tubule contain substantial amounts of AQP7, which presumably enables these patients to remain subclinical.\textsuperscript{5,12} Case 2 was discovered primarily because the altered AQP1 gene resulted in a rare Colton blood group antigen.

**Aquaglyceroporins AQP3, AQP7, and AQP9**

Aquaglyceroporins have considerable sequence homology with the AQP family, but are uniquely able to transport both glycerol and water.\textsuperscript{17,18,41-43} This strange combined specificity primarily facilitates glycerol’s uptake by liver cells as a substrate for gluconeogenesis, and its exit from fat cells following lipolysis.\textsuperscript{17,18,41-44} Studies of patients without functional AQP3 have shown decreased transport of glycerol in RBCs.\textsuperscript{1} In addition, glycerol-transport functions place AQP7 and AQP9 in important metabolic positions; understanding their function and control may significantly increase our understanding of metabolic syndrome. For example, insulin was shown to down-regulate both AQP7 and AQP9 in a report by Kuriyama and coworkers.\textsuperscript{18} Thus, insulin would limit gluconeogenesis by decreasing both the AQP7-mediated release of glycerol from fat cells and its AQP9-mediated uptake in the liver. Added to insulin’s well established role in enzyme regulation, insulin also limits gluconeogenesis through down-regulation of AQP7 and AQP9 were increased in patients with insulin-resistant conditions, compounding their tendency to develop hyperglycemia.\textsuperscript{18} One patient, who produced a non-functional AQP7, was shown to have a decreased release of glycerol from fat cells during exercise.\textsuperscript{17}

Strangely, AQP9 is also capable of transporting As(OH)\textsubscript{3}. This broadened specificity may be unfortunate, because it renders the liver more sensitive to arsenic poisoning.\textsuperscript{5,47} In India, where the World Health Organization estimates more than 100 million people are consuming toxic levels of arsenic in their drinking water, an epidemic of liver cancer may be emerging.\textsuperscript{5}

**Overexpression of AQP2 in cirrhosis and CHF**

Liver cirrhosis frequently leads to ascites in the peritoneal cavity, and CHF similarly involves excessive water retention. Schrier proposes the unifying theory that such excessive fluid retention starts with peripheral arterial vasodilation. At plasma osmolalities that would normally suppress ADH secretion, vasodilation temporarily decreases blood pressure, and in turn, increases ADH secretion and an overexpression of AQP2.\textsuperscript{5,47} Decreased blood pressure also stimulates release of renin, which initiates the RAAS system and increased sodium retention. Increased plasma osmolality further stimulates ADH secretion and promotes water retention. Thus, a vasodilation leads to retention of both sodium and water, as seen in conditions such as CHF, liver cirrhosis, or pregnancy.\textsuperscript{47} Schrier and coworkers found that AQP2-mediated water retention could be reversed by agonists of the ADH receptor (also called V\textsubscript{2}) in both animal models of cirrhosis and human patients with these conditions.\textsuperscript{5,9,47}

In animal models, AQP2 was induced 150% to 200% by administration of an ADH analog, dehydration, or in a model of cirrhosis produced by carbon tetrachloride.\textsuperscript{48} Data from patients with both CHF and cirrhosis were found to show elevated AQP2 levels even when plasma osmolalities would normally have suppressed ADH secretion and decreased AQP2 levels.\textsuperscript{5} Thus, it appears that AQP2 overexpression is directly involved in these conditions of volume overload.

**Sjogren’s syndrome associated with lack of AQP5 function?**

Sjogren’s syndrome (SS) is an autoimmune disease characterized by dry eyes and dry mouth, and lymphocytic infiltration of the salivary and lacrimal glands.\textsuperscript{20,26,27} The majority of SS patients are women in the 30 year to 50 year age group, and the diagnosis is confirmed by demonstration of antibodies
to SS-A and SS-B antigens (see Case 3). Figure 1 shows that AQP3, AQP4, and AQP5 are all expressed in secretory glands, such as salivary and lacrimal glands. Membrane localization of AQP5 in apical membranes of both glands suggests that a deficiency of functional AQP5 might be the cause of the lack of secretions. Controversy exists over the membrane localization and the role of specific AQPs in the Sjogren’s disease process. Surprisingly, Tsubota and coworkers found increased AQP5, rather than the decreased levels expected in Sjogren’s patients (88 g/mg protein compared to 55 g/mg in control patients). However, histochemical techniques demonstrated that the AQP5 in SS patients was cytoplasmic rather than inserted into the membranes, as was seen in controls. Thus, SS patients may synthesize AQP5, but not insert it into the cell membranes.

Other groups have observed differences in AQP5 localization between SS patients and controls, using histological staining and centrifugal fractionation. In addition, Beroukas and coworkers reported a 38% decrease in AQP1 of SS patients, but found no differences in levels of AQP3 and AQP5. “Knockout mice” lacking genes for AQP1, AQP3, AQP4, and AQP5 demonstrate that some combination of AQPs is essential. This controversy is pending, but it appears likely that AQP5 plays a critical role in this regulated secretion.

An intriguing mechanism for Sjogren’s pathology could involve a malfunction of the M3-muscarinic receptors that control secretion of tears and saliva. This seems more plausible with the report that AQP5 contains a phosphorylation site homologous with the site that controls AQP2 insertion in the CD cells of the kidney. This phosphorylation site, together with AQP5’s reported cytoplasmic localization, suggests a control mechanism for water secretion in these secretory glands analogous to control of renal water retention. Thus, signaling malfunctions analogous to the mutations of ADH receptors and AQP2 that cause NDI might be responsible for Sjogren’s syndrome. However, much of the

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**Case 3. Sjogren’s syndrome**

A 55 year old woman complained of dry eyes and dry mouth over the last six months. The physician suspected possible Sjogren’s syndrome and ordered the following autoimmune tests, including ANA, anti-DNA, anti-SS-A, anti-SS-B, anti-Sm, and anti-RNP. CRP and CH-50 tests were added to assess inflammatory activity. Urinalysis, chemistry, and hematology panels were unremarkable except for data shown below:

<table>
<thead>
<tr>
<th>Test</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBCs (white blood cells)</td>
<td>3,500/mm³</td>
</tr>
<tr>
<td>% Monocytes</td>
<td>15.9 %</td>
</tr>
<tr>
<td>BUN</td>
<td>20</td>
</tr>
<tr>
<td>hsCRP</td>
<td>&lt; 0.3</td>
</tr>
<tr>
<td>ANA</td>
<td>positive 1:160 (with homogeneous pattern)</td>
</tr>
<tr>
<td>anti-DNA</td>
<td>negative</td>
</tr>
<tr>
<td>anti-SS-A</td>
<td>1663 U/mL</td>
</tr>
<tr>
<td>anti-SS-B</td>
<td>543 U/mL</td>
</tr>
<tr>
<td>anti-Sm</td>
<td>28 U/mL</td>
</tr>
<tr>
<td>anti-RNP</td>
<td>34 U/mL</td>
</tr>
<tr>
<td>CH-50 complement</td>
<td>61 U/mL-60 U/mL</td>
</tr>
</tbody>
</table>

The extremely elevated SS-A and SS-B results confirmed the expected diagnosis of Sjogren’s syndrome. The normal level of hsCRP and slightly elevated CH-50 complement suggested that she was not experiencing an episode of excessive inflammatory activity. Although this patient was not assessed for AQP mutations or abnormal gene expression, it is likely that Sjogren’s cases involve abnormal AQP function of some type.
pathophysiology of SS ultimately relates to the lymphocytic infiltration and destruction of gland function, which may be induced by abnormal proteins of the AQP family.

Final resolution of the lacrimal gland controversy is pending, but it appears a general mechanism may occur in other secretory glands and ducts. For example, both AQP1 and AQP5 are observed in pancreatic ducts.

**AQUAPORINS AND RESPIRATORY FUNCTION**

The respiratory system involves numerous cell types and requires a consistently moist environment for effective function. Maintaining moist surfaces can be challenging when conditions range from desert desiccation to humid tropics to subzero arctic temperatures. Researchers are investigating the role that airway humidification plays in conditions such as asthma and the bacterial colonization that leads to pneumonia. Interestingly, corticosteroids have been shown to specifically increase the expression of AQP1. This may help explain part of the therapeutic benefits of corticosteroids in pulmonary infections.

As described above, AQP5 contains a phosphorylation sequence homologous to the regulatory portion of AQP2. This AQP5 sequence is responsive to hormonal signals and suggests that AQP5 function may also be regulated in the respiratory system. Again, by analogy with the renal-AQP2 scheme, signaling malfunctions and/or direct AQP malfunctions may prove to be involved with pulmonary pathogenesis.

**Cataracts and AQP0 mutations**

Cataracts are defined by abnormal opacities in the lens tissue of the eye. The major membrane protein in this tissue was originally designated MIP (major intrinsic protein) but is known to be an aquaporin (now designated as AQP0). The water content of lenses is lower than most other tissues, and unlike most tissues, the water content increases with age. It has been suggested that AQP0 plays a significant role in the maintenance of lens transparency by removing excess water and reducing the amount of light scattering in the lens.

Two families with inherited tendency to develop cataracts were found to have point mutations in AQP0. When the defective genes from both families were inserted into the *Xenopus laevis* oocyte expression system, the results confirmed that the water channel was defective. Shields and others have demonstrated that AQP0-deficient mice developed cataracts and optical dysfunction, and that the severity of the cataracts was dependent on the level of mutant gene expression. In effect, the expression of the mutant AQP0 may have led directly to the development of the proverbial blind mice.

**Aquaporins in brain tissues**

Brain tissues contain several members of the AQP family, but AQP1 and AQP4 predominate. Research suggests that AQP4 helps reduce excess fluids in the brain when hydrostatic pressure is increased. In addition, mice lacking AQP4 had altered tendency to suffer brain edema following water intoxication and ischemic stroke, but no gross abnormality under normal conditions.
Yamamoto and coworkers reported decreased expression of AQP4, AQP5, and AQP9 in cultured rat astrocytes stressed by hypoxia. Interestingly, AQP5 was transiently up-regulated upon reoxygenation, while expression of the other AQPs returned to normal. Obviously, a malfunction of the AQP4 or AQP5 systems could lead directly to conditions such as cerebral edema or hydrocephaly.

Saadoun and others proposed a fascinating explanation of cerebral edema in brain confusions, bacterial meningitis, and brain tumors. They studied the relationship of AQP4 in normal astrocytes with a specific K⁺ channel. Under normal conditions regulation of these two channels was coupled. However, in the damaged tissues the channels were uncoupled. AQP4 was upregulated in edematous tissue astrocytes, while the K⁺ channels were upregulated in the astrocytes of the damaged tissues.

Another interesting observation is the localization of AQP4 in the neurohypophysis, where osmoreceptors control the release of ADH by an undefined process. Thus, AQP4 may enable the rapid changes in cell volume in response to changes in plasma osmolality that are thought to control osmoregulation. When these osmoregulatory cells sense hyperosmolar plasma, they release ADH, which in turn causes AQP2-assisted water reabsorption by kidney collecting duct cells. Thus, the hyperosmolar condition is diluted back to normal, and both blood volume and pressure increase. If this view of osmoregulation proves to be correct, changes in AQP4 function or distribution could potentially result in disorders of ADH release, including CDI or the syndrome of inappropriate ADH secretion (SIADH). Ultimately, AQP4 may help control plasma osmolality and blood pressure, and malfunctions could contribute to “essential” or “idiopathic” hypertension.

**CONCLUSION AND SUMMARY**

Aquaporins span the cell membranes of virtually all human cells, facilitating the passive movement of water in response to osmotic gradients. Malfunction of AQPs and their regulatory systems are associated with numerous important conditions. AQP1 was originally isolated from RBCs, but has subsequently been shown to exist in numerous other cells. This channel is primarily responsible for the unregulated water reabsorption of the PCT. Hormonally regulated water reabsorption in the renal CD relies on mobilization of AQP2-mediated water movement. In this case, pre-synthesized AQP2 resides in internalized vesicles until ADH is bound to the receptor. Binding of ADH causes the AQP2-containing vesicles to fuse with the cell membrane and increase water reabsorption. A similar on/off mechanism is thought to control AQP5 function in secretory glands, such as salivary and lacrimal glands. Aquaporins 3, 7, and 9 have the unique ability to transport glycerol in addition to water. Their limited localization in fat cells and hepatocytes suggests that their physiological role involves glycerol transport. Responsiveness of these AQPs to insulin levels and physiological conditions such as fasting and exercise suggests that they may help control glycerol transport, and thus, lipolysis and gluconeogenesis. Patients with insulin-resistance, such as Type 2 diabetes mellitus or metabolic syndrome, have been shown to have elevated levels of AQP 7 and AQP9.

AQPs are implicated, either as the primary lesion or secondarily, in numerous diseases. For example, nephrogenic diabetes insipidus can be caused by either deficient or defective AQP2 or a malfunction in response to ADH-mediated control of...
AQP2 activity. Overexpression of AQP2 is indirectly involved in edematous conditions such as CHF, cirrhotic ascites formation, and pulmonary edema. AQP0 abnormalities are implicated in early-onset cataracts.\(^4,5\) In the brain and CSF, AQP4 predominates, and dysfunction of this system may result in cerebral edema and hydrocephaly. Localization of AQP4 in cells associated with osmoregulation suggests that this aquaporin might be involved with osmoregulation, and malfunctions of the system could result in such common conditions as hypertension.\(^6-9\)

Once such malfunctions are defined, they may immediately suggest an appropriate therapeutic strategy.

Although no assays detecting AQPs have yet arrived in the clinical laboratory, they will almost certainly become part of the menus within a few years. Urinary AQP2 is routinely detected by research EIA procedures, which could easily be automated.\(^8,9\) Dysfunctions in AQP2 and its regulation system are associated with NDI and SIADH, while elevated AQP2 levels are associated with conditions such as CHF and liver cirrhosis and quantitation of AQP2 levels may help assess the condition.\(^10-13\) Polymorphisms in AQP1 result in Colton blood group antigens, and although anti-Colton antibodies are rarely identified, they have been associated with serious cases of hemolytic disease of the newborn.\(^14,15\) Variant AQP function could also explain autoimmune diseases such as Sjogren's syndrome.\(^16,17\) Testing for specific autoantibodies to these AQPs may replace less-specific tests such as antinuclear antibodies.

ACKNOWLEDGEMENTS

The authors wish to thank Carol Gee of Decatur Memorial Hospital for her assistance in obtaining the case information for the Sjogren's syndrome case and Jean Gade for her editorial comments and clinical and scientific expertise.

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Clinical Laboratory Educators Conference
2006 Abstracts

POSTER PRESENTATIONS
Presenters are listed in bold face type.

