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Pandemic Calendar Reset

Heraklion Koules Fortress, Crete

We circulate this issue of *Daltoniana* at a time when scientific work and travel are severely interrupted by the COVID-19 pandemic. After this challenging year, many of us were looking forward to spending some time in Crete this coming summer. The Directorial Board of ICVS have had numerous discussions and have reluctantly decided that our planned meeting in Heraklion will not be feasible this year. The following plan has been approved by the Board of Directors. Basically, it is a reset of the calendar, meaning that:

1. We will extend the current membership for one additional year without charging dues.
2. We will extend the terms of office for the Board and Executive Officers by one year.
3. All future symposia will occur in even years. The meeting in Crete will thus occur in 2022; exact dates to be determined.
4. New memberships will start on Jan. 1st of even years.

We will provide further details, as well as plans for the next ICVS Summer School, as they become available.

Best wishes for the New Year,
John, Jack, Neil and the Board of Directors

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Newton's *Annus Mirabilis*

"For in those days I was in the prime of my age for invention…":
Newton's *Annus Mirabilis*

Alexander Pushkin
(painted by Kiprensky in 1827)

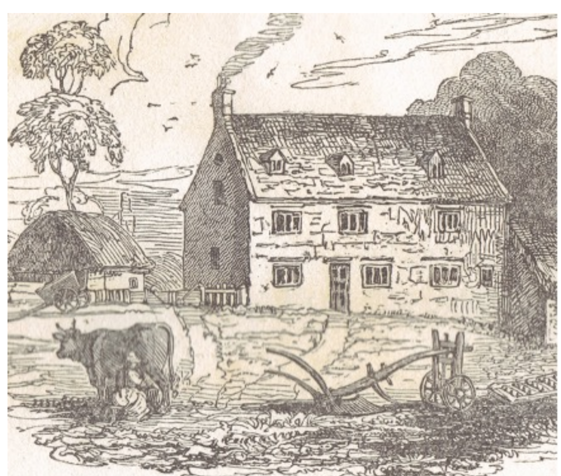
Russians have their own phrase for it – "Boldino autumn", a preternatural productivity that comes during enforced seclusion. In August, 1830, Alexander Pushkin (left) was about to marry the 18-year-old Natalia Goncharova. His father had settled on him part of the family estate at Boldino, east of Moscow, and he travelled there to deal with the formalities, arriving on September 3rd. An epidemic of cholera intervened, and he found himself separated from Moscow by five quarantine zones, each of which would have required a sojourn of 14 days. Pushkin's three months in seclusion at Boldino are judged to be the most creative period of his career. One brilliant work written that autumn was the poetic drama "A Feast in Time of Plague", set in London during the plague of 1665-6: the scene is a drunken feast at which the Master of Revels defiantly celebrates the Plague [1].

That plague reached Cambridge in the summer of 1665 [2]. The first victim, five-year-old John Morley of Holy Trinity parish, died on July 25th. His parents were shut up in their house; strangers without a certificate of health were turned away from the city; and 'searchers' of plague victims were hired. But the epidemic was already spreading and the 'pest house' – the isolation hospital was filling. The University and the colleges were soon closed; and on August 7th, a royal proclamation cancelled the great fair held annually on Stourbridge Common – a fair where Isaac Newton bought at least one of his prisms.

In that summer of 1665, Newton was aged 22 and had only recently graduated BA. In June, at the end of the University year, he had travelled from Trinity College to the Lincolnshire countryside where he had grown up. Now the closure of the University obliged him to stay there until the following March, when the plague had abated. A second wave of the epidemic came in the summer of 1666 and Newton returned to Lincolnshire until April 1667. During these two rustications, he spent time in the village of Boothby Pagnell (where his patron, Humphrey Babington, was rector) and at his mother's home, Woolsthorpe Manor, illustrated here (Many ICVS members will remember the house from the 2003 Symposium).

Writing much later in his life, in 1717, Newton recalled:

> "In the beginning of the year 1665 I found the Method of approximating series & the Rule for reducing any dignity of any Binomial into such a series. The same year in May I found the method of Tangents of Gregory & Slusius, and & in November had the direct method of fluxions & the next year in January had the Theory of Colours & in May following I had entrance into y^e^ inverse method of fluxions. And the same year I began to think of gravity extending to y^e^ orb of the Moon….I deduced that the forces w^ch^ keep the Planets in their Orbs must [be] reciprocally as the squares of their distances from the centres about w^ch^ they revolve: & thereby compared the force requisite to keep the Moon in her Orb with the force of gravity at the surface of the earth, and found them answer pretty nearly. All this was in the two plague years of 1665 & 1666. For in those days I was in the prime of my age for invention & minded Mathematicks & Philosophy more than at any time since…" [3]



THE BIRTH-PLACE OF NEWTON.

