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OPTOMETRY AND VISION SCIENCE

INVITED PERSPECTIVE

Optometric Trajectory—Gerald Westheimer

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ABSTRACT

A narrative starting with the author's entering the Optometry program at the Sydney Technical College in 1940, taking him through his days as an optometry and science student, an optometrist in private practice, and participant in organized optometry in Sydney. It described his steps to become an optometric scientist and his service as faculty member in three optometry schools in the United States. Finally, it follows him into a long career in vision science and neurophysiology at Berkeley.

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Key Words: optometric history, Australian optometry, optometric education, vision research

BEGINNING IN SYDNEY, AUSTRALIA

As the class schedule would have it, the 1940 incoming first-year optometry students at the Sydney Technical College first met in the Mechanical Optics Laboratory, where we were taught to block lens blanks preparatory to grinding surfaces with increasingly fine emery grades and then polishing with rouge. Lenses were of immediate practical concern to optometrists and hands-on experience in their production therefore regarded as obviously part of the curriculum.

Ours was the eighth class in the education program mandated by the Act establishing a New South Wales (NSW) Register of Optometrists in the early 1930s.[1] The majority of practitioners at the time had been "grandfathered" in, practicing in storefronts, refracting with trial lenses and frames. Dispensing was an integral part of their service. Lenses sometimes still had flat base curves and were fitted in round metal frames. "Fulvue" shape, "Numont" rimless mounts, and flat-top bifocals were rare; plastic, gradient bifocal and contact lenses were far in the future. After cataract extraction, patients wore high-power plus lenses, usually in "lenticular" configuration.

Optometry was a 4-year diploma course, entry requiring high school graduation. Sydney, with a population of more than a million, had a very small university with a few hundred Arts and Science students and thriving Faculties of Law and Medicine, which dominated the administration. Mid-level technical and management professionals, engineers, chemists, architects, and, yes, we optometrists, received our training at the Sydney Technical College, run by the Department of Education of the State of NSW, with the requirement that students obtain concurrent relevant practical experience. As a result, I became a paid intern in a small downtown optometric practice, immediately engaged in selecting, ordering, checking, and fitting eye ware. This was in February 1940 and I was about to turn 16, having just passed the high school equivalence test, a little more than a year after our family landed in Sydney. My parents had had the remarkable foresight to emigrate from Berlin in 1938 just as the Nazi persecution of Jews was about to turn from menacing to deadly.

Sydney's Optometry program in the days before it achieved University-degree status was staffed largely by clinicians. Their experience in private practice, their use of first-class textbooks (e.g., Laurence and Wood,[2] Emsley,[3] Duke-Elder,[4] Giles[5]), and the students' daily awareness of optometric exigencies as they worked in the field gave us a solid grounding, arguably rivaling that provided currently in the best optometry schools, given the relative state of advancement of the profession then and now. In some ways, we could serve our patients better: even a cursory look with the retinoscope gives insight lacking in the printed autorefractometer readout, and patient rapport is closer when one personally deals with all patient concerns, not only refractive but also the many mechanical ones of adjusting nose pads or temples or the height of bifocals. We dealt almost exclusively with correction of refractive errors and/or presbyopia and stable heterophorias. Anyone with the least sign of treatable eye disease was referred to an ophthalmologist, usually never to be seen again because optometric-ophthalmological relationships were essentially nonexistent, and once in ophthalmologists' hands, a patient was steered to dispensing establishments favored, and not