A Comparison of Learning Styles of Allied Health Students
Cynthia Adams Ed D MT(ASCP), Lillian Mundi MS MT(ASCP), Janet Vanik MS MT(ASCP), Rosalind Franklin, University of Medicine and Science, North Chicago IL.

This study assesses the learning style preferences of 236 allied health students in the following disciplines: Physical Therapy, Clinical Laboratory Sciences, Nutrition/Dietetics and Pathologists’ Assistants. In order to develop innovative teaching strategies and create a learning environment that will enhance student learning, educators must be able to determine how their students are able to learn so as to retain and apply information with long term results. The instrument selected, the Learning Type Measure (LTM), was developed by Dr. Bernice McCarthy in 1980. It is composed of fifteen questions designed to reflect the individuals’ degree of preference for each of four modes of learning.

The results show that students in Nutrition, Clinical Laboratory Sciences, and Pathologists’ Assistants favor quadrant three as a preferred learning type, whereas, the Physical Therapy students favor quadrant one. These findings indicate very similar learning styles among most student groups surveyed. With this information, healthcare educators can positively impact their students, particularly when teaching interdisciplinary courses, by modifying their teaching methods and stimuli to specifically target students’ preferred learning quadrants. For example, the prominent quadrant three learners perceive information abstractly and process it actively. Therefore, the educator should start by designing learning experiences for these learners that integrate theory with practice.

Career Advancement for the Working Professional
Robert Porter MT(ASCP), Ruth Paur MS CLS(NCA), University of North Dakota, Grand Forks ND; Sue Lehman MA MT(ASCP) SM(ASCP), Mayo Clinic, Rochester MN.

Mayo Clinic recognizes the need for employees with clinical laboratory science certification in their laboratories and has developed a partnership with the Clinical Laboratory Science (CLS) Program at the University of North Dakota (UND) to meet this need. Through this partnership, employees are able to advance from two year technical degrees or four year science degrees to become fully certified clinical laboratory scientists while maintaining full-time work schedules. Individualized programs of study are developed for each student. The curriculum plan consists of online and local college classes needed to fulfill general science and education requirements. Upon completion of the pre-requisites, the students enter the final phase of the cohort education model. The cohort model includes three semesters of class work and one semester of review. Each semester of class work is comprised of three unique experiences which include: CLS online courses available asynchronously, two weeks of intensive laboratory sessions, and bench training in the corresponding clinical laboratory. The final semester includes study guides and additional exams to review the entire curriculum. Presently, over 100 working professionals are participating in the program. The success of the CLS cohort educational model can be attributed to the flexible schedule for education developed by UND to meet the demands of the working professional, and the commitment by Mayo Clinic to allow laboratory professionals the opportunity to meet their individual educational goals.

Career Advancement through Distance Education Technology
Janice Tompkins MPH MT(ASCP), University of Nebraska Medical Center, Omaha NE.

The Career Advancement through Distance Education Technology (CADET) project provides opportunity and access for clinical laboratory technicians (CLT) to earn a Bachelor of Science degree in Clinical Laboratory Science (CLS) and advanced certification through distance education technology. This innovative approach utilizes online access...
to the University of Nebraska Medical Center (UNMC) Blackboard platform for the delivery of the coursework. These non-traditional students are able to continue employment in their home communities where shortages of allied health professionals remain critical. Prior to acceptance, they must complete the same prerequisites as the UNMC CLS traditional students and be CLT/MLT registry certified or eligible. During this Degree Completion Option (DCO), they take the same CLS courses as the traditional students. The clinical component of their course of study lies in continued demonstration of technical competence at their place of employment. UNMC CLS faculty provide academic advising and work with the practitioner to develop an individual plan of study that tailors the student’s educational process with career advancement and professional goals. All student services are provided online to meet the needs of the working practitioners. An approved local preceptor acts as a mentor and examination proctor. Students are allowed the flexibility to complete their degree in two to five years. Six students are currently enrolled in the program. Graduates of the program will enhance their opportunities for professional advancement and provide new levels of expertise to their institutions and communities.

**Evaluation of an On-campus Blood Bank Clinical Practicum Course**

*Faye E Coleman MS CLS MT(ASCP), Old Dominion University, Norfolk VA.*

In an attempt to address the decreasing opportunities for clinical practicum sites, the 2+2 Medical Technology/Clinical Laboratory Science Program at Old Dominion University modified an existing blood bank clinical practicum course with the goal of providing some of the clinical education on campus. The course was initiated in the fall of 2000 and has been repeated during the summer of each succeeding year. The on-campus clinical course offers six weekends of simulated clinical experience followed by a two-week rotation at clinical sites, reducing the traditional blood bank clinical practicum course by two weeks. This study was a retrospective comparison of the scores of the modified and traditional Blood Bank clinical practicum course students on the blood bank subject area of the American Society of Clinical Pathology (ASCP) national certification examination. Preliminary results indicate that there is no difference in the performance of the two groups, indicating that the modified format is effective. The shortened clinical practicum course time has resulted in an increase of clinical practicum sites willing to take program students for the blood bank clinical practicum course because of the reduced time commitment. This modified blood bank clinical practicum course serves as a model for other Medical Technology/Clinical Laboratory Science Programs facing a decline in clinical practicum sites offering clinical practicum courses in blood bank and other disciplines.

**Future Challenges for Clinical Laboratory Science Education**

*Anne Ranne MS MT(ASCP), Medical College of Georgia, Augusta GA.*

It is critical that present and future challenges of clinical laboratory science education be identified. Ongoing assessments of laboratory practices will play a pivotal role in the ability of laboratory educators to keep up with the present curriculum and forecast future educational needs. To identify the trends in laboratory medicine, the presenter sent a survey to ASCLS members who actively participate in a lab administration internet discussion forum. With a response rate of ten percent, the members indicated advances in three areas: technology, electronic connectivity, and management. The first area, technological advances, is in the fields of genetic testing, protein markers, automation, nanotechnology, and point-of-care. The second area of study is the development of connectivity including national electronic medical records, direct access testing, and web-based resource centers. The last area, laboratory management, includes the interfacing of clinical laboratory scientists within interdisciplinary health care teams, developing quality management systems, and creating customer/patient advocacy programs. The implications for CLS educators will be to provide exposure to these new subject areas. Career development for the CLS student should include the integration of current and future clinical testing arenas. Creation of new educational opportunities within the healthcare environment will meet these requirements.

**Growth and Evolution of a Distance Education Clinical Laboratory Science Program: One University’s Perspective**

*Janna Schill MS MT(ASCP), Robert Porter CLS(NCA), Karen Peterson MS MT(ASCP), University of North Dakota, Grand Forks ND.*

To aid in service to the region’s rural population, the Clinical Laboratory Science (CLS) Program at the University of North Dakota (UND) developed and implemented a distance education program. Beginning as a Master of Science degree in medical technology, the distance education component of the
program was designed for laboratory professionals looking for advanced laboratory-based coursework. Originally, the program delivered classroom instruction via audiocassettes and telephone conferencing. It has evolved into its current format utilizing the Internet and related computer software programs such as RealPlayer, Blackboard, and Macromedia Breeze. For students with limited internet access due to geographic location, all course material may be packaged in a CD-ROM format using either Toolbook or Authorware software. Due to the growth of online learning, enrollment in the Master of Science in Clinical Laboratory Science Program has grown significantly from ten students per semester to 60 per semester. The distance component of UND’s CLS Program has evolved into many aspects of laboratory education including undergraduate, graduate, post-baccalaureate certificates, and categorical opportunities to students both regionally and nationally. Future program growth will continue to supply highly trained laboratory professionals both regionally and nationally for a profession in high demand due to critical shortage.

Implementation of an Integrated, Case-based Course in Cell and Molecular Biology for Pre-clinical Laboratory Science and Pre-cytotechnology Students
Karen A Golemboski PhD MT(ASCP), Bellarmine University, Louisville KY.

Educators in Clinical Laboratory Science (CLS) are often challenged to include all the prerequisite and professional classes necessary to meet both professional needs and the requirements of the degree-granting institution in a four year program. Prerequisite courses taught by other departments may not address the needs of the future healthcare professional, and course sequences designed for other majors may not fit into pre-professional timelines. In our 2+2 University-based CLS program, the Biology Department changed their sequence of courses, making it impossible for pre-CLS and pre-Cytotechnology students to take Molecular Biology as previously required. Students were instead expected to take Cell Biology and Genetics, but these courses included considerable overlap of content, as well as material not relevant to a clinical program. As an alternative, an integrated course, Cell and Molecular Biology for Health Sciences, was developed specifically for pre-CLS and pre-cytotechnology students. This course is taught by CLS faculty during the second semester of the sophomore year, using a modified case-based model which presents each topic in the context of a disease or pathological process. The accompanying laboratory is designed to provide a solid foundation of transferable skills, from basic procedures to a variety of molecular techniques. Teaching molecular theory and procedures at the pre-professional level allows courses in the professional portion of both curricula to concentrate on clinical applications of specific methods. In addition, post-baccalaureate and transfer students who are entering the program without experience in molecular biology will be able to fulfill the prerequisite with one clinically-oriented class.

The Incorporation of Student Support in Distance Learning Course Structure
Gideon H Labiner MS MT(ASCP) CLS(NCA), Charity Einhaus Accurso PhD MT(ASCP), Jarrod Fortweneal PhD MT(ASCP), Ryan Megough MT(ASCP), Linda J Graeter PhD MT(ASCP), University of Cincinnati, Cincinnati OH.

The CLS Program at the University of Cincinnati introduced an AS to BS degree completion distance learning track (CLS DL) in June 2004. Individuals enter this program from a variety of professional and educational backgrounds. Many are returning to school after being out of the classroom for many years. Since this is typical of the type of student who is attracted to distance learning, the proper support for these students must be considered during the course development process. In our course model, several resources (UC Helpdesk, Blackboard support, Group Facilitators, etc.) are available to address concerns and provide guidance to students by developing and maintaining a very interactive relationship with them. In addition, the course model also encourages interaction within the student peer group. As a result, a class and small community learning environment is established. To understand how nontraditional students integrate into their new educational environment, a survey was developed and administered to 225 CLS DL students. The survey investigates the students’ perception of their growth both academically and professionally. Preliminary data indicates that the students are gratified by their newfound knowledge and by their changing roles in the laboratory in spite of the rigorous nature of the coursework. The data also indicates that the support provided by the use of an instructional team concept and by the program manager and coordinator has contributed to student academic success and retention. Additional data will be presented that provides a better understanding of which types of support are most beneficial to various student demographic groups. Outcomes will be used to emphasize best practices in making decisions for future courses.
Industry and Education: The Categorical Model of Learning
Robert Porter MT(ASCP), Ruth Paur MS CLS(NCA), University of North Dakota, Grand Forks ND; Sue Lehman MA MT(ASCP) SM(ASCP), Mayo Clinic, Rochester MN.

National studies confirm that the number of Clinical Laboratory Professionals is critically low, prompting the need for innovative approaches to professional clinical laboratory education. The University of North Dakota (UND) Clinical Laboratory Science (CLS) Program, in conjunction with Mayo Clinic, developed a model of learning that blends online didactic material with onsite laboratory training. This course successfully provided the 36 semester credits required by the National Credentialing Agency (NCA) in didactic and laboratory education in a combined format of distance education and onsite training. A biology degree with 36 total semester hours of science (including categorical) is required for admission into the program. The didactic material is presented online by UND’s CLS faculty and the clinical training is provided by Mayo Clinic’s clinical laboratories. The training schedule is individualized for the student to fit an intensive 14 week period. Each day involves approximately four hours of didactic material and four hours of laboratory training. Assessment is provided for each lecture and laboratory skill. Throughout the program students are given quizzes and exams by UND to determine the effectiveness of the categorical model of learning. To date, 6 employees of Mayo Clinic have completed the categorical training program in Immunohematology, and four of the six have taken and passed the NCA categorical certification examination. The categorical model has been expanded to other areas of the laboratory including microbiology, hematology, chemistry, and histology; two Mayo Clinic employees are currently enrolled in a 16-week pilot categorical program in Clinical Microbiology; and Hematology and Histology categorical program pilots will be implemented in 2006. This unique model, integrating academic education and clinical facility training, provides new options for mediating the employer’s need for appropriately trained personnel in the field of Clinical Laboratory Science.

LEAN: One Laboratory’s Solution
Brendon Sato MLT(ASCP), Darla Van Aselt MT(ASCP), Avera McKennan Hospital and University Health Center, Sioux Falls SD.

Like many other laboratories throughout the country, cost of health care is rising, budgets are increasingly restrained, workspaces are cramped, and the demand to provide higher quality service and results for patients and physicians is unceasing. In April 2004, our institution tackled these issues by adopting the LEAN concept. LEAN, taken from the Toyota Production System, is a disciplined approach to reducing waste and improving processes. To begin, the processes technical staff (operators) followed in order to produce laboratory test results were filmed. The actions that were taken on tubes of blood (product) were also filmed to help document what happened to the actual product. All video was analyzed using LEAN methods and philosophies. Based on the results of the analysis, several changes were made to laboratory processes, design, and layout, and to staff functionality. These changes have resulted in the creation of standard work, a 50% decrease in testing turnaround times, improved space utilization, a decrease in inventory, and annual savings in excess of $300,000 per year. To keep track of improvements and productivity, graphs and bar charts are used on a daily basis. As new ideas and concepts are presented, even greater gains are anticipated as world-class production levels are approached. Implementation of LEAN by clinical laboratories is increasing around the country and educators will need to learn about and incorporate LEAN principles into their curriculum so that future laboratory professionals are prepared to practice the LEAN way.

Managing a Clinical Laboratory Science Program Prior to, during, and after a Disaster
M Jane Hudson PhD CLS(NCA), The University of Southern Mississippi, Hattiesburg MS; Louann Lawrence DrPH CLS(NCA), Louisiana State University Health Science Center, New Orleans LA.

In August 2005, a major hurricane named Katrina impacted New Orleans and the Mississippi Gulf Coast. Two clinical laboratory science program directors located in these areas managed their programs prior to, during, and after the disaster. Disaster plans developed prior to the event and activities required during and after the event were analyzed by the two program directors by reflection on the disaster plans at the two institutions and reflection on the required activities. Similar disaster situations were reviewed. While planning was instrumental in addressing the disaster’s impact on the programs, the magnitude of this specific event provided the program directors with new insights for future disaster preparation. Program areas affected by the disaster included university decisions, faculty and student safety, displacement of students,
communications, faculty availability, access to buildings, counseling activities, travel, faculty offices and resources, student laboratory equipment and supplies, clinical rotations, affiliation agreements, accreditation standards, educational equipment and resources, and computer/Internet access. Recommendations regarding planning for the impact of disasters on clinical laboratory science programs are discussed in view of the experiences with Katrina. While clinical laboratory science programs may be greatly impacted by unavoidable disasters, knowledge regarding the possible impact will allow the programs to plan for management of the events.