Newton's Annus Mirabilis , continued from Page 2

At a distance of 50 years, the mature Newton may have been romanticising, even deliberately, about this period of his youth. But it does seem from his manuscript notebooks that his development of the calculus ("fluxions") was indeed largely carried through during the two plague years [4, 5]. What about the 'Theory of Colours'? In his first published paper of 1672, when his memory would be relatively fresh, Newton wrote:

> "To perform my late promise to you, I shall without further ceremony acquaint you, that in the beginning of the Year 1666 (at which time I applied my self to the grinding of Optick glasses of other figures than Spherical,) I procured me a Triangular glass-Prisme, to try therewith the celebrated *Phaenomena* of *Colours*." [6].

He goes on to describe his experiments in a darkened chamber, his surprise at the rectangular (rather than circular) form of the spectrum, and his logical progression to the *Experimentum Crucis*, where a second prism is introduced without comment [7].

Almost certainly, Newton was improving his account for presentation to the reader – as all scientists do to this day. In manuscript notes that have been dated to late 1665 or early 1666, he describes experiments in which he looks *through* a prism at coloured stimuli [5, 8]. He critically records:

> "That y^{e} rays which make blew are refracted more than y^{e} rays which make red appears from this experiment. If one hafe of y^{e} thred abc be blew and y^{e} other red a b c & a shade or black body be put behind it then lookeing on y^{e} thred through a prism one halfe of y^{e} thred shall appear higher than y^{e} other and not both in one direct line, by reason of y^{e} unequall refractions in the differing colours."

The experiments in a darkened chamber do not appear in Newton's notebooks until a little later, and their exact date, and whether they were performed at Woolsthorpe or at Trinity College, remain uncertain. (It may be worth recording that the window in the candidate room at Woolsthorpe is exactly 22 feet from the opposite wall, as required by the 1672 paper in *Philosophical Transactions* [9].) But unquestionably before the plague years were spent, Newton understood that rays of different colour were rays of different refrangibility – and thus he would have expected a projected spectrum to be rectangular.

We live in a harsh new time of pestilence, which has taken from us relatives and colleagues and has separated families at times of traditional celebration. Let us hope that there is at least one 22-year-old student member of ICVS who is enjoying a Boldino autumn, solving the problems of colour science that Isaac Newton left unsolved – even perhaps discovering the origin of the unique hues…

1. Pushkin, A., *Mozart and Salieri: The Little Tragedies. Translated by Antony Wood.* 1982, London: Angel Books.
2. Lord, E., *The Great Plague: A people's history*. 2014: Yale University Press.
3. Newton, I., *Manuscript letter to Pierre Des Maizeaux*. 1718, Cambridge University Library, Add 3968.41, 85r.
4. Whiteside, D.T., *Newton's marvellous year: 1666 and all that.* Notes and Records of the Royal Society, 1966. **21**: p. 32-41.
5. Westfall, R.S., *Newton's Marvelous Years of Discovery and Their Aftermath: Myth versus Manuscript.* Isis, 1980. **71**: p. 109-121.
6. Newton, I., *A Letter of Mr. Isaac Newton, Professor of the Mathematicks in the University of Cambridge; Containing His New Theory about Light and Colors: Sent by the Author to the Publisher from Cambridge, Febr. 6. 1671/72; In Order to be Communicated to the R. Society.* Philosophical Transactions of the Royal Society, 1672. **6**(80): p. 3075-3087.
7. Mollon, J.D., *The origins of modern color science*, in *The Science of Color*, S. Shevell, Editor. 2003, Optical Society of America: Washington.
8. Guerlac, H., *Can we date Newton's early optical experiments?* Isis, 1983. **74**: p. 74-83.
9. Mills, A.A., *Newton's prisms and his experiments on the spectrum.* Notes and Records of the Royal Society, 1981. **36**: p. 13-36.

John Mollon

2022 Verriest Medalist

The 2022 Verriest Medal will be awarded to Professor Paul Martin at our 26th Biennial Symposium, to be held on the Greek island of Crete. The award was established in 1991 in memory of the founder of the Society, Dr. Guy Verriest, and honors outstanding contributions in the field of colour vision.