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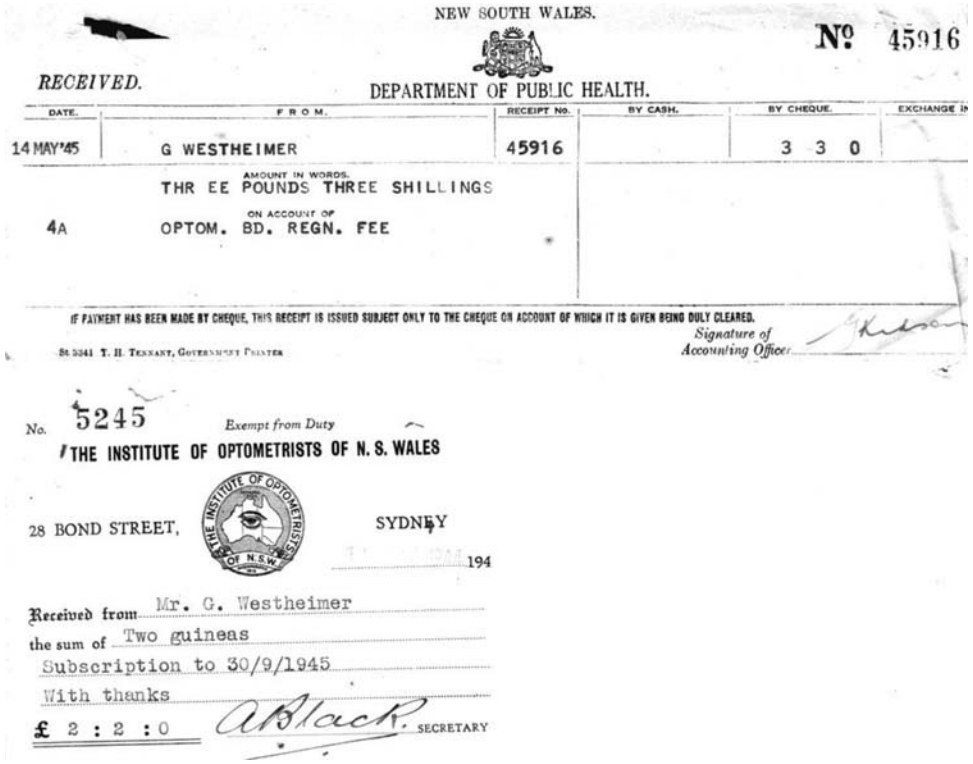

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FIGURE 1.

Upper: Receipt for the fee of three guineas, that is, £3:3:0, to become a registered optometrist, dated the day after my becoming of legal age. Lower: Two guineas subscription fee to become Fellow of the Institute of Optometrists of New South Wales in 1945.

infrequently owned, by these doctors. The often encountered pterygium or pinguecula instantly revealed a patient's geographical origin: the brutal climate of inland NSW ("the bush") takes toll on the conjunctiva.

When I completed the course, the various threads—my interest in the eye and optics, clinic-directed training at the Sydney Technical College, and the requirement to be actively working in a practice while a student—converged as my principal, Mr. E.J. Jackson, having observed my progress from a clueless teenager to a knowledgeable and assured clinician, offered me a partnership in his practice on George Street near Railway Square in Sydney. But this had to await my coming legally of age on May 13, 1945. Having paid the three guineas (£3:3:0) fee (Fig. 1), and satisfied the educational requirement, I was placed on the NSW state register of optometrists where I can still be found, albeit now in the "inactive" status.

I enthusiastically embarked on developing the practice. We acquired a synoptophore and took on postsurgical strabismus patients for fusion training. We ordered sets of Kollmorgen telescopic low-vision aids from the United States. Elected fellow of the Institute of Optometrists of NSW, I became active in optometric affairs (Fig. 2), rising through the ranks to be state delegate at the Australian Optometric Association triannual national congress in 1951 and serving, together with Don Schultz from Adelaide, South Australia, and Eric Padman, from Launceston, Tasmania, on a committee on national standards for spectacle lenses.

Not to leave unmentioned an important facet of my life, I continued violin study by enrolling at the Sydney Conservatorium of Music with Haydn Beck, concertmaster of the Sydney Symphony Orchestra. All the switches had apparently been set, and you might have predicted a prominent career in clinical and organizational optometry in one of the world's greatest cities.

FIGURE 2.

Optometrist, Sydney, Australia, 1945.

BECOMING A SCIENTIST

But you would have been wrong. Preceding, paralleling, and now neatly dovetailing this eagerly embraced clinical optometric track had always been a penchant for science. When the family arrived in Sydney in 1938, penniless refugees and foreign in language and culture, financial pressure necessitated that my older brother and I immediately enter the workforce. High school leading to the university was out of the question. The part-time study, part-time work optometry program at the Sydney Technical College, on the other hand, had the dual attraction of a future as an independent professional and a field whose scientific basis had long gripped me.