National Tuberculosis Curriculum Consortium

Sandra Latshaw MA, University of Nebraska Medical Center, Omaha NE; Kathleen Magoon M Ed, University of Arkansas for Medical Sciences Little Rock, AR; Maribeth Flaws PhD, Rush University Medical Center, Chicago IL.

Tuberculosis is currently on the decline in the USA; however, it is imperative that all medical disciplines remain alert to the detection, identification and treatment of this deadly disease. Therefore, the National Tuberculosis Curriculum Consortium (NTCC) was established in October 2003 under a contract from the National Heart, Lung, and Blood Institute of the National Institutes of Health (N01-HR-36157). The mission of the NTCC is to create test-bed environments for designing, implementing and evaluating tuberculosis (TB) curricula; to develop a network of organizations to impact TB education throughout the USA; and to create access to educational and training opportunities for post-graduates and the public. The NTCC is led by Dr. Antonino Catanzaro and the University of California San Diego School of Medicine and consists of faculty from around the country representing clinical laboratory science, medicine, nursing, pharmacy, public health, respiratory therapy, and physician assistants. This poster provides an introduction to the NTCC and its activities related to TB education in CLS/CLT programs. Projects completed to date include: suggested TB competencies, a student survey to assess comprehension of TB upon graduation, and preliminary work products including test questions, games, computer-based learning objects, and case studies. A sampling of all completed or preliminary work products will be presented. By determining current deficiencies in TB curricula for health professionals and developing active learning modules to correct deficiencies, it is the hope that we will prevent a resurgence of TB infections in the USA.

PCR Laboratory Exercises for Clinical Microbiology Students

Scott Wright MS CLS(M)(NCA), Weber State University, Ogden UT.

Developing PCR (polymerase chain reaction) protocols for use as student molecular biology laboratory exercises for the clinical microbiology educator is a daunting task. This poster illustrates three PCR protocols which were developed for students at Weber State University in the Clinical Laboratory Sciences program. The first two exercises involve detection of clinically significant infectious diseases and are 1) PCR amplification of Neisseria gonorrhoea from vaginal swabs, and 2) Screening for MRSA (methicillin resistant Staphylococcus aureus) in student nasal cavities. The third project that is described is called “Who did it?”, a forensic demonstration of human DNA fingerprinting using seven primers in two multiplex PCR reactions. The three exercises provide students with hands-on experience using protocols that have been shown to be reproducible over the course of three semesters of student laboratories. The poster will provide a brief summary of the protocols and results. In addition, a link to the faculty’s web site is provided where there are detailed protocols for the three exercises, including: sample collection and preparation, DNA extraction, PCR components, amplification conditions, and gel electrophoresis techniques. The web site has been developed in hopes that other CLS educators will also share protocols that are being done in their student laboratories. The web site can either contain the actual protocols or a link to a professor’s own web site.

Status of Molecular Diagnostics Incorporation into Clinical Laboratory Science Curricula: Results of a National Survey

Barbara Kraj MS CLS(NCA), Medical College of Georgia, Augusta GA.

Current NAACLS Accreditation Standards (v.2001) require that the CLS Educational Programs incorporate molecular diagnostics into the curriculum including performance of assays. This study was prompted by an article which reported a significant number of educators being dissatisfied with the molecular diagnostics instruction they provided (Miller and Abbate, 2002). In June 2005 a survey was designed to evaluate the progress that has been made in introducing this discipline and to find out what teaching materials were used by the participants. Forty (40) NAACLS accredited CLS/MT Program Directors or Faculty listed on the NAACLS website responded to an informal, e-mail survey containing six (6) questions. Results were expressed as row numbers or percentages, or were assigned casual frequency description.
All but one respondent stated that molecular diagnostics was taught in their programs although only in half of these as a separate subject. One-fourth of the programs included laboratory instruction. The inquiry about teaching materials has revealed frustration among the educators and only 40% recommended specific sources all of which are presented. No textbook was preferred by a statistically significant number of instructors. One school planned opening a Diagnostic Molecular Scientist (DMS) program in 2006. Only 16% reported familiarity with the “Human Genetics Curricula for the Health Professionals Project” in which the NAACLS has participated since 2000. These results indicate that CLS educators still need guidance with incorporating molecular diagnostics into their curricula in order to comply with NAACLS requirements.

Teaching Techniques to Increase First Year Success

Lyne Brodeur CLS(NCA), Elizabeth Correiro CLS(NCA), University of Massachusetts – Dartmouth, North Dartmouth MA.

The attrition rate of first year Medical Laboratory Science students is the highest in the College of Arts and Sciences at the University of Massachusetts Dartmouth. It is of great concern to the faculty to find ways to increase retention and success rate of students enrolled in our program. The faculty at the University of Massachusetts – Dartmouth has developed a collection of teaching strategies to help achieve first year student success. The goal of the program was to have faculty modify one of their courses to promote the retention and success of students in their first year of college. One MLS faculty member instituted the use of “entrance and exit” passes for the Introduction to Clinical Laboratory Science course. For the “entrance pass”, students answer three questions pertaining to the experiment prior to participating in the laboratory exercise. The questions selected for the entrance pass were designed to facilitate student preparedness and check the level of understanding of key concepts. This encourages students to read the laboratory protocol and privately ask questions. The “exit” pass consists of three reflective questions that engage students in thinking about the purpose as well as the clinical significance of the experiments they have performed. These passes target the heterogeneous mix of learning styles in the classroom, as determined by a learning style survey. Based upon increased quiz and exam grades, it has been found that students have a better sense of what they are doing and why. The passes also help cut down on the expense of reagents and supplies being wasted due to non-preparation on the students’ part. The student leaves the laboratory session feeling confident and the general laboratory experience is a positive one.

Twelve Month, Second Degree Track in Medical Technology

Cherry Childs MS MT(ASCP)SM, Kathleen Mugan M Ed MT(ASCP)SH, University of Arkansas for Medical Sciences, Little Rock AR.

Individuals with a Bachelor of Science degree are reluctant to enter a two-year allied health program and prefer programs that require one year of additional training. To attract students who already have a degree, the College of Health Related Professions of the University of Arkansas for Medical Sciences initiated a 12-month accelerated, second degree track in medical technology starting in the fall semester of 2004. The program includes two semesters of professional curriculum taken concurrently with traditional 2+2 students. The 16-week clinical experience includes approximately three weeks in both the fall and spring semesters and ten weeks in the summer. The accelerated student must meet the same clinical competencies as the 2+2 students. Admission requirements for the accelerated track include a bachelor’s degree in biology, chemistry, microbiology or related science field, 3.0 math/science, and general education grade point average (4.0 scale), and fulfilled pre-professional math/science curriculum. Five accelerated track students have graduated and six students are currently enrolled. On exit interviews, all five graduates rated the program quality as very good or excellent. All of the accelerated track graduates are currently working as clinical laboratory scientists. The authors are evaluating the performance of the accelerated students (n = 5) and the traditional students (n = 12) as measured by graduate and employer surveys six months after graduation and national certification exam results. These results should provide data that will help other 2+2 programs that are considering a 12-month track.

Western College Alliance for Clinical Laboratory Science Education

Karen Peterson MS MT(ASCP), Ruth Paur MS CLS(NCA), Janna Schill MS MT(ASCP), University of North Dakota, Grand Forks ND.

The critical shortage of qualified people to fill vacancies in the clinical laboratory has prompted the formation of an alliance among students interested in clinical laboratory science, regional medical centers, regional colleges, and the Clinical Laboratory Science (CLS) Program at the University of North Dakota (UND). The Western College Alliance gives a student the opportunity to complete clinical training in a regional medical center, receive a BS degree from their local college, and be eligible to take a national certification
exam in clinical laboratory science with a minimum of time away from their home. The student is required to spend 12 weeks of intensive lecture/laboratory on the UND campus; the remainder of the coursework and laboratory experiences can be completed at the student’s local medical center. One advantage for medical centers is an opportunity to train prospective employees without the expense of providing accreditation and faculty lectures. An advantage for the regional college is the ability to attract students into a cost effective program while furnishing the region with needed, skilled graduates. An advantage for UND’s CLS Program is an income to assist in the expenses of providing intensive laboratory experiences for the students before the clinical affiliation. The Western College Alliance has proven to be an example of a partnership which can benefit all parties while fulfilling the critical need of providing Clinical Laboratory Scientists in the region.

TECHNOLOGY DEMONSTRATIONS

Blended Learning in the Practice, Wet Laboratory Learning Environment
Karen Honeycutt M Ed, University of Nebraska Medical Center, Omaha NE.

To make the most efficient use of instructor-teaching and student-learning time, The University of Nebraska Medical Center’s Clinical Laboratory Science (CLS) Program has incorporated a blended-learning environment during its 11-week, introductory student laboratory phase. In the practice wet-laboratory environment, one Internet accessible computer is available at each two-student work station. As students complete independent laboratory exercises, they have on-line access to concise (i.e., fewer than five minutes) technical procedure videos (Real™) and graphics of test interpretations and staining results. At the click of a mouse, streaming media and graphics are available to the student on an on-demand basis or as needed. Examples of procedure videos include preparation of blood smears, immunohematology tube procedures, pipetting techniques, performing a serial dilution, setting up a urine culture, and rapid immunochromatographic tests. Color graphics are available for color-dependent interpretation results, such as microbiology biochemical tests. Digital graphics of microscopic results are available so students can compare unknown samples (e.g., Gram stains and slides for parasites) to known samples. Students are required to utilize this online resource center preparing them for using similar resources during clinical rotations. Students like the asynchronous availability of the laboratory material, allowing review of visuals previously available only during laboratory sessions. All such multimedia material is available to students for review during clinical rotations. This technology demonstration will provide an overview of the navigation and content of this student laboratory resource center, including the various types of multimedia used.

Bringing the Classroom Online: How to Set Up and Maintain the Discussion Board Tool in Online CLS Courses
William B Zundel MS, Weber State University, Ogden UT.

A common barrier to effective learning in online courses is a lack of interactivity, both social and instructional, for the teacher/student and student/student relationships. On campus these interactions occur routinely in the classroom, laboratory, and socially in the halls and elsewhere. This interaction promotes the learning process. Effective set-up and maintenance of an asynchronous discussion board can break down many of these barriers encountered by online students. For example, setting up a discussion board just for social interaction, beginning with an introduction during the first week of class, can create camaraderie and unity among student peers and the faculty before the course even starts. Having a Question and Answer (QA) discussion board every week to discuss new content is similar to asking questions on campus before each lecture. Also having students post assignments (e.g., case studies) in a discussion board and receiving feedback from peers can also be quite powerful as they encourage and support each other. The outcomes include helping detached (often by thousands of miles) online students feel close to each other and comfortable with their instructor. It enhances learning by providing increased access to the faculty and their expertise. A properly set up and maintained discussion board can be a very effective tool to keep track of student progress and well being. How to set up and maintain a discussion board using WebCT will be demonstrated. In addition, examples will show student interactivity from previous semesters demonstrating the interactive processes and their outcomes.

Classroom Clicking for Enhanced Student Learning
Susan Stalewski MBA MT(ASCP), University of Wisconsin – Milwaukee, Milwaukee WI.

Assessing student understanding and participation as well as maximizing active learning are ongoing concerns for instructors regardless of the size and type of class. Student response systems, also known as “clickers”, are a technological innovation
designed to increase student engagement in the classroom, while also enhancing the ability of the instructor to probe student attitudes and assess depth of understanding, data interpretation, and critical thinking. The interactive nature of student response systems provides real time feedback for all course participants, improving their awareness of learning (metacognition). Radio frequency student response systems (Turning Technologies, LLC) were integrated into a large lecture course, Introduction to Diagnostic Medicine. This is a course for Clinical Laboratory Science majors and non-majors. The student demographic spans all levels, with a concentration of freshmen and sophomores. Measurements of success of this project include student attendance and participation rates, test scores, final grades and pass rates, and faculty and student evaluations. This is a new innovation in the fall 2005 semester. Prior evidence indicates that use of student response systems increases student learning and engagement. Data collected from this project is expected to mirror that of similar studies. Evidence and experience gained from this large class project will be used to further integrate electronic student response systems throughout the CLS curriculum. This technology presentation will include demonstration of software and student response devices in a variety of formats suitable to lecture and laboratory class settings.

Conversion of Existing Clinical Chemistry Web-based Materials into Sharable Learning Objects
Wendy L Arneson MS, Vicki S Freeman PhD, University of Texas Medical Branch, Galveston TX.

In a review of electronic educational materials available to CLS programs, very little can be found in a format that is easily identifiable or transferable between programs. Limited videodisc and CD image collections are available from only a few textbook publishers and professional associations. These collections are not user friendly for faculty, have not been appropriately cataloged for easy faculty accessibility, and are not readily available to students without additional expense. In terms of web-accessible materials, few sites can be found that distribute more than un-cataloged images. Existing materials are primarily embedded in platform specific course delivery systems, are course specific, and are not readily sharable. This presentation will demonstrate how Clinical Chemistry course materials were broken down into small instructional units called learning objects. It will then be demonstrated how these “mini” instructional units are cataloged into a web-accessible database and shared with faculty to provide lecture and laboratory teaching to a variety of audiences in a variety of settings. Usage data, user evaluations, and access information on the developed learning objects will be shared. The information presented will demonstrate the broad potential that this format has for CLS educators across the country and internationally for use in clinical chemistry education.

Interdisciplinary Healthcare Training: Bridging Clinical Laboratory Science, Genetic Counseling, and Physical Therapy
Lorraine Doucette, MS, MT(ASCP), Karen Gordes DScPT, Stephanie Ashley MS, Fran Huber EdD PT OCS, Shannon DeLany MS, Lisa Steinberg MS, Niharika Khanna MD, University of Maryland School of Medicine; Howard Levy MD, Johns Hopkins University School of Medicine; Baltimore MD.

Interdisciplinary healthcare is specific health care disciplines working together as a team to provide care to patients. At the University of Maryland School of Medicine three allied health programs, Medical and Research Technology (MRT), Genetic Counseling (GC), and Physical Therapy (PT), entered into a collaborative effort that led to the awarding of a three-year Allied Health Special Project grant from the Health Resources and Services Administration (HRSA) entitled “Interdisciplinary Healthcare Training and Delivery”. The project’s goal is to increase the number of allied health professionals trained in interdisciplinary delivery of healthcare, regulatory updates, health promotion and disease prevention, multiculturalism, geriatrics, long term care, home health and hospice care, ethics, disaster preparedness, and bioterrorism. A web-based interdisciplinary course was developed to meet this goal for the graduate students within each of the three allied health programs. A secondary goal is to increase awareness of each other’s professions to students and the general public. This will be accomplished during the clinical component where interdisciplinary teams of students will provide healthcare to underserved individuals during ten health fairs in the Baltimore MD metropolitan area. Students will be assessed both during the didactic course and while participating in the health fairs by means of three interdisciplinary projects, pre and post surveys, and discussion board participation. The didactic course will become available to practitioners in each field to further the reach of interdisciplinary training. In conclusion, disparate allied health fields can work collaboratively to benefit patients and each other’s field of practice.

