



Timothy G. Bromage

**The integrative single
double life of a hard
tissue naturalist**

Donald H. Enlow

Donald H. Enlow: The integrative single double life of a hard tissue naturalist

Timothy G. Bromage*

Hard Tissue Research Unit, Department of Biomaterials & Biomimetics and Department of Basic Science and Craniofacial Biology, New York University College of Dentistry, 345 East 24th Street, New York, NY, 10010-4086, USA

Dr. Donald Hugh Enlow, MS, PhD, passed away at the age of 87 on July 5th, 2014 at Mercy Hospital in Janesville, Wisconsin. He was born January 22, 1927 in Mosquero, New Mexico to Martie and Donald C. Enlow. He married Martha McKnight on September 3, 1945.

First to the particulars of his professional life. Don earned a BS in 1949 from the University of Houston, following his World War II service in the Coast Guard. From 1951–56, he earned an MS in Biology from A&M College of Texas (later renamed Texas A&M University), taught zoology and botany at the University of Houston and at West Texas University, earned a PhD in Vertebrate Anatomy from A&M, and did post-doctoral work in human anatomy at the Medical University of South Carolina. In 1957, Don joined the University of Michigan School of Medicine as an Instructor of Anatomy, and later was appointed a Professor of Anatomy, a Fellow of the Center for Human Growth and Development, and the Director of the Center's Craniofacial Growth Program.

After 15 years at Michigan, Don joined West Virginia School of Medicine, where he served for five years as Professor and Chairman of Anatomy. He then joined the Case Western Reserve University (CWRU) School of Dentistry, where he was appointed Thomas Hill Distinguished Professor and Chairman of Orthodontics and Assistant Dean for Graduate Studies and Research. Don also was the dental school's Acting Dean for three years, which, according to him, imparted the gift of a quintuple bypass. He retired after serving fifteen years at Case.

Apparent in his biography is what seems to be at least one double life. Don was at first a biologist, which led to his doctoral dissertation in vertebrate paleontology. He then carved out a niche in craniofacial growth and development, which occupied the latter part of his career. What is not obvious from a simple reading of his biography is that, from Don's perspective, one field found refuge in the other; they were not separate fields in his mind.

"I had just been on a marvelous lark having a young man's great time looking for dinosaurs. I did not realize that I had entered, unexpectedly, a long research road which I did not realize could end up with a working understanding of how the vertebrate face, especially the complex human craniofacial assembly, grows and develops."

The unity of vertebrate paleontology and craniofacial growth and development would also come to represent a principal frustration in his life. With his focus on studying paleontology, Don might have collaborated with Jack Wilson, who founded the Vertebrate Paleontology



Dr. Donald Hugh Enlow.

*Correspondence to: Timothy G. Bromage, Hard Tissue Research Unit, Department of Biomaterials & Biomimetics and Department of Basic Science and Craniofacial Biology, New York University College of Dentistry, 345 East 24th Street, New York, NY, 10010-4086, USA. Tel: +1 212 998-9597, Email: tim.bromage@nyu.edu

Don's family would appreciate contributions to the Donald H. Enlow Scholarship Fund at the Case Western Reserve University School of Dental Medicine - c/o Department of Development/Alumni Relations Office, 2124 Cornell Rd., Cleveland, OH 44106. I will be contributing in the hope that the CWRU will find and support a plucky student who will press on with Don's lifetime dream.

DOI: 10.1002/ajpa.22603
Published online 28 August 2014 in Wiley Online Library (wileyonlinelibrary.com).

Laboratory at the University of Texas at Austin, just west of A&M. However, the academic pursuit of paleontology in 1950s Texas was centered in departments of geology, as it still is. Don had a keen knowledge of geology, and even applied its principles to understanding bone micro-anatomy, but his interests had been honed in the biological disciplines. In 1951, Don began extensive fossil field prospecting around West Texas. During one expedition, Don picked up a bone fragment and got the idea to make a "ground" thin section. In this pursuit, Don had many supporters in A&M's Biology and Zoology Departments, who proceeded to provide him with comparative extant material for his studies. However, Harvard University Professor of Biology Alfred Sherwood Romer, then Director of the Museum of Comparative Zoology and something of a silent co-supervisor of Don's PhD, had the greatest influence on Don. Romer was enthusiastic about Don's idea of making thin sections of fossil bones, and appointed Stanley John Olsen, a vertebrate paleontologist and preparator, to assist Don with specimens.

When Don completed his dissertation, he coauthored a landmark set of three papers entitled "A Comparative Histological Study of Fossil and Recent Bone Tissues," in the *Texas Journal of Science* with Sidney Brown, an A&M histologist and radiologist (Enlow and Brown, 1956–1958). The importance of these papers and the bone histodiversity studies that followed are legend and helped to establish a field of research in which bone growth and organismal life history were told through paleohistology (de Ricqles, 2007).

Upon joining the University of Michigan, Don shifted his expertise in bone histology to the study of craniofacial growth and development. He wrote numerous papers and several books, including the *Handbook of Facial Growth* (Enlow, 1975). After moving to CWRU he wrote *Essentials of Facial Growth* with Mark Hans, which was recently re-edited (Enlow and Hans, 2008). It was my own combined interest in bone development and facial growth that led me to CWRU in 1981 and to my first meeting with Don. I planned to study facial growth and development in Plio-Pleistocene hominins, and hoped to develop an approach that did not require thin sectioning. Because the foundation for studies of bone growth remodeling were based in histology, who better than Don to train me in this science and art. Don spent a week with me at his Zeiss Ultraphot microscope, using slides of histological thin sections to illustrate how to make dynamic interpretations from static morphology.