But becoming a scientist under these circumstances was a slow and arduous process. First, it took the form of taking extra courses in mathematics and physics during the optometry curriculum. Then, while in practice, I embarked in stages on the Science degree course at the University of Sydney, majoring in physiology and mathematics. Later, I added the new physics major offered at the Sydney Technical College. Finally, to cap the educational opportunities open in optometry in Sydney, I prepared a thesis, ''Studies in the Optical Theory of Contact Lenses,'' for the rarely sought-after fellowship of the Sydney Technical College, more or less equivalent to a master's. Submitted in 1949 and awarded in 1950, it was the first higher optometric qualification ever in Australia and included sections on the Gaussian matrix formulation in geometrical optics. It manifested an abiding interest in the optics of visual aids, which, as will be seen, had a significant impact on my later career.

It requires talent to succeed as a scientist, but that does not suffice. Curiosity, enterprise, discipline, training, technical fluency, luck, and opportunity—all are also needed in varying proportions. The one ingredient in the mix that I felt was beyond my reach in Sydney in the late 1940s was the last. Research opportunities in local institutions either had little relevance to the eye and vision or were not open. When I applied to the master's program, I was not accepted by Frank Cotton, the Professor of Physiology at the University of Sydney. John Eccles, Australia's great neurophysiologist, was still in New Zealand, and Peter Bishop, later to establish a world-class vision laboratory in Sydney and then in Canberra, was just on the way back from London. Going overseas was the only option, much more wrenching in those days before jet travel and especially so for a clinician actively tending to a growing private practice.

Nor was the path clear. A well-established process funneled top mathematics, physics, and chemistry graduates or medical specialists to Oxford, Cambridge, or London. But because optometry had no such mechanism, it was left to me to explore possibilities myself. Accordingly, I wrote to various overseas institutions. Typical of the almost universal negative responses was the letter from Dean K. Stoddard of Berkeley, who explained that pressure from local applicants for limited slots did not give any application from me much of a chance. The one exception was Glenn Fry, director of the School of Optometry at Ohio State: if documentary evidence of my academic credentials were supplied, I could be admitted to graduate school with a stipend. Not much was familiar to me about The Ohio State University (OSU), a prominent state university perhaps 10 times the size of the Sydney University I had attended, but Dr. Fry was not an unknown. In fact, I have just then been studying one of his articles in the *American Journal of Optometry*, a tour-de-force in which spherical aberration was factored in the diffraction calculations for various planes near the focus.[6] (Only later did I learn that the computation was performed by a mechanical device designed by Fry and constructed in the school's extensive metal and wood shop.)

Here then was an opening, and it forced me to confront the divergence of the paths: clinic or science? The absence of any way of pursuing the latter because of Australia's geographical isolation made this into a decision whether to suspend, more likely abandon, the prospects in clinical and organizational optometry and travel halfway around the world into a daunting foreign academic and scientific environment. No one around could provide meaningful advice or guidance. In the event, it was not a contest. A mutually acceptable agreement was reached with Mr. Jackson, and I prepared the departure for Columbus, Ohio. The fandango involving the U.S. visa and Dr. Fry's failure to respond to a request for the needed paper (i.e., read his mail) has been told elsewhere,[7] but I bought a one-way air ticket and in September 1951 embarked on a new life.

OHIO STATE

The trip itself was interesting. Breaking the journey in San Francisco, I visited the School of Optometry in Berkeley and was warmly welcomed by then graduate students Merton Flom and Darrell Carter. They were surprised to learn of Stoddard's coolness to my approach, there was no dearth of graduate student slots. Stoddard's caution and my ignorance of a certain give-and-take attitude in the United States, as distinct from the peremptory stance of Australian academic administrators, had me regard Berkeley as closed when an appeal might readily have succeeded and, in retrospect, short-circuited almost a decade's remove from the Pacific Rim. I did not meet Meredith Morgan then, he was away being interviewed for dean in Houston. But I was subjected to an hour-and-a-half discourse by Gordon Walls, in shirt sleeves and looking like a janitor with a bunch of keys dangling from his belt, on his view that Maxwell's spot was not caused by macular pigment but represented a distribution of color receptors. It was an eye opener: although Australia was supposed to be an egalitarian society, it was unthinkable that any professor I had encountered there would look like that or address more than a cursory remark to a beginning graduate student. And, of course, I hadn't the faintest clue what Maxwell's spot was.