Online Orientation: A Tool to Increase Student Success
Kara Hansen-Suchy M Ed MT(ASCP)SH, Weber State University, Ogden UT.

Despite the increasing popularity of online college degree programs, the attrition rate of students enrolled in these programs is higher than that of the conventional classroom. Initially, not all students are equipped with the skills required
to do well in an online environment. Technical and communication problems can create frustrations with homework and assessments. There can be feelings of isolation and a tendency to procrastinate when routine attendance is not mandated. Response time for instructor questions is not immediate and provides no visual cues for the online student. Research has indicated the need to support students and prepare them for the rigors of an online environment by addressing the issues that hamper students from excelling in this environment. By improving student interaction, technical skills, resource availability, and the quality of the initial online experience, it is likely that students will be more successful in the pursuit of an online education. The development of an online orientation course allows for these issues to be addressed specifically for students in the Online Clinical Laboratory Sciences (CLS) Degree Program at Weber State University (WSU). Will the implementation of an orientation class contribute to the initial success of the student? Success was defined as completion of the orientation class and continued enrollment in online classes in the subsequent semester. The results demonstrate an excellent positive correlation between the addition of an orientation class and student success. Implications may benefit other online degree programs or those administrators beginning the implementation of online studies.

Student Information Management for Dummies
Jean Brickell EdD, Jane B Finley, Toby L Smith MDivBL, Michelle S Kanuth PhD CLS(NCA), University of Texas Medical Branch, Galveston TX.

The University of Texas Medical Branch (UTMB) Clinical Laboratory Sciences Program has developed a student information management system that allows access to student contact information, degree plan, grades, GPA, prerequisite completion data, and courses remaining within the CLS program to be completed. The concepts that are embodied in the Internet-based system may be generalized to the management of any large database. This system also provides a means of scheduling preceptorships, courses, and examinations. Password-protected full access is granted to all faculty. Students have limited password protected access to their own information and some general information, such as that regarding preceptorship sites.

This customized web application manages recruiting and admissions processes in addition to student and alumni information. Examination grading may be accessed and assessments may be re-keyed through this system as well. UTMB uses the Questionmark Perception system for offering on-line assessments. A web-based database-driven application linked with the Perception server manages the post-assessment process independent of the test administrator. Faculty may manipulate questions, adjust scoring and view final grades. The management system schedules students into preceptorship sites using clinical site information and student prerequisite completion data. This customized web-based information system provides an efficient, departmental-specific student management system.
# Annual Meeting 2006 Program

## Tuesday, July 25, 2006

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>8:00 am</td>
<td><strong>WK-01 Earth, Wind, Fire and Flu...What's a Lab Got to Do? GEN, ADM</strong> (8:00 am – 12:30 pm) (40 attendees only—will be repeated on Monday if necessary, 1:00 pm – 4:30 pm)</td>
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<tr>
<td>9:00 am</td>
<td><strong>Clinical Lab Expo</strong> (9:30 am – 5:00 pm)</td>
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<td>10:00 am</td>
<td><strong>Break</strong> (10:00 am – 10:30 am)</td>
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<td>12:00 pm</td>
<td><strong>Lunch Break</strong> (12:00 pm – 1:00 pm)</td>
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<tr>
<td>2:00 pm</td>
<td><strong>Break</strong> (2:30 pm – 2:45 pm)</td>
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<tr>
<td>4:00 pm</td>
<td><strong>Break</strong> (4:15 pm – 4:30 pm)</td>
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<tr>
<td>6:00 pm</td>
<td><strong>NCA/NAACLS Update</strong> (6:00 pm – 7:30 pm)</td>
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<tr>
<td>7:00 pm</td>
<td><strong>First Timers’ Reception</strong> (All first time professional and student registrants invited) (7:00 pm – 8:00 pm)</td>
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**Governance**

<table>
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<tr>
<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>8:30 am – 10:00 am</td>
<td><strong>ASCLS Board of Directors Meeting</strong></td>
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<tr>
<td>10:30 am – 12:00 pm</td>
<td><strong>ASCLS Board of Directors Meeting (continued)</strong></td>
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<tr>
<td>1:00 pm – 2:30 pm</td>
<td><strong>Committee Chairs Orientation</strong></td>
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<tr>
<td>2:45 pm – 4:15 pm</td>
<td><strong>Abstract Review Committee</strong></td>
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<td>2:45 pm – 4:45 pm</td>
<td><strong>Clin Lab Sci Consulting Editors</strong></td>
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<td>2:45 pm – 4:45 pm</td>
<td><strong>Continuing Education Advisory Council (CEAC)</strong></td>
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<td>2:45 pm – 4:45 pm</td>
<td><strong>First Year Professional Committee (FYPC)</strong></td>
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<td>2:45 pm – 4:45 pm</td>
<td><strong>Nominations Committee</strong></td>
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<tr>
<td>2:45 pm – 4:45 pm</td>
<td><strong>Political Action Committee (PAC) Board</strong></td>
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<td>2:45 pm – 4:45 pm</td>
<td><strong>Professional Affairs Committee</strong></td>
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<td>2:45 pm – 4:45 pm</td>
<td><strong>Scientific Assembly Chairs (SAC)</strong></td>
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<td>2:45 pm – 4:45 pm</td>
<td><strong>Presidents-Elect Seminar</strong></td>
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<td>4:30 pm – 6:00 pm</td>
<td><strong>Awards Committee</strong></td>
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<td>4:30 pm – 6:00 pm</td>
<td><strong>Educational Affairs Committee</strong></td>
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<td>4:30 pm – 6:00 pm</td>
<td><strong>Government Affairs Committee (GAC)</strong></td>
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<td>4:30 pm – 6:00 pm</td>
<td><strong>Membership Development Committee</strong></td>
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<td><strong>P.A.C.E.® Committee</strong></td>
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<td>4:30 pm – 6:00 pm</td>
<td><strong>Publications Committee</strong></td>
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<td>4:30 pm – 6:00 pm</td>
<td><strong>Student Forum Orientation</strong></td>
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- **Requires pre-registration and additional fee ($)**
- **Included in full registration**
### Wednesday, July 26, 2006

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>8:00 am</td>
<td>Opening and Awards Ceremony (8:00 am – 9:00 am)</td>
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<tr>
<td>9:00 am</td>
<td>#1 Opening Keynote: GEN Galileo Players (9:00 am – 10:00 am)</td>
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<td>10:00 am</td>
<td>Awards Reception (10:00 am – 10:30 am)</td>
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<td>• Shuttles to Convention Center (10:30 am – 11:00 am)</td>
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<tr>
<td>11:00 am</td>
<td>• Shuttles to Convention Center (11:30 am – 12:00 pm)</td>
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<tr>
<td>12:00 pm</td>
<td>Men's Luncheon (Ticket Required) (12:00 pm – 1:00 pm)</td>
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<td>2:00 pm</td>
<td>#2 Pharmacogenomics: An Overview GEN, ADM, MOL (2:00 pm – 3:00 pm)</td>
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<td>#3 A New Look at Chronic Lymphocytic Leukemia HEM (2:00 pm – 3:00 pm)</td>
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<td>3:00 pm</td>
<td>• Break (3:30 pm – 3:45 pm)</td>
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<td>4:00 pm</td>
<td>#6 Transfusion Management in Trauma and Mass Disaster ADM, I/IH (3:45 pm – 5:15 pm)</td>
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<td></td>
<td>#7 The Current State of Advance Practice GEN, EDU (3:45 pm – 5:15 pm)</td>
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<td>#8 Member Submitted Case Studies GEN (3:45 pm – 5:15 pm)</td>
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<tr>
<td>5:00 pm</td>
<td>• Shuttles to Hotels (4:45 pm – 5:45 pm)</td>
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<td>7:00 pm</td>
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<tr>
<td>8:00 pm</td>
<td>Welcome Mixer and E&amp;R Fund Silent Auction (8:00 pm – 11:00 pm)</td>
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* = Requires pre-registration and additional fee ($)  ♦ = included in full registration

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**Governance**

- (10:30 am – 11:30 am) Presidents' Council and 1st House
- (12:00 pm – 1:30 pm) Student Forum
- (12:30 pm – 2:00 pm) CLEC 2007 Planning Committee
- (6:00 pm – 7:30 pm) Issues Update
<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>7:00 am</td>
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</tr>
<tr>
<td>8:00 am</td>
<td>#11 The Myelodysplastic Syndromes HEM</td>
</tr>
<tr>
<td></td>
<td>#12 New Developments in Microbiology to Improve Patient Care MIC</td>
</tr>
<tr>
<td></td>
<td>#13 Open Forum: Professional Issues GEN</td>
</tr>
<tr>
<td>10:00 am</td>
<td>• Break (10:00 am - 10:15 am)</td>
</tr>
<tr>
<td>11:00 am</td>
<td>#14 Applying Quality Improvement Tools to Improve Processes-Part I ADM, HEM, MIC, CON, QA</td>
</tr>
<tr>
<td></td>
<td>#15 Case Studies in Transfusion Medicine I/H</td>
</tr>
<tr>
<td></td>
<td>#16 Teaching Method Validation in the Clinical Laboratory Science Curriculum EDU</td>
</tr>
<tr>
<td>12:00 pm</td>
<td>• Lunch Break and Lunch n’ Learns (11:45 am - 1:15 pm)</td>
</tr>
<tr>
<td></td>
<td>Box Lunch May Be Purchased (Noon - 1:15 pm)</td>
</tr>
<tr>
<td>1:00 pm</td>
<td>• Break (1:15 pm - 1:30 pm)</td>
</tr>
<tr>
<td>2:00 pm</td>
<td>#18 Applying Quality Improvement Tools to Improve Processes-Part II ADM, C/U, CON, I/H</td>
</tr>
<tr>
<td>3:00 pm</td>
<td>• Break (3:00 pm - 3:15 pm)</td>
</tr>
<tr>
<td>4:00 pm</td>
<td>#22 Crosstalk Between the Inflammation and Coagulation Systems HEM</td>
</tr>
<tr>
<td>5:00 pm</td>
<td>• Shuttlrs to Hotels (4:45 pm - 5:45 pm)</td>
</tr>
<tr>
<td>6:00 pm</td>
<td>T’nT Boot Scootin’ Boogie Bash (All registrants invited)</td>
</tr>
<tr>
<td>7:00 pm</td>
<td>(6:30 pm - 8:30 pm)</td>
</tr>
<tr>
<td>8:00 pm</td>
<td>• Student Forum Elections</td>
</tr>
</tbody>
</table>

= Requires pre-registration and additional fee ($)  = included in full registration
FRIDAY, JULY 28, 2006

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
</tr>
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<tbody>
<tr>
<td>7:00 am</td>
<td>Break (8:30 am – 9:00 am)</td>
</tr>
<tr>
<td>8:00 am</td>
<td>ZEBRA HR Public, Are We Pulling in the Same Direction and is the Laboratory Professional Involved GEN, ADM, CON, QA</td>
</tr>
<tr>
<td>9:00 am</td>
<td>ZEBRA HEM, Targeted Therapies for Non-Hodgkin Lymphoma</td>
</tr>
<tr>
<td>10:00 am</td>
<td>Break (10:30 am – 10:45 am)</td>
</tr>
<tr>
<td>11:00 am</td>
<td>ZEBRA MRC, Ischemia Modified Albumin: A Cardiac Marker C/U</td>
</tr>
<tr>
<td>12:00 pm</td>
<td>Break (12:15 pm – 12:30 pm)</td>
</tr>
<tr>
<td>1:00 pm</td>
<td>ZEBRA FMC, Minority Forum Luncheon (Ticket Required)</td>
</tr>
<tr>
<td>2:00 pm</td>
<td>ZEBRA MRC, Forum for Concerns of Minorities Board</td>
</tr>
<tr>
<td>3:00 pm</td>
<td>ZEBRA MRC, Break (3:45 pm – 4:00 pm)</td>
</tr>
<tr>
<td>4:00 pm</td>
<td>ZEBRA MRC, Bullet Proof Yourself Against Blood Collection Malpractice Liability GEN, ADM, PHL, CON</td>
</tr>
<tr>
<td>5:00 pm</td>
<td>ZEBRA MRC, EMT, Emergency Viral Diseases MIC</td>
</tr>
<tr>
<td>6:00 pm</td>
<td>ZEBRA MRC, EMT, Career Alternatives for a Clinical Laboratory Scientist GEN</td>
</tr>
</tbody>
</table>

= Requires pre-registration and additional fee ($) ♦ = included in full registration
### SATURDAY, JULY 29, 2006

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>7:00 am</td>
<td></td>
</tr>
<tr>
<td>8:00 am</td>
<td>#42 Closing Keynote: GEN</td>
</tr>
<tr>
<td></td>
<td>Balancing Work and Family: Keeping Your Job, Your Family and Your Sanity (8:30 am – 9:30 am)</td>
</tr>
<tr>
<td>9:00 am</td>
<td>• Break (9:30 am – 10:00 am)</td>
</tr>
<tr>
<td>10:00 am</td>
<td>(10:00 am – 1:30 pm) House of Delegates</td>
</tr>
<tr>
<td>11:00 am</td>
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<tr>
<td>12:00 pm</td>
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</tr>
<tr>
<td>1:00 pm</td>
<td>• Lunch Break (On Own) (1:30 pm – 3:00 pm)</td>
</tr>
<tr>
<td></td>
<td>National Past Presidents’ Luncheon</td>
</tr>
<tr>
<td></td>
<td>(Invitation Only)</td>
</tr>
<tr>
<td></td>
<td>(1:30 pm – 3:00 pm)</td>
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<td>2:00 pm</td>
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<tr>
<td>4:00 pm</td>
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<tr>
<td>5:00 pm</td>
<td>President’s Reception (Invitation Only)</td>
</tr>
<tr>
<td></td>
<td>(5:00 pm – 6:00 pm)</td>
</tr>
<tr>
<td>6:00 pm</td>
<td></td>
</tr>
</tbody>
</table>

○ = Requires pre-registration and additional fee ($)  ♦ = included in full registration

### 2006 Annual Meeting - New this year!

Electronic handouts - print session handouts from the ASCLS Annual Meeting webpage, www.ascls.org/conferences/2006AM/index.asp, or receive a CD at onsite registration; no handouts will be provided onsite.

Lunch 'n Learn - these Thursday lunchtime sessions replace the “roundtable discussions” from past years; advance registration is required; select to attend with or without a lunch purchase on registration form; limited to 20 participants, so register early to avoid disappointment.

