B. Background and Significance

B.1 Traditional media in the otological curriculum

To date, temporal bone surgery has been learned through contemporary media: textbooks and atlases (Schuknecht and Gulya 1986, Glasscock and Shambaugh 1990, Donaldson 1992, Swartz and Harnsberger 1998); illustrations; CDROMS (Brodie 1997, Blevins 1998); models (Golding-Wood 1994, Pettigrew 2002); and cadaver dissections (Nelson 1991, Sando 1986)). Although CDROMs provide a cost-effective solution through the integration of photographs, illustrations, movies, computer graphics and tomographic images, the solutions from interaction remain pre-determined. Selections are from a limited number of choices and the results are not unique to the individual. We present a system that provides unique approaches to learning.

It is difficult to achieve a consummate comprehension of the subtle spatial relationships required for temporal bone surgery without diligent studies through dissection over a period of four to five years (Nelson 1991, Sando 1996). To facilitate understanding of the intricacies of the regional anatomy of the temporal bone, some authors have presented techniques for tissue preservation and display (Golding-Wood 1994). The resulting displays provide the student with only limited and passive means to study the intricate relationships of structures found in the temporal bone. In addition, the physical limitation of the material, associated risk of infection (HIV, Hepatitis), and decreasing availability make this method increasingly problematic. To increase the availability of material and reduce the risks of infection, Pettigrew introduced a plastic model of the otic capsule and middle ear for drilling practice (Pettigrew 2002). These models are highly realistic and serve as substitute materials for drilling practice. However, plastic models are subject to similar physical limitations as cadaver specimens, i.e., to start over, a new plastic specimen must be used) and provide limited force correlates to actual bone.

B. 2 Use of Computer Simulations in Histopathological and Moprpholoogy Studies

Three-dimensional reconstructions from computed tomography have been integrated with computer aided design (CAD) techniques to provide a non real-time system for use in the diagnosis and surgical planning of craniofacial disorders (Vannier 1983). Methods for characterizing the morphology and histopathology of the temporal bone soon followed (Sando 1986). Subsequently these methods were combined with computer-aided reconstruction techniques for visualization and morphometric analysis (Takagi 1988, 1989, Nakashima 1993, Yasumura 1993, Fujita 1994, Sakashita 1995, Sando 1996, Rosowski 1996, Hinojosa 1996, Ikui 1997, Sando 1998, 2000). Although specimen preparation and integration of the photomicrographs through manual methods was time intensive, the advantage of three-dimensional reconstructions to demonstrate subtle morphological relationships and changes was evident.

B. 3 Use of Computer Simulations in Surgical Assessment and Training

Harada first introduced the concept of exploiting 3D volumetric reconstructions from computed tomography for emulating drilling and exposing the intricate regional anatomy of the temporal bone (Harada 1988). However, owing to the computational overhead of volumetric representation at the time, real-time interactions were unavailable. Subsequently, surface-based approaches were predominantly employed for modeling structure to exploit the hardware-accelerated surface rendering techniques that have been developed for other applications such as video gaming. Similar techniques using reconstructions from histological sections to derive iso-surfaces have focused on clarifying the spatial relationships of the regional anatomy (Takagi and Sando 1988, Green 1990, Kuppersmith 1997, Mason 1998). Stereo presentations of surface-based models acquired from the Visible Human Project (VHP-NLM 2002) have recently been presented for trans-petrosal, retro-sigmoid, and middle fossa approaches to the cerebro-pontine angle (Serra 2002). Albeit surface-based representations of soft tissues and bone structures have been developed, the current systems does not provide haptic feedback to the user, and can provide only schematic emulation of dissection and surgical technique. The development of stereo volumetric, physically based simulations have been presented (John 2001, Agus 2002, 2003). These systems do not support real-time viewing and aural simulation. Although volumetric data sets have been integrated, no multimodal, multiscale acquisitions have been reported. Agus has extensively explored efforts to present secondary characteristics, such as bleeding, debris formation, and fluid flow simulation, although basic utility has yet to be demonstrated. Ray-casting techniques have been developed to provide stereo simulations of cutting and drilling based on reconstructions from computing tomography (Pflesser 2000), although metrics of interactivity have not been presented. Although all investigators present initial enthusiasm from local surgeons and residents, ***no local or extensive multi-institutional studies have been conducted to validate the efficacy of these systems as compared to traditional methods of training and assessment.***