Optometry at Ohio State had recently opened its new building on 10th Street in the middle of the sprawling medical precinct and, although still under the Dean of Arts and Science, had become the professional School of Optometry instead of a subdivision of the Physics Department, and the head, Glenn A. Fry, now had the title Director.[8] The Optometry program had just been increased in length to 3 years. Fry had been a PhD advisor to a sequence of optometry graduates: Henry Hoftstetter, later first dean of the Optometry program at Indiana University; Vincent Ellerbrock, at one time researcher with Ogle at the Dartmouth Eye Institute, associate professor at The OSU; Merrill Allen, son of a Corpus Christi, Texas, optometrist and one of the most gifted laboratory vision scientists I have encountered who went on to help a generation of optometry experimenters

as professor in Indiana; Matthew Alpern, first and so far only optometrist ever to be elected to the U.S. National Academy of Science. Just left with his newly minted PhD was Henry Knoll, later to become vice president of Bausch and Lomb. So I took my place among the cohort, then including Charles Stewart, founder and long-time head of the Optometry program at the University of Houston, and Neal Bailey, a significant influence in optometric contact lens practice, and, later, Earl Miller, who died young as a promising vestibulo-ocular researcher at the University of Pittsburgh. Ted Grosvenor, Jay Enoch, and Brad Wild, destined for future prominence in optometric research and education, were close behind.

Clinical training and practice in Australia had failed to expose me to the deep, almost philosophical, chasm that divided American optometry then: the Optometric Extension Program (OEP) versus the so-called eyeball school. Ohio State and Berkeley were regarded as bastions of the latter, alleged to insist on a purely optical, as contrasted with what would now be called a holistic, approach to the patient. And sure enough, immediately on arrival, I was made aware of my ignorance of graphical analysis, more or less invented by Fry,[9] based on a linear and invariant accommodation-convergence association. Whereas we measured phorias and prism vergences (called by us ''ductions'') at distance and near and kept relationships in mind, adherence of graphical analysis did just that with paper and pencil. It was ironic that the competing OEP procedure followed an even more formulaic method, called chaining, to determine the prescription. In reality, the OEP dealt not so much with the optometrist as refractionist than operated as a giant self-help network, bolstering the self-esteem of optometrists many of whom had trained in poorly recognized private, not-infrequently for-profit, colleges. The time was only just past when the American Optometric Association's accreditation arm had to step in and clean up some of the more egregious optometric diploma mills who skyrocketed their enrollment by plugging in on veterans' GI Bill benefits.

Graphical analysis aside, optometric practice in Ohio wasn't greatly different from Sydney's. There was a larger selection of frames, contact lenses were more widely used, and so were Univis and other types of flat-top bifocals. The emphasis on AO Tillyer and B&L Orthogon lenses was surprising especially because no one could seriously explain the advantage of the small differences in base curves. Aniseikonia was taught at the school where Ellerbrock had an elaborate testing facility. Spearheaded by the American Optical Company's Bureau of Visual Science in aid of their aniseikonia diagnosis and correction initiative, there was a disconnect between the rigor of the approach and the more common ability of patients to adapt to optically induced geometrical distortions.

Some degree of cooperation with ophthalmology had been achieved in Columbus, and the two departments were joined in an entity called Institute for Research in Vision, with Fry as codirector and some financial support from the university. Research followed one of Fry's several directions of interest, in those days especially color vision and the influence of stray light on retinal interaction. It took me almost a year to figure out how to sidestep Fry's predilection for constructing mechanical devices for collecting and analyzing data and get down to a thesis research on input-output relationships in normal human eye movements. Although it had strong roots in the rigorous mathematics, physics, and physiology training I had received in Sydney, I couldn't have done this work in Australia for two reasons. The first was the significant influence on my thinking of Paul Fitts,[10] professor of Engineering Psychology who in the brief span of a couple of months at the end of 1951 introduced me to the new world of Wiener's Cybernetics, Shannon's Information Theory, and the systems approach. The other was the guidance provided by Merrill Allen in making the experimental apparatus simple and looking to electronics rather than mechanics for components. The PhD dissertation submitted in June 1953 was short, and the systems theoretical analysis of oculomotor behavior was so well received that, a couple of years down the road, it earned me the accolade of invitation to submit a research proposal to the U.S. Office of Naval Research. Their funding supported my laboratory for more than a dozen years, Australian citizenship notwithstanding.