Tuesday Workshop - “Earth, Wind, Fire, Flu...What’s a Lab Got to Do?” - a hands on workshop to assist laboratorians to develop and implement a functional laboratory emergency plan; register early to avoid disappointment.
Learning and Utilization of Generic Skills by Practitioners in the Field of Clinical Laboratory Science/Medical Technology

H JESSE GUILES, KORY WARD-COOK

OBJECTIVE: To determine whether and to what extent generic skills that are learned by practitioners are used on their clinical laboratory science/medical technologist (CLS/MT) jobs; and to determine if there are any significant differences in learning and/or using these skills by practitioners who were CLS/MT vs. Other BA/BS degree majors.

DESIGN: In the field (ITF) laboratory practitioners were surveyed as to whether or not they: 1) were CLS/MT program graduates; 2) utilized the following generic skills in their jobs: analytical reasoning, communication, computer use, data correlation, decision making, precision studies, problem solving, quality assessment, supervision, teaching, technical writing, troubleshooting, research and utilization review; 3) learned these skills as students or practitioners.

SETTINGS AND PARTICIPANTS: Data were collected from 515 CLS/MT ITF participants who were part of an ongoing longitudinal study.

MAIN OUTCOME MEASURES: Participants were asked if they were CLS/MT program graduates; whether they used the skills frequently, sometimes, rarely or never; and whether they initially learned the skills as students or developed them on the job (OTJ). Chi square analyses were performed to test for differences among groups.

RESULTS: The response rate was 44%. Frequencies for using the skills were generally over 90% with three exceptions reported as rarely or never used by the majority of the respondents, and two exceptions reported as being approximately equally used or not used by the respondents. A sizable minority (23% to 45%) of the sample reported never learning six of the skills. Significant ($p < 0.05$) chi square results occurred between learning and utilizing the following skills: computer use, participation in research, problem solving, supervision, technical writing and utilization studies. Although a consistently higher proportion of the CLS/MT graduates reported learning the skills as students and Other BA/BS graduates reported learning them OTJ, no significant differences between these sub-groups were observed for either learning or using these skills.

CONCLUSION: For this sample group, most generic skills learned as CLS/MT students and/or practitioners are applied to the ITF jobs and are generally congruent with what is being taught in CLS/MT programs. However, there are some notable exceptions.

ABBREVIATIONS: ASCP BOR = American Society of Clinical Pathology Board of Registry; BA/BS = Bachelor of Arts/Bachelor of Science; CLS = clinical laboratory scientist; CLS/MT graduate = practitioners graduating from a NAACLS approved program; LTF = left the field; MT = medical technologist; NAACLS = National Accrediting Agency for Clinical Laboratory Sciences; Other BA/BS graduate = practitioners graduating from other than a NAACLS approved program; OTJ = on the job.

INDEX TERMS: ASCP BOR; CLS/MT career patterns; CLS skills; education.

Clin Lab Sci 2006;19(2):104

H Jesse Guiles EdD is Professor, Department of Clinical Laboratory Sciences, University of Medicine and Dentistry of New Jersey, Newark NJ.

Kory Ward-Cook PhD is Chief Executive Officer, National Certification Commission for Acupuncture and Oriental Medicine, and Past Executive Director, ASCP BOR, Chicago IL.
The ability to learn and apply generic skills such as: analytical reasoning, communication skills, computer use, data correlation, decision making, participation in research, precision studies, problem solving, quality assessment, supervision, teaching, technical writing, troubleshooting, and utilization studies is often considered the apogee of competent CLS/MT program graduates and practitioners. In 2002, Guiles and Tatum looked at the acquisition and utilization of these skills by a cohort of MTS/CLS who reported that they had left the field (LTF). Participants self-reported whether they were graduates of National Accrediting Agency for Clinical Laboratory Sciences (NAACLS) Accredited programs (NAACLS BS) or held other baccalaureate degrees (Other BS/BA). No significant differences were found in the utilization of these skills by these groups in the LTF jobs, however, significant differences were found in how the groups learned the skills. The NAACLS BS graduates reported a significantly higher proportion of learning many of the skills as students than did the Other BS/BA graduates. It was proposed that these same skills be examined for CLS/MT graduates who remained in the field (ITF). The following research questions were proposed for the study: 1.) To what extent are the generic skills used ITF? 2.) To what extent is there congruency between learning and using these skills (if they are learned, are they used)? 3.) Is there a significant difference in the perception of how NAACLS BS vs. Other BS/BA graduates use the skills? 4.) Is there a significant difference in the perception of how NAACLS BS vs. Other BS/BA graduates learned the skills, e.g., either as a student or on the job (OTJ)?

MATERIALS AND METHODS
Data were collected from a nationwide sample of 515 laboratory practitioners (44% response rate). Individuals in the sample group were participating in a ten year longitudinal study on career patterns of MTS by the ASCP BOR Research and Development Committee. At the time of the study, participants were in the field approximately seven years post certification. Because eligibility for the certifying exam can be obtained by several routes, the data were broken down into NAACLS BS graduates (n = 464, 90%) and Other BS/BA graduates (n = 51, 10%).

Questions were asked in terms of whether the skills were utilized frequently = at least once a day, sometimes = at least once a week but not every day, rarely = at least once a month but not every week, or never. Data were self-reported. For statistical analyses, the data were reclassified into two categories: “Frequently/Sometimes” and “Rarely/Never” (Table 1). The responses for learning the skills were as follows: A = “Learned as a MT/CLS student”, B = “Developed while working as an MT/CLS”, C = “Learned as an MT/CLS student and developed while working as an MT/CLS”, D = “Neither learned as a student, nor developed as an MT/CLS”. Before statistical analyses, choices A and C were regrouped to “Initially Learned as a Student”, whereas B was renamed to “Developed OTJ” (Table 1).

The responses were analyzed in terms of the frequencies of ways in which the skills were learned and how much they were used. Three major chi-square analyses were performed: 1) CLS/MTS
learning the skills vs. using the skills in their current, ITF jobs. 2) Being a NAACLS or Other BS/BA major vs. using the skills in the ITF jobs and 3) Being a NAACLS or Other BS/BA major vs. initially learning the skills as a student or OTJ. Statistical analyses were done using the JMP (SAS Institute, Cary NC) statistical program. Significance between groups was defined as ($p \leq 0.05$) for each generic skill.

RESULTS
Various demographic characteristics of the sample are presented in Table 2. Of the 429 participants answering the questions regarding job titles, 70% (299) reported they were staff technologists, 13% (n = 55) managers, five percent (n = 23) supervisors and 12% (n = 52) held “other” job titles. The frequencies for using the generic skills in the CLS/MT ITF jobs are shown in Figure 1. Most of the skills were reported as being utilized frequently or sometimes by approximately 90% or more of the respondents. However, participation in research, technical writing, and utilization studies were reported as being used rarely or never by the majority of the respondents. Furthermore, supervision and teaching were almost as likely to be used or not used by the respondents.

The frequencies for learning the skills as a student or OTJ for the entire sample group are depicted in Table 3. Learning the skills initially as a student generally showed higher percentages, with some exceptions: supervision, teaching and technical writing had higher or equal reported frequencies for being developed OTJ as opposed to being initially learned as a student. A sizable percentage ($\geq 25\%$) of graduates coming from both NAACLS BS and Other BS/BA programs reported

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>n</th>
<th>%</th>
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<tbody>
<tr>
<td><strong>Gender</strong></td>
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<tr>
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<td>Other</td>
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<tr>
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<td>Total reporting</td>
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<td>Rotating</td>
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<tr>
<td>Total reporting</td>
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<table>
<thead>
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<td>medium 100-300 beds</td>
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<tr>
<td>large &gt; 300 beds</td>
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<td>Independent lab</td>
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<tr>
<td>Total reporting</td>
<td>431</td>
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</table>
never learning research, teaching, technical writing, utilization studies and supervision.

Table 4 presents the frequencies of learning the skills according to type of degree. The frequencies for learning the skills as students were consistently higher for NAACLS BS graduates than Other BS/BA graduates. Conversely, the frequencies for developing the skills OTJ were consistently higher for the Other BS/BA graduates than NAACLS BS graduates. Note that in this dichotomy, the frequencies for never learning certain skills are consistent with that of the overall sample (Table 2) for both NAACLS BS and Other BS/BA graduates.

With the exception of learning computer skills ($\chi^2 = 8.060, p = 0.0178$), chi square analyses showed no significant differences between NAACLS BS vs. Other BS/BA graduates in either using or learning the generic skills. However, when comparing learning vs. using the skills for the entire sample group, several significant differences were observed (Table 5).

**DISCUSSION**

The study is a short encapsulation regarding the perception of the utilization and learning of certain generic skills by CLS/MT professionals in their eighth year of practice post certification. These type of skills rank high in the hierarchy of learning and application by MT/CLS educators and employers alike, and are embedded in the competencies for CLS/MTs as described in the new NAACLS “Standards of Accredited Educational Programs for the Clinical laboratory Scientist/Medical Technologist”. Results, however, did not totally parallel those reported in a previous study of MTS/CLS who had LTE.

In an attempt to answer the research questions proposed for the study, several observations regarding the results were made: A sizable proportion of participants said they never used and/or learned some of the generic skills. Participation in research, for example was seldom or never used by 73% of the sample group, and never learned by 43% of the group. Other skills that were reported by the sample group as seldom used or
never learned were technical writing (63% not used, 26% never learned) and utilization studies (e.g., creating / following critical pathway algorithms for testing) (61% not used, and 34% never learned). It should be noted that all of the participants in the study had been in the field for at least seven years and those qualifying to take the certification exam by the experience route were in the field at least three additional years. Furthermore, the group was heterogeneous in terms of job titles consisting of bench technologists, supervisors, and managers. The lack of use of these skills in current job roles appears to be in contrast to future roles of baccalaureate level laboratory practitioners envisioned by NAACLS. On the other hand, the majority of the generic skills: problem solving, data correlation, precision studies, decision making, communication skills, analytical reasoning, troubleshooting, computer use and quality assessment, were frequently/sometimes used by 85 percent to 99 percent of the participants.

No significant differences were observed regarding the use of these skills ITF between NAACLS BS vs. Other BS/BA graduates. This seems sensible inasmuch as the job responsibilities requiring the use of these skills should be the same for everyone. On the other hand, there was a distinct pattern of responses seen in learning the skills (Table 4). The NAACLS BS graduates consistently reported a higher frequency for initially learning the skills as students whereas the Other BS/BA graduates consistently reported a higher frequency for developing the skills OTJ. These findings should be gratifying for CLS/MT educators whose curricula embed these competencies, and to employers who want to minimize OTJ training time. The differences in frequencies between NAACLS BS and Other BS/BA graduates for all the skills evidently were not enough to make them significant (with the exception of Computer skills). These results are in contrast to the LTF study results. In that study, there were several significant differences observed in learning the skills between NAACLS BS and the Other BS/BA groups. Like this study, the LTF study found NAACLS BS graduates consistently reporting a higher percent of learning the skills as students. There, however, the comparison was based upon the skills learned by NAACS BS and Other BS/BA CLS/MT practitioners who were going into other fields, so a distinct division could be made between what the participants perceived they learned at their new jobs vs. what they learned before they left the MT/CLS field. In the present study all practitioners remained ITF and thus learned the skills ITF. Therefore, there may not be as clear a demarcation to the participants regarding where they initially learned the skills.

Several significant chi square analyses were found when comparing using vs. learning the skills for the overall sample data (Table 5). The phi coefficients indicated a weak to moderate strength of the relationship for those variables that were significant (0.2054 - 0.4277). Skills with low frequencies for use ITF showed significant differences between learning vs. using the skills. It is logical to speculate that the significance could have occurred because these skills were learned but not used. The lack of opportunities to use these types of generic skills ITF reflects a common complaint of MT/CLS educators and graduates alike. In fact, the lack of opportunities for using generic, as opposed to

<table>
<thead>
<tr>
<th>Generic skill</th>
<th>Learned first as student</th>
<th>Developed OTJ</th>
<th>Never learned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analytical reasoning</td>
<td>69</td>
<td>20</td>
<td>11</td>
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<tr>
<td>Communication skills</td>
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<td>23</td>
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<td>Computer use</td>
<td>43</td>
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<td>17</td>
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<tr>
<td>Correlating data</td>
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<td>27</td>
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</tr>
<tr>
<td>Decision making</td>
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<td>39</td>
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<td>Participation in research</td>
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<td>Precision studies</td>
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<td>12</td>
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<tr>
<td>QA/QC/TQM</td>
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<td>20</td>
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<tr>
<td>Supervision</td>
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<td>Teaching</td>
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<td>Technical writing</td>
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<td>26</td>
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<td>Troubleshooting</td>
<td>55</td>
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<td>6</td>
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<tr>
<td>Utilization studies</td>
<td>36</td>
<td>30</td>
<td>34</td>
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</table>
technical, skills may be more prohibitive to MT/CLS career advancement and sense of self-actualization ITF.

On the other hand, it is not logical to speculate that significance occurred because skills that were never learned were being used. One exception to that logic may be computer skills. This may also help to explain the significance seen for computer skills between NAACLS BS program graduates and Other BS/BA graduates. During the 1990s, the personal computer revolution took hold. It is believed that CLS/MT programs recognized this early on and saw a relationship between abilities on personal computers and the transfer of such skills to laboratory / instrument computer systems. Thus requirements for computer use were quickly established in MT/CLS curricula in the early 1990s. Other BS/BA programs may not have had such an immediate need to incorporate computer skills in their curricula. However, these Other BS/BA graduates still had to adapt to the laboratory / instrumentation computers they found OTJ. Thus they may have perceived that they used their computer skills before they learned them.

The findings of the study have implications for both educators and employers. It appears that most of these skills are appropriately placed inside of MT/CLS curricula, as they do appear to be part of the professional role of current CLS/MT practitioners. On the other hand, some skills may be overemphasized in today’s CLS/MT BS curricula (e.g. research, supervision, utilization studies) in relation to job responsibilities. This is in contrast to the findings of the LTF study where virtually all of the skills were reported as being used in the non-laboratory jobs. If the “best and brightest” are leaving the field, it may be that they see this lack of opportunity for self-actualization ITF, and feel they can achieve it by leaving. MT/CLS employers have an opportunity to stop this drain of practitioners by providing mechanisms for their employees to use the skills they possess, and rewarding their MT/CLS employees accordingly. Such provisions could include establishing a system of job levels / career mobility (with appropriate remuneration) that recognizes expertise, education, and performance. Otherwise, these practitioners will apply the skills they learned ITF, to jobs outside the field that do provide such opportunities.