Professor Martin did his doctoral work in physiology at the University of Sydney, Australia and then postdoctoral fellowships in Germany at the Max Planck Institute for Biophysical Chemistry in Göttingen and the Max Planck Institute for Brain Research in Frankfurt. Here he commenced his studies on the visual system of primates. In 1992, he returned to the University of Sydney where he rose to the rank of associate professor in the Department of Physiology before moving in 2003 to the University of Melbourne as a Professorial Research Fellow and Director of Research in the Department of Optometry and Vision Sciences. He returned to the University of Sydney in 2010 where he is Professor of Experimental Ophthalmology.

Professor Martin's work concentrates on early visual processing in primates. His work on visual signals in magno-, parvo- and konio-cells in the primate retina and lateral geniculate nucleus is internationally acclaimed and highly influential. The significance of his scientific advances is amplified by his talent for presenting complex results in an easily understood manner for scientific and non-scientific audiences alike. He has generously served on boards of many funding organizations, in editorial positions at *Visual Neuroscience* and *Vision Research*, and on the ICVS Board of Directors. A prolific mentor, he has trained more than 25 Ph.D. students and postdoctoral researchers.

ICVS Summer School

From 3rd to 6th August 2020, Pembroke College (Oxford) hosted the 3rd ICVS Summer School. As with many events last year, the pandemic mandated that this was an entirely virtual version of the summer school, implemented using a combination of Zoom and Slack. Of the original 44 applicants, 40 signed up to participate on-line. Students and faculty came from around the globe, with attendees from Europe (UK, France, Germany, Portugal, Spain, Finland, Latvia and Switzerland), Australia, United States, Argentina, Japan, China, India, the Philippines and Iran. Eight lectures from faculty covered a range of topics, and were selected to give the students a grounding in the basics of colour vision and perception. Each lecture was followed by a Q&A-style discussion, and there was an overall discussion and feedback session concluding the school.

The organisers (David Brainard, Hannah Smithson, Manuel Spitschan and Neil Parry) were aided by demonstrators Allie Hexley and Takuma Morimoto. They are particularly grateful to the teaching faculty, who were available throughout the summer school for advice and encouragement, and who provided an outstanding syllabus. In chronological order, the lecturers were:

Andrew Stockman: "Photoreceptors"
Michael Webster: "Postreceptoral color vision"
Jenny Bosten: "Polymorphisms of the L and M opsin genes and their consequences for colour vision"
Paul Martin :"Colour vision anatomy and physiology: from retina to V1"
Karl Gegenfurtner: "Color vision for natural objects"
John Mollon: "'Jove's wondrous bow, of three celestial dyes': A brief history of colour science"
Jack Werner: "Changes in vision across the life span and in retinal and optic nerve disease"
Anya Hurlbert: "Colour constancy""

One of the key features of summer schools is, of course, the opportunity to interact and network with peers and faculty. To bring some of this to a virtual school, students worked in groups throughout the week, with guidance from the faculty, to prepare an outreach presentation and Q&A session. This was delivered to a group of high school students aged 16-17 years, who themselves were attending Access Week, a Pembroke College widening participation scheme, at the same time. This outreach event itself was also done via Zoom, and the high school students were asked to vote for their favourite presentation. The winning group was Jingyi He, Zoey Isherwood, Yanjun Li, Yesenia Taveras and Lingqi Zhang, who prepared a video about diurnal illumination variation, blue light and screen time. Their prize, donated by the society, was 3 years' free student ICVS membership. All of the groups worked hard and well into the night every day of the summer school (mostly using Slack) to produce their videos, which were of a uniformly high standard. They can all be congratulated for their collaborative and presentational skills.

Although the feedback from the students and faculty was overwhelmingly positive, everyone missed the fully interactive nature of the in-person summer school, where students and faculty learn, work, eat, and play together. We look hopefully forward to an in-person summer school in a few years' time.

Recent Papers on Colour Vision Recommended by the Board

(ICVS Members in Bold)

Aher, A.J., Jacob, M.M., & **Kremers, J.** (2019). High-frequency characteristics of L- and M-cone driven electroretinograms. ***Vision Research, 159,*** 35-41. **https://doi.org/10.1016/j.visres.2019.03.010**

Azimipour, M., Valente, D., Vienola, K.V., **Werner, J.S**., Zawadzki, R.J. & Jonnal, R.S. (2020) Optoretinography: optical measurements of human cone and rod photoreceptor responses to light. ***Optics Letters, 45,*** 4658-4661. **https://doi.org/10.1364/OL.398868**

Barbur, J.L., **Rodriguez-Carmona, M**. & **Evans, B.E.W.** (2020) Color vision assessment – 3. An efficient, two-step, color assessment protocol. ***Color Research and Application, in press.*** **https://doi.org/10.1002/COL.22599**