HOUSTON 1953 TO 1954

The PhD was then becoming an essential requirement for a career in optometric education, so the handful of PhD-optometrists was in demand. This was especially so in 1953 when two new optometry schools, Indiana and Houston, were going on line. I received an offer of an assistant professorship, remuneration in the low $4000s per annum, from the Chicago College of Optometry, and former fellow graduate student Charles Stewart, now heading the College of Optometry at the University of Houston, with whom I always got on well, wanted me to join him. I judged Indiana's scholarly and research prospects to be superior and visited Henry and Jane Hofstetter during the Christmas holidays 1952 to present myself. Henry preferred Merrill Allen, to whom he was close, and in the spring of 1953, as I was preparing my thesis and contemplating the relative merits of American academia and Australian optometric practice, there was a curious game of musical chairs. When the music stopped, Merrill was in Indiana, I in Houston, and an empty chair in Columbus. This was the consequence of a whole host of factors, including the national OEP/Eyeball rift and regional, cultural, and religious preferences of some of the involved parties. The trends and streams in mid-20th century, mid-American, mid-level academic and professional life deserve laying out in better detail than can be done here.

I spent one of the most challenging years of my life as inaugural professor of physiological optics in Houston. There was no time or opportunity for research; all my effort was spent on preparing and delivering five or more optometry school lectures per week, covering the full range of topics in the optics and vegetative physiology of the eye, electrophysiology, retinal function, psychophysics of brightness and color, oculomotility, binocular and spatial vision, and visual perception. To this should be added setting up demonstrations and experiments in the associated laboratory. True, the subjects' scope was much more modest then than now, but this way of spending the immediate post-PhD year might be contrasted with the postdoctoral stints now common, not to speak of the expectations of teaching relief, spacious laboratory, and generous research equipment allowance to new faculty in top institutions. Being forced to become familiar with all

of vision science and understanding it clearly enough to communicate it at the undergraduate level, however, have proved invaluable.

ON THE OPTOMETRY AND PHYSIOLOGICAL OPTICS FACULTY, COLUMBUS, OHIO

When the conflicting strands of my geographical location and career expectations in optometric practice, teaching, and research had finally been sorted out in the summer of 1954, I found myself on the Optometry and Physiological Optics faculty back at The OSU, teaching ophthalmic, geometrical, and physiological optics and engaging in research in oculomotility and on the optics of the eye and visual aids. I entered the wider field of national activities when Vince Ellerbrock recruited me to help organize the continuing education courses now bearing his name and when I assumed the chairmanship of the committee on uniform entrance requirements of the Association of Schools and Colleges of Optometry.

The nationwide community of optometric and physiological optics scientists and educators in the 1950s was compact by current standards. The majority of the dozen or so schools concentrated exclusively on routine preclinical and clinical training. The handful of researchers would gather at the annual Academy meetings early in December held mostly at the Drake Hotel, Chicago. Sessions on vision were part of spring and fall meetings of the Optical Society of America. There, except for the occasional well-attended plenary sessions featuring a talk by Harvard's George Wald or Edwin Land of the Polaroid Corporation, anywhere from one to three dozens of us, well known to each other, would give 15-min talks. Research, using psychophysical methods or eye movement records, was done on a shoestring with devices constructed usually by the experimenter himself—it is unnecessary to add, as is customary now, "or herself." Vision science sessions, with about the same attendance, were scheduled also at meetings of the American Psychological Association. A small group of scientists working in ophthalmology departments met at ARO, the Association for Research in Ophthalmology, predecessor of ARVO. They published in a supplement to the *American Journal of Ophthalmology*. The trickle of funding from the National Institutes of Health's division NINDB, the National Institute of Neurological Diseases and Blindness, was quite deliberately channeled away from optometry schools. Just a very few were fortunate to be awarded contracts for specified investigations, for example, focusing problems with instruments or in dark fields, contrast or chromaticity detection under different illumination, from a branch of the Armed Forces.