B.4 Significance

"For although we often credit advancements to the introduction of the operating microscope, chemotherapeutic drugs, and antibiotics, we sometimes forget that many new concepts and surgical approaches are a result of temporal bone dissections."

Howard P. House, M.D.

The psychological impact of balance and communicative disorders related to the temporal bone is tremendous. Nearly half the population of the United States will be affected by vestibular system impairment, with 30-50% of individuals 65-75 years of age requiring hearing aids, and 75% of children experiencing otitis media by the age of 3 (Wackym 1997). Otitis media remains the most frequent reason for a pediatric office visit, exceeding $5 billion a year in the United States (NIDCD2002). Chronic otitis media with effusion is the leading cause of hearing loss in children and is most commonly treated by elective surgery (Maw 1999). Balance disorders are attributed to more than half of the falls experienced by the elderly, leading to patient-care-costs between $3-8 billion annually (NIDCD 2002, AAO-HNS 2002). Cochlear implants have been recognized for improving communication for both children and adults with severe and profound deafness (NIH 1995). Advances in temporal bone surgery present treatment options to those who suffer these impairments. Middle ear exploration to diagnose and reconstruct congenital ossicular deformities with secondary conductive hearing loss, extirpation of cholesteatomas, and translabyrinthe approaches to acoustic tumors and implantable hearing aid placement demonstrate the spectrum of surgical techniques that offer hope to patients with these pathologies. These techniques have evolved and continue to be refined through the use of temporal bone dissection laboratories.

During the calendar year (50 weeks) of 1997-1998, two surgeons at The Ohio State University (OSU) Hospitals performed 165 temporal bone surgeries, averaging slightly more than 1.5 per surgeon/week (OSU, 1999). More recently (2001-2002), three surgeons at OSU performed 534 surgeries involving the temporal bone, averaging slight more than 3.5 per surgeon/week (OSU 2002). There are 102 otolaryngological residency programs in the United States (CareerMD 2002). With the average program accepting 3-4 residents per year, there are approximately 1,530 residents in the United States. The importance of temporal bone dissections to otologic practice cannot be overstated. Dissections remain the basis for learning and developing sound fundamental techniques for application to safe surgery. The development of novel surgical approaches will remain a vital strategy for intervention in hearing and balance disorders.

Several authors have called for the integration and validation of surgical simulators in the curriculum. Through analogies with flight simulators, Satava sees the extent of their use not only for screening, training, and assessment, but also, eventually, for licensing and annual recertification (Satava 1996).

More recently, the Institute of Medicine has recommended the use of simulation and simulators to quantify performance of basic and crisis skills (IOM 2000). The technical requirements for simulating the complexity of surgical interactions and the inherent cost of simulation environments have prevented early adoption. Active interactions with hard and soft tissues are inherently more difficult to simulate than the passive interaction of the user flying passively over the terrain in a flight simulator (Dawson and Kaufman, 1998). Others have identified the trade-offs of current simulations, i.e., interaction vs. realism (Meier 2001) and the challenges of increased realism, multimodal interface integration (stereo, haptics, auditory), and delivery on cost-efficient platforms (Robb 1996). However, all authors emphasize the promise and benefits of simulation technology to increase user proficiency and provide training in a safe and efficient manner. As the cost for resident training continues to increase, simulation environments provide a plausible -auxillary to traditional training methods. The exploitation of commodity-based computing, we believe, will facilitate the adoption and early adaptation of simulation technologies (NRC–1997). Acceptance of these environments can take place only after data sets have been certified and system efficacy has been proven through controlled validation studies involving multiple institutions.