Bimler D. L., Snellock M. & **Paramei G. V.** (2019). Art expertise in construing meaning of representational and abstract artworks. ***Acta Psychologica, 192***, 11-22. **https://doi.org/10.1016/j.actpsy.2018.10.012**

Bosten, J. (2019) The known unknowns of anomalous trichromacy. ***Current Opinion in Behavioral Sciences, 30,*** 228-237. **https://doi.org/10.1016/j.cobeha.2019.10.015**

Danilova, M.V. & **Mollon, J. D.** (2020) Discrimination of hue and discrimination of saturation assessed with a common metric. ***Journal of the Optical Society of America*** **37,** A226-A236. https://doi.org/10.1364/JOSAA.382382

Evans, B.E.W., **Rodriguez-Carmona, M.** & **Barbur, J.L.** (2020) Color vision assessment – 1.: Visual signals that affect the results of the Farnsworth D-15 test. ***Color Research and Application, in press.*** **https://doi.org/10.1002/COL.22596**

Feigl, B., Adhikari, P., **Zele, A. J.**, **Cao, D.**, **Kremers, J**. (2019) The melanopsin-directed white noise electroretinogram (wnERG). ***Vision Research, 164***, 83-93. **https://doi.org/10.1016/j.visres.2019.08.007**

Feitosa-Santana, C.; Gaddi, C.M.; **Gomes, A.E.**; **Nascimento, S.M.C.** (2020) Art through the colors of graffiti: From the perspective of the chromatic structure. ***Sensors***, ***20***, 2531. **https://doi.org/10.3390/s20092531**

Foster, D.H. & Amano, K. (2019) Hyperspectral imaging in color vision research: Tutorial. ***J. Opt. Soc. Am. A 36***, 606-627. **https://doi.org/10.1364/JOSAA.36.000606**

Goddard, E., & **Mullen, K.T.** (2020). fMRI representational similarity analysis reveals graded preferences for chromatic and achromatic stimulus contrast across human visual cortex. ***Neuroimage, 15***, 116780. **https://doi.org/10.1016/j.neuroimage.2020.116780**

Grünert, U. & **Martin, P.R.** (2020) Cell types and cell circuits in human and non-human primate retina. ***Progress in Retinal and Eye Research, 78***, 100844. **https://doi.org/10.1016/j.preteyeres.2020.100844.**

Hagen, L.A., Arnegard, S., **Kuchenbecker, J.A.**, **Gilson, S.J.**, **Neitz, M.**, **Neitz, J.**, & **Baraas, R.C.** (2019). The association between L:M cone ratio, cone opsin genes and myopia susceptibility. ***Vision Research, 162,*** 20-28. **https://doi.org/10.1016/j.visres.2019.06.006**

Hurlbert, A. (2019) Challenges to color constancy in a contemporary light. ***Current Opinion in Behavioral Sciences, 30,*** 186-193. **https://doi.org/10.1016/j.cobeha.2019.10.004**

Jordan, G. & **Mollon, J**. Tetrachromacy: the mysterious case of extra-ordinary color vision. ***Current Opinion in Behavioral Sciences, 30,*** 122-129. **https://doi.org/10.1016/j.cobeha.2019.08.002**

Kuriki, I. (2019) Emergence and separation of color categories: an NIRS study in prelingual infants and a k-means analysis on Japanese color-naming data. ***Current Opinion in Behavioral Sciences, 30,*** 21-27. **https://doi.org/10.1016/j.cobeha.2019.04.012**

Liu, Y., Li, M., **Zhang, X.**, Lu, Y., Gong, H., Yin, J., . . . Wang, W. (2020). Hierarchical representation for chromatic processing across macaque V1, V2, and V4. ***Neuron***, ***108***, 538-550.e5. **doi:10.1016/j.neuron.2020.07.037**

Ma, R., Liao, N., P. Yan & **Shinomori, K**. (2019) Influences of lighting time course and background on categorical colour constancy with RGB-LED light sources. ***Color Research & Application, 44,*** 694-708. **https://doi.org/10.1002/col.22392**

Martinovic J., **Paramei G. V.** & MacInnes W. J. (2020). Russian blues reveal the limits of language influencing colour discrimination. ***Cognition***, 201:104281. https:doi.org/10.1016/j.cognition.2020.104281

Mizokami, Y. (2019) Three-dimensional stimuli and environment for studies of color constancy. ***Current Opinion in Behavioral Sciences, 30,*** 217-222. **https://doi.org/10.1016/j.cobeha.2019.10.008**

Mollon, J.D. & **Danilova, M.** (2019) Cortical communication and the comparison of colors. ***Current Opinion in Behavioral Sciences, 30, 203-209***. https://doi.org/10.1016/j.cobeha.2019.10.002

Mullen, K.T. (2019) The response to colour in the human visual cortex: the fMRI approach. ***Current Opinion in Behavioral Sciences, 30,*** 141-148. https://doi.org/10.1016/j.cobeha.2019.08.001

Neitz, M., Patterson, S. S., & Neitz, J. (2020). The genetics of cone opsin based vision disorders. In B. Fritzsch & **P. R. Martin** (Eds.), ***The Senses: A Comprehensive Reference, Volume 1, Vision*** (2 ed., pp. 493-506). Oxford: Elsevier, Academic Press.