Mention might be made of the Armed Forces National Research Council Committee on Vision. A panel of top scientists convened to advise on sensory problems during WWII had by the 1950s become dormant and was resurrected in 1957 under this name, with the intent of keeping track of available talent in the United States in areas of expertise that may be needed for defense purposes. There were annual meetings, workshops, and task forces that routinely included optometrists.

My scientific vista was widened by a summer postdoctoral fellowship in the nerve-muscle program instituted by Kuffler at the Woods Hole Marine Biological Laboratory and then by a year at the Cambridge Physiological Laboratory with Fergus Campbell and John Robson. Our studies on accommodation[11] were informed equally by the laboratory prowess of these two researchers and by Campbell's background in the clinic as ophthalmologist and mine as optometrist. I made some contact with British optometry, getting to know George Giles at the British Optical Association and facilitating contacts that made Arnold Sorsby have Campbell appointed to the British State Board officially recognizing optometry.

BERKELEY SINCE 1960

All along, I continued to till a field that had triggered my interest as optometrist in Sydney, the effect on spectacle lenses and other optical devices on the image generated by the eye. By the late 1950s, I had published more than a dozen articles on the optical, prismatic, and magnification properties of contact lenses, bifocal additions, telescopic lenses first in the *Australasian Journal of Optometry*, edited by W.G. Kett, and then, as they were the subject of presentations at the meeting of the American Academy of Optometry, which I regularly attended, in the *American Journal of Optometry and Archives of American Academy of Optometry*, edited by Carel Koch. These presentations and articles had not escaped the notice of Meredith Morgan. Early in 1960, when Morgan became acting dean of the School of Optometry at Berkeley because of Stoddard's illness and when Jack Hobson, who had been teaching mechanical optics there for decades retired,[12] he had the opportunity of inviting me to take over Hobson's portfolio. So soon enough I received a letter, handsigned by Clark Kerr, president of the University of California, confirming tenure and faculty status and then, accompanied by Meredith, I joined the welcoming line for new faculty by Chancellor Glenn Seaborg.

All faculty members in the school who had an optometric qualification participated in clinic teaching (Fig. 3), which in my case represented two afternoons a week supervising final-year students in the senior clinic. In addition to the mechanical and

FIGURE 3.
The author, in clinical garb of tie and white coat, talking with Dean Meredith W. Morgan in his office in the School of Optometry, Berkeley, about 1961.

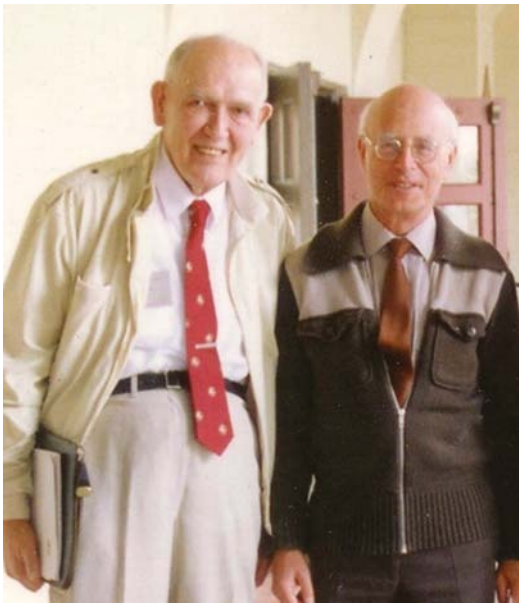

FIGURE 4.

Two optometric scientists of very different backgrounds but a shared devotion to research in physiological optics. With Glenn Fry (left) at the author's 65th birthday celebration in Berkeley.

physiological optics lecturing for which I was hired, there was a very active research effort, supported by the Office of Naval Research and two grants from the National Institutes of Health. In part, it was still devoted to the eye's optics, now including also electronic measurement of corneal shape,[13] for which a patent was issued jointly to me and Lee Felsenstein, later designer of the first portable computer.

Then, as the circle of collaborators widened and the research, while still, of course, in the field of vision, took on a more neurophysiological slant, Berkeley Optometry's physical facilities were inadequate to provide the needed space and resources, and in 1967, the campus administration relocated my laboratory to the vast Life Sciences Building and the departmental affiliation to Physiology.