<table>
<thead>
<tr>
<th>Generic skill</th>
<th>Learned first as a student</th>
<th>Developed OTJ</th>
<th>Never learned</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>NAACLS BS</td>
<td>Other BA/BS</td>
<td>NAACLS BS</td>
</tr>
<tr>
<td>Analytical reasoning</td>
<td>69</td>
<td>65</td>
<td>20</td>
</tr>
<tr>
<td>Communication skills</td>
<td>47</td>
<td>33</td>
<td>31</td>
</tr>
<tr>
<td>Computer use</td>
<td>46</td>
<td>20</td>
<td>38</td>
</tr>
<tr>
<td>Correlating data</td>
<td>67</td>
<td>67</td>
<td>27</td>
</tr>
<tr>
<td>Decision making</td>
<td>48</td>
<td>30</td>
<td>36</td>
</tr>
<tr>
<td>Participation in research</td>
<td>35</td>
<td>31</td>
<td>21</td>
</tr>
<tr>
<td>Precision studies</td>
<td>73</td>
<td>64</td>
<td>23</td>
</tr>
<tr>
<td>Problem solving</td>
<td>57</td>
<td>36</td>
<td>31</td>
</tr>
<tr>
<td>QA/QC/TQM</td>
<td>70</td>
<td>69</td>
<td>28</td>
</tr>
<tr>
<td>Supervision</td>
<td>18</td>
<td>14</td>
<td>48</td>
</tr>
<tr>
<td>Teaching</td>
<td>26</td>
<td>15</td>
<td>48</td>
</tr>
<tr>
<td>Technical writing</td>
<td>38</td>
<td>34</td>
<td>36</td>
</tr>
<tr>
<td>Troubleshooting</td>
<td>55</td>
<td>47</td>
<td>39</td>
</tr>
<tr>
<td>Utilization studies</td>
<td>36</td>
<td>32</td>
<td>29</td>
</tr>
</tbody>
</table>

The three categories (i.e., Learned first as a student, Developed OTJ, and Never learned) add up to 100% in both the NAACLS BS group and the Other BA/BS group.
ACKNOWLEDGMENTS
A special thank you goes to Michelle Brown MLT(ASCP), a student in the UMDNJ-SHRP, Department of Interdisciplinary Studies, for her help in the statistical analysis of the data used in the development of a preliminary poster. This report was commissioned by the ASCP BOR Research and Development Committee 2002. Members included: Betty Bergstrom PhD (chair), Gary Blau PhD, H Jesse Guiles EdD, Stephanie H Summers PhD, Rebecca L Johnson MD, and Gail Jones PhD.

Table 5. Chi square results – learning vs. using skills in CLS/MT jobs for total sample group

<table>
<thead>
<tr>
<th>Generic skill</th>
<th>Chi square</th>
<th>Probability?</th>
<th>Phi co-efficient</th>
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</thead>
<tbody>
<tr>
<td>Analytical reasoning</td>
<td>0.279</td>
<td>0.8697</td>
<td>0.0528</td>
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<tr>
<td>Communication skills</td>
<td>4.379</td>
<td>0.1120</td>
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<tr>
<td>Computer use</td>
<td>15.534</td>
<td>&lt;0.001*</td>
<td>0.3941</td>
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<tr>
<td>Correlating data</td>
<td>0.727</td>
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<tr>
<td>Decision making</td>
<td>0.592</td>
<td>0.7439</td>
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<tr>
<td>Participation in research</td>
<td>15.593</td>
<td>&lt;0.001*</td>
<td>0.3949</td>
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<td>2.054</td>
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<td>Utilization studies</td>
<td>18.292</td>
<td>&lt;0.001*</td>
<td>0.4277</td>
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</tbody>
</table>

Phi coefficient is an indicator of the strength of the relationship of significant differences between the variables.

*Significant Difference (p < 0.05)

REFERENCES

INSTRUCTIONS TO AUTHORS
Detailed Instructions to Authors can be found on the ASCLS website (http://www.ascls.org) by following the Publications links, or by going directly to http://www.ascls.org/leadership/cls/index.asp. Questions may be addressed to Managing Editor Margaret LeMay at the Clinical Laboratory Science editorial office, IC Ink, 858 Saint Anne’s Drive, Iowa City IA 52245. (319) 354-3861, fax (319) 338-1016. ic.ink@mchsi.com
FOCUS: EDUCATIONAL TECHNOLOGY

Advances and Innovations

YASMEN SIMONIAN

Representatives from twelve professional clinical laboratory organizations and two government agencies participated in a June 2000 summit to address the shortage of clinical laboratory personnel. The summit was sponsored by the Education Scientific Assembly of the American Society for Clinical Laboratory Science (ASCLS). The shortage was noted by Bureau of Labor Statistics, which projected that for the period from 1998 to 2008 there will be 53,000 new jobs in the field of clinical laboratory science and 40,000 vacancies due to retirement an average of 9,000 per year. The National Accrediting Agency for Clinical Laboratory Sciences (NAACLS) estimated 4990 graduates from all CLS schools in 1999. There have been additional summit meetings hosted by ASCLS for the development of strategic plans to address the shortage and tactics for data collection, recruitment, marketing, and financial assistance.

The documented shortage presents opportunities for innovation: changes in educational modes of delivery, methods of recruitment, and more. Colleagues at the University of North Dakota School of Medicine and Health Sciences, Bruce, Behm, and Hammami, developed an interdisciplinary health professions course for high school juniors and seniors and college freshmen via the Internet. Kanuth and St. John from the University of Texas Medical Branch in Galveston describe an intensive on-campus student laboratory as a component of web-based curriculum. They explain their method for clinical laboratory technicians in rural Texas to obtain additional education to become clinical laboratory scientists.

Finally, while online education grows in volume and sophistication, various methodologies emerge to improve instruction. One such improvement addresses the need to bring collegiality and face to face disposition to the online students by increasing interaction, follow up and completing communication loops. Zundel from Weber State University in Utah describes several methods he uses for online interactivity including discussion boards, PowerPoint™ presentations, and emails using WebCT Vista™.

Given the incessant advances in technology, medicine, and health care, there is a need for additional education. The methodology for delivering state-of-the-art effective education is only limited to one’s imagination.

Yasmen Simonian PhD is the Focus: Educational Technology guest editor.

EDITORIAL NOTE

The articles in Focus: Government Regulations in the Winter 2006 issue of Clinical Laboratory Science did not appear in their intended order. Following the section introduction by guest editor Susan Leclair, the intended order was as follows: "Government 101: How an Idea Becomes Law" by James T Griffith; “Regulatory Agencies Involved with the Clinical Laboratory” by Elissa Passiment; and “Government 103: What Happened to the Great Idea?” by James T Griffith. The editorial office sincerely regrets the error.
FOCUS: EDUCATIONAL TECHNOLOGY

Breezing Up—An Interdisciplinary Health Professions Course for High School Juniors and Seniors and College Freshmen

A WAYNE BRUCE, KYLIE J BEHM, NASSER HAMMAMI

Recruiting students into the health professions is an ever growing problem as young people are faced with many attractive options for career choices. At the same time, a rapidly growing elderly population will require more health professionals to maintain the health system. To address this recruitment issue an interdisciplinary health professions course delivered to high schools and college campuses in North Dakota via the Internet was developed at the University of North Dakota (UND) School of Medicine and Health Sciences (SMHS). The participating high schools embedded the course in the health professions curriculum and students were given the option of receiving college credit. The course features presentations by professionals representing 16 different health professions and were developed using a new software called Macromedia Breeze™ that allows for easy recording of PowerPoint™ audio presentations and importing video content into the presentation. Blackboard™ was utilized for course management.

ABBREVIATIONS: LRSC = Lake Region State College; OCMEO = Office of Continuing Medical Education and Outreach; SMHS = School of Medicine and Health Sciences; UND = University of North Dakota.

INDEX TERMS: healthcare shortage; health professions recruitment; online course delivery.

Clin Lab Sci 2006;19(2):112

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Yasmen Simonian PhD is the Focus: Educational Technology guest editor.

Focus Continuing Education Credit: see pages 127 to 128 for learning objectives, test questions, and application form.

As Americans age and expectations for healthcare grow, shortages have developed leading to a decrease in the quality of care as well as an increase in cost.1,2 Rural communities are experiencing an even greater problem as they have limited ability to compete for the health professionals available.3 North Dakota, with a size approximating one third of Texas and less than 650,000 in population, is experiencing this phenomenon and anticipates the problem to worsen. A variety of solutions have been proposed from developing career ladders to importing health workers from foreign countries.4 A significant suggestion has been to work with high schools to familiarize students with health careers. Another solution, proposed by Edward Salsberg in a published report of the Mibank Memorial Fund and the Reforming States Group, was the development of innovative methods for the delivery of educational training such as the Internet and personal computers.4

The University of North Dakota School of Medicine and Health Sciences Office of Continuing Medical Education and Outreach (OCMEO) has developed a unique distance learning course to familiarize North Dakota high school students and college freshmen with various health career op-
opportunities. The course Medicine 100: Introduction to the Health Professions, one credit, consists of 16 lectures covering a variety of professions delivered via the Internet (Table 1). Faculty for the course were recruited from UND and surrounding colleges. They were either responsible for teaching in the various professions or actively working health professionals. The presentations are approximately one hour in length and include objectives and a short quiz. Printable slides are also available for the students. The presentations are audio PowerPoint™ productions with a video inserted showing the healthcare worker in the work setting. In locations where Internet connectivity was a problem, the presentations were delivered via a CD-ROM. Student performance evaluation, course evaluation and student tracking were done for all students on the Internet using BlackBoard Learning System (Release 6)™. The course description, purpose, and format are described in Table 2.

MATERIALS AND METHODS
The presentations were produced using Macromedia Breeze™,6 Macromedia FlashMX 2004 Professional™,7 PowerPoint, and Serious Magic Visual Communicator Professional™.9 Macromedia Breeze allows the presenter to capture a high quality audio PowerPoint presentation and also insert video clips with ease once the video clips have been compressed using Macromedia FlashMX. When produced, it is ready for application to the Internet or onto a CD-ROM. Serious Magic Visual Communicator allows for the production of studio quality presentations that can be inserted into the Breeze program or can stand alone. The production can be done in an office environment without any props.

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**FOCUS: EDUCATIONAL TECHNOLOGY**

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
<th>Week</th>
<th>Topic</th>
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</thead>
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<td>9</td>
<td>Nursing</td>
</tr>
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<td>2</td>
<td>Radiologic technician</td>
<td>10</td>
<td>Social work</td>
</tr>
<tr>
<td>3</td>
<td>Sports medicine</td>
<td>11</td>
<td>Pharmacy</td>
</tr>
<tr>
<td>4</td>
<td>Physician assistant</td>
<td>12</td>
<td>Clinical laboratory science</td>
</tr>
<tr>
<td>5</td>
<td>Cytotechnology</td>
<td>13</td>
<td>Biomedical communications</td>
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<tr>
<td>6</td>
<td>Communications sciences</td>
<td>14</td>
<td>Optometry/disorders</td>
</tr>
<tr>
<td>7</td>
<td>Occupational therapy</td>
<td>15</td>
<td>Nutrition/dietetics</td>
</tr>
<tr>
<td>8</td>
<td>Public health administration</td>
<td>16</td>
<td>Medicine</td>
</tr>
</tbody>
</table>

**Table 1. Medicine 100: Introduction to the Health Professions, spring semester 2005**

**Instructor:** A Wayne Bruce PhD, Professor of Pathology; Director, Office of Continuing Medical Education & Outreach (OCMEO); UND School of Medicine and Health Sciences.

**Online Course Coordinator:** Kylie Behm BBA, Education Coordinator, OCMEO

**Table 2. Medicine 100: Introduction to the Health Professions, one credit for high school juniors and seniors and college freshmen**

**Description:** Introduction to the roles, ethics, certification, education, employment, and fundamental knowledge and skills related to the health sciences professions.

**Purpose:** The purpose of the course is to introduce students to the health professions so they can make informed decisions regarding pursuing a career in one of the health disciplines. Experienced leaders in the various health professions will describe the major responsibilities of those employed in the profession, the rewards and challenges, the education required, their role in the total health care team, the employment opportunities, and other unique aspects of their profession.

**Format:** The course will be delivered as an on-line course. The presentation will be audio-PowerPoint with short video clips inserted in various lessons to enhance student understanding of a range of health professions. This course will be provided online or with presentations on a CD-ROM. Quizzes after each presentation will be online using Blackboard.™ The midterm and final exam will be online. The course is embedded into the health occupations course curriculum for high school students. One college credit will be awarded for successful completion of the course.
The final product was developed so students could either access the entire course directly from the Internet or have the presentations on a CD-ROM, with student performance assessment and course evaluation completed on the Internet. If the CD-ROM option was chosen for viewing the presentations, Sum Total Systems Tool Book Instructor 8.5™ was used to package them.9

To market the course, the North Dakota Department of Career and Technical Education was asked to participate in the planning and to endorse the course for high schools in North Dakota. A presentation was given to high school career counselors at their annual meeting. In addition, UND partnered with a community college in the center of the state to offer the course as part of their dual credit offerings to high school juniors and seniors. The course developer provided further marketing by visiting several high schools in the state. High school students were given the opportunity to take the course for college or high school credit. Those who chose college credit paid the appropriate college tuition. The Department of Career and Technical Education provided 20 scholarships for college credit and these were awarded on a first come basis. Students taking the course for high school credit were required to pay $20.

RESULTS
Medicine 100 was offered in the spring semester of 2005 by the UND SMHS and by Lake Region State College (LRSC) to high school students and college freshmen. Figure 1 is a map showing the location and numbers of students enrolled at UND and at LRSC. One-hundred forty-two students enrolled in the course, 43 were UND freshmen, and 99 were high school students. Twenty-seven of the high school sites where students participated were from rural communities with populations less than 10,000. Many of these sites did not have a health occupation curriculum in their high school, so this course provided primary exposure.
The course evaluation indicated that students overall were very satisfied. They highly rated the quality of the presentations and were pleased with the content. They rated the classroom management, evaluation process and the presenters’ skill in teaching as above average. Specific comments from students regarding the course can be found in Table 3.

DISCUSSION
Medicine 100: Introduction to the Health Professions provides a valuable mechanism for high school students and college freshmen in rural and urban settings to learn about opportunities for careers in the health field because they do not have the resources to offer a health occupation course. The offering of the course to high schools in North Dakota serves several purposes:

• It helps build recognition and status of individuals in the community working in the various health occupations.
• It stimulates interest among young people who were previously unaware of opportunities in healthcare.
• It is a cost effective way to recruit young people to the health professions.

Developing the course for online or computer and online delivery allowed students maximum flexibility in participating in the course and made it available at any site, regardless of their Internet connectivity. This is especially important in rural communities with very small high schools that do not have the technical capabilities of the high schools in the larger communities. Providing the option of taking the course for high school and college credit or for high school credit only, and providing scholarships for those seeking college credit, makes the course affordable for all students, regardless of economic status. The development of partnerships between the SMHS, North Dakota Department of Career and Technical Education, and LRSC provided a mechanism to market the course to a wider audience and to gain acceptance in the various rural communities in the state.