Pandiyan, V.P., Jiang, X., Maloney-Bertelli, A., **Kuchenbecker, J.A.**, Sharma, U., & **Sabesan, R**. (2020). High-speed adaptive optics line-scan OCT for cellular-resolution optoretinography. ***Biomedical Optics Express, 11(9)***, 5274-5296. https://doi.org/10.1364/BOE.399034

Patterson, S.S., **Kuchenbecker, J.A**., Anderson, J.R., **Neitz, M.**, & **Neitz, J.** (2020). A color vision circuit for non-Image-forming vision in the primate retina. ***Current Biology, 30(7)***, R316-R318. https://doi.org/10.1016/j.cub.2020.01.040

Rajendran, S., **Maule, J.**, Franklin, A., & **Webster, M. A.** (2020). Ensemble coding of color and luminance contrast. ***Attention, Perception, & Psychophysics***, 1-14. **DOI: *10.3758/s13414-020-02136-6***

Retter, T.L., Gwinn, O.S., O'Neil, S.F., Jiang, F., & **Webster, M.A.** (2020). Neural correlates of perceptual color inferences as revealed by #thedress. ***Journal of Vision, 20(3)***, 7. **https://doi.org/10.1016/j.visres.2019.06.006**

Rider, A.T., Henning, G.B., & **Stockman, A.** (2019) Light adaptation controls visual sensitivity by adjusting the speed and gain of the response to light. ***PLoS ONE 14(8)***: e0220358. **https://doi.org/10.1371/journal.pone.0220358**

Rodrigo-Diaz, E., Tahir, H.J., Kelly, J.M., **Parry, N.R.A.**, Aslam, T., & Murray, I.J. (2019). The light and the dark of early and intermediate AMD: Cone- and rod-mediated changes are linked to fundus photograph and FAF abnormalities. ***Investigative Ophthalmology & Visual Science, 60(15)***, 5070-5079. https://doi.org/10.1167/iovs.19-27971

Rodriguez-Carmona, M., **Evans, B.E.W.** & **Barbur, J.L.** (2020) Color vision assessment – 2. Color assessment outcomes using single and multi-test protocols. ***Color Research and Application, in press.*** https://doi.org/10.1002/COL.22598

Shapiro, A.G. & **Hedjar, L.** (2019) Color illusion as a spatial binding problem. ***Current Opinion in Behavioral Sciences, 30,*** 149-155. **https://doi.org/10.1016/j.cobeha.2019.08.004**

Siuda-Krzywicka, K., **Witzel, C.**, Bartolomeo, P., & Cohen, L. (2020). Color naming and categorization depend on distinct functional brain networks. ***Cerebral Cortex.*** doi:10.1093/cercor/bhaa278

Sousa, B. R. S., Loureiro, T. M. G., Goulart, P. R. K., Cortes, M. I. T., **Costa, M. F.**, Bonci, D. M. O., ... & Souza, G. S. (2020). Specificity of the chromatic noise influence on the luminance contrast discrimination to the color vision phenotype. ***Scientific Reports***, ***10***(1), 1-11. **DOI: 10.1038/s41598-020-74875-3**

Spitschan, M. (2019) Melanopsin contributions to non-visual and visual function. ***Current Opinion in Behavioral Sciences, 30,*** 67-72. https://doi.org/10.1016/j.cobeha.2019.06.004

Stockman, A. (2019) Cone fundamentals and CIE standards. ***Current Opinion in Behavioral Sciences, 30,*** 87-93. https://doi.org/10.1016/j.cobeha.2019.06.005

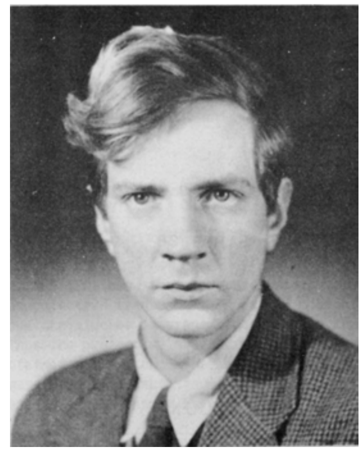
Tregillus, K.E.M., **Isherwood, Z.J**., Engel, S.A., **MacLeod, D.I.A**., **Kurikki, I.** & **Webster, M.A.** (2020) Color compensation in anomalous trichromats assessed with fMRI. ***Current Biology, 31,*** 1-7. https:// doi.org/10.1016/j.cub.2020.11.039