In retrospect, the transition from clinical practice in Sydney to physiological optics graduate student and later faculty member was not as far-reaching as the one in which my title in the University of California became Professor of Physiology. After all, from the first day at the Sydney Technical College, I had always been embedded in the professional and institutional structure of optometry. If validation was needed, it was provided by my entry in *Who's Who in American Science* where, in the 1968 edition, I was identified as "optometrist, educator." It speaks volumes for Dr. Fry to have built at Ohio State in the 1940s a recognized research unit within an optometry school (Fig. 4). But a lot had changed in the following 20 years: the gap had widened vastly between what could be achieved by an individual researcher with modest facilities and prominent teaching responsibilities and the demands of working at the cutting edge.

How this shaped my scientific and academic activities during the intervening, now almost 50, years is told in the Appendix, available at http://links.lww.com/OPX/A227. Collegial interactions and personal friendship with Berkeley's optometry faculty continued and, although I have not played any role in teaching optometry or vision science courses, Jay Enoch when he became dean arranged an appointment to the *pro forma* title clinical professor (Fig. 5). In this period, about a dozen publications have appeared in optometric journals, and optometric professional recognitions such as the American Academy of Optometry's Prentice Medal, Australian Optometric Association's Barry Collin Research Medal, and Ohio State College of Optometry's Glenn A. Fry Medal have confirmed the bond with the optometric profession that was first forged in the lens-grinding exercise of the Mechanical Optics Laboratory of the Sydney Technical College 75 years ago.

Nearing my 90th birthday, I returned to my roots and started work on methods that might supplement the Snellen chart in first-round evaluations of a patient's spatial visual capacity. It was sparked by a resurrection of the 100-year-old Bates procedure to improve uncorrected visual acuity through training, this time claiming support from current research in cortical plasticity. But optical information lost through refractive error cannot be recovered, so any apparent improvement must be the result of memory or cue prompting, or of a failure of size-diminishing optotypes to fully capture the limit of a patient's spatial visual performance. A variety of methods of image degradation were tried in addition to the resolution-based Snellen chart and the contrast-reduction Pelli-Robson kind of test. In particular, blur and noise degradation have the advantage that letters can remain constant in size and reduction in image quality can be expressed in a single degradation parameter. A substantial study in *Clinical and Experimental Optometry*, comparing five methods of handicapping letter recognition in normal observers,[14] enabled me to fulfill a long-standing dream, namely, marking the 70th anniversary of my 1945 debut publication[15] in the same journal,

FIGURE 5.

The author receiving 65th birthday congratulations from Berkeley Optometry School Dean Jay Enoch.

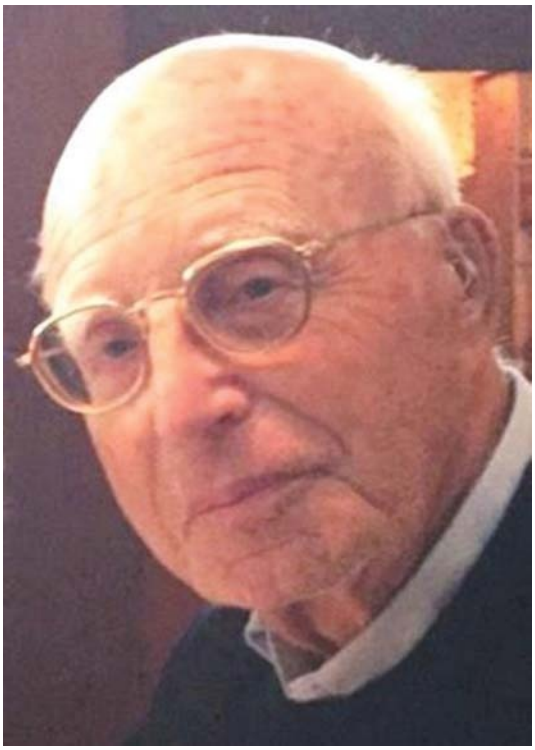

FIGURE 6.
Emeritus Professor, Berkeley, 2015.

then called *Australasian Journal of Optometry*, both translational/clinical optometric projects conceived, executed, and written just by myself (Fig. 6).

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APPENDIX

The Appendix, detailing the author's life experience of vision science in a nonoptometric setting, is available at http://links.lww.com/OPX/A227.

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