SUMMARY
Medicine 100: Introduction to the Health Professions course delivered via the Internet provided a unique way to address an ever growing healthcare shortage problem in North Dakota. It provided for inclusion of key stakeholders and

Table 3. Student comments about Medicine 100: Introduction to the Health Professions

- I like that each occupation was a separate lecture. It was very well organized and I learned a lot from taking this class, I also like the different ways each lecture was presented.
- The printable slides were great; after listening to the lectures, I had something to refer back to.
- I like how the course covered a wide variety of professions. It let me get a look at a lot of career choices.
- I am a visual and listening learner, so having the lecture there and being able to hear the presentation and see the slides at the same time made the class easy to understand and comprehend. What also helped was that the presenters made each lecture and each slide very interesting. I found myself sitting on the edge of my seat because it was so interesting.
- This course helped greatly in discovering the many occupations in the medical field. It helped me see which ones I would be interested in. I would recommend this course to anyone who is thinking about a career in the medical field.
- The basic concept of the course was incredible. It was very interesting to be able to explore many different areas of health careers from people who actually have experience in that specific field.
- It taught me how to take an online course and what to expect from future courses.
- I would definitely recommend this course to anyone interested in health and medicine, even if they have already decided on a career; this course is a wonderful way to learn more about other career opportunities.
- I would recommend this class because it really opens your eyes to all of the medical professions to explore. In the beginning I knew that I wanted to be a physician; now I know what steps I need to take to increase my chances of getting into medical school. Also, I am more informed about the various areas from sports medicine, social work, nursing, information resources, etc. I think that anyone who plans to work in the medical field should definitely take this class because it allows students to see how all the professions must work together in order to keep things running smoothly.
gave convenient cost effective access to all communities that wished to participate.

REFERENCES
FOCUS: EDUCATIONAL TECHNOLOGY

Student Laboratories as a Component of a Web-based Curriculum

E CAMELLIA ST JOHN, MICHELLE S KANUTH

OBJECTIVE: To enable place-bound working clinical laboratory technicians (CLTs) to benefit from hands-on student laboratory sessions taught in University of Texas Medical Branch (UTMB) facilities by UTMB professors.

DESIGN: Weekend student laboratory sessions similar to “wet workshops” were implemented and integrated into regular coursework. Student laboratory sessions of 12 hours to 16 hours in length were provided.

SETTING: The UTMB student laboratories.

PARTICIPANTS: Web-based education in Clinical Laboratory Science (WEBCLS) students who are working CLTs in rural place-bound situations.

MAIN OUTCOME MEASURES: Course grades and certification examination scores on laboratory and comprehensive examinations given to both on-campus students and WEBCLS students.

RESULTS: Of 68 WEBCLS students enrolled in laboratory courses during the calendar years 2003, 2004, and 2005, 66.2% earned grades of A or B in the course compared with 64.2% of students enrolled in the same laboratory courses on-campus. Over a three year period, the WEBCLS students averaged 564.8 on certification exam scores, while on-campus students averaged 470.9.

ABBREVIATIONS: CAP = College of American Pathologists; CLSs = clinical laboratory scientists; CLTs = clinical laboratory technicians; RBCs = red blood cells; UTMB = University of Texas Medical Branch; WEBCLS = web-based education in Clinical Laboratory Science (a program designed for off-campus CLT students to pursue the Bachelor of Science degree in CLS through distance education using web-based materials).

INDEX TERMS: clinical laboratory science programs; distance education; rural and underserved areas; web-based education; student laboratories.

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Yasmen Simonian PhD is the Focus: Educational Technology guest editor.

Focus Continuing Education Credit: see pages 127 to 128 for learning objectives, test questions, and application form.

CLTs daily take on the responsibilities of clinical laboratory scientists (CLSs) because of the limited number of CLS graduates available to be employed in their area of the country.1-3 There is only a 76% overlap in the job responsibilities of CLTs and CLSs, indicating that some job responsibilities may be underperformed in these situations.4 The shortage of qualified personnel creates difficulty for the clinical facility in meeting Medicare reimbursement regulations for supervisory personnel.5-7 Many of these individuals would like to continue their education but are limited by the declining number of CLS programs, the absence of such programs within their geographical area, and their increasing work obligations, current job and family responsibilities, and the financial burden of uprooting their families to move to an area where a CLS...
program is available. Lack of the ability to move upward in the laboratory is a major dissatisfier in job satisfaction. In a study by Doig and Beck, 85.5% of respondents to a survey felt that they lacked the availability of career advancement. 8 While parts of Texas are rural, and parts of the state are medically underserved, most CLS programs in the state are located in urban, well-served areas. The university-based CLS programs in Texas and the populations of those areas are detailed in Table 1. Sensitivity to these needs is critical in providing competent, well-educated, and dedicated CLS graduates to fill positions in all regions of Texas.

With 151 CLS programs having closed in the past ten years, those that continue need to operate in both cost-effective and in non-traditional manners. 9-11 Virtual laboratories have been used successfully as portions of courses taught in nursing, pathology, histology/cytopathology, and pharmacy, however, their situations vary considerably from CLS education. These faculty report that student performance in virtual laboratory classes did not vary significantly from that of students educated in traditional student laboratory classes. 12-15 It was with these thoughts in mind that we developed WEBCLS to facilitate the educational transition from the associate degree CLT to the baccalaureate CLS for place-bound, working individuals. WEBCLS builds on the concept of CLT to CLS articulation, in which individuals having an associate degree in laboratory science follow a prescribed curriculum in a baccalaureate CLS program. Articulation agreements provide for the CLS program to give university credit for the medical laboratory courses already taken at the associate level. A major component and concern was the delivery of laboratory experiences to these students.

We needed to make certain that at least three criteria were met: 1) provide WEBCLS students with at least the same quality of experiences that we offered to on-campus students, 2) provide experiences which could be completed while employed in any geographical location, as long as the student could travel to Galveston occasionally, and 3) facilitate laboratory sessions of a length that would minimize travel and lodging expenses while providing appropriate laboratory experiences. The types of laboratory experiences considered were three-fold: introduction to and familiarization with laboratory experiences, problem-solving dry laboratory experiences, and “wet” laboratory testing experiences.

### Types of Laboratory Experiences

Introduction to and familiarization with appropriate techniques and routine instrumentation can be accomplished for articulating WEBCLS students using videotapes, narrated PowerPoint™ presentations, and written materials. These presentations may demonstrate the criticality of each step,

<table>
<thead>
<tr>
<th>Table 1. University-based programs and area populations in Texas</th>
</tr>
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<tbody>
<tr>
<td><strong>University-based programs</strong></td>
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<td>University of Texas-Southwestern Medical Center</td>
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<td>Texas A&amp;M University</td>
</tr>
<tr>
<td>University of Texas Medical Branch</td>
</tr>
<tr>
<td>Population outside metropolitan areas</td>
</tr>
<tr>
<td>Total Texas population</td>
</tr>
</tbody>
</table>
FOCUS: EDUCATIONAL TECHNOLOGY

explain the principle, discuss the purpose and use of controls and standards, and describe or demonstrate sources of false results. These presentations may include lectures, but are most often in the form of the demonstration of a technique, a video of the proper performance of a technique, a video of the improper performance of a technique with the student expected to find the errors, or the presentation of a situation in the laboratory upon which the student is to comment in some way. This format has been applied to the introduction of a new technique or re-familiarization with a previously used technique that will be performed in subsequent on-campus laboratory sessions. Evaluation entails written multiple choice and essay questions.

Problem-solving through the use of simulated laboratory experiences encompasses the preparation of laboratory scenarios that provide information regarding the performance of a procedure and may include the steps taken during the procedure, results of the controls and testing. Simulations, usually a single analyte run, do not involve patient scenarios or comparisons of several tests, in contrast to case studies. In some cases, the students are referred to previously distributed procedures, handouts, or textbooks. The student is expected to analyze the information provided and determine whether errors were made, discuss correction of the errors, appropriately interpret the results of controls and tests, and determine whether or not the results are reportable.

Case studies that include clinical history and test results have also been provided. Students are expected to answer questions related to the test results. These may include interpretation, possible causes of the test results, and whether or not the results are consistent with clinical information, including other test results obtained on the same patient. The student is also expected to determine whether technical errors have been made, what corrections are needed, and what further testing is appropriate.

Extensive explanation and justification of all answers is required. When answering cases, application of the WEBCLS student’s previous laboratory education and experience is required. WEBCLS students are given much more detailed and extensive cases than would be provided to a non-articulation student. Cases include abbreviations and other laboratory information that the student is expected to understand from previous experiences, and explanations are not provided. For example, a patient history, type and screen results, and panel results may be provided, with the student required to interpret the results and recommend further testing. Or a case history of a patient with an infection may be provided, along with growth and biochemical characteristics of one or more organisms, requiring the student to identify the organism and discuss whether or not the organism(s) is/are likely the causative agent or normal flora in the site of the infection.

However, even using simulations and case studies, we felt some hands-on experiences were needed. Some procedures are technically difficult and hard to understand without direct intervention. Students must be able to test the effects of variables on outcome and ask their questions of immediately available experts. Practice laboratories provide the opportunity for the student to perform techniques with which they are not familiar in a non-clinical setting and allow faculty to assess the preparation provided by the familiarization and dry laboratory methods. For this to occur, the WEBCLS students needed to be on-campus. While on-site mentoring and checklists can aid the learner, attention to detail is variable and such instruction usually occurs in a work setting where teaching is not a priority. Tailoring of instruction to the individual learner is also more possible when the faculty can provide undivided attention to teaching, without the demands of patient care. The CLS faculty came to an agreement that the distance students would come to campus no more than two weekends a semester. The laboratories would start on Friday and Saturday mornings about 9:00 a.m. and finish between 5:00 p.m. and 6:00 p.m. If students were taking two courses that required such “weekend laboratories”, the faculty would coordinate the work so that both laboratory courses could be dealt with in one weekend, realizing that this might run into Sunday. The reasons for this structure were two-fold: 1) students needed to be able to plan these sessions around their work schedules and 2) the cost to students of travel, lodging, and meals while away from home needed to be as reasonable as possible.

PROVIDING AN OPTIMAL EXPERIENCE

Early learning experiences for the instructors included several things:

1. Our facility is in a tourist town with limited hotel facilities. Scheduling so that students are not competing for hotel space with major tourist attractions is essential.
2. Having on hand spare procedural handouts and extras of all materials that students are expected to print out and bring with them is absolutely necessary.
3. Providing time for professional socialization facilitates student bonding, both with faculty and with other students, is critical to student retention and development.
4. Because of specialization, CLTs cannot be expected to be
immediately conversant with all the techniques covered in prior CLT courses.

5. Despite the best laid plans, the antibodies for that weekend may still die, instruments may refuse to work properly, and dilution errors may still occur, so faculty need to be prepared with more materials than they expect to need for the entire weekend.

The following preparations are crucial to a successful laboratory experience:

**Planning time:** Planning specific times for each procedure for the entire weekend is crucial to success. If a procedure is not completed during the allotted time, it cannot be postponed to the next laboratory session. Miscalculations mean that time is lost, students become uneasy, and there is a loss of momentum.

**Sharing plans:** Share plans with attendees. Providing the students with schedules, handouts and reading assignments ahead of the planned laboratory experience helps students prepare and saves considerable time during the sessions.

**An initial assessment of student skill levels:** Diversity of individual experience necessitates a brief session where basic skills and techniques are monitored and refreshed. This places the group on a more equal footing for learning and allows for discussion of diverse approaches, along with inherent strength and weaknesses. This enables faculty to identify and correct suboptimal habits while increasing theoretical understanding. Absence of such basic technical skills causes a student to miss the total picture of the patient’s problem that can be gained from advanced techniques and case studies.

**Reagents, equipment, and supplies:** Everything necessary for each procedure must be readily available. When each moment with the students is both limited and precious, locating materials in an unfamiliar laboratory can consume both time and patience. These students come with work experience and do not require education in laboratory materials management, as inexperienced students often do.

**Preparing specimens for use:** One way to provide samples for students to analyze is to obtain salvage specimens from clinical associates. This allows the students to observe a variety of different specimens, but makes it difficult to detect a specimen that performs in an unexpected way. Weekend laboratories involve reactions with which students are not practiced, so there is an advantage to having sets of specimens. Not all students get the same specimens, but several people within the group do. Several students observing the same reaction in a poorly performing specimen alerts the instructor to the need to check and verify, as opposed to convincing one student that he or she does not understand the technique.

**ADDED COST FOR STUDENTS ATTENDING WEEKEND LABORATORY**

Direct costs include transportation, lodging, and meals. Lodging averages about $80.00 per night per student. Meals average $25.00 to $30.00 per person per day. The cost of transportation varies considerably depending on travel distance and model of automobile, but averages about $60.00 for the weekend. Thus, the average two-day weekend laboratory costs a student about $300.00, or $600.00 per semester.

**OUTCOMES ASSESSMENT**

The WEBCLS program at UTMB includes four courses with weekend laboratories: Advanced Microbiology and Mycology, Immunology/Immunohematology, Hematology and Coagulation II, and Molecular Biology. In these courses, the same laboratory and comprehensive examinations are administered to WEBCLS and on-campus students. The WEBCLS students performed as well or better on these examinations as the on-campus students. In Advanced Microbiology and Mycology over the past three years, 23 WEBCLS students have completed the course with an average grade of 82%, compared with the on-campus traditional students’ average grade of 79%. In Molecular Biology, both groups averaged 77%. A total of 68 WEBCLS students and 218 on-campus students enrolled in all laboratory courses during the calendar years 2003, 2004 and 2005. During that time, 66.2% of the WEBCLS students earned grades of A or B in the course compared with 64.2% of on-campus students enrolled in the same laboratory courses. WEBCLS student scores on certification examinations from 2002 through 2005 averaged 564.8, while traditional on-campus students averaged 470.9 during the same period. The probability value from an unpaired student’s T-test, \( p = 0.034743 \), showed a significant difference in favor of the WEBCLS students.

Because the outcomes assessment shows parity on examinations, we believe that this course structure provides a student laboratory experience for WEBCLS students comparable to our regular on-campus laboratories for individuals with no previous clinical laboratory science education. With organization, faculty can cover a basic check up on techniques, numerous advanced techniques, and still have time for problem-solving.
solving discussions and case studies in each weekend laboratory session. The WEBCLS students have sacrificed time and money for this opportunity and typically bring an enthusiasm that can be infectious even on a day off. Weekend laboratories provide a solution for place-bound and non-traditional student access to laboratory educational opportunities that are minimally disruptive to their lives and work.