Werner, J.S., Marsh-Armstrong, B. & **Knoblauch, K.** (2020) Adaptive changes in color vision from long-term filter usage in anomalous but not normal trichromacy. ***Current Biology, 30,*** 3011-30015. https://doi.org/10.1016/j.cub.2020.05.054

Wuerger, S., Ashraf, M., Kim, M., **Martinovic, J.**, Pérez-Ortiz, M., Mantiuk, R.K. (2020). Spatio-chromatic contrast sensitivity under mesopic and photopic light levels. ***Journal of Vision, 20(4)***, 23. https://doi.org/

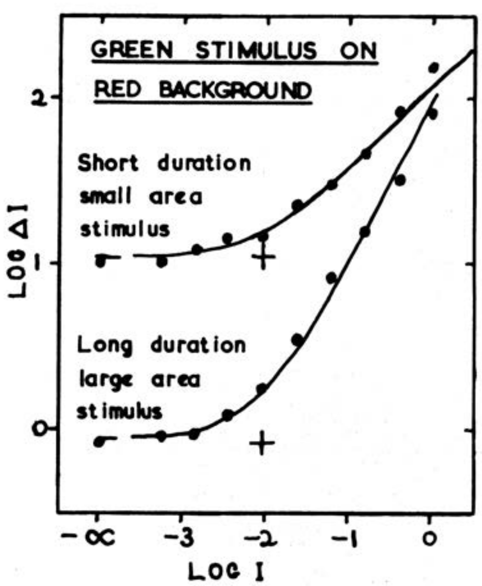
Contributions to Colour Science of Professor Horace Basil Barlow FRS

Following his death on July 5th, 2020 at the age of 98, there have been many admiring obituaries of Horace Barlow. The writers have rightly emphasised his experimental work on feature detectors in frogs and mammals; his analyses of visual discrimination in terms of signal detection, redundancy reduction, and efficiency; and his discussions of the relationship between the activity of single units and phenomenological experience. But little has been said about his work on colour. It is true that Horace seldom ventured into our field, but by his own account he first became interested in vision when he prepared an undergraduate talk on colour perception for the Natural Sciences Club at Cambridge [1]; and he went on to make two important contributions to colour science, each marked by his characteristic originality.



H.B. Barlow (1921-2020)
Photograph taken c. 1957

The first was published in the proceedings of the greatest of all colour conferences, the 1957 symposium on 'Visual Problems of Colour', organised by W. S. Stiles and held at the National Physical Laboratory, Teddington [2]. In the autumn of 1956, Barlow had sent to Stiles a draft of what became his 1957 *Nature* paper, explaining the Purkinje shift in terms of the thermal stability of photopigment molecules [3]. The topic was manifestly attractive to Stanley Stiles, who was prompted to devote several pages of his private journal to working out his own views of how visual thresholds were limited by noise. In what appears to be a draft letter to Barlow, he writes: *"I had a good deal of difficulty with your discussion of Müller's work...It is hardly possible in a letter to argue these points but if you are coming to town and can come along to the Lab. we might have a good discussion on this rather tricky question.'*



Threshold vs intensity (tvi) curves, from Barlow (1958)

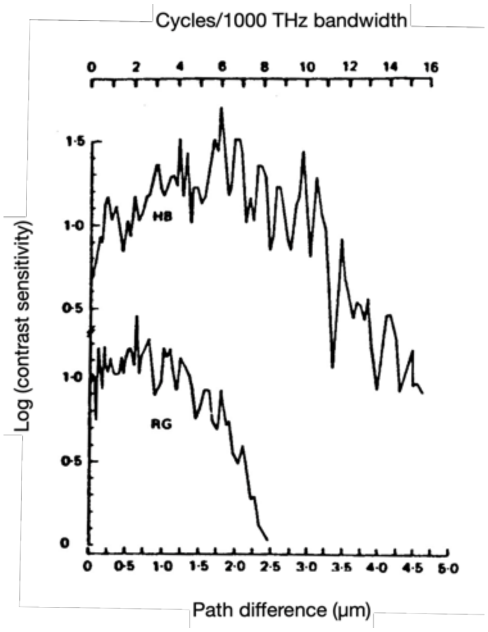
It is from these interactions that Barlow's paper in the NPL Symposium emerged. He measured *tvi* functions for Stiles' middle- and long-wave cone channels, π_4 and π_5, using either very brief (7 ms) and tiny (5.2 arcmin) targets or long (1 s), large (55 arcmin) targets (*v* figure to left for π_4). In the former case, both π_4 and π_5 obey the DeVries-Rose law, whereas in the latter case they approximate Weber's law. Barlow's paper goes on to estimate the "dark lights" of the several cone mechanisms (as equivalent quanta $[\lambda_{max}]$/s.deg^2) and the overall quantum efficiency of each mechanism (*F*) – the "smallest fraction of the quanta sent into the eye which would enable it to perform the task which it does perform". *F* is substantially lower for cones than for rods; and is very low for Stiles' short-wave mechanisms compared to the values for π_4 and π_5.