We discussed the mental reconstruction of growth from two-dimensional histological thin sections to interpretations of size and shape change in three dimensions. This was not a common research pursuit in dentistry, but Don seemed to have opened the field wide enough to encompass all that those in the profession, particularly orthodontists, would need to know. However, it's not so clear that orthodontic students in the US and elsewhere today fully appreciate Don's pioneering principles. When a prominent University of Toronto orthodontist, Frank Popovich, was asked about the relevance of bone growth mechanisms in light of facial growth templates that Popovich had championed, his livid retort was, "I don't need to know anything about how growth occurs. I know where Point B will be in two years, and that's all I care about!" An extreme view perhaps, but the US orthodontic community has not continued its basic science or translational respon-

sibility. An example of this neglect should shock all that hear it. While Don performed some important bone growth remodeling variability studies on isolated maxillae and mandibulae, the analyses he used in his books to explain how the composite facial skeleton increases in size and changes in shape according to architectural principles is based on histological analyses performed on *six* skulls purchased from Carolina Biological Supply of unknown age or sex. Don was acutely aware of the high proportion of relapse in orthodontics, which he regarded as due to treatments that ignore patients' growth, displacement, and functionally balanced predispositions. From Don's perspective, if a knowledge of differences in craniofacial form were important to orthodontics - such differences as one may observe between regional human populations - then why hadn't orthodontists undertaken studies of the developmental mechanisms responsible for these differences? Could therapeutics be designed to target specific growth sites and to take advantage of a knowledge of differences in growth exhibited by our remarkably variable species?

In 1989, on the precipice of his retirement, I received a frantic telephone call from Don informing me that CWRU buildings staff were depositing his lifetime collection of slide boxes into a dumpster. I hired a van and sped to Cleveland where I recovered about 25,000 slides from the rubbish. Later that day, I also retrieved the complete set of slides that Don and Sydney Brown had published in 1956–1958, which Don had hidden deep to the rear of a cabinet, protected from the space reclamation and cleansing.

The Hard Tissue Research Unit of the New York University College of Dentistry (NYUCD) now curates this historic collection of histological thin sections from all major vertebrate groups and fossil vertebrates, from the earliest geological periods through the ages to the present. My own graduate students learned their bone histology from this collection and its papers, and Don has participated in their doctoral theses. In 2006, Don was honored for his lifelong contributions when NYUCD held the *Donald H. Enlow International Research Symposium* in conjunction with the 50th anniversary of the publication of his papers. Twenty-two professionals representing the disciplines of anthropology, bone biology, dentistry, and paleontology spoke about how Don's works impacted their professions.

Don maintained his research collaborations even after he was diagnosed with myasthenia more than a decade ago and having moved to Milton, Wisconsin, to be near family. During this period, we collaborated on the discovery of long period (e.g., near weekly) chronobiological rhythms in bone microstructure (Bromage et al., 2009). Coincidentally, this rhythm is named after Franz Halberg, the father of chronobiology, who was born on July 5th, 1919. On July 5th it seems, sometimes we win, and sometimes we lose.

In recent years, things became difficult for Don and his academic friends. The myasthenia trapped Don's avid mind in a body that could barely make the daily journey from his bedroom to his living room. Don's impatience at not making timely progress on his ideas flared now and then, and there was little we could do but listen, be strong, and maintain our collaborations and friendships.

Recently Don wrote in his inimitable style about a new project he had in mind:

"In the human, the spine is upright, the PM Plane is more or less parallel with the spine, and the Neutral Optical plane continues perpendicular to the PM Plane (the 90 degree mammalian rule). And today, here we are, fit and fiddle and ready to kill each other in the next World War. BUT, what if the brain CONTINUES to progressively enlarge. We are going to choke and suffocate because facial rotation will be impinging on the esophagus and trachea. Then what???? We have already developed Class II and III malocclusions as partial "normal" answers. But what next?"

Indeed, what next? We have two papers pending with Don, one of which concerns this interest in cranio-facial architectural responses to postural differences and brain enlargement over the course of human evolution.

LITERATURE CITED

- Bromage TG, Lacruz RS, Hogg R, Goldman HM, McFarlin SC, Warshaw J, Dirk, W, Perez-Ochoa A, Smolyar I, Enlow DH, Boyde A. 2009. Lamellar bone is an incremental tissue reconciling enamel rhythms, body size, and organismal life history. *Calcif Tissue Int* 84: 388–404.
- Enlow DH. 1975. *Handbook of Facial Growth*. W.B. Saunders Company: Philadelphia.
- Enlow DH, Brown SO. A comparative histological study of fossil and recent bone tissues. Part 1, *Texas Journal of Science* 8 1956. 405–443; part 2, *ibid* 9 1957. 186–214; part 3, *ibid* 10 1958. 187–230.
- Enlow DH, Hans MG. 2008. *Essentials of Facial Growth*. Needham Press: Ann Arbor.
- de Ricqlès AJ. 2007. Fifty years after Enlow and Brown's Comparative histological study of fossil and recent bone tissues (1956–1958): A review of Professor Donald H. Enlow's contribution to palaeohistology and comparative histology of bone. *C R Palevol* 6: 591–601.