REFERENCES
Interactivity: Key to CLS Online Instruction

WILLIAM B ZUNDEL

Learning is the attainment and application of knowledge or skill. Effective online instruction should integrate interactivity. Online interactivity 1) includes a message loop, 2) occurs from the learner’s point of view, 3) provides for content and affective outcomes, and 4) is mutually coherent. These characteristics must be woven into online interactive devices such as discussion boards, PowerPoint™ slides, email, and chat rooms to insure learning. Interactivity must be consistent with the course objectives. Increased interactivity enhances learning in online courses just as it does on campus.

INDEX TERMS: distance education; interactivity; online instruction.

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Yasmen Simonian PhD is the Focus: Educational Technology guest editor.

Focus Continuing Education Credit: see pages 127 to 128 for learning objectives, test questions, and application form.

The following paper was presented at the Clinical Laboratory Educators Conference, February 2005 in Williamsburg VA.

This article describes the intimate relationship between interactivity and instruction. Dick and Carey define instruction as “the systematic process in which every component; (i.e. teacher, students, materials, and learning environment) is crucial to successful learning.” Instruction is more than the dissemination of information. Instruction occurs when all factors work together to facilitate learning: the attainment and proper application of knowledge and/or skill.

Interactivity is not simple. There are a multitude of interactive processes in a face-to-face classroom: lectures, questioning, laboratory exercises, case studies, and non-verbal cues. Do we apply interactivity with online instruction as with face-to-face instruction? Online interactivity can include all of the above through formats such as email, discussion boards, and chat rooms.

Interactivity has several definitions. In “Interactivity Demystified: A Structural Definition for Distance Education and Intelligent CBT” Michael Yacci discusses four essential characteristics:

1. Instructional interactivity is a message loop.
2. Instructional interactivity occurs from the learner’s point of view.
3. Instructional interactivity has two outputs: content learning and affective benefits.
4. Messages must be mutually coherent.

MESSAGE LOOP

Instructional interactivity is a message loop. Online interactivity is a circuit of messages flowing from an originating entity to a target entity and back. Entities can be students, instructors, computers, or other media capable of receiving and sending messages. For example, when a teacher posts a question on a discussion board and a student answers, the loop has been completed, but from whose perspective?

A STUDENT’S POINT OF VIEW

Instructional interactivity must occur from a student’s perspective. In the example the loop was complete for the teacher, but what about the student? If the student does not receive feedback the loop is incomplete. Did instruction oc-
cur? Think for just a moment how this would play out in a classroom: An instructor poses a question. A student answers and the instructor moves on with disregard for the response. The effect is the same for online instruction. Our challenge is to ensure the message loop is complete from the student’s point of view, and to make appropriate changes.

CONTENT LEARNING
Content learning is purposeful learning directed toward an instructional goal or objective. Wagner writes, “When focusing upon interaction outcomes rather than interaction agents, interactions can more effectively serve as a means to the ends of learning and performance improvement. In this context interactivity has two purposes: it must change the learners and it must move learners toward an action state of goal attainment. By emphasizing the outcome of an interaction, it is easier to see the impact that an interaction has on learners.” Interactivity should lend itself to achieving the course objectives. For example, discussion board questions or case studies must be written at the same cognitive level as the course objective from which they are written.

AFFECTIVE BENEFITS
Affective benefits are defined as emotions and values toward instructional objects that are amplified. We hope for amplification of learning through social interaction with the faculty and other students in the course. Students on campus get to know each other and interact socially by forming study groups, discussing how to prepare for exams, and in cramming for exams. The same social interactions among online students can be coordinated through collaboration projects or discussion boards, thus enhancing the achievement of learning objectives.

MUTUAL COHERENCE
Mutual coherence describes the relationship between a message and its response. The content of both the outgoing and returning messages must be considered if we are to make sense of an interaction. Mutual coherence labels the shared meaning between both messages in an interaction. Interactions with low mutual coherence are easy to spot. For example, an interaction with zero mutual coherence goes something like this. Student: “I feel lost in this course.” Teacher: “I love to watch college football.”

An interaction with very low mutual coherence might sound like this. Student: “I feel lost in this course.” Teacher: “The midterm exam for this course is really hard.”

An interaction with high mutual coherence might be: Student: “I feel lost in this course.” Teacher: “People often feel lost in an online course.”

Yacci mentions that while it is difficult to specify the “meaning” of messages; he believes the extent of the shared meaning connecting messages influences the perceived degree of interactivity. If a student does not feel a connection with the faculty or content of an online class, he or she will feel that the interactivity is not worth the effort.

PERSONAL EXPERIENCE WITH ONLINE INTER-ACTIVITY: EMAIL
Email is used extensively in my online courses. The course syllabus outlines specifically what is expected from both the faculty and students: email is to be checked every day except Sunday and a 24 hour response time is expected. We also establish which email account both faculty and students will use during the semester.

Email promotes the discussion board. Many students email questions that represent a need of the class. I email back
that I will answer the question as soon as the student posts it in the discussion board for all to see. I also use email for the students’ personal needs. Email is private, so students can address personal issues. Finally, email is very good for sending attachments to and from students such as antibody identification panels and case study assignments. I also archive all of my online course email, both sent and received, for documentation and follow-up purposes.

MICROSOFT POWERPOINT
What online instructor does not use Microsoft PowerPoint for some aspect of online instruction? Is it interactive? Figure 1 shows a common format I use. Microsoft Producer for PowerPoint enables the addition of audio or video to any PowerPoint presentation. Several faculty members at Weber State University have added audio to each PowerPoint slide in their online course lectures. We burn our course audio lectures onto a CD-ROM which is sent to each online student in the course. Each student has essentially the same lecture that is presented on campus. It is an arduous process that begins with a written script for each slide in the lecture using the “Notes” function in PowerPoint. Then we capture the audio with a microphone connected directly into a desktop computer. The audio is imported into Producer, which enables synchronization of the audio with the content of the corresponding PowerPoint slides. Each lecture takes approximately six to eight hours. The following are just a few of the comments from online students regarding the addition of audio to the online lectures:

“…this is the best format of a class, online especially, that I have ever had and I am SO APPRECIATIVE of the time and effort you put into this class! I’ve been going along on your lecture and I just keep thinking how awesome this is! This is BETTER than an on campus class because it is 2 a.m. (I study when the baby sleeps) and I can pause you as much...
in a blood bank. I give them the assignment to follow up on the question and answer session questions. Students report individual and collaborative course projects with appropriate feedback from peers and faculty.

5. Case studies are developed and presented by groups or pairs using the discussion board. Different cases are assigned to each student to be reported and critiqued.

INSTRUCTIONAL OUTCOMES
There are no instructional outcome studies that measure online interactivity. Perhaps there are so many variables it is hard to conclude a specific interactive process enhanced the cognitive process. Most authors believe that there is a direct correlation, which has been my experience. Figure 3 records the times a student has entered the website or discussion board. Those students with the most interactions had the highest scores. That has been consistent with every online course I have taught.

Design is one more characteristic of effective online interactive instruction. Interactivity must be designed into instruction and be consistent with the course objectives.

Thomas Edison once said, “Opportunity is often missed because it is dressed in coveralls and looks a lot like work.” Online instruction in laboratory medicine is in its infancy, and we have an opportunity to greatly impact the industry through the development of quality online instruction. Online instruction doesn’t just happen. It requires work to design and develop interactive courseware that enables students to become effective professionals.
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POSITION ADVERTISEMENT

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Applications: Candidates should submit a letter of interest (noting control #925N), curriculum vitae, and names of three current professional references with complete contact information to Linda J Graeter, PhD, Department Head, Department of Analytical and Diagnostic Sciences, University of Cincinnati, College of Allied Health Sciences, PO Box 670394, Cincinnati OH 45267-0394 or via email to linda.graeter@uc.edu. Applications will be accepted until the position is filled.

The University of Cincinnati is an affirmative action, equal opportunity employer; minorities, women, disabled persons, Vietnam era and disabled veterans are encouraged to apply.
To receive 1.5 contact hours of basic level P.A.C.E.® credit for the Focus: Educational Technology questions, insert your answers in the appropriate spots on the immediately following page; then complete and mail the form as directed.

NOTE: There may be more answer spaces on the sheet than needed. If so, please leave them blank. Make sure the number of the answer space being filled matches the number of the question being answered.

LEARNING OBJECTIVES

After reading the three Focus: Educational Technology articles in this issue, the reader will be able to:

1. List several possible solutions proposed to address the healthcare shortage.
2. Describe the purpose of offering Medicine 100: Introduction to the Health Professions to high school students.
3. List two software applications used in the development of Medicine 100: Introduction to the Health Professions.
4. Describe the marketing strategy for Medicine 100: Introduction to the Health Professions.
5. Discuss the impact of traveling to campus for weekend laboratory sessions on WEBCLS students.
6. Identify three reasons that on-campus experiences were preferred over on-site mentoring of WEBCLS students at their workplace.
7. Identify five areas essential to the preparation and delivery of a weekend laboratory experience.
8. Compare the performance of WEBCLS students on examinations to that of traditional on-campus students.
9. Define instruction and instructional interactivity as they apply to online education.
10. Describe the four characteristics of online interactivity.
11. Compare and contrast the four characteristics of online instructional interactivity to existing online interactive courseware. Propose interactive devices that could be used in a CLS/CLT online course that integrate the four characteristics.

CONTINUING EDUCATION QUESTIONS

1. The Medicine 100: Introduction to the Health Professions course was designed for:
   a. high school juniors.
   b. high school seniors.
   c. college freshmen.
   d. all of the above.

2. A software application used in the design and delivery of the Medicine 100 course is:
   a. Macromedia Breeze™.
   b. Macromedia FlashMX™.
   c. Serious Magic Visual Communicator Professional™
   d. all of the above.

3. The Medicine 100 course was marketed by:
   a. partnerships with stakeholders.
   b. advertisements in local newspapers.
   c. television advertisement.
   d. all of the above.

4. The Medicine 100 course was offered for:
   a. high school credit.
   b. college credit.
   c. continuing education.
   d. “a” and “b” of the above.

5. The impact of traveling to campus for weekend labs was minimized for WEBCLS students by:
   a. covering student travel costs.
   b. minimizing time on-campus.
   c. providing transportation to campus.
   d. providing meals during labs.

6. One reason that on-campus laboratory experiences were preferred over work-site mentoring for WEBCLS students is that:
   a. faculty do not have patient care responsibilities.
   b. on-site mentors did not want to have students.
   c. students preferred to travel to campus.
   d. student laboratories are better equipped than clinical sites.
7. All of the following are essential to the preparation and delivery of on-campus weekend student laboratories EXCEPT:
   a. having students provide their own specimens.
   b. having all materials needed available in abundance.
   c. planning time for each procedure.
   d. providing students with as much information as possible prior to the laboratory session.

8. WEBCLS weekend laboratories provide:
   a. an excellent opportunity to justify funding a teaching assistant.
   b. a learning experience suited to all learning styles.
   c. an inexpensive alternative to traditional programs.
   d. face-to-face discussions with the faculty.

9. WEBCLS weekend laboratories characteristically:
   a. assume that students are adept at all basic techniques.
   b. avoid use of virtual laboratory classes.
   c. focus on theoretical knowledge to the exclusion of technical knowledge.
   d. provide experiences that are equal to the on-site program.

10. What percentage of WEBCLS students earned grades of A or B in laboratory classes from 2003 to 2005?
   a. 64%
   b. 66%
   c. 79%
   d. 82%

11. WEBCLS students’ averages on national certification examinations compared to those of traditional students were:
   a. equivalent.
   b. higher.
   c. lower.
   d. no comparison was done.

12. In performing advanced techniques in weekend labs, instructors must be prepared to compensate for:
   a. differences in learning styles.
   b. student lack of familiarity with the location of basic lab supplies.
   c. students from rural settings having little exposure to advanced laboratory techniques.
   d. uniform student experiences in basic laboratory techniques.

13. When a teacher posts a question on a discussion board and an online student answers the question as a thread in the discussion board:
   a. mutual coherence has occurred.
   b. a message loop has occurred from the teacher’s perspective.
   c. the student has experienced affective benefits.
   d. effective instructional online interactivity has occurred.

14. When two online students meet in the discussion board during a collaborative project and realize that they grew up in the same community and have mutual memories and acquaintances, this is an example of:
   a. mutual coherence.
   b. content learning output.
   c. message loop from the students’ perspective.
   d. affective benefits output.

15. To meet the “Content Learning” output of instructional online interactivity, questions posted in an online discussion board must:
   a. be mutually coherent with the students’ cognitive level.
   b. be written at the same cognitive level as the course objectives.
   c. promote amplified affective benefits for each online student.
   d. be easy so each student can answer the question with minimal effort.
Continuing Education Registration Form

To earn continuing education (PACE) credit, (1) complete the form below, (2) record your answers, and (3) mail a photocopy with a check or money order ($18 for ASCLS members, $28 for non-members) to:

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P.O. Box 79154, Baltimore MD 21279-0154

A certificate and credit will be awarded to participants who achieve a passing grade of 70% or better. Participants should allow eight weeks for notification of scores and receipt of certificates.

Focus: Educational Technology carries 1.5 hours of basic level P.A.C.E.* credit. This form can be submitted for credit for up to one year from the date of issue.

Print or type carefully.

(01) NAME ______________________________________________________________________________________________

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Answers
Circle correct answer (questions are on previous two pages).

1. a b c d e 9. a b c d e 17. a b c d e 25. a b c d e
2. a b c d e 10. a b c d e 18. a b c d e 26. a b c d e
3. a b c d e 11. a b c d e 19. a b c d e 27. a b c d e
4. a b c d e 12. a b c d e 20. a b c d e 28. a b c d e
5. a b c d e 13. a b c d e 21. a b c d e 29. a b c d e
6. a b c d e 14. a b c d e 22. a b c d e 30. a b c d e
7. a b c d e 15. a b c d e 23. a b c d e 31. a b c d e
8. a b c d e 16. a b c d e 24. a b c d e 32. a b c d e

2. Specialty: (a) biochemistry/urinalysis (b) microbiology (c) lab administration (d) hematology/hemostasis (e) education (f) immunology (g) immunohematology

3. Workplace: (a) hospital over 500 beds (b) hospital 200–499 beds (c) hospital 100–199 beds (d) hospital under 100 beds (e) private lab (f) community blood bank (g) group practice (h) private physician (i) clinic (j) other

4. Salary range: (a) under $10,000 (b) $10,000 to $20,000 (c) $20,000 to $30,000 (d) $30,000 to $40,000 (e) over $40,000

5. Did these articles achieve their stated objectives?
   (a) yes (b) no

6. How much of these articles can you apply in practice?
   (a) all (b) some (c) very little (d) none

7. Employment status: (a) full time (b) part time (c) student (d) not employed (e) retired

8. How long did it take you to complete both the reading and the quiz? ____________ minutes

9. What subjects would you like to see addressed in future Focus articles?
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