Barlow's second contribution to colour science came with his paper "What causes trichromacy" in the Rushton Memorial Issue of *Vision Research* [4]. It is a paper thronged with ideas – on the function of oil droplets, on the spectral proximity of the long- and middle-wave photopigments, and on the similarity of opsin absorption curves when plotted on an abscissa of $\lambda^{1/4}$. But in particular Barlow modelled the response of the visual system to spectral energy distributions that were sinusoidal functions of wavelength – 'comb-filtered spectra' of varying modulation frequencies. He made an explicit analogy with the study of spatial vision by means of sinusoidal modulations of luminance, an approach so dominant in Cambridge during that era.

In our Berlin *Proceedings* [5], Roland Gemperlein had described a distinct but related approach using a scanning interferometer. Horace Barlow was prompted to travel to Munich to make empirical measurements in Gemperlein's lab [6, 7].

Contributions to Colour Science of Professor Horace Basil Barlow, FRS, continued from Page 7

The figure to the right shows contrast sensitivity functions for HB, a normal trichromat, and for RG, a deuteranope. Variation of the path difference (abscissa) changes the modulation frequency of the comb-filtered spectrum. Contrast sensitivity was measured by finding how far the comb-filtered spectrum needed to be diluted with white light to bring the observer to threshold for detecting colour changes. This work was carried forward by Valérie Bonnardel, using a template colorimeter with a liquid-crystal display in the plane of the spectrum. An account can be found in our Pau *Proceedings* [8].



Barlow was much inspired by his undergraduate Director of Studies at Trinity College, the neurophysiologist and colour scientist, William Rushton. Assessing Rushton's later career, Horace wrote*: "Where he perhaps had the greatest effect was in making us look at the whole system. He was not content with specialized knowledge of one part, be it horizontal cells, exchange thresholds, or the pigments themselves. He aimed at understanding the whole process, from captured quantum to the sensation it released, and he made his listeners think in similar terms. Hearing a man of his intellect reasoning on these lines had a major effect in raising the quality of those who entered the field, the quality of discourse within it, and hence the whole quality of research in vision."*[9] These words apply well to Horace himself.

1. Husbands, P., *An interview with Horace Barlow*, in *The mechanical mind in history*, P. Husbands, M. Holland, and M. Wheeler, Editors. 2008, MIT Press. p. 409-430.
2. Barlow, H.B., *Intrinsic noise of cones*, in *Visual Problems of Colour*, W.S. Stiles, Editor. 1958, Her Majesty's Stationery Office: London. p. 616-630.
3. Barlow, H.B., *Purkinje shift and retinal noise.* Nature, 1957. **179**(4553): p. 255-6.
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J. D. Mollon

As *Daltoniana* was going to press, the unhappy news arrived of the death of Peter Gouras, a loyal and distinguished member of our Society. He gave an invited talk at the Parma meeting of IRGCVD in 1977 and subsequently contributed several experimental and theoretical papers to our proceedings (see volumes IX, X, XII and XII). Many members of IRGCVD were particularly influenced by his 1968 paper in *Journal of Physiology*, in which, inspired by the psychophysics of W. S. Stiles, he used action spectra to identify the cone signals reaching different types of ganglion cell in the macaque retina. The same paper includes a physiological analogue of the phenomenon later called 'transient tritanopia'; and Peter retained an especial affection for the short-wave cones throughout his life.

Eberhart Zrenner, a student, friend, and collaborator of Peter Gouras, has generously written an obituary at short notice and we are very pleased to include it below.

The Editors

Obituary for Peter Gouras (1930 - 2021)

It is with great sadness that we learned of the passing of world class vision scientist Peter Gouras on January 8, 2021 in Baden-Baden, Germany at the age of 90. Born 1930 in Brooklyn, New York, N.Y. he received his B.A. degree in Biology in 1951 and his MD degree in 1955 at Johns Hopkins University, Baltimore, Maryland. Peter joined the National Institutes of Health in 1959 and became chief of the Neurophysiology Section of the National Eye Institute in 1970. In 1978 he joined Columbia University in New York as Professor of Ophthalmology, where he continued working and publishing until 2019. He was married to Ute Keppler-Gouras; they raised two sons, Eckhardt and Gunnar, and daughter Roswitha, all becoming highly successful professionals.

Peter`s passion for science was boundless, and his discoveries were innumerable. In1958 he presented the first demonstration of optical changes (spreading depression) caused by neural activity; in 1960 he provided evidence that retinal horizontal cells are forming an electrical syncytium. For the next ten years a very fruitful era followed, together with John Armington and Ralf Gunkel, Ron Carr and Eliot Berson, resulting in a spectacular widespread recognition of the value of clinical application of electroretinography. Multiple discoveries ensued, pertaining to numerous retinal diseases published in top journals, including several articles in *Science*. From 1966 on, Peter focused on cellular electrophysiology, identifying the responses from parvo-, magno- and S-cone systems in primate retina, and describing rod and cone signals and the characteristics of processing chromatic information in the retinal circuitry, together with Günther Niemeyer, Helga Kolb, Ralph Nelson, Francisco de Monasterio, Ted Famiglietti, Eberhart Zrenner, David Tolhurst and Jürgen Krüger, among others, including work in isolated arterially perfused eyes and monkey striate cortex. In parallel he continued his clinical work, publishing a series of papers on electroretinography and electrooculography and their applications in hereditary and acquired retinal diseases. He discovered a unique form of retinal degeneration with supernormal rod responses and other progressive cone-rod degenerations – bridging findings with non-invasive electrophysiology, achieved together with coworkers Dan Finkelstein, Cynthia McKay, Suichi Yamamoto, Masamoto Saeki, Daniel Salchow and Stephen Tsang. with cellular functions of neurons and retinal pigment epithelium, which he was studying in his lab in parallel, together with Mary Flood, Jim Haley, Hild Kjeldbye, Robert Lopez, Shonit Das and Bill Blaner.

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Later in his career he focused on a new field, transplantation of cultured human retinal cells for development of remedies for progressive retinal degeneration. Further outstanding discoveries were made in studying the genetic and biochemical mechanisms of retinal degeneration, together with Stephen Tsang, Debora Farber, Stephen Goff, Rando Allikmets, Janet Sparrow, Jana Zernant, Antje Biesemeyer, Martha Neuringer, and many others over the years.

I admired Peter enormously, for his infectious enthusiasm, his perseverance in seeking to understand especially serendipitous findings during the long hours and night shifts when recording from primate retina, his ability never to be victim of circumstances, his dedication to stay on track once he had set his mind to a goal, even if he knew that he probably never might reach it but that he might make interesting discoveries on the way. He always was very open speaking about his ideas, discussing and sharing know-how, knowledge and experience, not minding that others might continue to work on such ideas. At the same time he could fiercely criticize weak research or fight hypotheses that to his opinion led into a wrong direction.

I enjoyed very much the friendliness of Peter's family family when I had the privilege of living in their house in Bethesda for one and a half years, meeting the family members and the small kids almost daily. I was invited every few weeks to family dinners with guests, mostly high-ranking scientists. After 1.5 years at NIH I also had the chance to join him at Columbia University for week-long visits, working in the laboratory, again staying in the wonderful Gouras-House in Riverdale. I have collected unforgettable memories, speaking all day long about findings in the lab, discussing new publications and sketching out new experiments and developing hypotheses about observations we could not understand initially.

Peter was always an original thinker, often swimming against the established stream of thoughts which not always made him friends. In many ways I always saw in him a sort of Christopher Columbus, who knew that there must be something important beyond the horizon. Like Columbus, Peter wanted to know what there is – and it was he who was assembling a crew to join him, who did not give up when there were storms, who encouraged his team to keep up their efforts, and who could read the little signs telling him that he was on the right path. Like Columbus, he might have arrived at places different from what he imagined when starting his journey, but he found instead places where new things were still to discover. Like Columbus, he easily left areas that he had charted already, coming back in a while, and he was on a lifelong journey of discovery until the last year of his life. He rather lived three lives, as physician caring for his patients, as neurophysiologist trying to understand the neural signals, and as cell biologist looking for structural and functional restoration.

We will miss him as a role model of a most dedicated original scientist, always full of joy, spreading his ideas and sharing his findings, and we will miss him as companion and friend. However, he will remain in our hearts and he will remain a legend in ophthalmological research.

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